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Semiconductor Equipment and Materials International

SEMI INTERNATIONAL STANDARDS

EQUIPMENT AUTOMATION HARDWARE

Semiconductor Equipment and Materials International

SEMI E1-0697
SPECIFICATION FOR 3 inch, 100 mm, 125 mm, AND 150 mm PLASTIC AND METAL WAFER CARRIERS

1 Scope

1.1 This specification covers the dimensional requirements for plastic and metal wafer carriers used for the processing and handling of 3 inch, 100 mm, 125 mm, and 150 mm diameter wafers. The specification has two classifications: General Usage and Auto Transport Usage. General Usage is a basic guideline that covers 3 inch, 100 mm, 125 mm, and 150 mm wafer sizes. Auto Transport Usage is intended to meet the in-use requirements for the interface of wafer carriers with automated wafer processing equipment. Auto Transport Usage covers the 125 mm and 150 mm sizes.

1.2 To meet these specifications, carriers must be manufactured within the dimensional limits and be dimensionally stable within the specification when used in accordance with manufacturers' recommendations.

NOTE: Recommended usage should be agreed to between user and supplier, since wafer carriers are manufactured from a number of different materials by several manufacturing methods.

2 Selected Definitions

For a pictorial explanation of most of the selected definitions, see Figure 1. Figure 1 symbols are defined in Table 1.

bar — (See "crossbar.")

bar end — The end surface of the carrier that has only one crossbar.

bar radius — The radius nearest the bar end of the carrier on the crossbar. (See Figure 1, D5b, Type II.)

bar web — The mass of material for structural support which may or may not be present on the crossbar. (See Figure 1, D5a, Type II.)

bar width — The distance or thickness of the bar when measured perpendicular to the top face. (See Figure 1, D5b.)

cassette — (See "wafer carrier.")

crossbar — The mass of material connecting the two sides of the carrier at the bar end of the carrier.

edge perimeter distance — The distance from the edge of the wafer to the top face of the carrier. (See Figure 1, D7.)

end wall — The wall of the carrier opposite the bar end of the carrier.

flange — Mass of material on the exterior and perpendicular to the side walls.

hole — The area for the pin on another carrier to enter for transferring wafers. (See Figure 1, C8.)

lot — (See "hole.")

parallelism tolerance — The minimum and maximum dimension allowance for the opposite pockets to vary in relation to their distance from the crossbar end of the carrier. (See Figure 1, D1.)

pin — The mass of material which enters the hole or slot of another carrier for transferring wafer. (See Figure 1, C7.)

pin and hole center distance from pocket centerline — The distance from centerline of either the pin or hole to the closest pocket centerline. (See Figure 1, C9.)

pocket — The area in which the wafer is located in the carrier.

pocket centerline — The imaginary line which bisects each pocket.

pocket depth — The distance from the pocket flat to its own pocket nose, not to the opposite pocket. (See Figure 1, C2.)

pocket flat — The width of the pocket along the vertical walls at its narrowest distance. (See Figure 1, C3.)

pocket nose — The top of the mass of material between adjacent pockets.

pocket nose radius — The radius on the pocket nose.

pocket size — The distance between opposite pocket flats. (See Figure 1, C4.)

pocket spacing — The distance between pocket centerlines. (See Figure 1, B2.)

pocket width — The width of the pocket at its widest distance. (See Figure 1, C1.)

top face — The plane or surface of the carrier from which side wafers enter into or out of the carrier.

track clearance — The unobstructed area between the two carrier sides on the bar end. (See Figure 1, D6; Figure 1a, D6a, D6b, D6c.)

wafer carrier — A device for the holding of wafers for various processing steps in semiconductor manufacturing.

wafer tilt — The possible unparallel position of the wafer in relation to the bar end of the carrier when the carrier is resting on the bar end. (Not shown in Figure 1.)

wafer transfer — The act of relocating wafers from one carrier into another. This can be accomplished by several methods.

Table 1 Symbols Outline General Usage

Figure 1 Reference	*Description*
	Overall Dimensions
A1	Length
A2	Width (with/without flange)
A3	Height (excluding pin)
	Capacity
B1	Pockets per carrier
B2	Pocket spacing
B3	Center distance from the 1st to last pocket
	Detail Dimensions
C1	Pocket width
C2	Pocket depth
C3	Pocket flat
C4	Pocket size
C5	Pin and hole location (width)
C6	Pin and hole location (length)
C7	Pin diameter and height
C8	Hole or slot
C9	Pin and hole center distance from pocket center line
	Machine Fit Specifications
D1	From the outside of the bar end to the center line of the 1st pocket
D2	From the center line of the 1st pocket to the closest point on the crossbar or web
D3	From the bar end of the carrier to the start of the crossbar
D4	Center of the crossbar to the top face of the carrier
D5	Crossbar specifications
D5a	Bar web width on type II crossbar, or width of the type III crossbar
D5b	Bar width
D6	Track clearance
D7	Edge perimeter distance
Not shown — Wafer Tilt	

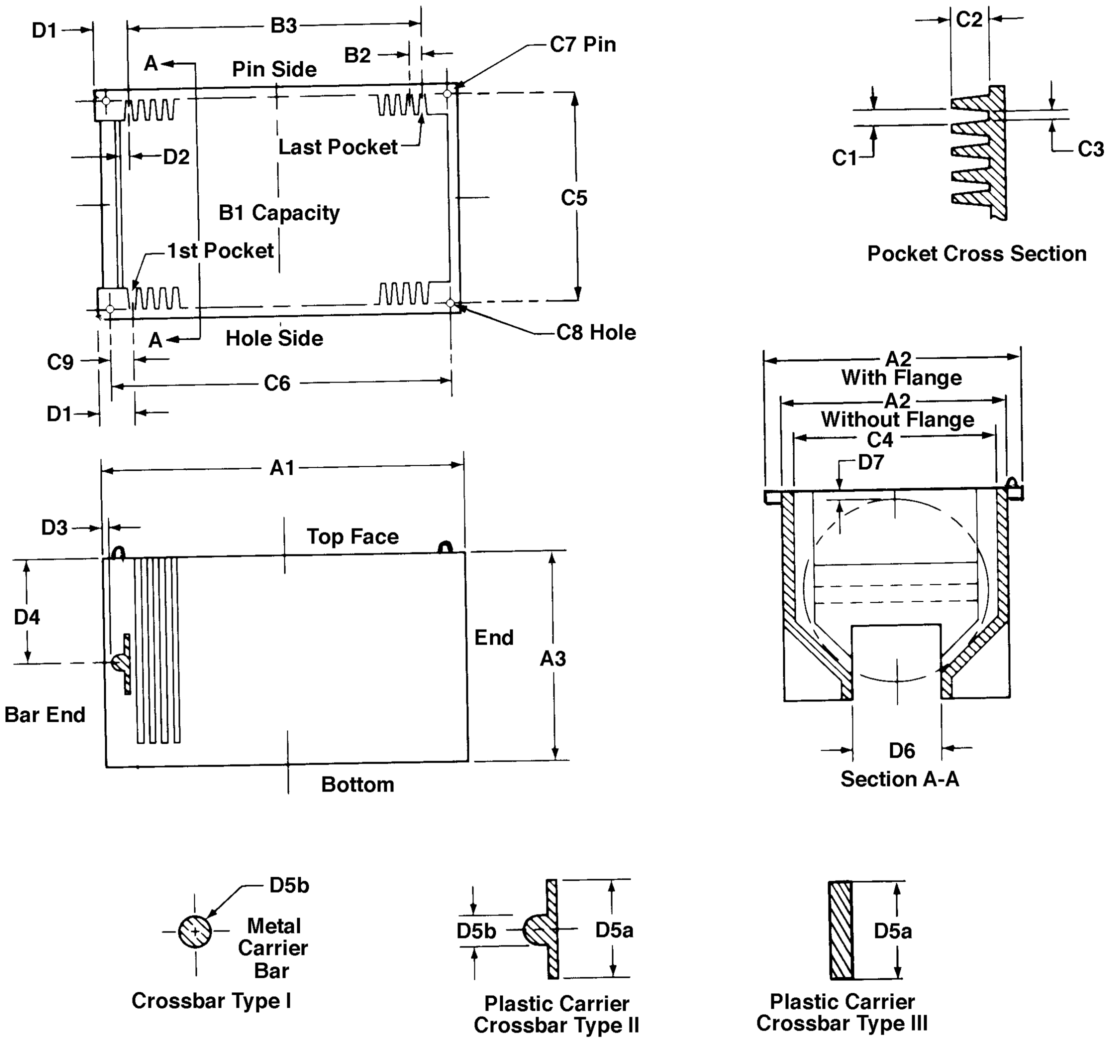


Figure 1
Wafer Carrier Outline — General Usage

NOTE: Used in conjunction with Table 1.

Table 2 Symbols Outline For Auto Transport Usage Specifications

Figure 1A Reference	*Description*
	Overall Dimensions
A1	Length
A2a	Width (with flange)
A2b	Body width (measured at the crossbar)
A3	Height (excluding pin)
	Capacity
B1	Pockets per carrier
B2	Pocket spacing (non-accumulative)
B3	Center distance from the 1st to last pocket
	Detail Dimensions
C1	Pocket width
C2	Pocket depth
C3	Pocket flat
C4	Pocket size
C5	Center of pin to center of hole

Figure 1A Reference	*Description*
C6	Center pin to pin and hole to hole
C7	Diameter of pin (2×) times height of pin
C8	Diameter of hole
C9	Center of pin/hole to center of first pocket
	Machine Fit Specifications
D1a	From the outside plane of the bar end to the center line of the 1st pocket opening
D1b	Slot parallelism-coincident tolerance for center line of slots
D2a	From the center line of the 1st pocket to the closest point on the crossbar or web
D2b	From the center of the 25th pocket to the closest point on the endwall
D3a	The step from the bar end of the carrier to the crossbar (the tolerance indicates allowable bow)
D3b	The step from the bar end of the carrier to the crossbar (the tolerance indicates the allowable deviation measured at a maximum distance of 1/2" from the crossbar/sidewall junction)
D4a	From the bottom of the carrier to the center of the crossbar, measured at the bar end of the carrier
D4b	From the bottom of the carrier to the center of a nominal 125 mm wafer, measured with wafer in place and carrier sitting on bottom
D5a	Bar web width which is the mass of material which may be present on the crossbar and is measured perpendicular to the top surface
D5b	Bar width measured perpendicular to the top surface
D5c	From the bar end of the carrier to the surface of the bar web (the tolerance indicates allowable bow)
D6a	Track clearance which is the unobstructed area between the two carrier sides on the bar end and the distance between the two sides at the bottom of the carrier for the entire length of the carrier
D6b	On the bar end surface, the distance between the two struts perpendicular to the crossbar
D6c	On the bar end surface, the thickness of each of the two struts perpendicular to the crossbar
D6d	On the bar end surface, the length of each of the two struts perpendicular to and extending above the crossbar
D6e	On the bar end surface, the length of each of the two struts perpendicular to and extending below the crossbar
D6f	Radius allowed on the crossbar
D6g	The overall width at the bottom of the carrier measured within 3/8 inch from the bottom
Wafer Tilt	The allowable deviation of the wafer from a parallel position in relation to the plane of the bar end of the carrier, when said wafer properly positioned and carrier is resting on the bar end. Wafer is said to be properly positioned when it is fully inserted in pocket and is centered.
Wafer Center	The allowable deviation of the center point of the wafer from the center line to the carrier (see Section A.A. Figure 5) when carrier is resting on bottom and wafer is fully inserted.
	Detailed Dimensions
	Handling Slots
D7 Dimensions	The handle slots are located on the bar end and the opposite endwall of the carrier. There are two slots on each end. These slots are intended to be used as points for engaging the carrier and picking it up. Currently, these slots are used in both manual and automated systems. Dimensions D7a through D7d detail this feature.
	Pickup Flanges
D8 Dimensions	The pickup flanges are located on the endwall of the carrier only. They are not present on the bar end. There are two flanges on the endwall. These flanges are intended to be used for engaging the carrier and picking it up. Currently, these flanges are used in both manual and automated systems. Dimensions D8a through D8e detail this feature.
	Center Alignment Features
D9 Dimensions	This feature is located on the bottom sidewalls of the carrier. The center alignment feature is used to find the location of the first pocket. It is intended to be used while the carrier is resting on its bottom. This feature is used in conjunction with wafer transfer machines and pick and place equipment. Dimensions D9a through D9k detail this feature.

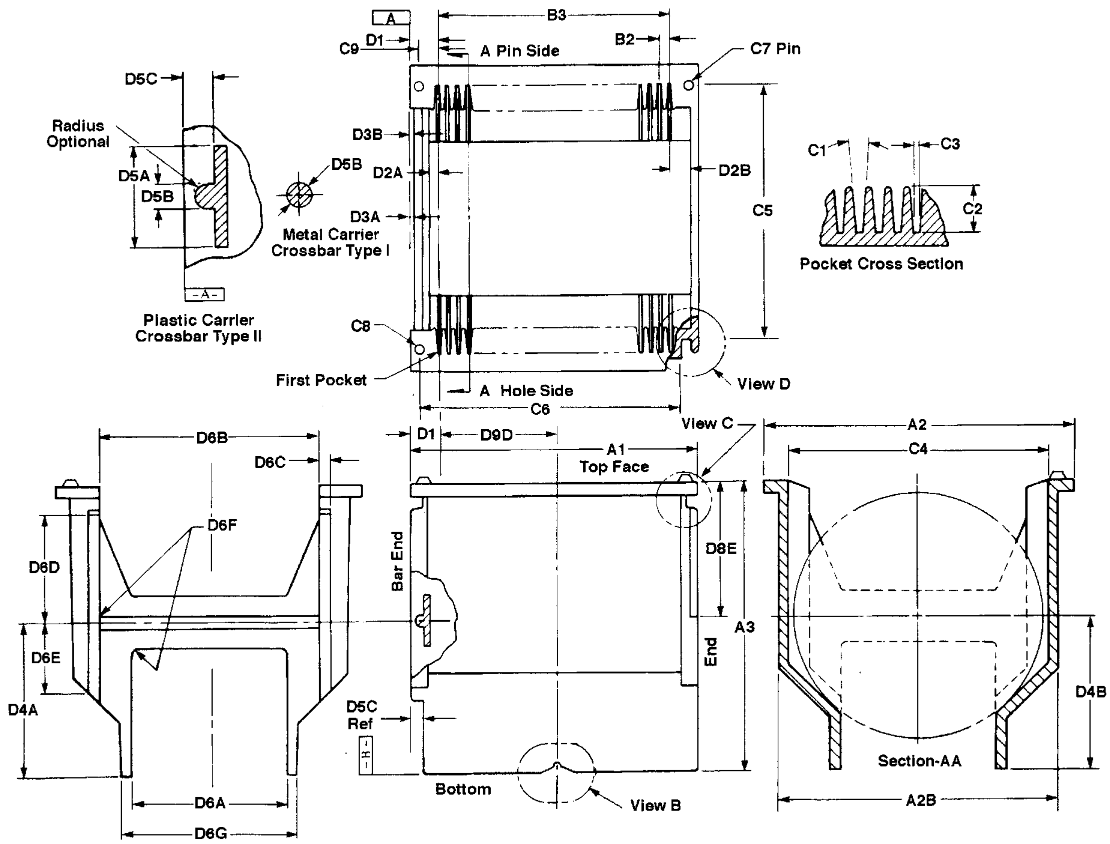
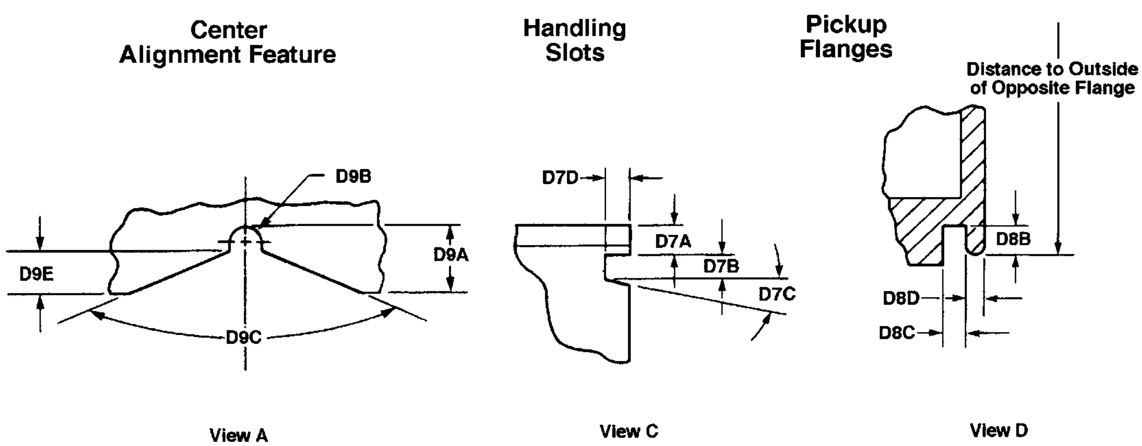


Figure 1A
Plastic & Metal Wafer Carrier Auto Transport



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SEMI E1.1-0697
STANDARD FOR 3 inch PLASTIC AND METAL WAFER CARRIERS, GENERAL USAGE

Figure 2 Reference		*Metal Carrier with Type I Crossbar*	*Plastic Carrier with Type II or III Crossbar*
	Overall Dimensions		
A1	144.02 mm (5.670 inch) max.	X	X
A2	93.73 mm (3.690 inch) max.	X	X
A3	95.25 mm (3.750 inch) max.	X	X
	Capacity		
B1	25	X	X
B2	4.76 mm ± 0.25 mm (0.1875 inch ± 0.010 inch)	X	X
B3	114.30 mm ± 0.25 mm (4.500 inch ± 0.010 inch)	X	X
	Detail Dimensions		
C1	(C3) + 0.50 mm (0.020 inch) min.	X	X
C2	9.53 mm (0.375 inch) max./7.87 mm (0.310 inch) min.	X	X
C3	2.03 mm (0.080 inch) max./1.40 mm (0.055 inch) min.	X	X
C4	79.76 mm (3.140 inch) max./77.22 mm (3.040 inch) min.	X	X
C5	81.89 mm ± 0.25 mm (3.224 inch ± 0.010 inch)	X	X
C6	134.52 mm ± 0.25 mm (5.296 inch ± 0.010 inch)	X	X
C7	2.54 mm + 0.00 mm/– 0.25 mm (0.100 inch + 0.000 inch/– 0.010 inch) by 3.43 mm ± 0.38 mm (0.135 inch ± 0.015 inch) (0.110 inch)	X	X
C8	2.79 mm + 0.51 mm/– 0.00 mm (0.110 inch + 0.020 inch/– 0.000 inch)	X	X
C9	10.11 mm ± 0.25 mm (0.398 inch ± 0.010 inch)	X	X
D1	14.55 mm ± 0.25 mm (0.573 inch ± 0.010 inch) or 13.97 mm ± 0.25 mm (0.550 inch ± 0.010 inch) Parallelism inclusive of all pockets ± 0.25 mm (0.10 inch).	X N/A	N/A X
D2	3.18 mm (0.125 inch)	X	X
D3	1.57 mm (0.062 inch) max.	X	X
D4	47.63 mm ± 0.25 mm (1.875 inch ± 0.010 inch)	N/A	X
	or 41.28 mm ± 0.25 mm (1.625 inch ± 0.010 inch)	N/A	X
D5	Crossbar specifications		
D5a	22.23 mm (0.875 inch) max.	N/A	X
D5b	6.35 mm + 0.00 mm/– 0.38 mm (0.250 inch + 0.000 inch/– 0.015 inch)	X	X
D6	38.10 mm (1.500 inch) min.	X	X
D7	1.57 mm (0.062 inch) min.	X	X
Wafer Tilt	0.45 mm (0.081 inch) max.	X	X

Usage Note: Because of the range of wafer carrier designs and wafer carrier feature tolerances allowed by this standard, and because of the range of wafer shapes and tolerances allowed by the wafer dimensional standards, not every possible SEMI Standards wafer carrier is compatible with every possible SEMI Standard wafer. Please verify the compatibility of your specific wafer and carrier with the respective vendors.

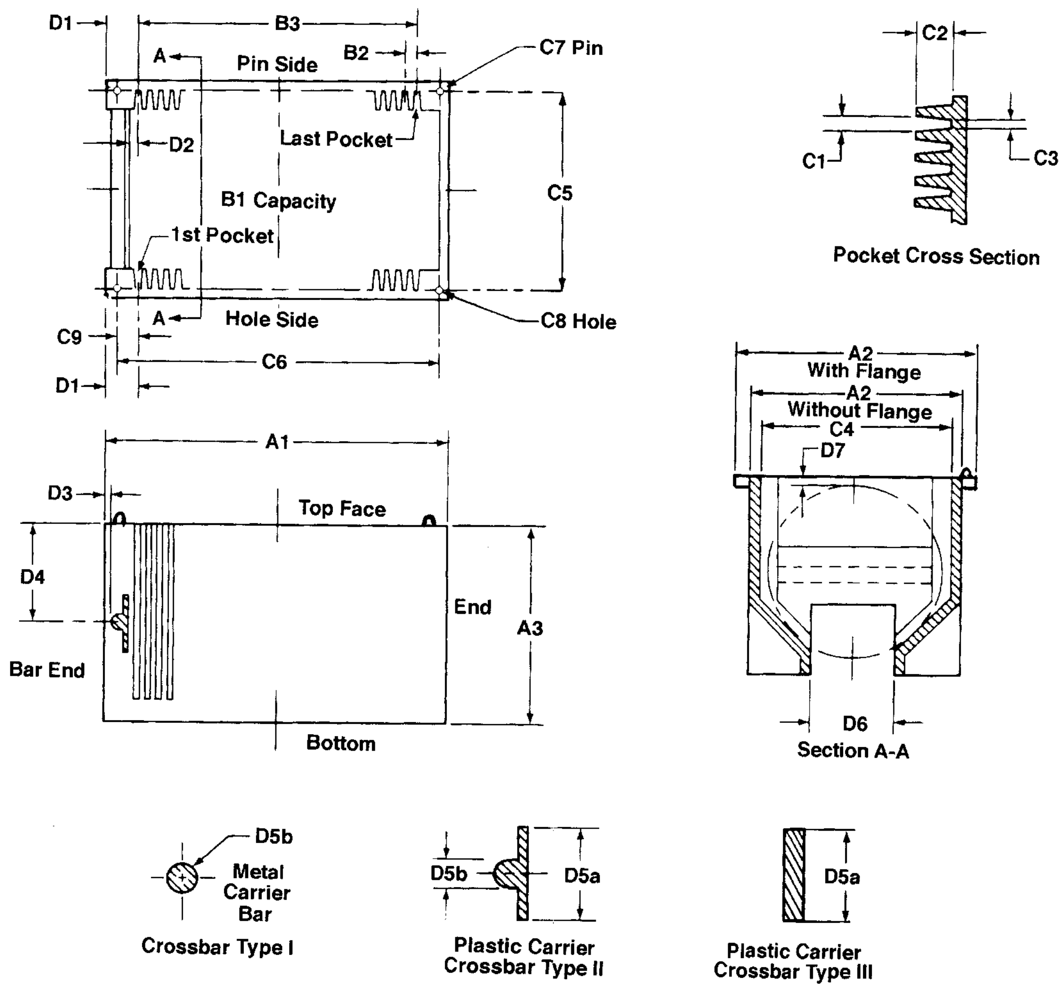

Figure 2
3 inch Plastic and Metal Wafer Carrier — General Usage

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SEMI E1.2-0697
STANDARD FOR 100 mm PLASTIC AND METAL WAFER CARRIERS, GENERAL USAGE

Figure 3 Reference		*Metal Carrier with Type I Crossbar*	*Plastic Carrier with Type II or III Crossbar*
	Overall Dimensions		
A1	144.02 mm (5.670 inch) max.	X	X
A2	125.48 mm (4.940 inch) max.	X	X
A3	114.30 mm (4.500 inch) max.	X	X
	Capacity		
B1	25	X	X
B2	4.76 mm ± 0.25 mm (0.1875" ± 0.010")	X	X
B3	114.30 mm ± 0.25 mm (4.500" ± 0.010")	X	X
	Detail Dimensions		
C1	(C3) + 0.51 mm (0.020 inch) min.	X	X
C2	11.18 mm (0.440) inch max./7.92 mm (0.312 inch) min.	X	X
C3	2.67 mm (0.105 inch) max./1.40 mm (0.055 inch) min. or 2.03 mm (0.080 inch) max./1.40 mm (0.055 inch) min.	X	N/A
		N/A	X
C4	104.65 mm (4.120 inch) max./102.62 mm (4.040 inch) min.	X	X
C5	107.29 mm ± 0.25 mm (4.224 inch ± 0.010 inch)	X	X
C6	134.52 mm ± 0.25 mm (5.296 inch ± 0.010 inch)	X	X
C7	2.54 mm + 0.00 mm/– 0.25 mm (0.100 inch + 0.000 inch/– 0.010 inch) by 3.43 mm ± 0.38 mm (0.135 inch ± 0.015 inch)	X	X
C8	3.05 mm + 0.25 mm/– 0.00 mm (0.120 inch + 0.010 inch/– 0.000 inch)	X	X
C9	10.11 mm ± 0.25 mm (0.398 inch ± 0.010 inch)	X	X
D1	14.55 mm ± 0.25 mm (0.573 inch ± 0.010 inch) or	X	X
	13.97 mm ± 0.25 mm (0.550 inch ± 0.010 inch) Parallelism ± 0.25 mm (0.010 inch) inclusive of all pockets.	N/A	X
D2	4.78 mm (0.188 inch)	X	X
D3	1.57 mm (0.062 inch) max.	X	X
D4	53.98 mm ± 0.25 mm (2.125 inch ± 0.10 inch)	X	X
D5	Crossbar specifications		
D5a	25.40 mm (1.000 inch) max.	N/A	X
D5b	6.35 mm + 0.00 mm/– 0.38 mm (0.250 inch + 0.000 inch/– 0.015 inch)	X	X
D6	60.33 mm (2.375 inch) min.	X	X
D7	1.57 mm (0.062 inch) min.	X	X
Wafer Tilt	0.51 mm (0.020 inch) max.	X	X

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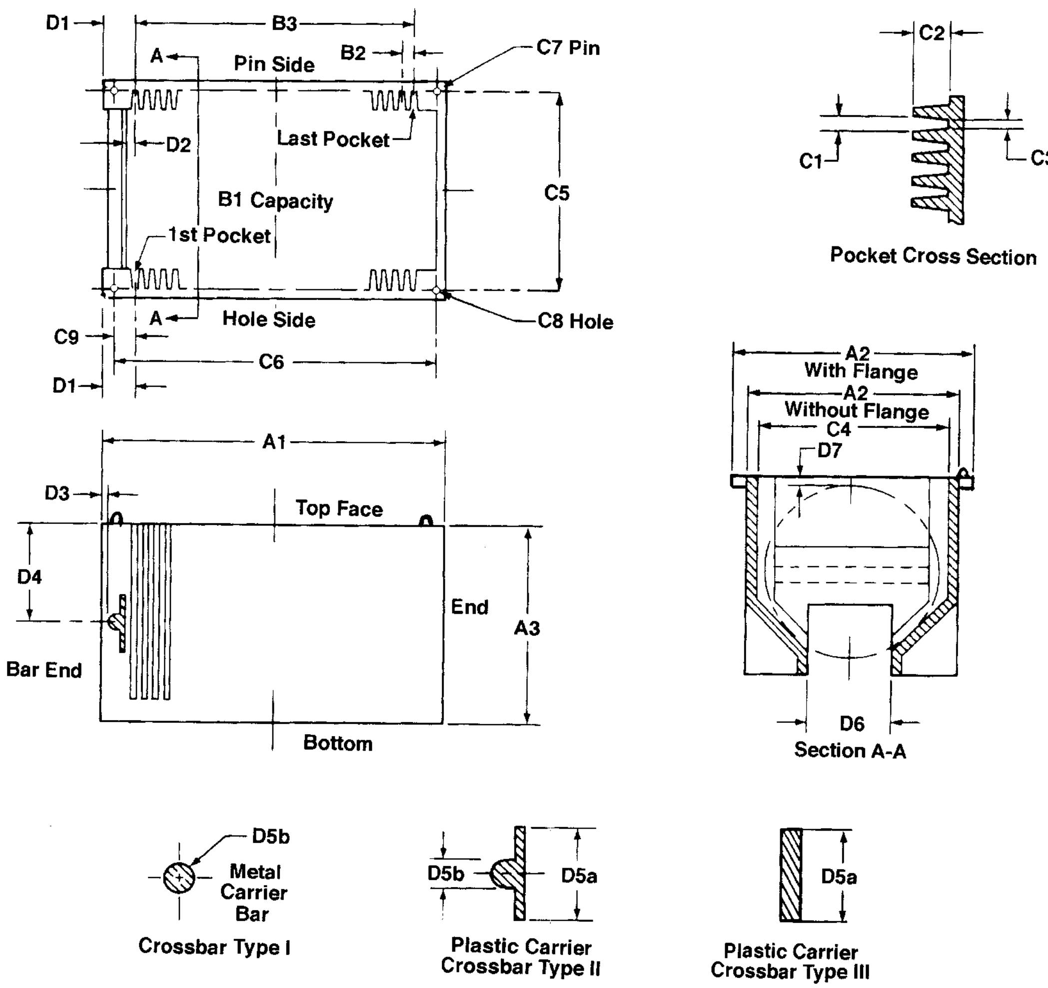

Figure 3
100 mm Plastic and Metal Wafer Carrier General Usage

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SEMI E1.3-0697
STANDARD FOR 125 mm PLASTIC AND METAL WAFER CARRIERS, GENERAL USAGE

Figure 4 Reference		*Metal Carrier with Type I Crossbar*	*Plastic Carrier with Type II Crossbar*
	Overall Dimensions		
A1	See section for 20 or 25 capacity carriers.	X	X
A2	152.40 mm (6.000 inch) max.	X	X
A3	146.05 mm (5.75 inch) max.	X	X
	Capacity		
B1	See section for 20 or 25 capacity carriers.	X	X
B2	See section for 20 or 25 capacity carriers.	X	X
B3	See section for 20 or 25 capacity carriers.	X	X
	Detail Dimensions		
C1	(C3) + 0.50 mm (0.020 inch) min.	X	X
C2	9.53 mm (0.375 inch) min./ 12.70 mm (0.500 inch) max.	X	X
C3	2.67 mm (0.105 inch) max./ 1.38 mm (0.055 inch) min. or 2.03 mm (0.080 inch) max./ 1.38 mm (0.055 inch) min.	X N/A	N/A X
C4	128.5 mm ± 1.0 mm (5.06 inch ± 0.040 inch)	X	X
C5	See section for 20 or 25 capacity carriers.	X	X
C6	See section for 20 or 25 capacity carriers.	X	X
C7	3.56 mm + 0.50 mm – 0.00 mm (0.140 inch + 0.000 inch – 0.015 inch) by 4.32 mm ± 0.50 mm (0.170 inch ± 0.020 inch) high	X	X
C8	3.96 mm + 0.50 mm – 0.00 mm (0.156 inch + 0.020 inch – 0.000 inch)	X	X
C9	10.11 mm ± 0.25 mm (0.398 inch ± 0.010 inch)	X	X
	Machine Fit Specifications		
D1	14.54 mm ± 0.25 mm (0.5725 inch ± 0.010 inch) or 13.97 mm ± 0.25 mm (0.550 inch ± 0.010 inch)	X N/A	X X
D2	4.76 mm (0.188 inch) min.	X	X
D3	1.57 mm (0.062 inch) max.	X	X
D4	68.25 mm ± 0.25 mm (2.687 inch ± 0.10 inch)	X	X
D5	Crossbar specifications	X	X
D5a	25.40 mm (1.000 inch) max.	NA	X
D5b	6.35 mm + 0.00 mm – 0.38 mm (0.250 inch + 0.00 inch – 0.15 inch)	X	X
D6	Track clearance specifications	X	X
D6a	66.68 mm (2.625 inch) min.	X	X
D6b	102.11 mm (4.020 inch) min.	X	X
D6c	45° min.	X	X
D7	1.57 mm (0.062 inch) min.	X	X
Wafer Tilt	0.64 mm (0.025 inch) max.	X	X
The following applies to 20-capacity carriers with 6.35 mm spacing:			
A1	150.37 mm (5.920 inch) max.		
B1	20 capacity		
B2	6.35 mm ± 0.25 mm (0.250 inch ± 0.010 inch)		
B3	120.65 mm ± 0.25 mm (4.750 inch ± 0.010 inch)		
C5	132.69 mm ± 0.38 mm (5.224 inch ± 0.015 inch)		
C6	140.87 mm ± 0.25 mm (5.546 inch ± 0.010 inch)		
The following applies to 25-capacity carriers with 4.76 mm spacing:			
A1	144.02 mm (5.670 inch) max.		
B1	25 capacity		
B2	4.76 mm ± 0.25 mm (0.1875 inch ± 0.010 inch)		
B3	114.30 mm ± 0.25 mm (4.500 inch ± 0.010 inch)		
C5	130.66 mm ± 0.38 mm (5.144 inch ± 0.015 inch)		
C6	134.52 mm ± 0.25 mm (5.296 inch ± 0.010 inch)		

Usage Note: Because of the range of wafer carrier designs and wafer carrier feature tolerances allowed by this standard, and because of the range of wafer shapes and tolerances allowed by the wafer dimensional standards, not every possible SEMI Standards wafer carrier is compatible with every possible SEMI Standard wafer. Please verify the compatibility of your specific wafer and carrier with the respective vendors.

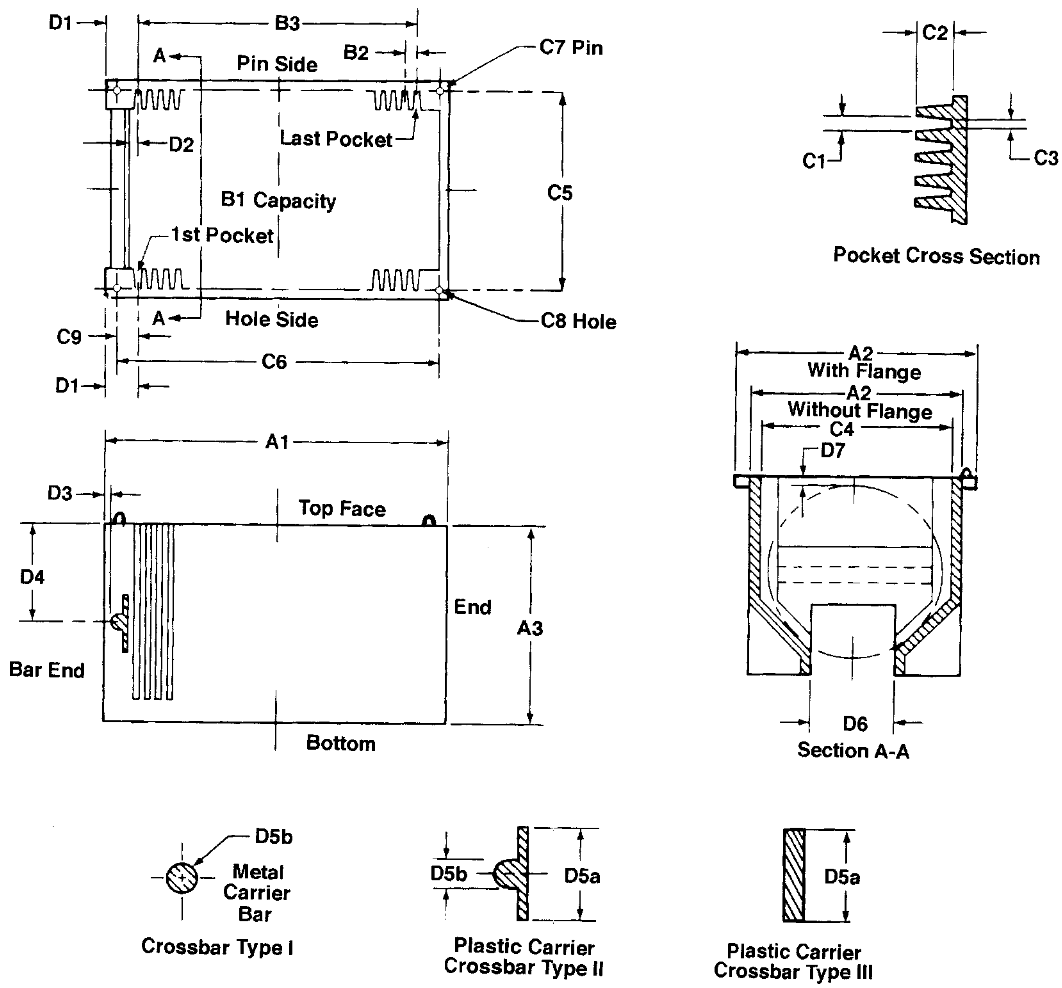

Figure 4
125 mm Plastic & Metal Wafer Carrier — General Usage

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SEMI E1.4-0697
STANDARD FOR 125 mm PLASTIC AND METAL WAFER CARRIERS, AUTO TRANSPORT USAGE

This standard is intended to meet the in use requirements necessary for the interface of wafer carriers with automated wafer processing equipment. Specifications for carriers intended for general use are outlined in SEMI E1.3. The complete specification for this product includes all general requirements of SEMI E1.

Figure 5 Reference	
	Overall Dimensions
A1	143.38 mm ± 0.25 mm (5.645 inch ± 0.010 inch)
A2a	152.4 mm ± 1.0 mm (6.00 inch ± 0.04 inch)
A2b	135.9 mm ± 1.0 mm (5.350 inch ± 0.04 inch)
A3	146.05 mm ± 0.76 mm (5.75 inch ± 0.03 inch)
	Capacity
B1	25 capacity
B2	4.76 mm ± 0.08 mm (0.1875 inch ± 0.003 inch)
B3	114.3 mm ± 0.25 mm (4.500 inch ± 0.010 inch)
	Detail Dimensions
C1	10° ± 2°
C2	11.18 mm ± 0.38 mm (0.440 inch ± 0.015 inch)
C3	1.52 mm ± 0.08 mm (0.060 inch ± 0.003 inch)
C4	128.52 mm ± 1.0 mm (5.060 inch ± 0.04 inch)
C5	130.66 mm ± 0.38 mm (5.144 inch ± 0.015 inch)
C6	134.52 mm ± 0.25 mm (5.296 inch ± 0.010 inch)
C7	3.56 mm – 0.38 mm (0.140 + 0.000 inch/– 0.015 inch) by 4.32 mm ± 0.5 mm (0.170 inch ± 0.020 inch) high
C8	3.96 mm + 0.5 mm/– 0.0 mm(0.156 inch + 0.020 inch/– 0.000 inch)
C9	10.11 mm ± 0.25 mm (0.398 inch ± 0.010 inch)
	Machine Fit Specifications
D1a	14.53 mm ± 0.13 mm (0.572 inch ± 0.005 inch)
D1b	± 0.13 mm (± 0.005 inch)
D2a	4.78 mm (0.188 inch) min.
D2b	6.35 mm (0.250 inch) min.
D3a	1.53 mm ± 0.77 mm (0.060 inch ± 0.030 inch)
D3b	1.53 mm ± 0.25 mm (0.060 inch ± 0.010 inch)
D4a	77.80 mm ± 0.51 mm (3.063 inch ± 0.020 inch)
D4b	77.80 mm ± 1.27 mm (3.063 inch ± 0.050 inch)

Figure 5 Reference	
D5a	25.40 mm ± 0.25 mm (1.000 inch ± 0.010 inch)
D5b	6.10 mm ± 0.13 mm (0.240 inch ± 0.005 inch)
D5c	5.33 mm ± 0.76 mm (0.210 inch ± 0.030 inch)
D6a	76.2 mm ± 1.0 mm (3.00 inch ± 0.04 inch)
D6b	107.44 mm ± 0.76 mm (4.230 inch ± 0.030 inch)
D6c	3.17 mm/6.35 mm (0.125 inch/0.250 inch) min./max.
D6d	31.75 mm (1.25 inch) min.
D6e	31.75 mm (1.25 inch) min.
D6f	3.2 mm radius (0.125 inch radius) max.
D6g	85.34 mm ± 1.0 mm (3.360 inch ± 0.04 inch)
Wafer Tilt	Within ± 0.38 mm (0.015 inch)
Wafer Center Horizontal	Within ± 0.38 mm (0.015 inch)
	Handling Slots
D7a	6.60 mm ± 0.25 mm (0.260 inch ± 0.010 inch)
D7b	5.59 mm ± 0.25 mm (0.220 inch ± 0.010 inch)
D7c	10° ± 2°
D7d	5.99 mm ± 0.25 mm (0.236 inch ± 0.010 inch)
	Pickup Flanges
D8a	133.35 mm ± 1.0 mm (5.25 inch ± 0.04 inch)
D8b	6.85 mm ± 0.25 mm (0.270 inch ± 0.010 inch)
D8c	5.1 mm (0.20 inch) min.
D8d	3.56 mm ± 0.25 mm (0.140 inch ± 0.010 inch)
D8e	68.33 mm ± 0.5 mm (2.69 inch ± 0.02 inch)
	Center Alignment Feature
D9a	5.08 mm ± 0.25 mm (0.200 inch ± 0.010 inch)
D9b	1.27 mm ± 0.05 mm (0.050 inch ± 0.002 inch)
D9c	135° included angle
D9d	57.15 mm ± 0.13 mm (2.250 inch ± 0.005 inch)

Usage Note: Because of the range of wafer carrier designs and wafer carrier feature tolerances allowed by this standard, and because of the range of wafer shapes and tolerances allowed by the wafer dimensional standards, not every possible SEMI Standards wafer carrier is compatible with every possible SEMI Standard wafer. Please verify the compatibility of your specific wafer and carrier with the respective vendors.

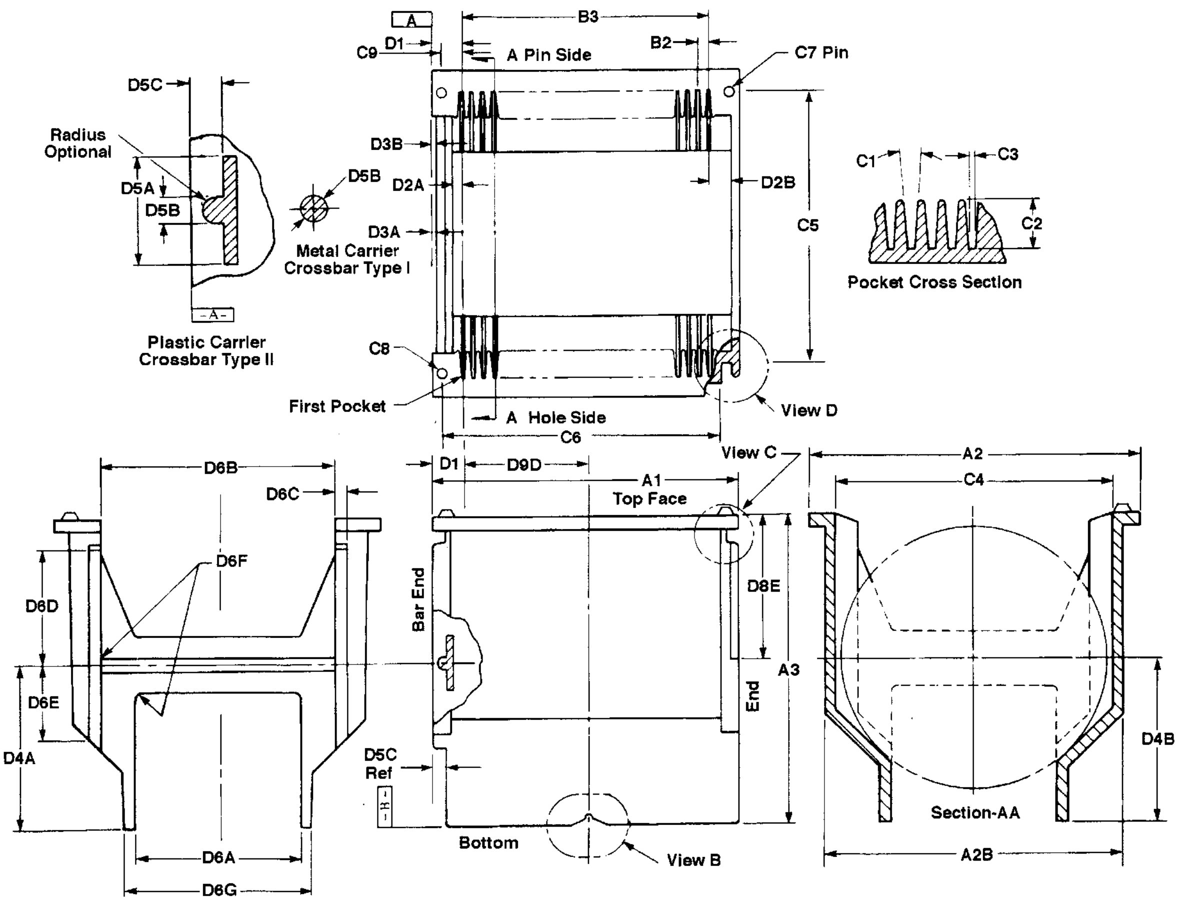
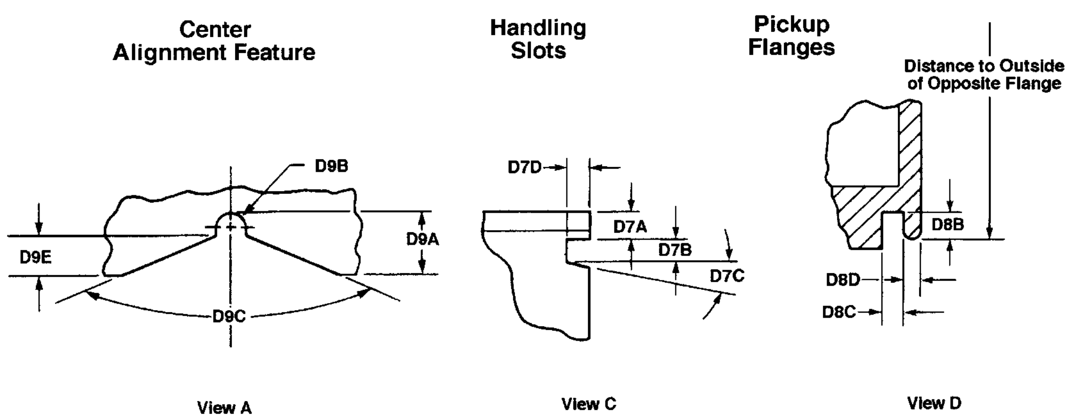


Figure 5
125 mm Plastic & Metal Wafer Carrier — Auto Transport Usage



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SEMI E1.5-91 (Reapproved 0299)
STANDARD FOR 150 mm PLASTIC AND METAL WAFER CARRIERS, GENERAL USAGE

Figure 6 Reference	
	Overall Dimensions
A1	143.4 mm + 0.64 mm/– 0.5 mm (5.645 inch + 0.025 inch/– 0.020 inch)
A2	177.80 mm (7.000 inch) maximum
A3	171.40 mm (6.750 inch) maximum
B1	25
B2	4.76 mm ± 0.25 mm (0.1875 inch ± 0.010 inch)
B3	114.30 mm ± 0.025 mm (4.500 inch ± 0.010 inch)
C1	(C3) + 0.50 mm (0.020 inch) minimum
C2	9.53 mm (0.375 inch) minimum / 12.70 mm (0.500 inch) maximum
C3	1.52 mm ± 0.13 mm (0.060 inch ± 0.005 inch) for plastic
	2.03 mm + 0.00 mm/– 0.50 mm (0.080 inch + 0.000 inch/– 0.020 inch) for metal
C4	153.5 mm ± 1.0 mm (6.043 inch ± 0.040 inch)
C5	156.0 mm ± 0.5 mm (6.142 inch ± 0.020 inch)
C6	134.52 mm ± 0.25 mm (5.296 inch ± 0.010 inch)
C7	3.56 mm + 0.13 mm/– 0.38 mm (0.140 inch + 0.005 inch/– 0.015 inch) diameter by 4.32 mm ± 0.50 mm (0.170 inch ± 0.020 inch) high
C8	3.96 mm + 0.50 mm/– 0.00 mm (0.156 inch + 0.020 inch/– 0.000 inch) diameter by 5.0 mm (0.197 inch) minimum depth

Figure 6 Reference	
C9	10.11 mm ± 0.25 mm (0.398 inch ± 0.010 inch)
D1	14.54 mm ± 0.25 mm (0.572 inch ± 0.010 inch)
D2	4.57 mm (0.18 inch) minimum
D3	1.57 mm ± 0.5 mm (0.062 inch ± 0.020 inch)
	Overall Dimensions
D4a	79.76 mm ± 0.50 mm (3.140 inch ± 0.020 inch) This specification is applicable only to full-depth wafer carriers, i.e., the wafer sits below the top of the carrier.
D4b	On center within ± 3.18 mm (± 0.125 inch) This specification describes the center point of the wafer in relationship to the centerline of the crossbar (for a 150 mm nominal wafer).
D5a	25.40 mm + 0.0 mm/– 0.5 mm (1.000 inch + 0.000 inch/– 0.020 inch)
D5b	6.35 mm + 0.00 mm/– 0.38 mm (0.250 inch + 0.000 inch/– 0.020 inch)
D5c	4.45 mm ± 0.75 mm (0.175 inch ± 0.030 inch)
D6	76.2 mm (3.000 inch) minimum 0.64 mm (0.025 inch) maximum

Usage Note: Because of the range of wafer carrier designs and wafer carrier feature tolerances allowed by this standard, and because of the range of wafer shapes and tolerances allowed by the wafer dimensional standards, not every possible SEMI Standards wafer carrier is compatible with every possible SEMI Standard wafer. Please verify the compatibility of your specific wafer and carrier with the respective vendors.

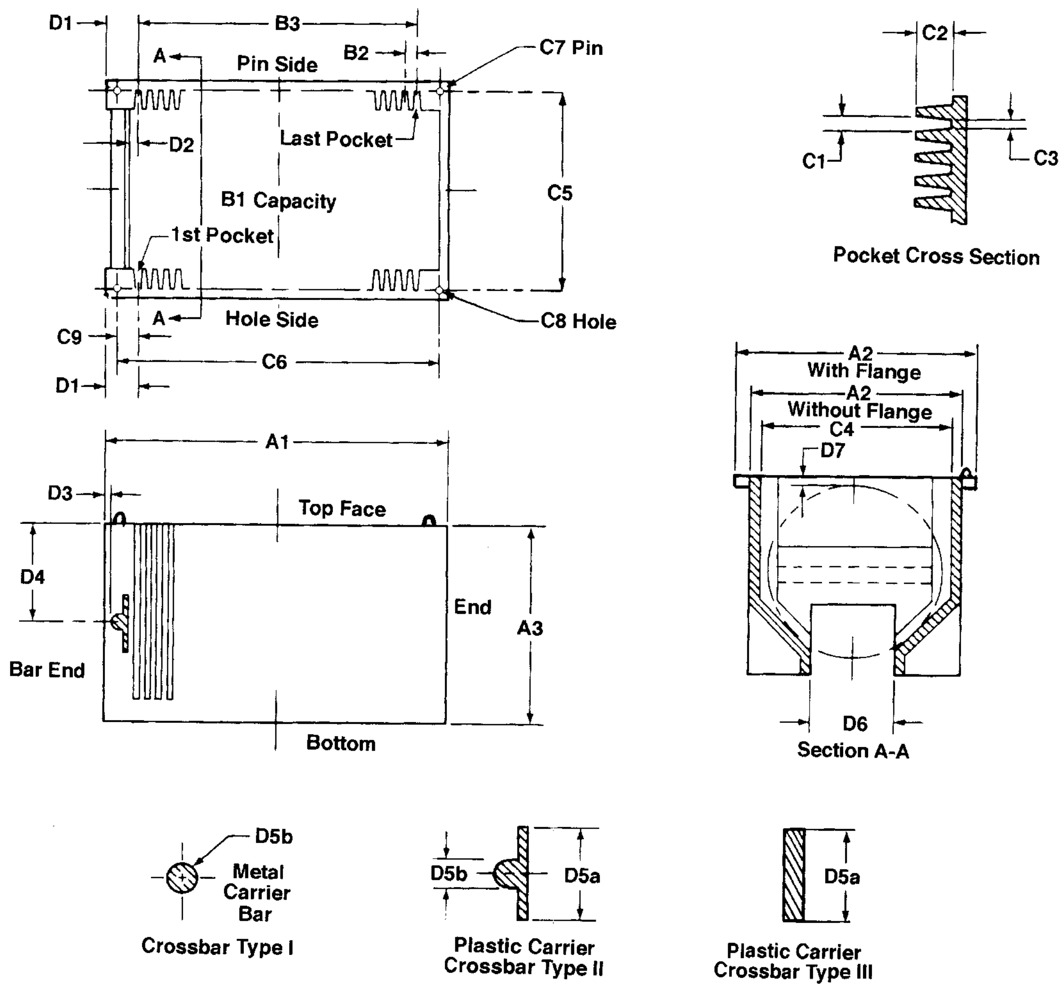

Figure 5
150 mm Plastic & Metal Wafer Carrier General Usage

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E1.9-0701
MECHANICAL SPECIFICATION FOR CASSETTES USED TO TRANSPORT AND STORE 300 mm WAFERS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 22 and April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1994; previously published June 1999.

1 Purpose

1.1 This standard specifies the cassettes used to transport and store 300 mm wafers in an IC manufacturing facility. This includes both manual and auto-transport use as well as high-speed extraction of the wafers in processing equipment.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions wit very few required surfaces. Only the mechanical interfaces for cassettes are specified; no materials requirements or micro-contamination limits are given. However, this standard has been written so that both metal and injection-molded plastic cassettes can be manufactured in conformance with it.

2.2 The cassette has the following components and sub-components, and other features. A "†" symbol indicates components or features that include dimensions required for boxes with non-removable cassettes.

Key:

- • Required feature
- ◊ Optional feature

- • 1 top domain
- • 2 optical wafer sensing paths
  - ◊ 4 robotic handling flanges (optional)
  - ◊ 1 top cassette identification tag area (optional)
- • 2 or 4 side domains (2 in front and 2 in rear, if needed)
- • supports (for 13 or 25 wafers) with correct wafer pitch (10 mm) †
- • 1 optical cassette sensing hole on each front side domain
  - ◊ 1 side cassette identification tag area on front right side domain only (optional)
  - ◊ features that prevent wafer creep-out (optional)
  - ◊ 2 pentagonal side grip pits on each front side domain (optional)
- • 1 bottom domain
- • 2 optical wafer sensing paths
- • 5 carrier sensing pads †
- • 4 info pads †
- • 1 pod latch-pin hole
- • 2 conveyor rails
- • 2 fork-lift pick-up areas
- • 2 fork-lift pin holes
- • 3 features that mate with kinematic coupling pins and provide a 10 mm lead in †
  - ◊ 3 features that mate with kinematic coupling pins and provide a 15 mm lead in (optional)
  - ◊ 1 bottom cassette identification tag area (optional)
- • Other features
- • multiple horizontal wafer sensing paths
- • 2 end-effector exclusion zones †

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.2 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.3 *carrier capacity* — the number of substrates that a carrier holds.

4.4 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

4.5 *cassette bottom domain* — volume (below *z*6 above the horizontal datum plane) that contains the bottom of the cassette.

4.6 *cassette sensing pads* — surfaces on the bottom of the cassette for triggering optical or mechanical sensors.

4.7 *cassette side domains* — volumes (from *z*6 above the horizontal datum plane to *z*15 above the top nominal wafer seating plane) that contain the mizo teeth or slots that support the wafer and the supporting columns on the sides and rear of the cassette.

4.8 *cassette top domain* — volume (higher than *z*15 above the top wafer) that contains the top of the cassette.

4.9 *conveyor rails* — parallel edges on the bottom of the cassette for supporting the cassette on roller conveyors.

4.10 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.11 *fork-lift slots* — rectangular holes (open to the front and rear) in the bottom of the cassette for picking up the cassette with a fork.

4.12 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62) (as defined in SEMI E47.1).

4.13 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.14 *nominal wafer center line* — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling) (as defined in SEMI E57).

4.15 *nominal wafer seating plane* — horizontal plane that bisects the wafer pick-up volume.

4.16 *optical wafer sensing paths* — lines of sight for optically sensing the positions of the wafers. Several horizontal optical wafer sensing paths are present in between the cassette side domains. In addition, two vertical optical wafer sensing paths are created by rectangular exclusion zones in the front of the cassette top and bottom.

4.17 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.18 *process batch* — a set of substrates that are processed simultaneously in a process chamber.

4.19 *robotic handling flanges* — four horizontal projections on top of the cassette for lifting and rotating the cassette.

4.20 *sensor hole* — an indentation on the bottom of the cassette for inserting optical sensors.

4.21 *side grip pits* — two rectangular indentations on each side of the cassette for lifting and rotating the cassette.

4.22 *transport group* — a set of substrates that are transported together between tools.

4.23 *virtual tracking unit* — an entity (which could be a number of substrates or an individual die or mask group) that the factory floor control system treats as a single unit for tracking purposes.

4.24 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

4.25 *wafer extraction volume* — the open space for extracting a wafer from the cassette.

4.26 *wafer pick-up volume* — the space that contains entire bottom of a wafer if the wafer has been pushed to the rear of the cassette.

4.27 *wafer set-down volume* — the open space for inserting and setting down a wafer in the cassette.

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify 300 mm cassettes over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser needs to specify a time period and the number and type of uses to which the cassettes will be put. It is under these conditions that the cassettes must remain in compliance with the requirements listed in Section 6.

5.2 *Temperature Ranges* — The purchaser of 300 mm cassettes needs to specify two sets of temperatures to which the cassettes might be exposed. An operating temperature range is the set of environmental temperatures in which the cassettes will remain in compliance with the requirements listed in Section 6. A temporary temperature range is the set of environmental temperatures to which the cassettes can be exposed such that when the cassettes return to the operating temperature range, the cassettes will be in compliance with the requirements listed in Section 6. Limits on exposure times to elevated temperatures should be specified. Also, the purchaser needs to specify a range of temperatures for the wafers that might be inserted in the cassettes.

5.3 *Info Pad Configurations* — The purchaser of 300 mm carriers needs to specify the desired info pad configuration (up or down). See Appendix 1 (Application Notes).

6 Requirements

6.1 *Kinematic Couplings* — The physical alignment interface on the bottom of the cassette consists of features (not specified in this standard) that mate with six pins underneath as defined in SEMI E57. Most of the dimensions of the cassette are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. All of the dimensions for the cassette are bilaterally symmetric about the bilateral datum plane. The three features that mate with the pins must provide a lead-in capability that corrects a cassette misalignment no greater than *r*19 in any horizontal direction. However, it is recommended that robots placing cassettes on kinematic couplings use as little of this lead-in capability as possible to avoid wear.

6.2 *Wafer Orientation and Numbering* — The wafers must be horizontal when the carrier is placed on the coupling, and the wafers are numbered in increasing order from bottom to top (so the bottom wafer is wafer number 1, the next wafer up is wafer number 2, etc.). After processing at a tool, each wafer should be returned to the same slot from which it was taken.

6.3 *Cassette Sides* — Figure 1 shows a cross-section of the horizontal boundaries of the cassette side domains (which contain the parts of the cassette higher than *z*6 above the horizontal datum plane and lower than *z*15 above the top wafer). In this and following figures, the most heavy lines are used for surfaces that have tolerances (not surfaces that have only maximum or minimum dimensions). Table 1 defines the dimensions shown in this and following figures. The maximum protrusions of any part of the cassette from the nominal wafer center line and from the bilateral datum plane is *r*5 and *x*9, respectively. There are two optional side grip pits on each side. For optically sensing whether a cassette is properly in place, from left to right under the bottom wafer is an optical cassette sensing hole. The radius of this hole is given with both upper and lower tolerances, but the upper tolerance is only to define a minimum aperture that must be met at only one section on each side. Other than through the optical cassette sensing holes, the cassette bottom and side domains must block any line of sight passing through both of the two rectangles at *x*10 on each side bounded by *z*4, *z*20, *y*2, and *y*3.

6.4 *Cassette Top* — Figure 2 shows a top view of the horizontal boundaries of the cassette top domain which contains any part of the cassette higher than *z*15 above the top nominal wafer plane. The top robotic handling flanges (optional), the side grip pits (optional), and optical cassette sensing hole on the side can be seen in Figure 3, which is an oblique view of the maximum cassette dimensions (see Figure 14 to see how cassettes need not take up all of that volume). The maximum radial protrusions of the cassette top in the front and rear are *r*6 and *r*12, respectively. Dimensions *x*6, *x*12 (shown in Figure 4), and *y*15 define a vertical path for optically sensing wafers through the top and bottom domains.

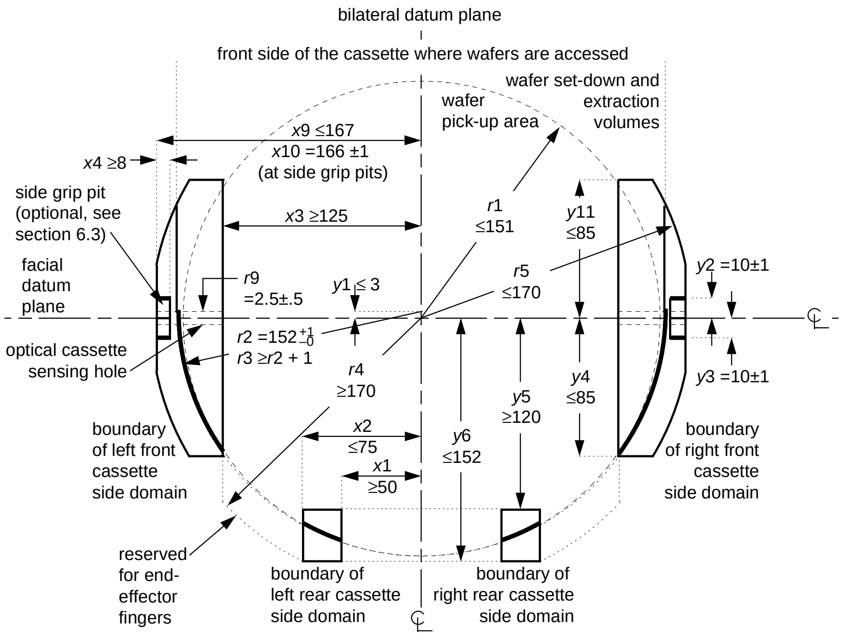

Figure 1
Cassette Side Domains

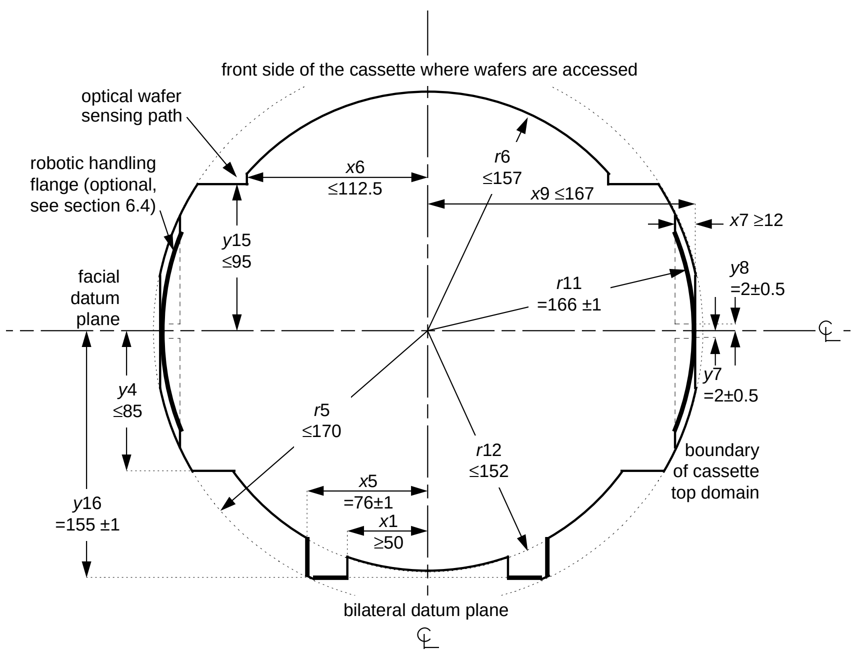

Figure 2
Cassette Top Domain

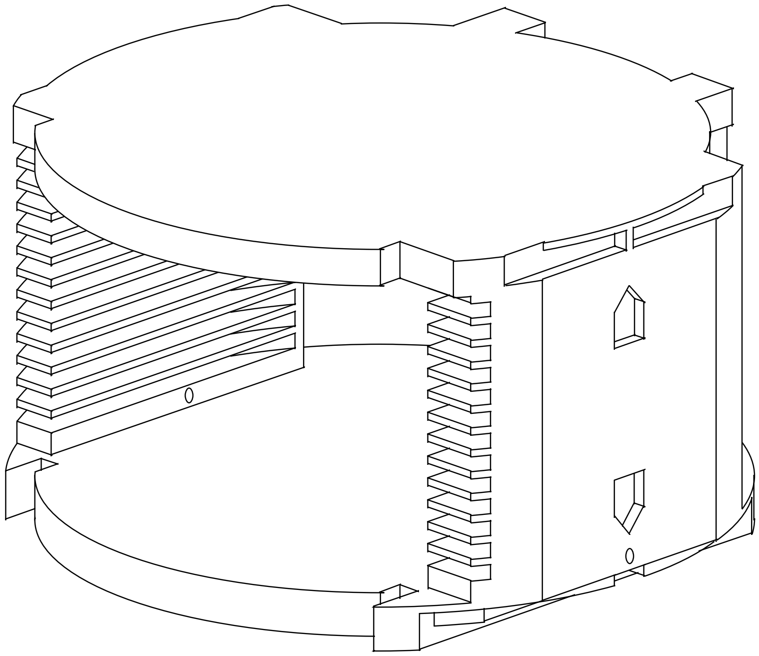

Figure 3
Oblique View of Maximum Cassette Dimensions

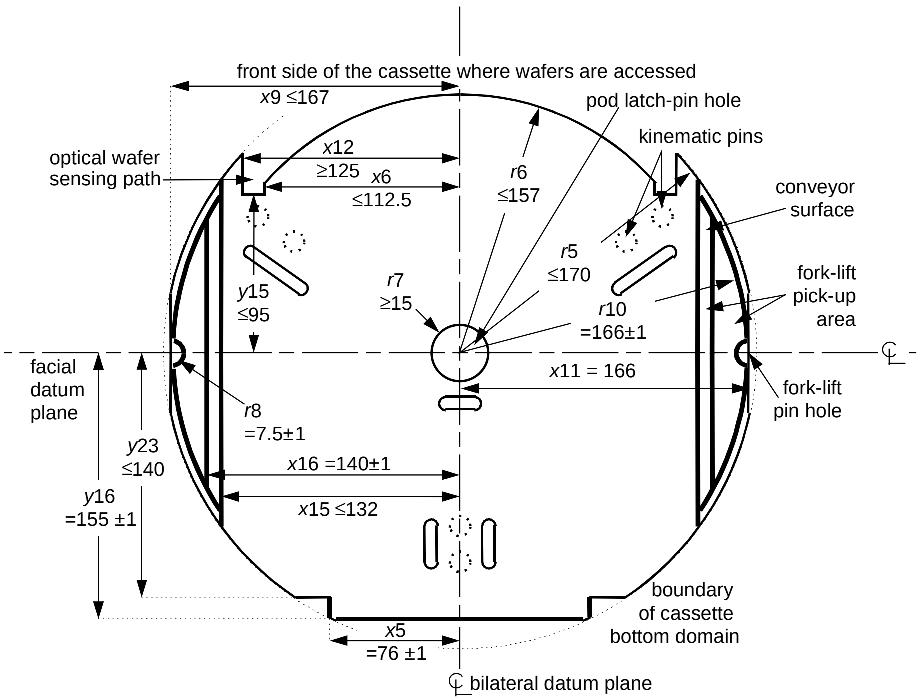

Figure 4
Cassette Bottom Domain

6.5 *Cassette Bottom* — Figure 4 shows a bottom view of the horizontal boundaries of the cassette bottom domain (which contains any part of the cassette lower than *z*6 above the horizontal datum plane). At the nominal wafer center line, a circular hole with a radius of *r*7 must be present (up to a height of *z*5) in the cassette bottom to avoid interfering with pod latch pins. For moving the cassette on roller conveyors and for picking up the cassette with a fork lift, the cassette must have surfaces on the left and right open to the bottom and outside bounded by *x*15, *x*16, *r*10, *z*3 and *z*4. A cylindrical section of radius *r*8 and axis at *x*11 on the facial datum plane must be clear up to a height of *z*22 to hold the cassette firmly on the lifting forks by the use of a cylindrical pin.

6.6 *Carrier Sensing Pads and Info Pads* — When the cassette is fully down, the carrier sensing pads (shown in Figure 5) must be *z*2 above the horizontal datum plane. It is recommended that the areas surrounding all of the carrier sensing pads be designed in conjunction with the features that mate with kinematic coupling pins so that a mechanical sensor pin cannot interfere with the lead-in function of the kinematic couplings. Other sensing pads (called info pads and given letter names) communicate information about the carrier. Carrier types that might need differentiation include the open cassette, the front-opening unified pod (FOUP), the single-wafer interface (SWIF), and the front-opening shipping box (FOSB) in both 13-wafer and 25-wafer capacities (and possibly other capacities if reduced-pitch versions are later standardized). Note that since this is a bottom view, the positions of sensors on a load port will be switched, with the sensor for info pad A on the right and the sensor for info pad B on the left as one faces the tool from the front.

6.7 *Vertical Dimensions* — Figures 6 through 13 show the vertical dimensions of the cassette. Note that *z*8 (the height of the bottom nominal wafer seating plane above the horizontal datum plane) and *z*12 (the distance between adjacent nominal wafer seating planes) are given as absolute distances with no tolerance. This means that the sum of actual height variations in the cassette from the kinematic coupling to the supporting features holding each wafer must be contained within the tolerance of *z*10 with no further stack-up at each higher wafer. The method for meeting this requirement is left up to the cassette supplier.

6.7.1 The open space for the wafer set-down volume consists of a cylindrical section with radius *r*2 and a main axis parallel to and *y*1 in front of the nominal wafer center line. The top of this cylindrical section is *z*11 above the nominal wafer seating plane and its bottom is *z*10 above the nominal wafer seating plane. The implications for wafer positioning of the tolerance on *r*2 are as follows. The wafers should be placed in the cassette within a circle of radius corresponding to the smaller bound on *r*2 to avoid touching the edge of the wafer to the side of the cassette. Once the wafer has been placed, the cassette must not allow a wafer to move outside of a circle of radius corresponding to the larger bound on *r*2. There are two exceptions to this limit on wafer movement. When the wafer is pushed toward the rear of the cassette, the location of the wafer is defined by the wafer pick-up volume (see Section 6.7.3). When the cassette is gently tilted forward up to 45°, the wafers may slide forward, but it is recommended that they not extend further than *y*20 from the facial datum plane. This may be accomplished by designing the teeth supporting the wafers to include a "wafer stopper" at the front (as shown in Figure 11) that is outside of *r*2 and under *z*29. Note that use of this feature will reduce the height of the wafer extraction volume.

6.7.2 The open space for the wafer extraction volume includes a cylindrical section with radius *r*3 and a main axis parallel to and *y*1 in front of the nominal wafer center line. The top of this cylindrical section is *z*11 above the nominal wafer seating plane and its bottom is *z*23 above the nominal wafer seating plane. The wafer extraction volume also includes the extrusion out the front of the cassette of this cylindrical section and the portion of the wafer set-down volume above *z*29. The implications for wafer extraction of the definition of dimension *r*3 ($r3 \geq r2 + 1$) are as follows. The cassette must give an extra 1 mm (0.04 in.) of horizontal clearance once the wafer is picked up from wherever it ends up (within the bounds of *r*2) after transport in the cassette.

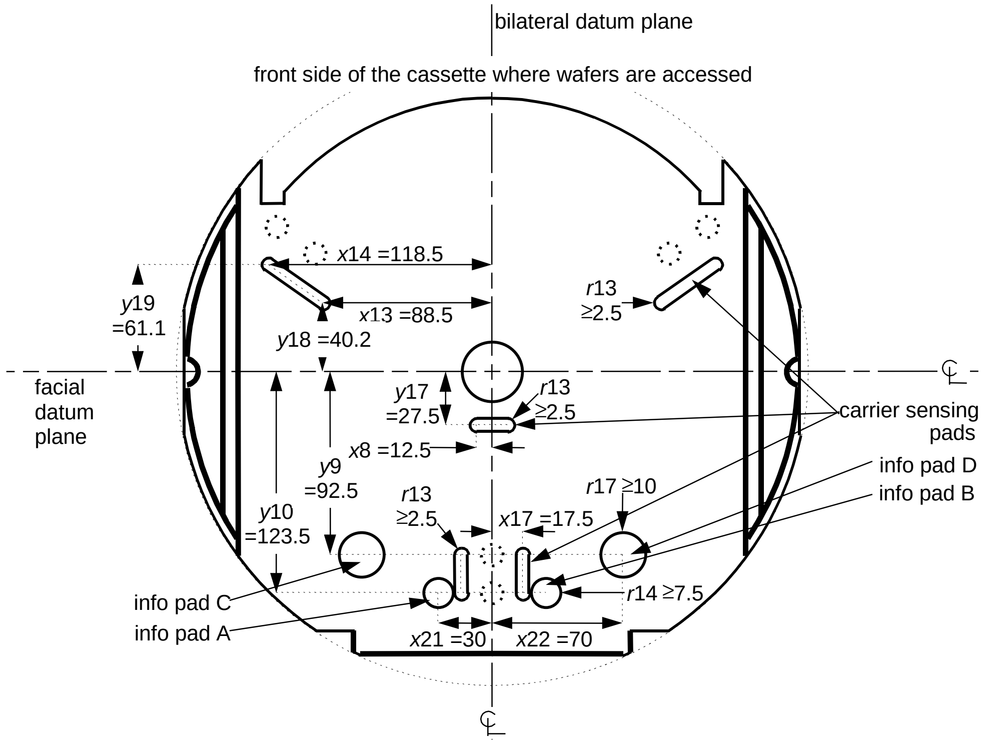

Figure 5
Carrier Sensing Pads in Bottom View

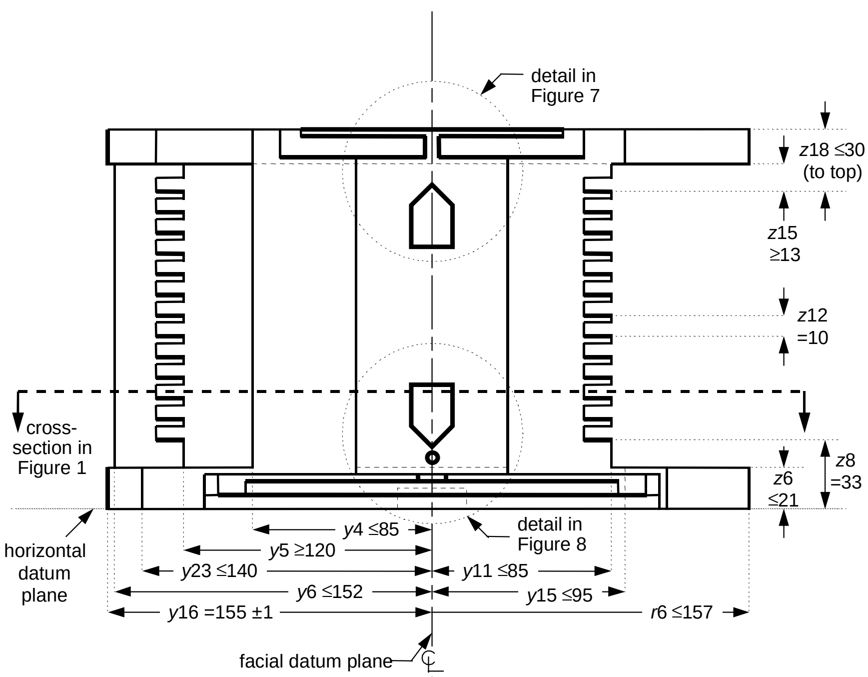

Figure 6
Side View of Cassette

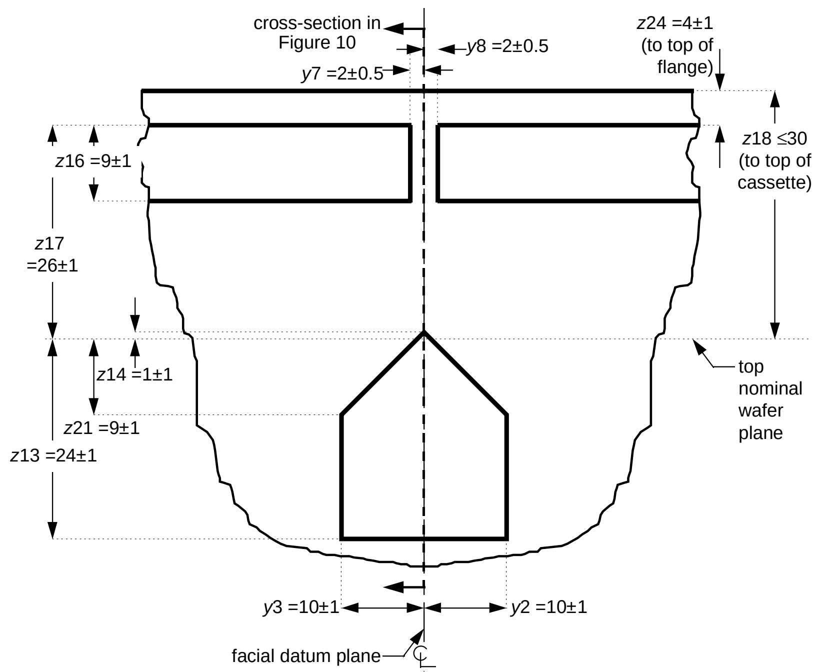

Figure 7
Top Side View Detail

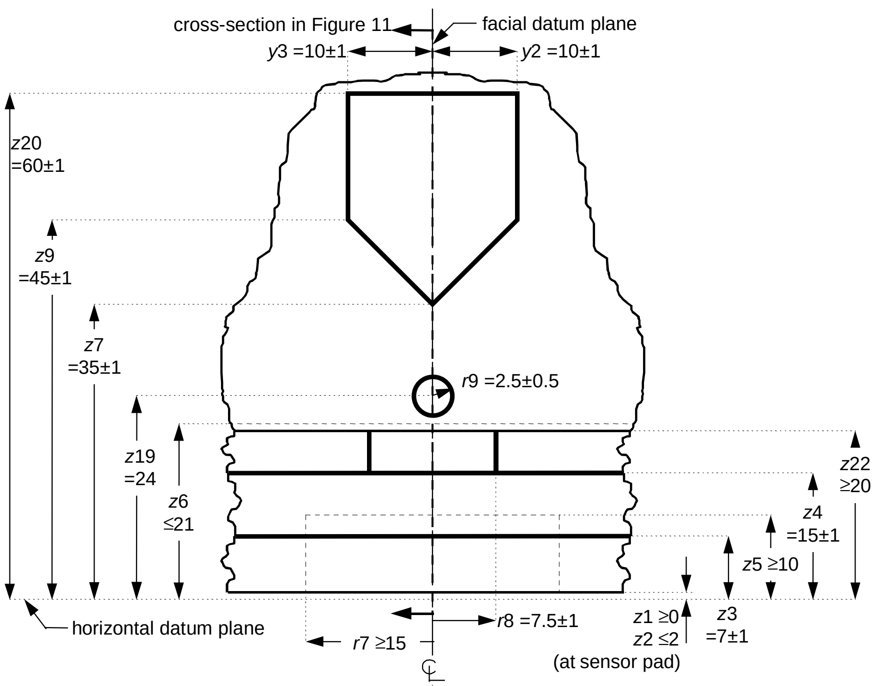

Figure 8
Bottom Side View Detail

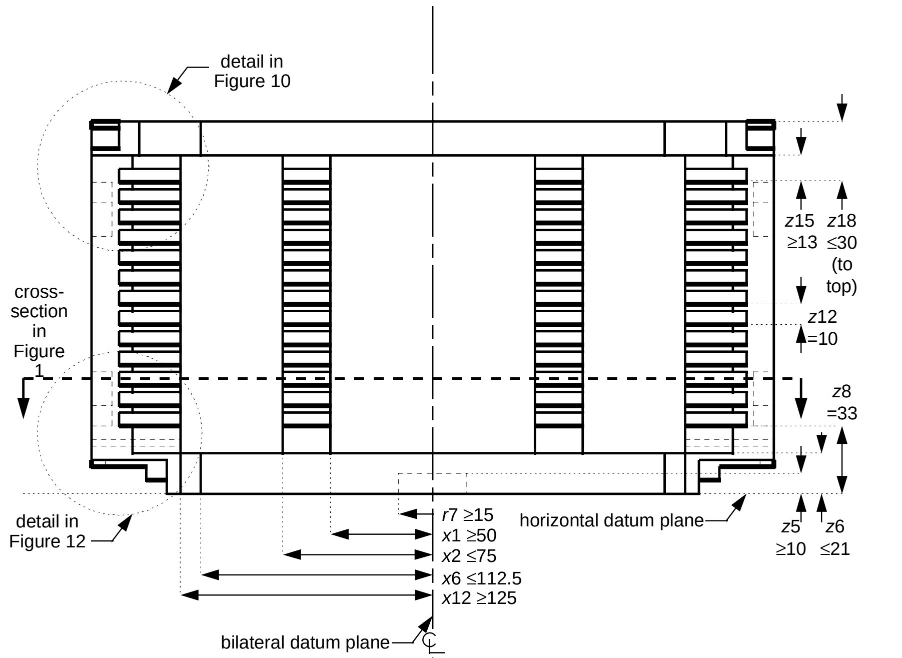

Figure 9
Front View of Cassette

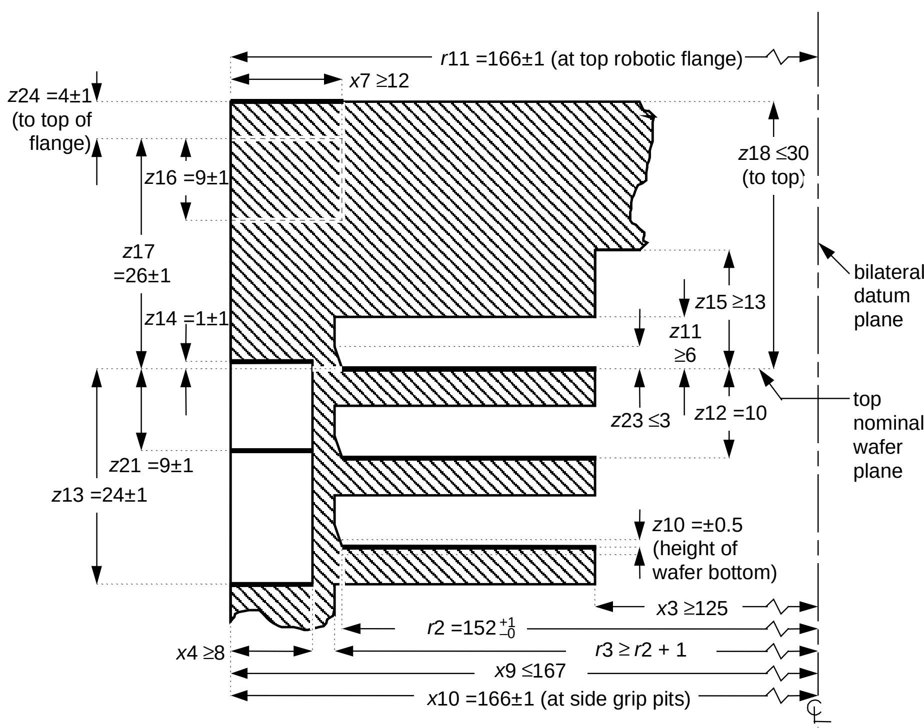

Figure 10
Upper Cross-Section at Facial Datum Plane

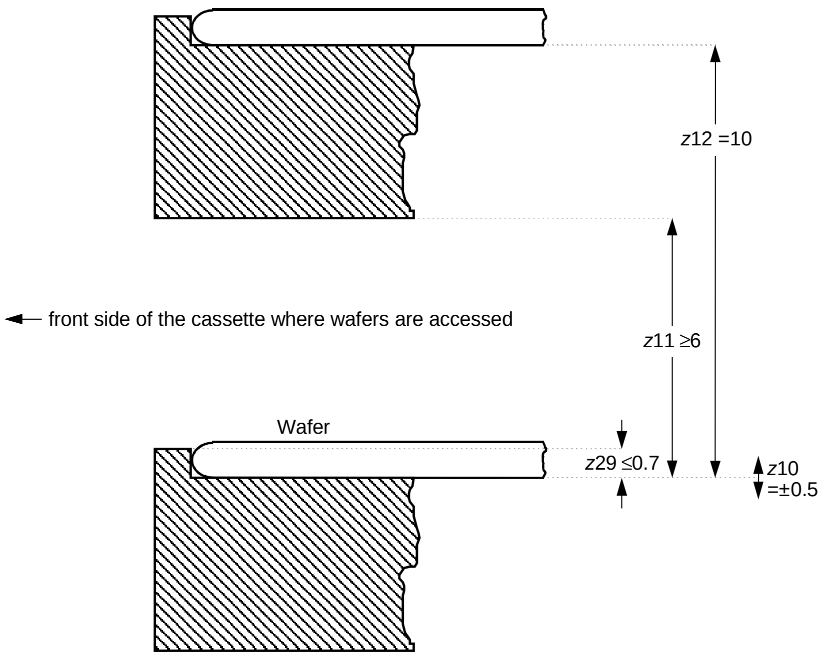

Figure 11
Optional Feature to Prevent Wafer Creep-Out

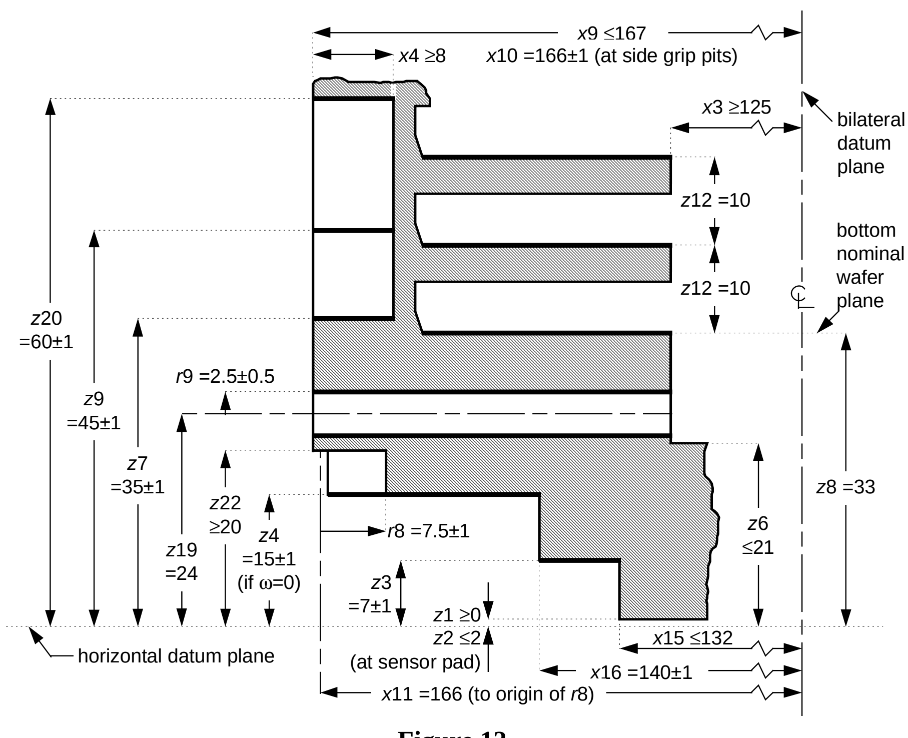

Figure 12
Lower Cross-Section at Facial Datum Plane

6.7.3 If a wafer is placed in the wafer set-down volume and is then pushed toward the rear of the cassette, then the entire bottom of the wafer must be contained in the wafer pick-up volume. However, if the wafer is not pushed toward the rear of the cassette (or the cassette is not tilted back during transport), then the wafer may only be somewhere within the wafer extraction volume. The wafer pick-up volume is defined by a cylindrical section with radius *r*1 and a main axis at the nominal wafer center line. Its top and bottom are the upper and lower tolerance of *z*10 around the nominal wafer seating plane.

6.7.4 To prevent wafers from creeping out of the cassette during transport, the fork-lift area may be slanted so that the front of the cassette is higher than the rear. Specifically, the surface defined by *z*4 may be rotated by an angle ω about the line where *z*4 intersects *y*29 (as shown in Figure 13). Only the surface behind y29 may be rotated. Thus, the height of *z*4 shown in Figure 12 might only be defined at *y*29, and *z*4 can be greater than 15 ± 1 behind *y*29. However, the flatness of the resulting tilted surface must still fall within the tolerance given for *z*4.

6.8 *Cassette Identification Tag Area* — The following areas are provided for putting identification tags on the cassette. Examples of such tags include thin electronic modules and printed labels designed to be read by either humans or machines. It is recommended that such tags be contained within the 18 mm by 60 mm (0.71 in. by 2.36 in.) region defined when the bounds are tight. It is also recommended that if such tags are smaller than the minimum bounds of the tag area, they should be centered within those bounds.

6.8.1 An optional place for an identification tag on the top of the cassette is shown in Figure 14. Although the height of this surface is not specified, the surface must be completely visible from above. The parallelism of the top identification tag with respect to the horizontal datum plane is given by *z*25. It is recommended that the identification tag should be centered on the bilateral datum plane at a point *y*21 behind the facial datum plane.

6.8.2 An optional place for an identification tag on the right-hand side of the cassette is shown in Figure 15 (where "right-hand" is defined as the right side of the cassette when it is oriented correctly and it is viewed from the rear). Although the left-right location of this surface is not specified, the surface must be completely visible from the right of the cassette. The parallelism of the side identification tag with respect to the bilateral datum plane is given by *x*27. It is recommended that the identification tag should be centered on the facial datum plane at a point *z*99 above the horizontal datum plane.

6.8.3 An optional place for an identification tag on the bottom of the cassette is shown in Figure 16. Although the height of this surface is not specified, the surface must be completely visible from below. The parallelism of the bottom identification tag with respect to the horizontal datum plane is given by *z*25. It is recommended that the identification tag should be centered on the bilateral datum plane at a point *y*22 behind the facial datum plane.

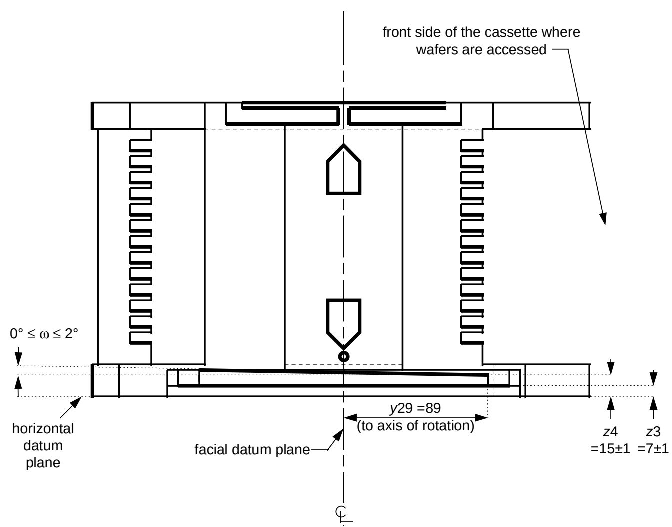

Figure 13
Slanting of Fork-Lift Area

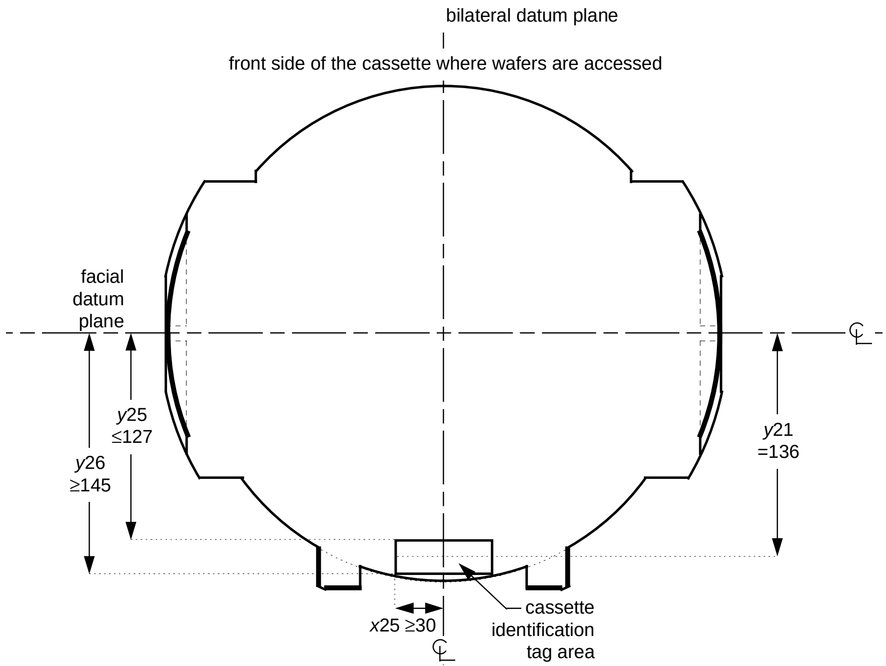

Figure 14
Optional Top Cassette Identification Tag Area

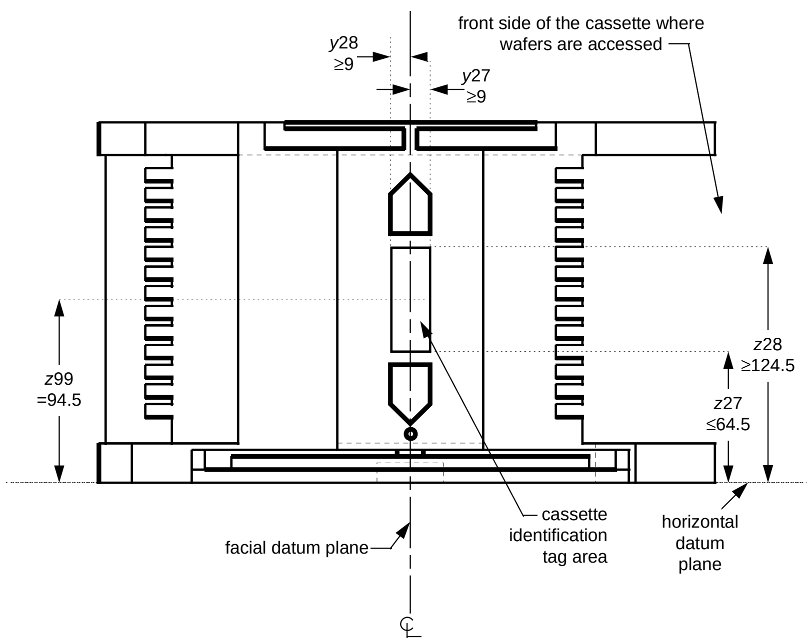

Figure 15
Optional Side Cassette Identification Tag Area

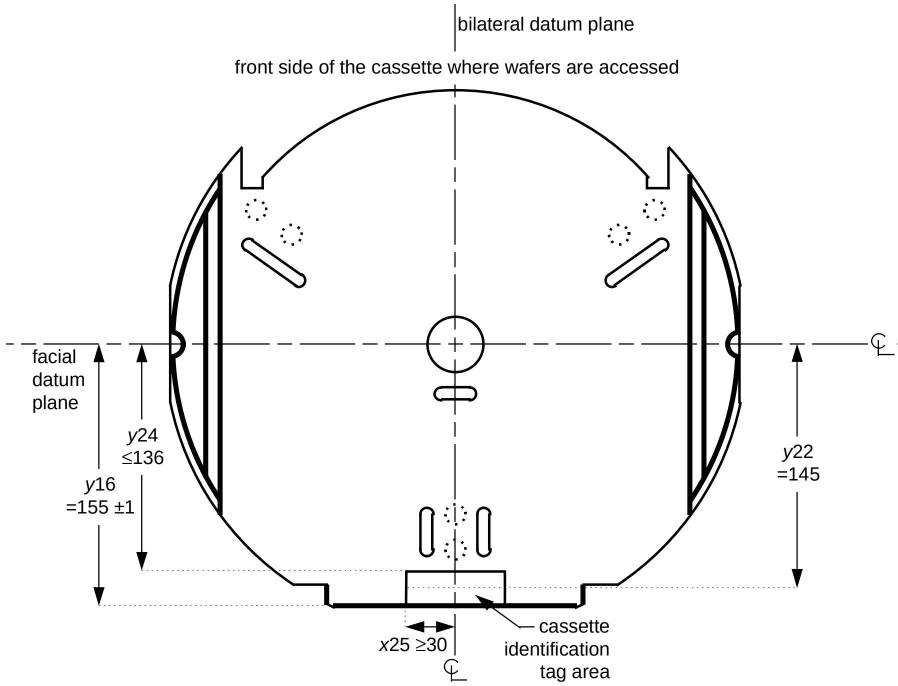

Figure 16
Optional Bottom Cassette Identification Tag Area

6.9 *Pitch and Capacity* — Table 2 shows the different options with regard to the wafer pitch (spacing) and the cassette capacity. Again, no tolerance is given on the wafer pitch (*z*12), for reasons given in Section 6.7.

6.10 *Inner and Outer Radii* — All concave features may have a radius no greater than *r*15 to allow cleaning and to prevent contaminant build-up. All required convex features must also have a radius of *r*16 to prevent small contact patches with large stresses that might cause wear and particles. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the rim of the fork-lift pin hole, the edges of the robotic handling flanges, and the corners at the rear of the cassette top and bottom domains).

6.11 *Vertical Wafer Access* — This standard does not cover accessing wafers in a vertical orientation.

7 Related Documents

7.1 *SEMI Standards*

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E22.1 — Cluster Tool Module Interface 300 mm: Transport Module End Effector Exclusion Volume Standard

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Provisional Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E103 — Provisional Mechanical Specification for a 300 mm Single-Wafer Box System that Emulates a FOUP

SEMI M28 — Specification for Developmental 300 mm Diameter Polished Single Crystal Silicon Wafers

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

Table 1 Cassette Dimensions

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
ω	13	0° minimum 2° maximum	horizontal datum plane	fork-lift area
*r*1†	1	151 mm (5.94 in.) maximum	nominal wafer center line	outer edge of wafer pick-up volume
*r*2†	1, 10	152 + 1 – 0 mm (5.99 + 0.03 – 0 in.)	*y*1 in front of nominal wafer center line	encroachment of cassette side domains on wafer set-down volume
*r*3†	1, 10	*r*2 + 1 mm (0.04 in.) minimum	*y*1 in front of nominal wafer center line	encroachment of cassette side domains on wafer extraction volume
*r*4†	1	170 mm (6.69 in.) minimum	nominal wafer center line	encroachment of tools or front-opening box on end effector exclusion zone between front and rear cassette side domains
*r*5	1, 2, 4	170 mm (6.69 in.) maximum	nominal wafer center line	outside of cassette domains
*r*6	2, 4, 6	157 mm (6.18 in.) maximum	nominal wafer center line	front of cassette top and bottom domains
*r*7	4, 8, 9	15 mm (0.59 in.) minimum	nominal wafer center line	encroachment of cassette bottom domain on pod latch-pin hole
*r*8	4, 8, 12	7.5 ± 1 mm (0.30 ± 0.04 in.)	vertical line contained in facial datum plane and *x*11 from bilateral datum plane	sides of fork-lift pin hole
*r*9	1, 8, 12	2.5 ± 0.5 mm (0.10 ± 0.02 in.)	horizontal line contained in facial datum plane and *z*19 above horizontal datum plane	surface of optical cassette sensing hole
*r*10	4	166 ± 1 mm (6.54 ± 0.04 in.)	nominal wafer center line	cassette bottom outside of *x*15 and below *z*22
*r*11‡	2, 10	166 ± 1 mm (6.54 ± 0.04 in.)	nominal wafer center line	outside of top robotic flange
*r*12	2	152 mm (5.98 in.) maximum	nominal wafer center line	rear of the cassette top domain above the area between the cassette side domains
*r*13*	5	2.5 mm (0.10 in.) minimum	line segment along center of cassette sensing pad	edge of cassette sensing pad
*r*14*	5	7.5 mm (0.30 in.) minimum	intersection of *x*21 and *y*10	edge of info pads A and B
*r*15	None	1 mm (0.04 in.) maximum	not applicable	all concave features (radius)
*r*16	None	2 ± 1 mm (0.08 ± 0.04 in.)	not applicable	all required convex features (radius)
*r*17*	5	10 mm (0.39 in.) minimum	intersection of *x*22 and *y*9	edge of info pads C and D
*r*19	None	10 mm (0.4 in.) minimum (required) 15 mm (0.6 in.) (recommended for ergonomic reasons)	not applicable	correctable cassette misalignment in any horizontal direction
*x*1†	1, 2, 9	50 mm (1.97 in.) minimum	bilateral datum plane	inside of rear cassette side domains and the part of the cassette top domain above them
*x*2†	1, 9	75 mm (2.95 in.) maximum	bilateral datum plane	outside of rear cassette side domains

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
*x*3†	1, 10, 12	125 mm (4.92 in.) minimum	bilateral datum plane	inside of front cassette side domains
*x*4‡	1, 10, 12	8 mm (0.31 in.) minimum	farthest protrusion of cassette from bilateral datum plane	encroachment of cassette side domain on side grip pits
*x*5	2, 4	76 ± 1 mm (2.99 ± 0.04 in.)	bilateral datum plane	outside of cassette top and bottom domains above and below rear cassette side domains
*x*6	2, 4, 9	112.5 mm (4.43 in.) maximum	bilateral datum plane	encroachment of cassette top and bottom domains on near side of vertical optical wafer sensing paths
*x*7‡	2, 10	12 mm (0.47 in.) minimum	farthest protrusion of cassette from bilateral datum plane	encroachment of cassette top domain on space underneath robotic handling flanges
*x*8*	5	12.5 mm (0.49 in.)	bilateral datum plane	end of line segment along center of center cassette sensing pad
*x*9	1, 2, 4, 10, 12	167 mm (6.57 in.) maximum	bilateral datum plane	left and right side of cassette
*x*10‡	1, 10, 12	166 ± 1 mm (6.54 ± 0.04 in.)	bilateral datum plane	rim of opening of side grip pits
*x*11	4, 12	166 mm (6.54 in.)	bilateral datum plane	origin of radius of fork-lift pin hole
*x*12	4, 9	125 mm (4.92 in.) minimum	bilateral datum plane	encroachment of cassette bottom domain on far side of vertical optical wafer sensing paths
*x*13*	5	88.5 mm (3.48 in.)	bilateral datum plane	near end of line segment along center of front cassette sensing pads
*x*14*	5	118.5 mm (4.67 in.)	bilateral datum plane	far end of line segment along center of front cassette sensing pads
*x*15	4, 12	132 mm (5.2 in.) maximum	bilateral datum plane	intersection of cassette bottom domain and conveyor rail
*x*16	4, 12	140 ± 1 mm (5.51 ± 0.04 in.) (required) 140 ± 0.25 mm (5.512 ± 0.010 in.) (recommended for roller conveyors)	bilateral datum plane	end of conveyor rail and encroachment of cassette bottom domain on fork-lift area
*x*17*	5	17.5 mm (0.69 in.)	bilateral datum plane	line segment along center of rear cassette sensing pads
*x*21*	5	30 mm (1.18 in.)	bilateral datum plane	origin of radius *r*14 at center of info pads A and B
*x*22*	5	70 mm (2.76 in.)	bilateral datum plane	origin of radius *r*17 at center of info pads C and D
*x*25‡	14, 16	30 mm (1.18 in.) minimum	bilateral datum plane	far end of top and bottom cassette identification tag areas
*x*27	None	± 1 mm (± 0.04 in.) flatness over tag area	bilateral datum plane	surface of side cassette identification tag area
*y*1†	1	3 mm (0.12 in.) maximum	facial datum plane	origin of *r*2 and *r*3 on bilateral datum plane
*y*2‡	1, 7, 8	10 ± 1 mm (0.39 ± 0.04 in.)	facial datum plane	front wall of side grip pits
*y*3‡	1, 7, 8	10 ± 1 mm (0.39 ± 0.04 in.)	facial datum plane	rear wall of side grip pits

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
*y*4	1, 2, 6	85 mm (3.35 in.) maximum	facial datum plane	rear of front cassette side domains and the part of the cassette top domain above them
*y*5†	1, 6	120 mm (4.72 in.) minimum	facial datum plane	front of rear cassette side domains
*y*6	1, 6	152 mm (5.98 in.) maximum	facial datum plane	rear of rear cassette side domains
*y*7‡	2, 7	2 ± 0.5 mm (0.08 ± 0.02 in.)	facial datum plane	rear side of top robotic handling flange supports
*y*8‡	2, 7	2 ± 0.5 mm (0.08 ± 0.02 in.)	facial datum plane	front side of top robotic handling flange supports
*y*9*	5	92.5 mm (3.64 in.)	facial datum plane	front end of the line segment along center of rear carrier sensing pads and origin of radius *r*17 at center of info pads C and D
*y*10*	5	123.5 mm (4.86 in.)	facial datum plane	rear end of the line segment along center of rear carrier sensing pads and origin of radius *r*14 at center of info pads A and B
*y*11†	1, 6	85 mm (3.35 in.) maximum	facial datum plane	front of front cassette side domains
*y*14‡	None	142 mm (5.59 in.) maximum	facial datum plane	front of the cassette top
*y*15	2, 4, 6	95 mm (3.74 in.) maximum	facial datum plane	encroachment of cassette top and bottom domains on vertical optical wafer sensing paths
*y*16	2, 4, 6, 16	155 ± 1 mm (6.10 ± 0.04 in.)	facial datum plane	rear end of cassette top and bottom domains
*y*17*	5	27.5 mm (1.08 in.)	facial datum plane	line segment along center of center cassette sensing pad
*y*18	5	40.2 mm (1.58 in.)	facial datum plane	near end of line segment along center of front cassette sensing pads
*y*19*	5	61.1 mm (2.41 in.)	facial datum plane	far end of line segment along center of front cassette sensing pads
*y*20‡	None	158 mm (6.22 in.)	facial datum plane	maximum protrusion of wafers toward the front of the cassette
*y*21	14	136 mm (5.35 in.)	facial datum plane	recommended center of label on top cassette identification tag area
*y*22	16	145 mm (5.71 in.)	facial datum plane	recommended center of label on bottom cassette identification tag area
*y*23	4, 6	140 mm (5.51 in.) maximum	facial datum plane	rear of cassette bottom domain outside of *x*5
*y*24‡	16	136 mm (5.35 in.) maximum	facial datum plane	near side of bottom cassette identification tag area
*y*25‡	14	127 mm (5.00 in.) maximum	facial datum plane	near side of top cassette identification tag area
*y*26‡	14	145 mm (5.71 in.) minimum	facial datum plane	far side of top cassette identification tag area
*y*27‡	15	9 mm (0.35 in.) minimum	facial datum plane	front side of side cassette identification tag area
*y*28‡	15	9 mm (0.35 in.) minimum	facial datum plane	rear side of side cassette identification tag area
*y*29	13	89 mm (3.50 in.)	facial datum plane	axis of rotation of fork-lift area
*z*1	8, 12	0 mm (0 in.) minimum	horizontal datum plane	bottom of cassette bottom domain

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
*z*2*	5, 8, 12	2 mm (0.08 in.) maximum	horizontal datum plane	bottom of carrier sensing pads and info pads (when down) and advancing box sensing pads (on FOUP only, see *SEMI E47.1*)
*z*3	8, 12	7 ± 1 mm (0.28 ± 0.04 in.)	horizontal datum plane	bottom of conveyor rail between *x*15 and *x*16
*z*4	8, 12	15 ± 1 mm (0.59 ± 0.04 in.)	horizontal datum plane	cassette bottom outside of *x*16
*z*5	8, 9	10 mm (0.39 in.) minimum)	horizontal datum plane	top of pod latch-pin hole
*z*6†	6, 8, 9, 12	21 mm (0.83 in.) maximum	horizontal datum plane	top of cassette bottom domain
*z*7‡	8, 12	35 ± 1 mm (1.38 ± 0.04 in.)	horizontal datum plane	bottom point of bottom side grip pits
*z*8†	6, 9, 12	33 mm (1.30 in.)	horizontal datum plane	bottom nominal wafer seating plane
*z*9‡	8, 12	45 ± 1 mm (1.77 ± 0.04 in.)	horizontal datum plane	bottom of vertical sides of bottom side grip pits
*z*10†	10, 11	0 ± 0.5 mm (0.00 ± 0.02 in.)	each nominal wafer seating plane	entire bottom of the wafer
*z*11†	10, 11	see Table 2	each nominal wafer seating plane	encroachment of cassette side domains on clearance above the wafer
*z*12†	6, 9, 10, 11, 12	see Table 2	each nominal wafer seating plane	adjacent nominal wafer seating planes
*z*13‡	7, 10	24 ± 1 mm (0.94 ± 0.04 in.)	top nominal wafer seating plane	bottom wall of top side grip pits
*z*14‡	7, 10	1 ± 1 mm (0.04 ± 0.04 in.)	top nominal wafer seating plane	top point of top side grip pits
*z*15†	6, 9, 10	13 mm (0.51 in.) minimum	top nominal wafer seating plane	bottom of cassette top domain
*z*16‡	7, 10	9 ± 1 mm (0.35 ± 0.04 in.)	lowest point of underside of top robotic flange	encroachment of cassette top domain on space underneath robotic handling flange
*z*17‡	7, 10	26 ± 1 mm (1.02 ± 0.04 in.)	top nominal wafer seating plane	bottom of top robotic handling flanges
*z*18	6, 7, 9, 10	30 mm (1.18 in.) maximum	top nominal wafer seating plane	top of cassette top domain
*z*19	8, 12	24 mm (0.94 in.)	horizontal datum plane	origin of radius of cassette sensing hole
*z*20‡	8, 12	60 ± 1 mm (2.36 ± 0.04 in.)	top nominal wafer seating plane	top wall of bottom side grip pits
*z*21‡	7, 10	9 ± 1 mm (0.35 ± 0.04 in.)	top nominal wafer seating plane	top of vertical sides of top side grip pits
*z*22	8, 12	20 mm (0.79 in.) minimum	horizontal datum plane	top of fork-lift pin hole and upper limit of volume bounded by *r*10
*z*23†	10	3 mm (0.12 in.) maximum	each nominal wafer seating plane	bottom of wafer extraction volume
*z*24‡	7, 10	4 ± 1 mm (0.16 ± 0.04 in.)	lowest point of underside of top robotic flange	top of top robotic handling flange
*z*25‡	None	± 1 mm (± 0.04 in.) flatness over tag area	horizontal datum plane	surface of top and bottom cassette identification tag areas
*z*26*	5	9 mm (0.35 in.) minimum	horizontal datum plane	bottom of info pads (when up)
*z*27‡	15	64.5 mm (2.54 in.) maximum	horizontal datum plane	bottom end of side cassette identification tag area

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
*z*28‡	15	124.5 mm (4.90 in.) minimum	horizontal datum plane	top end of side cassette identification tag area
*z*29	11	0.7 mm (0.028 in.) maximum	each nominal wafer seating plane	encroachment of cassette side domains under wafer extraction volume
*z*99	15	94.5 mm (3.72 in.)	horizontal datum plane	recommended center of label on side cassette identification tag area

* These dimensions define external features that are also required for boxes.

† These dimensions define internal features that are also required for boxes with non-removable cassettes.

‡ These dimensions define optional features.

Table 2 Pitch and Capacity Options

Option Number	*Cassette Capacity (c)*	*Wafer Pitch (z12)*	*Wafer Clearance (z11)*	*Resulting Cassette Height (z8 – z1 + z12* (c – 1) + z18)*
1	13 wafers	10 mm (0.39 in.)	6 mm (0.24 in.) minimum	183 mm (7.20 in.) maximum
2	25 wafers	10 mm (0.39 in.)	6 mm (0.24 in.) minimum	303 mm (11.93 in.) maximum
3	not yet defined			
4	not yet defined			

APPENDIX 1
APPLICATION NOTES

NOTE: The material in this appendix is an official part of SEMI E1.9 and was approved by full letter ballot procedures on December 18, 1998. The recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 The cassette capacity is intended to include one test wafer. It is recommended that process equipment be designed for 12 or 24 product wafers, but tool robotics should reach all slots.

NOTE: The carrier capacity need not be the same as the transport group size, the process batch size, or the virtual tracking unit size.

A1-2 The shape of the features holding the wafers is not specified in this standard. However, a mizo tooth shape (an exaggerated version of which is shown in Figure A1-1) is recommended. It is also recommended that the surface that touches the wafer have a large radius to minimize stress on the wafer and the supporting feature. It is recommended that the supporting feature touch the wafer only on the back side and far enough away from the edge to avoid contact with the wafer notch (if any) in any radial orientation.

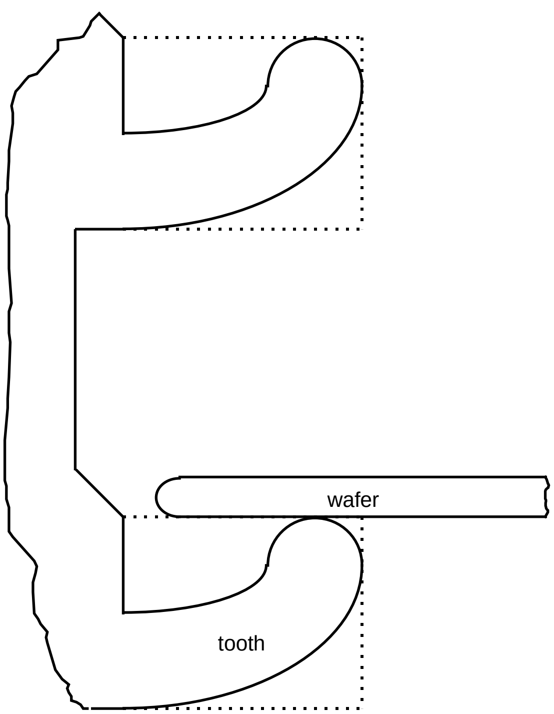

Figure A1-1
Mizo Tooth

A1-3 In general, it is recommended that the wafer notch and/or its fiducial identification marks be kept toward the front of the cassette and the front of the cassette top extend no farther than *y*14 from the facial datum plane, so that the identification marks on the top wafer can be read without removing the wafer.

A1-4 Extra clearance (larger than the pitch) has been added below the bottom wafer (for non-random sequential access to the wafers with a faster or less precise robot) and above the top wafer (for accessing the wafers in a vertical orientation), see Section 6.11.

A1-5 If wear at the kinematic couplings is a concern with plastic cassettes, ceramic or metal inserts can be used for the mating features.

A1-6 Skewness, warp, rock, and stiffness are implicitly defined in the geometric tolerances.

A1-7 To increase the stability of the cassette on the kinematic couplings, the points on the cassette bottom that are the most distant from the lines connecting each pair of coupling pins can be made as close as practical to the horizontal datum plane so that the cassette cannot tip very far off of the kinematic coupling pins.

A1-8 Figure A1-2 shows several paths for optically sensing the presence and planarity of wafers in the cassette. Also shown are the two vertical paths for sensing how far the wafers protrude.

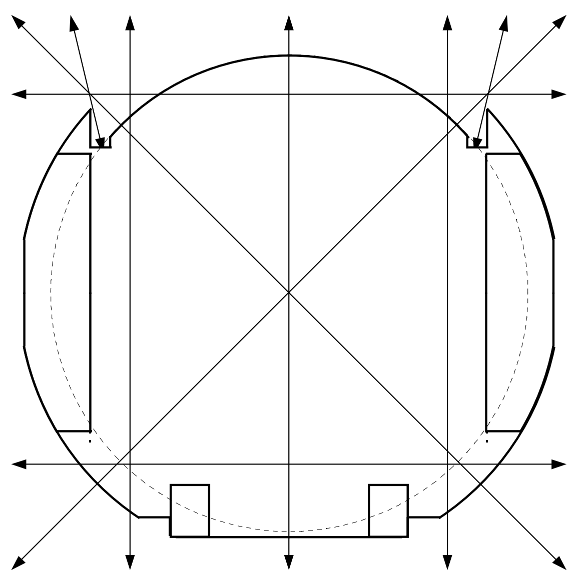

Figure A1-2
Optical Sensing Paths

A1-9 Figure A1-3 shows a small-footprint cassette that conforms to the requirements of this specification. In order to prevent such a small cassette from being set on the kinematic couplings in the wrong orientation, a frame such as shown in Figure A1-4 can be placed around the couplings. In order to not interfere with the kinematic couplings alignment function, the frame can extend no further than *r*19 from the maximum boundaries of a cassette.

NOTE: If the bottom of the cassette does not extend below the bottom conveyor rail, the conveyor rail may become contaminated and may distribute particles.

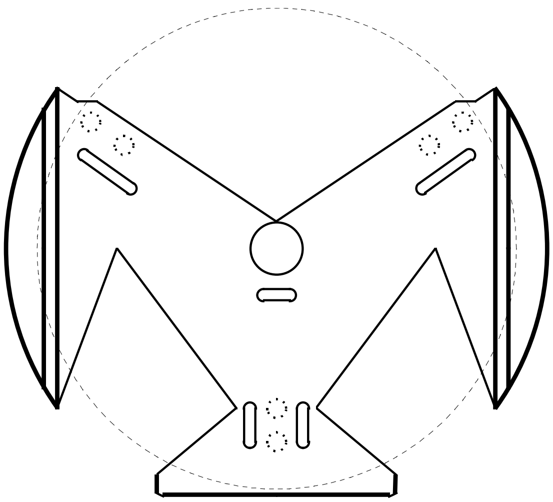

Figure A1-3
Small-Footprint Cassette

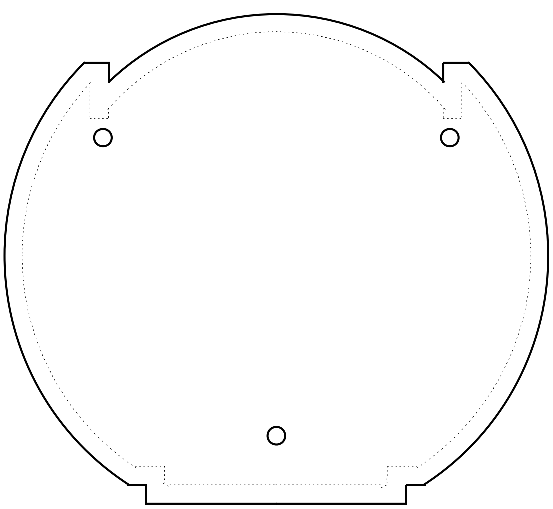

Figure A1-4
Frame to Prevent Misalignment

A1-10 Conveyor rail edges need to be well defined for smooth guidance and to avoid vibration. Thus, the minimum radius on the edge that does not create particles is recommended. For similar reasons, the tolerance on conveyor rail parallelism and on dimension *x*16 should be kept as small as possible for the materials used.

A1-11 Table A1-1 can be used for communicating which optional features are present on cassettes that comply with this specification.

A1-12 In general, info pad A (on the lower left in Figure 5) was intended to indicates the carrier capacity (the number of wafers). For example, info pad A was previously defined to be in the down position (at *z*2 above horizontal datum plane) if the carrier holds 13 wafers and was previously defined to be in the up position (at *z*26 above horizontal datum plane) if the carrier holds 25 wafers. Info pad A is intended to be read with a mechanical switch or optical sensor.

A1-13 In general, info pad B (on the lower right in Figure 5) was intended to indicates the carrier type (cassette or box, etc.). For example, info pad B was previously defined to be in the down position (at *z*2 above horizontal datum plane) if the carrier is a cassette and was previously defined to be in the up position (at *z*26 above horizontal datum plane) if the carrier is a box. Info pad B is intended to be read with a mechanical switch or optical sensor.

A1-14 Info pads C and D (slightly forward and to the outside of info pads A and B) are intended to show whether the carrier is dedicated to the front-end-of-line (FEOL) part of the fabrication process (before any metal layers have been deposited on the wafer) or to the back-end-of-line (BEOL) part of the fabrication process (during which metal contamination may be present). If such carrier differentiation is required by the user, info pads C and D are recommended to be down and up (respectively) for a front-end-of-line carrier and the opposite for a back-end-of-line carrier. Info pads C and D are intended to interact with a mechanical pin. See application note R1-2 in SEMI 15.1 for a discussion of how to use pins to differentiate FEOL and BEOL carriers.

Table A1-1 Open Cassette Optional Features Checklist

Section	*Optional Feature*	*Choice*
6.9	carrier capacity (c)	☐ 13 wafers or ☐ 25 wafers
6.7.4	slant on 2 required fork-lift pick-up areas	angle ω = ____ (0° ≤ ω ≤ 2°)
6.4	4 robotic handling flanges	☐ yes or ☐ no
6.3	4 pentagonal side grip pits	☐ yes or ☐ no
6.7.1	features that prevent wafer creep-out	☐ yes or ☐ no
6.1	full 15 mm lead in provided by 3 features that mate with kinematic coupling pins	primary kinematic coupling pins ☐ yes or ☐ no and secondary kinematic coupling pins ☐ yes or ☐ no
6.8.1	top cassette identification tag area	☐ yes or ☐ no
6.8.3	bottom cassette identification tag area	☐ yes or ☐ no
6.8.2	side cassette identification tag area (on front right side domain)	☐ yes or ☐ no

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E1.9, and it is not intended to modify or supersede the standard in any way. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 A revision ballot will be submitted to insert a statement that application of info pads C and D are reserved to be defined by the user (for example, distinguishing between FEOL and BEOL carriers).

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI

SEMI E2-93 (Reapproved 0299)
SPECIFICATIONS FOR QUARTZ AND HIGH TEMPERATURE WAFER CARRIERS

These specifications were technically reapproved by the Physical Interfaces & Carriers Committee and are the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1986; previous published revision in 1996.

1 Scope

1.1 These specifications cover the dimensional requirements for quartz and high temperature wafer carriers used in processing wafers. These general requirements assist in the compatibility of wafer carriers and most automated wafer processing equipment. Wafer pre-orientation is recommended before transferring wafers into quartz carriers to avoid interference between the flat fiducial(s) and carrier slots. These standards are intended to promote the interchangeability of wafer carriers and encourage the production of equipment suitable to a greater percentage of the market.

1.2 The design definitions of SEMI Wafer Carrier Specifications assume compliance to wafer dimensions defined in SEMI M1, M3, or M9. For a wafer carrier to be said to “meet the SEMI specifications,” it must be manufactured within the dimensional limits of the given specification, and in addition be dimensionally stable within specification when used in accordance with manufacturer's recommendations. Since wafer carriers are manufactured from a number of different raw materials and several different manufacturing methods, it is up to each manufacturer to determine the recommended usage for each wafer carrier type. The specifications were not established nor do they represent or suggest a means to obtain any ideal efficiencies in wafer processing results or quality of end product.

1.3 For referee purposes, SI (System International, commonly called metric) units shall be used for 80 mm and larger diameter wafers.

2 Selected Definitions

2.1 For illustrations of terms, see Figure 1 for Carrier Style 1, and Figure 2 for Carrier Style 2. Dimensions and tolerances are given in Table 1 of the standards for carriers of the appropriate wafer diameter.

2.1.1 *base* — the material at the bottom of the carrier that the carrier rests on when placed on a flat reference surface.

2.1.2 *bottom plane* — a horizontal plane tangent to the base.

2.1.3 *end* — either end of carrier parallel to wafer plane.

2.1.4 *lift access* — the clearance space used to insert an implement to pick up a wafer carrier.

2.1.5 *side* — either one of the sides perpendicular to the wafer plane.

3 Dimension Definitions

Symbol

A	Wafer Height — distance from the horizontal center line of the wafer to the bottom plane
B	Base Width — the outside dimension of the base from side to side
C	Base Length — length of the base from end to end
D	Lift Access Height — distance from horizontal centerline of lift access opening to bottom plane
E	Lift Access Spacing — distance from center line to center line of lift access opening
F	Lift Access Opening — size of opening for the insertion of an implement to pick up the carrier
G	Base End to First Slot — the distance from either end of the carrier to the first slot on same end
H	Slot Spacing — the distance from the center line of one slot to the center line of the adjacent slot
I	End Slot to other End Slot — the center line of the first slot on either end to the center line of the slot on the other end
J	Pocket Size — the diameter of a circle coincident to the bottom of all wafer slots in a wafer position
K	Base Side to Wafer Center line — horizontal distance from the vertical wafer center line to either side of the base
L	Carrier Region — region enclosed by the greatest included angle between a line drawn from the center point of the wafer and the outermost member of the carrier on one side and a similar line on the other side
P	Separation — separation of wafers when placed in slots

4 Referenced Documents

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M3 — Specifications for Polished Monocrystalline Sapphire Substrates

SEMI M9 — Specifications for Polished Monocrystalline Gallium Arsenide Slices

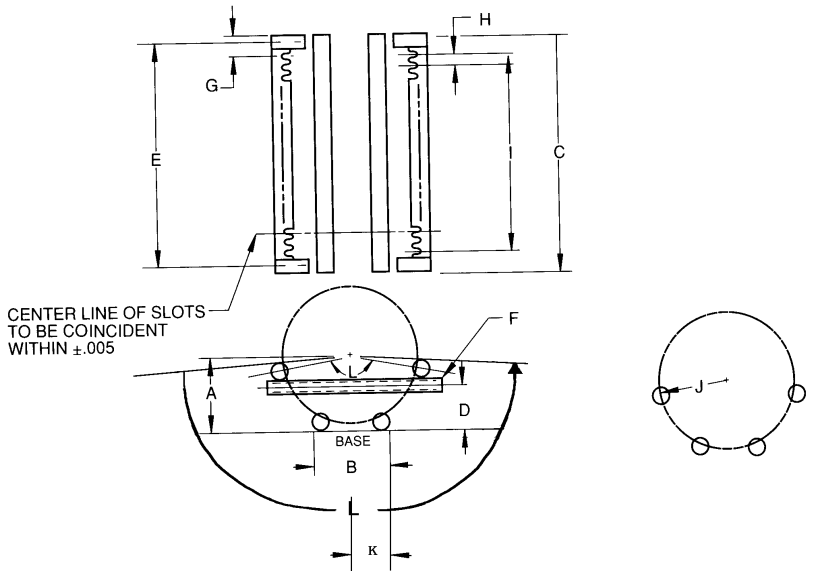

Figure 1
Style 1: Non-Contiguous 25 & 50 Slot

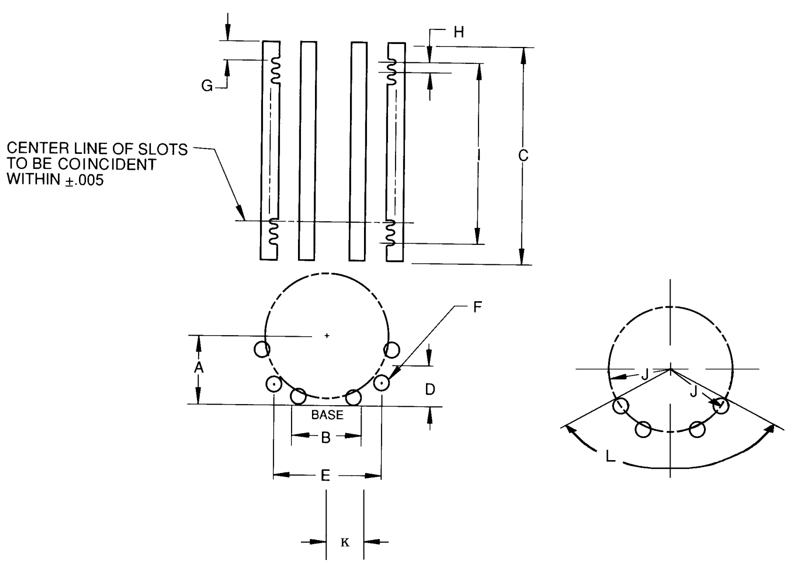

Figure 2
Style 2: Contiguous 25 & 50 Slot

APPLICATION NOTE

NOTE: The material contained in these application notes is not an official part of SEMI E2 and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard, as such, they are to be considered as reference material only. The standard should be referred to in all cases.

Table A1-1 lists the dimensions in linear, versus angular, measurements for ease of dimensional verification. The dimensions fall within SEMI specification; however, they correspond closer to an "L" angular dimension of 140 degrees versus the 150 degrees. The figures A1-1 and A1-2 illustrate these dimensions for non-contiguous and contiguous style quartz carriers.

A1-1 *Carrier — Dimension L*

Automated mass transfer of silicon wafers requires edge contact below the centerline of the wafer according to Table 1. These dimensions have been determined as the minimum distance below the wafer center line allowing the gripping mechanism to overlap the vertical tangent of the wafer edge below the centerline. This overlap allows the wafers to be passively crattled. Contacting the wafer any higher toward the centerline will require clamping force on the wafers.

Table A1-1

Wafer Size	*100 mm*	*125 mm*	*150 mm*	*200 mm*
A	18 mm	21 mm	25 mm	32 mm
Style I & II	(0.70")	(0.82")	(1.00")	(1.25")

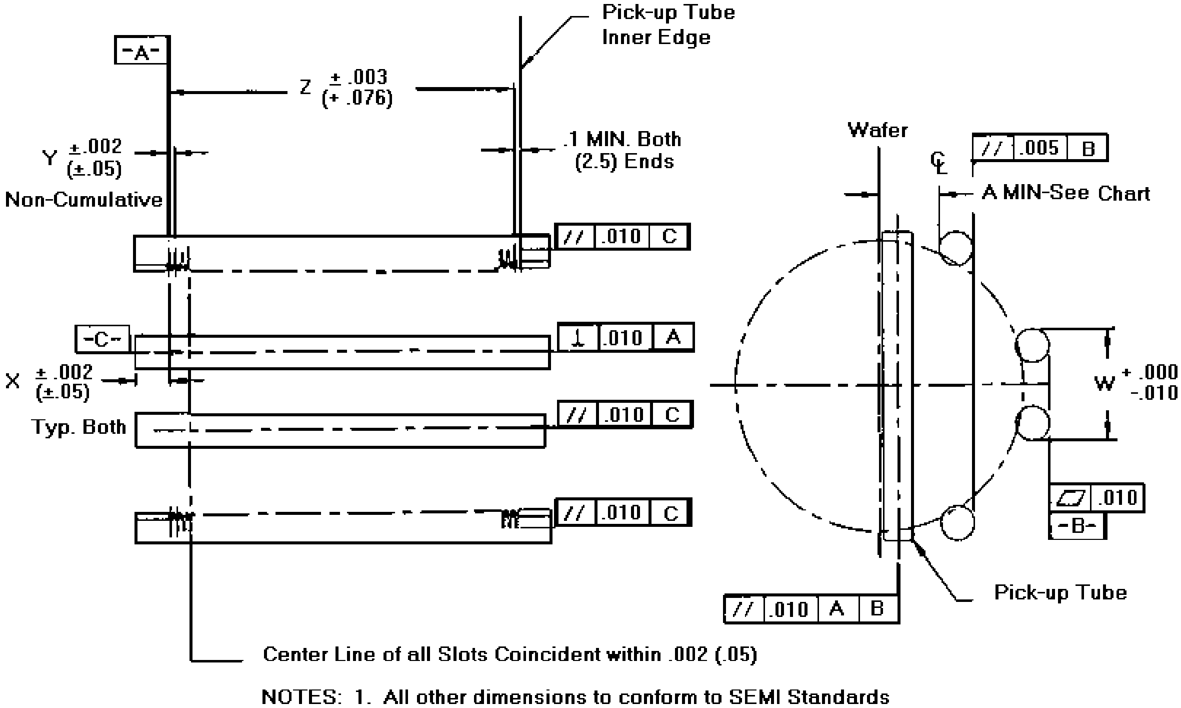

Figure A1-1
Style 1: Non-Contiguous

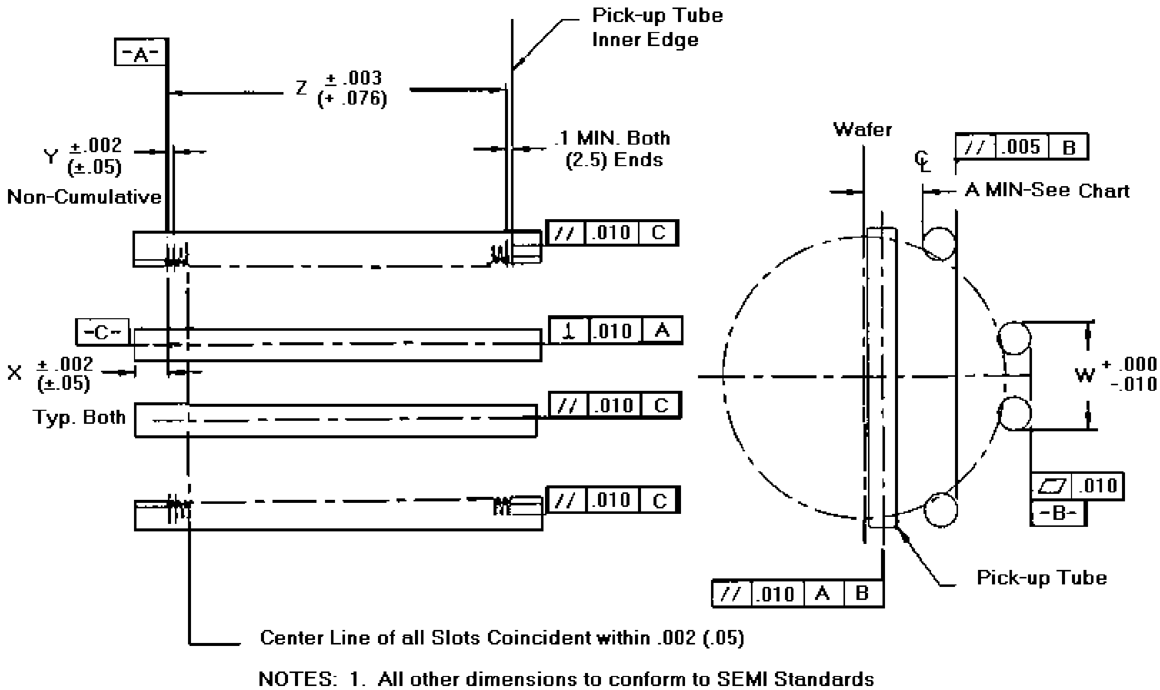

Figure A1-2
Style 2: Contiguous

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E2.2-93 (Reapproved 0299)
STANDARD FOR 200 mm QUARTZ AND HIGH TEMPERATURE WAFER CARRIERS

This standard was technically reapproved by the Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1988; previous published revision in 1996.

NOTE: Terms and Dimensions used in this specification are defined in SEMI E2.

	Description	*Style 1 — Non-Contiguous (Figure 1)*	*Style 2 — Contiguous (Figure 2)*
Symbol			
A	Wafer Height	105.6 mm REF (4.14 in. REF)	105.6 mm REF (4.14 in. REF)
B	Base Width	66.040 mm ± 0.508 mm (2.600 in. ± 0.020 in.)	66.040 mm ± 0.508 mm (2.600 in. ± 0.020 in.)
D	Lift Access Height	17.8 mm (0.70 in.)	17.8 mm (0.70 in.)
E	Lift Access Spacing	178.562 mm ± 0.760 mm (7.030 in. ± 0.030 in.)	154.940 mm ± 0.760 mm (6.100 in. ± 0.030 in.)
F	Lift Access Opening	6.0 mm (0.236 in.) min.	same
J	Pocket Size (DIA)	202 mm ± 0.500 mm (7.953 in. ± 0.020 in.)	202 mm ± 0.500 mm (7.953 in. ± 0.020 in.)
K	Base Side to Wafer Centerline	33.02 mm ± 0.254 mm (1.300 in. ± 0.010 in.)	1/2 B ± 0.254 mm (1.300 in. ± 0.010 in.)
L	Carrier Region	150° max.	125° max.
P	Separation — Wafer to Wafer	≥ 10% H	≥ 10% H
25 Capacity			
C	Base Length	C = 195.15 mm ± 0.076 mm (7.683 in. ± 0.003 in.)	157.750 mm ± 0.076 mm (6.250 in. ± 0.003 in.)
G	Base End to 1st Slot	G = 21.374 mm ± 0.076 mm (0.8415 ± 0.003 in.)	3.175 mm ± 0.076 mm (0.125 in. ± 0.003 in.)
H	Slot Spacing (non-accumulative)	6.350 mm ± 0.076 mm (0.250 in. ± 0.003 in.)	6.350 mm ± 0.076 mm (0.250 in. ± 0.003 in.)
I	End Slot to End Slot	152.400 mm ± + 0.076 mm (6.000 in. ± 0.003 in.)	152.400 mm ± + 0.076 mm (6.000 in. ± 0.003 in.)
50 Capacity			
C	Base Length	195.148 mm ± 0.076 mm (7.683 in. ± 0.003 in.)	158.750 mm ± 0.076 mm (6.260 in. ± 0.003 in.)
G	Base End to 1st Slot	19.787 mm ± 0.076 mm (0.779 in. ± 0.003 in.)	3.175 mm ± 0.076 mm (0.125 in. ± 0.003 in.)
H	Slot Spacing (non-accumulative)	3.18 mm ± 0.08 mm (0.125 in. ± 0.003 in.)	3.18 mm ± 0.08 mm (0.125 in. ± 0.003 in.)
I	End Slot to End Slot	155.575 mm ± 0.076 mm (6.125 in. ± 0.003 in.)	155.575 mm ± 0.076 mm (6.125 in. ± 0.003 in.)

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI

SEMI E2.3-93 (Reapproved 0299)
STANDARD FOR 100 mm QUARTZ AND HIGH TEMPERATURE WAFER CARRIERS

This standard was technically reapproved by the Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1993; previous published revision in 1996.

NOTE: Terms and Dimensions used in this specification are defined in SEMI E2.

	Description	*Style 1 — Non-Contiguous (Figure 1)*	*Style 2 — Contiguous (Figure 2)*
Symbol			
A	Wafer Height	57.0 mm ± 0.5 mm (2.25 in. ± 0.020 in.)	57.0 mm ± 0.5 mm (2.25 in. ± 0.020 in.)
B	Base Width	39.1 mm ± 0.25 mm (1.54 in. ± 0.010 in.)	39.1 mm ± 0.25 mm (1.54 in. ± 00.010 in.)
D	Lift Access Height	17.8 mm (0.70 in.) min.	17.8 mm (0.70 in.) min.
E	Lift Access Spacing	134.5 ± 0.50 mm (5.296 in. ± 0.02 in.)	109.2 mm ± 0.5 mm (4.30 in. ± 0.02 in.)
F	Lift Access Opening	8 mm I.D. (3.15 in. I.D.) min.	8 mm I.D. (3.15 in. I.D.) min.
J	Pocket Size (DIA)	101.6 mm ± 0.5 mm (4.00 in. ± 0.020 in.)	101.6 mm ± 0.5 mm (4.00 in. ± 0.020 in.)
K	Base Side to Wafer Centerline	1/2 B ± 0.25 mm (0.01 in.)	1/2 B ± 0.25 mm (0.01 in.)
L	Carrier Region	150° max.	125° max.
P	Separation — Wafer to Wafer	≥ 10% H	≥ 10% H
25 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	119.00 ± 0.076 mm (4.688 in. ± 0.003 in.)
G	Base End to 1st Slot	15.7 mm ± 0.076 mm (0.618 in. ± 0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H	Slot Spacing (non-accumulative)	4.76 mm ± 0.051 mm (0.1875 in. ± 0.002 in.)	4.76 mm ± 0.051 mm (0.1875 in. ± 0.002 in.)
I	End Slot to End Slot	114.3 mm ± 0.076 mm (4.500 in. ± 0.003 in.)	114.3 mm ± 0.076 mm (4.500 in. ± 0.003 in.)
50 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	121.46 mm ± 0.076 mm (4.782 in. ± 0.003 in.)
G	Base End to 1st Slot	14.50 mm ± 0.076 mm (0.571 in. ± 0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H	Slot Spacing (non-accumulative)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)
I	End Slot to End Slot	116.69 ± 0.076 mm (4.594 in. ± 0.003 in.)	116.69 mm ± 0.076 mm (4.594 in. ± 0.003 in.)

NOTE 1: 25 capacity slot spacing is derived from SEMI E1.2.

NOTE 2: 50 capacity slot spacing is SEMI E1.2 divided by 2; to insure compatibility for wafer transfer between Plastic & High Temperature Carriers, the U.S. customary dimension is carried out to 5 decimals to eliminate accumulation in rounding error when multiplying times 49 spaces to achieve I.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI

SEMI E2.4-93 (Reapproved 0299)
STANDARD FOR 125 mm QUARTZ AND HIGH TEMPERATURE WAFER CARRIERS

This standard was technically reapproved by the Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1993; previous published revision in 1996.

NOTE: Terms and Dimensions used in this specification are defined in SEMI E2.

	Description	*Style 1 — Non-Contiguous (Figure 1)*	*Style 2 — Contiguous (Figure 2)*
Symbol			
A	Wafer Height	69.1 mm + 0.5 mm (2.72 in. + 0.02 in.)	69.1 mm + 0.5 mm (2.72 in. + 0.02 in.)
B	Base Width	46.0 mm + 0.25 mm (1.80 in. + 0.01 in.)	46.0 mm + 0.25 mm (1.80 in. + 0.01 in.)
D	Lift Access Height	17.8 mm (0.70 in.) min.	17.8 mm (0.70 in.) min.
E	Lift Access Spacing	134.5 mm + 0.50 mm (5.296 in. + 0.02 in.)	109.2 mm + 0.5 mm (4.30 in. ± 0.02 in.)
F	Lift Access Opening	8 mm I.D. (0.315 in. I.D.) min.	8 mm I.D. (0.315 in. I.D.) min.
J	Pocket Size (DIA)	4.935 in. min.	same
K	Base Side to Wafer Centerline	1/2 B ± 0.25 mm (0.01 in.)	same
L	Carrier Region	150° max.	125° max.
P	Separation — Wafer to Wafer	≥ 10% H	≥ 10% H
25 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	119.00 mm ± 0.076 mm (4.688 in. ± 0.003 in.)
G	Base End to 1st Slot	15.7 mm ±0.076 mm (0.618 in. ±0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H (See NOTE 1.)	Slot Spacing (non-accumulative)	4.76 mm ± 0.51 mm (0.1875 in. ±0.002 in.)	4.76 mm ± 0.51 mm (0.1875 in. ± 0.002 in.)
I	End Slot to End Slot	114.3 mm ± + 0.076 (4.500 in. ± 0.003 in.)	114.3 mm ± + 0.076 mm (4.500 in. ± 0.003 in.)
50 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	121.46 mm ± 0.076 mm (4.782 in. ± 0.003 in.)
G	Base End to 1st Slot	14.50 mm ± 0.076 mm (0.571 in. ± 0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H (See NOTE 2.)	Slot Spacing (non-accumulative)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)
I	End Slot to End Slot	116.69 ± 0.076 mm (4.594 in. ± 0.003 in.)	116.69 mm ± 0.076 mm (4.594 in. ± 0.003 in.)

NOTE 1: 25 capacity slot spacing is derived from SEMI E1.3 and E1.4.

NOTE 2: 50 capacity slot spacing is SEMI E1.3 divided by 2 or E1.4 divided by 2; to insure compatability for wafer transfer between Plastic & High Temperature Carriers, the U.S. customary dimension is carried out to 5 decimals to eliminate accumulation in rounding error when multiplying by 49 spaces to achieve I.

SEMI E2.5-93 (Reapproved 0299)
STANDARD FOR 150 mm QUARTZ AND HIGH TEMPERATURE WAFER CARRIERS

This standard was technically reapproved by the Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1993; previous published revision in 1996.

NOTE: Terms and Dimensions used in this specification are defined in SEMI E2.

	Description	*Style 1 — Non-Contiguous (Figure 1)*	*Style 2 — Contiguous (Figure 2)*
Symbol			
A	Wafer Height	80.0 mm ± 0.5 mm (3.15 in. ± 0.02 in.)	80.0 mm ± 0.5 mm (3.15 in. ± 0.02 in.)
B	Base Width	54.91 mm ± 0.25 mm (2.16 in. ± 0.01 in.)	54.91 mm ± 0.25 mm (2.16 in. ± 0.01 in.)
D	Lift Access Height	17.8 mm (0.70 in.) min.	17.8 mm (0.70 in.) min.
E	Lift Access Spacing	134.5 mm ± 50 mm (5.296 in ± 02 in.)	109.2 mm ± 0.5 mm (4.30 in. ± 0.02 in.)
F	Lift Access Opening	8 mm I.D (0.315 in. I.D.) min.	8 mm I.D (0.315 in. I.D.) min.
J	Pocket Size (DIA)	5.920 in. min.	same
K	Base Side to Wafer Centerline	½ B ± 0.25 mm (.01 in.)	same
L	Carrier Region	150° max.	125° max.
P	Separation — Wafer to Wafer	≥ 10% H	≥ 10% H
25 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	119.00 mm ± 0.076 mm (4.688 in. ± 0.003 in.)
G	Base End to 1st Slot	15.7 mm ± 0.076 mm (0.618 in. ± 0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H (See NOTE 1.)	Slot Spacing (non-accumulative)	4.76 mm ± 0.051 mm (0.1875 in. ± 0.002 in.)	4.76 mm ± 0.051 mm (0.1875 in. ± 0.002 in.)
I	End Slot to End Slot	114.3 mm ± 0.076 mm (4.500 in. ± 0.003 in.)	114.3 mm ± 0.076 mm (4.500 in. ± 0.003 in.)
50 Capacity			
C	Base Length	145.7 mm ± 0.076 mm (5.736 in. ± 0.003 in.)	121.46 mm ± 0.76 mm (4.782 in. ± 0.003 in.)
G	Base End to 1st Slot	14.50 mm ± 0.076 mm (0.571 in. ± 0.003 in.)	2.390 mm ± 0.076 mm (0.094 in. ± 0.003 in.)
H (See NOTE 2.)	Slot Spacing (non-accumulative)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)	2.381 mm ± 0.051 mm (0.09375 in. ± 0.002 in.)
I	End Slot to End Slot	116.69 mm ± 0.076 mm (4.594 in. ± 0.003 in.)	116.69 mm ± 0.076 mm (4.594 in. ± 0.003 in.)

NOTE 1: 25 capacity slot spacing is derived from SEMI E1.5.

NOTE 2: 50 capacity slot spacing is SEMI E1.5 divided by 2; to insure compatibility for wafer transfer between Plastic & High Temperature Carriers, the U.S. customary dimension is carried out to 5 decimals to eliminate accumulation in rounding error when multiplying by 49 spaces to achieve I.

SEMI E6-1296
FACILITIES INTERFACE SPECIFICATIONS GUIDELINE AND FORMAT

1 Purpose

This guideline is intended to assist suppliers with the communication of information about the facilities needs of their equipment to those who are responsible for the facilities design and the equipment installation.

The successful installation and operation of semiconductor equipment is the mutual objective of the owner of the equipment, the operator, the installer, and the supplier. Within the semiconductor industry, the diversity and complexity of equipment have created significant problems for those who design the facilities and install the equipment. It is very difficult to stay current with the ever-changing requirements necessary for individual pieces of equipment. As a result, it is difficult to guarantee that the facilities will meet the needs of each piece of equipment.

2 Scope

Design and installation requirements vary with each owner and project. Therefore, this guideline is designed to cover all activities that may be included with equipment installation.

3 Impact

Any supplier who uses this format is expected to include within the document all requirements for the site facilities, equipment shipping, installation, startup, acceptance test, and training. This is a guiding document for those who design the facility and install the equipment. The format is to be used for all types of equipment. Therefore, it will be necessary for each supplier to make modifications as required to suit the complexity of the equipment. The intent is to have a simple, but complete, format for all equipment.

4 Referenced Documents

None.

5 Related Documents

NOTE: All documents cited shall be the latest published versions of an adopted standard. All documents shall cite those specifications in effect at the date of purchase.

5.1 *SEMI Documents*

SEMI C3 — Specifications for Gases

SEMI E1.1 — Standard for 3 inch Plastic and Metal Wafer Carriers, General Usage

SEMI E1.2 — Standard for 100 mm Plastic and Metal Wafer Carriers, General Usage

SEMI E1.3 — Standard for 125 mm Plastic and Metal Wafer Carriers, General Usage

SEMI E1.4 — Standard for 125 mm Plastic and Metal Wafer Carriers, Auto Transport Usage

SEMI E1.5 — Standard for 150 mm Plastic and Metal Wafer Carriers, General Usage

SEMI E1.7 — Standard for 200 mm Plastic and Metal Wafer Carriers, General Usage (Proposed)

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E7 — Specification for Electrical Interfaces for the U.S. Only

SEMI E8 — Specification for Wafer Transport Systems: Interface Coordinates

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

5.2 *Other Document*[1]

Federal Standard 209E — Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

6 Terminology

6.1 *P&ID* — Pipe and instrument drawings.

6.2 *interconnect* — Connection(s) between tool mainframe and peripheral tool sub-systems equipment.

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1 General Service Administration, Federal Supply Service Bureau, Specification Section, Suite 8167, 470 East L'Enfant Place, SW, Washington, D.C. 20407

6.3 *facilitization* — The provision of facilities or services.

7 Instructions and Sample

Following is a sample for equipment interface specifications. The sample below includes a table of contents and sample forms. Address each of the items in the table of contents with a comment, even if the item does not apply. Those responsible for the installation need to be sure every aspect has been considered and addressed. In the following sections, the instructions for each element of the table of contents is followed by a sample.

- Table of contents (sample)
- Introduction
- Administrative interface
- Safety
  - — Non-physical conditions
  - — Monitoring communications
  - — Clearances
- Facilities installation requirements
  - — Environment
  - — Schematic (single line) diagram and equipment data sheets
  - — Equipment facilitization drawings
- Shipping and receiving requirements
- Installation requirements
  - — Transport and positioning equipment tools
  - — Assembly and hookup tools and equipment
- Startup requirements
  - — Equipment
  - — Material
  - — Personnel
- Acceptance test
- Training
- Addenda (list by topic)

7.1 *Introduction*

7.1.1 *Instructions for Introduction* — The introduction should include general information about the scope of the document and any other introductory statements.

7.1.2 *Sample for Introduction* — This document contains the facilities design and equipment installation requirements for (indicate equipment name). It conforms to SEMI E6 (Facilities Interface Specifications Guideline and Format).

7.2 *Administrative Interface*

7.2.1 *Instructions for Administrative Interface* — The administrative interface should include the contacts for commercial questions and technical questions.

The equipment description should include:

- Functionality and intended use
- Wafer or material handling method
- Interface with other equipment (especially cluster tools)
- Special process requirements
- Number of pieces included as part of this equipment

Suppliers are encouraged to make the specifications document as specific as possible to the delivered equipment.

Include here information about the availability of facilities data in electronic formats. Specify the software format name and revision level, and indicate the names of data files contained in it.

7.2.2 *Sample for Administrative Interface*

Table 1 Administrative Interface

	Supplier — *Sales Rep.*	**Purchasing Agent**
Company Name		
Address		
Administrative:		
Contact & Title		
Phone/Fax		
	Supplier — *Mfg. Location*	**User** — *Installation Location*
Company Name		
Address		
Administrative:		
Contact & Title		
Phone/Fax		
Shipping (FOB):		
Contact & Title	**Supplier:**	**User:**
Phone/Fax		
Equipment Identification Data:		
Model		
Serial Number		
RFQ Number	N/A	
Quotation Number		N/A
Project Number	N/A	
Sales Order Number		N/A
Purchase Order No.	N/A	
Equipment Name		
Type:		
Description:		
Options Included:		

7.3 *Safety*

7.3.1 *Instructions for Safety* — Any special safety concerns relating to the facilities design or equipment installation, startup, or testing should be addressed here.

7.3.1.1 *Non-Physical Conditions* — Information should be provided by the supplier on all non-physical equipment emissions including radio frequencies, temperature, humidity, vibrations, noise, odors, and ionizing and non-ionizing radiation. This information should be formatted to show emissions during normal operation and potential emission or releases in the event of malfunction or abnormal conditions.

Information should be provided on any non-physical conditions that could exist in the user's facility that would adversely affect the operation of the equipment being supplied.

7.3.1.2 *Monitoring Communications* — The supplier should provide information on the protocol, number, type, and location of the data/communication connectors for external monitoring that are provided or desirable.

Examples of conditions that are typically monitored are: chemicals that could present a health hazard, flammable chemicals and other fire hazard conditions, equipment temperature, exhaust systems, radiation sources, and power supplies.

7.3.1.3 *Clearances* — Drawings required under Section 7.4.3, Equipment Facilitization Drawings, should include clearances required for operator access and equipment maintenance and the operation of doors, drawers, and panels integrated into the equipment. Notations should be given if the clearances shown are in compliance with standards or codes.

7.3.2 *Sample for Safety* — Safety-related checks should be performed to supplier specification prior to system acceptance. These safety checks at point of installation should be accepted by:

- Supplier(s) safety representative
- Customer safety representative

Installation site acceptance test should be signed off by a supplier and a customer. The following test should be performed prior to acceptance to verify that the system meets requirements:

- Statement of conformance to SEMI S2 (Safety Guidelines for Semiconductor Manufacturing Equipment)
- Safety interlocks function and shut-down correct hazards
- Ventilation flow test at specifications and location where this can be verified by measurement
- Preventive maintenance and operating procedures are clearly documented, and personnel are trained
- Chemical spill containment is adequate for 110% of the quantity of fluids in the system
- UPS output(s) are isolated when emergency shutdown occurs
- Manual operation of the tool is documented, and personnel are trained
- EMO circuit functions
- Ability to lock out hazardous energy sources prior to maintenance
- Onboard gas detection system is functional
- Onboard fire detection system is functional
- Auxiliary equipment tie-ins function as intended and do not increase level of risk (scrubbers, purging systems, alarms)
- Site-specific installation does not degrade tool's ergonomic design factors
- Interface to building systems functions as intended
-

7.4 *Facilities Installation Requirements*

7.4.1 *Environment*

7.4.1.1 *Instructions for Environment* — These requirements must address the temperature and humidity requirements of equipment when it is facilitized for operation. Any other requirements, such as vibration, may be addressed in the body of the specifications or in the addenda with backup information provided in the addenda.

7.4.1.2 *Sample for Temperature*

Table 2 Temperature

	*Non-Operating Range, min./max.**		*Operating Range, min./max.*		*Target Temp.*	*Tolerance ±*	*Maximum Rate of Change/Hour*
Tool Area							
Support Equipment Area							

* The temperature range which will prevent possible damage to the tool.

7.4.1.3 *Sample for Relative Humidity*

Table 3 Relative Humidity

	Range (%)			*Percent per Hour*
Tool Area		to		
Support Equipment Area		to		

7.4.1.4 *Sample for Special Lighting* — Provide Table for Special Equipment Requirements.

7.4.1.5 *Sample for Vibration Requirements*

___________This equipment gives forth vibration that may impact sensitive equipment installed nearby. (If yes, indicate worst-case criterion here:___________.)

___________This equipment is sensitive to vibration. (If the facility needs to meet Criteria A or better, indicate here:___________.) If the tool requirement is more stringent than Criteria A, provide the information required in the Addendum Section.

7.4.1.6 *Sample for Noise Requirements*

___________This equipment gives forth electromagnetic radiation that may impact sensitive equipment installed nearby.

___________This equipment is sensitive to or produces electromagnetic radiation, electromagnetic interference, radio frequency, acoustical vibrations, or electrostatic discharge. (If yes, provide data.)

7.4.1.7 *Sample for Seismic Requirements*

___________This equipment has brackets or other mechanisms to secure for earthquake protection. (If yes, provide data.)

7.4.1.8 *Sample for Environment Cleanliness*

___________This equipment requires a clean room to meet operational specifications. (If yes, provide minimum cleanliness data.) Different areas of a tool or subassemblies may need different minimums. If so, the supplier should state this information.

7.4.2 *Schematic (Single Line) Diagram and Equipment Data Sheet*

7.4.2.1 *Instructions for Schematic (Single Line) Diagrams* — The diagram(s) is required. It may be included in the body of the specification or in an addendum at the option of the supplier. Included in the application notes are samples of possible formats. These also serve as a checklist of information needed by the facilities design and installation people.

A schematic (single line) diagram and equipment data sheet are to be developed for the various facilities requirements. The diagram should be designed to give the facilities designer or equipment installer a detailed overview of the facility requirement being covered. The equipment data sheet should be designed to give the facilities designer or equipment installer the following specific information about the facility items covered in the diagram:

- A description
- Whether the customer or supplier provides the item
- The "to" and "from" connection points, with connections named
- The length or other applicable physical characteristics
- A reference designation to the interface diagram

For equipment with simple facilities requirements, the supplier may combine requirements to reduce the number of diagrams and diagram data sheets. The facilities interface diagrams will be contained in the body of the document.

It is also recommended that equipment data sheets be included for all equipment, especially those with multiple stand-alone components. The equipment data sheet should give the facilities designer or equipment installer detailed information on all facilities required for a given assembly. This should include, but is not limited to:

- A description
- All physical characteristics of the assembly
- Environmental requirements
- Detailed facility requirements for items listed
- A reference designation to the interface diagram
- Applicable notes to guide the designer or installer when installing the equipment

As with the facilities interface specifications format, it is recommended that the diagrams and data sheets list items "not needed" so the facilities provider will know that these subjects were considered by the equipment supplier.

7.4.2.2 *Sample for Schematic (Single Line) Diagram*

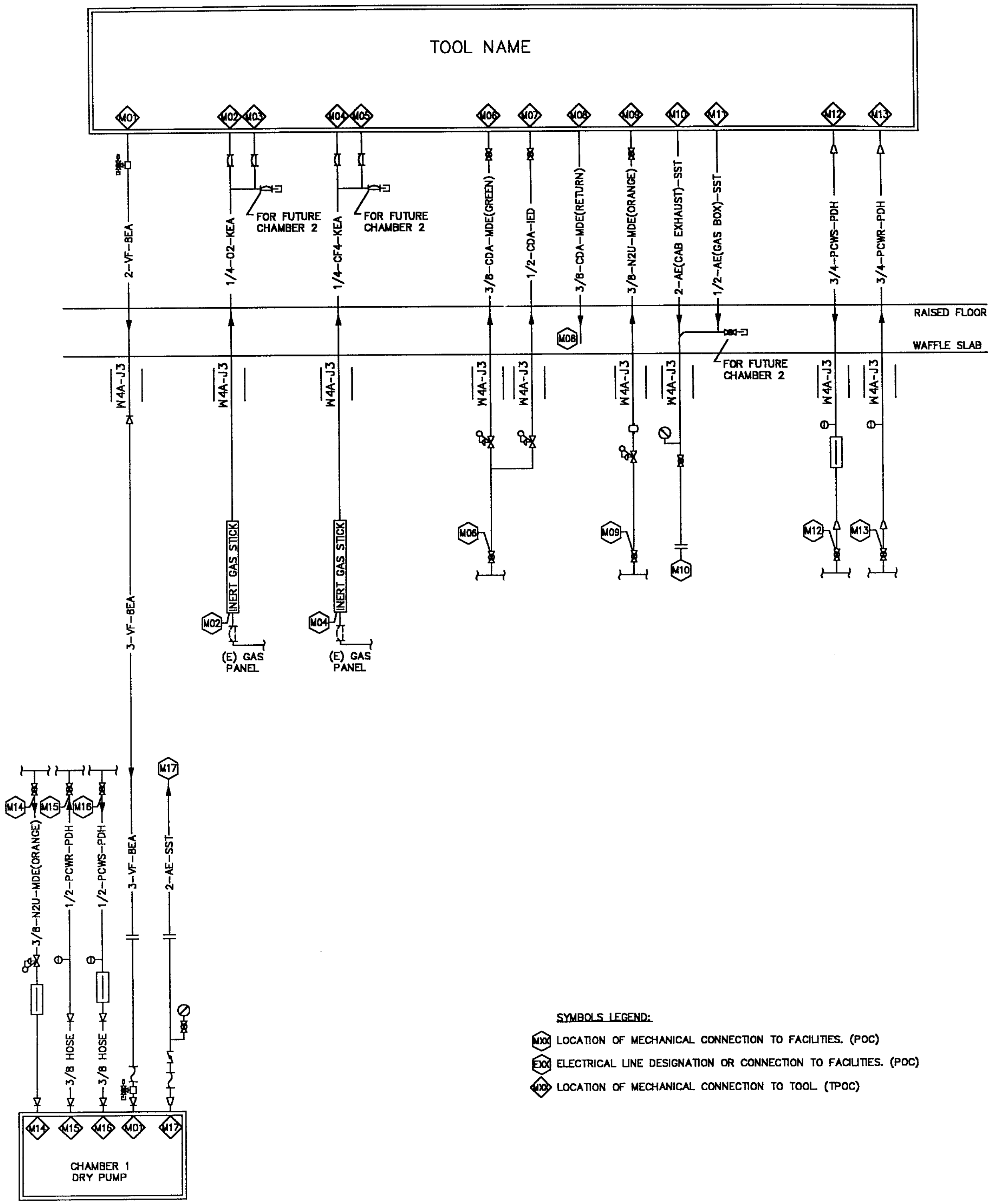

Figure 1
Schematic (Single Line) Diagram

7.4.2.3 *Notes on Equipment Data Sheet* — The equipment data sheet contains bold numbers in parentheses which refer to the key located at the end of the data sheet.

If more than one connection of a given utility exists for an equipment item, each should be indicated separately.

Flows, temperatures, etc. are for normal operating conditions. If there is a variation because of startup or emergency, those additional conditions should be indicated.

1. If there is a difference between normal operating current and peak current, it is necessary to know the duration of the peak to size the equipment circuit breaker. The equipment supplier may supply the peak duration or the size of the breaker.
2. Power connection should indicate the type of plug used or, if hard wired, indicate the number of wires with the minimum and maximum wire size that can be connected to the equipment lugs. Also, indicate the conduit connection opening size.

Please indicate if a drain trap is needed. If a drain trap is provided with the equipment, please indicate its height.

Table 4 Sample for Equipment Data Sheet

Equipment Name (**1.**)	Component Description (**2.**)	Sheet of Figure (**3.**)
Vendor (**4.**)		

Physical Properties	*Crated*	*Installed*	*Clearance*	*(units)*	*Environmental Requirements*	*Operate*	*Standby*
Height: (units)			Front:		Ambient Temperature		N/A
Depth: (units)			Back:		Ambient Humidity		N/A
Width: (units)			Left:		Heat Release to water (units)		
Weight: (units)			Right:		Heat Release to exhaust (units)		
Number of Pieces:			Top:		Heat to space: (units)		
					Room Class cleanliness		

*Ref (**5.**)*	*Power Equip-ment*	*Supply Point Inter-conn.*	*Voltage*	*Phases*	*FLA Amps*	*Breaker KVA*	*Peak KVA***	*Operate KVA**	*Standby KVA*	*Wire*	*Ground-ing*	*Other*
		(**6.**)										

* Average running load over 24 hour typical manufacturing cycle.

** Absolute maximum load.

Ref	*Exhaust Req.*	*Supply Point Inter-connect*	*Size (O.D.) (units)*	*Temp. (outlet)*	*Pressure (units)*	*Min. Flow (units)*	*Max. Flow (units)*	*Average Flow (units)*	*Material*	*Fitting Size (units)*	*Fitting Type*	*Other*
	(**7.**)											

Ref	*Liquid Req.*	*Supply Point Inter-connect*	*Pressure (units)*	*Temp. (inlet)*	*Reg. Req.? (**9.**)*	*Min. Flow (units)*	*Max. Flow (units)*	*Avg. Flow (units)*	*Fittings*	*Fitting Size (units)*	*Fitting Type*	*Min. Filtration*	*Other*
Drain Req.	(**8.**)												
									(**10.**)			(**11.**)	

Ref	*Gas Req.*	*Supply Point Inter-connect*	*Pressure (units)*	*Reg. Req.? (**9.**)*	*Clean-liness Req.*	*Min. Flow (units)*	*Max. Flow (units)*	*Avg. Flow (units)*	*Fitting Material*	*Fitting Size (units)*	*Fitting Type*	*Material*	*Other*

Ref	*Liquid Req.*	*Supply Point Inter-connect*	*Pressure (units)*	*P-Trap*	*Disch Temp.*	*Min. Flow (units)*	*Max. Flow (units)*	*Avg. Flow (units)*	*Fitting Material*	*Fitting Size (units)*	*Fitting Type*	*Material*	*Other*
	(**12.**)												

Ref	*Vacuum Req.*	*Supply Point Inter-connect*	*Size (O.D.)*	*Pressure (units)*	*Quantity*	*Min. Flow (units)*	*Max. Flow (units)*	*Avg. Flow (units)*	*Fitting Material*	*Fitting Size (units)*	*Fitting Type*	*Material*	*Other*
	(**13.**)												

Ref	Chemi-calDis-pense	Type of Chemi-cal (acid, solvent, base)	Size (O.D.)	No. of Lines	Flow	Fitting Size (units)	Temp. °C (units)	Fitting Type	Fitting Material	Material	Pressure	Supply Point Inter-connect	Other
	(**14.**)												

Notes

Key to Matrix:
1. Generic name
2. Make and model number
3. Refer to appropriate figure
4. Original manufacturer of this item
5. Refer to call out on applicable schematic
6. Source of service
7. Exhaust content (i.e., acid, solvent, heat process); refer to effluent data sheet if applicable
8. Process cooling water (PCW), high-purity water (DI)
9. Regulator required at the equipment
10. Material fitting made of (Cu, PVC, etc.)
11. Minimum filtration required. Particle size, nom/absolute, efficiency
12. Required drains (liquid)
13. This section includes both wafer handling vacuum and process vacuum (tool-to-vacuum pumps)
14. Chemical by trade and formula

Table 5 Equipment Effluent Data Sheet

Equipment Manufacturer/Model Number:						Date:	
System Component Description						Prepared by:	
Equipment Process Recipe Description							
Wafers/Cycle:							
INPUT CHEMICAL (GAS/LIQUID)			Chemical 1	Chemical 2	Chemical 3	Chemical 4	Chemical 5
Equipment Point of Connection # (see diagram below)			1	2	3	4	5
Process Step	Step Duration						
Step 1	(min.)	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM
Step 2	(min.)	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM
Step 3	(min.)	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM
Step 4	(min.)	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM
Step 5	(min.)	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM
Totals per Cycle	(min.)		SCCM	SCCM	SCCM	SCCM	SCCM
EFFLUENT CHEMICALS (GAS/LIQUID)		Chem. A	Chem. B	Chem. C	Chem. D	Chem. E	Chem. F
Equipment Point of Connection (see diagram below)		6	7	8	9	(X)	(X)

Process Step							
Step 1	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
Step 2	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
Step 3	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
Step 4	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
Step 5	Estimated total flow per step	SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
Total Effluent for Cycle (each chemical)		SCCM	SCCM	SCCM	SCCM	SCCM	SCCM
EMISSIONS PER WAFER		SCC/Wafer	SCC/Wafer	SCC/Wafer	SCC/Wafer	SCC/Wafer	SCC/Wafer

1. Indicate chemical by chemical formula and written name.
2. Specify estimated (E) or actual (A) measurements.

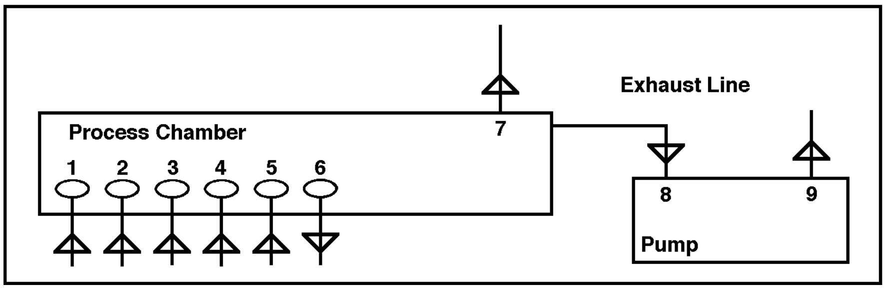

Table 6 Equipment Data Base Units

Item	*International Units*	*American Units*
Physical Properties		
Distance	mm	in.
Weight	kg	lb.
Temperature	°C	°F
Heat	Watts	Btu/Hr
Exhaust		
Size	mm	in.
Pressure	mm	in. of H_2O
Flow	NM^3-H	SCFM
Fitting Size	mm	in. (nominal)
Liquid		
Pressure	KPA	psig
Temperature	°C	°F
Flow	LPM	GPM
Fitting Size	cm (nominal)	in. (nominal)
Vacuum		
Size	cm (nominal)	in. (nominal)
Pressure	mm of Hg	in. Hg
Flow	SLPM	SCFM
Fitting Size	cm (nominal)	in. (nominal)
Chemical Dispense		
Container Size	liters	gal.
Fitting Size	cm (nominal)	in. (nominal)
Gas		
Pressure	KPA	psig
Flow	LPM or SCCM	SCFM or SCCM
Fitting Size	cm (nominal)	in. (nominal)
Liquid Source		
Pressure	KPA	psig
Flow	LPM or SCCM	GPM or SCCM
Fitting Size	cm (nominal)	in. (nominal)

7.4.3 *Equipment Facilitization Drawings*

7.4.3.1 *Instructions for Equipment Facilitization Drawings* — As a minimum, the overall dimensions and clearances of equipment are to be provided. These should include: plan and elevation drawings that show connection locations, and minimum, maximum, and typical interconnect distances.

Table-mounted equipment must indicate the minimum table size and structural requirement.

A system interconnect schematic is required for any equipment that consists of more than one item.

A facilities interface matrix should be included, following the format in this guideline. For complex equipment, it is recommended that a summary matrix be included first, followed by an extended matrix for each component. As with other sections of this document, it is recommended that the extended matrix list items “not applicable” (N/A) so the facilities provider will know that these subjects were considered by the equipment supplier.

Information should be provided on all minimum/maximum distance limitations of the equipment to other equipment, sources of chemicals, and auxiliary equipment. Insert equipment drawings here and provide table of distance parameters.

Table 7 Drawing Checklist

Hard Copy	*Soft Copy and Format*	*Included Drawings*
		Legends and symbols
		Plan views with maintenance and electrical clearances and operator access
		Plan and elevation views, including: Front, side, and top views Height, width, and depth dimensions Centerline dimensions for all facilities connections Isometric view(s)
		Captioned photos
		Floor-loading diagram showing: Weight load on each contact point to the floor Dimensions of support mechanism that contacts floor Center of gravity location
		Receptacle or terminal strip connections (to be included when user is required to make connections)
		Through-the-wall mounting drawings: Dimensions for cutout size Cross-sectional top view Assembly drawings when applicable
		External piping and instrument drawings (P&ID) included? If yes, see Table 4.
		Internal P&ID included? If yes, see Table 4.

7.5 *Shipping and Receiving Requirements*

7.5.1 *Instructions for Shipping and Receiving Requirements* — Suppliers should include information about the type and number of containers in which this equipment is shipped and how they are to be handled and stored. This should include clearances for oversize equipment, special staging and uncrating or preparation areas, etc. In addition, any special receiving information should be noted. This is especially important for sensitive equipment or if supplier involvement is required. If containers cannot be unloaded by hand, please state the equipment needed.

7.5.2 *Sample for Shipping and Receiving Requirements*

Number of Containers:___________

Table 8 Shipping and Receiving Requirements

Container #	*Dimensions (L x W x H) (units)*	*Weight (units)*	*Impact Monitor*	*Tilt Monitor*

Impact monitors, if included, will have a maximum of ___________G's.

The following equipment will be required to unload:

Equipment can/must be stored as follows:

___________Outside

___________In a store room

___________Out of weather in a dry location

___________Moved to a cleanroom on arrival

Temperature range ___________to___________°C (___________to___________°F) Temperature

Humidity range ___________to___________%

Dimension of largest piece to move:________________________________

Weight of largest piece to move into the cleanroom________________________________

Special receiving instructions:________________________________

7.6 *Installation Requirements*

7.6.1 *Instructions for Installation Requirements* — Consider every step from receiving to final hookup. The installation process usually includes the need for tools, transportation equipment, and personnel (quantity, duration, and skills). All requirements should be indicated so their availability will be assured.

During the assembly and installation, the following provisions will be required:

7.6.2 *Sample for Transport and Locating Equipment*

____

____

7.6.3 *Sample for Assembly and Hookup Tools and Equipment*

____

____

7.7 *Start-Up Requirements*

7.7.1 *Instructions for Start-Up Requirements* — Consider every step from initial powerup to release for acceptance test. The startup process usually includes the need for tools, measurement equipment, and personnel (quantity, skills, and expected duration). All requirements should be indicated so their availability will be assured. In addition, for some equipment, it may be necessary to use materials (such as wafers) and supplies during startup. The supplier should indicate the type, quantity, and specifications of any materials needed.

It may also be necessary to use special measurement or analytical instruments to test performance of equipment or sample product produced. Requirements for these should also be stated.

If the supplier supplies separate start-up documentation, or if the supplier is responsible for start-up, this should be referenced.

7.7.2 *Sample for Equipment*

____

____

7.7.3 *Sample for Material*

____

____

7.7.4 *Sample for Personnel*

____

____

7.8 *Acceptance Test*

7.8.1 *Instructions for Acceptance Test* — Suppliers should indicate if acceptance testing will be required, what tests will be required and provide an estimate of the duration of the acceptance tests. It is especially important to indicate if any tests or inspection of the facility will be required prior to the installation or start-up of the equipment.

7.8.2 *Sample for Acceptance Test* — Tests will be performed to demonstrate that the facilities meet requirements.

__________Yes___________No

The following tests will be required:

____

____

Tests will be performed to demonstrate that the equipment meets requirements.

__________Yes___________No

The following tests will be required:

____

____

7.9 *Training*

7.9.1 *Instructions for Training* — Please indicate if any special training is required to install or operate the machine. It is especially important to indicate if any training is required for the installation process. If required, indicate whether this is part of the system deliverables, or is the responsibility of the customer.

If the supplier supplies separate training documentation, or if the supplier is responsible for training, this should be referenced.

7.9.2 *Sample for Training*

Special training will be required.

__________Yes___________No

User's personnel are required to be trained in the following as a prerequisite to supplier-supplied training and prior to operation, use, or maintenance of the equipment:

____

____

Supplier will provide the following training at:

__________Supplier's site:

__________User's site:

7.10 *Addenda*

7.10.1 *Instructions for Addenda* — The addenda is to contain all additional information requested by customer or deemed necessary by supplier. It is necessary to convey the facilities interface needs of the equipment. List and cover only the items necessary. It is the responsibility of the equipment supplier to determine the requirements to be covered. The application notes to this guideline contain an initial checklist of addendum topics and, for selected topics, examples of how information may be presented.

8 Addendum Topics

Following is a checklist of topics that should be considered for inclusion in the addenda. The equipment supplier may add addenda as necessary.

8.1 *Topics without Examples Provided in this Document*

- Process gas purity (refer to SEMI C3 and related standards)
- Supplier-supplied interconnecting cables and lines
- Special utilities requirements (water, compressed air, other support liquids, waste drains — traps, trap liquid height)
- Electromagnetic requirements (safety, shielding)
- Ionizing radiation requirements (safety, shielding)

8.2 *Topics with Examples* — For selected addendum topics, the following samples and information are provided.

8.2.1 *Addendum A, Computer Interface* — If the equipment has provision and capability for communication with a host computer, provide the information and applicable documentation requested below.

Communication Interface

___________Serial interface

___________This equipment complies with SEMI E4 (SEMI Equipment Communications Standard 1 Message Transfer (SECS I)). Attach the documentation requested in Section 9 of SEMI E4.

___________This equipment complies with SEMI E37 and E37.1, High-Speed SECS Message Services, Single Session (HSMS-SS). Specify the physical network (e.g. Ethernet) and required cabling (e.g. 10-Base-T) in the following Network section.

___________Network. Specify by reference to a published standard. Include physical link and protocol.

___________Other. Specify by reference to a published standard. Include the physical link and protocol.

Message Content

___________This equipment complies with SEMI E5 (SEMI Equipment Communications Standard 2 Message Content (SECS II)).

___________Message sequences conform to the recommendations of SEMI E30

The following capabilities scenarios are implemented on this equipment:

___________establish communications

___________data collection

___________alarm management

___________remote control

___________process program management

___________material movement

___________equipment terminal services

___________error messages

___________clock

___________spooling

___________log file

___________Additional, or other, messages are implemented. Attach message documentation requested in Section 8 of SEMI E5. If process programs are unformatted (per the definition of SEMI E5), attach documentation defining the format of the program.

8.2.2 *Addendum B, Vacuum Requirements* — This equipment requires installation of a vacuum pump at some distance from the system. The equipment is designed to achieve its required performance with a pump and vacuum line capable of the following flow(s) and pressure levels at the connection port to the equipment:

These levels can be achieved with the following specified pump and line sizing (specify number of elbows and other restrictions):

____

____

Because the vacuum pump and its installation are critical elements in the proper performance of this equipment, any deviation from the above should be designed in consultation with the supplier.

The vacuum pump must be prepared for chemical service as follows:

____

____

An interlock or alarm signal indicating pump failure is required at the equipment. Details on contact rating and connector are provided:

____

____

8.2.3 *Addendum C, Electrical Requirements*

__________This equipment complies with SEMI E7 (Specification for Electrical Interfaces for the U.S. Only).

__________This equipment requires special electrical connectors. List the special plug and/or receptacle requirements.

__________This equipment requires AC power line conditioning. List the power purity requirements and wattage.

__________This equipment requires UPS. List the required capacity (watts and time) and response specifications. List any suggested supplier whose equipment will meet the specifications.

__________This equipment has other special electrical requirements. List and specify.

8.2.4 *Addendum D, Vibration Requirements*

Vibration Criterion Checklist

This checklist summarizes the information needed for a sensitive equipment vibration criterion to be properly defined.

I. Analysis methodology

A. If time domain analysis is to be used, use:

1. Frequency range __________Hz to__________Hz

[ ] acceleration, [ ] velocity

[ ] displacement

2. Allowable amplitude

[ ] peak-to-peak, [ ] 0-peak,

[ ] RMS value.

B. If frequency domain analysis is to be used, use:

1. [ ] 1/3 octave analysis, with second filter time constant

2. [ ] constant bandwidth analysis with a frequency resolution of __________Hz

3. [ ] linear averaging

[ ] exponential averaging

[ ] peak hold averaging

4. Allowable amplitudes

Provide a plot of allowable amplitude as a function of frequency. Amplitude is given in terms of:

[ ] peak-to-peak

[ ] 0-peak

[ ] RMS value

Equipment manufacturer:____

Equipment model number:____

Equipment use (e.g., microscope, stepper, etc.):____

Person to contact for questions:____

Phone number: (_____)______-_______

II. Plot of vibration criteria

The following plot of generic vibration criteria for sensitive equipment in buildings shows velocity vs. frequency, using 1/3 octave analysis.

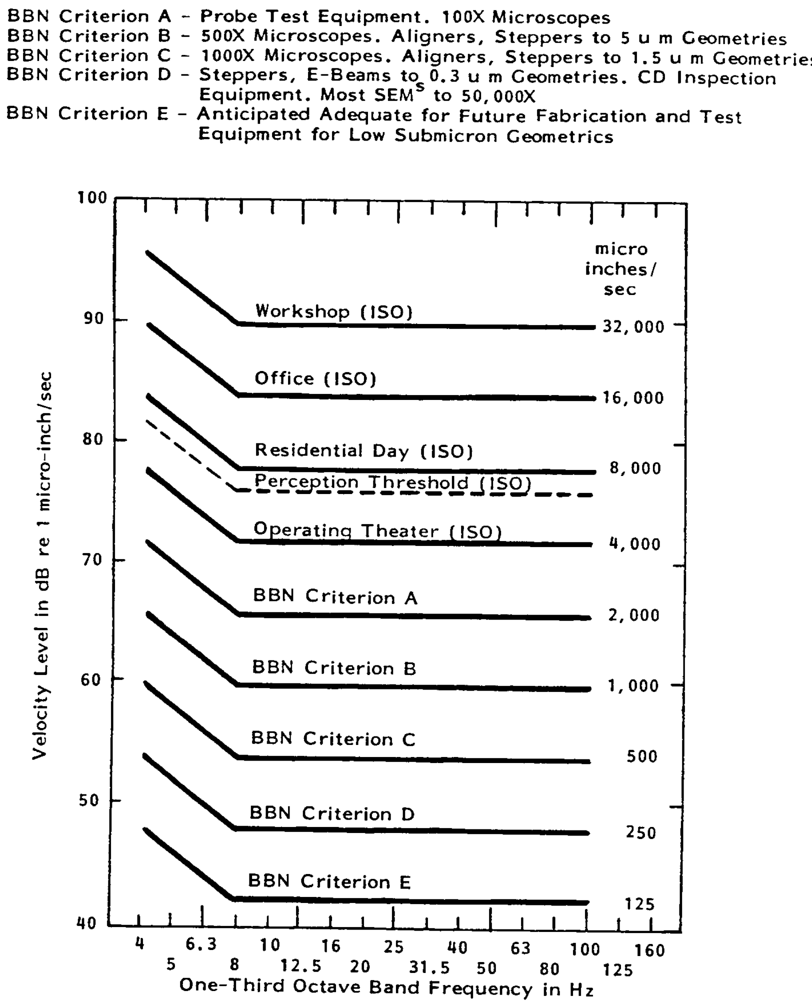

Figure 2
Floor Vibration Criterion for Equipment Used in the Production of Integrated Circuits
(Other Curves Represent Criteria Recommended by International Standards Organization)

8.2.5 *Addendum E, Floor Loading*

No.	Type	No. Places	Weight Each	Remarks
1	2" ϕ Foot	5	310 LBS	
2	6" ϕ Foot	2	1120 LBS	
3	18" × 24" Pad	1	2100 LBS	
Total Weight			5890 LBS	

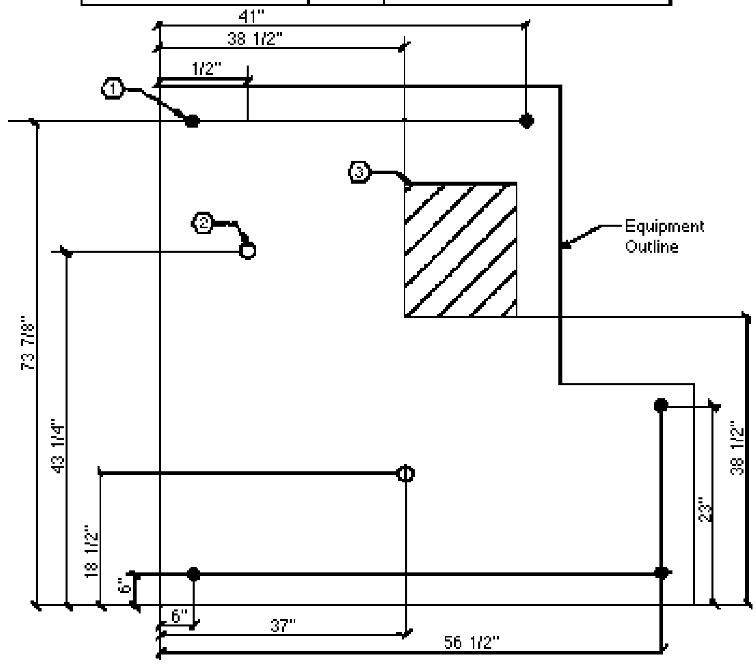

Figure 3
Sample Floor Loading Diagram

8.2.6 *Addendum F, Wafer Handling*

Wafer Size

This equipment, as delivered, is configured to handle_______mm wafers. It is capable of processing wafers of other sizes as follows:

Table 9 Wafer Size

Wafer Size	*As Delivered*	*By Adjusting Installed Parts*	*By Replacing Installed Parts*	*Supplier Must Modify*
3 inch				
100 mm				
125 mm				
150 mm				
200 mm				
___mm				

Wafer Interface

________________Wafers are inserted manually, one at a time, into this equipment.

________________This equipment is provided with a single-wafer transport mechanism and port in compliance with SEMI E8 (Specification for Wafer Transport Systems: Interface Coordinates). Show datum point and locations of input and output port centerlines on the equipment facilitization drawings. See Section 7.4.3.

________________Wafers are inserted into this equipment in wafer carriers (cassettes). Provide the information requested in the sections below.

Wafer Carriers Accommodated

________________This equipment, as delivered, is capable of accepting wafers delivered in SEMI standard carriers (cassettes) conforming to the following:

Table 10 Wafer Carriers

Wafer Size	*As Delivered*	*By Adjusting Installed Parts*	*By Replacing Supplied Parts*	*Supplier Must Modify*
3 inch/SEMI E1.1				
100 mm/SEMI E1.2				
125 mm/SEMI E1.3				
125 mm/SEMI E1.4				
150 mm/SEMI E1.5				
200 mm/SEMI E1.7				
___mm				

________________This equipment requires special wafer carriers:

______________________supplied with the equipment

______________________other — provide name of supplier and specification

Wafer Carrier Interface

Carriers are placed on the receiving platform in the following orientation:

________________wafers horizontal ________________degrees tilt

________________wafers vertical ________________degrees tilt

Wafer Alignment

Wafer flat/notch alignment__________is/_________is not required.

Inter-Equipment Material Transport

________________This equipment complies with SEMI E15 (Specification for Inter-Equipment Material Transport Interface), with the following parameters and exceptions:

________________equipment has an enclosed interface (e.g., load lock)

________________equipment allows use of cassettes only

________________equipment allows use of a box conforming to:

______________________SEMI E19 (Standard Mechanical Interface (SMIF))

______________________other — attach specification

________________vertical clearance, C3, is:

_____________________mm (________________inches)

_____________________unrestricted

____________________other exception — describe in detail

8.2.7 *Addendum H, Contractual Language* — Since facility performance and equipment performance-to-specifications are inter-related, a contractual section may be used to ensure that proper performance is achieved.

8.2.7.1 *Equipment Performance* — Performance of the equipment to specifications is based upon its installation in a facility which meets or exceeds the requirements of Exhibit X (the SEMI E6 furnished by the supplier). Accordingly, customer agrees to provide supplier with:

8.2.7.2 A monthly report which details the status of the facility design, construction, and materials in relation to schedule milestones;

8.2.7.3 Certified complete facility drawings, specifications and calculations at least _________days before the start of acceptance testing;

8.2.7.4 Facility supplier materials list, test procedures, and certifications at least _________days before the start of acceptance testing.

8.2.8 *Supplier Inspection* — Customer shall make its facility available for supplier's inspection __________days before the start of acceptance testing. At that time, supplier will verify that the facility meets or exceeds specifications. If the facility fails to meet specifications, supplier may recommend modifications that customer may choose to accept or reject. If customer chooses to reject supplier's recommendations, then customer must waive that portion of the specifications or acceptance criteria that may be affected by the lack of proper facilities as designated by supplier.

8.2.8.1 The determination that customer's facility is deficient will be a joint decision made by supplier and customer. Any re-audit of customer's facility by supplier will be at customer's expense.

8.2.8.2 If customer's facility is determined to be deficient, then the final system progress payment shall be due at supplier's scheduled shipment date for the system. If customer requests installation of the system without re-audit of the facility, customer shall be responsible for supplier's costs associated with failure of the facility to meet specifications.

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SEMI E7-91 (Reapproved 0699)
SPECIFICATION FOR ELECTRICAL INTERFACES FOR THE U.S. ONLY

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org April 1999; to be published June 1999. Originally published 1984, previously published 1991.

For Japan electrical interface requirements, see SEMI E31.

1 Introduction

1.1 *Intent* — The purpose of this standard is to simplify the design and implementation of future semiconductor facilities where both equipment suppliers and users can be assured of the exact electrical interfaces required.

1.2 *Overview* — This standard presents recommendations for the selection of specific electrical power interfaces:

- Service categories by voltage, current and phase for systems, motors, and other electrical loads
- Electrical connectors
- Cordage

1.3 *Applicable Documents and References*

NEMA — National Electrical Manufacturer's Association[1]

NFPA 70-1981 — National Electrical Code, (NEC) National Fire Protection Association[2]

1.4 *Service Categories*

1.4.1 Voltage, current, and phase for motors and other electrical/electronic loads:

1.4.2 *Motors* — (From Article 430-148, 150 of National Electrical Code)

Power	*Recommended Phase & Voltage*	*Recommended Current Range*
Motors 1/6 to 3/4 HP	120V 1Ø 208V 1Ø 230V 1Ø	4.4 to 13.8 AMPs 2.4 to 7.6 AMPs 2.2 to 6.9 AMPs
Motors 3/4 to 5 HP	208V 3Ø 230V 3Ø	3.1 to 16.7 AMPs 2.8 to 15.2 AMPs
Motors 5 HP and Larger	480V 3Ø	7.6 AMPs and up

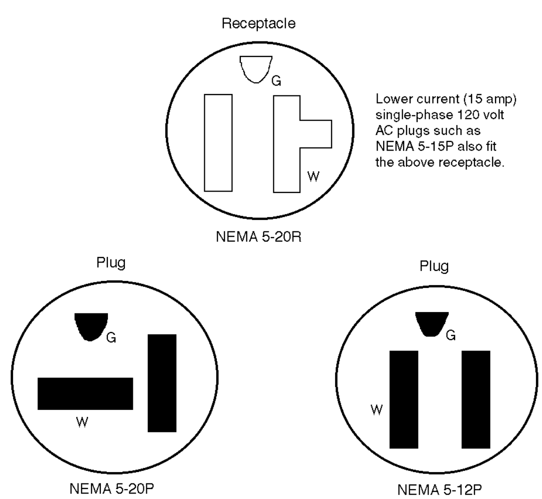
1.4.3 *Other Loads* — (By Calculation)

	Ampere Range for Recommended Volts & Phases			
Power	120V 1Ø	208V 1Ø	208V 3Ø	480V 3Ø
0-3000 Watts	0 to 25 A.	0 to 14 A.	0 to 8 A.	
3000-5000 Watts		14 to 24 A.	8 to 14 A.	
5000-30,000 Watts			13 to 83 A.	
30,000 and Above				36 A. and up

2 Electrical Connectors

2.1 The NEMA types listed below are available in many forms from many manufacturers. For example, the "receptacle" configurations shown also apply to connectors and flanged outlets.

2.1.1 125 Volt, 1Ø, 20 AMPs max., straight blade

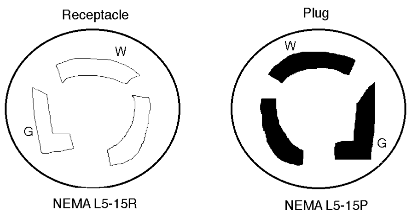


[1] *National Electrical Manufacturer's Association, 2101 "L" Street, N.W., Washington, D.C. 20037*

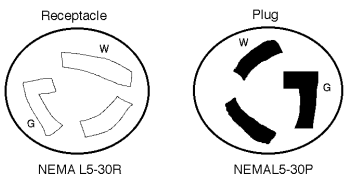
[2] *National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210*

Dead front plugs are preferred.

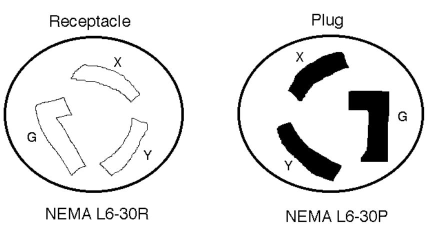
2.1.2 120 Volt, Ø, 30 AMPs max., locking type.



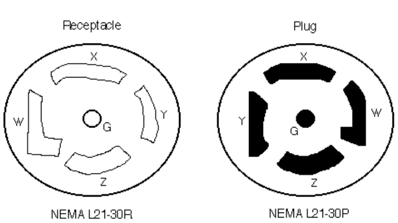
2.1.3 120 Volt, 1Ø, 30 AMPs max., locking blade type.



2.1.4 250 Volt, 1Ø, 30 AMPs max., locking type



2.1.5 120/208 Volt, 3ØY, 30 AMPs max., locking type (4 pole, 5-wire grounding)



2.1.6 Above 10,000 watts, use of connectors is discouraged. Wherever possible, such loads should be wired into junction boxes using appropriate crimped or pressure terminations.

3 Cordage and Cables

3.1 The flexible cord and cable types shown are examples; for more detail see the National Electrical Code.

3.2 The following table gives the allowable ampacity for the specified number of current-carrying copper conductors in a cord.

3.3 Type SO-ST-STO preferred with 600 Volt insulation.

AWG	*#18*	*#16*	*#14*	*#12*	*#10*	*#8*	*#6*	*#4*
2 cond.	10	13	18	25	30	40	55	70
3 cond.	7	10	15	20	25	35	45	60
4 cond.	5.6	8	12	16	20	28	36	48
5 cond.	5.6	8	12	16	20	28	36	48

Flexible Cord and Cable Conductor Color Code

No. Phases	*No. Wires*	*Voltage*	*ØA*	*BØ*	*CØ*	*N*	*Grd*
1	2[c]	120	Blk			Wht[a]	
1	2[c]	208	Blk	Red			
1	3	120	Blk			Wht[a]	Green[b]
1	3	208	Blk	Red			Green[b]
1	4	208/480	Blk	Red		Wht[a]	Green[b]
3	4	208/480	Blk	Red	Orange		Green[b]
3	5	208/480	Blk	Red	Orange	Wht[a]	Green[b]

Notes

a. Natural Grey or Light Blue may be used. Under no circumstances may White, Natural Grey or Light Blue be used for any purpose other than to identify neutral or rounded conductors.

b. Green/Yellow may be used. Green/Yellow will be Green with one or more Yellow stripes (Green = 50 to 70%; Yellow = 50 to 30%). Green/Yellow is the only color internationally accepted for use as an equipment grounding conductor. Under no circumstances may Green/Yellow, Green or Yellow be used for any purpose other than to identify grounding conductors.

c. For double insulated machines only.

4 Additional References

4.1 The following are sources of further information concerning electrical interfaces:

Electrical Industries Association (EIA), 2001 I Street, N.W., Washington, DC 20006

Joint Industrial Council (JlC), 7901 Westpark Dr., McLean, VA 22101

Western Electric Co., Inc. (WECO), "Standards for Electrical Design and Construction," Drawing #C-284805, Machine Design Dept., Allentown Works, Allentown, PA 18103

Occupational Safety & Health Administration, Standards (OSHA) Part 1910, Title 29, Code of Federal Regulations, Dated 7 Nov. 1978, Dept. of Labor, Washington, DC

Underwriter's Laboratories, Inc. (UL), 207 E. Ohio St., Chicago, IL 60611

IBM Corporate Bulletin, "Nonproduct Equipment Design Standard," "CB 3-0502-202 Support Equipment Standard," 1983-05, or succession thereto

American National Standards Institute, C73.73, American National Standards Institute, 1430 Broadway, New York, NY 10018

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SEMI E10-0701
SPECIFICATION FOR DEFINITION AND MEASUREMENT OF EQUIPMENT RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM)

This standard was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1986; previously published March 2001.

1 Purpose

1.1 This document establishes a common basis for communication between users and suppliers of semiconductor manufacturing equipment by providing standards for measuring RAM performance of that equipment in a manufacturing environment.

2 Scope

2.1 The document defines six basic equipment states into which all equipment conditions and periods of time must fall. The equipment states are determined by functional issues, independent of who performs the function. The measurement of equipment reliability in this specification concentrates on the relationship of equipment failures to equipment usage, rather than the relationship of failures to total elapsed time.

2.2 Section 5 (Equipment States) defines how equipment time is categorized. Section 6 (RAM Measurement) defines formulas for measurement of equipment performance. Section 7 (Uncertainty Measurement) gives additional methods for evaluating the statistical significance of calculated performance metrics.

2.3 Effective application of this specification requires that equipment performance (RAM) be tracked with regard to time and/or equipment cycles. Automated tracking of equipment states is not within the scope of this specification, but is covered by SEMI E58. Clear and effective communication among users and suppliers promotes continuous improvement in equipment performance.

2.4 The RAM indices in this specification may be applied directly to non-cluster tools at the whole equipment and sub-system levels. The RAM indices may be applied at the sub-system level (e.g., process module) for multi-path cluster tools.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *availability* — the probability that the equipment will be in a condition to perform its intended function when required.

4.2 *cluster tool* — a manufacturing system made up of integrated processing modules mechanically linked together (the modules may or may not come from the same supplier).

4.2.1 *single path cluster tool* — a cluster tool with only one process flow path (as used).

4.2.2 *multi-path cluster tool* — a cluster tool with more than one independent process flow path (e.g., multiple load ports/load-locks, multiple process chambers of the same type) and used as such.

4.3 *cycle* — one complete operational sequence (including unit load and unload) of processing, manufacturing, or testing steps for an equipment system or subsystem. In single unit processing systems, the number of cycles equals the number of units processed. In batch systems, the number of cycles equals the number of batches processed.

4.4 *downtime (DT)* — the time when the equipment is not in a condition, or is not available, to perform its intended function. It does not include any portion of non-scheduled time.

4.5 *downtime event* — a detectable occurrence significant to the equipment that causes the equipment to go from an uptime state to either a scheduled or an unscheduled downtime state.

4.6 *failure* — any unscheduled downtime event that changes the equipment to a condition where it cannot perform its intended function. Any part failure, software or process recipe problem, facility or utility supply malfunction, or human error could cause the failure.

NOTE 2: It is important to categorize and qualify failures in ways that facilitate the resolution of problems and improve overall equipment performance. Use of this specification requires agreement between supplier and user on categorizing failures.

4.6.1 *equipment-related failure* — any unplanned event that changes the equipment to a condition where it cannot perform its intended function solely caused by the equipment.

4.7 *host* — the intelligent system that communicates with the equipment, acts as a supervisory agent, and represents the factory and the user to the equipment.

4.8 *intended function* — a manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment and measurement functions for metrology equipment, as well as process functions such as physical vapor deposition and wire bonding. Complex equipment may have more than one intended function.

4.9 *maintainability* — the probability that the equipment will be retained in, or restored to, a condition where it can perform its intended function within a specified period of time.

4.10 *maintenance* — the act of sustaining equipment in or restoring it to a condition to perform its intended function. In this document, maintenance refers to function, not organization; it includes adjustments, change of consumables, software upgrades, repair, preventive maintenance, etc., no matter who performs the task.

4.11 *manufacturing time* — the sum of productive time and standby time.

4.12 *non-scheduled time* — the time when the equipment is not scheduled to be utilized in production.

4.13 *operations time (oper-time)* — total time minus non-scheduled time.

4.14 *operator* — any person who communicates locally with the equipment through the equipment's control panel.

4.15 *product* — units produced during productive time (see unit).

4.16 *ramp-down* — the portion of a maintenance procedure required to prepare the equipment for hands-on work. It includes purging, cool-down, warm-up, software backup, storing dynamic values (e.g., parameters, recipes), etc. Ramp-down is only included in scheduled and unscheduled downtime.

4.17 *ramp-up* — the portion of a maintenance procedure required, after the hands-on work is completed, to return the equipment to a condition where it can perform its intended function. It includes pump down, warm-up, stabilization periods, initialization routines, software load, restoring dynamic values (e.g., parameters, recipes), control system reboot, etc. It does not include equipment or process test time. Ramp-up is only included in scheduled and unscheduled downtime.

4.18 *reliability* — the probability that the equipment will perform its intended function, within stated conditions, for a specified period of time

4.19 *shutdown* — the time required to put the equipment in a safe condition when entering a non-scheduled state. It includes any procedures necessary to reach a safe condition. Shutdown is only included in non-scheduled time.

4.20 *specification (equipment operation)* — the documented set of intended functions within stated conditions for equipment operation as agreed upon between user and supplier.

4.21 *start-up* — the time required for equipment to achieve a condition where it can perform its intended function, when leaving a non-scheduled state. It includes pump down, warm-up, cool-down, stabilization periods, initialization routines, software load, restoring dynamic values (e.g., parameters, recipes), control system reboot, etc. Start-up is only included in non-scheduled time.

4.22 *support tool* — a tool that, although not part of a piece of equipment, is required by and becomes integral with it during the course of normal operation (e.g., cassettes, wafer carriers, probe cards, computerized controllers/monitors).

4.23 *total time* — all time (at the rate of 24 hrs/day, 7 days/week) during the period being measured. In order to have a valid representation of total time, all six basic equipment states must be accounted for and tracked accurately.

4.24 *training (off-line)* — the instruction of personnel in the operation and/or maintenance of equipment done outside of operations time. Off-line training is only included in non-scheduled time.

4.25 *training (on-the-job)* — the instruction of personnel in the operation and/or maintenance of equipment done during the course of normal work functions. On-the-job training typically does not interrupt operation or maintenance activities and can therefore be included in any equipment state (except standby and non-scheduled) without special categorization.

4.26 *unit* — any wafer, substrate, die, packaged die, or piece part thereof.

4.27 *uptime* — the time when the equipment is in a condition to perform its intended function. It includes productive, standby, and engineering time, and does not include any portion of non-scheduled time.

4.28 *user* — any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment's view point, both the operator and the host represent the user.

4.29 *utilization* — the percent of time the equipment is performing its intended function during a specified time period.

4.30 *verification run* — a single cycle of the equipment (using units or no units) used to establish that it is performing its intended function within specifications.

5 Equipment States

5.1 To clearly measure equipment performance (RAM), this document defines six basic equipment states into which all equipment conditions and periods of time must fall.

5.2 The equipment states are determined by function, not by organization. Any given maintenance procedure, for example, is classified the same way no matter who performs it, an operator, a production technician, a maintenance technician, or a process engineer.

5.3 Figure 1 is a stack chart of the six basic equipment states. These basic equipment states can be divided into as many sub-states as are required to achieve the equipment tracking resolution that a manufacturing operation desires. SEMI E10 makes no attempt to list all possible sub-states, but does give some examples for guidance.

5.4 Key blocks of time associated with the basic states and example substates are given in Figure 2. These blocks of time are used in the RAM equations given later in this document. The blocks of time associated with the basic states and example substates are described in the following sections.

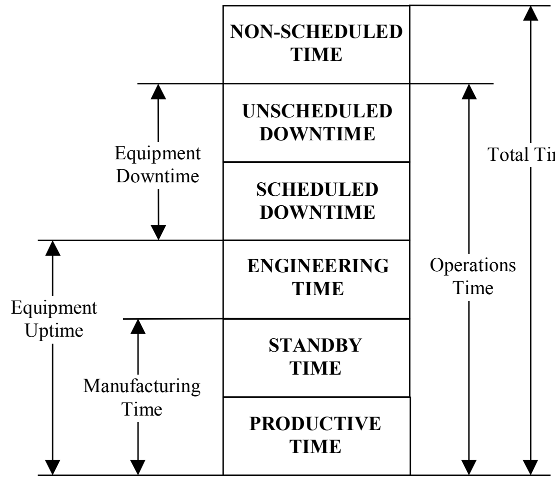

Figure 1
Equipment States Stack Chart

5.5 *PRODUCTIVE STATE* — The time (productive time) when the equipment is performing its intended function. The productive state includes:

- Regular production (including loading and unloading of units)
- Work for third parties
- Rework
- Engineering runs done in conjunction with production units (e.g., split lots and new applications)

5.6 *STANDBY STATE* — The time (standby time), other than non-scheduled time, when the equipment is in a condition to perform its intended function, chemicals and facilities are available, but it is not operated. The standby state includes:

- No operator available (including breaks, lunches, and meetings)
- No units available (including no units due to lack of available support equipment, such as metrology tools)
- No support tools (e.g., cassettes, wafer carriers, probe cards)
- No input from external automation systems (i.e., host)

5.7 *ENGINEERING STATE* — The time (engineering time) when the equipment is in a condition to perform its intended function (no equipment or process problems exist), but is operated to conduct engineering experiments. The engineering state includes:

- Process engineering (e.g., process characterization)
- Equipment engineering (e.g., equipment evaluation)
- Software engineering (e.g., software qualification)

5.8 *SCHEDULED DOWNTIME STATE* — The time (scheduled downtime) when the equipment is not available to perform its intended function due to planned downtime events. The scheduled downtime state includes:

- Maintenance delay (maint-delay)
- Production test
- Preventive maintenance
- Change of consumables/chemicals
- Setup
- Facilities related (fac-rel)

5.8.1 *Maintenance Delay* — The time (maint-delay downtime) during which the equipment cannot perform its intended function because it is waiting for either user or supplier personnel or parts (including consumables/chemicals) associated with maintenance. Maintenance delay may also be due to an administrative decision to leave the equipment down and postpone maintenance.

5.8.1.1 Maintenance delays may occur at any point in the maintenance process. These maintenance delay downtimes must be tracked separately from maintenance time. Delay downtime is included in time off-line, but not in time to repair (see Sections 6.3 and 6.4 Equipment Availability and Maintainability).

5.8.2 *Production Test* — The time (production test downtime) for the planned interruption of equipment availability for evaluation of units, as defined in the specifications of equipment operation, to confirm that the equipment is performing its intended function within specifications. It does not include testing that can be done in parallel with, or transparent to, the running of production, nor does it include any testing done following a preventive maintenance, setup, or repair procedure.

5.8.3 *Preventive Maintenance* — The sum of the times (preventive maintenance downtimes) for:

- Preventive action: A predefined maintenance procedure (including equipment ramp-down and ramp-up), at scheduled intervals, designed to reduce the likelihood of equipment failure during operation. Scheduled intervals may be based upon time, equipment cycles, or equipment conditions.
- Equipment test: The operation of equipment to demonstrate equipment functionality; (e.g., system reaches base pressure, wafers transfer without problem, gas flow is correct, plasma ignites, source reaches specified power).
- Verification run: The processing and evaluation of units after preventive action to establish that the equipment is performing its intended function within specifications.

NOTE 3: Equipment suppliers are responsible for specifying a preventive maintenance program to achieve a predetermined equipment performance level. Users are obligated to identify any deviation from the recommended program if they expect the supplier to meet or improve that performance level.

5.8.4 *Change of Consumables/Chemicals* — The time (change of consumables/chemicals downtime) for the scheduled interruption of operation to replenish the raw materials of semiconductor processing. It includes changes of gas bottles, acids, targets, sources, etc., and any purging, cleaning, or flushing normally associated with those changes. It does not include delays in obtaining those consumables/chemicals.

5.8.5 *Setup* — The sum of the times (setup downtimes) for:

- Conversion: The time required to complete an equipment alteration necessary to accommodate a change in process, unit, package configuration, etc. (excluding modifications, rebuilds, and upgrades).
- Equipment test: The operation of equipment to demonstrate equipment functionality; (e.g., system reaches base pressure, wafers transfer without problem, gas flow is correct, plasma ignites, source reaches specified power).
- Verification run: The processing and evaluation of units after conversion to establish that equipment is performing its intended function within specifications.

NOTE 4: Equipment suppliers are responsible for providing procedures which achieve setup conversion and testing within predetermined specifications. Users are obligated to identify any deviation from the procedures if they expect the supplier to make setups fall within those specifications.

5.8.6 *Facilities Related* — The time (facilities-related downtime) when the equipment cannot perform its intended function solely as a result of out of specification facilities. Those facilities include:

- Environmental (e.g., temperature, humidity, vibration, particle count)
- House hookups (e.g., power, cooling water, house gases, exhaust, LN2)

- Communications links with other equipment or host computers

5.8.6.1 Any downtime created by the items listed above shall be included in facilities-related downtime. For example, if, as a result of a scheduled 15-minute power outage an otherwise unnecessary cryo pump regeneration is needed, all time required to return the equipment to a condition where it can perform its intended function is included in facilities-related downtime.

5.9 *UNSCHEDULED DOWNTIME STATE* — The time (unscheduled downtime) when the equipment is not in a condition to perform its intended function due to unplanned downtime events:

- Maintenance delay (maint-delay)
- Repair
- Change of consumables/chemicals
- Out-of-spec input
- Facilities related (fac-rel)

5.9.1 *Maintenance Delay* — The time (maint-delay downtime) during which the equipment cannot perform its intended function because it is waiting for either user or supplier personnel or parts (including consumables/chemicals) associated with maintenance. Maintenance delay may also be due to an administrative decision to leave the equipment down and postpone maintenance.

5.9.1.1 Maintenance delays may occur at any point in the maintenance process. These maintenance delay downtimes should be tracked separately from maintenance time. Delay downtime is included in time off-line, but not in maintenance time (see Sections 6.3 and 6.4 Equipment Availability and Maintainability).

5.9.2 *Repair* — The sum of the times (repair downtimes) for:

- Diagnosis: The procedure of identifying the source of an equipment problem or failure.
- Corrective action: The maintenance procedure (including equipment ramp-down and ramp-up, re-booting, resetting, recycling, restarting, reverting to a previous software version, etc.) employed to address an equipment failure and return the equipment to a condition where it can perform its intended function.
- Equipment test: The operation of equipment to demonstrate equipment functionality (e.g., system reaches base pressure, wafers transfer without problem, gas flow is correct, plasma ignites, source reaches specified power).
- Verification run: The processing and evaluation of units after corrective action to establish that the equipment is performing its intended function within specifications.

5.9.3 *Change of Consumables/Chemicals* — The time (change of consumables/chemicals downtime) for the unscheduled interruption of operation to replenish the raw materials of semiconductor processing. It includes changes of gas bottles, acids, targets, sources, etc., and any purging, cleaning, or flushing normally associated with those changes. It does not include delays in obtaining these consumables/chemicals.

5.9.4 *Out-of-Spec Input* — The time (out-of-spec input downtime) when the equipment cannot perform its intended function solely as a result of problems created by out-of-specification or faulty inputs. Those inputs include:

- Support tools (e.g., warped cassettes or wafer carriers, faulty probe cards, reticles)
- Unit (e.g., upstream process problems, warped wafers, contaminated wafers, warped lead frames)
- Test data (e.g., metrology tool out of calibration, misread charts, erroneous data interpretation/entry)
- Consumables/chemicals (e.g., contaminated acid, leaky target bond, degraded photo resist, degraded mold compound)

5.9.4.1 Any downtime created by the items listed above shall be included in out-of-specification input downtime. For example, if, as a result of an intermittent probe card short, a prober/tester system is put down for repair, all downtime incurred prior to identifying the problem is re-categorized as out-of-specification input downtime.

5.9.5 *Facilities Related* — The time (facilities-related downtime) when the equipment cannot perform its intended function solely as a result of out-of-specification facilities. Those facilities include:

- Environmental (e.g., temperature, humidity, vibration, particle count)
- House hookups (e.g., power, cooling water, house gases, exhaust, LN2)
- Communications links with other equipment or host computers

5.9.5.1 Any downtime created by the items listed above shall be included in facilities-related downtime. For example, if, as a result of an unscheduled 15-minute power outage, an otherwise unnecessary cryo pump regeneration is needed, all time required to return the equipment to a condition where it can perform its intended function is included in facilities-related downtime.

5.10 *NON-SCHEDULED STATE* — The time (non-scheduled time) when the equipment is not scheduled to be utilized in production, such as unworked shifts, weekends, and holidays (including shutdown and start-up).

5.10.1 If equipment is out of the production plan due to off-line training or an installation, modification, rebuild, or upgrade (hardware or software) that cannot be accommodated by the regular preventive maintenance schedule, its status is the non-scheduled state. This includes any qualification time required to bring the equipment to a condition where it can perform its intended function from one of these states.

5.10.2 Any maintenance done to equipment during these periods cannot be counted in the non-scheduled state, since all maintenance must fall into either scheduled or unscheduled downtime (this includes automatic maintenance routines such as a programmed cryo pump regeneration).

5.10.3 By the same convention, any production or engineering work done during these periods must fall into either productive or engineering time (this includes an unattended operation that may shut itself off "after hours").

6 RAM Measurement

6.1 Reliability, availability, and maintainability are measures of equipment performance which have been used widely in industry for decades. This section defines them for the semiconductor industry in a manner that is consistent with existing industrial standards. Along with the definitions for RAM are given indicators by which these measures can be quantified.

6.2 *EQUIPMENT RELIABILITY* — The probability that the equipment will perform its intended function, within stated conditions, for a specified period of time.

NOTE 5: Two different methods of measuring this are presented, productive time (Sections 6.2.1 and 6.2.2) and equipment cycles (Sections 6.2.3 and 6.2.4):

- Productive time only considers what happens while making units (useful for manufacturing operation purposes).
- Equipment cycles take into account the wear and tear created by every machine cycle during all equipment states (useful for equipment reliability purposes).

6.2.1 $MTBF_p$ — Mean (productive) time between failures; the average time the equipment performed its intended function between failures; productive time divided by the number of failures during that time. Only productive time is included in this calculation. Failures that occur when an attempt is made to change from any state to a productive state are included in this calculation. Using $MTBF_p$, therefore, requires that the user not only have the capability of capturing failure information, but also tracking and categorizing total time accurately.

$$MTBF_p = \frac{\textit{productive time}}{\textit{\# of failures that occur during productive time}}$$

6.2.2 $E\text{-}MTBF_p$ — Mean (productive) time between equipment-related failures; the average time the equipment performed its intended function between these equipment-related failures; productive time divided by the number of equipment-related failures during that time. Only productive time is included in this calculation. Equipment-related failures that occur when an attempt is made to change from any state to a productive state are included in this calculation. Using $E\text{-}MTBF_p$, therefore, requires that the user not only have the capability of capturing failure information, but also tracking and categorizing total time and the root causes of failures accurately.

$$E\text{–}MTBF_p = \frac{\textit{productive time}}{\textit{\# of equipment-related failures that occur during productive time}}$$

6.2.3 *MCBF* — Mean cycles between failures; the average number of equipment cycles between failures; total equipment cycles divided by the number of failures during those cycles. This calculation transcends equipment states to include all cycles that the system, or subsystem, being considered experiences. It does not require tracking equipment states, only equipment cycles and equipment failures.

$$MCBF = \frac{\textit{total equipment cycles}}{\textit{\# of failures}}$$

6.2.4 *E-MCBF* — Mean cycles between equipment-related failures; the average number of equipment cycles between these equipment-related failures; total equipment cycles divided by the number of equipment-related failures during those cycles. This calculation transcends equipment states to include all cycles that the system, or subsystem, being considered experiences. It does not require tracking equipment states, only equipment cycles and equipment-related failures and their root causes.

$$E\text{–}MCBF = \frac{\textit{total equipment cycles}}{\textit{\# of equipment-related failures}}$$

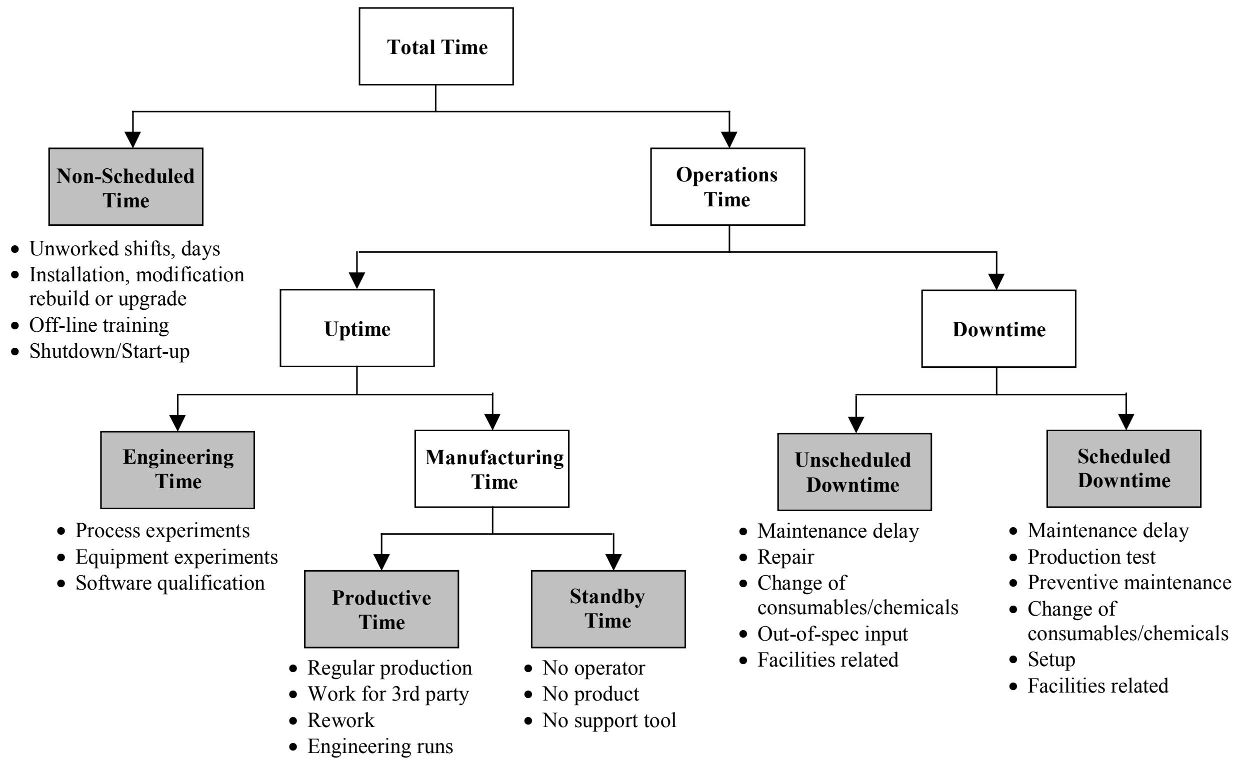

Figure 2
SEMI E10 Summary of Time

6.3 *EQUIPMENT AVAILABILITY* — The probability that the equipment will be in a condition to perform its intended function when required.

6.3.1 *Equipment Dependent Uptime* — The percent of time the equipment is in a condition to perform its intended function during the period of operations time minus the sum of all maintenance delay downtime, out-of-spec input downtime, and facilities-related downtime. This calculation is intended to reflect equipment reliability and maintainability based solely on equipment merit.

$$\textit{equipment dependent uptime (\%)} = \frac{\textit{equipment uptime} \times 100}{\textit{(oper-time – (all maint-delay DT + out-of-spec input DT + fac-rel DT))}}$$

6.3.2 *Supplier Dependent Uptime* — The percent of time the equipment is in a condition to perform its intended function during the period of operations time minus the sum of user maintenance delay downtime, out-of-spec input downtime, and facilities-related downtime. This calculation subtracts only user maintenance delay downtime from the period, thereby taking into account supplier delays for parts and service. The intention is to provide an effective performance measurement for use in supplier service contracts.

$$\textit{supplier dependent uptime (\%)} = \frac{\textit{equipment uptime} \times 100}{\textit{(oper-time – (user maint-delay DT + out-of-spec input DT + fac-rel DT))}}$$

6.3.3 *Operational Uptime* — The percent of time the equipment is in a condition to perform its intended function during the period of operations time. This calculation is intended to reflect overall operational performance for a piece of equipment.

$$\textit{operational uptime}\ (\%) = \frac{\textit{equipment uptime} \times 100}{\textit{operations time}}$$

6.4 *EQUIPMENT MAINTAINABILITY* — The probability that the equipment will be retained in, or restored to, a condition where it can perform its intended function within a specified period of time.

6.4.1 *MTTR* — Mean time to repair; the average time to correct a failure and return the equipment to a condition where it can perform its intended function; the sum of all repair time (elapsed time not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not including maintenance delay downtime), divided by the number of failures during that period.

$$MTTR = \frac{total\ repair\ time}{\#\,of\ \ failures}$$

6.4.2 *E-MTTR* — Mean time to repair equipment-related failures; the average time to correct an equipment-related failure and return the equipment to a condition where it can perform its intended function; the sum of all equipment-related failure repair time (elapsed time, not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not including maintenance delay downtime), divided by the number of equipment-related failures during that period.

$$E\text{–}MTTR = \frac{total\ repair\ time\ for\ equipment\text{-}related\ failures}{\#\ of\ equipment\text{-}related\ failures}$$

6.4.3 *MTOL* — Mean time off-line; the average time to maintain the equipment in or return the equipment to a condition where it can perform its intended function when downtime is incurred; the sum of all downtime (scheduled and unscheduled) during a specified time period, divided by the number of downtime events during that period.

$$MTOL = \frac{total\ equipment\ downtime}{\#\ \ of\ DT\ events}$$

6.4.4 *Equipment Dependent Scheduled Downtime* — The percent of time the equipment is not available to perform its intended function due to scheduled downtime events such as preventive maintenance. This time period does not include any maintenance delay downtime caused either by supplier or user. This calculation is intended to reflect the need for preventive maintenance based solely on equipment design.

$$equipment\ dependent\ scheduled\ downtime\ (\%) = \frac{equipment\ scheduled\ downtime \times 100}{(oper\text{-}time - (all\ maint\text{-}delay\ DT + out\text{-}of\text{-}spec\ input\ DT + fac\text{-}rel\ DT))}$$

6.4.5 *Supplier Dependent Scheduled Downtime* — The percent of time the equipment is not available to perform its intended function due to scheduled downtime events, such as preventive maintenance. This time period does not include any maintenance delay downtime caused by the user. This calculation is intended to reflect the need for preventive maintenance based solely on equipment design and supplier response to service.

$$supplier\ dependent\ scheduled\ downtime\ (\%) = \frac{equipment\ scheduled\ downtime \times 100}{(oper\text{-}time - (user\ maint\text{-}delay\ DT + out\text{-}of\text{-}spec\ input\ DT + fac\text{-}rel\ DT))}$$

6.5 *EQUIPMENT UTILIZATION* — The percent of time the equipment is performing its intended function during a specified time period.

6.5.1 *Operational Utilization* — The percent of productive time during operations time. This calculation is intended to be used for equipment utilization comparisons between operations with different work shift configurations, since it does not include non-scheduled time.

$$operational\ utilization\ (\%) = \frac{productive\ time \times 100}{operations\ time}$$

6.5.2 *Total Utilization* — The percent of productive time during total time. This calculation is intended to reflect bottom-line equipment utilization.

$$total\ utilization\ (\%) = \frac{productive\ time \times 100}{total\ time}$$

Table 1 RAM Measurement Metric Summary

EQUIPMENT RELIABILITY		
Metric	*How It Is Measured*	*Ref #*
$MTBF_p$: Mean (productive) time between failures	productive time/ # of failures that occur during productive time	6.2.1
E-$MTBF_p$: Mean (productive) time between equipment-related failures	productive time/ # of equipment-related failures that occur during productive time	6.2.2
MCBF: Mean cycles between failures	total equipment cycles/ # of failures	6.2.3
E-MCBF: Mean cycles between equipment-related failures	total equipment cycles/ # of equipment-related failures	6.2.4
EQUIPMENT AVAILABILITY		
Metric	*How It Is Measured*	*Ref #*
equipment dependent uptime (%)	equipment uptime × 100/(oper-time – (all maint-delay DT + out-of-spec input DT + fac-rel DT))	6.3.1
supplier dependent uptime (%)	equipment uptime × 100/(oper-time – (users maint-delay DT + out-of-spec input DT + fac-rel DT))	6.3.2
operational uptime (%)	equipment uptime × 100/ operations time	6.3.3
EQUIPMENT MAINTAINABILITY		
Metric	*How It Is Measured*	*Ref #*
MTTR: Mean time to repair	total repair time/ # of failures	6.4.1
E-MTTR: Mean time to repair for equipment-related failures	total repair time for equipment-related failures/ # of equipment-related failures	6.4.2
MTOL: Mean time off-line	total equipment downtime/ # of DT events	6.4.3
equipment dependent scheduled downtime (%)	equipment scheduled downtime × 100/(oper-time – (all maint-delay DT + out-of-spec input DT + fac-rel DT))	6.4.4
supplier dependent scheduled downtime (%)	equipment scheduled downtime × 100/(oper-time – (user maint-delay DT + out-of-spec input DT + fac-rel DT))	6.4.5
EQUIPMENT UTILIZATION		
Metric	*How It Is Measured*	*Ref #*
operational utilization (%)	productive time × 100/ operations time	6.5.1
total utilization (%)	productive time × 100/ operations time	6.5.2

NOTE: oper-time = operational time, DT = Downtime, fac-rel = facilities related, maint-delay = maintenance delay

7 Uncertainty Measurement

7.1 The measures of equipment reliability, availability, and maintainability defined in Section 6 are single value estimates. They do not indicate the uncertainty or precision of the estimate. Precision varies depending upon the number of failures observed and the amount of productive time contained within the observation period.

7.2 Precision is described by calculating a lower and upper confidence limit for the $MTBF_p$ and presenting this interval along with the $MTBF_p$ point estimate.

7.3 These procedures assume that the failure rate is constant and the times between failures are independently distributed according to the exponential distribution. Therefore, there are no improvement or degradation trends and it is meaningful to calculate $MTBF_p$. Section 8 applies when the failure times indicate that a non-constant failure rate is present (for example, when there is reliability growth or degradation). Section 8 would typically apply during prototype reliability improvement testing.

7.4 Since MTTR distributions are unlikely to follow an exponential distribution assumption, applying these procedures to put confidence limits on MTTR would be inappropriate.

7.5 Note that all procedures and tables referred to in this section apply equally well to measuring the precision of estimates for similar metrics, where hours are replaced by cycles or units, for example. These procedures apply to E-$MTBF_p$ or E-MCBF in the same way. It is also appropriate to combine data from identical tools being used the same way, in order to improve the precision of $MTBF_p$ estimates.

7.6 *Calculation of Lower and Upper Confidence Limits* — To obtain lower and upper $MTBF_p$ limits, multiply the $MTBF_p$ estimate by factors obtained by table look-up (Tables A1-1 and A1-2 in Appendix 1). For the case when there are zero failures during the measurement period, lower confidence limit factors for the $MTBF_p$ are given in the first row of Table A1-1 (they multiply the amount of productive time that had no failures to obtain the desired $MTBF_p$ lower limit). There is no upper limit estimate for performance when there are zero failures.

7.6.1 *Calculation of the $MTBF_p$ Lower Limit* — Use Table A1-1 in Appendix 1 to obtain a $k_{r;conf}$ factor, where r is the number of failures observed during the measurement period and *conf* is the confidence level desired. The rows of Table A1-1 correspond to different values of r and the columns correspond to different values of *conf*. Confidence levels ranging from 80 percent to 95 percent are typical choices.

7.6.1.1 Since the equipment being measured has demonstrated (at a given confidence level) that it is at least as good as the $MTBF_p$ lower limit, this lower limit is an important and useful performance statistic, and is often used contractually.

7.6.1.2 Note that the factors in Table A1-1 for 90% confidence are less than 0.5 until the number of failures equals or exceeds 4. This means that when the number of failures is under 4, the $MTBF_P$ lower limit will be less than half the $MTBF_p$ estimate, and confidence intervals will be wide. From the point of view of precision, it is advantageous to have had 4 or more failures.

7.6.1.3 *Example*: During a given calendar quarter, a tool was productive for 1200 hours and had 6 failures. The $MTBF_p$ estimate is 1200/6 = 200 hours. A 90 percent lower limit factor from Table A1-1 (corresponding to r = 6 failures) is 0.570. That means that 200 × 0.570 = 114.0 hours is a 90 percent lower confidence limit for the true tool $MTBF_p$.

7.6.2 *Calculation of the $MTBF_p$ Upper Limit* — Use Table A1-2 in Appendix 1 to obtain a $k_{r;conf}$ factor, where r is the number of failures observed during the measurement period and *conf* is the confidence level desired. The rows of Table A1-2 correspond to different values of r and the columns correspond to different values of *conf*. Confidence levels ranging from 80 percent to 95 percent are typical choices.

7.6.2.1 *Example*: During a given calendar quarter, a tool was productive for 1200 hours and had 6 failures. The $MTBF_p$ estimate is 1200/6 = 200 hours. A 90 percent upper limit factor from Table A1-2 (corresponding to r = 6 failures) is 1.904. That means that 200 × 1.904 = 380.8 hours is a 90 percent upper confidence limit for the true tool $MTBF_p$.

7.6.3 *Calculation of a Confidence Interval for the $MTBF_p$* — Lower and upper $100 \times (1 - \alpha/2)$ confidence limits for the $MTBF_p$ can be combined to give a $100 \times (1 - \alpha)$ confidence interval. Here $\alpha/2$ is the chance of missing on either end of the interval. A 90 percent lower limit has an $\alpha/2 = 0.1$ chance of not being low enough to capture the true $MTBF_p$, and the same is true for a 90 percent upper limit. Therefore, a 90 percent lower limit and a 90 percent upper limit combine to give an 80 percent confidence interval. Similarly, a 95 percent lower limit and a 95 percent upper limit would combine to give a 90 percent confidence interval.

7.6.3.1 *Example*: During a calendar quarter, a tool was productive for 1200 hours and had 6 failures. The $MTBF_p$ estimate is 1200/6 = 200 hours. The 90 percent lower and upper limits are 114 and 380.8 respectively (see Sections 7.6.1 and 7.6.2). The interval (114, 380.8) is then an 80 percent confidence interval for the true tool $MTBF_p$.

7.6.4 *Calculation of the $MTBF_p$ Lower Bound when there are Zero Failures* — Use the first row of Table A1-1 (corresponding to $r = 0$) to obtain a $k_{0;conf}$ factor corresponding to the desired confidence level. Multiply the length of the measurement period by this factor to obtain the lower limit estimate.

7.6.4.1 *Example*: During a calendar quarter, a tool was productive for 1200 hours and had zero failures. From Table A1-1, the 90% confidence level lower limit factor is 0.434. That means that 1200 × 0.434 = 520.8 hours, is a 90% lower confidence limit estimate for the true tool $MTBF_p$.

7.6.5 Choosing a test length in order to be able to demonstrate a required $MTBF_p$ at a given confidence, we first must pick a maximum number of failures, *r*, that can occur during the test period and still allow us to confirm a required $MTBF_p$ objective at a given confidence level. Next, the length of test time needed can be calculated using the factors in Table A1-4 in Appendix 1. The required $MTBF_p$ is multiplied by a factor based on *r* and the desired confidence level to obtain the total test time needed.

7.6.5.1 Note that minimum test times are obtained by allowing no failures. The cost, however, of using a minimum test length is to increase the possibility of an acceptable tool failing the test by chance. As mentioned in the discussion in Section 6.2.1, it is advantageous to design a test that allows up to 4 failures, whenever possible.

7.6.5.2 *Example*: We would like to confirm a tool $MTBF_p$ of 400 hours at an 80% confidence level. We want to be able to pass a qualification test with 4 or less failures. We look up the appropriate factor from Table A1-4 and find 6.72. That means the length of test time required is 400 × 6.72 = 2688 hours. We can do this on one tool or split the test time across several tools. When we have accumulated 2688 hours and if 4 or less failures have occurred, the $MTBF_p$ objective of 400 hours will have been confirmed at (at least) the 80% confidence level.

8 Reliability Growth or Degradation Measurement

8.1 The previous calculations are meaningful only when the $MTBF_p$ (or MCBF) and E-$MTBF_p$ (or E-MCBF) are constant over the measurement period. If reliability is improving (typical during design verification and debug and also early life run-in) or if reliability is degrading (typical near the end of life for the piece of equipment, or if certain sub-assemblies have been over-stressed and are wearing out) then an overall $MTBF_p$ calculation is inappropriate and misleading and other methods must be used. Exact time of failure recording is required in order to detect reliability improvement or reliability degradation trends, and to fit appropriate models.

8.2 *Exact Time of Failure Recording* — Clock times of failure must be converted to durations of cumulative productive time as measured from the initial productive use of the tool (set as time 0). This is easily accomplished if total time is continuously monitored by duration within each of the six equipment states.

8.2.1 *Example*: A machine is intended for use during first shift operation five days a week. For simplicity, assume 100% productive utilization. After the first three weeks of use, it fails half-way through the day, and is not repaired until the start of the next day's operation. No more failures occur before the end of the first four weeks of operation. The exact time of failure is 124 hours (three weeks of 5 × 8 = 40 hours per week plus half of an 8 hour day). If a second failure occurred two hours into the third day of the fifth week, the exact time of failure would be 174 hours.

8.3 *Reliability Growth (Degradation) Models* — A useful family of reliability growth (degradation) models was developed by the U.S. Army Materials Systems Analysis Activity. These AMSAA models are described in Appendix 2, along with a general test for reliability growth (degradation) trends. Exact time of failure data is needed to test for trends, fit an AMSAA model, and test the fit for adequacy. The failures used to fit the model must occur during productive time (other failures can occur, but these are not used to fit reliability models).

APPENDIX 1
CONFIDENCE BOUND FACTORS

NOTE: This appendix was approved as an official part of SEMI E10 by full letter ballot procedure. It offers detailed information related to Section 7.

A1-1 *Introduction*

A1-1.1 E-MTBF$_p$ may be substituted for MTBF$_p$ in all calculations in this section.

A1-1.2 Tables A1-1 and A1-2 contain factors that multiply an MTBF$_p$ point estimate to obtain upper and lower confidence limits. Table A1-1 applies in the common case where the equipment is observed for a fixed period of time and the number of failures that will occur is unknown in advance (time censored data). The alternative is failure censored data, where the number of failures is specified in advance and the equipment is observed until that many failures occur. Table A1-3 contains lower limit factors for failure censored data. Since failure censored data rarely occurs in tool or equipment reliability measurement, Table A1-3 is only included for completeness. The upper limit factors given in Table A1-2 apply to both kinds of censored data.

A1-1.3 Table A1-4 can be used to plan equipment assessment or qualification tests in order to be able to demonstrate a desired MTBF$_p$ at a given confidence level. In order to use Table A1-4, you must first choose a maximum number of failures, *r*, you might observe during the test period and still be able to meet the required MTBF$_p$ objective.

A1-1.4 For reference, here are the formulas for the lower and upper confidence limit factors for time censored data found in Tables A1-1 and A1-2:

$$MTBF_{LOWER} = \frac{2r}{X^2_{2r+2;1-\alpha}} \times MTBF_p$$

$$\text{where } r = \# \text{ of failures}$$

$$MTBF_{UPPER} = \frac{2r}{X^2_{2r;\alpha}} \times MTBF_p$$

A1-1.5 In both cases, the confidence level is 100 × (1 – α) that the true MTBF$_p$ is above MTBF$_{LOWER}$ and below MTBF$_{UPPER}$ and chi square distribution tables are used.

A1-1.6 For 0 fails, use:

$$MTBF_{LOWER} = \frac{\text{productive time}}{-\log_e \alpha}$$

A1-1.7 Factors to use when there are 0 failures based on this formula are given in the first row of Table A1-1.

A1-1.8 For failure censored data, MTBF$_{UPPER}$ is the same, but the lower limit factor in Table A1-3 is:

$$MTBF_{LOWER} = \frac{2r}{X^2_{2r;1-\alpha}} \times MTBF_p$$

Table A1-1 1-Sided Lower Confidence Bound Factors for the $MTBF_p$ (Time or Cycle Censored Data or Fixed Length Test)

Use for time or cycle censored data to multiply the $MTBF_p$ or MCBF estimate to obtain a lower bound at the given confidence level.
For 0 failures, multiply the operating hours or cycles by the factor corresponding to the desired confidence level.

	CONFIDENCE LEVEL						
# FAILS *r*	60%	70%	80%	85%	90%	95%	97.5%
0	1.091	0.831	0.621	0.527	0.434	0.334	0.271
1	0.494	0.410	0.334	0.297	0.257	0.211	0.179
2	0.644	0.553	0.467	0.423	0.376	0.318	0.277
3	0.718	0.630	0.544	0.499	0.449	0.387	0.342
4	0.763	0.679	0.595	0.550	0.500	0.437	0.391
5	0.795	0.714	0.632	0.589	0.539	0.476	0.429
6	0.817	0.740	0.661	0.618	0.570	0.507	0.459
7	0.834	0.760	0.684	0.642	0.595	0.532	0.485
8	0.848	0.777	0.703	0.662	0.616	0.554	0.508
9	0.859	0.790	0.719	0.679	0.634	0.573	0.527
10	0.868	0.802	0.733	0.694	0.649	0.590	0.544
12	0.883	0.821	0.755	0.718	0.675	0.617	0.572
15	0.899	0.841	0.780	0.745	0.704	0.649	0.606
20	0.916	0.864	0.809	0.777	0.739	0.688	0.647
30	0.935	0.892	0.844	0.816	0.783	0.737	0.700
50	0.953	0.918	0.879	0.856	0.829	0.790	0.759
100	0.969	0.943	0.915	0.897	0.877	0.847	0.822
500	0.987	0.976	0.962	0.954	0.944	0.929	0.916

Table A1-2 1-Sided Upper Confidence Bound Factors for the $MTBF_p$

Use to multiply the $MTBF_p$ estimate to obtain an upper bound at the given confidence level (time censored or failure censored data).

	CONFIDENCE LEVEL						
# FAILS *r*	60%	70%	80%	85%	90%	95%	97.5%
1	1.958	2.804	4.481	6.153	9.491	19.496	39.498
2	1.453	1.823	2.426	2.927	3.761	5.628	8.257
3	1.313	1.568	1.954	2.255	2.722	3.669	4.849
4	1.246	1.447	1.742	1.962	2.293	2.928	3.670
5	1.205	1.376	1.618	1.795	2.055	2.538	3.080
6	1.179	1.328	1.537	1.687	1.904	2.296	2.725
7	1.159	1.294	1.479	1.610	1.797	2.131	2.487
8	1.144	1.267	1.435	1.552	1.718	2.010	2.316
9	1.133	1.247	1.400	1.507	1.657	1.917	2.187
10	1.123	1.230	1.372	1.470	1.607	1.843	2.085
12	1.108	1.203	1.329	1.414	1.533	1.733	1.935
15	1.093	1.176	1.284	1.357	1.456	1.622	1.787
20	1.077	1.147	1.237	1.296	1.377	1.509	1.637
30	1.060	1.115	1.185	1.231	1.291	1.389	1.482
50	1.044	1.085	1.137	1.170	1.214	1.283	1.347
100	1.029	1.058	1.093	1.115	1.144	1.189	1.229
500	1.012	1.025	1.039	1.049	1.060	1.078	1.094

Table A1-3 1-Sided Lower Confidence Bound Factors for the $MTBF_p$ (Failure Censored Data)

Use for failure censored data to multiply the $MTBF_p$ estimate to obtain a lower bound at the given confidence level. Failure censored data means the test or observation period lasts as long as needed to obtain a preset number of failures.

	CONFIDENCE LEVEL						
# FAILS *r*	60%	70%	80%	85%	90%	95%	97.5%
1	1.091	0.831	0.621	0.527	0.434	0.334	0.271
2	0.989	0.820	0.668	0.593	0.514	0.422	0.359
3	0.966	0.830	0.701	0.635	0.564	0.477	0.415
4	0.958	0.840	0.725	0.665	0.599	0.516	0.456
5	0.955	0.849	0.744	0.688	0.626	0.546	0.488
6	0.954	0.856	0.759	0.706	0.647	0.571	0.514
7	0.953	0.863	0.771	0.721	0.665	0.591	0.536
8	0.954	0.869	0.782	0.734	0.680	0.608	0.555
9	0.954	0.874	0.791	0.745	0.693	0.623	0.571
10	0.955	0.878	0.799	0.755	0.704	0.637	0.585
12	0.956	0.886	0.812	0.771	0.723	0.659	0.610
15	0.958	0.895	0.828	0.790	0.745	0.685	0.639
20	0.961	0.906	0.846	0.812	0.772	0.717	0.674
30	0.966	0.920	0.870	0.841	0.806	0.759	0.720
50	0.971	0.935	0.896	0.872	0.844	0.804	0.772
100	0.978	0.952	0.923	0.906	0.885	0.855	0.830
500	0.989	0.978	0.964	0.956	0.945	0.930	0.918

Table A1-4 Test Length Guide

Use to determine the test time needed to demonstrate a desired $MTBF_p$ at a given confidence level if *r* failures occur. Multiply the desired $MTBF_p$ by the *k* factor corresponding to *r* and the confidence level.

	k FACTOR FOR GIVEN CONFIDENCE LEVELS					
# FAILS *r*	50%	60%	75%	80%	90%	95%
0	0.693	0.916	1.39	1.61	2.30	3.00
1	1.68	2.02	2.69	2.99	3.89	4.74
2	2.67	3.11	3.92	4.28	5.32	6.30
3	3.67	4.18	5.11	5.52	6.68	7.75
4	4.67	5.24	6.27	6.72	7.99	9.15
5	5.67	6.29	7.42	7.90	9.28	10.51
6	6.67	7.35	8.56	9.07	10.53	11.84
7	7.67	8.38	9.68	10.23	11.77	13.15
8	8.67	9.43	10.80	11.38	13.00	14.43
9	9.67	10.48	11.91	12.52	14.21	15.70
10	10.67	11.52	13.02	13.65	15.40	16.96
15	15.67	16.69	18.48	19.23	21.29	23.10
20	20.68	21.84	23.88	24.73	29.06	30.89

APPENDIX 2
RELIABILITY GROWTH OR DEGRADATION MODELS

NOTE: This appendix was approved as an official part of SEMI E10 by full letter ballot procedure. It offers detailed information related to Section 8.

A2-1 *Introduction*

A2-1.1 E-MTBF$_p$ may be substituted for MTBF$_p$ in all calculations in this section.

A2-1.2 If the times between failures (known as "interarrival times") of a repairable system or piece of equipment are independent random times sampled from the same exponential distribution, then the (theoretical) *rate of occurrence of failures* ("ROCOF") is a constant λ and the MTBF$_p$ is just $1/\lambda$. This situation is known in the reliability literature as a *homogeneous poisson process* (HPP). An HPP assumption underlies the definition of MTBF$_p$ given in Section 6, and the confidence limit factors described in Section 7 and Appendix 1. These concepts are described in detail in Ascher and Feingold [1] and Tobias and Trindade [2].

A2-1.3 If reliability is either improving or degrading with time, then the ROCOF is no longer a constant and a MTBF$_p$ calculation will be misleading.

A2-1.4 This appendix contains a simple test for trend that may be applied if a time-varying ROCOF is suspected, as well as a description of a well known and powerful model that may be used when reliability improvement trends are evident in the equipment failure time data.

A2-2 *Testing for Trends*

A2-2.1 A non-parametric *reverse arrangement test* (RAT) devised by Kendall [3] and further developed into a table by Mann [4] will be described. Begin by writing the interarrival times in the order they occurred. For a period with r failures, these might be X_1, X_2, …, X_r. Starting from left to right, define a reversal as any instance in which a lesser value occurs before any subsequent greater value in the sequence. In other words, any time we have $X_i < X_j$ and $i < j$, we count it as a reversal. For example, suppose a piece of equipment has $r = 4$ failures at 30, 160, 220, and 360 hours of productive time. The interarrival times are 30, 130, 60, and 140. The total number of reversals is 3 + 1 + 1 = 5.

A2-2.2 A larger than expected number of reversals indicates an improving trend; a smaller number of reversals than expected indicates a degradation trend.

A2-2.3 For r up to 12, use Table A2-1 below (adapted from [2]) to determine whether a given number of reversals, R, is statistically significant at the $100 \times (1 - \alpha)$ confidence level.

A2-2.4 For r greater than 12, approximate critical values for the number of reversals (based on Kendall's normal approximation) can be calculated from:

$$R_{(r;\,1\text{-}\alpha)} = z_{critical}\sqrt{\frac{(2r+5)(r-1)r}{72}} + \frac{r(r-1)}{4} - \frac{1}{2}$$

Table A2-1 Critical Values $R_{r;1-\alpha}$ the Number of Reversals for the Reverse Arrangement Test at a Given Confidence Level

Sample Size	*Single-Sided Lower Critical Value (Too Few Reversals Provide Evidence of Degradation)*			*Single-Sided Upper Critical Value (Too Many Reversals Provide Evidence of Improvement)*		
r	99%	95%	90%	90%	95%	99%
4		0	0	6	6	
5	0	1	1	9	9	10
6	1	2	3	12	13	14
7	2	4	5	16	17	19
8	4	6	8	20	22	24
9	6	9	11	25	27	30
10	9	12	14	31	33	36
11	12	16	18	37	39	43
12	16	20	23	43	46	50

A2-2.5 In this equation $z_{critical}$ comes from the critical values of the standard normal distribution (for 90% significance, $z_{critical}$ = 1.282, for 95% significance, $z_{critical}$ = 1.645, and for 99% significance, $z_{critical}$ = 2.33). The formula calculates the critical value for detecting an improvement trend. For degradation trends (a small number of reversals) use $(r)(r - 1)/2$ minus $R_{r;1-\alpha}$ as the critical value. Note that $(r)(r - 1)/2$ just the total possible number of reversals when there are r failures.

A2-2.6 For example, with 17 failures, the formula for $R_{r;1-\alpha,}$ using 95% significance, gives a critical number of reversals of $R_{17,95}$ = 88. The maximum number of reversals is 17 × 16/2 = 136. That means that observing 88 or more reversals signals a likely improvement trend, while observing 136 − 88 = 48 or less reversals signals a likely degradation trend.

A2-2.7 The example given in the next section shows an application for the reverse arrangement test using Table A2-1.

A2-2.8 The *AMSAA Reliability Growth Model*: Assume the sequence of interarrival time indicates an improvement trend. This will typically be the case during reliability improvement testing, where failures are analyzed down to root causes and actions are taken to improve the equipment's reliability. Duane [5] observed that a plot of t_k/k versus t_k, where t_k is the system age at the time of kth failure, typically appears linear on log versus log graph paper. The slope β of this line measures the rate of reliability growth. Typical empirical values of β lie between 0.3 and 0.6. Crow [6] developed this empirical observation into the power relationship model used by the U.S. Army Materials Systems Analysis Activity (AMSAA model). This model has proved successful in a wide range of applications.

A2-2.9 The AMSAA model assumes that during reliability improvement testing the $MTBF_p$ is improving with time and has an instantaneous value denoted by $MTBF_I$ (t). When the test ends at time T, the $MTBF_p$ becomes a constant with the value $MTBF_I$ (T). An estimate of the $MTBF_p$ after a test of T hours with r failures is given by:

$$MTBF_I(T) = \frac{T}{r \times (1 - \beta)} \quad (1)$$

A2-2.10 In this equation, β is the reliability improvement (Duane) slope, β is estimated by

$$\beta = 1 - \frac{r - 1}{\sum_{i=1}^{r} \ln \frac{T}{t_i}} \quad (2)$$

using the *modified maximum likelihood estimates* given by Crow [6]. Crow developed confidence limits for $MTBF_I$ (T) that are described in [2] and [6].

A2-2.11 *Example*: During a calendar quarter a tool has 550 hours of productive time. Eleven failures were recorded at the following points of productive time: 18, 20, 35, 41, 67, 180, 252, 287, 390, 410, and 511 hours. Determine whether there appears to be an improvement trend and use the AMSAA model to estimate the achieved $MTBF_I$ at the end of the quarter.

A2-2.12 *Solution:* The interarrival times are: 18, 2, 15, 6, 26, 113, 72, 35, 103, 20, and 101. The number of reversals is 7 + 9 + 7 + 7 + 5 + 0 + 2 + 2 + 0 + 1 = 40. Using Table A2-1, this is significant at greater than the 95% confidence level, indicating an improvement trend is likely. Figure A2-1 shows the Duane plot, which appears to show a linear improvement trend on log-log paper. The AMSAA model equations give an improvement slope estimate of 0.43 and an instantaneous $MTBF_P$ estimate at 550 hours of 87.2. Note that a standard calculation ignoring the improvement trend would yield an $MTBF_P$ estimate of 550/11 = 50, which is a 43% underestimate.

A2-2.13 Figure A2-2 summarizes the recommended procedure to follow when analyzing system or equipment reliability data, with appropriate references to SEMI E10 sections or appendices.

A2-3 *References*

1. Ascher, H. and H. Feingold, *Repairable Systems Reliability*, Marcel Dekkar, Inc., New York, 1984
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3. Kendall, M.G., "A New Measure of Rank Correlation", *Biometrika*, 1938, volume 30, pages 81-93
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5. Duane, J.T., "Learning Curve Approach to Reliability Monitoring," *IEEE Transactions on Aerospace*, 1964, volume 2, pages 563-566
6. Crow, L.H., "Reliability Analysis for Complex Repairable Systems," *Reliability and Biometry*, F. Proschan and R.J., Serfling, eds., SIAM, Philadelphia, 1974; pp. 126-134

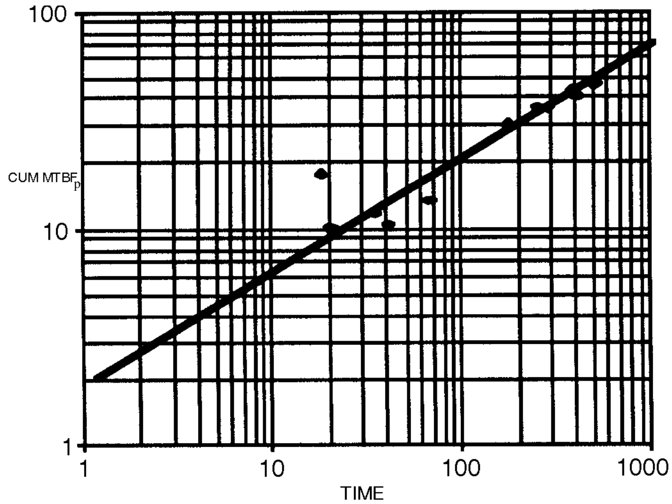

Figure A2-1
Duane Plot of CUM MTBF$_p$ vs. Time

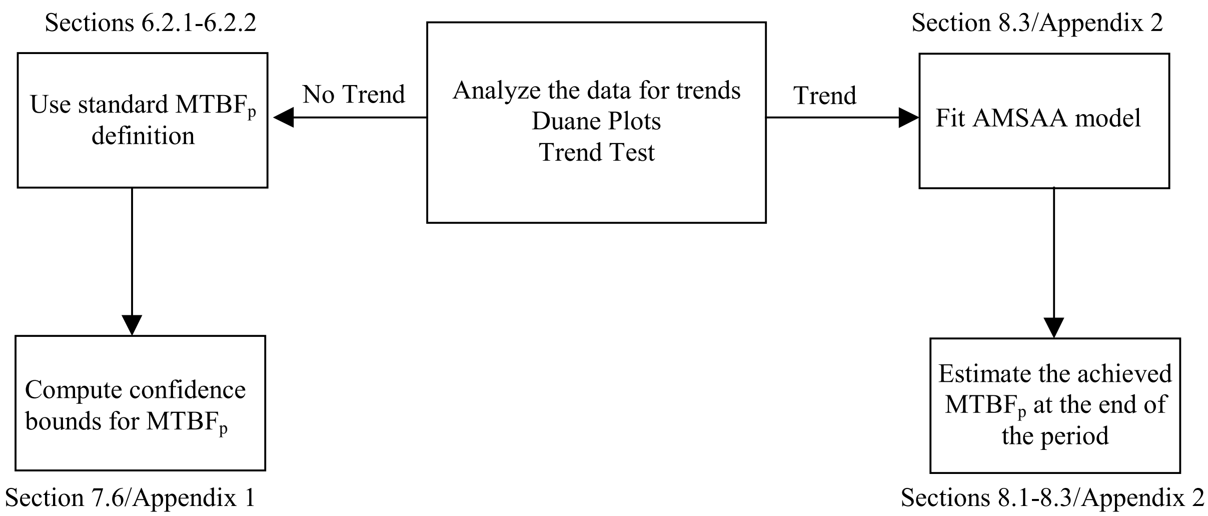

Figure A2-2
Flow Chart for Reliability Data Analysis

RELATED INFORMATION 1
MULTI-PATH CLUSTER TOOL RAM METRICS

NOTE: This related information is not an official part of SEMI E10 and was derived from the work of the SEMI Cluster Tool RAM Metrics Task Force. This related information was approved for publication by vote of the NA Metrics Technical Committee on March 21, 2001.

R1-1 Introduction

R1-1.1 Multi-path cluster tools (also called flexible-sequence cluster tools in E79-0200 "Standard For Definition And Measurement Of Equipment Productivity") have become as much a part of the fab as HEPA filters over the past decade, but we still cannot apply uniform RAM metrics to them to determine their performance. A new approach that evaluates the tool as a series of systems will provide us with the ability to measure the conventional E10 RAM metrics with relative ease. In this new approach we look at each intended process path (IPP) as a separate entity, and the overall performance of the multi-path cluster tool is derived from the performance of the individual IPPs.

R1-2 Limitations of Existing E10 Metrics

R1-2.1 Within E10 it is specifically stated that the metrics that exist presently cannot handle multi-path cluster tools at an overall level, however they can be applied to the individual process modules. This allows us to measure reliability (e.g., $MTBF_p$), availability (e.g., operational uptime), and maintainability (e.g., MTTR) for the modules, but does not give us those measurements for the multi-path cluster tool as an entity itself.

R1-2.2 With this approach a multi-path cluster tool with multiple process chambers could have at least one chamber incapable of processing wafers all month, and still be considered up all month. After all, it was producing product. However, at the same time that it was making product it still had significant problems, which required equipment maintenance personnel to fix them. The present E10 definition of uptime would apply (i.e., the time when the equipment is in a condition to perform its intended function). In fact, it would even be possible to consider the system to be in the productive state (i.e., the time (productive time) when the equipment is performing its intended function).

R1-3 Intended Process Paths

R1-3.1 A process path is the sequential module-to-module flow that a given process follows from load to processing to unload. A cluster tool configuration may allow multiple process paths within the cluster tool. Users would determine the intended process paths (IPPs) for their multi-path cluster tools based on configuration and processes. It is important to differentiate between possible process paths and those that are actually intended for operational use. Figure R1-1 illustrates the process path concept. This example is a simplified generic multi-path cluster tool configuration that represents some of the potential module-to-module relationships. Automated module-level state change data collection is required to effectively calculate multi-path cluster tool RAM metrics.

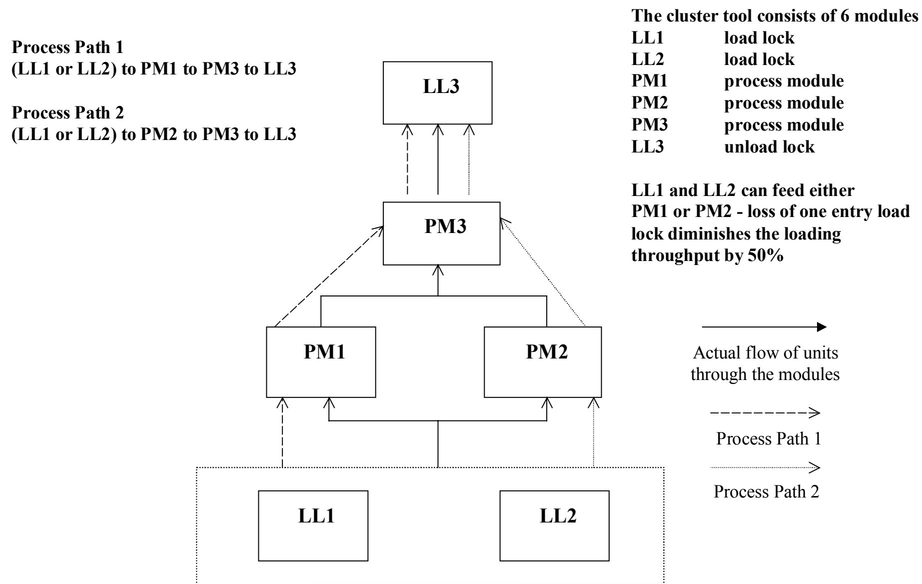

Figure R1-1
Multi-Path Cluster Tool Process Path Concept

R1-4 Determining What Makes up a Process Path

R1-4.1 A process path is comprised of a transport system and one or more process modules.

R1-4.2 The transport system in this scenario is considered to be a "non-processing module," as it is used in SEMI E79. It includes all other non-processing modules of the cluster tool besides the process modules and the hardware and software directly associated with them. A definition of a non-processing module is given below.

> Non-processing module — an equipment entity that supports the movement or conditioning of units through the system, such as,
>
> - robotic handler
> - load/unload lock
> - pre-aligner

R1-4.3 The processing modules are defined in SEMI E79 as:

> Processing module — an indivisible production entity within an equipment system, e.g., a processing chamber or station within a cluster tool.

R1-4.4 The intended process path is defined as the combination of one or more processing modules that are identified in the recipe per SEMI E79.

> Recipe — the pre-planned and reusable portion of the set of instructions, settings, and parameters under control of a processing agent, that determines the processing environment seen by the material. Recipes may be subject to change between runs or processing cycles (SEMI E38, SEMI E40, SEMI E42).

R1-4.5 For the example in Figure 1, the simplified process paths are shown below in Figure R1-2.

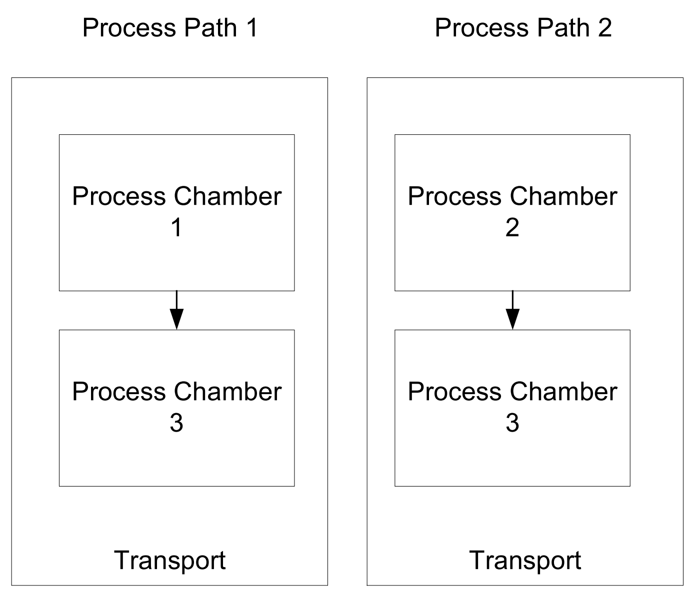

Figure R1-2
Simplified Process Paths

R1-5 Proposed New E10 Metrics

R1-5.1 By looking at the whole multi-path cluster tool as the sum of its intended process paths, we can produce valuable metrics that more accurately reflect the performance of the entire platform as a whole. The basis for this approach is in SEMI E79, where the concept of the multi-path cluster tool as an aggregate of its "virtual tools," is first described. By extending that concept to the E10 metrics as well, we can view the RAM performance similarly.

R1-5.2 Availability (e.g., operational uptime) is measured at the process path level. A process path is "Up" when its defined modules are in a state that allow the process path to execute its intended function.

R1-5.3 Operational uptime for the multi-path cluster tool would be defined as follows.

Operational Uptime (multi-path cluster tool) =

(Σ Uptime for All Intended Process Paths) ÷ [(# of Process Paths) × (Operations Time (as defined in E10) for the Multi-Path Cluster Tool)] × 100

NOTE: In cases where the loss of a module diminishes the throughput of a process path (e.g., the loss of one load lock which reduces throughput by 50%), the productivity loss is reflected in the overall equipment efficiency (OEE) rather than the availability.

R1-5.4 To determine the Process Path availability, a simple truth table could be used. Table R1-1 demonstrates availability determination for the multi-path cluster tool configuration noted in Figure R1-1.

Table R1-1 Simple Truth Table for Process Path Availability for Tool Configuration in Figure 1

LL1	LL2	PM1	PM2	PM3	LL3	IPP 1	IPP 2
Up	Up	Up	Up	Up	Up	Up	Up
Down	Up	Up	Up	Up	Up	Up	Up
Down	Down	Up	Up	Up	Up	Down	Down
Up	Up	Down	Up	Up	Up	Down	Up
Up	Up	Up	Down	Up	Up	Up	Down
Up	Up	Up	Up	Down	Up	Down	Down
Up	Up	Up	Up	Up	Down	Down	Down

R1-5.5 To determine the transport system availability, a simple truth table could be used. Table R1-2 demonstrates availability determination for the multi-path cluster tool configuration noted in Figure R1-1.

Table 2 Simple Truth Table for Transport System Availability for Tool Configuration in Figure 1

LL1	LL2	LL3	Transport
Up	Up	Up	Up
Down	Up	Up	Up
Up	Down	Up	Up
Down	Down	Up	Down
Up	Up	Down	Down

R1-5.6 To determine the process path availability, a simple truth table could be used. Table R1-3 demonstrates availability determination for the multi-path cluster tool configuration noted in Figure R1-1 by combining Tables R1-1 and R1-2.

Table 3 Simple Truth Table for Transport System Availability for Tool Configuration in Figure 1

PM1	PM2	PM3	Transport	IPP 1	IPP 2
Up	Up	Up	Up	Up	Up
Up	Up	Up	Up	Up	Up
Up	Up	Up	Down	Down	Down
Down	Up	Up	Up	Down	Up
Down	Down	Up	Up	Down	Down
Up	Down	Up	Up	Up	Down
Up	Up	Down	Up	Down	Down
Up	Up	Up	Down	Down	Down

R1-5.7 The following example shows how Table R1-3 can be used to determine operational uptime. Other availability metrics in E10 could be calculated in a similar fashion.

Given:

Uptime IPP 1 = 100 hours

Uptime IPP 2 = 140 hours

Operations Time = 168 hours

Operational Uptime (multi-path cluster tool) =

(Σ Uptime for All Intended Process Paths) ÷ [(# of Process Paths) × (Operations Time (as defined in E10) for the Multi-path Cluster Tool)] × 100

= (100 hours + 140 hours) / [(2 IPPs × 168 hours)] × 100 = 240/336 × 100 = 0.714 × 100 = 71.4%

R1-5.8 $MTBF_p$ is measured at the module level and can be aggregated for the multi-path cluster tool.

$MTBF_p$ (multi-path cluster tool) =

(Σ Productive Time for All Process Modules) ÷ (Σ Failures during Productive Time for All Modules)

R1-5.9 The following example shows how Table R1-4 can be used to determine $MTBF_p$. Other reliability metrics in E10 can be calculated in a similar fashion.

Table R1-4 Example Performance Data for Tool Configuration in Figure 1

Item	*Productive Hours*	*# Failures*	*$MTBF_p$*
Process Module 1	100	1	100
Process Module 2	140	1	140
Process Module 3	140	2	70
Transport	—	1	140
Multi-path cluster tool (total)	380	5	76

$MTBF_p$ (multi-path cluster tool) =

(Σ Productive Time for All Process Modules) ÷ (Σ Failures during Productive Time for All Modules)

= (100 hours + 140 hours + 140 hours) ÷ (1 + 1 + 2 + 1) = 380/5 = 76 hours

R1-5.10 A new metric suggested for multi-path cluster tools is total failures (multi-path cluster tool) per month (TFM).

TFM = Σ Total Failures for All Modules (Process and Transport) During the Month

For the above example, TFM = 5.

TFM provides a trending metric for equipment engineers and managers to monitor the effectiveness of equipment continuous improvement activity. When combined with MTTR data calculated for multi-path cluster tools per formulas in E10, this new metric provides maintenance planning capability to the equipment manager as well.

R1-5.11 In the special case of a single intended path (i.e., single-path cluster tool), these multi-path cluster tool RAM metrics should, and do, reduce to the standard E10 RAM metrics.

R1-6 Summary

R1-6.1 By using the E79 concept of virtual tools to develop the "intended process path" approach for multi-path cluster tool metrics in E10, we can demonstrate system-level RAM metrics for multi-path cluster tools. The operational uptime (multi-path cluster tool) metric can be used to provide input to capacity planning systems and allow modeling of multi-path cluster tool availability. $MTBF_p$ can now be calculated at the whole equipment level for multi-path cluster tools, based on existing sub-sytem level metrics. The new metric of total failures per month (TFM) provides a trending metric for the multi-path cluster tool at the whole tool level.

SEMI E11-0697
GUIDELINE FOR 125 mm, 150 mm, AND 200 mm PLASTIC AND METAL WAFER CARRIER APPLICATION

1 Scope

This guideline identifies the wafer carrier details required to properly register the carrier on semiconductor process and transport tools. Specific registration coordinates for both horizontal and vertical carrier orientation are defined to improve wafer and carrier transport operations.

Automated wafer and carrier transport applications require precision placement of carriers within the various types of semiconductor process, inspection and logistic equipment. In some applications it is necessary to adequately support the carrier to avoid deformation. Operations requiring adequate wafer handling must reference the carrier to the datums defined in the SEMI Carrier Specifications.

2 Applicable Documents

2.1 *SEMI Documents*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E1.4 — Standard for 125 mm Plastic and Metal Wafer Carriers, Auto Transport Usage

SEMI E1.7 — Standard for 200 mm Plastic and Metal Wafer Carriers, General Usage (Proposed)

3 Selected Definitions

horizontal orientation — Carrier position when wafers are in the horizontal plane.

vertical orientation — Carrier position when wafers are in the vertical plane.

Symbols Description:

S1 — Draft angle of both side walls of carrier for length defined by S4.

S2 — Draft angle of both carrier legs on outside surfaces only.

S3 — Height from bottom of carrier legs (Datum B) to start of side walls.

S4 — Minimum length of unobstructed side walls.

S5 — Height of carrier legs.

S6 — Angle from carrier leg to side wall.

V1 — Height from base of carrier legs (Datum B) to center of vertical alignment pin. Vertical alignment pin is a locating pin which is an equipment feature, not attached to the wafer carrier.

V2 — Diameter of vertical alignment pin.

4 Application Guides

4.1 *Centrifuge Equipment* — Wafer carriers require support during the centrifugal process operations. The following symbols represent the carrier coordinates that must be supported by the centrifuge tools to ensure adequate support: S1 through S6, A2b, D6a, D6g.

4.2 *Horizontal Carrier Registration* — Wafer carriers positioned with the "H-Bar" down on a stationary or elevator platform should reference the carrier at stable locations shown in Figure 2 to ensure dependable placement. D5b, D5c, and D6b are the recommended final detect points within the D6d and D6e envelope (including provision for D6f).

NOTE: Other features may be employed as prealignment guides, but only for coarse placement.

4.3 *Vertical Carrier Registration* — Wafer carriers positioned with the wafers in the vertical orientation should employ the "center alignment" feature shown in Figure 3. The D6a, D6g, and D9a through D9d details would be the final registration coordinates.

NOTE: Dimensions A1 and A2b may be used to guide the carrier to final placement.

Table 1 Carrier Dimensions for Centrifuge Equipment

Carrier Size	*125 mm*	*150 mm*	*200 mm*
S1	1/4°	1/4°	1/2°
S2	2°	2°	2°
S3	53.4 mm ± 1.0 mm (2.10 in. ± 0.040 in.)	60.5 mm ± 1.5 mm (2.38 in. ± 0.059 in.)	114.3 mm ± .51 mm (4.5 in. ± 0.020 in.)
S4	66.0 mm minimum (2.60 in.)	76.2 mm minimum (3.00 in.)	76.2 mm minimum (3.00 in.)
S5	25.4 mm ± 1.0 mm (1.00 in. ± 0.040 in.)	30.2 mm ± 1.27 mm (1.20 in. ± 0.050 in.)	30.0 mm ± 1 mm (1.18 in. ± 0.039 in.)
S6	45°	45°	Not Applicable
A2b	see Section 2	see Section 2	see Section 2
D6a	see Section 2	see Section 2	see Section 2
D6g	see Section 2	see Section 2	see Section 2

Table 2 Vertical Registration Dimensions

V1	3.81 mm – 0.13 mm (0.150 in. + 0.000 in. – 0.005 in.)
V2	2.38 mm ± 0.5 mm (0.094 in. ± 0.002 in.)

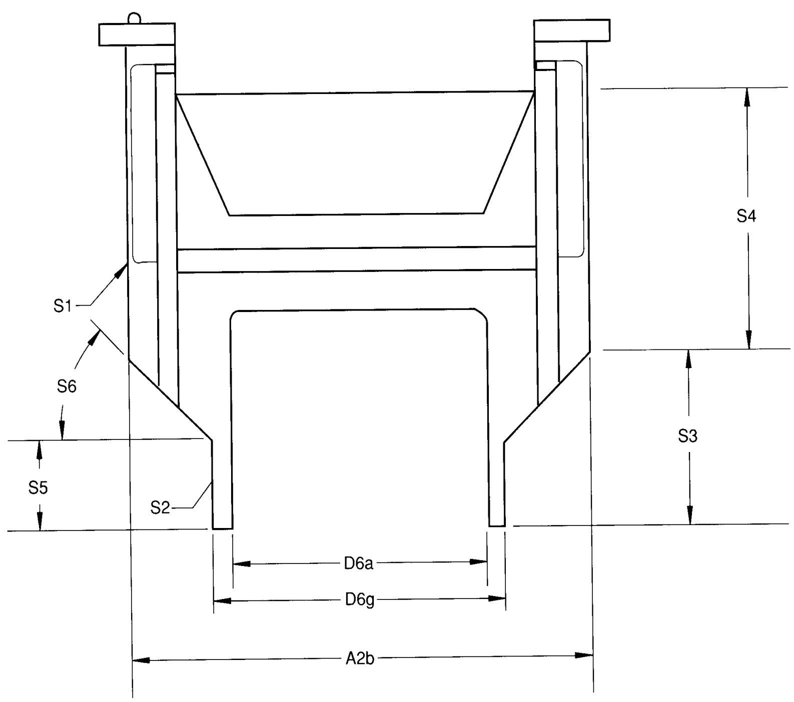

Figure 1
Wafer Carrier Profile for Centrifuge

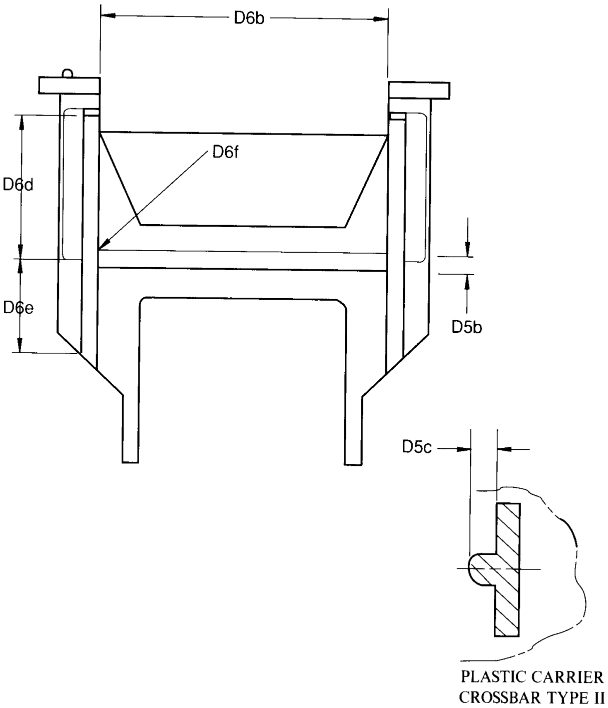

Figure 2
Horizontal Wafer Carrier

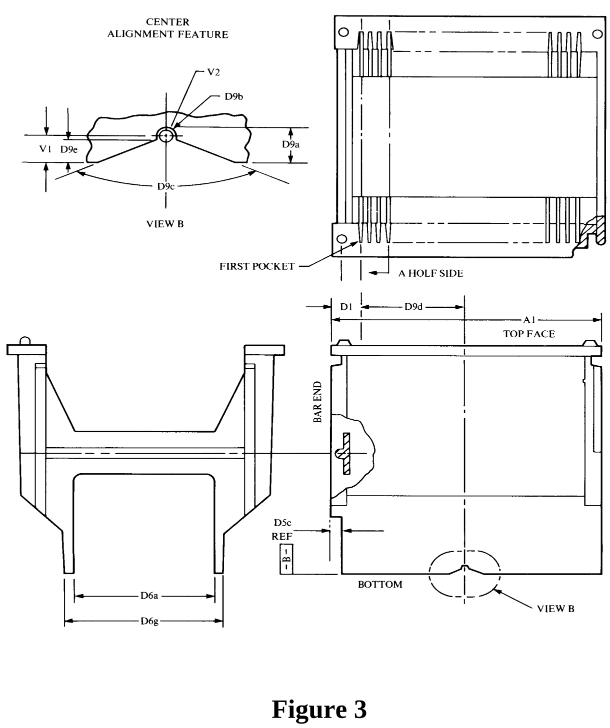

Figure 3
Vertical Wafer Carrier Registration Locations

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SEMI E12-96
STANDARD FOR STANDARD PRESSURE, TEMPERATURE, DENSITY, AND FLOW UNITS USED IN MASS FLOW METERS AND MASS FLOW CONTROLLERS

NOTE: This entire document was revised in 1995.

1 Purpose

1.1 In the past, confusion has existed in the values of standard temperature and standard pressure when gas flow is expressed in “standard” volumetric units. To eliminate this confusion, the Mass Flow Controllers Committee has established this standard.

2 Referenced Documents

2.1 *ASTM Standard*[1]

E 380-89a — Standard Practice for Use of the International System of Units (the Modernized Metric System)

3 Terminology

None.

4 Standard Temperature

4.1 Standard temperature is defined as 273.15 K (0.0°C).

5 Standard Pressure

5.1 Standard pressure is defined as 101,325 pascals (1 atm, 760 Torr).

6 Standard Density

6.1 The standard density is defined as Mw/22,413.6 grams per standard cubic centimeter (g/scc), where Mw is the molecular weight of the gas in grams per mole (g/mol), and 22,413.6 is the standard molar volume in cubic centimeters (scc/mol) (i.e., the volume of one mole of a perfect gas at standard temperature and standard pressure).

7 Standard Flow Rate

7.1 Standard flow rate is the volumetric flow rate of the gas at the standard density defined in Paragraph 6.1.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

8 Units

8.1 Units for standard flow rate may be expressed as standard cubic centimeters per minute (sccm), standard liters per minute (slm), standard cubic decimeters per minute (scdm), or as standard cubic meters per minute (scmm).

$$1 \text{ sccm} = 1 \times 10^{-3} * \text{slm}$$

$$= 1 \times 10^{-3} * \text{scdm}$$

$$= 1 \times 10^{-6} * \text{scmm}$$

NOTE: Units in this document have been editorially changed to sccm, slm, scdm, and scmm in line with international standards which require all units to be expressed in SI terms. While neither “minute” nor “liter” is a primary SI unit, each is acceptable under the system, and eliminating the use of these units in this standard would seriously diminish its acceptability.

9 Background

9.1 In the absence of this specification, there has been confusion in the definition of standard conditions. “Standard” temperature in particular has been variously defined as 59°F, 68°F, 70°F, 20°C, 22°C, etc. to reflect “normal” test conditions. The scientific community has generally accepted 0°C, as has the semiconductor industry, in its definition of sccm. Standard pressure has almost universally been accepted as one atmosphere, except for rounding errors in different units.

9.2 Further confusion has existed in the definition of standard density when extended to vapors. For perfect gases (most light gases are nearly perfect), the standard density can be defined as the density of the gas at standard temperature and pressure. Since one gram mole of a perfect gas occupies 22,414 cubic centimeters at standard pressure and standard temperature, it follows that a flow rate of 22,414 sccm of any perfect gas is one mole per minute.

9.3 By defining standard density as in Section 6.1, the correlation between sccm and moles/minute is retained, even for vapors. If standard density were defined as the actual density of the vapor at standard temperature and pressure, then the correlation with moles per minute would differ by the vapor's compressibility factor (Z). This is not an acceptable alternative because the compressibility of many vapors is not accurately known, and, in fact, does not exist for those materials that are liquid at standard temperature and pressure.

10 Implications for Calibration

10.1 Since the standard flow units are defined at a standard density, they represent units of mass flow rather than volumetric flow.

10.2 Gravimetric calibration readings in grams per minute (g/min) can be converted to standard cubic centimeters per minute (sccm) by dividing by the standard density (g/scc) as defined in Section 6.1.

10.3 Rate-of-rise (ROR) data will generally have negligible compressibility error when operated over a low absolute pressure range. If compressibility errors are significant, they will cause the rate of pressure rise to be reduced and become pressure-dependent as the pressure increases. In this case, the pressure range must be reduced, or correction made, for compressibility.

10.4 Volumetric flow data must be corrected from actual density of the real gas at the test conditions to the standard density. The actual density can be approximated for near-perfect gases by ratios of absolute pressure and temperature to the standard density. For vapors, the actual density at the test conditions must be known from other data.

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SEMI E14-93
MEASUREMENT OF PARTICLE CONTAMINATION CONTRIBUTED TO THE PRODUCT FROM THE PROCESS OR SUPPORT TOOL

CONTENTS

NOTES

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SEMI E14-93
MEASUREMENT OF PARTICLE CONTAMINATION CONTRIBUTED TO THE PRODUCT FROM THE PROCESS OR SUPPORT TOOL

1 Introduction

This document describes the methods, procedures, and application of a technique for determining the average number of particles added to a wafer as a result of the wafer being passed through a semiconductor process tool.

1.1 *Purpose* — The purpose of this document is to provide a standardized methodology and detailed procedure for measuring the contamination performance of a particular process or tool in terms of the number and size distribution of particles added to a silicon wafer as a result of having been passed through that process tool. This standardized procedure is primarily intended to be used for the qualification of new or repaired processing equipment, but may be extended to new processes or methods, continuous process or tool monitoring, and qualification of new materials. As a result, this document contains supporting information; however, one may not need to read all of the information to determine the particles per wafer pass (PWP) of the process tool.

The measurement of surface particulate contamination on a wafer as it passes through the tool requires an understanding of the overall environment as well as the equipment in question. A flow chart summarizing the decision–making process at each phase of the evaluation is found in Figure 1. Each of the subsections begins with a brief description of the methodology for carrying out the measurement, followed by the step–by–step data collection and statistical evaluation procedure. More extensive background information and detailed explanations for the procedures are given in the appendices.

The working portion of this document follows a workbook format; each section may be used as a stand-alone method. Definitions should be reviewed and understood before applying a method (or section).

1.2 *Scope and Application* — The methodology and procedures provided in this document are applicable for evaluating the PWP for virtually any semiconductor processing equipment located in a cleanroom that is used to transport, inspect, measure, or process silicon wafers. The complexity of the process to be evaluated by this methodology is determined by the user. It ranges from a relatively simple process of moving wafers into and out of an ellipsometer to the full simulation of a CVD process including transport of a wafer into quartzware, pushing quartzware into a reactor chamber, multiple purge/vent cycles, process simulation with inert gas flow including establishment of process pressure, temperature ramping and soak, venting, cooldown, and transport back to the cassette. Although this procedure may be extended to actual fabrication processes, it is primarily intended to be used to quantify contamination added by a process tool and not by the actual process.

The measurement of PWP performance is in terms of particles located on the front surface of the wafer; it does not apply to particles on the back surface of the wafer. It is important that both the customer and supplier follow the same test method. This will help to ensure that communication takes place on the same level and that actual performance of the equipment is discussed.

1.3 *Protocols* — Figure 1 shows the sections included in the applications portion of this document. The section of most importance is Section 6. This section details how to measure PWP during process tool characterization. Section 4 explains how to calibrate the measurement instrument. If the calibration of the measuring instrument has been validated, then skip to Section 6. However, be sure to also perform the routine monitoring of the measurement instrument as described in Section 5. Section 7 explains how to perform routine monitoring of the process tool once it is characterized and incorporated in the process.

1.4 *Impact* — This document supersedes SEMI E14-90 in its entirety.

1.5 *Limitations* — The application of the procedures and methodologies provided in this document is limited by the following constraints:

1.5.1 The measurement vehicle is an unpatterned wafer. Where appropriate and practical, the unpatterned wafer shall represent the physical state of a patterned wafer at a similar stage of the process. Due to the variety of processes and tools in use at each site, it is recommended that the user or supplier define the exact process recipe to be used, keeping in mind the impact that the process may have on the PWP measurement results.

1.5.2 The detection of particles added is limited by the performance capability of the particle detection instrument being used.

1.5.3 The identification of the source and composition of particles measured is outside the scope of this procedure.

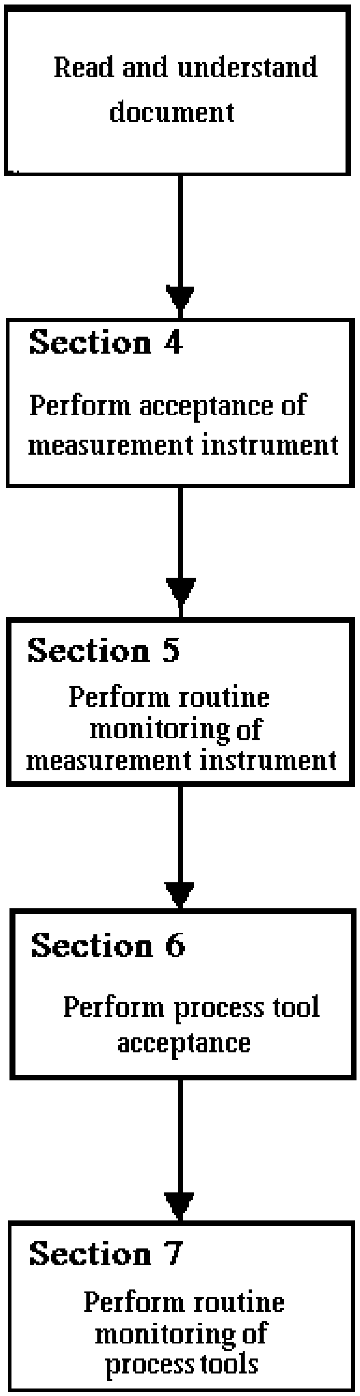

Figure 1
Decision-Making Procedure

2 Referenced Documents

2.1 ASTM 1241-90, Standard Terminology of Silicon Technology

2.2 EIA 557, Statistical Process Control Systems

2.3 General Services Administration. *Federal Standard Clean Room and Work Station Requirements, Controlled Environment,* FED–STD–209 (latest revision).

2.4 SEMI M10 — Standard Nomenclature for Identification of Structures and Features on Gallium Arsenide Wafers

2.5 Western Electric Co., *Statistical Quality Control Handbook,* 1956.

3 Terminology

3.1 *Abbreviations*

3.1.1 *CI* — confidence interval

3.1.2 *LCL* — lower confidence limit

3.1.3 *PSL* — polystyrene latex sphere

3.1.4 *PWP* — particles per wafer pass

3.1.5 *s* — standard deviation

3.1.6 *SL* — specification limit

3.1.7 *S/N* — signal to noise (ratio)

3.1.8 *UCL* — upper confidence limit

3.2 *Definitions*

3.2.1 *confidence interval (CI)* — Upper and lower bounds around an estimated value that will, within a certain percentage of confidence, include that estimated value.

3.2.2 *contaminant* — A broad category of foreign matter visible to the unaided eye on the wafer surface which is, in most cases, removable by gas blow-off, detergent wash, or chemical action. [ASTM 1241-90]

3.2.3 *control chart* — A graphic representation of a characteristic of a process, showing plotted values of some statistic gathered about that characteristic, and one or two control limits. [EIA 557] [Note: A control chart has two basic uses—as a judgment to determine if a process is in control, and as an aid in achieving and maintaining statistical control.]

3.2.4 *control limits* — A line (or lines) on a control chart used as a basis for process control. Variation beyond a control limit is evidence that special causes are affecting the process. Control limits are calculated from process data and are not to be confused with engineering specifications. [EIA 557]

3.2.5 *counting accuracy* — A percent of total known countable features on a wafer. Counting accuracy is determined by scanning a wafer with a known pattern of individual scattering centers.

3.2.6 *false negative* — A measurement that indicates the failure to count a particle that is present.

3.2.7 *false positive* — A measurement that indicates the presence of particles when no particles are present.

3.2.8 *in–line measurement* — A measurement made on a silicon wafer while the wafer resides in any portion of a processing tool or work cell except the processing chamber.

3.2.9 *in situ measurement* — A measurement made while a silicon wafer resides in the processing chamber of a processing tool.

3.2.10 *out–of–control actions* — A list of steps to be taken when the process is flagged as out–of–control. The desired outcome of executing the steps in the specified order is that the process comes back into control.

3.2.11 *particulate* — A discrete particle of dirt or other matter. [Reference ASTM 1241-90]

3.2.12 *polystyrene latex sphere* — Consistently sized and characterized spheres that represent particles on the wafer surface, but may not be indicative of actual particles encountered in the fab environment. These spheres are used to calibrate the particle counter response curve.

3.2.13 *process characterization* — Cycling a single wafer or batch of wafers through the tool with process or chemical changes. The purpose is to determine particle contributions from the mechanical and process aspects of the process tool.

3.2.14 *particles per wafer pass (PWP)* — The average number of particles added to a wafer as it passes through a tool, expressed in particles per wafer pass or in particles/cm^2/pass.

3.2.15 *scratch* — A long, narrow, shallow groove or cut below the established plane of the wafer surface. The ratio of the length of the groove to the width of the groove is typically greater than 5:1. [SEMI M10, ASTM 1241-90]

3.2.16 *signal-to-noise ratio* — The ratio of signal voltage at a given threshold to the background noise voltage.

3.2.17 *standard deviation* — A measure of the variation among the members of a statistical sample.

Equation : $$s = \sqrt{\frac{\sum_{i=1}^{n}\left(\overline{x} - x_i\right)^2}{n-1}}$$

3.2.18 *threshold* — A level set within the control software of a measurement instrument such that a signal which exceeds this level is recorded as an event and a signal below this level is ignored.

3.2.19 *U-chart* — An attributes chart used to track the number of nonconformities with varying sample size (for example, to track the particle density per wafer).

3.2.20 *wafer* — A thin slice with parallel faces cut from a semiconductor crystal. Also called *slice* and *substrate*. [ASTM1241-90]

3.2.21 *wafer, control* — A wafer that is allowed to pass entirely through a tool, being subject to a mechanical characterization without being subject to the actual process conditions.

3.2.22 *wafer, dummy* — A noncritical wafer added to a load–sensitive operation or run to complete a load of the equipment or process. Dummy wafers are never measured.

3.2.23 *wafer, test* — A wafer that is exposed to all of the conditions of process characterization, including, but not limited to, actual etch conditions or actual film deposition conditions.

3.2.24 *$\overline{X}$ -MR (mean-moving range) control chart* — A chart that tracks the difference between a current measurement and the value of the previous measurement.

3.3 *Descriptions of Terms*

3.3.1 *area defect (related to particle detection)* — A large single particle (≥ 10 µm in size) or a cluster of smaller particles that cannot be distinguished from each other.

3.3.2 *attributes* — Qualitative data that can be counted. For purposes of this document, examples include the number of particles per wafer, number of failed die per wafer, and particle density per wafer. Attributes are measured on a discrete scale.

3.3.3 *bin (of particle measurement instruments)* — A subset of the total range of particles counted, based on size. [Note: Many particle counting instruments measure the size of a particle while counting and then sort the total number of counts into bins. Some instruments have the size ranges of the bins set at the factory, while some designs allow the user to set the ranges of the bins. Also called *channel*.]

3.3.4 *C-chart* — An attributes chart used to track the number of nonconformities with a constant sample size. In this method, a C-chart can be used to track the total number of particles per wafer, assuming the underlying particle distribution is a Poisson distribution.

3.3.5 *calibration size* — The median size within the monodispersed size distribution that is produced for a deposit of PSL spheres on a calibration wafer. By definition, the count efficiency at the first threshold of minimum calibration particle size is 50%.

3.3.6 *interquartile range* — The range within which 50% of the data points fall.

3.3.7 *mechanical characterization* — When a single wafer or batch of wafers is cycled through the tool with no intentional process or chemical changes. The purpose is to determine particle contributions from the mechanical wafer movement throughout the process tool.

3.3.8 *particle* — A minute quantity of solid or liquid matter. For purposes of this document, particles are typically considered to be between 0.02 µm and 10.0 µm.

3.3.9 *repeatability* — The ability of a surface particle counter to repeat the total particle count on the wafer surface under the same conditions on the same wafer. [Note: For purposes of this method, at least 20 consecutive inspections are made.]

3.3.10 *size resolution* — The capability of a surface measurement instrument to differentiate between particles of nearly the same size.

3.3.11 *upper adjacent value* — Upper quartile range multiplied by 1.5 times the interquartile range.

3.3.12 *variables* — Those characteristics of a part or process which can be measured. Examples are thickness in Å, step height in ⌠m, and haze in parts per million. Variables are measured on a continuous scale.

3.3.13 *wafer, calibration* — A wafer with a known distribution of simulated particles to be used for sizing (e.g., PSL spheres) in terms of diameter in µm or a known number of simulated particles to be used for counting accuracy and location information (e.g., etch pits) on the wafer surface.

3.4 Control and Test Wafer Statistics and Definition of Variables

C_{ai} — Average "after"' count for each control wafer scanned five times.

C_{bi} — Average "before" count for each control wafer scanned five times.

$CI_{PWPtool}$ — Confidence interval of the average "particles added" contributed by the process tool.

n_c — Number of control wafers.

n_t — Number of test wafers.

P — Number of passes through the process tool.

PWP_{tool} — Average number of "particles added" contributed by the process tool ($X_{test}X_{control}$).

$S^{adj}_{control}$ — Standard deviation of the control wafers adjusted for the measurement error of the particle counter.

S^{adj}_{test} — Standard deviation of the test wafers adjusted for the measurement error of the particle counter.

$S_{calibration}$ — Standard deviation of the particle counter.

$S_{control}$ — Standard deviation of the control wafers.

SL (specification limit) — Total number of "particles added" allowed by the process tool.

S_{test} — Standard deviation of the test wafers.

T_{ai} — Average "after" count for each test wafer scanned five times.

T_{bi} — Average "before" count for each test wafer scanned five times.

$X_{control}$ — Average particles contributed by handling.

X_{test} — Average particles contributed by the test wafers.

4 Measurement Instrument Evaluation

4.1 *Methodology for Instrument Acceptance*

4.1.1 The purpose of evaluating the surface measurement instrument is to verify that the size accuracy, size resolution, PWP, repeatability, false negative test, false positive test, S/N ratio, and counting accuracy of the instrument are acceptable to evaluate the PWP performance of process and support tools.

4.1.2 This portion of the evaluation is to be completed upon user acceptance of the measuring instrument from the instrument manufacturer or upon a major preventive maintenance action to the instrument, such as a laser tube replacement.

4.1.3 It may not be practical to schedule this evaluation on a regular basis because of its complexity. Figure 2 details the steps in the calibration acceptance process. If the measurement instrument is shown to be in calibration using normal criteria, go to Section 5 for process tool PWP acceptance.

4.1.4 The methodology to measure noise on the measuring instrument may be restricted by the design of the instrument and the quality of the wafers. It is imperative to ensure that noise does not contribute false positive counts at the specified particle sensitivity of the instrument. Refer to Appendix A2, Section A2.1.3 for details on this procedure.

4.1.5 *Calibration Wafers* — To obtain representative results of the customer's operation, the calibration wafers must be produced on clean, bare silicon product wafers from that customer. Calibration wafers should be dedicated for instrument calibration only and should be stored in a clean cassette at all times until needed.

Calibration wafers with full or half deposition of PSL calibration monospheres of nominal diameter, which represent the first and subsequent thresholds, are indicated below. Also included is an etched pit wafer. The etched pit wafer can be either a four distribution or a single distribution wafer. Different PSL diameters are noted for HeNe and argon laser systems. Refer to Appendix A1 for application notes to produce PSL calibration wafers. Additional PSL calibration wafers may be used.

CAL	*PSL Diameter (nominal)*	
Wafer Count	*HeNe*	*Argon*
A appx 2000	see note*	see note*
B " 600	0.30 µm	0.20 µm
C " 600	0.50 µm	0.40 µm
D " 600	1.00 µm	1.10 µm

E Etched pit count accuracy wafer

* Specified sensitivity of the instrument.

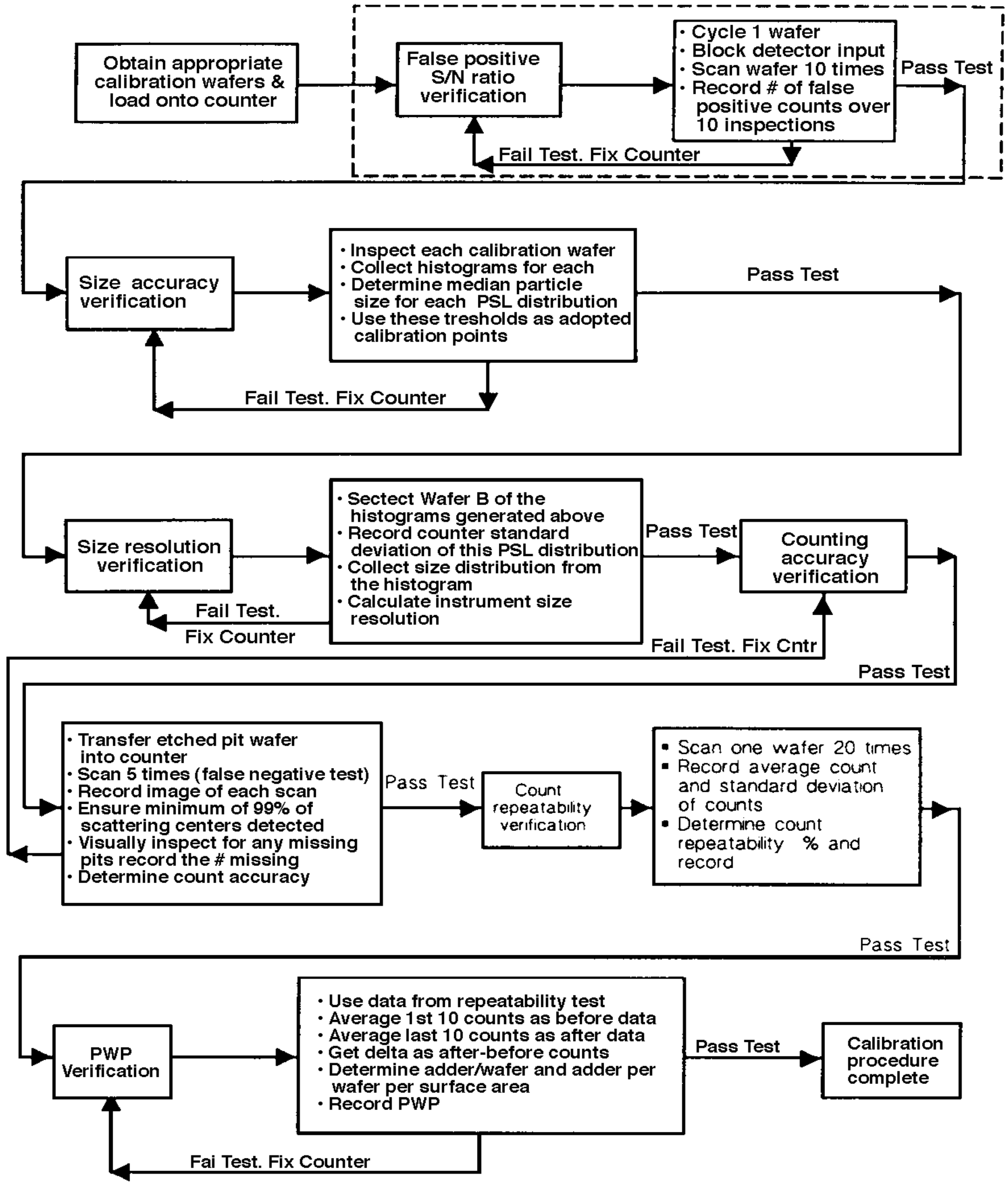

Figure 2
Instrument Calibration Acceptance Process

4.2 *Procedure for Instrument Calibration acceptance*

4.2.1 Load the calibration wafers onto the instrument load station (with the wafer flat/notch oriented to the back of the cassette) ensuring that Class 10 vertical laminar flow is extended beyond the load station at all times.

Additional calibration wafers can be used other than those noted above. Intersperse the calibration wafers in a clean cassette with several empty slots between each wafer.

4.2.2 Verify Noise

See Application Note, Appendix A2.

4.2.3 Verify Size Accuracy

4.2.3.1 Determine if the instrument has adequate dynamic range to collect full sphere distribution peaks for all four size PSL calibration wafers A, B, C, and D.

- Set the instrument program parameters (e.g., gain, threshold, maximum size) to collect a full peak for PSL calibration Wafer A. Record the settings.

Program parameters for Wafer A:

____

____

____

____

____

- Scan PSL calibration Wafers B, C, and D using the program parameters used to scan PSL Wafer A and determine if the sphere distribution peaks are fully resolved.
- If all four peaks are fully resolved, proceed to paragraph 4.2.3.2.
- If all four peaks were not fully resolved, determine the program setting needed to fully resolve the sphere peaks for each PSL wafer and record the results. [Note: In some cases, four different programs may be required; in some cases, two or three may be sufficient.]

Attach copies of each distribution. (See Appendix A2, Application Notes for discussion.)

Program parameters for Wafer B:

____

____

____

____

Program parameters for Wafer C:

____

____

____

____

Program parameters for Wafer D:

____

____

____

____

4.2.3.2 Set up the instrument with the setting needed to scan Wafer A.

4.2.3.3 Scan Wafer A.

4.2.3.4 Isolate the PSL sphere peak. [Note: The distribution is isolated by either manually moving the cursors to the left and right of the distribution and redisplaying the histogram or by letting the system isolate the distribution automatically, depending on the type of measurement instrument in use.] Record the median of the distribution in µm. (These numbers are displayed on the screen.)

Median of distribution___________________

[Note: If the median is displayed in units other than µm, use a manufacturer-supplied calibration curve to convert the units to µm.]

4.2.3.5 Scan Wafer A four additional times. Isolate the distribution and record the median as above.

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

4.2.3.6 Calculate the average median of the distribution. Record the results.

Average median________________________

4.2.3.7 Determine if the median is within 5% of the specified PSL calibration size. If not, resolve the problem or contact the instrument manufacturer for recalibration. Restart the calibration procedure.

Specified sphere diameter________________

4.2.3.8 If necessary, modify program parameters to scan Wafer B at a different level of sensitivity.

4.2.3.9 Scan Wafer B.

4.2.3.10 Isolate the PSL sphere distribution. Record the median and standard deviation of the distribution in µm.

Attach histogram for future use.

Median of distribution___________________

s of distribution________________________

4.2.3.11 Scan Wafer B four additional times. Isolate the distribution and record the median and standard deviation as above.

Median of distribution___________________

s of distribution________________________

Median of distribution___________________

s of distribution________________________

Median of distribution___________________

s of distribution________________________

Median of distribution___________________

s of distribution________________________

4.2.3.12 Calculate the average median of the distribution mean and standard deviation. Record the results.

Average mean__________________________

Average s______________________________

4.2.3.13 Determine if the median is within 5% of the specified PSL calibration size. If not, resolve the problem or contact the instrument manufacturer for recalibration. Restart the calibration procedure.

Specified sphere diameter________________

4.2.3.14 If necessary, modify program parameters to scan Wafer C at a different level of sensitivity.

4.2.3.15 Scan Wafer C.

4.2.3.16 Isolate the PSL sphere distribution. Record the median of the distribution in µm.

Median of distribution___________________

4.2.3.17 Scan Wafer C four additional times. Isolate the distribution and record the median as above.

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

4.2.3.18 Calculate the average median of the distribution median. Record the results.

Average mean__________________________

Average s______________________________

4.2.3.19 Determine if the median is within 5% of the specified PSL calibration size. If not, resolve the problem or contact the instrument manufacturer for recalibration. Restart the calibration procedure.

Specified sphere diameter________________

4.2.3.20 If necessary, modify program parameters to scan Wafer D at a different level of sensitivity.

4.2.3.21 Scan Wafer D.

4.2.3.22 Isolate the PSL sphere distribution. Record the median of the distribution in µm.

Median of distribution___________________

4.2.3.23 Scan Wafer D four additional times. Isolate the distribution and record the median as above.

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

Median of distribution___________________

4.2.3.24 Calculate the average median of the distribution. Record the results.

Average median________________________

4.2.3.25 Determine if the mean is within 5% of the specified PSL calibration size. If not, resolve the problem or contact the instrument manufacturer for recalibration. Restart the calibration procedure.

Average s______________________________

Specified sphere diameter________________

4.2.4 Verify Size Resolution

Determine size resolution using the calibration histogram of Wafer B.

4.2.4.1 Collect the PSL size distribution from the instrument in µm or extrapolate the size resolution from the manufacturer's primary calibration data and record the response.

Attach size resolution response and retain for reference.

4.2.4.2 Collect from the instrument, or record from Section 4.2.3.12, the standard deviation of this PSL sphere size.

Record the instrument standard deviation of the size distribution_________. If the instrument reports a coefficient of variance (CV) in percent (s%), multiply the CV times the mean diameter to acquire s.

Record the reported PSL standard deviation from the PSL bottle or from the certificate________. If the PSL bottle reports the coefficient of variance (CV), multiply CV times the mean deviation to acquire s.

4.2.4.3 Calculate the instrument size resolution in % as follows:

$$\frac{\sqrt{\text{Instrument } s^2 - \text{Reported PSL } s^2}}{\text{Particle Mean Diameter, } \mu\text{m}} \times 100$$

Record the calculated resolution___%___.

4.2.4.4 To minimize inter-instrument data variability, the percent resolution should not exceed 15%. If the variability is > 15% for the selected particle size, resolve problems and rerun 4.2.4. If resolution is ≤ 5%, go to 4.2.5.1.

4.2.5 Verify Counting Accuracy

4.2.5.1 Transfer Wafer E (etched pit wafer) into the instrument. Set the min and max display sensitivity to see only the etched pit distributions. Adjust the edge exclusion to see just the image of the etched pit pattern. Inspect the wafer five times. Use a 150-mm wafer if 200 mm is not available.

4.2.5.2 Print each image and attach the printouts. Specify the actual number of scattering centers on the wafer.

Attach count accuracy images as a reference. Record the actual number of scattering sights on the count accuracy wafer ____.

4.2.5.3 Using the patterned description provided by the producer of the count accuracy wafer, ensure that a minimum of 99% of the scattering centers are detected on each scan. Furthermore, ensure that there are no patterns of double counting of the scattering centers in any quadrant or on the XY axis.

4.2.5.4 Visually inspect each image for missing scattering centers within the defined pattern. Disregard any disparate particles outside or within the etched pit zone; these particles are not a part of the defined etched pit pattern. Average the missing pits over the 5 images and record to one decimal point.

Record the actual number of missing pits within the pattern. Do not confuse particles within the pattern as pits.

#1 image_____

#2 image_____

#3 image_____

#4 image_____

#5 image_____

Average missed sites to one decimal point = ___.

4.2.5.5 Determine count accuracy % as follows:

$$1 - \frac{\text{average number of missed or added pits}}{\text{actual number of pits}} \times 100$$

If the count accuracy is < 99%, resolve problems on the instrument and rerun 4.2.4. If count accuracy is 99 to 100% go to 4.2.5.1.

The acceptance calibration of the particle counter is complete.

Count accuracy = ___%.

4.2.6 *Verify Count Repeatability* — The purpose of this test is to verify the counting repeatability of the particle counter. Typically, count repeatability is determined with a PSL distribution on the wafer, but it can also be accomplished on a bare silicon wafer.

The equipment user and supplier must mutually agree on which wafer type will be used.

4.2.6.1 Inspect calibration Wafer B a minimum of 20 cycles while noting the total defect count from each inspection.

Record the total number of particles from each inspection (1–20).

4.2.6.2 Determine the average total particle count and the standard deviation of the count.

Average detected particles **X** = ___.

Standard deviation = ___.

4.2.6.3 Determine count repeatability at n.

$$\frac{n \times \sigma}{\overline{X}} \times 100 = \text{\% repeatability}$$

Select the value of n ______, which correlates to the confidence interval required.

4.2.6.4 Record the percentage of repeatability. If count repeatability is not ≤ that specified by the particle counter manufacturer's specification, resolve problems and rerun this test. If successful, go to 4.2.7.1.

Count repeatability = ___%, at n sigma.

4.2.7 Verify PWP of the Instrument

The purpose of this test is to measure the level of particle contributions from the particle counter to a wafer. PWP values of less than zero should be set to zero.

4.2.7.1 Using the data collected from the count repeatability test, determine PWP as follows:

- Average the first 10 total particle counts ("before count").

Average of first 10 counts = ___.

- Average the last 10 total particle counts ("after count").

Average of last 10 counts = ___.

- Delta = "after count" – "before count"

Delta = ___.

- Delta/10 = particles added per pass.

Delta/10 = ___.

PWP/cm^2 =

$$\frac{\left(\left[\frac{\text{wafer diameter mm}}{2}\right] - \text{edge exclusion mm}\right)^2 \times \pi}{100}$$

Particles added/included surface area = ___.

PWP =_______particles/cm^2 of a size ≥__µm.

- If PWP is not ≤ the equipment supplier's specification, verify cleanliness of the system and rerun 4.2.7.

5 Measurement Instrument Monitoring

5.1 *Methodology for Instrument Monitoring* — This procedure is included for completeness. Many fabs have existing SPC methodology for particle tool monitoring. Monitor the particle counter on a routine, regular basis (e.g., per day or per shift), regardless of the particle methodology chosen.

The purpose of monitoring the particle measurement instrument is to verify that the instrument is in calibration. Routinely verify the performance of the measurement instrument so that the results of process tool particle testing can be trusted. The instrument calibration is tested using an etched pit standard. The etched pit standard provides information about instrument count accuracy and size trend monitoring. Etched pit wafers are the standard of choice for routine monitoring because they can be cleaned and recertified when contaminated. PSL wafers should be replaced when contaminated.

The calibration wafer should be run regularly (e.g., once per shift, once per day, or once per week) for 25 tests, and the data should be recorded on control charts. When 25 points have been collected, control limits can be defined. $\overline{X}$ -MR control charts are used to track the collected information by measuring an identical sample repeatedly. $\overline{X}$ -MR charts track the difference between a current measurement and the value of the measurement the last several times the sample was run, which is the desired measured performance. For more information on $\overline{X}$ -MR charts, see Appendix A3.

Figure 3 details the steps outlined in this section.

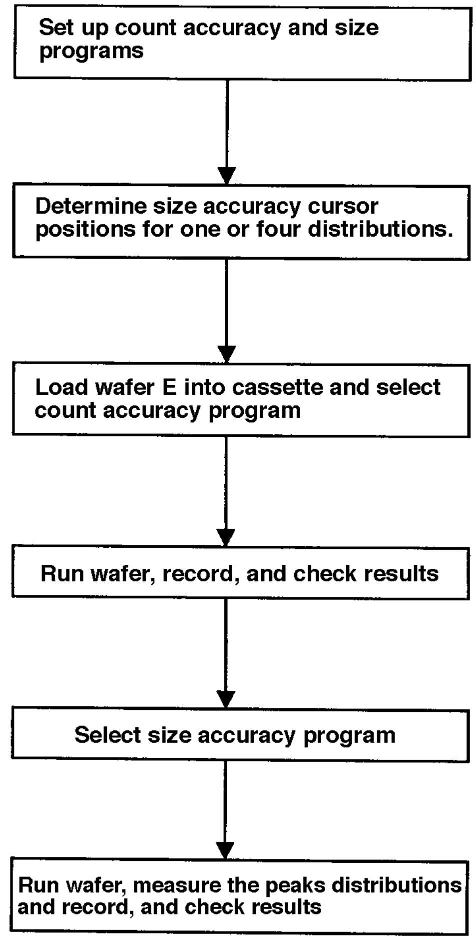

Figure 3
Procedure for Instrument Monitoring

5.2 *Procedure for Instrument Monitoring* — [Note: Reference Appendix A2, A2.1.6, and A3 for detailed discussion.]

5.2.1 Count Accuracy and Size Trend Monitoring

5.2.1.1 Program setup

Program name________________________________
Edge exclusion________________________________
Min display setting____________________________
Gain setting__________________________________
Max display setting____________________________
Equivalent size reference_______________________

5.2.1.2 Load the etched pit wafer into the cassette and place the cassette on the measuring instrument. Select the Count Accuracy Program.

5.2.1.3 Run the wafer with at least 25 scans. Record the median of the distribution and count on each scan.

Median of the distribution	Count:
#1__________________	______
#2__________________	______
#3__________________	______
#4__________________	______
#5__________________	______
#6__________________	______
#7__________________	______
#8__________________	______
#9__________________	______
#10__________________	______
#11__________________	______
#12__________________	______
#13__________________	______
#14__________________	______
#15__________________	______
#16__________________	______
#17__________________	______
#18__________________	______
#19__________________	______
#20__________________	______
#21__________________	______
#22__________________	______
#23__________________	______
#24__________________	______
#25__________________	______

5.2.1.4 Calculate and plot the average median of the distributions on the control chart.

$\overline{X}$ = ________µm____Average count

5.2.1.5 Determine whether the monitored size is in or out of specification of the control chart.

5.2.1.6 Determine if the averaged etched pits not detected or added from each of the 25 scans is > 99% and < 100%.

5.3 *Out-of-Control Actions* — If any of the distributions are out of control, recalibrate the instrument.

In control_________ Out of control_________

Count accuracy =

$$1 - \frac{\text{average number of missed or added pits}}{\text{actual number of pits}} \times 100$$

If count accuracy is < 99% or > 100%, recalibrate the instrument or contact the manufacturer for repairs.

6 Measuring PWP for Process Tool Acceptance

6.1 *Methodology for Process Tool Acceptance*

6.1.1 The purpose of performing process tool acceptance is to assure the customer and supplier that the tool meets all the criteria as agreed upon by the user and supplier. The acceptance process characterizes the tool so that its performance level can be documented. The purpose of this section is to determine the particles per wafer pass (PWP) of the process tool. This number is usually reported in particles/cm^2/pass. This section is intended to document a standard method of arriving at the PWP of the process tool. There are five areas that require the understanding of the customer and supplier. (See Figure 4.)

6.1.2 *Explanation of Steps in Methodology for Acceptance (see Figure 4)*

6.1.2.1 The first step is intended to ensure that both the customer and the supplier agree on a set of control and test parameters for the process tool. Some of the issues are the specification limit (SL) for the allowable number of particles added by the process tool (for example, 0.05 particles/cm^2/pass 0.1 µm); the number and timing of conditional cycles, whether or not to use dummy wafers in the cassette; and the recipes to be used for the process tool. The issues and parameters should be agreed upon before the start of data gathering and should replicate actual wafer processing as closely as possible.

6.1.2.2 The second step concerns the cleanliness of the control and test wafers. By obtaining the most consistently clean wafers available, the experiment will provide much higher confidence for a given number of replications. The end result is fewer replications for a chosen confidence interval and, therefore, a potential savings of experiment cost in time and money.

6.1.2.3 The third and fourth steps deal with the control and test wafers. The control wafers are used to determine the effect of handling on the PWP added. Minimize the amount of particles added by the handling so that it is clear which particles can be attributed to the process tool. Once the number of particles added by the handling is determined, this number can be subtracted from the test wafer total. For convenience, the number of control and test wafers is the same.

6.1.2.4 After determining the PWP of the process tool, the customer and supplier should discuss the results. This is the fifth step. The customer and supplier must agree with the results. If the process tool fails to meet specification limit, the customer and supplier should determine the next step.

Note: This document assumes a Class 10 or better cleanroom per FED-STD-209.

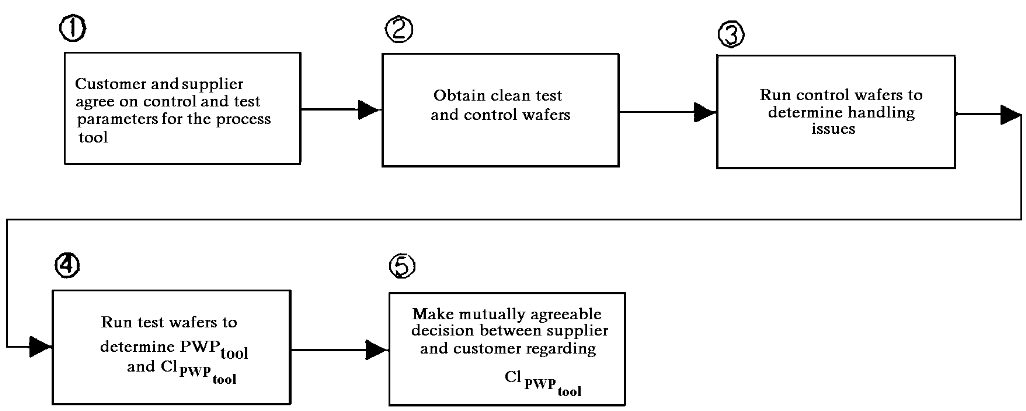

Figure 4
Steps in Methodology for Process Tool Acceptance

Figure 5 shows the basic steps necessary to complete the process tool characterization. It is intended to pictorially show the user of the document the derivation of each of the numbers determined in Sections 6.1 and 6.2.

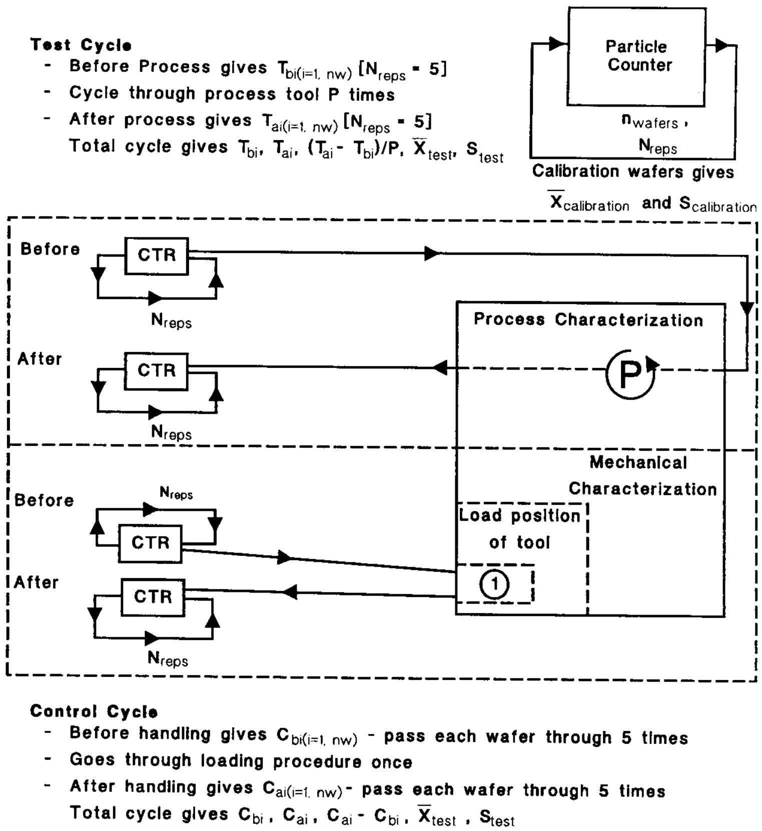

Figure 5
Basic Steps for Process Tool Characterization

6.2 *Procedure for Process Tool Acceptance*

6.2.1 *Step 1* — Determine control and test parameters as agreed upon by the user and supplier. These should include the following:

6.2.1.1 The specification limit (SL) shall be < ___ PWP, particles/cm^2 per wafer pass, of a size ≥___ µm.

6.2.1.2 The number of dummy wafers to be used in the test and/or control cassette is ____.

6.2.1.3 The number of conditioning run cycles to be used is ____.

6.2.1.4 Type and mechanical characteristics of the cassettes to be used, such as antistatic, supplier, and material (specify).

6.2.1.5 Surface preparation of the test and control wafers (for example, hydrophilic, hydrophobic, acid or base, and affinity for attracting particles) (specify).

6.2.1.6 Specifications for incoming material gases, liquids, etc. to be supplied to the process tool shall be agreed upon before the installation.

6.2.1.7 Installation requirements to be met.

6.2.1.8 Recipes to be used during this evaluation (specify).

6.2.1.9 Number of passes, P, through the process tool is ____.

6.2.2 *Step 2* — Ensure that the initial particle counts for the set of 25 wafers have a narrow spread. This is to ensure that little or no variability can be tied to wafer variation.

When deciding on the acceptable initial particle count, determine the expected number of particles added for the process tool.

Under ideal conditions, the ratio of the before-count of the control and test wafers to the PWP specification (the number of anticipated counts added by the process tool) should be 1:4; i.e., if the PWP specification is ≤ 20 particles larger than 0.3 µm, the before-count of the control and test wafer should be ≤ 5 particles larger than 0.3 µm. The upper limit of this ratio should not be less than 1:1. For example, the set of wafers may have pre-counts in the range of 20 ± 5 (at ± 0.3 µm) if the PWP specification of the process tool ≤ 80 particles added.

6.2.3 *Steps 3 and 4* — Figure 6 graphically depicts steps 3 and 4 of the process tool characterization. The procedure is presented in Section 6.2.4.

6.2.4 The numbers in parentheses (n) preceding paragraphs in this section correspond to the numbered blocks in the flow chart for steps 3 and 4. (See Figure 6.)

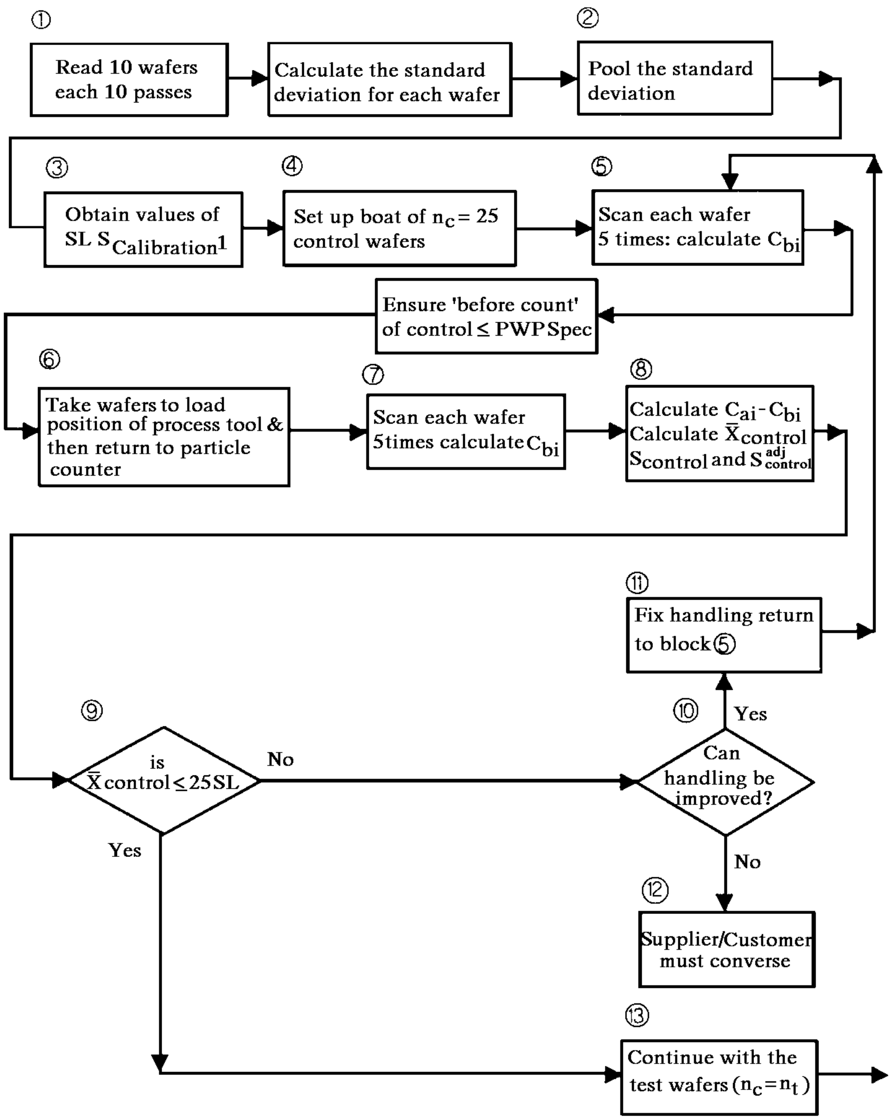

Figure 6
Detail of Steps 3 and 4

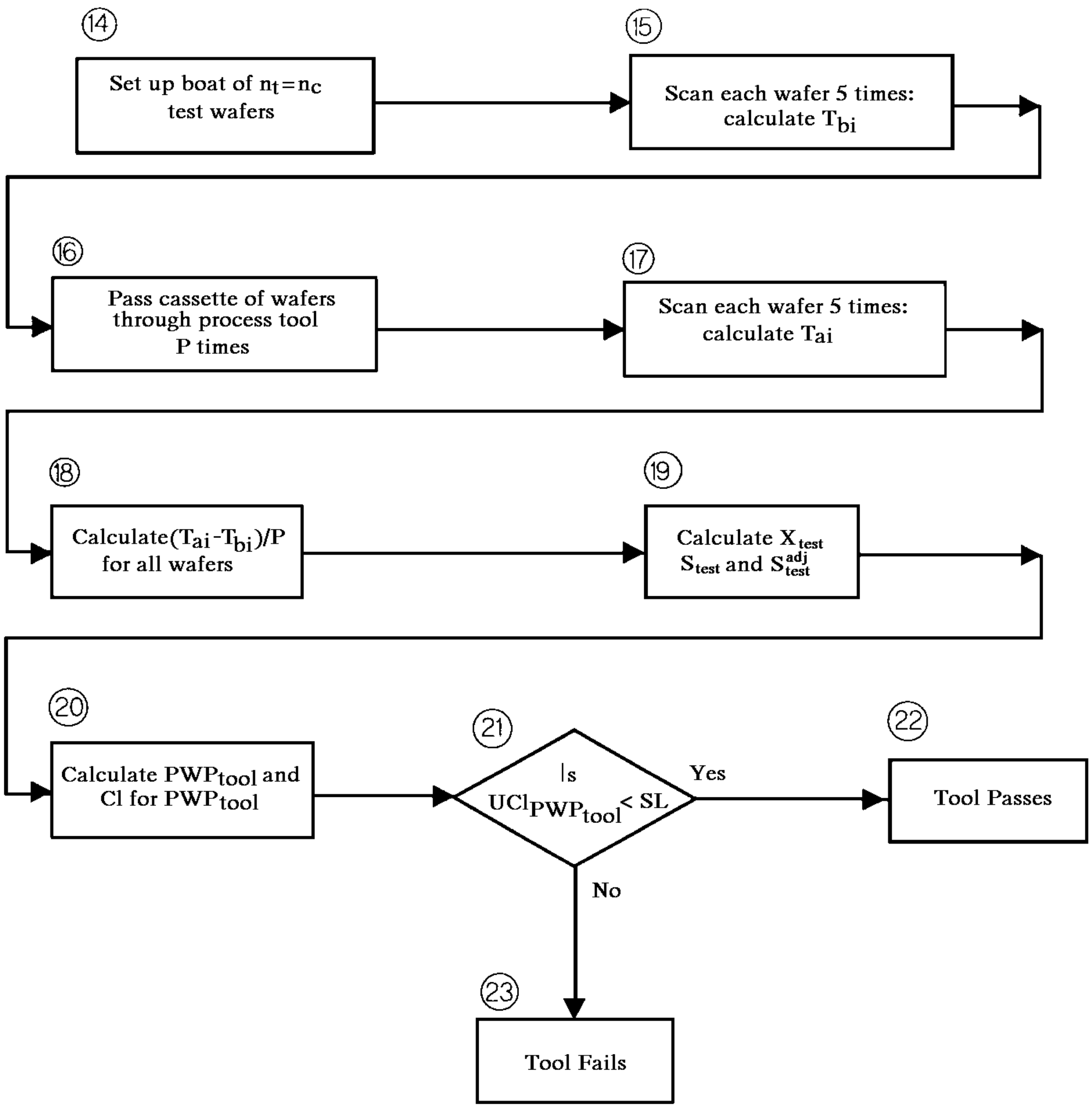

Figure 6
Detail of Steps 3 and 4

6.2.4.1 (1) To determine the value for **$S_{calibration}$**, begin by reading 10 wafers 10 times each, and record the standard deviation for each wafer. To ensure that the pre-counts of wafers are acceptable, reference paragraph 6.2.2.

6.2.4.2 (2) Calculate **$S_{calibration}$** by pooling the standard deviations for each wafer.

6.2.4.3 (3) Note the value of **SL** from 6.2.1.

6.2.4.4 (4) Set up a cassette of control wafers. **n_c** = 25 wafers.

6.2.4.5 (5) Scan each wafer five times and calculate **C_{bi}**(i=1->25).

j = # of reps for j=1->5

C_{b15} =______

(1) Standard deviations:

Wafer 1 s______

Wafer 2 s______

Wafer 3 s______

Wafer 4 s______

Wafer 5 s______

Wafer 6 s______

Wafer 7 s______

Wafer 8 s______

Wafer 9 s______

Wafer 10 s_____

(2)

$$S^2_{pooled} = \frac{\sum_{i=1}^{k}(n_i - 1)s_i^2}{N - k} \Rightarrow \text{general}$$

$$S^2_{pooled} = \sum_{i=1}^{k}\frac{s_i^2}{90}$$

where N = total number of measurements (100)

n = number of reps (10)

k = number of wafers (10)

$$S_{calibration} = \sqrt{S^2_{pooled}}$$

(3) SL =________

(4) **n_c** = 25, **N_{reps}** = 5

(5)

$$C_{bi(i=1->25)} = \frac{\sum_{j=1}^{N_{reps}} \text{counts}}{N_{reps}}$$

C_{b1} =______

C_{b2} =______

C_{b3} =______

C_{b4} =______

C_{b5} =______

C_{b6} =______

C_{b7} =______

C_{b8} =______

C_{b9} =______

C_{b10} =_______

C_{b11} =_______

C_{b12} =_______

C_{b13} =_______

C_{b14} =_______

6.2.4.6 **(6)** Transfer the wafers to the load position of the process tool. Return the wafers to the particle counter.

6.2.4.7 **(7)** Scan each wafer five times and calculate C_{ai}(i=1->25).

C_{b15} =_______
C_{b16} =_______
C_{b17} =_______
C_{b18} =_______
C_{b19} =_______
C_{b20} =_______
C_{b21} =_______
C_{b22} =_______
C_{b23} =_______
C_{b24} =_______
C_{b25} =________

(7)

$$C_{ai(i=1->25)} = \frac{\sum_{j=1}^{N_{reps}} counts}{N_{reps}}$$

C_{a1} =______
C_{a2} =______
C_{a3} =______
C_{a4} =______
C_{a5} =______
C_{a6} =______
C_{a7} =______
C_{a8} =______
C_{a9} =______
C_{a10} =_______
C_{a11} =_______
C_{a12} =_______
C_{a13} =_______
C_{a14} =_______
C_{a15} =_______
C_{a16} =_______
C_{a17} =_______
C_{a18} =_______
C_{a19} =_______
C_{a20} =_______
C_{a21} =_______
C_{a22} =_______
C_{a23} =_______
C_{a24} =_______
C_{a25} =_________

6.2.4.8 (8) Calculate $\mathbf{C_{ai} - C_{bi}}$, $\overline{X}_{control}$, $\mathbf{S_{control}}$, and $S_{control}^{adj}$

(8)

$\mathbf{C_{a1} - C_{b1}}$ =_____
$\mathbf{C_{a2} - C_{b2}}$ =_____
$\mathbf{C_{a3} - C_{b3}}$ =_____
$\mathbf{C_{a4} - C_{b4}}$ =_____
$\mathbf{C_{a5} - C_{b5}}$ =_____
$\mathbf{C_{a6} - C_{b6}}$ =_____
$\mathbf{C_{a7} - C_{b7}}$ =_____
$\mathbf{C_{a8} - C_{b8}}$ =_____
$\mathbf{C_{a9} - C_{b9}}$ =_____
$\mathbf{C_{a10} - C_{b10}}$ =_____
$\mathbf{C_{a11} - C_{b11}}$ =_____
$\mathbf{C_{a12} - C_{b12}}$ =_____
$\mathbf{C_{a13} - C_{b13}}$ =_____
$\mathbf{C_{a14} - C_{b14}}$ =_____
$\mathbf{C_{a15} - C_{b15}}$ =_____
$\mathbf{C_{a16} - C_{b16}}$ =_____
$\mathbf{C_{a17} - C_{b17}}$ =_____
$\mathbf{C_{a18} - C_{b18}}$ =_____
$\mathbf{C_{a19} - C_{b19}}$ =_____
$\mathbf{C_{a20} - C_{b20}}$ =_____
$\mathbf{C_{a21} - C_{b21}}$ =_____
$\mathbf{C_{a22} - C_{b22}}$ =_____
$\mathbf{C_{a23} - C_{b23}}$ =_____
$\mathbf{C_{a24} - C_{b24}}$ =_____
$\mathbf{C_{a25} - C_{b25}}$ =_____

$$\overline{X}_{test} = \sum_{i=1}^{n_t} \frac{(T_{ai} - T_{bi})/P}{n_t}$$

$\overline{X}_{test}$ = _____

$$S_{test} = \sqrt{\frac{\sum_{i=1}^{nt} \left[(T_{ai} - T_{bi}/P) - \overline{X}_{te}\right]^2}{n_t - 1}}$$

S_{test} = _____

$$S_{test}^{adj} = \sqrt{S_{test}^2 - \frac{(2)S_{calibration}^2}{N_{reps}}}$$

S_{test}^{adj} = _____

6.2.4.9 (9) Check to see if $\overline{X}_{control}$ <SL/4. If true, go to (13). If false, continue to next block.

6.2.4.10 (10) If $\overline{X}_{control}$ is > SL/4, check to see if handling can be improved.

6.2.4.11 (11) Improve handling and rescan all wafers starting at block (5). Run through blocks (5), (6), (7), (8) and (9).

6.2.4.12 (12) If handling cannot be improved, but $\overline{X}_{control}$ > SL/4, the supplier and customer need to decide what action to take.

6.2.4.13 (13) Continue with test wafers; $\mathbf{n_t} = \mathbf{n_c}$.

6.2.4.14 (14) Set up a boat of $\mathbf{n_t}$ = 25 test wafers.

6.2.4.15 (15) Scan each test wafer 5 times and calculate $\mathbf{T_{bi}}$(i=1->25).

(9) $\overline{X}_{control} \leq$ SL/4?

(10) Blocks (10)–(12) deal with handling issues if (9) is false.

(13) Set $\mathbf{n_t} = \mathbf{n_c}$.

(15)

$$T_{bi(i=1->25)} = \frac{\sum_{j=1}^{N_{reps}} counts}{N_{reps}}$$

$\mathbf{T_{b1}}$ =______
$\mathbf{T_{b2}}$ =______
$\mathbf{T_{b3}}$ =______
$\mathbf{T_{b4}}$ =______
$\mathbf{T_{b5}}$ =______
$\mathbf{T_{b6}}$ =______
$\mathbf{T_{b7}}$ =______
$\mathbf{T_{b8}}$ =______
$\mathbf{T_{b9}}$ =______
$\mathbf{T_{b10}}$ =_______
$\mathbf{T_{b11}}$ =_______
$\mathbf{T_{b12}}$ =_______
$\mathbf{T_{b13}}$ =_______
$\mathbf{T_{b14}}$ =_______
$\mathbf{T_{b15}}$ =_______
$\mathbf{T_{b16}}$ =_______
$\mathbf{T_{b17}}$ =_______
$\mathbf{T_{b18}}$ =_______
$\mathbf{T_{b19}}$ =_______
$\mathbf{T_{b20}}$ =_______
$\mathbf{T_{b21}}$ =_______
$\mathbf{T_{b22}}$ =_______
$\mathbf{T_{b23}}$ =_______
$\mathbf{T_{b24}}$ =_______
$\mathbf{T_{b25}}$ =_______

6.2.4.16 (16) Pass each wafer **P** times through the process tool.

(16) P =_____

6.2.4.17 (17) Scan each wafer 5 times and calculate T_{ai}(i=125).

(17)

$$T_{ai(i=1->25)} = \frac{\sum_{j=1}^{N_{reps}} counts}{N_{reps}}$$

T_{a1} =______
T_{a2} =______
T_{a3} =______
T_{a4} =______
T_{a5} =______
T_{a6} =______
T_{a7} =______
T_{a8} =______
T_{a9} =______
T_{a10} =_______
T_{a11} =_______
T_{a12} =_______
T_{a13} =_______
T_{a14} =_______
T_{a15} =_______
T_{a16} =_______
T_{a17} =_______
T_{a18} =_______
T_{a19} =_______
T_{a20} =_______
T_{a21} =_______
T_{a22} =_______
T_{a23} =_______
T_{a24} =_______
T_{a25} =_______

6.2.4.18 (18) Calculate differences between "before" and "after" counts and divide by the number of passes, **P**, through the process tool.

(18)

$(T_{a1} - T_{b1})/P$ =______
$(T_{a2} - T_{b2})/P$ =______
$(T_{a3} - T_{b3})/P$ =______
$(T_{a4} - T_{b4})/P$ =______
$(T_{a5} - T_{b5})/P$ =______
$(T_{a6} - T_{b6})/P$ =______
$(T_{a7} - T_{b7})/P$ =______
$(T_{a8} - T_{b8})/P$ =______
$(T_{a9} - T_{b9})/P$ =______
$(T_{a10} - T_{b10})/P$ =______
$(T_{a11} - T_{b11})/P$ =______
$(T_{a12} - T_{b12})/P$ =______
$(T_{a13} - T_{b13})/P$ =______
$(T_{a14} - T_{b14})/P$ =______
$(T_{a15} - T_{b15})/P$ =______
$(T_{a16} - T_{b16})/P$ =______
$(T_{a17} - T_{b17})/P$ =______
$(T_{a18} - T_{b18})/P$ =______
$(T_{a19} - T_{b19})/P$ =______
$(T_{a20} - T_{b20})/P$ =______

$(T_{a21} - T_{b21})/P =$_____
$(T_{a22} - T_{b22})/P =$______
$(T_{a23} - T_{b23})/P =$______
$(T_{a24} - T_{b24})/P =$______
$(T_{a25} - T_{b25})/P =$_______

6.2.4.19 (19) Calculate X_{test}, S_{test} and S_{text}^{adj} of the test wafers.

(19)

$$\overline{X}_{test} = \frac{\sum_{i=1}^{n_t} (T_{ai} - T_{bi})/P}{n_t}$$

$\overline{X}_{test} =$ ____

$$S_{test} = \sqrt{\frac{\sum_{i=1}^{n_t} \left[\left((T_{ai} - T_{bi})/P\right) - \overline{X}_{te}\right]^2}{n_{t-1}}}$$

$S_{test} =$ ____

$$S_{test}^{adj} = \sqrt{s_{test}^2 - \frac{(2)s_{calibration}^2}{N_{reps}}}$$

$S_{test}^{adj} =$ ____

6.2.4.20 (20) Calculate the average number of "particles added" contributed by the process tool, **PWP_{tool}**, **S_{tool}**, and the respective **UCL**.

υ is the degrees of freedom (in this case it is n – 2); α is the confidence level chosen (for example, α gives a 95% confidence for the value).

(20)

$$S_{tool} = \sqrt{\frac{S_{test}^{adj^2}}{n_t} + \frac{S_{control}^{adj^2}}{n_c}} =$$

$$PWP_{tool} = \overline{X}_{tool} = \overline{X}_{test} - \overline{X}_{control}$$

$$UCL_{pwp_{tool}} = \left(\overline{X}_{test}\ \overline{X}_{control}\right) + t_{(\alpha,\upsilon)} S_{tool}$$

Select the desired confidence level and appropriate t value.

Examples:

for α = 0.05, υ = 23, t(α, υ) = 1.714

for α = 0.01, υ = 23, t(α, υ) = 1.319

Refer to a Student t table in any statistics handbook for additional values.

6.2.4.21 (21) Check to see if $\mathbf{UCL_{PWPtool}} \leq \mathbf{SL}$.

(21) $UCL_{PWPtool} \leq SL$?

6.2.4.22 (22) If (21) is true, the tool meets the PWP specification limit.

6.2.4.23 (23) If (21) is false, the tool does not meet the PWP specification limit.

6.2.4.24 Record the final values in the following Summary Table.

Summary Table	*Process Tool*
$\overline{X}_{control}$	
$S^{adj}_{control}$	
$\overline{X}_{test}$	
S^{adj}_{test}	
PWP_{tool}	
# wafers used	
pass/fail	

7 Process Tool Monitoring

7.1 *SPC Methodology* — Routine monitoring of the process tool is important to ensure that the tool is stable. There are many methods for statistical process control (SPC) in use. Be aware of the nature of the data before choosing an SPC methodology. Two major areas of importance are the distribution of the data (i.e., normal, Poisson, or log-normal) and the correlation of the data. The following methodology is relatively insensitive to non-normality of the distribution; however, it does not take correlated data into account.

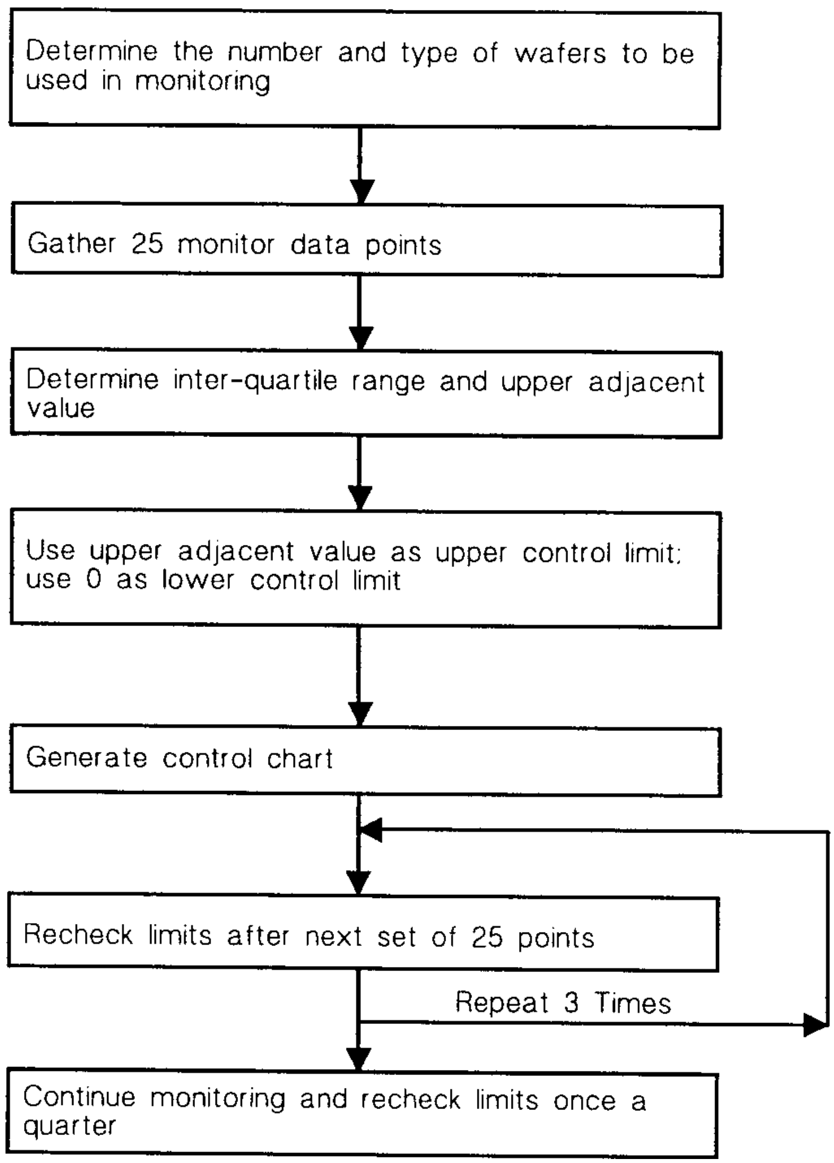

Figure 7
Methodology for Process Tool Particle Monitoring

7.2 Suggested Procedure for Process Tool Particle Monitoring

7.2.1 Determine the number of wafers to be used for monitoring. Read one wafer for 25 monitoring cycles, i.e., for 25 days or 25 shifts.

7.2.2 Gather 25 monitor points.

7.2.3 If using n = 1 wafers, then $D_i = post_i - pre_i$ for i = 1 to 25

where:

D = difference of particle counts before and after test.

7.2.4 If using n > 1 wafers, then

$$D_i = \sum_{i=1}^{n} \frac{post_i - pre_i}{n}$$

where n = # of wafers

n =_____

for n = 1:

$D_i = post_i - pre_i$

D_1 =______

D_2 =______

D_3 =______

D_4 =______

D_5 =______

D_6 =______

D_7 =______

D_8 =______

D_9 =______

D_{10} =________

D_{11} =________

D_{12} =________

D_{13} =________

D_{14} =________

D_{15} =________

D_{16} =________

D_{17} =________

D_{18} =________

D_{19} =________

D_{20} =________

D_{21} =________

D_{22} =________

D_{23} =________

D_{24} =________

D_{25} =________

Gather 25 monitor points. For example, if n = 25, gather one data point per wafer. If 1 < n < 25, scan each wafer 25/n times to collect 25 monitor points.

for n > 1, n =_____:

D_1 =____
D_2 =____
D_3 =____
D_4 =____
D_5 =____
D_6 =____
D_7 =____
D_8 =____
D_9 =____
D_{10} =___
D_{11} =___
D_{12} =___
D_{13} =___
D_{14} =___
D_{15} =___
D_{16} =___
D_{17} =___
D_{18} =___
D_{19} =___
D_{20} =___
D_{21} =___
D_{22} =___
D_{23} =___
D_{24} =___
D_{25} =___

7.2.5 Sort from lowest to highest.

7.2.6 Compute the upper adjacent value and median as follows:

Note:

UAV = upper adjacent value

UQR = upper quartile range

LQR = lower quartile range

IQR = interquartile range

Int = integer

If the number of passes or wafers is even:

median = average of value @ n/2 + value @ n/2 + 1
value @ n/2 + value @ n/2 + 1

UQR = average of value @ 3(n/4)
+ value @ 3(n/4 + 1)

LQR = average of value @ n/4
+ value @ n/4 + 1

IQR = UQR - LQR

UAV = UQR + 1.5 (IQR)

If the number of passes or wafers is odd:

median = Int(value @ n/2) + 1
LQR = (value @ n/4)Int + 1
UQR = (value @ 3n/4)Int + 1
IQR = UQR - LQR
UAV = UQR + 1.5(IQR)

7.2.7 Recheck limits after the next set of 25 data points (to make a total of 50 data points) is taken and validate data. Occasionally (every quarter) recheck limits using the above parameters.

8 Additional References

8.1 Donovan, R.P. ed., *Particle Control for Semiconductor Manufacturing.* New York: Marcel-Dekker, Inc., 1990.

8.2 Grant, Eugene L, and Leavenworth, Richard S. *Statistical Quality Control*, 6th ed. New York: McGrawHill Book Company, 1988.

8.3 Sachs, Lothar. *Applied Statistics: A Handbook of Techniques*. 2nd ed. New York: Springer-Verlag, 1984.

8.4 Tullis, Barclay J. "Measuring and Specifying Particle Contamination by Process Equipment: Part II Statistical Considerations." *Microcontamination* (December 1985): 15-21.

8.5 Walpole, Ronald E, and Myers, Raymond H. *Probability and Statistics for Engineers and Scientists*. 4th ed. New York: Collier Macmillan Publishers, 1989.

APPENDIX 1

Note: The material contained in this appendix is not an official part of SEMI E14, and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such they are to be considered as reference material only. The standard should be referred to in all cases.

A1 Notes on Preparing PSL Calibration Wafers

Light scattering from a particle is a major technique for counting and sizing particles in air, water, vacuum systems, or wherever they exist, including on surfaces. Although the theory of light scattering is well understood for a single particle suspended in a homogeneous medium, the addition of a reflecting plane next to the particle introduces enough additional complexities that the scattering problem cannot be solved analytically and requires considerable machine capacity for numerical solutions. Refer to A.1.2, Wojcik, Vaughan, and Galbraith, 1987; and Liu, 1990 for information on solutions to a few specific problems.

The primary calibration of specific instruments is empirical, correlating the instrument response to monodisperse particles (usually polystyrene latex spheres) of known size on surfaces of known optical properties. These measurements generate curves relating instrument (Figure A1) response to the diameter of the monodisperse PSL spheres. These curves vary with instrument design and also with surface type, typically necessitating a new empirical calibration for each type of surface examined. Coating composition and thickness can make significant differences. (See Figure A2 and, for example, Allen and Duty, 1991, Reference A.1.2). In addition, over at least a narrow range of sphere diameters, the calibration curves are not monotonic.

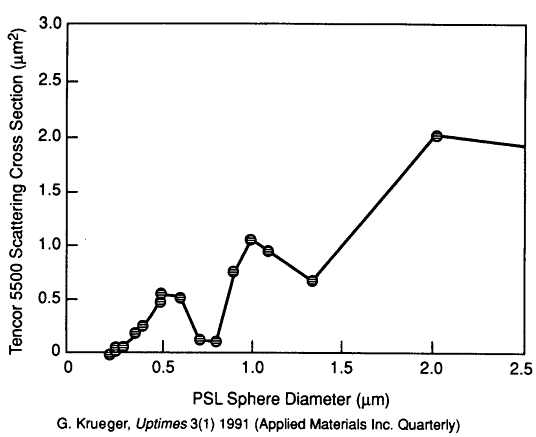

Figure A1
Substrate Dependence of Light Scattering by PSL Spheres

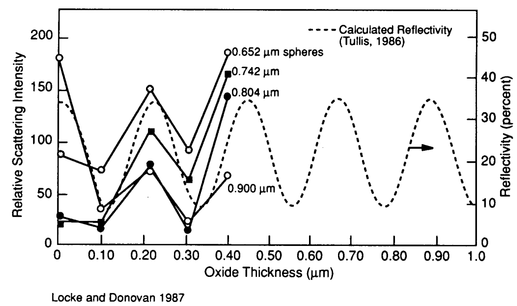

Figure A2
The Effect of Wafer Surface Reflectivity upon Surface Particle Light Scattering

Calibration is in terms of PSL sphere size, a convenient test particle of known optical properties but not a common contaminating particle in production environments. Thus, although a particle is considered a 0.2 μm particle if it generates a signal similar to that of a 0.2 μm PSL sphere, it is highly likely that the unknown particle is not spherical and has no specific dimension that is actually 0.2 μm.

A1.1 *PSL Deposition Procedures* — Procedures for counting surface particles using a commercial light scattering instrument depend on the specific equipment used. For all instruments, calibration curves corresponding to the surface being counted should be used. If not available, the instruments should be prepared to define the lower size detection limits and regions of multivalued response.

Construction of a calibration curve requires a set of 5-10 surfaces identical to that surface from which particle counts are desired. Each of these surfaces should have its own specific diameter of polystyrene latex (PSL) spheres spanning the diameter range from about 0.1 μm to 1-2 μm in increments defined by the size regions of highest interest. Typically, calibration curves exhibit the highest variation in size within the vicinity of wavelength of the incident light. Size increments should be the smallest over the size region. While some surfaces, such as bare silicon wafers, can be purchased with appropriately sized spheres already deposited, most surfaces of interest need to be prepared by the user. Three procedures for doing so follow.

The first procedure uses an aerosol generator, dryer, and neutralizer to feed aerosol through an electrostatic classifier and into a deposition chamber; it requires aerosol instrumentation for monitoring and control of the deposition. While less elaborate procedures are often satisfactory for depositing particles of diameters greater than 0.2 µm, this procedure minimizes extraneous particle deposition arising from contaminants in the deionized water supply, the PSL sphere supply, or other sources. These contaminants are probably more objectionable in the preparation of calibration wafers with PSL sphere diameters less than 0.1 µm.

The second procedure consists of the aerosol generator, dryer, and neutralizer. This simpler procedure sacrifices control over particle concentration and uniformity in return for simplicity of materials required and operation.

The third procedure is nonaerosol-based, using only a spinner similar to that typically used in films of liquid photoresist. The major advantage of this simplest procedure is that it requires no apparatus or materials beyond a source of PSL spheres and a high-speed spinner. Purity and uniformity of deposits by this third procedure are generally inferior to those of the other methods but may be adequate for inexpensively producing contaminated wafers dominated by a known PSL sphere size.

A1.1.1 Method 1: PSL Deposition from an Aerosol (Highly Controlled Procedure) — Materials:

PSL calibration spheres

PSL atomizer

Aerosol dryer

Aerosol neutralizer

Electrostatic classifier — A device for selecting particle populations according to electrical mobility.

Deposition chamber — An enclosure into which aerosol can be injected and deposited on the calibration surfaces also placed in the chamber. The chamber design should be such that it can be made particle-free by HEPA (or better) filtration prior to injecting the PSL aerosol and exposing the surfaces. To meet this requirement, the chamber may be located in a cleanroom. If the chamber is not located in a cleanroom, the surfaces must be loaded into the chamber in protective housings and not uncovered until the chamber atmosphere is particle-free.

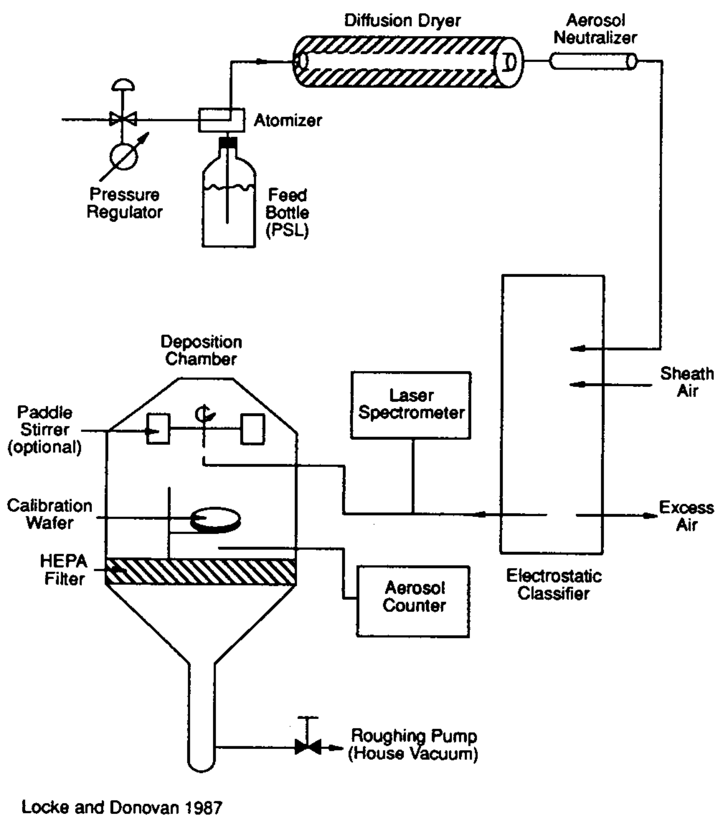

Figure A.3
Method 1 Aerosol Deposition System

Instrumentation and Components:

The chamber interior must remain isolated from all particle sources except the PSL aerosol both before and during surface exposure. The chamber design must be such that the wafer surfaces can be sealed in protective housing before unloading.

Particle-free source of compressed air (clean, dry air) or nitrogen

Regulators and tubing as needed

Aerosol particle spectrometer — A high-resolution spectrometer

Blank calibration wafer — Bare silicon or a silicon surface covered with a uniform film; this wafer should be as particle free as possible (particle concentration less than 10% of the anticipated PSL sphere population).

Steps

(1) Assemble components in the configuration of Figure A3. Connecting tubing should be as short as possible; inductive tubing should be used downstream of the atomizer.

(2) Charge the feed bottle with appropriately sized PSL spheres — 1 to 2 drops from the sphere manufacturer's solution into 800–1000 ml of deionized water is a good starting concentration.

(3) Initiate gas flow.

(4) Adjust electrostatic classifier voltage and flow rates for maximum particle concentration (calibration of the classifier may not agree with the PSL sphere diameter specified by the manufacturer); note PSL particle diameter measured by the laser spectrometer.

(5) Measure particle concentration, C_0, inside the deposition chamber.

(6) Insert clean calibration wafer into deposition chamber (or uncover a preloaded wafer).

(7) Expose wafer to the aerosol for a time period determined by:

$$t = \frac{DN}{AC_o V_D}$$

where:

t = time of wafer exposure

DN/A = desired area density of PSL particles on the calibration wafer

C_o = measured PSL aerosol concentration in the deposition chamber

VD = deposition velocity of the PSL spheres (estimate from Figure A4)

Deposition velocity depends on a number of variables. The curve calculated for a Boltzmann distribution in Figure A4 is a reasonable initial estimate.

A1.1.2 *Method 2: PSL Deposition from an Aerosol (Abbreviated Procedure)* — This method, though not as tightly controlled as Method 1, provides good calibration wafers with half depositions or partial wafer depositions as defined by the nozzle motion.

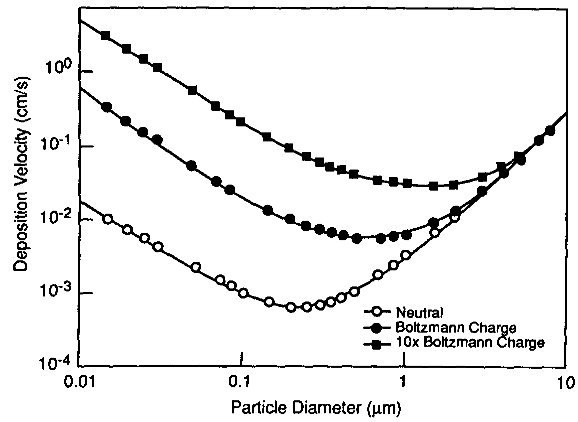

Figure A4
Calculated Deposition Velocity Including Effects of Diffusion, Setting, and Electric Field
Figure A3 — Method 1

Materials

This procedure omits the classifier and the deposition chamber used in Method 1. The configuration is the same as shown in Figure A3 until after the aerosol neutralizer. All apparatus downstream of the neutralizer can be omitted; or an arrangement such as shown in Figure A5 can be used, which includes an aerosol spectrometer. The items within the boxed area in Figure A5 can be purchased in an integrated package.

Steps

(1) Assemble components in the configuration of Figure A3. Connecting tubing should be as short as possible; inductive tubing should be used downstream of the atomizer.

(2) Charge the feed bottle with appropriately sized PSL spheres — 1 to 2 drops from the sphere manufacturer’s solution into 800–1000 ml of deionized water is a good starting concentration.

(3) Initiate gas flow.

(4) If an aerosol spectrometer is used, adjust the gas flow rate so that the spectrometer reads the most

monodispersed distribution in the proper size range. (Without the spectrometer the PSL sphere diameter is assumed to be that listed on the vial label by the manufacturer.)

(5) Using a backside vacuum pick, hold a blank calibration wafer vertically in front of the nozzle. This step should be in a particle-free space, such as in the vertical laminar flow downstream of a HEPA (or better) filter.

(6) Pass the nozzle several times across that portion of the wafer on which spheres are to be deposited.

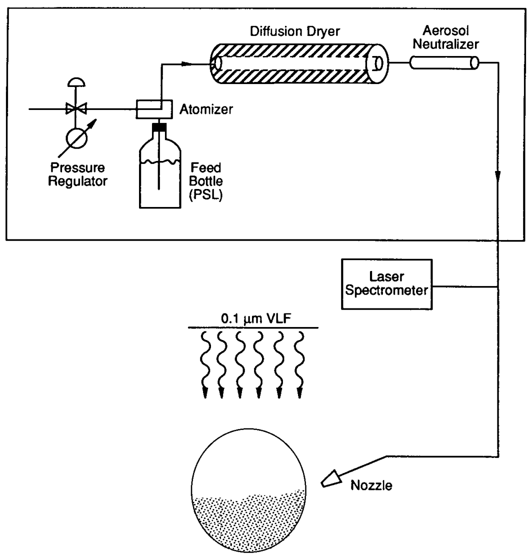

Figure A5
Method 2 Deposition Schematic

A1.1.3 Method 3: PSL Deposition from a Hydrosol — Materials:

Method 3 is a nonaerosol deposition procedure and requires only PSL calibration spheres, a blank calibration wafer, and a variable speed spinner with a vacuum hold down chuck.

Steps
(1) Prepare a dilute aqueous solution of PSL spheres of the desired size — 1 to 2 drops from the sphere manufacturer's solution into 800–1000 ml of deionized wafer is a good starting concentration.

(2) Place the blank calibration wafer on the vacuum chuck of the spinner.

(3) Start the spinner and add several drops of dilute PSL solution to the center of the wafer when the spinner is up to speed (dynamic dispense).

The strength of the PSL solution, the quantity of solution placed on the wafer, and the spinner speed should be optimized by trial and error.

A1.2 *References*

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Locke, B. R. and R.P. Donovan. Particle Sizing Uncertainties in Laser Scanning of Silicon Wafers. J. Electrochem. Soc., 134(7):1763-1771, July 1987. Figures A2 and A3 printed with permission from the Electrochem Society.

Tullis, B. J. Measuring and Specifying Particle Contamination by Process Equipment: Part III, Calibration. Microcontamination, 4(1):51-55, 86, January 1986.

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Figure A1 printed with permission from Applied Materials, Inc. Quarterly.

A2 Notes on Measurement Instrument Calibration

A2.1 The particle measuring instrument should have the following minimum performance requirements:

Although this document is designed for 0.1 µm particle counting instruments, the minimum measurable particle size for consistent performance should be no greater than 0.3 µm. At its first threshold, the instrument should not generate an average background internal noise level > 1 false particle count per ten (10) wafer (review) cycles. A primary signal-to-size calibration curve should be available from the instrument manufacturer, covering a minimum size range of 0.3 µm–1.0 µm. The instrument must have a dynamic range of particle size sufficient to span below 0.3 µm and above 1.0 µm PSL (polystyrene latex) calibrating spheres without sensitivity or gain adjustments. The instrument should not add more than .003 particles/cm/pass > 0.1 µm in size per measurement cycle per wafer.

A2.2 *Acceptance Calibration*

A2.2.1 *Loading Wafers* — Some instruments may have the propensity to detect a different number of particles on the wafer surface as the wafer is changed in orientation from inspection to inspection. Loading the calibration wafers at a constant orientation ensures a minimal amount of count orientation effects. This will help minimize count variations from instrument to instrument and site to site.

Slot separation minimizes effects of particle migration from the back of one wafer to the front of the next wafer.

A2.2.2 *Electrical False Positive Test* — The instruments used must provide false positive test capability.

The purpose of the false positive test is to determine that, when the instrument's optical detector is blocked from light input, the electronic output at the specified sensitivity equals less than or equal to one false positive count over ten scans.

If the first threshold, specified sensitivity, is adjusted too close to the background noise band, particle counts will be noted when no count should be present.

Electrical False Positive Test Procedure:

(1) Adjust the gain or display for specified sensitivity of the instrument.

(2) Scan a wafer with the specified distribution to observe sensitivity.

(3) Block the optical detector input.

(4) Scan the same wafer 10 times while observing each count output.

(5) If the total number of counts is > 1, the particle counter cannot be used at the present gain setting or display sensitivity.

If the count is ≤ 1, continue to A2.2.3.

A2.2.3 *First Threshold Signal-to-Noise Ratio Test* — This test is designed to show that the instrument's first threshold can be sufficiently detected to verify normal operation of wafer inspections.

If the instrument's first threshold is too close to the scatter band, count repeatability and accuracy can be affected. The noise that affects counts at maximum sensitivity is due to molecular scatter from the laser, shot noise from detector dark (leakage) current, and surface roughness generated noise. It is necessary to design the laser and shot noise out of the instrument, it is also necessary to discriminate between the particle signal and the surface roughness signal; when this is done, the surface roughness signals should not be counted as particles.

Gainsetting____

Scan 1 ___,2 ___,3 ___,4 ___,5 ___,

6 ___,7 ___,8 ___,9 ___,10 ___.

Readjust gain or display and restart this procedure at step 3. If the test continues to fail, readjust gain until test is successful and note the noise-free display sensitivity.

First Threshold Signal-to-Noise Ratio Test Procedure:

(1) Scan a very clean, bare silicon wafer of typical surface roughness. The displayed output should approximate the first figure below.

Under normal conditions, the total particle count should be relatively low, and the counts should increase as 0.1-µm sensitivity is approached.

For 0.1-µm instruments, the far left side of the particle distribution should not move toward zero. If this occurs, the electronic software may be partially forcing the display to zero.

(2) Nebulize onto the wafer a 1/2 deposition of PSL spheres representing the specified sensitivity of the instrument.

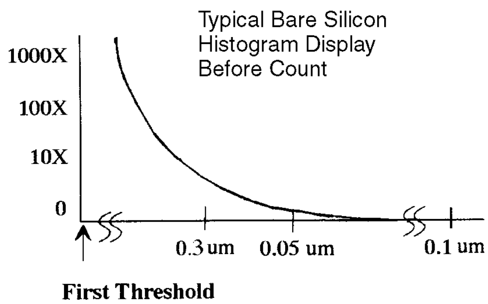
(3) Review the displayed output to calculate the S/N ratio. Use the second figure below for calculations. The figure represents a 0.1-µm instrument. Instruments with less sensitivity can use the same calculation.

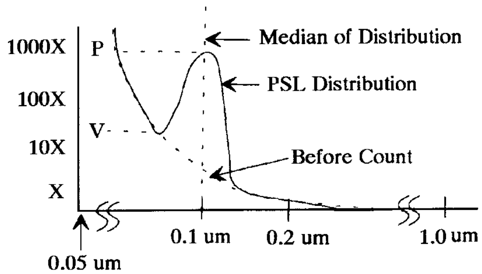
(4) Determine the median of the distribution, which is the same point as the first threshold of the instrument. Determine the particle count at the median of the peak.

Determine the particle count at the valley on the left side of the distribution.

$S/N = P/V \geq 2.0$

Be aware that if the S/N ratio > 2.0 and the distribution is clearly separate from the far left noise region, the instrument has a potential to provide excellent separation between particle counts introduced as a result of surface scatter.

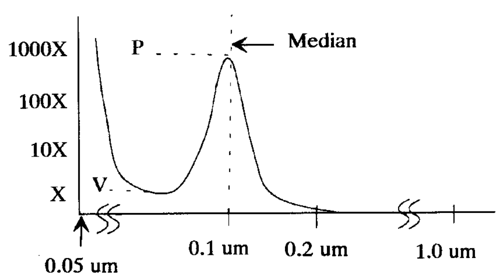




Peak count =____________.

Valley count =__________.

S/N ratio =_____________.



If the first threshold does not meet specifications, determine whether there is an instrument electrical problem. If the instrument is operating properly, verify that a new threshold is required and adjust the first threshold slightly above its present setting (away from the noise band) and rerun this test until the specification is met.

A2.2.3.1 *Surface Roughness* — Surface roughness is a term which describes the effects of the bare silicon polish (or a metal/film deposition) to the scattered light. The design of the particle counter also determines how the surface roughness data is collected. Surface roughness is also known as surface texture scatter or haze. Surface roughness is a noise produced by an ensemble of microimperfections in the surface and not attributable to a single point. Even in the case of highly-polished wafers, the roughness is measurable, and the relative scattering generated is a continuum. The noise thus arises from the variations and nonuniformity of the surface texture. A typical value of texture–generated scatter from a typical polished wafer is 1 ppm ("ppm" refers to parts per million; i.e., the ratio of incident light intensity to scattered light intensity as measured when the incident light illuminates a clean wafer surface—whether the surface is bare silicon or deposited with a metal or film process).

In some particle counters, the light source is mechanically manipulated by mirrors or optics to scan the surface. If the optics are not totally uniform in reflectivity or transmission, the beam steering process effectively modulates the source of illumination. It is difficult to prevent such modulation from increasing the noise by several percent.

All of these noise components are of an AC nature and are all that need to be considered when analyzing for particles on the wafer surface. Texture or roughness–generated scatter is optically unresolvable and pervasive over the entire surface. It is thus a DC term and can be quite large.

If 100% of the scattered light is collected, the texture–related scatter is related to the rms roughness according to:

$$\Delta \text{rms} = \frac{\lambda}{4\pi}\sqrt{s}$$

where Δrms = root mean square roughness height

λ = wavelength of illumination

s = fractional texture - related scatter

If the wafer surface were perfectly smooth, 100% of the light illuminating the surface would be reflected with no texture-generated scatter captured by the optical detector. However, as the roughness worsens, texture-generated scatter increases, causing the DC term to increase and the sensitivity of the particle counter to decrease. As the DC term increases above the threshold of display sensitivity, the wafer image will appear to have many thousands of particles. The gain, therefore, must be adjusted up or down accordingly to optimize the particle counter's ability to detect particles, but not texture-generated noise. In the case of some films and metal depositions, the amount of surface roughness can be as high as 25,000 ppm, requiring the gain to be adjusted quite high (2 µm to 5 µm sensitivity).

Other sources of noise, which combine with texture-related scatter, are molecular noise from the light source and stray light. Molecular noise is generated from the light source prior to illuminating the wafer surface. This provides an unwanted DC term to the optical detector. Consider whether or not the optical detector is protected from this unwanted noise.

A2.2.4 *Size Accuracy* — Calibration wafers with polystyrene latex (PSL) calibration monospheres can be prepared by test personnel on-site or purchased from a qualified source. Additional calibration wafers can be used. If on-site personnel are using aerosol nebulizers, care should be taken to minimize agglomerates and the lack of cogenerated residue particles sufficient in size to contribute significant particle background.

The operator should set the calibration points as close to the median of each PSL distribution as possible. The setting may be slightly below or above the actual median according to the histogram. If one is trying to compare two different process tools for particle contributions, it is best to use the same calibration wafers for particle counter instrument calibration at both locations. However, this methodology is not a guarantee of absolute correlation between instruments.

As a result of calibrating the instrument response at the median of each PSL distribution, by definition the first threshold has a count efficiency of 50% at the first threshold. It is much simpler and more accurate to identify the median of a monodispersed distribution for a calibration point. It is also advantageous to know the point on the response curve above the first threshold where 100% of the particles are being detected, as this is the point from which count repeatability is determined.

If the particle counting instrument has the ability to discriminate between particles and surface roughness at the first threshold, this issue poses no problem. If an instrument has difficulty in discriminating between surface roughness and particles, the particle count can be misrepresented. One will need to determine the minimum sensitivity at which particle counts are not affected by surface roughness of the wafer.

A2.2.5 *Size Resolution* — Size resolution of an instrument defines how accurately the instrument can differentiate between two particles of nearly the same size. As the percentage of resolution increases, the instrument begins to lose its ability to differentiate between particle sizes. This effect is greatest at the first threshold where particle counts are usually highest. Ideally, it is good to know the size resolution of the instrument at all calibration points. If determining size resolution at only one calibration point is required, it should be at the minimum particle size affecting the process.

Resolution is quantified by measuring the increase in standard deviation (s) caused by the instrument to the true standard deviation of a deposit of monosized particles as reported by the particle producer. (See 4.2.4.3.)

Instrument Size Resolution(in %):

$$\frac{\sqrt{\text{Instrument s}^2 \text{ - Reported PSL s}^2}}{\text{Particle Mean Diameter } \mu\text{m}}$$

A2.2.6 *Count Accuracy* — Count accuracy is critical to define as it signifies an instrument's ability to provide an accurate particle count. Although the etched pit wafers in use today have anywhere from 300 to 800 scattering sites, it would be ideal to have an etched pit wafer with only 20 scattering sites on the surface in the pattern of a plus sign. In addition, it would be ideal to have 5 scattering sites in each quadrant, each of which forms a plus (+) sign across the X and Y axis of the wafer. If this type of standard is not available, use existing etched pit standards. The count accuracy wafer is to be used to evaluate the ability of the instrument to detect a known number of scattering centers at discrete positions on the surface of the wafer.

The edge exclusion should be set to include only the desired pattern of scattering sites. The lower and upper size display should be set to display only the distributions of the peaks. Some etched pit wafers have only one size of scattering site while others have 4 sizes. Count accuracy is determined with these parameters. Particles related to the etched pit pattern are to be disregarded from the count accuracy test. One should review each image of the inspected etched pit wafer to discern if particular scattering sites are repeatedly not detected. This does not necessarily mean that the particle counter is at fault.

For example, if the scattering site in question has residue at the bottom of the site, it is possible for the particle counter to incorrectly size the scattering sites repeatedly or not to detect them. Steps should be taken to resolve any uncertainty.

The exact number of the features on the etched pit wafer is either a function of which of four sizes (if a 4 distribution etched pit wafer is used) is displayed on the scanner or a function of the amount of edge exclusion used. For example, if only one of four sizes is displayed to the screen, the maximum total count (excluding non-planned features) will be one-fourth the total feature count. If a single-sized etched pit wafer is used, it is possible to vary the measurement tool by varying the edge exclusion.

Consistently use the same etched pit wafer exactly (not just the same model number) on a given machine to do trend monitoring or to construct control charts.

If there is a significant amount of background particle contamination or surface scratches on the etched pit wafer, the standard should be cleaned properly or discarded. Contact the etched pit manufacturer for cleaning instructions.

A2.2.7 *Count Repeatability* — Repeatability is often determined with a PSL distribution of a known size on the wafer surface, but can also be determined on bare silicon with far fewer particle counts. Significant differences in instrument response may be noted between the two approaches. The number of counts and wafer orientation may contribute to this problem. Hence, the equipment user and equipment manufacturer must mutually agree as to whether bare silicon or PSL spheres on the wafer are to be used.

Count repeatability is determined from a particle sensitivity greater than or equal to the threshold at which 100% count efficiency is specified. If there are any noise problems in the instrument's response, count repeatability is immediately affected. If the PWP performance of the instrument itself is poor, the count repeatability is unacceptable.

If the wafer orientation is permitted to change, each particle on the wafer will present a different surface area to the illuminated light. If this circumstance is permitted by the instrument or the operator, particle sizing and particle counts may vary, possibly affecting count repeatability. It is recommended that wafer orientation remain the same on all wafers.

The three basic designs that are currently in use by the various instrument suppliers illuminate the wafer surface by raster scan, telecentric scan, and orthogonal scan. Raster scanning the wafer surface with a laser provides a changing angle of illumination to the particle. If the wafer orientation is not held constant (i.e., no wafer prealignment), the effect of a changing angle of illumination and a varying orientation may cause the particle sizing and count to vary.

If the operator were to scan a wafer one time with the wafer at 0° orientation (wafer flat or notch down in the cassette) a certain number of particles would be noted in each size bin. By changing the wafer orientation over a number of scans, the operator may note a deviation in each bin-i.e., varying size. The solution to the orientation problem is to prealign the wafer flat or notch to a constant orientation before each scan. It should not be assumed that one particular orientation is more correct than another. Prealignment of the wafer simply minimizes the effects of a changing wafer orientation.

Telecentric scanning instruments provide a constant angle of illumination. However, if the wafers are not prealigned to a common reference every time, wafer orientation may cause the same problem as with a raster scanning system.

Orthogonally scanning instruments provides a constant angle of illumination while spinning the wafer. The wafer flat can be at any orientation at the beginning of the scan, but the particle will always be illuminated at the same angle of orientation. Hence, the effects of wafer orientation are greatly reduced.

A2.2.8 *PWP* — Collecting 20 or more inspections of a wafer serves two purposes. Not only does it provide a good check for count repeatability, but it also provides the data to develop the PWP profile of the particle counting instrument. If the slope of the count repeatability is too high, both repeatability and PWP will fail. By averaging the first ten (before) and last ten (after) data points of the 20 inspections, a line having a specific slope can be ascertained. While the deviation from the mean of all the individual points reflects the count repeatability, the slope of the line determines the PWP performance. The delta is divided by 10 to determine average contributions per pass. The number of particles added is divided by the inspected surface area to determine the instrument PWP/cm^2.

A3 Notes on Measurement Instrument Monitoring

The following routine may be used to implement instrument monitoring or to complement a current implementation.

The purpose of monitoring the particle measurement instrument is to verify that the instrument is in calibration. Routinely verify the performance of the measurement instrument so that results can be trusted. The instrument calibration is tested using an etched pit standard, which provides information about instrument count accuracy and sizing accuracy. Etched pit wafers are the standard of choice for routine monitoring because they may be cleaned and recertified when they get contaminated. PSL wafers, on the other hand, need to be replaced when they become contaminated.

Count accuracy is verified by recording the total number of particles counted by the system. Simply recording the total number of particles is valid if care is taken in handling the wafer, so as to minimize extraneous contamination. The program used to run the standard should be similar to the program used during instrument acceptance. That is, the edge exclusion should be maximized to isolate the scattering centers, and care should be taken in regard to wafer orientation.

Sizing accuracy is verified by recording the location of the median of the Gaussian distribution corresponding to each of the four different size scattering centers. The absolute sizing is not as important as the day-to-day position of the distributions. Programs should be set up which enable the four different distributions to be collected. If the instrument has sufficient dynamic range, one program may be sufficient. If the instrument has limited dynamic range, two or more programs may be required. The instrument manufacturer may supply the necessary measurement program parameters.

The calibration wafer should be run regularly (for example, once per shift, once per day, or once per week) for 25 tests, and the data should be recorded on $\overline{X}$-MR control charts. Once 25 points have been collected, control limits can be defined. $\overline{X}$-MR control charts are used to track information collected by measuring an identical sample over and over again. $\overline{X}$-MR charts track the difference between a current measurement and the value of the measurement the last time the sample was run.

$\overline{X}$-MR charts are constructed by recording the mean of the variable being tracked, perhaps the total number of particles for count accuracy or the mean diameter or scattering cross-section for sizing accuracy. The moving range can be calculated, once two data points have been recorded, by taking the absolute value of the difference between today's measurement and the previous measurement. For example,

	Sept 15		Sept 16		Sept 17		Sept 18		Sept 19
$\overline{X}$	425		430		428		424		425
MR		5		2		4		1	

Note that there will always be one less MR value than there are $\overline{X}$ values. The $\overline{X}$ and MR values should be plotted on separate charts.

Once 20 points have been collected, control limits can be calculated as follows:

1. Calculate the mean of the Xs, $\overline{X}$.
2. Calculate the mean of the MRs, $\overline{MR}$.
3. Calculate the upper and lower control limits for the X chart.

$$UCL = \overline{X} + 1.88 \bullet \overline{MR}$$

$$LCL = \overline{X} - 1.88 \bullet \overline{MR}$$

4. Calculate the upper and lower control limits for the MR chart.

$$UCL = 3.27 \bullet \overline{MR}$$

$$LCL = 0.00$$

These upper and lower control limits represent three sigma limits. One sigma and two sigma levels can be indicated on the charts. Reference these levels during testing for out-of-control points.

The area between the center line and the three sigma level is Zone A. The area between the center line and the two sigma level is Zone B. The area between the center line and the one sigma level is Zone C. Subsequent measurements are "out-of-control" if they violate any one of the following rules:

1. One point beyond Zone A.
2. Two out of three consecutive points in Zone B.
3. Four out of five consecutive points in Zone C.
4. Five rising or five falling consecutive points.
5. Seven points on one side of the center line.
6. Six consecutive up and down pairs (applies only during setup).
7. Thirteen consecutive points in Zone C (applies only during setup).
8. Five consecutive points outside of Zone C (applies only during setup).

In-house monitoring should be used. If no SPC methodology exists, the above method is appropriate.

A4 Notes on Process Tool Monitoring

Particle Test Definition — Particle test definition requires prioritizing of the process tools, identification of the number and type of wafers to be used to test each tool, definition of the procedure to be followed when the test is run, and definition of ultimate uses for the data.

Process tools should be prioritized so that fab personnel are not overwhelmed and so that the testing can be implemented in a controlled and systematic manner. An example of tool prioritization follows:

Type A: Equipment used to process critical levels, Equipment known to generate high-particle counts

Type B: Equipment known to generate low-particle counts, Baths and spin dryers

Type C: Metrology equipment, Noncritical processing equipment

Identify the number and type of wafers to be used to test each tool to ensure that the test is statistically significant and that all key subprocess steps are tested. These steps are generally best accomplished when the contamination control engineer works directly with the process engineer responsible for each tool. The two engineers should analyze the wafer flow for each processing step. For example:

Metal Etch

hard bake
load into etcher
pump down
flow gases for metal etch
start plasma
stop plasma
flow gases for passivation
start plasma
stop plasma
vent
unload from etcher
inspect
wet strip
dry strip

With these breakdowns the two engineers should identify the key subprocessing steps to be tested for particles. For example,

From these key subprocessing steps particle test wafers should be identified. For example,

Metal etch:

load/unload	1 wafer
load/pump/vent/unload	1 wafer
load/p/flow gases/v/unload	1 wafer

After the particle test steps have been identified, the type of wafers and sampling plan should be defined. For example,

1. The number of acceptable wafers before particle counts
2. The number of passes per wafer (to ensure reasonable statistics for low particle contributions)
3. Use of control wafers

One wafer should be run per subprocessing step. The use of control wafers should be limited to cases where day-to-day environmental conditions may vary widely and seriously compromise the test outcome (for example, when the processing tool is located near a door that people could open during particle testing). Running only one wafer per subprocessing step is valid during tool monitoring because these tests are run frequently enough to generate valid statistics. In addition, the tests may be cost and time prohibitive if rigorous multiple wafer testing were employed.

Once the tests have been defined, the test procedure can be defined. The test procedure should include the following information: when the tests should be run; who is responsible for running each part of the test; what test protocol is used (for example, how the wafer should be transferred from the measurement instrument to the processing tool and back or how the wafer should be transferred from cassette to cassette); what instrument and tool measurement programs are used; and what should be done with the data once it is collected.

A4.2 *Tool Baselining* — Tool baselining is the systematic collection of the data needed to construct a control chart and define statistically significant control limits. Tool baselining quantifies the variations in particle counts due to random fluctuations. For this reason, collect baselining data in a controlled and systematic manner. This allows variations in particle counts to be attributed first only to variation in the process tool and second as variations with different people at different shifts.

As many factors as possible should be held constant during the tool baselining timeframe. People and shift variations must be isolated from the process tool baseline. For example,

1. The tests should be run at the same time each shift or each day.
2. The tests should be run by the same people. The process tool should be operated by the process engineer or technician responsible for the tool, and the particle measurement instrument should be operated by the contamination control engineer or technician responsible for the instrument.
3. Calibration of the measurement instrument should be verified.
4. Wafer before particle counts should be approximately the same.

Plot the data on baseline charts while it is being collected. The pattern of points should be tested for a pattern of six consecutive up-down pairs (see Figures A7, A8, A9). This pattern indicates that a nonrandom special cause is influencing the test, and the test procedure should be reevaluated. This baseline chart establishes optimal tool performance with no variation associated with people or shift changes. For defining control limits based on actual operating conditions, see Section A.3.

A4.3 *Routine Tool Monitoring* — Routine tool monitoring has two purposes. First, routine tool monitoring provides the periodic testing needed to ensure that the tool remains in control. Second, routine tool monitoring provides a means of improving microcontamination awareness and operating protocol.

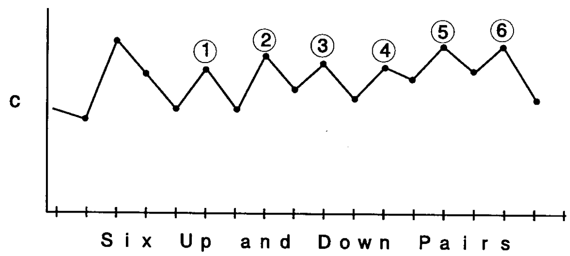


Figure A7
Six Up-Down Pairs

Both of these tasks are accomplished simultaneously because, as routine tool monitoring begins, the rigorous systematic and controlled test conditions applied in the tool baselining phase tend to be relaxed. As a result, routine particle monitoring begins to more closely approximate normal processing conditions.

For example,

1. The tests are not necessarily to be run at the same time each shift or each day.
2. Responsibility for running the particle tests is transferred to the processing engineers and technicians.
3. A range of acceptable before particle counts (usually “not greater than some number”) is to be defined.

To define control limits, collect 25 data points, vary people and shifts on a routine basis (e.g., daily, per shift change). Plot this data on a control chart while it is being collected.

In addition to training processing engineers and technicians in particle testing procedures, this transfer-of-responsibility stage is a good time for contamination control engineers to review protocol practices. In the initial stages, contamination control engineers should be highly visible so that out-of-control conditions are dealt with in a controlled manner. For example, if a processing technician logs an out-of-control datapoint, the contamination control engineer should be available to ensure that the source of the problem is the processing tool and not the test procedure.

Out-of-control conditions are identified by testing the C-chart patterns against the Western Electric rules (see Referenced Documents, Section 2). The Western Electric rules define conditions where the probability of a pattern of points on a control chart occurring by chance alone is less than 1%. Because C-charts represent Poisson (asymmetric) distributions, only the following Western Electric rules apply:

1. one point outside control limits
2. five rising or five falling segments (see Figure A8).

Due to the nature of particle counts, rule one above is usually applied as one point above the upper control limit; particle counts below the lower control limit are advantageous and, therefore, not considered out-of-control. Other Western Electric rules are not applied to C-charts because they assume normal distributions.

When routine tool monitoring begins, the charts for the key subprocessing steps should be reviewed to determine if additional information is gleaned by monitoring the different steps independently. For example:

1. Did deviations in particle levels track together, implying that running the different wafers was redundant?
2. Were deviations independent, implying different particle sources and requiring that all subprocesses needed to be monitored?
3. Did one subprocess capture all the deviations while other subprocesses were constant, implying that just monitoring that one subprocess was sufficient?

The routine monitoring phase is also the time to define out-of-control actions. Out-of-control actions are a list of procedures that should be followed if the particle level of a processing tool goes out-of-control. For example:

Etcher Out-of-Control Actions:

1. Retest

If still out-of-control:

2. Put tool “down”
3. Run 5 conditioning runs
4. Retest

If still out-of-control:

5. Call maintenance technician
6. Wipe down chamber
7. Run 5 conditioning runs
8. Retest

If still out-of-control:

9. Call responsible engineer

This list of actions enables particle problems to be addressed in a rapid and systematic manner.

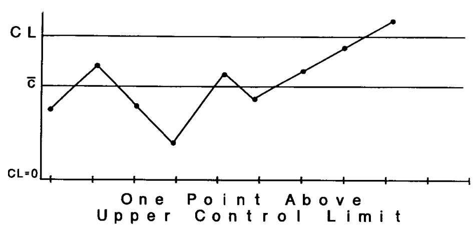


Figure A8
One Point Above Upper Control Limit

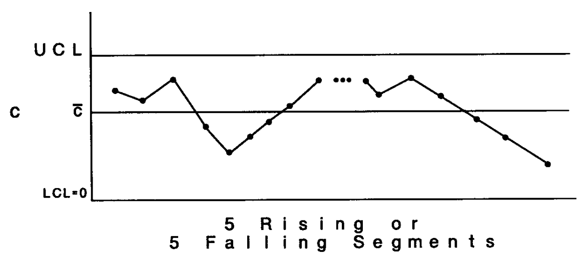


Figure A9
5 Rising or Five Falling Segments

Due to the nature of particle counts, rule one above is usually applied as one point above the upper control limit; particle counts below the lower control limit are advantageous and therefore not considered out-of-control. Other Western Electric rules are not applied to C-charts because they assume normal distributions.

SEMI E15-0698
SPECIFICATION FOR TOOL LOAD PORT

1 Purpose

This standard is intended to unify the interface between process/inspection tools and automated wafer carrier transport systems while maintaining compatibility with human transport.

2 Scope

This specification deals with the mechanical interface (load port) for wafer carrier transfer between wafer carrier material transport systems, including humans, and wafer fabrication/inspection equipment (tools). The concept defines the placement and orientation of a wafer carrier on a tool to allow reasonable interfacing with mechanized material movement systems without compromising human access to perform the material exchange function.

3 Impact

Compliance with this specification requires the placement of load ports on tools to specific heights, orientations, and load depths. Restrictions are also placed on clearances to obstructions which may be adjacent to such ports.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E1.7 — Standard for 200 mm Plastic and Metal Wafer Carriers, General Usage (Proposed)

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

5 Terminology

5.1 *Selected Definitions*

5.1.1 *box* — A protective portable carrier for a cassette and/or substrate(s) per SEMI E44.

5.1.2 *cassette* — An open structure that holds one or more substrates per SEMI E44.

5.1.3 *cassette centroid* — A datum representing the theoretical center of a stack of wafers in a cassette formed by the pocket centerline and the "center" pocket as defined by the location associated with dividing dimension B3 by two (see SEMI E1, Figure 1).

5.1.4 *cassette envelope* — A rectangular volume with vertical sides which completely contains a cassette, even if the cassette is tilted (see Figure 1).

5.1.5 *enclosed load port* — A load port with overhead clearance obstructed by the tool.

5.1.6 *global orientation* — The general orientation of a wafer carrier in a tool; may be vertical or horizontal.

5.1.7 *load depth* — The horizontal distance from the load face plane to cassette centroid or carrier centroid (see Figures 2 and 3 (D)).

5.1.8 *load face plane* — The furthest physical vertical boundary plane from cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (see Figures 2 and 3).

5.1.9 *load height* — The distance from the bottom of the cassette or carrier to the floor at the load face plane (see Figure 3 (H)).

5.1.10 *load port* — The interface location on a tool where wafer carriers are delivered. It is possible that wafers are not removed from, or inserted into, the carrier at this location.

5.1.11 *open load port* — A load port with overhead clearance unobstructed by the tool.

5.1.12 *pod* — A box having a Standard Mechanical Interface (SMIF) per SEMI E19 and SEMI E44.

5.1.13 *spacing* — The minimum spacing between centroids (see Figure 2, S).

5.1.14 *tool* — Any piece of semiconductor fabrication or inspection equipment designed to process wafers delivered in wafer carriers.

5.1.15 *tilt* — A small angle of offset from the normal horizontal or vertical orientation of a cassette or wafer carrier designed to preferentially align or keep wafers in their intended place within the carrier/cassette (see Figure 1, T).

5.1.16 *wafer carrier* — Any cassette, box, pod, or boat that contains wafers.

5.1.17 *wafer carrier centroid* — A datum representing the theoretical location of the center of a stack of wafers in the carrier.

5.1.18 *wafer carrier envelope* — A rectangular volume with vertical sides which completely contains a carrier, even if the carrier is tilted (see Figure 1).

5.2 *Description of Terms Specific to this Standard*

5.2.1 *carrier* — Wafer carrier.

6 Ordering Information

6.1 The following items require communication between the tool supplier and user and shall be included in any request for quotation, quotation, or purchase order:

6.1.1 If the tool has multiple load ports, provide the spacing, S, between carrier centroids (see Section 7.8).

6.1.2 Specify what carrier (e.g., SEMI standard cassette, pod) is to be accommodated by the load port.

6.1.3 Specify whether the load port is open or enclosed.

6.1.4 Specify whether the wafer orientation is horizontal (per Section 6.3.1) or vertical (per Section 6.3.2).

7 Requirements

7.1 The dimensions for the placement of a wafer carrier on the load port of a tool are given in Table 1.

7.2 The standard is based upon the concept that any wafer carrier can be used. Dimensions are usually specified as clearances to wafer carrier envelopes (see envelope concept in Figure 1).

7.3 The global orientation of the cassette or wafer carrier is constrained to be parallel or perpendicular to the load face plane. Allowable cassette orientations are:

7.3.1 For wafers horizontal, the opening of the cassette must be opposite the load face plane, and the front surface of the wafer must face up (see Figure 4a);

7.3.2 For wafers vertical, the opening of the cassette must face up, and the front surface of the wafer must face the load face plane (see Figure 4b).

7.3.3 This requirement also applies to cassettes in pods.

7.4 The maximum tilt is 10 degrees.

7.5 The load height is specified as follows (see Figure 3):

7.5.1 Dimension H is 900 mm (~35.4 in.), fully adjustable over ± 10 mm (~0.4 in.).

7.6 The maximum height above H of an obstruction between the load face plane and the carrier envelope (such as for an alignment device or identification tag reader) is 50 mm (~2 in.) (see Dimension H1 in Figure 3).

7.7 Clearances (C1, C2, and C3) are defined with respect to the largest carrier envelope required. For cassettes, envelopes are defined using cassette dimensions from SEMI E1 or SEMI E1.7. For pods or other wafer carriers, envelopes are defined using the carrier standard (if any) or the carrier manufacturer's specifications (see Figure 1 for concept and Figures 2 and 3 for use).

7.8 Dimension S specifies the recommended minimum spacing between cassette/wafer carrier centroids. In any case, if S violates clearance C1 in any application, then C1 prevails (see Figure 2).

7.9 Tools with enclosed load ports shall have a minimum vertical clearance, C3, above the cassette or carrier at the load port. Open load ports shall have a vertical clearance above the load port which is unrestricted by the tool.

Table 1 Dimension Requirements, mm (inches)

Dimension	*Application*	*Value, mm (in.)*	*Notes*
C1	minimum	75 (3)	
C2	minimum	30 (1.2)	
C3	minimum	225 (9)	See Note 1
D	maximum	250 (0)	
H	range	900 (35.4) ± 10 (.4)	See Note 2
H1	maximum	50 (2.0)	
S	≤ 150 mm carriers 200 mm carriers	350 (13.8) 400 (15.7)	See Section 7.8
T	maximum	10 degrees	

NOTE 1: Applies to tools with enclosed port; otherwise, clearance above the port must be unrestricted by the tool (see Section 5.8).

NOTE 2: Fully adjustable over ± 10 mm (~0.4 in.) range.

Dimension Definitions

C1 — Minimum side clearance between one carrier envelope and another, or to vertical obstruction.

C2 — Minimum rear clearance from carrier envelope to vertical obstruction.

C3 — Minimum clearance above carrier envelope to horizontal obstruction on the tool.

D — Maximum load depth to carrier centroid.

H — Allowable load height to bottom of carrier envelope.

H1 — Maximum height of horizontal obstruction above load height between load face plane and carrier envelope.

S — Recommended minimum spacing between carrier centroids.

T — Maximum cassette or wafer carrier tilt.

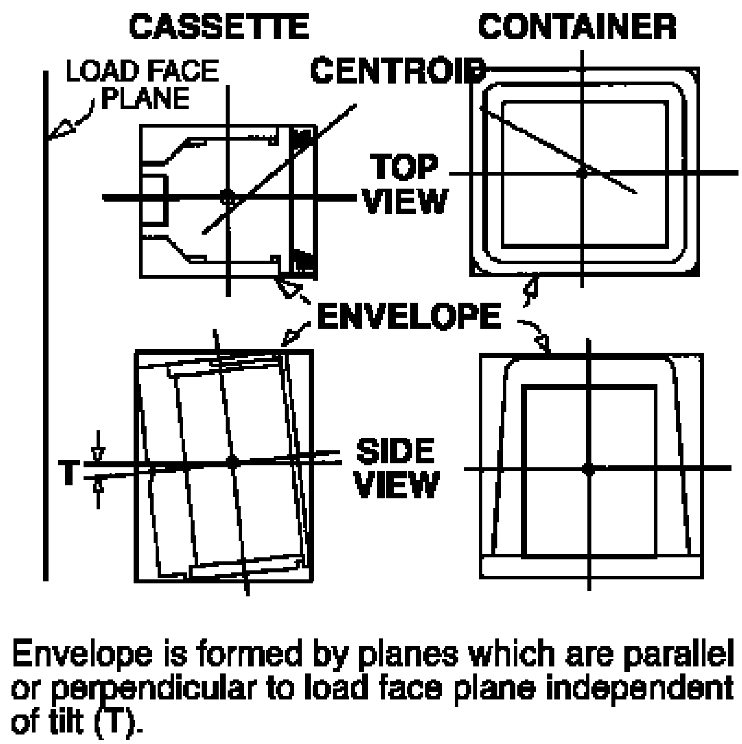


Figure 1
Envelope Concept

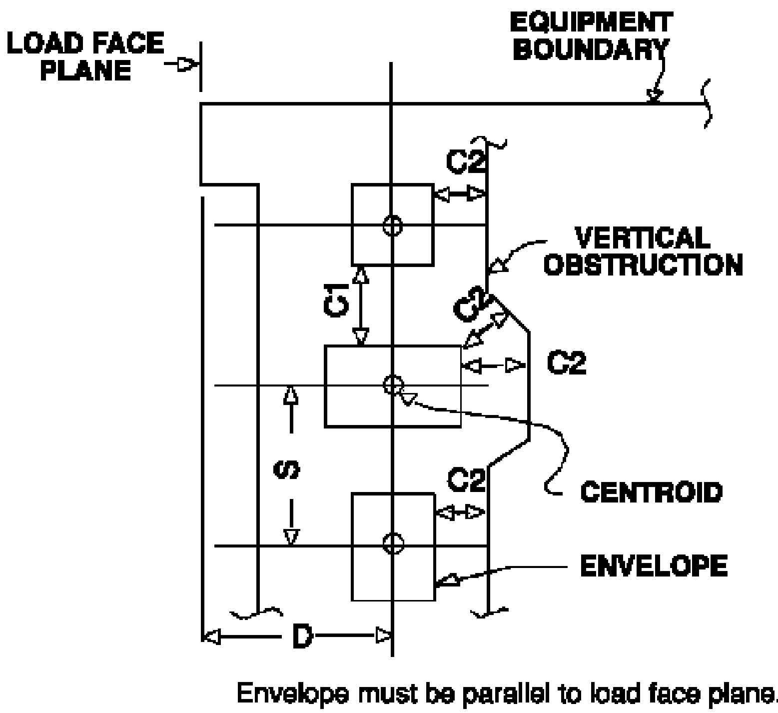


Figure 2
Load Port Requirements, Plan View

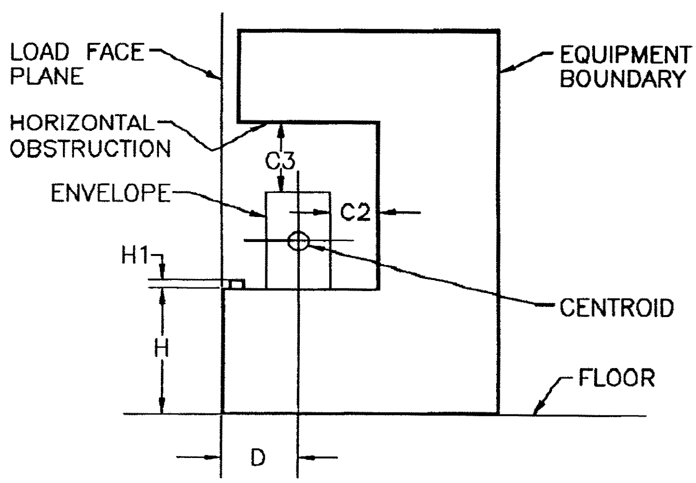


Figure 3
Load Port Requirements, Elevation View

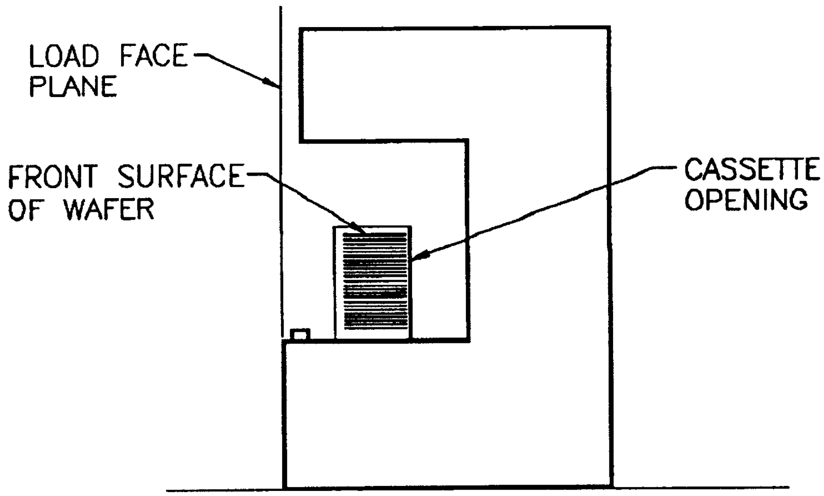


Figure 4a
Wafer and Cassette Orientation, Wafers Horizontal

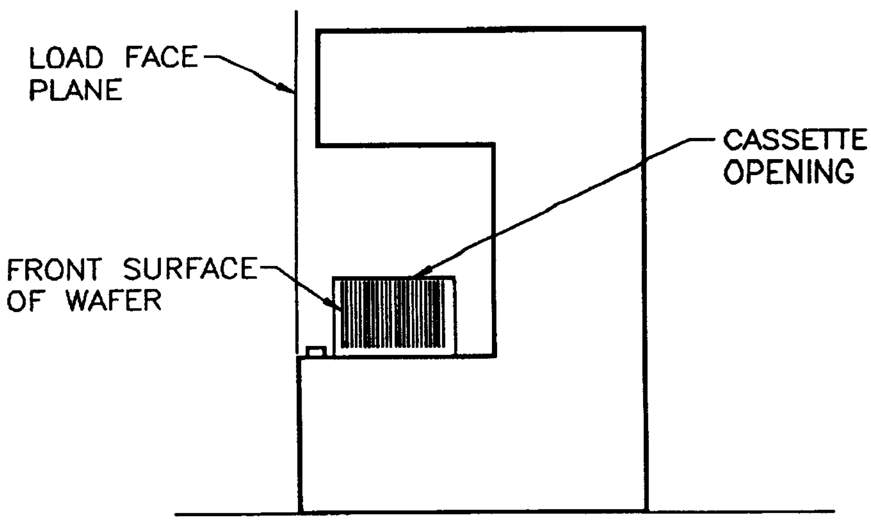


Figure 4b
Wafer and Cassette Orientation, Wafers Vertical

8 Related Documents

8.1 *SEMI Documents*

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

SEMI E47 — Specification for 150 mm/200 mm Pod Handles

SEMI E48 — Specification for SMIF Indexer Volume Requirement

SEMI T4 — Specification for 150 mm and 200 mm Pod Identification Dimensions

SEMI Compilation of Terms

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as an official part of SEMI E15 by full letter ballot procedure.

Material transport automation can come in a number of forms, including AGV's (automated guided vehicles) and tracks (conveyers), which operate anywhere from tool loading level to ceiling level. Wafers may be transported in cassettes or in carriers (such as cassettes in pods). Automation provides flexibility with regard to the range of interface coordinates it can accommodate. On the other hand, it is clear that humans will continue to load carriers on tools in many fabs. SEMI E15 is an attempt to satisfy all of these needs, including continued human compatibility. In fact, compatibility of automation and human ergonomics has been considered of primary importance in the rewrite of this standard.

The increased value for C1, of 75 mm, over the previous value in this standard is determined by the ergonomic requirement to accommodate a 95th percentile human male hand carrying a pod by its handles. Limitation of the load port height to 900 mm was, again, driven by ergonomic considerations, as the previously allowed value of up to 1300 mm was clearly "user unfriendly."

Equipment suppliers must consider the dimension, S, in order to ensure that their tool will be compatible with automation systems and pods. This fact applies to tools with more than one load port per tool. In order to enable space for two pods on side-by-side load ports, the dimension, S, must be greater than or equal to 350 mm for tools processing 150 mm or smaller wafers, and 400 mm for 200 mm wafer tools. The dimension, S, is defined as the distance between wafer carrier centroids. Driving factors for S are that the size of a pod is larger than a cassette and that ergonomic guidelines suggest a clearance of at least 75 mm between the box and an adjacent object in order to provide space for the human hands to grasp and pick up the box by its handles.

A global horizontal placement tolerance of 15 mm of the carrier centroid should be allowed by the alignment means of the load port. (That is, a misalignment by up to ± 7.5 mm in both the x and y directions of the carrier centroid will still allow the alignment means to guide the carrier to its correct final location on the load port). The misplacement dimension is made large to be consistent with the tactile/visual capabilities of humans and the placement accuracy of AGV's. This requires that the load port provide some alignment aid to bring the carrier centroid to within the final registration tolerance (generally 0.5 mm) required by the automated wafer handling of the tool. Standards for this registration tolerance will generally be found in the SMIF documents.

The standard purposely does not address vacuum load locks. Since minimization of volume is usually a design requirement for a vacuum load lock, the minimum clearances (C1 – C3) of this standard are not compatible with optimum load lock design. It is not intended that vacuum load locks would be the load port of a tool in which vacuum processing is performed. Simple solutions exist today for transportation of a cassette, or of individual wafers, from a SEMI E15-compatible load port to a vacuum load lock. Open load ports are intended to be specified for use with overhead transport systems for automation.

It is not easy to formulate a standard which allows compatibility with such a wide range of requirements. Nor is it easy to design equipment compatible with a number of different standards affecting the same hardware. SEMI E15 covers a wide range of applications without causing undue compromise in any particular implementation, while remembering that most of our fabs will continue to use human transport in the immediate future. We hope this short discussion of key issues aids in your understanding of the intent and details of the standard.

SEMI E15.1-0600
SPECIFICATION FOR 300 mm TOOL LOAD PORT

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1996; previously published February 2000.

1 Purpose

1.1 This specification defines dimensional requirements for the load ports of 300 mm wafer process and inspection equipment. It is intended to promote a uniform physical interface between equipment and the factory, to facilitate the use of automated wafer carrier transport systems, and/or to meet ergonomic requirements for manually loaded equipment.

2 Scope

2.1 This standard covers 300 mm equipment only. Similar requirements covering equipment for 200 mm wafers and smaller are covered in SEMI E15.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is not met by direct loading/ unloading of vacuum load locks. Requirements of such interfaces may differ from those in this document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57— Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

See SEMI E15.

6 Ordering Information

6.1 Per Section 6 of SEMI E15, except for Sections 6.1.3 and 6.1.4. Also, the user must specify which of the three options (defined in Section 7.5) is required for each load port, and whether a cover is needed over the exclusion volume for photo-coupled I/O interfaces (defined in Section 7.8).

7 Requirements

7.1 The dimensional requirements for the load port of a tool are given in Table 1 with reference to the figures in this document. Although the carrier transport systems shown in these figures appear similar to overhead monorails, they are intended to represent any type of transport system (AGV, PGV, conveyor, overhead track, etc.).

7.2 The dimensional requirements for the placement of a wafer carrier on the load port are given in Table 1 with reference to the figures of this document. The carriers shown in these figures are intended to represent any type of carrier (cassette or box).

7.3 The wafers are to be oriented horizontally face up with zero nominal tilt at the time they are placed on the load port. The tolerance in the horizontal plane is determined by the registration and alignment feature between the carrier and the load port, as specified in SEMI E57.

7.3.1 The carrier shall be loaded and unloaded with its front parallel to and away from the load face plane (see Figure 1).

7.4 Dimension H is nominally 900 mm, fully adjustable at installation over the range of 890 to 910 mm. The precision with which the load port height must be maintained is dictated by the needs of the carrier delivery system.

7.5 As shown in Figure 3, the maximum allowable height of an obstruction on the load port over which the carrier must be lifted (before being set down on the kinematic couplings) is H1. Examples of such obstructions include alignment devices and identification tag readers as well as the kinematic couplings themselves. Below H1 above the horizontal datum plane, clearances C1 and C2 no longer apply.

7.5.1 Two exclusion volumes on the left and right side of the load port must also be kept clear so that fork-lifts or conveyors may be used. Each exclusion volume extends from the load face plane to D0 beyond the facial datum plane and extends H0 below the horizontal datum plane between W1 and W2 from the bilateral datum plane. Although the carrier shown in Figure 3 is an open cassette, these exclusion volumes are also required on load ports that are configured with a FIMS interface (conforming to SEMI E62) for front-opening boxes. However, these exclusion volumes are not required on load ports that are configured for bottom-opening (SMIF) pods, because SEMI E19.5 already defines that part of the load port.

7.5.2 A load port that advances the carrier from the undocked position (where the carrier is initially delivered to the load port) to the docked position (where the carrier is ready for wafer extraction or insertion) must reserve an exclusion volume that is intended for (but not limited to) containing automated units that read or write to an ID tag on the rear of a carrier in the *undocked* position (where the carrier is initially delivered to the load port). This exclusion volume extends W4 to either side of the bilateral datum plane and between D3 and D4 from the facial datum plane. When the load port is in the correct position to read or write to the ID tag, the exclusion volume must extend from the carrier down to H3 plus H4 below the horizontal datum plane. When the load port is in a different position, the volume from the carrier down to H3 below the horizontal datum plane may be occupied temporarily. The value of H3 is at the load port supplier's choice. As a result, reader/writer units (for this exclusion volume) must fit in a space no taller than H4, no wider than 2 times W4, and no deeper than D4 minus D3. If no reader/writer unit is installed, the exclusion volume may be covered by a panel. See Table 2 for dimensions of this exclusion volume.

7.5.3 Also, the load port must reserve another exclusion volume that is intended for (but not limited to) containing automated units that read or write to an ID tag on the rear of a carrier in the *docked* position (where the carrier is ready for wafer extraction or insertion). In this case, dimensions D3´, D4´, and W4´ are measured with respect to the datum planes defined by the kinematic couplings in the docked position (unlike all other use of datum planes in this standard). The distance between these two sets of datum planes (in the docked vs. undocked position) is not defined, and if the carrier is rotated during the advance motion, the two facial (or bilateral) datum planes will not be parallel. At the load port supplier's choice, the reader/writer unit in this exclusion volume may be mounted either on the advance mechanism of the load port (so it is very close to the carrier and it moves with the kinematic couplings) or below the advance mechanism (so it is farther from the carrier, is stationary, and may be covered temporarily by the advance mechanism). Again, this exclusion volume extends W4´ to either side of the bilateral datum plane and between D3´ and D4´ from the facial datum plane. When the load port is in the correct position to read or write to the ID tag, the exclusion volume must extend from the carrier down to H3 plus H4 below the horizontal datum plane. When the load port is in a different position, the volume from the carrier down to H3 below the horizontal datum plane may be occupied temporarily. The value of H3 is at the load port supplier's choice. As a result, reader/writer units (for this exclusion volume) must fit in a space no taller than H4, no wider than 2 times W4´, and no deeper than D4´ minus D3´. If no reader/writer unit is installed, the exclusion volume may be covered by a panel. See Table 2 for dimensions of this exclusion volume.

7.5.4 A load port that is configured for open cassettes (with bar-code ID tags on the bottom) or for FOUPs (with bar-code ID tags on the rear) must provide the appropriate exclusion volume a bar-code reader defined in Table 2.

7.6 As shown in Figure 2, tool load ports must conform to one of the following configuration options. If no option is specified, Option 1 is assumed.

7.6.1 In Option 1, the load port must nominally be at 900 mm, and it must be open from above to facilitate automatic carrier delivery from an overhead transport system. The open volume required for vertical delivery is defined by a projection of the tool load port area, including the area required for C1 and C2 clearances, projected upward to the top of the tool. Note that this condition need only be met when the tool is being loaded. For example, the load port may be formed by a surface that extends outward during loading to provide overhead access.

7.6.2 In Option 2 (which allows faster automatic carrier delivery from an overhead transport system), the horizontal datum plane of the load port may be at any height above H that leaves the top of the carrier under H2, but it must be open from above.

7.6.3 In Option 3 (which allows bulkhead mounting of tools with fan/filter units at C3), the load port must nominally be at 900 mm, and it must have a clearance C3 above the maximum height of the carrier.

7.7 Clearances C1, C2, and C3 are defined with respect to the maximum dimensions of the carrier (defined in SEMI E47.1 for a box or in SEMI E1.9 for an open cassette), not to the rectangular wafer carrier envelope (defined in SEMI E15). To prevent interference between transport systems on the same or adjacent load ports, it is recommended that floor-based transport vehicles not exceed clearances C2 and C3 and over-head hoist vehicles not exceed clearance C2 when picking up or placing a carrier on the load port.

7.8 Dimension S specifies the recommended minimum spacing between cassette/wafer carrier centroids. In any case, if S violates C1, then C1 prevails. As shown in Figure 1, below each load port must be an exclusion volume (defined by dimensions D7, D8, H7, H8, and W8) for photo-coupled I/O interfaces to floor-based transport vehicles. This exclusion volume is centered on the bilateral datum plane, but its distance behind the load face plane may vary between zero and the upper limit on D7. If no photo-coupled I/O interfaces unit is installed, the exclusion volume may be covered by a panel. If a photo-coupled I/O device is installed, the center of its horizontal beam line must be within W9 of the bilateral datum plane and within H9 of a point H7 above the floor. On each tool, load ports are numbered in increasing order (beginning with 1) from left to right (as seen by a person facing the load face plane) beginning with load ports that are nominally at 900 mm (Option 1 or Option 3) and then continuing (from left to right) with any load ports that are higher (Option 2).

7.9 To add clearance for overhead carrier transport, no part of the tool in front of the plane defined by C2 may be higher than H2 from the floor. The volume below H2 may contain carriers stored in an internal buffer by the tool.

7.10 If the tool occupies the space behind the load port and above any interface to the carrier, then the front of that upper part of the tool (shown as the equipment boundary in Figure 1) must be at a distance D1 from the facial datum plane. This equipment boundary is parallel to the load face plane, and carriers may be moved or rotated below this surface after loading.

7.11 If the load port provides the option to use roller conveyors for carrier loading, the conveying surface of the rollers must be H5 above the horizontal datum plane (as shown in Figure 3) at the time of carrier loading or unloading. When not in use, the conveyors must be lowered below H0 under the horizontal datum plane.

7.12 *Dimension Definitions* — See SEMI E15 for applicable definitions.

8 Related Documents

8.1 *SEMI Standards*

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E64 — Provisional Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

Table 1 Dimensional Requirements for 300 mm Load Ports

Dimension	*Application*	*Value, mm (in.)*	*Notes*
C1	minimum	75 (3.0)	
C2	minimum	30 (1.2)	
C3	minimum	150 (5.91)	
D	range	250 +0/-10 (9.8 + 0 – 0.4)	
D0	minimum	110 (0.59)	
D1	range	200 + 10 – 4 (7.9 +0.4/-0.2)	
D7	maximum	450 (17.72)	
D8	minimum	30 (1.18)	
Dimension	*Application*	*Value, mm (in.)*	*Notes*
H	nominal	900 (35.4)	(See NOTE 1.)
H0	minimum	15 (5.12)	

H1	maximum	25 (1.0)	
H2	maximum	2600 (102.4)	
H5	Range	33 ± 1 (1.30 ± 0.04)	height of roller conveyors
H7	nominal	250 (9.84)	center of optical beam line
H8	minimum	50 (1.97)	
H9	maximum	12 (0.47)	tolerance on photo-coupled I/O device beam line
S	minimum	420 (16.5)	open cassette (SEMI E1.9) only
		475 (18.7)	box (SEMI E47.1) without manual side handles
		505 (19.9)	box (SEMI E47.1) with manual side handles
W1	maximum	130 (5.12)	
W2	minimum	205 (8.07)	
W8	minimum	100 (3.94)	
W9	maximum	22 (0.87)	tolerance on photo-coupled I/O device beam line

NOTE 1: This value is ergonomically compatible with the proposed 13 wafer carriers and may not be ergonomically compatible with the proposed 25 wafer carriers. Such carriers may require assisted loading. H to be fully adjustable at installation over the range of 890 to 910 mm (35 to 35.8 inches).

Table 2 Required Exclusion Volume Dimensions for Carrier ID Reader/Writer Units

	Load Port Type			
Carrier Type (See NOTE 1.)	FOUP (SEMI E47.1) only	FOUP (SEMI E47.1) only	FOUP (SEMI E47.1) only	open cassette (SEMI E1.9) only
Carrier ID Type (See NOTE 1.)	electronic (read/write)	electronic (read/write)	bar-code (read only)	bar-code (read only)
Carrier Position (See NOTE 1.)	docked	undocked	undocked	not applicable
Dimension	mm (in.)	mm (in.)	mm (in.)	mm (in.)
D3 or D3′	D3' = 165 (6.50) max.	D3 = 190 (7.48) max.	D3 = 190 (7.48) max.	D3 = 136 (5.35) max.
D4 or D4′	D4' = 205 (8.07) min.	D4 = 235 (9.25) min.	D4 = 240 (9.45) min.	D4 = 230 (9.06) min.
H3	0 min. 75 (2.95) max.	15 (0.59) min. 36 (1.42) max.	0 min. 0 max.	0 min. 0 max.
H4	H4 = 30 (1.18) min.	H4 = 80 (3.15) min.	H4 = 80 (3.15) min.	H4 = 150 (5.91) min.
W4 or W4′	W4' = 35 (1.38) min.	W4 = 75 (2.95) min.	W4 = 75 (2.95) min.	W4 = 75 (2.95) min.

NOTE 1: Automated units to read or write to an ID tag, which are mounted in one of the exclusion volumes as defined by this standard, are not limited to be used on load ports in the Carrier Position, for the Carrier ID type or Carrier type indicated by this table.

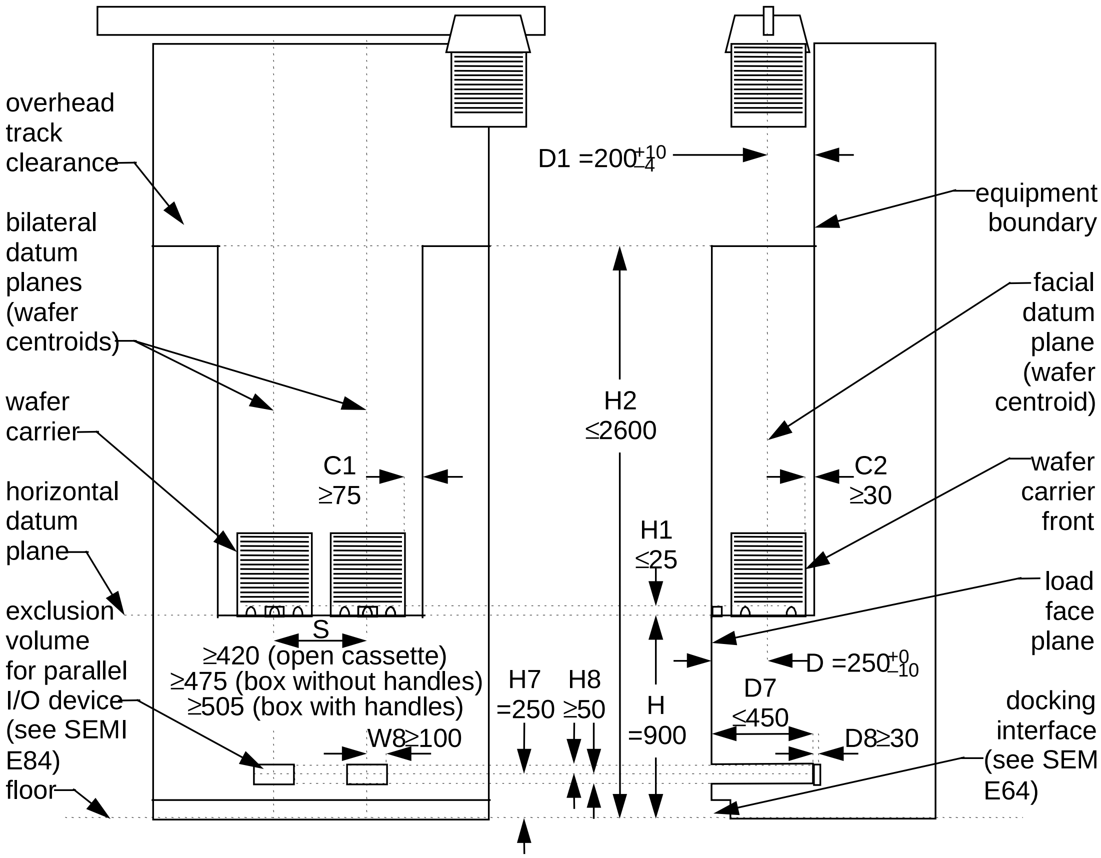


Figure 1
Load Port Requirements

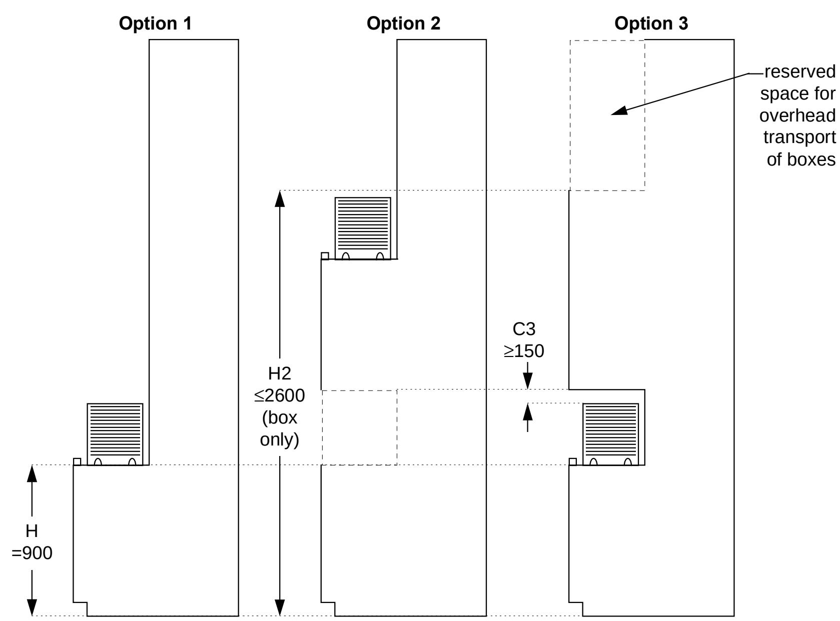


Figure 2
Load Port Options

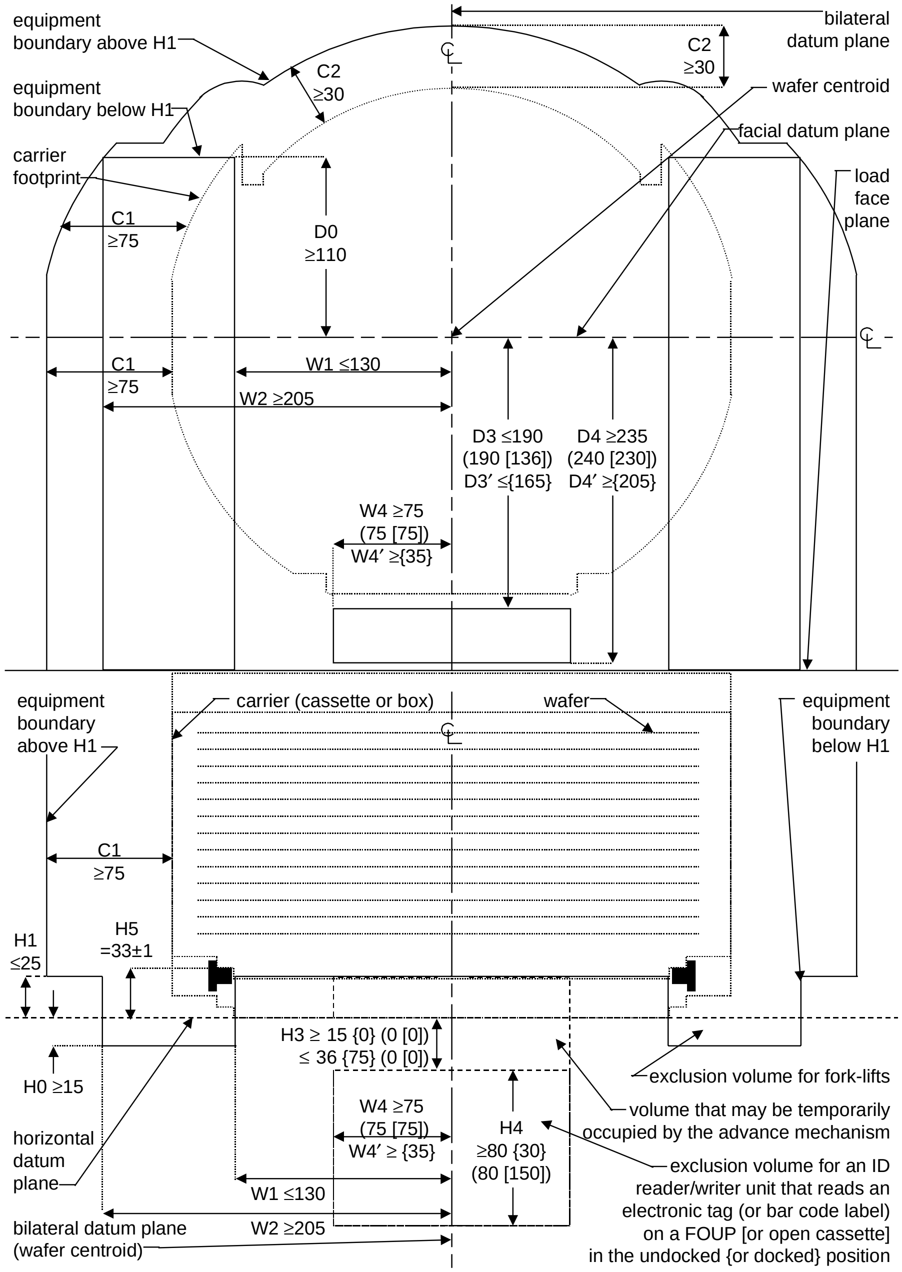


Figure 3
Exclusion Volumes at Horizontal Datum Plane

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E15.1 and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such, they are to be considered as reference material only. The standard should be referred to in all cases.

R1-1.1 This standard is meant to address both bottom-opening and front-opening boxes, as well as open cassettes. The C2 dimension applies to the initial placement of the carrier on the load port. Front-opening boxes, as defined in SEMI E47.1, and SEMI E62, would subsequently move forward to dock against a vertical surface. Consideration of reduction of C2 is deferred pending approval of the standards for wafer transport carriers.

R1-1.2 It is the device makers' expectation that process equipment suppliers are ultimately responsible for ensuring that their equipment (as installed in the device makers' facility) complies with SEMI E15.1. This expectation is the same whether the equipment load port is developed internally by the process equipment supplier or is purchased from a third party source. In either case, the process equipment supplier is responsible for understanding all of the requirements contained in this standard. Compliance with SEMI E15.1 can only be determined after the load port is integrated with the process equipment and is directly affected by process equipment design features (such as user interfaces and light towers).

R1-1.3 In the case of a front-opening-box, dimension C2 is a required clearance between the box and the tool's front-opening interface when the box is placed on the load port. After the box is placed on the load port, the kinematic couplings will move the box forward to engage with the tool's front-opening interface. The possibility of human fingers being pinched between the box and the tool's front-opening interface may be a safety concern for tool designers. The possibility of human fingers being pinched between the carrier and a carrier ID reader/writer unit may also be a safety concern for tool designers.

R1-1.4 There is some interest in roll-in transport of front-opening carriers to the load port. The implementation of such a scheme will require dealing with a number of issues related to registration mechanisms, tag readers and guide-in. Resolution of these issues may make it desirable to reduce the minimum value of H1.

R1-1.5 A tool load port may need to accommodate a device or system that is capable of automatically storing and retrieving additional carriers. Such a storage device is alternately referred to as a local buffer, a micro-stocker, tool-based storage, and other names. When defining the load port as in SEMI E15, the exact definition may become blurred. The transfer station or drop off location for a local buffer becomes the tool load port and must comply with SEMI E15. In this case, it may not be essential that the tool-buffer port also comply.

R1-1.6 Another case is in factories that employ overhead delivery of carriers onto tool load ports. In this case, it is possible that the transfer station or drop-off location where the intra-bay transport system delivers carriers may actually be located 8 or 10 feet above the floor. We assume that in these cases there would also need to be a transfer station that would be suitable for human loading. The ergonomic-driven requirements of SEMI E15 (height, clearances) would apply to the human-based transfer station.

R1-1.7 To avoid interfering with the lead-in capability (misalignment correction) function of the kinematic couplings, it is recommended that no part of the tool (other than the kinematic couplings) come horizontally closer than 10 mm (0.39 in.) to the carrier between the horizontal datum plane and H1 above it.

R1-1.8 It is recommended that the systems that deliver carriers to tool load ports have a mechanism to correct for misalignment of tools and load ports.

R1-1.9 A revision ballot will be submitted to allow projections in front of the OHT zone.

R1-1.10 Equipment can be configured with a variety of load ports chosen from the three options defined in Section 7.6. Figure R1-1 (a) shows a tool with two Option 1 load ports, which may work with any carrier. Although the tool is shown occupying the space on either side of the load ports, it is recommended that tool designers reserve this volume for installation of carrier buffers. Figure R1-1 (b) shows a tool with one Option 2 load port and one Option 3 load port, which may work with boxes delivered by an overhead transport system with manual back-up. Figure R1-1 (c) shows a tool with two Option 3 load ports, which may work with open cassettes and bulk head-mounted tools with AGV or manual delivery.

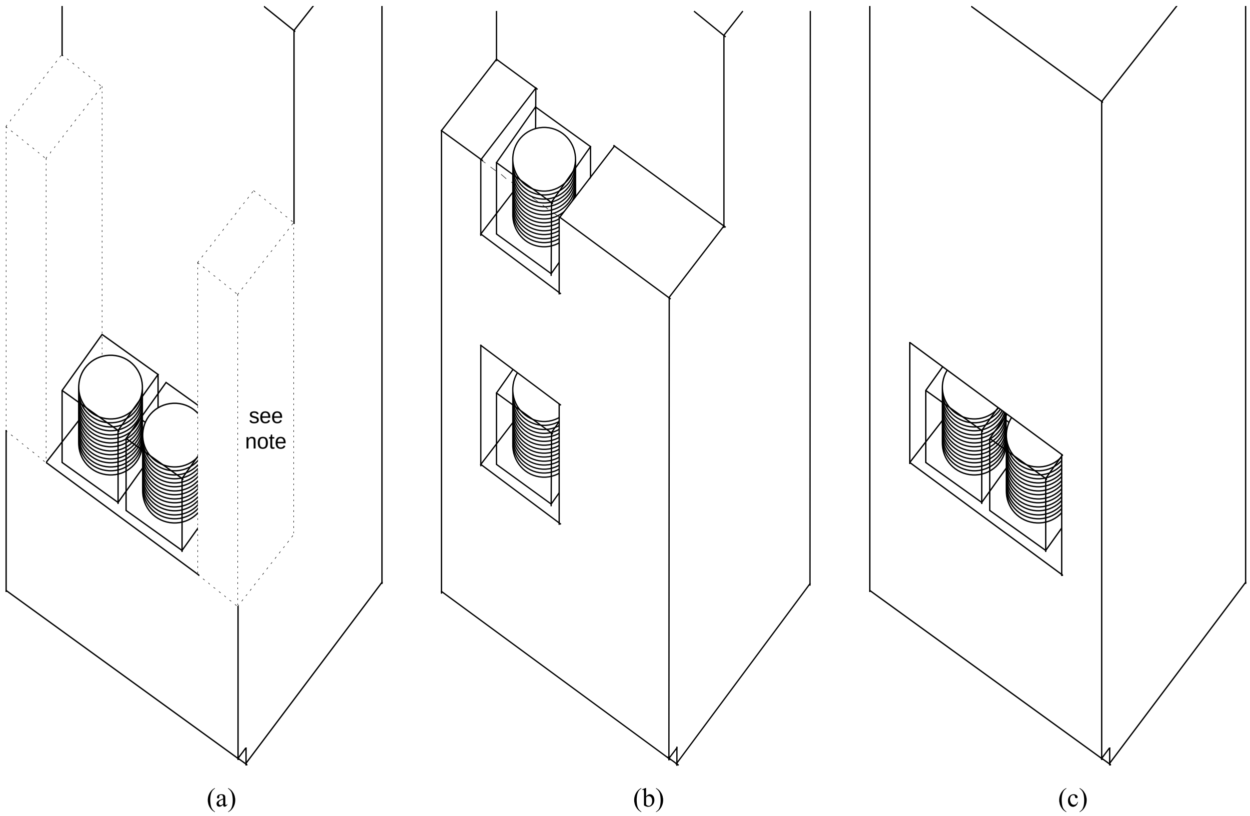


Figure R1-1
Example Combinations of Load Port Options

R1-1.11 Safety and process contamination issues can arise when using SEMI E15.1-compliant load ports in conjunction with SEMI E47.1-compliant FOUPs, and the corresponding FIMS ports. An empty FOUP, when mounted to a load port and retained only by the mandatory front clamping/retaining feature described in Section 6.10 of SEMI E47.1, can potentially be removed with no more effort than an operator would exert in trying to remove a full FOUP (perhaps 70 N of 16lbf. Lifting force can accomplish this). Therefore, the potential exists that an operator may mistake an empty FOUP for a full one, lift it off, and create both a mechanical safety hazard (an unguarded FIMS opening into the wafer handling robotics area) and a process contamination risk.

R1-2 Mechanical Interference Lockout Pins for FEOL and BEOL Load Ports

R1-2.1 *Background* — Many device manufacturers are planning to use process options for 300 mm wafers that pose significant risk of cross-contamination of wafers and production (process and metrology) equipment. In such a case, equipment load ports and carriers may be dedicated to front-end-of-line (FEOL) processing or back-end-of-line (BEOL) processing only. To eliminate the possibility of cross-contamination, device manufacturers want to ensure that FEOL carriers cannot be processed on production equipment with BEOL load ports and vice versa.

R1-2.1.1 In addition to traditional lockout methods (software, electronic, and visual approaches) to eliminate mis-processing, device manufacturers also want a “hard” mechanical lockout that makes it physically impossible for a carrier to register correctly on the kinematic coupling on a wrong load port. This application note describes one possible procedure for achieving a hard mechanical interference lockout (MIL) using pins located on FEOL and BEOL 300 mm load ports. Corresponding pads on FEOL and BEOL carriers are also discussed.

R1-2.2 *Info Pads C and D on Carriers* — FEOL carriers must have info pad C low and info pad D high. BEOL carriers must have info pad D low and info pad C high. Locations and dimensions for pads C and D are defined in SEMI E1.9 for 300 mm carriers and shown in Figure R1-2.

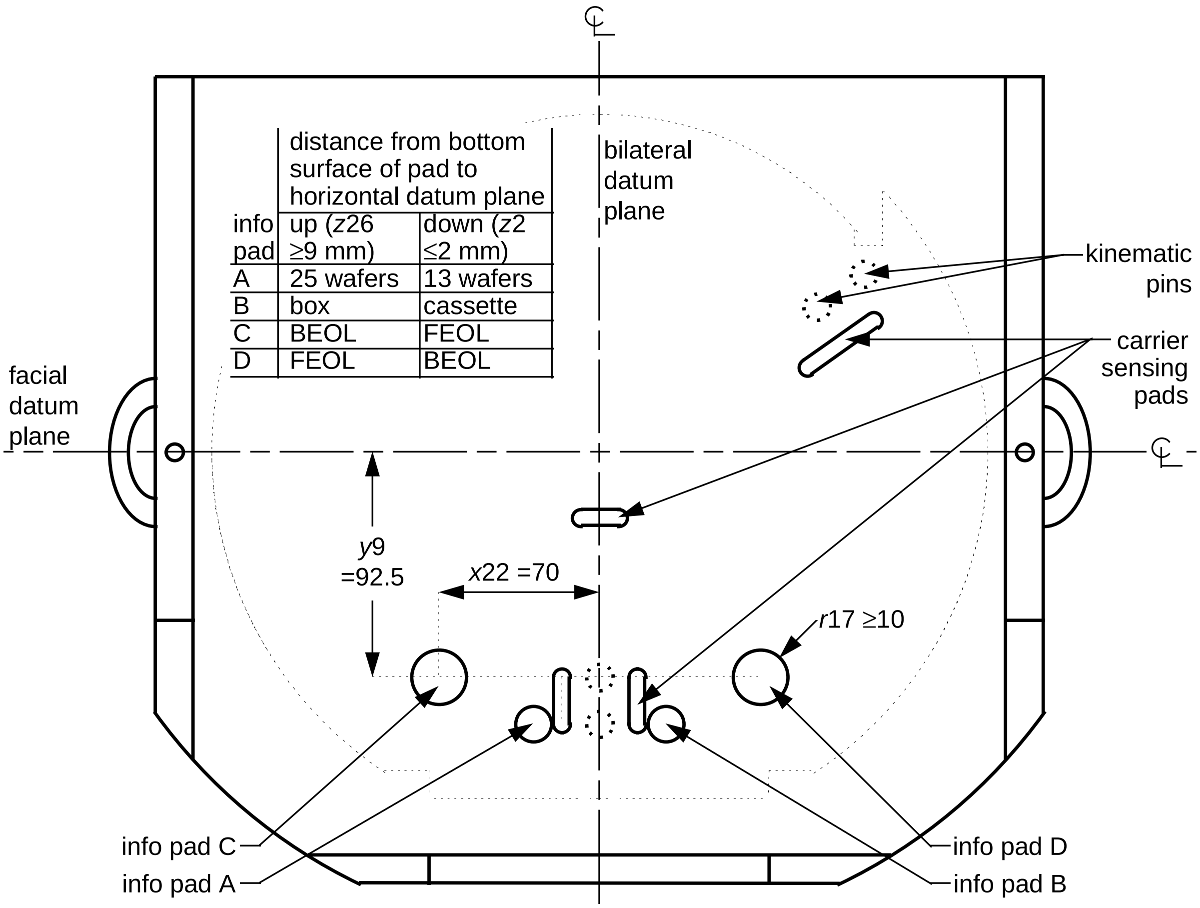


Figure R1-2
Carrier Bottom View Showing Info Pads C and D

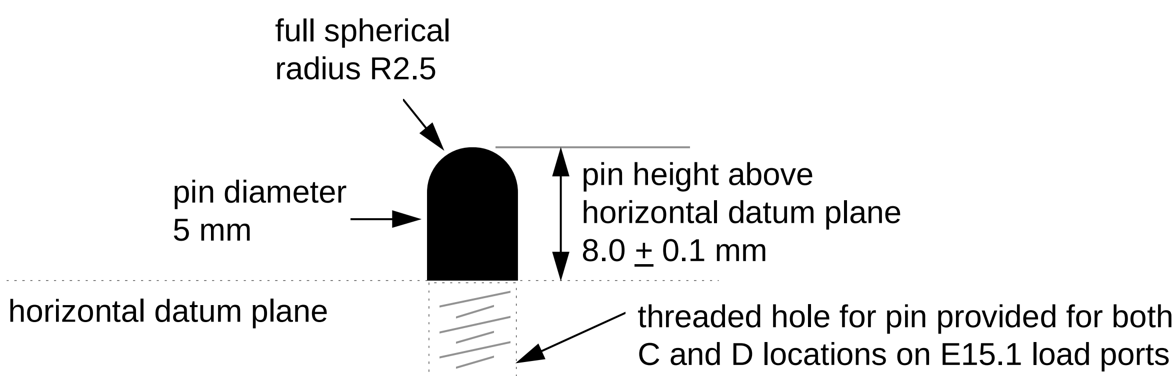


Figure R1-3
Detail of Pin C or D on the Load Port

R1-2.3 *Mechanical Interference Lockout Pins* — FEOL load ports must have a lockout pin D centered under info pad D, and BEOL carriers load ports must have a lockout pin C centered under info pad C. The dimensions for pins C or D are shown in Figure R1-3. When a carrier is placed on the wrong load port, the info pad and lockout pin will interfere with each other, preventing the carrier from being seated correctly on the kinematic coupling pins. As a result, the carrier placement OK sensor (or nested OK sensor) does not get triggered. Manual operator intervention may be required when this happens.

R1-2.4 *Lockout Pin Installation in the Fab* — Since it will be impossible for device manufacturers to specify in every case whether production equipment will be a FEOL equipment or an BEOL equipment at the time of ordering (when placing a purchase order), it is their expectation that the production equipment is delivered to the fab with the lockout pins, but without the pins installed on any load port. During tool install in the cleanroom, device manufacturers will decide whether the equipment is dedicated as an FEOL or BEOL equipment. At that time, equipment must be capable of having lockout pins C or D installed on the load ports in the fab. To meet this requirement, each load port must have pre-drilled holes at both C and D positions prior to shipment to the customer factory. The production equipment supplier must provide and install the lockout pins in the field. Table R1-1 summarizes the lockout requirements and corresponding sensor actions when different types of carriers are placed on different types of load ports during fab processing. Note that the carrier Placement OK Sensor and the carrier Presence Sensors are identified as requirements in the I300I/J300 CIM Global Joint Guidance document published in December, 1997.

R1-2.5 *Operation* — During normal operation, the pins and pads don't interfere with each other as shown in Figure R1-4. Normal operation is when a FEOL carrier is placed on a FEOL load port or when a BEOL carrier is placed on a BEOL load port, as shown below. Both the carrier placement OK sensor and the carrier presence sensors are triggered OK and wafer processing is allowed to continue.

R1-2.5.1 When a FEOL carrier is placed on a BEOL load port or vice versa, the pads and pins interfere with each other as shown in Figure R1-5, and the carrier does not nest correctly on the kinematic coupling of the load port. Note that the extent of interference is highly exaggerated in Figure R1-5, and is so depicted only for clarity. When interference occurs, the carrier rests in a secure manner on the front two kinematic coupling pins and the mechanical interference pin. As a result, the Carrier Placement OK sensor is not triggered OK, although the Carrier Presence sensor detects the presence of the carrier. Wafer processing does not start, thereby eliminating any wafer and equipment cross-contamination opportunity. When such a condition occurs, a production operator may be required to correct the problem.

R1-2.5.2 Some device manufacturers may identify certain type of fab equipment as not being sensitive to FEOL and BEOL contamination issues. In such a situation, the device manufacturer end user has the option to not install either FEOL or BEOL pin. In this case, FEOL and BEOL carriers will work on these load ports without any interference.

Table R1-1 Operational Summary

Carrier Type	*Load Port Type*	*Pad and Pin Interference Requirement*	*Carrier Placement OK Sensor State*	*Carrier Presence Sensor State*
FEOL	FEOL	No interference.	Sensor is triggered OK since carrier is nested correctly.	Sensor detects carrier presence.
FEOL	BEOL	Pad C and pin D interfere with each other.	Sensor is not triggered since carrier does not nest correctly.	Sensor detects carrier presence.
BEOL	BEOL	No interference.	Sensor is triggered OK since carrier is nested correctly.	Sensor detects carrier presence.
BEOL	FEOL	Pad D and pin C interfere with each other.	Sensor is not triggered since carrier does not nest correctly.	Sensor detects carrier presence.

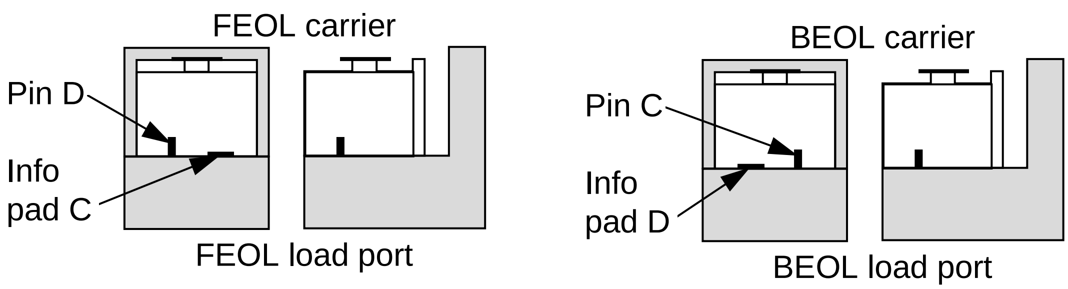
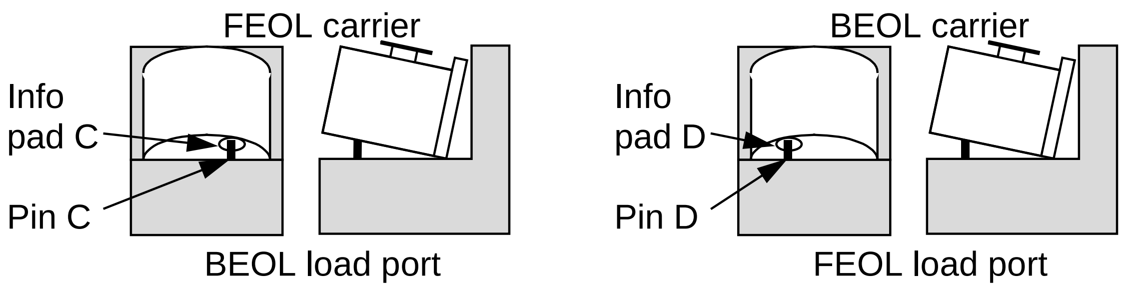


Figure R1-4
Pad and Pin Non-Interference with Each Other During Normal Operation



NOTE: Pads and pins interfere with each other. The carrier does not nest correctly on the kinematic coupling.

Figure R1-5
Pin and Pad Interference When a Carrier Is Placed on a Wrong Load Port

SEMI E16-90 (Reapproved 0699)
GUIDELINE FOR DETERMINING AND DESCRIBING MASS FLOW CONTROLLER LEAK RATES

This Guideline was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org February 1999; to be published June 1999. Originally published in 1990.

Editorial changes were made to Sections 4.2.2, 4.3.1, and 4.3.2.

1 Purpose

1.1 The purpose of this guideline is to establish a uniform, worldwide means for describing and measuring leak rates of mass flow controllers. The leak integrity of a gas delivery system is important to maintaining product quality and performance. This guideline is intended to prevent confusion and misunderstanding between manufacturers and users. In particular, it distinguishes between mechanical and diffusion leak rates.

2 Scope

2.1 This guideline contains definitions of terms and procedures for determining the Leak Rates of mass flow controllers as used in the semiconductor industry.

3 Definitions

3.1 *Leak* — A path or paths in a sealed system which will pass helium when a partial pressure differential exists. A partial pressure differential can exist for helium even though a total gas pressure differential may not exist. There are two major leak mechanisms, a mechanical passage or a material through which gas can diffuse or permeate. In a real system, a leak may have both mechanisms operating in parallel.

3.1.1 A mechanical leak may be a physical crack, pit, scratch or other imperfection in a sealing surface, or contamination or debris on the seals. A diffusion or permeation leak is caused by the movement of helium through gaskets, O-rings, polymers, or other materials through which helium can diffuse.

3.2 *Standard Leak Rate* — The quantity of helium at 25°C and 101.3 kPa (760 Torr) flowing through a leak when the high pressure side is at 101.32 kPa and the low pressure side is below 100 Pa (approximately 1 Torr). Standard Leak Rate shall be expressed in the following units:

Pa-m^3/s (He) = "Pascal cubic meters per second, helium"

or, alternatively,

atm-cc/s (He) = "atmospheric cubic centimeters per second, helium"

NOTE 1: The Pascal (1Pa = 1 N/m^2) is defined as the pressure unit of the international unit system SI. Therefore, the SI units above are preferred. Atm-cc/s is acceptable, as it is widely used in the semiconductor industry.

3.2.1 The "mass spectrometer helium leak detector" is generally used for leak rate testing of high and medium level vacuum apparatus. Units of sccs, Torr-L/s, and m bar-L/s, have been used in the past but are not encouraged. Reference materials include MIL STD-202E, C-1.

3.3 *Measured Leak Rate* — The leak rate of a given system measured under specified conditions and employing a specified test gas (helium). For the purposes of comparison with rates determined by other methods of testing, measured leak rates must be converted to equivalent standard leak rates.

3.4 *Sensitivity (Minimum Detectable Leak Rate)* — The smallest standard leak rate that an instrument, method or system is capable of measuring under specified conditions.

3.5 For the purposes of this document, the Measured Leak Rate shall be corrected to Standard Leak Rate by multiplying by the ratio of 101.32 kPa to the absolute value of the pressurizing helium unless otherwise called for by the MFC specifications.

$$\frac{\text{Measure Leak Rate} \times 101.32 \text{ kPa}}{\text{He Actual Pressure}} = \text{Standard Leak Rate}$$

4 Testing

4.1 *General Requirements*

4.1.1 *Leak Detector* — The leak detector shall be of the helium mass spectrometer type. It shall have a sensitivity at least equal to or smaller than the specified leak rating of the mass flow controller to be tested. If the actual leak rate is to be reported, the sensitivity shall be five times smaller than the leak to be measured. If the sensitivity is not five times smaller, the actual leak rate may be reported if the sensitivity of the detector is also reported.

4.1.2 Helium must have access to all primary seals.

4.1.3 Connections between the MFC and the leak detector must be leak-tight.

4.1.4 The ambient temperature of the MFC should be 25° ± 5°C unless otherwise specified. If another test temperature is used, it must be recorded during the test.

4.2 *Test Procedures* — There are two basic setups which may be used to measure the leak rate from the external environment to the internal gas passages of the MFC or from the internal passages to the external environment. Results for either test method may be reported. The method used must be reported as well. A third test, the through-the-valve setup, is intended to measure the quality of the valve seat shutoff.

4.2.1 *Internally-Pressurized Leak Test* — The purpose of this test set-up is to simulate operation of the MFC under conditions where the internal pressure is above ambient. The recommended internal pressure is 300 kPa absolute (30 psig) of helium. (See Figure 1.)

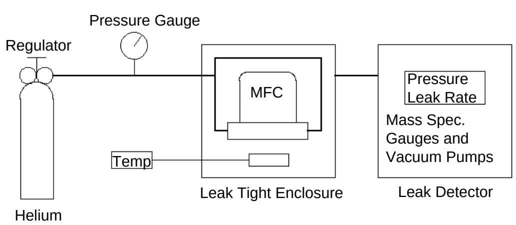


Figure 1

Internally-Pressurized Leak Test

4.2.2 *Externally-Pressurized Leak Test* — The purpose of this test is to simulate operation of the MFC under conditions where the internal pressure is at vacuum. The external pressure should be equal to atmospheric pressure. The internal pressure should be less than 100 kPa. (See Figure 2.)

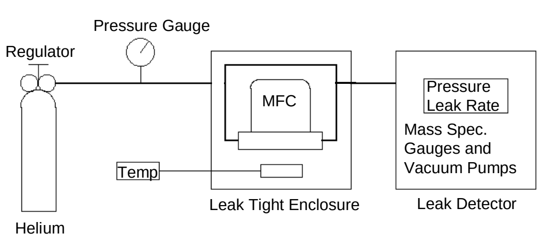


Figure 2

Externally-Pressurized Leak Test

4.2.3 *Control Valve Seat Leak Test* — The purpose of this test is to determine the leakage through the control valve under simulated operation in the closed control mode. The MFC should be electrically energized for normal operation and placed in the closed position as specified for the operation of the MFC. The input pressure to the MFC should be 100 kPa ± 20%. The outlet should be connected directly to the helium leak detector, and pressure should be as low as possible using good leak detector practice. (See Figure 3

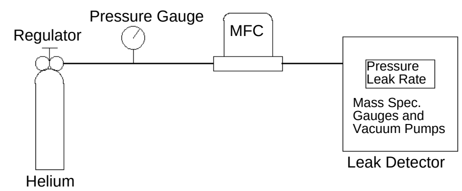


Figure 3

Control Valve Seat Leak Test

4.2.3.1 In the case of MFCs which are not designed for positive shutoff at the control valve, alternative methods may be employed if documented and reported.

4.3 *Reporting Results* — The example shown in Figure 4 is a plot of leak detector output value vs. time for a representative elastomer-sealed MFC. This curve is the sum of mechanical and permeation leak components.

NOTE 2: All times are from application of helium, starting with a leak detection system pumped down to base reading.

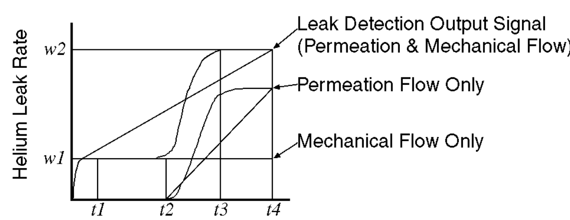


Figure 4

Leak Detector Output Value vs. Time

Interval	*Rate*	*Example*
t1 Initial System Response		Less than 10 seconds
t2 Leak Prior to Onset of Permeation	*w1*	10 seconds to 1 minute
t3 Increasing Permeation		1 minute to 30 minutes
t4 Total Saturation	*w2*	Beyond 30 minutes

4.3.1 The actual shape of these curves and time intervals is dependent on the design of the MFC under test, the elastomer used, if any, and the characteristics of the leak detection system. These time intervals must be determined using sound engineering judgment following qualification testing of the specific MFC model and test set-up. Once determined, it is recommended that receiving inspection consist of measuring for leak rate value *w1* at the end of interval *t2*.

4.3.2 Following qualification testing, report typical values for *t1* through *t4* and *w1* and *w2*. *w1* is primarily the mechanical portion of the leak, and *w2* is mechanical plus permeation. In the case where *w2* is significantly greater than *w1*, *w2* is primarily permeation. In the case of a gross mechanical leak, *w1* could greatly exceed, and thereby mask, *w2*.

NOTE 3: This test must be performed with elastomers that are devoid of helium. Such elastomers have either not been previously exposed to helium or have been degassed following exposure. Once this test has been performed, the elastomers must be purged of helium by the passage of time and/or baking.

4.3.3 In good leak testing practice, the background level should be verified before the application of helium to ensure that the elastomers are in a helium degassed state and that the leak detecting system is in proper operation.

SEMI E17-0600
GUIDELINE FOR MASS FLOW CONTROLLER TRANSIENT CHARACTERISTICS TESTS

This guideline was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on April 10, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1991.

1 Scope

1.1 This guideline is intended to establish a common basis for communication between users and suppliers of semiconductor equipment. It provides terminology and methodology aimed at eliminating confusion regarding what previously has been referred to as MFC "response time." The conditions and procedures are given for determining and expressing the transient characteristics of a mass flow controller (MFC) to a step change in set point. This guideline applies to mass flow controllers for gases used in semiconductor fabrication equipment.

1.2 This guideline does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Definitions (Figures 1 and 2)

2.1 *Actual Flow* — For the purpose of this standard, the output value of the master reference standard.

2.2 *Dead Time* — The interval of time between the set point step change and the start of the resulting observable response.

2.3 *Final Steady State Value* — The average value of the actual flow, after the effects of the input transient have expired to a value equal to or below the intrinsic drift and noise.

2.4 *Settling Time* — The time between the set point step change and when the actual flow remains within the specified band.

2.5 *Step Response Time* — The time between the setpoint step change and when the actual flow first enters the specified band.

2.6 *Transient Overshoot* — The maximum change in actual flow minus the steady state change in actual flow, expressed as a percentage of the set point step change.

2.7 *Transient Undershoot* — The maximum amount that the actual flow passes the final steady state value, in the opposite direction of overshoot, expressed as a percentage of the set point step change.

2.8 *Set Point* — The electrical input signal to the MFC which sets the desired value of the controlled flow.

2.9 *Specified Band* — The region between ± 2% of the final steady state value or ± 0.5% of full scale, whichever is greater.

3 Test Setup

3.1 The purpose of the flow system is to furnish the mass flow controller under test with a constant pressure supply of suitable gas. It must also provide a means of determining the gas flow rate through the mass flow controller that responds to changes in gas flow significantly faster than the device under test. The recommended flow system for testing the speed of response of MFCs is shown in Figure 3a.

3.2 The flow system shall have straight tubing or pipe connecting the MFC to the master reference standard. The inside diameter of the interconnecting tubing or pipe shall be of sufficient size to preclude any pressure drop that would affect the performance of the MFC.

3.3 The pneumatic time constant, Tau, should be minimized. (See Section 3.7.)

Tau =	(V*DPm) / (Qm*Pa)

Where:

V =	Internal volume of the flow system between the MFC under test and the master reference standard, including tubing, fittings and the side of the master reference standard that is connected to the MFC under test.
Qm =	Maximum volumetric flow expected during the test.
DPm =	Pressure drop of the master reference standard at flow Qm.
Pa =	The absolute pressure present at the outlet of the master reference standard at final steady state value.

3.4 The source of the test gas shall be capable of delivering an essentially constant upstream pressure to the mass flow controller under test during the transient characterization. A maximum variation of ± 2% from the median absolute pressure is considered adequate for most mass flow controllers.

3.5 Nitrogen is the recommended gas for the standard test shown in Figure 3a. The inlet pressure is 25 psig (1.75 kg/cm^2G). Outlet pressure is the prevailing atmospheric pressure. The temperature of the gas entering the flow controller and the temperature surrounding the flow controller shall be the same. Neither shall vary during the test so as to have a significant effect.

3.5.1 The preceding conditions are recommendations. Deviations may be made to more accurately reproduce the conditions that the MFC will experience in use, such as the variation shown in Figure 3b. Any deviation from the above gas and pressure conditions and/or test setup must be noted with the test results.

3.6 The master reference standard is used to provide a representation of the instantaneous actual flow. It is customary to refer to the output of the master reference standard as the actual flow. It shall have an accuracy of ± 5% of reading (including linearity), or better, over the flow range for which results will be reported. The pressure drop across the master reference standard at the test flow shall be small enough to not effect the response of the MFC under test.

3.6.1 Typical master reference standards are Hot-Wire flow meters (or similar immersible thermal flow sensors), laminar flow elements with a differential pressure transducer, and Rate of Rise (RoR) systems.

3.7 The measuring system response time is the sum of the pneumatic time constant, master reference response time and the recording system response time. The measuring system response time shall be less than 1/5 of any reported transient characteristic. If the measuring system response time is greater than 1/5 of a specific transient characteristic, that characteristic may be reported if the measuring system response time is also reported.

3.8 The test setup shall provide a step change in the setpoint to the mass flow controller, along with a time-zero cue to the data acquisition system. The step change transient time shall be less than 1% of the step response time of the MFC under test.

3.9 The test setup is recommended for MFC full scale flow rates above 10 sccm. In those cases where the flow rate is below 10 sccm and the pneumatic time constant is not less than 1/5 of the step response time of the MFC the pneumatic time constant shall be reported.

3.10 The MFC shall be electrically energized for the supplier recommended “warm up” time prior to the start of the test.

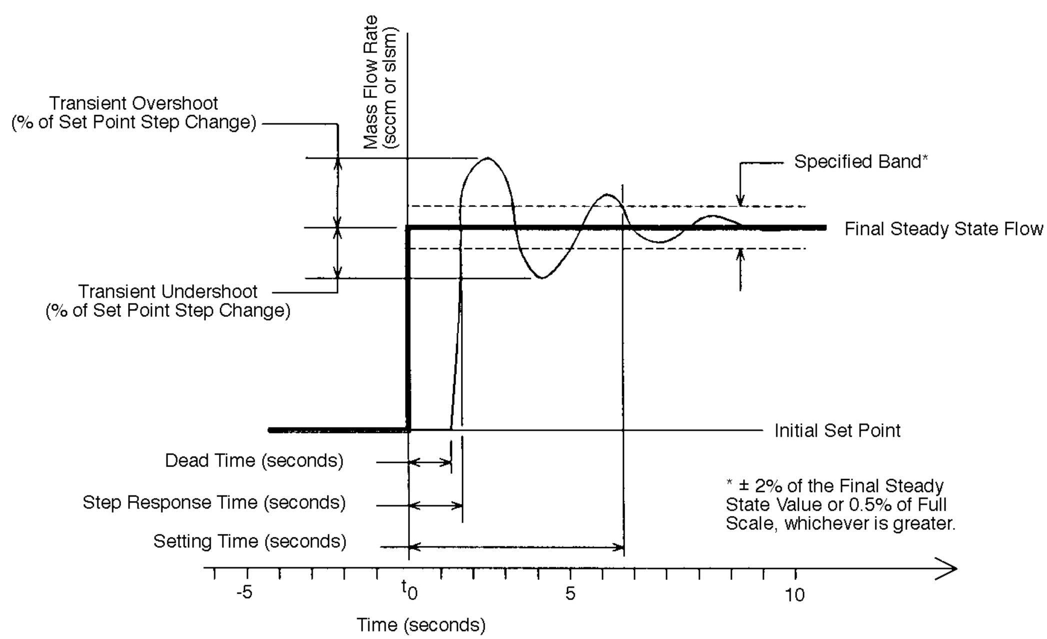


Figure 1
Definitions of MFC Transient Characteristics Terminology in the Case Where the Final Set Point Is Higher than the Initial Set Point

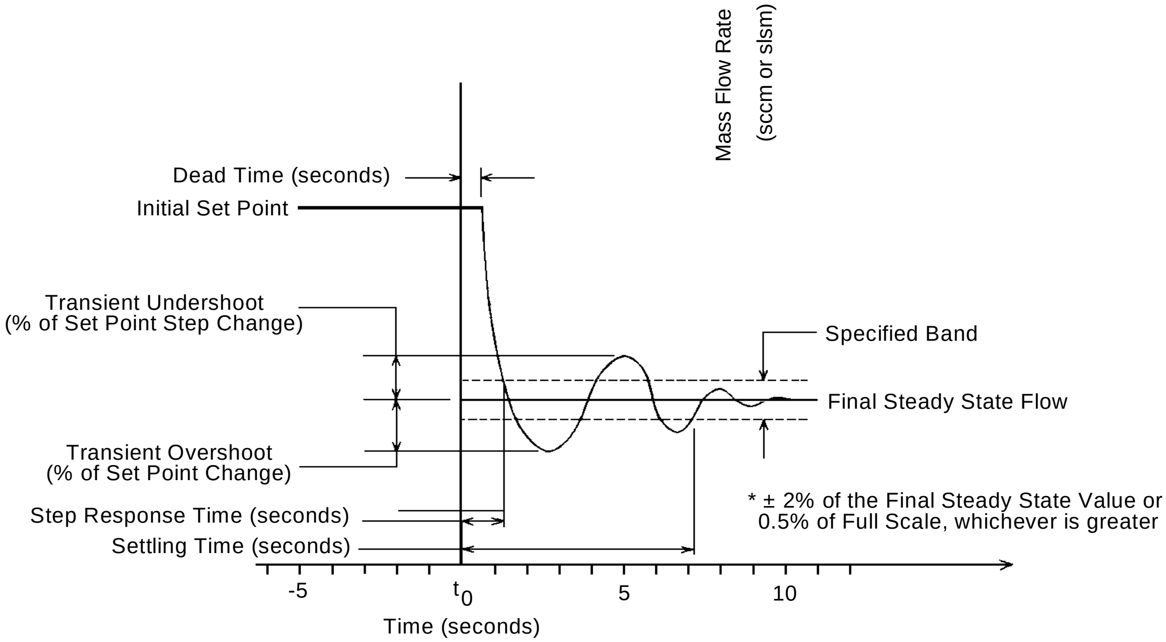


Figure 2
Definitions of MFC Transient Characteristics Terminology in the Case Where the Final Set Point Is Lower than the Initial Set Point

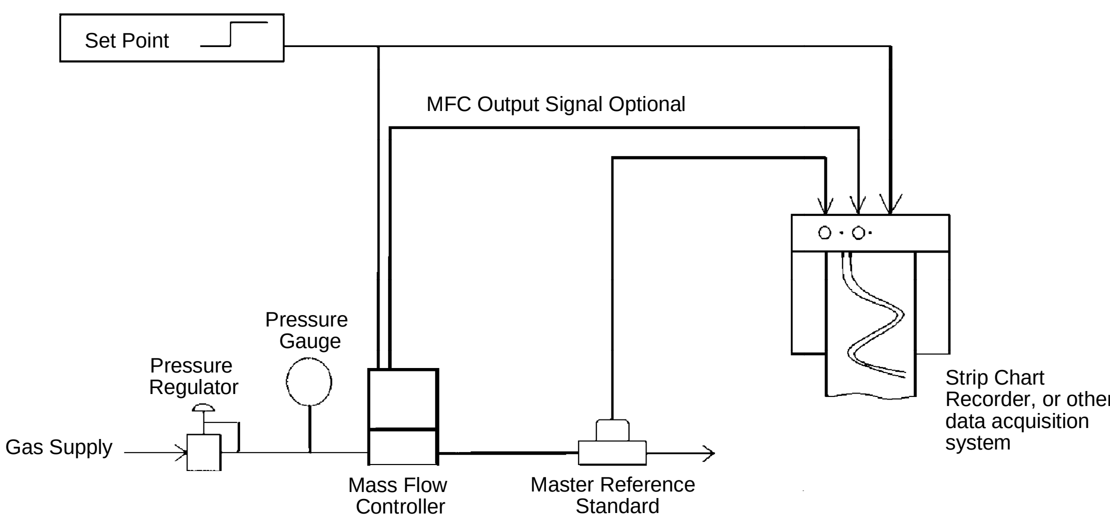


Figure 3a
MFC Transient Characteristics Test Setup with Outlet at Atmospheric Pressure

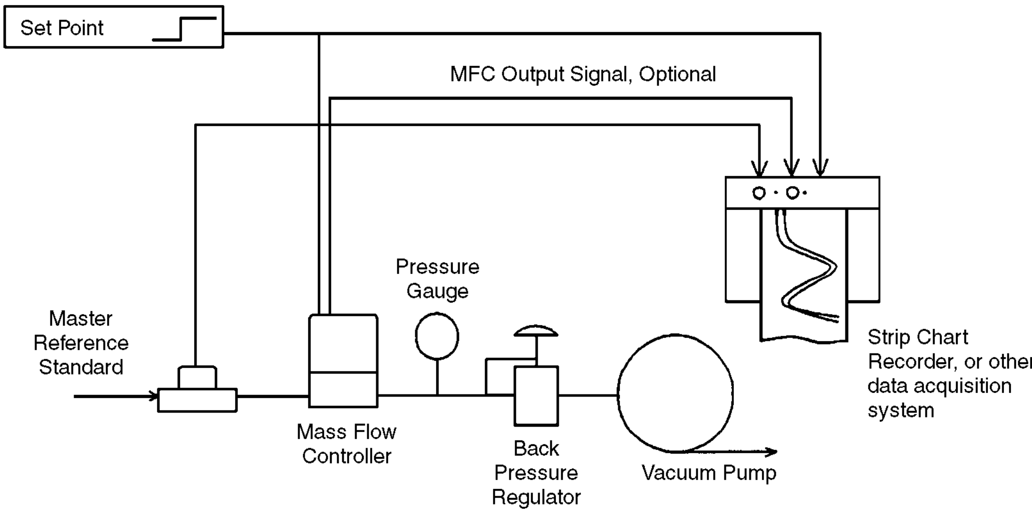


Figure 3b
MFC Transient Characteristics Test Setup with Outlet at Vacuum

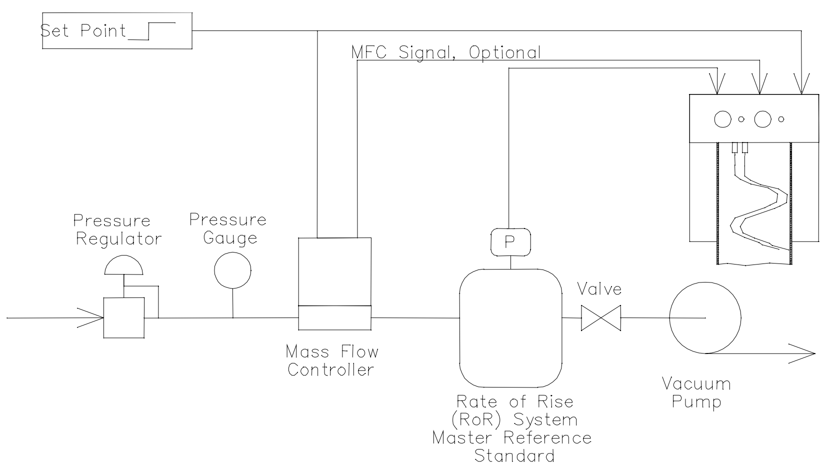


Figure 3c
VFC Transient Characteristics Test Setup with Rate of Rise (RoR) System

4 Test Procedure

4.1 Evaluate the transient characteristics from “OFF” to a flowing condition at final set point by a transition in set point voltage only.

4.1.1 Apply a set point voltage sufficient to close the control valve following the manufacturer’s recommendation. This may be a voltage other than zero, either positive or negative. Allow the output of the mass flow controller and the actual flow, if any, to stabilize.

4.1.2 Apply the final set point value as shown in Table 1.

4.2 Evaluate the transient characteristics from "OFF" to a flowing condition at final set point by using an auxiliary input to an MFC designed for the purpose.

4.2.1 Establish an "OFF" condition following the manufacturer's recommendation. The setpoint should be applied as shown in Table 1. Allow the output of the mass flow controller and the actual flow, if any, to stabilize.

4.2.2 Change the state of the auxiliary input to achieve control.

4.3 Evaluate the testing transient characteristics between two non-zero set point controlled flows.

4.3.1 Adjust the command to the "initial set point" in Table 1, and allow the actual flow (as measured by the master reference standard) to stabilize.

4.3.2 Apply final set point as shown in Table 1.

4.4 Refer to Figures 3 and 4 to determine the dead time, step response time, settling time, overshoot, and undershoot. Record the results in Table 1.

5 Test Results

5.1 Transient characteristics test results shall be presented as follows:

(1) "OFF" means the MFC set point is zero or the lowest value permitted.

(2) The control valve leak rate at shut-off shall be recorded.

(3) Other initial and final set points may be tested and reported.

(4) The transient characteristics of the MFC electrical output signal shall also be recorded during the above testing for purposes such as comparison with the actual flow.

Table 1

Initial Set Point (% of Full Scale)	**OFF (1)**	**OFF (1)**	25	75	**OTHER (3)**
Final Set Point (% of Full Scale)	100	25	75	25	**OTHER**(3)
Dead Time (Seconds)					
Step Response Time (Seconds)					
Settling Time (Seconds)					
Transient Overshoot (Percent of set point step change)					
Transient Undershoot (Percent of set point step change)					

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SEMI E18-91 (Reapproved 0299)
GUIDELINE FOR TEMPERATURE SPECIFICATIONS OF THE MASS FLOW CONTROLLER

This guideline was technically reapproved by the Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1991; previously published in 1996.

1 Purpose

1.1 The purpose of this guideline is to establish a uniform, worldwide means to describe the temperature parameters which are characteristic of mass flow controllers. It is intended to prevent confusion and misunderstanding between manufacturers and users.

2 Scope

2.1 This guideline contains definitions of terms which describe the effects of temperature upon mass flow controllers as used in the semiconductor industry.

3 Definition of Terms (See Figure 1)

3.1 *Units* — Degrees Celsius (C) is used as the temperature unit.

3.2 *Ambient Temperature* — The temperature of the medium surrounding the device.

Note: The ambient temperature assumes that the instrument is not exposed to significant radiant energy sources.

3.3 *Gas Temperature* — The actual temperature of the flowing gas at the primary flow standard.

3.4 *Calibration Temperature* — The ambient temperature at which the mass flow controller was calibrated.

Description Form: ___°C

CAUTION — Calibration Temperature is not to be confused with Gas Temperature or Standard Temperature.

3.5 *Standard Temperature* — The temperature to which a volumetric flow rate (measured at the Gas Temperature) is referenced through the ideal gas law (PV = nRT). SEMI E12 defines Standard Temperature as 0.0°C.

CAUTION — Standard Temperature is not the same as the Gas Temperature or Calibration Temperature.

3.6 *Reference Operating Temperature* — The range within which accuracy statements apply without requiring correction for Temperature Effects (see 3.11).

Description Form: ___°C – ___°C

3.7 *Normal Operating Temperature* — The temperature range within which the influence of ambient temperature on the performance is stated.

Description Form: ___°C – ___°C

3.8 *Operating Temperature Limits* — Operation is permitted within this range but performance is not specified beyond the Normal Operating Temperature. If the instrument is operated outside these limits damage may occur.

Description Form: ___°C – ___°C

3.9 *Maximum Baking Temperature* — The highest temperature to which the Mass Flow Controller or its components in contact with the gas can be heated in accordance with a specified baking procedure. The specified baking process will not impair the performance characteristics per the manufacturers specifications. ("Baking" is a process whereby a device is heated to accelerate the removal of adsorbed gases and/or other volatile material.)

Description Form: MAX. ___°C

3.10 *Storage Temperature Limits* — The temperature limits to which the mass flow controller may be subjected in an unpowered condition. No permanent impairment shall take place, however minor adjustments may be needed to restore performance to normal.

Description form: ___°C – ___°C

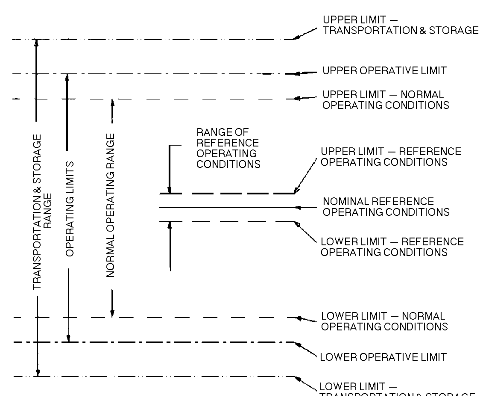

Figure 1

3.11 *Temperature Effects* — See Figure 2.

NOTE 1: This section requires that Gas Temperature be the same as Ambient Temperature.

3.11.1 *Total Effect* — The change in output, including zero and span, due to a change in Ambient Temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

3.11.2 *Zero Effect* — The change in zero due to a change in ambient temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

The effect of temperature change on zero may be expressed as a coefficient calculated as the ratio of full scale percent change in output to the corresponding change in temperature. The change in ambient temperature should be specified. This coefficient is defined as the "temperature coefficient of zero."

Example: Temperature coefficient of zero may be expressed as:

$$\frac{2\% \text{ of Full Scale}}{40°\text{C} - 20°\text{C}} = 0.1\% \text{ of Full Scale}/°\text{C}$$

NOTE 2: If the relation between temperature and change in output is linear, one coefficient will suffice.

If the temperature influence is non-linear a different method of expression may be used. Two examples:

1. The percent of full scale change in output will not exceed a specified value for any value of temperature within a specified temperature range.

Example: "± 1.5% of full scale maximum error over 10°C to 50°C"

2. It may be desirable to state a series of coefficients for successive increments of temperature within a specified temperature range.

3.11.3 *Span Effect* — The change in span due to a change in ambient temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions.

The effect of temperature change on span may be expressed as a coefficient calculated as the ratio of percent of reading change in output to the corresponding change in temperature. The change in ambient temperature should be specified. This coefficient is defined as the "temperature coefficient of span."

Example: Temperature coefficient of span may be expressed as:

$$\frac{1\% \text{ of reading}}{40°\text{C} - 20°\text{C}} = 0.05\% \text{ of reading}/°\text{C}$$

NOTE 3: If the relation between temperature and change in output is linear, one coefficient will suffice.

If the temperature influence is non-linear a different method of expression may be used. Two examples:

1. The percent of span change in output will not exceed a specified value for any value of temperature within a specified temperature range.

Example: "± 1.0% of reading maximum error over 10°C to 50°C"

2. It may be desirable to state a series of coefficients for successive increments of temperature within a specified temperature range.

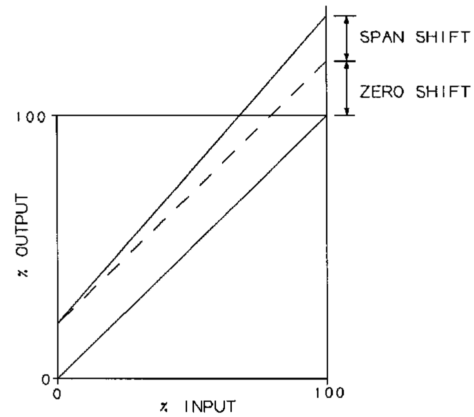

Figure 2
Span and Zero Shift

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SEMI E19-0697 (Reapproved 0702)
STANDARD MECHANICAL INTERFACE (SMIF)

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

NOTE: This standard has been purposely restricted to 100 mm (4 in.), 125 mm (5 in.), and 150 mm (6 in.) versions of the SMIF port. This has been done to establish a base for SMIF port standardization. Aspects of the 200 mm (8 in.) version have been negotiated by interested parties and published as SEMI E19.4.

1 Purpose

1.1 A standard interface is required for containers intended to control the transport environment of cassettes containing wafers or disks. The interface must address the proper container orientation for material transfer and maintain continuity between the container and equipment environment in order to control particulate matter.

2 Scope

2.1 This specification describes one approach to interfacing a clean cassette transport box to a clean environmental housing on a piece of semiconductor processing equipment or to other clean environments. The system concept involves mating a door on a cassette container to a door on an equipment canopy and transferring the cassette into, and out of, the equipment without exposing the cassette and wafers to outside contamination.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Impact

3.1 The incorporation of this standard requires equipment designers to include the features of the interface into the tool design. Spacing between open cassette ports is inadequate for incorporation of this interface. Designers are directed to the recommendations made in SEMI E15 in this regard.

4 Limitations

4.1 This standard is specific to the size of the designated wafer and references the appropriate SEMI cassette and wafer diameter. A single numerical suffix is assigned to this base standard number or each wafer diameter. This specification focuses on applications in which the interface port is positioned horizontally. The standard is focused exclusively on the box-to-canopy interface. Other considerations of box and equipment design are purposely excluded.

NOTE 1: Hewlett-Packard has stated that it is seeking patent coverage for this design and is offering non-exclusive licenses on an equal basis to any company. Companies intending to manufacture products to this standard should be aware of Hewlett-Packard's position.

NOTE 2: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position with respect to the validity of any patent rights asserted in connection with any item mentioned in this document. Users of this document are expressly advised that determination of any such patent rights and the risk of infringement of such rights are entirely their own responsibility.

5 Referenced Standards

5.1 *SEMI Standards*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E15 — Specification for Tool Load Port

6 Terminology

(See Figure 1 for a pictorial depiction of most terms.)

6.1 *Definitions*

6.1.1 *box* — an environmentally controlled enclosure for a cassette containing wafers or disks. For purposes of this standard, a box has features that conform to the specified interface. A box includes a box door and box latches. (A box is also referred to as a *container*.)

6.1.2 *box door* — a removable bottom for the box that contains a means (such as registration holes) for properly positioning the wafer cassette.

6.1.3 *box latches* — mechanical latches that hold the box door in position until activated by the latch pins. Upon activation, a portion of each box latch engages a latch cavity and smaller, thereby locking the box to the port plate.

6.1.4 *guide rail* — a component of a port plate that provides coarse location for placing the box on the port assembly.

6.1.5 *latch cavities* — spaces located in the port assembly guide rails that accommodate the box latches in the open position of the box door.

6.1.6 *latch pins* — pins that engage the box latches and accomplish the lock/unlock functions. Latch pins are on the port plate.

6.1.7 *port* — a port assembly appropriately sized for the wafers or disks that are to be transferred. Three port sizes are specified for the purposes of this standard: 100 mm (4 in.) for 100 mm (4 in.) wafer cassettes, 125 mm (5 in.) for 125 mm (5 in.) wafer cassettes, and 150 mm (6 in.) for 150 mm (6 in.) wafer cassettes.

6.1.8 *port assembly* — an assembly of the port plate and port door that includes the guide rails, registration pins, latch pins, and latch cavities.

6.1.9 *port door* — a door for the port plate opening that provides a mating surface for the bottom of the box door when the box is in place on the port plate. The port door contains the registration pins.

6.1.10 *port plate* — a horizontal mating surface for the base of the box that provides a seal surface to the bottom surface of the box perimeter. The port plate contains the guide rails and the latch pins.

6.1.11 *registration holes* — holes in the bottom of the box door that fit over registration pins in the top of the port door when the box is placed on the port door.

6.1.12 *registration pins* — pins that provide fixed position and orientation between the port door and box door and assist in final positioning of the box on the port assembly. The registration pins fit into the registration holes in the bottom of the box door.

7 Requirements

7.1 *Cassette Sizes* — The requirements and dimensions for the design of mechanical interface standard ports and boxes are given in this section. All dimensions of the interface between box and port are specified in reference to the port. Different sets of port dimensions are standardized to accommodate the following three cassette sizes:

100 mm (4 in.)	per SEMI E1.2
125 mm (5 in.)	per SEMI E1.3 and E.4
150 mm (6 in.)	per SEMI E1.5

7.2 *Port Design Requirements* — The general design of the port is shown in Figures 2 and 3. Specific dimensions for the different cassette sizes are given in SEMI E19.1, SEMI E19.2, and SEMI E19.3. Design requirements for the interface components are provided in Sections 7.2.1 through 7.2.5. The general design of the port is shown in Figures 2 and 3. Specific dimensions for the different cassette sizes are given in SEMI E19.1, SEMI E19.2, and SEMI E19.3. Design requirements for the interface components are provided in Sections 7.2.1 through 7.2.5.

7.2.1 *Port Door* — Dimensions A1 through A3 specify the port door top view. The gap between port door and port plate is not specified, but should be kept to a minimum distance to restrict particle movement.

7.2.2 *Guide Rails* — The inside distance of the guide rails on the four sides of the port is specified (B1 and B2). The guide rail can be continuous or in sections. If connected at the corners, the inside radius shall not exceed B9. The maximum height of the rail is given by B5. The guide rails include cavities. Two cavities are provided for the 100 mm (4 in.) port size or four cavities for the the 125 mm (5 in.) and 150 mm (6 in.) port sizes.

7.2.3 *Latch Pins* — The 100 mm (4 in.) port requires two latch pins (C5), located on the port center line at a distance specified by C1 in the unactivated position. The 125 mm (5 in.) and 150 mm (6 in.) ports require four latch pins, positioned by C1 and C3. The displacement to move the latch pins from the unactivated (box door closed) to the activated (box door unlatched) position is specified by the linear dimension C2 . The minimum available force per pin to unlatch and latch the box door is specified by F1 and F2. The latch pins can move in a linear or circular motion as long as the position of the activated pins falls within the target area dimensioned by C8.

7.2.4 *Registration Pins* — The three registration pins on the port door are located asymmetrically, and spaced by dimensions D1 through D4. The size of the pins is specified by D5 through D7.

7.2.5 *The Box* — The bottom surfaces of the box body and box door shall conform to the specified port dimensions. The upper part of the box body and top surface of the box door must fit and hold in place the wafer cassette specified by SEMI E1, for 100 mm (4 in.), 125 mm (5 in.), and 150 mm (6 in.) cassettes. Although the box dimensions are not explicitly specified by this standard, the following requirements apply:

7.2.5.1 The bottom surface of the box door at its perimeter shall match the dimensions of the port door top (A1 through A3). The tolerances shall be chosen so that the box door does not extend over the port door in any instance, even when the port door is built to its minimal acceptable dimensions and potential variance between registration pins and holes is considered. This is to ensure interference free passage of the box door through the port opening.

7.2.5.2 The base of the box body shall fit freely but with close tolerance between the guide rails (B1, B2, and B9), which not only hold the box in place while the port is open, but also provide proper alignment for the closure of the box at the end of the open/shut cycle.

7.2.5.3 The bottom surface of the box requires three registration holes to engage with the registration pins on the port. The registration pins shall be positioned in the door bottom so that the registration pins prevent seating of the box with the port in the event that the box is improperly rotated by 180 degrees from the correct orientation. The correct orientation is illustrated in Figure 2.

7.2.5.4 The perimeter of the bottom surface of the box body shall be continuous (except possibly at the latch locations) and shall be positioned against the port surface. This positioning assures the activation of an optional limit switch placed in an unspecified location along the port perimeter for the sensing of proper box placement.

7.2.5.5 Each box door latch requires a hole to engage its corresponding port latch pin. The hole shall be elongated to provide a target area for the activated pin (box door open) as shown by dimension C8. A protrusion from each latch shall engage with its corresponding cavity in the guide rail to prevent the removal of the box while the port is open.

7.2.5.6 The center of the cassette crossbar shall coincide with the center of the box door, with the cassette orientated as shown in Figure 2. The top surface of the box door requires registration bars that hold the cassette in place. The horizontal cassette movement is limited by the tolerances G2. The vertical position of the cassette while located on the box door is specified by the distance G1 between the top of the port surface and the bottom surface of the cassette.

7.2.5.7 The external top of the box shall not exceed the top of the cassette by more than two inches. This is to prevent possible interference between the box and the equipment.

8 References

The following articles describe the standard mechanical interface concept:

8.1 “The Challenge to Control Contamination: A Novel Technique for the IC Process,” *The Journal of Environmental Sciences* (May/June 1984) , page 23.

8.2 “SMIF, A Technology for Wafer Cassette Transfer in VLSI Manufacturing,” *Solid State Technology* (July 1984), page 111.

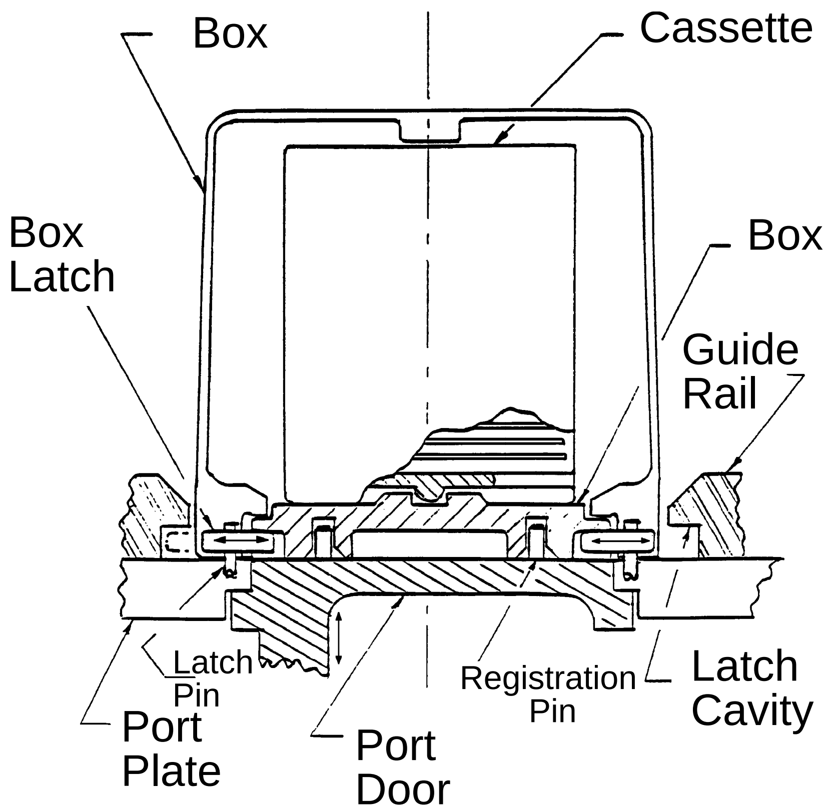

Figure 1
Port Terminology

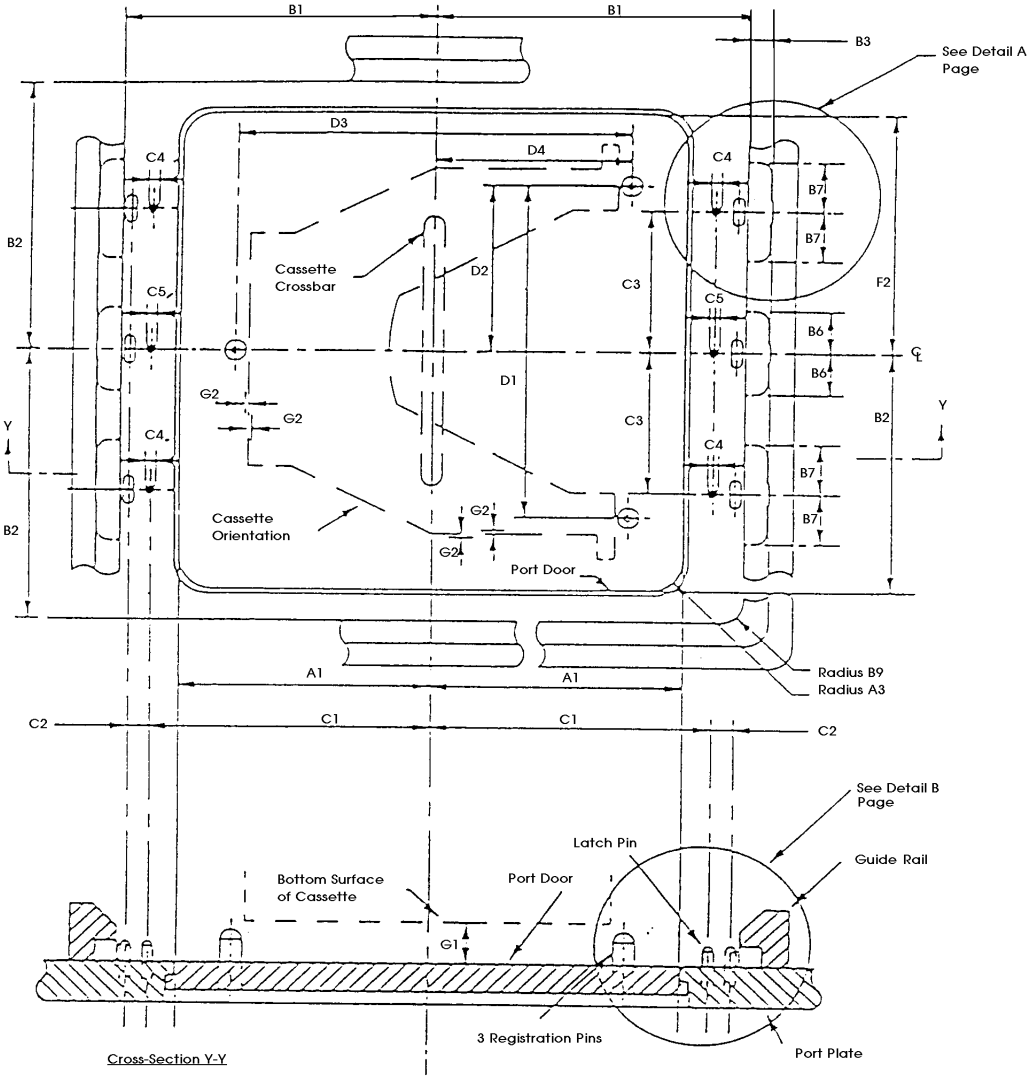
B1
B1
B3
See Detail A Page
D3
D4
C4
C4
B7
B7
B2
Cassette Crossbar
D2
C3
F2
C5
C5
B6
℄
B6
D1
G2
G2
Y
C3
B2
Y
C4
C4
B7
B2
B7
G2
Cassette Orientation
G2
Port Door
Radius B9
Radius A3
A1
A1
C2
C1
C1
C2
See Detail B Page
Latch Pin
Guide Rail
Bottom Surface of Cassette
Port Door
G1
3 Registration Pins
Port Plate
Cross-Section Y-Y

Figure 2

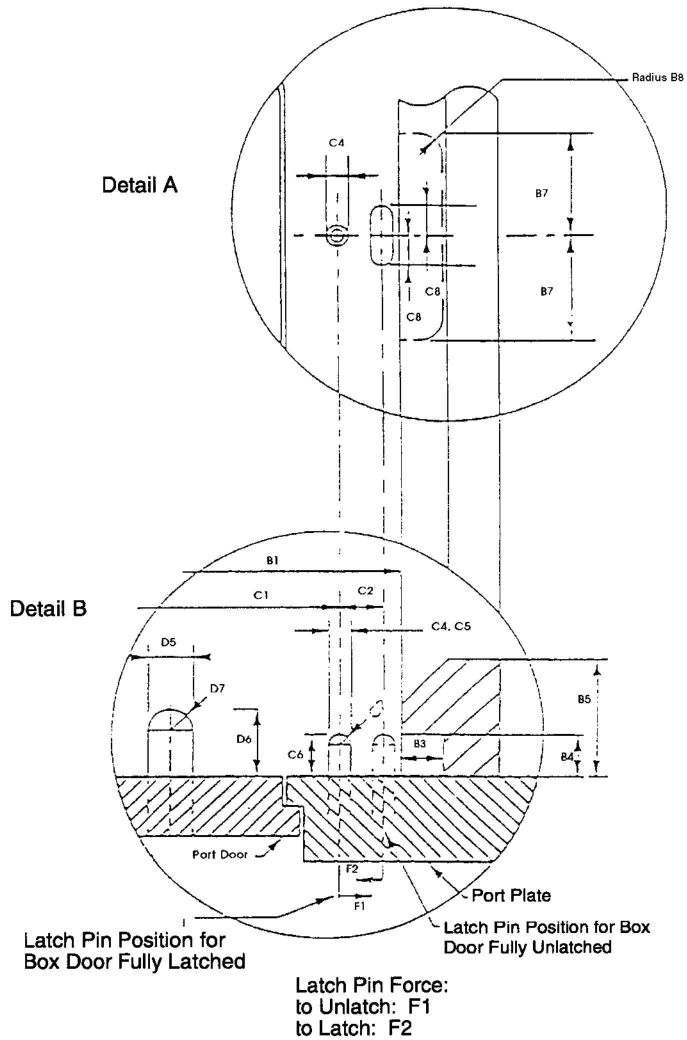

Figure 3

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SEMI E19.1-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 100 mm (4 inch) PORT

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1 Port Dimensions for 100 mm (4 in.) Wafer Cassette

Port Door	A1	73.02 mm ± 0.13 mm	(2.875 in. ± 0.005 in.)
	A2	73.02 mm ± 0.13 mm	(2.875 in. ± 0.005 in.)
	A3	9.53 mm ± 0.25 mm	(0.375 in. ± 0.010 in.)
Guide Rails	B1	90.17 mm ± 0.13 mm	(3.550 in. ± 0.005 in.)
	B2	82.55 mm ± 0.13 mm	(3.250 in. ± 0.005 in.)
	B3	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B4	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6	12.70 mm (0.500 in.)	minimum
	B7		
	B8	3.18 mm ± 0.25 mm	minimum
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	81.25 mm ± 0.13 mm	(3.200 in. ± 0.005 in.)
	C2	6.35 mm ± 0.13 mm	(0.250 in. ± 0.005 in.)
	C3		
	C4		
	C5	3.18 mm ± 0.05 mm	(0.125 in. ± 0.002 in.)
	C6	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration Pins	D1	101.60 mm ± 0.13 mm	(4.000 in. ± 0.005 in.)
	D2	50.80 mm ± 0.13 mm	(2.000 in. ± 0.005 in.)
	D3	114.30 mm ± 0.13 mm	(4.500 in. ± 0.005 in.)
	D4	57.15 mm ± 0.13 mm	(2.250 in. ± 0.005 in.)
	D5	6.35 mm ± 0.08 mm	(0.250 in. ± 0.003 in.)
	D6	10.16 mm ± 0.25 mm	(0.400 in. ± 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

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SEMI E19.2-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 125 mm (5 inch) PORT

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1 Port Dimensions for 125 mm (5 in.) Wafer Cassette

Port Door	A1	85.72 mm ± 0.13 mm	(3.375 in. ± 0.005 in.)
	A2	85.72 mm ± 0.13 mm	(3.375 in. ± 0.005 in.)
	A3	9.53 mm ± 0.25 mm	(0.375 in. ± 0.010 in.)
Guide Rails	B1	102.87 mm ± 0.13 mm	(4.050 in. ± 0.005 in.)
	B2	95.25 mm ± 0.13 mm	(3.750 in. ± 0.005 in.)
	B3	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B4	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6		
	B7	12.70 mm (0.500 in.)	minimum
	B8	3.18 mm ± 0.25 mm	(0.125 in. ± 0.010 in.)
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	93.98 mm ± 0.13 mm	(3.700 in. ± 0.005 in.)
	C2	6.35 mm ± 0.13 mm	(0.250 in. ± 0.005 in.)
	C3	63.50 mm ± 0.13 mm	(2.500 in. ± 0.005 in.)
	C4	3.18 mm ± 0.05 mm	(0.125 in. ± 0.002 in.) diameter
	C5		
	C6	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration Pins	D1	127.20 mm ± 0.13 mm	(5.000 in. ± 0.005 in.)
	D2	63.50 mm ± 0.13 mm	(2.500 in. ± 0.005 in.)
	D3	139.70 mm ± 0.13 mm	(5.500 in. ± 0.005 in.)
	D4	69.85 mm ± 0.13 mm	(2.750 in. ± 0.005 in.)
	D5	6.35 mm ± 0.08 mm	(0.250 in. ± 0.003 in.)
	D6	10.16 mm ± 0.25 mm	(0.400 in. ± 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels,

product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI

SEMI E19.3-0697 (Reapproved 0702)
PORT STANDARD FOR MECHANICAL INTERFACE OF WAFER CASSETTE TRANSFER, 150 mm (6 inch) PORT

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published in 1991; previously published June 1997.

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1 Port Dimensions for 150 mm (6 in.) Wafer Cassette

Port Door	A1	98.48 mm ± 0.13 mm	(3.875 in. ± 0.005 in.)
	A2	98.48 mm ± 0.13 mm	(3.875 in. ± 0.005 in.)
	A3	9.53 mm ± 0.25 mm	(0.375 in. ± 0.010 in.)
Guide Rails	B1	115.57 mm ± 0.13 mm	(4.550 in. ± 0.005 in.)
	B2	107.95 mm ± 0.13 mm	(4.250 in. ± 0.005 in.)
	B3	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B4	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	B5	17.78 mm (0.700 in.)	maximum
	B6		
	B7	12.70 mm (0.500 in.)	minimum
	B8	3.18 mm ± 0.25 mm	(0.125 in. ± 0.010 in.)
	B9	6.35 mm (0.250 in.)	maximum radius
Latch Pins	C1	106.68 mm ± 0.13 mm	(4.200 in. ± 0.005 in.)
	C2	6.35 mm ± 0.13 mm	(0.250 in. ± 0.005 in.)
	C3	63.50 mm ± 0.13 mm	(2.500 in. ± 0.005 in.)
	C4	3.18 mm ± 0.05 mm	(0.125 in. ± 0.002 in.) diameter
	C5		
	C6	6.35 mm ± 0.25 mm	(0.250 in. ± 0.010 in.)
	C7	Full spherical radius	
	C8	4.44 mm (0.175 in.)	minimum
Registration	D1	152.40 mm ± 0.13 mm	(6.000 in. ± 0.005 in.)
	D2	76.20 mm ± 0.13 mm	(3.000 in. ± 0.005 in.)
	D3	165.10 mm ± 0.13 mm	(6.500 in. ± 0.005 in.)
	D4	82.55 mm ± 0.13 mm	(3.250 in. ± 0.005 in.)
	D5	6.35 mm ± 0.08 mm	(0.250 in. ± 0.003 in.)
	D6	10.16 mm ± 0.25 mm	(0.400 in. ± 0.010 in.)
	D7	Full spherical radius	
Latch Pin Force each	F1	1.36 kg (3 lb)	minimum
	F2	1.36 kg (3 lb)	minimum
Position of Cassette	G1	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
	G2	0.50 mm (0.020 in.)	maximum

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels,

product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E19.4-0998
200 mm STANDARD MECHANICAL INTERFACE (SMIF)

NOTE: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position with respect to the validity of any patent rights asserted in connection with any item mentioned in this document. Users of this document are expressly advised that determination of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1 Purpose

1.1 A standard interface is required for containers intended to control the transport environment of cassettes containing substrates. The interface must address the proper container orientation for material transfer and maintain continuity between the container and equipment environment in order to control particulate matter.

2 Scope

2.1 This specification describes one approach to interfacing a clean cassette transport box to a clean environmental housing on a piece of semiconductor processing equipment or to other clean environments. The system concept involves mating a door on a cassette container to a door on an equipment enclosure and transferring the cassette into, and out of, the equipment without exposing the cassette and substrates to outside contamination.

2.2 The incorporation of this standard may require equipment designers to include the features of the interface into the tool design. Spacing between open cassette ports must be considered when incorporating this interface. Designers are directed to the specifications and recommendations made in SEMI E15 in this regard.

3 Limitations

3.1 This standard is specific to 200 mm wafers. This specification focuses on applications in which the interface port is positioned horizontally. The standard is focused exclusively on the box-to-canopy interface. Other considerations of box and equipment design are purposely excluded.

NOTE: Hewlett Packard has patent coverage for this concept and is offering non-exclusive licenses on an equal basis to any company. Companies intending to manufacture products to this standard should be aware of Hewlett Packard's position.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

5 Terminology

(See Figure 1 for a pictorial depiction of most terms.)

5.1 *box* — A protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

5.2 *cassette* — An open structure that holds one or more substrates (wafers, masks, etc.) (as defined in SEMI E44).

5.3 *guide rail* — A component of a port plate that provides coarse location for placing the pod on the port assembly.

5.4 *hold-down latch* — A mechanism for locking the pod to the port plate.

5.5 *latch pins* — Pins that engage the pod door latch and accomplish the pod door lock/unlock functions. Latch pins are carried by the port door.

5.6 *pod* — A box having a Standard Mechanical Interface per SEMI E19 (as defined in SEMI E44).

5.7 *pod door* — A removable bottom for the pod that contains a means for properly positioning the cassette.

5.8 *pod latch* — A mechanical latch that holds the pod door to the pod until activated by the latch mechanism pins. Upon activation, the pod door is released from the pod.

5.9 *pod latch holes* — Holes near the center of the pod door bottom which accept the latch pins.

5.10 *port assembly* — An assembly of the port plate and port door that includes the guide rails, registration pins, latch pins, and pod hold-down latches.

5.11 *port door* — A door for the port plate opening that provides a mating surface for the bottom of the pod door when the pod is in place on the port plate. The port door contains the registration pins and the pod door latch pins.

5.12 *port plate* — A horizontal mating surface for the base of the pod that provides a seal surface for the bottom surface of the pod perimeter. The port plate contains the guide rails and the pod hold-down latches.

5.13 *registration holes* — Holes in the bottom of the pod door that fit over registration pins in the top of the port door when the pod is placed on the port door.

5.14 *registration pins* — Pins that provide fixed position and orientation between the port door and pod door and assist in the final positioning of the pod on the port assembly. The registration pins fit into the registration holes in the bottom of the pod door.

6 Requirements

NOTE: The requirements and dimensions for the design of mechanical interface standard ports and pods are given in this section. See Table 1 for 200 mm (8 inch) Port Dimensions.

6.1 *Cassette Sizes* — All specifications are related to 200 mm wafers held in an appropriate cassette. It is understood that smaller diameter wafers and other substrates may be contained in pods which are compatible with this standard.

6.2 *Port Design Requirements* — The general design of the port is shown in Figures 2 and 3. Design requirements for the interface components are provided in Sections 6.2.1 through 6.2.5.

6.2.1 *Port Door* — Dimensions A1 through A3 specify the port door top view. The gap between port door and port plate is not specified, but should be kept to a minimum distance to restrict particle movement.

6.2.2 *Pod Guide* — The inside distance of the corner guides of the port is specified by B1 and B2. The length of the corner is specified by B12. The corner guides may be connected by guide rails if desired.

6.2.3 *Latch Pins* — Two latch pins are located around the port door center. For location of the pins, see C1, C2, and C3.

6.2.4 *Registration Pins* — The three registration pins on the port door are located asymmetrically, and spaced by dimensions D1 through D4. The size of the pins is specified by D5 through D7.

6.2.5 *Pod* — The bottom surfaces of the pod body and pod door shall conform to the specified port dimensions. The upper part of the pod body and top surface of the pod door must fit and hold in place the cassette for 200 mm (8 inch) wafers. Although the pod dimensions are not explicitly specified by this standard, the following requirements apply:

6.2.5.1 The bottom surfaces of the pod door at its perimeter shall match the dimensions of the port door top (A1 through A3). The tolerances shall be chosen so that the pod door does not extend over the port door in any instance, even when the port door is built to its minimal acceptable dimensions and potential variance between registration pins and holes is considered. This is to ensure an interference-free passage of the pod door through the port opening.

6.2.5.2 The base of the pod body shall fit freely but with close tolerance between the guide rails (B1, B2, and B9), which not only hold the pod in place while the port is open, but also provide proper alignment for closure of the pod at the end of the open/shut cycle.

6.2.5.3 The bottom surface of the pod requires three registration holes to engage with the registration pins on the port. The registration pins shall be positioned in the door bottom so that the registration pins prevent seating of the pod with the port in the event that the pod is improperly rotated by 180 degrees from the correct orientation. The correct orientation is illustrated in Figure 2.

6.2.5.4 The perimeter of the bottom surface of the pod body shall be continuous and shall be positioned against the port surface. This positioning assures the activation of an optional limit switch, placed in an unspecified location along the port perimeter, for the sensing of proper pod placement.

6.2.5.5 The center of the cassette crossbar shall coincide with the center of the pod door, with the cassette oriented as shown in Figure 2. The top surface of the pod door requires the registration bars that hold the cassette in place. The horizontal cassette movement is limited by the tolerances G2. The vertical position of the cassette while located on the pod door is specified by the distance G1 between the top of the port surface and the bottom surface of the cassette.

6.2.5.6 A pod hold-down latch is required. The available latch area is specified by dimension B11 in Figure 2. Latch detail dimensions are specified in Figure 3.

6.2.5.7 The pod latch holes have a dimension of I1 perpendicular to the plane connecting both holes.

Positions for latches are identified in Figure 2 by positions 1, 2, 3, and 4. The following options for hold-down latch positions are defined by this specification:

Option A	Positions 1 and 2
Option B	Positions 3 and 4
Option C	Positions 1, 2, 3, and 4

7 References

The following articles describe the standard mechanical interface concept:

7.1 "The Challenge to Control Contamination: A Novel Technique for the IC Process," The Journal of Environmental Sciences (May/June 1984), page 23

7.2 "SMIF, A Technology for Wafer Cassette Transfer in VLSI Manufacturing," Solid State Technology (July 1984), page 111

The complete specification for this interface includes all general requirements of SEMI E19.

Table 1 Port Dimensions for 200 mm (8 inch) Wafer Cassette

Feature	*Dimension Label*	*Metric*	*English*
Port Door	A1	135.84 mm ± 0.13 mm	(5.348 in. ± 0.005 in.)
	A2	131.06 mm ± 0.13 mm	(5.160 in. ± 0.005 in.)
	A3	13.08 mm ± 0.25 mm	(0.515 in. radius ± 0.010 in.)
	A4	0.38 mm ± 0.13 mm	(0.015 in. ± 0.005 in.)
Guide Rails	B1	146.48 mm ± 0.13 mm	(5.767 in. ± 0.005 in.)
	B2	141.71 mm ± 0.13 mm	(5.579 in. ± 0.005 in.)
	B3		
	B4		
	B5	29.97 mm maximum	(1.18 in. maximum)
	B6		
	B7	16 mm minimum	(0.630 in. minimum)
	B8	45° maximum	(45° maximum)
	B9	22.22 mm radius maximum	(0.875 in. radius maximum)
	B10		
	B11	50.8 mm maximum	(2.00 in. maximum)
	B12	26.9 mm minimum	(1.06 in. minimum)
Latch Pins	C1	16° ± 0° 30'	(16° ± 0° 30')
	C2	86° ± 0° 30'	(86° ± 0° 30')
	C3	26.72 mm ± 0.05 mm	(1.052 in. diameter ± 0.002 in.)
	C4	3.175 mm ± 0.025 mm	(0.125 in. diameter ± 0.001 in.)
	C5		
	C6	9.14 mm ± 0.25 mm	(0.360 in. ± 0.010 in.)
	C7	Full Spherical Radius	Full Spherical Radius
	C8		
Registration Pins	D1	183.39 mm ± 0.25 mm	(7.22 in. ± 0.010 in.)
	D2	91.69 mm ± 0.13 mm	(3.610 in. ± 0.005 in.)
	D3	231.78 mm ± 0.25 mm	(9.125 in. ± 0.010 in.)
	D4	116.59 mm ± 0.13 mm	(4.590 in. ± 0.005 in.)
	D5	6.35 mm ± 0.025 mm	(0.250 in. diameter ± 0.001 in.)
	D6	16.26 mm ± 0.25 mm	(0.640 in. ± 0.010 in.)
	D7	Full Spherical Radius	Full Spherical Radius
Latch Pin	F1	0.8 Nm minimum	(7 in. lbf. minimum)
Force (Torque)		1.7 Nm maximum	(15 in. lbf. maximum)
Position of Cassette	G1	20.70 mm ± 0.25 mm	(0.815 in. ± 0.010 in.)
	G2	H-Bar Centered ± 0.51 mm	(H-Bar Centered ± 0.020 in.)
Pod Latch Holes	I1	3.4 mm ± 0.1 mm	(0.135 in. ± 0.004 in.)

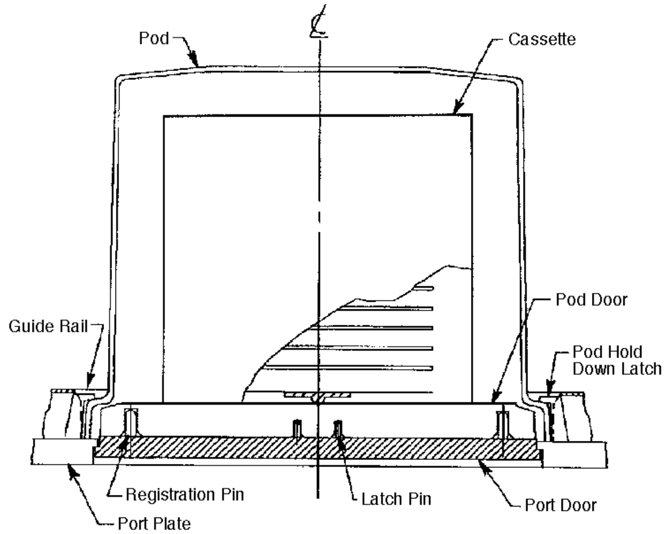

Figure 1
Port Terminology

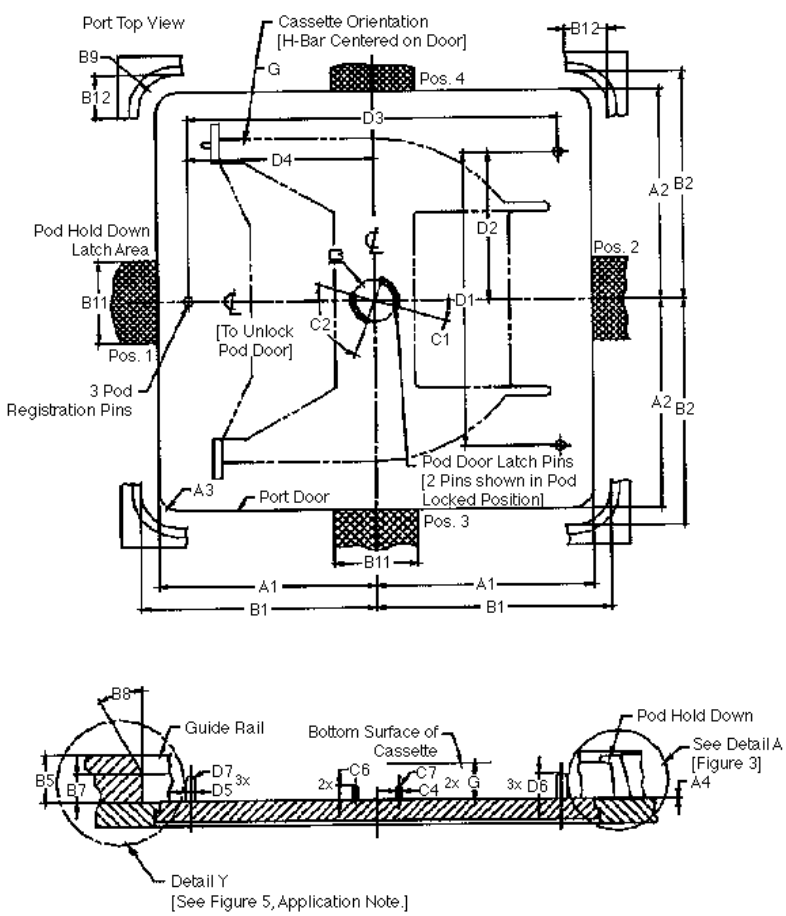

Figure 2
Port Dimensions

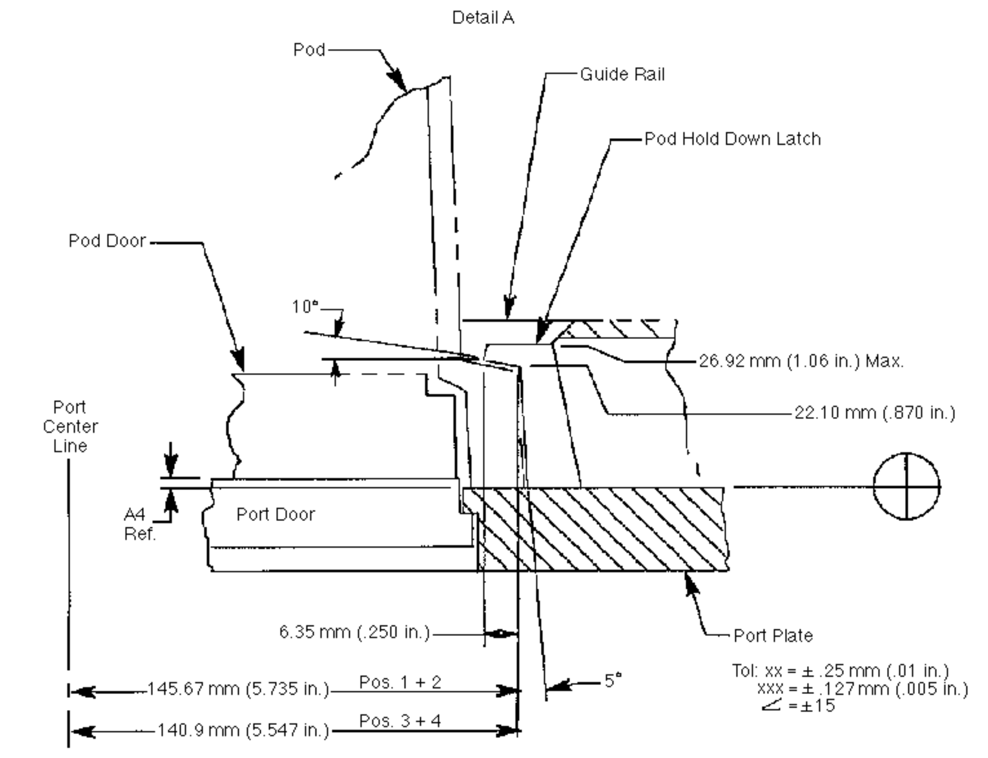

Figure 3
Dimensions of Pod Hold Down Latches

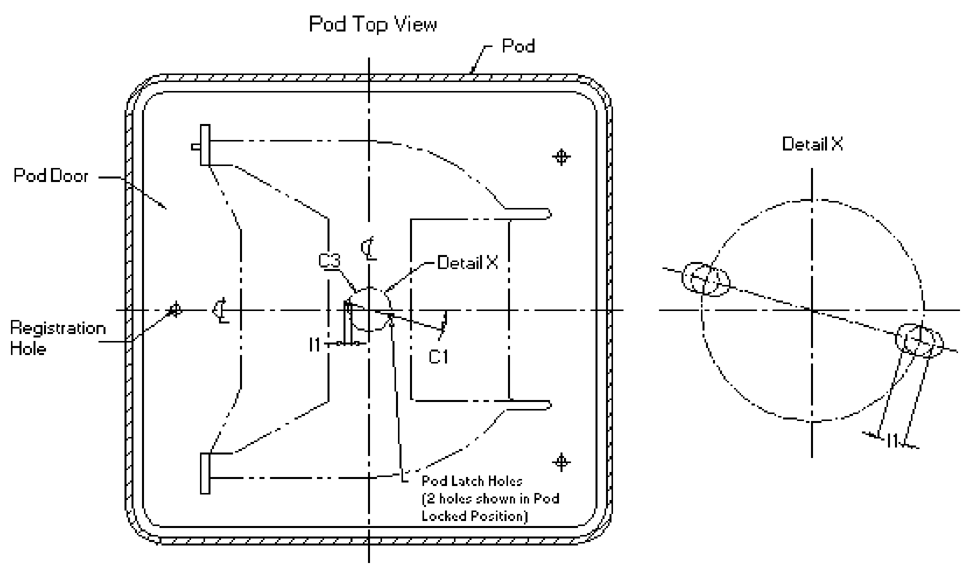

Figure 4
Dimensions of Pod Latch Hole

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as an official part of SEMI E19.4 by full letter ballot procedure, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Notes

A1-1.1 Automated pod transfer between load port and automated material handling system (AMHS) might require a lead-in capability of more than 5 mm. This can be achieved by increasing the height of the guide rails (dimension B5). SEMI standard E15 limits this height to 50 mm (1.97 inches) maximum (see Figure 5). The capture range can be increased to more than 15 mm (.6 inches) if supplier and customer agree to increase the guide rail height without violating SEMI E15.

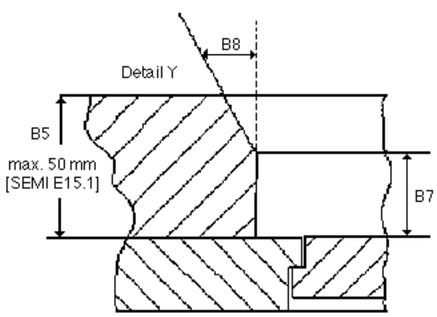

Figure 5
Optional Rail Dimensions

A1-1.2 The dimensions of the pod bottom are not specified in this standard (see Section 6.2.5.1). It is recommended that these dimensions should not exceed 282.0 mm (11.14 inches) in one direction and 292.6 mm (11.52 inches) in the other direction. These maximum outer dimensions ensure a sufficient gap around the pod and the guide rails in relation to B1 and B2 to allow a reliable motion of the pod onto the port plate.

A1-1.3 It is important that the external top of the pod does not exceed the top of the cassette by more than 50 mm (1.97 inches). This is to prevent possible interference between the pod and the equipment.

SEMI E19.5-0996
SPECIFICATION FOR 300-mm BOTTOM-OPENING STANDARD MECHANICAL INTERFACE (SMIF)

NOTICE: Hewlett-Packard has patent coverage for this concept and is offering non-exclusive licenses on an equal basis to any company. Companies intending to manufacture products to this standard should be aware of Hewlett-Packard's position.

The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position with respect to the validity of any patent rights asserted in connection with any item mentioned in this document. Users of this document are expressly advised that determination of any such patent rights, and the risk of infringement of such rights are entirely their own responsibility.

1 Purpose

This standard specifies a standard interface for containers intended to control the transport environment of contained wafers. The interface must address the proper container orientation for material transfer and maintain continuity between the container and equipment environment in order to control particulate and non-particulate contamination.

2 Scope

This specification describes an approach to interfacing a clean transport container (pod) to a clean environmental housing on a piece of semiconductor processing equipment or to other clean environments. The system concept involves mating a pod door to a port door in an equipment interface and transferring the wafers into, and out of, the equipment without exposing the wafers to outside contamination.

The incorporation of this standard may require equipment designers to include the features of the interface into the tool design. Spacing between equipment interface ports must be considered when incorporating this interface. Designers are directed to the recommendations made in SEMI E15.1 in this regard.

This standard is specific to the size of the designated wafer and references the appropriate Semiconductor Equipment and Materials International (SEMI) cassette and wafer diameter. This specification focuses on applications in which the interface port is positioned horizontally.

3 Referenced Documents

3.1 *SEMI Standard*

SEMI E15.1 — Provisional Specification for 300-mm Tool Load Port

4 Terminology

(See Figure 1 for a pictorial depiction of most terms.)

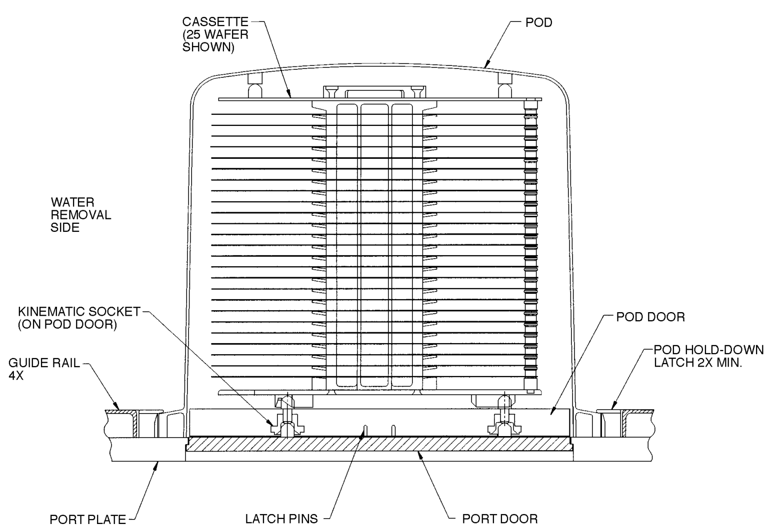

Figure 1
Port Terminology

4.1 *box* — A protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.2 *cassette* — An open structure that holds one or more substrates (as defined in SEMI E44).

4.3 *horizontal datum plane* — A plane that is parallel to the floor and coincides with the tool interface surface. A more detailed definition will be included in a companion document currently under development.

4.4 *guide rail* — A component of a port plate that provides coarse and final location for placing the pod on the port assembly.

4.5 *hold-down latch* — A mechanism for securing the pod to the port plate.

4.6 *kinematic socket (pod door)* — Grooves in the bottom of the pod door that fit over kinematic pins on the top of the port door when the pod is placed on the port door.

4.7 *kinematic pins (port door)* — Pins that provide fixed position and orientation between the port door and pod door. The kinematic pins fit into the kinematic sockets in the bottom of the pod door.

4.8 *latch pins* — Pins that engage the pod door latch and accomplish the pod door lock/unlock functions. Latch pins are carried by the port door.

4.9 *pod* — A box having a Standard Mechanical Interface (as defined in SEMI E19, SEMI E44).

4.10 *pod door* — A removable bottom for the pod that contains a means for properly positioning the wafer cassette.

4.11 *pod lock* — A mechanical latch that holds the pod door to the pod until activated by the latch mechanism pins. Upon activation, the pod door is released from the pod.

4.12 *port assembly* — An assembly of the port plate and port door.

4.13 *port door* — A door for the port plate opening that provides a mating surface for the bottom of the pod door when the pod is in place on the port plate. The port door contains the kinematic location pins and the pod door latch pins.

4.14 *port plate* — A horizontal mating surface for the base of the pod that provides a seal surface for the bottom surface of the pod perimeter. The port plate contains the guide rails and the pod hold-down latches.

5 Requirements

(See Table 1 for 300 mm (12-inch) port dimensions.)

Table 1 Port Dimensions for 300 mm (12-inch) Wafer Cassette

Port Door:	A1	185.00 mm rad. ± 0.13 mm	(7.283 in. rad. ± 0.005 in.)
Guide Rails:	B1	208.71 mm rad. ± 0.13 mm	(8.217 in. rad. ± 0.005 in.)
	B2	106.00 mm ± 0.13 mm	(4.190 in. ± 0.005 in.)
	B3	119.00 mm ± 0.13 mm	(4.690 in. ± 0.005 in.)
	B4	25.00 mm max.	(0.984 in. max.)
	B5	70.0 mm max.	(2.75 in. max.)
Latch Pins:	C1	16 deg. ± 0 deg. 30 min.	(16 deg. ± 0 deg. 30 min.)
	C2	86 deg. ± 0 deg. 30 min.	(86 deg. ± 0 deg. 30 min.)
	C3	26.72 mm dia. ± 0.05 mm	(1.052 in. dia. ± 0.002 in.)
	C4	3.175 mm dia. ± 0.025 mm	(0.125 in. dia. ± 0.001 in.)
	C5	-----------	----------
	C6	9.14 mm ± 0.25 mm	(0.360 in. ± 0.010 in.)
	C7	Full Spherical Radius	Full Spherical Radius
Pod Hold-Down Latches:	D1	22.10 mm ± 0.25 mm	(0.870 in. ± 0.010 in.)
	D2	10 deg. ± 0 deg. 30 min.	(10 deg. ± 0 deg. 30 min.)
Pod in Place Sensor:	E1	26.92 mm ± 0.25 mm	(1.060 in. ± 0.010 in.)
	E2	12.70 mm ± 0.25 mm	(0.500 in. ± 0.010 in.)
Activation Height:	E3	4.32 mm min.	(0.170 in. min.)
Latch Pin Force (Torque):	F1	8.08 kg cm min.	(7 lbs. in. min.)
		17.27 kg cm max.	(15 lbs. in. max.)

The requirements and dimensions for the design of 300 mm standard mechanical interface ports and pods are given in this section. All external dimensions of the interface between a pod and port are specified in SEMI E15.1.

5.1 *Port Design Requirements* — The general design of the port is shown in Figures 2 and 3. Design requirements for the interface components are provided in Sections 5.1.1 through 5.1.6.

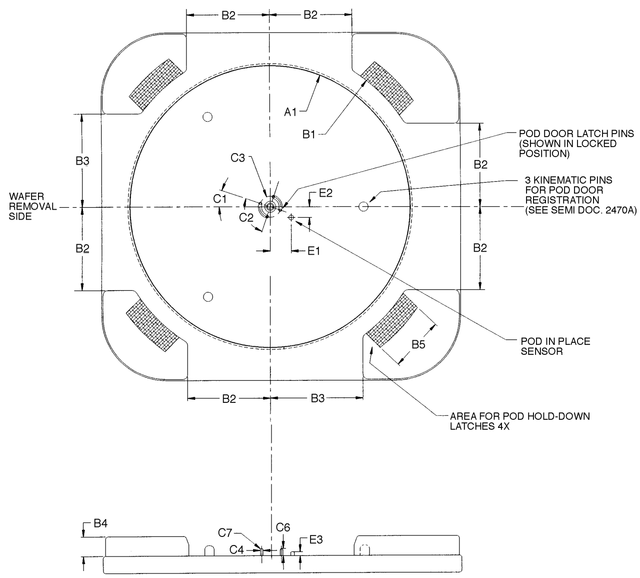

Figure 2
Port Dimensions

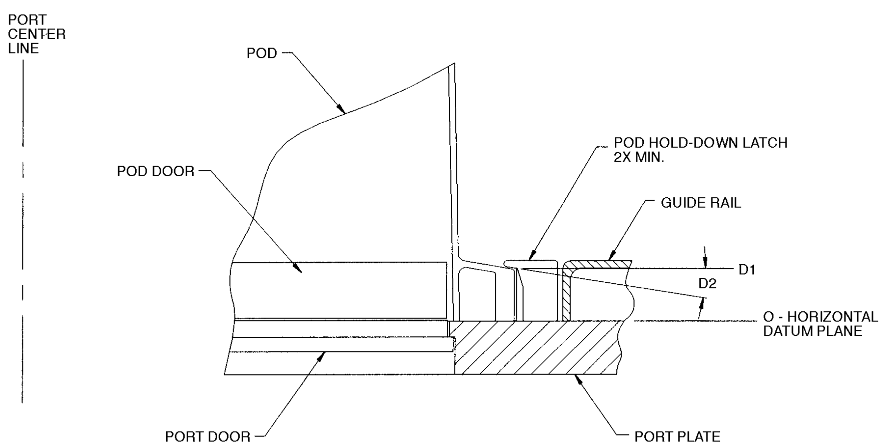

Figure 3
Port Detail

5.1.1 *Port Door* — Dimension Al specifies the port door radius. The gap between port door and port plate is not specified, but should be kept to a minimum distance to restrict particle transport.

5.1.2 *Pod Guide Rails* — The inside feature of the pod guides rails of the port are specified by B1, B2, and B3. The features provide alignment for the pod top.

5.1.3 *Pod Hold-Down Latches* — The available latch area is specified by dimensions B1, B4, and B5 in Figure 2. Latch detail dimensions are specified by D1 and D2 in Figure 3.

5.1.4 *Pod Door Latch Pins* — Two latch pins are located around the port door center and are specified by C1, C2, and C3.

5.1.5 *Kinematic Pins* — Three kinematic pins provide registration of the pod door to port plate. Details and locations of the kinematic pins are not specified in this standard. They are being addressed in a separate document currently under development.

5.1.6 *Pod in Place Sensor* — An optional sensor, for the sensing of proper pod placement shall be located on the port door as specified by E1 and E2. The sensor shall have a minimum activation height of E3 and full travel to the port plate.

5.2 *Pod* — The bottom surfaces of the pod body and pod door shall conform to the specified port dimensions. Although the pod dimensions are not explicitly specified by this standard, the following requirements apply. (Pod dimensions are being addressed in a separate document currently under development.)

5.2.1 The upper part of the pod body and the top surface of the pod door must fit and hold in place the wafer cassette, which will be specified in a separate document currently under development.

5.2.2 The center of the wafers and pod door shall coincide. The top surface of the pod door incorporates kinematic features that position the cassette on the pod door.

5.2.3 The bottom surface of the pod door at its perimeter shall match the radius of the port door top (dimension Al). The tolerances shall be chosen so that the pod door does not extend over the port door in any instance, even when the port door is built to its minimal acceptable dimensions and potential variance between kinematic pins and socket is considered. This is to ensure an interference-free passage of the pod door through the port opening.

5.2.4 The base of the pod body shall fit freely but with close tolerance between the pod guide rails, which not only hold the pod in place while the port is open, but also provide proper alignment for closure of the pod at the end of the open/close cycle.

6 Related Documents

The following articles describe the standard mechanical interface concept:

6.1 “The Challenge to Control Contamination: A Novel Technique for the IC Process,” The Journal of Environmental Sciences, (May/June, 1984), page 23.

6.2 “SMIF, A Technology for Wafer Cassette Transfer in VLSI Manufacturing,” Solid State Technology, (July, 1984), page l11.

SEMI E20-0697
CLUSTER TOOL MODULE INTERFACE: ELECTRICAL POWER AND EMERGENCY OFF STANDARD

1 Introduction

1.1 *Scope* — The standard deals with the delivery and emergency interruption of electrical power to the modules of a cluster tool.

1.2 *Purpose* — The purpose of the standard is to specify the Emergency Off capability to the modules of a cluster tool; to allow module Emergency Off disconnect and reconnect in a safe manner without removing power from the rest of the tool; and to prevent power from being applied to a module when its Emergency Off is non-functional.

1.3 *Impact* — The standard requires that power can be delivered to an individual module only if its Emergency Off is functional. This does not preclude removal of power from the module by non-emergency means.

The standard specifies the Emergency Off circuit functions that must be provided at the Emergency Off interfaces of a cluster tool, including the plug, momentary bypass switch and bypass jumper plug. Pinouts for the Emergency Off plug and bypass jumper plug are specified.

2 Applicable Documents and References

2.1 *SEMI Documents*

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

2.2 *Military Standards*[1]

MIL-C-26500E — General Specification for Connectors — General Purpose, Electrical, Miniature, Circular, Environmental Resisting

3 Definitions

3.1 *daisy-chained* — Connected so that the removal of one component causes the interruption of the circuit to another component.

3.2 *emergency off (EMO)* — Fail-safe control switch or circuit which, when de-energized, will stop the operation of associated equipment and will shut off all potential hazards outside the main power enclosure.

3.3 *EMO interface* — The location at which a process or cassette module EMO cable is connected into the cluster tool circuit.

4 Requirements

4.1 *Power Distribution*

4.1.1 *Mains* — Each cluster tool (as defined in SEMI E21) shall have its power provided by one or more contactors enabled by the EMO. The power is to be delivered to one or more power distribution enclosures, where voltage transformation may take place before distribution to the module (as defined in SEMI E21).

4.1.2 *Module Power Distribution* — The power distribution to each module is provided through a dedicated circuit breaker in the power distribution enclosure. The rated current and voltage in each circuit is determined by the tool configuration. A discussion of how this standard may be implemented is given in Application Note A.1.

4.1.3 *Operation of the EMO* — Activation of the EMO shall not cause or allow an unsafe condition to exist (see Application Note A.2).

4.2 *EMO Circuit*

4.2.1 *Description* — Each module attached to the cluster tool is to have at least one EMO button operating an EMO switch (see Application Note A.3). The switches are daisy chained into a circuit, or circuits, that disconnect the main power and any backup power sources. The 24 VAC power to energize this circuit is provided from within a main power enclosure, so that the EMO circuit is independent of module power. Each module EMO is connected to the chain at its EMO interface. A momentary bypass switch, also located at each module EMO interface, allows separation of the module from the cluster tool without tripping the EMO, provided that electrical power is removed from the module by turning off the dedicated circuit breaker (see Application Note A.4). Jumpers in the bypass jumper plug connect the EMO circuit in series with contacts that open if the dedicated circuit breaker is turned on.

4.2.2 *Wiring* — Copper wire used in the EMO circuits shall be 0.82 mm^2 cross-section (#18 AWG) or larger.

4.2.3 *Labeling* — A label with the following legend is to be affixed to the power distribution enclosure near each module circuit breaker: Caution: Energizing this circuit with the associated EMO bypass jumper plug installed will interrupt power to the entire cluster tool.

1 Military Standards, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

4.3 *Connection at EMO Interface*

4.3.1 *EMO Connector* — The connector at the EMO interface is reserved for EMO functions only. Metal shell bayonet-type connectors are specified per MIL-C-26500E as follows: MS24265R16B10SN on the panel, and MS24266R16B10PN on the cable and on the EMO bypass jumper plug. The receptacle is panel mounted at the EMO interface and the plug is mounted on the module EMO cable.

4.3.2 *Module EMO Connector Pinouts* — Pins 1 and 2 of the EMO cable plug connect across contacts in the module EMO switch. In the receptacle, pins 1 and 2 connect to the EMO circuit and pins 3 and 4 connect across the contacts specified in Section 4.2.1.

4.3.3 *EMO Bypass Jumper Plug* — Pin 1 is jumpered to pin 4 and pin 2 is jumpered to pin 3 in the plug. This will result in placing the contacts specified in Section 4.2.1 into the EMO circuit when the plug is installed.

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APPLICATION NOTES

NOTE: The material contained in these application notes is not an official part of SEMI E20 and is not meant to modify or supersede it in anyway. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such, they are to be considered as reference material only. The standard should be referred to in all cases.

A.1 AC Power Distribution

One method of providing power and EMO functions to a cluster tool is shown in Figure F1 (see Section 4.1.2). A standby power supply (SPS) or uninterruptible power supply (UPS) is included to maintain EMO and selected cluster tool functions in the event of main power failure. It may be desirable to include additional circuit breakers in the main power enclosure if individual module disconnects are needed at level I in Figure F1. Disconnect at level II in Figure F1 is made possible by the module circuit breakers; SEMI E7, “Electrical Interfaces Specification,” should be used for loads up to 10 kW. Additional main power enclosures could be provided for modules with heavy AC loads, provided that each main contactor is operated by one common EMO circuit, however, some user’s safety codes may demand a single source of supply.

A.2 Operation of Remote Equipment

Activation of the EMO shall stop, by fail-safe means at the tool, the delivery of potentially hazardous energy (e.g., high voltage, laser) or hazardous material (e.g., toxic process gas, coolant) to the cluster tool (see Section 4.1.3).

A.3 EMO Switch Placement

The EMO switches on each module (see Section 4.2.1) need to be placed so that they are accessible to any person in the vicinity of the cluster tool. Local safety codes may take precedence in matters of EMO switch placement. The standard ensures that each module has at least one EMO switch and that its operation, when the module is attached, removes power from the entire cluster tool.

A.4 EMO Bypass

A.4.1 *Implementation* — The functions, specified in Section 4.2.1, to allow EMO bypass and to ensure that module power is off when the EMO is removed from the cluster tool EMO circuit, can be implemented as shown in Figure F2. A relay or switch, operated in parallel with the dedicated circuit breaker specified in Section 4.1.2 for the module, provides 24 VAC to the coil of a double pole relay when the circuit breaker is de-energized. An indicator light in parallel with the coil illuminates when the bypass is enabled and the power to the module is off. One set of contacts of this relay is used to enable the momentary EMO bypass switch. The other set is connected across pins 3 and 4 of the EMO receptacle at the EMO interface and is in the EMO circuit when the EMO bypass jumper plug is installed. Both sets of contacts are wired to open when voltage is removed from the relay coil, i.e., when the circuit breaker is closed.

A.4.2 *Module Disconnect* — The dedicated circuit breaker (see Section 4.2.1) to the module must be turned off prior to disconnect. This causes the contacts in series with the momentary EMO bypass switch to close, rendering it operational. At this point, the EMO switch on the module is still in the cluster tool EMO circuit. To disconnect, the operator holds in the EMO bypass switch while removing the module EMO plug from the EMO interface and then connecting the EMO bypass jumper plug. The momentary bypass switch can then be released.

A.4.3 *Module Connect* — To connect a module, the dedicated circuit breaker (see Section 4.2.1) must be off at the power distribution point to the module. The power cable may be attached to the module at this time. The operator holds in the momentary bypass switch while disconnecting the EMO bypass jumper plug from the EMO interface and connecting the module EMO Plug. The momentary bypass switch can then be released. Power cannot be applied to the module unless the EMO is connected (as shown in Figure F2).

A.5 Additional Documents and References

In implementing the standard, documents that may provide additional guidance include:

A.5.1 *SEMI Document*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

A.5.2 *Other Documents*

International Electrotechnical Commission (IEC)

Standard 204, Sections 1, 2 and 3.

(U.S.) National Electrical Code (NEC).[2]

2 National Fire Protection Association, Batterymarch, Quincy, MA 02269.

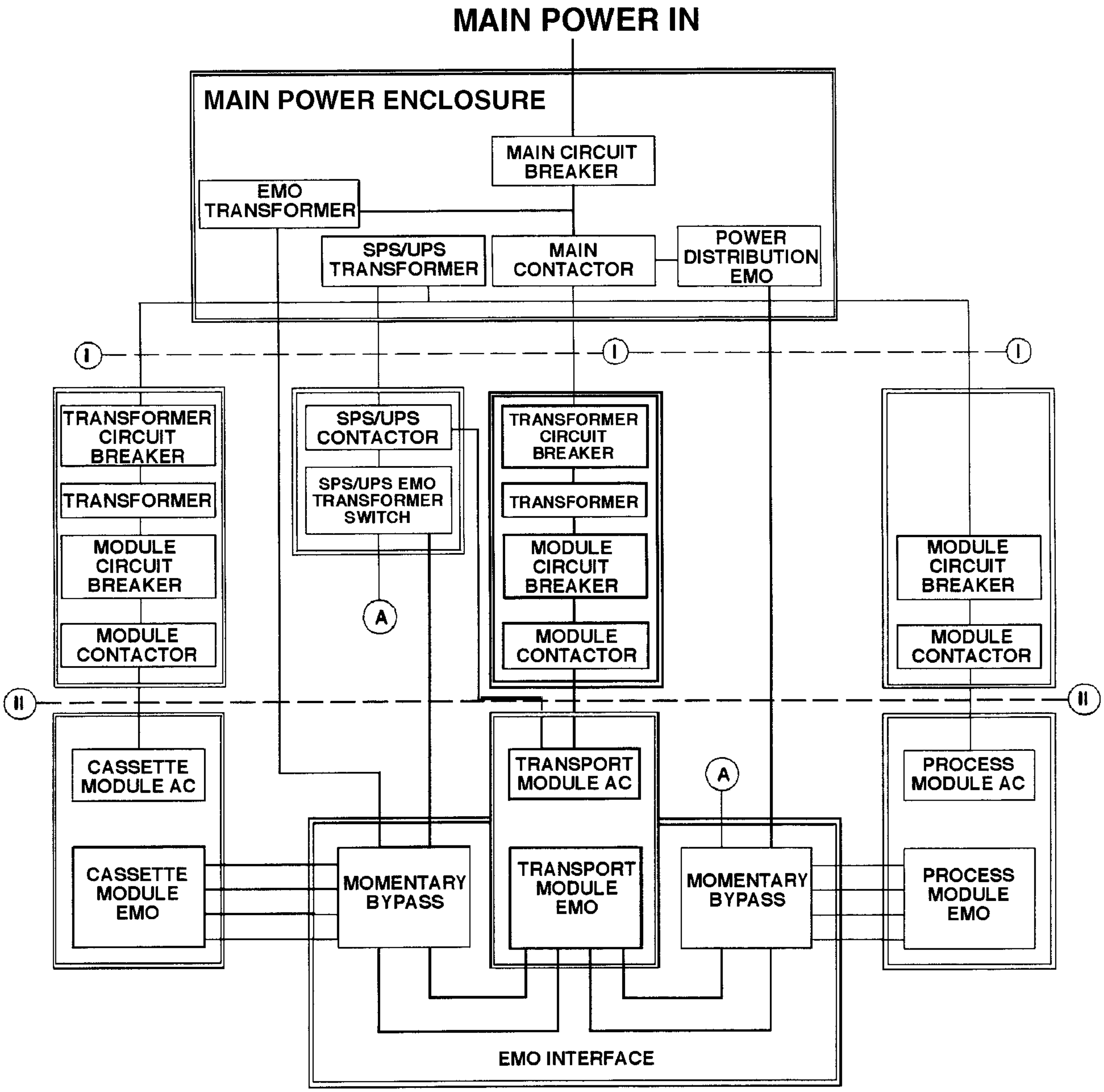

Figure F1
Example: AC Distribution/EMO Block Diagram

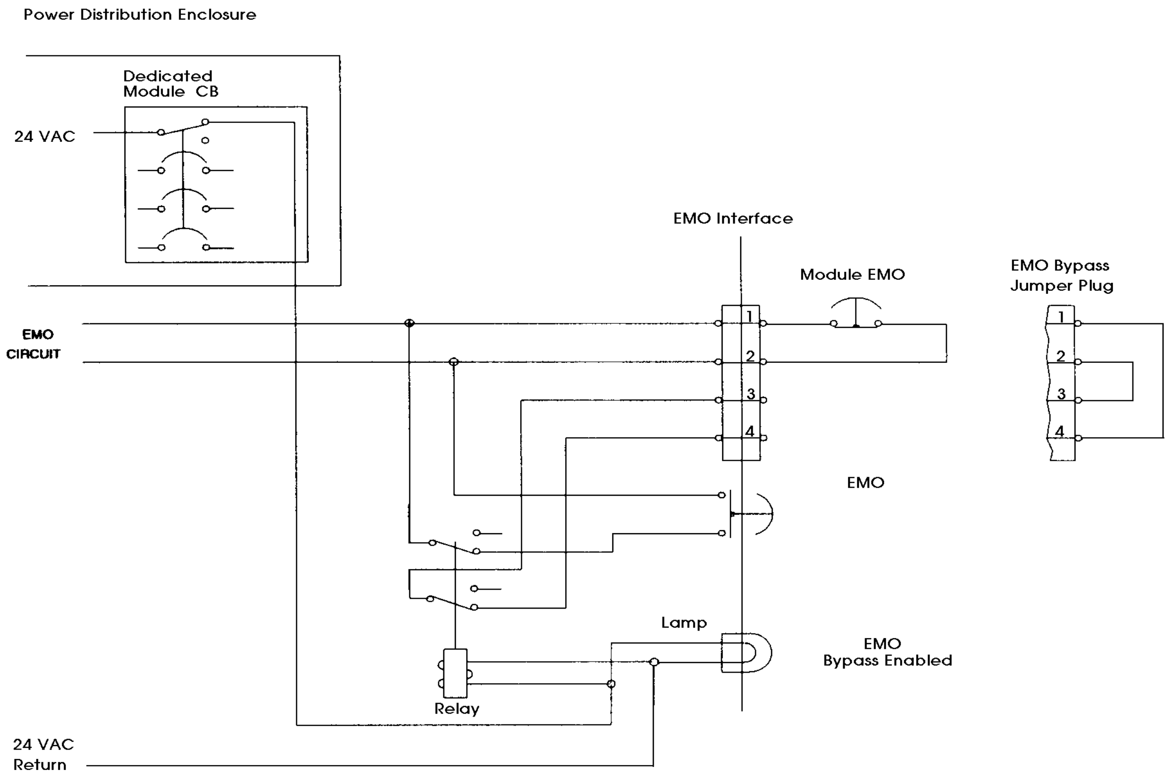

Figure F2
Example: EMO Connect/Disconnect Circuit(Module Power is "off," as drawn.)

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SEMI E21-94 (Reapproved 0699)
CLUSTER TOOL MODULE INTERFACE: MECHANICAL INTERFACE AND WAFER TRANSPORT STANDARD

This standard was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition reapproved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1991; previously published in 1994.

Minor editorial changes were made to this document to conform to editorial guidelines.

1 Introduction

1.1 *Scope* — The standard defines the interface plane between modules in a cluster tool. It provides the mechanical specifications at the interface that allow modules from different suppliers to be connected together; no requirements are imposed on the module content.

1.1.1 The standard is limited to wafers which are 200 mm (~8 in.) in diameter or smaller and to the interface between cluster tool modules, with the following exception. The transport module operates across the interface plane; thus, a definition of the wafer transport plane within cassette and process modules is required.

1.2 *Purpose* — The purpose of the standard is to simplify cluster tool implementation in the fab. Equipment suppliers are required to provide modules that can be connected into any cluster tool using the specifications contained herein.

1.2.1 Process and cassette modules accept wafers at locations that may vary substantially from one module to another. This places a burden on the capabilities of transport modules to move wafers to and from various modules in a cluster tool. This specification defines wafer transport planes within cassette and process modules. This obviates the wafer transport problem to a large extent, but does not unduly restrict module content.

1.3 *Impact* — The adoption of the standard requires cluster tool equipment designers to limit the wafer transport height to a nominal value at the interface plane between two modules. It also requires equipment designers to assure that wafer transport planes within cassette and process modules be clear for wafer transport. The transport module requires the capability for a minimum reach outside the module across the interface plane. Modules may be connected using a quick connect/disconnect clamping system. Constraints are placed on sealing surfaces.

2 Referenced Documents

ISO 1609-1986 (E)[1] — "Vacuum Technology — Flange Dimensions," International Organization for Standardization (ISO).

3 Definitions

3.1 *cassette module* — a two-port module. One port accepts or presents a cassette of wafers or possibly, in an automated factory, an individual wafer for intertool transport; the second port accepts or presents a single wafer within the module for intratool transport.

3.2 *cluster tool* — an integrated, environmentally isolated manufacturing system consisting of process, transport, and cassette modules mechanically linked together. The modules may or may not come from the same supplier.

3.3 *environmental isolation* — separated from the ambient atmospheric environment.

3.4 *interface plane* — the vertical surface defined by the mating surfaces of two joined modules.

3.5 *interface seal zone* — an absolute surface or face reserved for establishing an environmental seal between modules.

3.6 *intertool transport* — wafer or cassette movement between independent tools.

3.7 *intratool transport* — wafer movement inside a cluster tool.

3.8 *module* — an independently-operable unit that is part of a tool or system.

3.9 *process module* — a module that accepts or presents a single wafer inside the module for intratool transport.

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[1] *ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland, website: www.iso.ch*

3.10 *reach* — the distance measured from the interface plane to the wafer centroid within a process or cassette module.

3.11 *transport module* — a module that accepts or presents a single wafer outside the module across the interface plane for intratool transport.

3.12 *wafer transport plane* — the horizontal surface a wafer traverses between modules.

3.13 *wafer transport zone* — the area of the interface plane free of physical obstructions, reserved for wafer movement between modules.

4 Requirements

4.1 *Wafer Transport and Placement*

4.1.1 *Horizontal Transport Plane* — The dimensions for wafer placement during wafer transport are referenced from the interface plane in the plan view shown in Figure 1. The transport module is required to present or accept a horizontal wafer outside the module *anywhere* along an axis perpendicular to the center of the interface plane to a maximum 305 mm (12 in.) from the interface plane. Thus, a transport module is required to have the capability to reach 305 mm (12 in.) beyond its interface plane to a wafer centroid (see Section R1-1). However, location of the wafer at a distance less than 305 mm (12 in.) from the interface plane requires that the transport module be capable of addressing the intermediate location. Similarly, a cassette module or process module accepts a horizontal wafer inside the module *anywhere* along an axis perpendicular to the center of its interface plane up to a maximum 305 mm (12 in.) from the interface plane as required by the application.

4.1.1.1 *Placement Accuracy* — The requirements for placement accuracy of a wafer in the horizontal plane within a module are 1.0 mm (0.04 in.) true position, ± 0.5 mm (± 0.020 in.) radially, with less than one degree angular rotation for every module-to-transport-to-module wafer transport (B_n:A:B_n + 1as shown in Figure 1). If the wafer is displaced in the process module, it must be returned to the original position within the non-culmulative placement accuracy of 1.0 mm (0.04 in.) true position, ± 0.5 mm (± 0.020 in.) radially.

4.1.2 *Vertical Position of Transport Plane* — The elevation of the wafer transport plane is measured from the facility floor as shown in Figure 2. The transport module is required to present or accept a horizontal wafer outside the module at a nominal wafer transport height of 1100 mm (43.307 in.) from the facility floor (see Section R1-2).

4.1.2.1 *Vertical Motion* — The transport module is required to move the wafer to within ± 0.5 mm (0.020 in.) in the wafer transport plane. The transport module is also required to posess a vertical motion capability to a second plane 6.0 mm ± 0.5 mm (0.236 in. ± 0.020 in.) below the wafer transport plane in order to allow wafer handoff to or from passive cassette or process modules (see Figure 2 and Section R1-3).

4.1.2.2 *Reference Plane* — The interface plane alignment pins define a reference plane 9.5 mm (.374 in.) below the wafer transport plane (see Figure 2).

4.2 *Interface Plane* — The interface plane contains the interface seal zone and the wafer transport zone, which do not overlap, and the location of the interface plane alignment pins (see Figures 3 and 4).

4.2.1 *Interface Seal Zone* — The interface seal zone is rectangular and symmetrically referenced to the interface plane alignment pins. The inside boundary dimension of the interface seal zone is 46 mm (1.811 in.) by 236 mm (9.291 in.). The outside boundary is 76 mm (2.992 in.) by 266 mm (10.472 in.). A seal zone is either a seal surface or an O-ring face. All interface seal zones facing toward a transport module are seal surfaces polished to a surface finish less than or equal to 0.8 micrometer (32 microinches) parallel to the circumference (see Section R1-4). All interface seal zones facing toward a cassette or process module are O-ring faces equipped with the appropriate capture groove for the sealing method employed (see Figure 3 and Section R1-4.1).

4.2.2 *Wafer Transport Zone* — The wafer transport zone is the area within the interface seal zone reserved for moving the wafer between modules. The wafer transport zone which cannot be compromised by any module is defined as the area at least 16 mm (.630 in.) above and below the alignment pin centerlines, and 111 mm (4.370 in.) to the left and right of the centerline between the two alignment pins (see Figure 3 and Section R1-5).

4.2.3 *Interface Plane Alignment Pins* — Provisions are made for two 10 mm (.394 in.) diameter locating pins (see Figure 4) to be used as alignment aids between modules. Under no circumstances should the flanges at the interface plane and the alignment pins be subject to a total load exceeding 500N (112 lbf) in shear. The alignment pins have an absolute centerline separation of 300.0 mm (11.811 in.) in the horizontal plane. The pins reside in the seal surface side of the flange pair, opposite the O-ring, facing toward the transport module. Mild press fit holes are provided in the seal surface flange face. A clearance hole and a slot are provided in the O-ring flange face as shown in Figure 1 and specified in Figure 3. Alignment pin height above the flange face is 6 mm (.24 in.) minimum to 8 mm (.31 in.) maximum (see Section R1-6).

4.2.4 *Isolation Valves* — The transport module is always equipped with a valve for environmental isolation at each module interface plane. The intratool transport port on a process or cassette module may be equipped with an environmental isolation valve (see Section R1-7).

4.3 *Flange* — A flange is specified as 162 mm (6.378 in.) by 340 mm (13.386 in.). One horizontal edge is specified to be 50 mm (1.969 in.) from the alignment pins' centerline (see Figure 4).

4.3.1 *Clamping* — Clamping grooves as specified in the International Standards Organization document, Vacuum Technology, Flange Dimensions (ISO 1609-1986), Table 2, nominal bores 40 mm-250 mm (1.575 in.Ð9.843 in.) are located at the flange perimeter (see groove detail in Figure 4). Clamps for ISO flanges can be used to generate the force necessary to produce an environmental seal (see Section R1-8).

4.3.2 *Non-Flanged Surfaces* — A non-flanged surface may be used to join with a flanged surface. An attachment means to engage the flange must be provided. If a flanged adaptor piece is necessary to join two non-flanged surfaces, then the adaptor piece shall be located on the process or cassette side of the interface plane.

LIST OF FIGURES

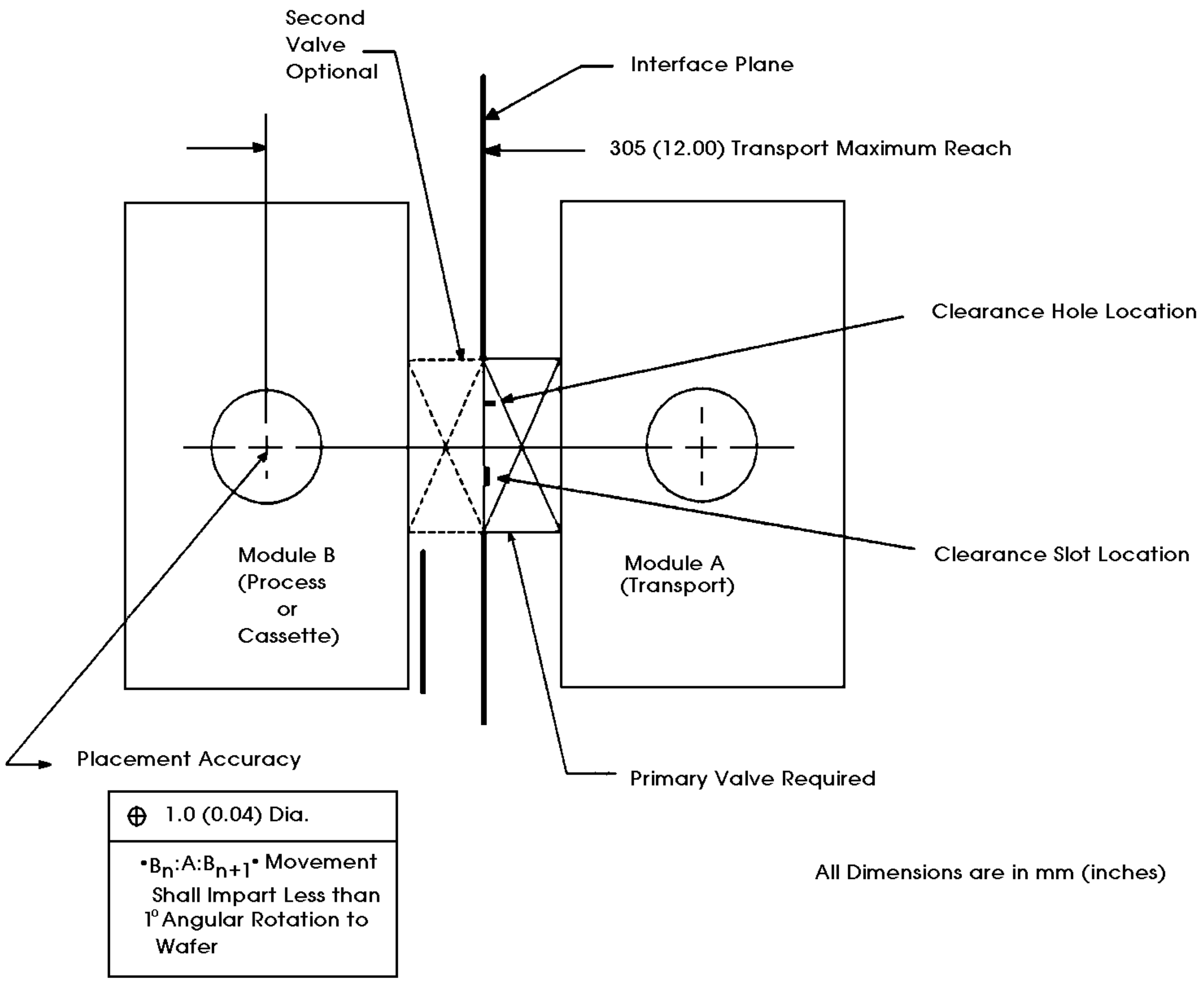

Figure 1

Module Interface with Wafer Transport and Placement Detail (Plan View)

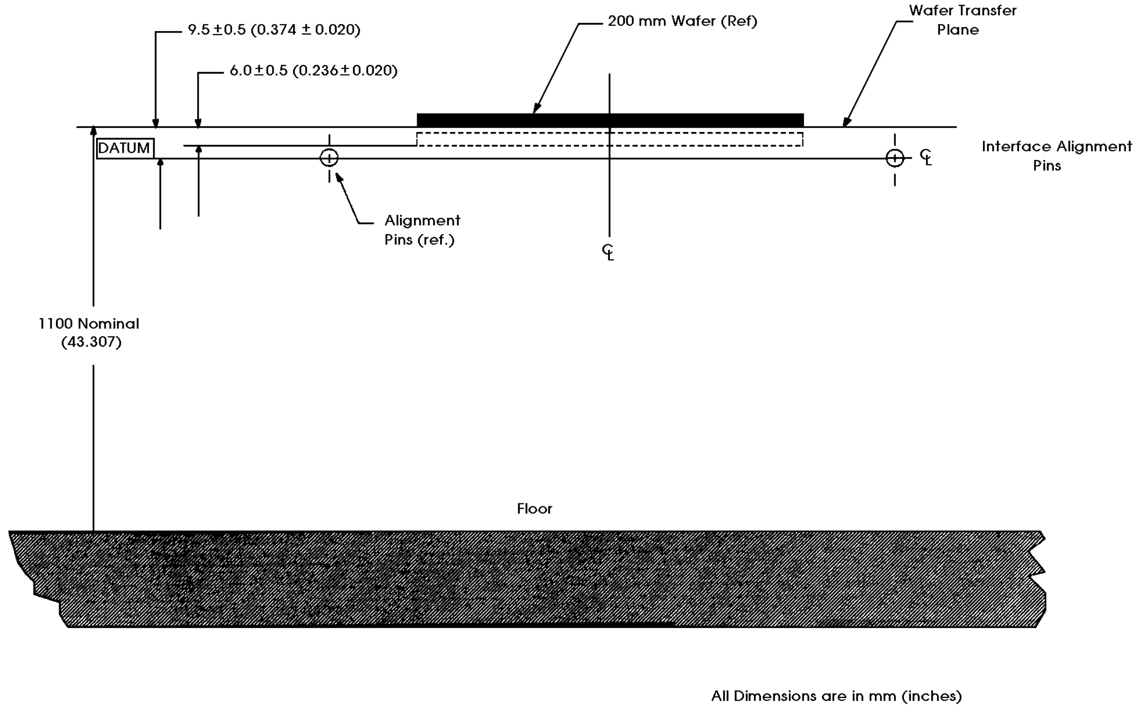

Figure 2

Wafer Transport Plane Elevation

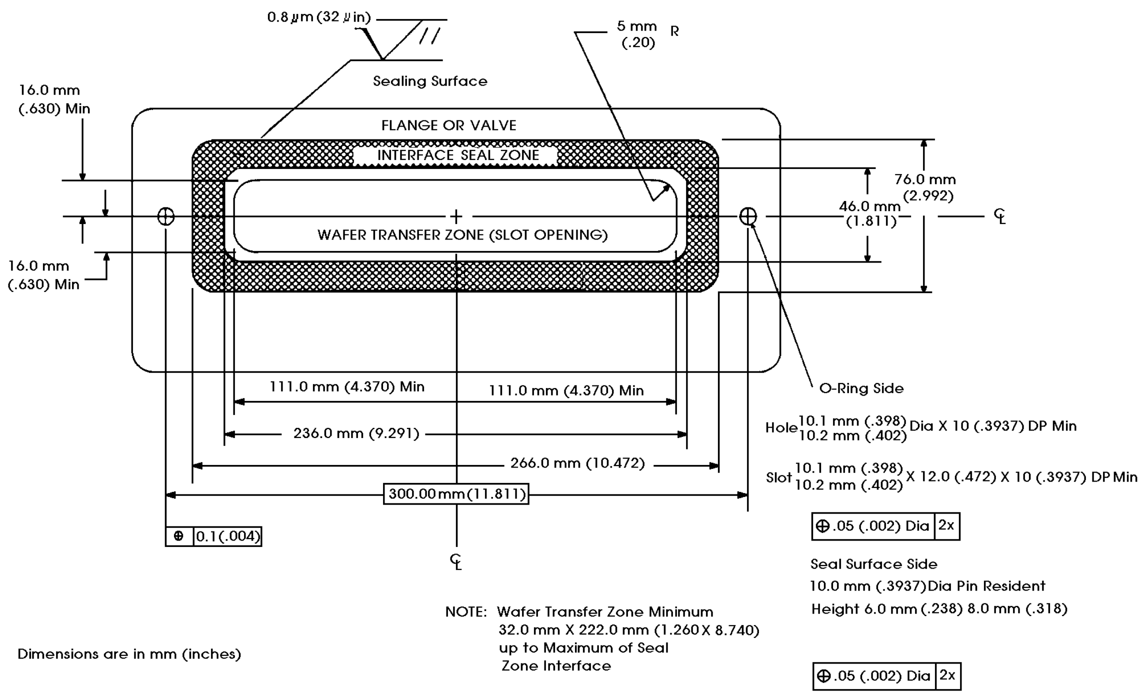

Figure 3

Interface Plane

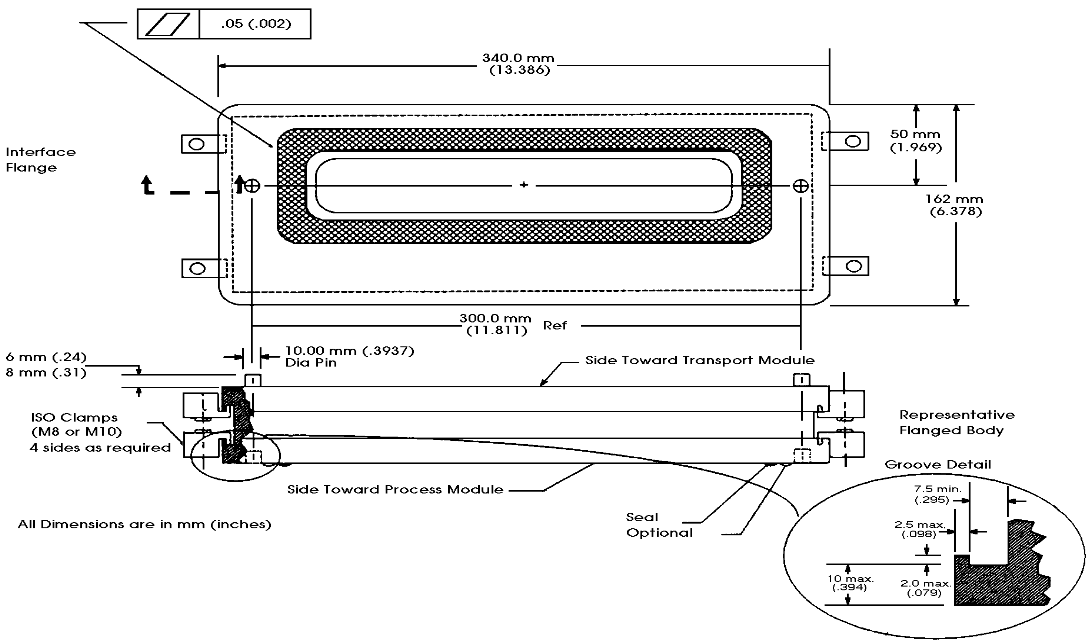

Figure 4

Flange Specification

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E21 but was reapproved for publication by full letter ballot procedures on February 28, 1999.

R1-1 Transport Module Reach

R1-1.1 The reach (see Section 4.1.1) permits a wafer of 200 mm (8 in.) diameter or smaller to be placed on a wafer support platform in a process chamber with allowance for the optional isolation valve on the process module and the chamber wall thickness. The substantial clearance between the wafer and the chamber wall is to allow freedom for process-specific design requirements.

R1-1.2 Individual process chamber designs may place the wafer closer to the interface plane than 305 mm (12 in.) and still conform to the standard.

R1-1.3 Wafers are transported individually in a horizontal attitude. Modules may contain any number of wafers. For example, batch processing is allowed.

R1-2 Vertical Position of Transport Plane

R1-2.1 The transport plane elevation of 1100 mm (43.307 in.) (see Section 4.1.2) is positioned within the constraints placed on the cluster tool by the Inter-Equipment Automation requirement for cassette placement (SEMI E15). SEMI E15 specifies the load height for cassettes to be 900 mm (35.46 in.) ± 10 mm (.394 in.) outside an environmental load-lock.

R1-2.2 The vertical position of the transport plane is derived from the following contributions:

— 910 mm (35.854 in.) is a worst-case cassette load height position.

— 12 mm (.473 in.) is a nominal pickup clearance to zero a wafer elevator indexer after the cassette is drawn into the environmental load-lock.

— 178 mm (7.01 in.) is the location of the top slot in a standard 200 mm (8 in.) wafer carrier (SEMI E1.7).

R1-2.3 These additive contributions assure that the transport plane elevation allows as much space as possible for location of support equipment such as pumps, electronics, and power supplies below the process chamber. The 1100 mm (43.307 in.) "nominal" dimension could be adjustable by the module(s) to within ± 25 mm (1 in.).

R1-3 Vertical Motion

R1-3.1 The standard (see Section 4.1.2.1) requires that the transport module be capable of moving in two planes. An ability to move in other planes is optional.

R1-3.2 The transport module moves the wafer in the horizontal wafer transport plane (see Definition 3.12). The transport module has a vertical motion capability for wafer handoff or pickup. It is assumed that the transport module moves in the lower plane after wafer handoff or prior to wafer pickup.

R1-4 Interface Seal Zone

R1-4.1 The interface seal zone (see Section 4.2.1) is sufficiently wide to permit double seals with intermediate pumping.

R1-4.2 *Blank-Off Plates* — The location of the seals on the transport module allows plain blank-off plates to be used for environmental sealing.

R1-5 Wafer Transport Zone

R1-5.1 The minimum specified height of 32 mm (1.184 in.) (see Section 4.2.2) provides sufficient clearance for passage of a knuckle joint or pivot point in the transport module end effector (see SEMI E22, "Cluster Tool Module Interface: Transport Module End Effector Exclusion Volume Standard") and for 6 mm (.238 in.) of vertical motion. The wafer transport zone may be expanded up to the boundary of the interface seal zone when a module requires a larger opening (see Section 4.2.1 and Figure 3).

R1-6 Interface Plane Alignment Pins

R1-6.1 The standard (see Section 4.2.3) implies the normal engineering practice of chamfering pin ends and countersinking pin locating holes. Actual dimensions for this have been specified or recommended by other authorities.

R1-6.2 Pins reside in the sealing surface to avoid accidental damage to the surface finish during assembly and disassembly. With centrally placed pins, valves may be mounted in either orientation if this simplifies servicing or accessibility.

R1-6.3 A clearance hole and slot arrangement allows use of dissimilar flange materials in a dynamic thermal environment.

R1-7 Isolation Valves

R1-7.1 The standard (see Section 4.2.4) allows the valves to be integral to the modules or discrete separable units.

R1-8 Clamping

R1-8.1 The standard (see Section 4.3.1) allows a universal clamping scheme to be employed. Claw clamps designed for use with ISO flanges are accommodated by the use of a perimeter groove around the flange.

R1-8.2 The clamping scheme provides several benefits:

— Independence from any hole pattern requirements.

— Flanges may be connected to flat plates or to other flanges.

— The number of clamps and the number of sides used to draw the flanges together may be varied as required by the compression forces necessary for the sealing method used. For example, clamps may be spaced on 30 mm (1.191 in.) centers for metal seals and on 150 mm (6 in.) centers for elastomeric seals.

— Any type of clamp may be used that accommodates the perimeter groove.

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SEMI E21.1-1296
CLUSTER TOOL MODULE INTERFACE 300 mm: MECHANICAL INTERFACE AND WAFER TRANSPORT STANDARD

1 Introduction

The standard provides the requirements to extend the limits of SEMI E21 from 200 mm diameter wafers or smaller to 300 mm diameter wafers or smaller.

2 Applicable Documents

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

3 Requirements

The standard is identical to E21 (see Application Note A.1) except for the requirements listed in Table 1 and Figures 1 and 2.

Table 1 Mechanical Interface Requirements for 300 mm Diameter Wafers

	E21 Requirements	*300 mm Wafer Requirements*
Transport Maximum Reach[1]	305.0 mm (12.01 in.)	380.0 mm (14.96 in.)
Inside Boundary Width-Interface Seal Zone[2]	236.0 mm (9.29 in.)	336.0 mm (13.23 in.)
Outside Boundary Width-Interface Seal Zone[2]	266.0 mm (10.47 in.)	366.0 mm (14.41 in.)
Wafer Transfer Zone Minimum Width[2]	222.0 mm (8.74 in.)	322.0 mm (12.68 in.)
Alignment Pins Centerline Separation[2]	300.0 mm (11.81 in.)	400.0 mm (15.75 in.)
Flange Width[2]	340.0 mm (13.39 in.)	440.0 mm (17.32 in.)
Vertical Slot Opening (Inner boundary of Seal Zone)	46 mm (1.811 in.) Maximum	50 mm (1.969 in.)
Distance of Wafer Transfer Plane above Alignment Pin Datum Line (see Figure 1)	9.5 ± 0.5 mm (0.37 ± 0.02 in.)	15.5 ± 0.5 mm (0.61 ± 0.02 in.)
Vertical Motion Capability (see Figure 1)	6 ± 0.5 mm (0.24 ± 0.02 in.)	10 ± 0.5 mm (0.39 ± 0.02 in.)
Minimum Distance of Slot Top above Alignment Pin Datum on Attached Modules	(13 mm)	23 mm (0.906 in.)
Minimum Distance of Slot Bottom below Alignment Pin Datum on Attached Modules	(13 mm)	13 mm (0.512 in.)

1. See Application Note A.2.
2. See Application Note A.3.

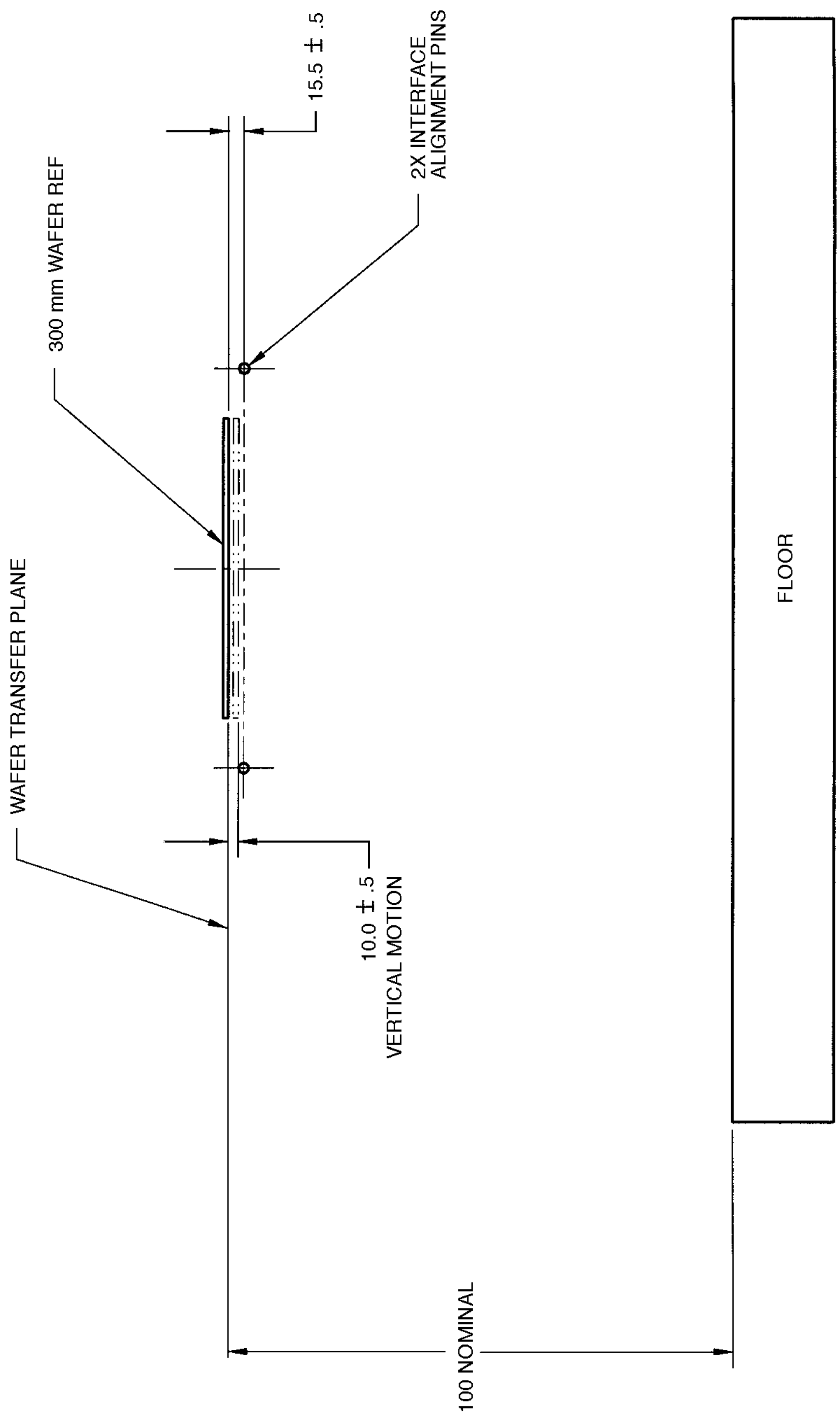

Figure 1
Proposed 300 mm Wafer Transport Plane Elevation

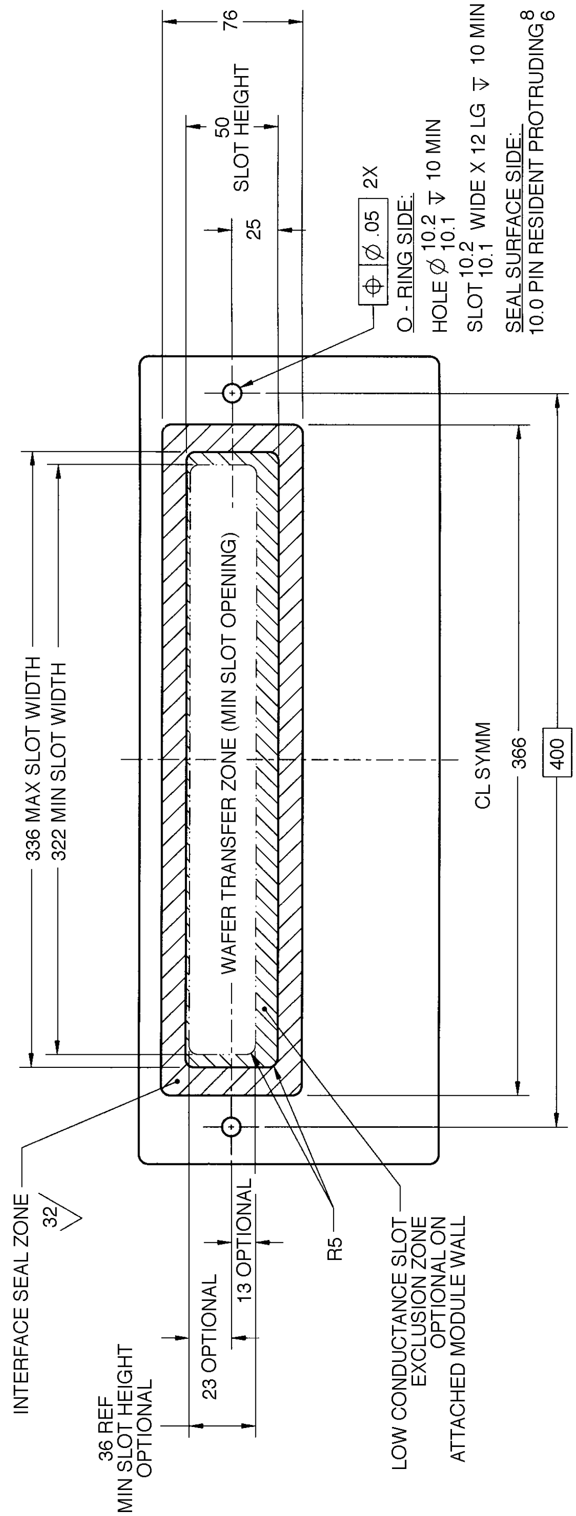

Figure 2
Proposed 300 mm Interface Plane

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APPENDIX 1
APPLICATION NOTES

NOTE: The material contained in these application notes is not an official part of SEMI E21.1, and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such they are to be considered as reference material only. The standard should be referred to in all cases.

A.1 Vertical Requirements

Changes in vertical requirements are made because of the need to provide adequate transport arm stiffness (thickness) for the longer reach specified for 300 mm. However, for many processes, it is desirable to limit the slot size as far as possible. An option is now allowed to reduce the vertical slot opening on the Attached Modules side of the Interface Plane (see Figure 1, E21), but any such reduction will compromise the space otherwise available for transport arm vertical thickness and/or movement. Specification of the extent of this option will be needed in each case it is used.

A.2 Transport Maximum Reach

The maximum reach beyond the interface plane (see Table 1) is increased by 75 mm (from 305.0 mm to 380.0 mm); a 50 mm increase in wafer radius (from 100 mm to 150 mm) and a 25 mm increase in clearance between the wafer and the chamber walls.

A.3 Width Requirements

The increase in wafer diameter from 200 mm to 300 mm necessitates a 100 mm increase in all width values (see Table 1) specified in SEMI E21.

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SEMI E22-0697
CLUSTER TOOL MODULE INTERFACE: TRANSPORT MODULE END EFFECTOR EXCLUSION VOLUME STANDARD

1 Introduction

1.1 *Scope* — The standard describes the volume within any process or cassette module which shall be accessible to the transport module end effector in a cluster tool. The standard is limited to modules which accommodate wafer sizes from 100 mm up to and including 200 mm in diameter.

1.2 *Purpose* — The purpose of the standard is to provide sufficient detail to allow the transport module end effector to move wafers to and from process and cassette modules in a cluster tool without mechanical interference.

1.3 *Impact* — The adoption of the standard requires equipment designers to allow specific unobstructed volumes within process and cassette modules for wafer transport and places restrictions on the design of the transport module end effector. Some restrictions are dependent on the wafer size.

2 Applicable Documents

2.1 *SEMI Documents*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

3 Definitions

3.1 *exclusion zone* — A restricted area within a process or cassette module reserved for access by the transport module end effector during wafer handling.

3.2 *fork* — A two-prong transport module end effector designed to hold the wafer around its periphery.

3.3 *paddle* — A blade transport module end effector designed to support the wafer.

3.4 *pedestal* — A support pillar axially symmetric to the wafer transport position in a process or cassette module.

3.5 *slot* — A two-sided support, for example as defined for a standard wafer carrier in SEMI E1 when the carrier is oriented with its axis in a vertical attitude.

3.6 *transport module end effector* — That part of the transport module that supports the wafer and can extend beyond the interface plane (defined in SEMI E21).

3.7 *wafer support platform* — A slot, pedestal, or set of pins used to hold a wafer in a horizontal attitude.

3.8 *wafer transport axis* — The centerline of transport module end effector motion. This centerline is symmetric with the wafer transport zone as described in SEMI E21.

3.9 *wafer transport position* — A location within a process or cassette module where the wafer is accepted or presented by the transport module end effector. This is also the location of the wafer centroid.

4 Requirements

4.1 *Wafer Transport* — The wafer is to be transported in a horizontal attitude (see Application Note A.1).

4.2 *Wafer Transport Plane Exclusion Zone* — The exclusion zone is illustrated in Figure 1, and the variables are defined in Table 1 and specified in Table 2 (see Application Note A.2). The clear areas between B and C and along the wafer transport axis are specified to allow the transport module end effector to be retracted after the wafer has been placed on the support platform in the process or cassette module. The right-hatched (////) area denotes the exclusion zone which could be occupied by a paddle. The left-hatched (\ \ \ \ ) area denotes the additional exclusion zone which could be occupied by a fork. The cross-hatched (XXXX) area denotes the reduction in the dimensions of the paddle exclusion zone to accommodate a pedestal and or pin(s) in a process or cassette module (referred to as a pedestal or pin exclusion zone).

4.3 *Maximum Pedestal Diameter* — The diameter is not to exceed dimension H given in Table 2.

4.4 *Pin Location* — Wafer support pins to be located relative to the wafer transport plane exclusion zone. The pins are to be located at radii dependent upon wafer diameter as specified in Table 2.

4.5 *Vertical Plane Exclusion Zone* — The extent of the exclusion zone in the vertical plane is indicated by the hatched area and the dashed outline in Figure 2. The maximum extent of the exclusion zone allows the transport module end effector to clear the minimum wafer transport zone at the interface plane (see Application Note A.3). The vertical plane exclusion zone is decreased in height in the vicinity of the wafer transport position to allow the presence of shields, electrodes, etc. in the process or cassette module.

4.6 *Transport Module End Effector Exclusion Volume* — The exclusion volume within a process or cassette module reserved for access by the transport module end effector is defined by the intersection of the two orthogonal exclusion zones described in Sections 4.2 and 4.5. This exclusion volume allows the transport module end effector to accept or present a wafer at the wafer transport position within a process or cassette module (see Application Note A.4).

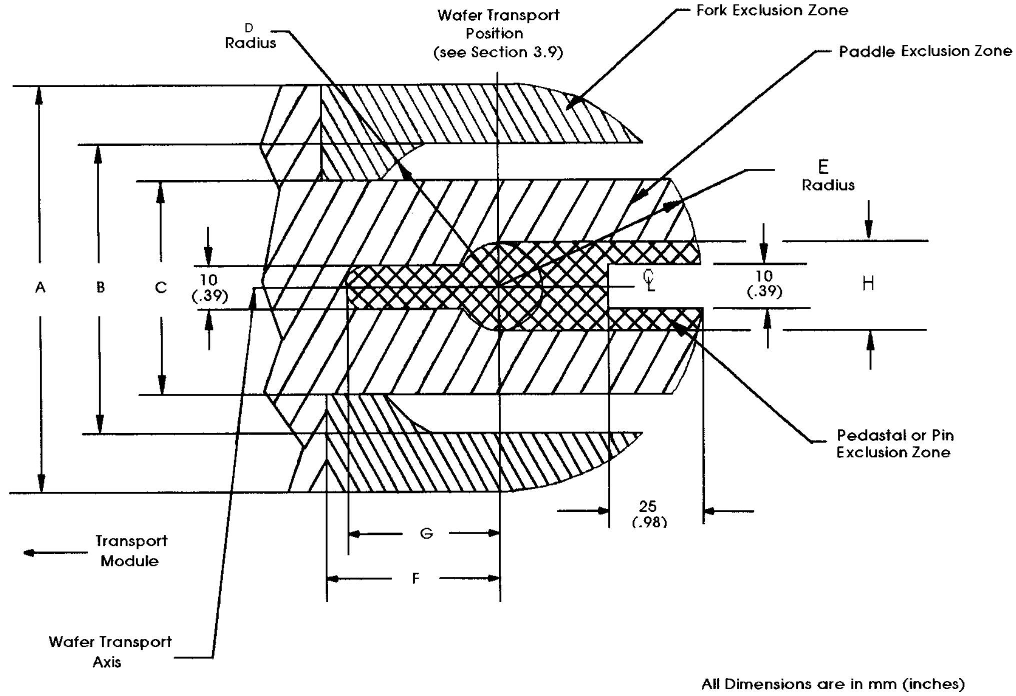
LIST OF FIGURES

Table 1 Wafer Transport Plane Exclusion Zone Variables

A	Maximum width of the wafer transport plane exclusion zone
B	Minimum outside clearance for support pins
C	Maximum inside clearance for support pins and/or slot
D	Minimum radial clearance for support pins
E	Outermost radius of wafer transport plane exclusion zone
F	Minimum clearance for entry into SEMI Standard Wafer Carrier
G	Maximum clearance for support pins
H	Maximum clearance for support pedestal

Table 2 Wafer Transport Plane Exclusion Zone Dimensions

Variables	*Wafer Size*			
	100 mm (4 in.)	*125 mm (5 in.)*	*150 mm (6 in.)*	*200 mm (8 in.)*
A	120 mm (4.72 in.)	145 mm (5.71 in.)	170 mm (6.69 in.)	220 mm (8.66 in.)
B	86 mm (3.39 in.)	107 mm (4.21 in.)	129 mm (5.08 in.)	172 mm (6.77 in.)
C	50 mm (1.97 in.)	66 mm (2.60 in.)	78 mm (3.07 in.)	104 mm (4.09 in.)
D	47 mm (1.85 in.)	60 mm (2.36 in.)	72 mm (2.83 in.)	97 mm (3.82 in.)
E	60 mm (2.36 in.)	72 mm (2.83 in.)	85 mm (3.35 in.)	110 mm (4.33 in.)
F	70 mm (2.76 in.)	82 mm (3.23 in.)	95 mm (3.74 in.)	120 mm (4.72 in.)
G	47 mm (1.85 in.)	60 mm (2.36 in.)	72 mm (2.83 in.)	97 mm (3.82 in.)
H	30 mm (1.18 in.)	38 mm (1.50 in.)	45 mm (1.77 in.)	60 mm (2.36 in.)



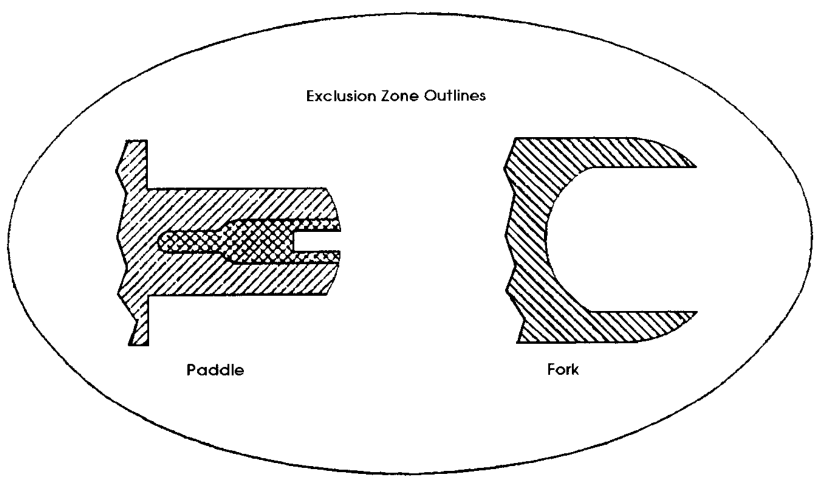


Figure 1
Wafer Transport Plane Exclusion Zone (Plan View)

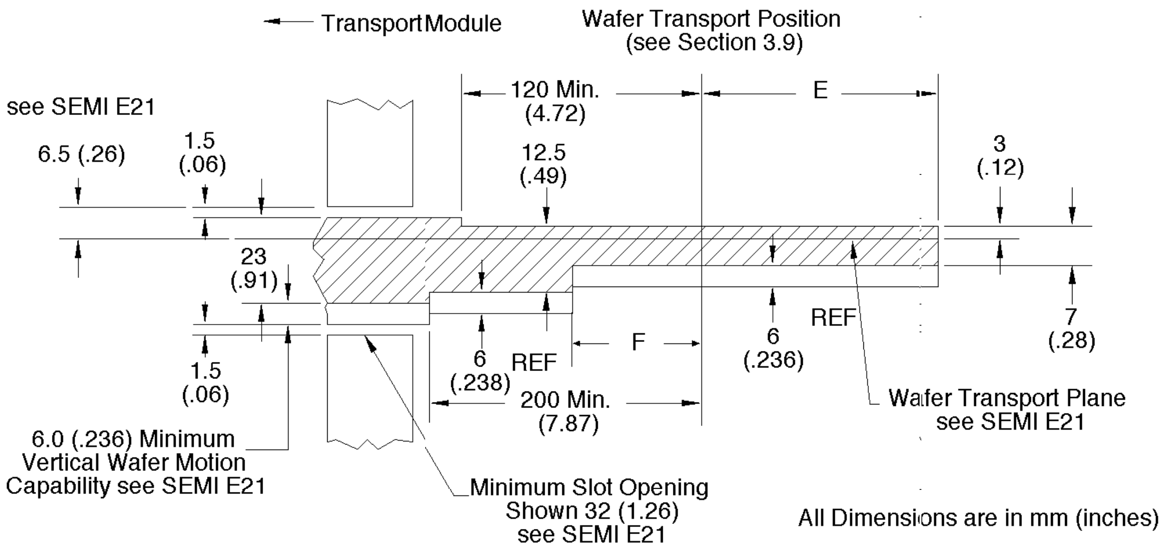


Figure 2
Vertical Plane Exclusion Zone (Elevation View)

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APPLICATION NOTES

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A.1 Wafer Transport

The standard (see Section 4.1) does not require that the entire transport module end effector move in a horizontal attitude while the wafer does have this requirement. For example, the transport module end effector may have a component of motion in a plane other than the horizontal during wafer transport across the interface plane.

A.2 Variables — Definitions and Dimensions

The function of Table 2 (see Section 4.2) is to list the numerical values for the wafer dependent variables used in Figures 1 and 2. The values are wafer size dependent so as not to penalize the design of a transport module end effector when handling only small diameter wafers. For example, the physical size of a transport module end effector for a 100 mm diameter wafer may be smaller than that for a 200 mm diameter wafer.

A.3 Vertical Plane Exclusion Zone

The development of the numeric values specified in the standard (see Section 4.5) and given in Figure 2 are described below.

The 3 mm height above the wafer transport plane (defined in SEMI E21) allows for transport module end effectors which use contraints (e.g., a cupped device or pins) to ensure the wafer does not slide. Also, this may be necessary if the wafer is transported with the circuit side facing down.

The 7 mm value allows for a 4 mm thickness below the wafer transport plane to accommodate a structurally and thermally strong transport module end effector design.

The 12.5 mm thickness allows for process or cassette modules with a minimum slot opening value of less than 32 mm (see SEMI E21).

The 200 mm minimum length part of the exclusion zone allows for a transport module end effector of limited reach to pass into modules with slot openings smaller than the minimum value of 32 mm.

The 23 mm thickness allows for the presence of a “wrist” joint or for additional rigidity in the transport module end effector.

The 120 mm length is specified as a fixed number to ensure that multiple wafer sizes (and transport module end effectors) do not necessarily demand a change in geometry of the receiving module around the wafer transport position.

The minimum nominal clearance above and below the exclusion zone is 1.5 mm on both sides of the transport module end effector when it passes through the minimum slot opening. This takes into account the exclusion zone size due to the vertical travel the transport module end effector may experience.

A subset of the vertical plane exclusion zone (see Figure A.1) is required by a transport module end effector which must access wafers directly from SEMI standard or equivalent cassettes. The vertical plane exclusion zone described in the standard (see Figure 2) was not subject to these restrictions since a single generic transport module end effector design was found not to be practical.

A.4 Transport Module End Effector Exclusion Volume

This volume as described in Section 4.6 is intended to be the volume within which the transport module end effector has complete autonomy. Therefore, process and cassette modules are not allowed to violate this volume during wafer transport. This prevents mechanical interference between the transport module end effector and the process or cassette module.

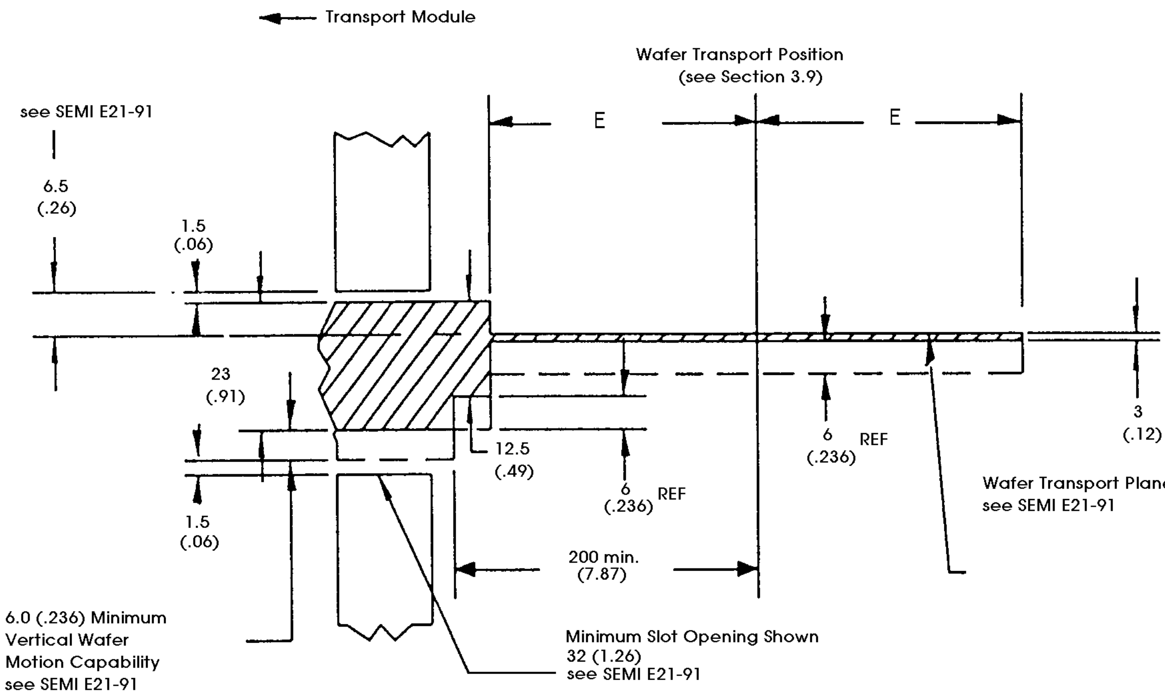

Figure A.1
Vertical Plane Exclusion Zone (Elevation View)
(Restricted Case for SEMI Standard Cassette Access)

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SEMI E22.1-1296
CLUSTER TOOL MODULE INTERFACE 300 mm: TRANSPORT MODULE END EFFECTOR EXCLUSION VOLUME STANDARD

1 Introduction

The standard provides the requirements to change the limits of applicability of SEMI E22 from 100 mm to 200 mm diameter wafers to 300 mm diameter wafers.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E22 — Cluster Tool Module Interface: Transport Module End Effector Exclusion Volume Standard

3 Requirements

3.1 *Wafer Transport Plane Exclusion Zone* — All fixed dimensions remain the same as for SEMI E22 with the following exception. The 25 mm and 10 mm dimenions for the rectangular space excluded from the front of the Paddle Exclusion Zone are expanded and defined by Variables I and H respectively. These variables are shown in Figure 1. Variables for 250 mm and 300 mm diameter wafers are specified in Table 1.

Table 1 Wafer Transport Plane Exclusion Zone Dimensions for 250 mm and 300 mm Diameter Wafers

Variables	*Wafer Size*	
	250 mm (10 in. nom.)	*300 mm (12 in. nom.)*
A	270 mm (10.63 in.)	320 mm (12.60 in.)
B	215 mm (8.46 in.)	250 mm (9.84 in.)
C	130 mm (5.12 in.)	225 mm (8.86 in.)
D	122 mm (4.80 in.)	147 mm (5.79 in.)
E	135 mm (5.31 in.)	160 mm (6.30 in.)
F	145 mm (5.71 in.)	170 mm (6.69 in.)
G	122 mm (4.80 in.)	147 mm (5.79 in.)
H	75 mm (2.95 in.)	154 mm (6.06 in.)
I		117 mm (4.61 in.)

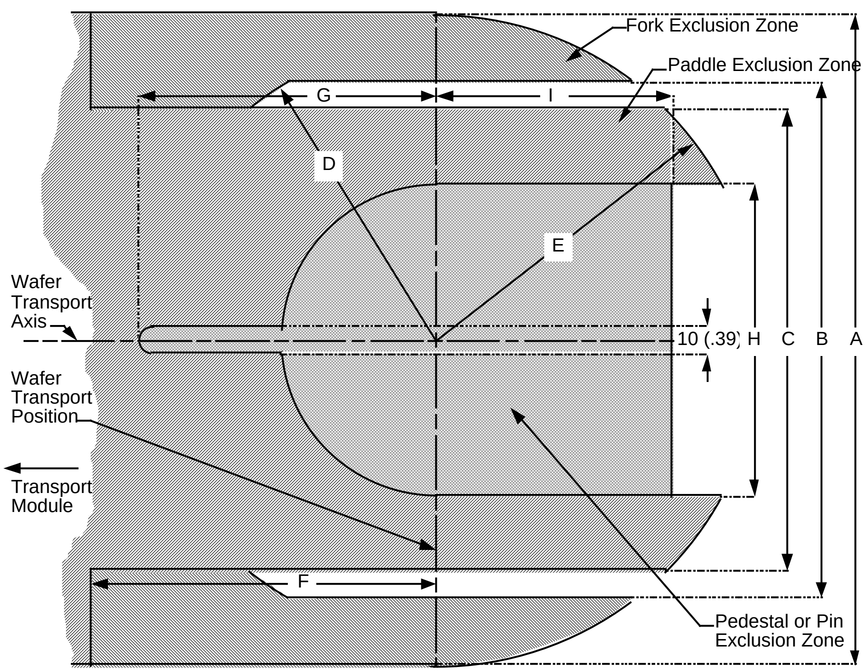

Figure 1
New Wafer Transport Plane Exclusion Zone Dimensions

3.2 *Vertical Plane Exclusion Zone* — This zone is illustrated in Figure 2, which defines dimensional values.

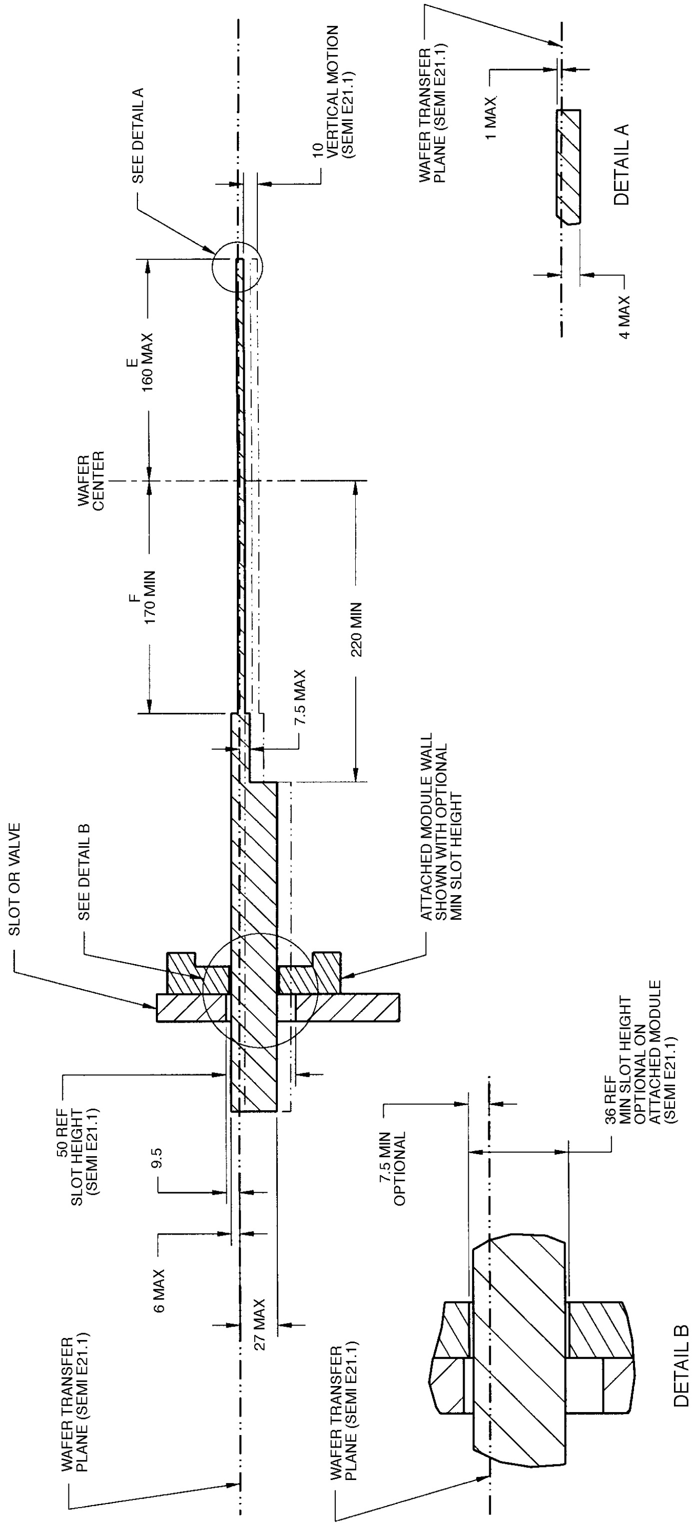

Figure 2
Proposed 300 mm Vertical Plane Exclusion Zone (Elevation View)

APPENDIX 1
APPLICATION NOTES

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The standard applies to both attached modules and wafer carriers; there is no special subset for carriers. The extreme end of the exclusion zone should allow adequate stiffness for end effectors and also permit insertion into carriers (with a 10 mm pitch).

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SEMI E23-96 (Reapproved 0702)
SPECIFICATION FOR CASSETTE TRANSFER PARALLEL I/O INTERFACE

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1991; previously published in 1996.

1 Purpose

1.1 Cassette transfer between process equipment and transport equipment is performed by means of a mechanical operation in the interactive area and requires quick response and reliable interlock signals.

1.2 The purpose of this specification is to provide a cassette transfer parallel input/output (I/O) interface for control of the interface mechanism that supplements the SECS standard for material movement.

2 Scope

2.1 This specification deals with the parallel I/O interface for the cassette transfer between two pieces of equipment, such as a piece of process equipment and a piece of transport equipment.

2.2 This standard defines the wire-connected parallel I/O interface between two pieces of equipment and the photo-coupled parallel I/O interface between the process equipment and the transport equipment.

2.3 The application of the parallel I/O interface to the cassette transport is as follows.

2.4 Each piece of equipment is connected to the HOST at the SECS interface, and each of the two pieces of equipment between which the cassette transfer will be made is connected at the parallel I/O interface as shown in Figure 1.

2.5 The cassette transfer request, or load/unload command, is notified by the SECS-II message. The actual cassette transfer action is executed using the parallel I/O interface, interlocking each mechanism. (An example of a cassette transfer transaction using the parallel I/O interface is shown in Related Information 1.)

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

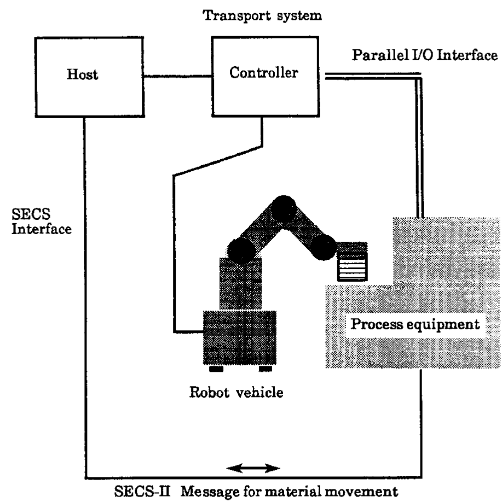


Figure 1
Application of Parallel I/O Interface to Cassette Transport

3 Referenced Standards

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

3.1 *SEMI Standards*

SEMI E1 — Specification for 3 inch, 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

3.2 *ISO Standards*[1]

ISO 4902 — Connector

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

3.3 *Japanese Industrial Standards Committees*[2]

JIS-X-5103 — The Interface Between Data Circuit Terminating Equipment (DCE) and Data Terminal Equipment (DTE) (37/9-Pin Interface)

4 Terminology

4.1 *Definitions*

4.1.1 *active equipment* — Equipment that loads a cassette onto the cassette stage of another piece of equipment or unloads a cassette from the cassette stage of another piece of equipment.

4.1.2 *cassette* — A plastic or metal wafer carrier as defined in SEMI E1.

4.1.3 *cassette stage* — A stage on a piece of equipment on which a cassette is placed or from which it is removed that allows the cassette transfer.

4.1.4 *cassette transfer robot* — A robot that transfers cassettes (see Figure 2).

4.1.5 *load* — To place a cassette on the cassette stage of the equipment.

4.1.6 *passive equipment* — Equipment that is loaded or unloaded by the active equipment.

4.1.7 *photo-coupled interface* — A parallel I/O interface connected without contact by means of a photo-coupled device.

4.1.8 *process equipment* — Fabrication equipment, inspection equipment, and cassette stage equipment used in semiconductor manufacturing.

4.1.9 *robot vehicle* — A piece of equipment having a cassette transfer robot on the vehicle that moves to another piece of equipment and transfers cassettes (see Figure 2).

4.1.10 *transfer* — To either load or unload.

4.1.11 *transport equipment* — A piece of equipment (or system) which transports or transfers cassettes. It mainly consists of a transport vehicle, a robot vehicle, and a cassette transfer robot.

4.1.12 *transport vehicle (see Figure 2)* — A vehicle which transports cassettes but which has no mechanism for cassette transfer.

4.1.13 *unload* — To remove a cassette from the cassette stage of the equipment.

4.1.14 *wire-connected interface* — A parallel I/O interface connected by means of wire and a connector.

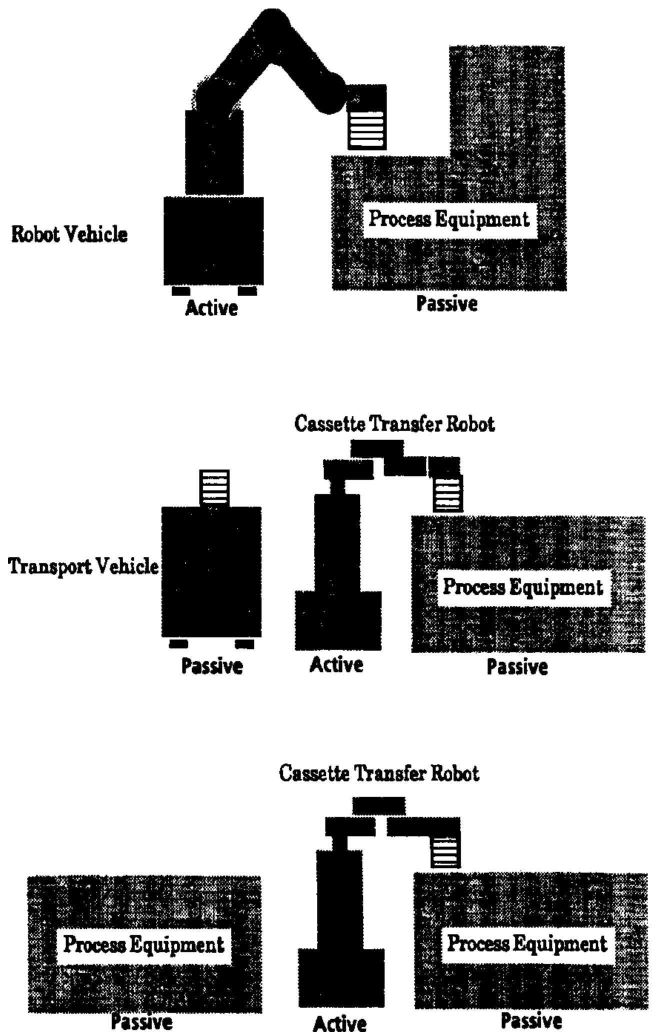


Figure 2
Cassette Transfer between Active Equipment and Passive Equipment

5 Parallel I/O Interface Specification

5.1 This standard refers only to the cassette transfer between active and passive equipment.

5.2 *Wire-Connected Parallel I/O Interface Specification* — The equipment is to have a parallel I/O interface for the passive mode when it becomes passive, and the parallel I/O interface for the active mode when it becomes active.

5.2.1 *Signals for Each Cassette Stage* — The cassette stage is to have the input/output signal lines listed in Table 1.

2 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

Table 1 Signals for Each Cassette Stage (Wire-Connected Interface)

Signal Type	*P/A*	*Description*
L_REQ (LOAD REQUEST)	P->A	This signal means that the CS can be loaded. The signal turns OFF when the cassette is detected on the CS. (The CS is a cassette stage.)
U_REQ (UNLOAD REQUEST)	P->A	This signal means that the CS can be unloaded. The signal turns OFF when it is detected that the cassette has been removed from the CS.
READY	P->A	This signal means that the CS is in a state where it can be accessed by the active equipment. It turns ON when the CS is in the READY state after the TR_REQ signal from the active turns ON. The signal turns OFF by handshakes with the COMPT signal.
TR_REQ (TRANSFER REQUEST)	A->P	This signal turns ON when the active equipment is going to start transferring the cassette. It turns OFF when the BUSY signal is OFF. (Active equipment starts transferring the cassette with the BUSY ON after recognizing the READY ON.)

5.2.2 *Common Signals* — The signals in Table 2 show the status of the cassette transfer action of the active equipment. The CS's are allowed to input these signals commonly from active equipment.

Table 2 Common Signals (Wire-Connected Interface)

Signal Type	*P/A*	*Description*
BUSY	A->P	This signal turns ON when the active equipment starts transferring the cassette to the CS while it is in READY and turns OFF after the robot has loaded or unloaded a cassette and has moved away from the interactive zone. The passive equipment does not perform any mechanical action in the interactive zone while this signal is ON.
COMPT (COMPLETE)	A->P	This signal means the active equipment has completed the transfer action. It turns OFF after handshaking with the READY signal.

It is recommended that the BUSY signal turn OFF after the active equipment has confirmed L_REQ (or U_REQ) is OFF.

5.2.3 *Cassette Transfer Sequence* — Time charts for the cassette transfer sequence are shown in Figures 3 (a) and (b).

5.2.3.1 The TR_REQ from the active equipment initiates the cassette transfer sequence. The active equipment starts carrying out the transfer action with the BUSY ON as soon as it recognizes that the READY signal of the passive equipment is ON. The handshake is finished after the cassette transfer action has been completed.

5.3 *Photo-Coupled Parallel I/O Interface Specification* — This interface is concerned only with the cassette transfer between the process equipment and the transport robot vehicle. The robot vehicle is active and the process equipment is passive.

5.3.1 This interface is defined between the robot and the cassette stages to which the robot can transfer a cassette at the same stopping position.

5.3.2 *Signals* — The signals for the photo-coupled parallel I/O interface are listed in Table 3. The CS_0, CS_1, and CS_2 signals specifying the CS to or from which the active equipment transfers and the VALID signal indicating effectiveness of the data of CS_0~ CS_2, are newly added to the signals defined in the wire-connected parallel I/O interface.

Table 3 Signals for the Photo-Coupled Parallel I/O Interface

Signal Type	*P/A*	*Description*
VALID	A->P	This signal remains high (ON) while the data of CS_0, CS_1, CS_2 is effective. (The data of CS_0, CS_1, CS_2 is not effective when VALID signal is OFF.)
CS_0 (LSB) CS_1 CS_2 (MSB)	A->P	The 3-bit signals specify the cassette stage number (0 ~ 7) of the passive equipment, to or from which the active equipment (robot vehicle) is going to transfer a cassette. They are set before the VALID signal turns ON. VALID and CS_0~ CS_2 signal.
TR_REQ	A->P	This is the same in the wire-connected parallel I/O specification and is valid for the specified CS.
L_REQ	P->A	This is the same in the wire-connected parallel I/O specification and is valid for the specified CS.
U_REQ	P->A	This is the same in the wire-connected parallel I/O specification and is valid for the specified CS.
READY	P->A	This is the same in the wire-connected parallel I/O specification and is valid for the specified CS.
BUSY	A->P	This is the same in the wire-connected parallel I/O specification.
COMPT	A->P	This is the same in the wire-connected parallel I/O specification.

5.3.3 *Cassette Transfer Sequence* — Time charts for the cassette transfer sequence in the case of the photo-coupled interface are shown in Figure 4 (a) and (b). After the active equipment (robot vehicle) reaches the process equipment, it sets the CS_0, CS_1, CS_2 3-bit-signals to specify the CS number of the passive equipment, to or from which the active equipment (robot vehicle) is going to transfer a cassette. Then the robot vehicle turns the VALID signal ON, which shows the date of the CS_0, CS_1, CS_2 signal is effective. After the cassette stage is specified, cassette transfer sequence is the same as in the wire-connected parallel I/O specification. TR_REQ, L_REQ,U_REQ, READY signals show the data for the specified CS while the VALID signal is ON, and the CS_0, CS_1, CS_2 signals are inhibited to change their data while the VALID signal is ON.

5.4 *Error Detection and Recovery* — The cassette transfer using this interface in the practical manufacturing lines will need handshake time interval control, cassette misalignment detection, and report of alarm or error to find an error or abnormal termination in the cassette transfer. An error recovery procedure with appropriate assist by human operators will be also required. This standard, however, does not define the specifications related to the error detection and recovery because of difference in process time, failure mode, and error recovery procedure of individual equipment and system.

5.4.1 The recommendation for basic error detection is that the active equipment should control handshake time intervals, and at least the interval time T between the beginning of the cassette transfer and the end of the transfer should be controlled — see the time chart of the cassette transfer sequence shown in Figures 3(a), 3(b), 4(a), and 4(b), describing the time chart of the cassette transfer sequence.

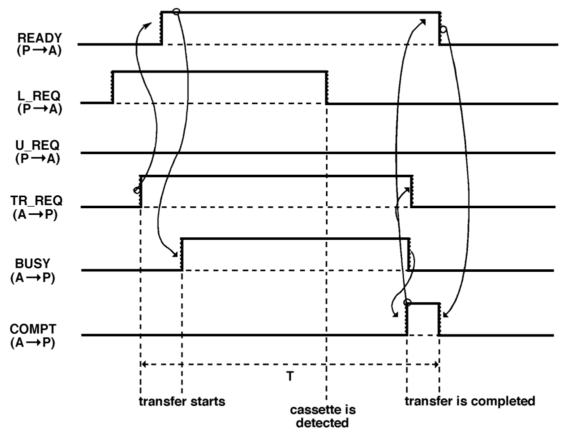


Figure 3A
Cassette Load Sequence
(Wire-Connected Interface)

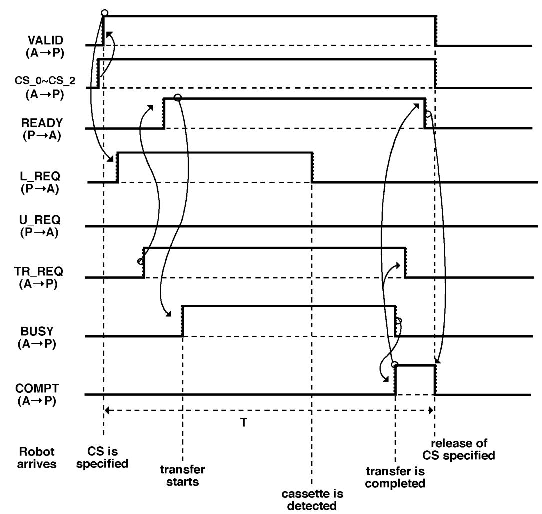


Figure 4A
Cassette Load Sequence
(Photo-Coupled Interface)

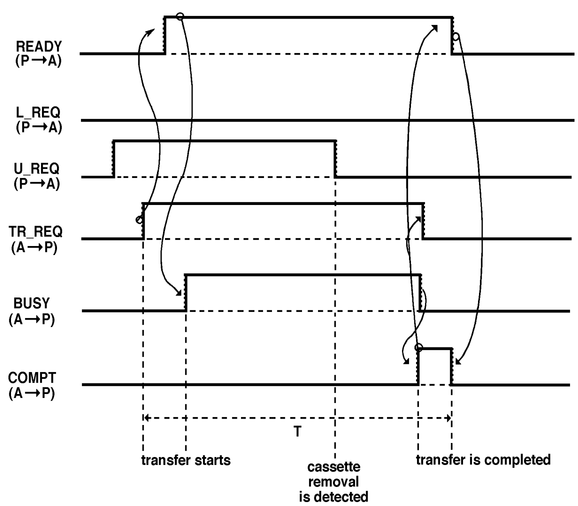


Figure 3B
Cassette Unload Sequence
(Wire-Connected Interface)

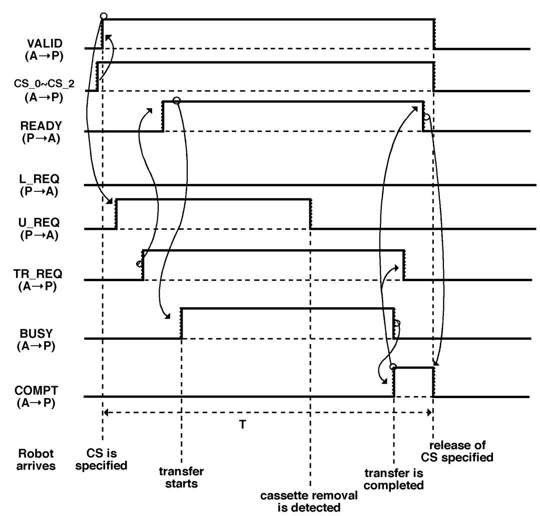


Figure 4B
Cassette Load Sequence
(Photo-Coupled Interface)

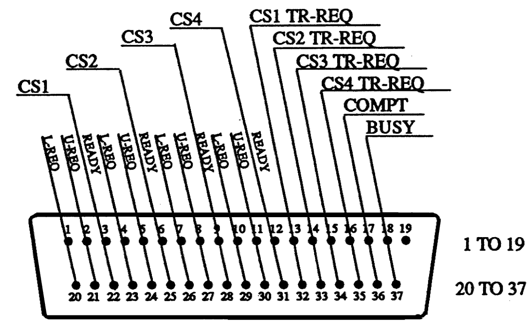
6 Connector and Interface Circuit

6.1 *Wire-Connected Interface* — One set of connectors is provided for the CS's that commonly input the BUSY and COMPT signals.

6.1.1 *Connector and Pin Assignment*

1. Connector JIS-X-5103 (D-SUB type) ISO-4902 Every piece of equipment is to have female type connectors.

2. *Pin Assignment* — The connector with 37 pins is used. One connector is used for 1 to 4 cassette stages and another connector is used for 5 to 7 cassette stages. The pin assignment is listed in Tables 4a and 4b. Figure 5 shows the pin assignment of the connector for 4 cassette stages.



JIS-X-5103 37-pin connector

Figure 5
Pin Assignment for Wire-Connected Parallel I/O Interface

Table 4 Pin Assignment for Wire-Connected Parallel I/O Interface (Connector 2)

Pin No.	*Signal*	*Pin No.*	*Signal*
1	CS1 L_REQ	20	CS1 L_REQ*
2	CS1 U_REQ	21	CS1 U_REQ*
3	CS1 READY	22	CS1 READY*
4	CS2 L_REQ	23	CS2 L_REQ*
5	CS2 U_REQ	24	CS2 U_REQ*
6	CS2 READY	25	CS2 READY*
7	CS3 L_REQ	26	CS3 L_REQ*
8	CS3 U_REQ	27	CS3 U_REQ*
9	CS3 READY	28	CS3 READY*
10	CS4 L_REQ	29	CS4 L_REQ*
11	CS4 U_REQ	30	CS4 U_REQ*
12	CS4 READY	31	CS4 READY*
13	CS1 TR_REQ	32	CS1 TR_REQ*
14	CS2 TR_REQ	33	CS2 TR_REQ*
15	CS3 TR_REQ	34	CS3 TR_REQ*
16	CS4 TR_REQ	35	CS4 TR_REQ*
17	COMPT	36	COMPT*
18	BUSY	37	BUSY*
19		38	

*Vcc side (power source) for the current-driven type circuit. Common side for the voltage-driven type circuit.

6.1.1.1 When one connector is used for only one cassette stage, the connector with 15 pins may be used. The pin assignment is listed in the Table 5.

6.1.2 *Interface Circuit* — The following two types of interface circuits are used. (Interface circuit examples are shown in Related Information 3.)

1. Voltage-driven Type Circuit — Driving voltage: DC24 ± 2 V

2. Current-driven Type Circuit — Driving current: 10 mA ~ 20 mA

Table 5 Pin Assignment for Wire-Connected Parallel I/O Interface (Connector 1)

Pin No.	*Signal*	*Pin No.*	*Signal*
1	CS5 L_REQ	20	CS5 L_REQ*
2	CS5 U_REQ	21	CS5 U_REQ*
3	CS5 READY	22	CS5 READY*
4	CS6 L_REQ	23	CS6 L_REQ*
5	CS6 U_REQ	24	CS6 U_REQ*
6	CS6 READY	25	CS6 READY*
7	CS7 L_REQ	26	CS7 L_REQ*
8	CS7 U_REQ	27	CS7 U_REQ*
9	CS7 READY	28	CS7 READY*
10		29	
11		30	
12		31	
13	CS5 TR_REQ	32	CS5 TR_REQ*
14	CS6 TR_REQ	33	CS6 TR_REQ*
15	CS7 TR_REQ	34	CS7 TR_REQ*
16		35	
17		36	
18		37	
19			

*Vcc side (power source) for the current-driven type circuit. Common side for the voltage-driven type circuit.

Table 6 Pin Assignment for Wire-Connected Parallel I/O Interface 15 Pins Connector

Pin No.	*Signal*	*Pin No.*	*Signal*
1	CS1 L_REQ	9	CS1 L_REQ*
2	CS1 U_REQ	10	CS1 U_REQ*
3	CS1 READY	11	CS1 READY*
4		12	
5	CS1 TR_REQ	13	CS1 TR_REQ*
6	COMPT	14	COMPT*
7	BUSY	15	BUSY*
8			

*Vcc side (power source) for the current-driven type circuit. Common side for the voltage-driven type circuit.

6.2 Photo-Coupled Interface

6.2.1 *Photo-Coupled Device and Bit Assignment* — To date, there is no applicable documentor standard for photo-coupled devices. This defines the usage of a photo-coupled device of 8 bit-input/8 bit-output two-way communications type. The bit assignment is shown in Figure 6.

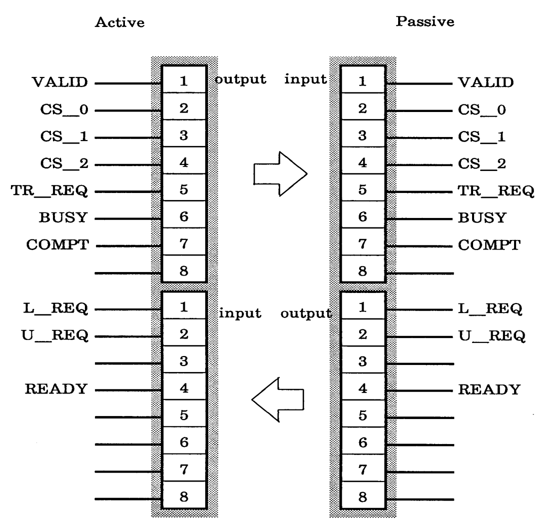


Figure 6
Bit Assignment of Photo-Coupled Device for the Photo-Coupled Parallel I/O Interface

7 Installation Space

7.1 *Wire-Connected Interface* — Not specified.

7.2 *Photo-Coupled I/O Interface* — The photo-coupled I/O interface must be located within the hatched area indicated in Figure 7.

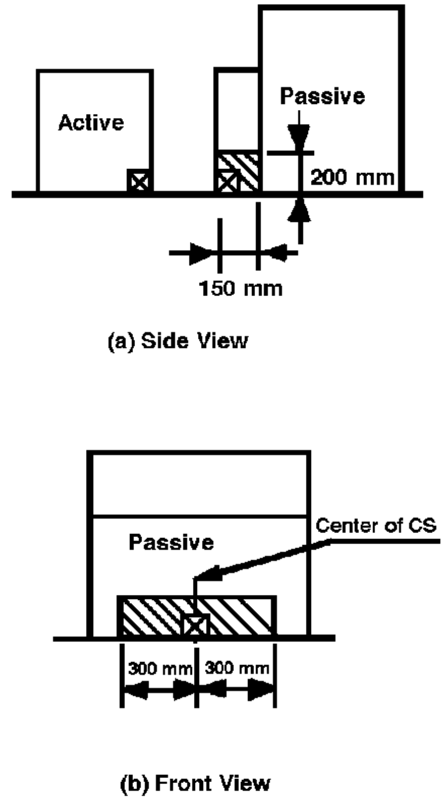


Figure 7
Installation Space of Photo-Coupled I/O interface

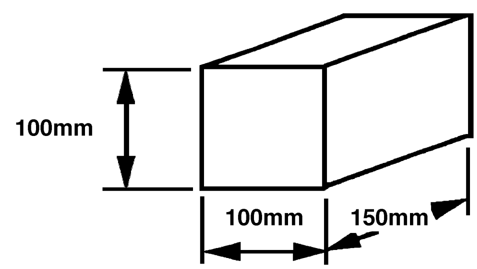


Figure 8
Maximum Size of Photo-Coupled I/O Interface

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that some implementations of this standard may involve use of inventions covered by U.S. patents 4,306,292 and other patents issued or pending, held by Texas Instruments Incorporated. By publication of this standard, SEMI takes no position respecting either the applicability or the validity of these or other patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
EXAMPLE OF A CASSETTE TRANSFER TRANSACTION USING THE PARALLEL I/O INTERFACE

NOTE: This example of a cassette transfer transaction using the parallel I/O interface is not an official part of this document and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

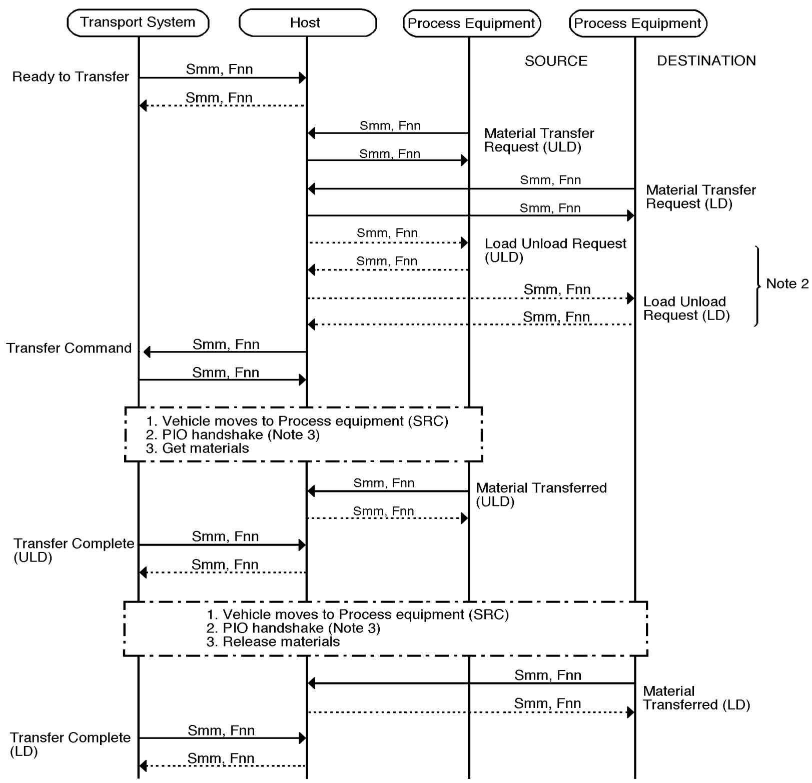


Figure R1-1
Example of a Cassette Transfer Transaction Using the Parallel I/O Interface

NOTES:

1. LD = load, ULD = unload.

2. The load/unload request (Smm, Fnn) may be eliminated if the material transfer request (Smm, Fnn) issued after the materials have been prepared on the specified port for unloading or specified port has been readied for loading.

3. Multiple PIO handshakings may be required if material transfer request message (Smm, Fnn) has multiple MID's and PIN's for multiple material transfers. MID: Material ID, PIN: Port number.

4. The dotted line means optional message.

5. In the future, the appropriate specific SECS-II message may be assigned for above Smm, Fnn message, respectively.

RELATED INFORMATION 2
APPLICATION EXAMPLES OF INTERFACING

NOTE: This application example of interfacing is not an official part of this document and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

Figure R2-1 shows some application examples for the wire-connected parallel I/O interface. One set of connectors is provided for the CS's that commonly input the BUSY and COMPT signals.

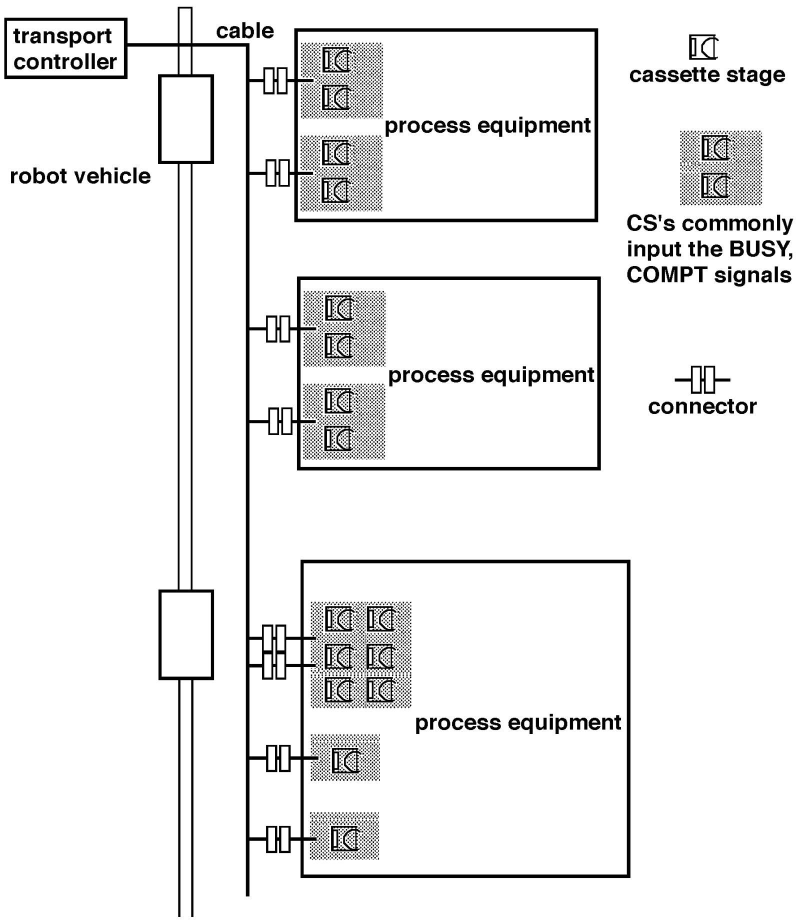


Figure R2-1
Application Example of the Wire-Connected Parallel I/O Interface

Figure R2-2 shows some application examples for the photo-coupled parallel I/O interface. One connector is provided for the CS's to or from which the robot vehicle transfers a cassette at the same stopping position.

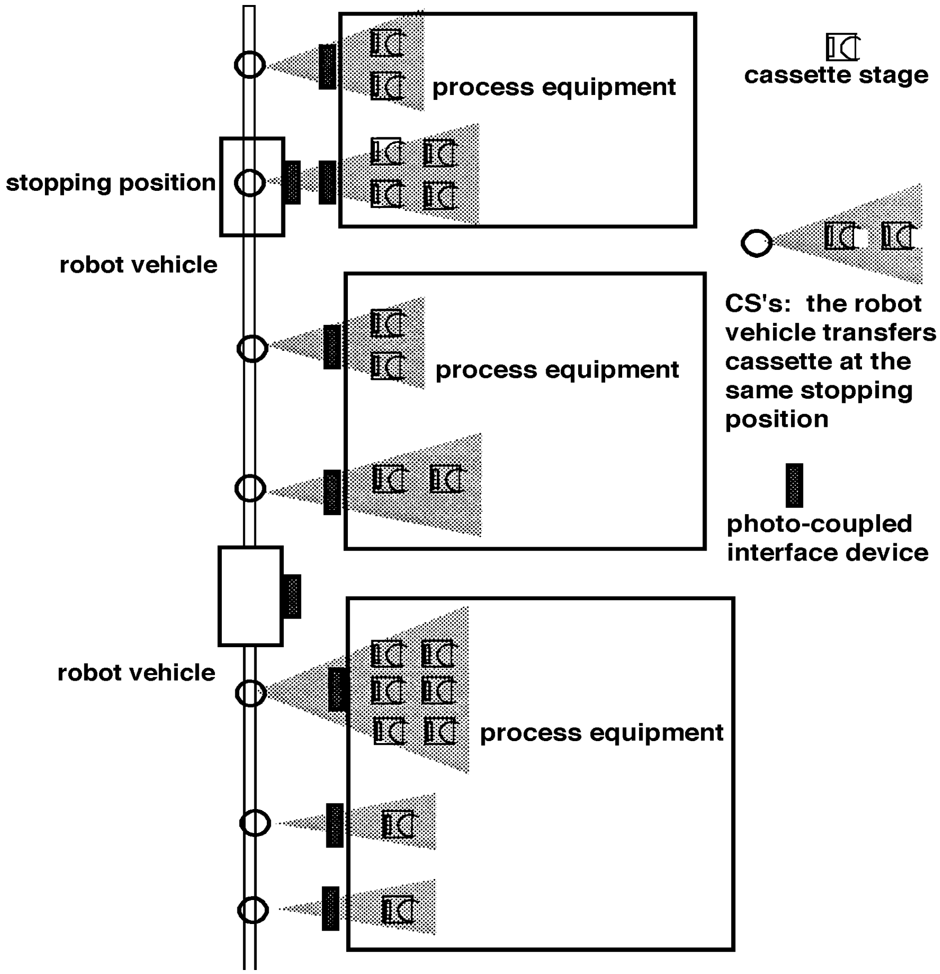
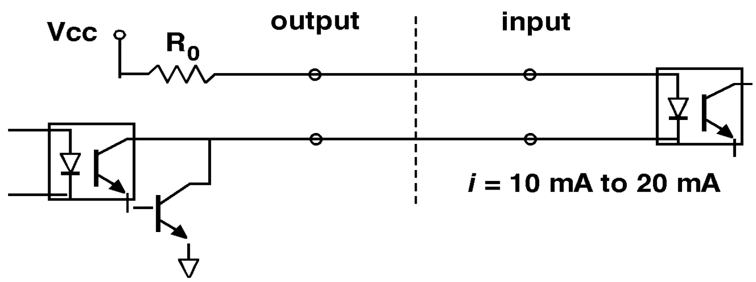


Figure R2-2
Application Example of the Photo-Coupled I/O Interface

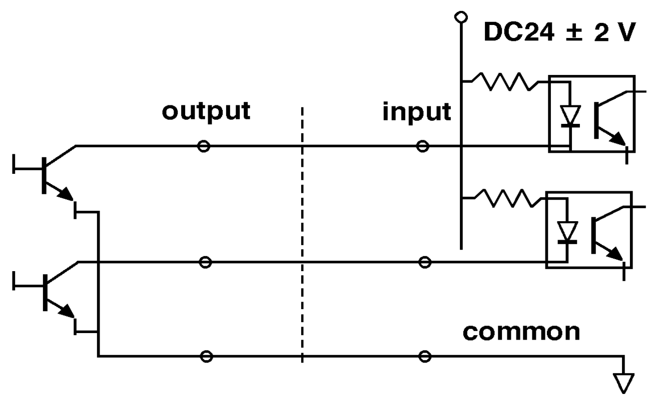
RELATED INFORMATION 3
INTERFACING CIRCUIT EXAMPLES

NOTE: These examples of interfacing circuit examples are not an official part of this document and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

Figure R3-1 shows typical examples of the two types of the interface circuits for the wire-connected interface.



Current-Driven Type Circuit Example



Voltage-Driven Type Circuit Example

Figure R3-1
Interface Circuit Examples for Wire-Connected Interface

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SEMI E24-92 (Reapproved 0699)
CLUSTER TOOL MODULE INTERFACE: ISOLATION VALVE INTERLOCKS STANDARD

This standard was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition reapproved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1992.

Minor editorial changes were made to this document to conform to editorial guidelines.

1 Introduction

1.1 *Scope* — This standard requires hardware interlocks that govern the opening and closing of the environmental isolation valve(s) at the interface planes of a cluster tool. This standard applies to all modules of a cluster tool (as defined in SEMI E21).

1.2 *Purpose* — The purpose of this standard is to prevent any opening or closing of the isolation valve(s) which would result in an unsafe condition or possible damage to material or equipment.

1.3 *Impact* — This standard requires cluster tool module suppliers to implement the interlock and to define the conditions that trip the interlock.

2 Referenced Documents

2.1 *SEMI Documents*

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

2.2 *Other Documents*

MIL-C-26500E[1] — General Specification for Connectors — General Purpose, Electrical, Miniature, Circular, Environmental Resisting

3 Requirements

3.1 *Interlock Provision and Use* — Each module joined to another module, across a common interface plane (as defined in SEMI E21), must provide a fail-safe interlock that enables opening and closing of the isolation valve of the other mocule. Each module that has an isolation valve must use the interlock provided by the module it is joined to across their common interface plane.

3.2 *Interlock Trip* — Conditions that trip the interlock must be defined by the module supplier. (See Section R1-1.)

3.3 *Interlock Logic* — The interlock is to consist of two normally open relays and associated actuation circuitry in each module. (See Section R1-2.)

3.3.1 *First Relay* — One relay enables opening of the isolation valve of the attached module. Contact closure indicates a safe condition, enabling valve opening. Contact opening disables valve opening if the valve is closed. Contact opening does not cause the valve to close if the valve is open. (See Section R1-3.)

3.3.2 *Second Relay* — The other relay enables closure of the isolation valve of the attached module. Contact closure indicates a safe condition, enabling valve closure. Contact opening disables valve closure if the valve is open. Contact opening does not cause the valve to open if the valve is closed.

3.3.3 *Monitoring* — Situations can arise where the module A interlock inhibits an operation of the valve on module B, when that valve is already in the inhibited condition. This potential conflict must be detected and resolved within module B. (See Section R1-3.)

3.4 *Contact Rating* — The relay contacts shall be rated for a minimum of 1 A at 24 VDC.

3.5 *Wiring* — Copper wire used in the interlock circuit shall be 0.82 mm^2 cross section (18 AWG) or larger.

3.6 *Interlock Connectors* — Metal shell bayonet-type connectors are specified per MIL-C-26500E as follows: MS24265R18B11SN panel mounted receptacles on each of the modules and MS24266R18B11PN plugs terminating each end of the cable which interconnects the interlock receptacles of two connected modules.

3.7 *Interlock Connector Pinouts*

3.7.1 *Receptacle* — Pins 2 and 3 of the receptacle are connected across the contacts of the relay specified in Section 3.2.1. Pins 5 and 6 are connected to the circuit which enables opening of the module's isolation valve at that interface. Pins 7 and 8 are connected across the contacts of the relay specified in Section 3.2.2. Pins 9 and 10 are connected to the circuit which enables closure of the module's isolation valve at that interface.

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[1] *Military Standards, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.*

3.7.2 *Cable and Plugs* — Pins 2 and 3 of each plug on the interlock cable are connected to pins 5 and 6 respectively of the other plug. Pins 7 and 8 of each plug on the interlock cable are connected to pins 9 and 10 respectively of the other plug. The resulting interlock cable is symmetric.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E24 but was reapproved for publication by full letter ballot procedures on February 28, 1999.

R1-1 Interlock Situations

R1-1.1 Examples are given below, for the different types of modules, of situations in which it might be considered hazardous for a connected module to operate its isolation valve. Note that some of these conditions prevent opening and others prevent closing of the valves. (See Section 3.1.). Module types are defined in SEMI E21. SEMI S2 provides guidance in defining potential safety hazards. It is common practice to detect valve positions and so verify operation, but this is not an interface matter.

R1-1.2 *Transport Module Examples* — The transport module end effector (see SEMI E22) is extended beyond the interface plane. The connected module should not close its isolation valve, as such an operation could damage the end effector.

R1-1.2.1 The transport module is not at an acceptable transfer pressure. Opening the isolation valve of the connected module could result in damage to the valve or wafer.

R1-1.3 *Process Module Examples* — The transport module end effector exclusion volume (see SEMI E22) is obstructed. The transport module should not open its isolation valve and attempt to extend its end effector.

R1-1.3.1 The process module is not at an acceptable transfer pressure. For instance, the module may be at atmospheric pressure for preventive maintenance. The transport module should not open its isolation valve.

R1-1.3.2 An unsafe partial pressure of a hazardous gas exists in the process module. The transport module should not attempt to open its isolation valve.

R1-1.4 *Cassette Module Example* — The cassette port (loading door) is open, indicating the possibility of a person's hand in the cassette module. The transport module should not operate its isolation valve to avoid the possibility of injury to personnel.

R1-2 Illustration of Logic

R1-2.1 The interlock logic is illustrated in Figure A1 and described in Section 3.2. In the figure, the contacts in module B are closed, enabling operation of the isolation valve controlled by module A, while one of the contacts in module A is open, preventing closure of the isolation valve controlled by module B.

R1-3 Interlock Example

R1-3.1 This example elucidates some of the interlock logic described in Section 3.2. In the case described here, the Transport Module (TM) end effector is extended into a Process Module (PM), which is equipped with an isolation valve. This valve is inhibited from closing by the interlock in the TM.

R1-3.2 A situation arises in the PM which results in its interlock inhibiting the opening of the isolation valve (which is already open) on the TM. As specified in Section 3.2.3, the TM detects the interlock change and immediately withdraws its end effector from the PM. The TM interlock enables the closure of the PM isolation valve (which the PM may do if that is the appropriate response to the situation) and the TM can close its isolation valve.

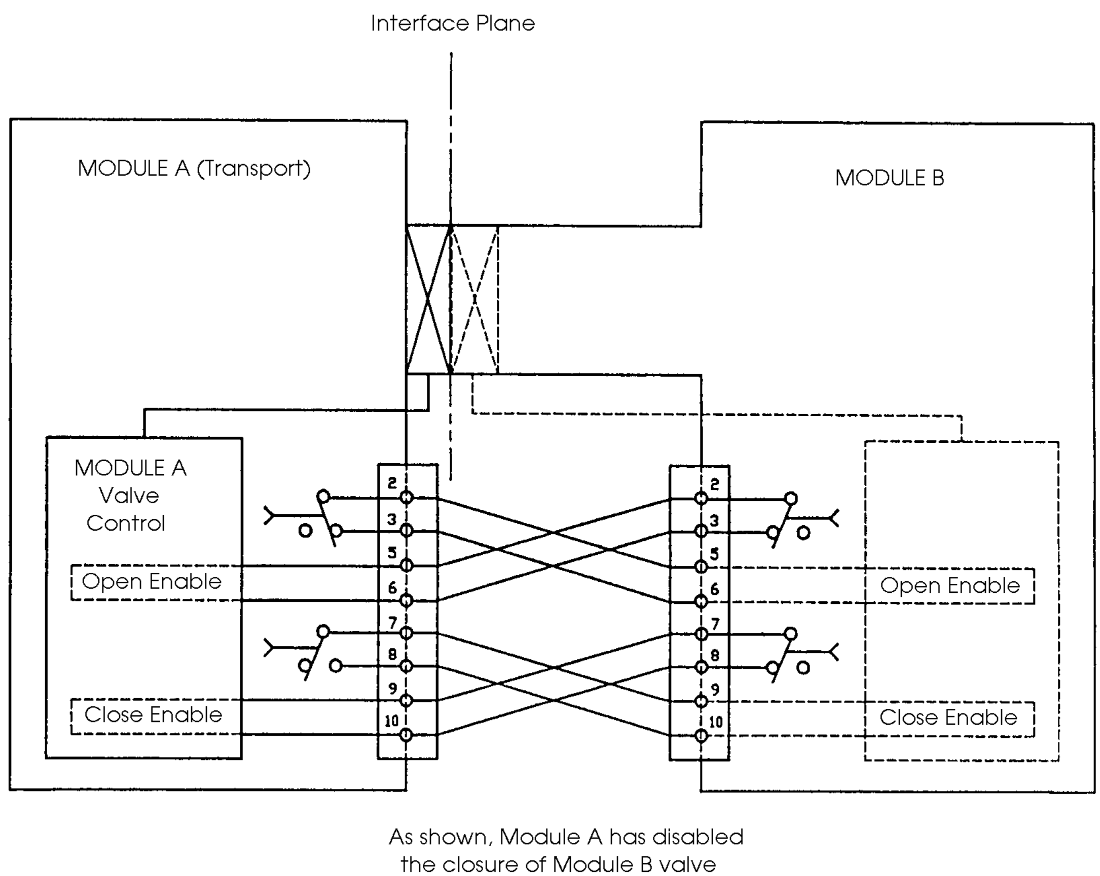

Figure R1-1

Illustration of Isolation Valve Interlock Standard

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These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E25-92 (Reapproved 0699) CLUSTER TOOL MODULE INTERFACE: MODULE ACCESS GUIDELINE

This guideline was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition reapproved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1992.

Minor editorial changes were made to this document to conform to editorial guidelines.

1 Introduction

1.1 *Scope* — This guideline specifies an envelope within which a cluster tool module is situated. Entry and exit locations through the envelope and connection locations to the module for utilities and facility services are recommended.

1.2 *Purpose* — The purpose of the cluster tool module access guideline is to provide assistance in the placement of utilities and facility services to cluster tool modules in order to improve access for maintenance and service and to simplify cluster tool installation.

1.3 *Impact* — This guideline recommends that equipment designs limit the placement of utility lines and facility services to specific portions of the module envelope.

1.4 *Exceptions* — Local safety regulations must always take precedence over this guideline. Local conditions may justify exceptions to this guideline.

2 Referenced Documents

2.1 *SEMI Documents*

SEMI E20 — Cluster Tool Module Interface: Electrical Power and Emergency Off Standard

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

SEMI E24 — Cluster Tool Module Interface: Isolation Valve Interlocks Standard

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

3 Module Envelope

3.1 For the purpose of this guideline, the module envelope is taken to be a set of six surfaces that completely encloses a module. Individual module envelopes may contact but not penetrate adjacent module envelopes. The six surfaces are the inboard and outboard planes, the two sides, the bottom and the top.

3.2 The inboard plane is the interface plane between a transport module and any other module as defined in SEMI E21; thus, a transport module possesses multiple inboard planes. The outboard surface is parallel to the interface plane and normally coincides with that part of the module which is farthest from the interface plane. Each side of the module envelope consists of several vertical planes. The bottom surface generally coincides with the floor, and the top is a horizontal plane that contains the highest point of the module.

3.3 In the sections that follow, the distinction between the physical module and the space reserved for the module within the envelope must be kept in mind. Section 4 refers to where utility lines penetrate the envelope, and Section 5 refers to constraints on where these lines connect to the physical module.

4 Allocation of Module Envelope Surfaces

4.1 The allocation of surfaces is subject to the need for access to the interface plane, module movement, maintenance access space, and protection of module components (particularly electrical components) from liquid leaks.

4.2 *Inboard Plane* — To allow access to the isolation valve(s), no utilities or facility services should be routed through the inboard surface close to the valve boundary. (See SEMI E21) The inboard surface is preferred for intra-tool communications, EMO (see SEMI E20) and the interlock interface between the transport module and the attached modules. (See SEMI E24.)

4.3 *Outboard Plane* — The outboard surface should be limited to non-rigid lines. To minimize potential mechanical damage, chemical utilities should not enter through the lower half of this surface.

4.4 *Sides* — In order to facilitate maintenance access, utilities and facility services should not penetrate the module envelope sides.

4.5 *Top Surface* — The top surface is preferred for power, exhaust, process gases and make-up air. Communications and electronic control harnesses could also enter through this surface.

4.6 *Bottom Surface* — The bottom surface is preferred for vacuum lines and all liquid supplies, returns and drains. The location of all lines should not restrict the removal of the module.

5 Module Considerations

5.1 The locations of utility and facility lines and connections to the module, which is located within the module envelope, are given below.

5.2 *Exhaust, Vacuum and Make-up Air* — The size of piping for exhaust, vacuum and make-up air suggests that the module sides are undesirable locations for connections.

5.3 *Maintenance Access* — Utility and facility lines and connections to the module sides should not compromise maintenance access to the module. Connections should be located above or below areas requiring periodic maintenance access.

5.4 *Liquids* — Liquid supply connections to the module sides should be as low as practical.

5.5 *Electrical Components* — Electrical components that need to be accessible for maintenance while energized should not be located at the sides of the module. (See SEMI S2.)

5.6 *Remote Equipment* — For ease of maintenance access, some pieces of equipment (for example, coolant chiller and RF power supplies) may be located outside the module envelope. In such cases, the lines and connections between the remote equipment and the module should follow this guideline.

6 Examples

6.1 The relationship between the location of specific utility and facility lines entering the module envelope and their subsequent routing and connection to the module within the module envelope is illustrated by the following examples.

6.2 *Liquid Connections* — Two suggested methods of providing liquid connections are shown in Figures 1 and 2. The liquid lines enter through the bottom of the module envelope (see Section 4.5) then connect to either the side of the module or the bottom of the module (see Section 5.3).

6.3 *Gas Connections* — Two suggested methods of providing gas connections are shown in Figure 2. The gas lines pass through the top of the module envelope (see Section 4.4), and then connect to the module either at the top or at the side.

6.4 *Exhaust and/or Make-Up Air* — Two suggested methods of providing exhaust and/or make-up air connections are shown in Figure 2. The exhaust line passes through the top of the module envelope (see Section 4.4) and then connects to the module at or near the top. Exhaust and make-up air connections are flanged in Figure 2.

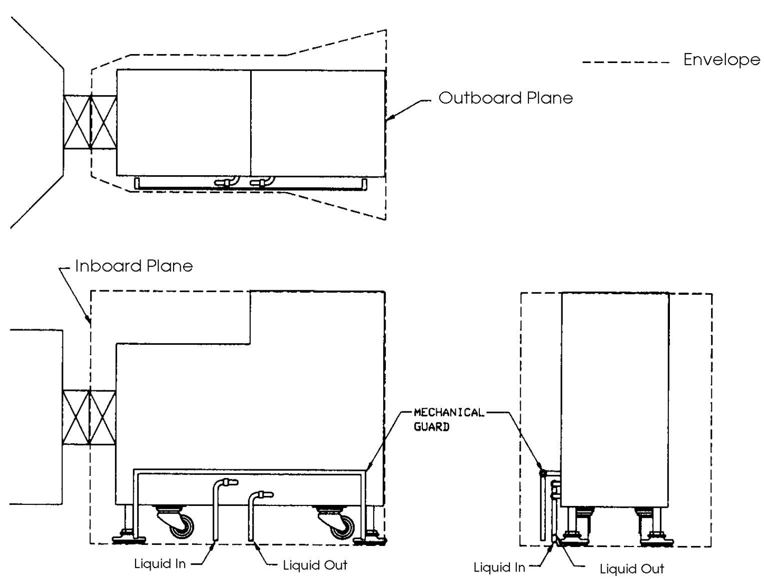

Figure 1

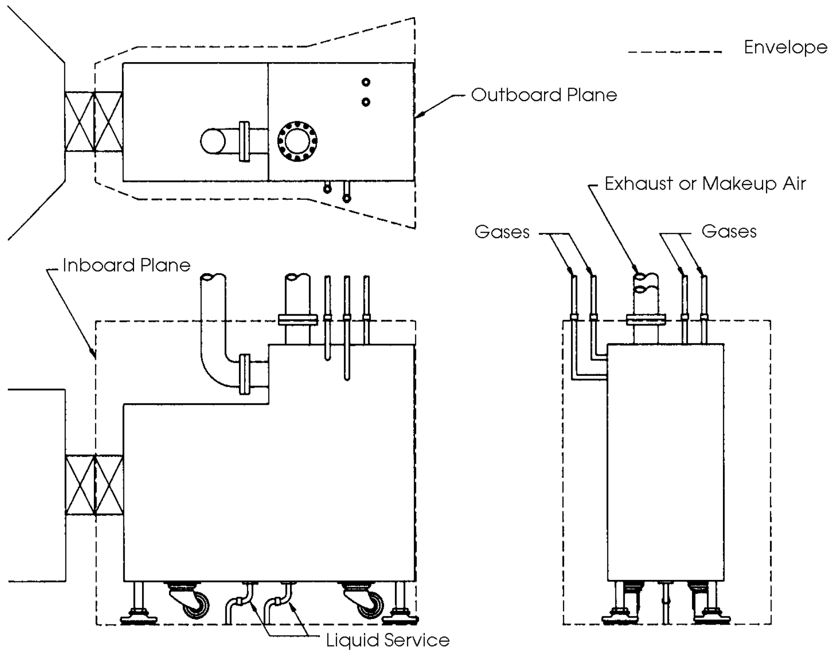

Figure 2

7 Related Documents

7.1 *SEMI Documents*

SEMI E6 — SEMI Facilities Interface Specifications Guideline and Format

SEMI E26 — Radial Cluster Tool: Module Footprint Standard.

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SEMI E26-92 (Reapproved 0699)
RADIAL CLUSTER TOOL FOOTPRINT STANDARD

This standard was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition reapproved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1992.

Minor editorial changes were made to this document to conform to editorial guidelines.

1 Introduction

1.1 *Scope* — The standard specifies the footprints within which the modules of a radial cluster tool must be accommodated and the restricted areas between such footprints. The standard also applies to those portions of nonradial cluster tools that possess radial elements. The standard is limited to wafers 200 mm (8 in.) in diameter or smaller.

1.2 *Purpose* — The purpose of the standard is to ensure that modules from different suppliers can be integrated into a radial cluster tool. It provides design specifications to equipment manufacturers so that physical interference between adjacent modules in a radial cluster tool is avoided and access to all modules of the cluster tool is guaranteed.

1.3 *Impact* — The standard requires equipment designers to ensure that modules attached to a transport module be confined within a specific footprint and its vertical boundaries.

2 Referenced Documents

2.1 *SEMI Documents*

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

SEMI E22 — Cluster Tool Module Interface: Transport Module End Effector Exclusion Volume Standard

SEMI E25 — Cluster Tool Module Interface: Module Access Guideline

3 Definitions

3.1 *radial cluster tool* — A cluster tool (as defined in SEMI E21) in which all wafer transport axes (as defined in SEMI E22) intersect at a common point within the transport module (as defined in SEMI E21).

4 Requirements

4.1 *Module Footprint Description* — The footprint within which modules (as defined in SEMI E21) attached to the transport module must be accommodated is illustrated in Figure 1. The variables are given in Table 1 and defined in Table 2 (see Sections R1-1 through R1-6).

4.2 *Restricted Areas* — Modules shall not intrude upon the shaded region between adjoining module footprints in Figure 1 (see Section R1-7). Furthermore, utilities are restricted from entering the module through the vertical planes bordering the module footprint (see SEMI E25).

4.3 *Restriction on Alpha* — The values of alpha (see Table 1) are restricted to $36° \leq \alpha \leq 90°$ (see Section R1-8).

4.4 *Module Connect and Disconnect* — Space for module connect to and disconnect from the transport module and for any related tools must be provided by the module manufacturer within the boundaries of the module footprint and the adjacent restricted areas. Access from any other module footprint, including that of the transport module, is not allowed (see Section R1-9).

LIST OF TABLES AND FIGURES

Table 1 Modular Footprint Variables

L	Transport module side length
α (alpha)	Angle subtended by a side of the transport module at the common point (see Section 3.1)
a_α	Half-minimum separation of adjacent module footprints
A_R	Half-width of reach area within the restricted area
A_M	Half-width of maintenance access area within the restricted area
W1	Module footprint primary width
W2	Module footprint secondary width
X1	Minimum distance to the interface plane for the module footprint primary width
X2	Maximum distance to the interface plane for the module footprint primary width
X3	Minimum distance to the interface plane for the module footprint secondary width
X4	Maximum distance to the interface plane for the module footprint secondary width

Table 2 Definition of Module Footprint Variables (Units are in mm)

$$L \geq 420.0$$

$$A_R = \frac{1}{2}\left[720.0 + (L - 420.0)\times \sin\left(90 - \frac{\alpha}{2}\right)\right] \quad \text{or} \quad 360.0 + \left(\frac{L}{2} - 210.0\right)\cos\frac{\alpha}{2}$$

$$A_M = A_R + \frac{195.0}{2} \quad \text{or} \quad 457.5 + \left(\frac{L}{2} - 210.0\right)\cos\frac{\alpha}{2}$$

$$a_\alpha = \frac{1}{2}(L - 400.0)\times \sin\left(90 - \frac{\alpha}{2}\right) \quad \text{or} \quad \left(\frac{L}{2} - 200.0\right)\cos\frac{\alpha}{2}$$

$$W1 = 2\times 320.0\times \cos\left(90 - \frac{\alpha}{2}\right) + 400.0 \quad \text{or} \quad 640.0\sin\frac{\alpha}{2} + 400.0$$

$$W2 = 2\times 270.0\times \cos\left(90 - \frac{\alpha}{2}\right) + W1 \quad \text{or} \quad 1180.0\sin\frac{\alpha}{2} + 400.0$$

$$X1 = 320.0\times \sin\left(90 - \frac{\alpha}{2}\right) \quad \text{or} \quad 320.0\cos\frac{\alpha}{2}$$

$$X2 = \left(\frac{720.0}{2} - a_\alpha\right)\times \sec\left(90 - \frac{\alpha}{2}\right) + X1 \quad \text{or} \quad 360.0\,\mathrm{cosec}\frac{\alpha}{2} - \left(\frac{L}{2} - 200.0\right)\cot\frac{\alpha}{2} + 590.0\cos\frac{\alpha}{2}$$

$$X3 = \frac{1}{2}(W2 - W1)\times \tan\left(90 - \frac{\alpha}{2}\right) + X2 \quad \text{or} \quad 360.0\,\mathrm{cosec}\frac{\alpha}{2} - \left(\frac{L}{2} - 200.0\right)\cot\frac{\alpha}{2} + 590.0\cos\frac{\alpha}{2}$$

$$X4 = \frac{1}{2}(915.0 - 720.0)\times \sec\left(90 - \frac{\alpha}{2}\right) + X5 \quad \text{or} \quad 457.5\,\mathrm{cosec}\frac{\alpha}{2} - \left(\frac{L}{2} - 200.0\right)\cot\frac{\alpha}{2} + 590.0\cos\frac{\alpha}{2}$$

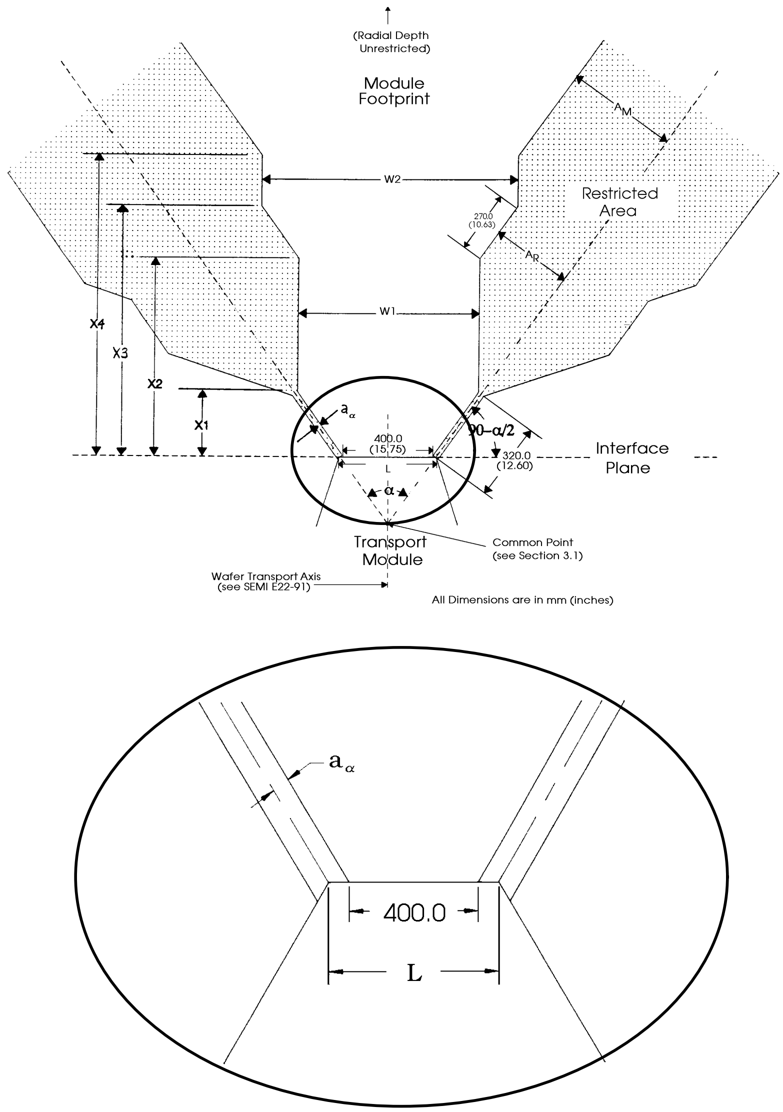

Figure 1
Radial Cluster Tool Module Footprint

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E26 but was reapproved for publication by full letter ballot procedures on February 28, 1999.

R1-1 Alpha Values

R1-1.1 A transport module in the shape of an N-sided regular polygon possesses an alpha value of 360/N (see Section 4.1 and Figure 1).

R1-2 Transport Module Side Length

R1-2.1 The specified transport module side length (L) of 420 mm (16.54 in.) given in Table 2 is a minimum value that will ensure clearance at the interface plane valve (see SEMI E21), assuming a 340 mm (13.39 in.) flange width at the interface plane plus additional clearance for side-mounted clamps. The side length is specified as a minimum value since a single transport module could have various side lengths and/or alpha values. Longer side lengths may ease access to the transport module, but will have the negative impact of increasing the transport module handler extension, which is the distance from the common point (in Figure 1) to the wafer transport position (defined in SEMI E22). For a radial cluster tool with the transport module handler having the "home" position at the common point, the maximum extension in millimeters is related to the side length, alpha, and the transport maximum reach, which is specified as 305 mm (12 in.) in SEMI E21 by:

$$\left(\frac{L}{2}\right) \times \tan\left(90 - \frac{\alpha}{2}\right) + 305$$

R1-3 Evaluation of Footprint Shapes

R1-3.1 Access (see Section 4.1) for a variety of purposes is severely restricted in a radial cluster tool, because all modules converge toward one areR1-Achieving access to clamps at the interface plane and to the module (usually a process module) in proximity to the interface plane is especially difficult. Thus, several footprint shapes were modelled: A radial architecture comprising an N-sided regular polygon transport module with L = 420 mm (see Table 2 and Section R1-2) was used, and the dimensional effects on the module footprint were investigated for $4 \leq N \leq 10$. Anatomical data was used to evaluate access to various parts of the radial cluster tool. The configuration chosen provides a short, fat footprint. It allows maximum freedom for the module designer and accommodates modules near the interface plane without forcing the design of additional wafer transport mechanisms. Guidance in setting W1 and W2 values (see Figure 1) was provided by the need for a single wafer sputter module to be placed directly on an N = 8 regular polygon transport module and a batch processing module with an intermediate "buffer" station on the same transport module.

R1-4 Module Width at Interface Plane

R1-4.1 Although L can be longer than 420 mm (16.54 in.), the module attached to the transport module cannot possess a width greater than 400 mm (15.75 in.) at the interface plane in order to be interchangeable among all transport module interfaces (see Figure 1).

R1-5 Flexibility for Module Suppliers

R1-5.1 Module footprint dimensions (calculated from the expressions in Table 2) and transport module handler extensions (calculated from the expression in Section R1-2) for L = 420 mm and for selected values of alpha are given in Table A1 to provide guidance for weighing design targets. Alpha values corresponding to values of N for an N-sided regular polygon transport module are noted.

R1-5.2 Modules designed for an N = 8 (α = 45º) transport module will fit on any transport module with $N \leq 8$ ($\alpha \leq 45$º), providing for greater flexibility, but possessing a more restrictive footprint, than a module designed for an N = 6 (α = 60º) transport module.

R1-6 Nonradial Cluster Tool Applicability

R1-6.1 An example of a nonradial transport module is shown in Figure R1-1. Sides 1, 3, 4, and 5 of the transport module are equivalent to a radial cluster tool. The standard applies to these four sides (see Section 4.1).

R1-7 Restricted Areas

R1-7.1 Access (see Section 4.2) for maintenance activities that involve the lifting of heavy components or crouching, requires a minimum separation of 2 AM = 915 mm (36 in.) between integrated module hardware (see Table 2). When a width of 915 mm (36 in.) for the entire restricted area was used in the model (see Section R1-3), it became apparent that footprints would comprise narrow corridors. This would force the design of buffer chambers and additional wafer handling mechanisms for many applications. For practical purposes, the concept of a smaller reach area (the hatched region in Figure R1-2), where the module should be detached from the transport module for heavy lifting or crouching tasks, was considered acceptable.

R1-7.2 *Dependence on L* — A transport module side length (L) greater than the minimum value of 420.0 mm will result in a larger restricted area by increasing the half widths A_M, A_R, and a_α beyond their respective minimum values of 457.5 mm, 360.0 mm, and 10×cos[α/2] mm (see Table 2).

R1-7.3 *Restricted Area Temporary Residence* — Equipment such as roll-out drawers or swing-out equipment may temporarily reside in the restricted area (see Section 4.2).

R1-8 Restriction on Alpha

R1-8.1 The maximum value of alpha was based on an N = 4 (α = 90º) regular polygon transport module design (see Section 4.3).

R1-8.2 In order for a module manufacturer to adequately design for access, some knowledge of the adjacent modules must be available. This can be done by setting a minimum value for alpha, which then defines the adjacent footprint leading to the most stringent "half" access area. For the purposes of the standard, the minimum value of alpha was based on an N = 10 (α = 36º) regular polygon transport module (see Figure R1-2).

R1-9 Module Connect and Disconnect

R1-9.1 The number of components and the degree of complexity at the interfaces of a radial cluster tool are high. To ensure non-interference between modules, the concept of an impenetrable wall at the interface plane and adjacent module footprints should be used. Within this area, requirements for module connect and disconnect are the responsibility of the module manufacturer (see Section 4.4).

Table R1-1 Module Footprint Dimensions and Transport Module Handler Extensions*

α(degrees)	a_α*(mm)*	*W1(mm)*	*W2(mm)*	*X1(mm)*	*X2(mm)*	*X3(mm)*	*X4(mm)*	*TMHE**(mm)*
90 (N=4)	7.1	852.5	1234.4	226.3	725.4	916.3	1054.2	515.0
84	7.4	828.2	1188.6	237.8	764.7	965.4	1111.1	538.2
78	7.8	802.8	1142.6	248.7	808.4	1018.2	1173.1	564.3
72 (N=5)	8.1	776.2	1093.6	258.9	857.6	1076.0	1241.9	594.0
66	8.4	748.6	1042.7	268.4	914.0	1140.4	1319.4	628.4
60 (N=6)	8.7	720.0	990.0	277.1	979.8	1213.6	1408.6	668.7
56	8.8	700.5	954.0	282.5	1030.6	1269.0	1476.6	700.0
51.428 (N=7)	9.0	677.7	912.0	288.3	1097.3	1340.5	1585.2	741.1
48	9.1	660.3	879.8	292.3	1155.0	1401.6	1641.3	776.7
45 (N=8)	9.2	644.9	851.6	295.6	1212.2	1461.7	1716.5	812.0
42	9.3	629.4	822.9	298.7	1277.2	1529.3	1801.4	852.1
40 (N=9)	9.4	618.9	803.6	300.7	1325.8	1579.5	1864.6	882.0
38	9.5	608.4	794.2	302.6	1379.3	1634.5	1834.0	914.9
36 (N=10)	9.5	597.8	764.6	304.3	1438.5	1695.3	2010.8	951.3

* Calculated for L = 420 mm

** Transport Module Handler Extension

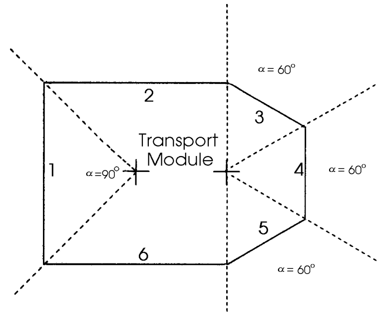

Figure R1-1

Example of Nonradial Cluster Tool Applicability

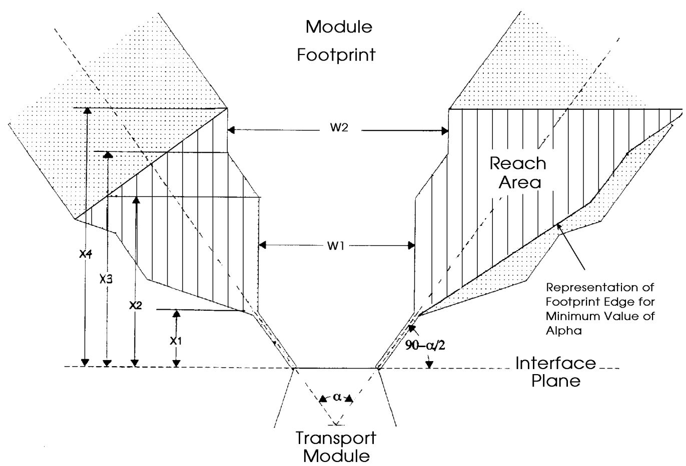

Figure R1-2

Reach Space and Footprint Restrictions

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SEMI E26.1-92 (Reapproved 0699)
RADIAL CLUSTER TOOL FOOTPRINT 300 mm STANDARD

This standard was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition reapproved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1992.

Minor editorial changes were made to this document to conform to editorial guidelines.

1 Introduction

1.1 The standard provides the requirements to extend the limits of applicability of SEMI E26 from 200 mm diameter wafers or smaller to 300 mm diameter wafers or smaller.

2 Referenced Documents

2.1 *SEMI Documents*

SEMI E26 — Radial Cluster Tool Footprint Standard

3 Requirements

3.1 *Fixed Dimensions* — Two of the fixed dimensions given in SEMI E26 are changed (see Section R1-1): The fixed distance along the interface plane is increased from 400.0 mm (15.75 in.) to 500.0 mm (19.69 in.) and the slant distance separating X2 and X3 (see Section R1-2) is increased from 270.0 mm (10.63 in.) to 420.0 mm (16.54 in.).

3.2 *Variables* — The variables given in SEMI E26 are restated in Table 1 to reflect the increase in fixed dimensions (see Sections 3.1 and R1-3).

3.3 *Restriction on Alpha* — The values of alpha are restricted to 45° ≤ α ≤ 90° (see Section R1-4).

Table 1 Definitions of Module Footprint 300 mm Variable (Units are in mm)

$$L \geq 520.0$$

$$a_\alpha = \left(\frac{L}{2} - 250.0\right)\cos\frac{\alpha}{2}$$

$$A_R = 360.0 + \left(\frac{L}{2} - 260.0\right)\cos\frac{\alpha}{2}$$

$$A_M = 457.5 + \left(\frac{L}{2} - 260.0\right)\cos\frac{\alpha}{2}$$

$$W1 = 640.0\sin\frac{\alpha}{2} + 500.0$$

$$W2 = 1480.0\sin\frac{\alpha}{2} + 500.0$$

$$X1 = 320.0\cos\frac{\alpha}{2}$$

$$X2 = 360.0\cos ec\frac{\alpha}{2} - \left(\frac{L}{2} - 250.0\right)\cot\frac{\alpha}{2} + 320.0\cos\frac{\alpha}{2}$$

$$X3 = 360.0\cos ec\frac{\alpha}{2} - \left(\frac{L}{2} - 250.0\right)\cot\frac{\alpha}{2} + 740.0\cos\frac{\alpha}{2}$$

$$X4 = 457.5\cos ec\frac{\alpha}{2} - \left(\frac{L}{2} - 250.0\right)\cot\frac{\alpha}{2} + 740.0\cos\frac{\alpha}{2}$$

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E26.1 but was reapproved for publication by full letter ballot procedures on February 28, 1999.

R1-1 Interface Plane Reach Dimension

R1-1.1 The 320.0 mm slant distance adjacent to the interface plane (see Figure 1 in SEMI E26) accommodates the reach of the human arm and therefore applies to the 200 mm standard and to the 300 mm standard (see Section 3.1).

R1-2 Large Modules

R1-2.1 Large modules such as batch process modules can be accommodated in the region of the module footprint defined by the width W2 (see Figure 1 in SEMI E26). An increase in the slant distance between X2 and X3 from 270.0 mm to 420.0 mm leads to an increase in W2 sufficient to accommodate most large modules (see Section 3.1).

R1-3 Selected Design Data

R1-3.1 The transport module handler extension is the distance from the common point (see SEMI E26) to the wafer transport position (defined in SEMI E22, "Cluster Tool Module Interface: Transport Module End Effector Exclusion Volume Standard"). The maximum extension in millimeters is related to L, alpha, and the transport maximum reach (specified as 380.0 mm in SEMI E21.1, "Cluster Tool Module Interface 300 mm: Mechanical Interface and Wafer Transport Standard") by:

$$\frac{L}{2} \times \cot \frac{\alpha}{2} + 380.0$$

R1-3.2 Transport module handler extensions and module footprint dimensions (calculated from the expressions in Table 1) for selected values of alpha are given in Table R1-1. Alpha values corresponding to values of N for an N-sided regular polygon transport module are noted (see Section 3.2).

R1-4 Restriction on Alpha

R1-4.1 If $\alpha < 45^\circ$ ($N > 8$ for an N-sided regular polygon transport module), process modules must be reduced in size or located further from the interface plane than would be the case for $45^\circ \leq \alpha \leq 90^\circ$.

Table R1-1 Module Footprint Dimensions and Transport Module Handler Extensions*

α(degrees)	a_α	*W1(mm)*	*W2(mm)*	*X1(mm)*	*X2(mm)*	*X3(mm)*	*X4(mm)*	*TMHE**(mm)*
90 (N=4)	7.1	952.5	1546.5	226.3	725.4	1022.4	1160.3	640.0
84	7.4	928.2	1490.3	237.8	764.7	1076.8	1222.5	668.8
78	7.8	902.8	1431.4	248.7	808.4	1134.8	1289.7	701.1
72 (N=5)	8.1	876.2	1369.9	258.9	857.6	1197.4	1363.3	737.9
66	8.4	848.6	1306.1	268.4	914.0	1266.2	1445.2	780.4
60 (N=6)	8.7	820.0	1240.0	277.1	979.8	1343.5	1538.5	830.3
56	8.8	800.5	1194.8	282.5	1030.6	1401.4	1609.1	869.0
51.428 (N=7)	9.0	777.7	1142.1	288.3	1097.3	1475.7	1700.4	919.9
48	9.1	760.3	1102.0	292.3	1155.0	1538.7	1778.4	964.0
45 (N=8)	9.2	744.9	1066.4	295.6	1212.2	1600.3	1855.0	1007.7

* Calculated for L = 520.0 mm

** Transport Module Handler Extension

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SEMI E27-92 (Reapproved 0299)
STANDARD FOR MASS FLOW CONTROLLER AND MASS FLOW METER LINEARITY

This standard was technically reapproved by the Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1992.

1 Purpose

The purpose of this standard is to establish a uniform, worldwide definition of linearity in order to prevent confusion and misunderstanding between manufacturers and users of mass flow devices. A linearity specification is used to allow prediction to a known level of uncertainty, the output of an MFC at points other than those at which its output is known.

2 Scope

The scope is to define the linearity of the mass flow controller (controller with integral flow transducer and control valve) and the mass flow meter (flow transducer only). Terminal-based linearity is used to describe the linearity of MFCs and MFMs.

3 Background

There are three commonly-used methods of describing linearity: independent, zero-referenced, and terminal-based linearity. Terminal-based linearity best describes the performance requirements for MFCs and MFMs because of its ease of application. In addition, it also yields the maximum expression of deviation. See reference documents regarding independent and zero-referenced linearity.

4 Referenced Documents

4.1 *International Electrotechnical Commission (IEC) Standard*[1]

TC-65 — Industrial Process Measurement and Control Terms and Definitions

4.2 *Instrument Society of America (ISA) Standard*[2]

S51.1 — Process Instrumentation Terminology

5 Definitions (See Figures 1 and 2)

5.1 *Actual Flow* — The gas flow as measured by an external standard, not the electrical output of a mass flow meter. (See Section 4.2.)

5.2 *Linearity* — The closeness to which a curve approximates a straight line. It is measured as a non-linearity and expressed as a linearity. (See Section 4.2.)

5.3 *Range* — The region between the limits within which a quantity is measured, expressed by stating the lower and upper range values. (See Section 4.2.)

5.4 *Span* — The algebraic difference between the upper and lower range values.

e.g.,

Range = 4% to 100%, Span = 96%

Range = 0% to 100%, Span = 100%

5.5 *Lower Range Input Value* — Lowest value of input at which the instrument is specified to operate. In mass flow controllers this is zero or the lowest set point at which the instrument is specified. In mass flow meters this is no flow or the lowest actual flow value at which the instrument is specified.

5.6 *Upper Range Input Value* — Highest value of input at which the instrument is specified to operate. In mass flow controllers this is full scale or the highest set point at which the instrument is specified. In mass flow meters this is full scale or the highest actual flow value at which the instrument is specified.

5.7 *Terminal-Based Linearity* — Maximum deviation of the calibration curve from a straight line which intercepts the calibration curve at upper and lower input range values.

6 Significance and Use

6.1 The linearity of a mass flow controller (MFC) is expressed in terms of its actual flow output as a function of the setpoint input (control voltage). (See Figure 2.)

6.2 The linearity of a mass flow meter (MFM) is expressed in terms of its electrical output as a function

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2 Instrument Society of America, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709

of the actual flow (input) through the device. (See Figure 1.)

6.3 Terminal-based linearity shall be used to describe the linearity of MFCs and MFMs. The maximum deviation is expressed as a percentage of the algebraic difference between the output at the upper range value and the output at the lower range value.

$$\text{Linearity} = \pm \frac{d_{MAX}}{O_U - O_L} \times 100$$

where O_U = output at the upper range value

O_L = output at the lower range value

d_{MAX} = maximum deviation

6.3.1 Terminal-based linearity may be expressed as a percentage of some other value (such as a percentage of reading) if it is so identified.

6.3.2 If results are reported using range values other than zero and full scale, the actual range values used in the calculation shall be reported.

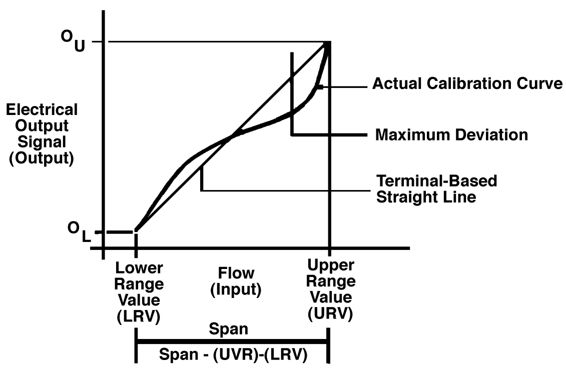

Figure 1
Terminal-Based Linearity for Mass Flow Meter

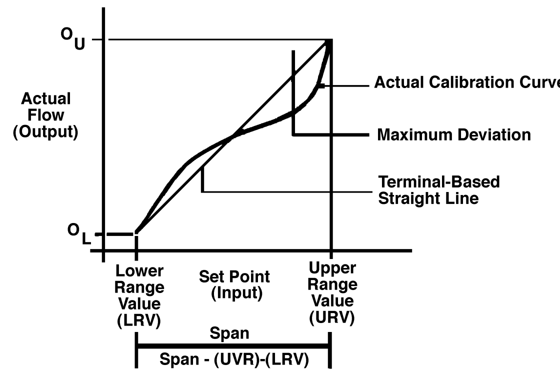

Figure 2
Terminal-Based Linearity forMass Flow Controller

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SEMI E28-92 (Reapproved 0299)
GUIDELINE FOR PRESSURE SPECIFICATIONS OF THE MASS FLOW CONTROLLER

This guideline was technically reapproved by the Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1992.

1 Purpose

The purpose of this guideline is to establish a uniform, worldwide means to describe pressure parameters as they relate to mass flow controllers. It is intended to prevent confusion and misunderstanding between manufacturers and users.

2 Scope

This guideline contains definitions of terms which describe gas pressure in mass flow controllers as used in the semiconductor industry. SI units are the reference units for this document.

3 Applicable Documents

3.1 *SEMI Standard*

SEMI E12 — Standard for Standard Pressure and Standard Temperature for Flow Units Used in Mass Flow Meters and Mass Flow Controllers

4 Definition of Terms

4.1 *units of pressure* — Several units of pressure are commonly used in conjunction with MFC's. The Pascal is the preferred unit of pressure for use within the semiconductor industry. Units of pressure include the following:

— Pascal (Pa)
— Pounds per square inch (psi)
— Torr (T)
— Kilograms per square centimeter (kg/cm^2)
— Bar (B)

NOTE: Units of pressure are sometimes expressed as an equivalent height of a column of some liquid, such as millimeters of mercury or inches of water. These units require correction to some standard for liquid density and gravity. As these corrections are neither broadly standardized nor often even addressed, their use should be avoided.

4.2 *absolute pressure* — The pressure measured relative to zero pressure (perfect vacuum). (See Figure 1.)

NOTE: Absolute pressure is the pressure illustrated by the ideal gas law, PV = nRT. For example, when the number of moles, n, equals zero (no molecules), absolute pressure, P, equals zero. To indicate unambiguously that a pressure measurement is absolute, the following abbreviations should be used:

Pa — Pascal (absolute assumed)
psi (a) — Pounds per square inch, absolute
Torr — Torr (absolute assumed)
kg/cm^2(a) — Kilograms per square centimeter, absolute
B (a) — Bar, absolute

Units such as Pascal and Torr are customarily absolute units.

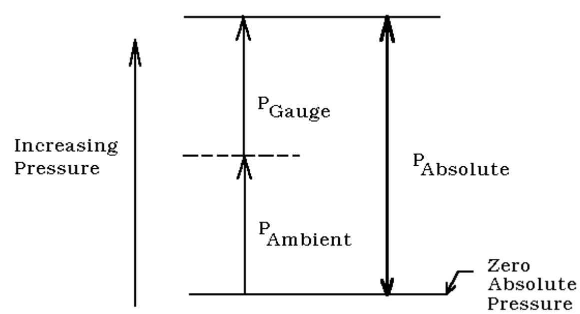

Figure 1
Relationship Between Absolute, Gauge, and Ambient Pressure

4.3 *differential pressure* — The difference in absolute pressure between two points of measurement in a system. (See Figure 2.)

NOTE — To indicate unambiguously that a pressure measurement is differential, the following abbreviations should be used:

Pa (d) — Pascal, differential
psi (d) — Pounds per square inch, differential
Torr (d) — Torr, differential
kg/cm^2(d) — Kilograms per square centimeter, differential
B (d) — Bar, differential

4.3.1 Gauge pressures may also be used in the differential pressure calculation if consistency is maintained. A common error would be to take the difference between an inlet gauge pressure and an outlet absolute pressure without first converting to common units.

4.3.2 As it applies to an MFC, differential pressure is usually the measured difference in pressures between the gas inlet and outlet fittings of the MFC.

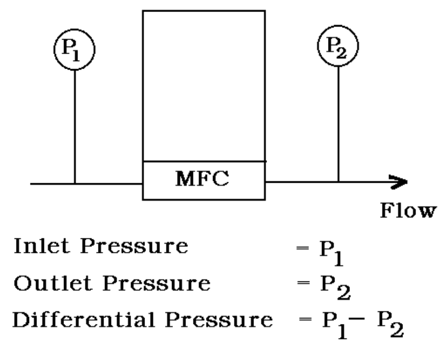

Figure 2
Definition of Differential Pressure for MFCs

4.4 *ambient pressure* — The absolute pressure of the medium surrounding the MFC. (See Figure 3.)

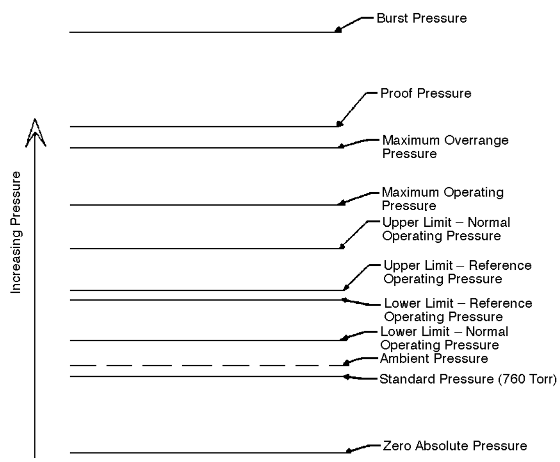

Figure 3
Pressure Definitions for MFCs

4.5 *reference ambient* — The composition and pressure range of the ambient medium surrounding the MFC within which performance specifications apply without requiring correction for changes in the ambient medium.

4.6 *gauge pressure* — The differential pressure measured relative to ambient pressure. For example, when the pressure within a system equals the prevailing ambient pressure, the gauge pressure equals zero. (See Figure 1.)

NOTE — To indicate unambiguously that a pressure measurement is gauge, the following abbreviations should be used:

Pa (g) — Pascal, gauge

psi (g) — Pounds per square inch, gauge

Torr (g) — Torr, gauge

kg/cm^2 — Kilograms per square centimeter, gauge

B (g) — Bar, gauge

NOTE : The performance of MFCs can vary significantly with gas density. Atmospheric pressure varies with the weather and altitude at various geographical locations. Gauge pressure units commonly reference atmospheric pressure. Therefore, the same gauge pressures measured at different geographical locations may correspond to different gas densities. For this reason, the use of gauge pressure units with MFCs can be imprecise and should be avoided.

4.7 *inlet pressure* — The pressure at the inlet fitting of the MFC. (See Figure 2.)

4.8 *outlet pressure* — The pressure at the outlet fitting of the MFC. (See Figure 2.)

NOTE: To completely specify the pressure operating environment for MFCs, at least two of the following three pressures must be listed: inlet, outlet, and differential.

4.9 *MFC calibration pressure, inlet and outlet* — The inlet and outlet pressure at which the MFC was calibrated. (See Figure 3.)

4.10 *reference operating pressure, inlet and outlet* — The range of gas pressures on the inlet of the MFC and across the MFC within which performance specifications apply without requiring correction for gas pressure effects. (See Figure 3.)

4.11 *normal operating pressure, inlet and outlet* — The pressure range within which the MFC meets its stated performance specifications. (See Figure 3.)

4.12 *normal operating differential pressure* — The range of differential pressure (see Section 4.3) required by the MFC to meet its stated performance specifications.

NOTE: The upper and lower limits are dependent upon the absolute inlet or outlet pressure. These limits are manufacturer-specific.

4.13 *maximum operating pressure* — Operation is permitted up to this inlet pressure, but performance is not specified above normal operating pressure. (See Figure 3.)

4.14 *maximum overrange pressure* — The maximum gas pressure to which the MFC may be subjected without degrading specified performance. When returned to normal operating pressure, the MFC must require no adjustment to return to specified performance. (See Figure 3.)

4.15 *proof pressure* — The maximum gas pressure the MFC may be subjected to without permanent damage. Some adjustment may be necessary to make it meet its specified performance when returning to normal operating pressure. (See Figure 3.)

4.16 *burst pressure* — The gas pressure at which the MFC may rupture.

4.17 *standard pressure* — SEMI E12 defines standard pressure as 760 Torr (101.32 kPa). (See Figure 3.)

5 Gas Pressure Effects

5.1 *Specified Gas* — Gas pressure effects may be gas species sensitive. The gas must be specified when stating gas pressure effects. Nitrogen is recommended as the standard gas.

5.2 *Pressure Measurement Point* — In this section, pressure is assumed to be measured at the fitting of the MFC, inlet or outlet, that is adjacent to the flow transducer.

5.3 *Total Calibration Effect* — The change in output, including zero and span, due to a change in gas pressure from one normal operating pressure to a second normal operating pressure. All other conditions must be held within the limits of reference operating conditions.

5.4 *Zero Calibration Effect* — The change in zero due to a change in gas pressure from one normal operating pressure to a second normal operating pressure. All other conditions must be held within the limits of reference operating conditions. (See Figure 4)

5.4.1 The effect of gas pressure change on zero may be expressed as a coefficient calculated as the ratio of full-scale percent change in output to the corresponding change in gas pressure. The change in gas pressure should be specified. This coefficient is defined as the "pressure coefficient of zero."

EXAMPLE — Pressure coefficient of zero may be expressed as:

$$\frac{0.2\% \text{ of full scale}}{240 \text{ kPa} - 220 \text{ kPa}} = 0.01\% \text{ of full scale/kPa with } N_2$$

NOTE: If the relation between gas pressure and change in output is linear, one coefficient will suffice.

5.4.2 If the gas pressure influence is non-linear, a different method of expression may be used. Two examples:

1) The percent of full-scale change in output will not exceed a specified value for any value of gas pressure within a specified gas pressure range.

EXAMPLE — "± 0.15% of full-scale maximum error over 200 kPa to 250 kPa with N_2"

2) It may be desirable to state a series of coefficients for successive increments of gas pressure within a specified gas pressure range.

5.5 *Span Calibration Effect* — The change in span due to a change in gas pressure from one normal operating pressure to a second normal operating pressure. All other conditions must be held within the limits of reference operating conditions. (See Figure 4.)

5.5.1 The effect of gas pressure change on span may be expressed as a coefficient calculated as the ratio of percent of reading change in output to the corresponding change in gas pressure. The change in gas pressure should be specified. This coefficient is defined as the "pressure coefficient of span."

EXAMPLE — Pressure coefficient of span may be expressed as:

$$\frac{0.1\% \text{ of reading}}{240 \text{ kPa} - 220 \text{ kPa}} = 0.005\% \text{ of reading/kPa with } N_2$$

NOTE: If the relation between gas pressure and change in output is linear, one coefficient will suffice.

5.5.2 If the gas pressure influence is non-linear, a different method of expression may be used. Two examples:

1) The percent of span change in output will not exceed a specified value for any value of gas pressure within a specified pressure range of a particular gas.

EXAMPLE — "± 0.1% of reading maximum error over 200 kPa to 250 kPa with Nitrogen"

2) It may be desirable to state a series of coefficients for successive increments of gas pressure within a specified pressure range.

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SEMI E29-93 (Reapproved 0299)
STANDARD TERMINOLOGY FOR THE CALIBRATION OF MASS FLOW CONTROLLERS AND MASS FLOW METERS

This standard was technically approved by the Global Faclities Committee and is the direct responsibility of the North American Facalities Committee. Current edition approved by the North American Regional Standards Committee on October 1998. Initially available at www.semi.org February 1999; to be published Febrauray 1999. Originally published 1993.

1 Purpose

This standard defines terms commonly used in the calibration of mass flow controllers (MFC) and mass flow meters (MFM). It is intended to provide for worldwide terminology to be used by manufacturers and users.

2 Scope

This standard defines terminology related to MFC/MFM calibration. At present, there are often several words used by the semiconductor industry to describe the same concept or device. This standard is intended to eliminate confusion and provide for a common language which users and manufacturers can employ to discuss MFC/MFM calibration.

3 Limitations

This standard attempts to provide basic definitions. In some instances, it may be impossible to provide definitions which thoroughly explain a concept. It is suggested, in such instances, that the user consult other sources or SEMI standards related to this topic.

4 Related Standards/Documents

SEMI E12 — Standard for Standard Pressure and Standard Temperature for Flow Units Used in Mass Flow Meters and Mass Flow Controllers

5 Referenced Documents

SEMI E18 — Guideline for Temperature Specifications of the Mass Flow Controller

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

6 Terminology

6.1 *attitude* — For mass flow controllers and mass flow meters, the relationship between the base mounting plane of the MFC, the gas flow direction and the gravity vector. It may be stated as horizontal (base down), vertical (inlet up), vertical (inlet down), horizontal (upside down), or horizontal (either side down).

6.2 *calibration gas* — For mass flow controllers and mass flow meters, the gas which is flowed while the device is being calibrated.

6.3 *calibration temperature* — For mass flow controllers and mass flow meters, the ambient temperature at which the device is calibrated. (SEMI E18)

6.4 *mass flow controller (MFC)* — A self-contained device, consisting of a mass flow transducer, control valve, and control and signal-processing electronics, commonly used in the semiconductor industry to measure and regulate the mass flow of gas.

6.5 *mass flow meter (MFM)* — A self-contained device, consisting of a mass flow transducer and signal-processing electronics, commonly used in the semiconductor industry to measure the mass flow of gas.

6.6 *molar flow* — The number of moles per unit of time flowing in a closed channel.

6.7 *nameplate gas* — For mass flow controllers and mass flow meters, the gas, as labeled on the product, intended to be controlled or measured.

6.8 *primary flow standard* — A device or system which measures flow using a method based on some or all of the primary measurements of length, time, temperature, volume, pressure, or mass.

6.9 *process gas* — For mass flow controllers and mass flow meters, the principal gas which the user requires the device to control or measure.

6.10 *standard pressure* — The pressure in pascals specified as a reference for measurement and comparison. It is defined for use in the semiconductor industry as 101.32 kilo pascals (760 torr).

6.11 *standard temperature* — The temperature, in degrees Celsius, specified as a reference for measurement and comparison. It is defined for use in semiconductor industry as 0.0°C.

6.12 *standard volumetric flow* — For mass flow controllers and mass flow meters, the calculated volumetric flow, at standard temperature and pressure, of gas in a closed fluid channel. Volume at standard temperature and pressure assumes the ideal gas law, PV=nRT. Units of standard volumetric flow are commonly used to express mass flow in mass flow controllers and mass flow meters.

6.13 *surrogate gas* — For mass flow controllers and mass flow meters, a gas intended to simulate the calibration characteristics of another gas.

6.14 *transfer standard* — For mass flow controllers and mass flow meters, a device typically calibrated against a primary standard which can guarantee sufficient accuracy to, in turn, calibrate another device.

6.15 *warm-up time* — For mass flow controllers and mass flow meters, the time required, after going from an unpowered to a powered state, for the device to achieve sufficient electrical and thermal stability such that rated performance specifications can be met.

SEMI E31-93
SPECIFICATION FOR ELECTRICAL INTERFACE, JAPAN ONLY

NOTE: For U.S. electrical interface requirements, see SEMI E7.

1 Introduction

1.1 *Purpose* — The purpose of this standard is to ensure common electrical interfaces that fulfill the requirements of equipment suppliers and users in the Japan region and to ease the design and functionality of semiconductor equipment manufacturing facilities in the future.

1.2 *Scope* — This standard recommends electrical interfaces for selected power supplies as follows:

— Facilities-Systems Motors and electrical loads having various voltages, currents, and phases

— Electrical connectors

— Cords/cables

2 Referenced Documents

2.1 *JIS-C-8303* — Japanese Industrial Standard[1]

2.2 *JCS 168C-73* — Japanese Cable Standard[2]

JEAC-78 — Japanese Electrical Association Committee[3]

3 Facilities

3.1 *Motor*

Power (W)	*Phase/Voltage*	*JEAC-78 Specified Current (A)*
35 to 400	1P 100 V 1P 200 V	2.2 to 9.5 1.1 to 4.4
200 to 3700	3P 200 V	1.8 to 17.4
200 to 7500	3P 400 V	0.9 to 17

Note: Specified currents are 0.9 times each current, respectively, in the case of 110 V/220 V/440 V. Direct current motors are excluded.

3.2 *Voltage, Current, and Phase of Electrical Loads (for calculation)*

Power (W)	*1P 100V*	*1P 200V*	*3P 200V*	*JEAC-78 3P 400V*
0 to 3000	0 to 30A	0 to 15A	0 to 8.7A	
3000 to 5000		15 to 25A	8.7 to 14.5A	
5000 to 30000			14.5 to 87A	
30000 or more			88A or more	44A or more

Note: Specified currents are 0.9 times each current respectively, in the case of 110V/220V/440V.

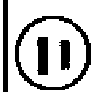
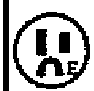
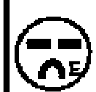
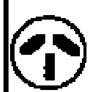
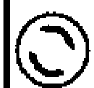
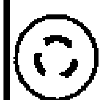
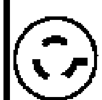
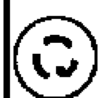
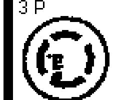
1 Japan Standard Association, 4-1-24 Akasaka, Minato-ku, Tokyo

2 Japan Cable Industry Association, 1-12-22 Tsukiji, Chuo-ku, Tokyo

3 Japan Electrical Association, 1-7-1 Yurakucho, Chiyoda-ku, Tokyo

4 Electrical Connectors (shown as receptacle)

JIS-C-8303

Current	Resisting Voltage					lock type		
		2 P	2 P Grd	3 P	3 P Grd.	2 P	3 P	2P/3P Grd
15A	125V							
15A	250V							
10A 15A	250V 125V							2 P 
20A	250V							3 P 
30A	250V							3 P 

Note: Direct terminal connections are used for most fixed facilities and loads, which require higher current than the value specified above. 30A/250V shows at reference which is specified by the NEMA standards L6-30R and L15-30R.

5 Cable Current Tolerances

Key:

VV	Vinyl insulation, vinyl sheathed cable
CV	Construction polyethylene insulation, vinyl sheathed cable

JCS 168C-73 Unit (A)

		1.0Ø	2.0Ø	2sq	3.5sq	5.5sq	8sq	14sq	22sq
VV	*	11	14	19	28	38	47	67	91
	**	10	12	18	25	33	42	60	79
	***	9	10	15	22	29	37	53	70
CV	*	16	23	33	46	59	74	105	135
	**	17	20	28	40	52	66	94	125
	***	14	17	24	34	45	56	79	105

* Single Conductor Three Cables
** Twin Conductors One Cable
*** Three Conductors One Cable

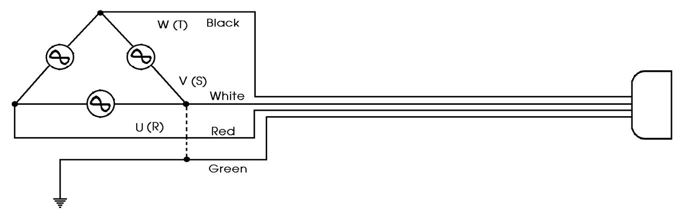
Note: The above specification is for cable in conduit in air. Current tolerance of CV is different than that of VV due to the difference in temperature tolerances (VV/60°C and CV/90°C).

Ø: Diameter of Conductor (mm)

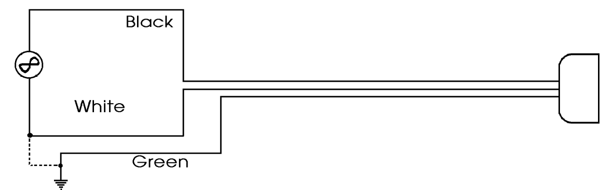
Sq: Cross-Sectional Area of Conductor (mm2)

APPENDIX

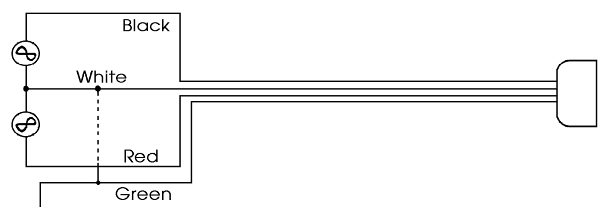
Examples of Wire Connection of Power Supply in Japan



2) 1 P 2w 2w (AC100)

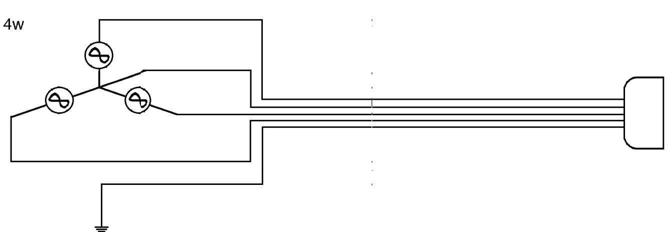


3) 1 P 3w (AC100, 200V)

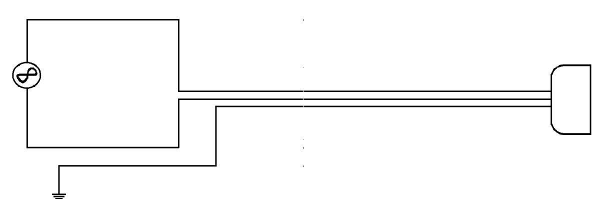


Examples of Wire Connection of Power Supply in United States (Reference)

1) 3 P 4w



2) 1 P 2w



Notes: White wire connected at the grounded side. [White is also used for a neutral line (grounded side) in the U.S.] A single green wire other than a cable is typically used for ground. In the case of a single wire, sometimes a black wire is substituted for blue. - - - - indicates that the wires are normally grounded, with some exceptions. There are no special rules regarding colors of wires except a wire used for ground (green). However, the figure shows common examples in Japan.

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SEMI E33-94
SPECIFICATION FOR SEMICONDUCTOR MANUFACTURING FACILITY ELECTROMAGNETIC COMPATIBILITY

NOTICE: This standard does not purport to address safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to the use.

1 Introduction

1.1 *Purpose* — The purpose of this specification is to assure that semiconductor manufacturing facilities and the equipment used for manufacturing semiconductor devices will operate together reliably without failures caused by electromagnetic interference or electrostatic discharge. This goal is generally known as "electromagnetic compatibility" or EMC.

1.2 *Scope* — This specification applies to facilities and equipment constructed for the purpose of manufacturing semiconductor devices including all facilities alarm, safety, communications and control systems, processing equipment, metrology equipment, automation equipment, and information technology equipment.

1.3 *Limitations* — This specification does not apply to the equipment and facilities used for the assembly and functional testing of integrated circuits. This specification does not apply to process-specific charging that may occur to semiconductors under manufacture.

2 Referenced Documents

2.1 *ANSI, C63.4-1991*[1] — American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

2.2 *CISPR, Publication 22, 19852*[2] — Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment

2.3 *CENELEC, EN 55 022, 1987*[2] — Modifications to CISPR 22

Draft British Standard EN 50 082-2[3] — Electromagnetic Compatibility — Generic Immunity Standard: Industrial (CLC/TC 110 (Sec) 44)

2.4 *Emerald Book*[1] — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment, IEEE, 1992

2.5 *EOS/ESD Association Advisory for Electrostatic Discharge Terminology*[4] — Glossary, 1992

2.6 *FIPS (Federal Information Processing Standards) Publication 94, 21 September 1983*[5] — Guideline on Electrical Power for ADP Installations

2.7 *IEC 801-2, Second Edition, 1991-04*[2] — Electrostatic Discharge Requirements

2.8 *IEC 801-3, First Edition, 1984*[2] — Radiated Electromagnetic Field Requirements

2.9 *IEC 801-4, First Edition, 1988*[2] — Electrical Fast Transient/Burst Requirements

2.10 *IEC TC 65 (Sec.) 137 (801-5) Committee Draft, July 1992*[2] — Surge Immunity Requirements

2.11 *IEC TC 65 (Sec.) 144 (801-6) Committee Draft, February 1992*[2] — Immunity to Conducted Disturbances Induced by Radio Frequency Fields above 9 kHz.

3 Terminology

3.1 *earth port* — European term for an equipment ground. This term is used extensively in the basic standards.

3.2 *electromagnetic compatibility (EMC)* — The ability of electronic equipment to function properly with respect to environmental EMI and ESD.

3.3 *electromagnetic interference (EMI)* — Any electrical signal in the non-ionizing (sub-optical) portion of the electromagnetic spectrum with the potential to cause an undesired response in electronic equipment.

1 *IEEE Service Center, 445 Hoes* Lane, P.O. Box 1331, Piscataway, NJ 08855.

2 Sales Department of the Central Office of the IEC, P.O. Box 131, 3, Rue de Varembe, 1121 Geneva 20, Switzerland. Some of the IEC publications are available from the Sales Department, American National Standards Institute, 11 W. 42nd Street, New York, NY 10036.

3 Sales Administration (Drafts), BSI, Linford Wood, Milton Keynes MK 14 6LE, United Kingdom.

4 EOS/ESD Association, Inc., 200 Liberty Plaza, Rome, NY 13440.

5 National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

3.4 *electrostatic discharge (ESD)* — The transfer of electrostatic charge between bodies at different electrostatic potentials.

3.5 *ELF* — Extremely low frequency (about 1 Hz to 1 kHz) magnetic fields generated by current flow (most commonly 60 Hz in the U.S. and 50 Hz in Europe) within equipment and facilities.

3.6 *ELF sensitive equipment* — Any equipment whose performance is adversely affected by ELF, such as a scanning electron microscope (SEM).

3.7 *EUT* — Equipment under test.

3.8 *port* — (For purposes of this specification), a particular interface of the specified equipment with the external electromagnetic environment, (see Figure 1).

3.9 *enclosure port* — (For purposes of this specification), the physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.

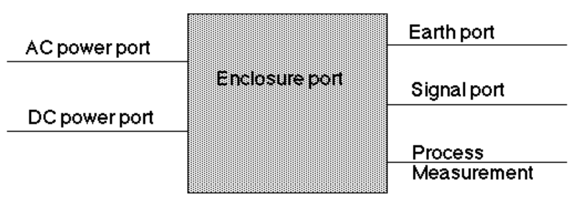

Figure 1

4 Requirements

4.1 *Performance Criteria* — The following are generic failure criteria for the various classes of equipment and electronic systems used in semiconductor manufacturing. However, any kind of failure or aberration during EMC testing shall be noted in the test report.

4.1.1 *Performance Criteria A* — The equipment operates as intended during and after the test. In the case of process equipment, all process results are within specifications. No safety hazards nor false alarms are present. In some cases, the performance level may be replaced by a documented permissible loss of performance if such loss is minor and agreeable to the concerned parties.

4.1.2 *Performance Criteria B* — The equipment operates as intended after the test, but experiences a loss of function or degradation of performance during the test to a level specified by the manufacturer. No change of operating state or loss of stored data is allowed. Restoration of performance or function does not require human intervention.

4.1.3 *Performance Criteria C* — Temporary loss of function is allowed, provided the loss of function is recoverable, either automatically or through operation of the controls. Any failure of control or alarm systems is in a fail-safe mode, such as a false alarm or equipment shutdown.

4.1.4 *Safety Criteria* — Equipment will automatically fail if testing results in an unsafe or potentially unsafe condition, such as threat to life or property. Examples would be failure of an emergency machine off (EMO) button to operate or faulty opening of a toxic gas valve.

4.1.5 *Conditions during Testing* — All EMC testing is to be done with the equipment installed and operational. As much as possible, the test installation should be identical to the final production installation. Substitutes may be used for hazardous gases and chemicals, and other modifications may be made as deemed reasonable to ensure testing can be performed in a completely safe and environmentally acceptable manner. Special EMC facilities are not required by this standard.

5 Test Methods

The tables below are organized by ports to which the tests apply, as defined above. The basic standards provide the test setup and procedures to be followed, except as noted. In all events, EMC testing is intended to prevent EMC problems when the equipment is installed and operating in a semiconductor manufacturing facility. Any modification or interpretation of the test setup and procedure should be judged by this overriding goal.

5.1 *Immunity Tests*

Table 1 Enclosure Ports

	Test Type	*Specification*	*Basic Standard*	*Remarks*	*Performance Criteria*
1.1	ESD immunity	4 kV Contact 8 kV Air discharge	IEC 801-2 (1991)	See Appendices A and B	A
1.2	Radiated immunity Amplitude modulated	10 V/m 450-520 MHz 800-950 mHz 80% AM (1 kHz)	IEC 801-3	See facilities requirements (See Section 5.1.1)	A
1.3	ELF immunity	Level A - E as required	ELF testing (See Section 5.1.2)	Required only of ELF-sensitive equipment	A
1.4	Radiated immunity Pulse modulated	3 V/m 1.89 GHz 50% Duty cycle 100 Hz rep freq.	TC 65 (Sec.) 136 Draft	Europe only Cellular phone band	A

5.1.1 *Facilities Requirements* — Due to the size and complexity of much semiconductor factory equipment, testing in a shielded enclosure, anechoic chamber, or other special facility is not required. If such facilities can be used, the results will be more reproducible and accurate.

Note that radiated immunity testing is required only at frequencies used for mobile communications. As shown in Table 1, Row 1.2. Testing should be conducted in conformance with national and local emission requirements at the frequencies specified (see Appendix D).

5.1.2 *ELF Testing* — The following sensitivity levels are defined:

Level A — ELF of less than 0.25 milliGauss rms
Level B — ELF of less than 0.50 milliGauss rms
Level C — ELF of less than 1.00 milliGauss rms
Level D — ELF of less than 2.00 milliGauss rms
Level E — ELF of 2.00 milliGauss rms and greater

ELF sensitivity is to be determined by applying ELF through a coil or set of coils designed to produce a uniform magnetic field at or near the power-line frequency at the position of maximum ELF sensitivity of the EUT. The direction of the applied field shall be set to produce the maximum disturbance to the EUT. The field level shall be determined using a calibrated ELF meter.

If allowable performance degradation is permitted at the higher ELF levels, the performance shall be specified at each level.

Table 2 Ports for Signal Lines and Short Distance (< 30 m) Data Buses Not Involved in Process Control

	Test Type	*Specification*	*Basic Standard*	*Remarks*	*Performance Criteria*
2.1	Fast transients common mode	1 kV (peak) 5/50 Tr/Th ns 5 kHz rep. frequency	IEC 801-4 Capacitive clamp	Applicable to cables whose length can exceed 3 m	B
2.2	Radio Frequency common mode 1 kHz 80% AM	0.15-100 MHz 3 V (rms) (unmod) 150 Ω source impedance	IEC TC 65 (Sec.) 144	Applicable to cables whose length can exceed 1 m	A

Table 3 Ports for Process, Measurement and Control Lines, and Long Bus and Control Lines

	Test Type	*Specification*	*Basic Standard*	*Remarks*	*Performance Criteria*
3.1	Fast transients common mode	2 kV (peak) 5/50 Tr/Th ns 5 kHz rep. frequency	IEC 801-4 Capacitive clamp		B
3.2	Radio Frequency common mode 1 kHz 80% AM	0.15-100 MHz 3 V (rms) (unmod) 150 Ω source impedance	IEC TC 65 (Sec.) 144	Applicable to cables whose length can exceed 1m	A

Table 4 Input and Output DC Power Ports

	Test Type	*Specification*	*Basic Standard*	*Remarks*	*Performance Criteria*
4.1	Fast transients common mode	2 KV (peak) 5/50 Tr/Th ns 2.5 kHz rep. frequency	IEC 801-4	4 kV (peak) when coupling with capacitive clamp	B
4.2	Radio Frequency common mode 1 kHz 80% AM	0.15-100 MHz 3 V (rms) (unmod) 150 Ω source impedance	IEC TC 65 (Sec.) 144	Applicable to cables whose length can exceed 1 m	A

Note: Direct injection method shall be used if current consumption is less than 100 A. This test is not applicable to input ports intended for connection to dedicated non-rechargeable power supplies.

Table 5 Input and Output AC Power Ports

	Test Type	*Specification*	*Basic Standard*	*Remarks*	*Performance Criteria*
5.1	Fast transients common mode	4 kV (Peak) 5/50 Tr/Th ns 5 kHz rep. frequency	IEC 801-4	4 kV (peak) when coupling with capacitive clamp	B
5.2	Radio Frequency common mode 1 kHz 80% AM	0.15-100 MHz 150 Ω source impedance	IEC TC 65 (Sec.) 144	Applicable to cables whose length can exceed1 m	A
5.3	Surge	4.0 kV	IEC TC 65 (Sec.) 137	Use combination wave test generator:1.2/50 µs open circuit, 8/20 µs short circuit wave form	C

5.2 *Emissions Test*

5.2.1 *EMI Testing Required* — Equipment shall be tested in accordance with CISPR 22 and EN 55 022. Test limits are Class A, which is generally limited to non-residential use.

As noted above for radiated immunity testing, the size and complexity of semiconductor factory equipment may rule out the use of special facilities. Thus, the tests in CISPR 22 may be adapted as required due to test site limitations. Again, use of such facilities will yield more reproducible and accurate data, and is recommended whenever possible.

In any event, emissions greater than 6 dB above the Class A limits are not allowed.

5.2.2 ELF Testing Required — ELF emission testing is required for all ELF-sensitive equipment, since such equipment is commonly grouped together. ELF emission testing for other types of equipment is required on request of a purchaser intending installation of ELF-sensitive equipment in the immediate vicinity.

ELF emissions shall be measured using a calibrated ELF meter. Equipment emissions shall be measured at a distance of 1.5 meters from the entire perimeter of the EUT at a height of 1 meter. Facility ELF shall be measured at a height of 1 meter in the region where ELF-sensitive equipment installation is intended. Measurement points shall be no greater than 0.5 meter apart in the regions specified above. Facilities electrical systems and adjacent equipment should be in normal operation to assure accurate measurement of the actual operating environment.

At each measurement point, the ELF sensor should be oriented to produce the maximum reading. The maximum from all the measurement points is then used to determine the level from the table below:

Level A — ELF of less than 0.25 milliGauss rms

Level B — ELF of less than 0.50 milliGauss rms

Level C — ELF of less than 1.00 milliGauss rms

Level D — ELF of less than 2.00 milliGauss rms

Level E — ELF of 2.00 milliGauss rms and greater

6 Equipment Installation and Grounding

Special installation, power, and grounding requirements necessary to meet this standard shall be thoroughly documented by the equipment supplier. FIPS Publication 94 and the IEEE Emerald Book are suggested sources of information for recommended practices in this area.

Removable shielded panels or doors that must be properly secured to meet this standard should be labeled "SECURE THIS PANEL TO REDUCE ELECTROMAGNETIC EMISSIONS." This labeling requirement is not applicable to interlocked panels that must be in place for the equipment to operate.

7 Documentation

Upon request of the purchaser a report of the test results against this standard shall be furnished. Similarly, the supplier may use this standard as a reference in specifying the environmental requirements of equipment.

8 Alternate Testing

Testing completed under a different, but substantially similar standard may be substituted for the basic standards specified herein if the performance criteria and test levels are similar to those above. Such substitution shall be noted in the test report, and must be agreed to by the concerned parties. Examples include substitution of ANSI C63.4-1991 testing for CISPR 22.

Similarly, equipment which satisfies the European EMC Directive and bears the CE mark meets this specification.

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APPENDICES

The appendices are not an official part of this standard. However, they contain relevant information for customizing the basic standards for testing of semiconductor equipment and facilities, and point out areas of concern for which no standard currently exists.

A.1 Appendix A: Charged Wafer Testing

Due to overriding microcontamination concerns, non-static-dissipative wafer carriers must be used during semiconductor fabrication. It is suggested that any equipment which handles wafers be tested with wafers charged to 18 kV/in. The charge generator used for 801-2 testing can be used to charge the wafer. Some experimentation will be required to determine the best means to carry out this test. Alternately, the handling mechanism may be challenged by air or contact discharge directed to the mechanism.

It is suggested that wafer handlers be designed to dissipate charge on incoming wafers in a controlled, non-sparking manner. A simple AM radio tuned between stations and placed near the handler has been found to be a good qualitative means to detect sparking. Sparking will result in pops and static being heard on the radio.

A.2 Appendix B: ESD Test Methods

Although the contact method of ESD testing has been found to be much more reproducible than the air discharge, the air discharge is a more realistic simulation of possible events that can occur in the semiconductor factory. Also, the air discharge method is the only realistic way to test objects that are primarily fabricated from insulators, such as wet stations and keyboards.

In addition to testing surfaces that come in contact with humans and wafers, it is important to test any area of the equipment that can be exposed to ESD. For instance, wet stations are composed of assemblies involving large masses of insulators in proximity to metallic sensors and controllers. It is possible for the insulating surfaces to build up charge, which then sparks to a sensor or controller — all internal to the equipment itself.

A.3 Appendix C: Future Directions

Items in this section are not requirements of this standard, but are included to indicate currently ill-defined goals for further improvements to semiconductor factory EMC.

A.3.1 *Static Charge* — Minimization of static charge promotes cleanliness, and avoids damage to material in process and reticles.

It is suggested that electrostatic fields be held to under 200 V/cm (500 V/in). This would be applicable to personnel, wafers, cassettes, cassette boxes, reticles, reticle boxes, and all equipment and facility surfaces in proximity to these items as well as all surfaces exposed to filtered airflow. Measurements shall be made using a properly-grounded electrostatic field meter in accordance with its manufacturer's instructions.

A.4 Appendix D: National Requirements

A.4.1 *U.S.* — Section 5.1.1 Table 1, row 1.2: Radiated immunity testing outside a shielded enclosure is legally accomplished by obtaining an experimental license from the FCC using FCC form 442. The FCC recommends using techniques such as scanning or hopping to avoid interference.

A.4.2 *Europe* — The earth port: Refer to Table 1.6 of the informative annex to EN 50 082-2 for test requirements applicable to the earth.

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SEMI E34-95
GUIDELINE FOR MASS FLOW DEVICE RETURN

NOTICE: This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Purpose

Mass flow devices (mass flow controllers, mass flow meters and flow control valves) are used as an integral part of the chemical delivery system in semiconductor processing equipment. Many of the chemicals used in semiconductor processes can be hazardous to equipment and personnel. Once exposed to these chemicals, the contaminated mass flow devices can present a hazard to repair personnel and equipment if not handled properly.

Implementing the procedures outlined in this guideline provide a mechanism to reduce the risk associated with shipping and/or receiving any potentially hazardous mass flow device used to monitor or control gases or liquids.

2 Scope

This guideline is intended to:

Recommend and encourage the purging of devices used with hazardous materials prior to removal to reduce the risk of handling them.

Alert the recipient of possibly hazardous mass flow devices to the nature of the hazard.

Establish mechanism for properly identifying and documenting possibly hazardous mass flow devices by using an orange tag and a health and safety disclosure form.

3 Referenced Documents

49 CFR[1] — Title 49 of the Code of Federal Regulations (CFR)

NFPA 704[2] — Standard System for the Identification of Fire Hazards of Materials

1 United States Government Printing Office, Washington, D.C. 20402

2 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

4 Terminology

4.1 *hazardous materials* — Those chemicals or substances that are physical hazards or health hazards as defined and classified in NFPA 704 whether the materials are in use or in waste conditions.

4.2 *mass flow controller (mfc)* — A self-contained device, consisting of a mass flow transducer, control valve, and control- and signal-processing electronics, commonly used in the semiconductor industry to measure and regulate the mass flow of gas.

4.3 *mass flow meter (mfm)* — A self-contained device, consisting of a mass flow transducer and signal-processing electronics, commonly used in the semiconductor industry to measure the mass flow of gas.

4.4 *material safety data sheet (msds)* — Written or printed material concerning a hazardous material which is prepared in accordance with the provisions of 29 CFR 1910.1200.

4.5 *protective container* — A sealable plastic bag or other container which will keep hazardous material from the mass flow device from contaminating the outer package. The container should be transparent, if possible.

4.6 *purge* — To dilute potentially harmful material in the mass flow device by flowing an inert gas through the device. Purging a chemical delivery line containing a mass flow device with an inert substance is intended to dilute hazardous materials and reduce the level of the hazard. To be effective, the inert substance must be able to reach all points within the chemical delivery system in sufficient quantity to dilute the hazardous material to safe levels. The nature of the hazard and the physical configuration of the chemical delivery system must be considered when developing a purge procedure.

4.7 *safe* — Free of conditions that can cause occupational illness, injury, or death to personnel or damage to or loss of equipment or property or the environment.

5 Procedure

5.1 *Disclosure Form*

- Complete the disclosure form for mass flow device return.
- Send the completed form via Fax or other suitable method to the recipient of the mass flow device.

- Attach a copy of the form to the exterior of the shipping container.
- Enclose another copy inside the package attached to the protective plastic bag containing the mass flow device during shipment.
- Retain the original form for your records.

5.2 *Purging Prior to Removal* — Thoroughly purge the mass flow device following the applicable purge procedure. Purge procedures are usually unique to the equipment and installation. Obtain purging procedures from your facilities manager, corporate safety department, and/or the equipment manufacturer. If a formal purge procedure is available, note on the disclosure form the purge procedure document number and source.

5.3 *Equipment Removal* — WARNING: Do not remove the mass flow device until it has been properly purged.

5.3.1 The person removing the mass flow device should fill out an orange-colored device tag indicating the process gas(es) or chemicals used, possible exterior contamination and the purge procedure document number prior to removal of the device. A sample orange device tag is shown in Figure 1.

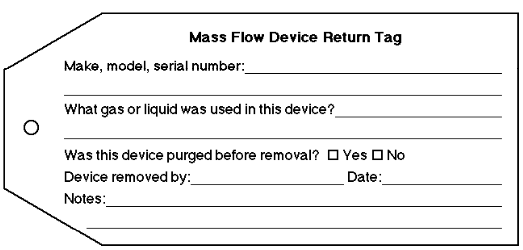

Figure 1

Sample Orange Device Tag

5.3.2 Carefully remove the mass flow device from the installation or system.

5.3.3 The inlet and outlet ports should be sealed to prevent any leakage into or out of the mass flow device.

5.3.4 The person removing the mass flow device should attach the orange tag to the device.

5.4 *Equipment Packaging* — Package all mass flow devices for shipment per government regulations including the following:

5.4.1 Seal the device in a protective container to prevent the contamination of the shipping package. If the orange tag is not visible through the container, an additional tag should be attached to the outside of the container.

5.4.2 Place the device in a shipping container with adequate packing to avoid damage to the device and the protective container during shipment.

5.5 *Shipping* — Ship the device so that it conforms to all applicable regulations of the countries of origin, trans-shipment, and destination governing the shipment of materials.

HEALTH AND SAFETY DISCLOSURE FORM FOR MASS FLOW DEVICE RETURN

1. Mass Flow Device Information

1.1 Manufacturer ____________________________________

1.2 Model Number ____________________________________

1.3 Serial Number ____________________________________

1.4 Nameplate Gas __________ Nameplate Range ___________

1.5 Details of all substances to which the equipment has been exposed, Interior and Exterior:

Chemical name(s) and attach applicable MSDS(s)

	Interior	Exterior
a) ____	o	o
b) ____	o	o
c) ____	o	o
d) ____	o	o
1.6 Was this device purged with an inert gas?	o Yes	o No

1.7 Any further safety information that you consider to be relevant:

____

____

____

1.8 Document number and source of purge procedure used.

____

____

____

1.9 Person to contact regarding the above information:

Name:____

Company:____

Title:____

Phone Number: (_______)__(______)__(__________)_(_____)

Country Code Area Code Number Extension

Address:____

____

____

Signature of Sender:___________________________________

1.10 Carrier to be used

____

Expected Delivery date

____

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SEMI E35-0701
COST OF OWNERSHIP FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT METRICS

This guideline was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1995; previously published February 2000.

1 Purpose

1.1 The purpose of this guide is to provide standard metrics for evaluating unit production cost effectiveness of factory equipment subsystems in the semiconductor industry. The guideline is appropriate for application to any type of equipment processing semiconductor units, which may be wafers, devices, or other material.

1.2 The guideline establishes a well-defined practice to facilitate an understanding of equipment-related costs by providing definitions, classifications, algorithms, methods, and default values necessary to build a full or constrained cost of ownership (COO) calculator. A number of constraint types are defined. Related Information 1 provides some discussion of COO to expand upon the guideline presentation. Default values which can be used in a COO calculation are presented in Related Information 2 to provide representative data. Such default data are not meant to be a substitute for having actual data appropriate to the process being analyzed.

2 Scope

2.1 The definitions provide a metric which can be applied to any factory equipment system, but are specialized to silicon integrated circuit wafer and device production. The guideline is formulated in terms of units which are wafers or wafer equivalents of the devices produced and is thus appropriate to both front-end and back-end considerations. Application specific guidelines based upon this general guideline will be developed in the future and will address particular aspects of various types of equipment, materials, gases, etc.

2.2 Effective use of the metric to build a COO model requires identification of the constraints, parameter values, and data values within the adopted category classification. Default data is provided in Related Information 2 to this document and may be updated periodically through support documents. Where possible, use direct values for inputs rather than deriving them from secondary models or using default values.

2.3 Full calculation of COO often requires data held proprietary and is coupled to the overall factory through yield and the related cost of yield loss. It is envisioned that this guide will be used for internal factory and equipment optimization as well as investment evaluation by IC manufacturers.

2.4 The companion guide, "Guide for Cost of Equipment Ownership Comparison," is intended for competitive evaluation of equipment and is an alternative to the full analysis defined in this guideline. Both guidelines identify elements that are attributable to the equipment and to the operating decisions made by manufacturers in using the equipment.

2.5 Section 7 lists limitations of the guideline.

2.6 This guideline does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Documents*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E35.1 — Guide for Cost of Equipment Ownership Comparison Metric

SEMI Compilation of Terms

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

NOTE 2: Additional definitions are contained in Sections 10 and 11, Classification Element Details.

4.1 *Abbreviations and Acronyms*

4.1.1 *CEO* — Cost of equipment ownership

4.1.2 *COO* — Cost of ownership

4.1.3 *CYL* — Cost of yeld loss

4.1.4 *DLY* — Defect limited yield

4.1.5 *EY* — Equipment yield

4.1.6 *GWE* — Good wafer equivalents

4.1.7 *P/T* — Precision tolerance ratio

4.1.8 *PLY* — Parametric limited yield

4.1.9 *PRY* — Product yield

4.1.10 *PU* — Production utilization

4.1.11 *SR* — Systems required - integer number

4.1.12 *TP* — Throughput

4.1.13 *α* — Type 1 test yield for false bad

4.1.14 *β* — Type 2 test yield for false good

4.2 *Definitions*

4.2.1 *baseline cost of ownership* — a constraint version of cost of ownership which only includes equipment yield, i.e., defect limited yield and parametric limited yield are not included.

4.2.2 *comprehensive cost of ownership* — cost of ownership calculated with no constraints.

4.2.3 *constraint version* — cost of ownership version with a set of defined restrictions to facilitate comparisons or to remove ambiguity. An example is baseline as defined in SEMI E35.1, which excludes defect limited yield and parametric limited yield.

4.2.4 *consumables* — cost of all parts of the equipment that are worn out by the process operation of equipment and require replacement after less than one (1) year of operation.

4.2.5 *cost footprint* — the area (A) of the smallest horizontal rectangle that contains all of the shadow footprint and half of the easement space around a tool. This is computed as:

$$A = \left[Wt + 1/2\left(Ws - Wt\right)\right] * \left[Dt + 1/2\left(Ds - Dt\right)\right]$$
$$= 1/4\left(Wt + Ws\right) * \left(Dt + Ds\right)$$

where:
Dt = Depth of tool
Ds = Combined depth of tool and easement space
Wt = Width of tool
Ws = Combined width of tool and easement space

4.2.6 *cost of equipment ownership (CEO)* — a factor in cost of ownership (see Sections 5.1.1 and 8.3).

4.2.7 *cost of ownership* — full cost of embedding, operating, and decommissioning in a factory environment a process system needed to accommodate the required volume of product material (see Section 5.1.1 for further description).

4.2.8 *cost of yield loss (CYL)* — a unit lost at the end of a given step represents the loss of the cost of manufacturing to that point. In addition, units leaving a step may be lost at some later step. Calculating cost of yield loss (CYL) therefore requires knowing the accumulated cost of manufacturing before the wafer is lost. Therefore, cost of yield loss should be tracked as a separate cost for factory optimization. CYL is given in Equation 4.

4.2.9 *default or default value* — value to be used if actual data are not available. In lieu of actual data, data should fall within the range specified by default values given in the Related Information section. Where possible, actual data should be used in COO calculations.

4.2.10 *defect limited yield (DYL)* — devices not lost from defects added by the equipment. For front-end process, defect yield is usually derived from a model.

4.2.11 *easement space* — the floor space that must remain clear to the rear and sides of the tool (but not in front of the load face plane). This includes safety aisles, ergonomic maintenance access space, component removal space, and room for doors to swing out.

4.2.12 *equipment availability* — equipment dependent uptime or the percent of time the equipment is in a condition to perform its intended function during the period of operations time minus the sum of all maintenance delay, out-of-spec input downtime, and facilities-related downtime. This calculation is intended to reflect equipment reliability and maintainability based solely on equipment merit see SEMI E10. (NOTE: Equipment availability is the responsibility of the equipment supplier and should reflect the need for unscheduled maintenance and any scheduled maintenance that cannot be accomplished within the semiconductor manufacturer's standard allotment.)

4.2.13 *equipment production lifetime* — the number of years a piece of equipment is used for manufacturing.

4.2.14 *equipment yield (EY)* — the percentage of units received by the equipment which can be passed to the next step based on any criteria such as damaged material, or material determined to be defective by inspection or test. Inclusion of equipment yield results in a decreasing population of units flowing through the factory. At later steps, equipment will process fewer units than the full factory wafer starts. For test equipment, validly rejected material is scrap, but not a component of equipment yield.

4.2.15 *factory utilization (FU)* — a measure of the allocation for operating hours, scheduled maintenance shifts, and other nonproduction hours as defined by SEMI E10. Expressed as hours and % of 365 × 24 =

8,760 hours per year. As defined, FU is determined by the semiconductor manufacturer.

4.2.16 *fixed costs* — costs incurred once and usually associated with the acquisition and incorporation of equipment into the factory.

4.2.17 *good wafer equivalents (GWE)* — derived from the number of good product die at wafer probe or devices at test and expressed as completely good product wafers.

4.2.18 *lifetime* — the time over which the fixed and recurring costs are spread for an annualized basis. Examples are: 1) tax lifetime - lifetime used for tax depreciation and 2) equipment production lifetime.

4.2.19 *materials* — bulk gases, specialty gases, general or specialty chemicals used in the process. Test and filler wafers consumed in the support of the equipment.

4.2.20 *monitor units* — test or filler units (wafers or devices) consumed in the support of the equipment. Also called test units.

4.2.21 *parametric limited yield (PLY)* — an estimate of devices that are not lost from device parameters being outside the required range.

4.2.22 *precision-tolerance ratio (P/T)* — characterization of test equipment being used to evaluate product quality for yield determination.

4.2.23 *production utilization (PU)* — a measure of factory utilization and equipment availability expressed as hours and % of 8,760 hrs per year.

PU = factory utilization * equipment availability

As defined, PU has a component attributable to the manufacturer and a component attributable to the equipment supplier.

4.2.24 *product yield (PRY)* — the percentage of units expressed as good unit equivalents which pass through the factory and result in good product. Product yield for wafers is the composite yield from Equation 2. The components are defined in this section. Since defect limited yield (DLY) is generally a wafer level phenomena, Equation 2 may be simplified for other types of units by setting DLY=1. Particle additions are a predictor of defect yield loss at a future step, but not a complete predictor of all the possible loss since there may be other defects or parametric problems.

(See Equation 2, Section 5.5.2).

4.2.25 *recurring costs* — costs that are incurred on an accrued basis.

4.2.26 *rework* — any units being reprocessed by the equipment because of a fault or defect.

4.2.27 *service contract* — an agreement for the supplier to provide equipment maintenance under specified terms and conditions.

4.2.28 *shadow footprint* — the area of the floor space directly under every part of the tool during its operation. This includes any temporary projections from the tool during loading or processing (such as carriers that stick out from the tool or tool load ports that protrude only when the tool is being loaded).

4.2.29 *spare parts* — pre-purchased inventory of components maintained to service the equipment. Repair parts are paid for at the time of repair.

4.2.30 *supplier* — provider of equipment or services to the semiconductor manufacturer, same as a vendor or equipment manufacturer.

4.2.31 *system throughput* — see throughput.

4.2.32 *systems required (SR)* — the integer number of systems required to obtain the throughput for the step.

4.2.33 *test wafers* — see monitor units.

4.2.34 *test yield* — incorrect test determination of a die being good or bad:

α or type 1 is percentage of false bad.

β or type 2 is percentage of false good.

4.2.35 *throughput (TP)* — the number of units (wafers or devices) per hour the process system delivers to the factory, including all input, output, and internal overhead operation. Throughput includes all test or monitor wafers processed, since the cost of these non-product wafers is accounted for directly.

4.2.36 *tool* — often used synonomously with equipment in the silicon wafer processing industry.

4.2.37 *unit* — any wafer, die, packaged device, or piece part thereof (includes product and non-product units) see SEMI E10. For the purposes of this guideline, units are converted to wafer equivalents so that cost of ownership is expressed on a per wafer basis.

4.2.38 *volume requirement* — the number of units required to be processed by the equipment in a specific time period, normally units per week.

4.2.39 *warranty contract or service contract* — an alternate method for handling maintenance beyond that which is supplied with the equipment.

4.2.40 *yield* — see product yield.

5 Cost of Ownership

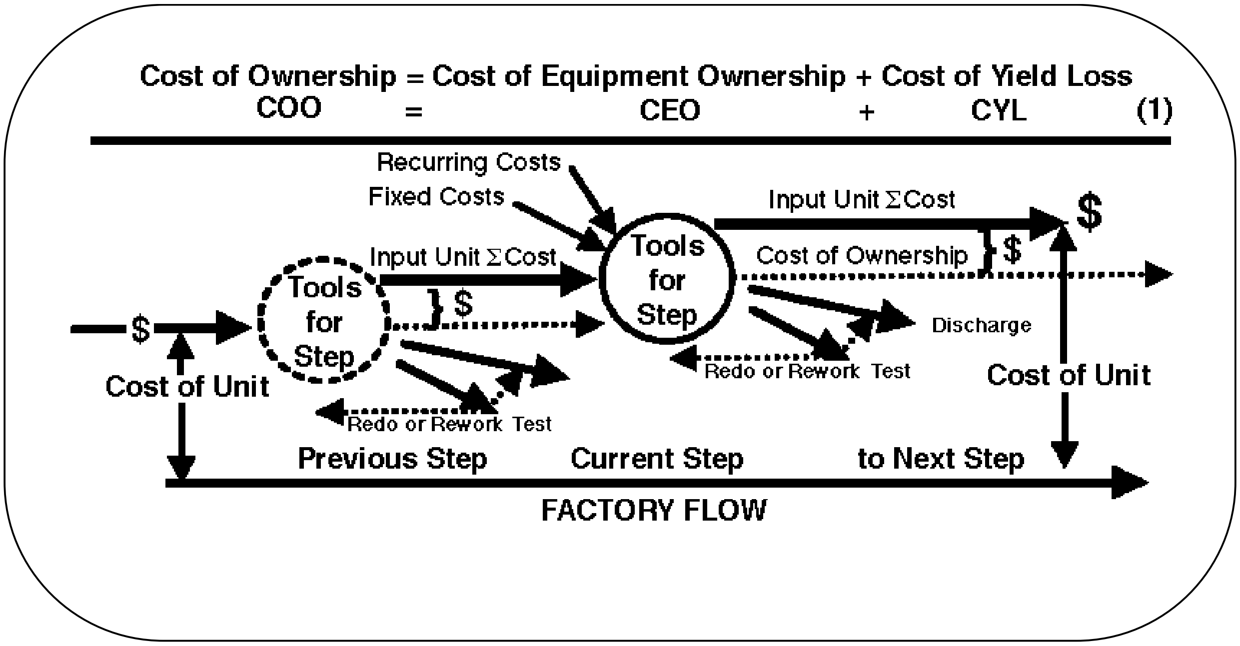

Figure 1
Factory Flow

5.1 *Description*

5.1.1 A cost of ownership metric is the incremental cost added to a unit of good product material flowing through a volume-sized process system embedded in a factory environment for a specified lifetime plus the cost of yield loss. COO is calculated on an annualized basis. The metric is expressed as cost per good wafer equivalents (GWE) for one pass through the system. GWE is determined from the good die yield at wafer probe or at a later stage if appropriate. Figure 1 depicts this accumulation of cost which can be factored into two components, cost of equipment ownership (CEO) and cost of yield loss (CYL).

5.1.2 COO is the full cost of embedding, operating, and decommissioning in a factory environment a process system needed to accommodate the required volume of product material.

5.2 *Constraint Version*

5.2.1 A constraint version of cost of ownership imposes a set of defined restrictions to facilitate comparisons or to remove ambiguity. An example is: baseline cost of ownership which only includes equipment yield, i.e., defect limited yield and parametric limited yield are not included. Cost of ownership calculated with no constraint is referred to as comprehensive.

5.2.2 The constraint type definition will also provide a unique description of the elements included in the classification system defined in Section 9 as well as other details. SEMI E35.1, "Guide for Cost of Equipment Ownership Comparison Metric," is a specific constraint version equivalent to a baseline cost of ownership.

5.3 *Lifetimes*

5.3.1 The time over which the fixed and recurring costs are spread for the annualized basis is the equipment production lifetime. Tax life-depreciation is customarily used in COO, based upon standard accounting practice.

5.3.2 The equipment usually remains in production much longer than the tax life, so it is often useful to consider the equipment production lifetime in evaluating the value of equipment.

COO Lifetimes

1. Tax life - depreciation

2. Equipment production lifetime

5.4 *CEO: Fixed and Recurring Costs*

5.4.1 Determining CEO requires enumerating all of the fixed and recurring costs that are incurred in the life cycle of the equipment. Fixed costs are those incurred once and are usually associated with the acquisition and incorporation of equipment into the factory. Recurring costs are those which arise on an annual basis from the operation and maintenance of the equipment. The calculation is shown in Section 8.

5.5 *Yield*

5.5.1 Yield is a metric of the percentage of the unit volume that results in good product. Yield affects the cost of ownership in a number of ways.

1. Volume of units that must be processed for the required product requirements.

2. Cost of units that do not produce good product.

5.5.2 Product yield (PRY) is the percentage of units expressed as good unit equivalents which pass through the factory and result in good product. Product yield for wafers is the composite yield from Equation 2. The components are defined in Section 4. Since defect limited yield (DLY) is generally a wafer-level phenomena, Equation 2 may be simplified for other types of units by setting DLY = 1. Particle additions are a predictor of defect yield loss at a future step, but not a complete predictor of all the possible loss since there may be other defects or parametric problems.

$$\mathrm{PRY} = \mathrm{EY} \times (1 - \alpha) \times (1 - \beta) \times \mathrm{DLY} \times \mathrm{PLY} \times (1 - \mathrm{Rework}) \quad (2)$$

5.6 *Cost of Yields*

5.6.1 A unit lost at the end of a given step represents the loss of the cost of manufacturing to that point. In addition, units leaving a step may be lost at some later step. Calculating cost of yield loss (CYL) therefore requires knowing the accumlated cost of manufacturing before the wafter is lost. Therefore, cost of yield loss should be tracked as a separate cost for factory optimization. CYL is given in Equation 4 in Section 8.1.

5.7 *Volume Requirement*

5.7.1 The volume requirement is the unit flow to be processed and can be derived from specification of the product units needed corrected for yield and the number of other units required to be processed by equipment in a specific time period such as those being redone. One complication in accurately dealing with the volume requirement is that the volume of units actually reaching the equipment will depend on the volume loss from equipment yield for all the prior steps. One common approach is to deal with volume parametrically.

5.8 *Good Wafer Equivalents (GWE)*

5.8.1 Good wafer equivalents (GWE) is derived from the number of good product units or good product die at wafer probe or at a later stage, if appropriate, and is expressed as completely good wafers.

5.9 *Systems Required*

5.9.1 Once the volume is specified, the number of systems required (SR) is obtained from the throughput (TP), and the production utilization (PU).

$$\mathrm{SR} = \mathrm{VOLUME\ REQUIRED}/(\mathrm{TP} \times \mathrm{PU}) \quad (3)$$

6 Reporting Results

6.1 Reports on cost of ownership should always show the following items. Other data items should be reported as required by clarity.

6.1.1 *Input Items*

1. Identification of standard conformance

2. Declarations

    1. Classification system: functional, cost center, or other
    2. Summed categories: all or enumerate
    3. Volume requirement
    4. Factory utilization
    5. Equipment availability
    6. Production utilization
    7. Equipment throughput
    8. Number of systems and chambers

6.1.2 *Output Items:*

1. Cost per unit

2. Classification summary cost distribution

3. Related statistics

7 Limitations

7.1 Certain factors are more difficult than others to accurately determine. Figure 2 depicts the relation-ship of some of the cost of ownership factors. Thus, the accuracy of a cost of ownership calculation may be prone to a variety of errors or omissions.

7.2 In addition, line balance considerations are not included in cost of ownership calculation. Line balance considerations are not included because an individual COO model does not have the capability to know what impact the process being modeled has on the rest of the fab.

7.3 A cost of ownership calculation may have more detail than presented explicitly in this guideline. The structure of the guideline, however, allows for the proper handling of these situations.

8 Procedures

8.1 *COO Calculation*

8.1.1 The COO algorithm requires the specification or calculation of the volume level, the determination of the number of systems required to process the volume, the enumeration of all fixed and recurring costs associated with processing the volume by the systems, and the yield related costs. The COO metric is a function defined by equation 1 to be:

$$COO = CEO + CYL$$

The cost of yield loss (CYL), is given by Equation 4, and is broken into two components. The CEO component is described in Equation 5 and is expressed in Equation 6 as the sum of a number of categories which constitute a classification system. The classification system is described in Section 9. Constrained versions of COO restrict certain elements included in calculation.

8.1.2 The algorithm for CEO is depicted in diagrams presented in Related Information 1. The CEO is expressed as a sum over the elements in the Category Table 1 as expressed in Equation 5. Each item in the classification system is defined, and a method for evaluating its expression given as described in Section 9. Default values or handling are specified in Related Information 2. All costs must be assigned through the defined classification system and calculated per system for the number of production hours.

8.1.3 Figure 2 depicts some of the elements in terms of the difficulty in establishing various costs.

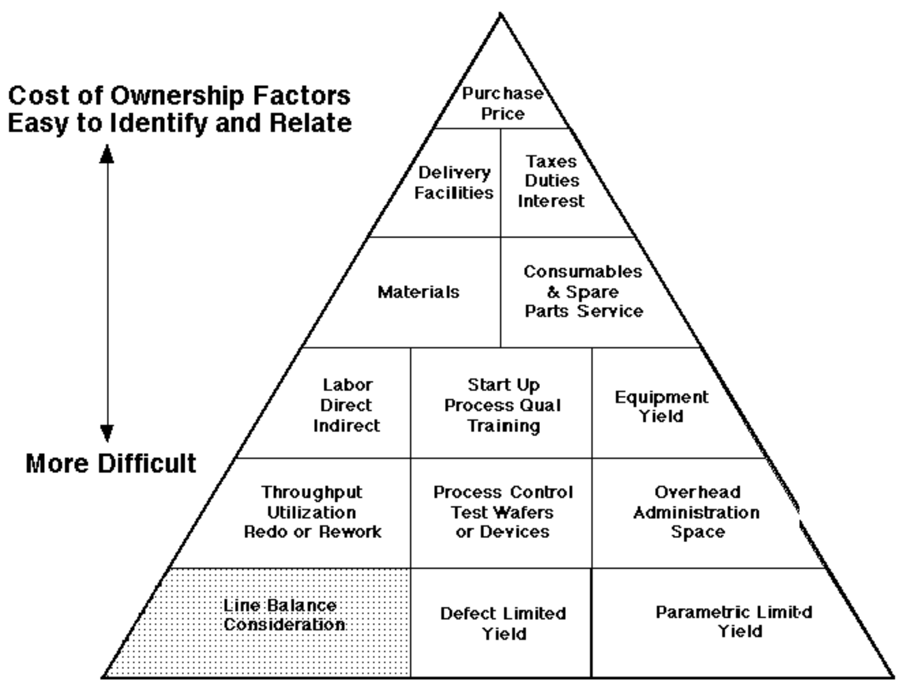

Figure 2

8.2 *Cost of Yield Loss*

$$\text{CYL} = \left(\begin{array}{c} \text{annualized} \\ \text{cost of} \\ \text{wafers lost to} \\ \text{equipment yield} \end{array} + \begin{array}{c} \text{annualized} \\ \text{attributed cost of} \\ \text{wafers lost to} \\ \text{die \& parametric yield} \end{array} \right) * \frac{1}{\begin{array}{c}\text{good units} \\ \text{per year}\end{array}} \quad (4)$$

8.3 *Cost of Equipment Ownership*

$$\text{CEO} = \left(\begin{array}{c} \text{annualized} \\ \text{fixed cost} \\ \text{per system} \end{array} + \begin{array}{c} \text{annualized} \\ \text{recurring cost} \\ \text{per system} \end{array} \right) * \frac{\begin{array}{c}\text{volume required} \\ \text{\# systems}\end{array}}{\begin{array}{c}\text{good units} \\ \text{per year}\end{array}} \quad (5)$$

$$= \left(\sum_{j} F_{j0} + \sum_{k} R_{k0} \right) * \left(\frac{\begin{array}{c}\text{volume required} \\ \text{\# systems}\end{array}}{\begin{array}{c}\text{good units} \\ \text{per year}\end{array}} \right) \quad (6)$$

$$= \left(\sum_{ij} F_{ij} + \sum_{kl} R_{kl} \right) * \left(\frac{\begin{array}{c}\text{volume required} \\ \text{\# systems}\end{array}}{\begin{array}{c}\text{good units} \\ \text{per year}\end{array}} \right) \quad (7)$$

Where j and k are the number of primary categories in Table 1, and ij and kl are the number of detailed elements in Sections 10 and 11.

8.3.1 Fj0 and Rk0 are the primary categories in Table 1 and in the expansions shown in Sections 10 and 11. Fij and Rkl are the detailed elements, each of which is defined.

9 Cost Classifications and Categories

9.1 Cost classifications may be defined as a tree starting with the superclass/class category structure shown in Table 1. The superclass structure starts from the fixed and recurring cost categories. Detailed element expansion is shown in Sections 10 and 11. Equation 5 shows the way the tables are used to represent the CEO calculation. The purpose of this format is to remove ambiguity that often results in trying to follow calculations done with spreadsheets.

Note that any class expansion should give the same results since they are just different views of the same fixed and recurring costs.

9.2 Subclass elements may be expanded into further items and then summed up to the next level if more detail is required. The cost center example in Table 1 is one view of the categories. Another view is given in section 11 for a functional view of the costs. Note that since both views are summing the same fixed and recurring costs, they give equivalent results. Category tables can be developed as required to expose particular details of the cost structure with the requirement that the table be reported in the documentation.

9.3 Constrained versions of the COO calculation are created by defining a modification of the calculation such as the way yield is included or in restricting the items in the classification tables that are used.

Table 1 Example Classification Structure for Expanding COO

VIEW	*SuperClass*		*Class*	*SubClass*
Cost Center	Fixed	1	Equipment	
		2		
		3		
	Recurring	1	Consumables	
		2	Material	
		3	Maintenance	
		4	Labor	
		5	Support personnel	
		6	Scrap	
		7	Support Services	
		8		
		9		

This set is similar to the original Sematech COO model. Another example is given in Section 11, which is called a Functional Classification. Definitions used by both classification examples are included in the guideline.

10 Classification Element Details: Cost Center

Fixed Cost Classification

CF	*1*	*2*	*3*	*4*
.0	*Equipment*			
.1	Depreciation			
.2	Qualification			
.3	Installation			
.4	Training			
.5	Moves & Rearrange			
.6	Floor Space			
.7				

Recurring Cost Classification

CR	*1*	*2*	*3*	*4*	*5*	*6*	*7*
.0	*Material*	*Consumables*	*Maintenance*	*Labor*	*Support Personnel*	*Scrap*	*Support Services*
.1	Test/Filler Wafers		Labor	Operation	Supervision	Equipment Yield	
.2	Utilities		Spare Parts		Engineering	Defect Yield	
.3	Supplies		Repair Parts			Parametric Yield	
.4	Waste Disposal		Service Contract				
.5			Training				
.6							
.7							

On the following pages are given the definitions of the items included in the classification and the methods for calculating the items if the values are not available. Default values are given in Related Information 2.

CF1.0 Equipment

Definition	Fixed cost categories associated with the purchase of equipment.
Method	Sum of all subcategories.

CF1.1 Equipment: Depreciation

Definition	Equipment purchase price divided by the appropriate depreciation schedule.
Method	Any accepted depreciation schedule (straight-line, double declining balance, etc.).

CF1.2 Equipment: System Qualification

Definition	The cost of qualifying for production.
Method	Expressed in person-hours of expended effort and material costs.

CF1.3 Equipment: Installation

Definition	The cost of installing a system for production.
Method	Expressed in terms of actual cost.

CF1.4 Equipment: Training

Definition	The initial training requirements for new equipment for operators, supervision, engineers, and maintenance personnel.
Method	The training person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Training course costs will be added if applicable.

CF1.5 Equipment: Moves & Rearrangements

Definition	The cost of displacing existing equipment in order to install the new equipment.
Method	Provided by semiconductor manufacturer.

CF1.6 Equipment: Floor Space

Definition	The cleanroom overhead allocated to the equipment.
Method	The cost footprint of the equipment is multiplied by the cost of cleanroom space for each class of cleanroom space utilized.

CR1.0 Material

Definition	Material cost categories associated with the operation of equipment.
Method	Sum of all subcategories.

CR1.1 Material: Test/Filler Wafers

Definition	Test and/or filler wafers consumed in the support of the equipment.
Method	Number of wafers consumed multiplied by the cost of the wafer.

CR1.2 Material: Utilities

Definition	Cost of electricity, city water, deionized water, and chilled water used by the equipment.
Method	Cost of electricity, city water, deionized water, and chilled water per system per year.

CR1.3 Material: Supplies

Definition	Cost of all supplies used by, or in support of, the equipment to produce water. This would include bulk gases, specialty gases, and specialty chemicals.
Method	Cost of supplies per system per year.

CR1.4 Material: Waste Disposal

Definition	Removing spent chemical or effluent. Gas exhaust charges.
Method	Cost per system per year.

CR2.0 Consumables

Definition	Cost of all parts of the equipment that are worn out by the process operation of equipment and require replacement after less than 1 year of operation.
Method	Consumable costs per system per year.

CR3.0 Maintenance

Definition	Maintenance cost categories associated with the operation of a manufacturing equipment.
Method	Sum of all subcategories.

CR3.1 Maintenance: Labor

Definition	IC manufacturer's internal repair and maintenance labor costs.
Method	Scheduled and unscheduled downtime are calculated by the COO model from E10 inputs and multiplied by the maintenance labor rate. Actual cost may be affected by warranty and service contract coverage.

CR3.2 Maintenance: Spare Parts

Definition	Spares Inventory Cost of IC manufacturer.
Method	Spare parts costs per system per year.

CR3.3 Maintenance: Repair Parts

Definition	Repair parts charged to the IC manufacturer.
Method	Repair parts costs per system per year.

CR3.4 Maintenance: Service Contracts

Definition	Service contracts charged to the IC manufacturer.
Method	Service contract costs per system per year.

CR3.5 Maintenance: Training

Definition	The ongoing training requirements for operators, supervision, engineers, and maintenance personnel.
Method	The training costs per system per year.

CR4.0 Labor

Definition	Labor cost categories associated with the operation of a manufacturing equipment.
Method	Sum of all subcategories.

CR4.1 Labor: Operation

Definition	The operator labor required to support the equipment set needed to meet the wafer start requirements of the IC manufacturer.
Method	Calculated by the COO model from equipment and tab specifications.

CR5.0 Support Personnel

Definition	Support personnel cost categories associated with the operation of a manufacturing equipment.
Method	Sum of all subcategories.

CR5.1 Support Personnel: Supervision

Definition	The supervisor labor required to support the equipment set needed to meet the wafer start requirements of the IC manufacturer.
Method	Supervision person-hours/week multiplied by the burdened salary rate.

CR5.2 Support Personnel: Engineering

Definition	The engineering labor required to support the equipment set needed to meet the wafer start requirements of the IC manufacturer.
Method	Engineering person-hours/week multiplied by the burdened salary rate.

CR6.0 Scrap

Definition	Scrap cost categories associated with the operation of a manufacturing equipment.
Method	Sum of all subcategories.

CR6.1 Scrap: Equipment Yield

Definition	The percent of units that are not broken or irreversibly misprocessed by the equipment.
Method	(1- Equipment Yield) multiplied by the value of the unit at that step in the process.

CR6.2 Scrap: Defect Yield

Definition	The percent of equivalent wafers that are not lost due to electrical malfunctions caused by particulate defects.
Method	(1- Defect Yield) multiplied by the value of the wafer at the end of the process. Defect yield is calulated by the COO model using a modified Seed’s formula. $$Y = \frac{1}{1 + (A_a \times D \times P)}$$ Where A_a is the active area of the device, D is the defect density, and P is the probability that a defect will be fatal.

CR6.3 Scrap: Parametric Yield

Definition	The percentage of equivalent wafers that are not lost due to electrical malfunction caused by device parameters being outside the required range.
Method	(1- Parametric Yield) multiplied by the value of the wafer at the end of the process.

CR7.0 Support Services

Definition	Support services cost categories associated with the support of a manufacturing equipment.
Method	Support service cost per system per year.

11 Classification Element Details: Functional

View	*SuperClass*		*Class*	*SubClass*
Functional	Fixed	1	Acquisition	
		2	Facilities	
		3	Decommission	
	Recurring	1	Factory Interface	
		2	Equipment Management	
		3	Maintenance	
		4	Control	
		5	Inputs	
		6	Operation Labor	
		7	Quality/Performance	
		8	Non-Product Waste	
		9	Product Waste	

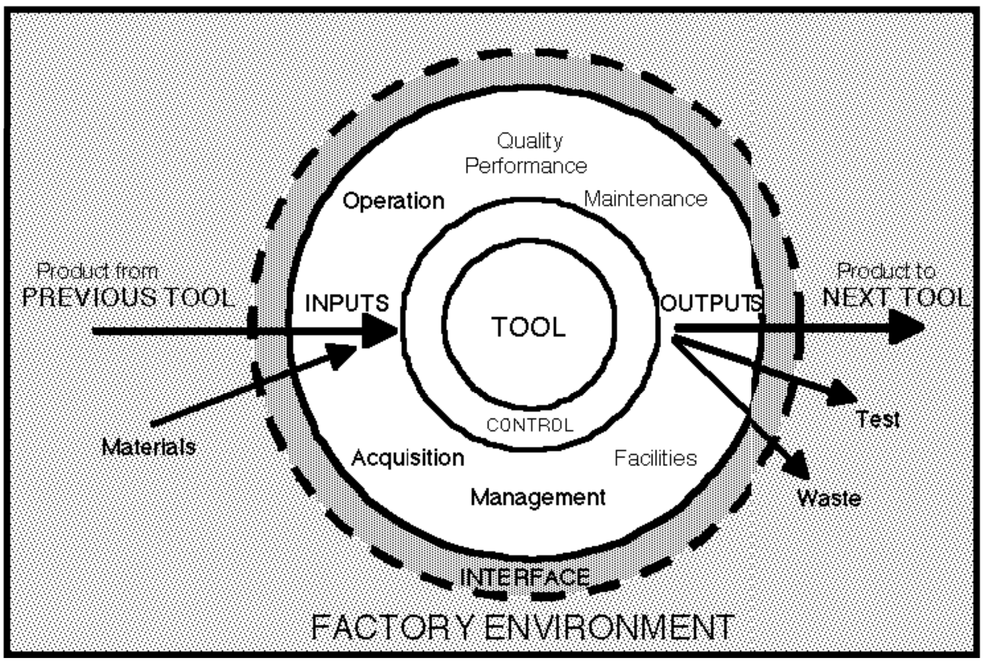

Figure 3
Functional Categories, Cost of Ownership

Fixed Cost Classification

FF	*1*	*2*	*3*
.0	*Acquisition*	*Facilities*	*Decommission*
.1	1 Price	1 Space	1 Removal
.2	2 Purchasing	2 Infrastructure	2 Disposal
.3	3 Evaluation	1 utilities	3 Cleanup
.4	4 Installation	2 services	
.5	5 Training		
.6			
.7			

Recurring Cost Classification

FR	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
.0	*Factory Interface*	*Equipment Management*	*Maintenance*	*Control*	*Inputs*	*Operation Labor*	*Quality/ Performance*	*Non Product Waste*	*Product Waste*
.1	Labor	Supervision	Contracts	Software	Consumables		Metrology	Discharge	Defect Yield Loss
.2	Safety	Support	Labor - Other	Training	Materials		Labor	Scrap	Scrap
.3	CIM	Administration	Repair Parts	Support	Utilities				1 breakage
.4	Infrastructure	Training - Other	Spares	Backup					2 equipment yield
.5									Parametric Yield Loss
.6									

FF1.0 Acquisition

Definition	All cost categories associated with defining, evaluating, purchasing, and installing the equipment.
Method	Sum of all subcategories.

FF1.1 Acquisition: Price

Definition	The direct price to purchase the equipment.
Method	Actual price and accepted depreciation schedule (straight-line, double declining balance, etc.).

FF1.2 Acquisition: Purchasing

Definition	The cost of the process of initiating and completing the purchase of the equipment.
Method	Determine burdened person-hours cost.

FF1.3 Acquisition: Evaluation

Definition	The cost of qualifying a system for production.
Method	Expressed in person-hours of expended effort and consumable costs.

FF1.4 Acquisition: Installation

Definition	Cost to bring the equipment to an operational state.
Method	Expressed in dollars of actual cost.

FF1.5 Acquisition: Training

Definition	The initial training requirements for new equipment for operators, supervision, engineers, and maintenance personnel.
Method	The training person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Training course costs will be added if applicable.

FF2.0 Facilities

Definition	Facilities cost categories associated with requirements of equipment such as floor space and services.
Method	Sum of all subcategories.

FF2.1 Facilities: Space

Definition	The space overhead allocated to the equipment.
Method	The cost footprint of the equipment is multiplied by the cost of cleanroom space for each class of cleanroom space utilized.

FF2.2 Facilities: Infrastructure

Definition	Facilities Infrastructure cost categories associated with the cleanroom, other space, and service requirements of equipment.
Method	Sum of all subcategories.

FF2.2.1 Facilities: Infrastructure: Utilities

Definition	The costs allocated to the equipment for utilities connection.
Method	Provided by Semiconductor Manufacturer.

FF2.2.2 Facilities: Infrastructure: Services

Definition	The costs allocated to the equipment for miscellaneous services.
Method	Provided by Semiconductor Manufacturer.

FF3.0 Decommissioning

Definition	Cost categories associated with the disposition of spent equipment.
Method	Sum off all subcategories.

FF3.1 Decommissioning: Removal

Definition	The cost of removing existing equipment after it is no longer used for production.
Method	Provided by Semiconductor Manufacturer.

FF3.2 Decommissioning: Disposal

Definition	The cost of disposing of equipment after it is no longer used for production.
Method	Provided by Semiconductor Manufacturer.

FF3.3 Decommissioning: Cleanup

Definition	The cost of cleaning the fab after the equipment has been removed.
Method	Provided by Semiconductor Manufacturer.

Recurring Costs: FR1.0 Factory Interface

Definition	Factory cost categories associated with the interface of equipment to the factory systems.
Method	Sum of all subcategories.

FR1.1 Factory Interface: Labor

Definition	The labor requirements for interfacing equipment to the factory system.
Method	The person-hours for each personnel classification will be multiplied by their respective burdened wage or salary.

FR1.2 Factory Interface: Safety

Definition	The safety requirements for equipment run in producation.
Method	The safety person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional safety costs will be added if applicable.

FR1.3 Factory Interface: CIM

Definition	The computer integrated manufacturing (CIM) requirements for equipment run in production.
Method	The CIM person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional CIM costs will be added if applicable, such as port, communications, and server.

FR1.4 Factory Interface: Infrastructure

Definition	Period costs for overhead from factory infrastructure.
Method	Actual software and hardware costs.

FR2.0 Equipment Management

Definition	Equipment management cost categories associated with the operation of equipment in a production environment.
Method	Sum of all subcategories.

FR2.1 Equipment Management: Supervision

Definition	The supervisor labor required to support the equipment set needed to meet the wafer start requirements of the IC manufacturer.
Method	Supervision person-hours/week multiplied by the burdened salary rate.

FR2.2 Equipment Management: Support

Definition	The support required by the equipment to meet the wafer start requirements of the IC manufacturer.
Method	Provided by Semiconductor Manufacturer.

FR2.3 Equipment Management Administration

Definition	The administration costs allocated to the equipment to meet the wafer start requirements of the IC manufacturer.
Method	Provided by Semiconductor Manufacturer.

FR2.4 Equipment Management: Training-Other

Definition	The ongoing training requirements for operators, surpervision, engineers, and maintenance personnel.
Method	The training costs per system per year.

FR3.0 Maintenance

Definition	Maintenance cost categories associated with the operation of equipment.
Method	Sum of all subcategories.

FR3.1 Maintenance: Contracts

Definition	Service contracts charge to the IC manufacturer.
Method	Service contract costs per system per year.

FR3.2 Maintenance: Labor-Other

Definition	IC manufacturer's internal repair and maintenance labor costs.
Method	Scheduled and unscheduled downtime are calculated by the COO model from E10 inputs and multiplied by the maintenance labor rate.

FR3.3 Maintenance: Spare Parts

Definition	Spares Inventory Cost of IC manufacturer.
Method	Spare parts costs per system per year.

FR3.4 Maintenance: Repair Parts

Definition	Repair parts charged to the IC manufacturer.
Method	Repair parts costs per system per year.

FR4.0 Control

Definition	Equipment control cost categories.
Method	Sum of all subcategories.

FR4.1 Control: Software

Definition	The software purchase requirements for equipment run in production.
Method	Actual software costs.

FR4.2 Control: Training

Definition	The software training requirements for equipment run in production.
Method	The training person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional training costs will be added if applicable.

FR4.3 Control: Support

Definition	The software support requirements for equipment run in production.
Method	The support person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional support costs will be added if applicable.

FR4.4 Control: Backup

Definition	The software backup requirements for equipment run in production.
Method	The backup person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional backup costs will be added if applicable.

FR5.0 Inputs

Definition	Cost categories for items consumed in the manufacture of a wafer.
Method	Sum of all subcategories.

FR5.1 Inputs: Consumables

Definition	Cost of all parts of the equipment that are worn out by the process of operation of equipment and require replacement after less than 1 year of operation.
Method	Cost of supplies per system per year.

FR5.2 Inputs: Material

Definition	This includes bulk gases, specialty gases, and specialty chemicals. Test and/or filler wafers consumed in the support of the equipment.
Method	Number of wafers consumed multiplied by the cost of the wafer plus the cost of the process gas or chemicals used.

FR5.3 Inputs: Utilities

Definition	Cost of electricity, city water, deionized water, and chilled water or such used by the equipment.
Method	Determine from equipment usage or specification.

FR6.0 Operation Labor

Definition	The operator labor required to support the equipment set needed to meet the wafer start requirements of the IC manufacturer.
Method	Calculated by the COO model from equipment and fab specifications.

FR7.0 Quality/Performance

Definition	Quality/Performance cost categories associated with the operation of the equipment.
Method	Sum of all subcategories.

FR7.1 Quality/Performance: Metrology

Definition	The metrology requirements for supporting the equipment in production.
Method	Provided by Semiconductor Manufacturer.

FR7.2 Quality/Performance: Labor

Definition	The quality/performance labor requirements for equipment for operators, supervision, engineers, and maintenance personnel.
Method	Provided by Semiconductor Manufacturer. The quality/performance person-hours for each personnel classification will be multiplied by their respective burdened wage or salary. Additional quality/ performance costs will be added if applicable.

FR8.0 Non-Product Waste

Definition	Discharge cost categories associated with the equipment.
Method	Sum of all subcategories.

FR8.1 Non-Product Waste: Discharge

Definition	Cost of disposal of spent chemicals or effluent.
Method	Cost of disposal per system per year.

FR8.2 Non-Product Waste: Scrap

Definition	Scrap cost categories associated with the equipment.
Method	Sum of all costs.

FR9.0 Product Waste

Definition	Output product cost categories associated with the operation of equpment.
Method	Sum of all subcategories.

FR9.1 Product Waste: Breakage

Definition	The percent of wafers that are not broken or irreversibly misprocessed by the equipment.
Method	(1-Equipment Yield) multiplied by the value of the unit at that step in the process.

FR9.2 Defect Yield Loss

Definition	The percent of equivalent wafers that are not lost due to electrical malfunctions caused by particulate defects.
Method	(1-Defect Yield) multiplied by the value of the wafer at the end of the process. Defect yield is calculated by the COO model using a modified Seed's formula. $Y = \frac{1}{1 + (A_a \times D \times P)}$ Where A_a is the active area of the device, D is the defect density, and P is the probability that a defect will be fatal.

FR9.3 Product Waste: Parametric Yield

Definition	The percentage of equivalent wafers that are not lost due to electrical malfunction caused by device parameters being outside the required range.
Method	(1-Parametric Yield) multiplied by the value of the wafer at the end of the process.

APPENDIX 1
COST OF OWNERSHIP FOR GAS DELIVERY SYSTEMS

NOTE: This appendix is an official part of SEMI E35, but is not intended to modify or supersede the official standard. It was developed by a Task Force that was formed as a follow-on to a SEMI/SEMATECH project on modular surface mount gas boxes. Publication was by full ballot procedures on April 30, 2001. Determination of the suitability of the material is solely the responsibility of the user.

A1-1 Purpose

A1-1.1 The purpose of this information is to illustrate how to apply the cost of ownership (COO) metrics to gas delivery systems. Users should be able to calculate the COO for any piece of gas delivery equipment using this Related Information. A spreadsheet (Microsoft Excel) has been provided as an illustrative example.

A1-2 Description of Model

A1-2.1 The formula for computing COO is given in Equation 1.

$$\mathbf{COO = (F\$+R\$+Y\$)/(L*T*Y*U)} \quad (1)$$

where

$$\mathbf{U = 1 - (SM+USM+A+S+Q+E)/H} \quad (2)$$

A1-2.1.1 Definitions for each term are repeated here for convenience.

F$	=	annualized fixed costs, $
R$	=	annualized recurring costs, $
Y$	=	annualized yield costs, $
L	=	useful life of equipment, yrs
T	=	tool throughput, wafers/yr
Y	=	composite yield, dimensionless
U	=	equipment utilization, dimensionless
SM	=	scheduled maintenance, hrs/week
USM	=	unscheduled maintenance, hrs/week
A	=	assist time, hrs/week
S	=	standby time, hrs/week
Q	=	production qualification time, hrs/week
E	=	process engineering time, hrs/week
H	=	total number of production hours scheduled per week, hrs/week

A1-2.2 *F$* is computed by summing the fixed cost categories CF1.0–CF1.6 listed in E35. *R$* is computed by summing the recurring cost categories CR1.0–CR5.2 and CR7.0 listed in E35. *Y$* is computed by summing the recurring cost categories CR6.0–CR6.3 listed in E35. The parameters *L* and *T* are input directly into the model. The model computes *Y* from two user inputs. The model computes *U* from inputs for *SM*, *USM*, *A*, *S*, *Q*, *E*, and *H*.

A1-2.3 While the example uses specific currency units, any currency may be used as long as it is applied consistently throughout the document.

A1-3 Sample Input to Model

A1-3.1 To effectively illustrate use of the COO model, it was run with a hypothetical set of input data. This input data is listed in Table A1-1. When studying this example, the user should remember that parameter values are for the gas delivery equipment only, not the entire process tool.

A1-4 Sample Model Output

A1-4.1 The model computes each term in the numerator of Equation 1 and then sums these results and applies the denominator to get COO. To enhance the user’s understanding of the components of COO, this appendix and the spreadsheet show interim results. For the set of inputs listed in Table A1-1, *F$* are shown in Table A1-2, *R$* are shown in Table A1-3, and *Y$* are shown in Table A1-4. Each of these terms is computed from the cost factors listed in E35. The italicized rows in Tables A1-2, A1-3, and A1-4 correspond to these cost factors and show the subtotal for that cost factor. The breakdown for each cost factor is shown in the rows below it.

A1-4.2 Tables A1-2, A1-3, and A1-4 show costs for years 1 through 7. The last year is based on user input. It is the longest of useful life or depreciable life. In the example shown, depreciable life was set to 7 years and useful life was set to 5 years. The depreciable life was deliberately made longer than the useful life to illustrate the feature of the spreadsheet that allows these two parameter values to differ. This often occurs in practice since equipment is sometimes “obsoleted” before it is fully depreciated. The user can enter any value up to 10 for these two parameters.

A1-4.3 Table A1-5 shows the COO results.

Table A1-1 Input Data for COO Model

Row [1]	*Parameter*	*Units*	*Sample Value*
TA8	*This Section Contains Equipment Procurement Cost Data*		
TA9	**Equipment Cost Data**		
TA10	For Straight Line Depreciation, input SLN. For Fixed Declining Balance Depreciation, input DB. For Double Declining Balance Depreciation, input DDB.	not applicable	SLN
TA11	Floor Space Rental Rate	$\$/m^2/yr$	2691
TA12	Gas Box (or Stick or Component) Purchase Price	$	100,000
TA13	Gas Box (or Stick or Component) Depreciable Life (Must be 10 or Less)	yrs	7
TA14	Gas Box (or Stick or Component) Scrap Value	$	1,000
TA15	Gas Box (or Stick or Component) Useful Life (Must be 10 or Less)	yrs	5
TA16	Floor Space Required for Gas Box (or Stick or Component)	m^2	0.23
TA17	Support Equipment Purchase Price	$	5,000
TA18	Support Equipment Depreciable Life (must be same as Gas Box Depreciable Life for purposes of COO)	yrs	7
TA19	Support Equipment Scrap Value	$	100
TA20	Support Equipment Useful Life (must be same as Gas Box Useful Life for purposes of COO)	yrs	5
TA21	Floor Space Required for Support Equipment	m^2	0.093
TA22	*This Section Contains Data Specific to the Process Tool and Costs Specific to a Particular Fab*		
TA23	**Tool-Specific Data**		
TA24	Tool Throughput	wafers/hr	33
TA25	**Fab-Specific Data**		
TA26	Value of Wafer Entering Tool or Starting Value of Wafer	$/wafer	1,422
TA27	Value of Wafer Exiting Tool or Ending Value of Wafer	$/wafer	2,244
TA28	Cost of Test Wafer	$/wafer	500
TA29	Scheduled Production Hours per Year	hrs/yr	8,400
TA30	Inflation Rate	%	3
TA31	Burdened Equipment Engineering Salary	$/yr	111,000
TA32	Burdened Process Engineering Salary	$/yr	111,000
TA33	Burdened Supervision Salary	$/yr	111,000
TA34	Burdened Operator Rate	$/hr	25.00
TA35	Burdened Maintenance Technician Rate	$/hr	35.00
TA36	OEM Field Service Rate Billed to Fab	$/hr	175.00
TA37	OEM Field Process Rate Billed to Fab	$/hr	45.00
TA38	Electricity Charge	$/kWh	0.10
TA39	DI Water Charge	$\$/m^3$	1.00
TA40	Chilled Water Charge	$\$/m^3$	1.00
TA41	Purge Gas Charge	$\$/m^3$	1.00
TA42	Waste/Exhaust Charge	$\$/m^3$	1.00
TA43	*This Section Contains Data Related to Equipment Installation*		
TA44	**Initial Training Data (One-Time Training at Installation. On-Going Training is Accounted for under Maintenance.)**		
TA45	Time Required for Training	hrs/person	8.0

1 Row numbers begin with 8 to align with the corresponding rows in the sample spreadsheet. The row numbering convention is the Table number (using a lettering scheme to simplify the formulae) followed by the row in that table.

Row[1]	*Parameter*	*Units*	*Sample Value*
TA46	Hourly Rate Paid for Training	$/hr	200.00
TA47	Number of Equipment Engineers Trained	person	2.0
TA48	Number of Process Engineers Trained	person	2.0
TA49	Number of Supervisors Trained	person	2.0
TA50	Number of Operators Trained	person	6.0
TA51	Number of Maintenance Technicians Trained	person	6.0
TA52	Materials Consumed for Training	$	2,000
TA53	**Installation Data**		
TA54	Fab Costs Incurred to Move/Rearrange Equipment to Accommodate Gas Box	$	30,000
TA55	Equipment Engineering Time Required for System Installation	hrs	200
TA56	Process Engineering Time Required for System Installation	hrs	2.0
TA57	Supervision Time Required for System Installation	hrs	2.0
TA58	Operator Time Required for System Installation	hrs	2.0
TA59	Maintenance Technician Time Required for System Installation	hrs	6.0
TA60	OEM Field Service Time Required for System Installation	hrs	6.0
TA61	OEM Field Process Time Required for System Installation	hrs	6.0
TA62	**Qualification Data**		
TA63	Equipment Engineering Time Required for System Prove-In	hrs	40.0
TA64	Process Engineering Time Required for System Prove-In	hrs	40.0
TA65	Supervision Time Required for System Prove-In	hrs	2.0
TA66	Operator Time Required for System Prove-In	hrs	2.0
TA67	Maintenance Technician Time Required for System Prove-In	hrs	2.0
TA68	OEM Field Service Time Required for System Prove-In	hrs	6.0
TA69	OEM Field Process Time Required for System Prove-In	hrs	6.0
TA70	Materials Consumed for System Prove-In	$	2,000
TA71	*This Section Contains Data for Routine Operation of the Equipment*		
TA72	**Materials Used During Operation of the Equipment**		
TA73	Unit Volume of Purge Gas Consumed	m^3/wafer	1.00E-04
TA74	Unit Volume of Waste Generated	m^3/wafer	2.00E-04
TA75	Test/Filler Wafers	number/wafer	1.00E-06
TA76	Electricity Consumed on an Ongoing Basis	kWh/wafer	0.067
TA77	DI Water Consumed on an Ongoing Basis	$/$m^3$	0
TA78	Chilled Water Consumed on an Ongoing Basis	$/$m^3$	0
TA79	**Consumables (Parts that are Worn Out During Normal Operation and Require Replacement after Less than One Year of Operation)**		
TA80	Consumable Purchase Price	$	1,200
TA81	Consumable Life	yrs	1.0
TA82	**Labor Required to Operate the Equipment**		
TA83	Operator	hrs/wafer	0.0033
TA84	**Labor Required to Support the Equipment**		
TA85	Equipment Engineering	hrs/wafer	0.0
TA86	Process Engineering	hrs/wafer	0.0
TA87	Supervision	hrs/wafer	0.0
TA88	Maintenance Technician	hrs/wafer	0.0
TA89	OEM Field Service	hrs/wafer	0.0
TA90	OEM Field Process	hrs/wafer	0.0

Row[1]	*Parameter*	*Units*	*Sample Value*
TA91	**Support Services**		
TA92	Annual ESH Charge	$/yr	500
TA93	Other Annual Charge	$/yr	100
TA94	*This Section Contains Data Related to Reliability, Availability, and Maintainability (RAM)*		
TA95	**RAM Data**		
TA96	Scheduled Maintenance Downtime	hrs/week	0.0
TA97	Mean Time Between Failure	hrs	4,200
TA98	Average Response Time	hrs	0.3
TA99	Mean Time to Repair	hrs	7.0
TA100	Mean Time to Test	hrs	0.3
TA101	Mean Time to Restart Production	hrs	1.3
TA102	Assist Time	hrs/week	0.0
TA103	Standby Time (independent of process tool standby time)	hrs/week	0.0
TA104	Process Engineering Time	hrs/week	2.0
TA105	**Non-Personnel Maintenance Costs**		
TA106	Service Contract	$/yr	0.0
TA107	Spares Inventory Cost to Fab	$/yr	3,800
TA108	Repair Parts	$/maintenance event	5.0
TA109	Electricity Consumed Solely during Maintenance	kWh/maintenance event	1,000
TA110	**On-Going Training**		
TA111	Frequency of Training	events/yr	1.0
TA112	Time Required for Training	hrs/person	8.0
TA113	Hourly Rate Paid for Training Per Student	$/hr	200.00
TA114	Number of Equipment Engineers Trained	person	2.0
TA115	Number of Process Engineers Trained	person	2.0
TA116	Number of Supervisors Trained	person	0.0
TA117	Number of Operators Trained	person	6.0
TA118	Number of Maintenance Technicians Trained	person	6.0
TA119	Materials Consumed for Training	$	2,000
TA120	**Labor per Maintenance Event**		
TA121	Equipment Engineering Time Required per Maintenance Event	hrs/maintenance event	8.0
TA122	Process Engineering Time Required per Maintenance Event	hrs/maintenance event	1.0
TA123	Supervision Time Required per Maintenance Event	hrs/maintenance event	1.0
TA124	Operator Time Required per Maintenance Event	hrs/maintenance event	0.5
TA125	Maintenance Technician Time Required per Maintenance Event	hrs/maintenance event	0.5
TA126	OEM Field Service Time Required per Maintenance Event	hrs/maintenance event	8.0
TA127	OEM Field Process Time Required per Maintenance Event	hrs/maintenance event	0.0
TA128	**Tool Requalification Costs**		
TA129	Equipment Engineering Time Required per Maintenance Event	hrs/maintenance event	1.5
TA130	Process Engineering Time Required per Maintenance Event	hrs/maintenance event	0.0
TA131	Supervision Time Required per Maintenance Event	hrs/maintenance event	0.0
TA132	Operator Time Required per Maintenance Event	hrs/maintenance event	0.0
TA133	Maintenance Technician Time Required per Maintenance Event	hrs/maintenance event	1.5
TA134	OEM Field Service Time Required per Maintenance Event	hrs/maintenance event	1.5
TA135	OEM Field Process Time Required per Maintenance Event	hrs/maintenance event	0.0
TA136	Number of Test Wafers Consumed	wafers/maintenance event	1.0
TA137	Other Consumables Required to Requalify Tool	$/maintenance event	100

Row[1]	*Parameter*	*Units*	*Sample Value*
TA138	*This Section Contains Data Related to Yield*		
TA139	*NOTE: Yield Costs Can be Only those Caused by Gas Box Problems, Not Other Problems on the Tool.*		
TA140	**Composite Yield**		
TA141	Equipment Yield	dimensionless	1.00
TA142	Probe Yield	dimensionless	1.00
TA143	**Inputs for Annualized Yield Costs**		
TA144	Number of Wafers Lost to Equipment Yield	wafer	0.0
TA145	Number of Equivalent Wafers Lost to Defect Limited Yield	wafer	0.0
TA146	Number of Equivalent Wafers Lost to Parametric Limited Yield	wafer	0.0

Table A1-2 Annualized Fixed Costs for the Input Data Listed in Table I.

Rows in italics correspond to cost factors. Rows below each cost factor show the breakdown of that factor and when summed, equal the cost factor.

Row		*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Formula*
TB1	*Depreciation*[2]*, $*	*14,843*	*14,843*	*14,843*	*14,843*	*14,843*	*14,843*	*14,843*	=Σ(TB2:TB9)
TB2	Gas Box, $								
TB3	Straight Line, $	14,143	14,143	14,143	14,143	14,143	14,143	14,143	
TB4	Fixed Declining Balance, $	-	-	-	-	-	-	-	
TB5	Double Declining Balance, $	-	-	-	-	-	-	-	
TB6	Support Equipment, $								
TB7	Straight Line, $	700	700	700	700	700	700	700	
TB8	Fixed Declining Balance, $	-	-	-	-	-	-	-	
TB9	Double Declining Balance, $	-	-	-	-	-	-	-	
TB10	*System Qualification, $*	*7,817*	*0*	*0*	*0*	*0*	*0*	*0*	=Σ(TB11:TB18)
TB11	Cost to Equipment Engineering, $	2,135							=TA63*TA31/52/40
TB12	Cost to Process Engineering, $	2,135							=TA64*TA32/52/40
TB13	Cost to Supervision, $	107							=TA65*TA33/52/40
TB14	Cost to Operations, $	50							=TA66*TA34
TB15	Cost to Maintenance, $	70							=TA67*TA35
TB16	Cost of OEM Field Service Billed to Fab In Addition to Purchase Price, $	1,050							=TA68*TA36
TB17	Cost of OEM Field Process Billed to Fab in Addition to Purchase Price, $	270							=TA69*TA37
TB18	Materials Consumed, $	2,000							=TA70
TB19	*Installation, $*	*12,467*	*0*	*0*	*0*	*0*	*0*	*0*	=Σ(TB20:TB26)
TB20	Cost to Equipment Engineering, $	10,673							=TA55*TA31/52/40

2 Depreciation formulas may be found in standard accounting textbooks.

Row		*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Formula*
TB21	Cost to Process Engineering, $	107							=TA56*TA32/52/40
TB22	Cost to Supervision, $	107							=TA57*TA33/52/40
TB23	Cost to Operations, $	50							=TA58*TA34
TB24	Cost to Maintenance, $	210							=TA59*TA35
TB25	Cost of OEM Field Service Billed to Fab In Addition to Purchase Price, $	1,050							=TA60*TA36
TB26	Cost of OEM Field Process Billed to Fab in Addition to Purchase Price, $	270							=TA61*TA37
TB27	*Training, $*	*30,800*	*0*	*0*	*0*	*0*	*0*	*0*	=Σ(TB28:TB29)
TB28	Training Time Billed by OEM, $	28,800							=TA45*TA46*Σ(TA47:TA51)
TB29	Materials Consumed, $	2,000							=TA52
TB30	*Moves & Rearrangements, $*	*30,000*	*0*	*0*	*0*	*0*	*0*	*0*	=TB31
TB31	Moves & Rearrangements, $	30,000							=TB54
TB32	*Floor Space, $*	*875*	*875*	*875*	*875*	*875*	*0*	*0*	=Σ(TB33:TB34)
TB33	Gas Box, $	625	625	625	625	625	0	0	=IF(TA15>=1,TA16*TA11,0)
TB34	Support Equipment, $	250	250	250	250	250	0	0	=IF(TA20>=1,TA21*TA11,0)
TB35	*Total Fixed Costs, $*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	
TB36	*Annual, $*	*96,800*	*15,718*	*15,718*	*15,718*	*15,718*	*14,843*	*14,843*	For Year n, sum the corresponding year's value from these rows: TB1+TB10+TB19+TB27+TB30+TB32
TB37	*Cumulative, $*	*96,800*	*112,518*	*128,236*	*143,954*	*159,672*	*174,515*	*189,358*	=Σ(Year 1 value + Year 2 value + … + Year n value)

Table A1-3 Annualized Recurring Costs for the Input Data Listed in Table I.

Rows in italics correspond to cost factors. Rows below each cost factor show the breakdown of that factor and when summed, equal the cost factor.

Row[3]		*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Formula*
TC1	*Material, $*	*2,079*	*2,141*	*2,206*	*2,272*	*2,340*	*0*	*0*	=Σ(TC2:TC5)
TC2	Test/Filler Wafers, $	139	143	147	151	156	0	0	=TA75*TA24*TA29*TA28
TC3	Utilities, $	1,857	1,913	1,970	2,029	2,090	0	0	=(TA76*TA38+TA77*TA39+TA78*TA40)*TA24*TA29
TC4	Supplies, $	28	29	29	30	31	0	0	=TA73*TA41*TA24*TA29
TC5	Waste Disposal, $	55	57	59	61	62	0	0	=TA74*TA24*TA29*TA42
TC6	*Consumables, $*	*960*	*989*	*1,018*	*1,049*	*1,080*	*0*	*0*	=TC7
TC7	Consumables, $	960	989	1,018	1,049	1,080	0	0	=IF(TA81<TA15,TA80/TA15*ROUNDUP((TA15-TA81)/TA81,0),0)
TC8	*Maintenance, $*	*37,527*	*38,653*	*39,813*	*41,007*	*42,237*	*0*	*0*	=Σ(TC9:TC13)
TC9	Labor, $	4,717	4,859	5,005	5,155	5,309	0	0	=TA29/TA97*(((TA121+TA129)*TA31/52/40)+((TA122+TA130)*TA32/52/40)+((TA123+TA131)*TA33/52/40)+((TA124+TA132)*TA34)+((TA125+TA133)*TA35)+((TA126+TA134)*TA36)+((TA127+TA135)*TA37))
TC10	Spare Parts, $	3,800	3,914	4,031	4,152	4,277	0	0	=TA107
TC11	Repair Parts, $	1,410	1,452	1,496	1,541	1,587	0	0	=TA29/TA97*(TA108+TA109*TA38+TA136*TA28+TA147)
TC12	Service Contract, $	0	0	0	0	0	0	0	=TA106
TC13	Training, $	27,600	28,428	29,281	30,159	31,064	0	0	=(TA112*TA113*Σ(TA114:TA118)+TA119)*TA111
TC14	*Labor, $*	*22,869*	*23,555*	*24,262*	*24,990*	*25,739*	*0*	*0*	=TC15
TC15	Operations, $	22,869	23,555	24,262	24,990	25,739	0	0	=TA83*TA34*TA24*TA29
TC16	*Support Personnel, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=Σ(TC17:TC22)
TC17	Equipment Engineering, $	0	0	0	0	0	0	0	=TA85*TA24*TA31
TC18	Process Engineering, $	0	0	0	0	0	0	0	=TA86*TA24*TA32
TC19	Supervision, $	0	0	0	0	0	0	0	=TA87*TA24*TA33
TC20	Maintenance, $	0	0	0	0	0	0	0	=TA88*TA35*TA24*TA29

3 The row numbering convention is the Table number followed by the row in that table.

Row[3]		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Formula
TC21	OEM Field Service, $	0	0	0	0	0	0	0	=TA89*TA36*TA24*TA29
TC22	OEM Field Process, $	0	0	0	0	0	0	0	=TA90*TA37*TA24*TA29
TC23	*Scrap, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=0 Note: These are accounted for in Y$
TC24	*Support Services, $*	*600*	*618*	*637*	*656*	*675*	*0*	*0*	=Σ(TC25:TC26)
TC25	ESH, $	500	515	530	546	563	0	0	=TA92
TC26	Other, $	100	103	106	109	113	0	0	=TA93
TC27	*Total Recurring Costs, $*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	
TC28	*Annual, $*	*64,035*	*65,956*	*67,935*	*69,973*	*72,072*	*0*	*0*	=IF(TA15>=1,Σ(TC1+TC6+TC8+TC14+TC16+TC23+TC24),0)
TC29	*Cumulative, $*	*64,035*	*129,992*	*197,927*	*267,900*	*339,973*	*339,973*	*339,973*	=Σ(Year 1 value + Year 2 value + … + Year n value)

Table A1-4 Annualized Yield Costs for the Input Data Listed in Table I.

Rows in italics correspond to cost factors. Rows below each cost factor show the breakdown of that factor and when summed, equal the cost factor.

All yield costs are zero for this example.

Row[4]		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Formula
TD1	*Equipment Yield, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=TA144*TA26
TD2	*Defect Limited Yield, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=TA145*TA27
TD3	*Parametric Limited Yield, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=TA146*TA27
TD4	*Total Yield Costs, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	
TD5	*Annual, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=IF(TA15>=1,Σ(TD1:TD3),0)
TD6	*Cumulative, $*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	=Σ(Year 1 value + Year 2 value + … + Year n value)

4 The row numbering convention is the Table number followed by the row in that table.

Table A1-5 COO for the Input Data Listed in Table I.

For the results shown in the table, Useful Life of Equipment = 5 yrs; Depreciable Life of Equipment = 7 yrs; Tool Throughput = 33 wafers/hr = 277,200 wafers/yr; Equipment Utilization = 0.9855.

Row		*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Formula*
TE1	Fixed Costs, $	96,800	15,718	15,718	15,718	15,718	14,843	14,843	For Year n, =IF(TA13>=1,TB36 value for year n,"Asset Fully Depreciated")
TE2	Recurring Costs, $	64,035	65,956	67,935	69,973	72,072	Asset Retired	Asset Retired	For Year n, =IF(TA15>=1,TC28 value for year n,"Asset Retired")
TE3	Yield Costs, $	0	0	0	0	0	Asset Retired	Asset Retired	For Year n, =IF(TA15>=1,TD5 value for year n,"Asset Retired")
TE4	Total Costs, $	160,836	81,674	83,653	85,691	87,790	14,843	14,843	=Σ(TE1:TE3)
TE5	Cumulative Fixed Costs, $	96,800	112,518	128,236	143,954	159,672	174,515	189,358	=Year n value in row TB37
TE6	Cumulative Recurring Costs, $	64,035	129,992	197,927	267,900	339,973	339,973	339,973	=Year n value in row TC29
TE7	Cumulative Yield Costs, $	0	0	0	0	0	Asset Retired	Asset Retired	=Year n value in row TD6
TE8	Cumulative Total Costs, $	160,836	242,510	326,163	411,854	499,644	514,487	529,330	=Σ(TE5:TE7)
TE9	Yearly Cost, $/wafer	0.5887	0.2990	0.3062	0.3137	0.3214	Asset Retired	Asset Retired	=IF(TA15>=1,TE4/TA15/(TA24*TA29)/(TA141*TA142),"Asset Retired")
TE10	Cumulative Cost, $/wafer	0.5887	0.4439	0.3980	0.3769	0.3658	0.3767	0.3875	=IF(TA15>=1,TE8/TA15/(TA24*TA29)/(TA141*TA142),TE8/TA15/TA15/(TA24*TA29)/(TA141*TA142))

Total Cost = $529,330

Total COO = $0.3875/wafer. (The Cumulative Cost in the last year equals the Total COO.)

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RELATED INFORMATION 1
COST OF OWNERSHIP

NOTE: This related information is not an official part of SEMI E35 and is not intended to modify or supercede the official guideline. This related information has been derived the development of the guideline and was felt by the committee to be useful supplemental material. Publication was authorized by vote of the responsible committee. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 A discussion of cost of ownership is provided in this related information to suppliment the presentation within the guideline.

R1-2 The COO calculation is shown graphically in Figures R1-1 and R1-2. These figures are not a flow-chart, but rather meant to illustrate the elements of the calculation.

R1-3 The left side of the diagram shows various cost factors, while the rate side shows how they are incorporated in the calculation. The upper section is the determination of the number of systems required to process the specified value. In the middle section, the fixed costs are converted to an annual basis and combined with the recurring costs. The total cost is then divided by the number of good wafer equivalents.

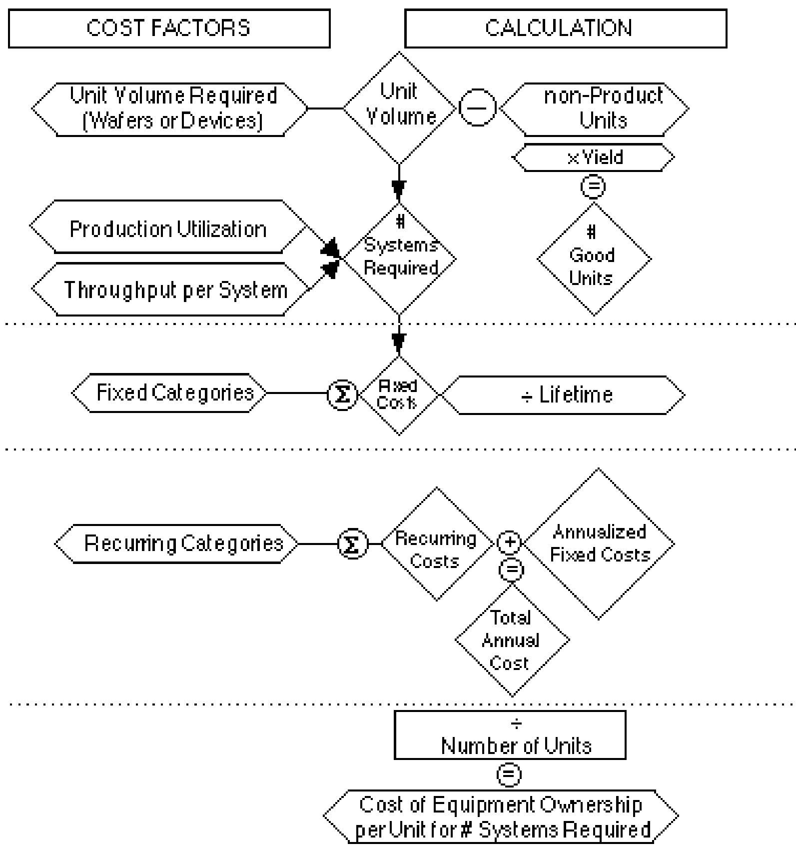

Figure R1-1
Cost of Equipment Ownership

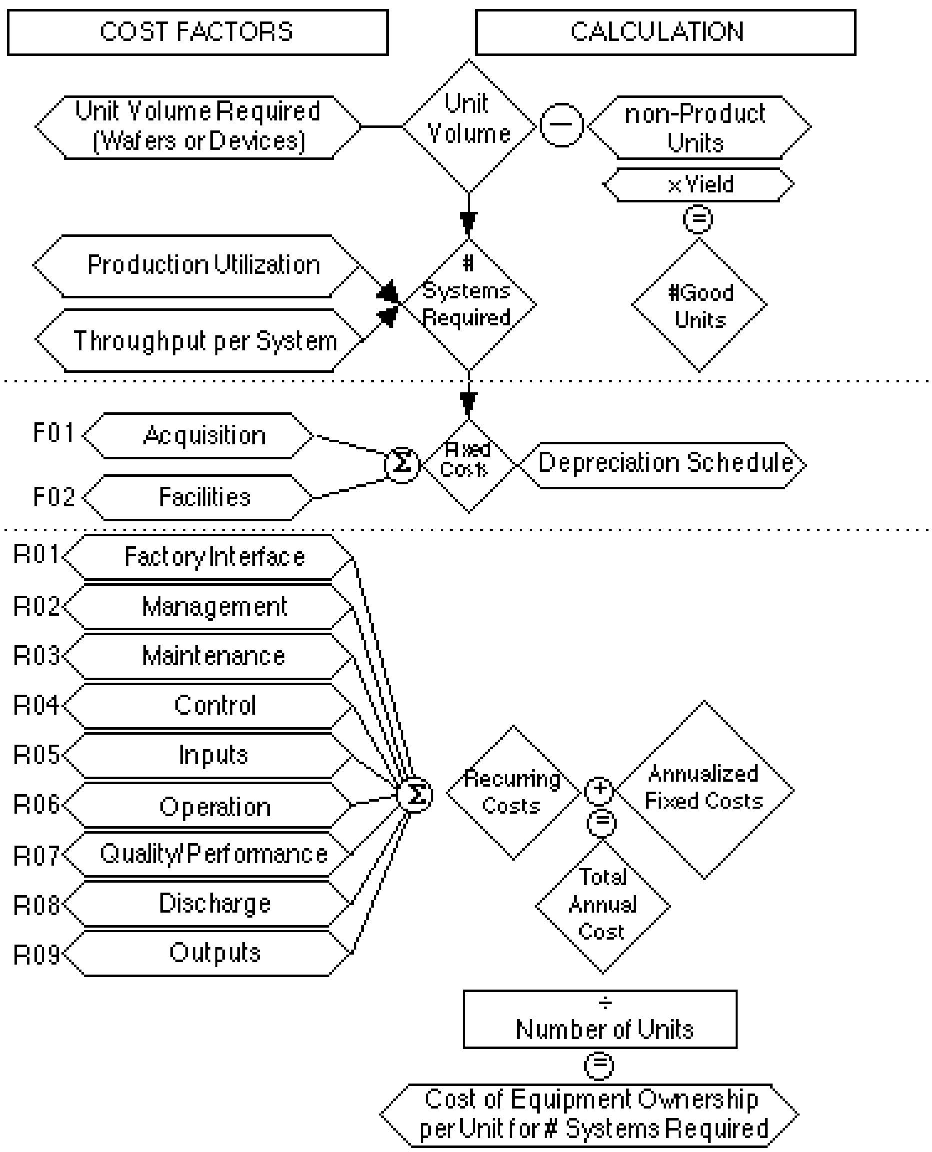

Figure R1-2
Cost of Equipment Ownership

RELATED INFORMATION 2
COO REPRESENTATIVE DATA VALUES

NOTE: This related information is not an official part of SEMI E35 and is not intended to modify or supersede the official guideline. This related information has been derived the development of the guideline and was felt by the committee to be useful supplemental material. Publication was authorized by vote of the responsible committee. Determination of the suitability of the material is solely the responsibility of the user.

R2-1 This related information presents selected representative data values (also called default values) for use in COO calculations if actual data is not available. Such representative data are not meant to be a substitute for having actual data appropriate to the problem being anaylzed.

Table R2-1 Example Classification Structure for Expanding COO

VIEW	*SuperClass*		*Class*	*Subclass*
Cost Center	Fixed	1	Equipment	
		2		
		3		
	Recurring	1	Consumables	
		2	Material	
		3	Maintenance	
		4	Labor	
		5	Support personnel	
		6	Scrap	
		7	Support Services	
		8		
		9		

R2-2 *Cost Center Default Values*

CF1.0 Equipment

Default	Sum of subcategories.
Comment	

CF1.1 Equipment: Depreciation

Default	5 year straightline depreciation.
Comment	

CF1.2 Equipment: System Qualifications

Default	Actual equipment specification, consumable costs, and fully burdened man-hour cost by personnel category. Labor rates: Operator \$25/hr; Maintenance: \$25/hr; Supervision: \$75,000/yr; Engineering: \$100,000/yr.
Comment	

CF1.3 Equipment: Installation

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CF1.4 Equipment: Training

Default	Actual equipment specification, consumable costs, and fully burdened man-hour cost by personnel category. Labor rates: Operator \$25/hr; Maintenance: \$25/hr; Supervision: \$75,000/yr; Engineering: \$100,000/yr.
Comment	

CF1.5 Equipment: Moves & Rearrangements

Default	Actual cost to semiconductor manufacturer.
Comment	

CF1.6 Equipment: Floor Space

Default	Actual equipment specification and floor space including safety aisles by cleanroom class, including:
	Class 1: \$350/ft^2
	Class 10: \$250/ft^2
	Class 100: \$100/ft^2
	Class 100+: \$ 50/ft^2
Comment	

CR1.0 Material

Default	Sum of subcategories.
Comment	

CR1.1 Material: Test/Filler Wafer

Default	Actual equipment specification and cost of test/ filler wafers. Test Filler wafer: \$100.
Comment	

CR1.2 Material: Utilities

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CR1.3 Material: Supplies

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CR1.4 Material: Waste Disposal

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CR2.0 Consumables

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CR3.0 Maintenance

Default	Sum of subcategories.
Comment	

CR3.1 Maintenance: Labor

Default	Actual equipment specification and fully burdened man-hour cost of maintenance. Labor rates: Maintenance \$25/hr.
Comment	

CR3.2 Maintenance: Spare Parts

Default	Actual equipment specification and inventory carrying cost to semiconductor manufacturer.
Comment	

CR3.3 Maintenance: Repair Parts

Default	Actual equipment specification and cost to semiconductor manufacturer.
Comment	

CR3.4 Maintenance: Service Contracts

Default	Actual equipment specification.
Comment	

CR3.5 Maintenance: Training

Default	Actual equipment specification.
Comment	

CR4.0 Labor

Default	Sum of subcategories.
Comment	

CR4.1 Labor: Operation

Default	Actual equipment specification and fully burdened man-hour cost for operators. Labor rates: Operator $25/hr.
Comment	

CR5.0 Support Personnel

Default	Sum of subcategories.
Comment	

CR5.1 Support Personnel: Supervision

Default	
Comment	

CR5.2 Support Personnel: Engineering

Default	Actual equipment specification and fully burdened man-hour cost for engineering. Labor rates: Engineering $100,000/yr.
Comment	

CR6.0 Scrap

Default	Sum of subcategories.
Comment	

CR6.1 Scrap: Equipment Yield

Default	Actual equipment specifications and cost of wafer lost at that point in the process. Equipment Yield: 99.99%. Value of incoming wafer: $250.
Comment	

CR6.2 Scrap: Defect Yield

Default	Calculated from actual equipment specifications, device parameters, and cost of wafer lost at the end of the process. Fault probability: 0%. Value of completed wafer: $500.
Comment	

CR6.3 Scrap: Parametric Yield

Default	Actual equipment specifications, device parameters, and cost of wafer lost at the end of the process. Parametric Yield: 100%. Value of completed wafer: $500.
Comment	

CR7.0 Support Services

Default	Actual equipment specifications and cost to semiconductor manufacturer.
Comment	

Supplemental supporting values:

Production schedule: 168 hours/week

Operator/maintenance productivity: 80%

Wafer size: 150 mm

Water coverage: 80%

NOTE: These values represent a 150 mm wafer fab running standard products at 0.8 µm design rules. This was a state-of-the-art factory in 1990.

R2-3 *Classification Elements Details; Functional Default Values*

VIEW	*SuperClass*		*Class*	*SubClass*
Functional	Fixed	1	Acquisition	
		2	Facilities	
		3	Decommission	
	Recurring	1	Factory Interface	
		2	Equipment Management	
		3	Maintenance	
		4	Control	
		5	Inputs	
		6	Operation Labor	
		7	Quality/Performance	
		8	Non-Product Waste	
		9	Product Waste	

Fixed Cost Classification

FF	*1*	*2*	*3*
.01	*Acquisition*	*Facilities*	*Decommission*
.1	1 Price	1 Space	1 Removal
.2	2 Purchasing	2 Infrastructure	2 Disposal
.3	3 Evaluation	1 utilities	3 Cleanup
.4	4 Installation	2 services	
.5	5 Training		
.6			
.7			

Recurring Cost Classification

FR	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
.0	*Factory Interface*	*Equipment Management*	*Maintenance*	*Control*	*Inputs*	*Opera-tion Labor*	*Quality/ Performance*	*Non Product Waste*	*Product Waste*
.1	Labor	Supervision	Contracts	Software	Consumables		Metrology	Waste	Die Yield Loss
.2	Safety	Support	Labor - Other	Training	Materials		Labor	Scrap	Scrap
.3	CIM	Administration	Repair Parts	Support	Utilities				1 breakage
.4	Infrastructure	Training - Other	Spares	Backup					2 equipment yield
.5									
.6									

FF1.0 Acquisition

Default	See subcategories.
Comment	

FF1.1 Acquisition: Price

Default	5 year straight-line depreciation of purchase price.
Comment	

FF1.2 Acquisition: Purchasing

Default	
Comment	

FF1.3 Acquisition: Evaluation

Default	
Comment	Actual equipment specification and consumable costs.

FF1.4 Acquisition: Installation

Default	Actual equipment specification.
Comment	

FF1.5 Acquisition: Training

Default	Actual equipment specification. Labor rates: Operator, Maintenance, Supervision/yr, engineering/yr.
Comment	

FF2.0 Facilities

Default	See subcategories.
Comment	

FF2.1 Facilities: Space

Default	Actual equipment specification. Cleanroom space: Class 1, Class 10, Class 100, > Class 100
Comment	

FF2.2 Facilities: Infrastructure

Default	See subcategories.
Comment	

FF2.2.1 Facilities: Infrastructure: Utilities

Default	0
Comment	

FF2.2.2 Facilities: Infrastructure: Services

Default	0
Comment	

FF3.0 Decommissioning

Default	See subcategories.
Comment	

FF3.1 Decommissioning: Removal

Default	0
Comment	

FF3.2 Decommissioning: Disposal

Default	0
Comment	

FF3.3 Decommissioning: Cleanup

Default	0
Comment	

FR1.0 Factory Interface

Default	See subcategories.
Comment	

FR1.1 Factory Interface: Labor

Default	Provided by semiconductor manufacturer. Labor rates: Operator, Maintenance, Supervision, Engineering.
Comment	

FR1.2 Factory Interface: Safety

Default	Provided by semiconductor manufacturer. Labor rates: Operator, Maintenance, Supervision, Engineering.
Comment	

FR1.3 Factory Interface: CIM

Default	Provided by semiconductor manufacturer. Labor rates: Operator, Maintenance, Supervision, Engineering.
Comment	

FR1.4 Factory Interface: Infrastructure

Default	Actual equipment specifications. Labor rates: Operator, Maintenance, Supervision, Engineering.
Comment	

FR2.0 Equipment Management

Default	See subcategories.
Comment	

FR2.1 Equipment Management: Supervision

Default	Actual equipment specifications. Labor rates: Supervision.
Comment	

FR2.2 Equipment Management: Support

Default	0
Comment	

FR2.3 Equipment Management: Administration

Default	0
Comment	

FR2.4 Equipment Management: Training - Other

Default	Actual equipment specification.
Comment	

FR3.0 Maintenance

Default	See subcategories.
Comment	

FR3.1 Maintenance: Contracts

Default	Actual equipment specification.
Comment	

FR3.2 Maintenance: Labor-Other

Default	Actual equipment specification. Labor rates: Maintenance.
Comment	

FR3.3 Maintenance: Spare Parts

Default	Actual equipment specification.
Comment	

FR3.4 Maintenance: Repair Parts

Default	Actual equipment specification.
Comment	

FR4.0 Control

Default	See subcategories.
Comment	

FR4.1 Control: Software

Default	Actual equipment specifications.
Comment	

FR4.2 Control: Training

Default	Actual equipment specifications. Labor rates: operator; maintenance; supervision; engineering.
Comment	

FR4.3 Control: Support

Default	Actual equipment specifications. Labor rates: operator; maintenance; supervision; engineering.
Comment	

FR4.4 Control: Backup

Default	Actual equipment specifications. Labor rates: operator; maintenance; supervision; engineering.
Comment	

FR5.0 Inputs

Default	See subcategories.
Comment	

FR5.1 Inputs: Consumables

Default	Actual equipment specification for parts that do not last 1 year.
Comment	

FR5.2 Inputs: Materials

Default	Actual equipment specification. Consumed wafer cost.
Comment	

FR5.3 Inputs: Utilities

Default	Actual equipment specification.
Comment	

FR6.0 Operation Labor

Default	Actual equipment specifications. Labor rates: Operator $25/hr.
Comment	

FR7.0 Quality/Performance

Default	See subcategories.
Comment	

FR7.1 Quality/Performance: Metrology

Default	0
Comment	

FR7.2 Quality/Performance: Labor

Default	Actual equipment specifications. Labor rates: Operator; Maintenance; Supervision; Engineering.
Comment	

FR8.0 Non-Product Waste

Default	See subcategories.
Comment	

FR8.1 Non-Product Waste: Discharge

Default	Actual equipment specification.
Comment	

FR8.2 Non-Product Waste: Scrap

Default	See subcategories.
Comment	

FR9.0 Product Waste

Default	See subcategories.
Comment	

Default	Actual equipment specifications. Average wafer value.
Comment	

FR9.2 Product Waste: Yield Loss

Default	Actual equipment specifications.
Comment	

RELATED INFORMATION 3
EXAMPLE VALUES TABLE

NOTE: This related information is not an official part of SEMI E35 and is not intended to modify or supersede the official standard. It has been derived from multiple sources. Publication was authorized by vote of the SEMI Metrics Committee. These values are provided only as examples. Actual values should be determined by considering company experience, specific tool characteristics, applications, process technology, product type, regional differences and analysis objectives. Determination of the suitability of the material is solely the responsibility of the user.

Example Values Description	*150 mm Example*[5]	*200 mm Example*[6]	*300 mm Example*[7]
1. Fab Parameters			
Engineering Usage	0	0	0
Standby Time	0	0	0
Production Tests	127	14	14
MTTT	0.31	0.25	0.3
Whole Systems	NA	1	1
2. Scheduled Production			
Hours/Week/Shift	42	42	42
Shifts per Week	4	4	4
Hours/Day	24	24	24
Days/Year	350	365	365
Supplier Shifts/Week	NA	4	4
3. Labor and Salary Rates			
Engineering	$100,000	$111,000 (See NOTE 1.)	$111,000
Supervision	$80,000	$111,000 (See NOTE 1.)	$111,000
Operator/Hour	$26	$25	$25
Maintenance/Hour	$26	$30	$30
Productivity	80%	80%	80%
4. Space Rates			
Class 1	$360	$400	$400
Class 10	$240	$250	$250
Class 100	$100	$100	$100
Other	$50	$50	$50
5. Wafer Costs			
Test Wafer	$5.50	$100	$500
Test Wafer Reuse Times (See NOTE 1.)	1	10	10
Incoming Wafer	$250	$500	$1317
Completed Wafer	$500	$1000	$2034
6. Depreciation Parameters			
Life of Equipment Years	5	7	7
Depreciation Life Years	NA	5	5
Salvage Value	$0	$0	$0
Depreciation Method	Straight Line	Straight Line	Straight Line
7. Other Parameters			
Systems/Engineer	5	10	10
Systems/Supervisor	20	30	30

5 Derived from SEMATECH Cost of Ownership Rev. B December 1990.

6 Approved, Metrics Committee, July 11, 1995.

7 Derive from joint Selete and International 300mm Initiative (I300I) inputs, 1997.

Example Values Description	*150 mm Example*[5]	*200 mm Example*[6]	*300 mm Example*[7]
Systems/Operator	2	3	3
Defect Fault Probability	0.167	0.05	0.08
8. Installation Cost as Percent of Equipment Cost			
Lithography	NA	NA	8%
Metrology	NA	NA	5%
Other	NA	NA	12%

NOTE 1: Revised from 1995 version.

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SEMI E35.1-95
GUIDE FOR COST OF EQUIPMENT OWNERSHIP COMPARISON METRIC

1 Purpose

1.1 The purpose of this guide is to provide a standard constrained version of the Cost of Ownership for Semiconductor Manufacturing Equipment Metrics Guide to provide a baseline metric for comparing cost effectiveness of competitive factory equipment subsystems in the semiconductor industry. The major constraints are the inclusion of only Equipment Yield and the exclusion of the Cost of Yield Loss consisting of defect limited yield and parametric yield.

1.2 The guide establishes well-defined practice to facilitate cost comparisons of equipment by using definitions, classifications and methods necessary to build a useful cost of equipment ownership comparator as a constraint version of SEMI E35. The guide should facilitate communication about cost of ownership.

2 Scope

2.1 This guide is a subset of a full COO calculator as presented in SEMI E35 and constitutes a fully conforming standard constraint version. The baseline metric is meant to reflect those equipment aspects over which an equipment supplier has responsibility and seeks to minimize aspects which couple costs for individual equipment to the entire factory system. The use of the metric is for competitive evaluation of equipment sets to be used for a specific process step.

2.2 Effective use of the metric to build a COO model requires identification of the constraints, parameter values within the adopted category classification. The primary calculators should, where possible, use direct values for inputs rather than deriving them from secondary models or using the default values provided in Related Information 1 and 2 in SEMI E35. A COO model requires data for many parameters. Default data for the COO is provided within this document and may be updated periodically through support documents.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI E10 — Guideline for Definition and Measurement of Equipment Reliability, Availability, and Maintainability

SEMI E35 — Guideline for Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI Compilation of Terms

4 Terminology

All terminology in this guideline is defined in SEMI E35.

5 Cost of Equipment Ownership Comparator

The Cost of Equipment Ownership Comparator (CEOC) metric is the incremental cost added to a good wafer or IC device flowing through a volume sized process system embedded in a factory environment for a specified lifetime. The metric is expressed as Cost per Good Wafer Equivalent for one pass through the system. CEOC should reflect the full cost of embedding and operating in a factory environment a process system needed to accommodate a specified number of wafers but does not include defect yield or parametric yield loss.

5.1 *CEOC: Fixed and Recurring Costs* — Determining the Cost of Ownership requires enumerating all of the Fixed and Recurring costs. Fixed costs are those incurred once and are usually associated with the acquisition and incorporation of equipment into the factory. Recurring costs are those which arise on an annual basis from the operation and maintenance of the equipment.

5.2 *Yield*

5.2.1 Production yield (PY) is often tied to a large number of factors which are principally the responsibility of the IC manufacturer and equipment comparisons for production yield should be done directly in the context of the production flow. Yield is a metric of the percentage of the wafer volume that results in good wafers and enters the picture in a number of ways which can complicate comparisons. Yield-related comparisons of equipment should be dealt with directly rather than lumping them into the CEO.

$$\text{CEO} = \overbrace{\left(\begin{array}{c}\text{annualized}\\ \text{Fixed Costs}\\ \text{per system}\end{array} + \begin{array}{c}\text{annualized}\\ \text{Recurring Costs}\\ \text{per system}\end{array}\right)}^{\substack{\text{COST of}\\ \text{Embedding + Operating}}} * \frac{\begin{array}{c}\text{Volume Required}\\ \text{\# Systems}\end{array}}{\begin{array}{c}\text{Good Units}\\ \text{Per Year}\end{array}}$$

5.2.2 Particles additions for example are often used as a predictor of yield loss. Equipment should be compared directly on the basis of particles or other direct metrics such as uniformity.

5.2.3 The Cost of Equipment Ownership should only reflect Equipment Yield. The percentage of wafers which can be passed to the next step can be based on any criteria, such as broken wafers or wafers determined to be defective by inspection or test.

5.3 *Life* — Time over which the fixed and recurring costs are spread for the annualized basis. Tax Life is customarily used in COO based upon standard accounting practice.

COO Lifetimes

1. Tax Lifetime - Depreciation
2. Equipment Production Lifetime

5.4 *System Throughput* — Wafers per hour capability for the process system.

5.5 *Volume Requirement*

5.5.1 The volume requirement is the wafer or IC (unit) flow to be processed. The volume requirement can be derived from specification of the product wafers or IC devices needed corrected for yield and the required number of other wafers which might be designated as test, dummy, or monitor wafers. One complication in accurately dealing with the volume requirement is that the volume of wafers actually reaching the equipment will depend on the volume loss from equipment yield for all the prior steps.

5.5.2 For CEOC, volume should be dealt with parametrically based upon factory wafer starts. For multi-chamber equipment, the impact of added chambers to increase capacity should be included as well as the impact of adding whole systems.

5.6 *Good Wafer Equivalents (GWE)* — GWE is derived from the number of good product die at wafer probe and is expressed as completely good wafers.

5.7 *Systems Required* — See SEMI E35.

6 Reporting Results

Conform to SEMI E35.

7 Limitations

7.1 Certain factors are more difficult than others to accurately determine. Thus, the accuracy of a COO calculation may be prone to a variety of errors or omissions. In addition, line balance considerations are not included in cost of ownership calculation.

7.2 A COO calculation may have more detail than presented explicitly in this guide. The structure of the guide however allows for the proper handling of these situations.

8 Procedures

8.1 The CEOC algorithm requires the specification of the volume level and the enumeration of appropriate fixed and recurring costs associated with processing that volume. The CEOC metric is a function expressed as the sum of a number of categories which constitute a classification system as given in SEMI E35. Each item in the classification system should be defined, a method for evaluating its expression given, and default values or handling specified. The cost of equipment ownership is a sum over the elements in the Category Table as expressed in Equation 2 and defined in SEMI E35.

8.2 Each item in the classification system is defined, a method for evaluating its expression given, and default values or handling specified. All costs must be assigned through the classification system and calculated per system for the number of production hours.

$$\text{CEOC} = \left| \sum_{j} F_{0j} + \sum_{k} R_{0k} \right| * \left(\frac{\text{Volume Required} \ \# \ \text{Systems}}{\# \ \text{Good Units per year}} \right) =$$

$$\left(\sum_{ij} F_{ij} + \sum_{kl} R_{kl} \right) * \left(\frac{\text{Volume Required} \ \# \ \text{Systems}}{\# \ \text{Good Units per year}} \right) \qquad (2)$$

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E43-0301
GUIDE FOR MEASURING STATIC CHARGE ON OBJECTS AND SURFACES

This guide was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001. Originally published in 1995.

This document was entirely rewritten in 2001.

1 Purpose

1.1 The purpose is to establish a guide for reproducible measurement of electrostatic charge(s) on any surface or object, consistent with the scope and limitations set forth below.

2 Scope

2.1 The measurement methods described herein can be applied to characterize the general electrostatic charge level(s) on objects and surfaces in all environments. Acceptable instrumentation, calibration, and measurement techniques are described in this document. Appendices include background information on the equipment specified and calibration procedure, as well as information and advice on performing a useful general static survey.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 Direct measurement of charge usually requires the use of a coulombmeter. Charges on an isolated conductor can be measured by transferring the charge into the coulombmeter by contacting the isolated conductor with the coulombmeter input probe. Charges on isolated conductors and insulators can be measured by transferring the charged object into a Faraday enclosure that is connected to the coulombmeter. These measurements can be relatively precise if care is taken in the transfer process to avoid changing the charge level when making the measurements.

3.2 Direct measurement of charge is often impractical. In these instances, charge is indirectly evaluated by detecting the electrostatic field from a charged surface using an electrostatic fieldmeter or an electrostatic voltmeter.

3.3 This guide does not describe instrumentation and techniques capable of making highly precise measurement of electrostatic charge. It is not suitable for measurement of electrostatic charge on small objects, such as packaged devices (i.e., reading(s) obtained are indicative/general area and not precise/minute). No methods of preconditioning the surface prior to measurements and no methods of characterizing the basic electrostatic performance of materials, such as tribocharging, resistance, and decay rate are a part of this document. Measurements made using this guide on the same surface or object may differ due to differences in the environment or history of the surface or object between the times any two measurements are made.

4 Referenced Standards

4.1 None.

5 Terminology

5.1 *electrostatic discharge (ESD)* — the rapid spontaneous transfer of electrostatic charge induced by a high electrostatic field.

5.2 *ground* — a conducting connection between an object, electrical equipment, and earth, such as the portion of an electrical circuit of the same electrical potential as earth.

5.3 *grounded* — connected to earth or some other conducting body that serves in the place of earth.

6 Safety

6.1 *Measurements of Very High Static Potentials (> 30,000 Volts)* — Measurements of very high static potentials (> 30,000 V) may need to be done at larger distances to avoid exceeding the measurement range of the meter and/or an ESD event to the meter.

6.2 *Measurements on Moving Objects or Surfaces* — Care should be taken, when attempting to read electrostatic charges on moving objects or surfaces, to maintain correct distance and avoid any contact; this is to assure “good” readings with no mechanical damage or personal injury.

6.3 *Measurements Using Electrostatic Voltmeters* — Avoid handling electrostatic voltmeter probes during operation as their surfaces may be at elevated potentials that represent a shock hazard to the operator.

7 Equipment and Performance Verification Methods

7.1 *Equipment*

7.1.1 *Electrostatic Locator/Field Sensor/Field Meter* — An electrostatic fieldmeter measures the value of the electrostatic field at its sensor. Electrostatic fieldmeters are calibrated and recommended for use at a particular distance from the charged object. Fieldmeters are best suited for making general surveys or audits, for making measurements of surfaces at very high potentials *(charge levels)*, and for making measurements when long-term stability is not important. They are not well suited for measurements of surfaces with very low potentials or when high spatial resolution of the surface potential is needed.

7.1.1.1 The electrostatic locator/field sensor/field meter will henceforth be referred to as “the fieldmeter.” Note that for measurements to be taken in the presence of air ionization, a chopper stabilized fieldmeter is required. The fieldmeter must be capable of making field measurements at a distance of 2.54 centimeters (cm) = 1 inch or less, from the field source to the sensor for this guide, as written. However, see Section 7.2.5 for fieldmeters that are operated at fixed distance(s), and adjust values in this document where applicable.

7.1.2 *Electrostatic Voltmeter* — An electrostatic voltmeter nulls the electrostatic field at its sensor (probe). An electrostatic voltmeter indicates the presence and approximate level of the charge(s) creating the electrostatic field. Under appropriate conditions, electrostatic voltmeters provide a better approximation of the charge level as compared to electrostatic fieldmeters. Electrostatic voltmeters are relatively free of drift and more environmentally stable as compared to fieldmeters.

7.1.2.1 Electrostatic voltmeters are well suited for fixed installation in equipment. Electrostatic voltmeters exhibit a high degree of accuracy that is independent of the distance from the charge. Thus, they are considered better suited for making more accurate and repeatable measurements as compared to fieldmeters. The probe can be located very close to a charged surface without arc-over, and, under appropriate conditions, can resolve a small spatial area on a surface.

7.1.2.2 Electrostatic voltmeters are best suited for making measurements of surfaces at potentials below 20kV, or when a calibrated or fixed distance from the probe to the surface cannot be maintained. They are also best suited for measuring low surface potentials, or when it is desired to resolve a small area on the surface. Electrostatic voltmeters are unsuitable for measuring surfaces at very high potentials, such as above 20kV.

7.1.2.3 The electrostatic voltmeter will henceforth be referred to as “the voltmeter.”

7.1.3 *Electrometer* — An electrometer is a contact voltmeter with a very high input impedance. Ideally, this input impedance would be infinite. In practice, it is limited by intrinsic physical materials properties of insulators and by stray leakage paths between the input terminals. Low voltage electrometers (below 200 Volt) have typical input resistances of 10^{14} ohms, accuracies better than 0.1%, and can resolve microVolt type potentials. High voltage electrometers (Kilovolts) usually rely on resistive voltage dividers and have typical input resistances in the 10^{11} ohms range with accuracies in the 1% range. It is important to evaluate and understand the burden that the input impedance of an electrometer represents when measuring voltage potentials on very small charged structures.

7.1.4 *Charged Plate Monitor* — A charged plate monitor is an instrument typically used to monitor the performance of air ionization equipment. Monitoring is done with an electrically isolated 15 cm × 15 cm (6 inches × 6 inches) metal plate, henceforth referred to as “the plate.” The instrument typically provides a means to charge the plate to a known voltage (1000 or 5000 volts of either polarity), a plate sensor to determine the voltage on the plate, and timing circuitry to determine the time required to discharge the plate to a percentage of its initial charge. For the purposes of this guide, the charged plate monitor, or a separate isolated plate assembly, can be used for performance verification purposes as explained in Section 7.2.

7.2 *Equipment Performance Verification (Confidence Test)*

7.2.1 *Performance Verification of a Coulombmeter* — Refer to Figure 1.

7.2.1.1 Zero the coulombmeter prior to each measurement.

7.2.1.2 Maintain a reference calibration capacitor. It should be a polystyrene or polypropylene 10 nF capacitor (Mallory SX-110 or equivalent). Measure the value of the capacitor to better than 1%. It is important to handle the reference calibration capacitor very carefully. Do not hold the capacitor by its body or discharge it by touching both leads with the fingers. Hold the capacitor by one lead only. Use a clip lead connected between ground and this lead of the capacitor to maneuver the other lead of the capacitor between the “hot” side of the charging source and the input terminal of the coulombmeter.

7.2.1.3 Charge the reference calibration capacitor to 1 volt with a charging source (power supply). Calculate the amount of charge on the capacitor by multiplying the voltage by the value of the capacitor. Example: 1V x 10 nF = 10 nC of charge.

7.2.1.4 Disconnect the charging source from the capacitor.

7.2.1.5 Connect the coulombmeter input probe to the capacitor and discharge the capacitor into the coulombmeter. The coulombmeter should indicate the calculated value.

7.2.2 *Performance Verification of Fieldmeters and Voltmeters* — Refer to Figure 2.

7.2.2.1 *Choosing Test Voltage(s)* — Choose one or more test voltage(s) from Table 1, based upon the electrostatic field level of concern:

Table 1 Test Voltages

Field of Concern	*Test Voltage*
Under 4,000 volts/meter or 100 volts/2.5 cm	100 volts
Under 40,000 volts/meter or 1000 volts/2.5 cm	1,000 volts
Over 200,000 volts/meter or 5,000 volts/2.5 cm (See NOTE 1.)	5,000 volts

NOTE 1: If fieldmeter or voltmeter performance verification is needed above 5,000 volts, it is left to the user to select values using the table as guide.

7.2.2.2 *Instrument Performance Verification* — Charge a conductive test plate to the desired verification voltage. Use of a suitable power supply or a charged plate monitor for test purposes is recommended.

7.2.2.3 *Assuring Meters and Operator Are Grounded* — Assure that the fieldmeter, voltmeter and operator are grounded. Turn on the meter and zero it as required according to manufacturer's instructions.

7.2.2.4 *Directing or Pointing the Sense Head* — Direct or point the sense head of the fieldmeter or voltmeter at the center and parallel to the surface of the plate at a distance at least twice the manufacturer's recommended measurement. Slowly move the sense head toward the center of the charged plate until a reading equal to the voltage applied to the plate in Section 7.2.2.1 above is displayed by the meter. Measure and record the distance from the sense head to the surface to the plate. Using the plate voltage from Section 7.2.2.1 above and the recorded distance, compute the field strength for the fieldmeter. See Figure 2, Fieldmeter and Voltmeter Verification Check.

7.2.2.5 *Alternative to Section 7.2.2.4* — Take measurements at a specified/fixed distance per manufacturer's instructions. Locate the sense head of the fieldmeter or voltmeter as in Section 7.2.2.4, but, at specified distance; reading displayed (on meter) should be within 5% of applied voltage to plate.

NOTE 1: Section 7.2.2.4 or 7.2.2.5 should be applicable to most meters. However, in every case, the electrostatic fieldmeter or voltmeter manufacturer's instructions should be read, understood, and followed.

7.2.2.6 *Other Desired Test Voltages* — Repeat Sections 7.2.2.4 and 7.2.2.5 for any other desired test voltages.

7.2.3 *Performance Verification of an Electrometer* — It is good practice to occasionally check the performance of the electrometer by connecting it to a known voltage source, and comparing its readings with readings taken by another reference voltmeter.

7.2.4 *Meter Stability* — All measurement devices should be turned on and pre-conditioned for as long a warm-up period as recommended by the manufacturer

7.2.4.1 Reset (zero) the coulombmeter prior to each measurement.

7.2.4.2 Check the zero on the fieldmeter or voltmeter as specified by the manufacturer. Usually this is done while the probe is positioned to view a grounded surface. If the zero of the meter has drifted by more than 5% of the test voltage for any range contained in Table 1, the meter is not suitable for use for measurements over that range. It may be suitable for use over other ranges contained in Table 1, using other test voltages. Reverify the meter's calibration at the selected test voltage.

7.2.4.3 *Zeroing an Electrometer* — Except on some older analog models, there are usually no provisions to zero an electrometer. Some electrometers with analog or digital read-outs do allow offsetting of a reading, as well as relative (delta) measurements. However, the electronic zero of the electrometer is usually set by the manufacturer, and should be part of the normal calibration. It is good practice to occasionally check the zero by shorting the input terminals together and verifying that the zero reading is within the manufacturer's specifications.

7.2.4.4 See Related Information 1 for notes on equipment accuracy and limitations.

8 Sampling

8.1 Sampling methods for this guide should be determined by the requirements of the user's application. Electrostatic surveys can be repeated at different times to make them more representative of actual static charge conditions in the surveyed area. The results will vary due to environment (e.g., humidity) and workstation setup/conditions. However, any measurement that is in excess of a (user) defined maximum or that is a benchmark value, should be repeated more than once, after performing a zero check of the measuring equipment. This is to validate previous reading(s) and/or establish a range/bounds in the case of varying-moving fields on previous reading(s).

9 Test Methods & Measurements

9.1 *Coulombmeter Measurements*

9.1.1 *Verifying the Coulombmeter* — Verify the performance of the coulombmeter as in Section 7 above. Check/reset the zero before each measurement and/or per manufacturer's instructions. Assure that the coulombmeter and operator are grounded.

9.1.2 *Equipment Selection* — Use a coulombmeter for direct measurement of charge. A feedback-type coulombmeter is recommended for charge measurements for the most complete transfer of charge. Shunt-type coulombmeters do not completely transfer charge and are not as straightforward to use as feedback-type coulombmeters. When using a Faraday enclosure, the Faraday enclosure must be large enough to hold the objects to be measured. The Faraday enclosure is used to measure charge on insulating materials as well as on conductors.

9.1.3 *Measurements* — Best results are achieved when all surfaces surrounding the measurement area are grounded (to minimize the effects of stray fields on the measurement) and when a consistent, systematic handling method is used during the measurement process. The operator should be grounded using a grounded wrist strap.

9.1.3.1 *Isolated Conductors* — To measure the charge on an isolated conductor, touch the lead from the coulombmeter to the isolated conductor.

9.1.3.2 *Faraday Enclosure Measurements* — Refer to Figure 3. To measure the charge on an object, carefully pick up the object with an insulated tool and place the charged object into the Faraday enclosure. Special handling considerations: Be careful not to add or subtract any charge in the process of moving the charged object into the Faraday enclosure. Don't let the charged object rub or slide against any other surface, as this may add or subtract charge from the object.

9.1.4 *Limitations* — Do not attempt to measure charges of magnitudes that are below the drift rate of the coulombmeter.

9.2 *Electrostatic Fieldmeter Measurements*

9.2.1 *Verifying the Fieldmeter* — Verify the performance of the fieldmeter as in Section 7 above. Check/reset the zero periodically and/or per manufacturer's instructions. Assure that the fieldmeter and operator are grounded.

9.2.2 *Measurements* — Measurements made to this guide should be taken/reported in units that conform to the customer specifications. Most common fieldmeters manufactured to date have operating instructions that reflect the user doing calibration and taking measurements in English units of volts/inch or volts at a fixed distance in inch(es) and in these cases, raw data are reported/listed directly. The international community specifies that units shall be in SI (Standard International) Metric units and the SI conversion factor in Section 7.1.1.1 will apply. However, by definition, electric field is expressed in volts per meter, and thus would be expressed according to Table 2.

9.2.2.1 For instance, when using a meter calibrated only at 100 volts, measurements under 4,000 volts/m would be expressed to the nearest 400 volts/m. Measurements over 4,000 volts/m would be expressed as > 4,000 volts/m. For a meter calibrated to all three voltages, measurements under 4,000 volts/m would be expressed to the nearest 400 volts/m, measurements between 4,000 and 40,000 volts/m would be expressed to the nearest 4,000 volts/m, and measurements over 40,000 volts/m would be expressed to the nearest 40,000 volts/m.

Table 2 Measurement Units

Test Voltage	*For Readings of*	*Express in Multiples of*	*For Readings of*	*Express as*
100 V	< 4,000 V/m	400 V/m	> 4,000 V/m	> 4,000 V/m
1,000 V	< 40,000 V/m	4,000 V/m	> 40,000 V/m	> 40,000 V/m
5,000 V	< 200,000 V/m	20,000 V/m	> 200,000 V/m	multiples of 200,000 V/m

Note: Measurements above 1000 volts/2.54 cm may be made based on verification of the meter at 1000 volts where less precision is acceptable due to safety concerns with verification equipment/setup or availability of such equipment.

9.2.3 *Measurement Limitations* — Measurements made to this guide are only valid for surfaces that are flat to a radius of 1.5 times the measurement distance from a point directly below the sensor head. For surfaces that are not flat, measurements should be made by moving the sensor over the surface such that the specified measurement distance is maintained as closely as possible. These measurements may only be stated as a range, with rounding as applicable to the meter's measurement range according to Section 9.2.2. See Figure 4, Example of a Survey of a Carrier of Semiconductor Wafers. See Related Information 2 for notes on test methods environment and measurements.

9.3 *Electrostatic Voltmeter Measurements* — Refer to Figure 4.

9.3.1 *Verifying the Voltmeter* — Verify the performance of the voltmeter as in Section 7 above. Check/reset the zero periodically per manufacturer's instructions. Assure that the voltmeter and operator are grounded.

9.3.2 *Selecting the Voltmeter* — Select an electrostatic voltmeter with a measurement range consistent with the anticipated levels of charge on the objects to be measured. The selection of too high a measurement range will sacrifice voltage resolution, while selection of too low a range will cause out-of-range operation (saturation).

9.3.2.1 To measure moving objects, select an electrostatic voltmeter with a response speed fast enough to detect the objects when they are moving past the electrostatic voltmeter probe at the highest anticipated velocity.

9.3.2.2 Select a side- or end-viewing probe for the electrostatic voltmeter as is best suited to view the target object or surface when the probe is installed in an apparatus.

9.3.3 *Measurements* — Position the probe in front of the surface to be measured. Best results are obtained when the probe is placed less than two (probe) aperture diameters from the object or surface to be measured. At these closer spacings, the effects of extraneous fields are minimized.

9.3.3.1 To resolve a small surface area, the distance between the probe and the surface-under-measurement must be less than $1/5^{th}$ of the diameter of the surface area to be measured. At wider spacings the surface area resolved by the probe will exceed the surface area of interest, and measurement accuracy may be reduced together with the possibility of introducing effects of extraneous fields to the measurement.

9.3.4 *Measurement Limitations* — Voltage levels on isolated conductors can be measured. Insulators do not have a uniform surface charge distribution. Therefore, it is considered that voltage levels measured on insulators indicate an electrostatic field strength in a particular area.

9.4 *Electrometer Measurements* — Measuring with an Electrometer is very similar to measuring with any other voltmeter or multimeter.

9.4.1 Connect the “common” terminal of the electrometer through a test lead to the reference plane or ground. Connect the “hot” or signal lead to the object or test point of interest. Some electrometer measurements will use a separate wire or shield connected to the electrical ground or a guard ring. Connect this as recommended by the manufacturer of the equipment.

9.4.2 The major difference between the ordinary voltmeter and the electrometer is the orders of magnitude higher input impedance of the electrometer. An electrometer will therefore pick up voltage signals produced by stray electric fields, potentials associated with noise currents, and artifacts caused by intentional or unintentional ionization of the ambient air when measuring high voltages. An electrometer can, for example, be used to measure the triboelectric and the piezoelectric properties of a piece of coaxial cable: connect the cable under test to the electrometer, and flex it or tap on it with a finger. The voltages induced on the center conductor can be measured by the electrometer.

10 Certification

10.1 Certification to survey areas to this guide is for the person doing the certification (certifier) to assure that the person being certified (certifyee) can calibrate the meter and make acceptable measurement of known static field(s) per Section 7 and applicable example(s) per Section 9. The certifier shall be someone qualified by education and/or training to calibrate and make measurements with the equipment called out in this guide or someone previously certified. The ESD Association conducts such training programs and the National Association of Radio and Television Engineers (NARTE) administers an ESD Engineer and ESD technician certification program.

10.2 *Demonstrating Ability to Verify the Performance of the Meter Against Known Source* — The certifyee shall charge the test plate, zero the meter, and perform the measurement a minimum of two times per Section 7; record values per Section 11. Readings obtained shall be within 5% of expected values.

10.3 *Demonstrating Ability to Measure Example Item(s) Acceptably* — The certifier will have charged/uncharged example(s) of items/objects for measurement of static field(s) by certifyee(s) a minimum of two times per Section 9; record values per Section 11.

10.4 *Certifying* — Readings obtained per Section 10.2 shall be within 12% of expected values and methodology of obtaining readings shall be acceptable per certifier observation(s). A permanent record of certification is realized by certifyee when certifier signs record sheet(s) for file in personnel records and/or when certifier issues a certificate. Refer to Section R1-3.

11 Documentation

11.1 Meter calibration check(s), benchmark or laboratory measurements, items/areas surveys, and/or any other electrostatic field measurements should be recorded in permanent records. Recorded are initial reading, second/validation reading, and any subsequent readings taken to acceptable range/bound levels observed. Record sheet(s) should show meter used, area (name), location, date, and items listed opposite readings, name of person who took readings, and space for comments.

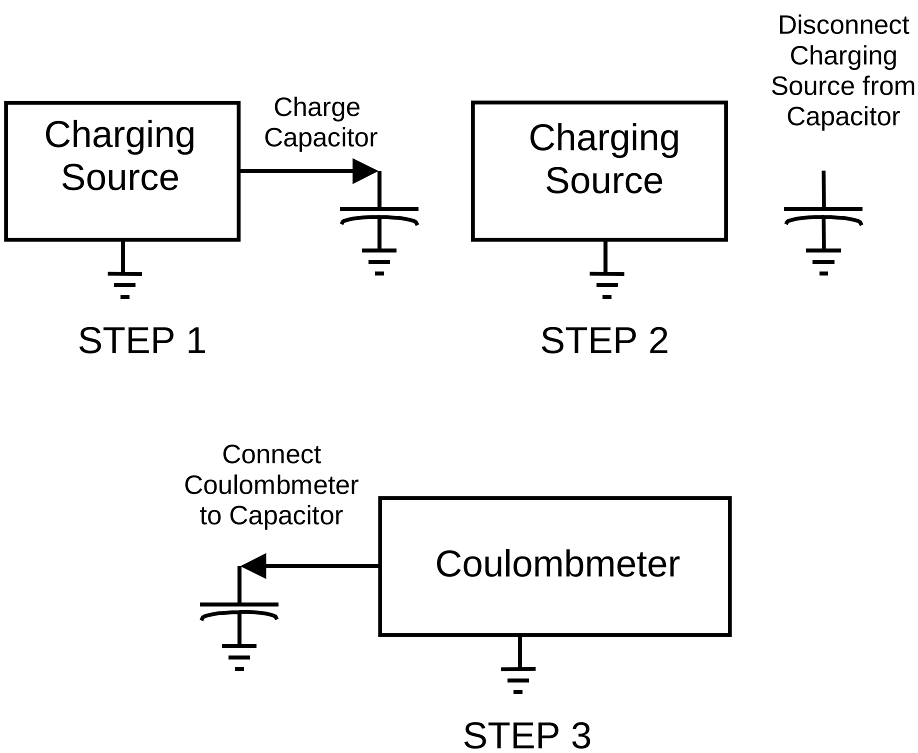

Figure 1
Verifying Performance of the Coulombmeter

A) Connect meter directly to charged plate ground reference.
B) Meter approximately 2.54 cm and parallel to charge plate.
C) Meter reading should be within 5% of voltage applied to plate.
D) Assure that both the meter and the operator are properly grounded.

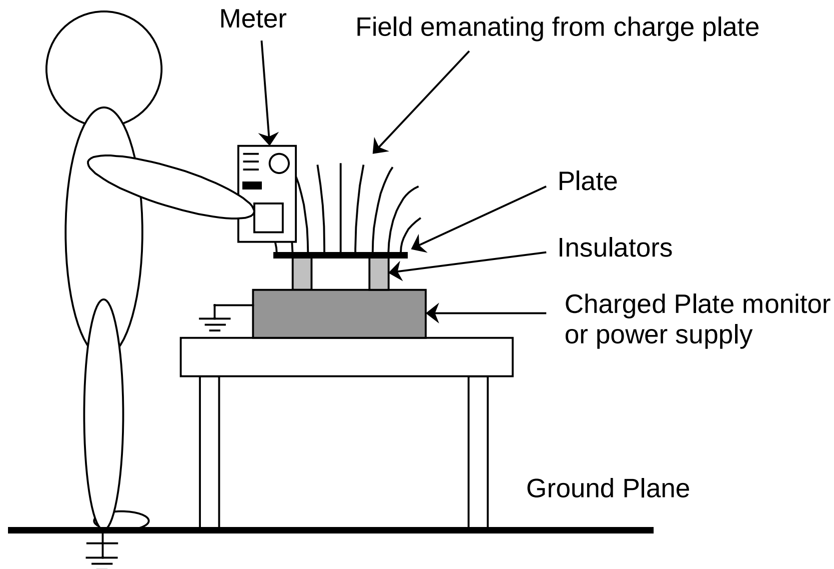

Figure 2
Fieldmeter and Voltmeter Verification Check

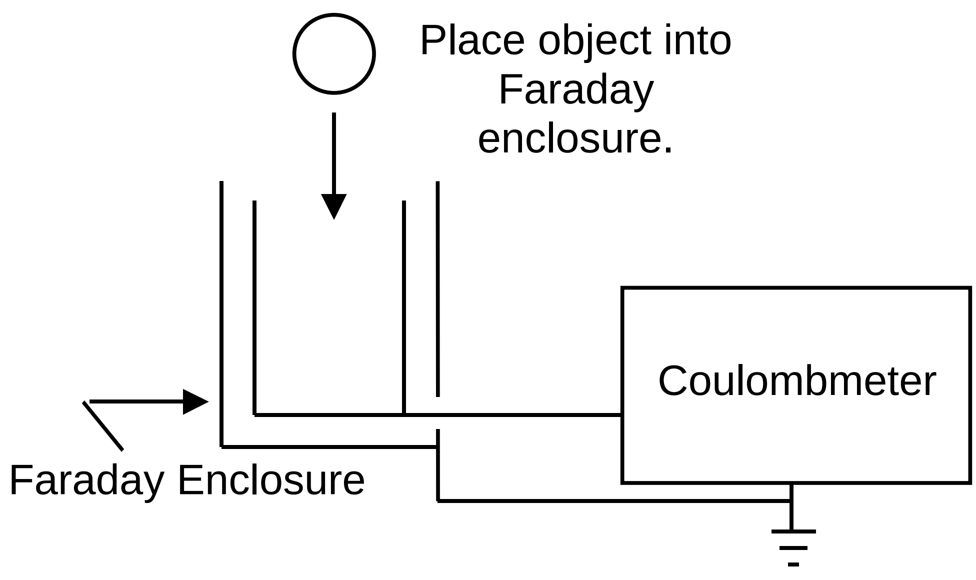

Figure 3
Measurement With a Coulombmeter and Faraday Enclosure

A) Make sure meter is properly grounded according to manufacturer's instructions.
B) Scan approximately 2.54 cm along both sides and ends of carrier.
C) Scan approximately 2.54 cm length of carrier and top-center of wafers with meter.
D) Note high-low values for B) & C).
E) Assure that the operator is properly grounded.

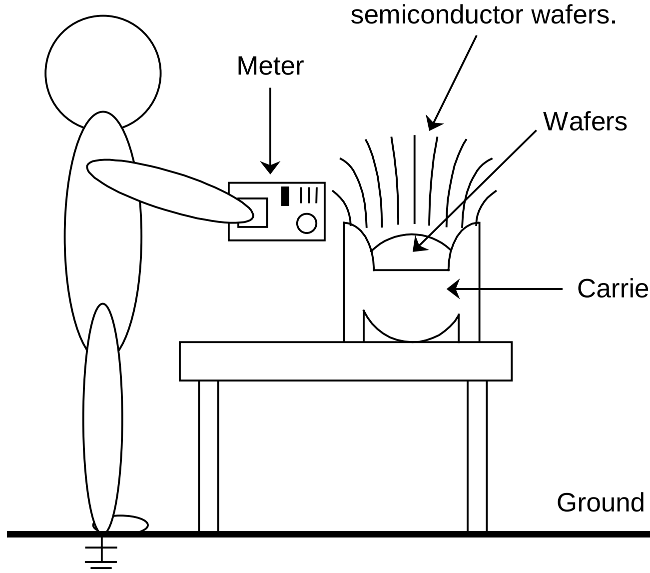

Figure 4
Example of a Survey of a Carrier of Semiconductor Wafers

12 Related Documents

NOTE 2: These documents are for information only; in the case of conflict, this document takes precedence. Also read/be aware of appendices to this document before use.

12.1 *ESD Association Standards*[1]

ANSI EOS/ESD S3.1: Ionization. Test methods and procedures for evaluating and selecting air-ionization equipment and systems are provided in this standard, which establishes measurement techniques to determine ion balance and charge-neutralization time for ionizers.

ESD STM4.2: Worksurfaces — Charge Dissipation Characteristics. This standard test method prescribes a procedure for measuring the electrostatic-charge-dissipation characteristics or work surfaces used for ESD control.

ESD STM5.1: ESD Sensitivity Testing — Human Body Model. This standard test methods defines procedures for testing, evaluating, and classifying the ESD sensitivity of components to the defined Human Body Model (HBM).

ESD S5.2: ESD Sensitivity Testing — Machine Model. This standard established a test procedure for evaluating the ESD sensitivity of components to a defined Machine Model, and outlines a system whereby the sensitivity of such components may be classified.

ESD STM5.3.1: ESD Sensitivity Testing — Charged Device Model. This standard is a test method for evaluating active and passive components' ESD sensitivity to a defined Charged Device Model.

ANSI/ESD S20.20: ESD Control Program. This standard specifies the requirements that must be satisfied in designing, establishing, implementing, and maintaining ESD control programs for ESD-sensitive

1 ESD Association, 7900 Turin Rd., Bldg. 3, Suite 2, Rome, NY 13440-2069, website: www.esda.org

items susceptible to discharges equal to or greater than 100 V HBM.

ESD SP10.1 — Automated Handling Equipment. This document covers test methods for evaluating the ESD ground integrity of automated handling equipment as well as charge generation, and charge accumulation on devices in automated handling equipment.

12.2 *ESD Association Advisory Documents*

ESD ADV1.0 — Glossary of Terms. Definitions and explanations of various terms used in Association Standards and documents are covered in this advisory. It also includes other terms commonly used in the ESD industry.

ESD ADV2.0 — ESD Handbook. The ESD Handbook is a complete guide to static control in the work place. Nineteen chapters cover ESD basics, control procedures, auditing, symbols, device testing, and standards.

ESD ADV11.2 — Triboelectric Charge Accumulation Testing. The complex phenomenon of triboelectric charging is discussed in this Advisory. It covers the theory and effects of tribocharging. It reviews procedures and problems associated with various test methods that are often used to evaluate triboelectrification characteristics.

12.3 *Other Related Documents*

12.3.1 *Military Standards*[2]

MIL-STD-1686C: ESD Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Devices). This military standard establishes requirements for ESD control programs. It applies to U.S. military agencies, contractors, subcontractors, suppliers, and vendors. It requires the establishment, implementation, and documentation of ESD control programs for static-sensitive devices but does not mandate or preclude the use of any specific ESD control materials, products, or procedures.

MIL-HDBK-263B: ESD Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding Electrically Initiated Explosive Devices). This reference provides guidance, but not mandatory requirements, for the establishment and implementation of an ESD control program in accordance with the requirements of MIL-STD-1686.

2 Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A

12.3.2 *JEDEC Standards*[3]

JESD625A: Requirements for Handling ESD-Sensitive Devices. This voluntary standard establishes minimum requirements for ESD control methods and materials designed to protect electronic devices having Human Body Model (HBM) sensitivities of 200 V or greater. It is intended for use by semiconductor distributors, semiconductor processing and testing facilities, and semiconductor end users.

12.3.3 *EIA Standards*[4]

EIA 541 – Packaging Material Standards for ESD Sensitive Items — This standard presents requirements and tests methods for selecting packaging materials to be used with ESD sensitive devices.

EIA 583 – Packaging Material Standards for Moisture Sensitive Items — This standard contains information regarding packaging materials used for the protection of ESD sensitive items when moisture levels are also important.

EN100015: Protection of Electrostatic Sensitive. This European Norm covers ESD handling practices for electronic devices.

12.3.4 *IEC Standards*[5]

IEC 61000-4-2 – Transient Immunity Standard. This IEC document provides requirements and test methods for ESD transient immunity.

IEC 61340-5-1:1998, Electrostatics, Part 5-1: Protection of Electronic Devices from Electrostatic Phenomena-General Requirements. This IEC (International Electrotechnical Commission) document provides guidance for establishing a static control program.

IEC 61340-5-2:1999, Protection of Electronic Devices from Electrostatic Phenomena-Users Guide. This IEC handbook supplement the information contained in Part 5-1 above.

3 Joint Electron Device Engineering Council, 2500 Wilson Blvd., Arlington, VA 22201, website: www.jedec.org

4 EIA Engineering Department, Standards Sales Office, 2001 Eye Street, NW, Washington, D.C. 20006, website: www.eia.org

5 International Electrotechnical Commission, 3, rue de Varembé, Case postale 131, CH-1211 Genève 20, Switzerland, website: www.iec.ch

APPENDIX 1
MEASUREMENT SELECTION MATRIX

NOTE: This appendix offers information related to selecting the appropriate measurement methods from those contained in this document. It was approved as an official part of SEMI E43 by full letter ballot procedure.

A1-1 The matrix contained in Table A1-1 is intended to assist in the selection of an appropriate measurement method for static charge. Users should note that a variety of measurement methods is available for any given situation. Consult manufacturers of the equipment for additional information concerning its proper use and applicability.

Table A1-1 Measurement Method Recommendations

Object	*Electrostatic Fieldmeter*	*Charged Plate Monitor*	*Electrostatic Voltmeter*	*Electrometer*	*Coulombmeter*	*Oscilloscope*	*EMI Detector*
Small object/device charge	X		X		X		
Surface charge	X		X				
Ionization system charge neutralization		X	X	X			
ESD event detection				X		X	X
Human body voltage	X		X	X			
Product cart charge level	X		X	X			
Chair charge level	X		X	X			
Charge decay	X	X	X	X			
Product material handling	X		X	X			
Ionizer Offset Voltage (Balance)		X		X			
Wafer charge	X		X		X		
Process equipment – Charge and ESD generation	X		X	X			X

RELATED INFORMATION 1
NOTES ON EQUIPMENT

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 A charged conductive plate establishes a uniform electrostatic field as long as measurements are not made close to the edges and the measurement distance is small relative to the dimensions of the plate. This specification requires meters capable of making field measurements at a distance of 2.54 cm (1 inch) or less from a 15 cm (6 inch) square plate as a practical means to ensure performance verification to a known field.

R1-2 Charged plate monitors using 15 cm square plates with a 20 picofarad capacitance are commonly used to determine the performance of air ionization systems. Isolators are used to assure minimal leakage to ground. A 15 cm square plate of any metal approximately 1 mm thick and isolated from adjacent surfaces using insulative standoffs is a perfectly acceptable substitute.

R1-3 The verification procedure is intended to ensure that the meter used does not drift excessively (less than 5% in 5 minutes) and can repeatedly measure a known field to within 5%. When actually using the meter to do a field survey, maintaining the correct distance from the sensor head to the surface or object being measured becomes the greatest source of error. If the ability of the meter operator to maintain the correct distance is within 10%, then the total error of the measurement would be within about 12% using this calibration procedure (RMS of the 5% drift, 5% repeatability, and 10% distance errors).

R1-4 If two operators using two different meters follow the verification procedure, and they both are able to maintain the correct distance to within 10% as above, then they both would be within 12% of the true field strength when measuring the same surface or object. Taking the RMS of these errors, the two operators using two meters should be within 17% of each other.

R1-5 Many meters read out in volts/inch. 100 volts/inch is about 4,000 volts/m.

RELATED INFORMATION 2
NOTES ON TEST METHODS

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R2-1 Prior handling and environmental conditions will significantly impact the field strength to be measured. Below are a number of these considerations:

- The presence of nearby grounded surface or object will tend to reduce the measured field strength. This phenomena is known as field suppression and is illustrated in Figure R2-1.
- Ionization of the surrounding air will tend to reduce the measured field strength by neutralizing the static charge on the surface of the object.
- Rubbing or contacting the surface being measured with another object or surface will tend to increase the measured field strength depending upon the tendency of the two materials in question to tribocharge.
- Increasing humidity will tend to reduce the field strength to be measured because it in turn will reduce the magnitude of the charge generated on objects and, over time, assist in the neutralization of charge on objects.
- Projections and sharp protrusions on the object being measured, or nearby objects, will increase the field strength.
- Insulating objects may have very irregular charge distributions.
- As a result of these considerations, a static measurement or survey made using this standard is only useful if these factors are taken into account in a realistic manner. For example:
    - If a surface is only used in a humidity or temperature controlled environment, field strength measurements made under these conditions are the main ones of interest. Measurements made at different humidities may be irrelevant.
    - An object may present close to zero field in an ionized environment, yet when contacted by another object may become highly charged. This charge may persist for a period of seconds or minutes while it is neutralized by the ionized environment. The time required to return the object to its original state may be a parameter of interest.
    - An object resting on a grounded metal surface may have very low external field strength. If the object is picked up and measured the field may be much higher.
    - Objects of irregular shape and size will give highly variable readings, depending on the position of the sensor relative to the object.
    - Dielectric objects may give highly variable readings, depending upon the position of the sensor relative to the charge distribution on the object.
    - The simple act of handling an object while performing a static survey can change the charge on the object. The best results will derive from making sure that objects and surfaces are treated and handled within the bounds of their actual use.
- During equipment verification, maintaining constant/steady voltage is important. If the plate is initially charged and allowed to float, its voltage will change as the meter is moved close to it.

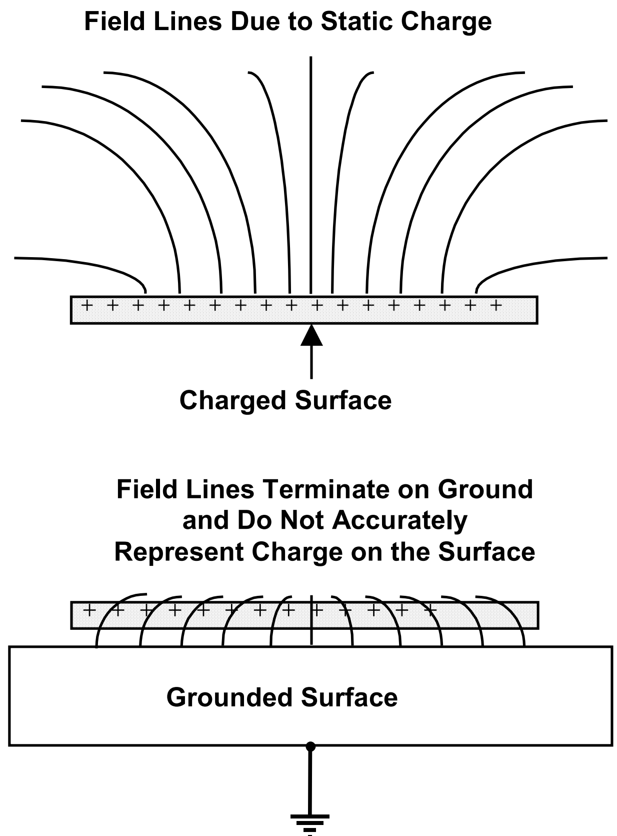

Figure R2-1
Field Suppression

RELATED INFORMATION 3
ESD DAMAGE SIMULATORS

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R3-1 ESD Damage Simulators

R3-1.1 ESD Simulators are used to replicate ESD events. Common types used to characterize semiconductor devices and equipment include:

- Component Level HBM ESD Simulator.
- Component Level MM ESD Simulator.
- Component Level CDM ESD Simulator
- System Level HBM/metal ESD Simulator

R3-1.2 The component level HBM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a typical human body. These parameters are 1500 ohms and 100 pF for the representative resistance and capacitance respectively of the human body.

R3-1.3 The component level MM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a charged metallic arm of a machine (automatic handler etc). These parameters are 200 pF and zero resistance for the representative capacitance and DC resistance respectively of the machine. We note here that the resulting waveform is dependent on the impedance of the circuity.

R3-1.4 The component level CDM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a charged device. These parameters are defined by the resulting waveform and depend almost exclusively on the capacitance, resistance and inductance of each device relative to ground. These parameters must not be confused with the equipment parameters, which affects the resulting waveform.

R3-1.5 The system level HBM/metal ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a human holding a metallic instrument. These parameters are the lower resistance 350 ohms and 150 pF for the representative resistance and capacitance respectively of the human holding a metallic instrument. Note here that the waveform is greatly affected by the equipment parasitics.

R3.1.6 The above component level ESD simulators have also been used in simulating ESD damage to tooling, such as reticles and photomasks. This simulation is left to user discretion.

R3-2 Summary of procedures

R3-2.1 *HBM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. ANSI and the ESD Association approved the HBM standard, ESD STM5.1, which contains a specific device pin combination sequence for stress testing. This test procedure is generally referred to as a Pin to Ground test since one pin is always grounded while the selected second pin is stressed. Calibration before use requires added equipment components like a current probe, high bandpass cable, a short wire, a 500 ohm resistor and a very high band width waveform recorder/digitizer.

R3-2.2 *MM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. The ESD S5.2 approved MM standard specifies a specific device pin combination sequence for stress testing. This test procedure is also generally referred to as a Pin to Ground test since one pin is always grounded while the selected second pin is stressed. This procedure is exactly the same as for HBM. Calibration before use requires added equipment components like a current probe, high bandpass cable, short wire, a 500 ohm resistor and a very high band width waveform recorder/digitizer.

R3-2.3 *CDM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. The ESD STM 5.3.1 approved CDM standard does not use a pin combination procedure. Here the device sits on a charge plate (CP) "dead-bug" style (package on CP and leads/pins vertical) and each pin is discharged successively after each charge to the device package. This procedure is different from that of HBM and MM. Calibration before use requires added equipment components like a capacitance/inductance calibrator, high bandpass cable and a very high band width waveform recorder/digitizer.

R3-2.4 *HBM-metal Simulator- system level* — The procedure for using this hand-held simulator for testing systems (ATE testers, Automatic handlers, computers, printers, ESD Simulators etc) is based upon the standard requirements. The IEC 61000-4-2, 1996 (formally-801-2,1992) standard uses direct contact or air discharge to the system under test and is a different procedure from the other three procedures mentioned above. Calibration before use requires the use of a very large vertical ground plane (at least 4 ft by 4 ft square), a high BW current probe, cables and high bandwidth waveform recorder/digitizer.

R3-3 Industry Classifications

R3-3.1 *HBM classification*

1. < 250 volts
2. 250 to < 500
3. 500 to < 1000
4. 1000 to < 2000
5. 2000 to < 4000
6. 4000 to < 8000
7. = or > 8000

R3-3.2 *MM classification*

1. M1 < 100
2. M2 100 to < 200
3. M3 200 to < 400
4. M4 400 to < 800
5. M5 = or > 800

R3-3.3 *CDM classification*

1. C1 < 125
2. C2 125 to < 250
3. C3 250 to < 500
4. C4 500 to < 1000
5. C5 1000 to < 2000
6. C6 = or > 2000

R3-3.4 *Hand-Held Metal HBM classification*

Direct Contact Discharge

	Voltage	Current
1.	2,000	12.0 amps
2.	4,000	24.0
3.	6,000	36.0
4.	8,000	48.0

Air Discharge

	Voltage	Current
1.	2,000	15.0 amps
2.	4,000	25.0
3.	6,000	30.0
4.	10,000	35.0
5.	15,000	52.0

Note that the currents for the same voltage level are not the same for contact versus air discharge.

RELATED INFORMATION 4
OTHER METHODS FOR DETECTING STATIC CHARGE AND ESD EVENTS IN EQUIPMENT

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R4-1 Introduction

R4-1.1 Static charge generation is unavoidable whenever materials come in contact. Without a static control program, the problems caused by static charge are also unavoidable. The most common problem caused by static charge is electrostatic discharge (ESD). ESD results in damaged semiconductor ICs, photomask defects, magneto-resistive (MR) read head defects in disk drives, and failures of the drive circuits for flat panel displays (FPD). ESD also creates a significant amount of electromagnetic interference (EMI). Often mistaken for software errors, EMI resulting from ESD interrupts the operation of production equipment. This is particularly true of equipment depending on high-speed microprocessors for control. Results include unscheduled downtime, increased maintenance requirements, and frequently, product scrap. Technology trends to smaller device geometries, faster operating speeds, and increased circuit density make ESD problems worse.[6]

R4-1.2 For many years static control programs concentrated on protecting components from the charge generated on the personnel that handled them. Many static control methods were devised to control the charge on people including wrist and heel straps, dissipative shoes and flooring, and garments. Increasingly, however, the production of electronic components is done by automated equipment, and personnel never come into contact with the static-sensitive devices. Solving the ESD problem means assuring that ESD events do not occur in the equipment used to manufacture and test electronic components.

R4.2 Static Control in Equipment

R4-2.1 An effective static control program in equipment starts with grounding all materials that might come close to, or in contact with the static sensitive components. This prevents the generation of static charge on machine components and eliminates them as a source of the charge creating ESD events. Care must be taken in a grounding program to assure that moving equipment parts remain grounded when they are in motion. In some cases, static dissipative materials may be substituted for conductive materials where flexibility, thermal insulation, or other properties not available in conductive materials are needed. If charging of components is unavoidable, static dissipative materials may be used to slow the resulting discharges and prevent component damage.

R4-2.2 Most semiconductors use insulating packaging materials such as ceramics and epoxy. Handling these insulating materials inevitably generates static charge, and this charge cannot be removed by grounding the materials. If charge generation is unavoidable, the only effective method of neutralizing the charge on insulators or isolated conductors is to use air ionization. Ionizers are typically mounted in the load stations and process chambers of the automated equipment to neutralize the static charge.

R4-3 Verifying Equipment Static Control

R4-3.1 A static control program begins when the automated equipment is designed by the OEM, and then continues throughout the lifetime of the equipment. Two basic issues need to be demonstrated. First, are all components in the product-handling path connected to ground? Second, as the product passes through the equipment, is it handled in a way that does not generate static charge above an acceptable level on the component? ESD Association Standard Practice, EOS/ESD SP 10.1-1999[7]. This document contains test methods to verify the integrity of the ground path to equipment parts, as well as to determine if the product is being charged during its passage through the equipment. The test methods are applicable during the original design of the equipment and during acceptance testing by the end user.

R4-3.2 While the test methods of EOS/ESD SP10.1-1999 can also be used for periodic verification of the equipment performance, they have one drawback. The automated equipment must be taken off-line to do the testing. This means that there is lost production time, and often the periodic testing is eliminated to maintain product throughput. Other test methods are available

6 Levit, L. et al, "It's the Hardware. No, Software. No, It's ESD! ", Solid State Technology, May 1999, Pennwell Publishing Company, 98 Spit Brook Road, Nashua NH 03062.

7 EOS/ESD SP10.1 - 1999 "Standard Practice for Protection of Electrostatic Discharge Susceptible Items - Automated Handling Equipment", ESD Association, 700 Turin Road, Rome NY 13440.

that can be performed with the equipment operating on-line, without altering or disturbing its operation.

R4-4 ESD and EMI

R4-4.1 When ESD occurs, the discharge time is usually 10 nanoseconds or less. Discharging energy in this short time interval results in the generation of broadband electromagnetic radiation[8], as well as the heat that damages semiconductor components. This electromagnetic radiation, especially in the 10 MHz to 2 GHz frequency range, is the EMI that can affect the operation of production equipment. In addition to ESD damage to semiconductor devices and reticles, ESD-caused EMI results in a variety of equipment operating problems including stoppages, software errors, testing and calibration inaccuracies, and mishandling causing physical component damage.

R4-4.2 *EMI Locators*

R4-4.2.1 When component damage or equipment problems due to ESD are suspected, it may be useful to detect the electromagnetic interference (EMI) generated by the ESD event. This type of testing is both a starting point for determining that static charge has been generated, and it is a measurement point to ascertain that any static control methods have been successful. EMI locators measure dynamic operating conditions, as it is usually not necessary to interrupt equipment operations to make measurements.

R4-4.3 *Types of EMI Locators*

R4-4.3.1 EMI locators are available in a number of different forms. In its simplest form, it consists of an AM radio tuned off station. A popping noise will be heard when an ESD event occurs. At the most complex it consists of a wideband (greater than 1 GHz) digital storage oscilloscope with a set of appropriate antennas, probes, and software. Measurements of radiated interference can be made using antennas while probes can be connected to equipment parts or electronics and power lines.

R4-4.3.2 An oscilloscope attached to a single antenna can assist in pinpointing the actual location of the ESD event.[8, 9, 10, 11] A set of antennas can be used to not only detect the presence of an ESD event, but to determine the location of the pulse in 3 dimensions.[12, 13] Using the same concept as a global positioning system (GPS), the difference in the arrival times of the signal to multiple antennas is directly related to the difference in the distance of each antenna from the ESD source. With the time deltas and the locations of the antennas known, the location of the spark can be uniquely identified employing the appropriate analysis program.

R4-4.3.3 Several other types of EMI locating equipment are currently in use. Most consist of high frequency receiving circuitry followed by level detectors to determine the magnitude of the signal. For the purpose of detecting EMI from ESD events, the equipment should have some way of differentiating the short impulse of EMI from the ESD event from the continuous high frequency radiation of other EMI sources. Some instruments contain a counter to total the number of ESD events above the threshold, or alarms to indicate when the number of ESD events exceeds a preset number. This type of instrument can be placed near a piece of equipment that is suspected of causing ESD events and left in place to monitor.

R4-4.3.4 Several EMI Locators are battery-operated handheld devices that can be easily carried around a facility or placed directly in equipment to check for ESD events. This allows the Locator to detect signals that might otherwise be shielded by the equipment's cover panels. (Note that EMI shielding is usually an important part of the design of most production equipment to prevent radiation from the equipment. This makes the detection of ESD events outside the equipment more difficult.) It allows pinpointing of the location of an ESD event, which can then be correlated to particular machine operations.[8, 14]

R4-4.4 *Limitation in Using EMI Locators*

R4-4.4.1 One caution needs to be observed when using EMI locators to detect ESD events that cause component damage. The signal received by these devices is generated in areas usually surrounded by grounded metal components. It may have to pass through equipment panels and travel some distance through the air before it reaches the detector. There may

8 Tonoya, Watanabe and Honda, "Impulsive EMI Effects from ESD on Raised Floor," 1994 EOS/ESD Symposium, pp. 164-169, ESD Association.

9 Takai, Kaneko and Honda, "One of the Methods of Observing ESD Around Electronic Equipments," 1996 EOS/ESD Symposium, pp. 186-192, ESD Association.

10 Greason, Bulach and Flatley, "Non-Invasive Detection and Characterization of ESD Induced Phenomena in Electronic Systems," 1996 EOS/ESD Symposium, pp. 193-202, ESD Association.

11 Smith, "A New Type of Furniture ESD and Its Implications," 1993 EOS/ESD Symposium, pp. 3-7, ESD Association.

12 Bernier, Croft, and Lowther "ESD Sources Pinpointed by Analysis of Radio Wave Emissions," Journal of Electrostatics (44) pp. 149-157, Nov. 1998, Elsevier Science B.V., P.O. Box 211, 1000 AE Amsterdam Netherlands.

13 Lin, DeChiaro and Jon, "A Robust ESD Event Locator System with Event Characterization," 1997 EOS/ESD Symposium, pp. 88-98, ESD Association.

14 Fujie, A., "Pinpointing Sources of Static Electricity with EMI Locator", Parts 1 and 2, Nikkei Electronics Asia, December 1992 and January 1993, Nikkei Business Publications Asia Ltd., 533 Hennessy Road, Causeway Bay, Hong Kong.

be other radio frequency sources and reflecting or absorbing materials in the area. The actual location of the ESD event may be a considerable distance from the EMI locator. It will be difficult to establish any correlation between the amplitude of the signal received by the EMI locator and the energy in the ESD event that produced the signal. The EMI locator primarily indicates the occurrence of an ESD event and can be used to illustrate that a particular static control method has eliminated it. It should not be assumed that every ESD event detected results in damage to components or equipment problems. Additional testing will be needed to establish that connection.

R4-5 Static Event Detectors

R4-5.1 Static event detectors (SED) are devices that are installed directly on products to detect the presence of an ESD event. They may be attached in proximity to an ESD-sensitive component, connected to the external device leads, or integrated into the device package. Typically they detect the current pulse of an ESD event through an antenna or direct connection to the device circuitry.

R4-5.2 SEDs can be useful in determining the occurrence of ESD events in operating production equipment. The SED has the ability to indicate ESD events of a known level, aiding in the design and performance verification of automated equipment. While costly analysis of failed devices can also provide this information, correlation to machine operations is usually difficult. An SED that can be monitored optically as it passes through operating equipment provides a convenient method to verify that automated equipment is not generating levels of static charge that result in ESD damage.

R4-5.3 Types of SED Devices

R4-5.3.1 In some SED devices, the signal is amplified and processed to produce a reflectance change in the built-in Liquid Crystal Display (LCD). The SED is designed to trip at a predetermined threshold voltage, detecting ESD transients above the selected amplitude. Some devices can be reset magnetically or optically making them reusable.

R4-5.3.2 Other devices use the controllable ESD damage threshold of metal oxide semiconductor field effect transistors (MOSFET). The test methodology is to amplify an ESD transient to create sufficient energy to destroy the gate oxide. The device may be used until the specified ESD level is achieved, and then the SED fails. A similar device is based on the metal oxide semiconductor capacitor (MOSCAP). The current leakage through the device significantly increases if the ESD amplitude is sufficient to damage the MOS structure. Both of these types of SED must be removed from where they are installed and require additional instrumentation to determine their status.

R4-5.3.3 Another type of SED employs the magnetic fields from a current flow to affect a series of magneto-optic thin films. The magnetic field from the ESD current alters the film's magnetic state and affects the degree of polarization of visible light reflected from the film. Varying the distance between the film and the ESD current-carrying conductor indicates different thresholds. This SED can be read using a microscope equipped with a polarizing element and does not need to be removed from the circuitry to be read. It can be reset with a magnet.[15]

R4-6 Conclusion

R4-6.1 There is little question that static charge problems continue to result in significant losses in high technology manufacturing. Increasingly, static control methods must be applied in the equipment that produces the product. It will be important to develop and utilize a range of diagnostic methods and measurement equipment for ESD in equipment.

15 Jackson, Tan, and Boehm, "Magneto Optical Static Event Detector," 1998 EOS/ESD Symposium, pp.233-244, ESD Association.

SEMI E44-96 (Withdrawn 0301)
GUIDE FOR PROCUREMENT AND ACCEPTANCE OF MINIENVIRONMENTS

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Purpose

1.1 It is widely felt that the requirements of buyers can be standardized. The purpose of this guide is to provide standardized procedures for the procurement and acceptance of minienvironments. It should assist the buyer in producing a procurement specification by providing a comprehensive and structured overview and checklists of all the parameters relating to procurement of minienvironments.

SEMI E45-1101
TEST METHOD FOR THE DETERMINATION OF INORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING VAPOR PHASE DECOMPOSITION-TOTAL REFLECTION X-RAY SPECTROSCOPY (VPD/TXRF), VPD-ATOMIC ABSORPTION SPECTROSCOPY (VPD/AAS), OR VPD/INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (VPD/ICP-MS)

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995; previously published March 2001.

1 Purpose

1.1 This test method provides the analytical procedures to determine the level of inorganic contamination from a minienvironment.

2 Scope

2.1 This document relates to inorganic impurities, which includes metallic contaminants, whether they occur as atoms, molecules, or particles. The number of metals to be analyzed is restricted to the four elements sodium (Na), calcium (Ca), iron (Fe), and copper (Cu) in order to rapidly characterize minienvironments from a practicable point of view. While Na, Ca, and Fe represent one ensemble of highly detrimental impurities with respect to contamination from human sources (Na), the environment (Ca), or from equipment and corrosive effects (Fe), Cu is analyzed due to its increasing importance in semiconductor manufacturing. Additionally, they are easily analyzed with sufficiently low detection limits. It is up to the user of this test method to quantify additional elements. A list of suggested polished wafer surface metal contamination inappropriate to circuits and devices is shown in Table 1 (based on SEMI M1). The inorganic contamination on silicon wafer surfaces is collected by VPD.

2.2 To quantify Ca and Fe, VPD/TXRF is used due to its sufficiently low detection limits. Na and Cu are quantified by VPD/GFAAS or VPD/ICP-MS. All analytical methods are widely used for the characterization of surface cleanliness.

2.3 This measurement technique can also be used to check the influence of certain process steps on minienvironments.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 1 Suggested Polished Wafer Surface Metal Contamination Inappropriate to Circuits and Devices

Element	*Test Method*
Na	VPD/(AAS or ICP-MS)
Al	VPD/(AAS or ICP-MS)
K	VPD/(AAS or ICP-MS or TXRF)
Cr	VPD/(AAS or ICP-MS or TXRF)
Fe	VPD/(AAS or ICP-MS or TXRF)
Ni	VPD/(AAS or ICP-MS or TXRF)
Cu	VPD/(AAS or ICP-MS or TXRF)
Zn	VPD/(AAS or ICP-MS or TXRF)
Ca	VPD/(AAS or ICP-MS or TXRF)

3 Referenced Standards

3.1 *SEMI Standards*

SEMI C28 — Specifications and Guidelines for Hydrofluoric Acid

SEMI C35 — Specifications and Guidelines for Nitric Acid

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

3.2 *ISO Standards*[1]

ISO 9001 — Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

ISO 14644-1 — Cleanrooms and associated environments – Classification of air cleanliness

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Website: http://www.iso.ch

3.3 *DIN Standards*[2]

DIN 12650 Part 6 — Mechanical, physical and electrical laboratory apparatus; Piston operated volumetric apparatus; Gravimetric assessment of metrological reliability

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *GFAAS* — Graphite Furnace Atomic Absorption Spectroscopy

4.1.2 *ICP-MS* — Inductively Coupled Plasma – Mass Spectroscopy

4.1.3 *PFA* — Perfluoroalkoxy

4.1.4 *PTFE* — Polytetrafluoroethylene

4.1.5 *PVDF* — Polyvinylidene fluoride

4.1.6 *TXRF* — Total Reflection X-Ray Fluorescence Spectroscopy

4.1.7 *ULSI* — Ultra Large Scale Integration

4.1.8 *VPD* — Vapor Phase Decomposition

4.2 *Definitions*

4.2.1 *box* — a protective portable container for a cassette and/or substrates.

4.2.2 *cassette* — an open structure that holds one or more substrates (e.g., wafer, masks).

4.2.3 *DI water* — deionized water (specified with specific resistivity ≥ 18 MΩcm, cations: Na, Cu, Fe, Ca ≤ 0.2 µg/L).

4.2.4 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.2.5 *pod* — a box having a Standard Mechanical Interface (SMIF) (See SEMI E19).

4.2.6 *reference wafer* — a cleaned wafer (see Section 8.2).

4.2.7 *sampling wafer* — a cleaned wafer (see Section 8.2), which will be or was exposed to the minienvironment for a certain time.

4.2.8 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment (see SEMI E19).

4.2.9 *vapor phase decomposition* — a method in which impurities on the surface are collected by the so-called VPD procedure, i.e., the non-volatile products formed by acid decomposition of the oxide at the wafer surface are collected by a droplet of collecting agent, usually ultra-pure hydrofluoric acid or other reagent or combination of reagents, and the droplet subsequently being analyzed by AAS or ICP-MS, or dried in a manner which gives the least environmental contamination, the residue from the droplet subsequently being analyzed by TXRF.

5 Interferences

5.1 For worst cases, preconditioning of wafers can result in different surface properties indicated by different sensitivities for contamination absorption.

5.2 Non-linearity effects of the TXRF detector are significant at higher concentration levels (> 10^{13} atoms/cm^2 under the detector area).

5.3 The collection efficiency of VPD depends on:

- the chemistry of the collecting solution
- the bonding of the metal impurities to the silicon surface
- the speed of the droplet, which is rolled over the wafer surface

5.3.1 Careful control of contamination and all other factors affecting the results such as solution concentrations, scanning methods and other procedures are necessary to obtain reproducible analytical results.

5.4 The measured TXRF intensity depends on the accuracy of the procedure to localize and to adjust to the sampled residue. It also depends on the distribution of different elements in and around the residue.

5.5 The detection of Fe or Ca using ICP-MS can be interfered with by background ions originated from the plasma unless some controlled measures are taken to minimize these interferences to acceptable levels.

6 Safety Precautions

6.1 Handling hydrofluoric acid is dangerous and shall be performed according to local regulations for laboratories. Operators shall be trained to deal with dangerous chemicals and vapors, especially hydrofluoric acid and HF vapor. Protective clothes and glasses must be worn when handling hydrofluoric acid.

7 Apparatus

7.1 The VPD treatment and contamination collection particularly, but also the handling and measurement of the specimen wafer is to be carried out in a specified

2 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany. Website: http://www.din.de

and controlled ambient (e.g., ISO Class 4 (as defined in ISO 14644-1)).

7.2 The VPD and the advisable drying chamber(s) shall have opening(s) made of PVDF, PFA, PTFE or similar resistant and pure polymer materials that are not attacked by HF. The chamber(s) may contain one or more wafer stacks. After evacuation, the chamber shall be flushed with filtered N_2 until the complete drying of the microdroplet residue is achieved.

7.3 For the aliquots of standard stock and scanning solutions, validated micropipettes shall be used. DIN 12650 Part 6 provides an applicable validation procedure.

8 Procedure

These procedures show the determination of Na, Ca, Cu, and Fe on a silicon wafer surface with VPD/GFAAS, VPD/ICP-MS and VPD/TXRF. For achieving best detection limits, VPD/GFAAS and VPD/ICP-MS shall be used for NA and Cu whereas VPD/TXRF shall be used for Ca and Fe.

8.1 *Test Requirements* — The evaluation of the minienvironment and the analysis shall be carried out under appropriate clean conditions. Any potential for cross contamination shall be checked in advance. Possible contamination sources are:

- VPD preparation
- storage
- contaminated GFAAS or ICP-MS vessels
- environment
- measurement methods and collection efficiency of VPD
- handling

8.1.1 The capability of the analytical lab has to be checked carefully for compliance with Sections 8.2, 8.6, and 9.

8.2 *Surface Conditions and Cleaning Procedure* — Polished silicon wafers with the following specifications must be used:

- Specific resistivity = 1–100 Ωcm
- CZ crystal growth method
- Cleaned to leave a native oxide with hydrophilic surface conditions and with Na, Ca, Cu, and Fe concentrations lower than 1×10^{10} atoms/cm^2

8.2.1 Wafer cleaning must be done less than ten minutes before any further processing. This restricted time limitation is necessary to ensure cross contamination avoidance.

8.3 *VPD Preparation* — The vessel for (opening > 25 cm^2) inside the VPD box is filled with 25 vol-% HF by mixing DI water with 50 vol-% VLSI-grade hydrofluoric acid (see SEMI C28) allowing hydrofluoric acid of between 25 to 50 wt % to be used. The wafers are then exposed to the hydrofluoric acid vapor. Allow wafers exposure to hydrofluoric acid vapor for 15 to 30 minutes, at which time the wafer should become hydrophobic due to oxide removal. The liquid reaction products are collected by rolling a DI water droplet over the whole wafer surface using up to 100 µL for advisable machine operation or an appropriate volume for manual operation. Any cross contamination is minimized by using DI water as solvent.

8.4 *Collection Procedure* — An automatic scanning procedure is preferable, but if the collection procedure is manual the following procedure should be used.

8.4.1 Use appropriate method to exclude the wafer edge.

8.4.2 A droplet of collecting agent, usually ultra-pure hydrofluoric acid or another reagent or a combination of reagents, is rolled over the whole surface of the wafer in a parallel pattern.

8.4.3 The same droplet is then moved over the whole surface, this time in a pattern orthogonal to the first.

8.4.4 Finally, the droplet is rolled in a spiral pattern from the wafer periphery to its center.

8.5 *Pre-analysis Procedure*

8.5.1 *GFAAS Analysis* — The wafer droplet is diluted to 500 µL.

8.5.2 *TXRF Analysis* — The droplet is evaporated on the wafer surface in a clean environment at room temperature under a nitrogen purge.

8.5.3 *ICP-MS Analysis* — The wafer droplet is diluted to 500 µL.

8.6 *Sodium and Copper Analysis by GFAAS*

8.6.1 *Calibration Standards* — 1 µg/L for Na.

8.6.2 The calibration frequency and procedures shall be in accordance with the requirements of the ISO 9001 quality system. The temperature program for the graphite furnace (dry, ash, atomize) is optimized for maximum sensitivity. Volatility (e.g., NaF) should be avoided by spiking the liquid samples with nitric acid (VLSI grade—see SEMI C35). Prior to analysis of the liquid sample, a three-point calibration of the element with an elemental standard is carried out (blank — 0.5 µg/L – 1 µg/L).

8.6.3 A detection limit for sodium and copper better than 5×10^9 atoms/cm^2 (approximately 0.1 µg/L for GFAAS analysis) is recommended.

8.6.4 The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve).

8.6.5 The surface concentration is calculated as follows:

$$C_s = C_1 \times V \times NA \times 10^{-9} / (W \times A)$$

with:

C_s (atoms/cm^2): surface concentration

C_1 (µg/L): analyzed concentration

V(mL): volume of diluted sample

$NA = 6.023 \times 10^{23}$ mol^{-1} : Avogadro number

A (cm^2): wafer surface area

W (g/mol): atomic weight of element (22.99 for sodium, 86.54 for copper)

8.7 *Sodium and Copper Analysis by ICP-MS*

8.7.1 *Calibration Standards* — 1 µg/L for both sodium and copper.

8.7.2 A detection limit for sodium and copper better than 5×10^9 atoms/cm^2 (e.g., for 200–300 mm wafers) is recommended.

8.7.3 The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve).

8.7.4 The surface concentration is calculated as follows:

$$C_s = C_1 \times V \times NA \times 10^{-9} / (W \times A)$$

with:

C_s (atoms/cm^2): surface concentration

C_1 (µg/L): analyzed concentration

V(ml): volume of diluted sample

$NA = 6.023 \times 10^{23}$ /mol : Avogadro number

A (cm^2): wafer surface area

W (g/mol): atomic weight of element (22.99 for Na, 86.54 for copper)

8.8 *Calcium and Iron Analysis by TXRF*

8.8.1 *Calibration Standards* — The ISO 9001 quality system shall be applied to the calibration. The instrument is calibrated by analyzing the calibration wafer. The calibration wafer is prepared by dropping a solution of metal standard (e.g., Ni or Co) on a clean wafer surface. The volume of the droplet is the same as used for VPD preparation (up to 100 µL), and the resulting surface concentration must be in the lower 10^{11} atoms/cm^2 range. The droplet is then evaporated on the wafer surface at room temperature under nitrogen purge until the liquid matrix is removed. Its residue is analyzed by TXRF. The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve). Note that the droplet area must be smaller than the spot area of the detector.

8.8.2 Reproducibility shall be first established following the procedure below.

8.8.3 Define a grid of 3 × 3 measurement points with an inter distance of 3 mm. The reside position, found by optical inspection, shall be located at the center of the matrix.

8.8.4 Determine the intensity by short analyses of each of the nine measurement locations. The analysis area is at maximum intensity for the standard element of the calibration wafer.

8.8.4.1 Calibration shall be checked weekly and after each equipment service (e.g., after an exchange of filament, anode, or repair of anode) with the same calibration wafer.

8.8.4.2 The surface concentration is calculated as follows:

$$C_s = RSF_m \times (C_0/I_0) \times I$$

with:

C_s (atoms/cm^2): surface concentration of analyzed metal M

I (counts/s): analyzed intensity of metal M

C_0 (atoms/cm^2): surface concentration of standard metal S (Ni or Co) on calibration wafer

I_0 (counts/s): analyzed intensity of standard metal S on calibration wafer

RSF_m: relative sensitivity factor of investigated metal M to standard metal S

8.8.4.3 The constants RSF_m are implemented in the software of the TXRF equipment.

8.9 *Sampling Procedure* — If the average elemental concentration for the sampling wafers is higher than the average elemental concentration plus three standard deviations for the analyzed reference wafers, then the sampled minienvironment is considered to cause significant contamination.

8.9.1 *Minienvironment Exposure* — The following exposure time for sampling specific minienvironments shall be used:

Minienvironments used to store wafers: 168 h

Minienvironments as an interface to process tools: 24 h

8.9.2 *Minienvironments for Storing Wafers* — Fill the minienvironment with six wafers. Measure wafers by VPD/GFAAS or VPD/ICP-MS in front, back, and center slots. Use the adjacent wafers for VPD/TXRF.

8.9.3 *Minienvironments for Introducing Wafers to Process Tools* — Introduce six wafers into the minienvironment. Measure three wafers with VPD/GFAAS or VPD/ICP-MS, one in the center position and two at the edge positions opposite to each other. Use the adjacent wafers for VPD/TXRF. In the case of single wafer minienvironments, wafers are processed sequentially. To ensure that no cross contamination is introduced from conditions prevailing in storing, transportation, or any of the handling processes, precautions must be adhered to at all times.

9 Results

9.1 The investigated minienvironment must be described in detail (e.g., construction, materials, history, process, cleaning procedures, storage conditions). All surface concentrations must be fully reported.

9.2 The number of tested sampling and reference wafers, average elemental concentration, and standard deviation of the reference wafers, slot positions, position in the minienvironment, and number of repeated experiments (if applicable) must be documented.

9.3 All equipment, tools, and chemicals used must be specified within the report.

10 Related Documents

10.1 *SEMI Standards*

SEMI C30 — Specifications and Guidelines for Hydrogen Peroxide

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

10.2 *Other Documents*

A. Shimazaki, H. Hiratsuka, Y. Matsushita, S. Yoshii, *Ext. Abs. 16th Conference on Solid State Devices and Materials*, Kobe, 281 (1984).

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SEMI E46-0301
TEST METHOD FOR THE DETERMINATION OF ORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING ION MOBILITY SPECTROMETRY (IMS)

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on December 20, 2000. Initially available at www.semi.org February 2001; to be published March 2001. Originally published in 1995.

1 Purpose

1.1 The purpose of this test method is to provide an analytical procedure—Ion Mobility Spectrometry (IMS)—for the determination of organic contamination from minienvironments which has the capability of testing their construction material.

2 Scope

2.1 Silicon wafers passed through or stored in minienvironments may be affected by organic contamination originating from construction materials. Knowledge of this contamination assists the decision about the application of minienvironments in semiconductor manufacturing.

2.2 Ion Mobility Spectrometry was chosen as the method to determine this contamination because it provides an easy, widely applicable, fast and sensitive way to measure organic contamination on surfaces.

2.3 Furthermore, IMS provides the possibility of checking the contaminating effects of processing, chemical carryover, and the characterization of future polymeric materials for use in semiconductor technology.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI Minienvironment Terminology Workshop Proceedings, April 2, 1993

4 Terminology

4.1 Box/Cassette/Minienvironment/Pod

4.2 *DOP* — Dioctylphthalate

4.3 *Headspace* — The volume above the sample containing the gas to be analyzed

4.4 *HPB* — Hexaphenylbenzene

4.5 *IMS* — Ion Mobility Spectrometry

4.6 *IMS/MS* — Ion Mobility Spectrometry/Mass Spectrometry

4.7 *NS* — Standardized Ground Joint

4.8 *SMIF (Standard Mechanical Interface)* — The interface plane between a pod and another minienvironment as per SEMI E19.

4.9 *PFA* — Polyfluoroalkoxy

4.10 *PP* — Polypropylene

5 Summary of Method

5.1 This test method defines a fast, sensitive technique for the determination of organic contamination from minienvironments. The contamination is measured directly from the silicon surface. Three important aspects are covered:

a. Contamination due to the minienvironment alone,

b. Contamination from the use of minienvironments for wafer processing, and

c. Contamination from future materials to be used in semiconductor technology.

5.2 Silicon wafers are either placed in the minienvironment or used for headspace sampling experiments. The sample is heated and the target compound is either desorbed or outgassed. These compounds are swept by the carrier gas into the Ion Molecule Reactor. Here the molecules are chemically ionized under atmospheric pressure. The target ions are separated in a drift cell by electrophoreses in the gaseous state and detected by an electrometer. Additionally, a quadrupole mass spectrometer could be used as a second detector. The result is a quantitative value for the total amount of organic surface contamination.

6 Interferences

6.1 To adequately measure organic contaminants from minienvironments, an extremely sensitive method for analyzing volatiles is required. At this time, the only analytical method meeting these requirements is IMS. The absolute determination of organic contamination by the IMS method is still limited, especially in the presence of many analytes, but this proposed test method permits the comparison of quantitative results from different laboratories.

7 Apparatus

7.1 *Minimum Requirements for the Ion Mobility Spectrometer* — For the successful performance of the experiments using the IMS instrument, the following requirements are essential:

— minimum length of the drift cell: 4 cm

— sample inlet has to be lockable (no sniffing devices)

— sample desorption oven must have a programmable temperature control

— the electronics must guarantee a linear amplification of the observed signal

— intensity over at least five orders of magnitude

— documentation of all single measurement results.

7.2 *Measuring Parameters* — For measurements with the ion mobility spectrometer, the following parameters have to be used:

temperature of the desorption furnace: 200°C*

temperature of the drift cell and IMS detector: 205°C*

maximum dwell time or channel length corresponding to minimum time resolution: 80 µs**

measuring time per spectrum: 40 ms*

(for 200 V/cm and 10 cm length of drift cell)

gatewidth: 200 µs**

number of scans: 2000**

drift gas and carrier gas: zero grade (synthetic) air*

- approx. 10 ppm H_2O*
- max 0.1 ppmv total hydrocarbons*

carrier gas flow: 100 mL/min* (for a diameter of 3.9 mm)

drift gas flow: 500 mL/min** (for a diameter of 4.25 cm)

* specified; ** suggested

8 Reagents

8.1 The chemicals must be of the described quality or better and supplied with a certificate of analysis.

Benzene: ultrapure quality for trace residue analysis. Minimum quality: pro analysi.

- content of benzene: min. 99.8%
- content of water: max. 0.02%
- nonvolatile residue: max. 0.0005%

Ethanol: ultrapure quality for trace residue analysis. Absolute.

- content of ethanol: min. 99.8%
- content of water: max. 0.1%
- nonvolatile residue: max. 0.0005%

DOP: normal pure quality.

- content of DOP: better than 96%

HPB: normal pure quality.

- content of HPB: better than 96%

9 Safety Precautions

9.1 All preparation and measurement work has to be done according to local regulations for laboratories.

10 Procedure

10.1 *Preparation Tools and Auxiliaries* — The following equipment is needed for the preparation of polymer headspace substrates:

- protective eye wear
- 1 fume cupboard
- 1 butane burner
- 2 pairs of crucible tongs made of stainless steel
- scalpel with changeable blades
- 4 pairs of cross tweezers with tips made of steel
- 1 metal vernier calliper
- Si-wafer-chips: formate 20 × 10 mm^2
- watch glass
- weighing bottle with lid, both made of glass

  inner diameter: 80 mm

  height: 30 mm

ground joint NS80

- aluminum foil
- 2 metal saws
- table vice
- finely toothed metal file
- steel ruler (30 cm)

10.2 *Preconditioning Procedure (Thermal Decontamination)* — In order to assure that all environmental influences are eliminated, all thermal decontamination procedures described in the following have to take place immediately before the appropriate measurements or experiments are performed.

10.2.1 *Preconditioning of Aluminum Foil* — Two cross tweezers are flamed with a butane torch in the fume cupboard (1 min., red heat). A piece of aluminum foil (20×30 cm^2) is folded multiply and, by using tweezers, is carefully heated in the flame until fully converted. After cooling down, the foil is stored on a fire resistant surface (ceramics preferred).

10.2.2 *Preconditioning of Weighing Bottles* — The jaws of the crucible tongs are heated in the butane torch until they are red hot for two minutes. After a short cooling period (15 s), the bottom of the weighing bottle is picked up. For several times, the inner and the outer surfaces of the glass are heated alternately in the torch (2 minutes for each run). After approximately 30 s of cooling down - held in air by the tongs - the flamed weighing bottle is put down on the preconditioned aluminum foil. The tongs are allowed to cool for 15 s, then the lid is prepared in the same way. After 10 minutes of cooling, the lid can be placed on the weighing bottle.

10.2.3 *Preconditioning of Watch Glass* — The watch glass is picked up with preconditioned cross tweezers and carefully heated in the butane torch for 30 s (without deformation by melting).

10.2.3.1 Simultaneously, the tips of a second pair of cross tweezers are heated to red heat. After 30 s, the watch glass is transferred by these tweezers, carefully heated for another 30 s to red heat (total heating time, 1 min), and placed on the preconditioned aluminum foil. After a cooling period of 5 minutes, the watch glass is picked up with a clean pair of preconditioned cross tweezers and placed inside the weighing bottle.

10.2.4 *Preconditioning of Si-chips* — Wafers, as received, are cut into chips of 20×10 mm^2 in size. The use of cotton gloves is recommended to avoid organic contamination through fingerprints. Then one Si-chip is picked up with a pair of cross tweezers and heated to red hot in a butane torch (30 s). Simultaneously, the tips of a second pair of cross tweezers are heated to red hot. After 30 s, the Si-chip is transferred to these tweezers and heated for another 30 s to red heat (total heating time, 1 min). After cooling, the Si-chip is transferred into the preconditioned weighing bottle. The weighing bottle must be opened and closed only with the thermally decontaminated crucible tongs.

10.2.4.1 The lid must be placed only on the preconditioned aluminum foil. Five more Si-chips are preconditioned as described above and placed into the weighing bottle. The six Si-chips must not overlap or touch one another. The Si-chips should be placed on the preconditioned watch glass.

10.2.5 *Preparation of Polymer Material* — The table top vice is mounted on a clean work-bench. The cross tweezers, the blade of a metal saw, the scalpel, the metal vernier calliper (within the measuring range), the steel ruler (in the range of 0 to 3 cm), and the finely toothed metal file are thermally decontaminated. Having decontaminated the metal saw, an area of approximately 50×50 mm^2 is sawed off the polymeric material and fixed with the clean cross tweezers. This piece of polymer material is then clamped vertically between the jaws of the vice. An area 12×20 mm^2 is carefully marked with the scalpel and cut out with the metal saw. Before total separation, the polymer sample is clamped with cross tweezers while the jaws of the vice are covered with the decontaminated aluminum foil. After clamping the polymer sample between the jaws of the vice, all sides of the polymer sample are carefully filed to length wit ha metal file (size control with metal vernier caliper). Then the polymer sample is placed on a clean watch glass by cleaned tweezers. The watch glass is positioned on the thermally cleaned aluminum foil. Both parts are stored inside the preconditioned weighing bottle which is carefully closed with its lid. The weighing bottle, within which the Si-chips are stored, is wrapped in preconditioned aluminum foil for storage and transportation.

10.3 *IMS Measurements Procedure*

10.3.1 *Blank Measurement* — The background signal level (noise) of the equipment must be defined by measuring the clean and stabilized IMS-equipment, without sample, three times for each polarity.

10.3.2 *Reference Measurement* — All manipulations etc. with the reference chemicals (Hexaphenylbenzene and Dioctylphthalate) have to take place entirely in PFA containers etc. Following equipment is needed:

2 narrow necked flasks (PFA), 250 mL

2 weighing boats (PFA)

! ! low weight, diameter smaller than diameter of narrow necked flask! !

2 pipettes (glass), 100 mL

1 micro dropper with changeable tips of 2 µL (may be PP)

1 micro spatula (metal)

1 micro balance, measuring range 10^{-6} g to 1 g at least

10.3.2.1 Preparation of the reference measurement with HPB:

10.3.2.1.1 Before the HPB is weighed, the PFA-bottle and the weighing boat have to be cleaned. For this the weighing boat and 10 mL benzene are given into the bottle. The bottle is closed and shaken well for approx. 1 minute. The benzene is discarded. This procedure is repeated four times. After the last cleaning the empty open bottle and the weighing boat, placed on a decontaminated aluminum foil (see Section 10.2.1). are allowed to dry at room temperature in a fume cupboard for ten minutes. Then the bottle is closed. The weighing boat is placed onto the micro balance by thermally decontaminated cross tweezers. Approx. 5 mg of HPB are weighed into the weighing boat by use of a thermally decontaminated micro spatula. The weight is recorded exactly for the later calculation. The weighing boat is placed into the PFA bottle by the cross tweezers.

10.3.2.1.2 The volume of the benzene is measured using a 100 mL-pipette. Before use, the pipette has to be washed 5 times using 10 mL benzene each time. The 100 mL benzene are filled into the PFA flask, which is closed immediately.

10.3.2.1.3 First the bottle, now containing HPB and benzene, is shaken well for three minutes. Often this is not sufficient for a complete dissolution of the HPB (visible inspection). To assure complete dissolution, the PFA flask is placed into an ultrasonic bath for 5 minutes (not longer, because solution may get hot). Two minutes before the end of that time the preparation of the silicon chip is started. The piece of silicon is heated to red heat for one minute, placed on the thermally decontaminated aluminum foil and given 5 minutes to cool. When the treatment in the ultrasonic bath is finished, the PFA flask is shaken for three minutes again, then given 2 minutes for just standing.

10.3.2.1.4 The bottle is opened. By the micro dropper 2 µL are taken from near the surface (tip not more than 1 mm under surface of liquid). The 2 µL are spread onto the silicon chip in such a way that the liquid on the chip covers the smallest possible area. Care is to be taken to prevent large spreading or even dropping off the liquid (e.g., the Si chip has to be positioned flat). The liquid is given 5 minutes to evaporate (room temperature, no extensive blowing of air). Then the measurement of the HPB reference can be started.

10.3.2.1.5 Before each following HPB measurement the flask again has to be shaken 3 minutes, 5 minutes ultrasonic bath, shaking 3 minutes, allow two minutes of resting. The solution of the HPB in benzene must not be kept longer than 10 days.

10.3.2.1.6 The reproducibility of the integral value (see calculation) achieved by this procedure is better than 4%. Sample measurements shall be performed only, if the reference measurement has provided a reproducibility equal to or better than 10%.

NOTE 1: Hexaphenylbenzene has been chosen as a reference compound because its signal is well-defined and its mobility value is well separated from the peaks of nearly all other relevant organic contaminants. It provides positive ions only. A different reference, Dioctylphthalate, is needed for negative ions.

10.3.2.1.7 DOP-reference samples: All the same as HPB, except replacing the benzene by ethanol. The DOP is weighed using a micro dropper (not spatula).

10.3.2.1.8 The mobility spectrum of dioctylphthalate is also well separated but there are several peaks due to thermal decomposition (phthalic anhydride etc.). This compound is a frequently used plasticizer and therefore one of the most critical polymer additives.

10.3.3 *Measurement of the Headspace Samples* — Positive and negative ions are detected successively in two separate runs. At least two independent measurements are carried out for each polarity. Every measurement to be saved consists of 2000 single scans and is then repeated. Hence, an automated measurement is required.

10.3.3.1 The silicon chip is placed in the furnace of the IMS using thermally decontaminated cross tweezers. The measurement of the drift time spectrum (positive or negative polarity) has to be started immediately after loading the desorption furnace with the sample (time delay between sample introduction and starting of the measurement: 15 s).

10.3.4 *Termination of the Measurement* — The measurement is terminated when the signal intensity has decreased to about 10% above the noise of the blank measurement spectrum. If this point is not reached after two hours, the measurement should be terminated; in this case, the investigated sample does not show suitable material properties.

10.4 *Headspace Sampling in Minienvironments* — The crucible tongs are preconditioned as described in Section 10.2, and the preconditioned aluminum foil is placed beside the minienvironment that is to be examined. After opening the minienvironment, the lid of the weighing bottle is picked up with the crucible tongs and carefully placed on the aluminum foil. Both the weighing bottle (holding the Si-chips) and its lid are separately put inside the minienvironment. Then the minienvironment is closed and kept closed for a defined period of time. For this test method, one week (168 h) is defined. After expiry of the storage time, the weighing bottle is closed with its lid and removed from the minienvironment.

10.4.1 The same procedure applies to standard wafer boxes or to SMIF and similar boxes.

10.5 *Headspace Sampling of Polymer Material at Different Temperatures* — The prepared polymer material inside the wrapped weighing bottle (see Section 10.2.5) is stored:

- either under clean laboratory conditions at room temperature for a defined period of time
- or in a suitable oven at a temperature of 70°C or 120°C for exactly 1 hour followed by a cooling period of 1 hour.

10.5.1 The wrapped weighing bottle is handled with a pair of crucible tongs only.

10.6 *Testing Requirements* (check for device overload during measurement)

10.6.1 *Positive Ions: Water Cluster Signal Intensity* — The water cluster signal intensity must not decrease by more than 10% of the blank spectra intensity during measurement time; otherwise, the ion molecule reactor has been overloaded. If this is the case, the polymer sample is not likely to be suitable for use in semiconductor processing because of unacceptable properties.

10.6.2 *Negative Ions: Oxygen Cluster Signal Intensity* — The same procedure as that in Section 10.6.1 must be performed for negative ions; in this case, the oxygen cluster signal intensity must not decrease by more than 20%.

11 Calculation

11.1 *Description of Mobility Spectra Evaluation* — The signal intensities of the detected sample contaminants are integrated over a specific interval for both polarities. The background signal intensity is integrated, outside the specific measurement interval, with preference to spectral region prior to the peaks of the reactant ions. The total background intensity (integration of the relevant background signal) is subtracted from the integrated contamination intensity (background correction). The mean value of the contamination signal from the blank measurement (Section 10.3.1) spectra is subtracted accordingly. This leads to individual contamination values from each sample spectrum.

11.2 Calculation of reduced mobility:

$K = E^{-1}\, l_d / t_d$ and

$K_0 = K\,(p/p_0)\,(T_0/T)$

K : ion mobility (cm^2/Vs)

K_0 : reduced ion mobility (cm^2/Vs)

p : pressure

p_0 : standard pressure

T : temperature

T_0 : standard temperature (273.15K)

l_d : drift length (cm)

t_d : drift time (s)

E : electric field strength (V/cm)

K : Kelvin

11.2.1 Table 1 shows the specified integration range; all reduced mobility values are given in units of cm^2/Vs.

11.2.2 The resulting integrals for each spectrum are summed up for the whole desorption time. This value is compared to the appropriate value of the reference sample (HPB or DOP).

11.2.3 This procedure ensures the comparison of the evaluated sample contamination values between different laboratories and measurement equipments.

12 Related Documents

12.1 K. Budde, "Application of Ion Mobility Spectrometry to Semiconductor Technology," Proceedings of the Satellite Symposium to ESSDERC 89 (Berlin) of the Electrochemical Society (the Electrochemical Society Pennington, 1990) PV 90-11, p.215.

12.2 K. Budde, W. J. Holzapfel, "Measurement of Organic Contamination from Silicon Surfaces," Proceedings, 38th Meeting, Institute of Environmental Sciences, 3.-8.5.1992, Nashville, TN, p.483.

12.3 K. Budde, W. J. Holzapfel, "Detection of Volatile Organic Surface Contaminations Arising from Wafer Boxes and Cleaning Processes," Proceedings of the First International Symposium on Semiconductor Wafer Bonding, (the Electrochemical Society Pennington, 1992) PV 92-7, p. 271.

12.4 Proposal: SEMATECH Test Method for Determining Outgassing Products from Semiconductor Product Carriers.

12.5 S.N. Ketkar, S.M. Penn, and W.L. Fite, "Influence of Coexisting Analytes in Atmospheric Pressure Ionization Mass Spectrometry," Anal. Chem. 63, (1991) 924.

12.6 R.E. Clement, K.W.M. Siu, and H.H. Hill Jr., "Instrumentation for Trace Organic Monitoring," Lewin Publishers, Boca Raton 1991.

Table 1 Integration Range for the Evaluation of Ion Mobility Spectra

Polarity of Target Ions	*Sample*	*Background*	*Signal Range (sample)*
positive	HPB	42.10–5.81	0.86–0.77
negative	DOP	37.30–7.35	1.99–1.63
positive	Sample	42.10–5.81	2.24–0.84
negative	Sample	37.30–7.35	2.30–0.91

SEMI E47-0301
SPECIFICATION FOR 150 mm/200 mm POD HANDLES

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on October 26, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1995; previously published October 2000.

1 Purpose

1.1 This specification provides a unified form and location for pod handles to enable automatic pod handling.

2 Scope

2.1 This specification defines the dimensions and location of handles on 150 mm/200 mm pod. These provide automatic handling and take into consideration manual handling. The design of individual manual handles is open to be accomplished within the dimensional limitations of the standard.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification applies only to automatic handling of the pod with a SMIF interface in the horizontal plane (see limitations of SEMI E19.3 and E19.4). Dimensional restrictions for manual handling are given in SEMI E15 and SEMI T4.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19.3 — 150 mm Standard Mechanical Interface (SMIF)

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI T4 — Specification for 150 mm and 200 mm Pod Identification Dimensions

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment per SEMI E19.

5.2 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

5.3 *box* — a protective portable container for a cassette and/or substrate(s).

5.4 *cassette* — an open structure that holds one or more substrates (wafer, masks, etc.).

5.5 *handle of a pod* — a mechanical aid designed for automatic handling of a pod, which may also be used for manual handling.

5.6 *handling area* — minimum free space around the pod for automatic handling.

5.7 *handling of a pod* — automatic and manual movement and/or placement of a pod.

5.8 *orientation notch* — notch located at the pod handles to allow sensing the orientation of the pod. See Figure 1.

5.9 *position notch* — notch located at the center lines of the pod handles to allow positioning. See Figure 1 (PN1 to PN4).

6 Requirements

6.1 Handling Dimensions: the handling dimensions for 150 mm and 200 mm pods shall be per Table 1 (see Figure 1 for dimensional locations).

6.2 A8 is given as a minimum and can be extended up to A1.

6.3 Number of handles shall be:

6.3.1 four (H1–H4 in Figure 2) or

6.3.2 two (H1 and H3) in Figure 2.

6.4 The handling area is defined by A5 (which is in reference to A1) and by B2. B1 is the minimum distance between the interface plane and the nearest extension of the handle.

6.5 The orientation possibilities of the pod are given in Figure 2 and Table 2.

6.6 An optional handle to be placed at the top of the pod is specified in SEMI E47.1 (Section 6.9, Figure 12, and Table 1). If used for 150 mm or 200 mm pods, this "top robotic handling flange" has to meet the required dimensions as specified in SEMI E47.1 (see Figure 12 of SEMI E47.1). Its center is to be placed above the center of the cassette in the pod with the two orientation notches at the side where the cassette is accessed to remove wafers. The orientation possibilities of the pod are then the same as described in Section 6.5 above and Table 2.

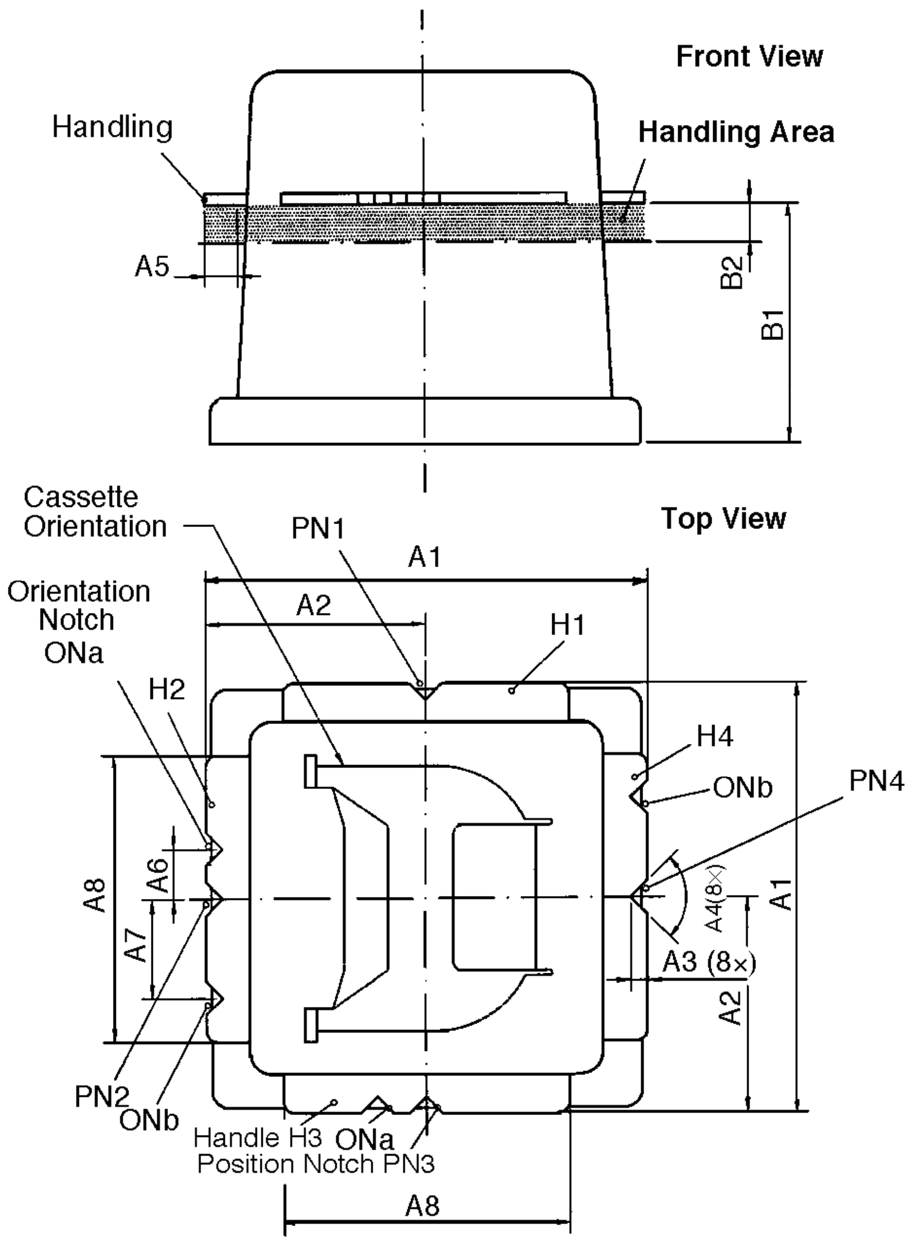


Figure 1
Pod Handling Terminology and Dimensions

Table 1

		Handling Dimensions for 150 mm (6 in.) Pod	*Handling Dimensions for 200 mm (8 in.) Pod*
Handle:	A1	215.0 mm ± 0.5 mm (8.464" ± 0.019")	305.0 mm ± 0.5 mm (12.008" ± 0.019")
	A2	107.50 mm ± 0.25 mm (4.232" ± 0.01")	152.50 mm ± 0.25 mm (6.004" ± 0.01")
	A3	6.0 mm ± 0.2 mm (0.236" ± 0.008")	5.65 mm ± 0.2 mm (0.222" ± 0.008")
	A4	90° ± 0.2°	90° ± 0.2° (90° ± 0.2°)
	A5	14 mm min. (0.551" min.)	20 mm min. (0.787" min.)
	A6	30 mm ± 0.2 mm (1.181" ± 0.008")	30.0 mm ± 0.2 mm (1.181" ± 0.008")
	A7	50 mm ± 0.2 mm (1.969" ± 0.008")	50.0 mm ± 0.2 mm (1.969" ± 0.008")
	A8	148 mm min., 215 mm max. (A1) (5.827" min., 8.464" max.)	148 mm min., 305 mm max. (A1) (5.827" min., 12.008" max.)
Handle Height:	B1	158 mm ± 1.0 mm (6.220" ± 0.039")	150.4 mm ± 1.0 mm (5.921" ± 0.039")
Handling Area:	B2	30 mm min. (1.181" min.)	30 mm min. (1.181" min.)

Table 2

Orientation #	*Orientation Notch*
1	void
2	ON a
3	ON b
4	ON a+b

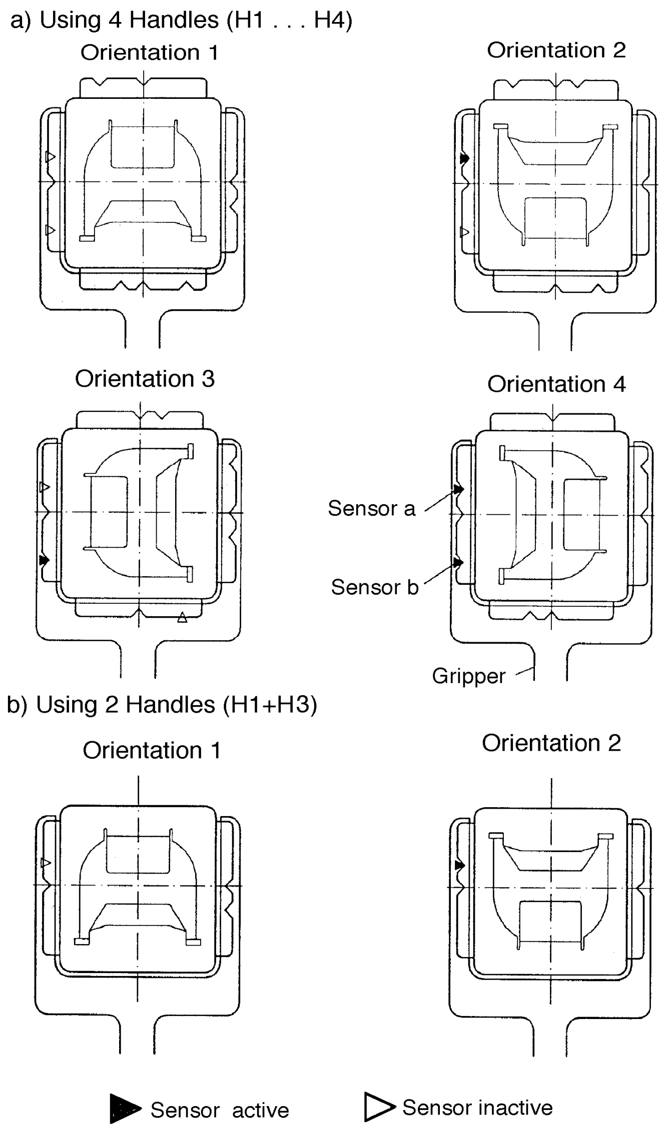


Figure 2
Orientation Possibilities

SEMI E47.1-1101
PROVISIONAL MECHANICAL SPECIFICATION FOR BOXES AND PODS USED TO TRANSPORT AND STORE 300 mm WAFERS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1997; previously published July 2001.

1 Purpose

1.1 This standard partially specifies the boxes and pods used to transport and store 300 mm wafers (which may or may not be in removable cassettes) in an IC manufacturing facility.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces (other than the door mechanism and kinematic couplings) for boxes and pods are specified; no materials requirements or micro-contamination limits are given. The enclosure specified in this standard can be a sealed minienvironment, but it could also just be a box with well-defined interfaces.

2.2 The box has the following components and subcomponents:

Key:
- • Required feature
- ◊ Optional feature

- • top
- • top handling flange
- • center hole on top handling flange
- ◊ 3 kinematic grooves on top handling flange (optional)
- • interior
  - • cassette (removable or non-removable with supports for 13 or 25 wafers)
  - • wafer capture mechanism
  - • 2 end effector exclusion zones
- • sides
  - ◊ 2 side fork-lift flanges (optional)
  - ◊ 4 side conveyor rails (bottom-opening only) (optional)
  - ◊ ergonomic manual handles (optional)
- • door (on the bottom or front)
- • holes for latch keys that lock the door to the FIMS interface when the door is unlatched from the box (front-opening only)
- • holes for registration pins
- • door sensing pads (front-opening only)
- • bottom
  - • 4 bottom conveyor rails (with the bottom of the front seal zone acting as the fourth rail and the rear rail optional in the front-opening box)
  - • 2 fork-lift pin holes (front-opening only)
  - • 5 carrier sensing pads
  - • center retaining feature (front-opening only)
  - • front retaining feature (front-opening only)
  - • 4 info pads
  - • 2 advancing box sensing pads (front-opening only)
  - • 3 features that mate with kinematic coupling pins and provide a 10 mm lead in
  - ◊ 3 features that mate with kinematic coupling pins and provide a 15 mm lead in (optional)

2.3 This standard is provisional because of concerns about the kinematic coupling pins causing excessive wear on carriers and the usefulness of the robotic handling flanges and conveyor rails. Once box testing is done, this standard should be modified and upgraded from provisional status.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47 — Specification for 150 mm/200 mm Pod Handles 150 mm and 200 mm SMIF Pod Handles

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.2 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.3 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.4 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

4.5 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.6 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62).

4.7 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.8 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.9 *nominal wafer center line* — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling) (as defined in SEMI E57).

4.10 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.11 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box.

4.12 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify 300 mm boxes over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser needs to specify a time period and the number and type of uses to which the boxes will be put. It is under these conditions that the boxes must remain in compliance with the requirements listed in Section 6.

5.2 *Temperature Ranges* — The purchaser of 300 mm boxes needs to specify two sets of temperatures to which the boxes might be exposed. An operating temperature range is the set of environmental temperatures in which the boxes will remain in compliance with the requirements listed in Section 6. A temporary temperature range is the set of environmental temperatures to which the boxes can be exposed such that when the boxes return to the operating temperature range, the boxes will be in compliance with the requirements listed in Section 6. Limits on exposure times to elevated temperatures should be specified. Also, the purchaser needs to specify a range of temperatures for the wafers and cassettes that might be inserted in the boxes (if the cassettes are removable).

5.3 *Fire Resistance* — The purchaser of 300 mm boxes may need to consider the flammability of the boxes.

5.4 *Info Pad Configurations* — The purchaser of 300 mm carriers needs to specify the desired info pad configuration (up or down).

6 Requirements

6.1 *External Kinematic Couplings* — The physical alignment mechanism from the cassette to the box (if the cassette is removable) and from the box to the tool load-port (or a nest on a vehicle or in a stocker) consists of features (not specified in this standard) on the top entity that mate with three or six pins underneath as defined in SEMI E57. Most of the dimensions of the box are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. All of the dimensions for the box are bilaterally symmetric about both the bilateral and facial datum planes with the following exceptions:

- The features that mate with the kinematic coupling pins and the box sensing pads are symmetrical only about the bilateral datum plane.
- The front-opening box has a door only on the front and conveyor rails on the left and right sides that are required to extend all the way to the front.
- The orientation notches on the robotic handling flange are different for each of the four sides.

The three features that mate with the kinematic coupling pins must provide a lead-in capability that corrects a box misalignment of up to *r*69 in any horizontal direction.

6.2 *Internal Kinematic Couplings* — If the cassette is removable, the horizontal position of each of the three primary kinematic coupling pins on the inside bottom of the box must be within *r*62 of the horizontal positions of the corresponding pin on which the box is set, so that the vertical datum planes defined by the two sets of kinematic couplings must be nearly identical. Each of the three pins on the inside bottom of the box must be *z*44 higher than the corresponding pin on which the box is set, so that the horizontal datum planes defined by the two sets of kinematic couplings will be parallel and separated by dimension *z*44.

6.3 *Nonremovable Cassettes* — If the cassette is nonremovable, there need not be a kinematic coupling between the box and cassette. However, the interior of such a box must have the interior dimensions of the cassette specified in SEMI E1.9. Many of these dimensions are measured from a horizontal datum plane, so an internal horizontal datum plane is still specified to be *z*44 above the horizontal datum plane under the box.

6.4 *Door* — There are two options for the location of the box door.

6.4.1 In the Bottom-Opening Door Option, the box door is on the bottom of the box (so the door is parallel to the wafers and the horizontal datum plane) and the door and its frame must be designed to mate with a port that conforms to SEMI E19.5.

6.4.2 In the Front-Opening Door Option, the box door is on the front side of the box (corresponding to the front side of the cassette where wafers are accessed so the door is perpendicular to the wafers and parallel to the facial datum plane), and the door and its frame must be designed to mate with a port that conforms to SEMI E62. Specifically, the box door and its frame must have surfaces that mate with the seal zones and the reserved spaces for vacuum application (which includes all of the circles bounded by *r*38 except for the holes for the registration pins at the center of each circle) defined in Sections 5.3 and 5.6 of SEMI E62 (which specifies *r*38). These box door and frame surfaces must be a distance of *y*52 from the facial datum plane and must have a flatness of *y*42. No surface on the box door may project further from the facial datum plane than the door seal zone and the reserved spaces for vacuum application. The door of the front-opening box must also be designed so that when the box is pressed against the FIMS port, both latch keys on the port are inserted to their full length. Furthermore, when the latch keys are turned more than 45° toward the position that unlocks the box door from the box, the latch key holes on the door must be such that the door is not removable from the latch keys.

6.5 *Wafer Capture and Centering* — When the box is closed, the cassette and the wafers must be captured in the box to prevent movement during transport. Wafer capture must include gently pushing the wafers to the rear of the cassette to center them.

6.6 *Internal Dimensions* — If the cassette is removable, the interior of the box (other than the kinematic coupling pins or the devices to capture the cassette and the wafers) must not intrude on any of the cassette domains defined in SEMI E1.9. Furthermore, the cassette must have a clearance of at least *r*68 in any direction while it is being inserted into the box. The interior of any front-opening box must also not intrude on the end effector exclusion zone, and the inside of the door must not intrude more that *y*51 toward the facial datum plane. If the cassette is not removable, the interior of the box between *y*11 and the door opening must not protrude higher than *z*6 above the internal horizontal datum plane and lower than *z*15 above the top nominal wafer plane. Horizontally, it must not protrude closer to the bilateral datum plane than *x*51 between *y*11 and *y*49 or closer than *x*52 between *y*49 and *y*52 (as shown in Figure 10). Dimensions *x*51, *x*52, *y*49, and *y*52 are specified in Table 1, and *y*11, *z*6, and *z*15 are specified in SEMI E1.9.

6.7 *External Dimensions* — Figures 1 through 4 respectively show the side view, rear view, top view, and bottom view for the bottom-opening box, and Figures 5 through 8 show the same views of the front-opening box. Table 1 defines all of the dimensions. In this and following figures, the heaviest lines are used for surfaces that have tolerances (not surfaces that have only maximum or only minimum dimensions). If a box identification tag is used, it must be located at the bottom rear centered on the bilateral datum plane and must be contained within the maximum outer dimensions of the box.

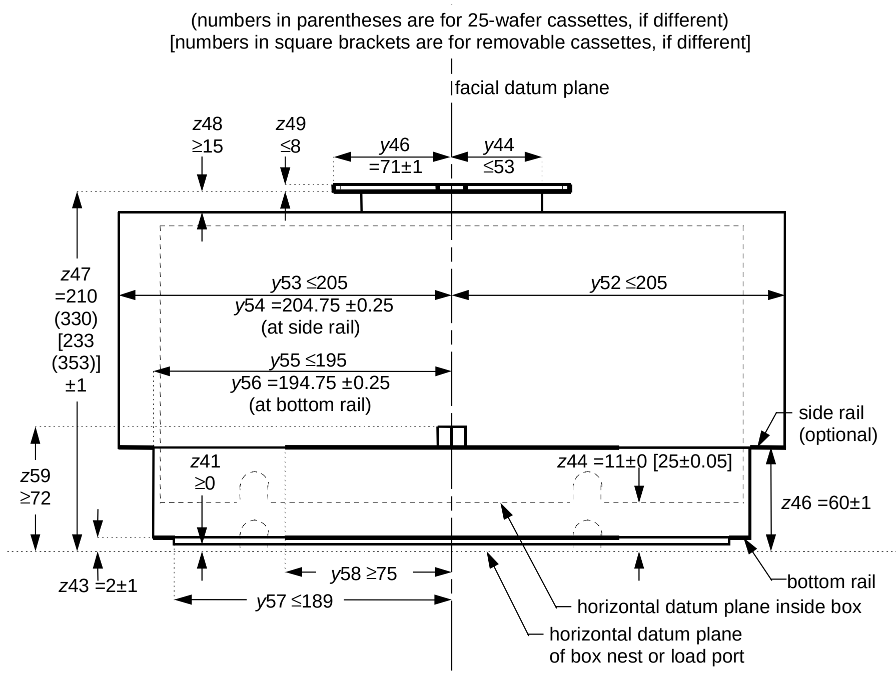


Figure 1
Side View of Bottom-Opening Box

(numbers in parentheses are for 25-wafer cassettes, if different)
[numbers in square brackets are for removable cassettes, if different]

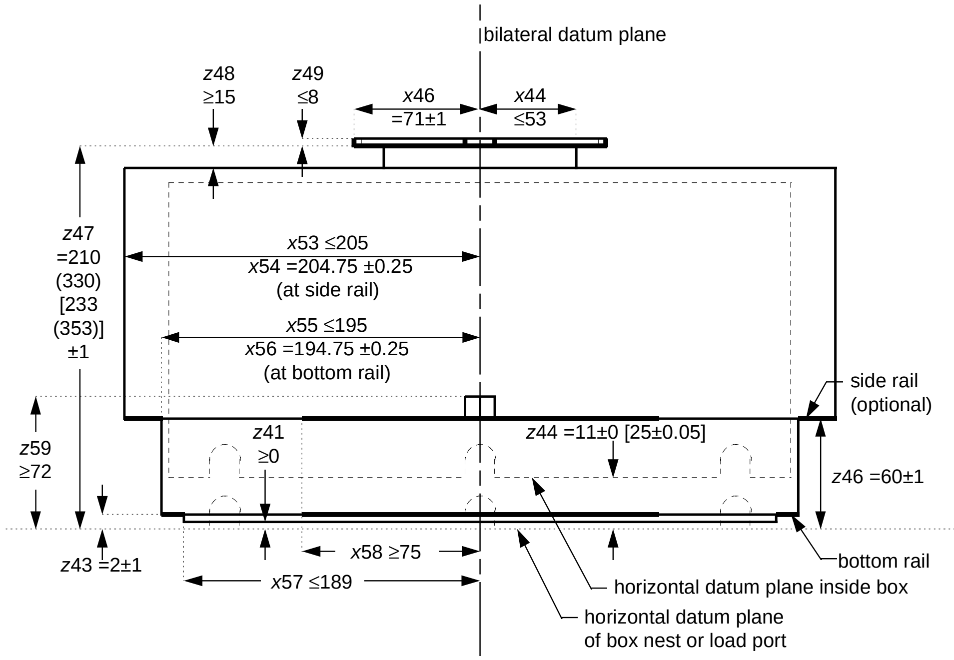


Figure 2
Rear View of Bottom-Opening Box

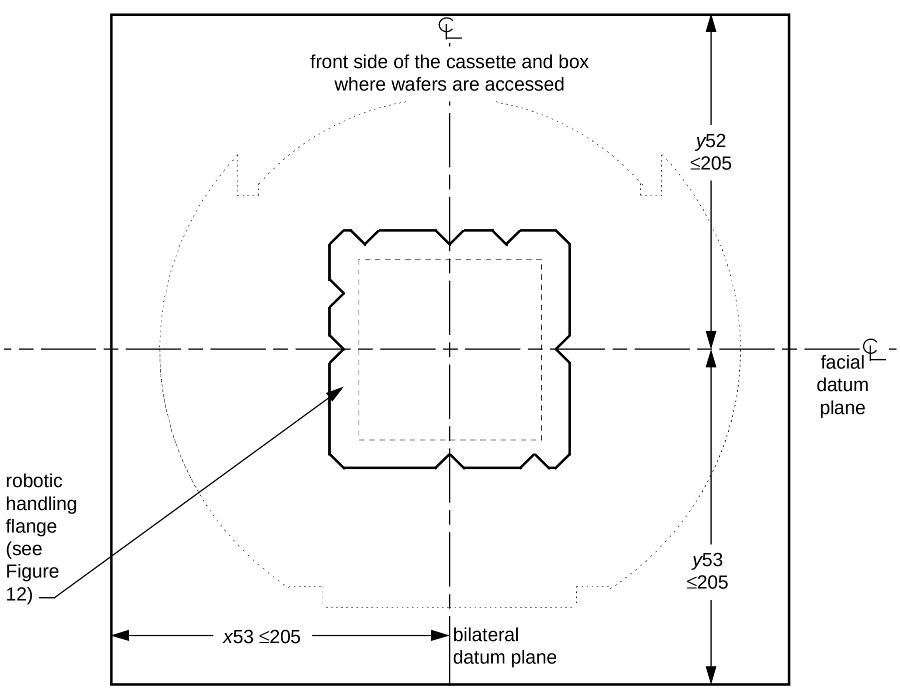


Figure 3
Top View of Bottom-Opening Box

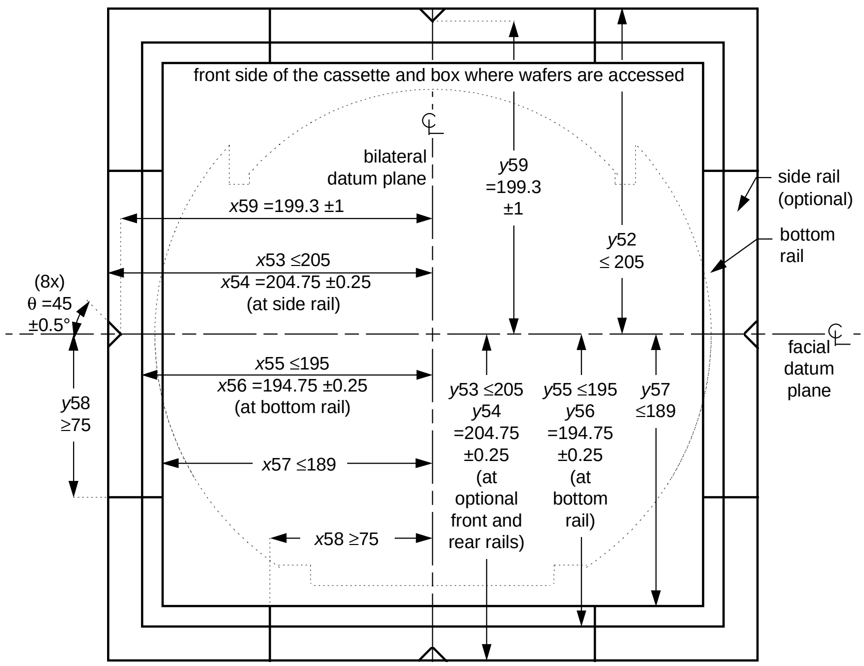


Figure 4
Bottom View of Bottom-Opening Box

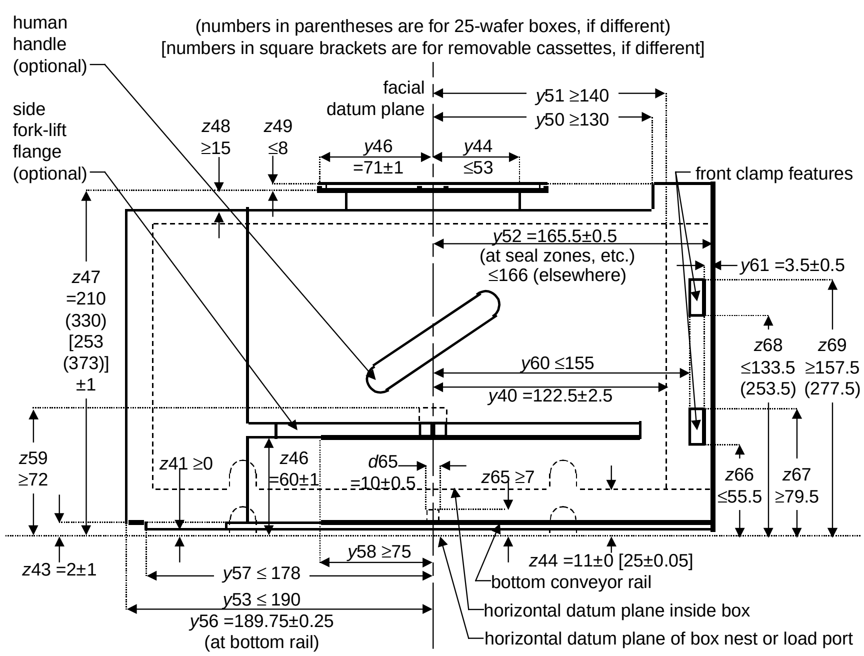


Figure 5
Side View of Front-Opening Box

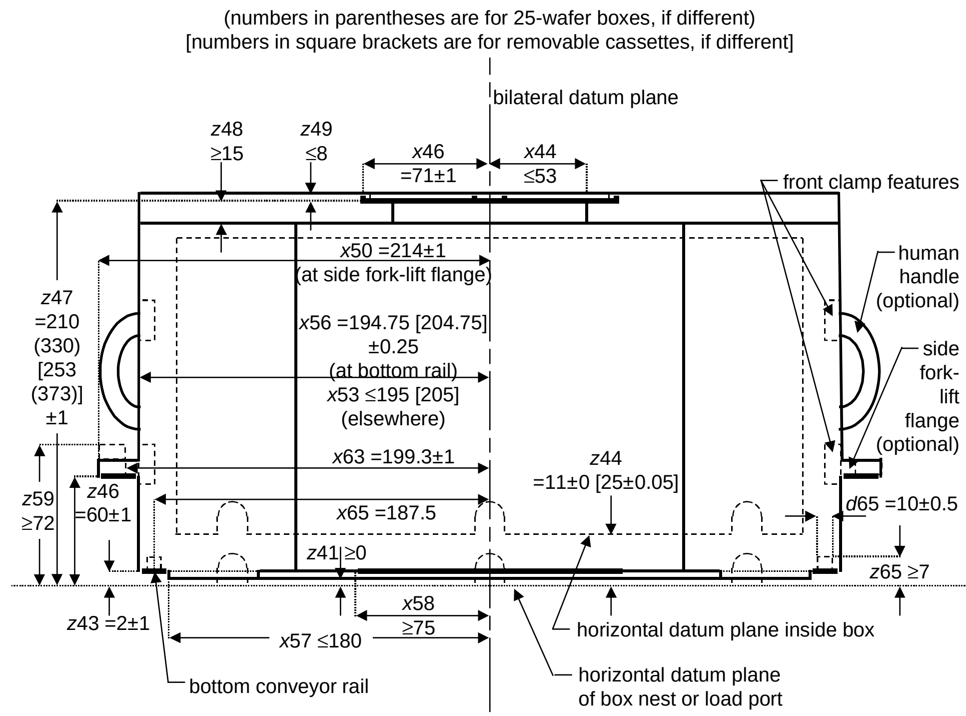


Figure 6
Rear View of Front-Opening Box

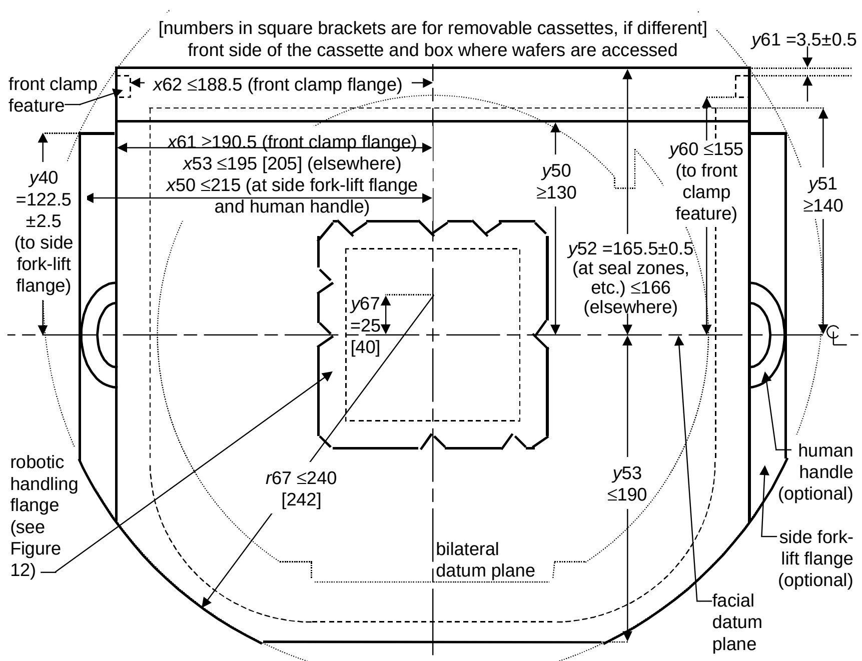


Figure 7
Top View of Front-Opening Box

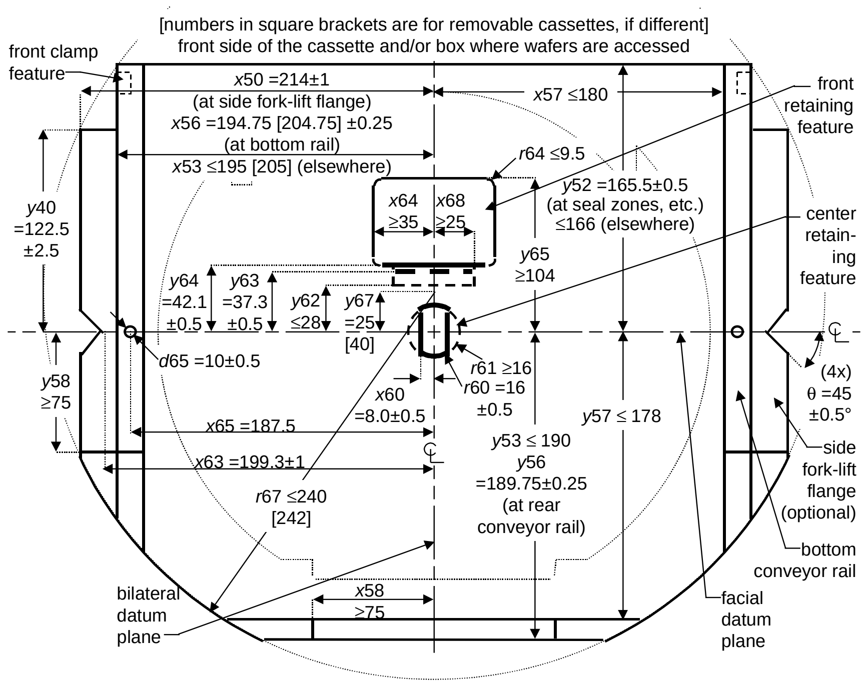


Figure 8
Bottom View of Front-Opening Box

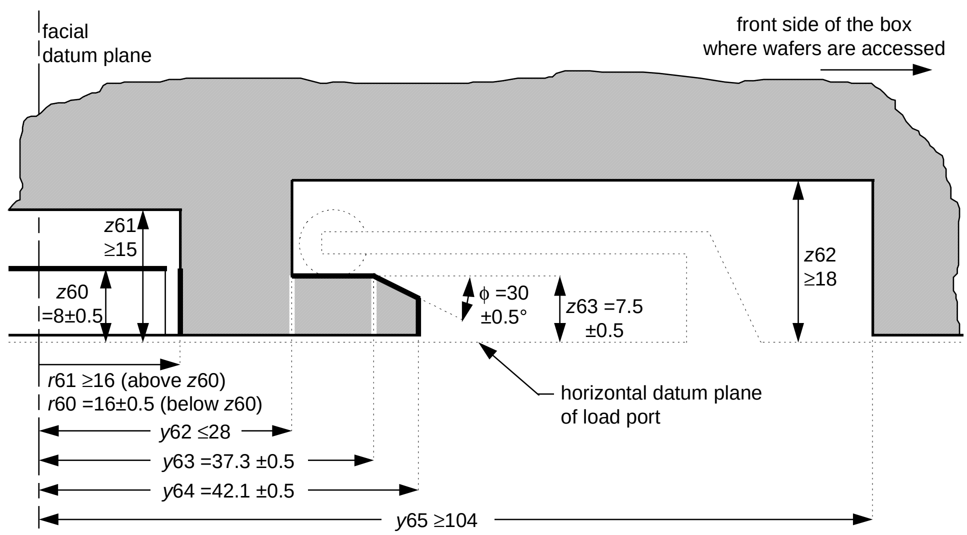


Figure 9
Side View of Retaining Features on Bottom of Front-Opening Box

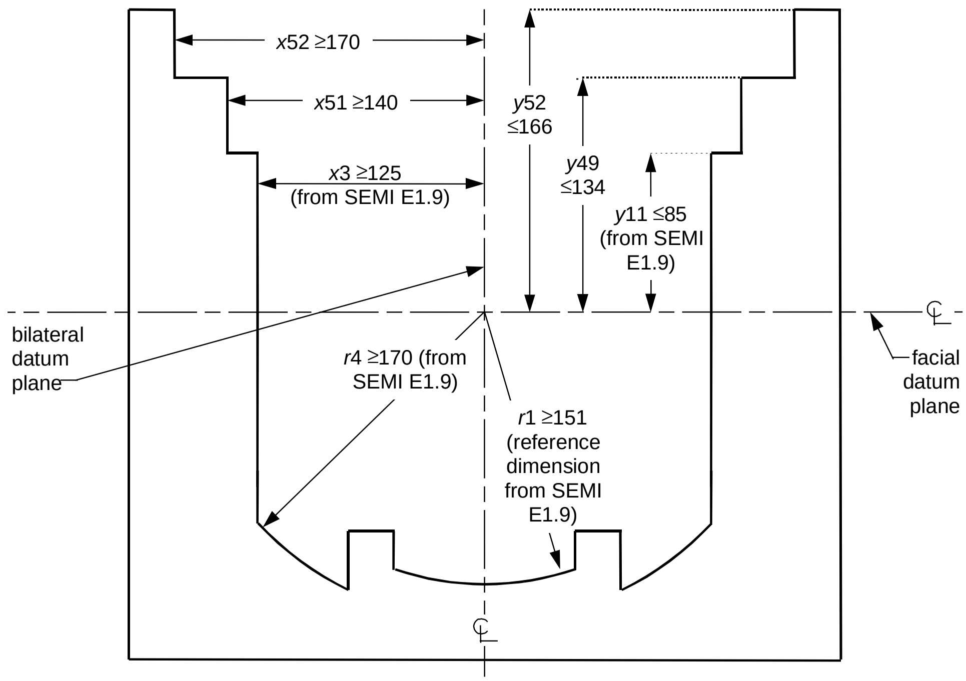


Figure 10
Exclusion Volume Inside Front-Opening Box with Non-Removable Cassette

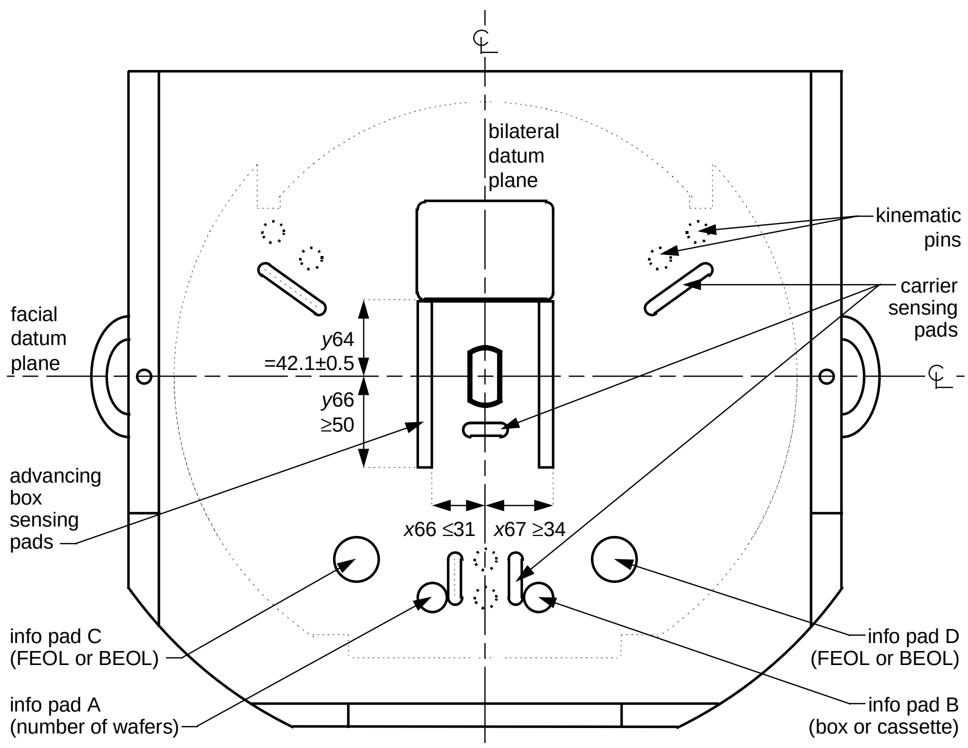
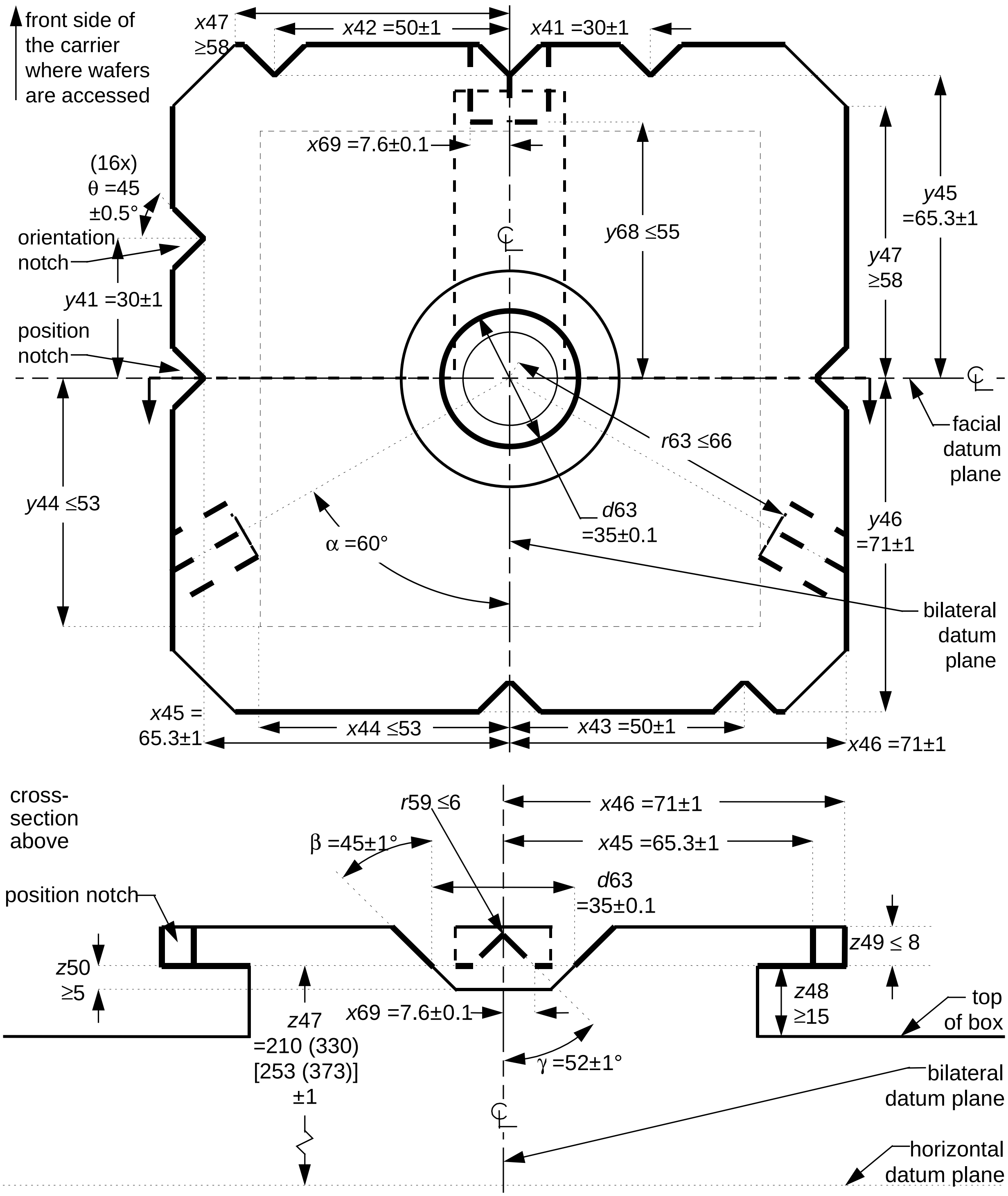


Figure 11
Sensing Pads on Bottom of Front-Opening Box



(numbers in parentheses are for 25-wafer boxes, if different)
[numbers in square brackets are for removable cassettes, if different]

Figure 12
Top Robotic Handling Flange

Table 1 Dimensions for Bottom-Opening and Front-Opening Boxes

Symbol Used	*Value Specified*		*Datum Measured From*	*Feature Measured To*
	Bottom-Opening	*Front-Opening*		
α‡	60°		bilateral datum plane	center line of the right and left kinematic grooves in the top robotic handling flange
β	45 ± 1°		nominal wafer center line	surface of the center hole in the top robotic handling flange
γ‡	52 ± 1°		bilateral datum plane or vertical plane rotated α away from it about nominal wafer center line	angled surface of the kinematic grooves in the top robotic handling flange
θ‡	45 ± 0.5°		either vertical datum plane	sides of notches in the top robotic handling flange and in the side fork-lift flanges
ϕ	not applicable	30 ± 0.5°	horizontal line on bilateral datum plane	ramp of front retaining feature
*d*63	35 ± 0.1 mm (1.378 ± 0.004 in.)		diameter centered on the nominal wafer center line	sides the center hole in the top robotic handling flange at height *z*47
*d*65	not applicable	10 ± 0.5 mm (0.39 ± 0.02 in.)	diameter centered on the intersection of *x*65 and the facial datum plane	surface of cylindrical fork-lift pin holes in left and right bottom conveyor rails
*f*60	not applicable	175 N (39.3 lbf.) minimum	not applicable	force in any direction which both retaining features are able to withstand
*r*59‡	6 mm (0.24 in.) maximum		not applicable	radius on peak of kinematic grooves in the top robotic handling flange
*r*60	not applicable	16 ± 0.5 mm (0.63 ± 0.02 in.)	nominal wafer center line	ends of slot for center retaining feature
*r*61	not applicable	16 mm (0.63 in.) minimum	nominal wafer center line	walls of chamber above slot in center retaining feature
*r*62	0.05 mm (0.002 in.) maximum		both vertical datum planes defined by the external kinematic couplings	both vertical datum planes defined by the internal kinematic couplings
*r*63‡	66 mm (2.60 in.) maximum		nominal wafer center line	near end of the right and left kinematic grooves in the top robotic handling flange
*r*64	not applicable	9.5 mm (0.37 in.) maximum	not applicable	corners of front retaining feature
*r*65	1 mm (0.04 in.) maximum		not applicable	all concave features (radius)
*r*66	2 mm (0.08 in.) maximum		not applicable	all required convex features (radius)
*r*67	not applicable	240 mm (9.45 in.) maximum for non-removable cassette and 242 mm (9.53 in.) maximum for removable cassette	*y*67 in front of nominal wafer center line	any part of box
*r*68	6 mm (0.24 in.) minimum		not applicable	clearance in any direction between the box and cassette while the cassette is being inserted or removed

Symbol Used	*Value Specified*		*Datum Measured From*	*Feature Measured To*
	Bottom-Opening	*Front-Opening*		
*r*69	10 mm (0.4 in.) minimum (required) 15 mm (0.6 in.) (recommended for ergonomic reasons)		not applicable	correctable box misalignment in any horizontal direction
*x*41	30 ± 1 mm (1.18 ± 0.04 in.)		bilateral datum plane	front right orientation notch on robotic handling flange
*x*42	50 ± 1 mm (1.97 ± 0.04 in.)		bilateral datum plane	front left orientation notch on robotic handling flange
*x*43	50 ± 1 mm (1.97 ± 0.04 in.)		bilateral datum plane	rear orientation notch on robotic handling flange
*x*44	53 mm (2.09 in.) maximum		bilateral datum plane	encroachment of box underneath robotic handling flange
*x*45	65.3 ± 1 mm (2.57 ± 0.04 in.)		bilateral datum plane	nearest point of side position and orientation notches on robotic handling flange
*x*46	71 ± 1 mm (2.80 ± 0.04 in.)		bilateral datum plane	sides of robotic handling flange
*x*47	58 mm (2.28 in.) minimum		bilateral datum plane	end of robotic handling flange front and rear
*x*50‡	not applicable	214 ± 1 mm (8.43 ± 0.04 in.)	bilateral datum plane	outer edge of side fork-lift flanges and furthest reach of human handles
*x*51	not applicable	140 mm (5.51 in.) minimum	bilateral datum plane	interior of box sides between *y*11 and *y*49 in a box with a non-removable cassette
*x*52	not applicable	170 mm (6.69 in.) minimum	bilateral datum plane	interior of box sides between *y*49 and *y*52 in a box with a non-removable cassette
*x*53	205 mm (8.07 in.) maximum	195 mm (7.68 in.) maximum for non-removable cassette and 205 mm (8.07 in.) maximum for removable cassette	bilateral datum plane	box sides (apart from human handles)
*x*54‡	204.75 ± 0.25 mm (8.061 ± 0.010 in.)	not applicable	bilateral datum plane	outside edge of upper conveyor rails
*x*55	195 mm (7.68 in.) maximum	not applicable	bilateral datum plane	box sides underneath side conveyor rails
*x*56	194.75 ± 0.25 mm (7.667 ± 0.010 in.)	194.75 ± 0.25 mm (7.667 ± 0.010 in.) for non-removable cassette and 204.75 ± 0.25 mm (8.061 ± 0.010 in.) for removable cassette	bilateral datum plane	outside edge of bottom conveyor rails
*x*57	180 mm (7.09 in.) maximum		bilateral datum plane	box sides underneath bottom conveyor rails
*x*58‡	75 mm (2.95 in.) minimum		bilateral datum plane	end of front (bottom-opening only) and rear conveyor rails
*x*59‡	199.3 ± 1 mm (7.85 ± 0.04 in.)	not applicable	bilateral datum plane	nearest point of position notch on side conveyor rails
*x*60	not applicable	8 ± 0.5 mm (0.31 ± 0.02 in.)	bilateral datum plane	sides of slot for center retaining feature
*x*61	not applicable	190.5 mm (7.50 in.) minimum	bilateral datum plane	outer edge of front clamp flange

Symbol Used	*Value Specified*		*Datum Measured From*	*Feature Measured To*
	Bottom-Opening	*Front-Opening*		
*x*62	not applicable	188.5 mm (7.42 in.) maximum	bilateral datum plane	encroachment of box behind front clamp flange
*x*63‡	not applicable	199.3 ± 1 mm (7.85 ± 0.04 in.)	bilateral datum plane	nearest point of notches in side fork-lift flanges
*x*64	not applicable	35 mm (1.38 in.) minimum	bilateral datum plane	sides of front retaining feature
*x*65	not applicable	187.5 mm (7.38 in.)	bilateral datum plane	vertical axis of cylindrical fork-lift pin holes in left and right bottom conveyor rails
*x*66	not applicable	31 mm (1.22 in.) maximum	bilateral datum plane	near side of advancing box sensing pads
*x*67	not applicable	34 mm (1.34 in.) minimum	bilateral datum plane	far side of advancing box sensing pads
*x*68	not applicable	25 mm (0.98 in.) minimum	bilateral datum plane	sides of volume above ramp on front retaining feature
*x*69‡	7.6 ± 0.1 mm (0.299 ± 0.004 in.)		bilateral datum plane or vertical plane rotated α away from it about nominal wafer center line	beginning of angled surface of the kinematic grooves in the top robotic handling flange
*y*40	not applicable	122.5 ± 2.5 mm (4.82 ± 0.10 in.)	facial datum plane	front of side fork-lift flanges and furthest reach of human handles toward the front
*y*41	30 ± 1 mm (1.18 ± 0.04 in.)		facial datum plane	left orientation notch on robotic handling flange
*y*42	not applicable	± 0.5 mm (± 0.02 in.) flatness over each area	not applicable	door and frame seal zones and the reserved spaces for vacuum application
*y*44	53 mm (2.09 in.) maximum		facial datum plane	encroachment of box underneath robotic handling flange
*y*45	65.3 ± 1 mm (2.57 ± 0.04 in.)		facial datum plane	nearest point of front and rear position and orientation notches on robotic handling flange
*y*46	71 ± 1 mm (2.80 ± 0.04 in.)		facial datum plane	front and rear edge of robotic handling flange
*y*47	58 mm (2.28 in.) minimum		facial datum plane	end of robotic handling flange sides
*y*49	not applicable	134 mm (5.28 in.) maximum	facial datum plane	interior of box sides between *x*51 and *x*52 in a box with a non-removable cassette
*y*50	not applicable	130 mm (5.12 in.) minimum	facial datum plane	rear of upper door frame volume
*y*51	not applicable	140 mm (5.51 in.) minimum	facial datum plane	rear of door
*y*52	205 mm (8.07 in.) maximum	165.5 ± 0.5 mm (6.52 ± 0.02 in.) at door and frame seal zones and at reserved spaces for vacuum application and 166 mm (6.54 in.) maximum elsewhere on door or box shell	facial datum plane	box front

Symbol Used	*Value Specified*		*Datum Measured From*	*Feature Measured To*
	Bottom-Opening	*Front-Opening*		
*y*53	205 mm (8.07 in.) maximum	190 mm (7.48 in.) maximum	facial datum plane	box rear
*y*54‡	204.75 ± 0.25 mm (8.061 ± 0.010 in.)	not applicable	facial datum plane	outside edge of front and rear upper conveyor rails
*y*55	195 mm (7.68 in.) maximum	not applicable	facial datum plane	encroachment of box front and rear upper conveyor rails
*y*56‡	194.75 ± 0.25 mm (7.667 ± 0.010 in.)	189.75± 0.25 mm (7.470 ± 0.010 in.)	facial datum plane	outside edge of front and rear bottom conveyor rails
*y*57‡	189 mm (7.44 in.) maximum	178 mm (7.01 in.) maximum	facial datum plane	encroachment of box front and rear underneath bottom conveyor rails
*y*58	75 mm (2.95 in.) minimum		facial datum plane	end of left and right conveyor rails
*y*59‡	199.3 ± 1 mm (7.85 ± 0.04 in.)	not applicable	facial datum plane	nearest point of position notch on front or rear conveyor rails
*y*60	not applicable	155 mm (6.10 in.) maximum	facial datum plane	encroachment of box behind front clamp flange
*y*61	not applicable	3.5 ± 0.5 mm (0.14 ± 0.02 in.)	front of front clamp flange at box front	rear of front clamp flange
*y*62	not applicable	28 mm (1.10 in.) maximum	facial datum plane	rear of front retaining feature
*y*63	not applicable	37.3 ± 0.5 mm (1.47 ± 0.02 in.)	facial datum plane	rear of ramp on front retaining feature
*y*64	not applicable	42.1 ± 0.5 mm (1.66 ± 0.02 in.)	facial datum plane	front of ramp on front retaining feature and front side of advancing box sensing pads
*y*65	not applicable	104 mm (4.09 in.) minimum	facial datum plane	front of front retaining feature
*y*66	not applicable	50 mm (1.97 in.) minimum	facial datum plane	rear side of advancing box sensing pads
*y*67	not applicable	25 mm (0.98 in.) for non-removable cassette and 40 mm (1.57 in.) for removable cassette	facial datum plane	origin of *r*67 on bilateral datum plane
*y*68‡	55 mm (2.17 in.) maximum		facial datum plane	near end of the front kinematic groove in the top robotic handling flange
*z*2	not applicable	2 mm (0.08 in.) maximum	horizontal datum plane	bottom of carrier sensing pads and info pads (when down)
*z*41	0 mm (0 in.) minimum		external horizontal datum plane	bottom of box
*z*43	2 ± 1 mm (0.08 ± 0.04 in.)		external horizontal datum plane	bottom conveyor rails
*z*44	11 ± 0 mm (0.43 ± 0 in.) for non-removable cassette and 25 ± 0.05 mm (0.984 ± 0.002 in.) for removable cassette		external horizontal datum plane	internal horizontal datum plane
*z*46‡	60 ± 1 mm (2.36 ± 0.04 in.)		external horizontal datum plane	bottom of side fork-lift flanges

Symbol Used	*Value Specified*		*Datum Measured From*	*Feature Measured To*
	Bottom-Opening	*Front-Opening*		
z47	210 ± 1 mm (8.27 ± 0.04 in.) for non-removable 13-wafer cassette and 330 ± 1 mm (12.99 ± 0.04 in.) for non-removable 25-wafer cassette		external horizontal datum plane	bottom of robotic handling flange
	233 ± 1 mm (9.17 ± 0.04 in.) for removable 13-wafer cassette and 353 ± 1 mm (13.90 ± 0.04 in.) for removable 25-wafer cassette	253 ± 1 mm (9.96 ± 0.04 in.) for removable 13-wafer cassette and 373 ± 1 mm (14.69 ± 0.04 in.) for removable 25-wafer cassette		
z48	15 mm (0.59 in.) minimum		bottom of robotic handling flange	encroachment of box top underneath robotic handling flange
z49	8 mm (0.31 in.) maximum		bottom of robotic handling flange	top of robotic handling flange and upper door frame volume
z50	5 mm (0.20 in.) minimum		bottom of robotic handling flange	encroachment of box top underneath the center hole in the top robotic handling flange
z59	72 mm (0.31 in.) minimum		external horizontal datum plane	top of notches in side fork-lift flanges
z60	not applicable	8.0 ± 0.5 mm (0.31 ± 0.02 in.)	external horizontal datum plane	top of slot in center retaining feature
z61	not applicable	15 mm (0.59 in.) minimum	external horizontal datum plane	top of chamber above slot in center retaining feature
z62	not applicable	18 mm (0.71 in.) minimum	external horizontal datum plane	top of front retaining feature
z63	not applicable	7.5 ± 0.5 mm (0.30 ± 0.02 in.)	external horizontal datum plane	top of ramp on front retaining feature
z65	not applicable	7 mm (0.28 in.) minimum	horizontal datum plane	upper boundary of cylindrical fork-lift pin holes in left and right bottom conveyor rails
z66	not applicable	55.5 mm (2.19 in.) maximum	external horizontal datum plane	encroachment of box behind bottom front clamp flange
z67	not applicable	79.5 mm (3.13 in.) minimum	external horizontal datum plane	encroachment of box behind bottom front clamp flange
z68	not applicable	133.5 mm (5.26 in.) maximum for 13-wafer box and 253.5 mm (9.98 in.) maximum for 25-wafer box	external horizontal datum plane	encroachment of box behind top front clamp flange
z69	not applicable	157.5 mm (6.20 in.) minimum for 13-wafer box and 277.5 mm (10.93 in.) minimum for 25-wafer box	external horizontal datum plane	encroachment of box behind top front clamp flange

‡ These dimensions define optional features.

6.8 *Human Handles* — All handles for use by humans must either be contained within the maximum outer dimensions of the box, be detached when not in use, or be retractable into the maximum outer dimensions when not in use. On the front-opening box, although such handles may extend past *x*53, they must still be contained within the upper limits of *x*50, *y*40, and *r*67. Handles for use by humans (if present) must follow SEMI S8, and they must require the use of both hands (each using a full wrap-around grip, given the minimum clearance requirement in SEMI E15.1). Automation handling features shall not be considered dual purpose unless they are designed to meet SEMI S8 guidelines.

6.9 *Automation Handling Features* — On the top of the box is a robotic handling flange for manipulating the box. Shown in Figure 12 (on the top robotic handling flange) are a center hole and 3 optional kinematic grooves (which, if present, must be implemented entirely including the radius at the peak). On the left and right sides of the box (and on the front and back of the bottom-opening box) are optional flanges (of unspecified thickness) for use with fork lifts. On the bottom of the box are rails for use with roller conveyors. Although they are only required to extend *x*58 to the rear (and front for the bottom-opening box) and *y*58 to the left and right, it is recommended that they be as long as possible. Beyond *x*58 and *y*58, only the lower bounds on *z*43 and *z*46 apply. On the bottom-opening box, optional conveyor rails (defined by *x*54, *x*55, *y*54, *y*55, and *z*46) are located on all four sides and required conveyor rails (defined by *x*56, *x*57, *y*56, *y*57, and *z*43) are located on all four bottom edges. The side fork-lift flanges and the left and right bottom conveyor rails of the front-opening box also have vertical cylindrical pin holes for fork lift centering. On the bottom edges of the front-opening box, 2 required conveyor rails (defined by *x*56, *x*57, *y*58, and *z*43) are located on the left and right, and an optional conveyor rail (defined by *x*58, *y*56, *y*57, and *z*43) is located on the rear.

6.10 *Retaining Features* — Figures 8 and 9 show two features on the bottom of the front-opening box that may be used for retaining the box onto the kinematic couplings. This may be needed to prevent the box from being knocked off the kinematic couplings by the action of pushing the box against the front-opening interface. The front retaining feature contains a ramp that a wheel might roll up while the box is being pushed toward the front-opening interface. The arm with the wheel (not specified here) then holds the box down on the kinematic couplings. The center retaining feature consists of an oblong slot with a chamber above it. The box can be clamped onto the kinematic couplings by inserting an oblong head on a shaft (not specified here) through the slot and rotating it 90° in either direction. Either retaining feature would only engage after the box is fully seated on the kinematic coupling pins. Either retaining feature must be able to withstand a force in any direction of at least *f*60. It is recommended that SEMI E15.1 tool load ports be designed to accommodate the minimum hole dimensions of the retaining features to ensure carrier interchangeability. Projections on the tool load ports that mate with the retaining features should also not interfere with the misalignment correction function of the kinematic couplings. Figures 5 through 8 also show front clamp flanges and exclusion volumes (defined by x62, y60, y61, z66, z67, z68, and z69) behind them that can be used to clamp the box to the box opener when the box is purged with Nitrogen. However, it is strongly recommended that the front clamp flanges not be used for pulling the FOUP from the undocked position into the FIMS interface. Also, all of the dimensions of the FOUP (such as the wafer location, etc.) are defined with reference to the kinematic coupling pins, and most FOUPs are designed so that all of the their features are in the proper location only when the FOUP is held in place on the kinematic coupling pins only by gravity. Thus, if the front clamp flanges are used, the wafers and the FOUP features may be in a different position than defined in SEMI E1.9 (possibly resulting in damage to wafers, wafer handlers, and the FOUP).

6.11 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier. Note also that this radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

6.12 *Box Placement Sensing Pads* — The box must have the same carrier sensing pads as is required of the cassette in SEMI E1.9, including the info pads that communicate information about the carrier such as the carrier capacity (number of wafers) and type (cassette or box). See SEMI E1.9 for information about info pad configurations for different wafer carriers similar to FOUPs including front-opening shipping boxes (as defined in SEMI M31) and single-wafer interface (SWIF) systems (as defined in SEMI E103). Two additional sensing pads (that can be used continuously while the front-opening box is advancing into the FIMS interface) must be located near the center of the bottom at the same distance from the horizontal datum plane as the carrier sensing pads. In addition, the surfaces on the door of the front-opening box that mate with the seal zones and the reserved spaces for vacuum application may also be used for door-presence sensing.

7 Related Documents

7.1 *SEMI Standards*

SEMI E63 — Provisional Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E103 — Provisional Mechanical Specification for a 300 mm Single-Wafer Box System that Emulates a FOUP

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

APPENDIX 1
APPLICATION NOTES

NOTE: The material in this appendix is an official part of SEMI E47.1 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 The automation handling features do not need to be molded into the plastic shell of the box, but can be attached as a framework around the shell.

A1-2 To increase the stability of the box on the kinematic couplings, it is recommended that the points on the box bottom extend as close as practical to the horizontal datum plane to minimize tipping of the box.

A1-3 Skewness, warp, rock, and stiffness are implicitly defined in the geometric tolerances.

A1-4 Dimension *y*52 is given as a maximum based on the maximum distance to the port door specified in SEMI E62.

A1-5 The position tolerance of the door of the front-opening box is likely to be much larger than the position tolerance of the registration pins. To make both manual and automated door opening easier, it is recommended that the holes for the registration pins on the door of the front-opening box have openings with a lead-in capability.

NOTE A1-1: If the bottom of the box does not extend below the bottom conveyor rail, the conveyor rail may become contaminated and may distribute particles.

A1-6 Although both of the retaining features on the bottom of the front-opening box must be able to withstand a force in any direction of *f*60, continuously applied stress may result in plastic deformation.

A1-7 In order to minimize particle generation when the box door is opened or closed, it is recommended that the tolerance between the box door and its frame be larger than the tolerance between the box door registration holes and FIMS registration pins.

A1-8 One type of carrier presence sensor uses a beam of light with an optical detector that is triggered when the beam of light is attenuated as it passes through the box shell.

A1-9 The use of the registration pins for FOUP door lead-in to the loadport door is not recommended. The registration pins should be only used to limit the maximum displacement of the FOUP door while on the loadport door. Neither the FOUP nor FOUP door positions should change as a result of engaging or disengaging the registration pins. When the Loadport experiences utility loss (such as EMO, vacuum loss, electrical failure, etc.), the registration pins may be used to maintain the FOUP door's position, and to ensure that the FOUP door does not to fall off. The clearance between the Registration Pins and the Registration Pin Holes should be less than the clearance between the outer edge of the FOUP Door and the inner edge of the FOUP Door Frame. Balancing these tolerances is a FOUP design issue related to the E62 Seal Zone specification. The diameter of the Registration Pin Holes should be designed to accommodate the Registration Pin tolerance defined in E62 (x31, z31, d31) and the Registration Pin Hole location tolerance in a FOUP.

A1-10 It is recommended that the FOUP have a capability to roughly position the FOUP door in the FOUP frame during the door close sequence (during either return of the FOUP door or during latching of the FOUP door). This positioning capability should keep the clearance between the FOUP frame and the FOUP door larger than sum of the FOUP (self) tolerance and the E62 registration pin tolerance along with the FOUP door's circumference. Possible methods for accomplishing this may include positioning by latch motion and positioning by a slope between the FOUP frame and the FOUP door.

A1-11 It is recommended that the FOUP have a lead-in mechanism on its latch key holes. This lead-in mechanism should compensate for the FOUP's latch key hole location error, as shown in Figure A1-1.

A1-12 It is recommended that the latch key hole mechanisms have some flexibility in their position for compliance with the latch key positions. The purpose of this is to adjust for any discrepancy in rotation axis between the latch key and the latch key hole mechanism. As shown in Figure A1-2, if only one side of the latch key pushes on the inside of the latch key hole, the latch key can not rotate more than half way.

A1-13 It is recommended that the torque required to rotate the FOUP latch key holes be kept small enough that it will not produce movement of the FOUP door in the *x* and *z* directions during latch key rotation.

A1-14 It is recommended that the latch key holes be maintained in the position that unlocks the box door from the box ($\psi = 0 \pm 1°$ as defined in E62) while the box is open and in the position that locks the box door to the box ($\psi = 90 \pm 1°$) while the box is closed. One method to accomplish this is to have the FOUP latch key hole mechanisms snap into both end points of their rotation ($\psi = 0 \pm 1°$ and $\psi = 90 \pm 1°$) using a detent mechanism. The torque required to overcome such a detent mechanism should not exceed *f*30 (as defined in E62).

A1-15 Table A1-1 can be used for communicating the compliance of boxes to this standard and the options chosen:

Table A1-1 Optional Features Checklist

Section	*Optional Feature*	*Choice*
4.3	carrier capacity (*c*)	☐ 13 wafers or ☐ 25 wafers
6.4	door location	☐ bottom (complying with SEMI E19.5) or ☐ front (complying with SEMI E62)
6.3	cassette type	☐ removable or ☐ non-removable (complying with interior dimensions of SEMI E1.9)
6.1	full 15-mm lead in provided by 3 features that mate with kinematic coupling pins	Primary kinematic coupling pins ☐ yes or ☐ no and secondary kinematic coupling pins ☐ yes or ☐ no
6.9	4 side conveyor rails (bottom-opening only)	☐ yes or ☐ no
6.8	ergonomic manual handles	☐ yes or ☐ no
6.9	side fork-lift flanges	☐ yes or ☐ no
6.9	3 kinematic grooves on the top robotic handling flange	☐ yes or ☐ no
6.9	rear conveyor rail	☐ yes or ☐ no
6.12	info pad A height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad B height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad C height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad D height	☐ up (pad missing) or ☐ down (pad present)

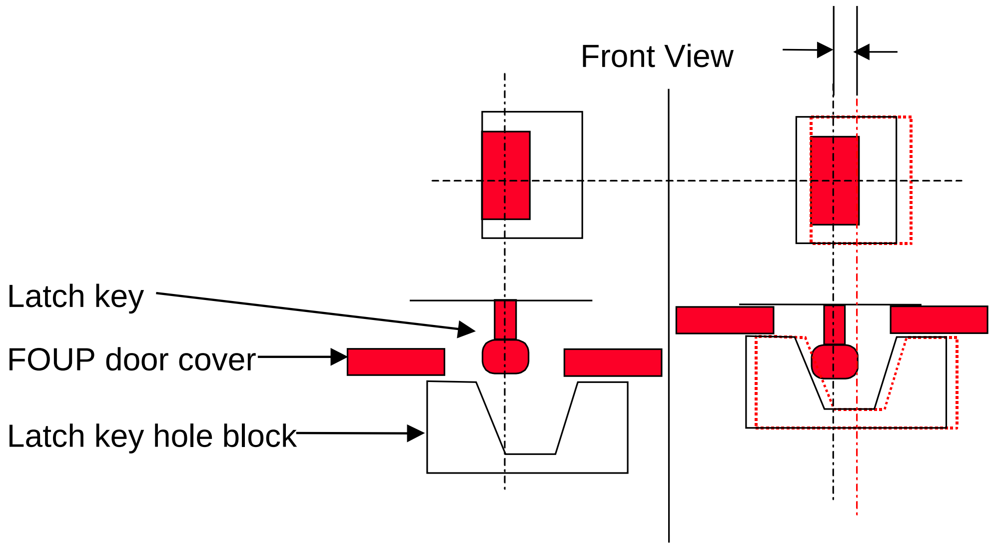
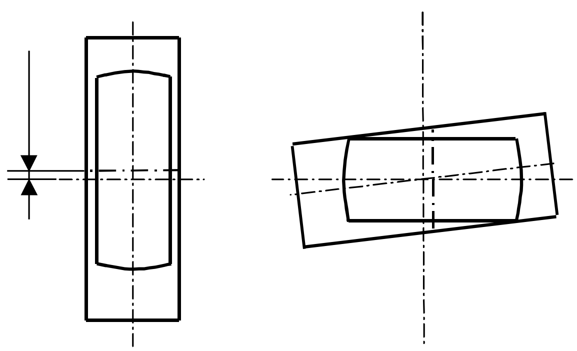
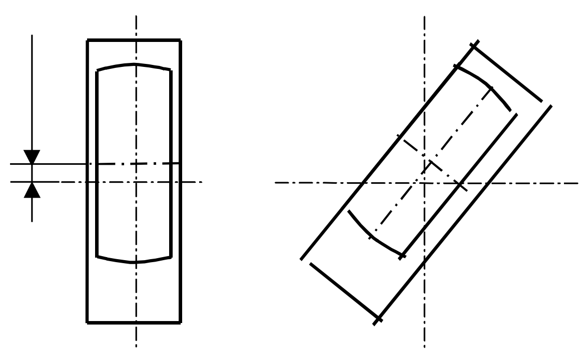


Figure A1-1
Displacement Enabled by Flexibility Around Latch Key Hole Block



Latch key can rotate full 90°



Latch key rotation stops before 90°

Figure A1-2
Need for Latch Key Hole Flexibility

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E47.1, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 A revision ballot will be submitted to require the same bottom carrier ID label area as in SEMI E1.9.

R1-2 A revision ballot will be submitted to increase the maximum thickness of the top robotic flange by 3 mm.

R1-3 A design exists for a box and adapter mechanism that holds only on wafer and is supposed to comply with SEMI E47.1. A new activity to standardize a "One Wafer FOUP" is being considered.

SEMI E48-1101
SPECIFICATION FOR SMIF INDEXER VOLUME REQUIREMENT

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on April 24, 2001. Initially available at www.semi.org August 2001; to be published November 2001. Originally published in 1995; previously published July 2001.

1 Purpose

1.1 The purpose of this specification is to provide the volume required within a tool that enables integration of SMIF into tools with single or multiple ports.

2 Scope

2.1 This specification defines the space necessary within a tool with respect to the interface plane. The specification refers to the Standard Mechanical InterFace (SMIF) Standard, SEMI E19.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *cassette* — an open structure that holds one or more substrates (e.g., wafers, masks).

4.2 *integrated SMIF* — a unit including a SMIF port and a mechanism for indexing the port door. The entire unit being incorporated within the tool.

4.3 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment per SEMI E19.

4.4 *wafer transfer plane* — a plane with a maximum distance from the interface plane to the level where a wafer can be transferred.

5 Requirements

5.1 Figure 1 depicts the height dimensions and terminology for integrated SMIF. Figure 2 shows the necessary footprint for the integrated SMIF on a tool. The dimensions are given with reference to SEMI E15.

5.2 The minimum distance between the interface plane and the wafer transfer plane A1 is limited by the thickness of the port plate and any wafer sensing system. This distance should be kept as small as possible for ergonomic reasons.

5.3 The dimension A2 below the interface plane takes into account the distance A1, the cassette dimensions, and the mechanical components. Process tools must provide this free space to allow integration of SMIF.

5.4 Referring to Figure 2, it can be seen that the axis of the wafer transfer, B2, does not necessarily correspond to the center line of the integrated SMIF unit. This is to allow the indexing mechanism to be placed in different locations, so that multiple ports can be furnished, still adhering to SEMI E15.

Table 1 Integrated SMIF Dimensions

		Up to 150 mm	*200 mm*
Installation Height	A1	63 mm max. (2.48" max.)	63 mm max. (2.48" max.)
	A2	400 mm min. (15.75" min.)	400 mm min. (15.75" min.)
Footprint	B1	355 mm min. (13.98" min.)	355 mm min. (13.98" min.)
	B2	177.5 mm max. (6.99" max.)	177.5 mm max. (6.99" max.)
	B3	157 mm max. (6.18" max.)	182 mm max. (7.17" max.)
	B4	390 mm min. (15.35" min.)	390 mm min. (15.35" min.)
	B5	20 mm max. (0.79" max.)	20 mm max. (0.79" max.)
SEMI E15 (Recommendation)	S	350 mm (13.8")	400 mm (15.7")

Dimension Definitions

A1 — Maximum distance from the SMIF interface plane to the wafer transfer plane.

A2 — Minimum depth, from the interface plane, required in a tool.

B1 — Minimum width required in a tool.

B2 — Maximum distance from the side of the indexer unit to the cassette or container centroid.

B3 — Maximum distance from the front of the indexer unit to the cassette or container centroid.

B4 — Minimum breadth required for the indexer unit in a tool.

B5 — Maximum distance that can be penetrated underneath the port plate.

S — Recommended minimum spacing between cassette or container controids.

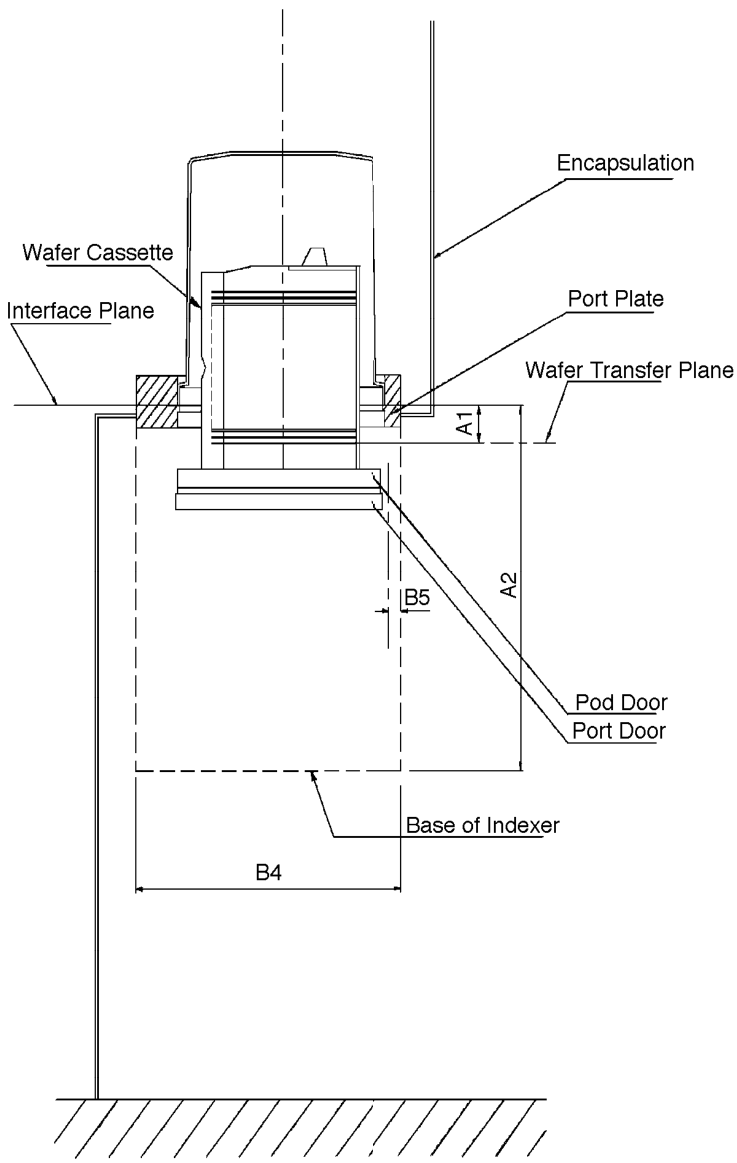


Figure 1
Integrated SMIF Side View

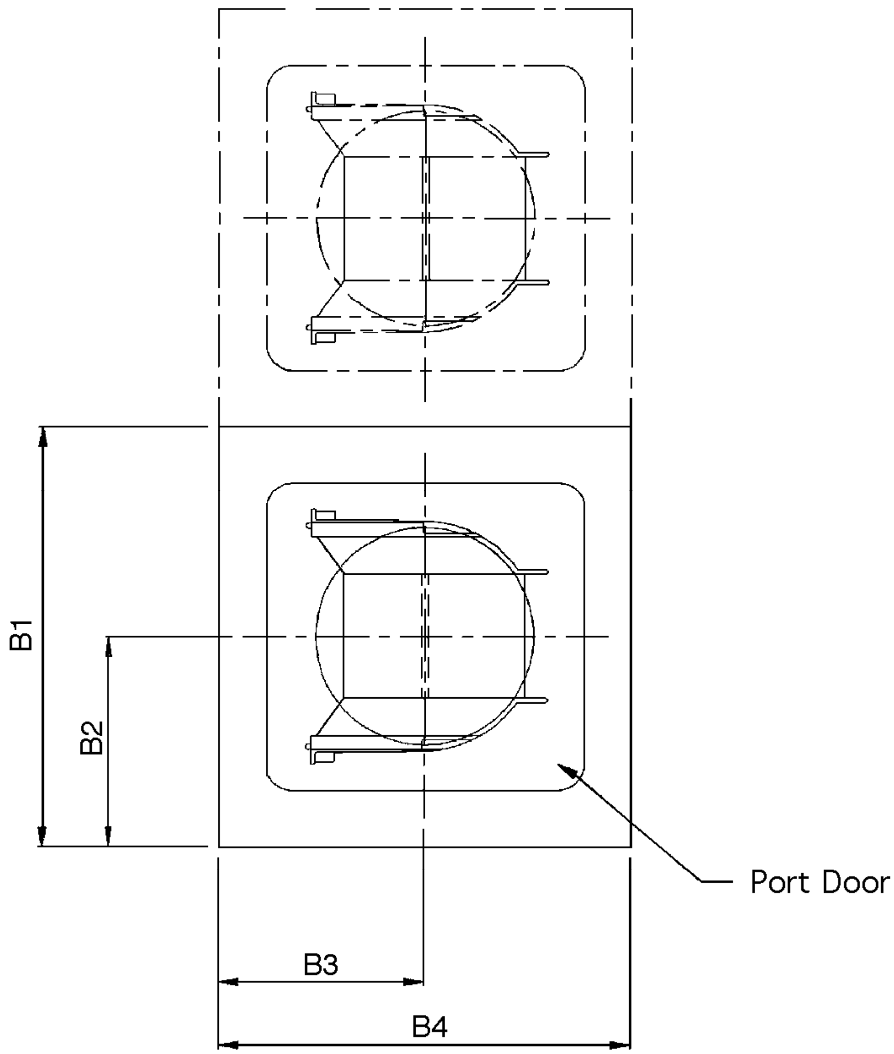


Figure 2
Integrated SMIF Top View

NOTICE: SEMI makes no warranties or representations as to the suitability of the specification set forth herein for any particular application. The determination of the suitability of the specification is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These specifications are subject to change without notice.

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SEMI E49-0702
GUIDE FOR STANDARD PERFORMANCE, PRACTICES, AND SUB-ASSEMBLY FOR HIGH PURITY PIPING SYSTEMS AND FINAL ASSEMBLY FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

The purpose of this overview is to provide a basic set of definitions and reference documents for SEMI E49.1 - SEMI E49.9.

2 Scope

These documents reference many performance and method standards that were developed in North America. For semiconductor equipment that will be installed or manufactured in other countries, the users should request compliance to the equivalent or similar performance requirements in their equipment proposal request or purchase order documents.

2.1 The documents in this guide are organized by types of piping distribution systems — gas, DI/chemical, solvent — and by types of assembly and testing procedures — sub-assembly for stainless steel, sub-assembly for polymer and final tool assembly.

2.2 The piping distribution documents include guidelines for system design, performance, materials, and components. Two purity and performance grades are described for each of the three types of distribution systems:

2.2.1 *High Purity (HP)* — For industry standard systems consisting of high grade materials, components, and standard design/configuration, assembly method, and performance capability.

2.2.2 *Ultrahigh Purity (UHP)* — For advanced or special systems consisting of higher grade materials and components, with advanced or integrated design and configuration, the latest assembly methods, and enhanced performance capabilities, especially related to purge or rinse time and contamination levels.

2.2.3 HP systems should have only marginal effect on overall tool purchase price. UHP systems are more customized and have a higher purchase price than HP systems, but the very expensive exotic and/or highly specialized materials and components are not in the scope of UHP. Users should complete an overall tool cost of ownership analysis to determine the optimum application of HP or UHP tool features. Key parameters should include facilities cost and installation cycle time, piping system reliability and maintainability factors, tool and sub-system contribution to contamination, and resultant effects on wafer quality and wafer throughput factors.

3 Referenced Documents

3.1 *SEMI Standards*[1]

SEMI E10 — Guideline for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures - Polymer Systems

SEMI F1 — Specification for Leak Integrity of Toxic Gas Piping Systems

3.2 *American Society of Mechanical Engineers*[2]

ASME SA479 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels (ASTM A 479/A 479-90) (Boiler and Pressure Vessel Codes, 1989)

3.3 *ASTM Standards*[3]

ASTM A 269 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM A 479 — Standard Specification for Stainless and Heat-Resisting Steel Bar and Shapes for Use in Boilers and Other Pressure Vessels

ASTM A 632 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

ASTM D 4327 — Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography

ASTM F 1372 — Standard for Scanning Electron Microscope (SEM) Analysis of Metallic Surface Condition for Gas Distribution System Components

ASTM F 1373 — Test Method for Determination of Cycle Life of Automatic Valves for Gas Distribution System Components

1 Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043

2 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

3 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

ASTM F 1375 — Test Method for EDX Analysis of Metallic Surface Condition for Gas Distribution System Components

ASTM F 1394 — Standard for Determination of Particle Contribution from Gas Distribution System Valves

ASTM F 1397 — Test Method for Determination of Moisture Contribution for Gas Distribution System Components

ASTM F 1400 — Test Method for Determination of Helium Leak Rate for Gas Distribution System Components

ASTM F 1438 — Test Method for Determination of Surface Roughness by Scanning Tunneling Microscopy for Ultra Pure Water Distribution Components

3.4 *Federal Information Processing Standard*

FED-STD — Federal Standard Cleanroom and Work Station Requirements, Controlled Environment

3.5 *Institute of Environmental Sciences Documents*[4]

IES-RP-CC-001 — Recommended Practices for HEPA Filters

IES-RP-CC-002 — Recommended Practices for Laminar Flow Clean Air Devices

IES-RP-CC-003 — Recommended Practices for Garments Required in Cleanrooms and Controlled Environmental Areas

IES-RP-CC-006 — Recommended Practices for Testing Cleanrooms

3.6 *National Fire Protection Association*[5]

NFPA 49 — Hazardous Chemicals Data

NFPA 704 — Standard System for the Identification of the Fire Hazards of Materials

3.7 *Military Standards*[6]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

4 Terminology

4.1 *Abbreviations and Acronyms*

Ar — Argon

ASME — American Society of Mechanical Engineers

ASTM — American Society of Testing and Materials Standards

C_v — valve flow coefficient

CVD — chemical vapor deposition

DSF — dead space free

DIW — deionized; for this document, used as deionized water

EDX — Energy-dispersive X-ray

ESCA — Electron spectroscopy for chemical analysis (also known as XPS)

FTIR — Fourier transform infrared

HD — high density, i.e., polymer

HP — high purity

HPM — Hazardous production material

IEEE — Institute of Electrical and Electronics Engineers, Inc.

ID/OD — inside/outside (i.e., diameter)

IPA — Isopropyl alcohol

MFC — mass flow controller

MTBA — mean time between assists

MTBF — mean time between failure

MTTR — mean time to repair

PFA — perfluoroalkoxy

PPB — parts per billion

PTFE — polytetrafuorethylene

PVDF — polyvinylidend fluoride

QA — quality assurance

QC — quality control

R_a — Roughness average (e.g., surface)

SEMI — Semiconductor Equipment and Materials International

SMTR — Smelter's test report

SPC — Statistical process control

TEOS — Tetraethylorthosilicate

TOC — total organic carbons

UHP — Ultrahigh purity

WC — water column, inches (cm) of water

4 Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056

5 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

6 Military Specifications, Commanding Officer, Naval Publications, and Forms Center, Attention: MPFC 105, 5801 Tabor Avenue, Philadelphia, PA 19120

5 Impact

5.1 The impact of improved tool quality and standardization is:

5.1.1 Reduced tool purchase price for customized piping distribution systems, by employing standard designs and practices for HP and UHP systems.

5.1.2 Reduced tool installation cost and cycle time.

5.1.3 *Reliability, Maintainability* — Improved tool up-time, repair time, and availability will positively affect cost of ownership. Primary improvement is in system MTBF and MTTR.

5.1.4 *Sub-Assembly Contamination Control* — Cost of ownership will also be improved by lower long-term contamination levels in the process chamber or bath, resulting in wafer defect reductions and/or yield improvement. Long-term flow accuracy for mass flow controllers (MFC's) will also be improved for better wafer level uniformity.

5.1.5 *Final Assembly Contamination Control* — Will result in reduced possibility of cleanroom contamination upon tool delivery, and avoid time delay of tool cleaning at wafer fab site.

SEMI E49.1-95
GUIDE FOR TOOL FINAL ASSEMBLY, PACKAGING, AND DELIVERY

1 Purpose

The objective of this document is to establish standard guidelines for cleanroom activities specific to the final assembly, packaging, and delivery of semiconductor manufacturing equipment.

2 Scope

This standard has been developed as a guide for final tool assembly and packaging. This standard covers both high and ultrahigh purity applications. Process specifications related to wafer particles and/or quality are not in the scope of this document. Parameters such as particles per wafer pass (PWP) should be in the user's specific equipment process performance specification.

3 Referenced Documents

Note: Refer to the latest version of the following documents for general cleanroom protocol.

3.1 *FED-STD Federal Standard Cleanroom and Work Station Requirements, Controlled Environment*[1]

3.2 *Institute of Environmental Sciences Documents*[2]

IES-RP-CC-001 — Recommended Practices for HEPA Filters

IES-RP-CC-002 — Recommended Practices for Laminar Flow Clean Air Devices

IES-RP-CC-003 — Recommended Practices for Garments Required in Clean Rooms and Controlled Environmental Areas

IES-RP-CC-006 — Recommended Practices for Testing Cleanrooms

4 Terminology

See Section 4 of SEMI E49.

5 Pre-Packaging Procedures

5.1 All components of the equipment should be thoroughly cleaned before assembly and assembly in at least a Class 1000/100 cleanroom (HP/UHP).

5.2 *Tools* — Maintain a set of clean tools in the clean assembly area. If this is not possible, tools should be cleaned according to the following section (cleaning) each time they reenter the clean assembly area.

5.3 *Cleaning* — Assembly tools and all system components should be vacuumed, blown off with filtered air, and cleaned with a solution of 10% IPA in DI water immediately prior to being brought in to the clean assembly area. Use swabs and wipes rated for Class 100 service.

Cutting oils, lubricants, and solder flux should be removed before parts are brought into the clean assembly area.

5.4 *Exclusions* — Machining, sawing, welding, brazing, grinding, and sanding operations must be completed before components are brought into the clean assembly area.

5.5 The equipment should be subject to a thorough cleanliness inspection. The supplier should provide a copy of the inspection results (e.g., marked checklist) with the equipment.

5.6 All equipment with water, except DI water, or other liquids should be fully emptied and completely dried using dry, oil-free air or nitrogen.

5.7 The equipment should be clearly marked showing correct lifting points for removal from shipping container.

5.8 All utility lines should be capped during shipment.

5.9 All vacuum systems should be shipped under vacuum.

6 Packaging Procedures

6.1 The equipment and separate subassemblies or support equipment should be totally enclosed and sealed in at least two layers of clean, oil-free clear 6 mil polyethylene so each layer forms a seal against moisture and particles.

6.2 A humidity indicator should be included inside of the initial wrapping layer.

6.3 *Triple Wrap Strategy* — The individual wraps are intended to be removed in stages and should adhere to the following guidelines:

6.3.1 *Inner Wrap* — This wrap should stay with the tooling all the way into the final cleanroom or a staging area of the same order wipe down. The wrap should be cleaned prior to movement into the cleanroom.

1 Available from Federal Information Processing Standard

2 Available from Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056

6.3.2 *Middle Wrap* — This wrap should stay with tooling until it reaches a Class 10,000 intermediate staging area. The wrap should be cleaned before leaving the receiving area and again before it is removed in the staging area.

6.3.3 *Outer Wrap* — This wrap is used to protect the tooling while in transit to the loading dock. While the equipment is on the loading dock, outer shipping material should be removed and the wrap cleaned and removed.

6.4 *Clean Assembly Area* — Following final assembly and test, all exposed parts should be thoroughly wiped down with deionized water, using cleanroom wipes. Approved materials for cleaning are described in Section 10.3.4. Tooling should then be totally enclosed in a clean, oil-free inner wrap using transfer tape as required. If two sets of pallets are used, the inner pallet should meet the requirements of Section 5.2.2 and should be enclosed with the tool. Jacking points should be identified to facilitate rigging.

6.5 *Dedicated Packaging Area* — After the first wrap has been applied, the equipment should be moved to a dedicated clean (Class 10,000 or better) packaging area. Here the outer two wraps of clear polyethylene are installed and taped.

After the equipment is triple wrapped, it should be placed on a pallet so that the triple wrapping is not damaged or violated. The pallet should be movable (with equipment attached to it) with a conventional pallet jack or fork lift. The equipment should also be capable of placement on and removal from the pallet with a conventional pallet jack or fork lift without compromising or tearing any of the triple wrapping.

After the equipment is on the pallet, the manufacturer may use any conventional packaging materials (e.g., bubble wrap, styrofoam, or wood) to ensure that the equipment is not damaged in transit. However, these conventional materials cannot compromise or tear the triple wrapping.

6.6 *Recommended Materials*

6.6.1 For cleaning and triple wrap packaging:

- DI water, resistivity 18.0 Megohm-cm, minimum
- UHP isopropyl alcohol (IPA)
- Cleaning solution, 10% IPA + DI water
- Lintfree cleaning swabs
- Polyester cleanroom wipes with thermally sealed edges
- Oil-free 6 mil polyethylene sheeting (for middle and outer wrap)
- A non-shedding polyethylene wrap is recommended for inner wrap
- Nonparticulate adhesive tape

6.7 For packaging outside the triple wrap:

- Paper or cardboard of any type
- Wood
- Bubble wrap, styrofoam, and foam rubber
- Masking tape, duct tape, and paper tape
- Noncleanroom wipers

6.8 The equipment should be securely fastened to its shipping container.

6.9 All shipping containers should have integral pallets or be mounted securely to pallets.

6.10 Each shipping container should be clearly marked with its tare weight and an equipment identification number provided by the customer.

6.11 Each shipping container should have three axis shock sensors, tilt sensors, and temperature indicators located both inside and outside the container for parts sensitive to the above requirements.

6.12 All support hardware or separate components (e.g., cables, spare parts) should be packaged in separate containers from the main unit.

6.13 The packing list should specify which container each component is in.

7 Delivery

The equipment should be transported in air ride vans.

SEMI

SEMI E49.2-0298
GUIDE FOR HIGH PURITY DEIONIZED WATER AND CHEMICAL DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for high purity (HP) deionized water and chemical distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of polymer piping designed to supply the following types of liquid chemicals to the process:

- Acids, bases, and oxidizers
- Deionized water
- Corrosive solvents

2.2 Typical tools include wet clean stations, wafer scrubbers, and photolithography coaters and developers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures - Polymer Systems

3.2 *ASTM Standards*[1]

See Section 3.3 of SEMI E49.

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Leak Tests*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N^2)
- Pressure — 2.1 kg/cm^2 (30 psig) maximum
  — 1.75 kg/cm^2 (25 psig) minimum
- Time — 120 minutes
- Fail-Pressure Loss — > 2% of test pressure, after compensation for temperature variation.

5.1.2 *Hydrostatic Pressure Test*

- Test Media — DI water (pumped)
- Pressurization Media — Nitrogen (N_2)
- Pressure — 2 times operating pressure or 7.0 kg/cm^2 (100 psig), whichever is less
- Time — 4 hours
- Fail-Pressure Loss — Any pressure loss or any visible leakage, compensated for temperature gradient and/or material expansion.

5.2 *Purity Indices*

5.2.1 *Particle Count (ptc) at ≥ 0.5 µm Size*

- < 10 ptc/L average single count
- < 50 ptc/L maximum single count
- Test media is DI water

5.2.2 *DI Water Flush Test* — The specified limit is the difference between incoming and outgoing DI water.

- Resistivity — ± 0.5 Mega ohm-cm
- Total Organic Carbons (TOC) — < 4 ppb

5.3 All performance measures are absolute values, relative to respective test instrument background level.

5.4 See SEMI E49.7 for recommended DI/chemical system testing procedures.

5.5 *Reliability and Maintainability Indices* — Equipment supplier should provide actual DIW/Chemical system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

6 Design Guidelines

6.1 All polyvinylidene fluoride (PVDF) should be thermally socket welded, as a minimum, using interactive automated welding equipment. Thermal butt welding is preferred.

6.2 All perfluoroalkoxy (PFA) tubing should be joined with flare compression type technique. Flaring can be done at room temperature or at elevated temperature, depending on the technique required by the component supplier.

6.3 All PFA pipe should be thermally butt welded, using interactive automated welding equipment.

6.4 Dead volume areas should be minimized by the use of close connected bypass or bleed-through loops. Dead legs should be < 5 pipe diameters.

6.5 System internal volume should be minimized by the use of close fit adapters and fittings. Dead Space Free (DSF) branch valves and/or multi-component integrated assemblies are optional.

6.6 The DIW distribution system should have a continuous flow with a velocity of ≥ 0.3 m/s (1 fps).

6.7 Pipe thread type connections should not be used.

6.8 Flow meters should be installed in return side of DI water system.

6.9 Backflow/back pressure protection should be included in the system.

6.10 The system should use tee fittings and branch valves to accomplish flush, test, and sample ports. Sample ports should be located as close as possible to the chemical supply point, either to bath/tank or process chamber and also at the DIW return header, immediately before exit.

6.11 Provisions to flush and drain the chemical system completely with DIW should be included in the system.

6.12 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.13 Filters should be included on all chemical mixture recirculation loops.

6.14 All filters should be able to be isolated from process stream for maintenance.

6.15 For processes requiring pressure control, regulators should be included in the system.

6.16 The system should have a means of manifolding supply and drain lines onboard, so that there is a single point of connection for each individual liquid.

7 Materials Guidelines

7.1 All polymers for wetted flow streams should be virgin materials without filler or inert additives.

7.2 *Polymer Material Types*

7.2.1 High purity grade PFA or a material specified by the customer should be used for the chemical distribution system (acids/caustics).

7.2.2 High purity grade PVDF or high purity grade PFA should be used for the DI distribution system.

7.2.3 Valves, regulators, diaphragms, and custom components in both the DI water and chemical distribution systems can also be PTFE.

7.3 *Source Material Mechanical Characteristics*

7.3.1 All piping, tubing, and other components should conform to the manufacturer's published data regarding the following: dimensional tolerances, flow characteristics, mechanical strength characteristics, and melt temperature indices.

7.3.2 When such data is unavailable from the manufacturer, historical information of most similar products should be used for comparative purposes.

7.3.3 Manufacturer should advise purchaser in writing of any liquid stream that causes degradation of the material after purchaser states the intended use of the product.

7.3.4 Components made by the same manufacturer and intended to be joined together should have inner and outer diameters within ± 2% of the wall thickness.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are polymer qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Hydraulic Pressure Test		
Maximum pressure above manufacturer's recommended working pressure	120	%
Test Period	≥ 30	min.
Test Temperature	ambient	°C
Internal Surface Defects		
Photos per test method		value
Maximum count per photo	≤ 50	value
For an example of a test method, see SEMASPEC 92010955B (SEM)		
Particulate Contribution		
at > 0.07 µm size	≤ 750	ptc/L
at > 0.1 µm size	≤ 200	ptc/L
at > 0.3 µm size	≤ 5.0	ptc/L
at > 0.5 µm size	≤ 2.0	ptc/L
at > 1.0 µm size	≤ 1.0	ptc/L
For an example of a test method, see SEMASPEC 92010949B		
Internal Surface Roughness		
Measure type	non-contact	n/a
Roughness average (R_a) for extruded surfaces	≤ 0.38 (≤ 15)	µm (µin.)
Maximum surface R_a for molded surfaces	≤ 0.51 (≤ 20)	µm (µin.)
Maximum surface R_a for machined surfaces	≤ 0.89 (≤ 35)	µm (µin.)
Test procedures per ASTM F 1438		
Total Anionic Contamination		
Ammonium	≤ 1.00	µg/comp
Bromide	≤ 0.50	µg/comp
Chloride	≤ 0.50	µg/comp
Fluoride	≤ 5.00	µg/comp
Nitrate	≤ 0.50	µg/comp
Nitrite	≤ 1.00	µg/comp
Phosphate	≤ 0.50	µg/comp
Potassium	≤ 0.50	µg/comp
Sodium	≤ 0.50	µg/comp
Sulfate	≤ 0.50	µg/comp
Test procedures per ASTM D 4327 (Total Anions)		
Total Metallic Contamination		
Aluminum	≤ 0.15	µg/comp
Boron	≤ 0.15	µg/comp
Calcium	≤ 1.00	µg/comp
Cadmium	≤ 0.10	µg/comp
Iron	≤ 1.00	µg/comp
Lead	≤ 0.15	µg/comp
Lithium	≤ 0.15	µg/comp
Magnesium	≤ 0.15	µg/comp
Nickel	≤ 1.00	µg/comp
Silver	≤ 0.15	µg/comp
Zinc	≤ 0.15	µg/comp
For an example of a test method, see SEMASPEC 92010936B (Metallics)		

Organic contamination shall be:		
Below detection limits of Fourier Transform Infrared (FTIR) spectroscopic techniques		
For an example of a test method, see SEMASPEC 92010937B (FTIR)		

7.5 *Filter Requirements*

7.5.1 The housing should be PFA or PVDF, as required.

7.5.2 *Media (Membrane, Support Cage, and Net)*

- Cartridge Type — PFA or PTFE, compatible with the chemical used in the system
- Disposable Type — PFA or PTFE media, as required

7.6 Gaskets, O-rings, and diaphragms should be chemically compatible to process or sanitation fluids and should not contribute any measurable secondary contamination.

8 Component Guidelines

8.1 Components should be tested at ≥ 1.5 times the distribution system's operating pressure, over the entire operating temperature range.

8.2 Regulators should be diaphragm type.

8.3 Check valves should be springless type with O-ring seals, as a minimum. Springless disk type check valves are optional.

8.4 Valve types should be diaphragm type or bellows.

8.5 Flow meters should be all polymer construction.

9 Subsystem Assembly Guidelines

See SEMI E49.7 for recommended polymer system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[2]

SEMASPEC 92010936B — Provisional Test Method for Determining Leachable Trace Inorganics in Ultra Pure Water Distribution System Components

SEMASPEC 92010937B — Provisional Test Method for the Evaluation of Bulk Polymer Samples of Ultra Pure Water Distribution System Components

SEMASPEC 92010949B — Provisional Test Method for Determining Particle Contribution and Retention by Ultra Pure Water Distribution System Components

SEMASPEC 92010955B — Provisional Test Method for Analyzing Plastic Surface Condition of Ultra Pure Water Distribution System Components (SEM Method)

2 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

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SEMI

SEMI E49.3-0298
GUIDE FOR ULTRAHIGH PURITY DEIONIZED WATER AND CHEMICAL DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for ultrahigh purity (UHP) deionized water and chemical distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of polymer piping designed to supply the following types of liquid chemicals to the process:

- Acids, bases, and oxidizers
- Deionized water
- Corrosive solvents

2.2 Typical tools include wet clean stations, wafer scrubbers, and photolithography coaters and developers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures - Polymer Systems

3.2 *ASTM Standards*[1]

See Section 3.3 of SEMI E49.

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Leak Tests*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N_2)
- Pressure — 2.1 kg/cm^2 (30 psig) maximum
  — 1.75 kg/cm^2 (25 psig) minimum
- Time — 120 minutes (2 hours)
- Fail-Pressure Loss — > 2% of test pressure, after compensation for temperature variation.

5.1.2 *Hydrostatic Pressure Test*

- Test Media — DI water (pumped)
- Pressurization Media — Nitrogen (N_2)
- Pressure — 2 times operating pressure or 7.0 kg/cm^2 (100 psig), whichever is less
- Time — 4 hours
- Fail-Pressure Loss — Any pressure loss or any visible leakage, compensated for temperature gradient and/or material expansion.

5.2 *Purity Indices*

5.2.1 *Particle Count (ptc) at ≥ 0.2 μm Size*

- < 2 ptc/L average single count
- < 4 ptc/L maximum single count
- Test media is DI water

5.2.2 *DI Water Flush Test* — The specified limit is the difference between incoming and outgoing DI water.

- Resistivity — ± 0.2 Mega ohm-cm
- Total Organic Carbons (TOC) — < 2 ppb

5.3 All performance measures are absolute values, relative to respective test instrument background level.

5.4 See SEMI E49.7 for recommended DI/chemical system testing procedures.

5.5 *Reliability and Maintainability Indices* — Equipment supplier should provide actual DIW/Chemical system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

6 Design Guidelines

6.1 All polyvinylidene fluoride (PVDF) should be thermally butt welded, as a minimum, using interactive automated welding equipment. Thermal butt welding is preferred.

6.2 All perfluoroalkoxy (PFA) tubing should be joined with a flare compression type technique. Flaring can be done at room temperature or at elevated temperature, depending on the technique required by the component supplier.

6.3 All PFA pipe should be thermally butt welded, using interactive automated welding equipment.

6.4 Dead volume areas should be minimized by the use of close connected bypass or bleed-through loops. Dead legs should be < 3 pipe diameters.

6.5 System internal volume should be minimized by the use of Dead Space Free (DSF) branch valves and/or multi-component integrated assemblies.

6.6 The DIW distribution system should have a continuous flow with a velocity of ≥ 0.3 m/s (1 fps).

6.7 Pipe thread type connections should not be used.

6.8 Flow meters should be installed in return side of DIW system.

6.9 Backflow/back pressure protection should be included in the system.

6.10 The system should use DSF type valves to accomplish flush, test, and sample ports. Sample ports should be located as close as possible to the chemical supply point, either to bath/tank or process chamber and also at the DIW return header, immediately before exit.

6.11 Provisions to flush and drain the chemical system completely with DIW should be included in the system.

6.12 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.13 Filters should be included on all chemical mixture recirculation loops.

6.14 All filters should be able to be isolated from mainstream for maintenance.

6.15 Provisions for system sanitization (e.g., DSF injection ports) should be included.

6.16 For processes requiring pressure control, regulators should be included in the system.

6.17 The system should have a means of manifolding supply and drain lines onboard, so that there is a single point of connection for each individual liquid.

7 Materials Guidelines

7.1 All polymers for wetted flow streams should be virgin materials without filler or inert additives.

7.2 *Polymer Material Types*

7.2.1 High purity grade PFA or a material specified by the customer should be used for the chemical distribution system (acids/caustics).

7.2.2 High purity grade PVDF or high purity grade PFA should be used for the DIW distribution system.

7.2.3 Valves, regulators, diaphragms, and custom components in both the DI water and chemical distribution systems can also be PTFE.

7.3 *Source Material Mechanical Characteristics*

7.3.1 All piping, tubing, and other components should conform to the manufacturer’s published data regarding the following: dimensional tolerances, flow characteristics, mechanical strength characteristics, and melt temperature indices.

7.3.2 When such data is unavailable from the manufacturer, historical information of most similar products should be used for comparative purposes.

7.3.3 Manufacturer should advise purchaser in writing of any liquid stream that causes degradation of the material after purchaser states the intended use of the product.

7.3.4 Components made by the same manufacturer and intended to be joined together should have inner and outer diameters within ± 2% of the wall thickness.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are polymer qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user’s materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Hydraulic Pressure Test		
Maximum pressure above manufacture's recommended working pressure	120	%
Test Period	≥ 30	min.
Test Temperature	ambient	°C
Internal Surface Defects		
Surface defects	≤ 15	
Photos per test method	5	value
Maximum count per photo	≤ 40	value
For an example of a test method, see SEMASPEC 92010955B (SEM)		
Particulate Contribution		
at > 0.07 µm size	≤ 500	ptc/L
at > 0.1 µm size	≤ 100	ptc/L
at > 0.3 µm size	≤ 2.0	ptc/L
at > 0.5 µm size	≤ 1.0	ptc/L
at > 1.0 µm size	≤ 0.3	ptc/L
For an example of a test method, see SEMASPEC 92010949B		
Internal Surface Roughness		
Measure type	non-contact	n/a
Roughness average (R_a) for extruded surfaces	≤ 0.25 (≤ 10)	µm (µin.)
Maximum surface R_a for molded surfaces	≤ 0.38 (≤ 15)	µm (µin.)
Maximum surface R_a for machined surfaces	≤ 0.62 (≤ 25)	µm (µin.)
Test procedures per ASTM F 1438		
Total Anionic Contamination		
Ammonium	≤ 0.40	µg/comp
Bromide	≤ 0.10	µg/comp
Chloride	≤ 0.20	µg/comp
Fluoride	≤ 2.00	µg/comp
Nitrate	≤ 0.10	µg/comp
Nitrite	≤ 0.40	µg/comp
Phosphate	≤ 0.10	µg/comp
Potassium	≤ 0.20	µg/comp
Sodium	≤ 0.20	µg/comp
Sulfate	≤ 0.20	µg/comp
Test procedures per ASTM D 4327 (Total Anions)		
Total Metallic Contamination		
Aluminum	≤ 0.05	µg/comp
Boron	≤ 0.05	µg/comp
Calcium	≤ 0.50	µg/comp
Cadmium	≤ 0.01	µg/comp
Iron	≤ 0.50	µg/comp
Lead	≤ 0.05	µg/comp
Lithium	≤ 0.05	µg/comp
Magnesium	≤ 0.02	µg/comp
Nickel	≤ 0.50	µg/comp
Silver	≤ 0.05	µg/comp
Zinc	≤ 0.05	µg/comp

For an example of a test method, see SEMASPEC 92010936B (Metallics)		
Organic contamination shall be:		
Below detection limits of Fourier Transform Infrared (FTIR) spectroscopic techniques		
For an example of a test method, see SEMASPEC 92010937B (FTIR)		

7.5 *Filter Requirements*

7.5.1 The housing should be PFA or PVDF, as required.

7.5.2 *Media (Membrane, Support Cage, and Net)*

- Cartridge Type — PFA or PTFE, compatible with the chemical used in the system
- Disposable Type — PFA or PTFE media, as required

7.6 Gaskets, O-rings, and diaphragms should be chemically compatible to process or sanitation fluids and should not contribute any measurable secondary contamination.

8 Component Guidelines

8.1 Components should be tested at ≥ 1.5 times the distribution system's operating pressure, over the entire operating temperature range.

8.2 Regulators should be diaphragm type.

8.3 Check valves should be springless disk type. The disk should not have O-ring seals.

8.4 Valves should be diaphragm type, Weir design, or equivalent.

8.5 Flow meters should be all polymer construction.

9 Subsystem Assembly Guidelines

See SEMI E49.7 for recommended polymer system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[2]

SEMASPEC 92010936B — Provisional Test Method for Determining Leachable Trace Inorganics in Ultra Pure Water Distribution System Components

SEMASPEC 92010937B — Provisional Test Method for the Evaluation of Bulk Polymer Samples of Ultra Pure Water Distribution System Components

SEMASPEC 92010949B — Provisional Test Method for Determining Particle Contribution and Retention by Ultra Pure Water Distribution System Components

SEMASPEC 92010955B — Provisional Test Method for Analyzing Plastic Surface Condition of Ultra Pure Water Distribution System Components (SEM Method)

2 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E49.4-0298
GUIDE FOR HIGH PURITY SOLVENT DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for high purity (HP) solvent distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of stainless steel (SS) piping designed to supply flammable solvents only.

2.2 Typical processes are photolithography track equipment, solvent wet stations, and isopropyl alcohol vapor dryers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASTM Standards*[1]

See Section 3.3 of SEMI E49.

3.3 *ASM Document*[2]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.4 *ASME Document*[3]

ASME SA479 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels (ASTM A 479/A 479-90) (Boiler and Pressure Vessel Codes, 1989)

4 Terminology

See Section 4 of SEMI E49.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 American Society of Metals, Metals Park, OH 44073

3 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

5 Performance Guidelines

5.1 *Leak Test and Purity Indices*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N_2)
- Pressure — 2 times system operating pressure
- Time — 24 hours
- Temperature — Constant
- Fail-Pressure Loss — > 1% of test pressure

5.1.2 N_2 Particle Count (ptc), at ≥ 0.2 µm Size

- < 0.18 ptc/L (< 5 ptc/ft^3) average single count
- < 1.8 ptc/L (< 50 ptc/ft^3) maximum single count

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended gas system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Mechanical fittings should be used where required for component removal/replacement.

6.3 Dead volumes should be less than five pipe diameters in length/height. Pressure gauges with gauge protectors should be used. Pressure transducers are optional.

6.4 A means of process liquid sampling should be installed as close as possible to point of dispense.

6.5 Incoming process liquids require filters and should be located downstream of any regulator and as close as possible to point of dispense.

6.6 Design should include a means of flow through flushing and draining for removable components or assemblies.

6.7 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.8 Supply and drain lines on a recirculation system should be separated by an isolation valve. The system should not use one line to perform both functions.

6.9 All filters should be able to be isolated from process stream for maintenance.

6.10 Backflow/back pressure protection should be included in the system.

6.11 For processes requiring pressure control, regulators should be included in the system.

6.12 The system should have a means of manifolding supply and drain lines onboard, so that there is a single point connection for each individual liquid.

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479 or ASME SA479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR ≤ 0.030%
- Carbon as reported by the SMTR ≤ 0.030%

7.2 Stainless steel should be 316L electropolished for solvent system wetted flow streams or as specified by the customer.

7.3 Materials for valve seats, diaphragms, gaskets, and O-rings should be chemically compatible to the process liquid.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user’s materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER) Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level For an example of a test method, see SEMASPEC 90120573B (ESCA)	≥ 15	Å
Internal Surface Chemistry (ESCA) Total chromium to iron ratio including both reduced and oxidized stated For an example of a test method, see SEMASPEC 90120403B (ESCA)	≥ 1.25:1	value
Internal Surface Chemistry (EDX) Surface foreign elements, those elements not in the Smelter's Test Report (SMTR) Test procedures per ASTM F 1375 (EDX)	0	value
Internal Surface Defects Photos per test method Counts per photo Test procedures per ASTM F 1375 (SEM)	5 ≤ 50	value value
Internal Surface Roughness Average surface roughness Roughness average (R_a) Maximum surface R_a (individual reading) For example of a test method, see SEMASPEC 90120400B (Contact Profilometry)	≤ 0.25 (≤ 10) ≤ 0.38 (≤ 15)	µm (µin.) µm (µin.)
Particulate Contribution at ≥ 0.1 µm size at ≥ 0.02 µm size Test procedures per ASTM F 1394 (Particles)	≤ 0.71 (20) ≤ 2.6 (75)	ptc/L (ptc/ft^3) ptc/L (ptc/ft^3)
Internal Absorbed Moisture Time to recover to base line from a 2 ppm spike for low surface area component (valve, regulator) Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing) Test procedures per ASTM F 1397	≤ 4 ≤ 6	hour hour
Total Anionic Contamination Total anionic contamination added to test water Individual anionic contaminant Test procedures per ASTM D 4327 (Total Anions)	≤ 1 ≤ 0.2	ppm ppm
Leak Rate Inboard leak rates for He Outboard leak rate for He Cross-seat leak rates for He Test procedures per SEMI F1 (Leak Rate)	$\leq 1 \times 10^{-9}$ $\leq 1 \times 10^{-5}$ $\leq 1 \times 10^{-8}$	scc/s scc/s scc/s
Cycle Life Manual values pressure automatic valves High Pressure automatic valves Low Pressure automatic valves Test procedures per ASTM F 1375 (Cycle Life)	≥ 25 K ≥ 25 K ≥ 500 K	cycles cycles cycles

8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7, Materials Guidelines.

8.2 Valves should be ball (dry assembly, lubricant-free) or bellows type. Metal diaphragm valves are optional.

8.3 Regulators should be packless in design with all metal bonnet seals.

8.4 Regulators and valve flow coefficient (C_v) should be selected based on liquid flow requirements and liquid characteristics.

8.5 Mechanical fittings should be compression type or metal face seal type with solid nickel gaskets.

8.6 Pressure gauges should be liquid-filled type with compression or metal face seal fittings. Gauge isolators are recommended.

8.7 Filters should be PTFE media rated at 0.1 µm pore size.

8.8 Check valves should be disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[4]

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

4 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

SEMI E49.5-0298
GUIDE FOR ULTRAHIGH PURITY SOLVENT DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for ultrahigh purity (UHP) solvent distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of stainless steel (SS) piping designed to supply flammable solvents only.

2.2 Typical tools include photolithography track equipment, solvent wet stations, and isopropyl alcohol vapor dryers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASM Document*[1]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.3 *ASTM Standards*[2]

See Section 3.3 of SEMI E49.

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Leak Test and Purity Indices*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N_2)

Pressure — 2 times system operating pressure

- Time — 24 hours
- Temperature — Constant
- Fail-Pressure Loss — > 1% of test pressure

5.1.2 *N_2 Particle Count (ptc), at ≥ 0.1 μm Size*

- < 0.18 ptc/L (< 5 ptc/ft^3) average single count
- < 1.8 ptc/L (< 50 ptc/ft^3) maximum single count

5.1.3 *Moisture Level* — ≤ 200 ppb

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended solvent system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Mechanical fittings should be used where required for component removal/replacement.

6.3 Dead volumes should be less than three pipe diameters in length/height. Blind runs such as pressure gauges should not be used.

6.4 A means of process liquid sampling should be installed as close as possible to point of dispense.

6.5 Incoming process liquids require filters and should be located downstream of any regulator and as close as possible to point of dispense.

6.6 The system internal volume should be minimized by use of Dead Space Free (DSF) branch valves and/or multi-component integrated assemblies.

1 American Society of Metals, Metals Park, OH 44073

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

6.7 Design should include a means of flow through flushing and draining for removable components or assemblies.

6.8 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.9 Supply and drain lines on a recirculation system should be separated by an isolation valve. The system should not use one line to perform both functions.

6.10 All filters should be able to be isolated from process stream for maintenance.

6.11 Ball and needle type valves should not be used.

6.12 Backflow/back pressure protection should be included in the system.

6.13 For processes requiring pressure control, regulators should be included in the system. Pressure transducers and a means of pressure display should be included on the equipment.

6.14 The systems should have a means of manifolding supply and drain lines onboard, so that there is a single point connection for each individual liquid.

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR ≤ 0.030%
- Carbon as reported by the SMTR ≤ 0.030%

7.2 Stainless steel should be 316L electropolished for solvent system wetted flow streams.

7.3 Materials for valve seats, diaphragms, gaskets, and O-rings should be chemically compatible to the process gas.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically valid data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER)		
Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level	≥ 15	Å
For an example of a test method, see SEMASPEC 90120573B (AUGER)		
Internal Surface Chemistry (ESCA)		
Total chromium to iron ratio including both reduced and oxidized states	≥ 1.25:1	value
For an example of a test method, see SEMASPEC 90120403B (ESCA)		
Internal Surface Chemistry (EDX)		
Surface foreign elements, those elements not in the Smelter's Test Report (SMTR)	0	value
Test procedures per ASTM F 1375 (EDX)		
Internal Surface Defects		
Photos per test method	5	value
Counts per photo	≤ 50	value
Test procedures per ASTM F 1372 (SEM)		
Internal Surface Roughness		
Average surface roughness	≤ 0.25	µm
Roughness average (R_a)	(≤ 10)	(µin.)
Maximum surface R_a	≤ 0.38	µm
(individual reading)	(≤ 15)	(µin.)
For an example of a test method, see SEMASPEC 90120400B (Contact Profilometry)		
Particulate Contribution		
at ≥ 0.1 µm size	≤ 0.71 (20)	ptc/L (ptc/ft^3)
at ≥ 0.02 µm size	≤ 2.6 (75)	ptc/L (ptc/ft^3)
Test procedures per ASTM F 1394 (Particles)		
Internal Absorbed Moisture		
Time to recover to base line from a 2 ppm spike	≤ 4	hour
for low surface area component (valve, regulator)	≤ 6	hour
Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing)		
Test procedures per ASTM F 1397		
Total Anionic Contamination		
Total anionic contamination added to test water	≤ 1	ppm
Individual anionic contaminant	≤ 0.2	ppm
Test procedures per ASTM D 4327 (Total Anions)		
Leak Rate		
Inboard leak rates for He	$\leq 1 \times 10^{-9}$	scc/s
Outboard leak rates for He	$\leq 1 \times 10^{-5}$	scc/s
Cross-seat leak rates for He	$\leq 4 \times 10^{-8}$	scc/s
Test procedures per SEMI F1 (Leak Rate)		
Cycle Life		
Manual valves	≥ 25 K	cycles
High pressure automatic valves	≥ 25 K	cycles
Low pressure automatic valves	≥ 500 K	cycles
Test procedures per ASTM F 1373 (Cycle Life)		

8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7.

8.2 Valves should be springless, packless, metal diaphragm type with all metal bonnet seals.

8.3 Regulators should be threadless, packless type with all metal bonnet seals.

8.4 Regulators and valve flow coefficient (C_v) should be selected based on liquid flow requirements and liquid characteristics.

8.5 Mechanical fittings should be all metal face seal type with solid nickel gaskets.

8.6 Pressure transducers should be used in place of bourdon tube pressure gauges.

8.7 Filters should be PTFE media rated at 0.05 µm pore size.

8.8 Check valves should be disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[3]

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

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SEMI E49.6-95
GUIDE FOR SUBSYSTEM ASSEMBLY AND TESTING PROCEDURES - STAINLESS STEEL SYSTEMS

1 Purpose

The objective of this document is to establish standard guidelines for cleanroom activities specific to the manufacturing, assembly, testing, and integration of materials and components used in stainless steel semiconductor process equipment.

2 Scope

This standard has been developed as a guide for the assembly and testing of high purity and ultrahigh purity gas and solvent subsystems.

3 Referenced Documents

Note: Refer to the latest version of the following documents for general cleanroom protocol.

3.1 *Federal Standard (FED-STD)*[1]

Federal Standard Cleanroom and Work Station Requirements, Controlled Environment

3.2 *Institute of Environmental Sciences (IES)*[2]

IES-RP-CC-001 — Recommended Practices for HEPA Filters

IES-RP-CC-002 — Recommended Practices for Laminar Flow Clean Air Devices

IES-RP-CC-003 — Recommended Practices for Garments Required in Cleanrooms and Controlled Environmental Areas

IES-RP-CC-006 — Recommended Practices for Testing Cleanrooms

4 Terminology

See Section 4 of SEMI E49.

5 Facility Guidelines

5.1 *Gowning Area Class 10,000/1,000 (HP/UHP)* — All personnel working in cleanrooms should wear paper booties prior to entering the gowning area. Personnel should wear polyester gowns, hood, and boots, pure latex gloves (no talc), and safety glasses before entering clean areas.

5.2 *Materials Staging Area Class 10,000/1,000 (HP/UHP)* — Materials used in the cleanroom should have the outer bag removed and the inner bag wiped down with cleanroom wipes saturated with a 50/50 IPA/DI mix in the materials staging area prior to entry into the cleanroom.

5.3 *Cutting Area Class 10,000 or Better* — Cutting area should be a Class 1,000 area while in normal (at rest) operation. Work areas should maintain a Class 1,000 average at all times.

5.4 *Welding and Cleaning Area Class 1,000/100 (HP/UHP)* — Welding and cleaning area — ultrasonic tanks, DI rinse stations, and dry-down stations — should be Class 1,000 or 100, depending on purity classification. After final cleaning operation, there should be a Class 100 station for final bagging of cleaned parts prior to their entry into the cleanroom.

5.5 *Assembly, Final Integration, and Final Test Class 100/10 (HP/UHP)* — All areas used for gas/liquid system assembly, integration, and test should be Class 100/10 under all working conditions. This area should be segregated by hard or soft walls from all other fabrication areas.

5.6 *Common Plenums* — Adjoining clean areas of varying classifications should be separated with floor-to-ceiling hard or soft walls, have separate return air grilles, and be positively pressurized to a minimum of 1.3 mm (0.05 in.) H_20 (W.C.) over the lower adjacent class clean area when otherwise common by access or pass-through.

6 Utility System Guidelines

6.1 *Nitrogen for Drying after Cleaning (Both HP and UHP Classes)*

- Filtration — 0.01 µm rated
- Oxygen Content — < 1.5 ppm
- Moisture Content — < 1.0 ppm
- Hydrocarbon Content — < 2.0 ppm

6.2 *Purge Gases* — Argon or nitrogen for purging gas systems during assembly and for testing, using cryogenic source and 0.01 µm filtered. The following purity levels should be as certified by the gas supplier.

1 Available from General Service Administration, Federal Supply Service Bureau, Specification Section, Suite 8167, 470 East L'Enfant Place SW, Washington, D.C. 20407.

2 Available from Institute of Environmental Sciences, 940 E. Northwest Hwy., Mount Prospect, IL 60056.

	HP	*UHP*
Oxygen Content	< 40 ppb	< 10 ppb
Moisture Content	< 20 ppb	< 10 ppb
Total Hydrocarbon Content	< 40 ppb	< 20 ppb
Particles	< 0.1 particles per ft^3 ≥ 0.1 µm and 0 > 0.2 µm (both classes)	
Purified at POC	Optional	Required

6.3 *Weld Gases* — Welding argon (minimum specification, purifiers and 0.01 µm rated filter), recommended for ID/OD purge for both HP and UHP systems):

- Oxygen Content — < 50 ppb
- CO Content — < 50 ppb
- CO_2 Content — < 50 ppb
- THC as Content — < 50 ppb
- Moisture Content — < 50 ppb
- These contaminant levels should be as measured at the POC to the parts to be welded.

6.4 *DI Water - HP/UHP Classes*

- Resistivity — ≥ 18 mega ohm-cm @ 25°c (77°F)
- TOC — < 20 ppb
- Silica — < 5 ppb
- Particles — < 1 particle/millimeter @ ≥ 0.1 µm
- Bacteria — < 10 colonies/100 millimeter
- Hot DI Temperature — 80°C (176°F), minimum

7 Materials Procedures

7.1 *Procedures for Incoming Materials and Components (Component Suppliers)*

7.1.1 *Identification Guidelines*

7.1.1.1 Every deliverable item should have some scheme of positive and permanent identification, so that traceability is provided from the steel melt source to the final metal finishing and packaging through site installation.

7.1.1.2 This identification should provide nondestructive post installation traceability.

7.1.1.3 Clearly visible labeling (without the need to open the package) should be provided at each level of packaging.

7.1.2 *Packaging and Shipping Guidelines*

7.1.2.1 Double bagging should be required.

7.1.2.2 The inner bag should be nonpermeable (minimum six mil polyethylene or Nylon 6) and should prevent damage from normal handling.

7.1.2.3 Vacuum sealing or dry inert gas purging should be used on the inner bag.

7.1.2.4 The ends of the component should be protected using some noncontaminating method.

7.1.2.5 The outer bag may be any suitable material but should be purged with a dry inert gas prior to sealing.

7.1.3 *Documentation*

7.1.3.1 Test results should be provided for each shipment.

7.1.3.2 Shipment should be in complete lot sizes.

7.1.3.3 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically valid data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.1.3.4 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

7.2 *Receiving*

7.2.1 All incoming material should be segregated from "acceptable material" until it has been formally accepted through documented procedure.

7.2.2 All cartons should be opened (100%); all goods should be checked visually for damage (e.g., torn bags, inadequate padding causing damage).

7.2.3 Material should be stored in original packaging. Do not open until ready to use or inspect. Inspection involving opening sealed plastic bags should be conducted within the materials staging prefab cleanroom. After inspection, purge and heat-seal the material into a clean polyethylene bag.

7.2.4 Any material failing initial inspection should be immediately "red tagged" and set aside in a "quarantine" area until the supplier of the material is notified and disposition is determined.

7.3 *Acceptance and Rejection*

7.3.1 All material should be uniquely identified with a heat number, lot number, and serial number, allowing traceability back to source and documentation. Only material so marked should be accepted.

7.3.2 All material should meet a purchasing specification and be provided with documentation demonstrating compliance. Only material so documented should be accepted.

7.3.3 A certain percentage of material should undergo incoming QA checks for parameters such as: surface contamination (e.g., hydrocarbon, particulate), tubing quality, wall thickness, nicks, scratches; surface roughness, pits, stringers, particle count, weldability, helium leak rate (inboard/outboard/across seat), and dimensions.

The material should be accepted only after these incoming QA checks are completed. A statistically valid sample size should be determined. This means that sufficient pieces must be checked to guarantee that no defective parts arrive at the buyer's location.

7.3.4 Any material that does not pass the basic incoming QA requirements should be "red tagged" and placed in "quarantine" pending final disposition.

7.3.5 Material that passes incoming QA should be uniquely tagged.

8 Construction Procedures

8.1 *Tube Cutting and Preparation*

8.1.1 Stainless steel tubing should be opened, cut, faced, and deburred in a required cleanroom environment, leaving no visible particulates inside the cut end.

8.1.2 For tube cutting, use a wheel cutter with lathe-type facing tool or a special designed power saw with alignment guide. Do not use lubricant. If any "nicks" are found, reface or discard the tube.

8.1.3 When practical during cutting and during all facing operations, use an argon or nitrogen purge (50-100 f/s) to preclude particles from entering tubing.

8.1.4 The prepared end should conform to ASTM A 632 (or ASTM A 269 ≥ 1/2" O.D.) tubing specification with regard to ovality and wall thickness.

8.1.5 The prepared end should be square to tube run within 1/4 deg. (angle).

8.1.6 After preparing, debur the inside diameter carefully and lightly. Do not scratch the inside diameter. Any scratched tubes should be reprepped or scrapped. Chamfering is not required.

8.1.7 Avoid cross-contamination from dissimilar materials.

8.2 *Tube Cleaning*

8.2.1 After cut and prep, tubing should be cleaned using a process which removes all debris and assures that the surface is totally free of hydrocarbons. This process should be custom-tailored to the supplier's need based on tubing supplier quality control (QC) and on purity grade requirement (HP/UHP).

8.2.2 If using tubing certified "hydrocarbon-free" from a tubing supplier, a cleaning procedure as follows is recommended:

- Primary rinse in cold running DI water.
- Secondary rinse in hot [80°C (176°F)] DI water.
- Final rinse in cold DI water with "pressure flush."
- Blow dry with high velocity > 305 meters/min. (> 1,000 feet/min.) hot (150°C (318°F) N_2. Ensure that drying occurs immediately after final rinse to prevent evaporation of DI from the tubing ID surface.
- Use immediately or seal in plastic sleeves.
- Document the process through ESCA elemental chemical composition analysis and SEM photographs that procedure does remove all contaminants. Once process is documented, audit periodically to assure process continues to produce noncontaminated goods.

8.3 *Orbital Welding* — All orbital welding should be performed only by certified welders. Certification procedures should include, at the minimum, producing three acceptable welds in a row of all types of typical orbital weld joints of all sizes of tubing to be welded. Welding parameters should be set by the welder without the use of any written aids. Certification process should be performed every six months.

8.3.1 *Weld Equipment Setup*

8.3.1.1 All welding fixtures should be clean and free of any particulates and excessive discoloration. Weld head should rotate freely and smoothly at all speeds. All clamping and holding fixtures should fit tightly around applicable fittings/tubing, allowing no fitting movement after clamping in excess of 0.008 cm (0.003 in.).

8.3.1.2 Electrodes should be precision ground. Electrode gap should be set using tooling and procedures which provide accurate and repeatable gaps to be set to within 0.005 cm (0.002 in.).

8.3.1.3 Documented procedures should exist for each weld configuration including all parameters (including purge times, orifice sizes, purge rates, and internal pressure).

8.3.1.4 Purge gas apparatus should be stainless steel tubing and components with face seal fittings. Plastic tubing is acceptable as the final run to allow flexibility for hook-up. Lengths should be restricted to less than ten feet. All components which come into contact with the weldment should be stainless steel.

8.3.2 *Weld Bead Characteristics*

8.3.2.1 All weld beads should conform to the following specifications:

1. All welds should exhibit complete penetration around the entire internal surface.
2. Internal weld bead width should be 1.5 times wall thickness (± 20%).
3. Bead "snaking" should not exceed 20% of bead width.
4. ID encroachment of the weld bead should not exceed 0.0013 cm (0.005") from the tubing ID surface. Weld bead should be zero undercut at all points.
5. Misalignment of welded pieces should be less than 10% of wall thickness.
6. Zero oxidation visible on internal surfaces.
7. Light straw oxidation on external surfaces permissible.

8.3.3 *Sample Welds*

8.3.3.1 Sample welds or coupons should be performed at the beginning of each shift, after breaks, and after any alteration to the weld parameters. Coupons should be cross-sectioned and inspected visually for penetration, bead concavity, bead variation, and oxidation. Coupons should be logged with the date and time and operator identification. Coupons and coupon logs should be retained for one year.

8.3.4 *Purging* — Extreme care should be taken to ensure that all contiguous flowpaths are fully purged. All dead legs must be purged out completely prior to welding. All welds should be performed with full purge flow sweeping the weld area during and after welding. Vacuum devices may be required to overcome back-pressure in components such as regulators, filters, purifiers, check valves, or others. Dead-end components such as gauges may be purged using a small-diameter tube placed inside the tubing to be welded and back-flowing purge through the weld zone. Pre-purging should occur for as long as necessary to assure that moisture and oxygen levels in the weld zone are less than 100 ppb. Post-purging should continue after the welding process until the weld zone has cooled to below 200°C (424°F). Light external oxidation should be removed with a stainless steel wire brush immediately after welding. Purge should be maintained during the brushing process, and care should be taken to perform the brushing process in an appropriate area so as not to contaminate the work area.

8.3.5 *Welding Electrode*

8.3.5.1 Welding electrodes should be changed as frequently as necessary to prevent weld deterioration. At the least, electrodes should be changed every 25 welds.

8.3.6 *Weld Inspection*

8.3.6.1 All welds should be 100% inspected to insure conformance to the weld bead specifications listed in 8.3.2 and 8.3.7.

8.3.6.2 Bore scope inspections should be performed by the welder of at least 20% of his work-in-process. All accessible welds should be bore scope inspected during final inspection process, while protecting tubing from scratches.

8.3.7 *Dimensional and Configuration Inspection* — Dimensional and configuration inspection should be performed as follows:

1. One hundred percent subassemblies should be inspected within a cleanroom of same class as assembly area.
2. Confirm spool fabrication drawing is attached to the assembly; if not, reject.
3. Use spool sheet to verify conformance of assembly to drawing. Check dimensions, squareness, offsets, straightedges, and levels to verify all dimensions.
4. Inspect each weld externally for undercut, width oxidation, overlap, uniformity, and alignment. Where possible, use sightube/bore scope to inspect interior of welds (scratch preventers essential). Where welds are not inspectable, a statistically significant sample of the welds will need to be cut out to verify that the welding is done correctly.
5. When subassemblies have passed inspection, they should be tagged as such, rebagged, and released for final testing.
6. Any items found defective during inspection and repairable may be repaired if they will not degrade the system quality measurably. If a cut must be made into a closed system, a purge from both sides (upstream and downstream) should be established.

8.4 *Subsystem Assembly Protocol* — Gas panel and solvent system assembly should be performed only by trained competent personnel. Proper procedures for tightening face seal and other connections, valve bonnets, regulator bonnets, and other components should be followed at all times. Manufacturers recommended torque values should be followed at all times, using a calibrated torque wrench. Purge gas at the required purity level should be flowing through components and subassemblies at all times during the assembly process to minimize entrained contaminants. Partially assembled gas panels should be under purge or capped at all times. Assemblers should at all times be wearing clean gloves; soiled, discolored or torn gloves should be replaced immediately. Components, assemblies or subassemblies which are dropped or damaged during the assembly process should be red-tagged and inspected before use. Face seal gaskets which are dropped should be discarded. It is recommended that two technicians should work as a team during the assembly process. One should be designated as the handler and should position all components. The other should exclusively handle the face seal gaskets and hand-tighten the mating fit set.

9 Testing Procedures

9.1 Tests should be successfully completed and results documented for all performance parameters (purity indices) specified.

9.2 Leak rate tests should be conducted on 100% of all subsystems. For UHP, use hydrocarbon free test instruments.

9.3 *Design Qualification* — Gas delivery system design performance should be qualified in three parameters: particulate generation, contaminant spike recovery, and mass flow controller replacement recovery. This testing should be performed on the initial gas delivery system prototype and on any design revision which significantly impacts the component selection or system configuration. Test results should be kept on file and made available to the end user upon request.

9.3.1 *Particulate Generation* — Static and dynamic particle testing should be performed with a flow rate of at least 3 times the maximum process flow rate at the recommended supply pressure, except during mass flow controller testing when test flow rates should be between 0% and 80% of the MFC value. Testing should be performed on all flow paths that differ significantly in components or configuration. Dynamic test protocols should be as follows:

- Each valve in the test flow path should be cycled individually.
- Starting with the valve furthest upstream, cycle each valve once every 20 seconds.
- MFC valves should be cycled from 0% to 100%.
- Test interval should last until 0.085 std. m^3/hr. (3 std. ft^3/hr.) of gas flow through the test flow path has been sampled by the particle counter.

9.3.2 *Contaminant Spike Recovery* — Contaminant spike recovery testing should be performed on all flow paths which differ significantly in configuration or components. This test should be performed at a flow rate equivalent to typical flow rates achieved in purge and vent cycles for the specific flow path. Contaminant spike recovery test protocols are:

- With all components placed in the full open position, mass flow gas moisture level should be at baseline for 30 minutes prior to testing to establish stable background.
- When a stable background is achieved, initiate a 2 ppm (v) moisture spike until the outlet moisture concentration reaches 2 ppm. (Remove the moisture source from the test gas, and monitor elapsed time until moisture level reaches specified level.)
- Spike recovery time should be ≤ 8 hours for high purity systems and ≤ 4 hours for ultra high purity systems.
- Similar procedure should be conducted for oxygen and THC level tests where required.

9.3.3 *Mass Flow Controller Replacement Recovery* — MFC replacement recovery testing should be performed on all flow paths differing significantly in components and configuration. This test should be performed with a flow rate equivalent to flow rates achieved in typical purge and vent cycles for the specific flow path. MFC replacement recovery test protocols should be:

- Valves and purge flows should be set up in the component replacement mode, and the MFC should be removed from the flow path.
- After 15 minutes, a replacement MFC should be installed.
- Cycle purging should be performed at the recommended pressures and for the recommended number of cycles.
- Typical purge and vent flow rates should then be established, and the moisture level of the test gas should be monitored over time.
- For high purity systems, the moisture level should achieve background levels within one hour.
- For ultra high purity systems, the moisture level should achieve background levels within 15 minutes.

9.4 *Manufacturing Qualification* — Manufacturing qualification tests should be performed to verify the manufacturing and quality control procedures followed in the manufacturing of the gas delivery system. As the configuration of gas systems varies greatly from process to process, no specification should be given here other than to state that static and dynamic particle testing, moisture level, oxygen level, and hydrocarbon testing should be performed to provide statistically significant data showing that the gas delivery system will meet the purity levels required.

9.5 *Certification* — Certification for gas delivery systems should include: leak rate certification, particle counts with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested and which components were cycled; moisture level plotted against time with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested; and oxygen or hydrocarbon levels plotted against time with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested.

10 Labeling Protocol

All lines should be labeled by gas type and flow direction.

11 Pre-Packaging Protocol

11.1 After testing is completed, the subassembly should be pressurized with UHP grade Argon or N_2. Each process line should be sealed with a closed valve and metal fitting cap or plug; all nonprocess lines should be sealed with a plastic cap or plug before being shipped.

11.2 Lines separate from gas system should be shipped double bagged from the cleanroom. Bags should be nonpermeable material and purged with inert gas, then sealed from atmosphere.

12 Documentation Protocol

Documentation logs should be kept for all shop activities. Example log sheets are shown as Tables 1–6 below.

Table 1 Stainless Steel Component Inspection Log

Stainless Steel Component Inspection Log							
Customer:						Date:	
Location:						Page __ of __	
Project:						Cert: Yes/No	
Date Received:		Lot No.:		Heat No.:			
Description	Wall Thickness		Diameter		Visual	Surface Finish RA	QA
	Min.	Max.	Min.	Max.			

Table 2 Weld Log or Weld Coupon Log

Weld Log or Weld Coupon Log									
Customer:							Date Begun:		
Location:							Page __ of __		
Project:							Welder:		
Number	Size	Description	Visual	Color	Uniformity	Heat/Lot	Coupon Date	Comments	QA

Table 3 Pressure Hold Test Report

Pressure Hold Test Report	
Customer:	Date:
Location:	Report:
Project:	
System:	
Time Started:	Time Finished:
Start Temperature:	Finish Temperature:
Start Pressure:	Finish Pressure:
Elapsed Time:	Finish Pressure Corrected:
Pressure Difference Corrected:	
Elapsed Time:	
Gas (or Mixture) Used for Test:	
Pressure Gauge Range:	
Comments:	
Tested by:	Date:
QA Representative:	Date:

Table 4 Particle Count Test Report

Particle Count Test Report				
Customer:			Date:	
Location:			Report:	
Counter		Instrument/Model	Serial Number	
LPC				
CNC				
Date	Time	System	Particle Counts > 0. µm	Flow Rate/Pressure
Comments:				
Tested by:				
QA Representative:				

Table 5 Trace Moisture and Oxygen Test Report

Trace Moisture and Oxygen Test Report				
Customer:			Date:	
Location:			Report:	
Type		Instrument/Model	Serial Number	
Trace O_2				
Trace H_2O				
Date	Time	System	Inboard Leak Rate	Comments
Comments:				
Tested by:				
QA Representative:				

Table 6 Helium Leak Test Report

Helium Leak Test Report				
Customer:			Date:	
Location:			Report:	
Project:				
Type		Instrument/Model	Serial Number	
He MSLD				
Date	Time	System	Inboard Leak Rate	Comments
Comments:				
Tested by:				
QA Representative:				

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E49.7-0702
PURITY GUIDE FOR THE DESIGN AND MANUFACTURE OF ULTRAPURE WATER AND LIQUID CHEMICAL SYSTEMS IN SEMICONDUCTOR PROCESS EQUIPMENT

This guide was technically approved by the Global Liquid Chemicals Committee and is the direct responsibility of the North American Liquid Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published 1995.

This document as balloted replaces SEMI E49.7 in its entirety. The title for the previous revision of E49.7 was, "GUIDE FOR SUBSYSTEM ASSEMBLY AND TESTING PROCEDURES - POLYMER SYSTEMS."

1 Purpose

1.1 The objective of this document is to provide recommendations that will help maintain the quality of the liquid being delivered. Recommendations are given for activities specific to polymer ultrapure water and liquid chemical systems used in Semiconductor process equipment.

NOTE 1: As with any SEMI guide, the practices outlined herein are recommendations, not specifications. Users of this document should recognize that alternate practices are not excluded as long as they produce results that are equivalent to those produced using the recommendations outlined here and meet the requirements of the end user.

2 Scope

2.1 It is within the scope of this standard to recommend procedures that complement the requirements in SEMI F57 with the goal of ensuring the quality of the liquid being delivered. Recommendations are provided in the following areas:

- Manufacturing Facility
- Utilities
- System Design
- Pre-Production and Inspection
- Assembly
- System Testing
- Packaging
- Traceability

2.2 For the purposes of this document, systems include all liquid delivery components inside semiconductor process equipment and ancillary support equipment, as well as additional plumbing provided by the OEM with the processing equipment. This includes any assembly of two or more liquid delivery components provided with or within semiconductor process equipment.

2.3 Typical semiconductor process equipment with ultrapure water and liquid chemical delivery systems includes, but is not limited to the following:

- Wafer Handling Equip.
- Wafer Cleaning Systems
- Chemical Filtration/Mixing Skids provided by OEM
- Wet Clean Stations
- Wafer Scrubbers
- CMP
- Photolithography coaters and developers
- Ion Implanters
- Metrology equipment

2.4 This standard does not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not define the performance requirements of components, which may be addressed by SEMI F57. Nor does this standard define the performance requirements of equipment systems. Facility distribution systems are also outside the scope of this standard.

3.2 Organic liquids, such as isopropyl alcohol and methyl alcohol, are typically in contact with stainless steel or other non-polymeric components. The polymer systems described within this document are NOT intended for use with such organic liquids. Refer to SEMI E49.4, SEMI E49.5, and SEMI E49.6 for information on stainless steel components.

3.3 System design issues outside those that directly impact liquid purity or quality are not within the scope of this document's recommendations and are left to the individual system designers.

3.4 Polymer systems described within this document are intended for use in ultrapure water and liquid chemical delivery only. Their performance requirements may exceed the needs of systems used in drainage and other lesser quality liquids.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C3.28 — Standard for Nitrogen (N2), VLSI Grade in Cylinders, 99.9996% Quality

SEMI C41 — Specifications and Guidelines for 2-Propanol

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures – Stainless Steel Systems

SEMI F34 — Guide for Liquid Chemical Pipe Labeling

SEMI F57 — Provisional Specification for Polymer Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI F61 — Guide for Ultrapure Water System Used in Semiconductor Processing

4.2 *Federal Standard (FED-STD)*[1]

Fed Stand 209E — Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

1 Available from General Service Administration, Federal Supply Service Bureau, Specification Section, Suite 8167, 470 East L' Enfant Place SW, Washington, D.C. 20407.

4.3 *ISO Document*[2]

ISO 14644 — Cleanrooms and Associated Controlled Environments – Part 1 Classification of Air Cleanliness

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 See Section 4 of SEMI E49.

6 Manufacturing Facility Recommendations

6.1 Cleanroom Class designations as used within this document are defined within Federal Standard 209E Airborne Particulate Cleanliness Classes in Clean rooms and Clean Zones. (ISO standard 14644-1 classifications are listed parenthetically.)

6.2 *Materials Storage Area* — The storage area for components and assemblies should be a dedicated enclosed area, protected from the elements and separated from other materials. Only components and assemblies that have passed inspection, and are clean and packaged should be placed in the storage area.

6.3 *Gowning Area* — Gowning area should be Class 10,000 (ISO Class 7) or better. All personnel working in cleanrooms should follow appropriate gowning protocol such as: wear booties prior to entering the gowning area; and wear gowns, hood, boots, gloves, and safety glasses before entering clean areas.

6.4 *Staging Area* — Staging Area should be Class 10,000 (ISO Class 7) or better. The staging area (if used) should be located immediately outside the assembly cleanroom, with appropriate access to the assembly cleanroom.

6.5 *Assembly Areas* — All production operations such as cutting, welding, cleaning, assembly, final integration, final test, and packaging (if applicable) should be performed in a class 10,000 (ISO Class 7) cleanroom or better.

7 Utility Recommendations

7.1 *Nitrogen* (Uses include leak testing of non-brittle materials, drying, and purging.)

- Nitrogen quality should meet requirements of SEMI C3.28.
- Particle filtration should be 99.99999% removal of 0.003 micron particles.

2 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

NOTE 3: Use 316L electropolished tubing or PFA tubing for purge piping. (Use tubing that does not degrade N_2.)

7.2 *Ultrapure Water* (Uses include cleaning and rinsing.)

- Resistivity ≥ 18 mega ohm-cm @ 25° C (77° F)
- TOC — < 20 ppb
- Silica — < 5 ppb
- Particles — < 1 particle/milliliter @ 0.1 μm size
- Bacteria — < 10 colonies/100 milliliter
- Hot Ultrapure Water Temperature — 80° C (176° F), minimum

NOTE 4: If testing requirements dictate, access to higher quality ultrapure water may be appropriate in portions of the facility. Additional information related to ultrapure water facility design and terminology may be obtained in SEMI F61.

7.3 *2-Propanol/IPA* (Uses include cleaning.)

- 2-Propanol/IPA quality should meet requirements of SEMI C41, Grade 1

7.4 *Clean Dry Air (CDA) or Oil Free Air* (Uses include pneumatic control and air actuation.)

7.4.1 CDA is not recommended for use on cleaned wetted surfaces. Nitrogen is recommended for drying cleaned wetted surfaces because the purity level is clearly defined and controlled.

8 System Design Recommendations

8.1 *General Recommendations* — The intent of this section is to recommend design practices that ensure the quality of the liquid being delivered. These recommendations should be considered along with design constraints such as minimizing liquid consumption, cost, ensuring maintainability, and limiting complexity. In addition, the appropriateness and simplicity of the facility interface should be considered.

8.2 *Component Recommendations* — Components should limit system exposure to ionic, metallic, total organic carbon, and particle contamination.

8.2.1 All applicable components should comply with SEMI F57.

8.2.2 For components not addressed in SEMI F57, a discussion of recommended materials (similar to that found in SEMI F57) may benefit the reader and is therefore provided.

8.2.2.1 Care should be taken to ensure that the materials are compatible with the liquid streams for long term applications. Additionally, it is important that the materials used be compatible with the application temperature and/or sanitization methods such as ozone, UV light and/or hydrogen peroxide.

8.2.2.2 These recommendations often imply the use of existing materials of choice, such as high purity grades of perfluoroalkoxy (PFA), polytetrafluoroethylene (PTFE), and polyvinylidene fluoride (PVDF). However, unique design specifications or new materials may result in instances where significant efficiencies may be achieved while maintaining substantially equivalent performance. These scenarios could result in the use of new or existing materials such as ethylenechlorotrifluoroethylene (ECTFE), polyether-etherketone (PEEK), polypropylene (PP), acetal resin (such as Delrin®™[3], Celcon®™[1] and others), polyvinyl chloride (PVC), perfluoromethylether-based perfluoroalkoxy (MFA), etc.

8.2.2.3 Due to purity and traceability issues, reprocessed or regrind material is not recommended.

8.3 *Joining Recommendations* — Joining technology that is free of dead space and entrapment areas is recommended to reduce negative effects such as microbial proliferation and impacts to slurry particle size distribution. For this reason pipe thread connections are not recommended.

8.3.1 Tubing should be joined with flare fittings, or similar dead space free technology. Preparation and joining of fittings should be performed in accordance with component manufacturer recommendations.

8.3.1.1 Care should be taken to ensure that dissimilar flare fittings are not joined together. When possible, one style of fitting should be used throughout the system. Manufacturers should be consulted prior to using similar style fittings from different manufacturers interchangeably.

8.3.2 Pipe should be joined with welds that minimize dead space and entrapment areas. Preparation and welding should be performed in accordance with component manufacturer's recommendations.

NOTE 5: Users of this guideline are cautioned that suitable welding methods, such as thermal butt welding, may be covered by patents or other intellectual property.

8.3.2.1 Glue, solvent, or thermal socket welding of pipe is not recommended.

8.4 *System Volume Recommendations* — When possible, dead volumes should be eliminated and overall system volume should be minimized to reduce negative effects on purity as well as flush times.

3 Delrin is a trademark of DuPont; Celcon is a trademark of Hoechst Celanese.

8.4.1 In instances where dead volumes are unavoidable, the dead leg should be ≤ 3 nominal flow path diameters.

8.4.2 Examples of components and practices which help minimize system volume include:

- Dead-space-free branch valves
- Multi-component integrated assemblies
- Use of direct flow paths
- Trickle bypass valves
- Sampling valves

8.5 *Flow Recommendations* — Due to issues related to equipment complexity and the cost of excessive liquid consumption, general flow recommendations for ultrapure water and liquid chemical delivery systems are not provided. However, Related Information 1 provides a list of practices that tend to reduce microbial proliferation in ultrapure water Systems. Because not all liquid chemicals are subject to these effects, the user is advised to obtain additional flow information related to ensuring the quality of liquid chemicals from the liquid chemical manufacturer.

8.6 *Slurry System Recommendations* — In addition to the other design recommendations within this section, the following recommendations are provided specifically for slurry liquid delivery systems used within CMP process equipment.

8.6.1 Areas of high shear can damage the quality of many slurries resulting in large particle count (LPC) growth. Sharp edges projecting into flow path, large pressure drops, tight bends, and sudden large reductions in tubing size can cause high shear.

8.6.2 Dead legs are of particular importance with respect to slurries because the abrasives may settle and agglomerate, creating LPC growth. To help minimize this issue branch lines should be oriented such that they project vertically above the main line to prevent the abrasive from settling and agglomerating.

8.6.3 If point of use filtration is incorporated, provisions to sample the slurry before and after the filter should be provided for LPC monitoring.

8.7 *Protection and Sampling Recommendations* — These recommendations are intended to protect liquids from back flow or cross contamination and to ensure that sampling is adequate for evaluating liquid quality throughout system.

8.7.1 Backflow/back pressure and cross contamination protection should be included in the system.

8.7.2 The system should have provisions to accomplish sampling. Sampling ports should be located as close as possible to the liquid supply point, to bath/tank or process chamber, and to the return header immediately before exit.

8.7.3 Provisions to completely flush, drain, and sanitize the liquid system completely (with ultrapure water or 2-propanol/IPA for example) should be included in the system.

8.8 *Filtration Recommendations* — These recommendations are intended to reduce negative effects such as particle contamination, metallic contamination, and micro bubbles.

8.8.1 Filters should be considered for all liquid delivery systems. Location, selection, installation, start up, and rinse of filters should be based on input from customer, chemical manufacturer and equipment manufacturer.

8.8.2 Process stream isolation should be provided for all filters to allow for maintenance and replacement.

8.9 *Labeling Recommendations* — In addition to the recommendations in Section 10.7, functional labels/schematics should be included with assembly for vents, drains, and other components as necessary to ensure the proper operation of the system(s).

8.10 *Maintainability Recommendations*

8.10.1 Components that require operation, inspection, or maintenance (i.e., valves, filters, pumps, gauges, etc.) should be located where readily accessible.

8.10.2 Provide support on each side of components, such as valves, where operation or assembly transmits torque to the piping/tubing.

8.10.3 Design should allow for thermal expansion if system operates at an elevated temperature.

9 Pre-Production Acceptance and Inspection Recommendations

9.1 *Identification Recommendations*

9.1.1 Applicable components should meet the traceability requirements found in SEMI F57. Where practical, the traceability requirements of SEMI F57 should also be followed for components not covered within SEMI F57 and assemblies, to ensure traceability is provided from the resin source. Component and assembly identification should provide nondestructive post installation traceability. In addition, packaging should have labels allowing for traceability as described above that are clearly visible (without the need to open the package).

NOTE 6: Practical limitations such as component size may not allow for permanent post installation marking of every component.

9.2 *Packaging Recommendations*

9.2.1 Applicable components should meet the packaging requirements found in SEMI F57. Where practical, the packaging requirements of SEMI F57 should also be followed for other components and assemblies to avoid contamination of wetted surfaces.

9.3 *Documentation*

9.3.1 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their assemblies meet the user' s performance requirements. Similar requirements for maintaining component documentation are covered in SEMI F57 and are the responsibility of the component manufacturer.

9.4 *Receiving, Inspection, and Storage*

9.4.1 All incoming components and assemblies should be segregated until they have been formally accepted through a documented procedure.

9.4.1.1 Cartons should be checked visually for damage (e.g., torn bags, inadequate padding causing damage).

9.4.1.2 A statistically significant sample size should undergo minimum QA checks such as visual inspection and critical dimension inspection. In some instances further inspection of components to ensure compliance with SEMI F57 may be required.

9.4.1.3 Components and assemblies should be stored in original packaging until ready for inspection. Inspection involving opening sealed plastic bags should be conducted within the staging prefab cleanroom. After inspection, heat-seal the component (and if appropriate the assembly) into a clean and dry polyethylene bag.

9.4.2 Any component or assembly failing initial inspection should be immediately " red tagged" and set aside in a "quarantine" area until the supplier of the component is notified and disposition is determined.

9.4.3 Components and assemblies should be accepted only after these incoming QA checks are completed.

9.4.4 Accepted component and assemblies should have traceability to the appropriate incoming QA check.

9.4.5 Components and assemblies should be stored in the original shipping containers when possible. Pipe may be stored on racks with appropriate supports.

9.5 *Staging*

9.5.1 Prior to entry into the cleanroom components and assemblies should have the outer bag removed and the inner bag wiped down with cleanroom wipes using 2-propanol/IPA or 2-propanol/IPA and ultrapure water mix in the staging area.

10 Assembly Recommendations

10.1 *General*

10.1.1 Assembly should take place in assembly/cleanroom (see Section 6.5).

10.1.2 Inner bags should be removed within the assembly/cleanroom.

NOTE 7: In the event components must be handled outside cleanroom areas, personnel should wear protective gloves at all times and components returning to the cleanroom should be clean. All ends should be capped to avoid exposure of wetted surfaces.

10.1.3 If work must stop for an extended period, assemblies should be purged with nitrogen and capped immediately to isolate wetted materials from contamination.

10.2 *Pipe/Tube Cutting*

10.2.1 Use dedicated clean tools for piping/tubing system fabrication and installation. Clean tools at the start of each shift with 2-propanol/IPA, rinse with ultrapure water, and blow dry with nitrogen. Maintain tools in accordance with manufacturers' recommendations.

10.2.2 Cut piping/tubing in accordance with manufacturers recommendations. Saws are prohibited.

10.2.3 The cut end of the pipe/tube should be finished before use to comply with the manufacturers' recommendations for squareness and finish. Cut surfaces should be clean and free of loose particles and debris.

10.3 *Component and Assembly Cleaning*

10.3.1 What follows are limited and general recommendations for cleaning components or assemblies. It is the equipment manufacturer's responsibility to ensure that cleaning procedures and solutions are adequate and do not impact equipment performance.

10.3.1.1 Every effort should be made to keep the interior of the pipe clean during cutting and prepping. If, however, the pipe has become contaminated and nitrogen (Section 7.1) will not dislodge the particles it can be cleaned by blowing an ultrapure water soaked swab (often called a "pig") through it using nitrogen (see Section 7.1). The pig should be constructed of a clean, unused, cleanroom approved, cloth soaked in ultrapure water and wrapped around a plug of a diameter less than the ID of the pipe to be cleaned. The length of the pig should be about 2× its diameter.

10.3.1.2 Components or assemblies that have become contaminated should be cleaned. The procedure for cleaning cannot be defined but frequently includes:

- Rinse in ultrapure water.
- Soak in cleaning solution if necessary and compatible with process
- Rinse in flowing ultrapure water (see Section 7.2).
- After rinse, check cleanliness.
- If necessary, repeat the procedure until clean.

10.3.2 Use 2-Propanol/IPA to remove any ink markings from the exterior of the pipe.

10.4 *Welded Connections*

NOTE 8: Refer to Sections 8.3 and 8.3.2 for general joining and weld recommendations.

10.4.1 *Welder Qualification*

10.4.1.1 Welders should have prior experience in the specific welding method of specific types of polymer components. To be qualified, the welder should be able to safely cut, prep, clean, purge, fit, and weld the sizes for which he or she is seeking qualification and produce consistently acceptable weld joints. It is recommended that welders undergo weld training and certification by a pipe manufacturer.

10.4.2 *Weld Qualification*

10.4.2.1 During fabrication, each welder should submit weld samples daily to the QA manager at the beginning of the shift. The welds should be representative of the types of welds the welder will perform during the shift.

10.4.2.2 These welds should meet a defined criteria of acceptability, which may include inspection for visible discoloration, uniformity of weld area, maximum weld misalignment, and weld bead height. These criteria may be derived from sources such as the component manufacturer, the process equipment manufacturer, and the end user. General recommendations for weld inspection are included in Section 10.4.4.

10.4.3 *Welding Procedures*

10.4.3.1 In general the use of weld methods that minimize dead space and entrapment areas are the preferred means of welding plastic pipe/tubing (i.e., PVDF, PFA, and Polypropylene). The weld method should be as shown on the fabrication drawings.

NOTE 9: Users of this guideline are cautioned that suitable welding methods, such as thermal butt welding, may be covered by patents or other intellectual property. When possible, use reduced bead welding method and fixturing to reduce areas on inside diameter where bacteria may accumulate.

10.4.3.2 Welding equipment should be maintained in accordance with manufacturer recommendations. For example, tools and heating elements should be kept clean and thermostat should be calibrated regularly.

10.4.3.3 Components should be firmly and accurately clamped in the welding equipment. Check alignment and clamp adjustment regularly.

10.4.3.4 Logs should be kept for each weld to ensure traceability back to the welding equipment, welder, date of weld, and inspector.

10.4.4 *Weld Inspection Criteria*

NOTE 10: Refer to manufacturer recommendations for socket weld inspection criteria.

10.4.4.1 All welds should exhibit little or no visible discoloration.

10.4.4.2 The maximum weld misalignment should be 10% of the wall thickness of the material.

10.4.4.3 Visual inspection for voids should be performed in accordance with manufacturers recommendations.

10.4.4.4 The physical characteristics of the weld bead should be in accordance with criteria which may be derived from component manufacturer, process equipment manufacturer, and end user recommendations.

10.5 *Mechanical Connections*

NOTE 11: Joining technology that is free of dead space and entrapment areas is recommended. See Sections 8.3 and 8.3.1 for general joining recommendations and specific mechanical connection recommendations. In the event that these recommendations cannot be followed, assembly recommendations for other commonly used mechanical connections are provided.

10.5.1 Flaring should be performed at the temperature and with the equipment recommended by the fitting manufacturer.

10.5.2 O-rings used in mechanical connections should be positioned per manufacturer recommendations before closing the fitting. Manufacturer recommendations for torque should be applied.

10.5.3 Gaskets used in flanged connections should be positioned per manufacturer recommendations before closing the fitting. Manufacturer recommendations for torque should be applied.

10.5.4 For tapered threaded connections, such as National Pipe Thread (NPT) and Japenese Industrial Standard (JIS), wrap tapered threads with a suitable tape, (such as PTFE tape) prior to assembly. Use of ¼” wide tape is recommended on nominal sizes of ½” or smaller. Wrap the threads three times in the direction that does not unravel during installation of the fitting. To reduce the possibility of tape entering the liquid stream, do not cover the last two threads at the narrow end of the fitting.

10.6 *Tubing and Pipe Support*

10.6.1 Route flexible tubing neatly and secure with tie-wraps or similar mechanical fastener.

10.6.2 Support distances and support clamps for pipe should employ the manufacturer’s recommendations, where possible. These clamps typically cradle the pipe within a plastic fixture. Metal and/or constrictive types of clamps may induce stress into piping components and should be avoided. However, if they must be used then elastomer inserts between the pipe and clamp are recommended.

10.7 *Labeling Recommendations*

10.7.1 All ultrapure water and Liquid Chemical systems should be labeled in accordance with SEMI F34 when possible.

10.7.2 Additional labeling to support proper operation of the system(s) should be included when indicated on assembly drawing(s).

10.8 *Final Assembly Inspection Recommendations*

10.8.1 Inspect the system within the appropriate assembly environment.

10.8.2 Verify the following:

- System is complete per drawings
- Critical dimensions, squareness, offsets, and straightness are per drawings and assembly specifications
- Overall configuration is correct
- Support is adequate
- No pipe, tube, or fitting is nicked, cracked, or abused
- Each weld is visually acceptable
- Gaskets are in place and bolts are torqued to proper values
- Proper installation of valves per manufacturer’s recommendations
- Unions and mechanical connections are tight
- Tubing, pipe, inlets, and outlets are labeled appropriately

10.8.3 Shop drawings that have been marked up should be returned to the engineering department for updates. The QA manager should be notified that the assembly has passed inspection, been tagged as such, and is ready for final testing.

11 System Testing Recommendations

11.1 The equipment manufacturer should successfully complete functional testing (for example leak and pressure decay testing). In addition, testing may be required to demonstrate that the system is not adversely affecting the quality of the liquid.

NOTE 12: As outlined in limitations Section 3.1, it is beyond the scope of this document to define the performance requirements of the equipment systems.

12 Packaging Recommendations

12.1 Packaging is recommended to ensure the cleanliness and dryness of wetted surfaces during transport or storage. All open connections should be capped to isolate wetted materials from contamination. Additional guidelines for packaging can be found in other SEMI documents. For smaller assemblies refer to the requirements found in SEMI F57. For larger assemblies refer to the requirements found in SEMI E49.1.

13 Traceability Recommendations

13.1 A completed assembly should have permanent identification such that it is traceable to the documentation recommended within this guide. The manufacturer is responsible for maintaining records that include but are not limited to the following:

- Test methods and results
- Final assembly inspection
- Assembly drawing modifications
- Weld logs

RELATED INFORMATION 1
FLOW CONSIDERATIONS FOR ULTRAPURE WATER SYSTEMS

NOTE: This related information is not an official part of SEMI E49.7 and was derived from North American Liquid Chemicals. This related information was approved for publication by full letter ballot on April 30, 2002.

R1-1 Ultrapure Water Considerations

R1-1.1 An ultrapure water system may benefit from maintaining continuous flow with a velocity greater than or equal to those listed in the following table:

Nom. Size	*Tube ID (inches)*	*V (ft/s)*	*Tube ID (cm)*	*V (cm/s)*
¼”	0.125	5.2	0.3175	158.1
3/8”	0.250	2.6	0.6350	79.0
½”	0.375	1.7	0.9525	52.7
¾”	0.625	1.0	1.5875	31.6
1”	0.875	0.7	2.2225	22.6

R1-1.2 For reference this information is based on the following equations, using a Reynolds number of 5000 and water at a temperature of 20°C.

$$\mathrm{Re} = \frac{\rho \cdot V \cdot D}{\mu}$$

$$V = \frac{\mathrm{Re} \cdot \mu}{D \cdot \rho}$$

example:

$$V = \frac{(5000) \cdot (0.01002)}{(0.3175) \cdot (0.9982)} = 158.1$$

Where:

Re is Reynolds number (dimensionless)
ρ is density (g/cm^3)
V is fluid velocity (cm/sec)
D is tube diameter (cm)
μ is viscosity (g/cm-s)

SEMI E49.8-0298
GUIDE FOR HIGH PURITY GAS DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for high purity (HP) gas distribution systems in semiconductor production equipment.

2 Scope

2.1 Gas distribution systems consist of stainless steel (SS) piping designed to supply the following types of gases to the process chamber:

2.1.1 *Specialty Gases* — Corrosive, flammable, pyrophoric, oxidizer, toxic, inert, and mixtures.

2.1.2 *Bulk Gases* — Nitrogen, oxygen, argon, hydrogen, and helium.

2.2 Typical processes include diffusion, anneal, plasma etch, chemical vapor deposition, physical vapor deposition, and ash.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASM Document*[1]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.3 *ASTM Standards*[2]

See Section 3.3 of SEMI E49.

3.4 *NFPA Documents*[3]

NFPA 49 — Hazardous Chemicals Data

NFPA 704 — Standard System for the Identification of the Fire Hazards of Materials

1 American Society of Metals, Metals Park, OH 44073

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Purity Indices*

- Particle Count (ptc), at ≥ 0.1 µm
  - — ≤ 0.18 ptc/L (5 ptc/ft^3) average single count
  - — ≤ 1.8 ptc/L (50 ptc/ft^3) maximum single count
- Moisture Level — ≤ 100 ppb
- Oxygen Level — ≤ 100 ppb
- Total Hydrocarbon (THC) — ≤ 100 ppb
- Inboard Helium Leak Rate — $\leq 10^{-9}$ atm. cc/sec.

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended gas system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Directional changes in the process flow path should be minimized. Required directional changes should be accomplished by butt weld elbows or block components. Tube bends may be used up to sizes of $\leq$ 1/2 in. O.D., with a minimum of 8× tube diameter.

6.3 Metal face seal type mechanical fittings should be used where required for component removal/replacement.

6.4 Dead volumes and system internal volume should be minimized by use of miniature type weld fittings. Multi-valve arrangements are optional.

6.5 Purge and vent connections to process gas stream should be accomplished by tee fittings and branch valves. Flow through branch valves or multivalve block arrangements are optional.

6.6 All corrosive, toxic, and flammable gases (i.e., reactive) should have upstream and downstream purge/vacuum capability for MFC maintenance. A gas should be defined to be reactive if it has a Hazardous Production Material (HPM) rating of 3 or 4 per NFPA 49 and NFPA 704.

6.7 All inert gases should have downstream purge capability as a minimum. Atmospheric gas services (e.g., N_2, Ar) can use the process gas as a purge gas.

6.8 For low pressure equipment, the vacuum path from the MFC manifold to the pump should be through the process chamber as a minimum. Piping for chamber bypass to vacuum pump foreline is optional.

6.9 For atmospheric pressure equipment, a vacuum venturi to vent/exhaust method should be required for reactive gases.

6.10 Design should include a means of flow-through purging for removable components or component sticks for reactive gases and should include a means of flow-through purging for all removable components.

6.11 Backflow/back pressure protection should be included for all gases in the system.

6.12 All incoming gas lines should have filters included. Filters for process gases should be located downstream of any regulator or check valve and upstream of any MFC. Screen filters (e.g., wire mesh) should not be used.

6.13 6.13 Any additional filters for reactive gases, located at point of use before a process chamber or loadlock, should have a means of isolation from atmosphere.

6.14 For processes requiring pressure control, regulators should be included in the gas system and located upstream of MFC's. Pressure gauges or transducers, with a display, should be used for process measurement.

6.15 The gas system should have a means of manifolding supply lines onboard, so that there is a single point connection for each individual gas (consisting of the same chemical composition and purity level).

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR $\leq$ 0.030%
- Carbon as reported by the SMTR $\leq$ 0.030%

7.2 Stainless steel should be 316L electropolished for gas system wetted flow streams and/or as specified by the customer.

7.3 Materials for valve seals, diaphragms, gaskets, and O-rings should be chemically compatible with the process gas.

7.4 Material Performance Guidelines

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER)		
Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level	≥ 15	Å
For an example of a test method, see SEMASPEC 90120573B (AUGER)		
Internal Surface Chemistry (ESCA)		
Total chromium to iron ratio including both reduced and oxidized states	≥ 1.25:1	value
For an example of a test method, see SEMASPEC 90120403B (ESCA)		
Internal Surface Chemistry (EDX)		
Surface foreign elements, those elements not in the Smelter's Test Report (SMTR)	0	value
Test procedures per ASTM F 1375 (EDX)		
Internal Surface Defects		
Photos per test method	5	value
Counts per photo	≤ 50	value
Test procedures per ASTM F 1372 (SEM)		
Internal Surface Roughness		
Average surface roughness	≤ 0.25	µm
Roughness average (R_a)	(≤ 10)	(µin.)
Maximum surface R_a	≤ 0.33	µm
(individual reading)	(≤ 15)	(µin.)
For an example of a test method, see SEMASPEC 90120400B (Contact Profilometry)		
Particulate Contribution		
at ≥ 0.1 µm size	≤ 0.71 (20)	ptc/L (ptc/ft^3)
at ≥ 0.02 µm size	≤ 2.6 (75)	ptc/L (ptc/ft^3)
Test procedures per ASTM F 1394 (Particles)		
Internal Absorbed Moisture		
Time to recover to base line from a 2 ppm spike for low surface area component (valve, regulator)	≤ 4	hour
Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing)	≤ 6	hour
Test procedures per ASTM F 1397		
Total Anionic Contamination		
Total anionic contamination added to test water	≤ 1	ppm
Individual anionic contaminant	≤ 0.2	ppm
Test procedures per ASTM D 4327 (Total Anions)		
Leak Rate		
Inboard leak rates for He	$\leq 1 \times 10^{-9}$	scc/s
Outboard leak rates for He	$\leq 1 \times 10^{-5}$	scc/s
Cross-seat leak rates for He	$\leq 4 \times 10^{-8}$	scc/s
Test procedures per SEMI F1 (Leak Rate)		
Cycle Life		
Manual valves	≥ 25 K	cycles
High pressure automatic valves	≥ 25 K	cycles
Low pressure automatic valves	≥ 500 K	cycles
Test procedures per ASTM F 1373 (Cycle Life)		

8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7.

8.2 Valves should be springless and packless inverted bellows type with all metal bonnet seals. Springless diaphragm type valves are optional.

8.3 Regulators should be a threadless type (wetted stream) with all metal bonnet seals and should meet the following minimum requirements:

- Supply Pressure Effect — ≤ 0.021 kg/cm^2 rise/7 kg/cm^2 drop (≤ 0.3 psi rise/100 psi drop)
- Repeatability — ± 0.5% of outlet pressure range
- Setpoint Sensitivity — ≤ 0.0175 kg/cm^2 (≤ 0.25 psi)
- Setpoint Stability — ± 1% of setpoint

For an example of a test method, see SEMASPEC 90120392B.

8.4 Regulators and valve flow coefficient (C_v) should be selected based on gas flow requirements and gas characteristics. For an example of a test method, see SEMASPEC 90120394B.

8.5 Filter performance should be 9-LOG retention value at most penetrating particle size and should meet the following minimum requirements.

- Media-rated at 0.01 µm pore size
- PTFE or stainless steel media for noncorrosive gases
- PTFE or nickel media for corrosive gases
- Sized for 0.35 kg/cm^2 (5 psi) maximum pressure drop at design flow conditions

For an example of a test method, see SEMASPEC 90120393B.

8.6 MFC's should have as a minimum:

- Metal seals and seats for reactive gases.
- Optional soft start feature.
- High flow purge capability of ≥ 50 times full scale flow for range for MFC's sized for ≤ 200 sccm in reactive gas service. High flow purge feature is optional for all other gases and flow rates.

8.7 All mechanical fittings should be a metal face seal type with solid nickel gaskets.

8.8 Pressure gauges should be a compound type and have metal face seal connections. Pressure gauges or transducers should be used for process measurement.

8.9 Pressure transducers should be flow-through or flush-mount, with digital displays. No deadleg-type transducers or pressure gauges should be used for process gas streams. Pressure transducers should meet the following minimum requirements.

- Accuracy (combined linearity, hysteresis, and repeatability) — ± 0.25% of full scale maximum
- Repeatability — ± 0.08% of full scale maximum
- Span Shift — ± 0.1% of full scale maximum due to change in ambient conditions
- Functionally unaffected by RFI/EMI (radio frequency interference/electromagnetic interference) in frequency ranges up to 350 – 950 Mhz, at a distance of 0.61 m (2 ft.) from a 2W source.

8.10 Check valves should be a disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Controls Guidelines

10.1 The cycle purge and flow-through purge sequences may be operated by manual means such as toggle switches and push buttons. Automatic controllers for gas system maintenance are optional.

10.2 Detailed instructions for purge sequence operation should be included with equipment.

11 Related Documents

11.1 *SEMATECH Documents*[4]

SEMASPEC 90120392B — Test Method for Determination of Regulator Performance Characteristics for Gas Distribution System Components

SEMASPEC 90120393B — Test Method for Determination of Filter Flow Pressure Drop Curves for Gas Distribution System Components

SEMASPEC 90120394B — Test Method for Determination of Valve Flow Coefficients for Gas Distribution System Components

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

4 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E49.9-0298
GUIDE FOR ULTRAHIGH PURITY GAS DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for ultrahigh purity (UHP) gas distribution systems in semiconductor production equipment.

2 Scope

2.1 Gas distribution systems consist of stainless steel (SS) piping designed to supply the following types of gases to the process chamber:

2.1.1 *Specialty Gases* — Corrosive, flammable, pyrophoric, oxidizer, toxic, inert, and mixtures.

2.1.2 *Bulk Gases* — Nitrogen, oxygen, argon, hydrogen, and helium.

2.2 Typical processes include diffusion, anneal, plasma etch, chemical vapor deposition, physical vapor deposition, and ash.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASM Document*[1]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.3 *ASTM Standards*[2]

See Section 3.3 of SEMI E49.

3.4 *NFPA Documents*[3]

NFPA 49 — Hazardous Chemicals Data

NFPA 704 — Standard System for the Identification of the Fire Hazards of Materials

1 American Society of Metals, Metals Park, OH 44073

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

4 Terminology

See Section 4 in SEMI E49.

5 Performance Guidelines

5.1 *Purity Indices*

Particle Count (ptc), at $\geq$ 0.02 µm

— $\leq$ 0.18 ptc/L (5 ptc/ft^3) average single count

— $\leq$ 1.8 ptc/L (50 ptc/ft^3) maximum single count

Moisture Level — $\leq$ 20 ppb

Oxygen Level — $\leq$ 10 ppb

Total Hydrocarbon (THC) — $\leq$ 20 ppb

Inboard Helium Leak Rate — $\leq 10^{-10}$ atm. cc/sec.

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended gas system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Directional changes in the process flow path should be minimized. Required directional changes should be accomplished by butt weld elbows or block components. Tube bends may be used up to sizes of $\leq$ 12 in. O.D., with a minimum of 10× tube diameter.

6.3 Metal face seal type mechanical fittings should be used where required for component removal/replacement.

6.4 Dead volumes should be minimized in the process gas stream. There should be no blind runs such as pressure gauges. Bypasses should not be used for MFC's.

6.5 The system internal volume should be minimized by using multi-component weldments, dead space free (DSF) branch valves, multi-valve block arrangements, and weld fittings.

6.6 All corrosive, toxic, and flammable gases (i.e., reactive) should have upstream and downstream purge/vacuum capability for MFC maintenance. A gas should be defined to be reactive if it has a Hazardous Production Material (HPM) rating of 3 or 4 per NFPA 49 and NFPA 704.

6.7 All inert gases should have downstream purge capability as a minimum. Atmospheric gas services (e.g., N_2, Ar) can use the process gas as a purge gas.

6.8 For low pressure equipment, the vacuum path from the MFC manifold to the pump should bypass the process chamber and should connect directly to the foreline.

6.9 For atmospheric pressure equipment, a vacuum venturi to vent/exhaust method should be required for reactive gases.

6.10 Design should include a means of cycle purging upstream and downstream of removable components or components sticks for reactive gases and should include a means of flow-through purging for all removable components.

6.11 Backflow/back pressure protection should be included for all gases in the system.

6.12 All incoming gas lines should have filters included. Filters for process gases should be located downstream of any regulator and upstream of any MFC. Screen filters (e.g., wire mesh) should not be used.

6.13 Any additional filters for reactive gases, located at point of use before a process chamber or loadlock, should have a means of isolation from atmosphere.

6.14 Test/sample ports should be located on each process chamber supply line or the designated purge/vent line. Ports should be isolated from gas stream by DSF branch valves or multivalve blocks.

6.15 For processes requiring pressure control, regulators should be included in the gas system and located upstream of MFC's. Transducers should be used for pressure measurement.

6.16 A means of pressure display should be included on the equipment.

6.17 For processes requiring purified gases, purifiers should be included in the gas system and located upstream of MFC's. The system should include a means of purging and removing purifiers in a safe manner.

6.18 The gas system should have a means of manifolding supply lines onboard, so that there is a single point connection for each individual gas (consisting of the same chemical composition and purity level).

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479 or ASME SA479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

7.1.4.1 *Sulfur as Reported by the SMTR*

Tubing ≥ 1.27 cm (1/2 in.) 0.005 – 0.015%

Tubing ≤ 1.27 cm (1/2 in.) ≤ 0.003 – 0.012%

Bar Stock ≤ 0.015%

7.1.4.2 *Carbon as Reported by the SMTR* — ≤ 0.030%

7.2 Stainless steel should be 316L electropolished secondary remelt for gas system wetted flow streams or as specified by the customer.

7.3 Materials for valve seals, diaphragms, gaskets, and O-rings should be chemically compatible with the process gas.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER) Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level For an example of a test method, see SEMASPEC 90120573B (AUGER)	≥ 25	Å
Internal Surface Chemistry (ESCA) Total chromium to iron ratio including both reduced and oxidized states For an example of a test method, see SEMASPEC 90120403B (ESCA)	≥ 1.5:1	value
Internal Surface Chemistry (EDX) Surface foreign elements, those elements not in the Smelter's Test Report (SMTR) Test procedures per ASTM F 1375 (EDX)	0	value
Internal Surface Defects Photos per test method Counts per photo Test procedures per ASTM F 1372 (SEM)	5 ≤ 40	value value
Internal Surface Roughness Average surface roughness Roughness average (Ra) Maximum surface Ra (individual reading) For an example of a test method, see SEMASPEC 90120400B (Contact Profilometry)	≤ 0.18 (≤ 7) ≤ 0.25 (≤ 10)	µm (µin.) µm (µin.)
Particulate Contribution at ≥ 0.1 µm size at ≥ 0.02 µm size Test procedures per ASTM F 1394 (Particles)	≥ 0.18 (5) ≥ 0.71 (20)	ptc/L (ptc/ft^3) ptc/L (ptc/ft^3)
Internal Absorbed Moisture Time to recover to base line from a 2 ppm spike for low surface area component (valve, regulator) Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing) Test procedures per ASTM F 1397	≤ 1 ≤ 4	hour hour
Total Anionic Contamination Total anionic contamination added to test water Individual anionic contaminant Test procedures per ASTM D 4327 (Total Anions)	≤ 1 ≤ 0.2	ppm ppm
Leak Rate Inboard leak rates for He Outboard leak rates for He Cross-seat leak rates for He Test procedures per SEMI F1 (Leak Rate)	$\leq 1 \times 10^{-9}$ $\leq 1 \times 10^{-5}$ $\leq 4 \times 10^{-8}$	scc/s scc/s scc/s
Cycle Life Manual valves pressure automatic valves High pressure automatic valves Low pressure automatic valves Test procedures per ASTM F 1373 (Cycle Life)	≥ 25 K ≥ 25 K ≥ 500 K	cycles cycles cycles

8 Component Guidelines

8.1 For materials guidelines and component leak rate and cycle life requirements, see Section 7.

8.2 Valves should be springless, packless diaphragm type with all metal bonnet seals.

8.3 Regulators should be threadless type (wetted stream) with all metal bonnet seals and should meet the following minimum requirements:

- Supply Pressure Effect — ≤ 0.021 kg/cm^2 rise/7 kg/cm^2 drop (≤ 0.3 psi rise/100 psi drop)
- Repeatability — ± 0.5% of outlet pressure range
- Setpoint Sensitivity — ≤ 0.0175 kg/cm^2 (≤ 0.25 psi)
- Setpoint Stability — ± 1% of setpoint

For an example of a test method, see SEMASPEC 90120392B.

8.4 Regulator and valve flow coefficient (C_v) should be selected based on gas flow requirements and gas characteristics. For an example of a test method, see SEMASPEC 90120394B.

8.5 Filter performance should be 9-LOG retention value at most penetrating particle size and should meet the following minimum requirements.

- Media-rated at 0.01 µm pore size
- Predried to ≤ 10 ppb H2O and sealed from atmosphere
- PTFE or stainless steel media for noncorrosive gases
- PTFE or nickel media for corrosive gases
- Sized for 0.14 kg/cm^2 (2 psi) maximum pressure drop at design flow conditions

For an example of a test method, see SEMASPEC 90120393B.

8.6 MFC's should have as a minimum:

- Metal seals and seats for reactive gases.
- Metal seals for inert and atmospheric gases.
- Optional soft start feature.
- High flow purge capability of ≥ 50 times full scale flow control range.

8.7 Mechanical fittings should be all metal face seal with solid nickel gaskets and antitorque capability.

8.8 Pressure transducers should be flow-through or flush-mount, with digital displays. No deadleg-type transducers or pressure gauges should be used for process gas streams. Pressure transducers should meet the following minimum requirements.

- Accuracy (combined linearity, hysteresis, and repeatability) — ± 0.25% of full scale maximum
- Repeatability — ± 0.08% of full scale maximum
- Span Shift — ± 0.1% of full scale maximum due to change in ambient conditions
- Functionally unaffected by RFI/EMI (radio frequency interference/electromagnetic interference) in frequency ranges up to 350 – 950 Mhz, at a distance of 0.61 m (2 ft.) from a 2W source.

8.9 Mechanical type check valves should not be used. Required backflow protection should be by other means, such as electronic pressure sensing and appropriate valve interlocks.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Controls Guidelines

10.1 The equipment controller should be capable of automatic purge sequences for gas system maintenance.

10.2 The equipment controller should be capable of automatic vent-then-run sequences included in the process recipe.

11 Related Documents

11.1 *SEMATECH Documents*[4]

SEMASPEC 90120392B — Test Method for Determination of Regulator Performance Characteristics for Gas Distribution System Components

SEMASPEC 90120393B — Test Method for Determination of Filter Flow Pressure Drop Curves for Gas Distribution System Components

SEMASPEC 90120394B — Test Method for Determination of Valve Flow Coefficients for Gas Distribution System Components

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

4 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E51-0200
GUIDE FOR TYPICAL FACILITIES SERVICES AND TERMINATION MATRIX

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org January 2000; to be published February 2000. Originally published in 1995; previously published February 1998.

1 Purpose

1.1 The objectives of this guide are to ensure a timely and cost-effective tool installation with minimum impact on the existing customer facilities, systems, and services, and to insure that the quality of facilities supplied (e.g., water, gases, chemicals, electricity) is not compromised once internal to the tool.

1.2 This guide provides the equipment supplier with an understanding of the facilities available at the point of connection (POC) at the "typical" customer site. If these typical facility services are considered by tool manufacturers during their tool design, additional cost and lead times associated with customizing each tool installation can be minimized resulting in reduced costs to build and install semiconductor equipment.

2 Scope

2.1 This document does not include site-specific conditions. The Typical Facilities Services and Termination Matrix Example—United States (see Table 1) identifies utilities, performance, and connections at typical semiconductor facilities. When site specifications differ, the user should create a Site-Specific Facilities Services and Termination Matrix (see Table 2) that is submitted with the request for a quote. Each tool should be supplied in a "facility ready" state. This document represents the range of conditions in which equipment should be capable of operating.

2.2 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Impact

3.1 A reference to this guide and the Typical Facilities Services and Termination Matrix (see Table 1) or a completed Site-Specific Facilities Services and Termination Matrix (see Table 2) should be included with other applicable tool purchase specifications. When the supplier receives these documents, a dialogue can be established to resolve any installation issues prior to customer purchase or tool installation. Any additional facility requirements not identified should be determined when the tool quote is reviewed.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI E7 — Specification for Electrical Interfaces for the U.S. Only

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI F47 — Specification for Semiconductor Processing Equipment Voltage Sag Immunity

4.2 *ANSI Standard*[1]

ANSI B16.5 — Steel Pipe Flanges, Flanged Valves and Fittings, as it refers to 150 lb. flanges

4.3 *IEEE Standards*[2]

IEEE 1100 — Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)

4.4 *NFPA Document*[3]

NFPA 70 — National Electrical Code

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *amb* — ambient temperature conditions

1 American National Standards Institute (ANSI), 11 W. 42nd Street, New York, NY 10036

2 Institute of Electrical and Electronic Engineers (IEEE), 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331

3 National Fire Protection Association (NFPA), 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

5.1.2 *atm* — atmospheric conditions, 14.7 psi at sea level

5.1.3 *CPVC* — chlorinated polyvinyl chloride

5.1.4 *Cu* — copper

5.1.5 *EP* — electropolished

5.1.6 *Galv.* — galvanized

5.1.7 *Hg* — mercury

5.1.8 kPa — kiloPascals

5.1.9 *µ* — micron

5.1.10 *NFPA* — National Fire Protection Association

5.1.11 *NPT* — National Pipe Thread (U.S. Standard)

5.1.11.1 *FNPT* — Female National Pipe Thread

5.1.11.2 *MNPT* — Male National Pipe Thread

5.1.12 *NW Flange* — ISO NW flange

5.1.13 *P. Flange* — ANSI B16.5 pipe flange (for the purpose of this guide)

5.1.14 *PFA* — Perfluoralkoy, resin

5.1.15 *POC* — point of connection (POC is the point where the facility utility connects to the exterior of the tool.)

5.1.16 *POU* — point of use

5.1.17 *PP* — Polypropylene

5.1.18 *psia* — pounds per square inch, absolute

5.1.19 *psig* — pounds per square inch, gauge

5.1.20 *PVC* — Polyvinyl Chloride

5.1.21 *PVDF* — Polyvinylidene Fluoride

5.1.22 *RES.* — resistivity

5.1.23 *S.M. Flange* — sheet metal flange

5.1.24 *SS* — stainless steel

5.1.25 *Stub* — pipe or tube stub

6 Typical Facilities Services and Termination Matrix

6.1 This section of the guide identifies utilities, performance and connections at typical semiconductor facilities. This includes a Typical Facilities Services and Termination Matrix Example—United States (see Table 1). The guide identifies typical utilities and is not intended to be limited to the listed utilities. A Site-Specific Facilities Services and Termination Matrix (see Table 2) is also provided to document differences from Table 1 utilities.

6.2 The following is an explanation of the table headings in the Typical Facilities Services and Termination Matrix.

6.2.1 *Utilities* — This is a list of process or process-related services typically found in semiconductor facilities. The list is divided into water service, gas service, drains, bulk chemical distribution, exhaust and electrical services.

6.2.2 *Supply Temperature* — Temperature and ranges are measured in °C (°F). Equipment or tool cooling systems should be sized to accommodate these ranges.

6.2.3 *Supply/Return Pressure* — Pressure and ranges are measured in kPa (psig). Where possible, equipment should be designed to operate at lower pressure which reduces energy and safety risks. Regulators should be specified by the customer and provided with the tool by the supplier.

6.2.4 *Filtration* — Filtration provides an indicator of particle size expectation at POC to the tool. The fabrication and quality of point of use (POU) filtration should be specified by the customer and provided with the tool by the supplier.

6.2.5 *Specification* — The specification column is a condensed version of typical customer specifications. The column should be used by customers to specify service quality at POC to the tool. Specified quality should not be compromised or lessened in any way internally by the supplier's tool. When the tool purchase specification is prepared, expanded, and detailed, quality requirements should be documented.

6.2.6 *POC Material* — Material that the facility typically uses for connections to tools. Additional material quality characteristics should be identified in the tool purchase specification. Interior piping or tubing should be specified by the customer and provided with the tool by the supplier to meet or exceed the facility POC material quality. (See SEMI E49.)

6.2.7 *POC Fitting* — Compatible connectors are critical to ensure that a tool is "facility ready" once it arrives at a customer site. It is recommended that equipment be supplied with matching connections as requested by customer.

6.2.8 *Notes* — Special conditions or exceptions.

7 General Considerations

7.1 In addition to typical utilities, other facility-related issues should be addressed prior to tool installation.

7.1.1 *Point of Connection Locations* — Due to age of construction or design, all semiconductor facilities are not the same. To interface with equipment or tool, three suggested POC locations have been determined.

(See Figure 1). The POC locations are the top, the bottom, or the back of the tool. The customer should identify a POC location in the tool purchase specification. Suppliers should design tools to allow for internal routing to all locations, to avoid customization for every installation.

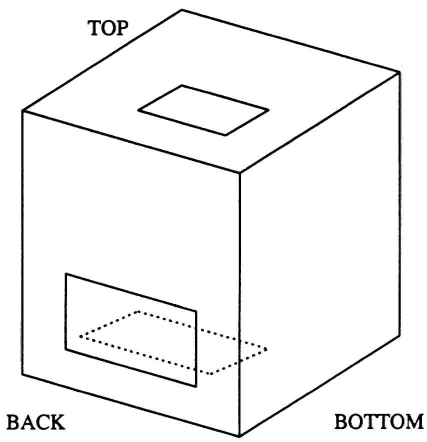


Figure 1
Three Point of Connection Locations

7.1.2 *Seismic* — The customer should specify the applicable earthquake zone for the installation site. The supplier should provide appropriate seismic restraints and installation instructions.

7.1.3 *Vibration* — The customer should specify that the supplier should provide the vibration sensitivity of the tool prior to purchase. (See SEMI E6.)

7.1.4 *Control and Signal Circuits* — The customer should specify and the supplier should provide control and signal circuits that when routed external to the tool are compliant with Article 725, Class 1, Class 2, and Class 3, Remote Control, Signaling and Power Limited — Control Circuits of the National Electrical Code. (See NFPA 70.)

Class 1 — No power limitation, 600 volts max.

Class 2 — Derived from listed Class 2 power supply.

Class 3 — Derived from listed Class 3 power supply.

7.1.5 *Installation Requirements Provided by Suppliers* — See SEMI E6.

7.1.6 *High Purity Distribution Systems Recommendations* — See SEMI E49.

7.1.7 *POC Labeling* — To ensure accurate connection of facility utilities to each tool POC, the customer should specify and the supplier should provide labeling for each POC. Service labeling should match descriptions listed in the supplier provided installation documentation. (See SEMI E6.)

7.1.7.1 If required, mechanical POC labels should include:

- Service purpose,
- Maximum pressure or pressure range, and
- Flow rate (if appropriate).

POC Label Example: Process Purge, Nitrogen, 80 psig Max.

7.1.7.2 If required, electrical power POC labels should include:

- Service purpose,
- Voltage & phase, and
- Current (Full load ampere continuous).

POC Label Example: Cryo Pump No. 2, 208 V, 1-phase, 28.2 FLA

7.1.7.3 If required, control and signaling POC labels should include:

- Purpose, and
- Class of control (see Section 7.1.4).

POC Label Example: Cryo Pump No. 2 Control, Class 2

Table 1 Typical Facilities Services and Termination Matrix Example — United States

Water Service	*Supply Temp.*	*Supply Pressure (Return Pressure where noted)*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Non-Potable Water	4°C - amb (40°F - amb)	S = 258–552 kPa (40–80 psig)	N/A	non-human consumption	Cu/ PVC SCH 40/ PVC SCH 80	NPT	
Ultra Pure Water	20–24°C (68–76°F)	S = 310–379 kPa (45–55 psig)	< 0.1 µ	18+ M ohms RES	PVDF/PFA	stub/p. flange ≥ 5 cm (2 in.) stub/union < 5 cm (2 in.)	
Deionized Water	20–24°C (68–76°F)	S = 310–379 kPa (45–55 psig)	0.1–0.2 µ	17.5 M ohms RES	PVC SCH80/ PVDF/PFA	stub/p. flange ≥ 5 cm (2 in.) stub/union < 5 cm (2 in.)	
Hot Ultra Pure Water	60–90°C (140–194°F)	S = 310–379 kPa (45–55 psig)	< 0.1 µ	site-specific	PVDF	stub/p. flange ≥ 5 cm (2 in.) stub/union < 5 cm (2 in.)	
Fire Protection	amb	NFPA 13	N/A	NFPA 13	N/A	Carbon Steel/SS	
Process Cooling Water	10–16°C (50–60°F)	S = 310–552 kPa (45–80 psig) R = 0–207 kPa (0–30 psig)	1.0–40 µ	50 K ohms RES	PVC SCH80/ Cu/SS	NPT	

Gas Service	*Supply Temp.*	*Supply Pressure*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Nitrogen, Ultra Pure	amb	586–655 kPa (85–95 psig)	0.01–0.1 µ	-	316L EP SS	face seal	
Nitrogen, Process	amb	552–621 kPa (80–90 psig)	0.01–0.1 µ	-	316L EP SS	face seal	
Nitrogen, Non-Process	amb	552–655 kPa (80–95 psig)	0.01–0.1 µ	-	Cu/SS	face seal	
Compressed Air	amb	655–758 kPa (95–110 psig)	0.1–5.0 µ	–73 to –40°C (–100 to –40°F) dew point	Cu/SS	compression	
Oxygen	amb	552–586 kPa (80–85 psig)	0.01–0.1 µ	-	316L EP SS	face seal	
Hydrogen, Bulk	amb	414–552 kPa (60–80 psig)	0.01–0.1 µ	-	316L EP SS	face seal	See NOTE 2.
Argon	amb	448–586 kPa (65–85 psig)	0.01–0.1 µ	-	316L EP SS	face seal	
Helium	amb	448–586 kPa (65–85 psig)	0.01–0.1 µ	-	316L EP SS	face seal	

Gas Service	*Supply Temp.*	*Supply Pressure*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Natural Gas	-	7–21 kPa (1–3 psig)	-	-	-	NPT	
Process Vacuum	-	53–58 cm Hg (21–23 in. Hg)	-	-	SS/Brass/ PVC SCH 80	NPT	
Specialty Gases	-	site-specific	0.01–0.1 µ	site-specific	site-specific	face seal	See NOTE 3.

Drains	*Waste Temp.*	*Pressure*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Acid Waste	< 43°C (110°F) See NOTE 1.	atm	-	-	CPVC SCH80/ PVC SCH 80	stub	See NOTE 4.
H_2SO_4	See NOTE 1.	atm	-	-	PVDF/PVC SCH 80/CPVC SCH 80/ PP	flare type compression	See NOTE 4.
Solvent Waste	See NOTE 1.	atm	-	* Review Chemistry Flash Point	Carbon Steel / 304 SS	NPT or p. flange	See NOTE 4.
Industrial	< 43°C (110°F) See NOTE 1.	atm	-	-	PVC SCH 40/ PVC SCH 80	stub	
DI Reclaim	Varies See NOTE 1.	atm	-	-	PVC SCH 40/ PVC SCH 80/ PVDF	stub	
Fluoride Waste	See NOTE 1.	atm	-	-	PP/PVC SCH 80/PVDF	stub	See NOTE 4.
HF Reclaim	See NOTE 1.	-	-	No water dilution	PVDF/PFA	stub	See NOTE 4.
Slurry	See NOTE 1.	-	-	-	PVC SCH 40 CLEAR/ PVC SCH 40/ PVC SCH 80/ PP	stub	

Bulk Chemical Distribution	*Supply Temp.*	*Supply Pressure (Return Pressure where noted)*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Acids, Bases, Oxidizers	amb	-	0.1 µ	PFA Filtration	PVC SCH 40 Clear/PP for secondary, PFA for primary	5 cm (2 in.) FNPT for secondary, flare type compression for primary	Capability of secondary containment to tool interior
Solvents	amb	-	0.1 µ	-	316 SS	face seal/ compression	See NOTE 4.

Exhaust	*Temp.*	*Supply*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Heat/General	-	-2.5 to -7.6 cm (-1 to -3 in H_2O)	-	-	304 SS/Galv./Acid Res. SS	stub/s.m. flange	within -2.5 to -7.6 cm range (-1 to -3 in H_2O) ± 30% variability
Solvent	-	-2.5 to -7.6 cm (-1 to -3 in H_2O)	-	-	304 SS/Galv.	stub/s.m. flange	within -2.5 to -7.6 cm range (-1 to -3 in H_2O) ± 30% variability
Vacuum Pump	-	-2.5 to -7.6 cm (-1 to -3 in H_2O)	-	-	304 SS	NW flange	within -2.5 to -7.6 cm range (-1 to -3 in H_2O) ± 30% variability
Acid	-	-2.5 to -7.6 cm (-1 to -3 in H_2O)	-	-	Acid Res. SS/PVC SCH 40/PP	stub/p. flange	within -2.5 to -7.6 cm range (-1 to -3 in H_2O) ± 30% variability

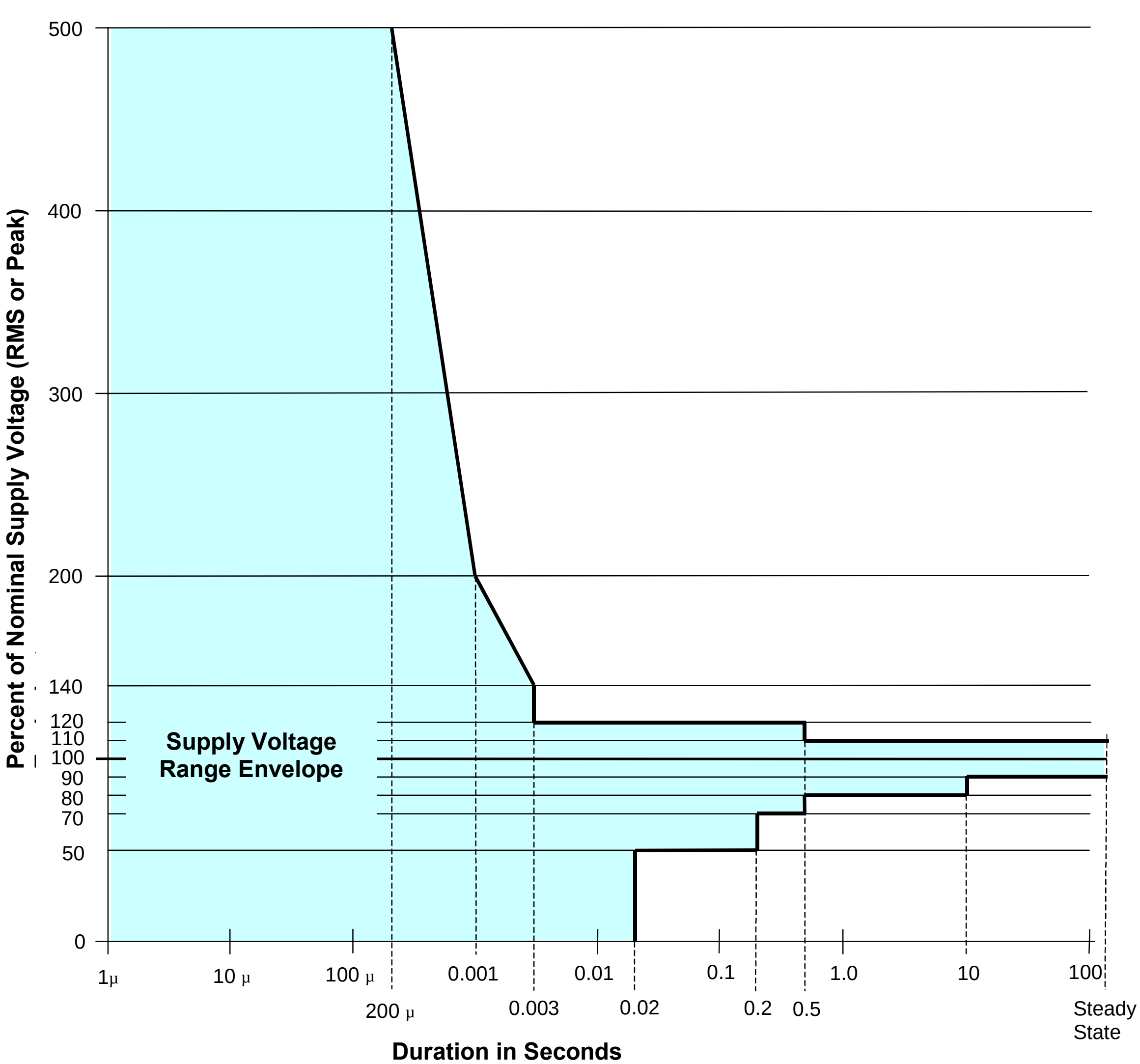
NOTE 1: Review waste composition, concentration, and temperature for material compatibility.

NOTE 2: Tool to have POC mechanical joint secondarily-contained and exhausted.

NOTE 3: Tool to have POC mechanical joint for toxic or hazardous gas POC mechanical joint secondarily-contained and exhausted.

NOTE 4: Tool to have POC mechanical joint secondarily-contained.

Electrical Services	
Applicable Code	See NFPA 70 (National Electrical Code).
Supply Voltage, Nominal	120/208V and 277/480V single-phase, 208/120V and 480/277V three-phase
Typical Supply Voltage Range	See Figure 2.
EMI Noise	See SEMI E33.
ESD Ambient	See SEMI E33.
Ground Currents	See IEEE 1100.
Computer Interfaces	See SEMI E30.
Electrical Interface	See SEMI E7.
UPS	Electrical standards as described by customer



NOTE 1: For Equipment Voltage Sag Immunity Specification see SEMI F47.

Figure 2
Typical Facilities Supply Voltage Range Envelope

Table 2 Site-Specific Facilities Services and Termination Matrix

Water Service	*Supply Temp.*	*Supply Pressure (Return Pressure where noted)*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Non-Potable Water							
Ultra Pure Water							
Deionized Water							
Hot Ultra Pure Water							
Fire Protection							
Process Cooling Water							

Gas Service	*Supply Temp.*	*Supply Pressure*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Nitrogen, Ultra Pure							
Nitrogen, Process							
Nitrogen, Non-Process							
Compressed Air							
Oxygen							
Hydrogen, Bulk							
Argon							
Helium							
Natural Gas							
Process Vacuum							
Specialty Gases							

Drains	*Waste Temp.*	*Pressure*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Acid Waste							
H_2SO_4							
Solvent Waste							
Industrial							
DI Reclaim							
Fluoride Waste							
HF Reclaim							
Slurry							

Bulk Chemical Distribution	*Supply Temp.*	*Supply Pressure (Return Pressure where noted)*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Acids, Bases, Oxidizers							
Solvents							

Exhaust	*Temp.*	*Supply*	*Filtration (absolute)*	*Specification*	*POC Material*	*POC Fitting*	*Notes*
Heat/General							
Solvent							
Vacuum Pump							
Acid							

Electrical Services	
Applicable Code	
Supply Voltage, Nominal	
Supply Voltage Range	
EMI Noise	
ESD Ambient	
Ground Currents	
Computer Interfaces	
Electrical Interface	
UPS	

Site-Specific Notes:	
Freight Elevator:	
Height/Width/Depth Load Rating	
Bldg./Fab Restrictions:	
Cleanroom Parameters	
Noise Level	
Ceiling Heights	
Max. Clearances in Support Areas	
Other:	

8 Related Documents

8.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI E37.2 — High-Speed SECS Message Services General Session (HSMS-GS)

SEMI E76 — Guide for 300 mm Process Equipment Points of Connection to Facility Services

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S6 — Safety Guideline for Ventilation

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SEMI E52-0302
PRACTICE FOR REFERENCING GASES AND GAS MIXTURES USED IN DIGITAL MASS FLOW CONTROLLERS

This practice was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standard Committee on November 27, 2001. Initially available at the www.semi.org December 2001; to be published March 2002. Originally published in 1995; previously published October 2000.

NOTE: This document was entirely rewritten for publication in 2002.

1 Purpose

1.1 To provide a numerical index of gases and gas mixtures used in the semiconductor industry that will give an ordered reference for the gases and gas mixtures when used in mass flow devices. This index or list will facilitate the production and use of digital mass flow devices.

2 Scope

2.1 The list includes gases, gas mixtures, and vaporizable materials that can be used in mass flow devices. The list will supplement, not replace, existing DOT/OSHA or other identification systems. For ease of use, the list is presented sorted by gas code, gas name, and symbol for gases and vaporizable materials and by code and mixture percentage for gas mixtures.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This list does not provide information related to the safe use and intended application of listed materials.

4 Referenced Standards

4.1 *ISBN Standard*[1]

ISBN 0080223699 — Nomenclature of Organic Chemistry, authored by International Union of Pure and Applied Chemistry (IUPAC), edited by J. Rigaudy, © 1979

4.2 *NIST Standard*[2]

NIST AD732-043 — JANAF Thermochemical Tables, 2nd Edition

4.3 *Miscellaneous Publications*

Dangerous Properties of Industrial Materials, 5th Edition, N. Irving Sax, © 1979[3]

Encyclopedia of Gas, Air Liquide, © 1976[4]

Matheson Gas Data Book, 6th Edition, © 1980[5]

The Merck Manual Index, 6th Edition[6]

4.4 *Data Sheets*

Air Products & Chemicals Data Sheet, © 1991[7]

American Cyanamid Data Sheet[8]

Callery Chemical Borazine Data Sheet, © 1984[9]

DuPont Data Sheet[10]

Schumacher Material Safety Data Sheet, No. R&D 49.3 JN, Revision Date 1/95[11]

Schumacher Product Data Sheet, No. 23, Revision 3

4.5 *Handbooks*

Chemical Engineers' Handbook, 5th Edition[12]

CRC Handbook of Chemistry and Physics, 75th Edition, © 1994[12]

1 This publication is available from Franklin Book Company, 7804 Montgomery Ave., Elkon's Park, PA 19027, 215.635.5252

2 National Institute of Standards and Technology, (Headquarters) 234 Hectare Campus, Gaithersburg, MD, and 84 Hectare Campus, Boulder, CO, (Standards Information Center), 301.975.4040

3 CRC Press LLC, (Headquarters) 2000 Corporate Blvd., NW, Boca Raton, FL 33431, 561.994.0555

4 Litton Publishing

5 Matheson Gas Products, Inc., 959 Route 46 East, P.O. Box 624, Parsippany, NJ 07054, 973.257.1100

6 This publication is available from Franklin Electronic Publishers, 1 Franklin Plaza, Burlington, NJ 08060, 1.800.266.5626

7 Air Products & Chemicals Inc.-PA, Rural Route 1, Tamaqua, PA 18252, 717.467.2981

8 American Cyanamid Company, CALI Corporation Center, 50 Tice Blvd., Woodcliff Lake, NJ 07675, 201.930.0455

9 Callery Chemical Company, P.O. Box 429, Pittsburgh, PA 15230, 412.967.4100

10 E.I. du Pont de Nemours and Company, 1007 Market St., Wilmington, DE 19898, 302.774.1000

11 Schumacher, 1969 Palomar Oaks Way, Carlsbad, CA 92009-1307, 619.931.9555

12 McGraw-Hill Inc., Princeton Rd., Hightstown, NJ 08520, 609.426.5934

5 Terminology

5.1 *formula* — The structural representation of a gas, indicating the molecular groupings. Formulas are unique and unambiguous except in the case of isomers.

5.2 *gas code* — An integer that is uniquely associated with a particular gas.

5.3 *gas name* — The accepted name for a gas as specified in *Nomenclature of Organic Chemistry*.

5.4 *symbol* — Commonly accepted, unambiguous, and unique identification using ASCII characters with no subscripts, superscripts, or parenthesis.

6 Gas Table Sorted by Code

Table 1 Gases Sorted by Code

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
1	Helium	He	He		1
2	Neon	Ne	Ne		1
3	Radon	Rn	Rn		2
4	Argon	Ar	Ar		1
5	Krypton	Kr	Kr		1
6	Xenon	Xe	Xe		1
7	Hydrogen	H2	H_2		1
8	Air	Air			1
9	Carbon Monoxide	CO	CO		1
10	Hydrogen Bromide	HBr	HBr		1
11	Hydrogen Chloride	HCl	HCl		1
12	Hydrogen Fluoride	HF	HF		1
13	Nitrogen	N2	N_2		1
14	Deuterium	D2	H_2^2	D2	2
15	Oxygen	O2	O_2		1
16	Nitric Oxide	NO	NO		2
17	Hydrogen Iodide	HI	HI		1
18	Fluorine	F2	F_2		1
19	Chlorine	Cl2	Cl_2		1
20	Water Vapor	H2O	H_2O		2
21	Bromine	Br2	Br_2		2
22	Hydrogen Sulfide	H2S	H_2S		1
23	Hydrogen Selenide	H2Se	H_2Se		1
24	Hydrogen Cyanide	HCN	HCN		1
25	Carbon Dioxide	CO2	CO_2		1
26	Nitrogen Dioxide	NO2	NO_2		1
27	Nitrous Oxide	N2O	N_2O		1
28	Methane	CH4	CH_4		1
29	Ammonia	NH3	NH_3		1
30	Ozone	O3	O_3		1
31	Phosphine	PH3	PH_3		1
32	Sulfur Dioxide	SO2	SO_2		1
33	Methyl Fluoride	CH3F	CH_3F	Fluoromethane or Methane, Fluoro	1
34	Carbonyl Sulfide	COS	COS		1
35	Arsine	AsH3	AsH_3		1
36	Methyl Chloride	CH3Cl	CH_3Cl	Chloromethane or Methane, Chloro	1

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
37	Cyanogen Chloride	ClCN	ClCN		1
38	Ethylene	C2H4	CH_2=CH_2	Ethene	1
39	Silane	SiH4	SiH_4		1
40	Carbon Disulfide	CS2	CS_2		2
41	Oxygen Difluoride	OF2	OF_2		1
42	Acetylene	C2H2	HC≡CH	Ethyne	1
43	Germane	GeH4	GeH_4		1
44	Methyl Bromide	CH3Br	CH_3Br	Bromomethane or Methane, Bromo	1
45	Ethylene Oxide	C2H4O	C_2H_4O	Acetaldehyde	1
46	Carbonyl Fluoride	CF2O	CF_2O		1
47	Methyl Mercaptan	CH4S	CH_3SH		1
48	Boron Trifluoride	BF3	BF_3		1
49	Fluoroform	CHF3	CHF_3	Trifluoromethane or Methane, Trifluoro, F-23, R-23	1
50	Hydrazine	N2H4	H_2NNH_2		2
51	Vinyl Fluoride	C2H3F	H_2C=CHF		1
52	Methylamine	CH5N	CH_3NH_2	Amino Methane, Monomethylamine	2
53	Nitrogen Trifluoride	NF3	NF_3		1
54	Ethane	C2H6	CH_3CH_3		1
55	Vinyl Chloride	C2H3Cl	CH_2=CHCl	Chloroethylene	1
56	Vinyl Bromide	C2H3Br	CH_2=CHBr		1
57	Chlorodifluoromethane	CHClF2	$CClHF_2$	F-22, R-22	1
58	Diborane	B2H6	B_2H_6		1
59	Cyanogen	C2N2	NCCN	Oxalodinitrile	1
60	Phosgene	CCl2O	CCl_2O	Carbonyl Chloride	1
61	Cyclopropane	C3H6	C_3H_6		1
62	Phosphorus Trifluoride	PF3	PF_3		1
63	Carbon Tetrafluoride	CF4	CF_4	Tetrafluoromethane or Methane, Tetrafluoro	1
64	Difluoroethylene	C2H2F2	CH_2=CF_2	G-1132A,Vinylidenefluoride	1
65	Dichlorofluoromethane	CHCl2F	$CHCl_2F$	F-21, R-21	1
66	Allene	C3H4	CH_2=C=CH_2	Propadiene	1
67	Dichlorosilane	SiH2Cl2	SiH_2Cl_2		1
68	Methyl Acetylene	C3H4	CH_3C≡CH	Propyne	1
69	Propylene	C3H6	CH_3CH=CH_2	Propene	1
70	Boron Trichloride	BCl3	BCl_3		1
71	Chloroform	CHCl3	$CHCl_3$	Trichloromethane or Methane, Trichloro	2
72	Perchloryl Fluoride	ClO3F	ClO_3F		1
73	Dimethyl Ether	C2H6O	CH_3OCH_3	Methylether	1
74	Chlorotrifluoromethane	CClF3	$ClCF_3$	F-13, R-13	1
75	Ethyl Chloride	C2H5Cl	C_2H_5Cl	Chloroethane or Ethane, Chloro or Ethyl Chloride	1
76	Bromine Trifluoride	BrF3	BrF_3		1
77	Chlorine Trifluoride	ClF3	ClF_3		1
78	Nitrogen Trioxide	N2O3	N_2O_3		1
79	Boron Tribromide	BBr3	BBr_3		1
80	Bromotrifluoromethane	CBrF3	$BrCF_3$	F-13B1, R-13B1	1
81	Methyl Vinyl Ether	C3H6O	CH_3OCH=CH_2		1
82	Difluoroethane	C2H4F2	CH_3CHF_2	Ethylidene Fluoride, R-152A	1
83	Tribromomethane	CHBr3	$CHBr_3$		2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
84	Dichlorodifluoromethane	CCl2F2	CCl_2F_2	F-12, R-12	1
85	Dimethylamine	C2H7N	$(CH_3)_2NH$		1
86	Sulfur Tetrafluoride	SF4	SF_4		1
87	Sulfuryl Fluoride	SO2F2	SO_2F_2		1
88	Silicon Tetrafluoride	SiF4	SiF_4		1
89	Propane	C3H8	$CH_3CH_2CH_3$		1
90	Intentionally Left Blank				
91	Trichlorofluoromethane	CCl3F	CCl_3F	F-11, R-11	1
92	Intentionaly Left Blank				
93	Ethyl Acetylene	C4H6	$CH_3CH_2C{\equiv}CH$		1
94	Tetrafluorethylene	C2F4	$F_2C{=}CF_2$		1
95	Nitrogen Tetroxide	N2O4	N_2O_4	Dinitrogenoxide	2
96	Arsenic Pentafluoride	AsF5	AsF_5		2
97	Disilane	Si2H6	Si_2H_6		2
98	Transbutene	C4H8	$CH_3CH{=}CHCH_3$		2
99	Germanium Tetrafluoride	GeF4	GeF_4	Tetrafluorogermane	2
100	Butadiene	C4H6	$CH_2{=}C{=}CHCH_3$	Methylallene	1
101	Carbon Tetrachloride	CCl4	CCl_4	Tetrachloromethane or Methane, Tetrachloro	2
102	Phosphorous Oxychloride	POCl3	$POCl_3$		2
103	Difluorochloroethane	C2H3ClF2	CF_2ClCH_3	F-142B, R-142B	1
104	Butene	C4H8	$CH_3CH_2CH{=}CH_2$	1-Butene	1
105	Bromotrifluoroethylene	C2BrF3	CF_2CFBr		1
106	Isobutene	C4H8	$(CH_3)_2C{=}CH_2$	Isobutylene, Methylpropene	2
107	Cisbutene	C4H8	$CH_3CH{=}CHCH_3$	Cis-2-Butene	2
108	Silicon Tetrachloride	SiCl4	$SiCl_4$	Tetrachlorosilane	2
109	Trimethylamine	C3H9N	$(CH_3)_3N$	Methylamine	1
110	Sulfur Hexafluoride	SF6	SF_6		1
111	Isobutane	C4H10	$(CH_3)_2CHCH_3$	2-Methylpropane or Propane, 2-Methyl	1
112	Trichloroethane	C2H3Cl3	CH_3CCl_3	TCA, Methylchloroform	2
113	Germanium Tetrachloride	GeCl4	$GeCl_4$	Tetrachlorogermane	2
114	Titanium Tetrachloride	TiCl4	$TiCl_4$		2
115	Iodine Pentafluoride	IF5	IF_5		1
116	Bromine Pentafluoride	BrF5	BrF_5		1
117	Butane	C4H10	$CH_3(CH_2)_2CH_3$		1
118	Hexafluoroethane	C2F6	F_3CCF_3	F-116, Perfluoroethane	1
119	Chloropentafluoroethane	C2ClF5	$ClCF_2CF_3$	F-115, R-115	1
120	Methylbutene	C5H10	$CH_3CH_2CCH_3{=}CH_2$	2-Methyl-1-Butene	1
121	Tungsten Hexafluoride	WF6	WF_6		2
122	Dimethylpropane	C5H12	$(CH_3)_4C$	Neopentane	2
123	Uranium Hexafluoride	UF6	UF_6		2
124	Molybdenum Hexafluoride	MoF6	MoF_6		2
125	Dichlorotetrafluoroethane	C2Cl2F4	F_3CCCl_2F	F-114, R-114	1
126	Trichlorotrifluoroethane	C2Cl3F3	CF_2ClCCl_2F	F-113, R-113	1
127	Hexane	C6H14	$CH_3(CH_2)_4CH_3$		2
128	Perfluoropropane	C3F8	$CF_2(CF_3)_2$		1
129	Octafluorocyclobutane	C4F8	$(CF_2)_4$	Perfluorocyclobutane or Cyclobutane, Perfluoro	1
130	Dibromotetrafluorethane	C2Br2F4	BrF_2CCF_2Br	F-114B2, R-114B2	1
131	Trimethoxyborine	C3H9BO3	$B(OCH_3)_3$	TMB, Trimethylborate	2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
132	Trimethylphosphorous	C3H9P	$(CH_3)_3P$	Trimethylphosphine, TMP	2
133	Trimethylphosphite	C3H9PO3	$(CH_3O)_3P$	TMPi, Trimethoxyphosphine	2
134	Difluorosilane	SiH2F2	SiH_2F_2		10
135	Dimethylzinc	C2H6Zn	$(CH_3)_2Zn$		3
136	Ethanol	C2H6O	CH_3CH_2OH		2
137	Halothane	C2HBrClF3	$BrClHCCF_3$		6
138	Hexafluoropropylene	C3F6	$CF_3CF{=}CF_2$	Perfluoropropylene or Propylene, Perfluoro	1
139	Hexamethyldisilane	C6H18Si2	$(CH_3)_3Si_2(CH_3)_3$	HMDSi, HMDS	3
140	Nickel Carbonyl	C4O4Ni	$Ni(CO)_4$		1
141	Nitrosyl Chloride	NOCl	$NOCl$		1
142	Pentaborane	B5H9	B_5H_9		2
143	Phosphorus Pentafluoride	PF5	PF_5		1
144	Tetraethoxysilane	C8H20O4Si	$(C_2H_5O)_4Si$	TEOS	2
145	Tin Tetrachloride	SnCl4	$SnCl_4$	Tetrachlorostannane	2
146	Tributylaluminum	C12H27Al	$(CH_3CH_2CH_2CH_2)_3Al$	TBAl	3
147	Trichlorosilane	SiHCl3	$SiHCl_3$		5
148	Triethylgallium	C6H15Ga	$(C_2H_5)_3Ga$	TEGa	4
149	Trimethylaluminum	C3H9Al	$Al(CH_3)_3$	TMA, TMAl	4
150	Trimethylantimony	C3H9Sb	$(CH_3)_3Sb$	Trimethylstibene	2
151	Trimethylarsenic	C3H9As	$(CH_3)_3As$	Trimethylarsine, TMAs	2
152	Trimethylgallium	C3H9Ga	$Ga(CH_3)_3$	TMGa	4
153	Trimethylindium	C3H9In	$(CH_3)_3In$	TMIn	3
154	Diethylsilane	C4H12Si	$(C_2H_5)_2SiH_2$		2
155	Pentafluoroethane	C2HF5	CF_3CHF_2	F-125, R-125	9
156	Tetrafluoroethane	C2H2F4	CH_2FCF_3	R-134A, F-134A	2
157	Tetrafluorohydrazine	N2F4	F_2NNF_2	Dinitrogen Tetrafluoride	1
158	Tetramethylcyclotetra-siloxane	C4H16Si4O4	$(CH_3)_4H_4(SiO)_4$	TOMCATS	7
159	Tritium	T2	H_3^2	T2	2
160	Difluoromethane	CH2F2	CH_2F_2	Methylene Fluoride	2
161	Tertiarybutylarsine	C4H11As	$C(CH_3)_3AsH_2$	TBA	8
162	Tertiarybutylphosphine	C4H11P	$C(CH_3)_3PH_2$	TBP	8
163	Triethylborate	C6H15O3B	$B(OC_2H_5)_3$	TEB, Triethoxyborane	2
164	Dimethylaluminum-hydride	C2H7Al	$(CH_3)_2AlH$	DMAH	13
165	Trimethylaminealane	C3H12AlN	$(CH_3)_3NAlH_3$	TMAA	11
166	Dimethylethylaminealane	C4H14NAl	$(CH_3)_2C_2H_5NAlH_3$	DMEAA	14
167	Nitric Acid	HNO3	HNO_3		2
168	Tetrachloroethylene	C2Cl4	$Cl_2C{=}CCl_2$	Perchloroethylene or Ethylene, Perchloro	2
169	Ethyleneglycol	C2H6O2	$HOCH_2CH_2OH$	Ethanediol, Glycol	2
170	Hexanediol-1,6	C6H14O2	$HO(CH_2)_6OH$	Hexyleneglycol, Hexamethyleneglycol	2
171	Sulfuric Acid	H2SO4	H_2SO_4		2
172	Chlorobenzene	C6H5Cl	C_6H_5Cl	Chlorobenzol, Phenylchloride	2
173	Acetonitrile	C2H3N	CH_3CN		2
174	Ethylbenzene	C8H10	$C_6H_5C_2H_5$		2
175	Intentionaly Left Blank				
176	Methanol	CH4O	CH_3OH	Methyl Alcohol	2
177	Methylcyclohexane	C7H14	$CH_3C_6H_{11}$	Hexahydrotoluene	2
178	4-Methyl, 1-Pentene	C6H12	$(CH_3)_2CHCH_2CH{=}CH_2$		2
179	o-Xylene	C8H10	$1,2\text{-}(CH_3)_2C_6H_4$	1,2-Dimethylbenzene	2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
180	Phenol	C6H6O	C_6H_5OH		2
181	Toluene	C7H8	$C_6H_5CH_3$	Methylbenzene	2
182	Tetrahydrofuran	C4H8O	C_4H_8O		2
183	Methyltrichlorosilane	CH3Cl3Si	CH_3SiCl_3	MTS	2
184	Acetone	C3H6O	CH_3COCH_3		2
185	Methylsilane	CH6Si	CH_3SiH_3	Monomethylsilane	2
186	2,2 Dichloro1,1,1 Trifluoroethane	C2HCl2F3	$CHCl_2$-CF_3	Freon 123, Suva 123	2
187	Isopropyl Alcohol	C3H8O	$(CH_3)_2CHOH$	2-Propanol	2
188	Diethoxy Dimethyl Silane	C6H16O2Si	$(C_2H_5O)_2Si(CH_3)_2$		2
189	Sulfur Monochloride	S2Cl2	S_2Cl_2		2
190	Trimethyl Silane	C3H10Si	$(CH_3)_3SiH$		2
191	Dichloroethylene -trans	C2H2Cl2	CHCl=CHCl		2
192	Hexafluorobenzene	C6F6	C_6F_6		2
193	Phosphorus Trichloride	PCL3	PCl_3		2
194	Titanium Tetraisopropoxide	$C12H28O_4Ti$	$Ti(OC_3H_7)_4$		1
195	Arsenic Trifluoride	AsF3	AsF_3		2
196	Arsenic Triiodine	AsI3	AsI_3		2
197	Benzene	C6H6	C_6H_6		2
198	Borazine	B3N3H6	$H_3B_3N_3H_3$		14
199	Bromochlorodifluoromethane	CBrClF2	$BrClCF_2$		2
200	Carbon Tetrabromide	CBr4	CBr_4		2
201	Chlorine Dioxide	ClO2	ClO_2		2
202	Chlorine Pentafluoride	ClF5	ClF_5		2
203	Chlorodifluoroethane	C2H3ClF2	CH_3-CF_2Cl	R-142b	4
204	Chlorodifluoroethylene	C2HClF2	CF_2=CHCl	R-1122, FREON-1122	4
205	Chlorosilane	SiH3Cl	SiH_3Cl		2
206	Chlorotrifluoroethylene	C2ClF3	FCCl=CF_2	R-1113, FREON-1113	2
207	Cyclobutane	C4H8	C_4H_8	Tetramethylene	2
208	Diazomethane	CH2N2	CH_2N_2	Acomethylene	2
209	Dibromodifluoromethane	CBr2F2	Br_2CF_2	R-12B2, FREON-12B2	2
210	Dichloroethylene	C2H2Cl2	CH_2=CCl_2	Vinylidene Chloride	2
211	Dichloroethylene -cis	C2H2Cl2	CHCl=CHCl		2
212	Dichlorodimethylsilane	C2H6SiCl2	$(CH_3)_2SiCl_2$		2
213	Diethylamine	C4H11N	$(C_2H_5)_2NH$		2
214	Diethylzinc	C4H10Zn	$Zn(C_2H_5)_2$		2
216	Arsenic Trichloride	AsCl3	$AsCl_3$		2
217	Digermane	Ge2H6	Ge_2H_6		2
218	Dimethylcadmium	C2H6Cd	$(CH_3)_2Cd$		2
219	Dimethylsilane	C2H8Si	$(CH_3)_2SiH_2$		2
220	Dimethyltellurium	C2H6Te	$(CH_3)_2Te$		2
221	Ethyl Fluoride	C2H5F	CH_3CH_2F	Fluoroethane, R-161, FREON-161	2
222	Ethylene Dichloride	C2H4Cl2	$ClCH_2CH_2Cl$	1,2 Dichloroethane	2
223	Fluoroacetylene	C2HF	FC≡CH		2
224	Fluorotriethoxysilane	C6H15OSiF	$(C_2H_5O)_3SiF$		2
225	Hexafluoroacetone	C3F6O	$(CF_3)_2CO$		2
226	Aluminum Trifluoride	AlF3	AlF_3		2
227	Hexamethyldisilazane	C6H19Si2N	$(CH_3)_6Si_2NH$		2
228	Hexamethyldisiloxane	C6H18Si2O	$(CH_3)_6Si_2O$		2

Code	Gas Name	Symbol	Formula	Synonym	Ref
229	Hydrogen telluride	H2Te	H_2Te		2
230	Iron Carbonyl	C5O5Fe	$Fe(CO)_5$		2
231	Isopentane	C5H12	$CH_3CH_2CH(CH_3)_2$	2-Methylbutane	2
232	Difluoroamidogen	NF2	NF_2		2
233	Monoethylamine	C2H7N	$C_2H_5NH_2$		2
234	Monomethyl Hydrazine	CH6N2	$CH_3N_2H_3$		2
235	Nitromethane	CH3NO2	CH_3NO_2		2
236	Octafluorobutane	C4F8	C_4F_8		3
237	Octane	C8H18	$CH_3(CH_2)_6CH_3$		2
238	Oxygen Dichloride	OCl2	OCl_2		2
239	Pentaborane (11)	B5H11	B_5H_{11}		2
240	Pentane	C5H12	$CH_3(CH_2)_3CH_3$		2
241	Perfluorobutane	C4F10	C_4F_{10}		3
242	Arsenic Tribromide	AsBr3	$AsBr_3$		2
243	Rhenium Hexafloride	ReF6	ReF_6		2
244	Deuteriumsilane	SiD4	SiH_4^2		2
245	Stibine	SbH3	SbH_3		2
246	Sulfur Trioxide	SO3	SO_3		2
247	Tellurium Hexafluoride	TeF6	TeF_6		2
248	Tetrachlorodiborane	B2Cl4	B_2Cl_4		2
249	Tetrafluorodiborane	B2F4	B_2F_4		2
250	Tetramethylgermanium	C4H12Ge	$(CH_3)_4Ge$		2
251	Tetramethylsilane	C4H12Si	$(CH_3)_4Si$		2
252	Tetramethyl Tin	C4H12Sn	$(CH_3)_4Sn$		2
253	Tetrasilane	Si4H10	Si_4H_{10}		2
254	Titanium Tetraiodide	TiI4	TiI_4		2
255	Tribromostibine	SbBr3	$SbBr_3$		2
256	Trichlorostibine	SbCl3	$SbCl_3$		2
257	Triethylaluminum	C6H15Al	$(C_2H_5)_3Al$		2
258	Triethylantimony	C6H15Sb	$(C_2H_5)_3Sb$		2
259	Trifluoroacetic Acid	CF3CO2H	CF_3CO_2H		2
260	Trifluoroacetonitrile	C2F3N	F_3CCN		2
261	Trifluorosilane	SiHF3	$SiHF_3$		2
262	Triisobutylaluminum	C12H27Al	$(C_4H_9)_3Al$		2
263	Xylene m-	C8H10	$1,3\text{-}(CH_3)_2C_6H_4$	1,3 Dimethyl Benzene	3
264	Xylene p-	C8H10	$1,4\text{-}(CH_3)_2C_6H_4$	1,4 Dimethyl Benzene	3
265	Dichloromethane	CH2Cl2	CH_2Cl_2		
266	Octafluorocyclopentene	C5F8	$CF_2{=}C(CF_3)\text{-}CF{=}CF_2$		3
267	Hexafluoro Propane	C3H2F6	$CH_2FCF_2CF_3$	1,1,1,2,2,3-Hexafluoropropane	2
268	Methylene Bromide	CH2Br2	CH_2Br_2	UN 2664; Methyl dibromide, Dibromomethane	1
269	Hydrazoic Acid	HN3	HN_3		1
270	Hexafluoro-2-Butyne	C4F6	$CF_3C{\equiv}CCF_3$	Bis(trifluoromethyl)acetylene; Perfluoro-2-butyne	3
271	Butanol-1	C4H10O	$CH_3CH_2CH_2CH_2OH$		3
272	Hexafluoro Acetylacetone	C5H2F6O2	$C_5H_2F_6O_2$		1
273	Tungsten Hexacarbonyl	C6O6W	$W(CO)_6$		1
274	TEAsat	C6H15O4As	$(C_2H_5O)_3AsO$		1
275	Hafnium Tetranitrate	HfN4O12	$Hf(NO_3)_4$		1

Code	Gas Name	Symbol	Formula	Synonym	Ref
276	Acrylonitrile	C3H3N	CH_2=CHCN	Acrylon; Propenenitrile	3
277	Trimethylborane	C3H9B	$(CH_3)_3B$		2
278	Silicon Tetrabromide	Br4Si	Br_4Si	SiBr4; Tetrabromosilane; Silicon (IV) bromide	2
279	Tantalum (V) Ethoxide	C10H25O5Ta	$C_{10}H_{25}O_5Ta$	Ta(Oet)5	2
280	Diphenylmethylenediamine	C13H14N2	$C_{13}H_{14}N_2$		2
281	Diphenylmethan-4,4'-diisocyanat	C15H10N2O	$C_{15}H_{10}N_2O$	UN2489; Benzene,1,1'-methylenebis(isocyanatophenyl)	2
282	Tetrakis(diethylamino) titanium	C16H40N4Ti	$C_{16}H_{40}N_4Ti$		2
283	Acetic acid	C2H4O2	CH_3COOH	Ethanoic acid; UN 2789;	2
284	Dimethyl Selenide	C2H6Se	C_2H_6Se	(CH3)2Se; Selenium dimethyl; Dimethylselenium	2
285	Ethoxy Silane	C2H8OSi	C_2H_8OSi		2
286	Hexafluoropropylene oxide	C3F6O	C_3F_6O	Hexafluoroepoxypropane	2
287	Trimethoxy Silane	C3H10O3Si	$C_3H_{10}O_3Si$		2
288	Pentafluoropropanol	C3H3F5O	$C_2F_5CH_2OH$	Perfluorodihydropropanol, 1,1,1,2,2-Pentafluoropropane	2
289	Acrylic acid	C3H4O2	$C_3H_4O_2$	2-Propenoic acid; CH2=CHCOOH	2
290	Trifluoropropane	C3H5F3	$C_3H_5F_3$	1,1,1-Trifluoropropane; CH3CH2CF3	2
291	Ethyl Formate	C3H6O2	$HCO_2C_2H_5$	Ethyl ester formic acid; HC00C2H5	3
292	Methyl Acetate	C3H6O2	$CH_3CO_2CH_3$	Methyl ester acetic acid; UN 1231	3
293	Propenamine	C3H7N	C_3H_7N	Allylamine; Monoallylamine; UN2334	2
294	Trimethyl Ester Phosphoric acid	C3H9O4P	$C_3H_9O_4P$	Methyl phosphate; Trimethoxyphosphine oxide	2
295	Heptafluoropropane	C3HF7	C_3HF_7	1,1,1,2,3,3,3-Heptafluoropropane, Freon 227	2
296	Hexafluorocyclobutene	C4F6	C_4F_6	Perfluorocyclobutene; 1,2,3,3,4,4-Hexafluorocyclobutene	3
297	Hexafluoro butadiene-1,3	C4F6	CF_2=CF-CF=CF_2	Perfluorobutadiene-1,3;	3
298	Diethyl Sulfide	C4H10S	$C_4H_{10}S$	UN2375; Ethyl sulfide;	2
299	Tetramethoxygermanium	C4H12GeO4	$(CH_3O)_4Ge$	Ge(OMe)4	2
300	Dimethoxydimethyl silane	C4H12O2Si	$(CH_3O)_2Si(CH_3)_2$	KBM 22	2
301	Tetramethoxy Silane	C4H12O4Si	$(CH_3O)_4Si$	Silicic Acid (H4SiO4); Tetramethyl ester; Tetramethyl silicate	2
302	Tetramethyl Lead	C4H12Pb	$(CH_3)_4Pb$	(CH3)4Pb; Plumbane, tetramethyl;	2
303	Trimethylvinylsilane	C5H12Si	$C_5H_{12}Si$	Vinyltrimethylsilane; CH2=CHSi(CH3)3	2
304	Pyridine	C5H5N	C_5H_5N	Azabenzene; Azine	2
305	Methyl methacrylate polymer	C5H8O2	$C_5H_8O_2$	Poly(methyl methacrylate); 2-Methyl 1-2-propenoic acid	2
306	Triethyl Arsine	C6H15As	$(C_2H_5)_3As$	Arsine; Triethylarsenic	2
307	Triethoxy Arsine	C6H15AsO3	$(C_2H_5O)_3As$	Triethyl ester arsenous acid; Triethyl arsenite	2
308	Triethoxyborane	C6H15BO3	$(C_2H_5O)_3B$	Boron triethoxide;	2
309	Triethylindium	C6H15In	$(C_2H_5)_3In$	Indium triethyl	2
310	Triethylamine	C6H15N	$(C_2H_5)_3N$	UN 1296; Ethanamine;	2
311	Triethoxyphosphine	C6H15O3P	$(C_2H_5O)_3P$	Triethyl phosphite; UN2323; Phosphorous acid, triethyl ester	2
312	Triethoxy Silane	C6H16O3Si	$(C_2H_5O)_3SiH$		2
313	Triethyl Silane	C6H16Si	$(C_2H_5)_3SiH$	(C2H5)3SiH;	2
314	Trimethylisoxazole	C6H9NO	CH_3CH=CHCH=CHCONH_2	3,4,5-Trimethylisoxazole, Sorbamide	3
315	Tetraethylgermane	C8H20Ge	$(C_2H_5)_4Ge$	(C2H5)4Ge; Germanium tetraethyl	2

Code	Gas Name	Symbol	Formula	Synonym	Ref
316	Tetraethyl lead	C8H20Pb	$(C_2H_5)_4Pb$	Plumbane, tetraethyl; UN1649	2
317	Tetraethyl silane	C8H20Si	$C_8H_{20}Si$	Tetraethylsilane; Tetraethylsilicon; (C2H5)4Si	2
318	Tetrakis(dimethylamino) titanium	C8H24N4Ti	$C_8H_{24}N_4Ti$		2
319	Styrene	C8H8	C_8H_8	Ethenylbenzene; Un 2055	2
320	Triallylamine	C9H15N	$C_9H_{15}N$		2
321	Trifluoromethylhypofluorite	CF4O	CF_4O	CF3OF; Hypofluorous acid; trifuoromethyl ester	2
322	Formaldehyde	CH2O	CH_2O	H2C0; UN1198; BFV	2
323	Iodomethane	CH3I	CH_3I	Methyl iodide; Un 2644	2
324	Xenon difluoride	XeF2	XeF_2	F_2Xe; Xenon fluoride	2
325	Selenium Hexafluoride	SeF6	SeF_6	UN 2194; Selenium fluoride	2
326	Disilane Hexafluoride	SiF6	SiF_6	F_6Si_2; Hexafluorodisilane	2
327	Fluoro Silane	SiH3F	SiH_3F	H_3FSi	2
328	Trisilane	Si3H8	Si_3H_8	Silicopropane; Trisilicane; H_8Si3	2
329	Mercury	Hg	Hg	UN2809	2
330	Zinc	Zn	Zn	UN 1383	2
331	Acetaldehyde Methoxy	C3H6O2	CH_3OCH_2CHO		3
332	Acetone, Hydroxy	C3H6O2	$CH_3COCH2OH$	Acetol	3
333	Glycol Methylene Ether	C3H6O2	$C_3H_6O_2$	1,3-Dioxolane	3
334	Propanoic acid	C3H6O2	$CH_3CH_2CO_2H$	Propionic acid	3
335	Glycidol	C3H6O2	CH_2CHCH_2OH	1-Propanol, 2,3 epoxy	3
336	Butanol-2	C4H10O	$CH_3CH_2CH(OH)CH_3$		3
337	Tertiary Butyl Alcohol	C4H10O	$(CH_3)_3COH$		3
338	Diethyl Ether	C4H10O	$C_2H_5OC_2H_5$		3
339	Methyl Propyl Ether	C4H10O	$CH_3OC_3H_7$		3
340	Methyl Isopropyl Ether	C4H10O	$(CH_3)_2CHOCH_3$		3
341	Isobutyl Alcohol	C4H10O	$(CH_3)_2CHCH_2OH$		3
342	3-one-2,5-dimethyl hexadiene	C8H10	$CH_2{=}C(CH_3)C{\equiv}CC(CH_3)CH_2$		3
343	1,7-Octadiyne	C8H10	$HC{\equiv}C(CH_2)_4C{\equiv}CH$		3
344	2,6-Octadiyne	C8H10	$CH_3C{\equiv}CCH_2CH_2C{\equiv}CCH_3$		3
345	1,3,5,7-Octatetraene	C8H10	$CH_2{=}CHCH{=}CHCH{=}CHCH{=}CH_2$		3

7 Gas Table Sorted by Name

Table 2 Gases Sorted by Name

Code	Gas Name	Symbol	Formula	Synonym	Ref
345	1,3,5,7-Octatetraene	C8H10	$CH_2{=}CHCH{=}CHCH{=}CHCH{=}CH_2$		3
343	1,7-Octadiyne	C8H10	$HC{\equiv}C(CH_2)_4C{\equiv}CH$		3
186	2,2 Dichloro1,1,1 Trifluoroethane	C2HCl2F3	$CHCl_2$-CF_3	Freon 123, Suva 123	2
344	2,6-Octadiyne	C8H10	$CH_3C{\equiv}CCH_2CH_2C{\equiv}CCH_3$		3
342	3-one-2,5-dimethyl hexadiene	C8H10	$CH_2{=}C(CH_3)C{\equiv}CC(CH_3)CH_2$		3

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
178	4-Methyl, 1-Pentene	C6H12	$(CH_3)_2CHCH_2CH{=}CH_2$		2
331	Acetaldehyde Methoxy	C3H6O2	CH_3OCH_2CHO		3
283	Acetic acid	C2H4O2	CH_3COOH	Ethanoic acid; UN 2789;	2
184	Acetone	C3H6O	CH_3COCH_3		2
332	Acetone, Hydroxy	C3H6O2	$CH_3COCH2OH$	Acetol	3
173	Acetonitrile	C2H3N	CH_3CN		2
42	Acetylene	C2H2	HC≡CH	Ethyne	1
289	Acrylic acid	C3H4O2	$C_3H_4O_2$	2-Propenoic acid; CH2=CHCOOH	2
276	Acrylonitrile	C3H3N	$CH_2{=}CHCN$	Acrylon; Propenenitrile	3
8	Air	Air			1
66	Allene	C3H4	$CH_2{=}C{=}CH_2$	Propadiene	1
226	Aluminum Trifluoride	AlF3	AlF_3		2
29	Ammonia	NH3	NH_3		1
4	Argon	Ar	Ar		1
96	Arsenic Pentafluoride	AsF5	AsF_5		2
242	Arsenic Tribromide	AsBr3	$AsBr_3$		2
216	Arsenic Trichloride	AsCl3	$AsCl_3$		2
195	Arsenic Trifluoride	AsF3	AsF_3		2
196	Arsenic Triiodine	AsI3	AsI_3		2
35	Arsine	AsH3	AsH_3		1
197	Benzene	C6H6	C_6H_6		2
198	Borazine	B3N3H6	$H_3B_3N_3H_3$		14
79	Boron Tribromide	BBr3	BBr_3		1
70	Boron Trichloride	BCl3	BCl_3		1
48	Boron Trifluoride	BF3	BF_3		1
21	Bromine	Br2	Br_2		2
116	Bromine Pentafluoride	BrF5	BrF_5		1
76	Bromine Trifluoride	BrF3	BrF_3		1
199	Bromochlorodifluoromethane	CBrClF2	$BrClCF_2$		2
105	Bromotrifluoroethylene	C2BrF3	CF_2CFBr		1
80	Bromotrifluoromethane	CBrF3	$BrCF_3$	F-13B1, R-13B1	1
100	Butadiene	C4H6	$CH_2{=}C{=}CHCH_3$	Methylallene	1
117	Butane	C4H10	$CH_3(CH_2)_2CH_3$		1
271	Butanol-1	C4H10O	$CH_3CH_2CH_2CH_2OH$		3
336	Butanol-2	C4H10O	$CH_3CH_2CH(OH)CH_3$		3
104	Butene	C4H8	$CH_3CH_2CH{=}CH_2$	1-Butene	1
25	Carbon Dioxide	CO2	CO_2		1
40	Carbon Disulfide	CS2	CS_2		2
9	Carbon Monoxide	CO	CO		1
200	Carbon Tetrabromide	CBr4	CBr_4		2
101	Carbon Tetrachloride	CCl4	CCl_4	Tetrachloromethane or Methane, Tetrachloro	2
63	Carbon Tetrafluoride	CF4	CF_4	Tetrafluoromethane or Methane, Tetrafluoro	1
46	Carbonyl Fluoride	CF2O	CF_2O		1
34	Carbonyl Sulfide	COS	COS		1
19	Chlorine	Cl2	Cl_2		1
201	Chlorine Dioxide	ClO2	ClO_2		2
202	Chlorine Pentafluoride	ClF5	ClF_5		2
77	Chlorine Trifluoride	ClF3	ClF_3		1

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
172	Chlorobenzene	C6H5Cl	C_6H_5Cl	Chlorobenzol, Phenylchloride	2
203	Chlorodifluoroethane	C2H3ClF2	CH_3-CF_2Cl	R-142b	4
204	Chlorodifluoroethylene	C2HClF2	CF_2=CHCl	R-1122, FREON-1122	4
57	Chlorodifluoromethane	CHClF2	$CClHF_2$	F-22, R-22	1
71	Chloroform	CHCl3	$CHCl_3$	Trichloromethane or Methane, Trichloro	2
119	Chloropentafluoroethane	C2ClF5	$ClCF_2CF_3$	F-115, R-115	1
205	Chlorosilane	SiH3Cl	SiH_3Cl		2
206	Chlorotrifluoroethylene	C2ClF3	FCCl=CF_2	R-1113, FREON-1113	2
74	Chlorotrifluoromethane	CClF3	$ClCF_3$	F-13, R-13	1
107	Cisbutene	C4H8	CH_3CH=$CHCH_3$	Cis-2-Butene	2
59	Cyanogen	C2N2	NCCN	Oxalodinitrile	1
37	Cyanogen Chloride	ClCN	ClCN		1
207	Cyclobutane	C4H8	C_4H_8	Tetramethylene	2
61	Cyclopropane	C3H6	C_3H_6		1
14	Deuterium	D2	H_2^2	D2	2
244	Deuteriumsilane	SiD4	SiH_4^2		2
208	Diazomethane	CH2N2	CH_2N_2	Acomethylene	2
58	Diborane	B2H6	B_2H_6		1
209	Dibromodifluoromethane	CBr2F2	Br_2CF_2	R-12B2, FREON-12B2	2
130	Dibromotetrafluorethane	C2Br2F4	BrF_2CCF_2Br	F-114B2, R-114B2	1
84	Dichlorodifluoromethane	CCl2F2	CCl_2F_2	F-12, R-12	1
212	Dichlorodimethylsilane	C2H6SiCl2	$(CH_3)_2SiCl_2$		2
210	Dichloroethylene	C2H2Cl2	CH_2=CCl_2	Vinylidene Chloride	2
211	Dichloroethylene -cis	C2H2Cl2	CHCl=CHCl		2
191	Dichloroethylene -trans	C2H2Cl2	CHCl=CHCl		2
65	Dichlorofluoromethane	CHCl2F	$CHCl_2F$	F-21, R-21	1
265	Dichloromethane	CH2Cl2	CH_2Cl_2		
67	Dichlorosilane	SiH2Cl2	SiH_2Cl_2		1
125	Dichlorotetrafluoroethane	C2Cl2F4	F_3CCCl_2F	F-114, R-114	1
188	Diethoxy Dimethyl Silane	C6H16O2Si	$(C_2H_5O)_2Si(CH_3)_2$		2
338	Diethyl Ether	C4H10O	$C_2H_5OC_2H_5$		3
298	Diethyl Sulfide	C4H10S	$C_4H_{10}S$	UN2375; Ethyl sulfide;	2
213	Diethylamine	C4H11N	$(C_2H_5)_2NH$		2
154	Diethylsilane	C4H12Si	$(C_2H_5)_2SiH_2$		2
214	Diethylzinc	C4H10Zn	$Zn(C_2H_5)_2$		2
232	Difluoroamidogen	NF2	NF_2		2
103	Difluorochloroethane	C2H3ClF2	CF_2ClCH_3	F-142B, R-142B	1
82	Difluoroethane	C2H4F2	CH_3CHF_2	Ethylidene Fluoride, R-152A	1
64	Difluoroethylene	C2H2F2	CH_2=CF_2	G-1132A,Vinylidenefluoride	1
160	Difluoromethane	CH2F2	CH_2F_2	Methylene Fluoride	2
134	Difluorosilane	SiH2F2	SiH_2F_2		10
217	Digermane	Ge2H6	Ge_2H_6		2
300	Dimethoxydimethyl silane	C4H12O2Si	$(CH_3O)_2Si(CH_3)_2$	KBM 22	2
73	Dimethyl Ether	C2H6O	CH_3OCH_3	Methylether	1
284	Dimethyl Selenide	C2H6Se	C_2H_6Se	(CH3)2Se; Selenium dimethyl; Dimethylselenium	2
164	Dimethylaluminum-hydride	C2H7Al	$(CH_3)_2AlH$	DMAH	13
85	Dimethylamine	C2H7N	$(CH_3)_2NH$		1
218	Dimethylcadmium	C2H6Cd	$(CH_3)_2Cd$		2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
166	Dimethylethylaminealane	C4H14NAl	$(CH_3)_2C_2H_5NAlH_3$	DMEAA	14
122	Dimethylpropane	C5H12	$(CH_3)_4C$	Neopentane	2
219	Dimethylsilane	C2H8Si	$(CH_3)_2SiH_2$		2
220	Dimethyltellurium	C2H6Te	$(CH_3)_2Te$		2
135	Dimethylzinc	C2H6Zn	$(CH_3)_2Zn$		3
281	Diphenylmethan-4,4'-diisocyanat	C15H10N2O	$C_{15}H_{10}N_2O$	UN2489; Benzene,1,1'-methylenebis(isocyanatophenyl)	2
280	Diphenylmethylenediamine	C13H14N2	$C_{13}H_{14}N_2$		2
97	Disilane	Si2H6	Si_2H_6		2
326	Disilane Hexafluoride	SiF6	SiF_6	F_6Si_2; Hexafluorodisilane	2
54	Ethane	C2H6	CH_3CH_3		1
136	Ethanol	C2H6O	CH_3CH_2OH		2
285	Ethoxy silane	C2H8OSi	C_2H_8OSi		2
93	Ethyl Acetylene	C4H6	$CH_3CH_2C{\equiv}CH$		1
75	Ethyl Chloride	C2H5Cl	C_2H_5Cl	Chloroethane or Ethane, Chloro or Ethyl Chloride	1
221	Ethyl Fluoride	C2H5F	CH_3CH_2F	Fluoroethane, R-161, FREON-161	2
291	Ethyl Formate	C3H6O2	$HCO_2C_2H_5$	Ethyl ester formic acid; HC00C2H5	3
174	Ethylbenzene	C8H10	$C_6H_5C_2H_5$		2
38	Ethylene	C2H4	$CH_2{=}CH_2$	Ethene	1
222	Ethylene Dichloride	C2H4Cl2	$ClCH_2CH_2Cl$	1,2 Dichloroethane	2
45	Ethylene Oxide	C2H4O	C_2H_4O	Acetaldehyde	1
169	Ethyleneglycol	C2H6O2	$HOCH_2CH_2OH$	Ethanediol, Glycol	2
18	Fluorine	F2	F_2		1
327	Fluoro silane	SiH3F	SiH_3F	H_3Fsi	2
223	Fluoroacetylene	C2HF	$FC{\equiv}CH$		2
49	Fluoroform	CHF3	CHF_3	Trifluoromethane or Methane, Trifluoro, F-23, R-23	1
224	Fluorotriethoxysilane	C6H15OSiF	$(C_2H_5O)_3SiF$		2
322	Formaldehyde	CH2O	CH_2O	H2C0; UN1198; BFV	2
43	Germane	GeH4	GeH_4		1
113	Germanium Tetrachloride	GeCl4	$GeCl_4$	Tetrachlorogermane	2
99	Germanium Tetrafluoride	GeF4	GeF_4	Tetrafluorogermane	2
335	Glycidol	C3H6O2	CH_2CHCH_2OH	1-Propanol, 2,3 epoxy	3
333	Glycol Methylene Ether	C3H6O2	$C_3H_6O_2$	1,3-Dioxolane	3
275	Hafnium Tetranitrate	HfN4O12	$Hf(NO_3)_4$		1
137	Halothane	C2HBrClF3	$BrClHCCF_3$		6
1	Helium	He	He		1
295	Heptafluoropropane	C3HF7	C_3HF_7	1,1,1,2,3,3,3-Heptafluoropropane, Freon 227	2
272	Hexafluoro Acetylacetone	C5H2F6O2	$C_5H_2F_6O_2$		1
297	Hexafluoro Butadiene-1,3	C4F6	$CF_2{=}CF{-}CF{=}CF_2$	Perfluorobutadiene-1,3;	3
267	Hexafluoro Propane	C3H2F6	$CH_2FCF_2CF_3$	1,1,1,2,2,3-Hexafluoropropane	2
270	Hexafluoro-2-Butyne	C4F6	$CF_3C{\equiv}CCF_3$	Bis(trifluoromethyl)acetylene; Perfluoro-2-butyne	3
225	Hexafluoroacetone	C3F6O	$(CF_3)_2CO$		2
192	Hexafluorobenzene	C6F6	C_6F_6		2
296	Hexafluorocyclobutene	C4F6	C_4F_6	Perfluorocyclobutene; 1,2,3,3,4,4-Hexafluorocyclobutene	3
118	Hexafluoroethane	C2F6	F_3CCF_3	F-116, Perfluoroethane	1

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
138	Hexafluoropropylene	C3F6	$CF_3CF{=}CF_2$	Perfluoropropylene or Propylene, Perfluoro	1
286	Hexafluoropropylene Oxide	C3F6O	C_3F_6O	Hexafluoroepoxypropane	2
139	Hexamethyldisilane	C6H18Si2	$(CH_3)_3Si_2(CH_3)_3$	HMDSi, HMDS	3
227	Hexamethyldisilazane	C6H19Si2N	$(CH_3)_6Si_2NH$		2
228	Hexamethyldisiloxane	C6H18Si2O	$(CH_3)_6Si_2O$		2
127	Hexane	C6H14	$CH_3(CH_2)_4CH_3$		2
170	Hexanediol-1,6	C6H14O2	$HO(CH_2)_6OH$	Hexyleneglycol, Hexamethyleneglycol	2
50	Hydrazine	N2H4	H_2NNH_2		2
269	Hydrazoic Acid	HN3	HN_3		1
7	Hydrogen	H2	H_2		1
10	Hydrogen Bromide	HBr	HBr		1
11	Hydrogen Chloride	HCl	HCl		1
24	Hydrogen Cyanide	HCN	HCN		1
12	Hydrogen Fluoride	HF	HF		1
17	Hydrogen Iodide	HI	HI		1
23	Hydrogen Selenide	H2Se	H_2Se		1
22	Hydrogen Sulfide	H2S	H_2S		1
229	Hydrogen Telluride	H2Te	H_2Te		2
90	Intentionally Left Blank				
92	Intentionally Left Blank				
175	Intentionally Left Blank				
115	Iodine Pentafluoride	IF5	IF_5		1
323	Iodomethane	CH3I	CH_3I	Methyl iodide; Un 2644	2
230	Iron Carbonyl	C5O5Fe	$Fe(CO)_5$		2
111	Isobutane	C4H10	$(CH_3)_2CHCH_3$	2-Methylpropane or Propane, 2-Methyl	1
106	Isobutene	C4H8	$(CH_3)_2C{=}CH_2$	Isobutylene, Methylpropene	2
341	Isobutyl Alcohol	C4H10O	$(CH_3)_2CHCH_2OH$		3
231	Isopentane	C5H12	$CH_3CH_2CH(CH_3)_2$	2-Methylbutane	2
187	Isopropyl Alcohol	C3H8O	$(CH_3)_2CHOH$	2-Propanol	2
5	Krypton	Kr	Kr		1
329	Mercury	Hg	Hg	UN2809	2
28	Methane	CH4	CH_4		1
176	Methanol	CH4O	CH_3OH	Methyl Alcohol	2
292	Methyl Acetate	C3H6O2	$CH_3CO_2CH_3$	Methyl ester acetic acid; UN 1231	3
68	Methyl Acetylene	C3H4	$CH_3C{\equiv}CH$	Propyne	1
44	Methyl Bromide	CH3Br	CH_3Br	Bromomethane or Methane, Bromo	1
36	Methyl Chloride	CH3Cl	CH_3Cl	Chloromethane or Methane, Chloro	1
33	Methyl Fluoride	CH3F	CH_3F	Fluoromethane or Methane, Fluoro	1
340	Methyl isopropyl ether	C4H10O	$(CH_3)_2CHOCH_3$		3
47	Methyl Mercaptan	CH4S	CH_3SH		1
305	Methyl methacrylate polymer	C5H8O2	$C_5H_8O_2$	Poly(methyl methacrylate); 2-Methyl 1-2-propenoic acid	2
339	Methyl Propyl Ether	C4H10O	$CH_3OC_3H_7$		3
81	Methyl Vinyl Ether	C3H6O	$CH_3OCH{=}CH_2$		1
52	Methylamine	CH5N	CH_3NH_2	Amino Methane, Monomethylamine	2
120	Methylbutene	C5H10	$CH_3CH_2CCH_3{=}CH_2$	2-Methyl-1-Butene	1
177	Methylcyclohexane	C7H14	$CH_3C_6H_{11}$	Hexahydrotoluene	2
268	Methylene Bromide	CH2Br2	CH_2Br_2	UN 2664; Methyl dibromide, Dibromomethane	1

Code	Gas Name	Symbol	Formula	Synonym	Ref
185	Methylsilane	CH6Si	CH_3SiH_3	Monomethylsilane	2
183	Methyltrichlorosilane	CH3Cl3Si	CH_3SiCl_3	MTS	2
124	Molybdenum Hexafluoride	MoF6	MoF_6		2
233	Monoethylamine	C2H7N	$C_2H_5NH_2$		2
234	Monomethyl Hydrazine	CH6N2	$CH_3N_2H_3$		2
2	Neon	Ne	Ne		1
140	Nickel Carbonyl	C4O4Ni	$Ni(CO)_4$		1
167	Nitric Acid	HNO3	HNO_3		2
16	Nitric Oxide	NO	NO		2
13	Nitrogen	N2	N_2		1
26	Nitrogen Dioxide	NO2	NO_2		1
95	Nitrogen Tetroxide	N2O4	N_2O_4	Dinitrogenoxide	2
53	Nitrogen Trifluoride	NF3	NF_3		1
78	Nitrogen Trioxide	N2O3	N_2O_3		1
235	Nitromethane	CH3NO2	CH_3NO_2		2
141	Nitrosyl Chloride	NOCl	NOCl		1
27	Nitrous Oxide	N2O	N_2O		1
236	Octafluorobutane	C4F8	C_4F_8		3
129	Octafluorocyclobutane	C4F8	$(CF_2)_4$	Perfluorocyclobutane or Cyclobutane, Perfluoro	1
266	Octafluorocyclopentene	C5F8	$CF_2=C(CF_3)-CF=CF_2$		3
237	Octane	C8H18	$CH_3(CH_2)_6CH_3$		2
15	Oxygen	O2	O_2		1
238	Oxygen Dichloride	OCl2	OCl_2		2
41	Oxygen Difluoride	OF2	OF_2		1
179	o-Xylene	C8H10	$1,2-(CH_3)_2C_6H_4$	1,2-Dimethylbenzene	2
30	Ozone	O3	O_3		1
142	Pentaborane	B5H9	B_5H_9		2
239	Pentaborane (11)	B5H11	B_5H_{11}		2
155	Pentafluoroethane	C2HF5	CF_3CHF_2	F-125, R-125	9
288	Pentafluoropropanol	C3H3F5O	$C_2F_5CH_2OH$	Perfluorodihydropropanol, 1,1,1,2,2-Pentafluoropropane	2
240	Pentane	C5H12	$CH_3(CH_2)_3CH_3$		2
72	Perchloryl Fluoride	ClO3F	ClO_3F		1
241	Perfluorobutane	C4F10	C_4F_{10}		3
128	Perfluoropropane	C3F8	$CF_2(CF_3)_2$		1
180	Phenol	C6H6O	C_6H_5OH		2
60	Phosgene	CCl2O	CCl_2O	Carbonyl Chloride	1
31	Phosphine	PH3	PH_3		1
102	Phosphorous Oxychloride	POCl3	$POCl_3$		2
143	Phosphorus Pentafluoride	PF5	PF_5		1
193	Phosphorus Trichloride	PCL3	PCl_3		2
62	Phosphorus Trifluoride	PF3	PF_3		1
89	Propane	C3H8	$CH_3CH_2CH_3$		1
334	Propanoic acid	C3H6O2	$CH_3CH_2CO_2H$	Propionic acid	3
293	Propenamine	C3H7N	C_3H_7N	Allylamine; Monoallylamine; UN2334	2
69	Propylene	C3H6	$CH_3CH=CH_2$	Propene	1
304	Pyridine	C5H5N	C_5H_5N	Azabenzene; Azine	2
3	Radon	Rn	Rn		2

Code	Gas Name	Symbol	Formula	Synonym	Ref
243	Rhenium Hexafloride	ReF6	ReF_6		2
325	Selenium Hexafluoride	SeF6	SeF_6	UN 2194; Selenium fluoride	2
39	Silane	SiH4	SiH_4		1
278	Silicon Tetrabromide	Br4Si	Br_4Si	SiBr4; Tetrabromosilane; Silicon (IV) bromide	2
108	Silicon Tetrachloride	SiCl4	$SiCl_4$	Tetrachlorosilane	2
88	Silicon Tetrafluoride	SiF4	SiF_4		1
245	Stibine	SbH3	SbH_3		2
319	Styrene	C8H8	C_8H_8	Ethenylbenzene; Un 2055	2
32	Sulfur Dioxide	SO2	SO_2		1
110	Sulfur Hexafluoride	SF6	SF_6		1
189	Sulfur Monochloride	S2Cl2	S_2Cl_2		2
86	Sulfur Tetrafluoride	SF4	SF_4		1
246	Sulfur Trioxide	SO3	SO_3		2
171	Sulfuric Acid	H2SO4	H_2SO_4		2
87	Sulfuryl Fluoride	SO2F2	SO_2F_2		1
279	Tantalum (V) Ethoxide	C10H25O5Ta	$C_{10}H_{25}O_5Ta$	Ta(Oet)5	2
274	TEAsat	C6H15O4As	$(C_2H_5O)_3AsO$		1
247	Tellurium Hexafluoride	TeF6	TeF_6		2
337	Tertiary Butyl Alcohol	C4H10O	$(CH_3)_3COH$		3
161	Tertiarybutylarsine	C4H11As	$C(CH_3)_3AsH_2$	TBA	8
162	Tertiarybutylphosphine	C4H11P	$C(CH_3)_3PH_2$	TBP	8
248	Tetrachlorodiborane	B2Cl4	B_2Cl_4		2
168	Tetrachloroethylene	C2Cl4	$Cl_2C{=}CCl_2$	Perchloroethylene or Ethylene, Perchloro	2
144	Tetraethoxysilane	C8H20O4Si	$(C_2H_5O)_4Si$	TEOS	2
316	Tetraethyl Lead	C8H20Pb	$(C_2H_5)_4Pb$	Plumbane, tetraethyl; UN1649	2
317	Tetraethyl Silane	C8H20Si	$C_8H_{20}Si$	Tetraethylsilane; Tetraethylsilicon; (C2H5)4Si	2
315	Tetraethylgermane	C8H20Ge	$(C_2H_5)_4Ge$	(C2H5)4Ge; Germanium tetraethyl	2
94	Tetrafluorethylene	C2F4	$F_2C{=}CF_2$		1
249	Tetrafluorodiborane	B2F4	B_2F_4		2
156	Tetrafluoroethane	C2H2F4	CH_2FCF_3	R-134A, F-134A	2
157	Tetrafluorohydrazine	N2F4	F_2NNF_2	Dinitrogen Tetrafluoride	1
182	Tetrahydrofuran	C4H8O	C_4H_8O		2
282	Tetrakis(diethylamino) titanium	C16H40N4Ti	$C_{16}H_{40}N_4Ti$		2
318	Tetrakis(dimethylamino) titanium	C8H24N4Ti	$C_8H_{24}N_4Ti$		2
301	Tetramethoxy silane	C4H12O4Si	$(CH_3O)_4Si$	Silicic Acid (H4SiO4); Tetramethyl ester; Tetramethyl silicate	2
299	Tetramethoxygermanium	C4H12GeO4	$(CH_3O)_4Ge$	Ge(OMe)4	2
302	Tetramethyl lead	C4H12Pb	$(CH_3)_4Pb$	(CH3)4Pb; Plumbane, tetramethyl;	2
252	Tetramethyl Tin	C4H12Sn	$(CH_3)_4Sn$		2
158	Tetramethylcyclotetra-siloxane	C4H16Si4O4	$(CH_3)_4H_4(SiO)_4$	TOMCATS	7
250	Tetramethylgermanium	C4H12Ge	$(CH_3)_4Ge$		2
251	Tetramethylsilane	C4H12Si	$(CH_3)_4Si$		2
253	Tetrasilane	Si4H10	Si_4H_{10}		2
145	Tin Tetrachloride	SnCl4	$SnCl_4$	Tetrachlorostannane	2
114	Titanium Tetrachloride	TiCl4	$TiCl_4$		2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
254	Titanium Tetraiodide	TiI4	TiI_4		2
194	Titanium Tetraisopropoxide	C12H28OTi	$Ti(OC_3H_7)_4$		1
181	Toluene	C7H8	$C_6H_5CH_3$	Methylbenzene	2
98	Transbutene	C4H8	$CH_3CH{=}CHCH_3$		2
320	Triallylamine	C9H15N	$C_9H_{15}N$		2
83	Tribromomethane	CHBr3	$CHBr_3$		2
255	Tribromostibine	SbBr3	$SbBr_3$		2
146	Tributylaluminum	C12H27Al	$(CH_3CH_2CH_2CH_2)_3Al$	TBAl	3
112	Trichloroethane	C2H3Cl3	CH_3CCl_3	TCA, Methylchloroform	2
91	Trichlorofluoromethane	CCl3F	CCl_3F	F-11, R-11	1
147	Trichlorosilane	SiHCl3	$SiHCl_3$		5
256	Trichlorostibine	SbCl3	$SbCl_3$		2
126	Trichlorotrifluoroethane	C2Cl3F3	CF_2ClCCl_2F	F-113, R-113	1
307	Triethoxy Arsine	C6H15AsO3	$(C_2H_5O)_3As$	Triethyl ester arsenous acid; Triethyl arsenite	2
312	Triethoxy Silane	C6H16O3Si	$(C_2H_5O)_3SiH$		2
308	Triethoxyborane	C6H15BO3	$(C_2H_5O)_3B$	Boron triethoxide;	2
311	Triethoxyphosphine	C6H15O3P	$(C_2H_5O)_3P$	Triethyl phosphite; UN2323; Phosphorous acid, triethyl ester	2
306	Triethyl Arsine	C6H15As	$(C_2H_5)_3As$	Arsine; Triethylarsenic	2
313	Triethyl Silane	C6H16Si	$(C_2H_5)_3SiH$	(C2H5)3SiH;	2
257	Triethylaluminum	C6H15Al	$(C_2H_5)_3Al$		2
310	Triethylamine	C6H15N	$(C_2H_5)_3N$	UN 1296; Ethanamine;	2
258	Triethylantimony	C6H15Sb	$(C_2H_5)_3Sb$		2
163	Triethylborate	C6H15O3B	$B(OC_2H_5)_3$	TEB, Triethoxyborane	2
148	Triethylgallium	C6H15Ga	$(C_2H_5)_3Ga$	TEGa	4
309	Triethylindium	C6H15In	$(C_2H_5)_3In$	Indium triethyl	2
259	Trifluoroacetic Acid	CF3CO2H	CF_3CO_2H		2
260	Trifluoroacetonitrile	C2F3N	F_3CCN		2
321	Trifluoromethylhypofluorite	CF4O	CF_4O	CF3OF; Hypofluorous acid; trifuoromethyl ester	2
290	Trifluoropropane	C3H5F3	$C_3H_5F_3$	1,1,1-Trifluoropropane; CH3CH2CF3	2
261	Trifluorosilane	SiHF3	$SiHF_3$		2
262	Triisobutylaluminum	C12H27Al	$(C_4H_9)_3Al$		2
287	Trimethoxy Silane	C3H10O3Si	$C_3H_{10}O_3Si$		2
131	Trimethoxyborine	C3H9BO3	$B(OCH_3)_3$	TMB, Trimethylborate	2
294	Trimethyl Ester Phosphoric Acid	C3H9O4P	$C_3H_9O_4P$	Methyl phosphate; Trimethoxyphosphine oxide	2
190	Trimethyl Silane	C3H10Si	$(CH_3)_3SiH$		2
149	Trimethylaluminum	C3H9Al	$Al(CH_3)_3$	TMA, TMAl	4
109	Trimethylamine	C3H9N	$(CH_3)_3N$	Methylamine	1
165	Trimethylaminealane	C3H12AlN	$(CH_3)_3NAlH_3$	TMAA	11
150	Trimethylantimony	C3H9Sb	$(CH_3)_3Sb$	Trimethylstibene	2
151	Trimethylarsenic	C3H9As	$(CH_3)_3As$	Trimethylarsine, TMAs	2
277	Trimethylborane	C3H9B	$(CH_3)_3B$		2
152	Trimethylgallium	C3H9Ga	$Ga(CH_3)_3$	TMGa	4
153	Trimethylindium	C3H9In	$(CH_3)_3In$	TMIn	3
314	Trimethylisoxazole	C6H9NO	$CH_3CH{=}CHCH{=}CHCONH_2$	3,4,5-Trimethylisoxazole, Sorbamide	3
133	Trimethylphosphite	C3H9PO3	$(CH_3O)_3P$	TMPi, Trimethoxyphosphine	2

Code	Gas Name	Symbol	Formula	Synonym	Ref
132	Trimethylphosphorous	C3H9P	$(CH_3)_3P$	Trimethylphosphine, TMP	2
303	Trimethylvinylsilane	C5H12Si	$C_5H_{12}Si$	Vinyltrimethylsilane; CH2=CHSi(CH3)3	2
328	Trisilane	Si3H8	Si_3H_8	Silicopropane; Trisilicane; H_8Si3	2
159	Tritium	T2	H_3^2	T2	2
273	Tungsten Hexacarbonyl	C6O6W	$W(CO)_6$		1
121	Tungsten Hexafluoride	WF6	WF_6		2
123	Uranium Hexafluoride	UF6	UF_6		2
56	Vinyl Bromide	C2H3Br	CH_2=CHBr		1
55	Vinyl Chloride	C2H3Cl	CH_2=CHCl	Chloroethylene	1
51	Vinyl Fluoride	C2H3F	H_2C=CHF		1
20	Water Vapor	H2O	H_2O		2
6	Xenon	Xe	Xe		1
324	Xenon Difluoride	XeF2	XeF_2	F_2Xe; Xenon fluoride	2
263	Xylene m-	C8H10	1,3-$(CH_3)_2C_6H_4$	1,3 Dimethyl Benzene	3
264	Xylene p-	C8H10	1,4-$(CH_3)_2C_6H_4$	1,4 Dimethyl Benzene	3
330	Zinc	Zn	Zn	UN 1383	2

8 Gas Table Sorted by Symbol

Table 3 Gases Sorted by Symbol

Code	Gas Name	Symbol	Formula	Synonym	Ref
8	Air	Air			1
226	Aluminum Trifluoride	AlF3	AlF_3		2
4	Argon	Ar	Ar		1
242	Arsenic Tribromide	AsBr3	$AsBr_3$		2
216	Arsenic Trichloride	AsCl3	$AsCl_3$		2
195	Arsenic Trifluoride	AsF3	AsF_3		2
96	Arsenic Pentafluoride	AsF5	AsF_5		2
35	Arsine	AsH3	AsH_3		1
196	Arsenic Triiodine	AsI3	AsI_3		2
248	Tetrachlorodiborane	B2Cl4	B_2Cl_4		2
249	Tetrafluorodiborane	B2F4	B_2F_4		2
58	Diborane	B2H6	B_2H_6		1
198	Borazine	B3N3H6	$H_3B_3N_3H_3$		14
239	Pentaborane(11)	B5H11	B_5H_{11}		2
142	Pentaborane	B5H9	B_5H_9		2
79	Boron Tribromide	BBr3	BBr_3		1
70	Boron Trichloride	BCl3	BCl_3		1
48	Boron Trifluoride	BF3	BF_3		1
21	Bromine	Br2	Br_2		2
278	Silicon tetrabromide	Br4Si	Br_4Si	SiBr4; Tetrabromosilane; Silicon (IV) bromide	2
76	Bromine Trifluoride	BrF3	BrF_3		1
116	Bromine Pentafluoride	BrF5	BrF_5		1
279	Tantalum (V) Ethoxide	C10H25O5Ta	$C_{10}H_{25}O_5Ta$	Ta(Oet)5	2
146	Tributylaluminum	C12H27Al	$(CH_3CH_2CH_2CH_2)_3Al$	TBAl	3
262	Triisobutylaluminum	C12H27Al	$(C_4H_9)_3Al$		2
194	Titanium Tetraisopropoxide	C12H28OTi	$Ti(OC_3H_7)_4$		1

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
280	Diphenylmethylenediamine	C13H14N2	$C_{13}H_{14}N_2$		2
281	Diphenylmethan-4,4'-diisocyanat	C15H10N2O	$C_{15}H_{10}N_2O$	UN2489; Benzene,1,1'-methylenebis(isocyanatophenyl)	2
282	Tetrakis(diethylamino) titanium	C16H40N4Ti	$C_{16}H_{40}N_4Ti$		2
130	Dibromotetrafluorethane	C2Br2F4	BrF_2CCF_2Br	F-114B2, R-114B2	1
105	Bromotrifluoroethylene	C2BrF3	CF_2CFBr		1
125	Dichlorotetrafluoroethane	C2Cl2F4	F_3CCCl_2F	F-114, R-114	1
126	Trichlorotrifluoroethane	C2Cl3F3	CF_2ClCCl_2F	F-113, R-113	1
168	Tetrachloroethylene	C2Cl4	$Cl_2C{=}CCl_2$	Perchloroethylene or Ethylene, Perchloro	2
206	Chlorotrifluoroethylene	C2ClF3	$FCCl{=}CF_2$	R-1113, FREON-1113	2
119	Chloropentafluoroethane	C2ClF5	$ClCF_2CF_3$	F-115, R-115	1
260	Trifluoroacetonitrile	C2F3N	F_3CCN		2
94	Tetrafluorethylene	C2F4	$F_2C{=}CF_2$		1
118	Hexafluoroethane	C2F6	F_3CCF_3	F-116, Perfluoroethane	1
42	Acetylene	C2H2	HC≡CH	Ethyne	1
191	Dichloroethylene -trans	C2H2Cl2	CHCl=CHCl		2
210	Dichloroethylene	C2H2Cl2	$CH_2{=}CCl_2$	Vinylidene Chloride	2
211	Dichloroethylene -cis	C2H2Cl2	CHCl=CHCl		2
64	Difluoroethylene	C2H2F2	$CH_2{=}CF_2$	G-1132A,Vinylidenefluoride	1
156	Tetrafluoroethane	C2H2F4	CH_2FCF_3	R-134A, F-134A	2
56	Vinyl Bromide	C2H3Br	$CH_2{=}CHBr$		1
55	Vinyl Chloride	C2H3Cl	$CH_2{=}CHCl$	Chloroethylene	1
112	Trichloroethane	C2H3Cl3	CH_3CCl_3	TCA, Methylchloroform	2
103	Difluorochloroethane	C2H3ClF2	CF_2ClCH_3	F-142B, R-142B	1
203	Chlorodifluoroethane	C2H3ClF2	$CH_3\text{-}CF_2Cl$	R-142b	4
51	Vinyl Fluoride	C2H3F	$H_2C{=}CHF$		1
173	Acetonitrile	C2H3N	CH_3CN		2
38	Ethylene	C2H4	$CH_2{=}CH_2$	Ethene	1
222	Ethylene Dichloride	C2H4Cl2	$ClCH_2CH_2Cl$	1,2 Dichloroethane	2
82	Difluoroethane	C2H4F2	CH_3CHF_2	Ethylidene Fluoride, R-152A	1
45	Ethylene Oxide	C2H4O	C_2H_4O	Acetaldehyde	1
283	Acetic Acid	C2H4O2	CH_3COOH	Ethanoic acid; UN 2789;	2
75	Ethyl Chloride	C2H5Cl	C_2H_5Cl	Chloroethane or Ethane, Chloro or Ethyl Chloride	1
221	Ethyl Fluoride	C2H5F	CH_3CH_2F	Fluoroethane, R-161, FREON-161	2
54	Ethane	C2H6	CH_3CH_3		1
218	Dimethylcadmium	C2H6Cd	$(CH_3)_2Cd$		2
73	Dimethyl Ether	C2H6O	CH_3OCH_3	Methylether	1
136	Ethanol	C2H6O	CH_3CH_2OH		2
169	Ethyleneglycol	C2H6O2	$HOCH_2CH_2OH$	Ethanediol, Glycol	2
284	Dimethyl selenide	C2H6Se	C_2H_6Se	(CH3)2Se; Selenium dimethyl; Dimethylselenium	2
212	Dichlorodimethylsilane	C2H6SiCl2	$(CH_3)_2SiCl_2$		2
220	Dimethyltellurium	C2H6Te	$(CH_3)_2Te$		2
135	Dimethylzinc	C2H6Zn	$(CH_3)_2Zn$		3
164	Dimethylaluminum-hydride	C2H7Al	$(CH_3)_2AlH$	DMAH	13
85	Dimethylamine	C2H7N	$(CH_3)_2NH$		1
233	Monoethylamine	C2H7N	$C_2H_5NH_2$		2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
285	Ethoxy Silane	C2H8OSi	C_2H_8OSi		2
219	Dimethylsilane	C2H8Si	$(CH_3)_2SiH_2$		2
137	Halothane	C2HBrClF3	$BrClHCCF_3$		6
186	2,2 Dichloro1,1,1 Trifluoroethane	C2HCl2F3	$CHCl_2\text{-}CF_3$	Freon 123, Suva 123	2
204	Chlorodifluoroethylene	C2HClF2	$CF_2{=}CHCl$	R-1122, FREON-1122	4
223	Fluoroacetylene	C2HF	FC≡CH		2
155	Pentafluoroethane	C2HF5	CF_3CHF_2	F-125, R-125	9
59	Cyanogen	C2N2	NCCN	Oxalodinitrile	1
138	Hexafluoropropylene	C3F6	$CF_3CF{=}CF_2$	Perfluoropropylene or Propylene, Perfluoro	1
225	Hexafluoroacetone	C3F6O	$(CF_3)_2CO$		2
286	Hexafluoropropylene oxide	C3F6O	C_3F_6O	Hexafluoroepoxypropane	2
128	Perfluoropropane	C3F8	$CF_2(CF_3)_2$		1
287	Trimethoxy Silane	C3H10O3Si	$C_3H_{10}O_3Si$		2
190	Trimethyl Silane	C3H10Si	$(CH_3)_3SiH$		2
165	Trimethylaminealane	C3H12AlN	$(CH_3)_3NAlH_3$	TMAA	11
267	Hexafluoro Propane	C3H2F6	$CH_2FCF_2CF_3$	1,1,1,2,2,3-Hexafluoropropane	2
288	Pentafluoropropanol	C3H3F5O	$C_2F_5CH_2OH$	Perfluorodihydropropanol, 1,1,1,2,2-Pentafluoropropane	2
276	Acrylonitrile	C3H3N	$CH_2{=}CHCN$	Acrylon; Propenenitrile	3
66	Allene	C3H4	$CH_2{=}C{=}CH_2$	Propadiene	1
68	Methyl Acetylene	C3H4	$CH_3C{\equiv}CH$	Propyne	1
289	Acrylic Acid	C3H4O2	$C_3H_4O_2$	2-Propenoic acid; CH2=CHCOOH	2
290	Trifluoropropane	C3H5F3	$C_3H_5F_3$	1,1,1-Trifluoropropane; CH3CH2CF3	2
61	Cyclopropane	C3H6	C_3H_6		1
69	Propylene	C3H6	$CH_3CH{=}CH_2$	Propene	1
81	Methyl Vinyl Ether	C3H6O	$CH_3OCH{=}CH_2$		1
184	Acetone	C3H6O	CH_3COCH_3		2
291	Ethyl Formate	C3H6O2	$HCO_2C_2H_5$	Ethyl ester formic acid; HC00C2H5	3
292	Methyl Acetate	C3H6O2	$CH_3CO_2CH_3$	Methyl ester acetic acid; UN 1231	3
331	Acetaldehyde methoxy	C3H6O2	CH_3OCH_2CHO		3
332	Acetone, Hydroxy	C3H6O2	CH_3COCH2OH	Acetol	3
333	Glycol methylene ether	C3H6O2	$C_3H_6O_2$	1,3-Dioxolane	3
334	Propanoic Acid	C3H6O2	$CH_3CH_2CO_2H$	Propionic acid	3
335	Glycidol	C3H6O2	CH_2CHCH_2OH	1-Propanol, 2,3 epoxy	3
293	Propenamine	C3H7N	C_3H_7N	Allylamine; Monoallylamine; UN2334	2
89	Propane	C3H8	$CH_3CH_2CH_3$		1
187	Isopropyl Alcohol	C3H8O	$(CH_3)_2CHOH$	2-Propanol	2
149	Trimethylaluminum	C3H9Al	$Al(CH_3)_3$	TMA, TMAl	4
151	Trimethylarsenic	C3H9As	$(CH_3)_3As$	Trimethylarsine, TMAs	2
277	Trimethylborane	C3H9B	$(CH_3)_3B$		2
131	Trimethoxyborine	C3H9BO3	$B(OCH_3)_3$	TMB, Trimethylborate	2
152	Trimethylgallium	C3H9Ga	$Ga(CH_3)_3$	TMGa	4
153	Trimethylindium	C3H9In	$(CH_3)_3In$	TMIn	3
109	Trimethylamine	C3H9N	$(CH_3)_3N$	Methylamine	1
294	Trimethyl Ester Phosphoric Acid	C3H9O4P	$C_3H_9O_4P$	Methyl phosphate; Trimethoxyphosphine oxide	2
132	Trimethylphosphorous	C3H9P	$(CH_3)_3P$	Trimethylphosphine, TMP	2
133	Trimethylphosphite	C3H9PO3	$(CH_3O)_3P$	TMPi, Trimethoxyphosphine	2

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
150	Trimethylantimony	C3H9Sb	$(CH_3)_3Sb$	Trimethylstibene	2
295	Heptafluoropropane	C3HF7	C_3HF_7	1,1,1,2,3,3,3-Heptafluoropropane, Freon 227	2
241	Perfluorobutane	C4F10	C_4F_{10}		3
270	Hexafluoro-2-Butyne	C4F6	$CF_3C{\equiv}CCF_3$	Bis(trifluoromethyl)acetylene; Perfluoro-2-butyne	3
296	Hexafluorocyclobutene	C4F6	C_4F_6	Perfluorocyclobutene; 1,2,3,3,4,4-Hexafluorocyclobutene	3
297	Hexafluoro butadiene-1,3	C4F6	$CF_2{=}CF{-}CF{=}CF_2$	Perfluorobutadiene-1,3;	3
129	Octafluorocyclobutane	C4F8	$(CF_2)_4$	Perfluorocyclobutane or Cyclobutane, Perfluoro	1
236	Octafluorobutane	C4F8	C_4F_8		3
111	Isobutane	C4H10	$(CH_3)_2CHCH_3$	2-Methylpropane or Propane, 2-Methyl	1
117	Butane	C4H10	$CH_3(CH_2)_2CH_3$		1
271	Butanol-1	C4H10O	$CH_3CH_2CH_2CH_2OH$		3
336	Butanol-2	C4H10O	$CH_3CH_2CH(OH)CH_3$		3
337	Tertiary Butyl Alcohol	C4H10O	$(CH_3)_3COH$		3
338	Diethyl ether	C4H10O	$C_2H_5OC_2H_5$		3
339	Methyl propyl ether	C4H10O	$CH_3OC_3H_7$		3
340	Methyl isopropyl ether	C4H10O	$(CH_3)_2CHOCH_3$		3
341	Isobutyl Alcohol	C4H10O	$(CH_3)_2CHCH_2OH$		3
298	Diethyl sulfide	C4H10S	$C_4H_{10}S$	UN2375; Ethyl sulfide;	2
214	Diethylzinc	C4H10Zn	$Zn(C_2H_5)_2$		2
161	Tertiarybutylarsine	C4H11As	$C(CH_3)_3AsH_2$	TBA	8
213	Diethylamine	C4H11N	$(C_2H_5)_2NH$		2
162	Tertiarybutylphosphine	C4H11P	$C(CH_3)_3PH_2$	TBP	8
250	Tetramethylgermanium	C4H12Ge	$(CH_3)_4Ge$		2
299	Tetramethoxygermanium	C4H12GeO4	$(CH_3O)_4Ge$	Ge(OMe)4	2
300	Dimethoxydimethyl silane	C4H12O2Si	$(CH_3O)_2Si(CH_3)_2$	KBM 22	2
301	Tetramethoxy silane	C4H12O4Si	$(CH_3O)_4Si$	Silicic Acid (H4SiO4); Tetramethyl ester; Tetramethyl silicate	2
302	Tetramethyl Lead	C4H12Pb	$(CH_3)_4Pb$	(CH3)4Pb; Plumbane, tetramethyl;	2
154	Diethylsilane	C4H12Si	$(C_2H_5)_2SiH_2$		2
251	Tetramethylsilane	C4H12Si	$(CH_3)_4Si$		2
252	Tetramethyl Tin	C4H12Sn	$(CH_3)_4Sn$		2
166	Dimethylethylaminealane	C4H14NAl	$(CH_3)_2C_2H_5NAlH_3$	DMEAA	14
158	Tetramethylcyclotetra-siloxane	C4H16Si4O4	$(CH_3)_4H_4(SiO)_4$	TOMCATS	7
93	Ethyl Acetylene	C4H6	$CH_3CH_2C{\equiv}CH$		1
100	Butadiene	C4H6	$CH_2{=}C{=}CHCH_3$	Methylallene	1
98	Transbutene	C4H8	$CH_3CH{=}CHCH_3$		2
104	Butene	C4H8	$CH_3CH_2CH{=}CH_2$	1-Butene	1
106	Isobutene	C4H8	$(CH_3)_2C{=}CH_2$	Isobutylene, Methylpropene	2
107	Cisbutene	C4H8	$CH_3CH{=}CHCH_3$	Cis-2-Butene	2
207	Cyclobutane	C4H8	C_4H_8	Tetramethylene	2
182	Tetrahydrofuran	C4H8O	C_4H_8O		2
140	Nickel Carbonyl	C4O4Ni	$Ni(CO)_4$		1
266	Octafluorocyclopentene	C5F8	$CF_2{=}C(CF_3){-}CF{=}CF_2$		3
120	Methylbutene	C5H10	$CH_3CH_2CCH_3{=}CH_2$	2-Methyl-1-Butene	1
122	Dimethylpropane	C5H12	$(CH_3)_4C$	Neopentane	2
231	Isopentane	C5H12	$CH_3CH_2CH(CH_3)_2$	2-Methylbutane	2

Code	Gas Name	Symbol	Formula	Synonym	Ref
240	Pentane	C5H12	$CH_3(CH_2)_3CH_3$		2
303	Trimethylvinylsilane	C5H12Si	$C_5H_{12}Si$	Vinyltrimethylsilane; CH2=CHSi(CH3)3	2
272	Hexafluoro Acetylacetone	C5H2F6O2	$C_5H_2F_6O_2$		1
304	Pyridine	C5H5N	C_5H_5N	Azabenzene; Azine	2
305	Methyl Methacrylate Polymer	C5H8O2	$C_5H_8O_2$	Poly(methyl methacrylate); 2-Methyl 1-2-propenoic acid	2
230	Iron Carbonyl	C5O5Fe	$Fe(CO)_5$		2
192	Hexafluorobenzene	C6F6	C_6F_6		2
178	4-Methyl, 1-Pentene	C6H12	$(CH_3)_2CHCH_2CH{=}CH_2$		2
127	Hexane	C6H14	$CH_3(CH_2)_4CH_3$		2
170	Hexanediol-1,6	C6H14O2	$HO(CH_2)_6OH$	Hexyleneglycol, Hexamethyleneglycol	2
257	Triethylaluminum	C6H15Al	$(C_2H_5)_3Al$		2
306	Triethyl Arsine	C6H15As	$(C_2H_5)_3As$	Arsine; Triethylarsenic	2
307	Triethoxy Arsine	C6H15AsO3	$(C_2H_5O)_3As$	Triethyl ester arsenous acid; Triethyl arsenite	2
308	Triethoxyborane	C6H15BO3	$(C_2H_5O)_3B$	Boron triethoxide;	2
148	Triethylgallium	C6H15Ga	$(C_2H_5)_3Ga$	TEGa	4
309	Triethylindium	C6H15In	$(C_2H_5)_3In$	Indium triethyl	2
310	Triethylamine	C6H15N	$(C_2H_5)_3N$	UN 1296; Ethanamine;	2
163	Triethylborate	C6H15O3B	$B(OC_2H_5)_3$	TEB, Triethoxyborane	2
311	Triethoxyphosphine	C6H15O3P	$(C_2H_5O)_3P$	Triethyl phosphite; UN2323; Phosphorous acid, triethyl ester	2
274	TEAsat	C6H15O4As	$(C_2H_5O)_3AsO$		1
224	Fluorotriethoxysilane	C6H15OSiF	$(C_2H_5O)_3SiF$		2
258	Triethylantimony	C6H15Sb	$(C_2H_5)_3Sb$		2
188	Diethoxy Dimethyl Silane	C6H16O2Si	$(C_2H_5O)_2Si(CH_3)_2$		2
312	Triethoxy Silane	C6H16O3Si	$(C_2H_5O)_3SiH$		2
313	Triethyl Silane	C6H16Si	$(C_2H_5)_3SiH$	(C2H5)3SiH;	2
139	Hexamethyldisilane	C6H18Si2	$(CH_3)_3Si_2(CH_3)_3$	HMDSi, HMDS	3
228	Hexamethyldisiloxane	C6H18Si2O	$(CH_3)_6Si_2O$		2
227	Hexamethyldisilazane	C6H19Si2N	$(CH_3)_6Si_2NH$		2
172	Chlorobenzene	C6H5Cl	C_6H_5Cl	Chlorobenzol, Phenylchloride	2
197	Benzene	C6H6	C_6H_6		2
180	Phenol	C6H6O	C_6H_5OH		2
314	Trimethylisoxazole	C6H9NO	$CH_3CH{=}CHCH{=}CHCONH_2$	3,4,5-Trimethylisoxazole, Sorbamide	3
273	Tungsten Hexacarbonyl	C6O6W	$W(CO)_6$		1
177	Methylcyclohexane	C7H14	$CH_3C_6H_{11}$	Hexahydrotoluene	2
181	Toluene	C7H8	$C_6H_5CH_3$	Methylbenzene	2
174	Ethylbenzene	C8H10	$C_6H_5C_2H_5$		2
179	o-Xylene	C8H10	$1,2\text{-}(CH_3)_2C_6H_4$	1,2-Dimethylbenzene	2
263	Xylene m-	C8H10	$1,3\text{-}(CH_3)_2C_6H_4$	1,3 Dimethyl Benzene	3
264	Xylene p-	C8H10	$1,4\text{-}(CH_3)_2C_6H_4$	1,4 Dimethyl Benzene	3
342	3-one-2,5-dimethyl hexadiene	C8H10	$CH_2{=}C(CH_3)C{\equiv}CC(CH_3)CH_2$		3
343	1,7-Octadiyne	C8H10	$HC{\equiv}C(CH_2)_4C{\equiv}CH$		3
344	2,6-Octadiyne	C8H10	$CH_3C{\equiv}CCH_2CH_2C{\equiv}CCH_3$		3
345	1,3,5,7-Octatetraene	C8H10	$CH_2{=}CHCH{=}CHCH{=}CHCH{=}CH_2$		3
237	Octane	C8H18	$CH_3(CH_2)_6CH_3$		2

Code	Gas Name	Symbol	Formula	Synonym	Ref
315	Tetraethylgermane	C8H20Ge	$(C_2H_5)_4Ge$	(C2H5)4Ge; Germanium tetraethyl	2
144	Tetraethoxysilane	C8H20O4Si	$(C_2H_5O)_4Si$	TEOS	2
316	Tetraethyl Lead	C8H20Pb	$(C_2H_5)_4Pb$	Plumbane, tetraethyl; UN1649	2
317	Tetraethyl Silane	C8H20Si	$C_8H_{20}Si$	Tetraethylsilane; Tetraethylsilicon; (C2H5)4Si	2
318	Tetrakis(dimethylamino) titanium	C8H24N4Ti	$C_8H_{24}N_4Ti$		2
319	Styrene	C8H8	C_8H_8	Ethenylbenzene; Un 2055	2
320	Triallylamine	C9H15N	$C_9H_{15}N$		2
209	Dibromodifluoromethane	CBr2F2	Br_2CF_2	R-12B2, FREON-12B2	2
200	Carbon Tetrabromide	CBr4	CBr_4		2
199	Bromochlorodifluoromethane	CBrClF2	$BrClCF_2$		2
80	Bromotrifluoromethane	CBrF3	$BrCF_3$	F-13B1, R-13B1	1
84	Dichlorodifluoromethane	CCl2F2	CCl_2F_2	F-12, R-12	1
60	Phosgene	CCl2O	CCl_2O	Carbonyl Chloride	1
91	Trichlorofluoromethane	CCl3F	CCl_3F	F-11, R-11	1
101	Carbon Tetrachloride	CCl4	CCl_4	Tetrachloromethane or Methane, Tetrachloro	2
74	Chlorotrifluoromethane	CClF3	$ClCF_3$	F-13, R-13	1
46	Carbonyl Fluoride	CF2O	CF_2O		1
259	Trifluoroacetic Acid	CF3CO2H	CF_3CO_2H		2
63	Carbon Tetrafluoride	CF4	CF_4	Tetrafluoromethane or Methane, Tetrafluoro	1
321	Trifluoromethylhypofluorite	CF4O	CF_4O	CF3OF; Hypofluorous acid; trifuoromethyl ester	2
268	Methylene Bromide	CH2Br2	CH_2Br_2	UN 2664; Methyl dibromide, Dibromomethane	1
265	Dichloromethane	CH2Cl2	CH_2Cl_2		
160	Difluoromethane	CH2F2	CH_2F_2	Methylene Fluoride	2
208	Diazomethane	CH2N2	CH_2N_2	Acomethylene	2
322	Formaldehyde	CH2O	CH_2O	H2C0; UN1198; BFV	2
44	Methyl Bromide	CH3Br	CH_3Br	Bromomethane or Methane, Bromo	1
36	Methyl Chloride	CH3Cl	CH_3Cl	Chloromethane or Methane, Chloro	1
183	Methyltrichlorosilane	CH3Cl3Si	CH_3SiCl_3	MTS	2
33	Methyl Fluoride	CH3F	CH_3F	Fluoromethane or Methane, Fluoro	1
323	Iodomethane	CH3I	CH_3I	Methyl iodide; Un 2644	2
235	Nitromethane	CH3NO2	CH_3NO_2		2
28	Methane	CH4	CH_4		1
176	Methanol	CH4O	CH_3OH	Methyl Alcohol	2
47	Methyl Mercaptan	CH4S	CH_3SH		1
52	Methylamine	CH5N	CH_3NH_2	Amino Methane, Monomethylamine	2
234	Monomethyl Hydrazine	CH6N2	$CH_3N_2H_3$		2
185	Methylsilane	CH6Si	CH_3SiH_3	Monomethylsilane	2
83	Tribromomethane	CHBr3	$CHBr_3$		2
65	Dichlorofluoromethane	CHCl2F	$CHCl_2F$	F-21, R-21	1
71	Chloroform	CHCl3	$CHCl_3$	Trichloromethane or Methane, Trichloro	2
57	Chlorodifluoromethane	CHClF2	$CClHF_2$	F-22, R-22	1
49	Fluoroform	CHF3	CHF_3	Trifluoromethane or Methane, Trifluoro, F-23, R-23	1
19	Chlorine	Cl2	Cl_2		1
37	Cyanogen Chloride	ClCN	ClCN		1

Code	Gas Name	Symbol	Formula	Synonym	Ref
77	Chlorine Trifluoride	ClF3	ClF_3		1
202	Chlorine Pentafluoride	ClF5	ClF_5		2
201	Chlorine Dioxide	ClO2	ClO_2		2
72	Perchloryl Fluoride	ClO3F	ClO_3F		1
9	Carbon Monoxide	CO	CO		1
25	Carbon Dioxide	CO2	CO_2		1
34	Carbonyl Sulfide	COS	COS		1
40	Carbon Disulfide	CS2	CS_2		2
14	Deuterium	D2	H_2^2	D2	2
18	Fluorine	F2	F_2		1
217	Digermane	Ge2H6	Ge_2H_6		2
113	Germanium Tetrachloride	GeCl4	$GeCl_4$	Tetrachlorogermane	2
99	Germanium Tetrafluoride	GeF4	GeF_4	Tetrafluorogermane	2
43	Germane	GeH4	GeH_4		1
7	Hydrogen	H2	H_2		1
20	Water Vapor	H2O	H_2O		2
22	Hydrogen Sulfide	H2S	H_2S		1
23	Hydrogen Selenide	H2Se	H_2Se		1
171	Sulfuric Acid	H2SO4	H_2SO_4		2
229	Hydrogen Telluride	H2Te	H_2Te		2
10	Hydrogen Bromide	HBr	HBr		1
11	Hydrogen Chloride	HCl	HCl		1
24	Hydrogen Cyanide	HCN	HCN		1
1	Helium	He	He		1
12	Hydrogen Fluoride	HF	HF		1
275	Hafnium Tetranitrate	HfN4O12	$Hf(NO_3)_4$		1
329	Mercury	Hg	Hg	UN2809	2
17	Hydrogen Iodide	HI	HI		1
269	Hydrazoic Acid	HN3	HN_3		1
167	Nitric Acid	HNO3	HNO_3		2
115	Iodine Pentafluoride	IF5	IF_5		1
5	Krypton	Kr	Kr		1
124	Molybdenum Hexafluoride	MoF6	MoF_6		2
13	Nitrogen	N2	N_2		1
157	Tetrafluorohydrazine	N2F4	F_2NNF_2	Dinitrogen Tetrafluoride	1
50	Hydrazine	N2H4	H_2NNH_2		2
27	Nitrous Oxide	N2O	N_2O		1
78	Nitrogen Trioxide	N2O3	N_2O_3		1
95	Nitrogen Tetroxide	N2O4	N_2O_4	Dinitrogenoxide	2
2	Neon	Ne	Ne		1
232	Difluoroamidogen	NF2	NF_2		2
53	Nitrogen Trifluoride	NF3	NF_3		1
29	Ammonia	NH3	NH_3		1
16	Nitric Oxide	NO	NO		2
26	Nitrogen Dioxide	NO2	NO_2		1
141	Nitrosyl Chloride	NOCl	NOCl		1
15	Oxygen	O2	O_2		1
30	Ozone	O3	O_3		1

Code	*Gas Name*	*Symbol*	*Formula*	*Synonym*	*Ref*
238	Oxygen Dichloride	OCl2	OCl_2		2
41	Oxygen Difluoride	OF2	OF_2		1
193	Phosphorus Trichloride	PCL3	PCl_3		2
62	Phosphorus Trifluoride	PF3	PF_3		1
143	Phosphorus Pentafluoride	PF5	PF_5		1
31	Phosphine	PH3	PH_3		1
102	Phosphorous Oxychloride	POCl3	$POCl_3$		2
243	Rhenium Hexafloride	ReF6	ReF_6		2
3	Radon	Rn	Rn		2
189	Sulfur Monochloride	S2Cl2	S_2Cl_2		2
255	Tribromostibine	SbBr3	$SbBr_3$		2
256	Trichlorostibine	SbCl3	$SbCl_3$		2
245	Stibine	SbH3	SbH_3		2
325	Selenium Hexafluoride	SeF6	SeF_6	UN 2194; Selenium fluoride	2
86	Sulfur Tetrafluoride	SF4	SF_4		1
110	Sulfur Hexafluoride	SF6	SF_6		1
97	Disilane	Si2H6	Si_2H_6		2
328	Trisilane	Si3H8	Si_3H_8	Silicopropane; Trisilicane; H_8Si3	2
253	Tetrasilane	Si4H10	Si_4H_{10}		2
108	Silicon Tetrachloride	SiCl4	$SiCl_4$	Tetrachlorosilane	2
244	Deuteriumsilane	SiD4	$SiH^2{}_4$		2
88	Silicon Tetrafluoride	SiF4	SiF_4		1
326	Disilane Hexafluoride	SiF6	SiF_6	F_6Si_2; Hexafluorodisilane	2
67	Dichlorosilane	SiH2Cl2	SiH_2Cl_2		1
134	Difluorosilane	SiH2F2	SiH_2F_2		10
205	Chlorosilane	SiH3Cl	SiH_3Cl		2
327	Fluoro Silane	SiH3F	SiH_3F	H_3FSi	2
39	Silane	SiH4	SiH_4		1
147	Trichlorosilane	SiHCl3	$SiHCl_3$		5
261	Trifluorosilane	SiHF3	$SiHF_3$		2
145	Tin Tetrachloride	SnCl4	$SnCl_4$	Tetrachlorostannane	2
32	Sulfur Dioxide	SO2	SO_2		1
87	Sulfuryl Fluoride	SO2F2	SO_2F_2		1
246	Sulfur Trioxide	SO3	SO_3		2
159	Tritium	T2	$H_3{}^2$	T2	2
247	Tellurium Hexafluoride	TeF6	TeF_6		2
114	Titanium Tetrachloride	TiCl4	$TiCl_4$		2
254	Titanium Tetraiodide	TiI4	TiI_4		2
123	Uranium Hexafluoride	UF6	UF_6		2
121	Tungsten Hexafluoride	WF6	WF_6		2
6	Xenon	Xe	Xe		1
324	Xenon difluoride	XeF2	XeF_2	F_2Xe; Xenon fluoride	2
330	Zinc	Zn	Zn	UN 1383	2
90	Intentionally Left Blank				
92	Intentionally Left Blank				
175	Intentionally Left Blank				

semi

9 Mixed Gas Table Sorted by Code

Table 4 Mixed Gases Sorted by Code

Mixed Game Name	*Symbol*	*Code*
15%PHOSPHINE/NITROGEN	15%PH3/N2	0500
5%PHOSPHINE/NITROGEN	5%PH3/N2	0501
20%SILANE/NITROGEN	20%SiH4/N2	0502
40%ARGON/TUNGSTEN HEXAFLUORIDE	40%Ar/WF6	0503
10%ARSINE/HYDROGEN	10%AsH3/H2	0504
40%OXYGEN/HEXAFLUOROETHANE(FREON-116)	40%O2/C2F6	0505
2%TRICHLOROETHANE/NITROGEN	2%C2H3Cl3/N2	0506
20%CARBON DIOXIDE/HYDROGEN	20%CO2/H2	0507
30%CARBON DIOXIDE/AIR	30%CO2/Air	0508
10%GERMANE/HYDROGEN	10%GeH4/H2	0509
5%HYDROGEN SELENIDE/HYDROGEN	5%H2Se/H2	0510
10%HYDROGEN SELENIDE/HYDROGEN	10%H2Se/H2	0511
13%HYDROGEN CHLORIDE/1.32%XENON/NEON	13%HCl/1.32%Xe/Ne	0512
20%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	20%O2/CF4	0513
1%PHOSPHINE/NITROGEN	1%PH3/N2	0514
1.6%PHOSPHINE/21%SILANE/ARGON	1.6%PH3/21%SiH4/Ar	0515
10%PHOSPHINE/HYDROGEN	10%PH3/H2	0516
25%PHOSPHINE/SILANE	25%PH3/SiH4	0517
50%PHOSPHINE/NITROGEN	50%PH3/N2	0518
15%SILANE/NITROGEN	15%SiH4/N2	0519
21%SILANE/4%PHOSPHINE/ARGON	21%SiH4/4%PH3/Ar	0520
50%SILANE/HELIUM	50%SiH4/He	0521
20%TRICHLOROSILANE/HYDROGEN	20%SiHCl3/H2	0522
5%TETRAETHYLORTHOSILICATE(TEOS)/NITROGEN	5%Si(C2H5O)4/N2	0523
5%TRIETHYLANTIMONY(TESb)/HYDROGEN	5%(C2H5)3Sb/H2	0524
20%TRIMETHYLALUMINUM(TMAI)/HYDROGEN	20%(CH3)3Al/H2	0525
1%TRIMETHYLBORATE(TMB)/HYDROGEN	1%(CH3O)3B/H2	0526
10%PHOSPHINE/NITROGEN	10%PH3/N2	0527
4.5%PHOSPHINE/NITROGEN	4.5%PH3/N2	0528
20%SILANE/HELIUM	20%SiH4/He	0529
20%PHOSPHINE/SILANE	20%PH3/SiH4	0530
1%PHOSPHINE/SILANE	1%PH3/SiH4	0531
10%HYDROGEN/NITROGEN	10%H2/N2	0532
1.5%PHOSPHINE/SILANE	1.5%PH3/SiH4	0533
3%PHOSPHINE/ARGON	3%PH3/Ar	0534
4%PHOSPHINE/NITROGEN	4%PH3/N2	0535
20%OXYGEN/HELIUM	20%O2/He	0536
1%PHOSPHINE/ARGON	1%PH3/Ar	0537
10%PHOSPHINE/ARGON	10%PH3/Ar	0538
2%PHOSPHINE/ARGON	2%PH3/Ar	0539
20%ARGON/SILANE	20%Ar/SiH4	0540
20%SILANE/ARGON	20%SiH4/Ar	0541
5%HYDROGEN/NITROGEN	5%H2/N2	0542
16%CARBON DIOXIDE/NITROGEN	16%CO2/N2	0543
2%SILANE/HYDROGEN	2%SiH4/H2	0544
15%HYDROGEN/NITROGEN	15%H2/N2	0545

Mixed Game Name	*Symbol*	*Code*
1%PHOSPHINE/HELIUM	1%PH3/He	0546
.01%DIBORANE/HYDROGEN	.01%B2H6/H2	0547
.01%SILANE/HYDROGEN	.01%SiH4/H2	0548
.5%DIBORANE/ARGON	.5%B2H6/Ar	0549
.5%PHOSPHINE/NITROGEN	.5%PH3/N2	0550
.5%SILANE/HYDROGEN	.5%SiH4/H2	0551
.8%PHOSPHINE/NITROGEN	.8%PH3/N2	0552
.8%PHOSPHINE/SILANE	.8%PH3/SiH4	0553
.9%ARSINE/HYDROGEN	.9%AsH3/H2	0554
1%ARSINE/NITROGEN	1%AsH3/N2	0555
1%ARSINE/SILANE	1%AsH3/SiH4	0556
1%DIBORANE/HYDROGEN	1%B2H6/H2	0557
1%DIBORANE/NITROGEN	1%B2H6/N2	0558
1%BORON TRICHLORIDE/HYDROGEN	1%BCl3/H2	0559
1%BORON TRICHLORIDE/NITROGEN	1%BCl3/N2	0560
1%HYDROGEN/NITROGEN	1%H2/N2	0561
1%OXYGEN/NITROGEN	1%O2/N2	0562
1%PHOSPHINE/HYDROGEN	1%PH3/H2	0563
1.5%ARSINE/HYDROGEN	1.5%AsH3/H2	0564
10%SILANE/ARGON	10%SiH4/Ar	0565
10%FLUORINE/HELIUM	10%F2/He	0566
5%WATER VAPOR/AIR	5%H2O/Air	0567
10%WATER VAPOR/NITROGEN	10%H2O/N2	0568
2%OZONE/OXYGEN	2%O3/O2	0569
10%NITROGEN TRIFLUORIDE/OXYGEN	10%NF3/O2	0570
10%OZONE/OXYGEN	10%O3/O2	0571
10%PHOSPHINE/SILANE	10%PH3/SiH4	0572
10%SILANE/HELIUM	10%SiH4/He	0573
8%CARBON TETRAFLUORIDE(FREON-14)/OXYGEN	8%CF4/O2	0574
10%SILANE/HYDROGEN	10%SiH4/H2	0575
10%NITROGEN/ARGON	10%N2/Ar	0576
20%SILANE/HYDROGEN	20%SiH4/H2	0577
15%ARGON/PHOSPHINE	15%Ar/PH3	0578
15%ARSINE/HYDROGEN	15%AsH3/H2	0579
15%DIBORANE/NITROGEN	15%B2H6/N2	0580
15%PHOSPHINE/15%SILANE/NITROGEN	15%PH3/15%SiH4/N2	0581
15%PHOSPHINE/ARGON	15%PH3/Ar	0582
15%PHOSPHINE/HYDROGEN	15%PH3/H2	0583
15%PHOSPHINE/SILANE	15%PH3/SiH4	0584
17%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	17%O2/CF4	0585
2%ARSINE/NITROGEN	2%AsH3/N2	0586
2%DIBORANE/ARGON	2%B2H6/Ar	0587
2%HYDROGEN/NITROGEN	2%H2/N2	0588
2%SILANE/HELIUM	2%SiH4/He	0589
20%ARSINE/HYDROGEN	20%AsH3/H2	0590
20%DIBORANE/SILANE	20%B2H6/SiH4	0591
20%HYDROGEN/CARBON MONOXIDE	20%H2/CO	0592
20%PHOSPHINE/HYDROGEN	20%PH3/H2	0593

Mixed Game Name	*Symbol*	*Code*
21%OXYGEN/NITROGEN	21%O2/N2	0594
3%DIBORANE/NITROGEN	3%B2H6/N2	0595
3%HYDROGEN/HELIUM	3%H2/He	0596
3%HYDROGEN/NITROGEN	3%H2/N2	0597
3%OXYGEN/HELIUM	3%O2/He	0598
3%OZONE/AIR	3%O3/Air	0599
3%PHOSPHINE/NITROGEN	3%PH3/N2	0600
3%PHOSPHINE/SILANE	3%PH3/SiH4	0601
3%SILANE/HELIUM	3%SiH4/He	0602
30%HELIUM/OXYGEN	30%He/O2	0603
30%OXYGEN/HELIUM	30%O2/He	0604
4%DIBORANE/NITROGEN	4%B2H6/N2	0605
4%HYDROGEN/HELIUM	4%H2/He	0606
4%HYDROGEN/NITROGEN	4%H2/N2	0607
4%NITROGEN/HYDROGEN	4%N2/H2	0608
4%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	4%O2/CF4	0609
4%PHOSPHINE/HELIUM	4%PH3/He	0610
4%PHOSPHINE/SILANE	4%PH3/SiH4	0611
40%HELIUM/SILANE	40%He/SiH4	0612
8%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	8%O2/CF4	0613
5%ARSINE/HYDROGEN	5%AsH3/H2	0614
5%DIBORANE/ARGON	5%B2H6/Ar	0615
5%BORON TRICHLORIDE/HYDROGEN	5%BCl3/H2	0616
5%PROPANE/HYDROGEN	5%C3H8/H2	0617
5%CARBON DIOXIDE/NITROGEN	5%CO2/N2	0618
5%HYDROGEN/ARGON	5%H2/Ar	0619
8%PHOSPHINE/NITROGEN	8%PH3/N2	0620
5%NITROGEN/HYDROGEN	5%N2/H2	0621
5%NITROGEN/PHOSPHINE	5%N2/PH3	0622
5%OXYGEN/ARGON	5%O2/Ar	0623
5%OZONE/OXYGEN	5%O3/O2	0624
5%PHOSPHINE/5%SILANE/NITROGEN	5%PH3/5%SiH4/N2	0625
5%PHOSPHINE/ARGON	5%PH3/Ar	0626
5%PHOSPHINE/SILANE	5%PH3/SiH4	0627
5%DICHLOROSILANE/ARGON	5%SiH2Cl2/Ar	0628
5%SILANE/ARGON	5%SiH4/Ar	0629
50%HELIUM/OXYGEN	50%He/O2	0630
50%NITROGEN/OXYGEN	50%N2/O2	0631
50%PHOSPHINE/SILANE	50%PH3/SiH4	0632
50%SILANE/HYDROGEN	50%SiH4/H2	0633
6.5%DIBORANE/15%SILANE/NITROGEN	6.5%B2H6/15%SiH4/N2	0634
6.5%DIBORANE/HYDROGEN	6.5%B2H6/H2	0635
8%PHOSPHINE/SILANE	8%PH3/SiH4	0636
30%OXYGEN/HYDROGEN	30%O2/H2	0637
25%AMMONIA/HYDROGEN	25%NH3/H2	0638
8%OZONE/OXYGEN	8%O3/O2	0639
2%PHOSPHINE/NITROGEN	2%PH3/N2	0640
15%OZONE/OXYGEN	15%O3/O2	0641

Mixed Game Name	*Symbol*	*Code*
40%OXYGEN/SULFURHEXAFLUORIDE	40%O2/SF6	0642
13%HYDROGEN/NITROGEN	13%H2/N2	0643
1%HYDROGEN SULFIDE/HYDROGEN	1%H2S/H2	0644
1%HYDROGEN SELENIDE/HYDROGEN	1%H2Se/H2	0645
10%SILANE/NITROGEN	10%SiH4/N2	0646
10%DISILANE/HELIUM	10%Si2H6/He	0647
20%DISILANE/HELIUM	20%Si2H6/He	0648
10%OXYGEN/HELIUM	10%O2/He	0649
50%HYDROGEN BROMIDE/HYDROGEN CHLORIDE	50%HBr/HCl	0650
12%OZONE/OXYGEN	12%O3/O2	0651
15%NITRIC OXIDE/NITROGEN	15%NO/N2	0652
2%SILANE/NITROGEN	2%SiH4/N2	0653
5%DIBORANE/NITROGEN	5%B2H6/N2	0654
.5%BORON TRICHLORIDE/HYDROGEN	.5%BCl3/H2	0655
.5%PHOSPHINE/HYDROGEN	.5%PH3/H2	0656
3%DIBORANE/HYDROGEN	3%B2H6/H2	0657
1%GERMANE/NITROGEN	1%GeH4/N2	0658
3%DIBORANE/5%SILANE/NITROGEN	3%B2H6/5%SiH4/N2	0659
.3%PHOSPHINE/SILANE	.3%PH3/SiH4	0660
30%NITROGEN TRIFLUORIDE/NITROGEN	30%NF3/N2	0661
.8%DIBORANE/NITROGEN	.8%B2H6/N2	0662
2%ARSINE/SILANE	2%AsH3/SiH4	0663
8%GERMANE/HYDROGEN	8%GeH4/H2	0664
3%ARSINE/HYDROGEN	3%AsH3/H2	0665
10%DIBORANE/NITROGEN	10%B2H6/N2	0666
8%PHOSPHINE/HELIUM	8%PH3/He	0667
10%AMMONIA/NITROGEN	10%NH3/N2	0668
5%FLUORINE/NITROGEN TRIFLUORIDE	5%F2/NF3	0669
10%DISILANE/ARGON	10%Si2H6/Ar	0670
3%PHOSPHINE/5%SILANE/NITROGEN	3%PH3/5%SiH4/N2	0671
3%NITROGEN/HYDROGEN	3%N2/H2	0672
.7%ARSINE/HYDROGEN	.7%AsH3/H2	0673
10%PHOSPHINE/HELIUM	10%PH3/He	0674
.8%PHOSPHINE/HELIUM	.8%PH3/He	0675
7.5%PHOSPHINE/SILANE	7.5%PH3/SiH4	0676
20%FLUORINE/HELIUM	20%F2/He	0677
22%PHOSPHINE/SILANE	22%PH3/SiH4	0678
5%TRICHLOROSILANE/HYDROGEN	5%SiHCl3/H2	0679
25%TRICHLOROSILANE/HYDROGEN	25%SiHCl3/H2	0680
.8%PHOSPHINE/DISLANE	.8%PH3/Si2H6	0681
13%TRICHLOROSILANE/HYDROGEN	13%SiHCl3/H2	0682
5%DIBORANE/SILANE	5%B2H6/SiH4	0683
1%SILANE/DIBORANE	1%SiH4/B2H6	0684
7%METHYLENE CHLORIDE/3%OZONE/AIR	7%CH2Cl2/3%O3/Air	0685
50%FLUOROFORM/ARGON	50%CHF3/Ar	0686
20%HELIUM/OXYGEN	20%He/O2	0687
3%ARSINE/ARGON	3%AsH3/Ar	0688
10%METHYLSILANE/HYDROGEN	10%CH6Si/H2	0689

Mixed Game Name	*Symbol*	*Code*
.05%DIBORANE/HYDROGEN	.05%B2H6/H2	0690
4%PHOSPHINE/ARGON	4%PH3/Ar	0691
8%HYDROGEN/ARGON	8%H2/Ar	0692
5%PHOSPHINE/HELIUM	5%PH3/He	0693
15%HYDROGEN/ARGON	15%H2/Ar	0694
2%DIBORANE/NITROGEN	2%B2H6/N2	0695
2%PHOSPHINE/SILANE	2%PH3/SiH4	0696
15%DIBORANE/ARGON	15%B2H6/Ar	0697
10%GERMANE/ARGON	10%GeH4/Ar	0698
5%METHANE/HELIUM	5%CH4/He	0699
4%HYDROGEN/ARGON	4%H2/Ar	0700
10%DIBORANE/HYDROGEN	10%B2H6/H2	0701
40%SILANE/HELIUM	40%SiH4/He	0702
2%ARSINE/HYDROGEN	2%AsH3/H2	0703
10%GERMANE/HELIUM	10%GeH4/He	0704
9.4%ARGON/NITROGEN TRIFLUORIDE	9.4%Ar/NF3	0705
8.6%ARGON/NITROGEN TRIFLUORIDE	8.6%Ar/NF3	0706
.8%PHOSPHINE/HYDROGEN	.8%PH3/H2	0707
.06%ARSINE/HYDROGEN	.06%AsH3/H2	0708
5%PHOSPHINE/HYDROGEN	5%PH3/H2	0709
10%METHANE/ARGON	10%CH4/Ar	0710
5%ACETONE/NITROGEN	5%C3H6O-m)/N2	0711
5%BENZENE/NITROGEN	5%C6H6/N2	0712
20%DISILANE/HYDROGEN	20%Si2H6/H2	0713
8%PROPANE/10%AMMONIA/AIR	8%C3H8/10%NH3/Air	0714
8.2%PROPANE/9.8%AMMONIA/AIR	8.2%C3H8/9.8%NH3/Air	0715
10%CYCLOPROPANE/HELIUM	10%C3H6-a)/He	0716
2%METHYSILANE/HYDROGEN	2%CH6Si/H2	0717
10%ETHYLENE/HELIUM	10%C2H4/He	0718
5%CHLORINE/HELIUM	5%Cl2/He	0719
5%FLUORINE/HELIUM	5%F2/He	0720
.7%ARSINE/HELIUM	.7%AsH3/He	0721
5%DIBORANE/HYDROGEN	5%B2H6/H2	0722
20%OZONE/NITROGEN	20%O3/N2	0723
1%ARSINE/HYDROGEN	1%AsH3/H2	0724
40%HYDROGEN/HELIUM	40%H2/He	0725
5%HYDROGEN CHLORIDE/NITROGEN	5%HCl/N2	0726
8%HYDROGEN/NITROGEN	8%H2/N2	0727
20%CARBON TETRAFLUORIDE/NITROGEN	20%CF4/N2	0728
10%CARBON MONOXIDE/CARBON DIOXIDE	10%CO/CO2	0729
10%CARBON MONOXIDE/AIR	10%CO/Air	0730
10%DISILANE/HYDROGEN	10%Si2H6/H2	0731
5%FLUORINE/NITROGEN	5%F2/N2	0732
1%FLUORINE/NEON	1%F2/Ne	0733
5%CARBON DIOXIDE/15%OXYGEN/NITROGEN	5%CO2/15%O2/N2	0734
10%CARBON DIOXIDE/10%OXYGEN/NITROGEN	10%CO2/10%O2/N2	0735
20%OXYGEN/NITROGEN	20%O2/N2	0736
25%HELIUM/ARGON	25%He/Ar	0737

Mixed Game Name	*Symbol*	*Code*
4%HELIUM/NITROGEN	4%He/N2	0738
10%TRIMETHYSILANE/HYDROGEN	10%(CH3)3SiH/H2	0739
2%GERMANE/ARGON	2%GeH4/Ar	0740
.8%ARSINE/HYDROGEN	.8%AsH3/H2	0741
.8%GERMANIUM TETRAFLUORIDE/HYDROGEN	.8%GeF4/H2	0742
.8%DIBORANE/HYDROGEN	.8%B2H6/H2	0743
10%METHANE/HELIUM	10%CH4/He	0744
1%SILANE/HELIUM	1%SiH4/He	0745
25%FLUORINE/NITROGEN	25%F2/N2	0746
50%GERMANE/ARGON	50%GeH4/Ar	0747
7%CARBON DIOXIDE/10%HYDROGEN/20%CARBON MONOXIDE/NITROGEN	7%CO2/10%H2/20%CO/N2	0748
10%HELIUM/HYDROGEN	10%He/H2	0749
1%BUTADIENE/BUTENE	1%C4H6-e)/C4H8-i)	0750
40%GERMANE/ARGON	40%GeH4/Ar	0751
5%HELIUM/NITROGEN	5%He/N2	0752
5%OXYGEN/CARBON TETRAFLUORIDE	5%O2/CF4	0753
10%FLUORINE/ARGON	10%F2/Ar	0754
25%FLUORINE/ARGON	25%F2/Ar	0755
50%FLUORINE/ARGON	50%F2/Ar	0756
50%FLUORINE/HELIUM	50%F2/He	0757
25%FLUORINE/HELIUM	25%F2/He	0758
10%FLUORINE/NITROGEN	10%F2/N2	0759
50%FLUORINE/NITROGEN	50%F2/N2	0760
5%FLUORINE/ARGON	5%F2/Ar	0761
5%HYDROGEN/HELIUM	5%H2/He	0762
5%SULFUR DIOXIDE/HELIUM	5%SO2/He	0763
2%DISILANE/HELIUM	2%Si2H6/He	0764
5%GERMANE/HELIUM	5%GeH4/He	0765
5%DIBORANE/HELIUM	5%B2H6/He	0766
20%PHOSPHINE/NITROGEN	20%PH3/N2	0767
3.5%HYDROGEN/NITROGEN	3.5%H2/N2	0768
50%HEXAFLUOROETHANE/OXYGEN	50%C2F6/O2	0769
25%HEXAFLUOROETHANE/OXYGEN	25%C2F6/O2	0770
.7%GERMANIUM/HYDROGEN	.7%GeH4/H2	0771
1%ACETYLENE/ETHYLENE	1%C2H2/C2H4	0772
5%SILANE/NITROGEN	5%SiH4/N2	0773
.8%CO/.8%O2/20%CO2/32%N2/H2	SELOX GAS MIX	0774
1.5%GERMANE/HYDROGEN	1.5%GeH4/H2	0775
5%BORON TRIFLUORIDE/HELIUM	5%BF3/He	0776
5%PHOSPHORUS PENTAFLUORIDE/HELIUM	5%PF5/He	0777
15%CARBON DIOXIDE/NITROGEN	15%CO2/N2	0778
5%OXYGEN/HELIUM	5%O2/He	0779
5%SILANE/HELIUM	5%SiH4/He	0780
1%NITROGEN DIOXIDE/NITROGEN	1%NO2/N2	0781
1%SULFUR DIOXIDE/NITROGEN	1%SO2/N2	0782
10%CARBON DIOXIDE/NITROGEN	10%CO2/N2	0783
.02%CARBON MONOXIDE/NITROGEN	.02%CO/N2	0784
5%HEXAFLUOROETHANE/OXYGEN	5%C2F6/O2	0785

Mixed Game Name	*Symbol*	*Code*
.1%CARBON MONOXIDE/NITROGEN	.1%CO/N2	0786
15%GERMANIUM TETRACHLORIDE/OXYGEN	15%GeCl4/O2	0787
2%NITROGEN/3%CARBON MONOXIDE/17%CARBON DIOXIDE/HYDROGEN	2%N2/3%CO/17%CO2/H2	0788
.1%PHOSPHINE/NITROGEN	.1%PH3/N2	0789
.1%HYDROGEN CHLORIDE/NITROGEN	.1%HCl/N2	0790
.1%NITROGEN DIOXIDE/AIR	.1%NO2/Air	0791
.1%NITROGEN DIOXIDE/NITROGEN	.1%NO2/N2	0792
.1%PHOSPHINE/HYDROGEN	.1%PH3/H2	0793
.2%SULFUR DIOXIDE/AIR	.2%SO2/Air	0794
.25%CARBON MONOXIDE/.1%HYDROGEN/1%OXYGEN/NITROGEN	.25%CO/.1%H2/1%O2/N2	0795
.25%DIBORANE/HYDROGEN	.25%B2H6/H2	0796
.25%OXYGEN/.5%HYDROGEN/1.5%CARBON MONOXIDE/NITROGEN	.25%O2/.5%H2/1.5%CO/N2	0797
.4%HYDROGEN CHLORIDE/AIR	.4%HCl/Air	0798
.5%ARSINE/SILANE	.5%AsH3/SiH4	0799
1%CARBON DIOXIDE/NITROGEN	1%CO2/N2	0800
1%CARBON MONOXIDE/19% NITROGEN/30%OXYGEN/CARBON DIOXIDE	1%CO/19%N2/30%O2/CO2	0801
1%CARBON MONOXIDE/AIR	1%CO/Air	0802
1%CARBON MONOXIDE/CARBON DIOXIDE	1%CO/CO2	0803
1%CHLORINE/NITROGEN	1%Cl2/N2	0804
1%DIBORANE/ARGON	1%B2H6/Ar	0805
1%HYDROGEN SULFIDE/NITROGEN	1%H2S/N2	0806
1%METHANE/49.5%CARBON DIOXIDE/ARGON	1%CH4/49.5%CO2/Ar	0807
1%NITROGEN DIOXIDE/AIR	1%NO2/Air	0808
1%SULFUR DIOXIDE/ARGON	1%SO2/Ar	0809
1.5%SILANE/ARGON	1.5%SiH4/Ar	0810
1.8%SILANE/NITROGEN	1.8%SiH4/N2	0811
1.9%SILANE/NITROGEN	1.9%SiH4/N2	0812
10%CARBON DIOXIDE/ARGON	10%CO2/Ar	0813
10%FLUORINE/OXYGEN	10%F2/O2	0814
10%METHANE/HYDROGEN	10%CH4/H2	0815
10%OXYGEN/30%CARBON DIOXIDE/ARGON	10%O2/30%CO2/Ar	0816
10%OZONE/NITROGEN	10%O3/N2	0817
10%SULFUR DIOXIDE/NITROGEN	10%SO2/N2	0818
12%HYDROGEN/NITROGEN	12%H2/N2	0819
15%DIBORANE/HYDROGEN	15%B2H6/H2	0820
15%SILANE/ARGON	15%SiH4/Ar	0821
2%NITRIC OXIDE/NITROGEN	2%NO/N2	0822
2%SILANE/ARGON	2%SiH4/Ar	0823
2%SULFUR DIOXIDE/NITROGEN	2%SO2/N2	0824
2.5%DIBORANE/HYDROGEN	2.5%B2H6/H2	0825
2.5%METHANE/AIR	2.5%CH4/Air	0826
20%FLUOROFORM/OXYGEN	20%CF4/O2	0827
22%OXYGEN/HELIUM	22%O2/He	0828
25%CARBON MONOXIDE/HYDROGEN	25%CO/H2	0829
25%PROPANE/PROPYLENE	25%C3H8/C3H6	0830
3%AMMONIA/NITROGEN	3%NH3/N2	0831
3%BORON TRICHLORIDE/HYDROGEN	3%BCl3/H2	0832

Mixed Game Name	*Symbol*	*Code*
3%HYDROGEN/ARGON	3%H2/Ar	0833
3%PHOSPHINE/HELIUM	3%PH3/He	0834
3.5%CARBON DIOXIDE/HELIUM	3.5%CO2/He	0835
30% ISOBUTANE /HELIUM	30%CH(CH3)3/He	0836
30%GERMANE/ARGON	30%GeH4/Ar	0837
30%SILANE/ARGON	30%SiH4/Ar	0838
30%SILANE/NITROGEN	30%SiH4/N2	0839
33.3%HYDROGEN/CARBON MONOXIDE	33.3%H2/CO	0840
35%PHOSPHINE/SILANE	35%PH3/SiH4	0841
4%SILANE/NITROGEN	4%SiH4/N2	0842
5%AMMONIA/NITROGEN	5%NH3/N2	0843
5%CARBON MONOXIDE/ARGON	5%CO/Ar	0844
5%ETHENE/NITROGEN	5%C2H4/N2	0845
5%HELIUM/ARGON	5%He/Ar	0846
5%SILANE/HYDROGEN	5%SiH4/H2	0847
50%CARBON DIOXIDE/NITROGEN	50%CO2/N2	0848
50%HELIUM/ARGON	50%He/Ar	0849
50%HYDROGEN/NITROGEN	50%H2/N2	0850
50%NITROGEN DIOXIDE/AMMONIA	50%NO2/NH3	0851
50%NITROGEN/HELIUM	50%N2/He	0852
50%SULFUR DIOXIDE/NITRIC OXIDE	50%SO2/NO	0853
6%CARBON DIOXIDE/NITROGEN	6%CO2/N2	0854
6%HYDROGEN CHLORIDE/OXYGEN	6%HCl/O2	0855
6%HYDROGEN/NITROGEN	6%H2/N2	0856
6%OZONE/OXYGEN	6%O3/O2	0857
6.5%DIBORANE/NITROGEN	6.5%B2H6/N2	0858
7%HYDROGEN/ARGON	7%H2/Ar	0859
8%DIBORANE/ARGON	8%B2H6/Ar	0860
8%DIBORANE/NITROGEN	8%B2H6/N2	0861
5%CARBON MONOXIDE/NITROGEN	5%CO/N2	0862
2%OXYGEN/ARGON	2%O2/Ar	0863

10 Mixed Gas Table Sorted by Percentage

Table 5 Mixed Gases Sorted by Percentage

MIXED GAS NAME	*SYMBOL*	*CODE*
.01%DIBORANE/HYDROGEN	.01%B2H6/H2	0547
.01%SILANE/HYDROGEN	.01%SiH4/H2	0548
.02%CARBON MONOXIDE/NITROGEN	.02%CO/N2	0784
.05%DIBORANE/HYDROGEN	.05%B2H6/H2	0690
.06%ARSINE/HYDROGEN	.06%AsH3/H2	0708
.1%CARBON MONOXIDE/NITROGEN	.1%CO/N2	0786
.1%HYDROGEN CHLORIDE/NITROGEN	.1%HCl/N2	0790
.1%NITROGEN DIOXIDE/AIR	.1%NO2/Air	0791
.1%NITROGEN DIOXIDE/NITROGEN	.1%NO2/N2	0792
.1%PHOSPHINE/HYDROGEN	.1%PH3/H2	0793
.1%PHOSPHINE/NITROGEN	.1%PH3/N2	0789
.2%SULFUR DIOXIDE/AIR	.2%SO2/Air	0794

MIXED GAS NAME	*SYMBOL*	*CODE*
.25%DIBORANE/HYDROGEN	.25%B2H6/H2	0796
.25%CARBON MONOXIDE/.1%HYDROGEN/1%OXYGEN/NITROGEN	.25%CO/.1%H2/1%O2/N2	0795
.25%OXYGEN/.5%HYDROGEN/1.5%CARBON MONOXIDE/NITROGEN	.25%O2/.5%H2/1.5%CO/N2	0797
.3%PHOSPHINE/SILANE	.3%PH3/SiH4	0660
.4%HYDROGEN CHLORIDE/AIR	.4%HCl/Air	0798
.5%ARSINE/SILANE	.5%AsH3/SiH4	0799
.5%DIBORANE/ARGON	.5%B2H6/Ar	0549
.5%BORON TRICHLORIDE/HYDROGEN	.5%BCl3/H2	0655
.5%PHOSPHINE/HYDROGEN	.5%PH3/H2	0656
.5%PHOSPHINE/NITROGEN	.5%PH3/N2	0550
.5%SILANE/HYDROGEN	.5%SiH4/H2	0551
.7%ARSINE/HYDROGEN	.7%AsH3/H2	0673
.7%ARSINE/HELIUM	.7%AsH3/He	0721
.7%GERMANIUM/HYDROGEN	.7%GeH4/H2	0771
.8%ARSINE/HYDROGEN	.8%AsH3/H2	0741
.8%CO/.8%O2/20%CO2/32%N2/H2	SELOX GAS MIX	0774
.8%DIBORANE/HYDROGEN	.8%B2H6/H2	0743
.8%DIBORANE/NITROGEN	.8%B2H6/N2	0662
.8%GERMANIUM TETRAFLUORIDE/HYDROGEN	.8%GeF4/H2	0742
.8%PHOSPHINE/HYDROGEN	.8%PH3/H2	0707
.8%PHOSPHINE/HELIUM	.8%PH3/He	0675
.8%PHOSPHINE/NITROGEN	.8%PH3/N2	0552
.8%PHOSPHINE/DISLANE	.8%PH3/Si2H6	0681
.8%PHOSPHINE/SILANE	.8%PH3/SiH4	0553
.9%ARSINE/HYDROGEN	.9%AsH3/H2	0554
1%TRIMETHYLBORATE(TMB)/HYDROGEN	1%(CH3O)3B/H2	0526
1%ARSINE/HYDROGEN	1%AsH3/H2	0724
1%ARSINE/NITROGEN	1%AsH3/N2	0555
1%ARSINE/SILANE	1%AsH3/SiH4	0556
1%DIBORANE/ARGON	1%B2H6/Ar	0805
1%DIBORANE/HYDROGEN	1%B2H6/H2	0557
1%DIBORANE/NITROGEN	1%B2H6/N2	0558
1%BORON TRICHLORIDE/HYDROGEN	1%BCl3/H2	0559
1%BORON TRICHLORIDE/NITROGEN	1%BCl3/N2	0560
1%ACETYLENE/ETHYLENE	1%C2H2/C2H4	0772
1%BUTADIENE/BUTENE	1%C4H6-e)/C4H8-i)	0750
1%METHANE/49.5%CARBON DIOXIDE/ARGON	1%CH4/49.5%CO2/Ar	0807
1%CHLORINE/NITROGEN	1%Cl2/N2	0804
1%CARBON MONOXIDE/19% NITROGEN/30%OXYGEN/CARBON DIOXIDE	1%CO/19%N2/30%O2/CO2	0801
1%CARBON MONOXIDE/AIR	1%CO/Air	0802
1%CARBON MONOXIDE/CARBON DIOXIDE	1%CO/CO2	0803
1%CARBON DIOXIDE/NITROGEN	1%CO2/N2	0800
1%FLUORINE/NEON	1%F2/Ne	0733
1%GERMANE/NITROGEN	1%GeH4/N2	0658
1%HYDROGEN/NITROGEN	1%H2/N2	0561
1%HYDROGEN SULFIDE/HYDROGEN	1%H2S/H2	0644
1%HYDROGEN SULFIDE/NITROGEN	1%H2S/N2	0806
1%HYDROGEN SELENIDE/HYDROGEN	1%H2Se/H2	0645

MIXED GAS NAME	*SYMBOL*	*CODE*
1%NITROGEN DIOXIDE/AIR	1%NO2/Air	0808
1%NITROGEN DIOXIDE/NITROGEN	1%NO2/N2	0781
1%OXYGEN/NITROGEN	1%O2/N2	0562
1%PHOSPHINE/ARGON	1%PH3/Ar	0537
1%PHOSPHINE/HYDROGEN	1%PH3/H2	0563
1%PHOSPHINE/HELIUM	1%PH3/He	0546
1%PHOSPHINE/NITROGEN	1%PH3/N2	0514
1%PHOSPHINE/SILANE	1%PH3/SiH4	0531
1%SILANE/DIBORANE	1%SiH4/B2H6	0684
1%SILANE/HELIUM	1%SiH4/He	0745
1%SULFUR DIOXIDE/ARGON	1%SO2/Ar	0809
1%SULFUR DIOXIDE/NITROGEN	1%SO2/N2	0782
1.5%ARSINE/HYDROGEN	1.5%AsH3/H2	0564
1.5%GERMANE/HYDROGEN	1.5%GeH4/H2	0775
1.5%PHOSPHINE/SILANE	1.5%PH3/SiH4	0533
1.5%SILANE/ARGON	1.5%SiH4/Ar	0810
1.6%PHOSPHINE/21%SILANE/ARGON	1.6%PH3/21%SiH4/Ar	0515
1.8%SILANE/NITROGEN	1.8%SiH4/N2	0811
1.9%SILANE/NITROGEN	1.9%SiH4/N2	0812
2%ARSINE/HYDROGEN	2%AsH3/H2	0703
2%ARSINE/NITROGEN	2%AsH3/N2	0586
2%ARSINE/SILANE	2%AsH3/SiH4	0663
2%DIBORANE/ARGON	2%B2H6/Ar	0587
2%DIBORANE/NITROGEN	2%B2H6/N2	0695
2%TRICHLOROETHANE/NITROGEN	2%C2H3Cl3/N2	0506
2%METHYSILANE/HYDROGEN	2%CH6Si/H2	0717
2%GERMANE/ARGON	2%GeH4/Ar	0740
2%HYDROGEN/NITROGEN	2%H2/N2	0588
2%NITROGEN/3%CARBON MONOXIDE/17%CARBON DIOXIDE/HYDROGEN	2%N2/3%CO/17%CO2/H2	0788
2%NITRIC OXIDE/NITROGEN	2%NO/N2	0822
2%OXYGEN/ARGON	2%O2/Ar	0863
2%OZONE/OXYGEN	2%O3/O2	0569
2%PHOSPHINE/ARGON	2%PH3/Ar	0539
2%PHOSPHINE/NITROGEN	2%PH3/N2	0640
2%PHOSPHINE/SILANE	2%PH3/SiH4	0696
2%DISILANE/HELIUM	2%Si2H6/He	0764
2%SILANE/ARGON	2%SiH4/Ar	0823
2%SILANE/HYDROGEN	2%SiH4/H2	0544
2%SILANE/HELIUM	2%SiH4/He	0589
2%SILANE/NITROGEN	2%SiH4/N2	0653
2%SULFUR DIOXIDE/NITROGEN	2%SO2/N2	0824
2.5%DIBORANE/HYDROGEN	2.5%B2H6/H2	0825
2.5%METHANE/AIR	2.5%CH4/Air	0826
3%ARSINE/ARGON	3%AsH3/Ar	0688
3%ARSINE/HYDROGEN	3%AsH3/H2	0665
3%DIBORANE/5%SILANE/NITROGEN	3%B2H6/5%SiH4/N2	0659
3%DIBORANE/HYDROGEN	3%B2H6/H2	0657
3%DIBORANE/NITROGEN	3%B2H6/N2	0595

MIXED GAS NAME	*SYMBOL*	*CODE*
3%BORON TRICHLORIDE/HYDROGEN	3%BCl3/H2	0832
3%HYDROGEN/ARGON	3%H2/Ar	0833
3%HYDROGEN/HELIUM	3%H2/He	0596
3%HYDROGEN/NITROGEN	3%H2/N2	0597
3%NITROGEN/HYDROGEN	3%N2/H2	0672
3%AMMONIA/NITROGEN	3%NH3/N2	0831
3%OXYGEN/HELIUM	3%O2/He	0598
3%OZONE/AIR	3%O3/Air	0599
3%PHOSPHINE/5%SILANE/NITROGEN	3%PH3/5%SiH4/N2	0671
3%PHOSPHINE/ARGON	3%PH3/Ar	0534
3%PHOSPHINE/HELIUM	3%PH3/He	0834
3%PHOSPHINE/NITROGEN	3%PH3/N2	0600
3%PHOSPHINE/SILANE	3%PH3/SiH4	0601
3%SILANE/HELIUM	3%SiH4/He	0602
3.5%CARBON DIOXIDE/HELIUM	3.5%CO2/He	0835
3.5%HYDROGEN/NITROGEN	3.5%H2/N2	0768
4%DIBORANE/NITROGEN	4%B2H6/N2	0605
4%HYDROGEN/ARGON	4%H2/Ar	0700
4%HYDROGEN/HELIUM	4%H2/He	0606
4%HYDROGEN/NITROGEN	4%H2/N2	0607
4%HELIUM/NITROGEN	4%He/N2	0738
4%NITROGEN/HYDROGEN	4%N2/H2	0608
4%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	4%O2/CF4	0609
4%PHOSPHINE/ARGON	4%PH3/Ar	0691
4%PHOSPHINE/HELIUM	4%PH3/He	0610
4%PHOSPHINE/NITROGEN	4%PH3/N2	0535
4%PHOSPHINE/SILANE	4%PH3/SiH4	0611
4%SILANE/NITROGEN	4%SiH4/N2	0842
4.5%PHOSPHINE/NITROGEN	4.5%PH3/N2	0528
5%TRIETHYLANTIMONY(TESb)/HYDROGEN	5%(C2H5)3Sb/H2	0524
5%ARSINE/HYDROGEN	5%AsH3/H2	0614
5%DIBORANE/ARGON	5%B2H6/Ar	0615
5%DIBORANE/HYDROGEN	5%B2H6/H2	0722
5%DIBORANE/HELIUM	5%B2H6/He	0766
5%DIBORANE/NITROGEN	5%B2H6/N2	0654
5%DIBORANE/SILANE	5%B2H6/SiH4	0683
5%BORON TRICHLORIDE/HYDROGEN	5%BCl3/H2	0616
5%BORON TRIFLUORIDE/HELIUM	5%BF3/He	0776
5%HEXAFLUOROETHANE/OXYGEN	5%C2F6/O2	0785
5%ETHENE/NITROGEN	5%C2H4/N2	0845
5%ACETONE/NITROGEN	5%C3H6O-m)/N2	0711
5%PROPANE/HYDROGEN	5%C3H8/H2	0617
5%BENZENE/NITROGEN	5%C6H6/N2	0712
5%METHANE/HELIUM	5%CH4/He	0699
5%CHLORINE/HELIUM	5%Cl2/He	0719
5%CARBON MONOXIDE/ARGON	5%CO/Ar	0844
5%CARBON MONOXIDE/NITROGEN	5%CO/N2	0862
5%CARBON DIOXIDE/15%OXYGEN/NITROGEN	5%CO2/15%O2/N2	0734

MIXED GAS NAME	*SYMBOL*	*CODE*
5%CARBON DIOXIDE/NITROGEN	5%CO2/N2	0618
5%FLUORINE/ARGON	5%F2/Ar	0761
5%FLUORINE/HELIUM	5%F2/He	0720
5%FLUORINE/NITROGEN	5%F2/N2	0732
5%FLUORINE/NITROGEN TRIFLUORIDE	5%F2/NF3	0669
5%GERMANE/HELIUM	5%GeH4/He	0765
5%HYDROGEN/ARGON	5%H2/Ar	0619
5%HYDROGEN/HELIUM	5%H2/He	0762
5%HYDROGEN/NITROGEN	5%H2/N2	0542
5%WATER VAPOR/AIR	5%H2O/Air	0567
5%HYDROGEN SELENIDE/HYDROGEN	5%H2Se/H2	0510
5%HYDROGEN CHLORIDE/NITROGEN	5%HCl/N2	0726
5%HELIUM/ARGON	5%He/Ar	0846
5%HELIUM/NITROGEN	5%He/N2	0752
5%NITROGEN/HYDROGEN	5%N2/H2	0621
5%NITROGEN/PHOSPHINE	5%N2/PH3	0622
5%AMMONIA/NITROGEN	5%NH3/N2	0843
5%OXYGEN/ARGON	5%O2/Ar	0623
5%OXYGEN/CARBON TETRAFLUORIDE	5%O2/CF4	0753
5%OXYGEN/HELIUM	5%O2/He	0779
5%OZONE/OXYGEN	5%O3/O2	0624
5%PHOSPHORUS PENTAFLUORIDE/HELIUM	5%PF5/He	0777
5%PHOSPHINE/5%SILANE/NITROGEN	5%PH3/5%SiH4/N2	0625
5%PHOSPHINE/ARGON	5%PH3/Ar	0626
5%PHOSPHINE/HYDROGEN	5%PH3/H2	0709
5%PHOSPHINE/HELIUM	5%PH3/He	0693
5%PHOSPHINE/NITROGEN	5%PH3/N2	0501
5%PHOSPHINE/SILANE	5%PH3/SiH4	0627
5%TETRAETHYLORTHOSILICATE(TEOS)/NITROGEN	5%Si(C2H5O)4/N2	0523
5%DICHLOROSILANE/ARGON	5%SiH2Cl2/Ar	0628
5%SILANE/ARGON	5%SiH4/Ar	0629
5%SILANE/HYDROGEN	5%SiH4/H2	0847
5%SILANE/HELIUM	5%SiH4/He	0780
5%SILANE/NITROGEN	5%SiH4/N2	0773
5%TRICHLOROSILANE/HYDROGEN	5%SiHCl3/H2	0679
5%SULFUR DIOXIDE/HELIUM	5%SO2/He	0763
6%CARBON DIOXIDE/NITROGEN	6%CO2/N2	0854
6%HYDROGEN/NITROGEN	6%H2/N2	0856
6%HYDROGEN CHLORIDE/OXYGEN	6%HCl/O2	0855
6%OZONE/OXYGEN	6%O3/O2	0857
6.5%DIBORANE/15%SILANE/NITROGEN	6.5%B2H6/15%SiH4/N2	0634
6.5%DIBORANE/HYDROGEN	6.5%B2H6/H2	0635
6.5%DIBORANE/NITROGEN	6.5%B2H6/N2	0858
7%METHYLENE CHLORIDE/3%OZONE/AIR	7%CH2Cl2/3%O3/Air	0685
7%CARBON DIOXIDE/10%HYDROGEN/20%CARBON MONOXIDE/NITROGEN	7%CO2/10%H2/20%CO/N2	0748
7%HYDROGEN/ARGON	7%H2/Ar	0859
7.5%PHOSPHINE/SILANE	7.5%PH3/SiH4	0676
8%DIBORANE/ARGON	8%B2H6/Ar	0860

MIXED GAS NAME	*SYMBOL*	*CODE*
8%DIBORANE/NITROGEN	8%B2H6/N2	0861
8%PROPANE/10%AMMONIA/AIR	8%C3H8/10%NH3/Air	0714
8%CARBON TETRAFLUORIDE(FREON-14)/OXYGEN	8%CF4/O2	0574
8%GERMANE/HYDROGEN	8%GeH4/H2	0664
8%HYDROGEN/ARGON	8%H2/Ar	0692
8%HYDROGEN/NITROGEN	8%H2/N2	0727
8%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	8%O2/CF4	0613
8%OZONE/OXYGEN	8%O3/O2	0639
8%PHOSPHINE/HELIUM	8%PH3/He	0667
8%PHOSPHINE/NITROGEN	8%PH3/N2	0620
8%PHOSPHINE/SILANE	8%PH3/SiH4	0636
8.2%PROPANE/9.8%AMMONIA/AIR	8.2%C3H8/9.8%NH3/Air	0715
8.6%ARGON/NITROGEN TRIFLUORIDE	8.6%Ar/NF3	0706
9.4%ARGON/NITROGEN TRIFLUORIDE	9.4%Ar/NF3	0705
10%TRIMETHYSILANE/HYDROGEN	10%(CH3)3SiH/H2	0739
10%ARSINE/HYDROGEN	10%AsH3/H2	0504
10%DIBORANE/HYDROGEN	10%B2H6/H2	0701
10%DIBORANE/NITROGEN	10%B2H6/N2	0666
10%ETHYLENE/HELIUM	10%C2H4/He	0718
10%CYCLOPROPANE/HELIUM	10%C3H6-a)/He	0716
10%METHANE/ARGON	10%CH4/Ar	0710
10%METHANE/HYDROGEN	10%CH4/H2	0815
10%METHANE/HELIUM	10%CH4/He	0744
10%METHYLSILANE/HYDROGEN	10%CH6Si/H2	0689
10%CARBON MONOXIDE/AIR	10%CO/Air	0730
10%CARBON MONOXIDE/CARBON DIOXIDE	10%CO/CO2	0729
10%CARBON DIOXIDE/10%OXYGEN/NITROGEN	10%CO2/10%O2/N2	0735
10%CARBON DIOXIDE/ARGON	10%CO2/Ar	0813
10%CARBON DIOXIDE/NITROGEN	10%CO2/N2	0783
10%FLUORINE/ARGON	10%F2/Ar	0754
10%FLUORINE/HELIUM	10%F2/He	0566
10%FLUORINE/NITROGEN	10%F2/N2	0759
10%FLUORINE/OXYGEN	10%F2/O2	0814
10%GERMANE/ARGON	10%GeH4/Ar	0698
10%GERMANE/HYDROGEN	10%GeH4/H2	0509
10%GERMANE/HELIUM	10%GeH4/He	0704
10%HYDROGEN/NITROGEN	10%H2/N2	0532
10%WATER VAPOR/NITROGEN	10%H2O/N2	0568
10%HYDROGEN SELENIDE/HYDROGEN	10%H2Se/H2	0511
10%HELIUM/HYDROGEN	10%He/H2	0749
10%NITROGEN/ARGON	10%N2/Ar	0576
10%NITROGEN TRIFLUORIDE/OXYGEN	10%NF3/O2	0570
10%AMMONIA/NITROGEN	10%NH3/N2	0668
10%OXYGEN/30%CARBON DIOXIDE/ARGON	10%O2/30%CO2/Ar	0816
10%OXYGEN/HELIUM	10%O2/He	0649
10%OZONE/NITROGEN	10%O3/N2	0817
10%OZONE/OXYGEN	10%O3/O2	0571
10%PHOSPHINE/ARGON	10%PH3/Ar	0538

MIXED GAS NAME	*SYMBOL*	*CODE*
10%PHOSPHINE/HYDROGEN	10%PH3/H2	0516
10%PHOSPHINE/HELIUM	10%PH3/He	0674
10%PHOSPHINE/NITROGEN	10%PH3/N2	0527
10%PHOSPHINE/SILANE	10%PH3/SiH4	0572
10%DISILANE/ARGON	10%Si2H6/Ar	0670
10%DISILANE/HYDROGEN	10%Si2H6/H2	0731
10%DISILANE/HELIUM	10%Si2H6/He	0647
10%SILANE/ARGON	10%SiH4/Ar	0565
10%SILANE/HYDROGEN	10%SiH4/H2	0575
10%SILANE/HELIUM	10%SiH4/He	0573
10%SILANE/NITROGEN	10%SiH4/N2	0646
10%SULFUR DIOXIDE/NITROGEN	10%SO2/N2	0818
12%HYDROGEN/NITROGEN	12%H2/N2	0819
12%OZONE/OXYGEN	12%O3/O2	0651
13%HYDROGEN/NITROGEN	13%H2/N2	0643
13%HYDROGEN CHLORIDE/1.32%XENON/NEON	13%HCl/1.32%Xe/Ne	0512
13%TRICHLOROSILANE/HYDROGEN	13%SiHCl3/H2	0682
15%ARGON/PHOSPHINE	15%Ar/PH3	0578
15%ARSINE/HYDROGEN	15%AsH3/H2	0579
15%DIBORANE/ARGON	15%B2H6/Ar	0697
15%DIBORANE/HYDROGEN	15%B2H6/H2	0820
15%DIBORANE/NITROGEN	15%B2H6/N2	0580
15%CARBON DIOXIDE/NITROGEN	15%CO2/N2	0778
15%GERMANIUM TETRACHLORIDE/OXYGEN	15%GeCl4/O2	0787
15%HYDROGEN/ARGON	15%H2/Ar	0694
15%HYDROGEN/NITROGEN	15%H2/N2	0545
15%NITRIC OXIDE/NITROGEN	15%NO/N2	0652
15%OZONE/OXYGEN	15%O3/O2	0641
15%PHOSPHINE/15%SILANE/NITROGEN	15%PH3/15%SiH4/N2	0581
15%PHOSPHINE/ARGON	15%PH3/Ar	0582
15%PHOSPHINE/HYDROGEN	15%PH3/H2	0583
15%PHOSPHINE/NITROGEN	15%PH3/N2	0500
15%PHOSPHINE/SILANE	15%PH3/SiH4	0584
15%SILANE/ARGON	15%SiH4/Ar	0821
15%SILANE/NITROGEN	15%SiH4/N2	0519
16%CARBON DIOXIDE/NITROGEN	16%CO2/N2	0543
17%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	17%O2/CF4	0585
20%TRIMETHYLALUMINUM(TMAI)/HYDROGEN	20%(CH3)3Al/H2	0525
20%ARGON/SILANE	20%Ar/SiH4	0540
20%ARSINE/HYDROGEN	20%AsH3/H2	0590
20%DIBORANE/SILANE	20%B2H6/SiH4	0591
20%CARBON TETRAFLUORIDE/NITROGEN	20%CF4/N2	0728
20%FLUOROFORM/OXYGEN	20%CF4/O2	0827
20%CARBON DIOXIDE/HYDROGEN	20%CO2/H2	0507
20%FLUORINE/HELIUM	20%F2/He	0677
20%HYDROGEN/CARBON MONOXIDE	20%H2/CO	0592
20%HELIUM/OXYGEN	20%He/O2	0687
20%OXYGEN/CARBON TETRAFLUORIDE(FREON-14)	20%O2/CF4	0513

MIXED GAS NAME	*SYMBOL*	*CODE*
20%OXYGEN/HELIUM	20%O2/He	0536
20%OXYGEN/NITROGEN	20%O2/N2	0736
20%OZONE/NITROGEN	20%O3/N2	0723
20%PHOSPHINE/HYDROGEN	20%PH3/H2	0593
20%PHOSPHINE/NITROGEN	20%PH3/N2	0767
20%PHOSPHINE/SILANE	20%PH3/SiH4	0530
20%DISILANE/HYDROGEN	20%Si2H6/H2	0713
20%DISILANE/HELIUM	20%Si2H6/He	0648
20%SILANE/ARGON	20%SiH4/Ar	0541
20%SILANE/HYDROGEN	20%SiH4/H2	0577
20%SILANE/HELIUM	20%SiH4/He	0529
20%SILANE/NITROGEN	20%SiH4/N2	0502
20%TRICHLOROSILANE/HYDROGEN	20%SiHCl3/H2	0522
21%OXYGEN/NITROGEN	21%O2/N2	0594
21%SILANE/4%PHOSPHINE/ARGON	21%SiH4/4%PH3/Ar	0520
22%OXYGEN/HELIUM	22%O2/He	0828
22%PHOSPHINE/SILANE	22%PH3/SiH4	0678
25%HEXAFLUOROETHANE/OXYGEN	25%C2F6/O2	0770
25%PROPANE/PROPYLENE	25%C3H8/C3H6	0830
25%CARBON MONOXIDE/HYDROGEN	25%CO/H2	0829
25%FLUORINE/ARGON	25%F2/Ar	0755
25%FLUORINE/HELIUM	25%F2/He	0758
25%FLUORINE/NITROGEN	25%F2/N2	0746
25%HELIUM/ARGON	25%He/Ar	0737
25%AMMONIA/HYDROGEN	25%NH3/H2	0638
25%PHOSPHINE/SILANE	25%PH3/SiH4	0517
25%TRICHLOROSILANE/HYDROGEN	25%SiHCl3/H2	0680
30% ISOBUTANE /HELIUM	30%CH(CH3)3/He	0836
30%CARBON DIOXIDE/AIR	30%CO2/Air	0508
30%GERMANE/ARGON	30%GeH4/Ar	0837
30%HELIUM/OXYGEN	30%He/O2	0603
30%NITROGEN TRIFLUORIDE/NITROGEN	30%NF3/N2	0661
30%OXYGEN/HYDROGEN	30%O2/H2	0637
30%OXYGEN/HELIUM	30%O2/He	0604
30%SILANE/ARGON	30%SiH4/Ar	0838
30%SILANE/NITROGEN	30%SiH4/N2	0839
33.3%HYDROGEN/CARBON MONOXIDE	33.3%H2/CO	0840
35%PHOSPHINE/SILANE	35%PH3/SiH4	0841
40%ARGON/TUNGSTEN HEXAFLUORIDE	40%Ar/WF6	0503
40%GERMANE/ARGON	40%GeH4/Ar	0751
40%HYDROGEN/HELIUM	40%H2/He	0725
40%HELIUM/SILANE	40%He/SiH4	0612
40%OXYGEN/HEXAFLUOROETHANE(FREON-116)	40%O2/C2F6	0505
40%OXYGEN/SULFURHEXAFLUORIDE	40%O2/SF6	0642
40%SILANE/HELIUM	40%SiH4/He	0702
50%HEXAFLUOROETHANE/OXYGEN	50%C2F6/O2	0769
50%FLUOROFORM/ARGON	50%CHF3/Ar	0686
50%CARBON DIOXIDE/NITROGEN	50%CO2/N2	0848

MIXED GAS NAME	*SYMBOL*	*CODE*
50%FLUORINE/ARGON	50%F2/Ar	0756
50%FLUORINE/HELIUM	50%F2/He	0757
50%FLUORINE/NITROGEN	50%F2/N2	0760
50%GERMANE/ARGON	50%GeH4/Ar	0747
50%HYDROGEN/NITROGEN	50%H2/N2	0850
50%HYDROGEN BROMIDE/HYDROGEN CHLORIDE	50%HBr/HCl	0650
50%HELIUM/ARGON	50%He/Ar	0849
50%HELIUM/OXYGEN	50%He/O2	0630
50%NITROGEN/HELIUM	50%N2/He	0852
50%NITROGEN/OXYGEN	50%N2/O2	0631
50%NITROGEN DIOXIDE/AMMONIA	50%NO2/NH3	0851
50%PHOSPHINE/NITROGEN	50%PH3/N2	0518
50%PHOSPHINE/SILANE	50%PH3/SiH4	0632
50%SILANE/HYDROGEN	50%SiH4/H2	0633
50%SILANE/HELIUM	50%SiH4/He	0521
50%SULFUR DIOXIDE/NITRIC OXIDE	50%SO2/NO	0853

11 Related Document

11.1 *Data Sheet*

Schumacher Material Safety Data Sheet, No. 48.1 JN, Revision Date 8/94[13]

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E56-1296
TEST METHOD FOR DETERMINING ACCURACY, LINEARITY, REPEATABILITY, SHORT-TERM REPRODUCIBILITY, HYSTERESIS, AND DEADBAND OF THERMAL MASS FLOW CONTROLLERS

1 Purpose

The purpose of this document is to provide a standardized method to quantify the accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband of a thermal mass flow controller.

The intent of this document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters that are covered by this method. The user might use this document to check significant performance characteristics such as accuracy, precison, bias, repeatability, linearity, short-term reproducibility, and deadband under a set of closely controlled test conditions.

The significance of the accuracy calculations in this method is to allow an MFC user to transfer a process from one manufacturing tool to another and to exchange MFCs within a single manufacturing tool while maintaining process control.

2 Scope

2.1 This document describes the conditions and procedures for testing the accuracy, linearity, repeatability, hysteresis, and deadband of thermal mass flow controllers (MFCs). Because of the generic nature of this document, not all test procedures apply to all types of MFCs.

2.2 This document provided a common basis for communication between manufacturers and users.

3 Limitations

It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory conditions; its intent is to collect sufficient data to form a judgement of the field performance of the MFC being tested.

4 Referenced Documents

4.1 *SEMI Standard*

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

4.2 *ASME Document*[1]

ASME MFC-10M — Method for Establishing Installation Effects on Flowmeters

4.3 *ISA Document*[2]

ISA S51.1 — Process Instrumentation Terminology

5 Terminology

5.1 *Acronyms*

5.1.1 A — Measured Value

5.1.2 A_a — Average measured value

5.1.3 A_a — Average measured value at 100% setpoint

5.1.4 AD — Accuracy of the DUT

5.1.5 AD_f — Accuracy of the flow standard

5.1.6 AS — Accuracy of setpoint

5.1.7 A_l — Measured value, down cycle

5.1.8 A_u — Measured value, up cycle

5.1.9 B — Bias

5.1.10 D — Deadband value

5.1.11 DBD — Deadband of device

5.1.12 DBS — Deadband of setpoint

5.1.13 D_l — Lower deadband value

5.1.14 D_u — Upper deadband value

5.1.15 DUT — Device under test

5.1.16 FS — Full scale flow rate

5.1.17 HD — Hysteresis of device

5.1.18 $HDBS$ — Hysteresis plus deadband at a setpoint

5.1.19 HS — Hysteresis at a setpoint

5.1.20 i — Reading number in a cycle for a given set-point

5.1.21 I — Intermediate value

1 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

2 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709

5.1.22 *j* — Cycle for a given setpoint

5.1.23 *k* — Up cycle number for a given setpoint

5.1.24 *kPa* — Kilopascal

5.1.25 *LD* — Linearity of DUT

5.1.26 *LS* — Linearity of setpoint

5.1.27 *m* — Slope

5.1.28 *m* — Down cycle number for a setpoint

5.1.29 *n* — Number of up scale readings

5.1.30 *NC* — Normally closed

5.1.31 n_j — Number of readings at a setpoint at a given cycle

5.1.32 *NO* — Normally open

5.1.33 *P* — Precision

5.1.34 *psia* — Pounds per square inch absolute

5.1.35 *RPD* — Repeatability of the DUT

5.1.36 *RPS* — Repeatability at a setpoint

5.1.37 *S* — Setpoint

5.1.38 S_a — Average of setpoint

5.1.39 *sccm* — Standard cubic centimeters per minute

5.1.40 S_l— Setpoint, down cycle

5.1.41 S_u — Setpoint, up cycle

5.1.42 *slm* — Standard liters per minute

5.1.43 *SRD* — Short-term reproducibility of the device

5.1.44 *SRS* — Short-term reproducibility at a setpoint

5.1.45 v_i — The ith measured value at a setpoint for a given cycle

5.1.46 *Y* — Ideal linearity value

5.1.47 *Z* — Zero offset of DUT

5.1.48 Z_a — Indicated flow at zero actual flow

5.2 *Definitions*

5.2.1 *accuracy* — The closeness of agreement between an observed value and the true value; the total uncertainty of an observed value, including both precision and bias.

5.2.2 *accuracy curve* — The curve fitted through the average measured values over the specified range of the device under test.

5.2.3 *accuracy device* — The total uncertainty over a specified range of the device. Device accuracy over a range is stated as the worst case accuracy taken over all tested setpoints in this range.

5.2.4 *actual flow* — The gas flow as measured by an external standard, not the electrical output of a mass flow meter.

5.2.5 *bias* — The difference, at a setpoint, between the measured value and the sum of the setpoint value and the zero offset. The measured values of a flow standard include its total uncertainty.

5.2.6 *cardinal setpoint* — A specific setpoint to assess the accuracy of the device under test (DUT). For this test method, the cardinal setpoints are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% of full scale.

5.2.7 *deadband* — The range through which a setpoint may be varied, upon reversal of direction, without initiating an observable change in output signal.

5.2.8 *device under test* — Mass flow device is being tested by this method.

5.2.9 *downscale reading* — A reading approached from a setpoint greater than the current setpoint and beyond the deadband.

5.2.10 *downscale value, average* — The sum of all downscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.11 *drift* — The change in output over a specified time period for a constant input under specified reference operating conditions.

5.2.12 *drift, long-term* — The drift between a series of tests over a specified time interval. This specified time interval is generally much greater than the time necessary to run an individual test.

5.2.13 *drift, short-term* — The drift between sets of measurements over the duration of the test.

5.2.14 *hysteresis* — That property of an element evidenced by the dependence of the value of the output, for a given excursion of the input, upon the history of the prior excursions and the direction of the current traverse.

5.2.15 *indicated flow* — Flow indicated by MFC under test. Electrical output of the DUT.

5.2.16 *linearity* — The closeness to which a curve approximates a straight line.

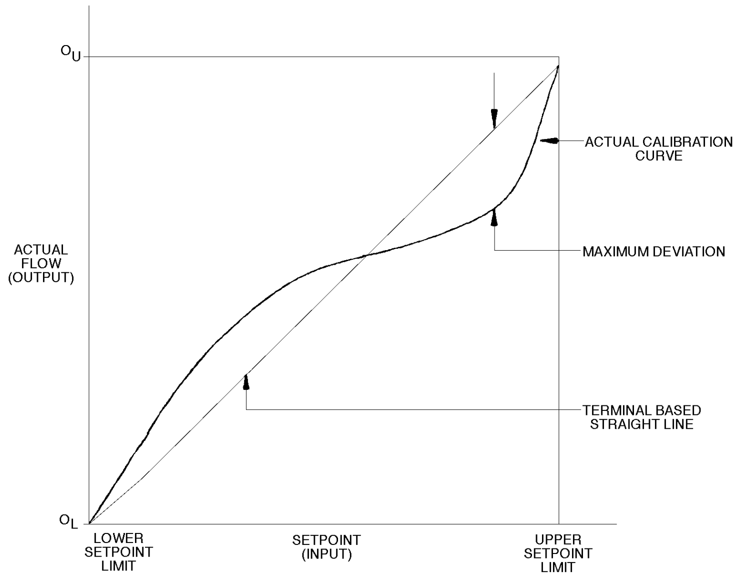

Figure 1
Terminal-Based Linearity for Mass Flow Controller

5.2.17 *linearity, terminal-based* — The maximum absolute value of the deviation of the accuracy curve (average of upscale and downscale values) from a straight line through the upper and lower setpoint limits of the accuracy curve (see Figure 1).

5.2.18 *measured value* — The actual flow through a device under test, expressed in sccm or slm, as measured by a standard, preferably primary.

5.2.19 *measured value, average* — The sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.20 *operating conditions, normal* — The range of operating conditions within which a device is designed to operate and for which operating influences are stated [ISA S51.1].

5.2.21 *operating conditions, reference* — The range of operating conditions of a device within which operating influences are negligible [ISA S51.1].

5.2.22 *operating influence* — The change in a performance characteristic caused by a change in a specified operating condition from reference operating conditions, all other conditions being held within the limits of reference operating conditions [ISA S51.1].

5.2.23 *pneumatic noise* — Localized, random variations in pressure and flow.

5.2.24 *precision* — The closeness of agreement among the measured values at a setpoint. It is often expressed as a standard deviation.

5.2.25 *repeatability* — The closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time. It is usually measured as a nonrepeatability and expressed as a repeatability in percent of reading.

5.2.26 *reproducibility* — The closeness of agreement among repeated measured values at a setpoint, within the specified reference operating conditions, made over a specified period of time, approached from both directions. Reproducibility includes hysteresis, deadband, long-term drift, and short-term reproducibility.

NOTE: Between repeated measurements, the input may vary over the range, and operating conditions may vary within normal operating conditions.

5.2.27 *reproducibility, short-term* — The closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory and short intervals of time, approached from both directions. The approach must be from beyond the deadband. Short-term reproducibility includes repeatability, hysteresis, deadband, and short-term drift.

5.2.28 *setpoint* — The input signal provided to achieve a desired flow, reported as sccm, slm, or percent-full scale.

5.2.29 *setpoint limit, lower* — The lowest setpoint at which the instrument is specified to operate.

5.2.30 *setpoint limit, upper* — The highest setpoint at which the instrument is specified to operate, usually full scale.

5.2.31 *settling time* — The time between the set point step change and when the actual flow remains within the specified band (see SEMI E17).

5.2.32 *span* — The full-scale range of the DUT.

5.2.33 *stability* — The ability of a condition to exhibit only natural, random variation in the absence of unnatural, assignable-cause variation.

5.2.34 *standard conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F)

5.2.35 *uncertainty, total* — The range within which the true value of the measured quantity can be expected to fit; an indication of the variability associated with a measured value that takes into account the two major components of error, bias and the random error attributed to the imprecision of the measurement process.

5.2.36 *upscale reading* — A reading approached from a setpoint less than the current setpoint and beyond the deadband.

5.2.37 *upscale value, average* — The sum of all upscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.38 *zero drift* — The undesired change in electrical output, at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.39 *zero offset* — The deviation from zero, at a no-flow condition, reported in sccm or slm.

6 Summary of Test Method

Specific procedures are given for characterizing MFCs discharging to atmospheric pressure or into a vacuum using accepted reference standards to determine accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband (see Figure 2).

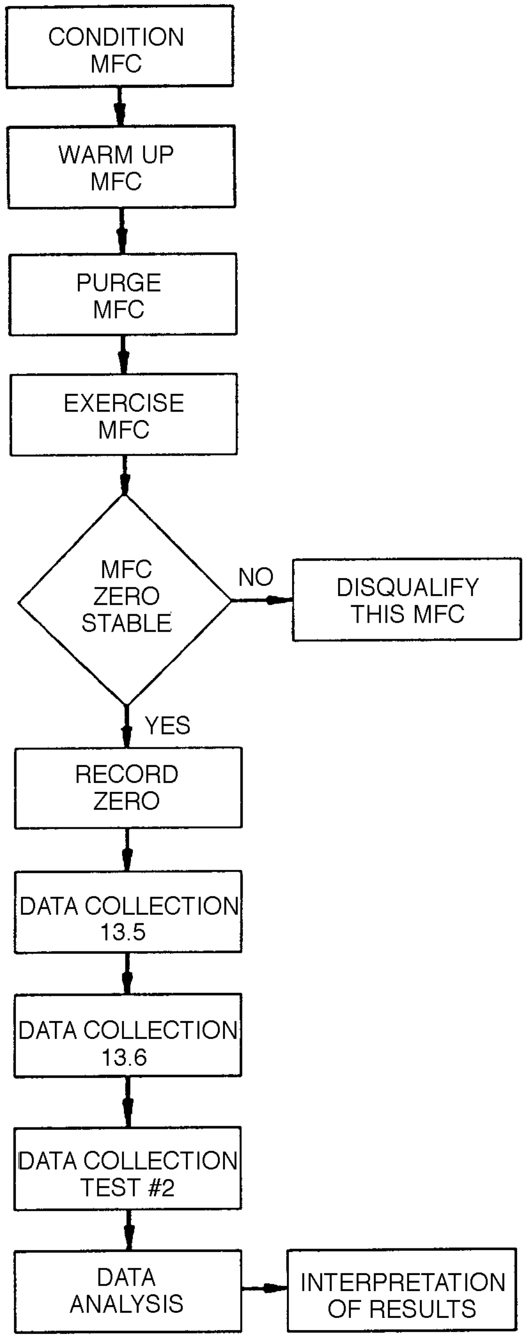

Figure 2
Test Flowchart

7 Interferences

7.1 The accuracy rating of the measuring equipment must include superior measurement capability compared with that of the DUT. In no instance should the accuracy rating of the measuring equipment be less than twice that of the DUT (e.g., if the accuracy of the DUT is ± 1 sccm, then the accuracy of the measuring device must be better than or equal to ± 1/2 sccm). The traceability of all the pertinent measuring instruments and devices should be realistically established and quantified.

In addition, take care when using test instruments with a specified accuracy expressed in percent of full scale. For example, if an instrument with a specified accuracy of ± 0.1% of full scale is used to measure the output of the DUT, but this output signal falls only within the lower third of the scale of the instrument, the effective accuracy over the range of the instrument being used may be ± 0.3%, which is unsuitable for many applications.

7.2 Use special precautions to ensure that minimum effects result from pneumatic noise in flow lines. Monitor pressure both upstream and downstream of the MFC to ensure that pneumatic noise is minimized.

7.3 The DUT should be installed so that the inlet flow can be fully developed, pulsation-free, for the specific conditions. This can be achieved by plumbing a straight length of tubing 40–50 diameters long upstream and another straight length 5 diameters long downstream of the DUT. (For additional information about inlet effects, refer to ASME MFC-10M.)

7.4 At regular calibration intervals, verify electrical signals directly at the MFC connector to ensure that there are no unacceptable line losses in the cables.

8 Apparatus

8.1 heat exchanger

8.2 flow standard

8.3 pressure transducer

8.4 back pressure regulator

8.5 temperature probe

8.6 digital voltmeter

8.7 setpoint generator

8.8 power supply

9 Technical Precautions

9.1 Many analog-to-digital converter cards do not differentiate between measurements of less than zero and zero. It may be necessary to use a digital voltmeter to record measurements below zero volts. Some MFCs do not differentiate between measurements of less than zero and zero. This may bias the results.

9.2 The manufacturer’s specifications and instructions for installation and operation must be applied during all testing.

9.3 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

9.4 The mounting position of the device must be in accordance with the manufacturer's specifications. No external mechanical constraints beyond the manufacturer’s recommended mounting position shall be permitted.

10 Preparation of Apparatus

Figure 3 is a representation of a recommended generic testing apparatus. The flow standard is shown downstream of the device under test (DUT). It may be placed upstream of the DUT if the flow standard cannot be exposed to a low pressure environment. In this case, the user should be aware of possible back pressure effects on the flow standard.

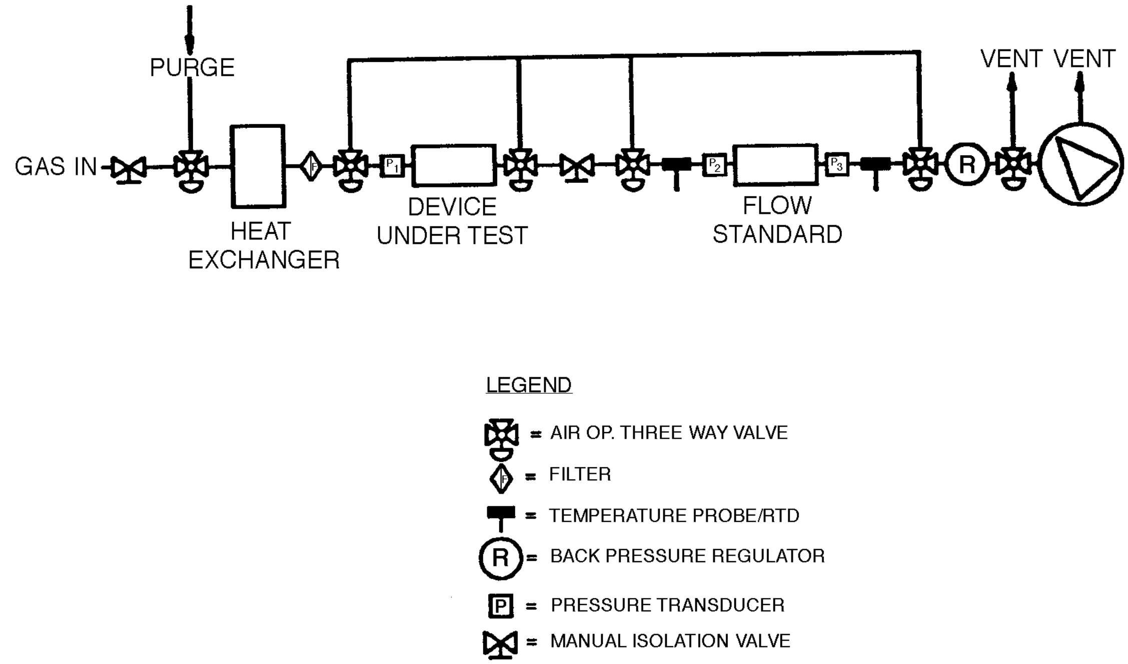

Figure 3
Mass Flow Controller Test Fixture

11 Calibration Standardization

All measurement devices must have valid calibration certificates.

12 Conditioning

12.1 Place the MFC to be tested in the testing environment. Apply power to the MFC for the 24 hours prior to initiating warm-up as defined by the manufacturer. The valve should be in its "off" position (closed for a NC valve, open for a NO valve).

12.2 Following the conditioning period, install and warm up the device according to manufacturer's specifications.

12.3 Purge the MFC with clean, dry nitrogen or argon following the warm up period.

12.4 Allow the test gas to flow through the DUT for a minimum of 10 minutes at 100% of flow.

12.5 Apply a 100% full-scale setpoint to the DUT and wait for the flow to stabilize for 10 seconds. Apply the lower setpoint limit to the DUT and wait for the flow to stabilize for 10 seconds. Repeat this cycle two more times. This process exercises the device before initiating the test.

12.6 *Test Conditions*

12.6.1 The reference operating conditions shall be as follows if the downstream pressure is atmospheric pressure:

Table 1

Ambient temperature	23 ± 2°C
Gas temperature	Same as actual ambient
Ambient pressure	101.32 kPa. (+ 4.7 or – 15.3 kPa)
Gas pressure P_1, Inlet	274 ± 34 kPa
Gas pressure P_3, Outlet	101.32 kPa. (+ 4.7 kPa or – 15.3 kPa)
Relative humidity	40% ± 10%, noncondensing
Magnetic field	≤ 50 µT
Electromagnetic field	< 100 µ V/m
Vibration	< 0.5 m/s
Shock	≤ 3 g

12.6.2 The reference operating conditions shall be as follows if the downstream pressure is at vacuum:

Table 2

Ambient temperature	23 ± 2°C
Gas temperature	Same as actual ambient
Ambient pressure	101.32 kPa. (+ 4.7 or – 15.3 kPa)
Gas pressure P1, Inlet	172 ± 34 kPa
Gas pressure P3, Outlet	< 0.13 kPa
Relative humidity	40% ± 10%, noncondensing
Magnetic field	≤ 50 µT
Electromagnetic field	< 100 µ V/m
Vibration	< 0.5 m/s
Shock	≤ 3 g

12.7 *Power Supply Conditions*

12.7.1 The reference power supply conditions used shall be the reference values specified by the manufacturer. For those instances when a range of values is specified rather than a reference value, the midpoint of the range shall be taken to be the reference value.

12.7.2 The reference power supply must be sufficiently rated for the DUT. In addition, the following supply conditions and tolerances shall apply:

Table 3

DC supply reference voltage	± 0.1% of operating voltage
Noise and ripple of DC supply	≤ 0.1% rms

13 Procedure

13.1 *Zero Offset* — Close the gas shut-off valve upstream of the DUT and apply a 100% setpoint to the DUT to equilibrate the pressure across the MFC. Wait for the flow to stabilize at a value near zero; then close the downstream shut-off valve. Deactivate the MFC's control valve (open for (NO) valves, closed for (NC) valves), and allow the MFC to auto-zero if the an auto-zero option is available. After the electrical output signal has stabilized for at least three minutes, record the MFC zero offset in Table 1. (Consult the manufacturer's specifications for the stabilization time and report this time on Table 2.)

Table 4 Data Tabulation Table One

Input %	*Set Point (sccm)*	*Indicated Flow (sccm)*	*Actual Flow (sccm)*
40	Wait 5 minutes.	Record no data.	
50			
60			
70			
80			
90			
100			
90			
80			
70			
60			
50			
40			
30			
20			
10			
5			
Minimum *			
5			
10			
20			
30			
40			

Input %	Set Point (sccm)	Indicated Flow (sccm)	Actual Flow (sccm)
50			
60			
70			
80			
90			
100			
90			
80			
70			
60			
50			
40			
30			
20			
10			
5			
Minimum *			
5			
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
90			
80			
70			
60			
50			
40			
30			
20			
10			
5			
Minimum *			
5			
10			
20			
30			
40			
50			

* Per Section 13.5.4.1

NOTE: Test for accuracy, linearity, repeatability, short-term reproducibility, and hysteresis.

Table 5 Test Data Cover Sheet

MFC			
Manufacturer________	Model________	Serial Number_________	Attitude________
Nameplate Gas________	Seal Material________	Valve Seat Material________	Full Scale Range________
Environment			
Ambient Temp. (°C)________	Ambient Press. (kPa)________	Humidity (%)________	
Test Gas________	Inlet Gas Press. (Kpa)________	Outlet Gas Press. (kPa)________	Gas Temp. (°C)________
Test Facility			
Name________	City/State________	Telephone ( )________	Fax ( )__________
Standard Used________	Standard Accuracy________	Facility Bias________	Certification Date________
Other Equipment________	Accuracy________	Certification Date________	
Other Equipment________	Accuracy________	Certification Date________	
Other Equipment________	Accuracy________	Certification Date________	
Other Equipment________	Accuracy________	Certification Date________	
Comments or Special Instructions:____			
____ Technical:________________			
____ Date:____________________			

13.2 Use the cardinal setpoints and any other setpoints of specific interest. These setpoints will be used to determine the accuracy of the MFC. The setpoint increments should exceed the expected deadband of the DUT.

13.3 At each setpoint under test, maintain the input signal until the output of the DUT becomes stabilized at its apparent final value. Observe and record the output values in Table 1 for each input value.

13.4 Record five readings at each setpoint during testing. The time between readings shall be between 1 and 100 times the settling time of the DUT.

[NOTE: If the data points show a trend in one direction, either up or down, the DUT is not stable enough for the test to proceed to the next setpoint. Record another five readings at this setpoint. If the results continue to show a trend, repeat the measurements at the previous setpoint. If the results are not satisfactory at this setpoint, stop the test for this MFC. If the results are not satisfactory, halt the test and verify the performance of the testing apparatus.]

13.5 *Test for Accuracy, Linearity, Repeatability, Short-Term Reproducibilty, and Hysteresis*

NOTE: Record data in Table 1.

13.5.1 Provide a setpoint to the DUT of 40% and hold it there for 5 minutes. Do not collect any data at this point. Apply a 50% setpoint to the MFC and record data.

13.5.2 Begin collecting data at the midpoint of the span. Use data tabulation table in Table 1.

13.5.3 Step the MFC's setpoint to the upper setpoint limit in the increments previously chosen; record data at each setpoint.

13.5.4 After data is recorded at the upper setpoint limit, step the setpoint to the lowest setpoint chosen, again taking data at each of the intermediate setpoints.

13.5.4.1 If the lowest setpoint chosen is greater than the lower setpoint limit, apply the lower setpoint limit to the device and wait for five minutes. This allows hysteresis to be calculated at the lowest setpoint chosen.

13.5.5 Continue collecting data, increasing the setpoint until the midpoint of the span is reached again.

13.5.6 Perform the cycle described in Sections 13.5.1–13.5.4 a total of three times.

13.6 *Test for Deadband*

13.6.1 Begin collecting data at the lowest setpoint chosen. Record on Table 3.

Table 6 Data Tabulation Table Two

Setpoint	*Lower Deadband (sccm)*	*Upper Deadband (sccm)*
10%		
20%		
30%		
40%		
50%		
60%		
70%		
80%		
90%		
100%		

13.6.2 Step the MFC's setpoint to the highest setpoint chosen that is less than the upper setpoint limit in the increments previously chosen; record data at each setpoint.

13.6.3 At each setpoint, slowly increase the setpoint signal to the DUT until a detectable flow output change is observed in the flow standard.

13.6.4 Record the setpoint signal when the flow output changes and call this the upper deadband value.

13.6.5 Return to the setpoint selected in Section 13.6.3.

13.6.6 Slowly decrease the setpoint signal until a detectable flow output change is observed.

13.6.7 Record the setpoint signal and call it the lower deadband value. Use Table 3.

14 Data Analysis

14.1 *Calculations*

NOTE: Record calculations on Table 4.

Table 7 Worksheet for Table 1

Setpoint	*Up Ave. Flow (sccm)*	*Down Ave. Flow (sccm)*	*Up/Down Ave. Flow (sccm)*	*Precision (sccm)*	*Bias (sccm)*	*Accuracy (%)*	*Linearity (%)*	*Repeatability*	*Reproducibility*
0									
10									
20									
30									
40									
50									
60									
70									
80									
90									
100									
Over-all									

14.1.1 *Accuracy*

14.1.1.1 Determine the precision at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint.

$$P = \frac{\sqrt{\Sigma(\Sigma(v_i - A_a)^2)_j}}{\Sigma n_j}$$

P = Precision

v_i = The ith measured value at a setpoint for a given cycle

A_a = Average measured value

n_j = Number of readings at a setpoint at a given cycle

i = Reading number in a cycle for a given setpoint

j = Cycle for a given setpoint

14.1.1.2 Determine the bias at a setpoint by averaging the difference between the measured value and the sum of the setpoint and zero offset. Perform this calculation at each setpoint.

$$B = \frac{\Sigma[\Sigma(A - S - Z)_i]_j}{\Sigma n_j}$$

B = Bias

A = Measured Value

S = Setpoint

Z = Zero offset of DUT

14.1.1.3 Determine the accuracy at each setpoint by summing the absolute values of the precision and bias. Divide the sum by the average of the setpoint and multiply by 100%. The sign of the accuracy is the same as the sign of the bias. Perform this calculation at each setpoint.

$$AS\% = \frac{|P| + |B|}{S_a} \times 100 \times \left(\frac{B}{|B|}\right)$$

AS = Accuracy of setpoint

S_a = Average of setpoint

14.1.1.4 Determine the overall accuracy of the DUT by adding the absolute value of the flow standard accuracy to the maximum absolute accuracy value from Section 14.1.1.3. This value is expressed as ± percentage of reading.

NOTE: This assumes that the flow standard accuracy is expressed as a percentage of reading.

$$\pm AD\% = |AS|_{MAX} + |AD_f|$$

AD = Accuracy of the DUT

AD_f = Accuracy of the flow standard

14.1.2 *Linearity*

14.1.2.1 Determine an equation for the straight line passing through the indicated flow at zero actual flow and the average measured value at a 100% setpoint.

$$m = \frac{A_a - Z_a}{100}$$

$$Y = mS + b$$

Z_a = Indicated flow at zero actual flow

A_a = Average measured value at 100% setpoint

m = Slope

Y = Ideal linearity value

14.1.2.2 Determine the linearity at a setpoint by averaging the difference between the measured value and the value of y at a given setpoint. Divide this number by the full scale range of the DUT and multiply by 100. Perform this calculation at each setpoint. Record this value in Figure 7.

$$LS\% = \frac{\Sigma[\Sigma(A - Y)_i]_j}{FS\,\Sigma n_j} \times 100$$

LS = Linearity of setpoint

FS = Full scale flow rate

14.1.2.3 The overall linearity of the DUT is the maximum absolute value calculated in 14.1.2.2. This value is expressed as a ± percentage of full scale.

$$\pm LD\% = |LS|_{max}$$

LD = Linearity of DUT

14.1.3 *Repeatability*

14.1.3.1 Determine the intermediate value by calculating the standard deviation of the measured values for all cycles approaching from a given direction. Divide this by the average setpoint for these cycles. Perform this calculation at each setpoint for both directions. The 100% setpoint will only be approached from the upscale direction.

$$I\% = \frac{\sqrt{\frac{\Sigma(v_i - A_a)^2}{n_i}}}{S_a} \times 100$$

I = Intermediate value

14.1.3.2 The repeatability at a setpoint is the maximum intermediate value at each setpoint calculated in Section 14.1.3.1. This value is expressed as a ± percentage of reading. Perform this calculation at each setpoint.

$$\pm RPS = I_{max}$$

RPS = Repeatability at a setpoint

14.1.3.3 The overall repeatability of the DUT is the maximum value calculated in Section 14.1.3.2.

$$\pm RPD = RPS_{max}$$

RPD = Repeatability of the DUT

14.1.4 *Short-Term Reproducibility*

14.1.4.1 Determine the short-term reproducibility at a setpoint by dividing the precision of the setpoint by the average setpoint. This is expressed as a percentage of reading. Perform this calculation a each setpoint.

$$SRS = \frac{P}{S_a} \times 100$$

SRS = Short-term reproducibility at a setpoint

14.1.4.2 The overall short-term reproducibility of the DUT is the maximum value calculated in Section 14.1.4.1.

$$\pm SRD = SRS_{max}$$

SRD = Short-term reproducibility of the device

14.1.5 *Deadband*

14.1.5.1 Determine the absolute deadband value by subtracting the lower deadband value from the upper value at each setpoint. Perform this calculation at each setpoint.

$$D = D_u - D_l$$

D = Deadband value

D_u = Upper deadband value

D_l = Lower deadband value

14.1.5.2 Determine the deadband at setpoint by dividing the absolute deadband value by the initial setpoint and multiplying by 100. This is expressed as a percentage of reading. Perform this calculation at each setpoint.

$$DBS = \frac{D}{S} \times 100$$

DBS = Deadband of setpoint

14.1.5.3 The overall deadband of the DUT is the maximum value calculated in Section 14.1.5.2.

$$\pm DBD = DBS_{max}$$

DBD = Deadband of device

14.1.6 *Hysteresis*

14.1.6.1 Determine the hysteresis plus deadband by subtracting the average of the difference between the downscale measured value and the downscale setpoint from the average of the difference between the upscale measured value and the upscale setpoint. Perform this calculation at each setpoint.

$$HDBS = \frac{\Sigma[\Sigma(A_u - S_u)_i]_k}{\Sigma n_k} - \frac{\Sigma[\Sigma(A_l - S_l)_i]_n}{\Sigma n_m}$$

$HDBS$ = Hysteresis plus deadband at a setpoint

A_u = Measured value, up cycle

A_l = Measured value, down cycle

S_u = Setpoint, up cycle

S_l = Setpoint, down cycle

n = Number of up scale readings

k = Up cycle number for a given setpoint

m = Down cycle number for a setpoint

14.1.6.2 Determine the hysteresis by subtracting the deadband from hysteresis plus deadband and divide the result by the initial setpoint and multiply by 100. This is expressed as a percentage of reading. Perform this calculation at each setpoint.

$$HS = \frac{HDBS - D}{S} \times 100$$

HS = Hysteresis at a setpoint

14.1.6.3 The overall hysteresis of the DUT is the maximum value calculated in Section 14.1.6.2.

$$\pm HD\% = HS_{max}$$

HD = Hysteresis of device

15 Data Presentation

15.1 *Accuracy* — Plot the accuracy data at each setpoint on a graph. The x-axis is the setpoint, and the y-axis is accuracy as a percentage of the reading.

15.2 *Linearity* — Plot the linearity at each setpoint on a graph. The x-axis is the setpoint, and the y-axis is linearity as a percentage of full scale.

15.3 *Repeatability* — Report a single number, as calculated above, as a percentage of the reading.

15.4 *Hysteresis* — Report a single number, as calculated above.

15.5 *Deadband* — Report a single number, as calculated above.

16 Related Documents

16.1 *SEMI Document*

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

16.2 *ANSI Documents*[3]

ANSI C39.5 — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

ANSI C42.100 — Dictionary of Electrical and Electronics Terms

ANSI MC4.1 — Dynamic Response Testing of Process Control Instrumentation

16.3 *ASME Document*[4]

ASME MFC-1M — Glossary of Terms Used in the Measurement of Fluid Flow in Pipes

16.4 *IEC Documents*[5]

IEC 160 — Standard Atmospheric Conditions for Test Purposes

IEC 546 — Methods of Evaluating the Performance of Controllers with Analogue [sic] Signals for Use in Industrial Process Control

16.5 *ISA Document*[6]

ISA S7.3 — Quality Standards for Instrument Air

16.6 *SEMASPEC*[7]

92071224B-STD — SEMATECH Provisional Test Method for Determining Reliability of a Mass Flow Controller — refer to this standard if reliability data is needed for some of the parameters tested in this method.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

3 American National Standards Institute, Inc. 1430 Broadway, New York, NY 10018

4 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

5 International Electrochemical Commission, 3, rue de Varembe, CH-1211 Geneva 20, Switzerland

6 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709

7 SEMATECH, 2706 Montopolis Drive, Austin, TX 78741

SEMI E57-0600
MECHANICAL SPECIFICATION FOR KINEMATIC COUPLINGS USED TO ALIGN AND SUPPORT 300 mm WAFER CARRIERS

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1996; previously published February 1999.

1 Purpose

1.1 This standard specifies the mechanical couplings used to ergonomically align and precisely support 300 mm wafer carriers (including transport cassettes, process cassettes, quartz boats, pods, lot boxes, and shipping boxes). Such a kinematic coupling can be used at several interfaces, including:

- between a box or cassette and a tool load-port or vehicle nest,
- between a transport cassette and a box, and
- between a process cassette or quartz boat and the floor of a process chamber.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Only the bottom half of the kinematic coupling is specified so that suppliers can be flexible in designing wafer carriers that can mate with it.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

3.2 *ISO Document*[1]

ISO 4287 — Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes.

4.2 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.3 *cassette* — a open structure that holds one or more substrates (as defined in SEMI E44).

4.4 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded.

4.5 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface.

4.6 *nominal wafer center line* — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling).

4.7 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.8 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

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1 ISO Central Secretariat, 1, rue de Varembé, C.P. 56, CH-1211 Genève 20, Switzerland; available in the U.S. from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

5 Requirements

5.1 *Kinematic Coupling Pin Shapes* — The physical alignment interface on the bottom of the wafer carrier consists of features (not specified in this standard) that mate with six pins underneath. As shown in Figure 1 and defined in Table 1, each pin is radially symmetric about the vertical center axis line and can be seen as the intersection of a cylinder of diameter *d*91 and a sphere of radius *r*93 (which might contact a flat plate). An additional rounding radius *r*95 provides contact with angled mating surfaces, and blend radii *r*94 and *r*96 smooth the resulting edges. The final roughness height of the over-all surface finish must be less than or equal to *r*97. Dimensions *r*92 and *z*91 have zero tolerance because they only give a distance to another toleranced dimension. (Dimensions in parenthesis are not part of the requirements in this standard but are intended to clarify the preparation of manufacturing instructions.)

5.2 *Kinematic Coupling Pin Locations* — The pins are arranged in three sets with two pins in each set. As shown in Figure 2, the outer pin in each set is designated the primary pin for use on a tool load-port or vehicle nest or inside a box, and the inner pin in each set is designated the secondary pin for use on a robotic arm that would pick up the carrier (typically from the side opposite the load face plane). The location of each pin is determined with respect to the three orthogonal datum planes defined in Section 4: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. Figure 3 shows the locations of the kinematic coupling pins as viewed from above, and Table 2 defines the locations (all of which are bilaterally symmetric about the bilateral datum plane). Angle θ is shown in Figure 3 for clarity and is not part of the requirements in this standard.

5.3 *Empirical Determination of Datum Plane Locations* — Given a set of three primary or secondary kinematic coupling pins, the datum planes should be determined as follows. The two pins that are closest together are the front pins which (along with a known vertical direction) define a Cartesian coordinate system. The center axis line of each pin is defined to be the vertical line whose *x* (left-right) coordinate is the average of the maximum protrusions of the pin to the left and to the right and whose *y* (front-back) coordinate is the average of the maximum protrusions of the pin to the front and to the back. The bilateral datum plane is defined to be the vertical plane that contains the center axis line of the rear pin and that is equally distant from the center axis lines of the front pins. The facial datum plane is defined to be the vertical plane that is perpendicular to the bilateral datum plane and whose distance to the center axis line of the rear pin is 1.5 times the average of the distances to the center axis lines of the front pins. The horizontal datum plane is defined to be the horizontal plane that is 13 mm (0.51 in.) below the average of the heights of the highest and lowest pin tops. Once these datum planes have been determined, the three kinematic coupling pins can be evaluated to see if they conform to Section 5.1 and 5.2 of this specification. If they comply, the kinematic coupling pins and datum planes can be used to evaluate the compliance of carriers to standards cited in Section 6.

6 Related Documents

6.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

6.2 *Other Documents*

Alexander H. Slocum, *Precision Machine Design*, Society of Manufacturing Engineers, Item Code 2597, 1992 (originally published by Prentice-Hall, 1992)

Table 1 Kinematic Coupling Pin Dimensions

Symbol Used	*Value Specified*	*Dimension Description*
*d*91	12 ± 0.05 mm (0.4724 ± 0.002 in.)	Diameter of pin centered on the center axis line
*r*92	6 mm (0.2362 in.)	Radial distance from the center axis line to the origin of the shoulder radius *r*95
*r*93	15 ± 0.05 mm (0.5906 ± 0.002 in.)	Radial distance from the intersection of the center axis line and *z*91 to the top of the pin
*r*94	2 ± 0.1 mm (0.0787 ± 0.004 in.)	Blend radius for the intersection of *r*93 and *r*95
*r*95	15 ± 0.05 mm (0.5906 ± 0.002 in.)	Radial distance from the intersection of the horizontal datum plane and *r*92 to the far shoulder of the pin
*r*96	2 ± 0.1 mm (0.0787 ± 0.004 in.)	Blend radius for the intersection of *r*95 and *d*91
*r*97	0.30 µm (12 µin.) maximum	Roughness (R_a) as defined in *ISO 4287*
*z*91	2 mm (0.08 in.)	Vertical distance from the horizontal datum plane to the origin of top radius *r*93

Table 2 Distances to the Center Axis Lines of the Coupling Pins

Symbol Used	*Value Specified*	*Datum Plane Measured from*	*Pin Center Axis Line(s) Measured to*
*r*97	0.30 µm (12 µin.) maximum	Roughness (R_a) as defined in *ISO 4287*	*r*97
*x*91	115 ± 0.05 mm (4.5276 ± 0.002 in.)	bilateral	front right and left primary
*x*92	92 ± 0.05 mm (3.6220 ± 0.002 in.)	bilateral	front right and left secondary
*y*91	80 ± 0.05 mm (3.1496 ± 0.002 in.)	facial	front right and left primary
*y*92	120 ± 0.05 mm (4.7244 ± 0.002 in.)	facial	rear primary
*y*93	64 ± 0.05 mm (2.5197 ± 0.002 in.)	facial	front right and left secondary
y94	96 ± 0.05 mm (3.7795 ± 0.002 in.)	facial	rear secondary

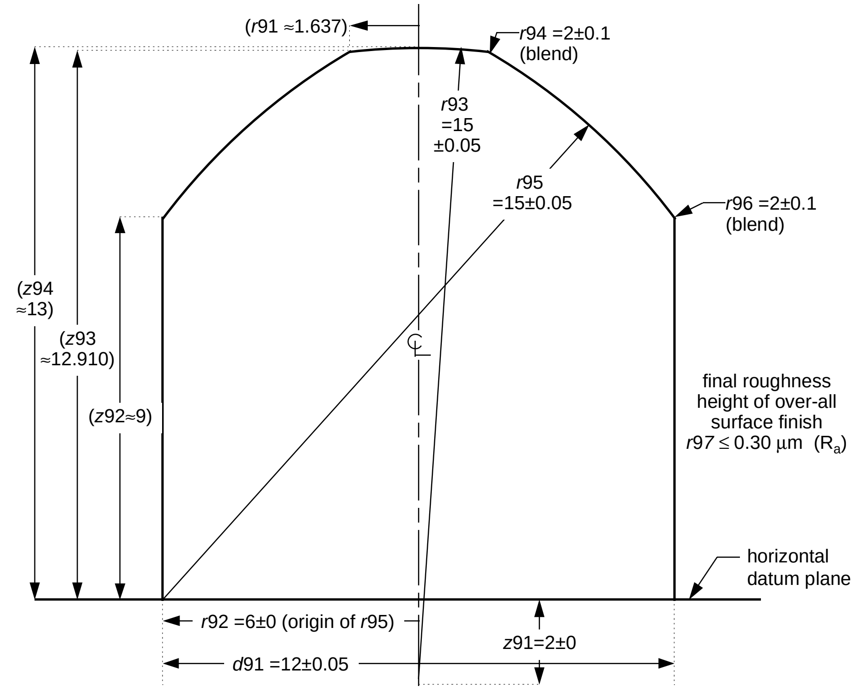

Figure 1
Kinematic Coupling Pin Shape

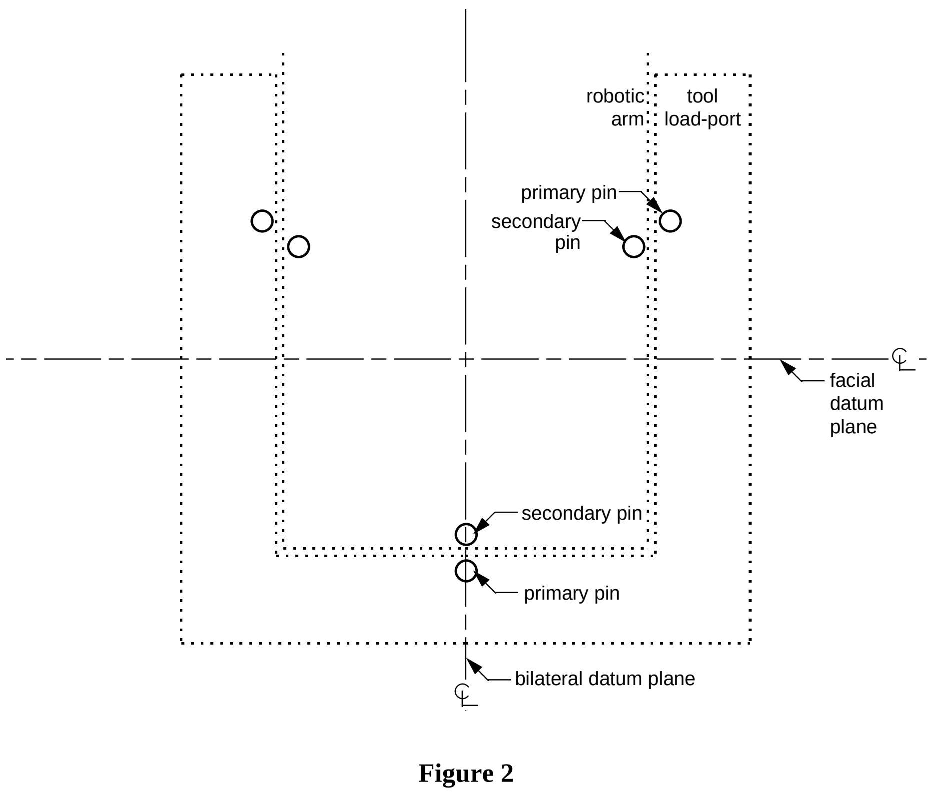

Figure 2
Primary and Secondary Kinematic Coupling Pins

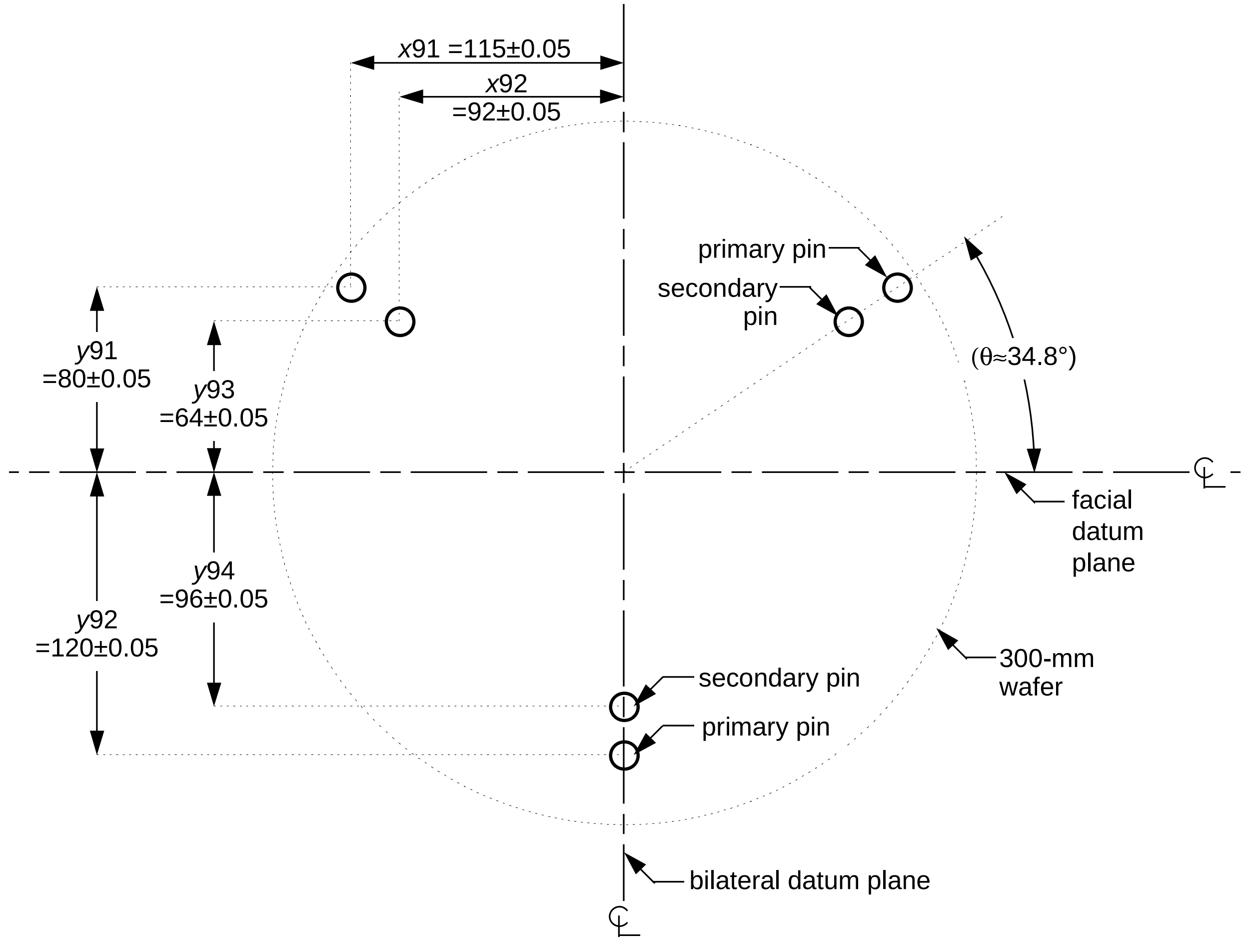

Figure 3
Kinematic Coupling Pin Locations

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E57 but was approved for publication by full letter ballot procedures. It is not intended to modify or supercede the official standard.

R1-1 The three features on the bottom of the wafer carrier that mate with the six pins underneath are not specified in this standard. These three features are recommended to be inverted V-shaped grooves, each of which extends along a line that is perpendicular to, and co-planar with, the nominal wafer center line (as shown in Figure R1-1). Such grooves are likely to work well even when shrunken or slightly misaligned (such as when they do not all line up with the nominal wafer center line). Other mating features are also possible, such as those shown in Figure R1-2 where one pin is contacted on the top. Front-opening boxes may need to contact the pins on the side to provide pressure against a front mechanical interface. Such options are why the top and sides of the pins are toleranced so tightly. When designing the mating features on the bottom of the wafer carrier, it is suggested that designers follow the recommendations given in the book (listed in Section 6) by Dr. Alexander H. Slocum.

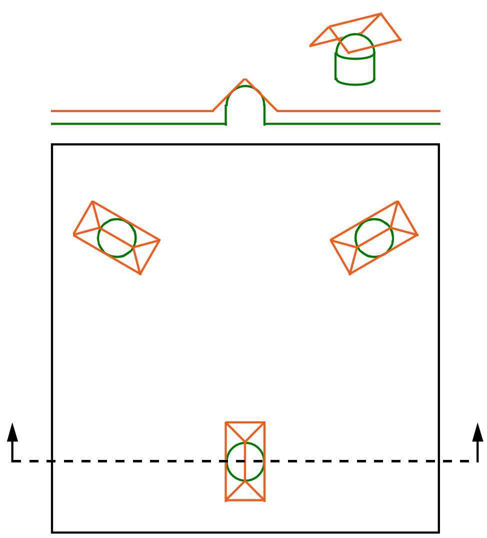

Figure R1-1
Recommended Mating Features

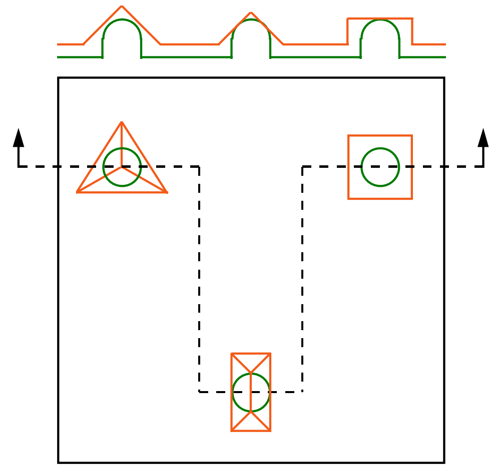

Figure R1-2
Alternative Mating Features

R1-2 All of the dimensions for the kinematic coupling pin surfaces and locations are given as ranges so that any roundness, cylindricity, perpendicularity, bending, or misalignment of the pins must be contained within the limits given.

R1-3 As shown in Figure R1-3, these couplings can also be used to support 200 mm pods as an addition to the requirements given in SEMI E19.4. However, concurrent implementations for both 200 and 300 mm wafer carriers may be covered by patent claims.

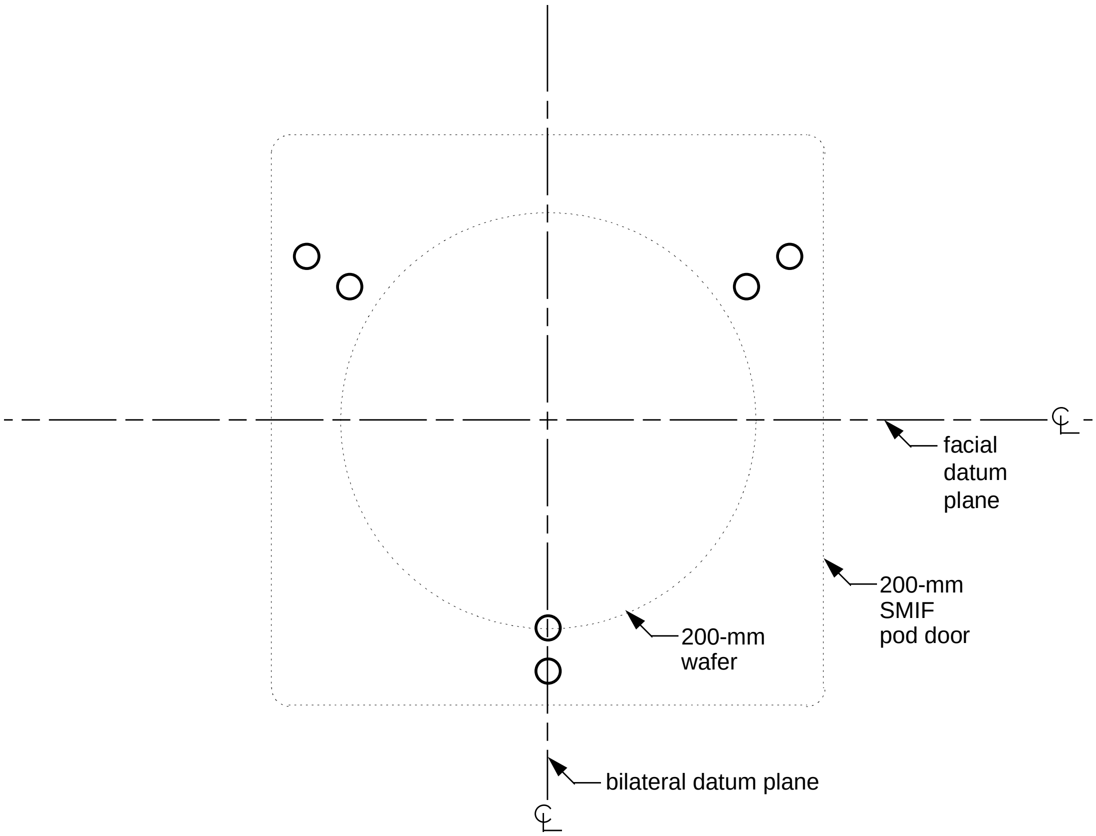

Figure R1-3
Application to 200 mm Pods

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E62-0302A
PROVISIONAL SPECIFICATION FOR 300 mm FRONT-OPENING INTERFACE MECHANICAL STANDARD (FIMS)

This provisional specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces & Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on December 3, 2001. Initially available at www.semi.org January 2002; to be published March 2002. Originally published in 1997; previously published November 2001.

NOTE: This document was published twice during the March 2002 (0302) publishing cycle.

1 Purpose

1.1 This standard specifies the tool side of the interface between a process or metrology tool and a front-opening box used to transport and store 300 mm wafers (which may or may not be in removable cassettes) in an IC factory.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Only the physical interface is specified; no materials requirements or micro-contamination limits are given. The interface specified in this standard can be for a sealed mini-environment, but it could also just be a well-defined automation interface.

2.2 This standard is provisional because the front-opening interface is a new technology. Once interface testing is done, this standard should be modified and upgraded from provisional status.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

3.2 *ISO Standard*[1]

ISO 4287 — Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *Definitions*

4.1.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.1.2 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.1.3 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.1.4 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

4.1.5 *door seal zone* — a surface on the exterior side of the port door for sealing to the box door.

4.1.6 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

4.1.7 *frame seal zone* — a surface on the exterior side of the frame of the port door for sealing to the frame of the box door.

4.1.8 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.1.9 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.1.10 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.1.11 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.1.12 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

5 Requirements

5.1 *Datum Planes* — The physical alignment mechanism from the box to the tool load port consists of features (not specified in this standard) on the box that mate with three or six pins underneath as defined in SEMI E57. Most of the dimensions of the interface from the box to the tool load port are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. However, the dimensions in this standard do not apply when the box is placed on the load port, but rather when the box has been moved horizontally into place against the front-opening interface. Otherwise, the front-opening interface would interfere with the kinematic coupling during loading, and the minimum rear clearance in E15 would be violated.

5.2 *Symmetry* — All of the dimensions for the interface are bilaterally symmetric about the bilateral datum plane and about a plane *z*30 above the horizontal datum plane with the following exceptions (as viewed by a person standing in front of the tool and facing the interface):

- The registration pins are in the lower right and upper left quadrants of the port door.
- The areas reserved for purge ports are in the upper right and lower left quadrants of the port door.
- Both latch keys turn 90° counter-clockwise from vertical to unlatch the box door from the box.

5.3 *Door Alignment Maintenance Mechanism* — The two registration pins that are used to limit the maximum displacement of the box door while on the port door are shown in Figures 1 and 2 and specified in Table 1. The over-all surface finish of the registration pins must have a final roughness height less than or equal to *r*47. The registration pins are surrounded by reserved space for optional vacuum application.

5.4 *Locking Mechanism* — The box door is locked and unlocked by a set of two 13.5 mm by 5 mm heads on shafts that have a 5 mm diameter. These latch keys must unlatch the box door from the box by rotating counter-clockwise to horizontal and must latch the box door to the box by rotating clockwise to vertical (as viewed by a person standing in front of the tool facing the *interface*). The latch keys must not rotate beyond these limits of the rotation angle ψ. To allow seal compression by latches, the torque delivered by the port to turn the latch keys must be at least *f*30. Thus, it is recommended that no box door be designed that needs more torque than this. Figure 3 shows front, side and top views of the latch keys. In addition, convex features on the outer edges of the latch keys (adjacent to the surface defined by *y*36) must have a blend radius of *r*41 to prevent small contact patches with large stresses that might cause wear and particles. Other convex features on the latch keys need only be de-burred and rounded off. The over-all surface finish of the latch keys must have a final roughness height less than or equal to *r*47.

5.5 *Seal Zones* — On the exterior side of the port must be two areas for sealing to the box. The door seal zone must be just inside the rim of the port door in the area between *x*32 and *x*33 from the facial datum plane and between *z*32 and *z*33 from the vertical center line of the port (which is *z*30 above the facial datum plane). Similarly, the frame seal zone must be on the frame of the port door in the area between *x*34 and *x*35 from the facial datum plane and between *z*34 and *z*35 from the vertical center line of the port. The door and its frame must be designed to mate with a front-opening box that conforms to SEMI E47.1. Specifically, the port door and its frame must have surfaces that mate with the seal zones and the reserved spaces for vacuum application (which includes all of the circles bounded by r38 except for the holes for the registration pins at the center of each circle). It is recommended that a gap be maintained between mating surfaces on the box and load port (unless the minienvironment is purged with an inert gas, in which case a tight seal is recommended).

5.6 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*45 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*46 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the interface supplier. Note also that this radius applies to every required feature unless another radius is called out specifically.

5.7 *Force Between Box and Port* — The force with which the load port holds the box in place against the FIMS interface must be greater than the force with which the load port presses the box door into the box.

5.8 *Force Between Box Door and Box* — The load port must press the box door into the box with a force of *f*34.

5.9 *Door Return Repeatability* — The load port must return the port door to the closed position after opening with a repeatability given by the dimensions *x*37 and *z*37.

5.10 *Force Applied by Latch Keys* — If the load port uses retracting latch keys, once the latch keys have been turned to the position that unlocks the box door from the box (ψ = 0±1°), the force (in a direction perpendicular to the facial datum plane) applied by each latch key to the FOUP door must be no greater than *f*35.

5.11 *Door Accommodation* — The load port must mate completely with the box at the FIMS interface. One method to accomplish this is to have the load port door protrude sufficiently (with some cushioning ability) to meet the FOUP door (however far the FOUP door protrudes within what SEMI E47.1 allows). The load port door (at least on the seal zone plate) must also accommodate variations in angle (with respect to the Facial Datum Plane) of the FOUP door (however much the FOUP door varies in angle within what SEMI E47.1 allows).

6 Related Documents

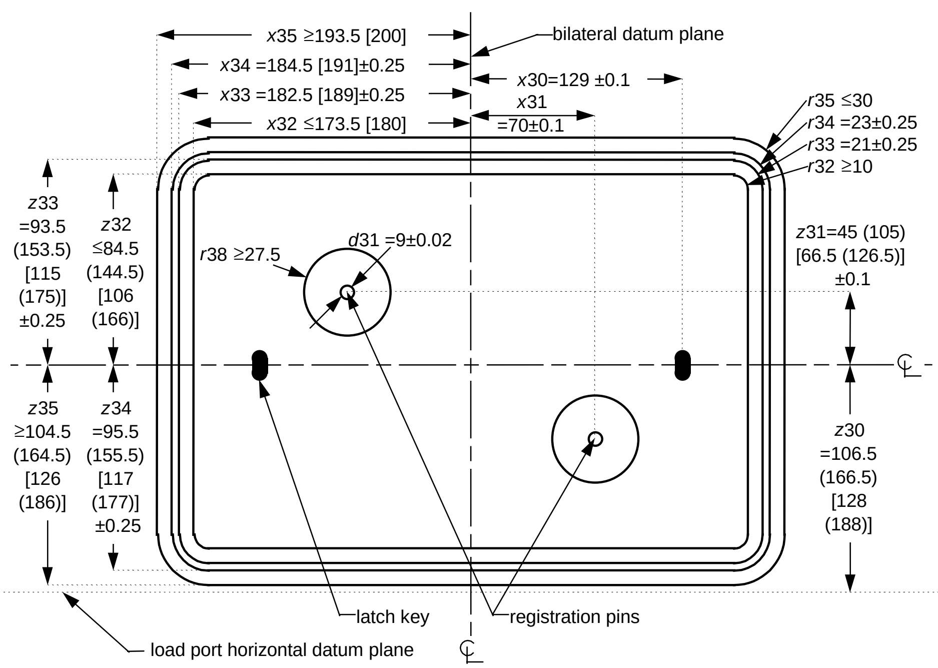
6.1 *SEMI Standards*

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers



(numbers in parentheses are for 25-wafer boxes, if different)
[numbers in square brackets are for boxes with removable cassettes, if different]

Figure 1
Dimensions for Front-Opening Interface

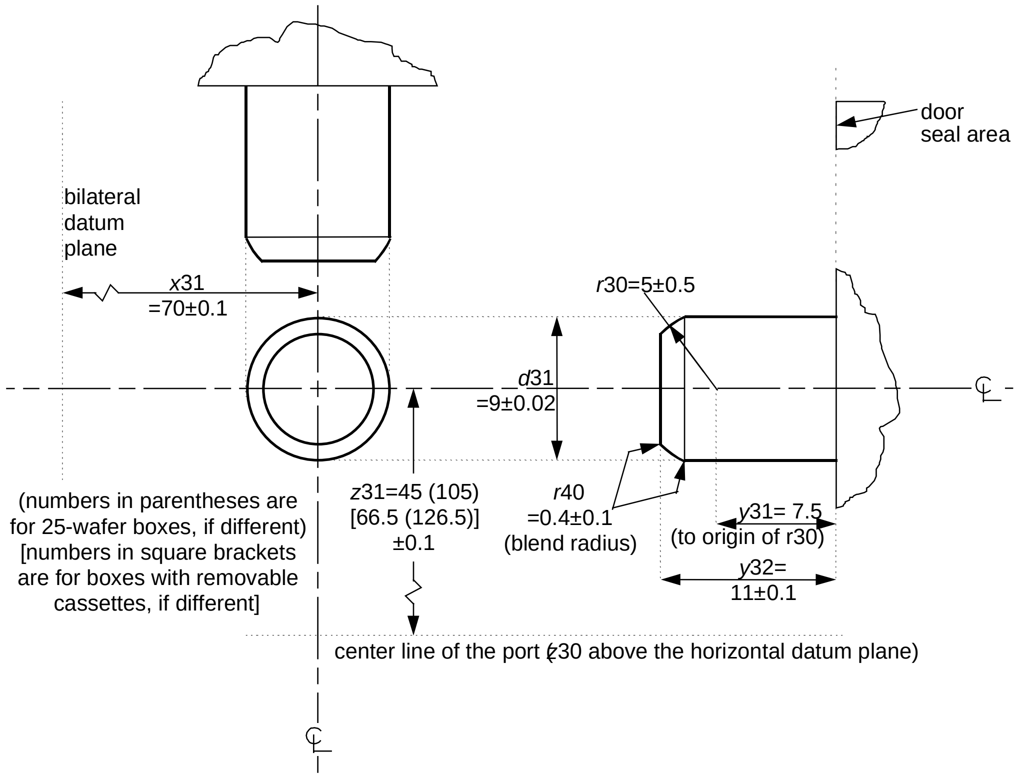


Figure 2
Registration Pin Dimensions

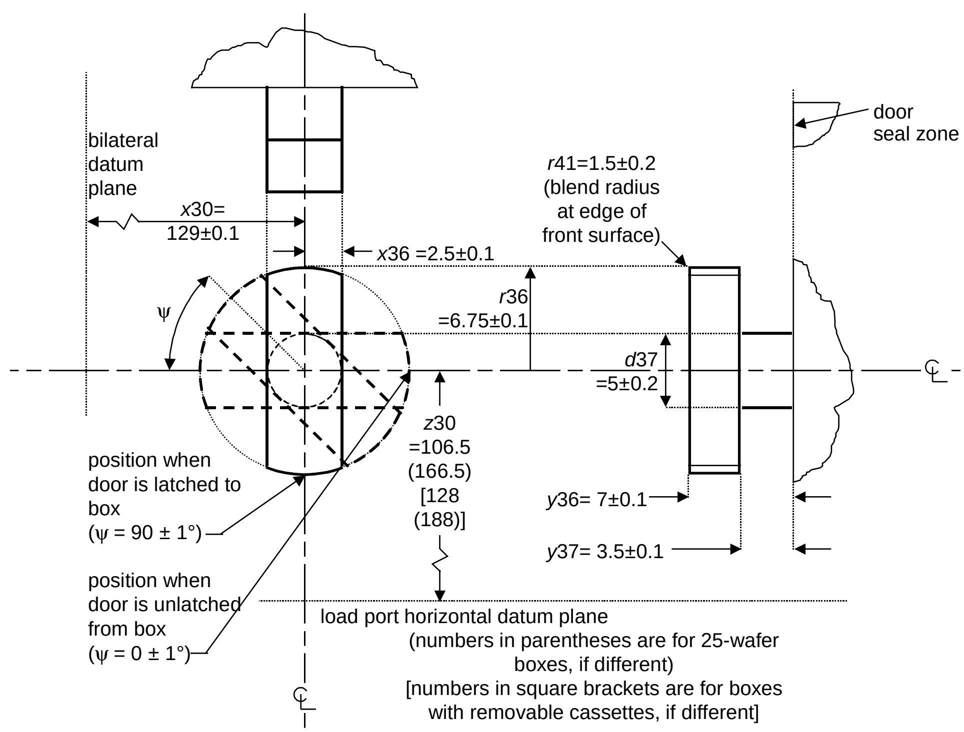


Figure 3
Latch Key Dimensions

Table 1 Dimensions for Front-Opening Interface Mechanical Specification (FIMS)

Symbol Used	*Value Specified*	*Datum Measured from*	*Feature Measured to*
ψ	0 ± 1° (to unlatch the box door from the box) 90 ± 1° (to latch the box door to the box)	horizontal datum plane	clockwise rotation of latch key
*d*31	9 ± 0.02 mm (0.3543 ± 0.0008 in.)	diameter centered on the intersection of *x*31 and *z*31	surface of registration pin shaft
*d*37	5 ± 0.2 mm (0.197 ± 0.008 in.)	diameter centered on the intersection of *x*30 and *z*30	surface of latch key shaft
*f*30	1.7 N-m (15 in.-lbf.) minimum	not applicable	torque delivered by the port to turn the latch keys
*f*34	9 N (2 lbf.) minimum	not applicable	force with which the port presses the box door into the box
*f*35	20 N (4.5 lbf.) maximum	not applicable	force per latch key applied to the FOUP door (in a direction perpendicular to the facial datum plane)
*r*30	5 ± 0.5 mm (0.20 ± 0.02 in.)	intersection of *x*31, *y*31, and *z*31	shoulder of registration pin
*r*32	10 mm (0.39 in.) minimum	not applicable	inside corner of door seal zone
*r*33	21 ± 0.25 mm (0.827 ± 0.010 in.)	not applicable	outside corner of door seal zone
*r*34	23 ± 0.25 mm (0.906 ± 0.010 in.)	not applicable	inside corner of frame seal zone
*r*35	30 mm (1.18 in.) maximum	not applicable	outside corner of frame seal zone
*r*36	6.75 ± 0.1 mm (0.266 ± 0.004 in.)	intersection of *x*30 and *z*30	ends of latch key head
*r*38	27.5 mm (1.08 in.) minimum	intersection of *x*31 and *z*31	boundary of vacuum application zone around registration pin
*r*40	0.4 ± 0.1 mm (0.016 ± 0.004 in.)	not applicable	blend at intersection of *r*30 with *r*31 and *y*32
*r*41	1.5 ± 0.2 mm (0.059 ± 0.008 in.)	not applicable	blend at convex features on the outer edge of the latch keys (adjacent to the surface defined by *y*36)
*r*45	1 mm (0.04 in.) maximum	not applicable	all concave features (radius)
*r*46	2 mm (0.08 in.) maximum	not applicable	all required convex features (radius)
*r*47	0.80 μm (32 μin.) maximum Roughness (R_a) as defined in ISO 4287	not applicable	surface finish of the registration pins and latch keys
*x*30	129 ± 0.1 mm (5.08 ± 0.004 in.)	bilateral datum plane	center line of latch key rotation
*x*31	70 ± 0.1 mm (2.756 ± 0.004 in.)	bilateral datum plane	center of registration pins
*x*32	173.5 mm (6.83 in.) maximum for nonremovable cassette and 180 mm (7.09 in.) maximum for removable cassette	bilateral datum plane	inside edge of door seal zone

Symbol Used	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*x*33	182.5 ± 0.25 mm (7.185 ± 0.010 in.) for nonremovable cassette and 189 ± 0.25 mm (7.441 ± 0.010 in.) for removable cassette	bilateral datum plane	outside edge of door seal zone
*x*34	184.5 ± 0.25 mm (7.264 ± 0.010 in.) for nonremovable cassette and 191 ± 0.25 mm (7.520 ± 0.010 in.) for removable cassette	bilateral datum plane	inside edge of frame seal zone
*x*35	193.5 mm (7.62 in.) minimum for nonremovable cassette and 200 mm (7.87 in.) minimum for removable cassette	bilateral datum plane	outside edge of frame seal zone
*x*36	2.5 ± 0.1 mm (0.098 ± 0.004 in.)	*x*30 from bilateral datum plane	side of latch key head
*x*37	± 0.2 mm (± 0.008 in.)	position of the load port door before opening	position of the load port door after closing
*y*31	7.5 mm (0.30 in.)	point on door seal zone closest to facial datum plane	origin of *r*30 (shoulder radius) on registration pin
*y*32	11.0 ± 0.1 mm (0.43 ± 0.004 in.)	point on door seal zone closest to facial datum plane	end of registration pin
*y*36	7.0 ± 0.1 mm (0.28 ± 0.004 in.)	point on door seal zone closest to facial datum plane	far side of latch key head
*y*37	3.5 ± 0.1 mm (0.14 ± 0.004 in.)	point on door seal zone closest to facial datum plane	near side of latch key head
*z*30	106.5 ± 0 mm (4.19 ± 0 in.) for nonremovable 13-wafer cassette and 166.5 ± 0 mm (6.56 ± 0 in.) for nonremovable 25-wafer cassette and 128 ± 0 mm (5.04 ± 0 in.) for removable 13-wafer cassette and 188 ± 0 mm (7.40 ± 0 in.) for removable 25-wafer cassette	horizontal datum plane	vertical center line of port and center line of latch key rotation
*z*31	45 ± 0.1 mm (1.772 ± 0.004 in.) for nonremovable 13-wafer cassette and 105 ± 0.1 mm (4.134 ± 0.004 in.) for nonremovable 25-wafer cassette and 66.5 ± 0.1 mm (2.618 ± 0.004 in.) for removable 13-wafer cassette and 126.5 ± 0.1 mm (49.80 ± 0.004 in.) for removable 25-wafer cassette	*z*30 above horizontal datum plane	center of registration pins

Symbol Used	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*z*32	84.5 mm (3.33 in.) maximum for nonremovable 13-wafer cassette and 144.5 mm (5.69 in.) maximum for nonremovable 25-wafer cassette and 106 mm (4.17 in.) maximum for removable 13-wafer cassette and 166 mm (6.54 in.) maximum for removable 25-wafer cassette	*z*30 above horizontal datum plane	inside edge of door seal zone
*z*33	93.5 ± 0.25 mm (3.681 ± 0.010 in.) for nonremovable 13-wafer cassette and 153.5 ± 0.25 mm (6.043 ± 0.010 in.) for nonremovable 25-wafer cassette and 115 ± 0.25 mm (4.528 ± 0.010 in.) for removable 13-wafer cassette and 175 ± 0.25 mm (6.890 ± 0.010 in.) for removable 25-wafer cassette	*z*30 above horizontal datum plane	outside edge of door seal zone
*z*34	95.5 ± 0.25 mm (3.760 ± 0.010 in.) for nonremovable 13-wafer cassette and 155.5 ± 0.25 mm (6.122 ± 0.010 in.) for nonremovable 25-wafer cassette and 117 ± 0.25 mm (4.606 ± 0.010 in.) for removable 13-wafer cassette and 177 ± 0.25 mm (6.969 ± 0.010 in.) for removable 25-wafer cassette	*z*30 above horizontal datum plane	inside edge of frame seal zone
*z*35	104.5 mm (4.11 in.) minimum for nonremovable 13-wafer cassette and 164.5 mm (6.48 in.) minimum for nonremovable 25-wafer cassette and 126 mm (4.96 in.) minimum for removable 13-wafer cassette and 186 mm (7.32 in.) minimum for removable 25-wafer cassette	*z*30 above horizontal datum plane	outside edge of frame seal zone
*z*37	± 0.2 mm (± 0.008 in.)	position of the load port door before opening	position of the load port door after closing

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as an official part of SEMI E62, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Perpendicularity and parallelism are implicitly defined in the geometric tolerances.

A1-2 Section 5.1 discusses the need for clearance between the box and the tool's front-opening interface when the box is placed on the load port. After the box is placed on the load port, the kinematic couplings will move the box forward to engage with the tool's front-opening interface. The possibility of human fingers being pinched between the box and the tool's front-opening interface may be a safety concern for tool designers.

SEMI E63-0600A

MECHANICAL SPECIFICATION FOR 300 mm BOX OPENER/LOADER TO TOOL STANDARD (BOLTS-M) INTERFACE

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1997, previously published February 2000.

NOTE: This document was published twice during the June 2000 (0600) publishing cycle.

1 Purpose

1.1 This standard specifies the tool side of the mechanical interface between the main part of a process or metrology tool and the component that opens boxes and presents the boxes to the tool wafer handler for unloading and loading 300 mm wafers. The box opener/loader unit would include one or more load ports (that would conform to SEMI E15.1) as well as storage capacity for empty boxes or waiting lots (if needed by the tool throughput). The box opener/loader unit might not only be configured to handle boxes (that would conform to SEMI E47.1, SEMI E62, or SEMI E19.5) but also to open cassettes (that would conform to SEMI E1.9). This standard defines one interface for all such carriers and for any carrier capacity (13 and 25 wafers).

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Only the mechanical interface is specified; no materials requirements or micro-contamination limits are given. The interface specified in this standard is designed for a tool with a sealed minienvironment, but it could also just be a well-defined automation interface. This interface is not intended to provide high repeatability or rapid removal (both of which can be provided by other couplings in the box opener/loader unit). This specification also does not apply when load ports are stacked one on top of the other. This specification does not apply when inserting open cassettes into load-lock chambers directly.

2.2 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

3.2 *ISO Specification* [1]

ISO/DIS 68-1 — ISO General Purpose Screw Threads – Basic Profile – Part I: Metric Screw Threads

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

1 This ISO specification is available from ANSI: American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036

4.2 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached.

4.3 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.4 *box opener/loader* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's wafer handler for unloading and loading wafers.

4.5 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.6 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

4.7 *equipment front end module (EFEM)* — consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in *SEMI E15.1*), opens the carriers (if needed), and may include a substrate handler for unloading and loading wafers from the carrier to the process part of the equipment.

4.8 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.9 *horizontal datum plane* — a horizontal plane from which project the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.10 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.11 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.12 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.13 *seal zone* — a surface on the tool at the BOLTS plane for sealing to the box opener/loader.

4.14 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

5 Requirements

5.1 *Datum Planes* — The physical alignment mechanism for the box consists of features (not specified in this standard) on the box that mate with three or six pins underneath as defined in SEMI E57. Many of the dimensions of the BOLTS interface are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. The BOLTS plane is defined to be parallel to and at a distance *y*70 from the facial datum plane of the carrier (when the carrier is docked and in position for wafer extraction and insertion). If the carrier is rotated after being placed on the loadport, the facial datum plane of the carrier and the BOLTS plane may no longer be parallel to the load face plane of the equipment. If the carrier is not rotated, the distance (called the docking stroke) between the facial datum plane when the carrier is placed on the loadport (undocked) and the facial datum plane when the carrier is in position for wafer extraction and insertion (docked) must be *y*76 (but this is only a requirement for equipment delivered in the year 2000 or later). The tolerance on *y*70 is the installation tolerance. The cycle-to-cycle repeatability on *y*70 (without replacing the box opener/loader unit) must be within *y*75.

5.2 *Symmetry* — All of the dimensions for the interface are bilaterally symmetric about the bilateral datum plane. These dimensions are shown in Figure 1 and specified in Table 1.

5.3 *Hole Opening* — The BOLTS interface consists of a hole in the front of the tool at the BOLTS plane, a seal zone surrounding the hole, six threaded holes for bolting on the box opener/loader, reserved spaces for the box opener/loader inside the tool from the hole, and an exclusion volume for the box opener/loader outside of the hole. The dimensions of the hole are defined by *x*71, *z*71, and *z*76.

5.4 *Seal Zone* — On the BOLTS plane surrounding the hole opening must be a flat area for sealing between the tool and the box opener/loader. The inner dimensions of the seal zone are the same as the hole opening, and the outer dimensions of the seal zone are defined by *x*72, *z*72, and *z*77. The flatness of the seal zone must be within *y*71, and the perpendicularity of the seal zone to the facial and horizontal datum planes must be within σ.

5.5 *Bolt Holes* — At six points on the BOLTS plane there must be threaded holes for bolting on the box opener/loader. The opening of the threaded holes must be within the flatness of the seal zone (*y*71), and the holes must be at least *y*73 deep. The internal threads must conform to the ISO/DIS 68-1 specification which has a nominal diameter of 8 mm (0.31 in.), a thread pitch of 1.25 mm (0.05 in.), a normal length of engagement from 4 to 12 mm (0.16 to 0.47 in.), and no allowance (variation from basic diameter). The centers of the threaded holes are to be located at *x*73 to the left and right of the bilateral datum plane, and centers of the top, middle, and bottom pairs of threaded holes are to be located at *z*78 above, *z*75 below, and *z*73 below the horizontal datum plane, respectively. Not all of these bolt holes need to be used by every box opener/loader, but all six threaded holes must be present on the tool. Note that the middle pair of threaded holes is in the seal zone, and so it may be covered up by some gaskets (which are not specified here).

5.6 *Reserved Spaces* — Inside the tool from the BOLTS plane are volumes reserved for the box opener/loader into which tool and its wafer handler may not protrude. A permanent reserved space is bounded by *x*70, *y*74, *z*70, and *z*80. When the door is closed, there is an additional temporary reserved space bounded by *x*70, *y*72, and *z*81. When the door is being opened or closed by the box opener/loader, there is a further temporary reserved space bounded by *x*70, *y*74, and *z*81. When the door is fully open, it will be withdrawn into the permanent reserved space, and the tool wafer handler may extend into the box to extract or insert wafers.

5.7 *Exclusion Volume* — Outside the tool from the BOLTS plane is a volume reserved for the box opener/loader into which the exterior of the tool may not protrude. This exclusion volume is bounded by *x*74, *z*79, and the floor. Within these boundaries and outside of the seal zone, no part of the tool may protrude closer to the facial datum plane than the closest point of the seal zone. Also, it is recommended that no part of the tool should overhang the box opener/loader, even above *z*79. Note that *x*74 has been chosen to allow the minimum width between adjacent load ports defined in SEMI E15.1.

5.8 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*75 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*76 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded-off too much. The lower bound on the radius is up to the tool supplier. Note also that this radius applies to every required feature unless another radius is called out specifically.

6 Related Documents

6.1 *SEMI Standards*

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

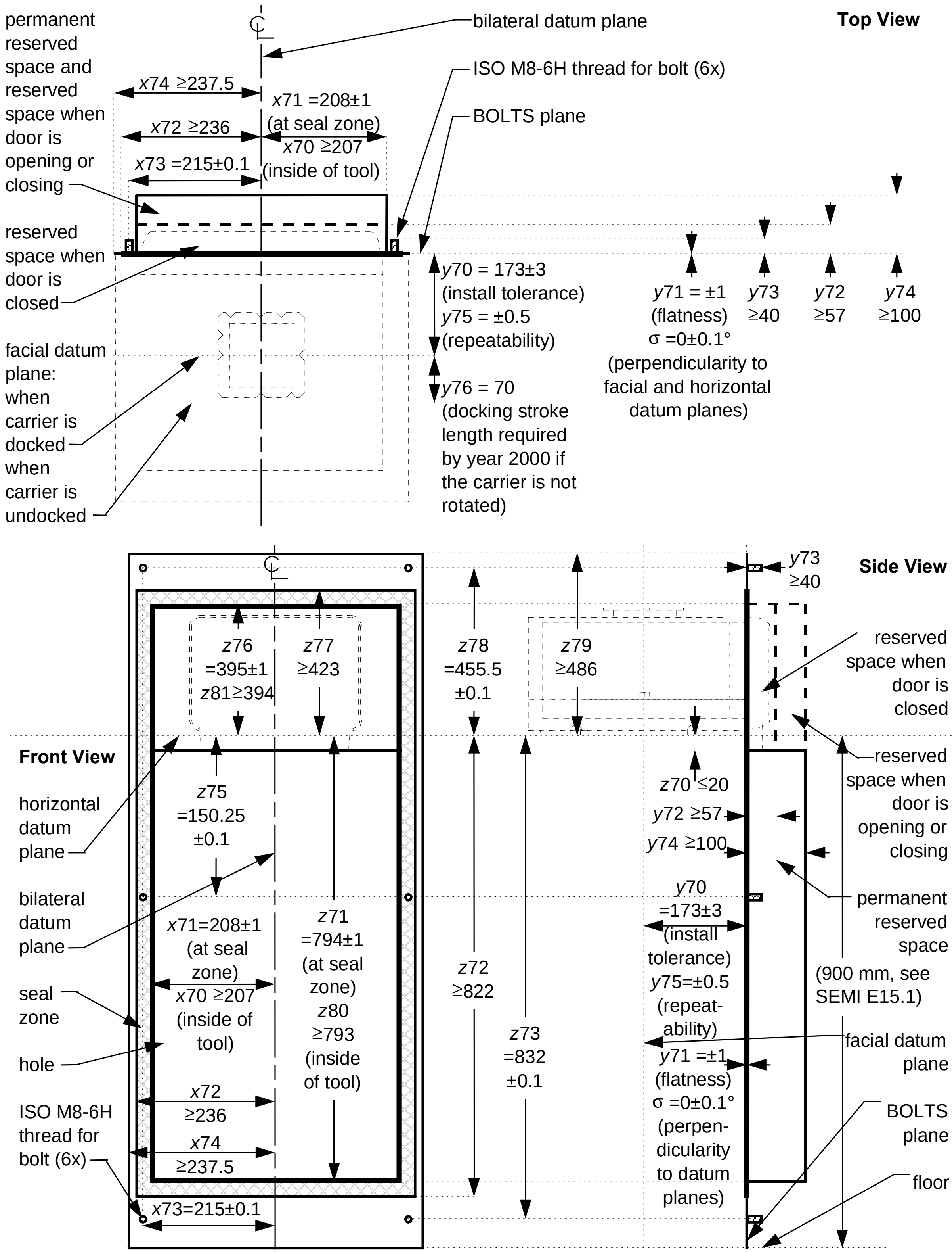


Figure 1
Top, Front, and Side Views of Box Opener/Loader to Tool Standard (BOLTS) Interface

Table 1 Dimensions for Box Opener/Loader to Tool Standard (BOLTS) Interface

Symbol	*Value Specified*	*Datum Measured from*	*Feature Measured to*
σ	0 ± 0.1°	facial and horizontal datum planes	perpendicularity of seal zone
*r*75	1 mm (0.04 in.) maximum	not applicable	all concave features (radius)
*r*76	2 mm (0.08 in.) maximum	not applicable	all required convex features (radius)
*x*70	207 mm (8.15 in.) minimum	bilateral datum plane	encroachment of tool on the sides of the reserved spaces inside the tool
*x*71	208 ± 1 mm (8.19 ± 0.04 in.)	bilateral datum plane	edge of hole opening and inside edge of seal zone
*x*72	236 mm (9.29 in.) minimum	bilateral datum plane	outside edge of seal zone
*x*73	215 ± 0.1 mm (8.465 ± 0.004 in.)	bilateral datum plane	center of threaded holes
*x*74	237.5 mm (9.35 in.) minimum	bilateral datum plane	encroachment of tool on the sides of the box opener/loader outside of the BOLTS plane
*y*70	173 ± 3 mm (6.8 ± 0.1 in.)	facial datum plane (when carrier is docked)	BOLTS plane (including seal zone and boundaries of equipment exclusion zones) installation tolerance
*y*71	± 1 mm (± 0.04 in.) flatness over seal zone	facial datum plane (when carrier is docked)	surface of seal zone
*y*72	57 mm (2.24 in.) minimum	facial datum plane (when carrier is docked)	encroachment of tool on the reserved space inside the tool when the door is closed
*y*73	40 mm (1.57 in.) minimum	facial datum plane (when carrier is docked)	depth of threaded holes
*y*74	100 mm (3.94 in.) minimum	facial datum plane (when carrier is docked)	encroachment of tool on the permanent reserved space and on the reserved space when the door is opening or closing
*y*75	± 0.5 mm (± 0.02 in.)	not applicable	the docked facial datum plane of the box opener/loader
*y*76	70 +2 –0 mm (2.76 +0.07 –0 in.)	facial datum plane when the carrier is undocked	facial datum plane when the carrier is docked
*z*70	20 mm (0.79 in.) maximum	horizontal datum plane	encroachment of tool on the top of the permanent reserved space inside the tool
*z*71	794 ± 1 mm (31.26 ± 0.04 in.)	horizontal datum plane	bottom edge of hole opening and inside edge of seal zone
*z*72	822 mm (32.36 in.) minimum	horizontal datum plane	outside edge of seal zone on bottom
*z*73	832 ± 0.1 mm (32.756 ± 0.004 in.)	horizontal datum plane	center of bottom threaded holes
*z*75	150.25 ± 0.1 mm (5.915 ± 0.004 in.)	horizontal datum plane	center of middle threaded holes
*z*76	395 ± 1 mm (15.55 ± 0.04 in.)	horizontal datum plane	top edge of hole opening and inside edge of seal zone
*z*77	423 mm (16.65 in.) minimum	horizontal datum plane	outside edge of seal zone on top
*z*78	455.5 ± 0.1 mm (17.933 ± 0.004 in.)	horizontal datum plane	center of top threaded holes
*z*79	486 mm (19.13 in.) minimum	horizontal datum plane	encroachment of tool on the top of the box opener/loader between the BOLTS plane and the load face plane
*z*80	793 mm (31.22 in.) minimum	horizontal datum plane	encroachment of tool on the bottom of the permanent reserved space inside the tool
*z*81	394 mm (15.51 in.) minimum	horizontal datum plane	encroachment of tool on the top of the reserved space inside the tool when the door is closed or is opening or closing

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RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E63 but was approved for publication by full letter ballot procedures.

R1-1 Unless otherwise stated, perpendicularity and parallelism are implicitly defined in the geometric tolerances.

SEMI E64-0600
SPECIFICATION FOR 300 mm CART TO SEMI E15.1 DOCKING INTERFACE PORT

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on April 10, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1997; previously published June 1998.

1 Purpose

1.1 This specification defines a standard location on SEMI E15.1-compliant tools and requirements to be used for installing a docking interface for carrier transport carts. It is intended to promote a consistent interface location between carrier transport carts and SEMI E15.1-compliant wafer process or inspection equipment.

2 Scope

2.1 This standard covers 300 mm SEMI E15.1-compliant tools only. Similar requirements for other tools are not defined here.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not define interface functionality, lead-in, accuracy, carrier transfer, compliance, impact, or vibration restrictions. Cart and docking interface designs should comprehend physical limitations of tools to which they are being applied.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *automatic docking* — Contact motion is controlled or limited by the design of the cart or interface.

5.2 *carrier* — Any cassette, box, pod, or boat that contains wafers (per SEMI E15).

5.3 *cart* — A floor-based carrier transfer vehicle.

5.4 *docking* — The act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment.

5.5 *load face plane* — The furthest physical vertical boundary plane from carrier centroid on the side(s) of the equipment where loading of the tool is intended (per SEMI E15).

5.6 *load port* — The interface location on a tool where carriers are placed to allow the tool to process wafers (per SEMI E15).

5.7 *manual docking* — Contact motion controlled by the operator of the cart.

5.8 *transfer* — To either load or unload (per SEMI E15).

6 Requirements

6.1 The following exclusion volume is reserved on SEMI E15.1-compliant tools for the installation of a docking interface device. This volume is referred to as Zone L.

6.1.1 *Interface Zone L* — A volume, just above floor level, reserved in SEMI E15.1 for installation of a contact docking device.

6.1.1.1 The vertical bounds of Zone L are defined by the floor from which Dimension H is measured in SEMI E15.1 and the Height L_h, per Table 1.

6.1.1.2 The depth of Zone L into the tool is L_d, measured from the load face plane as defined in SEMI E15.1.

6.1.1.3 The width of Zone L, L_w, is the full width of the tool measured at the load face plane.

6.1.1.4 A device mounted in Zone L is to be physically isolated from the tool and should be mounted such that the tool and tool load port are protected from the impact incurred during docking.

6.1.1.5 Since docking devices must be mounted on the floor in Zone L, the equipment must not require the use of support pedestals or other support structures under the floor below Zone L.

Table 1 Dimensional Requirements for Docking Zone L

Dimension	*Value, mm (in.)*
Zone L depth, L_d	100 (3.9)
Zone L width, L_w	Width of tool
Zone L height, L_h	100 (3.9)

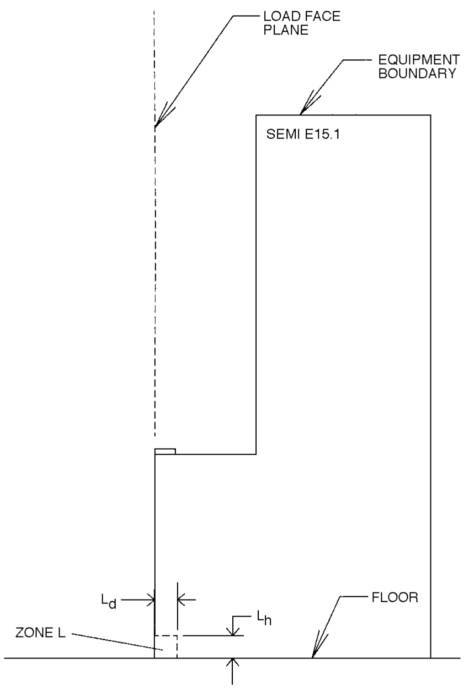

Figure 1
Side Elevation View

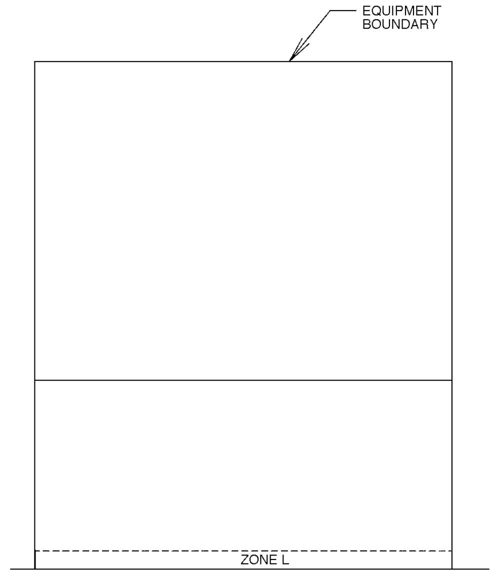

Figure 2
Front Elevation View

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RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E64 but was approved for publication by full letter ballot procedures.

R1-1 The intent of this standard is (1) To provide manually guided 300 mm carrier transport carts a standard location for docking to process and other tools; and (2) To facilitate development of a rapid repeatable cart to load port carrier transfer method or mechanism. Standardization of the size and location will allow for a modularity of the docking interface while minimizing limits on functionality of the interface.

R1-2 Zone L is defined as an exclusion zone in tools that comply with SEMI E15.1. It is intended that the tool side of a “cart/tool” docking interface be mounted in this zone.

R1-3 The docking interface (cart or tool side) may include all or some of the following features/functionality:

- Stopping cart motion,
- Dampening impact of docking,
- Compliance, Lead-in guidance for cart,
- Alignment of cart to docking interface, and
- Securely locking position of cart during carrier transfer.

R1-4 It is likely that the alignment error and tolerance stack-up between a device in Zone L and the tool port will not provide sufficient accuracy alone for accurate pick/placement of a carrier onto the kinematic couplings on the load port.

R1-5 Possible sources of alignment errors are

- Cleanroom floor height and level,
- Cart wheels and framework,
- Installation accuracy of device in Zone L, and
- Stability of mounting (floor changes).

R1-6 It may be necessary to use additional alignment methods to improve accuracy of carrier placement onto the kinematic couplings.

R1-7 It is expected that the interface device will be floor-mounted. SEMI E64 allows for automatic docking but does not specify the means or interfaces required. Cart/interface designers may find it advantageous to add registration features to the tool or load port which facilitate automatic docking and/or carrier transfer.

NOTE R1: Exclusion Zone L partially overlaps the installation space for the photo-coupled interface in SEMI E23. Compliance with both standards is possible. Suppliers should be aware of both standards and design accordingly.

R1-8 Compatibility with SEMI E23 can be maintained by reserving the area just above Zone L for installation of the photo-coupled I/O interface specified in SEMI E23 as shown in Figure R1-1.

R1-9 Zone L should remain clear of any physical obstructions to allow for installation of docking interface devices. End users may require other features that occupy this space, but should be aware that this could limit cart to tool docking solutions.

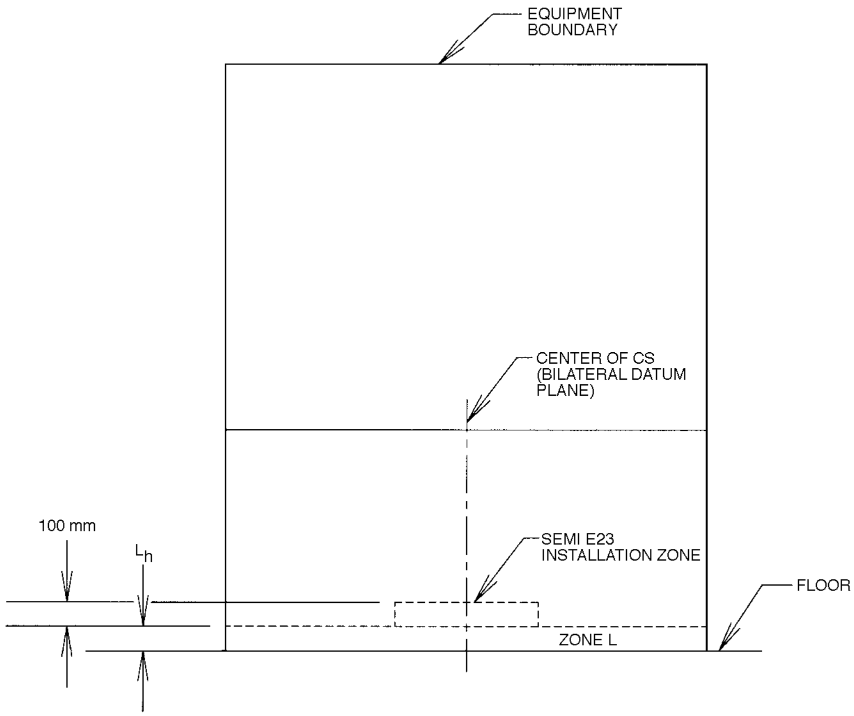

Figure R1-1
Front Elevation View

R1-10 Note that an installed docking interface may cause a potential trip hazard as shown in Figure R1-2. Equipment suppliers and/or docking interface suppliers may be required to eliminate the potential of this hazard (e.g., by adding covers or shields).

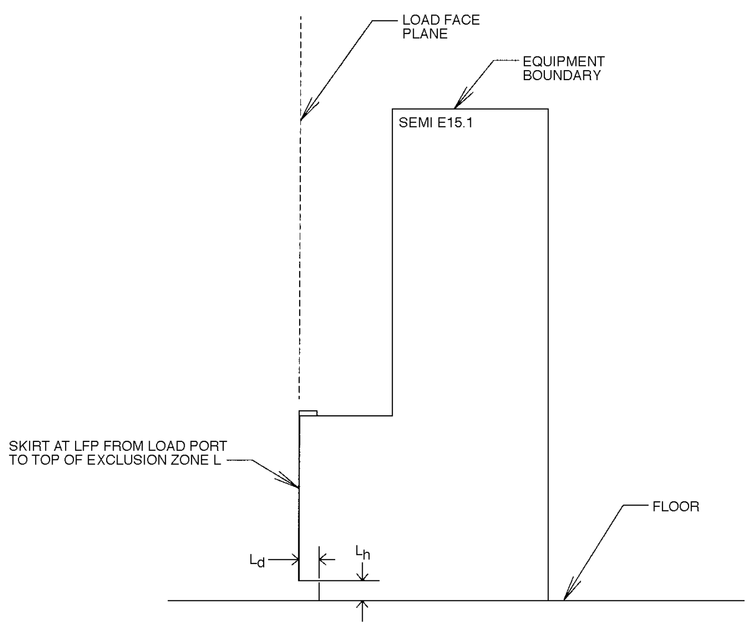

Figure R1-2
Side Elevation View

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SEMI E66-0997
TEST METHOD FOR DETERMINING PARTICLE CONTRIBUTION BY MASS FLOW CONTROLLERS

1 Purpose

1.1 The purpose of this test is to measure particle contribution by mass flow controllers (MFCs) in high-purity gas systems.

2 Scope

2.1 This document describes a test method that yields statistically significant comparisons of particle contribution among mass flow controllers under test conditions.

3 Limitations

3.1 This document is not intended as a method for monitoring in situ particulate performance once a particular MFC has been tested.

3.2 The test medium is limited to nitrogen. Actual performance under normal operating conditions may differ.

3.3 The accuracy of the data generated by this method is limited to the accuracy of the particle measuring instruments used.

3.4 This test method is intended for use by operators who understand the use of the apparatus at a level equivalent to one year of experience.

3.5 This test method should not be expected to yield comparable results from one test set up to another, due to the limitations of current particle counting technology.

3.6 Results may be compromised by the methods used to construct the apparatus.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI F1 — Specification for Leak Integrity of HighPurity Gas Piping Systems and Components

4.2 *Federal Standard*[1]

FED-STD 209 — Federal Standard Clean Room and Work Station Requirements, Controlled Environment

4.3 *ANSI Standards*[2]

ANSI B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

5 Terminology

5.1 *Acronyms*

5.1.1 *CNC* — condensation nucleus counter

5.1.2 *dof* — degrees of freedom

5.1.3 *DUT* — device under test

5.1.4 *FS* — full scale

5.1.5 *IKS* — isokinetic sampler

5.1.6 *kPa* — kiloPascal

5.1.7 *LPC* — laser particle counter

5.1.8 *ppm* — parts per million

5.1.9 *psia* — pounds per square inch absolute

5.1.10 *psid* — pounds per square inch differential

5.1.11 *psig* — pounds per square inch gauge

5.1.12 *Ra* — roughness average per ANSI B46.1

5.1.13 *RH* — relative humidity per ANSI B46.1

5.1.14 *Rmax* — roughness maximum

5.1.15 *scfm* — standard cubic feet per meter

5.1.16 *SFC* — supply mass flow controller

5.1.17 *slpm* — standard liters per minute

5.1.18 *SPC* — statistical process control

5.2 *Definitions*

5.2.1 *background counts* — Counts contributed by the test apparatus (including counter electrical noise) with the spool piece in place of the test object.

5.2.2 *condensation nucleus counter (CNC)* — A light scattering instrument that detects particles in a gaseous stream by condensing supersaturated vapor on the particles.

5.2.3 *dynamic control mode test* — A test performed to determine particle contribution as a result of test flow

1 Naval Publications and Forms Center, 5801 Tabor Avenue Philadelphia, PA 19120

2 American National Standards Institute, 1430 Broadway, New York, NY 10018

variation within the normal range of MFC operation (i.e., 0 to 100% flow).

5.2.4 *impact or vibration test* — A test performed to determine particle contribution as a result of test flow variation within the normal range of MFC operation (i.e., 10 to 100% flow).

5.2.5 *normal statistical distribution* — Measurements that randomly fall about an average, within a range of ± 3 standard deviations.

5.2.6 *observation* — A 10-minute sample/data collection period.

5.2.7 *purge mode* — Control valve fully open.

5.2.8 *sample flow* — The volumetric flow drawn by the counter for particle detection.

5.2.9 *sampling time* — The time increment over which counts are recorded.

5.2.10 *spool piece* — A null component consisting of a straight piece of electropolished tubing and appropriate fittings used in place of the test component to establish the background.

5.2.11 *stable particle level* — Particle level that has been consistent, as described in Appendix 1, for at least eight consecutive readings.

5.2.12 *standard reference conditions* — 101.32 kPa, 0.0_C (14.7 psia, 32_F) (see SEMI E29)

5.2.13 *statistical process control* — A method used by this standard for analyzing experimental data that follows a normal statistical distribution to determine if the test is stable.

5.2.14 *steady state control mode test* — A test performed to determine particle contribution during steady state test flow within the normal operating range of the MFC (i.e., 10 to 100% full scale).

5.2.15 *supply pressure* — Pressure immediately upstream of filter F1. (See Figures 1 and 2.)

5.2.16 *test flow* — Mass flow through the device under test.

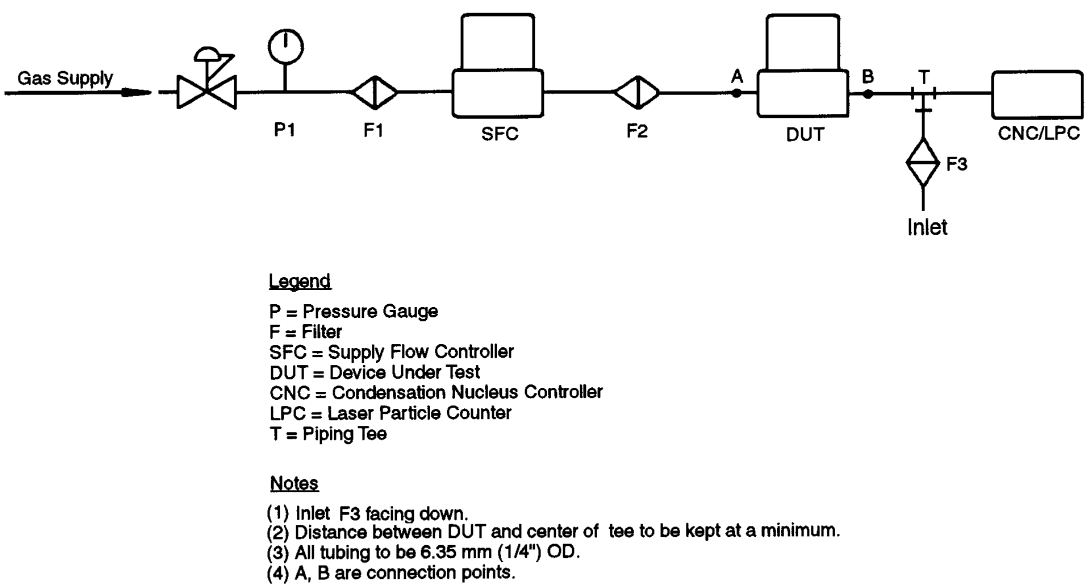


Figure 1
Test Set-Up when Test Flow < Sample Flow

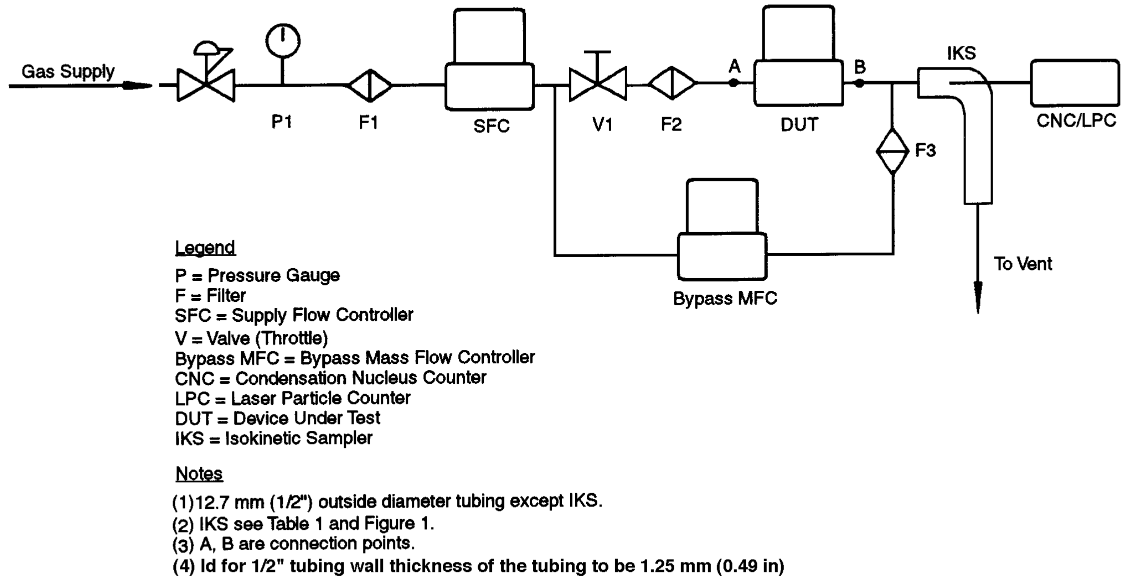


Figure 2
Test Set-Up when Test Flow > Sample Flow

6 Summary of Test Method

6.1 Background count is determined for steady state control, dynamic control, and impact tests. The steady state control mode test, dynamic control mode test, and impact test are run by counting particles for the time necessary to achieve a stable particle level. Background testing is performed again.

7 Significance and Use

7.1 The significance of this test method is that it defines a procedure for testing mass flow controllers intended for installation into a high-purity gas system. It is intended for use by manufacturers and end users.

8 Apparatus

8.1 *Test Gas* — Nitrogen of minimum dryness, with -40°-C (-40_°F) dew point at 790.57 kPa (100 psig) and with < 10 ppm of total hydrocarbons.

8.2 *Membrane Filters* — To provide filtered test gas, nine-log retentive to larger than 0.01 mm particles, with a pressure drop of less than 7.91 kPa (1 psid) at 283,170 sccm (10 scfm) for a 790.57 kPa (100 psig) inlet, and capable of achieving less than one particle[3] 0.01 mm per cubic foot of test gas under test conditions.

8.3 *Pressure Regulator* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) R_a and 0.25 mm (10 µin.) Rmax, to maintain system test pressure.

8.4 *Pressure Gauge or Transducer* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) R_a and 0.25 mm (10 µin.) Rmax, to monitor system test pressure.

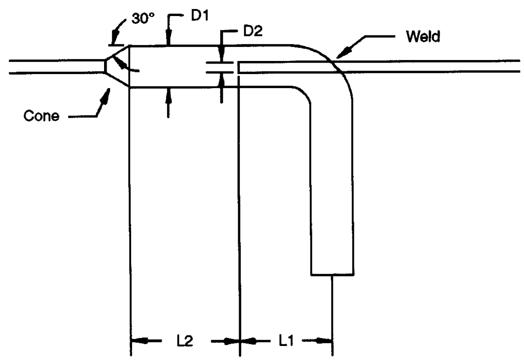
8.5 *Throttle Valve* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) R_a and 0.25 mm (10 µin.) Rmax, to proportion flow in test system.

8.6 *Tubing* — Made of electropolished 316L stainless steel, with an internal surface finish of 0.18 mm (7 µin.) Ra and 0.25 mm (10 µin.) Rmax.

8.7 *Supply Flow Controller (SFC)* — Metal-sealed, used to establish a flow rate through the spool piece in the absence of the DUT, with a settling time less than or equal to that of the DUT. More than one range SFC may be required to run all the tests.

8.8 *Sampler* — Constructed according to the drawing and design parameters shown in Figure 3 and Table 1, to collect gas from the stream exiting the test device, where the sample is near-isokinetic in design.

8.9 *Upstream Adapter* — To connect 12.7 mm (1/.2 in.) tubing to the test device. For 12.7 mm (1/.2 in.) test devices, the adapter is a simple face-seal connector. For 6.35 mm (1/4 in.) test devices, the adapter is a tapered cone between 6.35 mm and 12.7 mm (1/4 in. and 1/2 in.) face-seal connections.



D1 = Sampler Diameter
D2 = Probe Diameter
L1 = Length of Sampling Tube (minimum 15 x D1)
L2 = Length of Straight Section (minimum 15 x D1)

Notes

1. Transition cone to be 30°.
2. Material: Electropolished 316L, (0.25 mm) Ra, (0.375 mm) Rmax.
3. The volume of tubing downstream of the 90 degrees bend in the IKS must be large enough to contain the volume of gas drawn by the CNC/LPC when a DUT with a full scale equal to the IKS maximum is at 10% command to prevent ambient air from being sampled.

Figure 3
Isokinetic Sampler Design

Table 1

Maximum IKS Inlet Flow (liters/min.)	*ID Probe D_2 (note)mm (inches)*	*ID Sampler D_1 - mm (inches)*	*Worst-Case Dilution*
300	4.62 (0.180)	68.58 (2.700)	3:1
100	4.62 (0.180)	39.62 (1.560)	3:1
30	4.62 (0.180)	21.44 (0.844)	3:1
10	4.62 (0.180)	11.99 (0.472)	3:1
3	7.75 (0.305)	12.57 (0.495)	2:1

NOTE: For 300,000 to 10,000 cc/min. test flow:

- Constant sample velocity = 132 cm/sec.
- D2 = 4.57 mm (0.180 in.) ID standard 6.35 mm (1/4 in.) tubing (see Figure 3)
- For 1.41 l/min. CNC

NOTE: For 3,000 cc/min. test flow:

- Constant sample velocity = 49.9 cm/sec.
- D_2 = 7.75 mm (0.305 in.) ID standard 9.53 mm (3/8 in.) tubing (see Figure 3)
- For 1.41 l/min. CNC

8.10 *Downstream Adapter* — To connect 12.7 mm (1/2 in.) sampler tubing to the test device. For 12.7 mm (1/2 in.) test devices, the adapter is a simple face-seal connector. For 6.35 mm (1/4 in.) test devices, the adapter is a tapered cone between 6.35 mm and 12.7 mm (1/4 in. and 1/2 in.) face-seal connections.

8.11 *Spool Pieces* — Of the same inside diameter as the inside diameter fittings on the test piece and of a length representative of the DUT, to be installed in the system in place of the test device while obtaining background counts for the system.

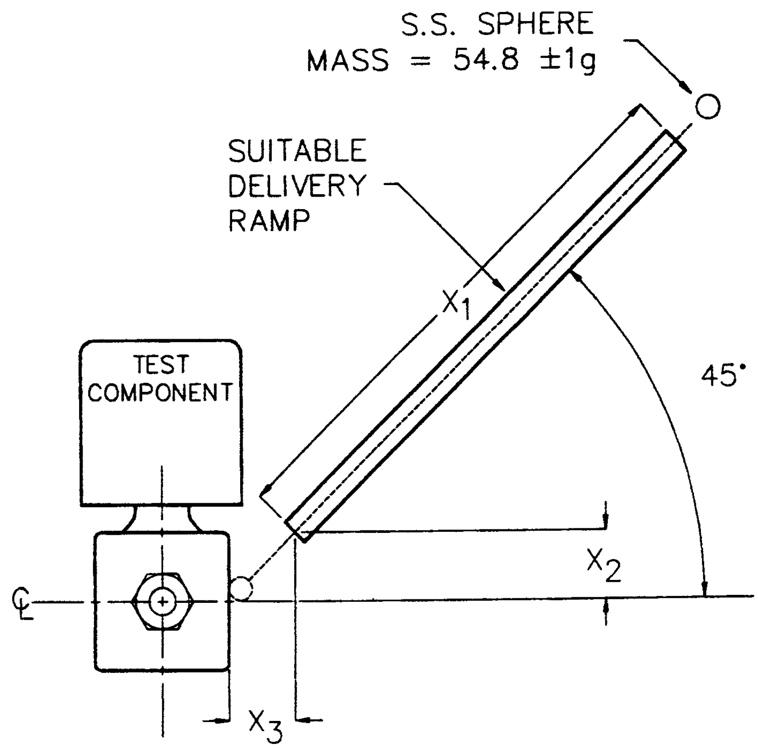
8.12 *Fittings* — Face seal connectors or compression fittings, depending on test component end connections. The end connection fittings of each DUT being compared must be of the same type.

8.13 *Metal Gaskets* — New gaskets should be used for each new connection.

8.14 *Mechanical Shock Device* — To provide mechanical shock by impact to the test device. (See Figure 4.)

8.15 *Instrumentation* — Condensation nucleus counter (CNC) or laser particle counter (LPC) to collect particle count data.

8.16 *Isokinetic Sampler (IKS)* — A static device used to collect a representative sample that is not influenced by flow characteristics and/or particle size (see Figure 3). Other designs of isokinetic samplers are permitted as long as they collect a representative sample of the flow.



NOTE: X_3 WILL CHANGE WITH A CHANGE IN SPHERE SIZE.
X_1 = 30.5cm ±0.5cm
X_2 = 0cm OR VERY CLOSE TO IT(DUE TO ANGLE AND BALL SIZE)
X_3 = 2.4cm ±0.1cm(DIA OF THE SS SPHERE)

Figure 4
Mechanical Shock Test Device

NOTE: Position the delivery ramp so that the position of impact is at the midpoint of the axial centerline of the device under test.

9 Sampling, Test Specimens, and Test Units

9.1 MFCs regulate flows greater than or less than the flow requirements of particle counters; therefore, two different sampling techniques have been defined, isokinetic sampling and direct sampling.

9.1.1 *Direct Sampling* — The direct sampling method is used when the test flow is less than or equal to the sample flow. (See Figure 1.)

9.1.1.1 In this case, gas exiting the DUT is introduced directly into the CNC. A tee, equipped with a filtered branch, is inserted between the DUT and the CNC to provide make-up flow to the CNC. The volume and overall length of the tubing connecting the DUT to the tee assembly should be minimized.

9.1.2 *Isokinetic Sampling* — Isokinetic sampling is used when the test flow is greater than the sample flow. (See Figure 2.)

NOTE 1: An alternative size IKS may be substituted for the IKS described in Sections 9.2.1 through 9.2.8 as long as it collects a representative sample of particles that is not influenced by flow characteristics and/or particle size.

9.1.2.1 Select the appropriate IKS (see Figure 3) from Table 1 for the test flow. This is the smallest IKS that exceeds the flow of the DUT.

9.1.2.2 The average velocity of the gas through the sampling probe shall approximate the average velocity in the tubing in which the sampling probe is inserted. The sample flow used to calculate the sampling probe diameter is the total flow drawn by the counter.

9.1.2.3 The tip of the sampling probe is to have a 30_ taper on the outside diameter.

9.1.2.4 The pick-off point is to be centered within the flow stream.

9.1.2.5 The pick-off point is to be at a minimum distance of 15 diameters of the primary flow tube upstream or downstream from any connection.

9.1.2.6 Flow stability within the isokinetic sampler is maintained by the bypass MFC.

9.1.2.7 To determine the dimensions of the isokinetic sampler, as shown in Table 1, the following equations and conditions are used:

10 Preparation of Apparatus

10.1 *Setup and Schematic for Direct Sampling* — See Figure 1.

10.1.1 Install the spool piece between points A and B.

10.1.2 Set nominal supply pressure to 308.10 kPa (30 psig).

10.1.3 Cycle the supply MFC, switching between a low flow and maximum purge flow as quickly as is reasonably possible. Cycle every five seconds for at least 30 minutes. The maximum purge flow should be as high as possible and no less than twice the test rate. During this initial cleanup, the particle counter should be off-line.

10.1.4 Moisture from an inboard leak can cause particle counts on some particle counters. Test the system for leak integrity per SEMI F1 – Subsystems Inboard Leak Test.

10.2 *Setup and Schematic for Isokinetic Sampling* — See Figure 2.

10.2.1 Install the spool piece between points A and B.

10.2.2 Set nominal supply pressure to 308.10 kPa (30 psig).

10.2.3 Cycle the supply MFC, switching between a low flow and maximum purge flow as quickly as is reasonably possible. Cycle every five seconds for at least 30 minutes. The maximum purge flow should be as high as possible and no less than twice the test rate. During this initial cleanup, the particle counter should be off-line.

10.2.4 Moisture from an inboard leak can cause particle counts on some particle counters. Test the system for leak integrity per SEMI F1 – Subsystems Inboard Leak Test.

10.3 Select the appropriate isokinetic sampler based on the maximum test flow of the DUT, using Table 1 and Figure 3. The size of the sampler should be equal to or greater than the maximum test flow.

11 Calibration and Reference Standards

11.1 Calibrate instruments regularly according to the manufacturer's recommendations.

12 Test Procedure

The test apparatus is to be enclosed in a Class 100 environment (in accordance with FED-STD 209). Test must be performed in the sequence described below. (See Figures 5 and 6.)

Measure DUT in purge mode to determine flow or use the value supplied by the manufacturer. This will determine which apparatus to use, direct sampling (Figure 1) or IKS (Figure 2). Both of the test apparatus may be required for testing a wide range of flow controllers.

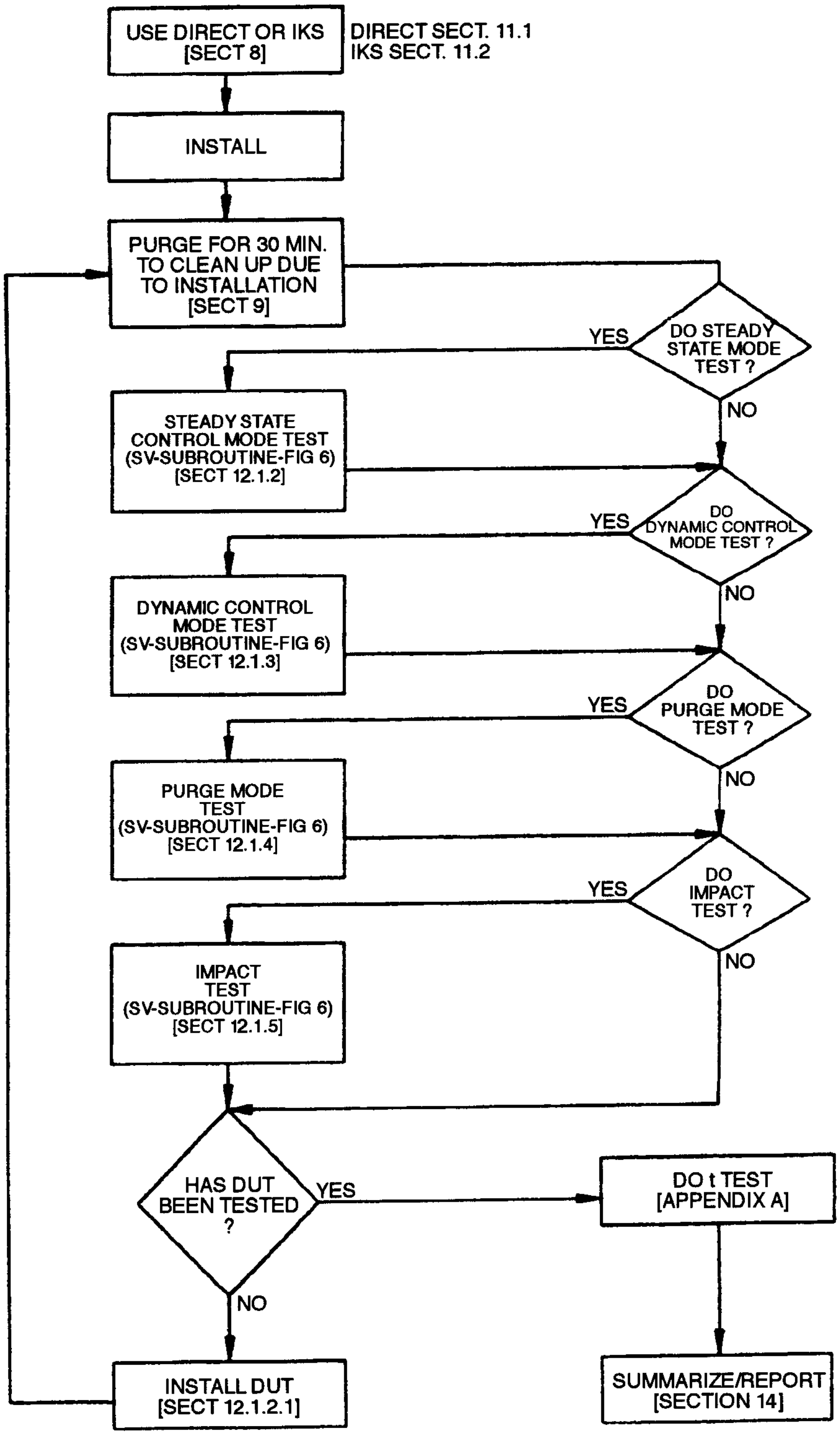


Figure 5
Particle Test Flow Chart

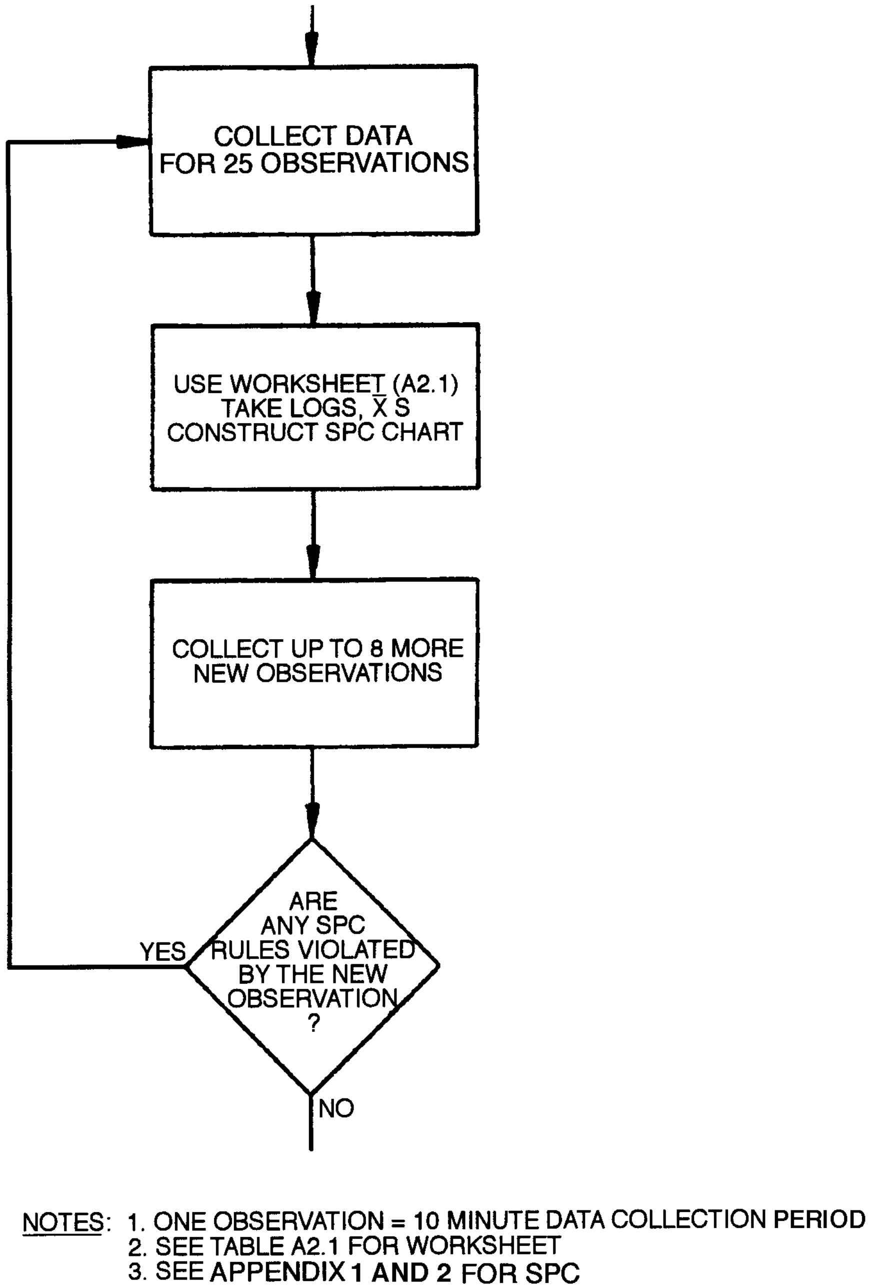


Figure 6
Statistical Validity Subroutine

12.1 *Procedure for Direct Sampling* — See Figures 5 and 6.

12.1.1 *Background Count Determination* — Insert spool piece between points A and B (see Figure 1).

12.1.2 *Steady State Control Mode Background Test* — Set supply MFC (SFC) to the intended test flow value of the DUT. For this test, the 100% full scale value is recommended.

12.1.2.1 Count particles for the time necessary to achieve a stable particle level.

12.1.3 *Dynamic Control Mode Background Test* — Cycle the SFC from 10% to 100% of the DUT's rated flow. The cycle period is equal to two times the settling time of the DUT with the longest settling time. (This will ensure that all MFCs in a given test are tested at the same cycle time.)

12.1.3.1 Count particles for the time necessary to achieve a stable particle level.

12.1.4 *Purge Mode Background Test* — Set the SFC to 100% of the rated flow of the DUT.

12.1.4.1 Count particles for the time necessary to achieve a stable particle level.

12.1.5 *Impact Background Test (optional)* — Set the SFC to the intended flow value of the DUT. For this test, the 100% full scale (FS) value is recommended.

12.1.5.1 Maintain the test flow in the spool piece to achieve a constant particle level. Strike the spool piece once a minute (using the mechanical shock device) until a constant particle level is achieved. (See Figure 4.)

12.1.5.2 Count particles for the time necessary to achieve a stable particle level.

12.1.6 *Steady State Control Mode Test* — Set SFC to 10% setpoint of the DUT's rated flow.

12.1.6.1 Remove the spool piece by disconnecting the downstream fitting and then the upstream fitting. Immediately install the test component in a fully open position by connecting the upstream fitting and then the downstream fitting. Take extreme care to minimize contamination of the test apparatus during this operation.

12.1.6.2 Set the SFC in purge mode (emulates tubing).

12.1.6.3 Set the DUT to the desired flow. For this test, the 100% full scale value is recommended.

12.1.6.4 Count particles for the time necessary to achieve a stable particle level.

12.1.7 *Dynamic Control Mode Test* — Keep the SFC in purge mode (emulates tubing).

12.1.7.1 Cycle the DUT from 10% to 100% of the DUT's rated flow. The cycle period is equal to two times the settling time of the DUT with the longest settling time. (This will ensure that all MFCs in a given test are tested at the same cycle time.)

12.1.7.2 Count particles for the time necessary to achieve a stable particle level.

12.1.8 *Purge Mode Test* — Set SFC to 100% of the DUT's rated flow.

12.1.8.1 Operate DUT in the purge mode until a stable particle level is achieved.

12.1.9 *Impact Test (optional)* — This test is to immediately follow the purge mode test.

12.1.9.1 Keep the SFC set to 100% of the DUT's rate flow.

12.1.9.2 Operate the DUT in the purge mode until a stable particle level is achieved.

12.1.9.3 Strike the DUT once a minute until consistent particle transients are achieved using the mechanical shock device. (See Figure 4.)

12.1.10 *Background Test* — Repeat all background tests performed in Section 12.1.1.

12.1.10.1 *Procedure for Isokinetic Sampling* — Follow the procedures described in Section 12.1, with the following exceptions:

12.1.10.2 To establish the background, see Figure 2 and the example below. With the spool piece in place, the throttle valve V1 fully open, and the bypass MFC in purge mode, set the SFC to the maximum inlet flow of the IKS. Adjust V1 and monitor the flow through the bypass MFC until the difference between the SFC flow and the bypass MFC flow is equal to the intended test flow of the DUT. The throttle valve V1 should remain fully open for all other tests that use the test set-up in Figure 2.

Example	*Given Test Flow:*	*Set SFC Flow:*	*Adjust V1 for Bypass MFC Flow:*
	25 slpm	30 slpm	5 slpm
	50 slpm	100 slpm	50 slpm

12.1.10.3 During steady state and dynamic testing of the DUT, use the bypass MFC to make up the difference between the intended flow value of the DUT and the maximum inlet flow of the sampler selected from Table 1.

13 Data Analysis

13.1 Appendix 1 contains information on statistical process control charting. Appendix 2 contains information on performing the t-test, a statistical method of comparing the mean background particle count with the mean device particle count.

14 Data Presentation

14.1 The following test conditions are to be reported in the data presentation:

14.1.1 Date and time of test

14.1.2 Operator

14.1.3 Test flow rate (sccm)

14.1.4 Test pressure (kPa)

14.1.5 Ambient temperature (_C)

14.1.6 MFC orientation

14.1.7 MFC location in test bed if multiple station test set-up used.

14.1.8 Cleanroom or environment classification

14.1.9 MFC type, manufacturer, serial number, sample flow rate (sccm), model number, calibration date, and particle range

14.1.10 Test gas type and dew point (_C)

14.1.11 A schematic of the test apparatus, including manufacturers and model numbers of all test apparatus components

14.1.12 Calibration dates for the flow meters

14.2 Refer to Figure A1-2 as an example of a typical cleanup curve. Graph the static, dynamic, and impact portions of the test separately as counts/minute (measured by the counter) versus time. Include the appropriate background (measured with the spool piece in place) for each. Also graph the entire data set as counts per minute versus time. If different MFCs are to be compared, graph their entire data sets together.

14.3 Present the entire raw data set in tabular form (see Table A2-1).

15 Precision and Bias

15.1 The precision and bias of the data generated by this test method is limited to the precision and bias of the particle measuring instruments used.

16 Related Documents

16.1 *SEMI Document*

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

16.2 *Manufacturer's Document*

Manufacturers Operating Manual — The appropriate particle counters manufacturer operating and maintenance manuals should be consulted when using this test method.

APPENDIX 1
STATISTICAL PROCESS CONTROL CHARTING

NOTE: This appendix was approved as an official part of SEMI E66 by full letter ballot procedure.

The following rules should be used to interpret the statistical process control chart, Figure A1-1:

1. If one observation is outside UCL/LCL, the process is out of control.
2. If two consecutive observations are > halfway, the process is out of control.
3. If at least eight successive points are in control, the process is stable.

It has been assumed that the data is approximately normal under log transform and that samples are independent.

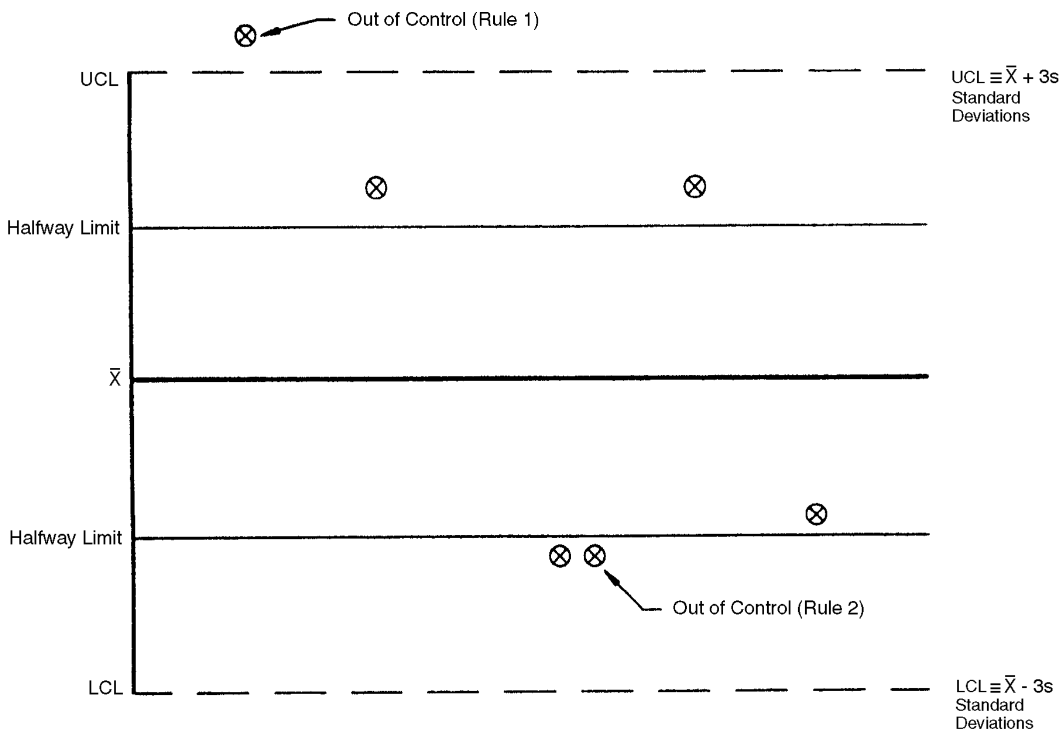


Figure A1-1
Statistical Process Control Chart

$$S = \sqrt{\frac{\sum_{1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where n = # of observations

Figure A1-2 gives an overall picture of the data collection specified by Table A2-1 for both “BACKGROUND” and “DEVICE”. There are three phases of data collection:

1. Cleanup
2. Steady-state performance
3. Statistical process control (SPC)

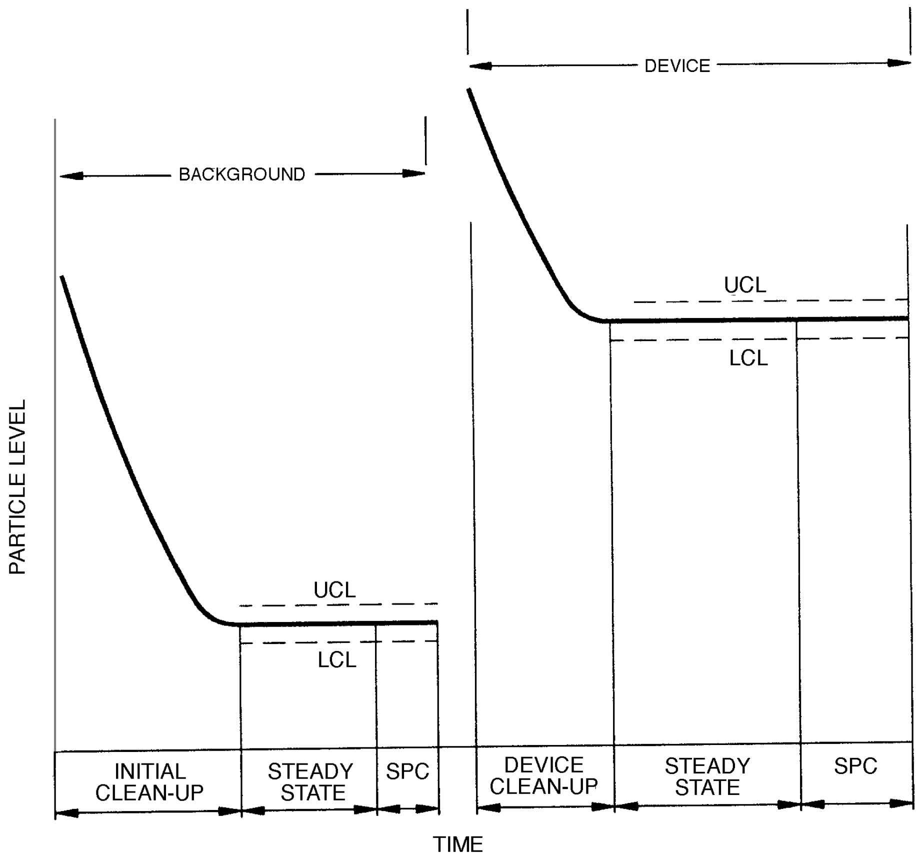


Figure A1-2
Graphical Representation of Data Collection

APPENDIX 2
t-TESTING; COMPARISON OF BACKGROUND MEAN AND DEVICE MEAN

NOTE: This appendix was approved as an official part of SEMI E66 by full letter ballot procedure.

A2-1 The background and DUT are expected to have low particle counts. Therefore, a statistical method is needed to determine if there is a difference between background and DUT particle counts. The t-test is a method of determining the actual statistical difference between the mean background particle count and the mean device particle count. It can be used to characterize the particle contribution by the MFC Record results in Table A2-1.

Table A2-1 Test Worksheet

	#	*Observation*	*log Observation*	*Remarks*
Spool Cleanup	1 ... Nx			All computations are in the logs of original observations.
Stable Level		X1 ... X25		Compute $X_{1, S1, UCL, LCL.}$
SPC		X26 ... X334		Use all 8 values to recompute new values ($X_{1,S1}$).
Connect Device				
Device Cleanup		X34 ... X35 + n		
Stable Level		X34 + n + 1 ... X34 + n + 25		Compute $X_{2, S2, UCL, LCL}$.
SPC		X34 + n + 26 ... X34 + n + 34		Use all 8 values to recompute new values ($X_{2, S2}$).

NOTE: Use t-test to compare X's. (See Appendix 2.)

A2-2 Calculate pooled standard deviation using the following equation:

$$S_{pooled} = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

where :

S_1 = background standard deviation

S_2 = device standard deviation

n_1 = background sample size

n_2 = device sample size

A2-3 Calculate the value of T (the t-test's namesake) as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{pooled} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where :

1 = background mean

2 = device mean

A2-4 The degrees of freedom (dof) is $n_1 + n_2 - 2$. For example, if $n_1 = n_2 = 8$, then dof = 14.

A2-5 Interpretation

If | t| ≥ $t_{.975}$, then the two means are significantly different at the 95% level. If | t| ≥ $t_{.995}$, then the two means are significantly different at the 99% level (e.g., by “95% confidence,” it is meant that the difference/no-difference decision based on the t-test will be correct 95% of the time).

$t_{.975}$ = 2.145 (2-sided)

$t_{.995}$ = 2.977 (2-sided)

NOTE:

- All readings are log particle counts, not particle counts.
- Since logs are used, zeros have to be replaced by positive values (e.g., 1/2).
- To determine t value for a particular confidence level and (dof), refer to any statistical reference book.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user’s attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringment of such rights, are entirely their own responsibility.

SEMI E67-0997
TEST METHOD FOR DETERMINING RELIABILITY OF MASS FLOW CONTROLLER

1 Purpose

This document describes a method to help determine the ability of an MFC to meet the manufacturer's published specifications over its life time. The results of the test will also be useful in the comparison of MFCs.

2 Scope

This procedure applies to MFCs used in semiconductor gas systems.

3 Limitations

3.1 This procedure is to be used only in conjunction with another existing parametric test for mass flow controllers to obtain the reliability data for that particular parametric test.

3.2 New MFCs shall be used for reliability testing. An MFC that has been put through this test method may be tested for reliability again.

3.3 In addition to this procedure, the parametric test may also cycle the valve. These cycles should be ignored for determining the cumulative cycles that are described in the data table.

3.4 This test will not address root cause analysis of failures.

3.5 Read points have been selected for this test procedure so that the test will take approximately six months to complete. The read point schedule given is only a suggested schedule and if the user feels that a different read point schedule would better suit his needs, this test method can still be used to obtain reliability data.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

4.2 *SEMASPECs*[1]

NOTE: The SEMASPECs noted here will be superceded by the comparable SEMI documents when available.

90120391B-STD — SEMATECH Test Method for the Determination of the Helium Leak Rate for Gas Distribution System Components

92071220B-STD — SEMATECH Guide to Provisional Test Methods for Mass Flow Controllers

92071222B-STD — SEMATECH Provisional Test Method for Determining Reproducibility and Zero Drift for Thermal Mass Flow Controllers

92071226B-STD — SEMATECH Provisional Test Method for Determining Particle Contribution by Mass Flow Controllers

4.3 *Other Document*

Nelson, Wayne, Applied Life Data Analysis, New York, NY Wiley, 1982 (see Annex)

5 Terminology

5.1 *Acronyms*

5.1.1 *MFC* — Mass flow controller

5.1.2 *UHP* — Ultra-high purity

5.2 *Definitions*

5.2.1 *cycle* — A repeating sequence of setpoints applied to the MFC.

5.2.2 *hard failure* — A catastrophic mechanical failure or electrical failure that results in an inoperable MFC, or a deviation from a user-defined specification that results in a condition that makes the MFC inadequate for the user's process.

5.2.3 *parametric test* — The test method that determines the data for which reliability information is sought (e.g., accuracy test or particle test, SEMASPECs or 92071226B).

5.2.4 *readpoint* — Cumulative cycles applied to the MFC.

5.2.5 *reliability* — The probability that the equipment will perform its intended function, within stated conditions, for a specified period of time.

5.2.6 *soft failure* — Failure that occurs when an MFC no longer meets the manufacturer's specification for the parameter under test.

6 Summary of Test Method

The MFC is installed in a fixture capable of applying and recording a number of flow cycles. When the

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number of cycles specified in the readpoint schedule is reached, cycling is suspended, parametric tests are performed, and the cycling is resumed until either the next readpoint is reached, or the MFC experiences a hard failure. After the cycling is completed, the parametric test data is analyzed to determine the reliability of each parameter.

7 Significance and Use

7.1 This test provides an estimate of the reliability of a mass flow controller. The results of the test will also be useful in the comparison of MFCs. The data provided by this test can help end users determine the reliability of equipment that uses MFCs.

7.2 The following parameters and associated test methods should be tested with this test method to obtain reliability data:

Parameter	*Test Method*
Particle Contribution	SEMASPEC 90171226B-STD
Reproducibility & Zero Drift	SEMASPEC 90171222B-STD
Helium Leak Rate	SEMASPEC 90120391B-STD
Step Response	SEMI E17

7.3 The following modifications to the preceding parametric test methods are suggested to abbreviate the time required to complete the reliability test:

7.3.1 *SEMASPEC 90171226B-STD (Particle Contribution)* — Abbreviate this test method to perform only the dynamic control mode test. Perform Sections 11.1.1.2 and 11.1.3, and eliminate Sections 11.1.1.1, 11.1.1.3, 11.1.1.4, 11.1.2, 11.1.4, 11.1.5, and 11.1.6. Refer to Sections 3.2.1 (Background), 3.2.3 (Dynamic), and Figure 5 (Particle Test Flow Chart).

7.3.2 *SEMASPEC 90171222B-STD (Reproducibility & Zero Drift)* — Omit Sections 10.1, 10.2, 11.5.3, 11.5.5, 11.5.6, 11.6, and 11.7.

7.3.3 *SEMI F1 (Leak Integrity)* — The intent of the reliability test method is to detect the development of gross leaks in the DUT due to cycling of the DUT valve. The inboard component leak test portion of this standard should be performed.

7.3.4 *SEMI E17 (Step Response)* — No abbreviation is necessary for this test. However, perform this test with the modifications noted in the SEMATECH Guide to Provisional Test Methods for Mass Flow Controllers, SEMASPEC 92071220B-STD.

7.4 Change in the performance characteristics of the MFC, as measured by the above tests, may also be monitored and analyzed as indicative of drift.

8 Apparatus

8.1 In addition to the apparatus listed below, the user must also acquire any apparatus required to perform the parametric test for which reliability data is needed. (See documents cited in Section 7.2.)

8.1.1 power supply

8.1.2 *NIST (or equivalent recognized standards agency)* — traceable flow calibration system

8.1.3 MFC control cables, as many as required in Section 8.1.4

8.1.4 mass flow controllers for controlling test flows in addition to the DUT MFCs, as many as required for the test setup

8.1.5 cycling fixture

9 Materials

9.1 In addition to the materials listed below, the user must also acquire any materials required to perform the parametric test for which reliability data is needed. (See documents cited in Section 7.2.) Since reliability data for leak integrity is being sought, helium cannot be used during the cycling procedure.

9.1.1 source of nitrogen (99.999%)

10 Sampling, Test Specimens, and Test Units

Three MFCs are required for meaningful data analysis. However, 20 to 30 MFCs are a recommended minimum. A larger sample size provides a more precise estimate of reliability.

11 Preparation of Apparatus

The setup for the parameter under test is described in the document for that particular parameter (see Section 7.2).

12 Calibration and Reference Standards

Any required instrument calibration or use of reference standards must be done in accordance with the particular parametric test for which reliability data is needed.

13 Conditioning

Conditioning requirements are those of the particular parametric test for which reliability data is needed.

14 Procedure

14.1 Connect all MFCs under test in parallel.

14.2 Perform the parametric test before any cycling is done and note the resulting data on the data sheet (Table 1). This is the first readpoint (see Figure 1).

Table 1 Data Sheet for Reliability Testing

READPOINT (Cumulative cycles applied to the MFC)	*FAILURE TYPE — SOFT OR HARD*	*SOFT FAILURE TYPE**
0 (baseline)		
10,000		
40,000		
100,000		
200,000		
300,000		
450,000		
600,000		
750,000		
875,000		
1,000,000		

*Use the following soft failure types:

A = Accuracy/Repeatability

P = Particles

S = Step Response

L = Leakage

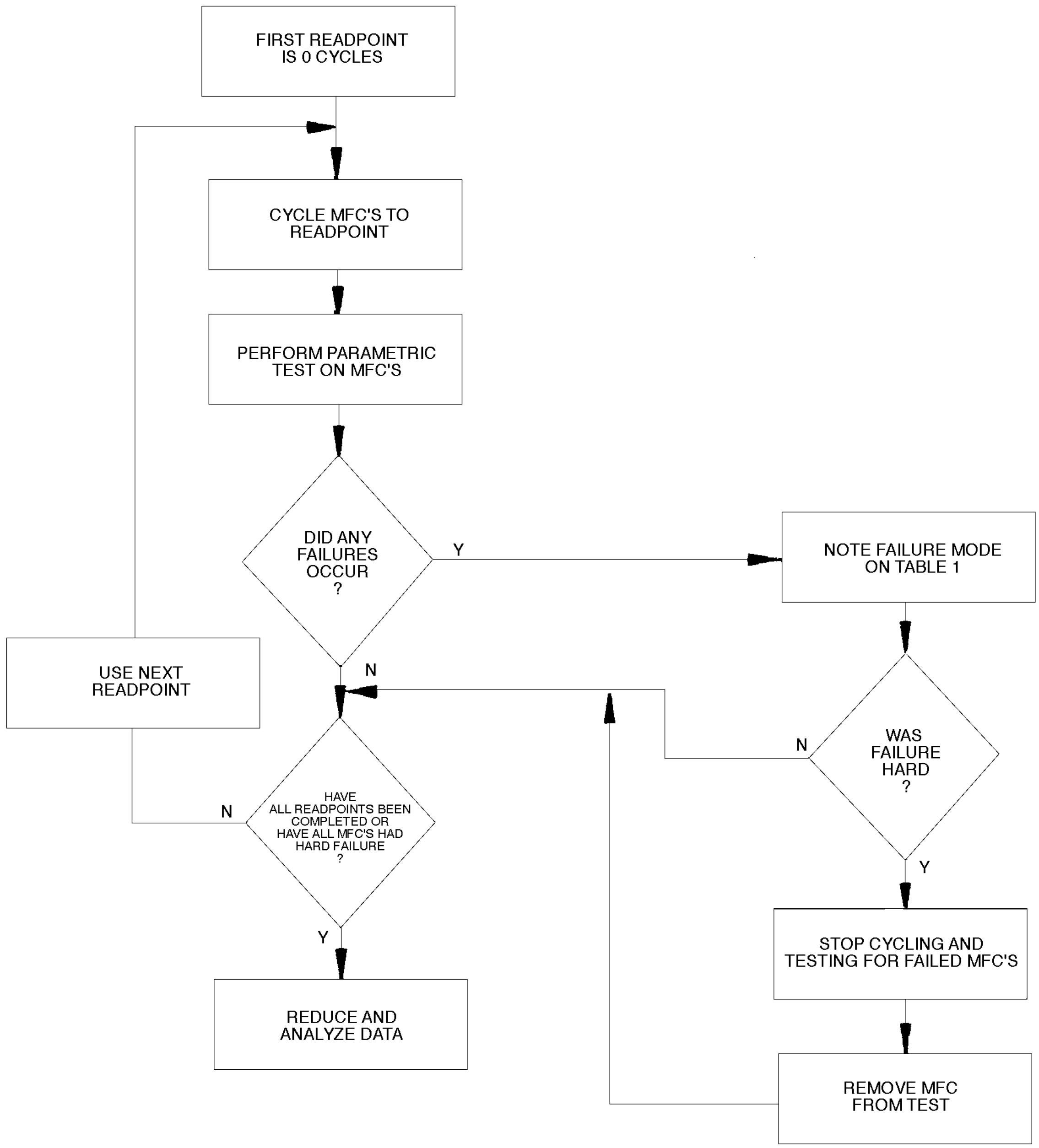

Figure 1
Flowchart for Reliability Test Procedure

NOTE: Do not count the cycles that occur during the parametric test.

14.3 Cycle the MFCs to the next readpoint in Table 1. Two types of cycles are applied to the MFC to simulate more realistically the MFC's field environment. Alternate between the two types of cycles as illustrated in Figure 2. Maintain each setpoint for a fixed period of time. Use one of the following times based upon the settling time of the slowest DUT. If the settling time is less than or equal to 1.25 seconds, use a time period of 2.5 seconds. If the settling time is less than or equal to 2.5 seconds and greater than 1.25 seconds, use a time period of 5 seconds. If the settling time is greater than 2.5 seconds, use a time period of twice the settling time.

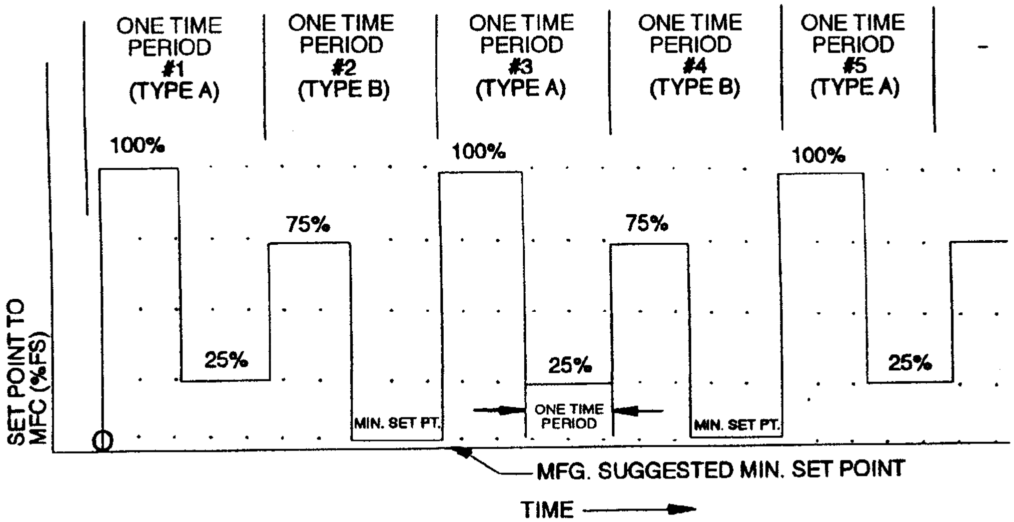

Figure 2
Types of Cycles

14.4 Discontinue cycling. Perform the parametric tests on all MFCs and record the results on the data sheet. If any MFC experiences a soft failure, record the data but do not stop the cycling procedure. However, if an MFC experiences a hard failure, record the data, discontinue testing this MFC, and take appropriate action to maintain system integrity.

NOTE: The test does not require mention of the cause for hard failure, as it is beyond the scope of this document.

14.5 The parametric tests should be performed in the following order: particle, accuracy, response, and leak.

14.6 Perform all of the parametric tests on a single MFC before proceeding to the next one. Record the order of the MFCs tested and the time since the test stand was idled.

14.7 If the readpoint is reached during a time when it is not possible to start the parametric testing, continue cycling until it is possible to begin. Record the number of cycles that occurred before beginning testing.

14.8 Average the particle count information over a 10-minute interval. Count particles for six 10-minute intervals. Record the data from only the last three 10-minute intervals.

14.9 Repeat steps 14.4 through 14.8 until all the readpoints have been completed or until all MFCs have experienced hard failures.

15 Data Analysis

15.1 *Calculations* — See Appendix 1 for a discussion on reliability calculation.

15.2 *Interpretation of Results* — The readpoints included in Table 1 are approximately equidistant on a log scale, and as data is collected, the number of readpoints needed to show trends and estimate life will decrease significantly.

16 Data Presentation

16.1 Plot each performance measure over number of cycles to look for trends and shifts as a function of use (see Figure 3). This gives a picture of dynamic performance vs. use.

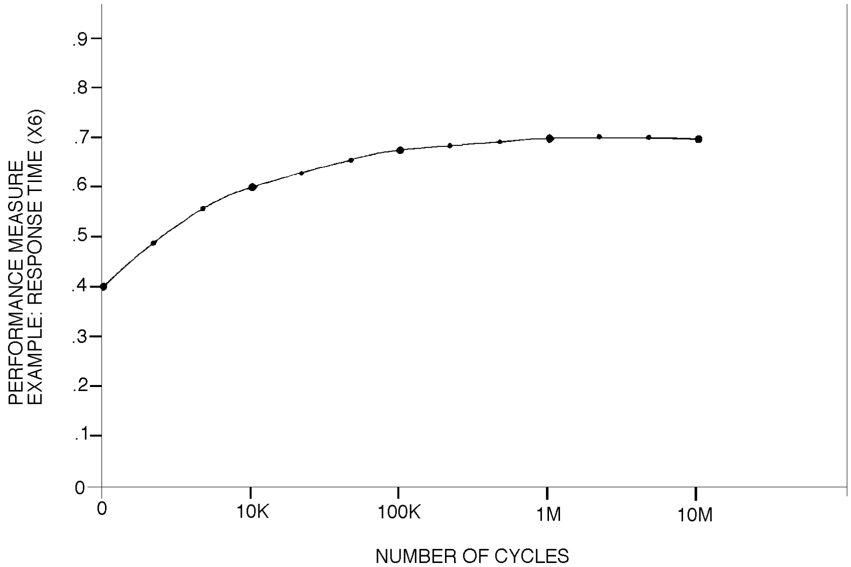

Figure 3
Typical Performance Measure vs. Number of Cycles

16.2 Record time to failure and plot failure times on lognormal or Weibull probability scales (see Figure 4). This plot gives an estimate of the useful life of an MFC (see Sections A1-1.1.4 – A1-1.1.5). Record data for the parameter tested in the data sheet given within the parametric test method.

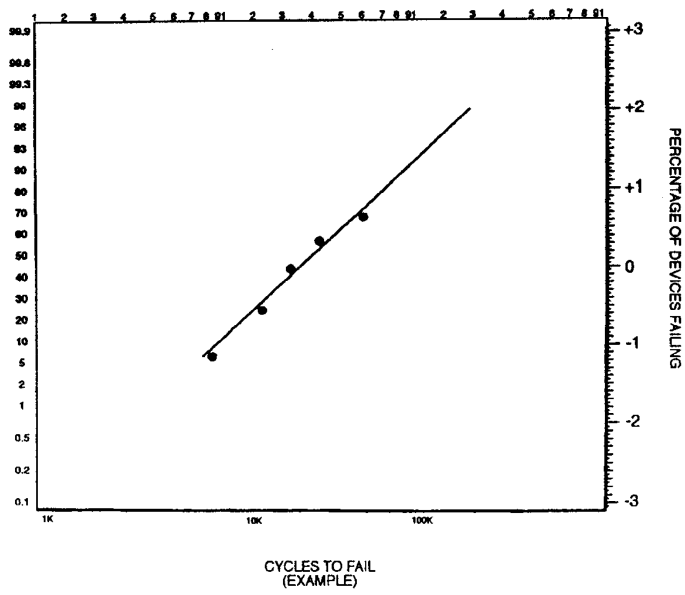

Figure 4
Time to Fail vs. Failure Percentage

16.3 Record data for the parameter tested in the data sheet given within the parametric test method.

16.4 The following test conditions are to be reported in the data presentation:

16.4.1 date and time of test

16.4.2 operator

16.4.3 test flow rate (SLM)

16.4.4 test pressure (kPa)

16.4.5 ambient temperature (°C)

16.4.6 MFC orientation

16.4.7 MFC location in test bed

16.4.8 cleanroom or environment classification

16.4.9 MFC type, manufacturer, serial number, lot number, and model number

16.4.10 LPC/CNC manufacturer, serial number, sample flow rate (SLM), model number, calibration date, particle range, and efficiency

16.4.11 test gas type and dew point (°C)

16.4.12 a schematic of the test apparatus, including manufacturers and model numbers of all test apparatus components

16.4.13 calibration dates for the flow meters

16.4.14 cycle time used for test

17 Precision and Bias

Precision and bias in this test are a function of the uncertainty of the measurement equipment used. The tester or end user is responsible for determining the precision and bias of a particular setup and test.

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI E67 by full letter ballot procedure.

NOTE: The method for reliability analysis provided herein is one of many possible methods which may be used. It is up to the user to determine if this method or another (e.g., Weibull) is to be used for determination of MFC reliability.

A1-1 Reliability Analysis

A1-1.1 Almost all reliability studies of entities whose failure is unplanned, focus on the time until a small percentage has failed (time until 10% of the population has failed, for example). Focus is on the left tail of the time-to-failure probability distribution. Nelson's book, *Applied Life Data Analysis*, (Wiley, 1982) gives a simple method for estimating the time to 10% failure for a lognormal distribution (n = 2 to 10) from units put on test. Table A1 (from page 272 of Nelson's book) can be used as follows:

A1-1.1.1 Calculate the % failed from the following equation:

Plot % failed vs. # cycles to failure for each MFC that failed on lognormal probability paper (see Figure 4).

A1-1.1.2 Estimate the mean, **μ***, and the standard deviation, **σ***, from the plot with the following equations:

A1-1.1.3 Calculate a 90% lower confidence limit for the (log of) 10% failure percentile ($y_{10,\ lcl}$) from the following equations:

$$y^* = \text{LOG}\ (y_{10,\ \text{lcl}}) = \mu^* + t^*\ [\delta = 0.10,\ P = 0.10,\ n = \#\ \text{tested},\ r = \#\ \text{failed}] \times \sigma^*$$

where t * is found from *Applied Life Data Analysis*, Table A1

$$y_{10,\ \text{lcl}} = 10^{y^*}$$

A1-1.1.4 Here is a sample set of data to illustrate the procedure.

i	*Cycles to Failure*	*% Failed*
1	6.3 K	8.3
2	15.8 K	25.0
3	25.1 K	41.7
4	40 K	58.3
5	63 K	75.0
6	did not fail	did not fail

The % failed column was calculated from the equation in Section A1-1.1.1.

A1-1.1.5 See Figure 4 for a plot of this data.

A1-1.1.6 Use Figure 4 to calculate **μ*** and **σ***.

\# of cycles to 50% failure = 3000 from graph

$\mu^* = \text{LOG}$ (# of cycles to 50% failure)

$\mu^* = \text{LOG}\ (30000)$

$\mu^* = 4.477$

\# of cycles to 16% failure = 11000 from graph

$\sigma^* = \mu^* - \text{LOG}$ (# of cycles to 16% failure)

$\sigma^* = 4.477 - \text{LOG}\ (11000)$

$\sigma^* = 4.477 - 4.041$

$\sigma^* = 0.436$

A1-1.1.7 From Table A1 (from page 272 of Nelson’s book), look up t*:

This data indicates, with a 90% confidence limit, that 10% of the devices will fail by 2443 cycles.

A1-1.1.8 Table A1 percentiles t* (d: 10, n, r) for limits for $y_{.10}$.

nφ	*rφ*	*pÆ* 0.005	*0.01*	*0.025*	*0.05*	*0.1*	*0.5*	*0.9*	*0.95*	*0.975*	*0.99*	*0.995*
2	2	-183.9	-88.09	-36.3	-16.4	-7.869	-1.405	-0.327	-0.118	0.083	0.444	0.888
3	2	-117.6	-59.41	-26.14	-13.45	-6.786	-1.38	-0.495	-0.256	-0.0715	0.898	2.072
3	2	-17.6	-12.28	-7.761	-5.497	-3.691	-1.326	-0.473	-0.305	-0.154	0.047`	0.172
4	2	-113.5	-56.59	-21.5	-11.55	-5.934	-1.348	-0.537	-0.28	0.236	1.864	4.305
4	3	-15.58	-11.52	-7.112	-5.071	-3.503	-1.313	-0.558	-0.399	-0.252	-0.0573	0.107
4	4	-9.617	-7.008	-4.985	-3.792	-2.921	-1.29	-0.559	-0.409	-0.265	-0.124	-0.0141
5	2	-112.9	-48.61	-18.13	-9.49	-4.988	-1.322	-0.567	-0.182	0.519	2.436	5.585
5	3	-13.33	-9.911	-6.294	-4.598	-3.208	-1.306	-0.622	-0.463	-0.285	-0.00405	0.271
5	4	-7.956	-6.415	-4.652	-3.636	-2.778	-1.292	-0.624	-0.475	0.335	-0.173	-0.0587
5	5	-5.565	-4.871	-3.892	-3.184	-2.585	-1.287	-0.622	-0.472	-0.344	-0.202	-0.109
6	2	-76.15	-37.64	-17.14	-8.573	-4.669	-1.313	-0.57	-0.0928	0.779	3.427	6.336
6	3	-14.2	-10.33	-6.289	-4.393	-3.107	-1.303	-0667	-0.503	-0.323	-0.0332	0.375
6	4	-7.414	-5.87	-4.386	-3.487	-2.721	-1.302	-0.673	-0.546	-0.427	-0.286	-0.197
6	5	-5.45	-4.681	-3.746	-3.083	-2.498	-1.297	-0.673	-0.547	-0.44	-0.309	-0.219
6	6	-4.663	-4.012	-3.336	-2.826	-2.371	-1.3	-0.678	-0.546	-0.438	-0.322	-0.246
7	2	-68.12	-32.41	-15.19	-8.208	-4.34	-1.303	-0.561	-0.016	0.989	4.067	9.64
7	3	-12.82	-9.162	-5.602	-4.099	-3.005	-1.301	-0.71	-0.529	0.33	-0.0654	0.292
7	4	-7.571	-5.812	-4.171	-3.346	-2.622	-1.298	-0.722	-0.587	-0.464	-0.289	-0.12
7	5	-5.523	-4.604	-3.705	-3.034	-2.417	-1.295	-0.723	-0.595	-0.495	-0.361	-0.243
7	6	-4.636	-4.112	-3.351	-2.791	-2.32	-1.288	-0.722	-0.597	-0.501	-0.381	-0.294
7	7	-4.282	-3.693	-3.041	-2.641	-2.228	-1.285	-0.725	-0.595	-0.501	-0.376	-0.287
8	2	-63.58	-29.95	-13.34	-6.948	-3.728	-1.293	-0.472	0.226	1.645	6.157	14.5
8	3	-10.54	-7.628	-4.967	-3.637	-2.756	-1.297	-0.732	-0.549	-0.309	0.13	0.54
8	4	-6.59	-5.172	-3.937	-3.119	-2.484	-1.286	-0.752	-0.609	-0.468	-0.266	-0.11
8	5	-5.363	-4.296	-3.443	-2.885	-2.361	-1.287	-0.757	-0.629	-0.507	-0.358	-0.242
8	6	-4.515	-3.855	-3.22	-2.756	-2.282	-1.287	-0.758	-0.633	-0.514	-0.386	-0.306
8	7	-4.086	-3.583	-3.019	-2.602	-2.205	-1.284	-0.755	-0.632	-0.514	-0.399	-0.336
8	8	-3.781	-3.414	-2.851	-2.485	-2.162	-1.29	-0.757	-0.63	-0.514	-0.404	-0.338
9	2	-56.28	-30.29	-11.44	-6.353	-3.55	-1.314	-0.465	0.353	2.089	6.581	11.57

nφ	*rφ*	*pÆ* 0.005	*0.01*	*0.025*	*0.05*	*0.1*	*0.5*	*0.9*	*0.95*	*0.975*	*0.99*	*0.995*
9	3	-11.84	-8.048	-5.062	-3.693	-2.704	-1.312	-0.739	-0.551	-0.304	0.209	0.744
9	4	-6.562	-5.165	-3.775	-3.043	-2.457	-1.31	-0.772	-0.64	-0.505	-0.3	-0.167
9	5	-5.034	-4.316	-3.446	-2.851	-2.318	-1.307	-0.777	-0.66	-0.548	-0.427	-0.326
9	6	-4.437	-3.901	-3.21	-2.714	-2.232	-1.305	-0.779	-0.663	-0.566	-0.444	-0.365
9	7	-4.103	-3.651	-3.08	-2.605	-2.177	-1.303	-0.78	-0.665	-0.57	-0.457	-0.373
9	8	-3.813	-3.408	-2.878	-2.49	-2.135	-1.3	-0.776	-0.665	-0.572	-0.459	-0.381
9	9	-3.624	-3.228	-2.752	-2.413	-2.067	-1.298	-0.78	-0.666	-0.571	-0.458	-0.396
10	2	-60.81	-27.39	-10.07	-5.683	-3.326	-1.299	-0.34	0.77	2.744	7.973	15.67
10	3	-9.675	-6.99	-4.618	-3.42	-2.572	-1.301	-0.758	-0.532	-0.255	0.306	1.018
10	4	-6.389	-5.028	-3.792	-2.993	-2.353	-1.297	-0.798	-0.657	-0.528	-0.332	-0.134
10	5	-5.258	-4.324	-3.357	-2.749	-2.257	-1.297	-0.801	-0.684	-0.581	-0.426	-0.315
10	6	-4.559	-3.701	-3.029	-2.569	-2.182	-1.294	-0.802	-0.689	-0.59	-0.488	-0.405
10	7	-3.838	-3.43	-2.853	-2.497	-2.121	-1.293	-0.803	-0.689	-0.593	-0.497	-0.428
10	8	-3.706	-3.173	-2.752	-2.401	-2.091	-1.292	-0.803	-0.688	-0.598	-0.502	-0.431
10	9	-3.458	-3.118	-2.636	-2.353	-2.046	-1.288	-0.804	-0.689	-0.598	-0.502	-0.438
10	10	-3.297	-2.996	-2.561	-2.284	-2.02	-1.29	-0.804	-0.693	-0.598	-0.501	-0.437

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SEMI E68-0997
TEST METHOD FOR DETERMINING WARM-UP TIME OF MASS FLOW CONTROLLERS

1 Purpose

1.1 The purpose of this method is to provide a standardized method for quantifying the warm-up time of an MFC.

NOTE: Warm-up times affect the initial performance of a mass flow controller (MFC). Warm-up time is necessary information in deciding if a process tool is ready to be put back into service. In addition, warm-up data will be useful in calibration labs.

2 Scope

2.1 The test conditions in this method are intended to simulate bench top warm-up, with an MFC that has been equalized to ambient conditions for 24 hours before the application of power.

3 Limitations

3.1 Conditions in the lab may be different from conditions found in the field and may influence test results. This test is intended to measure warm-up under a controlled condition.

3.2 The MFC is to be at ambient temperature before the beginning of the test.

3.3 Due to manufacturing variability, warm-up times may vary for the same model of MFC. This specification addresses a method for taking a single data point repetitively from the same MFC. Resulting data will show exactly how warm-up effects change the delivered flow of that particular MFC. To statistically quantify warm-up time for a particular model of MFC, multiple samples should be tested.

4 Referenced Documents

None.

5 Terminology

5.1 *Acronyms*

5.1.1 *DUT* — Device under test

5.1.2 *FS* — Full scale

5.1.3 *MFC* — Mass flow controller

5.2 *Definitions*

5.2.1 *device under test* — The MFC being tested for warm-up time.

5.2.2 *indicated flow* — Flow indicated by the MFC under test. Electrical output of the DUT.

5.2.3 *stability* — A condition that exhibits only natural, random variations in the absence of unnatural, assignable-cause variations. For the several purposes of this test, stability is defined as ±10% of the accuracy of the DUT at full scale.

5.2.4 *steady state* — State at which the indicated flow is stable for a 15-minute time period.

5.2.5 *warm-up* — A process where the MFC goes from an unpowered condition to a condition where the output is within ±1% full scale, of the final steady state output.

6 Summary of Test Method

6.1 The DUT is connected in series with shut-off valves on either side of the DUT. With no gas flow and the DUT powered, indicated flow is monitored until steady state is achieved. Power is briefly disconnected then reconnected and indicated flow is again monitored until steady state is achieved.

7 Significance and Use

7.1 Data generated by this method is used to estimate the amount of time an MFC should be powered up in a process tool before resuming production. When calibrating an MFC, the warm-up time can be used to estimate the waiting time before calibration. For power interruptions, the power interruption warm-up time may be used to determine the time required following a power interruption to resume production or calibration.

8 Apparatus

8.1 See Figure 1.

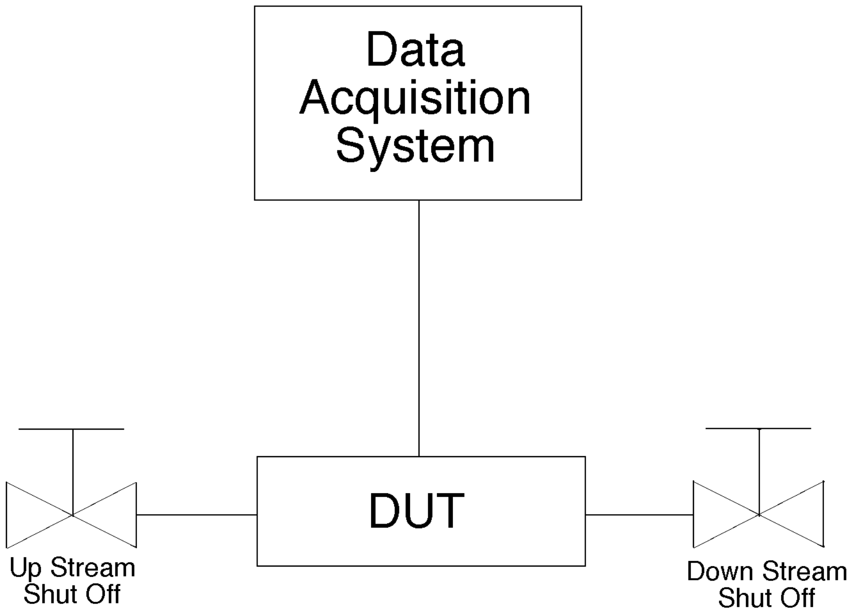

Figure 1
Test Set Up

8.2 *Time-Keeping Apparatus* — Capable of keeping accurate records within ± 10 seconds. Time-keeping requirements are not stringent, and almost any apparatus is acceptable.

8.3 *Data Acquisition System* — Having a resolution of one mV or better and a sample rate of one Hz.

9 Conditioning

9.1 Ambient temperature must be controlled and stable between 20°C and 25°C during testing for all tests. The DUT must be exposed to the ambient environment for 24 hours before the beginning of the test so that it is in equilibrium. The gas temperature must be measured and verified to be at equilibrium with both the DUT and with ambient temperature. Temperatures are in equilibrium if they are within 1°C of each other. Lab temperature may not change more than 1°C during test.

10 Procedure

10.1 Connect the DUT in series with the two shut-off valves, one upstream of the DUT and the other downstream. Electronically connect the DUT to a data acquisition system capable of recording indicated flow from the DUT. The test set-up should be set to give appropriate signals to the DUT so the DUT control valve will not dissipate power. For normally closed MFC's, the setpoint should be zero, and for normally open MFC's, the setpoint should be 100%. Suggested orientation of the DUT is horizontal (base down). If the DUT is positioned otherwise, the orientation should be reported in the test data (see Figure 1). Valves are to be opened in a downstream-to-upstream sequence and closed in reverse fashion. The data acquisition system must be warmed up as per the manufacturer's instructions.

10.2 Close shut-off valves.

10.3 In Table 1, record the time of day when power was applied to the DUT. Begin recording the indicated flow from the DUT at one sample per second.

Table 1 Format for Data Presentation

Warm-up Time	Date:____________		
	± 1% FS	Time to Achieve Steady State	Steady State Value
Cold Start			
Power Interruption			

10.4 *Cold Start* — Apply power to the DUT and continue collecting data until the indicated flow achieves a steady state value.

10.5 *Power Interruption* — Continue to collect data while disconnecting power from the test unit for 120 ± 10 seconds. Reconnect power to the DUT and monitor indicated flow until steady state is again achieved.

11 Data Analysis

11.1 Graph the data collected from the six test scenarios as directed in Section 10.

11.2 The time required for the DUT to achieve a steady state value can be visually determined from the graph of each test scenario. This data can be used to predict the warm-up times required by an MFC experiencing a field condition similar to the test scenario.

12 Data Presentation

For the two tests in Section 10, plot DUT indicated flow vs. time as illustrated in Figures 2 and 3. Note the following on these graphs and in Table 1.

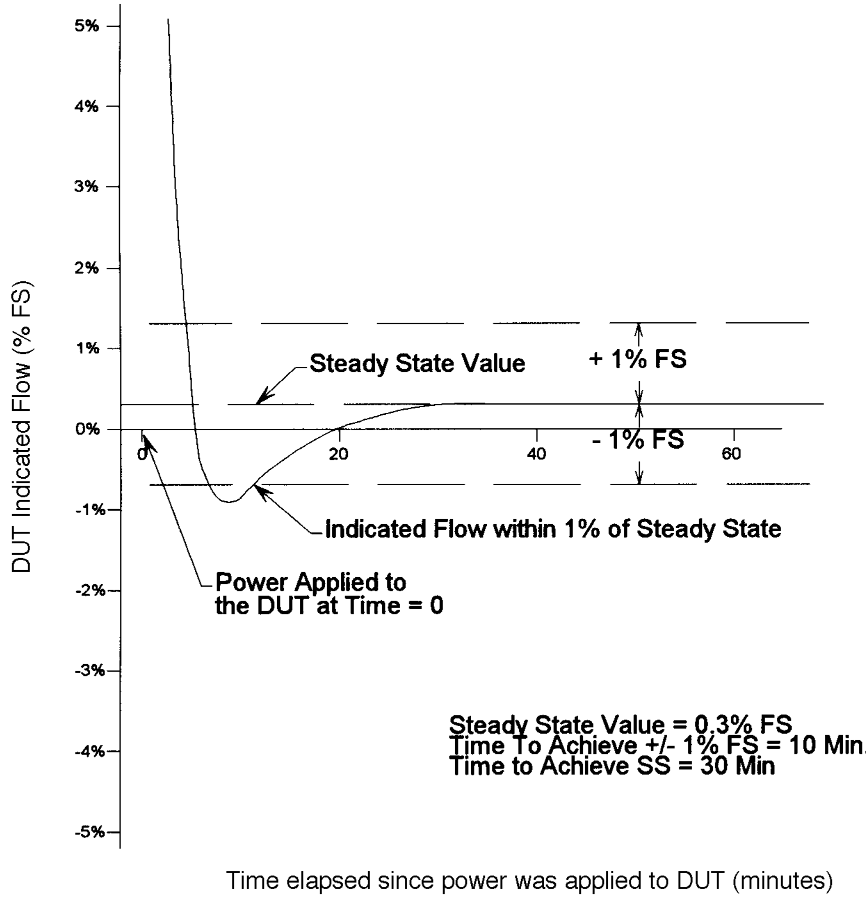

Figure 2
Cold Start Warm-Up Time

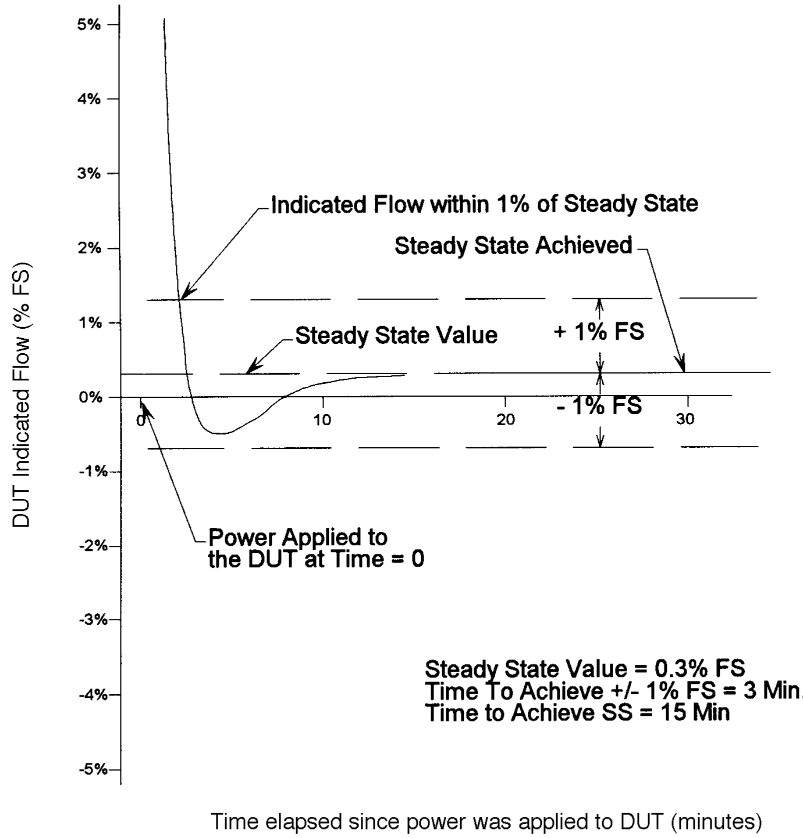

Figure 3
Two-Minute Power Interruption Warm-Up Time

12.1 Final steady-state value of the DUT.

12.2 Time to achieve a steady state value.

12.3 Use Table 1 to summarize warm-up times associated with each of the test scenarios.

13 Precision and Bias

13.1 Precision and bias in this test are a function of the uncertainty of the measurement equipment used. The tester or end user is responsible for determining the precision and bias of a particular setup and test.

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SEMI E69-0298
TEST METHOD FOR DETERMINING REPRODUCIBILITY AND ZERO DRIFT FOR THERMAL MASS FLOW CONTROLLERS

1 Purpose

1.1 The purpose of this document is to provide a standardized method to quantify the reproducibility and zero drift of a thermal mass flow controller.

1.2 The intent of this document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters that are covered by this method. The user might use this document to check significant performance characteristics, such as reproducibility and zero drift, under a set of closely controlled test conditions.

1.3 The significance of the accuracy calculations in this method is to allow an MFC user to transfer a process from one manufacturing tool to another and to exchange MFCs within a single manufacturing tool while maintaining process control.

2 Scope

2.1 This document describes the conditions and procedures for testing the reproducibility and zero drift of thermal mass flow controllers (MFCs). Because of the generic nature of this document, not all test procedures apply to all types of MFCs.

2.2 This document provides a common basis for communication between manufacturers and users.

3 Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory conditions; its intent is to collect sufficient data to form a judgement of the field performance of the MFC being tested.

4 Referenced Documents

4.1 *SEMI Document*

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

4.2 *ANSI Documents*[1]

ANSI C39.5 — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

ANSI C42.100 — Dictionary of Electrical and Electronics Terms

ANSI MC4.1 — Dynamic Response Testing of Process Control Instrumentation

4.3 *ASME Document*[2]

ASME MFC-1M — Glossary of Terms Used in the Measurement of Fluid Flow in Pipes

4.4 *IEC Documents*[3]

IEC 160 — Standard Atmospheric Conditions for Test Purposes

IEC 546 — Methods of Evaluating the Performance of Controllers with Analogue [sic] Signals for Use in Industrial Process Control

4.5 *ISA Documents*[4]

ISA S7.3 — Quality Standards for Instrument Air

ISA S51.1 — Process Instrumentation Terminology ANSI/ISA-1 979 (reaffirmed 1993)

5 Terminology

5.1 *Acronyms*

5.1.1 *FS* — Full scale

5.1.2 *kPa* — Kilopascal

5.1.3 *MFC* — Mass flow controller

5.1.4 *NC* — Normally closed

5.1.5 *NO* — Normally open

5.1.6 *psia* — Pounds per square inch absolute

5.1.7 *sccm* — Standard cubic centimeters per minute

5.1.8 *slm* — Standard liters per minute

5.2 *Definitions*

5.2.1 *accuracy* — The closeness of agreement between an observed value and the true value; the total

1 American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018

2 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

3 International Electrochemical Commission, 3, rue de Varembe, CH-1211 Geneva 20 Switzerland

4 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709

uncertainty of an observed value, including both precision and bias.

5.2.2 *accuracy curve* — The curve fitted through the average measured values over the specified range of the device under test (DUT).

5.2.3 *accuracy, device* — The total uncertainty over a specified range of the device. Device accuracy over a range is stated as the worst case accuracy taken over all tested setpoints in this range.

5.2.4 *bias* — The difference, at a setpoint, between the measured value and the sum of the setpoint value and the zero offset. The measured values of a flow standard include its total uncertainty.

5.2.5 *cardinal setpoint* — A specific setpoint to assess the accuracy of the device under test. For this test method, the cardinal setpoints are 10%, 50%, and 100% of full scale.

5.2.6 *deadband* — The range through which a setpoint may be varied, upon reversal of direction, without initiating an observable change in output signal.

5.2.7 *downscale reading* — A reading approached from a setpoint greater than the current setpoint and beyond the deadband.

5.2.8 *downscale value, average* — The sum of all downscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.9 *flow standard* — A device used to measure the actual mass flow through the DUT.

5.2.10 *linearity* — The closeness to which a curve approximates a straight line. It is measured as a non-linearity and expressed as a linearity.

5.2.11 *linearity, terminal-based* — The maximum absolute value of the deviation of the accuracy curve (average of upscale and downscale values) from a straight line through the upper and lower setpoint limits of the accuracy curve (see Figure 1).

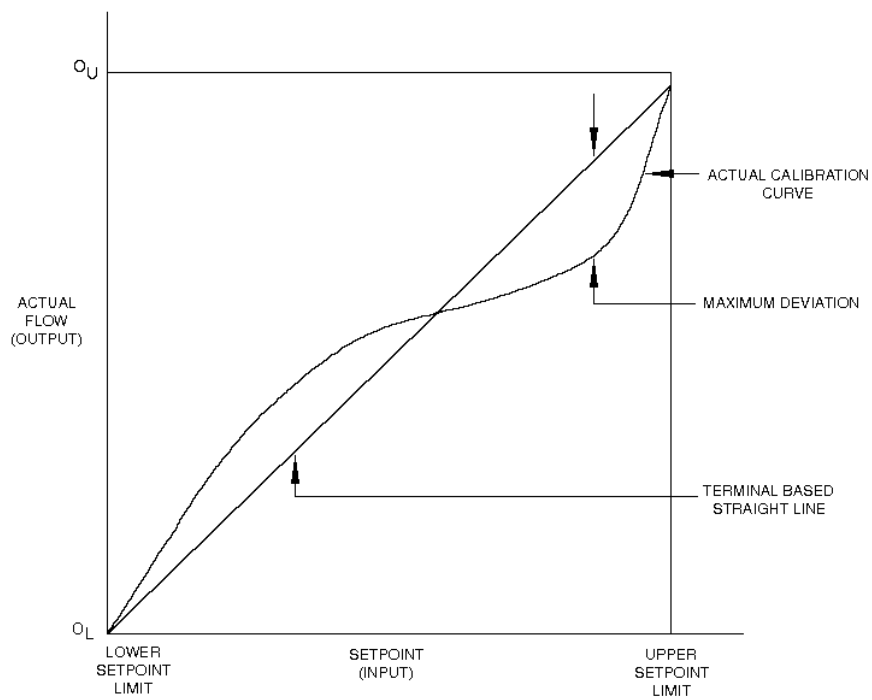

Figure 1
Terminal-Based Linearity for Mass Flow Controller

5.2.12 *measured value* — The actual flow through a device under test, expressed in sccm or slm, as measured by a standard, preferably primary.

5.2.13 *measured value, average* — The sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.14 *operating conditions, normal* — The range of operating conditions within which a device is designed to operate and for which operating influences are stated [ISA S51.1].

5.2.15 *operating conditions, reference* — The range of operating conditions of a device within which operating influences are negligible [ISA S51.1].

5.2.16 *operating influence* — The change in a performance characteristic caused by a change in a specified operating condition from reference operating conditions, all other conditions being held within the limits of reference operating conditions [ISA S51.1].

5.2.17 *precision* — The closeness of agreement among the measured values at a setpoint. It is often expressed as a standard deviation.

5.2.18 *repeatability* — The closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time. It is usually measured as a nonrepeatability and expressed as a repeatability in percent of reading [ISA S51.1].

5.2.19 *reproducibility* — The closeness of agreement among repeated measured values at a setpoint, within the specified reference operating conditions, made over a specified period of time, approached from both directions. It is usually measured as a non-reproducibility and expressed as a reproducibility in percent of average reading. Reproducibility includes hysteresis, deadband, long-term drift, and short-term reproducibility [ISA S51.1].

NOTE: Between repeated measurements, the input may vary over the range, and operating conditions may vary within normal operating conditions.

5.2.20 *reproducibility, short-term* — The closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time, approached from both directions. The approach must be from beyond the deadband. It is usually measured as a nonreproducibility and expressed as a reproducibility in percent of reading. Short-term reproducibility includes repeatability, hysteresis, deadband, and shortterm drift.

5.2.21 *setpoint* — The input signal provided to achieve a desired flow, reported as sccm, slm, or percent-full scale.

5.2.22 *setpoint limit, lower* — The lowest setpoint at which the instrument is specified to operate.

5.2.23 *setpoint limit, upper* — The highest setpoint at which the instrument is specified to operate, usually full scale.

5.2.24 *span* — The full-scale range of the DUT.

5.2.25 *stability* — The ability of a condition to exhibit only natural, random variation in the absence of unnatural, assignable-cause variation.

5.2.26 *standard conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F)

5.2.27 *uncertainty, total* — The range within which the true value of the measured quantity can be expected to fit; an indication of the variability associated with a measured value that takes into account the two major components of error — bias and the random error attributed to the imprecision of the measurement process.

5.2.28 *upscale reading* — A reading approached from a setpoint less than the current setpoint and beyond the deadband.

5.2.29 *upscale value, average* — The sum of all upscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.30 *zero drift* — The undesired change in electrical output, at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.31 *zero offset* — The deviation from zero, at a no-flow condition, reported in sccm or slm.

6 Summary of Test Method

6.1 Specific procedures are given for characterizing MFCs discharging to atmospheric pressure or into a vacuum using accepted reference standards to determine reproducibility and zero drift (see Figure 2).

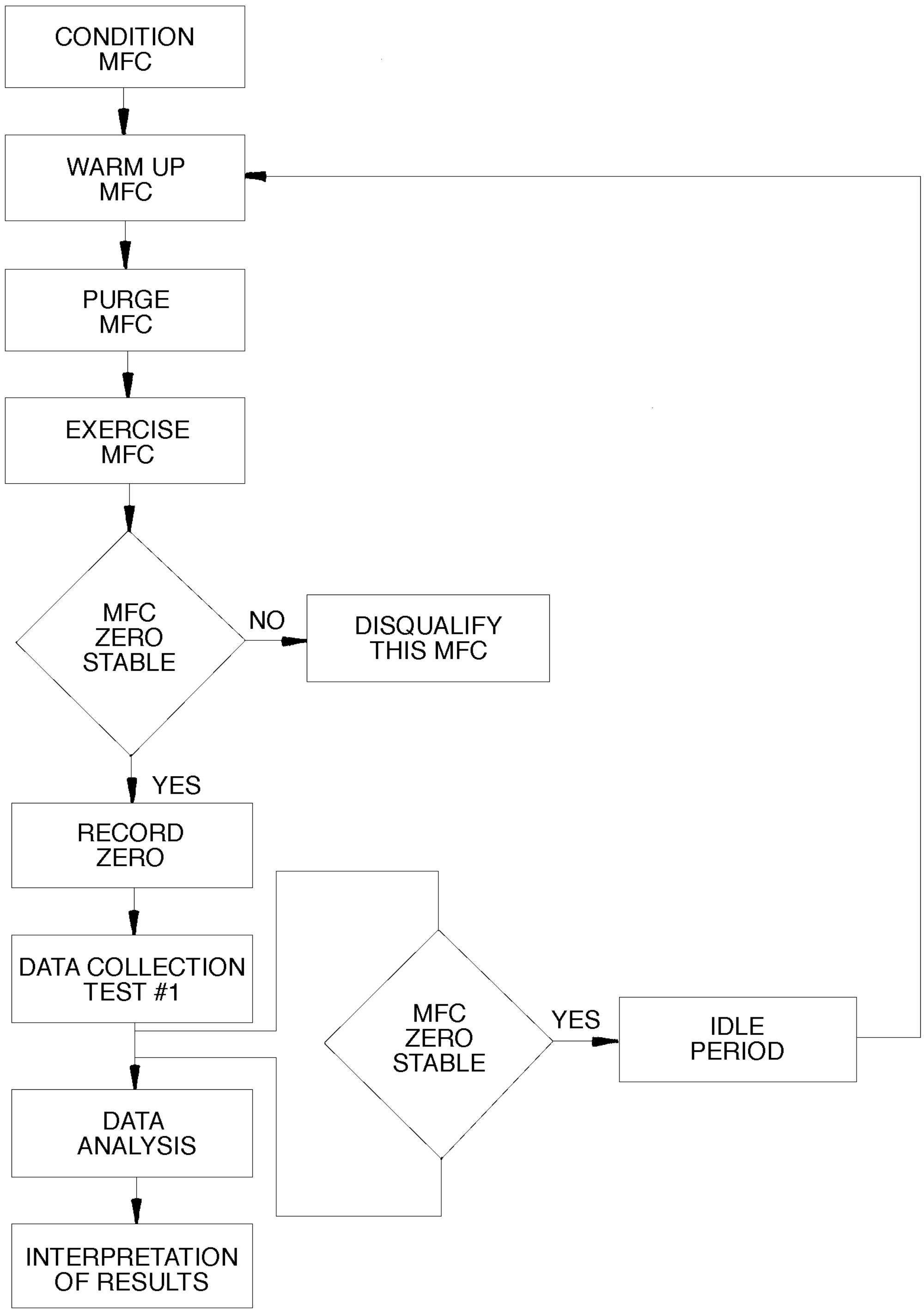

Figure 2
Test Flowchart

7 Interferences

7.1 The accuracy rating of the measuring equipment must include superior measurement capability compared with that of the DUT. In no instance should the accuracy rating of the measuring equipment be less than twice that of the DUT (e.g., if the accuracy of the DUT is ± 1 sccm, then the accuracy of the measuring device must be better than, or equal to, ± 1/2 sccm). The traceability of all the pertinent measuring instruments and devices should be realistically established and quantified.

7.1.1 In addition, take care when using test instruments with a specified accuracy expressed in percent of full scale. For example, if an instrument with a specified accuracy of ± 0.1% of full scale is used to measure the output of the DUT, but this output signal falls only within the lower third of the scale of the instrument, the effective accuracy over the range of the instrument being used may be ± 0.3%, which is unsuitable for many applications.

7.1.2 Use special precautions to ensure that minimum effects result from pneumatic noise in flow lines. Monitor pressure both upstream and downstream of the MFC to ensure that pneumatic noise is minimized.

7.1.3 The DUT should be installed so that the inlet flow can be fully developed, pulsation-free, for the specific conditions. This can be achieved by plumbing a straight length of tubing 40–50 diameters long upstream and another straight length 5 diameters long downstream of the DUT. (For additional information about inlet effects, refer to ASME MFC-1M.)

7.1.4 At regular calibration intervals, verify electrical signals directly at the MFC connector to ensure that there are no unacceptable line losses in the cables.

8 Apparatus

8.1 back pressure regulator

8.2 digital voltmeter

8.3 flow standard

8.4 heat exchanger

8.5 power supply

8.6 pressure transducer

8.7 setpoint generator

8.8 temperature probe

9 Precautions

9.1 *Technical Precautions*

9.1.1 Many analog-to-digital converter cards do not differentiate between measurements of less than zero and zero. It may be necessary to use a digital voltmeter to record measurements below zero volts. Some MFCs do not differentiate between measurements of less than zero and zero. This may bias the results.

9.1.2 The manufacturer's specifications and instructions for installation and operation must be applied during all testing.

9.1.3 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

9.1.4 The mounting position of the device must be in accordance with the manufacturer's specifications. No external mechanical constraints beyond the manufacturer's recommended mounting position shall be permitted.

10 Preparation of Apparatus

10.1 Figure 3 is a representation of a recommended generic testing apparatus. The flow standard is shown downstream of the device under test (DUT). It may be placed upstream of the DUT if the flow standard cannot be exposed to a low pressure environment. In this case, the user should be aware of possible back pressure effects on the flow standard.

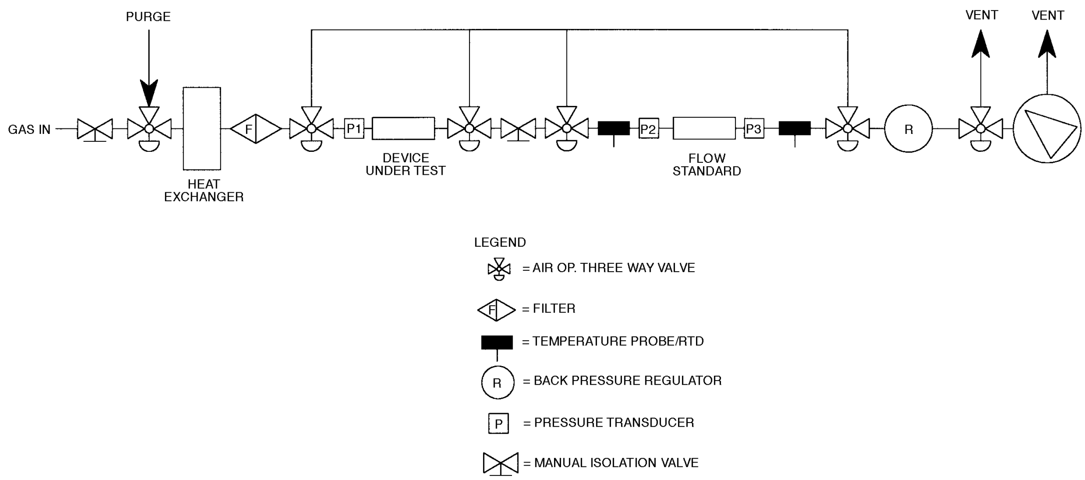

Figure 3
Mass Flow Controller Test Fixture

11 Calibration Standardization

11.1 All measurement devices must have valid calibration certificates.

12 Conditioning

12.1 Place the MFC to be tested in the testing environment. Apply power to the MFC for the 24 hours prior to initiating warm-up as defined by the manufacturer. The valve should be in its "off" position (closed for an NC valve, open for an NO valve).

12.2 Following the conditioning period, install and warm up the device according to manufacturer's specifications.

12.3 Purge the MFC with nitrogen or argon following the warm up period.

12.4 Allow the test gas to flow through the DUT for a minimum of 10 minutes at 100% of flow.

12.5 Apply a 100% full-scale setpoint to the DUT and wait for the flow to stabilize for 10 seconds. Apply the lower setpoint limit to the DUT and wait for the flow to stabilize for 10 seconds. Repeat this cycle two more times. This process exercises the device before initiating the test.

12.6 *Test Conditions*

12.6.1 The reference operating conditions shall be as follows if the downstream pressure is atmospheric:

Ambient temperature	23 ± 2°C
Gas temperature	Same as actual ambient
Ambient pressure	101.3 kPa (+ 4.7 or - 15.3 kPa)
Gas pressure P_1, Inlet	274 ± 34 kPa
Gas pressure P_3, Outlet	101.3 kPa (+ 4.7 kPa or - 15.3 kPa)
Relative humidity	40% ± 10%, noncondensing
Magnetic field	≤ 50 µT
Electromagnetic field	< 100 µV/m
Vibration	< 0.5 m/s
Shock	≤ 3 g

12.6.2 The reference operating conditions shall be as follows if the downstream pressure is at vacuum:

Ambient temperature	23 ± 2°C
Gas temperature	Same as actual ambient
Ambient pressure	101.3 kPa (+ 4.7 or - 15.3 kPa)
Gas pressure P_1, Inlet	172 ± 34 kPa
Gas pressure P_3, Outlet	< 0.13 kPa
Relative humidity	40% ± 10%, noncondensing
Magnetic field	≤ 50 µT
Electromagnetic field	< 100 µV/m
Vibration	< 0.5 m/s
Shock	≤ 3 g

12.7 *Power Supply Conditions*

12.7.1 The reference power supply conditions used shall be the reference values specified by the manufacturer. For those instances when a range of values is specified rather than a reference value, the midpoint of the range shall be taken to be the reference value.

12.7.2 The reference power supply must be sufficiently rated for the DUT. In addition, the following supply conditions and tolerances shall apply:

DC supply reference voltage	± 0.1% of operating voltage
Noise and ripple of DC supply	≤ 0.1% rms

13 Procedure

13.1 *Zero Offset*

13.1.1 Close the gas shut-off valve upstream of the device under test and apply a 100% setpoint to the DUT to equilibrate the pressure across the MFC. Wait for the flow to stabilize at a value near zero, then close the downstream shut-off valve. Deactivate the MFC's control valve (open for (NO) valves, closed for (NC) valves), and disable the MFC to auto zero if an auto-zero disable option is available. After the electrical output signal has stabilized for at least three minutes, record the MFC zero offset on Table 1. (Consult the manufacturer's specifications for the stabilization time and report this time on Table 2.)

Table 1 Data Tabulation

Week #___________											
Date______________	*Technician________________________*						*MFC_______________*				
Input %	*Set Point (sccm)*	*Indicated Flow (sccm)*					*Actual Flow (sccm)*				
0							0	0	0	0	0
50											
100											
50											
10											
5	Wait 10 minutes	Record no data									
10											
50											
100											
50											
10											
5	Wait 10 minutes	Record no data									
10											
50											
100											
50											
10											
5	Wait 10 minutes	Record no data									
10											

Table 2 Test Data Cover Sheet

MFC			
Manufacturer__________	Model__________	Serial Number__________	Attitude__________
Nameplate Gas__________	Seal Type__________	Valve Seat Matl.__________	Full Scale Range__________
Environment			
Ambient Temp. (°C)_________	Ambient Press. (kPa)________	Humidity (%)__________	
Test Gas__________	Inlet Gas Pres. (kPa)_________	Outlet Gas Press.__________	Gas Temp. (°C)__________
Test Facility			
Name__________	City/State__________	Telephone ( )__________	Fax ( )__________
Standard Used__________	Standard Accuracy__________	Facility Bias__________	Certification Date__________
Other Equipment__________	Accuracy__________	Certification Date__________	
Other Equipment__________	Accuracy__________	Certification Date__________	
Other Equipment__________	Accuracy__________	Certification Date__________	
Other Equipment__________	Accuracy__________	Certification Date__________	
Comments or Special Instructions:			
			Technician__________
			Date__________

13.1.2 Use the cardinal setpoints and any other setpoints of specific interest. These setpoints will be used to determine the reproducibility of the MFC. The setpoint increments should exceed the expected deadband of the DUT.

13.1.3 At each setpoint under test, maintain the input signal until the output of the DUT becomes stabilized at its apparent final value. Observe and record the output values in Table 1 for each input value.

13.1.4 Record five readings at each setpoint during testing.

NOTE: If the data points show a trend in one direction, either up or down, the DUT is not stable enough for the test to proceed to the next setpoint. Record another five readings at this setpoint. If the results continue to show a trend, repeat the measurements at the previous setpoint. If the results are not satisfactory at this setpoint, stop the test for this MFC. If the results are not satisfactory, halt the test and verify the performance of the testing apparatus.

13.1.5 At each point under test, maintain the input signal until the output of the device under test becomes stabilized at its apparent final value. Observe and record the output values for each input value.

13.2 *Reproducibility and Zero Drift Test*

13.2.1 Apply a 50% setpoint to the MFC and record data.

13.2.2 Move the setpoint to 100% and record data.

13.2.3 Move the setpoint to 50% and record data.

13.2.4 Move the setpoint to 10% and record data.

13.2.5 After recording data at 10%, apply a 5% setpoint for 10 minutes, but do not record any data at this setpoint.

13.2.6 Move the setpoint back up to 10% and record data.

13.3 Repeat Sections 13.2.1–13.2.6, for a total of three times, until at least six sets of data have been collected at each setpoint (with the exception of 100%).

13.4 Repeat Sections 13.1.1–13.3 weekly for a period of at least 12 weeks. During the idle time, the MFC should be continuously powered, with any exceptions so noted. Gas flow is not required during the idle time, but any gas flow shall be recorded. Finally, record all details about the conditions of the MFC during the idle time.

14 Data Analysis

14.1 *Calculations*

14.1.1 Determine the precision at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint:

$$P = \sqrt{\frac{\sum\left(\sum (V_i - A_a)^2\right)_i}{n_j}}$$

P = Precision

V_i = The i th reading at a setpoint for a given cycle

A_a = Average measured value

n_j = Number of readings at a setpoint for a given cycle

14.1.2 Determine the short-term reproducibilty at a setpoint by dividing the precision of the setpoint by the average setpoint. This is expressed as a percentage of reading. Perform this calculation at each point:

$$SRS\% = \frac{P}{S_a} \times 100$$

14.1.3 The long term reproducibility at a setpoint is the greatest absolute weekly reproducibility at a setpoint.

Determine the precision over the test period at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint:

$$P_L = \sqrt{\frac{\sum\left(\sum\left(\sum (V_i - A_a)^2\right)_j\right)_w}{\sum\left(\sum n_j\right)_w}}$$

P_L = Precision over the test period

V_i = The i[th] reading at a setpoint for a given

A_a = Average measured

n_j = Number of readings at a setpoint for a given cycle

w = Number of weeks

14.1.4 Determine the reproducibility at a setpoint by dividing the precision over the test period at this setpoint by the average setpoint. This is expressed as a percentage of reading. Perform this calculation at each setpoint:

$$RS\% = \frac{P_L}{S_a} \times 100$$

14.1.5 The overall reproducibility of the DUT is the maximum value calculated in Section 14.1.4:

$$\pm RD\% = RS_{max}$$

RD = Reproducibility of the device

14.1.6 Calculate zero drift by subtracting the minimum zero value from the maximum zero value and dividing by two. This number is reported as ± sccm or slm over the specified time period.

15 Data Presentation

15.1 Plot the average measured value of each setpoint (10%, 50%, 100%) for each measurement period on a graph, with the *x*-axis representing time, and the *y*-axis showing the actual flow output in sccm or slm.

15.2 Plot the measured value at zero for each measurement period on a graph, with the *x*-axis representing time and the *y*-axis showing flow output signal in sccm or slm.

15.3 *Reproducibility* — Report a single number, as calculated above, as a percentage of reading stated, with the time period of the test.

15.4 *Zero Drift* — Report a single number, as calculated above, stated with the time period of the test.

16 Related Documents

16.1 *SEMASPEC*[5]

92071224B-STD — SEMATECH Provisional Test Method for Determining Reliability of a Mass Flow Controller (Refer to this standard if reliability data is needed for some of the parameters tested in this method.)

5 SEMATECH, 2706 Montopolis Drive, Austin, TX 78741

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E70-0698
GUIDE FOR TOOL ACCOMMODATION PROCESS

NOTE: This entire document was revised in 1998.

1 Purpose

1.1 This document will provide an overview of the various elements of Tool Accommodation, a methodology by which semiconductor processing equipment is installed in a cost-effective and timely manner. This addition to the SEMI Tool Accommodation Standards set describes the process by which the referenced SEMI documents can be effectively used to achieve tool installation cost and schedule goals.

2 Scope

2.1 This overview document will provide process development, facilities, manufacturing, and sales engineers (as well as purchasing agents and managers) with a basic understanding of the various elements in a Tool Accommodation methodology. This process emphasizes quality, completeness, timeliness, and cost-effectiveness as key elements of successfully installing semiconductor processing equipment into wafer fabrication facilities. By describing a generic process flow, this document identifies a road map for using published standards that comprehend all the procedures involved in tool accommodation from procurement through acceptance. As a common ground for communication and comparison, terms and definitions are also included.

3 Referenced Documents

NOTE: All documents cited will be the latest published versions.

3.1 *SEMI Documents*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.1 — Guide for Tool Final Assembly, Packaging and Delivery

SEMI E49.2 — Guide for High Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.3 — Guide for Ultrahigh Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures - Polymer Systems

SEMI E49.8 — Guide for High Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.9 — Guide for Ultrahigh Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

3.2 *Other Document*[1]

Federal Standard 209E — Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

4 Summary of Referenced Documents

4.1 *SEMI E6* — Facilities Interface Specifications Guideline and Format

4.1.1 Purpose of SEMI E6 is to communicate from supplier to user the facilities requirements of semiconductor equipment.

4.1.2 Benefits of SEMI E6 include assurance of effective communication of process tool installation requirements.

4.1.3 *Roles and Responsibilities for SEMI E6* — Tool supplier submits information requested in SEMI E6, facilities interface specification. Equipment engineer, facilities engineer, and installation manager use tool requirements information provided by supplier to prepare facility and efficiently install the tool.

1 Institute of Environmental Sciences & Technology, 940 East NW Highway, Mount Prospect, IL 60056, 847.255.1561

Table 1 SEMI Tool Accommodation Standards

	Facility Services	*Process Tool*	*Process Tool Subsystems (internal distribution system for)*			
Guideline for			General	Water & Chemical	Solvent	Gas
Facility Services Matrix defines utilities available for tool	SEMI E51					
Facilities Interface Specification defines tool requirements of facilities		SEMI E6				
Subsystem terms and references			SEMI E49			
High purity (HP) subsystem requirements				SEMI E49.2	SEMI E49.4	SEMI E49.8
Ultrahigh purity (UHP) subsystem requirements				SEMI E49.3	SEMI E49.5	SEMI E49.9
Subsystem assembly and testing				SEMI E49.7	SEMI E49.6	SEMI E49.6
Tool packaging and delivery		SEMI E49.1				

4.2 *SEMI E49* — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

4.2.1 Purpose of SEMI E49 is to specify requirements for process distribution systems located inside of, and provided with, semiconductor processing tools. (SEMI E49 acts as a reference document for the series of SEMI E49 standards, SEMI E49.1 through SEMI E49.9. See Table 1, SEMI Tool Accommodation Standards for an explanation of the ten documents included in the SEMI E49 series.)

4.2.2 Benefits of the SEMI E49 series include assurance of compatibility in purity and performance between the tool and facility distribution systems.

4.2.3 *Roles and Responsibilities for SEMI E49 Series* — Facilities engineer and installation manager submit appropriate SEMI E49 requirements, either HP or UHP. Tool supplier uses information provided to ensure distribution system compatibility.

4.3 *SEMI E51* — Guide for Typical Facilities Services and Termination Matrix

4.3.1 Purpose of SEMI E51 is to communicate from customer to supplier factory facilities available at the utility point of connection (UPOC) for a semiconductor tool.

4.3.2 Benefits of SEMI E51 include assurance of cost-effective and timely tool installation with minimum retrofit to customer site.

4.3.3 *Roles and Responsibilities for SEMI E51* — Facilities engineer and installation manager submit utility specifications requested in SEMI E51 matrixes, either typical or site-specific. Tool supplier uses information provided about facility to assist in configuration of the process tool.

5 Terminology

5.1 *acceleration cost* — Additional costs incurred to complete the project sooner than the original scheduled baseline plan.

5.2 *as-built drawings* — Documentation describing the actual configuration and dimensions at the end of construction.

5.3 *base build* — Installation of base building, services, and equipment to establish functional environmental controls and utilities to support production equipment installation.

5.4 *bidding* — Obtaining sealed quotes for a defined scope of work.

5.5 *burdened/unburdened* — Identification of costs included or excluded from contractual labor rates.

5.6 *capital equipment* — Equipment that is depreciated according to tax guidelines for durable goods. Generally has a value greater than $1,000.00 and a useful life greater than 5 years.

5.7 *change order* — A document defining a formal change in drawings, specifications, and/or scope of work.

5.8 *cleanroom* — Confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters. Cleanroom classes are defined in Federal Standard 209, Airborne Particulate Cleanliness Classes in Clearness and Clean Zones.

5.9 *conditioned power* — Electrical power that is manipulated to maintain specified tolerances.

5.10 *construction* — The set of activities that transforms plans and specifications into functional systems capable of performing to specification.

5.11 *construction consumable* — Any material used up during construction.

5.12 *construction management* — The set of activities that define, direct, monitor, and report construction activities such as workmanship, adherence to design, cost, and schedule conformance.

5.13 *contingency* — A reserve of funds, time, and/or material that is allocated to maintain schedule and budget. A reserve for scope changes, unforeseen site conditions, change in material prices, or unanticipated events.

5.14 *contract award* — Notification to the successful bidder and subsequent signing of contract documents.

5.15 *contractor* — A licensed company hired to accomplish a contractually specified scope of work.

5.16 *cost of ownership (COO)* — The total lifetime cost associated with acquisition, installation, and operation of fabrication equipment [SEMI E35].

5.17 *cycle time, gross installation* — Total time to install and commission process equipment, typically starting from dock date to release for vendor startup.

5.18 *cycle time, net installation* — Actual time devoted to construction activities related to tool hookup from dock date to ready for inspection.

5.19 *damage* — Destruction or unintentional alteration resulting in a liability.

5.20 *dedicated truck* — Exclusive drayage of a shipment.

5.21 *design build* — A contract method whereby the contractor assumes responsibility for design generation and construction to accomplish a specified performance criteria.

5.22 *design start* — A milestone event that designates the initial conversion of equipment specifications and design concepts into engineering plans and specifications.

5.23 *detailing* — Generation of dimensioned shop fabrication plans based on process and instrumentation drawings (P&ID), field surveys, and configuration verifications.

5.24 *direct/indirect cost* — Direct costs are the cost of anything physically associated with the installation, removal, or modification of equipment. Indirect costs cannot be associated with a specific piece of equipment. Profit, overhead, and administrative costs are typically considered indirect.

5.25 *distribution system* — The collection of subsystems and components used in a semiconductor manufacturing facility to control and deliver process chemicals from source to point of use for wafer manufacturing processes.

5.26 *dock date* — The date when the fab equipment, including all ancillary components, is on-site at the loading dock.

5.27 *emergency power* — Electrical power supplied by alternate sources or backup systems, like generators that come on line when the main utility power supply fails.

5.28 *equipment engineering* — A group that focuses primarily upon the electrical, electronic, and mechanical characteristics of production equipment. Depending upon the site and the fab area, Equipment Engineering may be a distinct organization, or the equipment engineering responsibilities may be handled by other groups, such as Process Engineering or Manufacturing Engineering. Equipment Engineering is typically responsible for selection and physical configuration of production equipment.

5.29 *facilities interface specification* — Documentation provided by a tool supplier that contains the tool requirements for utilities and installation as defined in SEMI E6. So-called equipment data sheets are one section of this document that also includes requirements for safety, facilities services, shipping and receiving, install, startup, acceptance, and training.

5.30 *fast track* — A scheduling method that eliminates float and maximizes parallel activities, thereby reducing overall project duration. Selective use of overtime is typically used to reduce the duration of critical path activities.

5.31 *field change order* — A document defining a formal change in drawings, specifications, and/or scope of work generated after contract award by on-site personnel to incorporate conditions identified during construction.

5.32 *field fabrication* — Assembly and/or modification of components on the job site to accommodate site-specific conditions.

5.33 *float* — Unallocated time created when tasks are completed ahead of schedule or a task's duration is less than the allotted amount.

5.34 *free on board (FOB)* — Goods placed on a truck or other means of transportation at a point specified by the seller without charge to the buyer, but with all further transportation at the buyer's expense.

5.35 *gas cabinet* — A metal enclosure that is intended to provide local exhaust ventilation, protection for the gas cylinder from fire from without the cabinet, and protection for the surroundings from fire from within [SEMI S4].

5.36 *gas interface box (GIB)* — An enclosure located between the tool mainframe and facility services containing components for pressure regulation and filtration. Functions to consolidate all gas requirements to single points of connection. Provides location and ability to pre-facilitate tool hookups in advance of tool delivery.

5.37 *grounding* — Electrical wiring system to provide earth ground.

5.38 *hookup* — The set of activities and organization required to accept incoming process equipment, move it into place, connect the equipment to all facilities, and test the connections. The connection of all necessary facilities and interconnects required to make the equipment package fully operational. The hookup activity is complete when all of the following are met.

- The equipment positioning and bolting down is complete.
- The final equipment utility connections and interconnects are complete, tested, and certified.
- The process piping certification is complete. The wall system, including bulkheads as required, is complete.
- The final decontamination is complete.
- Government inspections have been conducted as required.

5.39 *inertia base* — A structural unit using mass damping to attenuate vibration for production equipment.

5.40 *interconnect* — Connections between tool mainframe and peripheral tool subsystem equipment [SEMI E6].

5.41 *issue for construction (IFC)* — A milestone event that identifies when drawings and specifications are released to subcontractors for construction.

5.42 *labor rate* — The contractually stipulated cost of labor.

5.43 *laterals/sublaterals* — Intermediate facility service distribution lines that run between mains and equipment-specific isolation valves.

5.44 *layout fixed* — The milestone date when the physical layout of equipment and components is fixed and all stockholders complete approval sign-off.

5.45 *local abatement* — Treatment of emissions at the point of generation at the tool.

5.46 *long lead materials* — Material requiring early ordering due to availability or long manufacturing time.

5.47 *mains/submains* — Central distribution lines from a facility services source to which laterals are connected. Individual equipment is not connected directly to mains.

5.48 *minienvironment* — A localized environment created by an enclosure to isolate the product from contamination and people [SEMI E44, SEMI E45].

5.49 *mobilization* — Initial assignment of resources to a project resulting in measurable work being accomplished.

5.50 *move-in* — The movement of the process equipment from the loading dock into the fab area, and into the final taped position. The piece of equipment is defined as the main body of the equipment and all its subsystems, assemblies, and components, excluding the hookup. If major subsystems such as pumps or chillers are missing, move-in will not be considered complete until they arrive.

5.51 *move-in date* — Milestone date indicating completion of step when processing equipment is moved into designated location in fab.

5.52 *not-to-exceed (NTE)* — An agreement to guarantee that the charges for a service or services will not be greater than a specified amount.

5.53 *on-the-job training (OJT)* — The instruction of personnel in the operation or maintenance, or both, of equipment done during the course of normal work functions. On-the-job training typically does not interrupt operation or maintenance activities and, therefore, can be included in any equipment state without special categorization [SEMI E10].

5.54 *overtime* — Time spent in excess of normal working hours.

5.55 *owner buys* — Material purchased by the owner and consigned to subcontractors for use in construction.

5.56 *pedestal* — Structural support element upon which equipment or raised floor rests.

5.57 *permits* — Legal governmental documents granting permission for specific construction activities.

5.58 *prefacilitation* — A stage in the equipment installation process that follows base build and precedes tool hookup. Prefacilitation brings the various facilities services close to the new equipment location, including new facilities services and structural modifications required to prepare the facility to accept the equipment.

Also known as rough-in, this step is performed as a time-saving operation. The activity requires the following conditions to be met:

- The raised floor is in (if required).
- The ceiling is in.
- The seismic or isolation frame is in.
- All utilities are within 1.8 meters (6 feet) of the equipment or terminated in a utility box.
- The floor is taped with the equipment location.

5.59 *prepurchase* — Purchase of materials and equipment in advance of total scope definition to accommodate long lead times.

5.60 *process and instrumentation drawing (P&ID)* — A diagram using graphic engineering symbols to represent the components, flows, and functions that make up a process delivery system.

5.61 *project management* — The set of activities that design, define, direct, monitor, and report on factory building construction.

5.62 *protocol* — Description of procedures, materials, and practices used to define a methodology for accomplishing a specific task. Typically refers to material and personnel handling to maintain cleanroom integrity.

5.63 *punch list* — A list of corrective actions required to fulfill contractual obligations.

5.64 *purchase order (P.O.)* — A document used by a buyer to acquire a product or service that usually contains the terms and conditions (including price) governing the sale.

5.65 *qualification* — Certification of compliance with contractual stipulations before release to manufacturing production use.

5.66 *quality assurance/quality control (QA/QC)* — Activities performed to ensure compliance with contractually stipulated conditions.

5.67 *raised floor* — The removable floor system installed above the actual building floor within cleanroom environments to control air flow and allow access for utility routing and connection.

5.68 *request for information (RFI)* — Documentation from contractor to request clarification.

5.69 *request for proposal (RFP)* — Documentation from purchasing agent to vendor to request a proposal to provide product and/or services.

5.70 *request for quote (RFQ)* — Documentation from purchasing agent to vendor to request a firm price to provide product and/or services.

5.71 *seismic bracing* — Structural reinforcement to minimize damage due to earthquakes.

5.72 *shifts* — Duration of routine work day, typically an 8, 10, or 12 hour as required to accrue a minimum of 40 equivalent hours (or local equivalent) within a 7-day (one week) period.

5.73 *single line drop* — A hookup strategy where a piece of processing equipment has only one point of connection per facility service. All manifolding for an individual service is handled with in the tool.

5.74 *site-specific facilities services and termination matrix* — A compilation of service types, quality, and capacity available for use at utility point of connection for a tool (see SEMI E51).

5.75 *slurry system* — A distribution system to convey abrasive slurries for use in chemical mechanical polishing (CMP) systems.

5.76 *source inspection* — Inspection at the equipment manufacturer's factory to confirm configuration details, review modifications, and confirm installation designs prior to shipment of equipment.

5.77 *specialty gas* — Non-bulk process gases typically stored in cylinders and used to supply one or more process tools through specialized manifolds.

5.78 *subfab* — The area within the cleanroom boundaries directly below the production level.

5.79 *submittal* — A written presentation for signed acceptance of a proposal in response to a request for services.

5.80 *support equipment* — Ancillary equipment not part of the main chassis.

5.81 *time and materials (T&M)* — A contracting method whereby cost is determined by the actual requirements of the project as opposed to an estimate and a fixed cost system.

5.82 *tool* — Any piece of semiconductor fabrication or inspection equipment designed to process wafers. Often used synonymously with equipment in the silicon wafer processing industry.

5.83 *tool accommodation* — A methodology by which semiconductor processing equipment is installed in a cost-effective and timely manner.

5.84 *turnkey* — Delivery of a fully functional and tested system.

5.85 *utility point of connection (UPOC)/tool point of connection (TPOC)* — UPOC is a fitting typically located at a valve on a lateral to provide service for a tool, the facilities end/termination of the hookup. TPOC is a fitting typically at a valve on a processing tool (either external or internal), the tool end/termination of the hookup.

5.86 *uninterruptable power supply (UPS)* — A power supply that provides an uninterrupted or continuous supply of electrical power even during a failure in the main utility power supply.

5.87 *union labor* — A group of trained craftpersons that are represented by a single bargaining organization. A labor bargaining unit.

5.88 *value engineering* — A set of reviews to determine minimum requirements at a minimum cost.

5.89 *valve manifold box (VMB)/valve manifold panel (VMP)* — A metal enclosure and/or panel including distribution valves and components required to distribute gases or liquids to multiple points of use from a single source.

6 Roles and Responsibilities

6.1 Definition and responsibility assignment are critical to a successful project. Communications mechanisms must be established as early as possible. SEMI E6 provides a template for establishing a format for administrative interface. Using this format for establishing interfaces will improve communication and avoid cost and schedule impacts that might arise from equipment or facilities modifications during the procurement cycle. (See Figure 1.)

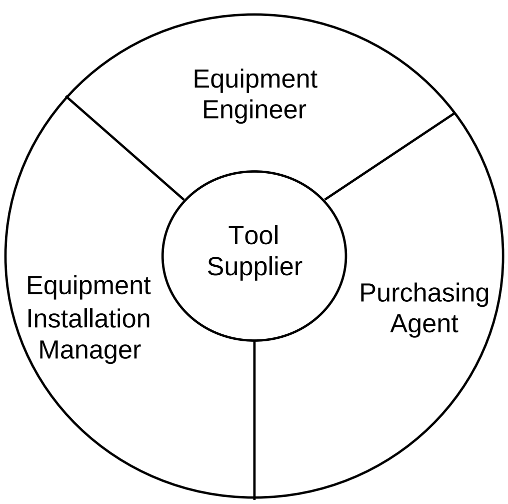


Figure 1
Information Exchange Relationships

7 Process

7.1 The following 15 steps describe a generic process flow for using published tool accommodation standards to achieve cost and schedule goals in a cycle of procurement through acceptance for a particular process tool. (See Figure 2.)

7.1.1 *Process Requirement Defined by Customer* — Process parameters are defined and documented by the process engineer and equipment engineer. Specific performance targets are established that are consistent with production requirements and cost of ownership expectations.

7.1.2 *Process Tool Location Identified by Customer* — Physical location is determined by collaboration between production, industrial, and facilities engineering. The location is typically selected to optimize production flow within the facility while minimizing accommodation costs and production interruptions. A layout document of record is generated and approved by all affected parties.

7.1.3 *Customer Generates Facilities Services Matrix* — Equipment and facilities engineering establish site-specific parameters by using the SEMI E51 format to define the available utilities and physical environment within which the production tool will have to function.

7.1.4 *Customer Specifies Internal Tool Piping and Distribution System Requirements* — Site-specific exceptions to SEMI E49 through SEMI E49.9 are identified and reviewed with equipment suppliers to determine the most cost- and schedule-efficient configuration.

7.1.5 *Customer Issues Formal Request for Quote* — A formal request for quotation (RFQ) is generated by the customer's procurement department soliciting quotations from qualified manufacturers. SEMI E49 and SEMI E51 data are included with request for quotation.

7.1.6 *Supplier Submits Quote Including the Facilities Interface Specification in SEMI E6 Format* — A "Statement of Conformance" to specified standards is normally required for a quotation to be considered valid. Exceptions to performance specifications must be thoroughly documented and resolved. Multiple re-quotation is sometimes required to establish a contractually valid agreement.

7.1.7 *Contractual Terms Finalized and Order is Placed by Customer* — Terms and conditions of the purchase agreement based upon the finalized quotation are negotiated and approved by all stakeholders.

7.1.8 *Supplier Manufactures Equipment* — Equipment is manufactured per purchasing agreement. To prevent errors and omissions during installation, change orders are documented, approved prior to implementation, and copies are distributed per administrative interfaces as defined in SEMI E6.

7.1.9 *Installation Detailed and Prefacilitation Performed by Customer* — Installation design documentation is generated, approved, and distributed to subcontractors for pricing. Long lead-time hookup materials are identified and prepurchased. Prefacilitation is performed to insure accurate and quick hookup of tool on arrival.

7.1.10 *Customer Source Inspects Equipment* — Source inspection is the final validation of all designs and capabilities of the specific tool. Functionality testing is performed and documented. Physical configuration is confirmed. Modifications to configurations are documented so that installation pricing can be adjusted accordingly.

7.1.11 *Supplier Ships Equipment to Customer* — Equipment is packaged per SEMI E49.1 and shipped as defined in SEMI E6. Equipment is shipped per purchase order stipulations. Customs clearance is obtained as required.

7.1.12 *Customer Verifies Equipment Matches Supplier Provided Facilities Interface Specification* — Upon arrival at the customer site, verification of compliance to purchase order is determined. Verification of physical dimensions, point of connections, and interface cabling and tubing is performed.

7.1.13 *Equipment Hookup by Customer* — Mechanical, electrical, process piping, and life safety system hookups are done, and all functional testing is completed. Equipment is ready for vendor startup and commissioning. Final payment to hookup contractor is authorized, and upon payment, construction liens are released. As-built drawings showing newly installed tool are updated and submitted to owner for inclusion in permanent records.

7.1.14 *Equipment Is Qualified and Customer Verifies Contract Completion* — Equipment startup is complete and functional testing to verify compliance to purchase agreement is complete and documented. Final payment to equipment vendor is released.

7.1.15 *Actual Cost and Schedules Are Reviewed* — Final accounting is performed to determine actual costs associated with the project. Actual duration of all activities is compared to original schedule to determine areas for improvement. Estimating models for future installations are updated to reflect new information.

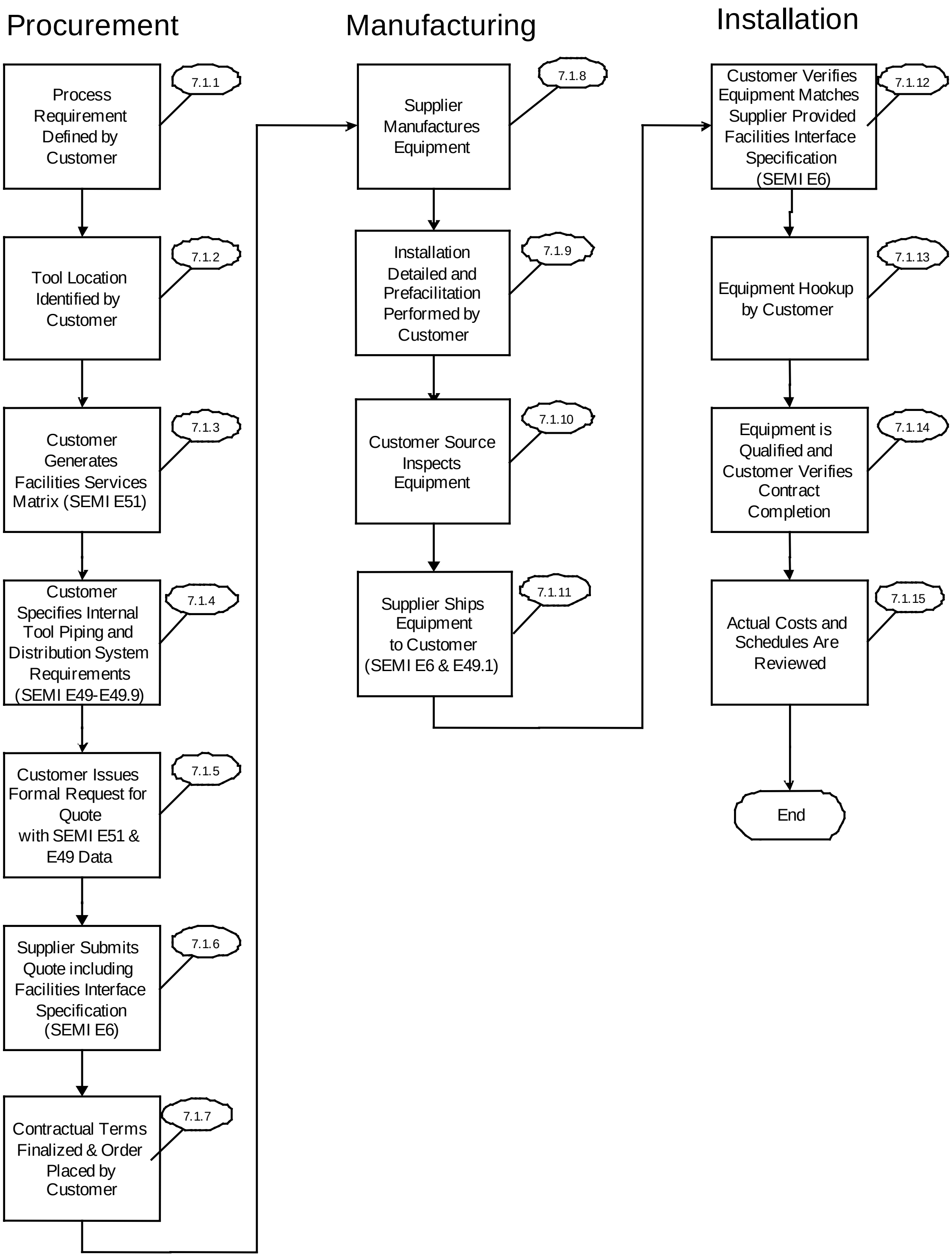


Figure 2
Tool Accommodation Process Flow Chart

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E72-0600
SPECIFICATION AND GUIDE FOR 300 mm EQUIPMENT FOOTPRINT, HEIGHT, AND WEIGHT

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org April 2000; to be published June 2000. Originally published in 1998, previously published June 1999.

1 Purpose

1.1 Currently, device manufacturers cannot easily plan or retrofit their fabs, because equipment volumes are not predictable. Similarly, equipment suppliers cannot predict fab designs, because there are too many configurations. In general, fab space is not used efficiently, and there seems to be a trade-off between space efficiency and maintainability. This standard is a guide for equipment design and a specification for maximum limits on equipment volume and weight.

2 Scope

2.1 This standard specifies limits on the footprint, height, and weight of equipment for 300 mm fabs. Separate limits are given for the parts of the equipment in the main fab and in the sub-fab. Separate limits are also given for the equipment after it is installed and for the components of the equipment as it is moved into the fab. The actual footprint may vary by equipment type.

2.2 This standard is intended to set an appropriate level of specification that places minimal limits on supplier innovation while ensuring opportunities for users to be globally (though possibly not locally) efficient with equipment volumes.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *cost footprint* — the area (A) of the smallest horizontal rectangle that contains all of the shadow footprint and half of the easement space around the equipment (for use as the floor space metric in Cost of Ownership calculations). As shown in Figure 1, this is computed as

$$A = [Wt + ½\,(Ws – Wt)] \times [Dt + ½\,(Ds – Dt)]$$
$$= ¼\,(Wt + Ws) \times (Dt + Ds)$$

Where W represents width and D represents depth

4.2 *depth* — the horizontal dimension perpendicular to the load face plane.

4.3 *easement space* — the floor space that must remain clear to the rear and sides of the equipment (but not in front of the load face plane). This includes safety aisles, ergonomic maintenance access space, component removal space, and room for doors to swing out (see Figure 1).

4.4 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.5 *shadow footprint* — the area of the floor space directly under every part of the equipment during its operation (see Figure 1). This includes any temporary projections from the equipment during loading or processing (such as carriers that stick out from the equipment or equipment load ports that protrude only when the equipment is being loaded).

4.6 *width* — the horizontal dimension parallel to the load face plane.

5 Requirements and Recommendations

The dimensions cited in the following sections are specified in Table 1.

5.1 *Sub-Fab vs. Main Fab Footprint*

5.1.1 *Requirements* — Both the cost footprint and the shadow footprint of the remote parts of any equipment in the sub-fab must be less than or equal to the cost footprint and the shadow footprint (respectively) of the parts of that equipment in the main fab (the cleanroom including both bays and chases, if any). Furthermore, the remote parts of the equipment in the sub-fab must be capable of being installed so that the rectangle defining the cost footprint in the sub-fab is entirely underneath the rectangle defining the cost footprint in the main fab. In some fab designs (such as slab on grade), there is no sub-fab (or basement). In such cases, these requirements apply to the remote parts of the equipment in whichever equipment support area contains the same remote parts of the equipment as a sub-fab. Also, some fabs have multiple sub-fab levels. In such cases, these requirements apply to the remote parts of the equipment in all sub-fab levels.

5.1.2 *Recommendations* — Since the sub-fab is likely to have more columns than the main fab, it is recommended that the remote parts of the equipment in the sub-fab come in modules that can be arranged to accommodate a variety of layouts.

5.2 *Equipment Height*

5.2.1 *Requirements* — The maximum height of any equipment (other than a stocker) must be less than or equal to *H* in the main fab and *Hs* in the sub-fab. Any connections for utilities and required overhead maintenance access must also be included within these limits. These limits also apply during installation, so if a part of the equipment must be rotated up into place, the diagonal measurement must be less than these limits.

5.2.2 *Recommendations* — Thus, equipment suppliers are advised to not plan on ceilings higher than these limits.

5.3 *Floor Loading*

5.3.1 *Requirements* — The maximum mass of any equipment in the main fab divided by its shadow footprint must be less than or equal to *M* (except when support pedestals are used). Furthermore, the maximum weight on any 0.6 m by 0.6 m (2 ft. by 2 ft.) floor tile (in any installation configuration) must be less than or equal to *Mt.* These limits also apply when the equipment is being moved into the fab and installed, unless spreader plates are used.

5.3.2 *Recommendations* — It is recommended that seismic loading also be considered when designing equipment weight distribution.

5.4 *Move-In-Size*

5.4.1 *Requirements* — To clarify the size of the doors and hallways needed in the fab, this paragraph specifies the size of the equipment's components after it has been uncrated, while it is being moved into the fab, and before it is installed. All parts of the equipment destined for the main fab must come in packages that are no taller than *Z* and that are smaller than *X* by *Y* in two orthogonal horizontal dimensions. All parts of the equipment destined for the sub-fab must come in packages that are no taller than *Zs* and that are smaller than *Xs* by *Ys* in two orthogonal horizontal dimensions. Furthermore, none of these packages may weigh more than *Mm* each. This paragraph does not apply to stockers and AMHS transport equipment.

5.4.2 *Recommendations* — Equipment suppliers and device manufacturers might also consider carrier stocker size, move-in timing, and move-in path during stocker and facility design. Equipment that conforms to these limits may still be too large to fit into standard truck trailers or aircraft cargo bays.

5.5 *Maintenance Access*

5.5.1 *Requirements* — To avoid interfering with carrier transport systems, equipment must not require regularly scheduled maintenance from the front. This requirement does not apply to maintenance performed on user interfaces, cart-docking interfaces, load ports, carrier buffers, and load locks.

5.5.2 *Recommendations* — It is recommended that as little regularly scheduled maintenance as possible be required from the side.

5.6 *Width vs. Depth*

5.6.1 *Recommendations* — In general, to minimize the number of bays required in a fab, it is recommended that equipment be designed to minimize width rather than depth.

5.7 *Linked Equipment*

5.7.1 *Recommendations* — To make linked equipment (such as cluster tools or steppers with litho tracks) jointly space efficient, it is recommended that they be designed to minimize the cost footprint of the entire system as a whole.

6 Related Documents

6.1 *SEMI Standards*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI E26.1 — Radial Cluster Tool Footprint 300 mm Standard

SEMI E35 — Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI E76 — Guide for 300 mm Process Equipment Points of Connection to Facility Services

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

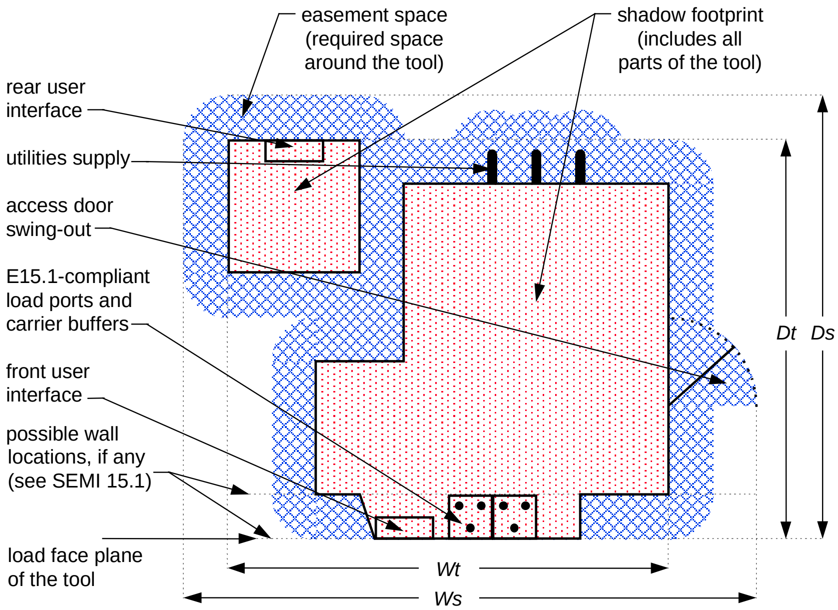


Figure 1
Equipment Footprint Dimensions

Table 1 Equipment Footprint, Height, and Weight Dimensions

Symbol Used	*Value Specified*	*Dimension Description*
H	3.5 m (11 ft. 5 in.) maximum	height of equipment in the main fab
Hs	2 m (6 ft. 6 in.) maximum	height of equipment in the sub-fab
M	1500 kg/m^2 (2.1 lbm./$in.^2$) maximum	mass of equipment divided by its shadow footprint
Mm	6000 kg (13227 lbm.) maximum	mass of equipment move-in packages
Mt	1000 kg (2204 lbm.) maximum	mass of equipment on any 0.6 m by 0.6 m (2 ft. by 2 ft.) floor tile
X	2.2 m (7 ft. 2 in.) maximum	Length (perpendicular to Y) of equipment move-in packages destined for the main fab
Xs	2 m (6 ft. 6 in.) maximum	Length (perpendicular to Ys) of equipment move-in packages destined for the sub-fab
Y	2.8 m (9 ft. 2 in.) maximum	Length (perpendicular to X) of equipment move-in packages destined for the main fab
Ys	1.7 m (5 ft. 6 in.) maximum	Length (perpendicular to Xs) of equipment move-in packages destined for the sub-fab
Z	2.8 m (9 ft. 2 in.) maximum	Height of equipment move-in packages destined for the main fab
Zs	2 m (6 ft. 6 in.) maximum	Height of equipment move-in packages destined for the sub-fab

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E72 but was approved for publication by full letter ballot procedures.

R1-1 The maximum height of equipment in the main fab was set so that the equipment could be installed in existing fabs with ceilings just above the equipment height of 3.5 m (11 ft. 5 in) or in fabs with ceiling heights of 3.66 m (12 ft. 0 in.) where more clearance is provided for such things as parts of some overhead carrier transport systems, fire sprinkler systems at the ceiling, and/or extra room for installation of equipment.

R1-2 The maximum height of equipment in the sub-fab was set so that no part of the equipment (other than connections to the main fab area) sticks up into the piping and duct-work immediately under the waffle slab. In those cases where a part of the equipment must be taller than 2 m (6 ft. 6 in.), it is recommended that it not be taller than 2.5 m (8 ft. 2 in.) to stay under the waffle slab.

R1-3 If equipment must have easement space on the side, it is recommended that they be designed in mirror-image configurations with easement space needed on only one side or the other, so that half of the total easement space on the sides can be deleted. However, it is recommended that the resulting increase in equipment cost, complexity, and spare parts inventory be taken into account.

R1-4 Equipment that conforms to the limits given in this standard may be too large or heavy to fit into buildings that were originally designed for equipment that processes smaller wafers.

SEMI E73-0301
SPECIFICATION FOR VACUUM PUMP INTERFACES - DRY PUMPS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces & Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on December 1, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published June 1998; previously published February 1999.

1 Purpose

1.1 This standard specifies the physical and electrical interfaces for dry pump (DRP) type vacuum pumps. Standardization of pump interfaces will allow for interchangeability of pumps. Device manufacturers use this standard when procuring processing equipment to specify to the equipment supplier the interface required for interchangeability of pumps. This document is also used by semiconductor processing equipment suppliers to specify standardized interfaces to pump suppliers.

2 Scope

2.1 This standard applies to vacuum pumps supplied with 300 mm semiconductor processing equipment.

2.2 The standard specifies the mechanical and electrical interfaces for dry pumps including the following.

- Mechanical connectors
- Control signals and connector
- Power supply and connector

2.3 Figure 1 shows the scope of the standardized interface.

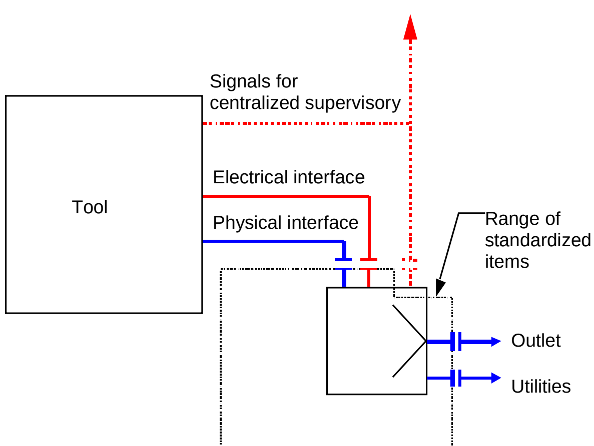


Figure 1
Scope of Standardized Interface

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guide is not intended to dictate how to build a vacuum pump but to specify interfaces that will allow for interchangeabilty of individual pumps.

3.2 This standard does not include specifications for sensor-bus compliant interfaces.

3.3 This standard is not intended to address design issues related to safety considerations and containment issues which are addressed elsewhere in the SEMI guidelines.

3.4 International, national, and local codes, laws, and regulations should be consulted to ensure that the equipment meets regulatory requirements in each location of use.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Documents*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *ISO Documents*[1]

ISO 7-1 — Pipe threads where pressure-tight joints are made on the threads - Part 1: Dimensions, tolerances and designation

ISO 1609 — Vacuum Technology - Flange dimensions

ISO 2861-1 — Vacuum technology - Quick-release couplings - Dimensions - Part 1: Clamped type

5 Terminology

5.1 *dry pump (DRP)* — Dry pumps are a type of mechanical vacuum pump. Dry pumps can work at

1 International Organization for Standardization, C.P. 56 CH-1211 Geneva 20, Switzerland

atmospheric pressure. They are called dry pumps because no liquid sealing materials are used on any surface contacted by gases. Hereafter, the term "DRP" is substituted for "dry pump".

5.2 *pump alarm* — A cautionary signal that the pump has stopped.

5.3 *pump warning* — A state of an abnormal or extraordinary event during pump operation which means there is a probability the pump will stop.

5.4 *vacuum pump* — A pumping apparatus which exhausts gas or air from an enclosed space to achieve a desired degree of vacuum.

6 Requirements

6.1 *Mechanical Interfaces* — Table 1 specifies the required DRP connector type and size by flange/port.

Table 1 Mechanical Connectors

No.	*Items*		*Connector Type*	*Connector Size*	*Referenced Standard*	*Remarks*
1	Inlet flange	Nominal bore 50 mm or less	ISO KF flange	≤ 50 mm Connector dimensions should be based on the referenced standard	ISO 2861-1	A port flange which connects the pump to a process tool to evacuate gases.
		Nominal bore over 63 mm size	ISO clamped flange	≥ 63 mm Connector dimensions should be based on the referenced standard	ISO 1609	
2	Outlet flange		ISO KF flange	Connector dimensions should be based on the referenced standard	ISO 2861-1	A port flange which connects the pump to the facility evacuation system.
3	Duct port (Option)		Not specified	50 mm or 100 mm diameter port		Port to connect duct for evacuating flames inside the pump.
4	Purge gas port		Compression type*	1/4" Connector		A connection port used to supply inert gas, typically N_2, to the pump. The purge gas protects the inside of the pump from corrosion due to process gases.
5	Cooling water port		ISO taper pipe thread (female on pump side)	1/4" or 3/8"	ISO 7-1	A connection port to supply water used to keep the pump cool.

* For example Swagelock®

6.2 *Electrical Interfaces*

6.2.1 *Control Signals*

6.2.1.1 Table 2 specifies the required DRP control signals. Table 3 and Figure 2 specify the required response time for DRP control signals. Table 4 specifies the required power and contacts for DPR control signals. Tables 5 and 6 and Figure 3 specify the required connector and pin assignments for DRP control signals.

Table 2 I/O Signals

No.	*Signal Name*	*Direction*	*Type*		*Remarks*
1	Start (Run)/Stop	Input signal to Pump	Alternate	Pump runs when closed	
2	Start (Run)/Stop	Output signal from Pump	Alternate	Close on pump start	Running status signals When input power is OFF, output status signals should become open (normally open).
3	Remote/Local	Output signal from Pump	Alternate	Close during remote operation	
4	Pump Warning	Output signal from Pump	Alternate	Open at warning	
5	Pump Alarm	Output signal from Pump	Alternate	Open at alarm	

Table 3 Response Time for Signals

No.	*Items*	*Acceptable Response Time*	*Remarks*
1	Input Power ON	Under 10 seconds After input power turns on	Objects: All status signals shall be ready.
2	Control Signals	Under 2 seconds After receiving a signal	See Figure 2 Objects: a) Start signal (input) ->> Start status (output) b) Stop signal (input) ->>Stop status (output)

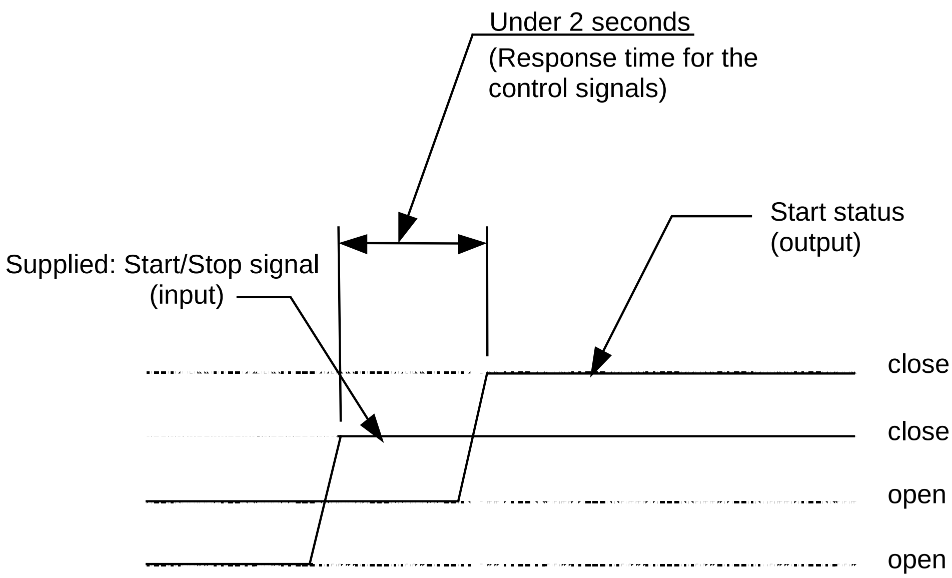


Figure 2
Example of Response Time for Start Signal and Start Status

Table 4 Signal Power and Contacts

No.	*Items*	*Power*		*Remarks*
1	Signal power supply	Input signals to DRP (Control signal)	Input signals shall be driven by the DC power supply in DRP.	Example: See Figure 4. a) Photocoupler Input. b) Relay Input.
		Output signals from DRP (Running status signal)	Output signals shall be driven by DC power supply in tools.	Example: See Figure 5. a) To photocoupler unit. b) To relay unit. c) To TTL unit.
2	Signal power supply voltage	Signal power supply voltage is between 5 V_{DC} and 24 V_{DC}		
3	Acceptable range of signal power supply voltage	Acceptable voltage range is 4 V_{DC} minimum, and 30 V_{DC} maximum.		
4	Running status signal contact	Dry contact or open collector	Acceptable current 100 mA maximum.	

Table 5 Control Signal Connector (pump side)

No.	*Items*	*Connector Type*	*Referenced Standard*	*Pin Assignments*	*Remarks*
1	Control and running status signals	15 pin D sub-miniature Female receptacle		See Table 6 and Figure 3	See Related Documents for an example of the specifications for this connector type.

Table 6 Pin Assignment for Control Signal Connector

No.	*Pin No.*	*Signal item (polarity)*	*Remarks*
1	1	DRP start input (+)	
2	2	(MBP start input) (+)	An upper pump, such as mechanical booster pump (MBP), to be used with dry pump systems.
3	3	DRP start/stop status (+)	
4	4	(MBP start/stop status) (+)	An upper pump, such as mechanical booster pump (MBP), to be used with dry pump systems.
5	5	Warning status (+)	
6	6	Alarm status (+)	
7	7	Remote/Local status (+)	
8	8		
9	9	DRP start input (-)	
10	10	(MBP start input) (-)	An upper pump, such as mechanical booster pump (MBP), to be used with dry pump systems.
11	11	DRP start/stop status (-)	
12	12	(MBP start/stop status) (-)	An upper pump, such as mechanical booster pump (MBP), to be used with dry pump systems.
13	13	Warning status (-)	
14	14	Alarm status (-)	
15	15	Remote/Local status (-)	
16	-		

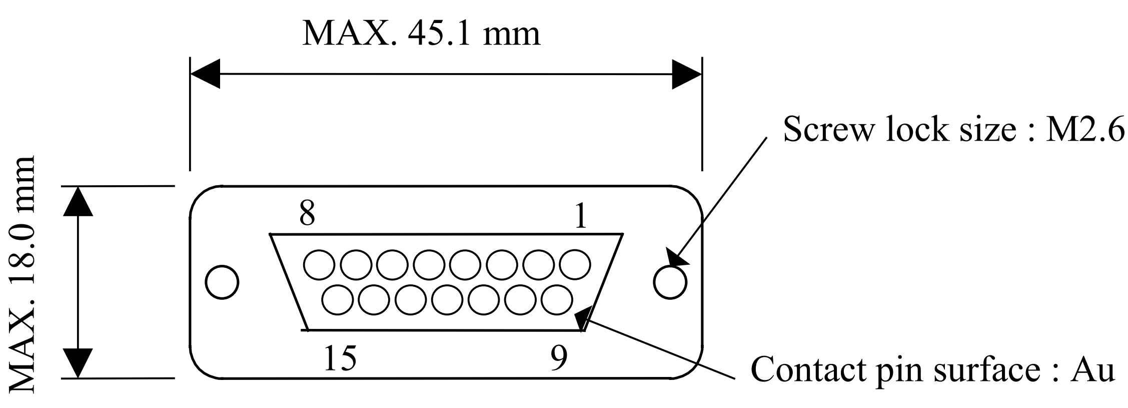


Figure 3
15 pin D Sub-Miniature Female Receptacle

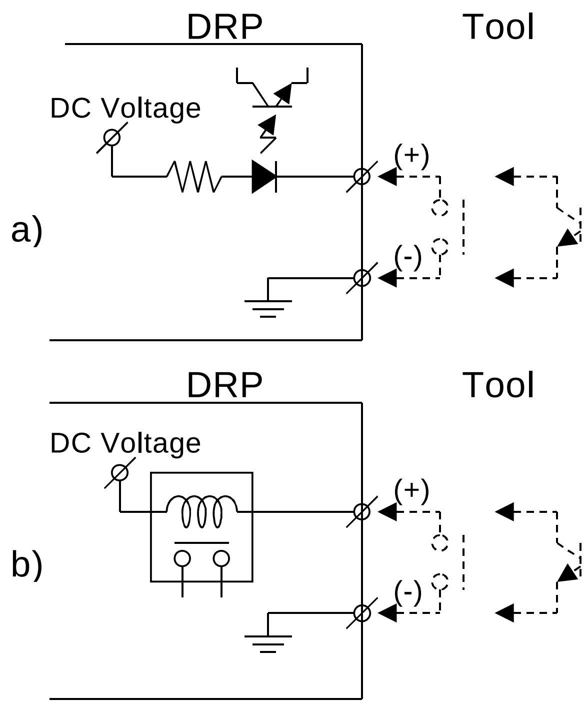


Figure 4
Schematic Example of DRP Input Signals

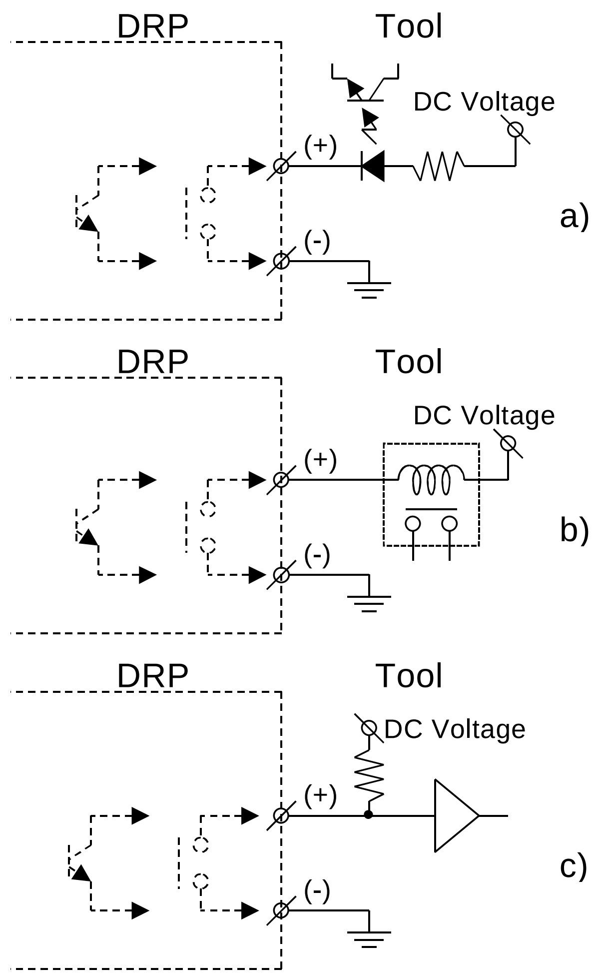


Figure 5
Schematic Example of DRP Output Signals

6.3 *Incoming Power Supply*

6.3.1 Tables 7 and 8 specify the required DRP incoming AC power supply connector and pin assignments.

Table 7 Incoming AC Power Supply Connector (Pump Side)

No.	*Items*	*Connector Type*	*Referenced Standard*	*Pin Assignments*	*Remarks*
1	Three phase: $200V_{AC} - 230V_{AC} \pm 10\%$ 50/60 Hz	Receptacle (male)	SEMI S2	See Table 8	

Table 8 Pin Assignment for Incoming Power Supply Connector

No.	*Pin No.*	*Item*		*Remarks*
1	1 or A	R	AC 3 phase	U
2	2 or B	S		V
3	3 or C	T		W
4	maximum or last pin number in the connector	Earth/Ground		When using a connector that has a special grounding pin not included in the standard pin arrangement, the last pin becomes a blank pin. (See Related Documents for an example of specification for this connector.)

7 Related Documents

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

7.1 *DIN Standard*[2]

DIN VDE 0627 — Connectors and plug-and socket devices; for rated voltages up to 1000 V a.c., up to 1200 V d.c. and rated currents up to 500 A for each pole

7.2 *Military Standard*[3]

MIL-PRF-24308 — General Specification for Connectors, Electric, Rectangular, Non-Environmental, Miniature, Polarized Shell, Rack and Panel

2 Deutsches Institut für Normung e.V., Beuth Verlag GmbH Burggrafenstrasse 4-10, D-10787 Berlin, Germany

3 Military Standards, Naval Publication and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E73 and is not intended to modify or supercede the official standard. This related information is optional and contains information that is not required to conform to this standard.

NOTE 1: While this standard was developed to specify vacuum pumps installed with 300 mm equipment, the standard should also be applied to vacuum pumps installed with 200 mm equipment.

NOTE 2: Signal items for centralized supervisory diagnostics and maintenance could not be standardized, because they are not consistent or technically well-established. Additional work is required for standardization of these signals.

NOTE 3: In order to save space and reduce cost, the connector for the control and running status signals should be the minimum size required for the number of pins specified in the standard. If additional signal connections are required, another connector should be added to the pump.

NOTE 4: Utilizing a 200 VAC system (range: 200 to 230 VAC) rather than a 400 VAC system (range: 380 to 480 VAC) can lower costs associated with manufacturing and purchasing pumps. To help minimize pump costs, this standard incorporates AC supply voltages in the range of 200 to 230 VAC. Many 400 VAC systems are now in use and may be more widespread in the future. However, standardizing on supply voltage of 200 VAC can reduce pump costs now without complications as long as pump manufactures accommodate customers requesting 400 VAC units.

SEMI E74-0301
SPECIFICATION FOR VACUUM PUMP INTERFACES - TURBOMOLECULAR PUMPS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces & Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on December 1, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published June 1998; previously published February 1999.

1 Purpose

1.1 This standard specifies the physical and electrical interfaces for turbomolecular pump (TMP) type vacuum pumps. Standardization of pump interfaces will allow for interchangeability of pumps. Device manufacturers use this standard when procuring processing equipment to specify to the equipment supplier the interface required for interchangeability of pumps. This document is also used by semiconductor processing equipment suppliers to specify standardized interfaces to pump suppliers.

2 Scope

2.1 This standard applies to vacuum pumps supplied with 300 mm semiconductor processing equipment.

2.2 The standard specifies the mechanical and electrical interfaces for turbomolecular pumps, including the following:

- Mechanical connectors and locations
- Control signals and connector
- Power supply and connector

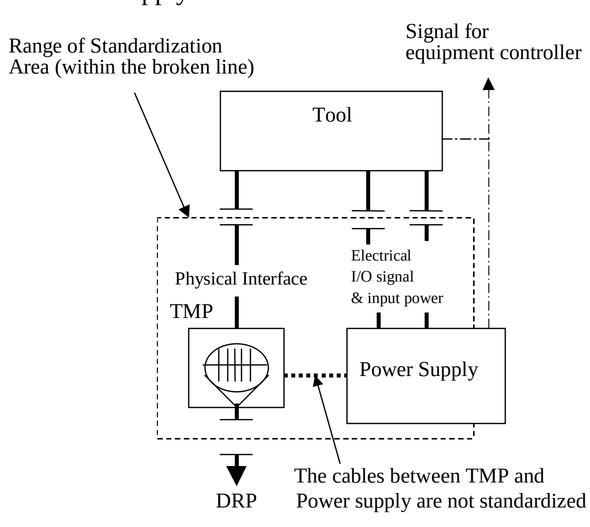


Figure 1
Scope of Standardized Interface

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is not intended to dictate how to build a vacuum pump, but to specify interfaces that will allow for interchangeability of individual pumps.

3.2 This standard does not include specifications for sensor-bus compliant interfaces.

3.3 This standard is not intended to address design issues related to safety considerations and containment issues which are addressed elsewhere in the SEMI guidelines.

3.4 International, national and local codes, regulations and laws should be consulted to ensure that the equipment meets regulatory requirements in each location of use.

3.5 This standard does not apply to turbomolecular pumps less than 300 l/s or greater than 3000 l/s. Pumps less than 300 l/s are too small and pumps greater than 3000 l/s pumps are not commonly used.

3.6 Double flow turbomechanical pumps are excepted from this standard, because their shapes and structures are different from turbomolecular pumps to be applied this standard.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *ISO Documents*[1]

ISO 7-1 — Pipe threads where pressure-tight joints are made on the threads - Part 1: Dimensions, tolerances and designation

1 International Organization for Standardization, C.P. 56 CH-1211 Geneva 20, Switzerland

ISO 1609 — Vacuum Technology - Flange dimensions

ISO 2861-1 — Vacuum technology - Quick-release couplings - Dimensions - Part 1: Clamped type

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *pump alarm* — A cautionary signal that the pump has stopped or is to be stopped.

5.2 *pump warning* — A state of an abnormal or extraordinary event during pump operation which means there is a probability the pump will stop.

5.3 *turbomolecular pump (TMP)* — Equipment used to create a high vacuum. Rapidly rotating blades force molecules to the bottom for removal by a mechanical pump.

5.4 *Vacuum Pump* — A pumping apparatus which exhausts gas or air from an enclosed space to achieve a desired degree of vacuum.

6 Requirements

6.1 *Mechanical Interfaces*

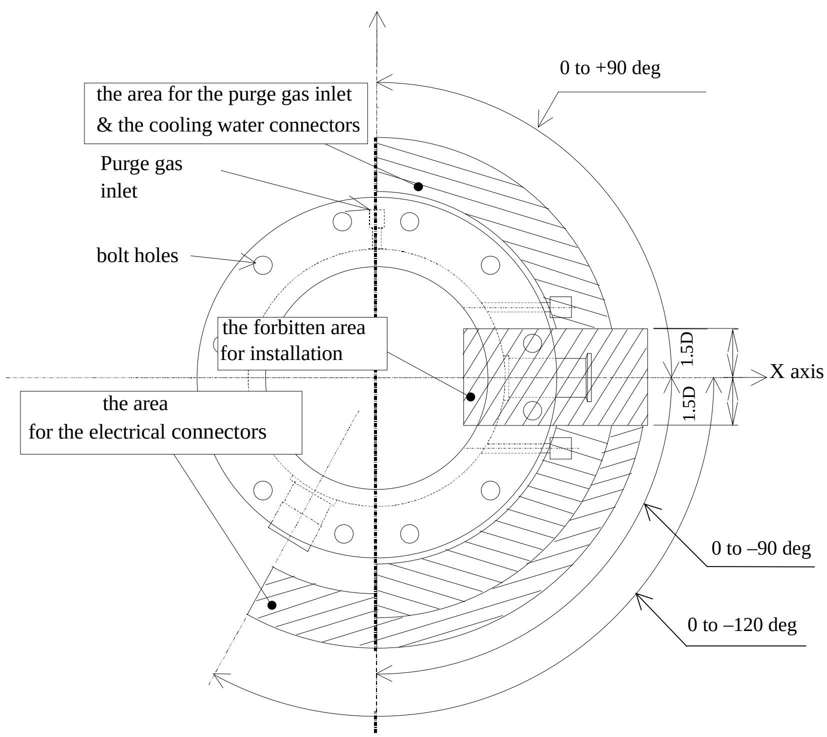
6.1.1 Table 1 specifies the required TMP connector type and size by flange/port. Axial orientation and position of the connectors are specified in Table 2 and Figure 2. Port and connector positions shall be at the periphery of the pump. Put inlet port on the *z*-axis and the outlet port on the *x*-axis. Other connector locations are specified by the angle between the *x*-axis and the center of the connector.

Table 1 Mechanical Connectors

No.	*Items*	*Connector Type*	*Connector Size*	*Referenced Standard*	*Remarks*
1	Inlet flange	ISO bolted flange	Connector dimensions should be based on the referenced standard	ISO 1609	A port flange which connects the pump to a process tool to evacuate gases.
2	Outlet flange	ISO KF flange	Connector dimensions should be based on the referenced standard	ISO 2861-1	A port flange which connects the pump to the DRP (Dry Pump).
3	Purge gas port	ISO KF flange	Size 10 or 16 connector	ISO 2861-1	A connection port used to supply inert gas, typically N_2, to the pump. The purge gas protects the inside of the pump from corrosion due to process gases.
4	Cooling water port	ISO taper pipe thread (female on pump side)	1/4" or 3/8"	ISO 7/1	A connection port to supply water used to keep the pump cool.

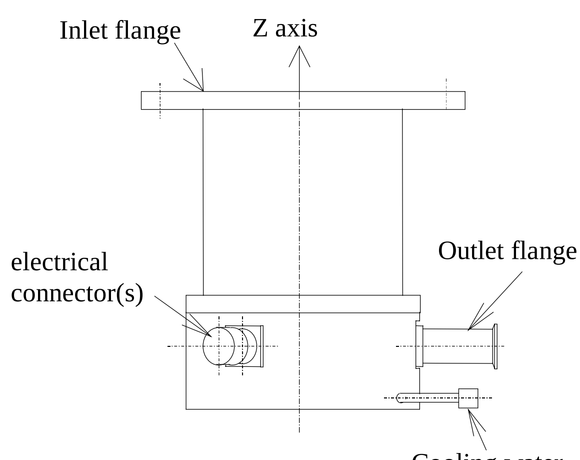
Table 2 Connector Locations

No.	*Items*	*Connector Location*	*Connector Angle (degrees)*	*Remarks*
1	Inlet flange	*z*-axis		Flange bolt holes shall be symmetrically located at equal distance from the center line of the outlet flange.
2	Outlet flange	transverse	0°	
3	Purge gas port	transverse	- 90° to + 90°	The forbidden area shall be symmetrically located at equal distances from the center of the outlet flange. Distance from the *x*-axis shall be more than 1.5 times the nominal bore of the outlet flange.
4	Cooling water port	transverse	- 90° to + 90°	
5	Electrical connections	transverse	0° to -120°	
6	Other ports	transverse	- 90° to + 90°	



D: nominal bore of the outlet flange

Top view



Side view

Figure 2
Connector Locations

6.2 *Electrical Interfaces*

6.2.1 *Control Signals*

6.2.1.1 Table 3.1 specifies the required TMP control signals. In cases where TMP are backed up by battery or regeneration power while input power failure, the status of output signals follows Table 3.2. Table 4 and Figure 3 specify the required response time for TMP control signals. Table 5 specifies the required power and contacts for TMP control signals. Tables 6 and 7 and Figure 4 specify the required connector and pin assignments for TMP control signals.

Table 3.1 I/O Signals

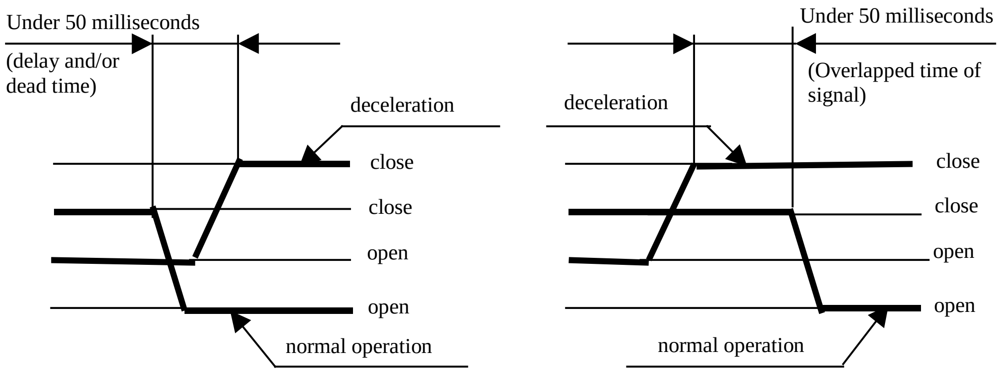
No.	*Signal Name*	*Direction*	*Type*		*Remarks*
1	Start (Run)/Stop	Input signal to Pump	Alternate	Pump runs when closed	
2	Acceleration	Output signal from Pump	Alternate	Close during acceleration	Running status signals When input power is OFF, output status signals should become open (normally open).
3	Normal operation	Output signal from Pump	Alternate	Close during normal operation	
4	Deceleration	Output signal from Pump	Alternate	Close during deceleration	
5	Remote/Local	Output signal from Pump	Alternate	Close during remote operation	
6	Pump Alarm	Output signal from Pump	Alternate	Open at alarm	

Table 3.2 Status of output signals during back up operation mode

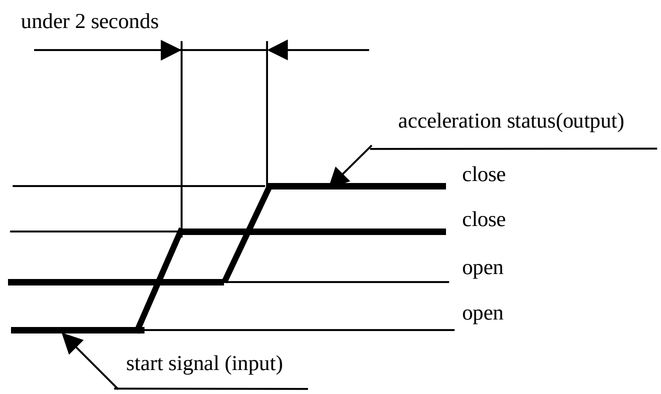
Status of pump	*Signal Name*	*Status of signals*
During back up operation mode	Acceleration	Open
	Normal operation	Open
	Deceleration	Close
	Remote/Local	Close during remote operation
	Pump alarm	Open

Table 4 Response Time and Timing for Signals

No.	*Items*		*Acceptable Response Time*	*Remarks*
1	Response Time	Input Power ON	Under 10 seconds After input power turns on	Objects All status signals shall be ready.
2		Control Signals	Under 2 seconds After receiving a signal	Objects Start signal (input) ->> Acceleration (output) Stop signal (input) ->> Deceleration (output)
3	Timing	Running status signals	Under 50 milliseconds Acceptable delay and/or dead time in a moment of shift of the running status Under 50 milliseconds Acceptable overlapped time in a moment of shift of the running status	Objects (Example) Normal ->> Deceleration The running status signals of alarm and remote/local can be overlapped with other signals.



Timing for the running status signals



Response Time and Timing for Control Signals

Figure 3
Response Time and Timing for Control Signals

Table 5 Signal Power and Contacts

No.	*Items*	*Power*		*Remarks*
1	Signal power supply	Input signals to TMP (Control signal)	Input signals shall be driven by DC power supply in TMP.	Example: See Figure 5. a) Photocoupler Input. b) Relay Input.
		Output signals from TMP (Running status signal)	Output signals shall be driven by DC power supply in tools.	Example: See Figure 6. a) To photocoupler unit. b) To relay unit. c) To TTL unit.
2	Signal power supply voltage	Signal power supply voltage is between 5 V_{DC} and 24 V_{DC}		
3	Acceptable range of signal power supply voltage	Acceptable voltage range is 4 V_{DC} minimum and 30 V_{DC} maximum.		
4	Running status signal contact	Dry contact or open collector	Acceptable current 100 mA maximum.	

Table 6 Control Signal Connector (Pump Side)

No.	*Items*	*Connector Type*	*Referenced Standard*	*Pin Assignments*	*Remarks*
1	Control and running status signals	15 pin D sub-miniature Female receptacle		See Table 7 and Figure 4	(See Related Documents for an example of the specification for this connector type.)

Table 7 Pin Assignment for Control Signal Connector

No.	*Pin No.*	*Signal item (polarity)*	*Remarks*
1	1	Start/Stop input (+)	
2	2		
3	3	Acceleration status (+)	
4	4	Normal status (+)	
5	5	Deceleration status (+)	
6	6	Alarm status (+)	
7	7	Remote/Local status (+)	
8	8		
9	9	Start/Stop input (-)	
10	10		
11	11	Acceleration status (-)	
12	12	Normal status (-)	
13	13	Deceleration status (-)	
14	14	Alarm status (-)	
15	15	Remote/Local status (-)	

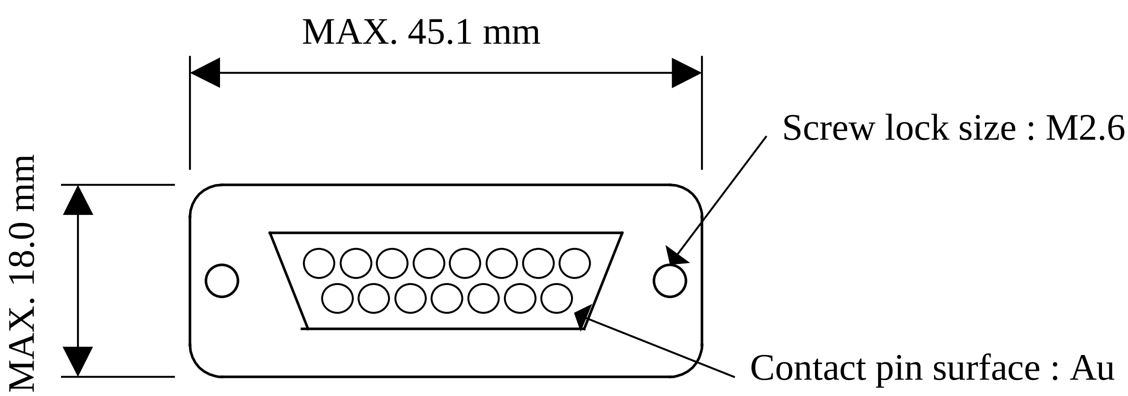


Figure 4
15 pin D sub-Miniature Female Receptacle

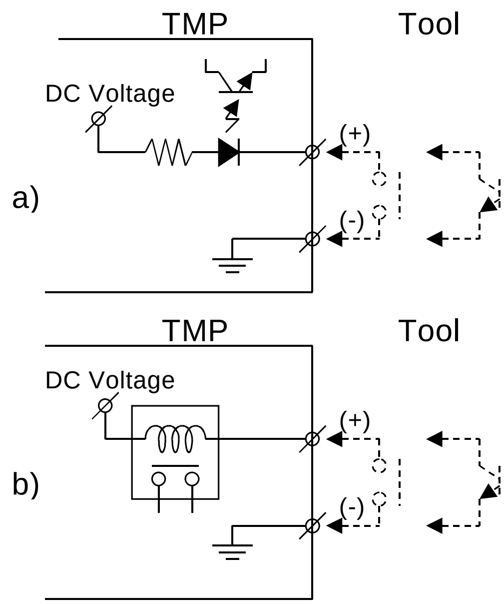


Figure 5
Schematic Example of TMP Input Signals

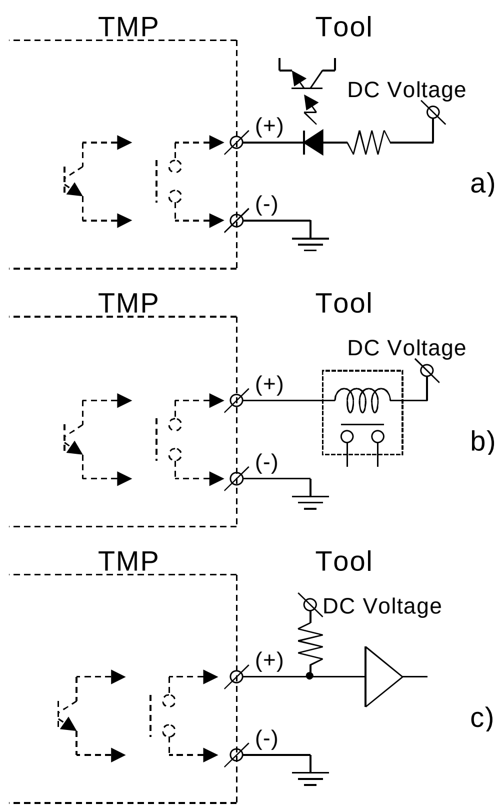


Figure 6
Schematic Example of TMP Output Signals

6.3 *Incoming Power Supply*

6.3.1 Table 8 and Table 9 specify the required TMP incoming AC power supply connector and pin assignments.

Table 8 Incoming AC Power Supply Connector (pump side)

No.	*Items*	*Connector Type*	*Referenced Standard*	*Pin Assignments*	*Remarks*
1	Single phase, $200V_{AC} - 230V_{AC} \pm 10\%$ 50/60 Hz	Receptacle (male)	SEMI S2	See Table 9	

Table 9 Pin Assignment for Incoming Power Supply Connector

No.	*Pin No.*	*Item*		*Remarks*
1	1 or A	Hot	AC single phase	
2	2 or B	Cold		
3	maximum or last pin number in the connector	Earth/Ground		When using a connector that has a special grounding pin not included in the standard pin arrangement, the last pin becomes a blank pin. (See Related Documents for an example of specification for this connector.)

7 Related Documents

NOTE 2: All documents cited will be the latest published versions.

7.1 *DIN Standard*[2]

DIN VDE 0627 — Connectors and plug-and-socket devices; for rated voltages to 1000 V_{AC}, up to 1200 V_{DC}, and rated currents up to 500 A for each pole

7.2 *Military Standard*[3]

MIL-PRF-24308 — General Specification for Connectors, Electric, Rectangular, Non-Environmental, Miniature, Polarized Shell, Rack, and Panel

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user’s attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

2 Deutsches Institut für Normung e.V., Beuth Verlag GmbH Burggrafenstrasse 4-10, D-10787 Berlin, Germany

3 Military Standards, Naval Publication and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E74 and is not intended to modify or supercede the official standard. This related information is optional and contains information that is not required to conform to this standard.

NOTE 1: While this standard was developed to specify vacuum pumps installed with 300 mm equipment, the standard should also be applied to vacuum pumps installed with 200 mm equipment.

NOTE 2: ICF flange is available on request for inlet flange.

NOTE 3: In order to save space and reduce cost, the connector for the control and running status signals should be a minimum size required for the number of pins specified in the standard. If the additional signal connections are required another connector should be added to the pump.

SEMI E75-0698 (Withdrawn 0301)
PROVISIONAL MECHANICAL SPECIFICATION FOR BOX/POD COMPATIBLE CASSETTES USED TO TRANSPORT AND STORE 300 mm WAFERS

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Purpose

1.1 This standard specifies the box/pod compatible cassettes used to transport and store 300 mm wafers in an IC manufacturing facility. This includes both manual and auto-transport use, as well as high-speed extraction of the wafers in processing equipment.

SEMI E76-0299
GUIDE FOR 300 mm PROCESS EQUIPMENT POINTS OF CONNECTION TO FACILITY SERVICES

This Guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 15, 1998. Initially available at www.semi.org January 1999; to be published February 1999. Originally published September 1998.

This document replaces E76-0998 in its entirety.

1 Purpose

1.1 Factory design variations make it difficult for equipment manufacturers to predict or agree on consistent points of connection for hookup of equipment to facility services. Similarly, device manufacturers cannot easily pre-facilitate their factories for equipment because the connections on the equipment are not consistently located. Standardization of connection locations and utilizing pre-facilitation strategies decreases the cost of and time required for equipment installation.

1.2 This document is a guide for 300 mm equipment manufacturers to define the positioning of the equipment points of connection (EPOC), required on semiconductor processing equipment for hookup to facility utility services. The document identifies locations for the EPOC's and provides EPOC consistency recommendations that should allow for efficient equipment installation. In addition, this document defines strategies to support the device manufacturer's ability to pre-facilitate the utility point of connection (UPOC). Recommendations for supplier-provided EPOC documentation are also included.

2 Scope

2.1 This guide addresses three areas that are necessary to improve the efficiency of and reduce the duration of equipment installations.

a) Recommendations for EPOC location, grouping, consistency and reduction to increase confidence in the accuracy and repeatability of EPOC's, and reduce the amount of work required to hookup equipment. As a result, device manufacturers can employ standard pre-facilitation strategies and increase the efficiency of equipment installation.

b) Pre-facilitation recommendations that provide the ability for UPOC's to be efficiently and accurately installed prior to equipment delivery, thus allowing immediate hook-up of the equipment upon arrival in the wafer fab. This includes recommendations for jigs, templates, mating pedestal bases, and associated interface panels.

c) Documentation recommendations to be required by the device manufacturer and provided by the equipment supplier relative to EPOC location, group, consistency, pre-facilitation strategies and hardware. This includes additional documentation recommended to support equipment installations but not directly related to EPOC's.

2.2 This guide applies to 300 mm semiconductor processing equipment and any supplier-provided support equipment for installation into new factories.

2.3 The following groups of utilities are covered in this guide.

- Electrical Power
- Data communications
- Exhaust and other process effluents
- Process fluids (liquids and gases)
- Support equipment interconnects

2.4 The primary focus for this guide is hookup of semiconductor processing equipment including but not limited to the following equipment types.

- Etch equipment (Dry and Wet)
- Film deposition equipment (CVD, PVD and Plating)
- Thermal equipment
- Surface prep and clean
- Photolithography equipment (Stepper and Tracks)
- Chemical Mechanical Polishing equipment
- Ion Implant equipment
- Metrology equipment

3 Limitations

3.1 This standard does not apply to assembly and test equipment.

3.2 International, national, and local codes, regulations and laws should be consulted to ensure that the equipment meets regulatory requirements in each location.

3.3 This guide is not intended to address design issues related to safety. Safety issues are addressed in other SEMI standards (See SEMI S2).

4 Referenced Documents

4.1 *SEMI documents*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI S2 — Safety Guideline for Semiconductor Manufacturing Equipment

NOTE: All documents cited will be the latest published versions.

5 Terminology

5.1 *bottom feed* — Equipment utility supply lines enter the equipment from its underside typically through the floor.

5.2 *equipment configuration* — Specifically, the arrangement, location, type and quantity of EPOC's needed for installation. Also know as tool configuration.

5.3 *equipment point of connection (EPOC)* — A fitting or other terminal provided with the processing equipment (either external or internal) for utility connection, the equipment end/termination of the hookup. Also know as tool point of connection.

5.4 *external connection* — An external connection is located outside the main frame of equipment.

5.5 *facilities interface specification* — Documentation provided by an equipment supplier that contains the equipment requirements for utilities and installation [SEMI E6].

5.6 *facility services* — Any gas, exhaust, liquid, power, data communications or other material which are supplied to or carried away from the equipment and used in the process. Also referred to as utilities or facilities.

5.7 *footprint* — The total area or floor space consumed by a piece of equipment when viewed perpendicular to the area of reference (e.g., normally, when viewed from directly overhead and considering the floor).

5.8 *hazardous production materials (HPM)* — A solid, liquid, or gas that has a degree of hazard rating in health, flammability, or reactivity of class 3 or 4 as ranked by NFPA 704 and that is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous.

5.9 *hookup* — The set of activities and organization required to accept incoming process equipment, move it into place, connect the equipment to all facilities, and test the connections. The connection of all necessary facilities and interconnects required to make the equipment package fully operational.

5.10 *interconnect* — Connections between equipment mainframe and peripheral equipment subsystem equipment [SEMI E6].

5.11 *internal connection* — An internal connection is a utility connection to the equipment which is located internal to the equipment and typically associated with hazardous utilities.

5.12 *interface box* — An enclosure located between the equipment mainframe and facility services typically containing components for pressure regulation and filtration. It functions to consolidate facility service requirements to single points of connection. The interface box can provide location and ability to pre-facilitate equipment hookups in advance of equipment delivery.

5.13 *jig* — A three dimensional fixture, typically a frame that contains equipment installation aides which serve to indicate location and type of connection needed for equipment hook-up.

5.14 *location plane* — The common area on a piece of equipment where EPOC's may be located (e.g., back, side, top, bottom).

5.15 *pedestal* — Structural support element upon which equipment or raised floor rests.

5.16 *pre-facilitation* — The stage in the equipment installation process that follows base build and precedes equipment delivery/equipment hookup. Pre-facilitation brings the various facilities services close to the new equipment location, including new facilities services and structural modifications required to prepare the facility to accept the equipment.

5.17 *pre-facilitation pedestal* — A matching equipment floor mounting surface intended to act as a means to expedite equipment hookup, as well as, save fab floor space by having pre-plumbed connections. Ideally, the pedestal would be installed and facilitated to the UPOC's prior to the equipment arrival.

5.18 *raised floor* — The removable floor system installed above the actual building floor within cleanroom environments to control air flow and allow access for utility routing and connection.

5.19 *seismic bracing* — Structural reinforcement to minimize damage due to earthquakes.

5.20 *single line drop* — A hookup strategy where a piece of processing equipment has only one point of connection per facility service. All manifolding for an individual service is handled with in the equipment.

5.21 *specialty gas* — Non-bulk process gases typically stored in cylinders and used to supply one or more process equipment through specialized manifolds.

5.22 *subfab* — The area below or outside of the cleanroom production area that can be a single or multiple levels and may or may not be clean.

5.23 *support equipment* — Ancillary equipment not part of the main chassis.

5.24 *template* — Provides a dimensional outline of the equipment footprint including overall dimensions, equipment datum point, utility connection/penetration locations, equipment interconnect/penetration locations, maintenance and access spaces, and wafer load/unload stations. It can be made from any cleanroom compatible material.

5.25 *tool* — Any piece of semiconductor fabrication or inspection equipment designed to process wafers. Often used synonymously with equipment in the silicon wafer processing industry.

5.26 *tool accommodation* — A methodology by which semiconductor processing equipment is installed in a cost-effective and timely manner.

5.27 *top feed* — Where utility supply lines enter the equipment from the topside.

5.28 *utility point of connection (UPOC)* — The mating fitting or terminal provided by the facility for interconnection with the EPOC for utility supply, the facility end/termination of the hookup at the equipment.

Table 1. Equipment Point of Connection Location Recommendations

Facility Service / Utility	**Bottom Location Plane Preference**	**Back Location Plane Alternate**	
Gas, Bulk	Bottom	Back (lower)	
Gas, Specialty	Bottom	Back (lower)	Back
Exhaust, Corrosive	Bottom	Back (lower)	Back
Exhaust, Flammable	Bottom	Back (lower)	Back
Exhaust, Solvent	Bottom	Back (lower)	Back
Exhaust, General	Bottom	Back (lower)	Back
Chemical Supply, Inorganic	Bottom	Back (lower)	
Chemical Supply, Organic	Bottom	Back (lower)	
Ultrapure Water	Bottom	Back (lower)	
Cooling Water	Bottom	Back (lower)	
Hot Ultrapure Water	Bottom	Back (lower)	
Drain, Inorganic	Bottom	Bottom	Back (lower)
Drain, Waste Chemical, Organic	Bottom	Bottom	Back (lower)
Power, 100V	Bottom	Back (above wet EPOC)	
Power, 200/400V	Bottom	Back (above wet EPOC)	
Fire Suppression	Bottom	Back	
Ancillary Component Interconnect	Bottom	Back (above wet EPOC)	
Signal Cable	Bottom	Back (above wet EPOC)	
Vacuum Foreline	Bottom	Bottom	Back
Process Vacuum	Bottom	Back	

NOTE: Connections located on the top are not recommended because of possible interference with overhead wafer handling and minienvironment equipment.

Table 2. EPOC Consistency Recommendations

Equipment Delivered Compared to	EPOC Locations	EPOC Types	EPOC Sizes
Supplier-provided Facilities Interface Specification	Should match	Should match	Should match
Similar Equipment (Same Model and Revision) for Same Process Application	Should match	Should match	Should match
Similar Equipment (Same Model and Revision) for Different Process Application	Should match for same utilities. Could match unique utilities to unique locations within the appropriate EPOC group.	Should match	Could match, technical reasons should exist for differences.
Similar Equipment (Different Model) for Same Application	Could match	Could match	Could Match

6 EPOC Recommendations

6.1 *Equipment Point of Connection Locations*

6.1.1 Table 1, EPOC Location Recommendations identifies the locations for the specified facility utility services. The locations noted apply to all equipment types, as listed in the document scope, and all equipment configurations including but not limited to boxed equipment, linked equipment, and cluster equipment.

6.1.2 Bottom Location Plane: Facility services are typically provided from the subfab below the waffle slab. The bottom location of EPOC's allows for straight up routing of supply lines, thus reducing equipment footprint and easing facilitation. The locations of EPOC's need to be readily accessible to facilitate hook-up to the UPOC (i.e., accessible from the back or sides). (See Table 1.)

6.1.3 Back Location Plane: If the bottom location plane option is not utilized for hookup, EPOC's should be on back plane of equipment just above the raised floor. (See Table 1.)

6.2 *Equipment Point of Connection Groups*

6.2.1 Equipment points of connection should be grouped together by service type to ensure ease of hookup and qualification of the equipment. The following groups should be considered during the configuration of the equipment.

a) Electrical Power Connections — Includes but is not limited to connections for main electrical utility power supply.

b) Data Communications Connections — Includes but is not limited to factory systems, automated material handling system, and support equipment communication cables and interface connectors.

c) Gas Delivery System Connections — Includes but is not limited to fittings for bulk and specialty gas lines.

d) Liquid Delivery System Connections — Includes but is not limited to fittings for liquid chemical, slurry, ultra pure water, process cooling water, temperature control unit fluids, and industrial water lines.

e) Equipment Effluent Connections — Includes but is not limited to fittings for exhaust, drain, and vacuum lines.

f) Life and Safety System Connections — Includes but is not limited to fire protection, leak detection, emergency machine off (EMO), and hazard warning systems.

6.2.2 A hierarchy should be adhered to when locating these groups of connections on equipment. Data communication wiring should be routed separately from power wiring and connections. Radio frequency (RF) interconnects should be routed and grouped separately. All electrical and electronic wiring should be away from and above water and drain lines.

6.3 *Equipment Point of Connection Consistency*

6.3.1 This section provides key elements to ensure the required consistency of the equipment points of connection. Connection locations on the equipment should be consistent with those defined in the Facilities Interface Specification and should not deviate from equipment to equipment of a specific model and revision. EPOC tolerances need to be +/- 6.35 mm (+/- 1/4 inch) in all directions as measured from the supplier defined equipment datum point. Tighter tolerances should be considered for inflexible or difficult to move hookups such as large diameter (over 2 inch) exhaust or water lines. Connector sizes and types should match exactly.

6.3.2 Table 2 - EPOC Consistency Recommendations identify equipment variations and levels of consistency required for equipment points of connection location, connector type and size.

6.3.3 In Table 2, the term “Should Match” identifies areas that have traditionally been the most costly and where significant gains can be made in achieving installation efficiency . The term “Could Match” identifies areas where modest gains can be made in installation efficiency .

6.4 *Equipment Point of Connection Reduction*

6.4.1 The number of connection points to the equipment should be kept to a minimum. The EPOC’s located on wafer processing equipment should follow a strategy commonly referred to as single line drops, where there is only one point of connection per service per piece of equipment. Where feasible, distribution of a particular facility (e.g., chilled water, waste drains for the same type of chemicals) should be distributed through internal manifolding. Internal equipment manifolding should be configured to allow for configurable equipment sub-systems like process chambers and gas panels. In addition to manifolding, all other interface box functions should be configured on-board the equipment this includes any required shut-off valves, regulators, filters, QC sample valves and pressure indicators.

6.5 *Equipment Point of Connection Interface Panel*

6.5.1 Once EPOC locations and groupings have been defined and standardized for purposes of consistency, the supplier could utilize an interface panel concept for simplifying equipment hook-up. The interface panel should consist of a physical panel that becomes part of the permanent equipment installation. All EPOC’s should be comprehended in the layout of the interface panel using the recommendations for location, grouping, and consistency as discussed in Sections 6.1, 6.2, and 6.3. The supplier should design a standard interface panel layout that supports a given equipment type and all associated revisions.

6.5.2 Common connector technologies, types, and sizes should be utilized along with provisions for containment of hazardous materials. Typically, hazardous production material connections are contained within the equipment

6.5.3 Spacing of multiple gas and liquid connections on the interface panel should provide sufficient access and spacing for installation and maintenance for multiple lines (i.e., orbital weld head, wrench, and test fittings).

7 Pre-facilitation Recommendations

7.1 The pre-facilitation strategy should provide the device manufacturer with the ability to efficiently and accurately install UPOC’s prior to equipment delivery, allowing immediate hook-up of the equipment upon arrival to the fab. The equipment supplier should provide a template and/or jig, as well as a EPOC interface panel (if applicable) or pre-facilitation pedestal prior to the equipment delivery as part of a strategy to support accurate pre-facilitation of utility points of connection. In situations where a pedestal is being utilized (see Section 7.4), the pedestal can serve as an aide to pre-facilitation. The supplier and device manufacturer should discuss and agree on the chosen strategy.

7.2 Templates: The template provides a two-dimensional guide that projects EPOC locations to a two-dimensional surface, typically the floor. This would allow the device manufacturer to open popouts, core holes, etc., and pre-facilitate to a point close to, but not necessarily including, the UPOC. See Figure 1 for a representative example of a Template.

7.3 Jigs: The jig provides a guide that locates the -EPOC’s in three-dimensional space. This would allow the device manufacturer to pre-facilitate to the UPOC’s or at least prefabricate the facility lines and UPOC’s such that final hookup could be accomplished immediately after setting the equipment. See Figure 2 for a representative example of a Jig.

7.4 Pre-facilitation Pedestal: Application notes and three representative examples of using pedestals to support pre-facilitation are included in the related information section at the end of this document.

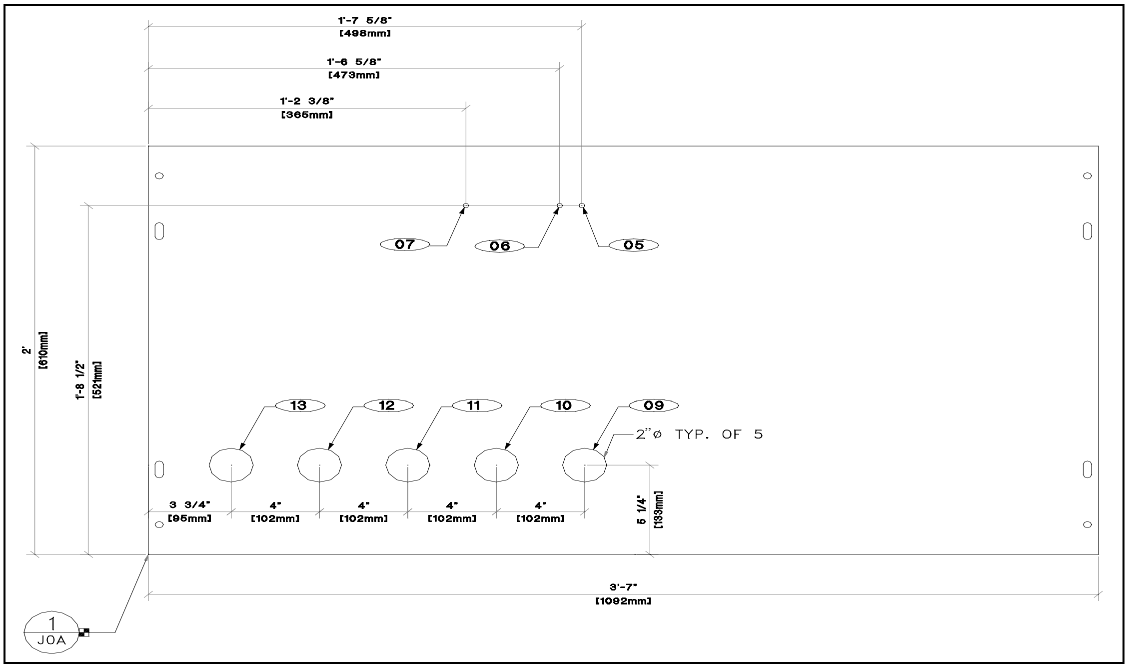


Figure 1
Template Example

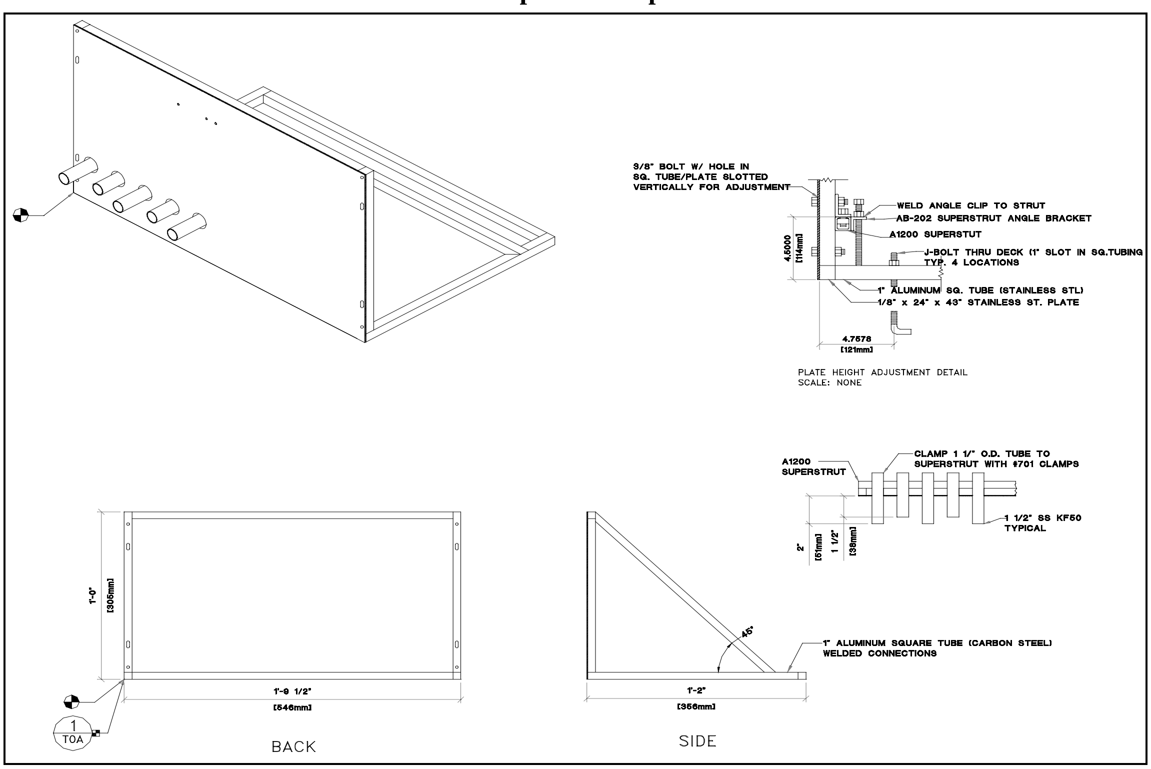


Figure 2
Jig Example

8 Documentation Recommendations

8.1 Equipment suppliers should provide the following documentation concerning equipment point of connections and/or template, jig, and pre-facilitation pedestal to the device manufacturers. The device manufacturer should provide to the supplier, the dates the documentation is required if it is not already specified in this guide.

a) All documentation should be supplied prior to the equipment delivery to the device manufacturer (as deemed appropriate by both the device manufacturer and supplier) and includes a minimum of two sets per piece of equipment .

b) Text and step-by-step procedures should be written in a concise, coherent manner enabling the device manufacturers to achieve and sustain all system performance goals.

c) All drawing documentation provided electronically should be in a format which is compatible with standard computer aided design (CAD) software used by device manufacturers. The CAD format should be compatible with common CAD systems, to include but not limited to, .DWG, .DXF, .DXB, .PS, and .WMF file extensions.

d) The documentation should match the revision of the equipment delivered.

8.2 The equipment supplier should notify the device manufacturer within 30 days of any equipment configuration changes which have an impact on the facility or installation requirements. These changes include, but are not limited to, equipment dimensions, equipment elevation, and equipment points of connection. There should be no changes made within 3 weeks of equipment shipment.

8.3 *EPOC Documentation*

8.3.1 Equipment requirements for utilities and installation should be provided by the equipment supplier. Included EPOC documentation should contain but not be limited to the following information.

a) Floor space requirements (footprint).

b) EPOC matrix indicating service, size/type of connection, location plane, and x,y,z dimensions relative to equipment datum point.

c) Two dimensional drawings showing the equipment points of connection that specify the protrusion depths.

8.3.2 For interface panels, the equipment supplier should provide documentation that includes clear instruction for assembly and positioning the interface panel, a key that clearly identifies which EPOC's are included, and appropriate design drawings such that the device manufacturer can include the interface panel in their respective construction designs.

8.3.3 The following documentation is also required to support the equipment installation activity but is not directly related to the EPOC.

a) Equipment elevation drawings representing all sides of the equipment.

b) Air conditioning and ventilation requirements (acceptable temperature and humidity ranges, exhaust plumbing, etc.).

c) Vibration requirements (acceptable amplitude and frequency).

d) Electrical requirements (voltage, current, wattage, number of phases, power quality, supply voltage wave form requirements, etc.).

e) Vacuum amounts, gases (grade and flow), chilled water flow and other environmental requirements including plumbing requirements (type, size, etc.) for each.

f) A section detailing the procedures to be followed during equipment unpacking and inspection.

g) A section detailing step-by-step set-up procedures that will specifically outline machine assembly and installation on the factory floor.

8.4 *Template, Jig, or Pre-facilitation Pedestal Documentation.*

8.4.1 For templates, jigs, and pre-facilitation pedestals, the equipment supplier should provide documentation that includes clear instruction for assembly, clear instruction for aligning the template, jig, or pre-facilitation pedestal relative to the equipment datum point, and a key that clearly identifies which EPOC's are included. The documentation should also clearly indicate which pieces of equipment (model and revision number) that are supported by a specific template, jig, or pre-facilitation pedestal.

8.4.2 For pre-facilitation pedestals, the equipment supplier should also provide appropriate design drawings and information such that the device manufacturer can include the pedestal design in their respective construction designs. In addition, the supplier should provide applicable documentation required for structural certification.

9 Related Documents

NOTE: All documents cited will be the latest published versions.

9.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.1 — Guide for Tool Final Assembly, Packaging and Delivery

SEMI E49.2 — Guide for High Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.3 — Guide for Ultrahigh Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures — Stainless Steel Systems

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures — Polymer Systems

SEMI E49.8 — Guide for High Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

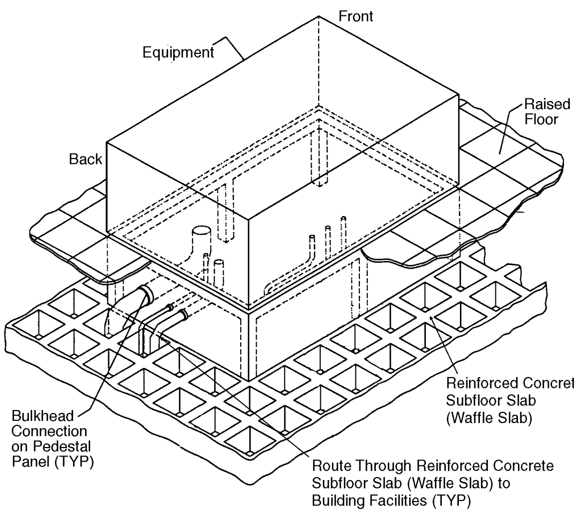
SEMI E49.9 — Guide for Ultrahigh Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment.

RELATED INFORMATION 1
Pre-facilitation Pedestal Application Notes

NOTE: This related information was balloted, but is not an official part of SEMI E76 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Determination of the suitability of the material is solely the responsibility of the user.



NOTE: This is only a representative example, a pre-facilitation pedestal can be of an open frame or enclosed box design. Due to bay design and pass thru hole locations a pedestal leg may sometimes become located over an opening thus, a design that allows flexible leg or foot locations should be incorporated.

Figure R1-1

Pre-facilitation Pedestal Example

R1-1. Pre-facilitation Pedestal

R1-1.1 A pedestal provides a permanent base or frame to support the equipment and could be considered an extension of the equipment mainframe In addition, the pedestal could emulate a docking station concept whereby all utilities points of connection could be located and installed prior to equipment delivery. Once the equipment is set on this pre-facilitation pedestal, hookup is relatively quick and easy. When a pre-facilitation pedestal is used, both the device manufacturer and supplier should agree who is responsible for coordinating space utilization within the pedestal.

R1-1.2 When pre-facilitation pedestals are used, the physical location of the EPOC's and corresponding UPOC's can be determined by utilizing templates, jigs, and/or EPOC interface panels in conjunction with the pedestal. The facility utility lines can be prefabricated and installed to the UPOC's prior to setting the equipment on the pre-facilitation pedestal. See Figure R1-1 for a representative example of a Pre-facilitation Pedestal.

R1-1.3 The pre-facilitation pedestal should be provided by the equipment supplier and standardized for a equipment type. In addition, the equipment supplier is responsible for providing the engineering and design of the pre-facilitation pedestal (with input from the device manufacturer as required). Installation of hardware within the pedestal should be done during manufacturing or during pre-facilitation. The following pedestal features (as required by the equipment supplier and end user) are the responsibility of the pre-facilitation pedestal supplier.

a) Vibration isolation, leveling, seismic reinforcing, and load distribution point loading.

b) Connection points from the pedestal to the facility which can be from any plane but should take into consideration potential interference with adjacent tools.

c) Routing of the plumbing and harnesses within the pedestal.

d) Containment of gases and liquids within the pedestal, including possible HPM.

e) Support equipment interconnects within the pedestal

R1-1.4 To use the pre-facilitation pedestal, the distance from the highest point on the waffle slab to the bottom of equipment (typically the top of the raised floor) should be equal to or greater than 0.6 meters (2 feet).

R1-1.5 The pre-facilitation pedestal is recommended for use when these conditions apply.

a) connections located on the bottom of the equipment,

b) maintenance access to the bottom of the equipment as required,

c) repair and spilled liquids access is required underneath the equipment,

d) pedestal is required as an appropriate structural base to set the equipment on,

e) large footprint and/or multiple module for equipment,

f) large number of connections required for the equipment (more than 10), and

g) peripheral components for the equipment (pumps, RF generators, chiggers, etc.) are typically located beneath the equipment in a subfab area.

R1-1.6 The pre-facilitation pedestal is not recommended for use when these conditions apply.

a) small table mounted equipment,

b) no more than one connection on the bottom of the equipment,

c) other connections located on back, top, or side,

d) no maintenance, repair, or spill clean up access requirements beneath equipment,

e) few connections required (less than 10), and

f) few if any peripheral components required or located below equipment in subfab area.

R1-1.7 These conditions are only recommendations and dialog between the supplier and device manufacturer is recommended to determine if a pre-facilitation pedestal is necessary or beneficial for a specific application.

R1-1.8 The Figure R1-2 shows the facility utility lines running up through the waffle slab directly underneath the equipment. The UPOC - EPOC connections occurs at the EPOC interface panel which is located on the top plane of the pre-facilitation pedestal. This concept is preferred by device manufacturers as the number of connections are minimized, no additional space is required on the sides or in back of the equipment for routing, and the HPM lines can be pre-facilitation to the UPOC without additional connections or special double containment requirements.

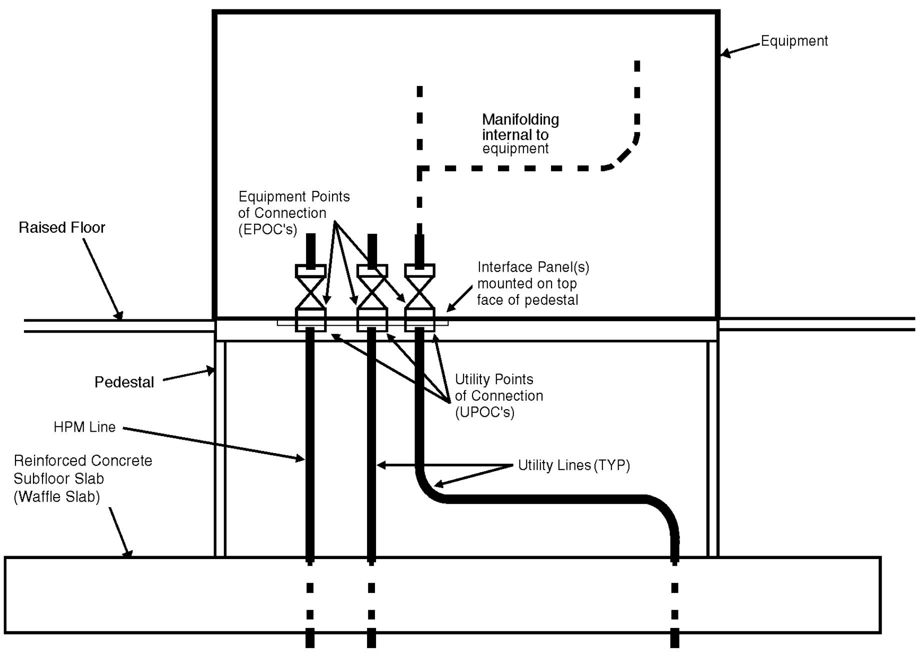


Figure R1-2
Pre-facilitation Pedestal with Top Mounted Interface Panel

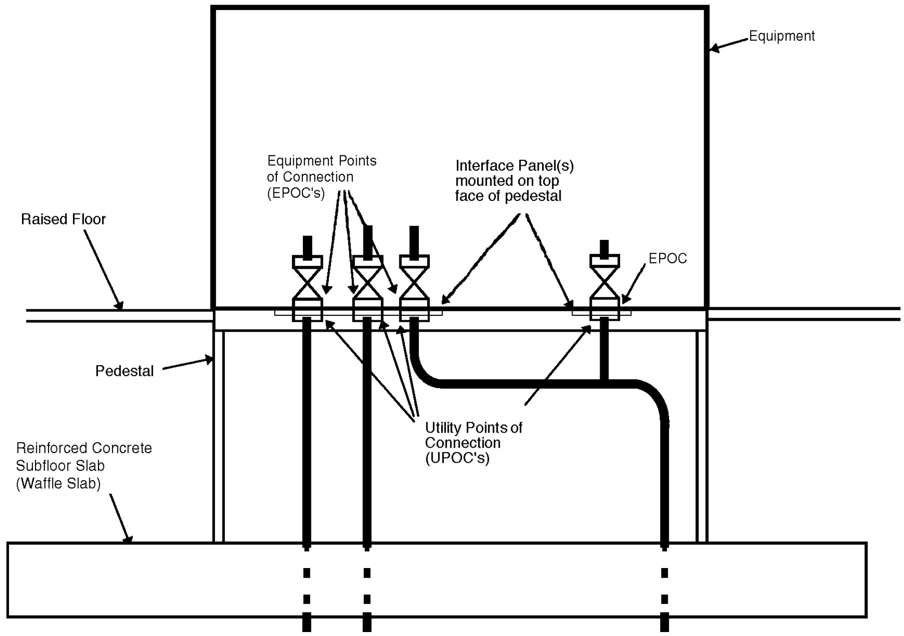


Figure R1-3
Pre-facilitation Pedestal with Multiple Top Mounted Interface Panels

R1-1.9 The Figure R1-3 also shows the facility line running through the waffle slab directly underneath the equipment. In addition, this example depicts situations where there is a physical requirement to manifold connections underneath the equipment. The same advantages as Example #1 apply with the exception of minimizing the number of connections to the equipment.

R1-1.10 The Figure R1-4 shows the facility utility lines running up through the waffle slab to the side/back of the pre-facilitation pedestal and connecting to the EPOC interface panel mounted on the side/back of the pre-facilitation pedestal. In this example a short section of line is required to complete the connection from the EPOC interface panel to the connection within the equipment itself. This short section of line should be prefabricated such that final hookup to the equipment can be accomplished quickly once the equipment is set. It is important to note that this option requires careful consideration on how to accommodate HPM lines. It is generally undesirable to have additional connections in HPM lines or to design the pre-facilitation pedestal itself to provide secondary containment. In this example, the equipment supplier is responsible for the volume in the pre-facilitation pedestal to route and manifold the plumbing as required

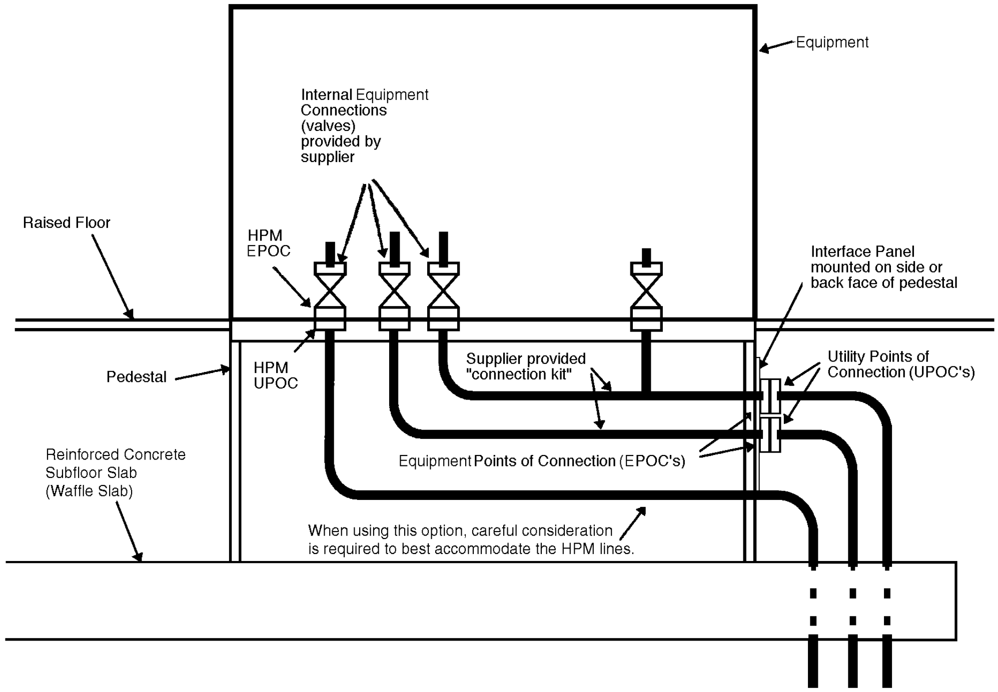


Figure R1-4
Pre-facilitation Pedestal with Side/Back Mounted Interface Panels

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SEMI E77-0998
TEST METHOD FOR CALCULATION OF CONVERSION FACTORS FOR A MASS FLOW CONTROLLER USING SURROGATE GASES

1 Purpose

1.1 The purpose of this test method is to quantify a nominal average conversion factor from one gas to another for an MFC and to quantify the conversion factor as function of flow for an MFC.

2 Scope

2.1 This procedure describes a method to determine the MFC conversion factor and function between two gases.

2.2 This document provides a common basis for communication between manufacturers and users.

2.3 The intent of this document is not to suggest any specific testing program, but to specify the test method to be used when testing for parameters covered by this method. Reference operating conditions represent the environmental conditions where the "best" performance can be expected.

3 Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory (reference) conditions; its intent is to collect sufficient data to form a judgment of the field performance of the MFC being tested.

3.1.1 The results from this test represent the performance of the specific device tested (i.e., make, model, full scale flow and operating conditions). The results may not apply to devices of different manufacture, model, full scale flow or under different operating conditions.

4 Referenced Documents

None.

5 Terminology

5.1 *Acronyms*

5.1.1 *CF (gasA/gasB)* — Conversion factor from Gas A to Gas B.

5.1.2 *D.U.T.*— Device under test

5.1.3 *kPa* — kiloPascal

5.1.4 *MFC* — Mass flow controller

5.1.5 *psia* — Pounds per square inch absolute

5.1.6 *sccm* — Standard cubic centimeters per minute

5.1.7 *slm* — Standard liters per minute

5.1.8 *%F.S.* — Percent full scale

5.2 *Definitions*

5.2.1 *actual flow* — The flow rate as determined by the flow standard used in the test procedure.

5.2.2 *conversion factor* — The ratio of the mass flow-rate of Gas A flowing through an MFC for a given setpoint to the mass flow rate of Gas B flowing through the same MFC and setpoint.

5.2.3 *conversion function* — A relationship that describes the flow dependency of the conversion factor. The conversion function is graphically determined.

5.2.4 *indicated flow* — The flow rate as determined by the output of the D.U.T.

5.2.5 *mean* — The sum of a group of measurements divided by the number of measurements; average.

5.2.6 *measured value* — The actual flow through a D.U.T., expressed in sccm or slm.

5.2.7 *measured value, average* — The sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.8 *nameplate gas* — The gas intended to be controlled by the MFC in operation.

5.2.9 *range* — The algebraic difference between the maximum and minimum values.

5.2.10 *setpoint* — The input signal provided to achieve a desired flow, reported as sccm, slm, or percent full scale.

5.2.11 *span* — The full scale range of the D.U.T.

5.2.12 *surrogate gas* — The gas substituted for the nameplate gas during the calibration process.

5.2.13 *zero drift* — The undesired change in electrical output (i.e., indicated flow), at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.14 *zero offset* — The deviation from zero at a "no-flow" condition reported in sccm, slm, or mV.

6 Summary of Test Method

6.1 Gas flow and setpoint data are collected for two gases. This data is reduced to quantify the relationship between the flow measurement by the MFC on one gas to another gas.

6.2 This method allows the user to determine the conversion factor between two gases for the MFC and to determine the onset of errors in the MFC calibration due to the conversion factor/function effects.

7 Interferences

7.1 The accuracy rating of the measuring equipment shall be superior to that of the D.U.T. Preferably the measuring equipment will have an accuracy that is four times better than the D.U.T. Calibration equipment must have a valid calibration certificate.

7.2 Take care when using test instruments with a specified accuracy expressed in percent of full scale.

7.3 Installation effects on the flow should be minimized. Monitor pressure upstream of the D.U.T. to ensure that flow variations due to pressure are minimized.

7.4 Verify electrical signals directly at the D.U.T. connector to ensure that the signals at the D.U.T. and standard agree with the signals at the data recording equipment.

7.5 Certain gases will contaminate the D.U.T. This test should be considered a destructive test in such cases.

7.6 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

7.7 The device mounting position must be in accordance with the manufacturer's specifications.

8 Apparatus (see Figure 1)

8.1 *Flow Standard* — A device or system that accurately measures the flow and reports the actual flow.

8.2 *Data Acquisition System* — The system that measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

8.3 *Temperature Probe* — A device to measure the temperature of the flowing gas.

8.4 *Three-Way Valve* — A special valve to switch the system from one gas source to another.

8.5 *Manual Isolation Valves* — Valves that will positively shut off the gas line.

8.6 *Pressure Regulator* — A device that regulates gas pressure to a set value.

8.7 *Pressure Transducer* — An instrument to measure the gas pressure and report it as an electrical signal.

9 Materials

9.1 *Clean, Dry* N_2 — With 99.999% minimum purity, to be used for purging.

9.2 Test Gas "A"

9.3 Test Gas "B"

10 Safety Precautions

10.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

10.2 Follow the manufacturer's specifications and instructions for installation and operation whenever possible. Note any exceptions in the test report.

11 Test Specimen

11.1 Allow all components in the test apparatus to warm up following the manufacturer's specification.

11.2 Take necessary steps when switching gases to ensure that only the desired gas is in the D.U.T. and flow standard at the time the test is performed.

12 Preparation of Apparatus

12.1 Locate the D.U.T. in the test environment to stabilize temperature for 24 hours prior to warm up.

12.2 The reference operating conditions shall be as follows:

12.2.1 *Ambient Temperature* — 23 ± 2°C

12.2.2 *Gas Temperature* — Same as ambient. In the case of a condensible gas, the gas temperature should be maintained as a gradient, with highest temperature at the outlet end of the test set up, and slightly reduced temperatures back to the source. This will ensure that condensing vapors do not accumulate in the test set up. Gradient should simulate actual process parameters where the MFC will be installed.

12.2.3 *Ambient Pressure* — 101.3 kPa (+ 4.7 or – 15.3 kPa)

12.2.4 *Gas Pressure, Inlet* — 172 ± 34 kPa unless the gas is not capable of delivering this pressure, then normal fab operating conditions should be observed.

12.2.5 *Gas Pressure, Outlet* — < 80 kPa

12.2.6 *Relative Humidity* — 40% ± 5%, non-condensing (suggestion: record if outside this range)

12.2.7 *Magnetic Field* — ≤ 50 µT

12.2.8 *Electromagnetic Field* — ≤ 100 µV/m

12.2.9 *Vibration* — ≤ 0.5 m/s at 50 to 200 Hz

12.3 Following the conditioning period (12.1), warm up the device according to manufacturer's specifications.

12.4 Perform an adequate nitrogen purge to ensure all previous gases and moisture have been removed from the system. Prior to corrosive gas testing, a cyclic pump and purge operation is recommended, alternately backfilling with nitrogen, and evacuating the test manifold.

12.5 Leak check the manifold, using available methodologies to verify the test system leak integrity. Introduce the test gas at a sufficient rate and time to ensure the test apparatus is completely filled with the test gas and only the test gas.

12.6 Record the zero offset with line pressure inside the MFC to best simulate normal operating conditions. Line pressure during testing is to be 170.30 kPa (24.7 psia) unless safety practices for the gas under test dictate that a lower line pressure be used.

NOTE: In addition, if this test is performed on hazardous gases, bleeding off gas pressure to obtain atmospheric pressure inside the MFC may not be easy to do.

12.7 Command 100%, and establish flow, then close the downstream isolation valve; then close the upstream isolation valve (see Figure 1).

12.8 With both isolation valves closed, and a 100% setpoint wait until the pressure drop across the MFC is dissipated, ensuring a "no flow" condition through the MFC. Dissipation of the pressure across the MFC is indicated when the indicated flow drops to a steady state value near zero.

12.9 After the electrical output signal has stabilized for at least three minutes, record the MFC zero offset in Table 1.

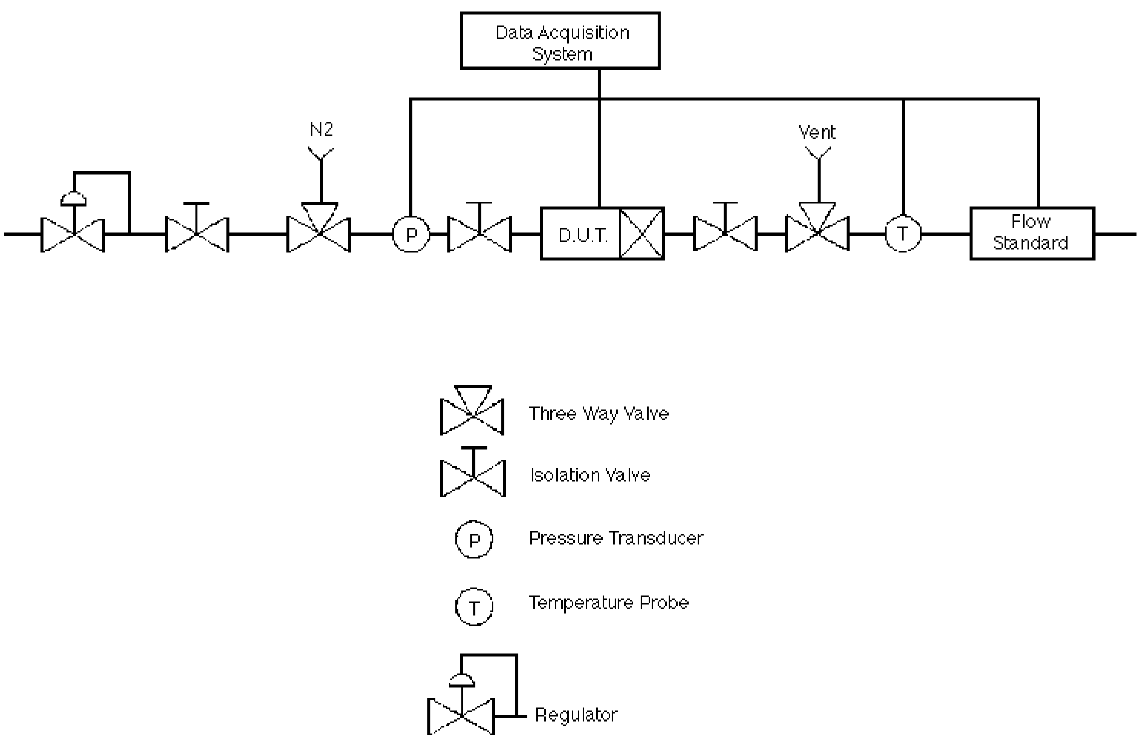

Figure 1
Mass Flow Controller Test Fixture

Table 1 Indicated and Actual Flow vs. Setpoint

MFC Mfg/Model/Serial # ______________________________
Name Plate Gas/Range ______________________________
Test Gas ______________________________
Temp ___________ Bar ___________ Date ___________
Factory Calibration Gas ______________________________

Column A D.U.T. Setpoint Indication in % F.S.	*Column B D.U.T. Flow Indication in % F.S.*	*Column C Flow Standard Raw Data*
0%*		0
50		
60		
70		
80		
90		
100		
90		
80		
70		
60		
50		
40		
30		
10		
0%	________________	0
10		
20		
30		
40		0
50		
60		
70		
80		
90		
100		
90		
80		
70		
60		
50		
40		
30		
10		
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30		
40		

50		
60		
70		
80		
90		
100		
90		
80		
70		
60		
50		
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30		
10		
0%	____	0
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
90		
80		
70		
60		
50		
40		
30		
10		
0%	____	0
10		
20		
30		
40		0
50		
60		
70		
80		
90		
100		
90		
80		
70		
60		
50		

40		
30		
10		
0%	________________	0
10		
20		
30		
40		
0%	________________	

NOTE: 0%*; the MFC is not controlling gas flow in this state but rather is in a no-flow condition during which MFC zero offset is to be recorded.

12.10 Set the D.U.T. output to zero per the manufacturer's procedure. This may entail automatic re-zeroing of the device, or may require an adjustment by the operator.

12.11 Record the adjusted zero reading in Table 1.

12.12 The reference supply conditions used shall be the reference values specified by the manufacturer. For those instances when a range of values is specified rather than a reference value, the midpoint of the range shall be taken to be the reference value.

12.13 The power supply must be sufficiently rated for the device under test. In addition, the following supply conditions and tolerances shall apply reference voltage:

12.13.1 *AC Supply* — ± 1%

12.13.2 *DC Supply* — ± 0.1%

12.13.3 *Reference Frequency* — ± 0.1 Hz

12.13.4 *Harmonic Distortion of AC Supply* — ≤ 1%

12.13.5 *Ripple of DC Supply* — ≤ 0.1% rms

13 Procedure

13.1 For the gas of interest, collect flow data for five cycles of 11 different setpoints. The setpoints are 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, and 0% of full scale. Begin collecting data at the 50% level then 60%, 70% and so on. Record the data on the form in Table 1.

13.1.1 When a non-zero setpoint is given, allow the MFC to stabilize at the desired setpoint by observing the reading on the flow standard. Record the data once the MFC has stabilized at the current setpoint.

NOTE: If, during data acquisition at a nominal setpoint, the instrument fails to stabilize, the D.U.T. is not stable enough for the test to proceed.

13.1.2 When a zero setpoint is given, perform the procedure described in Section 12.7–12.9 (do not rezero the MFC) to ensure a "no-flow" condition through the MFC and record the zero offset indicated by the MFC's output in Table 1.

13.2 Use Table 1 to record the following:

13.2.1 *Column A* — D.U.T. setpoint (% F.S.)

13.2.2 *Column B* — D.U.T. flow indication (% F.S.)

13.2.3 *Column C* — Raw flow standard reading (sccm)

14 Calculations or Interpretation of Results

14.1 For each test gas, calculate the mean and standard deviation of the corrected flow readings, for common setpoints on the same gas. For example, calculate the mean and standard deviation for all the 0% readings for a given gas, then repeat the calculations for the 10% readings, etc. Record the results on Table 2 in Columns B and C. Plot the result as illustrated in Figure 2.

Table 2 Statistical Performance

MFC Mfg/Model/Serial # ___________________________________
Name Plate Gas/Range ___________________________________
Test Gas ___________________________________
Temp ___________ Bar ___________ Date ___________
Factory Calibration Gas ___________________________________

Column A *D.U.T. Setpoint* *(% F.S.)*	*Column B* *Mean Corrected Standard Flow Reading (SCCM)*	*Column C* *Standard Deviation Flow (SCCM)*
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

Nameplate Gas/Range ___________ Test Gas ________________ Date _____________
MFG/Serial # _________________ Barometric Pressure _______________
Inlet Pressure _________________ Temperature _____________________

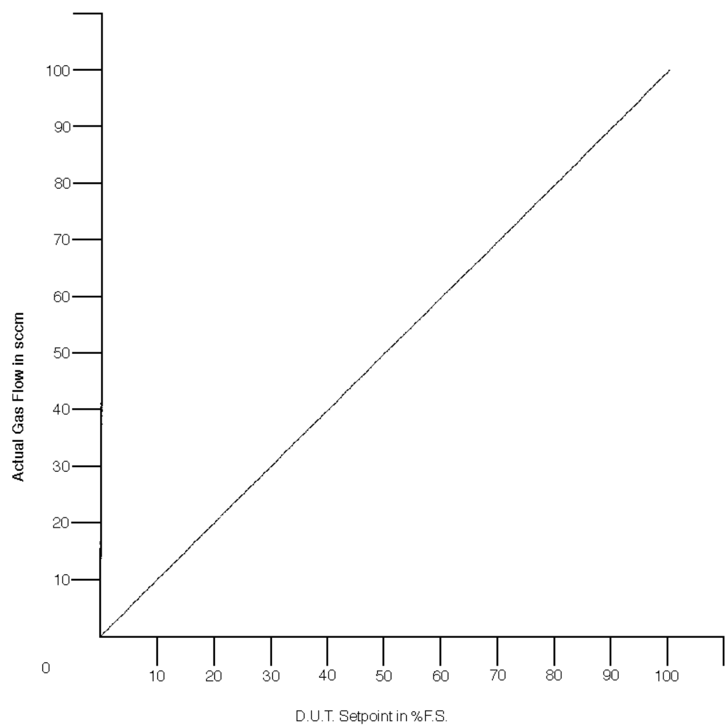

Figure 2
D.U.T. Setpoint vs. Gas Flow

14.2 *Conversion Factors* — The conversion factor between any Gas A and any Gas B at each setpoint is calculated as follows:

$$\textit{conversion factor (Gas A / Gas B) @ X\% setpoint} = \frac{\textit{average actual flow @ X\% setpoint on Gas A}}{\textit{average actual flow @ X\% setpoint on Gas B}}$$

where X = setpoint value

14.3 Calculate the conversion factors for the gas tested and record in Table 3.

Table 3 MFC Conversion Factors for Each Setpoint

MFC Mfg/Model/Serial # ___________________________________

Name Plate Gas/Range ___________________________________

Test Gas ___________________________________

Temp ___________ Bar ___________ Date ___________

Factory Calibration Gas ___________________________________

Column A *D.U.T. Setpoint* *(% F.S.)*	*Column B* *CF (Gas A/Gas B)*
100%	
90	
80	
70	
60	
50	
40	
30	
20	
10	

14.4 *Interpretation*

14.4.1 Figure 3 illustrates the conversion factor between two specific gases as a function of setpoint. It may be used to accurately map from one gas to the other and may predict the flow error that will result if the average conversion factor is used.

Nameplate Gas/Range ___________ Test Gas ________________ Date _____________
MFG/Serial # _________________ Barometric Pressure _______________
Inlet Pressure _________________ Temperature _____________________

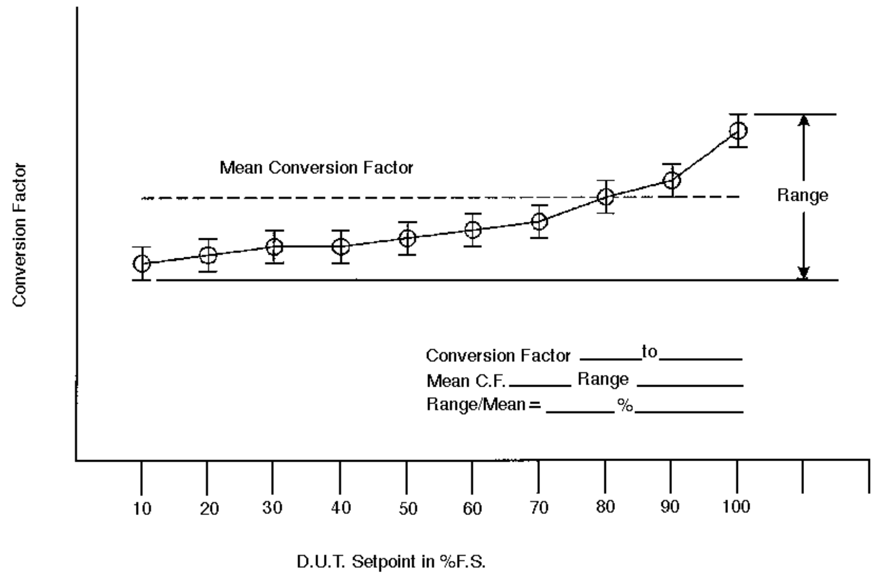

Figure 3
Conversion Factors vs. D.U.T. Setpoint

15 Reporting Results

15.1 *MFC Conversion Factors*

15.1.1 Plot the conversion factor from Gas A to Gas B against the D.U.T. setpoint. Note the mean value and range of values (see Figure 3).

16 Related Documents

16.1 *ANSI Documents*[1]

ANSI C39.5 — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

ANSI C42.100 — Dictionary of Electrical and Electronics Terms

ANSI MC4.1 — Dynamic Response Testing of Process Control Instrumentation

16.2 *IEC Document*[2]

IEC 546 — Methods of Evaluating the Performance of Controllers with Analogue Signals for Use in Industrial Process Control

16.3 *ISA Document*[3]

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1 American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018

2 International Electrochemical Commission, 3 rue de Varembe, CH-1211 Geneva 20, Switzerland

3 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709

ISA S51.1 — Process Instrumentation Terminology

16.4 *MIL-STD Document*

MIL-STD 45662 — Calibration Systems Requirements

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SEMI E78-0998
ELECTROSTATIC COMPATIBILITY - GUIDE TO ASSESS AND CONTROL ELECTROSTATIC DISCHARGE (ESD) AND ELECTROSTATIC ATTRACTION (ESA) FOR EQUIPMENT

1 Purpose

1.1 The purpose of this document is to minimize the negative impact on productivity caused by static charge in semiconductor manufacturing environments. It is a guide for establishing electrostatic compatibility of equipment used in semiconductor manufacturing.

1.2 Electrostatic surface charge causes a number of undesirable effects in semiconductor manufacturing environments. Electrostatic discharge (ESD) damages both products and reticles. ESD events also cause electromagnetic interference (EMI), resulting in equipment malfunctions. Charged wafer and reticle surfaces attract particles (electrostatic attraction or ESA) and increase the defect rate. Charge on products can also result in equipment malfunction or product breakage. Operating problems and additional product defects due to static charge can have a negative impact on the cost of ownership of semiconductor manufacturing equipment (refer to SEMI E35).

1.3 An increasing amount of semiconductor production is done in minienvironments or within the production equipment. The majority of static related problems occur while the product is in its carriers, or being transferred from them, by the production equipment.

1.4 Static control methods can be incorporated in the equipment design to reduce static charge to acceptable levels. This guide will be used primarily by equipment manufacturers during the design of their equipment. There are test methods available (see Sections 6 and 7 of this guide) to demonstrate the effectiveness of the static control methods. The end user will be able to use the same test methods to verify compliance with an equipment purchase specification.

2 Scope

2.1 The scope of this document is limited to methods of measurement and a guide for the maximum recommended level of static charge on:

— Product or reticles

— Carriers

— Parts of the input/exit ports of equipment and minienvironments

2.2 This document presents a matrix of maximum recommended levels of static charge on products, reticles, carriers, and the input and exit ports of production equipment or minienvironments. The purpose is to:

— Reduce product, reticle, and equipment damage due to ESD

— Reduce equipment lock-up problems due to ESD events.

— Reduce the attraction of particles to charged surfaces.

2.3 This document references SEMI E43 and other methods of measuring static charge. Related Information 1 of this document contains a theoretical investigation of electrostatic particle attraction, as well as case histories from users and equipment manufacturers as to the static charge problems encountered and how they were solved. A bibliography of related technical papers is also included. Related Information 2 describes static control methods commonly used in semiconductor manufacturing.

3 Limitations

3.1 *Static Measurements* — Measurements of electrostatic quantities such as charge, electric field, and voltage are difficult to make. The nature of the object (insulator or conductor), its geometry, its surroundings, and the measuring equipment itself, are only a few of the factors affecting the accuracy of an electrostatic measurement.

3.1.1 Similarly, it is difficult to relate the measurement of an electrostatic quantity to its effect on products or equipment. For example, an ESD simulator produces a standardized discharge waveform when a capacitor is discharged at a known voltage. This device is used to establish the ESD damage threshold for semiconductor products, or the effect of ESD on equipment. While the amount of charge transferred is known ($q = CV$), the maximum current that results is not. There is no guarantee that the same amount of charge would produce the same results if different values of capacitance and voltage were used.

3.2 *Location* — The test methods and maximum recommended levels of static charge on product, reticles, and carriers are meant to be applied at the input/exit ports of production equipment, and when possible within the equipment. This document is not meant to be applied in any way that affects the process within the equipment.

3.3 *Test Methods* — The test methods referenced in this document do not guarantee precise measurements of static charge levels. The maximum static charge levels recommended in this document have large tolerances. (See Section 15.1.)

3.4 *Static Charge Control* — There are a variety of static related issues in a semiconductor manufacturing environment. The issues are complex due to the wide range of electrostatic problems, and device or equipment sensitivities to these problems. This guide contains general recommendations. Users of this document are cautioned that specific static related problems may require or allow different levels of static charge than are recommended in this document.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E35 — Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI E43 — Recommended Practice for Measuring Static Charge on Objects and Surfaces

4.2 *ESD Association Standards and Advisories*[1]

ANSI EOS/ESD S5.1 — Standard for Electrostatic Discharge (ESD) Testing - Human Body Model (HBM) - Component Level

EOS/ESD ADV 1.0 — Advisory for Electrostatic Discharge Terminology - Glossary

EOS/ESD ADV 2.0 — Advisory for Protection and Sensitivity Testing of Electrostatic Discharge Susceptible Items - Handbook

EOS/ESD DS5.3 — Draft Standard for Electrostatic Discharge (ESD) Testing - Charged Device Model (CDM) - Component Level

EOS/ESD S5.2 — Standard for Electrostatic Discharge (ESD) Testing - Machine Model (MM) - Component Level

4.3 *Other Documents*

IEC 1000-4-2 — Transient Immunity Standard, International Electrotechnical Commission

89/336/EEC — European Union Directive on Electromagnetic Compatibility

5 Terminology

5.1 *Definitions*

5.1.1 *deposition velocity* — Particle flux to a surface (number of particles deposited per unit area per unit time) divided by the particle concentration adjacent to the surface boundary layer.

5.1.2 *electromagnetic interference (EMI)* — Any electrical signal in the non-ionizing (sub-optical) portion of the electromagnetic spectrum with the potential to cause an undesired response in electronic equipment.

5.1.3 *electrostatic attraction (ESA)* — The force between two or more oppositely charged objects. The result is increased deposition rate of particles onto charged surfaces, or movement of charged materials.

5.1.4 *electrostatic compatibility* — Charge control adequate for interequipment transfer of products, reticles, and carriers without electrostatic problems.

5.1.5 *electrostatic discharge (ESD)* — The rapid spontaneous transfer of electrostatic charge induced by a high electrostatic field.

NOTE: Usually the charge flows in a spark between two objects at different electrostatic potentials.

5.1.6 *equipment interrupt* — Any variance from the specifications of equipment operation, whether or not the equipment recovers automatically. Interrupts include, but are not limited to, equipment stoppage, equipment data errors, and physical mishandling of products (reference SEMI E10).

5.1.7 *ESD simulator* — An instrument providing a specified electrostatic discharge current waveform when discharged directly to a product or equipment part.

5.1.8 *input and exit ports* — The locations where product and/or product carriers are placed to allow the equipment to process them, or where they are removed from the equipment after processing.

5.1.9 *minienvironments* — A localized environment created by an enclosure to isolate the product from contamination and people.

5.1.10 *product* — Any unit intended to become a functional semiconductor device.

1 ESD Association, 7900 Turin Road, Rome, NY 13440

5.1.11 *sensitivity level 1* — Product, reticles, and equipment are extremely vulnerable to damage and/or problems from static charge.

5.1.12 *sensitivity level 2* — Product, reticles, and equipment are highly vulnerable to damage and/or problems from static charge.

5.1.13 *sensitivity level 3* — Product, reticles, and equipment have nominal vulnerability to damage and/or problems from static charge.

5.1.14 *sensitivity level 4* — Product, reticles, and equipment have negligible vulnerability to damage and/or problems from static charge.

5.2 *Description of Terms Specific to this Standard*

5.2.1 *carrier* — A device for holding wafers, dies, packaged integrated circuits, or reticles for various processing steps in semiconductor manufacturing.

6 Requirements

6.1 *Measurement Methods and Instrumentation* — No single method of testing for static charge can determine a "safe" level. The amount of static charge, the distribution of static charge on an object, and the nature of the static discharge will all interact to determine if the charge level is safe. It will be difficult to determine levels that ***guarantee*** static related problems are totally eliminated. The goal of this guide is to assist the user in identifying static charge levels likely to cause problems in process equipment. This guide should provide the user with enough insight to define a test methodology for each static problem and understand its limitations.

6.2 *ESD Damage*

6.2.1 When considering direct ESD damage to an object (product, reticle, or equipment), the important parameter is the current accompanying the charge transfer to or from the object. Under a fixed set of test parameters, the damaging amount of current due to the charge transfer to or from the object can be determined. Established test methods exist for determining the threshold of damage to a particular object. ESD simulators of various types are used for this purpose. Refer to EOS/ESD Association Standards listed in Section 4 for further information concerning device testing.

6.2.2 The end user should determine what is damaging current level due to charge transfer to product or reticles that will be handled in a particular piece of production equipment.

6.2.3 In the context of production equipment, it appears important to know the charge on the product, its carriers, and any other objects that might directly contact the product. Charge is measured in coulombs, or more conveniently in nanocoulombs (10^{-9} coulombs) for this purpose. The measurement is made with instrumentation known as a Faraday Cup, as shown in Section 7, Figure 1.

6.2.4 A charged object, like an integrated circuit, is placed in the Faraday Cup and a reading is taken of the charge on it. It will be necessary to obtain an instrument with a large enough "cup" for wafers, cassettes, and other equipment parts. It will also be necessary to get the objects into the cup without altering their charge levels. Further information on making these measurements should be available from the manufacturers of the measuring equipment.

6.2.5 The user should determine with an ESD simulator what levels of ESD cause product, or reticle damage. The equipment manufacturer will need to determine with an ESD simulator what levels of static charge cause equipment damage.

6.2.6 It will be the responsibility of the equipment manufacturer to demonstrate that equipment operation does not generate more than the allowable amount of charge on product, carriers or equipment parts. This is shown in Section 7, Figure 2.

6.3 *Particle Attraction*

6.3.1 Electrostatic attraction (ESA) of particles can occur due to the electrostatic field created by the charge on the surface of an object. Both the field strength and, usually to a lesser degree, the divergence of the field influence the electrostatic contribution to particle deposition velocity. Electrostatic particle deposition velocity also depends on particle size and particle electrical charge. Unfortunately, even under controlled laboratory conditions, accurate measurements of electric field strength, particle size distribution, and, especially, particle charge, are difficult. Of these three parameters, electric field measurements are the most likely to be available.

6.3.2 Measurements of electrostatic field can be made with a commonly available electrostatic fieldmeter. The units of electrostatic field are volts/cm (volts/inch). Precise measurements will be difficult as the presence of the measuring instrument changes the field characteristics and may overstate the actual level of electrostatic field. This is shown in Section 7, Figure 3. SEMI E43 describes measurement techniques using an electrostatic fieldmeter.

6.3.3 Electrostatic deposition velocity depends only on electric field, particle size and particle charge. However, the concentration of particles deposited on a surface also depends on the particle concentration in the equipment area and the length of the exposure time during which particle deposition occurs. Mechanisms other than electrostatic deposition, such as gravitational settling and diffusion, can also contribute to particle deposition. The concentration of particles deposited by these non-electrostatic mechanisms will also vary with particle concentration in the equipment ambient and exposure time.

6.3.4 Comparisons of the electrostatic deposition velocity with the deposition velocities associated with these other deposition mechanisms is the key for determining threshold values of allowed electrostatic field from the viewpoint of particle deposition. Such comparisons are the basis for estimating the allowed values of electrostatic field presented in Appendix A1-2.2 and Related Information R1-2. Users and equipment manufacturers should determine and agree on ambient particle sizes and concentrations, and product exposure times.

6.4 *Equipment ESD*

6.4.1 Equipment ESD immunity is being addressed in general through a number of international standards including IEC 1000-4-2 and EN50082-2 for European CE compliance. Measurements are made using an ESD simulator which is described in these standards.

6.4.2 The ESD simulator is used to create both a direct discharge to the surface of the equipment and an air discharge to a surface 10 cm (4 inches) away from the equipment. The ESD simulator charges a 150 picofarad capacitor (C) to a known voltage (V) and then discharges it to produce a standardized discharge waveform. Knowing the voltage and capacitance involved in this test means the total charge can be calculated by the equation $q = CV$. For example, a 4000 volt discharge (IEC 1000-4-2 test level) transfers a charge, $q = 600$ nanocoulombs.

6.4.3 The value of the capacitor (C) in the ESD simulator is specified in the international standards. It should not be assumed that a different value of capacitance and voltage that produce the same charge transfer of 600 nanocoulombs would have the same affect on a specific piece of equipment. Discharge currents will vary with the impedance of the discharge path and with the voltage. It is, however, impractical to test all possible combinations. For the purposes of this guide, the parameters of the ESD simulator specified in the standards for equipment ESD immunity will be used.

6.4.4 For true ESD immunity, an ESD event in equipment must not disturb either the equipment it occurs in, or another nearby piece of equipment. Charge on product or carriers transferred from one piece of equipment must not disturb the operation of subsequent equipment. It will be a systems issue to make sure that **all** equipment in a facility meets the required ESD immunity standards.

6.4.5 The range of reactions in equipment to an ESD event runs from *transient errors* that are automatically corrected, to *hard errors* that cannot be corrected without manual intervention or damage the equipment. While small numbers of transient errors may be acceptable from the point of view of equipment operation, they may still cause unacceptable product losses.

6.4.6 The user and manufacturer must determine with an ESD simulator what levels of ESD cause equipment interruptions. The user must determine if any of these equipment interruptions caused by ESD are acceptable.

6.4.7 In setting a level to provide ESD immunity for an individual piece of equipment from static charge on products and carriers, the charge on these items should be kept below the levels determined by ESD simulator testing.

6.4.8 The Faraday Cup measurement can be used for this purpose. If equipment has been tested for ESD immunity and passes a 4000 volt test, then total charge on product and carriers leaving this equipment should be kept below 600 nanocoulombs. Any product transferred at this level should not be handled by other equipment with a lower ESD immunity. A possible implementation of this test method is shown in Section 7, Figure 4.

7 Apparatus

7.1 *ESD Damage* — The apparatus for determining the ESD damage thresholds for products will depend on the test methods used. See Section 4 for additional information. For measuring the charge generated on product, reticles, or carriers, the Faraday Cup test method is shown in Figure 1.

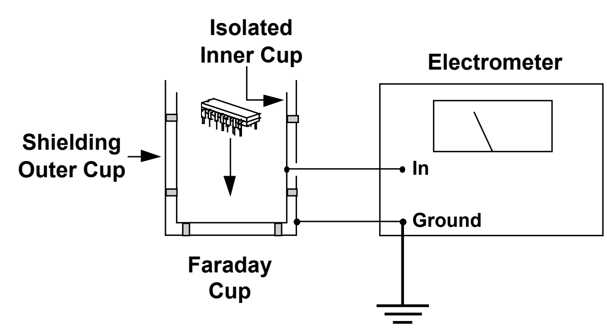

Figure 1
Faraday Cup Charge Measurement

7.1.1 The relationship between ESD simulator testing for product damage and charge measurements using the Faraday cup is shown in Figure 2.

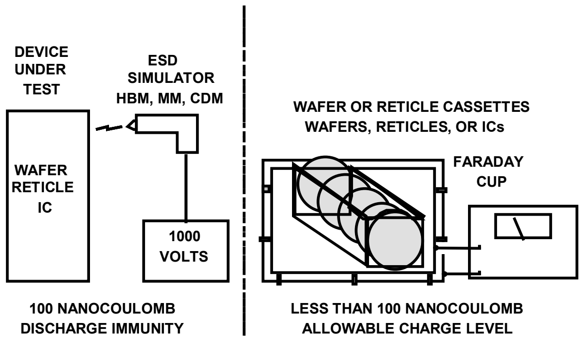

Figure 2
ESD Damage Testing

7.2 The instrument used for making electrostatic field measurements is known as an electrostatic fieldmeter. Instructions concerning its use should be obtained from the instrument manufacturer and SEMI E43. The measurement configuration shown in Figure 3 illustrates the effect of the instrument on the measurement. In most cases the presence of the fieldmeter will increase both the flux from the charged surface and the divergence of the electric field lines. The fieldmeter will generally indicate a higher value of electric field than would be present without the fieldmeter.

7.3 The instrumentation and test methods for determining the ESD sensitivity of equipment are described by IEC 1000-4-2 or other acceptable test methods. The amount of static charge determined by this test method is to be compared with the charge measured on products and carriers with the Faraday Cup test method. Figure 4 illustrates the two methods.

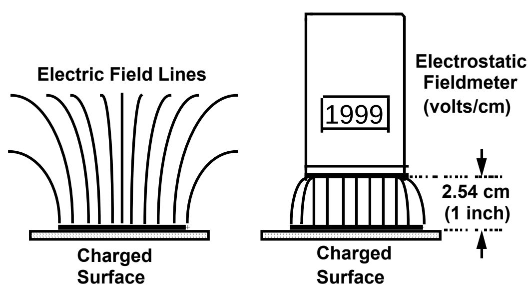

Figure 3
Electrostatic Field Measurement

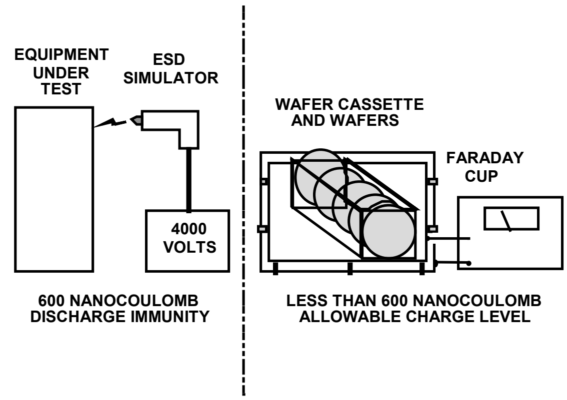

Figure 4
ESD Immunity Testing

8 Safety Precautions

8.1 *Personnel* — Static charges can create safety hazards during some semiconductor production processes. ESA or ESD events that result in the jamming or breakage of product in high speed equipment may create a personnel hazard. ESD events that produce sparks must be prevented in areas that use flammable or explosive chemicals or gases. ESD events to personnel are usually not harmful, but they may result in an unwanted reflex, or "startle" reaction. This reflex may create a personnel hazard, particularly in the vicinity of moving equipment or where caustic chemicals are in use. It may be necessary to use additional static charge control methods, beyond those used inside the equipment, to minimize these personnel hazards.

8.2 *Measurement Safety* — Users should exercise caution while making static charge measurements in the vicinity of moving parts of production equipment, or in areas where static potentials on ungrounded conductors may exceed 30,000 volts. Refer to SEMI E43 for additional measurement safety considerations.

9 Test Specimen

9.1 The user and equipment manufacturer will need to agree on:

— The type(s) of testing to be performed.

— Who will do the testing.

— The number and type of test samples.

— The number of measurements.

— Acceptable test results.

9.2 The operating history of the equipment prior to, or during testing (e.g., warm-up time, type of carrier, number of products processed, operating speed), and all appropriate environmental conditions (e.g., temperature, humidity, airflow) should be agreed upon and documented.

10 Preparation of Apparatus

10.1 Depending on the type of testing to be done, consult the appropriate testing document for apparatus preparation. See Sections 4 and 16 for additional information.

11 Calibration and Standardization

11.1 Depending on the type of testing to be done, consult the appropriate testing document for apparatus calibration and verification. See Sections 4 and 16 for additional information.

12 Procedures

12.1 Refer to Sections 6 and 7 and the appropriate test methods of Sections 4 and 16.

12.2 *ESD Damage*

12.2.1 Users shall establish product damage thresholds for their products. Measurement methods for integrated circuits are described in the documents contained in Sections 4 and 16. Appropriate measurement methods for ESD damage to wafers, reticles, and other items may be adapted from the instrumentation used in these test methods. Appendix A1-2.1 and Related Information R1-1 contain additional information to select an appropriate sensitivity level to reduce ESD damage.

12.2.2 Measurement of ESD damage thresholds are made in units of nanocoulombs (nC = 10^{-9} coulombs).

12.2.3 The Faraday Cup method is used to determine the static charge levels on products, product carriers and equipment parts. Each item shall be transported to the Faraday cup in a way that does not alter its charge level. Consult the measurement equipment manufacturer's instructions for recommendations on how to achieve this.

12.2.4 Measurements should be made of products, carriers, and materials in the equipment input/exit ports after significant amounts of product have been handled under normal manufacturing conditions. Measurements should be made of products and their carriers after they have undergone normal processing in the equipment under test. Typically five measurements of products and/or carriers should be sufficient to demonstrate compliance with the selected Sensitivity Level.

12.2.5 Measurements should be made on each of three successive days after equipment has stabilized in its normal operating mode (e.g., after two hours).

12.3 *Particle Attraction*

12.3.1 Users should work with equipment manufacturers to determine ambient particle levels and product exposure times during processing. Appendix A1-2.2 and Related Information R1-2 contain information to select an appropriate Sensitivity Level to reduce electrostatic attraction of particles.

12.3.2 Electrostatic field measurements on products, product carriers, and equipment surfaces should be made in at least three different locations on any item. Locations should be separated by approximately three times the distance between the measuring instrument and the measurement location. For most electrostatic fieldmeters measuring at 25.4 mm (1 inch), the measurement locations will be 76.2 mm (3 inches) apart. Refer to SEMI E43 for additional measurement considerations. Measurements of electrostatic field are expressed in volts/cm or volts/inch.

12.3.3 Measurements should be made on products, carriers, and materials in the equipment input/exit ports after significant amounts of product have been handled under normal manufacturing conditions. Measurements should be made of products and their carriers after they have undergone normal processing in the equipment under test. Typically five measurements of products and/or carriers should be sufficient to demonstrate compliance with the selected Sensitivity Level.

12.3.4 Measurements should be made on each of three successive days after equipment has stabilized in its normal operating mode (e.g., after two hours).

12.4 *Equipment ESD*

12.4.1 Equipment manufacturers should determine the effects of ESD on their equipment using an ESD Simulator and the appropriate test methods (IEC 1000-4-2 or others). Users should agree on the types of equipment interrupts that are acceptable (if any). Appendix A1-2.3 and Related Information R1-3 contain additional information to select an appropriate sensitivity level to reduce ESD-related equipment interruptions.

12.4.2 Compliance with the desired Sensitivity Level may be demonstrated using the Faraday Cup method described in Sections 6.4 and 7.3.

12.4.3 Measurements should be made on products, carriers, and materials in the equipment input/exit ports after significant amounts of product have been handled under normal manufacturing conditions. Measurements should be made of products and their carriers after they have undergone normal processing in the equipment under test. Typically, five measurements of products and/or carriers should be sufficient to demonstrate compliance with the selected Sensitivity Level.

12.5 Equipment used in semiconductor manufacturing should meet the following levels shown in Table 1 for protection from problems caused by static charge.

Table 1 Recommended Sensitivity Levels

	Electrostatic Discharge (Nanocoulombs)	*Particle Attraction (Volts/cm)*	*Equipment Malfunction (Nanocoulombs)*
Level 4	100	4000	1200
Level 3	50	400	600
Level 2	10	200	300
Level 1	1	100	150

12.5.1 Sensitivity Level 4 compliance means that products, reticles, and carriers can leave the equipment with up to the recommended amounts of static charge or electrostatic field measured on them according to the test method used. This level essentially states that the equipment is used in a process that has no significant problems handling charged product, nor are there issues associated with contamination or ESD damage.

12.5.2 At levels 1, 2, or 3 a decision should be made as to what is the most serious static charge problem. The Sensitivity Level and test methods are chosen accordingly. The lower the level of static charge allowed, the more static control measures the equipment manufacturer may need to install.

12.5.3 Level 1 may be used primarily by manufacturers of specialized components such as: gallium arsenide semiconductors or magneto-resistive (MR) disk drive read heads; those experiencing significant losses due to contamination; or those using specialized equipment with low immunity to ESD or EMI.

12.6 The levels listed in Table 1 have been determined as the result of analysis of working conditions, or experiments done in operating semiconductor facilities. Justifications for these levels are found in Appendix 1. The actual levels to be used for any piece of production equipment may be decided by agreement between the user and manufacturer of the equipment.

12.7 Other levels may be appropriate under specific equipment conditions and for specific devices.

13 Calculations

13.1 A series of five measurements should be made. The average of the five measurements should not exceed the recommended level.

14 Reporting Results

14.1 Data records should contain the following information:

— Description of equipment under test including model and serial numbers.

— Description of the equipment operating conditions and environment.

— Measurement equipment and last calibration date.

— Description of objects measured and measurement locations.

— Humidity and temperature at measurement location when measurements were made.

— Results of measurements.

— Personnel making the measurements.

— Any other relevant comments.

15 Precision and Accuracy

15.1 *Accuracy of Test Methods* — The test methods referenced in this document do not guarantee precise measurements of static charge levels. Similarly, maximum static charge levels recommended in this document are not stated as precise requirements. Accuracy of approximately ± 20% is acceptable in all measuring instrumentation. At low static charge levels or for more accurate measurements, alternative instrumentation and test methods may need to be used.

16 Related Documents

16.1 *EIA/JEDEC Standards*

EIA/JESD22-A114 — Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)

EIA/JESD22-A115 — Electrostatic Discharge (ESD) Sensitivity Testing Machine Model (MM)

Test Method C101 — Field-Induced Charged-Device Model Test Method for Electrostatic Discharge Withstand Thresholds of Microelectronic Components

16.2 *Other Documents*

EN 50082 — Generic Immunity Standard for CE Compliance, CENELEC European Union

MIL-STD 883C — Notice 8 – Method 3015.7 – Electrostatic Discharge Sensitivity Classification

APPENDIX 1
DETERMINING STATIC SENSITIVITY LEVELS

NOTE: This appendix was approved as an official part of SEMI E78 by full letter ballot procedure. This appendix offers information related to the Sensitivity Levels contained in Section 12.5.

A1-1 Recommended Levels

The recommended charge and electrostatic field levels in this guide are not based on specific protection thresholds for individual devices or process tools. Rather, their aim is to classify the types of ESD events or static levels that are likely to be of concern. Tool manufacturers and users should determine the type of events that are of most concern to their products and process, so as to apply this guide to their needs. Information on specific device damage thresholds and tool sensitivities is best determined on an individual basis.

A1-2 Justification of Guide Recommendations in Section 12.5 and Table 1

A1-2.1 *Recommendations for ESD Damage*

A1-2.1.1 Related Information R1-1 discusses test methods for determining ESD damage thresholds for semiconductor devices. Devices are qualified according to the highest ESD stresses they can withstand without measurable change in their operating parameters. This section attempts to develop guide recommendations for minimizing ESD damage based on that discussion.

A1-2.1.2 *Industry Device Damage Levels* — Each of the test methods, HBM, MM, and CDM have a set of qualification levels defined. These are contained below.

HBM Classification Levels

Class	*Voltage*
0	< 250
1A	250–499
1B	500–999
1C	1000–1999
2	2000–3999
3A	4000–7999
3B	≥ 8000

MM Classification Levels

Class	*Voltage*
M1	< 100
M2	100–199
M3	200–399
M4	≥ 400

CDM Classification Levels

Class	*Voltage*
C1	< 125
C2	125–249
C3	250–499
C4	500–999
C5	1000–1499
C6	1500–1999
C7	≥ 2000

A1-2.1.3 *Charge Levels for ESD Damage* — As discussed in Related Information R1-1.4, ESD Simulator testing uses different capacitances for each model. For HBM it is 100 picofarads, for MM it is 200 picofarads, and for CDM it depends on the capacitance of the actual device being tested. In any case, it is charge (charge = voltage × capacitance) that damages the device. It would seem appropriate, therefore, that the guide recommendations in Table 1 Section 12.5 be stated in units of charges (e.g. nanocoulombs).

A1-2.1.4 *Guide Recommendations* — Based on industry testing reflected in device data sheets, there appears to be a wide range for ESD immunity in semiconductor devices. This document deals primarily with ESD occurring within equipment. HBM type ESD discharges are the least likely to occur within equipment. Charged equipment parts contacting devices (MM) and charged devices contacting machine parts (CDM) are the most likely causes of ESD damage to devices in equipment. The following sensitivity levels are defined with respect to the existing industry MM and CDM classifications.

Level 4 — Devices are essentially unaffected by any reasonable level of ESD encountered in equipment. Devices pass testing at levels higher than MM Class M4 (400 volts × 200 picofarads = 80 nanocoulombs). Equipment should not create or store charge on itself or on devices in excess of the guide recommendation.

Guide recommendation (table 1 in Section 12.5) – 100 nanocoulombs.

Level 3 — Devices are affected by moderate levels of static charge in equipment. Devices pass testing for MM Class M4 (400 V × 200 picofarads = 80 nanocoulombs) and most of MM Class M3 (over 250 volts × 200 picofarads = 50 nanocoulombs). Guide recommendation (Table 1 in Section 12.5) – 50 nanocoulombs.

Level 2 — Devices are damaged by lower levels of static charge in equipment. Devices pass testing at MM Class M1 (100 V × 200 picofarads = 20 nanocoulombs) and CDM Class C4 (1 kV × 10 picofarad device = 10 nanocoulombs). Guide recommendation (Table 1 in Section 12.5) – 10 nanocoulombs.

Level 1 — Devices are easily damaged by even low levels of static charge in equipment. Devices pass testing at CDM Class 1 (125 V × 10 picofarads device = 1.25 nanocoulombs). In most cases simulator equipment is not designed to do testing at these very low levels for MM. Guide recommendation (Table 1 in Section 12.5) – 1 nanocoulombs.

A1-2.2 *Recommendations for Particle Deposition*

A1-2.2.1 Related Information R1-2 discusses the enhancement of particle deposition due to electrostatic fields from charges on the wafer surface. This section attempts to develop the guideline recommendations for minimizing particle deposition based on that discussion.

From Equation 3 of Related Information R1-2.2,

$$N/A = cv_{elect}t \qquad (12)$$

where N/A equals the particulate burden added to a wafer during exposure time t, exposed to a particle concentration c, in an environment characterized by an electrostatic particle deposition velocity, v_{elect}.

Target values for N/A are given in the National Technology Roadmap for Semiconductors (NTRS, 1994). These target values vary from 0.02–0.01 defects/cm^2, depending on the critical dimensions of the technology, and represent an upper value of the acceptable particulate concentration on a wafer at the conclusion of the fabrication sequence. For individual processing steps making up the fabrication sequence the target values are lower yet.

The variables c and t are process step dependent and may or may not be controllable. Clearly minimizing both of these variables is desirable in order to minimize particle deposition on a wafer in any environment.

The only variable in Equation 12 that depends on electrical forces is v_{elect}. Both the particle charge and the electric field in the vicinity of the wafer affect the magnitude of v_{elect}. Particle charge is generally unknown unless it is deliberately controlled by a neutralizing action, such as flooding the environment with both positive and negative charges. Under these conditions a Fuchs type charge distribution is a reasonable assumption for the particle charge. This assumption was used to calculate the values of E_0 in Table R1-2 of Related Information R1-2.3.2.

When the environmental electric field is less than E_0, deposition of electrically "neutralized" particles is dominated by diffusion. When the environmental electric field is greater than E_0, electrostatic forces dominate particle deposition even when particle charge has been "neutralized." Values of E_0 for a Fuchs charge distribution can be calculated from Related Information R1-2.3.2 Equation 10. For particle charge greater than the Fuchs charge, v_{elect} increases by a factor of q/q_{Fuchs}. Unfortunately, the actual particle charge q is generally unknown.

Using the process step values of c and t and the value of v_{elect} calculated from Equation 10, the value of N/A for any process step can be estimated. Alternatively, having a target value of N/A and estimating the value of v_{elect} as outlined in the previous paragraphs, allows one to calculate the tolerable value of ct:

$$ct = [N/A]/v_{elect} \qquad (13)$$

Setting N/A = 0.01/cm^2 and using Equation 10 to calculate v_{elect} for a 0.1 µm particle at various values of electric field and particle charge, target values of ct can be calculated from Equation 13. The allowed exposure times in an ISO Class 1 environment ($c \leq 10^{-5}$ particles/cm^3) can be deduced as shown in the following table:

Table A1-1 Allowed Exposure Times in an ISO Class 1 Environment

E V/cm at One Wafer Radius	q/q_{Fuchs}	v_{elect} cm/sec	*ct sec/cm^3*	*max t in ISO Class 1 sec*
4000	1	0.8	0.01250	1250
	2	1.6	0.00625	625
	10	8.0	0.00125	125
400	1	0.08	0.1250	12500
	2	0.16	0.0625	6250
	10	0.8	0.0125	1250
200	1	0.04	0.250	25000
	2	0.08	0.125	12500
	10	0.4	0.025	2500
100	1	0.02	0.50	50000
	2	0.04	0.25	25000

	10	0.2	0.05	5000

Using higher values of *N/A* in Equation 13 will increase the acceptable values of *ct* and max *t*. Accepting higher values of *c* will reduce max *t*. The guideline table provides an order of magnitude assessment of the degree of electric field and charge control needed in specific operations. Minimum field and minimum particle charge are always the goal but usually not practically achievable. This guideline table provides background estimates of envelopes for acceptable operation in electrically charged environments.

A1-2.2.2 The following simplified table is offered as an alternative to Table A1-2 based on the following assumptions:

1. Calculations made for Federal Standard 209E Class 1 ($c \leq 0.00124$ particles/cm^3).
2. The value of the electrostatic field is referenced at a distance of one wafer radius from the wafer. While electrostatic field measurements can certainly be made at this distance, they are typically made at 2.5 cm (1 inch) with common instrumentation. This is described in SEMI E43. Measurements made at this smaller distance will be proportionally higher, but under varying measurement conditions, it is difficult to determine a precise relationship between electric field and measurement distance. To provide a suitable safety factor, assume a linear relationship, rather than one proportional to the square of the distance. For example, with a 200 mm wafer, 4000 Volts/cm at 2.5 cm would result in 1000 Volts/cm at 10 cm, rather than 250 Volts/cm.
3. The proportionality effect of q/q_{Fuchs} has been explained, as has the difficulty in actually determining any value for it. For simplicity, the table includes only the $q = q_{Fuchs}$ condition.
4. *N/A* = 0.016 defects/cm^2 as specified for 0.25 µm technology in the National Technology Roadmap for Semiconductors.

Table A1-2.1 Alternative to Allowed Exposure Times in an ISO Class 1 Environment

EV/cm at 2.5 cm	*N/A defects per cm^2*	v_{elect} cm/sec	*ct sec/cm^3*	*max t in Class 1 sec*
4000	0.016	0.21	0.0762	61
400	0.016	0.021	0.762	610
200	0.016	0.0105	1.524	1220
100	0.016	0.00525	3.048	2440

A1-2.3 *Guide Recommendations for Equipment Malfunctions*

A1-2.3.1 *Equipment Survey* — Most semiconductor production equipment should comply with the ESD immunity requirements of the European Economic Community (EEC). The testing mandated by the EEC uses the test methods and ESD immunity levels specified in IEC 1000-4-2. A recent survey of 262 semiconductor equipment suppliers revealed that 71% were compliant with the EEC requirements. There is an expectation that all equipment to be used in future 300 mm wafer fabrication will meet or exceed the ESD immunity requirements of IEC 1000-4-2.

To test for compliance, measurements were made with the ESD simulator described by IEC 1000-4-2 on a representative sample of semiconductor equipment. The results were as follows:

ESD Simulator Testing Direct Contact Discharge

Equipment	*Test Voltage Level 1 (2 kV)*	*Test Voltage Level 2 (4 kV)*	*Test Voltage Level 3 (6 kV)*	*Test Voltage Level 4 (8 kV)*	*Test Voltage Level X (NOTE 1)*
A		X			
B		X			
C				X	
D		X			
E				X	
F		X			
G		X			
H		X			
I		X			
J		X			

ESD Simulator TestingAir Discharge at 10 cm

Equipment	*Test Voltage Level 1 (2 kV)*	*Test Voltage Level 2 (4 kV)*	*Test Voltage Level 3 (8 kV)*	*Test Voltage Level 4 (15 kV)*	*Test Voltage Level X (NOTE 1)*
A			X		
B			X		
C					X
D			X		
E					X
F		X			
G			X		
H			X		
I			X		
J			X		

"X" indicates that the equipment passes ESD simulator testing at this level.

NOTE 1: This level is subject to negotiation and has to be specified in the dedicated equipment specification. If higher voltages than those shown are specified, special test equipment may be needed.

A1-2.3.2 *Static Audit* — While equipment may meet the ESD immunity levels specified in IEC 1000-4-2, it should be remembered that static charge levels in manufacturing environments may be substantially higher. Direct measurements of static charge are difficult, and the presence of a charge does not always imply that an ESD event causing an equipment malfunction will occur. Some information may be gained by using a fieldmeter to measure the electrostatic field created by the surface charge. Instruments known as EMI locators may also be used in some cases to determine if ESD-related EMI is occurring. Some representative measurements of electric fields from objects in various areas of a semiconductor wafer fab are as follows:

— *Wet Etch* — 0.1 kV/inch to 30 kV/inch

— *Planarization* — 0.1 kV/inch to 20 kV/inch

— *Lithography* — 0.1 kV/inch to 20 kV/inch

— *Dry Etch* — 0.1 kV/inch to 15 kV/inch

— *Thin Film* — 0.1 kV/inch to 15 kV/inch

— *Diffusion* — 0.1 kV/inch to 30 kV/inch

— *Implant* — 0.1 kV/inch to 15 kV/inch

A knowledge of object capacitance and other physical properties is needed to determine if any of the above measurements indicate an equipment hazard due to ESD events. However, the range of the measurements strongly indicate that such ESD events can occur. The examples in Related Information R1-3.3 support this conclusion.

A1-2.3.3 *Guide Recommendations* — Based on the static audits and equipment test data, there appears to be a wide range of static immunity in equipment as well as in the static charge levels in work environments. As stated previously, it is difficult to establish a direct correlation between ESD events and fieldmeter measurements made on products, carriers, or any other objects in the work environment. The following sensitivity levels are defined with recommended test levels for each.

Level 4 — Field measurements of static charge at input/exit ports are expected to exceed 10 kV/inch. Equipment should pass ESD simulator testing at 8 kV direct contact discharge, 18 kV air discharge. Guide recommendation (Section 12.5) - 1200 nanocoulombs (8 kV × 150 picofarads).

Level 3 — Field measurements of static charge at input/exit ports are expected to exceed 4 kV/inch, but are less than 10 kV/inch. Equipment should pass ESD simulator testing at 4 kV direct contact discharge, 8 kV air discharge. Guide recommendation (Section 12.5) - 600 nanocoulombs (4 kV × 150 picofarads).

Level 2 — Field measurements of static charge at input/exit ports are expected to exceed 500 V/inch, but are less than 4 kV/inch. Equipment should pass ESD simulator testing at 2 kV direct contact discharge, 4 kV air discharge. Guide recommendation (Section 12.5) - 300 nanocoulombs (2 kV × 150 picofarads).

Level 1 — Field measurements of static charge at input/exit ports are expected to exceed zero, but are less than 500 V/inch. Equipment should pass ESD simulator testing at 1 kV direct contact, 2 kV air discharge. Guide recommendation (Section 12.5) - 150 nanocoulombs (1 kV × 150 picofarads).

RELATED INFORMATION 1
STATIC CHARGE PROBLEMS

NOTE: The material contained in this related information is not an official part of SEMI E78 and is not intended to modify or supersede the guide in any way. These notes are provided as a source of information to aid in the application of the guide, and are to be considered reference material. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 ESD Damage

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R1-1.1 *Introduction* — ESD damage to devices occurs when they come into contact with personnel and equipment. Either may store a residual charge large enough to destroy the device if a discharge occurs. In the semiconductor industry, it has been established that a significant proportion of customer field returns are attributed to damage resulting from ESD.

R1-1.2 *Description of ESD Damage Mechanisms* — ESD failures are the result of either a current-induced phenomenon or a charge-induced phenomenon, and the damage can either be junction, contact, dielectric or oxide related. The apparent similarity in current-induced damage resulting from ESD due to human body model discharges (HBM) or machine model discharges (MM) results from the thermal nature of both of these process. The HBM and MM damages result when the temperature (joule heating) of the region dissipating the ESD pulse energy reaches a critical value and melting occurs.

Charge-induced phenomena are predicted by the charged device model (CDM). For CDM type discharges, oxide punch through occurs when the ESD voltage applied across the oxide creates a high enough field to break down the oxide. Excessive current flow results, causing an oxide short, but there is no heat transfer (adiabatic process).

It should be noted here that the time duration for typical ESD events from charged objects and personnel ranges from 10 to 100 nanoseconds, while CDM type events occur in less than 1 nanosecond.

R1-1.3 *Device Testing Models*

R1-1.3.1 *Human Body Model (HBM)* — The Human Body Model is the oldest and the most widely used of the three ESD models. The model attempts to replicate the discharge from a real human when the latter touches a device that is at a lower potential. The human capacitance and resistance have been ideally chosen to be 100 picofarads and 1500 ohms respectively. The values were chosen after measurements were made on humans in varying positions with respect to their surroundings. The resulting discharge waveform has a double exponential shape with risetime range of 2–10 nsec and a decay constant (1/e position) of 150 ± 20 nsecs. The typical peak currents range from 0.67 Amps at 1000 volts to 2.67 Amps at 4000 volts.

R1-1.3.2 *Machine Model (MM)* — The Machine Model is described by Electronic Industries Association of Japan (EIAJ) as a worst case HBM. The model attempts to replicate the discharge from a metallic arm of an automatic handler coming into contact with the metallic leads of a semiconductor device which is at a lower potential. A capacitance of 200 picofarads and ideally zero resistance produces a sinusoidal decaying waveform with an effective pulse duration of 200 nsec. The typical peak currents range from 1.75 Amps at 100 volts to 14.0 Amps at 800 volts. Note that MM failures occur at 5–10 times lower voltage than HBM.

R1-1.3.3 *Charged Device Model (CDM)* — The Charged Device Model in its purest form is actually a field induced model because the device is actually part of model. This model attempts to describe a device which itself becomes charged due to an external field, or due to triboelectric charging of the device surfaces. During discharge, the parasitics (capacitance, inductance and impedance) in the device play a significant role in the resulting failure. The discharge pulse is a sinusoidal waveform with an extremely fast risetime of less than 500 picoseconds. The waveform decays rapidly with a total pulse duration of less than 5 nano-seconds. The peak currents range from 2.0 Amps at 250 volts charging voltage, to 18.0 Amps at 2000 volts charging voltage.

R1-1.3.4 *Correlation Between Models* — There is much debate on whether or not there is any type of correlation between HBM and MM. While some companies report a correlation of roughly 10:1 between the two models, other companies have seen anywhere from 5–20:1 differences in passing voltages between the two models. There is also no established voltage correlation between CDM damage and HBM or MM ESD events. In equipment, ESD damage events will be related to the MM or CDM types of ESD. Users will need to determine the type of ESD hazard to their devices and choose the test method accordingly.

R1-1.4 *ESD Laboratory Simulation Testing*

R1-1.4.1 *Description of Test Methods* — Test procedures discussed here for ESD simulation conform to those established by the ESD Association Standards ESD STM 5.1 (for HBM), ESD S5.2 (for MM), and MIL-STD-883, C/3015.7-method 8. The ESD Association is presently considering two documents related to CDM Testing. Details are to be found in these standards.

Devices are qualified at a level corresponding to the highest ESD stress they are able to withstand. These levels are discussed in more detail in Appendix A1-2.1.

R1-1.4.2 *Simulation Test Results* — In general all units must be data-logged both pre- and post-stress test. Any leakage current equal to or greater than a specific amount (company dependent — typically 10 micro-amps or less) is “flagged” as a failure, and any current shift greater than about 200 nano-Amp is marked on the record.

R1-1.4.3 *HBM Stress Testing* — An R-C network is used to simulate the ESD event. In an HBM ESD Simulator, a high voltage is used to charge the capacitor (100 pF) which discharges through the resistor (1500 ohms) into the device under test. The present draft standard (1997) requires a minimum of two discharges (1 positive and 1 negative) per voltage level.

R1-1.4.4 *MM Stress Testing* — An R-C network is also used in the MM ESD Simulator for ESD testing. High voltage charges the capacitor (200 pF) which discharges through the short wire (zero ohm) into the device under test. The present standard requires a minimum of six discharges (3 positive and 3 negative).

R1-1.4.5 *CDM Stress Testing* — The package and leadframe of the device are charged by direct charging or field induction. For the Direct Charging Method, direct contact is made to one of the device leads connected to the substrate or bulk material of the device. The device is then discharged via a one ohm resistor to ground.

For the Field Induced Method, the device is placed on a metallic charging plate with the device packaging material touching the plate. The potential of the device is raised by applying a voltage to the charging plate. The induced voltage on the device is discharged to ground through a 1 ohm resistor that contacts each device lead. The present draft standard (1996) requires a minimum of 6 discharges (3 positive and 3 negative) from each device lead.

R1-1.5 *Examples of Damage from Device Testing*

R1-1.5.1 *HBM ESD Damage*

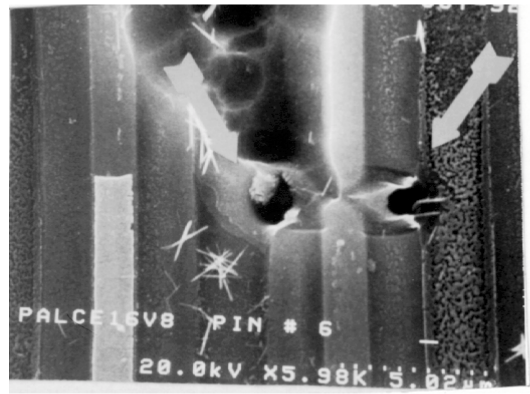

Figure R1-1
Example of HBM Damage

In this example of HBM damage (refer to Figure R1-1), de-processing (removal of the processed layers) down to the poly level and very high magnification (SEM) examination were required in order to see the failure site morphology of arcing from source to drain within the ESD protective structures. The electrical characteristics found were: resistive shorts, leakages, low breakdown voltages and Icc failures.

R1-1.5.2 *MM ESD Damage*

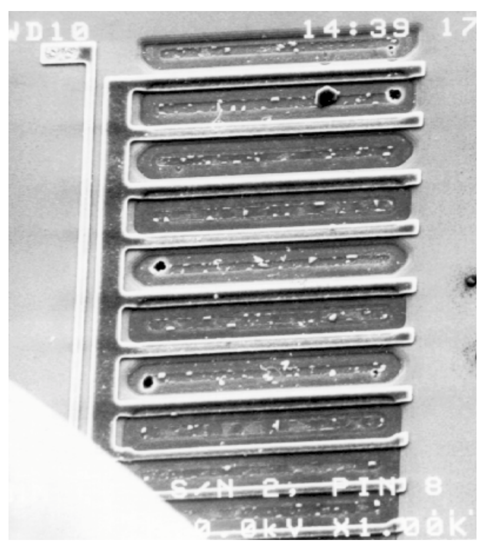

Figure R1-2
Example of MM Damage

In the above MM example (refer to Figure R1-2), the damage was more severe than for HBM. De-processing down to the poly level and the SEM examination showed the failure site morphology of large deep pits occurring at the contact(s) suggesting high current parasitic bipolar action deep in the substrate and also within the ESD protective structures. The electrical characteristics found also resistive shorts, leakages, low breakdown voltages and Icc failures.

R1-1.5.3 *CDM ESD Damage*

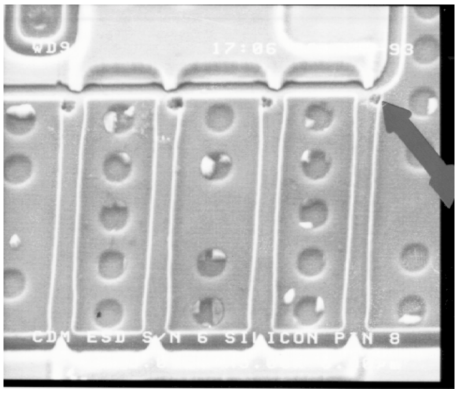

Figure R1-3
Example of CDM Damage

In the above CDM example (refer to Figure R1-3), the gate oxide damage is seen as a unique failure signature beyond the input protection structures at an internal location of the die. Most often the oxide failure is located beneath the poly at the field oxide edge, or is located at the poly edge adjacent to the source/drain junction. To date all CDM ESD damage has been found in the gate oxide at the input buffer circuitry.

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R1-2 Enhanced Particle Deposition Attributable to Electrical Charge on a Wafer

Contributed by Douglas W. Cooper, Ph.D., The Texwipe Company, Upper Saddle River, NJ 07458.

R1-2.1 *Introduction* — The presence of excess electrical charge on a wafer can create an electrostatic field that will lead to accelerated deposition of particles onto the wafer. This undesirable consequence is but one of several threats to product yield posed by the presence of excess electrical charge on a wafer. Sections R1-1 and R1-3 of this related information discuss two other important and potentially damaging consequences of surface charge.

The purpose of the discussion in this section is to estimate the magnitude of electrostatic field that can be tolerated before electrostatically enhanced particle deposition becomes the dominant particle deposition mechanism. Over the particle size range 0.01 to 0.3 µm, diffusion is the dominant, non-electrostatic mechanism of particle deposition. Thus, values of electrostatic fields that do not produce particle deposition velocities greater than those attributable to particle diffusion will be deemed tolerable. A set of such values calculated under a specific and very restrictive set of conditions are presented in this section.

R1-2.2 *Theoretical Background* — Although there are numerous electrostatic interactions between particles and surfaces, the dominant one is almost always the "Coulombic" interaction: the attraction (or repulsion) of a charged particle by a charged surface. This is the only electrostatic effect considered here.

For particles of one diameter, d, and one charge, q, the particle deposition flux, j, (the number of particles deposited per unit area per unit time) is the product of aerosol particle number concentration, c; particle charge, q; the electric field created by the charged wafer, E; and particle mechanical mobility, B (terminal velocity per unit external force):

$$j = cqEB \qquad (1)$$

The group qEB is the "electrostatic deposition velocity", v_{elect}

$$v_{elect} = qEB = j/c \qquad (2)$$

The variables q and E are those containing the electrical parameters that affect the magnitude of v_{elect}; B depends on particle diameter but not electrical properties.

It is the v_{elect} values that will be calculated for comparison with those of v_{diff} , the particle deposition velocity attributable to particle diffusion. Values of E for which $v_{elect} < v_{diff}$ will be those deemed tolerable in wafer manufacturing.

Note that the total number of particles, N, deposited on a wafer, obtained by integrating Equation (1) over the wafer area, A, and the time of exposure, t, depends on c as well as the deposition velocity:

$$N = cqEBAt \text{ or } N / A = ctv_{elect} \qquad (3)$$

Reducing c obviously reduces N, but the relative importance of the differing deposition mechanisms and the values of the deposition velocities associated with these mechanisms are assumed to not depend upon c, at least to a first-order approximation (see, for example, Peters and Cooper, 1991).

R1-2.2.1 *Effect of the Particle Charge, q* — There are many charging and discharging mechanisms for particles, so q is hard to predict and likely to be highly variable. In a normal atmosphere the positive and negative air ions tend to have roughly equal effectiveness in charging particles, so that the number of positively charged particles is roughly equal to the number of negatively charged particles. Thus, about half the particles will be attracted and half repelled by a net charge on the wafer. Special circumstances, such as corona discharge ionizers that are not balanced, could alter this conclusion. Without ionizers, cleanrooms tend to have relatively low levels of ions compared to the outdoor or other indoor atmospheres, because the HEPA/ULPA filters efficiently remove ions from the recirculating air.

A Boltzmann charge equilibrium, the charge distribution approximated by aerosol particles exiting a radioactive neutralizer, is a plausible *lower limit* for particle charge and will be assumed in the calculations of v_{elect}, using an improved version of this distribution developed by Fuchs (1964). *Upper limits* on particle charge are determined by ion emission limits or, in the case of water droplets, the Rayleigh limit. However, assuming higher particle charge distributions usually means that $v_{elect} > v_{diff}$ for virtually any value of $E > 0$ and that the only method for avoiding electrostatically enhanced particle deposition is to reduce wafer charge to zero. Thus, the Fuchs charge distribution will be assumed in calculating v_{elect} even though it represents the most favorable particle charge distribution for minimizing electrostatically enhanced particle deposition. Under many practical circumstances the particle charge will be greater and the maximum tolerable electrostatic field will be lower than that calculated for the Fuchs charge levels.

R1-2.2.2 *The Electrostatic Field, E, Induced by the Wafer Surface Charge* — The electrostatic field will depend on the charge on the wafer divided by a quantity with the units of length squared; either a distance squared (far from the wafer) or an area (close to the wafer) or some combination at intermediate distances. While field is not properly measured as a voltage, measuring the voltage, V, at a fixed distance, s, from the wafer allows inferring the field from V/s and the appropriate geometric and dimensional factors. The electrostatic field to be used in Equation (2) can be estimated from the ratio of the wafer charge to the wafer surface area, or the average field near the surface at the center, E_0.

Very far from the wafer, many wafer diameters away, the field created by the net wafer charge, Q, will be similar to that from a point charge:

$$E_1 = k_1 \; Q/r^2 \qquad (4)$$

where k_1 depends on the system of units used; and r is the distance from the center of the wafer to the particle.

Very close to the wafer, a fraction of a wafer diameter away, the field created by the net wafer charge is:

$$E_2 = k_2 \; Q'/r^2 \qquad (5)$$

where Q' is the net wafer charge, assumed to be uniformly distributed, contained within the intersection of a sphere of radius, r, and centered on the point of the wafer closest to the particle.

This equation indicates that the charge distribution on the wafer can make a difference close to the wafer. For an insulating wafer with a uniform charge and a radius, R:

$$E_2 = E_0 = k_2 \; Q/\pi R^2 \quad (6)$$

at a distance $r = R$ from the center of the wafer.

For a conductive wafer, or for a wafer with localized regions of charge, the electric field will vary over the surface, causing greater and lesser deposition velocities. A conductive wafer will have the charge concentrated near the edges, producing a relatively high field there and much lower fields as the center is approached.

Note that both E_1 and E_2 are proportional to Q and therefore, other variables being equal, electrostatic deposition is expected to be proportional to Q. Thus, the criterion to be specified is not the tolerable charge on the wafer but the tolerable electrostatic field near the wafer surface (such as that evaluated at a distance of one radius perpendicular to the wafer surface above its center), E_0. A maximum tolerable value of E_0 will be estimated by calculating the maximum E_0 values for which $v_{elect} < v_{diff}$, assuming a Fuchs distribution for the particle charge.

R1-2.3 *Tolerable Electrostatic Field*

R1-2.3.1 *Particle Deposition Velocity Attributable to Convective Diffusion (vdiff)* — In a microelectronics cleanroom, airflow is generally laminar ("unidirectional") downward at about 50 cm/sec (100 ft/min). If the flow is perpendicular to a surface, such as a wafer of diameter, *Dw*, a boundary layer forms across which particles diffuse to the surface. Liu and Ahn (1987) adapted the correlation of Sparrow and Geiger (1985) and obtained a correlation for the average diffusive deposition velocity as:

$$v_{diff} = 1.08 \, Sc^{1/3} Re^{1/2} D^{*}/D_w \quad (7)$$

where $Sc = \mu/\rho D^{*}$ is the Schmidt Number

μ is the gas viscosity

ρ is the gas density

and $D^{*} = kTB$ is the particle diffusivity

k is the Boltzmann constant

T is the absolute temperature and

B is the particle mobility

and $Re = \rho U D_w / \mu$ is the Reynolds number

U is the gas velocity and

D_w is the wafer diameter

Bae et al. (1994) reviewed the experimental work of others and presented their own, supporting this correlation; Cooper et al. (1990) obtained a similar equation by a somewhat different method. Oh et al. (1996) summarized prior experimental and theoretical work and extended the numerical analysis with a turbulent transport properties model, finding a small increase in deposition for the conditions modeled. These authors' publications support the approximation that the diffusional deposition velocity is about 0.006 cm/sec at particle diameter of 0.25 µm and about 0.03 cm/sec at particle diameter of 0.01 µm, or:

$$v_{diff} = (0.03 \; cm/sec)/(d/0.01 \; \mu m)^{1/2} \quad (8)$$

for $0.01 \; \mu m \le d \le 0.3 \; \mu m$ in cleanroom air.

R1-2.3.2 *Particle Deposition Velocity Attributable to Electrostatic Forces (v_{elect})* — Using a power law to approximate the Fuchs particle charge distribution yields the following approximation for electrical mobility (Cooper et al., 1990):

$$Z = qB = (0.002 \; cm/s)/(d/0.01 \; \mu m)(1 \; V/cm) \quad (9)$$

from which the deposition velocity attributable to electrostatic forces becomes:

$$v_{elect} = (0.002 \; cm/s)[E_0/(V/cm)]/(d/0.01 \; \mu m) \quad (10)$$

Setting $v_{elect}/v_{diff} = 1$ results in the following expression for tolerable E_0:

$$[(E_0/(V/cm)] = 15 \; [d/(0.01 \; \mu m)]^{1/2} \quad (11)$$

Table R1-2 lists the values of tolerable electrostatic field adjacent to a wafer surface as calculated from Equation (11). Note that the electrostatic fields are calculated at a distance of one wafer radius from the center of the wafer. E_0 is the value of electric field at which electrostatically enhanced particle deposition is estimated to match the particle deposition velocity attributable to diffusion, assuming a Fuchs charge distribution on the particles. This charge distribution represents a minimal particle charge. With most particle charge distributions to be encountered in practice, even lower values of electrostatic fields will produce enhanced deposition. A safe conclusion is that there is no safe value of electrostatic field that will avoid enhanced particle deposition unless neutralization of particle charge has been achieved, in which case the very modest values of electrostatic fields calculated from Equation (11) and tabulated in Table Rl-2 should be tolerable.

Table R1-2 Tolerable Levels of Electrostatic Field at a Distance of One Radius from the Center of a Wafer, Assuming a Fuchs Charge Distribution on the Particles

Minimum Particle Diameter d in µm	*Tolerable Field E_0, in Volts/cm*
0.01	15
0.02	21
0.03	26
0.05	34
0.10	47
0.20	67

0.30	82

R1-2.4 *Conclusions* — As indicated in Table R1-2, the calculated value of tolerable electrostatic field (the value of electrostatic field above which electrostatic particle deposition becomes the dominant mechanism of particle deposition) is just 47 V/cm for particles of 0.1 µm diameter when the particle electrical charge is that described by the Fuchs charge distribution, a minimum value of particle charge that is normally exceeded in most environments. In most realistic environments the particle charge will be greater and the tolerable electrostatic field, even lower. Hence the conclusion that in all practical processing environments electrical forces will be the dominant mechanism of particle deposition on wafers.

In a Federal Standard 209E Class 1 environment ($c \leq$ 0.00124 particles/cm^3) with v_{elect}, ~ 0.01 cm/s (the value predicted by Equation 10 for a 0.1 µm particle in an electric field of 47 Volts/cm) the target areal particle densities (N/A = 0.016 particles/cm^2 for the 0.25 µm technology of 1998) specified in the National Technology Roadmap for Semiconductors (NTRS, 1994) will be reached after an exposure time of about 1300 seconds, assuming c is at its maximum allowed concentration.

With less favorable electrical conditions, or higher particle concentration, the maximum allowed exposure time becomes shorter. In addition, the target values for N/A continue to decrease with each technology generation. Fortunately, one or more of the parameters, particle concentration in the ambient, the charge level on a surface, or the time a charged surface is exposed to a given particle ambient, can be controlled.

Charge Neutralization — Achieving the Fuchs charge distribution by means of radioactive isotopes or balanced corona neutralizers — is the first step in controlling particle deposition on wafers. This step, while clearly necessary, is unlikely to be sufficient to guarantee meeting the NTRS requirements of the future. Steps to minimize environmental particle concentration, c, and time of exposure, t, will have to be part of the strategy for creating acceptable processing environments. Minimizing these variables reduces particle deposition attributable to all mechanisms, not just electrostatic deposition.

Contemporary standards recognize the need for reduced particle concentrations in wafer environments. For example, the classification ISO Class 1 (of the proposed international standard for classifying cleanrooms according to concentration of airborne particulate cleanliness) describes an environment in which the concentration of particles > 0.1 µm is 10^{-5} particles/cm^3 or less. In an environment of this quality, wafer exposure can be as long as 10^5 seconds at the deposition velocity predicted for neutralized 0.1 µm particles (~0.01 cm/s) and still meet the target defect density that the NTRS recommends for the 0.1 µm technology anticipated in 2007. Fractional increases in the electric field above 47 Volts/cm will decrease the allowed exposure time by that same fraction (Equations 10, 12) — an electric field of 94 Volts/cm reduces the allowed exposure time to 5×10^4 seconds, etc.

R1-2.5 *References*

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R1-2.6 *Experimental Reference*

Deposition of 0.1 to 1.0 Micron Particles, Including Electrostatic Effects, onto Silicon Monitor Wafers (Experimental)

William J. Fosnight, Vaughn P. Gross, Kenneth D. Murray, Richard D. Wang, IBM Corporation published in 1993 Microcontamination Conference proceedings

Summary: Submicron particle contamination continues to be a concern in the manufacture of integrated circuits. Quantifying particle deposition velocity (the ratio of particle deposition rate to airborne particle concentration) is of fundamental importance in understanding the defect-density impact of airborne contamination.

As particle size decreases, the effect of electrostatic charge plays an increasing role in the deposition of particles onto surfaces. This four-trial study examines the deposition of 0.1 to 1.0 micron particles onto horizontal, grounded and electrostatically charged, silicon monitor wafers in an 80 feet per minute vertical unidirectional airflow. The experimental deposition velocity results were compared to theoretical predictions found in the literature.

Three primary observations were obtained from this study. First, measured values of deposition velocity agreed reasonably well with predicted values. However, deposition velocity was not observed to increase below 0.2 micron. Secondly, particles less than 0.5 micron were observed to deposit onto charged wafers approximately three to ten times faster than onto grounded (not charged) wafers. Finally, settling monitor wafers may be a time consuming (and expensive) means of certifying the cleanliness of a "clean" (less than 10 ppcf at scanner threshold particle size) environment. However, settling-monitor studies should not be confused with particles-per-wafer-pass (PWP) measurements; PWP measurements often provide useful information regarding the performance of the automation and/or process of a tool, even if it is in a very clean environment.

R1-3 ESD Impacts in Semiconductor Equipment

Contributed by Julian A. Montoya, Intel Corporation, 5200 NE Elam Young Parkway, Hillsboro OR, 97124-6497.

R1-3.1 *Introduction* — Electrostatic phenomena impact semiconductor manufacturing in many ways. These range from increased particle accumulation on wafer surfaces to electrostatic discharge (ESD) events which impact equipment performance, and in some cases impact factory yields and throughput.

All areas within a semiconductor manufacturing environment must be concerned with electrostatic control. This encompasses initial wafer receiving to shipping of final product. In addition, the equipment which will be housed within that environment must also be concerned with electrostatic control and electrostatic immunity.

This section highlights issues associated with static charge and ESD in a semiconductor manufacturing environment and its effects on production equipment.

R1-3.2 *Overview* — Static charge issues in semiconductor manufacturing manifest themselves in many ways. Problems occur by direct contact with charged items, by induction from electrostatic fields, and indirectly by radiated and conducted electromagnetic interference (EMI) emitted into the environment as a result of the ESD event.

R1-3.3 *Equipment ESD Examples* — The following section presents real world examples of the cause and impacts associated with electrostatic discharge and semiconductor manufacturing equipment.

R1-3.3.1 Charged operators came into direct contact with diffusion furnace control panel. Process aborted on many occasions resulting in loss of product and reduced equipment utilization.

R1-3.3.2 Numerous instances where charged reticles (photomasks) came into direct contact with a grounded object. This caused damage to reticles and impacted factory throughput. Costs were associated with replacing damaged reticles and requalifying reticle sets.

R1-3.3.3 Charged operators came into direct contact with electronic card cage of chemical vapor deposition tool. This resulted in process abort, loss of product, and reduced equipment availability.

R1-3.3.4 Charged wafer cassette induced charge onto robot arm on wafer transfer tool. Robot arm came into contact with grounded screw creating an ESD event. This resulted in data corruption which caused robot arms to open, dropping fully loaded wafer cassettes to the floor. Costs were associated with loss of product.

R1-3.3.5 Automated material handling system "car" became charged while coming in close proximity to ionizer. Car came into contact with grounded object during charging; creating data corruption which resulted in system downtime, impact to factory throughput, and cost associated with the replacement of control electronics.

R1-3.3.6 Wafer taping/detaping tool generated charge during normal operation. Chassis ground of the tool was inadvertently removed, causing high charge to be developed within the tool. Electrostatic Discharge occurred at random time intervals within the tool. Impact to equipment availability, and long solution time.

R1-3.3.7 Wafers became charged during spin rinse process. During transfer to wafer metrology tool electrostatic discharge occurred, causing data corruption. This resulted in unexpected tool lockups, and reduced equipment availability.

R1-3.3.8 Ungrounded wall panels became charged and generated ESD events. EMI produced from ESD events coupled into photolithography equipment and created data corruption. This resulted in impacts to equipment utilization. Long solution time.

R1-3.3.9 Insulative ceiling panels became charged and generated ESD events which produced high levels of radiated and conducted EMI in a test area. EMI coupled into tester/handler and produced data scramble. This resulted in reduced equipment availability.

R1-3.3.10 Finished product became charged during manual handling. Product came into direct contact with test/handler equipment. This resulted in damaged circuit cards which needed to be replaced, and decreased equipment availability.

R1-3.3.11 Wafer transfer cart became charged while rolling over temporary "insulative" floor. Cart came into contact with plasma etcher control cabinet. Resulting ESD event caused product loss and reduced equipment availability.

R1-3.3.12 Wafer polisher robot arm became charged during normal operation. Chassis ground wire for robot left off. ESD event occurred causing data scramble which resulted in process being aborted.

R1-3.4 *Conclusion* — Electrostatic Discharge (ESD) affects semiconductor manufacturing equipment in many ways. The issues are wide ranging from trivial lock-ups and aborts of process equipment to factory throughput and yields impacts. The scope of the ESD problem is very broad and encompasses every aspect of semiconductor manufacturing.

RELATED INFORMATION 2
STATIC CONTROL METHODS

NOTE: This related information is not an official part of SEMI E78 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

R2-1 Static Charge Control

It is usually impossible to totally eliminate static electricity from work areas, but with proper use of equipment and remedial procedures, most static problems can be controlled. Many approaches to controlling static charge have been tried over the years and it is clear that there exists no single method for controlling all static charge problems.

R2-2 Grounding Conductors and Static Dissipative Materials

An important consideration in selecting a method is whether the charged material is a conductor or an insulator. Static dissipative materials are created by lowering the resistivity of insulating materials through the addition of metal or carbon particles, or other chemical additives. Static charge on a conductive or static dissipative object can be easily controlled if the object is provided with a path for the charge to flow to earth ground. While charge is mobile in a conductor (or in a static dissipative material), in insulators charge is not mobile, and earth grounding is not an effective means of eliminating the static charge.

Equipment manufacturers can use both conductive and static dissipative materials to reduce the presence of static charge. If there is a path for the charge to flow to earth ground, the static charge on equipment, and materials handled by the equipment, can be rapidly, and harmlessly, neutralized. Obviously, the success of earth grounding depends on maintaining the integrity of the ground path. This is sometimes a problem when high-speed, moving parts of equipment must be connected to earth ground.

Static dissipative materials will need to retain their dissipative properties over the range of temperature and humidity conditions they will encounter, and not change significantly over time. In cleanrooms they must also meet requirements for avoiding micro-particle production and outgassing. As long as the ground connection is maintained, these "passive" procedures offer reasonable protection to the equipment and product from sources of static charge.

Unfortunately, these methods do not provide complete protection from static-related problems. Even when earth grounding is an option, it is subject to human error. In applications where contamination is an issue, additives and carbon particles used in static-dissipative materials may become sources of contamination themselves. When earth grounding or the use of dissipative materials is either inappropriate or not cost effective, ionization can be used.

R2-3 Ionization

More often than not, the product itself uses insulating materials, making earth grounding unavailable as an option. While silicon is a semiconductor, its oxide coating transforms it into an insulator. Teflon is used in many chemical processes, and quartz in high temperature processes. Epoxy and ceramic packages are used for integrated circuits. Insulators are easily charged, retain their charge for long periods of time, and are often close to the product. Dealing with static charge on insulators and isolated conductors will often require the use of some type of ionization. Ionizers are the most effective means of dealing with static charges on insulators and isolated conductors.

For purposes of static charge control, ions are molecules of the gases in air (nitrogen, oxygen, water vapor, and carbon dioxide) that have lost or gained an electron. Ions are present in normal outside air but are removed when air is subjected to filtration and air conditioning. Ionization systems work by increasing the conductivity of the air with the ionized gas molecules. When ionized air comes in contact with a charged surface, the charged surface attracts ions of the opposite polarity. As a result, the static electricity that has built up on products, equipment and surfaces is neutralized.

The most common methods of producing air ions are radioisotopes and "corona discharge" resulting from the electric field created when high voltage is applied to a sharp point.

The radioisotope most commonly used to produce ionization is Polonium^{210}, an alpha particle emitter. The alpha particle collides with the surrounding gas molecules, dislodging electrons, which results in pairs of positive and negative ions.

The corona discharge method produces a very high electric field that interacts with the electrons in the surrounding gas. The polarity of the ions depends on the polarity of the high voltage on the emitter point. Ions of opposite polarity to the charged surface are required. Either polarity of static charge may be created in the equipment or on the product.

Ionizers in equipment must deliver ionization over a wide range of humidity and temperature conditions. Back-end assembly and test areas often do not have the level of temperature and humidity control found in front-end wafer production. Ionizers installed in the cramped spaces of production equipment will be close to the product, in areas surrounded by grounded metal parts. Ionizers should isolate the emitter points from both the product and adjacent grounded surfaces. Ionizers should produce sufficient ions to discharge static on surfaces and products moving at high speeds despite losses to ground. Most ionizers require maintenance and periodic verification of their performance.

R2-4 Problem of Controlling Static Charge in Manufacturing Equipment

The interior of high speed production equipment presents a challenge to most static control methods. The cost of production space is high and requires that equipment occupying the space be compact and operate at as high a speed as practical. Product is moved through small spaces at high speed by a variety of robotic and other mechanisms. Triboelectric charging (charge generation due to friction or contact and separation of dissimilar materials) and contact with ground are almost unavoidable. Grounding of equipment parts that contact the product presents added difficulties when the equipment parts are moving at high speeds. Dissipating charge from insulating surfaces and integrated circuit (IC) packages may be difficult if the charged surfaces are not accessible. Using ionizers in these confined spaces presents challenges.

SEMI

SEMI E79-0200
STANDARD FOR DEFINITION AND MEASUREMENT OF EQUIPMENT PRODUCTIVITY

This standard was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org February 2000; to be published February 2000. Originally published February 1999.

NOTE: This document was rewritten in its entirety in 2000.

1 Purpose

1.1 The document provides metrics for measuring equipment productivity.

2 Scope

2.1 The document defines metrics and calculations for measurement of equipment productivity.

2.2 In the context of this document, it is important to note that "equipment productivity" is impacted greatly by factors far beyond the equipment itself, including (operator, recipe, facilities, material availability, scheduling requirements, etc.).

2.3 Effective application of this standard requires that equipment performance is tracked using the metrics for Equipment Reliability, Availability, and Maintainability (RAM) established in SEMI E10. Additionally, the Automated Reliability, Availability, and Maintainability Standard (ARAMS) SEMI E58 can be used for equipment with ARAMS capability. Productivity metrics for flexible-sequence cluster tools require tracking of SEMI E10 equipment states and recipes at the level of individual processing modules. Productivity performance of a flexible-sequence cluster tool is then calculated as the aggregate productivity performance of its individual processing modules.

2.4 This document is currently limited to measuring equipment productivity using Overall Equipment Efficiency (OEE) as the metric, and does not address the impact of productivity changes on cost, cycle time, or other measures. This document does not address any RAM issues over and above those in SEMI E10.

2.5 The previous SEMI E79 Standard (SEMI E79-0299) defined measurement of an Overall Equipment *Effectiveness* metric. In this revision of SEMI E79, the Overall Equipment Effectiveness metric has been renamed Overall Equipment *Efficiency*. The important differences include (1) the efficiency metric is expressed entirely in terms of time, while the effectiveness metric involved both factors expressed in terms of time and factors expressed in terms of production units, and (2) the efficiency metric is applicable to flexible-sequence cluster tools, while the effectiveness metric was not. The Overall Equipment Efficiency metric is a better estimate measure of true equipment efficiency, and it is applicable for the efficiency assessment of all semiconductor processing equipment.

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E38 — Cluster Tool Module Communications (CTMC)

SEMI E40 — Standard for Processing Management

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

3.2 *Other Documents*

CSM 21: Closed-Loop Measurement of Equipment Efficiency and Equipment Capacity; Engineering Systems Research Center, University of California, Berkeley, 1997.

CSM 42: Productivity Metrics for Flexible-Sequence Cluster Tools; Engineering Systems Research Center, University of California, Berkeley, 1998.

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Terminology Applicable to Computation of the OEE Metric*

4.1.1 *actual unit output* (units) — the number of units processed by the equipment during production time.

4.1.2 *availability efficiency* (time divided by time) — the fraction of total time that the equipment is in a condition to perform its intended function.

4.1.3 *cluster tool* — a manufacturing system made up of integrated processing modules mechanically linked together (the modules may or may not come from the same supplier) (SEMI E10).

4.1.4 *downtime (equipment downtime)* (time) — the time when the equipment is not in a condition, or is not available, to perform its intended function. It does not include any portion of non-scheduled time (SEMI E10).

4.1.5 *effective unit output* (units) — the number of units processed by the equipment during production time that were of acceptable quality, i.e., actual unit output less equipment assignable rework and equipment assignable scrap.

4.1.6 *equipment-assignable rework* (units) — any units being reworked due to a fault or defect assignable to the subject equipment. The units may be reworked at the equipment where the fault or defect occurred, or at other equipment.

4.1.7 *equipment-assignable scrap* (units) — any units that are permanently removed from production due to a fault or defect assignable to the subject equipment. The units may be removed from production at the operation where the fault or defect occurred, or at a subsequent operation.

4.1.8 *fixed-sequence cluster tool* — a cluster tool in which all units of production visit all processing modules making up the tool in a fixed sequence (CSM 42).

4.1.9 *flexible-sequence cluster tool* — a cluster tool in which the units of production visit a subset of the processing modules of the tool in sequences that may vary from unit to unit. In such tools, the processing modules that are engaged in processing activity vary from unit to unit according to dispatching decisions made by software internal to the tool (CSM 42).

4.1.10 *non-scheduled time* (time) — time when the equipment is not scheduled to be used in production (SEMI E10).

4.1.11 *operational efficiency* (time divided by time) — the fraction of equipment uptime that the equipment is processing actual units.

4.1.12 *operations time* (time) — total time minus non-scheduled time (SEMI E10).

4.1.13 *overall equipment efficiency (OEE)* (time divided by time) — a metric of equipment performance, expressing the theoretical production time for the effective unit output divided by the total time (CSM 21).

NOTE 2: The overall equipment efficiency metric accounts for all losses that reduce equipment performance from its maximum potential performance taking the existing equipment design and recipe specifications as given.

4.1.14 *performance efficiency* (time divided by time) — the fraction of equipment uptime that the equipment is processing actual units at theoretically efficient rates.

4.1.15 *processing module* — an indivisible production entity within an equipment system, e.g., a processing chamber or station within a cluster tool.

4.1.16 *processing module recipe* — all processing steps of a recipe performed within a single processing module without requiring reloading of that processing module (CSM 42).

4.1.17 *production time* (time) — sum of all periods of time in which a processing module is performing its intended function. For a non-cluster tool, a fixed-sequence cluster tool or an individual processing module within a flexible-sequence cluster tool, production time is equivalent to the SEMI E10 productive time for that entity. For a flexible-sequence cluster tool, production time is the aggregate of the production times for all processing modules encompassed by the cluster tool (CSM 42).

4.1.18 *productive state* — a period of time (*production time*) when the equipment is performing its intended function (SEMI E10).

4.1.19 *quality efficiency* (time divided by time) — the theoretical production time for Effective Units divided by the theoretical production time for Actual Units.

4.1.20 *rate efficiency* (time divided by time) — the fraction of production time that equipment is processing actual units at theoretically efficient rates.

4.1.21 *recipe* — the pre-planned and reusable portion of the set of instructions, settings, and parameters under control of a processing agent that determines the processing environment seen by the material. *Recipes* may be subject to change between runs or processing cycles (SEMI E38, SEMI E40, SEMI E42).

4.1.22 *theoretical production time per unit (THT)* (time per unit) — for a given production recipe performed by a given processing module, the minimum time to complete processing on one unit of production assuming no efficiency losses are present. The determination of theoretical production time per unit is based on continuous operation of the processing module, where the module is assumed to operate in an ideal condition. For equipment cycles that simultaneously process more than one unit, theoretical production time per unit is the minimum time to perform the cycle on an equipment load whose size is optimized for throughput divided by the number of units in that optimized load (CSM 21, CSM 42).

NOTE 3: Theoretical production time per unit varies by recipe.

4.1.23 *theoretical production time* (time) — production time during a period that is theoretically required to complete the unit quantities of the production recipes undertaken during the period. Theoretical production time is computed as the aggregation over all recipes of the theoretical production time per unit for the recipe applied to the unit quantity of that recipe (CSM 21, CSM 42).

NOTE 4: For flexible-sequence cluster tools, theoretical production time is the aggregate of the theoretical production times for the set of processing modules.

4.1.24 *theoretical unit throughput by recipe* (units per time) — for a given production recipe, the number of units per period of time that theoretically could be processed by the equipment. For each recipe, theoretical unit throughput is equal to the reciprocal of theoretical production time per unit.

4.1.25 *total time* (time) — all time (at the rate of 24 hours per day, seven days per week) during the period being measured. In order to have a valid representation of *total time* all six basic equipment states must be accounted for and tracked accurately (SEMI E10). For a flexible-sequence cluster tool, total time is defined as the aggregate total time of the set of processing modules encompassed by the cluster tool (CSM 42).

4.1.26 *unit* — any wafer, die, packaged device, or piece part thereof (includes product and non-product units) (SEMI E10).

4.1.27 *uptime (equipment uptime)* (time) — the hours when the equipment is in a condition to perform its intended function. It includes *production, standby, and engineering time,* and does not include any portion of *non-scheduled time* (SEMI E10). For a flexible-sequence cluster tool, uptime is defined as the aggregate uptime of the set of processing modules encompassed by the cluster tool (CSM 42).

4.1.28 *virtual machine* — an individual processing module within a flexible-sequence cluster tool, in combination with the transport module(s) serving that processing module. A flexible-sequence cluster tool has one virtual machine defined for each of its processing modules (CSM 42).

4.2 *Terminology Applicable to Computation of Additional Productivity Metrics Defined in Appendix 2*

4.2.1 *demand equipment efficiency (DEE)* (time divided by time) — a measure of equipment productivity during the time that products are planned to be available to process at the equipment.

NOTE 5: *DEE* is based on theoretical production time for effective units and the portion of operations time that excludes planned no product time. A factory model or production schedule that defines the expected or planned idle time at the equipment is required to calculate *DEE.*

4.2.2 *engineering overall equipment efficiency (E-OEE)* (time divided by time) — a measure of equipment productivity assuming process specifications are optimized for minimum production time.

NOTE 6: *E-OEE* is based on the *engineering theoretical production time per unit* and *total time.*

4.2.3 *engineering theoretical production time per unit (ETHT)* – (time per unit) – the theoretical time required to process a given recipe assuming the recipe specification is optimized for minimum production time. *ETHT* is based on minimum durations for the objective processing steps, e.g., implant time for ion implant systems, plus minimum allowances for any additional supporting process steps, e.g., heating, cooling, gas stabilization, that are deemed absolutely necessary.

NOTE 7: *ETHT* must be defined to be less than or equal to the corresponding *theoretical time per unit (THT)* used in calculating *OEE.*

4.2.4 *equipment down no product time* (time) — the period of *equipment downtime* during which there are no units available at the equipment to process.

4.2.5 *intrinsic equipment efficiency (IEE)* (time divided by time) — a measure of equipment productivity that considers the combined effect of rate efficiency losses, recipe design, and equipment design.

NOTE 8: *IEE* is based on *value-added in-process theoretical production time for actual units* and *production time*.

4.2.6 *no product time* (time) — the period of *standby time* that the equipment is idle because there are no units available at the equipment to process.

4.2.7 *planned no product time* (time) — the period of *operations time* that the factory model or production schedule expects the equipment to be idle because there are no units available to process at the equipment.

4.2.8 *production equipment efficiency (PEE)* (time divided by time) — a measure of equipment productivity during the time that products are available to process at the tool.

NOTE 9: One application of *PEE* is to measure the productivity of non-constraint tools that are expected to have periods of idle time due to lack of available work. *PEE* is based on *theoretical production time for effective units* and the portion of *operations time* that excludes *no product time* and *equipment unavailable no product time*.

4.2.9 *reference overall equipment efficiency (R-OEE)* (time divided by time) — a measure of equipment productivity relative to a benchmark theoretical production time.

NOTE 10: R-OEE is based on the reference theoretical production time per unit and total time.

4.2.10 *reference theoretical production time per unit (RTHT)* (time per unit) — the theoretical time required to process a given recipe on benchmark equipment (i.e., the fastest equipment model of similar type), for a benchmark product and process design.

NOTE 11: *RTHT* must be defined to be less than or equal to the corresponding *theoretical time per unit* (*THT*) used in calculating *OEE*.

4.2.11 *value-added in-process overall equipment efficiency (VA-OEE)* (time divided by time) — a measure of equipment productivity assuming all time except the value-added portion of processing cycles is wasted equipment time.

NOTE 12: *VA-OEE* is based on the *value-added in-process theoretical production time per unit* and *total time*.

4.2.12 *value-added in-process theoretical production time per unit (VTHT)* (time per unit) — theoretical production time per unit that credits only the objective processing steps that add value to products.

NOTE 13: *VTHT* must be defined to be less than or equal to *engineering theoretical production time per unit* (*ETHT*) used in calculating engineering OEE (*E-OEE)*.

5 Equipment Productivity Measurement

5.1 The OEE calculation has been stated in terms that are consistent with SEMI E10. Reference may be made to Figure 1.

5.1.1 Figure 2 indicates how total time may be divided into portions representing theoretical production time for effective units and various sources of productivity loss. The domain for productivity improvement of all losses except operational efficiency is shared between the equipment supplier and equipment user. Productivity improvement of operational efficiency is the exclusive domain of the equipment user.

5.1.2 The formulas introduced in this section require as inputs the following fundamental quantities: total time, equipment uptime, production time, and theoretical production time. Sample calculations for each of the formulas are provided in Appendix 1.

5.1.3 For efficiency measurement of individual processing modules or of fixed-sequence cluster tools, the fundamental quantities may be tallied in a straightforward manner, and consequently the formulas of this section may be applied in a straightforward fashion.

5.1.4 For efficiency measurement of flexible-sequence cluster tools, determination of the fundamental quantities requires more involved calculations. Formulas are provided in Section 6 for computing the fundamental quantities for flexible-sequence cluster tools. These fundamental quantities then may be used as inputs to the formulas of this section to compute the efficiency of a flexible-sequence cluster tool.

5.1.5 Additional supplemental efficiency metrics that will enable users to assess more specific aspects of equipment productivity are:

- Reference OEE,
- Engineering OEE,
- Value-Added In-Process OEE,
- Demand Equipment Efficiency,
- Production Equipment Efficiency, and
- Intrinsic Equipment Efficiency.

Definitions and formulas for these metrics are presented in Appendix 2.

5.2 *Overall Equipment Efficiency (OEE)* — The fraction of total time that equipment is producing effective units at theoretically efficient relates

Overall Equipment Efficiency (OEE)
= (Theoretical Production Time for Effective Units)
÷ (Total Time)
= (Availability Efficiency) X (Performance Efficiency)
X (Quality Efficiency)

5.2.1 *Availability Efficiency* — The fraction of total time that the equipment is in a condition to perform its intended function.

Availability Efficiency =
(Equipment Uptime) ÷ (Total Time)

5.2.2 *Performance Efficiency* — The fraction of equipment uptime that the equipment is processing actual units at theoretically efficient rates.

Performance Efficiency =
(Operational Efficiency) X (Rate Efficiency)

5.2.2.1 *Operational Efficiency* — The fraction of equipment uptime that the equipment is processing actual units.

$$\textit{Operational Efficiency} = (\textit{Production Time}) \div (\textit{Equipment Uptime})$$

5.2.2.2 *Rate Efficiency* — The fraction of production time that equipment is processing actual units at theoretically efficient rates.

$$\textit{Rate Efficiency} = (\textit{Theoretical Production Time for Actual Units}) \div (\textit{Production Time})$$

5.2.2.3 *Theoretical Production Time (for Actual Units or for Effective Units)* — Production time (for actual units or for effective units) during a period of observation that is earned at strictly theoretically efficient rates and assumes no efficiency losses.

$$\textit{Theoretical Production Time for Actual Units} = \Sigma_I (\textit{Actual Units of Recipe I x } THT_I)$$

$$\textit{Theoretical Production Time for Effective Units} = \Sigma_I (\textit{Effective Units of Recipe I x } THT_I)$$

where

THT_I = *theoretical production time per unit of recipe$_I$*

NOTE 14: Theoretical Production Time (for actual units or for effective units) may be calculated in terms of theoretical unit throughput by recipe.

$$\textit{Theoretical Production Time for Actual Units} = \Sigma_i (\textit{Actual Units of Recipe i} \div UPH_i)$$

$$\textit{Theoretical Production Time for Effective Units} = \Sigma_i (\textit{Effective Units of Recipe} \div UPH_i)$$

where

UPH_i = *theoretical unit throughput by recipe of recipe i*

5.2.3 *Quality Efficiency* — The theoretical production time for Effective Units divided by the theoretical production time for Actual Units.

$$\textit{Quality Efficiency} = (\textit{Theoretical Production Time for Effective Units}) \div (\textit{Theoretical Production Time for Actual Units})$$

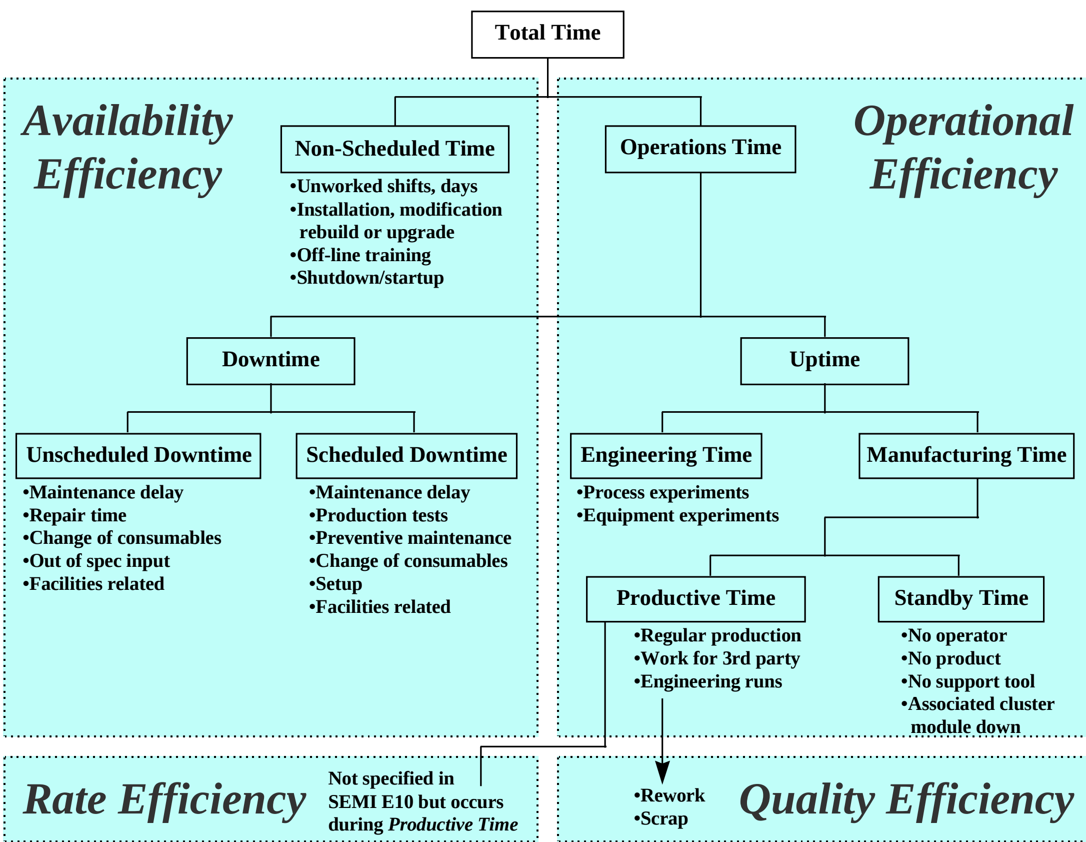

Figure 1
The Relationship Between SEMI E10 and OEE

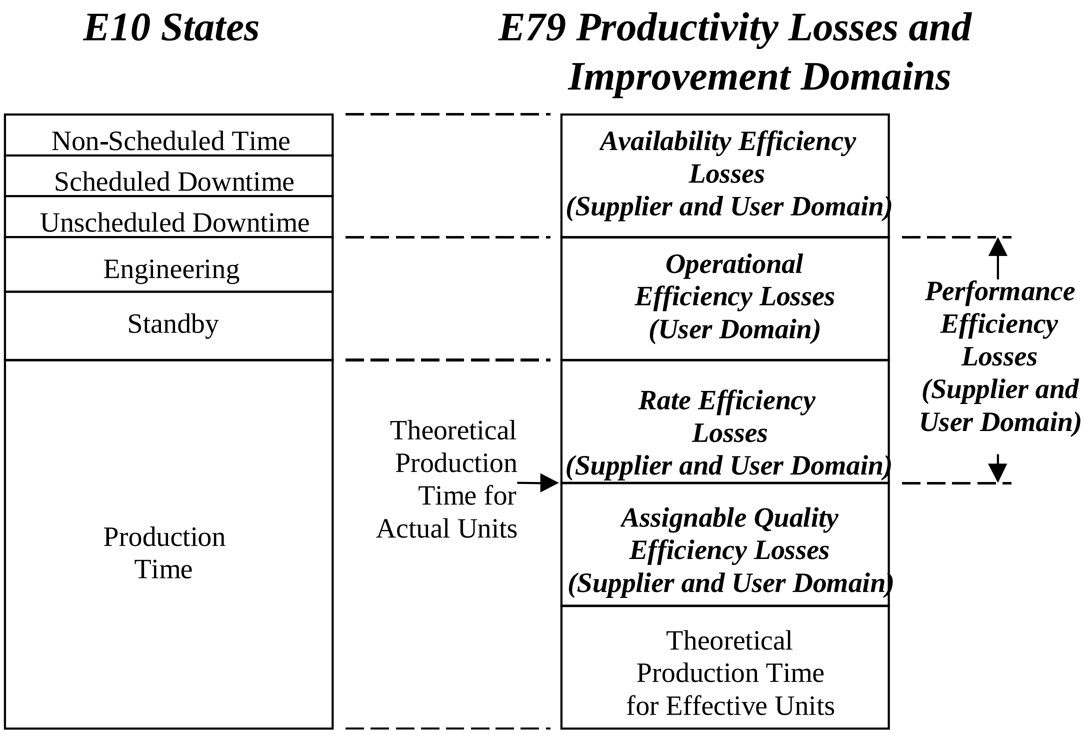

Figure 2
Stack Chart of Productivity Losses and Improvement Domains

6 Flexible-Sequence Cluster Tools

6.1 This section provides definitions and formulas applicable to flexible-sequence cluster tools for computing the following fundamental quantities: theoretical production time, production time, equipment uptime and total time. These quantities serve as inputs to the formulas of Section 5 for efficiency measurement.

6.1.1 Flexible-sequence cluster tool productivity is measured at the individual processing module level of detail according to a virtual machine model described in this section. Productivity performance for the entire flexible-sequence cluster tool is then calculated as the aggregate productivity performance of its individual processing modules.

NOTE 15: Evaluation of flexible-sequence cluster tool productivity does not necessarily apply to the evaluation of flexible-sequence cluster tool RAM.

6.2 *Virtual Machine Model*

6.2.1 A virtual machine is an individual processing module in combination with the transport mechanisms that serve that processing module. When a transport mechanism is engaged in a material handling operation that does not involve a particular processing module, it is not considered to be operating as part of the virtual machine defined for that processing module.

6.2.2 Theoretical production time per unit for a recipe is the sum of theoretical times for all required operational elements:

- Wafer loading,
- Elements occurring within a process module, and
- Wafer unloading.

6.2.2.1 Where appropriate, a combined loading and unloading time may be replaced with a single theoretical value for a *wafer exchange*.

6.3 *Fundamental Quantities for Processing Modules and Flexible-Sequence Cluster Tools* — This section defines fundamental quantities that are evaluated for individual processing modules and flexible-sequence cluster tools as inputs to the formulas presented in Section 5.0. In each case, the fundamental quantity is determined for each individual processing module within a flexible-sequence cluster tool. The equivalent fundamental quantity for the flexible-sequence cluster tool is the sum of the quantities for the individual processing modules.

NOTE 16: It is recognized that application-specific interactions between processing modules within flexible-sequence cluster tools may impose varying amounts of standby time on the individual processing modules. This approach treats these interactions as standby losses for the flexible-sequence cluster tool and does not make any allowances for them in either production time or theoretical production time.

6.3.1 *Theoretical Production Time (for Actual Units and for Effective Units)*

6.3.1.1 *Processing Module Theoretical Production Time (for Actual Units and for Effective Units)* — Theoretical production time earned by an individual processing module according to the virtual machine model.

Processing Module
Theoretical Production Time for Actual Units =
Σ_i*[(Theoretical Production Time Per Unit*
for Processing Module Recipe i)
X (Actual Units of Processing Module Recipe i)]

Processing Module
Theoretical Production Time for Effective Units
=Σ_i*[(Theoretical Production Time Per Unit*
for Processing Module Recipe i)
X (Effective Units of Processing Module Recipe i)]

6.3.1.2 *Flexible-Sequence Cluster Tool Theoretical Production Time (for Actual Units and for Effective Units)* — Aggregate theoretical production time earned by all processing modules according to the virtual machine model.

Flexible-Sequence Cluster Tool
Theoretical Production Time for Actual Units
= Σ_j*(Theoretical Production Time*
for Actual Units for Processing Module j)

Flexible-Sequence Cluster Tool
Theoretical Production Time for Effective Units
= Σ_j*(Theoretical Production Time*
for Effective Units for Processing Module j)

6.3.2 *Production Time*

6.3.2.1 *Processing Module Production Time* — The sum of all periods of manufacturing time in which a processing module or the transport module serving that processing module are performing operations according to the virtual machine model. When SEMI E10 equipment states are tracked at the virtual machine level, processing module production time is equivalent to *E10 productive time*. Automated tracking is required for accurate results.

6.3.2.2 *Flexible-Sequence Cluster Tool Production Time* — Aggregate production time for all processing modules tracked according to the virtual machine model.

Flexible-Sequence Cluster Tool Production Time =
=Σ_j*(Production Time for Processing Module j)*

NOTE 17: In this quantity, elapsed times for transport operations that reposition units from one processing module to another are intentionally credited to both modules. Also note that this aggregate measure may be larger than the elapsed time observed and can only be compared with similar aggregate flexible-sequence cluster tool metrics.

6.3.3 *Equipment Uptime*

6.3.3.1 Equipment uptime is defined to measure the total time, during a period of observation, that a processing module or a flexible-sequence cluster tool is in a condition to perform processing in some form.

6.3.3.2 SEMI E10 defines equipment uptime as including E10 productive time, engineering time, and standby time. This definition applies to individual processing modules of a flexible-sequence cluster tool. For the flexible sequence cluster tool as a whole, production time is the sum of production times for the individual processing modules. This production time is used in lieu of productive time.

NOTE 18: This representation of flexible-sequence cluster tool equipment uptime is for productivity purposes only, and may not apply for the determination of flexible-sequence cluster tool RAM.

6.3.3.3 *Processing Module Equipment Uptime*

Processing Module Equipment Uptime =
Processing Module Production Time
+ Processing Module Engineering Time
+ Processing Module Standby Time

6.3.3.3.1 *Processing Module Engineering Time* — The sum of all periods of time in which a processing module is user-selected for the exclusive use of engineering product, process, and/or equipment experiments. Engineering time may be declared for one processing module without having to declare engineering time for all processing modules.

6.3.3.3.2 *Processing Module Standby Time* — The sum of all periods of manufacturing time not counted in production time, when the virtual machine is *capable* of starting new work.

6.3.3.4 *Flexible-Sequence Cluster Tool Equipment Uptime*

Flexible-Sequence Cluster Tool Equipment Uptime =
Σ_j*(Processing Module Equipment Uptime*
for Processing Module j)

6.3.4 *Total Time*

6.3.4.1 *Processing Module Total Time* — For individual processing modules, processing module total time is trivially defined as all time observed (at the rate of 24 hours per day and seven days per week).

6.3.4.2 *Flexible-Sequence Cluster Tool Total Time*

Flexible-Sequence Cluster Tool Total Time =
Σ_j*(Processing Module Total Time*
for Processing Module j) =
(Total Time Observed) X (Number of Processing Modules)

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APPENDIX 1
CALCULATING PRODUCTIVITY METRICS

NOTE: The material in this appendix is an official part of SEMI E79 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A1-1 Example Calculations for an Individual Processing Module or a Fixed-Sequence Cluster Tool

A1-1.1 Sample Data — The calculations in this section are based on the following sample data. The sample data is for a seven-day period.

Non-Scheduled Time	*0.00 hours*
Unscheduled Downtime	*4.00 hours*
Scheduled Downtime	*8.00 hours*
Engineering Time	*3.00 hours*
Standby Time	*6.00 hours*
Production Time	*147.00 hours*
Total Time	*168.00 hours*

Recipe	*Theoretical Production Time Per Unit*	*Theoretical Units Per Hour*	*Actual Units of Recipe*	*Effective Units of Recipe*
A	0.03333 hr/unit	30.00 units/hr	1420	1400
B	0.04000 hr/unit	25.00 units/hr	600	600
C	0.05000 hr/unit	20.00 units/hr	800	800
D	0.06667 hr/unit	15.00 units/hr	500	480

A1-1.2 Fundamental Quantities

Equipment Uptime
= (Production Time) + (Standby Time) + (Engineering Time)
= (147.00 hours) + (6.00 hours) + (3.00 hours)
= 156.00 hours

Production Time (given)

Theoretical Production Time for Actual Units
$= \sum_i$ *(Actual Units of Recipe i X* THT_i *)*
= [(1420 units X 0.03333 hr/unit)
+ (600 units X 0.04000 hr/unit)
+ (800 units X 0.05000 hr/unit)
+ (500 units X 0 .06667 hr/unit)]
= 144.66 hours

Theoretical Production Time for Effective Units
$= \sum_i$ *(Effective Units of Recipe i X* THT_i *)*
= [(1400 units X 0.03333 hr/unit)
+ (600 units X 0.04000 hr/unit)
+ (800 units X 0.05000 hr/unit)
+ (480 units X 0.06667 hr/unit)]
= 142.67 hours

A1-1.3 Productivity Metrics

Availability Efficiency
= (Equipment Uptime) ÷ (Total Time)
= (156.00 hours) ÷ (168.00 hours)
= 0.9286

Operational Efficiency
= (Production Time) ÷ (Equipment Uptime)
= (147.00 hours) ÷ (156.00 hours)
= 0.9423

Rate Efficiency
= (Theoretical Production Time for Actual Units)
÷ (Production Time)
= (144.66 hours) ÷ (147.00 hours)
= 0.9840

Performance Efficiency
= (Operational Efficiency) x (Rate Efficiency)
= (0.9423) X (0.9840)
= 0.9272

Quality Efficiency
= (Theoretical Production Time for Effective Units)
÷ (Theoretical Production Time for Actual Units)
= (142.67 hours) ÷ (144.66 hours)
= 0.9862

Overall Equipment Efficiency (OEE)
= (Theoretical Production Time for Effective Units)
÷ (Total Time)
= (142.67 hours) ÷ (168.00 hours)
= 0.8492

A1-2 *Example Calculations for a Flexible-Sequence Cluster Tool*

A1-2.1 Sample Data — The calculations in this section are based on the following sample data. The sample data is over a seven-day period for a flexible-sequence cluster tool encompassing three processing modules. This example will calculate the theoretical OEE for the cluster tool without consideration of OEE degrading module interactions.

	Processing Module A	*Processing Module B*	*Processing Module C*
Non-Scheduled Time	*0.00 hours*	*0.00 hours*	*0.00 hours*
Unscheduled Downtime	*5.00 hours*	*5.00 hours*	*0.00 hours*
Scheduled Downtime	*0.00 hours*	*5.00 hours*	*0.00 hours*
Engineering Time	*3.00 hours*	*5.00 hours*	*0.00 hours*
Standby Time	*10.00 hours*	*5.00 hours*	*88.00 hours*
Production Time	*150.00 hours*	*148.00 hours*	*80.00 hours*
Total Time	*168.00 hours*	*168.00 hours*	*168.00 hours*

Process Sequence for Flexible-Sequence Cluster Tool	*Processing Module A Recipe*	*Processing Module B Recipe*	*Processing Module C Recipe*	*Actual Units of Sequence*	*Effective Units of Sequence*
S1	R1	R2		300	275
S2		R2	R4	100	100
S3	R2	R3		250	240
S4		R3	R4	400	400

Processing Module Recipe	*Theoretical Production Time Per Unit (THT_i) including Load/Unload Time*
R1	*0.3000 hr/wafer*
R2	*0.2000 hr/wafer*
R3	*0.1000 hr/wafer*
R4	*0.1500 hr/wafer*

A1-2.2 *Fundamental Quantities*

Processing Module Theoretical Production Time for Actual Units

$= \sum_i$ *(Actual Units of Recipe i X THT_i)*

Sequence	*Actual Units*	*Processing Module A*	*Processing Module B*	*Processing Module C*
S1	300	*300 units X 0.3000 hr/unit*	*300 units X 0.2000 hr/unit*	
S2	100		*100 units X 0.2000 hr/unit*	*100 units X 0.1500 hr/unit*
S3	250	*250 units X 0.2000 hr/unit*	*250 units X 0.1000 hr/unit*	
S4	400		*400 units X 0.1000 hr/unit*	*400 units X 0.1500 hr/unit*
	Processing Module Theoretical Production Time for Actual Units =	*Σ = 140.00 hours*	*Σ = 145.00 hours*	*Σ = 75.00 hours*

Flexible-Sequence Cluster Tool Theoretical Production Time for Actual Units

$= \sum_j$ *(Theoretical Production Time for Actual Units for Processing Module i)*

= (140.00 hours) + (145.00 hours) + (75.00 hours)

= 360.00 hours

Processing Module Theoretical Production Time for Effective Units

$= \sum_i$ *(Effective Units of Recipe i X THT_i)*

Sequence	*Effective Units*	*Processing Module A*	*Processing Module B*	*Processing Module C*
S1	275	*275 units X 0.3000 hr/unit*	*275 units X 0.2000 hr/unit*	
S2	100		*100 units X 0.2000 hr/unit*	*100 units X 0.1500 hr/unit*

S3	240	*240 units X 0.2000 hr/unit*	*240 units X 0.1000 hr/unit*	
S4	400		*400 units X 0.1000 hr/unit*	*400 units X 0.1500 hr/unit*
Processing Module Theoretical Production Time for Actual Units =		$\Sigma = 130.50$ *hours*	$\Sigma = 139.00$ *hours*	$\Sigma = 75.00$ *hours*

Flexible-Sequence Cluster Tool Theoretical Production Time for Effective Units
= $\sum_j$ (Theoretical Production Time for Effective Units for Processing Module i)
= (130.50 hours) + (139.00 hours) + (75.00 hours) = 344.50 hours

Processing Module Production Time (given)

Flexible-Sequence Cluster Tool Production Time
= $\sum_j$ (Production Time for Processing Module i)
= (150.00 hours) + (148.00 hours) + (80.00 hours) = 378.00 hours

Processing Module Equipment Uptime
= (Processing Module Production Time) + (Processing Module Standby Time)
+ (Processing Module Engineering Time)

	Processing Module A	*Processing Module B*	*Processing Module C*
Engineering Time	*3.00 hours*	*5.00 hours*	*0.00 hours*
Standby Time	*10.00 hours*	*5.00 hours*	*88.00 hours*
Production Time	*+150.00 hours*	*+148.00 hours*	*+80.00 hours*
Equipment Uptime	*163.00 hours*	*158.00 hours*	*168.00 hours*

Flexible-Sequence Cluster Tool Equipment Uptime = $\sum_j$ (Equipment Uptime for Processing Module j)
= (163.00 hours) + (158.00 hours) + (168.00 hours) = 489.00 hours

Processing Module Total Time (given)

Flexible-Sequence Cluster Tool Total Time = (Number of Processing Modules) X (Total Time Observed)
= (3 Processing Modules) X (168 hours) = 504 hours

A1-2.3 *Productivity Metrics*

Processing Module Availability Efficiency = (Processing Module Equipment Uptime) ÷ (Total Time)

Processing Module A	*Processing Module B*	*Processing Module C*
= (163.00 hours) ÷ (168.00 hours)	*= (158.00 hours) ÷ (168.00 hours)*	*= (168.00 hours) ÷ (168.00 hours)*
= 0.9702	*= 0.9405*	*= 1.000*

Flexible-Sequence Cluster Tool Availability Efficiency
= (Flexible-Sequence Cluster Tool Equipment Uptime) ÷ (Flexible-Sequence Cluster Tool Total Time)
= (489.00 hours) ÷ (504.00 hours)
= 0.9702

Processing Module Operational Efficiency
= (Processing Module Production Time) ÷ (Processing Module Equipment Uptime)

Processing Module A	*Processing Module B*	*Processing Module C*
= (150.00 hours) ÷ (163.00 hours)	*= (148.00 hours) ÷ (158.00 hours)*	*= (80.00 hours) ÷ (168.00 hours)*
= 0.9202	*= 0.9367*	*= 0.4762*

Flexible-Sequence Cluster Tool Operational Efficiency
= (Flexible-Sequence Cluster Tool Production Time) ÷ (Flexible-Sequence Cluster Tool Equipment Uptime)
= (378.00 hours) ÷ (489.00 hours)
= 0.7730

Processing Module Rate Efficiency
= (Processing Module Theoretical Production Time for Actual Units) ÷ (Processing Module Production Time)

Processing Module A	Processing Module B	Processing Module C
= (140.00 hours) ÷ (150.00 hours)	= (145.00 hours) ÷ (148.00 hours)	= (75.00 hours) ÷ (80.00 hours)
= 0.9333	= 0.9797	= 0.9375

Flexible-Sequence Cluster Tool Rate Efficiency
= (Flexible-Sequence Cluster Tool Theoretical Production Time for Actual Units)
÷ (Flexible-Sequence Cluster Tool Production Time)
= (360.00 hours) ÷ (378.00 hours)
= 0.9524

Processing Module Quality Efficiency
= (Processing Module Theoretical Production Time for Effective Units)
÷ (Processing Module Theoretical Production Time for Actual Units)

Processing Module A	Processing Module B	Processing Module C
= (130.50 hours) ÷ (140.00 hours)	= (139.00 hours) ÷ (145.00 hours)	= (75.00 hours) ÷ (75.00 hours)
= 0.9321	= 0.9586	= 1.0000

Flexible-Sequence Cluster Tool Quality Efficiency
=(Processing Module Theoretical Production Time for Effective Units)
÷ (Processing Module Theoretical Production Time for Actual Units)
= (344.50 hours) ÷ (360.00 hours)
= 0.9569

Processing Module Overall Equipment Efficiency (OEE)
= (Processing Module Theoretical Production Time for Effective Units) ÷ (Processing Module Total Time)

Processing Module A	Processing Module B	Processing Module C
= (130.5 hours) ÷ (168.00 hours)	= (139.00 hours) ÷ (168.00 hours)	= (75.00 hours) ÷ (168.00 hours)
= 0.7768	= 0.8274	= 0.4464

Flexible-Sequence Cluster Tool Overall Equipment Efficiency (OEE)
=(Flexible-Sequence Cluster Tool Theoretical Production Time for Effective Units)
÷ (Flexible-Sequence Cluster Tool Total Time)
= (344.50 hours) ÷ (504.00 hours)
= 0.6835

APPENDIX 2
SUPPLEMENTAL PRODUCTIVITY METRICS FOR FOCUSED PRODUCTIVITY STUDIES

NOTE: The material in this appendix is an official part of SEMI E79 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A2-1 Supplemental Productivity Metrics with Total Time as the Denominator

A2-1.1 OEE is based on "as-is" assumptions with respect to process specifications (recipes), equipment type, and equipment design. In this way, OEE measures the performance of the organizations of the manufacturer and the equipment supplier as they attempt to drive equipment performance to a potential defined by given process specifications and a given equipment type and design.

A2-1.2 This section presents three variations on the OEE calculation that additionally measure the performance of engineering and design organizations as they attempt to improve equipment selection, process specifications and equipment design. These three variants are each based on more discriminating definitions of the theoretical production time per unit, as shown in Figure A2-1. Total time is the denominator for each metric.

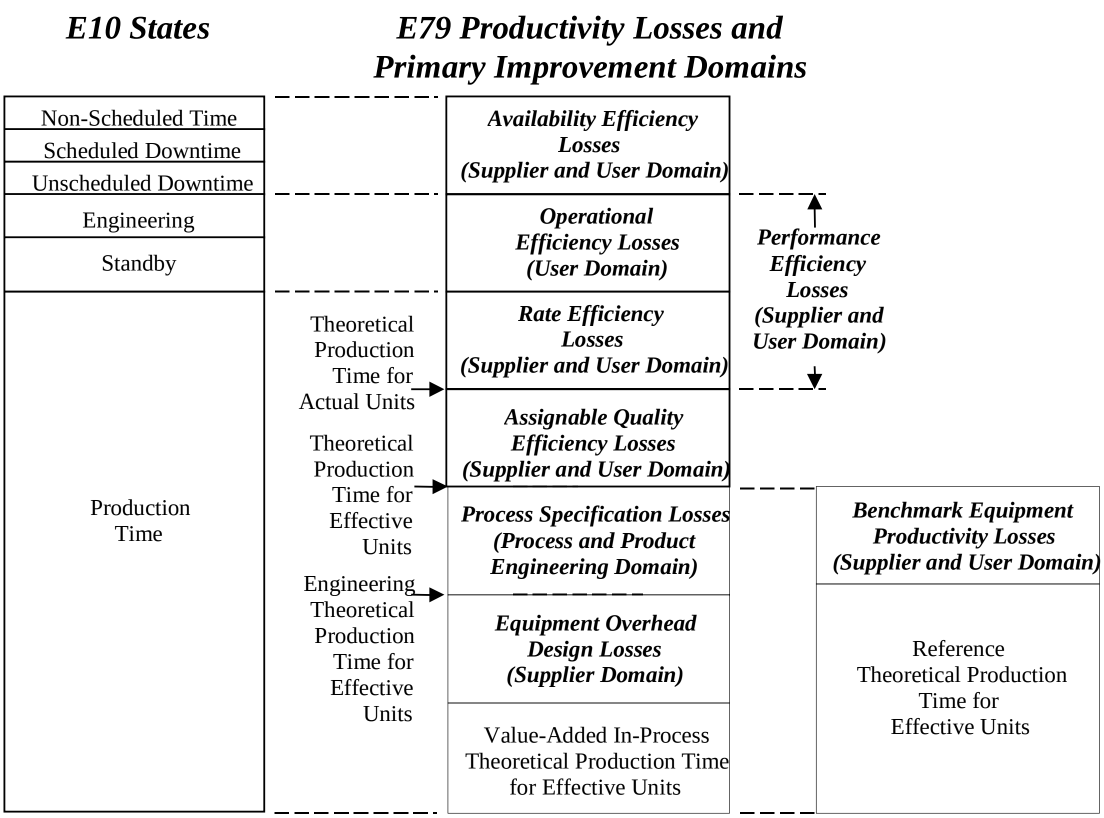


Figure A2-1
Incompatibility of R-OEE with E-OEE and VA-OEE
(Data for sample calculations are given on the following page.)

Operations Time = 168 hours
Theoretical Production Time
for Effective Units = 146 hours
No Product Time = 6 hours
Equipment Unavailable No Product Time = 4 hours
Planned No Product Time = 8 hours

Recipe	*Theoretical Production Time Per Unit (THT_i)*	*Reference Theoretical Production Time Per Unit ($RTHT_i$)*	*Engineering Theoretical Production Time Per Unit ($ETHT_i$)*	*Value-Added In-Process Theoretical Production Time Per Unit ($VTHT_i$)*	*Actual Units of Recipe*	*Effective Units of Recipe*
A	0.03333 hr/unit	0.03333 hr/unit	0.02500 hr/unit	0.01000 hr/unit	1500	1500
B	0.04000 hr/unit	0.03333 hr/unit	0.02000 hr/unit	0.00500 hr/unit	600	600
C	0.05000 hr/unit	0.03333 hr/unit	0.01500 hr/unit	0.00500 hr/unit	800	800
D	0.06667 hr/unit	0.03333 hr/unit	0.03250 hr/unit	0.01000 hr/unit	500	480

A2-1.3 *Reference OEE (R-OEE)*

A2-1.3.1 Reference OEE provides a measure of equipment productivity relative to a benchmark theoretical production time. The reference theoretical production time per unit for a given recipe is the time required by the benchmark equipment (i.e., the fastest equipment model of similar type), running the comparable recipe for a benchmark product and process design. Reference theoretical production time per unit (RTHT) must be defined to be less than or equal to theoretical time per unit (THT) used in calculating standard OEE. The *R-OEE* score may be compared against the standard *OEE* score to assess the productivity loss arising from the application of inferior equipment.

$$\text{Reference OEE (R-OEE)} = [\textstyle\sum_i (\text{Effective Units of Recipe } i \times RTHT_i)] \div (\text{Total Time})$$

where $RTHT_i$ = reference theoretical production time per unit of recipe *i* (based on the benchmark equipment performing a comparable recipe for a benchmark product and process design).

NOTE: Reference OEE utilizes an incompatible definition of theoretical production time for effective units compared to that utilized in Engineering OEE and Value-Added In-Process OEE. Productivity losses indicated by R-OEE and by E-OEE and VA-OEE may overlap. (See Figure A2-1.)

Sample *Reference OEE (R-OEE)* Calculation

Reference OEE (R-OEE)
$= [\sum_i (\text{Effective Units of Recipe } i \times RTHT_i)]$
$\div (\text{Total Time})$
$= [(3380 \text{ units} \times 0.03333 \text{ hr/unit})] \div (168.00 \text{ hours})$
$= 0.6706$

A2-1.4 *Engineering OEE (E-OEE)*

A2-1.4.1 Engineering OEE provides a measure of equipment productivity assuming process specifications are optimized for minimum production time. Engineering theoretical production time per unit (ETHT) must be defined to be less than or equal to theoretical time per unit (THT) used in calculating standard OEE. Engineering theoretical production time per unit may include minimum durations for the objective processing steps, e.g., implant time for ion implant systems, and minimum allowances for any additional supporting process steps, e.g., heating, cooling, gas stabilization, only if those steps are deemed absolutely necessary. Time to perform test wafers, sample wafers, send-aheads, clean cycles, seasoning cycles, and allowances for non-continuous cascading of lots through tools are to be specifically excluded.

$$\text{Engineering OEE (E-OEE)} = [\textstyle\sum_i (\text{Effective Units of Recipe } i \times ETHT_i)] \div (\text{Total Time})$$

where $ETHT_i$ = engineering theoretical production time per unit of recipe *i*.

Sample *Engineering OEE (E-OEE)* Calculation

Engineering OEE (E-OEE)
$= [\sum_i (\text{Effective Units of Recipe } i \times ETHT_i)]$
$\div (\text{Total Time})$
$= [(1500 \text{ units} \times 0.02500 \text{ hr/unit})$
$+ (600 \text{ units} \times 0.02000 \text{ hr/unit})$
$+ (800 \text{ units} \times 0.01500 \text{ hr/unit})$
$+ (480 \text{ units} \times 0.03250 \text{ hr/unit})] \div (168 \text{ hours})$
$= 0.4589$

A2-1.5 *Value-added In-Process OEE (VA-OEE)*

A2-1.5.1 Value-added In-Process OEE provides a measure of equipment productivity assuming the non-value-added portion of processing cycles is wasted equipment time. The non-value-added time should be the focus of efforts by the equipment supplier to reduce or eliminate it through improved equipment design. Value-added In-Process theoretical production time per unit (*VTHT*) must be defined to be less than or equal to engineering theoretical production time per unit (*ETHT*) used in calculating engineering E-OEE (OEE).

Value-Added In-Process OEE (VA-OEE)
= [Σ_i (Effective Units of Recipe i X $VTHT_i$)]
÷ (Total Time)

where $VTHT_i$ = value-added in-process theoretical production time per unit of recipe *i*.

A2-1.5.2 Value-added in-process theoretical production time per unit credits time only for the objective processing steps. The objective processing steps for recipes performed by major types of wafer fabrication equipment are indicated in Table A2-1.

A2-1.5.3 Value-added in-process theoretical production time per unit specifically excludes the following items (partial list):

- All wafer handling time,
- All load-lock time,
- Pre-etch and pre-deposition time,
- Thermal stabilization time,
- Gas stabilization time,
- Wafer heating and cooling time,
- Time for clean cycles, and
- High-etch and seasoning time.

Sample Value-Added In-Process OEE (VA-OEE) Calculation

Value-added In-Process OEE (VA-OEE)
= [Σ_i (Effective Units of Recipe i X $VTHT_i$)]
÷ (Total Time)
= [(1500 units X 0.01000 hr/unit)
+ (600 units X 0.00500 hr/unit)
+ (800 units X 0.01000 hr/unit)
+ (480 units X 0.0050 hr/unit)] ÷ (168 hours)
= 0.1690

Table A2-1 Identification of Objective Process Steps for Value-Added In-Process Theoretical Time Per Unit

Equipment Type	*$VTHT_i$ Includes*	*$VTHT_i$ Excludes*
Resist Processing	Coat, Develop, Bake, Cool Time at process temperature	Temp. ramp up/down
Photolithography Exposure	Exposure Time	Pre-Alignment, Align, Stepping Time
Etch, Oxide, Metal, Poly	Flood Expose Time	Chamber clean Time
Asher, Dry	Ashing Time	
Clean Wet Processing Station	Acid, Rinse and Dry Time	Robot Transport Time
Furnace Atmospheric Process, Furnace LPCVD Process, and Rapid Thermal Processing	Main Oxidation, Anneal Time at defined fixed process temperatures resulting in thermal (film) treatment	Ramp up/down, boat push/pull
Implanter HC, MC, HE …	Implant Time	Beam Setup Time
Metal Deposition - PVD, CVD	Metal Deposition Time	Chambers Clean Time
Dielectric - CVD	Dielectric Deposition Time	Chambers Clean Time
CMP Planarization	Polishing Time	Pad Dressing dedicated Time
Measure CD SEM	Measurement Time	Pattern Recognition Time
Measure Overlay	Measurement Time	Pattern Recognition Time
Defect Detection Patterned Wafers	Scanning Measurement Time	Pattern Recognition Time
Defect Detection Unpatterned Wafers	Scanning Measurement Time	
Measure Film Thickness	Measurement Time	Pattern Recognition Time

A2-2 Additional Productivity Metrics Involving Denominators Other Than Total Time

A2-2.1 This section presents three productivity metrics for assessing efficiency of the equipment resource relative to a time frame less than total time.

A2-2.2 *Production Equipment Efficiency* and *Demand Equipment Efficiency* exclude portions of *no product time* from productivity losses, as depicted in Figure A2-2. While the idle time due to no product is excluded from the operational losses in these particular measures of equipment efficiency, the user should be aware that the additional productivity losses due to sub-optimal load or batch sizes may also be present as rate efficiency losses. Such losses, which result from fluctuations in product flow or tool loading policies, are considered in any equipment efficiency calculation that uses theoretical time per unit.

A2-2.3 *Production Equipment Efficiency (PEE)* — A measure of equipment productivity during the time that work is available to process at the tool. One application of *PEE* is to measure the productivity of non-constraint tools, which are expected to have periods of idle time due to lack of available work.

Production Equipment Efficiency (PEE)
= (Theoretical Production Time for Effective Units)
÷ [(Operations Time) - (No Product Time)
- (Equipment Down No Product Time)]

= Overall Equipment Efficiency X Total Time
÷ [(Operations Time) - (No Product Time)
- (Equipment DownNo Product Time)]

A2-2.3.1 Sample *Production Equipment Efficiency (PEE)* Calculation

Production Equipment Efficiency (PEE)
= (146 hours) ÷ [(168 hours) - (6 hours) - (4 hours)]
= 0.9241

A2-2.4 *Demand Equipment Efficiency* (DEE) — A measure of equipment productivity during the time that work is planned to be available to process at the equipment. A factory model or production schedule that defines the expected or planned idle time at the equipment is required to calculate *Demand Equipment Efficiency*. *DEE* measures the productivity of the equipment relative to the requirements of the factory model or production schedule.

Demand Equipment Efficiency (DEE)
= (Theoretical Production Time for Effective Units)
÷ [(Operations Time) - (Planned No Product Time)]

= Overall Equipment Efficiency X Total Time
÷ [(Operations Time) - (Planned No Product Time)]

A2-2.4.1 Sample *Demand Equipment Efficiency (DEE)* Calculation

Demand Equipment Efficiency (DEE)
= (146 hours) ÷ [(168 hours) - (8 hours)]
= 0.9125

A2-2.5 *Intrinsic Equipment Efficiency (IEE)* — A measure of equipment productivity that compares value-added, in-process theoretical production time to the actual production time. IEE measures the combined productivity losses due to rate efficiency losses, recipe design, and equipment design.

Intrinsic Equipment Efficiency (IEE)
$= [\sum_i (\text{Actual Units of Recipe } i \ X \ VTHT_i)]$
$\div (\text{Production Time})$

where $VTHT_i$ = value-added in-process theoretical production time per unit for recipe *i*. See section A2-1.3.

A2-2.5.1 Sample *Intrinsic Equipment Efficiency (IEE)* Calculation

Production Time = 155.00 hours

Intrinsic Equipment Efficiency (IEE)
$= [\sum_i (\text{Actual Units of Recipe } i \ X \ VTHT_i)]$
$\div (\text{Production Time})$
= [(1500 units X 0.01000 hr/unit)
+ (600 units X 0.00500 hr/unit)
+ (800 units X 0.01000 hr/unit)
+ (500 units X 0.0050 hr/unit)] ÷ (155 hours)
= 0.1839

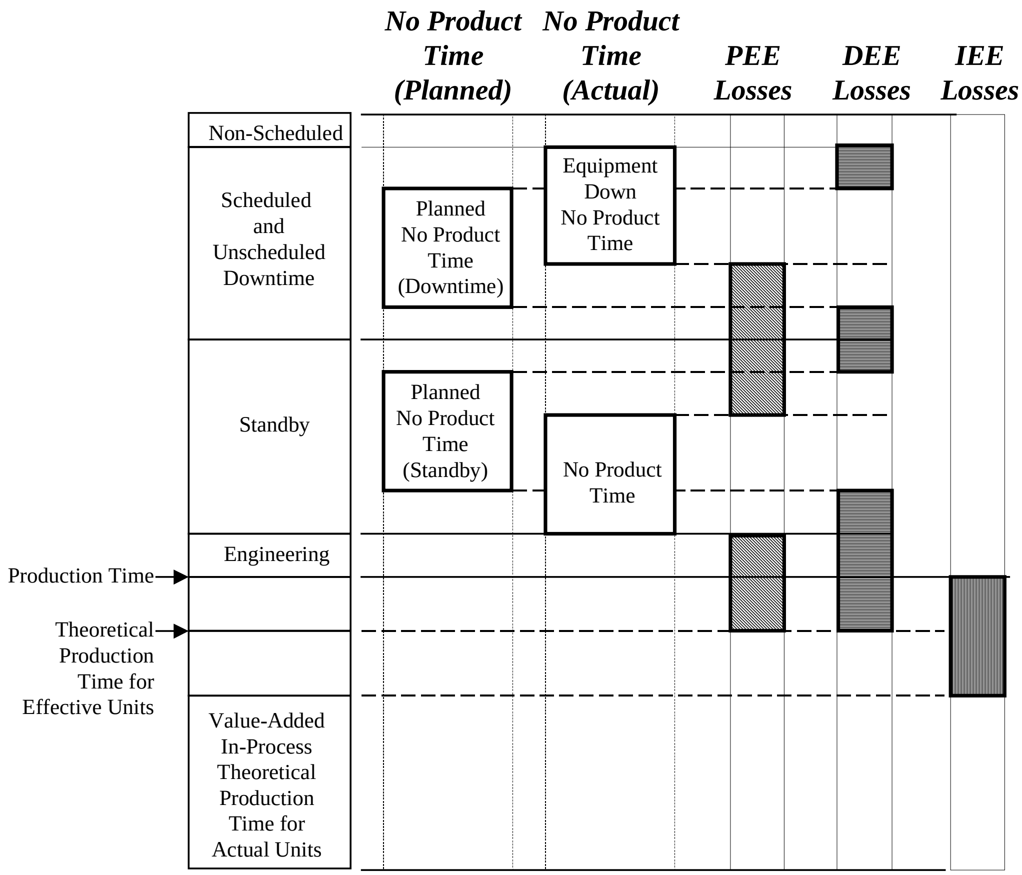


Figure A2-2
Productivity Losses Included in PEE and DEE, and IEE Metrics (shaded regions)

RELATED INFORMATION 1
GUIDELINES FOR DETERMINING THEORETICAL PRODUCTION TIME PER UNIT

NOTE: This related information is not an official part of SEMI E79. This related information was approved for publication by vote of the responsible committee on December 15, 1999.

R1-1 Background

R1-1.1 Overall Equipment Efficiency (OEE) is computed in terms of the theoretical production time per unit for each recipe performed. This theoretical time per unit is based on the actual recipe, the actual equipment design in use, and an assumed load size that optimizes equipment throughput (expressed in units of output per hour) for that recipe.

R1-1.2 OEE is intended to express the true efficiency of the equipment resource. A score of 50% OEE indicates that exactly half of the maximum productive potential of the equipment resource is being realized; a score of 100% indicates that no further increase in productivity is feasible, taking the existing process recipes and equipment design as given.

R1-1.3 To accurately calculate OEE in turn requires that theoretical production times per unit be accurately defined. In particular, theoretical production times per unit must be defined so that the speed losses are always non-negative, i.e.,

Speed Losses
= (Production Time) - (Theoretical Production Time for Actual Units) >= 0

R1-1.4 According to now-classical industrial engineering practice, standards for ideal performance are determined by application of the following:

- Break work methods down into their *operational elements* (hereafter simply referred to as *elements)*.
- Study each of these elements separately to determine its ideal duration.
- Design a new ideal method offering the shortest sequence of only the necessary elements (where the term “sequence” as used herein may involve parallel performance of some or all elements).

R1-1.5 It is remarked that even when the durations of all elements are ideal, if the sequence of elements is not ideal, ideal overall performance cannot be achieved. Based on this understanding, theoretical processing time for an equipment recipe must be based on both an ideal element sequence as well as ideal durations for all elements.

R1-2 Modeling Operational Element Sequences

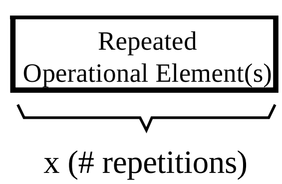
R1-2.1 A graphical model of the sequence of operational elements comprising the performance of an equipment recipe can be helpful for determining theoretical production time per unit. This model has the following components:

R1-2.2 *Resource Utilization Chart* — a Gantt chart displaying a separate timeline for each primary resource within the equipment. Utilization sequences displayed for each primary resource may be used to show how each resource within an equipment system is utilized, and how resources may interact.

R1-2.3 *Operational Element* — An operational element occurring within a utilization sequence is depicted by a box-shaped bar with a label. The time for this element to execute may be fixed, recipe-dependent, or calculated from parameters. Operational elements that are not related to material handling operations have a thick outline.

R1-2.3.1 Material handling elements have a thin outline.

R1-2.4 *Repeated Groups* — A bracket underneath a group of operational elements indicates that the group repeats multiple times based on the parameter shown. For elements that occur conditionally, the number of repetitions may be zero. These repetitions apply to all elements in all timelines positioned in the vertical range of the bracket.



R1-2.5 *Sub-Sequences* — A number in front of an element label indicates that the element represents a group of elements defined elsewhere. This group is referred to as a sub-sequence.

1.1 Sub-Sequence Operational Element

R1-2.6 *Calculating Theoretical Production Time Per Unit* — Any element sequence may be modeled as an activity-on-node network derived from precedence constraints on the operational elements and precedence constraints on the allocation of equipment resources to the elements. Using the network model, the duration of the element sequence is simply the duration of the critical path through the network.

R1-2.6.1 Theoretical production time per unit is then the theoretical duration for the element sequence divided by the number of units processed during the sequence.

Theoretical Production Time Per Unit for recipe i [THT_i] =
= (Theoretical Duration for the Element Sequence)
÷ (Number of Units Processed During Sequence)

R1-2.7 *Allowances for Non-Steady-State Processing* — For complicated batch-load equipment models, it is useful to divide resource sequences into a beginning phase, a steady-state-phase, and an ending phase. For modeling theoretical time, it is important to determine what allowances to make, if any, for the beginning and ending phases. For machines that are limited in the number of lots that can be processed in a continuous cascade, appropriate allowances must be made for beginning and ending phases. However, for machines that are capable of running continuously, the beginning and ending phases should not be considered in determining theoretical production time.

R1-2.7.1 Under certain conditions, setup type operations that are not tracked as part of downtime must be considered as part of the theoretical resource sequence for a tool. These conditions include operations that must occur in every machine cycle, e.g. recipe download, as well as operations that occur on other regular intervals, e.g., one clean cycle every 75 wafers. In general, any activity that occurs on predictable intervals and is a necessary part of a recipe specification should be considered in the equipment sequence for determining theoretical production time.

R1-2.7.2 Operations that occur at irregular intervals or that apply to an unpredictable quantity of wafers, lots, or loads are not counted. An example of an unpredictable frequency setup is a recipe changeover, when the machine is changed from the requirements of one process recipe to meet the needs of another, e.g., a species change as on an ion implant system. The ideal frequency of these events is taken as zero.

R1-2.8 *Optimality* — Theoretical sequences must be designed so as to optimize equipment throughput by using only the best configuration of elements and an optimal load size. Optimal sequences may differ for different recipes performed on the same machine. Optimal load sizes are not necessarily maximum load sizes.

R1-2.9 *Error-Checking Element Sequences* — Once a theoretical sequence is specified for a piece of equipment, it can be compared against actual equipment operations to check for errors. If discrepancies are found, three possibilities to investigate are:

- The sequence contains extraneous elements.
- The sequence is missing necessary elements.
- The series and parallel relationships between elements are not correctly specified.

R1-2.9.1 What may at first appear to be sequence specification errors may in fact be undiscovered rate efficiency losses embedded in the equipment sequence. Because sequences are fundamental to overall performance, it is important to rule out sequence specification errors to preclude erroneous assignment of rate efficiency losses to individual elements.

R1-2.10 *Example Resource Utilization Sequence* — An example of a resource utilization sequence is given in Figure R1-1. This example represents a particular instance of a photolithography stepper that exposes patterns from a reticle onto a wafer. This example assumes that the stepper receives individual unexposed wafers from a linked coat track and transfers individual exposed wafers to a linked develop track.

R1-2.10.1 First, a reticle box must be loaded into the stepper reticle handling system (“load box”). Before a wafer may be exposed, the reticle must be set and aligned. A wafer must also be loaded onto the pre-align chuck, pre-aligned, and transferred to the exposure stage. Each wafer is exposed then transferred to a post processing relay chuck. The transfer operation simultaneously removes an exposed wafer and replaces it with an unexposed wafer.

R1-2.10.2 The expose operation is represented by the sub-sequence shown in Figure R1-2. Depending on the recipe to be executed, the expose sub-sequence may consist of several different reticle images requiring changes of “blade” positioning. For each image, there is one “align” operation. For each individual exposure, there is a “step” operation, a “level” operation, and the “expose” operation itself. Within the same image, different exposures may require different leveling times, as well as different stepping times.

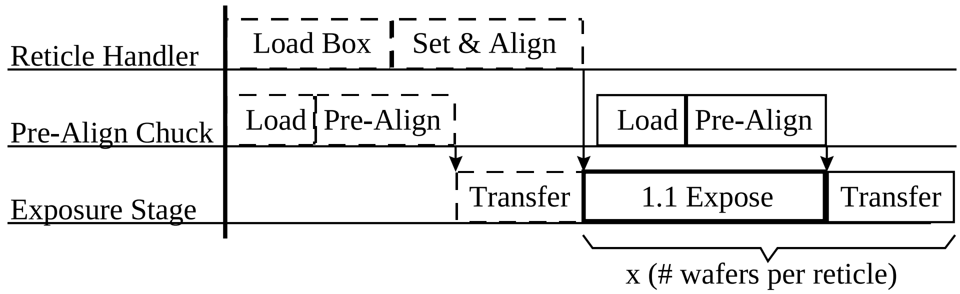


Figure R1-1
Example Resource Utilization Sequence

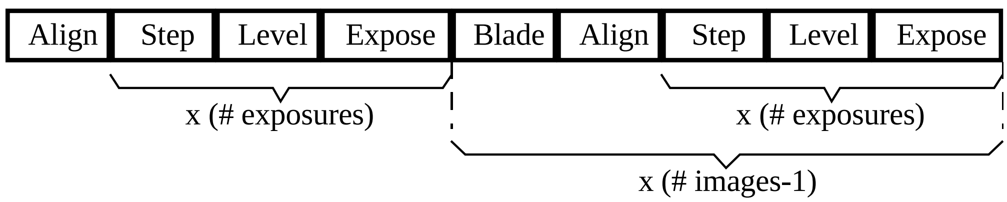


Figure R1-2
Example of Equipment Sub-Sequence

R1-2.10.3 The operations indicated by dashed boxes represent the beginning phase of the main equipment sequence. If the stepper is capable of processing wafers of the same reticle indefinitely, then the beginning phase is not included in theoretical production time. If, however, there is a hardware and/or software limit to the number of wafers that may be run consecutively, then the beginning phase must be counted in theoretical production time.

R1-3 Modeling Theoretical Durations for Operational Elements

R1-3.1 Once a theoretical equipment sequence is defined, the next step is to measure and/or model theoretical durations for each operational element in the sequence. As a rule, it is preferable to acknowledge in the model an elemental speed loss that can never be recovered in lieu of inadvertently overlooking another loss that could be reduced or eliminated.

R1-3.2 *Legitimate Observations* — Each theoretical element duration should always be less than or equal to any *legitimate observation* for that element, where a legitimate observation is a traceable instance of an operational element that does not result in a loss of quality. The time for any legitimate observation that is less than the existing theoretical element duration should become the new theoretical element duration. For legitimate instances of the same operational element on different instances of identically configured equipment, the best time observed among all equipment of that type should be used as the theoretical element duration.

R1-3.3 *Basis for Theoretical Element Durations* — Theoretical element durations may be based on time studies, nominal parameters, and/or parametric modeling.

R1-3.3.1 *Time Studies* — Most mechanical operational elements that have fixed execution times, like transport and load lock operations, can be accurately determined by time studies using either stopwatches, equipment data acquisition systems, timing systems built into the equipment, or stand-alone data acquisition systems that use sensors to detect equipment events and/or state changes.

R1-3.3.1.1 When it is difficult to directly measure individual elements, collections of elements may be observed and timed instead. On systems where a number of consecutive identical elements occur too fast to be measured individually, a set of elements should be timed, and the time should be divided by the number of elements in the set. For even more complicated situations, element times may be derived algebraically from observations of several linearly independent sets of operational elements.

R1-3.3.2 *Nominal Parameters* — There are instances where it is desirable to use nominal parameters to represent theoretical conditions rather than using direct observations, such as when:

- Nominal parameters are more representative of the physical systems being studied.
- Nominal parameters are more representative of the desired system performance.
- It is not practical to obtain reliable data.

R1-3.3.3 *Parametric Models* — For cases where the time for an operational element may have a range of values that are dependent on recipe specifications, theoretical time is best represented by a parametric model. Parametric models for representing semiconductor operations may be based on mathematical formulas, e.g., implant time versus beam current, and/or “lookup” tables, e.g., best observed etch time vs. etch end point.

R1-3.3.3.1 For the photolithography example, one of the recipe parameters is the exposure energy (EE). Given the ideal or theoretical lamp intensity (LI) of the stepper, the theoretical duration per exposure (THT_{EX}) for the recipe may be calculated as THT_{EX} = EE / LI .

RELATED INFORMATION 2
RAPID CHARACTERIZATION OF INTRINSIC EQUIPMENT EFFICIENCY (IEE) AND THE PRODUCTIVITY EFFICIENCY PLANE

NOTE: This related information is not an official part of SEMI E79. This related information was approved for publication by vote of the responsible committee on December 15, 1999.

R2-1 Rapid Characterization of Intrinsic Equipment Efficiency

R2-1.1 IEE may be rapidly characterized as follows using a limited number of production experiments.

R2-1.2 *Step 1: Design Production Experiments* — Select a limited number of scenarios to execute as equipment experiments. It may be of interest to characterize IEE according to either operating modes, processing diversity, or a combination of operating modes and process diversity.

R2-1.2.1 Determine the value-added in-process theoretical production time per unit (VTHT) – (time per unit) for all recipes involved. This information is required for determining IEE. See Table A2-1.

R2-1.2.2 For assessment of operating modes, experiments should examine only a single typical recipe that is likely to be used most frequently. Each experiment should examine a separate operating mode, where examples of various equipment operational modes may be as follows:

One wafer at a time mode (production monitor wafer).

One batch is run, then the tool stops.

Two batches are run, then the tool stops.

Three batches are run, then the tool stops.

Continuous (cascade) mode. A larger number of batches is run, then the tool stops.

R2-1.2.3 For assessment of process diversity, select a limited number of representative recipes that will be processed by a tool. This population should include at least one recipe representing the minimum expected processing duration and one representing the maximum.

R2-1.2.4 Each experiment should be designed and executed to eliminate rate efficiency losses to the greatest extent possible. It is further assumed that quality efficiency losses are zero. Under this approximation, (VA-OEE) = (OEE) x (IEE).

R2-1.3 *Step 2: Execute Process Experiments* — Perform process experiments recording all relevant input variables including the configuration of lots and wafers, and recipes. For each experiment, record the elapsed production time using convenient means, e.g., stopwatch or existing data acquisition system.

R2-1.4 *Step 3: Calculate Results* — Calculate IEE and throughput for each experiment. IEE may be used to measure the effect of *non-value-added overhead time* during equipment processing. Approximately:

Intrinsic Equipment Efficiency (IEE)
= (Value-Added In-Process Theoretical Time)
÷ (Non-Value-Added Overhead Time
+ Value-Added In-Process Theoretical Time)

R2-1.4.1 Hence, *non-value-added overhead time* for each experiment may be calculated as:

Non-Value-Added Overhead Time
= [(Production Time)
- (Value-Added In-Process Theoretical Time)]

R2-1.4.2 It should be the focus of efforts by the equipment supplier and the end-user to reduce or eliminate non-value-added overhead time through improved equipment design, including scheduling software, as well as hardware components (carrier and wafer handling systems, valves, pumps, heaters, coolers, etc.).

R2-1.4.3 Results may be shown in either tabular form or plotted graphically on a Productivity Effectiveness Plane. See next section R2-2.

Sample Rapid Characterization of Intrinsic Equipment Efficiency (IEE)

Four experiments were designed and executed with the following results:

Exp.	*Units of Recipe i per experiment*	*Value-Added In-Process Theoretical Production Time Per Unit ($VTHT_i$)*	*Production Time Per Experiment*
1	*50 of recipe A*	*0.00670 hr/unit*	*3.3333 hr*
2	*100 of recipe B*	*0.00550 hr/unit*	*5.0000 hr*
3	*150 of recipe B*	*0.00550 hr/unit*	*6.0000 hr*
4	*300 of recipe A*	*0.00670 hr/unit*	*10.0000 hr*

Effective Unit Throughput Per Experiment
= (Total Units Per Experiment)
÷ (Production Time Per Experiment)

Intrinsic Equipment Efficiency (IEE) Per Experiment
= [Σ_i (Units of Recipe i Per Experiment X $VTHT_i$)
÷ (Production Time Per Experiment)] X 100%

Non-Value-Added Overhead Time Per Experiment
= [(Production Time Per Experiment)
- Σ_i (Units of Recipe i Per Experiment X $VTHT_i$)]

Experiment	*Effective Unit Throughput*	*Intrinsic Equipment Efficiency*	*Non-value-added Time in Hours*
1	*15 units/hr*	*10.05%*	*2.9983 hr*
2	*20 units/hr*	*11.00%*	*4.4500 hr*
3	*25 units/hr*	*13.75%*	*5.1750 hr*
4	*30 units/hr*	*20.10%*	*7.9900 hr*

R2-2 Productivity Efficiency Plane (PEP)

R2-2.1 It is recognized that OEE and throughput are separate metrics whose relationship may not be straightforward. Because theoretical production time per unit may vary widely by recipe, good throughput performance may not indicate correspondingly good performance in terms of overall equipment efficiency. Similarly, a high OEE score may not be indicative of high throughput. Given this disparity, it is essential that both metrics be analyzed and compared as separate entities.

R2-2.2 Data from rapid characterization experiments may be displayed graphically on a Productivity Effectiveness Plane (PEP) diagram, Figure R2-1.

R2-2.3 In PEP diagrams, IEE is plotted as a function of throughput. Points that appear further to the right have higher throughput and points that appear higher up have higher IEE. It is desired to have combined equipment and process designs whose performance would appear in the upper right quadrant of the plane for the entire operating range of the tool.

R2-2.4 The four experimental data points from the sample problem are plotted in Figure R2-1 and, when connected, appear to approximate an upward sloping curve. This curve is referred to as a *tool signature*.

R2-2.5 Tool signatures may be used to describe tool performance relative to isolated variables. This representation helps equipment suppliers and users visualize the effects of tool operating modes on IEE and throughput. For more complex multi-dimensional experiment sets, the tool signature would appear as a hyper-surface.

R2-2.6 OEE can be plotted for comparison against tool signatures. In Figure R2-1, an OEE measurement of a typical week is plotted. For the known throughput corresponding to this OEE score, the value of IEE on the tool signature for the same throughput may be used to approximate the IEE score for the week without calculating IEE explicitly.

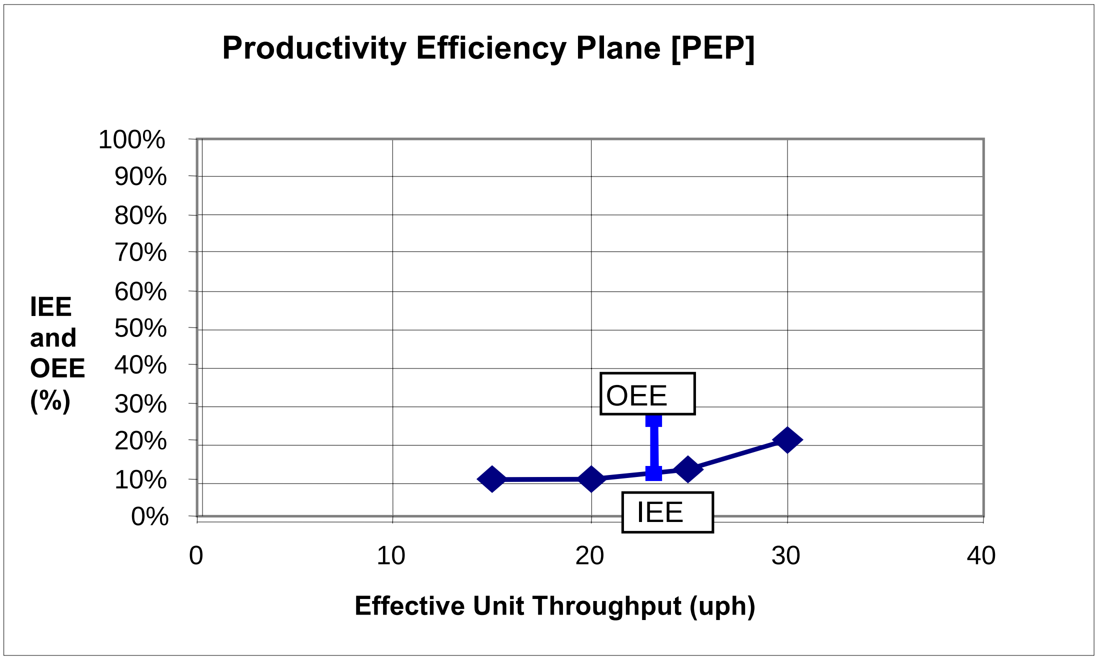


Figure R2-1
Productivity Efficiency Plane

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SEMI E80-0299
TEST METHOD FOR DETERMINING ATTITUDE SENSITIVITY OF MASS FLOW CONTROLLERS (MOUNTING POSITION)

1. Purpose

1.1 The purpose of this test method is to provide a standardized method for quantifying the effect of mounting attitude on an MFC.

1.2 This document provides a common basis for communication between manufacturers and users regarding testing and describing MFC mounting effects.

2. Scope

2.1 This procedure describes a method to determine the effect of attitude (mounting position) of a Mass Flow Controller on flow span and zero.

2.2 The intent of this document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters covered by this method. Reference operating conditions represent the environmental conditions where the "best" performance can be expected.

2.3 The minimum test described in this document is to test one MFC in 5 common mounting positions using Nitrogen gas at 135.8 kPa (19.7 psia) and 308 kPa (44.7 psia). This test method can be used to evaluate additional gases, pressures or mounting attitudes.

3. Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory (reference) conditions; its intent is to collect sufficient data to form a judgment of the field performance of the MFC being tested.

3.2 The results from this test represent the performance of the specific device tested i.e., make, model, full scale flow and operating conditions. The results may not apply to devices of different manufacture, model, full scale flow or under different operating conditions.

3.3 Due to manufacturing variability, attitude sensitivity may vary for the same model of MFC. To statistically quantify attitude sensitivity for a particular model of MFC, multiple samples should be tested.

4. Referenced Documents

4.1 None.

5. Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *% F.S.* — Percent full scale

5.1.2 *DUT* — Device under test

5.1.3 *HBD* — Horizontal Base Down. Mounting attitude 1 as shown in Figure 1.

5.1.4 *HED* — Horizontal Either side Down. Mounting attitude 3 as shown in Figure 1.

5.1.5 *HUD* — Horizontal Upside Down. Mounting attitude 5 as shown in Figure 1.

5.1.6 *kPa* — KiloPascal

5.1.7 *MFC* — Mass flow controller

5.1.8 *psia* — Pounds per square inch absolute

5.1.9 SAS_{max} — The maximum Span Attitude Sensitivity between two attitudes

5.1.10 SAS_{nm} — Span Attitude Sensitivity between attitudes n and m

5.1.11 *Sccm* — Standard cubic centimeters per minute

5.1.12 *Slm* — Standard liters per minute

5.1.13 *VFD* — Vertical Flow Down. Mounting attitude 2 as shown in Figure 1.

5.1.14 *VFU* — Vertical Flow Up. Mounting attitude 4 as shown in Figure 1.

5.1.15 *VID* — Vertical Inlet Down. Mounting attitude 4 as shown in Figure 1.

5.1.16 *VIU* — Vertical Inlet Up. Mounting attitude 2 as shown in Figure 1.

5.1.17 ZAS_{max} — The maximum Zero Attitude Sensitivity between two attitudes

5.1.18 ZAS_{nm} — Zero Attitude Sensitivity between attitudes n and m

5.2 *Definitions*

5.2.1 *actual flow* — The flow rate as determined by the flow standard used in the test procedure.

5.2.2 *attitude* — The mounting position of the MFC with respect to the surface of the earth as shown in Figure 1.

5.2.3 *indicated flow* — The flow rate as determined by the output of the DUT.

5.2.4 *measured value* — The actual flow through a DUT, expressed in sccm or slm.

5.2.5 *nameplate gas* — The gas intended to be controlled by the MFC in operation.

5.2.6 *setpoint* — The input signal provided to achieve a desired flow, reported as sccm, slm, or percent full scale.

5.2.7 *span* — The full scale range of the DUT.

5.2.8 *zero offset* — The deviation from zero at a "no-flow" condition reported in sccm, slm, % F.S. or mV.

5.2.9 *zero drift* — The undesired change in electrical output (i.e., indicated flow), at a no-flow condition, over a specified time period, reported in sccm or slm.

6. Summary of Test Method

6.1 Gas flow, indicated flow and setpoint data are collected for an MFC. This data is reduced to quantify the relationship between the flow control by the MFC and its relationship to the attitude of the MFC.

6.2 This method allows the user to determine the effect of different mounting attitudes on MFC zero and span.

6.3 The standard test is determining the effect of changing between attitudes 1 and 2 on Nitrogen. Other typical MFC attitudes and gases may also be tested. (See Figure 1.)

7. Interferences

7.1 The accuracy rating of the measuring equipment shall be superior to that of the DUT. Preferably the measuring equipment will have an accuracy that is four times better than the DUT. Calibration equipment must have a valid calibration certificate.

7.2 Take care when using test instruments with a specified accuracy expressed in percent of full scale.

7.3 Installation effects on the flow should be minimized. Monitor pressure upstream of the DUT to ensure that flow variations due to pressure are minimized.

7.4 Verify electrical signals directly at the DUT connector to ensure that the signals at the DUT and standard agree with the signals at the data recording equipment.

7.5 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

7.6 All instrumentation in the test apparatus must remain in a constant orientation except the device under test.

8. Significance and Use

8.1 The data generated by this method is used to estimate the effect-mounting attitude will have on the performance of a mass flow controller. It would typically be used to estimate the potential flow error caused by using an MFC in attitude other than the one it was calibrated for.

9. Apparatus (see Figure 2)

9.1 *Flow Standard* — A device or system that accurately measures the flow and reports the actual flow.

9.2 *Data Acquisition System* — The system that measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

9.3 *Isolation Valves* — Valves that will positively shut off the gas line.

9.4 *Pressure Regulator* — A device that regulates gas pressure to a set value.

9.5 *Pressure Transducer* — An instrument to measure the gas pressure and report it as an electrical signal.

9.6 *Flexible Gas Line* — Flexible tubing that will allow the DUT to be moved to the various test attitudes while the other components can remain in a fixed position.

10. Materials

10.1 Clean, Dry N_2, with 99.9% minimum purity.

10.2 MFC Calibration Test Gas as desired.

11. Safety Precautions

11.1 Follow the manufacturer's specifications and instructions for installation and operation whenever possible. Note any exceptions in the test report.

12. Test Specimen

12.1 Allow all components in the test apparatus to warm up following the manufacturer's specification.

12.2 Take necessary steps when switching gases to ensure that only the desired gas is in the DUT and flow standard at the time the test is performed.

13. Preparation of Apparatus

13.1 Locate the DUT in the test environment to stabilize temperature prior to warm up.

13.2 The reference operating conditions shall be as follows:

13.2.1 *Ambient temperature* — 21 ± 4 °C

13.2.2 *Ambient Temperature Stability* — Ambient temperature to stay constant within ± 1 °C during data acquisition period.

13.2.3 *Gas temperature* — Same as ambient.

13.2.4 *Gas pressure, Outlet* — Ambient Pressure

13.3 Following the conditioning period (Section 12.1), warm up the device according to manufacturer's specifications.

13.4 Perform an adequate purge to ensure all previous gases and atmospheric moisture have been removed from the system.

13.5 Leak check the test set up, using available methodologies to verify the test system leak integrity.

13.6 The power supply must be sufficiently rated for the device under test.

14. Procedure

14.1 Open V1 and V2. DUT and allow the flow to stabilize. Adjust the inlet pressure to 135.8 kPa (19.7 psia).

14.2 Close the downstream isolation valve (V2); then close the upstream isolation valve (V1). (See Figure 2.)

14.3 With both isolation valves closed, and a 100% setpoint wait until the pressure drop across the MFC is dissipated, ensuring a "no flow" condition through the MFC. Dissipation of the pressure across the MFC is indicated when the indicated flow drops to a steady state value near zero.

14.4 Once the indicated flow has dropped to a steady value set the MFC setpoint so there is no power being dissipated by the control valve. For a normally closed valve this is 0% and for a normally open control valve it is 100%.

14.5 After the electrical output signal has stabilized for at least three minutes, record the MFC indicated zero in Table 1.

14.6 Open V1 and V2, command 100%.

14.7 After the electrical output signal has stabilized for at least three minutes, record the actual flow as reported by the flow standard and the indicated flow in Table 1.

14.8 Change the attitude of the DUT to the next desired attitude.

14.9 Close the downstream isolation valve (V2); then close the upstream isolation valve (V1). (See Figure 2.)

14.10 With both isolation valves closed, and a 100% setpoint wait until the pressure drop across the MFC is dissipated, ensuring a "no flow" condition through the MFC. Dissipation of the pressure across the MFC is indicated when the indicated flow drops to a steady state value near zero.

14.11 Once the indicated flow has dropped to a steady value set the MFC setpoint so there is no power being dissipated by the control valve. For a normally closed valve this is 0% and for a normally open control valve it is 100%.

14.12 After the electrical output signal has stabilized for at least three minutes, record the MFC indicated zero in Table 1.

14.13 Open V1 and V2, command 100%.

14.14 After the electrical output signal has stabilized for at least three minutes, record the actual flow as reported by the flow standard and the indicated flow in Table 1.

14.15 Repeat Sections 14.8 to 14.14 for each of the desired attitudes.

14.16 Return the DUT to attitude 1.

14.17 Adjust the inlet pressure to 308 kPa (44.7 psia).

14.18 Repeat Sections 14.8 to 14.14.

15. Calculations or Interpretation of Results

15.1 Attitude sensitivity between two mounting positions is calculated as follows:

$$ZAS_{nm} = Z_m - Z_n$$

Where,

ZAS_{nm} = Zero attitude Sensitivity between attitude n and attitude m
Z_n= zero indication at attitude n

Z_m= zero indication at attitude m

$$SAS_{nm} = S_n - S_m$$

Where,

SAS_{nm} = Span attitude Sensitivity between attitude n and attitude m
S_n= Actual flow in attitude n

S_m= Actual flow in attitude mZAS_{max} = The maximum zero attitude sensitivity for all attitudes.

SAS_{max} = The maximum span attitude sensitivity for all attitudes

15.2 *Interpretation*

15.2.1 Table 2 shows examples of raw and reduced data. For the MFC tested, the maximum zero shift was 0.3% F.S. and the maximum span shift was 0.4% F.S.

Table 1. Attitude Test Data

MFC Mfg/Model/Serial # ___________________________
Name Plate Gas/Range ____________________________
Test Gas ____
Temp ___________________ Date ___________________
Factory Calibration Gas ____________________________

Attitude	*Pressure (kPa)*	*Indicated Flow by DUT with Zero Actual Flow (% F.S.)*	*Zero Attitude Sensitivity Compared to Attitude 1 (% F.S.)*	*Actual Flow by Flow Standard at 100% DUT Setpoint (% F.S.)*	*Span Attitude Sensitivity Compared to Attitude 1 (% F.S.)*
1	**135.8**		0		0
2	**135.8**				
3	**135.8**				
4	**135.8**				
5	**135.8**				
		ZAS_{max} =		SAS_{max} =	
1	**308**		0		0
2	**308**				
3	**308**				
4	**308**				
5	**308**				
		ZAS_{max} =		SAS_{max} =	

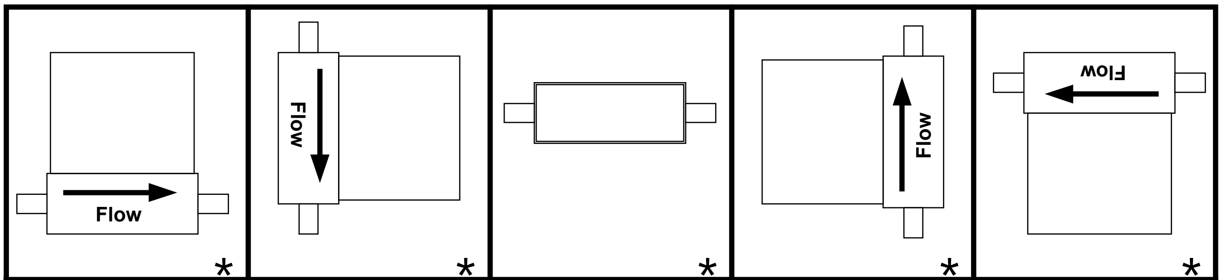
Table 2. Sample Attitude Test Data

MFC Mfg/Model/Serial # Acme/ XYZ-100/0001
Name Plate Gas/Range Nitrogen 100 sccm
Test Gas Nitrogen
Temp 20.2 °C Date 3/9/98
Factory Calibration Gas Nitrogen

Attitude	*Pressure (kPa)*	*Indicated Flow by DUT with Zero Actual Flow (% F.S.)*	*Zero Attitude Sensitivity Compared to Attitude 1 (% F.S.)*	*Actual Flow by Flow Standard at 100% DUT Setpoint (% F.S.)*	*Span Attitude Sensitivity Compared to Attitude 1 (% F.S.)*
1	**135.8**	0	***0***	100	***0***
2	**135.8**	0.1	***-0.1***	100.2	***0.2***
3	**135.8**	0	***0***	100	***0***
4	**135.8**	-0.1	***0.1***	99.8	***-0.2***
5	**135.8**	0	***0***	100	***0***
		ZAS_{max} =	***0.2***	SAS_{max} =	***0.4***
1	**308**	0	***0***	100	***0***
2	**308**	0.15	***-0.15***	100.2	***0.2***
3	**308**	0	***0***	100	***0***
4	**308**	-0.15	***0.15***	99.8	***-0.2***
5	**308**	0	***0***	100	***0***
		ZAS_{max} =	***0.3***	SAS_{max} =	***0.4***

NOTE: The values in ***bold italics*** are calculated values.

16. Illustrations



1	2	3	4	5
HBD	VIU	HED	VID	HUD
	VFD		VFU	

* For this test method the DUT must be mounted ±1° in all axes

HBD = Horizontal Base Down
VIU = Vertical Inlet Up
VFD = Veritical Flow Down
HED = Horizontal Either side Down
VID = Vertical Inlet Down
VFU = Vertical Flow Up
HUD = Horizontal Upside Down

Figure 1
MFC Mounting Attitudes

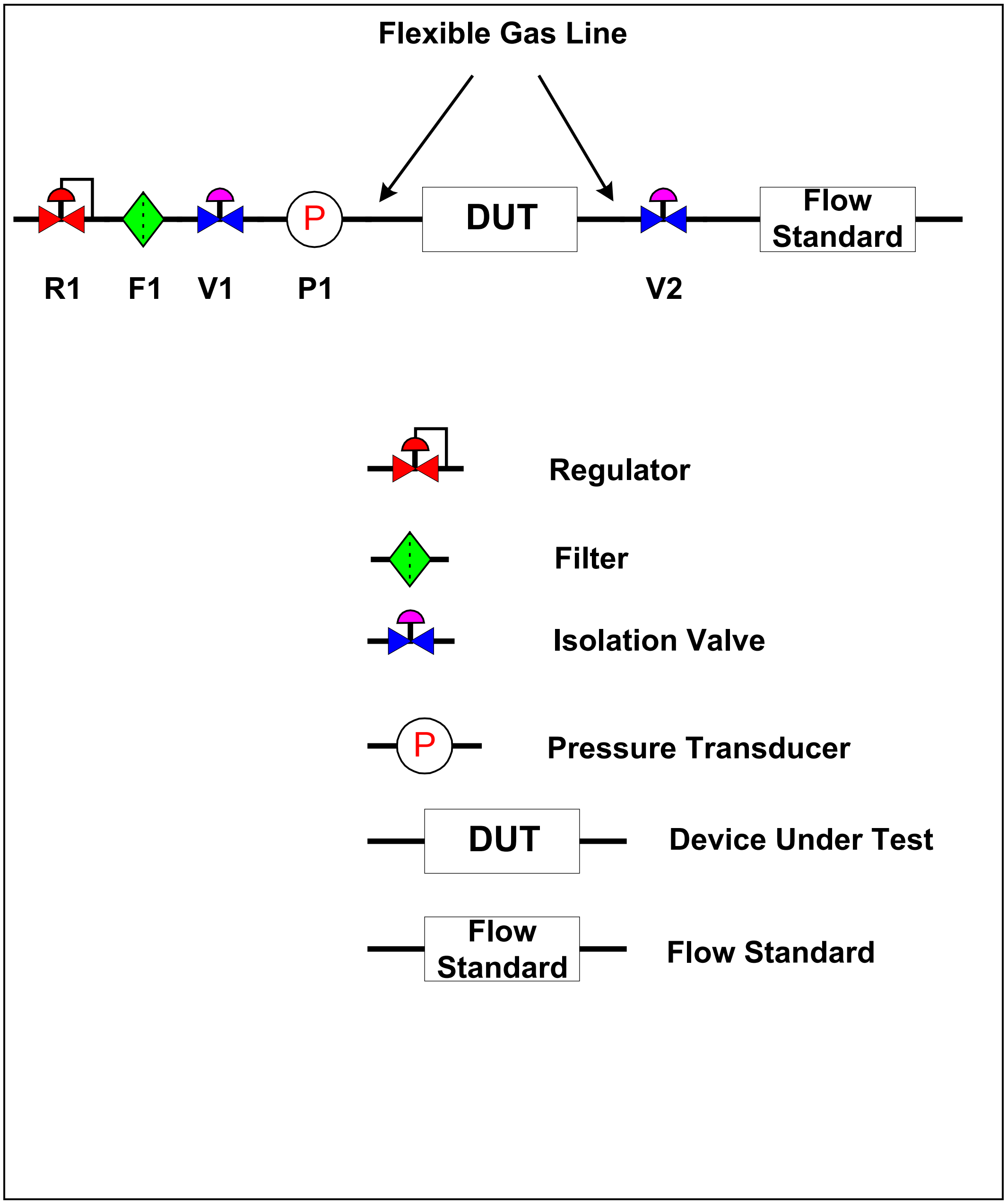


Figure 2
Test Setup

17. Related Documents

17.1 *ANSI Documents*[1]

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1 American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018

17.1.1 *ANSI C39.5* — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

17.1.2 *ANSI C42.100* — Dictionary of Electrical and Electronics Terms

17.2 *ISA Document*[2]

17.2.1 *ISA S51.1* — Process Instrumentation Terminology

17.3 *Other Document*[3]

17.3.1 *ISO 10012-1* — Quality Assurance Requirements for Measuring Equipment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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2 *Instrument Society of America, 67 Alexander Dr., Research Triangle Park, NC 27709*

3 *Internal Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland*

SEMI E83-1000
SPECIFICATION FOR 300 mm PGV MECHANICAL DOCKING FLANGE

This Provisional Specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on July 14, 2000. Initially available at www.semi.org August 2000; to be published October 2000. Originally published June 1999.

1 Purpose

1.1 This specification is intended to promote consistent interface features between Person Guided Vehicles and SEMI E15.1 equipment.

2 Scope

2.1 This specification defines a mechanical standard for the stationary (equipment) side of the docking flange used by 300 mm Person Guided Vehicles (PGVs). This flange is to be mounted to the floor within the volume defined by SEMI E64 at SEMI E15.1 and SEMI E64 compliant equipment.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not define the PGV (active) side of the docking interface or carrier transfer. The PGV and the PGV side of the docking interface designs should comprehend the physical limitations of equipment to which they are being applied.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E64 — Provisional Specification for 300mm Cart to SEMI E15.1 Docking Interface Port

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *PGV* — Person Guided Vehicle (cart)

5.2 *Definitions*

5.2.1 *carrier* — Any cassette, box, pod, or boat that contains wafers (per SEMI E15).

5.2.2 *cart* — A floor based carrier transfer vehicle (per SEMI E64).

5.2.3 *docking* — The act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment (per SEMI E64).

5.2.4 *facial datum plane* — A vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (per SEMI E57).

5.2.5 *load face plane* — The furthest physical vertical boundary plane from carrier centroid on the side(s) of the equipment where loading of the tool is intended (per SEMI E15).

5.2.6 *load port* — The interface location on a tool where carriers are placed to allow the tool to process wafers (per SEMI E15).

5.2.7 *transfer* — To either load or unload (per SEMI E15).

6 Requirements

6.1 The dimensions that define the universal docking flange are listed in Table 1 and shown on Figure 1.

6.1.1 The minimum length of the docking flange is defined by $2 \times w11$. This minimum length is intended to fit under the shadow of the smallest possible width SEMI E15.1 compatible load port. The PGV and PGV docking must provide full functionality given a minimum length docking flange. No maximum length has been specified.

6.1.2 One vertical pin (labeled VP in Figure 2) is intended to be used for horizontal registration of the PGV to the docking flange. This pin is also intended as a feature for an active mechanism on the PGV to lock on to.

6.2 There are three surfaces on the flange and a vertical pin that can be used as the initial docking contacts point(s) with the PGV. These have been identified as surfaces A, B and C and pin VP as shown in Figure 2. These features are the primary load bearing features during the act of docking, no other features or surfaces shall be used as initial docking contact points.

Table 1 Dimensional Requirements

Symbol	*Value, mm (in.)*	*Tolerance (mm)*	*Type*
a11	0 deg.	+/- 0.25 deg.	angle
∅d11	15.0 (.591)	+/- 0.2	diameter
d12	33.0 (1.299)	+/- 0.2	distance
d13	39.0 (1.535)	+/- 0.2	distance
d14	62.0 (2.441)	+/- 0.2	distance
d15	80.0 (3.150)	+/- 0.2	distance
d16	237.5 (9.350)	+/- 2.5	distance
d17	68.0 (2.677)	minimum	distance
h11	24.0 (.945)	+/- 0.2	distance
h12	39.0 (1.535)	+/- 0.2	distance
h13	40.0 (1.575)	+/-0.2	distance
h14	83.0 (3.268)	+/-0.2	distance
h15	20.0 (.787)	maximum	distance
r11	2.0 (.079)	+/-0.2	radius
r13	4.0 (.157)	+/-0.2	radius
r14	5.0 (.197)	+/-0.2	radius
w11	200 (7.874)	minimum	distance

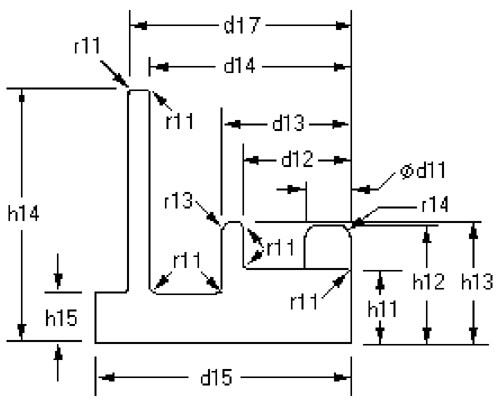

Figure 1
Side Elevation View I

6.3 The flange must be installed such that the vertical pin (VP) is capable of being aligned with the load port bilateral datum plane (as defined in SEMI E15.1) and surface A is a distance of *d*16 from the load port facial datum plane (as defined in SEMI E15.1). The angle of incidence between surface A and the facial datum plane should be capable of adjustment to *a*11 listed in Table 1.

6.3.1 The docking flange is to be physically isolated from the equipment and should be mounted such that the equipment and equipment load port are protected from the impact incurred during docking.

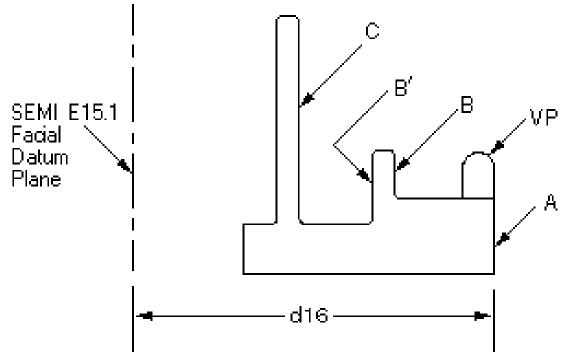

Figure 2
Side Elevation View II

6.4 When the flange is removed, no mounting hardware shall remain protruding from the floor.

6.5 Surfaces A, B, B' and C shown on Figure 2 must exist per tolerances listed in Table 1.

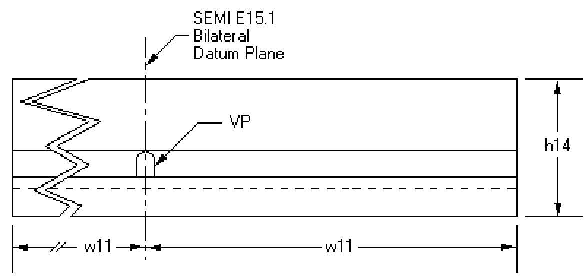

Figure 3
Front Elevation View

NOTICE:. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E83, but was approved for publication by full letter ballot procedures on July 14, 2000.

R1-1 The intent of this standard is to provide manually guided 300mm carrier transport PGVs a standard flange for docking and to facilitate a safe, quick, and repeatable PGV to load port carrier transfer method or mechanism. Standardization of features on the flange is intended to allow for interoperability between PGV designs and the docking flange.

R1-2 SEMI E64 defines Zone L as an exclusion zone in SEMI E15.1 compliant tools. It is intended that the docking flange be mounted in this zone.

R1-3 The docking interface flange includes features to allow for the following minimum functionality of the PGV to flange docking procedure:

- Stopping PGV motion
- Guidance of PGV to flange
- x, y & theta alignment of the PGV to the flange
- Locking of PGV to flange
- Docking parallel or perpendicular to the flange

R1-4 The PGV side of the interface may include additional features to allow for all or some of the following functionality:

- Compliance to the docking flange
- To dampen impact of docking forces

R1-5 No features on the standard docking flange provide an adjustable feature to indicate the height (dimension as H defined by SEMI E15.1) the load port horizontal datum plane has been adjusted to.

R1-6 It is likely that the alignment error and tolerance stack up between the docking interface flange and the equipment load port will not provide sufficient accuracy alone for accurate pick/placement of a pod onto the kinematic couplings on the load port.

R1-7 Possible sources of alignment error are:

- Cleanroom floor height and level
- PGV wheels and framework
- Installation accuracy of docking interface flange
- Stability of mounting

R1-8 It may be necessary to use additional alignment methods to improve accuracy of pod placement onto the kinematic couplings.

R1-9 It is expected that the interface device be floor mounted. Thus, the equipment must not require the use of support pedestals or other support structures under the floor below Zone L.

R1-10 The docking flange should sustain docking impact for the lifetime of the flange without any performance degradation.

- Assume 90kg (200lb) PGV moving at 0.3m/s (1ft/sec)
- Assume 250,000 docking cycles within a flange lifetime
- Recommended to design for 3x safety factor for single docking cycle

R1-11 Flange must be quick remove, replace, align and calibrate.

R1-12 Surface B' (shown on Figure 2) allows docking mechanism designs to grab onto the docking flange without using the docking pin for support.

R1-13 The method of attaching the vertical pin to the flange is not defined in this standard. Docking flange designers should be aware of the docking forces incurred on this pin and design the attachment method accordingly.

R1-14 The method of attaching the flange to the floor is not defined in this standard. Docking flange designers should be aware of the docking forces incurred on the flange and/or pin and design the attachment method accordingly.

R1-15 This standard specifies the radii of certain edges found on the docking flange. It is recommended that edges that do not have a specified radius are radiused or broken to eliminate sharp edges.

R1-16 It is left to user to define the needed flange length ($w2\times2$) at the time of placing an order.

respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E84-0302
SPECIFICATION FOR ENHANCED CARRIER HANDOFF PARALLEL I/O INTERFACE

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published June 1999; previously published November 2001.

1 Purpose

1.1 Due to the migration to large wafer sizes, future semiconductor factories will use extensive automated material handling systems (AMHS) to transfer wafer carriers, including FOUPs and open cassettes, of increasing weight. The parallel input/output (PI/O) control signals between the production equipment and the AMHS must be better defined for more reliable and efficient carrier handoffs (load/unload) at production equipment load ports.

1.2 The purpose of this specification is to enhance the capabilities of the parallel I/O interface defined in SEMI E23 in order to support improvements in the reliability and efficiency of carrier transfer. The enhanced capabilities include continuous handoff, simultaneous handoff, and the capabilities of error detection on the interface.

NOTE 1: The specifications in this document shall be considered independent from the specifications in SEMI E23; therefore, use of this specification does not require SEMI E23.

2 Scope

2.1 The scope of this specification is limited to communications associated with the material handoff operations between the active equipment (for example, AMHS equipment including AGV, RGV and OHT) and the passive equipment (for example, production equipment including process and metrology equipment; stockers, etc). This scope also extends to interbay AMHS active equipment (i.e., OHS and stockers equipped with transfer devices) and passive equipment (i.e., OHS and stockers not equipped with transfer devices). This specification defines the enhanced parallel I/O interface signals used to handoff carriers between the production equipment and the AMHS. Figures 1 and 2 show examples of types of AMHS equipment.

2.2 This enhanced carrier handoff parallel I/O interface specification includes:

- Signal definition including load port assignment signals (see Section 6.1),
- Carrier handoff sequence definitions and time diagrams (see Section 6.2),
- Error indication, detection, and recovery (see Sections 6.3 and 6.4),
- Connector type, signal, and pin assignment (see Section 6.4), and
- Interface sensor unit size to be located at load port defined by SEMI E15.1 (applicable for systems designed to handle 300 mm wafer carriers).

2.3 The enhanced carrier handoff parallel I/O interface controls the handoff of a carrier to and from the passive equipment by the active equipment. This parallel I/O interface only controls the automated handoff operation of the carrier. The handoff is the operation in which a carrier is transferred from one piece of equipment to another. Both the active and passive equipment manage this operation. The factory level controller (i.e., host) does not manage the handoff operation. Figure 3 shows applications for the parallel I/O interface specified in this document.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Data for the material that is transferred (handed off) is managed through the equipment's factory interface. Material management by the factory level controller is outside the scope of this document.

3.2 This specification defines the signals used to select a load port. The physical correspondence of the parallel I/O interface to the load port is not defined in this document.

3.3 Error recovery procedures may need operator assistance and/or proprietary procedures specific to the equipment. Therefore, error recovery procedures are not defined in this document.

3.4 Signal time diagrams apply to only one parallel I/O interface.

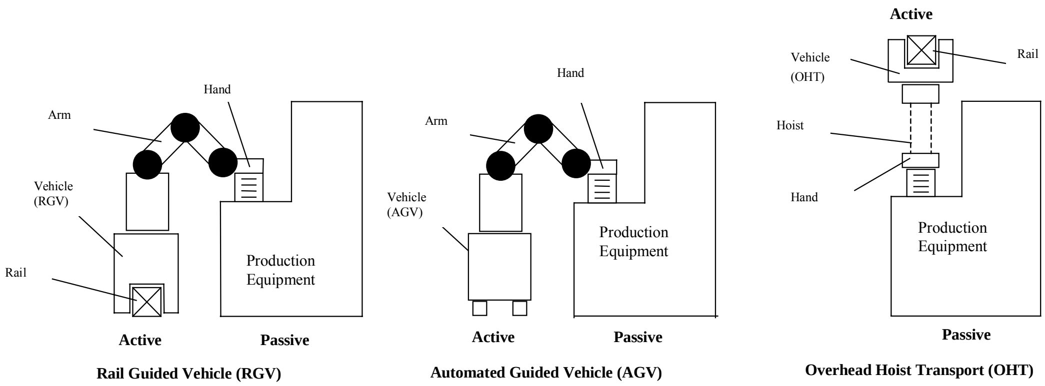


Figure 1
Examples of Automated Material Handling System Equipment (RGV, AGV, and OHT)

Figure 2
Examples of Interbay Automated Material Handling System Equipment (Stockers and OHS)

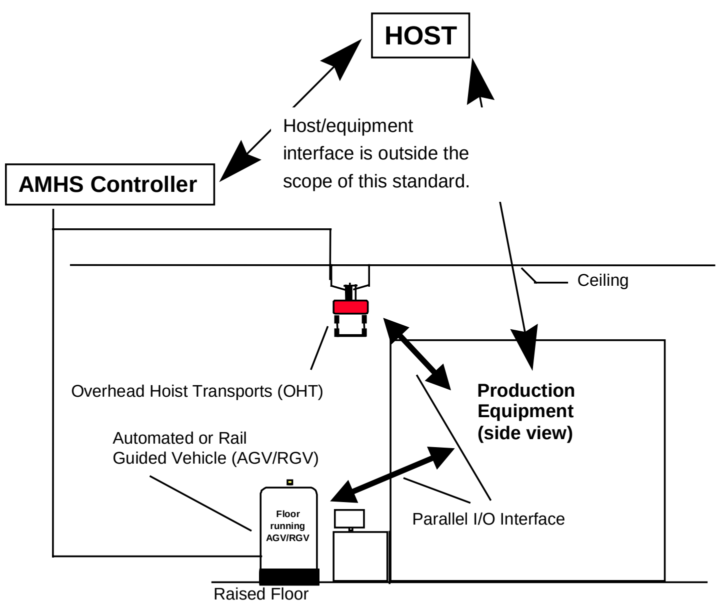


Figure 3
Examples of Enhanced Carrier Handoff Parallel I/O Interface Applications

3.5 The installation positions of the parallel I/O interface and the connector on the active and passive equipment are not defined.

3.6 The swap handoff will be considered beyond the scope of the standard for interbay AMHS equipment (i.e., OHS, stockers). During a swap handoff, loading and unloading occur simultaneously on the same loadport.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 Wafers

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E87 — Provisional Specification for Carrier Management (CMS)

4.2 *ISO Standard* [1]

ISO 4902 — Information technology — Data communication — 37-pole DTE/DCE interface connector and contact number assignments

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *access mode* — a mode in which passive equipment knows which AMHS equipment (i.e. RGV, AGV, and OHT/OHV) or operator is permitted to make a material handoff. In the case of interbay AMHS, this is a mode in which the passive equipment knows which AMHS equipment (i.e., OHS and stockers equipped with transfer devices) is permitted to make a material handoff.

5.2 *active equipment* — equipment that loads a cassette onto the cassette stage of another piece of equipment or unloads a cassette from the cassette stage of another piece of equipment [SEMI E23].

5.3 *active OHS vehicle* — an active OHS vehicle that contains a device that loads or unloads the carrier from one piece of equipment to another.

5.4 *automated material handling system (AMHS) equipment* — a piece of equipment which has a carrier transfer robot that transfers carriers from and to passive equipment. It includes rail guided vehicles (RGV), automated guided vehicles (AGV), overhead hoist transports (OHT), overhead shuttles (OHS), and stockers.

5.5 *automatic access mode* — a mode in which AMHS equipment performs a material handoff rather than an operator.

5.6 *boundary* — a change in the timing single state.

5.7 *carrier* — any cassette, box, pod, or FOUP that contains wafers [SEMI E1.9]. Also known as wafer carrier.

5.8 *cassette* — an open structure that holds one or more substrates [SEMI E1.9]. Also known as open cassette (OC).

5.9 *continuous handoff* — successive handoffs of two carriers. Continuous handoff is in series, meaning one carrier transfer occurs and is then immediately followed by another. The continuous handoff may involve: load and load, unload and unload, or unload and load operations.

5.10 *front opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (FIMS) [SEMI E47.1].

5.11 *handoff* — is the operation in which a carrier is transferred (loaded or unloaded) from one piece of equipment to another.

5.12 *handoff conflict area* — an area where the active equipment resource could interfere with the passive equipment resource during the handoff operation.

5.13 *handoff interlock abnormal* — the state, which indicates the passive equipment, has detected abnormal conditions in the handoff operation. It may indicate the possibility that the interference of the active equipment resource with the passive equipment resource has occurred in the handoff conflict area.

5.14 *handoff unavailable* — the state, which indicates the passive equipment, is not available for material handoff operation.

5.15 *load port* — the interface location on a tool where wafer carriers are placed to allow the tool to process wafers [SEMI E15].

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

5.16 *manual access mode* — an access mode in which an operator performs a material handoff of a carrier rather than the AMHS equipment.

5.17 *overhead shuttle (OHS)* — an AMHS vehicle that does not use a vertical hoist mechanism to transfer the carrier from one piece of equipment to another. An OHS is typically supported on top of transport rail while overhead hoist transport (OHT) vehicles hang from underneath the transport rail.

5.18 *passive equipment* — equipment that is loaded or unloaded by active equipment [SEMI E23]. Passive equipment includes process equipment, metrology equipment, stockers, etc.

5.19 *passive OHS vehicle* — An active OHS vehicle that does not contain a device that loads or unloads the carrier from one piece of equipment to another.

5.20 *simultaneous handoff* — concurrent handoff operations of two carriers. Simultaneous handoff is in parallel, meaning two carriers are transferred at the same time.

5.21 *single arm/double hand AMHS equipment* — AMHS equipment which hands off two carriers using a single arm mechanism with two hands (dual end effectors).

5.22 *single arm/single hand AMHS equipment* — AMHS equipment which hands off a carrier using a single arm mechanism with a single hand (single end effector).

5.23 *single handoff* — the transfer of a single carrier in a handoff operation.

5.24 *zone* — term used for describing the intervals during PIO communication.

6 Enhanced Carrier Handoff Parallel I/O Interface Requirements

6.1 *Signal Definitions*

6.1.1 Table 1 shows the signals required for the enhanced carrier handoff parallel I/O interface. The table defines signal name, the direction of the information (P/A: P represents passive equipment and A represents active equipment), and the description. In the description, the meaning of the signal and the indication of the signal level, and comments. Signals defined in Table 1 are:

VALID	Indicates that the signal transition is active and selected.
CS_0	Carrier Stage 0
CS_1	Carrier Stage 1
TR_REQ	Transfer Request
L_REQ	Load Request
U_REQ	Unload Request
READY	READY for Transfer
BUSY	BUSY for Transfer
COMPT	Complete Transfer
CONT	Continuous Handoff
HO_AVBL	Handoff Available
ES	Emergency Stop
VA	Vehicle arrived *
AM_AVBL	Transfer Arm Available *
VS_0	Carrier Stage 0 from Passive OHS Vehicle *
VS_1	Carrier Stage 1 from Passive OHS Vehicle *

* The VA, AM_AVBL, VS_0,1 signals are intended only for use with interbay AMHS equipment (passive OHS vehicles).

The VALID, CS_0, CS_1 signals are not intended for use with interbay AMHS equipment (passive OHS vehicles).

6.1.2 *Load Port Assignment Signals*

6.1.2.1 The signals CS_0 and CS_1 are used to select load ports to be used for the handoff. For the parallel I/O interface which is dedicated to a single load port, the signals must be set:

CS_0 ON

CS_1 OFF

See Figures 4 and 5.

6.1.2.2 The capability to control two load ports by a common parallel I/O interface is required; therefore, it is assumed in this specification that a common parallel I/O interface can be used to control handoffs of two load ports.

6.1.2.3 The assignment of the load port is relevant when two load ports use a common parallel I/O interface. The active equipment shall select the load port by means of the CS_0 and/or CS_1 signals (see Figure 6).

CS_0 selects the left hand load port as viewed when facing towards the equipment's load ports.

CS_1 selects the right hand load port as viewed when facing towards the equipment's load ports.

6.1.2.4 For the simultaneous handoff, both of CS_0 and CS_1 must be set to ON at the handoff. Figure 8 shows a piece of passive equipment with four load ports (LP1, LP2, LP3, LP4) and two parallel I/O interfaces (PI/O#1, PI/O#2), where PI/O#1 is common to load ports LP1 and LP2 and PI/O#2 is common to load ports LP3 and LP4. Tables 2 and 3 show the range of signal combinations.

6.1.3 *Load Port Assignment Signals for OHS (Passive type)*

6.1.3.1 The signals VS_0 and VS_1 are used to select load ports to be used for the handoff. For the parallel I/O interface which is dedicated to a single load port, the signals must be set;

VS_0 ON

VS_1 OFF

6.1.3.2 Two load ports can be controlled by using VS_0 and VS_1.

VS_0 ON: Selects left hand Load port.

OFF: Does not select Left hand Load port.

VS_1 ON: Selects Right hand Load port.

OFF: Does not select Right hand Load port.

VS_0 and VS_1 are controlled individually.

Table 1 Signals for the Enhanced Carrier Handoff Parallel I/O Interface

Signal Name	*P/A*	*Description*
VALID	A -> P	Indicates that the interface communication is valid. ON: the communication is valid OFF: the communication is not valid Before this signal is turned ON, the load port must be specified by the signal CS_0 and/or CS_1.
CS_0	A -> P	Specifies the load port used for carrier handoff (see Section 6.1.2, Load Port Assignment Signals). One PI/O device per load port ON: Use the load port for carrier handoff OFF: N/A One PI/O device per 2 load ports ON: Use the left load port for handoff OFF: Do not use the left load port of handoff
CS_1	A -> P	Specifies the load port used for carrier handoff (see Section 6.1.2, Load Port Assignment Signals). One PI/O device per load port Not used (OFF) One PI/O device per 2 load ports ON: Use the right load port for handoff OFF: Do not use the right load port of handoff
TR_REQ	A -> P	Requests the handoff to the passive equipment. ON: the active equipment has requested the handoff OFF: the active equipment has not requested the handoff This signal is turned OFF when the BUSY signal transitions to OFF.
L_REQ	P -> A	Indicates the load port is assigned to load a carrier. L_REQ always indicates a carrier transfer from Active to Passive equipment. ON: The load port is assigned to load a carrier OFF: The load port is not assigned to load a carrier This signal is turned ON when the load port is specified by CS_0 and/or CS_1 and the VALID signal is turned ON. This signal is turned OFF when the load port detects the carrier in the correct position. In simultaneous handoff, the carrier on both load ports shall not be present when this signal is turned ON, and the carriers shall be present in correct position on both load ports when this signal is turned OFF.

Signal Name	*P/A*	*Description*
U_REQ	P -> A	Indicates the load port is assigned to unload a carrier. U_REQ always indicates a carrier transfer from Passive to Active equipment. ON: The load port is assigned to unload a carrier OFF: The load port is not assigned to unload a carrier This signal is turned ON when the load port is specified by CS_0 and/or CS_1, and the VALID signal is turned ON. This signal is turned OFF when the carrier on the load port is removed. In simultaneous handoff, the carrier on both load ports shall be present in correct position when this signal is turned ON, and the carriers shall not be present on both load ports when this signal is turned OFF.
READY	P -> A	Indicates the passive equipment has accepted the transfer request from the active equipment. ON: the passive equipment is ready for the handoff OFF: the passive equipment is not ready for the handoff This signal is turned ON when the passive equipment accepts the transfer request, and it is turned OFF when the COMPT signal is turned ON.
BUSY	A -> P	Indicates the handoff is in progress by the active equipment. ON: the handoff is in progress OFF: no handoff is in progress This signal is turned ON when the active equipment starts handoff operation. READY must be ON when BUSY is turned ON. It must be turned OFF after the active equipment has completed the handoff and the active equipment resource position is outside the handoff conflict area. The passive equipment must not perform any mechanical action in the handoff conflict area while this signal is ON. The active equipment turns the BUSY OFF after confirming the L_REQ or U_REQ OFF.
COMPT	A -> P	Indicates the active equipment has completed the handoff operation. ON: the handoff is completed OFF: the handoff is not completed This signal is turned ON when the active equipment has completed the handoff (BUSY OFF), and it is turned OFF after the passive equipment has completed the handoff operation (READY OFF).
CONT	A -> P	Specifies the handoff is continuous handoff. ON: continuous handoff OFF: not continuous handoff This signal is turned ON by BUSY ON for the first carrier handoff, and it is turned OFF by BUSY ON for the last carrier handoff operation. If the passive equipment has a mechanism that interferes with the handoff (such as a shutter door), that mechanism must be held in the non-interfering state (the door must remain open) during the continuous handoff.
HO_AVBL	P -> A	Indicates the passive equipment is not available for the handoff operation. It may also indicate error in the passive equipment. ON: handoff is available OFF: handoff is unavailable with any error This signal is ON while the passive equipment’s operation is normal. This signal is turned OFF by VALID ON or TR_REQ ON when the passive equipment detects some exceptions at the load port specified by CS_0 and/or CS_1. This signal might be kept OFF, when other load ports of the passive equipment detects exceptions. The exceptions include: - Carrier detection is not correct. - The passive equipment has been changed to manual access mode. - The passive equipment is in handoff unavailable state. This signal indicates the state of the passive equipment to the active equipment before the start of handoff operation. See SEMI E87 for additional information and requirements about loadport access modes and availability states.

Signal Name	*P/A*	*Description*
ES	P -> A	Request to stop active equipment activity immediately. ON: normal operation OFF: request to stop Normally active equipment may monitor the ES signal from VALID ON to VALID OFF. This signal is turned OFF to stop the handoff operation immediately when a hazardous situation is detected by the passive equipment. Hazardous situations include possible harm to material, product, or operation. This signal is ON while the passive equipment's operation is normal. It turns OFF when the passive equipment needs to stop the activity of the active equipment. The passive equipment may turn the ES signal off when the ES button is pressed or, a handoff interlock abnormal has occurred.
VA	P -> A	Notifies active entity of passive OHS vehicle arrival. Indicates that the interface communication is valid when the vehicle has arrived at the load port. ON: Vehicle has arrived and communication is valid. OFF: Vehicle has not arrived and communication is not valid. Before this signal is turned ON, the load port must be specified by the signal VS_0 and/or VS_1. Note: This signal is for interbay passive OHS vehicle use only.
AM_AVBL	A -> P	Notifies passive OHS vehicle of handling arm availability. Indicates the active stocker is not available for handoff operation. It may also indicate error in the active stocker. ON: Handoff is available. OFF: Handoff is unavailable with any error. This signal is ON while active stocker's operation is normal. This signal is turned OFF, when the active stocker detects some exceptions. This signal might be kept OFF, when loader's of the active stocker detects exceptions. The exceptions include: - The active stocker has been changed to manual access mode. - The active stocker is in handoff unavailable state. - When the active stocker detected off the HO_AVBL signal of passive OHS. This signal indicates the state of the active stocker to the passive OHS vehicle before the start of handoff operation. Note: This signal is for interbay passive OHS vehicle use only.
VS_0	P -> A	Signal for the passive OHS vehicle to notify the active of the load or unload position. Specifies the load port used for carrier handoff. One PI/O device per Load Port. ON: Use the load port for carrier handoff. OFF: N/A One PI/O device per 2 load ports; but vehicle does not move when accessing to 2 load ports. ON: Use the left load port for handoff. OFF: Do not use the left load port for handoff. Note: This signal is for interbay passive OHS vehicle use only.
VS_1	P -> A	Signal for the passive OHS vehicle to notify the active of the load or unload position. Specifies the load port used for carrier handoff. One PI/O device per Load Port. OFF: Not used One PI/O device per 2 load ports. ON: Use the right load port for handoff. OFF: Do not use the right load port for handoff. Note: This signal is for interbay passive OHS vehicle use only.

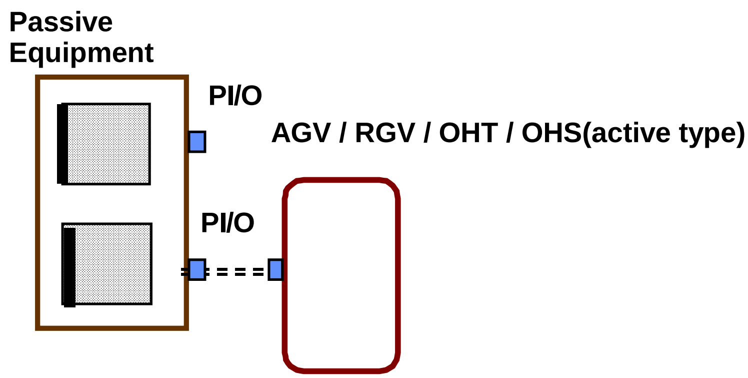
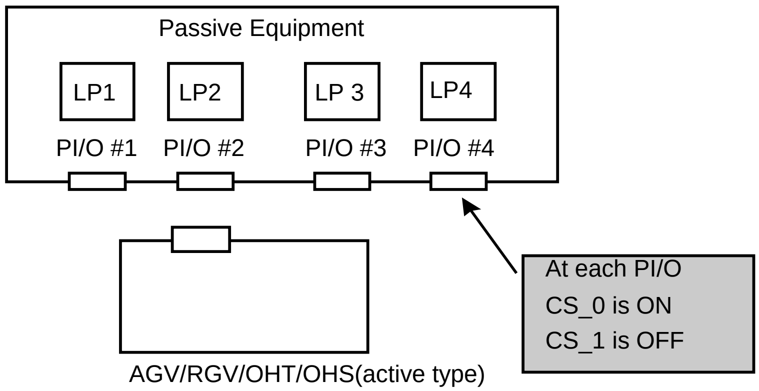
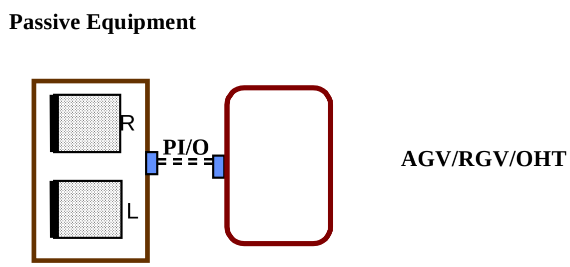


Figure 4
One Parallel I/O Interface for Each Load Port



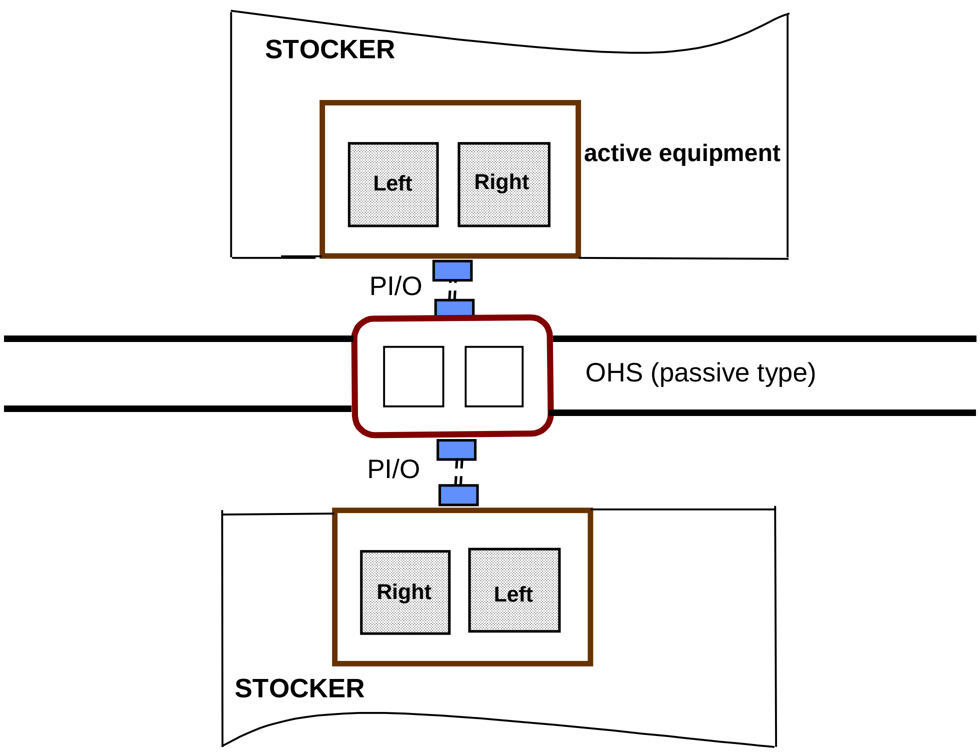
NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

Figure 5
Example of Correspondence of CS_0/CS_1 and Load Ports (Top View) - Single PI/O Controls 1 Load Port



NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

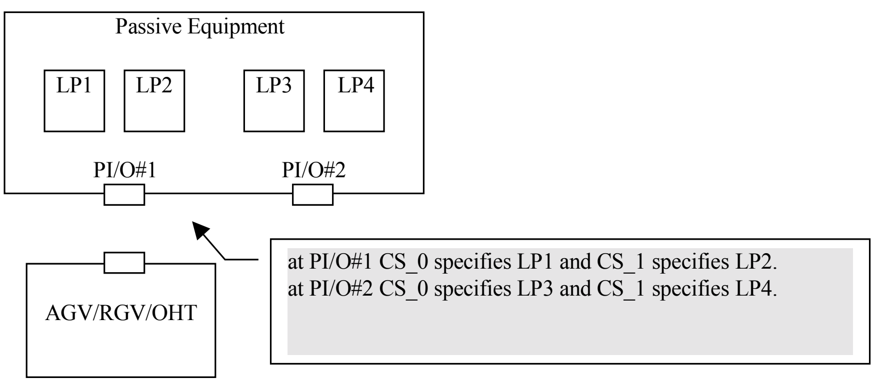
Figure 6
Common Parallel I/O for Two Load Ports



NOTE 1: This figure shows the logical concept only. Physical location is not defined by this standard.

NOTE 2: Decide the left side and right side according to the direction of the equipment from the vehicle.

Figure 7
Common Parallel I/O for Two Load Ports (Interbay AMHS Scenario)



NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

Figure 8
Example of Correspondence of CS_0/CS_1 and Load Ports (Top View) - Single PI/O Controls 2 Load Ports

Table 2 Example of the Load Port Specified by CS_0/CS_1 Signal (one PI/O per 2 load ports)

PI/O#	*CS_0*	*CS_1*	*Load Port*	*Comment*
1	ON	OFF	LP1	Single Handoff or Continuous Handoff
1	OFF	ON	LP2	Single Handoff or Continuous Handoff
1	ON	ON	LP1 & LP2	Simultaneous Handoff
2	ON	OFF	LP3	Single Handoff or Continuous Handoff
2	OFF	ON	LP4	Single Handoff or Continuous Handoff
2	ON	ON	LP3 & LP4	Simultaneous Handoff

Table 3 Example of the Load Port Specified by CS_0/CS_1 Signal (one PI/O per load port)

PI/O#	*CS_0*	*CS_1*	*Load Port*	*Comment*
1	ON	OFF	LP1	When a PI/O is dedicated to a single load port, CS_0 is always on, CS_1 is always off.
2	ON	OFF	LP2	
3	ON	OFF	LP3	
4	ON	OFF	LP4	

Table 4 Example of the Load Port Specified by VS_0/VS_1 Signal (One PI/O per 2 load ports)

		Left Load Port	*Right Load Port*
VS_0	ON OFF	○ ×	♦ ♦
VS_1	ON OFF	♦ ♦	○ ×

○ = Select
× = Not Select
♦ = Do not care

6.2 *Carrier Handoff Sequences*

6.2.1 The signals of the enhanced carrier handoff para-llel I/O interface compliant to this specification must follow these defined sequences. The time diagrams of the carrier handoff sequences are shown in Figures 10–22. Figure 10 is a summary of various handoffs including load/unload and single/simultaneous/continuous handoff sequences. Figure 11 is a transition model of zones. Each change in signal state is numbered in the time diagrams. These numbers are for reference only and may not correspond with the handoff steps or signal order requirements in Section 6.2.

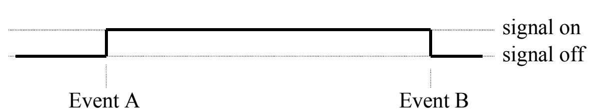


Figure 9
Key for Timing Diagram Signal States

6.2.2 *Load/Unload Boundaries*

6.2.2.1 Changes in the signal state are shown and described as boundaries to clarify each step during handshake and transfer as seen in the signal time diagram in Figure 10 and Tables 5 and 6.

Table 5 Boundary Description

	Description
A	Active equipment starts specifying the port
B	Active equipment tries to engage with the passive equipment in a transfer validating its request
C	Passive equipment indicates to the active equipment that it accepts to be engaged in a transfer based in its load port condition (Load or unload).
D	Active equipment agrees with passive equipment intent and indicates is ready for the transfer.
E	Passive Equipment replies it is also ready for transfer.
F	Start of physical handoff (Assign/resign continuous handoff).
G	Passive equipment detects that a carrier has been placed/removed.
H	Active equipmrent signals the end of physical handoff.
I	Active equipment terminates request for transfer.
J	Active equipment signals that the transfer engagement has completed.
K	Passive equipment indicates that no further transfer activity will occur between them.
L	Active equipment signals acknowledgement of completion of intent to transfer.
M	Active equipment indicates passive equipment no intent of further handshake.
N	Active equipment drops port request signal to leave.

6.2.3 *Zone*

6.2.3.1 Specific time intervals are clarified in nesting structure and defined as zones. Each zone is defined in Figure 10 and Table 6.

Table 6 Zones

Zone	*Definition/Description*
Handshake Active B to M	This zone indicates the state of communication that active equipment is intending to communicate with passive equipment. Start at: VALID ON End at: VALID OFF (last VALID OFF for continuous handoff) Requirements – Passive equipment is not bounded to any transfer activity previous to or after these transitions.
Handshake Engaged C to L	This zone is included in “Handshake Active”. This zone indicates the state of communication that passive equipment is responding to active equipment. Start at: L_REQ ON or U_REQ ON End at: COPY OFF (last COMPT OFF for continuous handoff) Requirement – Passive equipment does not perform any physical activity that changes the load or unload conditions in the equipment after setting L-REQ or U-REQ. Passive equipment shall perform necessary operation such as clamping or docking after the load operation only after it sets Ready signal OFF.
Handoff Request C to L	This zone is included in “Handoff Engaged”. The zone indicates the state of communication that load or unload is engaged between active equipment and passive equipment. Load Motion is engaged if L_REQ is ON and unload motion is engaged if U_REQ is ON. Start at: L_REQ ON or U_REQ ON End at: COMPT OFF Requirement – FOUP shall be kept Docked/Clamped while this request is becoming active and passive equipment shall not perform any physical action during the physical handoff other than the actions required to be ready for active handoff.

Zone	*Definition/Description*
Handoff Active E to J	This zone is included in “Handoff Request”. This zone indicates the state if communication and physical condition that passive equipment is ready for active equipment to perform “Physical Handoff”. Start at: READY ON End at: COMPT ON Requirement – Passive equipment is required to undock/unclamp the FOUP and place it at the load port if the FOUP is not at the port prior to enter this zone during unload. Passive equipment shall not activate dock/undock motion and clamp/unclamp motion during loading in this zone.
Physical Handoff F to H	This zone is inclued in “Handoff Active”. This zone indicates that the active equipment is engaged in physically delivering or removing FOUP to/from the equipment. One carrier is loaded or unloaded if CS_0 or CS_1 is ON. Two carriers are loaded or unloaded if CS_0 or CS_1 are ON Start at: BUSY ON End at: BUDY OFF Requirements – Active equipment is required to start the movement to load/unload carrier and completely move out from handoff conflict area.

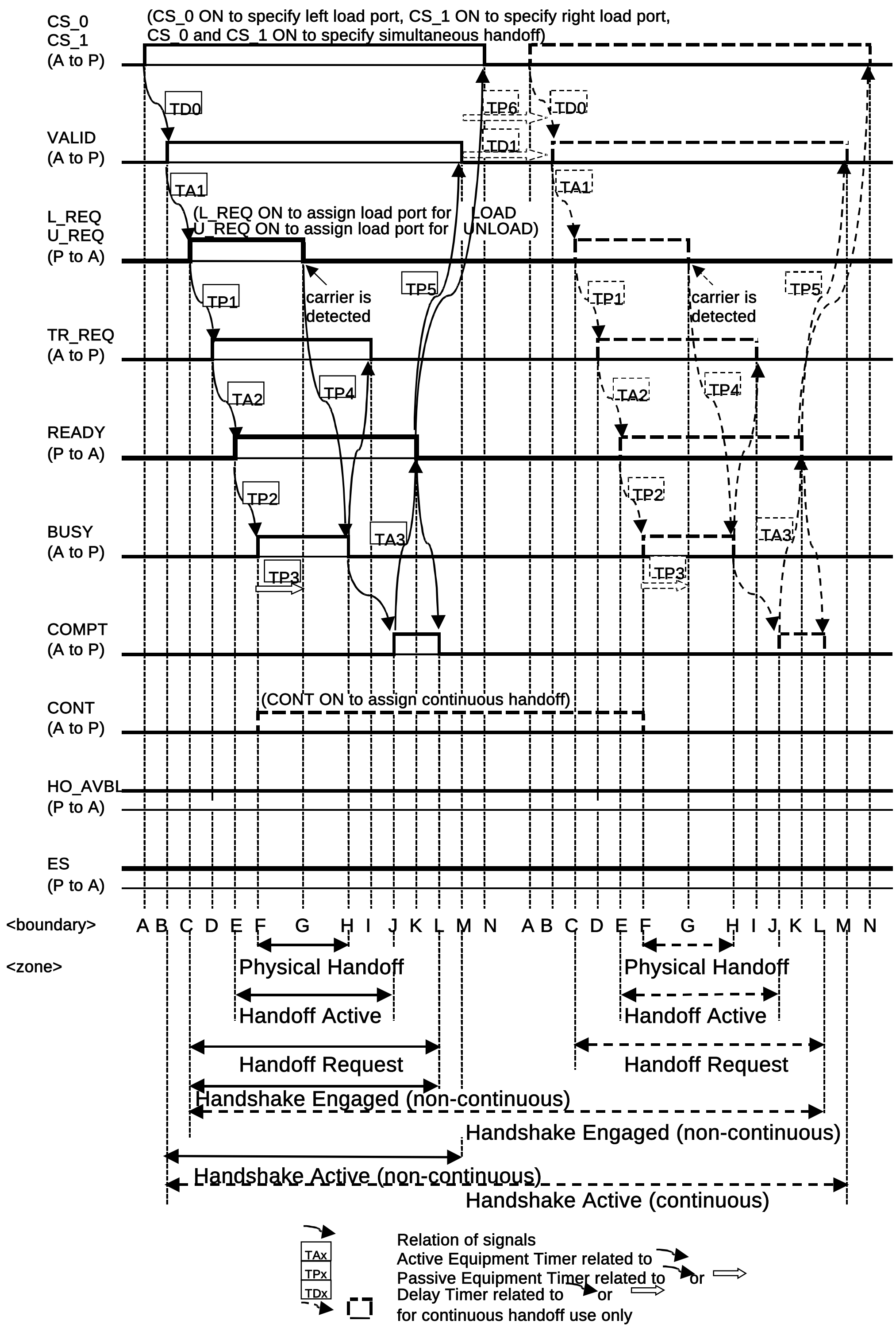
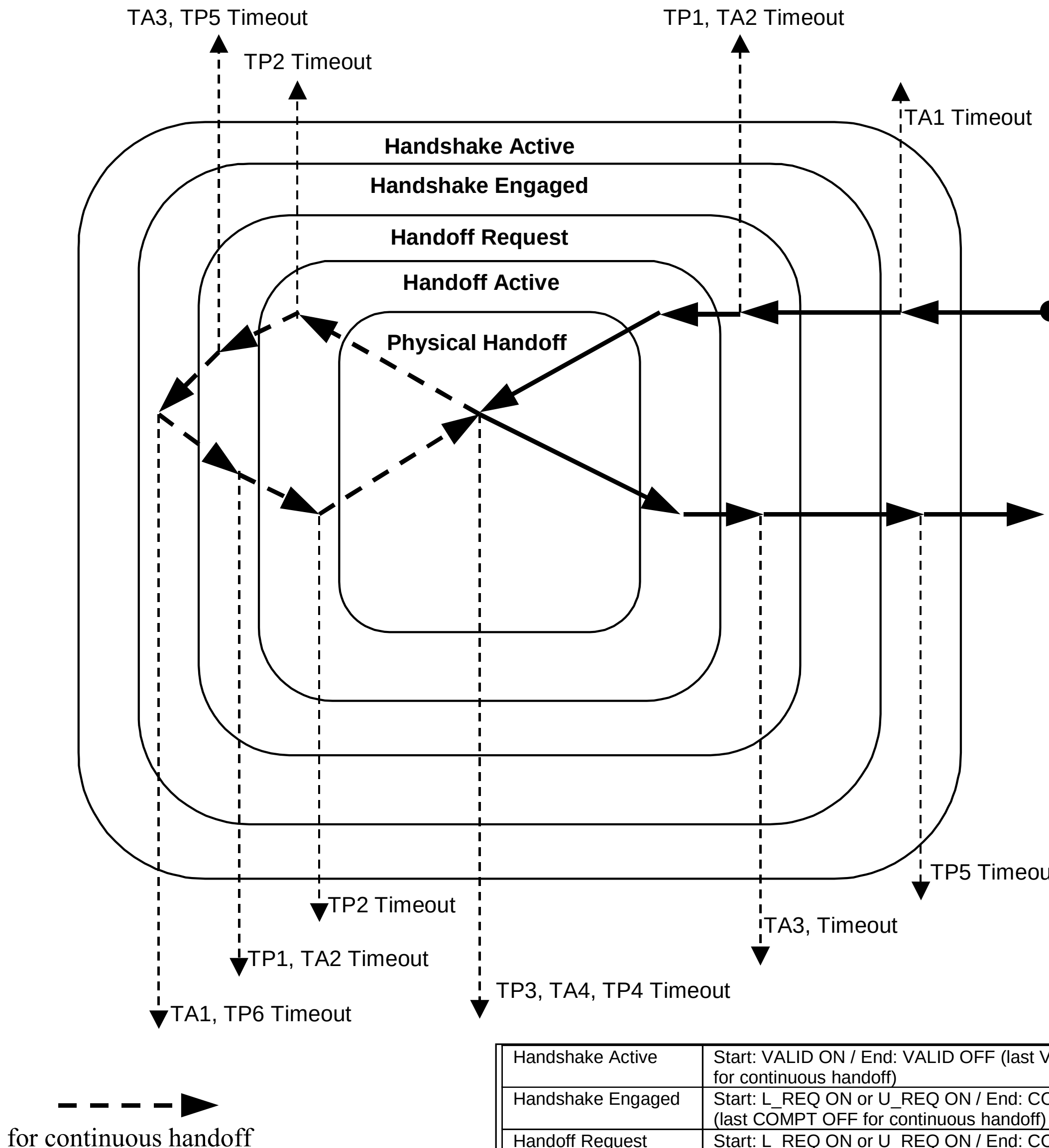


Figure 10
Summary of Time Diagram



Handshake Active	Start: VALID ON / End: VALID OFF (last VALID OFF for continuous handoff)
Handshake Engaged	Start: L_REQ ON or U_REQ ON / End: COMPT OFF (last COMPT OFF for continuous handoff)
Handoff Request	Start: L_REQ ON or U_REQ ON / End: COMPT OFF
Handoff Active	Start: READY ON / End: COMPT ON
Physical Handoff	Start: BUSY ON / End: BUSY OFF

Figure 11
State Transition Model

6.2.4 *Single Handoff Sequence (loading/unloading)*

6.2.4.1 The time diagrams of the loading and unloading operations in single handoff are shown in Figures 12 and 13, respectively. The sequence shown in Figures 12 and 13 is:

1) After the active equipment (AMHS equipment) reaches the handoff location in front of the load port, the active equipment specifies the load port number at which the active equipment is to handoff a carrier to the passive equipment using CS_0 and CS_1.

2) The active equipment turns the VALID signal ON. It shows that the signal transition of CS_0 and CS_1 is valid.

NOTE 3: The passive equipment should not verify if the CS_0 or CS_1 signals are ON until after the active equipment has turned the VALID signal ON, which signifies the interface communication is valid.

3) The passive equipment turns the L_REQ signal ON if the load port is ready to perform loading operation and turns the U_REQ signal ON if the load port is ready to perform unloading operation.

4) To request the passive equipment to start the carrier handoff operation, the active equipment turns the TR_REQ signal ON.

5) The passive equipment turns the READY signal ON when the passive equipment is ready for the handoff of the carrier.

6) After confirming the READY signal is ON, the active equipment turns the BUSY signal ON and starts the handoff operation.

7) The passive equipment turns the L_REQ (U_REQ) signal OFF when a carrier is placed correctly on the load port (when the carrier on the load port is removed).

8) After the completion of the load or unload operation and after the active equipment is clear of the handoff conflict area, the active equipment turns the BUSY signal OFF. The active equipment must confirm L_REQ signal (U_REQ signal) is turned OFF before the BUSY signal turn OFF.

9) The active equipment turns the TR_REQ signal OFF after the BUSY OFF.

10) The active equipment turns the COMPT signal ON to inform the passive equipment about the completion of the handoff operation.

NOTE 4: If the passive equipment verifies the BUSY and TR_REQ signals are OFF, it should verify these signals only after the active equipment has turned the COMPT signal ON, which signifies the active equipment has completed the handoff operation.

11) After confirming that the active equipment turned the COMPT signal ON, the passive equipment turns the READY signal OFF.

12) After the READY signal is turned OFF, the active equipment turns the COMPT, VALID, CS_0, and CS_1 signals OFF.

13) The handshake with the passive equipment is closed when the VALID signal is turned OFF.

NOTE 5: If the passive equipment checks for COMPT, VALID and CS_0 or CS_1 signals, it should allow the signals to turn OFF in any order without reporting an error.

6.2.4.2 This section defines the Single Handoff Sequence between the OHS (interbay passive type vehicle) and Stocker. The time diagrams of the loading and unloading operations in single handoff are shown in Figures 14 and 15, respectively. The sequence shown in Figure 14 and Figure 15 is:

1) When the passive equipment (i.e., OHS) arrives at the active equipment (i.e., STOCKER), the passive equipment specifies to the active equipment where the handoff will take place using VS_0 and VS_1.

2) At the same time as VS_set, the passive equipment turns the L_REQ signal ON if the load port is ready to perform a loading operation or turns the U_REQ signal ON if the load port is ready to perform an unloading operation.

3) The passive equipment turns the VA signal ON. It shows that the signal transition of VS_0 and VS_1, L_REQ or U_REQ is valid.

4) After the active equipment recognizes the VA signal, it checks the VS_0 and VS_1, L_REQ and U_REQ signal and turns the TR_REQ signal ON to request the passive equipment to start the carrier handoff operation.

5) The passive equipment turns the READY signal ON when the passive equipment is ready for the handoff of the carrier.

6) After confirming the READY signal is ON, the active equipment turns the BUSY signal ON and starts the handoff operation.

7) The passive equipment turns the L_REQ (U_REQ) signal OFF when a carrier is placed correctly on the load port (When the carrier on the load port is removed).

8) After the completion of the load or unload operation and after the active equipment is clear of the handoff conflict area, the active equipment turns

the BUSY signal OFF. The active equipment must confirm L_REQ signal (U_REQ) is turned OFF before the BUSY signal is turned OFF.

9) The active equipment turns the TR_REQ signal OFF at the BUSY OFF.

10) The active equipment turns the COMPT signal ON to inform the passive equipment about the completion of the handoff operation.

11) After confirming that the active equipment turned the COMPT signal ON, the passive equipment turns the READY signal OFF.

12) After the READY signal is turned OFF, the active equipment turns the COMPT OFF.

13) After confirming that the active equipment turned the COMPT signal OFF, the passive equipment turns the VS_0, VS_1 and VA OFF.

14) The handshake with the passive equipment is closed when the VA signal is turned OFF.

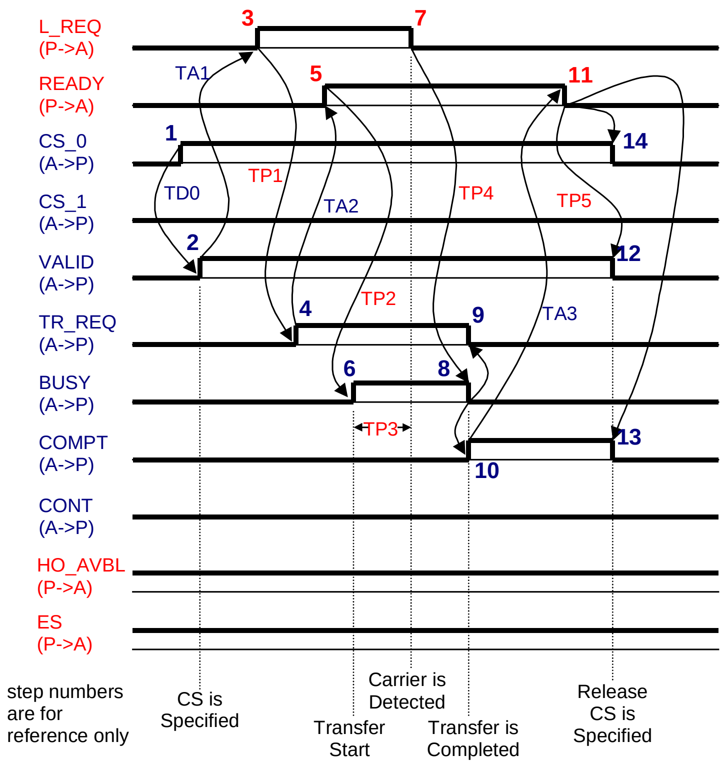


Figure 12
Signal Time Diagram for Single Handoff (LOAD)

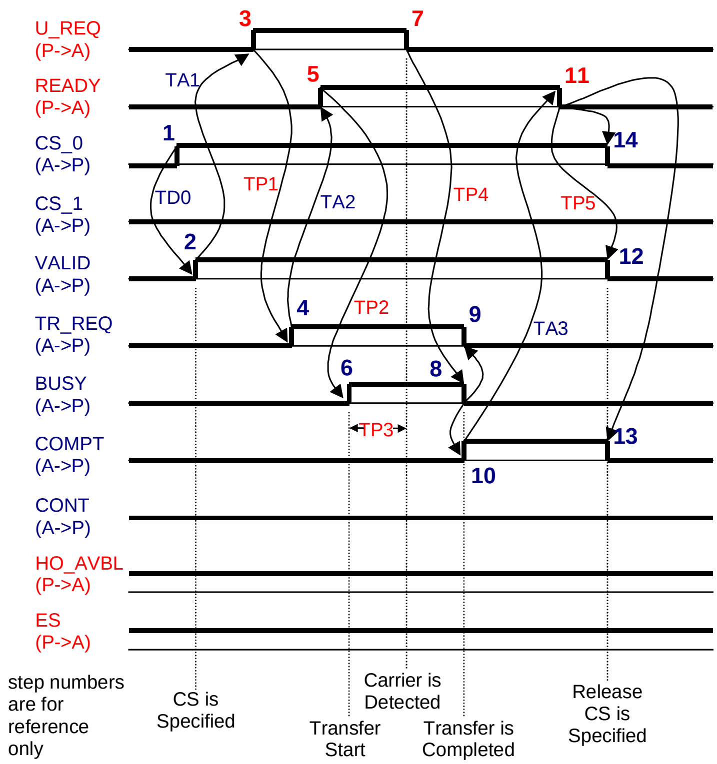


Figure 13
Signal Time Diagram for Single Handoff (UNLOAD)

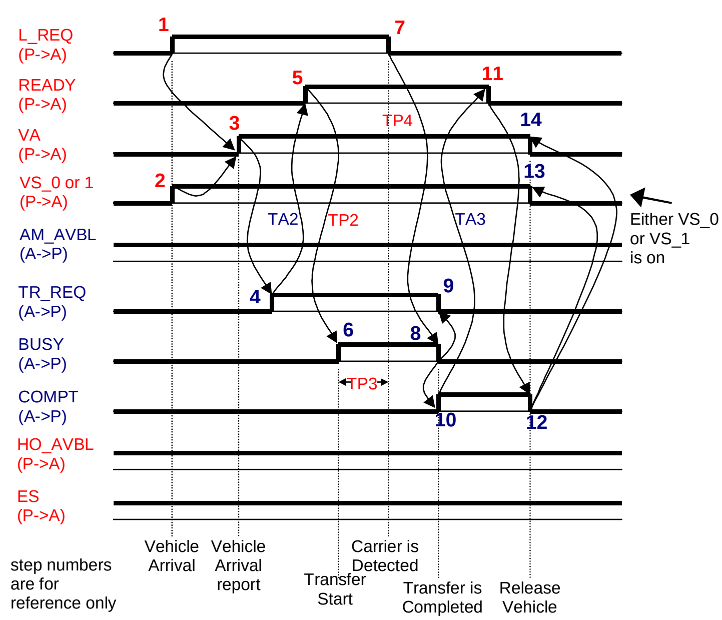


Figure 14
Signal Time Diagram for Single Handoff (LOAD)
(Interbay Passive OHS only)

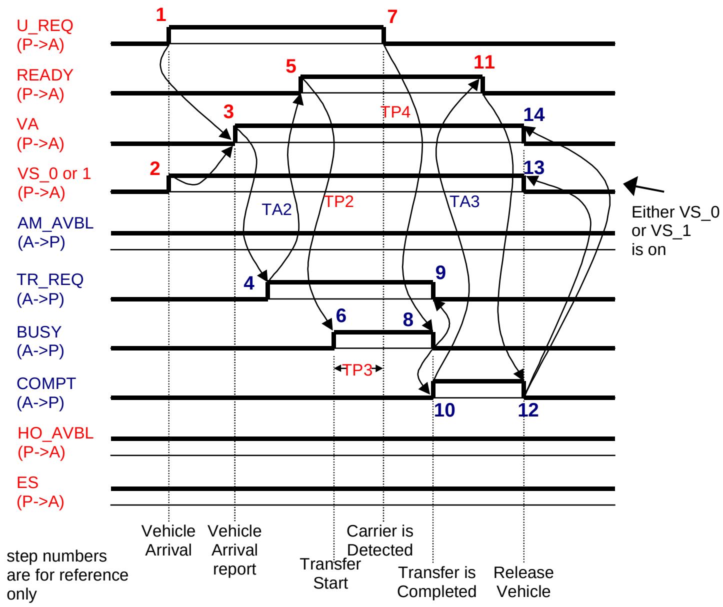


Figure 15
Signal Time Diagram for Single Handoff (UNLOAD)
(Interbay Passive OHS only)

6.2.5 *Simultaneous Handoff Sequence (loading)*

6.2.5.1 This specification defines the capability to control simultaneous handoff. Simultaneous handoff is the handoff operation in which active equipment transfers two carriers to two load ports simultaneously in a single transfer operation. Some types of AMHS equipment are able to transfer two carriers simultaneously in a transfer operation. The capability can be applied to increase the performance of the transfer. For example, simultaneous handoff can be applied to single arm/double hand AMHS equipment capable of transferring two carriers in a single transfer operation.

6.2.5.2 The time diagram of simultaneous handoff is shown in Figure 16. The figure shows only the load operation; however, L_REQ may be changed to U_REQ for the unload operation. The sequence of the simultaneous handoff is the same as that of the single handoff except that the specification of the load port with CS_0 and CS_1 signals and the definition of ON/OFF of the L_REQ and U_REQ signals are different. The following list describes the sequence which is different from Figures 12 and 13:

1) The active equipment turns the signals CS_0 and CS_1 ON to inform the passive equipment it is simultaneous handoff.

2) The active equipment turns the VALID signal ON after the transition of CS_0 and CS_1 is effective.

3) The passive equipment turns the L_REQ (U_REQ) signal ON when both carriers in the specified load ports (load ports of both CS_0 and CS_1) are ready to be loaded (unloaded).

4) When both carriers are detected (removed) at the two load ports, the L_REQ (U_REQ) signal is turned OFF.

6.2.5.3 This specification defines the capability to control simultaneous handoff. Simultaneous handoff is the handoff operation in which active equipment transfers two carriers to two load ports simultaneously in a single transfer operation. Some types of interbay AMHS equipment (i.e. stockers) are able to transfer two carriers simultaneously in a transfer operation. The capability can be applied to increase the performance of the transfer. For example, simultaneous handoff can be applied to single arm/double hand AMHS equipment capable of transferring two carriers in a single transfer operation.

6.2.5.3.1 The time diagram of simultaneous interbay handoff using a passive OHS vehicle is shown in Figure 15. The figure shows only the load operation, however L_REQ may be changed to U_REQ for the unload operation. The sequence of the simultaneous handoff is the same as that of the single handoff except that the specification of the load port with VS_0 and VS_1 signals and the definition of ON/OFF of the L_REQ and U_REQ signals are different.

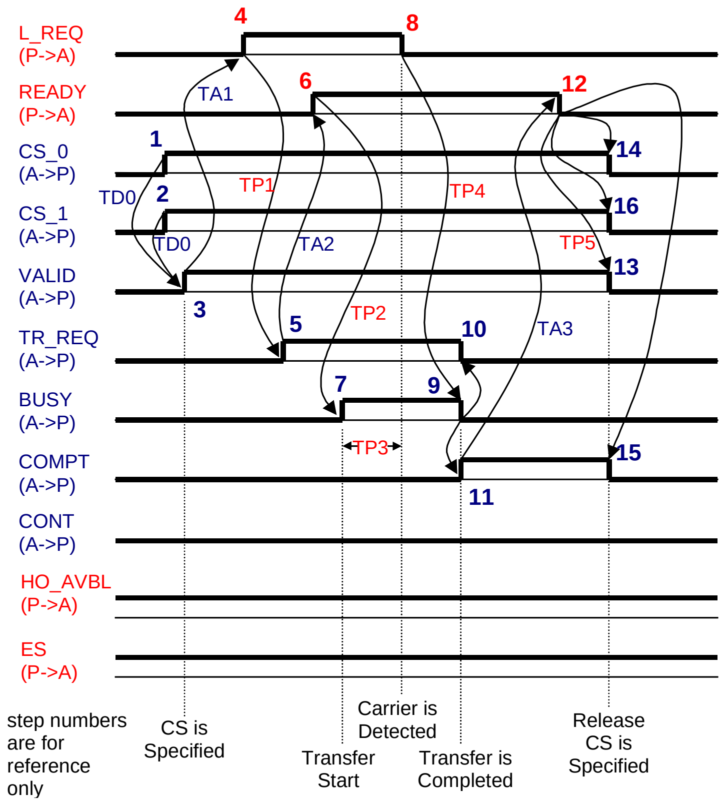


Figure 16
Signal Time Diagram for Simultaneous Handoff (LOAD)

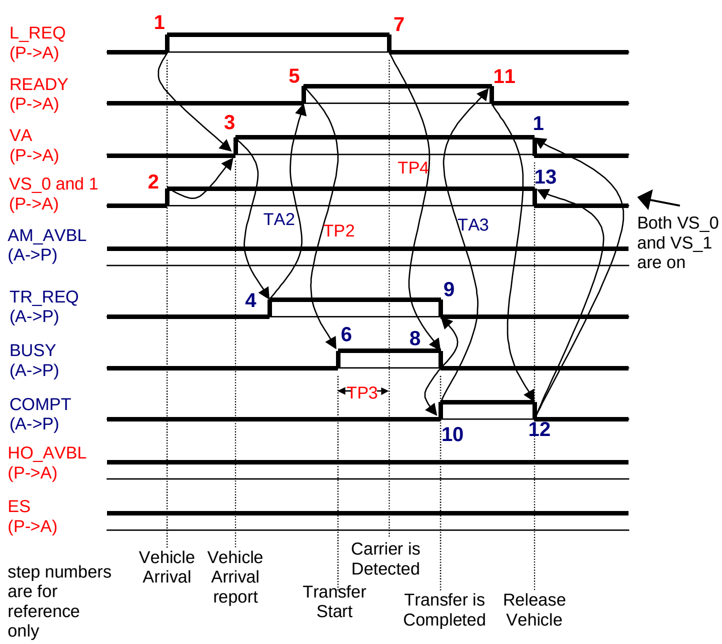


Figure 17
Signal Time Diagram for Interbay Simultaneous Handoff (LOAD) using a Passive OHS Vehicle

6.2.6 *Continuous Handoff Sequence*

6.2.6.1 This specification defines the capability to control continuous handoff. Continuous handoff is the handoff operation in which the active equipment transfers two or more carriers sequentially and continuously in a carrier transfer operation. Some types of AMHS equipment are able to handoff more than two carriers in a transfer operation. This capability can be applied to increase the performance of the transfer.

6.2.6.2 When the passive equipment has a door in front of the load port, the door on passive equipment must be opened before the carrier handoff starts by the active equipment. It is redundant to open and close the door for a carrier handoff when two or more carriers are transferred. Therefore, the door shall be kept open during the carrier transfer operation. Continuous handoff is applied to the transfer operation to avoid redundant operations.

6.2.6.3 Continuous handoff sequence for handoffs at a load port (Unload -> Load): The example time diagram for continuous handoff is shown in Figure 18. This example shows the sequence of unload and load operations performed continuously at the load port. Each sequence in the continuous handoff is the combination of the single handoff sequence. In addition, the CONT signal is used to indicate a continuous handoff. In the sequence shown in Figure 10, the carrier on the load port is unloaded first, and a new carrier is loaded on the load port. The CONT signal is turned ON at the time of active equipment BUSY ON of the first handoff to indicate that the handoff is continuous. In successive load sequences, the same load port number (CS_0 in this example) is specified to use the same load port. In this example, there are no more carriers that are to be transferred after the second load sequence, therefore the active equipment turns the CONT signal OFF when the BUSY signal is turned ON in the second handoff to indicate the continuous handoff is complete.

6.2.6.4 Continuous handoff sequence for handoffs at different load ports (Load -> Load): The example time diagram for continuous handoff on the different load ports is shown in Figure 19. In this example, the active equipment first transfers a carrier to the load port corresponding to CS_0, then another carrier is transferred to the load port corresponding to CS_1. In this example, the sequence is the same as that of the continuous handoff (handoff at a load port: Unload -> Load) shown in section above except for the specification of the load ports.

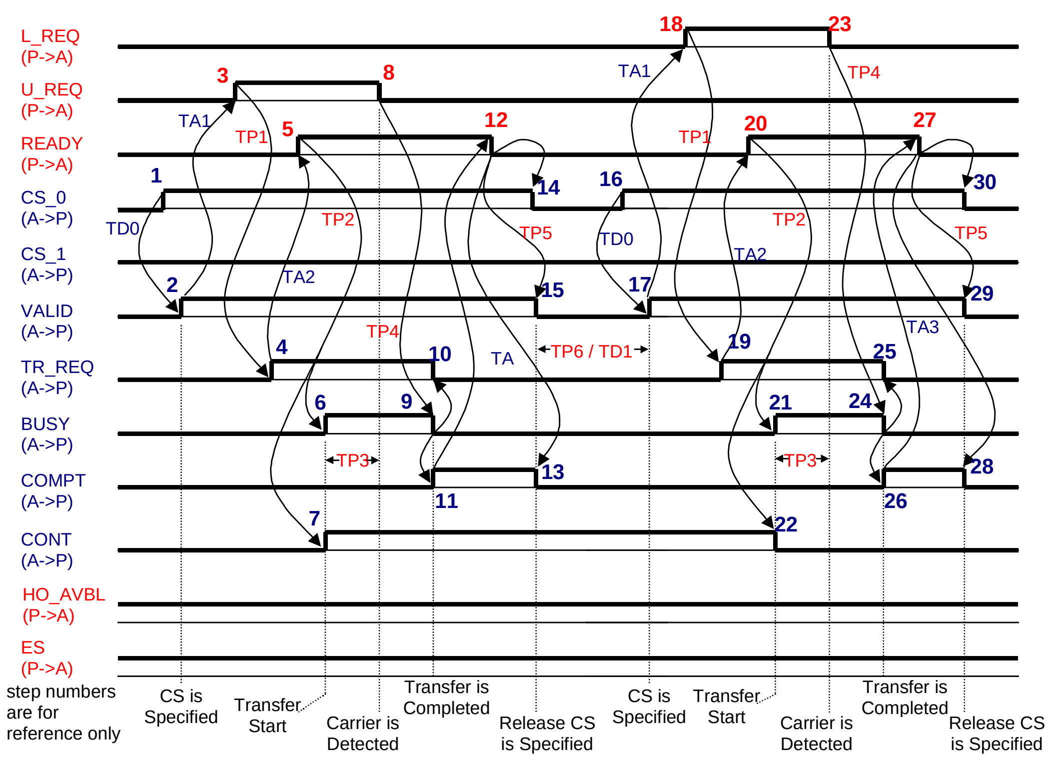


Figure 18
Signal Time Diagram for Continuous Handoff (UNLOAD and LOAD)

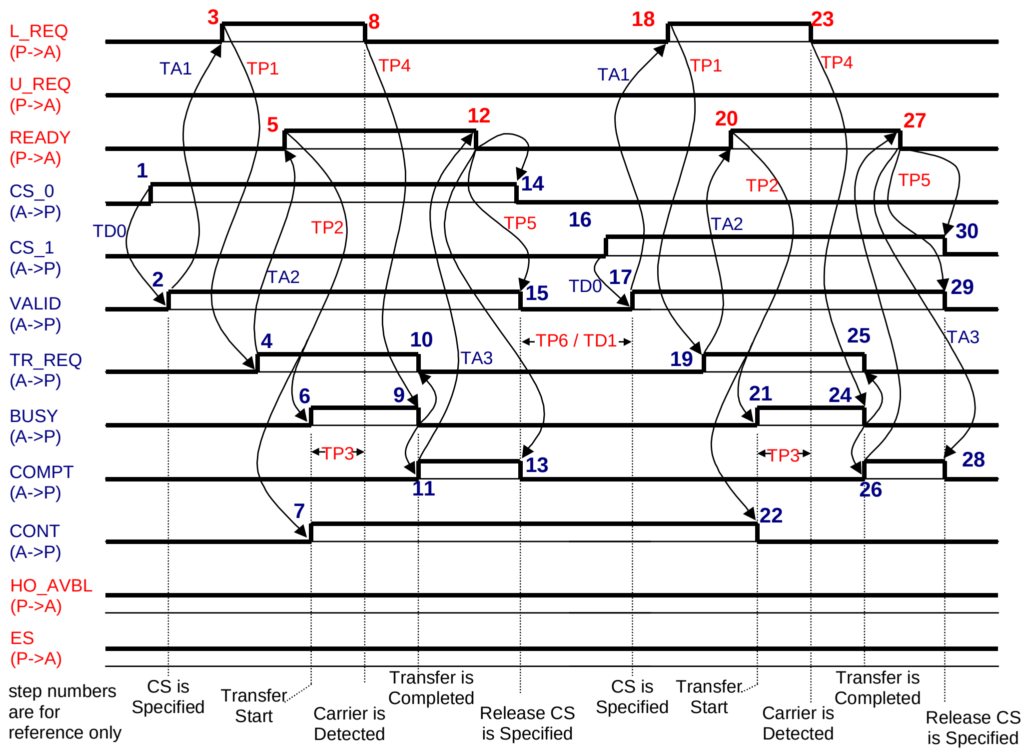


Figure 19
Signal Time Diagram for Continuous Handoff (LOAD and LOAD)

6.2.7 *Handoff Available Signal Operation Sequence (HO_AVBL)*

6.2.7.1 Example time diagrams for the HO_AVBL signal are shown in Figures 20 and 21. The HO_AVBL signal is ON during passive equipment normal operations and shall be turned OFF when the passive equipment detects any exception for the handoff. The active equipment is informed of the exception condition by the HO_AVBL signal. The active equipment is expected to confirm the HO_AVBL signal in the following periods:

a) From the time at which the VALID signal is turned ON to the time at which the L_REQ or U_REQ signal is turned ON.

b) From the time at which the TR_REQ signal is turned ON to the time at which the READY signal is turned ON.

6.2.7.2 Figure 20 is the time diagram to explain situation a) in section above. The active equipment stops the handoff operation when it detects that the HO_AVBL signal is turned OFF by the passive equipment. The active equipment turns the VALID signal OFF to close the handshake by the information (CS_0 and CS_1 signals must be set to OFF at this time). The passive equipment turns the HO_AVBL signal ON after the VALID signal is turned to OFF (L_REQ or U_REQ must be set to OFF).

6.2.7.3 Figure 21 is the time diagram to explain situation b) in section above. The active equipment stops the handoff operation when it detects that the HO_AVBL signal is turned OFF by the passive equipment. The active equipment turns the VALID signal OFF to close the handshake by the information (CS_0, CS_1, and TR_REQ signals must be set to OFF). The passive equipment turns the HO_AVBL signal ON after the VALID signal is turned to OFF (L_REQ or U_REQ must be set to OFF).

6.2.8 *Handoff Available Signal Operation Sequence (for interbay passive OHS and Stocker)*

6.2.8.1 Example time diagrams for the HO_AVBL signal are shown in Figures 20 and 21. The HO_AVBL signal is ON during passive OHS normal operations and shall be turned OFF when the passive OHS detects any exception for the handoff. The active stocker is informed of the exception condition by the HO_AVBL signal. The active stocker is expected to confirm the HO_AVBL signal in the following period:

a) From the time at which the TR_REQ signal is turned ON to the time at which the READY signal is turned ON.

6.2.8.2 Figure 22 is a diagram explaining the above item a). The active stocker stops transferring when the active stocker detects that the HO_AVBL signal has been turned OFF by the passive OHS. By turning off the AM_AVBL signal, the active Stocker closes the transfer sequence. In such a case, the TR_REQ signal must go OFF as the transfer sequence as ended. Also, the passive OHS must turn OFF the VS_0 and VS_1 signals. Next, the passive OHS must turn ON the HO_AVBL signal after the VA signal has gone OFF (the L_REQ or U_REQ must be set OFF).

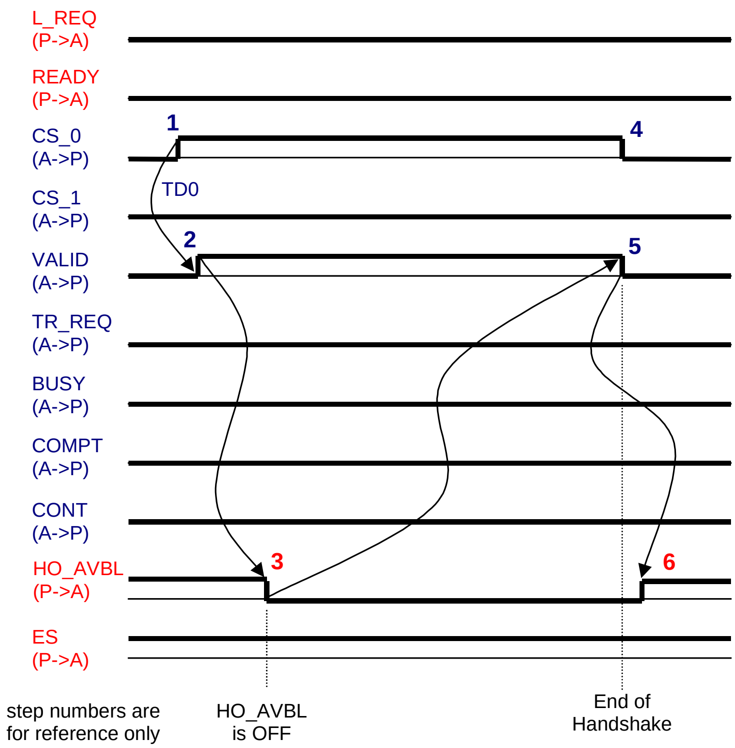


Figure 20
Example of Handoff Available Signal

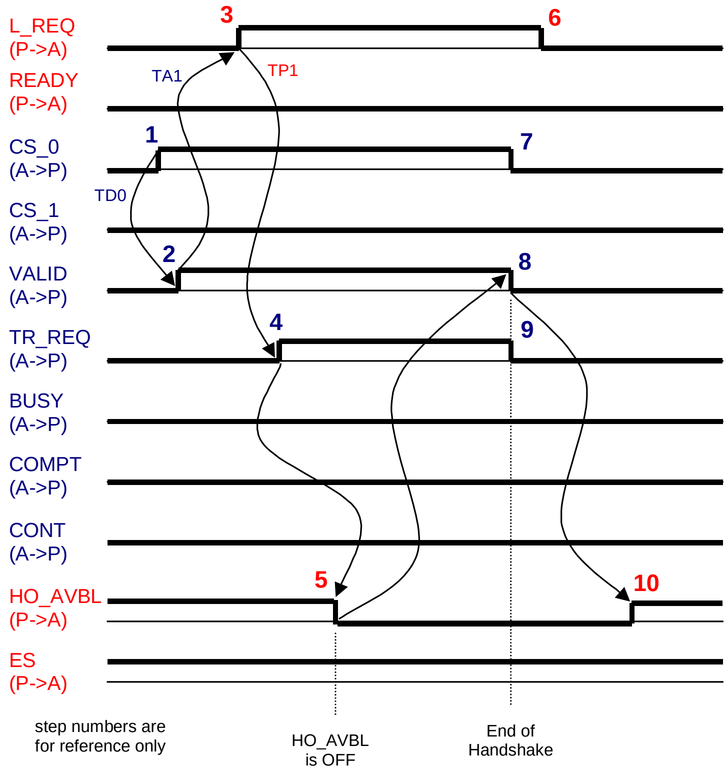


Figure 21
Example of Handoff Available Signal

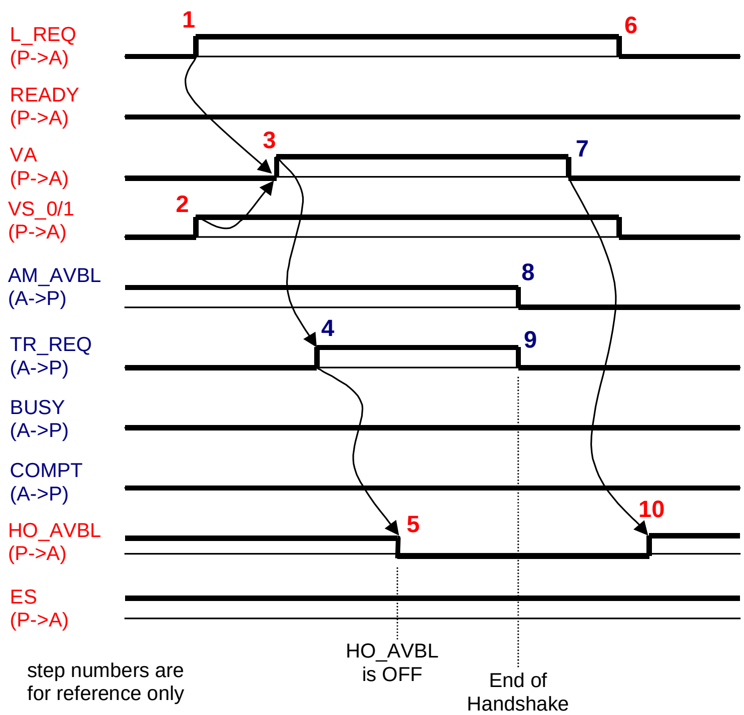


Figure 22
Example of Handoff Available Signal
(interbay passive OHS only)

6.3 *Error Indication and Detection*

6.3.1 *Error Indication*

6.3.1.1 To support operational reliability, this specification will define the following capabilities to indicate errors on the interface:

a) inform handoff unavailable which means the passive equipment (or passive OHS) is not available for material handoff operation to the active equipment.

b) inform emergency stop request to the active equipment (or active stocker).

c) inform handoff timeout error.

6.3.2 *Error Detection*

6.3.2.1 Interlock timeouts are required to detect handoff sequence error between the active and passive equipment. This specification defines the interlock timeouts to be monitored by the active equipment and the passive equipment. Table 7 shows the interlock timeouts for active equipment. Table 8 shows the timeouts for the passive equipment. TAx (x is a number) represents the timer for the active equipment, and TPx (x is a number) represents the timer for the passive equipment. The range for all timers (except TD0) shall be from 1 second to 999 seconds. All timer setpoints shall be user programmable.

6.3.2.2 The delay timer specifies the delay time between VALID signals within one continuous sequence of handoffs. Specifically, it signifies the delay following the VALID signal turning OFF on the completion of the first handoff and the VALID signal turning ON at the start of the second handoff. The delay timer is required because the passive equipment may need a certain time margin to detect the second VALID signal transition to ON. Table 9 shows the delay timer. All timer setpoints shall be user programmable.

6.3.2.3 The recommended and optional delay timer TD0 defines the timing between CS_0 or CS_1 ON and VALID ON for the active equipment as shown in the signal time diagrams. In this way, the passive equipment can predict the timing in which the active equipment will output the signal allowing the transfer interlock to be performed accurately.

Table 7 Active Equipment Timer

Timer Name	*Period (Signal Status) to Monitor the Timer*	*Range (SEC)*	*TYP (SEC)*
TA1	VALID ON - L_REQ ON VALID ON - U_REQ ON	1–999	2
TA2	TR_REQ ON - READY ON	1–999	2
TA3	COMPT ON - READY OFF	1–999	2

NOTE 1: The minimum timer value does not define the response time of the active equipment.

NOTE 2: These timer values must be implemented for detecting timeouts and are not meant to specify the delay time between signals. The equipment response time must be faster than the timeout of the timer.

Table 8 Passive Equipment Timer

Timer Name	*Period (Signal Status) to Monitor the Timer*	*Range (SEC)*	*TYP (SEC)*
TP1	L_REQ ON - TR_REQ ON U_REQ ON - TR_REQ ON	1–999	2
TP2	READY ON - BUSY ON	1–999	2
TP3	BUSY ON - CARRIER DETECT BUSY ON - CARRIER REMOVE	1–999	60
TP4	U_REQ OFF - BUSY OFF L_REQ OFF - BUSY OFF	1–999	60
TP5	READY OFF - VALID OFF	1–999	2
TP6	VALID OFF - VALID ON (Continuous handoff)	1–999	2

NOTE 1: The minimum timer value does not define the response time of the passive equipment.

NOTE 2: These timer values must be implemented for detecting timeouts and are not meant to specify the delay time between signals. The equipment response time must be faster than the timeout of the timer.

Table 9 Delay Timer

Timer Name	*Period (Signal Status) to Monitor the Timer*	*Range (SEC)*	*TYP (SEC)*
TD0	CS ON - VALID ON	0.1–0.2	0.1
TD1	VALID OFF - VALID ON	1–999	1

6.3.3 *Error Recovery*

6.3.3.1 Error recovery procedures are not defined in this specification. Recovery procedures may require operator assistance and/or proprietary procedures specific to the equipment. It is recommended that the recovery procedure (ex, abort interlock sequence and set to restart/complete) be provided on the active equipment and the passive equipment.

6.4 *Connector Type, Signal, and Pin Assignment*

6.4.1 The connector type for the passive equipment side must be type DB-25 socket housing (female) as specified in ISO 4902. The connector will have female 4-40 threaded jack screw locks. Suitable 25 pin connectors known as Type "D" are similar to Amphenol MIN RAC 17 series with jack screw locks. It is recommended that the connector on the passive equipment should be appropriately labeled. As shown in Figure 22, this standard specifies the connector on the passive side optical PI/O for floor based vehicles (RGV, AGV, others) (case 1), as well as the active to passive connector between an overhead delivery system and production equipment (case 2). Figure 23 defines the PI/O point of interface for the interbay AMHS (OHS and stocker). If the OHS is the active device in the interbay AMHS then the stocker is the passive device. Likewise, if the OHS is the passive device, then the stocker is the active device.

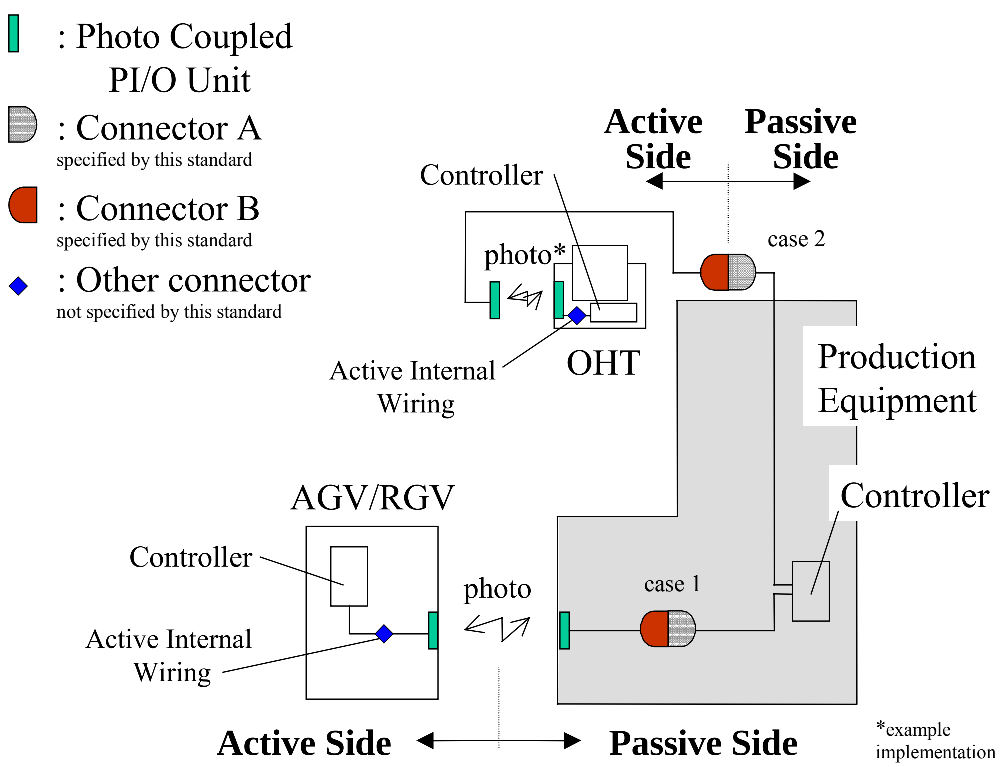


Figure 23
Connector Locations

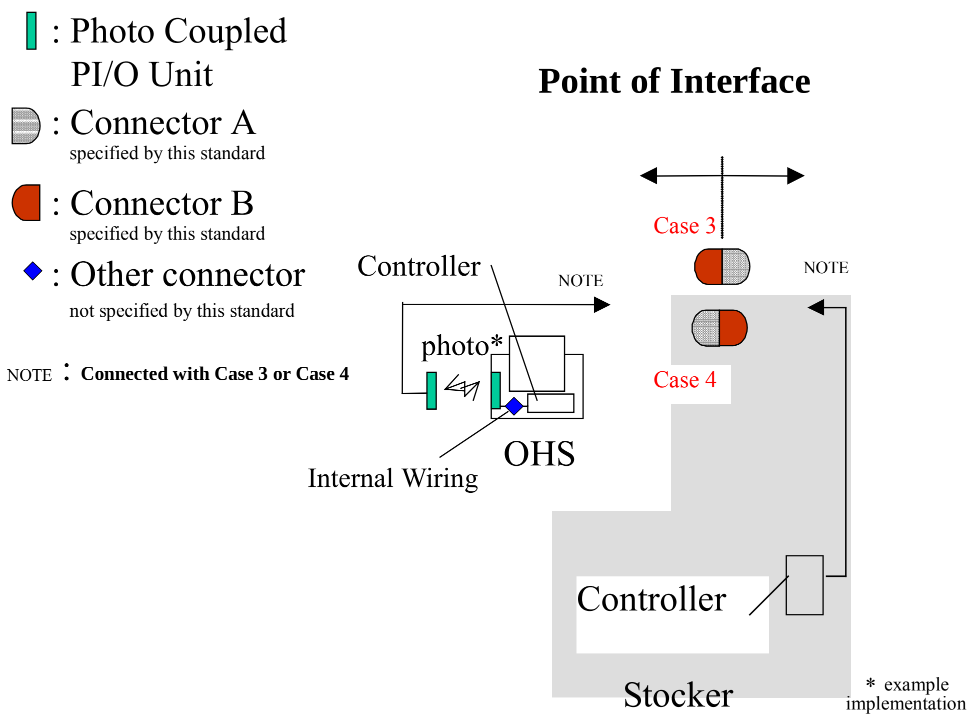


Figure 24
Connector Location Schematic for Interbay AMHS (i.e., OHS and STOKER)

6.4.2 Power and signal specifications are as follows:

Table 10 Input/Output Specifications

Active/Passive	*On State*		*Off State*	
	Current	*Voltage*	*Current*	*Voltage*
Input	Max. 10mA	Max.1.8 Vdc	Max. 200µA	Max. 30 Vdc
Output	Min. 25mA Sink	Max 1.8 Vdc	Max. 100µA Source	Max. 30 Vdc

6.4.2.1 Power Supply Voltage: +24 Vdc Nominal (Min. +18 Vdc, Max. +30 Vdc) from no load to full load (100mA).

6.4.2.2 For hardwired applications the power and power common of the passive must be isolated from the power and power common of the active. Also, internally to either the active or passive equipment, the power and power common must be isolated from the signal common.

6.4.3 Bit assignments are specified in Figure 27.

6.4.4 Connector pin assignments where required in Section 6.4.1 and Figures 23 and 24 are specified in Figures 28 and 29 and Table 11.

6.4.5 All configurations will include signal optoisolation within each equipment conforming to this standard to allow for optical transmission or hardwired configuration to coexist. See Figures 25 and 26 below.

6.4.6 Timing diagram signal state of Off corresponds to no current flow for the hardwired configuration or no optical signal transmitted for the optical transmitter configurations.

6.5 *Interface Sensor Unit Size*

6.5.1 The maximum dimensions in millimeters of the interface sensor are indicated in Figure 30. This size includes volume needed for rigid portions of the sensor's electrical connector and cable. For systems which are designed to handle 300 mm wafer carriers, the interface sensor unit must be designed in a way that allows mounting of the unit within the exclusion volume as defined per SEMI E15.1 with the optical axis centered in this exclusion volume.

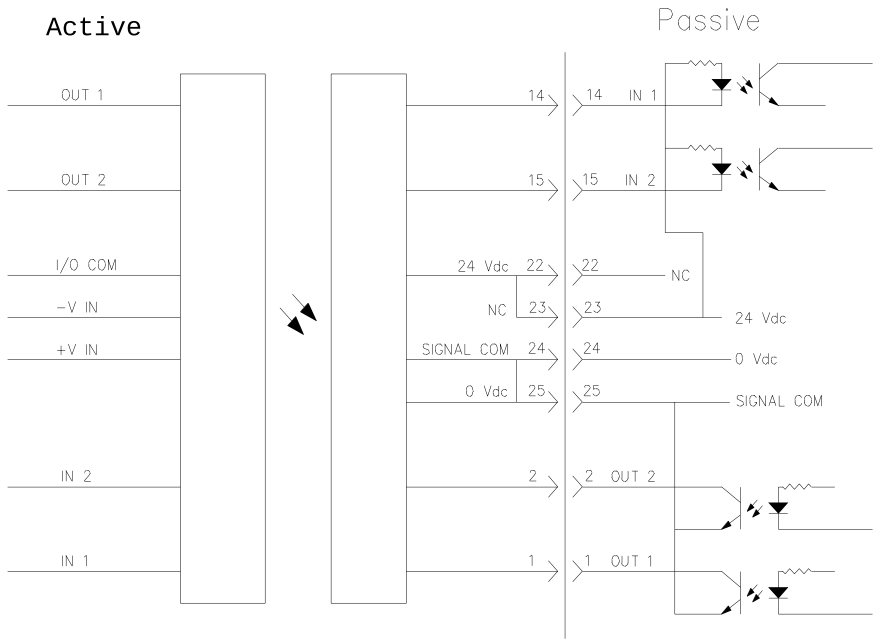


Figure 25
Optoisolated Implementation Using an Optical Transmission Device

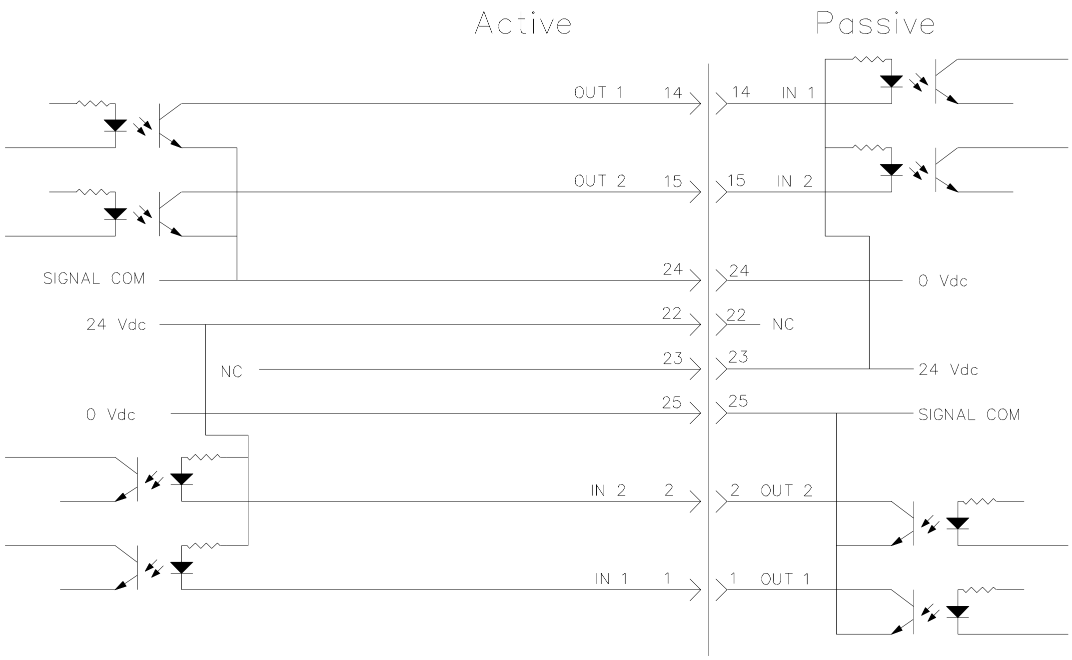
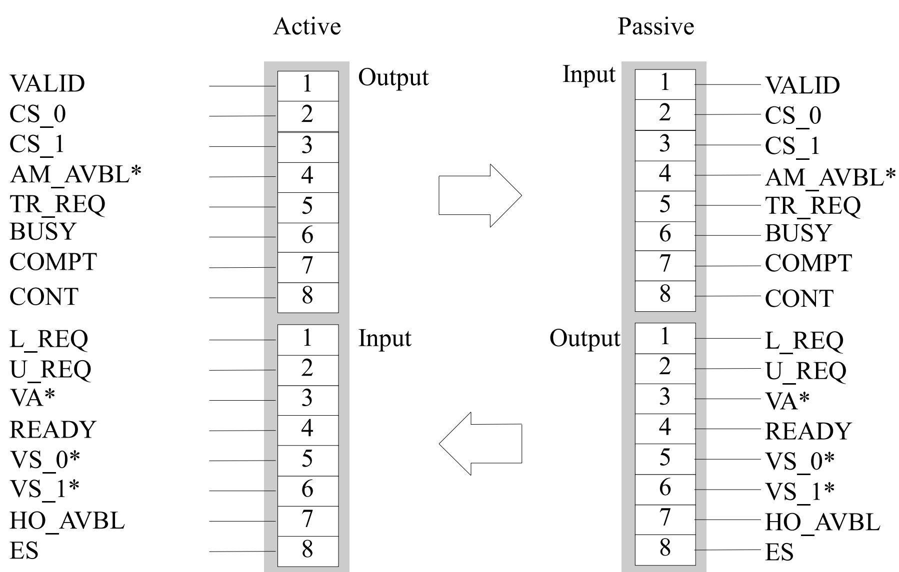
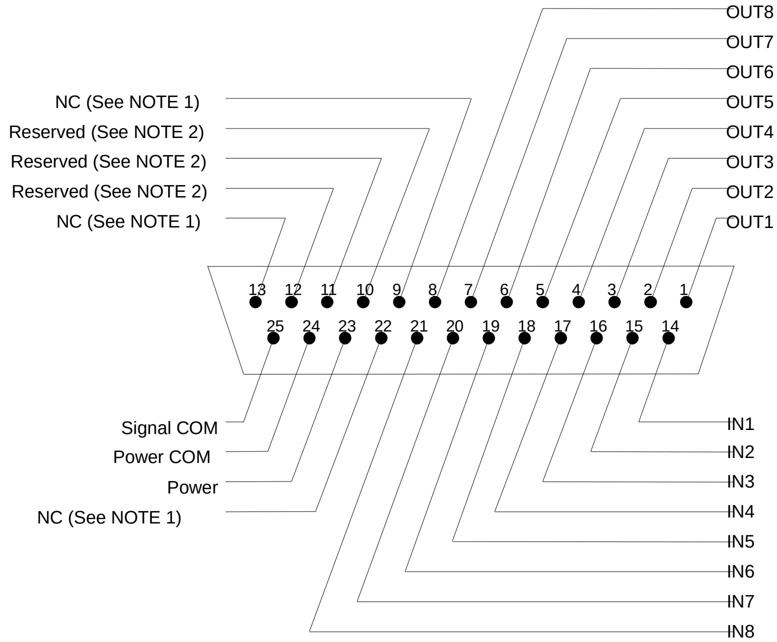


Figure 26
Optoisolated Implementation Using Hardwired Connection



* This signal is for interbay passive OHS vehicle use only.

Figure 27
Bit Assignments for Interlock Signal between Passive and Active



NOTE 1: NC = Not Connected

NOTE 2: Reserved = The pin may be used to support the signal required for a type of any interface unit. It cannot be used for current or future implementations of this specification.

Figure 28
Pin Assignments for Connector of Passive Equipment Side (Pin Side View)

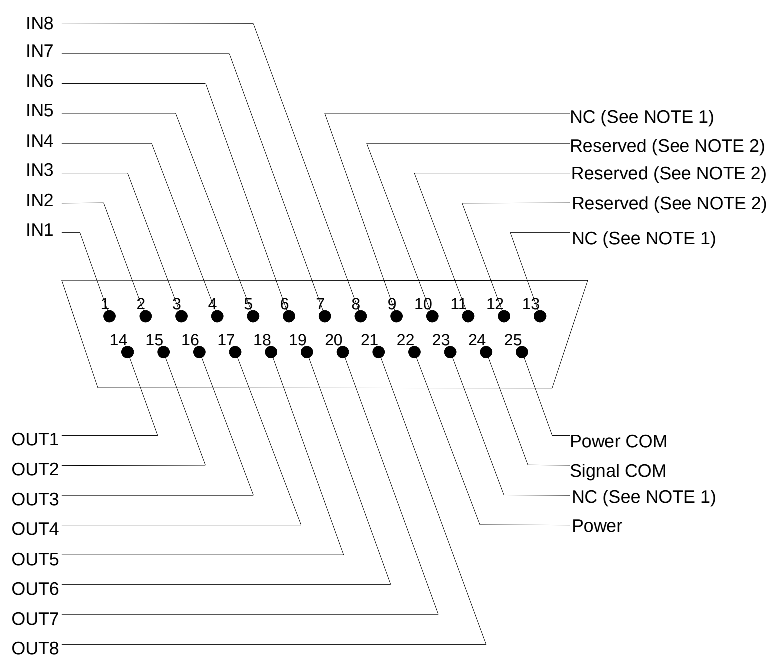


Figure 29
Pin Assignments for Connector of Active Equipment Side (Pin Side View)

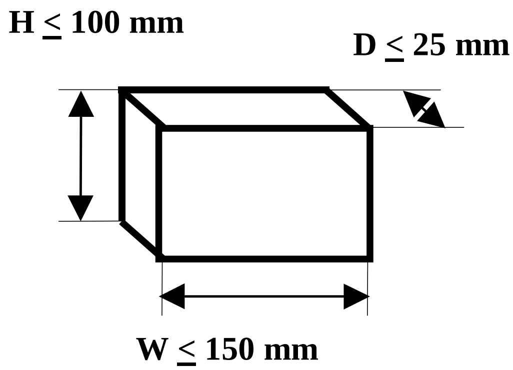


Figure 30
Size of Interface Sensor Unit

Table 11 Pin Assignments for Connector of Passive Equipment Side

Pin #	*Passive Side (connector A) Signal Name (See Figure 16)*	*Active Side (connector B) Signal Name (See Figure 16)*	*Symbol*	*Direction*	*Remarks*
1	OUT 1	IN 1	L_REQ	P -> A	
2	OUT 2	IN 2	U_REQ	P -> A	
3	OUT 3	IN 3	VA	P -> A	Interbay AMHS (used with passive OHS, stockers)
4	OUT 4	IN 4	READY	P -> A	
5	OUT 5	IN 5	VS_0	P -> A	Interbay AMHS (used with passive OHS, stockers)
6	OUT 6	IN 6	VS_1	P -> A	Interbay AMHS (used with passive OHS, stockers)
7	OUT 7	IN 7	HO_AVBL	P -> A	
8	OUT 8	IN 8	ES	P -> A	
9	NC (See NOTE 1.)	NC (See NOTE 1.)	NC (See NOTE 1.)		
10	Reserved (See NOTE 2.)	Reserved (See NOTE 2.)			
11	Reserved (See NOTE 2.)	Reserved (See NOTE 2.)			
12	Reserved (See NOTE 2.)	Reserved (See NOTE 2.)			
13	NC (See NOTE 1.)	NC (See NOTE 1.)	NC (See NOTE 1.)		
14	IN 1	OUT 1	VALID	A -> P	Not for interbay AMHS (used with passive OHS, stockers)
15	IN 2	OUT 2	CS_0	A -> P	Not for interbay AMHS (used with passive OHS, stockers)
16	IN 3	OUT 3	CS_1	A -> P	Not for interbay AMHS (used with passive OHS, stockers)
17	IN 4	OUT 4	AM_AVBL	A -> P	Interbay AMHS (used with passive OHS, stockers)
18	IN 5	OUT 5	TR_REQ	A -> P	
19	IN 6	OUT 6	BUSY	A -> P	
20	IN 7	OUT 7	COMPT	A -> P	
21	IN 8	OUT 8	CONT	A -> P	

Pin #	*Passive Side (connector A) Signal Name (See Figure 16)*	*Active Side (connector B) Signal Name (See Figure 16)*	*Symbol*	*Direction*	*Remarks*
22	NC (See Note 1.)	Power	not applicable		For wire based communication, power is isolated.
23	Power	NC (See NOTE 1.)	not applicable		For wire based communication, power is isolated.
24	Power COM	Signal COM	not applicable		For wire base communication, Power COM is routed to Signal COM.
25	Signal COM	Power COM	not applicable		For wire base communication, Power COM is routed to Signal COM.

NOTE 1: NC = Not Connected
NOTE 2: Reserved = The pin may be used to support the signal required for a type of any interface unit. It cannot be used for current or future implementations of this specification.

7 Related Documents

7.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E15 — Specification for Tool Load Port

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E64 — Provisional Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

7.2 *Japanese Industrial Standards Committees*[2]

JIS-X-5103 — The Interface between Data Circuit Terminating Equipment (DCE) and Data Terminal Equipment (DTE) (37/9-Pin Interface)

NOTE 6: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was balloted as an official part of SEMI E84, but the recommendation in this application note is optional and is not required to conform to this standard. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such, they are to be considered reference material only.

A1-1 If the connection to the equipment for overhead delivery is made using an electrical connector, Figure A1-1 defines a zone on the process or metrology equipment where the plug can be located. This zone is independent of the exclusion zones for parallel I/O devices defined by SEMI E15.1. The zones defined in SEMI E15.1 are designed to be used primarily for photo-coupled floor based delivery systems such as AGVs or RGVs, while the zone defined here on the top of the passive equipment applies primarily to a plug for overhead communication. The plug should be on the top or top edge of the equipment as shown and could be on either side of the bay/chase wall, depending on the location of the wall. In some implementations, the wall may not exist.

A1-2 Due to the inherent nature of parallel I/O communication the distance between the driver and receiver should be as close as possible. Optical transmission devices may further decrease this distance, consult the device manufacture.

A1-3 No application of parallel I/O communication can provide perfect isolation due to Electro-magnetic radiation into and between parallel conductors. Precautions should be taken, by all equipment suppliers, including but not limited to insuring a minimum capacitance of signal lines to reduce susceptibility to noise introduced into the equipment.

A1-4 There are two types of equipment, internal buffer equipment and fixed buffer equipment. Internal buffer equipment is equipment that uses locations other than load ports within the equipment to store carriers. Fixed buffer equipment is production equipment that has only fixed load ports and no internal buffer for carrier storage. Wafers are loaded and unloaded directly from the carrier at the load port for processing.

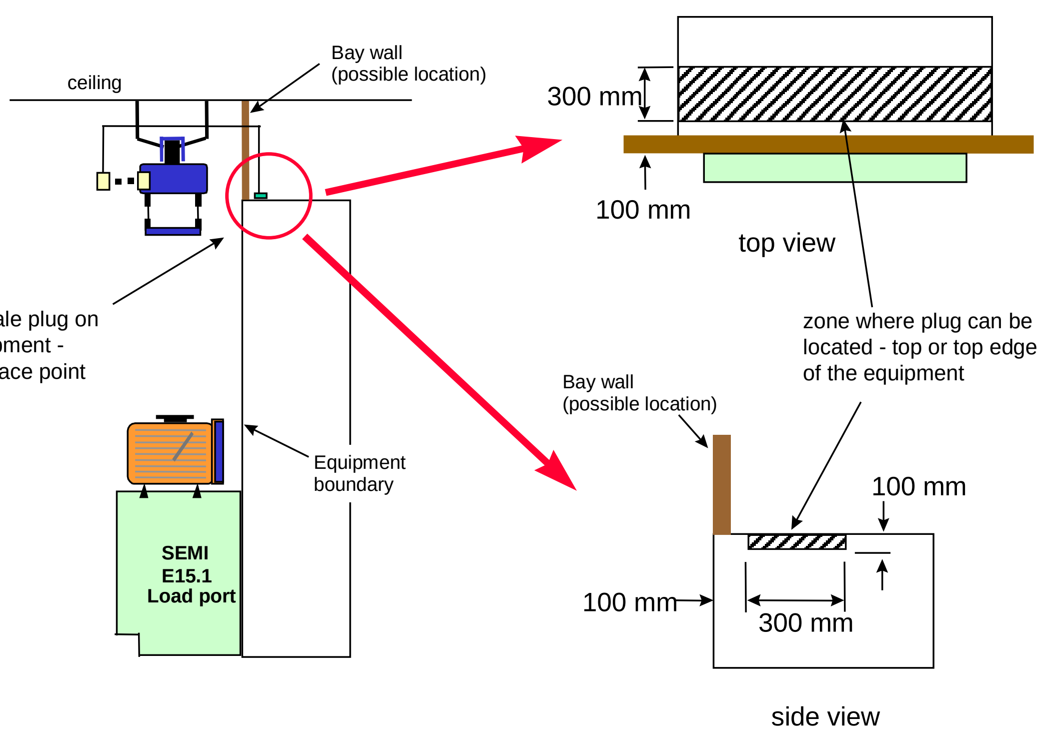


Figure A1-1
Connection Plug Location for Overhead Delivery

A1-5 This standard specifies two different PI/O configurations, one PI/O per load port and one PI/O per two load ports (Figure A1-2). Carrier transfer throughput and efficiency is higher if more than one carrier is transferred at the same time. Carrier transfer time is also reduced if the intrabay AMHS equipment can deliver two or more carriers at the same time from one parked position. Typically internal buffer equipment that allows hand-off of two carriers to two load ports either simultaneously or continuously can best take advantage of these throughput improvements. Thus, internal buffer equipment will require either one PI/O per load port (Figure A1-3, Concept A) or one PI/O per two load ports (Figure A1-3, Concept B), depending on the AMHS delivery system. Fixed buffer equipment will require one PI/O device per load port (Figure A1-4). Based on their production equipment and AMHS systems, end users will specify the SEMI E84 concept (one PI/O per load port or one PI/O per two load ports) and location that will be required on the manufacturing equipment.

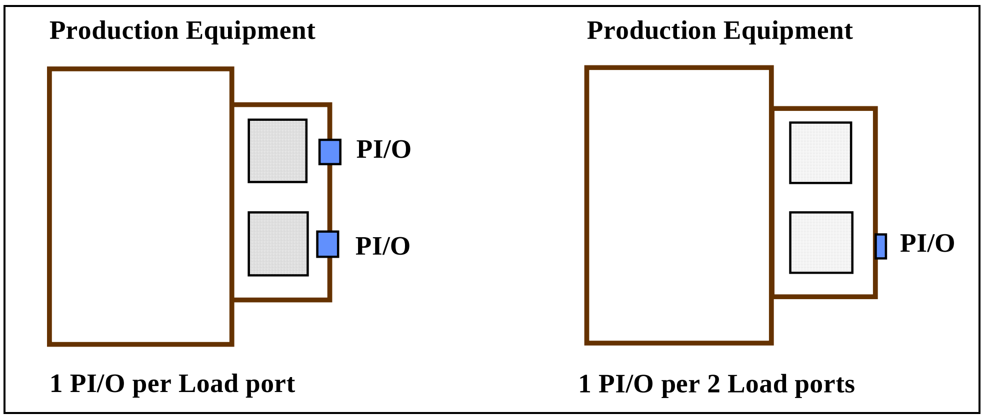
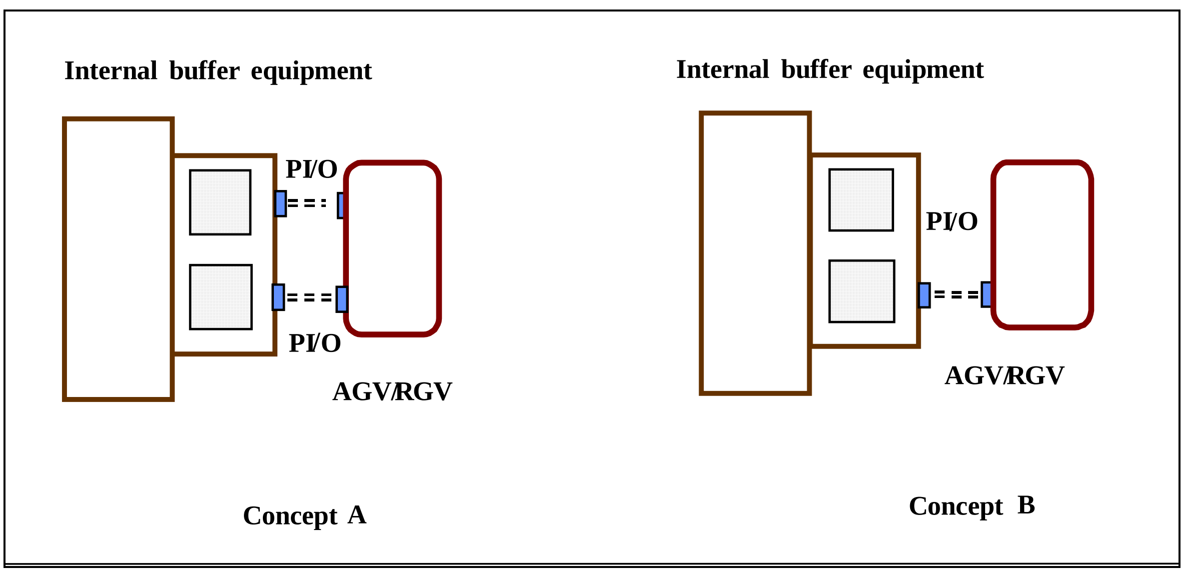


Figure A1-2
Two Different PI/O Configurations



NOTE 1: Simultaneous hand-off: use two PI/O at the same time.

NOTE 2: Continuous hand-off for different load port: use each PI/O sequentially.

Figure A1-3
Optional PI/O Configuration for Internal Buffer Equipment

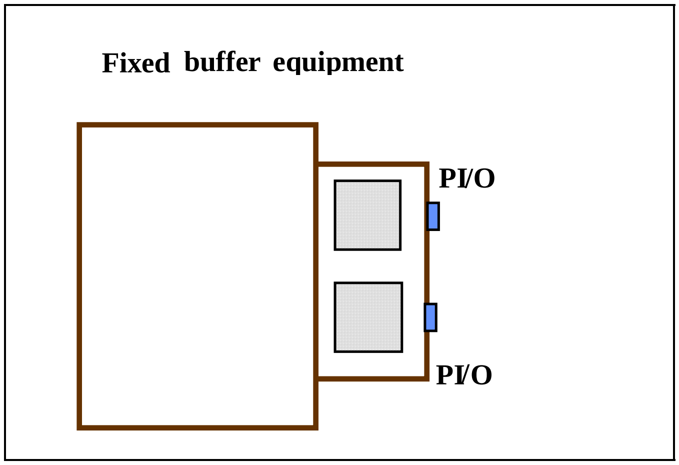


Figure A1-4
Typical PI/O Configuration for Fixed Buffer Equipment

A1-6 Figure 17 does not define a particular orientation of the PI/O interface sensor unit. Figure A1-5 shows how to orient the PI/O device for AGV/RGV of the exclusion volume in the load port. Refer to SEMI E15.1 for descriptions of D7, D8, H7, H8, and W8.

A1-7 This standard specifies a signal "on" state as 1.8 Vdc or less. Typical TTL circuits typically require a pull-down to 0.8 Vdc or less. For hard-wired connections, some TTL input circuits might not be able to sense an "on" state between 0.8 Vdc and 1.8 Vdc. One possible implementation is to provide an input receiver circuit.

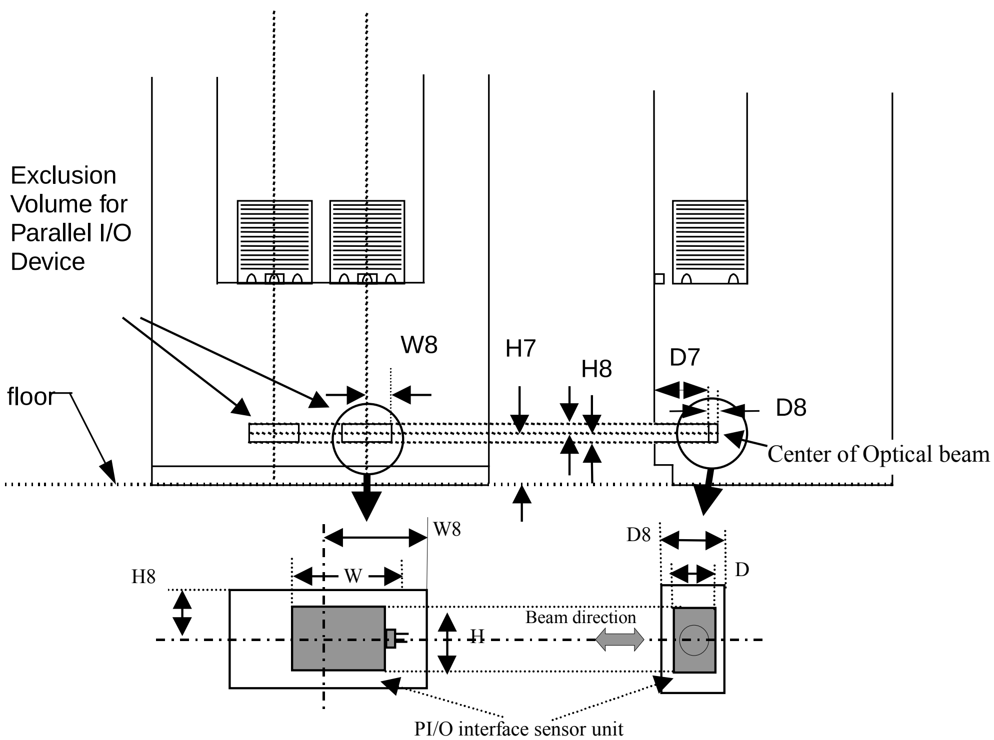


Figure A1-5
Example of the PI/O Interface Sensor Unit Implementation at Load Port for AGV/RGV

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information section was balloted as an official part of SEMI E84, but the recommendations in this section are optional and are not required to conform to this standard. Rather, these notes are provided primarily as a source of information to aid the in application of the standard. As such, they are to be considered reference material only.

This section describes error generation and recovery examples (mainly for active equipment) for interbay AMHS (i.e., OHS, stockers). The following are errors that could conceivably occur during transfer operations (load, unload). The procedures are designed for a technician with considerable knowledge of AMHS equipment. Error recovery should always follow the recovery procedures specified in the equipment manuals.

R1-1 OHS (Active Type) Error Examples

Table R1-1 Load Operation Errors

No.	*Error Description*	*OHS Reaction*
1	The L_REQ does not go OFF in the allotted amount of time during a load transaction.	The load operation sequence is stopped and an error is displayed.
2	Anytime during the transfer a load operation failure or stop positioning failure is detected.	
3	Anytime during the load operation the load presence status on the loader does not match the actual conditions of the current operation.	
4	The READY signal does not go ON within the specified amount of time after the TR_REQ signal is output.	
5	The READY signal goes OFF during the load operation.	
6	The L_REQ signal remains ON after the load operation is completed.	
7	The READY signal does not go OFF within the specified amount of time after the COMPT signal is output.	
8	Anytime during the load operation the optical transmission beam is interrupted.	

Table R1-2 Unload Operation Errors

No.	*Error Description*	*OHS Reaction*
1	The OHS moves to the stocker (for an unload operation) and outputs the VALID signal, but the U_REQ signal remains OFF for a specified amount of time.	The unload operation sequence is stopped and an error is displayed.
2	Anytime during the transfer an unload operation failure or stop positioning failure is detected.	
3	Anytime during the unload operation the load presence status on the loader does not match the actual conditions of the current operation.	
4	The READY signal does not go ON within the specified amount of time after the TR_REQ signal is output.	
5	The READY signal goes OFF during the unload operation.	
6	The U_REQ signal remains ON after the unload operation is completed.	
7	The READY signal does not go OFF within the specified amount of time after the COMPT signal is output.	
8	Anytime during the unload operation the optical transmission beam is interrupted.	

R1-1.1 *Example of the Signal Status When an Error is Generated During Transfer Operations*

R1-1.1.1 *OHS Side Error Generation*

R1-1.1.1.1 *OHS Side Signals* — When an error is generated, the BUSY signal must stay ON. This is to prevent secondary accidents due to the other device operating on its own.

R1-1.1.1.2 *Stocker Side Signals* — When an error is generated, each signal (except for the READY signal) should remain in the status it was in at the time of the error. The READY signal should go OFF.

R1-1.1.2 *Stocker Side Error Generation*

R1-1.1.2.1 *Stocker Side Signals* — When an error is generated, each signal should remain in the status it was in at the time of the error.

- The READY signal should be OFF.
- The ES signal should be OFF.
- HO_AVBL should be OFF.

R1-1.1.2.2 *OHS Side Signals* — When an error is generated, only the BUSY signal should go ON. All remaining signals should go OFF.

R1-1.2 *Recovery Sequences*

R1-1.2.1 Should an error occur during transfer operations (refer to Tables 1 and 2), the recovery should begin by returning the carrier to the stocker or OHS. Then, the error should be recovered. The four recovery scenarios are:

1. Load operation, carrier is returned to the stocker.
2. Load operation, carrier is returned to the OHS
3. Unload operation, carrier is returned to the stocker
4. Unload operation, carrier is returned to the OHS

R1-1.3 *Recovery Method*

R1-1.3.1 *OHS Side*

- In the case of sequence 2 (above), the load/unload sequence should be started over from the beginning.
- In the case of sequence 3 (above), the corresponding transfer operation should be canceled.
- In the case of sequences 1 and 4 (above) the corresponding transfer operation should be considered completed.

R1-1.3.2 *Stocker Side*

- In the case of sequences 1 and 4 (above) the corresponding transfer operation should be considered completed.
- In the case of sequences 2 and 3 (above), the load/unload sequence should be started over from the beginning.

R1-2 Stocker (Active Type) Error Examples

Table R1-3 Load Operation Errors

No.	*Error Description*	*Stocker Reaction*
1	The L_REQ does not go OFF in the allotted amount of time during an unload transaction.	The load operation sequence is stopped and an error is displayed.
2	Anytime during the transfer a load operation failure or stop positioning failure is detected.	
3	Anytime during the load operation the load presence status on the loader doesn't match the actual conditions of the current operation.	
4	The READY signal does not go ON within the specified amount of time after the TR_REQ signal is output.	
5	The READY signal goes OFF during the load operation.	
6	The L_REQ signal remains ON after the load operation is completed.	
7	The READY signal does not go OFF within the specified amount of time after the COMPT signal is output.	
8	Anytime during the load operation the optical transmission beam is interrupted.	

Table R1-4 Unload Operation Errors

No.	*Error Description*	*Stocker Reaction*
1	The stocker (for an unload operation) outputs the VALID signal, but the U_REQ signal remains OFF for a specified amount of time.	The unload operation sequence is stopped and an error is displayed.
2	Anytime during the transfer an unload operation failure or stop positioning failure is detected.	
3	Anytime during the unload operation the load presence status on the loader doesn't match the actual conditions of the current operation.	
4	The READY signal does not go ON within the specified amount of time after the TR_REQ signal is output.	
5	The READY signal goes OFF during the unload operation.	
6	The U_REQ signal remains ON after the unload operation is completed.	
7	The READY signal does not go OFF within the specified amount of time after the COMPT signal is output.	
8	Anytime during the unload operation the optical transmission beam is interrupted.	

R1-2.1 *Example of the Signal Status When an Error is Generated During Transfer Operations*

R1-2.1.1 *Stocker Side Error Generation*

R1-2.1.1.1 *Stocker Side Signals* — When an error is generated, the BUSY signal must stay ON. This is to prevent secondary accidents due to the other device operating on its own.

R1-2.1.1.2 *OHS Side Signals* — When an error is generated, each signal (except for the READY signal) should remain in the status it was in at the time of the error. The READY signal should go OFF.

R1-2.1.2 *OHS Side Error Generation*

R1-2.1.2.1 *OHS Side Signals* — When an error is generated, each signal should remain in the status it was in at the time of the error.

- The READY signal should be OFF.
- The ES signal should be OFF.
- HO_AVBL should be OFF.

R1-2.1.2.2 *Stocker Side Signals* — When an error is generated, only the BUSY signal should go ON. All remaining signals should go OFF.

R1-2.2 *Recovery Sequences*

R1-2.2.1 Should an error occur during transfer operations (refer to Tables 3 and 4), the recovery should begin by returning the carrier to the stocker or OHS. Then, the error should be recovered. The four recovery scenarios are:

1. Load operation, carrier is returned to the OHS.
2. Load operation, carrier is returned to the stocker
3. Unload operation, carrier is returned to the OHS
4. Unload operation, carrier is returned to the stocker

R1-2.3 *Recovery Method*

R1-2.3.1 *Stocker Side*

- In the case of sequences 2 and 3 (above), the load/unload sequence should be started over from the beginning.
- In the case of sequences 1 and 4 (above) the corresponding transfer operation should be considered completed.

R1-2.3.2 *OHS Side*

- In the case of sequences 1 and 4 (above) the corresponding transfer operation should be considered completed.
- In the case of sequences 2 and 3 (above), the load/unload sequence should be started over from the beginning.

RELATED INFORMATION 2
APPLICATION NOTES

NOTE: This related information section was balloted as an official part of SEMI E84, but the recommendations in this section are optional and are not required to conform to this standard. Rather, these notes are provided primarily as a source of information to aid the in application of the standard. As such, they are to be considered reference material only.

If the stocker is the active side of the interbay AMHS (i.e., OHS and stockers) it is conceivable that the loader will interfere with the OHS passing by the stocker in failure scenarios. As a result of this possibility, it is necessary for interbay AMHS equipment makers to establish an OHS "PASS OK" signal separate from the SEMI E84 interlock. However, this note has no direct bearing on the contents of SEMI E84. Therefore, readers of SEMI E84 should only treat this as a reference item.

Pass Interlock

Interlock Signal

Signal Name	*P/A*	*Description*
PASS OK	A->P	When this signal is HIGH (ON), the vehicle may pass. When this signal is LOW (OFF), the vehicle may not pass.

SEMI E85-0302

SPECIFICATION FOR PHYSICAL AMHS STOCKER TO INTERBAY TRANSPORT SYSTEM INTEROPERABILITY

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on October 14, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in June 1999; previously published in November 2001.

1 Purpose

1.1 This specification defines the dimensional requirements for the interbay load ports of 300 mm AMHS equipment. It is intended to promote a list of required features and dimensions that define the physical interfaces between different types of interbay equipment, to facilitate the use of different automated transport systems in order to meet the different material handling requirements found throughout the factory. This is done by defining six options of interfaces that both the stocker and interbay transport system must comply with. Options defined are as follows:

- Option A: Active transport loads a carrier to an internal stocker position
- Option B: Active transport loads a carrier to an external stocker position
- Option C: Passive transport presents a carrier to an internal stocker position
- Option D: Passive transport presents a carrier to an external stocker position (kinematic coupling pin pick-up)
- Option E: Passive transport presents a carrier to an external stocker position (conveyor flange pick-up)
- Option F: Passive transport presents a carrier to an external stocker position for pickup with either (a) all 3 kinematic pins, (b) all 3 secondary kinematic pins or (c) top robotic flange. Carrier is oriented with front of carrier perpendicular to load face plane.

2 Scope

2.1 This is a standard covering physical interface of 300 mm AMHS interbay equipment only. Similar requirements covering 300 mm AMHS intrabay equipment are covered in SEMI E15.1.

2.2 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not specify that every type of 300 mm stocker has to interface with every type of 300 mm interbay transport system. It only specifies six different options of physical interface. Within any option however, all stockers must be able to physically interface with all interbay transports. This standard only specifies single carrier handoff and not dual simultaneous handoffs as implied by the dimensions in the rest of this document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

NOTE 2: For many of the used terms, see SEMI E15.1.

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling Systems

5.2 *Definitions*

5.2.1 *active interbay transport system* — an interbay transport system that transfers the carrier to and from the stocker interbay load port itself using robotics that are located on the transport.

5.2.2 *drive through interbay transport (DT)* — an interbay transport system where the track runs internal to the stocker boundary for the entire width of the stocker (Option C application defined in Section 7.5.3).

5.2.3 *external stocker load port* — an interbay load port that is external to the stocker equipment boundary similar to a shelf or ledge on the stocker.

5.2.4 *horizontal transfer interbay transport (HT)* — an interbay transport system where a section of the track transfers or slides into an opening in the side of the stocker to present a passive interbay transport system to the stocker robot (Option C application defined in Section 7.5.3).

5.2.5 *interbay load port* — the interface location on a stocker where the interbay transport places wafer carriers to allow the stocker to store the carriers.

5.2.6 *interbay transport system* — is defined as the track and vehicle (if applicable) that transports the carrier to and from the interbay stockers.

5.2.7 *internal stocker load port* — an interbay load port that is recessed from the stocker equipment boundary (a cavity or cutout in the stocker).

5.2.8 *overhead delivery* — an interbay transport system that transfers the carrier to and from the stocker interbay load port itself from directly above the load port (raises and lowers the carrier to the load port).

5.2.9 *passive interbay transport system* — an interbay transport system that requires the stocker to transfer the carrier to and from the stocker interbay load port (stocker has robotics that transfers the carrier).

5.2.10 *stocker* — an AMHS storage device.

6 Ordering Information

6.1 Per Section 6 of SEMI E15, except for Sections 6.1.3 and 6.1.4.

6.2 The user and AMHS supplier will jointly own the responsibility of defining the height of the interbay load port defined by dimension H (the distance from the horizontal datum plan to the raised floor).

6.3 The user must specify which of the options (defined in Section 7.5) is required for each interbay load port. The user must also specify which carrier will be used: front-opening box or open cassette.

6.3.1 If the user specifies Option C, the user must also specify:

a) Which type of interbay transport system will be used. Dimensions A1 and S do not apply if it is a drive through (DT) type. Dimensions A1 and S do apply if it is a horizontal transfer (HT) type (defined in Section 7.5.3).

b) Which height of exclusion volume in the stocker will be used defined as dimension T3 in Tables 1 and 2.

c) Which length of center exclusion volume in the interbay transport will be used defined as dimension D10 in Tables 1 and 2.

6.3.2 If the user specifies Option D, the user must specify which length of exclusion volume will be used in the interbay transport as defined by dimension D10 in Tables 1 and 2.

6.3.3 If the user specifies Option E, the user must specify which length of exclusion volume will be used in the interbay transport as defined by dimension D10 in Tables 1 and 2.

6.3.4 If the user specifies option F, the user must specify top (robotic flange pickup) or bottom access (secondary kinematic pins pickup).

7 Requirements

7.1 The dimensional requirements for the load port of a storage device and the interbay transport system are given in Table 1 for front-opening box and Table 2 for open cassette.

7.2 The carriers shown in these figures are intended to represent any type of carrier (open cassette or front-opening box). Figure 11 is only applicable for open cassette type carriers.

7.2.1 Except for option F, the carrier shall be loaded and unloaded with its front parallel to and away from the load face plane as illustrated in Figures 1–11.

7.3 The wafers in the front-opening box are to be oriented horizontally face up with zero nominal tilt at the time they are placed on the load port. The tolerance in the horizontal plane is determined by the registration and alignment feature between the carrier and the load port, as specified in SEMI E57. The wafers in the front-opening open cassette are to be oriented horizontally face up with 2 degree nominal tilt at the time they are placed on the load port.

7.4 Dimension H of the load port is to be specified by the user and the AMHS supplier (Section 6.2). The height of the interbay transport system is to be fully configurable using the track hangers. The precision with which the interbay transport delivery system height must be maintained is dictated by the needs of the interbay load port.

7.5 AMHS interbay equipment load ports must conform to one of the following configuration options (see Section 6.3).

7.5.1 In Option A, an active transport loads a carrier to an internal stocker position. The stocker interbay load port must therefore maintain the center exclusion volume below the HDP defined in Section 7.6 and shown in Figures 1 and 10. This exclusion volume in the stocker load port facilitates carrier delivery from an active interbay transport system. The interbay transport may transfer the carrier to the passive stocker using the SEMI standard carrier handling features, which are compatible with the exclusion volumes in the stocker defined in this standard. Examples include the secondary set of kinematic pins and the top robotic flange. The use of the primary kinematic pins is reserved for the stocker load port. The two front kinematic pins and a guide are used to interface with a SEMI defined accurate outer carrier surface defined in SEMI E47.1 (front-opening box) or SEMI E1.9 (open cassette). Refer to Figure 1 and the Related Information for detail. The open volume internal to the stocker above the HDP is defined by dimensions A1, S, and a clearance C3 above the maximum height of the carrier.

7.5.2 In Option B, an active transport loads a carrier to an external stocker position. The stocker interbay load-port must therefore maintain the two fork-lift or conveyor exclusion volumes as defined in SEMI E15.1 to allow for an active interbay transport system to transfer a carrier to the fork-lift or conveyor rails. The stocker interbay load port must also be open from above to facilitate delivery from an overhead transport system. The open volume required for vertical delivery is defined by a projection of the stocker load port area. The stocker interbay load port features, exclusion volumes, and dimensions are defined in SEMI E15.1 with the exception of dimension S and H. This option is illustrated in Figure 2.

7.5.3 In Option C, a passive transport presents a carrier to an internal stocker position. The passive interbay transport must therefore maintain the center exclusion volumes defined in Section 7.6 and shown in Figures 3, 4, and 10 in order to facilitate automatic carrier transfer by the active stocker. The stocker may transfer the carrier to the passive interbay transport system using the SEMI standard carrier handling features, which are compatible with the exclusion volumes in the interbay transport system defined in this standard. Examples include the secondary set of kinematic pins and the top robotic flange. The use of the primary kinematic pins is reserved for the interbay transport system. The two front kinematic pins and a guide are used to interface with a SEMI defined accurate outer carrier surface defined in SEMI E47.1 (front-opening box) or SEMI E1.9 (open cassette). Refer to Figure 3 and the Related Information for detail. The open volume internal to the stocker to allow for the interbay transport to enter is defined by dimensions T3 and C5. This option is illustrated in Figures 3 and 4.

7.5.3.1 Option C allows for two different types of interbay transport (Section 6.3.1). The first type is a drive though (DT) interbay transport that will drive through the entire length of the stocker as illustrated in Figure 3. Dimensions A1 is therefore not applicable for this type of Option C interbay transport delivery. The other type of interbay transport is a horizontal transfer (HT) were a section of the track slides or advances into a predefined open volume in the side of the stocker as illustrated in Figure 4. Dimensions A1 and S are applicable for this type of Option C interbay transport delivery.

7.5.3.2 Option C prime (C’) is different from Option C in that the pins used to transfer the carrier are different. In Option C’, the transport vehicle uses the two front secondary, and single rear primary kinematic pins. This enables the stocker end-effector to use the two front primary pins and be of a wider configuration (see Figure 3a). All elevation dimensions for C’ are the same as for Option C.

7.5.4 In Option D, a passive transport presents a carrier to an external stocker position. The passive interbay transport must maintain the center exclusion volume shown in Figures 5 and 10 to allow for the stocker to use the secondary kinematic pins or top robotic flange to transfer the carrier. No open volume internal to the stocker is required.

7.5.4.1 Option D prime (D’) is different from Option D in that the pins used to transfer the carrier are different. In Option D’, the transport vehicle uses the two front secondary, and single rear primary kinematic pins. This enables the stocker end-effector to use the two front primary pins and be of a wider configuration (see Figure 4a). All elevation dimensions for Option D’ are the same as for Option D.

7.5.5 In Option E, a passive transport presents a carrier to an external stocker position. The passive interbay transport must maintain the side fork-lift/conveyor rail exclusion volumes shown in Figure 6 to allow the stocker to use the fork-lift/conveyor rails to transfer the carrier. No open volume internal to the stocker is required.

7.5.6 In option F and F’ the carrier is oriented with the front of the carrier perpendicular to the load face plane by a passive transport for pickup by an active stocker. In option F the transport uses the kinematic coupling pins (all 3 may be used) and the stocker uses either the secondary kinematic coupling pins (all 3 accessible) or the top robotic flange for pickup. In Option F' (F Prime) the transport uses the kinematic coupling pins, the secondary kinematic coupling pins or the conveyor runners, and the stocker uses the top robotic flange for pickup.

7.6 The center exclusion volume below the horizontal datum plane of the stocker for Option A (Section 7.5.1) or interbay transport system for Options C and D (Sections 7.5.3 and 7.5.4), is defined by dimensions H2, A2, and D (Figure 1 and 10). For Options C (Section 7.5.3) and D (Section 7.5.4), there are additional requirements that the center exclusion volume, defined by H2 and A2 extend from the facial datum plane a distance D10 (Sections 6.3.1 and 6.3.2), increase both in depth defined by dimension H4 and in width defined by dimension A3 from the plane defined by dimension D10 extending outwards for the rest of the interbay transport system. The conveyor flange exclusion volume below the horizontal datum plane of the interbay transport system (Section 7.5.4), is defined by dimensions H2, H4, A6, A8, and D10 (Figure 6). The center exclusion volume below the horizontal datum plane of the stocker for option F is defined by Figure 10, "Exclusion zone detail for option F". No exclusion volumes are required for option F' since stocker access is with the top robotic flange only. These exclusion volumes need to be open only during the carrier handoff between the stocker and the interbay transport system. For example, the stocker can temporarily occupy these exclusion volumes when transferring the carrier from the interbay load port to an internal shelf location.

7.7 Clearance C3 in Option A is defined with respect to the maximum dimensions of the carrier (defined in SEMI E47.1 for a box or in SEMI E1.9 for an open cassette), not to the rectangular wafer carrier envelope (defined in SEMI E15).

7.8 Dimension S specifies the required range for spacing between carrier centroids.

7.9 For active interbay transports (Option A) and passive interbay transports (Options C, D, and E and F), the communication method will be defined by SEMI E84 (same as OHT), and the available SEMI E84 connector areas are defined by the following dimensions, and are illustrated in Figure 9.

- Dimensions of the SEMI E84 connector zone are as follows:
- Width (measured from BDP) = 225 mm
- Depth (measured from Stocker facial plane) = 200 mm
- Height (measured from HDP) = 300 mm

NOTE 3: The bottom of the SEMI E85 exclusion volumes defines the top of the SEMI E84 connector zones. For Option A, the top of the connector zone is defined by dimension H2. For Option B, the top of the connector zone is defined by dimension H0. For Options C, D, and E and F, the top of the connector zone is defined by dimension H4.

Table 1 Dimensional Requirements for 300 mm AMHS Interbay Load Ports (FOUP ONLY)

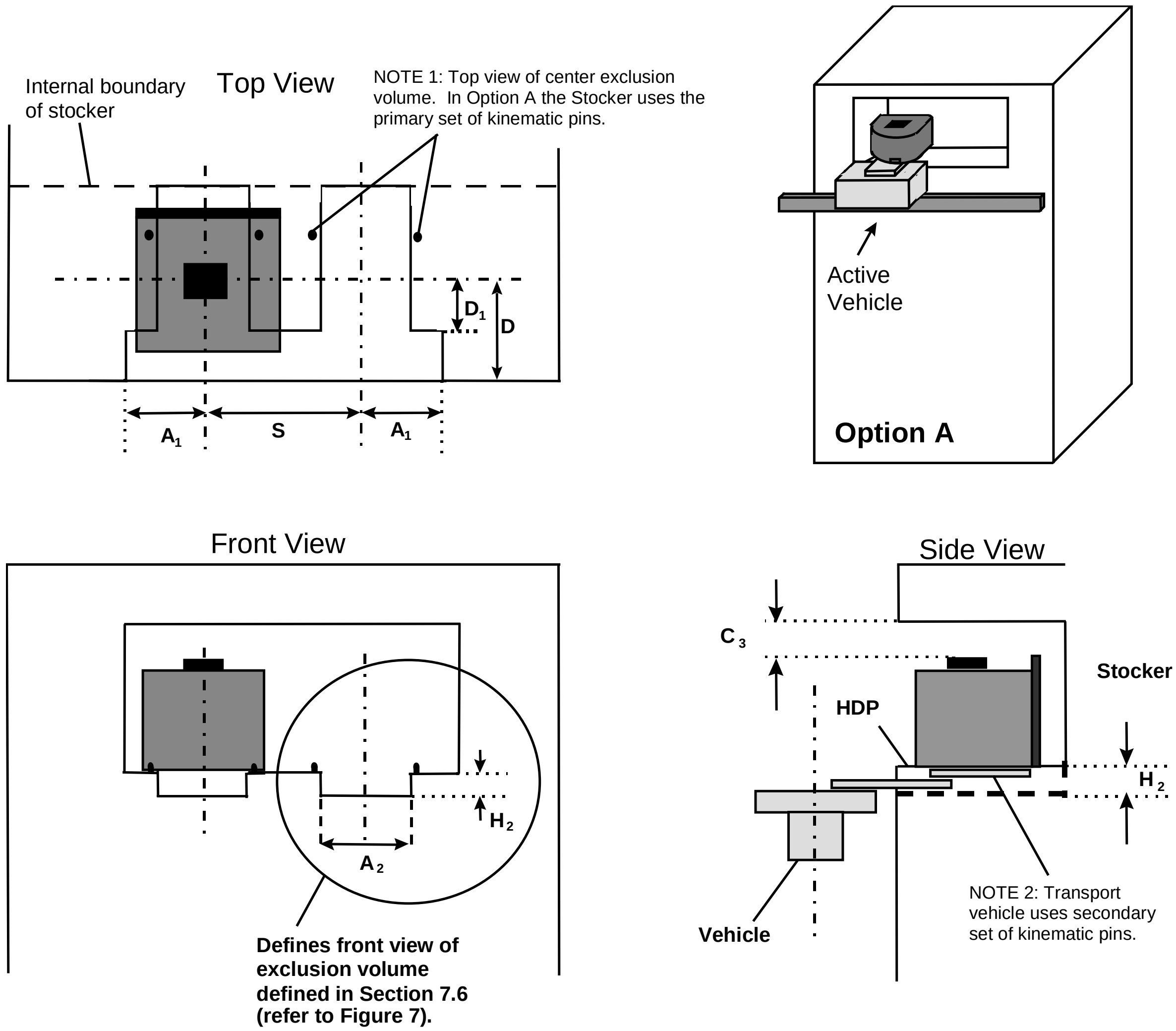
Dim	*Definition*	*Option A*	*Option B*	*Option C*	*Option D*	*Option E*	*Option F*
θ (deg)	tilt of the open cassette when placed to the load port	0	SEMI E15.1	0	0	0	N/A
A1	minimum width of the load port cavity or cut-out in the stocker measured from the facial datum plane to the nearest obstruction on the stocker	375 mm	N/A	600 mm for HT only (See NOTE 1.)	N/A	N/A	N/A
A2	width of the exclusion zone for center pickup using the secondary kinematic coupling pins (symmetric about the bilateral datum plane)	213 + 2/-0 mm	N/A	213 + 2/-0 mm	213 + 2/-0 mm		213 + 2/-0
A3	Minimum width if the exclusion zone (starting at a distance D10 from the FDP) for center pickup using the secondary kinematic coupling pins (symmetric about the bilateral datum plane)	N/A	N/A	225 mm	225 mm	N/A	N/A
A6	maximum protrusion of the interbay transport measured from the facial datum plan of the transport (start of the exclusion volume for fork-lift or	N/A	SEMI E15.1	N/A	N/A	165 mm	N/A

Dim	Definition	Option A	Option B	Option C	Option D	Option E	Option F
	conveyor rail transfer)						
A8	minimum width of the exclusion volume for the fork-lift or conveyor rail transfer mechanism measured from the facial datum plane (end of the exclusion volume for fork-lift or conveyor rail transfer)	N/A	N/A	N/A	N/A	245 mm (80 wide)	N/A
C3	height of the nearest stocker obstacle above the carrier during transfer measured from the HDP of the transport—the maximum height of the carrier. This creates an exclusion zone for use of the top robotic flange.	150 mm	SEMI E15.1	N/A	N/A	N/A	N/A
C5	distance from the facial datum plane of the transport to the internal stocker boundary	N/A	SEMI E15.1	250 ± 50 mm	N/A	N/A	250 ± 50 mm
D	distance from the stocker boundary to the facial datum plane on the stocker load port (A,B)	240 mm	SEMI E15.1 250 + 0/-10 mm	N/A	N/A	N/A	N/A
D1	maximum distance or protrusion of any load port feature measured from the facial datum plane on the load port (inside the stocker cut-out)	150 mm	SEMI E15.1 200 + 10/-4 mm	N/A	N/A	N/A	TBD
D5	distance from the facial datum plane of the interbay transport system to the stocker boundary	N/A	SEMI E15.1	N/A	250 ± 50 mm	250 ± 50 mm	N/A
D6 (See NOTE 2.)	minimum distance or length of the center exclusion volume of the interbay transport system measured backwards from the facial datum plane of the interbay transport system to allow for stocker pick up using the secondary kinematic pins	N/A	SEMI E15.1	90 mm	90 mm	TBD	TBD
D10	distance measured from the facial datum plane (FDP) where the depth of the center exclusion zone lowers from H2 to H4 in the interbay transport system (C,D)	N/A	SEMI E15.1	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)
H	Height of the horizontal datum plane of the interbay load port (stocker) or interbay transport system determined by user and supplier	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by 10 mm	TBD (See NOTE 1.) and must be adjustable by 10 mm	TBD (See NOTE 1.) and must be adjustable by 10 mm
H2	depth of exclusion zone below the horizontal datum plane (HDP) of the stocker load port (A,B) OR the interbay transport system (C,D)	130 mm	SEMI E15.1	100 mm	100 mm	100 mm	100 mm
H4	depth of the exclusion zone below the horizontal datum plane (HDP) of interbay transport system (C,D)	N/A	N/A	170 mm	170 mm	170 mm	170 mm

Dim	Definition	Option A	Option B	Option C	Option D	Option E	Option F
	starting at a distance D10 from the facial datum plane (FDP)						
S	distance between the bilateral datum plane of two adjacent load ports	450 mm	505 mm	N/A	N/A	N/A	N/A
T3	height of the open volume in that it allows the interbay transport system to enter the stocker the transport. This exclusion zone is occupied by the transport itself, the maximum height of the carrier, a clearance above carrier, and a clearance below the transport.	N/A	N/A	800 mm or 1150 mm (See NOTE 1.)	N/A	N/A	N/A

NOTE 1: User to specify which dimension (see Section 6).
NOTE 2: See Related Information 2 of this document.

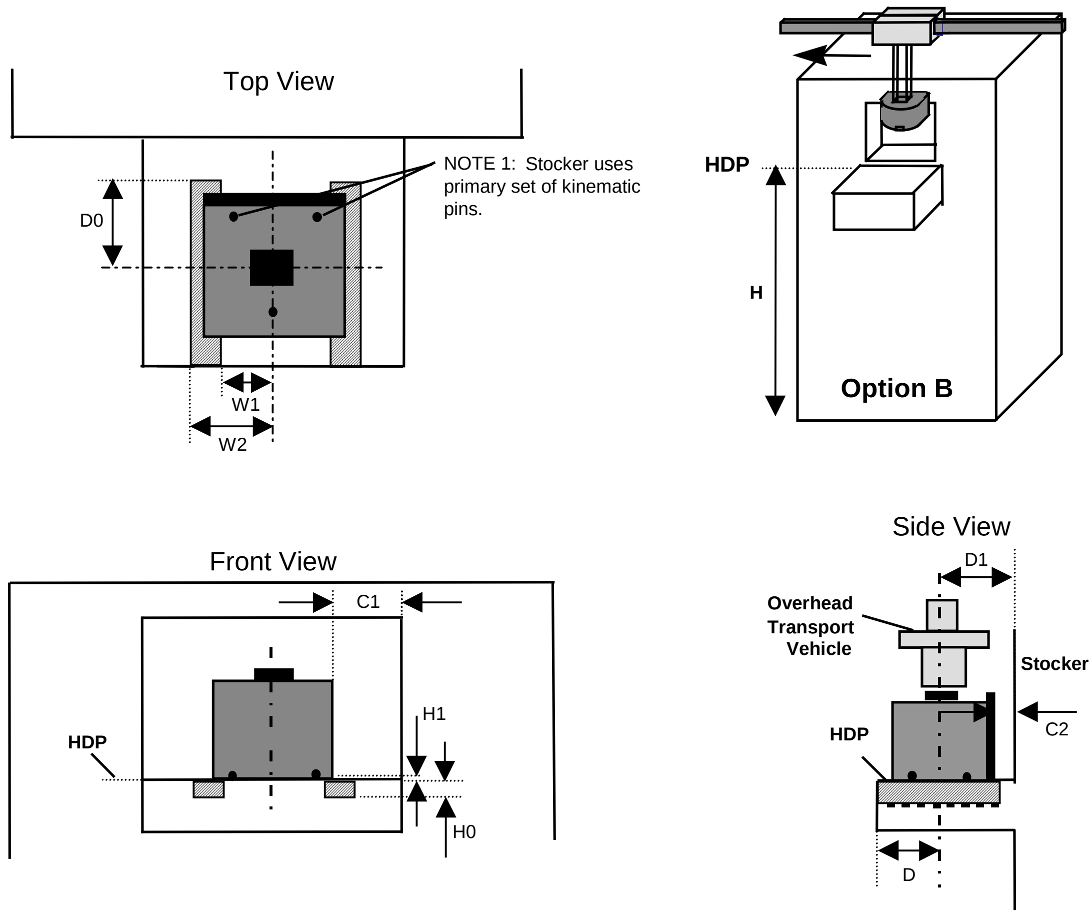
Active Transport Delivers a Carrier to an Internal Stocker Position



Option A	**H2** *(min)*	**A1** *(min)*	**A2** *(range)*	**C3** *(min)*	**D** *(max)*	**D1** *(max)*	**S** *(min)*	*Θ (deg)*
FOUP	130	375	213 + 2/-0	150	240	150	450	0
Open Cassette	140	375	213 + 2/-0	100	270	150	450	2

Figure 1
AMHS Interbay Load Port Option A

Active Transport Delivers a Carrier to an Internal Stocker Position

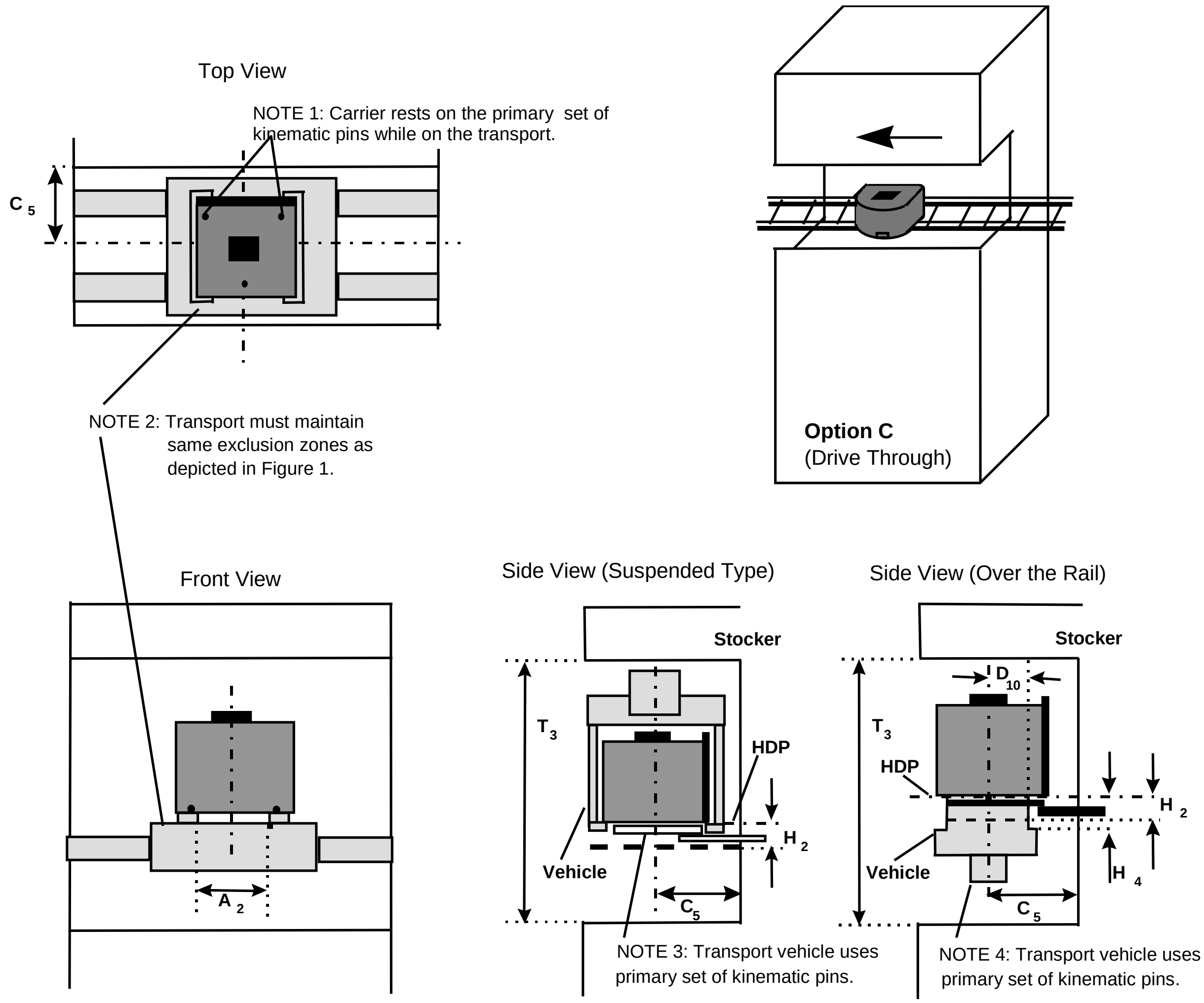


Option B	***H*** *(See NOTE 1.)*	***H0*** *(min)*	***H1*** *(max)*	***C1*** *(min)*	***C2*** *(min)*	***D0*** *(min)*	***D*** *(range)*	***D1*** *(range)*	***W1*** *(max)*	***W2*** *(min)*
FOUP	TBD	40	25	75	30	110	250 + 0/-10	200 + 10/-4	130	205
Open Cassette	TBD	50	25	75	30	110	250 + 0/-10	200 + 10/-4	130	205

NOTE 1: User to specify actual dimension (see Section 6.2).

Figure 2
AMHS Interbay Load Port Option B

Active Transport Delivers a Carrier to an Internal Stocker Position

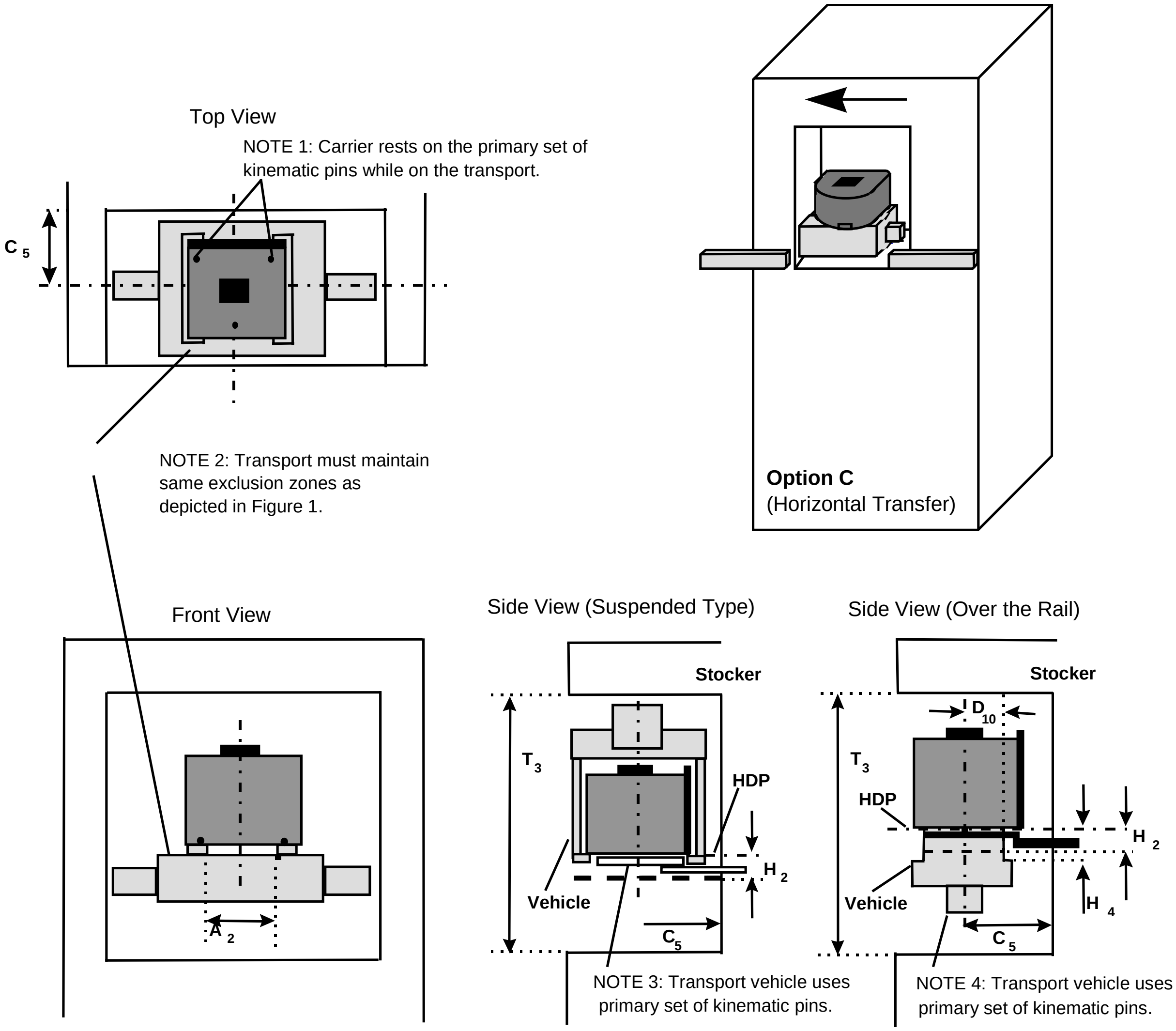


Option C (Drive Through)	***H2** (min) (See NOTE 2.)*	***H4** (min)*	***A1** (min)*	***A2** (range)*	***A3** (min)*	***C5** (range)*	***D10** (max) (See NOTE 1.)*	***D6** (min) (See NOTE 2.)*	***T3** (min) (See NOTE 1.)*	*Θ (deg)*
FOUP	100	170	N/A	213 + 2/-0	225	250 ± 50	150 or 230	112	800 or 1150	0
Open Cassette	110 (See NOTE 1.)	170	N/A	213 + 2/-0	225	250 ± 50	150 or 230	112	800 or 1150	2

NOTE 1: User to specify which dimension (see Section 6.3.1).
NOTE 2: See Related Information 2 of this document.

Figure 3
AMHS Interbay Load Port Option C (Drive Through)

Active Transport Delivers a Carrier to an Internal Stocker Position

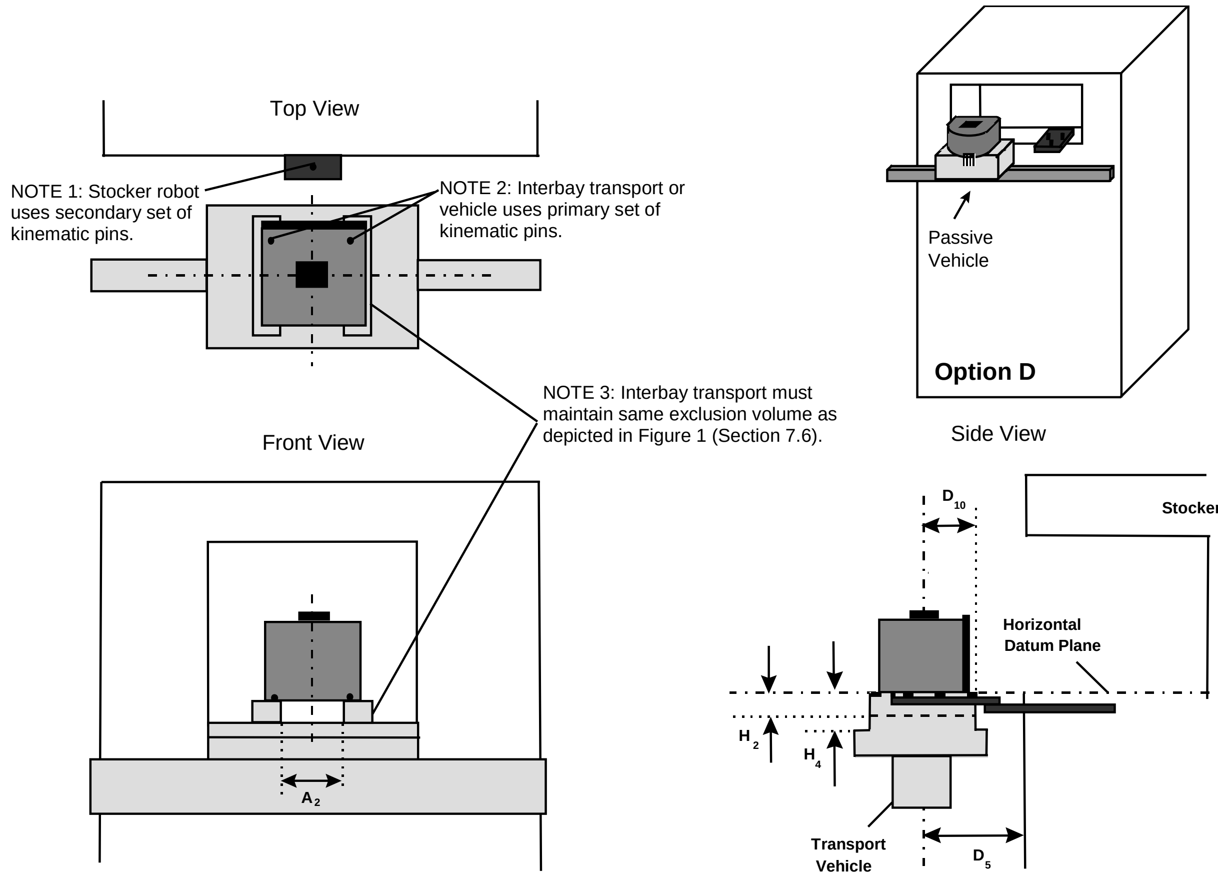


Option C (Horizontal Transfer)	***H2** (min) (See NOTE 2.)*	***H4** (min)*	***A1** (min)*	***A2** (range)*	***A3** (min)*	***C5** (range)*	***D10** (max) (See NOTE 1.)*	***D6** (min) (See NOTE 2.)*	***T3** (min) (See NOTE 1.)*	*Θ (deg)*
FOUP	100	170	600	213 + 2/-0	225	250 ± 50	150 or 230	112	800 or 1150	0
Open Cassette	110 (See NOTE 1.)	170	600	213 + 2/-0	225	250 ± 50	150 or 230	112	800 or 1150	2

NOTE 1: User to specify which dimension (see Section 6.3.1.)
NOTE 2: See Related Information 2 of this document.

Figure 4
AMHS Interbay Load Port Option C (Horizontal Transfer)

Active Transport Delivers a Carrier to an Internal Stocker Position

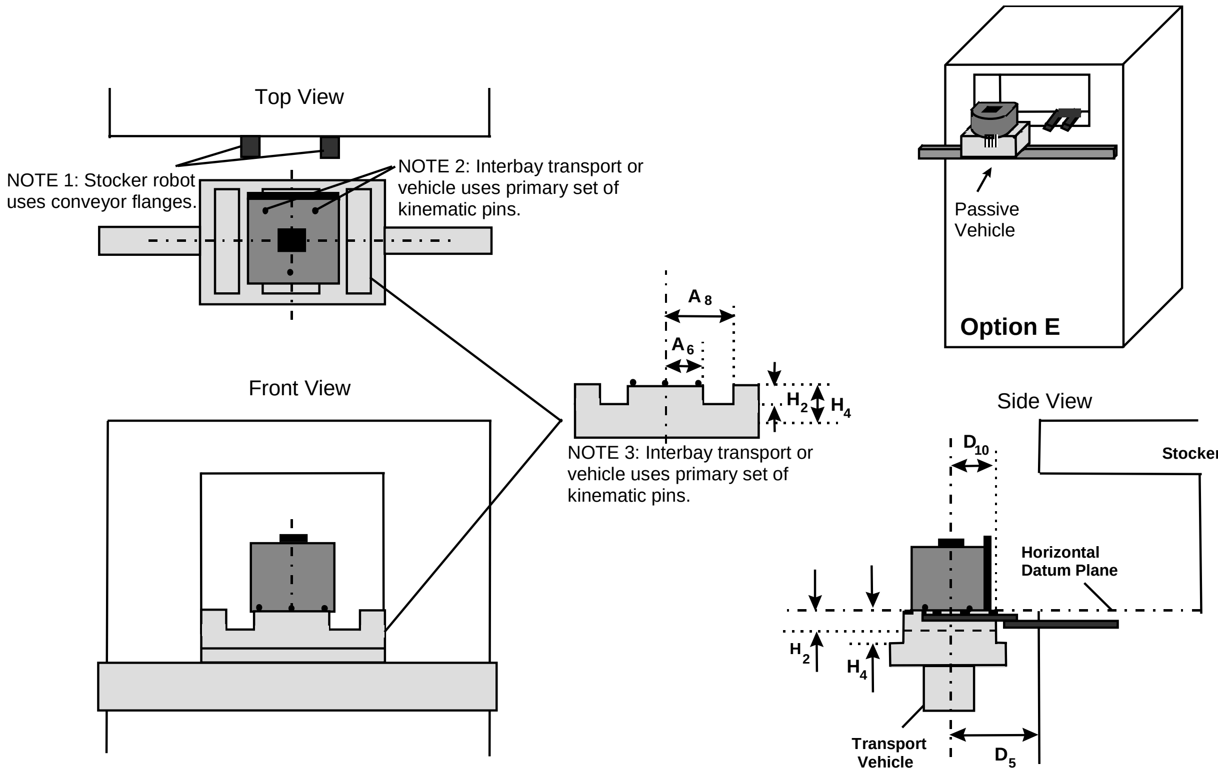


Option D (Kinematic Coupling Pin Pick-Up)	***H2*** *(min)*	***H4*** *(min)*	***A2*** *(range)*	***A3*** *(min)*	***D5*** *(range)*	***D10*** *(min) (See NOTE 1.)*	*Θ (deg)*
FOUP	100	170	213 + 2/ -0	225	250 ± 50	150 or 230	0
Open Cassette	110	180	213 + 2/ -0	225	250 ± 50	150 or 230	2

NOTE 1: User to specify which dimension (see Section 6.3.2).

Figure 5
AMHS Interbay Load Port Option D (Kinematic Coupling Pin Pick-Up)

Active Transport Delivers a Carrier to an Internal Stocker Position



Option E (Conveyor Flange Pick-Up)	***H2*** *(min)*	***H4*** *(min)*	***A6*** *(max)*	***A8*** *(min)*	***D5*** *(range)*	***D10*** *(min) (See NOTE 1.)*	*Θ (deg)*
FOUP	40	170	165	245 (80 wide)	250 ± 50	150 or 230	0
Open Cassette	50	180	123	203 (80 wide)	250 ± 50	150 or 230	2

NOTE 1: User to specify which dimension (see Section 6.3.3).

Figure 6
AMHS Interbay Load Port Option E (Conveyor Flange Pick-Up)

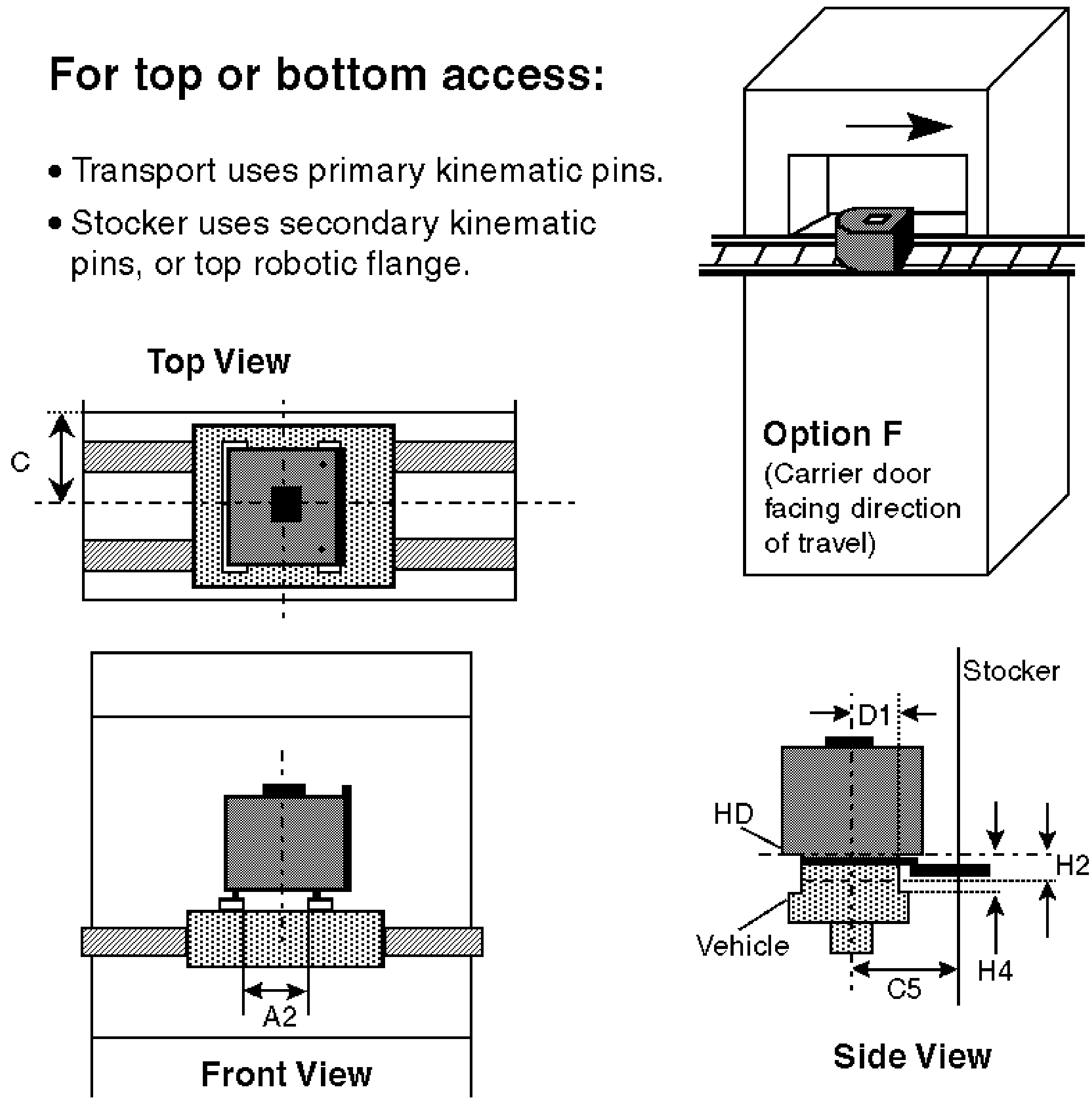


Figure 7
AMHS Interbay Load Port Option F (Carrier Oriented perpendicular to face plane) (Top and Bottom Access)

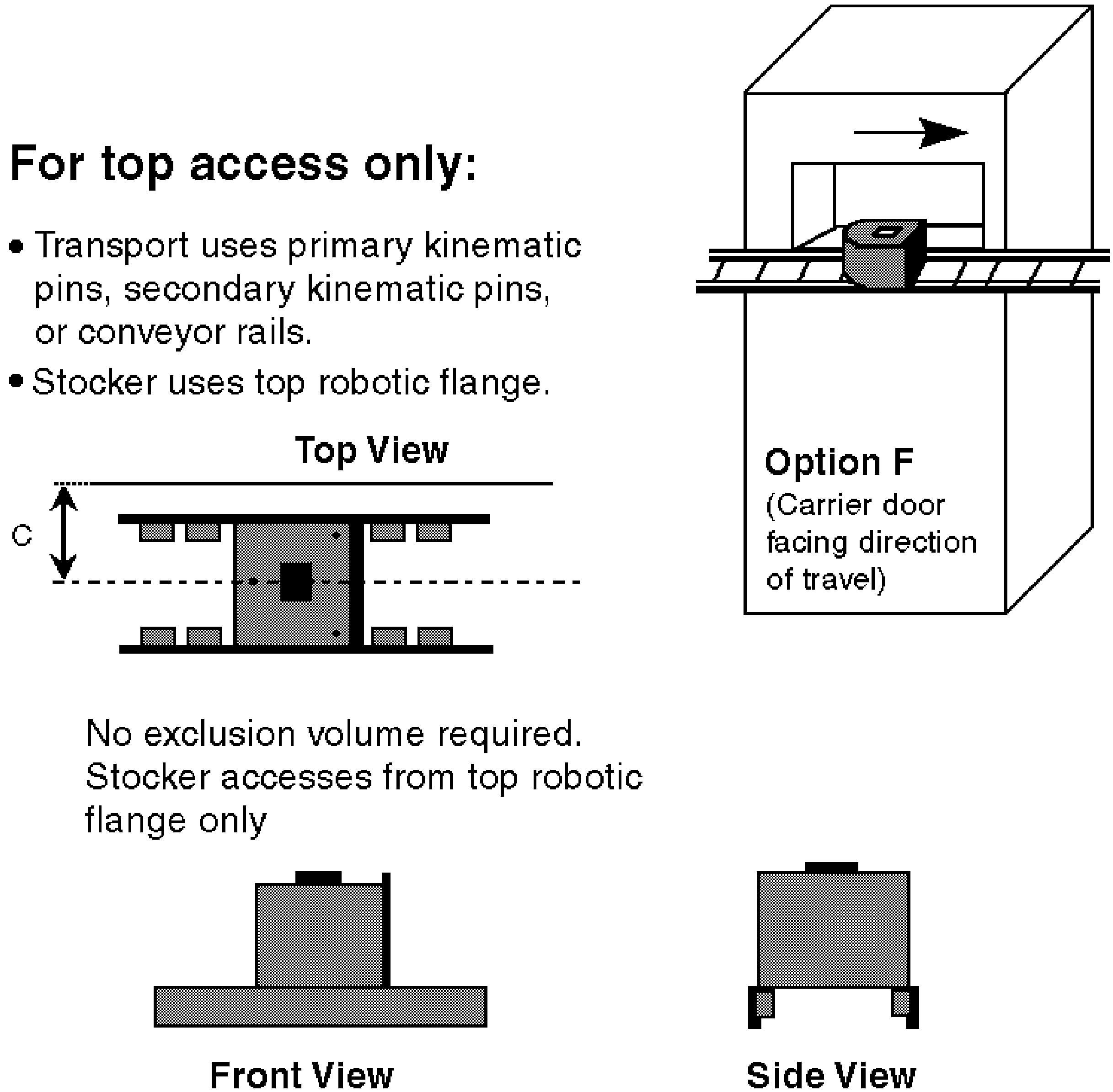


Figure 8
AMHS Interbay Load Port Option F' (Carrier Oriented perpendicular to face plane) (Top Access Only)

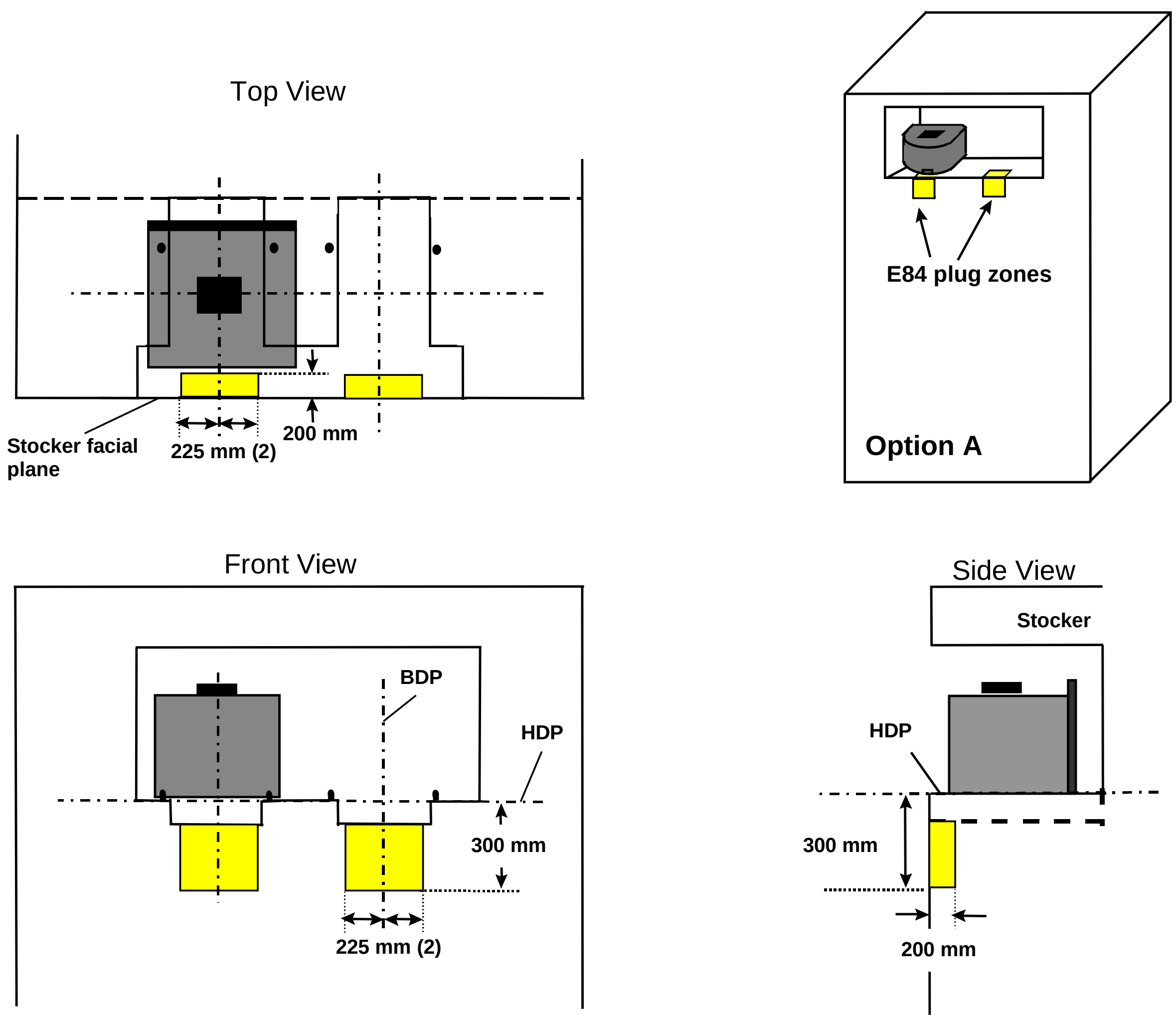
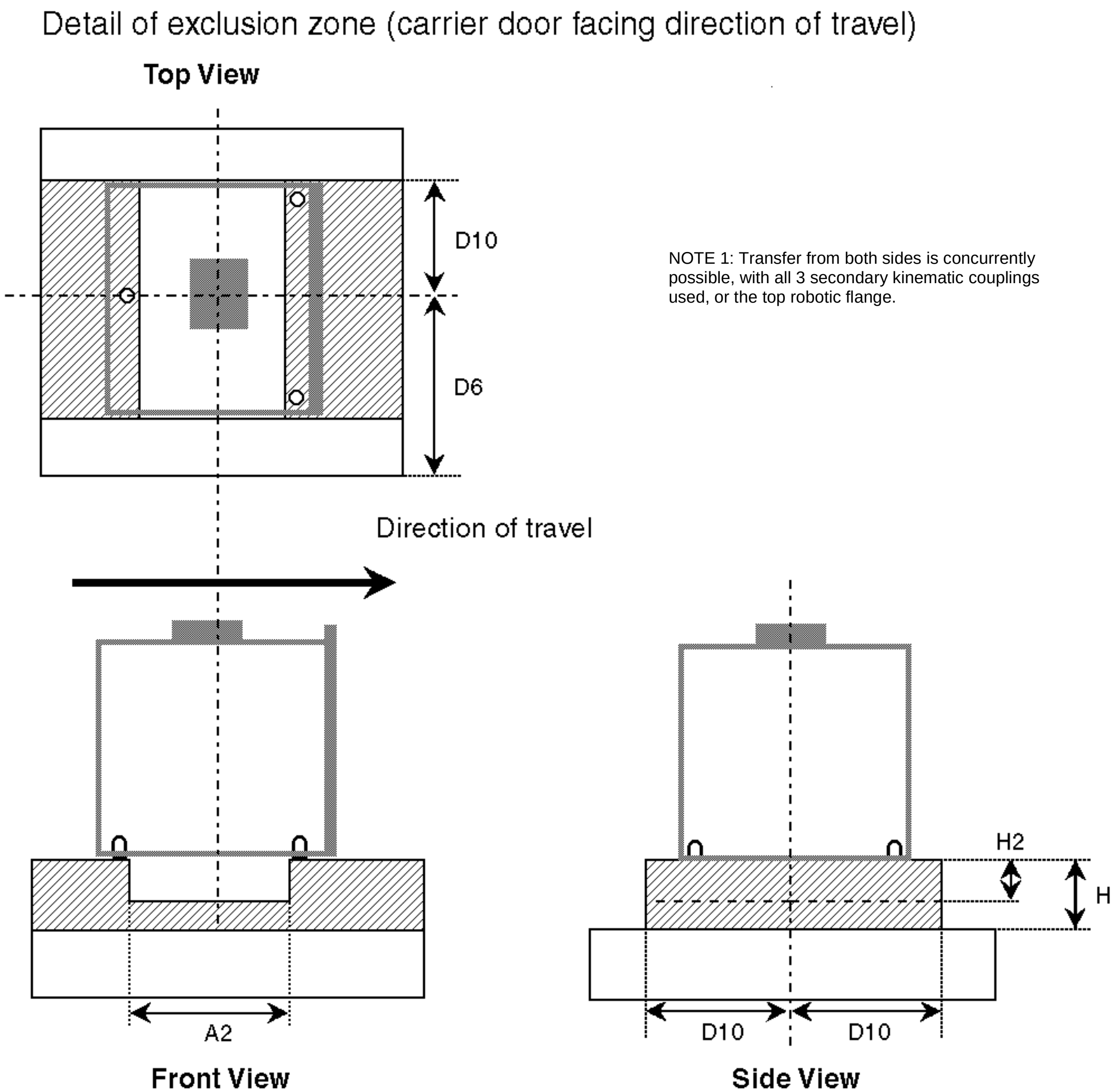


Figure 9
Drawing of Example Available Area for Connector on Stocker for Option A



NOTE 1: Transfer from both sides is concurrently possible, with all 3 secondary kinematic couplings used, or the top robotic flange.

NOTE 2: Figure 8 and all exclusion zone dimensions for Option F only apply if bottom access is required.

Figure 10
Exclusion Zone Detail – Option F

Table 2 Dimensional Requirements for 300 mm AMHS Interbay Load Ports (Open Cassette Only)

Dim	*Definition*	*Option A*	*Option B*	*Option C*	*Option D*	*Option E*	*Option F*
θ (deg)	tilt of the open cassette when placed to the load port	2	SEMI E15.1	2	2	2	2
A1	minimum width of the load port cavity or cut-out in the stocker measured from the facial datum plane to the nearest obstruction on the stocker	375 mm	N/A	600 mm for HT only (See NOTE 1.)	N/A	N/A	N/A
A2	width of the exclusion zone for center pickup using the secondary kinematic coupling pins (symmetric about the bilateral datum plane)	213 + 2/-0 mm	SEMI E15.1	213 + 2/-0 mm	213 + 2/-0 mm	213 + 2/-0 mm	213+ 2/-0 mm
A3	Minimum width if the exclusion zone (starting at a distance D10 from the FDP) for center pickup using the secondary kinematic coupling pins (symmetric about the bilateral datum plane)	N/A	N/A	225 mm	225 mm	N/A	N/A
A6	maximum protrusion of the interbay transport measured from the facial datum plan of the transport (start of the exclusion volume for fork-lift or conveyor rail transfer)	N/A	SEMI E15.1	N/A	N/A	123 mm	N/A
A8	minimum width of the exclusion volume for the fork-lift or conveyor rail transfer mechanism measured from the facial datum plane (end of the exclusion volume for fork-lift or conveyor rail transfer)	N/A	N/A	N/A	N/A	203 mm (80 wide)	N/A
C3	Height of the nearest stocker obstacle above the carrier during transfer measured from the HDP of the transport— the maximum height of the carrier. This creates an exclusion zone for use of the top robotic flange.	100 mm	SEMI E15.1	N/A	N/A	N/A	N/A
C5	distance from the facial datum plane of the transport to the internal stocker boundary	N/A	SEMI E15.1	250 ± 50 mm	N/A	N/A	250 ± 50 mm
D	distance from the stocker boundary to the facial datum plane on the stocker load port (A,B)	270 mm	250 + 0/-10 mm	N/A	N/A	N/A	N/A
D1	maximum distance or protrusion of any load port feature measured from the facial datum plane on the load port (inside the stocker cut-out)	150 mm	SEMI E15.1 200 + 10/-4 mm	N/A	N/A	N/A	TBD
D10	distance measured from the facial datum plane (FDP) where the depth of the center exclusion zone lowers from H2 to H4 in the interbay transport system (C,D)	N/A	SEMI E15.1	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)	150 mm or 230 mm (See NOTE 1.)
D5	distance from the facial datum plane of the interbay transport system (vehicle) to the stocker boundary	N/A	SEMI E15.1	N/A	250 ± 50 mm	250 ± 50 mm	TBD

Dim	*Definition*	*Option A*	*Option B*	*Option C*	*Option D*	*Option E*	*Option F*
D6 (See NOTE 2.)	distance of the inner cavity or cut-out of the interbay transport system as measured from the facial datum plane of the interbay transport system to allow for stocker pick up using the secondary kinematic pins	N/A	SEMI E15.1	90 mm (See NOTE 2.)	TBD	TBD	TBD
H	Height of the horizontal datum plane of the interbay load port (stocker) or interbay transport system (vehicle) determined by user and supplier	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm	TBD (See NOTE 1.) and must be adjustable by ± 10 mm
H2 (See NOTE 2.)	depth of exclusion zone below the horizontal datum plane (HDP) of the stocker load port (A,B) OR the interbay transport system (C,D)	140 mm	SEMI E15.1	100 mm	110 mm	50 mm	100 mm
H4	depth of the exclusion zone below the horizontal datum plane (HDP) of interbay transport system (C,D) starting at a distance D10 from the facial datum plane (FDP)	N/A	N/A	170 mm	180 mm	180 mm	170 mm
S	distance between the bilateral datum plane of two adjacent load ports	450 mm	SEMI E15.1	N/A	N/A	N/A	N/A
T3	Height of the open volume in that it allows the interbay transport system to enter the stocker the transport. This exclusion zone is occupied by the transport itself, the maximum height of the carrier, a clearance above carrier, and a clearance below the transport.	N/A	N/A	800 mm or 1150 mm (See NOTE 1.)	N/A	N/A	N/A

NOTE 1: User to specify which dimension (see Section 6).
NOTE 2: See Related Information 2 of this document.

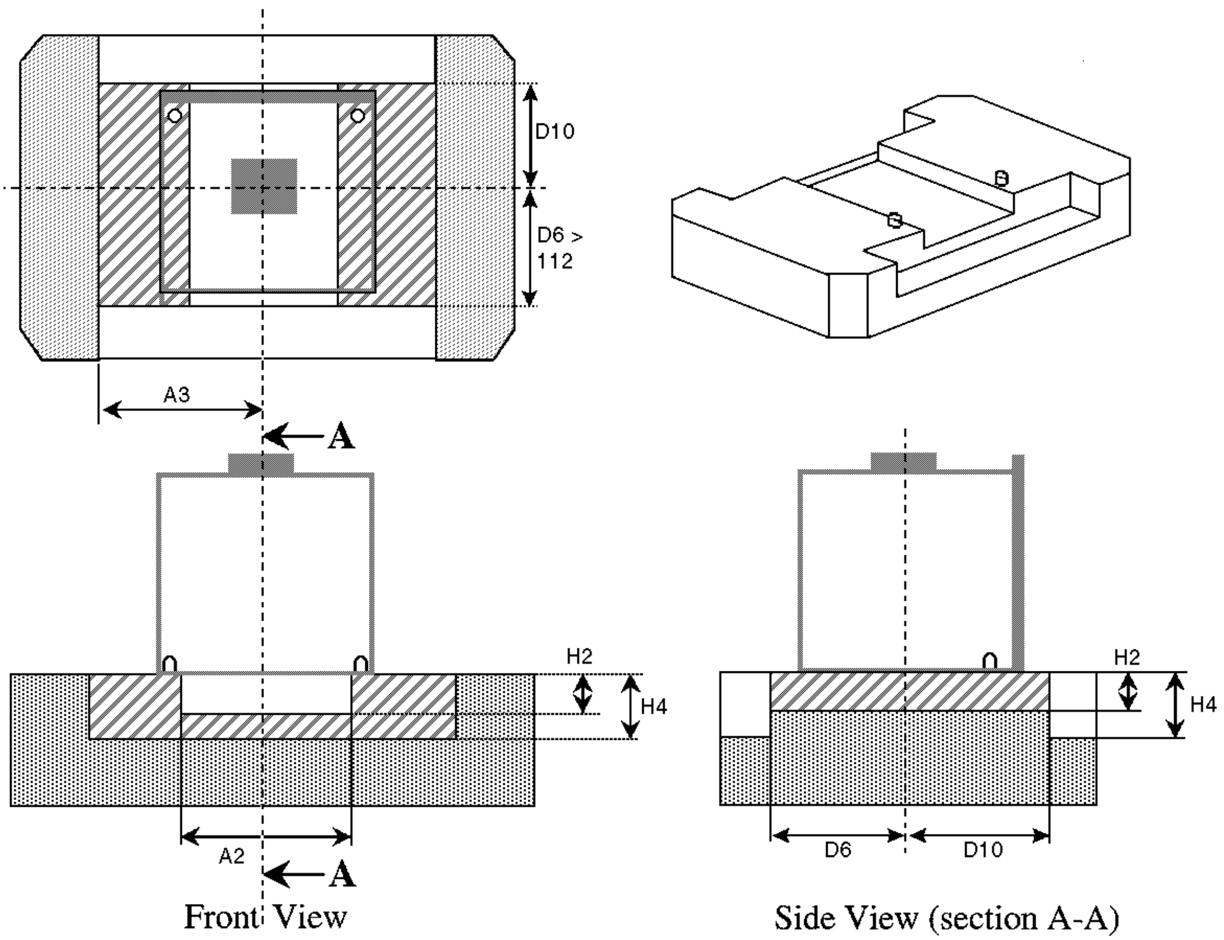


Figure 11
Detailed Views of Center Exclusion Volume
(where D6 > minimum to allow for transfer from both sides)

NOTE 1: Dimension D10 will be 150 mm or 230 mm as specified by the user.

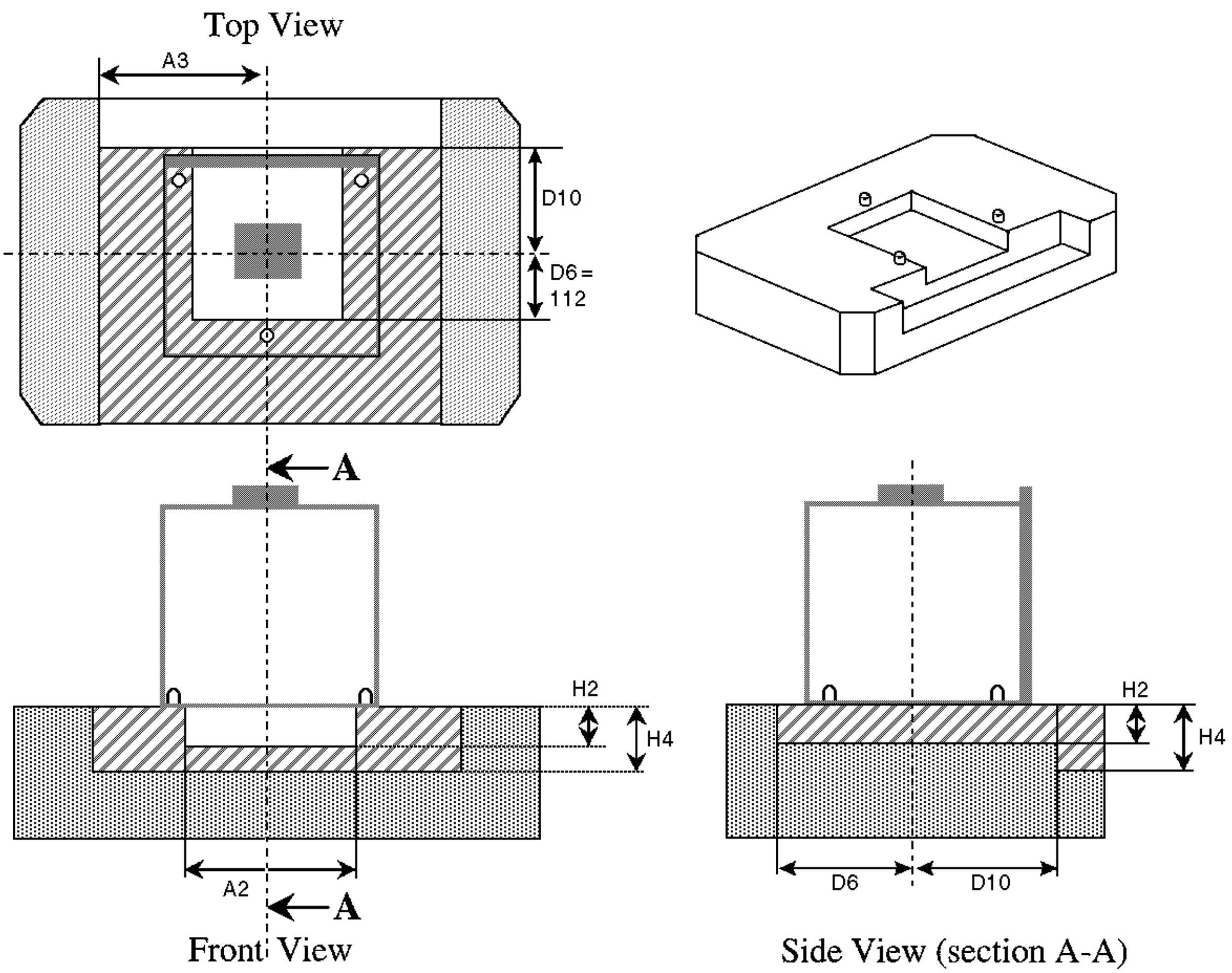


Figure 12
Detailed Views of Center Exclusion Volume
(where D6 = minimum to allow for the carrier to seat on all 3 kinematic pins)

NOTE 1: Dimension D10 will be 150 mm or 230 mm as specified by the user.

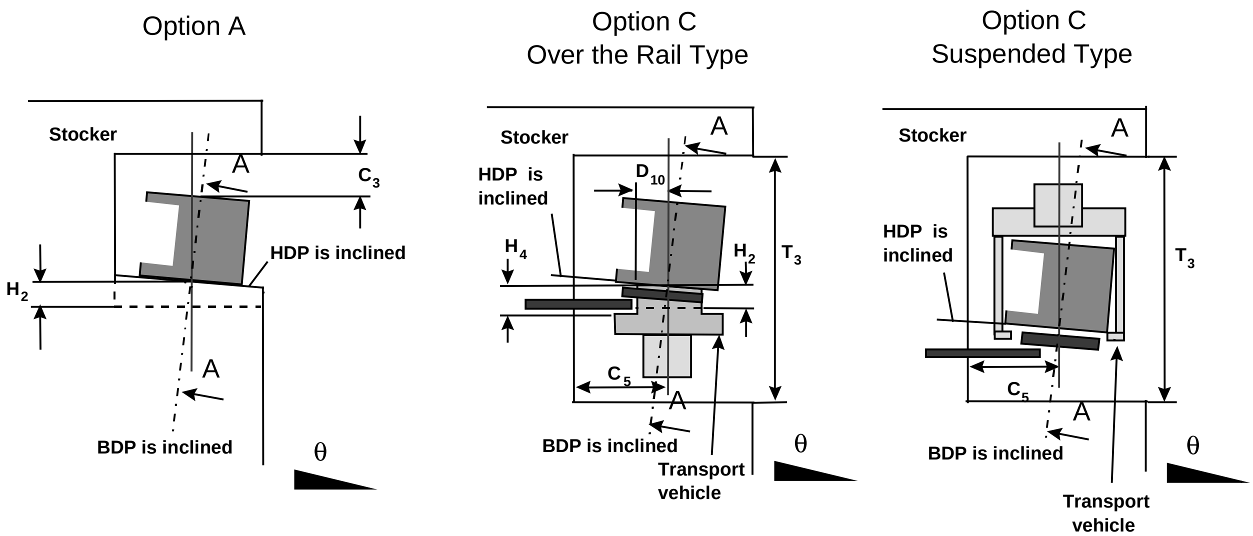
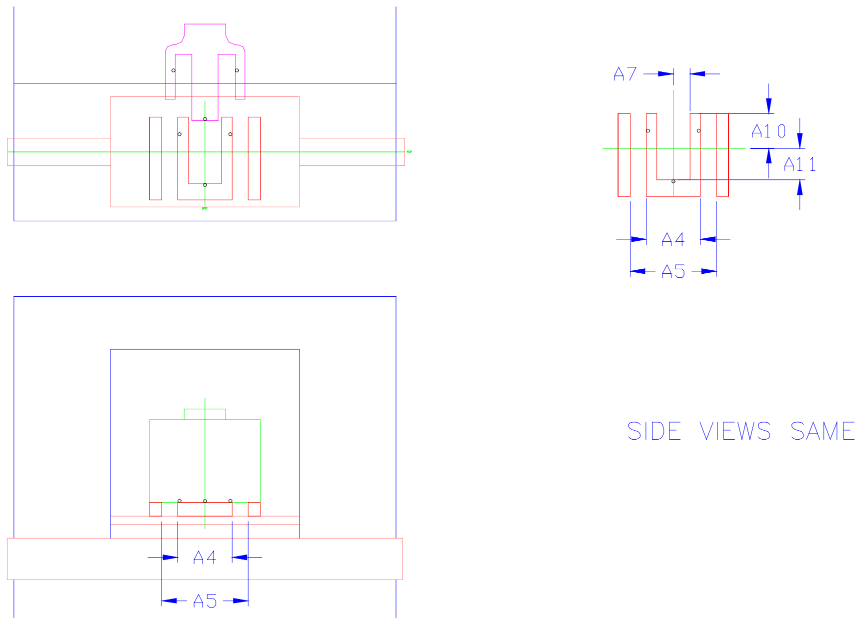


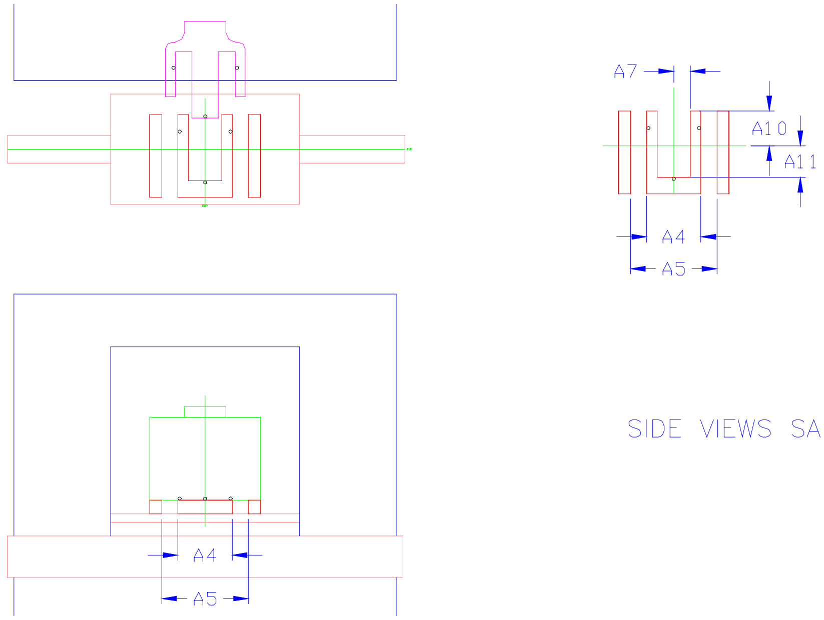
Figure 13
Views Illustrating Open Cassette Options

NOTE 1: The cross section views (A-A) of the exclusion volumes are the same as the views shown in the FOUP Figures 1–9.



A4	200 mm	A10	130 mm
A5	312 mm	A11	112 mm
A7	60 mm		

Figure 14
AMHS Interbay Loadport Option C'



A4	200 mm	A10	130 mm
A5	312 mm	A11	112 mm
A7	60 mm		

Figure 15
AMHS Interbay Loadport Option D'

NOTICE: SEMI makes no warranties or representations as to the suitability of the specification set forth herein for any particular application. The determination of the suitability of the specification is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These specifications are subject to change without notice.

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RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E85. This related information was approved for publication by full letter ballot procedures on July 19, 2001.

R1-1 Except for Option F and F', the carrier may only rest on two of the three kinematic pins as defined in SEMI E57 to allow for transfer using the secondary set of kinematic pins. The AMHS supplier must allow the rear of the carrier to rest on a SEMI defined surface defined in SEMI E47.1 (front-opening box) or SEMI E1.9 (open cassette) to ensure the carrier is properly supported. The AMHS supplier should also investigate the stability of the FOUP if it rests on only two pins. One possible solution would be to add a lead-in or retaining feature that interfaces with a SEMI defined outer carrier surface defined in SEMI E47.1 (front-opening box) or SEMI E1.9 (open cassette).

R1-2 To avoid interfering with the lead-in capability (misalignment correction) function of the kinematic couplings, it is recommended that no part of the storage device (other than the kinematic couplings) come horizontally closer than 10 mm (0.39 in.) to the carrier.

R1-3 It is recommended that the systems that deliver carriers to AMHS interbay load ports have a mechanism to correct for misalignment of storage devices and load ports.

R1-4 The dimension H2 which defines the depth of the exclusion zone that allows for carrier transfer using the secondary set of kinematic pins, might be reduced in the future.

R1-5 Dimension C5 (for Option C) and D5 (for Option D) define the range required for stocker reach. Through teaching or adjustment the stocker must be able to transfer carriers from passive interbay transport systems which have a centerline within this range (250 $\pm$ 50 mm). This dimension is measured from the center point of the wafers on the interbay transport system.

R1-6 AMHS equipment can be configured with a variety of load ports chosen from the options defined in Section 7.5. Figure R1-1a shows a storage device with two Option A interbay load ports, which may work with an active transport and any carrier.

R1-7 An IC manufacturer or user could also specify the same Option A stocker, but with only one interbay load port. Figure R1-1b shows a storage device with two Option B interbay load ports, which may work with carriers delivered by a passive transport or an overhead transport system. Again, an IC manufacturer or user could also specify the same Option B stocker, but with only one interbay load port.

R1-8 For Example Only: AMHS suppliers may implement lead-in features in various methods which promote registration using any of the SEMI defined dimensions and features of the carrier.

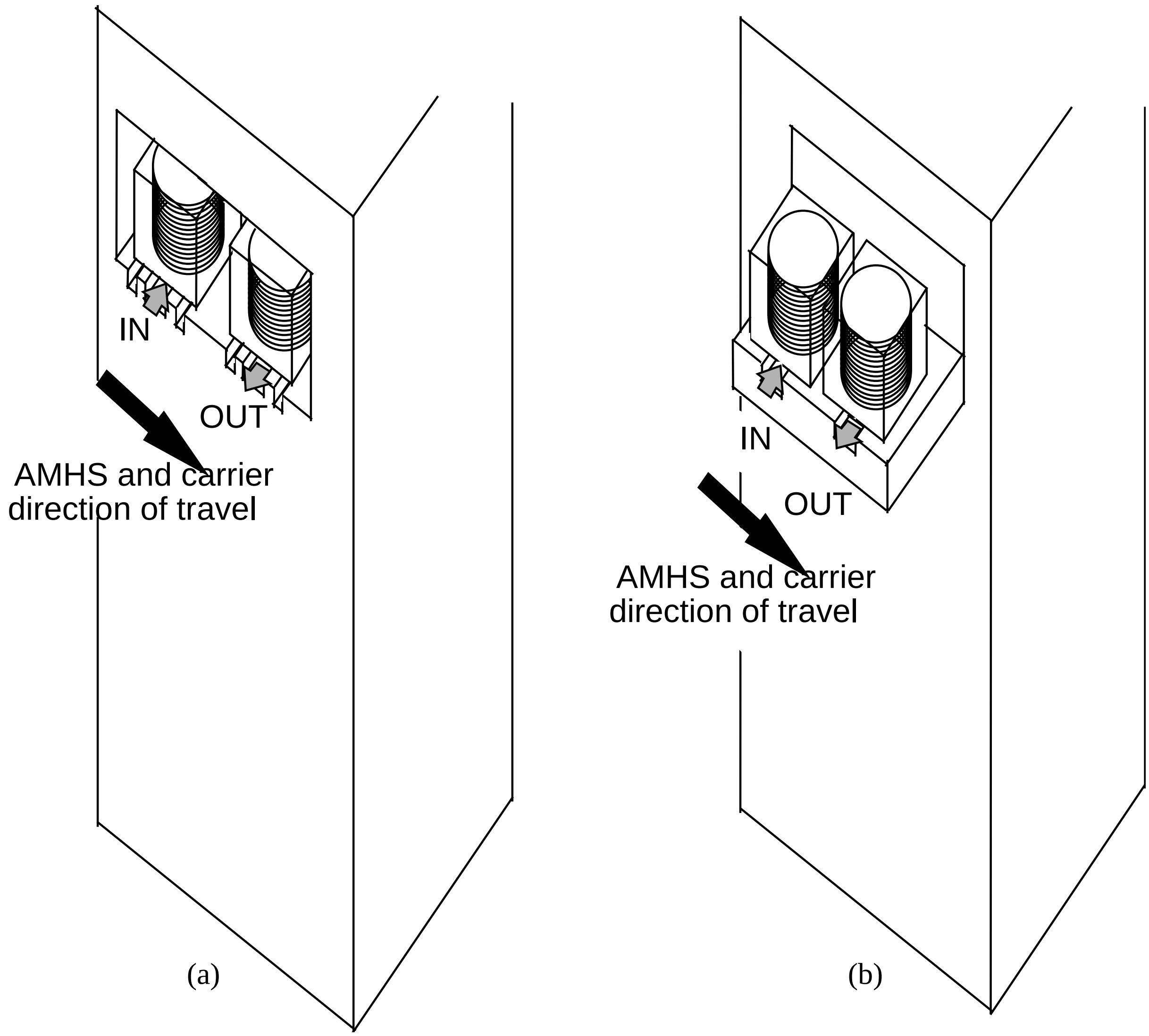

Figure R1-1
Example Combinations of Load Port Options

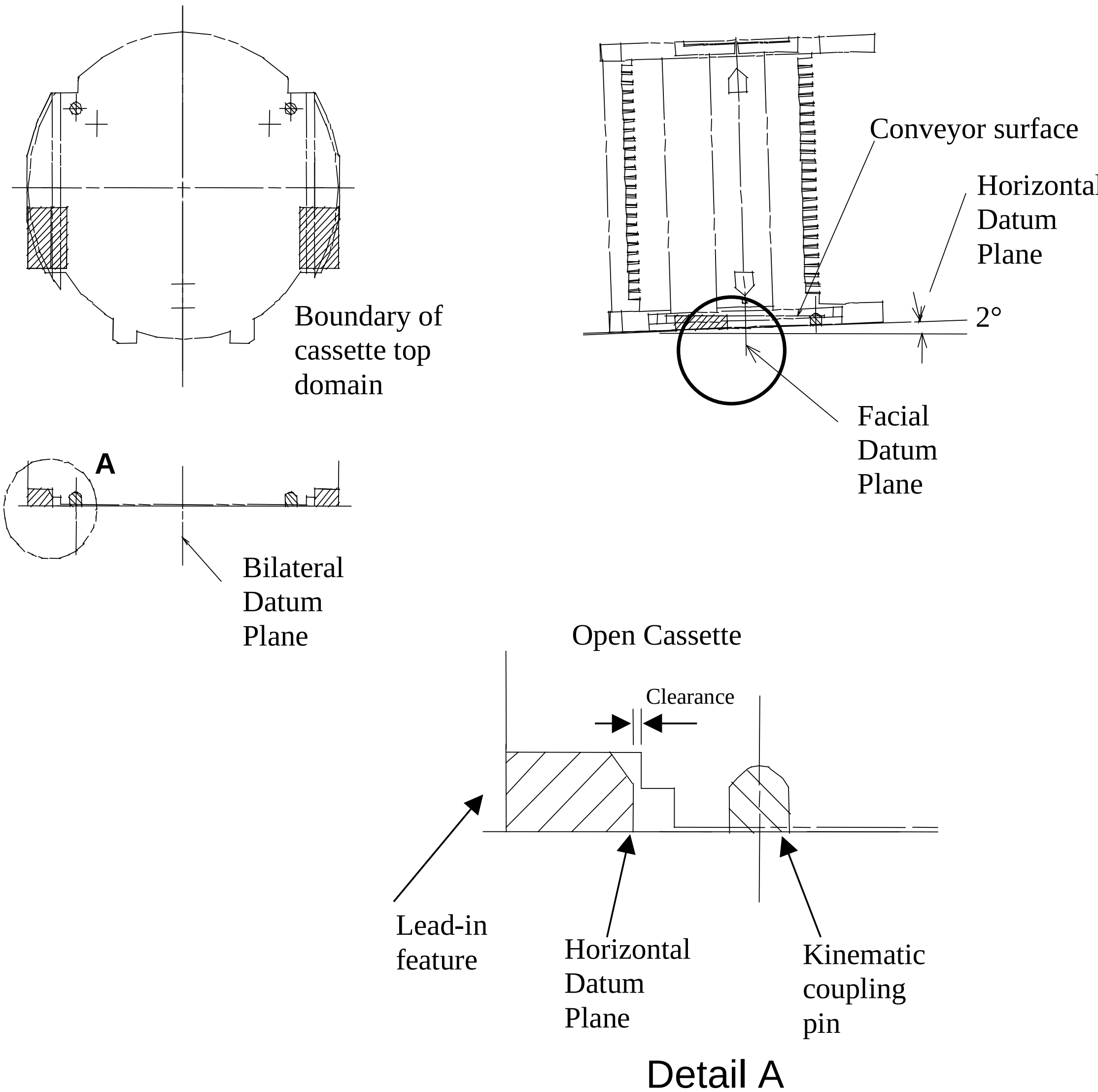

Figure R1-2
An Open Cassette Example of Using Two Kinematic Coupling Pins, Part 1

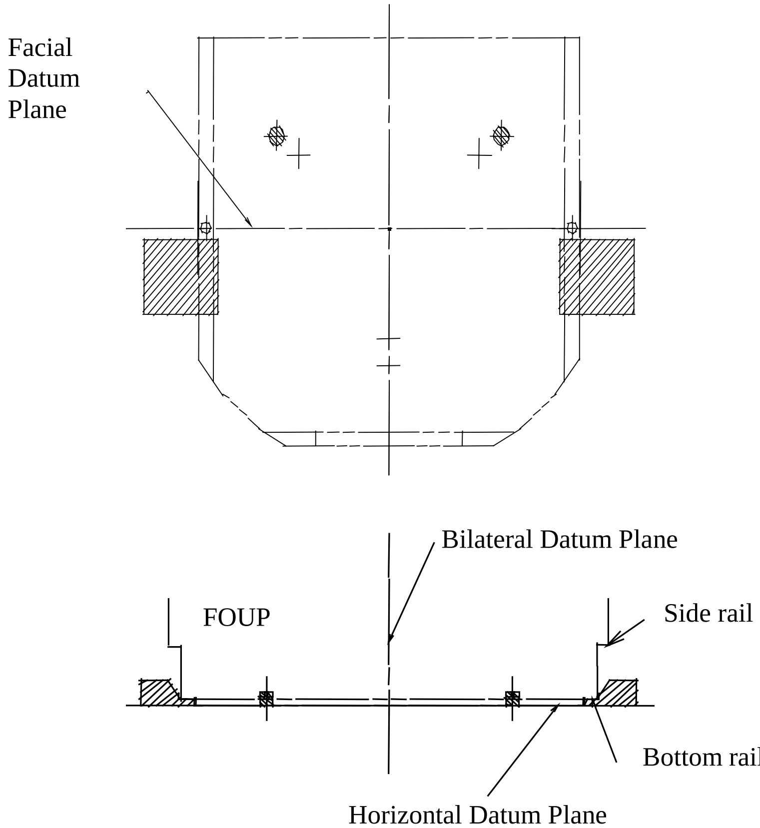

Figure R1-3
A FOUP Example of Using Two Kinematic Coupling Pins, Part 2

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SEMI E89-0999
GUIDE FOR MEASUREMENT SYSTEM CAPABILITY ANALYSIS

This guide was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 The purpose of this guide is to provide a consistent set of terminology and describe a constructive experimental approach to planning and carrying out a measurement system capability analysis.

2 Scope

2.1 Primary focus is on describing and estimating measurement uncertainty associated with the behavior of automated wafer measurement systems under normal operating conditions, but the definitions and methodologies are extendible to many other measurement situations involving items such as wafers, dies, packaged devices, flat panel displays, piece parts, etc. While examples are included to illustrate concepts, the intent is to avoid specific measurement situation details wherever possible and focus instead on general planning and analysis issues.

2.2 This guide does not address those aspects of measurement uncertainty associated with change in the object being measured, either spatially or temporally.

2.3 This guide does not address those aspects of measurement uncertainty associated with calibration of the measurement system.

2.4 This guide does not address estimating measurement capability in the case of destructive measurements on samples, or when the metrology system alters the object being measured as the measurement is made.

2.5 This guide does not apply to inter-laboratory measurements designed to measure inter-laboratory precision.

2.6 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standard*

SEMI M27 — Practice for Determining the Precision over Tolerance (P/T) Ratio of Test Equipment

3.2 *ISO Standards*[1]

Guide to the Expression of Uncertainty in Measurement

International Vocabulary of Basic and General Terms in Metrology, Second Edition

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *General Definitions*

accuracy — closeness of agreement between a measurement made on an object and its true value [International Vocabulary of Basic and General Terms in Metrology].

NOTE 2: This is a qualitative term measured by bias.

bias — the difference between the average of measurements made on the same object and its true value. Sufficient measurements are needed to mitigate the effects of variability.

NOTE 3: In many cases the true value is unknown. A value established by reference instruments or a consensus value might be used as a substitute.

capability (C_p) — a dimensionless figure of merit that indicates how many times larger the tolerance (see Section 4) is than the measurement system precision (see Section 4). Example: for a two sided specification, if USL is the upper specification limit, LSL is the lower limit and σ_R is reproducibility (see Section 4.1), then $C_p = (USL - LSL)/6\sigma_R$.

NOTE 4: This defines C_p for the measurement system in a particular application. If $\sigma_{Product}$ (see Section 4.1) is used, instead of σ_R, then C_p defines process capability.

gauge — any tool used to assign a value to a quantitative or qualitative characteristic of a physical entity or phenomenon. Example: film thickness is a quantitative characteristic and defect type is a qualitative characteristic.

gauge repeatability and reproducibility (R&R) study — see Section 4.1, measurement system capability analysis.

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linearity — the absence of changes in bias as measurements are made at different points within the measurement range. Bias and linearity issues are related to calibration and are beyond the scope of this document.

NOTE 5: Traditional definitions of linearity ignore the fact that variability can change over the measurement range, as well as bias. The assumption of constant variability over the measurement range should be verified during the measurement system capability study.

lower specification limit (LSL) — the lower (or minimum) engineering specification limit for a given parameter.

measurement — the value a gauge assigns to a characteristic. In most cases, measurements will be numerical, although this is not a requirement. Example: defect classification equipment assigns non-numerical types to wafer defects.

NOTE 6: Measurement may also be used as an adjective when referring to the measurement process of assigning a value to an object.

measurement subsystem — any set of entities, processes or conditions that share a common purpose in the measurement.

NOTE 7: A subsystem may contain one or more of its own subsystems. For example, a wafer handling mechanism may be further composed of wafer loading and wafer positioning subsystems.

measurement system — all entities, processes, and conditions that may affect measurements made

- on the same object or identical objects (apart from true value differences)
- with a specific set of measurement tools and
- under normal operating conditions as described in gauge specifications.

The measurement system may include, but is not limited to, operators, setup mechanics, wafers, locations on a wafer, environmental conditions, software used by the gauge, measurement method, etc. The system may be comprised of measurement subsystems.

NOTE 8: The purpose of a measurement system capability analysis is to characterize sources of variation associated with the measurement system. In most cases, however, the total number of contributors is exceedingly large. Typically, one focuses on a subset that accounts for a large portion of total measurement system variability.

measurement system capability analysis — the technique by which one estimates all relevant individual sources of variability associated with a gauge in a measurement system. It is also called a gauge study or a gauge repeatability and reproducibility (R&R) study.

measurement uncertainty — parameter, associated with a measurement, that characterizes the dispersion of values that can be reasonably attributed to the object being measured [International Vocabulary of Basic and General Terms in Metrology].

precision — a multiple of σ_R, often chosen to be $6\sigma_R$.

NOTE 9: The QS9000 Standard, as well as other automotive industry documents, uses $5.15\sigma_R$.

precision over tolerance (P/T) ratio — a relative comparison that shows how much of the tolerance (see Section 4) is used up by the measurement instrument's precision (see SEMI M27). Example: $P/T = 6\sigma_R/(USL - LSL) = 1/C_p$, where C_p is the measurement system capability defined in Section 4. P/T is often expressed as a percent, by multiplying the previous ratio by 100.

product variability ($\sigma_{Product}$) — the population standard deviation associated with the distribution of measurements taken on all possible realizations of an entity manufactured under specified operating conditions. It is estimated by taking a representative sample from the population and calculating its sample standard deviation ($s_{Product}$).

repeatability (σ_r) — the variability associated with repeated measurements taken under the most ideal (identical) conditions. The ideal estimate would require instantaneous measurements taken under conditions that hold all elements of the measurement system constant. Two different methods of estimating repeatability are common, because of the different ways measurement instruments are used. They are:

dynamic repeatability — the standard deviation of measurements taken under the following conditions:

- A very small amount of time, typically minutes or seconds, has lapsed between the first and last measurements.
- All factors that may influence the measurement are held constant.
- The object is removed and immediately put back into the gauge between measurements.

NOTE 10: When it is possible to calculate both kinds of repeatability, the Root Sum of Squares (RSS) difference (see Section 4.2) between dynamic repeatability and static repeatability is a measure of the variability introduced by the wafer insertion (or stage accuracy) process.

static repeatability — the standard deviation of measurements taken under the following conditions:

- A very small amount of time, typically minutes or seconds, has lapsed between the first and last measurements.
- All factors that may influence the measurement are held constant.
- The object is not reloaded in the gauge between measurements.

reproducibility (σ_R) — the total variability associated with the measurement system when measurements are made under different (but typical) conditions. Changes associated with subsystems or conditions are potential sources of variation to be estimated. Reproducibility is measured by the square root of the sum of all sources of variation. Repeatability is one of these sources. Other relevant sources of variability may include time, operator, wafer, location on a wafer, environment, etc. Reproducibility does not include variability due to measuring objects with different "true" measurement values.

resolution — the ability of the measurement system to detect and faithfully indicate small changes in the characteristic of the measured result.

NOTE 11: A general rule of thumb is that a gauge should have resolution that is more than two digits beyond what is required for the measurement result.

signal to noise ratio (SNR) — the ratio of the variation in the manufactured product to the precision of the measurement instrument. Since it is difficult to directly measure the standard deviation of the product without including variation due to the measurement instrument, SNR is generally defined as:

$$SNR = \sqrt{\frac{\sigma_{Total}^2 - \sigma_R^2}{\sigma_R^2}},$$

where σ_{Total}^2 is the variance obtained by measuring a large representative sample of the product.

NOTE 12: SNR is an objective measurement in the sense that it does not depend on a specification, which can be changed at any time. In practice, a SNR of 10 or more generally means the instrument is suitable for the product, while an SNR less than 3 or 4 might be a concern in a particular situation.

stability — the absence of additional variability due to taking measurements over time (typically several days or longer).

tolerance — the difference between the maximum and minimum engineering specification limits (as used in P/T ratio) for a given parameter. This is just (USL – LSL).

total variability (σ_{Total}) — the square root of the product variability squared plus the reproducibility squared.

$$\sigma_{Total} = \sqrt{\sigma_{Product}^2 + \sigma_R^2}$$

upper specification limit (USL) — the upper (or maximum) engineering specification limit for a given parameter.

4.2 *Statistical Definitions*

effect — the coefficient, or its estimate, associated with an input variable. It is a measure of influence that a particular variable level has on the output variable.

crossed effect — effects that do not possess a hierarchical relationship.

fixed effect — an effect associated with input variables that have a limited number of levels or in which a limited number of levels are of interest to the experimenter.

nested effect — an effect that is part of a hierarchical relationship such that it is contained within another effect.

random effect — an effect associated with input variables chosen at random from a population having a large or infinite number of possible values.

level — unique value associated with a nominal or categorical variable (see Section 4.2). Also called setting of a variable.

(statistical) model — a mathematical function relating one or more responses to known and measurable inputs plus one or more unknown stochastic (error) terms. The errors represent values from the distribution of differences between the model and observed values. An example of a statistical model is:

$$Y_j = \sum_{i=1}^{p} \beta_i X_i + e_j$$

where Y_j is the jth observation, β_i and X_i the ith input variable and its corresponding coefficient, respectively, and e_j the error associated with the jth observations. In many cases the error distribution(s) are specified before the model is fit (e.g., normal). If the model contains nested effects (see Section 4.2) there may be more than one error term.

root sum of squares (RSS) sum — the RSS sum of two or more numbers is the square root of the sums of the squares of the numbers.

root sum of squares (RSS) difference — the RSS difference of two numbers is the square root of the difference of the squares of the two numbers.

standard deviation — a numerical measure of dispersion.

population standard deviation — the square root of the population variance.

sample standard deviation — the square root of the sample variance.

variable — a quantitative or qualitative characteristic of an object, processes, or state that may take on more than one value. When the values occur unpredictably, it is a random variable.

variance — a numerical value that measures dispersion.

population variance (σ^2) — a measure of dispersion associated with a population distribution. For continuous distributions, it is the second central moment.

sample variance (s^2) — a measure of dispersion associated with a sample. The average squared deviation from the mean for a set of numbers. If X_i is an individual observation, $\overline{X}$ the average across all observations, and n the number of observations, then

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}$$

NOTE 13: The denominator value of $n - 1$ is used to make the sample variance an unbiased estimator of the population variance.

5 Measurement System Capability Analysis Considerations

5.1 The goal of a measurement system capability analysis is to characterize the measurement system by dividing the total measurement variability into portions coming from each significant source of variability. Tests of gauge tool performance should characterize the simultaneous performance capability of the various aspects of accuracy and repeatability just as the tool would be used in a manufacturing or laboratory setting.

5.1.1 Picture the total measurement system variability as a large bucket filled with contributions that come from many smaller buckets. Some of the variability in the smaller buckets causes erroneous measurement readings and some is due to real differences in what is being measured. A number of the buckets are "owned" by the measurement instrument, while some are "owned" by the user and some arise from possibly unavoidable conditions. Accurately identifying the size and nature of all these buckets allows one to know whether the instrument is capable of performing its intended function. Moreover, a well-designed measurement system capability analysis will identify and quantify which areas need the most improvement.

5.2 *Steps in Planning a Measurement System Capability Analysis*

5.2.1 List specific goals for the study. One or more of the following typical goals might be included:

- Assess gauge accuracy (requires standards or "golden specimens" with known true measurement values or agreed upon consensus values).
- Insure the gauge repeatability, precision and P/T is acceptable. Rule of thumb: a P/T based only on repeatability should be less than 0.05 and a full P/T should be under 0.3.
- Learn which are the largest sources of variability affecting measurements made by a given gauge (for focussing improvement efforts).
- Institute an appropriate routine of statistical process control for a gauge.
- Understand whether the gauge behaves linearly across the measurement range.
- Understand whether the gauge is stable over a period of days or possibly months. (Gauge maintenance and calibration schedules play a key role in determining how long a gauge needs to be stable.)

5.2.2 Obtain standards or specimens with consensus values, if possible. Bias can only be measured when true values are known.

5.2.3 Review prior studies – what sources of variability were significant and what were the repeatability and precision?

5.2.4 List all sources of variability (factors) and reach consensus on those that might be significant. Some of these might be:

- Operator
- Set-up procedure
- Shift
- Wafer handling hardware
- Location on a wafer
- Test wafer
- Environment conditions
- Temperature
- Humidity
- Day or week

5.2.5 Determine if the tool needs to be calibrated. Calibrate, if necessary, following the manufacturer's recommended procedure. Do not recalibrate during the gauge study unless specified by normal operating procedure.

5.2.6 An experiment to estimate bias, repeatability and reproducibility should be a goal of the study. As a general rule of thumb, a minimum of 16 measurements on a standard are needed to estimate bias, and 30 measurements (taken throughout the experiment, under repeatability conditions) are needed to estimate repeatability. Several examples of every factor that was decided on in Section 5.2.4 should be included.

5.2.6.1 Linearity should be estimated by taking a sample of observations that adequately span the measurement range.

5.2.6.2 To estimate stability over the long term, measurements should be taken over an appropriate time period (5 or more days is typical), and then, if behavior over longer periods is important, repeat the experiment several weeks or months later.

5.2.6.3 In order to plan and analyze an experiment properly, it is useful to write a statistical model for the experiment (see Appendix 1).

5.2.7 Carry out the experiment, randomizing both the sample specimens chosen and the order measurements are made, wherever possible. Keep track of the actual order all measurements are made.

5.2.8 Analyze the measurement data, calculating repeatability, reproducibility, system measurement error, P/T and all significant sources of error contributing to reproducibility. Check short term and long term stability by plotting repeatability measurements in time order within a day, and measurement averages and spread from day to day. Compare precision results obtained on a specimen to specimen basis, to check linearity.

6 Example of a Measurement Capability Analysis

6.1 The following example illustrates how a measurement capability analysis was performed on an automated wafer film thickness tool. The tool was calibrated prior to the analysis (the presence of bias, however, would not affect the estimation of variance components as long as the amount of bias does not change over the course of the measurement system capability analysis). Different wafer types were selected to span the range of both possible wafer types and typical thicknesses. Five standard wafers were manufactured with characteristics as shown in Table 1.

6.2 Wafers were measured on eight days, evenly spaced over a two-week period. Each day of the study each wafer was chosen twice, loaded each time into the tool and measured twice without unloading. The order of selection was at random. Therefore, on a given day, each wafer was measured exactly four times. Measurements were taken at three points on the wafers and averaged. The model (see Appendix 1) used was

$$M_{hkji} = \mu + d_h + w_k + wd_{hk} + c_{hkj} + r_{hkji}$$

where the terms are defined as follows:

M_{hkji} Measurement taken on day h, wafer k, cycle j, and repeat i.

μ The grand mean across all conditions.

d_h Effect or contribution due to day h = 1, .., 8. This measures stability and its variability is a part of reproducibility.

w_k Effect or contribution due to wafer k = 1, .., 5.

wd_{hk} Effect or contribution due to wafer by day interaction. Variability contributed by this term is part of reproducibility.

c_{hkj} Effect or contribution due to cycle j = 1, 2. Nested in wafer k and day h. Variability contributed by setting up for each cycle is part of reproducibility.

r_{hkji} Effect or contribution due to repeat i = 1, 2. Nested in cycle j, wafer k, and day h. Variability contributed by this term is repeatability.

Table 1 Wafers Used for Analysis

Film Type	*Total Thickness (Å)*
Oxide (wafers 1, 2, 3)	40, 1000, 8000 (for wafers 1, 2, 3, respectively)
Polysilicon over Oxide (wafer 4)	2500
Deep UV Resist over ARC over Oxide (wafer 5)	13000

NOTE: UV — Ultra Violet, ARC — Anti Reflective Coating.

6.3 Most analysis software programs report estimates as variances and produce the variance components analysis shown in Table 2. Sources of variation, such as σ_r and σ_R, are standard deviations found by taking the square roots of the appropriate variance component or sum of components.

6.4 Wafer variability (σ_{wafer}) was not reported because it is associated with a fixed effect. Variance components are only estimated for random effects. If, for example, the five wafers were randomly selected from a distribution for a single wafer type, wafer variability would be included in the table and could be used to estimate the SNR. However, wafer variability would still not be part of σ_R. For further details, see Appendix 1.

Table 2 Variance Components Estimates — All 5 Wafers

Variance Component	*Estimated Variance*	*Estimated Sigma*
DAY	11.183	3.344
REPEAT	0.286	0.535
CYCLE	0.797	0.893
WAFER*DAY	447.940	21.165

6.5 Reproducibility (σ_R) is calculated as the square root of the sum of the estimates, i.e.,

$$\sigma_R = \sqrt{11.183 + 0.286 + 0.797 + 447.940} = 21.452\,.$$

6.6 Repeatability (σ_r) is estimated by the repeated measurements.

$$\sigma_r = \sqrt{0.286}$$
$$= 0.535$$

6.7 Stability is estimated by the square root of the DAY component of the study, $\sigma_{stability} = 3.344$.

6.8 Figure 1 shows a Pareto chart of the effects sigmas.

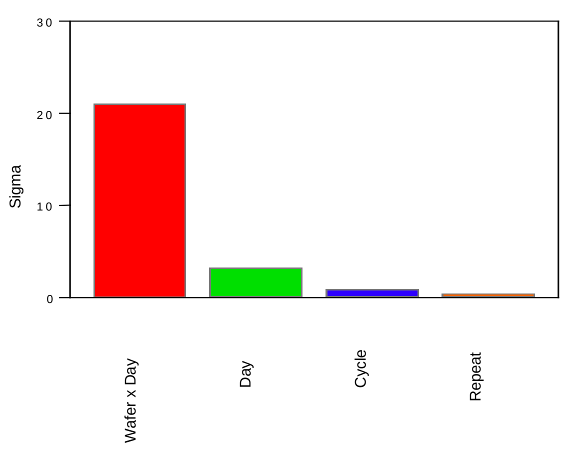

Figure 1
Pareto Chart for Effects Sigmas (All Five Wafers)

6.9 Linearity is more difficult to estimate. In general, it is measured by the differences in variability associated with the different wafer types. The large wafer by day interaction suggests that there may be a linearity problem. An examination of the standard deviations for each group by day (See Figure 2) indicates that Wafer Type 5 (Deep UV resist) may be responsible. These standard deviations were calculated from the 4 measurements made on every wafer each day.

6.10 When the variance components analysis was rerun, excluding Wafer Type 5 data, the new estimates obtained confirmed that Wafer Type 5 was problematic. An investigation into the potential cause suggested that the tool was degrading the resist at the point of measurement, causing the readings to decrease over time.

6.11 If one were interested in measuring only Wafer Types 1 through 4 (employing a different gauge for Wafer Type 5, for example), the improved variance components estimates from Table 3 could be used.

Table 3 Variance Components Estimates Wafers 1 – 4

Variance Component	*Estimated Variance*	*Estimated Sigma*
DAY	0.347	0.589
REPEAT	0.130	0.360
CYCLE	0.244	0.493
WAFER*DAY	1.023	1.011

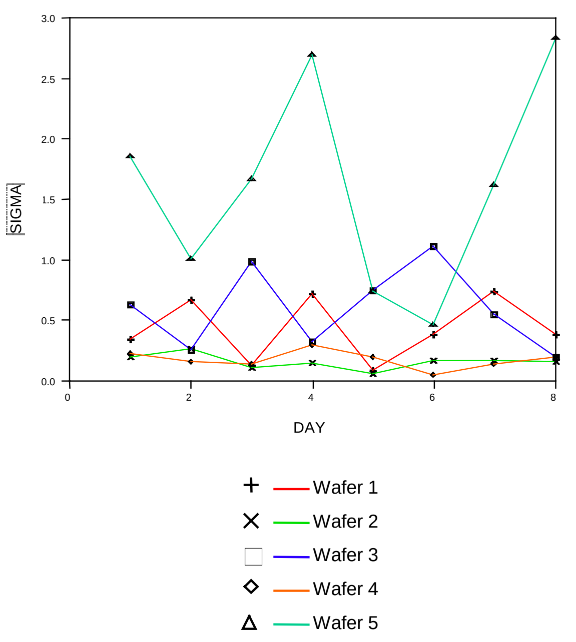

Figure 2
Wafer Sigmas by Day

6.12 The new estimates for σ_r and σ_R, are 0.360 and 1.271, respectively. Stability, as measured by day to day variability, improves to 0.589. The new Pareto chart of the effects sigmas is shown in Figure 3.

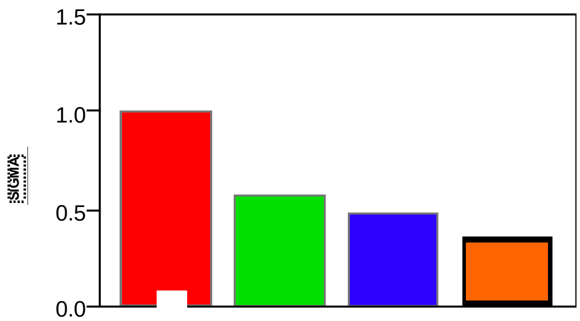

Figure 3
Pareto Chart for Effects Sigmas
(Wafer Type 5 Removed)

6.13 The specification range for the tool was given as 10Å, thus the capability for Wafer Types 1 to 4 is

$$Cp = \frac{10}{6*1.321} = 1.262$$

6.14 The P/T ratio is the reciprocal of this number, or P/T = 0.79. Since this is well above the "rule of thumb" 0.30 value, the gauge might not be suitable for some applications. Improvement activities would begin with an investigation of why the WAFER*DAY sigma is so large. This term indicates differences between the way certain wafers vary from day to day (stability differences between wafers).

7 Related Documents

7.1 The references listed below cover a wide range of approaches to the subject of measurement system capability analysis. The definitions and methodologies advocated in this guide most closely follow Eastman and John. The survey paper McCormack et al. provides an overview to the various historical approaches found in the literature and offers arguments favoring the design of experiments approach. Box, Hunter, & Hunter is a classical reference to design of experiments.

7.2 *ISO Documents*[2]

ISO 5725–1, Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions.

ISO 5725–2, Accuracy (trueness and precision) of measurement methods and results – Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.

ISO 5725–3, Accuracy (trueness and precision) of measurement methods and results – Part 3: Intermediate measures of the precision of a standard measurement method.

7.3 *SEMATECH Documents*[3]

Eastman, S.A. (1994), "Evaluating Automated Wafer Measurement Instruments" SEMATECH technology transfer document 94112638A-XFR:

John, P.W.M. (1994), "Alternative Models for Gauge Studies." SEMATECH technology transfer document 93081755A-TR

7.4 *Other Documents*

Automotive Industry Action Group (1993), *Measurement Systems Analysis.*

Box, G.E.P., Hunter, W.G., & Hunter, J.S. (1978), *Statistics For Experimenters*, Wiley, New York.

Barrentine, L.B. (1991), *Concepts for R&R Studies*, Milwaukee: ASQC Quality Press.

Crosby, D.C. (1988). Gauge R&R – the orphan of SPC. *Rubber World*, June 1988.

Duncan, A.J. (1971), *Quality Control and Industrial Statistics*, 4th Edition, Homewood, IL: Irwin.

McCormack, D.W., Ballard, D.H., Moore, T.L., Prins, J., Tobias, P.A., & Pore, M. (1997), "A Comparison of Gauge Study Practices", *1997 Proceedings of the Section on Quality and Productivity of the American Statistical Association.*

Montgomery, D.C. & Runger G. C. (1993), "Gauge Capability and Designed Experiments. Part I: Basic Methods", *Quality Engineering*, 6(1), 115–135.

Montgomery, D.C. & Runger G. C. (1993), "Gauge Capability and Designed Experiments. Part II: Experimental Design Models and Variance Component Estimation", *Quality Engineering*, 6(2), 289–305.

Potter, R.W. (1991), "Measurement System Capability Analysis", *IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, 121–125.

2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

3 available at the public web site: http://www.sematech.org/public/docubase/abstract/tech-23.htm

QS9000: Quality System Assessment (QSA), copyrighted 1994 and printed by Chrysler Corporation, Ford Motor Company, and General Motors Corporation. Available from the Automotive Industry Action Group (AIAG), (810) 358-3570.

Tsai, P. (1988), “Variable Gauge Repeatability and Reproducibility Study Using the Analysis of Variance Method”, *Quality Engineering*, 1(1), 107–115.

Wheeler, D.J. (1988), “Problems With Gauge R&R Studies”, *ASQC Quality Congress Transactions – Nashville*, 179–185.

APPENDIX 1
MODELS FOR MEASUREMENT CAPABILITY ANALYSIS STUDIES

NOTE: This appendix was balloted as an official part of SEMI E89 by full letter ballot procedure, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 This is a more detailed theoretical explanation that extends ideas described earlier in this guideline.

A1-2 A measurement model expresses each observed measurement value as the sum of a "true value" plus "bias" plus "random error". The "true value" may be the actual value for the object being measured or the average population value if a sample of objects are measured in the study. The random error term is further broken up into contributions from all the significant sources of error under investigation. If the experiment is well designed, standard statistical techniques (known as Analysis of Variance, or ANOVA) can be used to estimate the standard deviation contribution from each source of error, and from this the repeatability, reproducibility and precision of the measurement instrument are determined.

A1-3 Note that any instrument which is composed of several measurement subsystems (such as spectrometry and ellipsometry), designed for the measurement of different characteristics or types of samples, must be treated as composed of separate gauges which need to be analyzed independently.

A1-4 Writing an appropriate measurement model is the starting point, after which many software packages can be used to design the gauge study and calculate ANOVA estimates from the resulting measurement data.

A1-5 An example will illustrate what is meant by a measurement model.

A1-5.1 *Example of a Measurement Model* — A wafer oxide thickness measuring gauge is under investigation. A wafer is placed in the instrument, which then automatically positions the wafer and takes a measurement. While the wafer is positioned, the measurement can be repeated as many times as desired. Sources of variability that might affect a measurement include basic repeatability on a positioned wafer, variability due to the automatic positioning process, variability over time and variability from measuring several different wafers (to cover a range of "true" measurement values).

A1-5.2 An experiment that separates out all these possible sources of variability is the following: 10 wafers are chosen at random from normal production. Each wafer is put in the instrument in a random order and measured 3 times (3 repeats) on day 1 (cycle 1). Immediately after the thirty measurements are recorded, the same measurement process is repeated on the ten wafers (cycle 2). On day two, the same wafers are again measured using exactly the same procedure. This is repeated for a total of 5 days, yielding $3 \times 10 \times 2 \times 5 = 300$ measurements.

A1-5.3 Assuming the instrument has been calibrated (or bias is not a concern at the moment), a model for variability is constructed as follow: let $h = 1, 2, .., 5$, index the days; let $k = 1, 2, .., 10$, index the wafers; let $j = 1, 2$, index the repositions (cycles) each day and let $i = 1, 2, 3$, index the repeat measurements (taken under repeatability conditions) on a positioned wafer.

A1-5.4 The model for the i-th measurement at the j-th repositioning on the k-th wafer on the h-th day is:

$$M_{ijkh} = \mu + d_h + w_k + p_{hkj} + r_{hkji}$$

where:

- μ is the true oxide thickness average value for the population of wafers,
- d_h is an error term associated with the h-th day (due to day to day stability variation),
- w_k is the offset from the average due to the true thickness of the wafer k,
- p_{hkj} is the (short term) error due to the j-th positioning of the k-th wafer on the h-th day,
- r_{hkji} is the repeatability error term.

A1-5.5 In this model, the quantities d_h , p_{hkj} , and r_{hkji} are random error terms. They are usually assumed to have a normal distribution with zero mean and standard deviations σ_d, σ_p and σ_r, respectively. The wafer term w_k may be either a random term or a "fixed effect", depending on whether we consider the wafers measured to be a random sample from the entire population of possible wafers, or a fixed population used for experimental purposes. In either case, the estimates of repeatability and reproducibility will be the same.

A1-5.6 When error terms are known to have non-normal distributions, special methods and/or software (beyond the scope of this guide) are needed.

NOTE 14: The model might also include a "wafer/day" random error term wd_{hki}, if it is suspected that measurements made from day to day on some wafers might vary differently than measurements made from day to day on other wafers, and it is desired to obtain an estimate of this component of reproducibility.

A1-5.7 Reproducibility includes everything but wafer to wafer true thickness variability, so

$$\sigma_R = \sqrt{\sigma_d^2 + \sigma_p^2 + \sigma_r^2}\ .$$

A1-5.8 The ANOVA for this experiment provides all the variance estimates needed to calculate repeatability, reproducibility and precision. If the wafer term w_k is random, the ANOVA will also estimate σ_d, which is useful for characterizing the wafer population variability.

NOTE 15: When inputting this model into a statistical analysis program, the factors “day” and “wafer” are said to be *crossed*, since every wafer is measured on every day. The factor “positioning” is *nested* within wafer and day, and “repeatability“ is the residual error term and is *nested* within positioning, wafer and day. A factor “A” is *nested* within another factor “B” if the levels or values of “A” are different for every level or value of “B”.

A1-5.9 This example shows how a fairly complicated measurement capability analysis study can be set up. Each particular situation can lead to a different model and experimental design, depending upon the goals and agreed upon sources of (possibly significant) variation.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user’s attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E92-0302
SPECIFICATION FOR 300 mm LIGHT WEIGHT AND COMPACT BOX OPENER/LOADER TO TOOL-INTEROPERABILITY STANDARD (BOLTS/LIGHT)

This provisional specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces & Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on December 3, 2001. Initially available at www.semi.org January 2002; to be published March 2002. Originally published September 1999.

1 Purpose

1.1 *Provide Standard for Box Opener/Loader Interoperability* — This standard is intended to provide standard specifications such as interfaces between the component that opens the boxes and presents the boxes to the equipment wafer handler for unloading and loading 300 mm wafers (BOLTS/Light unit) and higher level part of equipment and its functions to provide: (see Figure 1)

- High level of interchangeability/ interoperability,
- Quick attachment/detachment capability with high mechanical repeatability,
- Light weight, and
- Compactness.

1.1.1 In order to provide a high level of interchangeability and interoperability, this standard specifies not only interfaces but also some of the box opener/loader's functions that affect interoperability.

1.2 *Usage of This Standard* — Interoperability specifications defined by this standard are intended to be used as interfaces and functionality between BOLTS/Light compliant box opener/loader and:

- A BOLTS/M compliant loadport unit (that would conform to SEMI E63).
- An integrated loadport such as four box opener/loader in one chassis.
- High-densely packaged equipment that uses the space under the box opener/loader.

1.3 *SEMI Standards Compatibility* — This standard is compatible with 300 mm SEMI standards including SEMI E15.1, E47.1, E1.9, E62, E63 and E64.

1.4 *Open Cassette Application* — The BOLTS/Light unit might be configured to handle boxes that would conform to SEMI E47.1 and SEMI E62.

1.5 A similar unit may be compatibly designed which does not have box opener capability, but facilitates placement of an open cassette (that would conform to SEMI E1.9).

1.6 *Carrier Capacities* — This standard defines one interface for 13 or 25 carrier capacity box opener/ loaders.

1.7 The interface specified in this standard is designed for equipment with a sealed mini-environment, but it is not limited to such.

2 Scope

2.1 *Items Specified* — This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity, interchange-ability, and interoperability including:

- Box opener/loader functions that affect interoperability.
- Mechanical interface features between the box opener/loader and equipment.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification does not apply to the following application:

- Direct insertion of open cassettes into load-lock chambers.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E64 — Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

4.2 *Other Standard*

I300I/J300 GJG — I300I/J300 Global Joint Guidance for 300 mm Semiconductor Factories

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling System

5.2 *Definitions*

5.2.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

5.2.2 *BOLTS/Light exclusion volume* — a volume reserved by equipment or loadport unit to put BOLTS/Light compliant box opener/loader.

5.2.3 *BOLTS/Light plane* — a vertical plane that interfaces BOLTS/Light compliant box opener/loader and equipment.

5.2.4 *bottom interface plane*— an interface means between the equipment and box opener/loader.

5.2.5 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

5.2.6 box opener/loader — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's wafer handler for unloading and loading wafers.

5.2.7 *carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E1.9). Also known as wafer carrier.

5.2.8 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

5.2.9 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

5.2.10 *control connection area* — an area to be used for placement of connectors for electrical signals, power supplies, and other inlets/outlets.

5.2.11 *docked facial datum plane* — a vertical plane that bisects the wafers at the carrier docked position. It is also parallel to the load face plane specified in SEMI E15.

5.2.12 *docking stroke* — the travel distance of the carrier center between its load position (facial datum plane) and the position where the door opening/closing is done.

5.2.13 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On equipment load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the equipment where the carrier is loaded and unloaded (as defined in SEMI E57).

5.2.14 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a nonremovable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62) (as defined in SEMI E47.1).

5.2.15 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On equipment load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

5.2.16 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the equipment where loading of the equipment is intended (as defined in SEMI E15).

5.2.17 *loading slider area* — two flat surfaces on equipment which may be used by a maintenance supporting mechanism (not defined in this standard) to support the box opener/loader during attachment and detachment.

5.2.18 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

5.2.19 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

5.2.20 *seal zone* — a surface on the equipment at the BOLTS/Light plane for sealing to the box opener/loader.

5.2.21 *side interface feature* — an interface means to perform a seal between the mini-environment of the equipment and box opener/loader.

5.2.22 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

6 Functional Requirements

6.1 This standard does not define actual implementation but requires functional compliance with the following standards for interchangeability and interoperability of box opener/loader.

6.2 The box opener/loader of this standard should be compliant with related sections of factory interface standards such as SEMI E15.1, SEMI E57, SEMI E47.1 and SEMI E62.

6.3 *Outer Dimensions and Physical Factory Material Delivery Interface Compatibility* — Physical dimensions, such as clearances and trenches required for factory delivery systems (human or automated), should be compliant with SEMI E15.1.

6.3.1 *Carrier Registration* — The physical alignment mechanism for the box consists of features (not specified in this standard) on the box that mate with three pins underneath as defined in SEMI E57. Primary kinematic coupling pins should be used.

6.3.2 *Loadport Pitch* — The loadport pitch which conforms to this standard is $S \geq 475$ mm (minimum value for FOUP without handles as defined in SEMI E15.1).

6.4 *Carrier ID Reader/Writer Head Exclusion Volume* — The box opener/loader compliant with this standard should have a carrier ID reader/writer head exclusion volume defined in SEMI E15.1 for automated units that read or write to an ID tag. Regarding the box opener/loader, the front end of this exclusion volume is limited by *y111*. And the rear end of this exclusion volume is defined in SEMI E15.1 D3. The difference between *y111* and SEMI E15.1 D4 should be supplied by the equipment.

6.5 *Carrier Sensing* — The box opener/loader compliant with this standard has to have the following capabilities:

6.5.1 *Carrier Presence Sensor* — Carrier sensing capability which detects carrier presence regardless of its correct placement.

6.5.2 *Carrier Placement Sensor* — Carrier sensing capability which detects correct carrier placement on the kinematic coupling.

6.6 *Info-pad Interfaces* — Optional info-pad sensing/detecting capability as defined in SEMI E1.9 and SEMI E15.1.

6.6.1 *Info-pad A, B Sensors* — Optional carrier sensing capability which detects carrier type as defined in SEMI E1.9 and SEMI E15.1.

6.6.2 *FEOL/BEOL Lockout Pin* — Optional pin that physically detects/rejects a misplaced carrier by using info-pads C and D to distinguish a FEOL carrier vs. a BEOL carrier. This pin should be capable of being installed easily after the equipment is delivered.

6.7 *Box to Equipment Sealing Interface and Door Lock/Unlock Interface* — This standard requires a box to equipment seal interface and door lock/unlock interface compliant with SEMI E47.1 and SEMI E62. This standard does not specify any of the actual design.

7 Mechanical Requirements

7.1 *Datum Planes and Dimensioning Rules* — Dimensions defined in this standard are determined with respect to the following datum planes and default dimensioning rules.

NOTE 2: Unless otherwise stated, perpendicularity and parallelism are implicitly defined in the geometric tolerances.

7.1.1 *Three Common Datum Planes* — Many of the dimensions of the BOLTS/Light interface are determined with respect to the three orthogonal datum planes defined in SEMI E57: the horizontal datum plane, the facial datum plane, and the bilateral datum plane.

7.1.2 *Symmetry* — All of the dimensions for the interface are bilaterally symmetric about the bilateral datum plane unless otherwise noted. These dimensions are shown in Figures 2 and 3 and specified in Table 1.

7.1.3 *Inner and Outer Radii* — All required concave features may have a radius of up to *r100* to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r101* to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the equipment supplier. Note also that this radius applies to every required feature unless another radius is called out specifically.

7.2 *BOLTS/Light Exclusion Volume* — Equipment or loadport unit compliant with this standard must provide a BOLTS/Light exclusion volume defined in this section. BOLTS/Light exclusion volume consists of multiple sub-volumes and spaces defined in this section. The box opener/loader compliant with this standard must be compatible with BOLTS/Light exclusion volume. Bolts/Light exclusion volume is shown in Figure 2.

7.2.1 *Loader Exclusion Volume* — Loader exclusion volume is an exclusion volume for the main part of box opener/loader that is defined by *x108, y101, y110, y111,* and *z107. y111* is intentionally shorter than SEMI E15.1 D dimension in order to allow the equipment integrators to place a safety door, a carrier ID reader/writer, and/or any other features required by the user. An additional removable cover can be mounted on the box opener/loader if it is to be supplied as a complete unit compliant with the SEMI E15.1 D dimension.

7.2.2 *Door Seal Exclusion Volume* — Door seal exclusion volume is an exclusion volume for the door seal portion of box opener/loader that is defined by the distance between the plane at the SEMI E15.1 D1 and *y101, x108,* and *z109.*

7.2.3 *BOLTS/Light Opening Exclusion Volume* — BOLTS/Light opening exclusion volume is an exclusion volume for the box opener/loader encroachment of equipment from BOLTS/Light plane at portion above the permanent reserved space. There should be an opening when the door is opened. Through this opening substrates may be moved between the box on the BOLTS/Light compliant box opener/loader and the equipment by a wafer handler in the equipment. BOLTS/Light opening exclusion volume is defined by *x102, y103, z103,* and *z108*.

7.2.4 *Permanent Reserved Space* — Space that is reserved permanently in the equipment defined by *x102, y102, z105,* and *z108*.

7.2.5 *Temporarily Reserved Space* — Space that is reserved temporarily during a door open/close motion is being done and when the door is closed. The temporarily reserved space during a door open/close is defined by *x102, y102, y103, z103,* and *z108*. The temporarily reserved space when a door is closed is defined by *x102, y103, y112, z103,* and *z108*.

7.2.6 *The Loader Bottom Flange Exclusion Volume* — The loader bottom flange exclusion volume is an exclusion volume for fixing the box opener/loader to bottom interface plane. Loader bottom flanges are located on the both bottom side of the box opener/loader and directly mounted on bottom interface plane. The loader bottom flange exclusion volume is defined by *x108, x109, y115, y116,* and *z113 measured* from the bottom end of *z107.*

NOTE 3: The spaces to access the fixing bolt should be reserved by equipment side. This document does not define these spaces.

7.3 *Side Interface Features* — This standard defines the equipment side of the side interface features. Side interface features are defined with respect to "Docked facial datum plane" instead of "Facial datum plane". The box opener/loader should mate with these features to provide the seal to the equipment. The side interface features are shown in Figure 2.

7.3.1 *BOLTS/Light Plane* — The BOLTS/Light plane is defined to be parallel to and at a distance *y101* from the docked facial datum plane. The Seal Zone is on this plane.

7.3.2 *Cycle-to-Cycle Repeatability* — The cycle-to-cycle repeatability of *y101* must be within *y113.*

7.3.3 *Seal Zone* — The equipment side of the BOLTS/Light plane specified by *x101, x103, z101, z102, z104,* and *z106* must be a flat area for sealing between the equipment and the box opener/loader.

7.3.3.1 The flatness of the seal zone must be within *y114* and the perpendicularity of the seal zone to the facial and horizontal datum planes must be within $\sigma 1$.

7.3.3.2 This standard only defines the seal zone on the equipment side. The actual seal is not defined in this standard, but should be mounted on the box opener/loader.

7.3.4 *Wafer Position* — This standard defines a typical wafer position when the box opener/loader positions the wafers to the equipment. The facial datum plane of a docked carrier is defined by *y110* from the facial datum plane. This provides compatible wafer center positions from the facial datum plane.

NOTE 4: This means that this standard defines a specified typical docking stroke.

7.4 *Bottom Interface Features* — This standard defines mainly the equipment side of the bottom interface features. Bottom Interface Features are shown in Figure 3.

7.4.1 Regarding the box opener/loader, parallelism of the bottom interface feature and the horizontal datum plane must be within $\sigma 2$.

7.4.2 *Bottom Interface Planes* — The Bottom Interface Feature should have two Bottom Interface Planes defined by *x104, x105, y104, y105,* and *z107*. Nothing other than locating pins can protrude above these planes. During maintenance, the front end of the loading slider area should be open *z112* under the bottom interface planes.

7.4.3 *Loader Locating Pins* — Equipment must have two Loader locating pins to locate the box opener/loader so as to provide highly repeatable and quick attachment/detachment. Horizontal locations of the loader locating pins are defined by *x106* and *y106*. Height of the loader locating pins is defined by *z110*. Diameter of the loader locating pins is defined by *d1*. A box opener/loader compatible with this standard must refer these two Loader Locating pins.

7.4.3.1 *Positioning Pin* — Loader locating pin on the left side from operator is a positioning pin that is used to hold box opener/loader both in *x* and *y* directions.

7.4.3.2 *Anti-Rotation Pin* — Loader locating pin on the right side from operator is an anti-rotation pin that is used to hold box opener/loader in *y* direction only (see Figure 4).

7.4.4 *Locking Screws* — Four locking screws defined by *x106, y107,* and *y108* to tighten the box opener/loader.

7.4.4.1 The equipment should have M8-16 tapped holes at these locations.

7.4.5 *Control Connection Area* — Area used to pass connectors, wires, and tubes for electrical signals, power supply and other inlets/outlets.

7.4.5.1 The control connection area is defined at the same height as the the bottom interface planes by *x107* and *y109*.

NOTE 5: This standard only defines the connection area for the box opener/loader itself. It is recommended that connectors will be located above this area for quick maintainability.

7.4.5.2 Other connections which will possibly be located in this area for other functions are listed below and may be defined in separate standards:

- Carrier ID reader/writer head interface (automated units that read or write to an ID tag defined in SEMI E15.1)
- Manual operation panel
- Wafer mapper

7.5 *Panel Interface Height* — This standard defines an optional panel interface height so as to provide panel installation height to enclose box opener/loader in the equipment. Panel interface height is defined by *z111* from horizontal datum plane. In case this option is used, both equipment and the box opener/loader should have forklifts exclusion volume defined by SEMI E15.1 H0.

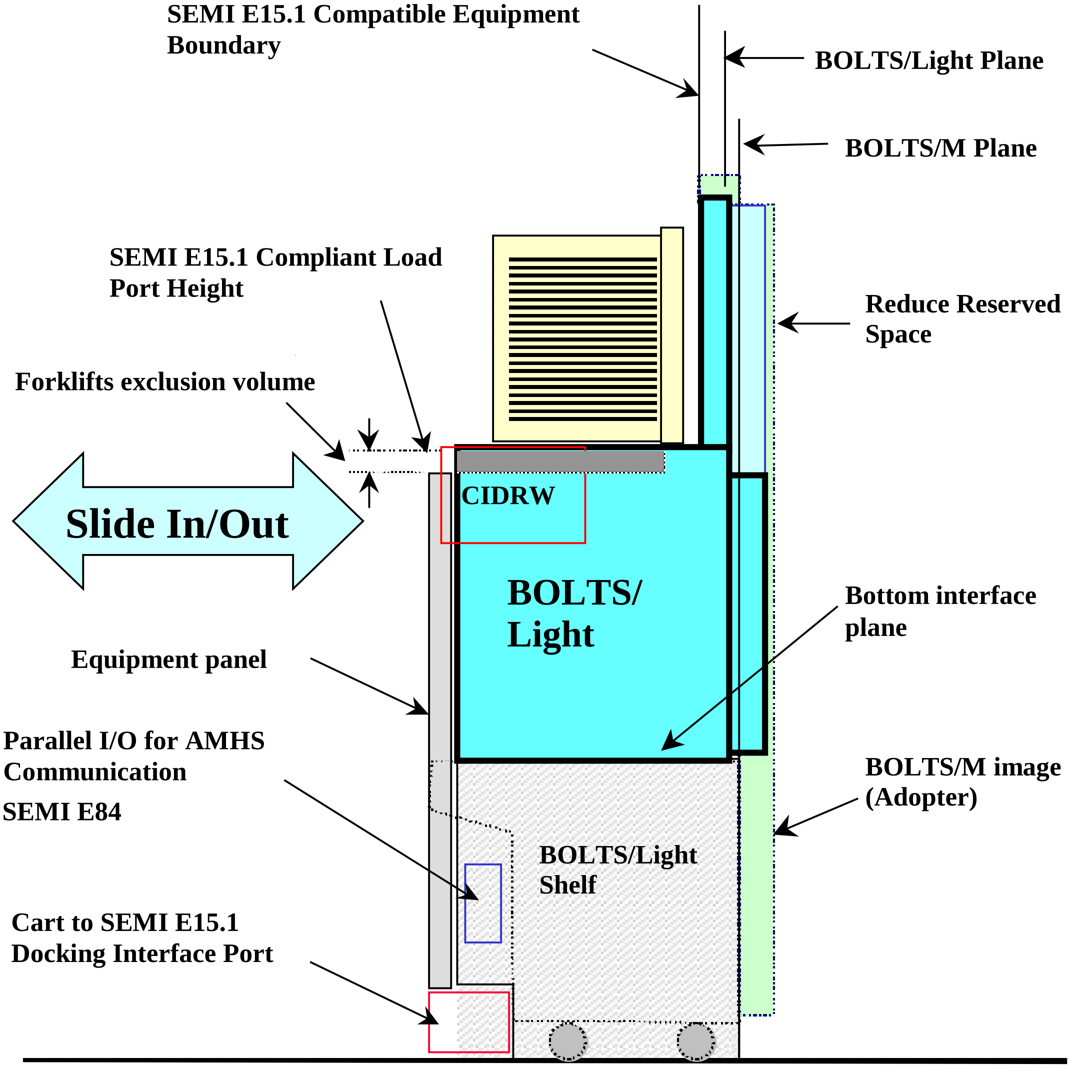

Figure 1
Diagram Concept of Light-Weight and Compact Box Opener/Loader and Tool-Interoperability Standard (BOLTS/Light)

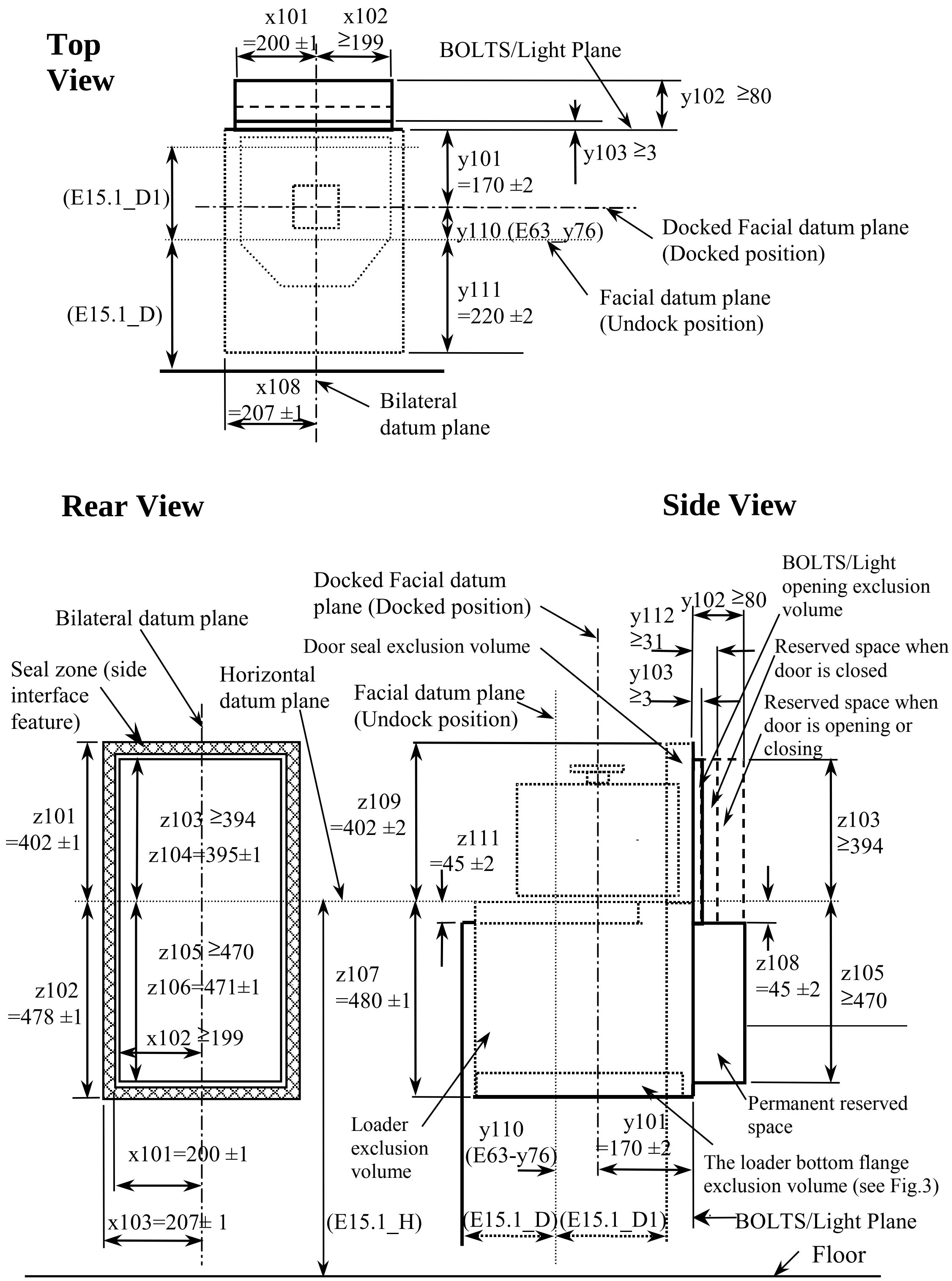

Figure 2
Top, Rear, and Side Views of BOLTS/Light Exclusion Volume and Equipment Side of the Side Interface Feature

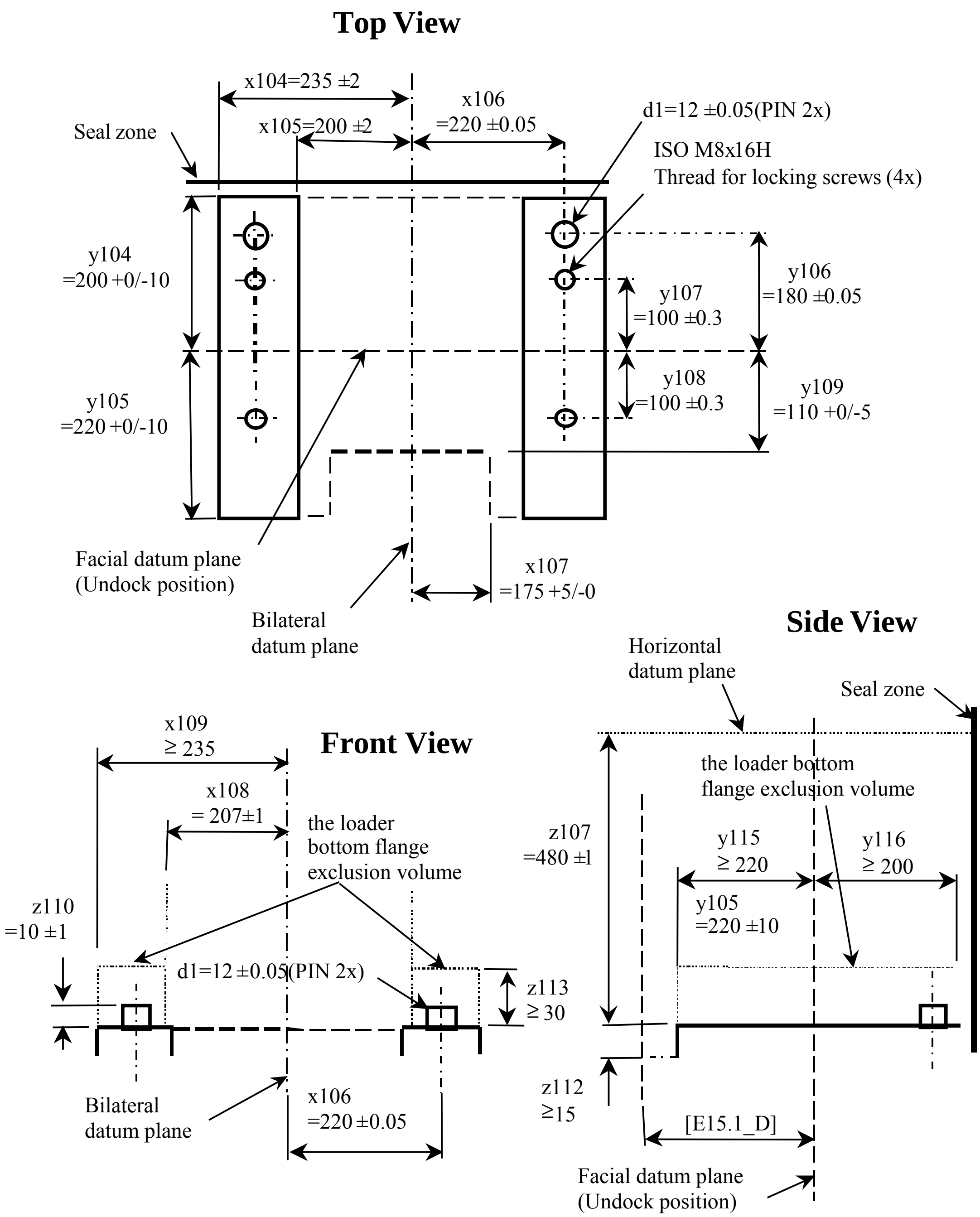

Figure 3
Equipment Side of the Bottom Interface Feature

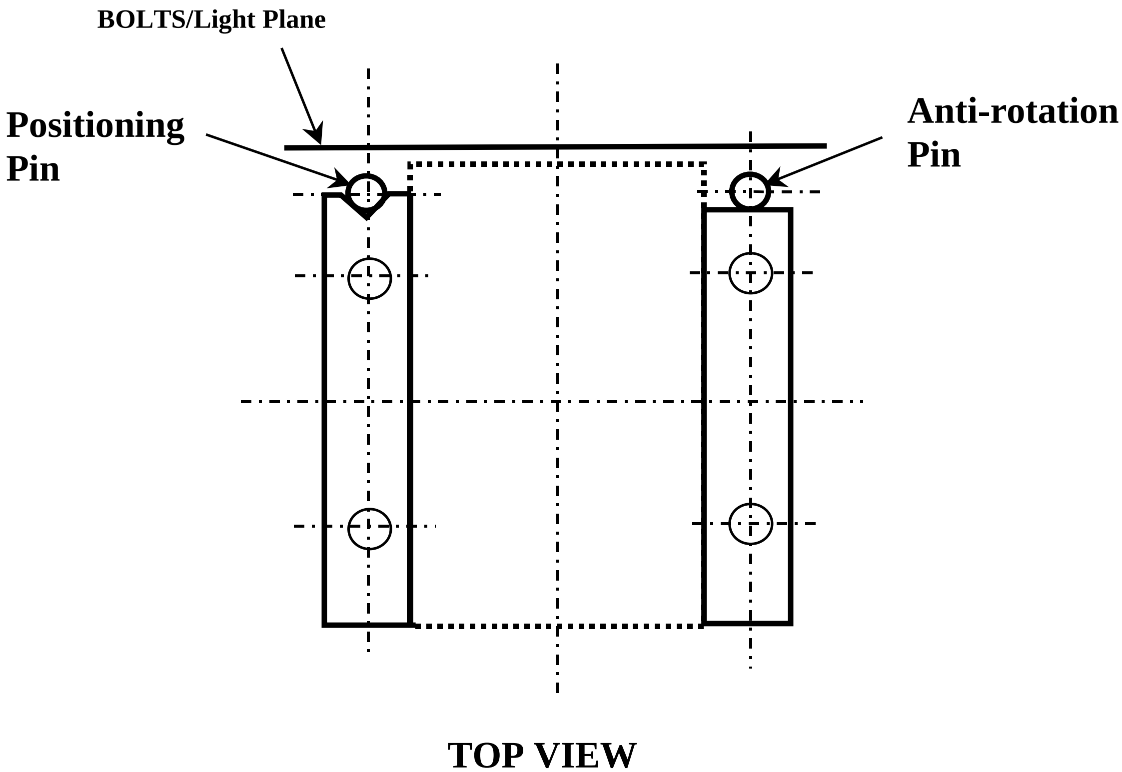

Figure 4
Usage of Loader Locating Pins

Table 1 Dimensions for Light-Weight and Compact Box Opener/Loader to Tool Standard (BOLTS/Light) Interface

Symbol	*Value Specified*	*Datum Measured from*	*Feature Measured to*
σ1	0 ± 0.1°	Facial and horizontal datum planes	Perpendicularity of seal zone.
σ2	0 ± 0.1°	Horizontal datum plane	Parallelism of bottom interface plane.
d1	12 ± 0.05 mm	-	Loader locating pin diameter.
r100	1 mm maximum	not applicable	All concave features. (radius)
r101	2 mm maximum	not applicable	All required convex features. (radius)
x101	200 ± 1 mm	Bilateral datum plane	Edge of hole opening and inside edge of seal zone.
x102	199 mm minimum	Bilateral datum plane	Encroachment of equipment on the sides of the reserved spaces inside the equipment.
x103	207 ± 1 mm	Bilateral datum plane	Outside edge of seal zone.
x104	235 ± 2 mm	Bilateral datum plane	Outside edge of bottom interface plane.
x105	200 ± 2 mm	Bilateral datum plane	Inside edge of bottom interface plane.
x106	220 ± 0.05 mm	Bilateral datum plane	Center of positioning pin location and tightening locking screw location.
x107	175 +5/-0 mm	Bilateral datum plane	Outside edge of control connection area.

Symbol	*Value Specified*	*Datum Measured from*	*Feature Measured to*
x108	207 ± 1 mm	Bilateral datum plane	Width of the door seal exclusion volume. Width of the loader exclusion volume. Width of the loader bottom flange exclusion volume. (Inside)
x109	235 mm minimum	Bilateral datum plane	Width of the loader bottom flange exclusion volume. (Outside)
y101	170 ± 2 mm	Docked Facial datum plane	BOLTS/Light plane. Seal surface on equipment.
y102	80 mm minimum	BOLTS/Light plane	Encroachment of equipment on the permanent reserved space and on the reserved space when the door is opening or closing.
y103	3 mm minimum	BOLTS/Light plane	Encroachment of equipment.
y104	200 + 0/-10 mm	Facial datum plane	Rear edge of bottom interface plane.
y105	220 + 0/-10 mm	Facial datum plane	Front edge of bottom interface plane.
y106	180 ± 0.05 mm	Facial datum plane	Positioning pin location.
y107	100 ± 0.3 mm	Facial datum plane	Front locking screw location.
y108	100 ± 0.3 mm	Facial datum plane	Rear locking screw location.
y109	110 + 0/-5 mm	Facial datum plane	Rear edge of control connection area.
y110	[E63]	Facial datum plane	Docked-facial datum plane.
y111	220 ± 2 mm	Facial datum plane	Front end of the loader exclusion volume.
y112	31 mm minimum	BOLTS/Light plane	Encroachment of equipment on the reserved space when the door is closed.
y113	± 0.5 mm	-	Cycle-to-cycle repeatability of y101.
y114	± 1 mm	-	Flatness of seal zone.
y115	220 mm minimum	Facial datum plane	Front face of the loader bottom flange exclusion volume.
y116	200 mm minimum	Facial datum plane	Rear face of the loader bottom flange exclusion volume.
z101	402 ± 1 mm	Horizontal datum plane	Outside edge of seal zone on top.
z102	478 ± 1 mm	Horizontal datum plane	Outside edge of seal zone on bottom.
z103	394 mm minimum	Horizontal datum plane	Encroachment of equipment on the top of the permanent reserved space inside the equipment.
z104	395 ± 1 mm	Horizontal datum plane	Top edge of hole opening and inside edge of seal zone.
z105	470 mm minimum	Horizontal datum plane	Encroachment of equipment on the bottom of the permanent reserved space inside the equipment.
z106	471 ± 1 mm	Horizontal datum plane	Bottom edge of hole opening and inside edge of seal zone.
z107	480 ± 1 mm	Horizontal datum plane	Height of the bottom interface planes.
z108	45 ± 2 mm	Horizontal datum plane	Encroachment of equipment on the top of the permanent reserved space inside the equipment.
z109	402 ± 2 mm	Horizontal datum plane	Encroachment of equipment on the top of the box opener/ loader between the BOLTS/Light plane and the SEMI E15.1_D1 plane.
z110	10 ± 1 mm	Bottom end of z107	locating pins height.
z111	45 ± 2 mm	Horizontal datum plane	Panel Interface Height.
z112	15 mm minimum	Bottom end of z107	Docking space to bottom interface plane during maintenance.
z113	30 mm minimum	Bottom end of z107	Height of loader bottom flange exclusion volume.

APPENDIX 1
APPLICATION NOTES

NOTE: The material in this appendix is an official part of SEMI E92 and was approved by full letter ballot procedures on December 3, 1999 by the Japanese Regional Standards Committee.

A1-1 NOTICE: Usage of Loader Locating Pins

A1-1.1 In order to provide quick interchangeability with accurate repeatability, it is recommended to use V shaped groove to couple with the positioning pin and use flat plane to couple with the anti-rotation pin as shown in Figure 4.

A1-2 NOTICE: BOLTS/Light Shelf

A1-2.1 BOLTS/Light Shelf may be used in order to keep compatibility with BOLTS/M interface. In this case, BOLTS/M interface provides backward compatibility of equipment interface and BOLTS/Light interface provides standardized precise quick attachment/ detachment interface. BOLTS/Light shelf is shown in Figure A-1.

A1-3 NOTICE: Box Opener/Loader Compatibility

A1-3.1 It is recommended that equipment suppliers design their process equipment to be capable of accepting box opener/loaders that interface with either a BOLTS/M interface or a BOLTS/Light interface. This standard has been structured to make the BOLTS/Light interface a component capable of being attached to a BOLTS/M interface. (It is not physically feasible to make the BOLTS/M interface an optional component capable of being attached to a BOLTS/Light interface).

A1-3.2 If an equipment supplier provides a BOLTS/M interface, their process equipment can be modularly configured to interface with either type of box/opener loader. This type of approach allows “two-way compatibility”:

- Process equipment with a BOLTS/M interface can attach a BOLTS/Light interface. This enables the process equipment to now accept a box opener/loader with a BOLTS/Light interface.
- Process equipment with a BOLTS/Light interface can remove the BOLTS/Light interface to expose a BOLTS/M interface. This enables the process equipment to now accept a box opener/loader with a BOLTS/M interface.

Equipment suppliers may provide only a BOLTS/Light interface at their discretion. However, it should be understood that process equipment designed in this manner can not be modularly configured to accept a box/opener loader with a BOLTS/M interface.

A1-4 NOTICE: Docking Stroke Variation for Backward Compatibility

A1-4.1 In order to provide the “Backward compatibility” requested in I300I/J300 GJG[1], vendors who want to use this standard to put BOLTS/Light unit in their existing BOLTS/M compliant loadport unit may vary docking stroke as their option to accommodate their existing designs. The unit that has a different docking stroke is no more a BOLTS/Light-Full-Compliant unit, but could be called as BOLTS/Light-Quasi-Compatible unit.

A1-5 NOTICE: Sliding Mechanism

A1-5.1 Actual design of the sliding mechanism is left to the box opener/loader and/or equipment designer. The equipment provides bottom interface planes as the loading slider areas.

A1-5.1.1 This implies several types of bottom interface planes are acceptable by the equipment; e.g., roller guided, plastic material based, etc.

A1-6 NOTICE: Maintenance Cart

A1-6.1 If the box opener/loader is too heavy to attach/detach manually by maintainer, this standard provides for the possibility/capability of cart-based maintenance.

A1-6.2 The cart may use the same cart to equipment docking mechanism as the cart for FOUP delivery.

A1-6.3 The maintenance cart may also use a connection with the bottom interface planes that are defined in this standard. Specification of how to make the carts is outside the scope of this standard.

A1-7 NOTICE: Finger Pinch Sensor

A1-7.1 This document does not define or specify a finger pinch sensor. Considering finger pinching with edges, the following approach may be recommended.

- Finger pinching with edges is more serious than it is with flat surfaces. So, it is recommended not to place the box flange seal in a narrow tunnel structure which have sharp edges but place it on a flat surface (or in a dimple that has chamfered edges).

1 I300I/J300 GJG — I300I/J300 Global Joint Guidance for 300 mm Semiconductor Factories. SEMATECH, 2706 Montopolis Drive, Austin, TX, 78741. http://www.sematech.org

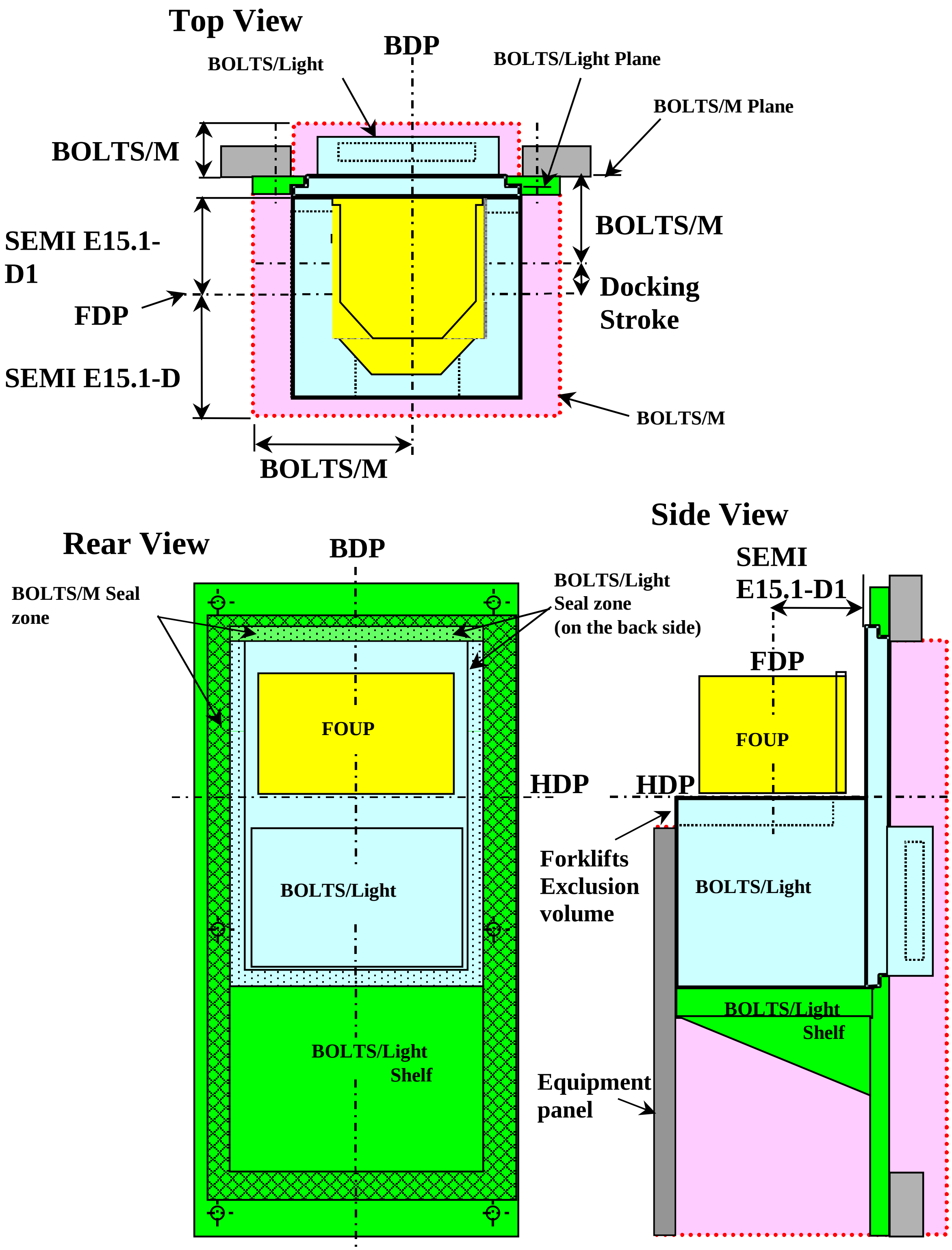

Figure A-1
Usage of BOLTS Shelf (Adopter)

- Placement of a finger pinch sensor in the approximately 11 mm space behind SEMI E15.1 D1 is recommended.

A1-8 NOTICE: Adjustment of BOLTS/Light Unit

A1-8.1 In order to maintain quick interchangeability and interoperability and quick attachment/detachment, adjustment capability should be provided separately by the box opener/loader and equipment to ensure the port is positioned correctly with respect to the wafer handling robot.

A1-8.2 As a result, adjustment means will be necessary on both the box opener/loader and the equipment. The box opener/loader may have a capability to calibrate its critical dimensions in advance, for example, the parallelism between bottom interface surface and HDP. In this case, it is not necessary to adjust the box opener/loader after installation. The equipment should have a capability to adjust bottom interface plane with respect to the wafer-handling robot. In case of changing the box opener/loader in the field, adjustment might then not be necessary on both the box opener/loader and the equipment side.

A1-8.3 A fixture may help facilitate this adjustment.

A1-8.4 If fine adjustment is needed after reattaching the box opener/loader (due to deficient adjustment of the box opener/loader or equipment side), it may be done on the equipment side by means of adjusting screws or other mechanism at bottom interface plane.

A1-9 NOTICE: Control Connection Area

A1-9.1 Connection should be completed after sliding in the box opener/loader. Disconnection should be completed before sliding out the box opener/loader.

SEMI E99-1000^E
THE CARRIER ID READER/WRITER FUNCTIONAL STANDARD: SPECIFICATION OF CONCEPTS, BEHAVIOR, AND SERVICES

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available at www.semi.org August 2000; to be published October 2000. Originally published February 2000; previously published June 2000.

E This document was modified in October 2000 to correct a typographical error. Changes were made to Table 7. This document was modified in December 2001 to correct a typographical error. Changes were made to Table R1-1 and Table R1-2.

1 Purpose

1.1 The purpose of the Carrier ID Reader/Writer Functional Standard effort is to provide a common specification for concepts, behavior, and services (functions) provided by a Carrier ID Reader and a Carrier ID Reader/Writer to an upstream controller. A standard interface will increase interchangeability of Carrier ID Reader/Writers so that users and equipment suppliers have a wider range of choices.

2 Scope

2.1 The Carrier ID Reader/Writer Interface Standard addresses the functional requirements for a generic Carrier ID Reader/Writer interface with an upstream controller.

2.2 The specification includes required behavior and required communications for both a Carrier ID Reader and a Carrier ID Reader/Writer.

2.3 This specification does not require, define, or prohibit asynchronous messages sent by the Carrier ID Reader or Reader/Writer.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not define the specific protocol to be used for the Carrier ID Reader/Writer. Supplements to this standard are required to describe how the functions of the Carrier ID Reader/Writer are implemented for specific protocols.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E87 — Provisional Specification for Carrier Management (CMS)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CIDRW* — represents both the Carrier ID Reader and the Carrier ID Reader/Writer

5.1.2 *FOUP* — Front Opening Unified Pod

5.2 *Definitions*

5.2.1 *attribute* — information about or associated with some entity or object.

5.2.2 *carrier* — 1. a container, such as a FOUP or open cassette, with one or more positions for holding substrates (SEMI E87). 2. any cassette, box, pod, or boat that contains wafers.

5.2.3 *carrier ID* — an identifier for a carrier. A value that uniquely identifies a given carrier in a factory. The identifier may be represented physically with any one of various technologies. For electronic tags with read/ write capability, in some cases the user may designate a portion of the data to be used as a carrier ID.

5.2.4 *carrier ID reader* — a unit (subsystem) that detects and decodes data from the ID tag.

5.2.5 *carrier ID reader/writer* — a unit (subsystem) with the functionality of both a carrier ID reader and a carrier ID writer.

5.2.6 *carrier ID tag (tag, ID tag)* — a physical device for storing Carrier ID and other information. There are two basic types of tags, read-only tags and read/write tags.

5.2.7 *carrier ID writer* — a unit which encodes data for and writes it to the carrier ID tag.

5.2.8 *cassette* — an open structure that holds one or more substrates (SEMI E44).

5.2.9 *controller* — a system that provides control (performs required operations when certain conditions occur or when interpreting and acting upon instructions) and communicates with a higher level manager. Controllers exist at all levels within a factory. Examples of controllers include the Multiple ID Reader/Writer Controller, the Equipment Controller, and the Load Port Controller.

5.2.10 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62).

5.2.11 *fundamental requirements* — the requirements for information and behavior that must be satisfied for compliance to a standard. Fundamental requirements apply to specific areas of application, objects, or services.

NOTE 2: All portions of the carrier ID reader/writer specification are considered to be fundamental requirements unless explicitly described as optional. See also optional requirement.

5.2.12 *load port* — the interface location on a tool where wafer carriers are delivered. It is possible that wafers are not removed from, or inserted into, the carrier at this location.

5.2.13 *message interleaving* — the practice of sending a new message request before receiving the reply to an earlier request.

5.2.14 *multiple ID reader/writer controller* — a unit controlling the Reader/Writer function of one or multiple ID Reader/Writer Heads, communicates the command/data with the equipment controller or the equivalent controller such as Load port Controller in the equipment configuration.

5.2.15 *optional capability* — a specification that is not required for an implementation to be compliant to a standard. The supplier developing the CIDWR has the option to provide these additional capabilities or not depending on supplier's product configuration. See also fundamental requirement.

5.2.16 *reader/writer head* — a structured portion which functions to detect the ID code and/or to write the ID code. The ID reader/writer unifying a head function inside its body can be placed as a head. The ID reader/writer not unifying a head function will be located separately from the head.

5.2.17 *tag fault* — any condition that causes errors when reading or writing to the tag, including power faults and tag damage.

5.2.18 *upstream controller* — a controller that directs the Carrier ID Reader/Writer through the communication interface.

5.3 *Data Types*

5.3.1 *enumerated* — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

5.3.2 *form* — type of data: positive integer, unsigned integer, integer, floating point (float), enumerated, boolean, text, formatted text, structure, list, ordered list.

5.3.3 *integer* — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

5.3.4 *structure* — a specific set of items, of possibly mixed data types, in a specified arrangement.

5.3.5 *text* — a character string. Messaging protocol may impose restrictions, such as length or ASCII representation.

5.3.6 *unsigned integer* — may take on the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

6 Conventions

6.1 *State Model Methodology*

6.1.1 This document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in "State Charts: A Visual Formalism for Complex Systems" written by D. Harel in Science of Computer Programming 8, 1987[1].

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

6.1.2 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

- Actions taken upon exit of the previous state.
- Actions taken upon entry of the new state.
- Actions taken which are most closely associated with the transition.

6.1.2.1 No differentiation is made between these cases.

6.2 *Object Notation*

6.2.1 The object models in Related Information 2 use the Object Modeling Technique (OMT) developed by Rumbaugh, James, et al, in Object-Oriented Modeling and Design.[2] An overview of this notation is provided in SEMI E39, Object Services Standard: Concepts, Behavior, and Services.

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

6.3 *Service Message Representation*

6.3.1 Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message, that does not require a response.

6.3.2 *Service Definition*

6.3.2.1 A service definition table defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*

Type can be either "N" = Notification or "R" = Request & Response.

6.3.2.2 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.3.3 *Service Parameter Dictionary*

6.3.3.1 A service parameter dictionary table defines the description, format and its possible value for parameters used by services, as shown in the following table:

Parameter Name	*Description*	*Format: Possible Value*

6.3.3.2 A row is provided in the table for each parameter of a service.

6.3.4 *Service Message Definition*

6.3.4.1 A service message definition table defines the parameters used in a service, as shown in the following table:

2 James Rumbaugh, Michael Blaha, William Premerlani, Frederick Eddy, William Lorensen, Object-Oriented Modeling and Design, Englewood Cliffs, New Jersey: Prentice-Hall, 1991.

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*

6.3.4.2 The columns labeled REQ/IND and RSP/CNF link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication" or the request. The receiver may then send a "Response" which the original sender terms the "Confirmation".

6.3.4.3 The following codes appear in the REQ/IND and RSP/CNF columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

Code	*Description*
M	Mandatory Parameter — Must be given a valid value.
C	Conditional Parameter — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.
U	User-Defined Parameter.
-	The parameter is not used.
=	(For response only.) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7 Overview

7.1 The Carrier ID Reader/Writer Model defines the behavior and services (functions) for both Carrier ID Readers and Carrier ID Reader/Writers. The Carrier ID Reader/Writer is a small intelligent system, typically used as a subsystem within equipment.

7.1.1 The primary functionality of the Carrier ID Reader/Writer is to read the identifier of the carrier (Carrier ID) from the Carrier ID tag. Various technologies may be used to encode the Carrier ID and to read it. Some technologies do not allow data to be written.

7.1.2 The acronym CIDRW is used to refer to both the Carrier ID Reader and the Carrier ID Reader/Writer. The requirements for the Carrier ID Reader are a subset of the requirements for the Carrier ID Reader/Writer.

7.1.3 An object model for the CIDRW is provided in Related Information 2 – Object Model.

7.2 *Number of Heads*

7.2.1 A Reader/Writer Head is a device that is positioned on a load port for reading or reading/writing information from a Carrier ID tag. A Carrier ID Reader/Writer provides one or more ID Reader/Writer Heads and is connected to an upstream controller by a single interface. This allows the upstream controller to control either one head or multiple heads using the same interface specification.

7.2.2 *Single Head Configuration*

7.2.2.1 In the case of a single head, the head may be presented as an integrated part of the CIDRW.

7.2.3 *Multiple Head Configuration*

7.2.3.1 In the case of multiple heads, some services are logically performed by the CIDRW, and the individual heads logically perform others. The individual heads are numbered sequentially and may be referenced individually by the upstream controller. Note that the upstream controller does not communicate directly with the heads. All communications are between the upstream controller and the CIDRW unit.

7.2.3.2 In the multi-head case, the CIDRW shall allow independent control of the heads. Multiple transactions invoking services performed by the individual heads may be open at the same time. For example, when a read command is sent to one head, the host can send additional commands such as a read command and a status confirmation command to another head before the first head sends the response to the first command.

7.3 *Upstream Controller*

7.3.1 The CIDRW provides certain services when requested by the upstream controller. The upstream controller sends a message requesting the specified service, and the CIDRW sends a message with the response.

7.3.2 This standard assumes that an upstream controller initiates each service message to the CIDRW, and the CIDRW sends its response to the upstream controller. The upstream controller must watch the response time to monitor the communication timeout. This standard will define the recommended method for handling exceptions caused by timeouts.

7.3.3 In addition, some CIDRW may provide asynchronous notification to the upstream controller. Examples of this include, but are not limited to, the detection of a fault condition resulting in an alarm. Asynchronous notification is not required for compliance to this standard.

8 Attributes

8.1 An attribute is an item of information about an entity that is maintained and is available by request. There is certain information concerning the CIDRW that is of potential interest to the upstream controller, including the manufacturer, the model, and the serial number of the device. This information is considered as attributes of the CIDRW and is available on request.

8.2 *CIDRW Attribute Definition Table*

8.2.1 Table 1 defines the attributes of the Carrier ID Reader/Writer subsystem.

Table 1 CIDRW Attribute Definitions

Attribute Name	*Description*	*Access*	*Reqd*	*Form*
Fundamental				
Configuration	Number of heads.	RO	Y	Text
Alarm Status	Current CIDRW substate of ALARM STATUS.	RO	Y	Enumerated: 0 = NO ALARMS 1 = ALARMS
Operational Status	Current CIDRW substate of OPERATIONAL.	RO	Y	Enumerated: IDLE BUSY MAINTENANCE
SoftwareRevisionLevel	Revision (version) of software.	RO	Y	Text
Optional				
DateInstalled	Date the subsystem was installed.	RO	N	Protocol dependent.
Device Type	Identifiers subsystem as either a Carrier ID Reader or a Carrier ID Reader/Writer.	RO	N	Text
HardwareRevisionLevel	Revision number of the hardware.	RO	N	Text
MaintenanceData	Supplier dependent.	RO	N	Text
Manufacturer	The name or identifier of the manufacturer.	RO	N	Protocol dependent.
ModelNumber	The manufacturers model designation.	RO	N	Text
SerialNumber	Subsystem serial number assigned by manufacturer.	RO	N	Protocol dependent.

8.3 *Read/Write Head Attributes*

8.3.1 Table 2 defines the attributes for the Read/Write Head.

NOTE 3: In the case of an integrated single head, the attributes in Table 2 are regarded as an extension of Table 1.

8.3.2 In the case of multiple heads, it must be possible to distinguish between the attributes of different heads.

Table 2 Read/Write Head Attribute Definitions

Attribute Name	*Description*	*Access*	*Reqd*	*Form*
Fundamental				
HeadStatus	The current state.	RO	Y	Enumerated: IDLE, BUSY, NOT OPERATING
HeadID	Head number 0–31	RO	Y if multi-head	Text. 2 digits.
Optional				
Cycles	Number of read and write operations performed.	RO	N	Unsigned integer
HeadCondition	The current Maintenance status.	RO	N	Enumerated: No alarms Needs Maintenance Read/Write fault Read/Write rate fault No power.
HeadDateInstalled	Date this head was installed.	RO	N	Protocol dependent.
HeadMaintenance-Data	Supplier dependent	RO	N	Text

9 State Models

9.1 To facilitate independent control of the individual heads, this section defines two separate state models, one for CIDRW subsystem and one to be applied to each of the individual heads.

9.2 *CIDRW State Model*

9.2.1 This section defines the state model for the CIDRW subsystem. Figure 1 shows the diagram for this model.

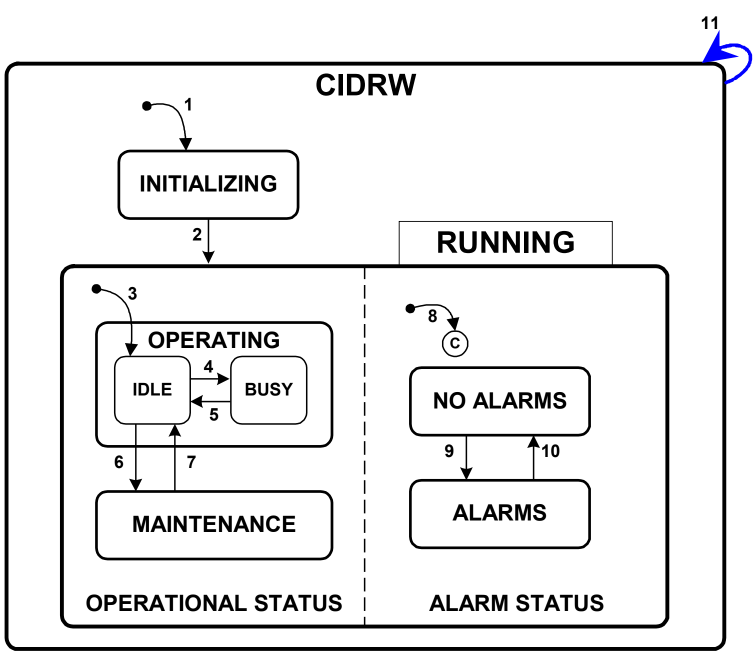

Figure 1
CIDRW State Model Diagram

9.2.2 Table 3 defines the states of the CIDRW. Definitions are in alphabetical order.

Table 3 CIDRW Subsystem State Definitions

State	*Definition*
ALARM STATUS	Shows the presence or absence of alarms.
ALARMS	An alarm condition exists.
BUSY	A service is being performed that affects the state of the hardware.
CIDRW	Superstate of CIDRW State Model. Always active when CIDRW powered on.
IDLE	No service is being performed. All heads are idle.
INITIALIZING	CIDRW is performing initialization and self diagnostics. Presence or absence of alarms is initially determined in this state.
NO ALARMS	No alarm conditions exist.
OPERATING	Normal operational states where reading and/or writing operations can be performed.
OPERATIONAL STATUS	The CIDRW is fully capable of performing all services that it supports.
RUNNING	The CIDRW is operational and able to communicate.
MAINTENANCE	Internal setup and maintenance activities.

9.2.3 Table 4 defines the transitions of the CIDRW State Model.

Table 4 CIDRW State Transitions

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(Any)	Powerup or reset	INITIALIZING	Initialize hardware and software components.	Default entry on powerup.
2	INITIALIZING	Initialization is complete.	RUNNING	None	The CIDRW is now able to communicate.
3	INITIALIZING	Default entry into OPERATING.	IDLE	None	Internal
4	IDLE	A service request to read or write or perform diagnostics is received.	BUSY	None	
5	BUSY	All service requests that affect the state of the hardware are completed.	IDLE	None	
6	IDLE	A user selects the MAINTENANCE state and all heads are idle.	MAINTENANCE	None	The upstream controller may send a request or the operator may set a switch to select the OPERATING or the MAINTENANCE state. Maintenance and setup activities may now be performed.
7	MAINTENANCE	A user selects the OPERATING state and all heads are idle.	IDLE	None	The upstream controller may send a request or the operator may set a switch to select the OPERATING or the MAINTENANCE state. Normal operating activities may now be performed.
8	INITIALIZING	Default entry into ALARM STATUS.	ALARMS or NO ALARMS	None	
9	NO ALARMS	An alarm condition is	ALARMS	None	

		detected.			
10	ALARMS	All alarm conditions have cleared.	NO ALARMS	None	
11	Any	A reset service request is received.	CIDRW	None	

9.3 *Read (Write) Head State Model*

9.3.1 For a CIDRW with multiple heads, this state model shall be provided for each Read/Write Head.

9.3.2 For the single head case, these states are covered in the CIDRW state model and no additional state model for the head is required. IDLE and BUSY correspond to substates of the same names in the CIDRW state model. If any head is NOT OPERATING, then the active substate of ALARM STATUS in the CIDRW state model is ALARMS.

9.3.3 The NOT OPERATING state is not required, if it is not possible to detect alarms related to the head. Note also that some alarm conditions are fatal (so that the head cannot operate with full functionality) while others may not be fatal.

9.3.4 Figure 2 shows the diagram for the Read (Write) Head State Model.

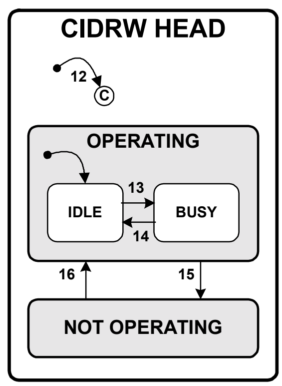

Figure 2
Read (Write) Head State Model

9.3.5 Table 5 defines the states for the Read (Write) Head.

Table 5 Read (Write) Head State Definitions

State	*Definition*
NOT OPERATING	Head is in a non-operational state or has reduced functionality. Maintenance is required.
OPERATING	Head is active and fully functional.
IDLE	Head is not performing a service.
BUSY	Head is performing a service.

9.3.6 Table 6 defines the transitions of the Read (Write) Head State Model.

Table 6 Read (Write) Head State Transitions

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
12	(unknown)	Initialization on powerup or reset.	Either NOT OPERATING or OPERATING	None	Default entry on power-up.
13	IDLE	Request to perform a service.	BUSY	None	
14	BUSY	Completion of service.	IDLE	None	

#	Previous State	Trigger	New State	Actions	Comments
15	OPERATING	An alarm condition is detected.	NOT OPERATING	None	
16	NOT OPERATING	Self-Diagnostic Service	OPERATING	None	All alarm conditions are clear.

10 Alarm Conditions

10.1 An alarm condition exists whenever one or more faults or exceptions that interfere with normal read/write operations is detected. A maintenance condition exists when the CIDRW determines the need for either maintenance (repair) or preventive maintenance activities.

10.2 The CIDRW is able to detect and report alarm conditions through its status attributes (when queried by the upstream controller). It may additionally report changes in alarm conditions asynchronously through alarm or event reports.

11 Services

11.1 To be compliant with this standard, the CIDRW shall support all services that are indicated as required. In addition, if the CIDRW provides other services that have the same or similar functionality as services defined in this document, then compliance to this standard requires they shall satisfy the requirements of the service as defined.

11.2 *List of Services*

11.2.1 Table 7 lists the services defined by this standard and indicates which are optional and which are required.

Table 7 List of Services

Service Name	*Description*
Fundamental Requirements	
Get Attributes	Get specified information about the CIDRW.
Get Status	Get the current status of the CIDRW.
Read ID	Read ID.
Requirement for Reader/Writer	
Read Data	Read back data written previously (not applicable to read-only devices).
Write Data	Write data (not applicable to read-only devices).
Optional Capabilities	
ChangeState	Change to MAINTENANCE state or to OPERATING state. This is required if the device supports the optional WriteID service.
Perform Diagnostics	Perform diagnostic tests.
Reset	Reset CIDRW hardware and software.
Set Attributes	Write specified information.
Write ID	Write ID field (device must also support ChangeState service).

11.3 *Parameter Definitions*

11.3.1 Table 8 defines the parameters that are used in one or more services, including individual items within parameter structures. Parameters are listed in alphabetical order.

Table 8 Parameter Definitions

Parameter	*Form*	*Description*
Action	Protocol-specific.	Specifies diagnostic action to perform.
Attribute ID	Text	Attribute identifier. Name of attribute.
Attribute Value	Varies with attribute.	Attribute value.

Parameter	*Form*	*Description*
Carrier ID	Text	User data.
Data	Text	User data.
DataSeg	Protocol-specific.	Indicates specific section of data to read or write.
DataSize	Unsigned integer	Indicates the number of bytes of data to read or write.
Head ID	Number 0–31	Identifies either an individual head (non-zero) or the CIDRW subsystem itself (zero).
PM Information	Enumerated: -Normal execution -Maintenance required	Preventive Maintenance Information
Result Status	Enumerated: -Normal operation -Execution Error -Communication Error -Hardware Error -Tag Fault	Result information on the status of the request concerning the service request. *Execution Error*: cannot read Tag data. Cannot Read ID sequence. But equipment is normal. *Communication Error*: syntax error of Message or Message format or Value. *Hardware Error*: ID reader/writer head fault, ID reader/writer head is powered off. Tag Fault: power fault, exceeded retry limit
Status	Structure	Information about the status of the CIDRW. Consists of PM Information and the current values of the CIDRW attributes AlarmStatus, OperationalStatus, and HeadStatus.

11.4 *Service Definitions*

11.4.1 This section defines the parameters used for each CIDRW service.

11.4.2 *ChangeState*

11.4.2.1 ChangeState is an optional service that requests the CIDRW to change its operational substate to MAINTENANCE or to OPERATING. Table 9 defines the parameters used for the ChangeState service.

Table 9 ChangeState Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
StateRequest	M	-	Specifies either MAINTENANCE or OPERATING substate.
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.3 *Get Attributes*

11.4.3.1 Get Attributes is a required service used to request the attributes of the CIDRW.

Table 10 Get Attributes Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head or Subsystem.
(list of) Attribute ID	M	-	Identifiers of one or more attributes
(list of) Attribute Value	-	M	Attribute Values in order as requested
Result Status	-	M	Result information on the status of the request

11.4.4 *Get Status*

11.4.4.1 Get Status is a required service used to get the current status of the CIDRW. The upstream controller may request current status at any time.

Table 11 Get Status Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head or Subsystem.
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.5 *Perform Diagnostics*

11.4.5.1 Perform Diagnostics is an optional service used to request the CIDRW perform its internal diagnostics. The supplier shall document the specific diagnostics performed.

Table 12 Perform Diagnostics Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head or Subsystem.
Action	C		Specifies diagnostic action to perform.
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.6 *Read Data*

11.4.6.1 Read Data is used to request a generic block of data by an ID Reader/Writer Head. This service is required for the Carrier ID Reader/Writer type and is optional otherwise. The Carrier ID Reader/Writer is not required to understand the content of the data.

Table 13 Read Data Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head.
DataSeg	C	-	Indicates specific section of data.
DataSize	C	-	Indicates number of bytes to read.
Data	-	M	Data Read from Head
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.7 *Read ID*

11.4.7.1 Read ID is used to request the Carrier ID be read by an ID Reader/Writer Head. This service is a fundamental requirement.

Table 14 Read ID Service Message Parameter Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head.
Carrier ID	-	M	Carrier ID
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.8 *Reset*

11.4.8.1 Reset is an optional service used to re-initialize the CIDRW.

Table 15 Reset Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Result Status	-	M	Result information on the status of the request

11.4.9 *Set Attributes*

11.4.9.1 Set Attributes is used to set attributes of the CIDRW that have read/write (R/W) access. This is an optional service. Attempts to set attributes with read-only (RO) access shall be denied. Attribute values returned are those as read following the set operation.

Table 16 Set Attributes Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head or Subsystem.
Attributes ID	M	-	Attribute Ids
Attribute Values	M	-	Attribute Values
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.10 *Write Data*

11.4.10.1 Write Data is used to request a generic block of data to an ID Reader/Writer Head. This service is required for the Carrier ID Reader/Writer type and is optional otherwise. The Carrier ID Reader/Writer is not required to understand the content of the data.

Table 17 Write Data Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head.
DataSeg	C	-	Indicates specific section of data.
DataSize	C	-	Indicates number of bytes to read.
Data	M	-	Write Data (from Host)
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.4.11 *Write ID*

11.4.11.1 Write ID is used to set the field for Carrier ID to an ID Reader/Writer Head. This service is optional. This shall be a protected operation that can be performed only in the MAINTENANCE state to prevent accidental overwriting of the ID field.

Table 18 Write ID Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Head ID	M	M	Specifies Head.
Data (ID)	M	-	Write ID Data.
Result Status	-	M	Result information on the status of the request
Status	-	M	Status information

11.5 *Service Operability*

11.5.1 Some services are performed by the CIDRW and others are logically performed by the individual heads. It is expected that the CIDRW will support multiple interleaved transactions to the various independent logical units. Table 19 shows which of the various services can be performed by the CIDRW when the CIDRW and its heads are in various individual states. Note that when in the initializing state after powerup or the reset service, the CIDRW may not be able to communicate.

Table 19 Valid Services per State

	Service									
	Write ID	*Write Data*	*Set Attributes*	*Reset*	*Read ID*	*Read Data*	*Perform Diagnostics*	*Get Status*	*Get Attributes*	*ChangeState*
CIDRW State										
INITIALIZING										
OPERATING		X	X	**X**	**X**	**X**	**X**	**X**	**X**	**X**
MAINTENANCE	X		X	**X**	**X** (See NOTE 1.)		**X**	**X**	**X**	**X**
Head State										
NOT OPERATING									**X**	
IDLE									**X**	
BUSY									**X**	

NOTE 1: May not be supported by all Readers.

12 Event Notifications

12.1 Event Notification is an optional capability where the CIDRW is able to detect events and report state and status changes independently of a service request from the upstream controller.

RELATED INFORMATION 1
SCENARIOS

NOTE: This related information is not an official part of SEMI E99. This related information was approved for publication by full letter ballot procedures on September 3, 1999.

R1-1 This section provides examples of typical scenarios for a CIDRW with two read heads.

Table R1-1 Reset Scenario

Controller	*CIDRW*			*Head 1*		*Head 2*	
Msg.	Msg.	Action	State	Action	State	Action	State
Reset→		Perform Reset	Init State		NORMAL		NORMAL
	←Reset Reply		Operating or Maintenance		Idle or NORMAL		Idle or NORMAL

Table R1-2 Get Status Scenario

Controller	*CIDRW*			*Head 1*		*Head 2*	
Msg.	Msg.	Action	State	Action	State	Action	State
Get Status 0→		Determine Status	Operating or Maintenance		Any		Any
	←Status Reply		Same		Any		Any

Table R1-3 Scenario for Interleaved Read ID from Both Heads

Controller	*CIDRW*			*Head 1*		*Head 2*	
Msg.	Msg.	Action	State	Action	State	Action	State
Read ID 01→			Operating	Start Read	Busy		Idle
Read ID 02→			Operating		Busy	Start Read	Busy
	←Read ID Reply 01		Operating		Idle		Busy
	←Read ID Reply 02		Operating		Idle		Idle

Table R1-4 Read Data from Both Heads

Controller	*CIDRW*			*Head 1*		*Head 2*	
Msg.	Msg.	Action	State	Action	State	Action	State
Read Data 01→			Operating	Start Read	Busy		Idle
Read Data 02→			Operating		Busy	Start Read	Busy
	←Read Data Reply 01		Operating		Idle		Busy
	←Read Data Reply 02		Operating		Idle		Idle

Table R1-5 Scenario to Write Data to Both Heads

Controller	*CIDRW*			*Head 1*		*Head 2*	
Msg.	Msg.	Action	State	Action	State	Action	State
Write Data 01→			Operating	Start Write	Busy		Idle
Write Data 02→			Operating		Busy	Start Write	Busy
	← Write Data Reply 01		Operating		Idle		Busy
	← Write Data Reply 02		Operating		Idle		Idle

RELATED INFORMATION 2
OBJECT MODEL

NOTE: This related information is not an official part of SEMI E99. This related information was approved for publication by full letter ballot procedures on August 28, 2000.

R2-1 Object models provide a graphic representation of entities. The models in this section use the Object Modeling Technique (OMT) described in Object-Oriented Modeling and Design. Object types are represented by rectangles with one, two, or three sections. The name of the object type is in the first, or only section. Attributes, information about the object, are shown in the second section. Operations or services are shown in a third section. Lines between objects represent relationships.

R2-2 Three models are shown for purposes of illustration. The general multi-head case is shown first with only the required attributes and services. Next, the full model for the multi-head case is shown with all attributes and services defined in this standard. Finally, the full model for the integrated single-head case is shown.

R2-3 Note that the Upstream Controller sends all service requests to the CIDRW controller, including services shown for the individual heads. Services shown on these models for CIDRW are those with a Head ID service parameter value of zero while services shown for the Head are those with a Head ID service parameter value between one and thirty-one.

R2-4 Fundamental Requirements Example Object Models

R2-4.1 The object model in Figure R2-1 shows objects for the general (multi-head) CIDRW satisfying fundamental requirements only. It shows the CIDRW subsystem as made up of one or more heads. It also illustrates the required attributes and services provided by the CIDRW and its relationships with its upstream controller and with its heads.

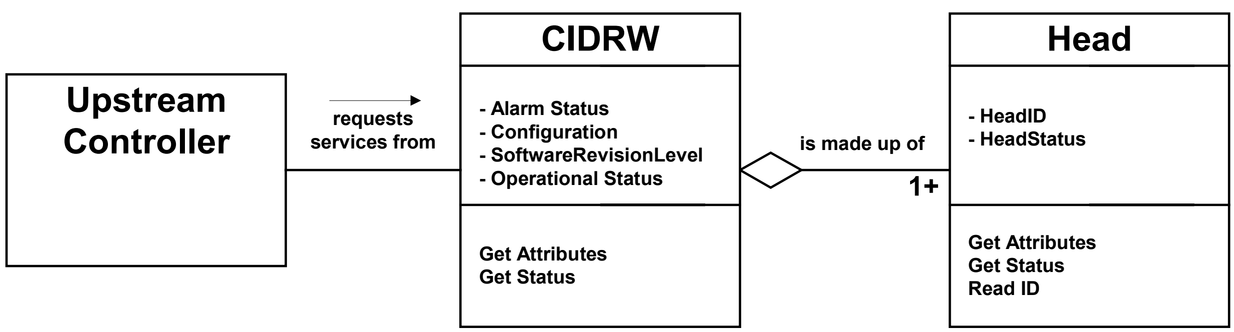

Figure R2-1
Object Model for Fundamental Requirements

R2-5 Full Capabilities

R2-5.1 Figure R2-2 shows the object model for a CIDRW with full capabilities, so that all optional attributes and services are supported.

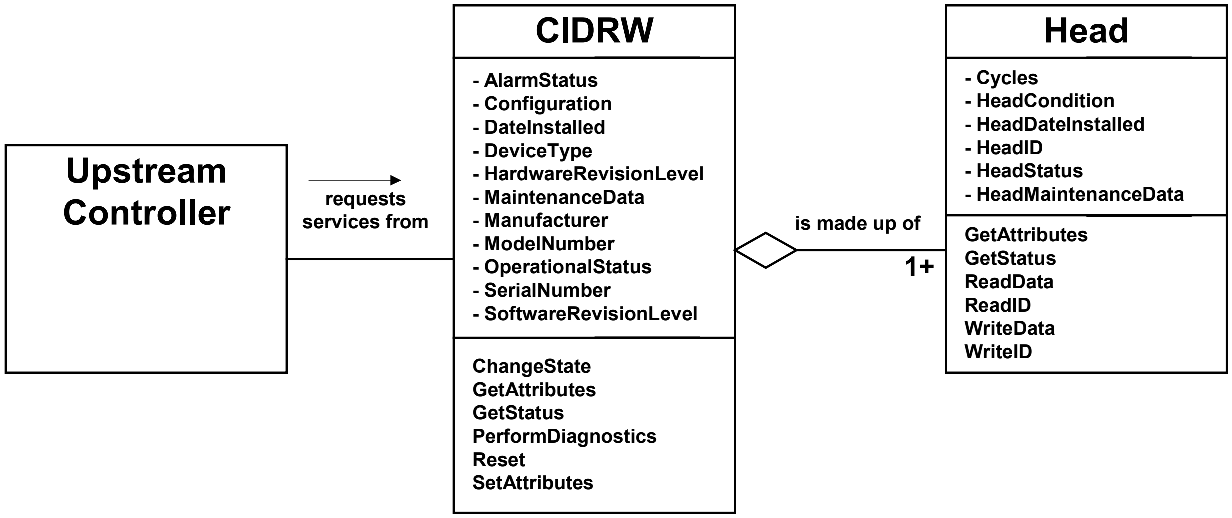

Figure R2-2
Object Model for Full Capabilities

R2-6 Integrated Model

R2-6.1 Figure R2-3 shows the object model for a CIDRW with full capabilities and a single integrated head. The head is not shown as a separate component in this case, and the head attributes and services have become part of the CIDRW subsystem itself.

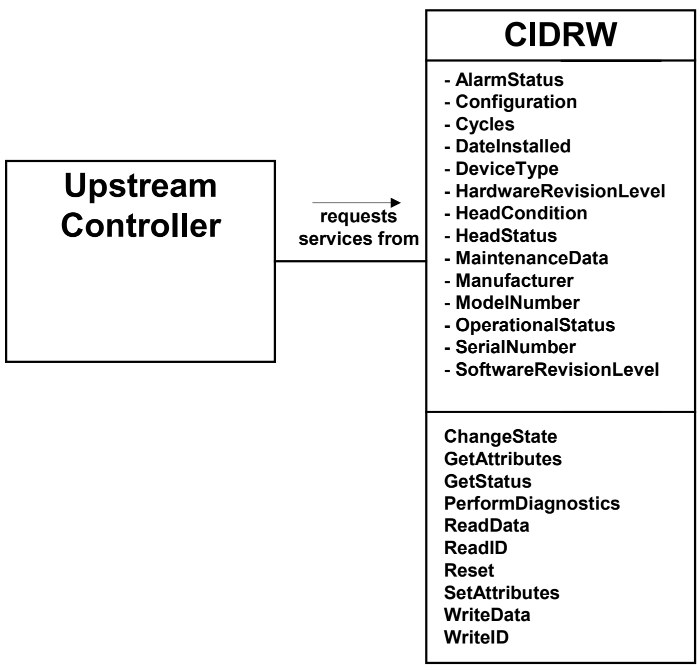

Figure R2-3
Integrated Model with Full Capabilities

RELATED INFORMATION 3
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E99. This related information was approved for publication by full letter ballot procedures on September 3, 1999.

R3-1 Combined State Model

R3-1.1 The following figure, R3-1 shows the combined state model for the CIDRW unit with nn heads, from HEAD01 TO HEADnn. The CIDRW is considered as IDLE when and only when it is in OPERATING and all of its heads are IDLE.

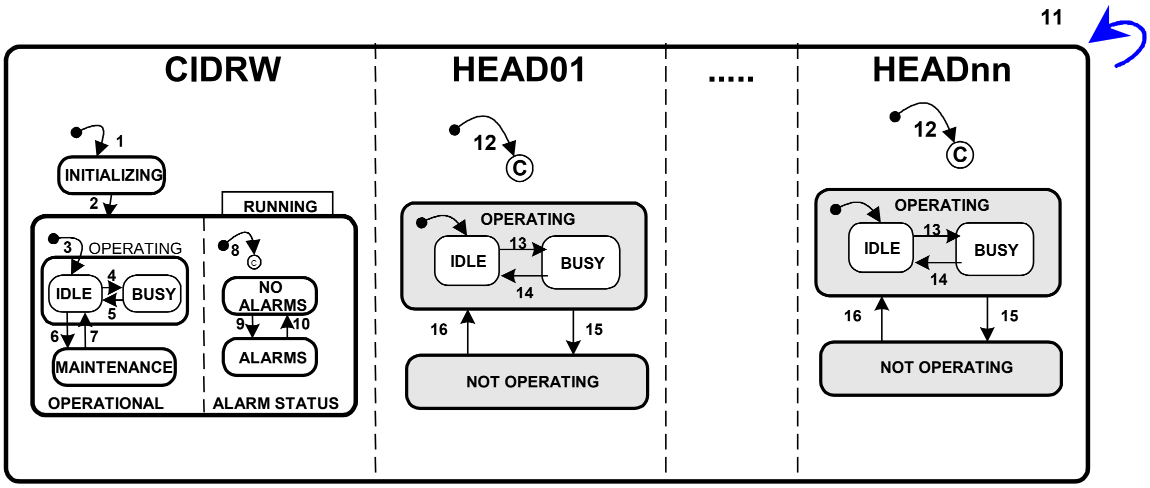

Figure R3-1
Combined State Model

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SEMI E99.1-0600^{E}
SPECIFICATION FOR SECS-I AND SECS-II PROTOCOL FOR CARRIER ID READER/WRITER FUNCTIONAL STANDARD

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on January 14, 2000. Initially available at www.semi.org March 2000; to be published June 2000.

E This document was modified in December 2001 to reflect a typographical error. Changes were made to Table 5 in Section 8.2.1.

1 Purpose

1.1 This document maps the services and data of the Carrier ID Reader/Writer (CIDRW) standard to SECS-II streams and functions and data definitions.

2 Scope

2.1 This document applies to all implementations of CIDRW that use the SECS-II message protocol (SEMI E5).

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *CIDRW* — Carrier ID Reader/Writer; represents both the Reader and the Read/Writer.

4.1.2 *SECS* — SEMI Equipment Communications Standard

5 Physical Requirements

5.1 The CIDRW using the SECS-I protocol shall use a 9-pin female connector.

6 Service Message Mapping

6.1 Table 1 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the service messages defined in SEMI E99.

6.2 Request and notification messages are mapped to primary (odd-numbered) SECS-II functions and response messages are mapped to secondary (even-numbered) SECS-II functions.

6.3 In some cases, a common set of parameters allows more than one service to be mapped to the same stream and function, with an additional SECS-II data item used to differentiate between the two services.

Table 1 Services Mapped to SECS-II Messages

Message Name	*Stream,Function*	*SECS-II Name*
ChangeState	S18,F13/F14	Subsystem Command Request/Acknowlege
Get Attributes	S18,F1/F2	Read Attribute Request/Data
Get Status	S18,F13/F14	Subsystem Command Request/Acknowledge
Perform Diagnostics	S18,F13/F14	Subsystem Command Request/Acknowledge
Read Data	S18,F5/F6	Read Request/Data
Read ID	S18,F9/F10	Read ID Request/Data
Reset	S18,F13/F14	Subsystem Command Request/Acknowledge
Set Attributes	S18,F3/F4	Write Attribute Request/Acknowledge
Write Data	S18,F7/F8	Write Request/Acknowledge
Write ID	S18,F11/F12	Write ID Request/Acknowledge

7 Service Parameter to Data Item Mapping

7.1 Table 2 shows the mapping between message parameters defined by CIDRW and data items defined by SECS-II. For parameters specified in the definitions of a CIDRW service, either the parameters themselves, or individual elements of complex parameters, map to a specific data item.

Table 2 Service Parameters to Data Item Mapping

Parameter Name	*SECS-II Data Item*	*Format*	*Values*
Attribute ID	ATTRID	20	Name of attribute
Attribute Value	ATTRVAL	20	
Carrier ID	MID	20	
Data	DATA	20	All characters 00H-0FFH
DataSize	DATALENGTH	52	
DataSeg	DATASEG	20	
PM Information	STATUS	20	"NE" = Normal execution, "MR" = Maintenance required
Result Status	SSACK	20	"NO" = Normal operation; "EE" = Execution error; "CE" = Communication error; "HE" = Hardware error; "TE" = Tag error
Status	List of STATUS	L,4 1. <PMInformation> 2. <AlarmStatus> 3. <OperationalStatus> 4. <HeadStatus>	Current values of PM Information with the corresponding attributes for CIDRW and Head (if applicable). See Tables 4 and 5.
StateRequest	CPVAL	20	"OP","MT"

NOTE 1: There are also data items used in SECS-II messages that do not map to specific services parameters. Services with the same set of parameters are mapped to the same SECS-II message by adding an additional data item to differentiate between the services. Table 3 contains the SECS-II data items that have not a corresponding CIDRW service parameter:

Table 3 Additional Data Requirements Table

SECS-II Data Item	*Function*	*Value*
SSCMD	Used to differentiate between different subsystem commands indicated.	"ChangeState" "GetStatus" "Perform Diagnostics" "Reset"

8 Data

8.1 *CIDRW Attributes*

8.1.1 Table 4 specifies the values for the CIDRW attribute identifiers and limitations on values.

Table 4 CIDRW Attribute Definitions

Attribute Name	*Description*	*Access*	*Format*	*Value*
Fundamental				
"Configuration"	Number of heads.	RO	20	"01"–"31"
"AlarmStatus"	Current CIDRW substate of ALARM STATUS	RO	20	"0" = NO ALARMS "1" = ALARMS

Attribute Name	*Description*	*Access*	*Format*	*Value*
"OperationalStatus"	Current CIDRW substate of OPERATIONAL	RO	20	"IDLE", "BUSY", "MANT"
"SoftwareRevisionLevel"	Revision (version) of software	RO	20	8 byte maximum
Optional				
"DateInstalled"	Date the subsystem was installed	RO	20	"YYYYMMDD" format
"DeviceType"	Identifies subsystem as either a Carrier ID Reader or a Carrier ID Reader/Writer.	RO	20	"CIDR_" or "CIDRW"
"HardwareRevisionLevel"	Revision number of the hardware	RO	20	8 byte maximum
"MaintenanceData"	Supplier dependent	RO	20	80 byte maximum
"Manufacturer"	The name or identifier of the manufacturer	RO	20	20 byte maximum
"ModelNumber"	The manufacturers model designation	RO	20	20 byte maximum
"SerialNumber"	Subsystem serial number assigned by manufacturer.	RO	20	20 byte maximum

8.2 *Read (Write) Head Attributes*

8.2.1 Table 5 shows the format and values for the Read (Write) Head.

Table 5 Read (Write) Head Attribute Definitions

Attribute Name	*Description*	*Access*	*Format*	*Value*
Fundamental				
"HeadStatus"	The current state.	RO	20	"IDLE", "BUSY", "NOOP"
"HeadID"	Head number 0–31	RO	20	2 digits, "00" through "31".
Optional				
"Cycles"	Number of read and write operations performed.	RO	54	
"HeadCondition"	The current Maintenance status	RO	20	"NO" = No alarms "NM" = Needs Maintenance "NP" = No power "RT" = Read/Write rate fault "RW" = Read/Write fault.
"HeadDateInstalled"	Date this head was installed	RO	20	"YYYYMMDD" format
"HeadMaintenanceData"	Supplier dependent	RO	20	Text

RELATED INFORMATION 1
SCENARIOS

NOTE: This related information is not an official part of SEMI E10#. This related information was approved for publication by full letter ballot procedures on January 14, 2000.

This section provides examples of typical scenarios for a Carrier ID Reader/Writer.

R1-1 Read ID

R1-1.1 The upstream controller sends a Read ID Request message to the CIDRW for Head 1. The CIDRW Head 1 reads the ID, and the CIDRW returns the ID to the upstream controller.

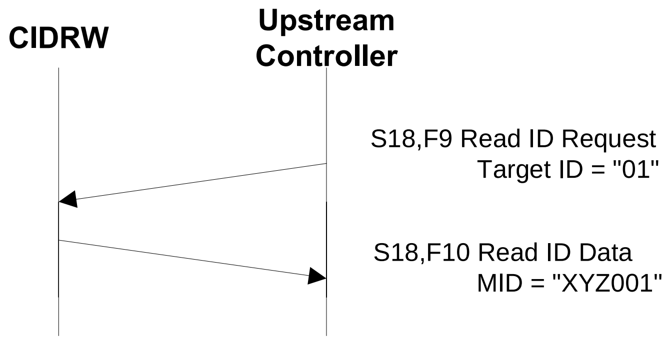

Figure R1-1
Read ID Scenario

R1-2 Read Data

R1-2.1 The upstream controller sends a Read Data Request message to the CIDRW for Head 1 and DataSeg 1. The CIDRW Head 1 reads the data, and the CIDRW returns the data to the upstream controller.

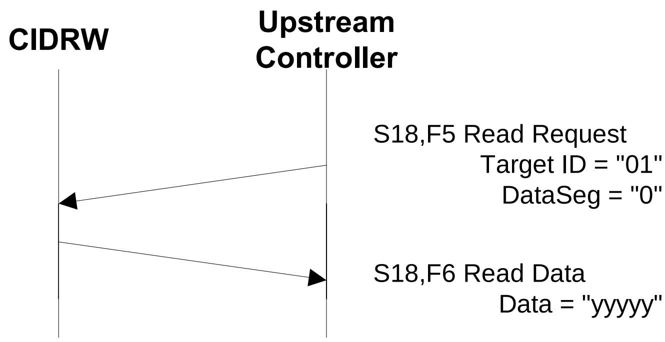

Figure R1-2
Read Data Scenario

R1-3 Write ID

R1-3.1 The CIDRW is in IDLE. The upstream controller requests the CIDRW change its operational status to MAINTENANCE.

R1-3.2 The CIDRW changes to MAINTENANCE and replies that it has changed state.

R1-3.3 The upstream controller sends a Write ID Request message to the CIDRW for Head 1. The CIDRW Head 1 reads the ID, and the CIDRW returns the ID to the upstream controller.

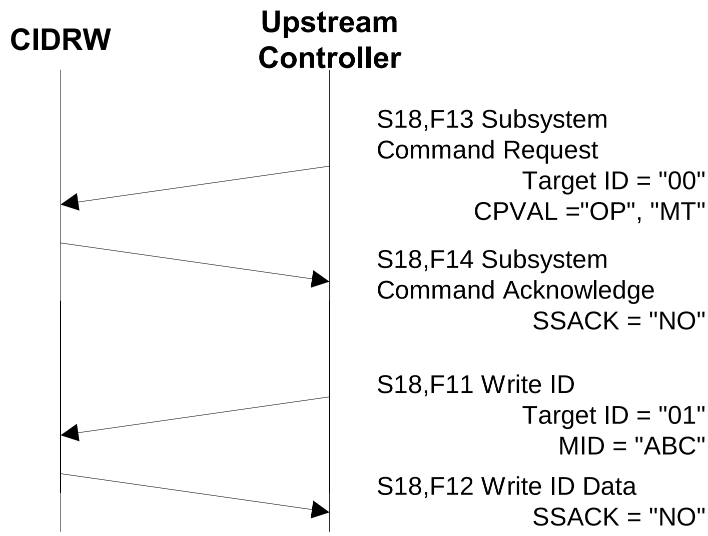

Figure R1-3
Write ID Data Scenario

R1-4 Write Data

R1-4.1 The upstream controller sends a Write Data Request message to the CIDRW for Head 1 and DataSeg 1. The CIDRW Head 1 writes the data, and the CIDRW returns the results to the upstream controller.

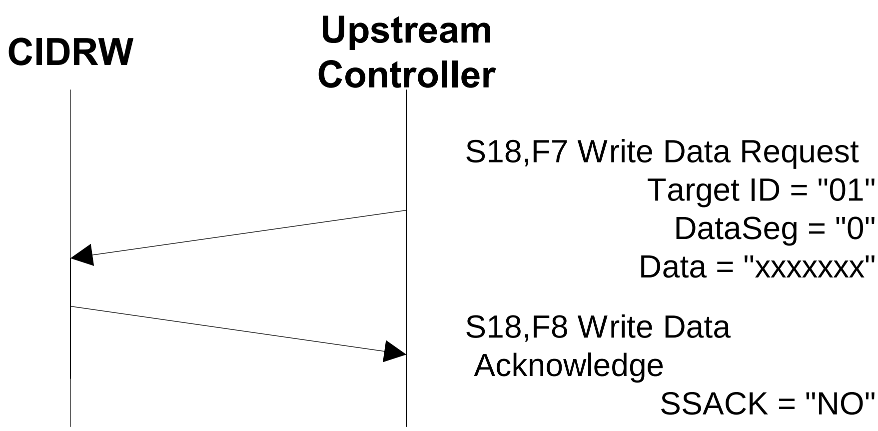

Figure R1-4
Write Data Scenario

SEMI E100-0302
SPECIFICATION FOR A RETICLE SMIF POD (RSP) USED TO TRANSPORT AND STORE 6 INCH OR 230 mm RETICLES

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on October 14, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published February 2000, previously published November 2001.

1 Purpose

1.1 This standard specifies the Reticle SMIF Pod (RSP) used to transport and store 6 inch or 230 mm reticles in a reticle (photomask) or integrated circuit (IC) manufacturing facility.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces for the RSP are specified; no materials requirements or micro-contamination limits are given in this specification.

2.2 The pellicle exclusion volumes of this specification accommodate pellicles which extend the full length of the reticles. The pellicle exclusion volume widths are limited to 151 mm for 230 mm reticles, and 129 mm for 6 inch reticles.

2.3 The RSP has the following components, sub-components, and other features. A "●" symbol indicates components or features which are *required* and a "◊" symbol indicates components or features which are *optional*.

- Top
  - ◊ robotic handling flange (optional)
- Interior
  - supports for one 6 inch or 230 mm reticle
  - reticle capture mechanism
  - end-effector exclusion volume
  - 2 safety rail exclusion volumes
  - pellicle exclusion volume
  - transverse pellicle exclusion volume
- Sides
  - ◊ 2 side handling flanges on the sides parallel to the bi-lateral reference plane (optional)
  - 1 carrier ID exclusion volume on the rear side
  - ◊ 2 side handling exclusion volumes
- Bottom
  - door compatible with SMIF as defined in SEMI E19.4
  - pod latch-pin holes
  - features which mate with kinematic coupling pins
  - carrier sensing pads as defined in SEMI E1.9
  - 4 info pads
  - ◊ 4 bottom conveyor rails

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI P5 — Specification for Pellicles

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *bilateral reference plane* — a vertical plane that bisects the reticle and is perpendicular to both the horizontal and facial reference planes. The bilateral reference plane is coplanar with the bilateral datum plane defined in SEMI E57.

4.2 *facial reference plane* — a vertical plane which bisects the reticle and is parallel to the front side of the pod (where reticles are removed or inserted). The facial reference plane passes through the center of the 200 mm SMIF as defined in SEMI E19.4. The facial reference plane is coplanar with the facial datum plane defined in SEMI E57.

4.3 *horizontal reference plane* — a horizontal plane coplanar with the top surface of the port door as defined in SEMI E19.4. The horizontal reference plane is coplanar with the horizontal datum plane defined in SEMI E57.

4.4 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.5 *nominal reticle center line* — the line that is defined by the intersection of the two vertical reference planes (facial and bilateral) and passes through the nominal center of the seated reticle (which must be horizontal when the carrier is placed on the SMIF as defined in SEMI E19.4).

4.6 *pellicle* — as defined in SEMI P5.

4.7 *reticle* — as defined in SEMI E30.1.

4.8 *Reticle SMIF Pod* (RSP) — a minienvironment compatible carrier capable of holding one 6 inch or one 230 mm reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.4.

4.9 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box (as defined in SEMI E47.1).

4.10 *side handling flanges* — horizontal projections on the sides of the pod (sides parallel to the bilateral reference plane) for manual or automated lifting, transportation or positioning of the pod.

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify reticle carriers over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser needs to specify a time period and the number and type of uses to which the carriers will be put. It is under these conditions that the carriers must remain in compliance with the requirements listed in Section 6.

5.2 *Reticle Size and Thickness* — The purchaser needs to specify the reticle size and thickness to be accommodated in the RSP.

5.3 *Optional Features* — The purchaser needs to specify whether optional components (identified in Section 2) are required.

5.4 *Temperature Ranges* — The purchaser needs to specify two sets of temperatures to which the RSPs might be exposed. An operating temperature range is the set of environmental temperatures in which the RSPs will remain in compliance with the requirements listed in Section 6. A temporary temperature range is the set of environmental temperatures to which the pods can be exposed such that when the RSPs return to the operating temperature range, the RSPs will be in compliance with the requirements listed in Section 6. Limits on exposure times to elevated temperatures should be specified.

5.5 *Electrostatic Dissipation* — The end user may require a continuous path to ground from the reticle to the carrier registration and handling features. The purchaser needs to specify whether electrostatic dissipation is required.

5.6 *Contamination Requirements* — The purchaser needs to specify their contamination requirements.

6 Requirements

6.1 *Symmetry* — Most of the dimensions of the RSP are determined with respect to the three orthogonal reference planes defined in this document: the facial reference plane, the horizontal reference plane and the bilateral reference plane. All dimensions are symmetric about the bilateral reference plane except the latch features. All dimensions are symmetric about the facial reference plane except the registration features, carrier sensing pads, info pads, and latch features.

6.2 *Door* — The pod door, and its frame on the bottom of the pod, must be compatible with a port which conforms to SEMI E19.4.

6.3 *Reticle Centering and Capture* — When the carrier is closed, the reticle must be secured in all degrees of freedom within the carrier to prevent movement during transport and must be centered with respect to the SMIF defined in SEMI E19.4. A bisecting plane through the reticle, parallel to the bilateral reference plane must be within x114 of the bilateral reference plane of the load port when the reticle is seated in the carrier. A bisecting plane through the reticle, parallel to the facial reference plane must be within y133 of the facial reference plane of the load port when the reticle is seated in the carrier. When the carrier is open, it must provide a horizontal reticle capture range of x135 and y135. This capture range must be provided at z162 above the horizontal reference plane.

6.4 *Exclusion Volumes* — The interior of the RSP must never intrude into the pellicle exclusion volumes, and must not intrude into the end-effector exclusion volumes or safety rail exclusion volumes when the carrier is open. Where the exclusion volumes overlap, the end-effector exclusion volume is reduced by the pellicle exclusion volume when handling pelliclized or chrome-down reticles.

6.4.1 *End-Effector Exclusion Volumes* — Volumes in an opened pod which must be free for the end-effector to enter and handle the reticle as defined by x116, x132, y136, x144, x146, y144, z159, and z160 for a 230 mm RSP, and by x118, x143, x145, y143, z159, and z160 for a 6 inch RSP. No obstructions should exist in the end-effector exclusion volume which extends in the direction normal to the facial reference plane.

6.4.2 *Pellicle Exclusion Volumes* — Volumes in the pod below the reticle which must remain free from intrusion to accommodate the pellicle mounted on the reticle. No obstructions should exist in the pellicle exclusion volume which extends in the direction normal to the facial reference plane as defined by x115, z159 and z161 for a 230 mm RSP, and by x119, z159 and z161 for a 6 inch RSP. No obstructions should exist in the transverse pellicle exclusion volume which extends in the direction normal to the bilateral reference plane as defined by y129, z159 and z163 for a 230 mm RSP, and by y130, z159 and z163 for a 6 inch RSP.

NOTE 2: The transverse pellicle exclusion volume is only intended to specify where the reticle supports in the pod cannot exist. Reticles with the pellicles transverse are typically handled with end-effectors which grip from above the reticle.

6.4.3 *Safety Rail Exclusion Volumes* — Volumes in an opened pod which must remain free from intrusion to accommodate safety rails which may be used on end-effectors to protect the edge of the reticle during handling. No obstructions should exist in the safety rail exclusion volumes which extend in the direction normal to the facial reference plane as defined by x137 and z167 for a 230 mm, and by x138 and z167 for a 6 inch RSP.

6.5 *External Dimensions* — Figures 1, 2 and 3 show, respectively, the external top view, a detail and the front view of the RSP. Table 2 defines all of the external dimensions of the RSP (equivalent for both the 6 inch and the 230 mm versions).

6.6 *Internal Dimensions* — Figures 4 through 8 show internal dimensions for the 6 inch and 230 mm versions of the RSP. Table 2 defines all internal dimensions which are common to the 6 inch and 230 mm RSP. Table 3 defines the internal dimensions which apply only to the 230 mm RSP. Table 4 defines the internal dimensions which apply only to the 6 inch RSP. The maximum height of the features which support the reticle are given by z164 for a 230 mm RSP and z165 for a 6 inch RSP.

NOTE 3: The maximum height of the reticle supports, plus the clearance between the reticle supports and reticle (chosen by the tool supplier) determine the height the reticle must be lifted before being extracted from, or inserted into the RSP.

6.7 *Robotic Handling Flange* — On the top of the pod is an optional handling flange for automated manipulation of the RSP. Figures 1, 3, and 5 show dimensions for the robotic handling flange. Table 2 defines the dimensions for the robotic handling flange.

6.8 *Side Handling Flanges* — On the sides of the pod parallel to the bilateral reference plane are optional handling flanges for automated manipulation of the RSP. Figures 1, 2, and 3 show dimensions for the side handling flanges. Table 2 defines the dimensions for the side handling flanges. No obstructions may exist in the side handling exclusion volumes which extend in the direction normal to the facial reference plane as defined by x136 and z166 when the side handling flanges are present.

6.9 *Kinematic Coupling* — The RSP door must have the capability of registering on the kinematic pins defined in SEMI E57. The features that mate with the pins must provide a lead-in capability that corrects an RSP misalignment no greater than r19 in any horizontal direction. However, it is recommended that robots placing RSPs on kinematic couplings use as little of this lead-in capability as possible to avoid wear.

6.10 *Carrier Sensing Pads* — The RSP door must have carrier sensing pads as defined in SEMI E1.9.

6.11 *Info Pads* — When the RSP is placed on a port, the info pads A, B, C, and D communicate information about the RSP configuration. Figures 6 and 8 show the dimensions of the info pads. Table 2 defines the info pad dimensions. A pad in the up position must be z26 above the horizontal reference plane. A pad in the down position must be z2 above the horizontal reference plane. Info pad assignments are shown in Table 1. Info pads that are “not defined” can be at either the up or down position unless specified by the end user. RSP configurations “to be assigned” may be assigned by the end user.

Table 1 Info Pad Assignments

RSP Configuration	*Info Pad*			
	A	*B*	*C*	*D*
230 mm reticle	not defined	not defined	up	down
6 inch reticle	not defined	not defined	down	down
to be assigned	not defined	not defined	up	up
to be assigned	not defined	not defined	down	up

6.12 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier. Note also that this radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

6.13 *Carrier ID Exclusion Volume* — Volume external to the pod which must remain free from intrusion to accommodate a carrier ID label or tag mounted on the pod. No obstructions should exist in the carrier ID exclusion volume as defined by x147, y137, y138, z180, and z181. Figures 1 and 3 show dimensions for the carrier ID exclusion volume. Table 2 defines the dimensions for the carrier ID exclusion volume. If a label is used, its surface must be at y139.

6.14 *Conveyor Rails* — Optional surfaces on the bottom for transporting the RSP on roller conveyors. The conveyor rail surfaces are bounded by x140, x141, x142, y140, y141 and y142 as shown in Figure 9. The height of the conveyor rail surface is defined by z171. Table 2 defines the dimensions for the conveyor rails.

7 Related Documents

7.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P33 — Provisional Specification for Developmental 230 mm Square Hard Surface Photomask Substrates

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

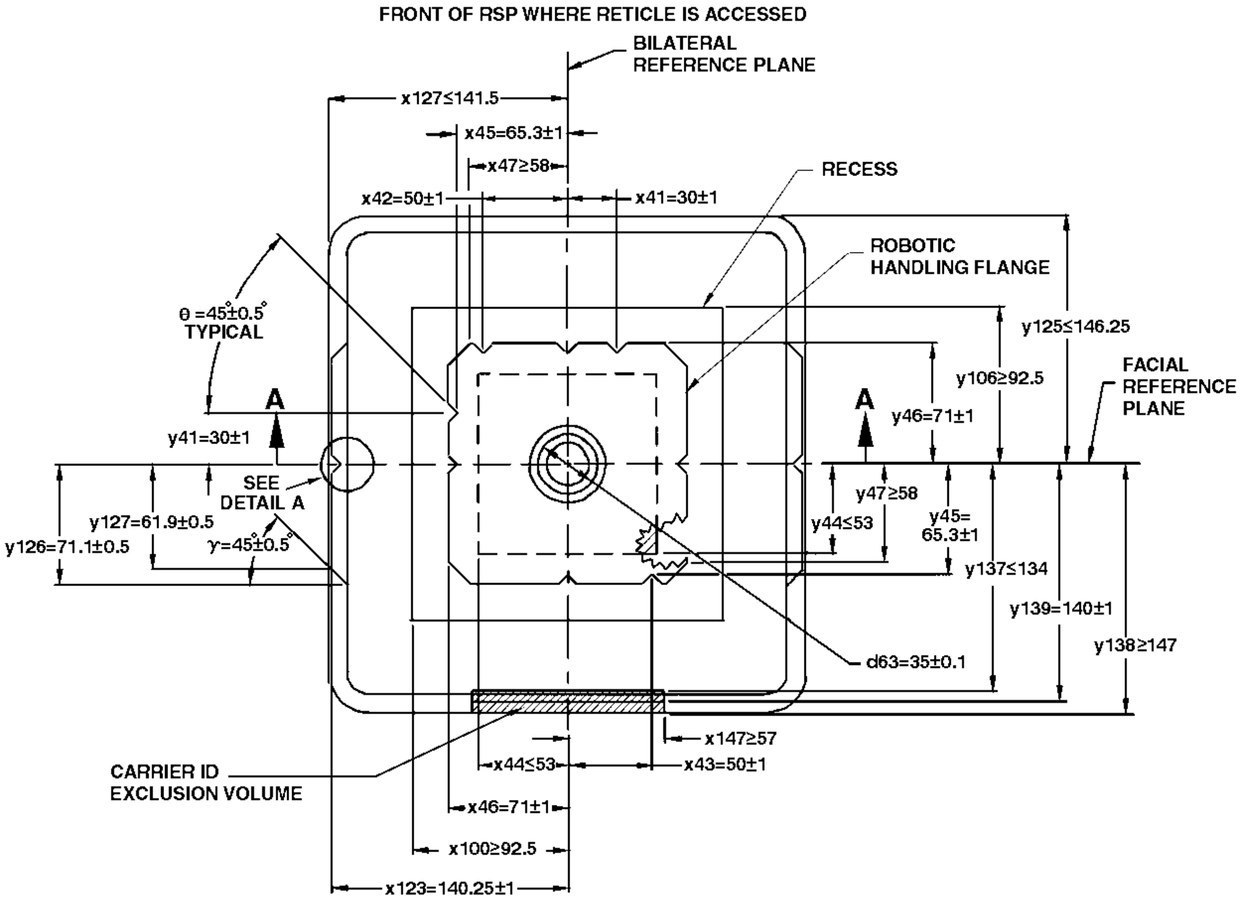

Figure 1
External Top View of 230 mm and 6 inch RSP

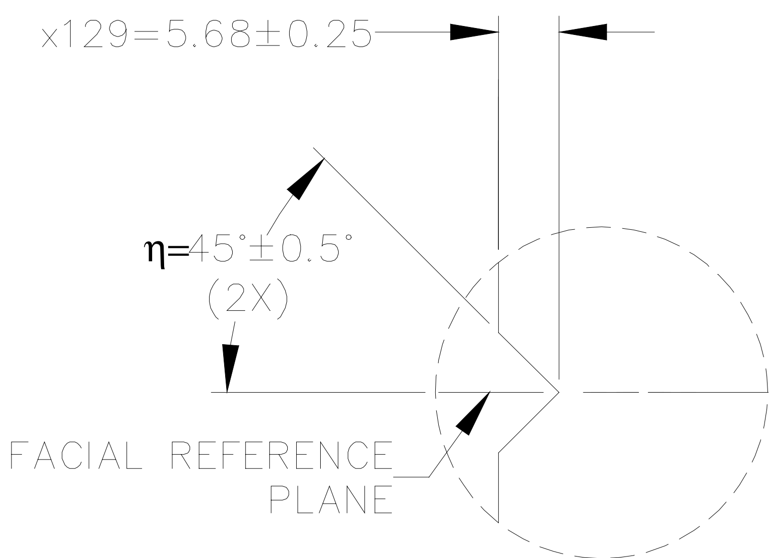

Figure 2
Detail A: External Top View of Side Handling Flange Alignment Hole

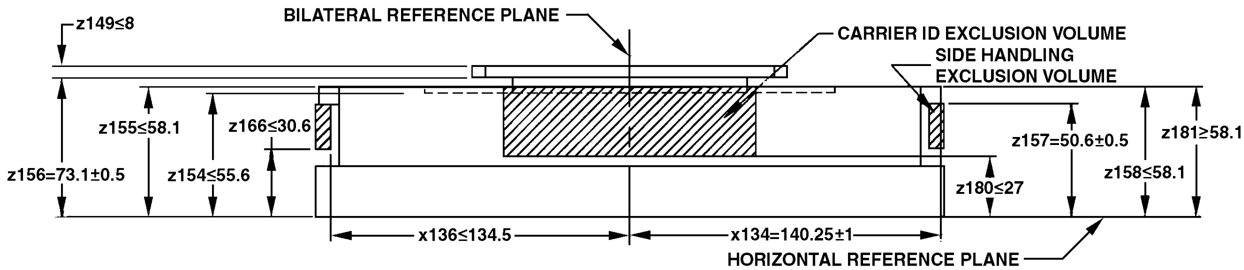

Figure 3
External Front View of 230 mm and 6 inch RSP

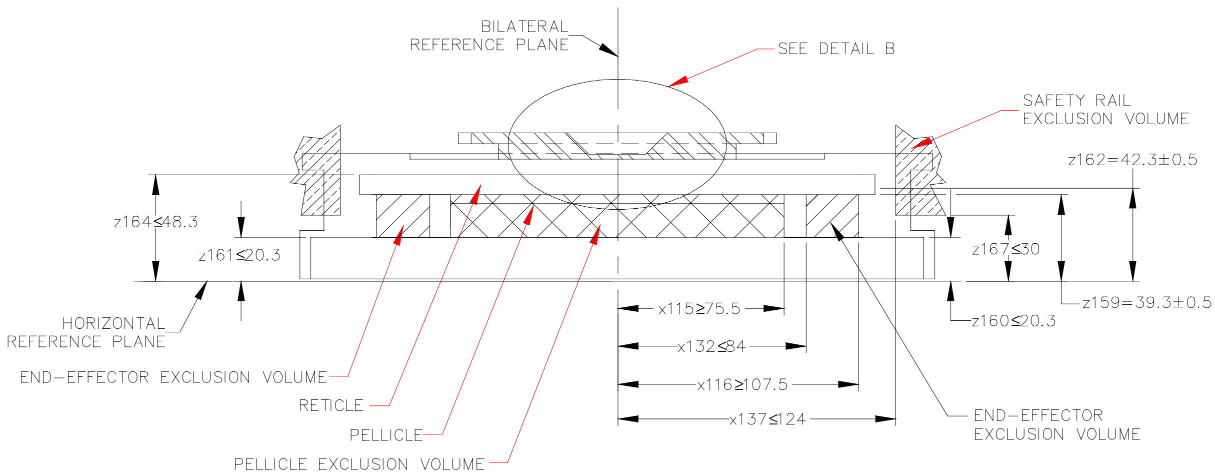

Figure 4
Section A-A: Internal Front View of 230 mm RSP

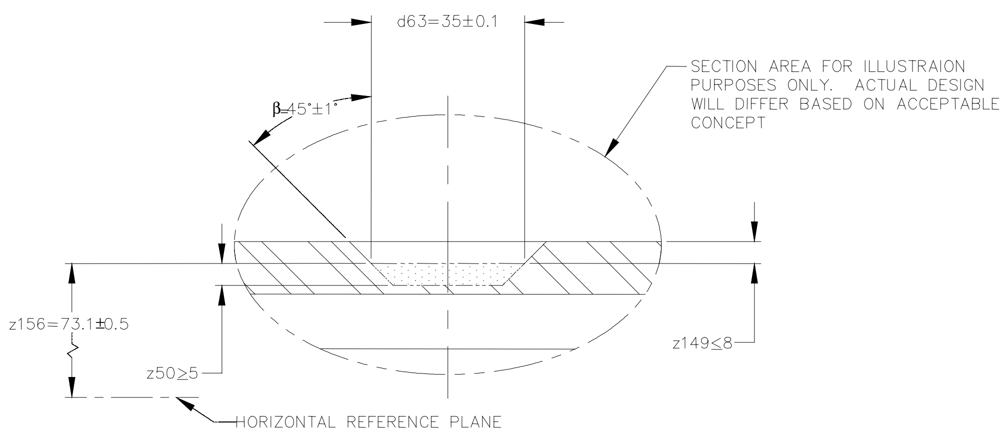

Figure 5
Detail B: Top Robotic Handling Flange Hole Feature

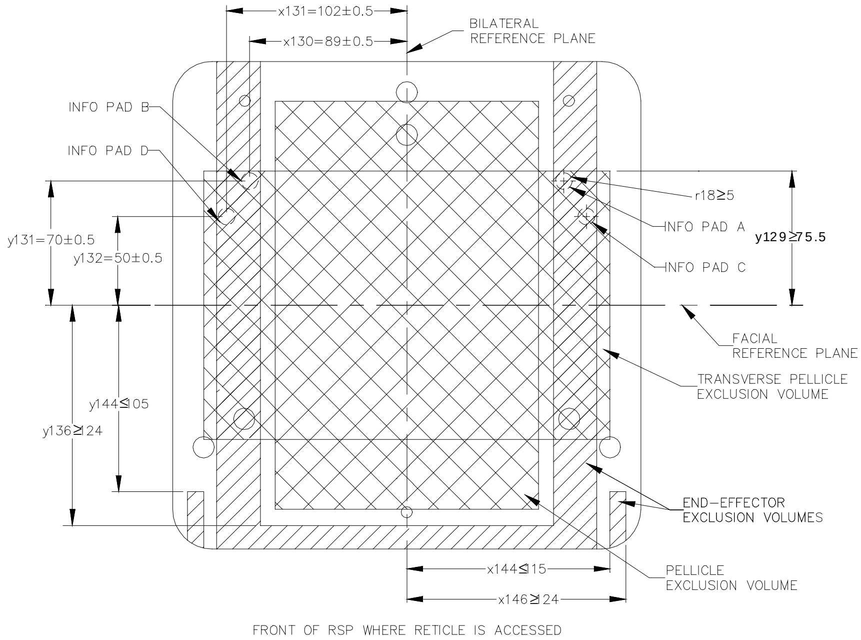

Figure 6
Door Only Top View of 230 mm RSP

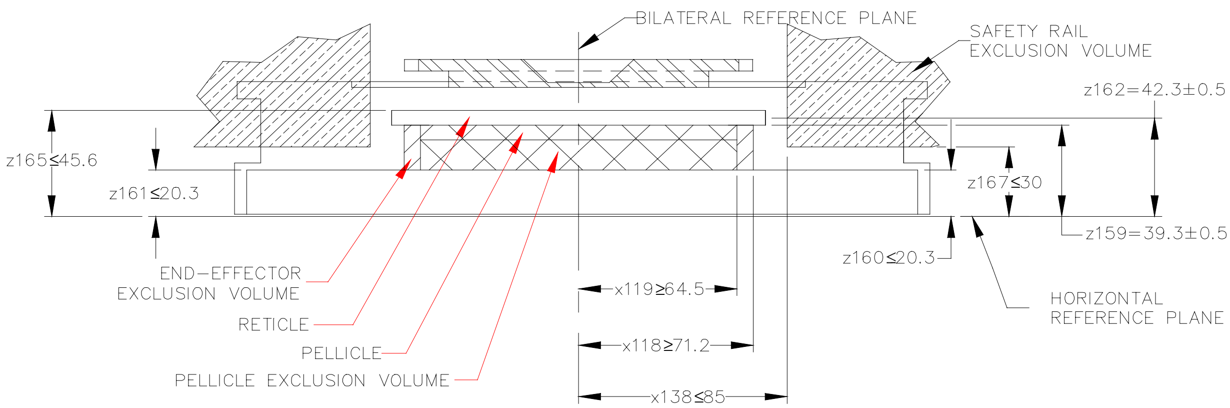

Figure 7
Section A-A: Internal Front View of 6 inch RSP

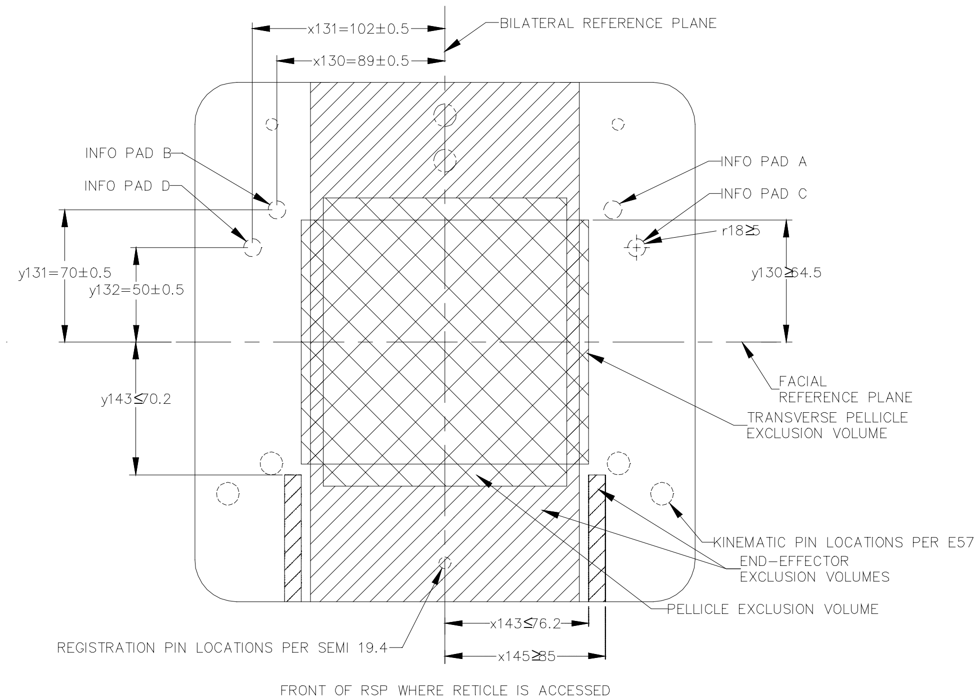

Figure 8
Door Only Top View of 6 inch RSP

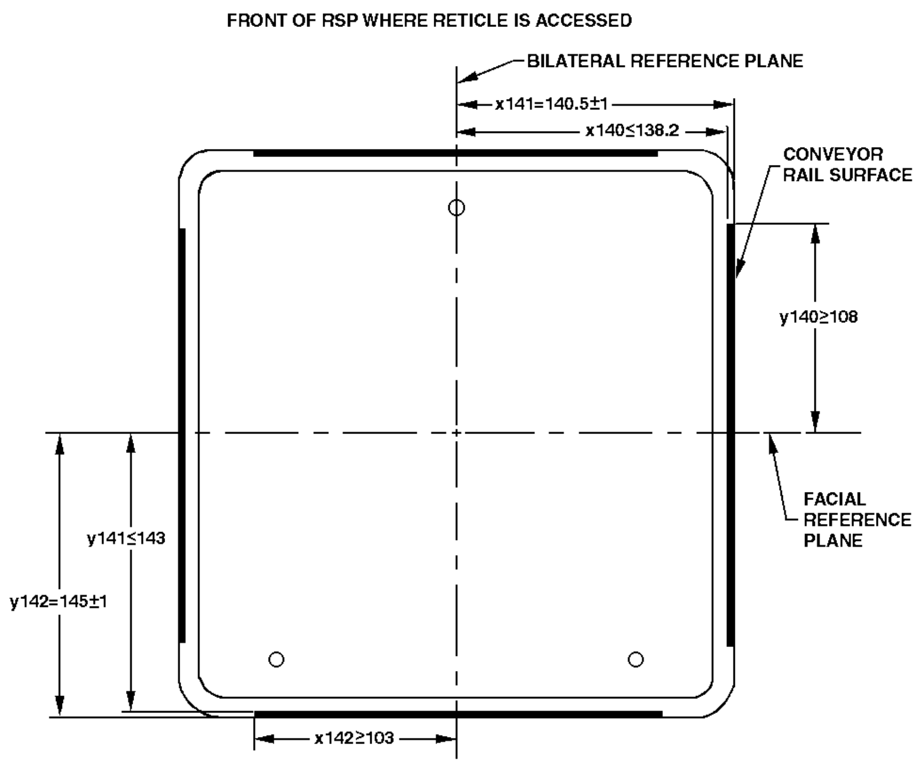

Figure 9
Exterior Bottom View of 6 inch and 230 mm RSP

Table 2 External Dimensions and Common Internal Dimensions for 6 inch and 230 mm RSP

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
θ	1	45° ± 0.5°	facial reference plane	sides of orientation notches
γ	1	45° ± 0.5°	facial reference plane	edge of side handling flange chamfer
η	2	45° ± 0.5°	facial reference plane	sides of side handling flange orientation notches
β	5	45° ± 1°	bilateral and facial plane intersection	surface of the center hole in the top robotic handling flange
r65	n/a	1 mm (0.039 in.) maximum	not applicable	all required concave features (radius)
r66	n/a	2 mm (0.079 in.) maximum	not applicable	all required convex features (radius)
r18	6, 8	5 mm (0.197 in.) minimum	info pad center	perimeter of info pad
*r*19	None	10 mm (0.394 in.) minimum	not applicable	correctable RSP misalignment in any horizontal direction
d63	5	35 ± 0.1 mm (1.378 ± 0.004 in.)	centered on bilateral and facial plane intersection	top robotic handling flange hole design feature
x41	1	30 ± 1 mm (1.181 ± 0.039 in.)	bilateral reference plane	orientation notch center
x42	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x43	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x44	1	53 mm (2.087 in.) maximum	bilateral reference plane	side of robotic handling flange column
x45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	bilateral reference plane	orientation notch tip
x46	1	71 ± 1 mm (2.795 ± 0.039 in.)	bilateral reference plane	edge of robotic handling flange
x47	1	58 mm (2.283 in.) minimum	bilateral reference plane	edge of robotic handling flange corner beveling
x100	1	92.5 mm (3.642 in.) minimum	bilateral reference plane	edge of recess
x114	None	0 ± 1 mm (0 ± 0.039 in.)	bilateral reference plane	bisecting plane through reticle
x123	1	140.25 ± 1 mm (5.522 ± 0.039 in.)	bilateral reference plane	side edge of side handling flange
x127	1	141.5 mm (5.571 in.) maximum	bilateral reference plane	side of pod
x129	2	5.68 ± 0.25 mm (0.224 ± 0.010 in.)	side edge of side handling flange	vertex of side handling flange alignment notch
x130	6, 8	89 ± 0.5 mm (3.504 ± 0.020 in.)	bilateral reference plane	center of info pads A and B

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
x131	6, 8	102 ± 0.5 mm (4.016 ± 0.020 in.)	bilateral reference plane	center of info pads C and D
x134	3	140.25 ± 1 mm (5.522 ± 0.039 in.)	bilateral reference plane	bottom edge of side handling flange
x135	None	0 ± 3 mm (0 ± 0.118 in.)	bilateral reference plane	bisecting plane through reticle
x136	3	134.5 mm (5.295 in.) maximum	bilateral reference plane	edge of side handling exclusion volume
x140	9	138.2 mm (5.441 in.) maximum	bilateral reference plane	edge of conveyor rail surface
x141	9	140.5 ± 1 mm (5.531 ± 0.039 in.)	bilateral reference plane	edge of conveyor rail surface
x142	9	103 mm (4.055 in.) minimum	bilateral reference plane	end of conveyor rail surface
x147	1	57 mm (2.244 in.) minimum	bilateral reference plane	edge of carrier ID exclusion volume
y41	1	30 ± 1 mm (1.181 ± 0.039 in.)	facial reference plane	center of orientation notch
y44	1	53 mm (2.087 in.) maximum	facial reference plane	edge of robotic handling flange column
y45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	facial reference plane	orientation notch tip
y46	1	71 ± 1 mm (2.795 ± 0.039 in.)	facial reference plane	edge of robotic handling flange
y47	1	58 mm (2.283 in.) minimum	facial reference plane	edge of robotic handling flange corner beveling
y106	1	92.5 mm (3.642 in.) minimum	facial reference plane	edge of recess
y125	1	146.25 mm (5.758 in.) maximum	facial reference plane	side of pod
y126	1	71.1 ± 0.5 mm (2.799 ± 0.020 in.)	facial reference plane	depth of side handles
y127	1	61.9 ± 0.5 mm (2.437 ± 0.020 in.)	facial reference plane	side handle chamfers
y131	6, 8	70 ± 0.5 mm (2.756 ± 0.020 in.)	facial reference plane	center of info pads A and B
y132	6, 8	50 ± 0.5 mm (1.969 ± 0.020 in.)	facial reference plane	center of info pads C and D
y133	None	0 ± 1 mm (0 ± 0.039 in.)	facial reference plane	bisecting plane through reticle
y135	None	0 ± 3 mm (0 ± 0.118 in.)	facial reference plane	bisecting plane through reticle
y137	1	134 mm (5.276 in.) maximum	facial reference plane	edge of carrier ID exclusion volume
y138	1	147 mm (5.787 in.) minimum	facial reference plane	edge of carrier ID exclusion volume

Symbol Used	Figure	Value Specified	Reference Measured From	Feature Measured To
y139	1	140 ± 1 mm (5.512 ± 0.039 in.)	facial reference plane	surface of ID label
y140	9	108 mm (4.252 in.) minimum	facial reference plane	end of conveyor rail surface
y141	9	143 mm (5.630 in.) maximum	facial reference plane	edge of conveyor rail surface
y142	9	145.5 ± 1 mm (5.728 ± 0.039 in.)	facial reference plane	edge of conveyor rail surface
z2	None	2 mm (0.079 in.) maximum	horizontal reference plane	surface of info pads (when down)
z26	None	9 mm (0.354 in.) minimum	horizontal reference plane	surface of info pads (when up)
z50	5	5 mm (0.197 in.) minimum	bottom of circular recess	midpoint of circular recess
z149	3, 5	8 mm (0.315 in.) maximum	bottom surface of robotic handling flange	height of robotic handling flange
z154	3	55.6 mm (2.189 in.) maximum	horizontal reference plane	top surface of dome recess
z155	3	58.1 mm (2.287 in.) maximum	horizontal reference plane	top surface of dome
z156	3, 5	73.1 ± 0.5 mm (2.878 ± 0.020 in.)	horizontal reference plane	bottom surface of robotic handling flange
z157	3	50.6 ± 0.5 mm (1.992 ± 0.020 in.)	horizontal reference plane	bottom edge of side handles
z158	3	58.1 mm (2.287 in.) maximum	horizontal reference plane	top surface of side handles
z159	4, 7	39.3 ± 0.5 mm (1.547 ± 0.020 in.)	horizontal reference plane	bottom surface of reticle
z160	4, 7	20.3 mm (0.799 in.) maximum	horizontal reference plane	edge of end-effector exclusion volume
z161	4, 7	20.3 mm (0.799 in.) maximum	horizontal reference plane	edge of pellicle exclusion volume
z162	4, 7	42.3 ± 0.5 mm (1.665 ± 0.020 in.)	horizontal reference plane	reticle capture height
z163	None	20.3 mm (0.799 in.) minimum	horizontal reference plane	edge of transverse pellicle exclusion volume
z166	3	30.6 mm (1.205 in.) maximum	horizontal reference plane	edge of side handling exclusion volume
z167	4, 7	30 mm (1.181 in.) maximum	horizontal reference plane	edge of safety rail exclusion volume
z171	None	0.5 mm (0.020 in.) maximum	horizontal datum plane	conveyor rail surface
z180	3	27 mm (1.063 in.) maximum	horizontal reference plane	bottom edge of carrier ID exclusion volume
z181	3	58.1 mm (2.287 in.) minimum	horizontal reference plane	top edge of carrier ID exclusion volume

Table 3 Internal Dimensions Unique to the 230 mm RSP

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
x115	4	75.5 mm (2.972 in.) minimum	bilateral reference plane	edge of pellicle exclusion volume
x116	4	107.5 mm (4.232 in.) minimum	bilateral reference plane	edge of end-effector exclusion volume
x132	4	84 mm (3.307 in.) maximum	bilateral reference plane	edge of end-effector exclusion volume
x137	4	124 mm (4.882 in.) maximum	bilateral reference plane	edge of safety rail exclusion volume
x144	4, 6	115 mm (4.528 in.) maximum	facial reference plane	edge of end-effector exclusion volume
x146	4, 6	124 mm (4.881 in.) minimum	facial reference plane	edge of end-effector exclusion volume
y129	6	75.5 mm (2.972 in.) minimum	facial reference plane	edge of transverse pellicle exclusion volume
y136	6	124 mm (4.882 in.) minimum	facial reference plane	edge of end effector exclusion volume
y144	6	105 mm (4.134 in.) maximum	facial reference plane	edge of end-effector exclusion volume
z164	4	48.3 mm (1.902 in.) maximum	horizontal reference plane	top of reticle supports

Table 4 Internal Dimensions Unique to the 6 inch RSP

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
x118	7	71.2 mm (2.803 in.) minimum	bilateral reference plane	edge of end-effector exclusion volume
x119	7	64.5 mm (2.539 in.) minimum	bilateral reference plane	edge of pellicle exclusion volume
x138	7	85 mm (3.346 in.) maximum	bilateral reference plane	edge of safety rail exclusion volume
x143	7, 8	76.2 mm (3.000 in.) maximum	facial reference plane	edge of end-effector exclusion volume
x145	7, 8	85 mm (3.346 in.) minimum	facial reference plane	edge of end-effector exclusion volume
y130	8	64.5 mm (2.539 in.) minimum	facial reference plane	edge of transverse pellicle exclusion volume
y143	8	70.2 mm (2.764 in.) maximum	facial reference plane	edge of end-effector exclusion volume
z165	7	45.6 mm (1.795 in.) maximum	horizontal reference plane	top of reticle supports

APPENDIX 1
APPLICATION NOTES

NOTE: The material in this appendix is an official part of SEMI E100 and was approved by full letter ballot procedures on September 3 and December 15, 1999 by the North American Regional Standards Committee, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Edge contact only with the photomask is preferred when handling, transporting, or storing.

A1-2 Skewness, warp, rock, and stiffness are implicitly defined in the geometric tolerances.

A1-3 A 6 inch reticle with a 140 mm wide pellicle can be accommodated in the RSP, but may require automation which approaches from above the reticle.

A1-4 Features on the RSP which enable stacking may be required by end users. It is preferred that these features allowing stacking in only one orientation.

A1-5 Features on the RSP which provide visual orientation of the RSP top and RSP door may be required by end users.

A1-6 In order to permit end-effectors, which can handle both 230 mm and 6 inch reticles, it is recommended to include the 230 mm end-effector exclusion volumes in RSPs configured for 6 inch reticles.

APPENDIX 2
ADDITIONAL INFORMATION

NOTE: The material in this appendix is an official part of SEMI E100 and was approved by full letter ballot procedures on September 3, 1999 by the North American Regional Standards Committee.

A2-1 Features on the RSP which enable stacking may be standardized in the future pending learning from first design approaches and standardization of reticle ID location.

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SEMI E101-1000
PROVISIONAL GUIDE FOR EFEM FUNCTIONAL STRUCTURE MODEL

This guide was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on July 14, 2000. Initially available at www.semi.org September 2000, to be published October 2000. Originally published February 2000; previously published June 2000.

1 Purpose

1.1 Productivity improvement is the task with the highest priority in semiconductor factories of the 300 mm generation, and computer-integrated manufacturing or factory automation (CIM/FA) technologies become more and more important to accomplish it. The standardization of these technologies is also necessary to provide the CIM/FA infrastructure in a short period of time at a low cost. Since the standards will have to cover a wide range of production equipment, communication hardware, and software tools, it is very important that the standards have a high degree of compatibility. In order to improve the compatibility, this guide provides a functional structure model of an Equipment Front End Module (EFEM) that handles carriers and substrates at the interface between the factory material handling system and the process equipment.

1.2 The major purposes of this guide are as follows:

1) provide a common understanding of functions of EFEM (Equipment Front End Module) and associated interfaces between functional elements (components with particular function roles),

2) provide a common understanding of the hierarchical structure of functions and their interfaces in an EFEM,

3) provide a common understanding of possible units used for maintenance, adjustment, and control, and

4) provide a map between EFEM functional elements and existing standards.

2 Scope

2.1 *Model Structure and Functions*

2.1.1 This document recognizes EFEM as a component of semiconductor manufacturing equipment. It creates an EFEM functional structure model to clearly describe EFEM, its functional elements, and the functions of each functional element. The functional structure model includes the following:

1) definition of functional elements that constitute EFEM,

2) definition of functions of functional elements, and

3) hierarchical description of functional elements.

2.1.2 For clarity, Fixed Buffer Type EFEM and Internal Buffer Type EFEM (see Terminology) are represented as independent functional structure models in this document.

2.2 *Preconditions for Modeling*

2.2.1 The models are created under the following conditions:

1) Modeling should be restricted to SEMI E15.1, Option 1, Options 2 and 3, and Option 3 types. (See SEMI E15.1, Figure 2 (Load Port Options)).

2) The model supports handling of open cassette (OC), and Front Opening Unified Pod (FOUP) (see Terminology).

3) The model is created for the maximum structure including options.

4) Functional elements that have interfaces with EFEM are also included in the model.

NOTE 1: Functional elements that don't belong to EFEM, but are important in defining interfaces among the functional elements, are represented in this model to clarify their functional positions and attributes in the entire equipment.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E64 — Provisional Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI E75 — Provisional Mechanical Specification for Box/Pod Compatible Cassette Used to Transport and Store 300 mm Wafers

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 AGV — automatic guided vehicle (cart)

4.1.2 *OHT* — overhead transport system with hoist for lifting carriers between load port level and transport level.

4.1.3 *PGV* — person guided vehicle (cart).

4.1.4 *PI/O* — parallel input/output interface, for example, as specified in SEMI E23.

4.1.5 *RGV* — rail guided vehicle (moving on the floor).

4.2 *Definitions*

4.2.1 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached (as defined in SEMI E63).

4.2.2 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.2.3 *box opener/loader* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's Substrate Handler for unloading and loading wafers.

4.2.4 *carrier* — any cassette, box, or pod that are used to transport substrates (as defined in SEMI E15).

4.2.5 *cart* — a floor-based carrier transfer vehicle.

4.2.6 *cassette* — an open structure that holds one or more wafer substrates (as defined in SEMI E44).

4.2.7 *docking* — the act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment.

4.2.8 *equipment front end module (EFEM)* — it consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in SEMI E15.1), opens the carriers (if needed), and may include a Substrate Handler for unloading and loading wafers from the carrier to the process part of equipment.

4.2.9 *fixed buffer* — EFEM configuration with carrier places only on load port units arranged in a load port group.

4.2.10 *front opening unified pod (FOUP)* — front opening type box/pod with non-removable cassettes (as defined in SEMI E47.1).

4.2.11 *internal buffer* — EFEM configuration with carrier places different from load port units.

4.2.12 *kinematic coupling* — the physical alignment mechanism on the bottom of the wafer carrier that consists of features that mate with three vertical pins on the load port (as defined in SEMI E57).

4.2.13 *load port* — the interface location on a tool where carriers are placed to allow the tool to process wafers (as defined in SEMI E15).

4.2.14 *open cassette (OC)* — a cassette (as defined in SEMI E1.9) without a protective barrier around it.

4.2.15 *transfer* — to either load or unload (as defined in SEMI E15).

5 Modeling Methodology (General Rules)

5.1 *Notation*

5.1.1 A functional element to be defined is represented by a rectangle.

5.1.2 The name of a functional element is written in the rectangle representing the element.

5.1.3 Numbers preceding the functional element name indicate the number of elements.

[0, 1] indicates the element may exist or may not exist.

[1+] indicates the element may exist one or more times.

5.2 *Rules of Notation Usage*

5.2.1 A functional element that is written on the border between adjacent layers indicates the element may belong to either of two functional elements in the adjacent layers.

5.2.2 Functional elements whose position in the Functional Structure Model diagram are similar in the two models of Fixed Buffer Type EFEM and Internal Buffer Type EFEM have the same name.

5.2.3 A functional element whose location is still undecided between two adjacent layers is located in between them.

6 Definition of Functional Elements

6.1 *Overall Structure*

6.1.1 Figures 1a, 1b and Figures 2a, 2b show conceptual structures of two types of Fixed Buffer Type EFEM model and two types of Internal Buffer Type EFEM model in overall structure of equipment. Two types of EFEM exist, when Substrate Handler is installed outside the Process Part, and when the Substrate Handler is included inside the Process Part.

6.1.2 *EFEM [1]* — This is a major module whose functions are to transfer carriers to and from the factory material handling system, to provide all carrier handling and storage functions for production equipment, and to load and unload substrates from the carrier for processing. It consists of a Carrier Handler and may contain a Substrate Handler.

6.1.3 *Carrier Handler [1]* — A Carrier Handler receives and passes the carriers from and/or to the external system (such as the factory material handling system). A Carrier Handler of the Internal Buffer Type has the functions of handling and storing the carriers. A carrier handler for FOUPs has the opener(s) for opening and closing FOUPs.

6.1.4 *Substrate Handler [0,1]* — A Substrate Handler transfers substrates between the carriers and the process part of the equipment.

6.1.5 *Load Port Group [1+]* — The load port group is where carriers are received and passed from or to the external system (such as the factory material handling system). Each equipment has at least one load port group. A load port group consists of one or more load ports.

6.1.5 *Internal Buffer [1+]* — This is a buffer that stores carriers inside equipment. It moves carriers from Load Port Group to Buffer and moves carriers from Buffer to Internal Substrate Port. It consists of a Carrier Transfer Robot that transfers the carriers to or from a Carrier Storage and a Carrier Storage where carriers are stored.

6.1.6 *Internal Substrate Port [0,1+]* — This is where substrates are loaded and unloaded from a carrier, and it contains any functionality required to present the carrier for substrate access.

6.2 *Definition of Functional Elements for EFEM Models*

6.2.1 *Model of Fixed Buffer Type EFEM (see Figure 3)*

6.2.1.1 *Load Port [1+]* — A load port is where an individual carrier is held for pickup and delivery with the factory material handling system. It consists of a Load Port Unit and may contain PI/O for OHT/AGV/RGV, Cart-to-Tool Docking Port Interface, and a Load Port Door.

6.2.1.2 *Load Port Unit [1]* — This physically receives carriers from/to external systems. It consists of a Carrier Opener/Loader, and it may contain a Carrier Operation Panel, a Carrier ID Reader/Writer, and a Carrier Slot Mapper.

6.2.1.3 *PI/O for AGV/RGV/OHT [0,1]* — This is a means of low-level communications that synchronizes the hand-off between Automated Material Handling equipment (such as AGV, RGV, OHT) and production equipment. One Parallel I/O may exist for each stop position of the AGV, RGV, or OHT. It may be a part of a Load Port or a Load Port Group depending on the number of ports that can be accessed from a single stop position.

6.2.1.4 *Cart-to-Tool Docking Port Interface [0,1]* — This is the mechanical interface allocated for installing the module to be used as a docking means for a person-guided vehicle (PGV) at the Load Port Group. One Cart-to-Tool Docking Port Interface may exists per Load Port Group or per Load Port.

6.2.1.5 *Load Port Door [0,1]* — This is the door that may be used to separate the space on a load port from the external environment, or to prevent the operator from interfering with the load port mechanism or OHT. This may be a part of a Load Port or a Load Port Group depending on the number of ports that can be accessed through a single Port Door.

6.2.1.6 *Carrier Operation Panel [0,1]* — This is an operation panel that may be used when manually loading or unloading a carrier to or from a Load Port. One operation panel may exist for each of SEMI E15.1's Load Port Option 1 and Option 3 types. No operation panel may exist for a Load Port of SEMI E15.1, Option 2 type.

6.2.1.7 *Manual Switches [0,1]* — These are the switches that may be used by an operator when manually loading or unloading a carrier. They are located on the Carrier Operation Panel.

6.2.1.8 *Carrier Indicators [0,1]* — These consist of a Carrier Presence Indicator (that indicates the presence of a carrier) and a Carrier Placement Indicator (that indicates whether the carrier is correctly seated). One set of Carrier Indicators may exist for each Load Port Unit. They are located on the Carrier Operation Panel.

6.2.1.9 *Carrier Opener/Loader [1]* — This is the unit that prepares a carrier for access for loading and unloading substrates and includes all mechanisms required for docking and undocking, purging, opening and closing FOUPs. In the case of an OC, it consists only of the Load Plate.

6.2.1.10 *Dock Plate [0,1]* — This is a mechanism that advances a FOUP up to the door opening/closing mechanism. It contains a Load Plate that a carrier is placed on, and it may contain the Dock/Undock mechanism that advances the carrier into the equipment, and/or a Carrier Purge Interface.

6.2.1.11 *Load Plate [1]* — This is the base plate on which carriers are placed. It consists of a Kinematic Coupling and may contain Carrier Sensors and/or Info Pad Sensors.

6.2.1.12 *Carrier Sensors [0,1]* — These are sensors to detect whether a carrier is present and/or a carrier is correctly placed.

6.2.1.13 *Info Pad Sensors [0,1]* — These are sensors to detect Info Pads as defined in SEMI E1.9.

6.2.1.14 *Carrier Purge Interface [0,1]* — This is a mechanical interface for injecting and withdrawing gasses.

6.2.1.15 *Dock/Undock Mechanism [0,1]* — This is the mechanism that advances a carrier to the FOUP opener and locks the carrier, or releases it from its locked state. In the FOUP-OC (as defined in SEMI E75) and OC (as defined in SEMI E1.9) case, this mechanism only moves carriers.

6.2.1.16 *FOUP Opener [0,1]* — This is the mechanism that opens and closes the FOUP door.

6.2.1.17 *Carrier Opener/Loader Maintenance Panel [0,1]* — This is a user interface for maintenance of the Carrier Opener/Loader.

6.2.1.18 *Carrier Slot Mapper [0,1]* — This is the mechanism that detects the presence or the absence of substrates and their positions in a carrier. It may be installed on the FOUP Opener, the Carrier Opener/Loader, the Load Port Unit, or the Substrate Handler.

6.2.1.19 *Carrier ID Reader/Writer [0,1]* — This is the unit that reads and/or writes to an ID tag attached to a carrier. At most, one Carrier ID Reader/Writer exists for each Load Port Unit.

6.2.1.20 *Status Indicator [0,1]* — This is a set of indicators which shows operating status of the Load Port Unit.

6.2.1.21 *Substrate ID Reader [0,1]* — This is the unit which reads the Identification Label on the Substrate.

6.2.1.22 *Aligner [0,1]* — This is the unit which aligns the angular orientation of substrates and may center the substrate.

6.2.1.23 *Substrate Transfer Robot [0,1+]* — This is the unit which transfers substrates between Carrier Handler, automation components (Aligner, Substrate ID Reader, etc.) and Process Part.

6.2.2 *Model of Internal Buffer Type EFEM (see Figure 4)*

6.2.2.1 This section defines functional elements that exist only in an Internal Buffer Type EFEM.

6.2.2.2 *Internal Buffer [1+]* — This is where an individual carrier is stored in an EFEM. It consists of a Carrier Transfer Robot that transfers carriers and a Carrier Storage where carriers are stored.

6.2.2.3 *Carrier Transfer Robot [1]* — This is a robot that handles carriers in Carrier Storage.

6.2.2.4 *Carrier Storage [1+]* — This is where an individual carrier is stored.

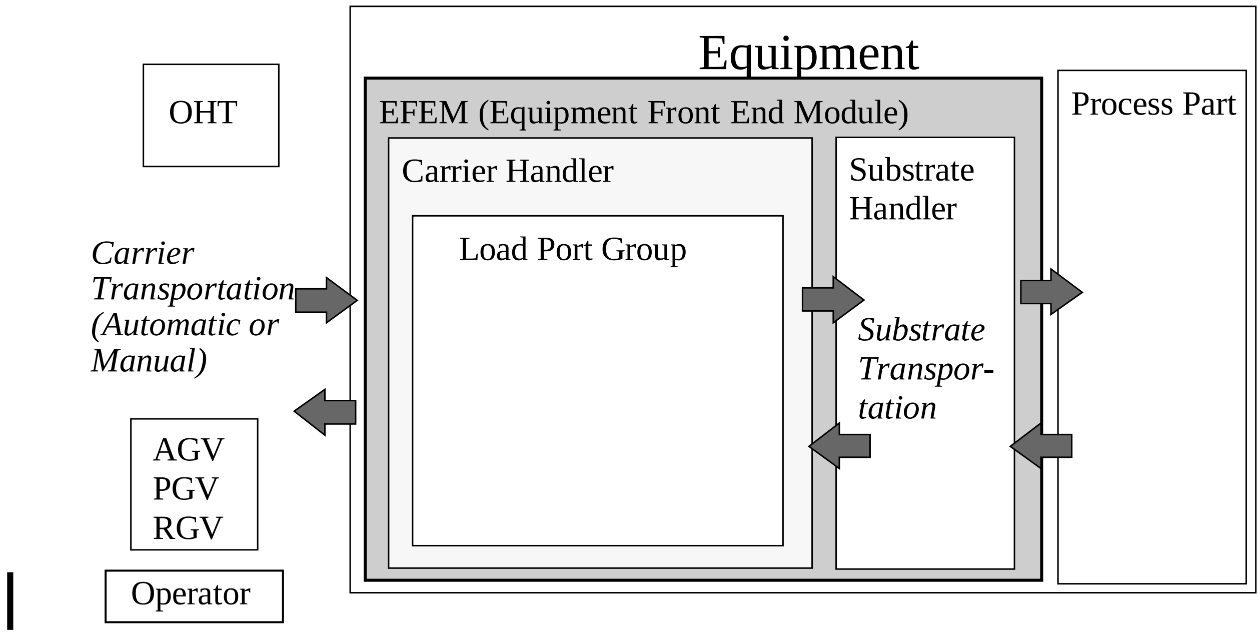

Figure 1a
Conceptual Structure of Fixed Buffer Type EFEM in Equipment W hen Substrate Handler Is Installed Outside Process Part

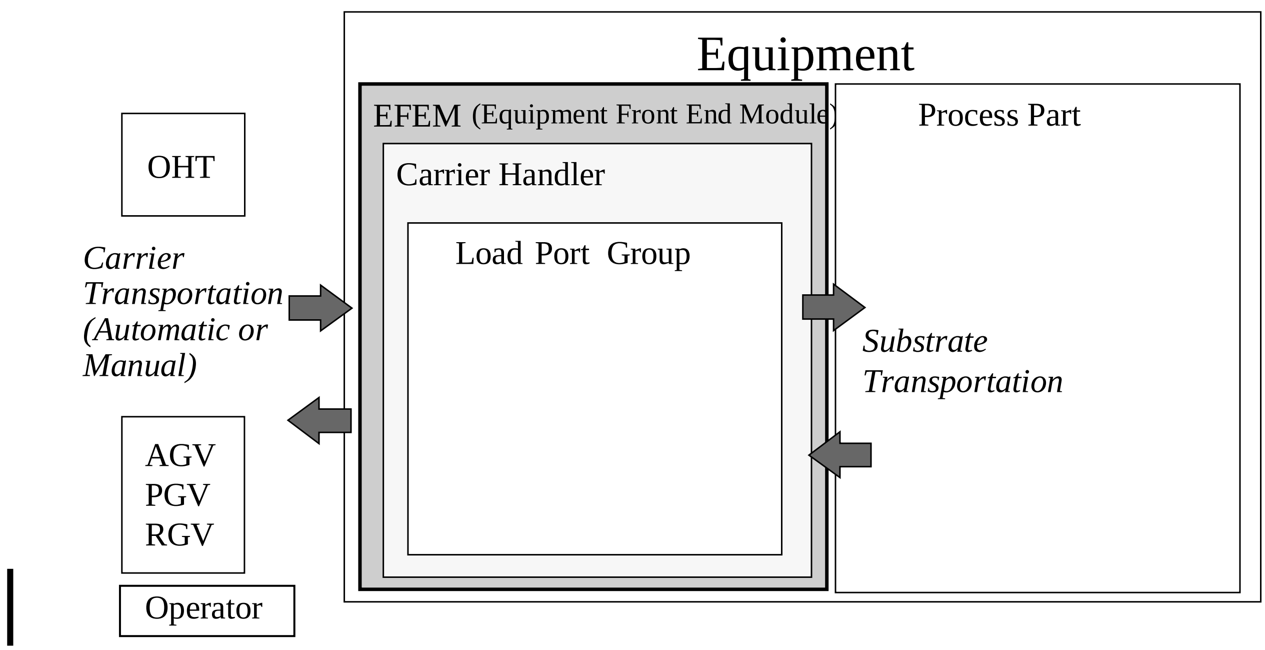

Figure 1b
Conceptual Structure Location of Fixed Buffer Type EFEM in Equipment When Substrate Handler Is Included Inside Process Part

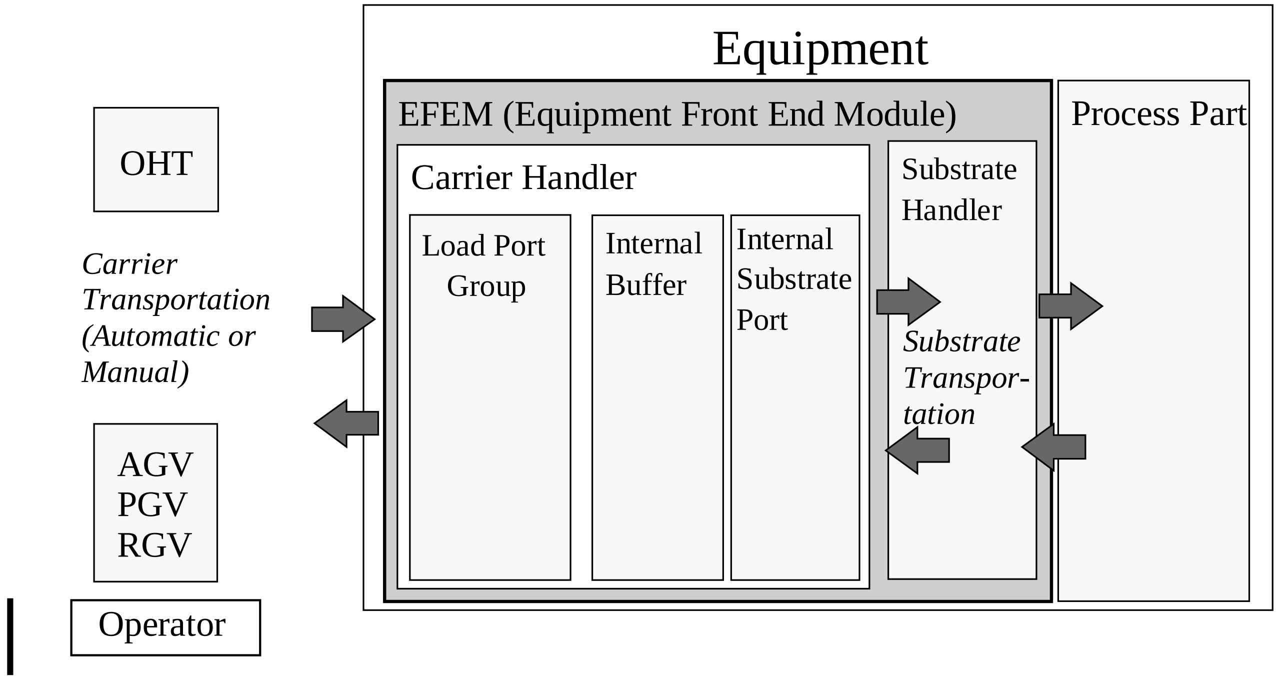

Figure 2a
Conceptual Structure of Internal Buffer Type EFEM in Equipment When Substrate Handler Is Installed Outside Process Part

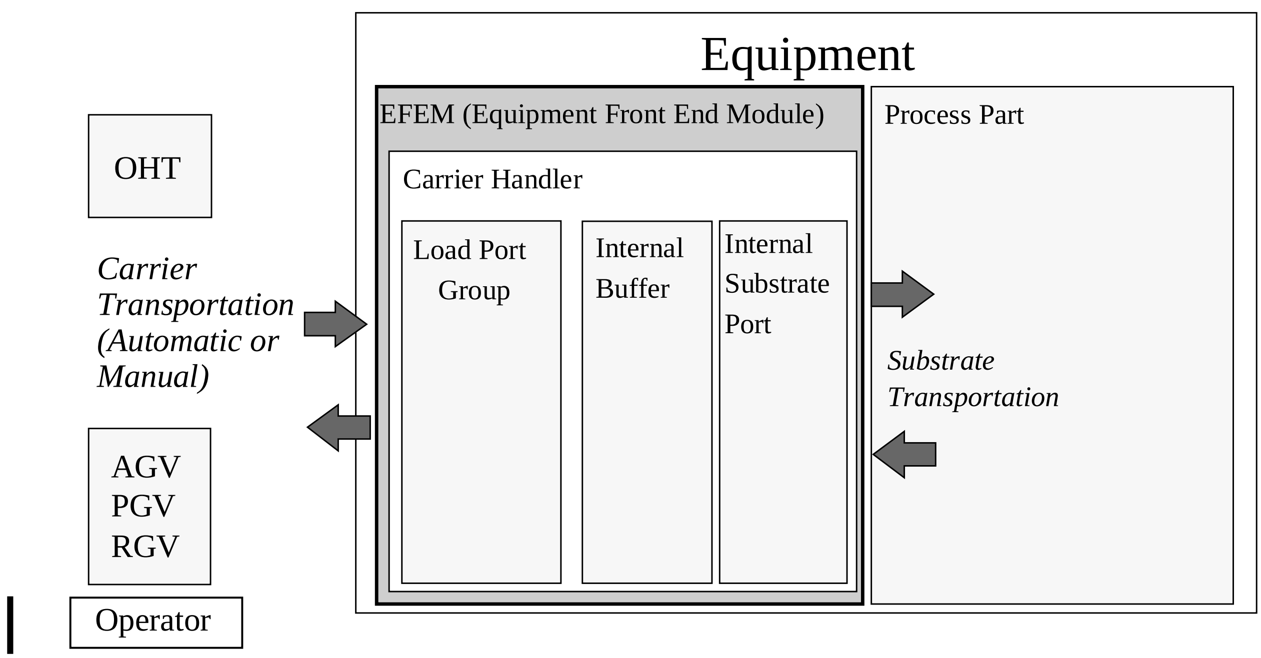

Figure 2b
Conceptual Structure of Internal Buffer Type EFEM in Equipment When Substrate Handler Is Included Inside Process Part

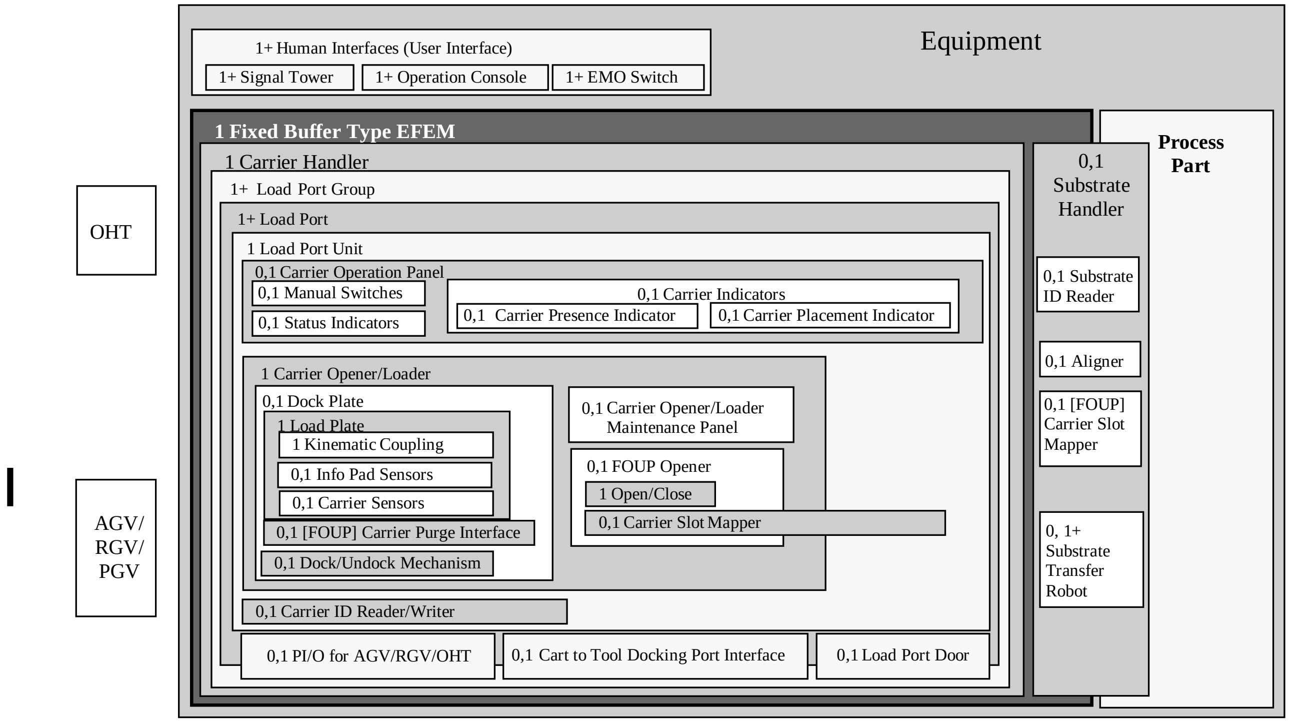

Figure 3
Fixed Buffer Type EFEM Functional Structure Model

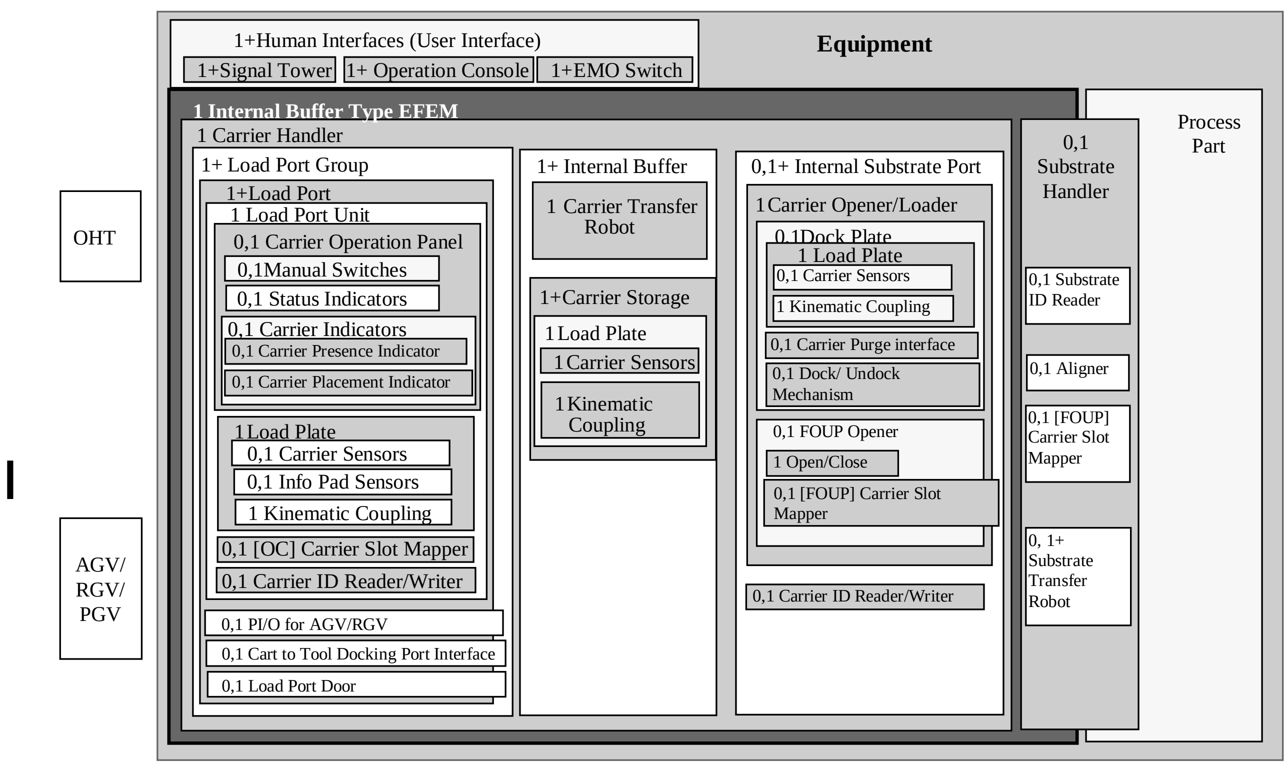

Figure 4
Internal Buffer Type EFEM Functional Structure Model

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI E101 and was approved by full letter ballot procedures on January 14, 2000 by the Japanese Regional Standards Committee.

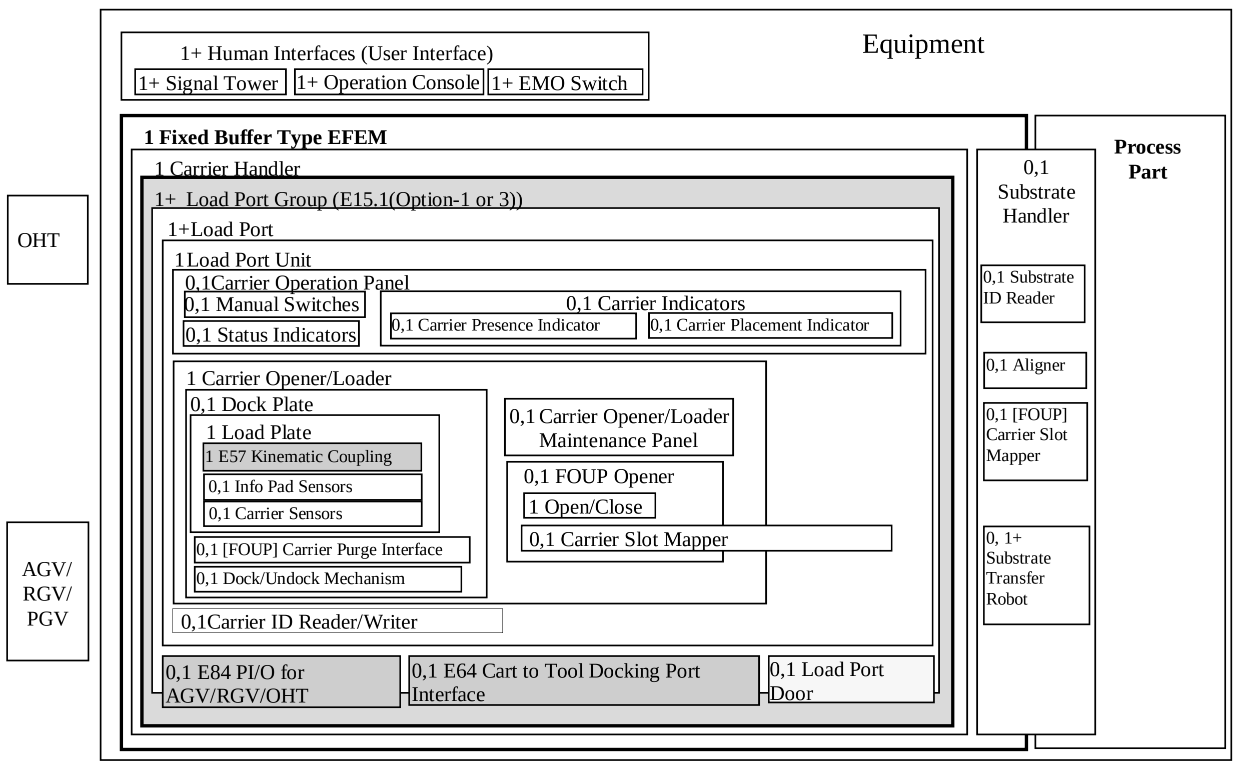

Figure A1-1
Relation between Fixed Buffer Type EFEM Functional Structure Model and Existing SEMI Standards

APPENDIX 2

NOTE: The material in this appendix is an official part of SEMI E101 and was approved by full letter ballot procedures on January 14, 2000 by the Japanese Regional Standards Committee.

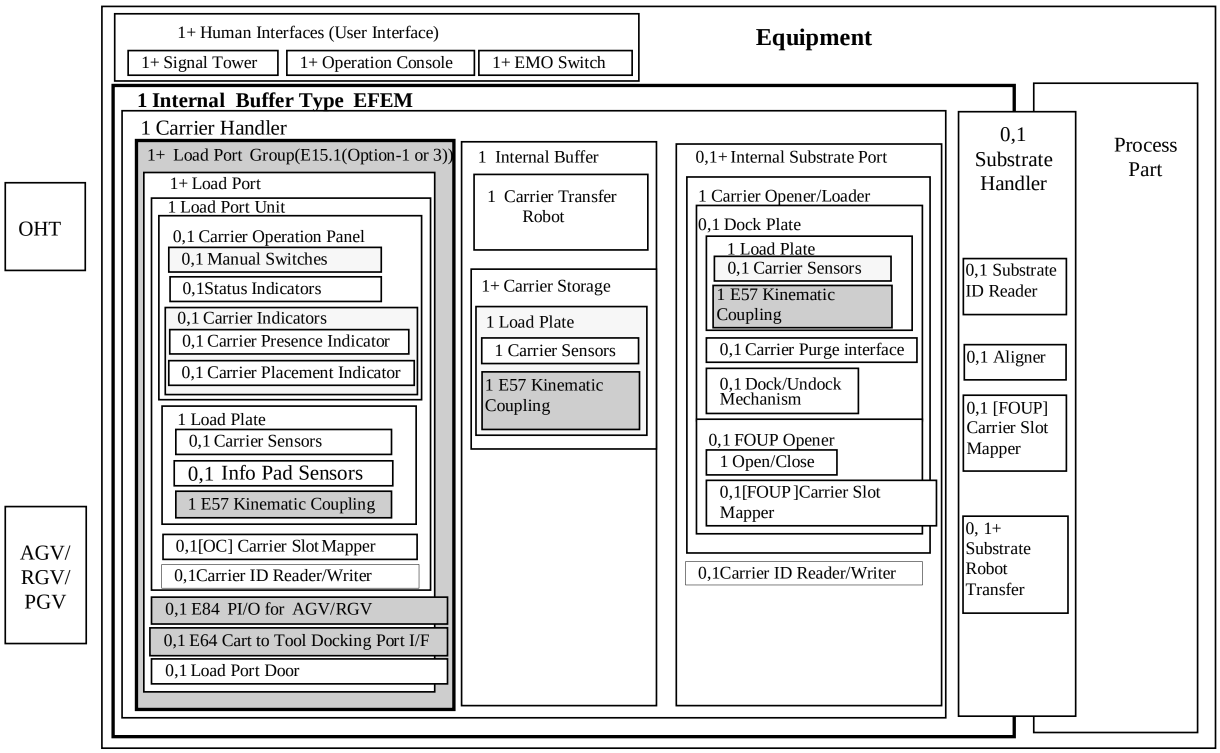

Figure A2-1
Relation between Internal Buffer Type EFEM Functional Structure Model and Existing SEMI Standards

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SEMI E103-1000
PROVISIONAL MECHANICAL SPECIFICATION FOR A 300 mm SINGLE-WAFER BOX SYSTEM THAT EMULATES A FOUP

This provisional specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on July 28, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000. Originally published June 2000.

1 Purpose

1.1 This standard specifies the carrier side of the mechanical interface between load ports (or buffers) with FIMS interfaces on process or metrology equipment and a system that includes a box that holds only one wafer (such as a test wafer) and that fits onto an adapter mechanism called a single-wafer interface (SWIF). This system appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at relevant mechanical interfaces. Only the mechanical interface between a load port with a FIMS interface and this system (of a single-wafer box and a SWIF) is specified here; the mechanical interface between the single-wafer box and the SWIF is not specified. Also not specified is the method by which the SWIF raises the carrier sensing pads when the single-wafer box is removed (see Section 5.3). This standard does not forbid the SWIF from holding more than just the single-wafer box mentioned in this standard.

2.2 This standard is provisional because the single-wafer box system is a new technology. Once interface testing is done, this standard should be modified and upgraded from provisional status.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Abbreviations & Acronyms*

4.1.1 *FOUP* — front-opening unified pod

4.1.2 *PGV* — person guided vehicle (cart)

4.1.3 *SWIF* — single-wafer interface

4.2 *Definitions*

4.2.1 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

4.2.2 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.2.3 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

4.2.4 *front-opening unified pod* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62) (as defined in SEMI E47.1).

4.2.5 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

4.2.6 *single-wafer interface* — an adapter mechanism that holds a single-wafer box and that appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

4.2.7 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

5 Requirements

5.1 *System Components* — A system that conforms to this standard must include a box that holds one wafer and that fits onto a SWIF.

5.2 *Relevant FOUP Dimensions* — The SWIF must have all of the required bottom and front features and be no larger than the maximum dimensions of a 13- or 25-wafer FOUP. However, this system (of single-wafer box and SWIF) must have info pad B in the down position (which ordinarily indicates that the carrier type is an open cassette). For example, the SWIF must comply with dimensions r67, x53, y50, y51, y52, y53, z41, z47 – z48, z47 + z49, and the upper limits on x50 and y40 (as specified in SEMI E47.1) and with dimension y33 (as specified in SEMI E62).

5.3 *Optional Automation Features* — Since the single-wafer box and/or SWIF will usually be delivered manually (possibly with a PGV), the SWIF is not required to have the other automation features of the FOUP such as the robotic handling flange on top or the fork-lift flanges on the side (although this standard does not forbid the SWIF from having such features).

5.4 *SWIF Door* — The SWIF must have a full FOUP-size door (which surrounds the door of the single-wafer box) that mates with a FIMS-compatible interface (as specified in SEMI E62) to avoid contaminating the environment on the equipment side of the FIMS interface.

5.5 *Wafer Position* — When the FIMS door is opened by the equipment, the end effector may only be able to access the middle wafer slot (wafer 7 for a SWIF that has info pad A in the down position indicating a 13-wafer carrier, and wafer 13 for a SWIF that has info pad A in the up position indicating a 25-wafer carrier), because a surface immediately behind the door may block access to the other wafer slots. Thus, batch wafer handlers will probably not work with this system.

5.6 *Wafer Clearances* — The clearance below the middle wafer must be the same as the clearance below the bottom wafer in an ordinary FOUP (z8 minus z6, both from SEMI E1.9), and the clearance above the middle wafer must be the same as the clearance above the top wafer in an ordinary FOUP (z15 from SEMI E1.9). These vertical clearances are defined in SEMI E1.9 and SEMI E47.1 and apply throughout the wafer set-down and extraction volumes for the middle wafer. The horizontal clearances shown in Figure 10 of SEMI E47.1 are also required. One possible example of such a system (of single-wafer box and SWIF) is shown in Figures 1 and 2 (with vertical clearances indicated).

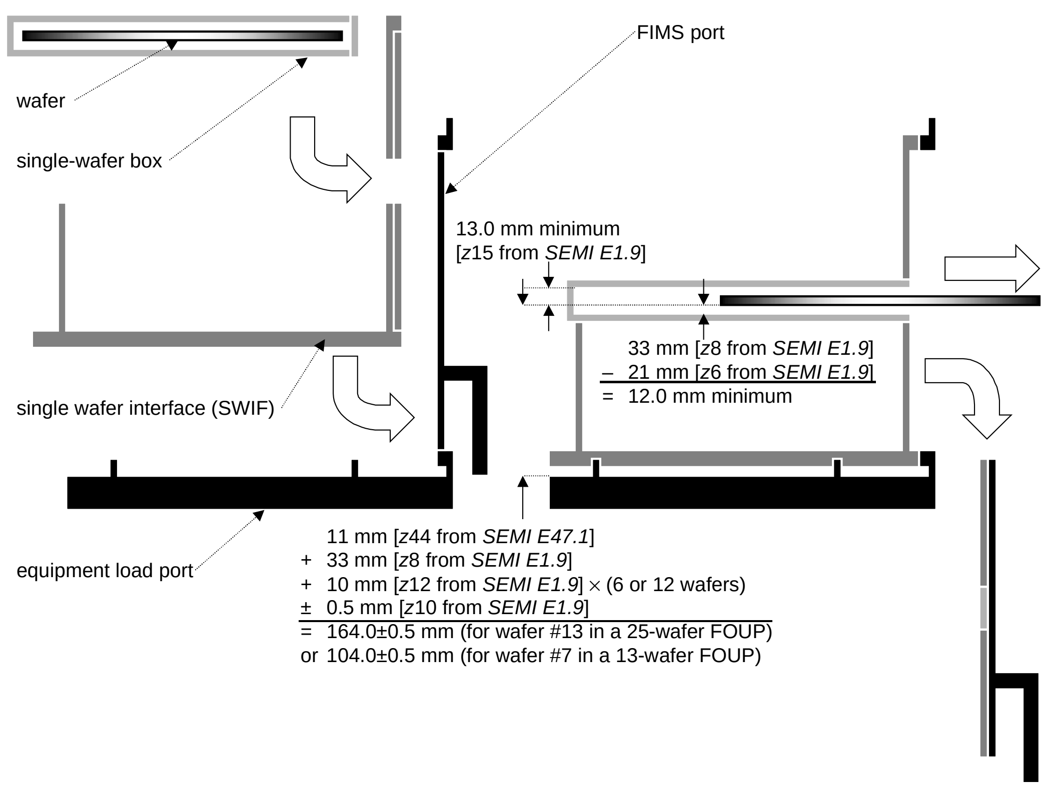


Figure 1
Side View of Example Single-Wafer Box and SWIF on a Load Port with a FIMS Interface

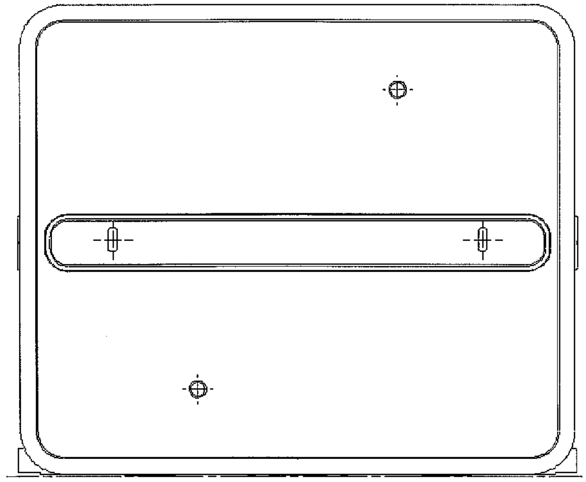


Figure 2
Front View of Example Single-Wafer Box and SWIF

5.7 *SWIF Sensing* — It is possible that the SWIF is not removed from the load port when single-wafer boxes are removed and replaced on the SWIF. However, when the single-wafer box is removed from the SWIF, all of the carrier sensing pads (defined in Section 6.6 of SEMI E1.9) on the bottom of the SWIF must be raised (so that the load port can sense a change of carriers by its carrier placement sensor, if any). However, in order to ensure that the SWIF triggers most optical carrier presence detectors on the load port, the SWIF (without a single-wafer box) must block any line of sight through a volume consisting of the smallest cylindrical section that contains all of the wafer pick-up volumes (defined in SEMI E1.9) of the corresponding FOUP (defined in SEMI E47.1). Note that this standard does not prevent the use of other kinds of carrier presence detectors (such as sensors that detect weight on the load port).

6 Related Documents

6.1 *SEMI Standards*

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E63 — Provisional Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E72 — Provisional Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI E92 — Provisional Specification for 300 mm Light Weight and Compact Box Opener/Loader and Tool-Interface Standard (BOLTS-Light)

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI S8 — Safety Guidelines for Ergonomics/ Human Factors Engineering of Semiconductor Manufacturing Equipment

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E103 but was approved for publication by full letter ballot procedures on July 28, 2000.

R1-1 In fabs in which this system (of single-wafer box and SWIF) is used, equipment should have control software algorithms that prevent end effectors and wafer slot mappers from entering the carrier except in the clearances around the middle wafer (defined in section 5.2) when the presence of this system is detected. A variety of methods for differentiating the system from ordinary FOUPs are possible.

R1-2 Using sensors, equipment can differentiate the system (of single-wafer box and SWIF) from ordinary FOUPs. For example, sensors below the info pad B location on the load port and on the FIMS door (opposite the seal zones or the reserved spaces for vacuum application on the box door) could indicate that the carrier type is an open cassette but with a FOUP door, together implying the presence of this system (of a single-wafer box and SWIF). Note that such sensors on the load port are not currently specified in any SEMI standard.

R1-3 Carrier ID tags can inform the equipment that the load port holds this system (of single-wafer box and SWIF) instead of an ordinary FOUP.

R1-4 Messages from the host computer system can inform the equipment that the load port holds this system (of single-wafer box and SWIF) instead of an ordinary FOUP.

SEMI E104-0302
SPECIFICATION FOR INTEGRATION AND GUIDELINE FOR CALIBRATION OF LOW-PRESSURE PARTICLE MONITOR

This specification was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on December 20, 2001. Initially available at www.semi.org January 2002; to be published March 2002. Originally published October 2000; previously published March 2001.

1 Purpose

1.1 The use of *in situ* particle monitoring (ISPM; particle measurements performed while the wafer resides inside the processing chamber) in low-pressure and vacuum applications provides a number of advantages for defect, process, and equipment management such as:

- Reduction of particle test wafers used for off-line tests and saving operator time,
- Optimization and real-time characterization of the process,
- Advanced process control,
- Advanced equipment control,
- Monitoring process chamber conditions, and
- Optimization of cleaning procedures and maintenance.

1.1.1 Therefore, ISPM achieves more equipment availability and faster ramp-up of the production, reduces cost of ownership, improves quality and yield. To reach these goals, ISPM needs to be easily integrated into new or existing process equipment and the acquisition as well as the analysis of the particle data needs to be automated. The ISPM sensor should not have any negative influence on the process and the measurement has to represent the main particle flow. The sensor should be designed to have a minimum negative impact on the parameters defined in SEMI E10 for the whole semiconductor process equipment, to achieve an advantage in capacity.

1.2 This standard is intended to stipulate operating conditions, mechanical, electrical, and communication interfaces for the use of Low-pressure Particle Detectors integrated in semiconductor process equipment. A guideline for a reference calibration of those sensors is intended to support correlation between measurements with different sensors.

2 Scope

2.1 This standard applies to particle measurement under low-pressure and vacuum conditions in semiconductor manufacturing equipment.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Standards*

SEMI C6.5 — Particle Specification for Grade 10/0.2 Nitrogen (N_2) and Argon (Ar) Delivered as Pipeline Gas

SEMI C6.6 — Particle Specification for Grade 10/0.1 Nitrogen (N_2) and Argon (Ar) Delivered as Pipeline Gas

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.10 — Specification for Sensor/Actuator Network Specific Device Model for an In-Situ Particle Monitor Device

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

3.2 *ASTM Standards*[1]

ASTM D1193 — Standard Specification for Reagent Water

ASTM F328 — Standard Practice for Calibration of an Airborne Particle Counter Using Monodisperse Spherical Particles

ASTM F649 — Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures

3.3 *BSI Standards*[2]

BS 3406-7 — Determination of Particle Size Distribution – Recommendations for Single Particle Light Interaction Methods

3.4 *IEC Standards*[3]

IEC 60625-1 — Programmable Measuring Instruments - Interface System (Byte Serial, Bit Parallel) - Part 1: Functional, Electrical and Mechanical Specifications, System Applications, and Requirements for the Designer and User

IEC 60625-2 — Programmable Measuring Instruments - Interface System (Byte Serial, Bit Parallel) - Part 2: Codes, Formats, Protocols, and Common Commands

IEC 60654-1 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 1: Climatic Conditions

IEC 60654-2 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 2: Power

IEC 60654-3 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 3: Mechanical Influences

IEC 60654-4 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 4: Corrosive And Erosive Influences

IEC 60801-1 — Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment - Part 1: General Introduction

3.5 *IEEE Standards*[4]

IEEE 488.1 — IEEE Standard Digital Interface for Programmable Instrumentation

IEEE 488.2 — IEEE Standard Codes, Formats, Protocols, and Common Commands for use with IEEE 488.1, IEEE Standard Digital Interface for Programmable Instrumentation

3.6 *IEST Standards*[5]

IEST RP-011 — A Glossary of Terms and Definitions Related to Contamination Control

3.7 *ISO Standards*[6]

ISO 1609 — Vacuum technology -- Dimensions (ISO-K style and ISO-F style)

ISO 2861-1 — Vacuum technology -- Quick-release couplings – Dimensions - Part 1: Clamped type (ISO-KF)

ISO 2861-2 — Vacuum technology -- Quick-release couplings – Dimensions - Part 2: Screwed type (ISO-MF)

ISO 3669 — Vacuum technology -- Bakeable flanges -- Dimensions (ISO-K-CF)

ISO 9000 — Suite of international quality standards and guidelines

ISO 13323-2 — Determination of particle size distribution – Single Particle Light Interaction Methods Part 2: Light scattering single particle light interaction devices design, performance specifications, and operation requirements

ISO 14644-1 — Cleanrooms and associated controlled environments - Part 1: Classification of air cleanliness

ISO 14644-5 — Cleanrooms and associated controlled environments - Part 5: Operation of cleanroom systems

3.8 *JIS Standards*[7]

JIS B 9921 — Light Scattering Automatic Particle Counter

3.9 *VDI Standards*[8]

VDI-Richtlinie 3489-3 — Messen von Partikeln: Methoden zur Charakterisierung und Überwachung von Prüfaerosolen - Optischer Partikelzähler (Particulate Matter Measurement: Methods of Characterizing and Monitoring Test Aerosols – Optical Particle Counter)

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA

2 British Standards Institute, Linford Wood, Milton Keynes, MK 16 6LE, Great Britain

3 International Electrotechnical Commission, 3 rue de Varembé, Case postale 131, CH-1211 Genève 20, Switzerland

4 Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA

5 Institute of Environmental Sciences and Technology, 940 East Northwest Highway, Mount Prospect, IL 60056, USA

6 ISO Central Secretariat, 1 rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

7 Japanese Standards Association, 1-24, Akasaka 4, Minatoku, Tokyo 107-8440, Japan

8 Beuth Verlag GmbH, Burggrafenstrasse 6, D-10787 Berlin, Germany

VDI-Richtlinie 3491 — Messen von Partikeln: Herstellungsverfahren für Prüfaerosole, Verdünnungssysteme (Particulate Matter Measurement: Generation of Test Aerosols, Dilution Systems)

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 COV — Coefficient of Variation

4.1.2 HEPA — High-Efficiency Particulate Air

4.1.3 ISPM — In Situ Particle Monitor

4.1.4 LDL — Lower Detectable Limit

4.1.5 LPPD — Low-Pressure Particle Detector

4.1.6 PHA — Pulse Height Analyzer

4.1.7 RPC — Reference Particle Counter

4.1.8 ULPA — Ultra-Low Penetration Air

4.2 *Definitions*

4.2.1 *accuracy of size* — the closeness of agreement between the ascertained size of the detected particle and its real size.

4.2.2 *coefficient of variation (COV)* — the width of a distribution (in %), obtained by dividing the standard deviation of the distribution by the mean of the distribution.

4.2.3 *coincidence* — the presence of two or more particles in the detection area of the particle detector at the same time, causing the particle detector to interpret the combined signal erroneously as resulting from one larger particle.

4.2.4 *concentration* — the number of particles per unit volume, at ambient temperature T_A and pressure p.

4.2.5 *concentration limit* — the particle concentration specified by the manufacturer of the particle detector at which the error due to coincidence is 10% or less.

NOTE 2: Manufacturers may specify concentration limits at error levels other than 10%.

4.2.6 *counting efficiency* — the ratio (in %) of detected concentration divided by the actual concentration of particles of a given size or range of sizes (see appendix 2).

4.2.7 *detection area* — the area, defined through the light beam and the detection optics, in which the particles are detected. Often this area is much smaller than the cross-section of the pump line or the process chamber.

4.2.8 *high-efficiency particulate air (HEPA) filter* — filter with a minimum particle-collection efficiency of 99.97% on all particles larger than 0.3 micrometer.

4.2.9 *in situ* — refers to processing steps or tests that are done without moving the wafer. Latin for “in original position”.

4.2.10 *in situ particle monitor (ISPM)* — particle monitor used under atmospheric conditions or in low-pressure, vacuum or liquid applications to detect particles while a process is running.

4.2.11 *isokinetic sampling* — sampling of particles in a moving aerosol or fluid by matching the sample probe inlet velocity (flow speed and direction) to the velocity of the moving aerosol or fluid.

4.2.12 *lower detectable limit (LDL)* — in particle measurement: the smallest particle size that a particle detector can measure at a given flow rate with a signal-to-noise ratio of at least 3 dB and with a counting efficiency of 50% ± 10%.

NOTE 3: This is a general definition of LDL. Due to the special design of most of the LPPDs, a counting efficiency of 50% can not be achieved.

4.2.13 *low-pressure particle detector (LPPD)* — optical particle sensor for use under low-pressure and vacuum conditions to measure particles or particle levels in semiconductor process equipment.

4.2.14 *monodisperse calibration particles* — particles with known optical properties, a sizing accuracy of at least 95%, and a size distribution in which the coefficient of variation is 5% or less.

4.2.15 *optical equivalent size* — the diameter of a monodisperse calibration particle that produces the same detected scattering intensity as the localized light scatterer (LLS) under investigation under identical test conditions.

4.2.16 *particle size* — for applications, size is the optical equivalent diameter of a reference sphere with known properties as detected by a given light-scattering particle counter [as defined in SEMI C6.5 and SEMI C6.6]. For calibration, size is the mean diameter of the monodisperse sphere.

4.2.17 *resolution* — the capability of the particle detector to differentiate between particles of similar size.

NOTE 4: The procedure to define resolution is discussed in Section 9.2.3.5.

4.2.18 *sensitivity* — in particle measurement: the smallest standard particle size specified by the manufacturer that an instrument, method, or system is capable of measuring under specified conditions (with a counting efficiency of 50%; see Appendix 2). Also called minimum detectable particle size.

4.2.19 *ultrafine particle* — a particle with an equivalent diameter less than 0.1 µm [as defined in ISO 14644-1].

4.2.20 *ultra-low penetration air (ULPA) filter* — filter with a minimum particle-collection efficiency of 99.9995% on the most penetrating particle size.

4.2.21 *zero count* — the maximum particle count indicated by a particle counter, in a specified period of time, that is sampling particle-free air. This value is specified by the manufacturer, and is commonly also referred to as false call rate, false count, noise, or noise level.

4.2.22 *zero gas* — in determining contaminant contribution by gas distribution system components, a purified gas that has an insignificant particle concentration above the lower detectable limit (LDL) of the analytical instrument. This gas is used for both instrument calibration and component testing.

4.3 *Symbols*

4.3.1 A_L — the detection area (mm^2), defined through detector optics and light beam of the LPPD.

4.3.2 A_{RC} — the opening area (mm^2) of the probe inlet of the reference particle counter.

4.3.3 C_L — the number concentration (cm^{-3}) of particles in the line at the LPPD.

4.3.4 C_G — the number concentration (cm^{-3}) of particles generated from aerosol generator at given V'_G.

4.3.5 D_L — the diameter of the pump line (mm) at the LPPD.

4.3.6 d_p — the diameter of the spherical particle (µm).

4.3.7 D_{RC} — the diameter of the sample drawing line (mm) for the reference particle counter.

4.3.8 D_{VM} — the diameter of the pump line (mm) at the velocity meter.

4.3.9 p — the line pressure (torr or mbar).

4.3.10 RH — the relative humidity (%).

4.3.11 T_A — the ambient temperature (° C) around the measurement or calibration system.

4.3.12 T_G — the gas temperature (° C).

4.3.13 v_L — the velocity (m/s) of the aerosol at the LPPD.

4.3.14 $v_{L,\ min}$, $v_{L,\ max}$ — for applications, the velocity range (m/s) of the aerosol at the LPPD specified by the manufacturer.

4.3.15 V'_L — the volume flow rate (l/min) in the line at the LPPD.

4.3.16 V'_G — the volume flow rate (l/min) of the aerosol sample (measured directly behind the aerosol generator).

4.3.17 v_{VM} — the velocity (m/s) of the aerosol at the velocity meter.

4.3.18 V'_{ZG} — the volume flow rate (l/min) of the zero gas.

4.3.19 $\sigma_{V,LPPD}$ — the standard deviation of the voltage sensor signal.

4.3.20 $\sigma_{p,LPPD}$ — the standard deviation of the observed particle distribution

4.3.21 $\sigma_{d,p}$ — the standard deviation of the particles given by the particle supplier

5 Mechanical Interfaces

5.1 *Flanges*

5.1.1 One of the following vacuum flanges should be used for mounting an LPPD into a pump line or on process equipment:

ISO 2861-1 and ISO 2861-2 (ISO-KF/MF)

ISO 1609 (ISO-K and ISO-F)

ISO 3669 (ISO-K-CF)

5.2 *Space, Distances, and Installation*

5.2.1 The use of an LPPD should not have a negative impact on the process performance. The sensor location in the equipment shall ensure an optimum use of the sensor sensitivity in order to allow a measurement which is representative of the main particle flow. The influence of the process and the process equipment on the LPPD shall be minimized (thermal background radiation, vibrations etc.)

5.2.2 The standard does not specify where an LPPD should be located in original equipment, or where space should be allowed for retro-fitting. It is recognized that the location is dependent on factors including transport behavior of particles, thermal background radiation etc. The designers of semiconductor process equipment should resort to the experience of application engineers of the LPPD suppliers and the end users. However, in either case designers shall take into account access requirements for maintenance and re-calibration. In the case of retro-fitting, the design should facilitate sensor installation rather than hinder it.

6 Electrical Interfaces

6.1 *Sensor/Controller Communication*

6.1.1 Depending on the choice of the LPPD supplier and the semiconductor equipment manufacturer, one of the following interfaces for data exchange between the LPPD and process equipment controller should be used.

6.1.2 *Sensor/Actuator Network (SAN)*

6.1.2.1 The electrical interfaces of the Sensor/ Actuator Network are described in the suite of SEMI E54 standards.

6.1.3 *Serial Communication*

6.1.3.1 RS 232 C (V.24/V.28)

6.1.3.2 RS 485

6.1.4 *Others*

6.1.4.1 IEEE 488 or IEC 60625

6.2 *Others*

6.2.1 *Sensor calibration output (direct analog output)*

6.2.1.1 The analog output for access to the sensor signal used for calibration purpose should be supported.

7 Communication Interfaces

7.1 *Sensor Bus Communication*

7.1.1 It is recommended to use a Sensor/Actuator Network (SAN) for the intra-tool communication between the LPPD controller and the controller of the process equipment. This communication is based on a suite of SEMI standards including a network communication standard, several common device models (DeviceNet, SDS, Lonworks, ProfiBus etc.), and the specific device model for the sensor. The Network is described by the following suite of SEMI standards: SEMI E54. The specific device model for ISPM is described by SEMI E54.10.

7.2 *SEMI Equipment Communication (SECS)*

7.2.1 If LPPD controllers provide the collected particle data to the process equipment controller, factory automation system, or SPC system, the SECS tool-to-host communication could be used. SECS is described in the following standards:

- SEMI E5
- SEMI E4
- SEMI E37

7.3 *Attribute Definitions*

7.3.1 SEMI E54.10 addresses the minimum attributes, services and behavior an ISPM-device shall support. If any attributes and services are used by communication of the ISPM and the equipment controller via IEEE 488 (IEC 60625) or serial communication, they should be concurring.

8 Operating Conditions

8.1 To specify the operating conditions of an LPPD (temperature, humidity, electromagnetic compatibility, vibrations etc.) refer to the following standards:

- IEC 60654-1
- IEC 60654-2
- IEC 60654-3
- IEC 60654-4
- IEC 60801-1

8.2 *Temperature*

8.2.1 The LPPD should work correctly at an ambient temperature range T_A as specified in ISO 14644-5. If the use of an LPPD at an extended ambient temperature range is required, the specific LPPD should comply with these conditions.

8.2.2 The temperature T_G inside the pump line or inside the process equipment depends on the actual application. The application engineers shall check the use of LPPDs under these specific conditions. The temperature T_G is measured at the flange which the LPPD is mounted on.

8.3 *Humidity*

8.3.1 The LPPD should work correctly at an ambient humidity range RH as specified in ISO 14644-5. If the use of an LPPD at an extended ambient humidity range is required, the specific LPPD should comply with these conditions.

8.4 *Electromagnetic Compatibility*

8.4.1 The equipment should comply with SEMI E33.

8.4.2 Sensors will be incorporated into equipment either as original equipment or retro-fitted. In either case, the sensors or the equipment of which they are a part should comply with the current regulations covering EMC in the country or region where the equipment or sensor is used.

8.5 *Vibrations*

8.5.1 Process equipment designers are advised to consider the impact of vibration on the performance of the sensor while it is collecting data. Therefore, they should minimize vibrations. The designers of the LPPD sensors are also advised to consider the impact of vibrations on the equipment at a time the sensor is not collecting any data. It might be possible that these vibrations are stronger than those occurring while the sensor is collecting data.

9 Reference Calibration Procedure

9.1 The response of real contamination particles, typically with refractive indices and shapes different from calibration particles, will differ slightly from the results obtained by the procedures in this document. It is known that LPPDs with different optical design may not produce the same data from identical aerosol samples. This may happen even with similar LPPDs if calibration differences have occurred. Therefore, before the first use the sensor should be calibrated by the manufacturer. This calibration should be compliant with or should be reviewed with the following reference calibration equipment and procedure. This reference calibration allows the characterization of the performance of the LPPD under test. The LPPD should be recalibrated at regular intervals and also in case of unusual measurement readings to ensure correct results.

9.1.1 The parameters calibrated for LPPDs with sizing capability are:

- Sizing calibration,
- Resolution,
- Zero counting,
- Counting efficiency, and
- Sensitivity.

9.1.2 The parameters calibrated for LPPDs with non-sizing capability are:

- Zero counting, and
- Counting efficiency.

9.1.3 Field calibration may not necessarily require the calibration of all parameters performed by calibration at the sensor manufacturers site.

9.1.4 Due to the fact that different LPPDs might be working with different detection areas A_L, the number of counts should be printed out in counts per mm^2 detection area. Therefore, a comparison of the measurement results of different LPPDs is possible. The size of the detection area A_L shall be reported in the calibration report form. Any changes of calibration parameters or of the calibration setup shall be reported in the calibration report form. A copy of the calibration report form shall be delivered with the sensor.

9.2 *Apparatus*

9.2.1 *Materials*

9.2.1.1 *Particles*

9.2.1.1.1 Calibration particles are polymer spheres composed of polystyrene or a similar polymer, having a refractive index of 1.58-1.61+ 0i (absorption coefficient $\alpha = 0$), a sizing accuracy of at least 95%, and a size distribution in which the coefficient of variation is 5% or less. They should be traceable to a nationally or internationally recognized standard (e.g. NIST[9]).

9.2.1.1.2 The calibration particles are normally supplied in concentrations too high to be used directly in aerosol generators. The particles should be dispersed and diluted in either deionized, distilled water in accordance with ASTM D1193, Type 1, or Isopropanol. The diluent should be cleaned using a filter with a pore size no more than 10% of the size of the particles being used. The solution should be stored in a clean container. For generation and dilution of the suspension see Appendix 3. After generation the particles should be neutralized to avoid surface charge. For all tests described in this document, the concentration should be no more than 25% of the maximum recommended concentration limit specified by the manufacturer. For calibration a suitable set of particle sizes shall be used. This set should contain at least 5 sizes that cover the LDL size to at least 80% of the specified maximum size measurement capability of the LPPD.

NOTE 5: Most of the ISPM sensors are based on light scattering. The intensity of the scattered light detected by a photodetector depends on intensity, polarization state, and wavelength of the incident light beam, diameter, shape, and refractive index of the particle and the suspension fluid, as well as on the geometrical layout of the collection optics and detector. In the particle size range near the wavelength ($0.1\lambda < d_P < 10\lambda$), large oscillations can be seen in the intensity curve of the light scattered by spherical particles as a function of all these parameters. This phenomenon should be taken into account when selecting a suitable set of particle sizes for calibration. The used calibration particles should be within a monotonic response range of the LPPD response curve.

9.2.1.2 *Zero Gas*

9.2.1.2.1 Clean air or nitrogen filtered with a ULPA filter.

NOTE 6: The calibration will be executed under atmospheric pressure and zero gas. In semiconductor manufacturing, pressure and process gases will differ from the calibration conditions. This will affect the refractive index ratio of the particles and the process gas and consequently the scattering from the particles.

9 National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899-0001, USA

9.2.1.3 *Surfaces*

9.2.1.3.1 The materials of pump lines and other components should be conductive to minimize electrostatic interaction with the particles.

9.2.2 *Instrumentation (see Figure 1)* — Some LPPDs may require specialized equipment not generally available. Please contact the LPPD manufacturer.

9.2.2.1 *Fan System*

9.2.2.1.1 The fan or pump system should be adjustable to transport the aerosol and the zero gas within the stipulated velocity range $v_{L,\ min}$ ... $v_{L,max}$, specified by the manufacturer of the LPPD.

9.2.2.2 *Filter System*

9.2.2.2.1 The ULPA filter system is used for generation of zero gas. The filter system should be capable of removing particles at the minimum size detectable by the LPPD or the reference particle counter.

9.2.2.3 *Aerosol Generator*

9.2.2.3.1 An atomizer converts the monodisperse particle suspension to an aerosol by using compressed zero gas for generation and transportation of the particles. The aerosol generator should generate monodisperse particles as defined in Section 9.2.1.1 in constant and reproducible concentration C_G under constant and reproducible volume flow rate V'_G. The variation in particle concentration shall be no more than 10% as measured by the reference particle counter over a time period of 10 times or more of the sample measurement time. The generation should comply with the German VDI-Richtlinie 3491, or an equivalent standard in other countries.

9.2.2.4 *Aerosol dryer*

9.2.2.4.1 The monodisperse polymer spheres in the test aerosol shall be thoroughly dry to avoid that the particles have a water layer which would increase their size. A diffusion dryer, another appropriate instrument, or adequately dry dilution air should be used to dry the particles. The diffusion dryer uses silica gel desiccant to remove the moisture. The desiccant shall either be new or freshly regenerated. The design flow rate of the aerosol dryer shall at least match the output flow rate of the aerosol generator.

NOTE 7: Some diffusion dryers may precipitate polymer spheres and add other particles when the aerosol gets in direct contact with the silica gel.

9.2.2.5 *Neutralizer*

9.2.2.5.1 An aerosol neutralizer should be connected in line with the dryer to reduce electrostatic charges on the dry polymer spheres and to avoid electrostatic interaction with each other or the line wall. The design flow rate of the aerosol neutralizer shall at least match the output flow rate of the aerosol generator.

NOTE 8: Some electrostatic neutralizers may produce a large number of ultra-fine particles which will combine with the calibration aerosol.

9.2.2.6 *Aerosol Size Separator*

9.2.2.6.1 In the case of calibration with ultra-fine particles, a system should be used to separate single polymer spheres from the residual particles resulting from vaporization of solutions and aggregate particles consisting of several spheres. The size separation could be achieved with an electrostatic classifier or a diffusion battery.

9.2.2.7 *Aerosol Dilution*

9.2.2.7.1 If the particle concentration behind the aerosol generator is too high, the particle flow shall be diluted to achieve the required concentration and to avoid coincidence errors. The dilution should comply with the German VDI-Richtlinie 3491, or an equivalent standard in other countries.

9.2.2.8 *Aerosol Line System*

9.2.2.8.1 The system consisting of

- the aerosol generator,
- the aerosol dryer,
- the neutralizer,
- the particle size separator,
- the dilution stage, and
- tubing connecting the devices with each other and the filtered, dried and compressed zero gas.

9.2.2.8.2 The line system should be smooth, conductive, and electrically grounded to minimize electrostatic interaction of the particles with line walls and the particles themselves. The line should be as short and straight as possible with no bends with a radius of curvature less than 100 mm. Leak-free connections of the line and all devices should be ensured using appropriate fittings.

9.2.2.8.3 Figure 1 illustrates a recommended calibration aerosol generation system.

9.2.2.9 *Flow Control*

9.2.2.9.1 The velocity of aerosol and the zero gas should be within the stipulated range $v_{L,\ min}$ ... $v_{L,max}$, specified by the manufacturer of the LPPD. Dependent on the line diameter D_L, a stipulated aerosol flow is necessary. The velocity meter (e.g. thermoanemometer) or flow meter should be mounted in a line with known diameter D_{VM}.

NOTE 9: The aerosol drawn by the reference particle counter influences the velocity or flow measured by the velocity meter or flow meter if it is mounted behind the probe inlet. This is taken into account when calculating and adjusting the flow and velocity v_L at the LPPD. If the velocity meter or flow meter is mounted in front of the probe inlet of the reference particle counter, the device should have no influence on the particle size distribution measured by the reference particle counter.

9.2.2.10 *Calibration Line System*

9.2.2.10.1 The system consisting of

- a device to inject the particles into the zero gas,
- a device to mix the aerosol sample with the zero gas to obtain uniform particle concentration,
- a device to adapt the LPPD into the line (diameter D_L),
- a device to adapt the velocity meter or the flow meter,
- a device (diameter $D_{RC} = D_L$, same particle concentration as at the LPPD) to draw a defined, isokinetic sample from the line for the reference particle counter (the opening area of the probe inlet should be reported in the calibration report form), and
- tubing connecting the devices with each other and with the fan and filter system.

9.2.2.10.2 The line system should be smooth, conductive, and electrically grounded to minimize electrostatic interaction of the particles with line walls and the particles themselves. The line should be as short and straight as possible with no bends with a radius of curvature less than 100 mm. Leak-free connections of the line and all devices should be ensured using appropriate fittings.

9.2.2.10.3 Figure 1 illustrates a recommended LPPD calibration system.

NOTE 10: The distance between the device to adapt the LPPD under test and the device for sample acquisition for the reference particle counter should be as short as possible to minimize particle loss and to ensure comparable particle concentrations.

9.2.2.11 *Reference Particle Counter (RPC)*

9.2.2.11.1 The reference particle counter is required to measure the actual concentration of the monodisperse aerosol and the quality of the zero gas inside the line. Therefore, the counting efficiency of the reference particle counter is defined as 100% over the range of particle sizes used in the test. The resolution should be better than 10% at the lower detection limit of the LPPD under test. The values of the measurement should be printed out in counts per mm^2 opening area A_{RC} of the probe inlet. The sample transit line from the probe inlet and the reference particle counter should be as short and as straight as possible. Smooth, conductive, and electrically grounded materials should be used.

9.2.2.12 *Sensor Window Temperature*

9.2.2.12.1 Some LPPDs have the capability to heat their sensor windows to avoid coating of the window. A device to measure and to adjust the sensor window temperature within the operating range (measurable to 5%) should be installed in the calibration setup. The thermometer should be calibrated with an accuracy of 0.2° C.

9.2.2.13 *Pulse Height Analyzer (PHA)*

9.2.2.13.1 The external analyzer is connected with the analog sensor calibration output. The PHA should have at least 64 channels and a resolution of at least 1% of the average voltage that will be measured. The use of a PHA, which is built into the sensor electronics, is allowed if this PHA meets the criteria mentioned above. The required range and speed will depend on the performance of the LPPD under test. These parameters should be obtained by the LPPD manufacturer.

9.2.2.14 *Environmental Monitoring*

9.2.2.14.1 The environmental temperature T_A is measured by a thermometer calibrated with an accuracy of 0.2° C.

9.2.2.14.2 The environmental relative humidity RH is measured by a hygrometer.

9.2.2.14.3 The atmospheric pressure p is measured by a barometer calibrated with an accuracy of 133 Pa.

9.2.2.15 All instruments used for the reference calibration procedure shall have been checked for valid calibration in accordance with ISO 9000. Record all calibration data.

9.2.3 *Setup and Schematic*

9.2.3.1 See Figure 1.

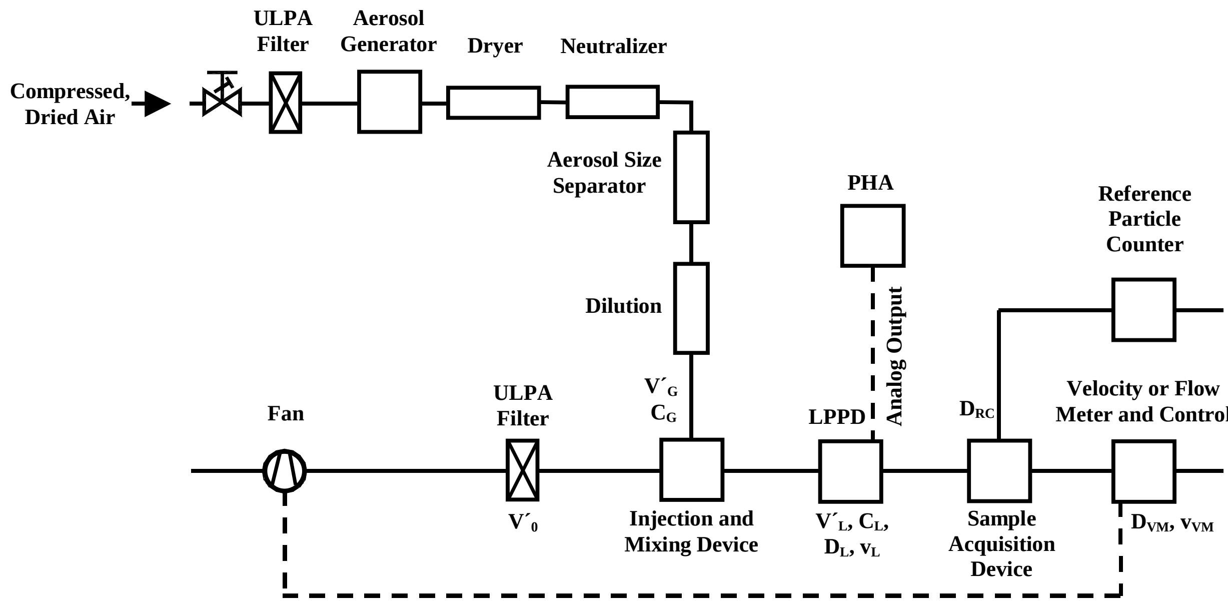


Figure 1
Calibration setup and schematic

9.3 *Calibration Procedure*

NOTE 11: Specific procedures for calibrating different LPPDs can vary considerably not only between manufacturers but between instrument models. For this reason, this document cannot provide detailed procedures for calibrating every LPPD. For detailed procedures for calibrating a specific LPPD, contact the manufacturer. The calibration should be performed by a skilled technician.

9.3.1 If the aerosol flow rate is varied, then particle residence time in the detection area A_L will also vary. This results in pulses of varying duration. Therefore, the particle velocity v_L at the LPPD should be constant and independent of the line diameter D_L. The fan has to be regulated so that the aerosol velocity at the velocity meter is $v_{VM} = v_L\ D^2_L\ /\ D^2_{VM}$. At a constant volume flow rate V'_G (depending on the pressure of the compressed air) and constant number concentration C_G the level of number concentration C_L reaches a value dependent on line diameter D_L at constant velocity v_L. With the known detection area A_L of the LPPD, the number of particles per time (counts per mm^2 detection area per time) is defined. The RPC monitors the number of particles C_L of the aerosol generator and the zero air inside the line.

9.3.2 If the response signal for the used particle size does not meet the expectations, the operator might use another particle size within the required size range.

9.3.3 *Calibration Parameters*

9.3.3.1 The sample measurement time for the calibration with each particle size should be at least 30 seconds to avoid statistical errors.

9.3.3.2 The calibration is to be performed at ambient atmospheric pressure in a controlled environment (temperature, humidity, vibrations).

9.3.3.3 The calibration of the LPPD is to be executed in a line diameter D_L in which the LPPD should be installed by the user.

9.3.3.4 Fixed particle concentration at the LPPD C_P to ensure that the coincidence error is always less than 10%.

9.3.3.5 Fixed velocity at the LPPD: v_L = 1 m/s (independent of line diameter at the LPPD).

9.3.3.5.1 Some LPPDs, e.g. a scanning LPPD for the use inside a process chamber, require a different velocity than 1 m/s for calibration. In such cases the used aerosol velocity at the location of the LPPD shall be reported in the calibration report form.

9.3.4 *Initial Setup*

9.3.4.1 Connect the aerosol generator to a supply of filtered, dried, and compressed zero gas (see Figure 1). Connect a dryer, neutralizer, and size separator (if necessary) to the aerosol outlet of the particle generator. If a dilution of the aerosol before the injection in the calibration line is necessary, install a dilution stage behind the size separator.

9.3.4.2 Connect the aerosol line to the calibration line. Mount the LPPD under test behind the injection and mixing device. Install the sample acquisition device and the velocity or flow meter into the calibration line.

9.3.4.3 Connect a PHA to the sensor calibration output if an appropriate built-in PHA is not available.

9.3.4.4 Before starting the following procedures, make sure all instruments are turned on and allow a certain time for warm-up and temperature stabilization.

9.3.4.5 Purge the aerosol line and the calibration line with filtered and dried air for a minimum of 30 minutes.

9.3.4.6 Check the quality of the zero gas and the condition of the calibration line using the RPC. Collect counts for three one-minute periods and determine the average number of particles reported in counts per minute. The volume flow of the zero gas shall be enough for correct operation of the RPC. Record the cumulative particle count reported for the zero gas for particles equal to and larger than the LDL of the LPPD under test.

9.3.4.7 Clean the aerosol generator liquid reservoir and fill it with clean diluent (particle-free deionized or destilled water or Isopropanol). Run the aerosol generator and adjust the pressure and flow rates as recommended by the aerosol generator manufacturer. Check the condition of the aerosol line using the RPC. Collect counts for three one-minute periods and determine the average number of particles reported per liter of air. If the number exceeds 1 particle per liter air, the diluent shall be refiltered before further use. The average number of particles (counts per minute) should be reported in the calibration report form.

9.3.4.8 Adjust the volume flow through the calibration line for the stipulated aerosol velocity at the LPPD under test.

9.3.4.9 Allow a certain time for stabilization of the adjusted calibration parameters before any test is performed.

9.3.5 *Sizing LPPD*

NOTE 12: For more information and background see Appendix 2.

9.3.5.1 *Size Calibration*

NOTE 13: To define the calibration settings either the mode or median of the voltage pulse distribution could be used. The use of the modal procedure is common. The calibration report form should identify the used method.

9.3.5.1.1 By running different monodisperse aerosols (with v_L and $V'_L = V'_0 + V'_G$), size calibration is performed. Begin with the largest particles for which a calibration value is required. Select the particle size range for which calibration is required. Be sure that the particle concentration is low enough that predominantly individual pulses are generated by the LPPD. Accumulate enough data to avoid statistical errors. The procedure is repeated for each particle size of interest. Determine the average LPPD pulse voltage amplitude with the PHA.

9.3.5.1.2 The mode of the voltage pulse distribution is determined by the highest point in the distribution. If the distribution is interfered with noise near the peak and the peak is not well defined, the data should be averaged and the peak of the averaged distribution should be used defining the mode.

9.3.5.1.3 The median voltage is determined by defining a “Region of Interest” (ROI) which includes the peak representing the voltage pulses from single polymer spheres. The PHA determines the total number of pulses under this peak. The median voltage is that voltage which devises the number of pulses in the region such that half are greater and half are less than the median.

NOTE 14: If the procedure is carried out for the smallest size of which the LPPD is specified, record the noise level of the LPPD. The average voltage for this size should be at least 10% higher than stated noise level voltage at which one noise pulse occurs in one minute.

9.3.5.1.4 The particle size and the average voltage should be reported in the calibration report form.

9.3.5.1.5 For calibration checks, a reference particle counter (RPC) with a good sizing capability could be used. The counting efficiency of the RPC is defined as 100% for the particle sizes used in test. The counts of the RPC and the LPPD under test in the corresponding channel should be normalized to a standard detection area (mm^2). The ratio of these counts (in %), the employed particle size and the threshold settings should be recorded in the calibration report form.

9.3.5.2 *Zero Counting*

NOTE 15: The intent of this procedure is not to adjust the thresholds for the zero count rate but to verify whether the LPPD is within its specification.

9.3.5.2.1 By running zero gas (with v_L and $V'_L = V'_0$) through the system the zero count rate, specified by the sensor manufacturer, is checked. The reference particle counter is used to check the quality of the zero gas. The minimum acceptable sample time is 10 minutes. The sampling time shall be long enough to provide adequate sampling statistics. The zero count rate (average counts per minute) should be recorded in the calibration report form.

9.3.5.3 *Counting Efficiency*

NOTE 16: The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

9.3.5.3.1 By running a monodisperse aerosol (with v_L and $V'_L = V'_0 + V'_G$), the maximum of detected particles is counted. The ratio of the counts of the LPPD standardized per mm^2 to the counts of the reference particle counter per mm^2 detection area (in %) for each particle size should be recorded in the calibration report form.

9.3.5.4 *Sensitivity*

9.3.5.4.1 By running different monodisperse aerosols (with v_L and $V'_L = V'_0 + V'_G$) with particle sizes at the expected sensitivity where the counting efficiency is between 40% and 60%, the sensitivity is verified. The counts of the LPPD per mm^2 detection area compared to the counts of the reference particle counter per mm^2 detection area (in %) should be determined. The determined particle size shall have a counting efficiency between 40% and 60% and should be recorded in the calibration report form.

9.3.5.5 *Particle Size Resolution*

NOTE 17: The particle size shall be at least twice the lower counting limit to ensure measurement of the entire distribution and accurate characterization of the calibration response curve below the particle size of interest. The resolution is specified by the coefficient of variation (in %) obtained by dividing the portion of the standard deviation of the distribution σ_{LPPD} that is contributed by the LPPD by the mean size of the distribution d_p.

9.3.5.5.1 Record the size d_p and the standard deviation $\sigma_{d,p}$ of the used particles in the calibration report form. By running a monodisperse aerosol (with v_L and $V'_L = V'_0 + V'_G$), determine the standard deviation of the observed particle distribution $\sigma_{p,LPPD}$. To determine the standard deviation of the pure sensor signal $\sigma_{V,LPPD}$, a pulse height analyzer can measure the voltage peaks at the analog sensor calibration output. The portion of the standard deviation of the distribution σ_{LPPD} that is contributed by the LPPD is calculated by the following formula:

$$\sigma_{LPPD} = \sqrt{(\sigma_{p,LPPD})^2 - (\sigma_{d,p})^2}$$

9.3.5.5.2 The value of the standard deviation of the observed distribution $\sigma_{p,LPPD}$, the standard deviation of the sensor signal $\sigma_{V,LPPD}$, and the coefficient of variation (in %) should be recorded in the calibration report form.

9.3.6 *Non-Sizing LPPD*

NOTE 18: For more information and background see Appendix 2.

9.3.6.1 *Zero Counting*

9.3.6.1.1 See Section 9.3.5.2.

9.3.6.2 *Counting Efficiency*

NOTE 19: The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

9.3.6.2.1 By running a monodisperse aerosol (using the smallest particles size which can be counted with v_L and $V'_L = V'_0 + V'_G$), the maximum of detected particles is counted. The counts of the LPPD per mm^2 detection area compared to the counts of the reference particle counter per mm^2 detection area (in %) and the employed particle size should be recorded in the calibration report form. These measurements should be executed for the defined set of particle sizes including one size no larger than 1.3 times the sensitivity limit as specified by the manufacturer.

9.3.7 *Interim Procedure*

9.3.7.1 Between the settings of the separate thresholds or the runs with different particle sizes, the system should be purged with zero gas for a sufficient time. The aerosol generator should be rinsed with clean diluent for a sufficient time before adding new suspension of particles with other size.

10 Calibration Report Form

10.1 The calibration report form shall contain the following information:

10.1.1 General part:

- Date and time of calibration
- Name of the operator
- Manufacturer of the LPPD
- Model and serial number of the LPPD to be calibrated (if sensor and counter are separate, model and serial number for each)
- Size of the detection area (if detection area is dependent on the particle size, all established values)
- Model, serial number, manufacturer, and date of last calibration of the reference particle counter
- Performance of the reference particle counter (volume flow, sensitivity, zero count rate)
- Environmental conditions: temperature T_A, relative humidity RH, pressure p
- Quality of zero gas as measured with the reference particle counter (counts per minute)
- Specifications of the particles used for calibration (manufacturer, certified size and tolerance, standard deviation $\sigma_{d,p}$, coefficient of variation, refractive index, lot number)
- Calibration parameters: particle concentration C_L, particle velocity v_L at the location of the LPPD, line diameter D_L, opening area A_{RC} of the probe inlet for each particle size
- Calibration procedure: sizing or non-sizing

10.1.2 For sizing LPPD:

- Size calibration: value of the average voltage of the different particle sizes, employed particle sizes, mode or median method
- Size calibration check: values of the thresholds, employed particle sizes, ratio of the normalized counts in the corresponding channel (in %)
- Zero counting: value of the zero count rate (average counts per minute), sampling time
- Particle size resolution: value of coefficient of variation, value of standard deviation of the observed distribution, mean size of the distribution, value of standard deviation of the sensor signal, employed particle sizes
- Counting efficiency: value of the counting efficiency (in %), employed particle sizes

10.1.3 For non-sizing LPPD:

- Zero counting: value of the zero count rate (average counts per minute), sampling time
- Counting efficiency: value of the counting efficiency (in %), employed particle sizes

10.2 Report significant variations from data reported from the previous calibration.

11 Related Documents

NOTE 20: These publications related to particle measurement, vacuum ISPM, and calibration are just informative to improve understanding of these standard.

Raasch, J.; Umhauer, H.: “Errors in Determination of Particle Size Distributions Caused by Coincidence in Optical Particle Counters” Particle Characterization 3, 1990, 424-427

Jaenicke, R.: “The Optical Particle Counter: Cross Sensitivity and Coincidence” J. Aerosol Sci., 30(5), 1972, 95-111

Borden, P.: “Monitoring Vacuum Process Equipment: In Situ Monitors – Design and Specification” Microcontamination, 1991, 43-47

Raabe, O.G.: “The Generation of Aerosols of Fine Particles” Fine Particles, Ed. Liu, B.; Academic Press, New York, 1976, 57-110

APPENDIX 1
PERFORMANCE TESTING

NOTE: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A1-1 The definitions of parameters and measurement of the terms described in SEMI E10 applies also to LPPDs and combined LPPD/process equipment.

APPENDIX 2
CALIBRATION NOTES

NOTE: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A2-1 Size Calibration

A2-1.1 Size calibration is performed with monodisperse particles with known sizes and known optical properties. The procedure establishes the voltage response of the LPPD for these particles. The reported size for unknown particles is the same size of the monodisperse particle whose voltage response is the voltage pulse produced by the unknown particle (called Optical Equivalent Size).

A2-1.2 If an LPPD is able to detect all of the distribution (see counting efficiency) generated by a monodisperse aerosol and the size of the particle standard is known, the calibrating of an LPPD without a reference particle counter is possible. Ideally, the data collected by the LPPD observing a monodisperse aerosol would describe a Gaussian particle size distribution. However, the reported voltage pulse height distribution is often not symmetric. Therefore, the mode and modal values of the pulse height distribution are not equal. The thresholds for different particle sizes are set as the mode or median value of the observed distribution. The modal voltage method is commonly used.

A2-1.3 The intensity of the scattered light detected by a photodetector depends on intensity, polarization state, and wavelength of the incident light beam, diameter, shape, and refractive index of the particle, as well as on the geometrical layout of the collection optics and detector. In the particle size range near the wavelength ($0.1\lambda < d_P < 10\lambda$), large oscillations can be seen in the intensity curve of the light scattered by spherical particles as a function of all these parameters. Therefore, the response curve might not be monotonic. Particles of more than one size will produce the same voltage output signal. The calibration particles should be chosen so that their response is not included in such reversals of the calibration curves.

A2-1.4 For calibration checks, a reference particle counter (RPC) with a good sizing capability could be used. The counting efficiency of the RPC shall be 100% for the particle sizes used in test. The counts of the RPC and the LPPD under test in the corresponding channel should be normalized to a standard detection area (mm^2).

A2-2 Particle Size Resolution

A2-2.1 Particle size resolution of a particle detector describes its capability to differentiate between particles of nearly the same size, or it is a measure of the range of sizes which the counter would assign to a particular particle if its size was determined repeatedly. The resolution is specified by the coefficient of variation (in %) obtained by dividing the portion of the standard deviation of the distribution σ_{LPPD} that is contributed by the LPPD by the mean particle size.

A2-2.2 The employed particle size should be at least 2 times larger than the lower detection limit of the instrument and is within a monotonic response range of the LPPD response curve. The size d_p and the standard deviation $\sigma_{d,p}$ of the used particles is necessary to calculate the resolution.

A2-2.3 To determine the resolution, the standard deviation of the observed particle distribution $\sigma_{p,LPPD}$ is calculated. The quality of the photodetector is checked by determining the standard deviation of the pure sensor signal $\sigma_{V,LPPD}$ at the analog calibration output with a pulse height analyzer. The σ_{LPPD} is calculated by the following formula:

$$\sigma_{LPPD} = \sqrt{(\sigma_{p,LPPD})^2 - (\sigma_{d,p})^2}$$

A2-3 Zero Counting

A2-3.1 The intent of this procedure is not to adjust the thresholds for the zero count rate but to verify whether the LPPD is within its specification. It is assumed that the zero count level of a correct operating LPPD is sufficiently better than its specification. Failure of the verification test is due to a physical failure within the LPPD and not to statistical variation in the measurement.

A2-3.2 The output of a photodetector and the electronic circuits of the particle detector is afflicted with noise. The zero count rate verification is carried out to ensure that data, especially near the detection limit of the LPPD, is generated by particles rather than by noise. To achieve this goal, the basic thresholds for the LDL are to be set so that a signal-to-noise ratio of at least 3 dB is ensured. The sampling time shall be long enough to provide adequate sampling statistics.

A2-4 Counting Efficiency

A2-4.1 The counting efficiency for a specific particle size is defined as the ratio of the detected concentration of particles to the concentration actually present. The determination of the counting efficiency of an LPPD requires particles of known size and concentration in the aerosol. The counting efficiency is affected by several factors.

- First, the counting efficiency is dependent on a specific particle size.
- The effect of particle concentration is addressed under zero counting and coincidence.
- Due to inhomogeneous light intensity within the detection area of the particle counter, not all small particles near the lower detection limit of the instrument are detected.
- If the sampling flow is not completely contained within the defined detection area, then some portions of the aerosol will not be counted.

A2-4.2 Ideally, the counting efficiency of a particle counter covering 100% of the line cross-section area as detection area would consist of a step function at the point of the LDL. Real particle detectors have a gradual transition (efficiency curve) instead of a step function. The point with 50% detection probability of all particles of a given size moving through the detection area is often used as a reference point. The corresponding particle size is called the minimum detectable particle size (see sensitivity). If the slope of the efficiency curve for two detectors with the same specified 50% efficiency point is different, the two detectors may show different particle counts for the same polydisperse aerosol. To define an efficiency curve, more than one particle size, e.g. 5 particle sizes around the LDL covering 0% to 100% efficiency, should be used. Acceptable counting efficiency for single particle counting instruments is 50% ± 20% at the minimum detection size and 100% ± 10% for all particles larger than 1.5 times the minimum size.

A2-4.3 The detection area of most LPPDs comprises only a small portions of the cross-section area of the line. Therefore, it is not possible to specify a 50% efficiency point. For this, the commonly used definition for sensitivity could not be used for such instruments.

A2-4.4 The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

A2-5 Sensitivity

A2-5.1 The particle size corresponding to the point with 50% counting efficiency of the particles of a given size is defined as the minimum detectable particle size. This is valid only for particle counters capable to reach 100% counting efficiency for a specific particle size. This does not apply to most LPPDs.

A2-6 Particle Concentration Effects

A2-6.1 All optical particle detectors are able to operate accurately only within a limited range of particle concentration. It is not the scope of this document to define how this limit is measured or how to verify the specification.

A2-6.2 *High Concentration Effects*

A2-6.2.1 The upper limitation of the particle concentration is chiefly based on coincidence effects.

A2-6.2.2 One effect is optical coincidence. If the particle concentration is too high, more than one particle is present within the detection area of the instrument. The reported particle concentration will be less than the true value, and the reported particle size distribution will be shifted towards the indication of larger particles than in reality.

A2-6.2.3 The other effect is electronic coincidence. It is defined as the inability of the electronic pulse processing system to detect and size individual pulses that are too closely spaced. If there are so many pulses that they cannot completely return to the baseline, they become superimposed. Electronic saturation occurs. Electronic coincidence introduces errors in both particle size and counts as well. Normally, this problem is not critical for modern electronic systems. Optical coincidence can become a problem at particle levels well below the point where electronic saturation occurs.

A2-6.2.4 Another error can occur when high concentrations of particles just smaller than the lower detection limit of the instrument are present. Even though no single one of these particles will be detected, scattering-light levels from these particles can increase the background optical noise level. So, errors might be produced in particle count data in the lower particle size ranges reported by the counter.

A2-6.3 *Low Concentration Effects*

A2-6.3.1 It is obvious that it is necessary to collect sufficient data to determine number and size of particles within an acceptable confidence limit.

APPENDIX 3
AEROSOL GENERATION AND AEROSOL DILUTION

NOTE: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A3-1 Monodisperse Particle Suspension

A3-1.1 Monodisperse suspensions of particles (PSL) are available in sizes from 0.02 µm. These particles are grown by emulsion polymerization and are stabilized in aqueous suspensions with an anionic surfactant. They carry a negative charge which contributes to their stability. The suspension normally contains 10% solids and 2% dissolved, highly viscous stabilizer. The solid contains up to 8% emulsifier and inorganics.

A3-1.2 After evaporation, these solids and the stabilizer will both increase the diameter of the single particle and generate a residual nucleus out of an empty droplet. These residual particles are called secondary aerosol. The diameter of residual nucleus could be up to 0.25 µm according to the PSL size and dilution of the suspension. Most of these secondary aerosol particles might be too small to be detectable with commonly used particle detectors, but they will have an influence on the noise level because of there high number.

A3-1.3 Out of a high-concentration suspension it is not possible to aerosolize only individual particles. Droplets containing more than one of the suspended particles will become undesirable agglomerates upon evaporation.

A3-1.4 For this, an adequate dilution of the suspension is necessary to avoid the formation of aggregates and the enlargement of the particles.

A3-2 Generation and Dilution of PSL Suspension

A3-2.1 A diluted PSL suspension for particle generation in an aerosol generator can be created by the following procedure:

- Shaking and/or ultrasonic treatment of the PSL bottle distributed by the PSL manufacturer.
- Placing one drop of PSL in one liter of deionized or destilled water or Isopropanol. The water could be cleaned using a filter with a pore size no more than 10% of the size of the particles being used.
- Shaking and/or ultrasonic treatment of the suspension to disperse the particles.

A3-2.2 The suspension will probably need to be diluted further to provide a required particle concentration. This is necessary to avoid the formation of agglomerates and to restrict the size of the secondary aerosol particles. An equation to calculate the required particle concentration is given in “The Generation of Aerosols of Fine Particles” by O. Raabe (see Section 11).

A3-2.3 The particle suspensions distributed by the PSL manufacturer shows no detectable variation in particle characteristics when they are stored in a cool place over the years. Diluted suspensions for atomization feature an aging process. Diluted suspensions of polymer spheres smaller than 1 µm should not be stored for more than one week.

NOTE A3-1: Care should be taken to avoid contamination of the polymer spheres and the suspension.

A3-3 Aerosol Generation

A3-3.1 The diluted suspension is nebulized in the aerosol generator. Great account is taken of concentration and size distribution of the generated droplets and of the volume flow rate V'_G. To achieve a constant aerosol production, the volume flow rate and the droplet size distribution should be constant and independent of the supplies of suspension in the reservoir. The variation in particle concentration should be no more than 10% as measured by the reference particle counter over a time period of 15 minutes or more.

NOTE A3-2: Care should be taken to avoid contamination of the aerosol generator.

A3-4 Aerosol Drying

A3-4.1 The water of the generated droplets will completely evaporate when the relative humidity of the aerosol flow behind the nebulizer is lower than 70%. The volume flow of the suspension in the nozzle increases the humidity of the filtered compressed air which has a relative humidity of 10%–15% in spite of predrying. The use of a diffusion dryer or another appropriate instrument allows a higher relative humidity of the aerosol flow behind the aerosol generator. The diffusion dryer uses silica gel desiccant to remove the moisture. The desiccant shall either be new or freshly regenerated. It is not wise to get the aerosol in direct contact with the desiccant. Polymer spheres will be precipitated and additional particles out of the desiccant will change the particle size distribution of the aerosol.

A3-5 Aerosol Neutralization

A3-5.1 When dispersing the suspension, the particles are charged. This surface charge should be removed after drying the aerosol flow to avoid electrostatic interactions with each other or the line walls. With the help of the discharging distance of an electrostatic neutralizer, the aerosol is exposed to a bipolar ion source. Some electrostatic neutralizers may produce a large number of ultra-fine particles which will combine with the calibration aerosol and affects the signal-to-noise-ratio of the LPPD and the reference particle counter.

A3-6 Aerosol Size Separation

A3-6.1 When calibrating with ultra-fine particles, a particle size separation might be necessary to remove the residue particles and agglomerates. An electrostatic classifier is most effective for particle sizes less than 1 μm. This instrument electrically charges the incoming aerosol. With electrostatic deflection, it separates selected particles of one mobility. The residue particles and the larger aggregate particles would be stripped out of the particle stream consisting of the desired polymer particles. To charge the aerosol, the electrostatic classifier uses a radioactive neutralizer. The aerosol exiting the instrument will contain singly charged particles. This low charge level makes the use of an additional aerosol neutralizer unnecessary. Nevertheless, conductive tubing should be used between the aerosol generator and the LPPD and reference particle counter to minimize electrostatic particle loss.

A3-7 Aerosol Dilution

A3-7.1 The particle concentration of the aerosol generated by the nebulizer might be too high. The aerosol should be further diluted to achieve the required concentration and to avoid coincidence errors. The dilution could be executed with a mixing chamber in which the aerosol is mixed with zero gas. The internal chamber pressure should be stable and very close to ambient atmospheric pressure at operational flow rates. The spatial particle distribution in the exiting aerosol should be as homogenous as possible.

APPENDIX 4
AEROSOL TRANSPORT AND AEROSOL SAMPLING

NOTE: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A4-1 Aerosol Transport

A4-1.1 Aerosol loss in lines occurs both for small and larger particles. Larger particles (approximately 5 µm and larger) are lost as a result of gravitational settling in horizontal lines and inertial effects in all lines. Smaller particles are lost to the line walls by diffusion and by electrostatic charge effects.

A4-1.2 A limitation of particle loss could be achieved with tubing as short and as straight as possible with no bends with a radius of curvature less than 100 mm. The tubing of the calibration setup should be smooth, conductive, and electrically grounded. Stainless, polished steel for rigid lines and Polyurethane or polyvinyl chloride for flexible lines is found acceptable for handling most aerosols with low electrostatic particle loss. If long transit lines are required, they should be sized to permit a Reynolds number in the range of 5,000 to 25,000 at the sample flow rate to minimize particle residence time in the tubing without causing excessive turbulence at high flow rates.

A4-2 Aerosol Sample Acquisition

A4-2.1 The term isokinetic sampling often is used in aerosol measurement and characterization. Isokinetic sampling of particles in a moving aerosol is performed by matching the sample probe inlet velocity (flow speed and direction) to the velocity of the moving aerosol. At velocities less than 15 m/s, anisokinetic sampling errors are negligible for most particles smaller than approximately 5 µm. Losses of larger particles might be significant. The larger the particle, the larger the loss due to inertial effects. Isokinetic sampling is not possible in environmental conditions with varying velocity, motionless air, and turbulent, random, or non-unidirectional flow. For better sampling inlet efficiency, isokinetic or at least isoaxial sampling is recommended at calibration.

SEMI E106-0301
PROVISIONAL OVERVIEW GUIDE TO SEMI STANDARDS FOR PHYSICAL INTERFACES AND CARRIERS FOR 300 mm WAFERS

This guide was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on October 19, 2000. Initially available at www.semi.org November 2000; to be published March 2001. Originally published October 2000. This document replaces SEMI PR6-0200 in its entirety.

1 Purpose

1.1 This document is intended to help users and suppliers of 300 mm carriers and production equipment to understand the complex interdependencies among the SEMI standards for 300 mm physical interfaces and carriers and to determine which standards apply to which products. As shown in Figure 1, these standards are highly inter-related, have many complex dependencies, and inherit a numbering system (from legacy 200 mm standards) that is non-intuitive.

2 Scope

2.1 This document describes how the SEMI standards for 300 mm physical interfaces and carriers work together. This document also clarifies the requirements (direct and indirect) on suppliers of each product, and suggests how users see these standards and options.

2.2 This document is provisional because the SEMI standards for 300 mm physical interfaces and carriers are not complete. Once all of the relevant standards have passed the balloting process, this document should be modified and upgraded from provisional status. Standards under development include documents that specify:

- carriers for thinned wafers
- load ports for frame cassettes at backend processes
- manual handoff operation interfaces at load ports

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

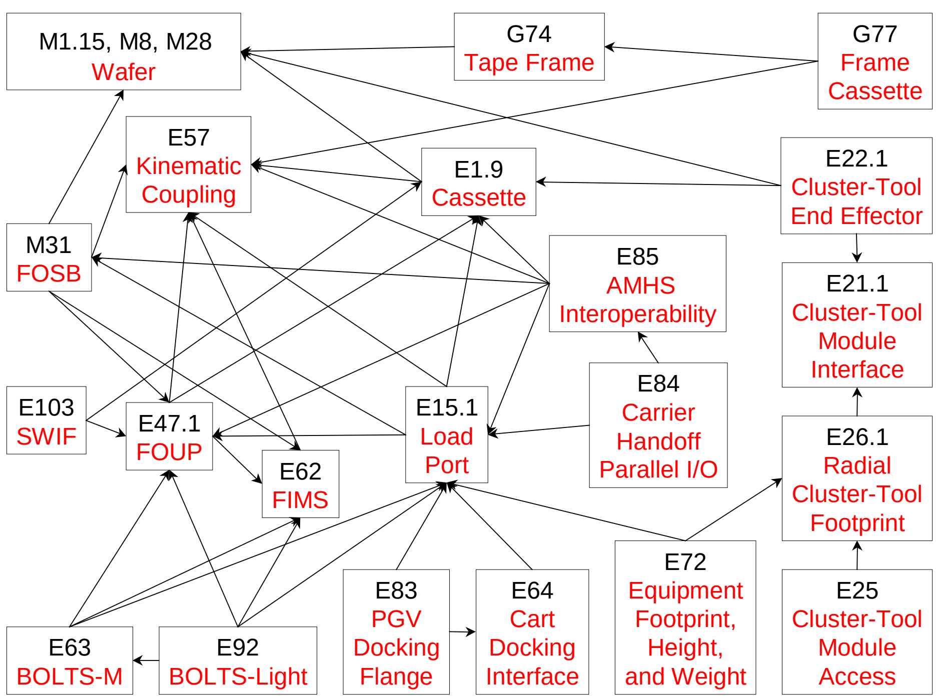


Figure 1
Complex Relationships and Dependencies Among 300 mm Standards

3 Limitations

3.1 *300 mm Only* — This document only covers SEMI standards that are specific to 300 mm, even though other standards may apply to 300 mm equipment. For example, standards not described here include:

- metrics documents such as SEMI E10;
- minienvironment documents such as SEMI E44, SEMI E45, and SEMI E46;
- facilities documents such as SEMI E70;
- reticle handling documents such as SEMI E100 which specifies a reticle SMIF pod for 6-inch or 230 mm reticles based on SEMI E19.4; or
- safety documents such as SEMI S2, SEMI S8, SEMI S11 and an upcoming Safety Guideline for Unmanned Transport Vehicle (UTV) Systems.

3.2 *Physical Interfaces and Carriers Only* — This document also does not cover standards that were generated by committees other than the SEMI Physical Interfaces and Carriers Committee, even though such standards may be specific to 300 mm. For example, standards not described here include:

- Information and Control documents such as SEMI E82; and
- Silicon documents such as SEMI M1.15, SEMI M8, and SEMI M28 (Developmental Wafers).

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E21.1 — Cluster Tool Module Interface 300 mm: Mechanical Interface and Wafer Transport Standard

SEMI E22.1 — Cluster Tool Module Interface 300 mm: Transport Module End Effector Exclusion Volume Standard

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E25 — Cluster Tool Module Interface: Module Access Guideline

SEMI E26.1 — Radial Cluster Tool Footprint 300 mm Standard

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments

SEMI E46 — Test Method for the Determination of Organic Contamination from Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E64 — Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI E70 — Guide for Tool Accommodation Process

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI E75 — Provisional Mechanical Specification for Box/Pod Compatible Cassettes Used to Transport and Store 300 mm Wafers

SEMI E82 — Specification for Interbay/Intrabay AMHS SEM (IBSEM)

SEMI E83 — Specification for 300 mm PGV Mechanical Docking Flange

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

SEMI E85 — Provisional Specification for Physical AMHS Stocker to Interbay Transport System Interoperability

SEMI E92 — Provisional Specification for 300 mm Light Weight and Compact Box Opener/Loader to Tool-Interoperability Standard (BOLTS-Light))

SEMI E99 — The Carrier ID Reader/Writer Functional Standard: Specification of Concepts, Behavior, and Services

SEMI E99.1 — Specification for SECS-I and SECS-II Protocol for Carrier ID Reader/Writer Functional Standard

SEMI E100 — Specification for a Reticle SMIF Pod (RSP) Used to Transport and Store 6 Inch or 230 mm Reticles

SEMI E101 — Provisional Guide for EFEM Functional Structure Model

SEMI E103 — Provisional Mechanical Specification for a 300 mm Single-Wafer Box System that Emulates a FOUP

SEMI G74 — Specification for Tape Frame for 300 mm Wafers

SEMI G77 — Specification for Frame Cassette for 300 mm Wafers

SEMI M1.15 — Standard for 300 mm Polished Monocrystalline Silicon Wafers (Notched)

SEMI M8 — Specification for Polished Monocrystalline Silicon Test Wafers

SEMI M28 — Specifications for Developmental 300 mm Diameter Polished Single Crystal Silicon Wafers

SEMI M29 — Specification for 300 mm Shipping Box

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

SEMI S11 — Environmental, Safety, and Health Guidelines for Semiconductor Manufacturing Equipment Minienvironments

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGV* — automatic guided vehicle (as defined in SEMI E101).

5.1.2 *PGV* — person guided vehicle (cart) (as defined in SEMI E101).

5.1.3 *RGV* — rail guided vehicle (moving on the floor) (as defined in SEMI E101).

5.2 *Definitions*

5.2.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

5.2.2 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached (as defined in SEMI E63).

5.2.3 *box* — a protective portable container for a cassette and/or substrate(s) (as defined in SEMI E44).

5.2.4 *box opener/loader* or *BOLTS unit* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's wafer handler for unloading and loading wafers (as defined in SEMI E63).

5.2.5 *carrier handler* — receives and passes the carriers from and/or to the external system (such as the factory material handling system). A carrier handler of the internal buffer type has the functions of handling and storing the carriers. A carrier handler for FOUPs has the opener(s) for opening and closing FOUPs.

5.2.6 *cart* — a floor-based carrier transfer vehicle (as defined in SEMI E101).

5.2.7 *cassette* — an open structure that holds one or more substrates (as defined in SEMI E44).

5.2.8 *docking* — the act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment (as defined in SEMI E101).

5.2.9 *equipment front end module (EFEM)* — consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in *SEMI E15.1*), opens the carriers (if needed), and may include a substrate handler for unloading and loading wafers from the carrier to the process part of the equipment (as defined in SEMI E101).

5.2.10 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

5.2.11 *fixed buffer* – EFEM configuration with carrier places only on load port units arranged in a load port group (as defined in SEMI E101).

5.2.12 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a

FIMS port that complies with SEMI E62) (as defined in SEMI E47.1).

5.2.13 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

5.2.14 *internal buffer* — EFEM configuration with carrier places different from load port units (as defined in SEMI E101).

5.2.15 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

5.2.16 *OHT* — overhead transport system with hoist for lifting carriers between load port level and transport level (as defined in SEMI E101).

5.2.17 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19 (as defined in SEMI E44).

5.2.18 *substrate handler* — transfers substrates between carriers and the process part of the equipment (as defined in SEMI E101).

5.2.19 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

6 Description of the Standards

6.1 *Overview* — Figure 2 shows roughly what most of the SEMI standards for 300 mm physical interfaces and carriers specify. However, this picture is greatly over-simplified. For example, a front-opening shipping box (FOSB) compliant with SEMI M31 (with its thicker door) generally cannot be opened by equipment load ports that are compliant with SEMI E63. Also, a wire link to an OHT for the carrier handoff parallel I/O can also be located at the top of the equipment. Furthermore, the atmospheric wafer handler for emptying the carrier will generally be different from the wafer handler used in the vacuum environment of the central handler module of a cluster tool.

6.2 *Kinematic Coupling* — The foundational document of the SEMI standards for 300 mm physical interfaces and carriers is SEMI E57 which specifies the mechanical couplings used to ergonomically align and precisely support 300 mm wafer carriers. The kinematic coupling consists of three pins that mate with grooves on the bottom of the wafer carrier (which are not specified) for physical alignment and support. Most of the dimensions in the SEMI standards for 300 mm physical interfaces and carriers are determined with respect to the three orthogonal datum planes defined in SEMI E57: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. Such a kinematic coupling can be used at several interfaces, including:

- between a FOUP or cassette and an equipment load port or vehicle nest,
- between a transport cassette and a box, and
- between a process cassette or quartz boat and the floor of a process chamber.

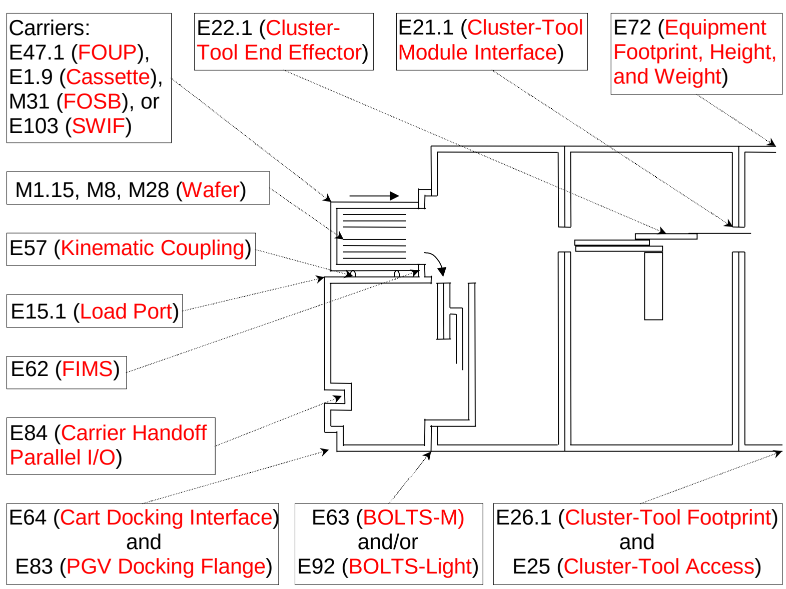


Figure 2
Key Standards for 300 mm Equipment

6.3 *Wafer Carriers* — SEMI E1.9 and SEMI E47.1 specify the carriers used to transport and store 300 mm wafers in an IC manufacturing facility. SEMI E47.1 specifies the outside features of the front-opening unified pod (FOUP). The inside features of the FOUP are specified in SEMI E1.9, which also specifies the open cassette. Both standards specify carriers that hold either 13 or 25 wafers. SEMI M31 specifies the front-opening shipping box (FOSB) used to transport and ship 300 mm wafers. SEMI E103 specifies a system that includes a box that holds only one wafer and that fits onto an adapter mechanism called a single-wafer interface (SWIF). This system appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

6.4 *Equipment Load Ports* — SEMI E15.1 specifies the carrier load ports at the front of 300 mm process or metrology equipment (or stockers). In addition, the substrate port that opens a FOUP door is specified in SEMI E62 (FIMS). At the floor below each load port is a cart docking interface exclusion volume specified in SEMI E64; this volume can contain a PGV docking flange as specified in SEMI E83. SEMI E63 (BOLTS-M) or SEMI E92 (BOLTS-Light) or both standards specify the mechanical interface between the main part of a process or metrology tool and the box opener/loader unit that opens FOUPs and presents them to the tool wafer handler for unloading and loading 300 mm wafers. Also associated with each load port is a wire or optical link (from the equipment to the AMHS carrier delivery system) specified in SEMI E84 which is the 300 mm version of SEMI E23. SEMI E99 and SEMI E99.1 specify the electronics and communication interface between a carrier ID reader/writer and the equipment controller. SEMI E101 specifies the functional structure model and component behavior for the entire equipment front-end module (EFEM).

6.5 *Cluster-Tools* — SEMI standards for 300 mm cluster tools include SEMI E22.1, SEMI E21.1, SEMI E26.1, and SEMI E25.

6.6 *AMHS* — SEMI standards for automated material handling systems (AMHS) include SEMI E85.

6.7 *Equipment Volume and Weight* — SEMI E72 specifies limits on the footprint, height, and weight of equipment for 300 mm fabs. Separate limits are given for the parts of the equipment in the main fab and in the sub-fab. Separate limits are also given for the equipment after it is installed and for the components of the equipment as it is moved into the fab.

6.8 *Back-End Standards* — SEMI G74 specifies the tape frames used for 300 mm wafers between the dicing process and the die-bonding process. SEMI G77 specifies the mechanical features of a metal or plastic frame cassette used for framed 300 mm wafers between the wafer mounting process and the die-bonding process. Future standards may also specify the carrier for thinned 300 mm wafers and the load port for back-end process or metrology equipment.

6.9 *Standards of Uncertain Use* — Some SEMI 300 mm standards that passed balloting have a scope of application or extent of use that is yet to be fully determined. Such standards include SEMI E19.5 which specifies the bottom-opening standard mechanical interface (SMIF), SEMI E75 which specifies FOUP-compatible cassettes, and SEMI M29 which specifies a manually-opening shipping box for 300 mm wafers. In the other SEMI 300 mm standards are also some options of uncertain use such as bottom-opening pods and pods with removable cassettes.

7 Application of Standards to Products

7.1 *One-Sided Interface Specifications* — The SEMI standards for 300 mm physical interfaces and carriers are intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability between different types of products. To accomplish this, only one side of each mechanical interface (between different types of products) is specified, leaving the supplier of the product on the other side of the interface more freedom to improve their product. For example, only the bottom half of the kinematic coupling (the pin) is specified by SEMI E57 so that suppliers can be flexible in designing wafer carrier grooves that can mate with it. Table 1 shows which standards apply to each type of product and shows which side of the interface is specified:

- "D" indicates if the standard directly specifies that type of product (by specifying that product's side of the relevant interface).
- "I" indicates if the standard indirectly specifies that type of product (by specifying the other side of the relevant interface).

7.2 *Carriers* — A FOUP is directly specified by SEMI E47.1 (for its outside features not including the door) and by SEMI E1.9 (for its inside features). The FOUP is indirectly specified by SEMI E57 (for its kinematic coupling grooves) and by SEMI E62 (for its FIMS door interface). Thus, if a FOUP door fails to open or close correctly on any load port that complies with SEMI E57 and SEMI E62, that FOUP is in violation of the standards. The wafer support function of all of the 300 mm carriers is specified directly (by specifying where the wafers must be located rather than specifying the shape and location of the supports), so the 300 mm wafer standards indirectly specify the carriers.

7.3 *Stockers* — A carrier stocker is directly specified by SEMI E57 (for the kinematic coupling pins on its shelves, if any, and on its manual/AGV/RGV and interbay load ports), by SEMI E15.1 (for its manual/AGV/RGV load ports), by SEMI E85 (for its interbay load ports), by SEMI E84 (for its carrier handoff parallel I/O at either kind of load port) and by SEMI E64 (for the cart docking interface exclusion volume below each manual/AGV/RGV load port). The carrier stocker is indirectly specified by the carrier standards (for the volume required to store and transfer the carriers).

7.4 *Carrier ID* — A carrier ID reader/writer unit is directly specified by a future standard that specifies the electronics and communication interface between a carrier ID reader/writer and the equipment controller. The carrier ID reader/writer unit is indirectly specified by the carrier standards (which specify reserved areas for carrier ID tags) and by SEMI E15.1 (for its exclusion volume in each load port).

7.5 *Load Port and Carrier Handler Modules* — A box opener/loader (the module on a piece of equipment that includes load ports and carrier handling) is directly specified by SEMI E57 (for the kinematic coupling pins on the load port and on its shelves if it includes an internal buffer in addition to its fixed buffer), by SEMI E15.1 (for its load ports), by SEMI E62 (for its FIMS door interface), by SEMI E84 (for its carrier handoff parallel I/O), by SEMI E64 (for the cart docking interface exclusion volume below each load port), and by SEMI E72 (for its limits on footprint, height, and weight). The module is indirectly specified by the carrier standards (for the volume required to store and transfer the carriers) and by SEMI E63 and/or SEMI E92 (for the mechanical interface to the main part of the process or metrology equipment that contains the substrate handler).

7.6 *Main Part of Process or Metrology Equipment* — The main part of process or metrology equipment (including the substrate handler) is directly specified by SEMI E63 and/or SEMI E92 (for the mechanical interface to the module that includes load ports and carrier handling) and by SEMI E72 (for its limits on footprint, height, and weight). The substrate handler is indirectly specified by SEMI E1.9 (for the features inside most carriers) and it is recommended to follow the direct specifications in SEMI E22.1 (which specifies cluster-tool end effectors).

7.7 *Material Handling Systems* — A carrier transport vehicle is directly specified by SEMI E57 (for the kinematic coupling pins on the carrier nest, if any) and by SEMI E84 (for its carrier handoff parallel I/O, if any). The AMHS system is indirectly specified by the carrier standards (for the volume required to hold and transfer the carriers), by SEMI E15.1 (for equipment load ports), by SEMI E85 (for stocker load ports, if it is an OHT), by SEMI E72 (to allow for equipment height, if it is an OHT), and by SEMI E64 and SEMI E83 (for the cart docking interface exclusion volume and the PGV docking flange, respectively, below each equipment load port, if it is a floor based vehicle).

Table 1 Standards Specifying Each Type of Product (D = Direct Specification, I = Indirect Specification)

Type of Product and its Components	*SEMI M1.15, M8, or M28 (Wafer)*	*SEMI E57 (Kinematic Coupling)*	*SEMI E1.9 (Cassette)*	*SEMI E47.1 (FOUP)*	*SEMI M31 (FOSB)*	*SEMI E103 (Single-Wafer Box System)*	*SEMI E62 (FIMS)*	*SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)*	*SEMI E15.1 (Load Port)*	*SEMI E64 (Cart Docking Interface)*	*SEMI E83 (PGV Docking Flange)*	*SEMI E84 (Carrier Handoff Parallel I/O)*	*SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)*	*SEMI E85 (Stocker to Interbay Transport System)*	*SEMI E22.1 (Cluster- Tool End Effector)*	*SEMI E21.1 (Cluster-Tool Module Interface)*	*SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)*	*SEMI E72 (Equipment Footprint, Height, and Weight)*	*SEMI G74 (Tape Frame)*	*SEMI G77 (Frame Cassette)*
FOUP:																				
wafer supports	I																			
coupling grooves		I																		
inside features			D	D																
outside features				D																
door				D			I													
open cassette:																				
wafer supports	I																			
coupling grooves		I																		
other features			D																	
shipping box:																				
wafer supports	I																			
coupling grooves		I																		
other features					D															
single-wafer box and SWIF system:																				
wafer supports	I																			
coupling grooves		I																		
inside features			D	D		D														
outside features				D		D														
door				D		D	I													
interbay transport vehicle:																				
carrier supports		D																		
carrier envelope			I																	I
hand-off I/O				I								D								
stocker load ports														I						
roller conveyor:																				
carrier rails			I	I																
carrier envelope			I	I																
equipment load ports										I										
hand-off I/O												D								
PGV:																				
carrier supports		D																		
carrier envelope			I	I																
carrier handler			I	I					I											
tool load port access									I											
docking features										I	I									

Type of Product and its Components	*SEMI M1.15, M8, or M28 (Wafer)*	*SEMI E57 (Kinematic Coupling)*	*SEMI E1.9 (Cassette)*	*SEMI E47.1 (FOUP)*	*SEMI M31 (FOSB)*	*SEMI E103 (Single-Wafer Box System)*	*SEMI E62 (FIMS)*	*SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)*	*SEMI E15.1 (Load Port)*	*SEMI E64 (Cart Docking Interface)*	*SEMI E83 (PGV Docking Flange)*	*SEMI E84 (Carrier Handoff Parallel I/O)*	*SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)*	*SEMI E85 (Stocker to Interbay Transport System)*	*SEMI E22.1 (Cluster- Tool End Effector)*	*SEMI E21.1 (Cluster-Tool Module Interface)*	*SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)*	*SEMI E72 (Equipment Footprint, Height, and Weight)*	*SEMI G74 (Tape Frame)*	*SEMI G77 (Frame Cassette)*
AGV or RGV:																				
carrier supports		D																		
carrier envelope			I	I																I
carrier handler			I	I					I											I
tool load port access									I											
hand-off I/O												D								
intrabay OHT vehicle:																				
carrier envelope				I																
carrier handler				I																
tool load ports									I											
hand-off I/O												D								
stocker load ports														I						
height																		I		
carrier stocker:																				
carrier supports		D																		
carrier envelope			I	I																I
carrier handler			I	I																I
floor based load ports									D											
PGV interface										D										
hand-off I/O												D								
carrier ID reader													D							
overhead load ports														D						
height and weight																		D		
carrier ID reader unit:																				
ID tags on carrier			I	I																I
volume in load port									I											
box opener/loader unit:																				
carrier supports		D																		
carrier envelope			I	I																
FOUP door opener							D													
interface to rest of tool								I												
load ports									D											
PGV interface										D										
hand-off I/O												D								
carrier ID reader													D							
height and weight																		D		
main part of process or metrology equipment:																				
substrate handler	I		I												D					
box opener interface								D												

Type of Product and its Components	*SEMI M1.15, M8, or M28 (Wafer)*	*SEMI E57 (Kinematic Coupling)*	*SEMI E1.9 (Cassette)*	*SEMI E47.1 (FOUP)*	*SEMI M31 (FOSB)*	*SEMI E103 (Single-Wafer Box System)*	*SEMI E62 (FIMS)*	*SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)*	*SEMI E15.1 (Load Port)*	*SEMI E64 (Cart Docking Interface)*	*SEMI E83 (PGV Docking Flange)*	*SEMI E84 (Carrier Handoff Parallel I/O)*	*SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)*	*SEMI E85 (Stocker to Interbay Transport System)*	*SEMI E22.1 (Cluster- Tool End Effector)*	*SEMI E21.1 (Cluster-Tool Module Interface)*	*SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)*	*SEMI E72 (Equipment Footprint, Height, and Weight)*	*SEMI G74 (Tape Frame)*	*SEMI G77 (Frame Cassette)*
tool controller													D							
height and weight																		D		
cluster tool central handler module:																				
substrate handler	I														D					
module interface																D				
footprint and access																	I			
height and weight																		D		
cluster tool process module:																				
process chamber	I														I					
module interface																D				
footprint and access																	D			
height and weight																		D		
wafer tape frame:																				
wafer contact	I																			
other features																			D	
frame cassette:																				
wafer/frame contact	I																		I	
other features																				D
back-end tool load port:																				
carrier envelope																				I

8 Related Documents[1]

Backend Global Joint Guidance for 300 mm Semiconductor Factories

Global Joint Guidance for 300 mm Semiconductor Factories

I300I Factory Guideline Compliance: Factory Integration Maturity Assessment for 300 mm Production Equipment

I300I Factory Guidelines

I300I Guidelines on 300 mm Process Tool Mechanical Interfaces for Wafer Lot Delivery, Buffering, and Loading

Integrated Minienvironment Design Best Practices

1 http://www.sematech.org/public/resources/300mm/guide.htm and http://www.sematech.org/public/resources/300mm/methods.htm

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E106 and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such, they are to be considered as reference material only. The standard should be referred to in all cases.

R1-1 *Standards Endorsed by Users* — Section 8 lists documents in which the members of I300I and/or J300E have endorsed SEMI 300 mm standards or have specified methods for testing compliance with those standards.

SEMI E108-0301
TEST METHOD FOR THE ASSESSMENT OF OUTGASSING ORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING GAS CHROMATOGRAPHY/MASS SPECTROSCOPY

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on December 20, 2000. Initially available at www.semi.org February 2001; to be published March 2001.

1 Purpose

1.1 The purpose of this standard is to define a test method for the determination of the outgassing organic contamination from minienvironments used for storage and transport of wafers using gas chromatography/mass spectroscopy (GC/MS).

1.2 This test method is intended as an alternative to SEMI E46. The main difference between SEMI E46 and this document is that SEMI E46 defines a test method which is based on ion mobility spectroscopy (IMS) as the measurement technique while this standard is based on gas chromatography/mass spectroscopy in combination with thermal desorption. Additionally, this test method provides a procedure for testing the outgassing of organic compounds in a complete minienvironment. The results of SEMI E46 and this document are given in different units.

2 Scope

2.1 The test method provided in this document is applicable to the assessment of the outgassing of organic contamination from minienvironments.

2.2 Gas chromatography/mass spectroscopy is chosen as the method to determine organic contamination because it is commonly used for characterization and quantification of organic compounds. In combination with thermal desorption, it provides a method for the identification of organic compounds in the atmosphere (i.e., inside the minienvironment) as well as directly from source materials, and transferred contaminants. This method can also be used to evaluate materials and processes used in semiconductor industry.

2.3 This test method is based on ASTM F1982.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 The test methodologies, metrics and applications provided in this standard are limited by the following constraints:

3.1.1 The specific recovery of compounds by the proposed standard method strongly depends on the setup of the apparatus used. This has been taken into account by the use of the "reference-cocktail", see Section 9.2.

3.2 Identification of the source of organic compounds inside the minienvironment is out of the scope of this test method. For a procedure for the analysis of outgassing organic compounds from individual materials using gas chromatography/mass spectroscopy, see IDEMA M11-99.

3.3 This test method does not provide a procedure how to use the obtained data for assessing the risks that come from individual compounds.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E46 — Test Method for the Determination of Organic Contamination from Minienvironments

SEMI F21 — Classification of Airborne Molecular Contaminant Levels in Clean Environments

4.2 *ASTM Standard*[1]

ASTM F1982 — Standard Test Methods for Analyzing Organic Contaminants on Silicon Wafer Surfaces by Thermal Desorption Gas Chromatography.

4.3 *IDEMA Standard*[2]

IDEMA M11-99 — General Outgas Test Procedure by Dynamic Headspace Analysis

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, website: www.astm.org

2 International Disk Drive Equipment and Materials Association, 3255 Scott Blvd., Suite 2-102, Santa Clara, CA 95054-3013, website: www.idema.org

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *analytical environment* — environment where all analytical measurements are taking place.

5.2 *headspace sampling* — in this standard defined as: collecting volatile organic compounds in an enclosed volume by means of a silicon wafer or silicon wafer chips.

5.3 *minienvironment* — A localized environment for transport and storage created by an enclosure to isolate the product from contamination and people.

5.4 *sample* — wafer or wafer chips used for the headspace sampling of organic contaminants.

5.5 *static storage conditions* — conditions excluding any active movement of test specimens.

5.6 *thermal desorption tube* — Analytical equipment capable of collecting organic compounds of interest (i.e., adsorbent filled glass tube).

5.7 *wafer* — Object made of semiconducting material to be processed, handled or stored in the minienvironment to be tested (i.e., prime or processed silicon wafer).

6 Summary of Method

6.1 This test method comprises storage tests of wafers in minienvironments under static storage conditions. The contamination is directly measured from the silicon wafer surface. Three important aspects are covered:

a) Contamination due to the minienvironment alone,

b) Contamination from the use of minienvironments for wafer processing, and

c) Contamination from future materials to be used in semiconductor technology.

6.2 The setup for each test comprises an analytical equipment in the analytical environment as well as a test equipment in the test environment. Each environment has to fulfill the following requirements:

6.2.1 *Analytical Environment* — shall be clean enough with respect to airborne organic contamination: recommendation is less than 100 pptM for organic compounds with boiling points > 150°C (Class MC-100, according to SEMI F21).

6.2.2 *Test Environment* — shall equal the environment in which the test specimen will be used.

6.3 Silicon wafers are placed in the minienvironment or used for headspace sampling experiments. These wafer samples are then analyzed by gas chromatography/mass spectrometry to determine the amount of contaminants.

6.4 The wafers or wafer chips to be used for the test method are decontaminated as described in ASTM F1982 for bare silicon wafers. The surface condition of the wafer (hydrophobic or hydrophilic) has to be adjusted in a reproducible way and has to be the same for all comparative measurements.

6.5 The wafer or the wafer chips are placed in the minienvironment and are left there under static conditions for the chosen static storage time (depending on the intended use of the minienvironment to be tested, a time between 1 h and 28 d may be used). When loaded into the minienvironment the wafer may have a temperature which reflects production circumstances (i.e., 80°C when unloading from furnace processes). In some situations wafers may be exposed to severe thermal conditions. The minienvironment should be evaluated under the conditions exposed to. Be sure that the material to be tested does not undergo phase transitions under the chosen temperature conditions.

6.6 After the static storage test period, the wafer is returned to the analytical equipment and the organic contamination on the wafer is measured immediately.

6.7 The quantitative value for the total amount of outgassed and adsorbed organics from the minienvironment is calculated as the difference between the detected amount of contamination on a blank sample vs. the amount on the exposed sample.

7 Interferences

7.1 The presence of organic contamination in the atmosphere of the test environment may lead to a significant contribution to the detected total amount of organic compounds on the test wafers or wafer chips. Care has to be taken when subtracting the blank value from the test value. Transport times from test environment to analytical environment have to be as short as possible.

8 Apparatus

8.1 For the analysis of organic compounds on wafers a gas chromatography/mass spectroscopy apparatus with thermal desorption unit is required: A gas chromatography (GC) instrument, which utilizes a capillary column to separate a wide variety of organic compounds, combined with mass spectrometer (MS). A thermal desorption unit is used to desorb organics from sample thermal desorption tubes and collect them in a trap. Two types of trapping may be used:

a) cooling the trap down to a minimum of -150°C does not require any adsorbent (glass wool may be used) or

b) a Tenax® filled trap has to be cooled down to a minimum of -25°C.

8.1.1 The thermal desorption unit is coupled to the gas chromatography instrument via a heated transfer line. This apparatus may be used directly for the desorption from wafer chips which are put in empty glass (or stainless steel) thermo desorption tubes (method A).

8.1.2 A desorption unit for complete wafers is specified in ASTM F1982. In this case sample thermal desorption tubes packed with adsorbent have to be used to trap compounds desorbed from the wafer. These thermal desorption tubes are analyzed within the thermal desorption unit (method B).

8.2 The analysis of outgassing organic contamination from minienvironments requires an extremely sensitive analytical equipment. Recovery and limit of detection for the different classes of compounds must be evaluated carefully in order to ensure reliable results.

9 Reagents and Materials

9.1 For the materials used for handling and transport of wafers clean, decontaminated equipment has to be used, e.g. tweezers heated in a propane flame. Refer to the reagent and materials described in SEMI E46 and ASTM F1982.

9.2 *Test Mixture* — For the calibration of equipment and the quantification of the amount of contamination a test mixture (”cocktail”) is used. This mixture was chosen in order to give an ”average” over typical substance classes present in semiconductor production lines, which have high sticking factors to the wafer surface. The response factor of the MS-detection for organics varies significantly. As this is true for all contaminants, the method gives a realistic trustworthy quantitative correlation to a ”typical average compound mixture” of contaminants on wafer surfaces.

9.3 *Preparation of Test Mixture*

9.3.1 The mixture consists of triethyl phosphate, ε-caprolactam, palmitic acid and diethylhexyl phthalate each 0.5 µg/µl in isooctane (as solvent). The preparation has to be done according to SEMI E46.

NOTE 2: A similar test mixture is suggested by the working group *WG 031* of the *Institute for Environmental Science and Technology* (IEST)

10 Safety Precautions

10.1 All preparation and analytical work has to be done according to local safety regulations.

11 Preparation of Minienvironment and Sample

11.1 *Minienvironment* — The minienvironment to be tested has to be used as received from the supplier. A cleaning step can be added but there must be no contribution from the cleaning procedure to the outgassing of organic compounds from the minienvironment. The cleaning method has to be defined by the supplier or agreed upon between supplier and user of the tested minienvironment.

11.2 *Sample* — The wafers shall be made organic-free before using them to monitor organic contamination. The surface condition of the wafer (hydrophobic or hydrophilic) has to be adjusted in a reproducible way and has to be the same for comparative measurements. Refer to SEMI E46 and ASTM F1982.

12 Procedure

12.1 The procedure described below is used for obtaining the baseline value of the method (method blank) as well as the test value for outgassing organic compounds of the minienvironment within a defined static storage time (storage time t_S = 1 h - 28 d).

12.1.1 Choose that static storage time according to the intended use of the minienvironment (i.e., if the maximum sit time of wafers in a process where the minienvironment is to be used is 4 h then choose a static storage time of 4 h). If no static storage time related to processes can be defined, a recommended value for the first static storage time is 1 day.

NOTE 3: Composition of adsorbed compounds may vary with static storage time.

12.2 For transport store the wafers or wafer chips used for testing in decontaminated, organic-free petri-dishes wrapped in organic-free aluminum foil. Refer to SEMI E46.

12.3 *Loading Procedure*

12.3.1 *For tests at room temperature:* open a minienvironment to be tested and load it with a decontaminated wafer using decontaminated handling tools (i.e., tweezers). Default storage location is the center slot of the minienvironment. Close the minienvironment. Leave the minienvironment closed for the chosen static storage time.

12.3.2 *For tests at elevated temperatures using a wafer furnace:* place the decontaminated wafers in a clean furnace used for production processes and heat the wafers under inert gas to a temperature > 120°C. Turn off the heating. When the temperature of the furnace has reached (90±10)°C open the minienvironment to be tested and fully load it with the hot wafers from the furnace. Close the minienvironment. Leave it closed for the chosen static storage time. For analysis use only one wafer. Default wafer is the one in the center slot.

12.3.3 *For tests at elevated temperatures using a heating chamber*: open the minienvironment to be tested and load it with a decontaminated wafer using decontaminated handling tools (i.e., tweezers). Default location is the center slot. Close the minienvironment. Wrap the minienvironment with decontaminated aluminum foil. Place the minienvironment in an inert and clean heating chamber heated to 70°C. Leave it for 1 h and then remove it from the heating chamber and place it at the test minienvironment. Leave it there closed for the chosen static storage time.

NOTE 4: The purpose of the aluminum foil is to prevent direct contact between the recirculating hot air inside the heating chamber and the minienvironment.

12.4 *Unloading Procedure* — Open the minienvironment and unload the wafer using decontaminated handling tools into decontaminated petri-dishes and wrap them into organic-free aluminum foil. Transport the wafer immediately to the measurement equipment and analyze the organic contamination on the wafer according to the standard ASTM F1982.

12.5 *Method Blank* — Perform the test sequence using a container made completely of glass or quartz instead of the minienvironment. Use the same static storage time for the method blank but perform this blank test at room temperature. The container has to be decontaminated with respect to organics inside by heat treatment (refer to SEMI E46). With this blank method the baseline contribution from the cleanroom air on the adsorption of organic contamination on the silicon wafer surface is determined.

12.6 *Analyzing Procedure* — Put the wafer or wafer chips in the precleaned desorption unit or thermal desorption tube and heat it for 10 min to a minimum of 275°C (but 400°C is better). The desorbed contaminants have to be trapped directly with the cold trap of the thermodesorption unit (method A) or first by adsorbent filled desorption tubes and then by the cold trap (method B). Desorption parameters for adsorbent filled desorption tube and cold trap may be taken from ASTM F1982 (see also Section 12.6.1).

12.6.1 The substances desorbed should be separated by an appropriate column temperature program. A recommended temperature program for standard analysis uses a polydimethylsiloxane/polydiphenylsiloxane (95/5) coated column (30 m × 0.25 mm × 0.25 µm), heated from 50°C to 250°C at a rate of 10°C/min followed by a temperature hold at 250°C for 10 min. Column flow should be about 1 ml/min He at constant flow.

12.6.2 All parameters (thermo desorption unit, gas chromatograph, mass spectrometer) should be set to yield the recommended detection limits and recovery rates (see Calibration Procedure Section 13.2).

12.7 *Materials Testing* — Materials testing can be done, using the sample preparation described in SEMI E46, but using gas chromatography/mass spectroscopy instead of IMS for the analysis of contaminants on the test wafers or wafer chips.

12.8 Perform the procedure for calibration, method blank and test (including sample preparation) in triplicate in order to obtain mean value and standard deviation for the analysis.

13 Calibration and System Performance

13.1 *Calibration* — The test mixture (2 µl liquid, equals 1 µg of each substance; see Section 9.3) is applied to the wafer or wafer chips as described in SEMI E46. The so produced reference wafer or wafer chips are handled in the same way as the samples. That means, they are put in the precleaned desorption unit or thermal desorption tube and heated for 10 min to minimum 275°C (but 400°C is better) and so on as described in Section 12.6.

13.2 *System Performance* — All parameters (thermodesorption unit, gas chromatograph, mass spectrometer) should be set to yield the specified detection limits and recovery rates (method B) for the components of the reference mixture. The limit of detection (3σ) must equal or be better than 250 ng for each of the four reference substances. The standard deviation (inaccuracy) of the calibration must be ≤ 10%. Sample measurements are not allowed, unless these requirements are fulfilled. For sample measurements the same parameters as for the calibration measurements have to be used.

14 Quantification

14.1 *Integration* — After the analysis measure the surface area (A_s) of the tested wafer or wafer chips. Summing up all the peak areas from gas chromatography/mass spectroscopy chromatogram of the wafer or wafer chips gives the total integral (I_s). Determine the total integral (I_b) of the blank wafer and the total integral of the four peaks of the gas chromatography/mass spectroscopy chromatogram of the test mixture (I_r) with the same technique.

14.2 *Calculation*

$$T_c = \left(\frac{I_s}{A_s} - \frac{I_b}{A_b} \right) \times \frac{W_r}{I_r}$$

where

$\mathbf{T_c}$	=	total of organic contaminants, [ng test mixture equivalent/cm^2]
$\mathbf{I_s}$	=	total integral from gas chromatography/mass spectroscopy chromatogram of the sample
$\mathbf{I_b}$	=	total integral from gas chromatography/mass spectroscopy chromatogram of the method blank
$\mathbf{I_r}$	=	total integral from gas chromatography/mass spectroscopy chromatogram of the peaks of the test mixture
$\mathbf{W_r}$	=	total weight amount of test mixture compounds applied to wafer [ng] { = 4000 ng}
$\mathbf{A_s}$	=	total area (cm^2) of the sample investigated (wafer or wafer chips)
$\mathbf{A_b}$	=	total area (cm^2) of the method blank (wafer or wafer chips)

15 Reporting Results

15.1 The essential results of carrying out the procedure are to be summarized in a data sheet for each experiment. The data sheet has to comprise the following information:

General data:

- Date
- Operator

Environmental data:

- Cleanroom class of analytical environment (cf. SEMI F21)
- Cleanroom class of test environment

Data concerning minienvironment:

- Type
- Manufacturer
- ID
- pretreatment (cleaning, etc.)

Data concerning sample:

- Manufacturer
- Type (resistivity, dopant)
- Surface condition (hydrophilic, hydrophobic)
- Decontamination procedure

Data concerning *analytical equipment (gas chromatography/mass spectroscopy, thermal desorption, wafer furnace or heating chamber)*:

- Manufacturer
- Type
- Limit of detection and standard deviation of calibration procedure

Data concerning *static storage test*:

- Storage temperature [°C]
- Storage relaive humidity [%]
- Time of static storage test [h]
- Wafer furnace or heating chamber used (if applicable)

Data concerning *storage test result*:

- Slot location of wafer
- Total of organic contaminants T_c
- Standard deviation of measurement (if applicable)

SEMI E110-1101[E]

GUIDELINE FOR INDICATOR PLACEMENT ZONE AND SWITCH PLACEMENT VOLUME OF LOAD PORT OPERATION INTERFACE FOR 300 mm LOAD PORTS

This guideline was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

[E] This document was modified in December 2001 to reflect proposed changes in ballot 3342A that was not made in the previous cycle. Changes were made to Table 3.

1 Purpose

1.1 This guideline defines the zones and volumes in which load port status indicators and load port operation switches should be placed. The purpose of this guideline is to give a similarity in the placement of them on a 300 mm load port. This guideline only defines the zones and volumes for them and the exact placement of them within these zone and volumes are at the direction of the load port suppliers.

1.2 The zones or volumes may be defined more precisely by standardization improvement on load port design and good unification of load port operation among device manufactures. This guideline may be improved to be a specification after this effort.

2 Scope

2.1 This guideline defines following recommended specifications for 300 mm load port.

- Indicator placement zone in which load port status indicators should be placed.
- Switch placement volume in which load port operation switch should be placed.

2.2 This guideline covers the specifications for both fixed buffer equipment and internal buffer equipment.

2.3 This guideline is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Only the physical interfaces for the load port are specified; no materials requirements, micro-contamination limits, use of or logic associated with the defined physical features are given in this specification.

2.4 This guideline does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E47.1 — Provisional Mechanical Specifications for Boxes and Pods Used to Transport and Store 300mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E87 — Provisional Specification for Carrier Management (CMS)

SEMI E101 — Provisional Guide for EFEM Functional Structure Model

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.2 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.3 *fixed buffer equipment* — production equipment that has only fixed load ports and no internal buffer for carrier storage. Substrates are loaded and unloaded directly from the carrier at the load port for processing (as defined in SEMI E87).

4.4 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.5 *indicator placement zone* — a zone in which load port status indicators are placed.

4.6 *internal buffer equipment* — equipment that uses an internal buffer (as defined in SEMI E87).

4.7 *load port operation interface* — any indicator (e.g. lamp, LED) to visualize status information of a load port to an operator and/or any switch to be used for manual handoff operation.

4.8 *load port operation switch* — any switch to be used for manual handoff operation.

4.9 *load port status indicator* — any indicator (e.g. lamp, LED) to visualize status information of a load port to an operator.

4.10 *switch placement volume* — a volume in which load port operation switch is placed.

5 Requirements

5.1 *Indicator placement zone*

5.1.1 *Indicator Placement Zone for a Load Port per SEMI E15.1 Option 1* — It is recommended that load port status indicators should be positioned within a zone given by x400, z400, and z401. The exact placement of them within this zone is at the direction of the load port supplier. They may be located at or behind (away from the operator) the equipment boundary. Clearances required by SEMI E15.1 cannot be violated.

NOTE 2: The indicator placement zone is not an exclusion zone. No assumption can be made that this zone needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the indicator placement zone.

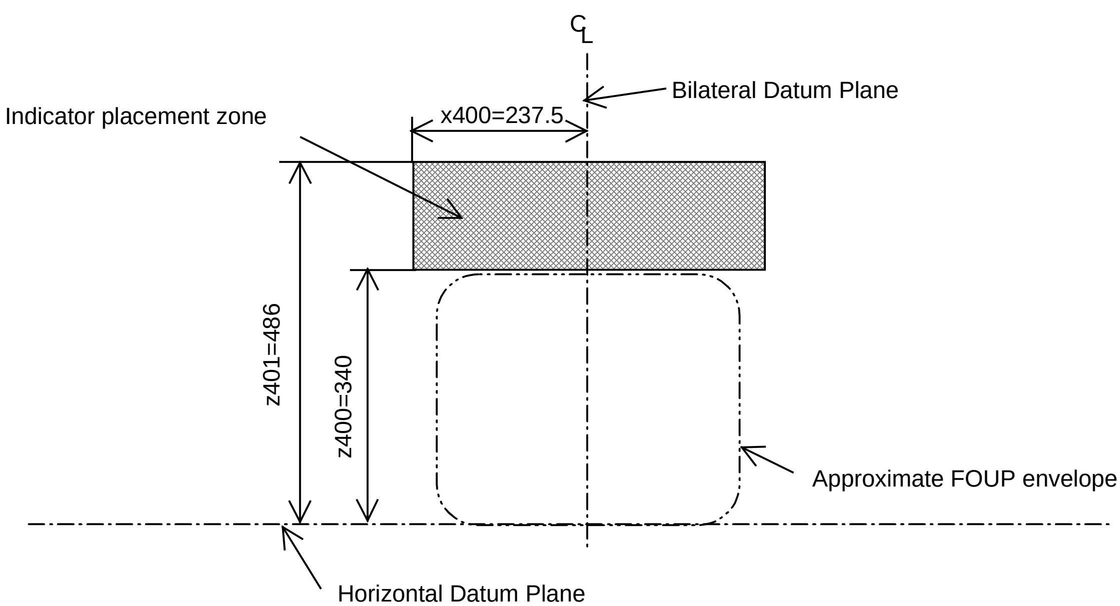


Figure 1
Indicator placement zone for a load port per SEMI E15.1 Option 1

Table 1 Dimensions of indicator placement zone for a load port per SEMI E15.1 Option1

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*
x400	1	237.5 mm (9.35 in.)	bilateral datum plane
z400	1	340 mm (13.39 in.)	horizontal datum plane
z401	1	486 mm (19.13 in.)	horizontal datum plane

5.1.2 *Indicator placement zone for a load port per SEMI E15.1 Option 3* — It is recommended that load port status indicators should be positioned within a zone given by x401, x402, z402 and z403. The exact placement of them within this zone is at the direction of the load port supplier. They may be located at or behind (away from the operator) the equipment boundary. Clearances required by SEMI E15.1 cannot be violated.

NOTE 3: The indicator placement zone is not an exclusion zone. No assumption can be made that this zone needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the indicator placement zone.

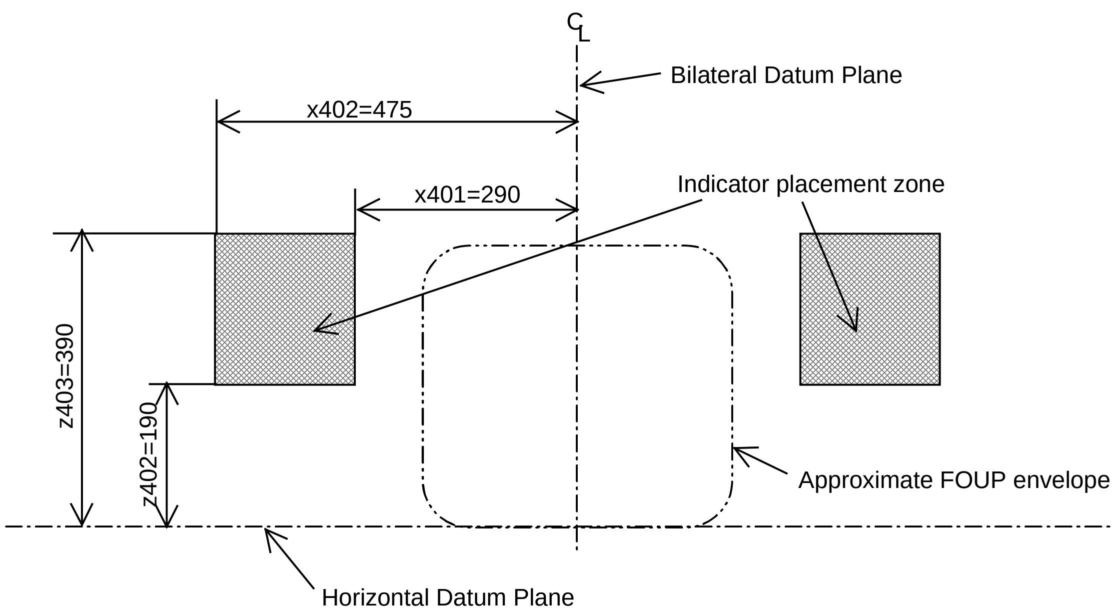


Figure 2
Indicator placement zone for a load port per SEMI E15.1 Option 3

Table 2 Dimensions of indicator placement zone for a load port per SEMI E15.1 Option3

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*
x401	2	290 mm (11.42 in.)	bilateral datum plane
x402	2	475 mm (18.79 in.)	bilateral datum plane
z402	2	190 mm (7.48 in.)	horizontal datum plane
z403	2	390 mm (15.35 in.)	horizontal datum plane

5.2 *Switch Placement Volume* — For a load port according to option 1 and 3 per SEMI E15.1, it is recommended that load port operation switches should be positioned in a way, that the surface of the switch is within a volume given by x403, x404, r400, y402 (equal to the maximum values of r67 and y53 defined in SEMI E47.1 respectively), y400, y401 (equal to the maximum value of D defined in SEMI E15.1), z404, and z405. The exact placement of the switches within this volume is at the discretion of the load port supplier.

NOTE 4: The switch placement volume is not an exclusion volume. No assumption can be made that this volume needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the switch placement volume.

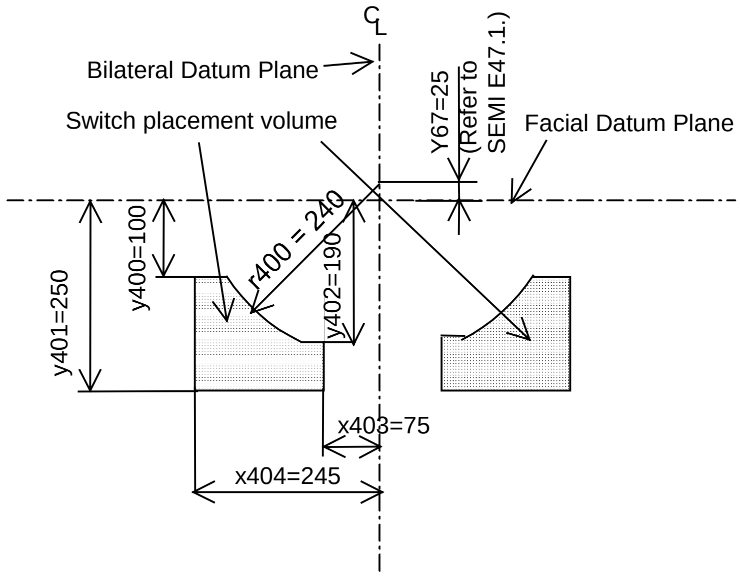


Figure 3
Top view of switch placement volume

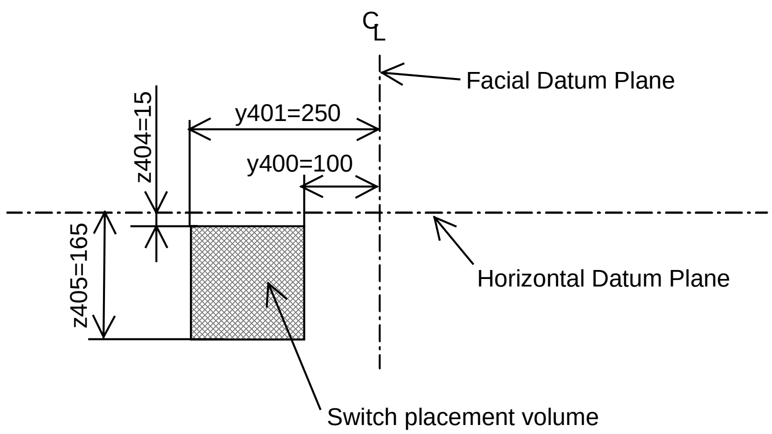


Figure 4
Side view of switch placement volume

Table 3 Dimensions of Switch Placement Volume

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Remarks*
r400	3	240 mm (9.45 in)	y67 in front of nominal wafer center line	Equal to the maximum value of r67 defined in SEMI E47.1
x403	3	75 mm (2.95 in.)	bilateral datum plane	-
x404	3	245 mm (9.65 in.)	bilateral datum plane	-
y400	3,4	100 mm (3.94 in)	facial datum plane (as shown in Figure 1 of SEMI E15.1)	-
y401	3,4	250 mm(9.843 in)	facial datum plane (as shown in Figure 1 of SEMI E15.1)	Equal to the maximum value of D defined in SEMI E15.1
y402	3	190 mm (7.48 in)	facial datum plane (as shown in Figure 1 of SEMI E15.1)	Equal to the maximum value of y53 defined in SEMI E47.1
z404	4	15 mm (0.59 in.)	horizontal datum plane	-
z405	4	165 mm (6.50 in.)	horizontal datum plane	-

6 Related Documents

6.1 *SEMI Standards*

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E92 — Provisional Specification for 300 mm Light Weight and Compact Box Opener/Loader to Tool-Interoperability Standard (BOLTS/Light)

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

SEMI E111-0302
PROVISIONAL MECHANICAL SPECIFICATION FOR A 150 mm RETICLE SMIF POD (RSP150) USED TO TRANSPORT AND STORE A 6 INCH RETICLE

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published November 2001.

1 Purpose

1.1 This standard specifies the 150 mm Reticle SMIF Pod (RSP150) used to transport and store a 6 inch reticle in an integrated circuit (IC) manufacturing facility.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces for the RSP150 are specified; no materials requirements or micro-contamination limits are given in this specification.

2.2 The pellicle exclusion volume of this specification accommodates pellicles which extend the full length of the reticle and up to a maximum pellicle width of 124 mm.

2.3 The RSP150 has the following components, sub-components, and other features. A "●" symbol indicates components or features which are *required* and a "◊" symbol indicates components or features which are *optional*.

- Top
    - ◊ robotic handling flange
- Interior
    - supports for one 6 inch reticle
    - reticle capture
    - reticle contact surfaces
    - end-effector exclusion volumes
    - 2 safety rail exclusion volumes
    - pellicle exclusion volumes
    - lateral constraints
    - 2 reticle backstops
- Sides
    - ◊ 2 side handling flanges on the sides parallel to the bi-lateral reference plane
    - 2 side handling exclusion volumes
- Bottom
    - door compatible with SMIF as defined in SEMI E19.3
    - pod latch-pin holes
    - 2 conveyor rails on the sides parallel to the bi-lateral reference plane

2.4 This standard is provisional because of the issues detailed in the related information section. Once investigation of issues in the Related Information section has been completed, this standard should be upgraded from provisional status.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E19.3 — 150 mm Standard Mechanical Interface (SMIF)

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI P5 — Specification for Pellicles

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *150 mm Reticle SMIF Pod* (RSP150) — a minienvironment compatible carrier capable of holding a 6 inch reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.2 *bilateral reference plane* — a vertical plane which bisects the RSP150 and is perpendicular to both the horizontal and facial reference planes and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.3 *facial reference plane* — a vertical plane which bisects the RSP150 and is parallel to the front side of the pod (where reticles are removed or inserted) and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.4 *horizontal reference plane* — a horizontal plane coplanar with the top surface of the port door as defined in SEMI E19.3.

4.5 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.6 *nominal reticle center line* — the line that is defined by the intersection of two perpendicular vertical planes each of which bisect the reticle at the mid-point of a side.

4.7 *pellicle* — as defined in SEMI P5.

4.8 *reticle* — as defined in SEMI E30.1.

4.9 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box (as defined in SEMI E47.1).

4.10 *side handling flanges* — horizontal projections on the sides of the pod (sides parallel to the bilateral reference plane) for lifting, transportation or positioning of the pod.

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify reticle carriers over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser should specify a time period and the number and type of uses to which the carriers will be put. It is under these conditions that the carriers must remain in compliance with the requirements listed in Section 6.

5.2 *Reticle Thickness* — The purchaser needs to specify the reticle thickness to be accommodated in the RSP150.

5.3 *Optional Features* — The purchaser needs to specify whether optional components (identified in Section 2) are required.

5.4 *Temperature Ranges* — The purchaser needs to specify two sets of temperatures to which the RSP150s might be exposed. An operating temperature range is the set of environmental temperatures in which the RSP150s will remain in compliance with the requirements listed in Section 6. A temporary temperature range is the set of environmental temperatures to which the pods can be exposed such that when the RSP150s return to the operating temperature range, the RSP150s will be in compliance with the requirements listed in Section 6. Limits on exposure times to elevated temperatures should be specified.

5.5 *Electrostatic Dissipation* — The end user may require a continuous path to ground from the reticle to the carrier registration and handling features. The purchaser needs to specify whether electrostatic dissipation is required.

5.6 *Contamination Requirements* — The purchaser needs to specify their contamination requirements.

6 Requirements

6.1 *Symmetry* — Most of the dimensions of the RSP150 are determined with respect to the three orthogonal reference planes defined in this document: the facial reference plane, the horizontal reference plane and the bilateral reference plane. All dimensions are symmetric about the bilateral reference plane.

6.2 *Door* — The pod door, and its frame on the bottom of the pod, must be compatible with a port which conforms to SEMI E19.3.

6.3 *Positioning* — The nominal reticle seating plane is defined by z291, as shown in Figure 4 and Table 1. The entire bottom surface of a reticle must lie within the z276 dimension of its nominal seating plane shown in Figure 6 and Table 1.

6.4 *Reticle Capture* — When the carrier is closed, a bisecting plane through the reticle, parallel to the bilateral reference plane must be constrained by the carrier within x114 of the bilateral reference plane of the load port when the reticle is seated in the carrier. A bisecting plane through the reticle, parallel to the facial reference plane must be constrained by the carrier within y228 of the facial reference plane of the load port when the reticle is seated in the carrier.

6.5 *Reticle Contact Surfaces* — The reticle contact surfaces are the only 4 locations where the RSP150 may contact the pellicle side of the reticle. These surfaces are shown in Figures 9 and 10 with dimensions given in Table 1. The contact surfaces are defined by x245, x246, y233, y234 and y235.

6.6 *Exclusion Volumes* — The interior of the RSP150 must never intrude into the pellicle exclusion volume, and must not intrude into the end-effector exclusion volumes, lift clearance exclusion volume or safety rail exclusion volumes when the carrier is open.

6.6.1 *End-Effector Exclusion Volumes* — Volumes in an opened pod which must be free for the end-effector to enter and handle the reticle as defined by x238, x239, x240, y227, y232, y237, y238, z297, z299 and z302. No obstructions should exist in the end-effector exclusion volumes which extend in the y direction (normal to the facial reference plane.) Table 1 defines the dimensions for the end-effector exclusion volumes shown in Figures 4, 6, 7 and 9.

6.6.2 *Pellicle Exclusion Volume* — Volume in the pod below the reticle which must remain free from intrusion to accommodate the pellicle mounted on the reticle. No obstructions should exist in the pellicle exclusion volume as defined by x119 and z290 which extends in the y direction (normal to the facial reference plane). The pellicle exclusion volume is defined in Table 1 and shown in Figure 4.

6.6.3 *Reticle Lift Clearance Exclusion Volume* — Volume in an opened pod which must be free above the reticle to allow the end-effector to lift and handle the reticles, having a width defined by x243 as shown in Table 1 and Figure 4. No obstructions should exist in the reticle lift clearance exclusion volumes which extend in the y direction (normal to the facial reference plane.)

6.6.4 *Safety Rail Exclusion Volumes* — Volumes in an opened pod which must remain free from intrusion to accommodate safety rails which may be used on end-effectors to protect the edge of the reticle during handling. No obstructions should exist in the safety rail exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by x241 and z301 in Table 1 and shown in Figure 4.

6.6.5 *Rear Retainer Volume* — Volume in an opened pod in which any reticle rear retainer must exist. The volume is defined by x242, y231 and z312 as shown in Figure 7 and Figure 8 and Table 1.

NOTE 2: This volume is never to be accessed by an end-effector.

6.6.6 *Reticle Backstops* — The interior of the RSP150 shall have a reticle backstop which may be used by end-effectors to position the reticle when being removed from the RSP150.

NOTE 3: These are the minimum required backstops, the backstops may be larger than this minimum specification, occupying any part of the rear retainer volume. The dimensions are defined by x249, x250, y239 and z313 as shown in Table 1 and in Figure 7.

6.7 *External Dimensions* — Figures 1, 2, 3, 5 and 11 show, respectively, the external top view, a detail, the rear view, the robotic handling flange and the conveyor rails of the RSP150. Table 1 defines the external dimensions of the RSP150.

6.8 *Internal Dimensions* — Figures 4, 6, 7, 8, 9 and 10 show internal dimensions of the RSP150. Table 1 defines the internal dimensions of the RSP150.

6.9 *Robotic Handling Flange* — On the top of the pod is an optional robotic handling flange for automated manipulation of the RSP150. Figures 1, 3 and 5 show dimensions for the robotic handling flange. Table 1 defines the dimensions for the robotic handling flange.

6.10 *Recess* — Surface on the top of the pod defined by dimensions x100, y106 and z303. Figures 1 and 3 show dimension for the recess. The recess provides clearance for use of robotic handling flange.

NOTE 4: The raised surface around the recess is not required.

6.11 *Side Handling Flanges* — On the sides of the pod parallel to the bilateral reference plane are optional handling flanges for automated manipulation of the RSP150. Figures 1, 2 and 3 show dimensions for the side handling flanges. Table 1 defines the dimensions for the side handling flanges. No obstructions may exist in the side handling exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by x236 and z308.

6.12 *Conveyor Rails* — Surfaces on the bottom of the RSP150 used to transport the RSP on conveyors. The rails consist of smooth portions of the bottom periphery, parallel with each other, on two opposite sides, and extending at least y236 from the facial reference plane (optionally the full length) on those sides. Surfaces on these portions of the bottom periphery should be uninterrupted (i.e. no notches in the surface along the bottom or the side). No other feature of the carrier may extend below the plane defined by the surfaces of the conveyor rails. The conveyor rail surfaces are bounded by x247, x248 and y236 as shown in Figure 11. Table 1 defines the dimensions for the conveyor rails.

6.13 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles.

NOTE 5: These limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier.

NOTE 6: This radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

7 Related Documents

7.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

NOTE 7: Unless otherwise indicated, all documents cited shall be the latest published versions.

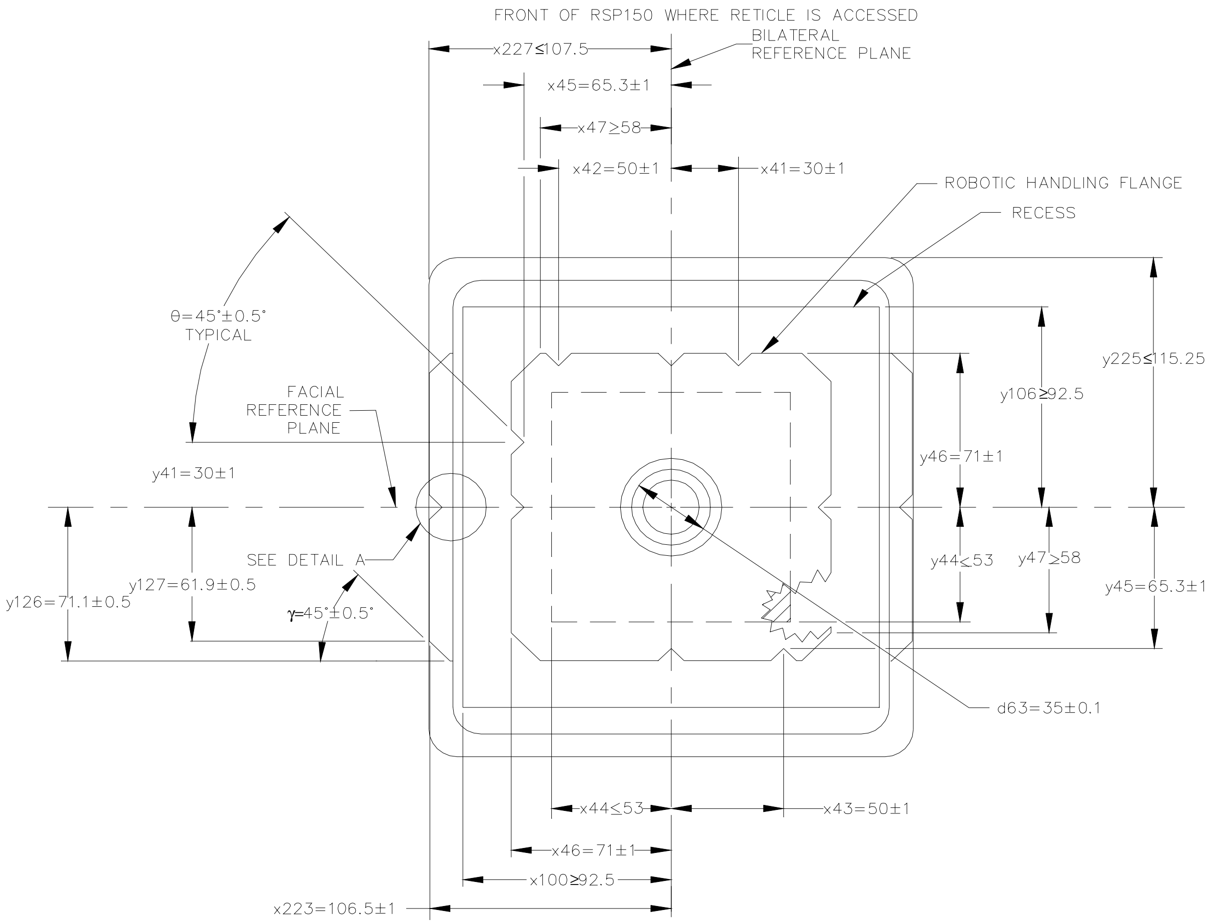


Figure 1
External Top View of RSP150

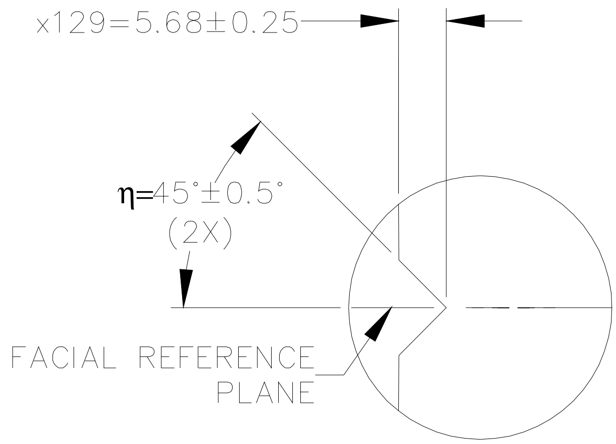


Figure 2
Detail A: External Top View of Side Handling Flange Alignment Notch

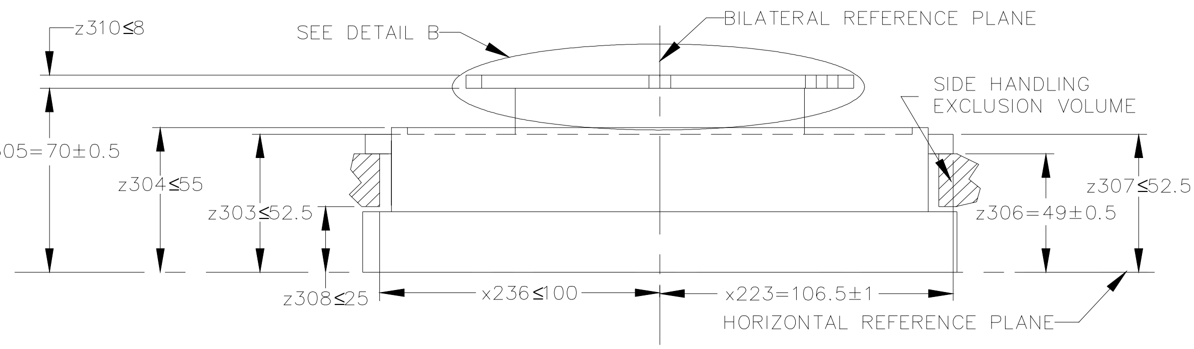


Figure 3
External Rear View of RSP150

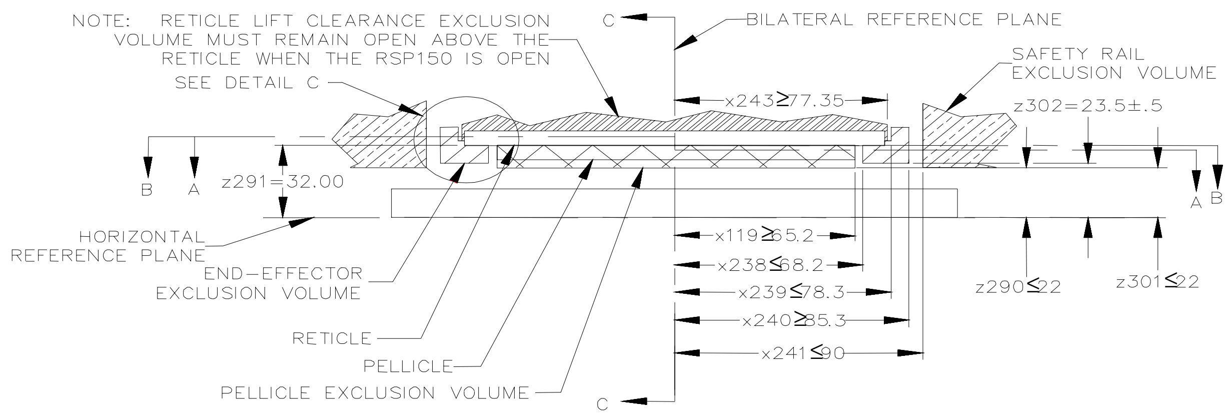


Figure 4
Internal Front View of RSP150

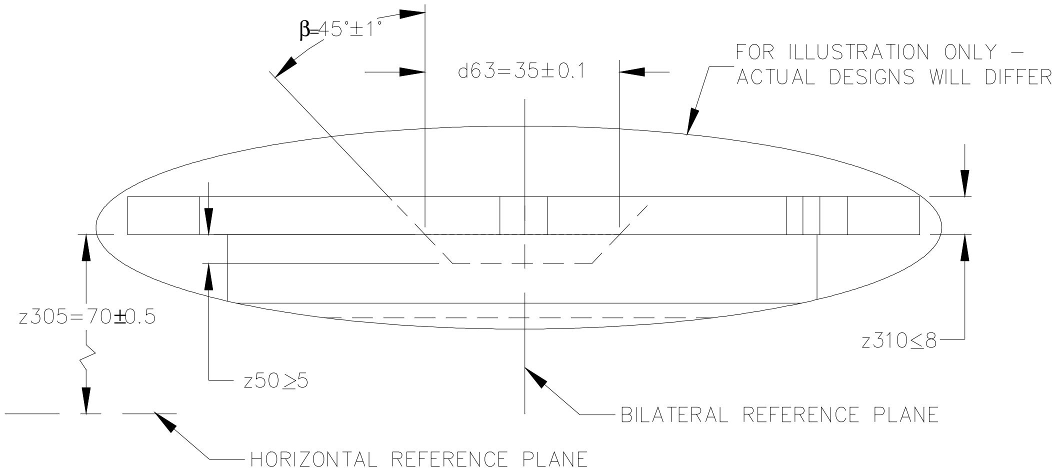


Figure 5
Detail B: Top Robotic Handling Flange Hole Feature

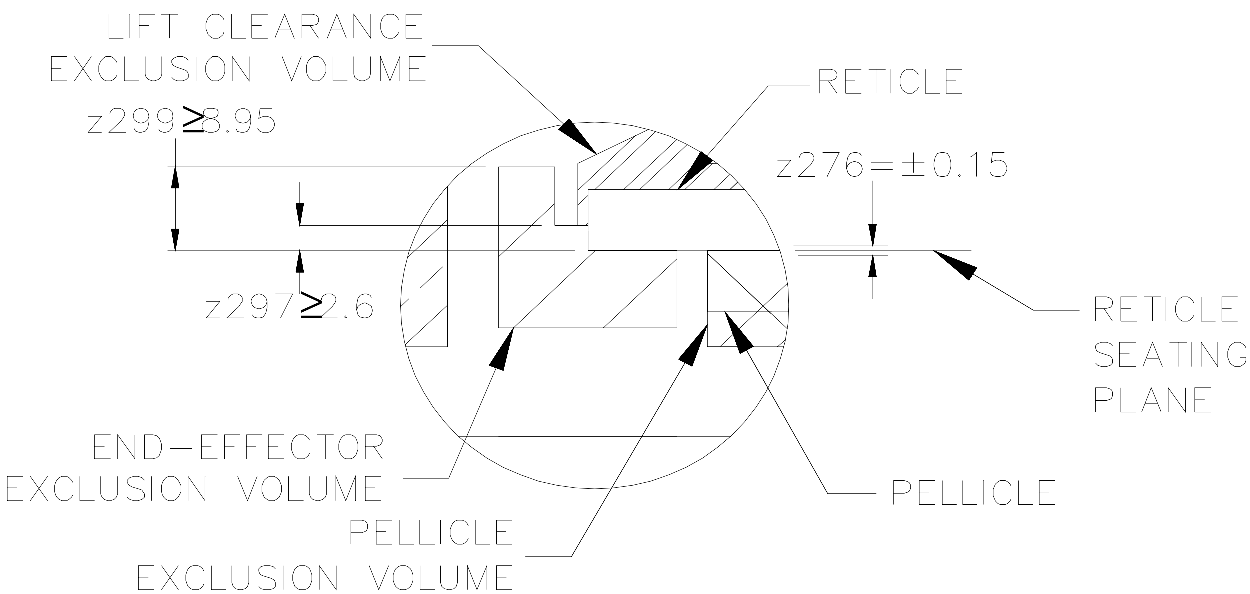


Figure 6
Detail C: Reticle Seating and Capture Detail

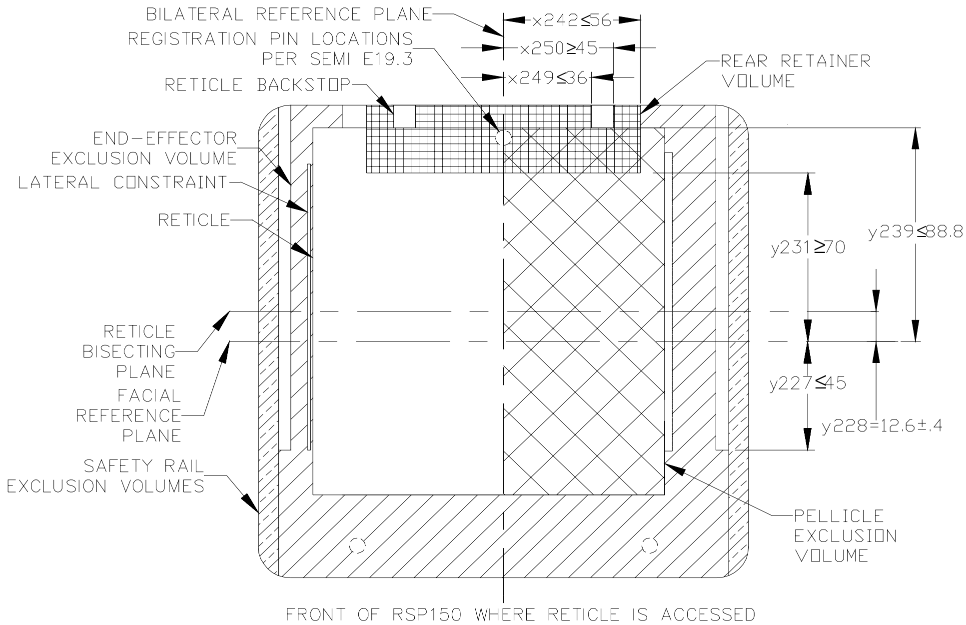


Figure 7
Section A-A: Door Only Top View of RSP150

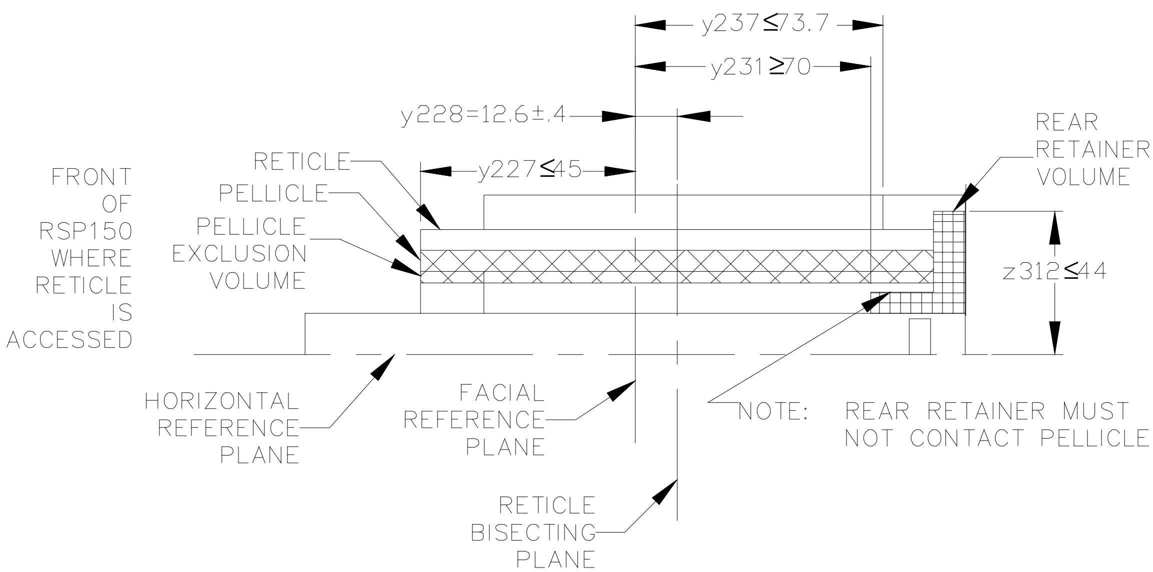


Figure 8
Section C-C: Door Only Side View of RSP150

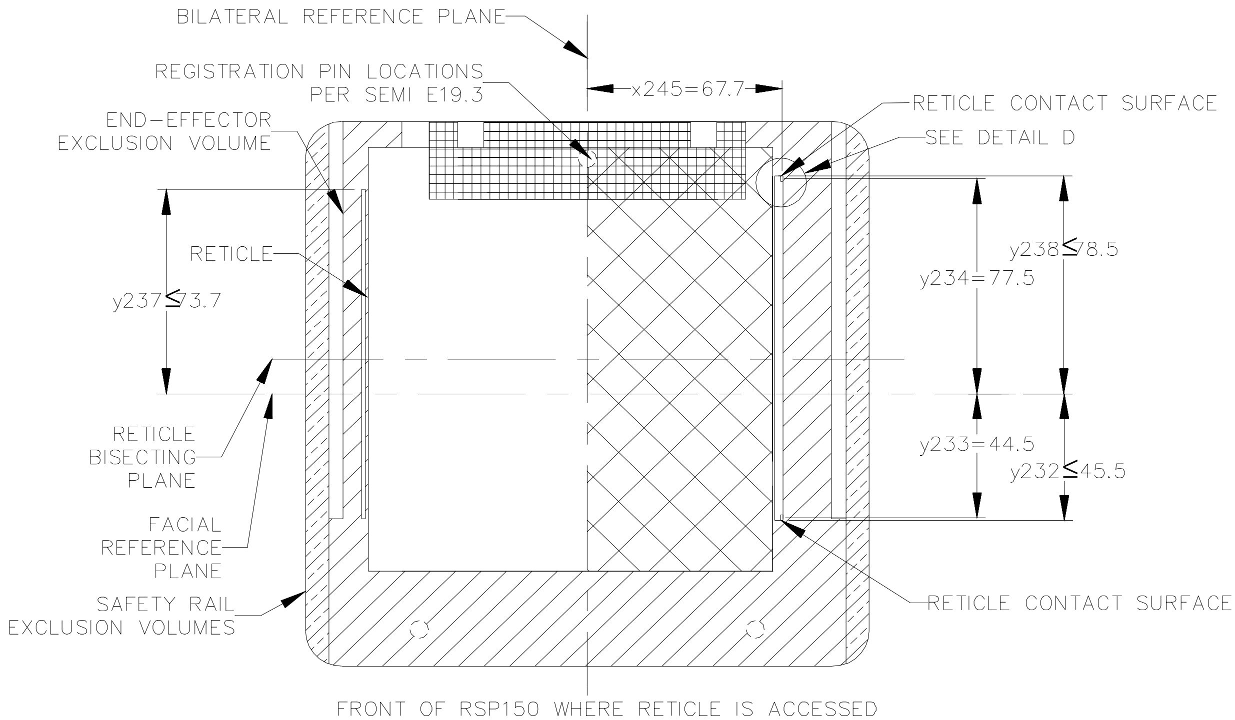


Figure 9
Section B-B: Door Only Top View of RSP150 with Reticle Contact Surfaces

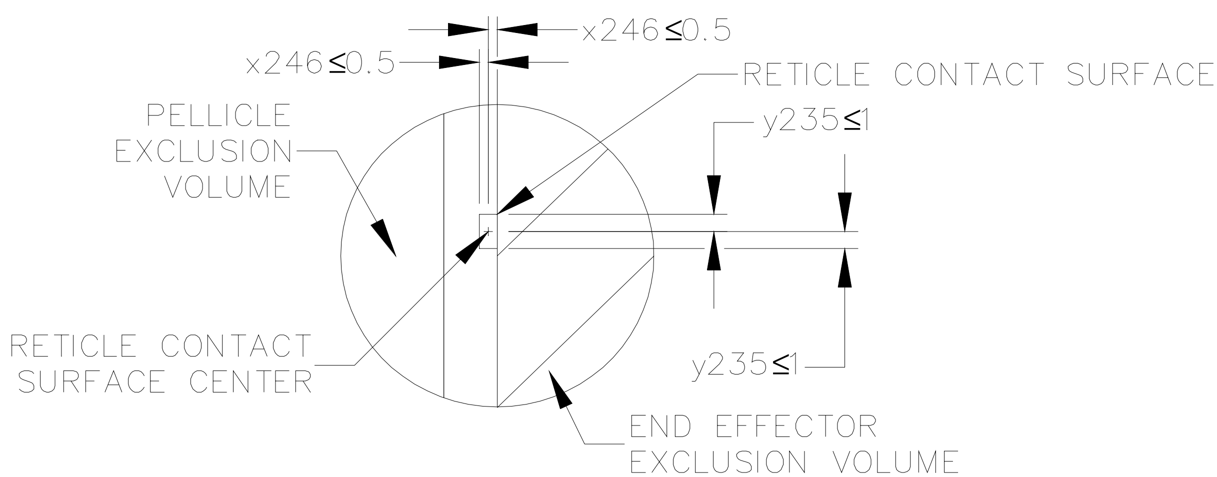


Figure 10
Detail D: Reticle Contact Surface

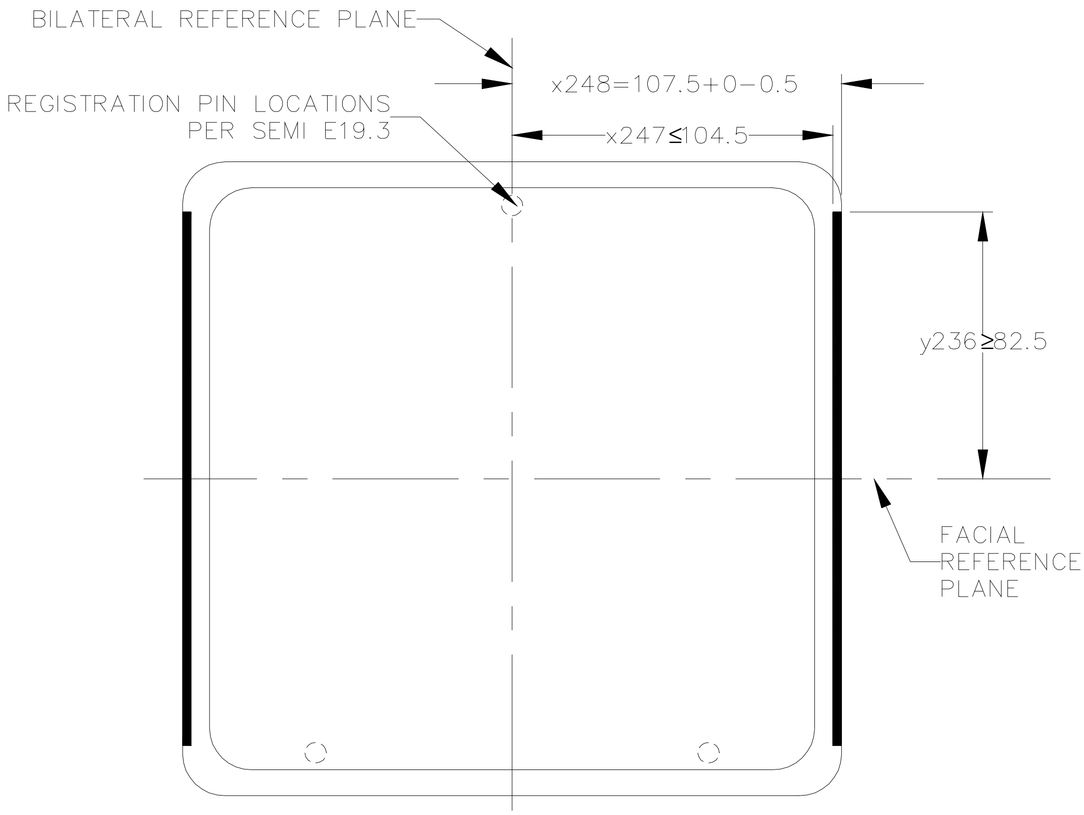


Figure 11
Exterior Bottom View of RSP150

Table 1 External and Internal Dimensions for RSP150

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
θ	1	45° ± 0.5°	facial reference plane	sides of orientation notches
γ	1	45° ± 0.5°	facial reference plane	edge of side handling flange chamfer
η	2	45° ± 0.5°	facial reference plane	sides of side handling flange orientation notches
β	5	45° ± 1°	bilateral and facial plane intersection	surface of the center hole in the top robotic handling flange
r65	n/a	1 mm (0.039 in.) maximum	not applicable	all required concave features (radius)
r66	n/a	2 mm (0.079 in.) maximum	not applicable	all required convex features (radius)
d63	5	35 ± 0.1 mm (1.378 ± 0.004 in.)	centered on bilateral and facial plane intersection	top robotic handling flange hole design feature
x41	1	30 ± 1 mm (1.181 ± 0.039 in.)	bilateral reference plane	orientation notch center
x42	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x43	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x44	1	53 mm (2.087 in.) maximum	bilateral reference plane	side of robotic handling flange column
x45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	bilateral reference plane	orientation notch tip
x46	1	71 ± 1 mm (2.795 ± 0.039 in.)	bilateral reference plane	edge of robotic handling flange
x47	1	58 mm (2.283 in.) minimum	bilateral reference plane	edge of robotic handling flange corner beveling
x100	1	92.5 mm (3.642 in.) minimum	bilateral reference plane	edge of recess
x114	None	0 ± 1 mm (0 ± 0.039 in.)	bilateral reference plane	reticle bisecting plane
x119	4	65.2 mm (2.567 in.) minimum	bilateral reference plane	edge of pellicle exclusion volume
x129	2	5.68 ± 0.25 mm (0.224 ± 0.010 in.)	side edge of side handling flange	side handling flange alignment notch tip
x223	1, 3	106.5 ± 1 mm (4.193 ± 0.039 in.)	bilateral reference plane	edge of side handling flange
x227	1	107.5 mm (4.232 in.) maximum	bilateral reference plane	side of pod
x236	3	100 mm (3.937 in.) maximum	bilateral reference plane	edge of side handling exclusion volume
x238	4	68.2 mm (2.685 in.) maximum	bilateral reference plane	edge of end-effector exclusion volume
x239	4	78.3 mm (3.083 in.) maximum	bilateral reference plane	edge of end-effector exclusion volume
x240	4	85.3 mm (3.358 in.) minimum	bilateral reference plane	edge of end-effector exclusion volume
x241	4	90 mm (3.543 in.) maximum	bilateral reference plane	edge of safety rail exclusion volume
x242	7	56 mm (2.205 in.) maximum	bilateral reference plane	edge of rear retainer volume

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
x243	4	77.35 mm (3.045 in.) minimum	bilateral reference plane	edge of lift clearance exclusion volume
x245	9	67.7 mm (2.665 in.)	bilateral reference plane	center of reticle contact surface
x246	10	0.5 mm (0.019 in.) maximum	center of reticle contact surface	edge of reticle contact surface
x247	11	104.5 mm (4.114 in.) maximum	bilateral reference plane	edge of conveyor rail surface
x248	11	107.5 +0 –0.5 mm (4.232 +0 –0.020 in.)	bilateral reference plane	edge of conveyor rail surface
x249	7	36 mm (1.417 in.) maximum	bilateral reference plane	edge of reticle backstops
x250	7	45 mm (1.772 in.) minimum	bilateral reference plane	edge of reticle backstops
y41	1	30 ± 1 mm (1.181 ± 0.039 in.)	facial reference plane	center of orientation notch
y44	1	53 mm (2.087 in.) maximum	facial reference plane	side of robotic handling flange column
y45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	facial reference plane	orientation notch tip
y46	1	71 ± 1 mm (2.795 ± 0.039 in.)	facial reference plane	edge of robotic handling flange
y47	1	58 mm (2.283 in.) minimum	facial reference plane	edge of robotic handling flange corner beveling
y106	1	92.5 mm (3.642 in.) minimum	facial reference plane	edge of recess
y126	1	71.1 ± 0.5 mm (2.799 ± 0.020 in.)	facial reference plane	depth of side handling flange
y127	1	61.9 ± 0.5 mm (2.437 ± 0.020 in.)	facial reference plane	edge of side handling flange corner bevel
y225	1	115.25 mm (4.537 in.) maximum	facial reference plane	side of pod
y227	7, 8	45 mm (1.771 in.) maximum	facial reference plane	edge of end-effector exclusion volume
y228	7, 8	12.6 ± 0.4 mm (0.496 ± 0.016 in.)	facial reference plane	reticle bisecting plane
y231	7, 8	70 mm (2.756 in.) minimum	facial reference plane	edge of rear retainer volume
y232	9	45.5 mm (1.791 in.) maximum	facial reference plane	edge of end effector exclusion volume
y233	9	44.5 mm (1.752 in.)	facial reference plane	center of reticle contact surface
y234	9	77.5 mm (3.051 in.)	facial reference plane	center of reticle contact surface
y235	10	1 mm (0.039 in.) maximum	center of reticle contact surface	edge of reticle contact surface
y236	11	82.5 mm (3.248 in.) minimum	facial reference plane	end of conveyor rail surface
y237	8, 9	73.7 mm (2.902 in.) maximum	facial reference plane	edge of end effector exclusion volume
y238	9	78.5 mm (3.091 in.) maximum	facial reference plane	edge of end effector exclusion volume
y239	7	88.8 mm (3.496 in.) maximum	bilateral reference plane	edge of reticle backstops

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
z50	5	5 mm (0.197 in.) minimum	bottom of circular recess	encroachment of RSP150 top underneath the center hole in the top robotic flange
z276	6	± 0.15 mm (0.006 in.)	each nominal reticle seating plane	entire bottom surface of the reticle
z290	4	22 mm (0.866 in.) maximum	horizontal reference plane	edge of first reticle pellicle exclusion volume
z291	4	32 mm (1.260 in.)	horizontal reference plane	nominal reticle seating plane
z297	6	2.6 mm (0.102 in.) minimum	each nominal reticle seating plane	edge of end-effector exclusion volume
z299	6	8.95 mm (0.352 in.) minimum	each nominal reticle seating plane	edge of end-effector exclusion volume
z301	4	22 mm (0.866 in.) maximum	horizontal reference plane	edge of safety rail exclusion volume
z302	4	23.5 ± 0.5 mm (0.945 ± 0.020 in.)	horizontal reference plane	edge of first reticle end-effector exclusion volume
z303	3	52.5 mm (2.067 in.) maximum	horizontal reference plane	top surface of dome recess
z304	3	55 mm (2.165 in.) maximum	horizontal reference plane	top surface of dome
z305	3, 5	70 ± 0.5 mm (2.756 ± 0.020 in.)	horizontal reference plane	bottom surface of robotic handling flange
z306	3	49 ± 0.5 mm (1.929 ± 0.020 in.)	horizontal reference plane	bottom edge of side handling flange
z307	3	52.5 mm (2.067 in.) maximum	horizontal reference plane	top surface of side handling flange
z308	3	25 mm (0.984 in.) maximum	horizontal reference plane	edge of side handling exclusion volume
z310	3, 5	8 mm (0.315 in.) maximum	bottom surface of robotic handling flange	top of robotic handling flange
z312	8	44 mm (1.732 in.) maximum	horizontal reference plane	top of rear retainer exclusion volume
z313	n/a	43 ± 1 mm (1.1693 ± 0.039 in.)	horizontal reference plane	top of reticle backstops

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix is an official part of SEMI E111 and was approved by full letter ballot procedures on August 27, 2001, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Skewness, warp, rock, and stiffness are implicitly defined in the dimensional tolerances.

A1-2 Features on the RSP150 which enable stacking may be required by end users. It is preferred that these features allowing stacking in only one orientation.

A1-3 Features on the RSP150 which provide visual orientation of the RSP150 top and RSP150 door may be required by end users.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E111, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 In the event end-effector and pellicle exclusion volumes can be developed which would satisfy all lithography equipment manufacturers and allow for a 126 mm pellicle, then the appropriate changes would be balloted to update the standard.

SEMI E112-0302
PROVISIONAL MECHANICAL SPECIFICATION FOR A 150 mm MULTIPLE RETICLE SMIF POD (MRSP150) USED TO TRANSPORT AND STORE MULTIPLE 6 INCH RETICLES

This specification was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org January 2002; to be published March 2002. Originally published November 2001.

1 Purpose

1.1 This standard specifies the 150 mm Multiple Reticle SMIF Pod (MRSP150) used to transport and store six 6 inch reticles in an integrated circuit (IC) manufacturing facility.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces for the MRSP150 are specified; no materials requirements or micro-contamination limits are given in this specification.

2.2 The pellicle exclusion volumes of this specification accommodates pellicles which extend the full length of the reticle and up to a maximum pellicle width of 124 mm.

2.3 The MRSP150 has the following components, sub-components, and other features. A "●" symbol indicates components or features which are *required* and a "◊" symbol indicates components or features which are *optional*.

- Top
  - ◊ robotic handling flange
- Interior
  - supports for six 6 inch reticles
  - reticle capture
  - reticle contact surfaces
  - end-effector exclusion volumes
  - 2 safety rail exclusion volumes
  - pellicle exclusion volumes
  - lateral constraints
  - reticle backstop
- Sides
  - ◊ 2 side handling flanges on the sides parallel to the bi-lateral reference plane
  - 2 side handling exclusion volumes
- Bottom
  - door compatible with SMIF as defined in SEMI E19.3
  - pod latch-pin holes
  - 2 conveyor rails on the sides parallel to the bi-lateral reference plane

2.4 This standard is provisional because of the issues detailed in the related information section. Once investigation of issues in the related information section has been completed, this standard should be upgraded from provisional status.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E19.3 — 150 mm Standard Mechanical Interface (SMIF)

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM)

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI P5 — Specification for Pellicles

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *150 mm Multiple Reticle SMIF Pod* (MRSP150) — a minienvironment compatible carrier capable of holding six 6 inch reticles in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.3.

4.2 *bilateral reference plane* — a vertical plane which bisects the MRSP150 and is perpendicular to both the horizontal and facial reference planes and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.3 *facial reference plane* — a vertical plane which bisects the MRSP150 and is parallel to the front side of the pod (where reticles are removed or inserted) and passes through the center of the 150 mm SMIF as defined in SEMI E19.3.

4.4 *horizontal reference plane* — a horizontal plane coplanar with the top surface of the port door as defined in SEMI E19.3.

4.5 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

4.6 *nominal reticle center line* — the line that is defined by the intersection of two perpendicular vertical planes each of which bisect the reticle at the mid-point of a side.

4.7 *pellicle* — as defined in SEMI P5.

4.8 *reticle* — as defined in SEMI E30.1.

4.9 *robotic handling flanges* — horizontal projections on the top of the box for lifting and rotating the box (as defined in SEMI E47.1).

4.10 *side handling flanges* — horizontal projections on the sides of the pod (sides parallel to the bilateral reference plane) for lifting, transportation or positioning of the pod.

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify reticle carriers over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser should specify a time period and the number and type of uses to which the carriers will be put. It is under these conditions that the carriers must remain in compliance with the requirements listed in Section 6.

5.2 *Reticle Thickness* — The purchaser needs to specify the reticle thickness to be accommodated in the MRSP150.

5.3 *Optional Features* — The purchaser needs to specify whether optional components (identified in Section 2) are required.

5.4 *Temperature Ranges* — The purchaser needs to specify two sets of temperatures to which the MRSP150s might be exposed. An operating temperature range is the set of environmental temperatures in which the MRSP150s will remain in compliance with the requirements listed in Section 6. A temporary temperature range is the set of environmental temperatures to which the pods can be exposed such that when the MRSP150s return to the operating temperature range, the MRSP150s will be in compliance with the requirements listed in Section 6. Limits on exposure times to elevated temperatures should be specified.

5.5 *Electrostatic Dissipation* — The end user may require a continuous path to ground from the reticle to the carrier registration and handling features. The purchaser needs to specify whether electrostatic dissipation is required.

5.6 *Contamination Requirements* — The purchaser needs to specify their contamination requirements.

6 Requirements

6.1 *Symmetry* — Most of the dimensions of the MRSP150 are determined with respect to the three orthogonal reference planes defined in this document: the facial reference plane, the horizontal reference plane and the bilateral reference plane. All dimensions are symmetric about the bilateral reference plane.

6.2 *Door* — The pod door, and its frame on the bottom of the pod, must be compatible with a port which conforms to SEMI E19.3.

6.3 *Numbering* — The reticles are numbered in increasing order from bottom to top (so the bottom reticle is reticle number 1, to the top reticle which is reticle number 6).

6.4 *Positioning* — The nominal reticle seating planes are defined by z291 through z296 as shown in Figure 4 and Table 1. The entire bottom surface of a reticle must lie within the z276 dimension of its nominal seating plane shown in Figure 6 and Table 1.

6.5 *Reticle Contact Surfaces* — The reticle contact surfaces are the only 4 locations where the RSP150 may contact the pellicle side of the reticle. These surfaces are shown in Figures 8 and 9 with dimensions given in Table 1. The contact surfaces are defined by x245, x246, y233, y234 and y235.

6.6 *Reticle Capture* — When the carrier is closed, a bisecting plane through the reticle, parallel to the bilateral reference plane must be within x114 of the bilateral reference plane of the load port when the reticle is seated in the carrier. A bisecting plane through the reticle, parallel to the facial reference plane must be within y228 of the facial reference plane of the load port when the reticle is seated in the carrier.

6.7 *Exclusion Volumes* — The interior of the MRSP150 must never intrude into the pellicle exclusion volume, and must not intrude into the end-effector exclusion volumes, lift clearance exclusion volumes or safety rail exclusion volumes when the carrier is open.

6.7.1 *End-Effector Exclusion Volumes* — Volumes in an opened pod which must be free for the end-effector to enter and handle the reticle as defined by x238, x239, x240, y227, y232, y237, y238, z297, z299, z302 (first reticle) and z300 (second through sixth reticle). No obstructions should exist in the end-effector exclusion volumes which extend in the y direction (normal to the facial reference plane.) Table 1 defines the dimensions for the end-effector exclusion volumes shown in Figures 4, 6, 7 and 8.

6.7.2 *Pellicle Exclusion Volume* — Volume in the pod below the reticle which must remain free from intrusion to accommodate the pellicle mounted on the reticle. No obstructions should exist in the pellicle exclusion volume as defined by x119, z290 (first reticle) and the previous reticle lift clearance exclusion volume (second through sixth reticle) which extends in the y direction (normal to the facial reference plane). The pellicle exclusion volume is defined in Table 1 and shown in Figure 4.

6.7.3 *Reticle Lift Clearance Exclusion Volumes* — Volumes in an opened pod which must be free to allow the end-effector to lift and handle the reticles, as defined by x243, z298 and z311 (sixth reticle) as shown in Table 1 and Figures 4 and 6. No obstructions should exist in the reticle lift clearance exclusion volumes which extend in the y direction (normal to the facial reference plane.)

6.7.4 *Safety Rail Exclusion Volumes* — Volumes in an opened pod which must remain free from intrusion to accommodate safety rails which may be used on end-effectors to protect the edge of the reticle during handling. No obstructions should exist in the safety rail exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by x241 and z301 in Table 1 and shown in Figure 4.

6.7.5 *Rear Retainer Volume* — Volume in an opened pod in which any reticle rear retainer must exist. The volume is defined by x242 and y226 as shown in Figure 7 and Table 1.

NOTE 2: This volume is never to be accessed by an end-effector.

6.7.6 *Reticle Backstops* — The interior of the RSP150 shall have reticle backstops which may be used by end-effectors to position the reticle when being removed from the RSP150.

NOTE 3: These are the minimum required backstops, the backstops may be larger than this minimum specification, occupying any part of the rear retainer volume. The dimensions are defined by x249, x250, y239 and z314 as shown in Table 1 and in Figure 7.

6.8 *External Dimensions* — Figures 1, 2, 3, 5 and 10 show, respectively, the external top view, a detail, the rear view, the robotic handling flange and the conveyor rails of the MRSP150. Table 1 defines the external dimensions of the MRSP150.

6.9 *Internal Dimensions* — Figures 4, 6 and 7 show internal dimensions of the MRSP150. Table 1 defines the internal dimensions of the MRSP150.

6.10 *Robotic Handling Flange* — On the top of the pod is an optional robotic handling flange for automated manipulation of the MRSP150. Figures 1, 3 and 5 show dimensions for the robotic handling flange. Table 1 defines the dimensions for the robotic handling flange.

6.11 *Recess* — Surface on the top of the pod defined by dimensions x100, y106 and z281. Figures 1 and 3 show dimension for the recess. The recess provides clearance for use of robotic handling flange.

NOTE 4: The raised surface around the recess is not required.

6.12 *Side Handling Flanges* — On the sides of the pod parallel to the bilateral reference plane are optional handling flanges for automated manipulation of the MRSP150. Figures 1, 2 and 3 show dimensions for the side handling flanges. Table 1 defines the dimensions for the side handling flanges. No obstructions may exist in the side handling exclusion volumes which extend in the y direction (normal to the facial reference plane) as defined by x236 and z286.

6.13 *Conveyor Rails* — Surfaces on the bottom of the RSP150 used to transport the RSP on conveyors. The rails consist of smooth portions of the bottom periphery, parallel with each other, on two opposite sides, and extending at least y236 from the facial reference plane (optionally the full length) on those sides. Surfaces on these portions of the bottom periphery should be uninterrupted (ie. no notches in the surface along the bottom or the side). No other feature of the carrier may extend below the plane defined by the surfaces of the conveyor rails. The conveyor rail surfaces are bounded by x247, x248 and y236 as shown in Figure 10. Table 1 defines the dimensions for the conveyor rails.

6.14 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles.

NOTE 5: These limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier.

NOTE 6: This radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

7 Related Documents

7.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

NOTE 7: Unless otherwise indicated, all documents cited shall be the latest published versions.

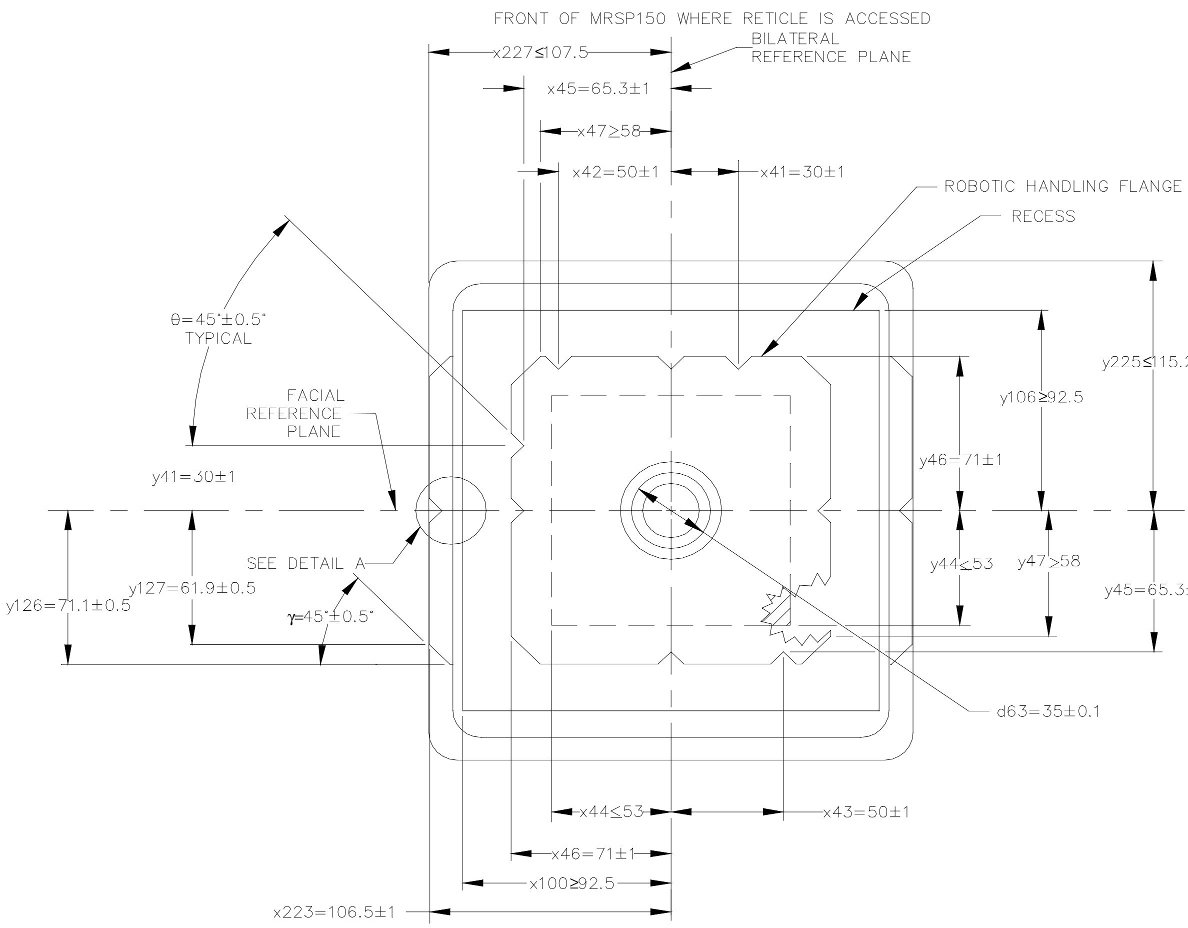


Figure 1
External Top View of MRSP150

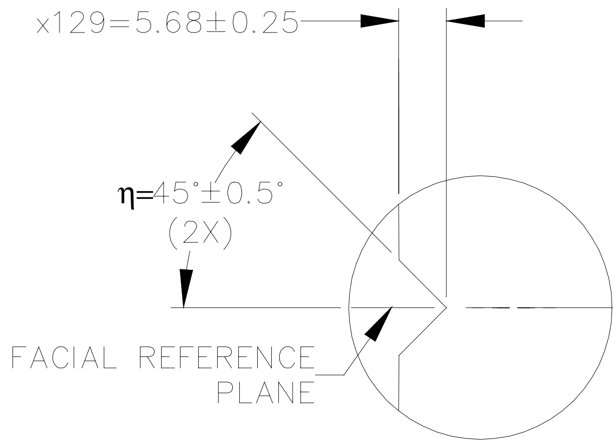


Figure 2
Detail A: External Top View of Side Handling Flange Alignment Notch

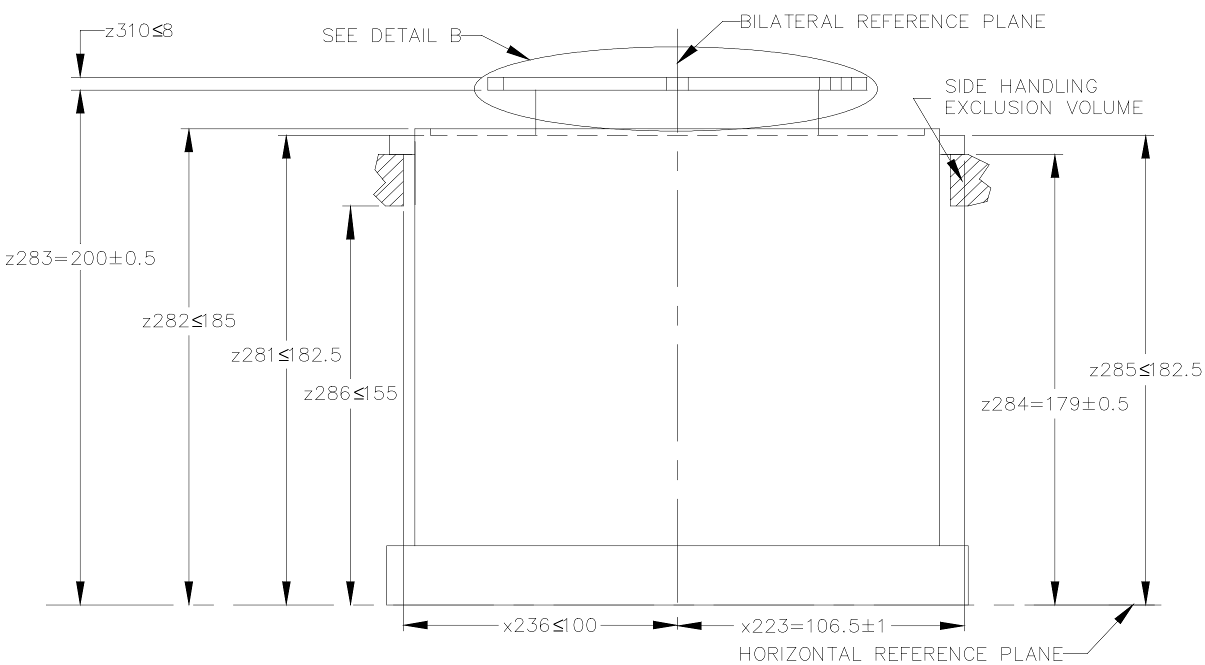


Figure 3
External Rear View of MRSP150

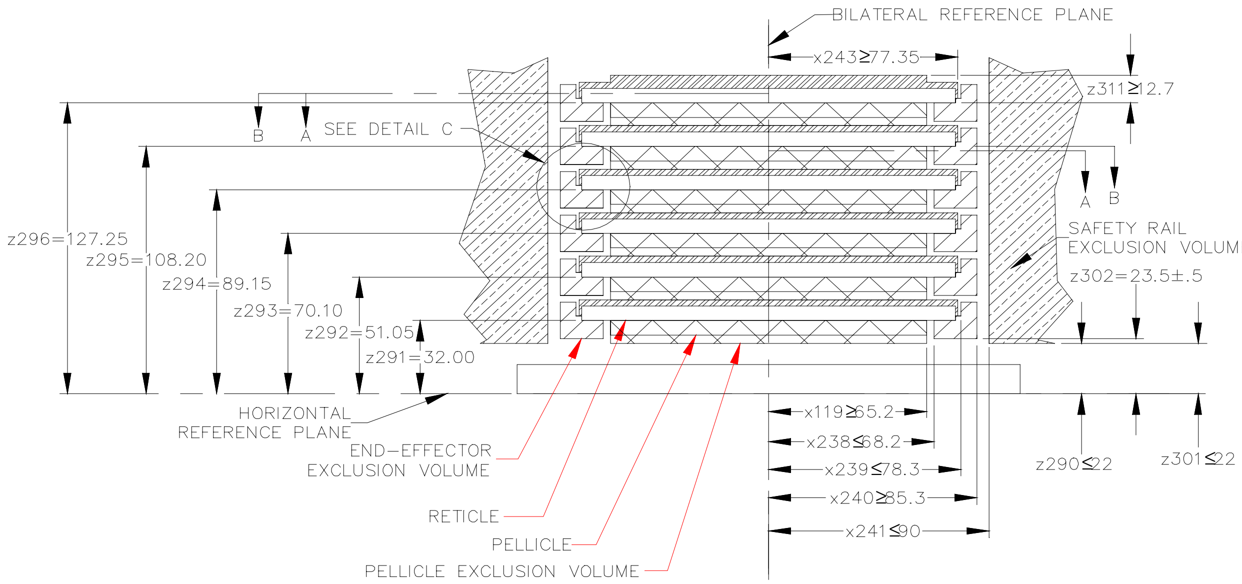


Figure 4
Internal Front View of MRSP150

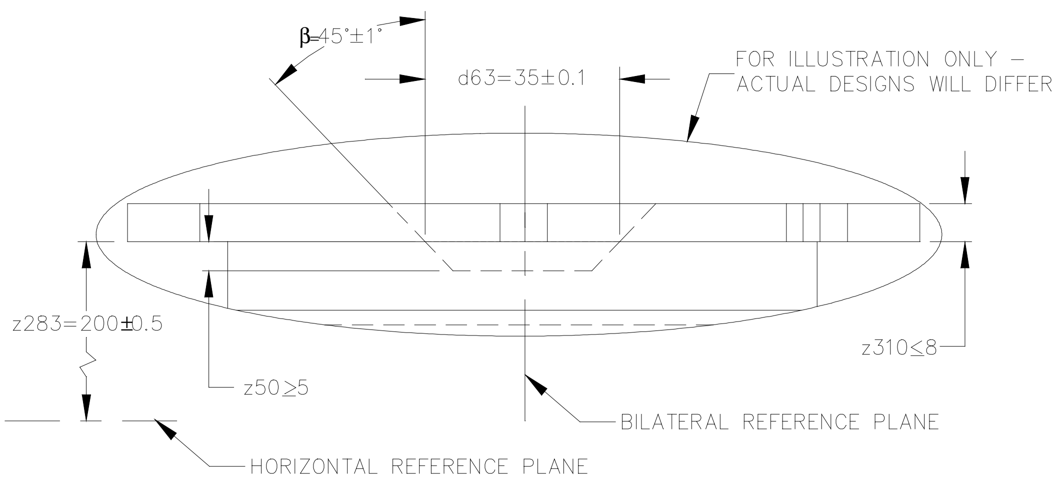


Figure 5
Detail B: Top Robotic Handling Flange Hole Feature

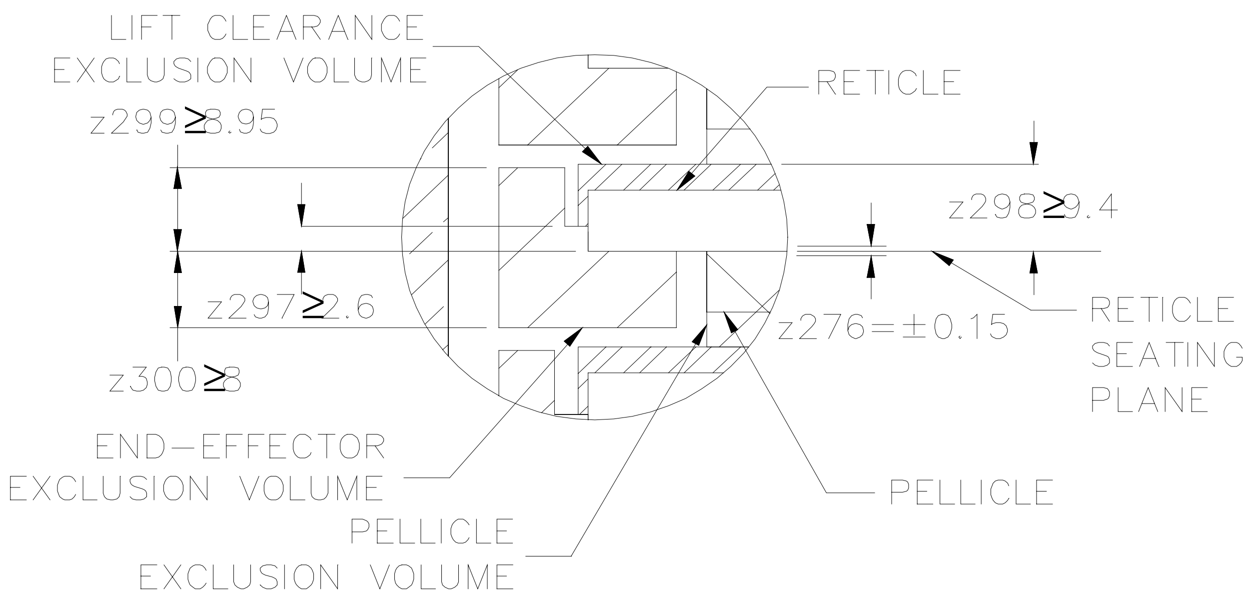


Figure 6
Detail C: Reticle Seating and Capture Detail

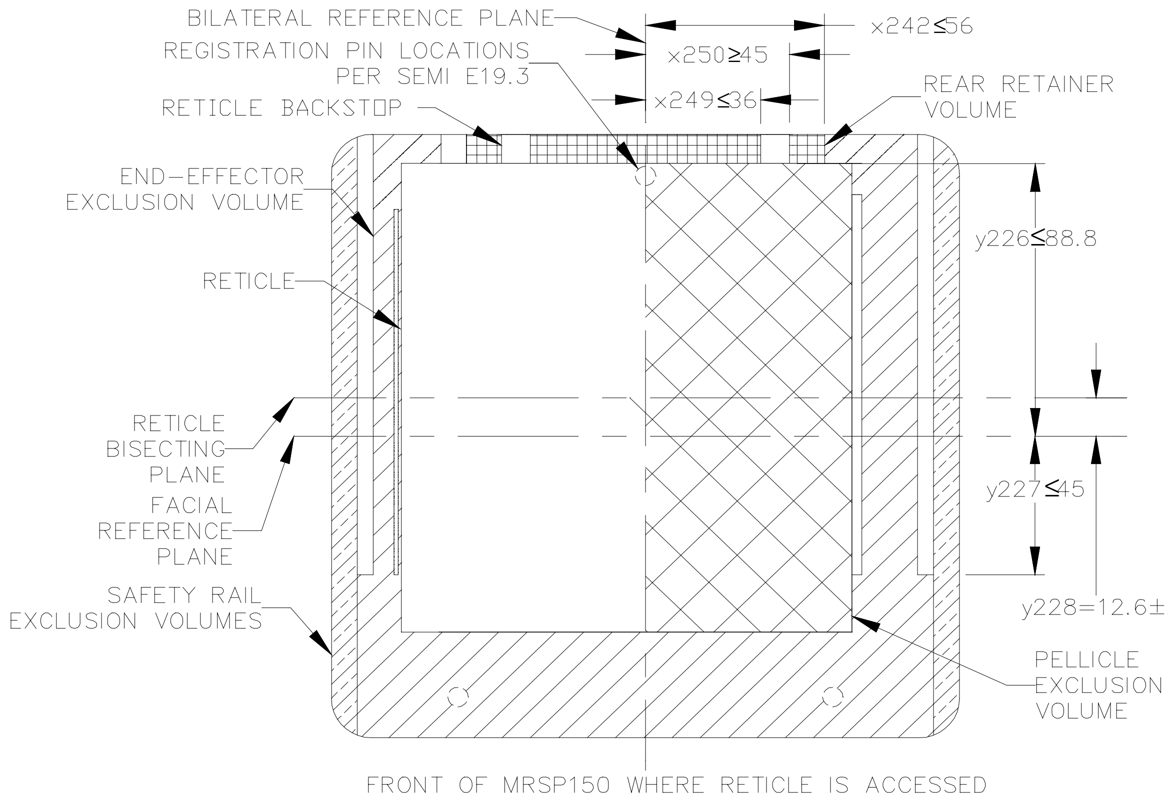


Figure 7
Section A-A: Door Only Top View of MRSP150

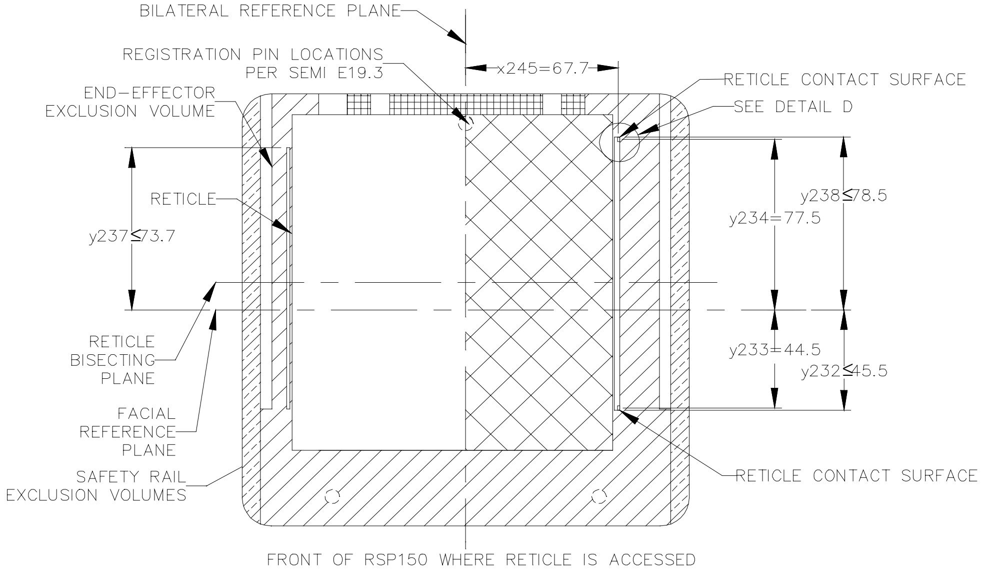


Figure 8
Section B-B: Door Only Top View of MRSP150 with Reticle Contact Surfaces

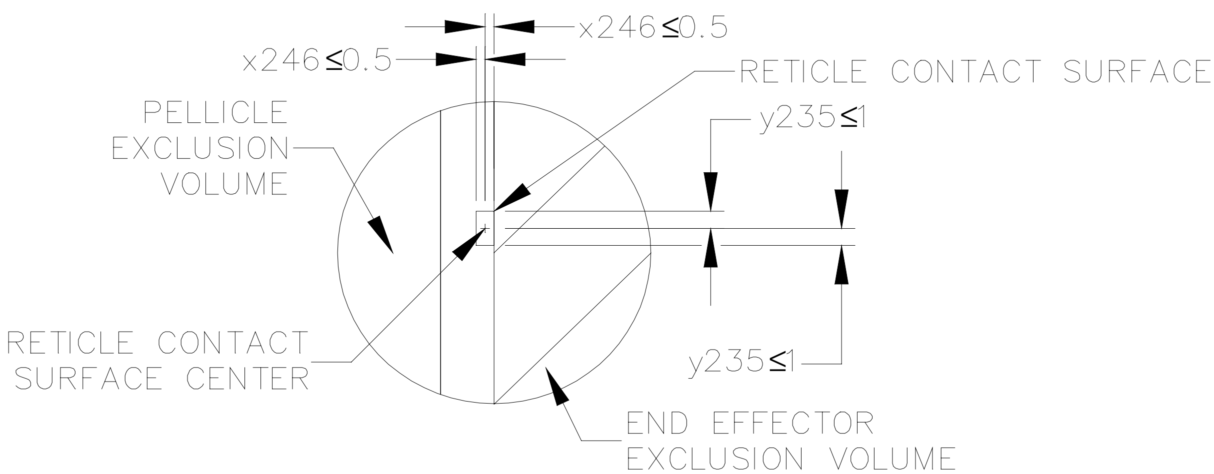


Figure 9
Detail D: Reticle Contact Surface

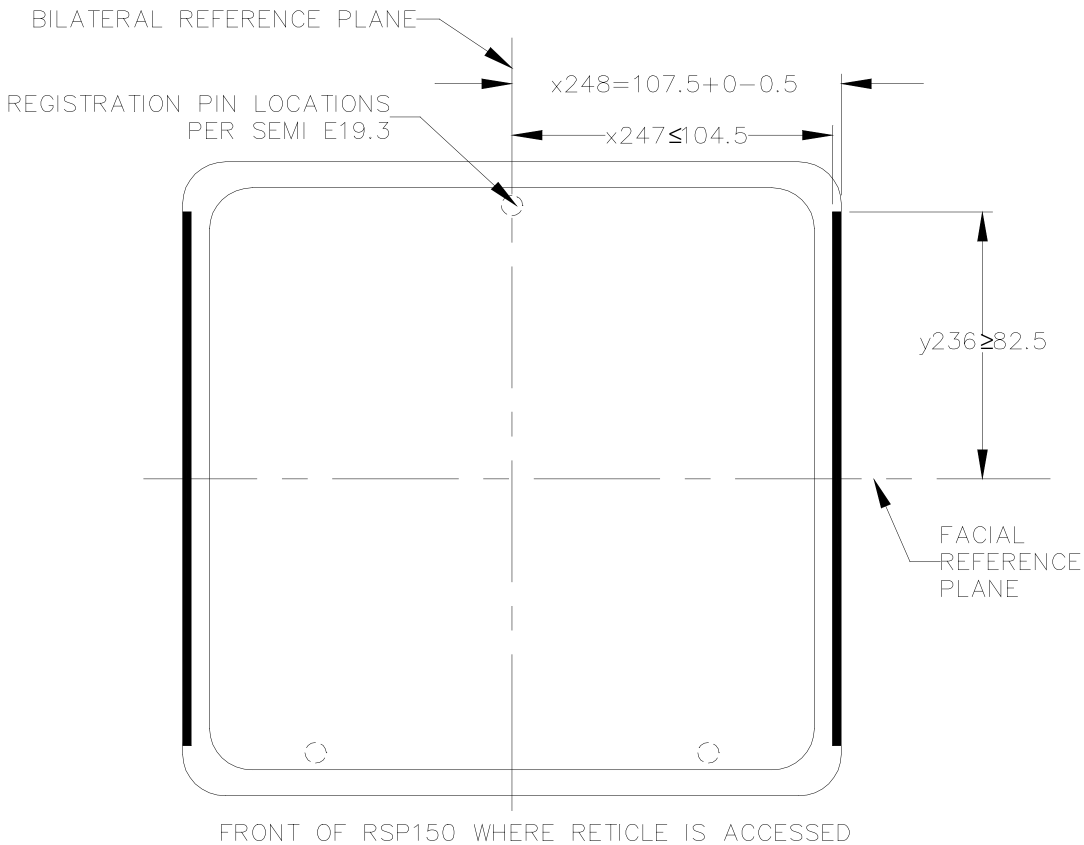


Figure 10
Exterior Bottom View of RSP150

Table 1 External and Internal Dimensions for MRSP150

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
θ	1	45° ± 0.5°	facial reference plane	sides of orientation notches
γ	1	45° ± 0.5°	facial reference plane	edge of side handling flange chamfer
η	2	45° ± 0.5°	facial reference plane	sides of side handling flange orientation notches
β	5	45° ± 1°	bilateral and facial plane intersection	surface of the center hole in the top robotic handling flange
r65	n/a	1 mm (0.039 in.) maximum	not applicable	all required concave features (radius)
r66	n/a	2 mm (0.079 in.) maximum	not applicable	all required convex features (radius)
d63	5	35 ± 0.1 mm (1.378 ± 0.004 in.)	centered on bilateral and facial plane intersection	top robotic handling flange hole design feature
x41	1	30 ± 1 mm (1.181 ± 0.039 in.)	bilateral reference plane	orientation notch center
x42	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x43	1	50 ± 1 mm (1.969 ± 0.039 in.)	bilateral reference plane	orientation notch center
x44	1	53 mm (2.087 in.) maximum	bilateral reference plane	side of robotic handling flange column
x45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	bilateral reference plane	orientation notch tip
x46	1	71 ± 1 mm (2.795 ± 0.039 in.)	bilateral reference plane	edge of robotic handling flange
x47	1	58 mm (2.283 in.) minimum	bilateral reference plane	edge of robotic handling flange corner beveling
x100	1	92.5 mm (3.642 in.) minimum	bilateral reference plane	edge of recess
x114	None	0 ± 1 mm (0 ± 0.039 in.)	bilateral reference plane	reticle bisecting plane
x119	4	65.2 mm (2.567 in.) minimum	bilateral reference plane	edge of pellicle exclusion volume
x129	2	5.68 ± 0.25 mm (0.224 ± 0.039 in.)	side edge of side handling flange	side handling flange alignment notch tip
x223	1, 3	106.5 ± 1 mm (4.193 ± 0.039 in.)	bilateral reference plane	edge of side handling flange
x227	1	107.5 mm (4.232 in.) maximum	bilateral reference plane	side of pod
x236	3	100 mm (3.937 in.) maximum	bilateral reference plane	edge of side handling exclusion volume
x238	4	68.2 mm (2.685 in.) maximum	bilateral reference plane	edge of end-effector exclusion volume
x239	4	78.3 mm (3.083 in.) maximum	bilateral reference plane	edge of end-effector exclusion volume
x240	4	85.3 mm (3.358 in.) minimum	bilateral reference plane	edge of end-effector exclusion volume
x241	4	90 mm (3.543 in.) maximum	bilateral reference plane	edge of safety rail exclusion volume
x242	7	56 mm (2.205 in.) maximum	bilateral reference plane	edge of rear retainer volume

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
x243	4	77.35 mm (3.045 in.) minimum	bilateral reference plane	edge of lift clearance exclusion volume
x245	8	67.7 mm (2.665 in.)	bilateral reference plane	center of reticle contact surface
x246	9	0.5 mm (0.019 in.) maximum	center of reticle contact surface	edge of reticle contact surface
x247	10	104.5 mm (4.114 in.) maximum	bilateral reference plane	edge of conveyor rail surface
x248	10	107.5 +0 –0.5 mm (4.232 +0 –0.020 in.)	bilateral reference plane	edge of conveyor rail surface
x249	7	36 mm (1.417 in.) maximum	bilateral reference plane	edge of reticle backstops
x250	7	45 mm (1.772 in.) minimum	bilateral reference plane	edge of reticle backstops
y41	1	30 ± 1 mm (1.181 ± 0.039 in.)	facial reference plane	center of orientation notch
y44	1	53 mm (2.087 in.) maximum	facial reference plane	side of robotic handling flange column
y45	1	65.3 ± 1 mm (2.571 ± 0.039 in.)	facial reference plane	orientation notch tip
y46	1	71 ± 1 mm (2.795 ± 0.039 in.)	facial reference plane	edge of robotic handling flange
y47	1	58 mm (2.283 in.) minimum	facial reference plane	edge of robotic handling flange corner beveling
y106	1	92.5 mm (3.642 in.) minimum	facial reference plane	edge of recess
y126	1	71.1 ± 1 mm (2.799 ± 0.039 in.)	facial reference plane	depth of side handling flange
y127	1	61.9 ± 0.5 mm (2.437 ± 0.020 in.)	facial reference plane	edge of side handling flange corner bevel
y225	1	115.25 mm (4.537 in.) maximum	facial reference plane	side of pod
y226	7	88.5 mm (3.484 in.) minimum	facial reference plane	edge of rear retainer volume
y227	7	45 mm (1.772 in.) maximum	facial reference plane	edge of end-effector exclusion volume
y228	7	12.6 ± 0.4 mm (0.496 ± 0.016 in.)	facial reference plane	reticle bisecting plane
y232	8	45.5 mm (1.791 in.) maximum	facial reference plane	edge of end effector exclusion volume
y233	8	44.5 mm (1.752 in.)	facial reference plane	center of reticle contact surface
y234	8	77.5 mm (3.051 in.)	facial reference plane	center of reticle contact surface
y235	9	1 mm (0.039 in.) maximum	center of reticle contact surface	edge of reticle contact surface
y236	10	82.5 mm (3.248 in.) minimum	facial reference plane	end of conveyor rail surface
y237	8	73.7 mm (2.902 in.) maximum	facial reference plane	edge of end effector exclusion volume
y238	8	78.5 mm (2.941 in.) maximum	facial reference plane	edge of end effector exclusion volume
z50	5	5 mm (0.197 in.) minimum	bottom of circular recess	encroachment of MRSP150 top underneath the center hole in the top robotic flange

Symbol Used	*Figure*	*Value Specified*	*Reference Measured From*	*Feature Measured To*
z149	3, 5	5 mm (0.197 in.) maximum	bottom surface of robotic handling flange	top of robotic handling flange
z276	6	± 0.15 mm (0.006 in.)	each nominal reticle seating plane	entire bottom surface of the reticle
z281	3	182.5 mm (7.185 in.) maximum	horizontal reference plane	top surface of dome recess
z282	3	185 mm (7.283 in.) maximum	horizontal reference plane	top surface of dome
z283	3, 5	200 ± 0.5 mm (7.874 ± 0.020 in.)	horizontal reference plane	bottom surface of robotic handling flange
z284	3	179 ± 0.5 mm (7.047 ± 0.020 in.)	horizontal reference plane	bottom edge of side handling flange
z285	3	182.5 mm (7.185 in.) maximum	horizontal reference plane	top surface of side handling flange
z286	3	155 mm (6.102 in.) maximum	horizontal reference plane	edge of side handling exclusion volume
z290	4	22 mm (0.866 in.) maximum	horizontal reference plane	edge of first reticle pellicle exclusion volume
z291	4	32 mm (1.260 in.)	horizontal reference plane	nominal reticle seating plane
z292	4	51.05 mm (2.010 in.)	horizontal reference plane	nominal reticle seating plane
z293	4	70.10 mm (2.760 in.)	horizontal reference plane	nominal reticle seating plane
z294	4	89.15 mm (3.510 in.)	horizontal reference plane	nominal reticle seating plane
z295	4	108.20 mm (4.260 in.)	horizontal reference plane	nominal reticle seating plane
z296	4	127.25 mm (5.010 in.)	horizontal reference plane	nominal reticle seating plane
z297	6	2.6 mm (0.102 in.) minimum	each nominal reticle seating plane	edge of end-effector exclusion volume
z298	6	9.4 mm (0.370 in.) minimum	each nominal reticle seating plane	edge of lift clearance exclusion volume
z299	6	8.95 mm (0.352 in.) minimum	each nominal reticle seating plane	edge of end-effector exclusion volume
z300	6	8 mm (0.315 in.) minimum	each nominal reticle seating plane	edge of end-effector exclusion volume
z301	4	22 mm (0.866 in.) maximum	horizontal reference plane	edge of safety rail exclusion volume
z302	4	23.5 ± 0.5 mm (0.925 ± 0.020 in.)	horizontal reference plane	edge of first reticle end-effector exclusion volume
z310	3, 5	8 mm (0.315 in.) maximum	bottom surface of robotic handling flange	top of robotic handling flange
z311	4	12.7 mm (0.500 in.) maximum	nominal reticle seating plane	edge of lift clearance exclusion volume
z314	n/a	133 mm (5.236 in.) minimum	horizontal reference plane	top of reticle backstops

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix is an official part of SEMI E112 and was approved by full letter ballot procedures on August 27, 2001, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Edge contact only with the photomask is preferred when handling, transporting or storing.

A1-2 Skewness, warp, rock, and stiffness are implicitly defined in the dimensional tolerances.

A1-3 Features on the MRSP150 which enable stacking may be required by end users. It is preferred that these features allow stacking in only one orientation.

A1-4 Features on the MRSP150 which provide visual orientation of the MRSP150 top and MRSP150 door may be required by end users.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E112, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 In the event end-effector and pellicle exclusion volumes can be developed which would satisfy all lithography equipment manufacturers and allow for a 126 mm pellicle, then the appropriate changes would be balloted to update the standard.

SEMI E113-1101
SPECIFICATION FOR SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This specification was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 Process plasmas are used throughout the semiconductor industry for the etching and deposition of thin films. The majority of the process chambers use RF power to produce and sustain the plasmas. Because the reliability and repeatability of the plasma directly impacts wafer-processing results, RF power delivery systems are a key element of semiconductor manufacturing technology. The accurate and reproducible performance of the entire RF power generation system, including the RF influenced parameters of the plasma, must be within commonly accepted tolerances.

1.2 Design criteria for RF reliability and repeatability demand standardized testing and evaluation of the performance of the RF power delivery systems and control instrumentation on a chamber. Not only must the subsystems (i.e., the generator, cable assemblies, matching network, chuck/coil) be characterized, but the performance of the integrated system must also be characterized over the intended operating range.

1.3 It is the intent of this standard to provide RF power delivery specifications for semiconductor processing equipment that leads to improved system and subsystem performance. It outlines performance criteria as well as required documentation that must be supplied with the system or subsystem components. The goal of the document is to provide the specifications needed to produce a well-characterized RF power delivery system, where stability, repeatability, and important electrical parameters such as delivered power, current/voltage, and the impedance of the system can be determined within the operating space.

2 Scope

2.1 This document specifies the minimum performance criteria for RF equipment used in the semiconductor industry. It does not address specific test methods or procedures for performance verification.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment, and
- Film deposition equipment (CVD and PVD).

2.3 This specification applies to semiconductor processing equipment RF power delivery systems whose power is directly used to produce and sustain the plasma.

2.4 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is meant to address RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard is intended to be a performance specification and is not intended to address design issues related to safety, which are covered elsewhere in the SEMI Standards.

3.3 This standard is not meant to address pulsed-power RF systems.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E78 — Electrostatic Compatibility - Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment

4.2 *IEEE*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *MIL-SPEC*[2]

MIL-C-17G — General Specification for Cables, Radio Frequency, Flexible and Semirigid

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions*

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *electrical length* — the length of the cable assembly at the operating frequency expressed in terms of degrees, where one wavelength at the nominal operating frequency is equal to 360°.

5.2.3 *matching network* — the device used to transform the impedance of the load (chamber/chuck) to match the impedance of the generator/cable assembly, which is typically 50 ohms.

5.2.4 *matching network load impedance* — the impedance of the load to which the matching network is matched.

5.2.5 *power efficiency* — the power efficiency of a matching network is defined as the power exiting the network (output power) divided by the power entering the network (input power).

5.2.6 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.7 *RF applicator/interface* — the part of the chamber where the RF system is terminated. This interface can either be a chuck (driven electrode) or the coil/antenna part of a plasma source.

5.2.8 *load Q* — the quality factor, Q, of the load is defined here as the magnitude of the reactive part of the load divided by the real part of the load. For example, a load impedance of 2 – j20 ohms would have a load Q of 10.

5.2.9 *matched load* — a matched load impedance is defined as typically having a magnitude of 50 ± 3.3 ohms at a phase angle of up to ± 3.8°. In other words, the load is considered matched if the reflection coefficient is no greater than 0.032 at any phase angle.

5.2.10 *tuning element position* — the position of the tuning element is defined as the output voltage or output encoder value that corresponds to the position of a variable tuning element in a Matching Network. For example, the voltage from a rotary potentiometer on the rotating shaft of a variable capacitor (the "Tuning Element") would be referred to as the capacitor's "Position". In this example, the position/voltage corresponds to a certain shaft location or position.

5.2.11 *tap point* — for some systems, partial tuning of the matching network is achieved by switching in a combination of fixed tuning elements, such as different values of capacitors. The tap point is defined as the position of the switch(es) that connect or disconnect tuning elements in the matching network circuit.

5.2.12 *RF system* — the RF system is defined as the combination of the generator, matching network, chamber interface, and the associated connecting cable assemblies that are specific to a particular tool/chamber.

5.2.13 $MTBF_p$ — mean (productive) time between failures; the average time the equipment performed its intended function between failures; productive time divided by the number of failures during that time. Only productive time is included in this calculation.

6 Ordering Information

6.1 Semiconductor manufacturers may use this standard when procuring processing equipment to specify RF power delivery system performance and documentation. The equipment suppliers may also use this document to specify the RF system components and subassemblies.

6.2 Orders for equipment in accordance with this standard shall include:

6.2.1 This specification number and date of issue.

6.2.2 Any certification showing passage of qualification tests required to be provided (optional).

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721 website: www.ieee.org

2 Available from Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A website: www.dodssp.daps.mil/products.htm.

6.2.3 Any test results required to be included in reports to be provided (optional).

7 Requirements

7.1 Semiconductor processing equipment shall be designed and built with a reliable RF power delivery system. The requirements defined in this specification address the integrated RF system as well as the following RF power delivery system components: the RF cable assemblies, the matching network, the generator, and the RF applicator/interface, as well as specific components of these assemblies or systems.

7.2 The mean (productive) time between failures ($MTBF_p$), as outlined in SEMI E10, of the generator, matching network, and the RF power delivery system as a whole shall be provided by the supplier, as well as the test method used to determine $MTBF_p$.

7.3 *RF Cable Assemblies (Transmission Lines)*

7.3.1 Many RF power delivery systems use RF cable assemblies to transfer power from the generator to the input of the matching network and, in some cases, from the output of the matching network to the process chamber (e.g., the chuck assembly). All cable assemblies shall adhere to industry standards for cables and connectors (e.g., MIL-C-17G, MIL-PRF-39012D, IEEE-STD-383) in terms of rated power/voltage/ current, allowed bending radius, expected variation in characteristic impedance, and attenuation at the expected operating frequency(s) for the specific cable type (e.g., RG-217, RG-218) per the cable manufacturer's specifications.

7.3.2 The length of the cable assemblies used to connect portions of the RF power delivery system shall be specified in terms of electrical length at the nominal operating frequency, in addition to the nominal physical length. The electrical length shall be given in terms of degrees of phase shift. Variations in the dielectric properties (e.g., phase velocity, characteristic impedance) of the cable assemblies can cause the electrical length to differ between assemblies.

7.3.3 The electrical length of cables used between the matching network and the chamber (if any) shall be specified to within 0.25° of the standard electrical length value at the operating frequency for fixed frequency systems or at the midpoint frequency for variable frequency systems, for frequencies less than or equal to 13.56 MHz. For frequencies above 13.56 MHz, the length should be specified to a value (in degrees) equal to the frequency in MHz multiplied by 0.018 (e.g., the specification for 60 MHz would be $60 \times 0.018 = 1.1°$). For example, at 13.56 MHz, the physical length of typical cable (RG-217) corresponding to 0.25° of phase shift (0.5° of reflection coefficient phase shift) would be approximately 1 cm. This specification would result in impedance variations seen by the matching network of less than approximately 1 percent between processing chambers.

7.3.4 The length of cables used between the matching network and the generator shall be specified to within 1.0° of the standard electrical length value at the operating frequency for fixed frequency systems or at the midpoint frequency for variable frequency systems, for frequencies less than or equal to 13.56 MHz. For frequencies above 13.56 MHz, the length shall be specified to a value (in degrees) equal to the frequency in MHz multiplied by 0.074 (e.g., the specification for 60 MHz would be $60 \times 0.074 = 4.44°$). For example, at 13.56 MHz, the physical length of typical cable (RG-217) corresponding to 1.0° of phase shift (2.0° of reflection coefficient phase shift) would be approximately 4 cm. This specification would minimize the impedance transformation at the harmonic frequencies (10° of phase shift at the 10^{th} harmonic frequency).

7.3.5 The expected power dissipation in the cable assembly(s) supplied with the system shall be provided as a function of the operating frequency(s) of the system. The amount of power transmitted through the cable assembly shall be given in terms of dB (decibels) and percentage. The relationship between dB and percentage is given as:

$$\text{Percentage} = 100 \times 10^{(dB/10)}.$$

For example, approximately 94.8% (–0.232 dB of loss) of the power at 13.56 MHz will be transmitted through a cable assembly made from RG-217 cable with a physical length of 15.24 meters (electrical length of 375.74°). In other words, 5.2% of the power is dissipated in the cable assembly at 13.56 MHz.

7.4 *Matching Networks*

7.4.1 Matching networks transform the impedance of the plasma load to match the impedance of the generator, which is nominally 50 ohms. The transformation is achieved by the use of various reactive components, such as capacitors and inductors, that "tune" the matching network by transforming the impedance at the output of the network to the input of the matching network. For a given frequency, there is a fixed relationship between the impedance at the input of the matching network and the impedance at the output of the matching network (the load impedance). In other words, the impedance to which the matching network is matched (the load impedance) can be determined if the transform properties of the network are known for a given frequency. Typically, there are two methods of impedance transformation. The first method uses a fixed frequency (e.g., 13.56 MHz) and variable tuning elements, while the second method uses a variable frequency and fixed tuning elements. Specifications for both methods are given below.

7.4.2 For those systems that use fixed frequency operation, matching networks typically have two variable tuning elements, which are usually variable capacitors and/or inductors. These variable tuning elements typically have an output voltage or encoder value that corresponds to a certain value of the element (i.e., an output voltage will correspond to a specific value of capacitance or inductance in the matching network). The value of the output voltage or encoder value is referred to as the tuning element position. To obtain information on the operation and performance of the matching network, the tuning element positions must be provided as outputs.

7.4.3 For those systems that use variable frequency operation, matching networks typically have fixed tuning elements (no variation) or tap points between fixed tuning elements, and the frequency is varied to obtain the best matched condition. In some cases, the tap points are also varied for matching. To obtain information on the operation and performance of these types of networks, the operating frequency and the input impedance (or reflection coefficient magnitude and phase angle) shall be provided. For those systems that have variable tap points, the tap point position shall also be provided as an output.

7.4.4 For matching networks run at a fixed frequency with variable tuning elements, the load impedance shall be provided as a function of the tuning element positions. In addition, the efficiency of the matching network shall be provided as a function of the tuning element positions. The information shall be provided in tabular form. The increment of the tuning element positions shall be in steps equal to or less than 10% of the full range. For example, a voltage increment of 1 volt or less shall be used in the case where the full range of the tuning element position is 10 volts. A plot providing an example of the real part of the load transformed to 50 ohms by the matching network as a function of tuning element position indicator is shown in Figure 1 and a plot of the reactive part of the load impedance is shown in Figure 2. A plot of the power efficiency is shown in Figure 3. An example of data to be provided in tabular form is shown in Table 1. The required uncertainty of the magnitude of the impedance is $\pm$ 1.5%, the required uncertainty in the phase angle of the impedance is $\pm$ 0.35°, and the required uncertainty of the power efficiency is $\pm$ 2.0%. For example, a load impedance of 2.0 – j20 ohms would have an uncertainty in the real part of $\pm$ 0.15 ohms and an uncertainty in the reactive part of $\pm$ 0.32 ohms.

7.4.5 For matching networks run at a variable frequency with fixed tuning elements and/or tap points, the efficiency and load impedance as a function of its output parameters (frequency, input impedance, and tap point value (if any)) shall be provided. The information shall be provided in tabular form. The increment of the output parameters shall be in steps equal to or less than 10% of the full range. For example, if the operating frequency parameter is given as an output voltage, a voltage increment of 1 volt or less shall be used in the case where the full range of the output parameter is 10 volts. The required uncertainty of the magnitude of the impedance is $\pm$ 1.5%, the required uncertainty in the phase angle of the impedance is $\pm$ 0.35°, and the required uncertainty of the power efficiency is $\pm$ 2.0%.

7.4.6 The tuning element positions/values for each matching network (of the same type/model) shall be adjusted to provide consistent efficiency and matching network input impedance when the matching network is connected to a fixed load impedance. The load impedance used shall be one that is typically encountered by the matching network during processing and/or shall be an impedance that is near the mid-range of the tuning space (e.g., 2 – j20 ohms). A simple way to ensure network-to-network consistency is to adjust the tuning element positions/values to have consistent values between matching networks when connected to a common/fixed load impedance. The variation in tuning element positions between matching networks shall be less than 1% of full scale for a common fixed load impedance and shall be less than 2% of full scale over 80% of the operating range. For example, if the fixed load impedance is chosen such that the tuning element positions on matching network A are both 5 volts (for a 10 volt range), the tuning element positions for matching network B shall be within 0.1 volts of 5.0 volts.

7.4.7 The maximum power that the system can safely sustain during nominal, steady state processing conditions shall be provided as a function of the positions of the tuning elements (i.e., the plasma load conditions). The operating specifications of the components used in the matching network shall be provided (voltage and current capability), and peak values of voltage and current shall not exceed 80% of the rated voltage and current at the operating frequency for these components over the operating range of the matching network. This specification does not pertain to transient (e.g., plasma strike) conditions.

7.4.8 The maximum power the system can safely sustain without plasma (pre-ignition conditions) shall be provided to the end user, as well as the maximum time limit allowed at the peak power.

7.4.9 To reduce variation between matching networks, the frequency response of the matching network at the harmonic frequencies shall be repeatable between networks up to the 5th harmonic frequency (inclusive). Over the expected operating range of the network, the reflection coefficient measured at the output of the matching network, when the input of the network is terminated with both an open and a short circuit, shall vary less than 5% in magnitude and phase at the harmonic frequencies. Comparisons between networks shall be made at three operating points, which include a nominal operating point (e.g., at the midpoint of the tuning range), a point within 10% of the maximum of the tuning range, and a point within 10% of the minimum operating range. Unless specifically designed to, power dissipation in the network of greater than 10% (reflection coefficient of 0.95) at the harmonic frequencies shall be avoided.

7.4.10 The matching network shall be able to reach a stable tuning solution for any given available preset condition (tuning element position/frequency) in less than 3 seconds when the network is operated into a test load that is in the middle of the network's tuning range. Measurements of the time to tune shall be taken with the preset conditions (tuning elements positions/ frequency) varied in increments equal to 20% or less of full scale. The input power level during this bench test shall be in the range of 20% to 100% of the nominal power rating of the matching network.

7.4.11 There shall be only one tuning solution over the entire tuning range of the matching network. In other words, multiple tuning points for the same loading conditions shall be avoided.

7.5 *Generators*

7.5.1 To maintain consistent process conditions, the generators providing RF power to establish and sustain process plasmas and provide required wafer bias conditions must deliver power to load that can vary in time and value. In general, testing the generator output when driving a 50-ohm load is not sufficient to determine proper operation. In the semiconductor process environment, the generator may be exposed to power from the match/plasma system at the harmonics of the generator output frequency and needs to provide stable output power when operating into typical processing conditions.

7.5.2 The generator shall maintain consistent output impedance at each of the harmonic frequencies. The value of the reflection coefficient measured at the output of the generator shall be consistent at each frequency to within ± 5% in both magnitude and phase up to at least the 10^{th} harmonic frequency (i.e., up to $10 \times$ fundamental frequency) over the lifetime of the generator. This specification should not be interpreted as meaning that the reflection coefficient shall be the same value for all the harmonic frequencies, but the reflection coefficient shall maintain its particular value at each particular harmonic frequency to within 5% over time.

7.5.3 Generators shall deliver power to a nominal 50 ohm fixed load within ± 2.0% of true power from 10% to 100% of the maximum rated output power.

7.5.4 Generators shall provide consistent power delivery with a variation of less than ± 1.0% of the requested power level (over time and during steady state wafer processing conditions) when operated into a matched load.

7.5.5 Generators shall deliver power with a power variation of less than ± 1.5% when operated into a load impedance with a reflection coefficient of at least 0.33 at any phase angle (VSWR of at least 2.0) from 10% to 100% of the maximum rated output power. For example, a 25-ohm resistive load with various lengths of transmission line between the load and the generator can be used to produce the required phase shift variation. An example plot of forward power output vs reflection coefficient phase angle is shown in Figure 4.

7.5.6 The output power spectrum of a generator shall have harmonic content of –40 dB or less when operated into a load impedance with a reflection coefficient of at least 0.33 at any phase angle (VSWR of at least 2.0) from 10% to 100% of the maximum rated output power.

7.5.7 The generator output circuit shall be provided with high VSWR protection.

7.5.8 The transient response of the generator operating into a nominal 50-ohm load shall be provided as a function of the change in set point. Data for set point changes from zero power to full power and back to zero power as well as set point changes in increments of 33% of full scale shall be provided. For example, data for a 1 kW generator would include changes from 0 W to 1000 W, 1000 W to 0 W, 0 W to 333 W, 333 W to 667 W, 667 W to 1000 W, 1000 W to 667 W, 667 W to 333 W, 333 W to 0 W.

7.5.9 The ramp rate for power changes shall be provided in terms of W/second over the power range of the generator.

7.6 *RF Applicator/Interface*

7.6.1 The RF applicator/interface (the driven electrode or the coil/antenna) shall be designed, built, and maintained to provide a high degree of process repeatability. The RF impedance that the applicator/interface presents to the matching network must have minimal variation in order to maintain consistent process conditions. A minimum requirement for consistent operation is for the capacitance between the interface and ground and the inductance (for coil/antenna systems) to vary less that 1.5% through maintenance cycles, during operation and over the expected lifetime of the applicator/interface.

7.6.2 The frequency response of the RF applicator/interface (chuck assembly or coil/antenna) shall be measured to determine the resonance frequency of the assembly up to 10 times the fundamental frequency. If possible, the frequency response should be measured at the operating temperature of the assembly. The increment of the frequency step shall be no greater than 4% of the fundamental frequency (e.g., for 13.56 MHz, incremental frequency step = 0.54 MHz). The data shall be presented in tabular form in terms of the reflection coefficient magnitude and phase angle. An example of tabular data is given in Table 2 and a graphical example is shown in Figures 5 and 6.

7.6.3 For wafer chuck assemblies, the DC leakage current shall be measured to determine the deterioration of the dielectric coating over time. Increased leakage current will flow if the water that cools the chuck has a low resistivity or if the anodization or other dielectric coating has deteriorated.

7.6.4 The RF plasma environment within the tool is a charged environment that alters the charge level on the product being processed. The RF power delivery system, in conjunction with the chamber hardware, shall be compatible with the user-specified sensitivity level(s) per SEMI E78.

7.7 *Tuning and Matching Control Circuits*

7.7.1 Automated matching networks require sensing circuits to determine how to drive their tuning elements in order to reach a matched condition. The performance of these control circuits and the error signals they generate are critical to the proper function of the matching network. For those networks that are designed to match to a nominal 50 ohm input impedance, the matching network input impedance magnitude shall be 50 ± 3.3 ohms with a phase angle of ± 3.8° when the automatic matching algorithm has driven the matching network to achieve a matched condition.

7.7.2 The sensing circuits in a generator and an automated matching network shall ensure that the control signals are insensitive to power in the harmonics of the drive frequency. For example, additional filtration (low pass or band pass filters) can be added to the sensing circuit to achieve this goal.

7.8 *RF System Tests*

7.8.1 The output power spectrum of a generator shall have a harmonic frequency content of −40 dB or less when operated into a matched system (matching network plus test load) that contains a load impedance with a Q of at least 10. In other words, the magnitude of reactive part of the load must be at least ten times greater than the real part of the load (e.g., 2 – j20 ohms). The cable assembly used during testing shall nominally be the specific type to be used between the output of the generator and the input of the matching network.

7.8.2 To reduce variation between matching networks on those systems that have multiple RF frequencies (i.e., one frequency for the source and another frequency for the bias), the frequency response of the matching network at the other operating frequencies and at the harmonics of the other frequencies shall be repeatable between networks (of the same type/model) up to the 5th harmonic frequency (inclusive). Over the expected operating range of the network, the reflection coefficient measured at the output of the matching network, when the input of the network is terminated with both an open and a short circuit, shall vary less than five percent in magnitude and phase at the harmonic frequencies. Comparisons between networks shall be made at three operating points, which include a nominal operating point (e.g., at the midpoint of the tuning range), a point within 10% of the maximum of the tuning range, and a point within 10% of the minimum operating range. Unless specifically designed to, power dissipation in the network greater than 10% (reflection coefficient of 0.95) at the harmonic frequencies shall be avoided.

7.8.3 On those systems that have multiple RF frequencies (i.e., one frequency for the source and another frequency for the bias), the sensing circuits in an automated matching network and the rf generators shall ensure that the control signals are insensitive to power in the other system frequencies and the harmonics of all the system frequencies.

7.8.4 The supplier shall provide system verification hardware (i.e., test fixtures/interfaces) for system verification after assembly and delivery. Nominally, this hardware shall be in the form of a nominal coaxial connector interface (e.g., type "N" connector) for ease of measurement. Example fixtures would include those for interfacing with the RF applicator/interface (i.e., chuck assembly or coil input) and the output of the matching network. The supplier shall provide recommended test methods and/or procedures for system verification.

8 Related Documents

8.1 *IEEE*[3]

IEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

IEEE C95.1 — IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

8.2 *Federal Communications Commission (FCC)*[4]

FCC 47CFR1.1310 — Radio frequency radiation exposure limits

FCC 47CFR2 Part 2 — Frequency Allocations and Radio Treaty Matters; General Rules and Regulations

FCC 47CFR2 Part 2 Subpart J — Equipment Authorization Procedures

8.3 *MIL-Specifications*[5]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables

MIL-STD-348A — Radio Frequency Connector Interfaces for MIL-C-3643, MIL-C-3650, MIL-C-3655, MIL-C-25516, MIL-C-26637, MIL-PRF-39012, MIL-PRF-49142, MIL-PRF-55339, and MIL C-83517

MIL-DTL-28875A — General Specification for Amplifiers, Radio-Frequency and Microwave, Solid-State

MIL-T-28732C — General Specification for Transformer, Impedance Matching, Balanced to Unbalanced (Balun)

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement

8.4 *International Emissions Standards*

FCC CFR47 Part 18 — Industrial, Scientific and Medical (ISM) Equipment (United States)[4]

DIN EN 55011 — Industrial, scientific and medical (ISM) radio-frequency equipment - Radio disturbance characteristics - Limits and methods of measurement[6]

V-2/97.04 — Regulations for Voluntary Control Measures[7]

CNS 13438 — Limits and Methods of Measurement of Radio Disturbance Characteristics of Information Technology Equipment[8]

3 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721 website: www.ieee.org

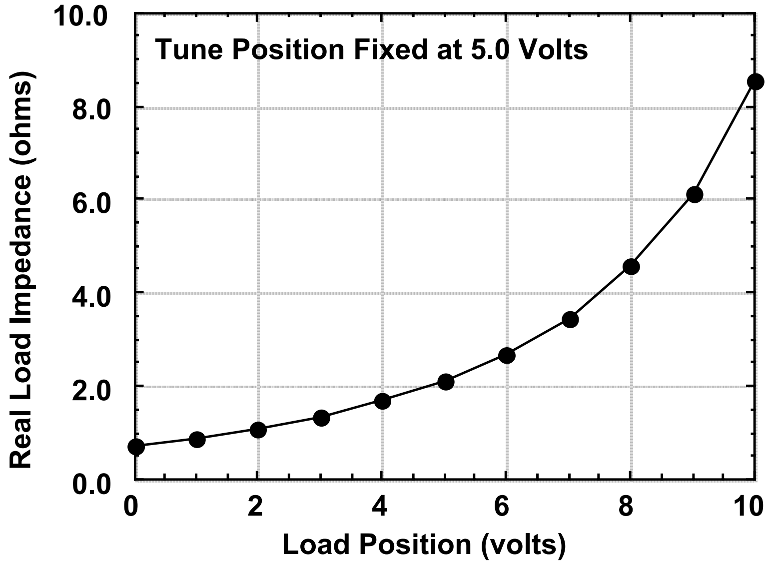
4 Federal Communications Commission, 445 12th St. S.W., Washington DC 20554

5 Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A Available from website: www.dodssp.daps.mil/products.htm

6 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, website: www.din.de

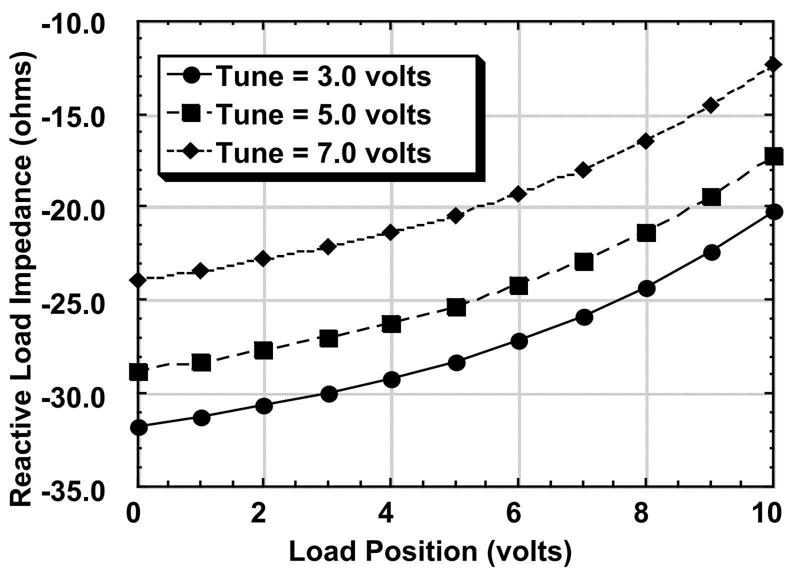
7 Voluntary Control Council for Interference by Information Technology Equipment, website: http://www.vcci.or.jp

8 Chinese National Standards, Available from NSSN (http://www.nssn.org) as Document CNS C6035700



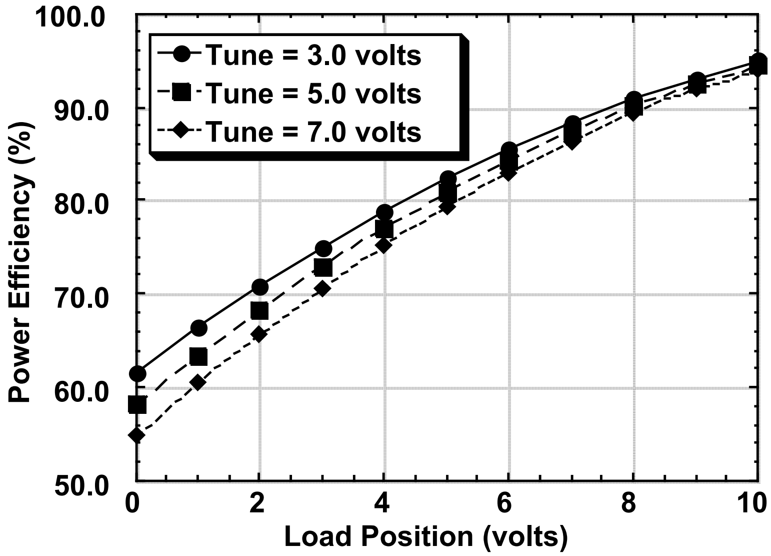
NOTE: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 5.0 V corresponds to 50% of full scale).

Figure 1
Example Plot of the Real Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



NOTE: The Tune Position is at the indicated fixed value for each set of data. For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 2
Example Plot of the Reactive Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



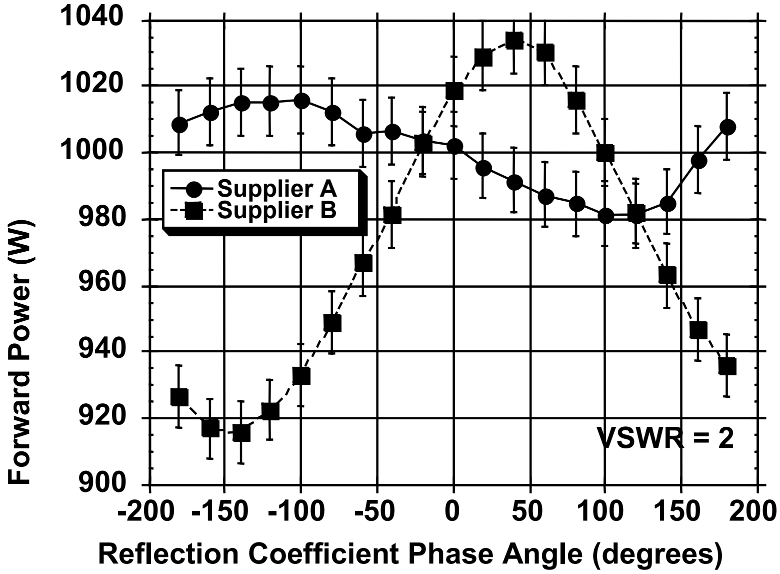
NOTE: The Tune Position is at the indicated fixed value for each set of data. For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 3
Example Plot of the Power Efficiency as a Function of the Load Position Tuning Element in the Matching Network

Table 1 Example Data Table Showing the Matching Network Load Impedance and Power Efficiency as a Function of the Positions of the Tuning Elements

Load Position, volts	*Tune Position, volts*	*Real Load, ohms*	*Reactive Load, ohms*	*Power Efficiency, %*
0	3	0.74	–31.75	61.51
1	3	0.91	–31.23	66.36
2	3	1.12	–30.64	70.86
3	3	1.38	–29.96	75.04
4	3	1.72	–29.18	78.88
5	3	2.15	–28.26	82.38
6	3	2.72	–27.17	85.56
7	3	3.50	–25.87	88.39
8	3	4.59	–24.31	90.90
9	3	6.18	–22.42	93.07
10	3	8.57	–20.15	94.91

NOTE: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale). This example only shows data for a fixed Tune position of 3.0 volts. Data is also required at a Tune position of 0.0 V, 1.0 V, etc.



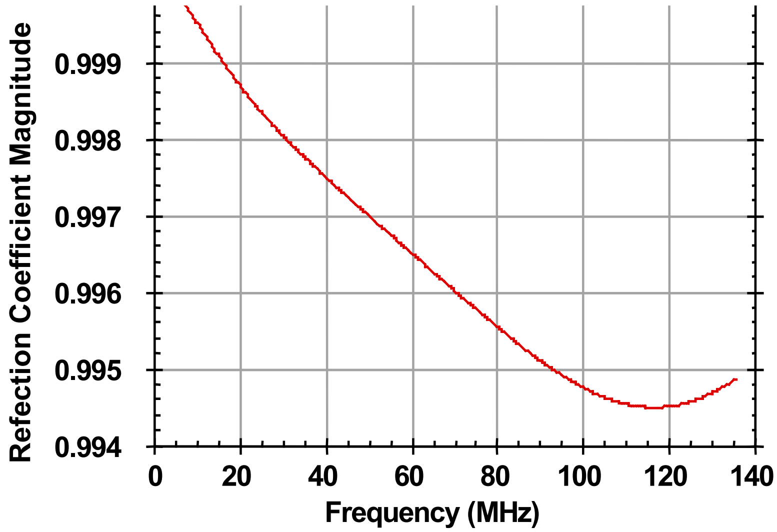
NOTE: The requested power was 1000 W. This plot shows a comparison of two different generators. The "Supplier A" data (circles with solid curve) is within the required ± 1.5% variation from requested power (within the error bars), while the "Supplier B" data (squares with dashed line) is not within the required ± 1.5% variation from requested power.

Figure 4
Example Data for the Forward Power as a Function of the Reflection Coefficient Phase Angle for a Nearly Constant Value of VSWR/Reflection Coefficient magnitude (VSWR = 2)

Table 2 Example Data Table (Partial) Showing the Frequency Response of a Chuck Assembly

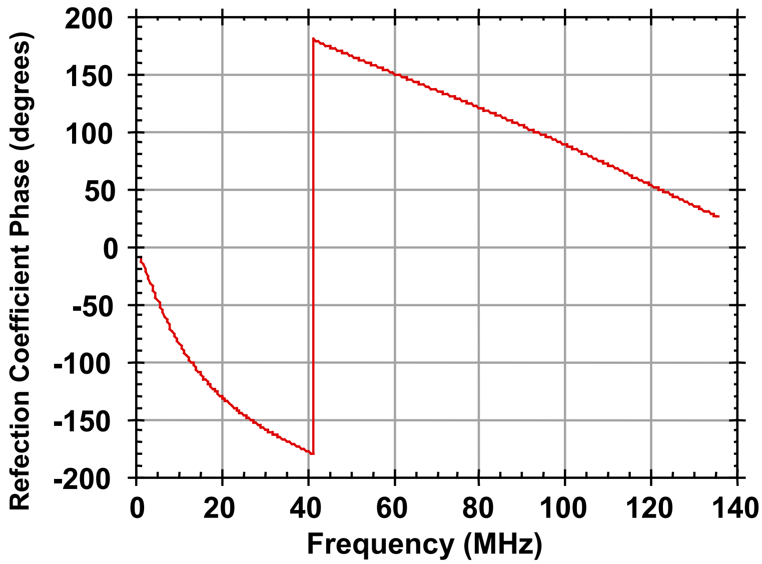
Test Frequency, MHz	*Refection Coefficient Magnitude*	*Refection Coefficient. Phase, degrees*
1.0	0.99973	–9.702
1.3365	0.99969	–12.95
1.673	0.99959	–16.18
. . .	. . .	. . .
41.097	0.9974	–180
. . .	. . .	. . .
135.2635	0.99488	25.94
135.6	0.99490	25.36

NOTE: The first column is the test frequency, the second column is the magnitude of the reflection coefficient, and the third column is the phase angle of the reflection coefficient.



NOTE: This plot is the graphical form of the data shown in Table 2.

Figure 5
Example Data of the Magnitude of the Reflection Coefficient of the Chuck Assembly Plotted as a Function of Frequency



NOTE: This plot is the graphical form of the data shown in Table 2.

Figure 6
Example Data of the Phase Angle of the Reflection Coefficient of the Chuck Assembly Plotted as a Function of Frequency

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SEMI E114-0302[E]
TEST METHOD FOR RF CABLE ASSEMBLIES USED IN SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on March 20, 2002. Initially available at www.semi.org June 2002; to be published July 2002.

[E] This document was editorially modified in May 2002. A change was made to Section 1.1.

1 Purpose

1.1 The purpose of this document is to define a test method used to determine the electrical length, power losses, and characteristic impedance variation of RF cable assemblies used in RF power delivery systems for semiconductor processing equipment.

2 Scope

2.1 This document specifies the testing procedures and test equipment required for the following:

- Determining the electrical length of RF cable assemblies at the nominal operating frequency in terms of degrees of phase shift.
- Determining the power dissipation (loss) in the RF cable assembly at the nominal operating frequency.
- Verifying the characteristic impedance of the RF cable assembly.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment,
- Film deposition equipment (CVD and PVD).

2.3 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is meant to address RF Cable Assemblies used in RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard assumes that the cable assemblies to be tested have a nominal characteristic impedance of 50 ohms. This standard can be used with cable assemblies with a different characteristic impedance if the appropriate standard termination loads are used.

3.3 International, national, and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meet regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

4.2 *IEEE Standards*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *Military Standards*[2]

MIL-C-17G — General Specification for Cables, Radio Frequency, Flexible and Semirigid

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

2 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions of Terms*

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *device under test (DUT)* — the cable assembly intended to be tested.

5.2.3 *electrical length* — the length of the cable assembly at the operating frequency expressed in terms of degrees, where one wavelength at the nominal operating frequency is equal to 360 degrees.

5.2.4 *half wave resonant frequency* — the frequency of the cable assembly where the electrical length of the assembly is equal to one half (0.5) of a wavelength. For example, the half wave resonant frequency of a cable assembly with an electrical length of 2 meters would be 74.95 MHz ((c/2-meters)/2).

5.2.5 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.6 *quarter wavelength* — the length equal to one quarter of the wavelength at a given frequency, where the wavelength is equal to the speed of light divided by the frequency.

5.2.7 *S-parameters* — the scattering matrix used to describe a network. The reflection coefficient is the S11 parameter and the transmission coefficient is the S21 parameter.

5.2.8 *speed of light (c)* — the speed of light in free-space is assumed to be 2.9979×10^8 meters/second.

5.2.9 *velocity of propagation (VP)* — the velocity of propagation, *VP*, is defined as the ratio of the speed of an electrical signal down a length of cable divided by the speed in free space. It is the reciprocal of the square root of the relative dielectric constant of the dielectric material between the inner and outer conductor of a coaxial assembly. For example, the *VP* for cable type RG-217 is nominally 0.66.

6 Test Apparatus

6.1 *RF Vector Network Analyzer* — The network analyzer is used to measure the electrical length and can also be used to determine the attenuation (power losses). The network analyzer requires vector capability so that both the magnitude and phase of the reflection coefficient and transmission coefficient can be measured as a function of frequency. The frequency range shall include the operating frequency and the quarter-wave resonant frequency of the RF cable assembly.

6.2 *Time Domain Reflectometer (TDR)* — The TDR is used to measure and verify the characteristic impedance as a function of distance along the transmission line.

6.3 *RF Adapters and Terminations* — Various adapters may be necessary to convert between different types of coaxial connectors (e.g., type N to type HN adapters, etc.). All adapters used shall have the same nominal characteristic impedance as the cable assembly to be tested (DUT), which is typically 50 ohms. For some measurements, additional coaxial cable assemblies may be necessary. These cable assemblies, which should not be confused with the DUT cable assembly, shall be of the same nominal characteristic impedance as the DUT cable assembly. Standard terminations will also be used, such as shorts, opens, and precision 50-ohm loads.

7 Safety Precautions

7.1 Work should be conducted in accordance with local safety requirements and test device manufacturer recommended safety procedures. The tests described in this document involve using low output power test instrumentation (typically less than 10 milli-Watt).

7.2 The area immediately surrounding the Test Setup should be keep free and clear of unnecessary equipment and materials. Some of the cable assemblies to be tested may be long and can be trip and lift/weight hazards.

8 Test Setup for Electrical Length Test

8.1 The Test Setup for the electrical length test consists of the Network Analyzer, the cable assembly to be tested (DUT), the appropriate adapter (if any) to connect the DUT to the network analyzer, and the appropriate adapter (if any) to connect a coaxial short circuit termination to the output of the DUT. A schematic of the Test Setup is shown in Figure 1. Care should be taken to ensure that the cable assemblies to be tested do not exceed the vendor specified bending radius, which is typically 5 times the outer diameter of the cable.

8.2 Prior to making any measurements, the Network Analyzer shall be turned on and allowed to warm up before the testing is to take place. This time allows for electronics to come to a stable operating condition for the measurements.

9 Test Procedure for Determining Electrical Length

9.1 Two test procedures can be used to determine the electrical length of a cable assembly. One method measures it directly at the operating frequency and the other measures the half-wave resonant frequency to determine the electrical length. Each method has advantages, depending on the length of the cable assembly. Prior to choosing a method, the equivalent free-space length of the DUT shall be estimated in units of distance (i.e., meters). This length can be estimated by dividing the physical length of the DUT by the velocity of propagation for the particular type of cable. For example, a DUT made from RG-217 cable with a physical length of 20 meters and a velocity of propagation of 0.66 would have an equivalent free-space length of 30.303 meters (20/0.66 = 30.303). A flow chart showing the steps for choosing which test method to use is shown in Figure 2.

9.2 The equivalent free-space length of the DUT shall be compared with the wavelength of the nominal operating frequency. Test Method 1 (Section 9.3) shall be used if the equivalent free-space length is less than a quarter wavelength of the nominal operating frequency. Test Method 2 shall be used if it is equal to or greater than a quarter wavelength of the nominal operating frequency. For example, if the estimated free-space length is 3 meters and the nominal operating frequency is 13.56 MHz (quarter wavelength = $0.25 \times c/13.56 \times 10^6$ = 5.527 meters), then Test Method 1 is recommended. If the estimated free-space length is 25 meters, then Test Method 2 is recommended.

9.3 *Test Method 1 for Determining Electrical Length*

9.3.1 This test method measures the phase angle of the reflection coefficient at the nominal operating frequency of the DUT when the DUT is terminated by a short circuit.

9.3.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place. The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement is equivalent to measuring the S11 S-parameter. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz).

9.3.3 After calibration, the cable assembly to be tested (DUT) shall be attached to Port 1 on the Network Analyzer. The other end of the DUT shall be terminated with a short circuit. After all connections have been visually inspected to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the reflection coefficient phase angle shall be recorded.

9.3.4 If the indicated phase angle of the reflection coefficient is positive, then the electrical length of the DUT is equal to one half of the value of the difference between 180 and the measured phase angle. For example, if the measure reflection coefficient phase angle is 120 degrees, then the electrical length is 30 degrees ((180-120)/2).

9.3.5 If the indicated phase angle of the reflection coefficient is negative, then the electrical length of the DUT is greater than a quarter wavelength. For this case, the electrical length is equal to one half of the absolute value of the measured value of the reflection coefficient phase angle plus 90. For example, if the measure reflection coefficient phase angle is -10 degrees, then the electrical length is 95 degrees (90 + 10/2).

9.4 *Test Method 2 for Determining Electrical Length*

9.4.1 This test method determines the electrical length of the cable assembly DUT by measuring the half wave resonant frequency when the DUT is terminated by a short circuit. For this measurement, the frequency of the network analyzer is swept. The frequency range of the sweep is determined from the estimated free-space length of the DUT.

9.4.2 Estimate the half wave resonant frequency of the DUT. This frequency is equal to one half of the ratio of the speed of light divided by the estimated free space length determined in Section 9.2. For example, if the estimated free space length of the DUT is 25 meters, then the estimated half wave resonant frequency is 5.996 MHz ($0.5 \times c/25$).

9.4.3 Calibrate the Network Analyzer. If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place. The center frequency of the frequency sweep shall be at the estimated half wave resonant frequency calculated in Section 9.4.2, and the frequency span of the sweep shall be no greater than 10% of the estimated frequency. For example, if the estimated half wave resonant frequency is 6.0 MHz, then the frequency span shall be no greater than 0.6 MHz. The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement is equivalent to measuring the S11 S-parameter. The calibration shall be performed using the lowest bandwidth possible (typically 10 Hz).

9.4.4 After calibration, the cable assembly to be tested (DUT) shall be attached to Port 1 on the Network Analyzer. The other end of the DUT shall be terminated with a short circuit. After all connections have been visually inspected to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the reflection coefficient phase angle can be examined.

9.4.5 The indicated frequency where the reflection coefficient phase angle is ± 180 degrees shall be recorded. The electrical length of the DUT at the desired nominal operating frequency (for example, 13.56 MHz) is equal to 180 degrees multiplied by the ratio of the nominal operating frequency divided by the measured frequency where the phase angle of the DUT is equal to ± 180 degrees. For example, if the measured frequency where the reflection coefficient is ± 180 degrees is 6.1 MHz, then the electrical length of the DUT at 13.56 MHz is 400.13 degrees (180 × 13.56 / 6.1).

10 Test Setup for Power Dissipation (Loss) Test

10.1 The Test Setup for the power dissipation (loss) test consists of the Network Analyzer, the cable assembly to be tested (DUT), an additional short test cable (for transmission calibration), the appropriate adapter (if any) to connect the DUT input to the network analyzer, and the appropriate adapter (if any) to connect the DUT output to the network analyzer. A schematic of the Test Setup is shown in Figure 3.

11 Test Procedure for Determining Power Dissipation

11.1 The test procedure for determining power dissipation in cable assemblies will also use a Network Analyzer. In this case, both Ports of the Network Analyzer will be used. The transmission coefficient will be measured (also called the S21 S-parameter).

11.2 Calibrate the Network Analyzer at the desired operating frequency (for example, 13.56 MHz). If adapters are to be used to connect the DUT to the Network Analyzer and/or to the short circuit termination, then the calibration shall be made with the adapters in place, along with the additional section of test cable needed for the calibration. The Network Analyzer shall be calibrated for measuring the transmission coefficient, S21 (see Figure 3). The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz).

11.3 Connect the cable assembly DUT between the two test Ports on the Network Analyzer (including the additional test cable used for calibration). After visually inspecting the connections to ensure proper contact and the Network Analyzer measurement has stabilized, the value of the transmission coefficient (S21) shall be recorded.

11.4 The recorded number shall be expressed in terms of dB (decibels) and percentage of power transferred in the DUT. The conversion between dB and percentage is expressed as:

$$\textit{Power Transfer}\ \% = 100 \times 10^{(\text{loss in dB}/10)}$$

For example, if the transmission coefficient is measured to be –0.4 dB, then the power transfer percentage would be 91.2%. In other words, 8.8% of the power is lost in the DUT.

12 Test Setup for Characteristic Impedance Variation Measurement

12.1 The Test Setup for the Characteristic Impedance variation measurement consists of a Time Domain Reflectometer (TDR), the cable assembly to be tested (DUT), the appropriate adapter (if any) to connect the DUT input to the TDR, and a standard 50-ohm load termination (see Figure 4).

12.2 Prior to making any measurements, the TDR shall be turned on and allowed to warm up. This time allows for electronics to come to a stable operating condition for the measurements.

13 Test Procedure for Determining Characteristic Impedance

13.1 Connect a standard 50-ohm load termination to the input of the TDR and measure the impedance. This measurement determines the normalization factor for the measured impedances. All reported measurements shall be scaled by this factor by multiplying subsequent measurements by the ratio of 50 divided by the impedance value measured with the 50-ohm standard load.

13.2 Prior to measuring the DUT, the nominal velocity of propagation of the cable shall be entered into the TDR. For example, the velocity of propagation is 0.66 for cable type RG-217.

13.3 Connect one end of the DUT to the TDR and terminate the other end of the DUT with a short circuit. Measure the characteristic impedance as a function of distance along the DUT by moving the measurement distance indicator of the TDR. Record the minimum and maximum impedance measured over the length of the cable assembly. The measurement shall be made throughout the length of the DUT, including the connectors, up to the short circuit termination.

13.4 At the short circuit termination, the measurement shall be made up to the point where the falling edge of the impedance is equal to 90 percent of the nominal impedance. For example, if the nominal impedance is 50 ohms, then the measurement can stop at the point where the measured value at the short circuit termination is equal to 45 ohms ($0.9 \times 50 = 45$). An example plot showing the measurement termination point is shown in Figure 5.

NOTE 1: The termination point can be verified by disconnecting the short circuit termination and observing that the impedance increases rapidly due to the open circuit.

14 Reporting Test Results

14.1 Report the type of Network Analyzer and the details of the Network Analyzer parameters used for the tests, including the bandwidth, the number of data points, the test frequency, and the frequency span (if any). An example data sheet is shown in Table 1.

14.2 Report the type of Time Domain Reflectometer used for the test.

14.3 Report the length of the cable assembly in terms of degrees at the nominal operating frequency.

14.4 Report the power dissipation in terms of dB (decibels) and percentage of power transfer.

14.5 Report the variation in characteristic impedance in terms of the minimum and maximum after the values have been scaled according to the reference 50-ohm load.

15 Related Documents

15.1 *IEEE Standards*[1]

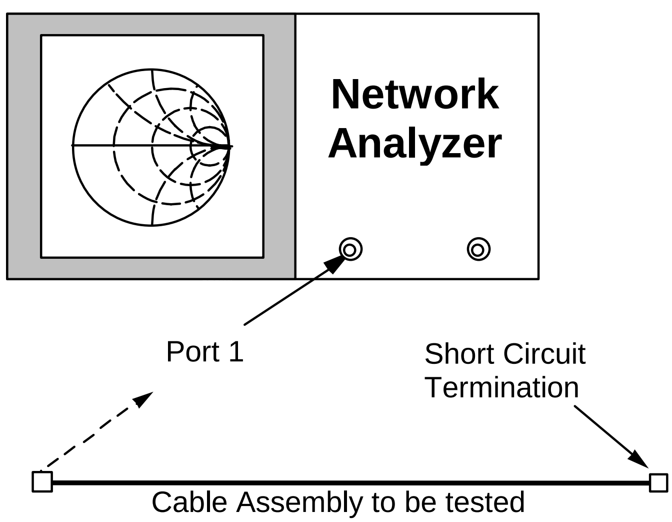
IEEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

15.2 *MIL-Specifications*[2]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables

MIL-STD-348A — Radio Frequency Connector Interfaces for MIL-C-3643, MIL-C-3650, MIL-C-3655, MIL-C-25516, MIL-C-26637, MIL-PRF-39012, MIL-PRF-49142, MIL-PRF-55339, and MIL C-83517

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement



NOTE: The reflection coefficient calibration is at the Port 1 output. The cable assembly to be tested (DUT) attaches to Port 1 and is terminated with a short circuit.

Figure 1
Schematic of the Network Analyzer Test Setup for the Electrical Length Measurement

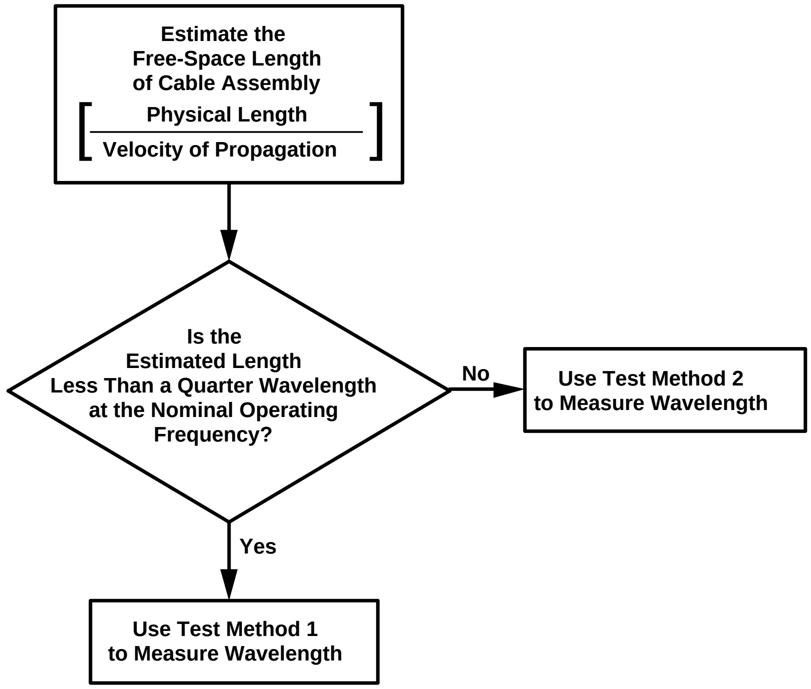
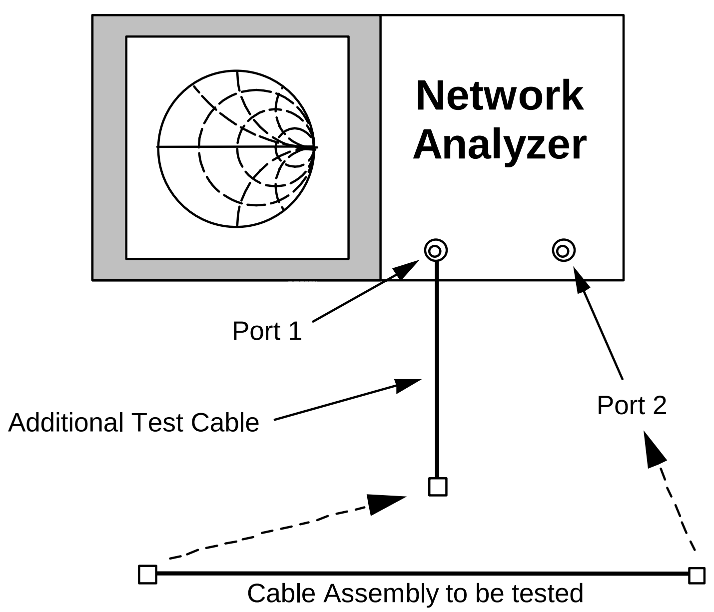
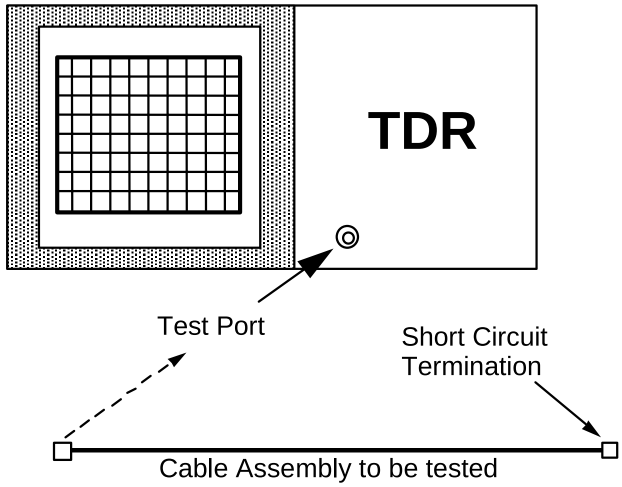


Figure 2
Flow Chart Showing the Steps to Chose the Appropriate Test Method for Determining Electrical Length of the Cable Assembly



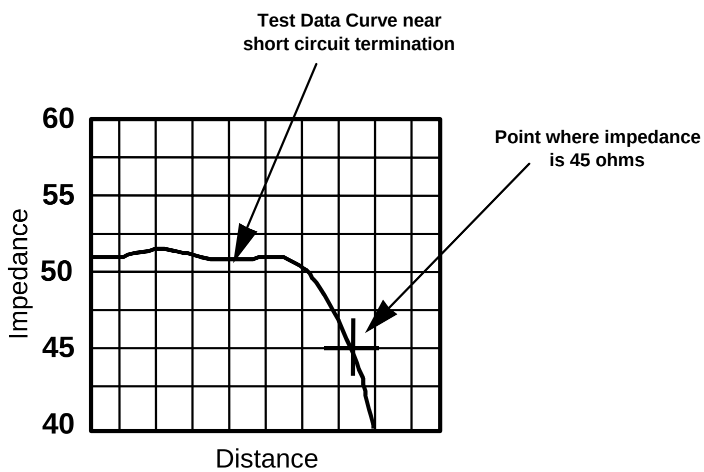
NOTE: Both the Port 1 and Port 2 outputs need to be used for the measurement. An additional test cable is needed for the transmission calibration between the two ports. The cable assembly to be tested (DUT) attaches between the additional test cable on Port 1 and Port 2.

Figure 3
Schematic of the Network Analyzer Test Setup for the Power Dissipation (loss) Measurement



NOTE: The cable assembly to be tested (DUT) attaches to the test port and is terminated with a short circuit.

Figure 4
Schematic of the Time Domain Reflectometer (TDR) Test Setup for the Characteristic Impedance Measurement



NOTE: The measurement termination point is defined as where the impedance at the short is equal to 0.9 times the nominal impedance value, which would be 45 ohms for a 50-ohm nominal impedance.

Figure 5
Example Plot of the Characteristic Impedance of a 50-ohm Cable Assembly Near the Short Circuit Termination

Table 1 Example Data Table for Presenting the Test Methods Parameters

Cable Length Test				
Instrument Parameters				
Model Number	Bandwidth (Hz)	Frequency (MHz)	Test Method (1 or 2)	Cable Assembly Length (°)
Power Loss Test				
Instrument Parameters				
Model Number	Bandwidth (Hz)	Frequency (MHz)	Loss (dB)	Power Transferred (%)
Characteristic Impedance Test				
Instrument Model Number	Normalization Factor	Minimum Impedance	Maximum Impedance	

SEMI E115-0302^E

TEST METHOD FOR DETERMINING THE LOAD IMPEDANCE AND EFFICIENCY OF MATCHING NETWORKS USED IN SEMICONDUCTOR PROCESSING EQUIPMENT RF POWER DELIVERY SYSTEMS

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on March 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Previously published March 2002.

^E This document was editorially modified in May 2002 to correct an errata. A change was made in Section 1.1.

1 Purpose

1.1 The purpose of this document is to define a test method used to determine the load impedance and efficiency of matching networks used in RF power delivery systems for semiconductor processing equipment.

2 Scope

2.1 This document specifies the testing procedures and test equipment required for determining the load impedance and power efficiency of a matching network based on the positions of the tuning elements in the matching network.

2.2 The primary focus for this specification is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment,
- Film deposition equipment (CVD and PVD).

2.3 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard addresses RF Matching Networks used in RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard is meant for analyzing matching networks that are designed to operate at fixed frequency with a 50-ohm input impedance.

3.3 International, national, and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meet regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

4.2 *IEEE Standards*[1]

IEEE-STD-383 — IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations

4.3 *Military Standards*[2]

MIL-PRF-39012D — General Specification for Connectors, Coaxial, Radio Frequency

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *PVD* — Physical Vapor Deposition

5.1.3 *VSWR* — Voltage Standing Wave Ratio

5.2 *Definitions of Terms*

5.2.1 *complex conjugate load impedance* — the complex conjugate load impedance has the same real part of the load impedance and the negative of the reactive part of the load impedance. For example, the

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

2 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

complex conjugate of a load impedance of 2.0 – j20 ohms would be 2.0 + j20 ohms.

5.2.2 *device under test (DUT)* — the matching network to be tested.

5.2.3 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.4 *"L" type matching network* — this type of network consists of a tuning element that is connected to ground, which is often a variable capacitor, and another tuning element that is in series with the output connection. The series section of the "L" matching network typically consists of an inductor and a capacitor, one of which is variable.

5.2.5 *load and tune position* — for some matching networks, the tuning elements are referred to as the *Load Position* and the *Tune Position*. This terminology is common for "L" type matching networks, which have a tuning element that is connected to ground and another tuning element that is in series with the output connection. The *Load Position* corresponds to the tuning element that is grounded and is associated with matching to the real part of the load impedance. The *Tune Position* corresponds to the tuning element that is in series with the output and is associated with matching to the reactive part of the load impedance.

5.2.6 *load impedance* — the load impedance is the impedance to which a matching network is matched.

5.2.7 *load impedance simulator* — the Load Impedance Simulator is a device that presents a load impedance to which a matching network can match. Details of a typical Load Simulator can be found in the Related Information section of this test method.

5.2.8 *matched input impedance* — a matched load impedance is defined as typically having a magnitude of 50 ± 3.3 ohms at a phase angle of up to ± 3.8 degrees. In other words, the load is considered matched if the reflection coefficient is no greater than 0.032 at any phase angle.

5.2.9 *matching network* — the device used to transform the impedance of the load (chamber/chuck) to match the impedance of the generator/cable assembly, which is typically 50 ohms.

5.2.10 *power efficiency* — the ratio of the power exiting the matching network divided by the power entering the matching network.

5.2.11 *S-parameters* — the scattering matrix used to describe a network. The reflection coefficient is the S11 parameter and the transmission coefficient is the S21 parameter.

5.2.12 *tuning element position* — the position of the tuning element is defined as the output voltage or output encoder value that corresponds to the position of a variable tuning element in a Matching Network. For example, the voltage from a rotary potentiometer on the rotating shaft of a variable capacitor (the "Tuning Element") would be referred to as the capacitor's "Position". In this example, the position/voltage corresponds to a certain shaft location or position.

6 Test Apparatus

6.1 *RF Vector Network Analyzer* — The Network Analyzer is used to measure the load impedance and efficiency of the matching network. The Network Analyzer requires vector capability so that both the magnitude of phase of the reflection coefficient and transmission coefficient can be measured at the operating frequency. The Network Analyzer shall have an up-to-date calibration per the manufacturer.

6.2 *Coaxial Output Adapter* — An adapter to convert the output connection of the matching network to a standard coaxial interface is required for some of the tests.

6.3 *RF Adapters and Terminations* — Various adapters may be necessary to convert between different types of coaxial connectors (e.g., type N to type HN adapters, etc.). All adapters used shall have the same nominal characteristic impedance as the system, which is typically 50 ohms. For some measurements, additional coaxial cable assemblies are used. These cable assemblies shall also be of the same nominal characteristic impedance as the system. Standard terminations are also used, such as shorts, opens, and precision 50-ohm loads.

6.4 *RF Load Impedance Simulator* — A device that can be attached to the output of the DUT to act as a load for the DUT is required for some of the measurements. The load simulator shall have an impedance range to match a minimum of 80% of the tuning space of the matching network to be tested.

7 Safety Precautions

7.1 Work should be conducted in accordance with local safety requirements and test device manufacturer recommended safety procedures. The tests described in this document involve using low output power test instrumentation (typically less than 10 milli-Watt).

7.2 The area immediately surrounding the Test Setup shall be keep free and clear of unnecessary equipment and materials.

8 Test Setup for Determining Load Impedance and Efficiency

8.1 Two test methods are described for analyzing matching networks. The first method for determining the load impedance and efficiency measures the complex conjugate of the load impedance and then corrects for the matching network losses to determine the load impedance and efficiency. A schematic of the Test Setup is shown in Figure 1. The method uses a Network Analyzer to measure the reflection coefficient, which is related to the load impedance, and the transmission coefficient, which is related to the efficiency. The Test Setup for this approach consists of the Network Analyzer, the matching network to be tested (DUT), coaxial test cables, and the appropriate adapters (if any) to connect the DUT to the Network Analyzer.

8.2 The second method for determining the load impedance and efficiency uses a Load Impedance Simulator attached to the output of the matching network. A schematic of the Test Setup is shown in Figure 2. The Test Setup for this approach consists of the Network Analyzer, the matching network to be tested (DUT), the load simulator, coaxial test cables, the appropriate adapter (if any) to connect the DUT to the Network Analyzer, and the appropriate adapter to connect the load simulator to the DUT.

8.3 Prior to making any measurements, the Network Analyzer shall be turned on and allowed to warm up before the testing is to take place. This time will allow for electronics to come to a stable operating condition for the measurements.

9 Test Procedure for Determining Load Impedance and Efficiency

9.1 Two test procedures can be used to determine the load impedance and efficiency of the matching network. The first method is designed for "L" type matching networks, where the losses are dominated by the loss resistance of the inductor that is in series with the load impedance. For the case where there are finite losses in the shunt capacitor, the capacitor losses can be lumped in with the inductor losses without introducing significant error (usually less than 0.5% for typical values of < 0.1 ohms). Lumping the total losses into an overall series loss will also cause a slight shift in the reactive part of the impedance, but the magnitude of the shift is on the same order as the impedance measurement uncertainty and can be ignored.

9.2 The second method is designed for other matching network types and uses a load simulator to determine the load impedance and efficiency.

9.3 *Test Method 1 for Determining Matching Network Load Impedance and Efficiency*

9.3.1 This test method shall be used for "L" type matching networks of the type shown schematically in Figure 1, where the losses in the network are dominated by the loss resistance of the inductor, RLOSS. The efficiency for this type of matching network is given as

$$Eff = \frac{RLOAD}{RLOAD + RLOSS} \quad (1)$$

where *RLOAD* refers to the real part of the load impedance and *RLOSS* refers to the losses of the matching network.

9.3.2 For this type of network, the real part of the complex conjugate impedance, Re(*Zout**), contains the real part of the load impedance plus twice the loss resistance, *RLOSS*.

$$\mathrm{Re}(Zout^*) = RLOAD + 2RLOSS \quad (2)$$

9.3.3 The load impedance, therefore, is equal to the complex conjugate impedance less twice the loss resistance (along with the sign change of the reactive part of the conjugate impedance). For example, if the conjugate impedance is measured as 3 + j20 and RLOSS is determined to be 0.5 ohms, then the load impedance is 2 – j20 ohms.

9.3.4 The efficiency of the matching network and the loss resistance, *RLOSS*, can be determined by measuring both the transmission coefficient, S21, and the reflection coefficient, S11, in the Test Setup shown in Figure 1. Note that the reflection coefficient measurement, S11, is equivalent to measuring the complex conjugate impedance. If the matching network is considered as a test load with an impedance equal to the complex conjugate impedance, then the loss resistance is found by measuring the efficiency of the test load. This efficiency, *Effm*, can be expressed as

$$Effm = \frac{\mathrm{Re}(Zout^*) - RLOSS}{\mathrm{Re}(Zout^*)} \quad (3)$$

where Re(*Zout**) is the real part of the complex conjugate load impedance, *Zout**. The measured efficiency, *Effm*, can be determined from the S21 and S11 measurements (as shown later in this section). Thus, the measurements of Re(*Zout**) and *Effm* can be used to determine *RLOSS* as

$$RLOSS = \mathrm{Re}(Zout^*) \times (1 - Effm) \quad (4)$$

and the load impedance and power efficiency of the matching network can then be determined from

$$Effc = \frac{\mathrm{Re}(Zout^*) - 2RLOSS}{\mathrm{Re}(Zout^*) - RLOSS} \quad (5)$$

$$RLOAD = \mathrm{Re}(Zout^*) - 2\,RLOSS \qquad (6)$$

$$XLOAD = -\,\mathrm{Im}(Zout^*) \qquad (7)$$

where *Effc* is the calculated power efficiency based on the measurement of Re(*Zout**) and *Effm*, *RLOAD* is the real part of the load impedance, and *XLOAD* is the imaginary part of the load impedance.

9.3.5 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

9.3.6 After calibration of the Network Analyzer, the cable connected to Port 1 of the Network Analyzer shall be connected to the output of the DUT. The cable connected to Port 2 of the Network Analyzer shall be connected to the input of the DUT.

9.3.7 The tuning elements shall be moved to their minimum positions before the measurement is initiated. After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the complex conjugate impedance (*Zout**), the magnitude of the reflection coefficient (S11), and the magnitude of the transmission coefficient (S21) shall be recorded.

9.3.8 The efficiency when the DUT is viewed as a test load, *Effm*, is determined from both the reflection and transmission coefficients. The efficiency can be calculated by taking the ratio of the output power divided by the input power. The output power is simply $(S21)^2$ and the input power is $(1\text{-}(S11)^2)$.

$$Effm = \frac{(S21)^2}{1-(S11)^2}$$

Typically, the reflection and transmission coefficients are expressed in terms of dB (decibels). The conversion between dB and efficiency is expressed as

$$Effm = \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

For example, if the transmission coefficient is measured to be –10.2 dB and the reflection coefficient is measured to be –0.61 dB, then *Effm* would be 0.7288. The efficiency based on this measurement can then be used to calculate *RLOSS*, *Effc*, *RLOAD*, and *XLOAD* by using the equations previously shown. All of these calculated numbers using equations 3–6 shall be recorded, as well as the positions of the tuning elements of the matching network.

9.3.9 For the next measurement, Tune Position shall remain fixed, and the Load Position shall be increased by an increment equal to no more than 10% of the full-scale range of the tuning element position. For example, if the range of the tuning element is 10 volts, then the tuning element should be moved in increments of no greater than 1 volt. A smaller increment shall be used for the case where the incremental change in Load Position results in an incremental impedance change of more than 20% of the total impedance variation measured by the full-scale variation of the Load Position. For example, if the real part of the load impedance varies 15 ohms over the 10 volt variation of the Load Position, then a smaller Load Position increment shall be used if the real load impedance varies by more than 3 ohms between increments (0.2 × 15 = 0.3). After the tuning elements have been moved to their new values, the previous measurement steps shall be repeated.

9.3.10 After the Load Position has been varied over its entire range, the Tune Position shall be increased by an increment equal to no more than 10% of the full-scale range of the tuning element position. The Load Position shall be moved back to its minimum position and the above steps shall be repeated until the entire tuning range of the matching network is measured.

9.3.11 The data shall be recorded and then presented in both graphical and tabular forms. An example of a typical impedance range graph is shown in Figure 3 for the real load impedance and in Figure 4 for the reactive load impedance. An example of a typical efficiency plot is shown in Figure 5. An example of data presented in tabular form is shown in Table I.

9.4 *Test Method 2 for Determining Matching Network Load Impedance and Efficiency*

9.4.1 This test method shall be used for matching networks that are not necessarily dominated by a series loss resistance as in an ideal "L" type network. This method uses a Load Simulator(s) attached to the DUT and assumes that the DUT has two tuning elements. The Load Simulator(s) shall have a tuning range that will cover no less than 80% of the tuning range of the matching network. Details of a typical Load Simulator can be found in the Related Information section of this Test Method. The test method outlined here assumes that the Load Simulator(s) contains variable tuning elements with position indicators to allow the load impedance to vary. An example of a load simulator would be a matching network used in reverse, where the output of the DUT would attach to the output of another matching network.

9.4.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure 1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

9.4.3 After calibration of the Network Analyzer, the test cable connected to Port 1 of the Network Analyzer shall be connected to the input of the matching network to be tested (DUT). The Load Simulator shall be connected to the output of the DUT. The cable connected to Port 2 of the Network Analyzer shall be connected to the output of the Load Simulator.

9.4.4 The tuning elements shall be moved to their minimum positions (or the positions that can match to lowest tuning point of the Load Simulator(s)) before the measurement is initiated. The variable elements in the Load Simulator shall be adjusted until the input impedance of the matching network is matched (i.e., input impedance = 50 ohms). After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the input impedance and the magnitude of the transmission coefficient (S21) shall be recorded. In addition, the positions of the tuning elements of the DUT and the Load Simulator shall be recorded.

9.4.5 The load impedance of the DUT corresponds to the input impedance of the Load Simulator. At this point in the process, the Load Simulator can be disconnected and its input impedance can be measured. Alternatively, the input impedance can be measured later by moving the Load Simulator tuning element values to the positions recorded in Section 9.4.4.

9.4.6 The efficiency of the Test Setup, which includes the DUT and the Load Simulator, is determined from the transmission coefficient. Typically, the transmission coefficient is expressed in terms of dB (decibels). The conversion between dB and percentage is expressed as:

$$Efficiency(\%) = 100 \times 10^{(\text{loss in dB}/10)}$$

For example, if the transmission coefficient is measured to be –3 dB, then the power transfer efficiency would be 50.1%. In other words, 49.9% of the power is lost in the Test Setup.

9.4.7 The efficiency of the DUT is determined by dividing the efficiency of the Test Setup by the efficiency of the Load Simulator. For example, if the efficiency of the Test Setup is 70% and the efficiency of the Load Simulator is 90%, then the efficiency of the DUT is 77.8% (0.7/0.9). The efficiency of the Load Simulator is typically determined separately (see Related Information Section at the end of this Test Method).

9.4.8 For the next measurement, one tuning element (element 1) shall remain fixed, and the other tuning element (element 2) shall be increased by an increment equal to no more than 10% of the full scale range of the tuning element position. For example, if the range of the tuning element is 10 volts, then the tuning element shall be moved in increments of no greater than 1 volt. A smaller increment shall be used for the case where the incremental change in tuning element position results in an incremental impedance change of more than 20% of the total impedance variation measured by the full-scale variation of the tuning element. For example, if the real part of the load impedance varies 15 ohms over the 10 volt variation of the tuning element, then a smaller tuning element increment shall be used if the real load impedance varies by more than 3 ohms between increments ($0.2 \times 15 = 0.3$). After the tuning elements have been moved to their new values, the previous measurement steps shall be repeated.

9.4.9 After the tuning element (element 2) has been varied over its entire range, the other tuning element (element 1) shall be increased by an increment equal to no more than 10% of its full-scale range. Tuning element 2 shall be moved back to its minimum position and the above steps shall be repeated until the entire tuning range of the matching network is measured.

9.4.10 The data shall be recorded and then presented in both graphical and tabular forms. An example of a typical impedance range graph is shown in Figure 3 for the real load impedance and in Figure 4 for the reactive load impedance. An example of a typical efficiency plot is shown in Figure 5. An example of data presented in tabular form is shown in Table 1.

10 Reporting Test Results

10.1 Report the type of Network Analyzer and the details of the Network Analyzer parameters used for the tests, including the bandwidth, the number of data points, and the test frequency. Also report which Test Method was used.

10.2 Report the matching network load impedance and efficiency as a function of tuning element positions. The data shall be presented in both graphical and tabular forms.

11 Related Documents

11.1 *IEEE Standards*[1]

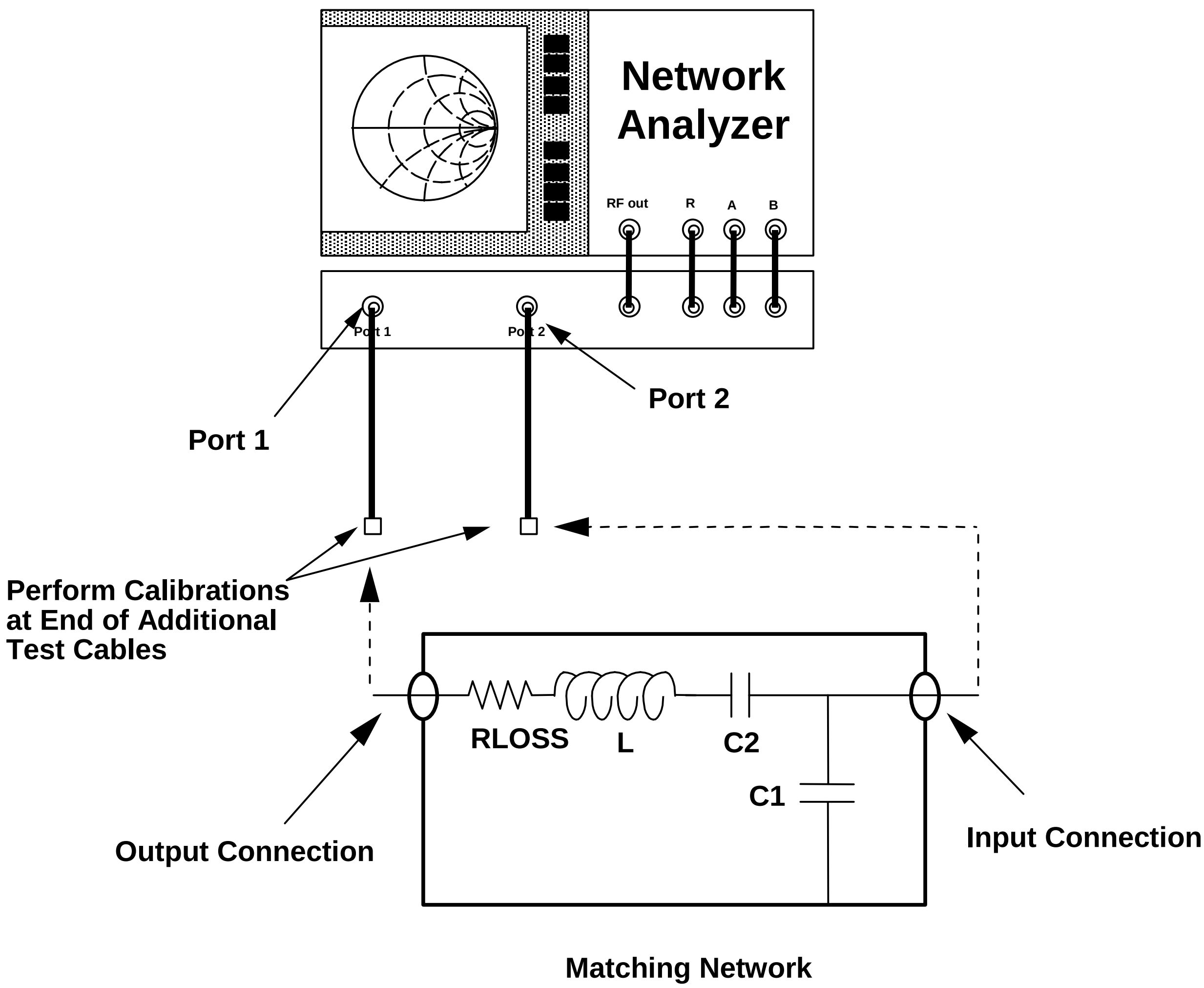
IEEE-STD-572 — IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations

11.2 *Military Standards*[2]

MIL-PRF-31031A — General Specification for Connectors, Electrical, Plugs and Receptacles, Coaxial, Radio Frequency, High Reliability, for Flexible and Semirigid Cables.

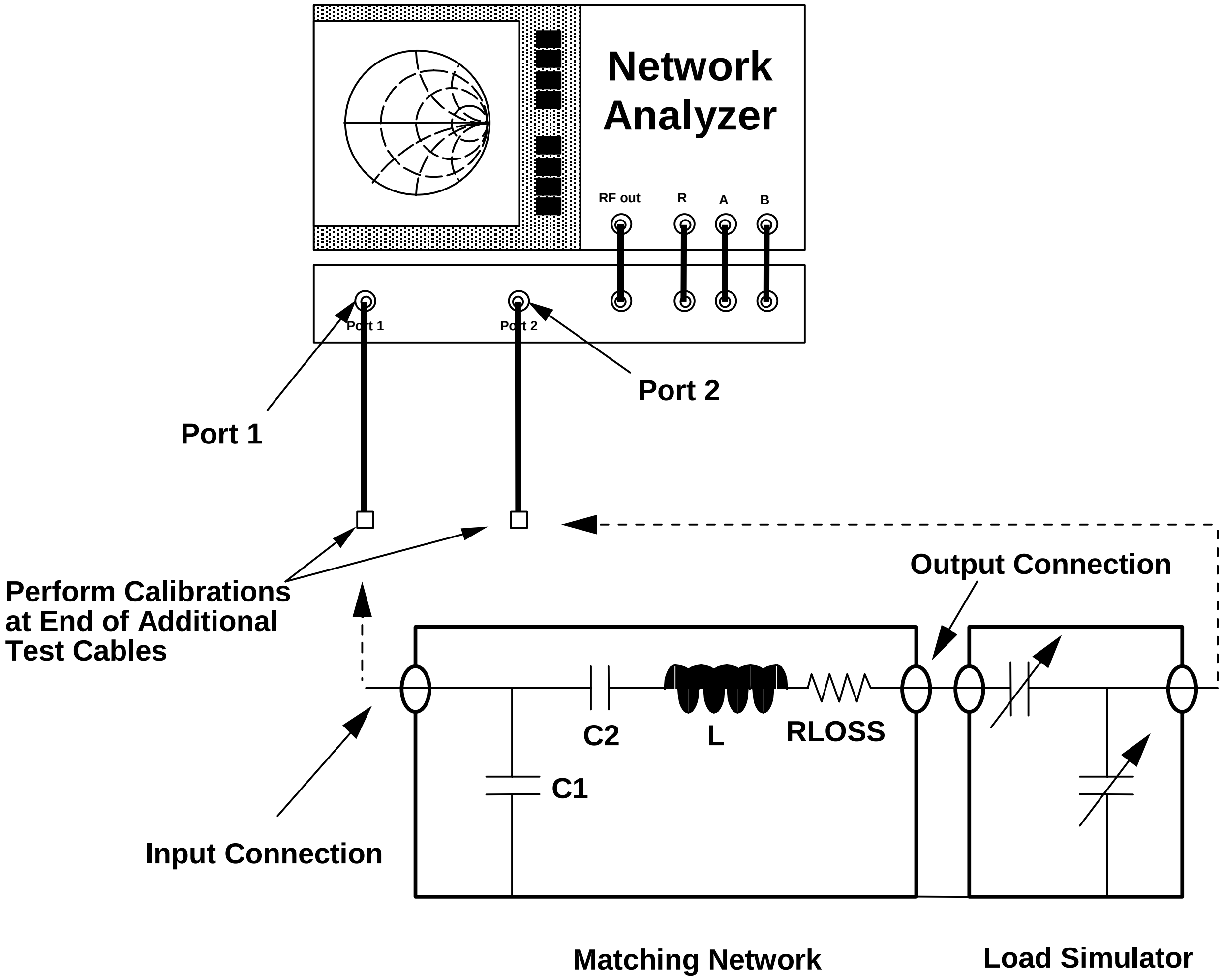
MIL-STD-348 — General Specification for Radio Frequency Connector Interfaces.

MIL-STD-220B — Test Method Standard: Method of Insertion Loss Measurement.



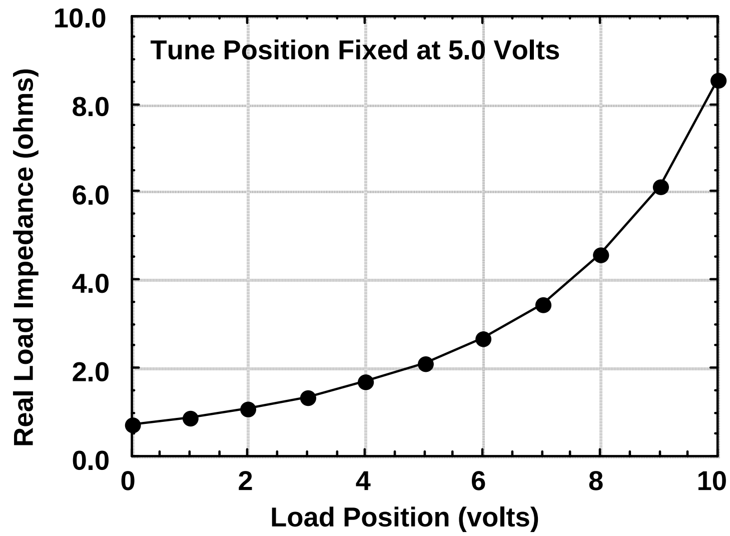
NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement. Additional test cables are needed for the transmission calibration between the two ports. The output connection of the matching network to be tested (DUT) attaches to Port 1 and the input connection of the matching network attaches to Port 2 of the Network Analyzer.

Figure 1
Schematic of the Test Method 1 Network Analyzer Test Setup for the Load Impedance and Efficiency Measurement for "L" Type Matching Networks



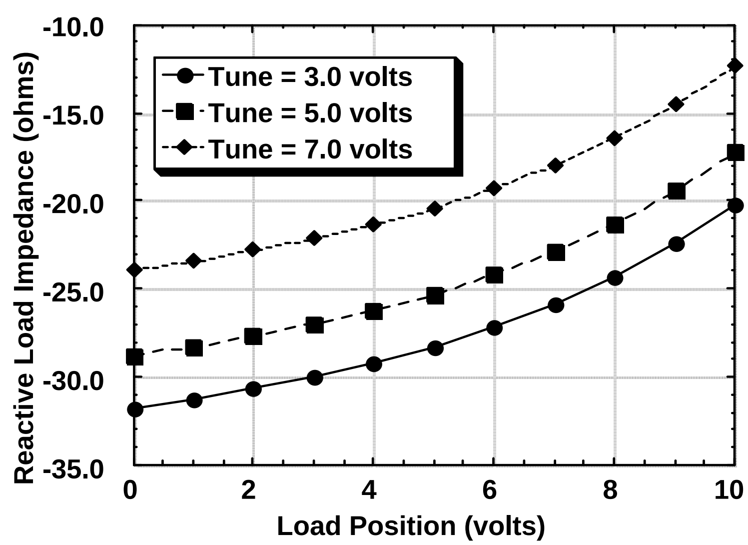
NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement and additional test cables are needed for the transmission calibration between the two ports. The input connection of the matching network to be tested (DUT) attaches to Port 1, the output connection of the matching network attaches to the input of the Load Simulator, and the output of the Load Simulator attaches to Port 2 of the Network Analyzer.

Figure 2
Schematic of the Test Method 2 Network Analyzer Test Setup for the Load Impedance and Efficiency Measurement



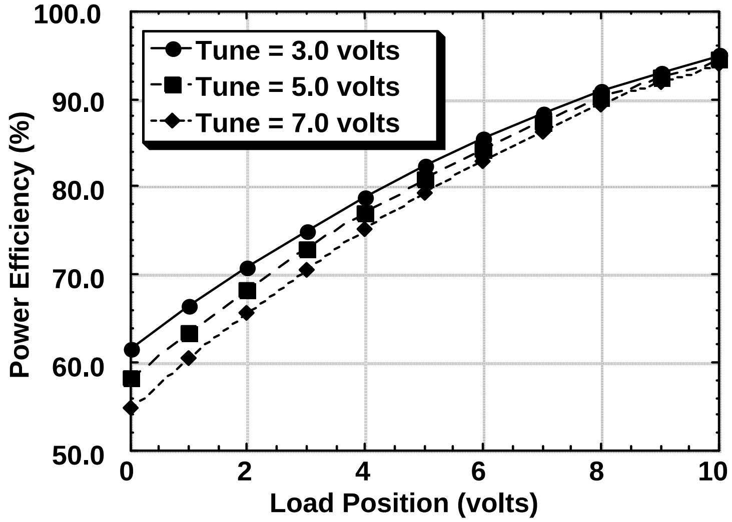
NOTE 1: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 5.0 V corresponds to 50% of full scale).

Figure 3
Example Plot of the Real Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



NOTE 1: The Tune Position is at the indicated fixed value for each set of data. For this example, the full scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 4
Example Plot of the Reactive Part of the Load Impedance as a Function of the Load Position Tuning Element in the Matching Network



NOTE 1: The Tune Position is at the indicated fixed value for each set of data. For this example, the full scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale).

Figure 5
Example Plot of the Power Efficiency as a Function of the Load Position Tuning Element in the Matching Network

Table 1 Example Data Table Showing the Matching Network Load Impedance and Power Efficiency as a Function of the Positions of the Tuning Elements

Load Position (Volts)	*Tune Position (Volts)*	*Real Load (ohms)*	*Reactive Load (ohms)*	*Efficiency (%)*
0	3	0.74	-31.75	61.51
1	3	0.91	-31.23	66.36
2	3	1.12	-30.64	70.86
3	3	1.38	-29.96	75.04
4	3	1.72	-29.18	78.88
5	3	2.15	-28.26	82.38
6	3	2.72	-27.17	85.56
7	3	3.50	-25.87	88.39
8	3	4.59	-24.31	90.90
9	3	6.18	-22.42	93.07
10	3	8.57	-20.15	94.91

NOTE 1: For this example, the full-scale voltage for both the Tune and Load Positions is 10 V (i.e., Tune = 3.0 V corresponds to 30% of full scale). This example only shows data for a fixed Tune position of 3.0 volts. Data is also required at a Tune position of 0.0 V, 1.0 V, etc.

RELATED INFORMATION 1
LOAD SIMULATORS

NOTE: This related information is not an official part of SEMI E115 and was derived RF Diagnostic Task Force in North America. This related information was approved for publication by full letter ballot on November 27, 2001.

R1-1 Types of Load Simulators

R1-1.1 Load Simulators are used to present a known load impedance to a matching network. One example of a Load Simulator would be a matching network used in reverse. This section will describe a Load Simulator that can be used with typical matching networks that operate at 13.56 MHz with capacitive load impedances. These applications include those networks used in parallel-plate capacitively coupled plasmas and also those networks used in wafer bias applications, where the plasma is mostly sustained by another power source, such as an inductively coupled plasma or a microwave ECR (electron cyclotron resonance) plasma.

R1-1.2 The typical impedance that is seen by the matching network depends on the geometry of the applicator (its capacitance to ground), the type of plasma (gases), the operating pressure, and the density of the plasma. Typical impedances seen by the matching networks operating at 13.56 MHz in capacitive-loading applications have a real part in the range of 0.5 to 10 ohms and a reactive part in the range of –10 to –50 ohms. If a transmission line is used between the output of the matching network and the applicator, the impedance will get transformed. The amount of transformation will depend on the length of the transmission line, but in general the effect will be to decrease the real part of the impedance and to decrease the reactive part of the load (make it less negative). If the transmission line is long enough, the impedance seen by the matching network may even look inductive instead of capacitive because of the impedance transformation.

R1-2 Load Simulator Design

R1-2.1 A typical design for a Load Simulator operated at 13.56 MHz uses two capacitors and a 50-ohm load. A schematic is shown in Figure R1-1. The Load Simulator consists of a series capacitor, C2, and a shunt capacitor, C1. The C1 capacitor is in parallel with a 50-ohm load. The 50-ohm load can be an input port to a Network Analyzer or a high-power 50-ohm load that can be used with high-power testing.

R1-2.2 A picture of a Load Simulator of this type of design is shown in Figure R1-2. Two vacuum variable capacitors are used, with a copper strap connecting them. The capacitors shown in the figure are variable from 8 to 1000 pF. Additional fixed capacitors can be easily added to the circuit to expand the operating range. The strap connecting the capacitors adds roughly 100 nH of inductance to the series part of the circuit for this example.

R1-2.3 The impedance range for this type of Load Simulator is fairly broad. A plot of the real part of the input impedance as a function of the value of the C1 shunt capacitor is shown in Figure R1-3. The real part of the load varies from close to 50 ohms to around 1.2 ohms at a C1 capacitance of 1500 pF. A plot of the reactive part of the input impedance is shown in Figure R1-4. The reactance can be varied as a function of both the C1 and C2 capacitances. A reactance range of –5 to –100 ohms is easily achieved for a C2 capacitance variation of 1500 pF to 100 pF.

R1-3 Measurement of Load Simulator Impedance and Efficiency

R1-3.1 The impedance and the efficiency of the Load Simulator can be measured in much the same way as a matching network. The test setup is shown in Figure R-5. A special fixture may be required to adapt the input connection of the Load Simulator to a coaxial connector.

R1-3.2 Calibrate the Network Analyzer at the desired operating frequency (e.g., 13.56 MHz). The Network Analyzer shall be calibrated for measuring the reflection coefficient at test Port 1 and for measuring the transmission coefficient at test Port 2 (see Figure R-1) using the calibration kit provided with the Network Analyzer. This measurement requires measuring the S11 and S21 S-parameters and requires a full 2-port calibration. The calibration shall be performed at fixed frequency (continuous-wave operation) using the lowest bandwidth possible (typically 10 Hz). The calibration for each port shall include the additional test cables and any additional adapters.

R1-3.3 After calibration of the Network Analyzer, the cable connected to Port 1 of the Network Analyzer shall be connected to the input of the Load Simulator. The cable connected to Port 2 of the Network Analyzer shall be connected to the output of the Load Simulator.

R1-3.4 The tuning elements (variable capacitors) shall be moved to their minimum positions before the measurement is initiated. After all connections are visually inspected for proper contact and the Network Analyzer has stabilized, the value of the input impedance, the magnitude of the reflection coefficient (S11), and the magnitude of the transmission coefficient (S21) shall be recorded. In addition, the positions of the tuning elements of the Load Simulator shall be recorded.

R1-3.5 The efficiency of the Load Simulator is determined from both the reflection and transmission coefficients. The efficiency can be calculated by taking the ratio of the output power divided by the input power. The output power is simply $(S21)^2$ and the input power is $(1-(S11)^2)$.

$$Load\ Simulator\ Efficiency = \frac{(S21)^2}{1-(S11)^2}$$

Typically, the reflection and transmission coefficients are expressed in terms of dB (decibels). The conversion between dB and efficiency is expressed as

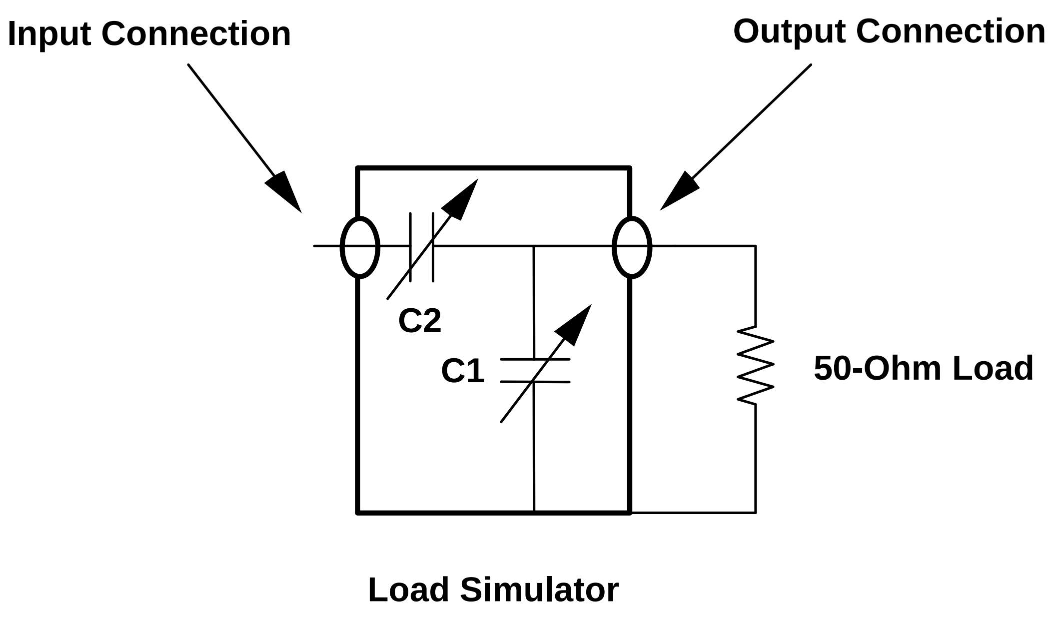
$$Load\ Simulator\ Efficiency = \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

$$Power\ Transfer\ \% = 100 \times \frac{10^{(\mathrm{S21\,in\,dB}/10)}}{1-10^{(\mathrm{S11\,in\,dB}/10)}}$$

For example, if the transmission coefficient is measured to be –10 dB and the reflection coefficient is measured to be –0.5 dB, then the power transfer efficiency would be 91.95%. In other words, 8.05% of the power is lost in the Load Simulator.

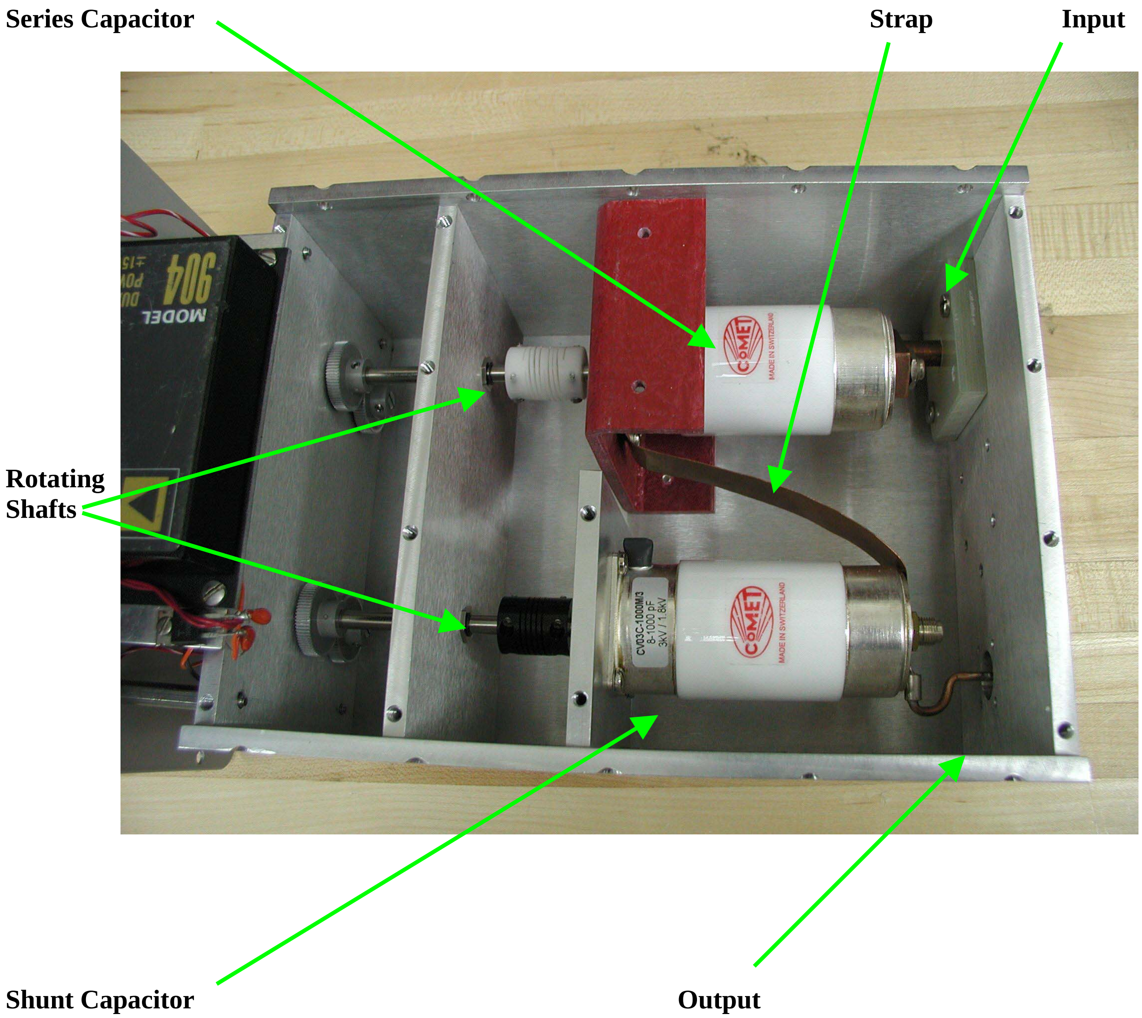
R1-3.6 For the next measurement, one tuning element shall remain fixed (C2), and the other tuning element (C1) shall be increased by an increment equal to no more than 10% of the full scale range of the tuning element position. After the tuning elements have been moved to their new values, steps 3.4 and 3.5 shall be repeated. This process shall be repeated until the tuning element (C1) has covered its entire range.

R1-3.7 After the tuning element (C1) has been varied over its entire range, the other tuning element (C2) shall be increased by an increment equal to no more than 10% of its full-scale range. The C1 tuning element shall then be moved back to its minimum position and the above steps (R1.3.4–R1.3.6) shall be repeated until the entire tuning range of the matching network is measured.



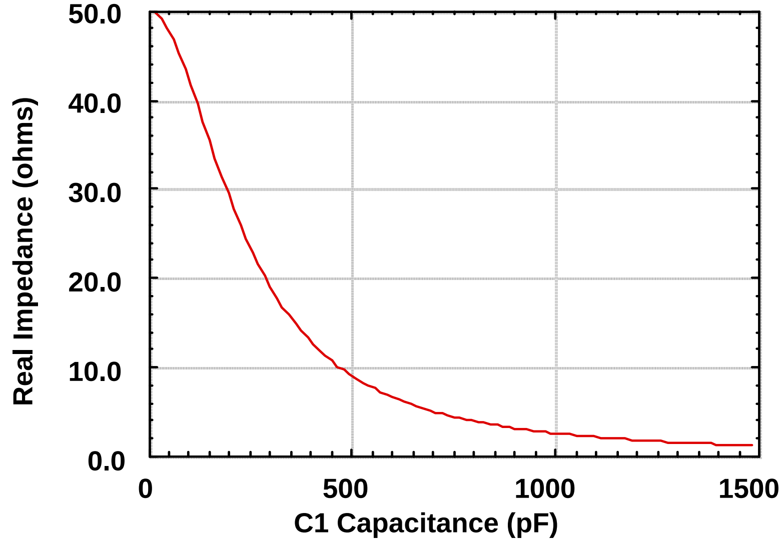
NOTE 1: The input connection is attached to a series variable capacitor, C2. The shunt variable capacitor, C1, is in parallel with a 50-ohm load.

Figure R1-1
Schematic of a Load Simulator



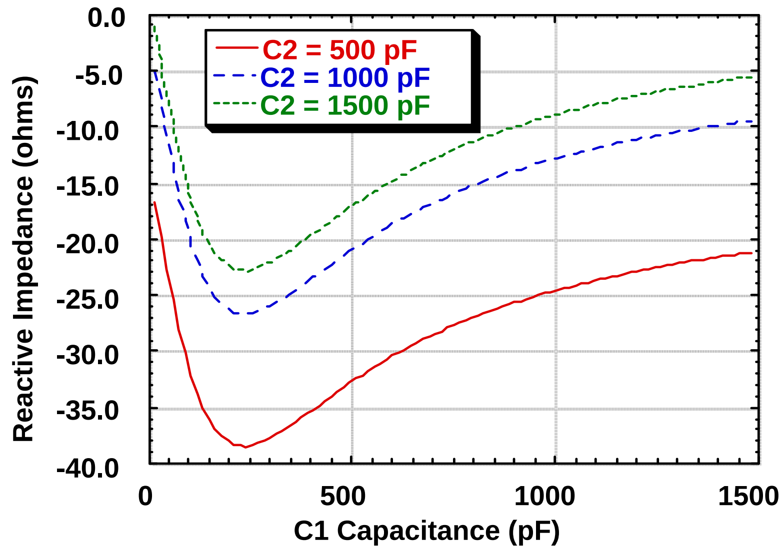
NOTE 1: Picture of a Load Simulator showing the variable capacitors. The capacitors are connected together by a strap that has an inductance of around 100 nH. The values of the capacitors are varied by rotating their shafts. The ends of the shafts are connected to a dial indicator to measure their positions.

Figure R1-2
Picture of a Load Simulator Showing the Variable Capacitors



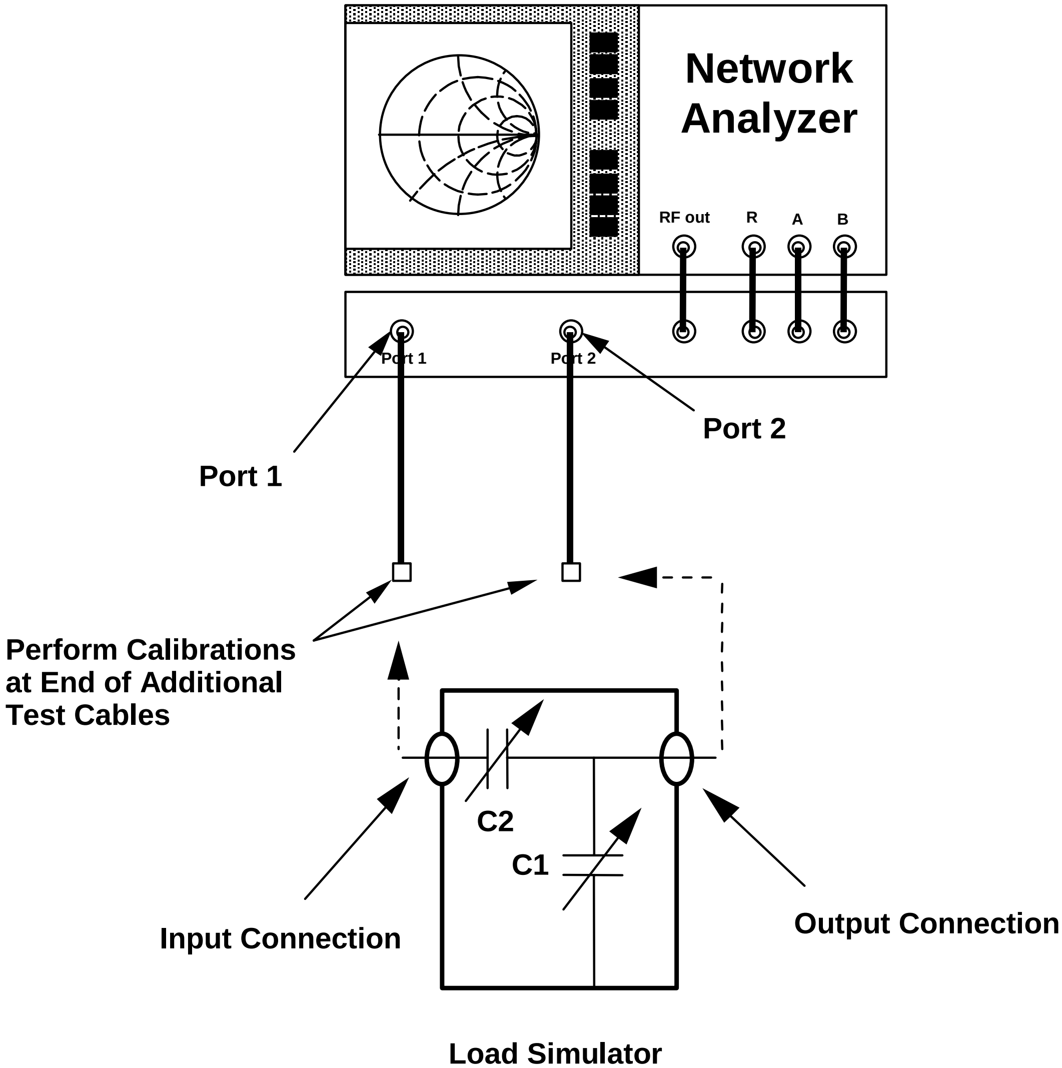
NOTE 1: The real impedance varies from 1.2 ohms to close to 50 ohms.

Figure R1-3
Example Plot of the Real Part of the Load Impedance as a Function of the C1 Shunt Capacitor in the Load Simulator



NOTE 1: The C2 capacitance is at the indicated fixed value for each set of data. For this example, the reactive impedance varies from around –40 ohms to –5 ohms. Decreasing C2 to 100 pF reduces the reactance to less than –100 ohms.

Figure R1-4
Example Plot of the Reactive Part of the Load Impedance as a Function of the C1 Shunt Capacitance in the Load Simulator



NOTE 1: Both the Port 1 and Port 2 outputs need to be used for the measurement. Additional test cables are needed for the transmission calibration between the two ports. The input connection of the Load Simulator attaches to Port 1 of the Network Analyzer. The output connection of Load Simulator attaches to Port 2 of the Network Analyzer.

Figure R1-5
Schematic of a Load Simulator Test Setup for the Load Impedance and Efficiency Measurement

SEMI INTERNATIONAL STANDARDS

EQUIPMENT AUTOMATION SOFTWARE

Semiconductor Equipment and Materials International

SEMI E4-0699
SEMI EQUIPMENT COMMUNICATIONS STANDARD 1 MESSAGE TRANSFER (SECS-I)

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org May 1999; to be published June 1999. Originally published in 1980; previously published January 1999.

1 Introduction

1.1 *Revision History* — This is the first major revision since the original release of SECS-I in 1980. Very little of the original intent of SECS-I has been altered, although there are a few significant additions. The changes are summarized in Appendix 1. This specification has been developed in cooperation with the Japan Electronic Industry Development Association Committee 12 on Equipment Communications.

1.2 *Scope* — The SECS-I standard defines a communication interface suitable for the exchange of messages between semiconductor processing equipment and a host. Semiconductor processing equipment includes equipment intended for wafer manufacturing, wafer processing, process measuring, assembly and packaging. A host is a computer or network of computers which exchange information with the equipment to accomplish manufacturing. This standard includes the description of the physical connector, signal levels, data rate and logical protocols required to exchange messages between the host and equipment over a serial point-to-point data path. This standard does not define the data contained within a message. The meaning of messages must be determined through some message content standard such as SEMI Equipment Communications Standard E5 (SECS-II).

1.3 *Intent* — This standard provides a means for independent manufacturers to produce equipment and/or hosts which can be connected without requiring specific knowledge of each other.

1.3.1 *Layered Protocol* — The SECS-I protocol can be thought of as a layered protocol used for point-to-point communication. The levels within SECS-I are the physical link, block transfer protocol, and message protocol. (See Related Information R1-1.1.)

1.3.2 *Speed* — It is not the intent of this standard to meet the communication needs of all possible applications. For example, the speed of RS-232 may be insufficient to meet the needs of transferring mass amounts of data or programs in a short period of time, such as might be required by high speed functional test applications.

1.3.3 *Network Support* — The method by which blocks of data are routed to a piece of equipment or find their way back to the proper host application is not specified by SECS-I. In a network, the roles of host and equipment might be assumed by any party in the network. In this situation, one end of the communications link must assume the role of the equipment and the other the role of the host.

1.4 *Applicable Documents*

1.4.1 *Electronics Industries Association Standards*[1]

EIA RS-232-C — Interface between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange

EIA RS-269-B — Synchronous Signaling Rates for Data Transmission

EIA RS-334 — Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Communication Equipment for Serial Data Transmission

EIA RS-422 — Electrical Characteristics of Balanced Voltage Digital Interface Circuits

EIA RS-423 — Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits

1.4.2 *European Computer Manufacturing Association*[2]

ECMA/TC24/82/18 — "Network Layer Principles," Final Draft (April, 1982)

1.4.3 *Japanese Industrial Standards Committees*[3]

JIS C 6361 — "The Interface between Data Circuit Terminating Equipment (DCE) and Data Terminal Equipment (DTE) (25-pin Interface)"

1.4.4 *International Organization for Standardization*[4]

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[1] *EIA Engineering Department, Standards Sales Office, 2001 Eye Street, N.W., Washington, D.C. 20006*

[2] *European Computer Manufacturing Association, 114 Rue du Rhone, 1204 Geneva, Switzerland*

[3] *Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo 107, Japan*

[4] *ANSI, 1430 Broadway, New York, NY 10018*

ISO 2110-1980 — Data Communications, Interface Connectors and Pin Assignment

1.4.5 *SEMI Specifications*

SEMI E5 — SEMI Equipment Communications Standard 2 — Message Content (SECS-II)

SEMI E6 — SEMI Facilities Interface Specification Format

1.5 *Overview of SECS-I* — The SECS-I standard defines point-to-point communication of data utilizing a subset of the international standard known in the U.S.A. as EIA RS-232-C and in Japan as JIS C 6361 for the connector and voltage levels. The actual transmission consists of 8-bit bytes sent serially with one start and one stop bit. The communication is bidirectional and asynchronous, but flows in one direction at a time. The direction is established by special characters and a handshake, after which the data itself is sent. Data is sent in blocks of 254 bytes or less. Each block consists of a 10-byte header followed by data. A message is a complete unit of communication in one direction and consists of 1 to 32,767 blocks. Each block header contains information for identifying the block as part of a specific message. Messages are paired by a request and its reply which together are called a transaction.

1.6 *Structure of Document* — This document is divided into sections which correspond to major aspects of the standard. The sections outline requirements as well as implications of the requirements. The standard may be implemented in a variety of ways, depending upon the computer environment where it is placed. Implementation is not part of the standard. Information which may be useful for implementation is included in the form of Related Information.

2 Terminology

2.1 The following brief definitions refer to sections providing further information.

2.1.1 *ACK* — "Correct Reception" handshake code. (See Section 5.2.)

2.1.2 *application software* — the software performing the specific task of the equipment or the host.

2.1.3 *block* — header plus up to 244 bytes of data. (See Sections 1.5, 6.7.)

2.1.4 *block length* — the number of bytes sent in the block transfer protocol. (See Section 5.6.)

2.1.5 *block number* — a 15-bit field in the header for numbering blocks in a message. (See Sections 6.7.)

2.1.6 *character* — a byte sent on the SECS-I serial line. (See Section 4.1.)

2.1.7 *checksum* — a 16-bit number used to detect transmission errors. (See Section 5.7.)

2.1.8 *communication failure* — a failure in the communication link resulting from a failed send. (See Section 5.4.)

2.1.9 *device ID* — a 15-bit field in the header used to identify the equipment. (See Section 6.3.)

2.1.10 *E-bit* — a bit in the header identifying the last block of a message. (See Section 6.6.)

2.1.11 *ENQ* — "Request to Send" handshake code. (See Section 5.2.)

2.1.12 *EOT* — "Ready to Receive" handshake code. (See Section 5.2.)

2.1.13 *equipment* — the intelligent system which communicates with a host.

2.1.14 *expected block* — the block of a message which is expected by the message protocol. (See Section 7.4.4.)

2.1.15 *header* — a 10-byte data element used by the message and transaction protocols. (See Section 6.)

2.1.16 *host* — the intelligent system which communicates with the equipment.

2.1.17 *length byte* — the character used to establish the block length during transmission. (See Section 5.6.)

2.1.18 *line control* — a portion of the block transfer protocol. (See Section 5.8.2.)

2.1.19 *master* — the block transfer designation for the equipment. (See Section 5.5.)

2.1.20 *message* — a complete unit of communication. (See Section 7.)

2.1.21 *message ID* — a 15-bit field in the header used in the process of message identification. (See Sections 6.5, 7.3.1.)

2.1.22 *multi-block message* — a message sent in more than one block. (See Sections 6.7, 7.2.2.)

2.1.23 *NAK* — "lncorrect Reception" handshake code. (See Section 5.2.)

2.1.24 *open message* — a multi-block message for which not all of the blocks have been received. (See Section 7.4.4.)

2.1.25 *open transaction* — a transaction in progress. (See Section 7.3.)

2.1.26 *primary message* — a message with an odd numbered message ID. Also the first message of a transaction. (See Section 6.5.)

2.1.27 *primary/secondary attribute* — the least significant bit of the lower message ID which indicates whether a block belongs to a primary or secondary message.

2.1.28 *R-bit* — a bit in the header signifying the direction of the message. (See Section 6.2.)

2.1.29 *receiver* — the end of the SECS-I link receiving a message. (See Section 5.8.4.)

2.1.30 *reply* — the particular secondary message corresponding to a primary message. (See Section 7.3.)

2.1.31 *reply linking* — the process of forming a transaction out of a primary and a secondary message. (See Section 7.3.1.)

2.1.32 *retry count* — the number of unsuccessful attempts to send a block in the block transfer protocol. (See Section 5.4.)

2.1.33 *RTY* — the retry limit or the number of times the block transfer protocol will attempt to retry sending a block before declaring a failed send. (See Section 5.4.)

2.1.34 *secondary message* — a message with an even numbered message ID. Also the second message of a transaction. (See Section 6.5.2.)

2.1.35 *sender* — the end of the SECS-I link sending message. (See Section 5.8.3.)

2.1.36 *slave* — the block transfer designation for the host (See Section 5.5.)

2.1.37 *system bytes* — a 4-byte field in the header used for message identification. (See Section 6.8.)

2.1.38 *T1* — receive inter-character timeout in the block transfer protocol. (See Section 5.3.1.)

2.1.39 *T2* — protocol timeout in the block transfer protocol. (See Section 5.3.2.)

2.1.40 *T3* — reply timeout in the message protocol. (See Sections 5, 7.3.2)

2.1.41 *T4* — inter-block timeout in the message protocol. (See Section 7.4.3.)

2.1.42 *transaction* — a primary message and its associated secondary message, if any. (See Section 7.3.)

2.1.43 *W-bit* — a bit in the header signifying that a reply is expected. (See Section 6.4.)

3 Coupling

3.1 Coupling refers to the physical interface at the equipment. The host will provide compatible signals at this point. No restrictions are implied for any interface other than for equipment covered by this standard.

3.2 *Electrical Interface* — The connection will include a serial interface according to EIA Standard RS-232-C for interface Type E, full duplex communication, modified by the deletions, additions and exceptions described in this section.

3.2.1 *Connector* — Either the 9-pin or 25-pin connector described in the EIA RS232 may be used. In the case of the 25-pin connector a female connector will be mounted on the equipment and a male connector will be mounted on the cable from the host. In the case of the 9-pin connector the male connector will be mounted on the equipment and a female connector will be mounted on the cable. The connector on the equipment will have female 4-40 threaded jack screw locks.

NOTE: Suitable 25-pin connectors known as Type "D" are similar to Amphenol MIN RAC 17 series with jack screw locks. Suitable 9-pin connector is also Type "D" with jackscrew locks. It is the type commonly implemented on desktop and notebook PCs.

3.2.2 *Signal Pins* — Pins on the connector have functions as defined in Table 1. Pins 1, 2, 3, and 7 of the 25-pin connector or pins 3, 2, and 5 of the 9-pin connector are required for all equipment complying with SECS-I. When using a 25-pin connector, the two power supply pins, 18 and 25, are optional as indicated. Any other pins, if used, shall comply with the RS-232-C standard.

Table 1 Signal Connections

25-Pin	*9-Pin*	*RS-232-C Circuit*	*Circuit Description*
1	--	AA	Shield
2	3	BA	Data from Equipment
3	2	BB	Data to Equipment
7	5	AB	Signal Ground
18	--	--	+12 to +15 volts (opt for the 25-pin connector)
25	--	--	-12 to -15 volts (opt for the 25-pin connector)

3.2.3 *Logic Levels* — For the signal pins 2 and 3, the logic 1 level will be a voltage less than -3 volts and the logic 0 level will be a voltage greater than +3 volts. Voltages will never exceed ± 25 volts. These values correspond to those specified by the RS-232-C standard.

3.2.4 *Power Supplies* — When using a 25-pin connector, pins 18 and 25 are optional power supplies for driving external isolation circuits. When provided, both shall be present and must be able to supply at least 50 mA. (See Related Information R1-2 for example use.)

3.3 *Data Rate* — The supported data rates on signal pins shall be 9600, 4800, 2400, 1200, and 300 baud. The same data rate shall apply for data sent to and from the equipment. The data rate shall be controlled to better than 0.5%. (See RS-269-B and RS-334.) Optional rates of 19,200 and 150 baud may be supplied if desired.

3.4 *Physical Medium* — The connection with the host may involve any medium that provides the required RS-232-C quality, signal levels and data rate at the equipment connector. The quality of signal should be such that the effective bit error rate is less than 1×10^{-6}. This rate can be achieved easily with hardwired systems. The distance limits specified in RS-232-C apply only to systems using the wiring technique described in RS-232-C. Since any method may be used in SECS-I as long as RS-232-C signals are supplied at the connector, the distance and isolation is dependent upon the design of the physical medium which is external to the SECS-I standard. (See Related Information R1-2.)

4 Character Structure

4.1 *Characters* — Data will be transmitted or received in a serial bit stream of 10 bits per character at one of the specified data rates. The standard character has one start bit (0), 8 data bits and one stop bit (1). All bit transmissions are of the same duration. The 8 data bits are numbered from 1 to 8 in the order sent (see Figure 1). The timing between characters is asynchronous with respect to the data rate. The 8 data bits may be any arbitrary code. The eight data bits will hereafter be referred to as a byte.

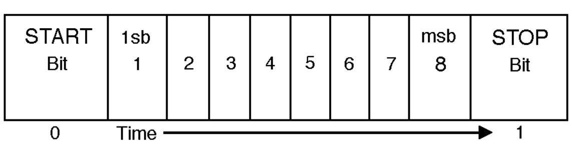


Figure 1

Character Structure

4.2 *Weighted Codes* — For bytes having weighted codes, bit one is the least significant and bit eight is the most significant. The most common weighted code is binary.

4.3 *Non-Weighted Codes* — For codes without numeric value such as ASCII, the bit numbers will be used as the entry into a standard code table for interpretation of the code. SECS-I performs no parity or other verification of the contents of individual bytes.

5 Block Transfer Protocol

5.1 The procedure used by the serial line to establish the direction of communication and provide the environment for passing message blocks is called the block transfer protocol. Most of the protocol is accomplished with a handshake of single bytes. When both ends of the line try to send at the same time, a condition known as line contention exists. The protocol resolves contention by forcing one end of the line, designated as the slave (always the host), to postpone its transmission and enter the receive mode. Retransmission of blocks is used to correct communication errors. The block transfer protocol is shown in flow chart form in Figure 2, and described below. Additional information is also contained in Related Information R1-3 and R1-4.

5.2 *Handshake Bytes* — The four standard handshake codes used in the block transfer protocol are shown in Table 2. The three letter names, ENQ, EOT, ACK, and NAK correspond to the ASCII code having the same pattern.

Table 2 Handshake Codes

Name	*Codeb8 b7.........b1*	*Function*
ENQ	00000101	Request to Send
EOT	00000100	Ready to Receive
ACK	00000110	Correct Reception
NAK	00010101	Incorrect Reception

5.3 *Timeout Parameters* — Timeouts are used to detect communications failures. A timeout occurs when the measured time between two events exceeds a predetermined limit. Generally, the length of time that must pass before it can be assumed that an error has occurred depends upon the particular systems involved. The time required in one situation might be excessively long in another. Thus, the timeout values must be "tuned" to meet the application. In the block transfer protocol, there are two situations requiring timeout values. The two timeout values are called parameters T1 and T2.

5.3.1 *Inter-Character Timeout, T1* — The inter-character timeout, T1, limits the time between receipt of characters within a block after the length byte has been received and until the receipt of the second checksum byte.

5.3.2 *Protocol Timeout, T2* — The protocol timeout, T2, limits the time between sending ENQ and receiving EOT, sending EOT and receiving the length byte, and sending the second checksum byte and receiving any character.

5.4 *Retry Limit, RTY* — The retry limit, RTY, is the maximum number of times the Block Transfer Protocol will attempt to retry sending a block before declaring a failed send. (See Section 5.8.2.)

5.5 *Master/Slave* — The master/slave parameter is used in the resolution of contention (see Section 5.8.2). The host is designated as the slave. The equipment is desig-nated as the master. This convention is based upon the assumption that the equipment is less able to store messages than the host.

5.6 *Block Lengths* — The unsigned integer value of the first byte sent after receipt of EOT is the length of the block being sent. The length includes all the bytes sent after the length byte, excluding the 2 bytes of the checksum. The maximum block length allowed by SECS-I is 254 bytes, and the minimum is 10 bytes.

5.7 *Checksum* — The checksum is calculated as the numeric sum of the unsigned binary values of all the bytes after the length byte and before the checksum in a single block. The checksum is sent as 16 bits in two bytes following the last byte of the block data. The high order eight bits of the checksum will be sent first, followed by the low order eight bits. The checksum is used by the receiver to check for transmission errors. The receiver performs the same checksum calculation on the received header and data.

5.8 *Algorithm* — The operation of the block transfer protocol is best understood by following the logic flow in Figure 2. This flow chart depicts the operation of the five states of the protocol - Receive, Idle, Send Line Control, and Completion. The flow chart shown in Figure 2 is not meant to imply that a particular implementation is required under this standard. However, any SECS-I block transfer protocol implementation must include all the logic described in Figure 2. The same algorithm is executed on each end of the SECS-I communications link.

5.8.1 *Idle State* — Both ends of the communications link are assumed to start in the Idle state. There are two primary activities of the protocol signified by the two exits from the Idle state. These are:

A. SEND — a message block is to be sent.

B. RECEIVE — the other end of the communications link has a message block to send

5.8.2 *Line Control* — The line control section establishes the transmission direction, resolves contention, and handles retries. When an ENQ is received in the Idle state, the Line Control responds with an EOT if the Block Transfer Protocol is ready to receive. The Block Transfer Protocol then goes to the Receive state. If a message block is to be sent, then an ENQ is sent. If an EOT is received in response to the ENQ within the time limit T2, the Block Transfer Protocol goes to the Send state.

5.8.2.1 If the slave receives an ENQ in response to the ENQ, contention has occurred. The slave postpones the send of its block until it receives a block from the master. The slave prepares to receive the incoming block and sends an EOT. When the block transfer protocol returns to the Idle state, the postponed block Send may be sent as if it were a new send request. After a master sends an ENQ, it can ignore all characters except an EOT. After a slave sends at ENQ, it can ignore all characters except an ENQ or EOT.

5.8.2.2 When the time between sending ENQ and receiving EOT exceeds T2, or the time between sending the second checksum byte and receiving any character exceeds T2, or a non-ACK character is received within time T2 after sending the second checksum byte, the Line Control will increment the retry count ("tries" in the flowchart). If the retry count does not exceed the value of the RTY parameter, then the Block Transfer Protocol will retry sending the block beginning with ENQ. If the retry count does exceed the value of the RTY parameter, then a failed send has occurred.

5.8.3 *Send* — Once a send state is established, the first byte sent is the length, N, of the data in the block. After N more bytes have been sent, the two bytes of the checksum are sent. The sender computes the checksum based on the data in the block and the block header, but not the length byte. When the sender receives the ACK before time T2, the block is deemed properly sent. However, if the sender receives a non-ACK character before time T2, or no character within time T2, it returns to the line control state for a possible retry. In the Send state, characters received prior to sending the last checksum byte can be ignored.

5.8.4 *Receive* — Once a receive state is established, the first byte received is the length byte, N. The receiver counts and saves the following N + 2 bytes. The last two bytes are the checksum. The receiver compares the two checksum bytes against its own computation of the checksum. In a good block, the computed and received checksum are the same.

5.8.5 *Receive Completion* — After a block is correctly received, an ACK character is sent and the message protocol is notified that a block has been received. If T2 is exceeded while waiting for the length character, or Tl is exceeded between characters being received, then an NAK is sent. If the length byte is invalid or if the received checksum does not agree with the computed checksum, the receiver continues to listen for characters to ensure that the sender is finished sending. This is detected when the inter-character time exceeds T1, at which point the receive is aborted and a NAK is sent. In any case when an NAK is sent, the receiver may discard any data it has received for the block. The receiver returns immediately to the Idle state after sending an ACK or NAK.

5.8.6 *Send Completion* — After the second checksum byte is sent, if an ACK is received within time T2, the message protocol is notified that the send was successful. If a failed send occurs, the message protocol is informed of the failure. Application-level software must take the possibility of a send failure into account.

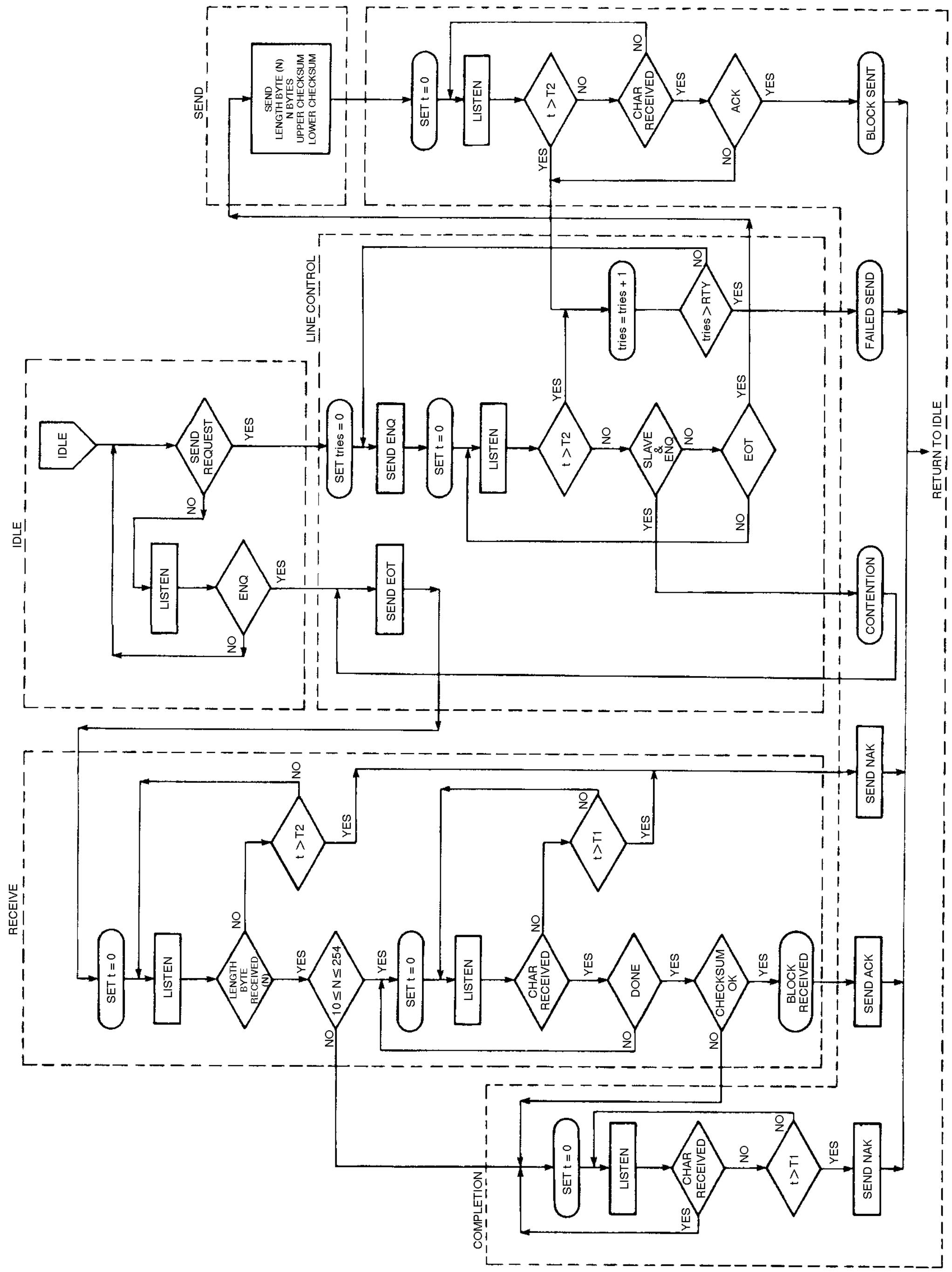


Figure 2

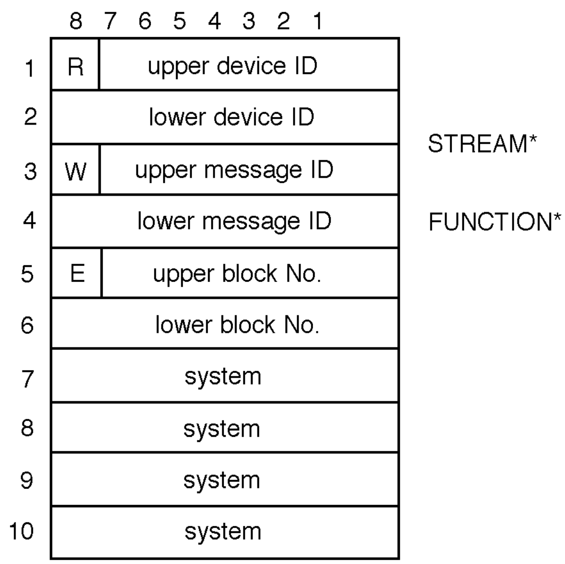
Block Transfer Protocol

6 Header Structure

6.1 The operation of all communications functions above the block transfer protocol is linked to information contained in a 10-byte data element called the header. The header is always the first 10 bytes of every block sent by the block transfer protocol. The information in the header is also used by the message protocol (see Section 7). The fixed format of the header is described in this section. The general header structure is shown in Figure 3.

NOTE: The header also contains information required by SECS-II.

6.2 *Reverse Bit (R-Bit)* — The reverse bit (R-bit) signifies the direction of a message. The R-bit is set to 0 for messages to the equipment and set to 1 for messages to the host. The R-bit is included in the header so that the direction of the message is contained in every block.



*Defined in SECS-II and included here for reference only.
(UPPER MEANS MOST SIGNIFICANT, LOWER MEANS LEAST SIGNIFICANT)

Figure 3

Block Header Structure

Table 3 Influence of the R-BIT

R-Bit	*Device ID*	*Message Direction*
0	Destination	Host to Equipment
1	Source	Equipment to Host

6.3 *Device ID* — The device ID defines the source or destination of the message depending upon the value of the R-bit as shown in Table 3. Device identification is a property of the equipment and must be settable according to Section 8. The host can view the device ID as a logical identifier connected with a physical device within the equipment. The host has no device ID.

6.4 *Wait Bit (W-Bit)* — The wait bit (W-bit) is used to indicate that the sender of a primary message expects a reply. A value of one in the W-bit means that a reply is expected. A value of zero in the W-bit means that no reply is expected. The W-bit must be set to zero in all secondary messages. For multi-block messages, the sender must ensure that the W-bit is the same in every block of the message.

6.5 *Message ID* — The message ID identifies the format and content of the message being sent (the particular message is one of many possible for the device in question). The exact message content is equipment-dependent. The upper message ID is the most significant portion of the ID.

6.5.1 *Primary Message* — A primary message is defined as any odd numbered message. An odd numbered message will have bit 1 of the lower message ID set to 1.

6.5.2 *Secondary Message* — A secondary message is defined as any even numbered message. An even-numbered message will have bit 1 of the lower message ID set to 0.

NOTE: In SECS-II, byte three of the header (excluding the W-bit) is known as the stream, and byte four of the header is known as the function. See SECS-II for more information.

6.6 *End Bit (E-Bit)* — The end bit (E-bit) is used to determine if a block is the last block of a message. A value of one in the E-bit means that the block is the last block. A value of zero means that more blocks are to follow.

6.7 *Block Number* — A message sent as more than one block is called a multi-block message. The first block is given a block number of one, and the block number is incremented by one for each subsequent block until the entire message is sent. The blocks of a multi-block message are sent in order. In a single-block message, the block number must have a value of zero or one. The maximum block number is 32,767. The upper block number is the most significant portion of the block number. (See also 7.2.)

6.8 *System Bytes* — The system bytes in the header of each message for a given device ID must satisfy the following requirements. (For a further discussion of system bytes, see Related Information R1-5.)

6.8.1 *Distinction* — The system bytes of a primary message must be distinct from those of all currently open transactions initiated from the same end of the communications link. They must also be distinct from those of the most recently completed transaction. (See Section 7.3.) They must also be distinct from any system bytes of blocks that were not successfully sent since the last successful block send.

6.8.2 *Reply Message* — The system bytes of the reply message are required to be the same as the system bytes of the corresponding primary message.

6.8.3 *Multi-Block Messages* — The system bytes of all blocks of a multi-block message must be the same.

7 Message Protocol

7.1 A message is a complete unit of communication in one direction. The message protocol uses the services of the block transfer protocol to send and receive messages. The message consists of the message data together with the following information from the header — R-bit, device ID, W-bit, message ID, and system bytes.

7.2 *Message Send* — When a message is ready to be sent, the message send protocol performs the functions described below. A block send failure terminates the message protocol action on that message.

7.2.1 *Message Length* — The maximum data length in a single block of a message is 244 bytes. The maximum number of blocks that can be sent in a multi-block message is 32,767, and so the maximum data length allowed in one message is 244 × 32,767 bytes.

7.2.2 *Message Blocking* — Message blocking is the division of the message data into blocks to be sent to the Block Transfer Protocol. For best performance, it is recommended, but not required, that the sender fill all blocks of a multi-block message, except possibly the last block, with the maximum 254 bytes. The receiver of a multi-block message should be able to accept any block size from 11 to 254 bytes, and should not require consecutive blocks necessarily to be the same size.

7.2.2.1 Certain older implementations may impose application-specific requirements on block sizes for certain incoming messages. Beginning with the 1988 revision of the standard, new applications may not impose application-specific requirements on incoming block sizes. Applications implemented before 1988 may impose such requirements.

NOTE: In SECS-II, certain messages are defined as single-block messages and must be sent as a single block in SECS-I.

7.2.3 *Header* — The message protocol must establish the header in each block of the message according to the requirements of Section 6.

7.2.4 *Interleaving Messages* — This standard allows, but does not require, the support of more than one concurrent open transaction. This standard allows, but does not require, the support of interleaving the blocks of different multi-block messages. (See documentation requirements in 9.)

7.3 *Transactions* — A transaction is a primary message and an optional corresponding secondary message is called the reply. A transaction is opened when a primary message is ready to be sent. A transaction is closed when the last block of a primary message requesting no reply has been sent, or when the last block of the reply has been received.

7.3.1 *Reply Linking* — When a reply is expected for a primary message, the message protocol starts the reply timer for the transaction after the last block of the message is successfully sent. When a primary message is sent for which a reply is requested, an expected block is established for the message receive algorithm. (See Section 7.4.) The expected block will have the complement of the R-bit, will have the same device ID, will be the first block of a secondary message, and will have the same system bytes as those of the given primary message.

NOTE: In SECS-II, the reply will have the same upper message ID (stream), and the lower message ID (function) will either be one greater than that of the corresponding primary message, or it will be zero.

7.3.2 *Reply Timeout, T3* — The reply timeout, T3, is a limit on the length of time that the message protocol is willing to wait after the last block of a primary message has been sent and before the arrival of the first block of the reply. If the first block of the reply does not arrive within the T3 limit, the expected block is removed from the list of expected blocks, and the transaction is aborted. A timer, called the reply timer, is used to measure the time between the last block of the primary message and the first block of its reply. Each open transaction for which a reply is expected requires a separate reply timer.

7.4 *Message Receive* — Each block successfully received by the block transfer protocol is passed to the message protocol. It is the task of the message protocol to identify the blocks and assemble them into the proper message.

7.4.1 *Routing Error* — When a piece of equipment receives a block of data which has a device ID in the block header which does not match its own device ID and it has no other knowledge of this device ID, it can assume that the block was sent in error.

7.4.2 *Duplicate Block Detection* — A duplicate block is a block which is exactly the same as the previous block received by the Block Transfer Protocol. This may occur when the receiver has sent an ACK but, for some reason, the ACK did not arrive in time at the sender, causing a send retry. A duplicate block is detected by the SECS-I message protocol by comparing the full 10-byte header of a block currently received by the block transfer protocol with the header of the last block accepted as non-duplicate by the message protocol. If the headers are identical, the new block is a duplicate and should be discarded. If the headers are different, the new block is a non-duplicate. The header of the non-duplicate block saved for comparison with the next block passed on by the block transfer protocol, and the block containing the header is further processed by the message receive algorithm.

NOTE: Some implementations which follow the 1980 version of SECS-I may not provide the unique headers required for duplicate block detection. An option for disabling the duplicate block detection is required to be compatible with these systems.

7.4.3 *Inter-Block Timeout T4* — The time interval between the successful receipt of a block in a multiblock message, and the successful receipt of the subsequent block of the same message, is limited to time T4. If this time is exceeded, the message is cancelled and the transaction is aborted. A time called the inter-block timer is used to measure the time between block arrivals in the message protocol. There must be one inter-block timer for each open multi-block message currently being received by the protocol. As each successive block of a message is received, the corresponding inter-block timer is reset.

7.4.4 *Algorithm* — When a block arrives at the message protocol, a combination of all the bytes in the header is used to determine what to do with the block. The operation of the message receive algorithm is to be understood by following the logic flow in Figure 4. The flow chart shown in Figure 4 and the description of the algorithm below are not meant to imply that particular implementation is required under this standard. However, any SECS-I message protocol implementation must include all the logic shown in Figure 4 on page 11.

7.4.4.1 The description of the message protocol uses the concepts of an expected block. When a (properly routed and non-duplicate) block is received by the message protocol, the first determination is whether the block is one of the expected blocks or not. In order to determine if a block is one of the expected blocks, the header information is compared with the header information in a list of expected blocks.

7.4.4.2 If the block is not one of the expected blocks, it must be the first block of a primary message, otherwise the block has been sent in error and can be discarded. If the block is the first block of a primary message, and it is not the last block of the message (E-bit = 0), an inter-block timer for the given message is established and set, and the expected block for the given message is set to have the same R-bit, device ID, system bytes, W-bit, message ID, and a block number one greater than that of the block just received.

7.4.4.3 If the block is one of the expected blocks, then it is either the first block of a reply message or it is part of an open message.

7.4.4.4 If the block is the first block of a reply message, the reply timer for the given message is cancelled. For the first block of a reply message, the expected block will have block number one (or possibly zero if the reply is a single block message) and will be a secondary message, but the full message ID is undetermined. (See Section 7.3.1.)

7.4.4.5 If the block is the last block of the given message (E-bit = 1), the message is complete. If the message is a primary message for which a reply is requested (W-bit = 1), the system bytes are saved for sending with the reply message. (See Section 7.2.3.)

7.4.4.6 If the block is not the last block of the message (E-bit = 0), then the inter-block timer for the given message is reset, and the (next) expected block for the given message is set to have the same R-bit, device ID, system bytes, W-bit, message ID, and a block number one greater than that of the block just received.

8 Parameter Setting

8.1 The eight protocol parameters are listed in Table 4. The selection of baud rate should be based on system performance. The value of the device ID is determined by the particular system requirements and is generally unique within one factory. The values of the next five parameters are determined by the performance characteristics of the host system and the baud rate of the communication channel. The first seven parameters must be adjustable by the user. All parameters must be stored in such a manner that the settings will be retained if the power fails or if the system software is reloaded. The range and resolution of protocol parameters must be at least as shown in Table 4. The M/S parameter is set to master in the equipment and to slave in the host.

Table 4 Protocol Parameters

Symbol	*Parameter Name*	*Typical Function*	*Typical Value*	*Range*	*Resolution*
BAUD	Baud Rate	Sets serial line speed	9600	300 - 9600	see Section 3.3
DEVID	Device ID	Identifier assigned to the equipment	—	0 - 32767	1
T1	Inter-Character Timeout	Detects an interruption between characters	0.5 sec.	0.1-10 sec.	0.1 sec.
T2	Protocol Timeout	Detects a lack of protocol response	10 sec.	0.2-25 sec.	0.2 sec.
T3	Reply Timeout	Detects a lack of reply message	45 sec.	1-120 sec.	1 sec.
T4	Inter-Block Timeout	Detects an interruption in a multi-block message	45 sec.	1-120 sec.	1 sec.
RTY	Retry Limit	The maximum number of send retries allowed	3	0 - 31	1
M/S	Master Slave	Contention resolution	—	—	—

9 Documentation

9.1 For equipment or host to comply with SECS-I, a document is required containing the following information. (See also SEMI E6, Facilities Interface Specifications Guideline and Format.)

1. Method for setting all the parameters in Table 4.
2. Range allowed and resolution for each parameter in Table 4.
3. Compatibility with duplicate block detection and the method for enabling and disabling the same if present (see Section 7.4.2).
4. Maximum expected inter-character, protocol, reply, and inter-block delays generated under normal operating conditions.
5. Whether multi-block messages are supported as a receiver.
6. Whether multi-block messages are used as a sender.
7. Whether there is a limit to the size of a message received and, if so, what the limit is.
8. Maximum expected size of a message being sent.
9. Whether message interleaving is supported as a receiver.
10. Whether message interleaving is used as a sender.
11. Number of device ID's supported on the port.
12. Maximum number of supported concurrent open transactions.

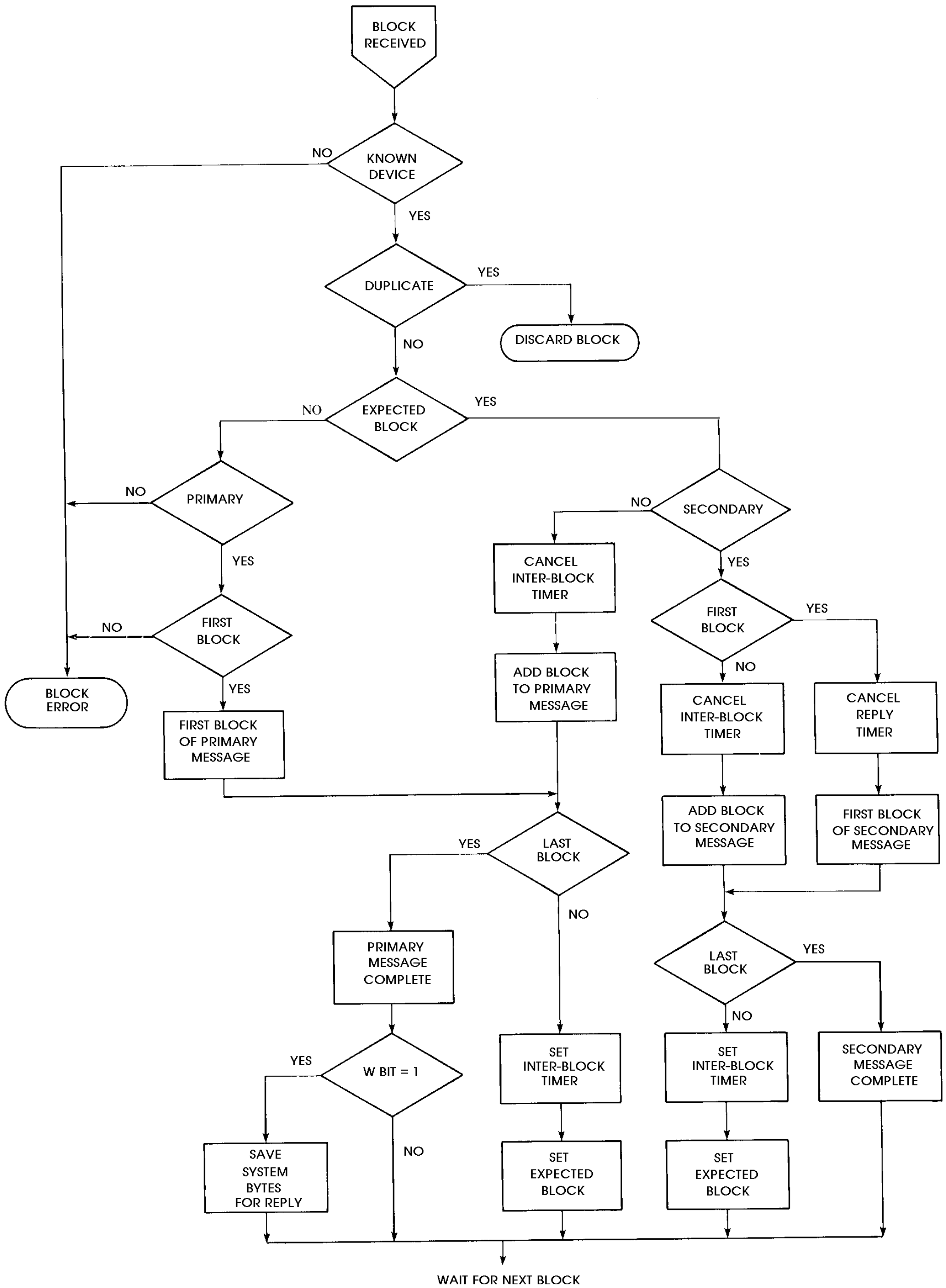


Figure 4

Message Receive Algorithm

APPENDIX 1

A1-1 Differences from SECS-I 1980

This appendix describes the major differences between this version of the standard and the version originally adopted in 1980.

A1-1.1 *Signal Connections* — The required voltage levels for pins 18 and 25 on the 25 pin "D" connector are now optional.

A1-1.2 *Data Rate* — The 150 baud data rate has been made optional.

A1-1.3 *Timeout Parameters* — The T4 timeout, which limits the inter-block arrival time of multi-block messages, has been added. Use of the T3 timeout has been clarified.

A1-1.4 *Time Before Length Byte* — The protocol time with limit T2 is now used while waiting for the length byte after sending an EOT.

A1-1.5 *Block Send Acknowledgment* — Any character other than an ACK received after sending the second checksum byte is treated as an NAK.

A1-1.6 *Illegal Block Lengths and Bad Checksums* — An NAK code is sent for an illegal block length or for a bad checksum, but only after waiting for the sender to stop sending by forcing an inter-character (T1) timeout.

A1-1.7 *Block Number* — The wording describing the block number has been clarified to say that the value, zero, is allowed only for single block messages.

A1-1.8 *System Bytes* — The handling of the system bytes for secondary messages sent by a host is now the same as for the equipment. Also, specific functional requirements have been added for the content of the system bytes field.

A1-1.9 *Duplicate Blocks* — A mechanism for the detection of duplicate blocks has been added.

A1-1.10 *Messages* — The discussion of message assembly from blocks has been clarified and expanded.

A1-1.11 *Transactions* — The discussion of transaction handling and reply linking has been moved from SECS-II and expanded.

A1-1.12 *Appendix* — Parts of the Appendix have been moved to a new section called Related Information to distinguish the content from the standard itself. The general node transaction flow chart has been moved from the Appendix in SECS-II to the Related Information in SECS-I.

A1-1.13 *Titles* — The title of SECS-I has been changed from "Data Link" to "Message Transfer." This phrase more accurately covers the content of the standard and avoids confusion with other uses of the term "data link." The title of the "Data Link" section of SECS-I has been changed to "Block Transfer." The "Data Link Control" portion of the Block Transfer Protocol has been retitled "Line Control."

A1-1.14 *W-Bit* — The W-bit is now required to be set consistently in all blocks.

A1-1.15 *Documentation* — A section has been added on the documentation required for compliance with the standard.

RELATED INFORMATION

NOTICE — The material contained in this Related Information is not an official part of SEMI E4 (SECS-I) and is not intended to modify or supercede the official standard. Rather, this information describes possible methods for implementing the protocol described by the standard and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

R1-1 Miscellaneous Notes on SECS-I

R1-1.1 *Layered Protocol (see Section 1.3.1)* — The lnternational Standards Organization (ISO) has published a model for Open Systems lnterconnection (OSI). The SECS-I protocol both predates the ISO/OSI model and is not a true "open system" and, therefore, does not correspond exactly to the ISO/OSI model. The SECS-I protocol is a communications interface rather than a network protocol. However, the SECS-I levels can be roughly compared to layers 1 through part of layer 5 of the ISO/OSI model. ISO/OSI layer 1, the physical link layer, corresponds to the SECS-I physical link. ISO/OSI layer 2, the data link layer, corresponds to the SECS-I block transfer protocol. lSO/OSI layer 3, the network layer, is a function of the host and is not defined in SECS-I beyond the provision for a bi-directional flow (see Section 6.2). Similarly, network management is assumed to be the responsbility of the host. ISO/OSI layer 4, the transport layer, is covered by the SECS-I block transfer protocol, duplicate block detection, and the message protocol. ISO/OSI layer 5, the session layer, is partially covered by the SECS-I message protocol.

R1-1.2 *Single Timer for T1 and T2 (see Section 5.3)* — A single timer can be used for both the inter-character timer and the protocol timer, since both are the time between receiving successive characters and both limits are never in effect at the same time.

R1-1.3 *Stalling (see Section 5.8.2)* — The line control portion of the block transfer protocol has the ability to delay the acceptance of a data block by not responding with an EOT immediately after receiving an ENQ. Such an action by the receiver is called "Stalling." If the delay exceeds the sender's T2 value, the sender will send another ENQ. This can be continued depending upon the sender's setting of T2 and RTY. Such a delay should be an occasional convenience to accommodate random short delays in the receiver's ability to accept a new block and should not be counted upon routinely to make up for poor response. In particular, the block transfer protocol should probably have at least two buffers available for storing incoming blocks. This allows one block to be inspected by the message protocol while the next block is being received, thus allowing a reasonably continuous reception of data. If both buffers are full and the message protocol is slow in freeing the buffer for the block transfer protocol, then the block transfer protocol will start stalling the sender. If the sender is stalled long enough, it will declare a send error, which is probably the correct thing to do. The sender cannot distinguish between a reluctance to receive and failure in the communications. In either situation, since no block gets through in a predetermined time limit, the communications link is effectively broken. Arbitrarily long delays are not acceptable in SECS-I.

R1-1.4 *Determining the Cause of an NAK (see Section 5.8.5)* —The block transfer protocol does not include a way for a sender to determine the cause of an NAK. If such information is useful for application purposes, it must be collected at the receiving end.

R1-1.5 *Master Sending a Long Message (see Section 5.8)* —When the master is sending a long message, the slave may be unable to send a block, which may result in timeouts. It is good practice for the master to introduce enough delay between blocks so that the slave has a chance to send a block every few seconds.

R1-1.6 *Device Identification (see Section 6.3)* — Although the 15 bits of the device ID can identify 32,767 different devices, the host may find it more convenient to use the upper seven bits to identify the type of device such as a spinner or diffusion furnace, and to use the lower eight bits to identify the specific device of that type.

R1-1.7 *Sending Multiple Open Messages (see Section 7.2.4)* —The message protocol algorithms defined in the standard are capable of inter-leaving the blocks of any number of open multi-block messages. Since the receiving protocol is sensitive to the time between blocks of each message being received, it is proper procedure for the sending algorithm to alternate between messages when sending blocks from interleaved multi-block messages.

R1-1.8 *Single Timer for T3 and T4 (see Sections 7.3.2 and 7.4.3)* — For a given transaction, a single timer can be used for both the inter-block timer and the reply timer, since both are the time between receiving successive blocks of a message, and both limits are never in effect at the same time.

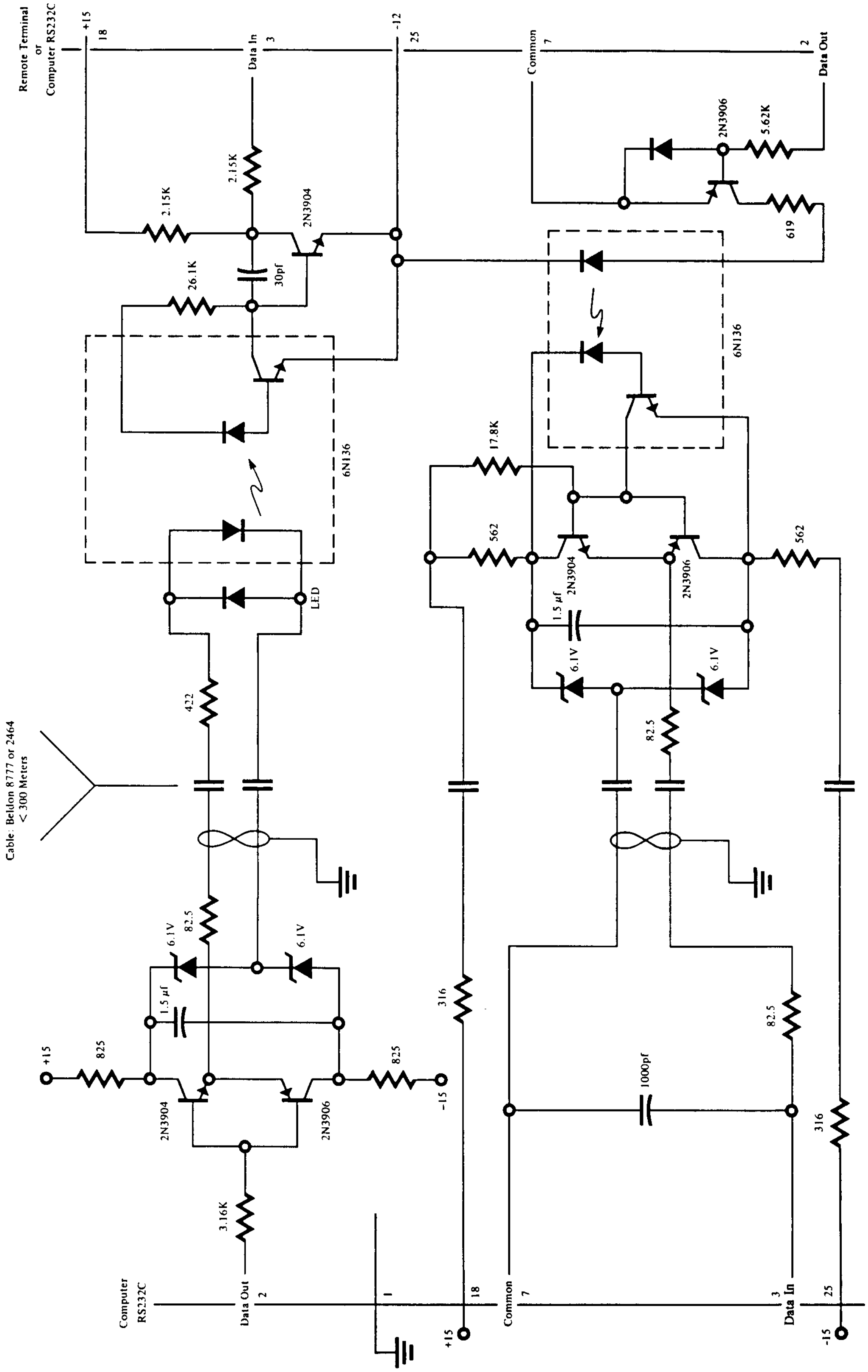


Figure R1-1

RS-232 Isolation Example

R1-2 Isolation

R1-2.1 As mentioned in Section 3.4, the standard RS-232-C line does not provide isolation between the grounds of remote equipment and a central computer. It is often desirable to provide isolation to minimize communications errors and to protect equipment. The following example is provided here to illustrate how such an isolation might be provided between two devices using RS-232-C, while at the same time providing the capability to drive longer lines. This description is provided for information only and is not part of the standard.

R1-2.2 Figure R1-1 illustrates a possible circuit for isolation which provides line isolation and line driving capability. The two wires used to provide power to the remote isolator are required since any local power supply would have the same isolation problems as the data wires. The power wires also eliminate extra supplies at every terminal or remote device. There are many other possible circuits. This example has been used successfully and works quite well at 9600 baud for lines less than 300 meters and illustrates the use of the voltages on pins 18 and 25 as mentioned in 3.2.4.

R1-3 Examples of Block Transfer Protocol

R1-3.1 Figures R1-2 and R1-3 illustrate some simple message interactions between the host and the equipment. Figure R1-2 shows the handshake sequence possible to acquire the status of the equipment. Fig-ure R1-3 shows the sequence of events when both the host and the equipment try to send at the same time.

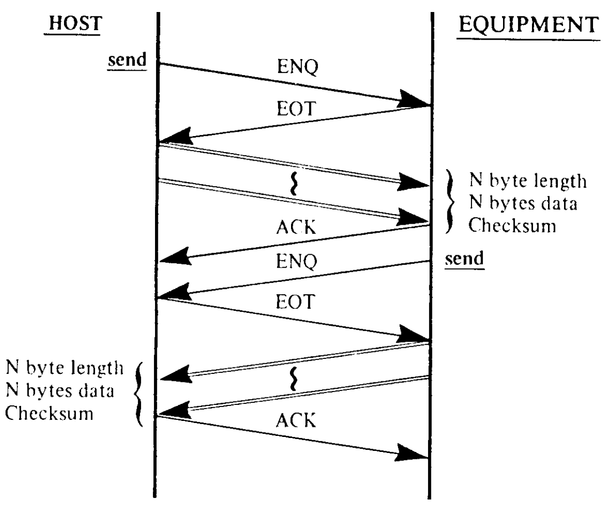


Figure R1-2

Ask for Status

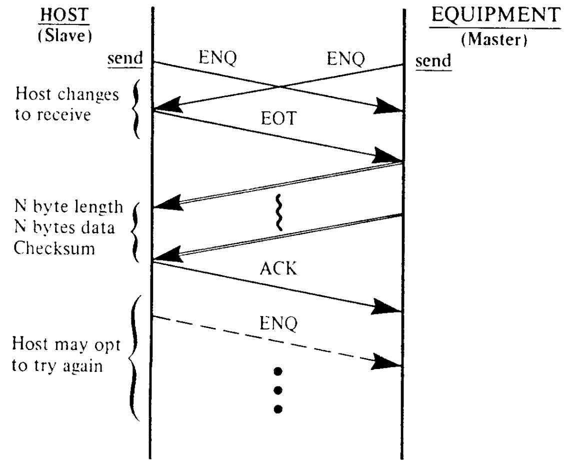


Figure R1-3

Contention Resolution

R1-4 Use of Buffers in the Block Transfer Protocol

R1-4.1 In the flow chart of the Block Transfer Protocol (Figure 2), the flow chart entry "LISTEN" implies that characters are recognized after entering the given state and not before. If the particular implementation uses buffers and stores all of the characters received before the "LISTEN" state is achieved, care must be taken in the proper handling of the data in the buffer to avoid problems due to "timing windows" between sending and receiving.

R1-4.2 If the buffer is cleared before sending the last character prior to the "LISTEN" (last checksum byte in sending a message, ENQ or EOT in line control), there is still a time, albeit small, where spurious characters could be received into the buffer.

R1-4.2.1 In addition, during the sending of the message, a delay between the checksum bytes while the buffer is cleared may cause an inter-character timeout by the receiver. If the buffer is cleared after the last character sent before the "LISTEN," there is a possibility that the desired character will be cleared from the buffer.

R1-4.3 One solution is to look at the buffer after entering the "LISTEN" state and examine the last character in the buffer, if any are there. This works while listening for an EOT after sending an ENQ. In the case where the sender is listening for an ACK after sending the second checksum byte, it is possible that the receiver also has a block to send, and follows the

ACK immediately with an ENQ. In this case the last character in the buffer might be an ENQ, and so the last two characters should be examined. If an ACK precedes the ENQ, then it should be assumed that the block was sent successfully, and the ENQ should be saved for establishing line control (i.e., send an EOT, or an ENQ if there is contention).

R1-4.4 The handling of the buffer when listening for the length byte is not improved by this suggestion. The buffer should be cleared after the ENQ is received and before the EOT is sent. Spurious characters received before the length byte will cause a send failure.

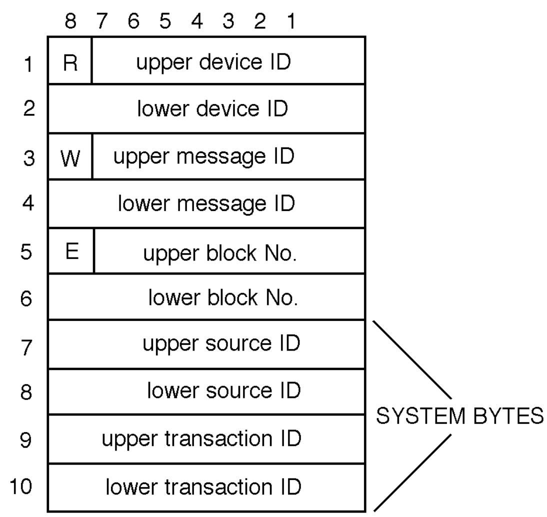


Figure R1-4

Possible Bock Header Structure

R1-5 System Bytes

R1-5.1 This section presents a sample scheme for generating and managing the system bytes field of the block header. There are many possible implementations which meet the requirements of SECS-I. This section describes one of those implementations.

R1-5.2 *Source ID and Transaction ID* — The system bytes are divided into two parts, a source ID and a transaction ID, as shown in Figure R1-4.

R1-5.3 Distinct source IDs are assigned to each application level originator of primary messages in a host or equipment. This allows a secondary message to be routed to the source of the corresponding primary message of the transaction. The transaction ID is an integer that is incremented for each primary message sent by the SECS-I interface. It is the same for all blocks of a multi-block message.

R1-5.4 *Actions* — When a SECS-II message is passed to the SECS-I protocol, the least significant bit of the lower message ID is examined to determine whether the message is primary (bit 1 = 1) or secondary (bit 1 = 0) message. If the message is primary, transaction ID is generated and placed in the transaction ID portion of the system bytes. One method for generating the transaction ID is to start with a value of 0 upon initialization, and increment by 1 for each new transaction, starting with 1 (not 0) when the largest transaction ID value has been used. At the same time, the application sender's source ID is placed in the source ID portion of the system bytes. If the message is secondary, the system bytes are the same as those of the corresponding primary message. It is assumed that the application generating the reply can identify the reply to the message protocol, which has saved the system bytes from the primary message.

R1-5.5 *Block Send Failures (see Sections 5.8.2 and 6.8.1)* — Since it is a requirement that the system bytes be distinct from those used in blocks that were not successfully sent since the last successful block send, the use of two bytes for the transaction ID would effectively satisfy the requirement by allowing for up to 65,536 consecutive block send failures.

R1-6 Using SECS in a Network

R1-6.1 The SECS standard can be used to control the flow of data within a network of computers. A network is an interconnection of computers or intelligent controllers communicating with one another over communications lines. Each intelligent entity is a node of the network. Each node may have a number of connections to other members of the network.

R1-6.2 One connection of equipment and computers is in the form of a tree network with the processing equipment at the ends of branches as shown in Figure R1-5. Intermediate Nodes A and B service like pieces of equipment; i.e., all the furnaces to Node A, all masking to Node B, and so on, for more nodes.

R1-6.3 Node A monitors the three stations 1A, 2A, and 3A. Node A handles most of the normal requirements of coordinating 1A, 2A, and 3A. Node A receives instructions from Node C regarding the behavior desired from 1A, 2A, and 3A. A CRT or operator interface connected to Node A is shared by 1A, 2A, and 3A. Any node can direct messages up or down the tree. A message such as an alarm can be sent from 1A to Node A and from Node A to Node C which might be considered the host of the network. Node A might be part of a system supplied by a company which has its own communications scheme for devices tied to Node A. As long as the company provides one connection to Node A which is consistent with this standard, then

Node A and its attached equipment can be connected to the host, Node C, and collectively be called one node.

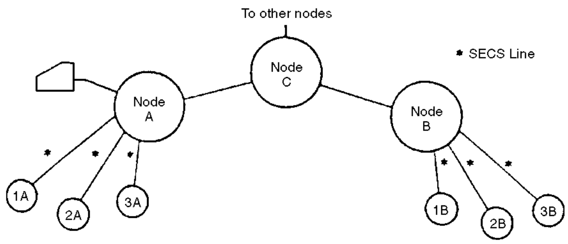


Figure R1-5

Tree Network

R1-6.4 This tree structure can be extended even further as shown in Figure R1-6 to include multiple manufacturing plants at remote sites. However, the primary intent of this standard is to address the communication between processing equipment and a host. At higher levels of the tree, the message is combined with more system level messages and more computer file manipulations. At these levels, the communications may require more complex or higher speed standards. Thus, the SECS line is intended to be used within one integrated circuit manufacturing area rather that between general purpose computer centers, although its only limitations for such a use would be speed.

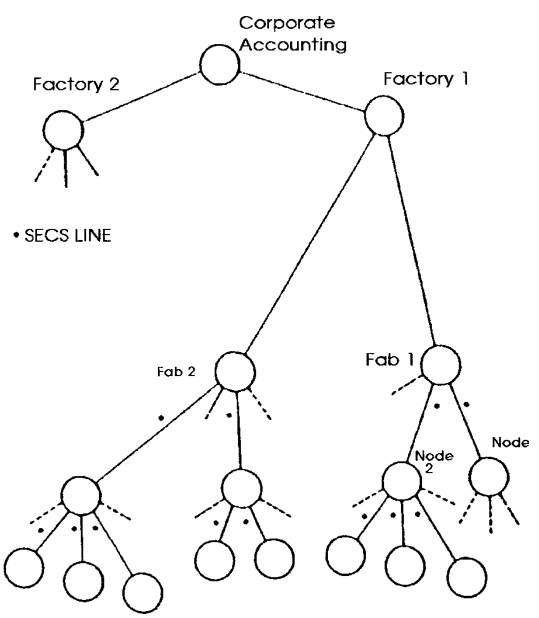


Figure R1-6

Extended Tree Network for a Large Organization

R1-6.5 The tree network is characterized by the fact that there is only one possible path between any two nodes in the network. This feature makes handling messages in the tree network relatively easy when compared to networks where more than one communication path exists between nodes. In these latter networks, the nodes must make some judgment about which path to take, perhaps based on the conditions of the lines or on the destination of the message.

R1-6.6 The device ID and the R (Reply) bit play an important role in directing messages in the network. Each node of the three maintains a table of the device below it. From the device code, it knows on which branch to send the data. When a message is going from the central node toward the device, the R-bit is set to 0. When a message is being sent from the device up the tree, the R-bit is set to 1. When a node sees the R-bit set to 1, the message must take the one communication direction that goes up the tree structure. Thus, the R-bit serves to direct messages up the tree or down the tree, depending on its value. At any given node, this behavior may be explained in Figure R1-7.

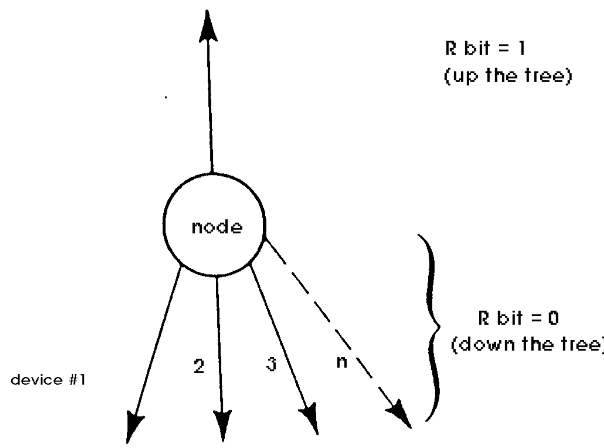


Figure R1-7

Message Handling at a Node by Using the R-Bit

R1-7 The General Node Transaction Protocol

R1-7.1 The transaction protocol has three primary functions. First, it coordinates the receiving of messages that arrive in multiple blocks. Second, it provides a mechanism for matching primary and secondary messages. Third, it does error detection on incomplete messages whether they are due to a break during multiple blocks or a lack of reply messages. The third function is vital to the maintenance of a working system, as can be seen from the following discussion. Once a transaction is begun with the first block of a primary message, the receiving machine will have some memory allocated to buffering or pointing to interpreting modules. If the transaction remains incomplete for some reasonable length of time, it may be assumed that an error has occurred and the receiving machine should release any memory it may be holding for the transaction. If memory were to remain allocated to incomplete transactions, conceivably the receiving machine could run out of available memory and would be unable to function properly. For this reason, the error detection of incomplete transactions is an essential part of the message transaction protocol in SECS-I.

R1-7.2 The message transaction protocol is based on a system of timers called transaction timers. These timers are maintained in software and are associated with a given transaction. Once a transaction is begun, there will exist a timer on the time interval between all blocks of the transaction independent of the direction of the message. The machine that expects to receive a block has the burden of timing and error detection. Timers are required in any machine that (1) makes a request and expects to receive data back; (2) must receive multiple block requests; or (3) sends data and expects an acknowledgement. A machine may require several transaction timers if it can conduct multiple transactions at one time on one port or has multiple ports. A message timer will exist for each link involved in the transaction. This allows the error detection to identify the particular link which has failed.

R1-7.3 A general algorithm can be constructed to handle an arbitrary number of SECS ports. Such an algorithm is presented in the form of a flow chart in Figure R1-8. There is one such algorithm for each device ID. The algorithm handles all SECS data blocks that enter, leave or pass the device ID. A new block causes the procedure to be executed starting from the point marked "block in" and continues until the point marked "block out." The block of data will then be directed to the proper destination.

R1-7.4 This algorithm makes use of a stored version of the message header for each transaction being handled. The stored header may be visualized as shown in Figure R1-9. The stored header has two system areas and an associated transaction timer. The two system areas are required to keep the incoming and the outgoing system areas independent in coding, yet related in meaning. The two system areas are referred to by the state of the R-bit in the message block header. One area is related to R = 0 and the other R = l. When a prime message is received that requires a reply, the system bytes from the block are stored in the system area corresponding to the opposite state of the R bit on the message. When the reply is sent, the system bytes are used from the store system bytes corresponding to the same R-bit as the reply. The system area corresponding to the same R-bit as the message is called OUTSYS while the system area corresponding to the opposite R-bit is called INSYS.

R1-7.5 When a block is presented to this algorithm, the first task is to determine if the block is part of an ongoing transaction, the first block of a new transaction, or some other unknown block. This test is accomplished by comparing the header of the block with the stored headers. If a match is not found, then a check is made to see if the block is the first of a primary message. If this is true, then a new header is added to the stored header list. If the primary message is only one block long and requires no reply, then no stored header is created. When a match is found, the algorithm modifies the stored header so that it will look like the next block of the transaction to be expected. On all blocks requiring a stored header, except the last, a transaction timer is set to a timeout value prior to sending the block to its destination. The last part of the algorithm directs the block to its destination or detects an error in the destination.

R1-7.6 Error recovery is an important part of the algorithm to ensure that the system will remain operational in spite of bad data blocks. For any block that does not pass the tests described in the algorithm, the header of the message is saved and sent in the host direction on a Stream 9 error message. This information can be useful in tracking down the source of the error. Another type of error occurs when one of the transaction timers times out. Such an error message means that the transaction has been interrupted. An error message is formed which sends the stored header in the host direction on Stream 9. The stored header and the timer are then released. This procedure aids in keeping software cleared and ready in case of difficulties in the network.

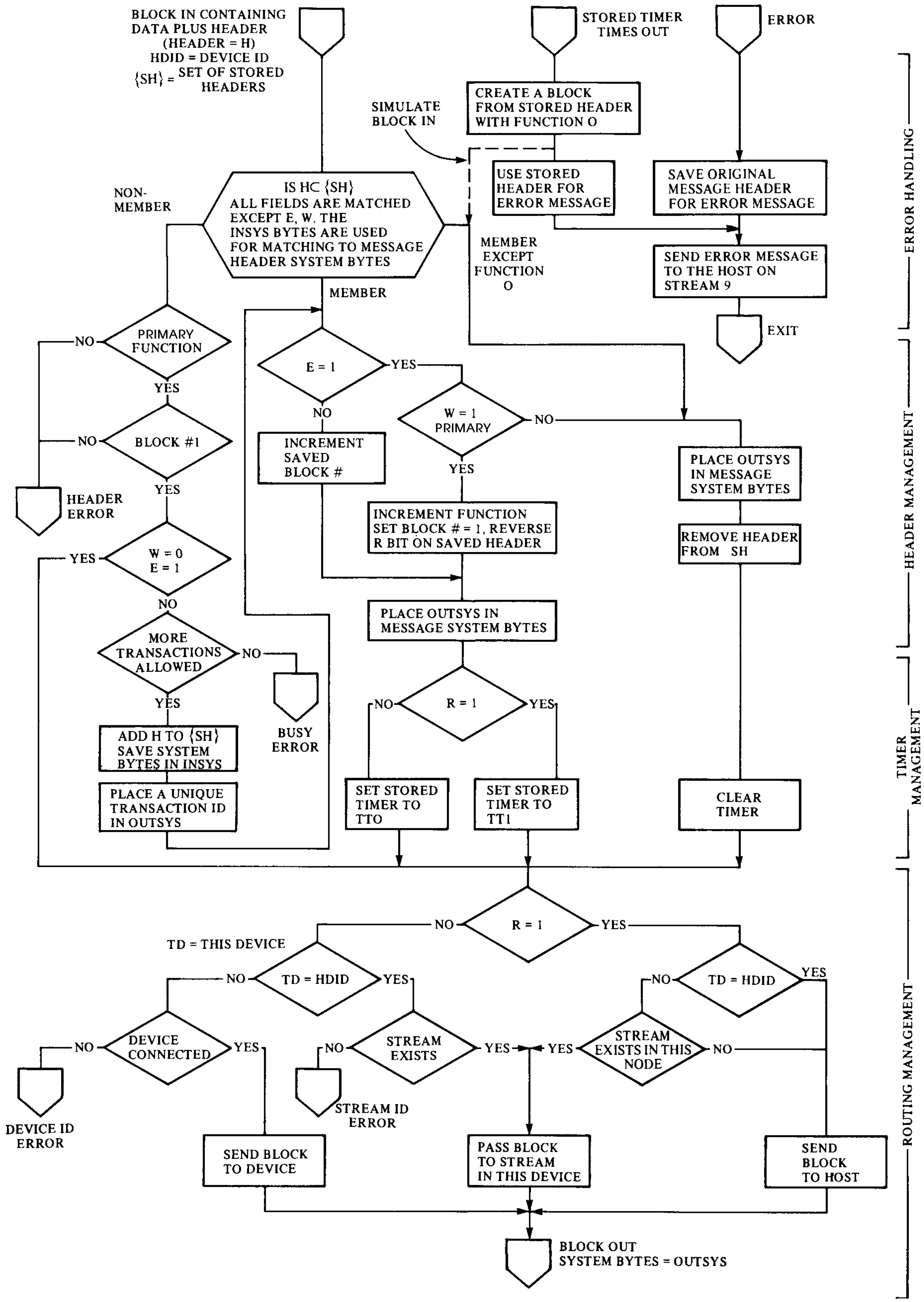


Figure R1-8

General Node Transaction Algorithm

R	Device ID
	Device ID
W	STREAM
	FUNCTION
E	Block No.
	Block No.
	S1(R=0)
	S2(R=0)
	S3(R=0)
	S4(R=0)
	S1(R=1)
	S2(R=1)
	S3(R=1)
	S4(R=1)
Transaction Timer	

Figure R1-9

Stored Header Model

SEMI E5-0702
SEMI EQUIPMENT COMMUNICATIONS STANDARD 2 MESSAGE CONTENT (SECS-II)

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current changes approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1982; previously published March 2002.

NOTICE: The user's attention is called to the possibility that some implementations of this standard, particularly those related to the use of Stream 4, may involve the use of inventions covered by U.S. patents 4,884,674 and 5,216,613, and by other patents issued or pending, held by Texas Instruments Incorporated. By publication of this standard, SEMI takes no position respecting either the applicability or the validity of these or other patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

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S2,F8 Service Program Run Acknowledge (CSA)
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S2,F10 Service Program Results Data (SRD)
S2,F11 Service Program Directory Request (SDR)
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S2,F13 Equipment Constant Request (ECR)
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S2,F21 Remote Command Send (RCS)
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S2,F30 Equipment Constant Namelist (ECN)
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S4,F3 Send Material (SMN)
S4,F4 Not Used
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S4,F6 Not Used
S4,F7 Not Ready to Send (ABN)
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S4,F10 Not Used
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S4,F28 Not Used
S4,F29 Handoff Command (HC)
S4,F30 Not Used
S4,F31 Handoff Command Complete (HCC)
S4,F32 Not Used
S4,F33 Handoff Verify (HV)
S4,F34 Not Used
S4,F35 Handoff Cancel Ready (HCR)
S4,F36 Not Used
S4,F37 Handoff Cancel Ready Acknowledge (HCA)
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S5,F15 Exception Recovery Complete Notify (EXRCN)
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S6,F1 Trace Data Send (TDS)
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S6,F4 Discrete Variable Data Acknowledge (DVA)
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S6,F6 Multi-block Grant (MBG)
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S8,F2 Boot Program Data (BPD)
S8,F3 Executive Program Request (EPR)
S8,F4 Executive Program Data (EPD)

7.13 Stream 9 System Errors
S9,F0 Abort Transaction (S9F0)
S9,F1 Unrecognized Device ID (UDN)
S9,F2 Not Used
S9,F3 Unrecognized Stream Type (USN)
S9,F4 Not Used
S9,F5 Unrecognized Function Type (UFN)
S9,F6 Not Used
S9,F7 Illegal Data (IDN)
S9,F8 Not Used
S9,F9 Transaction Timer Timeout (TTN)
S9,F10 Not Used
S9,F11 Data Too Long (DLN)
S9,F12 Not Used
S9,F13 Conversation Timeout (CTN)
S9,F14 Not Used

7.14 Stream 10 Terminal Services
S10,F0 Abort Transaction (S10F0)
S10,F1 Terminal Request (TRN)
S10,F2 Terminal Request Acknowledge (TRA)
S10,F3 Terminal Display, Single (VTN)
S10,F4 Terminal Display, Single Acknowledge (VTA)
S10,F5 Terminal Display, Multi-block (VTN)
S10,F6 Terminal Display, Multi-block Acknowledge (VMA)
S10,F7 Multi-block Not Allowed (MNN)
S10,F8 Not Used
S10,F9 Broadcast (BCN)
S10,F10 Broadcast Acknowledge (BCA)

7.15 Stream 11 Host File Services (Deleted)

7.16 Stream 12 Wafer Mapping
S12,F0 Abort Transaction (S12F0)
S12,F1 Map Set-Up Data Send (MSDS)
S12,F2 Map Set-up Data Acknowledge (MSDA)
S12,F3 Map Set-up Data Request (MSDR)
S12,F4 Map Set-up Data (MSD)
S12,F5 Map Transmit Inquire (MAPTI)
S12,F6 Map Transmit Grant (MAPTG)
S12,F7 Map Data Send Type 1 (MDS1)
S12,F8 Map Data Acknowledge Type 1 (MDA1)
S12,F9 Map Data Send Type 2 (MDS2)
S12,F10 Map Data Acknowledge Type 2 (MDA2)
S12,F11 Map Data Send Type 3 (MDS3)
S12,F12 Map Data Acknowledge 3 (MDA3)
S12,F13 Map Data Request Type 1 (MDR1)
S12,F14 Map Data Type 1 (MD1)
S12,F15 Map Data Request Type 2 (MDR2)
S12,F16 Map Data Type 2 (MD2)
S12,F17 Map Data Request Type 3 (MDR3)
S12,F18 Map Data Type 3 (MD3)
S12,F19 Map Error Report Send (MERS)
S12,F20 Not Used

7.17 Stream 13 Data Set Transfers
S13,F0 Abort Transaction (S13F0)
S13,F1 Send Data Set Send (DSSS)
S13,F2 Send Data Set Acknowledge (DSSA)

S13,F3 Open Data Set Request (DSOR)
S13,F4 Open Data Set Data (DSOD)
S13,F5 Read Data Set Request (DSRR)
S13,F6 Read Data Set Data (DSRD)
S13,F7 Close Data Set Send (DSCS)
S13,F8 Close Data Set Acknowledge (DSCA)
S13,F9 Reset Data Set Send (DSRS)
S13,F10 Reset Data Set Acknowledge (DSRA)
S13,F11 Data Set Object Multi-Block Inquire (DSOMGI)
S13,F12 Data Set Object Multi-Block Grant (DSOMBG)
S13,F13 Table Data Send (TDS)
S13,F14 Table Data Acknowledge (TDA)
S13,F15 Table Data Request (TDR)
S13,F16 Table Data (TD)

7.18 Stream 14 Object Services

S14,F0 Abort Transaction (S14F0)
S14,F1 GetAttr Request (GAR)
S14,F2 GetAttr Data (GAD)
S14,F3 SetAttr Request (SAR)
S14,F4 SetAttr Data (SAD)
S14,F5 GetType Request (GTR)
S14,F6 GetType Data (GTD)
S14,F7 GetAttrName Request (GANR)
S14,F8 GetAttrName Data (GAND)
S14,F9 Create Object Request (COR)
S14,F10 Create Object Acknowledge (CAO)
S14,F11 Delete Object Request
S14,F12 Delete Object Acknowledge (DOA)
S14,F13 Object Attach Request (OAR)
S14,F14 Object Attach Acknowledge (OAA)
S14,F15 Attached Object Action Request (AOAR)
S14,F16 Attached Object Action Acknowledge AOAA)
S14,F17 Supervised Object Action Request SOAR)
S14,F18 Supervised Object Action Acknowledge (SOAA)
S14,F19 Generic Service Request (GSR)
S14,F20 Generic Service Acknowledge (GSA)
S14,F21 Generic Service Completion Information (GSCI)
S14,F22 Generic Service Completion Acknowledge (GSCA)
S14,F23 Multi-block Generic Service Data Inquire (GSDI)
S14,F24 Multi-block Generic Service Data Grant (GSDG)
S14,F25 Get Service Name Request (GSNR)
S14,F26 Get Service Name Data (GSND)
S14,F27 Get Service Parameter Name Request (GPNR)
S14,F28 Get Service Parameter Name Data (GPND)

7.19 Stream 15 Recipe Management

S15,F0 Abort Transaction (S15F0)
S15,F1 Recipe Management Multi-block Inquire
S15,F2 Recipe Management Multi-block Grant
S15,F3 Recipe Namespace Action Request
S15,F4 Recipe Namespace Action Acknowledge
S15,F5 Recipe Namespace Rename Request
S15,F6 Recipe Namespace Rename Acknowledge
S15,F7 Recipe Space Request
S15,F8 Recipe Space Data
S15,F9 Recipe Status Request
S15,F10 Recipe Status Data
S15,F11 Recipe Version Request
S15,F12 Recipe Version Data
S15,F13 Recipe Create Request
S15,F14 Recipe Create Acknowledge
S15,F15 Recipe Store Request
S15,F16 Recipe Store Acknowledge
S15,F17 Recipe Retrieve Request
S15,F18 Recipe Retrieve Data
S15,F19 Recipe Rename Request
S15,F20 Recipe Rename Acknowledge
S15,F21 Recipe Action Request
S15,F22 Recipe Action Acknowledge
S15,F23 Recipe Descriptor Request
S15,F24 Recipe Descriptor Data
S15,F25 Recipe Parameter Update Request
S15,F26 Recipe Parameter Update Acknowledge
S15,F27 Recipe Download Request
S15,F28 Recipe Download Acknowledge
S15,F29 Recipe Verify Request
S15,F30 Recipe Verify Acknowledge
S15,F31 Recipe Unload Request
S15,F32 Recipe Unload Data
S15,F33 Recipe Select Request
S15,F34 Recipe Select Acknowledge
S15,F35 Recipe Delete Request
S15,F36 Recipe Delete Acknowledge
S15,F37 DRNS Segment Approve Action Request
S15,F38 DRNS Segment Approve Action Acknowledge
S15,F39 DRNS Recorder Segment Request
S15,F40 DRNS Recorder Segment Acknowledge
S15,F41 DRNS Recorder Modify Request
S15,F42 DRNS Recorder Modify Acknowledge
S15,F43 DRNS Get Change Request

SEMI E5-0702
SEMI EQUIPMENT COMMUNICATIONS STANDARD 2 MESSAGE CONTENT (SECS-II)

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current changes approved by the North American Regional Standards Committee on. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1982; previously published March 2002.

NOTICE: The user's attention is called to the possibility that some implementations of this standard, particularly those related to the use of Stream 4, may involve the use of inventions covered by U.S. patents 4,884,674 and 5,216,613, and by other patents issued or pending, held by Texas Instruments Incorporated. By publication of this standard, SEMI takes no position respecting either the applicability or the validity of these or other patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1 Introduction

1.1 *Intent* — The SEMI Equipment Communications Standard Part 2 (SECS-II) defines the details of the interpretation of messages exchanged between intelligent equipment and a host. This specification has been developed in cooperation with the Japan Electronic Industry Development Association Committee 12 on Equipment Communications.

1.1.1 It is the intent of this standard to be fully compatible with SEMI Equipment Communications Standard E4 (SECS-I). It is also the intent to allow for compatibility with alternative message transfer protocols. The details of the message transfer protocol requirements are contained in Section 3.

1.1.2 It is the intent of this standard to define messages to such a level of detail that some consistent host software may be constructed with only minimal knowledge of individual equipment. The equipment, in turn, may be constructed with only minimal knowledge of the host.

1.1.3 The messages defined in the standard support the most typical activities required for IC manufacturing. The standard also provides for the definition of equipment-specific messages to support those activities not covered by the standard messages. While certain activities can be handled by common software in the host, it is expected that equipment-specific host software may be required to support the full capabilities of the equipment.

1.2 *Overview* — SECS-II gives form and meaning to messages exchanged between equipment and host using a message transfer protocol, such as SECS-I.

1.2.1 SECS-II defines the method of conveying information between equipment and host in the form of messages. These messages are organized into categories of activities, called streams, which contain specific messages, called functions. A request for information and the corresponding data transmission is an example of such an activity.

1.2.2 SECS-II defines the structure of messages into entities called items and lists of items. This structure allows for a self-describing data format to guarantee proper interpretation of the message.

1.2.3 The interchange of messages is governed by a set of rules for handling messages called the transaction protocol. The transaction protocol places some minimum requirements on any SECS-II implementation.

1.3 *Application* — SECS-II applies to equipment and hosts used in the manufacturing of semiconductor devices. Examples of the activities supported by the standard are: transfer of control programs, material movement information, measurement data, summarized test data, and alarms.

1.3.1 The minimum compliance to this standard involves meeting the few constraints outlined in Section 5. It is expected that a given piece of equipment will require only a subset of the functions described in this standard. The number of functions and the selection of functions will depend upon the equipment capabilities and requirements. For each piece of equipment, the exact format for each function provided must be documented according to the form outlined in Section 7.

1.3.2 It is assumed that the equipment will define the messages used in a particular implementation of SECS-II. It is assumed the host will support equipment implementation.

1.4 *Applicable Documents*

1.4.1 *ANSI*[1]

X3.4-1977 — Code for Information Interchange (ASCII)

1.4.2 *IEEE*[2]

754 — Standard for Binary Floating Point Arithmetic

1.4.3 *SEMI Standards*[3]

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E6 — Facilities Interface Specifications Guideline and Format

1.4.4 The Japan Electronic Industry Development Association (JEIDA) has requested that the SECS-II standard incorporate support for the JIS-8 codes for data exchange. This code would allow support for katakana characters in Japanese implementations of SECS-II.

JIS 8-bit Coded Character Set (JIS-6226) for information Interchange, Japanese Industrial Standards.

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Selected Definitions

2.1 The following brief definitions refer to sections providing further information.

2.1.1 *block* — a physical division of a message used by the message transfer protocol (see Section 3.3).

2.1.2 *conversation* — a sequence of related messages (see Section 5.4).

2.1.3 *conversation timeout* — an indication that a conversation has not completed properly (see Section 5.4.1).

2.1.4 *device ID* — a number between 0 and 32767 used in identifying the particular piece of equipment communicating with a host (see Section 3.4.1).

2.1.5 *equipment* — the intelligent system which communicates with a host.

2.1.6 *function* — a specific message for a specific activity within a stream (see Section 4.2).

2.1.7 *host* — the intelligent system which communicates with the equipment.

2.1.8 *interpreter* — the system that interprets a primary message and generates a reply when requested (see Section 3.2).

2.1.9 *item* — a data element within a message (see Section 6.2).

2.1.10 *item format* — a code used to identify the data type of an item (see Section 6.2).

2.1.11 *list* — a group of items (see Section 6.3).

2.1.12 *message* — a complete unit of communication (see Section 3.2).

2.1.13 *message header* — information about the message passed by the message transfer protocol (see Section 3.4).

2.1.14 *multi-block message* — a message sent in more than one block by the message transfer protocol (see Section 3.3.2).

2.1.15 *originator* — the creator of a primary message (see Section 3.2).

2.1.16 *packet* — a physical division of a message used by the message transfer protocol (see Section 3.3).

2.1.17 *primary message* — an odd numbered message. Also, the first message of a transaction (see Sections 3.2 and 4.2).

2.1.18 *reply* — the particular secondary message corresponding to a primary message (see Sections 3.2 and 4.2).

2.1.19 *secondary message* — an even-numbered message. Also the second message of a transaction (see Sections 3.2 and 4.2).

2.1.20 *single-block message* — a message sent in one block by the message transfer protocol (see Section 3.3.1).

2.1.21 *stream* — a category of messages (see Section 4.1).

2.1.22 *transaction* — a primary message and its associated secondary message, if any (see Section 5.2).

2.1.23 *transaction timeout* — an indication from the message transfer protocol that a transaction has not completed properly (see Section 3.5).

3 The Message Transfer Protocol

3.1 *Intent* — SECS-II is fully compatible with the message transfer protocol defined by SECS-I. It is the

1 ANSI, 1430 Broadway, New York, NY 10018

2 IEEE Service Center, 445 Hoe Lane, Piscataway, NJ 08854

3 SEMI, 805 E. Middlefield Road, Mountain View, CA 94043

intent of this standard to allow for compatibility with alternative message transfer protocols. The purpose of this section is to define the requirements of the interaction between an application using SECS-II and the message transfer protocol. The methods used to implement these requirements are not covered as a part of this standard. The terms used in this standard are those used by SECS-I. Equivalent terms may be different for other message transfer protocols.

3.2 *Messages* — The message transfer protocol is used to send messages between equipment and host. The message transfer protocol must be capable of sending a primary message, indicating whether a reply is requested; and, if a reply is requested, it must be capable of associating the corresponding secondary message or reply message with the original primary message. The term originator will refer to the creator of the original primary message. The term interpreter will refer to the entity that interprets the primary message at its destination and generates a reply when requested.

3.3 *Blocking Requirements* — The message transfer protocol must support the following SECS-II message blocking requirements.

3.3.1 *Single-Block Messages* — SECS-II requires that certain messages be sent in a single block or single packet by the message transfer protocol. Those messages defined in this standard as single-block SECS-II messages must be sent in a single-block or packet. The method used by the application software to tell the message transfer protocol that a particular message must be sent as a single block is not covered as part of this standard. For compatibility with SECS-I, the maximum length allowed for a single-block SECS-II message is 244 bytes. The minimum requirement for the message transfer protocol is to be able to send single-block SECS-II messages.

3.3.2 *Multi-Block Messages* — For compatibility with SECS-I, SECS-II messages that are longer than 244 bytes are referred to as multi-block messages. Also, certain SECS-II messages are allowed to be multi-block messages even if they otherwise meet the single-block length requirements. Certain older implementations may impose application-specific requirements on block sizes for certain incoming messages. Beginning with the 1988 revision of the standard, new applications may not impose application-specific requirements on incoming block sizes. Applications implemented before 1988 may impose such requirements.

3.4 *Message Header* — The message transfer protocol must provide the following information, called the message header, with every message. Only the content of the message header is defined by this standard. The exact format of the message header passed between the application and the message transfer protocol is not covered as part of this standard.

NOTE 2: In SECS-I, this information is contained in the 10-byte header of each block of a message.

3.4.1 *Device ID* — The message transfer protocol must be capable of identifying the device ID (0-32767) which indicates the source or destination of a message.

3.4.2 *Stream and Function* — The message transfer protocol must be capable of identifying to SECS-II a minimum15-bit message identification code. In SECS-II, messages are identified by a stream code (0-127, 7 bits) and a function code (0-255, 8 bits). Each combination of stream and function represents a distinct message identification.

3.4.3 *Reply Requested* — The message transfer protocol must be capable of identifying whether a reply is requested to a primary message.

3.5 *Transaction Timeout* — It is presumed that the message transfer protocol will notify SECS-II in the event of failure to receive an expected reply message within a specified transaction timeout period.

NOTE 3: In SECS-I, a transaction timeout occurs if either the reply timeout (T3) is exceeded before the first block of a reply message is received or if the inter-block timeout (T4) is exceeded before an expected block of a multi-block message is received.

3.6 *Multiple Open Transactions* — This standard allows, but does not require, the support of more than one concurrent open transaction.

4 Streams and Functions

4.1 *Streams* — A stream is a category of messages intended to support similar or related activities.

4.2 *Functions* — A function is a specific message for a specific activity within a stream. All the functions used in SECS-II will follow a numbering convention corresponding to primary and secondary message pairs. All primary messages will be given an odd- numbered function code. The reply message function code is determined by adding one to the primary message function code. The even-numbered function following a primary message which requests no reply is reserved and is not to be used. Function code 0 is reserved in all streams for aborting transactions as described in Section 7.4.

4.3 *Stream and Function Allocation* — Some of the stream and function code combinations are reserved for this standard, while others are available for user definition. The stream and function codes reserved for this standard are as follows:

In Stream 0, Functions 0-255.

In Streams 1-63, Functions 0-63.

In Streams 64-127, Function 0.

The stream and function codes available for user definition are as follows:

In Streams 1-63, Functions 64-255.

In Streams 64-127, Functions 1-255.

4.3.1 The stream and function code assignment can also be represented by the diagram shown in Figure 1.

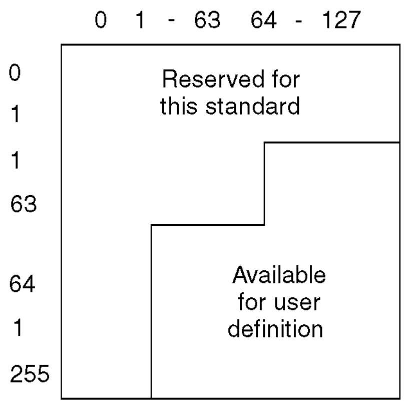


Figure 1
Stream and Function Allocation

4.3.2 The reserved codes assigned by this standard are listed in Section 7. It is recognized that there will be user needs beyond the specific definitions given in this standard. In these situations, the streams and functions reserved for user definition should be used subject to the guidelines for minimum compliance outlined in Section 5.

5 Transaction and Conversation Protocols

5.1 *Intent* — For an implementation to be in compliance with SECS-II, it must meet the minimum transaction requirements outlined in this section. The conversation protocols serve to further define the use and interaction between transactions.

5.2 *Transaction Definition* — A transaction forms the basis for all information exchanges in SECS-II. A transaction consists of either a primary message for which no reply is requested, or a primary message which requests a reply together with its corresponding secondary message. Secondary messages cannot request a reply.

5.3 *Transaction Level Requirements* — The following are the requirements to comply with the SECS-II protocol at the transaction level:

1. Respond to S1F1 with S1F2 as described in Section 7.5.
2. For any received message that cannot be processed by the equipment, send the appropriate error message on Stream 9. As described in Section 7.13, S9-F1, F3, F5, F7, or F11 are possible.
3. Format any other supported messages according to Section 7.
4. Upon detection of a transaction timeout at the equipment, send S9F9 to the host.
5. Upon receipt of function 0 as a reply to a primary message, terminate the related transaction. No error message should be sent to the host by the equipment.

5.4 *Conversation Protocols* — A conversation is a series of one or more related transactions used to complete a specific task. A conversation should include all transactions necessary to accomplish the task and leave both the originator and interpreter free of resource commitments at its conclusion.

5.4.1 *Conversation Timeout* — A conversation timeout is used to indicate that a conversation has not completed properly. A conversation timeout is application-dependent, and the methods used for detecting conversation timeouts are not covered as part of this standard. A conversation timeout will terminate further action on the conversation, and will allow for the clearing of any committed resources. Upon detection of a conversation timeout at the equipment, S9F13 should be sent to the host.

5.4.2 *Types of Conversations* — There are seven types of conversations which characterize all information exchanges in SECS-II:

1. A primary message with no reply is the simplest conversation. This message must be a single-block SECS-II message. The originator must assume that the interpreter responds to the message. This conversation is used where the originator can do nothing if the message is rejected.
2. If the interpreter has data that the originator wants, the data are requested with a primary message and the data returned to the originator as a reply message. It is assumed that the originator requesting the data is prepared to receive the amount of data returned. This is the request/data conversation.
3. If the originator wishes to send data in a single-block SECS-II message to the interpreter, then the originator sends the data and expects an acknowledgment from the interpreter. This is the send/acknowledge conversation.

4. If the originator has a multi-block SECS-II message to send for a particular exchange, then the originator must receive permission from the interpreter prior to sending the data. The first transaction requests permission to send, and the interpreter either grants or denies permission. If permission is granted, the originator sends the data and the interpreter replies appropriately. This is the inquire/grant/send/acknowledge conversation. Between the inquire and the send, the interpreter may commit some resources in preparation for the data. Consequently, a conversation timeout may be set by the interpreter at a time dependent upon the application, at which time the interpreter will free its resources and send an S9,F13 error message to the originator. Note that under the definition of S9,F13 in this standard, only the equipment should generate an error message to the host under these conditions.
5. There is a conversation related to the transfer of unformatted data sets between equipment and host. This conversation is described in detail in Stream 13. (See Section 7.17)
6. There is a conversation related to the handling of material between equipment. This conversation is described in detail in Stream 4. (See Section 7.8)
7. The originator may request information from the interpreter which requires some time to obtain (e.g., operator input is required). The first transaction requests the information and the interpreter responds in one of three ways: 1) the information is returned, 2) the interpreter indicates that the information cannot or will not be obtained, or 3) the interpreter indicates that the information will be obtained and returned in a subsequent transaction, as specified for this conversation. For case number 3, the interpreter will initiate the subsequent transaction when the information is available.

Case 3 is the request/acknowledge/send/acknowledge transaction.

The originator of the request/acknowledge/send/acknowledge conversation may commit some resources in anticipation of the send/acknowledge transaction. Consequently, a conversation timeout may be set by the originator at a time dependent on the application. On timeout, the originator will free its resources and restart the conversation with the ‘request' , or send an S9,F13 error message. Note that under the definition of S9,F13 in this standard, only the equipment should generate an error message to the host under these conditions.

5.4.3 The key words, request, data, send, acknowledge, inquire, and grant are used in the function names as an aid to understanding the relationship between the messages and the conversation. Single message transactions do not use these words.

6 Data Structures

6.1 *Intent* — All information transmitted according to this standard will be formatted using two data structures, items and lists. These data structures define the logical divisions of the message, as distinct from the physical divisions of the message transfer protocol. They are intended to provide a self-describing internal structure to messages passed between equipment and host.

6.2 *Item* — An item is an information packet which has a length and format defined by the first 2, 3, or 4 bytes of the item. These first bytes are called the item header (IH). The item header consists of the format byte and the length byte(s) as shown in Figure 2. Bits one and two of the item header tell how many of the following bytes refer to the length of the item. This feature allows for long items without requiring the byte overhead for shorter items. The item length refers to the number of bytes following the item header, called the item body (IB), which is the actual data of the item. The item length refers only to the item body not including the item header, so the actual number of bytes in the message for one item is the item length plus 2, 3, or 4 bytes for the item header. All bytes in the item body are in the format specified in the format byte.

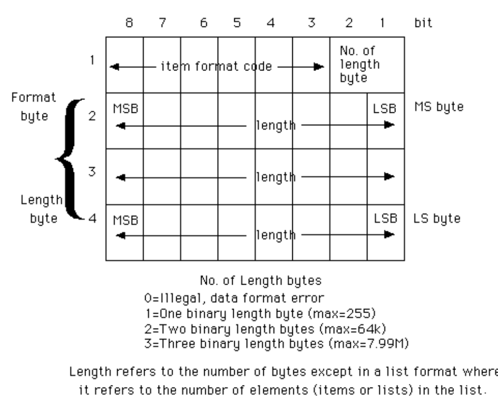


Figure 2
Item and List Header

6.2.1 A zero-length in the format byte is illegal and produces an error. A zero-length in the item length bytes has a special meaning as defined in the detailed message definitions.

6.2.2 Bits 3 through 8 of the format byte of the item header define the format of the data which follows. Of the 64 possible formats, 15 are defined as shown in Table 1. Format code 0 is called a list and is defined in

E5 6.3. Format code 22 (octal) is called a localized string and is defined in SEMI E5 Section 6.4. The remaining 14 item formats define unspecified binary, code 10 (octal); Boolean, code 11 (octal); ASCII character strings, code 20 (octal); JIS-8 character strings, code 21 (octal) signed integer, codes 30, 31, 32, 34 (octal); floating point, codes 40, 44 (octal); and unsigned integer, codes 50, 51, 52, 54 (octal). These formats are used for groups of data which have the same representation in order to save repeated item headers. Signed integers will be two' s complement values. Floating point numbers will conform to the IEEE standard 754. Boolean values will be byte quantities, with zero being equivalent to false, and non-zero being equivalent to true.

6.3 *List* — A list is an ordered set of elements, where an element can be either an item (6.2) or a list. The list header (LH) has the same form as an item header with format type 0. However, the length bytes refer to the number of elements in the list rather than to the number of bytes. The list structure allows grouping items of related information which may have different formats into a useful structure.

6.3.1 A zero-length in the format byte is illegal and produces an error. A zero-length in the list length bytes has a special meaning, which is defined in the detailed message definitions.

Format Code		*Meaning*
Binary		*The data after the heading*
Bit 876543	*Octal*	*has the following form*
000000	00	LIST (length in elements)
001000	10	Binary
001001	11	Boolean
010000	20	ASCII[1]
010001	21	JIS-8
010010	22	2-byte character[2, 4]
011000	30	8-byte integer (signed)[2]
011001	31	1-byte integer (signed)
011010	32	2-byte integer (signed)[2]
011100	34	4-byte integer (signed)[2]
100000	40	8-byte floating point[3]
100100	44	4-byte floating point[3]
101000	50	8-byte integer (unsigned)[2]
101001	51	1-byte integer (unsigned)
101010	52	2-byte integer (unsigned)[2]
101100	54	4-byte integer (unsigned)[2]

[1]Non-printing characters are equipment-specific.

[2]Most significant byte sent first.

[3]IEEE 754. The byte containing the sign bit is sent first.

[4]The code for Multi-byte character must be specified in the data in the first 2 bytes of the TEXT item.

NOTE: Changes in integer format codes may conflict with earlier implementations.

6.4 *Localized Character String Items* — A localized character string is an item which is used for representing a string of multi-byte character. Because there are many different encoding schemes and the information could be in any one of a number of languages, these characteristics must also be included in the item. Thus for localized character strings which use item format code 22 (octal), there is an additional localized string header (LSH) .

This localized string header follows the item header and precedes the string. The localized string header is part of the item data, thus the length of the header (2 bytes) is included in the length in the item header. The length of the localized string itself is the number of bytes that it occupies, regardless of the number of characters that represents the string. The localized string header followed by the string together comprise the localized string item. For example, a 2 byte localized string (which may represent a single character), because of the 2 byte length of the localized string header, will have a 4 byte length in the item header.

The LSH is a 16 bit number which specifies the encoding method used for the string. Defined values for the encoding are as follows:

Encoding Code (Decimal)	*Encoding Scheme*	*Notes*
0	none	reserved
1	ISO 10646 UCS-2	Unicode 2.0
2	UTF-8	Transformation of ISO 10646 UCS-2
3	ISO 646-1991	ASCII, 7-bit
4	ISO 8859-1	ISO Latin-1, Western Europe
5	ISO 8859-11 (proposed)	Thai
6	TIS 620	Thai (will be supported by ISO 8859-11)
7	IS 13194 (1991)	ISCII
8	Shift JIS	
9	Japanese EUC-JP	
10	Korean EUC-KR	
11	Simplified Chinese GB	
12	Simplified Chinese EUC-CN	
13	Traditional Chinese Big5	
14	Traditional Chinese EUC-TW	

Encoding Codes from 15 to 32767 are reserved for future expansion. Encoding codes from 32768 to 65535 are available for custom purposes.

6.5 *Example Data Structures* — The data structures for different types of items are illustrated in the following examples:

a. An item contains one binary code 10101010.

```
bit
87654321

00100001    Item, binary, 1 length byte
00000001    1 byte long
10101010    data byte
```

b. An item contains three ASCII characters ABC.

```
01000001    Item ASCII, 1 length byte
00000011    Three bytes long
01000001    ASCII A
01000010    ASCII B
01000011    ASCII C
```

c. An item contains three binary numbers in 2-byte signed integer form.

```
01101001 Item, 2-byte integers
00000110 6 bytes total (6/2=3 integers)
   xxxxxxxx    MSByte number x
   xxxxxxxx    LSByte number x
   yyyyyyyy    MSByte number y
   yyyyyyyy    LSByte number y
   zzzzzzzz    MSByte number z
   zzzzzzzz    LSByte number z
```

d. An item contains one 4-byte IEEE floating point number.

```
10010001    Item, 4-byte floating point
00000100    4 bytes (4/4=1 number)
ffffffff
ffffffff    Floating point number
ffffffff    in IEEE 754
ffffffff
```

e. A message is sent from device 66 telling the host that the temperature at point T1 has exceeded a preset process limit. The message ID is stream 5, function 1, and the data consists of a list of three items. The first item is a code for the alarm set and the alarm category code. The second item is the equipment-specific alarm number for this alarm (e.g., 17). The third item is a string of text giving a brief description of the alarm (e.g., " T1 HIGH.") No reply is requested. The complete message including the header is as follows:

```
10000000    R=1 (to the host)
01000010    Device Code=66
00000101    Stream 5, W=0
00000001    Function 1
10000000    E=1
00000001    Block 1
00000000
00000000    System bytes=0
00000000
00000000
00000001    List
00000011    3 Elements
00100001    Binary Item next byte length
00000001    1 byte long
00000100    Alarm set, category 4
01100101    Item, 1-byte integer, next byte length
00000001    1 byte long
00010001    Alarm 17
01000001    Item, ASCII, next byte length
00000111    7 characters
01010100    ASCII T
00110001    ASCII 1
00100000    ASCII space
01001000    ASCII H
01001001    ASCII I
01000111    ASCII G
01001000    ASCII H
```

The entire message contains 17 bytes of data, 1-byte length (not shown), 10 bytes of header, and 2 bytes checksum (not shown) for a total of 30 bytes. At 9600 baud transmission, the message would be sent in 31 milliseconds.

6.6 *Data Item Dictionary* — This section defines the data items used in the standard SECS-II messages described in Section 7, Message Detail.

Name: A unique mnemonic name for this data item. This name is used in message definitions.

Format: The allowable item format codes which can be used for this standard data item. Item format codes are shown in octal, as described in Table 1, Item Format Codes. The notation " 3()" indicates any of the signed integer formats (30, 31, 32, 34). The notation " 4()" indicates any of the floating point formats (40, 44). The notation " 5()" indicates any of the unsigned integer formats (50, 51, 52, 54). The notation " 0" indicates that a list with user-defined structure may be used. Where more than one format is shown, a given implementation can use any of the formats specified.

Description: A description of the data item, with the meanings of specific values.

Where Used: The standard messages in which this data item appears.

ABS Format: 10

Any binary string

Where Used: S2F25, F26

ACCESSMODE Format: 51

Load Port Access Mode. Possible values are:

```
0 = Manual
1 = Auto
```

Where Used: S3F27

ACDS Format: 32, 52

After Command Codes

```
Vector of all command codes which defined command must succeed within the
same block.
```

Where Used: S7F22

ACKA Format: 11

Indicates success of a request:

```
TRUE is successful else FALSE
```

Where Used: S5F14, F15, F18; S16F2, F4, F6, F12, F14, F16, F18, F24, F26, F28, F30; S17F4, F8, F14

ACKC3 Format: 10

Acknowledge code, 1 byte

```
0   =   Accepted
>0  =   Error, not accepted
1-63 Reserved
```

Where Used; S3F6, F8, F10

ACKC5 Format: 10

Acknowledge code, 1 byte

```
0   =   Accepted
>0  =   Error, not accepted
1-63 Reserved
```

Where Used; S5F2, F4

ACKC6 Format: 10

Acknowledge code, 1 byte

```
0   =   Accepted
>0  =   Error, not accepted
1-63 Reserved
```

Where Used; S6F2, F4, F10, F12, F14

ACKC7 Format: 10

Acknowledge code, 1 byte

```
0   =   Accepted
1   =   Permission not granted
2   =   Length error
3   =   Matrix overflow
4   =   PPID not found
5   =   Mode unsupported
>5  =   Other error
6-63 Reserved
```

Where Used: S7F4, F12, F14, F16, F18, F24, F32

ACKC7A Format: 31, 51

Acknowledge Code, 1 byte

```
0   =   Accepted
1   =   MDLN is inconsistent
2   =   SOFTREV is inconsistent
3   =   Invalid CCODE
4   =   Invalid PPARM value
5   =   Other error (described by ERRW7)
6-63 Reserved
```

Where Used: S7F27

ACKC10 Format: 10

Acknowledge Code, 1 byte

```
0   =   Accepted for display
1   =   Message will not be displayed
2   =   Terminal not available
3-63 Reserved
```

Where Used: S10F2, F4, F6, F10

ACKC13 Format: 10

Return code for secondary messages 1 byte.

```
0   =   O.K.
1   =   ERROR: Try Later
2   =   ERROR: Unknown Data Set name
3   =   ERROR: Illegal Checkpoint value
4   =   ERROR: Too many open Data Sets
5   =   ERROR: Data set open too many times
6   =   ERROR: No open Data Set
7   =   ERROR: Cannot continue
8   =   ERROR: End of Data
9   =   ERROR: Handle in Use
>10 =   ERROR: Pending Transaction
11-127 Reserved
```

Where Used: S13F2, F4, F6, F8

AGENT Format: 20

Where Used: S15F11, 12, 21, 22, 25

ALCD Format: 10

Alarm code byte

```
bit 8 = 1 means alarm set
bit 8 = 0 means alarm cleared
bit 7-1 is alarm category
0   =   Not used
1   =   Personal safety
2   =   Equipment safety
3   =   Parameter control warning
4   =   Parameter control error
5   =   Irrecoverable error
6   =   Equipment status warning
7   =   Attention flags
8   =   Data integrity
>8  =   Other categories
9-63 Reserved
```

Where Used: S5F1, F6

ALED Format: 10

Alarm enable/disable code, 1 byte

```
bit 8 = 1 means enable alarm
bit 8 = 0 means disable alarm
```

Where Used: S5F3

ALID Format: 3(), 5()

Alarm identification

Where Used: S5F1, F3, F5, F6

ALTX Format: 20

Alarm text limited to 40 characters

Where Used: S5F1, F6

ATTRDATA Format: 0, 10, 20, 3(), 4(), 5(), 11

Contains a specific attribute value for a specific object.

Where Used: S1F20; S3F17, F18; S13F14, F16; S14F1, F2, F3, F4, F9, F10, F11, F12, F13, F14, F15, F16, F17, F18; S18F2, F3

ATTRID Format: 20, 5()

Identifier for an attribute for a specific type of object.

Where Used: S1F19; S3F17, F18; S13F14, F16; S14F1, F2, F3, F4, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, F18; S18F1, F3

ATTRRELN Format: 51

The relationship that a specified qualifying value has to the value of an attribute of an object instance (the value of interest):

```
0  =  The qualifying value is equal to the value of interest,
1  =  The qualifying value is not equal to the value of interest,
2  =  The qualifying value is less than the value of interest,
3  =  The qualifying value is less than or equal to the value of interest,
4  =  The qualifying value is greater than the value of interest,
5  =  The qualifying value is greater than or equal to the value of
      interest,
6  =  The qualifying value is present (contained in the set of) the value
      of interest,
7  =  The qualifying value is absent (not contained in the set of) the
      value of interest,
>7 =  Reserved.
```

Where Used: S14F1

BCDS Format: 32, 52

Before Command Codes

Vector of all command codes which defined command must precede within the same block.

Where Used: S7F22

BCEQU Format: 20, 51

Bin code equivalents

Array of all codes that are to be processed. Must be the same format as BINLT and NULBC. Zero length indicates all codes be sent.

Where Used: S12F3, F4

BINLT Format: 20, 51

The Bin List

Is an array of bin values. Format must be the same as used in NULBC and BCEQU.

Where Used: S12F7, F9, F11, F14, F16, F18

BLKDEF Format: 31, 51

Block Definition

```
Blocks define the range for before/after code checking (specified by BCDS,
IBCDS, NBCDS, ACDS, IACDS, and NACDS). BLKDEF specifies whether the command
being defined starts a block (+1), terminates a block (-1), or is within the
body of a block (0). All other values are invalid. The outermost block of
a process program is implicit, and is bounded by the first and last command
of the process program. Before/after checks for a particular command are per-
formed with all other commands in the same block and at the same nesting
level. For the purpose of before/after checking, a set of commands making up
a block is considered to be a single body command of its containing block.
This command has the before/after restrictions of the start block command
which begins the block.
```

Where Used: S7F22

BPD Format: 10

Boot program Data

Where Used: S8F2

BYTMAX Format: 3(), 5()

Byte Maximum

```
Maximum length of process program. A value of zero indicates no limit.
Negative values are invalid.
```

Where Used: S7F22

CAACK Format: 51

Carrier Action Acknowledge Code. One byte.

```
0    =   Acknowledge, command has been performed.
1    =   Invalid command
2    =   Can not perform now
3    =   Invalid data or argument
4    =   Acknowledge, request will be performed with completion signaled later
         by an event.
5    =   Rejected.  Invalid state.
6    =   Command performed with errors.
7-63     reserved.
```

Where Used: S3F18, F20, F22, F24, F26, F30, F32

CARRIERACTION Format: 20

Specifies the action requested for a carrier.

Where Used: S3F17

CARRIERID Format: 20

The identifier of a carrier.

Where Used: S3F17

CARRIERSPEC Format: 20

The object specifier for a carrier. Conforms to OBJSPEC.

Where Used: F29, F31

CATTRDATA Format: 0, 10, 20, 3(), 4(), 5(), 11

The value of a carrier attribute.

Where Used: S3F17

CATTRID Format: 20

The name of a carrier attribute.

Where Used: S3F17

CCODE Format: 32, 52

Command Code

```
Each command code corresponds to a unique process operation the machine
is capable of performing.
```

Where Used: S7F22, F23, F26, F31

CEED Format: 11

Collection event or trace enable/disable code, 1 byte

```
FALSE = Disable
TRUE = Enable
```

Where Used: S2F37; S17F5

CEID Format: 20, 3(), 5()

Collected event ID

Where Used: S2F35, F37; S6F3, F8, F9, F11, F13, F15, F17; S17F5, F9, F10, F11, F12

CEPACK Format: 0, 51

Command Enhanced Parameter Acknowledge. If a specific value of CPNAME is defined to have a CEPVAL that is a LIST, then CEPACK shall have the same structure as the corresponding list format of CEPVAL as used in S2,F49. Otherwise CEPACK will be a 1 byte integer. Enumerated:

```
0    =   No error
1    =   Parameter name (CPNAME) does not exist
2    =   Illegal value specified for CEPVAL
3    =   Illegal format specified for CEPVAL
4    =   Parameter name (CPNAME) not valid as used
5-63 Reserved
```

Where Used: S2F50

CEPVAL Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Command Enhanced Parameter Value. A specific application of CEPVAL shall always be identified with a specific value of CPNAME. A CEPVAL has the following forms: a single (non-list) value (e.g., CPVAL), a list of single items of identical format and type, or a list of items of the form.

```
L,2
  1. CPNAME
  2. CEPVAL
```

Where Used: S2F49

CKPNT Format: 54

Checkpoint as defined by the sending system

Where Used: S13F3, F6

CMDA Format: 31, 51

Command acknowledge code

```
0    =   Completed or done
1    =   Command does not exist
2    =   Cannot perform now
>2   =   Other equipment-specific error
3-63 Reserved
```

Where Used: S2F22, F28

CMDMAX Format: 3(), 5()

Command Maximum

```
Maximum number of commands to be allowed in a process program. A value of
zero indicates no limit. Negative values are invalid.
```

Where Used: S7F22

CNAME Format: 20

Command Name = 16 characters

```
Text string unique among other CNAMEs in PCD which describes the processing
done by the equipment for the corresponding CCODE.
```

Where Used: S7F22

COLCT Format: 5()

Column count in die increments

Where Used: S12F1, F4

COLHDR Format: 20

Text description of contents of TBLELT. 1 - 20 characters

Where Used: S13F13, F16

COMMACK Format: 10

Establish Communications Acknowledge Code, 1 byte

```
0   =   Accepted
1   =   Denied, Try Again
2-63 Reserved
```

Where Used: S1F14

CPACK Format: 10

Command Parameter Acknowledge Code, 1 byte

```
1   =   Parameter Name (CPNAME) does not exist
2   =   Illegal Value specified for CPVAL
3   =   Illegal Format specified for CPVAL
>3  =   Other equipment-specific error
4-63 Reserved
```

Where Used: S2F42

CPNAME Format: 20, 3(), 5()

Command Parameter Name

Where Used: S2F41, F42, F49, F50; S4F21, F29; S16F5, F27

CPVAL Format: 10, 11, 20, 21, 3(), 5()

Command Parameter Value

Where Used: S2F41, F49; S4F21, F29; S16F5, F27; S18F13

CSAACK Format: 10

Equipment Acknowledgement code, 1 byte

```
0   =   Everything correct
1   =   Busy
2   =   Invalid SPID
3   =   Invalid data
>3  =   Equipment-specific error
4-63 Reserved
```

Where Used: S2F8

CTLJOBCMD Format: 51

Control Job command codes are assigned as follows:

```
1 – CJStart
2 – CJPause
3 – CJResume
4 – CJCancel
5 – CJDeselect
6 – CJStop
7 – CJAbort
8 – CJHOQ
```

Where used: S16F27

CTLJOBID Format: 20

Identifier for Control Job. Conforms to OBJID.

Where used: S16F27

DATA Format: 20

A vector or string of unformatted data.

Where Used: S3F29, F31; S18F6,F7

DATAACK Format: 10

Acknowledge code for data.

```
0   =   Acknowledge
1   =   Unknown DATAID
2   =   At least parameter is invalid
3–63 Reserved
```

Where used: S14F22

DATAID Format: 20, 3(), 5()

Data ID

Where Used: S2F33, F35, F39, F45, F49; S3F15, F17; S4F19, F25; S6F3, F5, F7, F8, F9, F11, F13, F16, F18, F27; S13F11, F13, F15; S14F19, F21, F23; S15F27, F29, F33, F35, F37, F39, F41, F43, F45, F47; S16F1, F3, F5, F11, F13; S17F1, F5, F9

DATALENGTH Format: 3(), 5()

Total bytes to be sent

Where Used: S2F39; S3F15, F29, F31; S4F25; S6F5; S13F11; S14F23; S16F1, F11; S18F5, F7

DATASEG Format: 20

Used to identify the data requested.

Where Used: S3F29, F31; S18F5,F7

DATASRC Format: 20

Object type for Data Source Objects

Where Used: S14F1, F3, F6, F7, F8; S17F1

DATLC Format: 51

Data location

```
Location of invalid data, represented in bytes, measured from the start of
the message in question, excluding all header bytes.
```

Where Used: S12F19

DRACK Format: 10

Define Report Acknowledge Code, 1 byte

```
0   =   Accept
1   =   Denied. Insufficient space
2   =   Denied. Invalid format
3   =   Denied. At least one RPTID already defined
4   =   Denied. At least VID does not exist
>4  =   Other errors
5-63 Reserved
```

Where Used: S2F34

DSID Format: 20, 3(), 5()

Data set ID

Where Used: S6F3, F8, F9

DSNAME Format: 20

The name of the Data Set

```
The minimum length is zero. The maximum is 50 characters.
```

Where Used: S13F1, F2, F3, F4

DSPER Format: 20

Data sample period. DSPER has two allowable formats

```
Format 1: hhmmss, 6 bytes
Format 2: hhmmsscc, 8 bytes

Where “hh” is hours, “mm” is minutes, “ss” is seconds’ and “cc” is
centiseconds.

Equipment shall either (1) support only Format 1, or (2) support both Format
1 and Format 2. Equipment shall document which formats it accepts.

Equipment which supports Format 2 need not necessarily support a minimum
DSPER of 1 centisecond, nor a trace resolution of 1 centisecond, but
equipment suppliers shall document its trace performance limits.
```

Where Used: S2F23

DUTMS Format: 20

Die Units of Measure

```
Use units description per SEMI E5 Section 9.
```

Where Used: S12F1, F4

DVNAME Format: 3(), 20, 5()

Data value name

Where Used: S6F3, F8

DVVAL Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Data value

Where Used: S6F3, F8, F9

EAC Format: 10

Equipment acknowledge code, 1 byte

```
0   =   Acknowledge
1   =   Denied. At least one constant does not exist
2   =   Denied. Busy
3   =   Denied. At least one constant out of range
>3  =   Other equipment-specific error
4-63 Reserved
```

Where Used: S2F16

ECDEF Format: 10, 11, 20, 21, 3(), 4(), 5()

Equipment constant default value

Where Used: S2F30

ECID Format: 3(), 20, 5()

Equipment Constant ID

Where Used: S2F13, F15, F29, F30

ECMAX Format: 10, 11, 20, 21, 3(), 4(), 5()

Equipment constant maximum value

Where Used: S2F30

ECMIN Format: 10, 11, 20, 21, 3(), 4(), 5()

Equipment constant minimum value

Where Used: S2F30

ECNAME Format: 20

Equipment constant name

Where Used: S2F30

ECV Format: 10, 11, 20, 21, 3(), 4(), 5()

Equipment Constant Value

Where Used: S2F14, F15

EDID Format: 10, 20, 3(), 5()

Expected data Identification

```
Three possible responses.
      MEXP     EDID    EDID
      S02F03, <SPID>   A[6]
      S03Fl3, <PTN>    B[1]
      S07F03, <PPID>   A[80], B[80]
```

Where Used: S9F13

EMID Format: 10, 20

Equivalent material ID (16 bytes maximum)

Where Used: S3F9

EPD Format: 10

Executive program data

Where Used: S8F4

EQNAME Format: 20

A unique ASCII equipment identifier assigned by the factory to the equipment. Limited to a maximum of 80 characters.

Where Used: S4F29

ERACK Format: 10

Enable/Disable Event Report

Acknowledge Code, 1 byte

```
0   =   Accepted
1   =   Denied. At least one CEID does not exist
>1  =   Other Errors
2-63 Reserved
```

Where Used: S2F38

ERRCODE Format: 5()

Code identifying an error

```
 0  =  No error
 1  =  Unknown object in Object Specifier
 2  =  Unknown target object type
 3  =  Unknown object instance
 4  =  Unknown attribute name
 5  =  Read-only attribute - access denied
 6  =  Unknown object type
 7  =  Invalid attribute value
 8  =  Syntax error
 9  =  Verification error
10  =  Validation error
11  =  Object identifier in use
12  =  Parameters improperly specified
13  =  Insufficient parameters specified
14  =  Unsupported option requested
15  =  Busy
16  =  Not available for processing
17  =  Command not valid for current state
18  =  No material altered
19  =  Material partially processed
20  =  All material processed
21  =  Recipe specification related error
22  =  Failed during processing
23  =  Failed while not processing
24  =  Failed due to lack of material
25  =  Job aborted
26  =  Job stopped
27  =  Job cancelled
28  =  Cannot change selected recipe
29  =  Unknown event
30  =  Duplicate report ID
31  =  Unknown data report
32  =  Data report not linked
33  =  Unknown trace report
34  =  Duplicate trace ID
35  =  Too many data reports
36  =  Sample period out of range
37  =  Group size to large
38  =  Recovery action currently invalid
39  =  Busy with another recovery currently unable to perform the recovery
40  =  No active recovery action
41  =  Exception recovery failed
42  =  Exception recovery aborted
43  =  Invalid table element
44  =  Unknown table element
45  =  Cannot delete predefined
46  =  Invalid token
47  =  Invalid parameter
48-63 Reserved
```

Where Used: S1F20; S3F16, F30, F32; S4F20, F22, F23, F33, F35; S5F14, F15, F18; S13F14, F16; S14F2, F4, F6, F8, F10, F12, F14, F16, F18, F26, F28; S15F28, F18, F20, F22, F24, F26, F30, F32, F34, F36, F38, F40, F42, F44, F48; S16F12, F14, F16, F18, F24, F26, F28; S17F2, F4, F6, F8, F10, F12, F14

ERRTEXT Format: 20

Text string describing the error noted in the corresponding ERRCODE. Limited to 80 characters maximum.

Where Used: S1F20; S3F16, F18, F20, F22, F24, F26, F30, F32; S4F20, F22, F23, F33, F35; S5F14, F15, F18; S13F14, F16; S14F2, F4, F6, F8, F10, F12, F14, F16, F18, F26, F28; S15F28, F30, F32, F34, F36, F38, F40, F42, F44, F48; S16F12, F14, F16, F18, F24, F26, F28; S17F4, F8, F14

ERRW7 Format: 20

Text string describing error found in process program.

Where Used: S7F27

EVNTSRC Format: 20

Object type for Event Source Objects

Where Used: S17F5, F9, F10, F11, F12

EXID Format: 20

Unique identifier for the exception. Maximum length of 20 characters.

Where Used: S5F9, F11, F13, F14, F15, F17, F18

EXMESSAGE Format: 20

Text which describes the nature of the exception.

Where Used: S5F9, F11

EXRECVRA Format: 20

Text which specifies a recovery action for an exception. Maximum length of 40 bytes.

Where Used: S5F9, F13

EXTYPE Format: 20

Text which identifies the type of an exception. It is usually a single word of text.

```
"ALARM"
"ERROR"
```

Where Used: S5F9, F11; S14F1, F2, F8

FCNID Format: 51

Function Identification

Where Used: S2F43, F44

FFROT Format: 52

Film Frame Rotation

In degrees from the bottom CW. (Bottom equals zero degrees.) Zero length indicates not used.

Where Used: S12F1, F3

FILDAT Format: 10, 20

Data from the Data Set

The maximum length is the RECLEN from Open Data Set Data.

Where Used: S13F6

FNLOC Format: 52

Flat/Notch Location

In degrees from the bottom CW. (Bottom equals zero degrees.) Zero length indicates not used.

Where Used: S12F1, F3, F4

FRMLEN Format: 3(), 5()

Formatted Process Program Length

If greater than zero, indicates PPID is available as a formatted process program and its length in bytes. If zero, the PPID is not available as a formatted program. Negative values are invalid.

Where Used: S7F34

GRANT Format: 10

Grant code, 1 byte

```
0   =   Permission Granted
1   =   Busy, Try Again
2   =   No Space Available
3   =   Duplicate DATAID
>3  =   Equipment Specific Error Code
4-63 Reserved
```

Where Used: S2F2, F40; S3F16; S4F26; S13F12; S14F24; S16F2, F12

GRANT6 Format: 10

Permission to send, 1 byte

```
0   =   Permission granted
1   =   Busy, try again
2   =   Not interested
>2  =   Other errors
3-63 Reserved
```

Where Used: S6F6

GRNT1 Format: 10

Grant code, 1 byte

```
0   =   Positive response, transfer ok
1   =   Busy, try again
2   =   No space
3   =   Map too large
4   =   Duplicate ID
5   =   Material ID not found
6   =   Unknown map format
>6  =   Error
7-63 Reserved
```

Where Used: S12F6

HANDLE Format: 3(), 5()

Logical unit or channel

Where Used: S13F3, F4, F5, F6, F7, F8

HCACK Format: 10

Host Command Parameter Acknowledge Code, 1 byte

```
0   =   Acknowledge, command has been performed
1   =   Command does not exist
2   =   Cannot perform now
3   =   At least one parameter is invalid
4   =   Acknowledge, command will be performed with completion signaled later
        by an event
5   =   Rejected, Already in Desired Condition
6   =   No such object exists
7-63 Reserved
```

Where Used: S2F42, F50

HOACK Format: 11

Conveys whether the corresponding handoff activity succeeded (=True) or failed (=False)

Where Used: S4F31, F33

HOCANCELACK Format: 51

Tells whether the cancel ready message was accepted or rejected

```
0   =   Cancel Ready Accepted
1   =   Atomic Transfer Unknown
2   =   Cancel Ready Rejected - Handoff Begun
```

Where Used: S4F13

HOCMDNAME Format: 20

Identifier for the handoff command to be executed

Where Used: S4F31

HOHALTACK Format: 51

Tells whether the halt command was accepted or rejected

```
0   =   Halt Accepted
1   =   Atomic Transfer Unknown
2-63 Reserved
```

Where Used: S4F41

IACDS Format: 32, 52

Immediately After Command Codes

```
Vector of all command codes which defined command must immediately succeed
within the same block.
```

Where Used: S7F22

IBCDS Format: 32, 52

Immediately Before Command Codes

```
Vector of all command codes which defined command must immediately precede
within the same block.
```

Where Used: S7F22

IDTYP Format: 10

Id type

```
0   =   Wafer ID
1   =   Wafer Cassette ID
2   =   Film Frame ID
>2  =   Error
3-63 Reserved
```

Where Used: S12F1, F3, F4, F5, F7, F9, F11, F13, F14, F15, F16, F17, F18

INPTN Format:10, 51

A specialized version of PTN indicating the InputPort.

Where Used: S3F35

LENGTH Format: 3(), 5()

Length of the service program or process program in bytes

Where Used: S2F1; S7F1, F29

LIMITACK Format: 10

Acknowledgment code for variable limit attribute set, 1 byte

```
1   =   LIMITID does not exist
2   =   UPPERDB > LIMITMAX
3   =   LOWERDB < LIMITMIN
4   =   UPPERDB < LOWERDB
5   =   Illegal format specified for UPPERDB or LOWERDB
6   =   ASCII value cannot be translated to numeric
7   =   Duplicate limit definition for this variable
>7  =   Other equipment-specific error
8-63 Reserved
```

Where Used: S2F46

LIMITID Format: 10

The identifier of a specific limit in the set of limits (as defined by UPPERDB and LOWERDB) for a variable to which the corresponding limit attributes refer, 1 byte.

Where Used: S2F45, F46, F48

LIMITMAX Format: 11, 20, 3(), 4(), 5()

The maximum allowed value for the limit values of a specific variable. The equipment manufacturer should specify this value, which would typically coincide with the maximum value of the variable being monitored. The format must match that of the referenced variable.

Where Used: S2F48

LIMITMIN Format: 11, 20, 3(), 4(), 5()

The minimum allowed value for the limit values of a specific variable. The equipment manufacturer should specify this value, which would typically coincide with the minimum value of the variable being monitored. The format must match that of the referenced variable.

Where Used: S2F48

LINKID Format: 54

Used to link a completion message with a request that an operation be performed. LINKID is set to the value of RMOPID in the initial request except for the last completion message to be sent, where it is set to zero.

Where Used: S6F25; S14F20, F21; S15F22, F30

LLIM Format: 3(), 4(), 5()

Lower limit for numeric value

Where Used: S7F22

LOC Format: 10

Machine material location code, 1 byte

Where Used: S2F27; S3F2

LOCID Format: 20

The logical identifier of a material location.

Where used: S3F29, F31

LOWERDB Format: 11, 20, 3(), 4(), 5()

A variable limit attribute which defines the lower boundary of the deadband of a limit. The value applies to a single limit (LIMITID) for a specified VID. Thus, UPPERDB and LOWERDB as a pair define a limit.

Where Used: S2F45, F48

LRACK Format: 10

Link Report Acknowledge Code, 1 byte

```
0   =   Accepted
1   =   Denied. Insufficient space
2   =   Denied. Invalid format
3   =   Denied. At least one CEID link already defined
4   =   Denied. At least one CEID does not exist
5   =   Denied. At least one RPTID does not exist
>5  =   Other errors
6-63 Reserved
```

Where Used: S2F36

LVACK Format: 10

Variable limit definition acknowledge code, 1 byte. Defines the error with the limit attributes for the referenceVID.

```
1   =   Variable does not exist
2   =   Variable has no limits capability
3   =   Variable repeated in message
4   =   Limit value error as described in LIMITACK
5-63 Reserved
```

Where Used: S2F46

MAPER Format: 10

Map Error

```
0   =   ID not found
1   =   Invalid Data
2   =   Format Error
>2  =   Invalid error
3-63 Reserved
```

Where Used: S12F19

MAPFT Format: 10

Map data format type

```
0   =   Row format
1   =   Array format
2   =   Coordinate format
>2  =   Error
3-63 Reserved
```

Where Used: S12F3, F5

MCINDEX Format: 5()

Identifier used to link a handoff command message with its eventual completion message. Corresponding messages carry the same value for this data item.

Where Used: S4F31, F33

MDACK Format: 10

Map data acknowledge

```
0   =   Map received
1   =   Format error
2   =   No ID match
3   =   Abort/discard map
>3  =   Error
4-63 Reserved
```

Where Used: S12F8, F10, F12

MDLN Format: 20

Equipment Model Type, 6 bytes max

```
Same data as returned by S1,F2
```

Where Used: S1F2, F13, F14; S7F22, F23, F26, F31

MEXP Format: 20

Message expected in the form SxxFyy where x is stream and y is function.

Where Used: S9F13

MF Format: 10, 20

Material format code 1 byte by Format 10

```
 Items with format 10 will be encoded as follows:
 1   =   Quantities in wafers
 2   =   Quantities in cassette
 3   =   Quantities in die or chips
 4   =   Quantities in boats
 5   =   Quantities in ingots
 6   =   Quantities in leadframes
 7   =   Quantities in lots
 8   =   Quantities in magazines
 9   =   Quantities in packages
10   =   Quantities in plates
11   =   Quantities in tubes
12   =   Quantities in waterframes
13   =   Quantities in carriers
14   =   Quantities in substrates
15-63 Reserved
Items with format 20 will be a unit identifier for one of the special SECS
generic units, as specified in Section 9
```

Where Used: S3F2, F4, F5, F7 S16F11, F13, F15

MHEAD Format: 10

SECS message block header associated with message block in error

Where Used: S9F1, F3, F5, F7, F11

MID Format: 10, 20

Material ID

```
80 Characters maximum
```

Where Used: S2F27; S3F2, F4, F7, F9, F12, F13; S4F1, F3, F5, F7, F9, F11, F13, F15, F17; S7F7, F8, F10, F11, F13, F35, F36; S12F1, F3, F4, F5, F7, F9, F11, F13, F14, F15, F16, F17, F18; S16F11, F13, F15; S18F10, F11

MIDAC Format: 10

Material ID Acknowledge Code, 1 byte

```
0   =   Accepted
1   =   Invalid port number
2   =   Material is not present at identified port
>2  =   Error
3-63 Reserved
```

Where Used: S3F14

MIDRA Format: 10

Material ID Acknowledge Code, 1 byte

```
0   =   Acknowledge, MID follows
1   =   Acknowledge, will not send MID
2   =   Acknowledge, will send MID later in S3F13
3-63 Reserved
```

Where Used: S3F12

MLCL Format: 5()

Message length

```
Defined by message size in (bytes)
```

Where Used: S12F4, F5

MMODE Format: 10

Matrix mode select, 1 byte

```
1 = Host source mode
    Use S7F7 and F8 to define the process program to be used.
2 = Local source mode
    Use the matrix defined by S7F9, F10, F11 and F13 to define the process
    program to be used. The equipment will initialize to local source mode at
    power up. The equipment will default to local source mode from host
    source mode in the event of loss of communication with the host.
3 = Host immediate mode
    Use the current process program for all material unless changed by S7F1-
    F4. The timing of the mode change is equipment-specific
```

Where Used: S7F15

NACDS Format: 32, 52

Not After Command Codes

```
Vector of all command codes which defined command may not succeed within the
same block.
```

Where Used: S7F22

NBCDS Format: 32, 52

Not Before Command Codes

```
Vector of all command codes which defined command may not precede within the
same block.
```

Where Used: S7F22

NULBC Format: 20, 51

Null bin code value

```
This value is the bin code value that is used for no die at a location.
(For X/Y coordinate format the ASCII value is a value with "n" length. For
other map formats, ASCII is a single byte per bin with "n" length per item;
thus, the total number of bins is the length, i.e., length "n"=10 for ASCII
format is 10 single byte bin codes.) The format used must be the same as the
one used for BINLT and BCEQU. Zero length indicates not used.
```

Where Used: S12F1, F3, F4

OBJACK Format: 51

Acknowledge code:

```
0   =   Successful completion of requested data
1   =   Error
>1 Reserved
```

Where Used: S14F2, F4, F6, F8, F10, F12, F14, F16, F18, F26, F28

OBJCMD Format: 51

Specifies an action to be performed by an object:

```
0   =   Reserved
1   =   Attach to requestor
2   =   Detach from requestor (requires authorization token)
3   =   Reattach to requestor
4   =   Set attributes (requires authorization token)
>4 Reserved
```

OBJID Format: 20, 5()

Identifier for an object

Where Used: S1F19; S14F1, F2, F3, F4

OBJSPEC Format: 20

A text string that has an internal format and that is used to point to a specific object instance. The string is formed out of a sequence of formatted substrings, each specifying an object’s type and identifier. The substring format has the following four fields:

```
object type, colon character “:”, object identifier, greater-than symbol “>”
```

where the colon character “:” is used to terminate an object type and the “greater than” symbol “>” is used to terminate an identifier field. The object type field may be omitted where it may be otherwise determined. The final “>” is optional.

Where Used: S2F49; S13F11, F13, F15; S14F1, F3, F5, F7, F9, F10, F11, F13, F15, F16, F17, F19, F25, F27; S15F43, F47

OBJTOKEN Format: 54

Token used for authorization.

Where Used: S14F14, F15; S15F37, F39, F41, F43

OBJTYPE Format: 20, 5()

Identifier for a group or class of objects. All objects of the same type must have the same set of attributes available.

Where Used: S1F19; S14F1, F3, F6, F7, F8, F25, F26, F27

OFLACK Format: 10

Acknowledge code for OFF-LINE request.

```
0   =   OFF-LINE Acknowledge
1-63 Reserved
```

Where Used: S1F16

ONLACK Format: 10

Acknowledge code for ON-LINE request.

```
0   =   ON-LINE Accepted
1   =   ON-LINE Not Allowed
2   =   Equipment Already ON-LINE
3-63 Reserved
```

Where Used: S1F18

OPID Format: 5()

Operation ID. A unique integer generated by the requestor of an operation, used where multiple completion confirmations may occur.

Where Used: S6F25; S14F19, F21; S15F21, F29, F30, F37, F41, F44, F46

ORLOC Format: 10

Origin Location

```
implicit value of (0,0)
0   =   Center die of wafer
(Determined by:

row or column count +1
            2

            truncated)
1   =   Upper right
2   =   Upper left
3   =   Lower left
4   =   Lower right
>4  =   Error
5-63 Reserved
Zero length indicates not available
```

Where Used: S12F1, F3, F4

OUTPTN Format: 10, 51

A specialized version of PTN indicating the OutPutPort

Where Used: S3F35

PARAMNAME Format: 20

The name of a parameter in a request.

Where Used: S3F21,F23

PARAMVAL Format: 1, 10, 11, 20, 3(), 4(), 5()

The value of the parameter named in PARAMNAME. Values that are lists are restricted to lists of single items of the same format type.

Where Used: S3F21,F23

PDFLT Format: 11, 20, 3(), 4(), 5()

Parameter Default Value

```
Specifies default value and data type of parameter. If no defaults are
provided, item data length will be zero. For numeric or Boolean data,
the default item may be a multi-varied vector if the parameter itself
can be a vector.
If RQPAR is false:
Position of data in a default item is significant. When obtaining a
default value to be used in the Nth position of a vector parameter, the
value is obtained from the Nth position of the default item. If the
default item has L entries, no default value will be provided for the
L+1,...,PMAX parameter entries.
If RQPAR is true:
The length of the default vector (L) specifies the minimum number of
entries which must be entered for the parameter. If > PMAX, only PMAX
entries are required.
```

Where Used: S7F22

PFCD Format: 10

Predefined form code, 1 byte

Where Used: S6F9

PGRPACTION Format: 20

The action to be performed on a port group.

Where Used: S3F23

PMAX Format: 3(), 5()

Parameter Count Maximum

```
Maximum amount of data to be accepted by the host for this parameter. When a
conflict arises between value of PMAX and length of PDFLT, PMAX takes
precedence.
For numeric and Boolean parameters:
   PMAX < 0 invalid
   PMAX = 0 specifies there is no upper bound
   PMAX = 1 specified a single value is expected
   PMAX > 1 specifies a vector of values is expected with a maximum of PMAX
        entries
For string parameters:
   PMAX < 0 invalid
   PMAX = 0 specifies there is no upper bound
   PMAX > 0 maximum length of parameter string
```

Where Used: S7F22

PNAME Format: 20

Parameter Name ≤ 16 characters

```
Text string identifying the parameter value expected by its parent process
command.
```

Where Used: S7F22

PORTACTION Format: 20

The action to be performed on a port.

Where Used: S3F25

PORTGRPNAME Format: 20

The identifier of a group of ports.

Where Used: S3F21,F23

PPARM Format: 11, 20, 3(), 4(), 5()

Process Parameter

```
Numeric or Boolean SECS data item, single or multiple value, or text string
which provides information required to complete the process command to
which the parameter refers.
```

Where Used: S7F23, F26, F31

PPBODY Format: 10, 20, 3(), 5()

Process program body

```
The process program describes to the equipment, in its own language, the
actions to be taken in processing the material it receives.
```

Where Used: S7F3, F6, F36

PPGNT Format: 10

Process program grant status, 1 byte

```
0   =   OK
1   =   Already have
2   =   No space
3   =   Invalid PPID
4   =   Busy, try later
5   =   Will not accept
>5  =   Other error
6-63 Reserved
```

Where Used: S7F2, F30

PPID Format: 10, 20

Process program ID.

```
Limited to a maximum of 80 bytes.
The format used in the PPID will be host-dependent. For internal use of the
equipment, the PPID can be treated as a unique binary pattern. If the local
equipment is not prepared to display the transmitted code, the display
should be in hexadecimal form.
```

Where Used: S2F27; S7F1, F3, F5, F6, F8, F10, F11, F13, F17, F20, F23, F25, F26, F27, F31, F33, F34, F36; S9F13

PRAXI Format: 10

Process axis.

```
0   =   Rows (X-axis), top, increasing
1   =   Rows (X-axis), top, decreasing
2   =   Rows (X-axis), bottom, increasing
3   =   Rows (X-axis), bottom, decreasing
4   =   Columns (Y-axis), left, increasing
5   =   Columns (Y-axis), left, decreasing
6   =   Columns (Y-axis), right, increasing
7   =   Columns (Y-axis), right, decreasing
>7  =   Error
8-63 Reserved
```

Where Used: S12F1, F3

PRCMDNAME Format: 20

Commands sent to a process job:

“START”
“STOP”
“PAUSE”
“RESUME”
“ABORT”
“CANCEL”

Where Used: S16F5

PRDCT Format: 5()

Process Die Count

```
Number of die to be processed or number of die which have been processed.
(Zero length indicates not used.)
```

Where Used: S12F1, F4

PREVENTID Format: 5()

Processing related event identification:

```
1 = Waiting for material
2 = Job state change
```

Where Used: S16F9

PRJOBID Format: 20

Text string which uniquely identifies a process job.

Where Used: S16F4, F5, F6, F7, F9, F11, F12, F13, F14, F15, F16, F17, F20, F23, F25

PRJOBMILESTONE Format: 5()

Notification of Processing status shall have one of the following values:

```
1 = Job Setup
2 = Job Processing
3 = Job Processing Complete
4 = Job Complete
5 = Job Waiting for Start
```

Where Used: S16F7

PRJOBSPACE Format: 52

The number of process jobs that can be created.

Where used: S16F22

PRMTRLORDER Format: 51

Defines the order by which material in the process jobs material list will be processed. Possible values are assigned as follows:

```
1 – ARRIVAL – process whichever material first arrives
2 – OPTIMIZE – process in an order that maximizes throughput
3 – LIST – follow the order in the list
```

Where used: S16F29

PRPAUSEEVENT Format: 00

The list of event identifiers, which may be sent as an attribute value to a process job. When a process job encounters one of these events it will pause, until it receives the PRJobCommand RESUME.

Where used: S16F11, F13, F15

PRPROCESSSTART Format: 11

Indicates that the process resource start processing immediately when ready:

```
TRUE – Automatic Start
FALSE – Manual Start
```

Where used: S16F11, S16F13, S16F15, S16F25

PRRECIPEMETHOD Format: 51

Indicates the recipe specification type, whether tuning is applied and which method is used.:

```
1 – Recipe only
2 – Recipe with variable tuning
```

Where used: S16F11, S16F13, S16F15

PRSTATE Format: 51

Enumerated value, 1 byte

Where used: S16,F20

PTN Format: 10, 51

Material Port number, 1 byte

Where Used: S3F17, F21, F25; S4F1, F3, F5, F7, F9, F11, F13, F15, F17; S16F13, F17, F21

QUA Format: 10

Quantity in format, 1 byte

Where Used: S3F2, F4, F5, F7

RAC Format: 31, 51

Reset acknowledge, 1 byte

```
0   =   Reset to be done
1   =   Reset denied
>1  =   Other errors
2-63 Reserved
```

Where Used: S2F20

RCMD Format: 20, 31, 51

Remote command code or string

Where Used: S2F21, F41, F49

RCPATTRDATA Format: 0, 10, 11, 20, 3(), 4(), 5()

The contents (value) of a recipe attribute.

Where Used: S6F25; S15F13, F15, F18, F27, F28, F30, F32

RCPATTRID Format: 20

The name (identifier) of a non-identifier recipe attribute.

Where Used: S6F25; S15F13, F15, F18, F27, F28, F30, F32

RCPBODY Format: 10, 20, 3(), 5()

Recipe body

Where Used: S15F13, F15, F18, F27, F32

RCPCLASS Format: 20

Recipe class

Where Used: S15F11

RCPCMD Format: 51

Indicates an action to be performed on a recipe

```
 5   =   Delete
 8   =   Unprotect
 9   =   Protect
10   =   Verify
11   =   Link
12   =   Unlink
13   =   Certify
14   =   De-certify
15   =   Download
16   =   Upload
0-4, 6-7, 17-63 Reserved
```

Where Used: S15F21, F22

RCPDEL Format: 51

```
0   =   Delete
1   =   Deselect
>1 Reserved
```

Where Used: S15F35

RCPDESCLTH Format: 5()

The length in bytes of a recipe section.

Where Used: S15F24

RCPDESCNM Format: 20

Identifies a type of descriptor of a recipe: “ASDesc”, “BodyDesc”, “GenDesc”.

Where Used: S15F24

RCPDESCTIME Format: 20

The timestamp of a recipe section, in the format “YYYYMMDDhhmmsscc”.

Where Used: S15F24

RCPID Format: 20

Recipe identifier. Formatted text conforming to the requirements of OBJSPEC.

Where Used: S15F21, F23, F28, F29, F30, F33, F35, F37, F41, F44

RCPNAME Format: 20

Recipe name

Where Used: S15F11

RCPNEWID Format: 20

The new recipe identifier assigned as the result of a copy or rename operation.

Where Used: S15F19, F41, F44

RCPOWCODE Format: 11

Indicates whether any pre-existing recipe is to be overwritten (=TRUE) or not (=FALSE) on download.

Where Used: S15F27

RCPPARNM Format: 20

The name of a recipe variable parameter. Maximum length of 40 characters.

Where Used: S15F25, F33; S16F3, F11, F13, F15, F23

RCPPARRULE Format: 20

The restrictions applied to a recipe variable parameter setting. Maximum length of 80 characters.

Where Used: S15F25

RCPPARVAL Format: 10, 11, 20, 3(), 4(), 5()

The initial setting assigned to a recipe variable parameter. Text form restricted to maximum of 80 characters.

Where Used: S15F25, F33; S16F3, F11, F13, F15, F23

RCPRENAME Format: 11

Indicates whether a recipe is to be renamed (= TRUE) or copied (= FALSE).

Where Used: S15F19

RCPSECCODE Format: 10

Indicates the sections of a recipe requested for transfer or being transferred:

```
 1   =   Generic attributes only
 3   =   Generic attributes and body
 4   =   All agent-specific datasets (zero or more)
 7   =   Generic attributes, body, and all agent-specific datasets
 8   =   Single agent-specific dataset (zero or one)
11   =   Generic attributes, body, and single agent-specific datasets
All other values reserved
```

Where Used: S15F15, F16, F17

RCPSECNM Format: 20

Recipe section name: “Generic”, “Body”, or “ASDS”.

Where Used: S15F15, F18

RCPSPEC Format: 20

Recipe specifier. The object specifier of a recipe.

Where Used: S15F1, F9, F13, F15, F17, F19, F27, F28, F31, F32, F45; S16F11, F13, F15, F23

RCPSTAT Format: 51

The status of a managed recipe

```
0   =   Does not exist
8   =   Unprotected
9   =   Protected
```

Where Used: S15F10

RCPUPDT Format: 11

Indicates if an existing recipe is to be updated (= True) or a new recipe is to be created (= False).

Where Used: S15F13

RCPVERS Format: 20

Recipe version

Where Used: S15F10, F12

READLN Format: 3(), 5()

Maximum length to read

Where Used: S13F5

RECLEN Format: 3(), 5()

Maximum length of a Discrete record

Where Used: S13F4

REFP Format: 3()

Reference Point

Where Used: S12F1, F4

REPGSZ Format: 20, 3(), 5()

Reporting group size

Where Used: S2F23; S17F5

RESC Format: 31, 51

Resolution code for numeric data

```
1 = Absolute. Value may be specified to nearest increment of RESV
2 = Significant Digits. Value may be specified with no more significant
    digits than RESV allows
```

Where Used: S7F22

RESPEC Format: 20

Object specifier for the recipe executor

Where Used: S15F29, F33, F35

RESV Format: 3(), 4(), 5()

Resolution value for numeric data

```
If RESC=1, then RESV contains smallest increment allowed for parameter
```

Where Used: S7F22

RETICLEID Format: 20

The object identifier for a reticle. Conforms to OBJSPEC

Where Used: S3F35

RETPLACEINSTR Format: 51

Instructions to indicate which pod slots will have reticles placed. Possible values for ReticlePlacementInstruction are

```
0 = PLACE
1 = PASS BY
```

Where Used: S3F35

RETREMOVEINSTR Format: 51

Instructions to indicate which pod slots will have reticles removed

```
0 = REMOVE
1 = PASS BY
```

Where Used: S3F35

RIC Format: 31, 51

Reset code, 1 byte

```
0   =   Not used
1   =   Power up reset
>1 Other reset conditions
2-63 Reserved
```

Where Used: S2F19

RMACK Format: 51

Conveys whether a requested action was successfully completed, denied, completed with errors, or will be completed with notification to the requestor.

```
0   =   Successful completion
1   =   Cannot perform action
2   =   Completed with errors
3   =   Action will be completed and notification sent
4   =   No request for this action exists
```

Where Used: S15F4, F6, F8, F10, F12, F14, F16, F18, F20, F22, F24, F25, F26, F28, F30, F32, F34, F36, F38, F40, F42, F44, F48

RMCHGSTAT Format: 5()

Indicates the change that occurred for an object.

```
 0   =   No change
 1   =   Created
 2   =   Updated
 3   =   Stored (new)
 4   =   Replaced
 5   =   Deleted
 6   =   Copied (new object)
 7   =   Renamed
 8   =   Unprotected
 9   =   Protected
10   =   Verified
11   =   Linked
12   =   Unlinked
13   =   Certified
14   =   De-certified
15   =   Selected
16   =   Deselected
```

Where Used: S15F25

RMCHGTYPE Format: 5()

Indicates the type of change for a recipe.

```
 0   =   No change
 1   =   Create
 2   =   Update
 5   =   Delete
 6   =   Copy (new object)
 7   =   Rename
 8   =   Unprotect
 9   =   Product
10   =   Verify
11   =   Link
12   =   Unlink
13   =   Certify
14   =   De-certify
15   =   Change generic attribute
16   =   Change agent-specific attribute
17   =   Change both generic and agent-specific attributes
```

Where Used: S15F37, F41, F44, F46, F47, F48

RMDATASIZE Format: 5()

The maximum total length, in bytes, of a multi-block message, used by the receiver to determine if the anticipated message exceeds the receiver's capacity.

Where Used: S15F1

RMGRNT Format: 10

Grant code, used to grant or deny a request. 1 byte.

```
0   =   Permission granted
1   =   Cannot accept now, try again
2   =   No space
3   =   Request is on hold
4-64 Reserved
```

Where Used: S15F2, F37, F46

RMNEWNS Format: 20

New name (identifier) assigned to a recipe namespace

Where Used: S15F5

RMNSCMD Format: 51

Action to be performed on a recipe namespace

```
1   =   Created
5   =   Deleted
0, 2-4, 6-63 Reserved
```

Where Used: S15F3

RMNSSPEC Format: 20

The object specifier of a recipe namespace.

Where Used: S15F3, F5, F7, F11, F21, F23, F25, F47

RMRECSPEC Format: 20

The object specifier of a distributed recipe namespace recorder.

Where Used: S15F39, F41, F43

RMREQUESTOR Format: 11

Set to TRUE if initiator of change request was an attached segment. Set to FALSE otherwise.

Where Used: S15F41, F44, F46

RMSEGSPEC Format: 20

The object specifier of a distributed recipe namespace segment.

Where Used: S15F37, F39, F41, F44, F46, F47

RMSPACE Format: 5()

The amount of storage available for at least one recipe in a recipe namespace, in bytes.

Where Used: S15F8

ROWCT Format: 5()

Row count in die increments

Where Used: S12F1, F4

RPMACK Format: 51

Reticle Pod management service acknowledge code. One byte

```
0 = Acknowledge, service has been performed
1 = Service does not exist
2 = Can not perform now
3 = At least parameter does not exist
4 = Acknowledge, service will be performed with completion notified with
with parameters for response
5 = Service is not completed or prohibited
6 = No such object exists
7-63 reserved
```

RPMDESTLOC Format: 20

The LocationID towards which a reticle must be moved. Conforms to OBJID.

Where Used: S14F19

RPMSOURLOC

The LocationID of the location from which to pick-up a reticle for moving it to another location. Conforms to OBJID.

Where Used: S14F19

RPSEL Format: 51

Reference Point Select

```
Number of reference point from 0-n.
```

Where Used: S12F1, F4

RPTID Format: 20, 3(), 5()

Report ID

Where Used: S2F33, F35; S6F11, F13, F16, F11, F19, F21, F22; S17F1, F2, F3, F4, F5, F9, F11, F12

RPTOC Format: 11

A Trace Object attribute for a flag which, if set TRUE, causes only variables which have changed during the sample period to be included in a report.

Where Used: S14F1, F2, F3, F4; S17F5

RQCMD Format: 11

Required Command

```
True = Command must be specified
False = Command is optional
```

Where Used: S7F22

RQPAR Format: 11

Required Parameter

```
True = Parameter must be specified
False = Parameter is optional
```

Where Used: S7F22

RRACK Format: 10

Request to Receive Acknowledge code, 1 byte

```
0   =   Acknowledge, OK (note that 'OK' differs from 'ready')
1   =   Invalid port number
2   =   Requested material is not at identified port
3   =   Busy. Try again
4   =   Sender does not have permission to perform this operation
5-63 Reserved
```

Where Used: S4F18

RSACK Format: 10

Ready to Send Acknowledge code, 1 byte

```
0   =   Acknowledge, OK (note that 'OK' differs from 'ready')
1   =   Invalid port number
2   =   Port is already occupied
3   =   Busy, unable to move material at this time. Try again
4   =   Receiver does not have permission to perform this operation
5-63 Reserved
```

Where Used: S4F2

RSDA Format: 10

Request Spool Data Acknowledge

```
0   =   OK
1   =   Denied, busy try later
2   =   Denied, spooled data does not exist
3-63 Reserved
```

Where Used: S6F24

RSDC Format: 51

Request Spool Data Code

```
0   =   Transmit Spooled Messages
1   =   Purge Spooled Messages
2-63 Reserved
```

Where Used: S6F23

RSINF Format: 3()

Starting location for row or column. This item consists of 3 values (x,y, direction). If direction value is negative, it equals decreasing direction. If the value is positive, it equals increasing direction. Direction must be a non-zero value.

Where Used: S12F7, F14

RSPACK Format: 10

Reset Spooling Acknowledge

```
0   =   Acknowledge, spooling setup accepted
1   =   Spooling setup rejected
2-63 Reserved
```

Where Used: S2F44

RTYPE Format: 3(), 5()

Type of record

```
0   =   Stream
1   =   Discrete
2-63 Reserved
```

Where Used: S13F4

SDACK Format: 10

Map set-up data acknowledge

```
0   =   Received data
>1  =   Error
1-63 Reserved
```

Where Used: S12F2

SDBIN Format: 10

Send bin information flag

```
0   =   Sent bin information
1   =   Don't send bin information
>1  =   Error
2-63 Reserved
```

Where Used: S12F17

SEQNUM Format: 3(), 5()

Command Number

```
Value which identifies a unique process program command by its position in
the list of commands relative to the first. For the first command of the
process program, SEQNUM is l.
```

Where Used: S7F27

SFCD Format: 10

Status form code, 1 byte

Where Used: S1F5

SHEAD Format: 10

Stored header related to the transaction timer

Where Used: S9F9

SLOTID Format: 51

Used to reference material by slot (a position that holds material/substrates) in a carrier. This item may be implemented as an array in some messages.

Where used: S16F11, F13, F15

SMPLN Format: 3(), 5()

Sample number

Where Used: S6F1

SOFTREV Format: 20

Software revision code 6 bytes maximum

Where Used: S1F2, F13, F14; S7F22, F23, F26, F31

SPAACK Format: 10

Equipment acknowledgement code, 1 byte

```
0   = Everything correct
1   = Invalid data
>1  = Equipment-specific error
2-63 Reserved
```

Where Used: S2F4

SPD Format: 10

Service program data

Where Used: S2F3, F6

SPID Format: 20

Service program ID, 6 characters

Where Used: S2F1, F5, F7, F9, F12; S9F13

SPNAME Format: 20

Service parameter name defined in specific standard. If service parameter is defined as an object attribute, this is completely the same as ATTRID except format restrictions above.

Where used: S14F19, F20, F21, F28

SPR Format: Device Dependent

Service program results

```
Device dependent
```

Where Used: S2F10

SPVAL Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Service parameter value, corresponding to SPNAME. If service parameter is defined as an object attribute, this is completely the same as ATTRDATA except format restrictions for the attribute.

Where used: S14F19, F20, F21

SSACK Format: 20

Indicates the success or failure of a requested action. Two characters.

Where Used: S18F2, F4, F6, F8, F10, F12, F14

SSCMD Format: 20

Indicates an action to be performed by the subsystem.

Where Used: S18F13

STATUS Format: 20

Provides status information for a subsystem component. Used in the data item STATUSLIST.

Where Used: See STATUSLIST.

STATUSLIST Format: 0

A list of STATUS data sent in a fixed order. STATUSLIST has the following form:

```
L,s
  1. <STATUS_1>
  .
  s. <STATUS_s>
```

Where used: S18F4, F8, F10, F12, F14

STEMP Format: 20

```
String template. ASCII text string acceptable to equipment as a parameter
value. A data string matches a template string if the data string is at
least as long as the template and each character of the data string matches
the corresponding character of the template. A null list indicates all
user data is acceptable to the machine.
```

Where Used: S7F22

STIME Format: 20

Sample time, 12 or 16 bytes

```
If 12 bytes the format is YYMMDDhhmmss
YY=Year                   00 to 99
MM=Month                  01 to 12
DD=Day                    01 to 31
hh=Hour                   00 to 23
mm=Minute                 00 to 59
ss=Second                 00 to 59
If 16 bytes the format is YYYYMMDDhhmmsscc
YYYY=Year                 0000 to 9999
MM=Month                  01 to 12
DD=Day                    01 to 31
hh=Hour                   00 to 23
mm=Minute                 00 to 59
ss=Second                 00 to 59
cc=Centisecond            00 to 99
```

NOTE 4: The 16-byte format is currently optional. After January 1, 1998, the 16-byte format shall be required on new and updated implementations. Support for the 12-byte format shall be supported as a configurable option using the equipment constant TimeFormat. This is a format requirement only and does not imply either precision or accuracy.

Where Used: S6F1

STRACK Format: 10

Spool Stream Acknowledge

```
1   =   Spooling not allowed for stream (i.e., Stream 1)
2   =   Stream unknown
3   =   Unknown function specified for this stream
4   =   Secondary function specified for this stream
```

Where Used: S2F44

STRID Format: 51

Stream Identification

Where Used: S2F43, F44

STRP Format: 3()

Starting position in die coordinate position. Must be in (X,Y) order.

Where Used: S12F9, F16

SV Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Status variable value

Where Used: S1F4; S6F1

SVCACK Format: 10

Service acceptance acknowledge code, 1 byte.

```
0   =   Acknowledge, service has been performed
1   =   Service does not exist
2   =   Cannot perform now
3   =   At least parameter is invalid
4   =   Acknowledge, service will be performed with completion notified later
        with parameters for response
5   =   Service is not completed or prohibited
6   =   No such object exists
7-63 Reserved
```

Where used: S14F20

SVCNAME Format: 20

Service name provided on specified object asking by the host.

Where used: S14F19, F26, F27, F28

SVID Format: 20, 3(), 5()

Status variable ID

```
Status variables may include any parameter that can be sampled in time such
as temperature or quantity of a consumable.
```

Where Used: S1F3, F11, F12; S2F23

SVNAME Format: 20

Status Variable Name

Where Used: S1F12

TARGETID Format: 20

Description. Identifies where a request for action or data is to be applied. If text, conforms to OBJSPEC.

Where Used: S18F1, F3, F5, F7, F9, F11, F13

TARGETSPEC Format: 20

Object specifier of target object

Where Used: S14F17; S15F43

TBLACK Format: 51

Indicates success or failure

```
0   =   Success
1   =   Failure
```

Where Used: S13F14, F16

TBLCMD Format: 51

Provides information about the table or parts of the table being transferred or requested. Enumerated:

```
0   =   Complete Table
1   =   New rows (add)
2   =   New columns (append)
3   =   Replace existing rows
4   =   Replace existing columns
```

Where Used: S13F13, F15

TBLELT Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Table element. The first table element in a row is used to identify the row.

Where Used: S13F13, F15, F16

TBLID Format: 20

Table identifier. Text conforming to the requirements of OBJSPEC.

Where Used: S13F13, F15, F16

TBLTYP Format: 20

A reserved text string to denote the format and application of the table. Text conforming to the requirements of OBJSPEC.

Where Used: S13F13, F15, F16

TEXT Format: 10, 20, 22, 3(), 5()

A single line of characters

Where Used: S10F1, F3, F5, F9

TIAACK Format: 10

Equipment acknowledgement code, 1 byte

```
0   =   Everything correct
1   =   Too many SVIDs
2   =   No more traces allowed
3   =   Invalid period
>3  =   Equipment-specified error
4-63 Reserved
```

Where Used: S2F24

TIACK Format: 10

Time Acknowledge Code, 1 byte

```
0   =   OK
1   =   Error, not done
2-63 Reserved
```

Where Used: S2F32

TID Format: 10

Terminal number, 1 byte

```
0   =   Single or main terminal
>0  =   Additional terminals at the same equipment
```

Where Used: S10F1, F3, F5, F7

TIME Format: 20

Time of day, 12 or 16 bytes

```
If 12 bytes the format is YYMMDDhhmmss
YY=Year                   00 to 99
MM=Month                  01 to 12
DD=Day                    01 to 31
hh=Hour                   00 to 23
mm=Minute                 0000 to 9999
ss=Second                 00 to 59
If 16 bytes the format is YYYYMMDDhhmmsscc
YYYY=Year                 0000 to 9999
MM=Month                  01 to 12
DD=Day                    01 to 31
hh=Hour                   00 to 23
mm=Minute                 00 to 59
ss=Second                 00 to 59
cc=Centisecond            00 to 99
```

NOTE 5: The 16-byte format is currently optional. After January 1, 1998, the 16-byte format shall be required on new and updated implementations. Support for the 12-byte format shall be supported as a configurable option using the equipment constant TimeFormat. This is a format requirement only and does not imply either precision or accuracy.

Where Used: S2F18, F31

TIMESTAMP Format: 20

A text string indicating the time of an event, which encodes time in the following format:

```
YYYYMMDDhhmmsscc
YYYY = year               0000 to 9999
MM = month                01 to 12
DD = day                  01 to 31
hh = hour                 00 to 23
mm = minute               00 to 59
ss = second               00 to 59
cc = centisecond          00 to 99
```

Where Used: S5F9, F11, F15; S15F41, F44; S16F5, F7, F9

TOTSMP Format: 20, 3(), 5()

Total samples to be made

Where Used: S2F23; S17F5

TRACK Format: 11

Tells whether the related transfer activity was successful (=True) or unsuccessful (=False).

Where Used: S4F20, F22, F23

TRATOMICID Format: 5()

Equipment assigned identifier for an atomic transfer

Where Used: S4F20

TRAUTOD Format: 11

A Trace Object attribute for a control flag which, if set TRUE, causes the Trace Object to delete itself when it has completed a report.

Where Used: S14F1, F2, F3, F4; S17F5

TRAUTOSTART Format: 11

For each atomic transfer, this data item tells the equipment if it should automatically start the handoff when ready (=TRUE) or await the host's "StartHandoff" command (=FALSE) following setup. This data item only affects the primary transfer partner.

Where Used: S4F19

TRCMDNAME Format: 20

Identifier of the transfer job-related command to be executed. Possible values:

"CANCEL"
"PAUSE"
"RESUME"
"ABORT"
"STOP"
"STARTHANDOFF" (requires a TRATOMICID as a parameter)

Where Used: S4F21

TRDIR Format: 51

Direction of handoff.

```
1   =   Send material
2   =   Receive material
0, 3-63 Reserved
```

Where Used: S4F19, F29

TRID Format: 20, 3(), 5()

Trace request ID

Where Used: S2F23; S6F1, F27, F28; S17F5, F6, F7, F8, F13, F14

TRJOBID Format: 10

Equipment assigned identifier for the transfer job.

Where Used: S4F20, F21

TRJOBMS Format: 51

Milestone for a transfer job (e.g., started or complete).

```
1   =   Transfer Job Started
2   =   Transfer Job Complete
0, 3-63 Reserved
```

Where Used: S4F23

TRJOBNAME Format: 20

Host assigned identifier for the transfer job. Limited to a maximum of 80 characters.

Where Used: S4F19, F23

TRLINK Format: 5()

Common identifier for the atomic transfer used by the transfer partners to confirm that they are working on the same host-defined task.

Where Used: S4F19, F29, F31, F33, F39

TRLOCATION Format: 5()

Identifier of the material location involved with the transfer. For one transfer partner, this will represent the designated source location for the material to be sent. For the other transfer partner, it will represent the designated destination location for the material to be received.

Where Used: S4F19, F29

TROBJNAME Format: 20

Identifier for the material (transfer object) to be transferred

Where Used: S4F19, F23, F29

TROBJTYPE Format: 5()

Type of object to be transferred

Where Used: S4F19, F29

TRPORT Format: 5()

Identifier of the equipment port to be used for the handoff

Where Used: S4F19, F29

TRPTNR Format: 20

Name of the equipment which will serve as the other transfer partner for this atomic transfer. This corresponds to EQNAME.

Where Used: S4F19, F29

TRPTPORT Format: 5()

Identifier of the transfer partner's port to be used for the transfer.

Where Used: S4F19, F29

TRRCP Format: 20

Name of the transfer recipe for this handoff. Limited to a maximum of 80 characters.

Where Used: S4F19

TRROLE Format: 51

Tells whether the equipment is to be the primary or secondary transfer partner.

```
1   =   Primary Transfer Partner
2   =   Secondary Transfer Partner
```

Where Used: S4F19, F29

TRSPER Format: 4()

A Trace Object attribute which holds the value for sampling interval time.

Where Used: S14F1, F2, F3, F4; S17F5

TRTYPE Format: 51

Tells whether the equipment is to be an active or passive participant in the transfer.

```
1   =   Active
2   =   Passive
```

Where Used: S4F19, F23, F29

TSIP Format: 10

Transfer status of input port, 1 byte

```
1   =   Idle state
2   =   Prep state
3   =   Track on state
4   =   Stuck in Receiver state
5-63 Reserved
```

Where Used: S1F10

TSOP Format: 10

Transfer status of output port, 1 byte

```
1   =   Idle state
2   =   Prep state
3   =   Track on state
4   =   Stuck in Sender state
5   =   Completion state
6-63 Reserved
```

Where Used: S1F10

TTC Format: 3(), 5()

Time to completion

Where Used: S3F4

ULIM Format: 3(), 4(), 5()

Upper limit for numeric value

Where Used: S7F22

UNFLEN Format: 3(), 5()

Unformatted Process Program Length

If greater than zero, indicates PPID is available as an unformatted process program and its length in bytes. If zero, the PPID is not available as an unformatted process program. Negative values are invalid.

Where Used: S7F34

UNITS Format: 20

Units Identifier

As allowed by SEMI E5 Section 9

Where Used: S1F12; S2F30, F48; S7F22

UPPERDB Format: 11, 20, 3(), 4(), 5()

A variable limit attribute which defines the upper boundary of the deadband of a limit. The value applies to a single limit (LIMITID) for a specified VID. Thus, UPPERDB and LOWERDB as a pair define a limit.

Where Used: S2F45, F48

V Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Variable data

Where Used: S6F11, F13, F16, F20, F22

VID Format: 20, 3(), 5()

Variable ID

Where Used: S2F33, F45, F46, F47, F48; S6F13, F18, F22; S17F1

VLAACK Format: 10

Variable Limit Attribute Acknowledge Code, 1 byte

```
0   =   Acknowledge, command will be performed
1   =   Limit attribute definition error
2   =   Cannot perform now
>2  =   Other equipment-specific error
3-63 Reserved
```

Where Used: S2F46

XDIES Format: 4(), 5()

X-axis die size (index)

Where Used: S12F1, F4

XYPOS Format: 3()

X and Y Coordinate Position. Must be in (X,Y) order

Where Used: S12F11, F18

YDIES Format: 4(), 5()

Y-axis die size (index)

Where Used: S12F1, F4

6.7 *Variable Item Dictionary* — This section defines variable data items which are available to the Host for data collection purposes.

Name: A unique mnemonic name for this variable data item. This name is provided for reference only.

Class: The data type classification (SV, ECV, or DVVAL) of the item. Status values (SV' s) always contain valid information, while data values (DVVAL' s) may only be valid upon the occurrence of a particular event. All equipment constants (ECV' s) are settable by the Host.

Format: The allowable item format codes which can be used for this variable data item. ...as in Data Item Dictionary...

Description: A description of the variable data item, with the meanings of specific values. Also, specify validity for item of class DVVAL.

AlarmID Format: 3(), 5()

Class: DVVAL

This variable is valid only upon the setting or clearing of an alarm condition and contains the current alarm identification (ALID), regardless of whether that alarm is enabled for reporting.

AlarmsEnabled Format: 0

Class: SV

Contains the list of alarms (ALIDs) enabled for reporting (via Stream 5).

Structure: L,n n= # of alarms enabled

```
1.<ALID1>
.
.
n.<ALIDn>
```

AlarmsSet Format: 0

Class: SV

Contents of this variable is a list of alarms (ALIDs) currently in the UNSAFE (alarm set) state, regardless of whether the alarms are enabled for reporting.

Structure: L,n n= # of alarms set

1.<$ALID_1$>
.
.
n.<$ALID_n$>

ARAMSAccumReset Format: 20

Class: SV

The timestamp of when the set of accumulators EngTime, InterruptionCtr, PrdTime, NSTime, SbyTime, SDTime, and UDTime were reset to zero. Uses format defined for CLOCK.

ARAMSInfo Format: 20

Class: SV

Text field set by the equipment to provide additional information concerning an ARAMS state change.

ARAMSState Format: 20

Class: SV

The ARAMS code corresponding to the current state/substate. Four characters.

ARAMSText Format: 20

Class: SV

Text describing the ARAMSState. 3-80 characters.

ARAMSTimeStamp Format: 20

Class: SV

The timestamp of the last ARAM state change. This is a format requirement only and does not imply precision or accuracy. Uses format defined for CLOCK.

CLOCK Format: 20

Class: SV

The value of the equipment' s internal clock. This is a format requirement only and does not imply precision or accuracy.

```
Format: YYYYMMDDhhmmsscc
YYYY = Year              0000 to 9999
MM = Month               01 to 12
DD = Day                 01 to 31
hh = Hour                00 to 23
mm = Minute              00 to 59
ss = Second              00 to 59
cc = centisecond         00 to 99
```

ControlState Format: 10, 51

Class: SV

This status variable contains the code which identifies the current control state of the equipment. When reported related to a control state transition, its value should represent the state current after the transition.

```
1   =   OFF-LINE/EQUIPMENT OFF-LINE
2   =   OFF-LINE/ATTEMPT ON-LINE
3   =   OFF-LINE/HOST OFF-LINE
4   =   ON-LINE/LOCAL
5   =   ON-LINE/REMOTE
6-63 Reserved
```

CycleCtr Format: 5()

Class: SV

The number of machine cycles during the lifetime of the equipment. Non-resettable.

DowntimeAlarm Format: 3(), 5()

Class: SV

Identifier of the last alarm or exception triggering an equipment-initiated transition to UNSCHEDULED DOWNTIME from the PRODUCTIVE or STANDBY states.

DowntimeAlarmText Format: 20

Class: SV

Text associated with DowntimeAlarm. 0-80 characters.

DowntimeData Format: 20

Class: SV

Equipment defined data associated with transitions to, or within, the SCHEDULED or UNSCHEDULED DOWNTIME states. For example, this may be used to carry fault information, the component serial number of a repaired component, or comments entered at the equipment's control panel. 0-256 characters.

EngTime Format: 5()

Class: ECV

Accumulation of time in ENGINEERING reported in minutes.

EqpModel Format: 20

Class: SV

Text string describing the equipment model. 1-80 characters.

EqpName Format: 20

Class: ECV

Text string containing a user-assigned name for equipment. 1-80 characters. Information in the data item EQNAME is a subset of EqpName.

EqpSerialNum Format: 20

Class: SV

Text string describing the product serial number assigned by the manufacturer. 1-80 characters. Information in the data item MDLN is a subset of EqpSerialNum.

EstablishCommunicationsTimeout Format: 52

Class: ECV

The length of time, in seconds, of the interval between attempts to send S1F13 when establishing communications.

EventsEnabled Format: 0

Class: SV

Contains the list of events (CEIDs) enabled for reporting (via Stream 6).

Structure: L,n n= # of events enabled

```
1.<CEID1>
.
.
n.<CEIDn>
```

EventLimit Format: 0, 10, 11, 20, 21, 3(), 4(), 5()

Class: DVVAL

Used with the Limits Monitoring capability, it contains the LIMITID of the limit reached or crossed by LimitVariable. Since multiple zone transitions for a variable may occur simultaneously (e.g., due to identical limit definitions or a slow data sampling rate), EventLimit has been defined to allow for a list of LIMITIDs.

InterruptionCtr Format: 5()

Class: ECV

The number of transitions to UNSCHEDULED DOWNTIME from PRODUCTIVE.

LastPowerdown Format: 20

Class: SV

Timestamp estimate of when the last powerdown or reset occurred. Uses format defined for Clock.

LimitVariable Format: 5()

Class: DVVAL

This variable contains the VID for the variable whose value changed monitoring zones.

MaxSpoolTransmit Format: 54

Class: ECV

The maximum number of messages which the equipment will transmit from the spool in response to an S6,F23 " Transmit Spooled Messages" request. If MaxSpoolTransmit is set to zero, no limit is placed on the messages sent from the spool. Multi-block inquire/grant messages are not counted in this total.

NSTime Format: 5()

Class: ECV

Accumulation of time in NON-SCHEDULED TIME, reported in minutes.

OperatorCommand Format: 5()

Class: DVVAL

This data variable is valid in the event the operator issues a command to the equipment. The codes for this variable are equipment-dependent.

OverWriteSpool Format: 11

Class: ECV

This Equipment Constant is used to indicate to the equipment either to overwrite data in the spool area or to stop spooling whenever the spool area limits are exceeded.

```
= TRUE to overwrite spooled data
= FALSE to stop spooling when limits exceeded
```

PowerdownTime Format: 20

Class: SV

This timestamp is periodically updated based on an interval set by the user. It is used to determine the approximate time that the equipment went down in the event of a power loss. Uses format defined for CLOCK.

PowerupState Format: 20

Class: SV

Specifies the powerup ARAMS state when powerdown occurs during manufacturing time. Single text digit: " 2" = STANDBY, " 5" = UNSCHEDULED DOWNTIME.

PPChangeName Format: 10, 20

Class: DVVAL

The PPID which was affected upon the event of the creation, editing, or deletion of a Process Program local to the equipment. If the PPID Data Item is also defined and implemented for the equipment, then the values for PPChangeName are subject to the same format restrictions defined for the PPID Data Item.

PPChangeStatus Format: 51

Class: DVVAL

The action taken on the Process Program named in PPChangeName. This variable is valid upon the event of the creation, editing, or deletion of a Process Program local to the equipment.

```
1   =   Credited
2   =   Edited
3   =   Deleted
4-63 Reserved
```

PPError Format: 20

Class: SV or DVVAL

Contains information about a failure to verify a text process program.

PPExecName Format: 0, 10, 20

Class: SV

The PPID(s) of the currently selected Process Program(s). The selection of a new Process Program updates this variable. If multiple Process Programs can be selected, then this variable is a list of PPIDs. If the PPID Data Item is also defined and implemented for the equipment, then the values for PPExecName are subject to the same format restrictions defined for the PPID Data Item.

PPFormat Format: 51

Class: SV

Indicates the type or types of process programs and recipes that are supported.

```
1   =   Unformatted process programs
2   =   Formatted process programs
3   =   Both unformatted and formatted process programs
4   =   Execution Recipes
>4 Reserved
```

PrdRecovery Format: 11

Class: ECV

A boolean value that enables (TRUE) or disables (FALSE) the equipment-initiated return to PRODUCTIVE from UNSCHEDULED DOWNTIME.

PrdState Format: 20

Class: SV

Default ARAMS Substate Code for automated transitions to PRODUCTIVE.

PrdTime Format: 5()

Class: ECV

Accumulation of time in PRODUCTIVE, reported in minutes.

PrevARAMSState Format: 20

Class: SV

The ARAMS code corresponding to the previous state/substate. Four characters.

PreviousProcessState Format: 51

Class: SV

The previous processing state of the equipment, before the most recent process state change.

```
0-63 Reserved
```

ProcessState Format: 51

Class: SV

The current processing state of the equipment.

```
0-63 Reserved
```

RcpChangeName Format: 20

Class: DVVAL

The identifier of the recipe affected upon the event of the creation, editing, or deletion of a recipe.

RcpChangeStatus Format: 51

Class: DVVAL

The type of change that occurred for the recipe indicated in RcpChangeName

```
0   =   No change
1   =   Created
2   =   Updated (modified)
3   =   Stored (new)
4   =   Replaced
5   =   Deleted
6   =   Copied
7   =   Renamed
8,9 Reserved
>10 Reserved
```

RcpExecName Format: 0, 20

Class: SV

The identifier, or a list of identifiers, of currently selected recipes. A zero-length item or list indicates no recipes are currently selected.

SbyRecovery Format: 11

Class: ECV

A boolean value that enables (TRUE) or disables (FALSE) the equipment-initiated return to STANDBY from UNSCHEDULED DOWNTIME.

SbyTime Format: 5()

Class: ECV

Accumulation of time in STANDBY, reported in minutes.

SDTime Format: 5()

Class: ECV

Accumulation of time in SCHEDULED DOWNTIME, reported in minutes.

SpoolCountActual Format: 5()

Class: SV

Used to keep a count of the messages actually contained in the equipment' s spool area. Multi-block inquire/grant messages are not spooled and not included in this count.

SpoolCountTotal Format: 5()

Class: SV

Used to keep a count of the total number of primary messages directed to the spool, regardless of whether placed or retained in the spool. Multi-block inquire/grant messages are not spooled and not included in this count.

SpoolFullTime Format: 20

Class: SV

Contains the timestamp from the time the spool last became full. If the spool was not filled during the last spooling period, this will contain a time value prior to the current SpoolStartTime. Uses the same format as the CLOCK variable data item.

SpoolStartTime Format: 20

Class: SV

Contains the timestamp from the time spooling last became active. Uses the same format as the CLOCK variable data item.

SymptomID Format: 5()

Class: SV

A numeric code representing the symptom that initiated the user-initiated state change. A value of zero indicates " no symptom" .

SymptomText Format: 20

Class: SV

Text describing the SymptomID. 0-80 characters.

TimeFormat Format: 5()

Class: ECV

NOTE 6: The setting of this ECV controls whether the equipment shall send the Data Items STIME and TIME in 12 or 16-byte format.

```
0   =   12-byte format
1   =   16-byte format
>1 Reserved
```

TransitionType Format: 10

Class: DVVAL

Used with the Limits Monitoring capability, it defines the direction of the zone transition which has occurred.

```
0   =   Transition from lower to upper zone.
1   =   Transition from upper to lower zone.
```

TRATID Format: 5()

Class: DVVAL

Contains the TRATOMICID of the atomic transfer referenced by the event.

TRJOBIDENT Format: 5()

Class: DVVAL

Contains the TRJOBID for the transfer job referenced by the event.

TRJOBNM Format: 20

Class: DVVAL

Contains the TRJOBNAME for the transfer job referenced by the event.

TRLNK Format: 5()

Class: DVVAL

Contains the TRLNK value for the atomic transfer referenced by the event.

UDTime Format: 5()

Class: ECV

Accumulation of time in UNSCHEDULED DOWNTIME, reported in minutes.

6.8 *Object Dictionary* — This section defines the public attributes of objects which are available through SECS-II messages.

The attributes of an object are defined in a table for each object in the following form:

Agent Attribute Definition

Attribute Name	*Definition*	*Access*	*Format*	*Value*
"ObjType"	Agent object type.	RO	20	"Agent"
"ObjID"	The agent's name, assigned by an *authorized user*.	RO	20	

Agent-Specific Dataset Object Attribute Definition

Attribute Name	*Definition*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"MRcpASDS"
"ObjID"	The object's identifier. Contains the value in AgentSpec Agent.	RO	20	

"AgentSpec_Agent"	The name of the *executing agent* to which the other attributes in the *dataset* apply. *Mandatory*.	RO	20	
"AgentSpec_AttrLength"	The length of the *agent-specific* attributes, in bytes. *Mandatory*.	RO	54	
"AgentSpec_ChgTime"	Timestamp of when an *agent-specific* attribute was last changed. *Mandatory*.	RO	20	
"AgentSpec_Comments"	Comments specific to the *agent* entered by the author.	RW	20	Maximum length is 80 characters.
"AgentSpec_LinkParam"	A list of *variable parameter definitions* modified from the list in LinkParam. Valid only for a *linked main* recipe. *Parameter name* and form may not be changed.	RO	00	List of structures composed of parameter name, value, and restrictions.
"Certified"	The certification level for the specific *agent*, assigned by an *authorized user*. Reset when AgentSpec LinkParam is modified. Required for *certification* support.	RW	52	
"AgentSpec_UD_"	Non-standard attribute defined by the supplier or user. Asterisk indicates the part of the attribute name that is provided in this definition. Must be preserved exactly except by the defining entity.	RO	10, 11 20, 3() 4(), 5()	Text form is limited to 80 characters.

Collection Event Object

Attribute Name	*Description*	*Access*	*Format*	*Related Data Items*	*Value*
"ObjType"	Collection Event Object type	RO	20	-	"COLLEVENT"
"ObjID"	Collection Event Identifiers	RO	20	CEID	-
"Enabled"	Boolean true means reporting is enabled for a specific CEID.	RW	11	CEED	-
"EventSource"	Object specifier for object which generates the event for a specific CEID.	RO	20	EVNTSRC	-
"DataReportList"	List of Report Identifiers linked to a specific CEID.	RO	20	-	(list of) RPTID

Data Report Object

Attribute Name	*Description*	*Access*	*Format*	*Related Data Items*	*Value*
"ObjType"	Data Report Object Type	RO	20	-	"DATARPT"
"ObjID"	Object identifier for a data report	RO	20	RPTID	-
"DataSource"	Source for the variable data, not writable for predefined provider reports	RO	20	DATASRC	-
"AttrList"	Returns the attribute (or variable) names that this report is requesting from the Data source.	RW	*	-	(list of) VID

Data Source Object

Attribute Name	*Description*	*Access*	*Format*	*Related Data Items*	*Value*
"ObjType"	Data Source Object Type	RO	20	-	"DataSource"
"ObjID"	Identifier of a specific Data Source Object	RO	20	DATASRC	-
"AttrList"	Name of attributes for a specific Data Source Object	RO	*	-	(list of) VID

Distributed Recipe Namespace Attribute Definition

Attribute Name	*Description*	*Access*	*Format*	*Value*

"ObjType"	The object type.	RO	20	"RNSD"
"ObjID"	Text.	RO	20	
"LockedRecipes"	A list of *identifiers* of all recipes with existing *change request records.*	RO	20	
"Recorder"	The *recorder specifier* of the attached *distributed recipe namespace recorder*.	RO	20	
"Segments"	A list of *specifiers* of the *distributed recipe namespace segments* attached to the *namespace.*	RO	20	

Distributed Recipe Namespace Manager Attribute Definition

Attribute Name	*Description*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"RNS_MgrD"
"ObjID"	The *manager's* name.	RO	20	

Distributed Recipe Namespace Recorder Attribute Definition

Attribute Name	*Description*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"RNSDRecorder"
"ObjID"	Text.	RO	20	
"LockedRecipes"	List of *identifiers* of recipes with existing *change request records.*	RO	00	
"Namespace"	Identifies the *namespace* to which the recorder is attached. May be set by the manager.	RO	20	
"NamespaceManager"	Identifies the *distributed recipe namespace manager*. May be set by the manager.	RO	20	
"Segments"	List of *specifiers* of currently attached segments.	RO	00	

Distributed Recipe Namespace Segment Attribute Definition

Attribute Name	*Description*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"RNSDSegment"
"ObjID"	The object name (identifier).	RO	20	
"Namespace"	The name (ObjID) of the *namespace* to which the *segment* belongs. May be set by the manager.	RO	20	
"NamespaceManager"	Identifies the *distributed recipe namespace manager*. May be set by the manager.	RO	20	
"RecipeReadOnlyLevel"	Used to track the corresponding attribute of the *namespace* to which the *segment* belongs. May be set by the manager.	RO	52	

Exception Attributes

Attribute Name	*Description*	*Access*	*Format*	*Related Data Items*	*Value*
"ObjType"	The object type	RO	20	-	"EXCEPTION"
"ObjID"	The identifier of a specific Exception	RO	20	EXID	-
"EXType"	Identifies the type of exception	RO	20	-	Select from set: "ALARM" "ERROR"
"EXMessage"	Text message describing the abnormal situation monitored.	RO	20	-	Max. length of 80 characters
"EXEnabled"	Indicates that reporting to the decision authority on the exception condition is enabled.	RW	11	-	Boolean; TRUE is enabled.
"EXRecoveryAction"	List of possible recovery actions (EXRecovery).	RO	20	-	list of text
"EXState"	Current state of an Exception Object. The Exception Object state is usually defined as a combination of substates and concurrent states.	RO	20	-	Composed from the set: "CLEARED" "SET" "NOTPOSTED" "POSTED" "NOTRECOVERING" "RECOVERING" "ABORTINGRECOVERY"

Execution Recipe Attribute Definition

Attribute Name	*Definition*	*Acc.*	*Rqmt*	*Form*	*Default Value*
Identification Attributes					
"ObjType"	The object type.	RO	Y	Text: "ERcp"	"ERcp"
"ObjID"	An identifier derived from Namespace, Class, Name, and Version.	RO	Y	Formatted text.	-
"Namespace"	The name of the *originating namespace*.	RO	Y	Text.	-
"Name"	A logical name assigned by the user when the recipe is *created*.	RO	Y	Text.	-
"Class"	The recipe's class (e.g., "/PROCESS/" OR "/PROCESS/LOADER/").	RO	Y	Formatted text: "CLASS/CLASS/.. /CLASS/"	-
"Version"	The version of the recipe.	RO	Y	Text.	-
Mandatory Attributes					
"ExecAttrLength"	The *length attribute* for the attributes of the *execution recipe*. Calculated when the recipe is *downloaded* and whenever an attribute changes. *Mandatory*.	RO	Y	Unsigned integer	-
"ExecChgTime"	The *timestamp* of a change to the attributes of the *execution recipe*. *Mandatory*.	RO	Y	Formatted text, *timestamp* format	-
"AttrLength"	Preserved. *Mandatory*.	RO	Y	Unsigned integer	-
"AttrChgTime"	Preserved. *Mandatory*.	RO	Y	Timestamp format	-
"EditTime"	Preserved unless recipe is modified. *Timestamp* of when the *body* was *created* or modified. *Mandatory*.	RO	Y	Formatted text *Timestamp* format	-

Attribute Name	*Definition*	*Acc.*	*Rqmt*	*Form*	*Default Value*
"BodyLength"	Preserved unless recipe is modified. Length of the recipe's body, in bytes. *Mandatory*.	RO	Y	Unsigned integer	-
"BodyFormat"	Indicates the form and format of the recipe's *body*.	RO	Y	Enumerated unsigned integer: 0 = *source*, 1 = *object*, > 1 reserved.	0
"Verified"	Indicates whether the recipe's body is syntactically correct.	RO	Y	Boolean.	FALSE
"Linked"	Indicates whether the recipe is *linked*.	RO	Y	Boolean.	FALSE
"ChangedBody"	Set to TRUE if the recipe body has changed without a subsequent upload to the originating namespace. Note: this attribute is never updated to a namespace. Required only if recipe can be changed or created.	RO	Y	Boolean.	FALSE
"ExecChgCtl"	Preserved. Specifies change control requirements for recipe.	RO	Y	Binary. Bitwise: 1 - may change 2 - change notification required 4 - recipe may be selected after change, 8 - most recent parameter settings shall be saved. Any combination of these four bits is allowed.	0
Optional Attributes					
"AgentSpec_ Comments"	Copied from the original *agent-specific* attribute when downloaded. Set by the user.	RO	N	Text. Maximum length is 80 characters.	-
"ApprovalLevel"	Indicates the level of approval assigned by an *authorized* user.	RO	N	Unsigned integer	0
"Certified"	Preserved from the *agent-specific* attribute as downloaded. May be used as control for production-worthy recipes.	RO	N	Unsigned integer	0
"Comments"	User comments. Preserved from the *generic* attribute as downloaded.	RO	N	Text. Maximum length is 80 characters.	-
"EditedBy"	Preserved unless recipe is modified. The name of the person or *executing agent* who last modified the recipe.	RO	N	Text. Maximum length is 40 characters.	-
"EstRunTime"	The nominal or estimated execution (run) time of the recipe, in seconds. Used for scheduling purposes. Preserved from the *generic* attribute as downloaded.	RO	N	Unsigned integer	0
"ExecLinkParam"	Preserved unless last value is changed (Section 6.7.4). Contains the list of *parameter definitions* including any *agent-specific* modifications. Required for *variable parameter* support.	RO	N	Structure composed of parameter name, initial value, and restrictions.	NULL
"LinkList"	Preserved. A complete list of recipe *specifiers* for a *linked recipe set*. Required for multi-part recipe support.	RO	N	List of formatted text.	NULL

Attribute Name	*Definition*	*Acc.*	*Rqmt*	*Form*	*Default Value*
"SrcRcpID"	For a derived *object form* recipe, contains the recipe *identifier* of the original *source form* recipe. Required only for *derived object form* recipes.	RO	N	Formatted text.	NULL
"VerificationID"	Identification code used by the *verifier* of the recipe. May be used to determine out-of-date formats that need to be *re-verified*.	RO	N	Text. Maximum length is 40 characters.	NULL
Non-Standard Attributes					
AgentSpec_UD_*	Preserved from the original *agent-specific* attributed as downloaded.	RO	N	Defined by supplier or user. Text limited to 80 characters.	-
UD_*	Non-standard attribute defined by supplier or *user*. Asterisk indicates the part of the attribute name that is provided in this definition. Shall be preserved exactly except by the entity that defined it.	RO	N	Varies with definition. Text form is limited to 80 characters.	-

Managed Recipe Attribute Definition

Attribute Name	*Description*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"MRcp"
"ObjID"	An identifier derived from Class, Name, and Version. No part of a recipe's identifier shall be changed except through *renaming*.	RO	20	
(other)	Description of the information contained.	RO or RW	Varies with definition.	Varies with definition.
"Name"	A logical name assigned by the user when the recipe is *created* or *renamed*.	RO	20	
"Class"	The recipe's class (e.g., "/PROCESS/" or "/PROCESS/LOADER/").	RO	20	Formatted text: "CLASS/CLASS/../CLASS/"
"Version"	The version of the recipe.	RO	20	
"AttrLength"	The total length of the *generic* attributes, in bytes. *Mandatory*.	RO	5()	
"AttrChgTime"	Timestamp of the last change to a *generic* attribute. *Mandatory*.	RO	20	
"BodyLength"	Length of the recipe's body, in bytes. *Mandatory*.	RO	5()	
"EditTime"	Timestamp of when the *body* was *created* or last *updated*. *Mandatory*.	RO	20	*Timestamp* format: "YYYYMMDDhhmmsscc"
"BodyFormat"	Indicates the form and format of the recipe's *body*. *Default* is zero.	RO	52	0 = source, 1 = object, >1 reserved.
"Verified"	Indicates whether the recipe's body is syntactically correct. Reset when the recipe is *created* or *updated*. Default is FALSE.	RO	11	
"Linked"	Indicates whether the recipe is linked. Reset when the recipe is *originated*, *verified*, or *unlinked*. Default is FALSE.	RO	11	
"ApprovalLevel"	Indicates the level of approval assigned by an *authorized user*. *Default* is zero. Reset when the recipe is *originated* or *linked*. For a *linked* recipe, may not be higher than any of its *subrecipes*.	RW	52	

Attribute Name	*Description*	*Access*	*Format*	*Value*
"Comments"	User comments.	RW	20	Maximum length is 80 characters.
"EditedBy"	The name of the person who last edited the recipe.	RO	20	Maximum length is 40 characters.
"EstRunTime"	The nominal or estimated execution (run) time of the recipe, in seconds. Reset when the recipe, is *created* or *updated*. Set when the recipe is *verified*. May be recalculated to total time for a *main* recipe when *linked*. Used for scheduling purposes. Algorithm for calculation shall be documented. Default is 0.	RW	54	
"ExecChgCtrl"	Specifies change control requirements for recipe. Default is 0. Combinations of bits are used to indicate multiple permissions.	RW	10	Binary. Bitwise (MSB = 8): 1 - the recipe body may be changed 2 - change notification required 4 - recipe may be selected after change, 8 - most recent parameter settings shall be saved. Any combination of these four bits is allowed
"ExtRef"	A list of all recipe *specifiers* as referenced within the recipe. Explicit *versions* not required. Reset when the recipe is *created*, *updated*, and *verified*.	RO	00	List of items of format 20.
"LinkList"	A complete list of recipe *specifiers* found in the ExtRef attribute of a *main* recipe and all of its *subrecipe*s, with duplicates removed and all *versions* explicitly determined. Set for the *main* recipe when linked. Reset when the recipe is *originated* or *verified*. Required for multi-part recipe support.	RO	00	List of items of format 20.
"LinkParam"	A list of all variable parameter definitions contained in the Parameters attribute of a *main* recipe and all of its *subrecipes*, with duplicates removed. Reset when the recipe is *created*, *updated*, or *verifie*d. Set when the recipe is *linked*. Required for *variable parameter* support.	RO	00	List of parameter definition structures composed of parameter name, initial value, and restrictions.
"Parameters"	A list of variable parameter definitions contained in the recipe. Reset when the recipe is *created*, *updated*, and *verified*. Set when the recipe is *verified*. Required only for *variable parameter* support.	RO	00	List of parameter definition structures composed of parameter name, initial value, and restrictions.
"SrcRecID"	*Identifier* of the *source form* recipe from which a *derived object form* recipe is derived. Value determined by the *verifier* of the recipe. Required only for support of *derived object form* recipes.	RO	20	
"VerificationID"	Identification code set by the *verifier* of the recipe. May be used to determine out-of-date formats that need to be *re-verified*.	RO	20	Maximum length is 40 characters.
"UD_"	Non-standard attribute defined by supplier or *user*. Asterisk indicates the part of the attribute name that is provided in this definition. Shall be preserved exactly except by the entity that defined it.	RO	10, 11, 20, 3(), 4(), 5()	Text form is limited to a maximum of 80 characters.

Process Job Attributes

Attribute Name	*Description*	*Access*	*Format*	*Related Data Item*	*Value*
"ObjType"	Name of the Object Type	RO	20	-	"PROCESSJOB"
"ObjID"	Identifier of a Process Job	RO	20	PRJOBID	-
"PRMt1Type"	Type of material being processed	RO	20	-	allowed values: "css" "wfr"
"PRMt1NameList"	Process Material Name, identifies material being processed by a job, which could be more than one item.	RO	20	-	(list of) Text
"RecID"	Object Specifier of Recipe used by a Process Job, see SEMI E39 and SEMI E42	RO	20	-	-
"PRRecipeMethod"	Indicates any special handling for a Process Job's Recipe	RO	20	-	allowed values: "STANDARD" "USETUNING"
"PRJobState"	Indicates the current state of a Process Job. The state of a job may be a combination of sub-states and concurrent states.	RO	20	-	Composed from the set: "WAITINGFOR JOB" "JOBQUEUED" "JOB CANCELLED" "JOBACTIVE" "SETUP" "WAITINGFORSTART" "PROCESSING" "NOTPAUSED" "PAUSING" "PAUSED" "NOTSTOPPING" "STOPPING" "NOTABORTING" "ABORTING" "PROCESSCOMPLETE" "JOBCOMPLETE"
"PRProcessStart"	Processing should start automatically after Job is defined when this Boolean is set TRUE	RO	11	-	Boolean

Recipe Executor Attribute Definition

Attribute Name	*Description*	*Access*	*Rqmt*	*Form*
"ObjType"	The object type	RO	Y	Text = "RcpExec"
"ObjID"	Text	RO	Y	Text
"DefaultNamespace"	The name of an *executing agent's name-space* used for all hardware-dependent and other *agent-specific* recipes.	RW	Y	Text
"ProdApprove"	The minimum value of a recipe's *approval level* accepted during productive and standby states. Required for SEMI E10 support only.	RW	N	Unsigned integer
"ProdCertify"	The minimum value of a recipe's *certification level* accepted during productive and standby states. Required for SEMI E10 support only.	RW	N	Unsigned integer
"RunCycleUnit"	The process unit on which the calculation of the estimated value of the recipe *generic attribute* EstRunTime is based.	RO	N	Case-sensitive formatted text composed of a unit of measure and an optional numeric suffix. Compliant with SEMI E5, Section 9.
"RecipeSelectID"	A list of recipe *identifiers* for the currently selected	RO	Y	List of formatted text.

	recipes.			
"RecipeSelect-Parameters"	A list of all *parameter definitions* in effect for the ith recipe *identifier* in RecipeSelectID. The maximum value for i is determined by the equipment supplier as the maximum number of recipes which may be *selected* at the same time. Required if variable parameters are supported.	RO	N	List of structures composed of parameter name, parameter value, parameter restriction.

Recipe Namespace Attribute Definition

Attribute Name	*Definition*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"RNS"
"ObjID"	The *name* of the *namespace*.	RO	20	A name of "Default" is prohibited.
"RecipeReadOnlyLevel"	The level of *approval* at which recipes are *read-only*.	RW	52	
"Members"	The *names* of *agents* capable of *verifying* and *executing* the recipes in the *namespace*.	RW	00	List of items of format 20.

Recipe Namespace Manager Attribute Definition

Attribute Name	*Definition*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"RNS_Mgr"
"ObjID"	The *manager's* name.	RO	20	
"NamespaceName"	The *name* of the *namespace* managed.	RO	20	

Table Attribute Definition

Attribute Name	*Definition*	*Access*	*Format*	*Value*
"ObjType"	The object type.	RO	20	"Table"
"ObjID"	The object's identifier.	RO	20	1-80 characters.
"NumCols"	Number of columns.	RO	5()	Non-zero.
"NumRows"	Number of rows.	RO	5()	Non-zero.
"TableLength"	Total number of bytes required to store the table elements, exclusive of any formatting required for storage.	RO	5()	Non-zero.

Trace Object

Attribute Name	*Description*	*Access*	*Format*	*Related Data Items*	*Value*
"ObjType"	Trace Report Object type	RO	20	-	"TRACE"
"ObjID"	Identifier of a specific Trace Report	RO	20	TRID	-
"Enabled"	Boolean true means the specific Trace Report is enabled.	RW	*	CEED	-
"ReportID"	List or report linked to this Trace Report	RO	20	-	(list of) RPTID
"SamplePeriod"	Time between report samples given in floating point seconds.	RW	4 ()	TRSPER	-
"TotalSamples"	The maximum number of samples that this Trace Report will perform.	RW	*	TOTSMP	-
"GroupSize"	Number of trace reports to be grouped before a report is sent.	RW	*	REPGSZ	-
"StartEventID"	Identifier of the event which starts trace reporting.	RW	20	CEID	-

“StartEvtSrcSpec”	Source for the start event	RW	20	EVNTSRC	-
“StopEventID”	Identifier of the event which stops trace reporting.	RW	20	CEID	-
“StopEvtSrcSpec”	Source for the stop event	RW	20	EVNTSRC	-
“AutoDelete”	Boolean true means this report is deleted when reporting is complete.	RW	11	TRAUTOD	-
“ReportChangeOnly”	Boolean, if true, then trace reports are sent only if at least one of the reported variables changes.	RW	11	RPTOC	-

attribute name — A reserved text string, of at most 40 characters, that is unique for that object.

description — A description of the attribute.

access — Indicates whether the attribute may be set through messages. Access is either read-only (RO) or read-write (RW).

format — Indicates the type of data (format code).

timestamp format — Text form indicating date and time in the format “YYYYMMDDhhmmsscc”.

related data items — Indicates an explicit relationship with a corresponding data item.

value — Specifies any restrictions on the possible values. Examples of restrictions include exclusion of zero for format 5(), a maximum length for text, a format imposed on text, an order imposed on a list, or an enumerated set of valid values.

Requirements:

- The attributes “ObjType” and “ObjID” are required for all object definitions and shall use format 20.
- The attribute “ObjType” shall be assigned a fixed value for each object.
- The value of “ObjID” may not be changed by using SetAttr (S14F3).

The value of “ObJType” may be used for messages using the data item OBJTYPE. The value of the attribute “ObjID” may be used for messages using the data item OBJID.

The name of a public attribute may be used for messages using the data item ATTRID. The value of a public attribute may be used for messages using the data item ATTRDATA.

Variable data items defined in Section 6.7 may be regarded as attributes of the object type “Equipment”, where SVs and DVVALs are RO and ECVs are RW.

6.9 With the use of Harel[4] state diagrams to describe the behavior of objects, an object’s state must be describable as a combination of a set of sub-states and concurrent states. The rules for describing the state of an object are: (1) use the comma (',') to deliminate concurrent states, (2) use the foreslash ('/') to delimit super-state and sub-state, (3) to deliver the set of lowest level concurrent states, and (4) optionally omit super-state names when there are no ambiguities in the names of the lowest level states.

Please refer to Figure 1 in order to follow the discussions for the notations. In Harel notation, 'pump' and 'vacuum' are concurrent states. The text to specify this relation in a response to a request for state is 'pump, vacuum'. The comma can be read as meaning 'and'. 'on' and 'off' are sub-states of 'pump'. 'vent', 'rough', and 'Hi-V' are sub-states of 'vacuum'. The sub-state syntax is 'state/sub-state' where the '/' can be read as 'in sub-state'. So using the example in Figure 1, if the pump is off and the vacuum is vented, then the text message which conveys this is ‘pump/off, vacuum/vent’. This message can be shortened to ‘off,vent’ because there is no ambiguity in doing so.

4 Harel D. “Statecharts: A Visual Formalism for Complex Systems”, Science of Computer Programming, 8, 1987, pp. 231-274. Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elvesier.nl/homepage/browse.htt

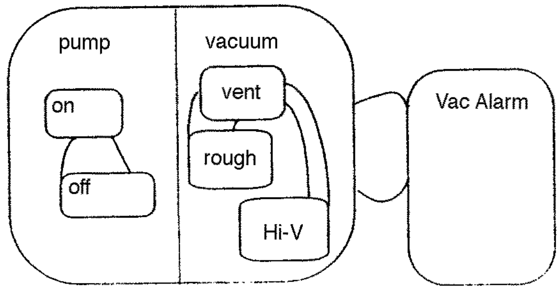


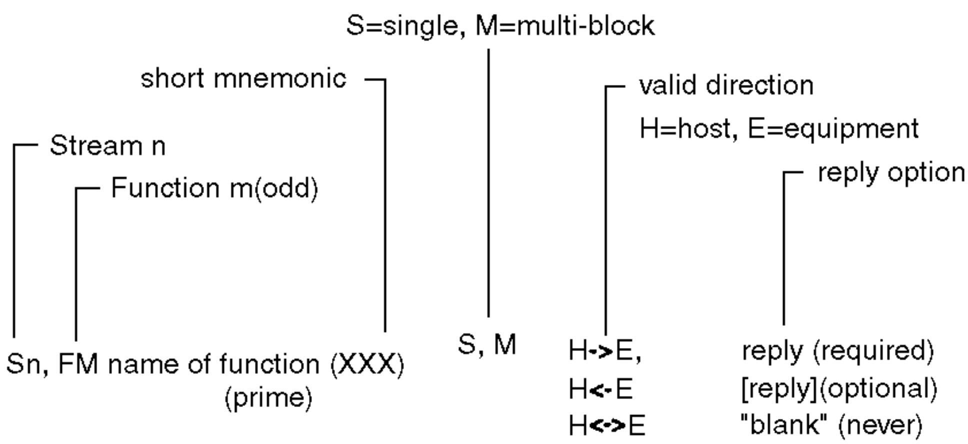
Figure 3
State Chart Example

7 Message Detail

7.1 *Intent* — This section defines a number of specific functions in different streams which can be used as a basis for communication between host and equipment. The functions are defined in the form of transaction message pairs according to the transaction level requirements specified in Section 5.

7.2 The functions are described in a standard form which involves specification of the number, name, single or multiple block, direction of communication, nature of reply required, description, variable definition, and the detailed structure of the message in terms of lists and items. Double lines separate streams, and single lines separate transactions to aid readability.

7.2.1 The abbreviations used in each transaction are as follows:



Description: A description of the action generated by the function.

Structure:
Detailed structure showing lists and defined items. Lists are denoted by a capital L followed by the length separated by a comma. The individual elements in the list are numbered on separate lines. Nested lists are indented to emphasize the structure. The detailed form of the items is given in the define section at the beginning of the transaction. The symbols "<" and ">" are used to enclose each item in the structure data and imply that there is an item header. A detailed description of each data item as well as a list of the allowable data formats can be found in the Data Item Dictionary.

Exception:
Special cases in the structure that have a different meaning.

Sn,Fm+ 1 Name of function (secondary) (same structure as above except never with reply)

7.3 *Message Usage* — This section discusses message features and where they may be used.

7.3.1 *Zero Length Items and Lists* — Certain message definitions may use zero length data items and zero length lists as a technique to convey specific information to the receiver of the message. For commands (i.e., “Do Something”) and requests (i.e., “Return Some Data”), it may be used to mean “Use default values for the data item(s) which were not included”. The default may be a specific value or a value chosen by the equipment.

7.3.1.1 For messages reporting data (either responses to requests or asynchronous reports), the technique may be used to indicate that the desired information is not available or not applicable. In some cases, the fact that data is unavailable may indicate success or failure of a command.

7.3.1.2 Certain message definitions may define a zero length data item or a zero length list to mean “the information is not supplied.” The receiving party should react to this lack of information as it deems appropriate.

7.3.2 *Compliance to Message Definitions* — Any given standard SECS-II message shall comply to the format shown in the Message Definition for that Stream and Function. Specifically:

1. The message shall contain all Lists and Data Items shown as required in the Message Definition.
2. The message shall not contain any Lists or Data Items not shown in the Message Definition, unless the Message Definition specifically allows this.
3. The message shall not contain any List Item or Data Item with zero length unless the Message Definition specifically defines a meaning for such a zero length item.

7.4 *Stream 0 and Function 0* — Stream 0 is always defined as not used since a 0 is the most likely error. No functions are defined in stream 0.

7.4.1 Function 0 exists in all streams and has the same special meaning in each stream. A function 0 message closes a transaction, so that the originator will not have to wait for a transaction timeout to proceed. Function 0 is sent in lieu of the expected secondary message when the interpreter cannot, because of a transmission error or some other reason, respond with the expected reply. It is not a requirement that the interpreter send function 0 to close a transaction.

7.5 *Stream 1 Equipment Status* — This stream provides a means for exchanging information about the status of the equipment, including its current mode, depletion of various consumable items, and the status of transfer operations.

S1,F0 Abort Transaction (S1F0) S,H<->E

Description: Used in lieu of an expected reply to abort a transaction. Function 0 is defined in every stream and has the same meaning in every stream.

Structure: Header only

S1,F1 Are You There Request (R) S,H<->E,reply

Description: Establishes if the equipment is on-line. A function 0 response to this message means the communication is inoperative. In the equipment, a function 0 is equivalent to a timeout on the receive timer after issuing S1,F1 to the host.

Structure: Header only

S1,F2 On Line Data (D) S,H<->E

Description: Data signifying that the equipment is alive.

Structure: L,2
1. <MDLN>
2. <SOFTREV>

Exception: The host sends a zero-length list to the equipment.

S1,F3 Selected Equipment Status Request (SSR) S,H->E,reply

Description: A request to the equipment to report selected values of its status.

Structure: The following structure is approved for all item formats and should be used by all new implementations:

L,n
1. <$SVID_1$>
.
.
n. <$SVID_n$>

The following structure is included for compatibility with previous implementations and may only be used for items of format 3() and 5():

<$SVID_1$,...,$SVID_n$>

Exception: A zero-length list (structure 1) or item (structure 2) means report all SVIDs.

S1,F4 Selected Equipment Status Data (SSD) M,H<-E

Description: The equipment reports the value of each SVID requested in the order requested. The host remembers the names of values requested.

Structure: L,n
1. <SV_1>
.
.
n. <SV_n>

Exceptions: A zero-length list item for SV_i means that $SVID_i$ does not exist.

S1,F5 Formatted Status Request (FSR) — S,H->E,reply

Description: A request for the equipment to report the status according to a pre-defined fixed format.

Structure: <SFCD>

S1,F6 Formatted Status Data (FSD) — M,H<-E

Description: The equipment reports the value of status variables according to the SFCD.

Structure: Depends upon the structure specified by the status form.

Exception: A zero-length item means that no report can be made.

S1,F7 Fixed Form Request (FFR) — S,H->E,reply

Description: A request for the form used in S1,F6.

Structure: <SFCD>

S1,F8 Fixed Form Data (FFD) — M,H<-E

Description: The form is returned with the name of each value and the data format item having a zero length as a two-element list in the place of each single item to be returned in S1,F6.

Structure: Depends upon the form being specified.

Exception: A zero-length item means the form is unavailable.

S1,F9 Material Transfer Status Request (TSR) — S,H->E,reply

Description: A request to report the status of all material ports to the host.

Structure: Header only

S1,F10 Material Transfer Status Data (TSD) — M,H<-E

Description: The equipment reports to the host the transfer status of all material ports.

Structure: L,2

1. <$TSIP_1$,...,$TSIP_n$>
2. <$TSOP_1$,...,$TSOP_n$>

Exception: A zero-length item means there are no such ports. A zero-length list means there are no ports.

S1,F11 Status Variable Namelist Request (SVNR) S,H->E,reply

Description: A request to the equipment to identify certain status variables.

Structure: L,n
1. <SVID$_1$>
.
.
n. <SVID$_n$>

Exception: A zero length means report all SVIDs.

S1,F12 Status Variable Namelist Reply (SVNRR) M,H<-E

Description: The equipment reports to the host the name and units of the requested SVs.

Structure: L,n
- 1. L,3
  - 1. <SVID$_1$>
  - 2. <SVNAME$_1$>
  - 3. <UNITS$_1$>
- 2. L,3
- .
- .
- n. L,3
  - 1. <SVID$_n$>
  - 2. <SVNAME$_n$>
  - 3. <UNITS$_n$>

Exceptions: Zero-length ASCII items for both SVNAME$_i$ and UNITS$_i$ indicates that the SVID does not exist.

S1,F13 Establish Communications Request (CR) S,H<->E,reply

Description: The purpose of this message is to provide a formal means of initializing communications at a logical application level both on power-up and following a break in communications. It should be the following any period where host and Equipment SECS applications are unable to communicate. An attempt to send an Establish Communications Request (S1,F13) should be repeated at programmable intervals until an Establish Communications Acknowledge(S1,F14) is received within the transaction timeout period with an acknowledgement code accepting the establishment.

Structure: L,2
1. <MDLN>
2. <SOFTREV>

Exception: The host sends a zero-length list to the equipment.

S1,F14 Establish Communications Request Acknowledge (CRA) S,H<->E

Description: Accept or deny Establish Communications Request (S1,F13). MDLN and SOFTREV are on-line data and are valid only if COMMACK = 0.

Structure:
```
L,2
  1. <COMMACK>
  2. L,2
       1. <MDLN>
       2. <SOFTREV>
```

Exception: The host sends a zero-length list for item 2 to the equipment.

S1,F15 Request OFF-LINE (ROFL) S,H->E,reply

Description: The host requests that the equipment transition to the OFF-LINE state.

Structure: Header only

S1,F16 OFF-LINE Acknowledge (OFLA) S,H<-E

Description: Acknowledge or error

Structure: <OFLACK>.

S1,F17 Request ON-LINE (RONL) S,H->E,reply

Description: The host requests that the equipment transition to the ON-LINE state.

Structure: Header only

S1,F18 ON-LINE Acknowledge (ONLA) S,H<-E

Description: Acknowledge or error

Structure: <ONLACK>.

Macro Level Messages

S1,F19 Get Attribute (GA) S,H<—>E,reply[5]

Description: Request for attribute data relating to the specified object or entity within the equipment.

Structure: L,3
  1.<OBJTYPE>
  2.L,m [m=number of objects for which attributes requested]
    1.<$OBJID_1$>
    .
    .
    m.<$OBJID_m$>
  3.L,n [n=number of attributes requested for each object]
    1.<$ATTRID_1$>
    .
    .
    n.<$ATTRID_n$>

Exception: A zero-length list (m=0) is a request for attributes of all objects of the specified type.
A zero-length list (n=0) is a request for all attributes of the object(s)to be returned in a predefined order.

5 Material Movement Management used only the Host to Equipment direction for this message. However, both directions are included for future compatibility with Recipe Management and other future services.

S1,F20 Attribute Data (AD) M,H<—>E

Description: This message is used to transfer the requested set of object attributes. The order of requested objects and attributes is retained from the primary message.

Structure:

```
L,2
  1. L,m        [m=number of objects for which data is sent]
       1.L,n      [n= number of attributes returned for OBJID1]
           1.<ATTRDATA1>
           .
           .
           n.<ATTRDATAn>
       .
       .
       m.L,n      [n= number of attributes returned for OBJIDm]
           1.<ATTRDATA1>
           .
           .
           n.<ATTRDATAn>
  2. L,p        [p=# errors reported]
       1.L,2
           1.<ERRCODE1>
           2.<ERRTEXT1>
           .
           .
       p.L,2
           1.<ERRCODEp>
           2.<ERRTEXTp>
```

Exception: If m=0, it indicates that the specified OBJTYPE is unknown.
If any n=0, it indicates that the corresponding object was not found.
If any ATTRDATA item is reported as a zero-length item, it indicates that the specified attribute does not exist.
If no errors were found, p=0.

7.6 *Stream 2 Equipment Control and Diagnostics* — Messages which deal with control of the equipment from the host. This includes all remote operations and equipment self-diagnostics and calibration but specifically excludes the control operations which are associated with material transfer (see Stream 4), loading of executive and boot programs (Stream 8), and all file and operating system calls (Streams 10, 13). See also continuations in Stream 17.

S2,F0 Abort Transaction (S2F0) S,H<->E

Description: Same form as S1,F0

S2,F1 Service Program Load Inquire (SPI) S,H<->E,reply

Description: Either the host or equipment wants to send the specified program.

Structure:

```
L,2
  1. <SPID>
  2. <LENGTH>
```

S2,F2 Service Program Load Grant (SPG) S,H<->E

Description: Provides permission to load

Structure: <GRANT>

S2,F3 Service Program Send (SPS) M,H<->E, reply

Description: The data associated with the S2,F1 inquire is sent. If S2,F3 is multi-block, it must be preceded by the S2,F1/S2,F2 Inquire/Grant transaction.

Structure: <SPD>

S2,F4 Service Program Send Acknowledge (SPA) S,H<->E

Description: Acknowledge or error

Structure: <SPAACK>

S2,F5 Service Program Load Request (SPR) S,H<->E,reply

Description: A service program is requested.

Structure: <SPID>

S2,F6 Service Program Load Data (SPD) M,H<->E

Description: A service program is sent.

Structure: <SPD>

Exception: A zero-length item means that the requested program cannot be returned.

S2,F7 Service Program Run Send (CSS) S,H->E,reply

Description: Start the requested program

Structure: <SPID>

S2,F8 Service Program Run Acknowledge (CSA) S,H<-E

Description: Acknowledge or error

Structure: <CSAACK>

S2,F9 Service Program Results Request (SRR) S,H->E,reply

Description: Ask for results of service program

Structure: <SPID>

S2,F10 Service Program Results Data (SRD) — M,H<-E

Description: Get the results back

Structure: <SPR>

Exception: A zero-length item means SPR does not exist.

S2,F11 Service Program Directory Request (SDR) — S,H<->E,reply

Description: There may be more than one service program.

Structure: Header only

S2,F12 Service Program Directory Data (SDD) — S,H<->E

Description: A list of service program names.

Structure:

L,n
  1. <SPID$_1$>
  .
  .
  n. <SPID$_n$>

Exception: If n = 0, there are no service programs.

S2,F13 Equipment Constant Request (ECR) — S,H->E,reply

Description: Constants such as for calibration, servo gain, alarm limits, data collection mode, and other values that are changed infrequently can be obtained using this message.

Structure: The following structure is approved for all item formats and should be used by all new implementations:

L,n
  1. <ECID$_1$>
  .
  .
  n. <ECID$_n$>

The following structure is included for compatibility with previous implementations and may only be used for items of format 3() and 5():

<ECID$_1$, . . . , ECID$_n$>

Exception: A zero-length list (structure1) or item (structure2) means report all ECV's according to a predefined order.

S2,F14 Equipment Constant Data (ECD) M,H<-E

Description: Data Response to S2,F13 in the order requested.

Structure: L,n
1. <ECV$_1$>
2. <ECV$_2$>
.
.
n. <ECV$_n$>

Exceptions: A zero-length list item for ECV$_i$ means that ECID$_i$ does not exist. The list format for this data item is not allowed, except in this case.

S2,F15 New Equipment Constant Send (ECS) S,H->E,reply

Description: Change one or more equipment constants.

Structure: L,n
1. L,2
    1. <ECID$_1$>
    2. <ECV$_1$>
2. L,2
.
.
n. L,2
    1. <ECID$_n$>
    2. <ECV$_n$>

S2,F16 New Equipment Constant Acknowledge (ECA) S,H<-E

Description: Acknowledge or error If EAC contains a non-zero error code, the equipment should not change any of the ECIDs specified in S2F15.

Structure: <EAC>

S2,F17 Date and Time Request (DTR) S,H<->E,reply

Description: Useful to check equipment time base or for equipment to synchronize with the host time base.

Structure: Header only

S2,F18 Date and Time Data (DTD) S,H<->E

Description: Actual time data

Structure: <TIME>

Exception: A zero-length item means no time exists.

S2,F19 Reset/Initialize Send (RIS) S,H->E,reply

Description: Causes equipment to reach one of several predetermined initialized conditions.

Structure: <RIC>

S2,F20 Reset Acknowledge (RIA) S,H<-E

Description: Acknowledge or error

Structure: <RAC>

S2,F21 Remote Command Send (RCS) S,H->E,[reply]

Description: Similar to pressing buttons on the front panel or causes some equipment activity to commence or to cease.

Structure: <RCMD>

S2,F22 Remote Command Acknowledge (RCA) S,H<-E

Description: Acknowledge or error

Structure: <CMDA>

S2,F23 Trace Initialize Send (TIS) M,H->E,reply

Description: Status variables exist at all times. This function provides a way to sample a subset of those status variables as a function of time. The trace data is returned on S6,F1 and is related to the original request by the TRID Multiple trace requests may be made to that equipment allowing it. If equipment receives S2,F23 with the same TRID as a trace function that is currently in progress, the equipment should terminate the old trace and then initiate the new trace. A trace function currently in progress may be terminated by S2,F23 with TRID of that trace and TOTSMP=0.

If S2,F23 is multi-block, it must be preceded by the S2,F39/S2,F40 Inquire/Grant transaction. Some equipment may support only single-Block S6,F1, and may refuse a S2,F23 message which would cause a multi-block S6,F1.

Each equipment shall document its trace performance limits. The Host Computer shall not send an S2,F23 which exceeds the equipment's performance limits, or the equipment may operate incorrectly.

Structure: The following structure is approved for all item formats and should be used by all new implementations:

```
L,5
  1. <TRID>
  2. <DSPER>
  3. <TOTSMP>
  4. <REPGSZ>
  5. L,n
       1. <SVID1>
       .
       .
       n. <SVIDn>
```

The following structure is included for compatibility with previous implementations and may only be used for items whose SVID is format 3() and 5():

```
L,5
  1. <TRID>
  2. <DSPER>
  3. <TOTSMP>
  4. <REPGSZ>
  5. <SVID1, . . . , SVIDn>
```

S2,F24 Trace Initialize Acknowledge (TIA) S,H<-E

Description: Acknowledge or error

Structure: <TIAACK>

S2,F25 Loopback Diagnostic Request (LDR) S,H<->E,reply

Description: A diagnostic message for checkout of protocol and communication circuits. The binary string sent is echoed back.

Structure: <ABS>

S2,F26 Loopback Diagnostic Data (LDD) S,H<->E

Description: The echoed binary string

Structure: <ABS>

S2,F27 Initiate Processing Request (IPR) S,H->E,reply

Description: Host requests equipment to initiate processing of the identified material at the specified location in the machine using the specified process program.

Structure:
```
L,3
  1. <LOC>
  2. <PPID>
  3. L,n
       1. <MID1>
       .
       .
       n. <MIDn>
```

Exception: A zero-length PPID indicates no process program is being specified and the equipment is to take whatever action is appropriate for it to determine the proper program to use. A zero-length MID list indicates no MID is to be associated with the material to be processed.

S2,F28 Initiate Processing Acknowledge (IPA) S,H<-E

Description: Response by equipment to Initiate Processing Request. Returned status indicates whether or not the request was honored by the equipment.

Structure: <CMDA>

S2,F29 Equipment Constant Namelist Request (ECNR) S,H->E,reply

Description: This function allows the host to retrieve basic information about what equipment constants are available in the equipment.

Structure:
```
L,n
  1. <ECID1>
  .
  .
  n. <ECIDn>
```

Exception: A zero-length list means send information for all ECIDs.

S2,F30 Equipment Constant Namelist (ECN) M,H<-E

Description: Data Response

Structure: L,n (number of equipment constants)

```
1. L,6
      1. <ECID_1>
      2. <ECNAME_1>
      3. <ECMIN_1>
      4. <ECMAX_1>
      5. <ECDEF_1>
      6. <UNITS_1>
2. L,6
.
.
n. L,6
      1. <ECID_n>
      2. <ECNAME_n>
      3. <ECMIN_n>
      4. <ECMAX_n>
      5. <ECDEF_n>
      6. <UNITS_n>
```

Exceptions: Zero-length ASCII items for $ECNAME_i$, $ECMIN_i$, $ECMAX_i$, $ECDEF_i$, and $UNITS_i$ indicates that the ECID does not exist.

S2,F31 Date and Time Set Request (DTS) S,H->E,reply

Description: Useful to synchronize the equipment time with the host time base.

Structure: <TIME>

S2,F32 Date and Time Set Acknowledge (DTA) S,H<-E

Description: Acknowledge the receipt of time and date.

Structure: <TIACK>

S2,F33 Define Report (DR) M,H->E,reply

Description: The purpose of this message is for the host to define a group of reports for the equipment.

The type of report to be transmitted is designated by a Boolean "Equipment Constant." An "Equipment Constant Value" of "False" means that an "Event Report"(S6,F11) will be sent, and a value of "True" means that an "Annotated Event Report"(S6,F13) will be sent.
If S2,F33 is Multi-block, it must be preceded by the S2,F39/S2,F40 Inquire/Grant transaction.

Structure:

```
L,2
  1. <DATAID>
  2. L,a                                    # reports
       1. L,2                                 report 1
            1. <RPTID1>
            2. L,b                      #VIDs this report
                 1. <VID1>
                 .
                 .
                 b.<VIDb>
       a. L,2                                 report a
            1. <RPTIDa>
            2. L,c                      #VIDs this report
                 1. <VID1>
                 .
                 .
                 c. <VIDc>
```

Exceptions:
1. A list of zero-length following <DATAID> deletes all report definitions and associated links. See S2,F35 (Link Event/Report).
2. A list of zero-length following <RPTID> deletes report type RPTID. All CEID links to this RPTID are also deleted.

S2,F34 Define Report Acknowledge (DRA) S,H<-E

Description: Acknowledge or error If an error condition is detected the entire message is rejected (i.e., partial changes are not allowed).

Structure: <DRACK>

S2,F35 Link Event Report (LER) M,H->E,reply

Description: The purpose of this message is for the host to link n reports to an event (CEID). These linked event reports will default to 'disabled' upon linking. That is, the occurrence of an event would not cause the report to be sent until enabled. See S2,F37 for enabling reports.

If S2,F35 is Multi-block, it must be preceded by the S2,F39/S2,F40 Inquire/Grant transaction.

Structure:

```
L,2
  1. <DATAID>
  2. L,a                                         # events
       1. L,2                                      event 1
            1. <CEID1>
            2. L,b
                 1. <RPTID1>
                 .
                 .
                 b. <RPTIDb>
       .
       .
       a. L,2                                      event a
            1. <CEIDa>                    # RPTIDS this event
            2.L,c
                1.<RPTID1>
                .
                .
                c. <RPTIDc>
```

Exception: A list of zero length following CEID deletes all report links to that event.

S2,F36 Link Event Report Acknowledge (LERA) S,H<-E

Description: Acknowledge or error If an error condition is detected the entire message is rejected (i.e., partial changes are not allowed).

Structure: <LRACK>

S2,F37 Enable/Disable Event Report (EDER) S,H- >E,reply

Description: The purpose of this message is for the host to enable or disable reporting for a group of events (CEIDs).

Structure:

```
L,2
  1. <CEED>                                        enable/disable
  2. L,n   #CEIDs
       1. <CEID1>
       .
       .
       n. <CEIDn>
```

Exception: A list of zero length following <CEED> means all CEIDs.

S2,F38 Enable/Disable Event Report Acknowledge (EERA) — S,H<-E

Description: Acknowledge or error If an error condition is detected the entire message is rejected, i.e., partial changes are not allowed.

Structure: <ERACK>

S2,F39 Multi-block Inquire (DMBI) — S,H->E,reply

Description: If a S2,F23 S2,F33, S2,F35, S2,F45, or S2,F49 message is more than one block, this transaction must precede the message.

Structure: L,2
- 1. <DATAID>
- 2. <DATALENGTH>

S2,F40 Multi-block Grant (DMBG) — S,H<-E

Description: Grant permission to send multi-block message.

Structure: <GRANT>

S2,F41 Host Command Send (HCS) — S,H->E,reply

Description: The Host requests the Equipment perform the specified remote command with the associated parameters.

Structure: L,2
- 1. <RCMD>
- 2. L,n # of parameters
  - 1. L,2
    - 1. <CPNAME$_1$> parameter 1 name
    - 2. <CPVAL$_1$> parameter 1 value
  - .
  - .
  - n. L,2
    - 1. <CPNAME$_n$>parameter n name
    - 2. <CPVAL$_n$>parameter n value

S2,F42 Host Command Acknowledge (HCA) S,H<-E

```
Description:   Acknowledge Host command or error. If command is not accepted due to
               one or more invalid parameters (i.e., HCACK=3), then a list of
               invalid parameters will be returned containing the parameter name and
               reason for being invalid.

Structure:     L,2
                 1. <HCACK>
                 2. L,n # of parameters
                    1. L,2
                         1. <CPNAME1> parameter 1 name
                         2. <CPACK1> parameter 1 reason
                    .
                    .
                    n. L,2
                         1. <CPNAMEn>parameter n name
                         2. <CPACKn>parameter n reason

Exception:     If there are no invalid parameters, then a list of zero length will
               be sent for item 2.
```

S2,F43 Reset Spooling Streams and Functions (RSSF) S,H->E,reply

```
Description:   This message allows the host to select specific streams and functions
               to be spooled whenever spooling is active.

Structure:     L,m
                 1. L,2
                      1.<STRID1>
                      2. L,n
                           1. <FCNID1>
                           .
                           .
                           n. <FCNIDn>
                      .
                      .
                      m. L,2
                           1. <STRIDm>
                           2. L,n
                              1. <FCNID1>
                              .
                              .
                              . <FCNIDn>

Exceptions:    1. A zero-length list, m=0, turns off spooling for all streams and
                  functions.
               2. A zero-length list, n=0, turns on spooling for all functions for
                  the associated stream.

Notes:         1. Turning off spooling for all functions for a specific stream is
                  achieved by omitting reference to the stream from this message.
               2. Spooling for Stream 1 is not allowed.
               3. Equipment must allow host to spool all primary messages for a
                  stream (except Stream 1).
               4. A defined list of functions for a stream in this message will
                  replace any previously selected functions.
```

S2,F44 Reset Spooling Acknowledge (RSA) M,H<-E

Description: Acknowledge or error

Structure: L,2

1. <RSPACK> (accept or reject)
2. L,m (m = number of streams with errors)
    1. L,3
        1. <$STRID_1$>
        2. <$STRACK_1$> (error in stream)
        3. L,n (n = number of functions in error)
            1. <$FCNID_1$>
            .
            .
            n. <$FCNID_n$>

    .
    .
    m. L,3
        1. <$STRID_m$>
        2. <$STRACK_m$> (error in stream)
        3. L,n (n = number of functions in error)
            1. <$FCNID_1$>
            .
            .
            n. <$FCNID_n$>

Exceptions:

1. If RSPACK=0, a zero-length list, m=0, is given, indicating no streams or functions in error.
2. A zero-length list, n=0, indicates no functions in error for specified stream.

S2,F45 Define Variable Limit Attributes (DVLA) M,H->E,reply

```
Structure:    L,2
              1. <DATAID>
              2. L,m (m=# of variables in this definition)
                   1. L,2
                        1. <VID_1>
                        2. L,n (n=# of limits being defined/changed for VID_1)
                             1. L,2
                                  1. <LIMITID_1>
                                  2. L,p (p={0,2})
                                       1. <UPPERDB_1>
                                       2. <LOWERDB_1>
                                       .
                                       .
                                       n. L,2
                                            1. <LIMITID_n>
                                            2. L,p (p={0,2})
                                                 1. <UPPERDB_n>
                                                 2. <LOWERDB_n>
              .
              .
              m.L,2
                  1. <VID_m>
                  2. L,n (n=# of limits being defined/changed for VID_m)
                       1. L,2
                            1. <LIMITID_1>
                            2. L,p (p={0,2})
                                 1. <UPPERDB_1>
                                 2. <LOWERDB_1>
                            .
                            .
                            n. L,2
                                 1. <LIMITID_n>
                                 2. L,p (p={0,2})
                                      1. <UPPERDB_n>
                                      2. <LOWERDB_n>

Exceptions:   1. A zero-length list, m=0, sets all limit values for all monitored
                 VIDs to "undefined."
              2. A zero-length list, n=0, sets all limits values for that VID to
                 "undefined."
              3. A zero-length list, p=0, sets that limit to "undefined."
```

S2,F46 Variable Limit Attribute Acknowledge (VLAA) M,H<-E

Description: Acknowledge definition of variable limit attributes or report error. If DVLA is not accepted due to one or more invalid parameters (e.g., LIMITACK=3), then a list of invalid parameters is returned containing the variable limit attribute and reason for rejection. If an error condition is detected, the entire message is rejected (i.e., partial changes are not allowed).

Structure:

```
L,2
  1. <VLAACK>
  2. L,m                           (m=number of invalid parameters)
       1. L,3
            1. <VID_1>             (VID with error)
            2.<LVACK_p>            (reason)
            3.L,n {n=0,2}
                1. <LIMITID_1>     (1st limit in error for VID_p)
                2. <LIMITACK_1>    (reason)
       .
       .
       m. L,3
            1. <VID_m>             (VID with error)
            2. <LVACK_m>           (reason)
            3. L,n {n=0,2}
                 1. <LIMITID_1>    (1st limit in error for VID_x)
                 2. <LIMITACK_1>   (reason)
```

Exceptions:

1. A zero-length list, m=0 indicates no invalid variable limit attributes.
2. A zero-length list, n=0 indicates no invalid limit values for that VID.

S2,F47 Variable Limit Attribute Request (VLAR) S,H->E,reply

Description: This message allows the host to query the equipment for current variable limit attribute definitions.

Structure:

```
L,m                                (m=# of VIDs this request)
  1. <VID_1>
  .
  .
  m. <VID_m>
```

Exception: A zero-length list, m=0, requests a list of all VID values that can have variable limit attributes.

S2,F48 Variable Limit Attributes Send (VLAS) M,H<-E

Description: Equipment sends values of requested variable limit attribute definitions in the order requested.

Structure:

```
L,m                               (m=# of VIDs this request)
  1.L,2
      1. <VID1>
      2. L,p {p=0,4}
           1. <UNITS1>
           2. <LIMITMIN1>
           3. <LIMITMAX1>
           4. L,n                 (n=# of limits defined for this VID)
                1. L,3
                     1. <LIMITID1>
                     2. <UPPERDB1>
                     3. <LOWERDB1>
                .
                .
                n. L,3
                     1.<LIMITIDn>
                     2.<UPPERDBn>
                     3.<LOWERDBn>
  .
  .
  m.L,2
      1.<VIDm>
      2. L,p {p=0,4}
           1.<UNITSm>
           2.<LIMITMINm>
           3.<LIMITMAXm>
           4. L,n                 (n=# of limits defined for this VID)
                1. L,3
                     1.<LIMITID1>
                     2.<UPPERDB1>
                     3.<LOWERDB1>
                .
                .
                n. L,3
                     1.<LIMITIDn>
                     2.<UPPERDBn>
                     3.<LOWERDBn>
```

Exceptions:

1. A zero-length list, p=0, indicates that limits are not supported for the VID.
2. A zero-length list, n=0, means no limits are currently defined for the specified variable.

S2,F49 Enhanced Remote Command — M,H->E

Description: The host requests an object to perform the specified remote command with its associated parameters. If multi-block, it shall be preceded by the S2,F39/S2,F40 Multi-Block Inquire/Grant transaction.

Structure:

```
L,4
  1. <DATAID>
  2. <OBJSPEC>
  3. <RCMD>
  4. L,m # of parameter groups
       1. L,2
            1. <CPNAME1> command parameter 1 name
            2. <CEPVAL1> command-enhanced parameter 1 value
       2. L,2
            1. <CPNAME2> command parameter 2 name
            2. <CEPVAL2> command-enhanced parameter 2 value
       .
       .
       .
       .
       m. L,2
            1. <CPNAMEm> command parameter m name
            2. <CEPVALm> command enhanced parameter m value
```

If a specific value of CPNAME is defined to have a CEPVAL defined as a LIST, it shall always be a LIST. If the CEPVAL that is associated to that specific value of CPNAME is defined to be anything other than LIST, it will result in a format error.

Exception: A zero length list, m = 0, indicates that no parameter groups are sent with the command. OBJSPEC can be a null length item.

Notes: 1. If CEPVAL is a LIST, the items that make up that list shall take on one of the following forms: (1) a list of items with an identical format, (2) a LIST of CPNAME, CEPVAL pairs, as illustrated below.

```
A) L,2
     1. <CPNAMEa>
     2. L,m
          1. <CPVALa1>
          2. <CPVALa2>
          .
          .
          .
          .
          .
          .
          m. <CPVALam>
```

```
B) L,2
     1. <CPNAMEb>
     2. L,n
          1. L,2
               1. <CPNAMEb1>
               2. <CEPVALb1>
          .
          .
          n. L,2
               1. <CPNAMEbn>
               2. <CEPVALbn>
```

S2,F50 Enhanced Remote Command Acknowledge M,H<-E

Description: The equipment acknowledges Enhanced Remote Command or reports any error(s). If the command is not accepted due to one or more invalid parameters, (i.e. HCACK = 3), then a list of invalid parameters will be returned containing the parameter name and reason for being invalid.

Structure: L,2
- 1. <HCACK>
- 2. L,n # of parameter groups
  - 1. L,2
    - 1. <CPNAME$_1$>
    - 2. <CEPACK$_1$>
  - .
  - .
  - n. L,2
    - 1. <CPNAME$_n$>
    - 2. <CEPACK$_n$>

7.7 *Stream 3 Materials Status* — The functions of the material status stream are used to communicate information and actions related to material, including carriers and material-in-process, time-to-completion information, and extraordinary material occurrences.

S3,F0 Abort Transaction (S3F0) S,H<->E

Description: Same form as S1,F0.

S3,F1 Material Status Request (MSR) S,H->E,reply

Description: Host requests the device to send the status of all material in process.

Structure: Header only

S3,F2 Material Status Data (MSD) M,H<-E

Description: Material-in-process information is sent from the equipment to the host. There are m locations.

Structure: L,2
- 1. <MF>
- 2. L,m
  - 1. L,3
    - 1. <LOC$_1$>
    - 2. <QUA$_1$>
    - 3. <MID$_1$>
  - 2. L,3
  - .
  - .
  - m. L,3
    - 1. <LOC$_m$>
    - 2. <QUA$_m$>
    - 3. <MID$_m$>

Exception: A zero-length list returned means no such data exists.

S3,F3 Time to Completion Request (TCR) S,H->E,reply

```
Description:   Host requests the equipment to send the time-to-completion of
               operations on all material in possession.

Structure:     Header only
```

S3,F4 Time to Completion Data (TCD) M,H<-E

```
Description:   Time-to-completion information is sent by the equipment to the host.

Structure:     L,2
                 1. <MF>
                 2. L,m
                      1. L,3
                           1. <TTC1>
                           2. <QUA1>
                           3. <MID1>
                      2. L,3
                      .
                      .
                      m. L,3
                           1. <TTCm>
                           2. <QUAm>
                           3. <MIDm>

Exception:     A zero-length list header returned means no such data exists.
```

S3,F5 Material Found Send (MFS) S,H<-E,[reply]

```
Description:   The equipment advises the host that unsolicited material has appeared
               at one of its sensors.

Structure:     L,2
                 1. <MF>
                 2. <QUA>
```

S3,F6 Material Found Acknowledge (MFA) S,H->E

```
Description:   Acknowledge or error

Structure:     <ACKC3>
```

S3,F7 Material Lost Send (MLS) S,H<-E,[reply]

```
Description:   The equipment advises the host that material has disappeared from its
               sensors.

Structure:     L,3
                 1. <MF>
                 2. <QUA>
                 3. <MID>
```

S3,F8 Material Lost Acknowledge (MLA) S,H->E

```
Description:   Acknowledge or error

Structure:     <ACKC3>
```

S3,F9 Material ID Equate Send (IES) — S,H<-E,reply

Description: Provide an alternative name to be used as equivalent to the original material ID.

Structure: L,2
1. <MID>
2. <EMID>

S3,F10 Material ID Equate Acknowledge (IEA) — S,H->E

Description: Acknowledge or error

Structure: <ACKC3>

S3,F11 Material ID Request (MIDR) — S,H<-E,reply

Description: The equipment requests the Material ID of the material at the specified port.

Structure: <PTN>

S3,F12 Material ID Request Acknowledge (MIRA) — S,H->E

Description: The host acknowledges the request for the Material ID. If the use of a request/acknowledge/send/acknowledge conversation is required, it indicated by the acknowledge code MIDRA=2. In this case, the send/ acknowledge transaction is S3,F13, S3,Fl4. A timeout when electing S3,F13 is indicated by S9,F13 or a restart of the conversation, with S3,F11.

Structure: L,3
1. <PTN>
2. <MIDRA>
3. <MID>

Note: For all cases except MIDRA=0 (accepted, <MID> follows), the <MID> will be ignored by the receiver of message S3,F12. When MIDRA=0, a zero-length MID indicates that no MID is available.

S3,F13 Material ID Send (MIS) — S,H->E,reply

Description: The host sends the Material ID of the material at the specified port.

Structure: L,2
1. <PTN>
2. <MID>

Note: A zero-length MID indicates that no MID is available.

S3,F14 Material ID Acknowledge (MIA) — S,H<-E

Description: Acknowledge or error

Structure: <MIDAC>

S3,F15 Materials Multi-Block Inquire (MMBI) — S,H->E,reply

Description: This message requests permission to send a multi-block message based upon a maximum length of the total message. It must be sent prior to sending any multi-block primary message in Stream 3.

Structure: L,2
1. <DATAID>
2. <DATALENGTH>

S3,F16 Materials Multi-Block Grant (MMBG) — S,H< - E

Description: This message grants or denies permission to send a multi-block primary message in Stream 3.

Structure: <GRANT>

S3,F17 Carrier Action Request — M,H->E,reply

Description: This message requests an action to be performed for a specified carrier. If multi-block, this message must be preceded by the S3,F11/F12 transaction.

Structure: L,5
1. <DATAID>
2. <CARRIERACTION>
3. <CARRIERID>
4. <PTN>
5. L,n — n = number of carrier attributes
   1. L,2
      1. <CATTRID$_1$>
      2. <CATTRDATA$_1$>
   .
   .
   n. L,2
      1. <CATTRID$_n$>
      2. <CATTRDATA$_n$>

Exception: If n = 0, then no carrier attributes are included. If CARRIERID is not a zero-length item, then PTN may be omitted (a zero-length item). ATTRID and ATTRDATA may be substituted for CATTRID and CATTRDATA Respectively.

S3,F18 Carrier Action Acknowledge — S,H<-E

Description: This message acknowledges the carrier action request.

Structure:
L,2
  1. <CAACK>
  2. L,n
     1. L,2
        1. <ERRCODE$_1$>
        2. <ERRTEXT$_1$>
     .
     .
     n. L,2
        1. <ERRCODE$_n$>
        2. <ERRTEXT$_n$>

Exception: If n = 0, no errors exist.

S3,F19 Cancel All Carrier Out Request — S,H->E, reply

Description: This message is used to cancel all pending carrier out requests.

Structure: Header only.

S3,F20 Cancel All Carrier Out Acknowledge — S,H<-E

Description: This message acknowledges the Cancel Carrier Out request.

Structure:
L,2
  1. <CAACK>
  2. L,n
     1. L,2
        1. <ERRCODE$_1$>
        2. <ERRTEXT$_1$>
     .
     .
     n. L,2
        1. <ERRCODE$_n$>
        2. <ERRTEXT$_n$>

Exception: If n = 0, no errors exist.

S3,F21 Port Group Definition — S,H->E, reply

Description: This message defines the port in a port group and provides the initial port access.

Structure:
L,3
  1. <PORTGRPNAME>
  2. <PORTACCESS>
  3. L,n
     1. <PTN$_1$>
     .
     .
     n. <PTN$_n$>

S3,F22 Port Group Definition Acknowledge S,H<-E

Description: This message acknowledges the port group definition.

Structure: L,2
1. <CAACK>
2. L,n
 1. L,2
  1. <ERRCODE$_1$>
  2. <ERRTEXT$_1$>
 .
 .
 n. L,2
  1. <ERRCODE$_n$>
  2. <ERRTEXT$_n$>

Exception: If n = 0, no errors exist.

S3,F23 Port Group Action Request S,H->E, reply

Description: This message requests an action be performed for a port group. The access mode may be changed or the port group may be deleted.

Structure: L,3
1. <PGRPACTION>
2. <PORTGRPNAME>
3. L,m
 1. L,2
  1. <PARAMNAME$_1$>
  2. <PARAMVAL$_1$>
 .
 .
 m. L,2
  1. <PARAMNAME$_m$>
  2. <PARAMVAL$_m$>

Exception: If m = 0, then no parameters are provided.

S3,F24 Port Group Action Acknowledge S,H<-E

Description: This message acknowledges the port group action.

Structure: L,2
1. <CAACK>
2. L,n
 1. L,2
  1. <ERRCODE$_1$>
  2. <ERRTEXT$_1$>
 .
 .
 n. L,2
  1. <ERRCODE$_n$>
  2. <ERRTEXT$_n$>

Exception: If n = 0, no errors exist.

S3,F25 Port Action Request — S,H->E, reply

```
Description:   This message requests an action be performed for a port.

Structure:     L,3
                 1. <PORTACTION>
                 2. <PTN>
                 3.  L,m
                       1.  L,2
                             1.  <PARAMNAME1>
                             2.  <PARAMVAL1>
                       .
                       .
                       m.  L,2
                             1.  <PARAMNAMEm>
                             2.  <PARAMVALm>

Exception:     If m = 0, then no parameters are provided.
```

S3,F26 Port Action Acknowledge — S,H<-E

```
Description:   This message acknowledges the port action request.

Structure:     L,2
                 1. <CAACK>
                 2. L,n
                      1. L,2
                           3. <ERRCODE1>
                           4. <ERRTEXT1>
                      .
                      .
                      n. L,2
                           1. <ERRCODEn>
                           2. <ERRTEXTn>

Exception:     If n = 0, no errors exist.
```

S3,F27 Change Access S,H->E, reply

Description: The Host requests the Equipment to change the Access Mode for the specified Load Ports. ACCESSMODE specifies the desired Access Mode. PTN specifies a desired Load Port Number.

```
Structure:    L,2
                 1. <ACCESSMODE>
                 2. L,n
                       1. <PTN1>
                       .
                       .
                       n. <PTNn>
```

Exceptions: If n=0, then the command applies to all Load Ports on the equipment. If any specified port is already in the specified Access Mode, then the Equipment shall accept the command, and toggle all loadports to specified mode. If the Equipment is unable to change one or more of specified Port(s) to the specified Access Mode, then the Equipment shall accept the command (with appropriate response acknowledgement), and shall change only the Access Mode of those Port(s) allowed by the equipment, supplying the host with an indication that not all ports were successfully changed.

S3,F28 Change Access Acknowledge S,H<-E

```
Structure:    L, 2
                 1. <CAACK>
                 2. L, n
                       1. L, 3
                             1. <PTN1>
                             2. <ERRCODE1>
                             3. <ERRTEXT1>
                       .
                       .
                       n. L, 3
                             1. <PTNn>
                             2. <ERRCODEn>
                             3. <ERRTEXTn>
```

Exceptions: If the command is successful, CAACK = 0, and n=0.
If the command was successful for some ports, CAACK = 6, and n>0.

S3,F29 Carrier Tag Read Request — S,H->E, reply

Description: The host requests the equipment to read data from the carrier tag of a carrier. The carrier must be identified either by its location identifier or its carrier identifier, or both. DATASEG may be used to indicate a specific section of data to be read. DATALENGTH is used to limit the amount of data for that section.

Structure:

```
L, 4
   1. <LOCID>
   2. <CARRIERSPEC>
   3. <DATASEG>
   4. <DATALENGTH>
```

Exceptions: Either LOCID and CARRIERSPEC can omitted (zero length item), but not both. If DATASEG and DATALENGTH are both omitted (are zero length items) then all data is requested. If DATALENGTH only is omitted, then all data within the indicated section is requested.

S3,F30 Carrier Tag Read Data (CTRD) — S,H<-E

Description: This message is used to return requested information from the carrier tag of the carrier indicated in the request and to acknowledge the results of the request.

Structure:

```
L, 2
   1. <DATA>
   2. <L, 2>
          1. <CAACK>
          2. L, s
                1. L, 2
                      1. <ERRCODE_1>
                      2. <ERRTEXT_1>
                .
                .
                s. L, 2
                      1. <ERRCODE_s>
                      2. <ERRTEXT_s>
```

Exceptions: If the carrier identifier or the carrier location originally specified is unknown, then DATA is zero length. If CAACK is non-zero, then DATA is zero length.

S3,F31 Carrier Tag Write Data Request (CTWDR) S,H->E, reply

Description: The host requests the equipment to write data to a carrier tag. The carrier must be indicated either by its location identifier or its carrier identifier, or both. DATASEG may be used to indicate a specific section of data to be written or overwritten. DATALENGTH may be used to indicate the length of the data to be written.

```
Structure:    L, 5
                 1. <LOCID>
                 2. <CARRIERSPEC>
                 3. <DATASEG>
                 4. <DATALENGTH>
                 5. <DATA>
```

Exceptions: Either LOCID and CARRIERSPEC can be omitted (zero length item), but not both. If DATASEG and DATALENGTH are both omitted (are zero length items) then all data is to be overwritten. If only DATALENGTH is omitted, then all data within the indicated section is to be written.

S3,F32 Carrier Tag Write Data Acknowledge (CTWDA) S,H<-E

Description: This message acknowledges the success or failure of writing data to the carrier tag requested.

```
Structure:    L, 2
                 1. <CAACK>
                 2. L, s
                       1. L, 2
                             1. <ERRORCODE1>
                             2. <ERRORTEXT1>
                       .
                       .
                       s. L, 2
                             1. <ERRORCODEs>
                             2. <ERRORTEXTs>
```

Exceptions: s = 0 if and only if there are no errors.

S3, F33 Cancel All Pod Out Request

Description: This message is used to cancel all pending pod out requests.

Structure: Header only.

S3,F34 Cancel All Pod Out Acknowledge

```
Description:   This message acknowledges the Cancel Pod Out request.

Structure:     L, 2
                 1. <CAACK>
                 2. L, n
                       1. L, 2
                             1. <ERRORCODE1>
                             2. <ERRORTEXT1>
                       .
                       .
                       n. L, 2
                             1. <ERRORCODEn>
                             2. <ERRORTEXTn>
Exceptions:    If n=0, no errors exist.
```

S3,F35 Reticle Transfer Job Request

```
Description:   This message requests a reticle transfer job be performed (or
cancelled) for a particular pod

Structure:     L, 6
                 1. <PODID>
                 2. <INPTN>
                 3. <OUTPTN>
                 4. L, n               n = number of attributes
                      1. L, 2
                           1. <ATTRID1>
                           2. <ATTRDATA1>
                      .
                      .
                      .
                      n. L, 2
                           1. <ATRRIDn>
                           2. <ATTRDATAn>
                 5. L, m               m = capacity
                      1. L, 3
                           1. <RETICLEID1>
                           2. <RETREMOVEINSTR1>
                           3. L, r     r = number of attributes
                                1. L, 2
                                   1. <ATTRID1.1>
                                   2. <ATTRDATA1.1>
                                .
                                .
                                r. L, 2
                                     1. <ATTRID1.r>
                                     2. <ATTRDATA1.r>
                       .
                       .
                       m. L, 3
                            1. <RETICLEIDm>
                            2. <RETREMOVEINSTRm>
                            3. L, r     r = number of attributes
                                 1. L, 2
                                      1. <ATTRIDm.1>
                                      2. <ATTRDATAm.1>
                                 .
                                 .
                                 r. L, 2
                                      1. <ATTRIDm.r>
                                      2. <ATTRDATAm.r>
                   6. L, m               m = capacity
                        1. L, 2
                             1. <RETICLEID1>
                             2. <RETPLACEINSTR1>
                        .
                        .
                        m. L, 2
                             1. <RETICLEIDm>
                             2. <RETPLACEINSTRm>
```

S3,F36 Reticle Transfer Job Request Acknowledgement

```
Description:    This message acknowledges the ReticleTransferJobRequest

Structure:     L, 2
                 1. <RPMACK>
                 2. L, n
                      1. L, 2
                           1. <ERRCODE1>
                           2. <ERRTEXT1>
                      .
                      .
                      n. L, 2
                           1. <ERRCODEn>
                           2. <ERRTEXTn>
```

7.8 *Stream 4 Material Control* — The material control stream contains the original material control protocol and the newer protocol which supports SEMI E32.

7.8.1 *Original Material Control Protocol* — The functions in the material control stream are used to effect the automatic transfer of material between equipment. A simple handshake is achieved which provides for a variety of error conditions which gracefully terminate the handshake. Separate messages advise the host of errors and completed material transfers.

7.8.1.1 Since the handshake and host messages are separate, the handshake may be achieved transparently through the host or by direct connection between equipment. The host completes the handshake by relaying messages between the equipment. Only a single port is required on the equipment, and the equipment has a simple message handling requirement. When a direct connection is desired, at least three ports are required, the receiving equipment must look like the host with respect to the sending equipment, and message handling in the equipment is significantly more complicated than in the host-only connection. Nevertheless, the direct connection may still be chosen in an attempt to provide operation without a host. Since the host is reasonably transparent in the material handshake, a simple explanation of the handshake may be achieved by just considering the exchange of messages between the sender, the equipment wanting to get rid of material, and the receiver (the equipment able to accept the material).

7.8.1.2 Figure S4.1 shows six possible handshake situations between the sender and the receiver. There are two normal handshakes. Figure S4.1(a) shows the normal three-message exchange when material is passed between equipment. The host is informed of a complete transfer of material. Figure S4.1(b) shows an alternative message exchange where the sender changes its mind and decides not to send the material. Figures S4.1(c) and (d) show two situations where the material gets stuck during the transfer. In each situation an error message is issued to the host from the equipment where the material is stuck. The other equipment terminates normally. When material is stuck, manual intervention is required to move the material towards the equipment which indicates the stuck condition. The manual intervention has two possible outcomes. One, the material can be moved to a position where the handshake can resume or, two, the material is broken or lost from the transfer. Lost material causes a lost material error message to be sent to the host prior to resuming the operation. The specific details of recovering front stuck material are equipment-dependent. The stuck material condition is determined by the amount of time the material transfer mechanism is turned on. The sender claims stuck material if the material is not clear of its sensor before a time t1. The receiver claims stuck material if the material is not received before time t2. Figures S4.1(e) and (f) show the possible error conditions in the unlikely event that for some reason a handshake message is lost. Figure S4.1(e) shows that time t3 is the longest that the sender will wait for material received message. Times t2 and t3 set an upper limit on the amount of time either material transport mechanism will operate.

7.8.1.3 Figure S4.2 summarizes the interaction of the timers, handshake messages, and the error messages in the form of a flow chart. It also identifies specific states for the sender and the receiver. These states are referred to in the messages.

The ranges of timer values are as follows:

tl — time to leave sender

tl+ 10<= t2<= 60sec.---time to receive

t2+ 10<= t3<= 70sec.---time to complete send

Default values, tl= 10 sec., t2= 60 sec., t3= 70 sec.

NOTE 7: t1, t2, t3 defined for Stream 4 are not to be confused with timeouts T1, T2, T3, and T4 defined in SEMI E4 (SECS-I).

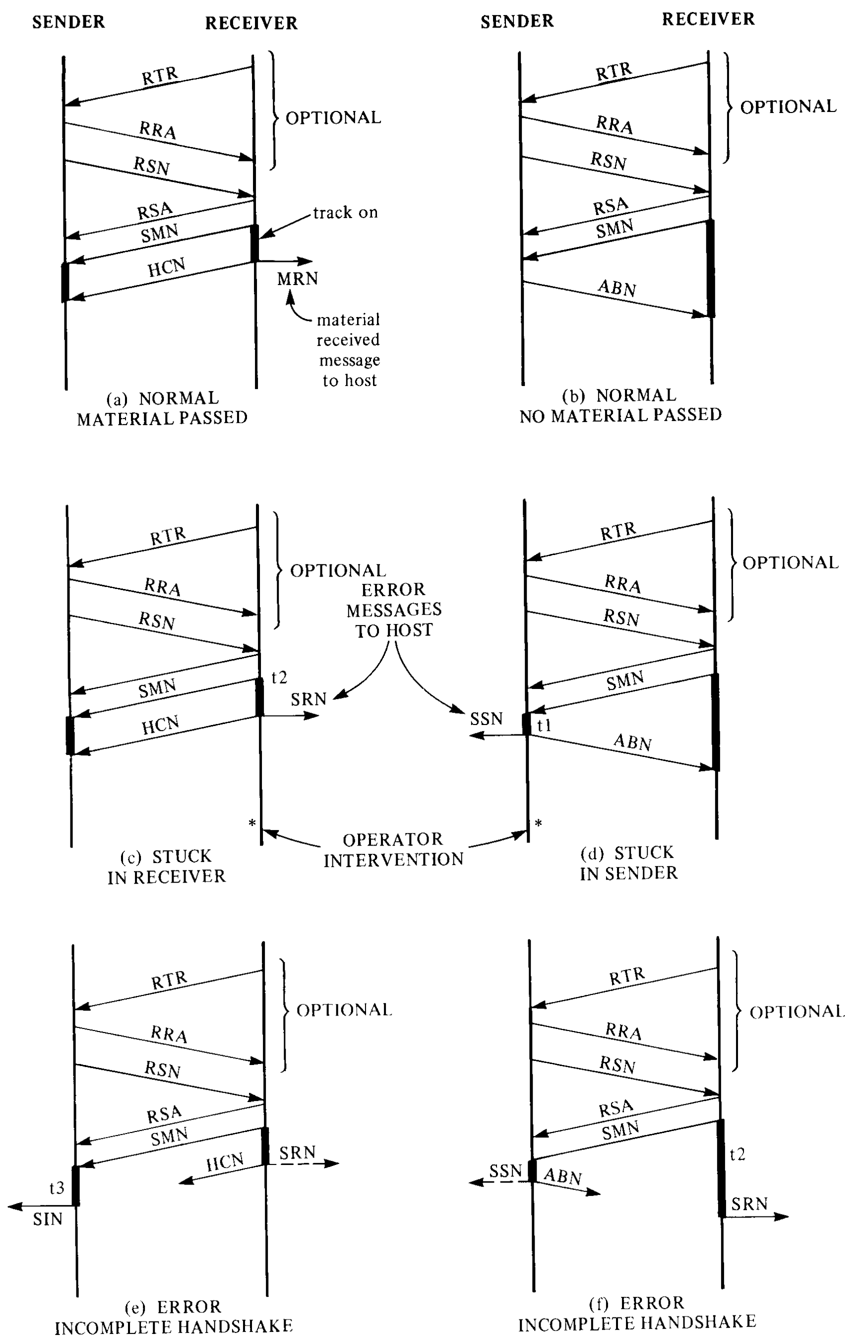


Figure S4.1
The Six Possible Handshakes

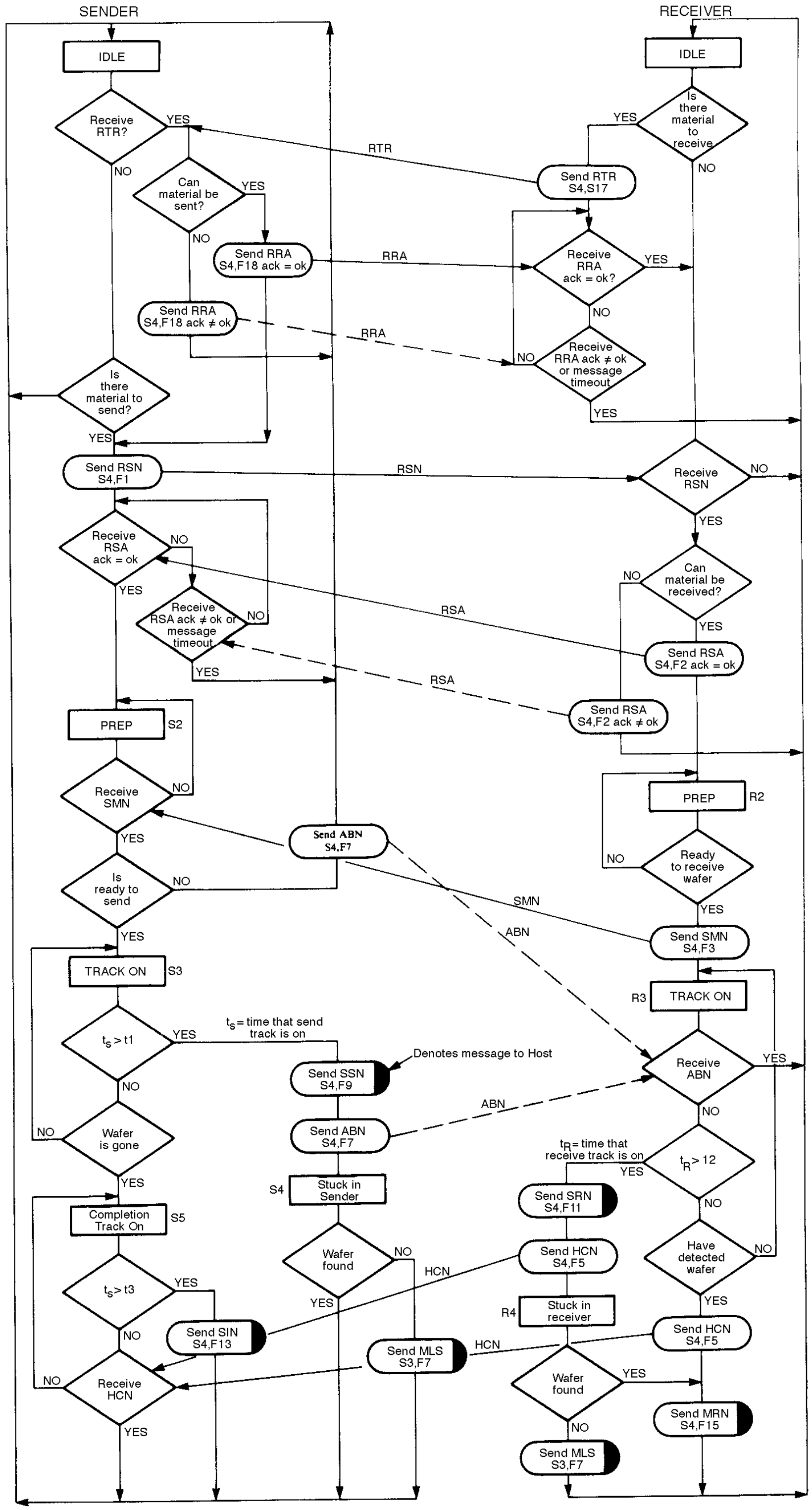


Figure S4.2
Material Control-Handshake Flowchart

S4,F0 Abort Transaction (S4F0) S,H->E

```
Description:   Same form as S1,F0.
```

S4,F1 Ready to Send Materials (RSN) S,H<->E,reply

```
Description:   The sender advises the receiver that some material is awaiting
               transfer.

Structure:     L,2
                 1. <PTN>
                 2. <MID>
```

S4,F2 Ready to Send Acknowledge (RSA) S,H<->E

```
Description:   Acknowledge or error

Structure:     <RSACK>
```

S4,F3 Send Material (SMN) S,H<->E

```
Description:   The receiver advises the sender that it is ready to receive material
               and that its transfer mechanism is running.

Structure:     L,2
                 1. <PTN>
                 2. <MID>
```

S4,F4 Not Used

S4,F5 Handshake Complete (HCN) S,H<->E

```
Description:   Receiver advises sender that the handshake is complete. The sender
               may now stop its transfer mechanism.

Structure:     L,2
                 1. <PTN>
                 2. <MID>
```

S4,F6 Not Used

S4,F7 Not Ready to Send (ABN) S,H<->E

```
Description:   Sender advises receiver that no material is being sent. The receiver
               may now stop its transfer mechanism.

Structure:     L,2
                 1. <PTN>
                 2. <MID>
```

S4,F8 Not Used

S4,F9 Stuck in Sender (SSN) S,H<-E

Description: An error from the sender to the host. The time between the receipt of Material (SMN) and the material leaving the sender's sensor exceeds the sender's t1 timeout. The sender goes to a hold state until the disposition of the stuck material is determined.

Structure: L,2
1. <PTN>
2. <MID>

S4,F10 Not Used

S4,F11 Stuck in Receiver (SRN) S,H<-E

Description: An error from the receiver to the host. The time between Send Material (SMN) and detection of the material at the receiver exceeds the receiver's t2 timeout. The receiver goes to a hold state until the disposition of material is determined.

Structure: L,2
1. <PTN>
2. <MID>

S4,F12 Not Used

S4,F13 Send Incomplete Timeout (SIN) S,H<-E

Description: An error from the sender to the host. The time between the receipt of the Send Material (SMN) and the receipt of Handshake-Complete (HCN) exceeds the sender's t3 timeout. There has been an error in the handshake and the transfer mechanism is turned off.

Structure: L,2
1. <PTN>
2. <MID>

S4,F14 Not Used

S4,F15 Material Received (MRN) S,H<-E

Description: A message from the receiver to the host. Material has been transferred to the receiver.

Structure: L,2
1. <PTN>
2. <MID>

S4,F16 Not Used

S4,F17 Request to Receive (RTR) S,H<->E,reply

Description: Receiver requests the sender initiate a conversation to send the specified material to the specified port.

Structure: L,2
1. <PTN>
2. <MID>

Exceptions: A zero-length MID means equipment doesn't know MID.

S4,F18 Request to Receive Acknowledge (RRA) S,H<->E

Description: Acknowledge or error

Structure: <RRACK>

7.8.2 *Support for Material Movement Management Services* — The following messages were defined to support SEMI E32.

7.8.2.1 *Macro Level Messages* — The following messages support the host supervised macro level of material movement as defined in SEMI E32. Stream 1 Macro Level Messages can be found in Section 7.5: S1F19, Get Attribute (GA); S1F20, Attribute Data (AD).

S4,F19 Transfer Job Create (TJ) M,H—>E,reply

Description: The host requests that the equipment undertake one or more discrete (or atomic) transfers to achieve a host defined objective. The host provides the transfer specifications for each atomic transfer. Atomic transfers on separate ports on the equipment are allowed to execute in parallel. Atomic transfers for a port must be executed sequentially or in some cases concurrently. Both equipment transfer partners for each atomic transfer must receive appropriate Transfer Job Request messages in order to execute a transfer. If S4,F20 is multi-block, it must be preceded by the S4,F25/S4,F26 Inquire/Grant transaction.

Structure:

```
L,2
  1.<DATAID>
  2.L,2
      1.<TRJOBNAME>
      2.L,n                   [n=#atomic xfrs defined for this job]
          1.L,12              [Specification for first atomic xfr]
               1.<TRLINK>      [Atomic transfer identifier]
               2.<TRPORT>      [Port to be used for transfer]
               3.<TROBJNAME>   [Transfer object identifier]
               4.<TROBJTYPE>   [Object type–what form is the material
                               in]
               5.<TRROLE>      [Role in transfer–primary/secondary]
               6.<TRRCP>       [Transfer recipe identifier]
               7.<TRPTNR>      [Identifier of transfer partner]
               8.<TRPTPORT>    [Partner's Port to be Used]
               9.<TRDIR>       [Transfer direction-send or receive]
              10.<TRTYPE>      [Active or Passive]
              11.<TRLOCATION>  [Location to send/receive mtl]
              12.<TRAUTOSTART> [Does eqp await host start command
                               after setup?]
          .
          .
          n.L,12              [Specification for nth atomic xfr]
               1.<TRLINK]
               ↓
              12.<TRAUTOSTART>
```

S4,F20 Transfer Job Acknowledge (TJA) S,H<—E

Description: The equipment informs the host of its acceptance or rejection of the Transfer Job Request.

Structure: L,3
1.<TRJOBID>
2. L,m [m=number of atomic transfers in the transfer job.]
1.<TRATOMICID$_1$>
.
.
m.<TRATOMICID$_m$>
3. L,2
1.<TRACK> [Accepted or rejected]
2. L,n [n=# errors reported]
1. L,2
1.<ERRCODE$_1$>
2.<ERRTEXT$_1$>
.
.
n. L,2
1.<ERRCODE$_n$>
2.<ERRTEXT$_n$>

Exception: A zero-length list (m=0) is sent if the transfer job is rejected.
A zero-length list (n=0) is sent if the transfer job is accepted.

S4,F21 Transfer Job Command (TC) S,H—>E,reply

Description: This message is used by the host to modify a current transfer job on an equipment.

Structure: L,3
1.<TRJOBID>
2.<TRCMDNAME> [identifier of the transfer command]
3.L,n [n=number of parameters=0 if none]
1.L,2
1.<CPNAME$_1$> [transfer parameter name]
2.<CPVAL$_1$> [transfer parameter value]
.
.
n. L,2
1.<CPNAME$_n$>
2.<CPVAL$_n$>

S4,F22 Transfer Command Acknowledge (TCA) — S,H<—E

Description: Equipment accepts or rejects the transfer command.

Structure: L,2
  1.<TRACK> [Accepted or rejected]
  2. L,n [n=# errors reported]
    1. L,2
      1.<ERRCODE$_1$>
      2.<ERRTEXT$_1$>
    .
    .
    n. L,2
      1.<ERRCODE$_n$>
      2.<ERRTEXT$_n$>

Exception: If the command is accepted, n=0.

S4,F23 Transfer Job Alert (TJA) — S,H<—E,[reply]

Description: Equipment informs the host that a transfer job milestone has been reached (e.g., job started or job complete). If complete, all equipment resources originally reserved for the transfer have been released.

Structure: L,4
  1.<TRJOBID>
  2.<TRJOBNAME>
  3.<TRJOBMS>
  4. L,2
    1.<TRACK> [success or failure]
    2. L,n [n=# errors reported]
      1. L,2
        1.<ERRCODE$_1$>
        2.<ERRTEXT$_1$>
      .
      .
      n. L,2
        1.<ERRCODE$_n$>
        2.<ERRTEXT$_n$>

Exception: If the transfer job is completed successfully, n=0.

S4,F24 Transfer Alert Acknowledge (TLA) — S,H—>E

Description: Acknowledge receipt of the S4,F23 message.

Structure: Header Only

S4,F25 Multi-block Inquire (MB14) S,H—>E,reply

```
Description:   If a Stream 4 host-initiated message is more than a single block in
               length, this transaction must precede the message.

Structure:     L,2
                 1.<DATAID>
                 2.<DATALENGTH>
```

S4,F26 Multi-block Grant (MBG4) S,H<—E

```
Description:   Grant (or deny) permission to send multi-block message.

Structure:     <GRANT>
```

7.8.2.2 *Micro Level Messages* — The following messages support the equipment-to-equipment micro level handoff of material as defined in SEMI E32.

7.8.2.2.1 The messages which support the micro level are passed directly between the equipment. For the purpose of the communication link, one of the equipment must be designated the host and the other the equipment. The choice is up to the implementer. Equipment which are configurable to act as either host or equipment are suggested for ease of installation.

7.8.2.2.2 The two equipment involved in a micro level transfer assume different roles. One equipment is designated the " Primary Transfer Partner," and the other is the " Secondary Transfer Partner" (see SEMI E32 for more definition). While some consistency of roles is expected, this designation is fluid and may change from one transfer to the next. The Primary Transfer Partner has more responsibility and thus initiates messages which the Secondary does not.

7.8.2.2.3 The selection of " Host" and " Equipment" for the communication link is not related to the fluid relationship of Primary and Secondary Transfer Partner. However, it is the designation of Primary or Secondary which determines the originator of certain messages. It is for this reason that the designation P = Primary and S = Secondary Transfer Partner.

Micro Level Messages

S4,F27 Handoff Ready (HR) S,P<—>S

```
Description:   Each transfer partner informs the other when they are ready to
               perform a specified atomic transfer. The TRLINK values from the two
               partners must match. The values contained in the atomic transfer
               specification pertain to the sender of the message (except where
               specified).

Structure:     L,2
                 1.<EQNAME>
                 2.L,11               [Specification for atomic xfr]
                      1.<TRLINK>      [Atomic transfer identifier]
                      2.<TRPORT>      [Port to be used for transfer]
                      3.<TROBJNAME>   [Transfer object identifier]
                      4.<TROBJTYPE>   [Object type-what form the material is in]
                      5.<TRROLE>      [Role in transfer-primary/secondary]
                      7.<TRPTNR>      [Identifier of transfer partner]
                      8.<TRPTPORT>    [Partner's Port to be Used]
                      9.<TRDIR>       [Transfer direction-send or receive]
                     10.<TRTYPE>      [Active or Passive]
                     11.<TRLOCATION>  [Location to send/receive mtl]
```

S4,F28 Not Used

S4,F29 Handoff Command (HC) S,P—>S

```
Description:   Command issued by the primary to the secondary transfer partner to
               achieve some physical action.

Structure:     L,4
                 1.<TRLINK>            [Atomic Transfer identifier]
                 2.<MCINDEX>           [Identified this specific Micro Cmd request]
                 3.<HOCMDNAME>         [Requested Micro Cmd]
                 4.L,n                 [n=number of parameters]
                     1.L,2
                         1.<CPNAME1>  [Micro Cmd parameter name]
                         2.<CPVAL1>   [Micro Cmd parameter value]
                     .
                     .
                     n.L,2
                         1.<CPNAMEn>
                         2.<CPVALn>

Exception:     n=0 if no parameters are used.
```

S4,F30 Not Used

S4,F31 Handoff Command Complete (HCC) S,P<—S

```
Description:   Completion status of the micro command. This is sent from the
               secondary to the primary transfer partner when the command is
               completed or terminated.

Structure:     L,3
                 1.<TRLINK>             [Atomic Transfer identifier]
                 2.<MCINDEX>            [Links to specific micro command (S4,F31)]
                 3.L,2
                     1.<HOACK>          [success or failure]
                     2.L,n              [n=# errors reported]
                         1.L,2
                             1.<ERRCODE1>
                             2.<ERRTEXT1>
                         .
                         .
                         n.L,2
                             1.<ERRCODEn>
                             2.<ERRTEXTn>
```

S4,F32 Not Used

S4,F33 Handoff Verified (HV) P<—>S

Description: Sent by the primary transfer partner to inform the secondary that no more micro commands will be issued for this atomic transfer and to request a verification that the transfer is complete and successful. Also sent by the secondary partner following the receipt of this message to verify that the transfer is complete and successful (or to report problems).

Structure:

L,2
  1.<TRLINK>
  2.L,2
    1.<HOACK> [success or failure]
    2.L,n [n=# errors reported]
      1.L,2
        1.<ERRCODE$_1$>
        2.<ERRTEXT$_1$>
      .
      .
      n.L,2
        1.<ERRCODE$_n$>
        2.<ERRTEXT$_n$>

S4,F34 Not Used

S4,F35 Handoff Cancel Ready (HCR) P<—>S

Description: Sent by either transfer partner to cancel a previous Handoff Ready message. This message is valid only before the handoff has begun.

Structure: <TRLINK>

S4,F36 Not Used

S4,F37 Handoff Cancel Ready Acknowledge (HCA) P<—>S

Description: Sent by the receiver of the Handoff Cancel Ready message to accept or deny the cancel. The cancel request is denied if the handoff process has begun.

Structure:

L,2
  1.<TRLINK>
  2.<HOCANCELACK>

S4,F38 Not Used

S4,F39 Handoff Halt (HH) P<—>S

Description: Sent by either transfer partner to cause all transfer related activity of the other to cease immediately. It is used when the equipment or material is at risk of damage.

Structure: <TRLINK>

S4,F40 Not Used

S4,F41 Handoff Halt Acknowledge (HHA) P<—>S

Description: Sent to equipment's transfer partner following completion of halt activities resulting from a previously received S4,F39.

```
Structure:    L,2
                1.<TRLINK>
                2.<HOHALTACK>
```

S4,F42 Not Used

7.9 *Stream 5 Exception Handling* — This stream contains messages regarding binary and analog equipment exceptions. Exceptions are classified into two categories: errors and alarms. Messages S5,F1 through S5,F8 of this section provide basic alarm messages. The messages S5,F9 through S5,F18 provide extended capabilities for Exception Handling. When using messages F1 - F8, alarms may be divided into categories as follows:

1. *personal safety* — Condition may be dangerous to people.
2. *equipment safety* — Condition may harm equipment.
3. *parameter control warning* — Parameter variation outside of preset limits — may harm product.
4. *parameter control error* — Parameter variation outside of reasonable control limits — may indicate an equipment malfunction.
5. *irrecoverable error* — Intervention required before normal use of equipment can resume.
6. *equipment status warning* — An unexpected condition has occurred, but operation can continue.
7. *attention flags* — A signal from a process program indicating that a particular step has been reached.
8. *data integrity* — A condition which may cause loss of data; usually related to Stream 6.

7.9.1 For messages F1 through F8, it will be the equipment' s responsibility to categorize the alarm. Some alarm conditions may cause more than one type of alarm to be issued. For example, a parameter control error on over temperature may also trip a protective device that makes the alarm irrecoverable without some intervention.

S5,F0 Abort Transaction (S5F0) S,H<->E

Description: Same form as S1,F0.

S5,F1 Alarm Report Send (ARS) S,H<-E,[reply]

Description: This message reports a change in or presence of an alarm condition. One message will be issued when the alarm is set and one message will be issued when the alarm is cleared. Irrecoverable errors and attention flags may not have a corresponding clear message.

```
Structure:    L,3
                1. <ALCD>
                2. <ALID>
                3. <ALTX>
```

S5,F2 Alarm Report Acknowledge (ARA) S,H->E

Description: Acknowledge or error

Structure: <ACKC5>

S5,F3 Enable/Disable Alarm Send (EAS) S,H->E,[reply]

Description: This message will change the state of the enable bit in the equipment. The enable bit determines if the alarm will be sent to the host. Alarms which are not controllable in this way are unaffected by this message.

Structure: L,2
  1. <ALED>
  2. <ALID>

Exception: A zero-length item for ALID means all alarms.

S5,F4 Enable/Disable Alarm Acknowledge (EAA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC5>

S5,F5 List Alarms Request (LAR) S,H->E,reply

Description: This message requests the equipment to send binary and analog alarm information to the host.

Structure: <$ALID_1$, . . . ,$ALID_n$>

Exception: A zero-length item means send all possible alarms regardless of the state of ALED.

S5,F6 List Alarm Data (LAD) M,H<-E

Description: This message contains the alarm data known to the equipment. There are “m” alarms in the list.

Structure: L,m
  1. L,3
      1. <$ALCD_1$>
      2. <$ALID_1$>
      3. <$ALTX_1$>
  2. L,3
  .
  .
  m. L,3
      1. <$ALCD_m$>
      2. <$ALID_m$>
      3. <$ALTX_m$>

Exception: If m=0, no response can be made. A zero-length item returned for $ALCD_i$ or $ALTX_i$ means that value does not exist.

S5,F7 List Enabled Alarm Request (LEAR) S,H->E,reply

Description: List alarms which are enabled.

Structure: Header only

S5,F8 List Enabled Alarm Data (LEAD) M,H<-E

Description: This message is similar to S5,F6 except that it lists only alarms which are enabled.

Structure: Same as S5,F6

S5,F9 Exception Post Notify (EXPN) S,H<-E,[reply]

Description: This message provides the means to inform a host system that an exception condition is 'set'. Optionally, recovery actions for the exception may be sent.

Structure:

```
L,5
  1. <TIMESTAMP>
  2. <EXID>
  3. <EXTYPE>
  4. <EXMESSAGE>
  5. L,n
       1. <EXRECVRA1>
       .
       .
       .
       n. <EXRECVRAn>
```

Exception: A zero-length list (n = 0) shall be sent when there are no possible recovery actions.

Exception: This is a single block message. The text in each of the EXRECVRA data items may need to be restricted in length to meet the single block requirement.

S5,F10 Exception Post Confirm (EXPC) S,H->E

Description: Host confirms receipt of S5,F9 message from the equipment.

Structure: Header only

S5,F11 Exception Clear Notify (EXCN) S,H <-E,[reply]

Description: This message provides the means to inform a host system that an exception/alarm condition is no longer active (set).

Structure:

```
L,4
  1. <TIMESTAMP>
  2. <EXID>
  3. <EXTYPE>
  4. <EXMESSAGE>
```

Exception: EXMESSAGE can be used to provide the reason that the exception cleared.

S5,F12 Exception Clear Confirm (EXCC) S,H->E

Description: Host confirms receipt of S5,F11 message from the equipment.

Structure: Header only

S5,F13 Exception Recover Request (EXRR) S,H->E,reply

Description: Request that the entity which is experiencing an error execute a recovery action.

Structure:
```
L,2
  1. <EXID>
  2. <EXRECVRA>
```

S5,F14 Exception Recover Acknowledge (EXRA) S,H<-E

Description: The entity indicates a response to the recovery request.

Structure:
```
L,2
  1. <EXID>
  2. L,2
       1. <ACKA>
       2. L,m (m = {0,2})
            1. <ERRCODE>
            2. <ERRTEXT>
```

Exception: The list m can be zero length, if the recovery request was accepted.

S5,F15 Exception Recovery Complete Notify (EXRCN) S,H<-E,[reply]

Description: Allows the service provider to inform the controller/host that the recovery operation completed on a specific exception and an error code if the recovery terminated abnormally.

Structure:
```
L,3
  1. <TIMESTAMP>
  2. <EXID>
  3. L,2
       1. <ACKA>
       2. L,m (m = {0,2})
            1. <ERRCODE>
            2. <ERRTEXT>
```

Exception: This list m can be of zero length if the recovery was successful.

S5,F16 Exception Recovery Complete Confirm (EXRCC) S,H->E

Description: Host confirms receipt of S5,F15 message from the equipment.

Structure: Header only

S5,F17 Exception Recovery Abort Request (EXRAR) S,H->E,reply

Description: Stop the recovery procedure on a specific exception.

Structure: 1. <EXID>

S5,F18 Exception Recovery Abort Acknowledge (EXRAA) S,H<-E

```
Description:   Indicate the success of the request for Recovery Abort.

Structure:     L,2
                 1. <EXID>
                 2. L,2
                      1. <ACKA>
                      2. L,m (m = {0,2})
                           1. <ERRCODE>
                           2. <ERRTEXT>

Exception:     The list m can be of zero length if the abort was successful.
```

7.10 *Stream 6 Data Collection* — This stream is intended to cover the needs of in-process measurements and equipment monitoring.

S6,F0 Abort Transaction (S6F0) S,H<->E

```
Description:   Same form as S1,F0.
```

S6,F1 Trace Data Send (TDS) M,H<-E,[reply]

```
Description:   This function sends samples to the host according to the trace setup
               done by S2,F23. Trace is a time-driven form of equipment status.

               Even if S6,F1 is multi-block, it is not preceded by an Inquire/Grant
               transaction, because the Host S2,F23 is an implicit grant. Some
               equipment may support only single-block S6,F1, and may refuse an
               S2,F23 (Trace Initiate Send) message which would cause a multi-block
               S6,F1.

Structure:     L,4
                 1. <TRID>
                 2. <SMPLN>
                 3. <STIME>
                 4. L,n
                      1. <SV1>
                      2. <SV2>
                      .
                      .
                      n. <SVn>

Exception:     A zero-length STIME means no value is given and that the time is to
               be derived from SMPLN along with knowledge of the request.
```

S6,F2 Trace Data Acknowledge (TDA) S,H->E

```
Description:   Acknowledge or error

Structure:     <ACKC6>
```

S6,F3 Discrete Variable Data Send (DVS) — M,H<-E,[reply]

Description: Any data report which is initiated by an event, such as the completion of a measurement, rather than passage of time is called a discrete variable. Some equipment may have several possible events on which to send the data. S2,F15 is used to select the desired reporting events. Reports requiring only one block of data may report directly to the host with this message. If S6,F3 is multi-block, it must be preceded by the S6,F5/S6,F6 Inquire/Grant transaction.

Structure: L,3
1.<DATAID>
2.<CEID>
3. L,n
 1. L,2
  1. <DSID$_1$>
  2. L,m
   1. L,2
    1. <DVNAME$_1$>
    2. <DVVAL$_1$>
   2. L,2
   .
   .
   m. L,2
    1. <DVNAME$_m$>
    2. <DVVAL$_m$>
 2. L,2
 .
 .
 n. L,2
  1. <DSID$_n$>
  2. etc.

S6,F4 Discrete Variable Data Acknowledge (DVA) — S,H->E

Description: Acknowledge or error

Structure: <ACKC6>

S6,F5 Multi-block Data Send Inquire (MBI) — S,H<-E,reply

Description: If the discrete data report S6F3, F9, F11, F13 can involve more than one block, this transaction must precede the transmission.

Structure: L,2
1. <DATAID>
2. <DATALENGTH>

S6,F6 Multi-block Grant (MBG) — S,H->E

Description: Grant permission to send

Structure: <GRANT6>

S6,F7 Data Transfer Request (DDR) S,H->E,reply

Description: The host may initiate a data transfer of specified data stored in the equipment with this function.

Structure: <DATAID>

S6,F8 Data Transfer Data (DDD) M,H<-E

Description: Equipment sends data to the host.

Structure: Similar to the structure of S6,F3

Exception: A zero-length item returned means the requested data cannot be sent.

S6,F9 Formatted Variable Send (FVS) M,H<-E,[reply]

Description: The same function as S6,F3 except that the DVNAMEs are supplied from a predefined form that is known to the host. Thus, the data are more compact. If S6,F9 is multi-block, it must be preceded by the S6,F5/S6, F6 Inquire/Grant transaction.

Structure:

```
L,4
  1.<PFCD>
  2.<DATAID>
  3.<CEID>
  4. L,n
       1. L,2
            1. <DSID1_1>
            2. L,m
                 1. <DVVAL_1>
                 .
                 .
                 m. <DVVAL_m>
       2. L,2
       .
       .
       n. L,2
            1. <DSID_n>
            2. etc.
```

S6,F10 Formatted Variable Acknowledge (FVA) S,H->E

Description: Acknowledge or error

Structure: <ACKC6>

S6,F11 Event Report Send (ERS) M,H<-E, reply

Description: The purpose of this message is for the equipment to send a defined, linked, and enabled group of reports to the host upon the occurrence of an event (CEID).

If S6,F11 is Multi-block, it must be preceded by the S6,F5/S6,F6 Inquire/Grant transaction.

Structure:

```
L,3
  1.<DATAID>
  2.<CEID>
  3.L,a
      1. L,2
           1. <RPTID1>
           2. L,b
                1.<V1>
                .
                .
                b.<Vb>
           .
           .
      a.L,2                   report a
          1. <RPTIDa>
          2. L,c#Vs           this report
               1. <V1>
               .
               .
               c.<Vc>
```

Exceptions: If there are no reports linked to the event a 'null' report is assumed. A zero-length list for # of reports means there are no reports linked to the given CEID.

S6,F12 Event Report Acknowledge (ERA) S,H->E

Description: Acknowledge or error

Structure: <ACKC6>

S6,F13 Annotated Event Report Send (AERS) M,H<-E,reply

Description: This message is the same as S6F11 with the exception that VID's are sent with data.

If S6,F13 is Multi-block, it must be preceded by the S6,F5/S6,F6 Inquire/Grant transaction.

Structure:

```
L,3
  1.<DATAID>
  2.<CEID>
  3. L,a
       1. L,2
            1. <RPTID1>
            2. L,b
                 1. L,2
                      1.<VID1>
                 .
                 .
                 b. L,2
                      1.<VIDb>
                      b.<Vb>
       .
       .
       a. L,2
            1. <RPTIDa>
            2. L,c
                 1. L,2
                      1.<VID1>
                      2.<V1>
                     .
                     .
                      c. L,2
                           1.<VIDc>
                           2.<Vc>
```

Exception: If there are no reports linked to the event a 'null' report is assumed. A zero-length list for # of reports means there are no reports linked to the given CEID.

S6,F14 Annotated Event Report Acknowledge (AERA) S,H->E

Description: Acknowledge or error

Structure: <ACKC6>

S6,F15 Event Report Request (ERR) S,H->E, reply

Description: The purpose of this message is for the host to demand a given report group from the equipment.

Structure: <CEID>

S6,F16 Event Report Data (ERD) M,H<-E

Description: Equipment sends reports linked to given CEID to host.

Structure: Identical to structure of S6,F11.

Exceptions: A zero-length item means there are no reports linked to the given CEID.

S6,F17 Annotated Event Report Request (AERR) S,H->E,reply

Description: Same as S6,F15, but requests annotated reports.

Structure: <CEID>

S6,F18 Annotated Event Report Data (AERD) M,H<-E

Description: Equipment sends annotated reports linked to given CEID.

Structure: Same as S6,F13.

Exceptions: A zero-length item means there are no reports linked to the given CEID.

S6,F19 Individual Report Request (IRR) S,H->E,reply

Description: The purpose of this message is for the host to request a defined report from the equipment.

Structure: <RPTID>

S6,F20 Individual Report Data (IRD) M,H<-E

Description: Equipment sends variable data defined for the given RPTID to the host.

Structure: L,n # of variable data items
  1. <V_1>
  .
  .
  n. <V_n>

Exceptions: A zero length list means RPTID is not defined.

S6,F21 Annotated Individual Report Request (AIRR) S,H->E,reply

Description: The purpose of this message is for the host to request an annotated defined report from the equipment.

Structure: <RPTID>

S6,F22 Annotated Individual Report Data (AIRD) M,H<-E

Description: Equipment sends annotated variable data defined for the given RPTID to the host.

Structure: L,n # of variable data items
  1.L,2
    1. <VID_1>
    2. <V_1>
  .
  .
  n. L,2
    1. <VID_n>
    2. <V_n>

Exceptions: A zero-length list for # of variable data items means RPTID is not defined.

S6,F23 Request Spooled Data (RSD) S,H->E,reply

Description: The purpose of this message is for the host to request transmission or deletion of the messages currently spooled by the equipment.

Structure: <RSDC>

S6,F24 Request Spooled Data Acknowledgement Send (RSDAS) S,H<-E

Description: The purpose of this message is to acknowledge the receipt of the Request Spooled Data (S6,F23) and to respond with an appropriate acknowledge code.

Structure: <RSDA>

S6,F25 Notification Report Send — M, H<->E,[reply]

Description: This message is used for change notifications or confirmation reports. A change notification is a report of an internal action and is not associated with a prior action requested by the host.

A confirmation report is always associated with an earlier request for action. A confirmation report is sent to the initial requestor of a delayed action at the time the action is completed. A delayed action is an action that is any action not performed before the response to the initial request is sent. OPID contains the value of OPID in the initial request. LINKID is set to a non-zero value if and only if additional completion reports with the same OPID will be sent. If S6,F25 is multiblock, it must be preceded by the S6,F5/S6,F6 Inquire Grant transaction.

Structure: L,7

- 1. <DATAID>
- 2. <OPID>
- 3. <LINKID>
- 4. <RCPSPEC>
- 5. <RMCHGSTAT>
- 6. L,m
  - 1. L,2
    - 1. <RCPATTRID$_1$>
    - 2. <RCPATTRDATA$_1$>
  - .
  - .
  - m. L,2
    - 1. <RCPATTRID$_m$>
    - 2. <RCPATTRDATA$_m$>
- 7. L,2
  - 1. <RMACK>
  - 2. L,p
    - 1. L,2
      - 1. <ERRCODE$_1$>
      - 2. <ERRTEXT$_1$>
    - .
    - .
    - p. L,2
      - 1. <ERRCODE$_p$>
      - 2. <ERRTEXT$_p$>

Exception: OPID and LINKID are zero-length items when and only when S6,F25 is sent as a change notification rather than as a confirmation report. p = 0 if and only if RMACK indicates no errors.

S6,F26 Notification Report Send Acknowledge — S, H<->E

Description: This message is used to acknowledge the confirmation report. It is defined for completeness and as an aid to the user in identifying problems.

Structure: <ACKC6>

Exception: None

S6,F27 Trace Report Send (TRS) — M,H <-E,[reply]

Description: The equipment sends a completed Trace Report to the host.

Structure:

```
L,3
  1. <DATAID>
  2. <TRID>
  3. L,n          (n cannot exceed group size specified by S2F53)
       1. L,p      (p is the number of reports for each trace sample)
            1. L,2
                 1. <RPTID1>
                 2. L,m (number of items in this data report)
                      1. <V1>
                      .
                      .
                      m. <Vm>
                         .
                         .
                         p. L,2
                               1. <RPTIDp>
                               2. L,m
                                     1. <V1>
                                     .
                                     .
                                     m. <Vm>
                         .
                         .
       n. L,p      (p is the number of reports for each trace sample)
            1. L,2
                 1. <RPTID1>
                 2. L,m (number of items in this data report)
                      1. <V1>
                      .
                      .
                      m. <Vm>
            .
            .
            p. L,2
                 1. <RPTIDp>
                 2. L,m
                      1. <V1>
                      .
                      .
                      m. <Vm>
```

Exception: The lists of variables associated with a unique RPTID are also unique. This structure illustrates the form of the message, so in general, V_1 for $RPTID_a$ and V_1 for $RPTID_b$ do not reference the same variable.

S6,F28 Trace Report Send Acknowledge — S,H ->E

Description: The host Acknowledges receipt of the Trace Report.

Structure: <TRID>

S6,F29 Trace Report Request (TRR) S,H->E

Description: Request that the data reports assigned to the trace report be sampled and returned to the host.

Structure: <TRID>

S6,F30 Trace Report Data (TRD) M,H<-E

Description: Message containing the requested data reports associated with the TRID of trace data report definition.

Structure:
L,3
  1. <TRID>
  2. L,n (n = number data reports defined for this TRID)
    1. L,2
      1. <RPTID$_1$>
      2. L,m (m = number of items in this RPTID)
        1. <V$_1$>
        .
        m. <V$_m$>
    .
    .
    n. L,2
      1. <RPTID$_n$>
      2. L,m (m = number of items in this RPTID)
        1. <V$_1$>
        .
        m. <V$_m$>
      3. <ERRCODE>

Exception: If TRID is unknown, a zero-length list (n = 0) shall be sent. Item 3 (ERRCODE) shall be set to zero length when there is no error.

7.11 *Stream 7 Process Program Management* — The functions in this stream are used to manage and transfer process programs. Process programs are the equipment-specific descriptions that determine the procedure to be conducted on the material by a single piece of equipment. Methods are provided to transfer programs as well as establish the link between the process program and the material to be processed with that program.

S7,F0 Abort Transaction (S7F0) S,H<->E

Description: Same form as S1,F0

S7,F1 Process Program Load Inquire (PPI) S,H<->E,reply

Description: This message is used to initiate the transfer of a process program or to select from stored programs. The message may be used to initiate the transfer of an unformatted process program (S7,F3/S7,F4) or a formatted process program (S7,F23/S7,F24),(S7,F31/S7,F32).

Structure:
L,2
  1. <PPID>
  2. <LENGTH>

S7,F2 Process Program Load Grant (PPG) S,H<->E

```
Description:    This message gives permission for the process program to be loaded.

Structure:      <PPGNT>
```

S7,F3 Process Program Send (PPS) M,H<->E,reply

```
Description:    The program is sent. If S7,F3 is multi-block, it must be preceded by
                the S7,F1/S7,F2 Inquire/Grant transaction.

Structure:      L,2
                  1. <PPID>
                  2. <PPBODY>
```

S7,F4 Process Program Acknowledge (PPA) S,H<->E

```
Description:   Acknowledge or error

Structure:     <ACKC7>
```

S7,F5 Process Program Request (PPR) S,H<->E,reply

```
Description:   This message is used to request the transfer of a process program.

Structure:     <PPID>
```

S7,F6 Process Program Data (PPD) M,H<->E

```
Description:   This message is used to transfer a process program.

Structure:     L,2
                 1. <PPID>
                 2. <PPBODY>

Exception:     A zero-length list means request denied.
```

NOTE 8: The equipment-to-host transfer of the process program, denoted by the R bit in the header (R=1), provides the mechanism for the host computer to receive process programs created on the equipment. This allows use of the equipment without having process program generation capabilities on the host.

S7,F7 Process Program ID Request (PIR) S,H<-E,reply

```
Description:   This message is used to request the PPID for use on the material
               identified.

Structure:     <MID>
```

S7,F8 Process Program ID Data (PID) S,H->E

```
Description:   This message is used to transmit a single matrix entry in response to
               S7,F7.

Structure:     L,2
                 1. <PPID>
                 2. <MID>

Exception:     A zero-length list returned means no such MID or other error.
```

S7,F9 M/P M Request (MMR) S,H<->E,reply

```
Description:   This message is used to request the transmission of the material/
               process matrix. If the message is from the host, the response will be
               the current matrix in the equipment. If the message is from the
               equipment, the response will be a new matrix to initialize the
               equipment.

Structure:     Header only
```

NOTE 9: M/PM defines the Material/Process Matrix. The Material/Process Matrix is a table which links the material to the process program to be used in processing the material.

S7,F10 M/P M Data (MMD) M,H<->E

Description: In the response to S7,F9, the equipment will transmit the current matrix it contains. The matrix will be the sum of all matrix updates transmitted since initialization less the completed material whose linkages have been deleted. Programs with no pending material will be deleted from the matrix but not from the equipment program directory.

Structure: L,n number of process programs

1. L,2
   1. <PPID$_1$>
   2. L,a (number of MID for this PPID)
      1. <MID$_1$>
      .
      .
      a. <MID$_a$>
2. L,2
.
.
n. L,2
   1. <PPID$_n$>
   2. L,b
      1. <MID$_1$>
      .
      .
      b. <MID$_b$>

Exception: a=0 indicates that this PPID will be used for all material processed. The last default transmitted will be the one used; all other entries will be deleted from the active matrix. A zero-length list returned means no such matrix.

Function 10 Example 2 process programs (1 and 3 MID, respectively)

L,2
  L,2
    1. <PPID$_1$>
    2. L,1
       1. <MID$_a$>
  L,2
    1. <PPID$_2$>
    2. L,3
       1. <MID$_b$>
       2. <MID$_c$>
       3. <MID$_d$>

S7,F11 M/P M Update Send(UMS) — S,H->E,[reply]

Description: This message is used by the host to add to the M/PM in the equipment.

Structure:

```
L,n (number of process programs)
  1. L,2
       1. <PPID1>
       2. L,a (number of MID's using PPID1)
            1. <MID1>
            .
            .
            a. <MIDa>
  2. L,2
  .
  .
   n. L,2
        1. <PPIDn>
        2. L,b
             1. <MID1>
             .
             .
             b. <MIDb>
```

Exception: If a=0, then the preceding PPID is to be used for all material processed. All other entries will be deleted from the active matrix.

S7,F12 M/P M Update Acknowledge (UMA) — S,H<-E

Description: Acknowledge or error

Structure: <ACKC7>

S7,F13 Delete M/P M Entry Send (DES) — S,H->E,[reply]

Description: This message is used to delete program to material linkages in the M/PM of the equipment.

Structure:

```
L,n (number of process programs)
  1. L,2
       1. <PPID1>
       L,a (number of MID's using PPID)
         1. <MID1>
         .
         .
         a. <MIDa>
  2. L,2
  .
  .
  n. L,2
       1. <PPIDn>
       2. L,b
            1. <MID1>
            .
            .
            b. <MIDb>
```

Exception: A delete consisting of a zero-length means delete all entries and generate a S7,F9 request to initialize matrix.

S7,F14 Delete M/P M Entry Acknowledge (DEA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC7>

S7,F15 Matrix Mode Select Send (MMS) S,H->E,reply

Description: This message is used by the host to change the method of process program selection in the equipment which might not support all modes.

Structure: <MMODE>

S7,F16 Matrix Mode Select Acknowledge (MMA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC7>

NOTE 10: The matrix structure allows the program linkages to be established for each MID or the multi-MID production plans for an extended period of time. The host system makes the choice of operating mode. By continuous updates to the equipment matrix, automatic system backup is achieved.

S7,F17 Delete Process Program Send (DPS) S,H->E,reply

Description: This message is used by the host to request the equipment to delete process programs from equipment storage.

Structure: L,n (Number of process programs to be deleted)

1. <PPID$_1$>
.
.
n. <PPID$_n$>

Exception: If n=0, then delete all.

S7,F18 Delete Process Program Acknowledge (DPA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC7>

S7,F19 Current EPPD Request (RER) S,H->E,reply

Description: This message is used to request the transmission of the current equipment process program directory (EPPD). This is a list of all the PPIDs of the process programs stored in the equipment.

Structure: Header only

S7,F20 Current EPPD Data (RED) — M,H<-E

Description: This message is used to transmit the current EPPD.

Structure:

```
 L,n (number of process programs in the directory)
   1. <PPID1>
   .
   .
   n. <PPIDn>
```

S7,F21 Equipment Process Capabilities Request (PCR) — S,H->E,reply

Description: This message is used to request the Equipment Process Capabilities Data(PCD).

Structure: Header only

S7,F22 Equipment Process Capabilities Data (PCD) — M,H<-E

Description: This equipment message provides the information necessary for the host to create and partially verify the contents of a new process program or display the object of a process program previously generated by a host or equipment. The PCD defines the process program content acceptable to the originating equipment.

Structure:

```
L,5
  1. <MDLN>
  2. <SOFTREV>
  3. <CMDMAX>
  4. <BYTMAX>
  5. L,c (c=Number of Possible Commands)
       1. L,11
             1. <CCODE>
             2. <CNAME>
             3. <RQCMD>
             4. <BLKDEF>
             5. <BCDS>
             6. <IBCDS>
             7. <NBCDS>
             8. <ACDS>
             9. <IACDS>
            10. <NACDS>
            11. L,p (p=Number of Parameters)
       1. (parameter specification)
          (see below)
       .
       .
       p. (parameter specification)
       2. L,11
       .
       .
       c. L,11
```

Parameter specifications depend on the data type of each parameter. The structure of each of the possible three groups is as follows:

Numeric Data	*String Data*	*Boolean Data*
L,9	L,5	L,4
1. <PNAME>	1. <PNAME>	1. <PNAME>
2. <RQPAR>	2. <RQPAR>	2. <RQPAR>
3. <PDFLT>	3. <PDFLT>	3. <PDFLT>
4. <PMAX>	4. <PMAX>	4. <PMAX>
5. <LLIM>	5. L,s	
6. <ULIM>	1. <$STEMP_1$>	
7. <UNITS>	.	
8. <RESC>	.	
9. <RESV>	s. <$STEMP_s$>	

S7,F23 Formatted Process Program Send (FPS) M,H<->E,reply

Description: This message allows movement of formatted process programs between a piece of equipment and its host system. The values of MDLN and SOFTREV are obtained from the PCD used to generate the process program. If S7,F23 is multi-block, it must be preceded by the S7F1/F2 Inquire/Grant transaction.

Structure:

```
L,4
  1. <PPID>
  2. <MDLN>
  3. <SOFTREV>
  4. L,c (c=Number of Process Commands)
       1. L,2
            1. <CCODE>
            2. L,p (p=Number of Parameters)
                 1. <PPARM1>
                 .
                 .
                 p. <PPARMp>
       2. L,2
       .
       .
       c. L,2
```

S7,F24 Formatted Process Program Acknowledge (FPA) S,H<->E

Description: Acknowledges reception of a formatted process program at its destination and whether the process program was accepted by the interpreter. A returned status of "accepted" by the interpreter means only that the message is understood. The validity of the contents of the process program is determined through a separate transaction (S7,F27/S7,F28).

Structure: <ACKC7>

S7,F25 Formatted Process Program Request (FPR) — S,H<->E,reply

Description: This message is used by either equipment or host to request a particular process program from the other.

Structure: <PPID>

S7,F26 Formatted Process Program Data (FPD) — M,H<->E

Description: This message transfers a process program in response to a request for the PPID. The values of MDLN and SOFTREV are obtained from the PCD used to generate the process program.

Structure:

```
L,4
  1. <PPID>
  2. <MDLN>
  3. <SOFTREV>
  4. L,c (c=Number of Process Commands)
       1. L,2
            1. <CCODE>
            2. L,p (p=Number of Parameters)
                 1. <PPARM1>
                 .
                 .
                 p. <PPARMp>
       2. L,2
       .
       .
       c. L,2
```

Exception: A zero length list indicates the request was denied.

S7,F27 Process Program Verification Send (PVS) — S,H<-E,reply

Description: This message indicates to the host that a process program has been received and checked by the equipment. The result of the check is specified by the list of errors. An empty error list (list of zero-length) or a one-element list with ACKC7A having a value of zero (0) indicates no errors were found in the process program. The equipment may report as many errors as it seems appropriate. The equipment is responsible for sending a single copy of this message to the host after any reception of a formatted process program (S7,F23 or S7,F26 or S7,F31). If S7,F27 is multi-block, it must be preceded by the S7,F29/S7,F30 Inquire/Grant Transaction.

Structure:

```
L,2
  1. <PPID>
  2. L,n (n=number of errors being reported)
       1. L,3
            1. <ACKC7A>
            2. <SEQNUM>
            3. <ERRW7>
       2. L,3
       .
       .
       n. L,3
```

S7,F28 Process Program Verification Acknowledge (PVA) S,H->E

Description: Reply by host to equipment acknowledging reception of Process Program Verification Send (PVS).

Structure: Header only

S7,F29 Process Program Verification Inquire (PVI) S,H<-E,reply

Description: This message allows a piece of equipment to ask a host for permission to send a multi-block PVS.

Structure: <LENGTH>

S7,F30 Process Program Verification Grant (PVG) S,H->E

Description: Reply by host to equipment providing response to Process Program Verification Inquire (PVI).

Structure: <PPGNT>

S7,F31 Verification Request Send (VRS) M,H->E,reply

Description: This message requests the interpreting equipment to check the contents of the provided process program and inform the host whether or not the process program is acceptable for processing at the machine. The values of MDLN and SOFTREV are obtained from the PCD used to generate the process program. If S7,F31 is multi-block, it must be preceded by the S7,F1/S7,F2 Inquire/Grant transaction.

Structure:
```
L,4
  1. <PPID>
  2. <MDLN>
  3. <SOFTREV>
  4. L,c (c=Number of Process Commands)
       1. L,2
            1. <CCODE>
            2. L,p (p=Number of Parameters)
                 1. <PPARM1>
                 .
                 .
                 p. <PPARMp>
       2. L,2
       .
       .
       c. L,2
```

S7,F32 Verification Request Acknowledge (VRA) S,H<-E

Description: Acknowledges reception of a formatted process program verification request at its destination and whether the process program was accepted by the equipment. A returned status of accepted by the interpreter means only that the message is understood. The validity of the contents of the process program is specified through a separate transaction (S7,F27/S7,F28).

Structure: <ACKC7>

S7,F33 Process Program Available Request (PAR) S,H<->E,reply

Description: This message requests the interpreting host or equipment to check its process program library and tell the requester if the PPID will be supplied if requested.

Structure: <PPID>

S7,F34 Process Program Availability Data (PAD) S,H<->E

Description: This message allows originator to tell requester whether it can provide the specified process program and whether it can provide it formatted, unformatted, or both.

Structure: L,3
1. <PPID>
2. <UNFLEN>
3. <FRMLEN>

S7,F35 Process Program for MID Request (PPMR) S,H<->E,reply

Description: This message is used to request the transfer of the process program to be used for the material identified.

Structure: <MID>

S7,F36 Process Program for MID Data (PPMD) M,H<->E

Description: This message is used to transfer the process program for the material identified.

Structure: L,3
1. <MID>
2. <PPID>
3. <PPBODY>

Exception: A zero-length list returned means no such MID or other error.

7.12 *Stream 8 Control Program Transfer* — The purpose of this stream is to provide the method for transmitting the programs used in the equipment to perform the control function or to execute the transmitted process program.

S8,F0 Abort Transaction (S8F0) S,H<->E

Description: Same form as S1,F0.

S8,F1 Boot Program Request (BPR) S,H<->E,reply

Description: This message is used to request the transmission of the boot program. It is assumed that there is only one boot program associated with any given equipment.

Structure: Header only

S8,F2 Boot Program Data (BPD) M,H<->E

Description: The boot program is required by some systems as a precursor to loading an operating system or executive program.

Structure: <BPD>

Exception: A zero-length item means no boot.

S8,F3 Executive Program Request (EPR) S,H<->E,reply

Description: This message is used to request the executive program. It is assumed that there is only one executive program associated with any given equipment.

Structure: Header only

S8,F4 Executive Program Data (EPD) M,H<->E

Description: The executive program is the master control program of the equipment. The executive may contain all the program required or it may contain the information required to request the rest of the program it needs on Stream 13.

Structure: <EPD>

7.13 *Stream 9 System Errors* — This stream provides a method of informing the host that a message block has been received which cannot be handled or that a timeout on a transaction (receive) timer has occurred. The messages indicate either a Message Fault or a Communications Fault has occurred but do not indicate a Communications Failure has occurred.

7.13.1 *Communications Failure* — A Communications Failure occurs in a SECS-I environment when, and only when, the RTY limit is exceeded.

NOTE 11: In the event of a Communications Failure, no Stream 9 message is sent.

7.13.2 *Communications Fault* — A Communications Fault occurs when the equipment does not receive an expected message (when a transaction timer or a conversation timer has expired).

7.13.3 *Message Fault* — A Message Fault occurs when the equipment receives a message which it cannot process because of a fault that arises from the content, context, or length of the message.

S9,F0 Abort Transaction (S9F0) S,H<->E

Description: Same form as S1,F0.

S9,F1 Unrecognized Device ID (UDN) S,H<-E

Description: The device ID in the message block header did not correspond to any known device ID in the node detecting the error.

Structure: <MHEAD>

S9,F2 Not used

S9,F3 Unrecognized Stream Type (USN) S,H<-E

Description: The equipment does not recognize the stream type in the message block header.

Structure: <MHEAD>

S9,F4 Not Used

S9,F5 Unrecognized Function Type (UFN) S,H<-E

Description: This message indicates that the function in the message ID is not recognized by the receiver.

Structure: <MHEAD>

S9,F6 Not Used

S9,F7 Illegal Data (IDN) S,H<-E

Description: This message indicates that the stream and function were recognized, but the associated data format could not be interpreted.

Structure: <MHEAD>

S9,F8 Not Used

S9,F9 Transaction Timer Timeout (TTN) S,H<-E

Description: This message indicates that a transaction (receive) timer has timed out and that the corresponding transaction has been aborted. It is up to the host to respond to this error in an appropriate manner to keep the system operational.

Structure: <SHEAD>

S9,F10 Not Used

S9,F11 Data Too Long (DLN) S,H<-E

Description: This message to the host indicates that the equipment has been sent more data than it can handle.

Structure: <MHEAD>

S9,F12 Not Used

S9,F13 Conversation Timeout (CTN) S,H<-E

```
Description:   Data were expected but none were received within a reasonable length
               of time. Resources have been cleared.

Structure:     L,2
                 1. <MEXP>
                 2. <EDID>
```

S9,F14 Not Used

7.14 *Stream 10 Terminal Services* — The functions of this stream is to pass textual messages between operator terminals attached to processing and/or testing equipment and the host. The equipment makes no attempt to interpret the text of the message, but merely passes it from terminal keyboard to the host or from the host to the display of the terminal. Management of human response times to information displayed on terminals is the responsibility of the host.

S10,F0 Abort Transaction (S10F0) S,H<->E

```
Description:   Same form as S1,F0.
```

S10,F1 Terminal Request (TRN) S,H<-E,[reply]

```
Description:   A terminal text message to the host.

Structure:     L,2
                 1. <TID>
                 2. <TEXT>
```

S10,F2 Terminal Request Acknowledge (TRA) S,H->E

```
Description:   Acknowledge or error

Structure:     <ACKC10>
```

S10,F3 Terminal Display, Single (VTN) S,H->E, [reply]

```
Description:   Data to be displayed.

Structure:     L,2
                 1. <TID>
                 2. <TEXT>
```

S10,F4 Terminal Display, Single Acknowledge (VTA) S,H<-E

```
Description:   Acknowledge or error

Structure:     <ACKC10>
```

S10,F5 Terminal Display, Multi-Block (VTN) M,H->E,[reply]

Description: Data to be displayed on the equipment's terminal.

Structure: L,2
1. <TID>
2. L,N
1. <TEXT$_1$>
.
.
n.<TEXT$_n$>

S10,F6 Terminal Display, Multi-block Acknowledge (VMA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC10>

S10,F7 Multi-block Not Allowed (MNN) S,H<-E

Description: An error message from a terminal that cannot handle a multi-block message from S10,F5.

Structure: <TID>

S10,F8 Not Used

S10,F9 Broadcast (BCN) S,H->E,[reply]

Description: This function is generally the same as S10,F3 except that specific TID in each equipment need not be specified. Instead, the text is directed to each terminal in the equipment when the function is received. This function assumes that this feature exists on all equipment, otherwise repeated S10,F3 messages should be used.

Structure: <TEXT>

S10,F10 Broadcast Acknowledge (BCA) S,H<-E

Description: Acknowledge or error

Structure: <ACKC10>

7.15 Stream 11 has been deleted and will not appear again in this publication.

It is the consensus of the Communications Committee that Stream 11 is obsolete. Its use is discouraged, and it has been removed from the 1989 edition of the standard. The reasons for removal are three-fold:

1. The purpose of this stream, as it was originally envisioned, is perceived to be of little use and can best be accomplished by other means beyond the scope of this standard;
2. The functions in this stream have many technical problems that severely limit their use;
3. There is a noticeable lack of implementations of this standard that utilize Stream11 in its originally intended form.

NOTE 12: Applications that need to transfer unformatted data between the host and equipment should use the facilities of Stream 13.

7.16 *Stream 12 Wafer Mapping* — Messages which deal with coordinate positions and data associated with those positions. This includes functions such as wafer mapping with coordinates of die on a wafer and the associated binning information.

7.16.1 *Structure* — Functions 1 through 20 address the variations required by semiconductor equipment manufacturers in transmitting wafer maps to and from the process equipment (wafer probe through die attach). The functions include three basic formats. The three formats developed are:

1. Row/column format where a coordinate row starting position is given with die count in the row and starting direction. The respective binning information follows for each die.
2. Array format is structured such that a matrix array captures all or part of a wafer with the associated binning information.
3. Coordinate format provides an X/Y location and bin code for die on the wafer.

7.16.2 *Definitions and Descriptions* — The following information is required to perform map association to the physical wafer as it relates to the archival use and transmission of wafer maps.

1. Flat/Notch Location
2. Frame Rotation
3. Row Count
4. Column Count
5. Die Units of Measure
6. Die Size
7. Process Die Count
8. Reference Points
9. Bin Code Equivalents
10. Process Axis
11. Null Bin Code Value
12. ID Type

7.16.2.1 *Flat/Notch Location* — The position in degrees that the flat or notch are oriented during processing relative to a " normal" position of zero degrees. See Figure S12.1.

7.16.2.2 *Frame Rotation* — The orientation of a film frame relative to a " normal" position of zero degrees. See Figure S12.2.

7.16.2.3 *Row/Column Count* — The row and column counts are the total number of rows and columns, respectively, on a wafer which must be correlated directly with the wafer map. These numbers will always be greater than zero.

7.16.2.4 *Die Sizes* — The die size is given in standard units as specified by the die unit of measure item DUTMS, and will also be greater than zero. The value of the die size is determined by measuring the distance from a point on one die to the same point on the next die, often referred to as an index. This is depicted in the lower portion of Figure 7, Section B in the General Rules Section.

7.16.2.5 *Process Die Count* — The process die count item is used by equipment that is being map driven to make determinations about how much material to prepare. For example, a die attach will epoxy lead frames in advance of the attach process. By knowing the total number of die to be processed within a wafer map, the equipment can stop epoxying lead frames equivalent to the last die to be attached. This item is also used by the equipment to tell the host how many total die it processed for that map. For example, a die attach would use PRDCT to report the total die actually attached from a particular wafer.

7.16.2.6 *Reference Points* — Reference points provide a means of relating a map to the physical wafer. The total number of these points, and the method for assigning and detecting them, is the responsibility of the equipment. This standard only provides a means for transmitting them.

7.16.2.7 *Origin* — The origin is in one of five locations which is specified by the equipment when generating a wafer map. The origin is on an array structure having dimensional values equal to those specified by the row and column count. The origin then lies on one of the four corners of that array or in a center location determined by the following formula:

$$\left(\frac{row \sim or \sim column + 1}{2}\right) truncated$$

7.16.2.7.1 It is implicit in determining the center location that the upper-left-hand corner of the area, in the normal position, be counted as the first row and column position. An equipment requesting a map provides the origin location that it wants the map to be based on before transmission. If the equipment does not provide an origin, the host must provide a default value. An equipment transmitting a map must provide the origin with the map setup data.

7.16.2.8 *Bin Code Equivalents* — Bin code equivalents is a list of bin codes that the receiving equipment will process. (i.e., if a map contains codes 1 through 10 and the good die are bins 1 and 2, then bin code equivalent list could indicate 1 and 2 if only the good die categories were needed. These are the only bin codes to which an equivalent will drive for its respective process function.) In the case of X/Y coordinate format, the locations transmitted will be only those with the bin codes stated in the Bin Code Equivalent list, unless the length byte is set to zero, in which all of the bin codes in the map will be transmitted.

7.16.2.9 *Process Axis* — The process axis is the axis, either rows or columns, increasing or decreasing, and the side of the map, (top, bottom, left, or right, respectively) that the map data will originate from. This is based on the coordinate system as described under the General Rules section of this document.

7.16.2.10 *ID Type* — ID type indicates the appropriate material ID type (i.e., wafer, cassette, or film frame).

7.16.3 *General Rules*

7.16.3.1 *Map Data Size* — Stream 12 provides for the transmission of a complete map regardless of size. Equipment requiring segmented maps for transmission or reception will not be able to use the Stream 12 functions to handle the complete conversation.

7.16.3.2 *Orientation Conventions* — The orientation of a wafer presented for processing will differ from equipment to equipment. Stream 12 specifies conventions for expressing wafer orientation so that a map can be translated from one geometric representation to another.

7.16.3.2.1 The bottom of the wafer is the notch or the line of the major flat. The orientation of a wafer is measured in positive degrees clockwise (CW) from the " normal" position. The " normal" position is where the bottom of the wafer is closest to you when the wafer is lying horizontally in front of you with the die side facing up. The " normal" position has an orientation of zero degrees. See Figure S12.1 for graphic representation of wafer orientations.

7.16.3.2.2 The bottom of a film frame is also the notch or the line of notches. Its orientation and " normal" position are measured in the same manner as for wafers. See Figure S12.2 for examples of bottoms of film frames.

7.16.3.2.3 The orientation of an unmounted wafer presented for processing is given by the parameter FNLOC, Flat/Notch LOCation.

7.16.3.2.4 The ultimate orientation of a wafer presented for processing after it has been mounted on a film frame is the cumulative rotation of the wafer from the " normal" position on the film frame and the rotation of film frame as it is presented to the equipment. This is determined by the sum of the parameters FNLOC and FFROT, Film Frame ROTation. It is possible for an application to represent the ultimate orientation of a wafer in one of these parameters only and pass the other parameter as zero length.

7.16.3.2.5 Figure 6 shows wafers oriented at 270 degrees with respect to the bottoms of a metal and round film frame. If one of these film frames were presented to an equipment rotated 90 degrees clockwise (CW), (bottom facing the left edge of the page), the ultimate orientation of the wafer would be zero degrees.

7.16.3.2.6 In the case where either FNLOC or FFROT are unknown or irrelevant information, a zero-length data item is transmitted, and the item will be ignored by the application. One of the items must exist.

7.16.3.3 *Coordinate Axis System* — The coordinate axis orientation is shown in Figure S12.3, Section A. The assumption is that the " X" or " column" coordinates increase to the right of the " Y-axis" and the " Y" or " row" coordinates increaseabove the " X-axis." In describing the physical wafer it is also given that the coordinate axis orientation never rotates. The wafer moves or rotates within the coordinate axis system. The origin within the array describing the wafer' s coordinate system must be in one of five locations on that array (the center, upper-left, lower-left, upper-right, or lower-right corner of the array).

7.16.3.3.1 Figures S12.4 and S12.5 summarize the conversation protocol in the form of a flow chart. Since a single transmit inquire/grant can be used for one of three message function pairs, the application is required to examine MAPFT, is received as part of the map setup data to determine the appropriate function to follow. If the appropriate function is not transmitted, the conversation is aborted and the error is reported using the appropriate error reporting stream and function.

S12,F0 Abort Transaction (S12F0) S,H<->E

Description: Same form as S1F0.

S12,F1 Map Set-up Data Send (MSDS) S,H<-E,reply

Description: Used to send all of the map set-up data common to all formats and required to link the data map with the physical wafer.

Structure: L,15
1. <MID>
2. <IDTYP>
3. <FNLOC>
4. <FFROT>
5. <ORLOC>
6. <RPSEL>
7. L,n
    1. <$REFP_x REFP_y$>
    .
    .
    n. <$REFP_x REFP_y$>
8. <DUTMS>
9. <XDIES>
10. <YDIES>
11. <ROWCT>
12. <COLCT>
13. <NULBC>
14. <PRDCT>
15. <PRAXI>

S12,F2 Map Set-up Data Acknowledge (MSDA) S,H->E

Description: Acknowledgment of receipt of complete set of map set-up parameters.

Structure: <SDACK>

S12,F3 Map Set-up Data Request (MSDR) S,H<-E,reply

Description: Used to request set-up data from the host for the product ready to be processed at the equipment (common to all formats).

Structure: L,9
1. <MID>
2. <IDTYP>
3. <MAPFT>
4. <FNLOC>
5. <FFROT>
6. <ORLOC>
7. <PRAXI>
8. <BCEQU...>
9. <NULBC>

S12,F4 Map Set-up Data (MSD) S,H->E

```
Description:   Used to send all of the map set-up data required to link the data map
               with the physical wafer.

Structure:     L,15
                  1.   <MID>
                  2.   <IDTYP>
                  3.   <FNLOC>
                  4.   <ORLOC>
                  5.   <RPSEL>
                  6.   L,n
                         1. <REFPxREFPy>
                         .
                         .
                         n. <REFPxREFPy>
                  7.   <DUTMS>
                  8.   <XDIES>
                  9.   <YDIES>
                 10.   <ROWCT>
                 11.   <COLCT>
                 12.   <PRDCT>
                 13.   <BCEQU>
                 14.   <NULBC>
                 15.   <MLCL>
Exception:      A zero-length list returned means no such MID.
```

S12,F5 Map Transmit Inquire (MAPTI) S,H<-E,reply

```
Description:   Used to prepare the host for map transmission. S12,F5 must precede
               all S12,F7-8,F9-10, & F11-12 transactions.

Structure:     L,4
                 1. <MID>
                 2. <IDTYP>
                 3. <MAPFT>
                 4. <MLCL>
```

S12,F6 Map Transmit Grant (MAPTG) S,H->E

```
Description:   Provides permission to transfer.

Structure:     <GRNT1>
```

S12,F7 Map Data Send Type 1 (MDS1) M,H<-E,reply

Description: Used to send map data from the equipment to the host in row or column compressed format. If S12,F7 is multi-block, it must be preceded by the S12,F5/S12,F6 Inquire/Grant transaction.

Structure: L,3
- 1. <MID>
- 2. <IDTYP>
- 3. L,n
  - 1. L,2
    - 1. <RSINF$_1$>
    - 2. <BINLT$_1$>
  - 2. L,2
  - .
  - .
  - n. L,2
    - 1. <RSINF$_n$>
    - 2. <BINLT$_n$>

S12,F8 Map Data Acknowledge Type 1 (MDA1) S,H->E

Description: Acknowledge or error

Structure: <MDACK>

S12,F9 Map Data Send Type 2 (MDS2) M,H<-E,reply

Description: Used to send map data from the equipment in array format. If S12,F9 is multi-block, it must be preceded by the S12,F5/S12,F6 Inquire/Grant transaction.

Structure: L,4
- 1. <MID>
- 2. <IDTYP>
- 3. <STRP$_x$STRP$_y$>
- 4. <BINLT...>

S12,F10 Map Data Acknowledge Type 2 (MDA2) S,H->E

Description: Acknowledge or error

Structure: <MDACK>

S12,F11 Map Data Send Type 3 (MDS3) M,H<-E,reply

```
Description:   Used to send map data from the equipment in cartesian coordinate
               format. Bin values may or may not be included in the message. If
               S12F11 is multi-block, it must be preceded by the S12,F5/S12,F6
               Inquire/Grant transaction.

Structure:     L,3
                 1. <MID>
                 2. <IDTYP>
                 3. L,n
                      1. L,2
                           1. <XYPOS1x XYPOS1y>
                           2. <BINLT1...>
                      2. L,2
                      .
                      .
                      n. L,2
                           1. <XYPOSn>
                           2. <BINLTn>
```

S12,F12 Map Data Acknowledge Type 3 (MDA3) S,H->E

```
Description:   Acknowledge or error

Structure:     <MDACK>
```

S12,F13 Map Data Request Type 1 (MDR1) S,H<-E,reply

```
Description:   Used to request map data for product at equipment process station in
               row or column format.

Structure:     L,2
                 1. <MID>
                 2. <IDTYP>
```

S12,F14 Map Data Type 1 (MD1) M,H->E

```
Description:   Used to send map data from the host to the equipment in row or column
               format.

Structure:     L,3
                 1. <MID>
                 2. <IDTYP>
                 3. L,n
                      1. L,2
                           1. <RSINFx1 RSINFy1RSINd>
                           2. <BINLT...>
                      2. L,2
                      .
                      .
                      n. L,2
                           1. <RSINFn>
                           2. <BINLTn>

Exception:     A zero-length list returned means no such MID.
```

S12,F15 Map Data Request Type 2 (MDR2) — S,H<-E,reply

Description: Used to request map data for product at an equipment process station, in array format.

Structure: L,2
1. <MID>
2. <IDTYP>

S12,F16 Map Data Type 2 (MD2) — M,H->E

Description: Used to send map data from the host to the equipment in array format.

Structure: L,4
1. <MID>
2. <IDTYP>
3. <STRP$_x$ STRP$_y$>
4. <BINLT...>

Exception: A zero-length list returned means no such MID.

S12,F17 Map Data Request Type 3 (MDR3) — S,H<-E,reply

Description: Used to request map data for product at an equipment process station in cartesian coordinate format.

Structure: L,3
1. <MID>
2. <IDTYP>
3. <SDBIN>

S12,F18 Map Data Type 3 (MD3) — M,H->E

Description: Used to send map data from the host to the equipment in cartesian coordinate format. Bin values may or may not be included.

Structure: L,3
1. <MID>
2. <IDTYP>
3. L,n
    1. L,2
        1. <XYPOS$_{x1}$ XYPOS$_{y1}$>
        2. <BINLT$_1$...>
    2. L,2

    .

    .

    n. L,2
        1. <XYPOS$_n$>
        2. <BINLT$_n$>

Exception: A zero-length list returned means no such MID.

S12,F19 Map Error Report Send (MERS) S,H<->E

```
Description:   Used to transmit map related errors.

Structure:     L,2
                 1. <MAPER>
                 2. <DATLC>
```

S12,F20 Not Used

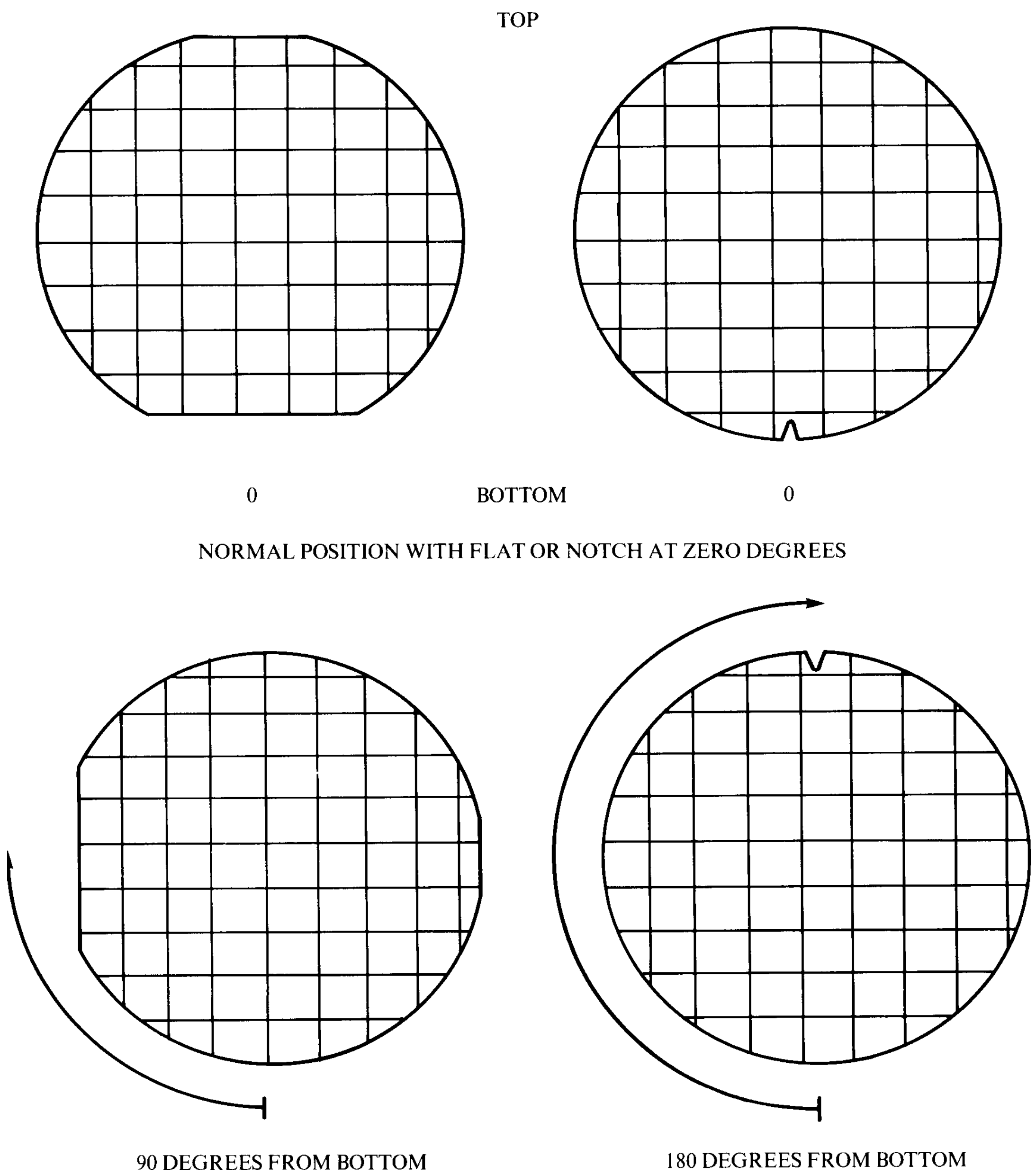


Figure S12.1
Wafer Rotation Position in Degrees

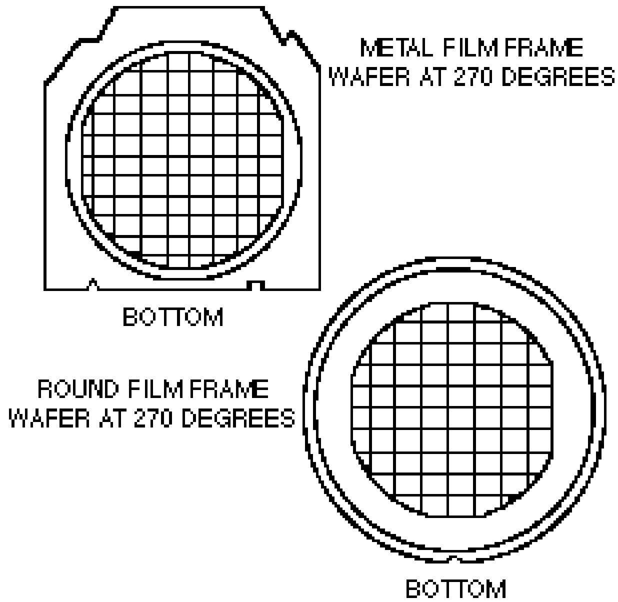


Figure S12.2
Wafer Rotation on Film Frame

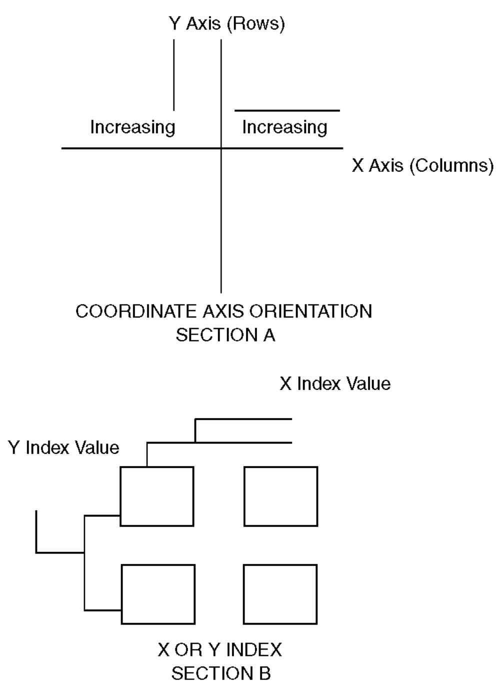


Figure S12.3
Orientation Reference and Index Determination

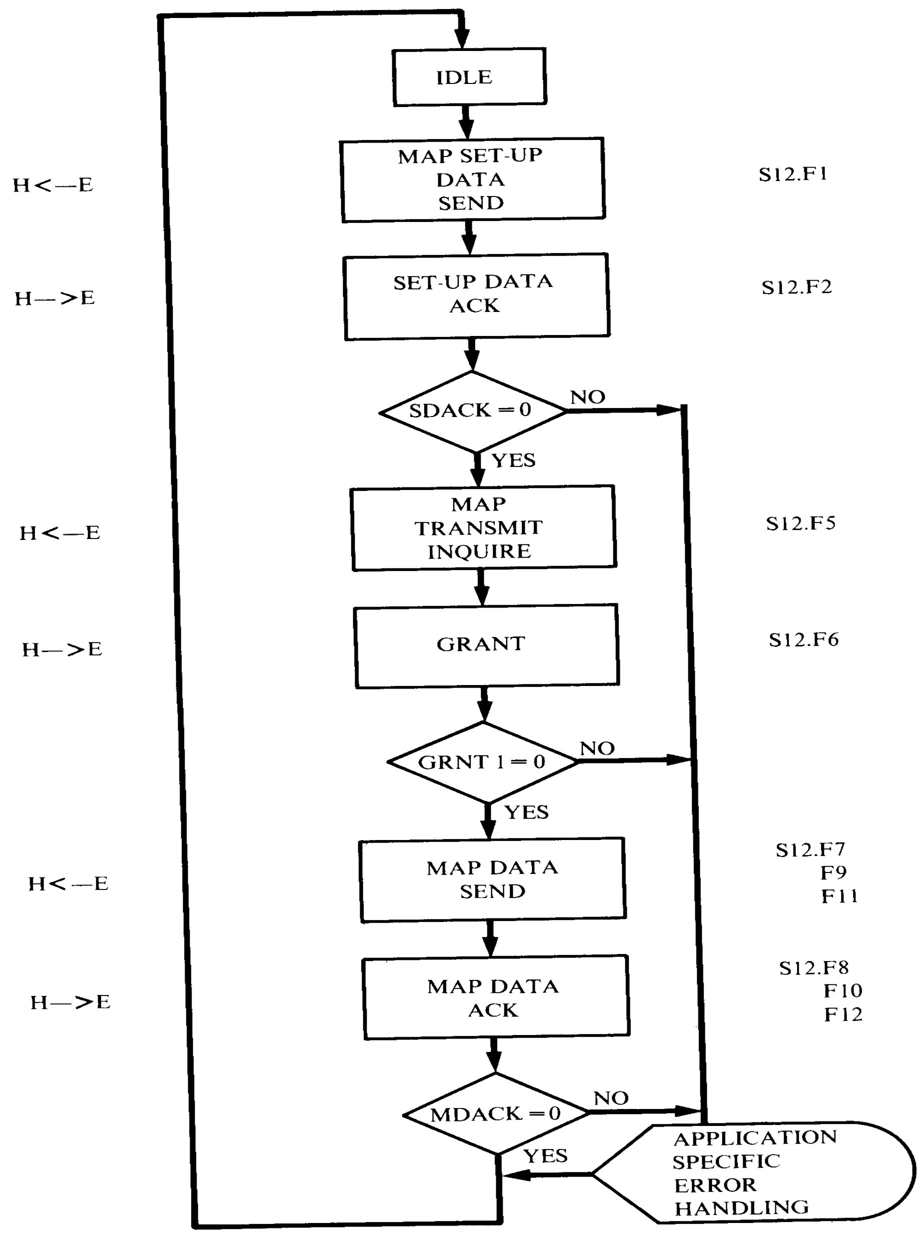


Figure S12.4
Wafer Map Transmitted by Equipment

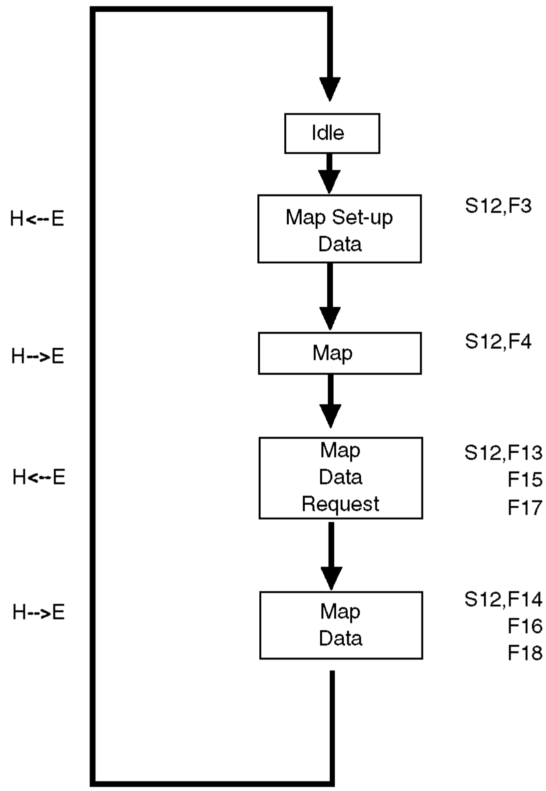


Figure S12.5
Wafer Map Received by Equipment

7.17 *Stream 13 Data Set Transfers* — This stream provides protocols to transfer data sets between systems. It is not intended to provide a general file access mechanism.

7.17.1 *Data Set Characteristics* — The data set may reside on the host or the equipment.

The term *data set* is used in a very general sense. A data set may represent a file, a data structure in memory, a collection of sensor values, or high density wafer profile data. The protocols define only the way data is sent from one system to another and do not define how the data set is stored by either the host or equipment.

The *sending* system is defined to be the system that has the data set. The *receiving* system is defined to be the system to which the data set is being transferred. The host or the equipment may assume either role.

7.17.2 *Unformatted Data Set Protocol* — The protocol for transferring unformatted data sets has the following characteristics:

1. Information about the record structure of the data set may be available.
2. ASCII records are transferred without the record terminating “noise” characters used by some operating systems.
3. Data sets do not need to be transferred in a single message.
4. No arbitrary limits are imposed on the length of one message. The maximum amount of data sent in each message is determined by both the sending and receiving systems, so there can be no data overruns.
5. There is a method of restarting a transfer in the event of an interruption.

7.17.2.1 *Data Set Name* — An ASCII string (format 20) which performs a function similar to the Message ID (Stream and Function) of the SECS-I protocol. This is a logical name which has meaning to both the equipment and the host. Neither the equipment nor the host is required to use the *Data Set Name* for the same information in any other context. For example, maintenance data may be stored in the equipment in the file "WIDGET.DAT" and in the host as records in a database, but the *Data Set Name* may be "S11,F2".

7.17.2.2 *Records* — The Record Type determines the way the data set is divided into messages for transfer to the receiving system. There are two types of records: Discrete and Stream.

1. A data set with *Discrete* records has a traditional record structure, such as ASCII text. *RecordLength* is the length of the longest record. Zero-length records are allowed. Each record from the data set is sent as a single item in a message.

2. If *Record Type* is *Stream,* then the data set has no internal structure which can be communicated with this protocol.

These kind of data set might be, for example, a dump of main memory, SECS-II structured data, or data which has implicit record boundaries. RecordLength has no meaning for this kind of data set. Items containing data from the data set have no relationship to the structure of the data set.

7.17.2.3 *Transactions* — The basic data transfer is performed by the OPEN, READ, and CLOSE transactions. There is no explicit write transaction. A write is performed indirectly using the SEND transaction. A RESET transaction is provided to allow a graceful recovery after a crash. This protocol describes the transactions over the communications channel only. No assumption is made about the implementation of the transactions. For example, the OPEN transaction on a data set which is stored on a disk file does not necessarily cause the sending system to open the file.

7.17.2.3.1 The OPEN, READ, and CLOSE transactions are initiated by the receiving system. The SEND transaction is initiated by the sending system. The RESET transaction is initiated by either system. The usual transaction timer operates between the primary and secondary messages of each transaction. The time between transactions, especially between READ transactions, is application-specific so no additional timer is defined.

7.17.2.3.2 Internally, the protocol uses a *Handle* to keep track of multiple open data sets, and a *Checkpoint* which aids in error recovery. A value called *ReadLength* is used to negotiate the amount of data sent at one time.

7.17.2.4 *Handle* — Between the sending and receiving systems, more than one data set may be open at a time, or one data set may be opened many times. The Handle is a short name used to keep track of the state of a particular data set and instance of OPEN between the sending and receiving systems (see Figure S13.1). This *Handle* may be thought of as a name for a single application level connection from the sending to the receiving system. Its value is assigned in the primary message of the OPEN transaction.

7.17.2.4.1 The value used for the *Handle* must not be used in another OPEN by the receiving system to the same sending system until it is used in a CLOSE to that sending system, or the RESET transaction is sent by either system. For example, assume a host system opens a data set on equipment 255 using *Handle 1*. The host may not issue another OPEN to equipment 255 using *Handle 1* until it closes 1 on 255. However, the host may use *Handle 1* to open a data set on another piece of equipment, and equipment 255 may use *Handle 1* to open a data set on the host.

7.17.2.4.2 The number of data sets which may be open at one time and the number of times one data set may be opened is not specified by this standard. Error codes are defined for situations where the limits are exceeded. It must be possible to have one outstanding transaction (i.e., a primary message for which there has not been a reply) for each open *Handle*. If the sending system receives a primary message for a Handle which already has an outstanding transaction, then the error code for Pending Transaction is returned in the secondary message (see Figure 10).

7.17.2.5 *Checkpoint* — The response to each READ transaction contains the data and a new Checkpoint value. The *Checkpoint* is defined by and has meaning only for the sending system. Its purpose is to allow a data transfer to be restarted from the point of the last complete message after some communication interruption. The exact nature of the *Checkpoint* is not specified. It could be the byte index in the data set, a record counter (for Discrete records), or some other system-dependent value.

NOTE 13: Checkpoint and the SECS-II transaction timer define a performance requirement for the sending system. The sending system must be able to get data from any checkpoint location within a data set between the receipt of the OPEN primary message and the time for reply to the first READ.

7.17.2.5.1 The value of *Checkpoint* must conform to several rules:

1. The Checkpoint value is exactly four bytes long.

2. The beginning of the data set has Checkpoint value with all bits reset.

3. A Checkpoint with all bits set is illegal.

4. A Checkpoint supplied by the sending system which does not have all bits set is usable in an OPEN

transaction to restart a data transfer without any lost data or duplicated data.

7.17.2.5.2 The receiving system defines the initial *Checkpoint* in the primary message of the OPEN transaction. The sending system returns the next *Checkpoint* in the response to each READ.

7.17.2.6 *Read Length* — The *Read Length* must be supplied by the receiving system with each READ transaction. It specifies the maximum number of data bytes which that system is prepared to process at one time. The sending system may supply less if it has limited resources. The sending system may supply more if *ReadLength* is zero, or is smaller than *RecordLength*.

7.17.2.7 *Reading a Data Set* — The basic data transfer is initiated with the OPEN transaction and completed with the CLOSE transaction. Information is sent from the sending to the receiving systems by a series of READ transactions.

7.17.2.8 *OPEN Transaction* — The receiving system sends a primary message containing the *DataSet Name* of the desired data set, the *Handle* to be used, and the *Checkpoint* of the initial READ transaction. The response from the sending system is a secondary message with a return code and the *RecordType* and *RecordLength* of the data set. If the return code is one of the error codes, then no data set was opened and the values of *RecordType* and *RecordLength* are undefined. If the *RecordType* is *Stream*, then the value of *RecordLength* is undefined. Notice that the undefined items will still appear in the secondary message.

7.17.2.8.1 The return code in the secondary message is one of the following:

OK.

ERROR: Unknown Data Set ID.

ERROR: Try later (i.e., the data set is in use).

ERROR: Too many open data sets.

ERROR: Data set open too many times.

ERROR: Handle in use.

ERROR: Pending Transaction.

7.17.2.9 *The READ Transaction* — The receiving system sends a primary message which contains the *Handle*, and the *ReadLength*. The sending system responds with a secondary message which has a return code, the next Checkpoint, and zero or more items with data. At least one data item must be supplied unless there is an error. The return codes are:

OK.

ERROR: End of Data.

ERROR: No open Data Set (i.e., incorrect Handle).

ERROR: Cannot continue (i.e., a disk read error on the sending system).

ERROR: Pending Transaction.

7.17.2.9.1 Any READ transaction which follows a READ which returned an error, except "Pending Transaction," will generate the same error. The value of *Checkpoint* must be illegal (i.e., all bits must be set) when the "End of Data," "No open Data Set," or "Pending Transaction" error is returned. The value of *Checkpoint* error must be a value from which recovery may be attempted without duplicating data when the "Cannot continue" error is returned. Recovery may be attempted by issuing a CLOSE, followed by an OPEN with the last value of *Checkpoint*, and then another READ.

7.17.2.9.2 Each secondary message for the READ transaction must contain a whole number of *Discrete* records. A record may be sent as an ASCII or a binary item. *Stream* data sets are broken into pieces by the READ transaction without regard to internal structure. Each piece would be sent as a single binary item. The number of items which contain data depends on the *RecordType, Record Length,* and *Read Length*. The algorithm is designed so that the maximum length of the secondary message is deterministic. It gives the receiving system the ability to control the amount of resources (such as SECS-I buffers) which it must allocate. The sending system may send less data than the maximum if it has limited resources. The performance (i.e., the packing of records into a message of some maximum size) should be very good for the case where records are all nearly the maximum length. This is assumed to be the usual case. The efficiency in pathological cases (e.g., many short records) will not be good, but the algorithm is robust enough to accommodate this without exceeding the maximum message size.

NOTE 14: If the *RecordType* is *Stream,* then there is exactly one item with a binary format whose length is not more than *ReadLength*. If the *RecordType* is *Discrete,* then the maximum number of items, MaxItems, is calculated by the formula:

$$\mathrm{MaxItems} = \max\left(1, \mathrm{int}\left(\frac{\mathrm{ReadLength}}{\mathrm{RecordLength}}\right)\right)$$

7.17.2.9.3 The size of the secondary message may be less because of limited resources in the sending system.

7.17.2.9.4 For data sets with *Discrete* records, the format of each item is either ASCII (format 20) or binary (format 10). There is no requirement that all records be in the same format, but mixed record formats are not encouraged. Items with ASCII format should have only data characters. Characters which the sending system uses for control information (e.g., newline for a record terminator) should not appear. If an application finds it necessary to include these characters, then format 10, or Stream should be used.

7.17.2.10 *CLOSE Transaction* — This transaction terminates a data transfer and frees the *Handle* for future use. The primary message is sent by the receiving system and contains only the *Handle.* The sending system responds with a secondary message which has a return code.

7.17.2.10.1 The return code is one of the following:

OK.

ERROR: No open Data Set (i.e., incorrect *Handle*).

ERROR: Pending Transaction.

7.17.2.11 *Sending a Data Set* — Writing a data set is performed by requesting that the receiving system read it. The sending system initiates the SEND transaction to request that a data set be read. The receiving system is expected to perform the OPEN, READ, and CLOSE transactions to transfer the data set if it accepts the request. The time between the secondary message of the SEND and the primary message of the OPEN depends on the application.

7.17.2.12 *The SEND Transaction* — The primary message sent from the sending system to the receiving system contains the *Data Set Name*.

7.17.2.12.1 The secondary message contains the *Data Set Name* and a return code which is one of the following:

OK.

ERROR: Unknown Data Set Name.

ERROR: Try later (i.e., the system is busy).

7.17.2.13 *Error Recovery* — The receiving system may crash while a data set is open but no READ transaction is pending. The sending system will not be able to tell that this has happened because there is no timeout value defined between READ transactions. When the receiving system is restarted it may have forgotten which data sets were open. States in the two systems are now inconsistent.

7.17.2.14 *RESET Transaction* — The RESET transaction offers a way to resynchronize the two systems. When one system issues the primary message of the RESET transaction, it is informing the other system that any data sets which may have been open are to be closed. This applies to all data sets open between both systems. It is not necessary to issue CLOSE transactions for each individual data set because the RESET transaction is a global close.

7.17.2.15 Any equipment which uses Stream 13 must issue the RESET transaction as part of its initialization or bootstrap procedure. A host system must issue a RESET to equipment which uses Stream 13 during the initialization for that equipment.

7.17.2.16 *SECS-II Protocol Definition* — Figure 10 shows the state diagram for the sending system while a data set is being transferred. Each circle shows a possible state of the sending system. The names of these states are for reference only. They are not meant to suggest an implementation. The arrows show transitions due to SECS-II messages received or sent by the sending system.

7.17.2.16.1 In the initial state (Idle) handle X is not open. The states marked with an asterisk are those in which a transaction is outstanding. If the sending system receives any primary message from the receiving system with handle X during the time it is in these states, then the secondary message for that transaction will contain the " Pending Transaction" error code, but the original transaction for handle X will not be affected. Some states, especially the error states, may take zero time in some implementations. In these cases, the " Pending Transaction" error code would not be returned from those states.

7.17.3 *Formatted Data Sets* — Formatted data sets are data sets transferred in a standard format. Stream 13 provides a method for transferring data sets in a table format. A table has both attributes and content. The attributes of the table provide information about the data set as a whole, such as the date and time that it was last modified, its size, etc. The content of the table consists of column headers and rows. A row is an ordered list of table elements. A column refers to all table elements at a specific position within all rows, where each column is identified by a corresponding text string as a column header. The table elements in the 1st column position are used as an identifier for the row.

S13,F0 Abort Transaction (S13F0) S,H<->E

Description: Same form as S1,F0

S13,F1 Send Data Set Send (DSSS) S,H<->E,reply

Description: Sent by the sending system to request that the other system read a dataset.

Structure: L,1
1. <DSNAME>

S13,F2 Send Data Set Acknowledge (DSSA) S,H<->E

Description: Sent by the receiving system in response to Send Data Set Send.

1. <DSNAME>
2. <ACKC13>

Exceptions: The possible ACKC13 codes for this message are:

0=O.K.
1=ERROR:Try later.
2=ERROR:Unknown Data Set Name.

S13,F3 Open Data Set Request (DSOR) S,H<->E,reply

Description: Sent by the receiving system to open a data set for reading.

Structure: L,3
1. <HANDLE>
2. <DSNAME>
3. <CKPNT>

S13,F4 Open Data Set Data (DSOD) S,H<->E

Description: Sent by the sending system in response to Open Data Set Request.

Structure: L,5
1. <HANDLE>
2. <DSNAME>
3. <ACKC13>
4. <RTYPE>
5. <RECLEN>

Exceptions: The possible ACKC13 codes for this message are:

0=O.K.
1=ERROR:Try later.
2=ERROR:Unknown Data Set Name.
3=ERROR:Illegal Checkpoint value.
4=ERROR:Too many open Data Sets.
5=ERROR:Data set open too many times.
9=ERROR:Handle in Use.
10=ERROR:Pending Transaction.

S13,F5 Read Data Set Request (DSRR) S,H<->E,reply

Description: Sent by the receiving system to read data from an open data set.

Structure: L,2
1. <HANDLE>
2. <READLN>

S13,F6 Read Data Set Data (DSRD) M,H<->E

Description: Sent by the sending system in response to Read Data Set Request.

Structure: L,4
1. <HANDLE>
2. <ACKC13>
3. <CKPNT>
4. L,n
   1. <FILDAT>
   .
   .
   n. <FILDAT>

Exceptions: The possible item formats, number of items (n), and length of each FILDAT item (|th) are given by the following table. MaxItems is defined in Section 7.17.10.2.

RTYPE	0 (Stream)	1 (Discrete)
Item Format	10 (binary)	10 (binary) or 20 (ASCII)
Maximum n	1	MaxItems
Maximum n	1 (ACKC13=0) 0(any error)	1 (ACKC13=0) 0(any error)
Maximum |th	READLN	RECLEN
Maximum |th	0	0

The possible ACKC13 codes for this message are:
0 = O.K.
6 = ERROR: No open Data Set
7 = ERROR: Cannot Continue
8 = ERROR: End of Data
10= ERROR: Pending Transaction

S13,F7 Close Data Set Send (DSCS) S,H<->E,reply

Description: Sent by the receiving system to close an open data set.

Structure: L,1
1. <HANDLE>

S13,F8 Close Data Set Acknowledge (DSCA) S,H<->E

```
Description:   Sent by the sending system in response to Close Data Set Send (DSCS).

Structure:     L,2
                 1. <HANDLE>
                 2. <ACKC13>

The possible ACKC13 codes for this message are:
               0 = O.K.
               6 = ERROR:No open Data Set.
               10= ERROR:Pending Transaction.
```

S13,F9 Reset Data Set Send (DSRS) S,H<->E,reply

```
Description:   Sent by either system to close all open data sets.

Structure:     Header only
```

S13,F10 Reset Data Set Acknowledge (DSRA) S,H<->E

```
Description:   Sent in response to Reset Data Set Send.

Structure:     Header only
```

S13,F11 Data Set Object Multi-Block Inquire (DSOMGI) S,H<->E,reply

```
Description:   This message requests permission to send a multi-block data set. If
               the receiving system does not grant permission in the reply, the
               multi-block data set may not be sent. OBJSPEC is used to identify the
               data set object type and identifier and may include a destination.
               DATALENGTH represents the total message length, not the length of the
               data set.

Structure:     L,3
                 1. <DATAID>
                 2. <OBJSPEC>
                 3. <DATALENGTH>
```

S13,F12 Data Set Object Multi-Block Grant (DSOMBG) S,H<->E

```
Description:   This message grants or denies permission to send a multi-block data
               set.

Structure:     <GRANT>
```

S13,F13 Table Data Send (TDS) M,H<->E,reply

Description: This message allows the host and the equipment to exchange predefined datasets in a tabular format. The first element of every row is used to reference that row for all other elements. If S13,F13 is Multi-block, it must be preceded by the S13,F11/S13,F12 Inquire/Grant transaction.

Structure:

```
L,8
  1. <DATAID>
  2. <OBJSPEC>
  3. <TBLTYP>
  4. <TBLID>
  5. <TBLCMD>
  6. L,n                      # of table attributes
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       n. L,2
            1. <ATTRID_n>
            2. <ATTRDATA_n>
  7. L,c                      # of column definitions
       1. <COLHDR_1>          1st column element description
       .
       c. <COLHDR_c>          cth column element description
  8. L,r                      # of row definitions
       1. L,c_1               # of entries per definition
            1. <TBLELT_11>    1st table element, 1st row
            .
            m. <TBLELT_1c1>   mth table element, 1st row
       .
       r. L,c_r               rth row definition
            1. <TBLELT_r1>    1st table element, rth row
           .
            m. <TBLELT_rcr>   mth table element, rth row
```

Exception: If OBJSPEC is a zero-length item, then the owner of the table is the receiver of the message. If r is zero, any existing table definition of the given type and id is to be deleted. Otherwise, c_1 may not be zero, and the value of c_1 shall be less than or equal to the value of c.

S13,F14 Table Data Acknowledge (TDA) — S,H<->E

Description: This message is used to acknowledge the receipt of a table and to indicate any errors.

Structure:

L,2
1. <TBLACK>
2. L,p
   1. L,2
      1. <ERRCODE$_1$>
      2. <ERRTEXT$_1$>

   .

   .

   P. L,2
      1. <ERRCODE$_p$>
      2. <ERRTEXT$_p$>

Exception: p = 0 if and only if TBLACK indicates no errors.

S13,F15 Table Data Request (TDR) — M,H<->E,reply

Description: This message allows the host or the equipment to request part or all of a specific table. Either specific columns or specific rows may be requested, but not both at the same time. If S13,F15 is Multi-block, it must be preceded by the S13,F11/S13,F12 Inquire/Grant transaction.

Structure:

L,7
1. <DATAID>
2. <OBJSPEC>
3. <TBLTYP>
4. <TBLID>
5. <TBLCMD>
6. L,p — # of column definitions
   1. <COLHDR$_1$> — 1st column element description

   .

   p. <COLHDR$_p$> — pth column element description
7. L,q
   1. <TBLELT$_1$> — 1st row identifier

   .

   .

   q. <TBLELT$_q$>

Exception: If OBJSPEC is a zero-length item, then the owner of the table is the receiver of the message. Either p or q, or both, must be zero. If p = 0 and q = 0, all rows are requested; otherwise, only the specified columns, or the rows referenced by TBLELT, are requested.

S13,F16 Table Data (TD) M,H<->E

Description: This message is used to return data from the requested table.

Structure:

```
L,6
  1. <TBLTYP>
  2. <TBLID>
  3. L,n                     # of table attributes
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       n. L,2
            1. <ATTRID_n>
            2. <ATTRDATA_n>
  4. L,c                     # of column definitions
       1. <COLHDR_1>         1st column element description
       .
       c. <COLHDR_c>         cth column element description
  5. L,r                     # of row definitions
       1. L,c_1              # of entries per definition
            1. <TBLELT_11>   1st table element, 1st row
            .
            m. <TBLELT_1c1>  last table element, 1st row
       .
       r. L,c_r              rth row definition
            1. <TBLELT_r1>   1st table element, rth row
            .
            m. <TBLELT_rcr>  mth table element, rth row
  6. L,2
       1. <TBLACK>
       2. L,p
            1. L,2
                 1. <ERRCODE_11>
                 2. <ERRTEXT_12>
            .
            P. L,2
                 1. <ERRCODE_p1>
                 2. <ERRTEXT_p2>
```

Exceptions: p = 0 if, and only if, TBLACK indicates no errors. The length c_{11} of a table row may not exceed the value of c.

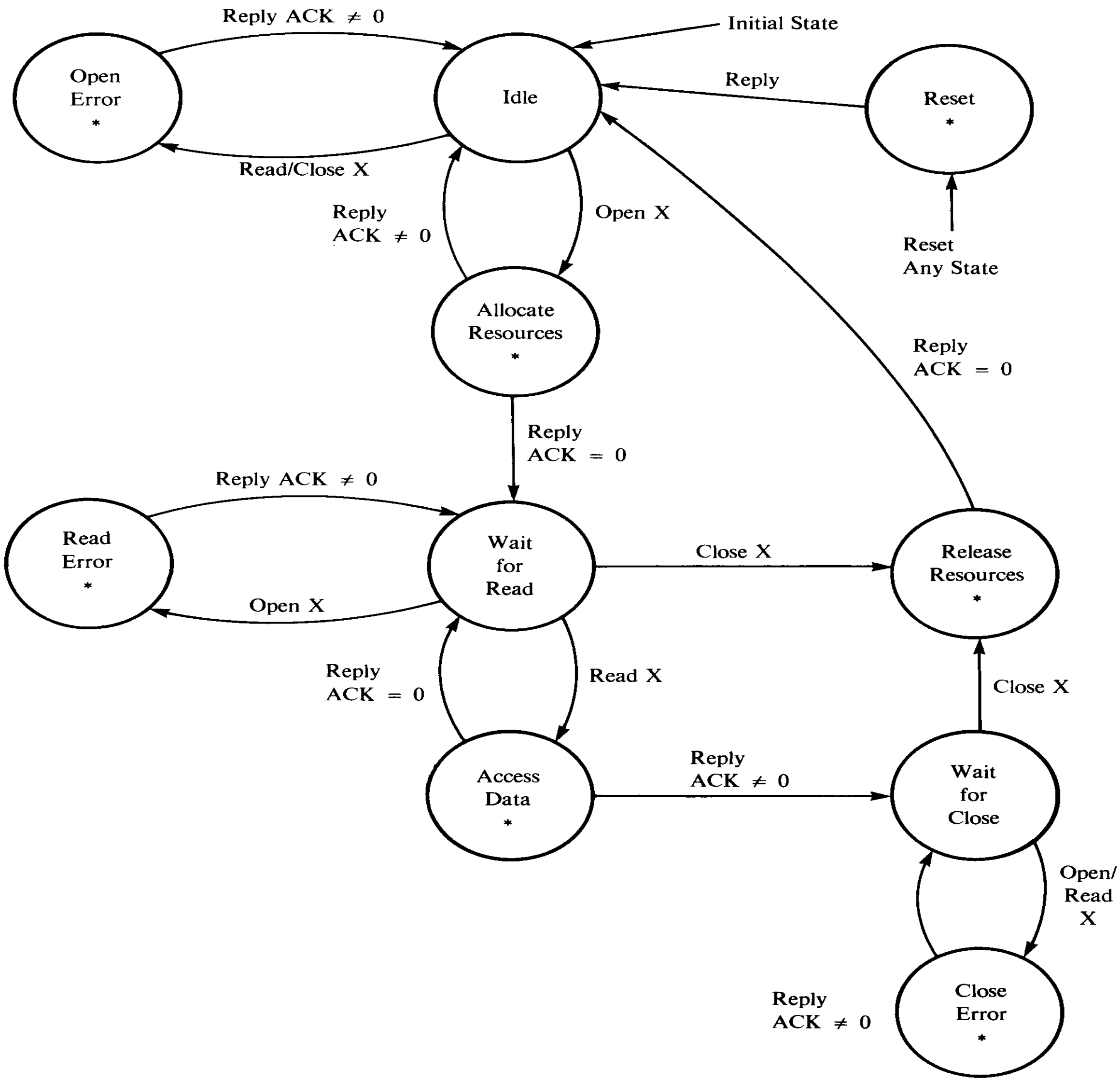


Figure S13.1
The Sending System's State Diagram During a Data Set Transfer
An Asterisk (*) marks the states where a primary message which uses handle X would result in a secondary message with the error code for "Pending Transaction."

7.18 *Stream 14 Object Services* — The functions in this stream are used for generic functions concerning objects, including obtaining information about objects and setting values for an object.

S14,F0 Abort Transaction (S14F0) S,H<->E

Description: Same form as S1,F0.

S14,F1 GetAttr Request (GAR) S,H<->E,reply

Description: This message is used to request a set of specified attributes for one or more objects. It consists of an "object specifier" for the owner of the target objects (the objects of interest), the target object type, a list of identifiers of the target objects, a filter (a list of qualifying relationships) that limits the target objects of interest to those that meet all of the qualifications in and the specific attributes whose values are requested.

The object specifier provides a specification of the owner of the target object(s). It contains a sequence of hierarchical object relationships. Each element of the object specifier identifies a specific object instance that is the superior of the following object instance in the sequence. The last object instance in the sequence is in a hierarchical relationship to the target objects.

The target object type designates the type of the target object, and the list of object identifiers indicates the specific instance of that type that are of interest. The target type may be omitted only if object identifiers are unique across all object types and the list of identifiers is not empty.

The object filter is an optional list of qualifications, each of which provides a condition to be applied to the object instances of interest. Each qualification objects of interest are those that meet all of the specified qualifications.

The attribute relationship quantifier is a logical binary relationship $ATTRRELN_i$ that the specified qualifying value $ATTRDATA_i$ has to the corresponding attribute of each instance of the desired object type(s). The objects that are to be qualified with this filter have an attribute value V_i such that the statement "$ATTRDATA_i$ $ATTRRELN_i$ V_i" is TRUE. If $ATTRRELN_i$ is omitted, the relationship of equality is intended.

For ASCII attribute values $ATTRDATA_i$, the characters for question mark "?" and asterisk "*" are used as "wild characters" to provide filtering for certain object types. The character "?" may be used in any attribute or key attribute value with an ASCII format to represent "any single character" and may be repeated. The asterisk character "*" may be similarly used to represent a variable-length string, including a null string. The string "*x" represents a string of any length that ends in "x", the string "x*" represents any string that begins with "x", and the string "*" represents any string of any non-zero length. The comparison for text characters is case insensitive.

Equipment is not required to support wild characters in particular, or attribute filters in general.

Structure: L,5

1. <OBJSPEC>
2. <OBJTYPE>
3. L,i — i = identifiers of the object instances requested
    1. <$OBJID_1$>
    .
    .
    i. <$OBJID_i$>
4. L,q — q = # object qualifiers to match
    1. L,3
        1. <$ATTRID_1$>
        2. <$ATTRDATA_1$>
        3. <$ATTRRELN_1$>
    .
    .
    q. L,3
        1. <$ATTRID_q$>
        2. <$ATTRDATA_q$>
        3. <$ATTRRELN_q$>
5. L,a — a = # attributes requested
    1. <$ATTRID_1$>
    .
    .
    a. <$ATTRID_a$>

Exception: If OBJSPEC is a zero-length item, no object specifier is provided. If i = 0,only the filter is to be applied. If q = 0, no filter is specified. If both i and q = 0, information for all instances of the objects are requested. If a = 0, all attributes are requested.

S14,F2 GetAttr Data (GAD) M,H<->E

Description: This message is used to transfer the set of requested attributes for the specified object(s). The order of attributes is retained from the primary message.

Structure:

```
L,2
  1. L,n                n = number of objects
       1. L,2
            1. <OBJID_1>
            2. L,a      a = number of attributes
                 1. L,2
                      1. <ATTRID_1>
                      2. <ATTRDATA_1>
                 .
                 .
                 a. L,2
                      1. <ATTRID_a>
                      2. <ATTRDATA_a>
                      .
                      .
       n. L,2
            1. <OBJID_n>
            2. L,b      b = number of attributes
                 1. L,2
                      1. <ATTRID_1>
                      2. <ATTRDATA_1>
                 .
                 .
                 b. L,2
                      1. <ATTRID_b>
                      2. <ATTRDATA_b>
  2. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: If OBJSPEC is a zero-length item, no object specifier is provided. If n = 0, no objects matched the specified filter. If p = 0, no errors were detected.

S14,F3 SetAttr Request (SAR) S,H<->E, reply

Description: This message is used to request that a given set of attributes be assigned specified values for all objects of the specified type and exactly matching the specified attribute requirements. Certain attributes may not be changed through the interface. For a description of filters, see S14,F1.

Structure:

L,4
- 1. <OBJSPEC>
- 2. <OBJTYPE>
- 3. L,i — i = number of object instances requested
  - 1. <OBJID$_1$>
  - .
  - .
  - i. <OBJID$_i$>
- 4. L,n — n = # attribute settings
  - 1. L,2
    - 1. <ATTRID$_1$>
    - 2. <ATTRDATA$_1$>
  - .
  - .
  - n. L,2
    - 1. <ATTRID$_n$>
    - 2. <ATTRDATA$_n$>

Exception: If OBJSPEC is a zero-length item, no object specifier is provided.

S14,F4 SetAttr Data (SAD) M,H<->E

Description: This message is used to acknowledge that the attributes for the specified objects have been set as requested or to indicate an error for each attribute value that was not set as requested. The order of attributes is retained from the primary message.

Structure:

```
L,2
  1. L,i                i = number of objects requested
       1. L,2
            1. <OBJID1>
            2. L,n      n = number of attributes set.
                 1. L,2
                      1. <ATTRID1>
                      2. <ATTRDATA1>
                 .
                 .
                 n. L,2
                      1. <ATTRIDn>
                      2. <ATTRDATAn>
       .
       .
       i. L,2
            1. <OBJIDi>
            2. L,n
                 1. L,2
                      1. <ATTRID1>
                      2. <ATTRDATA1>
                 .
                 .
                 n. L,2
                      1. <ATTRIDn>
                      2. <ATTRDATAn>
  2. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: If n = 0 for any object, the object was not found.
If p = 0, no errors were detected.

S14,F5 GetType Request (GTR) S,H<->E,reply

Description: This message is used to request the types of objects owned by an object. This is an operation performed on an object type rather than on object instances. Wild characters "?" and "*" may be used as a filter for object types. Equipment is not required to support wild characters.

Structure: <OBJSPEC>

Exception: If OBJSPEC is a zero-length item, no object specifier is provided.

S14,F6 GetType Data (GTD)

Structure: L,2
  1. L,n   n = number of object types
    1. <$OBJTYP_1$>
    .
    .
    n. <$OBJTYP_n$>
  2. L,2
    1. <OBJACK>
    2. L,p   p = number of errors reported
      1. L,2
        1. <$ERRCODE_1$>
        2. <$ERRTEXT_1$>
      .
      .
      p. L,2
        1. <$ERRCODE_p$>
        2. <$ERRTEXT_p$>

Exception: If n = 0, there are no owned object types. If p = 0, no errors were detected.

S14,F7 GetAttrName Request (GANR) S,H<->E,reply

Description: This message is used to request the names of the attributes of specified types of owned objects. This is an operation performed on an object type rather than on object instances. Wild characters "?" and "*" may be used as a filter for object types. Equipment is not required to support wild characters.

Structure: L,2
  1. <OBJSPEC>
  2. L,n   n = # of object types
    1. <$OBJTYP_1$>
    .
    .
    n. <$OBJTYP_n$>

Exception: If OBJSPEC is a zero-length item, no object specifier is provided.

S14,F8 GetAttrName Data (GAND) M,H<->E

Description: This message contains the names of the attributes of the requested objects.

Structure:

```
L,2
  1. L,n                n = number of object types
       1. L,2
            1. <OBJTYP1>
            2. L,a      a = number of attributes
                 1. <ATTRID1>
                 .
                 .
                 a. <ATTRIDa>
       .
       .
       n. L,2
            1. <OBJTYPn>
            2. L,b      b = number of attributes
                 1. <ATTRID1>
                 .
                 .
                 b. <ATTRIDb>
  2. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: If OBJSPEC is a zero-length item, no objects matched the specified filter.
If p = 0, no errors were detected.

S14,F9 Create Object Request (COR) M,H<->E,reply

Description: This message is used to request an object owner to create an object instance. OBJSPEC specifies the object owner.

Structure:
```
L,3
  1. <OBJSPEC>
  2. <OBJTYPE>
  3. L,a                a = # attributes requested
       1. L,2
            1. <ATTRID1>
            2. <ATTRDATA1>
       .
       .
       a. L,2
            1. <ATTRIDa>
            2. <ATTRDATAa>
```

Exception: If OBJSPEC is a null-length item, no object specifier is provided. If a = 0, no specific attribute settings are requested for the new object.

S14,F10 Create Object Acknowledge (CAO) M,H<->E

Description: This message is used to acknowledge the success or failure of creating the new object specified. If successful, OBJSPEC is the object specifier of the new object. The list of attributes returned is dependent upon the type of object specified.

Structure:
```
L,3
  1. <OBJSPEC>
  2. L,b                b = number of attributes returned
       1. L,2
            1. <ATTRID1>
            2. <ATTRDATA1>
       .
       .
       b. L,2
            1. <ATTRIDb>
            2. <ATTRDATAb>
  3. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: If OBJSPEC is a null-length item, no object was created. If b = 0, no attributes of the new object are returned. If p = 0, no errors were detected.

S14,F11 Delete Object Request — S,H<->E,reply

Description: This message is used to request that the object specified in OBJSPEC be deleted. The list of attribute settings depends upon the type of object to be deleted.

Structure:

```
L,2
  1. <OBJSPEC>
  2. L,a                n = # attribute settings
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       a. L,2
            1. <ATTRID_a>
            2. <ATTRDATA_a>
```

Exception: If n = 0, no attribute settings are provided.

S14,F12 Delete Object Acknowledge (DOA) — M,H<->E

Description: This message is used to acknowledge the success or failure of deleting the object specified. The list of attributes returned is dependent upon the type of object to be deleted.

Structure:

```
L,2
  1. L,b                n = number of attributes returned
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       b. L,2
            1. <ATTRID_b>
            2. <ATTRDATA_b>
  2. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: If n = 0, no attribute values are returned. If p = 0, no errors were detected.

S14,F13 Object Attach Request (OAR) M,H<->E,reply

Description: This message is sent by a supervisor to request the object specified in OBJSPEC to attach or reattach itself to the requestor.

Structure:

L,2
1. <OBJSPEC>
2. L,a — a = # attribute settings
   1. L,2
      1. <ATTRID$_1$>
      2. <ATTRDATA$_1$>

      .
      .

   a. L,2
      1. <ATTRID$_a$>
      2. <ATTRDATA$_a$>

Exception: If a = 0, no attribute settings are provided.

S14,F14 Object Attach Acknowledge (OAA) M,H<->E

Description: This message is used to acknowledge the success or failure of the requested attachment. If successful, a non-zero token shall be returned for the supervisor’s use in subsequent communications with the attached object.

Structure:

L,3
1. <OBJTOKEN>
2. L,b — b = number of attributes
   1. L,2
      1. <ATTRID$_1$>
      2. <ATTRDATA$_1$>

      .
      .

   b. L,2
      1. <ATTRID$_b$>
      2. <ATTRDATA$_b$>
3. L,2
   1. <OBJACK>
   2. L,p — p = number of errors reported
      1. L,2
         1. <ERRCODE$_1$>
         2. <ERRTEXT$_1$>

         .
         .

      p. L,2
         1. <ERRCODE$_p$>
         2. <ERRTEXT$_p$>

Exception: OBJTOKEN is zero if and only if p is non-zero. If b = 0, no attribute values are returned. If p = 0, no errors were detected.

S14,F15 Attached Object Action Request (AOAR) M,H<->E,reply

Description: This message is used by a supervisor (only) to request an attached object to perform an action.

Structure:
```
L,4
  1. <OBJSPEC>
  2. <OBJCMD>
  3. <OBJTOKEN>
  4. L,a                a = # attribute settings
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       a. L,2
            1. <ATTRID_a>
            2. <ATTRDATA_a>
```

Exception: If a = 0, no attribute settings are provided.

S14,F16 Attached Object Action Acknowledge (AOAA) M,H<->E

Description: This message is used to acknowledge the success or failure of an action requested by a supervisor.

Structure:
```
L,2
  1. L,b                b = number of attributes
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       b. L,2
            1. <ATTRID_b>
            2. <ATTRDATA_b>
  2. L,2
       1. <OBJACK>
       2. L,p           p = number of errors reported
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: If p = 0, no errors were detected.

S14,F17 Supervised Object Action Request (SOAR) S,H<->E,reply

Description: This message is used to request a supervisor to have a supervised attached object perform an action. OBJSPEC specifies the supervisor, and TARGETSPEC specifies the attached object.

Structure:
```
L,4
  1. <OBJSPEC>
  2. <OBJCMD>
  3. <TARGETSPEC>
  4. L,a                a = number of attribute settings
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       a. L,2
            1. <ATTRID_a>
            2. <ATTRDATA_a>
```

Exception: If a = 0, no attribute settings are provided.

S14,F18 Supervised Object Action Acknowledge (SOAA) M,H<->E

Description: This message is used to acknowledge the success or failure of an action requested of a supervisor.

Structure:
```
L,2
  1. L,b               b = number of attributes
       1. L,2
            1. <ATTRID_1>
            2. <ATTRDATA_1>
       .
       .
       b. L,2
            1. <ATTRID_b>
            2. <ATTRDATA_b>
  2. L,2
       1. <OBJACK>
       2. L,p          p = number of errors reported
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: If b = 0, no attributes are returned. If p = 0, no errors were detected.

S14,F19 Generic Service Request (GSR) M,H->E, Reply

Description: The host requests an object to perform the specified service with its associated parameters. If multi-block, it shall be preceded by the S14F23/F24 Multi-Block Inquire/Grant transaction. DATAID is given uniquely to each message. OPID is uniquely specified to identify delayed completion information for time consuming service. OPID could be zero if and only if the service cannot take a long time.

Structure: L,5

1. <DATAID>
2. <OPID>
3. <OBJSPEC>
4. <SVCNAME>
5. L,m # of parameter groups
    1. L,2
        1. <SPNAME$_1$> service parameter 1 name
        2. <SPVAL$_1$> service parameter 1 value
    2. L,2
        1. <SPNAME$_2$> service parameter 2 name
        2. <SPVAL$_2$> service parameter 2 value

    .

    .

    m. L,2
        1. <SPNAME$_m$> service parameter m name
        2. <SPVAL$_m$> service parameter m value

If a specific value of SPNAME is defined to have a SPVAL defined as a LIST, it shall always be a LIST. If the SPVAL that is associated to that specific value of SPNAME is defined to be anything other than LIST, it will result in a format error.

Exception: A zero length list, m = 0, indicates that no parameter groups are sent with the service request. OBJSPEC can be a null length item if no object provide the services is defined in the standards which are referred to and it is assumed that “Equipment” is delegated and handled as if it is an object.

Notes:

1. If some service parameters are attributes of the specified object, service parameter name-value pair, that is SPNAME and SPVAL, is actually attribute id-data pair, that is ATTRID and ATTRDATA. An example of parameter part in the message format could be interpreted as below.

    L,m
    1. L,2
        1. <SPNAME$_1$>
        2. <SPVAL$_1$>
    2. L,2

    .

    .

    .

    k. L,2
        1. <ATTRID$_k$>
        2. <ATTRDATA$_k$>

    .

    m. …

2. If SPVAL is a LIST, the items that make up that list shall take on

one of the following forms: (1) a list of items with an identical format, (2) a LIST of SPNAME, SPVAL pairs, as illustrated below. When SPVAL is actually ATTRDATA, even if it is a LIST, it or its parts are not required to expand into lower level items if their names have not been formally named in the corresponding SEMI standard.

```
A)            L,2
                1. <SPNAME_a>
                2. L,m
                     1. <SPVAL_a1>
                     2. <SPVAL_a2>
                     :
                     :
                     m. <SPVAL_am>
B)            L,2
                1. <SPNAME_b>
                2. L, n
                      1. L,2
                           1. <SPNAME_bl>
                           2. <SPVAL_bl>
                      :
                      :
                      n. L,2
                           1. <SPNANE_bn>
                           2. <SPVAL_bn>
```

S14,F20 Generic Service Acknowledge (GSA) M,H<-E

Description: The equipment acknowledges requested service or reports any error(s). If the service is accepted and completed at once, (i.e. SVCACK =0), then required parameter for response are listed with in this message. If the service is accepted but it takes relatively longer time to do due to some physical reason, (i.e. SVCACK = 4), then response of the service will be replied later with parameters when it is completed successfully or faultily. Criteria of the time whether it is delayed response or not depends on implementation. LINKID is set to a non-zero value if and only if additional completion reports will be sent.

```
Structure:    L,3
                1. <SVCACK>
                2. <LINKID>
                3. L,n                       # of parameter groups
                     1. L,2
                          1. <SPNAME_1>      service parameter 1 name
                          2. <SPVAL_1>       service parameter 1 value
                     2. L,2
                          1. <SPNAME_2>      service parameter 2 name
                          2. <SPVAL_2>       service parameter 2 value
                     :
                     :
                     n. L,2
                          1. <SPNAME_n>      service parameter n name
                          2. <SPVAL_n>       service parameter n value
```

S14,F21 Generic Service Completion Information (GSCI) M,H<-E, Reply

Description: The equipment notifies the original service requestor when requested service on an object is completed, either successfully or unsuccessfully. The equipment may send required information using reply parameters. If the service was accepted and completed at once, the information was carried with the acknowledge message, that is secondary message of requesting one, and this message is not provided.

OPID contains the value of OPID in the initial request, i.e. S14F19. LINKID is set to a non-zero value if and only if additional completion reports with the same OPID will be sent. If multi-block, it shall be preceded by the S14F23/F24 Multi-Block Inquire/Grant transaction.

Structure:
```
L,4
  1. <DATAID>
  2. <OPID>
  3. <LINKID>
  4. L,n                          # of parameter groups
       1. L,2
            1. <SPNAME1>          service parameter 1 name
            2. <SPVAL1>           service parameter 1 value
       2. L,2
            1. <SPNAME2>          service parameter 2 name
            2. <SPVAL2>           service parameter 2 value
       :
       :
       n. L,2
            1. <SPNAMEn>          service parameter n name
            2. <SPVALn>           service parameter n value
```

S14,F22 Generic Service Completion Acknowledge (GSCA) S,H->E

Description: The acknowledgement of generic Object Service Completion Information, i.e. S14F21.

Structure: <DATAACK>

S14,F23 Multi-block Generic Service Data Inquire (GSDI) S,H<->E, Reply

Description: If any of Object Service messages are larger than one block, then this transaction must precede that message.

Structure:
```
L, 2
   1. <DATAID>
   2. <DATALENGTH>
```

S14,F24 Multi-block Generic Service Data Grant (GSDG) S,H<->E

Description: Message to indicate if permission is granted to transmit a multi-block Object Service message.

Structure: <GRANT>

S14,F25 Get Service Name Request (GSNR) S,H->E

Description: This message is used to request to list the services of specified types of owned objects. This is an operation performed on an object type rather than on object instances. Wild characters “?”. and “*” may be used as a filter for object types. Equipment is not required to support wild characters.

```
Structure:      L,2
                  1. <OBJSPEC>
                  2. L,n                          n = # of object types
                       1. <OBJTYP_1>
                       .
                       .
                       n. <OBJTYP_n>
```

Exception: If OBJSPEC is a zero-length item, no object specifier is provided.

S14,F26 Get Service Name Data (GSND) S,H<-E

Description: This message contains a list of the services of the requested objects.

```
Structure:      L,2
                  1. L,n                          n = number of object types
                       1. L,2
                            1. <OBJTYP_1>
                            2. L,a                a = number of attributes
                                 1. <SVCNAME_1>
                                 .
                                 .
                                 a. <SVCNAME_a>
                            .
                            .
                            n. L,2
                                 1. <OBJTYP_n>
                                 2. L,b           b = number of attributes
                                      1. <SVCNAME_1>
                                      .
                                      .
                                      a. <SVCNAME_b>
                       2. L,2
                            1. L,2
                                 1. <OBJACK>
                                 2. L,p           p = number of errors reported
                                      1. L,2
                                           1. <ERRCODE_1>
                                           2. <ERRTEXT_1>
                                      .
                                      .
                                      p. L,2
                                           1. <ERRCODE_p>
                                           2. <ERRTEXT_p>
```

Exception: If p = 0, no errors were detected.

S14,F27 Get Service Parameter Name Request (GPNR) S,H->E

```
Description:   This message is used to request to list the parameters of specified
               services of owned object. This is an operation performed on an object
               type rather than on object instances.

Structure:     L,3
                 1. <OBJSPEC>
                 2. <OBJTYP>
                 3. L,n                        n = # of interesting services
                      1. <SVCNAME1>
                      .
                      .
                      n. <SVCNAMEn>

Exception:     If OBJSPEC is a zero-length item, no object specifier is provided.
```

S14,F28 Get Service Parameter Name Data (GPND) S,H<-E

```
Description:   This message contains a list of the service parameters of the
               requested services for the specified object.

Structure:     L,2
                 1. L,n                        n = number of services of interest
                      1. L,2
                           1. <SVCNAME1>
                           2. L,a              a = number of parameter names
                                1. <SPNAME1>
                                .
                                .
                                a. <SPNAMEa>
                      .
                      .
                      n. L,2
                           1. <SVCNAMEn>
                           2. L,b              b = number of parameter names
                                1. <SPNAME1>
                                .
                                .
                                b. <SPNAMEb>
                 2. L,2
                      1. <OBJACK>
                      2. L,p                   p = number of errors reported
                           1. L,2
                                1. <ERRCODE1>
                                2. <ERRTEXT1>
                           .
                           .
                           p. L,2
                                1. <ERRCODEp>
                                2. <ERRTEXTp>

Exception:  If p = 0, no errors were detected.
```

7.19 *Stream 15 Recipe Management* — The functions in this stream are used requesting information and operations concerning recipes, recipe namespaces, and recipe executors. A recipe is an object that is transferred in sections, where a section consists of either recipe attributes, agent-specific dataset attributes, or the body of the recipe. An attribute is information concerning the recipe body, the recipe as a whole, or the application of the recipe. An attribute consists of an attribute name/attribute value pair.

S15,F0 Abort Transaction (S15F0) S,H<->E

```
Description:   Same form as S1,F0.
```

S15,F1 Recipe Management Multi-block Inquire S,H<->E, reply

```
Description:   This message requests permission to send a multi-block message based
               upon a maximum length of the total message.

Structure:     L,3
                 1. <DATAID>
                 2. <RCPSPEC>
                 3. <RMDATASIZE>

Exception:    If RCPSPEC is zero-length, the multi-block message for which
              permission to send is requested does not contain a recipe.
```

S15,F2 Recipe Management Multi-block Grant S,H<->E

```
Description:   This message grants or denies permission to send a multi-block
               message.

Structure:     <RMGRNT>
```

S15,F3 Recipe Namespace Action Request S,H<->E, reply

```
Description:   This message requests that a recipe namespace be created or deleted.

Structure:     L,2
                 1. <RMNSSPEC>
                 2. <RMNSCMD>
```

S15,F4 Recipe Namespace Action Acknowledge M,H<->E

```
Description:   This message is used to confirm whether the requested action was
               completed successfully or to provide error information otherwise.

Structure:     L,2
                 1. <RMACK>
                 2. L,p
                      1. L,2
                           1. <ERRCODE1>
                           2. <ERRTEXT1>
                      .
                      .
                      p. L,2
                           1. <ERRCODEp>
                           2. <ERRTEXTp>

Exception:     p = 0 if and only if RMACK indicates no errors.
```

S15,F5 Recipe Namespace Rename Request S,H<->E, reply

Description: A request is made for a recipe namespace to be renamed.

Structure:
```
L,2
  1. <RMNSSPEC>
  2. <RMNEWNS>
```

S15,F6 Recipe Namespace Rename Acknowledge M,H<->E

Description: This message is used to acknowledge or deny a request to rename a recipe namespace.

Structure:
```
L,2
  1. <RMACK>
  2. L,p
       1. L,2
            1. <ERRCODE_1>
            2. <ERRTEXT_1>
       .
       .
       p. L,2
            1. <ERRCODE_p>
            2. <ERRTEXT_p>
```

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F7 Recipe Space Request S,H<->E, reply

Description: This message requests the amount of recipe storage available in the storage of a recipe namespace or recipe executor, as indicated by its object specifier OBJSPEC.

Structure: <OBJSPEC>

Exception: None.

S15,F8 Recipe Space Data M,H<->E

Description: This message contains the amount of storage available for recipes.

Structure:
```
L,2
  1. <RMSPACE>
  2. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F9 Recipe Status Request S,H<->E, reply

Description: This message is used to request the status of a recipe and the next available numeric version for that recipe class and name.

Structure: <RCPSPEC>

Exception: None.

S15,F10 Recipe Status Data M,H<->E

Description: This message contains the protected status of the recipe and the next available version number for that recipe class and name.

Structure:
```
L,3
  1. <RCPSTAT>
  2. <RCPVERS>
  3. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: RCPVERS is a zero-length item if and only if the recipe does not exist. p = 0 if and only if RMACK indicates no errors.

S15,F11 Recipe Version Request S,H<->E, reply

Description: This message is used to request the best version of a recipe for the specified agent.

Structure:
```
L,4
  1. <RMNSSPEC>
  2. <RCPCLASS>
  3. <RCPNAME>
  4. <AGENT>
```

Exception: If item 2 is zero length, the recipe class PROCESS is indicated. If item 4 is a zero-length item, no agent is specified.

S15,F12 Recipe Version Data M,H<->E

```
Description:   This message contains the recommended version.

Structure:     L,3
                 1. <AGENT>
                 2. <RCPVERS>
                 3. L,2
                      1. <RMACK>
                      2. L,p
                           1. L,2
                                1. <ERRCODE1>
                                2. <ERRTEXT1>
                           .
                           .
                           p. L,2
                                1. <ERRCODEp>
                                2. <ERRTEXTp>

Exception:     If AGENT is a zero-length item in the request, it shall also be a
               zero-length item in the reply. If it is not zero-length in the
               request, and it is of zero-length in the reply, then no qualifying
               recipe was found specific to that equipment. p = 0 if and only if
               RMACK indicates no errors.
```

S15,F13 Recipe Create Request M,H<->E, reply

```
Description:   This message is used to create or modify a recipe body. If multi-
               block, it shall be preceded by the S15,F1/F2 inquire/grant
               transaction.

Structure:     L,5
                 1. <DATAID>
                 2. <RCPUPDT>
                 3. <RCPSPEC>
                 4. L,m
                      1. L,2
                           1. <RCPATTRID1>
                           2. <RCPATTRDATA1>
                      .
                      .
                      m. L,2
                           1. <RCPATTRIDm>
                           2. <RCPATTRDATAm>
                 5. <RCPBODY>

Exception:     RCPBODY may be of zero length.
```

S15,F14 Recipe Create Acknowledge M,H<->E

Description: This message is used to acknowledge that a recipe has been created or updated with the body sent in the request.

Structure:
```
L,2
  1. <RMACK>
  2. L,2
       1. L,2
            1. <ERRCODE1>
            2. <ERRTEXT1>
       .
       .
       p. L,2
            1. <ERRCODEp>
            2. <ERRTEXTp>
```

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F15 Recipe Store Request M,H<->E, reply

Description: This message is used to send a recipe, or one or more recipe sections, to a recipe namespace. If multi-block, it shall be preceded by the S15,F1/F2 inquire/grant transaction.

Structure:

```
L,4
  1. <DATAID>
  2. <RCPSPEC>
  3. <RCPSECCODE>
  4. L,q                (q = 1,2,3)
       1. L,r           (r = 0 or 2)
            1. <RCPSECNM>
            2. L,g      (g = # generic attributes)
                 1. L,2
                      1. <RCPATTRID1>
                      2. <RCPATTRDATA1>
                 .
                 .
                 g. L,2
                      1. <RCPATTRIDg>
                      2. <RCPATTRDATAg>
       2. <RCPBODY>
       3. L,m           (m = # agent-specific datasets)
            1. L,2
                 1. <RCPSECNM1>
                 2. L,a
                      1. L,2
                           1. <RCPATTRID11>
                           2. <RCPATTRDATA11>
                      .
                      .
                      a. L,2
                           1. <RCPATTRID1a>
                           2. <RCPATTRDATA1a>
            .
            .
            m. L,2
                 1. <RCPSECNMm>
                 2. L,b
                      1. L,2
                           1. <RCPATTRIDm1>
                           2. <RCPATTRDATAm1>
                      .
                      .
                      b. L,2
                           1. <RCPATTRIDmb>
                           2. <RCPATTRDATAmb>
```

Exception: RCPBODY is a zero-length item when the body is omitted. If g = 0, no generic attributes are transferred and RCPBODY shall be a zero-length item. If m = 0, no agent-specific datasets are transferred.

S15,F16 Recipe Store Acknowledge M,H<->E

Description: This message is used to acknowledge that the specified recipe has been stored as requested or to indicate the error(s).

Structure:

```
L,2
  1. <RECPSECCODE>
  2. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F17 Recipe Retrieve Request S,H<->E, reply

Description: This message is used to get a recipe, or one or more recipe sections, from a recipe namespace.

Structure:

```
L,2
  1. <RCPSPEC>
  2. <RCPSECCODE>
```

Exception: None.

S15,F18 Recipe Retrieve Data M,H<->E

Description: This message is used to acknowledge that the specified recipe, or recipe sections, have been set as requested, or to indicate the error(s).

Structure:

```
L,2
  1. L,q                (q = 1,2,3)
       1. L,r           (r = 0 or 2)
            1. <RCPSECNM>
            2. L,g      (g = # generic attributes)
                 1. L,2
                      1. <RCPATTRID_1>
                      2. <RCPATTRDATA_1>
                 .
                 g. L,2
                      1. <RCPATTRID_g>
                      2. <RCPATTRDATA_g>
       2. <RCPBODY>
       3. L,m           (m = # agent-specific datasets)
            1. L,2
                 1. <RCPSECNM_1>
                 2. L,a
                      1. L,2
                           1. <RCPATTRID_11>
                           2. <RCPATTRDATA_11>
                      .
                      .
                      a. L,2
                           1. <RCPATTRID_1a>
                           2. <RCPATTRDATA_1a>
            .
            .
            m. L,2
                 1. <RCPSECNM>_m>
                 2. L,b
                      1. L,2
                           1. <RCPATTRID_m1>
                           2. <RCPATTRDATA_m1>
                      .
                      .
                      b. L,2
                           1. <RCPATTRID_mb>
                           2. <RCPATTRDATA_mb>
            2. L,2
                 1. <RMACK>
                 2. L,p
                      1. L,2
                           1. <ERROCODE_1>
                           2. <ERRTEXT_1>
                      .
                      .
                      p. L,2
                           1. <ERRCODE_p>
                           2. <ERRTEXT_p>
```

Exception: If r = 0, no generic attributes are transferred and RCPBODY shall be a zero-length item. If m = 0, no agent-specific datasets are transferred. p = 0 if and only if RMACK indicates no errors.

S15,F19 Recipe Rename Request — S,H<->E, reply

Description: This message is used to request that a recipe be copied to, or renamed to, a recipe with a new identifier.

Structure: L,3
1. <RCPSPEC>
2. <RCPRENAME>
3. <RCPNEWID>

Exception: None.

S15,F20 Recipe Rename Acknowledge — M,H<->E

Description: This message acknowledges the request to copy or rename a recipe and indicates whether the action was successfully performed or errors that occurred.

Structure: L,2
1. <RMACK>
2. L,p
    1. L,2
        1. <ERRCODE$_1$>
        2. <ERRTEXT$_1$>

    .
    .

    p. L,2
        1. <ERRCODE$_p$>
        2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F21 Recipe Action Request — M,H<->E, reply

Description: This message is used to acknowledge the request to perform an action on one or more recipes within a namespace.

Structure: L,6
1. <DATAID>
2. <RCPCMD>
3. <RMNSSPEC>
4. <OPID>
5. <AGENT>
6. L,n
    1. <RCPID$_1$>

    .
    .

    n. <RCPID$_n$>

Exception: AGENT may be a zero-length item except for requests for certify, de-certify, download, and upload.

S15,F22 Recipe Action Acknowledge M,H<->E

Description: This message is used to acknowledge the request to originate a new recipe.

Structure:
```
L,4
  1. <AGENT>
  2. <LINKID>
  3. <RCPCMD>
  4. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: LINKID is zero if and only if all requested actions have been completed. p = 0 if and only if RMACK indicates no errors.

S15,F23 Recipe Descriptor Request M,H<->E, reply

Description: This message is used to request the descriptors of a list of the specified recipes. If multi-block, it must be preceded by the S15,F1/F2 inquire/grant transaction. OBJSPEC is the object specifier of either a recipe namespace of a recipe executor.

Structure:
```
L,3
  1. <DATAID>
  2. <OBJSPEC>
  3. L,n
       1. <RCPID1>
       .
       .
       n. <RCPIDn>
```

Exception: None.

S15,F24 Recipe Descriptor Data M,H<->E

Description: This message returns the requested descriptors in the same order as requested.

Structure:

```
L,2
  1. L,n                (n = number of recipes from request)
       1. L,a           (descriptors for recipe #1)
            1. L,r      (r = 0 or 3) (1st component descriptor)
                 1. <RCPDESCNM_11>
                 2. <RCPDESCTIME_11>
                 3. <RCPDESCLTH_11>
            .
            .
            a. L,r      (r = 0 or 3)
                 1. <RCPDESCNM_1a>
                 2. <RCPDESCTIME_1a>
                 3. <RCPDESCLTH_1a>
       .
       .
       n. L,b           (descriptors for recipe #n)
            1. L,r      (r = 0 or 3) (1st component descriptor)
                 1. <RCPDESCNM_n1>
                 2. <RCPDESCTIME_n1>
                 3. <RCPDESCLTH_n1>
            .
            .
            b. L,r      (r = 0 or 3)
                 1. <RCPDESCNM_nb>
                 2. <RCPDESCTIME_nb>
                 3. <RCPDESCLTH_nb>
  2. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            p. L,2
                 1. <ERRCODE_p>
                 2. <ERRTEXT_p>
```

Exception: A zero-length recipe descriptor (r = 0) means that the specified recipe does not exist (could not be located). p = 0 if and only if RMACK indicates no errors.

S15,F25 Recipe Parameter Update Request M,H<->E, reply

```
Description:   This message is used to update the variable parameter definitions
               for a specific agent. If multi-block, it must be preceded by the
               S15,F1/F2 inquire/grant transaction.

Structure:     L,4
                 1. <DATAID>
                 2. <RMNSSPEC>
                 3. <AGENT>
                 4. L,n
                      1. L,3
                           1. <RCPPARNM1>
                           2. <RCPPARVAL1>
                           3. <RCPPARRULE1>
                      .
                      .
                      n. L,3
                           1. <RCPPARNMn>
                           2. <RCPPARVALn>
                           3. <RCPPARRULEn>

Exception:     None.
```

S15,F26 Recipe Parameter Update Acknowledge M, H<->E

```
Description:   This message indicates the successful performance of the request or
               otherwise indicates the nature of error(s) that occurred.

Structure:     L,2
                 1. <RMACK>
                 2. L,p
                      1. L,2
                           1. <ERRCODE1>
                           2. <ERRTEXT1>
                      .
                      .
                      p. L,2
                           1. <ERRCODEp>
                           2. <ERRTEXTp>

Exception:   p = 0 if and only if RMACK indicates no errors.
```

S15,F27 Recipe Download Request — M,H->E,reply

Description: This message is used to send a recipe to a recipe executor. If multi-block, it shall be preceded by the S15,F1/S15,F2 inquire/grant transaction.

Structure:

```
L,5
  1. <DATAID>
  2. <RCPOWCODE>
  3. <RCPSPEC>
  4. L,m
       1. L,2
            1. <RCPATTRID1>
            2. <RCPATTRDATA1>
       .
       .
       m. L,2
            1. <RCPATTRIDm>
            2. <RCPATTRDATAm>
  5. <RCPBODY>
```

Exception: None.

S15,F28 Recipe Download Acknowledge — M,H<-E

Description: This message is used to acknowledge that a recipe has been received by the recipe executor. If the recipe was successfully verified, the results are returned to the sender. RCPID contains the identifier of a derived object form recipe if created during verification.

Structure:

```
L,3
  1. <RCPID>
  2. L,n (n = # of attributes)
       1. L,2
            1. <RCPATTRID1>
            2. <RCPATTRDATA1>
           .
           .
       n. L,2
            1. <RCPATTRIDn>
            2. <RCPATTRDATAn>
  3. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: If item is a zero length item, no derived object form recipe was originated. n = 0 if and only if the recipe was not verified or failed verification. p = 0 if and only if RMACK indicates no errors.

Description: This message is used to request verification of one or more recipes by a recipe executor. If multi-block, it shall be preceded by the S15F1, F2 inquire/grant transaction. The operation identifier OPID, used where multiple verification requests may be outstanding, may be zero if no further verifications will be requested before all current verification requests are completed by the recipe executor. Otherwise, OPID is generated to be unique for the requestor. RESPEC is the object specifier for the recipe executor.

Structure:

```
L,4
  1. <DATAID>
  2. <OPID>
  3. <RESPEC>
  4. L,m
       1. <RCPID1>
       .
       .
       m. <RCPIDm>
```

Exception: If RESPEC is a zero length item, the target is the recipient of the message.

S15,F30 Recipe Verify Acknowledge M,H<-E

Description: This message is used to acknowledge the request to verify one or more recipes. If a single recipe verification was requested and the recipe was successfully verified, the results are returned to the sender in this message, and RCPID contains the identifier of a derived object form recipe if created during verification. If multiple recipe verifications were requested, then LINKID shall be non-zero.

Structure:
```
L,5
  1. <OPID>
  2. <LINKID>
  3. <RCPID>
  4. L,n (n = # attributes)
       1. L,2
            1. <RCPATTRID1>
            2. <RCPATTRDATA1>
       .
       .
       n. L,2
            1. <RCPATTRIDn>
            2. <RCPATTRDATAn>
  5. L,2
       1. <RMACK>
       2. L,p
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            p. L,2
                 1. <ERRCODEp>
                 2. <ERRTEXTp>
```

Exception: LINKID is zero if and only if a single recipe verification was requested and has been completed. If item 3 is zero length item, no derived object form recipe was originated. n = 0 if and only if the recipe was not verified or failed verification. p = 0 if and only if RMACK indicates no errors.

S15,F31 Recipe Upload Request S,H->E,reply

Description: This message is used to request an execution recipe from a recipe executor.

Structure: <RCPSPEC>

Exception: None.

S15,F32 Recipe Upload Data M,H<-E

Description: This message is used to send an execution recipe from a recipe executor.

Structure: L,4

1. <RCPSPEC>
2. L,m (m = # attributes)
    1. L,2
        1. <RCPATTRID$_1$>
        2. <RCPATTRDATA$_1$>

       .
       .

    m. L,2
        1. <RCPATTRID$_m$>
        2. <RCPATTRDATA$_m$>
3. <RCPBODY>
4. L,2
    1. <RMACK>
    2. L,p
        1. L,2
            1. <ERRCODE$_1$>
            2. <ERRTEXT$_1$>

           .
           .

        p. L,2
            1. <ERRCODE$_p$>
            2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F33 Recipe Select Request — M,H->E,reply

Description: This message is used to request the selection of one or more execution recipes. If multi-block, it shall be preceded by the S15,F1/S15,F2 inquire/grant transaction.

Structure:

```
L,3
1. <DATAID>
2. <RESPEC>
3. L,r            (r = # selections)
   1. L,2
      1. <RCPID_1> (1st recipe selection)
      2. L,p      (p = # parameter settings for 1st recipe)
         1. L,2
            1. <RCPPARNM_11>
            2. <RCPPARVAL_11>
         .
         .
        p. L,2
            1. <RCPPARNM_1p>
            2. <RCPPARVAL_1p>
   .
   .
   r. L,2
      1. <RCPID_r> (rth recipe selection)
      2. L,s      (s = # parameter settings for rth recipe)
         1. L,2
            1. <RCPPARNM_r1>
            2. <RCPPARVAL_r1>
         .
         .
         s. L,2
            1. <RCPPARNM_rs>
            2. <RCPPARVAL_rs>
```

Exception: If the list of parameter settings for a recipe selection is of zero length, then no parameter settings are specified for the corresponding recipe.

S15,F34 Recipe Select Acknowledge — M,H<-E

Description: This message is used to acknowledge the request for recipe selection.

Structure:

```
L,2
  1. <RMACK>
  2. L,p
       1. L,2
            1. <ERRCODE_1>
            2. <ERRTEXT_1>
       .
       .
       p. L,2
            1. <ERRCODE_p>
            2. <ERRTEXT_p>
```

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F35 Recipe Delete Request M,H->E,reply

Description: This message is used to request that one or more recipes be deleted or deselected. If multi-block, it shall be preceded by the S15,F1/ S15,F2 inquire/grant transaction.

Structure: L,4
  1. <DATAID>
  2. <RESPEC>
  3. <RCPDEL>
  4. L,n (n = # recipes deselected)
     1. <RCPID$_1$>
     .
     .
     n. <RCPID$_n$>

Exception: If n = 0 and recipes are to be deselected (RCPDEL = 1), then all currently-selected recipes are indicated.

S15,F36 Recipe Delete Acknowledge M,H<-E

Description: This message is used to acknowledge the request that recipes be deleted or deselected.

Structure: L,2
  1. <RMACK>
  2. L,p
     1. L,2
        1. <ERRCODE$_1$>
        2. <ERRTEXT$_1$>
     .
     .
     p. L,2
        1. <ERRCODE$_p$>
        2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F37 DRNS Segment Approve Action Request S,H<->E,reply

Description: This message is sent by a distributed recipe namespace manager to an attached distributed recipe namespace segment to approve an action previously requested by the segment. If multi-block, it shall be preceded by the S15,F1/S15,F2 inquire/grant transaction.

Structure: L,6
  1. <RMSEGSPEC>
  2. <OBJTOKEN>
  3. <RMGRNT>
  4. <OPID>
  5. <RCPID>
  6. <RMCHGTYPE>

Exception: None.

S15,F38 DRNS Segment Approve Action Acknowledge — M,H<->E

Description: This message is used to acknowledge or deny the approve action request.

Structure:

L,2
  1. <RMACK>
  2. L,p
    1. L,2
      1. <ERRCODE$_1$>
      2. <ERRTEXT$_1$>
    .
    .
    p. L,2
      1. <ERRCODE$_p$>
      2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F39 DRNS Recorder Segment Request — M,H<->E,reply

Description: This message is used by the distributed recipe namespace manager to request that an attached recorder create or delete a segment specifier record. If multi-block, it shall be preceded by the S15,F1/ S15,F2 inquire/grant transaction.

Structure:

L,5
  1. <DATAID>
  2. <RMNSCMD>
  3. <RMRECSPEC>
  4. <RMSEGSPEC>
  5. <OBJTOKEN>

Exception: None.

S15,F40 DRNS Recorder Segment Acknowledge — M,H<->E

Description: This message is used to acknowledge the request to add or delete a segment specifier record.

Structure:

L,2
  1. <RMACK>
  2. L,p
    1. L,2
      1. <ERRCODE$_1$>
      2. <ERRTEXT$_1$>
    .
    .
    p. L,2
      1. <ERRCODE$_p$>
      2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

S15,F41 DRNS Recorder Modify Request — M,H<->E,reply

```
Description:   This message is used by a distributed recipe namespace manager to
               a recorder to store or delete a change request record. If multi-
               block, it shall be preceded by the S15,F1/F2 inquire/grant
               transaction.

Structure:     L,5
                 1. <DATAID>
                 2. <RMRECSPEC>
                 3. <OBJTOKEN>
                 4. <RMNSCMD>
                 5. L,c      (c = 1 or 7)
                      1. <RCPID>
                      2. <RCPNEWID>
                      3. <RMSEGSPEC>
                      4. <RMCHGTYPE>
                      5. <OPID>
                      6. <TIMESTAMP>
                      7. <RMREQUESTOR>

Exception:     If RMNSCMD = create, then c = 7, otherwise c = 1.
```

S15,F42 DRNS Recorder Modify Acknowledge — M,H<->E

```
Description:   This message is used to acknowledge a request to store or delete a
               change request.

Structure:     L,2
                 1. <RMACK>
                 2. L,p
                      1. L,2
                           1. <ERRCODE1>
                           2. <ERRTEXT1>
                           .
                           .
                      p. L,2
                           1. <ERRCODEp>
                           2. <ERRTEXTp>

Exception:     p = 0 if and only if RMACK indicates no errors.
```

S15,F43 DRNS Get Change Request — M,H<->E,reply

```
Description:   This message is used to request a distributed recipe namespace
               recorder or manager to return change requests records for a specific
               recipe or assigned to a specific segment. If multi-block, it shall be
               preceded by the S15,F1/F2 inquire/grant transaction.

Structure:     L,3
                 1. <DATAID>
                 2. <OBJSPEC>
                 3. <TARGETSPEC>

Exception:     If TARGETSPEC is omitted, OBJSPEC identifies a recipe.
```

S15,F44 DRNS Get Change Request Data M,H<->E

```
Description:   This message is used to return the specified change request records.

Structure:     L,2
                 1. L,n      n = # change requests
                      1. L,7
                           1. <RCPID1>
                           2. <RCPNEWID1>
                           3. <RMSEGSPEC1>
                           4. <RMCHGTYPE1>
                           5. <OPID1>
                           6. <TIMESTAMP1>
                           7. <RMREQUESTOR1>
                      .
                      .
                      n. L,7
                           1. <RCPIDn>
                           2. <RCPNEWIDn>
                           3. <RMSEGSPECn>
                           4. <RMCHGTYPEn>
                           5. <OPIDn>
                           6. <TIMESTAMPn>
                           7. <RMREQUESTORn>
                 2. L,2
                      1. <RMACK>
                      2. L,p
                           1. L,2
                                1. <ERRCODE1>
                                2. <ERRTEXT1>
                           .
                           .
                           p. L,2
                                1. <ERRCODEp>
                                2. <ERRTEXTp>

Exception:     If n = 0, no change records were found matching the specification.
               p = 0 if and only if RMACK indicates no errors.
```

S15,F45 DRNS Manager Segment Change Approval Request M,H<->E,reply

```
Description:   This message is sent to a distributed recipe namespace manager by an
               attached distributed recipe namespace segment to request approval
               for a specific type of change to a recipe. If multi-block, it shall
               be preceded by the S15,F1/F2 inquire/grant transaction.

Structure:     L,4
                 1. <DATAID>
                 2. <RCPSPEC>
                 3. <RCPNEWID>
                 4. <RMCHGTYPE>

Exception:     RCPNEWID is a zero-length item except where RMCHGTYPE specifies a
               copy or rename change.
```

S15,F46 DRNS Manager Segment Approval Acknowledge S,H<->E

Description: This message is used to acknowledge the request to change a recipe.

Structure: L,3
1. <RMCHGTYPE>
2. <RMGRNT>
3. <OPID>

Exception: OPID is zero if and only if RMGRNT indicates the change is denied.

S15,F47 DRNS Manager Rebuild Request M,H<->E, reply

Description: This message requests a distributed recipe namespace manager specified in OBJSPEC to rebuild a distributed recipe namespace. Either a distributed recipe namespace recorder or a list of distributed recipe namespace segment specifiers shall be provided.If multiblock, it shall be preceded by the S15,F1/F2 inquire/grant transaction.

Structure: L,5
1. <DATAID>
2. <OBJSPEC>
3. <RMNSSPEC>
4. <RMRECSPEC>
5. L,n
    1. <RMSEGSPEC$_1$>
    .
    .
    n. <RMSEGSPEC$_n$>

Exception: If RMRECSPEC is a non-zero length item, then n is zero. If RMRECSPEC is a zero length item, then n is non-zero.

S15,F48 DRNS Manager Rebuild Acknowledge M,H<->E

Description: This message is used to acknowledge the request to rebuild a distributed recipe namespace.

Structure: L,2
1. <RMACK>
2. L,P
    1. L,2
        1. <ERRCODE$_1$>
        2. <ERRTEXT$_1$>
    .
    .
    p. L,2
        1. <ERRCODE$_p$>
        2. <ERRTEXT$_p$>

Exception: p = 0 if and only if RMACK indicates no errors.

7.20 *Steam 16 Processing Management* — This stream provides protocol for a set of messages that enable the control of material processing at equipment and equipment resources. Control is implemented by supporting two job types; the control job and the process job. A process job is a single unit of work that ensures that the appropriate processing is applied to a particular material by a processing resource. The Process Job provides a widely applicable supervisory control capability for automated processing of material in equipment, irrespective of the particular process being used. The Process Job creates a transient link between the three elements of the manufacturing process; the first is the material to be processed. The second is the equipment on which the process will occur. The third is the process specification, a Process Recipe. When a Process Job has completed, it ceases to exist; its Process Job ID is no longer valid. The control job is used to group a set of related process jobs. The group is logically related from the host's viewpoint. For instance; if a carrier contains multiple lots, then the process jobs for each lot (in the carrier) could be included in the control job specification. Control jobs also provide mechanisms for specifying the destination for processed material.

S16,F0 Abort Transaction (S16F0) S,H<->E

Description: Same form as S1F0.

S16,F1 Multi-block Process Job Data Inquire (PRJI) S,H->E,reply

Description: If any of Processing Management messages are larger than one block, then this transaction must precede that message.

Structure: L,2
1. <DATAID>
2. <DATALENGTH>

S16,F2 Multi-block Process Job Data Grant (PRJG) S,H<-E

Description: Message to indicate if permission is granted to transmit a multi-block Job Data message.

Structure: <GRANT>

S16,F3 Process Job Create Request (PRJCR) M,H->E,reply

Description: The purpose of this message is to request material to be processed on a Process Module.

Structure: L,5

- 1. <DATAID>
- 2. <MF>
- 3. L,n
  - 1. <MID$_1$>
  - .
  - .
  - n. <MID$_n$>
- 4. L,3
  - 1. <PRRECIPEMETHOD>
  - 2. <RCPSPEC>
  - 3. L,m (m = {c,2})
    - 1. L,2
      - 1. <RCPPARNM$_1$>
      - 2. <RCPPARVAL$_1$>
    - .
    - .
    - .
    - m. L,2
      - 1. <RCPPARNM$_m$>
      - 2. <RCPPARVAL$_m$>
- 5. <PRPROCESSSTART>

Exception: For the m length list m = 0 may be allowed value depending on the value of PRRECIPEMETHOD.

S16,F4 Process Job Create Acknowledge (PRJCA) S,H<-E

Description: Acknowledge or report error in the creation of a Process Job.

Structure: L,2

- 1. <PRJOBID>
- 2. L,2
  - 1. <ACKA>
  - 2. L,n
    - 1. L,2
      - 1. <ERRCODE$_1$>
      - 2. <ERRTEXT$_1$>
    - .
    - .
    - .
    - n. L,2
      - 1. <ERRCODE$_n$>
      - 2. <ERRTEXT$_n$>

Exception: This list may be zero length, generally the case when ACKA indicates success. When ACKA indicates a create failure, the equipment may supply one or more ERRCODE’s.

S16,F5 Process Job Command Request (PRJCMDR) M,H->E,reply

```
Description:   Send a job control command to a processing job.

Structure:     L,4
                 1. <DATAID>
                 2. <PRJOBID>
                 3. <PRCMDNAME>
                 4. L,n
                      1. L,2
                           1. <CPNAME1>
                           2. <CPVAL1>
                      .
                      .
                      .
                      n. L,2
                           1. <CPNAMEn>
                           2. <CPVALn>

Exception:      The CPNAME, CPVAL pairs are command parameter identifiers and
                values; n = 0 is valid for some commands (PRCMDNAME).
```

S16,F6 Process Job Command Acknowledge (PRJCMDA) S,H<-E

```
Description:   The processing service sends its confirmation for receipt of a
               command request.

Structure:      L,2
                  1. <PRJOBID>
                  2. L,2
                       1. <ACKA>
                       2. L,n          (n = {0,n})
                            1. L,2
                                 1. <ERRCODE1>
                                 2. <ERRTEXT1>
                            .
                            .
                            .
                            n. L,2
                                 1. <ERRCODEn>
                                 2. <ERRTEXTn>

Exception:     This list n may be zero length.
```

S16,F7 Process Job Alert Notify (PRJA) S,H<-E,[reply]

Description: The processing service may notify the controlling entity of important events. The Process Job Milestones only assume small number of different values. However, the conditions under which a process job meets one of these milestones may vary. For instance, a Job may reach Job Complete because the Process was Aborted. By using item 4, the status of the Alert (PRJOBMILESTONE) can be indicated. See the list of Error Codes for Processing in Data Item Dictionary.

Structure: L,4
  1. <TIMESTAMP>
  2. <PRJOBID>
  3. <PRJOBMILESTONE>
  4. L,2
      1. <ACKA>
      2. L,n (n = {0,n})
          1. L,2
              1. <ERRCODE$_1$>
              2. <ERRTEXT$_1$>
          .
          .
          .
          n. L,2
              1. <ERRCODE$_n$>
              2. <ERRTEXT$_n$>

Exception: The list n may be zero length.

S16,F8 Process Job Alert Confirm (PRJAC) S,H->E

Description: Host confirms receipt of Process Job Alert message from the equipment.

Structure: Header only

S16,F9 Process Job Event Notify (PRJE) S,H<-E,[reply]

Description: Send Processing Job related event to the controlling entity.

Structure: L,4
  1. <PREVENTID>
  2. <TIMESTAMP>
  3. <PRJOBID>
  4. L,n
      1. L,2
          1. <VID$_1$>
          2. <V$_1$>
      .
      .
      .
      n. L,2
          1. <VID$_n$>
          2. <V$_n$>

Exception: The VID, V pairs are variable data identifiers and values; exceptions n = 0 is valid for some events (PREVENTID).

S16,F10 Process Job Event Confirm (PRJEC) — S,H->E

Description: Host confirms receipt of S16,F9 message to equipment.

Structure: Header only.

S16,F11 PRJobCreateEnh — M,H->E,reply

Description: Request equipment to create a Process Job with the given PRJOBID. If multi-block, this message must be preceded by the S16,F1/F2 transaction.

Structure:

```
L,7
  1. <DATAID>
  2. <PRJOBID>
  3. <MF>
  4a. L,n                  [MF = carrier, n = # of carriers]
        1. L,2
             1. <CARRIERID_1>
             2. L,j         [j = # of slots, may be implemented as an
                                 array]
                  1. <SLOTID_1>
                  2. <SLOTID_2>
                  .
                  j. <SLOTID_j>
        .
        .
        n. L,2
             1. <CARRIERID_n>
             2. L,j         [j = # of slots, may be implemented as an
                                 array]
                  1. <SLOTID_1>
                  2. <SLOTID_2>
                  .
                  j. <SLOTID_j>

  4b. L,n                  [MF = substrate]
        1. <MID_1>
        .
        .
        n. <MID_n>
  5.  L,3
        1. <PRRECIPEMETHOD>
        2. <RCPSPEC>
        3. L,m             [m = # recipe parameters]
             1. L,2
                  1. <RCPPARNM_1>
                  2. <RCPPARVAL_1>
             .
             m. L,2
                  1. <RCPPARNM_m>
                  2. <RCPPARVAL_m>
  6. <PRPROCESSSTART>
  7. <PRPAUSEEVENT>
```

Exception: The list for specifying material (item 4a and 4b) is empty (L,0 instead of L,n), when no material is specified for the process job. The form of data item 4(a or b) depends on the value in MF.

S16,F12 PRJobCreateEnh Acknowledge S,H<-E

Description: This message acknowledges the request and reports any errors in the creation of a process job.

```
Structure:     L,2
                 1. <PRJOBID>
                 2. L,2
                      1. <ACKA>
                      2. L,n
                           1. L,2
                                1. <ERRCODE1>
                                2. <ERRTEXT1>
                           .
                           .
                           n. L,2
                                1. <ERRCODEn>
                                2. <ERRTEXTn>
```

Exception: If n = 0, no errors exist.

S16,F13 PRJobDuplicateCreate M,H->E,reply

Description: This function creates multiple process jobs. The same recipe and value of PRProcessStart are applied to each process job created. If multi-block, this message must be preceded by the S16,F1/F2 transaction.

```
Structure:     L,5
                 1. <DATAID>
                 2. L,p                  [p = # of process jobs being created]
                      1. L,3
                           1. <PRJOBID1>
                           2. <MF1>
                           3a. L,n         [MF = carrier, n = # of carriers]
                                 1. L,2
                                      1. <CARRIERID1>
                                      2. L,j   [j = # of slots, may be implemented
                                                  as an array]
                                           1. <SLOTID1>
                                           2. <SLOTID2>
                                           .
                                           j. <SLOTIDj>
                                 .
                                 .
                                 n. L,2
                                      1. <CARRIERIDn>
                                      2. L,j   [j = # of slots, may be implemented
                                                  as an array]
                                           1. <SLOTID1>
                                           2. <SLOTID2>
                                           .
                                           j. <SLOTIDj>
                           3b. L,n             [MF = substrate, n = # of MID]
                                 1. <MID1>
                                 .
                                 n. <MIDn>
                      .
                      .
```

```
p. L,3
     1. <PRJOBID_p>
     2. <MF_p>
     3a. L,n             [MF = carrier, n = # of carriers]
           1. L,2
                1. <CARRIERID_1>
                2. L,j   [j = # of slots, may be implemented
                              as an array]
                     1. <SLOTID_1>
                     2. <SLOTID_2>
                     .
                     j. <SLOTID_j>
           .
           .
           n. L,2
                1. <CARRIERID_n>
                2. L,j   [j = # of slots, may be implemented
                              as an array]
                     1. <SLOTID_1>
                     2. <SLOTID_2>
                     .
                     j. <SLOTID_j>
     3b. L,n             [MF = substrate, n = # of MID]
           1. <MID_1>
           .
           n. <MID_n>
3. L,3
     1. <PRRECIPEMETHOD>
     2. <RCPSPEC>
     3. L,m                   [m = # recipe parameters]
          1. L,2
               1. <RCPPARNM_1>
               2. <RCPPARVAL_1>
          .
          m. L,2
               1. <RCPPARNM_m>
               2. <RCPPARVAL_m>
4. <PRPROCESSSTART>
5. <PRPAUSEEVENT>
```

Exception: The list for specifying material (item 3a and 3b) is empty (L,0 instead of L,n), when no material is specified for the process job. The form of data item 3(a or b) depends on the value in MF.

S16,F14 PRJobDuplicateCreate Acknowledge — S,H<-E

Description: This message acknowledges the request and reports any errors in the creation of a process job. ERRTEXT contains the identifier of process jobs that were not created.

Structure:

```
L,2
  1. L,m                         [m = # of jobs created]
       1. <PRJOBID1>
       .
       m. <PRJOBIDm>
  2. L,2
       1. <ACKA>
       2. L,n
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            n. L,2
                 1. <ERRCODEn>
                 2. <ERRTEXTn>
```

Exception: If n = 0, no errors exist.

S16,F15 PRJobMultiCreate — M,H->E,reply

Description: Use this single message to Create Multiple Process Jobs, each of which may be unique in its association of material to process recipe. If multi-block, this message must be preceded by the S16,F1/F2 transaction.

Structure:

```
L,2
  1. <DATAID>
  2. L,p                         [p = # of process jobs being created]
       1. L,6
            1. <PRJOBID1>
            2. <MF1>
            3a. L,n              [MF = carrier, n = # of carriers]
                  1. L,2
                       1. <CARRIERID1>
                       2. L,j   [j = # of slots, may be implemented
                                     as an array]
                            1. <SLOTID1>
                            2. <SLOTID2>
                            .
                            j. <SLOTIDj>
                  .
                  .
                  n. L,2
                       1. <CARRIERIDn>
                       2. L,j   [j = # of slots, may be implemented
                                     as an array]
                            1. <SLOTID1>
                            2. <SLOTID2>
                            .
                            j. <SLOTIDj>
```

```
      3b. L,n              [MF = substrate, n = # of MID]
            1. <MID1>
            .
            n. <MIDn>
      4. L,3
           1. <PRRECIPEMETHOD1>
           2. <RCPSPEC1>
           3. L,m          [m = # recipe parameters]
                1. L,2
                     1. <RCPPARNM1>
                     2. <RCPPARVAL1>
                .
                m. L,2
                     1. <RCPPARNMm>
                     2. <RCPPARVALm>
      5. <PRPROCESSSTART1>
      6. <PRPAUSEEVENT1>
.
.
p. L,6
      1. <PRJOBIDp>
      2. <MFp>
      3a. L,n              [MF = carrier, n = # of carriers]
            1. L,2
                 1. <CARRIERID1>
                 2. L,j   [j = # of slots, may be implemented
                               as an array]
                      1. <SLOTID1>
                      2. <SLOTID2>
                      .
                      j. <SLOTIDj>
            .
            .
            n. L,2
                 1. <CARRIERIDn>
                 2. L,j   [j = # of slots, may be implemented
                               as an array]
                      1. <SLOTID1>
                      2. <SLOTID2>
                      .
                      j. <SLOTIDj>
      3b. L,n              [MF = substrate, n = # of MID]
            1. <MID1>
            .
            n. <MIDn>
      4. L,3
           1. <PRRECIPEMETHODp>
           2. <RCPSPECp>
           3. L,m          [m = # recipe parameters]
                1. L,2
                     1. <RCPPARNM1>
                     2. <RCPPARVAL1>
                .
                m. L,2
                     1. <RCPPARNMm>
                     2. <RCPPARVALm>
      5. <PRPROCESSSTARTp>
      6. <PRPAUSEEVENTp>
```

Exception: The list for specifying material (item 3a and 3b) is empty (L,0 instead of L,n), when no material is specified for the process job. The form of data item 3(a or b) depends on the value in MF.

S16,F16 PRJobMultiCreate Acknowledge S,H<-E

Description: This message acknowledges the request and reports any errors in the creation of a process job. ERRTEXT contains the identifier of process jobs that were not created.

Structure:
```
L,2
  1. L,m                          [m = # jobs created]
       1. <PRJOBID_1>
       .
       m. <PRJOBID_m>
  2. L,2
       1. <ACKA>
       2. L,n
            1. L,2
                 1. <ERRCODE_1>
                 2. <ERRTEXT_1>
            .
            .
            n. L,2
                 1. <ERRCODE_n>
                 2. <ERRTEXT_n>
```

Exception: If n = 0, no errors exist.

S16,F17 PRJobDequeue S,H->E,reply

Description: Used to remove process jobs from the equipment for jobs that have not begun processing.

Structure:
```
L,m                               [m = # jobs to remove]
  1. <PRJOBID_1>
  .
  m. <PRJOBID_m>
```

Exception: If m = 0, then de-queue all.

S16,F18 PRJobDequeue Acknowledge — S,H<-E

Description: Acknowledge the request to de-queue and report any errors. ERRTEXT will contain the identifier of any jobs that were not de-queued.

Structure:

```
L,2
  1. L,m                            [m = # jobs removed]
       1. <PRJOBID1>
       .
       m. <PRJOBIDm>
  2. L,2
       1. <ACKA>
       2. L,n
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            n. L,2
                 1. <ERRCODEn>
                 2. <ERRTEXTn>
```

Exception: If n = 0, no errors exist.

S16,F19 PRGetAllJobs — S,H->E

Description: Requests the equipment to return a list of process jobs which have not completed. They may be running or waiting to run.

Structure: header only

S16,F20 PRGetAllJobs Send — S,H<-E

Description: Returns the requested list of process jobs.

Structure:

```
L,m                                 [m = # jobs in the list]
  1. L,2
       1. <PRJOBID1>
       2. <PRSTATE1>
  .
  m. L,2
       1. <PRJOBIDm>
       2. <PRSTATEm>
```

Exception: If m = 0, then no process jobs are running or waiting to run.

S16,F21 PRGetSpace — S,H->E

Description: Requests the equipment to return the number of process jobs it has space to create.

Structure: header only

S16,F22 PRGetSpace Send — S,H<-E

Description: Sends the host the number of process jobs which can be created.

Structure: <PRJOBSPACE>

S16,F23 PRJobSetRecipeVariable — S,H->E

Description: Reset the value of recipe variable parameters for a specific process job.

Structure:

L,2
  1. <PRJOBID>
  2. L,m [m = # recipe variables]
    1. L,2
      1. <$RCPPARNM_1$>
      2. <$RCPPARVAL_1$>
    .
    .
    m. L,2
      1. <$RCPPARNM_m$>
      2. <$RCPPARVAL_m$>

S16,F24 PRJobSetRecipeVariable Acknowledge — S,H<-E

Description: Indicate the status of the request to set recipe variables. ERRTEXT will contain the RCPPARNM value for parameters that could not be reset.

Structure:

L,2
  1. <ACKA>
  2. L,n
    1. L,2
      1. <$ERRCODE_1$>
      2. <$ERRTEXT_1$>
    .
    .
    n. L,2
      1. <$ERRCODE_n$>
      2. <$ERRTEXT_n$>

Exception: If n = 0, no errors exist.

S16,F25 PRJobSetStartMethod — S,H->E

Description: Used to request to change the start method (USERSTART or AUTO) for one or more process jobs.

Structure:

L,2
  1. L,m [m = # of jobs]
    1. <$PRJOBID_1$>
    .
    .
    m. <$PRJOBID_m$>
  2. <PRPROCESSSTART>

S16,F26 PRJobSetStartMethod Acknowledge — S,H<-E

Description: Acknowledges request to set job start method and indicates any errors. ERRTEXT will contain the identifiers of any process jobs that did not accept the new process start method.

Structure:

```
L,2
  1. L,m                        [m = # of jobs]
       1. <PRJOBID1>
       .
       m. <PRJOBIDm>
  L,2
       1. <ACKA>
       2. L,n
            1. L,2
                 1. <ERRCODE1>
                 2. <ERRTEXT1>
            .
            .
            n. L,2
                 1. <ERRCODEn>
                 2. <ERRTEXTn>
```

S16,F27 Control Job Command Request — S,H->E

Description: Send a control job command to a control job.

Structure:

```
L,3
  1. <CTLJOBID>
  2. <CTLJOBCMD>
  3. L,2
       1. <CPNAME>
       2. <CPVAL>
```

Exception: 3. L,2 IS L,0 for commands that do not need parameters.

S16,F28 Control Job Command Acknowledge — S,H<-E

Description: Indicates success or failure of command request to a control job. If applicable ERRTEXT shall contain information on specific command parameter names or values that caused the error.

Structure:

```
L,2
  1. <ACKA>
  2. L,2
       1. <ERRCODE>
       2. <ERRTEXT>
```

Exception: 2. L,2 IS L,0 if no errors.

S16,F29 PRSetMtrlOrder (PRJSMO) — S,H -> E,reply

Description: This message requests the equipment’s Processing Management Service to use a specific strategy for the order in which materials are processed.

Structure:

```
<PRMTRLORDER>
```

S16,F30 PRSetMtrlOrder Acknowledge (PRJSMOA) S,H <- E

Description: This message acknowledges the request for change to the material process strategy by reporting back the value requested, if correct.

Structure: <ACKA>

7.21 *Stream 17 Equipment Control and Diagnostics* — This stream is a continuation of Stream 2.

S17,F0 Abort Transaction (S17F0) S,H<->E

Description: Same form as S1F0.

S17,F1 Data Report Create Request (DRC) M,H->E,reply

Description: Create a Data Report definition. This function allows the referencing of a Data Source for the items (variables or attributes) specified in the data report.

Structure:
```
L,4
  1. <DATAID>
  2. <RPTID>
  3. <DATASRC>
  4. L,n
       1. <VID1>
       2. <VID2>
       .
       .
       .
       n. <VIDn>
```

Exception: DATAID is a zero length item when the request can be sent in a single block. If RPTID is a zero length item, then the equipment shall return a value in RPTID by which the host can then reference the report efinition. If RPTID has a value, then the equipment shall retain this value by which the host can then reference the report definition.

S17,F2 Data Report Create Acknowledge (DRCA) S,H<-E

Description: Equipment confirms creation of a Data Report and returns RPTID.

Structure:
```
L,2
  1. <RPTID>
  2. <ERRCODE>
```

Exception: If ERRCODE is a zero length item, then no error occurred.

S17,F3 Data Report Delete Request (DRD) S,H->E,reply

Description: Delete one or more data reports. This shall cause those reports to be unlinked from any Event Reports to which they were linked. This shall cause the report to be excluded from any Trace Reports for in which it had originally been included.

Structure: L,n

1. <$RPTID_1$>
2. <$RPTID_2$>

.
.
.

n. <$RPTID_n$>

Exception: If this message is sent with a zero length list, then all reports shall be deleted.

S17,F4 Data Report Delete Acknowledge (DRDA) S,H<-E

Description: Equipment confirms or indicates any errors on the request to delete Data Reports. All Data Reports which could be deleted shall be listed in the response and the associated error code shall be included in the list.

Structure: L,2

1. <ACKA>
2. L,m
    1. L,3
        1. <$RPTID_1$>
        2. <$ERRCODE_1$>
        3. <$ERRTEXT_1$>

    .
    .

    m. L,3
        1. <$RPTID_m$>
        2. <$ERRCODE_m$>
        3. <$ERRTEXT_m$>

Exception: If ACKA is TRUE, then no errors were encountered, meaning all report requests were completed successfully and a zero-length list (m = 0) shall be sent.

Exception: If some reports could not be deleted, then their RPTID’s shall be given in a space separated list in ERRTEXT.

S17,F5 Trace Create Request (TRC) M,H->E,reply

```
Description:   Establish a Trace Report definition.

Structure:     L,6
                 1. <DATAID>
                 2. <TRID>
                 3. <CEED>
                 4. L,n
                      1. <RPTID1>
                      2. <RPTID2>
                      .
                      .
                      n. <RPTIDn>
                 5. <TRSPER>
                 6. L,m                (m = {0,8})
                      1. <TOTSMP>
                      2. <REPGSZ>
                      3. <EVNTSRC>     (Defines source for start Event)
                      4. <CEID>        (Defines ID of the start Event)
                      5. <EVNTSRC>     (Defines source for stop Event)
                      6. <CEID>        (Defines ID of the stop Event)
                      7. <TRAUTOD>
                      8. <RPTOC>

Exception:     The list m can be zero-length, or it can contain all eight data
               items.  Since specifying values for each item is optional, each of
               the eight items can be zero-length.  If the item is zero-length, the
               format of the item shall be the same format used in other instances
               of the S17,F5 message where the value is not zero-length.
```

S17,F6 Trace Create Acknowledge (TRCA) S,H<-E

```
Description:   Equipment confirms creation of an Event Report and returns a TRID.

Structure:      L,2
                  1. <TRID>
                  2. <ERRCODE>

Exception:     If ERRCODE is a zero length item, then no error occurred.
```

S17,F7 Trace Delete Request (TRD) S,H->E,reply

```
Description:   The host requests to delete one or more Trace Reports.

Structure:     L,n
                 1. <TRID1>
                 2. <TRID2>
                 .
                 .
                 n. <TRIDn>
```

S17,F8 Trace Delete Acknowledge (TRDA) — S,H<-E

Description: This message is required to inform the host when a Trace Report could not be deleted. This message does not need to be sent to confirm the successful deletion of a Trace Report. If the report is sent for a successfully deleted Trace Report, then the ERRCODE item length shall be set to zero.

Structure:

L,2
  1. <ACKA>
  2. L,m
    1. L,3
      1. <TRID$_1$>
      2. <ERRCODE$_1$>
      3. <ERRTEXT$_1$>
    .
    .
    m. L,3
      1. <TRID$_m$>
      2. <ERRCODE$_m$>
      3. <ERRTEXT$_m$>

Exception: If ACKA is TRUE, then no errors were encountered, meaning all report requests were completed successfully and a zero-length list (m = 0) shall be sent.

Exception: If some reports could not be deleted, then their TRID’s shall be provided in a space separated list in ERRTEXT.

S17,F9 Collection Event Link Request (CELR) — M,H->E,reply

Description: Establish a Collection Event Report definition with respect to a specific Event Source.

Structure:

L,4
  1. <DATAID>
  2. <EVNTSRC>
  3. <CEID>
  4. L,n (n is the number of Reports to be linked)
    1. <RPTID$_1$>
    2. <RPTID$_2$>
    .
    .
    n. <RPTID$_n$>

S17,F10 Collection Event Link Acknowledge (CELA) — S,H<-E

Description: Indicate the success or failure of a Collection Event Link Request.

Structure:

L,3
  1. <EVNTSRC>
  2. <CEID>
  3. <ERRCODE>

Exception: Item 3 should be set to zero length to indicate success.

S17,F11 Collection Event Unlink Request (CEUR) S,H->E,reply

Description: Request to unlink a specific Data Report from a Collection Event Report.

Structure: L,3
1. <EVNTSRC>
2. <CEID>
3. <RPTID>

Exception: Item one can be zero length, in which case the default event source is assumed.

S17,F12 Collection Event Unlink Acknowledge (CEUA) S,H<-E

Description: Indicates success or failure of a requested Unlink.

Structure: L,4
1. <EVNTSRC>
2. <CEID>
3. <RPTID>
4. <ERRCODE>

Exception: Item one can be zero length to indicate the default event source. Item 4 is set to zero length if the primary request was successful.

S17,F13 Trace Reset Request (TRR) S,H->E,reply

Description: The Host requests the equipment to clear the data and reset the specified trace reports. If n = 0, then all defined Trace Objects will be reset.

Structure: L,n
1. <$TRID_1$>
2. <$TRID_2$>
.
.
n. <$TRID_n$>

S17,F14 Trace Report Reset Acknowledge (TRRA) S,H<-E

Description: This list in item 1 contains the identifiers of all the Trace Objects which were reset. If all Trace Objects are successfully reset, then ACKA shall be set to TRUE.

Structure: L,2
1. <ACKA>
2. L,m
   1. L,3
      1. <TRID$_1$>
      2. <ERRCODE$_1$>
      3. <ERRTEXT$_1$>
   .
   .
   m. L,3
      1. <TRID$_m$>
      2. <ERRCODE$_m$>
      3. <ERRTEXT$_m$>

Exception: If ACKA is TRUE, then no errors were encountered, meaning all report requests were completed successfully and a zero-length list (m = 0) shall be sent.

Exception: If some reports could not be reset, then their TRID's shall be given in a space separated list in ERRTEXT.

7.22 *Stream 18 Subsystem Control and Data* — Messages exchanged between component subsystems and higher level controllers. Compared to similar messages exchanged between equipment and host, subsystem messages are less complex.

S18,F1 Read Attribute Request (RAR) S,H->E,reply

Description: This message requests the current values of specified attributes of the subsystem component indicated in TARGETID.

Structure: L,2
1. <TARGETID>
2. L,n   n = # attribute identifiers
   1. <ATTRID$_1$>
   .
   n. <ATTRID$_n$>

Exceptions: If n = 0, then all attributes of the target component are requested.

S18,F2 Read Attribute Data (RAD) S,H<-E

Description: This message returns the current values of requested attributes and the current status of the requested component indicated in TARGETID. Attributes are returned in the order requested.

Structure:
```
L,3
  1. <TARGETID>
  2. <SSACK>
  3. L,n
       1. <ATTRDATA1>
       .
       n. <ATTRDATAn>
```

Exceptions: Both n = 0 and s = 0 if the target component is unknown.

S18,F3 Write Attribute Request (WAR) S,H->E,reply

Description: This message requests the subsystem to set the value of read/write attributes of the component specified in TARGETID.

Structure:
```
L,2
  1. <TARGETID>
  2. L,n
       1. L,2
            1. <ATTRID1>
            2. <ATTRDATA1>
       .
       n. L,2
            1. <ATTRIDn>
            2. <ATTRDATAn>
```

S18,F4 Write Attribute Acknowledge (WAA) S,H<-E

Description: This message acknowledges the success of failure of the request to write attribute data to the subsystem indicated in TARGETID.

Structure:
```
L, 3
   1. <TARGETID>
   2. <SSACK>
   3. <STATUSLIST>
```

Exceptions: s = 0 if the target component is unknown.

S18,F5 Read Request (RR) S,H->E,reply

Description: The host requests the subsystem indicated in TARGETID to read information. DATASEG may be used to indicate a specific section of data to be read. DATALENGTH is used to limit the amount of data for that section.

Structure: L,3
1. <TARGETID>
2. <DATASEG>
3. <DATALENGTH>

Exceptions: If DATASEG and DATALENGTH are both omitted (are zero length items) then all data is requested. If DATALENGTH only is omitted, then all data within the indicated section is requested.

S18,F6 Read Data (RD) S,H<-E

Description: This message is used to return requested information from the subsystem indicated in TARGETID or to acknowledge the results of the request.

Structure: L,3
1. <TARGETID>
2. <SSACK>
3. <DATA>

Exceptions: If TARGETID is unknown, then DATA is zero length.

S18,F7 Write Data Request (WDR) S,H->E,reply

Description: This message requests to write data to the subsystem component indicated in TARGETID. DATASEG may be used to indicate a specific section of data to be written or overwritten.

Structure: L,4
1. <TARGETID>
2. <DATASEG>
3. <DATALENGTH>
4. <DATA>

Exceptions: If DATASEG and DATALENGTH are both omitted (are zero length items) then all data is to be overwritten. If only DATALENGTH is omitted or if DATALENGTH has a value of zero, then all data within the indicated section is to be written.

S18,F8 Write Data Acknowledge (WDA) S,H<-E

Description: This message acknowledges the success or failure of writing data to the subsystem indicated in TARGETID.

Structure: L,3
1. <TARGETID>
2. <SSACK>
3. <STATUSLIST>

Exceptions: s = 0 if and only if TARGETID is unknown.

S18,F9 Read ID Request (RIR) S,H->E,reply

Description: This message is used to request the subsystem indicated by TARGETID to read an identifier.

Structure: <TARGETID>

Exceptions: None.

S18,F10 Read ID Data (RID) S,H<-E

Description: This message returns a requested material identifier MID as read by the subsystem indicated in TARGETID.

Structure: L,4
1. <TARGETID>
2. <SSACK>
3. <MID>
4. <STATUSLIST>

Exceptions: s = 0 if and only if TARGETID is unknown.

S18,F11 Write ID Request (WIR) S,H->E,reply

Description: This message is used to request the subsystem indicated by TARGETID to write an identifier.

Structure: L,2
1. <TARGETID>
2. <MID>

Exceptions: None.

S18,F12 Write ID Acknowledge (WIA) S,H<-E

Description: This message acknowledges the success or failure of the subsystem specified in TARGETID in writing the ID.

Structure: L,3
1. <TARGETID>
2. <SSACK>
3. <STATUSLIST>

Exceptions: s = 0 if and only if TARGETID is unknown.

S18,F13 Subsystem Command Request (SCR) S,H->E,reply

Description: This message is used to request the subsystem indicated in TARGETID to perform a specific action.

Structure: L,3
1. <TARGETID>
2. <SSCMD>
3. L,n
   1. <$CPVAL_1$>
   .
   n. <$CPVAL_n$>

Exceptions: If n = 0, no parameters are provided.

S18,F14 Subsystem Command Acknowledge (SCA) S,H<-E

Description: This message reports the results from the subsystem specified in TARGETID for the requested action.

Structure: L,3
1. <TARGETID>
2. <SSACK>
3. <STATUSLIST>

Exceptions: s = 0 if and only if TARGETID is unknown.

8 Message Documentation

8.1 *Intent* — Equipment makers using SECS-II messages must communicate the equipment-specific details of each message to the host designer in order for the host to properly adapt to the equipment. The details are communicated in a document which will follow a standard form in order to convey most clearly the information required. The following form is presented here to act as a guide for organizing the equipment-specific details.

8.2 *Standard Form SECS-II Document* — The standard form will contain three clearly labeled parts as follows.

Part I — General Information

Part II — Message Summary

Part III — Message Detail

8.2.1 Part I will contain general information on the following:

Manufacturer and product number

General description of equipment function

Intended function of interface

Software revision code

Changes from previous versions

8.2.2 Part II will contain two lists of all messages understood and all messages sent by the equipment in terms of their stream and function codes. The first list will have pairs of columns: the first for the message received and understood and the second for the message sent in response. The second list will also have two columns: the first for the message sent and the second for the response understood. The message will be identified using the format " SxxFyy," where xx is the stream number and yy is the function number. Each transaction will be on a separate line. A " -" will indicate that one of a pair is not included. All messages not listed on the received side are implied to cause an error message to the host. All messages not listed on the sent side are assumed never to be sent from the equipment. Since some messages can be sent in two directions, the same message pair may appear in each list with the sent and received orders interchanged. A transaction listed in the standard as being allowed in two directions does not have to be implemented in both directions. This list will indicate which directions are implemented.

8.2.3 Part III will contain the details for every message listed in Part II. Messages that appear on both the sent and received sides must be detailed separately. The details shall include the following information on the data in each message:

1. For each fixed item, all the values or strings either understood or possible to send are listed along with their meaning to the equipment.
2. For each variable item, the restriction on or possible range of value or length of string.
3. Any other special interpretation of the message.

8.2.4 Each message so detailed must be clearly labeled with its stream and function code.

9 Units of Measure

9.1 *Intent* — Certain SECS-II transactions require specification of units of measure for data items passed between equipment and host. The concept of units of measure has been included as part of the SECS-II standard to enhance the ability of the host system to prompt its human operators for proper information when generating process programs, and also to facilitate automated handling of process programs by host systems and automated handling of data reported to a host by equipment.

9.2 *Units Symbols* — Under SECS-II, a units symbol is a text string of unspecified length which specifies the physical significance of a numeric value. Units of measure symbols under SECS-II may be either a SECS-II recognized unit identifier, a SECS-II unit identifier with prefix and/or suffix symbols, or an arithmetic expression of SECS-II identifiers.

9.2.1 A SECS-II units identifier is a text string which may be the full name, an abbreviation of the full name, or a special character which is unique for a specific unit of weight or measure. Identifier strings may consist of upper or lower case alphabetic characters and numerals or special characters of the ASCII character set. The first character of an identifier may not be a numeral. The case of alphabetic characters is significant (e.g., G and g, the units symbols for Gauss and gram, respectively).

9.2.2 A unit identifier may be nationally or internationally recognized, may be unique to the semiconductor industry, or, due to the special requirements of SECS-II, may be unique to this standard. Section 9.4 lists all units identifiers recognized by SECS-II. For each identifier defined in Section 9.4, six pieces of information are provided. They are:

1. Unit — Full name of the unit of measure in question.
2. Unit Identifier — SECS-II-recognized identifier for the unit.
3. Prefix Allowed — Specifies whether or not the unit identifier may be combined with a prefix symbol to generate a unit identifier which is a decimal multiple or submultiple of the base unit. Metric (or SI) units are usually capable of accepting a prefix symbol while English units may not.
4. Suffix Allowed — Specifies whether or not the unit identifier may be concatenated with a numeric suffix which provides additional information to the meaning of the associated unit symbol. The numeric suffix is composed of the ASCII digits 0 through 9 and represents a decimal value. This meaning of the numeric value is symbol-dependent and must be specified in the description section of the unit symbol' s definition.
5. Equivalence — In those cases where a unit can be expressed as an arithmetic expression (of simpler units), this column will contain the expression of simpler units. For those units which are non-standard to either of the standard systems of units of measure (English or SI), this column will contain an expression which relates the non-standard unit to the equivalent unit of the standard units system. In either case, the expression provided in this column may be substituted for the corresponding SECS-II units identifier whenever required.
6. Description — Additional information as may be required to uniquely define the unit of measure in question.

9.2.3 Any SECS-II identifier which Section 9.4 indicates as being capable of taking on a prefix symbol may be appended to one of the prefix symbols shown in Table 2, forming a new unit which is a decimal multiple or submultiple of the base unit. A prefix symbol may not be used alone. It must appear concatenated to one of the identifiers in Section 9.4. Finally, only one prefix symbol may appear before any identifier. A units symbol such as " mus" (micromillisecond) is not allowed. The proper symbol is " ns" (nanosecond).

Prefix Name	*Multiplicative Factor*	*Prefix Symbol*
exa	10^ 18	E
peta	10^ 15	P
Tera	10^ 12	T
giga	10^ 9	G
mega	10^ 6	M
kilo	10^ 3	k
hecto	10^ 2	h
deka (deca)	10^ 1	da
deci	10^ -1	d
centi	10^ -2	c
milli	10^ -3	m
micro	10^ -6	u
nano	10^ -9	n
pico	10^ -12	p
femto	10^ -15	f
atto	10^ -18	a

9.2.4 Any SECS-II identifier which Section 9.4 indicates as being capable of taking on a suffix value may have a numeric string appended to it. This decimal value allows the user to identify one of a family of symbol names with only the generic symbol name of the family being defined in Section 9.4. The meaning of a numeric suffix is dependent on the particular symbol with which it is being used and must be defined in the description section of the symbol definition.

9.2.5 Arithmetic expressions of units of measure identifiers are recognized by SECS-II as units symbols if they are formed by the following rules:

1. All units identifiers in the expression are SECS-II units identifiers defined in Section 9.4 or SECS-II prefixed units identifiers as defined above.
2. Exponentiation is denoted by a circumflex (^) between the identifier to be operated on and the exponent. Exponents may be positive or negative values. A negative value is denoted by a unary minus sign (-) between the circumflex and exponent. For positive values, the exponent will immediately follow the circumflex (A^ 2 or A^ -2).
3. Multiplication of units identifiers is expressed by an asterisk (*) positioned between the factors to be multiplied (A*B).
4. Division of units identifiers is expressed by a slash (/) positioned between the dividend and divisor. Division may also be expressed as the product of the dividend and the divisor with a negative exponent (A/B or A*B^ -1).
5. Parentheses may be used to specify the order in which the arithmetic operations will be performed.
6. Within expressions or sub-expressions where parentheses do not specify the order of operations, exponentiation will be carried out first, followed by left-to-right evaluation of all multiplication and division that is (A*B^ -2*30*C^ 2) is equivalent to (((A/(B^ 2))*30)*(C^ 2)).

9.3 *Compliance* — For the units of measure information to have any value and to be in compliance with SECS-II, equipment and host system manufacturers must ensure that only units symbols allowed by SECS-II are used by their systems. In those instances where SECS-II does not provide a units symbol required for a particular application, the manufacturer requiring the new symbol may submit a proposal to the SEMI Communications Subcommittee requesting the enhancement. A proposal must include all the information provided by each entry of Section 9.4 as described above.

9.3.1 A proposal must undergo the full approval cycle as prescribed by SECS-II for amending a standard (acceptance by committee, balloting, etc.). As a result, the proposal should be submitted as soon as possible, so that sufficient time is available to complete the standard amendment process and to notify all interested parties of the change before the product requiring the new symbol becomes available for use in a manufacturing facility.

9.4 *SECS-II Units of Measure Identifiers* — All units of measure symbols recognized by SECS-II are defined in this section or are compound symbols based on the identifiers defined here and formed by the rules specified in Section 9.2. Portions of the information provided below have been obtained from ANSI/IEEE 260-1978, ANSI X3.5-1976, ISO 2955-1974(E), Webster' s New World Collegiate Dictionary (copyright 1977), and the CRC Handbook of Chemistry and Physics (52nd edition for 1971-1972).

Unit — Non-dimensional quantities (pure numbers)
Unit Identifier — null string   Prefix Allowed — No
Equivalence — None   Suffix Allowed — No
Description — For all quantities which have no associated unit of measure, a zero length (null) text string is the appropriate 'identifier' to use when units of measure information is required.

Unit — ampere   Prefix Allowed — Yes
Unit Identifier — A   Suffix Allowed — No
Equivalence — None
Description — SI unit of electric current.

Unit — ampere (turn)   Prefix Allowed — Yes
Unit Identifier — AT   Suffix Allowed — No
Equivalence — None
Description — SI unit of magnetomotive force.

Unit — angstrom
Unit Identifier — Ang   Prefix Allowed — Yes
Equivalence — m*10^ -10   Suffix Allowed — No
Description — Unit of length used when measuring wavelength of light.

Unit — atmosphere, standard
Unit Identifier — atm   Prefix Allowed — No
Equivalence — 101325*Pa   Suffix Allowed — No
Description — A unit of pressure.

Unit — atmosphere, technical
Unit Identifier — at   Prefix Allowed — No
Equivalence — kgf/cm^ 2   Suffix Allowed — No
Description — A unit of pressure.

Unit — atomic mass unit (unified)
Unit Identifier — u   Prefix Allowed — No
Equivalence — 1.660531*10^ -27*kg   Suffix Allowed — No
Description — One twelfth the mass of an atom of carbon 12 nuclide.

Unit — bar
Unit Identifier — bar   Prefix Allowed — Yes
Equivalence — 100*kPa   Suffix Allowed — No
Description — CGS unit of pressure.

Unit — barn
Unit Identifier — barn   Prefix Allowed — Yes
Equivalence — 10^ -28*m^ 2   Suffix Allowed — No
Description — Unit for measuring capture cross sections of elements.

Unit — barrel (petroleum)
Unit Identifier — bbl   Prefix Allowed — No
Equivalence — 42*gal or 158.99*1   Suffix Allowed — No
Description — A unit of volume.

Unit — baud
Unit Identifier — Bd Prefix Allowed — Yes
Equivalence — bit/s Suffix Allowed — No
Description — Telecommunications measure of data transfer rate equivalent to one bit of information transferred per second.

Unit — bel
Unit Identifier — B Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — The logarithm of the ratio of two power signals.

Unit — Becquerel
Unit Identifier — Bq Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — SI unit of activity of a radionuclide.

Unit — bit
Unit Identifier — bit Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — A unit of computer information equivalent to the choice between two alternatives (as yes or no, on or off).

Unit — boat
Unit Identifier — boat Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a holder of wafers or packages with discrete positions. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — British thermal unit
Unit Identifier — Btu Prefix Allowed — No
Equivalence — 1054.35*J Suffix Allowed — No
Description — The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2˚F.

Unit — byte
Unit Identifier — byte Prefix Allowed — Yes
Equivalence — 8*bit Suffix Allowed — No
Description — Unit of storage for computer memory.

Unit — calorie (International Table)
Unit Identifier — callIT Prefix Allowed — Yes
Equivalence — 4.1868*J Suffix Allowed — No
Description — Defined by the 1929 International Stream Table Conference to be 1/860 international joules or l/859.858 joules.

Unit — calorie (thermochemical)
Unit Identifier — cal Prefix Allowed — Yes
Equivalence — 4.l840*J Suffix Allowed — No
Description — Unit of energy defined by the NBS to be 4.184 joules. Also, called the gram calorie.

Unit — candela
Unit Identifier — cd Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — SI unit of luminous intensity.

Unit — candle
Unit Identifier — cd Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — Alternate name for candela.

Unit — carrier
Unit Identifier — carrier Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a holder for substrates, wafers or wafer frames. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — cassette
Unit Identifier — css Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a holder for wafers or wafer frames. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — Coulomb
Unit Identifier — C Prefix Allowed — Yes
Equivalence — A*s Suffix Allowed — No
Description — SI unit of electric charge.

Unit — curie
Unit Identifier — Ci Prefix Allowed — No
Equivalence — 3.7*l0^ l0*Bq Suffix Allowed — No
Description — A unit of activity of radionuclide.

Unit — cycle
Unit Identifier — c Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — Unit equivalent to one complete performance of a periodic process.

Unit — darcy
Unit Identifier — D Prefix Allowed — No
Equivalence — cP*(cm/s)(cm/atm) or 0.986923*um^ 2 Suffix Allowed — No
Description — Unit of permeability of a porous medium. By traditional definition, a permeability of one darcy will permit a flow of 1 cm^ 3/s of fluid of 1 cP viscosity through an area of 1 cm^ 2 under a pressure gradient of 1 atm/cm.

Unit — day (mean solar)
Unit Identifier — d Prefix Allowed — No
Equivalence — 24*h Suffix Allowed — No
Description — The period required for the Earth to complete one rotation about its axis.

Unit — degree (plane angle)
Unit Identifier — deg Prefix Allowed — No
Equivalence — pi/180*rad Suffix Allowed — No
Description — One three hundred sixtieth part of the circumference of a circle.

Unit — degree Celsius
Unit Identifier — degC Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Unit of temperature where 0˚C corresponds to the freezing point of water and l00˚C corresponds to the boiling point at standard atmospheric conditions.

Unit — degree Fahrenheit
Unit Identifier — degF Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Unit of temperature where 32˚F corresponds to the freezing point of water and 212˚F corresponds to the boiling point at standard atmospheric conditions.

Unit — degree Kelvin
Unit Identifier — K Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — SI unit of temperature.

Unit — die
Unit Identifier — die Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Special SECS generic unit corresponding to an individual integrated circuit both on a wafer and after wafer separation. Also referred to as a bar or chip.

Unit — dyne
Unit Identifier — dyn Prefix Allowed — Yes
Equivalence — 10^ -5*N Suffix Allowed — No
Description — Unit of force in the cgs system. One dyne is the force required to provide a one grain mass with an acceleration of 1 cm/s^ 2.

Unit — electronvolt
Unit Identifier — eV Prefix Allowed — Yes
Equivalence — l.60209*10^ -19*J Suffix Allowed — No
Description — Energy acquired by a small particle carrying a unit electronic charge when it falls through a potential difference of one volt.

Unit — erg
Unit Identifier — erg Prefix Allowed — Yes
Equivalence — l0^ -7*J Suffix Allowed — No
Description — Unit of work or energy in the cgs system. One erg is equal to the work done or energy expended to exert a force of one dyne through a distance of 1 cm.

Unit — farad
Unit Identifier — F Prefix Allowed — Yes
Equivalence — A*s/V Suffix Allowed — No
Description — SI unit of capacitance.

Unit — foot
Unit Identifier — ft Prefix Allowed — No
Equivalence — 12*in Suffix Allowed — No
Description — English unit of length.

Unit — footcandle
Unit Identifier — Fc Prefix Allowed — No
Equivalence — lm/ft^ 2 Suffix Allowed — No
Description — Unit of illuminance. Also called lumen per square foot.

Unit — footlambert
Unit Identifier — FL Prefix Allowed — No
Equivalence — (1/pi)*cd/ft^ 2 Suffix Allowed — No
Description — A unit of luminance. One lumen per square foot leaves a surface whose luminance is one footlambert in all directions within a hemisphere.

Unit — gal
Unit Identifier — Gal Prefix Allowed — Yes
Equivalence — cm/s^ 2 Suffix Allowed — No
Description — A unit of acceleration used especially for values of gravity.

Unit — gallon (US)
Unit Identifier — gal Prefix Allowed — No
Equivalence — 23l*in^ 3 or 4*qt or 3.7854*1 Suffix Allowed — No
Description — United States version of English system unit of volume.

Unit — gallon (UK)
Unit Identifier — galUK Prefix Allowed — No
Equivalence — 4.546l*l Suffix Allowed — No
Description — United Kingdom version of English system unit of volume.

Unit — gauss
Unit Identifier — G Prefix Allowed — Yes
Equivalence — Mx/cm^ 2 Suffix Allowed — No
Description — Electromagnetic CGS unit of magnetic flux density.

Unit — gilbert
Unit Identifier — Gb Prefix Allowed — Yes
Equivalence — l0/(4*pi)*AT Suffix Allowed — No
Description — Electromagnetic CGS unit of magnetomotive force.

Unit — grain
Unit Identifier — gr Prefix Allowed — No
Equivalence — .0022857l43*oz Suffix Allowed — No
Description — English unit of weight.

Unit — gram
Unit Identifier — g Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — One thousandth of the SI unit of mass.

Unit — gram-force
Unit Identifier — gf Prefix Allowed — Yes
Equivalence — 9.80665*N*10^ -3 Suffix Allowed — No
Description — The weight of a gram mass when subjected to the mean gravitational attraction of the Earth.

Unit — gray
Unit Identifier — Gy   Prefix Allowed — Yes
Equivalence — Unknown   Suffix Allowed — No
Description — SI unit of absorbed dose in the field of radiation dosimetry.

Unit — henry
Unit Identifier — H   Prefix Allowed — Yes
Equivalence — V*s/A   Suffix Allowed — No
Description — SI unit of inductance.

Unit — hertz
Unit Identifier — Hz   Prefix Allowed — Yes
Equivalence — c/s   Suffix Allowed — No
Description — SI unit of frequency.

Unit — horsepower (electric)
Unit Identifier — hp   Prefix Allowed — No
Equivalence — 746*W   Suffix Allowed — No
Description — Archaic unit of power.

Unit — hour
Unit Identifier — h   Prefix Allowed — No
Equivalence — 60*min   Suffix Allowed — No
Description — Derived unit of time.

Unit — inch
Unit Identifier — in   Prefix Allowed — No
Equivalence — 2.54*cm   Suffix Allowed — No
Description — English unit of length.

Unit — conventional inch of mercury
Unit Identifier — inHg   Prefix Allowed — No
Equivalence — 3386.4*Pa   Suffix Allowed — No
Description — Unit equivalent to the pressure required to balance a one inch high column of mercury in a manometer at 32˚F.

Unit — conventional inch of water
Unit Identifier — inH_2O Prefix Allowed — No
Equivalence — 249.09*Pa   Suffix Allowed — No
Description — Unit equivalent to the pressure required to balance a one inch high column of water in a manometer at 4˚C.

Unit — ingot
Unit Identifier — ing   Prefix Allowed — No
Equivalence — None   Suffix Allowed — No
Description — Special SECS generic unit corresponding to the entity of semiconductor manufacture from which wafers are made.

Unit — ion
Unit Identifier — ion   Prefix Allowed — No
Equivalence — None   Suffix Allowed — No
Description — SECS II unique symbol equivalent to an atom that carries an electric charge as a result of losing or gaining electrons.

Unit — joule
Unit Identifier — J Prefix Allowed — Yes
Equivalence — N*m Suffix Allowed — No
Description — SI unit of energy, work, and quantity of heat.

Unit — kelvin
Unit Identifier — K Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — SI unit of temperature. Also referred to as degree Kelvin.

Unit — kilopound force
Unit Identifier — klbf Prefix Allowed — No
Equivalence — l000*lbf Suffix Allowed — No
Description — A multiple of the English unit of force or weight.

Unit — knot
Unit Identifier — kn Prefix Allowed — No
Equivalence — nmi/h Suffix Allowed — No
Description — Unit of velocity expressed in nautical miles per hour.

Unit — lambert
Unit Identifier — L Prefix allowed — Yes
Equivalence — (l/pi)*cd/cm^ 2 Suffix allowed — No
Description — CGS unit of luminance. One lumen per square centimeter leaves a surface whose luminance is one lambert in all directions within a hemisphere.

Unit — leadframe
Unit Identifier — ldfr Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a structure for leads which is removed after packaging. The structure may be fixed length or a reel. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — liter
Unit Identifier — l Prefix Allowed — Yes
Equivalence — 10^ -3*m^ 3 Suffix Allowed — No
Description — A metric unit of volume.

Unit — lot
Unit Identifier — lot Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Special SECS generic unit corresponding to a grouping of material which is undergoing the same processing operations. The amount of material represented by " 1 lot" is situation-dependent.

Unit — lumen
Unit Identifier — lm Prefix Allowed — Yes
Equivalence — cd*sr Suffix Allowed — No
Description — SI unit of luminous flux.

Unit — lux
Unit Identifier — lx Prefix Allowed — Yes
Equivalence — lm/m^ 2 Suffix Allowed — No
Description — SI unit of illuminance.

Unit — magazine
Unit Identifier — mgz Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special, SECS generic unit corresponding to a holder of fixed length leadframes. The unit capacity is specified by the symbols suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — maxwell
Unit Identifier — Mx Prefix Allowed — Yes
Equivalence — 10^ -8*Wb Suffix Allowed — No
Description — Electromagnetic CGS unit of magnetic flux.

Unit — meter
Unit Identifier — m Prefix Allowed — Yes
Equivalence — None Suffix Allowed — No
Description — SI unit of length.

Unit — metric ton
Unit Identifier — t Prefix Allowed — No
Equivalence — 10^ 3*kgf Suffix Allowed — No
Description — Unit of weight of force.

Unit — mho
Unit Identifier — mho Prefix Allowed — Yes
Equivalence — S Suffix Allowed — No
Description — Previous name for the SI unit siemens.

Unit — micron
Unit Identifier — um Prefix Allowed — No
Equivalence — l0^ -6*m Suffix Allowed — No
Description — Alternate name for a micrometer.

Unit — conventional micron of mercury
Unit Identifier — umHg Prefix Allowed — No
Equivalence — 133.32*Pa*10^ -3 Suffix Allowed — No
Description — Unit of pressure.

Unit — mil
Unit Identifier — mil Prefix Allowed — No
Equivalence — 10^ -3*in Suffix Allowed — No
Description — English unit of length.

Unit — mile
Unit Identifier — mi Prefix Allowed — No
Equivalence — 5280*ft Suffix Allowed — No
Description — English unit of length.

Unit — conventional millimeter of mercury
Unit Identifier — mmHg Prefix Allowed — No
Equivalence — 133.322*Pa Suffix Allowed — No
Description — Unit of pressure.

Unit — millimicron
Unit Identifier — nm Prefix Allowed — No
Equivalence — 10^ -9*m Suffix Allowed — No
Description — Alternate name for nanometer.

Unit — minute (plane angle)
Unit Identifier — mins Prefix Allowed — No
Equivalence — deg/60 Suffix Allowed — No
Description — One sixtieth of a degree (plane angle).

Unit — minute(time)
Unit Identifier — min Prefix Allowed — No
Equivalence — 60*s Suffix Allowed — No
Description — Unit of time.

Unit — mole
Unit Identifier — mol Prefix Allowed — No
Equivalence — 6.02252*l0^ 23 Suffix Allowed — No
Description — SI unit of number of entities within a substance.

Unit — month
Unit Identifier — mo Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Unit of time.

Unit — nautical mile
Unit Identifier — nmi Prefix Allowed — No
Equivalence — 1852*m Suffix Allowed — No
Description — English unit of measurement.

Unit — neper
Unit Identifier — Np Prefix Allowed — Yes
Equivalence — 0.1l51*dB Suffix Allowed — No
Description — Unit for expressing ratios of power levels.

Unit — newton
Unit Identifier — N Prefix Allowed — Yes
Equivalence — kg*m/s^ 2 Suffix Allowed — No
Description — SI unit of force.

Unit — nit
Unit Identifier — nt Prefix Allowed — Yes
Equivalence — cd/m^ 2 Suffix Allowed — No
Description — Alternate name for the SI unit of luminance, candela per square meter.

Unit — oersted
Unit Identifier — Oe Prefix Allowed — Yes
Equivalence — 79.577472*A/m Suffix Allowed — No
Description — Electromagnetic CGS unit of magnetic field strength.

Unit — ohm
Unit Identifier — ohm Prefix Allowed — Yes
Equivalence — V/A Suffix Allowed — No
Description — SI unit of resistance.

Unit — ounce (avoirdupois)
Unit Identifier — oz Prefix Allowed — No
Equivalence — lbf/16 Suffix Allowed — No
Description — English unit of weight.

Unit — package
Unit Identifier — pkg Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Special SECS generic unit corresponding to an individual entity both as a place for the die to reside and as a completed unit.

Unit — pascal
Unit Identifier — Pa Prefix Allowed — Yes
Equivalence — N/m^ 2 Suffix Allowed — No
Description — SI unit of pressure or stress.

Unit — percent
Unit Identifier — % Prefix Allowed — No
Equivalence — 1/100 Suffix Allowed — No
Description — Ratio of parts per hundred.

Unit — phot
Unit Identifier — ph Prefix Allowed — Yes
Equivalence — lm/cm^ 2 Suffix Allowed — No
Description — CGS unit of illuminance.

Unit — pH
Unit Identifier — pH Prefix Allowed — No
Equivalence — 1 Suffix Allowed — No
Description — Normalized measure of acidity or alkalinity.

Unit — pint (UK)
Unit Identifier — ptUK Prefix Allowed — No
Equivalence — 0.56826*1 Suffix Allowed — No
Description — United Kingdom version of English unit of capacity.

Unit — pint (US dry)
Unit Identifier — ptUS Prefix Allowed — No
Equivalence — 0.55061*1 Suffix Allowed — No
Description — United States version of English unit of dry capacity.

Unit — pint (US liquid)
Unit Identifier — pt Prefix Allowed — No
Equivalence — 0.47318*1 Suffix Allowed — No
Description — United States version of English unit of liquid capacity.

Unit — plate
Unit Identifier — plt Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a temporary fixture used to hold die during assembly operations. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — poise
Unit Identifier — P Prefix Allowed — Yes
Equivalence — 36*N*s/m^ 2, or 36*kg/(m*s) Suffix Allowed — No
Description — A CGS unit of viscosity equal to the viscosity of a fluid that would require a shearing force of one dyne to move a square centimeter area of either of two parallel layers of fluid one centimeter apart with a velocity of one centimeter per second relative to the other layer, with the space between the layers being filled with fluid.

Unit — pound
Unit Identifier — lb Prefix Allowed — No
Equivalence — 0.0310810*slug Suffix Allowed — No
Description — English unit of mass.

Unit — pound-force
Unit Identifier — lbf Prefix Allowed — No
Equivalence — 4.4482217*N Suffix Allowed — No
Description — English unit of force or weight.

Unit — poundal
Unit Identifier — pdl Prefix Allowed — No
Equivalence — 0.0310810*lbf Suffix Allowed — No
Description — Force required to accelerate a one pound mass at one ft/s^ 2.

Unit — parts per million
Unit Identifier — ppm Prefix Allowed — No
Equivalence — 1/I0^ 6 Suffix Allowed — No
Description — Ratio of parts per million.

Unit — quart (UK)
Unit Identifier — qtUK Prefix Allowed — No
Equivalence — 1.1365*1 Suffix Allowed — No
Description — United Kingdom version of an English unit of capacity.

Unit — quart (US dry)
Unit Identifier — qtUS Prefix Allowed — No
Equivalence — 1.1012*1 Suffix Allowed — No
Description — United States version of an English unit of dry capacity.

Unit — quart (US liquid)
Unit Identifier — qt Prefix Allowed — No
Equivalence — 0.94635*1 Suffix Allowed — No
Description — United States version of an English unit of liquid capacity.

Unit — rad
Unit Identifier — rd Prefix Allowed — Yes
Equivalence — 10^ -2*Gy Suffix Allowed — No
Description — A unit of absorbed dose in the field of radiation dosimetry.

Unit — radian
Unit Identifier — rad | Prefix Allowed — Yes
Equivalence — None | Suffix Allowed — No
Description — SI unit of plane angle.

Unit — rem
Unit Identifier — rem | Prefix Allowed — Yes
Equivalence — 10^ -2*Sv | Suffix Allowed — No
Description — A unit of dose equivalent in the field of radiation dosimetry.

Unit — revolution
Unit Identifier — r | Prefix Allowed — No
Equivalence — c | Suffix Allowed — No
Description — One complete cycle of a rotating body.

Unit — roentgen
Unit Identifier — R | Prefix Allowed — No
Equivalence — Unknown | Suffix Allowed — No
Description — A unit of exposure in the field of radiation dosimetry.

Unit — second (plane angle)
Unit Identifier — sec | Prefix Allowed — No
Equivalence — mins/60 | Suffix Allowed — No
Description — One sixtieth of a minute of a degree.

Unit — second (time)
Unit Identifier — s | Prefix Allowed — Yes
Equivalence — None | Suffix Allowed — No
Description — SI unit of time.

Unit — siemens
Unit Identifier — S | Prefix Allowed — Yes
Equivalence — 1/ohm | Suffix Allowed — No
Description — SI unit of conductance.

Unit — sievert
Unit Identifier — Sv | Prefix Allowed — Yes
Equivalence — Unknown | Suffix Allowed — No
Description — SI unit of dose equivalent in the field of radiation dosimetry.

Unit — slug
Unit Identifier — slug | Prefix Allowed — No
Equivalence — 145939*kg | Suffix Allowed — No
Description — English unit of mass.

Unit — standard cubic centimeter per minute
Unit Identifier — sccm | Prefix Allowed — No
Equivalence — cc/min | Suffix Allowed — No
Description — A unit of flow equivalent to one cubic centimeter of a gas at standard temperature and pressure flowing past a point in one minute.

Unit — standard liter per minute
Unit Identifier — slpm Prefix Allowed — No
Equivalence — 1/min Suffix Allowed — No
Description — A unit of flow equivalent to one liter of a gas at standard temperature and pressure flowing past a point in one minute.

Unit — steradian
Unit Identifier — Sr Prefix Allowed — Yes
Equivalence — Unknown Suffix Allowed — No
Description — SI unit of solid angle.

Unit — stilb
Unit Identifier — sb Prefix Allowed — Yes
Equivalence — cd/cm^ 2 Suffix Allowed — No
Description — A CGS unit of luminance.

Unit — stokes
Unit Identifier — St Prefix Allowed — Yes
Equivalence — P*cm^ 3/g Suffix Allowed — No
Description — A CGS unit of kinematic viscosity.

Unit — substrate
Unit Identifier — substrate Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Special SECS generic unit corresponding to the entity of material being operated on, processed or fabricated.

Unit — tesla
Unit Identifier — T Prefix Allowed — Yes
Equivalence — N/(A*m) or Wb/m^ 2 Suffix Allowed — No
Description — SI unit of magnetic flux density (magnetic induction).

Unit — therm
Unit Identifier — thm Prefix Allowed — No
Equivalence — 10^ 5*Btu Suffix Allowed — No
Description — An English unit of energy.

Unit — ton (short)
Unit Identifier — ton Prefix Allowed — No
Equivalence — 2000*lbf Suffix Allowed — No
Description — English unit of weight.

Unit — torr
Unit Identifier — torr Prefix Allowed — Yes
Equivalence — mmHg Suffix Allowed — No
Description — Pressure unit. Alternative name for millimeters of mercury.

Unit — tube
Unit Identifier — tube Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a holder of packages arranged in a flow. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — var
Unit Identifier — var Prefix Allowed — Yes
Equivalence — Unknown Suffix Allowed — No
Description — SI unit for reactive power.

Unit — volt
Unit Identifier — V Prefix Allowed — Yes
Equivalence — W/A Suffix Allowed — No
Description — SI unit of voltage.

Unit — wafer
Unit Identifier — wfr Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Special SECS generic unit corresponding to the entity of material on which semiconductor devices are fabricated.

Unit — waferframe
Unit Identifier — wffr Prefix Allowed — No
Equivalence — None Suffix Allowed — Yes
Description — Special SECS generic unit corresponding to a temporary fixture for wafers. The unit capacity is specified by the symbol's suffix, if provided. Otherwise, the capacity is situation-dependent.

Unit — watt
Unit Identifier — W Prefix Allowed — Yes
Equivalence — J/s Suffix Allowed — No
Description — SI unit of power.

Unit — watthour
Unit Identifier — Wh Prefix Allowed — Yes
Equivalence — 3600*J Suffix Allowed — No
Description — Unit of energy.

Unit — weber
Unit Identifier — Wb Prefix Allowed — Yes
Equivalence — V*s Suffix Allowed — No
Description — SI unit of magnetic flux.

Unit — year
Unit Identifier — yr Prefix Allowed — No
Equivalence — None Suffix Allowed — No
Description — Unit of time.

APPLICATION NOTES

NOTICE: The material contained in these Application Notes is not an official part of SEMI E5 (SECS-II) and is not intended to modify or supersede the official standard. Rather, these notes describe possible methods for implementing the protocol described by the standard and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

A1 The General Node Transaction Protocol

A1.1 This application note has been moved to follow SEMI E4 (SECS-I) as Application Note A7.

A2 Some Suggested Message Usage

A2.1 The number of messages implemented and the choice of messages are greatly influenced by the actual function of the equipment. To illustrate which messages might be appropriate, the following suggestions are offered for a variety of different types of equipment capabilities. It is assumed that the minimum message sets S1,F1; F2 and S9,F1; F3; F5; F7 are always implemented.

A2.2 For equipment which makes nondestructive in-process measurements using a fixed measurement procedure, it may be necessary only to implement S6, F9 to send the data according to a fixed format upon measurement. Optional remote control can be added with S2,F21 to start a measurement.

A2.3 If the equipment has a variety of measurement routines, it might be desirable to respond to S1,F5 with S1,F6, which would give the host a brief report of the test being made. The test can be thought of as a process program. Accordingly, S7,F1 and S7,F2 could be used for the host to select the program. The same messages in conjunction with S7,F3 and S7,F4 could load a new test procedure. S7,F19 could be used by the host to find out what tests were available.

A2.4 Some equipment which automatically processes wafers in a batch might make more extensive use of S1,F5 or S1,F3 and might include some error reporting on S5,F1. More sophisticated equipment may include some trace features with S2,F23 and S6,F1 or some control loop tuning by S2,F15.

A2.5 Equipment using in-line wafer movement could utilize Stream 4, S1,F9, and Stream 3 to keep track of wafers.

A2.6 Stream 7,F9 through F19 can be used to manage a local backup of process programs should the host fail for a short while.

A2.7 Microprocessor equipment can benefit from features such as provided by Stream 8 and S2,F1 through F12 which allow managing and servicing the software routines.

A2.8 Equipment, including a CRT, might elect to make it available to the host by including Stream 10 messages.

A2.9 Some equipment, such as functional testers, might have sufficient need to undertake remote file usage such as provided in Stream 13.

A2.10 These brief suggestions serve to illustrate that the final choice of the messages included in a given equipment depends upon its function. The messages can be viewed as interface features in the same way that other parts of the equipment are viewed as processing features or wafer handling features.

A3 Notes on SECS-II Data Transfers

A3.1 *Introduction*

A3.1.1 There are two primary ways to send and ask for data in SECS-II. One of these is to use the trace feature and the other is to use the event reporting method. The purpose of this note is to describe the intended operation of the messages described in the existing standard. Discussion of completeness or need for other reporting methods is left for task force and committee work.

A3.2 *Trace Data Collection and Reporting*

A3.2.1 This method of collecting data is intended for engineering and developmental use rather than routine data collection for production. The features included allow the collection of relatively large amounts of real time data over a finite amount of time. The data is generated at regular time intervals as determined by a timing generator in the equipment. The function of the host is to set up the trace and then to subsequently store the data as it is received from the equipment. It is assumed that some host resident applications will exist to analyze the data either as it is received or at some later time.

A3.2.2 The trace feature will only exist in equipment which implements it.

A3.2.3 The host sets up the trace with the S2,F23-24 transaction. At this time, the host assigns several important parameters. TRID is the trace request ID and is used later when the equipment sends back the data. Every trace data reply includes the TRID corresponding to the request that set up the trace. Several traces can theoretically be done at the same time if the equipment allows it and the TRID keeps the data for each trace distinct from other trace data. DSPER is the data sample period and is used to indicate how often the specified parameters should be sampled (that is, have their values saved). TOTSMP is the total number of samples to be made. Since TOTSMP is finite and the number of parameters is specified in this transaction, the host can reserve adequate file space for the reported data if required. The REPGSZ is the reporting group size and corresponds to the number of time samples that should be combined into one message prior to transmission. Thus, if it is desired to sample one or two parameters every second but only send those samples to the host once a minute, the reporting group size would be 60. Having the reporting group size parameter allows the host to have some control over how often it may be interrupted to handle the trace data. However, as presently defined in the standard, the trace data is reported as a single block message (S6,F1), which restricts both the number of status variables or the number of samples which can be combined into one message. The equipment may be able to accommodate this in several ways, to be described shortly.

The last element in the trace initialize request is a list of status variable IDs. The trace command only allows tracing variables that have been declared and are known to the equipment as status variables. It is assumed that the equipment will report the variable values in the same order as specified in the trace request. This will allow the host to identify the values returned.

A3.2.4 The trace data send message, S6,F1-2, sends the trace data as a single block message to minimize the overhead in reporting data. The TRID is the first item and identifies the request that asked for the data. The next item is SMPLN, the sample number of the last sample in this message, should more than one sample be combined. The next item is STIME which is the time of the last sample in this message. These three items are followed by the list of values. If five (5) values were requested with a reporting group size of 5, then 25 values would be in this list, each group of 5 in the same order as requested and in the time order sampled. Some flexibility is allowed in how the equipment chooses to report the data to the host when the reporting group size exceeds one block of data. The equipment can send the data when it has a complete block or it can reject the request when it is set up.

A3.3 *Event Driven Data Reporting*

A3.3.1 The second major type of data reporting is initiated by some event in the equipment. Data reporting is often desired after some event such as the completion of a measurement, the completion of a lot, the completion of a wafer, the occurrence of a special event command in the recipe, or some other action which is determined by the equipment. The two aspects involved in event driven data reporting are the control of which events cause data to be sent to the host and the formatting of the data sent to the host.

A3.3.2 It is assumed that a set of events has been established for a particular piece of equipment and that each event can produce a report of some sort. It is further assumed that a set of equipment constants exist in the machine such that they have control over the optional reporting of the events. For example, a boolean constant may exist for each possible reporting event, and when the host sets the constant to a logical 1, the corresponding event will cause a report to be sent to the host, when the host sets the constant to logical 0, the event will not send a report. S2,F15-16 in the equipment constant send transaction can be used to control the event reporting.

A3.3.3 When an event causes data to be sent to the host, there are several possible conversations, depending upon the length of the data and the complexity of the formatting. S6,F3-4 is the basic data transaction, which has a very general format. The parameters provide for an overall name, DATAID, for the type of data; a collection event identification, CEID, should there be more than one event that could generate the same type of data; and a list of data sets. This structure allows reporting such data as the measurements taken on each of the wafers in a lot. The measurements on each wafer make up one data set, and the list of data sets is the whole lot. The collection event would be the lot completion, and the data ID might be film thickness measurements. Other types of organizations are possible, depending upon the type of data being sent. The same type of data might be produced by a different CEID, such as the forced termination of the lot. This collection ID would indicate that the data is incomplete for the lot. Within each data set, each data value is reported as a pair of items, one item being the name of the value and the other being the value.

A3.3.4 Since many simple measuring devices have only a very few types of data sets, an alternative data format is provided in S6,F9-10, which has the same form as S6,F3-4 but does not require the value name in the data set. Instead, the order of the values is fixed format for the particular DSID in that particular equipment.

A3.3.5 When either of the above data messages is long enough to require multiple blocks, it must be preceded by S6,F5-6 to gain permission to send a multiple block message.

A3.3.6 The last data control transaction is S6,F7-8, which is initiated by the host and causes a specified DATAID to be sent to the host. The implementation of this function is highly equipment-dependent. In essence, it is equivalent to the host causing an event that triggers the sending of the data. Since the equipment may be generating the data, the actual data sent depend upon the equipment implementation. The equipment can respond with a zero length item if no data can be sent.

A3.4 *Event Reporting*

A3.4.1 The third major type of data reporting is similar to that described in A3.3 above, with the following enhancements:

a. Contents of data reports are not limited to DVVALs, but may include SVs or even ECVs.

b. Contents of data reports are user programmable.

A3.4.2 It is assumed that the equipment vendor supplies a list of all " events" identified within a particular piece of equipment. A Collection Event Identifier (CEID) must be specified for each of these events. It is further assumed that the vendor supplies a list of all available variables within the machine. This includes Status Variables (SVs) and their identifiers (SVIDs), Equipment constants (ECVs) and their identifiers (ECIDs), and Data Values (DVVALs) and their identifiers(DVNAMEs). Each of the identifiers must be unique. The term VID (Variable Identifier) encompasses all SVIDs, ECIDs, and DVNAMEs. Likewise, the term V (Variable Data) encompasses all SVs, ECVs, and DVVALs.

A3.4.3 Note that a Variable (V) may be a list (format code 0). This provides for referencing a group of related data values with one identifier. Consider the following:

```
VID1=1 zone 1 temperature ID  Format 32
V1    zone 1 temperature value Format 52
.
.
VIDn=n zone n temperature ID  Format 32
Vn    zone n temperature value Format 52
VIDx=x all temperatures ID    Format 32
Vx  L,n                       Format 0
      1. L,2
           1. <VID1>
           2. <V1>
      .
      .
      n. L,2
           1. <VIDn>
           2. <Vn>
```

Any V in a list may also be a list (for nesting).

A3.4.4 In a typical initialization sequence, the host would define all the desired programmable data reports with S2,F33/S2,F34 (Define Report) transactions. Then S2,F35/S2,F36 (Link Report/Event) transactions would be used to define which reports are to be made by the equipment upon specific events (CEIDs). An individual report may be linked to more than one event. At this point the host may request reports with the S6,F15/S6,F16 (Report Request) transactions to obtain initial report data and/or to verify reports as defined and linked. Finally, the desired reports would be enabled by the host with S2,F37/S2,F38 (Enable/Disable Event Report) transactions.

A3.4.5 There are two methods for the equipment to send event reports to the host. S6,F13 includes the Variable Identifier (VID) with each Variable Data item (V). S6,F11 is a shorter form, without the identifiers; some users prefer this form to reduce message size.

A3.4.6 When any message is long enough to require multiple blocks, it must be preceded by an inquire/grant transaction.The DATAID parameter is used only to link the inquire/grant transaction with a multiblock message. This linkage is to alleviate problems in the case of interleaved messages. A unique value for DATAID must be used for each Inquire/Grant/Send/Acknowledge conversation (similar to the use of SYSBYTES in SECS-I). The DATAID parameter should not be used for any other purpose.

A4 Process Programs

A4.1 *Introduction*

A4.1.1 Two forms of process programs are supported by SECS-II: unformatted and formatted. The contents of an unformatted process program conform to no set standard. The format of the program is defined by the vendor of the equipment and probably bears no similarity to the format used by other vendors for their equipment. Because special programming would be required at the host to understand the equipment' s unique data format, the process program is most likely generated at the machine and the host is only used as a data repository, saving the foreign data for later retransmission to the equipment. S7,F3 and S7,F6 are the SECS-II messages used to move unformatted process programs between host and equipment.

A4.1.2 Unformatted process programs were the original accepted means for moving processing instructions between host and equipment under SECS-II. However, the inability of a host to generate process programs for its subordinate machines was quickly recognized as a severe problem. As a result, the formatted process program and its associated transactions were added. Five transactions are provided under SECS-II for handling formatted process programs: S7,F23-24, S7,F25-26 allow movement of process programs between host and equipment; S7,F21-22 originates at a machine and provides a host with the information it needs to generate a process program for that machine; S7,F27-28 allows the equipment to tell the host whether or not the contents of the formatted process program received from the host are valid; and S7,F31-32 provides the host with the ability to ask the equipment to check the validity of a process program without actually downloading the program into the machine for production use.

A4.2 *Normal Sequence of Operations*

A4.2.1 Formatted process programs may be generated at a host or machine. The actions taken to generate one in a machine are left to the equipment manufacturer. If the process program is created at a host, a sequence of operations is assumed.

1. Once the host' s process program generator has been invoked and has been told for which machine a process program is to be created, the host editor must obtain a copy of the process capabilities data for that machine. The information may already be available on the host or it may be obtained directly from the machine. In either case, the information originates at the equipment and is obtained using S7,F21-22. (See Section A4.4 for additional information.)

2. With the machine' s process capabilities in its possession, the process program editor may proceed with creating the desired process program. At the conclusion of the editing session, the new machine process program will either be saved at the host or sent directly to the machine for storage and/or use.At this point, the process program is known to satisfy a number of constraints, but it is not necessarily completely acceptable to the machine due to interrelationships of the process program data which are too complex to be described in the machine process capabilities data. The host at any time may verify that a process program is truly valid by sending the process program to the machine and asking it to check the process program and tell the host whether or not the process program is, in fact, correct. If not correct, the equipment is expected to provide information on what data in the process program is unacceptable. This action is accomplished through S7,F31-32. This transaction is equivalent to S7,F23-24, with one important exception, the machine is not to do anything with the process program received under S7,F31 except acknowledge that it got the message (S7,F32) and, as soon as it is able, respond with S7,F27, which provides the host with information on the validity of the process program. In this way, a new version of a process program already held by a machine may be checked for validity without affecting the operation of the machine (i.e., a newer version of a particular process program may be checked while an older version is simultaneously being used by the equipment for material processing).

3. At some point, a host resident process program will be required by the equipment for material processing. Transfer of a program may be accomplished in either of two ways. First, the host may initiate transfer by transmitting S7,F23. In this case, immediately upon reception of the message, the equipment is required to respond with S7,F24, which tells the host that the process program arrived and whether or not the process program is accepted for further processing by the equipment. The second means is for the equipment to initiate the transfer by asking for a process program using S7,F25. In this case, the host will send the process program to the equipment or tell the equipment it is unable to satisfy the request. S7,F23 may also be used by a piece of equipment to transfer a process program to its host for archiving. In this case, the host will respond with S7,F24 and an appropriate completion code. Likewise, a host may request a process program transfer from its machine using S7,F25. The machine will respond with S7,F26, which will contain the process program or an error indication.

4. Following reception by the equipment of the process program, it is the machine' s responsibility to check the contents of the process program for validity and respond to the host with a S7,F27 message formatted with the appropriate information about the just received process program. To complete the process program exchange transaction, the host will acknowledge the S7,F27 message with S7,F28. What is done with the process program once accepted and checked for validity is dependent on the state of the process equipment.

A4.3 *Equipment Process Capabilities Data*

A4.3.1 The underlying assumption of SECS-II formatted process programs is that processing instructions for equipment can be expressed as sequences of commands with parameters. Commands are integer codes which tell the machine what to do. The parameters of each command are numeric (integer or floating point) values, Boolean values, or text strings which specify how to carry out the particular command. This provides a very flexible structure for building process programs but does not provide the specific information (code values, types and number of parameters, legal parameter values, etc.) required by a host system to generate a process program for a particular piece of equipment. Under SECS-II, this information is provided to a host via the machine' s Equipment Process Capabilities Data or PCD.

A4.3.2 A PCD provides three levels of information global data pertaining to the entire process program; definition of each possible command understood by the machine; and definition of each command parameter. Global process program definition data consist of MDLN, SOFTREV,CMDMAX, BYTMAX, and the list of command descriptors.

A4.3.3 MDLN and SOFTREV provide the same data to the host as the equipment' s response to the S1,F1 host interrogative, " Are youthere? " They are included in the PCD to provide a means of distinguishing between PCDs for different machines and revisions of PCDs for the same piece of equipment. Also, when a process program is generated, the MDLN/SOFTREV values of the PCD are provided in the process program to allow the machine an unambiguous method of determining if the process program was generated from a PCD it understands.

A4.3.4 BYTMAX and CMDMAX are two integer values which allow the equipment to limit the size of the process program which will be generated. BYTMAX specifies the maximum number of bytes a process program may occupy. CMDMAX specifies the maximum number of commands which may appear in the process program. Either value may be zero, which indicates that no maximum limit is being imposed by the equipment.

A4.3.5 The PCD command list identifies (in no particular order) each of the unique operations its associated machine is capable of performing. These operations may correspond to processing operations of the equipment (bake, spin), initialization of equipment components (set beamline controls), definition of data values referenced by later commands (define bond coordinates or inspection points), or even " pseudo-operations," which allow conditional execution of the process program (go to X; if temperature out of range, then go to y; repeat ramping until speed 200; etc.).

A4.3.6 Each command in the PCDlist has a number of data values associated with it which provide the host with the command' s personality. These are CCODE, CNAME, RQCMD, BLKDEF, BCDS, IBCDS, NBCDS, ACDS, IACDS, NACDS, and the commands parameter list.

A4.3.7 CCODE defines the unique numeric code which the equipment recognizes as representing the command being defined. CNAME is a text string which hopefully describes the function of the command. The string must be unique for each command since humans generating process programs at the host will use them, and the host process program generator will translate the CNAME to the corresponding CCODE.

A4.3.8 RQCMD. This Boolean value allows equipment to specify whether or not a command must appear at least once within their process program. If true, the command must be used. If RQCMD is set false, the command may or may not be used in the process program at the discretion of the person creating the process program.

A4.3.9 In addition to the information the PCD provides on allowed data content within a process program, it also can provide information to the host on possible interdependencies between the commands. Specifically, through the PCD the host can know such things as: command code A must appear before command code B; command code A must come after command code D; command code A must immediately precede command code X; command code A must not come before command code E; command code A must not come after command code F; and/or command code A must immediately come after command code T. Each of the PCD entries, BCDS (before codes), ACDS (after codes), IBCDS (immediately before codes), IACDS (immediately after codes), NBCDS (not before codes), and NACDS (not after codes), is a SECS item which may contain one or more command codes. Each particular item defines the relation to be satisfied. The elements of the item identify the command codes which are to satisfy the relation with the command being defined. A zero length item indicates that no restrictions apply for that type of checking. For example, if the values of the various fields take on the values shown in Figure A4-1, the host process program editor will assure that the TEST command (code 10) will occur before commands with codes 5, 6, and 8; that it will come after commands with codes 100 and 2; that TEST will not appear after the command with code 20; and that each occurrence of command code 3 will have a TEST command immediately before it, subject to the block checking limitations described elsewhere.

CNAME = TEST

CCODE = 10

BCDS = 5,6,8

IBCDS = 3

NBCDS = none

ACDS = 100.2

IACDS = none

NACDS = 20

Figure A4-1

A4.3.10 Associated with before/after checking is the concept of a block which allows setting of limits on before/after checking. A block consists of a start block command, a block terminator command and possibly body commands, commands which are included between the start and terminator commands. There are no specific command codes for start, or terminator commands in SECS-II formatted process programs. Instead, being a start block, terminator block, or body command is merely an attribute of each command defined in the PCD. The field BLKDEF defines this attribute for each command. A positive one indicates the command starts a new block. Zero indicates that the command is a body command and neither starts nor terminates a block. A value of negative one indicates that the command is a terminator command.

A4.3.11 Before/after checking for a particular command is performed only with other commands within the same block. To be within the same block, a command must have the same nesting level as the command of interest or the command must be a contained block.

The example data in Figure A4-2 shows six grouping of commands for before/after checking: (A,B' ,N), (B,C,D' ,G' ,M), (D,E,F), (G,H' ,L), (H,I' ,K), (I,J). A letter followed by an apostrophe (`) indicates a block which has been collapsed to a command and has the before/after attributes of its start block command. Note that body and terminator commands occur in only one grouping, while block start commands occur in two. Also, note that the outermost block is assumed to begin with the first command of the process program and to end with the last command.

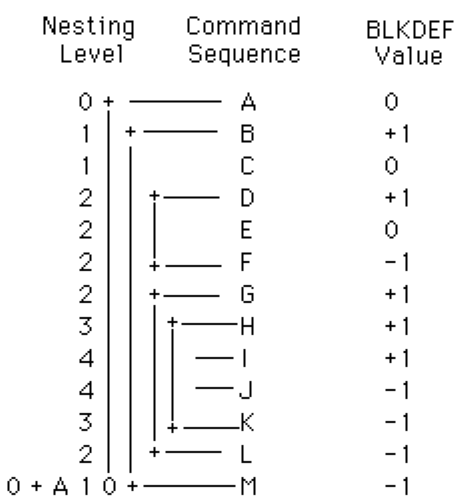


Figure A4-2

A4.3.12 Each command' s parameter list defines the parameters required by the equipment to carry out each particular command. The order in which each parameter descriptor appears in the PCD parameter list also defines the order in which parameters will appear in a process program command parameter list. Each parameter is one of three possible types: numeric, text, or Boolean.

A4.3.13 Regardless of parameter type, the first four elements of any parameter descriptor list are the same. The first field, PNAME, specifies the text string which names the parameter. This data will be displayed by a host when prompting a human for the parameter data. The second field, RQPAR, specifies if the value must be specified at the time the process program is generated (true) or if specifying the data is optional (false). The third field, PDFLT, identifies the type of data to be accepted for this parameter as well as providing default values to include in the process program if the RQPAR is false and no data is input for the parameter when the process program is generated. PDFLT will have zero length if no default value is provided.

A4.3.14 The final field, PMAX, specifies the maximum length of the parameter data placed in a process program. For numeric and Boolean data, it specifies the maximum number of data entries in the SECS-II item. For a string parameter, it specifies the maximum number of characters acceptable to the machine. In either case, negative values are invalid and a value of zero indicates there is no length restriction.

A4.3.15 For numeric and Boolean parameters which are multi-valued items, usage of PDFLT becomes a bit more complex. In these cases, PDFLT may also be a vector of values. When default values are to be included in a process program, the entry of the default vector in the same ordinal position as the parameter entry requiring the default is used. If the parameter is allowed to have N entries but only M defaults are provided, the last N-M parameter entries will have no defaults.

A4.3.16 If the numeric or Boolean vector parameter is required to be entered, PDFLT will contain no default data values, but dummy values must be provided so that the length of the item specifies the minimum number of entries the equipment expects to receive for the parameter. If this minimum number of entries exceeds the maximum number of entries allowed for the parameter (PMAX), then only PMAX entries will be provided in the process program.

A4.3.17 Numeric parameters may be any of the SECS recognized floating point or integer data types. PDFLT identifies the particular type. ULIM and LLIM will be of the same data type and specify the range of legal values for the parameter (LLIM≤ x ≤ULIM).UNITS is a character string formed according to E5, Section 9, which specifies the expected units of measure of the numeric value. RESC specifies whether the resolution of the data item to be entered is to be in terms of a fundamental increment or significant digits. In the case of the former, RESV will be of the same type as the expected parameter and will specify the base increment. In the case of the latter, RESV will be an integer and will specify the number of significant digits to accept for the parameter.

A4.3.18 In addition to the standard fields described above, string parameter descriptors have one unique field. This field provides a set of template strings. A text parameter will be assumed valid by a host process program generator if it matches one of the template strings. A match occurs if the input string is at least as long as the corresponding template and each position of the template and data strings match. A null string specified as a template will result in a match with any data string. A null data string will match only a null template string. A null template list indicates all strings are acceptable to the equipment.

A4.4 *Equipment Capabilities Descriptor Availability*

A4.4.1 Ideally, each piece of equipment should be able to respond to a host PCD request at any time. However, inasmuch as an equipment' s PCD may be rather large and the equipment may have limited storage capacity, constant availability may be impossible. In these cases, some compromise will have to be made such as making it available only at machine initialization or when idle. In extremely severe cases, an equipment manufacturer may have to provide the PCD data with the rest of the machine documentation, requiring his customer to manually enter the data into his host system.

A4.4.2 In light of this difficulty, host systems should maintain copies of PCD' s for each piece of equipment under its control and not expect to be able to obtain the PCD from the machine whenever it is required. Doing so, in fact, will permit more flexible process program development in the host, allowing creation of process programs even when equipment is not online and encourage the use of formatted process programs by equipment manufacturers.

A5 Suggested Baseline SECS Equipment Implementation

A5.1 *Purpose and Scope*

A5.1.1 This document provides a recommendation prepared by the Rigid Disk Subcommittee for generating a baseline implementation of the SECS (SEMI Equipment Communication Standard) standards on production process and test equipment. This document is not a tutorial to aid in understanding SECS but rather serves as an introduction to the requirements of SECS, and a brief guide to the selection of SECS messages for equipment. Actual system requirements of many implementations are beyond the scope of this document. The full standards, SEMI Equipment Communications Standard I (SECS-I), SEMI E4 and SEMI Equipment Communications Standard II (SECS-II), SEMI E5 should be consulted by all users.

A5.2 *Introduction*

A5.2.1 The SECS standards are an existing and developed set of communication standards currently used by the semiconductor and other industries to support automated production. The standards provide a means for communicating information and control between production equipment and a " host" computer. This transfer of information and control can be used to provide production tracking and location of WIP (Work-In-Process), scheduling of WIP and control of material transfer at the equipment. The process measurements and records can be used to provide process engineers with a database for statistical process control. SECS messages are appropriate to a wide variety of applications, including measurement, processing, and material transport equipment.

A5.3 *SECS-I Standard*

A5.3.1 SECS-I defines the lower protocol layers of a point-to-point interface between equipment and a host computer system. The standard requires a simple, well understood physical interface, RS-232. The SECS-I protocol allows the equipment control over the protocol: the equipment is the master of the link and can initiate the transfer of a message to the host. Likewise, the equipment can regulate the receipt of a message by its response to a handshake to receive the message. Thus, the interface takes place at the convenience of the equipment, and equipment with very limited computer resources can still support the standard.

A5.4 *SECS-II Standard*

A5.4.1 SECS-II defines the higher layer in the protocol, including message content, structure, and data types and their formats. SECS-II defines messages in sets with related functions called Streams. The actual content of the messages are specific to an application, but it is possible for a properly designed host software system to unpack a message and present the data in a meaningful way with no prior definition as to the content. Equipment need only implement those messages appropriate to meet its system requirements; thus, very simple equipment will require implementation of few messages.

A5.4.2 Application Note A2 contains some suggestions for message utilization, including some information on minimum message sets. It is the intent of this report to expand in a somewhat different direction, to identify those messages which typically constitute a sufficient set given a selected equipment function.

A5.4.3 To select a message set, the requirements for the equipment must be identified. This requirement, in turn, determines a message set. Identified below are a number of types of equipment requirements and a baseline set of messages supporting those requirements. The message sets identified are baseline recommendations. Actual equipment implementations may need more messages than those specified here to satisfy all system requirements. The published standards should be consulted for all applications. Issues such as handling of multi-block messages, optional replies, and others are described in detail in the SEMI specifications and are not a topic of this baseline recommendation.

A5.4.4 The implementation for a specific equipment type begins by specifying which tasks that equipment is required to perform from the following list, and then studying the expanded descriptions for those tasks chosen in the SECS-II implementation section.

Typical Tasks for Measurement and Process:

1. Measurement or Action Reports
2. Equipment Alarm Reports
3. Remote Request for Equipment Condition or State
4. Operator Interface to the Host
5. Remote Access to Process Programs
6. Remote Commands

Typical Tasks for Material Control and Transport:

1. Material Status Information
2. Material Transport Control

Additional Tasks for Special Situations:

1. File Transfer

A5.5 *Baseline SECS Implementation Recommendations: SECS-I*

A5.5.1 The baseline SECS-I requirement for equipment is to fully implement the SECS-I protocol as defined in SEMI E4. This requirement applies to all SECS compatible equipment independent of the equipment' s function. The flow chart (Figure 2 of SEMI E4) illustrates the block transfer protocol of SECS-I. The body of the SECS-I standard describes protocol timeouts and other requirements that are essential components of the specification.

A5.6 *Baseline SECS Implementation Recommendations: SECS-II*

A5.6.1 The SECS-II implementation begins with a choice or selection of messages for the equipment. In order for equipment to meet the baseline requirements for a viable SECS-II interface, the equipment must be capable of generating a certain set of messages and recognizing another set. The messages required for either set will depend on tasks of equipment and on system requirements for production and process control by the host. Equipment must accept S1,F1 and send S1,F2. Note that implementation in the reverse direction is optional. In order to ensure a viable data communication link, certain messages are required:

Messages for All Equipment — Required by SECS-II

a. Messages Generated by the Equipment

    S1,F2:On Line Data

    S9,F1: Unrecognized Device ID

    S9,F3: Unrecognized Stream Type

    S9,F5: Unrecognized Function Type

    S9,F7: Illegal Data

b. Messages Recognized by the Equipment

    S1,F1: Are You There Request

A5.6.2 In addition to those messages which are required, the following are strongly recommended. These messages are used for diagnostic purposes:

Messages for All Equipment — Strongly Recommended

A. Messages Generated by the Equipment

    1. S2,F25: String Diagnostic Request

B. Messages Recognized by the Equipment

    1. S2,F26: String Diagnostic Data

A5.6.3 Note that messages are identified by a " stream" number and a " function" number. All primary messages have an odd-numbered function, and the corresponding reply is the next consecutive even-numbered function. Thus, many messages are paired. For example, the Stream 1, Function 1 (S1,F1) message generated by either host of equipment has the reply of Stream 1, Function 2 (S1,F2).

A5.6.4 *Reports of Measurements or Process Actions —* The simplest task for measurement and process equipment is to report their measurements or actions to the host. This report could also include equipment setup parameters and sample identification. The ability to accurately transfer this data from equipment to a factory host is of prime importance in automating production. Depending on the equipment requirements, the function can be far greater.

A5.6.4.1 *Measurements or Action Reports* — Given an equipment requirement to relay data to a host computer, the equipment must handle one or both of the following messages as defined by SEMI E5.

S6,F3: Discrete Variable Send

S6,F9: Formatted Variable Send

A5.6.4.2 *Equipment Alarm Reports* — These messages are unsolicited by the host, they transmit information warning of conditions threatening personal safety, equipment safety, or out of limit equipment parameters which may cause harm to the product or indicate equipment malfunction:

S5,F1: Alarm Report Send

A5.6.4.3 *Remote Request for Equipment Condition or State* — This is the method where the host requests data from the equipment.

Messages Transmitted to the Equipment:

S6,F7: Data Transfer Request

Messages Transmitted by the Equipment in Reply:

S6,F8: Data Transfer Data

A5.6.4.4 *Operator Interface to the Host* — Many equipment systems will have an interactive operator's console; some will have computer terminals used for this purpose. SECS-II has a message type to transfer text from host to the equipment console. There are also messages through which equipment operators may transmit text from their console, directly to the host. This text may include desired information which is not accessible by the equipment computer directly.

Message Transmitted by the Equipment:

S10,F1: Terminal Request

Message Recognized by the Equipment:

S10,F3: Terminal Display, Single

A5.6.4.5 *Remote Access to Process Programs* — SECS-II defines a means for storing or retrieving equipment process programs. This function allows upload and download of such programs through the SECS interface. By this means, programs for equipment may be archived in the host computer system. Either the host or the equipment may request the transfer of a Process Program from the other. To do this:

The Requestor transmits:

S7,F5: Process Program Request

The Sender of the Process Program replies:

S7,F6: Process Program Data

In addition, either host or equipment may initiate sending the Process Program. In this case:

The sender transmits:

S7,F1: Process Program Load Inquire,

Receiver replies with:

S7,F2: Process Program Load Grant,

Sender transmits:

S7,F3: Process Program Send,

The receiver answers:

S7,F4: Process Program Acknowledge.

A5.6.4.6 *Remote Commands* — The host can initiate a command to the equipment in a manner similar to an operator pressing a button.

The host transmits:

S2,F21: Remote Command Send,

The equipment replies:

S2,F22: Remote Command Acknowledge.

Execution of the remote command may cause the equipment to transmit a message to the host at a time greater than the reply time required for the S2,F22 message. If this type of reply is desired, the S6,F3: Discrete Variable Data Send may be used to transfer data to the host.

A5.6.5 *Typical Tasks for Material Control and Transport*

A5.6.5.1 *Material Status Information* — The host may query the equipment for material-in-process information. The information is transmitted only as a answer to a host request.

The equipment recognizes:

S3,F1: Material Status Request.

The equipment transmits:

S3,F2: Material Status Data.

A5.6.5.2 *Material Transport Control* — The SECS-II protocol includes the means to affect automated transfer of material from one SECS-compatible device to another. Baseline compatibility requires the equipment to perform a simple material transfer process, an actual implementation may require means for graceful error recovery as well. This recommendation does not include messages to handle error conditions.

Receiving Material:

Equipment Recognizes S4,F1:

Ready to Send Material

Equipment Transmits:

S4,F3: Send Material,

S4,F5: Handshake

Sending Material:

Equipment Transmits:

S4,F1: Ready to Send Material

Equipment Recognizes:

S4,F3: Send Material,

S4,F5: Handshake Complete

Equipment Recognizes:

S4,F2: RTS Acknowledge

A5.7 *Conclusion* — The baseline requirements for equipment using the SECS standards includes all of SECS-I and a limited selection of messages from SECS-II. The choice of SECS-II messages, and data contained therein, is dictated by the equipment and system requirements. The benefits in using the standards are many, including support for growth in equipment function, and standardization needed for effective automation. The results include automated process monitoring and all of the associated benefits.

SEMI E30-1000
GENERIC MODEL FOR COMMUNICATIONS AND CONTROL OF MANUFACTURING EQUIPMENT (GEM)

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on July 14 and August 28, 2000. Initially available at www.semi.org August 2000; to be published October 2000. Originally published in 1992; previously published June 2000.

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1 Introduction

1.1 *Revision History* — This is the first release of the GEM standard.

1.2 *Scope* — The scope of the GEM standard is limited to defining the behavior of semiconductor equipment as viewed through a communications link. The SEMI E5 (SECS-II) standard provides the definition of messages and related data items exchanged between host and equipment. The GEM standard defines which SECS-II messages should be used, in what situations, and what the resulting activity should be. Figure 1.1 illustrates the relationship of GEM, SECS-II and other communications alternatives.

The GEM standard does NOT attempt to define the behavior of the host computer in the communications link. The host computer may initiate any GEM message scenario at any time and the equipment shall respond as described in the GEM standard. When a GEM message scenario is initiated by either the host or equipment, the equipment shall behave in the manner described in the GEM standard when the host uses the appropriate GEM messages.

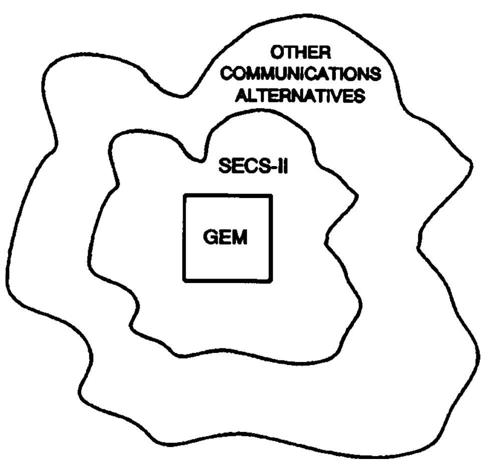


Figure 1.1
GEM Scope

The capabilities described in this standard are specifically designed to be independent of lower-level communications protocols and connection schemes (e.g., SECS-I, SMS, point-to-point, connection-oriented or connectionless). Use of those types of standards is not required or precluded by this standard.

This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.3 *Intent* — GEM defines a standard implementation of SECS-II for all semiconductor manufacturing equipment. The GEM standard defines a common set of equipment behavior and communications capabilities that provide the functionality and flexibility to support the manufacturing automation programs of semiconductor device manufacturers. Equipment suppliers may provide additional SECS-II functionality not included in GEM as long as the additional functionality does not conflict with any of the behavior or capabilities defined in GEM. Such additions may include SECS-II messages, collection events, alarms, remote command codes, processing states, variable data items (data values, status values or equipment constants), or other functionality that is unique to a class (etchers, steppers, etc.) or specific instance of equipment.

GEM is intended to produce economic benefits for both device manufacturers and equipment suppliers. Equipment suppliers benefit from the ability to develop and market a single SECS-II interface that satisfies most customers. Device manufacturers benefit from the increased functionality and standardization of the SECS-II interface across all manufacturing equipment. This standardization reduces the cost of software development for both equipment suppliers and device manufacturers. By reducing costs and increasing functionality, device manufacturers can automate semiconductor factories more quickly and effectively. The flexibility provided by the GEM standard also enables device manufacturers to implement unique automation solutions within a common industry framework.

The GEM standard is intended to specify the following:

— A model of the behavior to be exhibited by semiconductor manufacturing equipment in a SECS-II communication environment,

— A description of information and control functions needed in a semiconductor manufacturing environment,

— A definition of the basic SECS-II communications capabilities of semiconductor manufacturing equipment,

— A single consistent means of accomplishing an action when SECS-II provides multiple possible methods, and

— Standard message dialogues necessary to achieve useful communications capabilities.

The GEM standard contains two types of requirements:

— fundamental GEM requirements and

— requirements of additional GEM capabilities.

The fundamental GEM requirements form the foundation of the GEM standard. The additional GEM capabilities provide functionality required for some types of factory automation or functionality applicable to specific types of equipment. A detailed list of the fundamental GEM requirements and additional GEM capabilities can be found in Chapter 8, GEM Compliance. Figure 1.2 illustrates the components of the GEM standard.

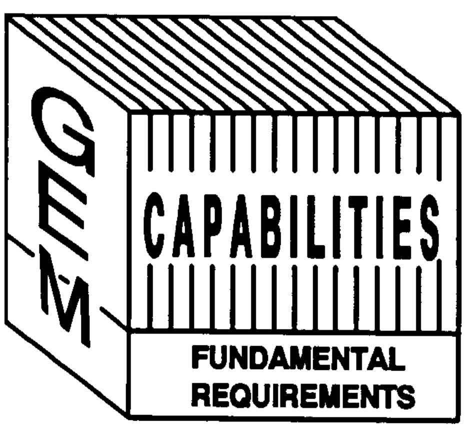


Figure 1.2
GEM Components

Equipment suppliers should work with their customers to determine which additional GEM capabilities should be implemented for a specific type of equipment. Because the capabilities defined in the GEM standard were specifically developed to meet the factory automation requirements of semiconductor manufacturers, it is anticipated that most device manufacturers will require most of the GEM capabilities that apply to a particular type of equipment. Some device manufacturers may not require all the GEM capabilities due to differences in their factory automation strategies.

1.4 *Overview* — The GEM standard is divided into sections as described below.

Section 1 — Introduction

This section provides the revision history, scope and intent of the GEM standard. It also provides an overview of the structure of the document and a list of related documents.

Section 2 — Definitions

This section provides definitions of terms used throughout the document.

Section 3 — State Models

This section describes the conventions used throughout this document to depict state models. It also describes the basic state models that apply to all semiconductor manufacturing equipment and that pertain to more than a single capability. State models describe the behavior of the equipment from a host perspective.

Section 4 — Capabilities and Scenarios

This section provides a detailed description of the communications capabilities defined for semiconductor manufacturing equipment. The description of each capability includes the purpose, definitions, requirements, and scenarios that shall be supported.

Section 5 — Data Definitions

This section provides a reference to the Data Item Dictionary and Variable Item Dictionary found in SEMI Standard E5. The first subsection shows those data items from SECS-II which have been restricted in their use (i.e., allowed formats). The second subsection lists variable data items that are available to the host for data collection and shows any restrictions on their SECS-II definitions.

Section 6 — Collection Events

This section provides a list of required collection events and their associated data.

Section 7 — SECS Message Subset

This section provides a composite list of the SECS-II messages required to implement all capabilities defined in the GEM standard.

Section 8 — GEM Compliance

This section describes the fundamental GEM requirements and additional GEM capabilities and provides references to other sections of the standard where detailed requirements are located. This section also defines standard terminology and documentation that can be used by equipment suppliers and device manufacturers to describe compliance with this standard.

Section A — Application Notes

These sections provide additional explanatory information and examples.

Section A.1 — Factory Operational Script

This section provides an overview of how the required SECS capabilities may be used in the context of a typical factory operation sequence. This section is organized according to the sequence in which actions are typically performed.

Section A.2 — Equipment Front Panel

This section provides guidance in implementing the required front panel buttons, indicators, and switches as defined in this document. A summary of the front panel requirements is provided.

Section A.3 — Examples of Equipment Alarms

This section provides examples of alarms related to various equipment configurations.

Section A.4 — Trace Data Collection Example

This section provides an example of trace initialization by the host and the periodic trace data messages that might be sent by the equipment.

Section A.5 — Harel Notation

This section explains David Harel's "Statechart" notation that is used throughout this document to depict state models.

Section A.6 — Example Control Model Application

This section provides one example of a host's interaction with an equipment's control model.

Section A.7 — Examples of Limits Monitoring

This section contains four limits monitoring examples to help clarify the use of limits and to illustrate typical applications.

1.5 *Applicable Documents*

1.5.1 *SEMI Standards* — The following SEMI standards are related to the GEM standard. The specific portions of these standards referenced by GEM constitute provisions of the GEM standard.

SEMI E4 — SEMI Equipment Communications Standard 1 — Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 — Message Content (SECS-II)

SEMI E13 — Standard for SEMI Equipment Communication Standard Message Service (SMS)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

1.5.2 *Other References*

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8 (1987) 231-274[1].

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 Definitions

2.1 *alarm* — An alarm is related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed. Such abnormal situations are defined by the equipment manufacturer based on physical safety limitations. Equipment activities potentially impacted by the presence of an alarm shall be inhibited.

2.1.1 Note that exceeding control limits associated with process tolerance does not constitute an alarm nor do normal equipment events such as the start or completion of processing.

2.2 *capabilities* — Capabilities are operations performed by semiconductor manufacturing equipment. These operations are initiated through the communications interface using sequences of SECS-II messages (or scenarios). An example of a capability is the setting and clearing of alarms.

2.3 *collection event* — A collection event is an event (or grouping of related events) on the equipment that is considered to be significant to the host.

2.4 *communication failure* — A communication failure is said to occur when an established communications link is broken. Such failures are

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elvesier.nl/homepage/browse.htt

protocol specific. Refer to the appropriate protocol standard (e.g., SEMI E4 or SEMI E37) for a protocol-specific definition of communication failure.

2.5 *communication fault* — A communication fault occurs when the equipment does not receive an expected message, or when either a transaction timer or a conversation timer expires.

2.6 *control* — To control is to exercise directing influence.

2.7 *equipment model* — An equipment model is a definition based on capabilities, scenarios, and SECS-II messages that manufacturing equipment should perform to support an automated manufacturing environment. (See also Generic Equipment Model.)

2.8 *event* — An event is a detectable occurrence significant to the equipment.

2.9 *GEM compliance* — The term "GEM Compliance" is defined with respect to individual GEM capabilities to indicate adherence to the GEM standard for a specific capability. Section 8 includes more detail on GEM Compliance.

2.10 *Generic Equipment Model* — The Generic Equipment Model is used as a reference model for any type of equipment. It contains functionality that can apply to most equipment, but does not address unique requirements of specific equipment.

2.11 *host* — The SEMI E4 and E5 standards define Host as "the intelligent system that communicates with the equipment."

2.12 *message fault* — A message fault occurs when the equipment receives a message that it cannot process because of a defect in the message.

2.13 *operational script* — An operational script is a collection of scenarios arranged in a sequence typical of actual factory operations. Example sequences are system initialization powerup, machine setup, and processing.

2.14 *operator* — A human who operates the equipment to perform its intended function (e.g., processing). The operator typically interacts with the equipment via the equipment supplied operator console.

2.15 *process unit* — A process unit refers to the material that is typically processed as a unit via single run command, process program, etc. Common process units are wafers, cassettes, magazines, and boats.

2.16 *processing cycle* — A processing cycle is a sequence wherein all of the material contained in a typical process unit is processed. This is often used as a measure of action or time.

2.17 *scenario* — A scenario is a group of SECS-II messages arranged in a sequence to perform a capability. Other information may also be included in a scenario for clarity.

2.18 *SECS-I* — SEMI Equipment Communications Standard 1 (SEMI E4). This standard specifies a method for a message transfer protocol with electrical signal levels based upon EIA RS232-C.

2.19 *SECS-II* — SEMI Equipment Communications Standard 2 (SEMI E5). This standard specifies a group of messages and the respective syntax and semantics for those messages relating to semiconductor manufacturing equipment control.

2.20 *SMS* — SECS Message Service. An alternative to SECS-I to be used when sending SECS-II formatted messages over a network.

2.21 *state model* — A State Model is a collection of states and state transitions that combine to describe the behavior of a system. This model includes definition of the conditions that delineate a state, the actions/reactions possible within a state, the events that trigger transitions to other states, and the process of transitioning between states.

2.22 *system default* — Refers to state(s) in the equipment behavioral model that are expected to be active at the end of system initialization. It also refers to the value(s) that specified equipment variables are expected to contain at the end of system initialization.

2.23 *system initialization* — The process that an equipment performs at power-up, system activation, and/or system reset. This process is expected to prepare the equipment to operate properly and according to the equipment behavioral models.

2.24 *user* — A human or humans who represent the factory and enforce the factory operation model. A user is considered to be responsible for many setup and configuration activities that cause the equipment to best conform to factory operations practices.

3 State Models

The following sections contain state models for semiconductor manufacturing equipment. These state models describe the behavior of the equipment from a host perspective in a compact and easy to understand format. State models for different equipment will be identical in some areas (e.g., communications), but may vary in other areas (e.g., processing). It is desirable to divide the equipment into parallel components that can be modeled separately and then combined. An example of a component overview of an equipment is provided as Figure 3.0.

Equipment manufacturers must document the operational behavior of their equipment using state model methodology. State models are discussed in Sections 3.1 and A.5 and in a referenced article. Documentation of a state model shall include the following three elements:

— A *state diagram* showing the possible states of the system or components of a system and all of the possible transitions from one state to another. The states and transitions must each be labeled. Use of the Harel notation (see A.5) is recommended.

— A *transition table* listing each transition, the beginning and end states, what stimulus triggers the transition, and any actions taken as a result of the transition.

— A *definition of each state* specifying system behavior when that state is active.

Examples of the above elements are provided in Section A.5.

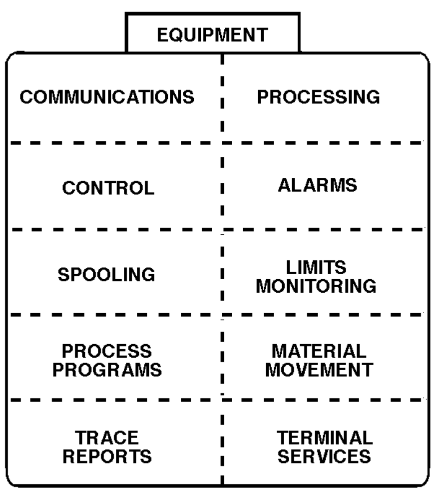


Figure 3.0
Example Equipment Component Overview

The benefits of providing state models are:

1. State machine models are a useful specification tool,
2. A host system can anticipate machine behavior based upon the state model,
3. End-users and equipment programmers have a common description of machine behavior from which to work,
4. "Legal" operations can be defined pertaining to any machine state,
5. External event notifications can be related to internal state transitions,
6. External commands can be related to state transitions,
7. State model components describing different aspects of machine control can be related to one another (example: processing state model with material transport state model; processing state model with internal machine safety systems).

3.1 *State Model Methodology* — To document the expected functionality of the various capabilities described in this document, the "Statechart" notation developed by David Harel has been adopted. An article by Harel is listed in Section 1.5 and should be considered "must" reading for a full understanding of the notation. The convention used in this and following sections is to describe the dynamic functionality of a capability with three items: a textual description of each state or substate defined, a table that describes the possible transitions from one state to another, and a graphical figure that uses the symbols defined by Harel to illustrate the relationships of the states and transitions. The combination of these items define the state model for a system or component. A summary of the Harel notation and a more detailed description of the text, table, and figure used to define behavior with this methodology is contained in the Application Note A.5.

The basic unit of a state model is the state. A state is a static set of conditions. If the conditions are met, the state is current. These conditions might involve sensor readings, switch positions, time of day, etc. Also part of a state definition is a description of reactions to specific stimuli (e.g., if message Sx,Fy is received, generate reply message Sx,Fy + 1). Stimuli may be quite varied but for semiconductor equipment would include received SECS messages, expired timers, operator input at an equipment terminal, and changes in sensor readings.

To help clarify the interpretation of this document and the state models described herein, it is useful to distinguish between a state and an event and the relationship of one to the other. An event is dynamic rather than static. It represents a change in conditions, or more specifically, the awareness of such a change. An event might involve a sensor reading exceeding a limit, a switch changing position, or a time limit exceeded.

A change to a new active state (state transition) must always be prompted by a change in conditions, and thus an event. In addition, a state transition may itself be termed an event. In fact, there are many events that may occur on an equipment, so it is important to classify events based on whether they can be detected and whether they are of interest. In this document, the term event has been more narrowly defined as a detectable occurrence that is significant to the equipment.

A further narrowing of the definition of event is represented by the term "collection event," which is an event (or group of related events) on the equipment that is considered significant to the host. It is these events that (if enabled) are reported to the host. By this definition, the list of collection events for an equipment would typically be only a subset of total events. The state models in this document are intended to be limited to the level of detail in which the host is interested. Thus, all state transitions defined in this standard, unless otherwise specified, shall correspond to collection events.

3.2 *Communications State Model* — The Communications State Model defines the behavior of the equipment in relation to the existence or absence of a communications link with the host. Section 4.1 expands on this section by defining the Establish Communications capability. This model pertains to a logical connection between equipment and host rather than a physical connection.

3.2.1 *Terminology* — The terms communication failure, connection transaction failure, and communication link are defined for use within this document only and should not be confused with the same or similar terms used elsewhere.

- See SEMI E4 (SECS-I) or SEMI E37 (HSMS) for a protocol specific definitions of communications failure.
- A connection transaction failure occurs when attempting to establish communications and is caused by
  - — a communication failure,
  - — the failure to receive an S1,F14 reply within a reply timeout limit, or
  - — receipt of S1,F14 that has been improperly formatted or with COMMACK[2] not set to 0.
- A reply timeout period begins after the successful transmission of a complete primary message for which a reply is expected. (See SEMI E4 (SECS-I) or SEMI E37 (HSMS) for a protocol-specific definition of reply timeout.)
- A communication link is established following the first successful completion of any one S1,F13/F14 transaction with an acknowledgement of "accept". The establishment of this link is logical rather than physical.
- Implementations may have mechanisms which allow outgoing messages to be stored temporarily prior to being sent. The noun queue is used to cover such stored messages. They are queued when placed within the queue and are dequeued by removing them from this storage.
- Send includes "queue to send" or "begin the process of attempting to send" a message. It does not imply the successful completion of sending a message.
- The host may attempt to establish communications with equipment at any time due to the initialization of the host or by independent detection of a communications failure by the host. Thus, the host may initiate an S1,F13/F14 transaction at any time.

3.2.2 *CommDelay Timer* — The CommDelay timer represents an internal timer used to measure the interval between attempts to send S1,F13. The length of this interval is equal to the value in the EstablishCommunicationsTimeout. The CommDelay timer is not directly visible to the host.

EstablishCommunicationsTimeout is the user-configurable equipment constant that defines the delay, in seconds, between attempts to send S1,F13. This value is used to initialize the CommDelay timer.

The CommDelay timer is initialized to begin timing. The CommDelay timer is initialized only when the state WAIT DELAY is entered.

The CommDelay timer is expired when it "times out," and the time remaining in the interval between attempts to send is zero. When the timer expires during the state WAIT DELAY, it triggers a new attempt to send S1,F13 and the transition to the state WAIT CRA[3] .

3.2.3 *Conventions*

- The attempt to send S1,F13 is made only upon transit into the state WAIT CRA. The CommDelay Timer should be set to "expired" at this time.

2 Establish Communications Acknowledge Code, defined in Section 4.1. See the SEMI E5 Standard for further definition of this Data Item.

3 CRA is the mnemonic defined for Establish Communications Request Acknowledge (S1,F14).

- The CommDelay timer is initialized only upon transit into the state WAIT DELAY. A next attempt to send S1,F13 shall occur only upon a transit to the state WAIT CRA.

3.2.4 *Communication States* — There are two major states of SECS communication, DISABLED and ENABLED. The system default state must be user-configurable at the equipment (e.g., via a jumper setting or non-volatile memory variable).

Once system initialization has been achieved, the operator shall be able to change the communication state selection at any time via equipment terminal functions or momentary switch. A two-position type switch must not be used due to possible conflict with the system default.

The ENABLED state has two substates, NOT COMMUNICATING and COMMUNICATING, described below. The equipment must inform the operator of the current communication state via continuous display at the equipment, including the NOT COMMUNICATING and COMMUNICATING sub-states.

In the event of a connection transaction failure, a user-configurable equipment constant EstablishCommunicationsTimeout is used to establish the interval between attempts to send an S1,F13 (Establish Communications Request) while in the NOT COMMUNICATING substate.

Figure 3.2.1 shows the relationship between the superstates and substates of the Communications State Model. A description of the events triggering state transitions and the actions taken is given in Table 3.2.

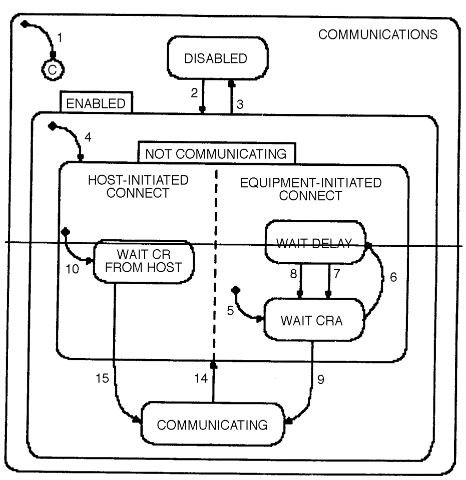


Figure 3.2.1
Communications State Diagram

The states of the Communications State Model are defined as follows:

DISABLED

In this state SECS-II communication with a host computer is non-existent. If the operator switches from ENABLED to DISABLED, all SECS-II communications must cease immediately. Any messages queued to send shall be discarded, and all further action on any open transactions and conversations shall be terminated.[4] Handling of messages currently being transmitted is an issue for lower level message transfer protocols and is not addressed in this standard.

The DISABLED state is a possible system default.

ENABLED

ENABLED has two substates, COMMUNICATING and NOT COMMUNICATING. Whenever communications are enabled, either during system initialization or through operator selection, the substate of NOT COMMUNICATING is active until communications are formally established. Lower-level protocols (such as SECS-I) are assumed to be functioning normally in that they are capable of supporting the communication of SECS-II syntax.

The ENABLED state is a possible system default.

ENABLED/NOT COMMUNICATING

No messages other than S1,F13, S1,F14, and S9,Fx shall be sent while this substate is active. The equipment shall discard any messages received from the host other than S1,F13 or S1,F14 (Establish Communications Acknowledge). It shall also periodically attempt to establish communication with a host computer by issuing an S1,F13 until communications are successfully established. However, only one equipment-initiated S1,F13 transaction may be open at any time.

The NOT COMMUNICATING state has two AND substates, HOST-INITIATED CONNECT and EQUIPMENT-INITIATED CONNECT, both of which are active whenever the equipment is NOT COMMUNICATING. These two substates clarify the behavior of the equipment in the event that both

4 Refer to SEMI E5, Section 5, for definitions of SECS-II transaction and conversation protocols.

the equipment and the host attempt to establish communications during the same period of time[5] .

NOT COMMUNICATING/EQUIPMENT-INITIATED CONNECT

This state has two substates, WAIT CRA and WAIT DELAY. Upon any entry to the NOT COMMUNICATING state, whenever EQUIPMENT-INITIATED CONNECT first becomes active, a transition to WAIT CRA occurs, the CommDelay timer is set to “expired,” and an immediate attempt to send S1,F13 is made.

NOT COMMUNICATING/EQUIPMENT-INITIATED CONNECT/WAIT CRA

An Establish Communications Request has been sent. The equipment waits for the host to acknowledge the request.

NOT COMMUNICATING/EQUIPMENT-INITIATED CONNECT/WAIT DELAY

A connection transaction failure has occurred. The CommDelay timer has been initialized. The equipment waits for the timer to expire.

NOT COMMUNICATING/HOST-INITIATED CONNECT

This state describes the behavior of the equipment in response to a host-initiated S1,F13 while NOT COMMUNICATING is active.

NOT COMMUNICATING/HOST-INITIATED CONNECT/WAIT CR FROM HOST

The equipment waits for an S1,F13 from the host. If an S1,F13 is received, the equipment attempts to send an S1,F14 with COMMACK = 0.

ENABLED/COMMUNICATING

Communications have been established. The equipment may receive any message from the host, including S1,F13. When the equipment is COMMUNICATING, SECS communications with a host computer must be maintained. This state remains active until communications are disabled or a communication failure occurs. If the equipment receives S1,F13 from the host while in the COMMUNICATING substate, it should respond with S1,F14 with COMMACK set to zero. If the equipment receives S1,F14 from a previously sent S1,F13, no action is required.

In the event of communication failure, the equipment shall return to the NOT COMMUNICATING substate and attempt to re-establish communications with the host.

It is possible that the equipment may be waiting for an S1,F14 from the host in EQUIPMENT-INITIATED CONNECT/WAIT CRA at the time an S1,F13 is received from the host in HOST-INITIATED CONNECT/WAIT CR FROM HOST. When this situation occurs, both equipment and host have an open S1,F13/S1,F14 transaction. Since communications are successfully established on the successful completion of any S1,F13/S1,F14 transaction, either of these two transactions may be the first to complete successfully and to cause the transition from NOT COMMUNICATING state to COMMUNICATING. In this event, the other transaction shall remain open regardless of the transition to COMMUNICATING until it is closed in a normal manner.

If the equipment has not yet sent[6] an S1,F14 to a previously received S1,F13 at the time when COMMUNICATING becomes active, the S1,F14 response shall be sent in a normal manner. A failure to send the S1,F14 is then treated as any other communication failure.

If the equipment-initiated S1,F13/S1,F14 is still open when the transition to COMMUNICATING occurs, subsequent failure to receive a reply from the host is considered a communication fault by equipment. An S9,F9 should be sent when a transaction timer timeout occurs[7]. (See Section 4.9 for definitions of communication faults and message faults, as well as detail on Stream 9 Error Messages.)

3.2.5 *State Transitions* — Table 3.2 contains a full description of the state transitions depicted in Figure 3.2.1.

When the operator switches from the DISABLED state to the ENABLED state, no collection event shall occur, since no messages can be sent until communications have been established. The process of establishing communications serves to notify the host that communications are ENABLED. No other collection events are defined for the Communications State Model.

5 Note that in the Harel notation, an exit from any AND substate is an exit from the parent state and thus from all other AND substates of that parent substate.

6 This includes transmissions that may have started but not yet successfully completed at the time that the transition to COMMUNICATING occurs.

7 The existence of a transaction timer is not a requirement in some protocols, such as SMS (SEMI E13).

Table 3.2 Communications State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	(Entry to COMMUNICA-TIONS)	System initialization.	System Default	None.	The system default may be set to DISABLED or ENABLED.
2	DISABLED	Operator switches from DISABLED to ENABLED.	ENABLED	None.	SECS-II communications are enabled.
3	ENABLED	Operator switches from ENABLED to DISABLED.	DISABLED	None.	SECS-II communications are prohibited.
4	(Entry to ENABLED)	Any entry to ENABLED state.	NOT COMMUNICATING	None.	May enter from system initialization to ENABLED or through operator switch to ENABLED.
5	(Entry to EQUIPMENT-INITIATED CONNECT)	(Any entry to NOT COMMUNICA-TING)	WAIT CRA	Initialize communications. Set CommDelay timer “expired.” Send S1,F13.	Begin the attempt to establish communications.
6	WAIT CRA	Connection transaction failure.	WAIT DELAY	Initialize CommDelay timer. Dequeue all messages queued to send.	If appropriate, dequeued messages shall be placed in spool buffer in the order generated. Wait for timer to expire.
7	WAIT DELAY	CommDelay timer expired.	WAIT CRA	Send S1,F13	Wait for S1,F14. May receive S1,F13 from Host.
8	WAIT DELAY	Received a message other than S1,F13.	WAIT CRA	Discard message. No reply. Set CommDelay timer “expired”. Send S1,F13.	Indicates opportunity to establish communications.
9	WAIT CRA	Received expected S1,F14 with COMMACK = 0.	COMMUNICATING	None.	Communications are established.
10	(Entry to HOST-INITIATED CONNECT)	(Any entry to NOT COMMUNICA-TING)	WAIT CR FROM HOST	None.	Wait for S1,F13 from Host.
14	COMMUNICATING	Communication failure. (See SEMI E4 or SEMI E37 for a protocol-specific definition of communication failure.)	NOT COMMUNICATING	Dequeue all messages queued to send.	Dequeued messages may be placed in spool buffer as appropriate.
15	WAIT CR FROM HOST	Received S1,F13.	COMMUNICATING	Send S1,F14 with COMMACK = 0.	Communications are established.

3.3 *Control State Model* — The CONTROL state model defines the level of cooperation between the host and equipment. It also specifies how the operator may interact at the different levels of host control. While the COMMUNICATIONS state model addresses the ability for the host and equipment to exchange messages, the CONTROL model addresses the equipment's responsibility to act upon messages that it receives.

The CONTROL model provides the host with three basic levels of control. In the highest level (REMOTE), the host may control the equipment to the full extent possible. The middle level (LOCAL) allows the host full access to information, but places some limits on how the host can affect equipment operation. In the lowest level (OFF-LINE), the equipment allows no host control[8] and only very limited information.[9]

The control model and communications model (when implemented) do not interact directly. That is, no action or state of one model directly causes a change in behavior of the other. It is true, however, that when the communication state is NOT COMMUNICATING then most message transaction are not functional. When messages cannot be transmitted, the control capabilities and all other GEM capabilities are affected.

Refer to Figure 3.3 as the CONTROL substates and state transitions are defined.

OFF-LINE

When the OFF-LINE state is active, operation of the equipment is performed by the operator at the operator console. While the equipment is OFF-LINE, message transfer is possible. However the use of messaging for any automation purpose is severely restricted. While the OFF-LINE state is active, the equipment will only respond to those messages used for the establishment of communications or a host request to activate the ON-LINE state.

While OFF-LINE, the equipment will respond with an Sx,F0 to any primary message from the host other than S1,F13 or S1,F17. It will process and respond to S1,F13 and S1,F17. S1,F17 is used by the host to request the equipment to transition to the ON-LINE state. The equipment will accept this request and send a positive response only when the HOST OFF-LINE state is active (see transition 11 definition below).

8 The host may establish communications. This does not affect equipment operation and for that reason is not termed a control operation.

9 The host may determine the equipment identification via the S1F13/F14 transaction.

While the OFF-LINE state is active, the equipment shall attempt to send no primary message other than S1,F13,[10] S9,Fx,[11] and S1,F1 (see ATTEMPT ON-LINE substate). If the equipment receives a reply message from the host other than S1,F14 or S1,F2, this message is discarded.

No messages enter the spool when the system is OFF-LINE. Spooling may be active when the Communications State of NOT COMMUNICATING is active. This might occur during OFF-LINE, but since the equipment will not attempt to send messages except as mentioned in the previous paragraph[12], no messages will enter the spool.

OFF-LINE has three substates: EQUIPMENT OFF-LINE, ATTEMPT ON-LINE, and HOST OFF-LINE.

OFF-LINE/EQUIPMENT OFF-LINE

While this state is active, the system maintains the OFF-LINE state. It awaits operator instructions to attempt to go ON-LINE.

OFF-LINE/ATTEMPT ON-LINE

While the ATTEMPT ON-LINE state is active, the equipment has responded to an operator instruction to attempt to go to the ON-LINE state. Upon activating this state, the equipment attempts to send an S1,F1 to the host.

Note that when this state is active, the system does not respond to operator actuation of either the ON-LINE or the OFF-LINE switch.

10 Sending of S1,F13 is based upon the COMMUNICATIONS state model.

11 S9,Fx messages may be issued only in response to the messages to which the equipment will normally respond while OFF-LINE (i.e. S1,F13 and S1,F17).

12 The equipment may send S1,F1 or S1,F13, but since Stream 1 messages are not eligible for spooling, they will not enter the spool either.

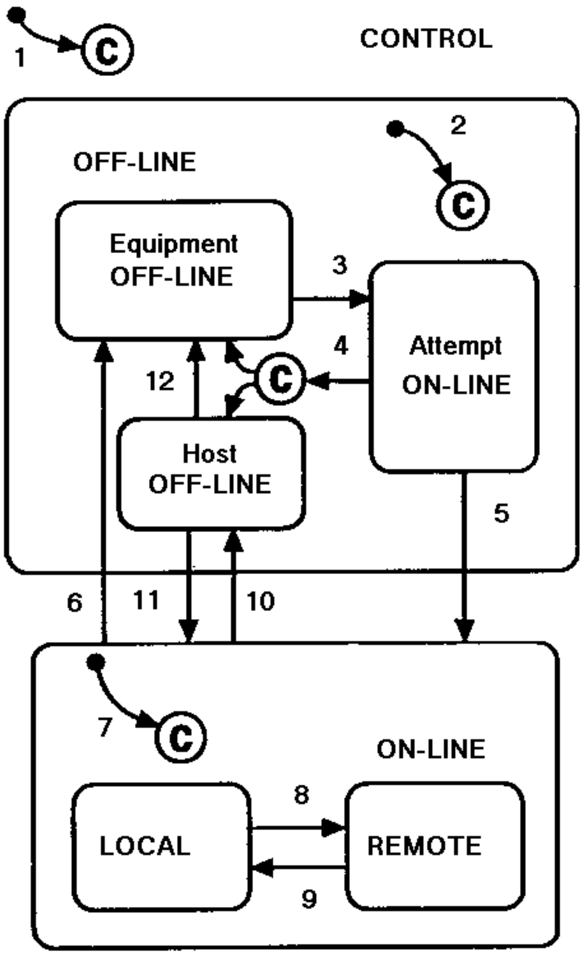


Figure 3.3
CONTROL State Model

OFF-LINE/HOST OFF-LINE

While the HOST OFF-LINE state is active, the operator's intent is that the equipment be ON-LINE. However, the host has not agreed. Entry to this state may be due to a failed attempt to go ON-LINE or to the host's request that the equipment go OFF-LINE from ON-LINE (see the transition table for more detail). While this state is active, the equipment shall positively respond to any host's request to go ON-LINE (S1,F17). Such a request shall be denied when the HOST OFF-LINE state is not active.

ON-LINE

While the ON-LINE state is active, SECS-II messages may be exchanged and acted upon. Capabilities that may be available to the host should be similar to those available from the operator console wherever practical.

The use of Sx,F0 messages is not required while the ON-LINE state is active. Their use is discouraged in this case. The only allowed use is to close open transactions in conjunction with message faults.

ON-LINE/LOCAL

Operation of the equipment is implemented by direct action of an operator. All operation commands shall be available for input at the local operator console of the equipment.

The host shall have the following capabilities and restrictions when the LOCAL state is active:

— The host shall be prohibited from the use of remote commands that cause physical movement or which initiate processing. During processing, the host shall be prohibited from the use of any remote command that affects that process.

— During processing, the host shall be prohibited from modifying any equipment constants that affect that process. Other equipment constants shall be changeable during processing. The host shall be able to modify all available equipment constants when no processing is in progress.

— The host shall be capable of initiating the upload and download of recipes to/from the recipe storage area on the equipment. The host shall be capable of selecting recipes for execution so long as this action does not affect any currently executing recipe.

— The host shall be able to configure automatic data reporting capabilities including alarms, event reporting, and trace data reporting. The host shall receive all such reports at the appropriate times.

— The host shall be able to inquire for data from the equipment, including status data, equipment constants, event reports, process program directories, and alarms.

— The equipment shall be able to perform Terminal Services as defined in GEM.

The host shall be allowed any other capabilities that were not specifically restricted in the above items as long as the LOCAL state is active.

NOTE 2: Capabilities mentioned above which are not implemented on a specific equipment may be ignored in this context.

ON-LINE/REMOTE

For equipment which supports the GEM capability of remote control (see Section 4.4), while the REMOTE state is active, the host shall have access, through the communications interface, to the necessary commands to operate the equipment through the full process cycle in an automated manner. The equipment does not restrict any host capabilities when REMOTE is active. The degree of control executed by the host may vary from factory to factory. In some cases, the operator maybe required to interact during remotely controlled processes. This interaction may involve set-up operations, operator assist situations, and others. This state is intended to be flexible enough to accommodate these different situations.

To support the different factory automation policies and procedures, it shall be possible to configure the equipment to restrict the operator in specific non-emergency procedures. These restrictions shall be configurable so that the equipment may be set up to allow the operator to perform necessary functions without contention with the host. The categories for configuration shall include (but are not limited to):

— change equipment constants (process-related),

— change equipment constants (non-process-related),

— initiate process program download,

— select process program,

— start process program,

— pause/resume process program,

— operator assist,

— material movement to/from equipment,

— equipment-specific commands (on a command-by-command basis if needed).

NOTE 3: Capabilities mentioned above which are not implemented on a specific equipment may be ignored in this context.

No capabilities that are available to the operator when the LOCAL state is active should be unconditionally restricted when the REMOTE state is active. The supplier may provide for configurable restriction of operator capabilities not included in the list above if desired. No configurability is necessary for any operator functions not available to the host.

The control functions must be shared to some degree between the host and the local operator. At the very least, the operator must have the capability to change the CONTROL state, actuate an Emergency Stop, and interrupt processing (e.g., STOP, ABORT, or PAUSE). All of these capabilities except Emergency Stop may be access-limited.[13]

The host software should be designed to be compatible with the capabilities allotted to the operator.

13 Definition of the method of limiting operator access (password, key, etc.) to a capability is not within the scope of this document.

Table 3.3 CONTROL State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comments*
1	(Undefined)	Entry into CONTROL state (system initialization).	CONTROL (Substate conditional on configuration).	None	Equipment may be configured to default to ON-LINE or OFF-LINE . (See NOTE 1.)
2	(Undefined)	Entry into OFF-LINE state.	OFF-LINE (Substate conditional on configuration.)	None	Equipment may be configured to default to any substate of OFF-LINE.
3	EQUIPMENT OFF-LINE	Operator actuates ON-LINE switch.	ATTEMPT ON-LINE	None	Note that an S1,F1 is sent whenever ATTEMPT ON-LINE is activated.
4	ATTEMPT ON-LINE	S1,F0.	New state conditional on configuration.	None	This may be due to a communication failure (See NOTE 2), reply timeout, or receipt of S1,F0. Configuration may be set to EQUIPMENT OFF-LINE or HOST OFF-LINE.
5	ATTEMPT ON-LINE	Equipment receives expected S1,F2 message from the host.	ON-LINE	None	Host is notified of transition to ON-LINE at transition 7.
6	ON-LINE	Operator actuates OFF-LINE switch.	EQUIPMENT OFF-LINE	None	"Equipment OFF-LINE" event occurs. (See NOTE 3.) Event reply will be discarded while OFF-LINE is active.
7	(Undefined)	Entry to ON-LINE state.	ON-LINE (Substate conditional on REMOTE/LOCAL switch setting.)	None	"Control State LOCAL" or "Control State REMOTE" event occurs. Event reported based on actual ON-LINE substate activated.
8	LOCAL	Operator sets front panel switch to REMOTE.	REMOTE	None	"Control State REMOTE" event occurs.
9	REMOTE	Operator sets front panel switch to LOCAL.	LOCAL	None	"Control State LOCAL" event occurs.
10	ON-LINE	Equipment accepts "Set OFF-LINE" message from host (S1,F15).	HOST OFF-LINE	None	"Equipment OFF-LINE" event occurs.
11	HOST OFF-LINE	Equipment accepts host request to go ON-LINE (S1,F17).	ON-LINE	None	Host is notified to transition to ON-LINE at transition 7.
12	HOST OFF-LINE	Operator actuates OFF-LINE switch.	EQUIPMENT OFF-LINE	None	"Equipment OFF-LINE" event occurs.

NOTE 1: The configuration mentioned for transitions 1 and 2 should be a single setting. This would provide the user with a choice of entering the EQUIPMENT OFF-LINE, ATTEMPT ON-LINE, HOST OFF-LINE, or ON-LINE states.

NOTE 2: Communication failures are protocol specific. Refer to the appropriate protocol standard (e.g., SEMI E4 or SEMI E37) for a protocol-specific definition of communication failure.

NOTE 3: Any host initiated transaction open at the equipment must be completed. This may happen either by sending the appropriate reply to the host prior to sending the event message or by sending an Sx,F0 message following the event message (i.e., after the transaction).

3.4 *Equipment Processing States* — The behavior of the equipment in the performance of its intended function must be documented. This processing state model is highly dependent on the equipment process, technology, and style. However, there are expected to be common aspects to these models.

The Processing State Diagram, Figure 3.4, is provided as an example of an implementation model. This model demonstrates the expected nature of the processing state model documentation. There is no requirement that these specific states be implemented.

The equipment must generate collection events for each processing state transition, as well as provide status variables (ProcessState, PreviousProcessState) whose values are the current processing state and the previous processing state.

In referring to the Processing State Diagram, note that the initialization state INIT is not an actual processing state. It is shown here simply to indicate that the IDLE processing state is entered upon completion of equipment system initialization. On the following pages detailed descriptions are provided for the equipment processing states and state transitions (numbered) as shown in the diagram.

3.4.1 *Description of Equipment Processing States*

IDLE

In this state the equipment is awaiting instructions.

PROCESSING ACTIVE

This state is the parent of all substates where the context of process program execution exists.

PROCESS

This state is the parent of those substates that refer to the active preparation and execution of a process program.

SETUP

In this state all external conditions necessary for process execution are satisfied, such as ensuring material is present at the equipment, input/output ports are in the proper state, parameters such as temperature and pressure values are within limits, etc. If all setup operations are already complete, then this becomes a fall through state and a transition to the next state takes place.

READY

In this state the equipment is ready for process execution and is awaiting a START command from the operator or the host.

EXECUTING

Executing is the state in which the equipment is executing a process program automatically and can continue to do so without external intervention.

PAUSE

In this state processing is suspended and the equipment is awaiting a command.

Each state transition is defined in the following table. Note that all transitions in this table should be considered collection events.

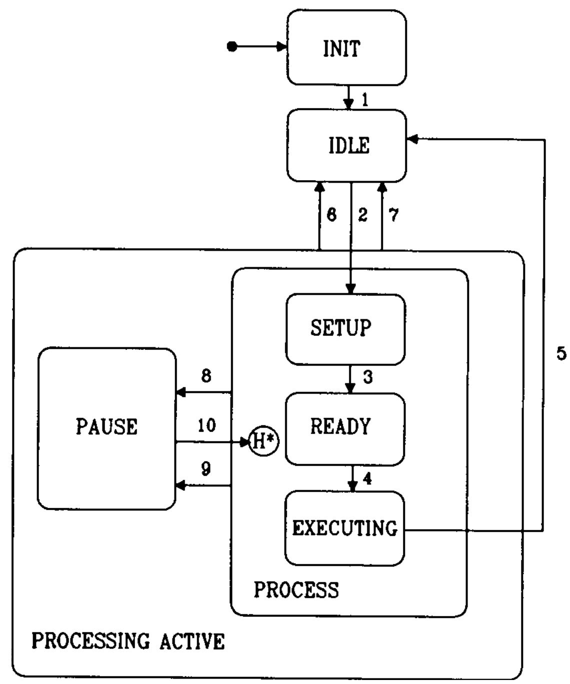


Figure 3.4
Processing State Diagram

Table 3.4 Processing State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comments*
1	INIT	Equipment initialization complete.	IDLE	None	None
2	IDLE	Commit has been made to set up.	SETUP	None	None
3	SETUP	All setup activity has completed and the equipment is ready to receive a START command.	READY	This activity is equipment-specific.	None
4	READY	Equipment has received a START command from the host or operator console.	EXECUTING	This activity is equipment-specific.	None
5	EXECUTING	The processing task has been completed.	IDLE	None	None
6	PROCESSING ACTIVE	Equipment has received a STOP command from host or operator console.	IDLE	None	None
7	PROCESSING ACTIVE	Equipment has received an ABORT command from host or operator console.	IDLE	This activity is equipment-specific.	None
8	PROCESS	The equipment decides to PAUSE due to a condition such as alarm.	PAUSE	This activity is equipment-specific.	For this type of problem, an operator assist is usually required.
9	PROCESS	Equipment has received a PAUSE command from host or operator console.	PAUSE	This activity is equipment-specific.	None
10	PAUSE	Equipment has received a RESUME command from host or operator console.	Previous PROCESS substate	This activity is equipment-specific.	None

4 Equipment Capabilities and Scenarios

This section describes the details of the capabilities required by GEM and provides scenarios for their use. Capabilities are operations performed by semiconductor manufacturing equipment. These operations are initiated through the communications interface using SECS-II messages. A scenario is a group of SECS-II messages arranged in a sequence to perform a capability. Other information may be included with the scenario for clarity. For each capability, the reader is provided with a statement of purpose, pertinent definitions, a detailed description, requirements, and scenarios.

The following capabilities are discussed:

Establish Communications

Event Notification

Dynamic Event Report Configuration

Variable Data Collection

Trace Data Collection

Limits Monitoring

Status Data Collection

On-line Identification

Alarm Management

Remote Control

Equipment Constants

Process Program Management

Material Movement

Equipment Terminal Services

Error Messages

Clock

Spooling

Control

4.1 *Establish Communications* — The Establish Communications capability provides a means of formally establishing communications following system initialization or any loss of communications between communicating partners, and thus of notifying the communication partner that a period of non-communication has occurred.

4.1.1 *Purpose* — Communications between host and equipment are formally established through use of the Establish Communications Request/Establish Communications Acknowledge transaction.

The use of S1,F1/F2 for this purpose is ambiguous since the transaction can be used for other purposes and may occur at any time.

The S1,F13/F14 transaction, used in conjunction with the Communications State Model, provides a means for equipment to notify the host, or the host to notify the equipment, that there has been a period of inability to communicate. The successful completion of this transaction also signals a possible need for synchronization activities between host and equipment.

4.1.2 *Definitions*

COMMACK — Acknowledge code returned in the Establish Communications Acknowledge message. See the SEMI E5 Standard for a full definition of this data item.

EstablishCommunicationsTimeout — An equipment constant used to initialize the interval between attempts to re-send an Establish Communications Request. This value specifies the number of seconds for the interval. See the SEMI E5 Standard for a full definition of this variable data item.

4.1.3 *Description* — There are potential problems when one side of the communications link fails and the other side does not detect it. From the point of view of the host, a loss of communications has many possible causes. In some cases, host-controlled settings on the equipment may need to be reset. In other cases, the equipment may have continued an automatic processing sequence during the period of no communication and may have changed states. The definition of a formal protocol for establishing communications alerts the host to the need to synchronize itself with the equipment's current status.

Equipment shall consider communications as formally established whenever either of the following conditions have been satisfied:[14]

— Communications Request has been sent to the host and an Establish Communications Acknowledge has been received within the transaction timeout period and with an acknowledge code of Accept, or

— Communications Request has been received from the host, and an Establish Communications Acknowledge response has been successfully sent with an acknowledge code of Accept.

When the equipment sends an Establish Communications Request to the host, this notifies the host of the possible need to synchronize itself with the equipment.

When the equipment is attempting to establish communications, an Establish Communications Request shall be sent periodically until communications have been formally established as described above. The interval between attempts must be user-configurable and begins as soon as a connection transaction failure is detected (see Section 3.2).

Attempting to establish communications is not a low-level connectivity issue, but rather a logical application issue used by either party to notify its partner that the host may need to perform synchronization activities with the equipment.

4.1.4 *Requirements*

— Equipment must support the Communication State Model (see Section 3.2).

— Equipment must provide the EstablishCommunicationsTimeout equipment constant described above.

14 Satisfaction of either of these conditions will result in a transition to the COMMUNICATING substrate. See Section 3.2 for further detail.

4.1.5 *Scenarios*

4.1.5.1 *Host Attempts to Establish Communications*

```
COMMENT                        HOST    EQUIPMENT                         COMMENT

                                                  Communications state is Enabled
                                                  (any substate)
Establish Communications  S1,F13-->
Request
                                 <--S1,F14        Reply COMMACK = Accept and
                                                  Communications state =
                                                  COMMUNICATING
```

4.1.5.2 *Equipment Attempts to Establish Communications and Host Acknowledges*

```
COMMENT                          HOST    EQUIPMENT                         COMMENT

                    Communications State = NOT COMMUNICATING
                                                  [LOOP]
                                                  [LOOP]--SEND
                                 <--S1,F13        Establish Communications Request
Establish Communications  S1,F14-->
Acknowledge                                       [IF] S1,F14 rcvd w/o timeouts
                                                  [THEN] exit_loop--SEND
                                                  [ELSE] Delay for interval in
                                                         Establish Commuications-
                                                         Timeout
                                                  [ENDIF]
                                                  [END_LOOP]--SEND
                                                  [IF] COMMACK = Accept
                                                  [THEN] Communications state=
                                                         Communicating
                                                         exit_loop--
                                                  [ELSE] Reset timer for delay,
                                                         and delay for interval
                                                         specified in
                                                         EstablishCommunications—
                                                         Timeout
                                                  [ENDIF]
                                                  [END_LOOP]
```

4.1.5.3 *Simultaneous Attempts to Establish Communications* — For equipment that supports interleaving, it is possible that either the host or equipment could send an Establish Communications Request before receiving the request from its partner. As communications are established by the successful acceptance of any one Establish Communications Request, it is immaterial who sends the request first. The roles of host and equipment may be reversed.

Equipment Receives S1,F14 From Host Before Sending S1,F14:

COMMENT	**HOST**	**EQUIPMENT**	**COMMENT**
Communications State = NOT COMMUNICATING			
		<--S1,F13	Establish Communications Request
Establish Communications Request	S1,F13-->		
Reply COMMACK = Accept	S1,F14-->		S1,F14 received from Host and Communications established[15] and Communications state = COMMUNICATING
		<--S1,F14	Reply COMMACK = Accept[16]

Equipment Sends S1,F14 To Host Before Receiving S1,F14:

COMMENT	**HOST**	**EQUIPMENT**	**COMMENT**
Communications State = NOT COMMUNICATING			
		<--S1,F13	Establish Communications Request
Establish Communications Request	S1,F13-->		
		<--S1,F14	Reply COMMACK = Accept[15] Communications established[15] and Communications state = COMMUNICATING
Reply COMMACK = Accept	S1,F14-->		S1,F14 received from Host

4.2 *Data Collection* — Data collection allows the host to monitor equipment activity via event reporting, trace data reporting, limits monitoring, and query of selected status or other variable data.

4.2.1 *Event Data Collection* — Event data collection provides a dynamic and flexible method for the user to tailor the equipment to meet individual needs with respect to data representation and presentation to the host. The event-based approach to data collection provides automatic notification to the host of equipment activities and is useful in monitoring the equipment and in maintaining synchronization with the equipment.

Event data collection may be broken into two logical parts: host notification when an event occurs and dynamic configuration of the data attached to the event notification.

4.2.1.1 *Event Notification* — This section describes the method of notifying the host when equipment collection events occur.

4.2.1.1.1 *Purpose* — This capability provides data to the host at specified points in equipment operation. This asynchronous reporting eliminates the need for the host to poll the equipment for this information. Events on the equipment may trigger activity on the part of the host. Also, knowledge of the occurrence of events related to

15 Communications are establisted at the successful completion of the S1,F13/14 transaction where COMMACK is set to zero.

16 Communications are established on the successful transmission of S1,F14, even if there is an open S1,F13.

the equipment state models allows the host to track the equipment state. An equipment's behavior is related to its current state. Thus, this capability helps the host understand how an equipment will behave and how it will react to host behavior.

4.2.1.1.2 *Definitions*

Collection Event — An event (or grouping of related events) on the equipment that is considered significant to the host.

Collection Event ID (CEID) — A unique identifier of a collection event. See the SEMI E5 Standard for a full definition of this data item.

Event — A detectable occurrence significant to the equipment.

Report — A set of variables predefined by the equipment or defined by the host via S2,F33/F34.

4.2.1.1.3 *Detailed Description* — The equipment supplier must provide a set of predefined collection events. Specific collection events are required by individual capabilities and state models. Examples of collection events include:

— The completion of each action initiated by a host requested command,

— Selected processing and material handling activities,

— Operator action detected by the equipment,

— A state transition,

— The setting or clearing of an alarm condition on the equipment, and

— Exception conditions not considered alarms.

See Section 6 for a list of required collection events.

The reporting of a collection event may be disabled per event by the user to eliminate unwanted messages. An event report message shall be sent to the host upon the occurrence of a particular collection event if the collection event (CEID) has been enabled. Attached to each event message is one or more event reports which contain variable data. Section 4.2.1.2 describes the capability which allows for the dynamic customization of event reports. The values of any data contained in an event report message must be current upon the occurrence of the event. This implies that event reports be built at the time of the event occurrence.

The equipment shall also provide the S6,F15/F16 transaction to allow the host to request the data from a specific event report.

4.2.1.1.4 *Requirements*

— The equipment supplier shall provide documentation of all collection events defined on the equipment and the conditions for each event to occur.

— The equipment supplier shall provide unique CEIDs for each of the various collection events that are available for reporting.

— The equipment supplier shall provide a method for enabling and disabling the reporting of each event. This method shall either be available via the host interface (see Section 4.2.1.2) or the equipment's operator console.

— For each event, the equipment supplier shall provide either

- a default set of report(s) linked to the event which contain data pertinent to that event, or
- the ability for the user to configure the data linked to that event via the equipment's operator console or host interface (see Section 4.2.1.2).

4.2.1.1.5 *Scenarios*

Collection Event Occurs on the Equipment:

```
COMMENT                            HOST    EQUIPMENT                        COMMENT

                                                    [IF] Event Report is Multi-block
                                           <--S6,F5    [THEN] send Multi-block inquire
Multi-block grant                 S6,F6-->
                                                    [ENDIF]
                                           <--S6,F11   Equipment sends Event Report
Host acknowledges Event Report S6,F12-->
```

Host Requests Event Report:

```
COMMENT                           HOST    EQUIPMENT                          COMMENTS

Host requests an event report S6,F15-->
                                         <--S6,F16    Equipment sends event report.
```

4.2.1.2 *Dynamic Event Report Configuration* — This section describes a capability which allows the host to dynamically modify the equipment event reporting setup.

4.2.1.2.1 *Purpose* — This capability is defined to provide the data reporting flexibility required in some manufacturing environments. It allows the host to increase or decrease the data flow according to need. For example, if the performance of an equipment degrades, the data flow from that equipment may be increased to help diagnose the problem.

4.2.1.2.2 *Definitions*

EventsEnabled — A variable data item that consists of a list of currently enabled collection events (CEIDs). See SEMI E5 for a full definition of this variable data item.

Report ID (RPTID) — A unique identifier of a specific report. See SEMI E5 for a full definition of this data item.

Variable Data (V) — A data item containing status (SV), data (DVVAL), or constant (ECV) values. See SEMI E5 for a full definition of this data item.

Variable Data ID (VID) — A unique identifier of a variable data item. The set of VID's is the union of all SVID's, ECID's, and ID's for DVVAL's (DVNAME's). See SEMI E5 for a full definition of this data item.

4.2.1.2.3 *Detailed Description* — The equipment shall support the following event report configuration functionality through the SECS-II interface:

— Host definition/deletion of custom reports,

— Host linking/unlinking of defined reports to specified collection events, and

— Host enabling/disabling the reporting of specified collection events.

NOTE 4: The equipment may also supply alternative means for defining reports and linking reports to events (e.g., via the operator console). Implementation of alternate means is not required.

The equipment can be instructed by the host to enable or disable reporting of collection events on an individual or collective basis. A status value (SV) shall be available that consists of a list of enabled collection events. (See Section 5.2, Variable Item List, EventsEnabled variable.)

Reports may be attached to an event report message (S6,F11). These reports are specifically linked to the desired event and typically contain variable data relating to that event. The reports may be provided by the equipment supplier or created by the user. The user must be able to create reports and link them to events via the SECS-II interface.

The data reported in the event report messages may consist of Status Values (SV's), Equipment Constant Values (ECV's), or Data Values (DVVAL's). Note that data values shall be valid and current on certain events and certain states and might not be current at other times. The implementor shall document when a data value will be current and available for reporting.

4.2.1.2.4 *Requirements*

— The equipment manufacturer must provide documentation of all variable data available from the equipment. This is to include variable name, variable type or class (SV, ECV, DVVAL), units, format codes, possible range of values, and a description of the meaning and use of this variable.

— The equipment manufacturer must provide unique VIDs for the various variable data (V) available for data collection in the equipment. For example, this means that no SV shall have a VID which is the same as the VID of any ECV or DVVAL.

— All variable data must be available for report definition and event data collection. See Section 5.2, Variable Item List, for a list of required variable data.

— All report definitions, report-to-event links, and enable/disable status of event reports must be retained in non-volatile storage.

4.2.1.2.5 *Scenario*

Collection Event Reporting Set-up:

```
COMMENT                                 HOST   EQUIPMENT                        COMMENT

[IF] Define Report is Multi-block
[THEN] send Multi-block inquire S2,F39-->
                                        <-- S2,F40   Multi-block grant.
[ENDIF]
Send report definitions S2,F33-->                    DATAIDs, RPTIDs, and VIDs
                                                     received.
                                        <-- S2,F34   DRACK[17] = 0 the reports are OK
[IF] Link Event/Report is Multi-block
[THEN] send Multi-block inquire S2,F39-->
                                        <-- S2,F40   Multi-block grant.
[ENDIF]
Link reports to events S2,F35-->                     CEIDs and the corresponding
                                                     RPTIDs are received.
                                        <-- S2,F36   LRACK = 0 the event linkages
                                                     are acceptable.
Enable specific collection S2,F37-->                 Enable/ disable codes (CEEDs)
events                                               and the respective event
                                                     reporting CEIDs received.
                                        <-- S2,F38   ERACK = 0 OK, will generate the
                                                     specified reports when the
                                                     appropriate collection events
                                                     happen
```

4.2.2 *Variable Data Collection*

4.2.2.1 *Purpose* — This capability allows the host to query for the equipment data variables and is useful during initialization and synchronization.

4.2.2.2 *Definitions*

Report ID (RPTID) — A unique identifier of a specific report. See SEMI E5 for a full definition of this data item.

Variable Data (V) — A variable data item containing status, discrete, or constant data. See SEMI E5 for a full definition of this data item.

4.2.2.3 *Detailed Description* — The host may request a report containing data variables from the equipment by specifying the RPTID. It is assumed that the report has been previously defined (e.g., using the Define Report S2,F33 transaction (see Section 4.2.1)). The values of any status variables (SV's) and equipment constants (ECV's) contained within the report must be current. Discrete data values (DVVAL's) are only guaranteed to be valid upon the occurrence of a specific collection event. If DVVAL cannot be specified in equipment due to some restrictions depend on hardware and/or software conditions, the zero length item is reported.

4.2.2.4 *Requirements*

— Variable data items (V's) and associated units of measure must be provided by the equipment manufacturer.

17 Define Report Acknowledge Code, see SEMI E5 for full definition of this Data Item.

4.2.2.5 *Scenario*

Host Requests Report:

```
COMMENT                            HOST   EQUIPMENT                          COMMENT

Host requests data variables
contained in report RPTID     S6,F19-->
                                       <--S6,F20     Equipment responds with a list of
                                                     variable data for the given
                                                     RPTID.
```

4.2.3 *Trace Data Collection*

4.2.3.1 *Purpose* — Trace data collection provides a method of sampling data on a periodic basis. The time-based approach to data collection is useful in tracking trends or repeated applications within a time window, or monitoring of continuous data.

4.2.3.2 *Definitions*

Data Sample Period (DSPER) — The time delay between samples. See SEMI E5 for a full definition of this data item.

Reporting Group Size (REPGSZ) — The number of samples included per trace report transmitted to the host. See SEMI E5 for a full definition of this data item.

Status Variable (SV) — Status data item (included in trace report). See SEMI E5 for a full definition of this data item.

Status Variable ID (SVID) — A unique identifier of a status variable. See SEMI E5 for a full definition of this data item.

Total Samples (TOTSMP) — Number of samples to be taken during a complete trace period. See SEMI E5 for a full definition of this data item.

Trace Request ID (TRID) — An identifier associated with a trace request definition. See SEMI E5 for a full definition of this data item.

4.2.3.3 *Detailed Description* — The equipment shall establish a trace report as instructed by the host (S2,F23). For a trace report (S6,F1), the host shall designate a name for the trace report (TRID), a time interval for data sampling (DSPER), the total number of samples to be taken (TOTSMP), the number of samples per trace report (REPGSZ), and a listing of which data will be sent with the report (SVID's). The number of trace reports sent to the host is determined by total samples divided by reporting group size (TOTSMP/REPGSZ).

The equipment shall sample the specified data (SV's) at the interval designated by the host (DSPER) and shall send a predefined trace report to the host for the specified reporting group size (REPGSZ). The trace report definition shall be automatically deleted from the equipment after the last trace report has been sent.

The host may modify or re-initiate a trace function currently in progress by specifying the same TRID in a trace request definition, at which point the old trace shall be terminated and the new trace shall be initiated, or the host can instruct the equipment to terminate a trace report prior to its completion by specifying TOTSMP = 0 for that TRID, at which point the trace report definition shall be deleted.

A detailed example is included as Application Note A.4.

4.2.3.4 *Requirements*

— The equipment must have a local mechanism (e.g., internal clock) for triggering the periodic sampling and transmission of trace reports to the host.

— A minimum of four (4) concurrent traces shall be supported by the equipment. The same SVID may be collected in multiple traces simultaneously.

— All SVID's available at the equipment shall be supported for trace data collection. The exception to this is any SV that will not fit into a single block.

NOTE 5: SEMI E5 provides for SV's to be of a list format. Since this may in practice be a variable list, there is a potential problem with such an SV supported by the Trace Data Collection capability. This is a problem with the SEMI E5 standard. Care should be exercised in the use of SV's using the list format.

4.2.3.5 *Scenario*

Host Initiates Trace Report:

```
COMMENT                            HOST  EQUIPMENT                      COMMENT

Trace Data initialization
requested                     S2,F23-->
                                      <--S2,F24     Acknowledge, trace initiated
                                                    [DO] TOTSMP REPGSZ times
                                                    [DO] REPGSZ many times: collect
                                                    SVID1,...SVIDn data, delay
                                                    time by DSPER.
                                                    [END_DO]
                                      <--S6,F1      Send SV1,...SVn
Acknowledge receipt            S6,F2-->
                                                    [END_DO]
Optional:
Request trace termination prior to
completion (TOTSMP = 0)       S2,F23-->
                                      <--S2,F24     Acknowledge premature termination
```

4.2.4 *Limits Monitoring* — This capability relates to the monitoring of selected equipment variables and has three primary aspects:

— Defines a standard set of monitoring zones and limits.

— Provides for reporting to the host when selected equipment variables transition between monitoring zones.

— Empowers the host to modify the values of the variable limit attributes for these same selected equipment variables.

4.2.4.1 *Purpose* — The limits monitoring capability provides the host a means of monitoring equipment conditions by a flexible, efficient, and asynchronous method which is consistent across equipment. It eliminates the need for constant polling of equipment by the host for current status values. Further, this capability allows the host to implement changes in the monitoring range as needed. This capability has application to both production operation and diagnostic/testing scenarios, and it also has applicability to statistical process control.

4.2.4.2 *Definitions*

LimitVariable — DVVAL containing the VID of a specific equipment variable for which a zone transition collection event has been generated.

EventLimit — DVVAL containing the LIMITID of the limit crossed by LimitVariable.

TransitionType — DVVAL which defines the direction of the zone transition which has occurred: 0 = transition from lower to upper zone, 1 = transition from upper to lower zone.

Limit — Used in this section to represent the set of variable limit attributes that completely describe a variable monitoring "barrier." The attributes include VID, Units, UPPERDB, LOWERDB, LIMITMAX, and LIMITMIN. In some contexts it may be interpreted more narrowly as the combination of UPPERDB and LOWERDB.

$LIMITID_n$ — Refers to the identifier of a specific limit (as defined by UPPERDB and LOWERDB) among the set of limits for a monitored equipment variable. LIMITIDs are consecutively numbered, beginning at one through the number of limits possible (seven minimum).

Monitoring Zone — A subset of the possible range of values for a variable of interest to the host. A single limit divides the range into two zones. Multiple limits may be combined to divide the range even further.

Zone Transition — The movement of a variable value from one monitoring zone to another. This transition is a collection event and has a corresponding CEID.

Deadband — An overlap of two zones implemented to prevent constant zone transitions by a variable sitting on or near a limit (i.e., "chattering").

UPPERDB — A variable limit attribute that defines the upper boundary of the deadband of a limit.[18] The value applies to a single limit (LIMITID) for a specified VID.

18 The format and units must be the same as the format of the variable being monitored.

Thus, UPPERDB and LOWERDB as a pair define a limit.

LOWERDB — A variable limit attribute that defines the lower boundary of the deadband of a limit.[18] The value applies to a single limit (LIMITID) for a specified VID. Thus, UPPERDB and LOWERDB as a pair define a limit.

UPPER ZONE — The range of values lying above a limit.

LOWERZONE — The range of values lying below a limit.

LIMITMAX — The maximum value for any limits of a specific equipment variable. This value is set by the equipment manufacturer and typically coincides with the maximum value allowed for the monitored variable.

LIMITMIN — The minimum value for any limits of a specific equipment variable.[19] This value is set by the equipment manufacturer and typically coincides with the minimum value allowed for the monitored variable.

Undefined — When used in reference to variable limits, it indicates that monitoring/reporting of zone transitions involving that particular limit are disabled.

4.2.4.3 *Description* — The limits monitoring capability provides the host with a minimum of seven configurable limits or barriers that may be applied to selected equipment status variables (SV's) of the types floating point, integer, and boolean. When one of these barriers is crossed, a collection event is generated to alert the host to a change in monitoring zone or state of the monitored variable. These seven limits may be combined in a variety of ways to match the needs of the host system.[19] An illustration of a combination of five of the limits to provide one type of variable monitoring is shown in Figure 4.2.1.[20] This section describes the key aspects of limits monitoring. Detailed implementation examples of limits monitoring are provided as Application Note A.7.

NOTE 6: While the SEMI E5 standard allows SV's to be lists, such variable lists are not allowed under this capability.

4.2.4.3.1 *Monitoring Limit Characteristics* — A limit is defined by a set of attributes that include the variable (VID) to which the limit corresponds, the units of that variable, the maximum and minimum possible values of the limit (LIMITMAX and LIMITMIN) and the specific borders of the limit (UPPERDB and LOWERDB). See Figure 4.2.2. There is a limitation to the values of UPPERDB and LOWERDB which may be stated as:

LIMITMAX≥UPPERDB≥LOWERDB≥LIMITMIN

A limit divides the possible range of variable values into two parts, the upper zone and the lower zone. At any time, the monitored variable is considered to be in one and only one of these zones. However, as Figure 4.2.2 shows, these two zones have an area of overlap. This is called the deadband.

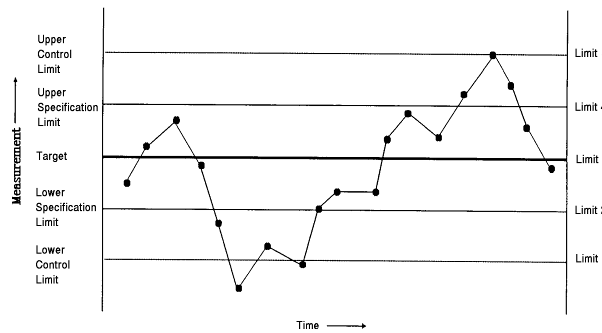


Figure 4.2.1
Limit Combination Illustration: Control Application

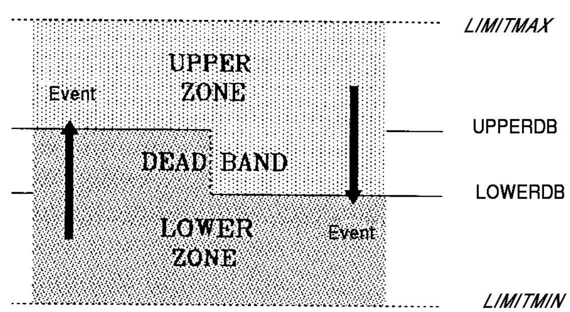


Figure 4.2.2
Elements of One Limit

The deadband is a key concept of limits monitoring, especially for floating point variables. Its purpose is to prevent a phenomenon known as chattering — the repeated changing of zones due to small, rapid fluctuations in variable value while near the zone boundary. In practice, the value of a variable must reach the opposite boundary of the deadband before a zone transition can occur. Thus, if a variable's value reaches the UPPERDB and transitions into the upper zone, it will not return to the lower zone until it falls back to the

19 Note that while at least seven limits per variable are available from the equipment, the host need not use all seven.

20 This illustration shows the reading which might be available to the equipment, not the limit excursions reported to the host. Reporting is covered later in the section.

LOWERDB. The difference between UPPERDB and LOWERDB should always be greater than the typical amplitude of those fluctuations deemed to be insignificant. In some cases, the width of the deadband may set to zero (i.e., UPPERDB = LOWERDB). At first glance, this would seem to make indeterminate the current zone when an integer value sits on the limit. This is not the case, however, when movement of the value is considered. To illustrate, an example is given, assuming that UPPERDB = LOWERDB = 100. The list shows consecutive readings of the variable and the resultant zone:

99 Lower Zone (Initial Reading)

101 Upper Zone (Zone Transition)

100 Lower Zone (Zone Transition)

100 Lower Zone

99 Lower Zone

100 Upper Zone (Zone Transition)

Transition from one zone into another generates a collection event, as might be reported via S6,F11. The host has the option of receiving notification by enabling event reporting for the event. For each variable that has monitoring capability, one CEID is reserved to indicate zone transitions for that variable. To aid in the determination of the nature of a transition event, three DVVAL's have been defined:

LimitVariable — The VID of the monitored variable to which the collection event refers.

EventLimit — Contains the LIMITID of the limit reached or crossed by LimitVariable.

TransitionType — Defines the direction of the zone transition which has occurred: 0 = transition from lower to upper zone, 1 = transition from upper to lower zone.

Sampling frequency is an important element of limits monitoring and should be considered during equipment specification. If changes in variable value are relatively fast compared to sampling frequency, it is possible for some zone transitions to be missed or for multiple zone transitions to occur between readings. Since it is possible for zone transitions to occur "simultaneously" or for limits to be identically defined, the DVVAL EventLimit has been defined to allow for a list of multiple zone transitions of a variable to be reported with a single collection event.

It also should be emphasized that a single CEID is used to report transitions in both directions across a limit. Thus, reporting for one direction but not the other cannot be configured.

The functionality of each limit for each variable can be described with the state model shown in Figure 4.2.3. Below, the three states are described more fully, followed by a table defining the transitions.

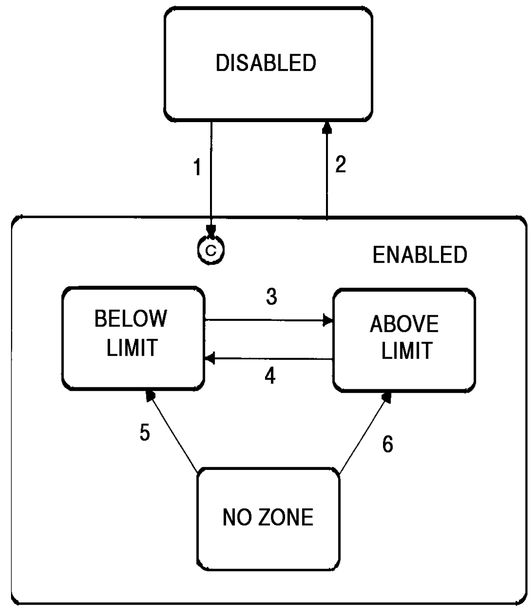


Figure 4.2.3
Limit State Model

ABOVE LIMIT

A variable is considered to be above a limit when its value increases to equal or exceed the upper boundary of the deadband, UPPERDB. The significance attached to this state is a function of the host's usage.

BELOW LIMIT

A variable is considered to be below a limit when its value decreases to equal or fall below the lower boundary of the deadband, LOWERDB. The significance attached to this state is a function of the host's usage.

NO ZONE

In some circumstances it is possible for the variable value to be in neither the upper zone nor the lower zone. This may occur upon definition of a new limit or upon equipment startup when the value of the variable lies in the deadband. In this case, the active state of the limit is considered to be NO ZONE. The limit shall remain in this state until the variable value reaches either boundary of the deadband.

4.2.4.3.2 *Modification of Limit Values* — Values for the monitoring limits on any monitored variable may be modified by the host using the message transaction

S2,F45/F46 (Define Variable Limit Attributes). The equipment must reject any S2,F45 message which contains limit information which conflicts with the following rules:

— LIMITMAX≥UPPERDB≥LOWERDB≥LIMITMIN;

— If either UPPERDB or LOWERDB is defined, both must be defined; if either UPPERDB or LOWERDB is undefined, both must be undefined.

The first rule is defined and graphically depicted in Figure 4.2.2. The second rule refers to the host's ability to turn any limit "on" or "off". While a minimum of seven limits must be available for each monitored variable, it will be common for the host application to require less than seven or even none of the limits be used. The limits not needed can be disabled by leaving the values for UPPERDB and LOWERDB "undefined". Limits may be disabled for a VID or for all monitored VIDs by using zero length lists in the S2,F45 message.

All monitored variables must be one of three types: integer, floating point, or Boolean. This may be accomplished by using the following formats: 11, 20, 3(), 4(), 5().

NOTE 7: The binary format is not allowed. If the ASCII format is used, the equipment shall perform a conversion into one of the numeric types before performing any value comparisons, both for limit validations and zone transitions.

4.2.4.3.3 *Limit Values Request* — The host may request the current limit values for a specified VID using the message transaction S2,F47/F48 (Variable Limit Attribute Request).

4.2.4.4 *Requirements*

— A minimum of seven limits per monitored variable must be available.

— One CEID per monitored variable must be supplied for zone transition reporting.

— All limit definitions must be kept in non-volatile storage.

— The equipment must enforce the limit validation rules defined above.

— The specification and documentation of which variables may be monitored with this capability is the responsibility of the equipment manufacturer based on the specific instance of equipment. This subject also may be addressed by equipment models of classes of semiconductor equipment.

Table 4.2 Limit State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	DISABLED	Limit attributed defined w/ S2,F45.	ENABLED	None	The substate of ENABLED is determined by the current value of the monitored variable.
2	ENABLED	Limit attributes set to undefined w/ S2,F45.	DISABLED	None	None
3	BELOW LIMIT	Variable Increased to be ≥UPPERDB	ABOVE LIMIT	None	Zone Transition.
4	ABOVE LIMIT	Variable decreases to be ≤LOWERDB	BELOW LIMIT	None	Zone Transition.
5	NO ZONE	Variable decreases to be ≤LOWERDB	BELOW LIMIT	None	Zone Transition.
6	NO ZONE	Variable increases to be ≥UPPERDB	ABOVE LIMIT	None	Zone Transition.

4.2.4.5 *Scenarios* — Zone Transition Event occurs in equipment:

```
COMMENTS                          HOST   EQUIPMENT                          COMMENTS

Send enabled event report to host as shown in Section 4.2.1.
```

Host defines Limit Attributes:

```
COMMENTS                          HOST   EQUIPMENT                          COMMENTS

[IF] S2,F45 is Multi-block
[THEN] Send Multi-block inquire S2,F39-->
                                        <--S2,F40    Multi-block grant.
[END IF]
Host defines new variable limit
attributes.                     S2,F45-->
                                        <--S2,F46    Equipment acknowledges host
                                                     request.
```

Host queries equipment for current Limits:

```
COMMENTS                          HOST   EQUIPMENT                          COMMENTS

Host queries equipment          S2,F47-->
for current variable limit
attribute definitions.
                                        <--S2,F48    Equipment returns report
                                                     containing requested variable
                                                     limit attribute values.
```

4.2.5 Status Data Collection

4.2.5.1 *Purpose* — This capability allows the host to query the equipment for selected status information and is useful in synchronizing with equipment status.

4.2.5.2 *Definitions*

Status variable value (SV) — A data item containing the value of a status variable. See SEMI E5 for a full definition of this data item.

Status variable ID (SVID) — A unique identifier of a status variable. See SEMI E5 for a full definition of this data item.

4.2.5.3 *Detailed Description* — The host may query equipment status by specifying the desired SVID's. Upon such a request, the equipment sends the host the value of the selected status variables. The host also may request the description (name and units) of any or all available status variables.

4.2.5.4 *Requirements*

— The equipment manufacturer must provide unique SVID's for the various status variables (SV) available for data collection in the equipment.

— All status data is available for status data collection. See Section 5.2, Variable Item List, for a list of status variables.

— All SV's must contain valid data whenever provided to the host.

4.2.5.5 *Scenario*

Request Equipment Status Report:

COMMENT	HOST	EQUIPMENT	COMMENT
Host requests report of selected status variable values	S1,F3-->		
		<--S1,F4	Equipment responds with the requested status variable data.

Request Equipment Status Variable Name list:

COMMENT	HOST	EQUIPMENT	COMMENT
Host requests equipment to identify selected status variables.	S1,F11-->		
		<--S1,F12	Equipment responds with the requested status variable descriptions.

4.2.6 *On-line Identification*

4.2.6.1 *Purpose* — Implementation of SEMI E5 (a GEM Fundamental Requirement) requires the equipment to accept the S1,F1 from the Host at any time while it is ONLINE and COMMUNICATING, and respond with S1,F2. The On-line Identification capability describes the host-initiated scenario. The equipment-initiated scenario is used for a different purpose and is defined in sections 3.3 and 4.12 describing the GEM "Control Model".

4.2.6.2 *Definitions*

Equipment Model Type (MDLN) — ASCII string containing the equipment model. See SEMI E5 for a full definition of this data item.

Equipment Software Revision Code (SOFTREV) — ASCII string containing the equipment software revision. See SEMI E5 for a full definition of this data item.

4.2.6.3 *Detailed Description* — On-line Identification allows the host to verify the presence and identity of the equipment.

4.2.6.4 *Requirements* — (Host-Initiated) An S1,F2 response from the equipment must provide MDLN and SOFTREV information which reflects the hardware and software configuration of the equipment.

SOFTREV must uniquely identify different releases of equipment software. Any change in equipment software must result in a corresponding change to SOFTREV.

The equipment-initiated S1,F1 is not required except as described in sections 3.3 and 4.12 describing the GEM "Control Model".

4.2.6.5 *Scenario:*

Host Initiated

COMMENT	HOST	EQUIPMENT	COMMENT
Are you there?	S1,F1-->		
		<--S1,F2	Equipment replies with MDLN and SOFTREV.

4.3 *Alarm Management* — The alarm management capability provides for host notification and management of alarm conditions occurring on the equipment.

4.3.1 *Purpose* — Historically, a precise definition of an equipment alarm has been absent. Consequently, differing interpretations have resulted in inconsistent implementations. This is addressed by providing a more rigorous definition (see definition in Section 4.3.2 below) of an alarm.

In addition, it is often important for equipment to report more extensive information to the host than has been available in the S5,F1/F2 (Alarm Report Send/ Acknowledge) transaction. The data required in such cases is very dependent on equipment type, host information requirements, and alarm situation. This issue is addressed by providing event reporting methods that are tied to alarm state changes.

Lastly, the alarm management capability provides mechanisms for:

— Reporting the time of an alarm state change,

— Uploading a list of alarm texts,

— Enabling and disabling the notification of specific alarms, and

— Host query of alarms set and enabled status on the equipment.

4.3.2 *Definitions*

Alarm — An alarm is related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed. Such abnormal situations are defined by the equipment manufacturer based on physical safety limitations. Equipment activities potentially impacted by the presence of an alarm shall be inhibited.

Note that exceeding control limits associated with process tolerance does not constitute an alarm nor do normal equipment events such as the start or completion of processing.

AlarmsEnabled — Status value consisting of a list of the alarm ID's currently enabled for reporting to the host. See SEMI E5 for a full definition of this variable data item.

AlarmsSet — Status value consisting of a list of the alarm ID's currently in the ALARM SET (or unsafe) state. See SEMI E5 for a full definition of this variable data item.

ALCD — Alarm code data item used in the S5,F1 (Alarm Report Send) and S5,F6 (List Alarm Data) messages. This code is divided into two parts, the alarm set/cleared bit and the 7 bit alarm category code. Only the set/cleared bit is used—bit 8 = 1 means alarm set, = 0 means alarm cleared. The alarm category code is not used. See SEMI E5 for a full definition of this data item.

ALID — Alarm identifier. See SEMI E5 for a full definition of this data item.

ALTX — Data item contained in the S5,F1 and S5,F6 messages containing a brief textual description of an alarm. See SEMI E5 for a full definition of this data item.

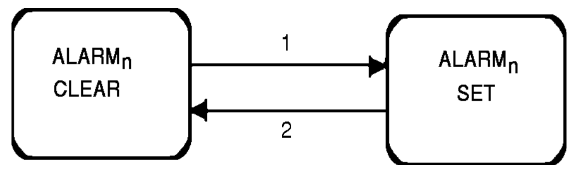


Figure 4.3
State Diagram for Alarm $ALID_n$

4.3.3 *Detailed Description* — Two alarm notification mechanisms are defined to achieve the flexibility necessary for the reporting required by host systems. First, stream 5 alarm reporting enables a brief, yet fixed, method for notification of alarm occurrences using the S5,F1/F2 transaction. Second, to address the host's potential need for more extensive and flexible data reporting, two collection events ("alarm set" and "alarm cleared") are defined for each possible alarm condition on the equipment to allow the use of event data collection mechanisms. In the latter case, reports are sent by the equipment using the Event Report/ Acknowledge transaction (see Section 4.2 on event data collection).

The $alarm_n$ detected and cleared events are derived from the state model for an alarm (see Figure 4.3 and Table 4.3.1). In this model each of n alarms can be in one of two possible states, either ALARM CLEAR or ALARM SET. The transition from the ALARM CLEAR to the ALARM SET state is defined as the collection event "$Alarm_n$ detected" (transition 1). Conversely, the transition from ALARM SET to ALARM CLEAR is defined as the collection event "$Alarm_n$ cleared" (transition 2).

NOTE 8: The alarm capability is intended as an addition to standard safety alarms (e.g., lights, horns). There is no intent to replace direct operator notification of such problems, nor is there the expectation that the host can prevent or directly address such alarms.

Table 4.3.1 Alarm State Transition Table

#	*Current*	*Trigger*	*New State*	*Action*	*Comment*
1	$ALARM_n$ CLEAR	$Alarm_n$ is detected on the equipment.	$ALARM_n$ SET	Initiate local actions (if any) to ensure safety. Update AlarmsSet and $ALCD_n$ values. Generate and issue alarm message if enabled.	Inhibited activities require operator or host intervention prior to resuming.
2	$ALARM_n$ SET	$Alarm_n$ is no longer detected on the equipment.	$ALARM_n$ CLEAR	Update AlarmsSet and $ALCD_n$ values. Generate and issue alarm message if enabled.	Inhibited activities require operator or host intervention prior to resuming.

The equipment manufacturer is responsible for identifying all alarms on their equipment by:

— Applying the above alarm definition,

— Consulting Application Note A.3 for examples of alarms for various equipment configurations,

— Noting that the presence of an alarm typically requires some action or intervention before resuming safe operation of the equipment, and by

— Referring to Table 4.3.2 below which delineates the differences between events and alarms.

Table 4.3.2

EVENT	*ALARM*
Any occurrence detectable by the equipment.	Related to only those occurrences that are abnormal, undesirable, AND endanger people, equipment, or physical material being processed.
Certain events may trigger a state transition(s).	Each alarm has an associated two-state state model: ALARM SET (or unsafe) and ALARM CLEAR (or safe).
Equipment activities are not necessarily inhibited by the occurrence of an event (unless it is associated with an alarm or intentional inhibit).	The presence of an alarm inhibits equipment activities to ensure safe operation until the alarm condition is cleared.
Certain events may occur in an expected sequence.	Alarms may occur at any time.

4.3.3.1 *Enable/Disable Alarms* — Upon request from the host, the equipment shall enable or disable reporting of certain alarms. Enabling or disabling a given alarm shall impact the communication of both the alarm set and clear messages equally (i.e., turn them both on or both off). This is not the case for enabling/disabling of the associated collection events, where the alarm-set and alarm-cleared events can be enabled and disabled separately. The current enable/disable settings must be stored in non-volatile memory. Changes to the enable/disable settings must be reflected in the AlarmsEnabled status value.

NOTE 9: The alarm itself is not being enabled or disabled, but the reporting of the alarm through SECS-II messages is being enabled or disabled.

4.3.3.2 *Send Alarm Report* — Upon detecting a change in the status of a given alarm, an associated alarm state model shall transition to the opposite state. Following initiation of local actions necessary to ensure safety, the equipment must update the AlarmsSet and associated ALCD values and send an alarm message and/or an event message to the host assuming one or both are enabled. Alarm messages must be sent before the corresponding event messages if both are enabled.

NOTE 10: The ALCD is divided into two parts, the alarm set/cleared bit and the 7 bit alarm category code. Only the set/cleared bit is used—bit 8 = 1 means alarm set, = 0 means alarm cleared. The alarm category code is not used.

4.3.3.3 *List Alarm Text* — Upon request from the host, the equipment sends values of alarm text associated with a specified list of alarm ID's using the S5,F5/F6 (List Alarms Request/Data) transaction.

4.3.3.4 *List Currently Set Alarms* — The host may obtain a listing of currently set alarms by employing any data collection method specified by GEM and referencing the variable data item called "AlarmsSet" (e.g., including " AlarmsSet in a report definition). When reported, AlarmsSet must contain a list of all currently set alarms. Each alarm set or clear occurrence must cause a change to the AlarmsSet status value prior to reporting it to the host.

4.3.3.5 *List Currently Enabled Alarms* — The host may obtain a listing of currently enabled alarms by employing any data collection method specified by GEM and referencing the variable data item called "AlarmsEnabled" (e.g., including AlarmsEnabled in a report definition). When reported, AlarmsEnabled must contain a list of all alarm ID's currently enabled for reporting. The equipment must update the value of AlarmsEnabled upon corresponding change(s) to the enable/disable settings.

4.3.4 *Requirements*

— A set of alarms relating to the physical safety limits of operator, equipment, or material being processed must be defined for the equipment by the equipment manufacturer.

— The equipment must maintain all enable/disable states and report definitions for alarms and collection events in non-volatile memory.

— Each alarm defined on the equipment must have a brief description of its meaning, an associated unique alarm identifier (ALID), alarm text (ALTX), an alarm status (ALCD) and two unique collection event identifiers (CEIDs), one for set and one for cleared.

— Enabled alarm reports must be sent prior to corresponding enabled event reports.

4.3.5 *Scenarios*

NOTE 11: Consult event reporting sections of this document for descriptions of enabling, disabling, and sending collection event reports.

Enable/Disable Alarms:

```
COMMENTS                         HOST   EQUIPMENT                          COMMENT

Enable/disable Alarm             S5,F3-->
                                        <-- S5,F4    Acknowledge
```

Upload Alarm Information:

```
COMMENTS                         HOST   EQUIPMENT                          COMMENT

Request alarm data/text          S5,F5-->
                                        <-- S5,F6    Send alarm data/text
```

Send Alarm Report:

```
COMMENTS                         HOST   EQUIPMENT                          COMMENT

Alarm occurrence detected by the equipment.
                                        <-- S5,F1    Send alarm report (if enabled).
Acknowledge                      S5,F2-->
                                        <-- S6,F11   Send event report (if enabled).
Acknowledge                     S6,F12-->
```

4.4 *Remote Control*

4.4.1 *Purpose* — This capability provides the host with a level of control over equipment operations.

4.4.2 *Definitions*

Host Command Parameter (CPNAME/CPVAL/CEPVAL) — A parameter name/value associated with a particular host command (S2,F41/S2,F49). The equipment manufacturer must provide unique names (CPNAMEs) for any supported command parameters. Command parameters are not specified in this document but are left to equipment manufacturers to define. Equipment models of specific classes of semiconductor equipment also may address this issue. Note that if there are no associated parameters a zero-length list is sent. The data item CEPVAL, which can be defined as a list, allows grouping of related parameters within a main parameter. If the CEPVAL is defined as a single (non-list) item, then it is the equivalent of a CPVAL.

The uses of OBJSPEC in the header structure of the S2,F49 Enhanced Remote Command allows the equipment supplier to define a set of unique identifiers for different objects within the equipment such as: equipment sub-systems, sub-system components, processing stations, ports, and exchange stations.

4.4.3 *Description* — The equipment responds to host commands that provide the following functions relative to individual equipment implementations:

— Start processing

— Select a process program or recipe

— Stop processing

— Temporarily suspend processing

— Resume processing

— Abort processing

Additional commands may be implemented by the equipment manufacturer (e.g., vent chamber, clear material, open door).

Remote commands shall be interpreted as “request action be initiated” rather than “do action.” The equipment may then respond via S2,F42/S2,F50 with HCACK = 4 if the command “is going to be performed.” This alleviates any transaction timeouts for commands that may take a long time to perform. The completion of the action initiated by the remote command (i.e., HCACK = 0 or 4) must result in either a state transition or other action that generates a collection event upon normal/abnormal completion.

The format for all remote commands is ASCII, with a maximum length of 20 characters. The character set is restricted to the printable characters (hexadecimal 21 through 7E). Note that spaces are not allowed.

The following remote commands (RCMDs), if implemented on the equipment, shall be supported as described below (see Section 3.4 for a description of Equipment Processing States).

NOTE 12: The terms “current cycle” and “safe break point” used below are to be defined by the supplier or within the models of classes of semiconductor equipment.

START — This command is available to the host when a process program or recipe has been selected and the equipment is in the “ready” processing state. The START command instructs the equipment to initiate processing. Variable parameter settings may be included as name/value command parameters CPNAME/CPVAL/CEPVAL.

PP-SELECT — This command instructs the equipment to make the requested process program(s) available in the execution area. The process programs (PPIDs) are specified via the command parameter list. A status variable (PPExecName) contains the PPID of the process program(s) currently selected.

RCP-SELECT — This command uses the Enhanced Remote Command S2,F49 to instruct the equipment to prepare the requested recipes for execution in the execution area. The recipes and variable parameters are specified via command parameter lists. Each recipe specification may be accompanied by new variable parameter settings, if any, in the command parameter list. A status variable RcpExecName contains the recipe specifiers or identifiers of the recipes currently selected.

STOP — Command to complete the current cycle, stop in a safe condition and return to the “idle” processing state. Stop has the intent of stopping the process. The equipment is not required to support the continuation of processing. Stop leaves material either fully processed or partially processed so that the processing can be later completed. For example, for a single wafer process tool, five wafers have been processed while the remaining wafers remain unprocessed.

PAUSE — Command to suspend processing temporarily at the next safe break point. Pause has the intent of resuming the process at the same point where it was paused. The process may be RESUMED, STOPPED, or ABORTED while in a PAUSED condition. RESUME shall be able to continue the process from the same point where it was paused.

RESUME — Command to resume processing from the point where the process was paused.

ABORT — Command to terminate the current cycle prior to its completion. Abort has the intent of immediately stopping the process and is used because of abnormal conditions. Abort makes no guarantee about the subsequent condition of material. In the above example, the wafers being processed at the time of the abort may not be completely processed. Other AbortLevels > 1 may be defined by the manufacturer or addressed by models of specific classes of semiconductor equipment.

CPNAME = AbortLevel, CPVAL = 1 means terminate current cycle at the next "safe break point," retrieve all material, stop in a safe condition and return to the idle state in the processing state machine.

4.4.4 *Requirements*

— The following Remote Commands, as defined under Descriptions, must be implemented on equipment to satisfy minimum requirements for this capability:

— START

— STOP

— The RCMD value for all commands supported on the equipment must be recognized if sent with all upper-case characters (e.g., "STOP", "START", "PP-SELECT", "PAUSE", etc.). In addition to accepting strings with all upper-case characters, the equipment can optionally accept strings with all lower-case characters or mixed-case strings. The equipment documentation should describe whether or not the optional lower-case or mixed-case strings are supported.

— Stream 2 currently provides for Host Command Send and Enhanced Remote Command. The equipment shall support one or both methods, based on appropriateness.

— The Enhanced Remote Command is used to address size, complexity, or the need to target a specific sub-system within the equipment, (i.e., processing station, port, exchange station, material handler, chamber).

4.4.5 *Scenarios*

4.4.5.1 *Host Command Send Scenario*

```
COMMENTS                          HOST    EQUIPMENT                      COMMENT

Host Command                 Send S2,F41-->
                                          <-- S2,F42   Host Command Acknowledge

                                                       [IF] Command Accepted
                                                       (HCACK = 0 or 4)

                                          <-- S6,F11   [THEN] Event Report-state
                                                       change or other collection
                                                       event occurrence.
Event Report Acknowledge          S6,F12-->
```

4.4.5.2 *Enhanced Remote Command Scenario*

COMMENTS	HOST	EQUIPMENT	COMMENT
Enhanced Remote Command	S2,F49-->		
		<--S2,F50	EnhancedRemote Command Acknowledge
			[IF] Command Accepted (HCACK = 0 or 4)
		<--S6,F11	[THEN] Event Report-state change or other collection event occurrence.
Event Report Acknowledge	S6,F12-->		

4.5 *Equipment Constants*

4.5.1 *Purpose* — This capability provides a method for the host to read and to change the value of selected equipment constants on the equipment.

4.5.2 *Definitions* — None.

4.5.3 *Description* — This capability allows the host to reconfigure equipment constants to support a variety of situations. The following functions are included:

Host Sends Equipment Constants — Allows the host to change the value of one or more equipment constants.

Host Equipment Constant Request — Allows the host to determine the current value of equipment constants.

Host Equipment Constant Namelist Request — Allows the host to retrieve basic information about the equipment constants available at the equipment.

4.5.4 *Requirements*

- Equipment constants must be stored in non-volatile memory.
- The equipment must be in a "safe" condition to accept new constant(s) settings as defined by the equipment manufacturer.
- The equipment must provide a collection event to alert the host whenever an equipment constant is changed by the operator. Information indicating which constant was changed shall be available for the event report.

4.5.5 *Scenarios*

Host Sends Equipment Constants:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends	S2,F15-->		
equipment constants		<-- S2,F16	EAC = 0 equipment sets constants

Host Equipment Constants Request:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host constant request	S2,F13-->		
		<-- S2,F14	Equipment constant data

NOTE: This capability also can be accomplished using S6,F19 & S6,F20. See Section 4.2.

Host Equipment Constant Namelist Request:

```
COMMENTS                          HOST    EQUIPMENT                        COMMENTS

Host constant namelist          S2,F29-->
request                                 <-- S2,F30   Equipment constant namelist
```

Operator Changes Equipment Constant

```
COMMENTS                               HOST  EQUIPMENT                     COMMENTS

                                                     Operator changes equipment
                                                     constant at equipment
                                                     operator console.
                                        <-- S6,F11   Equipment reports equipment
                                                     constant change.
Host acknowledges event         S6,F12-->
```

4.6 *Process Program Management* — Process programs and recipes must be managed through interaction between the equipment and the host system.

4.6.1 *Purpose* — Process program management provides a means to transfer process programs or recieps, and to share the management of those process programs or recipes, between the host and equipment.

4.6.2 *Definitions*

PPError — A text data value with information about verification errors of a process program that failed verification. If the equipment provides an event for recipe verification and/or recipe verification failure, then PPError shall be a DVVAL. Otherwise, PPError shall be an SV.

PPFormat — A variable (SV) indicating the type or types of process programs and recipes that are supported.

1 = Unformatted process programs

2 = Formatted process programs

3 = Both unformatted and formatted process programs

4 = Execution recipes

4.6.2.1 *Definitions for Process Programs*

Process Program — A process program is the pre-planned and reusable portion of the set of instructions, settings, and parameters under control of the equipment that determine the processing environment seen by the manufactured object and that may be subject to change between runs or processing cycles.

Process Program Identifier — A text string (PPID) used to identify a process program.

Formatted Process Program — A process program that is presented as an ordered sequence of command codes with their associated parameters as dictated by S7,F23, and S7,F26. Where formatted process programs are supported, equipment must also provide information sufficient to allow a user at the host to create, display, modify, and partially verify their contents (for example, that information provided in S7,F22).

Unformatted Process Program — An unformatted process program is transferred without structure as the single data item PPBODY (refer to SEMI E5 for a complete description of PPBODY).

Process Program Change Event — The collection event associated with the occurrence of the creation, modification, or deletion of a process program by the operator.

PPChangeName — A data value (DVVAL) containing the PPID of the process program affected by the event Process Program Change Event. See SEMI E5 for a full definition of this variable data item.

PPChangeStatus — The action taken on the process program named by PPChangeName. This variable is valid for the collection event Process Program Change Event. See SEMI E5 for a full definition of this variable data item.

PPExecName — The status variable containing the PPID(s) of the currently selected process program(s). See SEMI E5 for a full definition of this variable data item.

PP-SELECT — The remote command used to select one or more process programs for execution. The process programs are specified by PPID via the command parameter list.

Process Program Verification — Verification is syntax checking of a process program. Verification ensures only that a process program is structured correctly. It does not ensure that the program has the correct parameters to run a particular process or product (see Process Program Validation). Equipment supporting unformatted process programs should provide a variable DVVAL PPError that provides information to the user concerning the error or errors when an attempt to verify a process program fails.

NOTE 14: It may not be possible for the equipment to verify unformatted process programs other than to check the size of the program and internal program checksums. Equipment has no standard means of indicating the type of error encountered in an unformatted process program.

Process Program Validation — Validation is type-and-range checking of parameters in a process program, and is performed after verification.

4.6.2.2 *Definitions for Recipes*

Execution recipe — A type of recipe stored by the equipment for purposes of editing, verification, and execution.

For complete definitions of execution recipes and their standard attributes, see SEMI E42, Section 6.

Execution Recipe Change Event — The collection event associated with the occurrence of the modification or deletion of an execution recipe stored by the equipment.

Note 15: A recipe is modified whenever its body is changed.

New Execution Recipe Event — The collection event associated with the creation of a new execution recipe at the equipment.

Object form recipe — A recipe with body in a proprietary format that may be presented without structure.

RcpChangeName — A data value (DVVAL) containing the identifier of the recipe affected by the event Execution Recipe Change Event or New Execution Recipe Event. See the SEMI E5 Standard for a full definition of this variable data item.

RcpChangeStatus — The action taken on the recipe named by RcpChangeName. This variable is valid for the collection event Execution Recipe Change Event or New Execution Recipe Event. See the SEMI E5 Standard for a full definition of this variable data item.

RcpExecName — The status variable containing the specifiers of the currently selected recipe(s). See the SEMI E5 Standard for a full definition of this variable data item.

RCP-SELECT — The remote command used to select one or more recipes for execution. See Section 4.4.3.

Recipe Attribute — Information about the recipe that is transferred with the recipe as a name/value pair. The value may be a single item or a list.

Recipe — A recipe contains both a set of instructions, settings, and parameters that the equipment uses to determine the processing environment (its body or process program) and a set of attributes that provide information about the recipe, such as the date and time the body was last changed.

SEMI E42 defines two types of recipes: *managed recipes* and *execution recipes*. For purposes of GEM, the term *recipe* refers to an *execution recipe* only.

Recipe identifier — A recipe identifier is a formatted text string (RCPID) used to identify the recipe.

Recipe specifier — A formatted text string (RCPSPEC) used in messages to indicate a specific recipe. A recipe specifier includes the recipe identifier. It may also include additional information, such as the name of the specific component of the equipment where the recipe is to be executed (e.g. a process chamber) and the name of a recipe repository on the host.

Recipe Verification — Verification is syntax checking of a recipe's body. Verification ensures that a recipe body is structured correctly and has the correct syntax. It may also provide a check of semantics. It does not ensure that the body has the correct parameters to run a particular process or product (see Recipe Validation).

NOTE 16: Unverified recipes shall be verified upon download.

Recipe Validation — Validation is type-and-range checking of parameters in a recipe, and is performed when the recipe is selected for execution. The recipe may be correct in its syntax and semantics but should fail validation if it can not be executed with the current equipment configuration.

Source form recipe — A recipe with a body that is presented as an ordered sequence of text. A source form recipe may be created and edited off-line to the equipment. Definition of syntax requirements shall be documented, in order to allow proper off-line editing.

Variable Parameters — Variable parameters are recipe parameters that are defined in the body of the recipe and whose run-time values may be set outside of the recipe when the recipe is selected for execution and/or when processing is started. Both the host and the operator may specify new settings as a parameter name/value pair.

Variable Parameter Definition — A variable parameter definition has three parts: the name of the variable parameter, its default setting, and restrictions on the run-time value selected. Variable parameter definitions are stored in the recipe attribute "Parameters".

4.6.3 *Description*

4.6.3.1 *Process Program Description*

Process programs allow the equipment's process, and/or the parameters used by that process, to be set and modified by the engineer to achieve different results. Different process programs maybe required for different products, while often the same process program will be used for all lots of a given product. The engineer must be able to create such programs, to modify current programs, and to delete programs from equipment storage.

For the host to ensure that the proper process programs are in place at the equipment, there must be a means of transferring them from equipment to host and from host to equipment. The host also may need to delete process programs from the equipment's storage to make room for a process program to be downloaded. In addition, the host must be kept informed whenever a local change occurs in the contents or status of a process program.

Both formatted and unformatted process programs may be uploaded and downloaded. This capability provides for both host- and equipment-initiated transfers. The equipment-initiated transfer may be used at the request of the process engineer or operator at the equipment.

If a process program exists with the same PPID as the one given in the SECS-II message, the old process program must be replaced. The PPID in the e process program in non-volatile storage.

4.6.3.2 *Recipe Description*

Specifications in Section 4.6.3.1 apply to recipes as well as process programs, with the following differences:

- A recipe contains a body corresponding to a process program. In addition, it contains attributes defined for execution recipes in SEMI E42, Section 6. Recipe attributes are transferred whenever the recipe is downloaded or uploaded.
- The same SECS-II messages are used for all execution recipes, regardless of the internal structure of the recipe body.
- If an execution recipe already exists with the same identifier as the one given in the SECS-II message, the downloaded recipe shall be rejected (not stored) unless the host has specified a "forced overwrite" in the data item RCPOWCODE.
- A recipe currently being edited shall be protected from inadvertent change or overwriting by a recipe with the same identifier that is downloaded during this time. If the downloaded recipe is accepted (stored), the equipment shall require the operator either to save the edited recipe to a new (unused) identifier or to discard it.
- For the equipment to initiate either an upload or download of a recipe, it shall request the host to initiate an upload or download procedure. In addition, it may be necessary to also specify the name of the repository (recipe namespace) at the host.

4.6.4 *Requirements*

- The equipment manufacturer shall provide a method to create, modify, and delete process programs or recipes. This method shall exist on either the equipment or on a separate computing system.
- A CEID shall be defined for a collection event for the creation, the deletion, or the modification (completion of an editing session) of a process program (Process Program Change Event). For recipes, there are two separate CEIDs and collection events, one for the creation of a new recipe (New Execution Recipe Event) and one when a recipe is changed or deleted (Execution Recipe Change Event). A New Execution Recipe Event shall occur whenever a new recipe identifier is created through download, edit, copy, or rename operations. A Execution Recipe Change Event shall occur whenever the body of an existing recipe is modified.
- The name (identifier) that the engineer or operator uses to refer to the process program or recipe is the same as the identifier used by the host.
- Upon request from the host or operator, the equipment shall perform the following actions with regard to process programs and recipes stored in non-volatile storage: upload, download, delete, and list current equipment process program or recipe directory.
- The equipment shall be able to store in non-volatile memory the number of process programs or recipes sufficient to execute three unique process cycles. For example, if a wire-bonder requires both an "ALIGN" process program and a "BOND" process program for a full process cycle, then it must provide non-volatile storage for at least three pairs of process programs. These stored process programs or recipes may not be modified in any way by the execution process, nor may the execution process be affected by the modification of any process program or recipes in storage, either by downloading or by local editing, while that process program or recipes is being executed.

- The equipment must provide verification and validation of all downloaded process programs and recipes.
- Stream 7 provides for formatted and unformatted process programs, while Stream 15 provides for recipes. The equipment must support at least one of these three methods.
- The equipment supplier shall document any restrictions on the length or test format of PPID. The maximum length allowed by equipment may be less than that allowed by SECS-II.
- Where recipes are supported, the following requirements also apply:
  - The variable PPFormat shall be provided to indicate to the user the messages supported by the equipment.
  - The recipe and its attributes shall comply to the requirements for execution recipes as defined in SEMI E42, Section 6.

4.6.5 *Scenarios for Process Programs*

4.6.5.1 *Process Program Creation, Editing, or Deletion Process Program Created, Edited, or Deleted by Operator*

```
COMMENTS                          HOST    EQUIPMENT                       COMMENTS

                                                     New process program created,
                                                     edited, or deleted by operator
                                                     at equipment.
                                                     PPChangeName = PPID
                                                     PPChangeStatus = 1 (Created)
                                                                    = 2 (Edited)
                                                                    = 3 (Deleted)
                                                     [IF] CEID for Process Program
                                                     Change Event enabled
                                                     [THEN]
                                          <-- S6,F11  Send Event Report
Event Report Acknowledge          S6,F12-->
                                                     [END_IF]
```

Process Program Deletion by the Host:

```
COMMENTS                          HOST    EQUIPMENT                       COMMENTS

Delete Process Program Send       S7,F17-->
                                          <-- S7,F18  Delete Process Program
                                                     Acknowledge.
                                                     The process program is removed
                                                     from non-volatile storage.
```

4.6.5.2 *Process Program Directory Request*

```
COMMENTS                          HOST    EQUIPMENT                       COMMENTS

Current EPPD Request              S7,F19-->
                                          <-- S7,F20  Current EPPD Data
```

4.6.5.3 *Process Program Upload*

Host-Initiated Process Program Upload — Formatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Formatted Process Program Request	S7,F25-->		
		<-- S7,F26	Formatted Process Program Data

Host-Initiated Process Program Upload — Unformatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Process Program Request	S7,F5-->		
		<-- S7,F6[21]	Process Program Data

Equipment Initiated Process Program Upload — Formatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			[IF] Process program is multi-block
			[THEN]
		<-- S7,F1	Process Program Load Inquire
Process Program Load Grant	S7,F2-->		
			[END_IF]
		<-- S7,F23	Formatted Process Program Send
Formatted Process Program Acknowledge	S7,F24-->		

Equipment-Initiated Process Program Upload — Unformatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			[IF] Process program is multi-block
			[THEN]
		<-- S7,F1	Process Program Load Inquire
Process Program Load Grant	S7,F2-->		
			[END_IF]
		<-- S7,F3	Process Program Send
Process Program Acknowledge	S7,F4-->		

21 If the process program does not exist, a zero-length list will be sent.

4.6.5.4 *Process Program Download*

NOTE 17: Formatted process programs must be verified immediately following any download.

While the Process Program Load Inquire/Grant transaction (S7,F1/F2) is required only for the transfer of multi-block process programs, its use is recommended prior to all host-initiated downloads. It provides a means of verifying process program size.

Host-Initiated Process Program Download — Formatted:

```
COMMENTS                          HOST   EQUIPMENT                           COMMENTS

[IF]
Process program is multi-block
[THEN]
Process Program Load Inquire   S7,F1[22] -->
                                        <-- S7,F2    Process Program Load Grant
[ENDIF]
Formatted Process Program Send  S7,F23-->
                                        <--S7,F24    Formatted Process Program
                                                     Acknowledge Verify process
                                                     program
                                                     [IF] S7,F27 is multi-block
                                                     [THEN]
                                        <--S7,F29    Process Program Verification
                                                     Inquire
                                 S7,F30->            Process Program Verification
                                                     Grant
                                                     [END IF]
                                        <--S7,F27    Process Program Verification
                                                     Send
Process Program Verification
Acknowledge                     S7,F28-->
```

Host-Initiated Process Program Download — Unformatted:

```
COMMENTS                          HOST   EQUIPMENT                           COMMENTS

[IF]
Process program is multi-block
[THEN]
Process Program Load Inquire   S7,F1[21] -->
                                        <--S7,F2     Process Program Load Grant
[END_IF]
Process Program Send             S7,F3-->
                                        <--S7,F4     Process Program Acknowledge
```

22 S7,F1 should be used only to request permission to transfer a multi-block formatted or unformatted process program. It should not be used to select a process program. For selecting a process program for execution, the remote command PP-SELECT should be used.

Equipment-Initiated Process Program Download — Formatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
		<--S7,F25	Formatted Process Program Request
Formatted Process Program Data	S7,F26-->		
			[IF] S7,F27 is multi-block [THEN]
		<--S7,F29	Process Program Verification Inquire
	S7,F30-->		Process Program Verification Grant
			[END IF]
		<--S7,F27	Process Program Verification Send
Process Program Verification Acknowledge	S7,F28-->		

Equipment-Initiated Process Program Download — Unformatted:

COMMENTS	HOST	EQUIPMENT	COMMENTS
		<--S7,F5	Process Program Request
Process Program Send	S7,F6-->		

4.6.6 Scenarios for Recipes

4.6.6.1 *Recipe Creation, Editing, or Deletion*

Recipe Created by Operator:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			New recipe created by operator at equipment RcpChangeName = RCPID RcpChangeStatus = 1 (Created) [IF] CEID for New Execution Recipe Event enabled [THEN]
		<--S6,F11	Send Event Report
Event Report Acknowledge	S6,F12-->		
			[END_IF]

Recipe Edited or Deleted by Operator:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			New recipe edited, or deleted at equipment RcpChangeName = RCPID RcpChangeStatus = 2 (Modified) or 5 (Deleted) [IF] CEID for Execution Execution Recipe Change Event enabled [THEN]
		<--S6,F11	Send Event Report
Event Report Acknowledge	S6,F12-->		
			[END_IF]

Recipe Deletion by the Host:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Recipe Delete Request	S15,F35-->		
		<--S15,F36	Recipe Delete Acknowledge. The recipe is removed from non-volatile storage.

4.6.6.2 *Recipe Directory Request*

Host requests a list of identifiers of currently stored recipes.

COMMENTS	HOST	EQUIPMENT	COMMENTS
GetAttr Request	S14,F1-->		
		<--S14,F2	GetAttr Data

4.6.6.3 *Recipe Upload*

Host-Initiated Recipe Upload:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Recipe Upload Request	S15,F31-->		
		<--S15,F32	Recipe Upload Data

Equipment-Initiated Recipe Upload:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			RCPCMD = Upload [IF] multi-block request
		<--S15,F1	[THEN] Recipe Management Multi-block inquire
Recipe Management Multi-block Grant	S15,F2-->		
			[END_IF]
		<--S15,F21	Recipe Action Request
Recipe Action Acknowledge	S15,F22-->		
Host requests upload	S15,F31-->		
		<--S15,F32	Recipe Upload Data

4.6.6.4 *Recipe Download*

The Recipe Management Multi-block Inquire/Grant transaction (S15,F1/F2) is required for the transfer of multi-block recipes. However, its use is recommended prior to all downloads, as it provides recipe size to the equipment.

NOTE 18: If the data item RCPOWCODE is TRUE in S15,F27, then a pre-existing recipe with the same identifier shall be overwritten.

Host-Initiated Recipe Download:

```
COMMENTS                         HOST   EQUIPMENT                             COMMENTS
[IF]
Recipe is multi-block
[THEN]

Recipe Management Multi-
block Inquire                   S15,F1-->

                                        <--S15,F2    Recipe Management Multi-block
                                                     Grant
[END IF]
Recipe Download Request        S15,F27-->
                                                     [IF] RCPOWCODE  =  TRUE
                                                     delete any pre-existing recipe
                                                     with the same identifier before
                                                     storing new recipe
                                                     [END_IF]
                                        <--S15,F28   Recipe Download Acknowledge
```

Equipment-Initiated Recipe Download:

```
COMMENTS                         HOST   EQUIPMENT                             COMMENTS
                                                     RCPCMD  =  Download
                                                     [IF] multi-block request
                                        <--S15,F1    [THEN] Recipe Management Multi-
                                                     block inquire
Recipe Management Multi-block   S15,F2-->
Grant
                                                     [END_IF]
                                        <--S15,F21   Recipe Action Request

Recipe Action Acknowledge      S15,F22-->
[IF]
Recipe is multi-block
[THEN]

Recipe Management Multi-block   S15,F1-->
Inquire
                                        <--S15,F2    Recipe Management Multi-block
                                                     Grant
[END IF]
Recipe Download Request        S15,F27-->
                                                     [IF] RCPOWCODE  =  TRUE
                                                     delete any pre-existing recipe
                                                     with the same identifier before
                                                     storing new recipe
                                                     [END_IF]
                                        <--S15,F28   Recipe Download Acknowledge
```

4.6.6.5 *Recipe Verification*

Host requests equipment to verify a recipe that it has stored:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Recipe Verify Request	S15,F29-->		
			Equipment verifies recipe
		<--S15,F30	Recipe Verify Data

4.7 *Material Movement* — The material movement capability includes the physical transfer of material (WIP, tools, expendable materials, etc.) between equipment, buffers, and storage facilities. The transfer of material can be performed by operators, AGV robots, tracks, or dedicated fixed material handling equipment.

4.7.1 *Purpose* — This capability is limited in implementation, serving to notify the host of the appearance or removal of material at the equipment's ports.

4.7.2 *Definitions*

Port — A point or area on the equipment at which a change in equipment ownership of material may occur.

4.7.3 *Description* — This capability consists of alerting the host whenever material is sent or received from any of the ports on the equipment. Event-specific information, such as port identification and material identification, also may be useful, but definition of these and other related DVVAL's are left to the implementation.

4.7.4 *Requirements* — The equipment must supply two CEIDs, one to report when material is sent from any port and the other to report when material is received at any port.

4.7.5 *Scenarios*

COMMENTS	HOST	EQUIPMENT	COMMENTS
			Material is sent or received at an equipment port.
		<--S6,F11	Send collection event to host.
Host acknowledges.	S6,F12-->		

4.8 *Equipment Terminal Services* — Equipment Terminal Services allows the host to display information on the equipment's display device or the operator of the equipment to send information to the host.

4.8.1 *Purpose* — Equipment Terminal Services allows the factory operators to exchange information with the host from their equipment workstations.

4.8.2 *Definitions* —Message Recognition: a positive action by the equipment operator indicating the operator has viewed the text of a host initiated message.

4.8.3 *Detailed Description* — The equipment must be capable of displaying information passed to it by the host for the operator's attention. The information, or an indication of a message, must remain on the equipment's display until the operator indicates message recognition. Message recognition results in a collection event that informs the host that the operator has actually viewed the information.

The equipment must be capable of passing information to the host that has been entered from the operator's equipment console. This information is intended for host applications and is not processed by the equipment.

The equipment has no responsibility for interpreting any of the data passed to or from the host using this method.

4.8.4 *Requirements*

— Any new Terminal Display message sent by the host shall overwrite an unrecognized message at the same equipment terminal.

— The equipment must provide a display device capable of displaying at least 160 characters to the operator.

— The equipment must provide a mechanism for displaying information sent to it by the host.

— The equipment must provide an indicator to notify the operator when an unrecognized message is present.

— The equipment must provide a mechanism for the operator to indicate message recognition (e.g., push button, terminal function).

— The equipment must provide a means for alpha numeric data entry that can be used by the operator.

— The equipment must support operator entry of at least 160 characters per message.

— The equipment must have a mechanism to send operator-entered messages to the host.

— The equipment must support single-block messages as a minimum. Support of multi-block messages is optional.

— A Terminal Display message received by the equipment with a zero length TEXT data item shall be accepted and replace any previous unrecognized message, but shall not itself be considered an unrecognized message. This provides a method of clearing an unrecognized message and turning off the unrecognized message indicator.

4.8.5 *Scenarios*

Host sends information to an equipment's display device:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends textual information to equipment for display to the operator on terminal x.	S10,F3-->		
		<--S10,F4	Equipment acknowledges request to display text. (Equipment sets unrecognized message indicator.) Operator indicates message recognition. (Equipment clears unrecognized message indicator.)
		<--S6,F11	Message recognition event. (See Section 4.2.1, Event Data Collection, for details.)
Host acknowledges Optional:	S6,F12-->		
		<--S10,F1	Operator responds with text via terminal x.
Host acknowledges receipt of operator text.	S10,F2-->		

Host sends information to an equipment's display device and then overwrites the information before operator recognizes message:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends textual information to equipment for display to the operator on terminal x.	S10,F3-->		
		<--S10,F4	Equipment acknowledges request to display text. (Equipment sets unrecognized message indicator.)
Host sends textual information to equipment for display to the operator on terminal x. This message overwrites the first one sent by the host since it is still unrecognized.	S10,F3-->		
		<--S10,F4	Equipment acknowledges request to display text. (Equipment sets unrecognized message indicator.) Operator indicates message recognition. (Equipment clears unrecognized message indicator.)
		<--S6,F11	Message recognition event. (See Section 4.2.1, Event Data Collection, for details.)
Host acknowledges	S6,F12-->		

Operator sends information to the host:

COMMENTS	HOST	EQUIPMENT	COMMENTS
		<--S10,F1	Operator sends textual information via equipment terminal x.
Host acknowledges receipt of operator initiated message.	S10,F2-->		
Optional: Host responds with information for display to the operator on terminal x.	S10,F3-->		
		<--S10,F4	Equipment acknowledges receipt of request to display text. (Equipment sets unrecognized message indicator.) Operator indicates message recognition.
		<--S6,F11	Message recognition event. (See Event data collection for details.)
Host acknowledges	S6,F12-->		

Host sends a multi-block display message:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Send information	S10,F5-->		
		<--S10,F6	Accepted or denied. [IF] Message from host is multi-block and multi-block is not supported by the equipment, [THEN]
		<--S10,F7	Send Multi-block Not Allowed. [END_IF]

4.9 *Error Messages*

4.9.1 *Purpose* — Error messages provide the host with information describing the reason for a particular message or communication fault detected by the equipment.

4.9.2 *Definitions*

Communication Fault — Refer to Section 2 for the definition.

Message Fault — Refer to Section 2 for the definition.

4.9.3 *Detailed Description* — The equipment must inform the host that it cannot process a message due to an incorrect:

— device ID,

— message stream type,

— message function,

— message format, or

— data format.

The equipment must inform the host if the message has more data than it can handle.

The equipment must inform the host if the equipment's transaction timer expires.

The equipment shall treat the above conditions as application-level errors and shall not take any further action on any message in error.

Error messages are invoked whenever the equipment detects communication or message faults.

4.9.4 *Requirements* — Support of all Stream 9 messages.

4.9.5 *Scenario*

Message Fault Due to Unrecognized Device ID:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
			Equipment detects an unrecognized device ID within the message from the host.
		<--S9,F1	Equipment reports to the host that an "unrecognized device ID" was detected in the received message.

Message Fault Due to Unrecognized Stream Type:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
			Equipment detects an unrecognized stream type within the message from the host.
		<--S9,F3	Equipment reports to the host that an "unrecognized stream type" was detected in the received message.

Message Fault Due to Unrecognized Function Type:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
			Equipment detects an unrecognized function type within the message from the host.
		<--S9,F5	Equipment reports to the host that an "unrecognized function type" was detected in the received message.

Message Fault Due to Illegal Data Format:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
			Equipment detects illegal data format within the message from the host.
		<--S9,F7	Equipment reports to the host that "illegal data format" was detected in the received message.

Communication Fault Due to Transaction Timer Timeout:

COMMENTS	HOST	EQUIPMENT	COMMENTS
			Equipment does not receive an expected reply message from the host and a transaction timer timeout occurs.
		<--S9,F9	Equipment reports to the host that a transaction timer timeout occurred.

Message fault due to data too long:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
			Equipment detects that the message from the host contains more data than it can handle.
		<--S9,F11	Equipment reports to the host that "data too long" was detected in the received message.

Communication Fault Due to Conversation Timeout:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host sends a message.	Sx,Fy-->		
		<--Sx,Fy+1	Equipment sends reply. Equipment is now expecting a specific message from the host as a result of the previous transaction. Equipment has not received the expected message from the host and a conversation timeout occurs.
		<--S9,F13	Equipment reports to the host that a conversation timeout occurred.

4.10 *Clock* — The clock capability enables host management of time-related activities and occurrences associated with the equipment and across multiple pieces of equipment.

4.10.1 *Purpose* — The purpose of the clock capability is to enable time stamping of collection event and alarm reports. Time stamping is useful for resolving relative order of event/alarm occurrences and scheduling of equipment activities by the host.

The ability for the host to instruct the equipment to set an internal clock to a specified time value, and for the equipment to request the current date and time, is needed for effective time management and synchronization between host and equipment.

4.10.2 *Definitions*

Clock — Clock is a status variable containing the current value of time at the equipment. Clock may be included in report definitions and/or queried separately by the host. See SEMI E5 for a full definition of this variable data item and its required formatting.

TIME — TIME is a data item contained in messages used by the host to set time at the equipment and by the equipment or host to request the current time from the other. (See SEMI E5 for a full definition of this data item.)

4.10.3 *Detailed Description* — The clock capability assumes the existence of a relative time reference on the equipment. This time reference is used as a basis for updating the time value of an equipment status variable called "Clock." The time reference must reflect the current time to within a resolution range of seconds to centiseconds (refer to the format for Clock in the SEMI E5 Standard). The purpose of time stamping with centiseconds is to resolve the order in which nearly simultaneous events occur rather than to provide a more precise record of the time of day at which they occurred. Where more than one event occurs within a given period of clock resolution, the centiseconds reported in the time stamps for these events must reflect the actual order in which the events were detected. Equipment with a clock resolution of less than a second should report centiseconds. Otherwise, centiseconds should be assigned to reflect the relative order in which events were detected. Equipment unable to resolve time to less than a second and unable to reflect the relative order in which events were detected may report centiseconds as "00".

The host employs the “Date and Time Set Request” message (S2,F31) to initialize the value of Clock to the value contained in the TIME data item. Similarly, the equipment may employ the “Date and Time Request“ message (S2,F17) to obtain a new initialization time for Clock. As before, the value of TIME returned by the host is used to set Clock. Note, in the event that the precision of TIME is seconds and that for Clock is centiseconds, in both cases the initial value of Clock shall contain “00” for its Centisecond digits upon initialization. Additionally, for any field in TIME that is not supported by the equipment, the local value of this field is equipment dependent. For example, Equipment that cannot resolve time to less than a second might round or ignore centiseconds and always set the Centisecond field to “00”.

4.10.4 *Requirements*

— The resolution and update rate of the internal time reference must be sufficient to distinguish between two nearly simultaneous collection events and/or alarms.

— The equipment supplier shall provide documentation describing the resolution of the internal time reference.

— The equipment supplier shall provide documentation describing how centisecond values are assigned, including the case of unresolvable simultaneous events.

4.10.5 *Scenarios*

Equipment Requests TIME (Optional Scenario):

COMMENTS	HOST	EQUIPMENT	COMMENTS
		<--S2,F17	Equipment requests a time value from the host.
Host responds with a TIME value	S2,F18-->		
			Equipment sets its internal time reference to the value of TIME received from the host.

Host Instructs Equipment to Set Time:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host instructs equipment to set its time.	S2,F31-->		
		<--S2,F32	Equipment sets its internal time reference to the value of TIME received from the host and acknowledges completion.

Host Requests Equipment’s Current Time Value:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host requests equipment time.	S2,F17-->		
		<--S2,F18	Equipment returns its internal time reference value to the host.

4.11 *Spooling* — Spooling is a capability whereby the equipment can queue messages intended for the host during times of communication failure and subsequently deliver these messages when communication is restored. Spooling is limited to primary messages of user-selected streams.

4.11.1 *Purpose* — The purpose of spooling is to provide a method for retaining equipment message data that might otherwise be lost due to communication failure. The motive for producing this functionality is to retain valuable data used to track material and to improve product quality. The spooling capability fills a gap in the SEMI E5 standard. In the past, without a spooling capability, the equipment has typically discarded messages that could not be delivered, or turned messaging off altogether. It is intended that the host initiate the spool unload process immediately following the reestablishment of communications.

4.11.2 *Definitions*

MaxSpoolTransmit — An equipment constant containing the maximum number of messages that the equipment shall transmit from the spool in response to an S6,F23 "Transmit Spooled Messages" request. If MaxSpoolTransmit is set to zero, no limit is placed on the messages sent from the spool. Multi-block inquire/grant messages are not counted in this total.

OverWriteSpool — A boolean equipment constant used to indicate to the equipment whether to overwrite data in the spool area or to discard further messages whenever the spool area limits are exceeded.

Send Queue — Refers to the queue into which equipment generated SECS messages are placed in preparation for transmission to the host.

Spool — The spool is an area of non-volatile storage in which the equipment stores certain messages that cannot be delivered to the host (when the equipment is in the NOT COMMUNICATING substate of COMMUNICATIONS ENABLED). The spool area can be thought of as a sequential "ring" buffer. The term spool is also used to denote the action of placing messages into the spool area.

SpoolCountActual — A status variable used to keep a count of the messages actually stored in the equipment's spool area. Multi-block inquire/grant messages are not spooled and not included in this count.

SpoolCountTotal — A status variable used to keep a count of the total number of primary messages directed to the spool, regardless of whether placed or currently retained in the spool. Multi-block inquire/grant messages are not spooled and not included in this count.

SpoolFullTime — A status variable containing the timestamp when the spool last became full. If the spool was not filled during the last spooling period, this will contain a time value prior to the current SpoolStartTime.

SpoolStartTime — A status variable containing the timestamp from when spooling was last activated.

4.11.3 *Description*

4.11.3.1 *Spooling State Model* — There are two major states of spooling: SPOOL INACTIVE and SPOOL ACTIVE. SPOOL ACTIVE has two components: SPOOL UNLOAD and SPOOL LOAD. These are each broken into substates. A description of all spooling states, substates, and applicable state transitions follows. The POWER OFF and POWER ON parent states are common to all equipment subsystems. They are shown here to illustrate the retention of spooling context during a power down situation.

NOTE 20: Disabling SECS communications does not affect the current spooling state since no messages are generated until communications are subsequently enabled. Spooling is effectively frozen in this case.

POWER OFF

The equipment has lost power for any reason (e.g., power failure, power switch set to off).

POWER ON

The equipment is powered up.

SPOOL INACTIVE

This is the normal operating mode. No spooling occurs. The spool area is empty. Primary SECS-II messages are transmitted normally.

SPOOL ACTIVE

All primary SECS-II messages ready for sending and for which spooling is enabled (see S2,F43) are directed to the spool area. All other primary messages, except Stream 1, are discarded. The equipment shall attempt to send any secondary messages that are generated and discard these messages should the attempt to send fail.

Spool state transitions from SPOOL INACTIVE to SPOOL ACTIVE if the communications state changes from COMMUNICATING to NOT COMMUNICATING (Communication State Transition Table, #14) or from WAIT CRA to WAIT DELAY (Communication STATE Transition Table, #6).

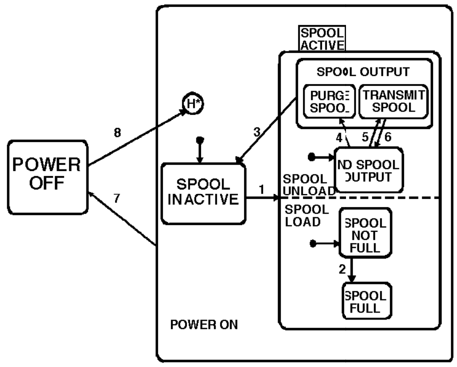


Figure 4.11
Spooling State Diagram

Once communications are established, the host must initiate the spool unload sequence to restore full functionality (see below). Since the equipment will deliver secondary messages, the host may inquire for information or send commands as needed.

The SPOOL ACTIVE state has two AND states: SPOOL LOAD and SPOOL UNLOAD. This means that they operate independently, though sharing data and some state change stimuli. See Section 3.1 for explanation of state model terms and notation.

SPOOL LOAD

The SPOOL LOAD component enters messages into the spool area. It is divided into two substates: SPOOL NOT FULL and SPOOL FULL. SPOOL NOT FULL is the default entry substate of the parent state SPOOL LOAD.

SPOOL NOT FULL

As primary SECS-II messages are directed to the spool area, the equipment shall "write" the SECS-II message to the end of the spool. Status variables SpoolCountTotal and SpoolCountActual shall be incremented each time a message is placed in the spool area.

SPOOL FULL

In this state, all of the allocated spooling area is filled. Choice of the following options shall be controlled by the setting of a Boolean equipment constant called "OverWriteSpool." The first message to be dealt with is that which could not be fit into the spool prior to transition from SPOOL NOT FULL (see transition table below).

OverWriteSpool is True: The equipment deletes as many of the "oldest" records (e.g., SECS-II messages) contained in the spool area necessary to make space for the new message and then adds the message. Status variable SpoolCountTotal shall be incremented whenever a message is submitted to the spool area. Status variable SpoolCountActual shall be manipulated to keep an accurate count of the number of messages contained in the spool area. For example, if it is necessary to delete three messages in the spool area to spool one message, SpoolCountActual would have three subtracted and then one added to the total.

OverWriteSpool is False: Any subsequent primary messages shall be discarded. When such a message is discarded, SpoolCountTotal is incremented.

SPOOL UNLOAD

The SPOOL UNLOAD component of SPOOLACTIVE deals with movement of messages out of the spool. It has an active substate (SPOOL OUTPUT) and a passive substate (NO SPOOL OUTPUT). NO SPOOL OUTPUT is the default entry substate, since the equipment is NOT COMMUNICATING at the time spooling is initiated. When communications between equipment and host are restored, there is an opportunity for the host to recover spooled messages. No action is taken until the host initiates the spool output process via the S6,F23 (Request Spooled Data). The host has the option to either receive the spooled messages (see substate TRANSMIT SPOOL) or discard all messages in the spool (see substate PURGE SPOOL).

NO SPOOL OUTPUT

In this state, no messages are removed from the spool.

SPOOL OUTPUT

The SPOOL OUTPUT state encompasses the removal of messages from the spool. Its substates are TRANS-MIT SPOOL and PURGE SPOOL.

TRANSMIT SPOOL

The host elects to receive all messages contained in the spool area. The equipment is expected to keep track of the oldest record (i.e., message) within the spool area. When communications are re-established with the host and transmission of the spool area is started, the oldest record must be the first record transmitted, then the next oldest record, etc. There is no prioritization of messages to be sent from the spool.

As each spooled message is successfully transmitted to the host, it is removed from the spool area upon successful completion of the transaction. Spool-CountActual is decremented as each message is removed from the spool. The equipment shall transmit messages only from the spool area until all spooled messages have been completely transmitted to the host.

Flow control of the spool transmit process is achieved in two ways. First, only one open transaction on the equipment is allowed during spool unload. Thus, if a message requires a reply, the equipment shall wait for that reply before transmitting the next spooled message. Messages which require no reply may be transmitted sequentially as rapidly as the message transfer mechanism will allow.

The second flow control method is to allow the host to limit the maximum number of messages sent from the spool in response to the S6,F23 request. An equipment constant named MaxSpoolTransmit may be set by the host to achieve this behavior. If MaxSpoolTransmit is set to five, for example, the equipment will send the first five messages from the spool and then transition to the NO SPOOL OUTPUT state, awaiting the next S6,F23 request. There is no event report generated when MaxSpoolTransmit is reached. The host is responsible for determining this situation by a) counting the messages received, b) timing out waiting for the next message, c) inquiring to the equipment for the curent value of the SpoolCountActual status variable, or d) some combination of the above. If MaxSpool-Transmit is set to zero, the spool shall be transmitted completely in response to S6,F23.

Normal spooling continues during the spool transmit process. If the SPOOL LOAD component should transition to SPOOL FULL, it shall not have any effect on the SPOOL UNLOAD component. Once full, the spool cannot make the transition back to SPOOL NOT FULL except via the SPOOL INACTIVE state. Space made available due to the spool unload process shall not be used in this case.

When a multi-block message is to be transmitted from the spool, any required inquire/grant transaction shall be initiated. If the host's response denies permission to send the multi-block message, the equipment shall discard that message and continue with the transmit process. This sequence shall count as one message in the MaxSpoolTransmit count.

There is one area where SPOOL LOAD and SPOOL UNLOAD may interact: When the spool is full and OverWriteSpool is True. During the spool transmit process, spooled messages are being removed and new primary messages are being written to the spool. These new messages are overwriting the oldest messages available, unless the unload process has freed sufficient spool space. There is a possibility that the unload and overwrite processes may compete for control of the same message area. For example, if the spool holds messages ABCDE, with A oldest and E newest, A might be sent to the host, B (and the space from A) overwritten by the new message F, C sent to the host, D and E (and the space from message C) overwritten by G, etc. The loss of continuity may be "disorienting" to the host program receiving the messages. It is expected that the unload process will be fast relative to the generation of new messages, so that this occurrence will be rare.

Should a communication failure occur during the spool transmit process, spooling shall continue as before the transmit process began. However, the spool unload sequence shall terminate (i.e., transition to NO SPOOL OUTPUT will occur — see transition table below).

PURGE SPOOL

The equipment shall discard all messages in the spool and, when the spool is empty, zero SpoolCountActual.

Spooling State Transitions

A table follows detailing all spooling state transitions as presented in the state transition diagram.

Table 4.11 Spooling State Transition

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	SPOOL INACTIVE	Communication state changes from COMMUNICATING to NOT COMMUNICATING or from WAIT CRA to WAIT DELAY and Enable Spool is true.	SPOOL ACTIVE	SpoolCountActual and SpoolCountTotal are initialized to zero. Any open transactions with the host are aborted. SpoolStartTime (SV) is set to current time. Alert the operator that spooling is active.	The default state in each AND substate is entered. The message which could not be sent remains in the send queue and is dealt with in Spool Active state. The collection event Spooling Activated has occurred.
2	SPOOL NOT FULL	Message generate which will not fit into spool area.	SPOOL FULL	SpoolFullTime (SV) is set to current time. Alert the operator that spool is full.	The message which would not fit into the spooling area is dealt with after the transition. No collection event is generated.
3	SPOOL OUTPUT	Spool area emptied.	SPOOL INACTIVE	Spooling process disabled. Alert the operator that spooling has been terminated.	The collection event Spooling Deactivated has occurred. Transition from the AND substate Spool Unload component occurs.
4	NO SPOOL OUTPUT	S6,F23 received w/RSDC = 1.	PURGE SPOOL	No action.	Initiates purging process. No collection event is generated since this is based on host request.
5	NO SPOOL OUTPUT	S6,F23 received w/RSDC = 0.	TRANSMIT SPOOL	No action.	Initiates message transmission from spool. No collection event is generated since this is based on host request.
6	TRANSMIT SPOOL	Communication failure or MaxSpoolTransmit reached.	NO SPOOL OUTPUT	Spool transmission process suspended.	If communications failure, the event Spool Transmit Failure has occurred. No collection event generated for MaxSpoolTransmit reached.
7	POWER ON	Equipment power source discontinued.	POWER OFF	No action.	Spooling context has been maintained in non-volatile storage prior to this transition.
8	POWER OFF	Equipment power source restored.	POWER ON	Spooling context restored from non-volatile memory.	If spooling were active prior to power down, it shall continue. If TRANSMIT SPOOL were active at powerdown, transition #6 is expected to follow since communications state is initially NOT COMMUNICATING.

4.11.3.2 *Enabling Spooling* — The equipment shall provide the host with the ability to enable and disable Spooling for any message (except Stream 1 messages (i.e., S1,F1, S1,F13)) via the S2,F43/F44 transaction. Spooling may be enabled for an entire Stream, for individual messages within a stream, or for any combination of the two. Streams and Functions not referenced in this message are not spooled. Spooling can be totally disabled by sending an S2,F43 with a zero length list for the first item (see S2,F43 definition). In addition, the equipment shall provide an equipment constant, EnableSpooling, to allow setting the enable or disable of spooling. NOTE: When EnableSpooling is false, the SPOOL state cannot transition from SPOOLINACTIVE to SPOOLACTIVE. Changing EnableSpooling does not change the spool state, purge the spool or change streams and functions enabled for spooling. Once the equipment is “SPOOL ACTIVE”, the host must initiate the spool unload sequence to restore full functionality even though "Enable Spooling" has changed to false.

4.11.4 *Requirements* — The following items are required to support the spooling capability:

- At a minimum, the equipment shall reserve for spooling non-volatile storage with sufficient capacity to store all of the primary SECS-II messages that would occur during a normal processing cycle.
- While spooling is enabled, the equipment shall reply to primary messages sent by the host with the appropriate secondary message.
- Secondary messages which cannot be delivered shall be discarded, never spooled.
- All spooling-related status variables and setup information (as per S2,F43) must be stored in non-volatile memory along with any other information required for the potential unloading of the spool area after a power loss.
- Upon powerup, the equipment shall retain all spooling context from the time the equipment was last shutdown or reset. This means that spooling, if previously active, continues upon system powerup.
- The Equipment must reject any message that attempts to set "Spooling" for Stream 1.
- If a multi-block primary message need for the inquire/grant is to be sent during SPOOL ACTIVE, the message should be placed in the spool and the grant resolved during spool transmit.

4.11.5 *Scenarios*

Define the Set of Messages to be Spooled:

This Scenario is used to set up the list of messages that the equipment should spool (or by defining none, to disable spooling).

```
COMMENTS                          HOST   EQUIPMENT                            COMMENTS

Host defines messages to be     S2,F43-->
spooled in case of communications
failure.
                                       <--S2,F44    Equipment acknowledges setup.
```

Define the Maximum Number of Messages to Send in Response to S6,F23:

This Scenario sets the value of the equipment constant MaxSpoolTransmit.

```
COMMENTS                          HOST   EQUIPMENT                            COMMENTS

Host sends value for            S2,F15-->
equipment constant MaxSpoolTransmit.
                                       <--S2,F16    Equipment acknowledges
                                                    equipment constant change.
```

Request or Delete Spooled Data (MaxSpoolTransmit = 0):

This Scenario is used to initiate the transfer of the spooled data from the equipment to the host or to purge the spool.

```
COMMENTS                          HOST    EQUIPMENT                           COMMENTS

                Communications were lost and then re-established.
Host requests data that
includes spool-related
status variables.                 S1,F3-->
                                          <--S1,F4     Send status data.
NOTE: S1,F3 is one of
various methods that
could be used. Request
or delete spooled data.          S6,F23-->
                                          <--S6,F24    Request spooled data
                                                       acknowledgement.
                                                       [IF] RSDC = 0 (Spool data
                                                       requested.)
                                                       [THEN]
                                                       The appropriate Streams and
                                                       Functions are used to transmit
                                                       the spooled data to the host.
                                                       [ELSE_IF] RSDC = 1
                                                       [THEN]
                                                       Spool data discarded.
                                                       [END_IF]
                                          <--S6,F11    Spooling Deactivated event
                                                       report sent.
Acknowledge                      S6,F12-->
```

Request or Delete Spooled Data (MaxSpoolTransmit > 0):

This Scenario shows the affect of MaxSpoolTransmit < SpoolCountActual on the Spool Transmit process. For the purpose of illustration, the value of MaxSpoolTransmit is 5 and the SpoolCountActual is 8 (at the time communications are re-established). No messages are added to the Spool during the transmit process.

```
COMMENTS                          HOST   EQUIPMENT                          COMMENTS

                Communications were lost and then re-established.
Host requests data that
includes spool-related
status variables.                  S1,F3-->
                                         <--S1,F4     Send status data (e.g.
                                                      SpoolCountActual = 8, MaxSpool-
                                                      Transmit = 5).
Host requests spooled data
(RSDC=0).                         S6,F23-->
                                         <--S6,F24    Request spooled data
                                                      acknowledgement.
                                                      The five oldest messages in the
                                                      Spool are transmitted to the
                                                      host. Spooling remains active.
Host recognizes that MaxSpoolTransmit
is reached.
Host requests additional          S6,F23-->
spooled data (RSDC = 0).
                                         <--S6,F24    Request spooled data
                                                      acknowledgement.
                                                      The three remaining messages
                                                      are transmitted from the spool.
                                         <--S6,F11    Spooling Deactivated event
                                                      report sent.
Acknowledge                       S6,F12-->
```

4.12 *Control* — The control-related capabilities allow for configuration and manipulation of the control state model. In this way the host and/or user may modify the equipment's control-related behavior.

4.12.1 *Purpose* — This section complements the CONTROL state model description found in Section 3.3. It defines the requirements for implementation of this model.

4.12.2 *Definitions* — None.

4.12.3 *Description*

4.12.3.1 *Control Configuration* — The control state model has two areas of configuration. The first area is related to default entry states of the state model. Upon system initialization, the system must activate either the ON-LINE or OFF-LINE state. Upon entry to OFF-LINE, the system must in turn activate one of the substates of OFF-LINE (EQUIPMENT OFF-LINE, ATTEMPT ON-LINE, or HOST OFF-LINE). In both these cases, the user shall configure the equipment to make the choices appropriate to that factory. Entry to the ON-LINE state also involves a choice of substates. In this case, the equipment reads the front panel REMOTE/LOCAL switch to determine the appropriate state.

The second area of configuration involves the transition to be made if the ON-LINE attempt should fail. The model may be set to transition to either HOST OFF-LINE or to EQUIPMENT OFF-LINE should the S1,F1 transaction be terminated unsuccessfully. Choosing HOST OFF-LINE allows the host to cause the equipment to transition to ON-LINE when the host becomes ready. This is accomplished via the message S1,F17 (see below).

4.12.3.2 *Changing Control State* — In the control state model, both the operator and the host can affect the control state. The operator retains ultimate authority to set the equipment OFF-LINE by means of an OFF-LINE switch mechanism. The operator also can cause the equipment to attempt to go ON-LINE. Under some circumstances, the host can initiate the transition to ON-LINE.

If the operator requests ON-LINE, the equipment will send an S1,F1 to the host. The host may confirm ON-

LINE with an S1,F2 or deny ON-LINE by sending an S1,F0.[23]

When the equipment is ON-LINE, the host may request that it transition to OFF-LINE. It will transition into the HOST OFF-LINE substate. When the equipment HOST OFF-LINE state is active, the host may request that it transition to ON-LINE. The combination of these two allow the host to cycle the equipment between ON-LINE and OFF-LINE.

Only the operator may change the ON-LINE substate (REMOTE or LOCAL).

4.12.4 *Requirements*

— The equipment shall supply a method for configuring the default CONTROL state to be activated upon system initialization. The choice of states must be among ATTEMPT ON-LINE, EQUIPMENT OFF-LINE, HOST OFF-LINE, and ON-LINE.

— The equipment shall supply a method for configuring which state should be activated when the attempt to go ON-LINE fails. The option is a transition to either the HOST OFF-LINE state or the EQUIPMENT OFF-LINE state.

— The equipment shall supply a momentary switch which will initiate the transition to OFF-LINE and another which will begin the process to go ON-LINE. Discrete position switches shall not be used. These should be designed so that they may not be actuated simultaneously. The switch may be mounted on the front panel or be available via keyboard input at the operator console.

— The equipment shall supply a discrete two-position switch which the operator may use to indicate the desired substate for ON-LINE (i.e., REMOTE or LOCAL). The switch may be mounted on the front panel or be available via keyboard input at the operator console. If implemented in software, this setting shall be retained in non-volatile storage.

— The equipment shall supply an indicator on the front panel which displays the full identification of the current CONTROL state/substate (e.g., OFF-LINE/ATTEMPT ON-LINE). This may be accomplished either with labelled display lights or via the operator console display. It is recommended that this indicator be visible at all times.

— The equipment shall supply a status variable that contains the current state/substate of the CONTROL state model.

— Whenever the ON-LINE/REMOTE state is active and the operator issues a command to the equipment, the equipment shall cause an “operator command issued” event.

23 If there is no host response (i.e. reply timeout), the equipment shall treat it as a denial.

4.12.5 *Scenarios*

4.12.5.1 *Operator-Initiated Scenarios*

Host Accepts ON-LINE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Operator actuates ON-LINE switch when equipment OFF-LINE state is active.			
		<--S1,F1	Equipment requests ON-LINE.
Host grants ON-LINE.	S1,F2-->		
		<--S6,F11	"Control State LOCAL (or REMOTE)" event.
Acknowledge.	S6,F12-->		

Host Denies ON-LINE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Operator actuates ON-LINE switch when equipment OFF-LINE state is active.			
		<--S1,F1	Equipment requests ON-LINE.
Host denies ON-LINE.	S1,F0-->		

Operator Sets OFF-LINE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Operator actuates OFF-LINE switch when equipment ON-LINE state is active.			
		<--S6,F11	"Equipment requests OFF-LINE" event.
Acknowledge.	S6,F12-->		

Operator Sets REMOTE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Operator sets switch from LOCAL to REMOTE.			
		<--S6,F11	"Control State REMOTE" event.
Acknowledge.	S6,F12-->		

Operator Sets LOCAL:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Operator sets switch from REMOTE to LOCAL.			
		<--S6,F11	"Control State LOCAL" event.
Acknowledge.	S6,F12-->		

4.12.5.2 *Host-Initiated Scenarios*

Host Sets OFF-LINE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host requests OFF-LINE.	S1,F15-->		
			[IF] Equipment is OFF-LINE
			[THEN]:
		<--S1,F0	Equipment does not process requests.
			[ELSE] Equipment ON-LINE
		<--S1,F16	Equipment acknowledges request and transitions to OFF-LINE.
		<--S6,F11	"Equipment OFF-LINE" event.
Acknowledge	S6,F12-->		
			[END_IF]

Host Sets ON-LINE:

COMMENTS	HOST	EQUIPMENT	COMMENTS
Host requests ON-LINE.	S1,F17-->		
			[IF] Equipment is HOST OFF-LINE state not active.
			[THEN]
		<--S1,F18	Equipment denies request (ONLACK = 1).
			[ELSE] Equipment HOST OFF-LINE state is active.
		<--S1,F18	Equipment acknowledges request (ONLACK != 1).
		<--S6,F11	"Control state LOCAL (or REMOTE)" event. (only if ONLACK = 0)
Acknowledge	S6,F12-->		
			[END_IF]

5 Data Items

The following sections specify which data items and variable data items are required.

Except for the specified format restrictions, all data items and variable data items follow the definitions contained in SEMI E5.

5.1 *Data Item Restrictions* — The following is a subset of the data items used by SECS-II messages specified in this standard. Each data item listed in this section is restricted in its SEMI E5-defined usage. Most are limited to a single format from their standard list of formats. Data items used by SECS-II messages contained in this document, but which have no restrictions are not duplicated here.

NOTE 21: One data item, ALCD, is restricted in other than its format. Take note of this restriction as described below.

NOTE 22: The equipment supplier shall document any restrictions on length or format of CPNAME. Suppliers shall document the behavior of spaces in a CPNAME. The maximum length of CPNAME shall be 40. This change became effective in September 1995.

ACKC7A	Format: 51
ALCD	Only bit 8 (alarm set/cleared) of the binary byte is used. Bits 1–7, denoting alarm category, are not used.
ALID	Format: 5()
CCODE	Format: 52
CEID	Format: 5()
CPNAME	Format: 20
DATAID	Format: 5()
DATALENGTH	Format: 5()
ECID	Format: 5()
LENGTH	Format: 5()
PPID	Format: 20
RCMD	Format: 20
REPGSZ	Format: 5()
RPTID	Format: 5()
SEQNUM	Format: 52
SMPLN	Format: 5()
SVID	Format: 5()
TEXT	Format: 20
TOTSMP	Format: 5()
TRID	Format: 5()
VID	Format: 5()

5.2 *Variable Item List* — The following variable data items from the Variable Item Dictionary in SEMI E5 are required. Format restrictions are noted.

DVVAL's:

AlarmID Format: 5()
EventLimit
LimitVariable
PPChangeName Format: 20
PPChangeStatus
PPError
RcpChangeName
RcpChangeStatus
TransitionType

ECV's:

EstablishCommunicationsTimeout
MaxSpoolTransmit
OverWriteSpool
TimeFormat

SV's:

AlarmsEnabled
AlarmsSet
Clock
ControlState
EventsEnabled
PPError
PPExecName Format: 0,20
PPFormat
PreviousProcessState
ProcessState
RcpExecName
SpoolCountActual
SpoolCountTotal
SpoolFullTime
SpoolStartTime

6 Collection Events

Table 6.1 provides the list of collection events required to support the capabilities addressed within this standard. Also shown are typical variable data that would most likely be included in the associated collection event report and a reference to the event trigger and to the appropriate section of the standard.

This list does not represent all events that might be needed to properly monitor/control equipment. Many events are unique to the specific equipment characteristics. The needed additions are a matter for other standards and for collaboration between equipment supplier and user.

See Section 5.2 for further detail of variable data items.

Table 6.1 GEM-Defined Collection Events

Event Designation	*Typical Variable Data*	*Reference*
Control-Related Events:		Section 3.3
Equipment OFF-LINE	ControlState, Clock	ON-LINE->OFF-LINE
Control State LOCAL	ControlState, Clock	REMOTE->LOCAL or OFF-LINE->LOCAL
Control State REMOTE	ControlState, Clock	LOCAL->REMOTE or OFF-LINE->REMOTE
Operator Command Issued	OperatorCommand	Operator Activity while REMOTE state is active.
Processing-Related Events:	Note: Any transition in the implemented processing state model must have a corresponding collection event.	Section 3.4
Processing Started	Clock, PreviousProcessState	Entry into EXECUTING state.
Processing Completed	Clock, PreviousProcessState	Normal exit of EXECUTING state.
Processing Stopped	Clock, PreviousProcessState	Result of STOP command from host or operator.
Processing State Change	Clock, ProcessState, PreviousProcessState	Any processing state transition.
Alarm Management Events:		Section 4.3
Alarm_nDetected	Clock, AlarmID, AlarmsSet, Associated variable data	ALARM_nCLEAR->ALARM_nSET
Alarm_nCleared	Clock, AlarmID, AlarmsSet	ALARM_nSET->ALARM_nCLEAR
Equipment Constant Events:		Section 4.5
Operator Equipment Constant Change	ECID	Operator activity
Limits Monitoring:		Section 4.2.4
Limit Zone Transition_n (separate CEID per variable)	Clock, LimitVariable, EventLimit, Transition Type	Entry into BELOW LIMIT or ABOVE LIMIT states.
Process Program Management Events:		Section 4.6
Process Program Change	PPChangeName, PPChangeStatus	Operator activity
Process Program(s) Selected	PPExecName	Operator/Host activity
Material Movement Events:		Section 4.7
Material Received	Clock	
Material Removed	Clock	
Spooling Events:		Section 4.11
Spooling Activated	SpoolStartTime	SPOOL INACTIVE->SPOOL ACTIVE
Spooling Deactivated	SpoolCountTotal	SPOOL OUTPUT->SPOOL INACTIVE
Spool Transmit Failure	Clock, SpoolCountActual SpoolCountTotal	TRANSMIT SPOOL->NO SPOOL OUTPUT
Terminal Services Events:		Section 4.8
Message Recognition	Clock	Operator
New Execution Recipe Event	RcpChangeName, RcpChangeStatus	Section 4.6.2.2
Execution Recipe Change Event	RcpChangeName, RcpChangeStatus	Section 4.6.2.2

7 SECS-II Message Subset

This section lists the required set of SECS-II messages as referenced in this document. Definitions for these messages can be found in SEMI E5. All primary messages (for which SEMI E5 defines replies) should have replies available. Replies are required or optional as specified in SEMI E5.

STREAM 1: Equipment Status

S1,F1 Are You There Request (R)	S,H<->E
S1,F2 On-Line Data (D)	S,H<->E
S1,F3 Selected Equipment Status Request (SSR)	S,H->E
S1,F4 Selected Equipment Status Data (SSD)	M,H<-E
S1,F11 Status Variable Namelist Request (SVNR)	S,H->E
S1,F12 Status Variable Namelist Reply (SVNRR)	M,H<-E
S1,F13 Establish Communications Request (CR)	S,H<->E
S1,F14 Establish Communications Request Acknowledge (CRA)	S,H<->E
S1,F15 Request OFF-LINE (ROFL)	S,H->E,reply
S1,F16 OFF-LINE Acknowledge (OFLA)	S,H<-E
S1,F17 Request ON-LINE (RONL)	S,H->E,reply
S1,F18 ON-LINE Acknowledge (ONLA)	S,H<-E

STREAM 2: Equipment Control and Diagnostics

S2,F13 Equipment Constant Request (ECR)	S,H->E
S2,F14 Equipment Constant Data (ECD)	M,H<-E
S2,F15 New Equipment Constant Send (ECS)	S,H->E
S2,F16 New Equipment Constant Acknowledge (ECA)	S,H<-E
S2,F17 Date and Time Request (DTR)	S,H<->E
S2,F18 Date and Time Data (DTD)	S,H<->E
S2,F23 Trace Initialize Send (TIS)	S,H->E
S2,F24 Trace Initialize Acknowledge (TIA)	S,H<-E
S2,F29 Equipment Constant Namelist Request (ECNR)	S,H->E
S2,F30 Equipment Constant Namelist (ECN)	M,H<-E
S2,F31 Date and Time Send (DTS)	S,H->E
S2,F32 Date and Time Acknowledge (DTA)	S,H<-E
S2,F33 Define Report (DR)	M,H->E
S2,F34 Define-Report Acknowledge (DRA)	S,H<-E
S2,F35 Link Event Report (LER)	M,H->E
S2,F36 Link Event Report Acknowledge (LERA)	S,H<-E
S2,F37 Enable/Disable Event Report (EDER)	S,H->E,reply

S2,F38 Enable/Disable Event Report Acknowledge (EDEA)	S,H<-E
S2,F39 Multi-Block Inquire (DMBI)	S,H->E
S2,F40 Multi-Block Grant (DMBG)	S,H<-E
S2,F41 Host Command Send (HCS)	S,H->E
S2,F42 Host Command Acknowledge (HCA)	S,H<-E
S2,F43 Reset Spooling Streams and Functions (RSSF)	S,H->E
S2,F44 Reset Spooling Acknowledge (RSA)	M,H<-E
S2,F45 Define Variable Limit Attributes (DVLA)	M,H->E
S2,F46 Variable Limit Attribute Acknowledge (VLAA)	M,H<-E
S2,F47 Variable Limit Attribute Request (VLAR)	S,H->E
S2,F48 Variable Limit Attributes Send (VLAS)	M,H<-E
S2,F49 Enhanced Remote Command	M,H->E
S2,F50 Enhanced Remote Command Acknowledge	M,H<-E

STREAM 5: Exception (Alarm) Reporting

S5,F1 Alarm Report Send (ARS)	S,H<-E
S5,F2 Alarm Report Acknowledge (ARA)	S,H->E
S5,F3 Enable/Disable Alarm Send (EAS)	S,H->E
S5,F4 Enable/Disable Alarm Acknowledge (EAA)	S,H<-E
S5,F5 List Alarms Request (LAR)	S,H->E
S5,F6 List Alarm Data (LAD)	M,H<-E

STREAM 6: Data Collection

S6,F1 Trace Data Send (TDS)	S,H<-E
S6,F2 Trace Data Acknowledge (TDA)	S,H->E
S6,F5 Multi-block Data Send Inquire (MBI)	S,H<-E
S6,F6 Multi-block Grant (MBG)	S,H->E
S6,F11 Event Report Send (ERS)	M,H<-E
S6,F12 Event Report Acknowledge (ERA)	S,H->E
S6,F15 Event Report Request (ERR)	S,H->E
S6,F16 Event Report Data (ERD)	M,H<-E
S6,F19 Individual Report Request (IRR)	S,H->E
S6,F20 Individual Report Data (IRD)	M,H<-E
S6,F23 Request Spooled Data (RSD)	S,H->E
S6,F24 Request Spooled Data Acknowledgement Send (RSDAS)	S,H<-E

STREAM 7: Process Program Load

S7,F1 Process Program Load Inquire (PPI)	S,H<->E, reply
S7,F2 Process Program Load Grant (PPG)	S,H<->E
S7,F3 Process Program Send (PPS)	M,H<->E
S7,F4 Process Program Acknowledge (PPA)	S,H<->E
S7,F5 Process Program Request (PPR)	S,H<->E
S7,F6 Process Program Data (PPD)	M,H<->E
S7,F17 Delete Process Program Send (DPS)	S,H->E
S7,F18 Delete Process Program Acknowledge (DPA)	S,H<-E
S7,F19 Current EPPD Request (RER)	S,H->E
S7,F20 Current EPPD Data (RED)	M,H<-E
S7,F23 Formatted Process Program Send (FPS)	M,H<->E
S7,F24 Formatted Process Program Acknowledge (FPA)	S,H<->E
S7,F25 Formatted Process Program Request (FPR)	S,H<->E
S7,F26 Formatted Process Program Data (FPD)	M,H<->E
S7,F27 Process Program Verification Send (PVS)	S,H<-E
S7,F28 Process Program Verification Acknowledge (PVA)	S,H->E
S7,F29 Process Program Verification Inquire (PVA)	
S7,F30 Process Program Verification Grant (PVG)	

STREAM 9: System Errors

S9,F1 Unrecognized Device ID (UDN)	S,H<-E
S9,F3 Unrecognized Stream Type (USN)	S,H<-E
S9,F5 Unrecognized Function Type (UFN)	S,H<-E
S9,F7 Illegal Data (IDN)	S,H<-E
S9,F9 Transaction Timer Timeout (TTN)	S,H<-E
S9,F11 Data Too Long (DLN)	S,H<-E
S9,F13 Conversation Timeout (CTN)	S,H<-E

STREAM 10: Terminal Services

S10,F1 Terminal Request (TRN)	S,H<-E
S10,F2 Terminal Request Acknowledge (TRA)	S,H->E
S10,F3 Terminal Display, Single (VTN)	S,H->E
S10,F4 Terminal Display, Single Acknowledge (VTA)	S,H<-E
S10,F5 Terminal Display, Multi-block (VMN)	M,H->E
S10,F6 Terminal Display, Multi-block Acknowledge (VMA)	S,H<-E
S10,F7 Multi-block Not Allowed (MNN)	S,H<-E

STREAM 14: Object Services

S14,F1 GetAttr Request	S,H <-> E
S14,F2 GetAttr Data	M,H <-> E

STREAM 15: Recipe Management

S15,F1 Recipe Management Multi-block Inquire	S,H <-> E
S15,F2 Recipe Management Multi-block Grant	S,H <-> E
S15,F21 Recipe Action Request	M,H <-> E
S15,F22 Recipe Action Acknowledge	M,H <-> E
S15,F27 Recipe Download Request	M,H -> E
S15,F28 Recipe Download Acknowledge	M,H <- E
S15,F29 Recipe Verify Request	M,H -> E
S15,F30 Recipe Verify Data	M,H <- E
S15,F31 Recipe Upload Request	S,H -> E
S15,F32 Recipe Upload Data	M,H <- E
S15,F35 Recipe Delete Request	M,H -> E
S15,F36 Recipe Delete Acknowledge	M,H <- E

8 GEM Compliance

This section defines compliance to the GEM standard. It describes the fundamental GEM requirements and additional GEM capabilities. It provides references to other sections of the standard where detailed requirements are located. This section also defines standard terminology and documentation that can be used by equipment suppliers and device manufacturers to describe compliance with this standard.

The GEM standard contains two types of specifications:

— fundamental GEM requirements and

— requirements pertaining to additional GEM capabilities.

The fundamental GEM requirements form the foundation of the GEM standard. The additional GEM capabilities provide functionality required for some types of factory automation or functionality applicable to specific types of equipment. Figure 8.1 illustrates the relationship of the fundamental GEM requirements and the additional GEM capabilities.

8.1 *Fundamental GEM Requirements* — All equipment shall comply with the fundamental GEM requirements listed in Table 8.1. Compliance to these requirements involves precise and complete adherence to all sections of the GEM standard referenced in Table 8.1.

Table 8.1 Fundamental GEM Requirements

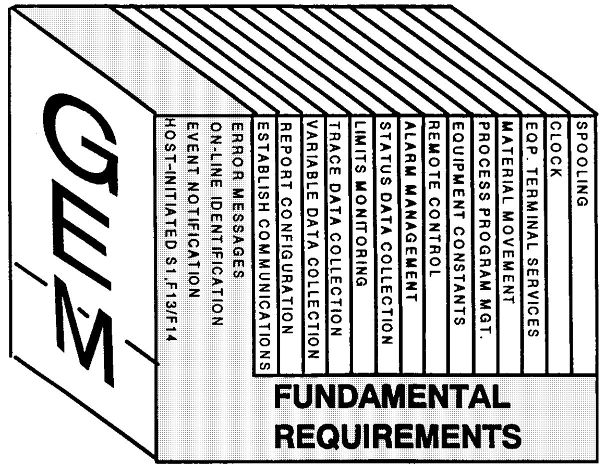
Requirement	*Section References*
State Models	3.0, 3.1, 3.3
Equipment Processing States	3.4
Host-Initiated S1,F13/F14 Scenario	4.1.5.1
Event Notification	4.2.1.1
On-line Identification	4.2.6
Error Messages	4.9
Control (Operator-Initiated)	4.12 (except 4.12.5.2)
Documentation	8.4

In addition, compliance requires adherence to the portions of the following sections that are applicable to the fundamental GEM requirements:

— Variable data items (GEM, Section 5)

— SECS-II data item restrictions (GEM, Section 5)

— Collection events (GEM, Section 6)



Vertical text represents capabilities.
Some capabilities are also fundamental requirements.

Figure 8.1
GEM Requirements and Capabilities

8.2 *GEM Capabilities* — The following table lists all GEM capabilities and the sections of the GEM standard where they are specified. These sections contain the detailed requirements for implementing a GEM capability. Requirements for an individual capability include any referenced portions of the document. As an example, the Alarm Management capability requires implementation of the status variables “AlarmsEnabled” and “AlarmsSet” as defined in Section 5.

Table 8.2 Section References for GEM Capabilities

Capability	*Section References*
Establish Communications	4.1, 3.2
Event Notification	4.2.1.1
Dynamic Event Report Configuration	4.2.1.2
Variable Data Collection	4.2.2
Trace Data Collection	4.2.3
Limits Monitoring	4.2.4
Status Data Collection	4.2.5
On-line Identification	4.2.6
Alarm Management	4.3
Remote Control	4.4
Equipment Constants	4.5
Process Program Management	4.6
Material Movement	4.7
Equipment Terminal Services	4.8
Error Messages	4.9
Clock	4.10

Capability	Section References
Spooling	4.11
Control (Operator-Initiated)	4.12 (except 4.12.5.1)
Control (Host-Initiated)	4.12.5.1

8.3 *Definition of GEM Compliance* — The term "GEM Compliance" is defined with respect to individual GEM capabilities to indicate adherence to the GEM standard for a specific capability. Equipment is GEM-compliant for a specific GEM capability if, and only if, the following three criteria are met:

— The fundamental GEM requirements are satisfied.

— The capability is implemented to conform with all applicable definitions, descriptions, and requirements defined for the capability in this standard.

— The equipment does not exhibit behavior related to this capability that conflicts with the GEM behavior defined for the capability.

For example, equipment that provides SECS-II messages for management of process programs must precisely implement the GEM Process Program Management capability to be "GEM-Compliant for Process Program Management."

Equipment may supply additional functionality not specified in the GEM standard by using any messages defined in the SECS-II standard as long as the additional functionality does not conflict with compliance to GEM capabilities.

Figure 8.2 illustrates the host view of equipment communications in relationship to the components of the GEM standard. The GEM capabilities are built upon the fundamental GEM requirements and present GEM-compliant behavior to the host when they are not obstructed by conflicting functionality. Additional non-GEM capabilities and non-obstructing extensions to GEM capabilities provide additional functionality while maintaining GEM behavior from the host view.

One additional term is defined to facilitate discussion of GEM capability. Equipment is "Fully GEM Capable" if and only if it meets the following two criteria:

— The equipment supplies all the GEM capabilities listed in Section 8.2.

— Every implemented GEM capability is GEM-Compliant.

8.4 *Documentation* — This section describes documentation requirements in addition to those specified in Sections 3 and 4 of this standard. All documentation of the SECS-II interface shall be supplied as a single volume, including Message Documentation, a Compliance Statement and the documentation required by Sections 3 and 4.

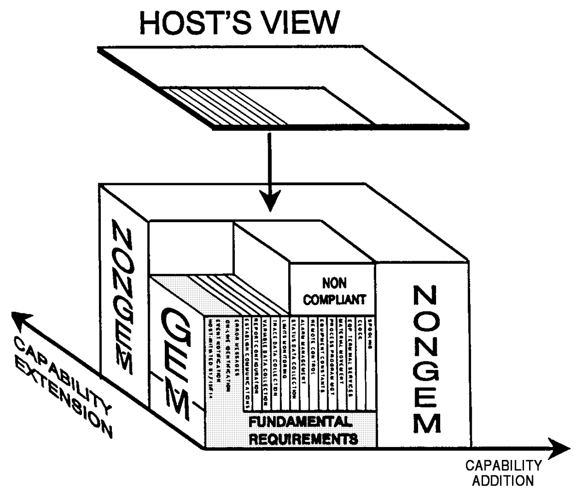


Figure 8.2
Host View of GEM

8.4.1 *Message Documentation* — The equipment supplier shall provide message documentation in conformance with Chapter 8 (Message Documentation) of SEMI E5.

8.4.2 *GEM Compliance Statement* — The SECS-II interface documentation provided by an equipment supplier shall address GEM compliance. This documentation shall include a GEM Compliance Statement that accurately indicates for each capability whether it has been implemented and whether it has been implemented in a GEM-compliant manner. The format for this statement is supplied as Table 8.3.

The table consists of three columns. The first column lists the requirements and capabilities. The other two columns pose questions to the supplier:

Implemented: Does the equipment provide functionality that is similar to that defined for the GEM requirement or capability?

GEM-Compliant: Has that requirement or capability been implemented in a GEM-compliant manner?

8.4.3 The equipment supplier may provide documentation on the format of required data items (see Section 5) using SECS Message Language™ Notation (SML®). The SML formats are provided in Table 8.4.

Table 8.3 GEM Compliance Statement

GEM COMPLIANCE STATEMENT				
FUNDAMENTAL GEM REQUIREMENTS	**IMPLEMENTED**		**GEM-COMPLIANT**	
State Models	❒ Yes	❒ No	❒ Yes (See NOTE 1.) ❒ No	
Equipment Processing States	❒ Yes	❒ No		
Host-Initiated S1= F13/F14 Scenario	❒ Yes	❒ No		
Event Notification	❒ Yes	❒ No		
On-Line Identification	❒ Yes	❒ No		
Error Messages	❒ Yes	❒ No		
Documentation	❒ Yes	❒ No		
Control (Operator Initiated)	❒ Yes	❒ No		
ADDITIONAL CAPABILITIES	**IMPLEMENTED**		**GEM-COMPLIANT** (See NOTE 2.)	
Establish Communications	❒ Yes	❒ No	❒ Yes	❒ No
Dynamic Event Report Configuration	❒ Yes	❒ No	❒ Yes	❒ No
Variable Data Collection	❒ Yes	❒ No	❒ Yes	❒ No
Trace Data Collection	❒ Yes	❒ No	❒ Yes	❒ No
Status Data Collection	❒ Yes	❒ No	❒ Yes	❒ No
Alarm Management	❒ Yes	❒ No	❒ Yes	❒ No
Remote Control	❒ Yes	❒ No	❒ Yes	❒ No
Equipment Constants	❒ Yes	❒ No	❒ Yes	❒ No
Process Program Management	❒ Yes	❒ No	❒ Yes	❒ No
Material Movement	❒ Yes	❒ No	❒ Yes	❒ No
Equipment Terminal Services	❒ Yes	❒ No	❒ Yes	❒ No
Clock	❒ Yes	❒ No	❒ Yes	❒ No
Limits Monitoring	❒ Yes	❒ No	❒ Yes	❒ No
Spooling	❒ Yes	❒ No	❒ Yes	❒ No
Control (Host-Initiated)	❒ Yes	❒ No	❒ Yes	❒ No

NOTE 1: Do not mark YES unless all fundamental GEM requirements are implemented and GEM-compliant.

NOTE 2: Additional capabilities may not be marked GEM-compliant unless the fundamental GEM requirements are GEM-compliant.

Table 8.4 SML Notation

Item Format	*SECS-II Format Code*		*SML Item Format Mnemonic*
	Binary	*Octal*	
LIST	000000	00	L [length]
Binary	001000	10	B
Boolean	001001	11	BOOLEAN
ASCII	010000	20	A [length] or A [min., max.]
JIS-8	010001	21	J [length] or J [min., max.]
8-byte integer (signed)	011000	30	I8
1-byte integer (signed)	011001	31	I1
2-byte integer (signed)	011010	32	I2
4-byte integer (signed)	011100	34	I4
8-byte floating point	100000	40	F8
4-byte floating point	100100	44	F4
8-byte integer (unsigned)	101000	50	U8
1-byte integer (unsigned)	101001	51	U1
2-byte integer (unsigned)	101010	52	U2
4-byte integer (unsigned)	101100	54	U4

A. Application Notes

NOTE: The material contained in these Application Notes is not an official part of this SEMI standard and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information describing possible methods for implementing the protocol described by the standard and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the materialis solely the responsibility of the user.

A.1 Factory Operational Script

An Operational Script is a series of capabilities arranged in a typical factory operation sequence. The intent of having an Operational Script is to help put the SECS-II message Scenarios into a context. Although this context will vary, it represents a typical operational sequence found in most semiconductor device manufacturers' applications.

— System Initialization

— Synchronization

— Machine Setup

— Production Setup

— Processing

— Post-Processing

— Shutdown

The following script is not intended to be complete, but to serve as an example to be further developed on an implementation basis.

A1.1 *Anytime Capabilities* — All capabilities can generally occur at anytime during the operational script sequence.

A1.2 *System Initialization and Synchronization* — Upon system initialization, the default setting for communication (enabled or disabled) becomes effective, as well as any equipment constants or other information retained in non-volatile storage. The initial communication status is displayed at the equipment.

Assuming the communication state is enabled, the equipment will attempt to establish communication with a host computer. See Section 4.1 for a description of the scenario for establishing communications.

Upon receiving an indication that the equipment was previously not communicating, the host would typically perform synchronization activities including setting the equipment's clock and requesting selected status information. Note that synchronization activity is host application-dependent and may be implemented using various scenarios.

A1.3 Production Set-Up — The host typically has the following information:

— what material

— what process step

— what process program to use (PPID)

— current equipment status, VID's, SVID's

— data collection requirements (trace data & event data)

— VID's needed

— Equipment constants (ECID's)

Based upon the above information, the host will perform setup activities as required. It must be verified that the correct process program is available and selected at the equipment.

A1.3.1 *Auxiliary Material and Manual Set-Up* — Auxiliary material can be checked and verified at this point. If status variables exist for auxiliary material, they may be requested by the host.

Any other manual, non-process, and/or non-product specific set-up also may take place at this point. The operator may interact with the equipment and the host. If the operator interacts with the equipment, the equipment communications link with the host should stay operational.

The operator and the host may exchange information via equipment terminal services.

A1.3.2 *Product/Process Set-Up* — Specific product and/or process information is communicated to the equipment prior to processing material.

A1.3.3 *Material Load* — The host may instruct an operator or a material handling system to deliver material to the equipment.

Once the material has arrived at the equipment, the equipment or the operator will notify the host.

A1.3.4 *Production Data Collection Set-Up* — The host instructs the equipment to collect event-based data. Reports are defined and linked to events. Event reports can be enabled or disabled.

The host instructs the equipment to collect data from the equipment based on time intervals.

The host configures the equipment to monitor specific variables and to send event reports when variables transition between monitoring zones.

A1.4 *Processing*

A1.4.1 *Start Process Executing* — The host or operator issues a command to start.

A1.4.2 *Equipment Signals End of Run* — When process execution is completed, the equipment generates events. If any of the events are enabled, they will be sent as event reports.

A1.5 *Post-Processing* — The equipment has completed processing material. It now makes the material available to the operator or material handling system for removal. The equipment signals the host that it is available for more work.

A1.5.1 *Material Unload* — Material is unloaded from the equipment by an operator or material handling system.

A.2 Equipment Front Panel

In the GEM standard, several requirements are stated that involve the display or input of information at the equipment front panel. The "equipment front panel" refers to an area on the equipment that is available to the operator under normal use (i.e., without removing maintenance access panels). This may include a CRT display, keyboard, switches, and lights.

This application note provides some guidance for implementation of the GEM front panel capabilities. All of these requirements map directly to state models and capabilities defined in Sections 3 and 4. All capabilities may be implemented in either hardware (buttons, switches, lights) or in a software/CRT equivalent.

A2.1 *Displays and Indicators* — The intent of various displays is to inform the operator of either the current state of the equipment or of a recent change of state (or both). Therefore, it is most useful if these displays are continuously visible and easily recognized at a distance. Required displays/indicators include:

Communications State: This means that three distinct states must be represented: DISABLED, ENABLED/NOT COMMUNICATING, and ENABLED/COMMUNICATING.

Terminal Services: An "New Host Message" indicator must be supplied.

A2.2 *Switches/Buttons* — Note that discrete switches also contain information for the user. However, these tend to represent the desired states of the operator/user. The equipment's response to a change of a switch may not be instantaneous. Still, the current position of switches should be available to the operator.

It may be appropriate to limit the access to some switches and buttons. This might be done via any of the standard methods, keys, passwords, combinations, etc. This is especially true for system default switches that would not often be changed. Required switches/buttons include:

Communications State System Default: In what communications state should the equipment be when system initialization is complete? The choices are DISABLED and ENABLED.

Communications State Selector: This is a toggle or button that will initiate a transition from ENABLED to DISABLED or vice versa.

Message Recognition Button: This button is used to initiate an event message to the host which indicates that the "New Host Message" has been read. This button should function only when the New Host Message Indicator is activated and when the received message is displayed in the terminal display.

A.3 Examples of Equipment Alarms

Table A.3 provides alarm examples pertaining to various configurational aspects of equipment.

NOTE: It is important to stress that these are just examples intended to illustrate that alarms pertain to situations in which there exists a potential for exceeding physical safety limits associated with people, equipment, and material being processed as per the GEM definition of an alarm.

NOTE: The alarm capability is intended as an addition to standard safety alarms (e.g., lights, horns). There is no intent to replace direct operator reaction to such problems. Nor is there the expectation that the host can necessarily prevent or directly address such alarms.

An actual machine shall have an associated set of alarms defined by the manufacturer that pertains to its specific configuration and design. The equipment manufacturer is responsible for supplying documentation associated with these alarm definitions.

Table A.3 Alarm Examples Per Equipment Configuration

Subsystem	*Alarm Description*	*ALID*	*Trigger*	*Reset*	*Operator*	*Equipment*	*Material*
Mainframe Power Supply	Overvoltage		Voltage supply over maximum limit			X	
	Undervoltage		Voltage supply under minimum limit			X	
Internal Power Distribution Bus	AC Low		AC under minimum limit			X	X
Cooling System	Overtemp		Temperature over maximum		X		X
	Pressure Low		Pressure below minimum				X

Subsystem	The subsystem of the equipment to which the alarm is related
Alarm Description	Description of the alarm
ALID	The Alarm ID as specified by SECS-II
Trigger	Text description of what caused the alarm
Reset	Description of how to resolve the alarm condition
Affected	Who or what is affected by the alarm trigger: Operator, Equipment, and Material

A.4 Trace Data Collection Example

This example shows an implementation of the Trace Data Collection capability defined in Section 4.2.3.

S2,F23 sent by host:

```
    TRID = ABCD
    DSPER = 000100 (One minute per
 period)
    TOTSMP = 9
    REPGSZ = 3
    SVID1 =  Temperature
    SVID2 =  Relative humidity
```

S6,F1 looks like this (starting at time 1 a.m.):

1st transmission <L,4>

```
    1. ABCD (trace ID)
    2. 3 (last sample of the
 transmission)
    3.    88   5   01   01   03   00
        Year Month Day  Hour Min  Sec
    4. <L, n> n = 2 SVID's x REPGSZ of
       3 = 2 x 3 = 6
       72 (temperature)
       0.29 (relative humidity)
       73 (temp.)
       0.30 (r.h.)
       71 (temp.)
       0.30 (r.h.)
```

2nd transmission <L,4>

```
    1. ABCD
    2. 6
    3. 88  05  01  01  06  00
                   hr  min
    4. <L,6>
          73
          0.31
          71
          0.32
          71
          0.31
```

3rd and last transmission <L,4>

```
1. ABCD
2. 9
3. 88  05  01  01  09  00
               hr  min
4. <L,6>
   71
   0.30
   72
   0.30
   71
   0.31
```

A.5 Harel Notation

Harel's statecharts extend traditional state-transition diagrams with several additional concepts, most important of which are hierarchy and concurrence. Statecharts depict the behavior of a system by showing states it may take, events that prompt a change of state, and the composition of states. What follows is a very brief description of the symbols defined for use and how these are useful to describe a system. See Figure A.5.1 for the basic notational symbols.

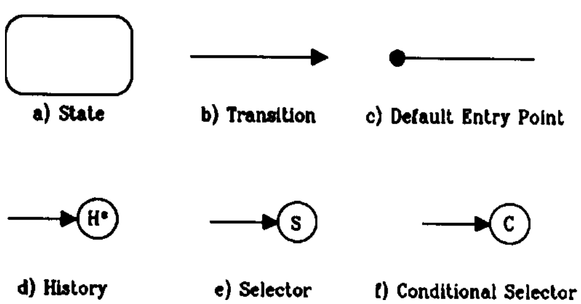


Figure A.5.1
Harel Statechart Symbols

States are represented by rounded boxes. A state transition is shown graphically with a line from the old state terminating with the arrow symbol at the new state. Transitions are unidirectional-while the reverse transition may be possible, it is considered a different transition with different conditions for initiation and different resultant actions.

States may be subdivided into substates to facilitate more concise definition of behavior. Thus, a hierarchy is defined whereby any state may be a substate of some parent state and in turn be the parent of its own substates. Substates must be one of two types, termed AND substates and OR substates.

A parent maybe divided into two or more OR substates of which one and only one is the active substate at any time. The accepted term for this exclusivity is XOR. Figure A.5.2 gives an example of a simple case of OR substates. In this example, some system (perhaps a motor) has a state named FUNCTIONAL. When the motor is FUNCTIONAL, it may be either ON or OFF, but never both.

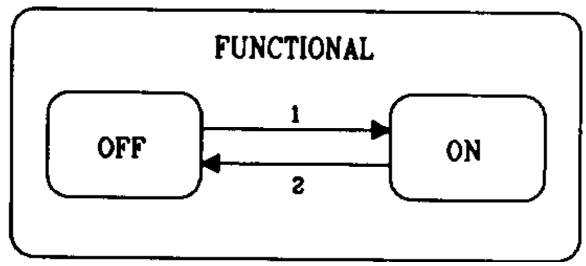


Figure A.5.2
Example of OR Substates

Another way of dividing a parent state corresponds roughly to subsystems. These AND substates represent parallelism, such that every AND substate of an active parent state is considered active. Harel also uses the term "Orthogonal Component" to refer to AND substates. However, these parallel substates tend to be highly interactive and interdependent. For this reason, the word orthogonal is considered confusing and has been excluded from use in this document. Figure A.5.3 shows an example of AND substates representing (in part) an automobile. Note the convention of attaching the name of the parent state AUTOMOBILE to the outside of the state in a small box. The substates shown are independent components and may have their own substates (of either the AND or OR type):

— LIGHTS may be ON or OFF;

— DOOR may be OPEN or CLOSED;

— ENGINE is constructed of components such as pumps, pistons, carburetor, etc.

Exiting one of a set of AND substates requires the exit of all others. In some cases, a transition arrow will be shown from only one of the substates with the others implied.

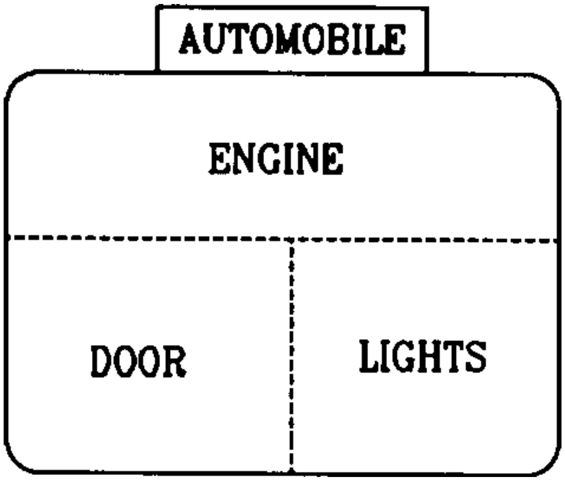


Figure A.5.3
Example of AND Substates

A simplification that also helps to prevent in determinacy is implemented with the symbol for default entry point. This symbol will indicate which OR substate is initially active when there is not an explicit choice. This lack of specification is indicated by a transition arrow from one state to another that does not cross the boundary of the parent to point specifically to a substate.

An entrance to a state terminating in a history symbol (see Figure A.5.1) indicates that the OR substate to be entered should be that which was active the last time the parent state was active (i.e., last time the car was running, the radio was on). The history symbol H refers to the choice of substates of the parent. The symbol H* extends further to the lowest level substates defined. In the absence of memory of a "last time", the default entry is used.

The selector and conditional selector symbols serve to abbreviate complex entrances to states. Their meaning is similar and indicate that the choice of OR substate upon entry of a parent state depends on some condition that is not shown. The selector is usually used to combine several similar transition events, while the conditional selector will typically require some computation or test of conditions external to the stimulus for state transition. Please examine the referenced article for more detail.

NOTE: Within the body of this document, the term statechart is not used in favor of the more traditional term state diagram.

A5.1 *State Definitions* — The state diagram provides a concise description of the function of a system. However, a full definition requires detail that cannot be included on the diagram. A description of each state is required that covers the boundaries of the state and any responses that occur within that state to the environment. The convention in this document is to provide state names in ALL CAPS to help the reader identify where these are used. A sample state description of the ON state depicted in the Figure A.5.2 might be:

ON

The switch is in the on position. Power is available to the motor. Speed of the motor will change in proportion to the speed knob adjustment.

A5.2 *Transition Table* — The last piece of the state model is the transition table. It consists of several columns that list the transition number from the diagram, the starting and ending state for the transition, and three columns titled trigger, action, and comment. The trigger column describes the combination of events and conditions that initiates the transition (e.g., message Sx,Fy received). The trigger should be related to a single clearly defined event at the equipment. The action column identifies the activities associated directly with the transition. These activities may be of three types: a) actions taken upon exit of the old state, b) actions taken upon entry to the new state, and c) actions not associated with either state. These are not differentiated in this document. The final column allows for additional comments that help to clarify the transition. Table A.5, an example of transition table, illustrates the motor example in Figure A.5.2.

Table A.5 Transition Table for Motor Example

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	OFF	Switch turned to on position.	ON	Power supplied to motor.	Power supply assumed available. Motor begins to turn.
2	ON	Switch turned to off position.	OFF	Power supply to motor dis-connected.	Motor begins deceleration.

A.6 Example Control Model Application

This section provides one example of a host's interaction with an equipment's control model. A host system must have a view of the control model to understand and predict equipment behavior. However, the implementor may simplify the host's view by assuming that some configuration settings are fixed and that the host-initiated features are not implemented. Applying these assumptions simplifies the behavior the host expects to see.

Figure A.6.1 shows the effective control model[24] based on the following host assumptions:

— The fundamental requirements are met, but the additional host-intiated control capability is not implemented.

— The configuration for the default entry to CONTROL is set to an OFF-LINE substate (either ATTEMPT ON-LINE or EQUIPMENT OFF-LINE).

— The destination state for transition 4 (failure of S1,F1 transaction) is configured to EQUIPMENT OFF-LINE.

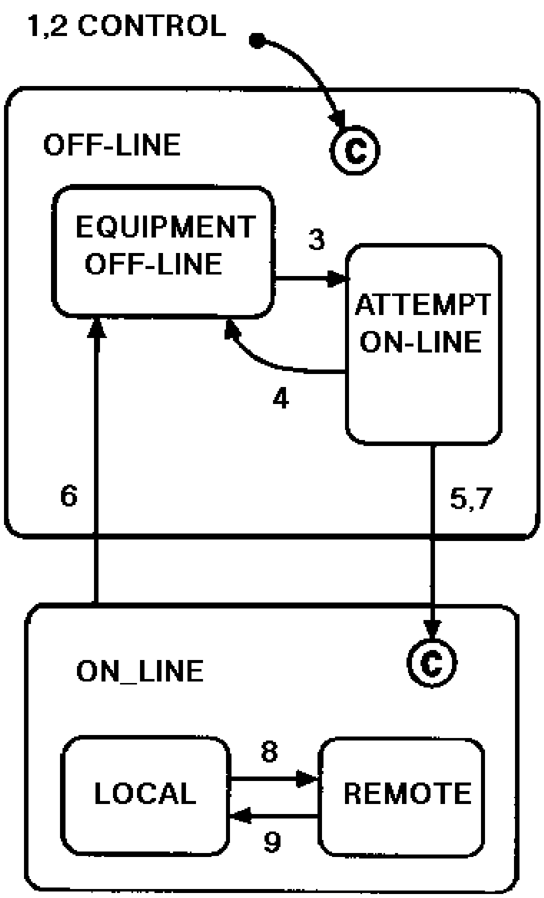


Figure A.6.1
Example of the Simplified "Effective" Control Model

This view of the model has two further settings that the host recognizes as changeable at the equipment. The first is the configuration of which substate of OFF-LINE to be activated upon system initialization. The second is the front panel switch that determines whether the active system substate is LOCAL or REMOTE when ON-LINE.

This application has the following implications:

— This application requires that the equipment begin with the OFF-LINE state active. Thus, an equipment initiated S1,F1/F2 transaction must be completed before the equipment will begin sending all messages to the host.

— If a failed attempt to go ON-LINE is made by the equipment, it will not allow the host to complete the transition at a later time. An operator will be required to re-initiate the transition to ON-LINE when the host becomes ready.

— Once ON-LINE, the equipment will remain ON-LINE until an operator sets the equipment OFF-LINE at the equipment front panel.

— Since all transitions into the HOST OFF-LINE state are eliminated, this state is effectively eliminated from the host view of the control model.

This application retains the following features:

— The ON-LINE state is achieved only after the host acknowledges the equipment by replying to the S1,F1 with and S1,F2. This confirms to the operator attempting to put the equipment ON-LINE that the host application is ready for work to begin.

— It provides the operator the means to set the equipment OFF-LINE for non-host-related activities[25] (e.g., maintenance, test lots).

— The operator has the ability to operate the equipment with either the REMOTE or LOCAL state active. As the equipment transitions to ON-LINE, the preferred substate is automatically chosen (based on a front panel switch).

— The user may configure which substate of OFF-LINE the equipment will initially activate at system initialization. If ATTEMPT ON-LINE is chosen, the equipment will automatically attempt the transition to the ON-LINE state as system initialization.

24 See Section 3.3 for details of the control model.

25 Which activities are "non-host-related" varies from factory to factory. In general, fewer activities are "non-host-related" as a factory's automation level increases.

A.7 Examples of Limits Monitoring

A7.1 *Introduction*

A7.1.1 Four limits monitoring examples are included below to help clarify the use of limits and to illustrate typical applications. The first example shows how to apply limits to boolean values. The second illustrates application of several limits to a floating point variable in a classical control zone style. The third example shows an integer counter variable used to prompt for equipment maintenance.

A7.2 *Examples*

A7.2.1 Example 1 — Valve Monitoring

A7.2.1.1 The ACME Shine-Um-Rite Model 13 includes a sump which contains the chemical agent used to clean bare wafers. A chemical feeder system serves to refill the sump when the level drops below a certain level. The fill is accomplished via an on-off value driven by sensors in the sump. Facilities must be informed of the proportion of the time the valve is open (approximates usage) and any time the value remains open for more than 5 minutes (valve likely broken).

A7.2.1.2 To implement this requirement, a limit was defined for the Boolean status variable which contains the current state of the valve (i.e., 0 = Closed, 1 = Open). See Figure A7.1 for illustration. LIMITID1 was defined with UPPERDB = LIMITMAX = 1 (Open) and LOWERDB = LIMITMIN = 0 (Closed). As a result, any time the valve opens, a collection event is generated with TransitionType = 0 and when the valve closes, a collection event is generated with TransitionType = 1. An event report containing the DVVAL LimitVariable was attached to each collection event and reporting for the event was enabled.

NOTE: Boolean values are defined as 0 = False/Closed/Off and any value > 0 = True/Open/On — never depend on a value of 1.

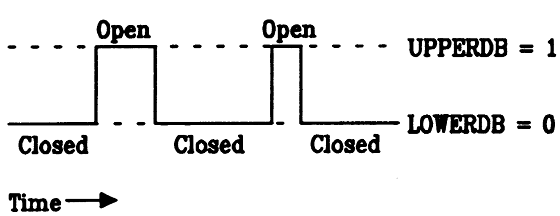


Figure A7.1
Valve Monitoring Example

A7.2.2 Example 2 — Environment Monitoring

A7.2.2.1 ACME also makes a Model 2 Stepper. The environmental control system of this equipment is designed to hold the internal temperature relatively constant, but is sensitive to large changes in the external environment, opening of access doors, etc. To ensure that processing conditions are appropriate, the internal stepper temperature is monitored to ensure it remains in a safe operating zone (within "Shutdown" limits). In addition, a second set of limits are used within the Shutdown limits to bound the "Normal" operating range. Frequent excursions from the normal range into the "warning" range will prompt service on the environmental control system. The target temperature range is specified as 98–100°, the shutdown limits as 95–103°.

A7.2.2.2 Event reports are desired when the internal temperature moves outside of the normal operating zone into a warning zone (above or below), when the temperature moves back into the normal operating zone from the warning zones, and when the temperature moves out of the warning zones into the shutdown zones. Furthermore, temperature fluctuations of 0.5° should not trigger multiple event reports.

A7.2.2.3 Probably the most intuitive use of the limits monitoring capability is in establishing normal, warning, and shutdown zones for a particular equipment variable. Limits may be combined to provide such a scenario. The method is described below and illustrated in Figure A7.2. Please note that in the figure, limits are denoted as solid lines for simplicity, with deadbands indicated using the ± notation.

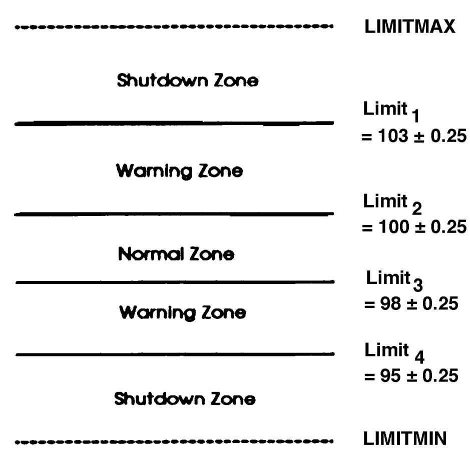


Figure A7.2
Environment Monitoring Example

A7.2.3 Example 3 — Calibration Counter

A7.2.3.1 Another ACME equipment is the multi-chamber Duz-It-All Model 7. This machine includes redundant chambers to increase throughput. One particular chamber on this equipment requires periodic calibration. The need for calibration is a non-linear function of the number of wafers processed in that chamber. A status variable exists which contains the number of wafers processed since the last calibration was performed. Maintenance is definitely required after every 8 cycles, but the machine must be checked after 5 and 7 cycles to determine whether early calibration is necessary. This checking may be done by examining certain other equipment status variables.

A7.2.3.2 To meet this need, three limits are defined for the counter variable. Three limits were set, at 5, 7, and 8. Deadbands are set to zero, since chattering is not a problem. All the pertinent information is placed in an event report which is attached to the CEID for the limits of the counter to negate the need for further message exchange. Event reports are generated as each limit is reached (one zone transition each), and when the counter is reset following calibration (one, two, or three zone transitions referenced in one report). Figure A7.3 illustrates this example. Note that disabling the report upon counter reset (downward transitions) is not possible.

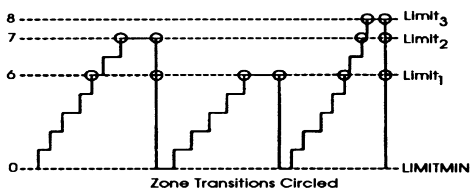


Figure A7.3
Calibration Counter Example

A7.2.4 Example 4 — Derived Variables

A7.2.4.1 The flagship of the ACME line is the new HotDog Furnace. This is a vertical furnace which exposes wafers to a variety of temperatures during processing. The temperature profile during the run is critical to the process and is typically contains a number of plateau's at different levels during the run. The owner wishes to monitor the temperature and be alerted whenever the actual temperature profile differs from the ideal by > 0.5°. The derived variable was created to provide a steady target range during the run, no matter what the desired temperature range happened to be. Deviation from "ideal temperature profile" was chosen as the new variable to be monitored. The equipment already had access to the profile for the run, which described the desired temperature at a given time into the process. The manufacturer added a calculation each time the actual temperature was sampled, subtracting the ideal temperature from the actual. They provided as status variables the actual temperature, the ideal temperature, and the new "deviation from profile" variable. One limit was activated and set to 0.5 degrees and a second set to –0.5 degrees (each with a deadband width of 0.05). Thus, when the temperature deviation from setpoint exceeds ± 0.5, an event is generated containing the current desired temperature and the actual temperature. For good measure, additional data was added, providing time since start of run to document the precise point in the process that the problem occurred.

A7.2.4.2 In order to achieve the desired behavior, the host defines four monitoring limits. Two of the limits establish the target zone. These are responsible for reporting transitions from normal to warning zones in either direction. The other two limits establish the transitions between the warning zones and the error zones. The difference between UPPERDB and LOWERDB for each limit is 0.5. This may also be expressed as limit ± 0.25. Combining limits does not change the way the equipment treats limits monitoring, but rather builds a method of interpreting limits from the host's point of view.

A.8 Process Parameter Modification for Process and Equipment Control

A8.1 *Introduction*

A8.1.1 In many equipment control applications there is a need for a GEM host to modify one or a small set of process parameters associated with a recipe. The number of parameters modified, frequency of modification (e.g., wafer-to-wafer, batch-to-batch, etc.), range of modification, etc., is largely a function of the equipment control application. Utilizing GEM, at least two methods are envisioned for modifying process parameters on a tool. With the first method, "Equipment Constants" can be used to relate process parameters of the updated recipe. Equipment Constants can also be used in a mode where they relate suggested modifications to process parameters from the stored recipe, i.e., the constants contain only the +/- differential from a nominal value. The former mode is preferred because it better ensures data integrity between the controller and tool. With the second method the entire recipe could be downloaded, but this results in an enormous amount of communication overhead. Note that, in all cases, the Equipment Constants do not replace the process parameters inside a recipe, but are associated with (e.g., linked to) these parameters to relate modifications. The remainder of this application note provides a description of how process parameter modification can be implemented using existing GEM capabilities. The method may be used in a GEM compliant system provided that the specific GEM capabilities described are supported.

A8.2 *Equipment Constants*

A8.2.1 Incremental process parameter modification for process and equipment control can be supported over a GEM interface by using the *Equipment Constants* GEM capability (see Section 4.5). With this capability, each process parameter (or process parameter at a step) that can be modified, e.g., for purposes of process control, is associated with an equipment constant. Using the Equipment Constant GEM scenarios (see Section 4.5.5) the host can (1), send process parameters or parameter modifications, (2), request current values of modifiable recipe parameters, (3), retrieve name lists of equipment constants associated with modifiable parameters, and (4), be informed by the equipment when an operator changes one of the modifiable process parameters.

A8.2.2 The equipment constants should represent the actual values of the process parameters with which they are associated. Depending on the equipment operation and control application, the equipment constant could represent the actual value of a process parameter at a recipe step, or over the entire recipe. The equipment constants could also be utilized to represent the differentials of process parameters from nominal values. However it is important to note that, when using differential values to relate process parameter modifications, any loss of synchronization between equipment and host could result in an incorrect assessment of the value of a process setpoint by the host. Note also that, upon system startup, and whenever the appropriate process parameters are modified, the equipment constants should also be modified as necessary to always reflect the (absolute or relative) values of the associated process parameters.

A8.2.3 In order to maintain synchronization between equipment and host, it is recommended that equipment constants associated with recipe parameters be applied to only override the currently selected and active recipe. A selected recipe is considered to be active whenever the equipment is in the "PROCESSING" state and the recipe is the currently selected recipe (process program). If multiple recipes are utilized during one process event, e.g., cluster tool scenario, it is recommended that separate equipment constants be utilized for each recipe/process parameter pair.

A8.2.4 Note that timing and traceability issues associated with utilizing the equipment constants capability (for process control) are application specific and beyond the scope of this application note. Equipment that provides for recipe parameter overrides though setting of Equipment Contstants should also provide additional Equipment Constants for the set that includes the name of the associated process program and a Boolean variable to enable and disable the override feature. In addition, the supplier should document for each parameter: (1), the associated Equipment Constant, and (2), any restrictions on the state (active or not) or the recipe in which the parameter may be modified. Also, since override of the process setpoints may be provided by a Host controller application element, it is recommended that the equipment provide an event report whenever the associated recipe has been modified.

A8.3 *Example*

A8.3.1 In the example of Figure A.8.1, a Chemical-Mechanical Planarizer (CMP) single wafer "polishing" system includes a GEM compliant planarizer (equipment), a thickness metrology unit and a (host) controller. The tool polishes a wafer to a target thickness. The post-process thickness is measured by the metrology unit and reported to the host controller. The controller utilizes a feedback control algorithm to determine the appropriate polish "time" recipe parameter for the next wafer. This time should be reported to the CMP equipment utilizing the equipment's GEM interface so that the information can be utilized for the next wafer processing event.

A8.3.2 The mechanism described in this application note could be utilized to implement process control as follows. A settable equipment constant is associated or "linked" with the "time" parameter on the equipment. Equipment system documentation indicates the linkage and the conditions under which the linkage is valid. When the controller determines an appropriate "time" parameter value for the next wafer to be polished, it sets the equipment constant to this value (see Section 4.5). The equipment is configured to accept this equipment constant change and, if the equipment is in (or possibly when the equipment reaches) the appropriate state, the recipe parameter is modified.

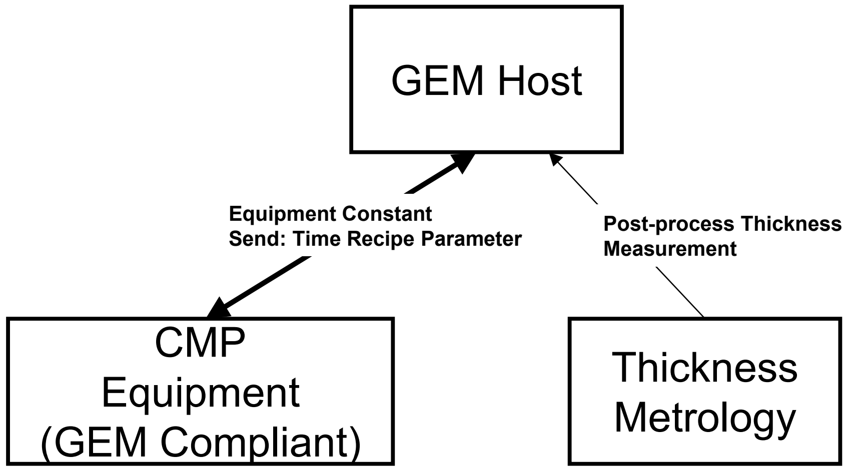


Figure A.8.1
CMP Single Wafer "Polishing" System with Host Recipe Parameter Modification Capability

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SEMI E30.1-0200
INSPECTION AND REVIEW SPECIFIC EQUIPMENT MODEL (ISEM)

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on September 3, 1999. Initially available at www.semi.org November 1999; to be published February 2000. Originally published June 1998.

CONTENTS

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1 Purpose

1.1 This standard establishes a Specific Equipment Model (SEM) for Inspection and Review Equipment (ISEM). The model consists of equipment characteristics and behavior that are to be implemented in addition to the SEMI E30 fundamental requirements and additional capabilities. The intent of this standard is to facilitate the integration of ISEM equipment into an automated (semiconductor fabrication) factory. This document accomplishes this by defining an operational model for ISEM equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior (e.g., control, state models, data reports, and reporting levels). Several topics require additional activity that are within the scope of this standard: substrate pattern maps; defect classification code management; and review data management.

2 Scope

2.1 The scope of this standard is limited to the definition of Inspection, Review, and Inspection/ Review equipment behavior as perceived by a SEMI Equipment Communications Standard II (SEMI E5/SECS-II) host that complies with SEMI E30. It defines the external view of the equipment through the SECS link; it does not define the internal operation of the equipment. This standard expands the SEMI E30 requirements and capabilities in the areas of the processing state model, remote commands, variable items, alarms, and data collection.

2.2 This standard is intended for ISEM equipment that generates data and information about anomalies and defects found on substrates. Inspection equipment finds anomalies. Anomalies are occurrences on a substrate that have been judged to be unexpected, abnormal, incongruous, or inconsistent. Anomalies may be examined using review equipment, at which time they may be classified as defects or non-defects. Some inspection equipment may generate, and some review equipment may use, coordinate data to locate anomalies on a substrate. The accuracy of the coordinate data generated or used is equipment-dependent.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document addresses three distinct types of equipment: inspection, review, and inspection/review. The term ISEM equipment refers to all three types of equipment. These three equipment types are differentiated by the basic functions they perform:

3.1.1 Inspection Equipment that looks for anomalies on a substrate and reports information regarding those anomalies. Inspection equipment may determine the location of anomalies relative to a coordinate system. Inspection equipment may also provide other types of data related to the anomaly.

3.1.2 Review Equipment that accepts information about anomalies on a substrate, gathers information on those anomalies, and reports that data.

3.1.3 Inspection/Review Equipment having the characteristics of both inspection and review equipment.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M21 — Specification for Assigning Addresses to Rectangular Elements in a Cartesian Array

4.2 *Other References*

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8, (1987), 231-274

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *GEM* — generic equipment model

5.1.2 *PE* — pattern element

5.1.3 *TCP/IP* — Transmission Communication Protocol/Internet Protocol

5.2 *Definitions*

5.2.1 *align* — to put into proper relative position or orientation.

5.2.2 *alignment* — a procedure in which a coordinate system is established on a substrate.

5.2.3 *alignment mark* — a feature on the substrate selectively used for alignment.

5.2.4 *anomaly* — an occurrence on a substrate that has been judged to be unexpected. Something abnormal, incongruous, or inconsistent.

NOTE 2: After an anomaly is reviewed, it may be classified as a defect.

5.2.5 *batch* — a group of substrates or lots intended for a process sequence versus single substrate processing.

5.2.6 *carrier* — a container with one or more fixed positions at which material can be held.

5.2.7 *carrier location* — a physical place within the equipment capable of holding a carrier.

5.2.8 *cassette* — a container with one or more substrate locations (see *slot*).

5.2.9 *defect* — 1) A physical, optical, chemical, or structural irregularity that degrades the ideal substrate structure or the thin films built over the substrate. 2) An undesirable classified anomaly.

5.2.10 *defect classification* — the categorization of defects according to some systematic division based on their physical, optical, chemical, or structural properties.

5.2.11 *die* — 1) A field sub-unit. 2) An area of substrate that contains the device being manufactured.

5.2.12 *ended* — the end of a state that may be when it is normally completed, or its early end due to an allowed or atypical condition (e.g., a STOP command, or an error or alarm condition).

5.2.13 *factory automation controller* — a computer system that provides integration of factory shop control and business systems with semiconductor equipment.

5.2.14 *feature* — 1) A line or a point (as a feature within a pattern). 2) A physical characteristic of the substrate (e.g., a substrate flat).

5.2.15 *field* — the printed pattern from a reticle.

5.2.16 *field of view* — the imaging area as seen at magnification of the inspection or review equipment.

5.2.17 *global alignment* — a procedure which establishes a coordinate system for the entire substrate (see *alignment*).

5.2.18 *group* — a logical collection of regions.

5.2.19 *group alignment* — a procedure which establishes a coordinate system for an area, which is a contiguous group (see *alignment*).

5.2.20 *inspect* — to detect anomalies and/or information about anomalies.

5.2.21 *inspection* — an examination to detect anomalies.

5.2.22 *inspection equipment* — equipment that looks for anomalies on a substrate and reports information regarding those anomalies. Inspection equipment may determine the location of anomalies relative to a coordinate system. Inspection equipment may also provide other types of data related to the anomaly.

5.2.23 *inspection/review equipment* — equipment having the characteristics of both inspection and review equipment.

5.2.24 *ISEM job* — the information required to specify an inspection or review that may include material identification and location and process program identifications as well as any other parameters required to obtain a desired result.

5.2.25 *layer* — one of a sequential series of overlaying photomasks that make up a device series.

5.2.26 *lot* — a group of one or more substrates of the same type (e.g., wafers, masks, CDs).

5.2.27 *major flat* — the flat of longest length that is commonly located with respect to a specific crystal plane (ASTM F 1241-89).

5.2.28 *mask* — a selective barrier to the passage of radiation. For example, a transparent plate containing an opaque pattern that is used to transfer that pattern to another substrate.

5.2.29 *material* — a piece or pieces of substrate, one or more substrates, a lot, a batch, or a run.

5.2.30 *metrology equipment* — any equipment that collects and reports information on specific predetermined locations or features on a substrate with consistent data structure or that reports general information about the entire substrate.

5.2.31 *notch* — a U-shaped cut on the edge of a substrate that is commonly located with respect to a specific crystal plane.

5.2.32 *overlay* — the actual distance between two features on different layers of a substrate, compared to the expected distance.

5.2.33 *pattern* — 1) The physical features on a substrate surface. 2) An ideal pattern is the arrangement of features expressed in a calculated or mathematical manner.

5.2.34 *pattern element* — 1) Any recognizable set of features. 2) A rectangular sub-unit of a pattern or a pattern element. There may be multiple levels of pattern elements.

5.2.35 *primary fiducial* — a key characteristic of a substrate used to align the substrate during processing (such as a *notch* or *major flat*).

5.2.36 *region* — a single field of view which may be a collection of sites.

5.2.37 *registration* — the actual distance between two features on the same layer of a substrate, compared to the expected distance.

5.2.38 *reticle* — a mask that contains the patterns to be reproduced on a substrate; the image may be equal to or larger than the final projected image.

5.2.39 *review* — the process of classification of anomalies which may result in the appending of additional data to inspection data. Used to create a field on a substrate.

5.2.40 *review equipment* — equipment that accepts information about anomalies on a substrate, gathers information on those anomalies, and reports that data.

5.2.41 *run (noun)* — the material processed during the EXECUTING state.

5.2.42 *run (verb)* — the actions of a process between the READY state and the STOPPING state.

5.2.43 *safe state* — a state in which the equipment presents no danger to the product or user. This implies that safety interlocks are in place such that the equipment can be serviced without harm to the operator and that the material being processed has been removed from the processing station into an accessible location.

5.2.44 *site* — a single x,y coordinate where an action can be performed (e.g., *alignment* or *review*). The area associated with a site is determined by the equipment accuracy (e.g., optics, stage algorithms).

5.2.45 *slot* — a physical location within a Carrier capable of containing a substrate. Also referred to as a carrier location.

5.2.46 *substrate* — the basic unit of material, processed by semiconductor equipment, such as wafers, CDs, flat panels, or masks.

6 Communication Requirements

6.1 It is required that any ISEM-compliant equipment follow the Communications State Model in SEMI E30. In addition, ISEM-compliant equipment shall support the High Speed Messaging Service Standard (SEMI E37/HSMS). It is a minimum requirement to support Single Session (SEMI E37.1/HSMS-SS) sending SECS-II messages over TCP/IP. The reason behind this requirement is the size of the process programs used by this class of equipment and the amount of data produced.

7 State Models

7.1 *Processing State Model Requirements*

7.1.1 The processing state model included in this standard is a requirement for ISEM equipment. This standard requires implementation of all SEMI E30 state models (such as control, communication, and on-line/off-line). A state model consists of state model diagrams, state definitions, and a state transition table. All state transitions in this standard, unless otherwise specified, shall correspond to collection events.

7.1.2 A state model is the host's view of the equipment and does not necessarily describe the internal equipment operation. All ISEM state model transitions shall be mapped sequentially into the appropriate internal equipment events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the ISEM state model for transition to another state. The equipment makes the required transition without any additional actions in this situation.

7.1.3 Some equipment may need to include additional states other than those in this standard. Additional states may be added but shall not change the ISEM-defined state transitions. All expected transitions between ISEM states shall occur.

7.2 *Processing State Model Diagram* — Processing state models are detailed for ISEM equipment in Figure 1. This diagram contains all states and transitions that are common to all three types of ISEM equipment. The WORKING state is different for each type of equipment. The same state names and transition identifiers are used to identify common states and transitions of the three types of equipment. The working states for the three types of equipment are presented in the following sections. All states and transitions are described in the section following the diagrams.

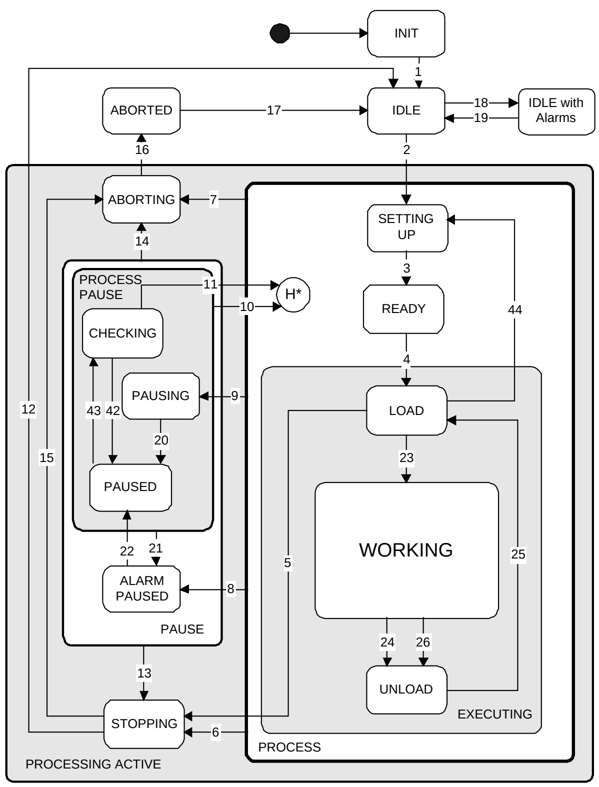

Figure 1
Generic ISEM Processing State Model Diagram

7.2.1 *Working State for Inspection Equipment Model* — The processing state model for inspection equipment is identical to the Generic ISEM Processing State Model (Figure 1). Only the WORKING state is unique to the inspection equipment processing state model. This is shown in Figure 2.

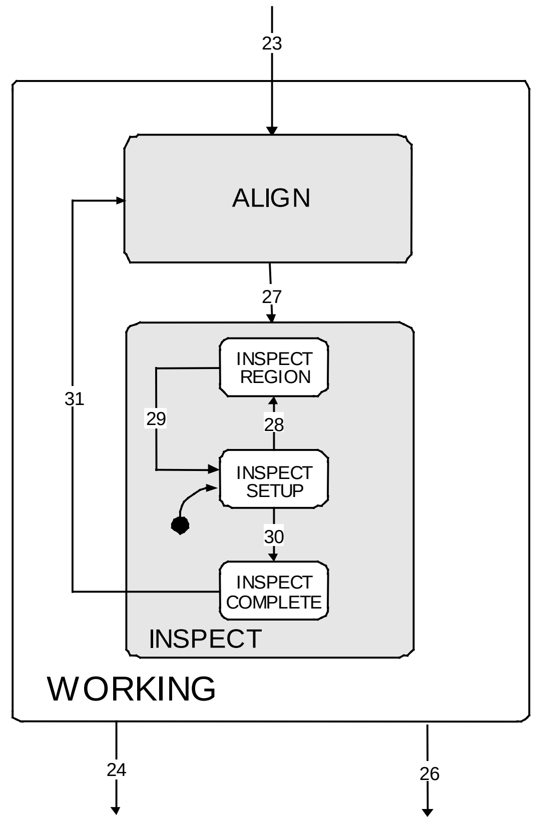

Figure 2
Working State for Inspection Equipment

7.2.2 *Working State for Review Equipment* — The processing state model for review equipment is identical to the generic ISEM Processing State Model (Figure 1). Only the WORKING state is unique to the review equipment processing state model. This is shown in Figure 3.

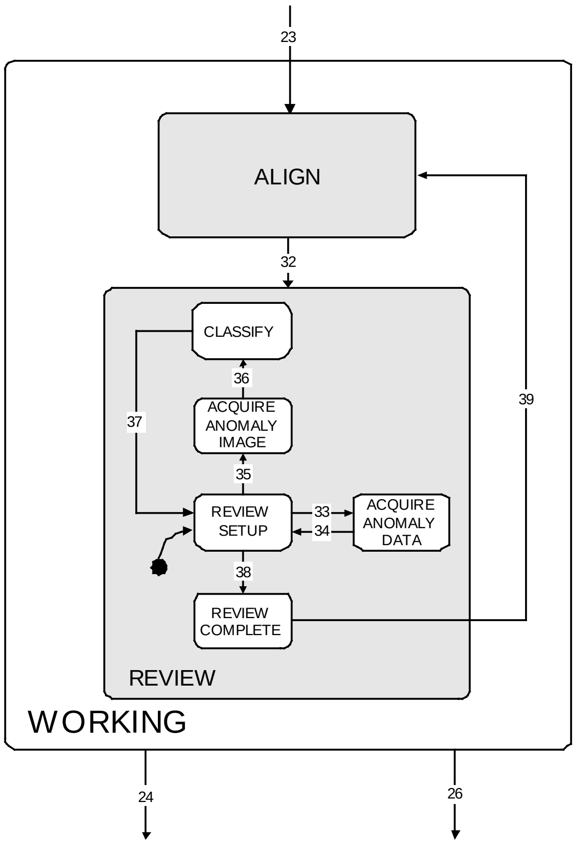

Figure 3
Working State for Review Equipment

7.2.3 *Working State for Inspection/Review Equipment* — The processing state model for inspection/review equipment is identical to the generic ISEM Processing State Model (Figure 1). Only the WORKING state is unique to the inspection/review equipment processing state model. This is shown in Figure 4.

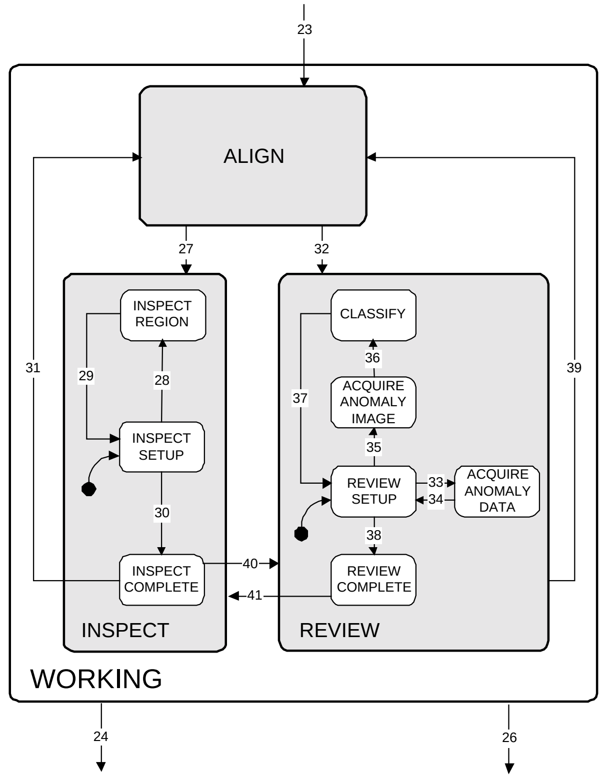

Figure 4
Working State for Inspection and Review Equipment

7.3 *Processing State Definitions*

7.3.1 *ABORTED* — All activity is suspended as a result of an ABORT command. Any alarm and abort conditions shall be cleared before exit from this state. The CLEANUP command is available to the operator or host to transition the equipment from the ABORTED state to IDLE state.

7.3.2 *ABORTING (PROCESSING ACTIVE Sub-State)* — The equipment has received an ABORT command. All normal activity is suspended. The equipment is taking appropriate action to put the equipment and material in a "safe state" where possible. Data may be invalid or not available.

7.3.3 *ACQUIRE ANOMALY DATA (REVIEW Sub-State)* — Data is being acquired about anomaly locations.

7.3.4 *ACQUIRE ANOMALY IMAGE (REVIEW Sub-State)* — The equipment is obtaining a view of the anomaly.

7.3.5 *ALARM PAUSED (PAUSE Sub-State)* — An alarm has occurred in the PROCESS or PROCESS PAUSE states, and the equipment is waiting for the alarm to be cleared or a command (STOP or ABORT).

7.3.6 *ALIGN (WORKING Sub-State*) — The equipment or operator is performing an alignment of the material to the equipment. If needed, within this state, the equipment shall refine or establish its SEMI M20 coordinate system and establish any secondary coordinate systems.

7.3.7 *CHECKING (PROCESS PAUSE Sub-State)* — The equipment verifies that the process program update request is valid. No process program parameters are changed unless "all" reported updates are valid. This is a similar procedure to that which is done in SETTING UP before the equipment is ready to transition to the READY state. Valid commands in this state are STOP, ABORT, and RESUME.

7.3.8 *CLASSIFY (REVIEW Sub-State)* — The operator or equipment is determining the classification of an anomaly.

7.3.9 *EXECUTING (PROCESS Sub-State)* — The equipment is processing material automatically and can continue to do so without external intervention but normally may include interaction with the host or operator.

7.3.10 *IDLE* — Checks for queued ISEM jobs or awaits a PP-SELECT, MAP-CARRIER, or PP-ASSIGN command. IDLE is free of alarm and error conditions. Any transition into this state shall deselect any selected Process program(s).

7.3.11 *IDLE with ALARMS* — An alarm has occurred in the IDLE state, and the equipment is waiting for all alarms to be cleared.

7.3.12 *INIT* — Equipment initialization is occurring. Equipment remains in this state unless initialization is successful.

7.3.13 *INSPECT (WORKING Sub-State)* — The current alignment area of the substrate is being inspected for anomalies.

7.3.14 *INSPECT COMPLETE (INSPECT Sub-State)* — The equipment has completed inspection of the current alignment area. Based on the recipe, the equipment determines if (a) additional alignment areas are required to do more inspections, (b) the recipe on this material is complete, or (c) a review of the current inspection area is required.

7.3.15 *INSPECT REGION* — A region on a substrate is being inspected for anomalies.

7.3.16 *INSPECT SETUP (INSPECT Sub-State)* — The equipment is in this sub-state immediately upon entering the INSPECT state. The equipment is determining if all conditions are satisfied to begin inspecting the regions in the current alignment as defined by the recipe and any commands.

7.3.17 *LOAD (EXECUTING Sub-State)* — The equipment is determining if the process program has completed. When additional processing is required, then the next unprocessed substrate shall be transferred to the equipment processing location, such as the stage. If equipment determines that there are more process programs in the "CARRIERBLD" ISEM job, the equipment makes the transition to setup for the next process program specified. Otherwise, the equipment transitions to IDLE through STOPPING.

7.3.18 *PAUSE (PROCESS ACTIVE Sub-State)* — PROCESS shall be suspended at the next opportunity. Actions to put the equipment in a "safe state" shall be performed. The equipment is awaiting a command (STOP or ABORT).

7.3.19 *PAUSED (PROCESS PAUSE Sub-State)* — PROCESS has been suspended, and the equipment is waiting for a command (RESUME, PP-UPDATE, STOP, or ABORT).

7.3.20 *PAUSING (PROCESS PAUSE Sub-State*) — PROCESS shall be suspended at the next opportunity, and the equipment shall be put in a "safe state." ABORT, STOP, and RESUME commands are valid in this state.

7.3.21 *PROCESS (PROCESSING ACTIVE Sub-State)* — This state is the parent of those sub-states which refer to the active preparation and execution of a process program.

7.3.22 *PROCESSING ACTIVE* — This state is the parent of all sub-states where the context of a process program execution exists.

7.3.23 *PROCESS PAUSE (PAUSE Sub-State)* — The equipment is free of alarm conditions in the PAUSE state. The equipment is awaiting for a command (ABORT, RESUME, or STOP).

7.3.24 *READY (PROCESS Sub-State)* — The equipment is ready to begin processing and is awaiting a START command from the operator or host.

7.3.25 *REVIEW (WORKING Sub-State)* — Classification is being done on anomalies previously found in the current alignment area of the substrate.

7.3.26 *REVIEW COMPLETE (REVIEW Sub-State)* — The equipment has completed review of the current alignment area. Based on the recipe, the equipment determines if (a) additional alignment areas are required to do more classifications, (b) the recipe on this material is complete, or (c) an inspection is required.

7.3.27 *REVIEW SETUP (REVIEW Sub-State)* — The equipment is in this sub-state immediately upon entering the REVIEW state. The equipment is determining if all conditions are satisfied to begin reviewing the anomalies in the current alignment as defined by the recipe and any commands.

7.3.28 *SETTING UP (PROCESS Sub-State)* — The equipment is being setup so that external conditions are satisfied to start processing the material. This includes the receipt of any process programs and material to be processed and their validation. Any of these conditions may be satisfied on entry to SETTING UP. For example, the selected process program may have already been loaded (e.g., if it was the default process program), or the specified material may have already been placed on the equipment material port. Additional information may come from the host during the execution of this state.

7.3.29 *STOPPING (PROCESSING ACTIVE Sub-State)* — The equipment has completed all process programs within a "CARRIERBLD" ISEM job or has been instructed to stop processing and shall do so gracefully at the next opportunity. All cleanup necessary is being completed within this state with regard to material, data, control system, etc. Data is normally preserved. Any alarm or error condition in this state causes a transition to ABORTING.

7.3.30 *UNLOAD (EXECUTING Sub-State)* — The substrate is being removed from the processing location.

7.3.31 *WORKING (EXECUTING Sub-State)* — The equipment is processing a specific material.

7.4 *Processing State Transition Table*

Table 1 Processing State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	INIT	All equipment initialization is complete with no alarms or error conditions.	IDLE	Equipment awaits for a PP-SELECT, PP-ASSIGN, or MAP-CARRIER command.	All equipment requires INIT to be free of errors and alarms when exited. IDLE state entry requires that no process program is selected.
2	IDLE	A ISEM job has been or is queued (PP-ASSIGN) or selected (PP-SELECT).	SETTING UP	The setup procedure is equipment-dependent.	Commit has been made to setup. Material may have been placed on the equipment before SETUP is entered. When the job becomes active, the process program gets selected.
3	SETTING UP	All setup activity has completed, and the equipment is ready to receive a START command.	READY	The equipment is waiting for a START command. START may be initiated by an operator or may be included in the process program.	The selected process program is available for execution. When running multiple process programs within a ISEM job, the equipment makes the next process program available for execution.
4	READY	The equipment receives a START command from the user or from within the body of the process program selected for execution.	LOAD	The equipment determines if processing is completed. If not, it transfers the next substrate to the processing location.	Equipment transitions to STOPPING when all process programs in the selected ISEM job are executed. If a new process program within the ISEM job needs to be executed, the equipment transitions to SETTING UP.
5	LOAD	The processing job is complete, and there are no more substrates to load or process programs to run.	STOPPING	Equipment initiates a cleanup to remove the completed ISEM job and process program.	Normal completion of the run.
6	PROCESS	The equipment has received a STOP command.	STOPPING	The equipment unloads the material and brings the equipment to a "safe state."	Data is typically preserved and is valid.

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
7	PROCESS	The equipment has received an ABORT command.	ABORTING	The equipment is put in a “safe state” if necessary.	Data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended, and the equipment is waiting for all alarms to be cleared.	ALARM PAUSED is a PAUSE Sub-State.
9	PROCESS	The equipment has received a PAUSE command.	PAUSING	PROCESS shall be suspended at the next opportunity. Actions to put the equipment in a “safe state” will be performed.	This transition is required if the user wants to make changes to the current process program being executed.
10	PROCESS PAUSE	The equipment has received a RESUME command.	Previous PROCESS State	Proceed with the suspended process Sub-State.	If a RESUME command is received in the CHECKING state, then the PP-UPDATE command is canceled. Some equipment may only allow RESUME remote command from the PAUSE state.
11	CHECKING	The equipment has validated “all” requested updates to the current process program being executed; changes are done before entering into the next state.	Previous PROCESS State	Verification is appropriate in this state to check the changes made to the process program updated.	If an alarm occurs in the CHECKING state, then the PP-UPDATE command is canceled.
12	STOPPING	The equipment cleanup is complete, and the equipment is free of alarms.	IDLE	Equipment waits for a command/or determines if there is a ISEM job queued.	IDLE state entry requires that no process program is selected.
13	PAUSE	The equipment has received a STOP command.	STOPPING	The equipment proceeds with cleanup.	Normally, data is preserved and is valid.
14	PAUSE	The equipment has received an ABORT command.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
15	STOPPING	The equipment has received an ABORT command or an alarm was received while STOPPING.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
16	ABORTING	Unsafe conditions have been resolved where possible.	ABORTED	The equipment is waiting for alarm and ABORT conditions to be cleared.	The only state change allowed is to IDLE.
17	ABORTED	All alarms and abort conditions have been cleared.	IDLE	Equipment is waiting for a command (PP-SELECT, PP-ASSIGN, or MAP-CARRIER).	If needed, the CLEANUP command clears the abort conditions. IDLE state entry requires that no ISEM job or process program be selected.
18	IDLE	An alarm is set.	IDLE with ALARMS	The equipment waits for all alarms to be cleared.	None
19	IDLE with ALARMS	All alarms have been cleared.	IDLE	None	IDLE is free of alarms.

Transi-tion #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
20	PAUSING	The equipment has achieved a "safe state."	PAUSED	The equipment is waiting for a command (PP-UPDATE, RESUME, STOP, or ABORT).	None
21	PROCESS PAUSED	An alarm is set.	ALARM PAUSED	The equipment waits for all alarms to be cleared or for a STOP or ABORT command.	None
22	ALARM PAUSED	All alarms are cleared.	PAUSED	The equipment is waiting for a command (RESUME, PP-UPDATE, STOP, or ABORT).	None
23	LOAD	Material transfer to processing location is complete.	WORKING	The substrate is being processed.	None
24	WORKING	The processing of the specific material being processed successfully completed.	UNLOAD	This material is transferred from the processing location.	Normal completion of the substrate.
25	UNLOAD	The material unload is complete.	LOAD	The equipment returns to LOAD and determines if processing is complete, if not, transfers the next substrate to the processing location.	None
26	WORKING	The processing of the specific material being processed abnormally ended.	UNLOAD	This material is transferred from the processing location.	Error exit from WORKING. Data may be invalid.
27	ALIGN	The material alignment is complete, and inspection is required.	INSPECT	The equipment determines if another region needs to be inspected.	This transition is to the INSPECT SETUP Sub-State of INSPECT.
28	INSPECT SETUP	All inspect setup activity is complete, and the inspection is not complete.	INSPECT REGION	The equipment inspects the current alignment region.	None
29	INSPECT REGION	The region inspection has ended.	INSPECT SETUP	The equipment determines if another region needs to be inspected.	None
30	INSPECT SETUP	Inspection of this alignment group is complete.	INSPECT COMPLETE	The equipment determines if (a) additional alignment areas are required to do more inspections, (b) the recipe on this material is complete, or (c) a review of the current alignment area is required.	The next transition is conditional.
31	INSPECT COMPLETE	The inspection of this alignment area ended, and additional inspections may be required.	ALIGN	An inspection group is complete, and additional inspections may be required.	None
32	ALIGN	The material alignment is complete, and review is required.	REVIEW	The material is reviewed.	This transition is to the REVIEW SETUP Sub-State of REVIEW.
33	REVIEW SETUP	Anomaly data is needed to perform the review.	ACQUIRE ANOMALY DATA	Anomaly data is being acquired.	Anomaly data may come from the host or equipment.

Transi-tion #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
34	ACQUIRE ANOMALY DATA	Anomaly data has been acquired for the review, or no more anomaly data is available.	REVIEW SETUP	The equipment determines what to do.	
35	REVIEW SETUP	The equipment has anomaly data, and the review is not complete.	ACQUIRE ANOMALY IMAGE	The equipment acquires the anomaly image at the specified site.	The image may be a stored image or from an imaging device.
36	ACQUIRE ANOMALY IMAGE	The equipment has acquired the anomaly image for the specified site.	CLASSIFY	The operator or equipment classifies the anomaly.	None
37	CLASSIFY	All anomalies have been classified for the site.	REVIEW SETUP	The equipment determines what to do.	None
38	REVIEW SETUP	The review of the align area is complete.	REVIEW COMPLETE	Transition to next state is to be determined.	None
39	REVIEW COMPLETE	The review of this alignment area ended, and additional review is required.	ALIGN	A review group is complete, and additional alignment is required.	None
40	INSPECT	The alignment area inspection is complete, and review is required.	REVIEW	The material is reviewed.	This transition is to the REVIEW SETUP Sub-State of REVIEW.
41	REVIEW COMPLETE	The review is complete, and inspection is required.	INSPECT	The material is inspected.	This transition is to the INSPECT SETUP Sub-State of INSPECT.
42	CHECKING	Validation of requested process program changes failed.	PAUSED	The equipment is waiting for a new command.	No process program parameters have been changed.
43	PAUSED	The equipment receives a PP-UPDATE command.	CHECKING	The equipment begins validating requested changes to the process program.	No process program parameters are updated or changed before “all” requested changes are validated.
44	LOAD	Previous process program has completed, and there are additional process programs assigned to the “CARRIERBLD”. See Section 13.	SETTING UP	The equipment performs setup according to specifications of the next process program.	PROCESS-BLD-GROUP may include an AUTOSTART command within its body. Otherwise, the equipment waits for a START command.

8 Collection Event List

This section identifies data collection events and defines (Stream 6) reporting levels for variable items. The host can use the report definition scenario defined in SEMI E30 to define reports at ISEM-defined levels. The intent of this section is to ensure data is available at specific events and to optimize data reporting to the SECS-II host by allowing data to be grouped at reporting levels.

8.1 *Requirements*

8.1.1 This standard requires all collection events listed in the SEMI E30 standard. This standard requires the ISEM events in Table 2 for data collection (RunDataComplete, SubstrateDataComplete, GroupDataComplete, RegionDataComplete, and AnomalyDataComplete). These events are separate from the processing state transitions. These collection events shall occur before or on the processing state transition specified in Table 1. This was done to ensure that the data and the material remain synchronous. As a result, in some cases material processing may be delayed due to extended data processing time.

8.1.2 The most fundamental level of data defined for ISEM equipment is the anomaly level for review equipment and region level for inspection equipment. For example, review equipment has data available for individual anomalies at the AnomalyDataComplete event. Anomaly data may be grouped for level reporting. For example, data for anomalies found within a region on a substrate would be available at the RegionDataComplete event. This data would be available as a list variable item for Region Anomalies. All anomalies found on a substrate would be available at the SubstrateDataComplete event. This could either be 1) a list of list variable items for Region Anomaly, or 2) a single list variable item of all Substrate Anomalies. In this way, data can be reported with less high-level event reports, rather than as more low-level event reports.

8.1.3 Data produced by ISEM equipment is customarily grouped for reporting by processing, material, and equipment constraints which are called reporting levels (i.e., run, substrate, group, site, and anomaly data). Level data is grouped by these constraints for a reporting level. Data shall be grouped within a reporting level according to other constraints by degree of processing (e.g., raw sensor, basic, or analyzed data), or statistically (e.g., summary, correlation, or comparison).

Table 2 Collection Events for ISEM Data Reporting

Reporting Level	*Data Collection Event*	*Inspection Equipment*	*Review Equipment*
Run	RunDataComplete	STOPPING → IDLE and LOAD → SETTING UP	STOPPING → IDLE and LOAD → SETTING UP
ProcessGroup	ProcessBuildGroup-Complete	LOAD → SETTING UP	LOAD → SETTING UP
Substrate	SubstrateDataComplete	UNLOAD → LOAD	UNLOAD → LOAD
Group	GroupDataComplete	INSPECT COMPLETE → ALIGN *or* WORKING → UNLOAD	REVIEW COMPLETE → ALIGN *or* WORKING → UNLOAD
Region	RegionDataComplete	INSPECT REGION → INSPECT SETUP	*Not Defined*
Anomaly	AnomalyDataComplete	*Not Defined*	CLASSIFY → REVIEW SETUP

NOTE 1: The data collection event shall occur before or on the processing state transition.

9 Variable Items

The purpose of this section is to define the list of variable item requirements for inspection and review equipment. Values of these variables shall be available to the host via collection event reports and host status queries. These variable items are separated into three categories: (a) common to all ISEM equipment; (b) specific to inspection equipment; (c) and specific to review equipment.

If equipment supports the data item functionality defined by ISEM, then it is required and shall be implemented as specified in Table 4 “Variable Item Dictionary”. That is, a variable item is only required if the equipment supports the functionality necessary to support it. For example, if an inspection instrument only has the hardware to count detected anomalies and lacks the hardware to determine their size, then the ISEM requires it to report anomaly count (e.g., as SubstrateAnomalyCount), but reporting anomaly size (as AnomalySize) is not required by the ISEM.

9.1 *Requirements*

- All variable items and data item restrictions defined in SEMI E30 are required on ISEM equipment.
- All variable items in the ISEM Variable Item Dictionary for specific equipment classifications are required for ISEM equipment. The data item restrictions are also required.

9.1.1 Variable items are categorized in the Variable Item Dictionary as follows:

- *Common Variables (CV)* — variables common to all ISEM equipment.
- *Inspection-Specific Variables (ISV)* — variables required only for inspection equipment.
- *Review-Specific Variables (RSV)* — variables required only for review equipment.

9.2 *Variable Items and Reporting Levels* — Table 3 defines reporting levels and associated Data Collection Events for which Variable Items are valid for.

Table 3 Variable Items and Reporting Levels

Level	*Reporting Level*	*Data Collection Event*
R	Run	RunDataComplete
P	ProcessGroup	ProcessGroupComplete
S	Substrate	SubstrateDataComplete
G	Group	GroupDataComplete
X	Region	RegionDataComplete
A	Anomaly	AnomalyDataComplete
ALL	Run, Substrate, Group, Region, and Anomaly	All of the above.

9.2.1 Variable items are documented in the ISEM Variable Item Dictionary using the following format:

Variable Name	*Type*	*Description*	*Level*	*Class*	*Format*	*Comments*

Where:

Variable Name: A unique name for the variable item (this name is for reference only).

Type: Defined as Common (CV), Inspection (ISV), Review (RSV), or Inspection/Review specific variables (IRSV).

Description: If class is DVVAL, then the description shall contain a statement of when data is valid in terms of ISEM events.

Level: The report level at which this variable is used <R| S| G| X| A| ALL> as defined in Table 3. It also indicates when the variable item is valid.

Class: The data type of the item.

Format: <SECS Message Language (SML) mnemonic> acceptable formats are SEMI E5 lists, ASCII, floating point, unsigned integer, or signed integer. A description of "ANY" indicates that only the above formats are acceptable and is left to the tool vendor to decide.

Comments: Any additional information pertinent to the variable name.

9.3 *Variable Item Types*

9.3.1 *Equipment Constants (ECV)* — The value can be changed by the host using S2,F15. The operator may have the ability to change some or all of the values. The value of an equipment constant may be queried at any time by the host using the S2,F13/14 transaction or Stream 6 reports.

9.3.2 *Status Variables (SV)* — The values are valid at all times. A SV may not be changed by the host or operator but may be changed by the equipment. A host or operator command may change an equipment status, thus changing an SV. The value of status variables may be queried by the host at any time using the S1,F3/4 or Stream 6 reports.

9.3.3 *Data Variables (DVVAL)* — These are variables which are valid upon the occurrence of a specific collection event and which may or may not be valid at other times, depending upon the equipment. An attempt to read a variable item when it is invalid will not result in an error, but the data reported may not have relevant meaning.

9.4 *Variable Item Dictionary*

9.4.1 *Data Validity* — The "Level" column in Table 4 defines when the variable item is valid. The entry in this column corresponds to a reporting level defined in Section 9.2 "Variable Items and Reporting Levels". For example, "RunAnomalyCount" is valid at the "RunDataComplete" event, and "AnomalySize" is valid at all reporting level data collection events.

Table 4 Variable Item Dictionary

Variable Name	*Type*	*Description*	*Level*	*Class*	*Format*	*Comment*
ActiveLocation	CV	The current carrier location that has substrates in the executing state of the processing state model.	ALL	SV	U2	Valid in all data collection events as defined in Table 3.
AlignList	CV	A list of alignment sites information being used by the current active process program.	ALL	DVVAL	L,n 1. <AlignName> : n.	The order in which the alignment name appears in the list is important and is equipment-dependent.
AlignName	CV	Alignment name	ALL	DVVAL	A[1..16]	An item in the AlignList variable.
AnomalyArea	CV	The area within the bounds of an anomaly (in units of $micron^2$).	ALL	DVVAL	F4	
Anomaly-Attributes	CV	Miscellaneous anomaly information that is equipment-dependent and defined by the equipment supplier.	ALL	DVVAL	L,n 1. <$attribute_1$> : n. <$attribute_n$>	Mainly used as part of other anomaly-related data (list) (i.e., AnomalySize).
Anomaly-Comment	RSV	Operator-generated comment associated with the anomaly.	A	DVVAL	A[1..80]	
AnomalyData2D	CV	Coordinate data for an anomaly.	A	DVVAL	L,5 1. <AnomalyID> 2. <CoordSys> 3. <Coord2D> 4. <Anomaly-Attributes>	
AnomalyID	CV	A unique anomaly identifier.	A	DVVAL	A[1..16]	
AnomalySize	CV	The X,Y extent of the anomaly in microns. The dimensions of the smallest rectangle that contains the anomaly whose sides are parallel to the X and Y axis.	A	DVVAL	L,2 1. <XExtent> 2. <YExtent>	XExtent and YExtent are of Format F4.
AnomalyTable-Name	CV	Name identifier of anomaly table.	ALL	SV	A[1..80]	
AnomalyTable-Type	CV	Type of anomaly table. (See Section 11.)	ALL	SV	A[1..20]	"TABLE-AREA-DEF", "TABLE-ALIGN-DEF", "TABLE-ANOMALY-DEF", "TABLE-M21-ANOMALY-DEF"
BatchID	CV	The batch identification of the current material inspected/reviewed.	ALL	DVVAL	A[1..16]	
CarrierBuild	CV	ID of the CARRIERBLD ISEM job that the inspection/review data is associated with.	ALL	SV	A[1..80]	See Section 14.
CarrierID	CV	Physical identification of the current material inspected/reviewed.	ALL	DVVAL	A[1..16]	
CarrierNumber	CV	Used to identify carriers in	ALL	DVVAL	A[1..16]	

Variable Name	*Type*	*Description*	*Level*	*Class*	*Format*	*Comment*
		multi-lot runs (batch).				
Classification	RSV	Classification code of an anomaly.	A	DVVAL	A[1..80]	
Coord2D	CV	The two-dimensional coordinate of an anomaly.	ALL	DVVAL	L,2 1. <CoordX> 2. <CoordY>	
CoordSys	CV	The identification for a coordinate system definition. SEMI M20, M20P, or SEMI M21.	ALL	DVVAL	A[1..16]	“M20” “M21” “M20P”
CoordX	CV	The coordinate in the X direction of a site (anomaly, alignment site, or the lower left-hand of an area or element).	ALL	DVVAL	F4	
CoordY	CV	The coordinate in the Y direction of a site (anomaly, alignment site, or the lower left-hand of an area or element).	ALL	DVVAL	F4	
DefaultPriority	CV	The default priority given a material location if none is assigned.	ALL	EC	U2	
DeltaX	CV	The X-axis translation of M20P coordinate system relative to the SEMI M20 coordinate system.	ALL	DVVAL	F4	
DeltaY	CV	The Y-axis translation of M20P coordinate system relative to the SEMI M20 coordinate system.	ALL	DVVAL	F4	
ElementID	CV	The SEMI M21 address for a specific rectangular element on a substrate.	ALL	DVVAL	I4[2]	May refer to a field or die.
ElementList	CV	A list of SEMI M21 elements where processing can be attempted.	ALL	DVVAL	L,n 1. <ElementID> : n.	
Fiducial	CV	The physical feature used to associate a fiducial line used for orientation (i.e., flat or notch on a substrate).	ALL	DVVAL	A[1..16]	“FLAT” “NOTCH”
GroupAnomaly-Count	CV	Anomaly count for the current or last group (i.e., field or die inspected).	G	DVVAL	U2	
GroupArea	CV	Square Area (microns^2) of the last group inspected.	G	DVVAL	F4	
GroupComment	RSV	Operator-generated comment associated with the group.	G	DVVAL	A[1..80]	
GroupID	CV	Inspection/review group identification for the current inspection/review.	ALL	DVVAL	U2	
InspectionPPID	CV	Process program used on the inspection/review tool	ALL	DVVAL	A[1..80]	

Variable Name	*Type*	*Description*	*Level*	*Class*	*Format*	*Comment*
		for the current inspection/review.				
InspectionRunID	CV	Run identification in the current inspection/review.	ALL	DVVAL	A[1..16]	
LotID	CV	Lot identification of the current material inspected/reviewed.	ALL	DVVAL	A[1..16]	
M20Data	CV	The silicon substrate size, fiducial type, and orientation to use.	ALL	DVVAL	L,3 1. <SubstrateSize 2. <Fiducial> 3. <Orientation>	
M21Data	CV	The data necessary to establish an ISEM SEMI M21 layout on a substrate.	ALL	DVVAL	L,2 1. L,3 1. <M21XSize> 2. <M21YSize> 3. <Tile> 2. L,n 1. L,3 1. <ElementID> 2. <CoordX> 3. <CoordY> : n.	
M21XSize	CV	The value of the SEMI M21 coordinate system in the X-direction.	ALL	DVVAL	F4	
M21YSize	CV	The value of the SEMI M21 coordinate system in the Y-direction.	ALL	DVVAL	F4	
Offset	CV	The distance of the actual or found location of a site relative to its defined or expected location.	ALL	DVVAL	L[2]	Refers to SiteDeltaX, SiteDeltaY which are of Format F4.
OperatorAction	CV	The action taken by the operator on the equipment's operator I/O.	ALL	DVVAL	A[1..80]	
OperatorComment	CV	Operator-generated comment, not associated with any reporting level.	ALL	DVVAL	A[1..80]	(See also Run-Comment, Substrate-Comment, Area-Comment, RegionComment, Site-Comment, and AnomalyComment.)
OperatorID	CV	Identification of the operator of the inspection/review equipment.	ALL	DVVAL	A[1..16]	This information may be added by the host in the ISEM Tables. (See Section 11.)
Orientation	CV	How the wafer is loaded on the equipment.	ALL	EC	F4	"0" degrees indicates that the wafer has the primary fiducial towards the operator.
ProcessBuild-GroupID	CV	Name of the current or last process program executed.	ALL	SV	A[1..80]	See Section 14.
ProcessEquipmentID	CV	Identification of the process equipment used with the	ALL	DVVAL	A[1..16]	This information may be added by the host in

Variable Name	Type	Description	Level	Class	Format	Comment
		current material immediately prior to the inspection/review.				the ISEM Tables. (See Section 11.)
ProcessEquipmentLocation	CV	Location (code) of the process equipment used with the current material immediately prior to the inspection/review.	ALL	DVVAL	A[1..16]	This information may be added by the host in the ISEM Tables. (See Section 11.)
ProcessEquipmentPPID	CV	Identification of the process program used with the process equipment used on the current material immediately prior to the inspection/review.	ALL	DVVAL	A[1..80]	This information may be added by the host in the ISEM Tables. (See Section 11.)
ProcessLevel	CV	Identification of the processing level of the current material.	ALL	DVVAL	A[1..16]	This information may be added by the host in the ISEM Tables. (See Section 11.)
ProcessRunID	CV	Run identification for the process prior to current inspection/review.	ALL	DVVAL	A[1..16]	This information may be added by the host in the ISEM Tables. (See Section 11.)
ProductID	CV	The product identification of the current material inspected/reviewed.	ALL	DVVAL	A[1..16]	This information may be added by the host in the ISEM Tables. (See Section 11.)
RegionComment	CV	Operator-generated comment associated with the region.	X	DVVAL	A[1..80]	
RunAnomaly-Count	ISV	Total number of all anomalies found on all substrates in the last run.	R	DVVAL	U2	
RunComment	CV	Operator-generated comment associated with the run.	ALL	DVVAL	A[1..80]	
RunInspected-AreasCount	ISV	The total number of inspected/reviewed areas on all substrates in the last run.	RS	DVVAL	U2	
RunInspection-PPCount	ISV	The total number of process programs used for the current or last run.	RS	DVVAL	U2	
RunSubstrate-Count	CV	The total number of substrates completed in the current inspection run, which remains valid until the next START command.	ALL	DVVAL	U2	
ScaleFactor	CV	A correction factor applied to the translation of one coordinate system to another.	ALL	DVVAL	F4	In most cases, a scaling of 1 (one) is expected.
SiteID	CV	Inspection/Review group identification for the current site inspection/review.	ALL	DVVAL	U2	
SlotID	CV	Carrier slot number from which the current substrate was taken.	ALL	DVVAL	U2	

Variable Name	*Type*	*Description*	*Level*	*Class*	*Format*	*Comment*
SlotList	CV	The list of carrier slots with substrates to be processed.	ALL	DVVAL	L,n 1. <SlotID> : n.	
SubstrateAnomalyCount	ISV	The total number of anomalies for the current substrate.	S	DVVAL	U2	For the most recent inspection.
Substrate-Comment	CV	Operator-generated comment associated with the substrate.	ALL	DVVAL	A[1..80]	
SubstrateID	CV	Substrate identification for the current inspection/review.	ALL	DVVAL	A[1..16]	
Substrate-InspectedAreas-Count	ISV	The total number of inspected areas on the current substrate.	S	DVVAL	U2	
SubstrateRegion-Count	CV	Total area count for the current or last substrate inspected.	ALL	DVVAL	U2	
SubstrateSize	CV	The nominal diameter (in mm) of the current or last substrate inspected/reviewed.	ALL	DVVAL	U2	
SubstrateTotal-AreaInspected	ISV	Total square area inspected/reviewed (micron^2) of the current substrate.	S	DVVAL	F4	
Theta	CV	The rotational difference in radians between a primary and secondary coordinate system.	ALL	DVVAL	F4	
Tile	CV	The layout of the pattern in the substrate.	ALL	DVVAL	A[1..16]	“NTILE” non-tiled, “CTILE” column-tiled, and “RTILE” row-tiled.
XLateData	CV	Variable for the equipment to report offset of the found or actual pattern-based coordinate system relative to the substrate-based coordinate system on the substrate being tested.	ALL	DVVAL	L,4 1. <DeltaX> 2. <DeltaY> 3. <Theta> 4. <ScaleFactor>	

10 Alarm List

Since each model of equipment differs in configuration, it is not practical to provide an exhaustive list of all possible alarms. Instead, the ISEM is requiring the two tables provided as described in SEMI E30 (document section). Alarm List Table, which is intended to provide for equipment configuration-specific alarms and Alarm ID, Alarm Set/Cleared Event Table.

10.1 *Alarm List Table*

10.1.1 The alarm list table contains examples of alarms that pertain to various configuration aspects of equipment. These examples are intended to illustrate that alarms pertain to situations in which there exists a potential for exceeding physical safety limits associated with people, equipment, and material being processed as per the SEMI E30 definition of an alarm. (See SEMI E30 for further reference.)

10.2 *Alarm ID, Alarm Set/Cleared Event Table*

10.2.1 The Alarm ID, Alarm Set/Cleared Event Table documents the association of each ALID to a set and cleared event as required by SEMI E30. (See SEMI E30 for further reference.)

11 ISEM Tables

A fundamental requirement of ISEM equipment is to transfer anomaly and review data between itself and the host. ISEM equipment may also be required to transfer “Area” and “Alignment Site” data needed for run setup. Anomaly and review data sets (as well as area and alignment site data sets) are commonly handled as lists and tables. ISEM equipment shall use tables when transferring this kind of data between itself and the host. List shall be used to refer to sub-sets of this table data.

11.1 *ISEM Table Data*

11.1.1 ISEM Tables are used to specify area, alignment site, and anomaly coordinate lists for ISEM equipment. ISEM Tables are transferred between the host and the equipment using SECS-II Stream 13 messages (Unformatted Data Set Transfers). For example, an ISEM Table may be used to transfer anomaly data (e.g., “M21” coordinates) generated by inspection equipment to the host, which in turn may then be transferred to review equipment from the host. ISEM Tables also include attributes items that are associated with the table, not with the table data. ISEM Table attributes are used to include information associated with table data, like the number of columns (NumCols), number of rows (NumRows), and table size (DataLength). (See SEMI E58 for additional information.) Product or process-related information may also be included on the attribute section of the ISEM Tables (e.g., LotID, ProductID, OperatorID, ProcessEquipmentID) (see Table 4). The ISEM does not specify additional table attribute variable items that may be associated with the table.

11.2 *TABLE-DEFs*

11.2.1 ISEM Tables are documented using TABLE-DEF structures (Figure 5). Each TABLE-DEF structure has a unique name (TableID) and type (TableType). Each column in the TABLE-DEF has a name (e.g., “AREANAME”, “ALIGNNAME”, OR “ANOMALYID”); row names are specific instances or values that correspond to the column headers in TABLE-DEF. A specific TABLE-DEF row is designated by referring to the TABLE-DEF name and the specific row name. ISEM Tables are transferred using standard (SECS-II message) Stream 13 messages (Figure 6), and each ISEM-defined TABLE-DEF item maps into a Stream 13 message item. Align and area data tables are host-defined, and anomaly tables are equipment-defined.

TableType = <*TableDef*> TableID = <*TableName*>

Row Name	*Column*$_1$	*Column*$_2$	*Column*$_3$	…	*Column*$_n$
Row$_1$ Name					
…					
Row$_m$ Name					

Figure 5
TABLE-DEF Structure

An example of usage of S13,F13 to transfer data sets is shown below:

```
L,7
   1. <DATAID>
   2. <OBJSPEC>
   3. “TableDef”                     <TBLTYP>
   4. “TableName”                    <TBLID>
   5. L,n                            # of table attributes
        1. L,2
               1. “NumRows”          <ATTRID1>
               2. <m>                <ATTRDATA1>
        2. L,2
               1. “NumCols”          <ATTRID2>
               2. <n>                <ATTRDATA2>
        3. L,2
               1. “DataLength”       <ATTRID3>
               2. <table length>     <ATTRDATA3>
        4. L,2
               1. “LotID”            <ATTRID4>
               2. “ABC123”           <ATTRDATA4>
           n. L,2
               1. “ProductID”        <ATTRIDn>
               2. “CPUTYPE”          <ATTRDATAn>
        6. L,n                       # of columns
            1. “AREANAME”            <COLHDR1>(1st column description)
            .
            n. “ATTRIBUTE5”          <COLHDRn>(nth column description)
        7. L,m                       # of rows
            1. L,n                   # of columns
               1. <Item 1,1>         table item in row 1, column 1
               .
               n. <Item 1,n>         table item in row 1, column n
               .
            m. L,n                   # of columns
               1. <Item m,1>         table item in row m, column 1
               .
               n. <Item m,n>         table item in row m, column n
```

Figure 6
S13,F13 with ISEM TABLE-DEF Data

11.3 *Required ISEM Tables* — ISEM equipment shall support all three table types: area, align, and anomaly. SEMI M21 anomaly table type may be supported, but it is optional. The ISEM equipment shall be able to store simultaneously at least 3 (three) defined tables of each type supported to guarantee the validity of any table while that table is being transferred (a table transfer transaction is in process).

ISEM align and area tables are stored by the equipment during the current inspection or review run (i.e., until a new remote command PP-SELECT or PP-ASSIGN is sent, or until they are modified with PP-UPDATE).

Table 5 ISEM Table Types (TABLE-DEFs)

Table Type	*Req/Opt*	*Description*
“TABLE-AREA-DEF”	R	*Area Definition* — A set of areas and their attributes, typically the list of areas to be inspected.
“TABLE-ALIGN-DEF”	R	*Alignment Site Definition* — A set of alignment sites and their attributes.
“TABLE-ANOMALY-DEF”	R	*Anomaly Coordinate Data Definition* — A set of anomalies and their attributes, with coordinates given in the SEMI M20 or M20P coordinate system.
“TABLE-M21-ANOMALY-DEF”	O	*Anomaly SEMI M21 Coordinate Data Definition* — A set of anomalies and their attributes, with coordinates given in the SEMI M21 coordinate system.

As indicated in Table 5, the SEMI M21 anomaly definition table “TABLE-M21-ANOMALY-DEF” is optional. The others are required.

ISEM requires that the following columns be included in the TABLE-DEFs. Table 6 defines the column headers and the allowed formats. Anomaly attributes and attribute headings are defined by the supplier, based on equipment capability.

11.3.1 “TABLE-AREA-DEF”

TableType: “TableAreaDef” TableID: <*AreaTableName*>

Area Name	*Coordx*	*Coordy*	*Coordsys*	*Xtentx*	*Xtenty*	*Attribute (1)*	…	*Attribute*

11.3.2 “TABLE-ALIGN-DEF”

TableType: “TableAlignDef” TableID: <*AlignTableName*>

AlignName	*Coordx*	*Coordy*	*Coordsys*	*Attribute (1)*	…	*Attribute(N)*

11.3.3 “TABLE-ANOMALY-DEF”

TableType: “TableAnomalyDef” TableID: <*AnomalyTableName*>

Anomalyid	*Coordx*	*Coordy*	*Coordsys*	*AnomalyAttribute*	…	*AnomalyAttribute*

11.3.4 “TABLE-M21-ANOMALY-DEF”

TableType = “TableM21AnomalyDef” TableID = <*M21AnomalyTableName*>

Anomalyid	*Coordx*	*Coordy*	*Elementid*	*AnomalyAttribute*	…	*AnomalyAttribute*

Defect data shall be transferred between the host and inspection/review/analysis equipment using SEMI E5, S13,F13. Columns in the table are defined by Table 11.3.5 below.

11.3.5 TABLE-STANDARD-DEFECT-DATA-SET-DEF

NOTE 1: Data for each substrate should be reported in column order shown below. Inspection tools should support relevant columns (see NOTE 6). Review and analysis tools should support all columns. Multiple data entries (list format data items) are allowed for a given attribute on a single defect.

NOTE 2: The inspection equipment must add a table attribute called “Substrate Header” (ATTRID). It must be a list that includes the following items in the given order: LotID (A[1..16]), SubstrateID (A[1..16]), ProcessEquipmentID (A[1..16]), substrate center[1] (L[2], CoordX (F4), CoordY (F4)) and centering method[2] (A[1..16]). Refer to Table 4, Variable Item Dictionary for descriptions of these items.

NOTE 3: See SEMI M21 for (0,0) die location methodology.

1 Vector from the origin of the substrate coordinate system to nominal substrate center location.
2 CoordSys (e.g., “SEMI M20”, “SEMI M21”, “M21P”, etc).

NOTE 4: Die origin is located at lower left-hand corner (LLHC).

NOTE 5: Data format must comply with the ISEM standard.

NOTE 6: In order to signify tool context, anomaly attributes are labeled as follows:

Column name starts with "insp*_" for inspection data, "rev*_" for defect review data, "and "anal*_" for analysis data, where "*" is a numeric string that ensures each set of columns added is uniquely named (e.g., "rev1_" and "rev2_").

NOTE 7: Inspection, review and analysis tools must add a table attribute called "insp*_ Header," "rev*_Header" and "anal*_Header" respectively (ATTRID) each time they add data to the table.[3] It must be a list that includes the following items in the given order: EquipmentID (A[1..16]), EquipmentType (A[1..16]), OperatorID (A[1..16]), and CLOCK[4] (A[16]).

Column #	*Column Name*	*Description*
1	Insp_Anomaly ID	ID # for the defect
2	Insp_Table specifier	Specifies table with other relevant information
3	Insp_Coordinate X	Intra die X Coordinate wrt LLHC of die in um
4	Insp_Coordinate Y	Intra die Y Coordinate wrt LLHC of die in um
5	Insp_X index	X axis die index wrt center of wafer (COW)
6	Insp_Y index	Y axis die index wrt center of wafer (COW)
7	Insp_X size	Defect size along X axis in microns
8	Insp_Y size	Defect size along Y axis in microns
9	Insp_Defect area	Defect area in square microns
10	Insp_Defect size	Linear measure of defect size in microns
11	Insp_Scatter intensity	Anomaly scattering intensity
12	Insp_Defect class number	Previously defined class number assigned to the defect
13	Insp_Test number	Inspection test in which defect was found
14	Insp_# Optical image count	Number of optical images stored for a given defect
15	Insp_Optical image data	Optical image data specifier
16	Insp_Cluster	= 1 if defect is part of a systematic defect cluster
17	Insp_Cluster class	Systematic defect class name
18	Sampled for SEM	= 1 if defect chosen for SEM review
19	Rev_SEM image data	SEM image data specifier
20	Rev_SEM class	SEM defect class name
21	Rev_Defect height	Defect height in microns
22	Sampled for analysis	= 1 if defect chosen for EDX, = 2 if defect chosen for FIB or other analysis
23	Anal_EDX data	EDX data specifier
24	Anal_FIB data	FIB data specifier

3 Where "*" is a numeric string that corresponds to the one in the column names the header refers to.

4 Date and time of the start of inspection, review, or analysis per SEMI E5 CLOCK data item variable.

11.4 TABLE-DEF Column Header Descriptions and Formats

Table 6 Description and Formats for ISEM Table Data

Column Header	*Description*	*Format*	*Comments*
"ALIGNNAME"	The identifier given to an alignment site.	A[1..16]	
ANOMALYATTRIBUTE (n) NOTE: String defined by equipment supplier.	Tool-specific information associated with an ANOMALY for which no specific ISEM data item has been defined.	U2, F4, F8, A[1..16]	Examples: Include information such as magnification, voltage, current, wavelength, brightness, color, height, or chemical spectra. The equipment supplier shall document all attributes that are supported.
"ANOMALYID"	A unique identifier for an anomaly.	A[1..16]	
"AREANAME"	A unique identifier given to an inspection area.	A[1..16]	
ATTRIBUTE(n) NOTE: String defined by equipment supplier.	Tool-specific information associated with an alignment or measurement site for which no specific ISEM data item has been defined.	U2, F4, F8, A[1..16]	Examples: Include information such as magnification, voltage, current, wavelength, number of scans, integration time, or film stack. The equipment supplier shall document all attributes that are supported.
"COORDSYS"	The identification for applicable coordinate system.	A[1..16]	Options are "M20", "M20P", and "M21".
"COORDX"	The x-coordinate for a site.	F4	Units are in microns.
"COORDY"	The y-coordinate for a site.	F4	Units are in microns.
"ELEMENTID"	The SEMI M21 address for a specific rectangular element on a substrate.	I4[2]	
"XTENTX"	The extent in the X-direction of an area to inspect as measured from the lower left-hand corner of the area given by CoordX.	F4	Units in microns.
"XTENTY"	The extent in the Y-direction of an area to inspect measured from the lower left-hand corner of the area given by CoordY.	F4	Units in microns.

12 Process Program Management

12.1 *Definition and Rules for ISEM Process Programs*

12.1.1 A process program contains information and/or instructions required for the Inspection/Review equipment to process a given run of material. The process program shall supply all of the information required for a remotely executed run to be processed without operator intervention.

12.2 *Requirements*

12.2.1 The ISEM requires that the SEMI E30 capability of Process Program Management be fully supported for this class of equipment. ISEM requires that the process program have a structure that enables the user to build process programs with default conditions that can be overridden for a run. ISEM requires the ability to vary the quantity of substrates processed, the alignment information used, and the number and/or location of the areas/anomalies to be inspected/reviewed through the uses of process program variable parameters. The concepts of process program structure and process program variable parameters are discussed in the following sections.

12.3 *Process Program Structure*

12.3.1 The purpose of this process program structure and the related concepts is to provide flexibility in using process programs to reduce the number of process programs needed. This structure enables the user or host to vary certain parameters of a given process program as needed for any particular run.

12.3.2 Often a process program may be very similar from one run to another and may differ only in a few parameters such as: which substrate slots to run, which areas to inspect, which parameters to run on each substrate, etc. Previously this small variation from run to run would require a large number of process programs to be created and maintained. The flexibility of the method described in this section will reduce the number of process programs.

12.4 *Process Program Variable Parameters* — A process program parameter specifies a value that temporarily modifies the value of a process program variable parameter. A process program variable parameter is formally defined within a process program body and contains (1) a variable parameter name that is unique in the body (CPNAME), and (2) a parameter default value for use when the process program is selected for execution without specification of an override value for this variable parameter (CPVAL/CPEVAL).

12.4.1 *Overriding Process Program Variable Parameters Default Values*

12.4.1.1 Any process-related information that is normally requested from the operator console in manual operation shall have a process program variable parameter identified in the process program and default values assigned in the body of the process program. An equipment would run the process program using the default values unless those values were overridden.

12.4.1.2 These process program variable parameters allow a host to tailor a process program for a specific run of material by temporarily modifying (replacing) the process program default values using a remote command of PP-UPDATE. The modification does not permanently change the process program; the modifications remain in effect only until the next run or until the next PP-UPDATE remote command is received.

12.4.2 *Requirements and Rules*

12.4.2.1 ISEM equipment is required to support variable process program parameters. Additionally, ISEM process programs are required to contain variable process program parameters that specify a name for each of the four previously defined ISEM table types. Specifically, parameters for "TABLE-AREA-DEF", "TABLE-ALIGN-DEF", "TABLE-ANOMALY-DEF", and "TABLE-M21-ANOMALY-DEF" table names are required. Only the names that refer to these TABLE-DEFs are required to be included in the process program body. The actual TABLE-DEF data is external to the process program body. The host may always assume that there are variable process program parameters for these four ISEM tables.

12.4.2.2 Before execution of a CARRIERBLD can begin, the presence of all the ISEM Tables that it references shall be verified by the equipment. If they are not all present, an error shall be reported. The equipment shall support data items that may be linked to the event report that specifies the name of missing ISEM Tables. S7,F27 is used for reporting this error condition.

12.4.2.3 The following table summarizes the variable process program parameters that ISEM equipment shall support and the remote command parameters that the host may use to override their values (as defined in Section 13 and Table 9).

Table 7 Required Variable Process Program Parameters

Variable Process Program Parameter and Host Command Parameter Name (CPNAME)	*Description*
"ALIGNLIST"	A list of location identifiers to be reviewed.
"ANOMALYLIST"	A list of location identifiers to be reviewed.
"AREALIST"	A list of area identifiers to be inspected or reviewed.
"ELEMENTLIST"	A list of array element identifiers to be inspected.
"SLOTLIST"	A list of carrier slot numbers with material to be inspected or to be reviewed.
"SUBSTRATELIST"	A list of substrate IDs with material to be inspected or to be reviewed.
"TABLE-ALIGN-DEF"	A set of alignment site definitions.
"TABLE-ANOMALY-DEF"	A set of (SEMI M20) anomaly location and attribute definitions.
"TABLE-AREA-DEF"	A set of area definitions.
"TABLE-M21-ANOMALY-DEF"	A set of SEMI M21 anomaly location and attribute definitions.

12.4.3 *Modifying Process Program Variable Parameters* — The remote commands of PP-SELECT, PP-ASSIGN, or PP-UPDATE are used to modify any of the identified process program variable parameters within the process program. The modification is done by including CPNAME/CPVAL pairs within the "PROCESS-BLD-GROUP", which is part of the remote commands of PP-SELECT or PP-ASSIGN, or by including a different list name in the PP-UPDATE remote command. A CPNAME in a process program shall be identical to the process program variable parameter name as specified in the "PROCESS-BLD-GROUP". See next section for details of these parameters.

12.5 *Use of Process Programs, Remote Commands, and "PROCESS-BLD-GROUP"* — This is a brief description of the steps involved in using the process program structure, the process program variable parameters, the TABLE-DEFs, and the modification of process program variable parameters through the use of "PROCESS-BLD-GROUP" and CPNAME/CEPVAL pairs in the enhanced remote command (S2,F49).

- A process program is created with certain items in the body identified as process program variable parameters, along with their default values.
- The host sends to equipment one or more TABLE-DEFs: such as "TABLE-AREA-DEF" and "TABLE-ALIGN-DEF", along with the names of those tables using Stream 13 commands (See SEMI E5). These tables are now resident on the equipment.
- The host sends an enhanced remote command (S2,F49) to the equipment (either PP-SELECT or PP-ASSIGN) that contains the information needed for processing ("CARRIERBLD"). The "CARRIERBLD" contains a "PROCESS-BLD-GROUP" for each different set of run parameters that are needed during the inspection or review process.
- "PROCESS-BLD-GROUP" shall contain the ProcessBuildGroupID to identify which program is selected.
- If the default list of slots in the process program needs to be changed for this run, then "PROCESS-BLD-GROUP" contains a "MATERIALLIST" and the list of selected slots or substrates, designated by SlotIDs or SubstrateIDs.
- If the default set of inspection areas in the process program needs to be changed for this run, then "PROCESS-BLD-GROUP" contains the name of a specific "TABLE-AREA-DEF" (in AreaTable Name). If not all of the inspection areas given in that "TABLE-AREA-DEF" are needed for this run, then "AREALIST" is used and includes a list of the names of the specific inspection areas which are needed. Those names refer to inspection areas defined in the "TABLE-AREA-DEF".
- If the default set of alignment sites in the process program needs to be changed for this run, then "PROCESS-BLD-GROUP" contains the name of a specific "TABLE-ALIGN-DEF" (in AlignTable Name). If not all of the alignment sites given in that "TABLE-ALIGN-DEF" are needed for this run, then "ALIGNLIST" is used and includes a list of the names of the specific alignment sites which are needed. Those names refer to alignment sites defined in the "TABLE-ALIGN-DEF".
- If the SEMI M21 coordinate system is being used and a pattern has been defined with pattern element names and if only certain of those elements need to be inspected for this run, then "PROCESS-BLD-GROUP" contains an "ELEMENTLIST" and the list of selected elements, designated by ElementIDs.
- If certain equipment-specific process program variable parameters need to have different values for this run, then for each needed parameter, "PROCESS-BLD-GROUP" contains a CPNAME (unique name of a specific process program variable parameter) and the new CEPVAL (new value for that parameter).
- The equipment executes the process program with the new values.
- If indicated in the process program, the equipment generates the list of anomalies found and sends it to the host in the format of a "TABLE-ANOMALY-DEF" using the ISEM table definition and Stream 13 transfer messages (see SEMI E5 for format specification).
- The host would send the "TABLE-ANOMALY-DEF" to a review equipment. The host might need to modify part of the table if required by the review equipment. This anomaly table is now resident on the review equipment. (NOTE: The host might choose to not send all of the table of anomalies, but rather a desired selection of them.)
- The host sends the equipment the enhanced remote command (PP-SELECT or PP-ASSIGN) that contains a "CARRIERBLD". The "CARRIERBLD" has a "PROCESS-BLD-GROUP" for each different set of run parameters that is needed by the review equipment. It is required for the host to use the Enhanced Remote Command S2,F49 for transferring the information

to the equipment. “PROCESS-BLD-GROUP” includes the name of a specific “TABLE-ANOMALY-DEF” in the parameter AnomalyTableName. If not all of the anomalies given in that “TABLE-ANOMALY-DEF” are needed for this run, then either “ANOMALYLIST” or “M21-ANOMALYLIST” is used and includes a list of the names of the specific anomalies which are desired. Those names refer to anomalies defined in the named “TABLE-ANOMALY-DEF”.

- The equipment runs the process program using the selected values and reviewing the specific anomalies indicated.
- The equipment adds review information to the ANOMALYATTRIBUTE list. Then the review equipment sends this modified “TABLE-ANOMALY-DEF” to the host.

13 Remote Commands

The purpose of this section is to identify remote commands, command parameters, and valid commands versus states pertinent to the SEM.

13.1 *Requirements*

- The equipment shall support the SEMI E30 required remote commands.
- All the remote commands defined by ISEM are required unless they have been qualified by the statement “if the equipment supports this functionality, it shall use this command.” In this case, they are only required if the equipment supports the functionality necessary to support the command. A good example of this is the MAP-CARRIER command. If the equipment does not have the hardware necessary to scan a carrier for the presence of substrates in slots, then the command is not required by the ISEM.
- The alphanumeric strings defined by ISEM for RCMD and CPNAME are required.

Host Command Parameter (CPNAME/CPVAL) — A parameter name/value associated with a particular host command when using stream function (S2,F41) and a (CPNAME/CEPVAL) parameter name/value when using the enhanced remote command (S2,F49). This document specifies unique names (CPNAMEs) and values (CPVALs and CEPVALs) for many command parameters. Note that if there are no associated parameters, a zero length list is sent.

The purpose of the remote commands is to allow host control over the following capabilities:

- Start processing
- Stop processing
- Temporarily suspend processing
- Resume processing
- Abort processing
- Select process programs, material, and/or sites to measure
- Report location of material found

The following remote commands (RCMDs) shall be supported as described below:

NOTE 3: The terms “current cycle” and “safe point” used below are to be defined by the supplier.

13.2 *Remote Commands Description*

1. *ABORT* — Terminate the current cycle prior to its completion. ABORT has the intent of immediately stopping the process and is used because of abnormal conditions. ABORT makes no guarantee about the subsequent condition of material except as noted in the “ABORTLEVEL” description.
2. *CLEANUP* — De-selection of the current ISEM job (“CARRIERBLD”) and process program (“PROCESS-BLD-GROUP”), including the removal of all material to output locations and any equipment-specific activities needed to transition into the IDLE state. Completion of this command should generate a collection event report. If the equipment supports this functionality, it will use this command.
3. *MAP-CARRIER* — Requests the equipment to provide a list of carrier slots that contain material. MAP-CARRIER has the intent of providing the host with enough information about the location and/or ID of material so it may select material for processing accordingly. Completion of this command shall generate a collection event report. If the equipment supports this functionality, it must use this command.
4. *NEXT-MATERIAL* — Processing of the current substrate is halted at the first safe point and unloaded to the target carrier location. NEXT-MATERIAL has the intent of allowing the host to skip measurement of the current substrate. This is a trigger for processing state transition from WORKING to UNLOAD. If the equipment supports this functionality, it will use this command.
5. *PAUSE* — Suspend processing temporarily at the next safe point. PAUSE has the intent of resuming the process at the same point where it was paused.

RESUME or PP-UPDATE may be used to resume the process.

6. *PP-ASSIGN* — Instructs the equipment that supports queuing to create a new ISEM job (“CARRIERBLD”) for the specified port (“LOCATIONID”) when more than one port is available for processing. If only one port is available, “LOCATIONID” is not required. Priority may optionally be specified with this command. The “PRIORITY” specifies the priority of the newly created job in the ISEM job queue (a value of 0 (zero) assigns the highest priority to the job). Without specifying a priority, the job is queued with the default priority. Jobs with equal priority are queued in the order the PP-ASSIGN commands are received. This command is valid in all PROCESSING states.

7. *PP-SELECT* — Instructs the equipment to make the requested ISEM job(s) (“CARRIERBLD”) available in the execution area. This is a trigger for the processing state transition from IDLE to SETTING UP. The first process program (“PROCESS-BLD-GROUP”) specified in the “CARRIERBLD” is also validated during SETTING UP.

8. *PP-UNASSIGN* — Removes the ISEM job assignment (“CARRIERBLD”) for a carrier or port. The carrier or port is removed from the process queue.

9. *PP-UPDATE* — Provides the ability to alter the current process program being executed during the PAUSED state. The process program variables specified in the PP-UPDATE command will replace previous definitions in the “PROCESS-BLD-GROUP”. This command will trigger transition to CHECKING for process program parameter verification. A RESUME command is implied with the validation of “all” replaced values to resume the process. If the PP-UPDATE fails, the process program variables present prior to the PP-UPDATE are retained. If no parameters values are specified, the defaults are used.

10. *RESUME* — Resume processing from the point where the process was paused. This is the trigger for processing state transition from PROCESS PAUSE to the previous PROCESS state.

11. *START* — Instructs the equipment to initiate processing. This is the trigger for the processing state transition from READY to LOAD. An “AUTOSTART” command parameter may be included to allow for continuous processing.

12. *STOP* — Complete the current cycle, stop in a safe condition, and return to the IDLE processing state. Stop has the intent of stopping the process entirely. This command can be used to both: stop the current ISEM job or to stop all queued jobs. The equipment is not required to support the continuation of processing.

13.2.1 *Remote Commands and Associated Host Command Parameters* — This table describes the allowable command parameters (CPNAME) for each remote command (RCMD). Equipment shall support all parameters. The column marked Req/Opt specifies which parameters are required to be sent by the host and which parameters may be optionally sent by the host.

Table 8 Allowable Command Parameters

Remote Command	*Parameters*		
	CPName	*Req/Opt*	*Comments*
ABORT	“ABORTLEVEL”	R	
CLEANUP	“CARRIERID” “LOCATIONID” “SLOTID”	O O O	PORT and SLOT may be used to define a different carrier/slot destination for the substrates.
MAP-CARRIER	“CARRIERID” “LOCATIONID”	R* R*	* One is required.
NEXT-MATERIAL	“CARRIERID” “LOCATIONID” “SLOTID”	O O O	PORT and SLOT may be used to define a different carrier/slot destination for the substrates.
PAUSE	None	NA	None
PP-ASSIGN	“PRIORITY” “CARRIERBLD”*	O R	* More than one “CARRIERBLD” may be specified.
PP-SELECT	“CARRIERBLD”*	R	* More than one “CARRIERBLD” may be specified.
PP-UNASSIGN	“CARRIERBLD”	R	None

PP-UPDATE	"PPBUILDID" "ALIGNLIST" "ANOMALYLIST" "AREALIST" "ELEMENTLIST" "SLOTLIST" "SUBSTRATELIST" "TABLE-ALIGN-DEF" "TABLE-AREA-DEF" "TABLE-ANOMALY-DEF" "TABLE-M21-ANOMALY-DEF"	R R* R* R* R* R* R* R* R* R* R*	* At least one is required.
RESUME	None	N/A	None
START	"CARRIERBLD"	0	None
STOP	"CARRIERBLD"	0	None

13.2.2 *Host Command Parameter Names and Values*

Table 9 Host Command Parameters CPNAMES

CPName	*Parameter Value*		
	Description	*Range*	*Format*
"ABORTLEVEL"	ISEM-defined abort levels: HALT — Process halts, and the ABORTING process state is entered. CLEANUP — Process halts, material cleanup is performed, and the ABORTING process state is entered.	"1= HALT" "2 = CLEANUP"	U2
"ALIGNLIST"	L,n 1. AlignName$_1$: n. For the SEMI M20 or M20P coordinate system.		List of A[1..16] data items
"ALIGNNAME"	Alignment name See the "TABLE-ALIGN-DEF" definition for further explanation.		A[1..16]
"ANOMALYLIST"	L,n 1. AnomalyID$_1$: n. For the SEMI M20 or M20P coordinate system.		List of A[1..16] data items
"ANOMALYID"	Anomaly identifier See the "TABLE-ANOMALY-DEF" or the "TABLE-M21-ANOMALY-DEF" definition for further explanation.		A[1..16]
"AREALIST"	L,n 1. AreaName$_1$: n.		List of A[1..16] data items
"AREANAME"	Unique identifier for an area to be inspected. See the "TABLE-AREA-DEF" definition for further explanation.		A[1..16]
"AUTOSTART"	Specifies whether a START command is required from an external source (operator or host) to exit the READY state. 0 = NoAutoStart (A START command required.) 1 = AutoStart (No external START command required to begin execution.)	0–1	U2
"CARRIERID"	Identifier of the carrier that the inspection/review data is associated with.		A[1..16]

CPName	Parameter Value		
	Description	*Range*	*Format*
“ELEMENTLIST”	L,n 1. ElementID$_1$: n. For the SEMI M21 coordinate system.		List of A[1..16] data items
“LOCATIONID”	Unique identifier of the location to be used for the “CARRIERBLD” assignment.		U2
“PPBUILDID”	ProcessProgramBuildID		A[1..80]
“PPNAME”	ProcessProgramName		A[1..80]
“PRIORITY”	Assignment priority	0–9 Highest priority corresponds to 0.	U2
“SLOTLIST”	Specifies carrier slots containing substrate for the ISEM job. L,n 1. SlotID$_1$: n. SlotIDn	Zero length list specifies all slots.	List of U2 data items
“STOPLEVEL”	Stop levels defined by the ISEM.	“1 = LOCATIONID” “2 = CARRIERID”	Use defined CPVALs
“SUBSTRATELIST”	Specifies identifiers of substrate for the ISEM job. L,n 1. SubstrateID$_1$: n. SubstrateID$_n$	Zero length list specifies all substrate (independent of substrate identifier).	List of A[0..16] data items
“CARRIERBLD” E5 Format	L, 3 Three ISEM required parameters 1. L, 2 ❖ 1. “CARRIERID” **A[9]** -- CPName 2. CarrierID **A[1..16]** -- CPValue 2. L, 2 ❖ 1. “LOCATIONID” **A[10]** -- CPName 2. LocationID **U2** -- CPValue 3. L, 2 1. “PROCESS-BLD-LIST” 2. L, n ❖ List of n jobs 1. L, 2 1. “PROCESS-BLD-GROUP” 2. L, m First ISEM job 2. L, 2 1. “PROCESS-BLD-GROUP” 2. L, m Next ISEM job . . . n. L, 2 1. “PROCESS-BLD-GROUP” 2. L, m Last ISEM job	m = 3	List
“PROCESS-BLD-GROUP” (for Inspection)	L,m 1. L,2 1. “PPBUILDID” 2. ProcessBuildGroupID	*m* ≥ 2	List of *m* data items

CPName	Parameter Value		
	Description	Range	Format
	2. L,2 1. "PPNAME" 2. ProcessProgramID 3. L,2 1. "SLOTLIST" 2. L,n 1. $SlotID_1$: n. ***Or*** 1. "SUBSTRATELIST" 2. L,n 1. $SubstrateID_1$: n. 4. L,2 1. "AUTOSTART" 2. AutoStart 5. L,2 1. "TABLE-AREA-DEF" 2. AreaTableName 6. L,2 1. "AREANAME" 2. L,n 1. $AreaName_1$: n. 7. L,2 1. "TABLE-ALIGN-DEF" 2. AlignTableName 8. L,2 1. "ALIGNNAME" 2. L,n 1. $AlignName_1$: n. 9. L,2 1. "ELEMENTLIST" ** 2. L,n 1. $ElementID_1$: n. 10. L,2 1. CPNAME* 2. CEPVAL* m. L,2 1. CPNAME* 2. CEPVAL* **NOTES:** "PPBUILDID" and "PPNAME" are required. "SLOTLIST", "SUBSTRATELIST", "AREALIST", and "ALIGNLIST" are optional. * Supplier shall define as many of these CPNAME, CEPVAL		

CPName	*Parameter Value*		
	Description	*Range*	*Format*
	pairs as are supported by the equipment. ** “ELEMENTLIST” is required when using the SEMI M21 coordinate system in the definition of an AlignName or AreaName.		
“PROCESS-BLD-GROUP” (for Review Equipment)	L,m 1. L,2 1. “PPBUILDID” 2. ProcessBuildGroupID 2. L,2 1. “PPNAME” 2. ProcessProgramID 3. L,2 1. “SLOTLIST” 2. L,n 1. $SlotID_1$: 2. $SlotID_n$ ***Or*** 1. “SUBSTRATELIST” 2. L,n 1. $SubstrateID_1$: n. $SubstrateID_n$ 4. L,2 1. “AUTOSTART” 2. AutoStart 5. L,2 1. “TABLE-ANOMALY-DEF” 2. AnomalyTableName 6. L,2 1. “ANOMALYNAME” or “M21-ANOMALYNAME” 2. L,n 1. $AnomalyID_1$ or $M21AnomalyID_1$: n. 7. L,2 1. “ALIGN-TABLE-DEF” 2. AlignTableName 8. L,2 1. “ALIGNNAME” 2. L,n 1. $AlignName_1$: n. 9. L,2 1. “ELEMENTLIST”** 2. L,n 1. $ElementID_1$: n. 10. L,2	$m \geq 2$	List of *m* data items

CPName	*Parameter Value*		
	Description	*Range*	*Format*
	1. CPNAME* 2. CEPVAL* m. L,2 1. CPNAME* 2. CEPVAL* **NOTES:** "PPBUILDID" and "PPNAME" are required. "SLOTLIST", "SUBSTRATELIST", "AREALIST", and "ALIGNLIST" are optional. * Supplier shall define as many of these CPNAME, CEPVAL pairs as are supported by the equipment. ** "ELEMENTLIST" is required when using the SEMI M21 coordinate system in the definition of an AlignName or AreaName.		

NOTE 1: ❖ Required ISEM parameters: "CARRIERID", "LOCATIONID", "PROCESS-BLD-GROUP"

13.2.3 *Remote Commands vs. Processing States* — The following table indicates states where the remote commands are allowed. This is indicated with a "X" mark.

Table 10 Remote Commands vs. Processing States

	COMMAND											
PROCESSING STATE	*STOP*	*START*	*RESUME*	*PP-UPDATE*	*PP-SELECT*	*PAUSE*	*NEXT-MATERIAL*	*MAP-CARRIER*	*PP-ASSIGN*	*CLEANUP*	*ABORT*	*PP-UNASSIGN*
IDLE					X			X	X			X
ABORTED									X	X		X
PROCESSING ACTIVE												
STOPPING									X		X	
ABORTING												
PAUSE												
ALARM PAUSED	X								X		X	
PROCESS PAUSE												
PAUSING	X								X		X	
PAUSED	X		X	X					X		X	
CHECKING	X								X		X	
PROCESS												
SETTING UP	X					X		X	X		X	X
READY	X	X				X			X		X	X
EXECUTING												
LOAD	X					X			X		X	
UNLOAD	X					X			X		X	
WORKING												
INSPECT	X					X	X		X		X	
ALIGN	X					X	X		X		X	
REVIEW	X					X	X		X		X	

14 Scenarios

14.1 *Run Level Reporting Scenario* — This scenario only has expected events (i.e., no alarms or errors).

COMMENT	HOST	EQUIPMENT	COMMENT
			The equipment is in the IDLE processing state and in The ONLINE REMOTE control state. The host has defined, linked, and enabled RUN level report for CEIDs 2, 3, and 5.
Host sends a PP-SELECT command specifying a ”CARRIERBLD”	S2,F49-->		
		<--S2,F50	Command Acknowledge
			The equipment transitions from IDLE to SETTING UP, and material arrives at input port.
		<--S6,F11	SETTING UP -> READY (CEID 3)
Event Report Acknowledge	S6,F12-->		
START	S2,F41-->		
		<--S2,F42	Host Command Acknowledge

			READY -> LOAD.
			[WHILE] Note End of Run
			   LOAD -> WORKING
			   WORKING -> UNLOAD
			   UNLOAD -> LOAD
			[END WHILE]

		<--S6,F11	LOAD -> STOPPING (CEID 5)
Event Report Acknowledge	S6,F12-->		
		<--S6,F11	Run Processed Data Valid event.
Event Report Acknowledge	S6,F12-->		
			The equipment transitions from STOPPING to IDLE.

14.2 *PP-UPDATE Remote Command Scenario* — Host issues the PP-UPDATE remote command.

COMMENT	HOST	EQUIPMENT	COMMENT
START	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	READY -> LOAD
Positive Acknowledge.	S6,F12-->		
			[WHILE] Not End of Run 1) LOAD -> WORKING 2) WORKING -> UNLOAD 3) UNLOAD -> LOAD [END WHILE]
Sometime during the [WHILE]:			
PAUSE	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	Transition to PAUSING
Positive Acknowledge.	S6,F12-->		
		<--S6,F11	PAUSING -> PAUSED
Positive Acknowledge.	S6,F12-->		
PP-UPDATE	S2,F49-->		
		<--S2,F50	Positive Acknowledge.
		<--S6,F11	PAUSED -> CHECKING
Positive Acknowledge.	S6,F12-->		
		<--S6,F11	CEID is posted. [IF] the updates are valid: Return to the previous process state through history. [ELSE] Return to the PAUSED state. The Process program remains unchanged. [ENDIF]
Positive Acknowledge.	S6,F12-->		

14.3 *PP-SELECT Remote Command Scenario*

COMMENT	HOST	EQUIPMENT	COMMENT
			The equipment is in the IDLE processing state and in the ONLINE REMOTE control state.
Host sends a TABLE-DEF to the equipment.(See Section 11.)	S13,F13-->		
		<--S13,F14	Table Data Acknowledge
Host sends more tables if needed.	S13,F13-->		
		<--S13,F14	Table Data Acknowledge
Host prepares the remote command to initiate an inspection run, including the “TABLE-AREA-DEF”, ”TABLE-ALIGN-DEF”, and ”ELEMENTLIST”, if required.			
Host sends a PP-SELECT command specifying a ”CARRIERBLD”.	S2,F49-->		
		<--S2,F50	Command Acknowledge The equipment transitions from IDLE to SETTING UP to READY.
START	S2,F41-->		
		<--S2,F42	Host Command Acknowledge READY -> LOAD. [WHILE] Not End of Run LOAD -> WORKING WORKING -> UNLOAD UNLOAD -> LOAD [END WHILE] LOAD -> STOPPING
		<--S13,F13	Equipment sends anomaly table with additional data, including the table name using Table Data Send command.
Table Data Acknowledge	S13,F14-->		
			The equipment transitions from STOPPING to IDLE.

14.4 *Event Report and ISEM Table Transfer Command Scenario*

COMMENT	HOST	EQUIPMENT	COMMENT
			The equipment is in the IDLE processing state and in the ONLINE REMOTE control state.
Host defines report with AnomalyTableName and AnomalyTableType	S2,F33-->		
		<--S2,F34	Define Report Acknowledge
Link report to RunDataComplete event	S2,F35-->		
		<--S2,F36	Link Event Report Acknowledge
Enable event	S2,F37-->		
		<--S2,F38	Enable Event Acknowledge
Host sends an ISEM table to the equipment.	S13,F13-->		
		<--S13,F14	Table Data Acknowledge
Host sends more tables if needed.	S13,F13-->		
		<--S13,F14	Table Data Acknowledge
Host sends a PP-SELECT command specifying a ”CARRIERBLD”	S2,F49-->		
		<--S2,F50	Remote Command Acknowledge The equipment transitions from IDLE -> SETTING UP -> READY.
START	S2,F41-->		
		<--S2,F42	Host Command Acknowledge READY -> LOAD. [WHILE] Not End of Run LOAD -> WORKING WORKING -> UNLOAD UNLOAD -> LOAD [END WHILE] LOAD -> STOPPING STOPPING -> IDLE
		<--S6,F11	RunDataComplete event with AnomalyTableName and AnomalyTableType.
Event Report Acknowledge	S6,F12-->		
Host sends Table DataRequest	S13,F15-->		
		<--S13,F16	Equipment sends requested table TBLACK = 0 if no errors.

15 GEM Capabilities

The purpose of this section is to specify any SEMI E30 additional capabilities that are required to be supported by this class of equipment.

15.1 *Requirements*

15.1.1 This standard requires that the SEMI E30 fundamental requirements and additional capabilities have been implemented on the ISEM equipment with the exception of limits monitoring and trace reporting. If these capabilities are implemented, they shall be implemented as required by the SEMI E30 document. The following SEMI E30 additional capabilities required by ISEM are:

- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Remote Control
- Equipment Constants
- Process Program Management
- Spooling
- Trace Data Collection (optional)
- Control (Host-Initiated)

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E30.1 and was approved for publication by full letter ballot procedures on September 3, 1999.

R1-1 Defect Classification Code Management

The purpose of this section is to provide a method and specific formats to define, identify, and communicate coordinate systems and site locations on substrates for alignment sites, anomaly locations, and other sites used by the ISEM equipment.

R1-1.1 *Classification Codes and Defect Classification* — One function of review equipment is to view previously identified anomalies and to associate a defect classification code with each anomaly. A classification code is an identifier for a classification description.

Typically, the review equipment has a set of defect classification codes and their descriptions available to the operator. Then, for each anomaly, the operator selects a particular code to be associated with that anomaly. This action is defect classification.

The set of valid classification codes and their descriptions may change from one run to another. For example, the same main process program could be used with different substrate levels, and each level may use a different set of classification codes. The purpose of this section is to provide the requirements so that a user can both define several sets of classification codes and their descriptions and can also manage these sets on ISEM equipment.

R1-1.2 *Requirements*

- Each set of classification codes and their descriptions shall have an identifier, known as a classification code set ID.
- Review equipment shall provide a means for the user (the host or the operator) to define a classification code set, consisting of (a) the classification code set ID and (b) the list of classification codes and their descriptions.
- Equipment shall provide a means to manage the various classification code sets.
- A main process program shall include a process program variable that specifies the particular classification code set ID to be used.
- Equipment vendor shall provide documentation to the user regarding how to define and manage classification code sets.

Comment: In one implementation, the equipment considers a classification code set to be a sub-process program or an ISEM table. This would allow the user to identify a classification code set by name (using a PPID) or a table name and thereby managing this sub-process program with the SEMI E30 Process Program Capability or with SEMI E58 ARAMS tables.

R1-2 Reporting Coordinates and Coordinate Systems

The purpose of this section is to provide a method and specific formats to define, identify, and communicate coordinate systems and site locations on substrates for alignment sites, anomaly locations, and other sites used by ISEM equipment.

The ISEM-required formats are intended to minimize the number and type of site location format transformations needing to be supported by both equipment suppliers and users.

All ISEM-required site location formats involve the use of an ISEM-defined right-handed Cartesian coordinate system, established on substrates in an ISEM-defined manner. The scope of the detailed methods in this section are specific to unpatterned and patterned wafers in this release, but the section is intended to be general enough in methodology so that it can be extended to other substrate types in future revisions of ISEM, if required.

The purpose of inspection and review equipment is to locate, evaluate, classify, and report anomalies on substrates. ISEM equipment may deal with either unpatterned or patterned substrates or both. In most cases, the anomaly location is part of the information reported and/or used by ISEM equipment. An anomaly location is reported at a particular site with x,y coordinates in a particular coordinate system. Site coordinates are also used by ISEM equipment for the alignment sites for defining a coordinate system on a substrate. A standard method is needed to define a coordinate system and to report site coordinates for both alignment sites, anomaly locations, and any other reference sites needed by ISEM equipment. A standard method is essential in order to transfer the anomaly site information from one equipment to another.

R1-2.1 *Site Location Accuracy* — Each equipment has an accuracy with which it can define or locate a site as being within a certain area. This area associated with a site is determined by the equipment accuracy, based on the accuracy of its motion and imaging systems to locate a site, as well as on the accuracy with which it can define the coordinate system on the substrate.

When equipment shall locate a particular site on a substrate based on the expected or design-based location, then the location of a site or feature on an actual substrate is further affected by the accuracy of the equipment which placed the pattern on the substrate.

R1-2.2 *Expected or Designed Locations vs. Actual Locations* — The placement of patterns, sites, and coordinate systems is designed to be at certain mathematically described locations relative to one another and to an ideal substrate. These are the expected or designed locations. When a pattern is written by equipment onto a specific substrate, the actual placement of the pattern, the pattern-elements, and their features may differ from the expected locations, due to variations in equipment performance and variations in substrate shape and dimensions.

R1-2.3 *Substrate Coordinate Systems (Unpatterned)* — A substrate coordinate system is a coordinate system which has both origin and axes defined by the shape and dimensions of the substrate and which does not depend on whether there is a pattern on the substrate or whether it is unpatterned. This coordinate system is used to locate or define sites relative to the substrate.

R1-2.4 *Substrate Pattern Coordinate System* — A substrate pattern coordinate system is a coordinate system which has its origin and axes defined by the pattern as a whole on the substrate. This coordinate system is used to locate or to define sites relative to the pattern on the substrate. The expected or designed location of the pattern on the substrate can be defined in terms of the placement of the origin and axes of the substrate pattern coordinate system relative to those of the substrate coordinate system. The actual location of a pattern on a substrate may differ from the expected location. The actual location is determined by locating two or more alignment sites on the patterned substrate. The alignment sites are specific points of certain features in the pattern. The coordinates of the alignment sites are given in the substrate pattern coordinate system. In many cases, equipment does not align to the specific pattern elements but instead uses the defined locations of the pattern elements within the substrate pattern coordinate system.

R1-2.5 *Pattern Element Coordinate System* — A pattern-element coordinate system is a coordinate system which has its origin and axes defined by the pattern of one specific rectangular element in a pattern (a defined arrangement) of equal-sized rectangular elements. This coordinate system is used to locate or to define sites relative to that specific pattern-element. The expected or designed location of the pattern-element within a pattern can be defined in terms of the placement of the origin and axes of the pattern-element coordinate system relative to those of the pattern coordinate system. The actual location of a pattern-element within a pattern on a substrate may differ from the expected location. The actual location is determined by locating two or more alignment sites within the pattern-element. The coordinates of the alignment sites are given in the pattern-element coordinate system.

R1-2.6 *Parallel Coordinate Systems* — A second coordinate system is considered to be parallel to a first coordinate system if the origin of the second can be defined as a translation from the origin of the first and if the axes of the second are parallel and in the same direction as those of the first.

R1-2.7 *Requirements* — The following is a list of requirements for ISEM equipment regarding coordinate systems and reporting site locations:

- ISEM equipment shall document whether it deals with coordinate systems based on (a) a substrate, (b) a substrate pattern, or (c) a pattern-element or whether it deals with several of these coordinate systems.
- ISEM equipment shall establish a substrate coordinate system using a standard, documented method. This coordinate system is not based on any pattern on the substrate. This coordinate system shall be a right-hand Cartesian coordinate system and shall be identified by a name.

  NOTE: For wafers, this method is defined in SEMI M20 (Specification for Establishing a Wafer Coordinate System), and the coordinate system is named “M20.”
- For equipment dealing with substrate pattern coordinates, the substrate pattern coordinate system shall be established in a standard, documented method relative to the substrate coordinate system (the “unpatterned” coordinate system). This substrate pattern coordinate system shall be a right-hand Cartesian coordinate system and shall be designed to be parallel to the substrate coordinate system. The substrate pattern coordinate system shall be identified by a name. The location of its origin and axes relative to the substrate coordinate system shall be communicated in terms of the substrate coordinate system.

  NOTE: For wafers, this method is the one described below, and the substrate pattern coordinate system is named “M20P”, and its origin and axis relative to the SEMI M20 coordinate system are given in terms of “M20” coordinates and are communicated using XlateData.
- For equipment dealing with pattern-element coordinates, the pattern-element coordinate system shall be established in a standard, documented

method relative either to the substrate pattern coordinate system or to another pattern-element coordinate system. The pattern-element coordinate system shall be a right-hand Cartesian coordinate system which is designed to be parallel to the substrate pattern coordinate system. The pattern-element coordinate system shall be identified by a name. The location of its origin and axis relative to the substrate pattern coordinate system shall be communicated in terms of the substrate pattern coordinate system.

NOTE: For wafers, this method is based on SEMI M21, and the coordinate system is named “M21” and its origin and axis relative to the “M20P” coordinate system are given in terms of the M20P coordinates.

- ISEM requires that equipment have the capability to use site location information that is based on the user’s product designs, which the user shall provide in the appropriate ISEM-required format.
- ISEM-compliant equipment shall have the capability to define, locate, and report site information using only the ISEM-defined right-handed Cartesian coordinate system formats. This requirement does not preclude equipment from having additional capability for defining or reporting site location information using other formats.
- Coordinate system name and placement relative to the “higher” coordinate system shall be defined and communicated using the following ISEM data items, in terms of either expected or actual placement: CoordSys, XlateData, and their included data items.
- Alignment site information shall be defined and communicated using the following ISEM items: the variable item AlignList, the “ALIGNLIST”, the Process program class of “TABLE-ALIGN-DEF”, and their included information.
- Areas to be inspected shall be reported using the specific coordinate system defined by the user. The following ISEM items are used to define and communicate area locations: the variable item “AREALIST”, the “AREALIST”, and the Process program class of “TABLE-AREA-DEF”, and their included information.
- The displacement of an actual coordinate system relative to its expected location shall be communicated using the ISEM data item: XlateData and its included data items.
- The displacement of an actual site location relative to its expected site location shall be communicated using the ISEM data item: Offset and its included data items.
- The equipment vendor shall document the requirements for the ISEM data items used in alignment of a coordinate system.
- The equipment vendor shall provide and document a means for the user to define and communicate a pattern map using SEMI M21 data. A pattern map defines the layout of equal-sized rectangular pattern-elements which make up a pattern. Each pattern-element shall have a name, using the SEMI M21 naming convention.

  NOTE: For patterned wafers, the naming method shall be that described in SEMI M21, and the pattern-element information shall be communicated using the ISEM data item of SEMI M21Data.

- For ISEM compliance, inspection equipment shall report various anomaly data; AnomalyID, coordinates, and attributes. Review equipment shall receive this data for anomalies and be able to locate them and perhaps modify the coordinates. Anomaly coordinates shall be reported using ISEM table named “TABLE-ANOMALY-DEF” and its included data.

R1-3 Coordinate System for a Substrate

R1-3.1 *SEMI M20 Coordinate System* — The SEMI M20 standard (Specification for Establishing a Wafer Coordinate System) describes how to map a right-handed Cartesian coordinate system to a substrate so that its origin is at the center of the substrate, and its negative *y*-axis bisects the substrate’s primary fiducial. This coordinate system is defined by ISEM to be the “M20” coordinate system. The only information required by equipment in order to establish an “M20” coordinate system is the substrate size and the type of fiducial, which are communicated using the ISEM data items named **SubstrateSize** and **Fiducial**. Another ISEM data item named **Orientation** identifies how the substrate is loaded on the equipment. Note that the SEMI M20 standard requires that the “M20” coordinate system is fixed on the substrate and is not affected by how the substrate is loaded on equipment. Also, as stated in the SEMI M20 standard, an orientation of “0” degrees designates a substrate loaded on equipment, with the primary fiducial towards the operator or “down.”

R1-3.2 *M20P Coordinate System* — ISEM defines the M20P coordinate system to be one which is aligned to the pattern on the substrate. The M20P coordinate system is useful because in many cases, it is more significant to the user to know the location of an anomaly relative to the pattern on the substrate rather than relative to the substrate shape and dimensions. ISEM also defines the M20P coordinate system to be one which is designed to be "parallel" to the SEMI M20 coordinate system. In practice, because of experimental errors, both the origins and the axes may differ slightly from their intended values of a simple translation and no rotation. Equipment should be designed to be able to locate the alignment sites, given the various possible experimental errors.

R1-3.3 *Establishing an M20P Coordinate System* — A minimum of two alignment sites is necessary to establish an M20P coordinate system on a substrate. Additional sites are often used to determine a scaling ratio of the dimensions of the actual coordinate system relative to the dimensions of the expected coordinate system and are reported using the ISEM data item of **ScaleFactor**.

XlateData is used to report actual coordinate system location. Most equipment cannot distinguish whether patterned substrate site location errors are due to the substrate, the layout on the substrate, or the equipment's ability to locate the sites. However, information that is available through the use of patterned-substrate alignment sites can provide a means for identifying potential equipment problems. For instance, assume that the only pattern-layout location error on a substrate is that due to the establishment of the location of the substrate center and fiducial. For many users and equipment systems, this is a good assumption. If this is the case, then the ISEM data item named **XlateData** can be used to track this error. Although the error may result from multiple sources, being able to track it on various equipment will enable users to apply statistical process control techniques to identify the specific sources.

Offset sites may be found by equipment at actual locations which deviate from their expected locations through either pattern layout errors or equipment "stage" or imaging errors. Again, in a controlled manufacturing process, these combined errors should be normally distributed, and non-normal deviations may indicate possible equipment problems. The actual position of a site relative to its expected position shall be reported through the use of the ISEM data item named **Offset**.

R1-4 Layout of Rectangular Pattern Elements on a Substrate Using SEMI M20 Coordinate System

Equipment shall be capable of routine, automated operation without needing substrate layout information (e.g., field or die maps). However, having the capability to provide substrate layout information to equipment from the host can be desirable. ISEM defines a means to do this in this section for substrates, based on SEMI M21 (Specification for Assigning Addresses to Rectangular Elements in a Cartesian Array.) The SEMI M21 standard is limited to defining how to assign "addresses" to elements and how to find the "array center" element. It does not specify how the rectangular pattern-elements are located on the substrate. In this section, ISEM defines how these pattern-elements are located on a substrate, using the data item named M21Data, and how to establish within-element coordinate systems. Any additional layout information, such as within-element structure details or element attribute information, is beyond the scope of ISEM.

R1-4.1 *ISEM "M21" Layouts*

- An "M21" layout consists of an array of equal-sized rectangular pattern-elements with no space between the pattern elements.
- ISEM defines the "M21" layout on a substrate to include all pattern-elements which are either wholly or partially within the circumference of the substrate.
- The ISEM approach is to define the pattern map by specifying the M20P coordinate for the lower left corner of the minimum number of pattern-elements needed to define the layout, along with the pattern-element addresses (names). For a non-tiled layout, the location and name of a single pattern-element is sufficient to establish the "M21" layout. For tiled layouts, the location and name of one pattern-element in each row or column are required. Note that the location of the lower left corner of some pattern-elements may be outside the circumference of the substrate.
- The "M21" pattern-element coordinate system shall have its *x* and *y* axes parallel to the respective M20P coordinate system axes and shall have their origins at the lower left corner of each element. The pattern-element coordinate system shall have a name and a specific pattern-element address identifier per SEMI M21.
- Layout definition is supported only for host-to-equipment communications. The user is responsible for ensuring that the pattern-element addresses provided to the equipment agree with the SEMI M21 specification. The equipment need not check this, other than to ensure that there are not conflicts within the provided layout, and shall report results with pattern-element addresses as provided by the user.

- "M21" layouts are established within the M20P coordinate system and need not require any additional alignment site data than is needed to establish the M20P coordinate system. However, as with M20P, additional alignment may be necessary because of errors in either the pattern layout or the equipment's ability to locate features. Offset shall be used to report the location corrections that result from any within-element alignments.

R1-5 How an M20P Coordinate System Is Established on a Substrate

The following example is fairly basic. For this example, the M20P coordinate system has a zero translation from the SEMI M20 coordinate system. Also, the equipment documentation states that 4 alignment sites are required. The equipment does M20P alignment on two alignment sites and does a low resolution and then a high resolution alignment at each site. Note that the specific alignment point is different at the two resolutions, so the coordinates are slightly different. The alignment sites are defined to the equipment via the process program class named "TABLE-ALIGN-DEF", as detailed below. The order of the sites in "TABLE-ALIGN-DEF" is not important. The sites are then selected via the CPNAME named "ALIGNLIST", which is included in the PP-SELECT command. The order of the sites listed in "ALIGNLIST" is important and is as-specified in the equipment's documentation. The first item is the alignment site for the first low resolution site, the second item is for the first high resolution site, the third item is the second low resolution site, and the fourth is the second high resolution site.

"TABLE-ALIGN-DEF"

AlignName	*Coordx*	*Coordy*	*Coordsys*	*Attribute (1)*
Coarse1	-60000	-200	"M20P"	
Fine1	-60020	-205	"M20P"	
Coarse2	+60000	+200	"M20P"	
Fine2	+59980	+195	"M20P"	

"ALIGNNAME"

L,4

1. <Coarse1>
2. <Fine1>
3. <Coarse2>
4. <Fine2>

Using this information, the equipment will go to the nominal "M20" location for Coarse1, then "find" where it actually is. The offset between the nominal "M20" location and the actual "M20" location is then used to "find" Fine1. The actual M20 location of Fine1 is saved. The process is then repeated for Coarse2 and Fine2. The equipment can now determine the "M20" to M20P offset from the nominal and actual coordinates. First, a summary of the data:

xN1 = -60020 yN1 = -205 Nominal *x* and *y* data for the first fine site

xA1 = -59800 yA1 = -150 Actual *x* and y data for the first fine site

xN2 = +59980 yN2 = +195 Nominal *x* and *y* data for the second fine site

xA2 = +60060 yA2 = +175 Actual *x* and *y* data for the second fine site

The equipment first calculates Theta, using, for example, the formula:

$$\Theta = tan^{-1}\left[\frac{MA - MN}{1 + MA \quad MN}\right]$$

where *MA* and *MN* are, respectively, the slopes of the lines connecting the two actual fine sites and the line connecting the two nominal sites, in “M20” coordinates, calculated as follows:

$$MA = \left[\frac{yA_2 - yA_1}{xA_2 - xA_1}\right] \quad MN = \left[\frac{yN_2 - yN_1}{xN_2 - xN_1}\right]$$

The equipment then calculates *DeltaX* and *DeltaY*, using, for example, the formulas:

$$DeltaX = \left[\frac{C\sin(\Theta) + D\cos(\Theta)}{(\sin(\Theta))^2 + (\cos(\Theta))^2}\right]$$

$$DeltaY = \left[\frac{C\sin(\Theta) - D\cos(\Theta)}{(\sin(\Theta))^2 + (\cos(\Theta))^2}\right]$$

where *C* and *D*, the adjusted site 1 coordinates in a rotation-adjusted coordinate system, are calculated, for example, using the formulas:

$$C = yA1 - ((xN1 \ \sin\Theta) + ((yN1 \ \cos\Theta)$$

$$D = xA1 - ((xN1 \ \cos\Theta) - ((yN1 \ \sin\Theta)$$

The equipment can also calculate a ScaleFactor term to indicate the relative ratio between the length of the vector connecting the nominal alignment sites and the length of the vector connecting the actual alignment sites. This can be used, for example, to judge whether there is a problem with the alignment process, since the difference between these two vectors should be small.

$$ScaleFactor = \frac{VA}{VN}$$

where *VA* and *VN* are the length of the vectors connecting the actual and nominal alignment sites, calculated using the formulas:

$$VN = \sqrt{(yN_2 - yN_1)^2 + (xN_2 - xN_1)^2}$$

$$VA = \sqrt{(yA_2 - yA_1)^2 + (xA_2 - xA_1)^2}$$

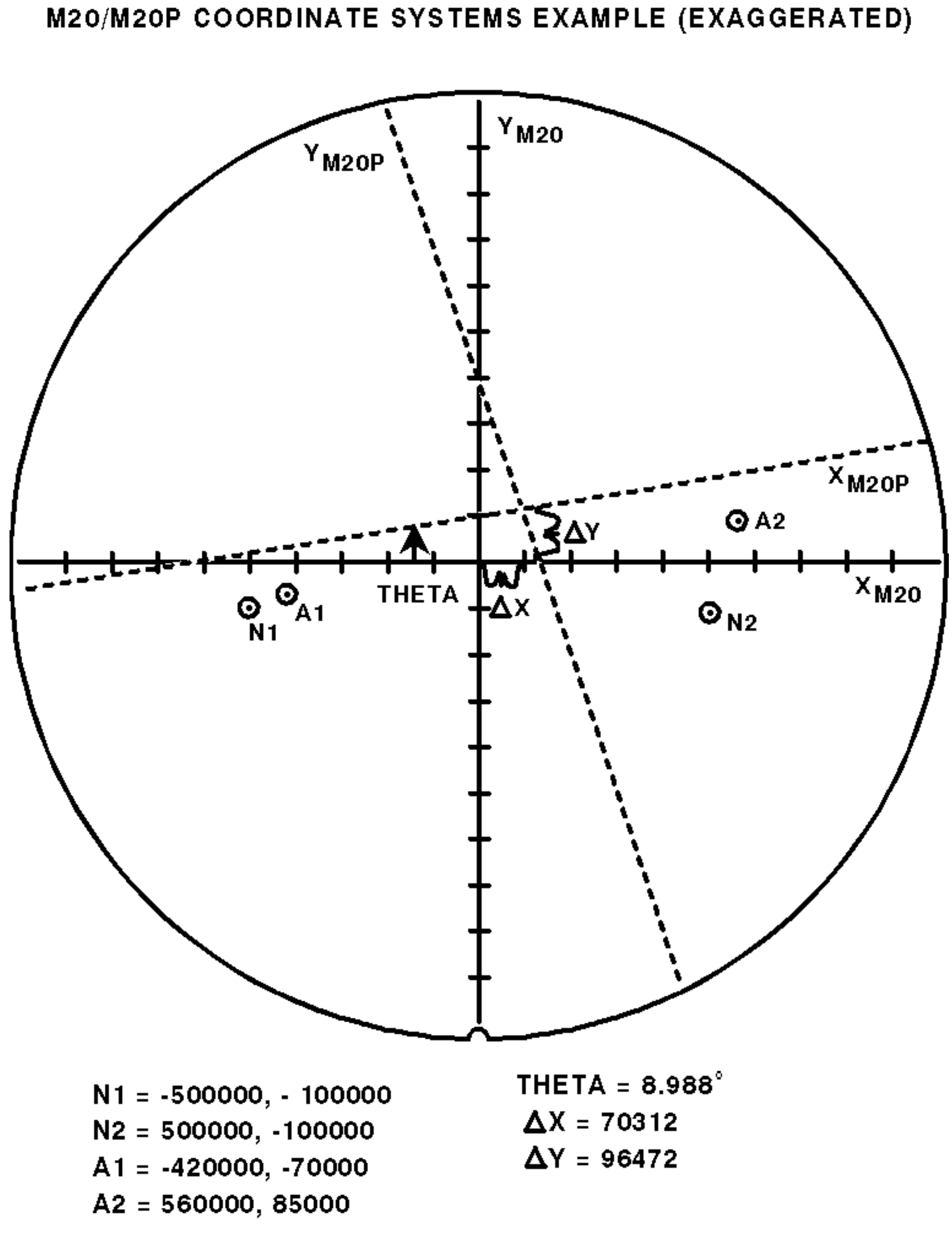

Figure 7
Review Data Management

RELATED INFORMATION 2
APPLICATION NOTES

NOTE: The material contained in these Application Notes is not an official part of SEMI E30.1 and is not intended to modify or supersede the official standard. Rather, these notes describe possible methods for implementing certain ISEM requirements described by the standard and are included as reference material.

R2-1 Using ISEM Table Attributes to Specify Process Related Data Item Variable Values

R2-1.1 Section 11.1 (ISEM Table Data) allows the host to use ISEM Table attributes to specify product and process related information related to the table data. The ISEM Variable Item Dictionary (Table 4) includes seven data items intended to be used for this purpose. They are identified with the comment "This information may be added by the host in the ISEM Tables." Identifying the value of variable data items in Table attributes is not covered in use of ISEM Tables. One method to accomplish this is to use attribute identifiers (ATTRID*n*) that are the same identifiers that are used for the equipment variable data items (Table R2-1). (This is very similar to the method specified in Section 12.5 to identify values to override the default values of variable process program parameters using the "PP-SELECT" remote commands).

Table R2-1 ISEM Variable Items and Their Equivalent ISEM Table Attribute Identifiers

Variable Item (Table 4)		*ISEM Table Attribute Identifier*	*Description*
Name	*Type*		
OperatorID	DV	OperatorID	Identification of the operator of the inspection/review equipment.
ProcessEquipmentID	DV	ProcessEquipmentID	Identification of the process equipment used with the current material immediately prior to the inspection/review.
ProcessEquipmentLocation	DV	ProcessEquipmentLocation	Location (code) of the process equipment used with the current material immediately prior to the inspection/review.
ProcessProgramID	DV	ProcessProgramID	Identification of the process program used with the process equipment used on the current material immediately prior to the inspection/review.
ProcessLevel	DV	ProcessLevel	Identification of the processing level of the current material.
ProductID	DV	ProductID	The product identification of the current material inspected/reviewed.
ProcessRunID	DV	ProcessRunID	Run identification for the process prior to current inspection/review.

NOTE 1: The variable item may be identified using any appropriate SECS II data item format.

R2-2 Example ISEM Table with Item Attributes That Specify ISEM Variable Values Using S13,F13 Table Data Send

R2-2.1 Typical values for Data Items are indicated.

L, 8

1. <DATAID>
2. <OBJSPEC=null>
3. <TBLTYP=DefectData>
4. <TBLID=null>
5. <TBLCMD=1>

6. L, 2
   1. L, 2
      1. <ATTRID= “ProcessProgramID”>
      2. <ATTRDATA= “My Recipe”>
   2. L, 2
      1. <ATTRID= “ProcessLevel”>
      2. <ATTRDATA= “My Level”>
7. L, c
   1. <COLHDR1= “Insp_Anomaly ID”>
   2. <COLHDR2= “Insp_Table specifier”>
   3. <COLHDR3= “Insp_Coordinate X”
   4. <COLHDR4= “Insp_Coordinate Y”
   : // etc…as defined by Table 11.3.5
   c. <COLHDRc>
8. L, r
   1. L, c
      1. <TBLELT11> // A[1..16]
      2. <TBLELT12> // I4
      3. <TBLELT13> // I4
      4. ETC…
      :
      c. <TBLELT1c> // A
   :
   r. L, c
      1. <TBLELTr1>
      :
      c. <TBLELTrc>

SEMI E30.2-0698
HANDLER EQUIPMENT SPECIFIC EQUIPMENT MODEL (HSEM)

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List of Tables

SEMI E30.2-0698
HANDLER EQUIPMENT SPECIFIC EQUIPMENT MODEL (HSEM)

1 Purpose

1.1 This document establishes a Specific Equipment Model (SEM) for Handling equipment (HSEM). The SEM consists of equipment characteristics and behaviors that are applicable to this class of equipment and are required to be implemented in addition to the SEMI E30 fundamental requirements and additional capabilities. The intent of this document is to facilitate the integration of Handling equipment into an automated (semiconductor) factory. This document accomplishes this by defining an operational model for Handling equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior.

2 Scope

2.1 The scope of this document is limited to the definition of Handling equipment behavior as perceived by a SECS-II host that complies with the SEMI E30 model. It defines the view of the equipment through the SECS communications link. It does not define the internal operation of the equipment. It includes a specific processing state model as the basis for the behavior of all equipment of this class.

2.2 This document requires that the SEMI E30 fundamental requirements and applicable additional capabilities (see Section 13, Additional SEMI E30 Capabilities) have been implemented on the handling equipment. This document expands the SEMI E30 standard requirements and capabilities in the areas of the processing state model, collection event, alarm documentation, remote commands, variable item, and process program management.

3 Limitations

3.1 *Communications* — It is required that any HSEM-compliant equipment follow the Communications State Model in SEMI E30. In addition, HSEM-compliant equipment shall support the High Speed Messaging Service (HSMS) communication standard sending SEMI E5 messages over TCP/IP. The reason behind this requirement is the amount of data available for monitoring from this class of equipment. This specification deals only with the behavior of the handler in communicating with the host. It is recognized that the handler may also have a communications link with other process equipment and that the other equipment may also have a communications link with the host. This specification is intentionally non-specific on the communications link requirements between handler and other process equipment to allow the user the greatest amount of flexibility in specific factory configurations.

3.2 *Multi-Process-Site HSEM Implementations* — This SEM makes some demands and assumptions about the Handler with multiple process-sites in a configuration. These requirements are as follows:

Handling equipment in a multiple process-site configuration (i.e., lead conditioning site, electrical test-site) provides identification and status information (see Variable Item) at both the site level and the subsite level. An example could be a handler with both a lead conditioning site and an electrical test-site, with the electrical test-site containing multiple subsites (i.e., test heads).

4 Referenced Documents

4.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

5 Terminology

5.1 *alignment location* — Location that individual packaged units are placed at the process-site (e.g., electrical test).

5.2 *chaining* — The process of execution over multiple lots or runs with the same Process Program and the same handler operating conditions.

5.3 *electrical test-site* — A process-site on the equipment which is coupled with electrical testing equipment for purposes of performing package electrical testing.

5.4 *execution area* — The area from which a current copy of the process program instructions is executed.

5.5 *handling equipment* — An equipment class generally consisting of integrated mechanisms and controls for the purpose of manipulating packaged devices, trays, and tubes during the manufacturing process.

5.6 *indexing* — The controlled stepped movement of material through the handler.

5.7 *kit* — Specific items of hardware and software as specified by the equipment manufacturer that adapt the equipment for a specific unit or unit package.

5.8 *leadconditioning site* — A process-site on the handler where some form of conditioning occurs on the package leadfingers (i.e., warming).

5.9 *leadfinger (or substrate connector lead)* — (1) In ceramic packages, an area of refractory metal that has been plated and is designated for the attachment to a process-site. (2) The area of the unit designated for attachment to a process-site.

5.10 *leadframe* — A sheet metal framework upon which a chip (sometimes chips) is attached, wire-bonded, and then either molded with plastic epoxy or with ceramic and/or metal.

5.11 *media* — A temporary material carrier used to hold and transport units/devices (tubes, trays, etc.).

5.12 *media map* — Formatted data used to map functionally good and bad units/devices to an X, Y, Z location in the media. Maps can be requested by the handler for use prior to processing and then updated after processing.

5.13 *off-line programming (OLP) utility* — Utility to create, edit, and format process programs on a computer, as opposed to creating process programs at the equipment.

5.14 *process-site* — A location on the equipment where work is performed on a packaged device (i.e, electrical test-site, lead conditioning site).

5.15 *process subsite* — An addressable portion of a process-site.

5.16 *reset* — The action of changing the value of a variable, such as wafer count (usually to zero).

5.17 *safe state* — A state in which the equipment presents no danger to the product or user. This implies that safety interlocks are in place such that the equipment can be serviced without harm to the operator and that the material being processed has been removed from the processing station into an accessible location.

5.18 *slot* — A position in a carrier where a leadframe, tray, tube, or other media element may reside.

5.19 *tray* — A flat rectangular form of media for holding singulated packaged units. Also referred to as waffle packs or matrix trays. A tray is generally molded plastic with a defined matrix of cells or pockets tailored for specific packages.

5.20 *tube* — A hollow form of media for holding packaged units. Also referred to as rails or sticks. A tube is generally composed of extruded polymer with internal section dimensions and features tailored for a specific package.

5.21 *unit* — The functional integrated circuit (or chip) that is being handed to a specific process-site.

6 Requirements

6.1 *State Models* — The purpose is to define the equipment-specific processing state model and other state models necessary to portray the expected operational states of the equipment to enable host tracking and control in place of a local operator.

6.2 *State Model Requirements*

6.2.1 The processing state models in this document are required for implementing an HSEM-compliant handler in addition to the required state models in SEMI E30. A state model consists of the following state model diagram, state definitions, and state transition tables.

6.2.2 A state model represents the host's view of the handler, not necessarily the actual handler's internal operations.

6.2.3 All HSEM state model transitions shall be mapped sequentially into the actual equipment events that satisfy the requirements of those transitions. In certain implementations, the handler may enter a state and have already satisfied all of the conditions required by the HSEM state model for transition to another state. The handler makes the required transition without any additional actions in this situation.

6.2.4 Some equipment may need to include additional states. However, any additional states must not change the HSEM-defined state transitions. All expected transitions between HSEM states must occur.

6.3 *HSEM State Model*

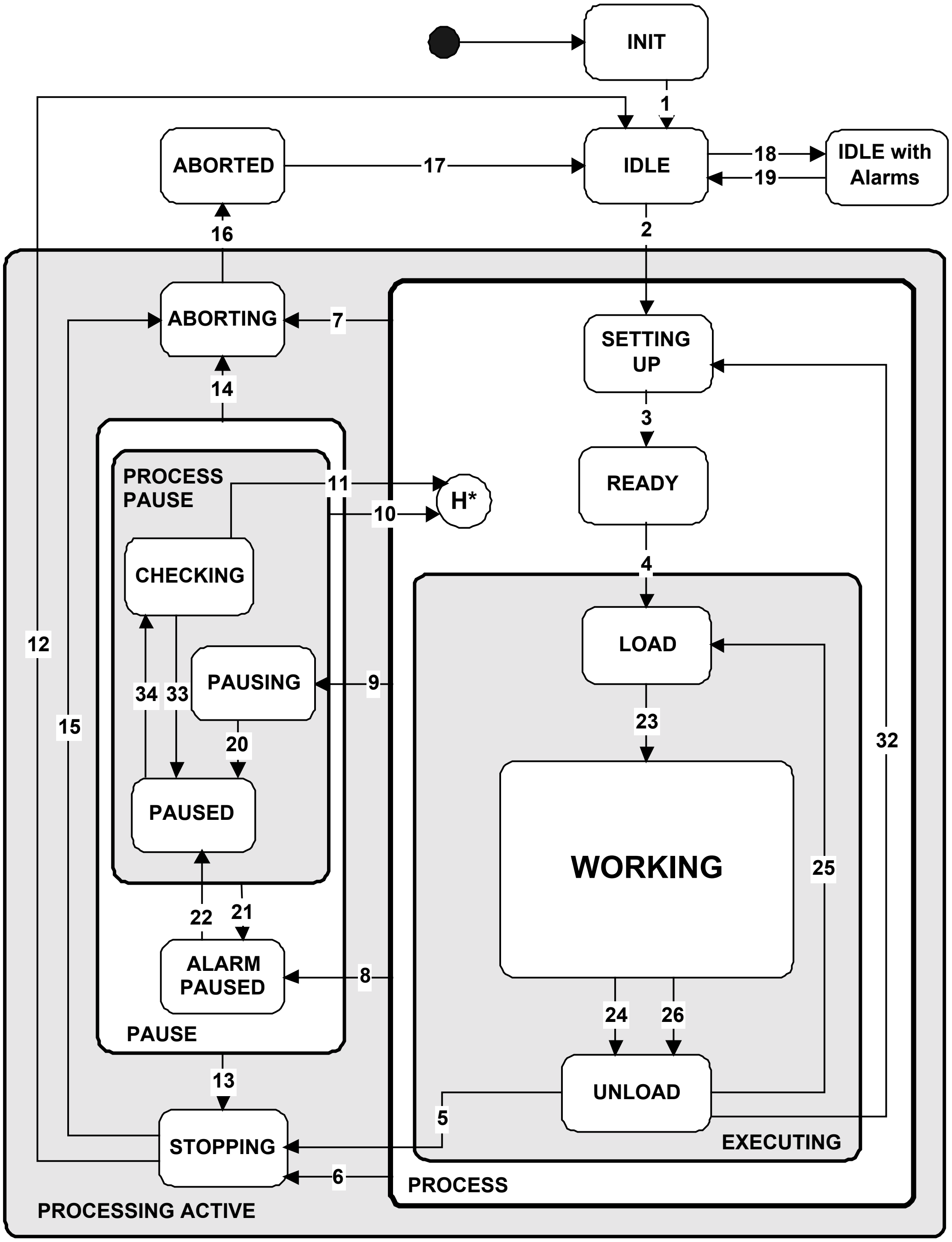

Figure 1
HSEM Processing State Model

6.4 *Description of Handler Processing States*

6.4.1 *ABORTED* — All activity is suspended as a result of an ABORT command. Any alarm and abort conditions must be cleared and verified by an operator before exit from this state.

6.4.2 *ABORTING (PROCESSING ACTIVE Sub-State)* — The handler has received an ABORT command. All activity is suspended. The handler is taking appropriate action to bring itself and material to a "safe" state where possible. Unit or Lot data may be invalid or not available.

6.4.3 *ALARM PAUSED (PAUSE Sub-State)* — An alarm has occurred in the PROCESS or PROCESS PAUSE states, and the handler is waiting for the alarm to be cleared.

6.4.4 *CHECKING (PROCESS PAUSED Sub-State)* — The handler verifies that updates made to the process program are valid (i.e., possible errors induced via an operator during the pause). This is a similar procedure to that which is done in SETTING UP before the handler is ready to transition to the READY state. At the completion of verification, an event is generated when the verification succeeds, and the operator or host must issue a RESUME command to the handler before it will resume processing from the point where it was paused.

6.4.5 *EXECUTING (PROCESS Sub-State*) — The handler is processing material automatically and can continue to do so without external intervention. This state may include interaction with the host or operator.

6.4.6 *IDLE* — Awaiting a command. IDLE is free of ALARMS and error conditions.

6.4.7 *IDLE with ALARMS* — An alarm has occurred in the IDLE state, and the handler is waiting for all alarms to be cleared.

6.4.8 *INIT* — Handler initialization is occurring.

6.4.9 *LOAD (EXECUTING Sub-State)* — This is the state the next unit or units are transferred from the input media to the process-site.

6.4.10 *PAUSE (PROCESSING ACTIVE Sub-State)* — The PROCESS state will be suspended at the completion of the current unit or next opportunity. Actions to put the handler in a safe state are performed. The handler is awaiting a command (RESUME, STOP, or ABORT) or for alarm(s) to be cleared.

6.4.11 *PAUSED (PROCESS PAUSE Sub-State)* — The PROCESS state has been suspended, and the handler is waiting for a command (RESUME, STOP, or ABORT). In this state, the operator may correct error conditions that do not affect the current Process Program selection. One of the possible corrective actions is for the operator to manually align the units being processed.

6.4.12 *PAUSING (PROCESS PAUSE Sub-State)* — The PROCESS state will be suspended at the completion of the current unit or next opportunity. The handler cannot transition to PAUSED state until the current unit is completed and the handler is in a "safe state".

6.4.13 *PROCESSING (WORKING Sub-State)* — Unit is moved to process-site (e.g., for electrical test, to insert into contactor).

6.4.14 *PROCESS COMPLETE (WORKING Sub-State)* — Unit process is complete. Unit is unloaded or returns to alignment for a step and repeat.

6.4.15 *PROCESS (PROCESS Sub-State)* — This state is the parent of those sub-states which refer to the preparation and execution of a process program.

6.4.16 *PROCESS PAUSE (PAUSE Sub-State)* — The handler is free of alarm conditions in the PAUSE state.

6.4.17 *READY (PROCESS Sub-State)* — The handler is ready to begin processing and is awaiting a START command from the operator or host.

6.4.18 *SETTING UP (PROCESS Sub-State)* — The handler is satisfying conditions so that processing can begin. This includes the receipt of any process programs, the material to be processed, and machine-specific calibration. While in this state, the handler can be single-stepped through each process in order for the operator to ensure that the handler is moving the unit correctly.

6.4.19 *STOPPING (PROCESSING ACTIVE Sub-State)* — The handler has completed a Process Program or has been instructed to stop processing and shall do so at the next opportunity. All necessary cleanup is completed within this state with regard to material, data, control system, etc. Data is preserved. Any error condition is cleared before exiting from this state.

6.4.20 *UNLOAD (EXECUTING Sub-State)* — The unit is being removed from the process-site, and the handler determines which transition to take.

6.4.21 *WORKING (EXECUTING Sub-State)* — The handler is processing a specific unit.

6.5 *HSEM Processing State Transitions Table*

Table 1 Processing State Transitions Table

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comments*
1	INIT	All handler initialization is complete with no alarms or error conditions.	IDLE	None	None
2	IDLE	A Process Program is selected.	SETTING UP	Handler-dependent	Commit has been made to setup.
3	SETTING UP	All setup activity has completed, and the handler is ready to receive a START command.	READY	The handler is waiting for a START command.	The selected Process Program is available for execution, and material is present at the input port.
4	READY	The handler receives a START command.	LOAD	Transfers the next unit to the process-site.	LOAD is an EXECUTING sub-state.
5	UNLOAD	The material unloaded completes.	STOPPING	The handler completes the last unit.	None
6	PROCESS	The handler has received a STOP command.	STOPPING	The handler completes the current unit in the WORKING state and unloads it.	The handler begins its cleanup procedure.
7	PROCESS	The handler has received an ABORT command from operator, host, or self-generated.	ABORTING	The handler is put in a “safe” state.	Unit or lot data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended, and the handler is waiting for all alarms to be cleared.	ALARM PAUSED is a PAUSE sub-state.
9	PROCESS	The handler has received a PAUSE command.	PAUSING	The PROCESS state shall be suspended at the completion of the current unit. Any necessary actions to put the handler in a safe state are performed.	PAUSING is a PAUSE sub-state.
10	PROCESS PAUSE	The handler has received a RESUME command.	Previous PROCESS State	Proceeds from the point where processing was previously suspended.	None
11	CHECKING	Parameter checking completes successfully.	STATE based on conditional table.	Return to previous state.	None
12	STOPPING	The handler cleanup is complete, and the handler is free of alarms.	IDLE	None	None
13	PAUSE	The handler has received a STOP command.	STOPPING	The handler proceeds with cleanup.	Data is preserved and is valid.
14	PAUSE	The handler has received an ABORT command.	ABORTING	Any unsafe condition is resolved, if possible.	Data may be invalid or unavailable.
15	STOPPING	The handler has received an ABORT command.	ABORTING	Any unsafe condition is resolved, if possible.	Data may be invalid or unavailable.
16	ABORTING	Unsafe conditions have been resolved where possible.	ABORTED	The handler is waiting for alarm and ABORT conditions to be cleared.	The only state change allowed is to IDLE.
17	ABORTED	An operator has verified that all alarms and abort conditions have been cleared.	IDLE	None	None
18	IDLE	An alarm is set.	IDLE with ALARMS	The handler waits for all alarms to be cleared.	None

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comments*
19	IDLE with ALARMS	All alarms have been cleared.	IDLE	None	The IDLE state is free of alarms.
20	PAUSING	The handler has completed Processing the Current unit in the WORKING state and achieved a safe condition.	PAUSED	The handler is waiting for a command (RESUME, STOP, or ABORT).	None
21	PROCESS PAUSED	An alarm is set by the handler.	ALARM PAUSED	The handler waits for all alarms to be cleared or for a STOP or ABORT command.	None
22	ALARM PAUSED	All alarms are cleared.	PAUSED	The handler is waiting for a command (RESUME, STOP, or ABORT).	None
23	LOAD	A unit(s) is loading to the process-sites.	WORKING	The unit(s) is being processed.	None
24	WORKING	The processing of the current unit(s) completes normally.	UNLOAD COMPLETED UNIT	This unit(s) is transferred from the process sites.	"Normal" completion of the unit(s).
25	UNLOAD COMPLETED	The material unloaded is complete, and material is available.	LOAD	Transfers the next unit(s) to the processing location.	None
26	WORKING	The processing of the current unit(s) completes abnormally.	UNLOAD COMPLETED	This unit(s) is transferred from the process-site.	"Abnormal" completion of the unit(s).
32	UNLOAD UNIT	The last unit *p* of a lot completes, and a new lot or last carrier is received.	SETTING UP	The handler waits for another SELECT command.	None
33	CHECKING	Error was detected in new parameter setting being validated in the CHECKING state.	PAUSED	None	None
34	PAUSED	A RESUME command was received.	CHECKING	Validation of the Process Program Parameters.	Host or operator is required to issue a RESUME command before processing shall continue.

6.6 *Process Model Conditions Table*

Table 2 Process Resume Conditions

Condition	*Next State*
Checking determines that process program conditions were changed.	SETTING UP
Previous State WORKING.	UNLOAD
Previous State READY.	READY
Previous State was SETTING UP.	SETTING UP

7 Collection Event List

7.1 *Requirements*

7.1.1 ALL SEMI E30-required Events are required by the HSEM. Since a Processing State Model is required by the HSEM, all state transitions are required Events.

7.1.2 All SEMI E30-required Events associated with the GEM Control, Communications, Alarm, and Spooling State Models are required.

7.1.3 This section of the HSEM lists only those collection events that are not associated with a change of state or those requiring specific data variables (DVVALs) or Reports defined in the HSEM.

7.2 *Collection Event Tables* — The first table contains required events and associated reports. The second table contains required events and associated data variables.

Table 3 Processing State Transitions Requiring Report Levels

Transition	*From State*	*To State*	*Required DVVALs or Report*
SETUP COMPLETE (3)	SETTING UP	READY	Setup Report

Table 4 Other Required Collection Events

Collection Event Name	*Required DVVALs*
LotComplete	See Lot Report.
DockStatusChange	DockingStatus
BinDataAvailable	See Bin Data Report.
LotStart	Lot/SubLot Start Report
CarrierEmpty	Media-ID, Lot-ID
CarrierFull	Media-ID, Lot-ID
SubLotComplete	SubLot-Report
ReaderFailed	Reader-Type, Barcode-Error-Type
UnitCntInterval	Unit-Count-Interval, Time-Stamp
MediaCntInterval	Media-Count-Interval
SkipCntInterval	Skip-Count-Interval
MediaChange	Media-ID, Product-ID, Media-Type
SubLotStart	Lot/SubLot Start Report

8 Variable Items

The purpose of this section is to define the list of variable items required by the HSEM. Values of these variables are available to the host through collection event reports and host status queries.

8.1 *Requirements*

8.1.1 All generic variable items defined in SEMI E30 are required by all HSEM equipment.

8.1.2 Variable items required by HSEM are categorized as follows:

- *Common Variables (CVs)* — Variables common to all testers.
- *Configuration-Specific Variables (CSVs)* — Variables associated with a specific configuration of the above equipment class.

8.1.3 Any supplier-defined variables shall be documented in the same format used by this document. The following minimum information is required:

<variable name> **Class:** <ECV, SV, or DVVAL> **Format:** <SML>

Description: <If class = DVVAL, description must contain statement of when data is valid.>

<If format = ASCII, then a length is required. It is assumed to be left-justified unless otherwise noted.>

8.2 *Data Types*

8.2.1 Equipment Constants (ECVs) can be changed by the host using S2,F15. The operator may be able to change some values, but the equipment does not change the values on its own. The value of an equipment constant may be queried by the host at any time, using the S2,F13/14 transaction. They reside in non-volatile memory of the equipment. Equipment constants remain in effect until they are overwritten, either by manual entry or by a NEW EQUIPMENT CONSTANT SEND.

8.2.2 Equipment constants have various uses in HSEM, including the following:

- Equipment offsets that match the performance of several pieces of equipment that would otherwise perform differently due to inherent manufacturing differences. Examples are home values and motion axis scaling factors.
- Setting the configuration of the equipment to allow for different material specifications, equipment options, material flows, frequency of automatic functions, etc. Examples are media and yield check frequency.
- Managing optional machine features. Examples are constants that indicate whether optional features, such as automated media stackers, are present and control the configuration and function of these optional subsystems when they are present.

8.2.3 Status Variables (SVs) are valid at all times. An SV may not be changed by the host but may be changed by the equipment or operator. The value of status variables may be queried by the host at anytime using the S1,F3/4 or S6,F19/20 transactions.

8.2.4 DVVALs are variables that are valid only upon the occurrence of specific collection events. An attempt to read a data variable at the wrong time shall not generate an error, but the data reported may not have relevant meaning.

8.2.5 *Data Item Requirements for Multi-Head, Multi-Site Equipment* — The identification for multi-head and multi-site data (data variable, status variables, events, etc.) is addressed in this specification through the use of status variables with list structures. In the table below, the subheading "Process-Site Group" contains variables which must be available for all process-sites on the handler equipment. When multiple process-sites exist, either a list structure or table structure may be used to show multiple occurrences of a specific variable.

8.3 *Variable Item Table*

Table 5 Variable Item Table

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*
		Physical Handler Group			
EquipSerialID	CV	Identification of Equipment	SV	A[1..16]	Valid in all states.
HandlerComStatus	CSV	Status of comm link between handler/s (0 = Disabled, 1 = 1-way enabled, 2 = 2-way enabled, 3 = Not communicating)	SV	U4	Valid in all states.
KitID	CSV	ID of unique tooling unit	SV	A[1..24]	Valid in all states.
LightPoleStatus	CSV	Color/status (i.e., Red/flash)	SV	A[1..16]	Valid in all states.
LinkPortStatus	CSV	(3 = Input/Output linked, 2 = Input linked, 1 = Output linked, 0 = HANDLER not Linked)	SV	U4	Valid in all sub-states.
MediaID	CV	Media Serial Number	SV	A[1..24]	Valid in Executing state.
OperationType	CSV	Current Operation Mode (i.e., maintenance, production)	ECV	A[1..24]	Valid in all states.
OperatorID	CSV	Current Operator ID	ECV	A[1..24]	Valid in all states.
QueueStatus	CV	PPID Queued to be run	SV	U4	Valid in all states.
ReaderErrorType	CSV	Type of error detected by the material reader.	DVVAL	A[1..24]	Supplier-defined.
		Process-Site Components			

Variable Name	Category	Description	Class	Format	Comments
AlignmentCount	CSV	Number of units since last alignment (i.e., Homing/Adjustment).	SV	U4	Valid in all states.
DockingStatus	CSV	Information on handler/docking status (0 = Yes, 1 = No)	SV	U4	Valid in all states.
HardBinID	CV	Process-Site Bin Out Number	DVVAL	U4	Valid at BIN-DATA-AVAILABLE Event.
HardBinName	CV	Process-Site Bin Out Name	DVVAL	A[1..40]	Valid at BIN-DATA-AVAILABLE Event.
InsertionForce	CSV	Insertion-Force energy	DVVAL	F8	Valid in PROCESSING state.
InsertionForceSetpoint	CSV	Insertion-Force set point (setpoint)	ECV	F8	Valid in all states.
LotID	CV	Lot Identification	SV	A[1..40]	Valid in all states.
LotProcessingTime	CV	The time since start of current Lot. HHMMSSCC	DVVAL	A[16]	Valid in Process-Sub-State.
MediaChangeTime	CV	Elapsed time to replace media and send ready.	SV	A[16]	Valid in all states.
MediaCount	CV	Number of media since last reset.	SV	U4	Valid in all states.
MediaCountInterval	CV	Event generated when number of media is completed.	SV	U4	Valid in all states.
PresentPositionActual	CSV	Present position actual.	ECV	U4	Valid in all states.
PresentPositionSetpoint	CSV	Present position set points (setpoint).	ECV	U4	Valid in all states.
ProcessSiteTemp	CSV	Process-site temperature (setpoint).	SV	F8	Celsius - Set point.
ProcessSiteID	CV	ID of process-site in configuration.	SV	U4	Valid in all states.
ProcessSiteStatus	CV	$Site_n$ Availability (1 = enabled, 0 = disabled)	DVVAL	F8	Valid in all states.
ProcessSubsiteID	CV	Subsite matrix location within process-site.	SV	U4	Valid in all states.
ProcessSubsiteStatus	CV	$Subsite_n$ Availability (1 = enabled, 0 = disabled)	DVVAL	F8	Valid in all states.
ProductID	CV	ID of product for which tester is currently configured.	DVVAL	A[1..40]	Valid in PROCESS states.
SkipCount	CSV	Number of units skipped since last reset (Skip + Process = Total)	SV	U4	Valid in all states.
SkipCountInterval	CSV	Event generated when number of units is skipped.	SV	U4	Valid in all states.
StartProcessPortID	CSV	Start process source (i.e., hand, keyboard, host)	SV	U4	Valid in all states.
SubLotID	CV	SubLot Identification	SV	A[1..40]	Valid in all states.
UnitCount	CV	Number of units since last reset.	SV	U4	Valid in all states.
UnitCountInterval	CV	Event generated when number of units is completed.	SV	U4	Valid in all states.
UnitPosition	CSV	X, Y, Z media location of a unit.	SV	U4	Valid in all states.
UnitStatus	CSV	(1 = Processed, 0 = Skipped)	SV	U4	Valid in all states.

8.4 *HSEM Required Reports* — The reports below are required as "canned" or preconfigured reports by HSEM. HSEM does not require the equipment to guarantee the accuracy of data identified in these reports outside the PROCESSING ACTIVE state defined in the HSEM process state model.

8.4.1 *Setup Report* — Table 6 contains variables that are required to be available at the setup complete event.

Table 6 Required Variables at Setup Complete Event

Variable Name	*Notes*
KitID	Configuration Kit
MediaID	Serial # of Media
LotID	
PPExecName	(per SEMI E30)
EquipID	
ProductID	Current
InsertionForceSetPoint	

8.4.2 *Process Report* — Table 7 contains variables that must be available when the equipment is in the PROCESSING state.

Table 7 Required Variables for PROCESSING State

Variable Name	*Notes*
AlignmentCount	
ProcessSiteTemp	
LotProcessTime	
OperatorID	
OperationType	

8.4.3 *Lot/SubLot Report* — Table 8 below contains variables that must be available at the completion of a wafer.

Table 8 Lot/SubLotStartVariables

Variable Name	*Notes*
OperatorID	
LotID	
SubLotID	
PPExecName	(per SEMI E30)
ProductID	
SkipCount	

8.4.4 *SPC Report* — The table below contains variables that must be available and reported at the completion of a unit.

Table 9 Required Variables at Completion of Unit

Variable Name	*Notes*
UnitCount	
SkipCount	
SkipCountInt	
UnitCountInt	
MediaCount	
MediaCountInterval	
HardBinID	
MediaID	
OperatorID	

9 Process Program Management

9.1 *Process Program Requirements*

9.1.1 The HSEM requires that the SEMI E30 capability of process program management be fully supported for this class of equipment. The HSEM also requires that the process program have a structure that enables the user to build process programs with default conditions that can be overridden for a run. The concepts of process program structure and process program variable parameters are discussed in the following sections. The HSEM also requires the following:

- Minimum, maximum, and default parameter values must be defined for all process programs.
- Verification will occur when a process program is downloaded to the equipment; the program syntax must be verified by the equipment manufacturer.
- Parameter validation will occur when a process program is downloaded. Parameters must be type and range checked.
- Equipment should provide the functionality to manually or interactively modify the parameters set in the process program.
- An error message must be generated from the handler if the process program parameters are outside the range of the machine calibration.

9.2 *Process Program Structure*

9.2.1 A handler process program must contain the following information:

- Machine-specific configuration parameters
- Process-Site-specific information section
- Media-Type-specific information section
- Unit (Unit/Package) information section

9.2.2 When combined, this information constitutes a complete process program. It is emphasized that the HSEM does not enforce the exact format and data type of each section. However, it does provide direction as to what each section should consist of.

9.2.3 *Machine-Specific Configuration Parameters* — Each brand or type of handler may have one or more machine-specific configuration parameters. Examples of such parameters would be input configuration, number of process-sites, and output configuration. Even though they are supplier-specific, these parameters nevertheless play a vital role in the overall generation or creation of a process program. Since the machine-specific parameters can differ from one equipment manufacturer to another, the HSEM does not specify the exact number, data types, and format of these parameters. These details are left to the sole discretion of the equipment manufacturer.

9.2.4 *Process-Site-Specific Information* — This process-site-specific section contains information necessary for the configuration and execution of the various process-sites configured on the equipment. Each equipment may contain different process-site configurations. Since these configurations will differ, the HSEM does not specify the exact number, data types, and format of these parameters. HSEM does recommend a minimum list of data items for the common handler process-sites. These include:

9.2.5 *Thermal Conditioning Site Parameters*

- Temperature Set Point
- Upper-Temp Guardband Set Point
- Lower-Temp Guardband Set Point
- Soak Time
- Test-Site Temp

9.2.6 *Test-Site Parameters*

- Device Pick Up/Place
- Speed of Device Pick Up/Place
- Device Insertion/Retraction
- Speed of Device Insertion/Retraction
- Speed of Index Mechanism
- Insertion/Place Force/Stroke

9.2.7 *Lead Condition Site Parameters*

- Device Pick Up/Place
- Speed of Device Pick Up/Place
- Speed of Insertion
- Insertion Force/Stroke

9.2.8 *Sort Sites Parameters*

- Device Pick Up/Place
- Speed of Device Pick Up/Place
- Device Index
- Insertion Force/Stroke
- Sort Category Set
- *Sort Category* – Full/Empty/Partial
- *Sort Media* – In place or empty.

9.2.9 *Unit/Device-Specific Information* — The unit/device-specific section contains information necessary for the configuration and execution of the specific units to be handled by the equipment. HSEM requires a minimum list of data items be available to determine package dimensions, terminal dimensions, package height, and coplanarity.

9.2.10 *Media-Type-Specific Information* — The media-type-specific information section contains information necessary for the configuration and execution of the specific media type in use on the equipment. HSEM requires a minimum list of data items be available to determine row/column count, X/Y distance to a cell, device height in tray, media height, and X/Y pitch.

9.3 *Methods of Process Program Creation* — The method by which an equipment manufacturer creates a process program may be unique to that manufacturer. However, it is required that the customer at least be given both of the following options for the creation of a process program.

9.3.1 *Off-Line Development* — Using this method, the customer is given a set of software tools (process program compilers, decompilers, and debuggers) that enables him/her to generate or create a process program using the above mentioned information (flow, parameter, functional test, etc.). The newly generated process program then is downloaded onto a specific handler, verified, and is now ready to be selected and executed locally by the operator or remotely by the host computer. If this process is used, the supplied software tools should closely mimic or simulate a handler so that a user can create a complete process program. In many situations, minor adjustments may be needed to the process program on the equipment before it is completely ready for execution.

9.3.2 *On-Line Development* — The second option is to enable the user to download the above-mentioned information (tables or files) onto the equipment and create the actual process program on the equipment itself.

10 Remote Commands

The purpose of this section is to identify remote commands, command parameters, and valid commands versus states in the processing state models.

10.1 *Requirements*

- The equipment must support the GEM-required remote commands. (Some of the SEMI E30-required remote commands are restated here to define HSEM-specific requirements.)
- All the remote commands defined by HSEM are required.
- The alphanumeric strings defined by HSEM for remote commands (RMCD) and command parameters (CPNAME) are required.
- If additional remote commands are supported, then the “Remote Command Versus Valid States” matrix must be generated for these additional commands. Place an “X” in the table for each state in which a given command is valid.

10.2 *Remote Command Descriptions*

10.2.1 *ABORT-LOT* — This command terminates the current processing. ABORT makes no guarantee about completion of the current unit. Levels of ABORT may be specified (see Table 10, Remote Command Descriptions, for details).

10.2.2 *PAUSE* — This command transitions the handler to the PAUSING process state when the current unit/media completes processing.

10.2.3 *RESUME* — This command resumes processing from the point where the process was PAUSED. This command is only recognized if the handler is in the PAUSED state.

10.2.4 *PP-SELECT* — This command instructs the handler to copy the indicated Process Program from non-volatile storage to the handler's Process Program execution area. Process Program Variable Parameters can be specified in this command which modify the default values for these Variable Parameters in the Process Program.

10.2.5 *START* — This command is only available to the host or operator when a process program has been selected and the handler is in the READY processing state. The START command instructs the handler to initiate processing.

10.2.6 *STOP* — This command completes the current unit, stops in a safe condition, and returns to the IDLE processing state. STOP has the intent of bringing about a normal termination after completion of the current unit.

10.2.7 *LAST-CARRIER* — This command instructs the handler to treat the current carrier being processed on the handler as the last carrier of the lot. This forces the subsequent carrier to be considered the first carrier of the next lot.

10.2.8 *NEW-LOT* — This command instructs the handler to treat the next carrier to be processed as a new lot. A new LOT-ID and carrier-list must accompany the new lot command. This command forces subsequent carriers to be considered part of the lot, until all carriers in the carrier list have been processed or until a LAST-CARRIER command is received.

10.2.9 *RESET-TOOL-COUNTS* — This command will initialize equipment tool counts. The minimum set are those contained in the Variable Items section.

10.2.10 *PURGE* — Purge flush or clean the equipment of process material.

10.3 *Associated Remote Command Parameters*

Table 10 Remote Command Descriptions

Command	*Parameter*			
Name	*Name*	*Opt./Req.*	*Description*	*Format*
ABORT	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"CLEANUP"	OPT	The handler finishes processing the current unit and removes all carriers that belong to the lot and enters the Aborting state.	A[7]
ABORT-CARRIER	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"CLEANUP"	OPT	The handler will finish processing the current carrier.	A[7]
NEW-LOT	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"LOTID"	REQ	ID of new LOT.	A[1..40]
PAUSE	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
PP-SELECT	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"LOTID"	OPT	Lot to be processed with thisprogram.	A[1..40]
	"PPID"	REQ	The ID of the program to be used.	A[80]
	"MEDIALIST"	OPT	One or more media to be processed with this program.	ASCII List
RESET-TOOL-COUNTS	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"SVIDLIST"	REQ	List of SVIDs to reset.	ASCII List
RESUME	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
START	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
STOP	"PROCESSSITEID"	OPT	ID of handler process-site.	U4
	"CLOSELOT"	OPT	Automatically close lot.	BOOL
PURGE			Purge handler of all material.	NO PARAMS

10.4 *Remote Commands and HSEM Process Model Mapping* — Table 11 illustrates the relationship between remote commands and states of the HSEM processing state model. An "X" indicates that a command is valid for use in this state. If a remote command is attempted during a non-valid state, the equipment would reject the remote command.

Table 11 Remote Commands vs. Process States

PROCESSING STATE \ COMMAND	STOP	START	RESUME	PP-SELECT	PAUSE	ABORT-MEDIA	ABORT
IDLE				X			
PROCESSING ACTIVE							
PROCESS							
SETTING UP					X		X
READY	X	X			X		X
EXECUTING							
LOAD	X					X	X
WORKING	X				X	X	X
UNLOAD	X					X	X
PROCESS PAUSE							
PAUSING							X
PAUSED	X		X			X	X
CHECKING				X			X
ALARM PAUSED			X				X
ABORTED						X	

Table 12 Remote Commands vs. Process States (cont.)

PROCESSING STATE \ COMMAND	PURGE	NEW-LOT	LAST-CARRIER	RESET-TOOL-COUNTS
IDLE		X		X
PROCESSING ACTIVE				
PROCESS				
SETTING UP			X	
READY	X	X	X	X
EXECUTING				
LOAD				
PROCESSING				
UNLOAD				
PROCESS PAUSE				
PAUSING				
PAUSED	X	X	X	X
CHECKING		X	X	
ALARM PAUSED	X			
ABORTED	X			

11 Scenarios

The purpose of this section is to document possible HSEM-specific operational scenarios.

11.1 *Normal Run Scenario*

This is an error-free run of a single lot with a single test-site. All optional SEMI E30 events are turned off by default.

COMMENT	HOST	EQUIPMENT	COMMENT
Host selects process program.	S2,F41-->		
		<--S2,F42	Equipment Ack
Setting Up			
Setup Complete			
		<--S6,F11	Event : PPLoadOk
Host Ack	S6,F12-->		
Process			
Process.SettingUp			
Process.Ready			
Host commands start-of-lot.	S2,F41-->		
		<--S2,F42	Equipment Acks Start.
			Handler cycles devices... ...until empty...
		<--S6,F11	Event : Empty
Host Acks Event	S6,F12-->		
Host commands end-of-lot.	S2,F41-->		
		<--S2,F42	Handler acks Rmt.Cmd.
Stopping			
		<--S6,F11	Event : Lot Completed
Host Acks Event	S6,F12-->		
Idle			

11.2 *Normal SPC Scenario* — This is a normal SPC run with all optional SEMI E30 events turned off by default.

COMMENT	HOST	EQUIPMENT	COMMENT
Host selects GEM Alarms to enable (list).	S5,F3-->		
		<--S5,F4	Alarms xyz ON
Host selects GEM Events to enable (list).	S2,F37-->		
		<--S2,F38	Events xyz ON
Host selects process program.	S2,F41-->		
		<--S2,F42	Equipment Ack
Setting Up			
Setup Complete			
		<--S6,F11	Event : PPLoadOk
Host Ack	S6,F12-->		
Process			
Process.SettingUp			
Process.Ready			
Host requests start-of-lot report.	S6,F15-->		
		<--S6,F16	Equipment sends report items.
Host commands start-of-lot.	S2,F41-->		
		<--S2,F42	Equipment Acks Start.
		<--S5,F1	Alarm : NoDevicesPresent
Host Acks Alarm	S5,F2-->		
		Time Passes.	
		<--S6,F11	Event : PortLoaded
Host Acks Event	S6,F12-->		
			Handler cycles devices... ... until ...
		<--S5,F1	Alarm : LoadDeviceFail
Host Acks Alarm	S5,F2-->		

ProcessPause			
Host sends operator to clear jam.			
Host sends resume.	S2,F41-->		
		<--S2,F42	Handler Acks and resumes.
Processing			
			Handler cycles devices... ... until ...
Host asks for Temperature x.	S6,F15-->		
		<--S6,F16	Handler sends Temp.x.
			...
		<--S6,F11	Event : HandlerEmpty
Host Acks Event	S6,F12-->		
Host commands end-of-lot.	S2,F41-->		
		<--S2,F42	Handler acks Rmt.Cmd.
Stopping			
		<--S6,F11	Event : Lot Completed
Host Acks Event	S6,F12-->		
Idle			
Host requests end-of-lot-report.	S6,F15-->		
		<--S6,F16	Handler sends report.

11.3 *Multi-Site Run Scenario* — This is a run scenario with 64 test-sites and optional GEM events all turned on with no errors of any type occurring.

COMMENT	HOST	EQUIPMENT	COMMENT
Host selects GEM Alarms to enable (list).	S5,F3-->		
		<--S5,F54	Alarms xyz ON.
Host selects GEM Events to enable (list).	S2,F37-->		
		<--S2,F38	Events xyz ON.
Host selects Trace Data Item(s).	S2,F23-->		
		<--S2,F24	Trace Data Item x ON.
Host selects process program.	S2,F41-->		
		<--S2,F42	Equipment Ack
Setting Up			
Setup Complete			
		<--S6,F11	Event : PPLoadOk
Host Ack	S6,F12-->		
Process			
Process.SettingUp			
Process.Ready			
Host requests start-of-lot report.	S2,F41-->		
		<--S2,F42	Equip sends report items.
Host commands start-of-lot.	S2,F41-->		
		<--S2,F42	Equip Acks Start. ... for each trace item period.
		<--S6,F1	Trace Event x SEND.
Host receives and Acks Trace Item x.	S6,F2-->		
			... for each port event (tray/ tube).

```
                                <--S6,F11       Event  :  PortLoaded

Host Acks Event          S6,F12-->

                                             ... Handler cycles devices ...
                                             ... for each device report
                                                 internal states.

                                <--S6,F11       Event : DeviceClearsInput

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceEntersTemp

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceClearsTemp

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceEntersQueue.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : StartTest.Contactor.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : EndTestReceived.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceBinReceived.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceClearsContactor.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event:DeviceEntersUnloadQueue.x

Host Acks Event          S6,F12-->

                                <--S6,F11       Event : DeviceUnloaded.HardbinX

Host Acks Event          S6,F12-->

                                           ... for each full/empty tray/tube on
                                               input,output.

                                <--S5,F1      Alarm : ContainerReplaceRequest.x

Host Acks request.       S5,F2-->
```

Note that the messages reporting the above internal states may require sub-addressing of test-sites and ports similar to the tester SEM.

```
                                                       Handler cycles devices...
                                                       ... random messages
                                                       (e.g., ... variable request)


Host asks for variable    S6,F15-->
x (devices tested).

                                    <--S6,F16          Handler sends variable.
                                                       ...
                                                       ... eventually ends

                                    <--S6,F11             Event  :  HandlerEmpty

Host Acks Event           S6,F12-->

Host commands             S2,F41-->
end-of-lot.

                                    <--S2,F42             Handler acks Rmt.Cmd

Stopping

                                    <--S6,F11                Event  :  Lot

Completed

Host Acks Event           S6,F12-->

Idle

Host requests             S6,F15-->
end-of-lot report.

                                    <--S6,F16          Handler sends report.
```

12 Additional GEM Requirements

The purpose of this section is to specify any GEM additional capabilities that are required to be supported by this class of equipment.

12.1 *Requirements* — The following GEM additional capabilities required by HSEM are:

- Establish Communications
- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Remote Control
- Equipment Constants
- Process Program Management
- Equipment Terminal Services
- Clock
- Spooling
- Control (Host-Initiated)

mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E30.3-0698
TESTING EQUIPMENT SPECIFIC EQUIPMENT MODEL (TSEM)

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SEMI E30.3-0698
TESTING EQUIPMENT SPECIFIC EQUIPMENT MODEL (TSEM)

1 Purpose

1.1 This document establishes a Specific Equipment Model for testing equipment (TSEM). The TSEM consists of equipment characteristics and behaviors that apply to this class of equipment and are required to be implemented in addition to the fundamental requirements and additional capabilities specified in the Generic Equipment Model (GEM), SEMI E30. The intent of this document is to facilitate the integration of testing equipment into an automated semiconductor factory. This document accomplishes this by defining an operational model for testing equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior.

2 Scope

2.1 The scope of this document is limited to the definition of testing equipment behavior as perceived by a Semiconductor Equipment Communications Standard (SEMI E5) host that complies with SEMI E30. The document defines the view of the equipment through the SECS communications link but does not define the internal operation of the equipment. It includes a specific processing state model as the basis for the behavior of all equipment of this class.

2.2 This document requires that the SEMI E30 fundamental requirements and applicable additional capabilities have been implemented on the test equipment. This document expands SEMI E30 Standard requirements and capabilities in the areas of the processing state model, collection events, alarm documentation, remote commands, variable items, and process program management.

3 Limitations

3.1 *Communications*

3.1.1 It is required that any TSEM-compliant equipment follow the Communications State Model in SEMI E30. In addition, TSEM-compliant equipment shall support the High-Speed Messaging Service (SEMI E37) Communication Standard sending SEMI E5 messages over TCP/IP to maximize the amount of data available for monitoring from this class of equipment. This specification deals only with the behavior of the tester in communicating with the host. It is recognized that the tester may also have a communications link with a test handler or prober and that the handler and/or prober may also have a communications link with the host. This specification is intentionally non-specific on the communications link requirements between handler and tester to allow the user the greatest amount of flexibility in specific factory configurations.

3.2 *Multi-Head and Multi-Site TSEM Implementation*

3.2.1 This SEM makes some demands and assumptions about the tester when it supports multiple test heads containing multiple sites per head. These requirements are as follows:

- Test systems that are capable of operating more than one virtual (or logical) test system at a time provide the virtual tester configuration data via the VirtualConfig variable specified in Section 8.
- The identification for multi-head and multi-site data (data variable, status variables, events, etc.) will be provided via list structures in SEMI E5 messages as detailed in Section 8.
- In the case where equipment supports more than one virtual (or logical) tester, all events and data items must have distinct CEIDs, DVIDs, and SVIDs for each virtual (or logical) tester.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

5 Terminology

5.1 *alignment location* — Site location that individual packaged units are aligned to at the process-site (e.g., electrical test).

5.2 *calibration fixture* — Any electromechanical fixture required to perform system calibration. May consist of multiple components with different part and serial numbers.

5.3 *class* — Classes represent the most coarse view of the test results. At a minimum, there should be two classes defined for each process program: one representing good devices and another representing failed devices.

5.4 *class, hard-bin, and soft-bin* — Equipment is to maintain DVVALs which provide three levels of granularity for test results: class, hard-bin, and soft-bin. Classes, hard-bins, and soft-bins are expected to be defined within a process program, and their names are made available as DVVALs. When device testing has completed, the process program is to determine the class, hard-bin, and soft-bin with which the device is to be associated, based on the results of the testing. Finally, a summation of the number of devices associated with each class, hard-bin, and soft-bin is also maintained throughout the execution of a process program, and these are also made available as DVVALs.

5.5 *diagnostic fixture* — Any electromechanical fixture required to perform system diagnostics. May consist of multiple components with different parts and serial numbers.

5.6 *execution area* — The area from which a current copy of the process program instructions is executed.

5.7 *hard-bin* — Hard-bins represent the typical view of the test results. Within a process program, each hard-bin is associated with a single class. Generally, multiple hard-bins are associated with a particular class.

5.8 *kit* — Specific items of hardware and software as specified by the equipment manufacturer that adapt the equipment for a specific unit or unit package.

5.9 *leadfinger (or substrate connector lead)* — (1) In ceramic packages, an area of refractory metal that has been plated and is designated for the attachment to a process-site. (2) The area of the unit designated for the attachment to a process-site.

5.10 *leadframe* — A sheet metal framework upon which a chip (sometimes chips) is attached, wire-bonded, then molded with plastic epoxy or with ceramic and/or metal.

5.11 *off-line programming (OLP) utility* — Utility to create, edit, and format process programs on a computer as opposed to creating process programs at the equipment.

5.12 *soft-bin* — Soft-bins represent the most detailed view of the test results. Within a process program, each soft-bin is associated with a single hard-bin. Generally, multiple soft-bins are associated with a particular hard-bin.

5.13 *system calibration* — Test system process required to bring the test system into compliance with the test system manufacturer's system specifications.

5.14 *test executive* — The tester software which controls test program execution.

5.15 *test head* — A resource of the tester. The electromechanical interface between the device/unit and the tester.

5.16 *test-site* — A specific site on a test head.

5.17 *test-board* — The electromechanical interface necessary to enable temporary electrical contact between the device/unit to be tested and the tester resource. May consist of multiple components.

5.18 *testing equipment* — An equipment class generally consisting of integrated mechanisms and controls for performing electrical tests of packaged devices and/or wafer die during the manufacturing process.

5.19 *unit* — The functional integrated circuit (or chip) that is to be electrically tested.

5.20 *virtual (or logical) tester* — That portion or portions of the complete test system that is capable of operating as an independent tester in accordance with the state model shown in this document. For a single test system with one test head and a single test-site on the test head, the physical and virtual (or logical) tester are the same. In a two-headed test system, where each head can execute a unique process program autonomously and there is only one test-site on each head, two virtual (or logical) testers may be operating at the same time. If there are multiple test-sites on multiple heads, each capable of autonomous execution of a unique program, there are as many virtual (or logical) testers in operation as there are autonomous sites. The number of virtual (or logical) testers operating at any time depends on how the test system is currently configured (hardware and software) and may range from one to the maximum capability of the particular test system.

6 Requirements

6.1 *State Models*

6.1.1 The purpose is to define the equipment-specific processing state model and other state models necessary to portray the expected operational states of the equipment to enable host tracking and control in place of a local operator.

6.2 *State Model Requirements*

6.2.1 The processing state models in this document are required for implementing a TSEM-compliant tester, in addition to the required state models in SEMI E30. A state model consists of a processing state model diagram, processing state definitions, and a processing state transitions table. A state model represents the host's view of the tester, but not necessarily the actual tester operations. All TSEM state model transitions shall be mapped sequentially into the actual equipment events that satisfy the requirements of those transitions. In certain implementations, the tester may enter a state and have already satisfied all of the conditions required by the TSEM state model for transition to another state. In this situation, the tester makes the required transition without any additional actions.

6.2.2 Some equipment may need to include additional states. However, any additional states must not change the TSEM-defined state transitions. All expected transitions between TSEM states must occur.

6.3 *TSEM Process State Model*

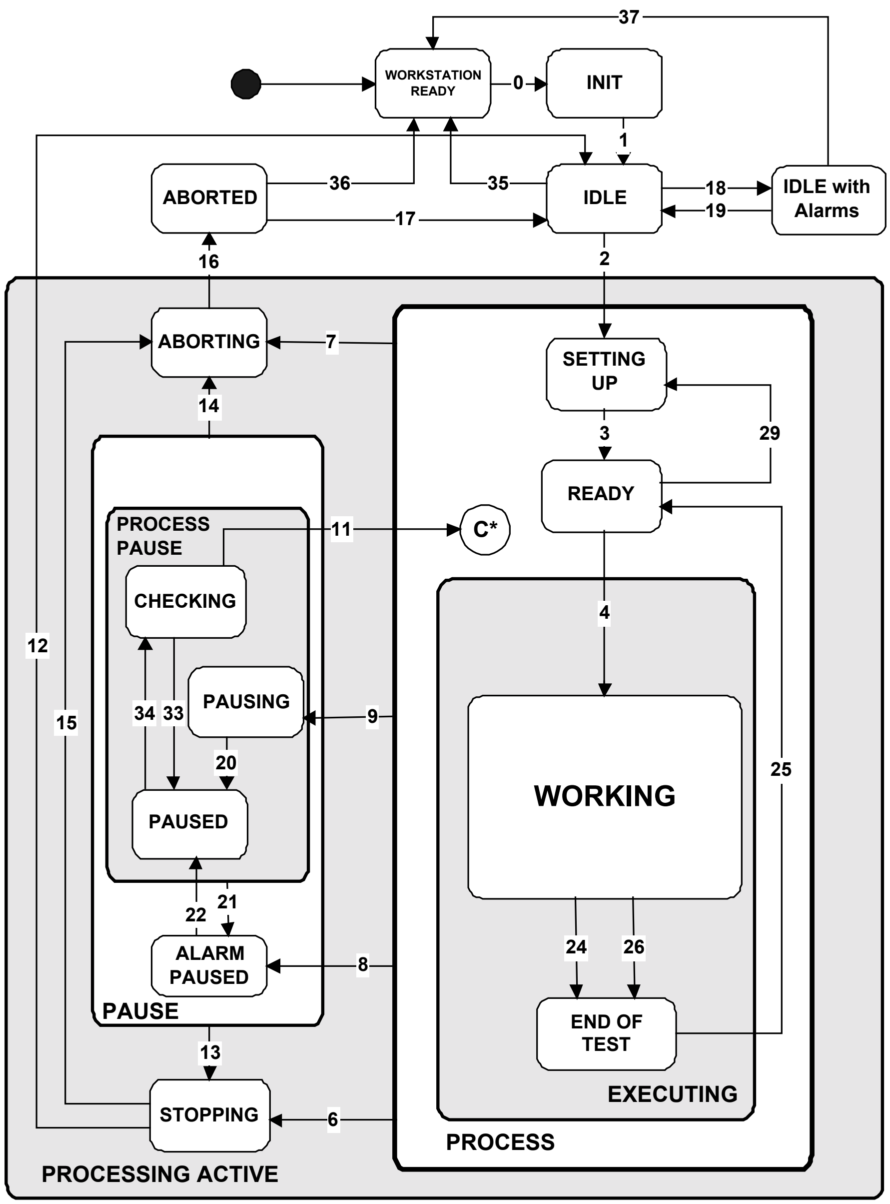

Figure 1
TSEM Processing State Model

6.4 *Description of Tester Processing States*

6.4.1 *ABORTED* — All activity is suspended as a result of an ABORT command. Any alarm and abort conditions must be cleared and verified by an operator before exit from this state.

6.4.2 *ABORTING (PROCESSING ACTIVE Sub-State)* — The tester has received an ABORT command. All activity is suspended. The tester is taking appropriate action to bring itself and material to a “safe” state where possible. Unit or Lot data may be invalid or not available.

6.4.3 *ALARM PAUSED (PAUSE Sub-State)* — An alarm has occurred in the PROCESS or PROCESS PAUSE states, and the tester is waiting for the alarm to be cleared.

6.4.4 *CHECKING (PROCESS PAUSE Sub-State)* — The tester verifies that updates made to the process program are valid. This is a similar procedure to that which is done in SETTING UP. At the successful completion of verification, a transition is made to the process state, based on the process model condition table.

6.4.5 *EXECUTING (PROCESS Sub-State)* — The tester is processing material automatically and can continue to do so without external intervention. This state may include interaction with the host or operator.

6.4.6 *IDLE* — Awaiting a command. IDLE is free of ALARMS and error conditions. A program may or may not be loaded in the execution space during this state.

6.4.7 *IDLE with ALARMS* — An alarm has occurred in the IDLE state, and the tester is waiting for all alarms to be cleared.

6.4.8 *INIT* — Tester initialization is occurring.

6.4.9 *PAUSED (PROCESS PAUSE Sub-State)* — The PROCESS state has been suspended, and the tester is waiting for a command (RESUME, STOP, or ABORT). In this state, the operator may correct error conditions and modify some conditions of the current Process Program selection.

6.4.10 *PAUSING (PROCESS PAUSE Sub-State)* — The current state will be suspended at the completion of the current unit(s), if any, and the tester will be brought to a “safe state.”

6.4.11 *PROCESS (PROCESS Sub-State)* — This state is the parent of those sub-states that refer to the preparation and execution of a process program.

6.4.12 *PROCESS PAUSE (PAUSE Sub-State)* — The tester is free of alarm conditions in the PAUSE state.

6.4.13 *READY (PROCESS Sub-State)* — The tester is ready to begin processing and is awaiting a START command.

6.4.14 *SETTING UP (PROCESS Sub-State)* — The tester is satisfying conditions so that processing can begin. This includes the initialization of any process programs and process program-specific calibration. This may be accomplished independently by the tester or may require interaction with the operator and/or host.

6.4.15 *STOPPING (PROCESSING ACTIVE Sub-State)* — The tester has completed a Process Program or has been instructed to stop processing and shall do so at the next opportunity. All necessary cleanup is completed within this state with regard to material, data, control system, etc. Data is preserved. Any error condition is cleared before exiting from this state.

6.4.16 *END OF TEST (PROCESS Sub-State)* — The UNITS testing is complete.

6.4.17 *WORKING (EXECUTING Sub-State)* — The tester is processing a specific unit or units.

6.4.18 *WORKSTATION READY* — The tester workstation is running and ready for tester initialization. The START EXEC remote command is valid in this state.

6.5 *TSEM Processing State Transitions Table*

Table 1 Processing State Transitions Table

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comments*
0	WORK-STATION-READY	Power on	INIT	None	None
1	INIT	All tester initialization is complete with no alarms or error conditions.	IDLE	None	None
2	IDLE	A Process Program is selected.	SETTING UP	Tester-dependent	Commit has been made to setup.
3	SETTING UP	All setup activity has completed, and the tester is ready to receive a START command.	READY	None	The selected Process Program is available for execution.
4	READY	The tester, operator, or host executes a START command, and auto-start is enabled.	WORKING	Begins testing the unit(s) at the test-site(s).	WORKING is an EXECUTING sub-state.
6	PROCESS	The tester has received a STOP command.	STOPPING	The tester completes the current unit(s) before entering the STOPPING state.	The tester begins its cleanup procedure.
7	PROCESS	The tester has received an ABORT command from operator, host, or self-generated.	ABORTING	The tester is put in a “safe” state.	Unit or lot data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended, and the tester is waiting for all alarms to be cleared.	ALARM PAUSED is a PAUSE sub-state.
9	PROCESS	The tester has received a PAUSE command.	PAUSING	The current state is suspended at the completion of the current unit(s). Any necessary actions to put the tester in a “safe” state will be performed.	PAUSING is a PROCESS PAUSE sub-state.
11	CHECKING	Parameter checking completes successfully.	STATE based on conditional table.	None	This is a conditional re-entry to the PROCESS state. (See Table 2.)
12	STOPPING	The tester cleanup is complete, and the tester is free of alarms.	IDLE	None	Data is preserved and is valid.
13	PAUSE	The tester has received a STOP command.	STOPPING	The tester proceeds with cleanup.	Data is preserved and is valid.
14	PAUSE	The tester has received an ABORT command.	ABORTING	Any unsafe condition is resolved, if possible.	Data may be invalid or unavailable.
15	STOPPING	The tester has received an ABORT command.	ABORTING	Any unsafe condition is resolved, if possible.	Data may be invalid or unavailable.
16	ABORTING	Unsafe conditions have been resolved, where possible.	ABORTED	The tester is waiting for alarm and ABORT conditions to be cleared.	The only state change allowed is to IDLE. Data is preserved and is valid.
17	ABORTED	An operator has verified that all alarms and abort conditions have been cleared.	IDLE	None	The IDLE state is a “clean” state.
18	IDLE	An alarm is set.	IDLE with ALARMS	The tester waits for all alarms to be cleared.	None

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comments*
19	IDLE with ALARMS	All alarms have been cleared.	IDLE	None	The IDLE state is free of alarms.
20	PAUSING	The tester has completed Processing the Current unit(s) and achieved a “safe” condition.	PAUSED	The tester is waiting for a command (RESUME, STOP, or ABORT).	None
21	PROCESS PAUSE	An alarm is set.	ALARM PAUSED	The tester waits for all alarms to be cleared or for a STOP or ABORT command.	None
22	ALARM PAUSED	All alarms are cleared.	PAUSED	The tester is waiting for a command (RESUME, STOP, or ABORT).	None
24	WORKING	The processing of the current unit(s) has completed normally.	END OF TEST	The tester processes end of test data.	“Normal” completion of the test program execution.
25	END OF TEST	Tester is ready to receive a new start of test command.	READY	Waiting for start of next test.	
26	WORKING	The processing of the current unit(s) has completed abnormally.	END OF TEST	The tester processes end of test data.	“Abnormal” completion of the test program execution, etc.
29	READY	New Lot is received by tester.	SETTING UP	The tester performs setup based on the new command.	None
33	CHECKING	Error detected in a new parameter setting.	PAUSED	The tester waits for the parameter correction by operator or host.	None
34	PAUSED	A RESUME command with variable parameters was received.	CHECKING	Validation of the process program parameters begins.	None
35	IDLE	The tester executive has been stopped by the operator.	WORKSTATION READY	Waiting for a START EXECUTIVE command.	None
36	ABORTED	The tester executive has been aborted by the operator.	WORKSTATION READY	Waiting for a START EXECUTIVE command.	None
37	IDLE with ALARMS	The tester executive has been stopped by the operator.	WORKSTATION READY	Waiting for an ALARM Clear and START EXECUTIVE command.	None

6.6 *Process Model Conditions Table*

Table 2 Process Resume Conditions

Condition	*Next State*
Checking determines that process program conditions were changed.	SETTING UP
Previous State WORKING.	END OF TEST
Previous State READY.	READY
Previous State was SETTING UP.	SETTING UP

7 Collection Event List

7.1 *Requirements*

7.1.1 ALL SEMI E30-required Events are required by the TSEM. Since a Processing State Model is required by the TSEM, all state transitions are required Events.

7.1.2 All SEMI E30-required events associated with the SEMI E30 Control, Communications, Alarm, and Spooling State Models are required.

7.1.3 This section of the TSEM lists only those collection events that are not associated with a change of state or those requiring specific data variables (DVVALs) or Reports defined in the TSEM.

7.2 *Collection Event Tables* — The first table contains required events and associated reports. The second table contains required events and associated data variables.

Table 3 Processing State Transitions Requiring Report Levels

Transition	*From State*	*To State*	*Required DVVALs or Report*
SETUP COMPLETE (3)	SETTING UP	READY	Setup Report

Table 4 Other Required Collection Events

Collection Event Name	*Required DVVALs*
LotComplete	See Lot Report.
BoardChg	TestBoardID, CalFixtureID, or DiagFixture ID (Valid in CHECKING and SETTING UP.)
DockStatusChange	DockingStatus
BinDataAvailable	See Bin-Data Report.
SubLotComplete	See SubLot Report.
LotStart	Lot/SubLot Start Report
SubLotStart	Lot/SubLot Start Report

8 Variable Items

The purpose of this section is to define the list of variable items required by the TSEM. Values of these variables will be available to the host through collection event reports and host status queries.

8.1 *Requirements*

8.1.1 All generic variable items defined in SEMI E30 are required by all TSEM equipment.

8.1.2 Variable items required by TSEM are categorized as follows:

- *Common Variables (CVs)* — Variables common to all testers.
- *Configuration-Specific Variables (CSVs)* — Variables associated with a specific configuration of the above equipment class.

8.1.3 Any supplier-defined variables shall be documented in the same format used by this document. The following minimum information is required:

<variable name> **Class:** <ECV, SV, or DVVAL> **Format:** <SML>

Description: <If class = DVVAL, description must contain statement of when data is valid.>

<If format = ASCII, then a length is required. It is assumed to be left-justified unless otherwise noted.>

8.2 *Data Types*

8.2.1 Equipment Constants (ECVs) can be changed by the host using S2,F15. The operator may be able to change some values, but the equipment does not change the values on its own. The value of an equipment constant may be queried by the host at any time, using the S2,F13/14 transaction. They reside in non-volatile memory of the equipment. Equipment constants remain in effect until they are overwritten either by manual entry or by a S2,F15 (NEW EQUIPMENT CONSTANT SEND).

8.2.2 Equipment constants have various uses in TSEM, including the following:

- Equipment offsets that match the performance of several pieces of equipment that would otherwise perform differently due to inherent manufacturing differences. Examples are home values and motion axis scaling factors.
- Setting the configuration of the equipment to allow for different material specifications, equipment options, material flows, frequency of automatic functions, etc. An example is yield check frequency.
- Managing optional machine features. Examples are constants that indicate whether optional features such as automated media stackers are present and control the configuration and function of these optional subsystems when they are present.

8.2.3 Status Variables (SVs) are valid at all times. An SV may not be changed by the host but may be changed by the equipment or operator. The value of status variables may be queried by the host at anytime using the S1,F3/4 or S6,F19/20 transactions.

8.2.4 DVVALs are variables that are valid only upon the occurrence of specific collection events. An attempt to read a variable item at the wrong time does not generate an error, but the data reported may not have relevant meaning.

8.2.5 *Data Item Requirements for Multi-Head, Multi-Site Equipment* — The identification for multi-head and multi-site data (variable items, status variables, events, etc.) is addressed in this specification through the use of status variables. In Table 5, the subscript “v” is used to denote the number of virtual testers, “h” is used to denote the number of tester heads, “s” to denote the number of tester head sites, and “b” to denote the number of bins or classes.

8.3 *Variable Item Table*

Table 5 Variable Item Table

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*
		Physical Tester Group			
BaseConfig	CV	Base Tester Configuration listing all physical heads and sites.	SV	L, h TestHeadID L, s TestBoardSiteID	Valid in all states. Contains number of possible heads and sites for the tester.
ConfigInfo	CSV	Configuration Information	SV	A[256]	Valid in all states.
ConfigInfoType	CSV	Configuration information source (0 = Auto, 1 = Manual/File)	SV	U4	Valid in all states.
DatalogConfig	CV	Data Log Configuration	SV	A[256]	Valid in all states.
EquipSerialID	CV	Identification of Equipment	SV	A[1..40]	Valid in all states.
HandlerComStatus	CV	Status of comm link between handler/s (0 = Disabled, 1 = 1-way enabled, 2 = 2-way enabled, 3 = Not communicating)	SV	U4	Valid in all states.
LightPoleStatus	CSV	Color/status (i.e., Red/flash)	SV	A[1..16]	Valid in all states.
VirtualConfig	CSV	Current Virtual Configuration listing all virtual IDs.	DVVAL	L, v ...VirtualID L, h TestHeadID L, s TestBoardSiteID	Valid in PROCESS states. Contains active heads and sites for tester. List by virtual tester, head, and site.
		Virtual Tester Group			
CalDate	CV	Date of last successful calibration.	SV	A[16]	Valid in all states. List by head.
CalInterval	CS	Time limit between calibrations.	SV	A[16]	Valid in all states. List by head.

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*
CalStatus	CV	Status of last calibration (1 = OK, 0 = Failure)	SV	U4	Valid in all states. List by head.
ClassName	CV	Name tag for high-level class information.	DVVAL	A[1..40]	Valid at BIN-DATA-AVAILABLE state. List by bin.
DiagStatus	CV	Status of last diagnostic (1 = OK, 0 = Failure)	SV	U4	Valid in all states. List by head.
HardBinName	CV	Test-Site Bin Out Name	DVVAL	A[1..40]	Valid at BIN-DATA-AVAILABLE Event. List by bin.
LotProcessingTime	CV	The time since start of current Lot.	DVVAL	A[16]	Valid in Process-sub-state.
OperatorID	CV	Current Operator ID	ECV	A[1..40]	Valid in all states.
ProductID	CV	ID of product for which tester is currently configured.	DVVAL	A[1..40]	Valid in PROCESS states.
SoftBinName	CV	Test-Site Category Name	DVVAL	A[1..40]	Valid at BIN-DATA-AVAILABLE Event. List by bin.
TestSiteInterval	CV	Interval count to generate event for a specific site $_{(n)}$ test.	ECV	U4	Valid in all states.
VirtualID	CV	ID of each virtual configuration.	SV	U4	
		Test Head Group			
CalFixtureID	CV	ID of calibration fixture in current configuration.	SV	A[1..40]	Valid in all states. List by head.
DiagDate	CV	Date of last diagnostic execution.	SV	A[16]	Valid in all states. List by head.
DiagFixtureID	CV	ID of diagnostic fixture in current configuration.	SV	A[1..40]	Valid in all states. List by head.
DiagFixtureList	CV	List of current diagnostic, calibration, and test boards in current configuration.	SV	L, h DiagFixtureID, CalFixtureID, TestBoardIDList	Valid in all states. List by head.
DockingStatus	CSV	Information on handler/docking status (0 = Yes, 1 = No)	SV	U4	Valid in all states. List by head.
HeadConfig	CV	Number of sites currently configured per head.	SV	U4	Valid in PROCESS states. List by head.
LotID	CV	Lot Identification	DVVAL	A[1..40]	Valid in all states.
StartTestPortID	CSV	Start Test Source (i.e., hand, keyboard, host)	SV	A[1..40]	Valid in all states. List by head.
SubLotID	CV	SubLot Identification	DVVAL	A[1..40]	Valid in all states.
TestBoardID	CV	ID of current test board.	SV	A[1..30]	Valid in all states. List by head.
TestBoardIDList	CV	List of IDs in current test board configuration.	SV	A[1..32]	Valid in READY state. List by head.
TestHeadID	CV	The ID of a test head.	SV	U4	Valid in READY state. List by head.
TestHeadStatus	CV	(2 = Not Available, 1 = enabled, 0 = disabled)	SV	U4	Valid in IDLE state. List by head.
		Test-Site Group			
ClassCnt	CV	Current count for a particular class.	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
ClassID	CV	High-level class ID	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
DeviceUnitID	CV	Unit Serial Number	DVVAL	U4	Valid in all states. List by head and site.

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*
ExecutionCnt	CV	Number of test executives since last reset for the current PPID and current LOT at this test-site.	DVVAL	U4	Valid at END OF TEST sub-state. List by head and site.
HardBinCnt	CV	Test-Site Bin Out Count	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
HardBinID	CV	Test-Site Bin Out Number	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
LotUnitOutput	CSV	Bin output for a specific site by lot.	DVVAL	U4	Valid in PROCESS states. List by head and site.
SoftBinCnt	CV	Test-Site Category Count	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
SoftBinID	CV	Test-Site Category Number	DVVAL	U4	Valid in PROCESS states. List by head, bin, and site.
SiteContacts	CSV	Number of contacts for a specific site.	DVVAL	U4	Valid in PROCESS states. List by head and site.
SubLotUnitOutput	CV	Bin output for a specific site by SubLot.	DVVAL	U4	Valid in PROCESS states.
TestBoardSiteContacts	CSV	Number of contacts for a specific site since last reset.	DVVAL	U4	Valid in PROCESS states. List by head and site.
TestBoardSiteID	CV	X, Y location within test board or probe card. (First element is the X coordinate, and second element is the Y coordinate.)	SV	U4(x)	Valid in all states. List by head and site.
TestBoardSiteInserts	CSV	Insertion-count on a test board site.	DVVAL	U4	Valid in PROCESSING state. List by head and site.
TestBoardSiteStatus	CV	Test Board Availability (1 = enabled, 0 = disabled)	DVVAL	U4	Valid in PROCESS states. List by head and site.
TestBoardStatus	CV	Test Board Availability (1 = enabled, 0 = disabled)	DVVAL	U4	Valid in PROCESS states. List by head and site.

8.4 *TSEM-Required Reports* — The reports below are required as “canned” or preconfigured reports by TSEM. TSEM does not require the equipment to guarantee the accuracy of data identified in these reports outside the PROCESSING ACTIVE state defined in the TSEM process state model.

8.4.1 *Setup Report* — Table 6 contains variables that are required to be available at the setup complete event.

Table 6 Setup Variables

Variable Name	*Notes*
DiagFixtureList	
LotID	
PPExecName	(per SEMI E30)
ProductID	Current
OperatorID	
TestBoardSiteStatus	
TestHeadID	
HandlerComStatus	
DockingStatus	

8.4.2 *Lot Complete Report* — Table 7 contains variables that must be available and reported at the completion of a lot.

Table 7 Lot Complete Variables

Variable Name	*Notes*
LotID	
PPExecName	(per SEMI E30)
DiagFixtureList	
SoftBinCnt	
HardBinCnt	
ClassCnt	
TestHeadID	
ContactCnt	
ExecutionCnt	
ProductID	
LotUnitOutput	
LotContacts	
LotProcessingTime	
OperatorID	

8.4.3 *SubLot Complete Report* — Table 8 below contains variables that must be available and reported at the completion of a SubLot.

Table 8 SubLot Complete Variables

Variable Name	*Notes*
SubLotID	
LotID	
PPExecName	(per SEMI E30)
DiagFixtureList	
SoftBinCnt	
HardBinCnt	
ClassCnt	
TestHeadID	
SubLotContacts	
SubLotUnitOutput	
ExecutionCnt	
ProductID	
OperatorID	

8.4.4 *Bin-Data-Report* — Table 9 contains variables that must be available once bin data is available.

Table 9 Bin-Data Variables

Variable Name	*Notes*
UnitID	
TestBoardSiteID	
HardBinID	
SoftBinID	
ClassID	

8.4.5 *Process Report* — Table 10 contains variables that must be available when the equipment is in the PROCESSING state.

Table 10 Process Variables

Variable Name	*Notes*
OperatorID	
LotID	
SubLotID	
PPExecName	(per SEMI E30)
OperationType	
DockingStatus	
HandlerCommStatus	
TestBoardSiteStatus	
LotProcessingTime	

8.4.6 *Lot/SubLot Report* — Table 11 contains variables that must be available at the completion of the lot or SubLot events.

Table 11 Lot/SubLot Start Variables

Variable Name	*Notes*
OperatorID	
LotID	
SubLotID	
PPExecName	(per SEMI E30)
DiagFixtureList	
TestHeadID	

Calibration Report — Table 12 below contains variables that must be available at the completion of a calibration.

Table 12 Calibration Variables

Variable Name	*Notes*
CalibrationInt	
PPExecName	(per SEMI E30)
OperatorID	
CalStatus	
TestHeadID	
CalFixtureID	

8.4.7 *Diagnostic Report* — Table 13 below contains variables that must be available at the completion of a diagnostic.

Table 13 Diagnostic Variables

Variable Name	*Notes*
OperatorID	
PPExecName	(per SEMI E30)
DiagFixtureList	
TestHeadID	
DiagStatus	

9 Process Program Management

9.1 *Process Program Requirements*

9.1.1 The TSEM requires that the GEM capability of process program management be fully supported for this class of equipment. The TSEM also requires that the process program have a structure that enables the user to build process programs with default conditions that can be overridden for a run. The concepts of process program structure are discussed in the following sections. The TSEM also requires the following:

- Minimum, maximum, and default parameter values must be defined for all process programs.
- *Verification* — When a process program is downloaded to the equipment, the program syntax must be verified by the equipment manufacturer. The process program may be rejected or may fail verification if the equipment is not in an allowable state to accept process program downloads (i.e., IDLE or SETUP).
- *Validation* — The downloaded process parameters must by type- and range-checked before execution.
- PPBODY — The contents of the downloaded process program body may contain the explicit parameters and data necessary for the runtime process program, or the body may contain reference information (i.e., PATH location) on where the explicit data is stored. In the latter case, it is required that the equipment combine or compile the reference data prior to the verification step.
- An error message must be generated from the tester if the process program parameters are outside the range of the machine capability.
- Diagnostic and calibration routines are considered process programs and must be verified and validated the same as a typical process program.

9.2 *Process Program Structure*

9.2.1 A tester process program must contain the following information:

- *Flow Information* — This provides information such as execution order of individual tests.
- *Parametric Information* — This section provides information such as AC/DC/IDC levels and timing.
- *Parameter Options/Values* — This section provides information such as test temperature, part frequency, etc.
- *Data Log Information* — This section provides information such as scope of data collection.
- *Functional Test Information* — This section provides information about vector and patterns.

9.2.2 This information must be supplied in a format that can be referenced as a complete process program. It is emphasized that the TSEM does not specify the exact number, data types, and format of this process program.

9.3 *Methods of Process Program Creation* — The method by which an equipment manufacturer creates a process program may be unique to that manufacturer. However, it is required that the customer at least be given both of the following options for the creation of a process program.

9.3.1 *Off-Line Development* — Using this method, the customer is given a set of software tools (process program compilers, decompilers, and debuggers) that will enable him/her to generate or create a process program using the above mentioned information (flow, parameter, functional test, etc.). The newly generated process program then is downloaded onto a specific tester, is verified, and is now ready to be selected and executed locally by the operator or remotely by the host computer. If this process is used, the supplied software tools should closely mimic or simulate a tester so that a user can create a complete process program. In many situations, minor adjustments or tweaks may be needed to the process program on the equipment before it is completely ready for execution.

9.3.2 *On-Line Development* — The second option made is to enable the user to download the above-mentioned information (tables or files) onto the equipment and create the actual process program on the equipment itself.

10 Remote Commands

The purpose of this section is to identify remote commands, command parameters, and valid commands versus states in the processing state models.

10.1 *Requirements*

- The equipment must support the GEM-required remote commands. (Some of the SEMI E30-required remote commands are restated here to define TSEM-specific requirements.)
- All the remote commands defined by TSEM are required.
- The alphanumeric strings defined by TSEM for remote commands (RMCD) and command parameters (CPNAME) are required.
- If additional remote commands are supported, then the “Remote Command vs. Valid States” matrix must be generated for these additional commands.

Place an "X" in the table for each state in which a given command is valid.

10.2 *Remote Command Descriptions*

10.2.1 *ABORT* — This command terminates the current processing. ABORT makes no guarantee about completion of the current test(s). Lot level data will be preserved. Levels of ABORT may be specified (see Table 14 for details).

10.2.2 *PAUSE* — This command transitions the tester to the PAUSING process state when the current test(s) completes processing.

10.2.3 *RESUME* — This command resumes processing from the point where the process was PAUSED. This command is only recognized if the tester is in the PAUSED or CHECKING state.

10.2.4 *PP-SELECT* — This command instructs the tester to copy the indicated Process Program from non-volatile storage to the tester's Process Program execution area. Process Program Variable Parameters can be specified in this command which modify the default values for these Variable Parameters in the Process Program. Process program verification (CHECKING state) must occur when variable parameters accompany this command.

10.2.5 *START* — This command is only available to the host or operator when a process program has been selected and the tester is in the READY processing state. The START command instructs the tester to initiate processing. Parameters can be specified in this command.

10.2.6 *STOP* — This command completes the current test(s), stops in a safe condition, and returns to the IDLE processing state. STOP has the intent of bringing about a normal termination after completion of the current test(s). Parameters can be specified in this command. Lot level data will be preserved.

10.2.7 *UNLOAD-PGM* — This command instructs the tester to unload the specified process program, or programs in the case of multiple heads, from the execution area. Parameters can be specified in this command.

10.2.8 *NEW-LOT* — This command instructs the tester to treat the next units to be processed as a new lot. A new-lot ID and process program variables must accompany the new lot command. This command will force subsequent units to be considered part of the lot. Parameters can be specified in this command.

10.2.9 *CLOSE-LOT* — This command instructs the tester to close the current lot. The next lot will require the setup procedure to be performed.

10.2.10 *CALIBRATE* — This command instructs the tester to execute its calibration program. Parameters can be specified in this command.

10.2.11 *START-EXEC* — This command instructs the tester to start the tester executive.

10.2.12 *STOP-EXEC* — This command instructs the tester to stop the tester executive. Lot level data will be preserved.

10.2.13 *RUN-DIAGNOSTICS* — This command instructs the tester to run the specified preventive maintenance diagnostic routine. Parameters can be specified in this command.

10.2.14 *RUN-CONTINUITY* — This command instructs the tester to run the specified continuity routine. Valid in PAUSE state only. Parameters can be specified in this command.

10.2.15 *ENABLE-SITE* — This command instructs the tester to enable a specified test board site(s). Parameters can be specified in this command.

10.2.16 *DISABLE-SITE* — This command instructs the tester to disable a specified test head site. Parameters can be specified in this command.

10.2.17 *RESET-SITE-CNT* — This command instructs the tester to reset the counts on the specified board test board site(s) to zero.

10.3 *Associated Remote Command Parameters*

Table 14 Remote Command Descriptions

Command	*Parameter*			
Name	*Name*	*Opt./Req.*	*Description*	*Format*
ABORT	“VIRTUALID”	OPT	ID of virtual tester to abort.	U4
	“LOTCLOSE”	OPT	The tester will close out the current lot and enter the ABORTING state.	A[7]
CALIBRATE	“PPID”	OPT	The ID of the program to be used.	A[80]
CLOSE-LOT	“VIRTUALID”	OPT	ID of virtual tester.	U4
DISABLE-SITE	“TESTHEADID”	REQ	ID of test head containing the site.	U4
	“TESTSITEID”	REQ	ID of test-site to be disabled.	U4
	“VIRTUALID”	OPT	ID of virtual tester.	U4
ENABLE-SITE	“VIRTUALID”	OPT	ID of virtual tester.	U4
	“TESTHEADID”	REQ	ID of test head containing the site.	U4
	“TESTSITEID”	REQ	ID of test-site to be enabled.	U4
NEW-LOT	“VIRTUALID”	OPT	ID of virtual tester.	U4
	“LOTID”	REQ	ID of New LOT.	A[1..40]
PAUSE	“VIRTUALID”	OPT	ID of virtual tester.	U4
PP-SELECT	“VIRTUALID”	OPT	ID of virtual tester.	U4
	“LOTID”	OPT	Lot to be processed with this program.	A[1..40]
RESET-SITE-CNT	“VIRTUALID”	OPT	ID of virtual tester.	U4
	“TESTHEADID”	REQ	ID of test head containing the site.	U4
	“TESTSITEID”	REQ	ID of test-site to be reset.	U4
RESUME	“VIRTUALID”	REQ	ID of virtual tester.	U4
RUN-CONTINUITY	“PPID”	OPT	The ID of the program to be used.	A[80]
RUN-DIAGNOSTICS	“PPID”	OPT	The ID of the program to be used.	A[80]
START	None			
START-EXEC	None			
STOP	“VIRTUALID”	REQ	ID of virtual tester.	U4
	“CLOSELOT	OPT	Automatically close lot.	BOOL
STOP-EXEC	“VIRTUALID”	REQ	ID of virtual tester.	U4
UNLOAD-PGM	“VIRTUALID”	OPT	ID of virtual tester to unload.	U4
	“PPID”	REQ	ID of program to unload.	A[80]
	“ALL”	OPT	Will unload all test programs.	BOOL

10.4 *Remote Commands and TSEM Process Model Mapping* — Table 15 illustrates the relationship between remote commands and states of the TSEM processing state model. An "X" indicates that a command is valid for use in this state. If a remote command is attempted during a non-valid state, the equipment would reject the remote command.

Table 15 Remote Commands vs. Process States

PROCESSING STATE \ COMMAND	STOP	START	RESUME	UNLOAD-PGM	PP-SELECT	PAUSE	NEW-LOT	STOP-EXEC	START-EXEC	ABORT
INIT									X	
IDLE				X	X			X		
IDLE with Alarms								X		
PROCESSING ACTIVE										
PROCESS										
SETTING UP	X					X	X			X
READY	X	X				X	X			X
ABORTING										
STOPPING										X
EXECUTING										
WORKING	X					X				X
ENDOFTEST	X					X				X
PROCESS PAUSE										
PAUSING										X
PAUSED	X		X				X			X
CHECKING										X
ALARM PAUSED	X									X
WORKSTATION READY									X	
ABORTED										

Table 16 Remote Commands vs. Process States #2

PROCESSING STATE	COMMAND: RESET-SITE-COUNT	RUN-CONTINUITY	CLOSE-LOT	RUN-DIAGNOSTICS	CALIBRATE
INIT					
IDLE	X	X	X	X	X
IDLE with Alarms					
PROCESSING ACTIVE					
PROCESS					
SETTING UP	X		X		
READY	X	X	X		
ABORTING					
STOPPING					
EXECUTING					
WORKING					
ENDOFTEST					
PROCESS PAUSE					
PAUSING					
PAUSED	X	X	X		
CHECKING					
ALARM PAUSED					
WORKSTATION READY					
ABORTED					

11 Scenarios

The purpose of this section is to document possible TSEM-specific scenarios illustrating the possible virtual configurations. The example below is for a single tester configured as two virtual testers configured as follows:

```
Physical Tester #1  EquipSerialID = T1000A
2 Virtual Equipment Instances,
          where VirtualID #10 represents
          Tester #0, Head #0, Sites 0 - 3.

          where VirtualID #20 represents
          Tester #0, Head #0, Sites 4 - 7,
          Head #1, ALL Sites (1-3).

Status Variable Request Scenario
Status Variable Request S1,F3 -->
L,1
  1. U4 1001 (SVID for VirtualConfig)
                              <--S1,F4 (status variable return)
                                     L,1
                                       1. L,2 = # of virtual testers
                                          1. L,2
                                             1. 10 (VirtualID = 10)
                                             2. L,1 = # of heads for Tester 10
                                                1. L,2
                                                   1. 0 (TestHeadID)
                                                   2. L,3 = # of sites for head 1
                                                      1. 01 = TestBoardSiteID #1
                                                      2. 02 = TestBoardSiteID #2
                                                      3. 03 = TestBoardSiteID #3
                                          2. L,2
                                             1. 20 (VirtualID = 20)
                                             2. L,2 = # of heads for Tester 20
                                                1. L,2
                                                   1. 0 (TestHeadID)
                                                   2. L,4 = # of sites for head 0
                                                      1. 04 = TestBoardSiteID #4
                                                      2. 05 = TestBoardSiteID #5
                                                      3. 06 = TestBoardSiteID #6
                                                      4. 07 = TestBoardSiteID #7
                                                2. L,2
                                                   1. 1 (TestHeadID)
                                                   2. L,3 = # of sites for head 1
                                                      1. 01 = TestBoardSiteID #1
                                                      2. 02 = TestBoardSiteID #2
                                                      3. 03 = TestBoardSiteID #3
```

11.1 *Normal Run Scenario* — This is an error-free run of a single lot, with no additional lots queued. The Host determines the available resources of the tester by requesting the status variable, VirtualConfig. This variable returns a list of virtual testers and the resources assigned to each of them.

```
COMMENT                        HOST      EQUIPMENT                                COMMENT
```

The Host would initiate a PP_SELECT using an available resource. PP_SELECT requires at least 2 parameters (PPID and VirtualID). Optional parameters are not shown.

```
Host Command Send              S2,F41-->
1. PP-SELECT
2. L,2
   1. L,2
        1. PPID
        2. A[80] "/home/recipes/tester_recipe"
   2. L,2
        1. VirtualID
        2. U4 10

                                         <--S2,F42    (host command acknowledge)
                                                              L,2
                                                                1. HCACK "0"
                                                                2. L,0
```

The tester then starts sending several events back to the host to identify transitions and non-transition events.

```
                                         <--S6,F11            (Event #2 Setting Up)
                               S6,F12-->
                                         <--S6,F11            (Event #3 Ready)
                               S6,F12-->
```

The host then sends a start to the tester. The START command requires the VirtualID only.

```
Host Command Send              S2,F41-->
1. START
2. L,1
     1. L,2
          1. VirtualID
          2. U4 10

                                         <--S2,F42    (host command acknowledge)
                                                              L,2
                                                                1. HCACK "0"
                                                                2. L,0
```

The tester then starts sending several events back to the host to identify transitions and non-transition events.

```
                                         <--S6,F11            (Event #4 Working)
                               S6,F12-->
                                         <--S6,F11            (Event # EndOfTest)
                               S6,F12-->
                                         <--S6,F11            (Event # EndOfTest)
                               S6,F12-->
                                         <--S6,F11            (Bin data available)
                               S6,F12-->
                                         <--S6,F11            (Event #25 Ready)
                               S6,F12-->
```

After several of these starts and events sequences, the tester notifies the host that the SubLot is complete and then receives close-lot and stop commands from the host.

```
                                          <--S6,F11            (Sub-lot complete)
                               S6,F12-->

   Host Command Send           S2,F41-->
   1. CLOSE_LOT
   2. L,0

                                          <--S2,F42    (host command acknowledge)
                                                               L,2
                                                                 1. HCACK "0"
                                                                 2. L,0

                                          <--S6,F11            (Lot-complete)
                               S6,F12-->
   Host Command Send           S2,F41-->
   1. STOP
   2. L,0

                                          <--S2,F42    (host command acknowledge)
                                                               L,2
                                                                 1. HCACK "0"
                                          <--S6,F11              (Event #12 IDLE)
                               S6,F12-->
```

11.2 *Run Diagnostics/Calibration Scenario*

```
Run Diag/Calibration
Host Command Send              S2,F41-->
1. CALIBRATE
2. L,1
   1. L,2
        1. START
        2. A[80] "DIAG-ID"

                                          <--S2,F42    (host command acknowledge)
                                                               L,2
                                                                  1. HCACK "0"
                                                                  2. L,0
                                          <--S6,F11    (Event #2)
   S6,F12-->
                                          <--S6,F11    (Event #3)
                               S6,F12-->

Host Command Send              S2,F41-->
1. START
2. L,0

                                          <--S2,F42    (host command acknowledge)
                                                               L,2
                                                                  1. HCACK "0"

                                          <--S6,F11            (Event #4)
                               S6,F12-->
                                          <--S6,F11            (Event #24)
                               S6,F12-->
                                          <--S6,F11            (Diag Report)
                               S6,F12-->

Host Command Send              S2,F41-->
1. STOP
2. L,0

                                          <--S2,F42    (host command acknowledge)
                                                               L,2
                                                                  1. HCACK "0"
```

12 Additional SEMI E30 Requirements

The purpose of this section is to specify any GEM additional capabilities that are required to be supported by this class of equipment.

12.1 *Requirements* — The following GEM additional capabilities required by TSEM are:

- Establish Communications
- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Remote Control
- Equipment Constants
- Process Program Management
- Equipment Terminal Services
- Clock
- Spooling
- Control (Host-Initiated)

13 TSEM Unique Capabilities

The purpose of this section is to specify additional capabilities required for the TSEM that are unique to this class of equipment.

13.1 *Test Handling Equipment Common Data* — The purpose of this subsection is to specify test handling variable item data and event data that must be available to the host during the electrical test process. Because equipment configurations vary regarding handling and test equipment, passing control and process information to the host system also can vary. By providing this information from either class of equipment, a greater variety of configurations is available to the user. The handler data identified in this section must be made accessible from the tester manufacturer's interface (i.e., placeholder IDs, events, and commands). The validity of the data will depend on the specific field configuration of the equipment. For example, if the field configuration places the handler as the primary contact to the host, the data identified in this section would not be needed, and the TSEM capability would be disabled. On the other hand, if the field configuration places the tester as the primary contact to the host, the data identified in this section would be necessary, and the TSEM capability then would be enabled.

13.2 *Variable Item Requirements* — Table 17 identifies variable items that must be available from the tester in addition to those identified in Section 8.

Table 17 Common Handler Variable Items

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*
EquipID (Handler)	CV	Identification of Handler Equipment (per Head)	SV	A[16]	Valid in all states.
LotID	CV	Lot ID	SV	A[16]	Valid in EXECUTING.
OperatorID	CSV	Current Operator ID	ECV	A[24]	Valid in all states.

13.3 *Collection Event Data Item Requirements* — Table 18 identifies common collection events that the tester must be able to provide to the host, if available from the handler.

Table 18 Common Handler Collection Events

Collection Event Name	*Event #*
LotComplete	Equipment Specific #
SetupComplete	Equipment Specific #
LotStart	Equipment Specific #

13.4 *Host Access to Tester Data Log Information* — TSEM requires the equipment manufacturer to make data log information available to the host via the SEMI E5, Stream 13 data set message. Because equipment configurations vary for data log content and format, the only requirement TSEM makes is that the equipment manufacturer document the format and content of data log information used by the equipment and make that information available across the communications interface via Stream 13. (See SEMI E5.)

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E30.3 and is not intended to modify or supercede the official standard. These notes are presented as possible methods for SEM implementations and are included only as reference material.

R1-1 TSEM ARAMS Sub-State Codes

For TSEM implementations which are also compliant with SEMI E58, the equipment will support the following ARAMS sub-states:

A. PRODUCTIVE

1. 1XYY "PRD/Initialization for process program"

2. 1XYY "PRD/Testing units"

3. 1XYY "PRD/Determining result information"

4. 1XYY "PRD/Cleanup for process program"

B. STANDBY

1. 2XYY "SBY/Waiting for process program selection"

2. 2XYY "SBY/Waiting for start test"

3. 2XYY "SBY/Waiting for user input, equipment-initiated"

4. 2XYY "SBY/Waiting for user input, user-initiated"

NOTE: The *X* sub-state codes are reserved by SEMI E58 for standard codes and the *Y* is for supplier usage.

R1-1.1 *Mapping of TSEM Processing State Model to ARAMS State Model* — The TSEM Processing state model and the ARAMS state model are separate models which must both be maintained and supported if the equipment is to be both TSEM-compliant equipment and ARAMS-compliant. Although these state models are separate, there is a definite relationship between the two. All TSEM-compliant equipment which is also ARAMS-compliant will support the following mapping between the TSEM Processing state model and the ARAMS state model. This mapping only applies while the equipment is performing its intended function, that is, while it is in the Manufacturing superstate defined by ARAMS.

R1-1.2 *ARAMS State Mapping to TSEM Processing States*

Table 19 ARAMS/TSEM Processing State Transitions Table

#	*Current State*	*Trigger*	*New State*	*ARAMS Actions*	*Comments*
0	WORK-STATION-READY	Power on.	INIT	Based on previous ARAMS.	Based on previous ARAMS state.
1	INIT	All tester initialization is complete with no alarms or error conditions.	IDLE	SBY/Waiting for PP selection.	Equipment is capable of performing the intended function.
2	IDLE	A Process Program is selected.	SETTING UP	PRD/Initialization for PP selection.	None
3	SETTING UP	All setup activity has completed, and the tester is ready to receive a START command.	READY	SBY/Waiting for start test.	Start Test may be received.
4	READY	The handler, operator, or host executes a START command, and auto-start is enabled.	WORKING	PRD/Testing Units	None
6	PROCESS	The tester has received a STOP command.	STOPPING	PRD/Cleanup	None
7	PROCESS	The tester has received an ABORT command from operator, host, or self-generated.	ABORTING	PRD/Cleanup	None
8	PROCESS	An alarm occurs.	ALARM PAUSED	UDT	Not capable of performing intended function.

#	Current State	Trigger	New State	ARAMS Actions	Comments
9	PROCESS	The tester has received a PAUSE command.	PAUSING	No state change.	PAUSING is incomplete, so no change.
11	CHECKING	Parameter checking completes successfully.	STATE based on conditional table.	Condition based on conditional state.	Reference # 2, 3, 4, 24, 26, and 29.
12	STOPPING	The tester cleanup is complete, and the tester is free of alarms.	IDLE	SBY/Waiting for PP selection.	Equipment is capable of performing the intended function.
13	PAUSE	The tester has received a STOP command.	STOPPING	PRD/Cleanup	None
14	PAUSE	The tester has received an ABORT command.	ABORTING	UDT or PRD Cleanup.	If uncleared alarms exist, then ARAMS state is UDT, else cleanup.
15	STOPPING	The tester has received an ABORT command.	ABORTING	UDT or no state change.	If uncleared alarms exist, then ARAMS state is UDT, else stopping.
16	ABORTING	Unsafe conditions have been resolved, where possible.	ABORTED	SBY/Waiting for input or UDT.	If uncleared alarms exist, then ARAMS state is UDT, else waiting for clear.
17	ABORTED	An operator has verified that all alarms and abort conditions have been cleared.	IDLE	SBY/Waiting for PP selection.	None
18	IDLE	An alarm is set.	IDLE with ALARMS	UDT	Equipment is NOT capable of performing the intended function.
19	IDLE with ALARMS	All alarms have been cleared.	IDLE	SBY/Waiting for PPselection.	Equipment is capable of performing the intended function.
20	PAUSING	The tester has completed processing the Current unit(s) and achieved a safe condition.	PAUSED	SBY/Waiting for input.	Waiting for resume.
21	PROCESS PAUSE	An alarm is set.	ALARM PAUSED	UDT	Equipment is NOT capable of performing the intended function.
22	ALARM PAUSED	All alarms are cleared.	PAUSED	SBY/Waiting for input.	Alarms cleared, waiting for resume.
24	WORKING	The processing of the current unit(s) has completed normally.	END OF TEST	PRD	ARAMS sub-state is active until the BIN-Data Available event occurs or the next start test is received.
25	END OF TEST	Tester is ready to receive a new start of test command.	READY	Either SBY/Waiting for start test or PRD determining results.	PRD/Determining sub-state has entered at END OF TEST. This sub-state is active until BIN-Data Available or until the next start test.
26	WORKING	The processing of the current unit(s) has completed abnormally.	END OF TEST	PRD determining results.	The sub-state is active until BIN-Data Available or until the next start test.
29	READY	New Lot is received by tester.	SETTING UP	PRD/Initialization for PP selection.	New lot requires process program initialization.
33	CHECKING	Error detected in a new parameter setting.	PAUSED	No state change.	None
34	PAUSED	A RESUME command with variable parameters was received.	CHECKING	No state change.	None

#	*Current State*	*Trigger*	*New State*	*ARAMS Actions*	*Comments*
35	IDLE	The tester executive has been stopped by the operator.	WORKSTATION READY	No state change.	The equipment may not be aware of this transition. ARAMS specifies the rules to be followed upon reinitialization.
36	ABORTED	The tester executive has been aborted by the operator.	WORKSTATION READY	No state change.	The equipment may not be aware of this transition. ARAMS specifies the rules to be followed upon reinitialization.
37	IDLE with ALARMS	The tester executive has been stopped by the operator.	WORKSTATION READY	No state change.	The equipment may not be aware of this transition. ARAMS specifies the rules to be followed upon reinitialization.

R1-1.3 *Additional ARAMS Capabilities* — ARAMS specifies fundamental ARAMS requirements which must be met to be ARAMS-compliant. ARAMS also specifies additional capabilities which may be provided by ARAMS-compliant equipment. All TSEM-compliant equipment which is also ARAMS-compliant is required to provide the following additional capabilities as defined by ARAMS:

a. Dynamic Event Report Configuration

b. Accumulator Data

c. User-Generated ARAMS Sub-State Table(s)

d. Equipment-Generated ARAMS Sub-State Table(s)

e. User-Generated ARAMS Symptom Table(s)

SEMI E30.5-0302
SPECIFICATION FOR METROLOGY SPECIFIC EQUIPMENT MODEL

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Global Information and Control Committee. Current edition approved by the North American Information and Control Committee on October 14 and November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published July 2001.

The complete specification for this product includes all general requirements of SEMI E30.

1 Purpose

1.1 This document establishes a Specific Equipment Model (SEM) for Metrology equipment (MSEM). The MSEM consists of equipment characteristics and behaviors that are applicable to this class of equipment and are required to be implemented in addition to the SEMI E30 fundamental requirements and additional capabilities.

2 Scope

2.1 The scope of this document is limited to defining the behavior of Metrology equipment as perceived by a SEMI Equipment Communications Standard II (SECS II/SEMI E5) host that complies with the SEMI E30 model. It defines the view of the equipment through the SECS II link. It does not define the internal operation of the equipment. It includes a specific processing state model as the basis for all equipment behavior of this class.

2.2 This document assumes that the SEMI E30 fundamental requirements and all additional capabilities except those noted in SEMI E30 Capabilities Section in this document have been implemented on the MSEM equipment. This document expands the SEMI E30 Standard requirements and capabilities in the areas of the processing state model, collection events, Process Program management, remote commands, data item variables, and coordinate systems.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The intent of this document is to facilitate the integration of Metrology equipment into an automated semiconductor factory. This document accomplishes this by defining an operational model for Metrology equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior. This document applies specifically to Metrology equipment as used in a semiconductor factory environment. It is possible that this methodology and techniques may apply to other industries.

3.2 MSEM job parameters that specify material (e.g., carrier ID and substrate ID) and material locations (e.g., carrier location ID and carrier slot ID) are intended for metrology equipment for 200 mm and smaller substrate.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard II (SECS II)

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M21 — Assigning Addresses to Rectangular Elements in a Cartesian Array

SEMI E37.1 — High Speed Messaging Service (HSMS-SS) Single Session

SEMI E58 — Automated Reliability and Availability Standard (ARAMS)

5 Terminology

5.1 *Definitions*

5.1.1 *alignment, n.* — a procedure in which a coordinate system is established on a substrate or a portion of a substrate.

5.1.2 *alignment mark, n.* — a feature on a substrate selectively used for alignment.

5.1.3 *alignment site, n.* — a point within a feature on a substrate selectively used for alignment.

5.1.4 *cleanup, n.* — deselection of the current Process Program and removal of all material to output locations and any equipment specific activities required to transition the equipment into the IDLE state.

5.1.5 *factory automation controller, n.* — a computer system that provides integration of factory shop control and business systems with semiconductor equipment.

5.1.6 *feature, n.* — a distinctive item in a pattern, or a physical characteristic of the substrate. (e.g., line, point, a wafer flat).

5.1.7 *field, n.* — an exposure repeated in a regular manner on a substrate.

5.1.8 *global alignment, n.* — procedure which establishes a coordinate system for the entire substrate (see alignment). For silicon wafers, this coordinate system is defined in MSEM as the SEMI M20 coordinate system.

5.1.9 *global pattern alignment, n.* — a procedure which establishes a coordinate reference system relative to repeating features on an entire substrate. For silicon wafers, this coordinate system is defined in MSEM as the M20P coordinate system.

5.1.10 *logical port, n.* — one or more physical input or input/output ports that are controlled by the same execution of a Process Program.

5.1.11 *M20P, adj.* — a designation used for the global coordinate system defined within MSEM, that is established relative to a pattern on a silicon wafer.

5.1.12 *material, n.* — a piece or pieces of substrate, one or more substrate, a lot, a batch, or a run.

5.1.13 *metrology equipment, n.* — any equipment that collects and reports information on specific predetermined sites or features on a substrate with consistent data structure, or reports general information about the entire substrate.

5.1.14 *notch, n.* — a cut on the edge of a wafer that is commonly located with respect to a specific crystal plane that adheres to the SEMI M1 standard.

5.1.15 *pattern, n.* — the physical features on a substrate.

5.1.16 *pre-align, n.* — any alignment done prior to placing a substrate on a measurement process location.

5.1.17 *registration, n.* — positioning error between two features on different layers of a substrate.

5.1.18 *safe state, n.* — a state in which the equipment presents no danger to the product or user. This implies that safety interlocks are in place such that the equipment can be serviced without harm to the operator and that the material being processed has been removed from the processing station into an accessible location.

5.1.19 *secondary alignment, n.* — a procedure which improves the accuracy of the coordinate system mapping on a substrate in a limited area of the substrate.

5.1.20 *site, n.* — a single point on a substrate used for alignment, or the center of an area of the substrate within which measurements are made.

5.2 *Abbreviations and Acronyms*

5.2.1 *GEM, n.* — Generic Equipment Model

5.2.2 *SEM, n.* — Specific Equipment Model

5.2.3 *SEM, n.* — Scanning Electron Microscope

5.2.4 *TCP/IP, n.* — Transmision Communication Protocol/Internet Protocol.

6 Communication Requirements

6.1 It is required that any MSEM compliant equipment follow the Communications State Model in SEMI E30. In addition MSEM compliant equipment shall support the High Speed Messaging Service (HSMS-SS) communication Standard, and the SECS-I standard for sending SECS II messages over TCP/IP or RS232. The user may determine which of these two lower level transmission protocols is used in each installation. The reason for HSMS-SS requirement is the large volume of data that can be generated by this class of equipment.

7 State Models

7.1 In this section are defined the equipment-specific processing state model and other state models necessary to portray the expected operational states of the equipment to enable host tracking and control in place of a local operator. See SEMI E30 and Other References section for additional information on state charts general rules and utilization.

7.2 *Processing State Model Requirements* — The Processing state model is required to be implemented as defined in the next sections of this document. A state model consists of the following: state model diagram, state definitions and a state transition table. A state model represents the host's view of the equipment, not necessarily the actual equipment operation. All MSEM state model transitions shall be mapped sequentially into the appropriate actual equipment events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the MSEM state model for transition to another state. The equipment makes the required transition without any additional actions in this situation.

7.3 Some equipment may need to include additional states. Additional states may be added, but shall not change the MSEM defined state transitions. All expected transitions between MSEM states must occur.

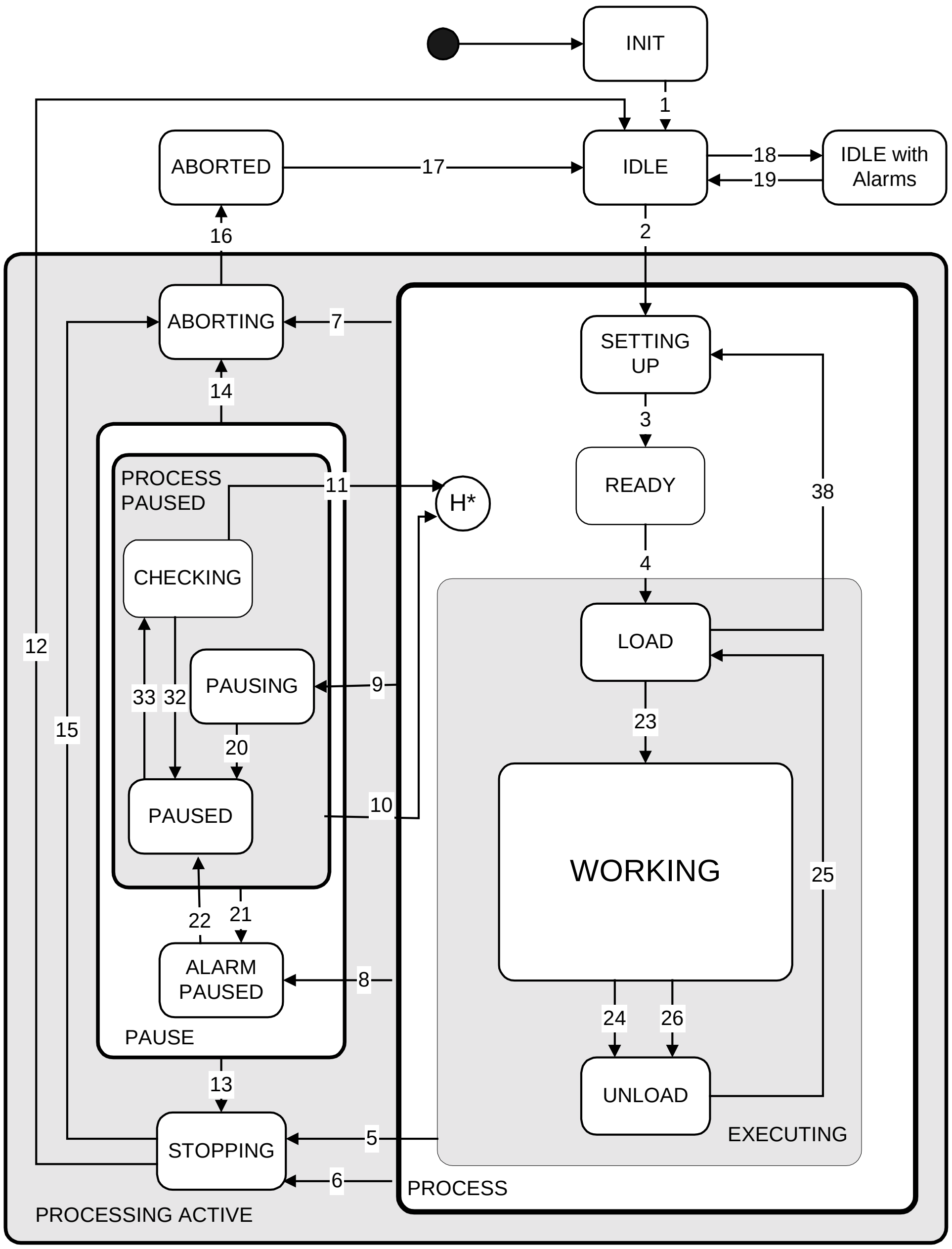

Figure 1
Generic MSEM Processing State Model Diagram

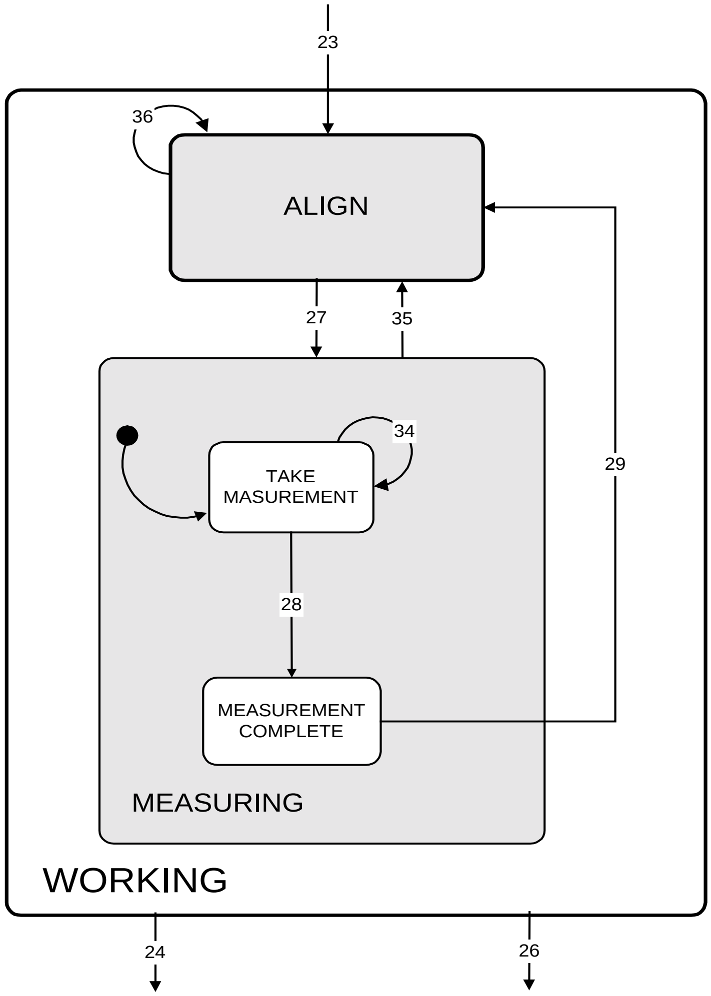

Figure 2
Working State of Processing State Model

7.4 *Processing State Model Diagram*

7.4.1 *Working State of Processing State Model*

7.4.2 *Working Sub-states of Processing State Model* — These states need not to be implemented in all Metrology equipment but if the equipment has the ability to multiple measurements at a site or provide raw scan date to the user this is how it is to be implemented.

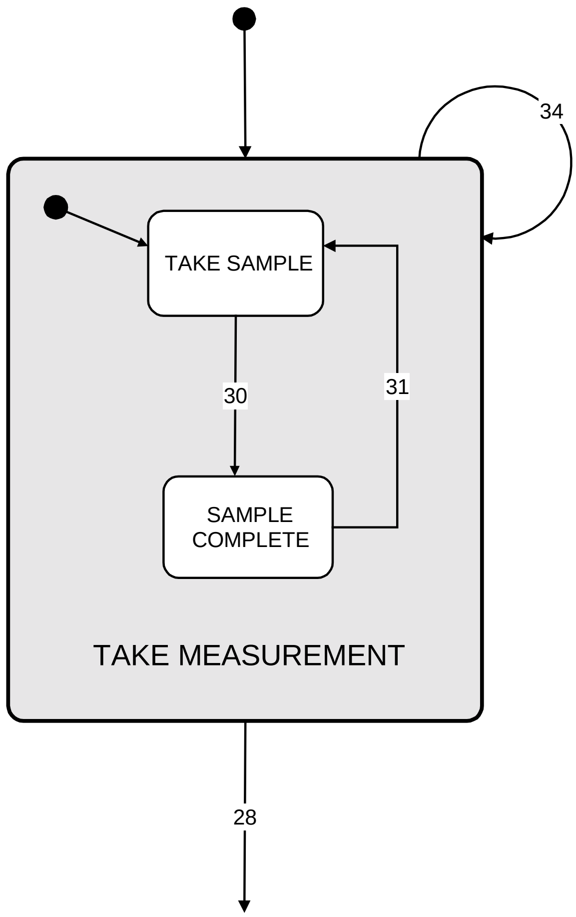

Figure 3
Working Sub-State of Processing State Model

7.5 *Processing State Definitions*

7.5.1 *ABORTED* — all activity is suspended as a result of an ABORT command. Any alarm and abort conditions must be cleared before exit from this state. The CLEANUP command is available to the operator or host to transition the equipment from the ABORTED state to IDLE state.

7.5.2 *ABORTING (PROCESSING ACTIVE Sub-state)* — the equipment has received an ABORT command. All normal activity is suspended. The equipment is taking appropriate action to put the equipment and material in a "safe state" where possible. Data may be invalid or not available.

7.5.3 *ALARM PAUSED (PAUSE Sub-state*) — an alarm has occurred in the Process or Process Pause states and the equipment is waiting for the alarm to be cleared.

7.5.4 *ALIGN (WORKING Sub-state)* — the equipment or operator is performing an alignment of the material to the equipment. Within this state the equipment shall refine or establish its SEMI M20 coordinate system and establish any secondary coordinate systems required.

7.5.5 *CHECKING (PROCESS PAUSE Sub-state)* — the equipment verifies that the updates made to the Process Program are valid. This is a similar procedure to that which is done in SETTING UP before the equipment is ready to transition to the READY state.

7.5.6 *EXECUTING (PROCESS Sub-state)* — the equipment is processing material automatically and can continue to do so without external intervention, but normally may include interaction with the host or operator.

7.5.7 *IDLE* — checks for queued process or awaits a command. IDLE is free of ALARM and error conditions. Any transitions into this state will clear the process area.

7.5.8 *IDLE with ALARMS* — an alarm has occurred in the IDLE state and the equipment is waiting for all alarms to be cleared.

7.5.9 *INIT* — equipment initialization is occurring.

7.5.10 *LOAD (EXECUTING Sub-state*) — the equipment is determining if processing is complete. If not, then the substrate is being transferred to the equipment processing location, such as the stage. A pre-alignment procedure may be performed prior to the LOAD state.

7.5.11 *PAUSE (PROCESS ACTIVE Sub-state*) — PROCESS is suspended at the next opportunity. Actions to put the equipment in a "safe state" shall be performed. The equipment is awaiting a command (RESUME, PP-UPDATE, STOP or ABORT), or for alarm(s) to be cleared.

7.5.12 *PAUSED (PROCESS PAUSE Sub-state*) — PROCESS shall be suspended and the equipment is waiting for a command (RESUME, PP-UPDATE, STOP or ABORT).

7.5.13 *PAUSING (PROCESS PAUSE Sub-state)* — PROCESS has been suspended at the next opportunity and the equipment is put in a "safe state".

7.5.14 *PROCESS (PROCESSING ACTIVE Sub-state)* — this state is the parent of those sub-states which refer to the active preparation and execution of a Process Program.

7.5.15 *PROCESSING ACTIVE* — this state is the parent of all sub-states where the context of a Process Program execution exists.

7.5.16 *PROCESS PAUSE (PAUSE Sub-state)* — the equipment is free of alarm conditions in the PAUSE state.

7.5.17 *MEASUREMENT COMPLETE (MEASURING Sub-State)* — the equipment has completed collecting data relative to an alignment location.

7.5.18 *MEASURING (WORKING Sub-State)* — the equipment is preforming an action between alignments.

7.5.19 *READY (PROCESS Sub-state)* — the equipment is ready to begin processing and is awaiting a START command from the operator or host. If an AUTOSTART is included, then the equipment starts processing immediately.

7.5.20 *SAMPLE COMPLETE (TAKE MEASUREMENT Sub-state)* — the equipment determines if additional samples need to be taken at this site.

7.5.21 *SETTING UP (PROCESS Sub-state)* — the equipment is being set up so that external conditions are satisfied to start processing the material. This includes the receipt of any Process Programs and material to be processed and their validation. Additional information may come from the host during the processing.

7.5.22 *STOPPING (PROCESSING ACTIVE Sub-state)* — the equipment has completed a Process Program or has been instructed to stop processing and shall do so gracefully at the next opportunity. All cleanup necessary is being completed within this state with regard to material, data, control system, etc. Data is normally preserved. Any alarm or error condition is cleared before exit from this state.

7.5.23 *TAKE MEASUREMENT (MEASURING Sub-state)* — the equipment is in the process of collecting data relative to an alignment location. (e.g. Site, Region, Substrate).

7.5.24 *TAKE SAMPLE (TAKE MEASUREMENT Sub-state)* — the equipment collects data from a single structure or of a single sample.

7.5.25 *UNLOAD (EXECUTING Sub-state)* — the substrate is being removed from the processing location.

7.5.26 *WORKING (EXECUTING Sub-state)* — the equipment is processing a specific material.

7.5.27 *Processing State Transition Table*

Table 1 Processing State Transition Table

Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
1	INIT	All equipment initialization is complete with no alarms or error conditions.	IDLE	None	If an alarm or error occurs during INIT, the equipment shall remain in this state.
2	IDLE	A process is queued or a command is received.	SETTING UP	The set up procedure is equipment dependent.	Commit has been made to set up.
3	SETTING UP	All setup activity has completed and the equipment is ready to receive a START command.	READY	The equipment is waiting for a START command. Start may be initiated by an operator.	The selected Process Program is available for execution.
4	READY	The equipment receives a START command.	LOAD	The equipment determines if processing is completed. If not, it transfers the next substrate to the processing location.	LOAD is an EXECUTING Substate.
5	EXECUTING	The processing is complete.	STOPPING	None	Equipment specific. Supplier must chose beween LOAD or UNLOAD states for completion.
6	PROCESS	The equipment has received a STOP command.	STOPPING	The equipment unloads the material and brings the equipment to a clean and safe state.	Data is typically preserved and is valid.
7	PROCESS	The equipment has received an ABORT command	ABORTING	The equipment is put in a "safe state" if necessary.	Data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended and the equipment is waiting for all alarms to be cleared.	ALARM PAUSED is a PAUSE Substate.
9	PROCESS	The equipment has received a PAUSE command.	PAUSING	PROCESS shall be suspended at the next opportunity. Actions to put the equipment in a "safe state" shall be performed.	PAUSING is a PAUSE Substate.
10	PROCESS PAUSED	The equipment has received a RESUME command.	Previous PROCESS State	Proceed with the suspended Substate.	PAUSED is a PROCESS PAUSE Substate.
11	CHECKING	The equipment has completed validating any updates made to the current Process Program being executed. Including a PP_UPDATE	Previous PROCESS State	Action is appropriate to the state and the changes made to the Process Program updated.	None

Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
12	STOPPING	The equipment clean up is complete and the equipment is free of alarms.	IDLE	None	None
13	PAUSE	The equipment has received a STOP command.	STOPPING	The equipment proceeds with clean up.	Normally, data is preserved and is valid.
14	PAUSE	The equipment has received an ABORT command.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
15	STOPPING	The equipment has received an ABORT command.	ABORTING	Any unsafe condition is resolved if possible.	Data may be invalid or not available.
16	ABORTING	Unsafe conditions have been resolved where possible.	ABORTED	The equipment is waiting for alarm and ABORT conditions to be cleared.	The only state change allowed is to IDLE.
17	ABORTED	All alarms and abort conditions have been cleared.	IDLE	None	If needed the CLEANUP command clears the abort conditions. IDLE is a “clean” state.
18	IDLE	An alarm is set.	IDLE w/ ALARMS	The equipment waits for all alarms to be cleared.	None
19	IDLE w/ ALARMS	All alarms have been cleared.	IDLE	None	IDLE is free of alarms.
20	PAUSING	The equipment has achieved a “safe state”.	PAUSED	The equipment is waiting for a command (RESUME, STOP or ABORT).	None
21	PROCESS PAUSE	An alarm is set.	ALARM PAUSED	The equipment waits for all alarms to be cleared, or a STOP or ABORT command.	None
22	ALARM PAUSED	All alarms are cleared.	PAUSED	The equipment is waiting for a command (RESUME, PP_UPDATE, STOP or ABORT).	None
23	LOAD	Material transfer to processing location is complete and global alignment has been completed.	WORKING	The substrate is being processed.	None
24	WORKING	The processing of the specific material being processed ended normally.	UNLOAD	This material is transferred from the processing location.	“Normal” completion of the substrate.
25	UNLOAD	The material unload is complete.	LOAD	The equipment checks if processing is complete and, if not, transfers the next substrate to the processing location.	None

Transition #	*Current state*	*Trigger*	*New State*	*Actions*	*Comments*
26	WORKING	The processing of the specific material being processed ended abnormally.	UNLOAD	This material is transferred from the processing location.	Abnormal exit from WORKING or Next Material command received.
27	ALIGN	The material alignment is complete.	MEASURING	The equipment determines if additional sites are required.	None
28	TAKE MEASURE-MENT	All data collection has been completed for the current site or alignment location.	MEASURE-MENT COMPLETE	The equipment determine if additional sites are required.	Determine if additional alignments are required or unload is required.
29	MEASURE-MENT COMPLETE	Additional sites are required.	ALIGN	The equipment moves and aligns to new data collection site.	None
30	TAKE SAMPLE	Data collection from scan or structure.	SAMPLE COMPLETE	Determine if additional samples are required.	None
31	SAMPLE COMPLETE	Additional samples are required.	TAKE SAMPLE	Start collecting next scan or structure data.	None
32	CHECKING	Validation of Process Program change fails or is cancelled. Includes PP_UPDATE.	PAUSED	The equipment is waiting for a new PP-UPDATE or RESUME command.	Process Program reverts to the conditions that existed prior to the PP-UPDATE.
33	PAUSED	The equipment receives a PP-UPDATE command.	CHECKING	The equipment begins validating the changes made to the Process Programs to be executed.	None
34	TAKE MEASURE-MENT	Another measurement is required at an alignment location.	TAKE MEASURE-MENT	The equipment performs a measurement.	None
35	MEASURING	An error or failure occurred during the measurement and a new alignment is required.	ALIGN	The equipment moves and aligns to new data collection site.	None
36	ALIGN	An error or failure occurred during alignment and a new alignment is required.	ALIGN	The equipment moves and aligns to new data collection site.	None
37	ASSIST	A failure occurred while executing and external assistance was required to continue.	PROCESS PAUSE	The execution is stopped and equipment waits for a resume command.	Resume command must be issued.
38	LOAD	Previous PROCESS-BLD-GROUP program has completed and there are additional process programs assigned to the “CARRIERBLD”. See Section 12.	SETTING UP	The equipment performs set up according to specifications of the next process program.	PROCESS-BLD-GROUP may include a AUTOSTART command within its body. Otherwise, the equipment waits for a START command.

Table 2 Processing State Events and Associated Reports

CENAME	*From State*	*To State*	*Required DVVAL's or Reports*
END of RUN	STOPPING	IDLE	RUN complete report available. All jobs specified by PROCESS-BLD-GROUP command parameter(s) in a CARRIERBLD command parameter complete.
END of JOB	LOAD	SETTING UP	JOB complete report available. A job specified by a PROCESS-BLD-GROUP command parameter in a CARRIERBLD command parameter that specifies multiple jobs for the same material completes.
END of SUBSTRATE	UNLOAD	LOAD	SUBSTRATE complete report available.
END of SITE	TAKE MEASURE	MEASURE COMPLETE	SITE complete report available. Only required if supporting sampling.
END of SAMPLE	TAKE SAMPLE	SAMPLE COMPLETE	SAMPLE complete report available. Only required if equipment performs measurements on individual sites.

8 Collection Event List

8.1 The purpose of this section is to identify data collection events for Metrology equipment and define reporting levels.

8.2 *Requirements* — Only those collection events that are not associated with a change of state, and those requiring specific DVVAL's or Reports defined in the SEM, are required to be included in this section. All SEMI E30 required events are required by this SEM.

8.2.1 *Common collection events* — collection events common to, and required on, all equipment of the class being addressed.

8.2.2 *Configuration-specific collection events*— collection events associated with a specific configuration of the equipment class being addressed.

8.3 *Collection Event Tables* — The first table contains processing state event transitions and associated reports. The second table contains additional events or actions and associated reports.

8.3.1 All remote commands (S2F41) that are not preformed by the equipment before responding to the host (S2F42) must generate an event indicating when the task was completed and whether it was successful.

Table 3 Additional Required Collection Events

ACTION or COMPLETED EVENT	*Required DVVAL's or Reports*
Remote command MAP-CASSETTE completed successfully.	SlotList
Operator hits button on equipment control panel.	OperatorAction

9 Data Item Variables

9.1 The purpose of this section is to define the list of data item variables pertinent to the specific equipment. Values of these variables shall be available to the host via collection event reports and host status queries.

9.2 *Requirement* — all generic variable data items defined in SEMI E30 are required by all Measurement equipment. Data item variables are categorized as follows:

9.2.1 *Common Variables (CV)* — variables common to all equipment of the class being addressed. These variables are covered in Table 4 and must be used to regardless of the measurement tool type.

9.2.2 *Configuration-specific variables (CSV)* — variables associated with a specific configuration of the above equipment class.

9.2.2.1 The following rules should be adhered to in the reporting of these variables.

- The information should be sent using the corresponding formats defined on Table 4 and 5.
- For ASCII variables A[n]. If the actual data does not fill the entire field, blanks shall be used to complete the field.
- For ASCII variables A[1..n]. All fields should be left justified.

9.3 Since MSEM is generic to all equipment it tries not to specify the names of the measurement variables to be sent to the host. MSEM does require that the data be reported at site, wafer and lot levels. It should include the option of reporting data at the individual scan level if supported by the equipment. It is a requirement that the equipment report at least: max, min, mean, standard deviation. Additional statistic calculations may be added by the equipment supplier. For each type of data collected by the equipment at the site level; the data must be summarized and available for reporting at the wafer and lot levels.

9.4 The following rules should be applied when reporting measurement values taken by the tool. The rules specify the units to be used whenever these values are reported.

- All values specified should be reported in floating point format.
- All critical dimensions (lines and spaces) should be in microns.
- All overlay measurements should be in microns.
- All FTIR transmittance values and corresponding wavelengths should be reported in percent units and microns, respectively.
- All film stress values should be reported in teradynes/cm-cm.
- All resistivity measurements should be reported in Ohm-cm.
- All film thickness measurements should be reported in Angstroms.

9.5 Data item variables should be documented in the MSEM data item variable dictionary using the following format:

Variable Name	*Category*	*Description*	*Class*	*Format*	*Comments*

Where:

Variable Name:	A unique name for the data item variable (this name is for reference only).
Category:	Defined as Common or Configuration-Specific variables.
Description:	If class is DVVAL, then the description must contain a statement of when data is valid in terms of MSEM events.
Class:	Data type of the item.
Format:	Acceptable formats are SEMI E5 lists, ASCII, floating point, unsigned integer or signed integer. A description of “ANY”, indicates that any of the above formats are acceptable and is left to the tool vendor to decide. When required use SECS Message Language format.
Comments:	Any additional information pertinent to the variable name.

9.6 *Data Item Variable Types*

9.6.1 *Equipment Constants (ECV)* — can be changed by the host using S2F15. The operator may have the ability to change some of the values, but the equipment does not change the values on its own. The value of the equipment constant may be queried by the host at any time using the S2F13/14 transaction.

9.6.2 *Status Variables (SV)* — are valid at all times. A SV may not be changed by the host but may be changed by the equipment or the operator. The value of status variables may be queried by the host at anytime using the S1F3/4 or S6F19/20 transactions.

9.6.3 *Data Variables (DVVAL)* — are variables which are valid only upon occurrence of specific collection events. An attempt to read a data variable at the wrong time shall not generate an error, but the data reported may not have relevant meaning.

9.6.4 *Variable Data (V)* — this is a class of variable data which includes all the previously defined types of variables.

Table 4 Data Item Variable List

Variable name	*Category*	*Description*	*Class*	*Format*	*Comments*
AlignList	CSV	A list of alignment site information being used by the currently active Process Program.	DVVAL	L,n 1. <AlignName> . . n.	See Table 5 for additional information.
CarrierID	CV	ID of the Carrier that the measurement data is associated with.	DVVAL	A[1..16]	Valid in processing substate.
Coord	CV	The X,Y coordinate for a site in microns.	DVVAL	L,2 1.<CoordX> 2.<CoordY>	See Table 5 for additional information.
Coordsys	CV	The identification for applicable coordinate system.	DVVAL	A[1..16]	Options for silicon wafers are: SEMI M20, M20P, SEMI M21.
Default-Priority	CV	The default priority given a location or carrier ID if none is assigned.	EC	U4	
DeltaX	CSV	The x axis translation between the origins of two coordinate systems, in µm.	DVVAL	F4	Units are in microns.
DeltaY	CSV	The y axis translation between the origins of two coordinate systems, in µm.	DVVAL	F4	Units are in microns.
ElementID	CSV	The M21 address for a specific rectangular element on a patterned silicon wafer.	DVVAL	I4[2]	M21 row number, M21 column number.
ElementList	CSV	A list of M21 elements where measurements were attempted.	DVVAL	L,n 1. <ElementID> . . n	See Table 5 for additional information.
EquipID	CV	Unique ID of measurement equipment.	SV	A[1..16]	Valid in all sub states.
EquipName	CV	Name of equipment	SV	A[1..16]	Valid in all sub states.
LotID	CV	Lot ID that is associated with the measurement data.	DVVAL	A[1..80]	
M20Data	CV	The silicon wafer size, fiducial type, and orientation to use.	DVVAL	L,3 1.<WaferSize> 2.<Fiducial> 3. <Orientation>	See Table 5 for additional information.

Variable name	*Category*	*Description*	*Class*	*Format*	*Comments*
M21Data	CSV	The data necessary to establish an MSEM SEMI M21 layout on a silicon wafer.	DVVAL	L,2 1. L,3 1.<M21XSize> 2.<M21YSize> 3. <Tile> 2. L,n 1. L,3 1.<ElementID> 2.<CoordX> 3.<CoordY> : n	Coord x and Coord y are the X and Y coordinates in the M20P coordinate system of the lower left-hand corner of the element. See Table 5 for additional information.
QueuedJobList	CSV	An ordered list of CarrierID data items (A[1..16]) of material that is queued to run. The first item in the list is the ID of next carrier to run. A soon as a job specified by a PROCESS-BLD-GROUP starts, the CarrierID it specifies is removed from the head of the list.	SV	L	
Offset	CSV	The difference between the defined location of a site and the location at which it is found.	DVVAL	F4[2]	SiteDeltaX, SiteDeltaY
Operator Action	CV	Action taken by operator on equipment's front panel.	DVVAL	A[1..80]	
OperName	CV	Tool Operator name	ECV	A[1..16]	
Orientation	CV	The direction, in degrees, from the equipment's "0" location for a wafer's primary fiducial when initially positioned for measurements.	ECV	F4	This parameter has no effect on the "M20" based wafer coordinate system as discussed in SEMI standard SEMI M20.
PP-Name	CV	The PPID that is being used for measuring.	SV	A[1..80]	
Process SlotList	CV	The list of cassette slots whose contents are to be processed.	DVVAL	L,n 1. <SlotID> . . .	L,0 indicates all slots are to be processed. See Table 5 for additional information.
SiteDeltaX	CSV	The x axis translation between the defined and found locations of a site, in µm.	DVVAL	F4	Units are in microns.
SiteDeltaY	CSV	The y axis translation between the defined and found locations of a site, in µm.	DVVAL	F4	Units are in microns
SiteList	CV	The list of sites where measurements are made.	DVVAL	L,n 1.<SiteName> . . n	See Table 5 for additional information.
SiteName	CV	A unique identifier for a site.	DVVAL	A[1..16]	

Variable name	Category	Description	Class	Format	Comments
SlotID	CV	The cassette slot number.	DVVAL	U4	
WaferID	CSV	Physical wafer identifier.	SV	A[1..24]	
WaferIDRead	CSV	Tool read wafer identifier.	SV	A[1..24]	
WaferSize	CV	The nominal diameter of a silicon wafer.	EC	A[1..16]	mm
XlateData	CSV	Variable for the equipment to report the pattern-based coordinate system offset from the wafer-based coordinate system found on the wafer being tested.	SV	L,4 1 <DeltaX> 2 <DeltaY> 3 <Theta> 4 <ScaleFactor>	See Appendix 1 for an example. See Table 5 for additional information.

9.6.5 *Data Item Sub-variable List*

Table 5 Data Item Sub-Variable List

Data Item Sub-variables	*Description*	*Format*	*Comment*
AlignName	The identifier given to a alignment site.	A[1..16]	
CoordX	The x coordinate for a site.	F4	Units are in microns.
CoordY	The y coordinate for a site.	F4	Units are in microns.
DeltaX	The x axis translation between the origins of two coordinate systems, in µm.	F4	Units are in microns.
DeltaY	The y axis translation between the origins of two coordinate systems, in µm.	F4	Units are in microns.
ElementID	The M21 address for a specific rectangular element on a patterned silicon wafer.	I4[2]	M21 row number, M21 column number
Fiducial	The type of primary fiducial on a silicon wafer.	A[1..16]	Options are “FLAT” or “NOTCH”
M21XSize	The M21 element size in the x direction, in µm.	F4	Units are in microns.
M21YSize	The M21 element size in the y direction, in µm.	F4	Units are in microns.
ScaleFactor	The scaling factor required by the equipment to adjust from its SEMI M20 coordinate system to the coordinate system established through the use of pattern alignment “alignment site” information. In most cases, a scaling factor of 1 is expected.	F4	
SiteDeltaX	The x axis translation between the defined and found locations of a site, in µm.	F4	Units are in microns.
SiteDeltaY	The y axis translation between the defined and found locations of a site, in µm.	F4	Units are in microns.
SiteName	A unique identifier for a site.	A[1..16]	
THETA (Θ)	The clockwise rotation, in radians, between the SEMI M20 and M20P coordinate system axes.	F4	Radians
Tile	A flag to indicate whether the SEMI M21 layout is tiled, and in which direction.	A[1..16]	Options are: “NTILE” is untitled “CTILE” is column tiled “RTILE” is row tiled

10 Alarm List

10.1 Since each model of equipment differs in configuration, it is not practical to provide an exhaustive list of all possible alarms. Instead, the MSEM is requiring the two tables provided as described in SEMI E30 (Document Section). Alarm List Table which is intended to provide for equipment configuration specific alarms and Alarm ID, Alarm Set/Cleared Event Table.

10.2 *Alarm List Table*

10.2.1 The alarm list table contains examples of alarms that pertain to various configurational aspects of equipment. These examples are intended to illustrate that alarms pertain to situations in which there exists a potential for exceeding physical safety limits associated with people, equipment, and material being processed as per the SEMI E30 definition of an alarm. See SEMI E30 for further reference.

10.3 *Alarm ID, Alarm Set/Cleared Event Table*

10.3.1 The Alarm ID, Alarm Set/Cleared Event table documents the association of each ALID to a set and cleared event as required by SEMI E30. See SEMI E30 for further reference.

11 Process Program Management

11.1 *Requirements* — The MSEM requires that the SEMI E30 capability of Process Program Management be fully supported for this class of equipment. The MSEM is also requiring that the Process Program have a structure that enables the user to build Process Programs with default conditions that can be overridden for a run. MSEM is requiring the ability to vary; the quantity of substrates measured, the alignment information used and the number and/or location of the sites to be measured through the uses of Process Program variable parameters. The concepts of Process Program Structure and Process Program variable parameters are discussed in the following sections.

11.2 *Process Program Structure*

11.2.1 *Definition and Rules for Process Programs* — A Process Program contains information and/or instructions required for the metrology equipment to process a given run of material. Equipment constants can be used to supplement the information contained in a Process Program.

11.2.1.1 The Process Program shall supply all of the information required for a remotely executed run to be processed without operator intervention. Any information that is normally requested from the operator console in manual operation shall have default values assigned in the body of the Process Program.

11.2.1.2 Process-program parameters are used to tailor a specific run of material and do not permanently modify the Process Program. They will remain in effect only until the next run or until the next PP-UPDATE or PP-SELECT, PP-ASSIGN remote command.

11.2.1.3 MSEM is requiring the ability to define specific Process Program variable parameters to; define what substrates are to be measured (Process SlotList), what sites are to be measured (SiteList or M21SiteList) and what aligns are used by the Process Program (AlignList or M21AlignList). If the MSEM equipment is using the SEMI M21 coordinate system then an additional Process Program variable parameter is required what elements are to be measured (ElementList).

11.2.2 *Definition of Process Program Variable Parameters* — A process-program parameter specifies a value that temporarily modifies the value of a variable parameter in a Process Program. A variable parameter is formally defined within a process-program body and contains:

- a variable parameter name that is unique in the body
- a parameter initial value, known as default value, for use when the Process Program is selected for execution without specification of an override value for this variable parameter.

11.2.3 The Equipment may also support the definition including:

- a parameter restriction that represents one or more conditions that any value specified for the parameter must satisfy.
- a CP-NAME in a remote command must be identical to a variable parameter name in the Process Program specified in the remote command. If the Equipment allows Sub-process Programs, a Sub-process Program reference may also specify parameters.

11.2.4 *Relationship of Process Program Variable Parameter* — The PP-SELECT, PP-ASSIGN or PP-UPDATE remote commands can be used to modify variables within the Process Program. The modification to process-program variables is done by using CP-NAME/CP-VAL pairs within the command.

11.2.5 *Sub-Process Programs* — Equipment may allow a main Process Program to reference Sub-process Programs. A main Process Program is one that can be referenced by the host. A Sub-process Program is a Process Program that is referenced by a main Process Program or by other Sub-process Programs. No Sub-process Program may reference its main Process Program. If the Equipment supports sub-process-program references, it must be possible for the host to determine which Sub-process Programs are referenced in all Process Programs.

11.2.5.1 Before execution of a main Process Program can begin, the presence of all the Sub-process Programs that it references must be verified by the Equipment. If they are not all present, an error collection event must occur. It must be possible to include in the event report which Sub-process Programs are missing. For a formatted Process Program, the error is reported using an S7F27 message.

11.2.6 *Component Descriptions and Allowed Formats*

Table 6 Process Program Component Description and Format Table

Component Name	*Description*	*Format*	*Comments*
ALIGN-ATTRIBUTE (n)	Tool specific information associated with alignment site for which no specific MSEM data item has been defined.		Examples include information such as magnification, voltage, current, wavelength, number of scans, integration time, or film stack. The equipment supplier shall document all attributes that are supported.
ALIGN-NAME	The identifier given to a alignment site.	A[1..16]	
COORDSYS	The identification for applicable coordinate system.	A[1..16]	Options for silicon wafers are: SEMI M20, M20P, SEMI M21
COORDX	The x coordinate for a site or the lower left hand corner of an element.	F4	Units are in microns.
COORDY	The y coordinate for a site or the lower left hand corner of an element.	F4	Units are in microns.
ELEMENTID	The element identifier in the SEMI M21 coordinate system	U4[2]	
M21XSIZE	The SEMI M21 element size in the x direction in µm.	F4	
M21YSIZE	The SEMI M21 element size in the y direction in µm.	F4	
SITE-ATTRIBUTE (n)	Tool specific information associated with a measurement site for which no specific MSEM data item has been defined.		Examples include information such as magnification, voltage, current, wavelength, number of scans, integration time, or film stack. The equipment supplier shall document all attributes that are supported.
SITENAME	A unique identifier for a site.	A[1..16]	

11.2.7 *DEF-LIST-TABLE Description* — DEF-LIST types of tables are used by the equipment in conjunction with the Process Programs. The DEF-LIST table structures provide a means to transfer to equipment a list of a particular type of information. The DEF-LIST table structures are used by the host to send information to equipment for later use in association with a Process Program. Each DEF-LIST that is sent has a unique Table name and each list element in the DEF-LIST has several components including a name (Site-Name, or Align-Name) as well as other components. A specific list row can be accessed for use with a specific Process Program by giving the DEF-LIST table name and the specific row name.

11.2.7.1 There are five types of DEF-LIST tables:

- SITE-DEF-LIST: A list of Sites and their attributes, typically the list of sites to be measured.
- ALIGN-DEF-LIST: A list of alignment sites and their attributes.
- M21-ELEMENT-DEF-LIST: A list of element ID and their low left hand location in M20P or SEMI M20 coordinates.
- M21-ELEMENT-SITE-DEF-LIST: A list of ElementID's and what sites are to be measured within that element.
- M21-ELEMENT-ALIGN-DEF-LIST: a list of ElementID's and the alignment sites to be used at each.

NOTE 2: The attributes are equipment-defined.

11.2.7.2 To support the SiteList, and AlignList, for SEMI M20, M20P and SEMI M21, the following types of tables must be implemented: SITE-DEF-LIST, ALIGN-DEF-LIST, or M21-ELEMENT-SITE- DEF-LIST, M21-ELEMENT-ALIGN-DEF-LIST and M21-ELEMENT-DEF-LIST. A host would send a DEF-LIST to equipment using standard transfer methods for tables as defined by ARAMS (SEMI E58). MSEM requires that the following columns be included in the DEF-LIST tables. The DEF-LIST-TABLE components table defines the DEF-LIST column names and their allowable format is given below.

Table 7 SITE-DEF-LIST

Sitename	*Coordx*	*Coordy*	*Coordsys*	*Site- Attribute(n)*

11.2.7.3 For SEMI M21 Coordinate system an additional table is required.

Table 8 M21-ELEMENT-SITE-DEF-LIST

Element id	*Sitename*

Table 9 M21-ELEMENT-DEF-LIST

Element id	*Coordx*	*Coordy*	*Coordsys*	*m21xsize*	*m21ysize*

Table 10 ALIGN-DEF-LIST

Align-Name	*Coordx*	*Coordy*	*Coordsys*	*Align- Attribute(n)*

Table 11 M21-ELEMENT-ALIGN-DEF-LIST

Element id	*Align-Name*

12 Remote Commands

12.1 The purpose of this section is to identify the MSEM required remote commands, command parameters, and valid commands versus MSEM states.

12.2 *Requirements* — The following capabilities are required:

- StartProcessing
- Stop Processing
- Temporaly Suspend Processing
- Resume Processing
- Abort Processing
- Select Process Programs, Material and/or Sites to Measure
- Report Location of Material Found within a cassette

12.3 All the remote commands defined by MSEM are required unless they have been qualified by the statement “if the equipment supports this functionality it shall use this command”. Then, they are only required if the equipment supports the functionality necessary to support the command. A good example of this is the MAP-CASSETTE command if the equipment does not have the hardware necessary to scan a cassette for the presence of substrates in slots then the command is not required by the MSEM. The alphanumeric strings defined by MSEM for RCMD and CPNAME are required.

12.4 *Definitions*

12.4.1 *Host Command Parameter (CPNAME/CPVAL)* — a parameter name/value associated with a particular host command (S2,F49). This document will specify unique names (CPNAMEs) and values (CPVALs) for many command parameters. Note that if there are no associated parameters a zero-length list is sent.

12.5 *Remote Commands Description* — this section describes required functionality, suppliers may implement additional commands. The following remote commands (RCMDs) must be supported as described below.

NOTE 2: The terms “current cycle” and “safe point” used below are to be defined by the supplier.

12.5.1 *ABORT* — terminate the current cycle prior to its completion. Abort has the intent of immediately stopping the process and is used because of abnormal conditions. Abort makes no guarantee about the subsequent condition of material except as noted in the CPNAME ABORT-LEVEL description.

12.5.2 *CLEANUP* — Process Program deselection, removal of all material to output locations and any equipment specific activities needed to transition into the IDLE state. Completion of this command should generate a collection event report.

12.5.3 *NEXT-MATERIAL* — processing of the current substrate is halted at the first safe point and unloaded to the target cassette location. Next-material has the intent of allowing the host to skip measurement of the current substrate. This is a trigger for processing state transition from WORKING to UNLOAD.

12.5.4 *PAUSE* — suspend processing temporarily at the next safe point. Pause has the intent of resuming the process at the same point where it was paused. RESUME or PP-UPDATE may be used to resume the process.

12.5.5 *PP-ASSIGN* — instructs the equipment to assign a process to a carrier ID(s)/location(s) and place the exchange station in the process queue with the given priority. Only one assignment is allowed for a exchange station. Without specifying a priority, the material is queued with the default priority. Material with equal priority are queued in the order the PP-ASSIGN commands are received. If the equipment supports the functionality of queuing material, it will use this command.

12.5.6 *PP-SELECT* — instructs the equipment to make the requested Process Program(s) available in the execution area. Additionally, to reduce the number of Process Programs on the equipment, PP-SELECT may define the material to be measured, measurement site locations, and/or the information needed for site alignment; default values shall be used if this information is not specified. This is a trigger for the processing state transition from IDLE to SETTING UP. All Process Programs specified in the command are to be validated

12.5.7 *PP-UPDATE* — provides the ability to alter Process Program variables during the PAUSED processing state. Any CPNAMEs specified in PP-UPDATE will replace the previous definitions. This command will RESUME the process. If the PP-UPDATE fails, the Process Program variables present prior to the PP-UPDATE are retained. If no parameters values are specified, the defaults are used.

12.5.8 *RESUME* — resume processing from the point where the process was paused. This is the trigger for processing state transition 10, from PROCESS PAUSE.

12.5.9 *START* — instructs the equipment to initiate processing. This is the trigger for the processing state transition from READY to LOAD.

12.5.10 *STOP* — complete the current cycle, stop in a safe condition and return to the IDLE processing state. Stop has the intent of stopping the process entirely. The equipment is not required to support the continuation of processing.

12.6 *Host Command Parameters Names (CPNAME)*

Table 12 Host Command Parameter Table

CPNAME	*CPVAL*		
	Description	*Range*	*Format*
CARRIERBLD	L,2 1. L,2 1. CP-CARRIERID ** 2. CARRIERID or 1. L,2 1. CP- LOCATIONID ** 2. (STORAGE)ID 2. L,N 1. L,2 1. PROCESS-BLD-GROUP 2. L,M : N. L,2 1. PROCESS-BLD-GROUP ** Both CP-CARRIERID and CP-LOCATION may be included if no carrier ID reader is available.		
CP-ABORT-LEVEL	MSEM defined abort levels HALT - halt, goto ABORTED CLEANUP - halt, preform cleanup procedure, goto ABORTED	"HALT" "CLEANUP"	A[7]
CP-ALIGNLIST	L,n 1. CP-ALIGNNAME : n. For the SEMI M20 or M20P Coordinate system		
CP-ALIGN-DEF-LIST	**As defined in Section 9**		
CP-ALIGNNAME	Alignment name		A[1..80]
CP-AUTOSTART	Defines if a START command is required from an external source (operator or host) to exit the READY state. 0 = START command required, 1 = AUTOSTART no external START command required to begin execution.	0–1	U1
CP-CARRIERID	ID of carrier that the measurement data is associated with.		A[1..16]
CP-ELEMENTID	The M21 address for a specific rectangular pattern on the wafer.		I4[2]

CPNAME	*CPVAL*		
	Description	*Range*	*Format*
CP-ELEMENTLIST	L,n 1. <CP-ELEMENTID> : n.		
CP-LOCATIONID	Unique identifier of the location to be used for the "CARRIERBLD" assignment.		U4
CP-LOTID	lot id		A[1..80]
CP-MATERIALLIST	L,n 1. <CP-SLOTID or CP-WAFERID> : n.		
CP-M21-ALIGNLIST	L,n 1. CP-ALIGNNAME : n. For the SEMI M21 Coordinate system		
CP-M21-SITELIST	L,n 1. CP-SITENAME : n. For the SEMI M21 coordinate system		
CP-PPNAME	Process Program name		A[1..80]
CP-PRIORITY	assignment priority	0–9 0–highest priority	U4
CP-SITELIST	L,n 1. CP-SITENAME : n. For the SEMI M20 or M20P coordinate system		
CP-SITE-DEF-LIST	As defined in Section 9.		
CP-SITENAME	unique identifier for a site		A[1..16]
CP-SLOTID	slot number	1–n	U4
CP-SLOTLIST	Specifies carrier slots that contains substrate to measure. L,n 1. CP-SLOTID : n.	0 indicates all slots	
CP-WAFERID	Physical wafer identifier		A[1..24]

CPNAME	*CPVAL*		
	Description	*Range*	*Format*
PROCESS-BLD-GROUP	L, n 1. L, 2 1. CP-PPBUILDID 2. PPBUILDGROUPID 2. L, 2 1. CP-PPNAME 2. PPNAME 3. L, 2 1. CP-LOTID 2. LOTID 4. L, 2 1. CP-AUTOSTART 2. START 5. L, 2 1. CP-MATERIALLIST 2. L, n 1. CP-SLOTID : n. ***or*** 1. CP-WAFERID 2. L, n : n.	$n \geq 2$	List of *n* data items

CPNAME	*CPVAL*		
	Description	*Range*	*Format*
PROCESS-BUILD-GROUP(continues)	6. L, 2 1. CP-SITE-DEF-LIST 2. SITE-TABLE-NAME 7. L, 2 1. CP-SITELIST 2. L, n 1. CP-SITENAME : n. 8. L, 2 1. CP-ALIGN-DEF-LIST 2. ALIGN-TABLE-NAME 9. L, 2 1. CP-ALIGNLIST 2.L, n 1. CP-ALIGN-NAME : n. 10. L, 2 1. CP-ELEMENTLIST ** 2. L, n 1. CP-ELEMENTID : n. **CP-ELEMENTLIST is required when using the SEMI M21 coordinate system in the definition of an ALIGNNAME or SITENAME . 10. L, 2 1. CPNAME supplier defines Process Program Variable Parameters 2. CPVAL CP-PPNAME is required, CP-SLOTLIST, CP-SITELIST, and CP-ALIGNLIST are optional.		

12.7 *Remote Commands and Associated Host Command Parameters* — This table describes the allowable command parameters (CPNAME) for each remote command (RCMD). Equipment must support all parameters. The column marked Req/Opt, specifies which parameters are required to be sent by the host and which parameters may be optionally sent by the host.

Table 13 Remote Command and Associated Host Command Parameters Table

Remote Command	*Parameter(s)*		
	CPNAME	*Req/opt*	*Description*
ABORT	CP-ABORT-LEVEL	O	
CLEANUP	CP-LOCATIONID CP-SLOTID	O O	Location and SLOT may be used to define a different cassette / slot destination for the substrates.
NEXT-MATERIAL	CP-LOCATIONID CP-SLOTID	O O	If no command parameters are specified, then the substrate is returned to its original source carrier and slot. If a CP-SLOT command parameter is specified, then the substrate is placed in that slot of its original source carrier. If a CP-LOCATIONID command parameter is specified, then the substrate is placed in an available slot of the carrier at the specified location. If both CP-SLOT and CP-LOCATION command parameters are specified, then the substrate is placed in specified slot of the carrier at the specified location.
PAUSE	None	N/A	None
PP-ASSIGN	CP-PRIORITY CARRIERBLD*	O R	* More than one CARRIERBLD may be specified. There may be more than one PROCESS-BLD-GROUP in each CARRIERBLD.
PP-SELECT	CARRIERBLD*	R	* More than one CARRIERBLD may be specified. There may be more than one PROCESS-BLD-GROUP in each CARRIERBLD.
PP-UNASSIGN	CP-LOCATIONID CP- CARRIERID	R* R*	* At least one is required.
PP-UPDATE	CP-SLOTLIST CP-SITELIST CP-ALIGNLIST	R* R* R*	* At least one is required. By default use the current active input port.
RESTAGE	CP-LOCATIONID	R*	* Some equipment may not support this feature.
RESUME	None	N/A	None
START	None	N/A	None
STOP	None	N/A	None

12.8 *Remote Command and Processing State Relationship*

Table 14 Remote Commands versus Processing States Table

Command / **PROCESSING STATE**	STOP	START	RESUME	PP-UPDATE	PP-SELECT	PAUSE	NEXT-MATERIAL	PP-ASSIGN	CLEANUP	ABORT
IDLE					X			X		
PROCESSING ACTIVE										
PROCESS										
SETTING UP	X					X		X		X
READY	X	X				X		X		X
EXECUTING								X		
LOAD	X					X		X		X
WORKING										
ALIGN	X					X	X	X		X
MEASURING	X					X	X	X		X
TAKE MEASURE	X					X	X	X		X
TAKE SAMPLE	X					X	X	X		X
SAMPLE COMPLETE	X					X	X	X		X
MEAS COMPLETE	X					X	X	X		X
UNLOAD	X					X		X		X
STOPPING								X		X
PAUSE										
PROCESS PAUSE										
PAUSING	X							X		X
PAUSED	X		X	X				X		X
CHECKING	X							X		X
ALARM PAUSED	X							X		X
ABORTED								X	X	

13 Scenarios

13.1 The purpose of this section is to document any MSEM specific scenarios that must be performed by this class of equipment.

13.2 *Normal Reporting*

COMMENTS	*HOST*	*EQUIPMENT*	*COMMENTS*
			The equipment is in the IDLE processing state and in the ONLINE REMOTE control state. Material arrives on input port 1.
PP-ASSIGN	S2,F63-->		
		<--S2,F64	Positive Acknowledge.
		<--S6,F11	IDLE -> SETTING UP
Positive Acknowledge.	S6,F12-->		
		<--S6,F11	SETTING UP -> READY
Positive Acknowledge.	S6,F12-->		
START	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	READY -> LOAD.
Positive Acknowledge.	S6,F12-->		
			[WHILE] Not End of Run
			1) LOAD->WORKING
			2) Sample and/or Site level data reporting.
			3) WORKING->UNLOAD
			4) Substrate level data reporting.
			5) UNLOAD->LOAD.
			[ENDWHILE].
		<--S6,F11	LOAD->STOPPING.
Positive Acknowledge.	S6,F12-->		
			Run level data reporting.
		<--S6,F11	STOPPING->IDLE.
Positive Acknowledge.	S6,F12-->		

13.3 *ABORT/ CLEANUP Remote Command Scenario* — Host issues the ABORT/CLEANUP remote command

COMMENTS	*HOST*	*EQUIPMENT*	*COMMENTS*
ABORT	S2,F41-->		("CLEANUP" not specified)
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	Transition to ABORTED.
Positive Acknowledge.	S6,F12-->		
CLEANUP	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
			Equipment performs cleanup activities.
		<--S6,F11	CEID is posted.
			[IF] cleanup is successful:
			Transition to IDLE
			[ELSE]
			Remain in the ABORTED state.
			[ENDIF].
Positive Acknowledge.	S6,F12-->		

13.4 *PP-UPDATE Remote Command Scenario* — Host issues the PP-UPDATE remote command.

COMMENTS	*HOST*	*EQUIPMENT*	*COMMENTS*
START	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	READY -> LOAD
Positive Acknowledge.	S6,F12-->		
			[WHILE] Not End of Run 1) LOAD->WORKING 2) WORKING->UNLOAD 3) UNLOAD->LOAD [ENDWHILE]
Sometime during the [WHILE]:			
PAUSE	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	Transition to PAUSING
Positive Acknowledge.	S6,F12-->		
		<--S6,F11	PAUSING -> PAUSED
Positive Acknowledge.	S6,F12-->		
PP-UPDATE	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
		<--S6,F11	PAUSED->CHECKING
Positive Acknowledge.	S6,F12-->		
		<--S6,F11	CEID is posted. [IF] the updates are valid: Return to the previous process state thru history [ELSE] Return to the PAUSED state. The Process Program remains unchanged. [ENDIF]
Positive Acknowledge.	S6,F12-->		

13.5 *PP-ASSIGN / PP-UNASSIGN Scenario* — Host issues the PP-ASSIGN/PP-UNASSIGN remote commands.

COMMENTS	*HOST*	*EQUIPMENT*	*COMMENTS*
PP-ASSIGN	S2,F41-->		
		<--S2,F42	Positive Acknowledge.
PP-UNASSIGN	S2,F41-->		
		<--S2,F42	Positive Acknowledge. This may occur during the STOPPING state.

13.6 The host may setup the material for additional processing without the cassette being removed and replaced on the equipment.

14 SEMI E30 Capabilities

14.1 The purpose of this section is to specify any SEMI E30 Capabilities required by MSEM class equipment.

14.2 *Requirement* — The following SEMI E30 additional capabilities required by MSEM are:

- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Remote Control
- Equipment Constants
- Process Program Management
- Spooling
- Trace Data Collection (optional)
- Control (Host Initiated)

15 Related Documents

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8 (1987) 231-274.

RELATED INFORMATION 1
SEM UNIQUE CAPABILITIES

NOTE: This related information is not an official part of SEMI E30.5 and was derived from work developed in the Metrology Specific Equipment Model Task Force in North America. This related information was approved for publication by full letter ballot on April 30, 2001.

R1-1. *Measurement Site Location* — Metrology equipment most often is used to make measurements and report results at specific sites on a substrate. Unfortunately, equipment suppliers and users have adopted different formats for describing measurement site location information. This has led to three problems which increase the cost of metrology. First, metrology equipment suppliers must provide formats which meet conflicting requirements of their customers, adding to equipment development costs. Second, users must transpose information from different systems to their own format in order to use metrology data. Third, site location information is often an integral part of recipe set up, often requiring that an actual product sample be available for "training" the site location information on the equipment. For users who manufacture many different products on common substrates, multiple metrology "recipes" must be developed where the only differences are site location information. This information is known to the user from product design data, and should not need to be "learned" uniquely on various metrology equipment.

R1-1.1 In order to avoid these problems, MSEM defines specific formats for identifying and reporting site location information on substrates. The MSEM-required formats are intended to minimize the number and type of site location format transformations needing to be supported by both metrology equipment suppliers and users. All MSEM-required site location formats involve the use of an MSEM-defined right-handed Cartesian coordinate system, established on substrates in an MSEM-defined manner. This release of MSEM defines these only for silicon wafer substrates, based on SEMI standard M20. Additional substrate types may be included in future revisions of MSEM, if required.

R1-1.2 MSEM requires that equipment have the capability to use site location information that is based on the user's product designs, which the user must provide in the appropriate MSEM-required format. In other words, equipment shall not require that a sample substrate be used to "train" site locations when users can provide this information from product design data.

R1-1.3 MSEM-compliant equipment shall have the capability to define, locate, measure, and report site information using only the MSEM-defined right-handed Cartesian coordinate system formats. This requirement does not preclude equipment from having additional capability for defining or reporting site location information using other formats. One such additional format is defined in MSEM for patterned silicon wafer substrates, based on SEMI standard SEMI M21. MSEM-compliant equipment is not required to have this "M21" format capability, but must use the MSEM "M21" format if it is provided.

R1-1.4 Specific MSEM information that defines site location information includes ; the data items AlignList and SiteList; the CPNAMEs CP-ALIGNLIST and CP-SITELIST and the TABLE type named ALIGN-DEF-LIST and SITE-DEF-LIST. Notice that multiple sites can first be Defined using the appropriate Process Program class named ALIGN-DEF-LIST or SITE-DEF-LIST, then selected by using the ALIGN-NAME or SITENAME in an MSEM defined remote command that use CP-ALIGNLIST AND CP-SITELIST. This information is similarly defined for the "M21" coordinate system plus an additional CPNAME of ELEMENTLIST which lists the ElementIDs to be measured on the silicon wafers.

R1-2 *Coordinate Systems For A Silicon Wafer*

R1-2.1 *Requirements* — MSEM defines two right-handed Cartesian coordinate systems for use on silicon wafers. These are identified as the "M20" and "M20P" coordinate systems. Both are based on SEMI standard M20. The SEMI M20 standard describes how to map a right-handed Cartesian coordinate system to a wafer so that its origin is at the center of the wafer, and its negative y-axis bisects the wafer's primary fiducial. This coordinate system is defined by MSEM to be the "M20" coordinate system. MSEM defines the "M20P" coordinate systems to be one which is aligned to the pattern on the wafer. Ideally, there is no difference between the "M20P" and "M20" coordinate system. In the real world, there is a difference, due to experimental errors. This is explained further in the following sections.

R1-2.2 *Implementation* — The only information required by equipment in order to establish an "M20" coordinate system is the wafer size and type of fiducial. This is provided by way of the MSEM data items named WaferSize and Fiducial. Another data item named Orientation provides for control over how the wafer is loaded on equipment. Note that the SEMI

M20 standard requires that the "M20" coordinate system is fixed on the wafer, and is not affected by how the wafer is loaded on equipment. Also, as stated in the SEMI M20 standard, an orientation of "0" is for a wafer loaded on equipment with the primary fiducial towards the operator or "down".

R1-2.2.1 Often, no other information is required for measurements to be made on a wafer. However, the "M20" coordinate system may not provide sufficient accuracy to locate measurement sites on patterned wafers. This is a result of any of a number of possible reasons, all of which can be described as "experimental errors". For instance, wafers are not perfectly round, fiducial dimensions may vary, and equipment (both steppers that place patterns on wafers and metrology equipment) capabilities to determine the location of the wafer center and fiducial vary.

R1-2.2.2 In order to deal with these errors, metrology equipment suppliers have developed various strategies, as discussed in the introduction section. Perhaps because the SEMI M20 standard's reference to "origins" of "other coordinate systems" is in the same sentence with "reference points", many suppliers adopted the location of one (or more) reference point(s) as the origin for their pattern-based coordinate system(s). Without a common reference site, multiple coordinate systems resulted. More nefarious strategies were developed to compensate for "stage errors" on equipment. These usually entail a series of reference points required to "zero in" on the measurement site, and this made comparison of locations determined on different equipment next to impossible.

R1-2.2.3 MSEM defines the "M20P" coordinate system to be one which is identical to the "M20" coordinate system, if there were no experimental errors. In other words, the location of the origin and axes of the "M20P" coordinate system are offset slightly from the origin and axes of the "M20" coordinate system because of experimental errors. If the location of reference points, called "alignment sites" in MSEM, is defined to be the "M20" coordinates where they are "expected" to be, and equipment is designed to be able to "find" the alignment sites, given the various possible experimental errors, the "found" and "expected" SEMI M20 coordinates can be used to determine the "M20-to-M20P" coordinate system transformation, as explained in appendix 1. Alignment site information is specified through the use of the MSEM data items named AlignList, the CPNAME CP-ALIGNLIST and, the table type named ALIGN-DEF-LIST.

R1-2.2.4 Most metrology equipment cannot distinguish whether patterned wafer site location errors are due to the wafer, the layout on the wafer, or the equipment's ability to locate the sites. However, information that is available through the use of patterned-wafer alignment sites can provide a means for identifying potential metrology equipment problems. For instance, assume that the only pattern-layout location error on a wafer is that due to the establishment of the location of the wafer center and fiducial. For many users and metrology systems, this is a good assumption. If this is the case, then the MSEM data item named XlateData can be used to track this error. Although the error may result from multiple sources, being able to track it on various metrology equipment will enable users to apply statistical process control techniques to identify the specific sources.

R1-2.2.5 Sites specified for measurements or additional alignments may be found by metrology equipment at locations which deviate from their expected locations through either pattern layout errors or metrology equipment "stage" errors. Again, in a controlled manufacturing process, these combined errors should be normally distributed, and non-normal deviations may indicate possible metrology equipment problems. These types of errors shall be reported through the use of the MSEM data item named Offset.

R1-2.2.6 A minimum of two alignment sites are necessary to establish an "M20P" coordinate system on a wafer. Additional sites are often used, as in the example given in appendix 1. The system supplier shall document the requirements for ALIGNLIST information, and detail how any "site-by-site" alignment sites (that is, those needed to obtain better location accuracy in the neighborhood of measurement site) are associated with the specific SITELIST measurement sites.

R1-2.2.7 Alignment site location information may be either provided to or by equipment. Some equipment have the capability to find and report the locations of "reference sites" without prior knowledge of their locations on the wafer. In this case, the equipment shall report the location of both alignment and measurement sites in "M20" coordinates. When alignment site information is provided to equipment to establish an "M20P" coordinate, measurement site locations shall be reported in the "M20P" coordinate system.

R1-2.2.8 MSEM encourages users to define "M20P" locations in reference to the user's device layout design within an ideal SEMI M20 wafer coordinate system. An alternative is to define "M20P" locations by "training" on a "benchmark" system.

R1-3 *Layout of Rectangular Elements on a Silicon Wafer* — Equipment shall be capable of routine, automated operation without needing wafer layout information (e.g., field or die maps). However, having the capability to provide wafer layout information to metrology equipment from the host can be desirable. In some cases, the amount of information required to define measurement site locations is less if a pattern-element-based format is used. MSEM defines a means to do this in this section, if desired, based on SEMI standard SEMI M21.

R1-3.1 SEMI standard SEMI M21, "Specification for assigning addresses to rectangular elements in a Cartesian array", is limited (for MSEM purposes) by the fact that nothing is specified about how the rectangular elements are located on the wafer. The SEMI M21 standard details how to assign "addresses" to elements and how to find the "array center" element. In this section, MSEM defines how these elements are located on a wafer, using the data item named "M21Data", and how to establish within-element coordinate systems.

R1-3.2 There are users who want or require much more layout information than is provided for by SEMI M21, such as within-element structure details or element attribute information. This additional layout information is beyond the scope of MSEM, since it is considered to be information which only is needed to aid operator-interactive use of metrology systems.

R1-3.3 *MSEM "M21" Layout* — The first pattern element layout issue to be addressed is that of determining which SEMI M21 elements are to be included in the MSEM "M21" layout. MSEM defines the "M21" layout to include all elements which either wholly or partially are within the circumference of the wafer. Thus the MSEM "M21" element layout does not correspond to the pattern layout exactly, since some "M21" elements may not contain patterns.

R1-3.4 The second layout issue is that of how best to specify the element locations on the wafer. The MSEM approach is to specify the "M20P" coordinate for the lower left corner of the minimum number of elements needed to define the layout, along with the element addresses. For a non-tiled layout, the location of a single element is sufficient to establish the "M21" layout. For tiled layouts, the location of one element in each row or column is required. Note that the location of the lower left corner of an element may be outside the circumference of the wafer.

R1-3.5 Layout definition is supported only for host-to-equipment communications. The user is responsible for ensuring that the element addresses provided to the equipment agree with the SEMI M21 specification. The equipment need not check this, other than to ensure that there are not conflicts within the provided layout, and shall report results with element addresses as provided by the user.

R1-3.6 M21 layouts are established within the "M20P" coordinate system, and need not require any additional alignment site data than is needed to establish the "M20P" coordinate system. However, as with "M20P", additional alignment may be necessary because of errors in either the pattern layout or the equipment's ability to locate features. OFFSET shall be used to report the location corrections that result from any within-element alignments.

R1-3.7 MSEM provides a means for element-based coordinate systems, if required. This capability is provided by the option of specifying "M21" as the coordinate system for ALIGN-DEF-DATA and SITEDEFDATA items. For element-based site locations, MSEM requires that SEMI M21 element coordinate systems have x and y axes parallel to the respective M20-based coordinate system axes, with their origins at the lower left corner of each element.

R1-4 *An Example of How an M20P Coordinate System is Established on a Silicon Wafer*

R1-4.1 The following example is fairly basic. For this example, the equipment does M20P alignment via a repeated two-step process. The first step is done at a low resolution, the second at a high resolution, and the process is done at two positions on the wafer.

R1-4.2 The equipment documentation states that 4 alignment sites are required. These are defined to the equipment via the table type named ALIGN-DEF-LIST, as detailed below. The order of the sites in ALIGN-DEF-LIST is not important. The sites are then selected via the CPNAME item named CP-ALIGNLIST, which is included in the PP-SELECT command. The order of the sites listed in CP-ALIGNLIST is important, and is as specified in the equipment's documentation. The first site is the alignment site for the first low resolution site, the second item is for the first high resolution site, the third item is the second low resolution site, and the fourth is the second high resolution site.

Table R1-1 ALIGN-DEF-LIST

Align-Name	*Coordx*	*Coordy*	*Coordsys*	*Align- Attribute(n)*
Coarse1	-60000	-200	M20P	
Fine1	-60020	-205	M20P	
Coarse 2	60000	200	M20P	
Fine2	59980	195	M20P	

R1-4.3 ALIGN-DEF-LIST

L,4

1. <Coarse1>
2. <Fine1>
3. <Coarse 2>
4. <Fine2>

R1-4.4 Using this information, the equipment will go to the nominal M20 location for Coarse, then "find" where it actually is. The offset between the nominal M20 location and the actual M20 location is then used to "find" Fine1. The actual M20 location of Fine1 is saved. The process is then repeated for Coarse 2 and Fine2. The equipment can now determine the M20 to M20P offset from the nominal and actual coordinates.

First, a summary of the data:

xN1=-60020	yN1=-205	Nominal x and y data for the first fine site
xA1=-59800	yA1=-150	Actual x and y data for the first fine site
xN2= 59980	yN2= 195	Nominal x and y data for the second fine site
xA2= 60060	yA2= 175	Actual x and y data for the second fine site

R1-4.5 The equipment first calculates THETA (Θ), using, for example, the formula:

$$\Theta = \tan^{-1}\left[\frac{MA - MN}{1 + MAMN}\right]$$

where MA and MN are, respectively, the slopes of the lines connecting the nominal and actual fine sites, in M20 coordinates, calculated as follows:

$$MA = \left[\frac{yA_2 - yA_1}{xA_2 - xA_1}\right] \quad MN = \left[\frac{yN_2 - yN_1}{xN_2 - xN_1}\right]$$

R1-4.6 The equipment then calculates DELTAX and DELTAY, using, for example, the formulas:

$$DELTAX = \left[\frac{C\,sin\,(\Theta) + D\,cos\,(\Theta)}{(sin\,(\Theta))^2 + (cos\,(\Theta))^2}\right]$$

$$DELTAY = \left[\frac{C\,sin\,(\Theta) - D\,cos\,(\Theta)}{(sin\,(\Theta))^2 + (cos\,(\Theta))^2}\right]$$

Where C and D are the adjusted site 1 coordinates in a rotation-adjusted coordinate system calculated, for example, using the formulas:

$$C = yA1 - ((xN1 \sin \Theta) + ((yN1 \cos \Theta)$$

$$D = xA1 - ((xN1 \cos \Theta) - ((yN1 \sin \Theta)$$

R1-4.7 The equipment can also calculate a SCALEFACTOR term to indicate the relative difference between the length of the vector connecting the nominal alignment sites and the length of the vector connecting the actual alignment sites. This can be used, for example, to judge whether there is a problem with the alignment process, since the difference between these two vectors should be small.

$$SCALEFACTOR = \frac{VA}{VN}$$

where VA and VN are the length of the vectors connecting the actual and nominal alignment sites, calculated using the formulas:

$$VN = \sqrt{\left(yN_2 - yN_1\right)^2 + \left(xN_2 - xN_1\right)^2}$$

$$VA = \sqrt{\left(yA_2 - yA_1\right)^2 + \left(xA_2 - xA_1\right)^2}$$

M20/M20P COORDINATE SYSTEMS EXAMPLE (EXAGGERATED)

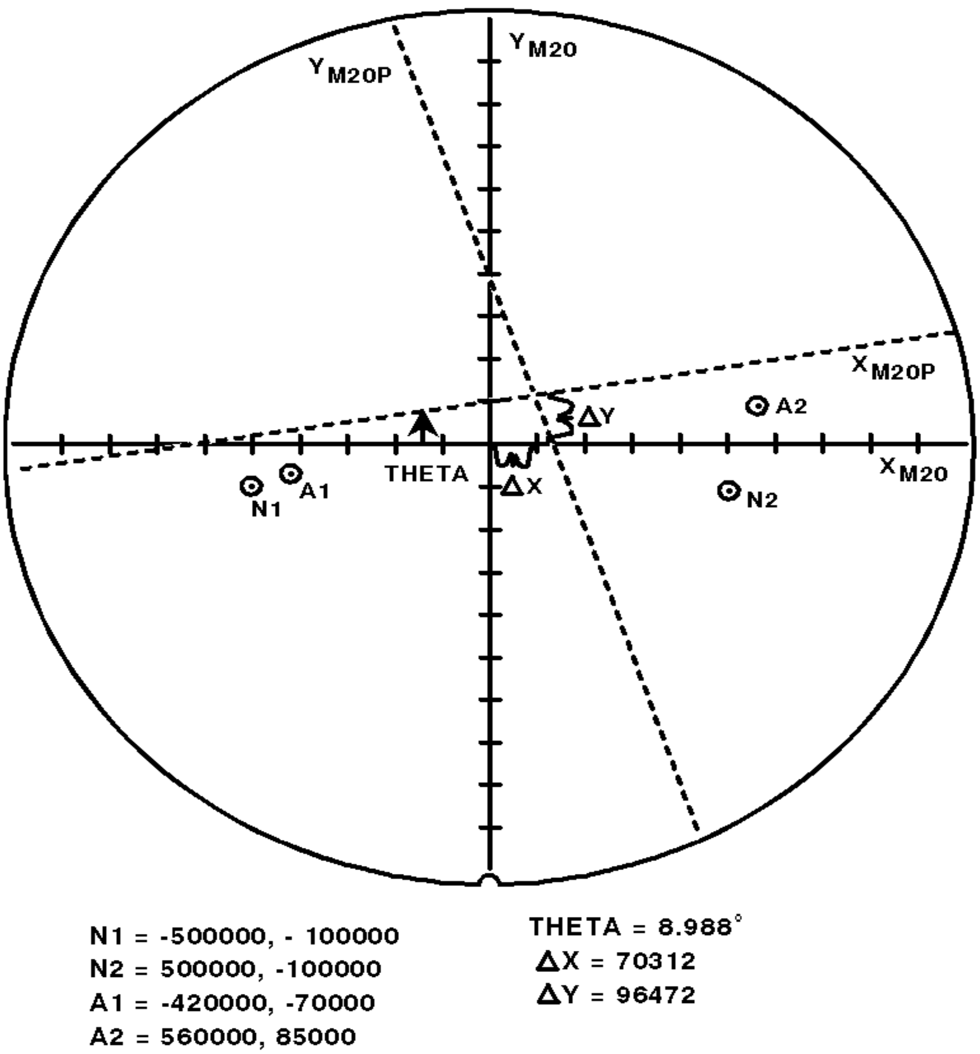

Figure R1-1
M20/M20P Coordinate Systems Example

R1-5 *Multi Measurement Station Metrology Equipment* — MSEM implementation on metrology equipment with multiple measurement stations should follow guidelines setablished for multi-processing station SEMS such as the Apply and Develop Track Specific Equipment Model (SEMATECH ID #: 95113021AENG Title: SEMATECH Apply/Develop Track Specific Equipment Model (ADTSEM), Version 0.8, January 4, 1996).

SEMI E32-0997
MATERIAL MOVEMENT MANAGEMENT (MMM)

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MATERIAL MOVEMENT MANAGEMENT (MMM)

1 Introduction

Automated material movement represents a significant milestone in the evolution of automation in semiconductor manufacturing. The standardization of the transfer process is critical to the economic viability of material movement automation. This standard addresses the communications needs of the semiconductor manufacturing facility with respect to material movement.

1.1 *Purpose* — This standard addresses automated material movement on the semiconductor factory floor—the task of transporting objects (material, et al) from one processing or storage location to another. It defines the concepts of material movement, the behavior of the equipment (including transfer devices) in relation to material movement, and the messaging services which are needed to accomplish the task.

1.2 *Scope* — The scope of this standard is defined from two viewpoints. The first is the breadth of the functionality covered. The second is the depth to which it is covered.

The breadth of functionality covered by this standard is limited to the activity required to transfer an object from a location on entity "A" to a location on entity "B" under the supervision of a factory host. This transfer may occur directly between two factory process equipment, or may involve the assistance of a "transfer agent", a device dedicated to material transfer. Thus, the material movement domain includes a maximum of four types of entities (see Figure 1.1):

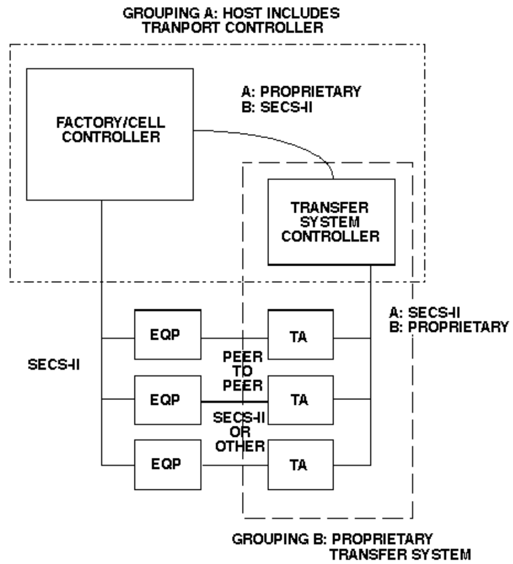

Figure 1.1
Illustration of Material Movement Scope

1. The factory host, which might, for example, be a factory controller or cell controller.
2. The set of process-related equipment, to which the host communicates.
3. The transfer agent, which performs the physical transport of the material in the factory. The transfer agent might communicate directly with the host or be controlled by an intermediate system.
4. This intermediate system, the transfer system controller, is the fourth type of entity.

This document assumes that the transfer system controller is either a part of the host or a part of a potentially complex transfer agent (as shown by the dotted boxes in Figure 1.1). Thus, the term "transfer system controller" seldom appears. The case where a "transfer agent" is actually a transfer system controller plus multiple transport devices is discussed further in Section 4.1.6.

There are some forms of material movement that do not fall within the domain of this standard and thus are not applicable to the methods described below. One example might be a non-deterministic system, such as a conveyer where generic parts are placed onto the system and circle until randomly selected by a workstation needing that type of part.

The subject of alarm reporting is not covered in this document. While material movement-related alarm situations will exist, the definition of the mechanism for reporting such alarms is left to other standards documents.

This standard presents a solution from the concepts and behavior down to the messaging services. It does not define the messaging protocol.

A messaging service includes the identification that a message shall be exchanged and definition of the data contained within that message. It does not include information on the structure of the message, how the data is represented within the message, or how the message is exchanged. This additional information is contained with the message protocol.

The defined services may be applied to multiple protocols. Information on the mapping of material movement services to specific protocols (e.g., SECS-II) are added as adjunct standards.

1.3 *References* — The following SEMI standards are related to the Material Movement standard:

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

Other References:

ISO/TR 8509:1987, Information Processing Systems, Open Systems Interconnection — Service Conventions

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8 (1987) 231–274[1]

1.4 *Conventions*

1.4.1 *State Models*

Definition of behavior of systems or subsystems is based upon state models using the Harel notation. A discussion of this notation is available in the article by David Harel referenced above.

The Harel notation does not include the concept of "creation" and "deletion" of state models to represent transient entities. The "transfer job" described in this document is such an entity, where each new transfer job created uses a copy of the same state model. In this document, the use of an oval is used to denote the creation of an entity and also the deletion of that entity.

Transition tables are provided in conjunction with the state diagrams to describe explicitly the nature of each state transition. A transition contains columns for Transition #, Current State, Trigger, New State, Action(s), and Comment. The "trigger" (column 3) for the transition occurs while in the "current" state. The "actions" (column 5) include a combination of (1) actions taken upon exit of the current state, (2) actions taken upon entry of the new state, and (3) actions taken which are most closely associated with the transition. No differentiation is made.

1.4.2 *Object Services* — SEMI E39 Object Services Standard (OSS) requires that standardized objects be subtypes of the Top Object, that their attributes be defined in a table format and include specification of the value for object type, and that the objects support the GetAttr and SetAttr services. See SEMI E39 for details.

1 A brief tutorial on the Harel Statechart Notation is provided as Application Note A.5 of the SEMI E30 (GEM) standard.

Standardized objects are supported by an attribute definition table with the following column headings:

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	Any valid form. (See below.)

Access — RO (Read Only) or RW (Read and Write) to indicate the access that users of the service have to the attribute.

Reqd — A "Y" or "N" in the Required (Reqt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

Form — Indicates the format of the attribute. (See Section 4.5.2 for definitions.)

2 Definitions

The following definitions are arranged in alphabetical order. Some are defined using terms defined elsewhere within this section. Please reference such definitions as needed. No references beyond this section should be necessary for a basic understanding of these terms.

Active Transfer Partner — (Opposite of Passive Transfer Partner) A transfer partner is considered active when it physically participates in the micro level portion of the transfer, either by moving the transfer object or by moving impediments within the transfer envelope (e.g., doors, clamps). This term refers to the micro level transfer phase only, and not to any setup activities prior to the transfer (e.g., a port door may be opened during setup phase by passive partner).

Atomic Transfer — The basic unit of movement. The transfer of a single transfer object from Equipment A directly to Equipment B where only one change in ownership occurs.

Compound Transfer — Combination of two or more atomic transfers executed sequentially or concurrently to achieve a single goal (e.g., exchange carriers or move a carrier between process machines using a transfer agent).

Dynamic Port — (Opposite of Static Port) A port with associated mechanisms capable of assisting with the physical movement of a transfer object or of interfering with the transfer of an object during the transfer. Such mechanisms may include doors, elevators, and robot arms. A transfer partner using a dynamic port for the transfer may be active or passive as required.

NOTE 1: The concepts of "dynamic" and "static" are associated with a port rather than equipment, as equipment may have both dynamic and static ports.

Equipment — Mechanical entity in the factory which plays a role in the manufacturing process. The equipment referenced in this document include machines used for processing, transport, and/or storage of material (see definition of material).

Host — In the context of material movement, the host is an entity, generally separate from either transfer partner, which coordinates and supervises a transfer job.

Interactive Transfer — A transfer in which both partners are active and must interact in the performance of the transfer.

Interfering — A dynamic port is interfering when any of its associated mechanisms are positioned where they are capable of physically obstructing the transfer.

Macro Level — Level of material movement that involves coordination by the host but may not require knowledge of the physical process used to accomplish the material transfer.

Material — A term used interchangeably with "transfer object" to refer to discrete objects which may be transferred to and from equipment. This may include product, carriers, reusable fixtures, etc. See transfer object definition.

Material Location — A physical position on a piece of equipment at which a transfer object may reside. Many material locations may be accessed directly through a port, but this is not a requirement. Some material locations internal to the equipment may not be accessible by a transfer agent.

Message Service/Service — A service (or a message service) represents a set of functions offered to a user by a provider. An unconfirmed service consists of a sequence of service primitives — the request from the sender to the communications facility and an indication to the receiver from the communications facility. Each of these service primitives is described by a list of parameters. A confirmed service adds a response to the initial request. The primitives for a response are called the response and the confirmation. A service excludes definition of message structure and protocol.

Micro Level — Level of material movement characterized by peer-to-peer interaction of the transfer partners to achieve synchronization of the detailed mechanical steps of material transfer.

Object — Webster's defines an object as "something perceptible." In the software world, an object is a combination of attributes and behavior. It may refer to something concrete, such as a transfer object, or to a concept, such as a transfer job.

Ownership — An equipment is said to "own" a transfer object from the time the object is transferred into one of its ports until it is transferred out of the equipment. This indicates that the equipment has physical control of the transfer object.

Passive Transfer — A transfer that involves one active and one passive partner. During a passive transfer, the active partner retains control of the transfer envelope during the entire physical transfer.

Passive Transfer Partner — (Opposite of Active Transfer Partner) A transfer partner is considered passive when it takes no part in the physical micro level transfer, moving nothing within the transfer envelope. This term refers to the physical micro level transfer phase only. Setup activities prior to the transfer may be performed by a Passive Transfer Partner (e.g., a port door may be opened during setup phase).

Port — A point on the equipment at which a change of equipment ownership of a transfer object occurs. A port is not itself a material location, but shall have an associated location. A port may be thought of as an access point to an a material location on an equipment. The definition of the term port includes any dedicated mechanisms that either prepare for, facilitate, or are capable of interfering with the transfer. All equipment shall have a minimum of one port.

NOTE 2: While they are of use to the host system, the commonly used designations "Input Port" and "Output Port" are irrelevant in the context of this document. They are based on a flow of material through an equipment rather than the movement of transfer objects (which may be carriers rather than the material itself). Transfer objects may have to be moved into and out of both these types of ports.

Receiving Port — For a specific transfer, the port into which a transfer object is to be placed.

Sending Port — For a specific transfer, the port from which a transfer object is to be removed.

Static Port — (Opposite of Dynamic Port) A port with no associated mechanisms capable of assisting or interfering with the transfer of an object. A transfer partner utilizing a static port for the transfer shall always be passive.

Transfer Agent — An equipment specialized to the transport of material from one equipment (or storage area) to another.

Transfer Envelope — The three-dimensional space occupied during the transfer by the transfer object and all associated transfer mechanisms of both transfer partners. This defines the space in which transfer activity occurs and in which the potential for physical interference with the transfer exists.

Transfer Job — The set of atomic transfers constructed by the host to accomplish a cohesive material movement objective. See the section on compound transfers below.

Transfer Object — A physical object that is transferred to and from equipment, such as a product material, an empty carrier, or a carrier containing material to be processed. Tools (e.g., stepper reticles) and expendable materials also may be transfer objects. The term "material" is used interchangeably with "transfer object."

Transfer Partners — In a given atomic transfer, the equipment sending a transfer object and the equipment receiving the transfer object are transfer partners.

Transfer Specification — The list of data provided by the host to define an atomic transfer.

Transfer System Controller — Entity that is responsible for management of multiple transfer agents. The transfer system controller presents a single communications interface to its host representing these multiple agents.

3 Overview

Material movement is concerned with the transfer of objects (WIP, tools, expendable materials, etc.) among process equipment, buffers, and storage facilities. These objects may optionally be contained (singly or in mass) within a carrier. Empty carriers may also be considered objects.

Material movement may include several different types of entities. These are divided into two classes: Host and Equipment. The host is the supervising entity which organizes the transfer and gives the appropriated instructions to each equipment involved. An equipment physically participates in the transfer, either sending or receiving material. The class of equipment may be divided into three types:

Process Equipment — Equipment which performs value-added operations on the factories' products. This includes those equipment which physically changes the product and those which measure/test the product.

Transfer Agent — A type of equipment specialized to the movement of transfer objects from place to place within a factory. Transfer agents themselves may be of different types and with widely-differing characteristics. These may be fixed-arm robots, robot arms on a fixed track, AGVs with or without robot arms, overhead gantries, cars on tracks, or even transfer systems containing a heterogenous collection of other transfer agents. Humans also may act as transfer agents.

Storage Areas — A type of equipment used to hold transfer objects pending further processing (if product) or use (if reticles, etc.) within the factory. A storage area may be as sophisticated as an automated WIP Bin or as simple as a shelf.

3.1 *Macro and Micro Levels* — Material movement is separated into two levels. The more abstract level, called the macro level, consists of all message transactions used by the host in its coordination role. At the macro level, the host is responsible for determining what material is to be moved, from where, to where, and when. The host shall provide each party involved in a transfer job with the information necessary to perform its part of that transfer job.

A transfer job may be composed of multiple handoff operations, or "Atomic Transfers." Each atomic transfer involves only two equipment, termed "Transfer Partners." In order to perform this handoff operation, the transfer partners must achieve a level of synchronization. The communications between the transfer partners is called the micro level of material movement.

These communications occur between the two partners in a "peer-to-peer" fashion. Micro communications may be implemented via a direct equipment-to-equipment connection[2] or by passing messages indirectly through the host.

The macro and micro levels are designed to work together so that the host may initiate the transfer and then allow the transfer partners to perform the job interactively. However, these two levels may be used separately. For instance, the macro level may be combined with functionality of the SEMI E23 (Cassette Transfer Parallel I/O Interface Specification) standard. Additionally, under some conditions there may not be a host coordinating the transfer. Instead, one of the transfer partners might be in control. Here, the micro level may still be used to accomplish the transfer. The controlling partner would perform the coordination functions normally in the domain of the host.

In this standard, the macro and micro levels are defined separately, each with its concepts, behavior, and services.

2 In this context, connection is intended to mean a direct logical link, rather than a hard wired connection.

3.2 *Ports and Locations* — A port may be considered a point of entry to the equipment. A location is a receptacle for a transfer object. At any time, a port shall be linked to at least one location. However, some locations may be internal and never be linked to a port.

For "typical" factory equipment, there is a permanent one-to-one correspondence between the port and a location. However, not all semiconductor equipment follows this pattern. For instance, the port on a transfer agent that includes a robot arm and multiple on-board storage locations is actually the gripper on the robot arm. The gripper is also a location. In another case, a port may actually feed a rotating carousel containing multiple locations. The port in this example would be the access door to the carousel. The location linked to this type of port would be the one in front of the door at transfer time and would change whenever the carousel rotates. Figure 3.1 helps to illustrate the difference between ports and locations.

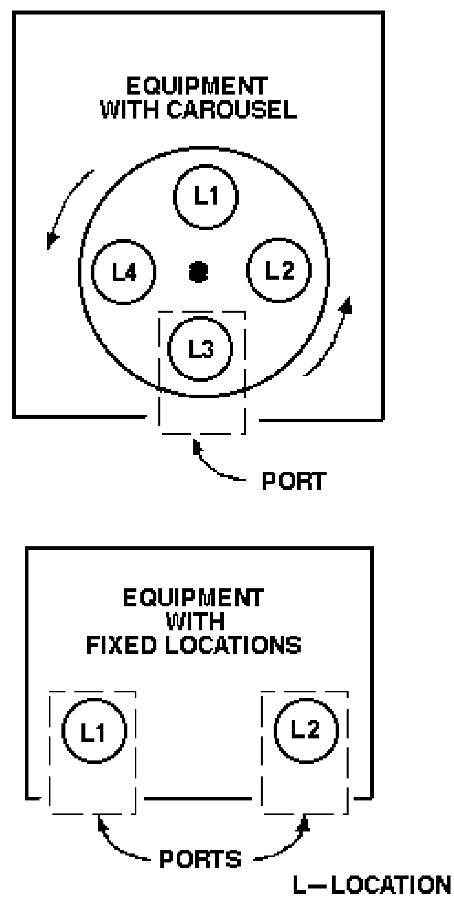

Figure 3.1
Port vs. Location

It is important to note that the attribute of “full” or “empty” belongs to a location rather than a port. A port that has just *received* a transfer object may be able to receive another immediately. Likewise, a port that has *sent* a transfer object may have more material available to send.

3.3 *Compliance* — Compliance to this standard includes adherance to all stated requirements in this document. This includes all defined messages services, state models, and communications scenarios.

This standard may be divided into two parts:

- Material Movement Macro Level, and
- Material Movement Micro Level.

An equipment may be compliant to one of these parts without the other. Details of compliance to each of these parts are defined in the body of this document.

4 Macro Level

The set of host<->equipment interactions needed to facilitate a transfer is called the macro level. These interactions concentrate on the definition of the transfer specification, and leave the details of the physical transfer to the micro level interactions.

In addition to the services defined in Section 4, the GetAttr service defined by SEMI E39, Object Services Standard, is supported by this standard. The definition for the GetAttribute service defined in Section 4 will be removed and no longer supported in 1998.

4.1 *Macro Level Concepts* — The macro level is designed with the intent of creating a widely applicable, host coordinated material movement capability. The result is a sequence of interactions from host to equipment that is used to accomplish the coordination of material movement required on the manufacturing floor.

The elements of material movement common to all transfers make up the framework. Other elements which differ from implementation–to–implementation are pushed, as much as possible, into the data portions of communications. The common elements identified are as follows:

- The host is responsible for designating the transfer partners which are compatible for transfer.
- The host must supply the necessary information for the transfer to each partner.
- Once transfer is defined, the responsibility moves to the transfer partners, especially the designated “primary” partner[3] . The host may monitor the transfer, but leaves the details to the transfer partners.
- The transfer partners inform the host of milestones during the process and of process completion.

Some of the elements which are more implementation-specific are:

- Which partner is the sender and which is the receiver of material. This has no intrinsic relationship to other details, such as the selection of the primary transfer partner.
- Whether a transfer partner is passive or actively participates in the transfer. This also becomes a data issue.
- The method (mechanism) of an interactive transfer. This may vary depending on the transfer partners' capabilities and system design. Interaction with different partners may require different methods. Transfer recipes containing this information may be specified by the host as a part of the transfer specification.

The host must have some knowledge of the capabilities of the transfer partners it designates to perform a transfer. It must understand which partners are compatible. If compatible, it must know the proper role for each partner of the transfer and what methods must be used. If an interactive transfer is warranted, the host must be able to determine which partner should be the primary. Definition of the mechanism for such determinations by the host is beyond the scope of this document.

4.1.1 *Macro Level Definitions*

Abort — The immediate termination of an active job, including a complete stop of all transfer job-related movement. An abort may be initiated by the host (and optionally by the operator). An abort by the host is directed at a transfer job, not at an individual atomic transfer. When told to abort, a transfer job shall, in turn, abort its atomic transfers. The abort command is intended to be used only in situations where there is risk of material or hardware damage.

Allocate — The formal reservation of an entity's resources for a specific purpose. In this document, it refers to the reservation of an equipment's resources for a specific transfer job or atomic transfer. Allocation of needed material locations for a transfer job occurs just prior to that job becoming active. Allocation of required port-related resources occurs just prior to the start of an atomic transfer.

Commit — The commit by the equipment indicates a readiness to begin the actual material handoff. The

3 See the definition for “primary transfer partner” in Section 4.1.1.

commit follows any setup activities and coincides with entry to the HANDOFF state. For example, an AGV may not be allowed to commit until it has moved to the point of transfer. The point at which an equipment may commit is equipment-specific. There is a separate commit for each atomic transfer in a job.

Deallocate — The release of allocated resources. In this document, it refers to the equipment's release of the resources reserved for a transfer job or an atomic transfer.

Port Resources — Equipment-controlled mechanisms that serve a port. An example of a port resource is a cassette indexer that changes to elevation of the material location. A port resource is available only to the atomic transfer that has allocated that port.

Primary Transfer Partner — The partner that controls the micro level transfer and that would receive the optional host command to initiate the transfer. The primary transfer partner shall always be an active partner for the transfer. For an interactive transfer, the nature of the transfer partners may determine which should be primary. Otherwise, the host may choose.

Restore — An operation associated with a transfer job which causes the resources used by that job to be returned to the preferred idle conditions (e.g., port access door closed). When a transfer job involves multiple ports on an equipment, restore activities are done on a port-by-port basis as each port is no longer needed by the transfer job.

Secondary Transfer Partner — The opposite of the primary transfer partner. This partner is either passive during the transfer or is controlled by the primary transfer partner. If active, this partner shall await communications from the primary partner before acting (see micro level).

Setup — A process associated with an atomic transfer that causes the port resources to achieve required pre–transfer conditions (e.g., port access door open).

Stop — A command available to the host that causes an orderly termination of a transfer job. Upon receipt of a stop command, the equipment shall complete all currently active atomic transfers, execute the "restore" process, and then terminate.

4.1.2 *Atomic Transfer* — An atomic transfer is the handoff of a transfer object from one equipment to another. This is the fundamental building block of material movement. An atomic transfer includes the minimum number of physical participants in the move: one sender and one receiver. Thus, only one change of ownership shall occur in an atomic transfer. All transfers required in practice can be constructed as a series of atomic transfers. A set of atomic transfers combined to make a complex but cohesive transfer is called a compound transfer.

4.1.3 *Compound Transfer* — On the factory floor, many material transfer situations will require multiple atomic transfers. For example, the host may determine that a material carrier needs to be moved from equipment "X" to equipment "Y" by transfer agent "T." To accomplish the transfer would require two atomic transfers, first "T" acquires the carrier from "X," then it delivers it to "Y." A compound transfer might involve several equipment and include parallel as well as sequential execution of atomic transfers.

4.1.4 *Parallel Transfers* — Each port on an equipment is a separate entity. It is possible, within the limitations of the equipment and transfer agents, to execute parallel transfers involving separate ports on an equipment. These parallel transfers may be with the same transfer partner, or with multiple partners. There are no inherent restrictions to a transfer job simultaneously executing multiple atomic transfers on an equipment. If an equipment's ports are static (i.e., always passive), the equipment should allow parallel transfers. If the ports are dynamic, there may be some sharing of resources which could limit this (e.g., use of the same robot arm). An equipment is not required to allow parallel transfers.

4.1.5 *Transfer Recipe* — The transfer recipe is an element of the transfer specification. The scope of a transfer recipe is one atomic transfer. A transfer recipe may contain information defining the following aspects of a transfer:

- setup/restore operations,
- sequence of handoff operations (see micro level),
- micro level commands to be issued by the primary partner to the secondary transfer partner,
- parameters relating to the transfer.

Thus, the host may use the transfer recipe to communicate the details that make it possible to prepare for and carry out the micro level transfer.

Use of transfer recipes is not a requirement. However, these recipes provide for dynamically "programming" an equipment to interact properly with what may be a completely different type of equipment. For instance, it may be possible to "teach" one transfer partner the proprietary commands that the other partner understands by embedding those commands in a transfer recipe. During the transfer, the primary partner could issue those commands at the proper time using standard micro level messages (see Section 5).

Transfer recipes should be created and managed according to applicable SEMI standards and in a similar manner to other types of recipes on the equipment (e.g., process recipes).

4.1.6 *Transfer System Controller as Transfer Agent* — A transfer agent is an entity to which transfer-related commands are given in order to carry out transfer jobs. A transfer system, which might include several material transport devices, can be described the same way. However, there are some important differences.

There are a number of ways that a host could view a transport system, including:

- as a single transfer agent with numerous ports,
- as a single transfer agent with a single port and numerous internal locations,
- as multiple logical transfer agents with their own ports, or
- as the set of real transfer agents that the transfer system controls.

The transfer system may conceal from the host the various internal operations (e.g., handoffs, travel paths) that it uses to complete a transfer. It may even hide the actual physical location (or series of locations) and provide a logical location for host reference.

4.1.7 *Transfer Job* — The host's material transfer objectives are defined in a transfer job. This transfer job may be a single atomic transfer or a compound transfer. A compound transfer job consists of multiple atomic transfers grouped together to accomplish a more complex objective. A typical compound transfer may also be accomplished by creating a separate transfer job for each required atomic transfer. The decision to group atomic transfers into a transfer job is application-dependent.

The key advantages to the use of compound transfer jobs are the reduction of the communication overhead to the host and the streamlining of the transfer process. The communication overhead is reduced by the fact that the host can define a number of atomic transfer operations with a single message to the equipment. The equipment are not required to wait for host commands between these atomic transfers.

The process is streamlined by virtue of the removal of redundant physical activities during the transfer job. Total setup and restore time for a port may be reduced if the setup for consecutive atomic transfers is similar.

One example of streamlining would be the "exchange" of carriers between equipment, where a transfer agent might bring an empty carrier to replace a full carrier on the "output port" of a machine. If the port has a door that is opened during transfer preparation and closed during the restore phase, the door would be better left open for both atomic transfers. Upon completion of the removal of the first transfer object, rather than close the door, the new transfer is begun and the door left open. The two atomic transfers would thus be executed as one smooth "swap" transfer without wasted time.

Equipment View of Transfer Job — A transfer job may involve a number of equipment and ports. Each of the involved equipment is given a Transfer Job Create request that specifies only the portion of the overall transfer job that involves that equipment. Only the host is guaranteed a complete picture of a compound transfer. In the example where a transfer job was created to move a transfer object from "X" to "Y" via transfer agent "T,"

- "X" would see send material to "T,"
- "Y" would see receive material from "T," and
- "T" would see get material from "X" and put material on "Y."

Atomic Transfer Sequencing Guidelines — When the transfer job given to an equipment contains multiple atomic transfers, the guidelines for performing those transfers are:

- Atomic transfers for a specified port are performed in the sequence given.
- When a transfer job references multiple ports on the equipment, these ports may execute their atomic job sequences in parallel to the other ports.

See Figure 4.1 for an illustration of the flow of a complex transfer job from the view of one equipment. The three parallel paths show a possible chronology for a transfer job.

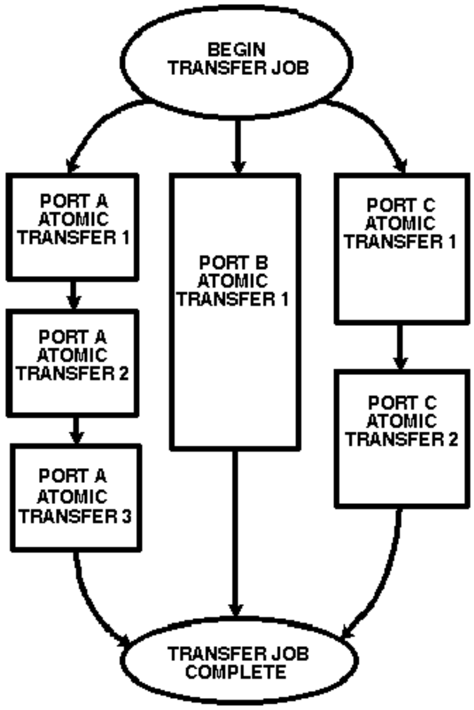

Figure 4.1
Transfer Job Sequencing

There are exceptions to the sequencing guidelines above. One case would be a device designed to simultaneously transfer from multiple ports on one machine to corresponding ports on another. This would translate into synchronized parallel atomic transfers on separate ports. Another case would be two atomic transfers involving the same port that might happen concurrently. That is, a transfer object is transferred out of the port at the same time[4] another is transferred in. In either of these cases, the equipment is responsible for:

1. recognizing that such transfers can and should be combined and
2. synchronizing the execution of the transfers.

Multiple Transfer Jobs — Multiple transfer jobs may exist simultaneously on an equipment. Although not a requirement, an equipment may

1. queue transfer jobs for later execution or
2. allow them to execute in parallel with other transfer jobs.

4 "At The Same Time" in this case means that both atomic transfers are in progress. It does not imply that both transfer objects must move simultaneously.

Queued transfer jobs and parallel transfer jobs are separate concepts, either of which may be supported.

Resource Allocation/Deallocation — Transfer jobs allocate the needed material locations prior to beginning. These material locations remain allocated until the transfer job chooses to release them. In many cases, a material location is physically linked with a single port, and the allocation of that location infers allocation of the port. However, this is not a requirement.

If the material locations for a transfer job are not available or are not in the proper state, the job shall be rejected or queued (if queuing supported and queue not full). For the transfer job to begin, each location referenced in the equipment's transfer job must contain the proper material for the first atomic transfer which would use that location.

If parallel transfer jobs are supported and the necessary locations are available, a second (or third, etc.) transfer job may begin execution.

In some cases a port may provide direct access to multiple locations. This may be true for the specialized ports described in Section 3.2 and in cases where the port serves as a pass–through to internal locations. For each atomic transfer, the needed port and its resources are allocated just prior to the start and released (deallocated) at the end of that atomic transfer.

4.2 *Macro Level Behavior*

4.2.1 *Macro Level Communications* — This section provides a high-level definition of the communications between the host and each transfer partner needed to achieve the macro level of material transport. This is not intended to define the messages, but rather to describe the concepts. The message detail is addressed in the Macro Level Services Section (4.4). Section 4.2.2 shows how these messages are integrated into the transfer job behavior model.

First, the control message flow is presented as Figure 4.2. Then additional informational messaging is described (see Figure 4.3). The arrows represent significant information exchange. Some replies that do not contain significant information may not be shown.

The ordering of the messages between one partner and host shall be retained. The key synchronization point between the partners at the macro level is that both partners shall complete their setup activities before the "atomic transfer started" event may occur.

4.2.1.1 *Macro Level Job Control* — Figure 4.2 illustrates the job control-related message flow expected on a normal transfer as seen by the host. These messages are used to control the material movement process. This diagram assumes a simple transfer job involving only two partners and only one port on each. It also assumes that the partners take the same role (primary or secondary) for each atomic transfer that occurs. The messaging is no different if these assumptions are not made, but diagrams become quite difficult to create.

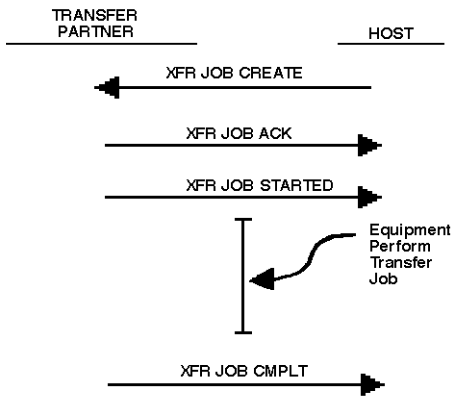

Figure 4.2
Macro Level Message Flow

Transfer Job Create — The host requests that the device participate in a specified transfer job. This may consist of a single atomic transfer or a compound job. This request may be acted upon immediately, or, if necessary resources are currently busy, saved for later execution[5]. The request shall supply a transfer specification for each atomic transfer, in which the host supplies such information as

- which port is to be used,
- whether the port is to send or receive material,
- identification of the material to be transferred,
- role of the equipment (primary or secondary transfer partner),
- mechanism or recipe to be used in the transfer,
- identification of the other transfer partner, and
- an identifier for the atomic transfer.

Upon receipt of the Transfer Job Create request and before acknowledging, the equipment should check the transfer specification(s) to ensure that they are valid. That is, that the specified parameters (ports, transfer recipes, role of the equipment, etc.) have legal values. Depending upon its ability to queue jobs, it may check such dynamic information as presence of transfer object, availability of resources, etc. to determine whether to accept or reject.

Transfer Job Create Acknowledge — The equipment responds to the host that the requested job is accepted or rejected, and if rejected, supplies the reason.

Transfer Job Complete — Once a transfer partner completes the restore operation, it declares the transfer job to be complete. This message is also used should a transfer job end abnormally. It declares the end of job. All movement of the involved mechanisms shall have ceased before this message is sent. This message shall provide information on the success or failure of the transfer.

Transfer Job Started — This message marks the beginning of the transfer job. It signifies that the setup activities for the first atomic transfer are beginning.

Get Attribute — The host may request information relating to a specific job. This may include portions of the transfer specification and current status information.

4.2.1.2 *Macro Level Information Messaging* — There are a number of material transfer-related events which may be of significance to the host. These are designated as "collection events" and shall be available for reporting to the host. This section describes those collection events and shows how they fit into the chronology of a transfer job. Refer to Figure 4.3 as each event is described.

Collection event messages provide valuable information to the host, but are not strictly required to perform material movement. Therefore, it is expected that some message protocol implementations will provide a method by which the factory host may disable those events which are not needed in a particular implementation.

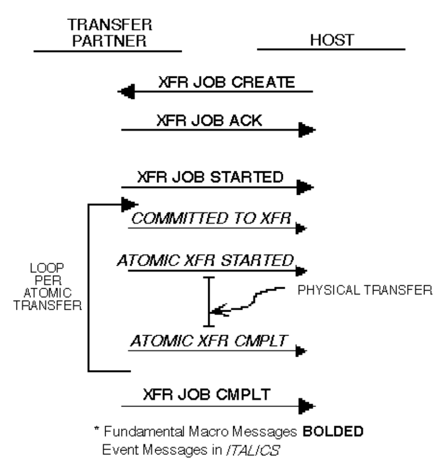

Figure 4.3
Macro Level Messaging With Events

5 If the equipment does not support queuing or if the queue is full, the request may be rejected.

Committed To Transfer — The equipment informs the host when it is fully prepared for a specific atomic transfer. This signifies the completion of the setup activities. It does not indicate that the two transfer partners have agreed to begin the physical handoff. This event coincides with the "Transfer Ready" message defined in the micro level (see Section 5 below).

Atomic Transfer Started — The transfer partners inform the host, via an event, when the atomic transfer has begun[6] . This may represent a logical start rather than physical movement. This indicates that any necessary coordination of the transfer partners has been done to ensure that the atomic transfer may start. A secondary partner may sense the start of transfer later than the primary partner.

NOTE 3: The physical transfer begins following the Atomic Transfer Started event and ends prior to the Atomic Transfer Complete event message.

Atomic Transfer Complete — This event indicates that an atomic transfer has completed. This indicates that either the next atomic transfer for this port will begin the setup phase, or, if none remain, restore activities may begin.

4.2.2 *Transfer Job State Model* — Message flow diagrams are useful to show simple situations. Material movement may range from very simple to quite complex. The transfer job state model presented in this section provides the information necessary to extrapolate the message flow diagrams above to fit all situations within the scope of this report. It does not cover the states of the various hardware which may exist (e.g., elevators, doors). See Section A1-1 for a discussion of the port hardware and related mechanisms.

The state model notation used in this report is that defined by Harel and is described in a reference cited in Section 1.3 above.

The transfer job is a transient entity. It is created by the host (Transfer Job Create message), executes, and then is dissolved by the equipment.

Figure 4.4 shows a basic state diagram for a transfer job. The ovals at top and bottom show where the job is created and then deleted. The portion between the ovals is standard Harel notation. This model is from an equipment view and assumes that only one port on the equipment is used by the transfer. It also assumes that pause, resume, abort, and stop activities do not exist (these are addressed later in the document).

6 The primary transfer partner will determine readiness to start based on micro level handshaking with the secondary transfer partner.

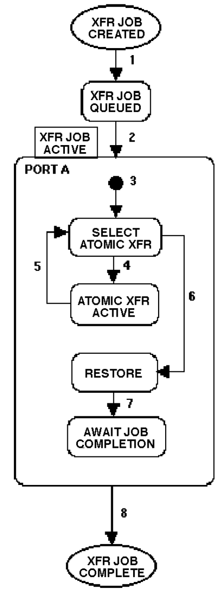

Figure 4.4
Transfer Job State Diagram for a Single Port

State definitions and then the state transition table follow.

TRANSFER JOB QUEUED

In this state, the transfer job has been accepted by the equipment through the Transfer Job Create/Acknowledge messages and is awaiting execution. Transfer jobs are begun sequentially in the order received by the equipment. Execution may not begin until all previously queued transfer jobs have been started and the material locations needed for this transfer job may be allocated.

All transfer jobs pass through this state. If the equipment allows queuing of transfer jobs, they may remain in this state for prolonged periods. A transfer job remains queued until the material locations needed for that transfer are available.

TRANSFER JOB ACTIVE

In the TRANSFER JOB ACTIVE state, all atomic transfers defined in the transfer job are performed.

PORT A

This substate of TRANSFER JOB ACTIVE encloses the job activities related to a single port on the equipment. Within this state, the atomic transfers involving this port are executed sequentially (except as noted in Section 4.1.7 under Atomic Transfer Sequencing Guidelines). Substates of PORT A (or PORT B, etc.) include SELECT ATOMIC

TRANSFER, ATOMIC TRANSFER ACTIVE, RESTORE, and AWAIT JOB COMPLETION.

SELECT ATOMIC TRANSFER

In this state, the next atomic transfer for this port is selected. Any prerequisites for the atomic transfer are checked (e.g., is material XYZ in Port A, Location 1). Atomic transfers are executed sequentially per port (except as noted in Section 4.1.7 under Atomic Transfer Sequencing Guidelines).

Prior to exiting this state, the port resources for the selected atomic transfer are allocated.

If no atomic transfer is ready for selection (e.g., the port resources are not available), the transfer job shall remain in this state, awaiting a change in conditions which would allow an atomic transfer to be selected.

ATOMIC TRANSFER ACTIVE

In this state, the next atomic transfer for this port is executed. See the atomic transfer state model for details on this process.

RESTORE

While in the RESTORE substate, the equipment shall perform any necessary post–transfer operations to return the port to the desired idle condition. These tend to be physical activities. No physical actions are required for restore, but some mechanism for determining port status is recommended.

The setup[7] and restore operations are expected to be "goal oriented," that is, oriented toward satisfying specific conditions (e.g., states such as "door open"). They should not depend on a fixed sequence of actions such as "initiate the door opening mechanism." Thus, a port left in a post–transfer condition from a previous atomic transfer would still be able to prepare properly for the next.

When queuing is allowed, the equipment may provide a look ahead capability so it may alter its restore phase to better accommodate the next transfer job. Such functionality is not required.

AWAIT JOB COMPLETION

In this substate, all atomic transfers on this port for the transfer job have completed. The transfer job continues to exist until all ports have completed their atomic transfers and restore operations. If only one port is used, this state will be occupied only briefly.

The following transition table defines the transitions between states for the transfer job state model. It applies to Figures 4.4 and 4.5.

7 Setup is more fully described in Section 4.2.3.

Table 4.1 Transfer Job State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	(Transfer Job Created)	The equipment accepts a Transfer Job from the host.	TRANSFER JOB QUEUED	Place the transfer job in the queue.	None.
2	TRANSFER JOB QUEUED	Necessary material locations have been allocated to transfer job and any equipment-specific prerequisites met.	TRANSFER JOB ACTIVE	Remove the transfer job from the queue. Send "Transfer Job Started" message.	None.
3	Any...	Default entry into the PORT A (or PORT B, etc.) state	SELECT ATOMIC TRANSFER	All atomic transfers are queued (by port).	None.
4	SELECT ATOMIC TRANSFER	Atomic transfer selected for execution on this port.	ATOMIC TRANSFER ACTIVE	Cause selected atomic transfer to transition from queued to setup.	See Sec. 4.2.3 for the atomic transfer state model.
5	ATOMIC TRANSFER ACTIVE	Atomic transfer complete event from the atomic transfer state model.	SELECT ATOMIC TRANSFER	None.	None.
6	SELECT ATOMIC TRANSFER	No atomic transfers remain for this port.	RESTORE	None.	None.
7	RESTORE	Port returned to desired idle conditions.	AWAIT JOB COMPLETION	None.	None.
8	TRANSFER JOB ACTIVE	All atomic transfers for the transfer job are completed.	(Transfer Job Complete)	Send "Transfer Job Complete" message.	None.

Figure 4.5 begins with the model in Figure 4.4 and is expanded to cover a transfer job with multiple ports. Each transfer job, as seen by the equipment, may include from one port to the total number of ports on the equipment.

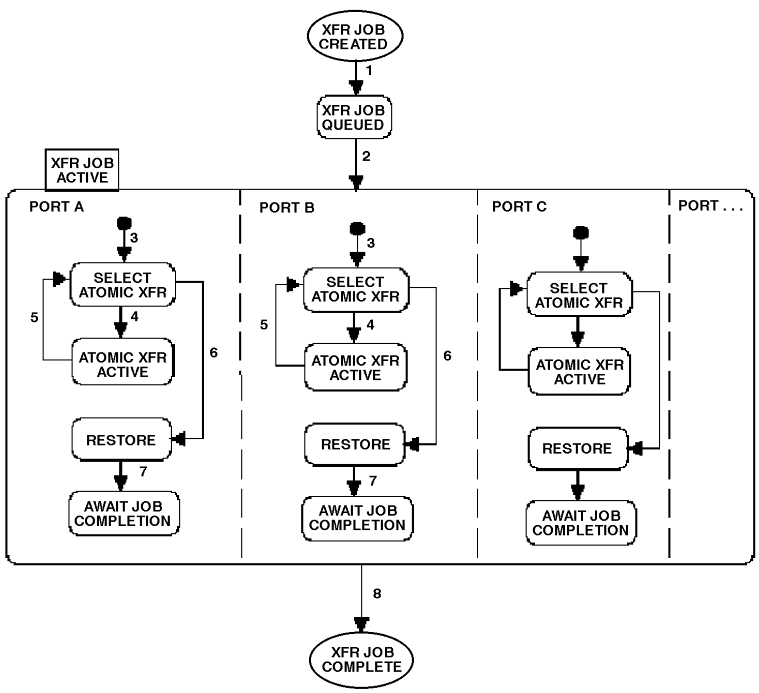

Figure 4.5
Transfer Job State Model for Multiple Ports

4.2.3 *Atomic Transfer State Model* — When a transfer job becomes active, it creates a queue of atomic transfers for each port (see Transition 2 of the transfer job state model). These atomic transfers are executed as described in the transfer job state model above. This section describes the behavior of the atomic transfer as it is created, executed, and finally deleted.

Figure 4.6 shows the state model for an atomic transfer as it moves through its life cycle. Each atomic transfer of an active transfer job is represented by a separate copy of this state model. These state models are not substates of the transfer job state model. Rather, transfer job and atomic transfers are separate entities which interact.

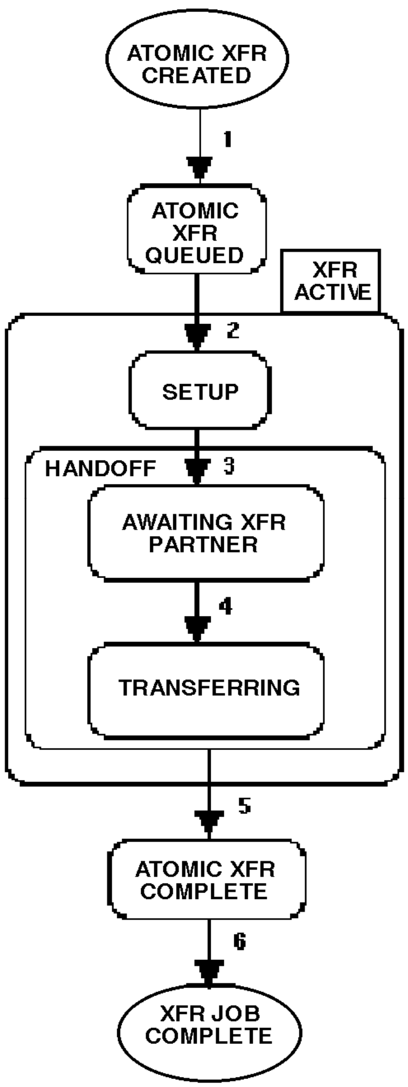

Figure 4.6
Atomic Transfer State Diagram

The definitions for the states and state transitions follow.

ATOMIC TRANSFER QUEUED

In this state, the atomic transfer is awaiting its turn to execute at the port.

TRANSFER ACTIVE

In this state, the transfer job has activated this atomic transfer. The atomic transfer is performed entirely within this state. The substates of TRANSFER ACTIVE are SETUP and HANDOFF.

The TRANSFER ACTIVE state in this model corresponds to the ATOMIC TRANSFER ACTIVE state in the transfer job state model. Thus, when the transfer job activates an atomic transfer on a port, both state models shall be in the (ATOMIC) TRANSFER ACTIVE state during the atomic transfer. This applies only to the specific atomic transfer being performed.

SETUP

While in the SETUP substate, the equipment performs any pre–transfer setup operations necessary for the current atomic transfer. These operations might include (but are not limited to) opening doors, unclamping carriers, and homing elevators. For transfer agents, it is reasonable to include as part of the setup such actions as a transfer agent moving into position near a specified process equipment.

The setup and restore[8] operations are expected to be "goal oriented," that is, oriented toward satisfying specific conditions (e.g., states such as "door open"). They should not depend on a fixed sequence of actions such as "initiate the door opening mechanism." Thus, a port left in a post–transfer condition from a previous atomic transfer would still be able to prepare properly for the next.

If no setup time is required for the transfer, this state may be exited immediately. This is the case for a static port since it can perform no physical actions related to setup.

HANDOFF

The equipment is committed to the transfer when no setup operations remain and the port is capable of performing the transfer. Entry into the HANDOFF state indicates that the port shall take no further action without the (expressed or implicit) cooperation of its transfer partner. Both transfer partners shall be in the HANDOFF state when the atomic transfer begins.

8 Restore is described in Section 4.2.2.

The HANDOFF substate is divided into two further substates: AWAITING TRANSFER PARTNER AND TRANSFERRING.

NOTE: If one transfer partner has not yet reached the HANDOFF substate when the other begins the transfer, interference could occur on the part of the uncommitted partner, with potential to damage equipment or material. The micro level Transfer Ready exchange will help prevent this (see Section 5 below).

AWAITING TRANSFER PARTNER

Once the port is ready for the transfer, the AWAITING TRANSFER PARTNER substate is entered. The port shall remain in this state until its transfer partner is ready.

TRANSFERRING

In this state, the physical handoff portion of the atomic transfer is in progress. Most micro level coordination occurs while the transfer partners are both in the TRANSFERRING state.

ATOMIC TRANSFER COMPLETE

In this state, the atomic transfer has completed and is awaiting the completion of the job. Upon entry to this state, the equipment shall release (deallocate) the port resources used for this atomic transfer. It shall also deallocate any material location used by this atomic transfer that is not needed by any further atomic transfer in this transfer job. This state exists primarily to allow the host to poll for current status of the individual atomic transfers (there is no status if the atomic transfer no longer exists).

The following transition table defines the transitions between states for the atomic transfer state model. It applies to Figure 4.6.

Table 4.2 Atomic Transfer State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	(Atomic Transfer Created)	The parent transfer job becomes active (see Table 4.1).	ATOMIC TRANSFER QUEUED	None.	None.
2	ATOMIC TRANSFER QUEUED	The parent transfer job selects this atomic transfer as next for a port and transitions to ATOMIC TRANSFER ACTIVE.	SETUP	None.	None.
3	SETUP	All preparation for this atomic transfer is complete.	AWAITING TRANSFER PARTNER	None.	"Committed To Transfer" event occurs. See micro level Transfer Ready message.
4	AWAITING TRANSFER PARTNER	Transfer partner is ready for transfer (see micro level).	TRANSFERRING	None.	"Atomic Transfer Started" event occurs. This transition might not occur for a static port.
5	HANDOFF	The atomic transfer is completed.	ATOMIC TRANSFER COMPLETE	None.	The "Atomic Transfer Complete" event occurs. This transition will occur after the appearance or removal of the material at the port. See the micro level Transfer Verify message.
6	ATOMIC TRANSFER COMPLETE	The parent transfer job is completed.	(Transfer Job complete)	The atomic transfer is deleted.	After this transition, the equipment maintains no status of the atomic transition.

4.3 *Extended Behavior Models* — In this section, the concepts of Pause/Resume, Stop/Cancel/Abort, and AutoStart/StartHandoff are added to the state models for the transfer job and the atomic transfer. In addition, the possibility that some transfers will end abnormally is discussed. While not every implementation requires these capabilities, all face the prospect of problems during transfer. This section describes how the basic state models provided above may be extended to include such features.

4.3.1 *Extended Communications* — This section describes the new commands the host may use to affect current transfer jobs and the events associated with these new capabilities.

Pause — The host may issue a command to pause a transfer job[9]. A command to pause shall cause the subject to continue to the first safe, continuable pausing place and then cease activity. The pause shall occur only at points that allow for the resumption of the activity (see the resume command). Pausing a transfer job results in the pausing of each atomic transfer for that transfer job (see Figure 4.8). The points where a pause may fall should be defined by the supplier. Note that a paused transfer job may be aborted or stopped as an alternative to the resume command. In this case, the stop command may cause the equivalent of a resume in order to allow the current atomic transfers to complete.

There are two actions that may cause a pause. The first is a host command as described in the paragraph above. The second is a decision by the equipment that a problem exists that requires outside intervention. For instance, if a port hardware problem exists, the equipment may pause the job automatically. The user or host may then resume the transfer job when the hardware problem is corrected, or alternately abort/stop the transfer job if the problem is severe.

Resume — The resume command is used to continue a previously paused transfer activity.

Stop — The host may command the involved partners to stop a transfer job. The stop command terminates a job in an orderly manner. The object of the stop command is to complete currently executing atomic transfers and leave the equipment and material in a safe state. While the time needed to stop should be kept as short as possible, this goal should be a lower priority.

If the specified transfer job is queued, the stop command acts as a cancel command.

9 It is expected that a host may also pause a port or other hardware. However, this document does not specify these hardware-related commands.

Cancel — The host may cancel a transfer job which has not yet become active (e.g., a job which is queued). This is useful when it is unacceptable to affect transfer which is in–progress. A canceled job is removed from the queue and discarded. No physical action may be associated with canceling a transfer job. If the specified transfer job is active, the equipment shall reject this command.

Abort — The host may command the involved partners to abort a transfer job. The goal of the abort command is to end the transfer activities (especially movement) as quickly as possible, while retaining equipment and material integrity. Aborting a transfer job shall cause the individual atomic transfers to also abort. As with stop, the abort command terminates the transfer job. Different from the stop command is that equipment executing an abort command shall require manual intervention before further material movement operations are performed. Abort is intended for use when serious problems are detected and further damage needs to be prevented.

The abort command takes precedence over the stop, pause, and cancel commands. If the specified transfer job is queued, the abort command acts as a cancel command.

Transfer Job Create — The Transfer Job Create is not new, but is extended to include the "AutoStart" option. There is a parameter added to each atomic transfer definition which allows selection of this option. If not selected, the atomic transfer shall enter a WAIT state after completing SETUP operations, but before informing its transfer partner that it is ready to begin. An event signals the host that the equipment is awaiting instructions.

This feature allows the host added flexibility in synchronizing material movement activities. The host may manually synchronize two transfer partners or it may wish to align a material movement activity with another equipment or factory-related activity.

StartHandoff — The StartHandoff command is issued by the host to cause a specific atomic transfer to transition from the WAIT state to the TRANSFER ACTIVE state.

4.3.2 *Extended Transfer Job State Model* — Figure 4.7 presents an extended transfer job state model. This model provides for the capability to pause/resume, stop, and abort. Except for the extensions, this model is the same as that in Figure 4.5. Therefore, only the extensions are discussed in this section.

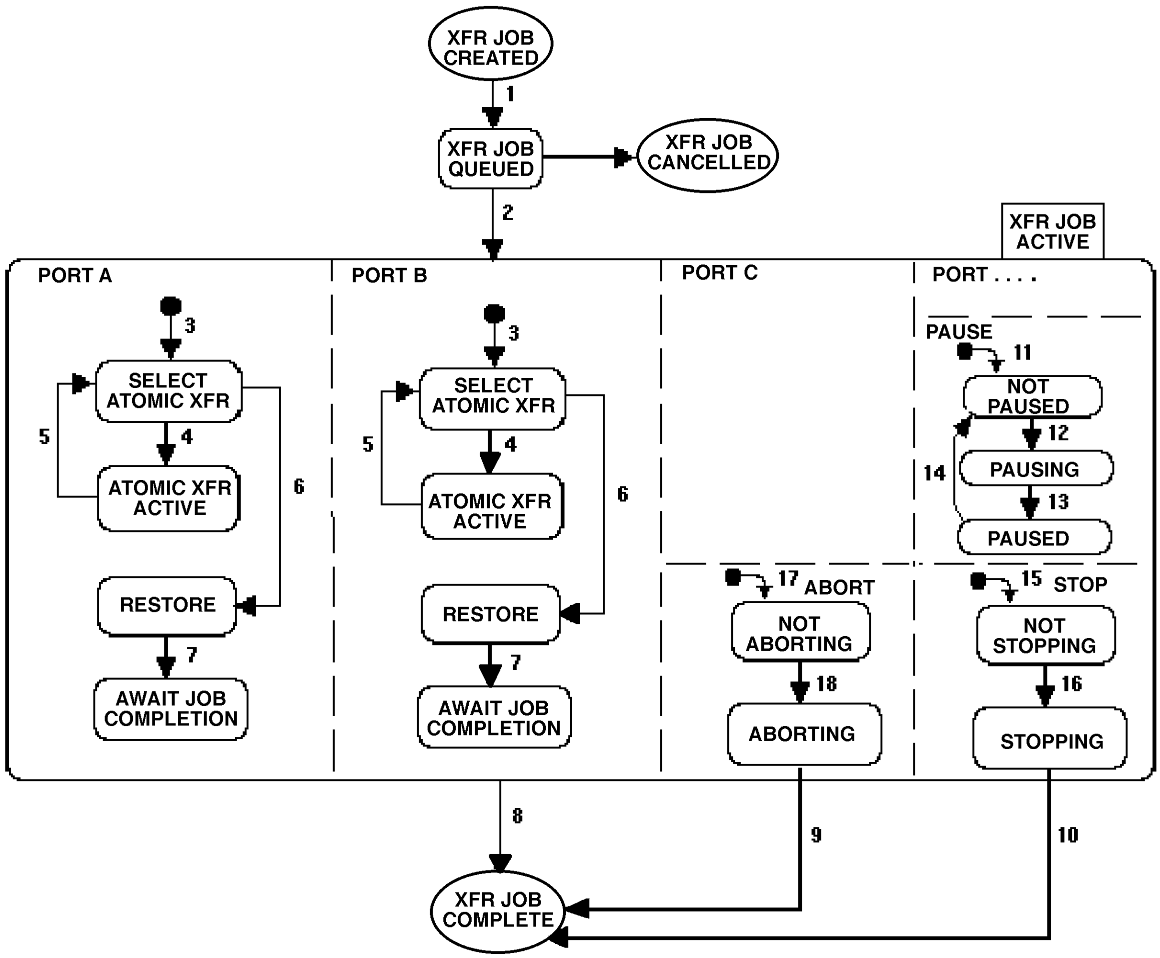

Figure 4.7
Extended Transfer Job State Model

ABORT

The ABORT state is an AND substate of TRANSFER JOB ACTIVE. This state is responsible for coordination of any activities necessary to abort[10] the active transfer job. The ABORT state has two substates: NOT ABORTING and ABORTING.

NOT ABORTING

In this state, the abort process is not in effect. The transfer job proceeds normally.

ABORTING

In this state the transfer job is causing its active atomic transfers to abort. This state is active only so long as any of the transfer job's atomic transfers remains active.

STOP

The STOP state is an AND substate of TRANSFER JOB ACTIVE. This state is responsible for coordination of any activities necessary to stop[11] the active transfer job. STOP has two substates: NOT STOPPING and STOPPING.

NOT STOPPING

In this state, the STOP process is not in effect. The transfer job proceeds normally.

STOPPING

In this state the process of stopping occurs. When the STOPPING state is active and the SELECT ATOMIC TRANSFER state is entered, that atomic transfer shall transition to the AWAIT JOB COMPLETION state. When all ports have reached that state, transition 10 from the STOPPING state occurs (see Figure 4.7).

10 See Section 4.1 for the defintion of abort.

11 See Section 4.1 for the definition of stop.

PAUSE

The PAUSE state is an AND substate of TRANSFER JOB ACTIVE. That is, the pause feature is concurrent with the execution of the transfer job. The PAUSE state has three substates: NOT PAUSED, PAUSING, and PAUSED.

NOT PAUSED

A newly activated job is NOT PAUSED by default. In this state, the transfer job proceeds as normal.

PAUSING

This state is coordinating the movement of the transfer job from NOT PAUSED to PAUSED. It is responsible for making sure that the current activity for each port for the job has ceased at an appropriate point. The transfer job is PAUSING until all of its active atomic transfers are paused.

PAUSED

All activity has ceased. The transfer job is awaiting a Resume command. Note that the PORT A, PORT B, etc., substates retain their current states, but their activity ceases when PAUSED.

The following transition table defines the added transitions between states for the extended transfer job state model. It applies to Figure 4.7.

Table 4.3 Extended Transfer Job State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
9	ABORTING	Abort process is complete.	(Transfer Job Complete)	Send “Transfer Job Complete” message to host indicating abnormal termination.	Host or equipment previously issued abort.
10	STOPPING	Stop process is complete.	(Transfer Job Complete)	Send “Transfer Job Complete” message to host indicating abnormal termination.	Host or equipment previously issued abort.
11	(Undefined)	Default entry into PAUSE state.	NOT PAUSED	None.	None.
12	NOT PAUSED	Host or equipment issued a directive to pause.	PAUSING	None.	None.
13	PAUSING	All transfer job activity has ceased.	PAUSED	None.	“Transfer Job Paused” event has occurred.
14	PAUSED	Host issued a directive to resume the transfer job.	NOT PAUSED	None.	“Transfer Job Resumed” event has occurred.
15	(Undefined)	Default entry into STOP state.	NOT STOPPING	None.	None.
16	NOT STOPPING	Stop initiated.	STOPPING	Begin stop activities.	None.
17	(Undefined)	Default entry into ABORT state.	NOT ABORTING	None.	None.
18	NOT ABORTING	Abort initiated.	ABORTING	Begin abort activities.	None.
19	TRANSFER JOB QUEUED	Cancel, Abort, or Stop command received.	TRANSFER JOB CANCELLED	Remove the transfer job from the queue.	None.

4.3.3 *Extended Atomic Transfer State Model* — Figure 4.8 presents an extended atomic transfer state model. This model extends the atomic transfer model in a way similar to the transfer job extension. It provides for the capability to pause/resume and to abort[12]. Except for the extensions, this model is the same as that presented as Figure 4.6. Therefore, only the extensions are discussed in this section.

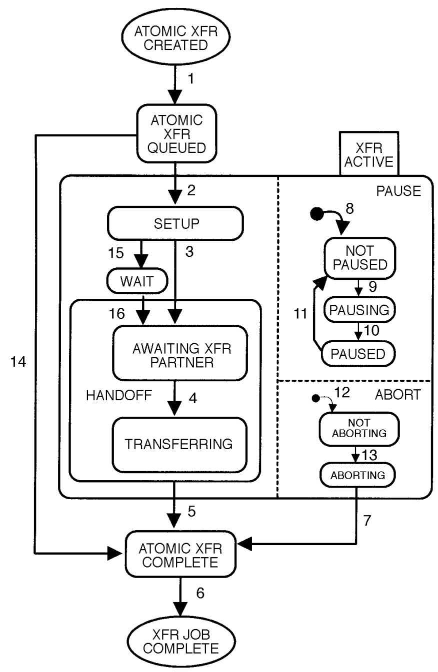

Figure 4.8
Extended Atomic Transfer State Diagram

WAIT

The atomic transfer stops activity and awaits a StartHandoff command from the host. This capability allows the host to precisely orchestrate the timing of the handoff in time critical operations.

ABORT

The ABORT state is an AND substate of TRANSFER ACTIVE. This state is responsible for coordination of any activities necessary to abort the active atomic transfer. The ABORT state has two substates: ABORTING and NOT ABORTING.

NOT ABORTING

In this state, the abort process is not in effect. The atomic transfer proceeds normally.

ABORTING

In this state, the process of aborting is performed. It is the responsibility of the equipment to cease physical activity as quickly as possible and end the current atomic transfer. This process is application-specific. It is the responsibility of the supplier to document this method.

PAUSE

The PAUSE state is an AND substate of ATOMIC TRANSFER ACTIVE. That is, the pause states are concurrent with the execution states of the atomic transfer. The PAUSE state has three substates: NOT PAUSED, PAUSING, and PAUSED.

NOT PAUSED

A newly activated atomic transfer is NOT PAUSED by default. In this state, the atomic transfer proceeds as normal.

PAUSING

This state is coordinating the movement of the atomic transfer from NOT PAUSED to PAUSED. It is responsible for making sure that the current activity for the atomic transfer has ceased at an appropriate point.

PAUSED

All activity has ceased. The atomic transfer is awaiting a Resume command. Note that the PORT A, PORT B, etc., substates retain their current states, but their activity ceases when PAUSED.

The following transition table defines the added transitions between states for the extended atomic transfer state model. It applies to Figure 4.8.

12 Note that "stop" does not apply to atomic transfers, since the active atomic transfers are allowed to complete when the transfer job is stopped.

Table 4.4 Extended Atomic Transfer State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
3	SETUP	Preparation for atomic transfer is complete, and TRAutoStart parameter is TRUE.	AWAITING XFR PARTNER	None.	"Committed to Transfer" event
7	ABORTING	Abort process is complete.	ATOMIC TRANSFER COMPLETE	None.	"Atomic Transfer Complete" event occurs noting abnormal termination.
8	(Undefined)	Default entry into PAUSE.	NOT PAUSED	None.	None.
9	NOT PAUSED	The transfer job transitioned to PAUSING state (Transition 12, Figure 4.7).	PAUSING	None.	None.
10	PAUSING	All atomic transfer activity has ceased.	PAUSED	None.	None.
11	PAUSED	The host issued a directive to resume the atomic transfer.	NOT PAUSED	None.	None.
12	(Undefined)	Default entry into ABORT.	NOT ABORTING	None.	None.
13	NOT ABORTING	Transfer job transitioned to ABORTING state (Transition 18, Figure 4.7).	ABORTING	Begin abort activities.	May be host- or equipment- initiated.
14	ATOMIC TRANSFER QUEUED	Abnormal Transfer Job termination.	ATOMIC TRANSFER COMPLETE	None.	May be caused by transfer job abort or stop.
15	SETUP	Preparation for atomic transfer is complete, and TRAutoStart parameter is FALSE.	WAIT	Wait for host command.	None.
16	WAIT	StartHandoff command is received from host.	AWAITING XFR PARTNER	None.	"Committed to Transfer 2" event

4.4 *Macro Level Services* — This section defines the messaging services required to implement the material movement concepts. The messages were introduced in Sections 4.2.1 and 4.3.1. These services are independent of the messaging protocol to be used. They may be mapped to SECS–II (SEMI E5) or to other comparable protocols.

These messaging services define the messages to be used, the nature of the data items or parameters to be contained within the messages, and data type of the parameters. Not defined here is the internal structure of the actual messages as transferred, including order of the parameters and how various data structures and data types are represented.

4.4.1 *Service List* — The following messages are exchanged between host and equipment for the purpose of accomplishing material movement tasks.

Host Initiated Services

Service Name	*Description*	*Confirmed**
TRJobCreate	Host request that a transfer job be performed.	Yes
TRJobCommand	Command which affects a transfer job.	Yes
GetAttribute	Request for attributes of an object (e.g., transfer job or atomic transfer). This message service has applicability beyond material movement.	Yes

* An unconfirmed service requires no response to the request message. This means that no data is required in the response. This does not preclude the implementation of a response message in the message protocol.

Equipment Initiated Services

Service Name	*Description*	*Confirmed*
TRJobAlert	Notification to host that transfer job is started or complete.	No
TrJobEvent	Notification to host that a transfer-related event has occurred.	No

4.4.2 *Service Detail* — The tables below define the parameters for each service. In some cases, parameters have additional detail which is defined in a following section. These parameters are marked with the "*" character.

The columns labelled REQ/IND and RSP/CONF link the parameters to the direction of the message. The message send by the initiator is called the "Request." When receiver terms this message the "Indication" or the request. The receiver may then send a "Response," which the original sender terms the "Confirmation."

The following codes appear in the REQ/IND and RSP/CONF columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" — Mandatory Parameter—must be given a valid value.

"C" — Conditional Parameter—may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of other parameter.

"U" — User Defined Parameter.

"–" — Not Used.

"=" — (for Response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

The column labelled "Form" is used to indicate the type of data contained in a parameter. The forms used in this document are defined below.

Unsigned Integer — May take the value of any non–negative integer. Messaging protocol may impose a limit on the range of possible values.

Enumerated — The parameter may take on one of a limited set of possible values. These values are generally given logical names but may be represented by any data type excluding lists and structures.

Boolean — The parameter may take on one of two possible values, equating to "True" and "False."

Text — A text string.

Structure — A complex structure which consists of a collection of values of one of the possible forms. The breakdown of all "Structure" parameters is provided within this document.

NOTE 4: To prevent the definition of numberous variables named "XxxList", this document adopts the convention of referring to the list as "(List of) Xxx." In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates an ordered collection (or set) of zero or more items of the same data type. List order is retained from the message request to the response. For this document, a list must contain at least one element unless zero elements are specifically allowed.

TRJobCreate

The host requests that the equipment participate in a material transfer job.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRJobName	C	-	Host created identifier of the transfer job. This allows the host to use a common name for the transfer job on each participating equipment.	Text
(List of) AtomicSpec	M	-	Specifications for the atomic transfer(s).	Structure
TRJobID	-	M	Equipment created ID of the transfer job.	Unsigned Integer
(List of) TRAtomicID	-	M	The equipment-created identifier of the atomic transfer(s).* Order matches that given in the (List of) AtomicSpec in the message req.	Unsigned Integer
TRStatus	-	M	Reports acceptance or rejection of the transfer job.	Structure

*All object IDs created by the equipment must be unique within that equipment for that object type. This includes TRJobID and TRAtomicID. These IDs are used by the host to inquire about those objects.

TRStatus Parameter Detail

Parameter	*RSP/CONF*	*Description*	*Form*
TRAck	M	Tells whether the activity was successful (=true) or unsuccessful (=false).	Boolean
(List of) Status	C	Reports any errors found. (May be list of 0.)	Structure

Status Parameter Detail

Parameter	*RSP/CONF*	*Description*	*Form*
ErrorCode	M	Contains the code for the specific error found.	Enumerated
ErrorText	M	Text in support of the error code.	Text

AtomicSpec Parameter Detail

Many of these parameters are conditional. The equipment shall decide if it has a sufficient amount of information to perform each atomic transfer.

Parameter	*REQ/IND*	*Description*	*Form*
TRLink	M	Used by the transfer partners to assure that their communications relate to the same atomic transfer. The host is responsible for assuring uniqueness.	Unsigned integer
TRPort	C	Material I/O port on the equipment through which the transfer is to occur. If not specified, the equipment shall select the port.	Unsigned integer
TRObjName	C	Textual identifier of the object to be transferred.	Text
TRObjType*	C	Identifies the type of transfer object. Not required if only one type is acceptable.	Enumerated
TRRole	M	Equipment's role (i.e., Primary or Secondary).	Enumerated
TRRecipe	C	Name of the transfer recipe (if needed).	Text
TRPartner	M	Identifier (Name* attribute of equipment) of the transfer partner.	Text
TRPartnerPort	C	Material I/O port on the equipment's partner to be used for this atomic transfer.	Unsigned integer
TRDirection	M	Send or Receive the transfer object?	Enumerated
TRType	M	Is the equipment to be Passive or Active?	Enumerated
TRLocation	C	Identifier of the location on the equipment of the source (or destination) of the transfer object.	Unsigned integer
TRAutoStart	M	Should the equipment start the handoff without waiting for the "StartHandoff" command.	Boolean

TRJobCommand

The host requests a change in an active transfer job. Possible commands include Pause, Resume, Stop, Cancel, Abort, StartHandoff.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRObjID	M	-	Equipment's identifier of the transfer job to which the command applies.	Unsigned integer
TRCmdName*	M	-	Indicates which command to perform.	Text
(List of) CmdParameter	C	-	Parameter(s) corresponding to the command type. (May be list of 0)	Structure
TRStatus	-	M	Describes the acceptance or rejection of the command.	Structure

CmdParameter Detail

Parameter	*RSP/CONF*	*Description*	*Form*
CmdParmName	M	The name of the parameter.	Text
CmdParmValue	M	Value of the parameter.	Varies per Parameter

TRJobAlert

The equipment indicates the start or completion of a transfer job.

Parameter	*REQ/IND*	*Description*	*Form*
TRJobID	M	Equipment's identifier of the transfer job.	Unsigned integer
TRJobName	M	Host created identifier of the transfer job.	Text
TRJobMS*	M	Transfer job milestone.	Enumerated
TRStatus	M	Status of the transfer milestone (i.e., success or failure).	Structure

GetAttribute

Information related to a specific object (e.g., transfer job) is requested.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
ObjType*	M	-	Type of object for which attributes are desired.	Enumerated
(List of) ObjectID	C	-	Identifier of each object for which attributes are desired. If omitted (i.e., list of zero elements), it implies a request for all objects of the specified ObjType.	Varies according to ObjType.
(List of) AttributeID*	M	-	Identifier of requested attribute.	Enumerated
(List of) AttrData	-	C	Attribute data. Returns the requested attribute list for each specified ObjectID (e.g., grouped per ObjectID). If the object does not exist, an empty list is returned for that object, if an attribute does not exist, a null member of the list is returned. If the ObjType is unknown, a single null list is returned.	Varies per attribute.
(List of) Status	-	C	Reports any errors found in the GetAttribute request. (May be list of 0.)	Structure

TRJobEvent

The equipment reports pertinent state changes related to a transfer job.

Parameter	*REQ/IND*	*Description*	*Form*
TREventID*	M	Identifier of the specific event which occurred.	Enumerated
TRJobID	M	Equipment's identifier of the job to which the event refers.	Unsigned integer
TREventData	C	Data related to the specific event. May be repeated if multiple data parameters are reported.	Varies per parameter reported.

4.4.3 *Parameter/Attribute Definitions* — This section gives further details on parameters not sufficiently defined above. It also defines attributes of the defined object types. Note that some parameters also serve as attributes (e.g., TRJobName).

AtomicSpec — If a list of AtomicSpec parameters is supplied, the order is important. The equipment shall execute atomic transfers in the order specified on a per–port basis.

AttributeID/AttrData — An attribute is a characteristic which applies to all instances of that (type of) object. Thus, the attributes available for an object depend upon the ObjType. The three object types available for material movement are TransferJob and AtomicTransfer, and Equipment. Below are listed the defined attributes for each.

Object (i.e., any object): ObjectID, ObjType.

TransferJob: TRJobState, TRAtomicList, TRJobName, TRJobID (=ObjectID).

AtomicTransfer: TRAtomicState, TRLink, TRPort, TRObjName, TRRole, TRRecipe, TRPartner, TRPartnerPort, TRDirection, TRType, TRLocation, TRAutoStart, TRObjType, TRAtomicID (=Object ID).

Equipment: Name (=ObjectID).

ErrorCode — This parameter is used to report the reasons why an activity was unsuccessful. This applies to the TRJob Create, TRJobComplete, and the TRJobCommand. While it is impossible to define all possible errors, the following is a list of values which may apply in many cases:

TRJobCreate:

- Parameters improperly specified.
- Insufficient parameters specified.
- Queue full or queuing not allowed.
- Error in atomic transfer specification.
- Material Location Status does not match Transfer Specification.
- Primary Transfer Partner Role not supported.
- Active Participation not supported.

TRJobComplete:

- Failed due to hardware error.
- Failed due to transfer partner error.
- Failed due to error during atomic transfer.
- Transfer Job aborted by host.
- Transfer Job stopped by host.
- Transfer Job canceled by host.

TRJobCommand:

- Parameters missing or improperly specified.
- Requested service not available from this equipment.
- Cancel not allowed after transfer start.
- Unknown Transfer Job.

GetAttribute:

- Invalid object type.
- Unknown objectid.
- Invalid attribute.

ObjType — The type or class of the object of interest. The three types of objects contained in this document are TransferJob, AtomicTransfer, and Equipment.

Timestamp — The format for this Text string is YYYYMMDDhhmmsscc where:

YYYY= Year

MM= Month (01–12)

DD= Day (01–31)

hh= Hour (00–23)

mm= Minute (00–59)

ss= Second (00–59)

cc= Hundredths of Second (00–99)

TRCmdName/CmdParameter — Possible values are:

Command	*Parameter*
CANCEL	none
PAUSE	none
RESUME	none
ABORT	none
STOP	none
STARTHANDOFF	TRAtomicID

TREventID/TREventData — The following table shows the defined events and the data which are required to be available. Any attribute of the object should be available for reporting with an associated collection event.

Event	*Typical Data*
Committed To Transfer	TRAtomicID, Timestamp
Waiting for StartHandoff	TRAtomicID, Timestamp
Transfer Job Paused	Timestamp
Transfer Job Started	Timestamp
Atomic Transfer Started	TRAtomicID, Timestamp
Atomic Transfer Complete	TRAtomicID, Timestamp

TRJobMS — Identifies which transfer job milestone is being alerted to the host. Possible values are:

- Transfer Job Started.
- Transfer Job Complete.

TRObjType — Identifies the type of object to be transferred. This parameter is used only in cases where a port is capable of transfers involving different object types. As an example, a list of possible values might include:

- Wafer Reticle Cassette
- 100 mm Wafer Carrier
- 125 mm Wafer Carrier
- 150 mm Wafer Carrier
- 200 mm Wafer Carrier
- 100 mm Wafer
- 125 mm Wafer
- 150 mm Wafer
- 200 mm Wafer

Attributes: (Note: Some parameters above are also attributes.)

Name — Each equipment must have a unique Name attribute, a factory-defined Text string.

TRAtomicList — List of the atomic transfers (TRAtomicIDs) contained within the specified transfer job. This is an attribute of a transfer job and is specified in the GetAttribute service.

TRAtomicState — Attribute of an atomic transfer. Possible values are defined by the state models defined in Sections 4.2.3 and 4.3.3.

TRJobState — An attribute of transfer job. Possible values are defined by the state models defined in Sections 4.2.2 and 4.3.2.

4.5 *Object Attribute Definitions* — This section defines the attributes of those objects required for Material Movement Management: Equipment, TransferJob, and AtomicTransfer.

4.5.1 *Equipment* — The attributes of the Equipment object are defined in Table 4.5.

Table 4.5 Equipment Object Definition Table

Attribute Name	*Definition*	*Access*	*Requirement*	*Form*
ObjType	Object type.	RO	Y	Text = “Equipment”
ObjID	User-definable name.	RW	Y	Text

4.5.2 *TransferJob Object* — The attributes of the TransferJob object are defined in Table 4.6. A TransferJob is created by the equipment when it accepts a transfer job create request from the host, and its attributes are based upon that request.

Table 4.6 TransferJob Object Definition Table

Attribute Name	*Definition*	*Access*	*Requirement*	*Form*
ObjType	Object type.	RO	Y	Text = "TransferJob"
ObjID	Textual version of TRJobID.	RO	Y	Text
TRJobID	Identifier assigned by the equipment.	RO	Y	Unsigned integer
TRJobName	Host-created job identifier.	RO	Y	Text
TRJobState	Current state.	RO	Y	Enumerated: TRJobQueued, TRJobActive, TRJobComplete
TRAtomicList	List of (TRAtomicID).	RO	Y	List of unsigned integers

4.5.3 *AtomicTransfer Object* — The attributes of the AtomicTransfer object are defined in Table 4.7. AtomicTransfer objects are created by the equipment when it accepts a transfer job create request from the host, and its attributes are based upon that request.

Table 4.7 Atomic Transfer Object Definition Table

Attribute Name	*Definition*	*Access*	*Requirement*	*Form*
ObjType	Object type.	RO	Y	Text = "AtomicTransfer"
ObjID	Textual version of TRAtomicID.	RO	Y	Text
TRAtomicID	Identifier assigned by the equipment.	RO	Y	Unsigned integer
TRAtomicState	Current state.	RO	Y	Enumerated: TRAtomicActive, TRAtomicComplete
TRLink	Assigned by the host to identify an atomic transfer.	RO	Y	Unsigned integer
TRPort	Material I/O Port identifier.	RO	Y	Unsigned integer
TRObjName	Textual identifier of transfer object.	RO	N	Text
TRObjType	Material type of transfer object.	RO	N	Enumerated
TRRole	Equipment's role.	RO	Y	Enumerated: Primary or Secondary
TRRecipe	Recipe identifier for transfer recipe.	RO	N	Text
TRPartner	Name of equipment's partner.	RO	Y	Text
TRPartnerPort	Identifier for partner's port.	RO	N	Unsigned integer
TRDirection	Indicates whether the equipment will send or receive.	RO	Y	Enumerated: Send Receive
TRType	Indicated the equipment is to be active or passive.	RO	Y	Enumerated: Passive Active
TRLocation	Identifies location on the equipment of the source (or destination) of the transfer object.	RO	N	Unsigned integer
TRAutoStart	Indicates whether the equipment may automatically start the handoff without waiting for a StartHandoff command.	RO	Y	Boolean: Automatically start (TRUE). Wait for StartHandoff (FALSE).

5 Micro Level

5.1 *Micro Level Concepts* — The micro level of material movement is defined below to allow for interaction between transfer partners on a step–by–step basis during a handoff. It was designed to be used in conjunction with the macro level defined above but may instead be used with some other transfer coordination mechanism.

5.1.1 *Micro Level Definitions*

Handoff — The process by which the transfer object moves from the sending transfer partner to the receiving transfer partner. The terms "handoff" and "micro level" refer to the same transfer activity.

Micro Move — One of a sequence of moves required during a micro level process to effect the transfer of an object. This is normally associated with physical activity within the transfer envelope.

5.1.2 *Micro Level Description* — While the macro level of material movement deals with coordination and preparation for a transfer, the micro level addresses the physical synchronization between two transfer partners during an atomic transfer. To control these physical interactions properly, communication between the transfer partners is required. Using these communications, the partners shall ensure that both are ready to perform the same specific transfer, that both agree on the mechanism, and that movement within the transfer envelope is properly coordinated.

There are three parts to the micro level interaction between transfer partners. Each of the three parts must occur in some form for the micro level to integrate properly with the macro level.

1. The first part is the exchange of "I'm ready" type messages, so that the partners can be sure that starting the transfer is appropriate.
2. The second part of the micro level interaction is the coordination of the physical transfer. During a transfer, control of the transfer envelope may belong to only one partner at any time. Joint or parallel movement is never allowed in this space[13]. The transfer itself is a series of steps called micro moves. Each step typically contains all the activities one partner can perform before the other must act. If the secondary partner is passive during the move, no micro level communications are needed for part two, since the primary partner shall control the transfer envelope during the entire physical transfer.
3. The third part of the micro level interaction is the verification that the transfer is complete.

The micro transfer mechanism assumes that the secondary partner will recognize and respond to some list of micro commands known to the primary partner. These commands might range from the very specific (e.g., "reach out and grasp the transfer object") to the very general (e.g., "perform the next step in your sequence").

5.2 *Micro Level Behavior*

5.2.1 *Micro Level Communications* — This section provides baseline definitions of the communications needed by the micro level of material movement. More detailed definitions of the messaging services can be found in Section 5.4 below. Refer to Figure 5.1 while reading the message definitions. In the figure, the messages in *italics* are macro level messages provided for reference. The **bolded** messages are the micro level messages.

The prefix "HO" (for **H**and**O**ff) is appended to the names of micro level messages to differentiate them from the "TR" transfer messages.

<u>HOReady</u> — Upon completion of any setup operations, each transfer partner shall declare to the other that it is prepared for the specified atomic transfer. Either partner may make this declaration first. When the HOReady exchange has been made, the primary partner shall start the transfer. The HOReady messages include a transfer identifier (see TRLink), which the partners match up. Looking back at the macro level atomic transfer state diagram (Figure 4.6), the combination of having sent and received a HOReady message for the specific transfer will spur the transition from the SETUP to AWAITING TRANSFER PARTNER states.

It is possible that an equipment will receive a HOReady message from its partner before it has received the corresponding Transfer Job Create request from the host (e.g., setup is instantaneous). An equipment shall be able to retain such a received message for a time to allow the host to deliver the corresponding Transfer Job Create request.

<u>HOCommand</u> — The HOCommand is the mechanism by which the primary transfer partner orchestrates the sequence of micro moves necessary for the transfer. The primary transfer partner shall successively perform its own micro move, then direct its partner to perform its next move. Thus, the partners may alternate control of the transfer envelope during the transfer. If the secondary partner is passive during the entire transfer and the primary performs all physical activity, no HOCommands are required — they are implicitly

13 The space outside the transfer envelope is not restricted, and some preparations for the next micro move may be possible in this space.

executed by the primary partner. Only one HOCommand may be active at any time.

The list of commands to execute may be included in a transfer recipe. See Section 4.2.4 above for more detail.

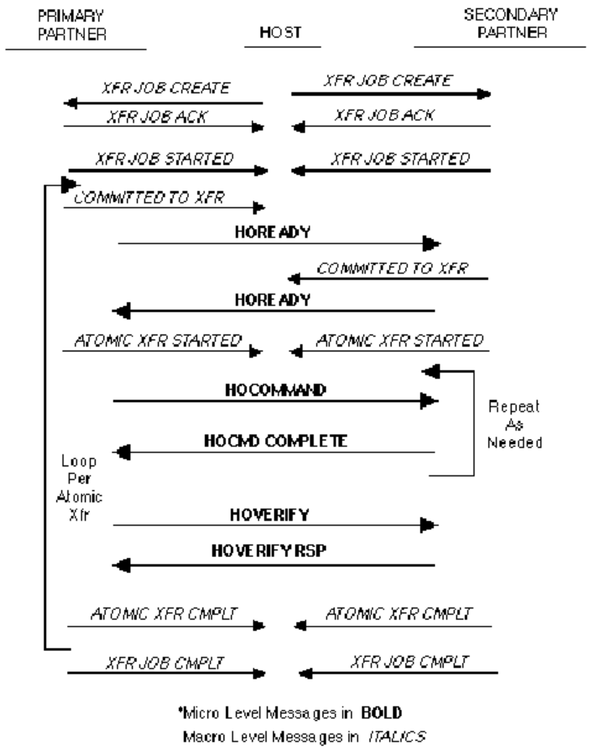

Figure 5.1
Micro Level Message Flow

When the secondary partner is passive, no HOCommands need be issued. In this case, all micro moves are conceived of and executed by the primary partner. The HOReady and HOVerify portions are still required in this case.

<u>HOCommand Complete</u> — Once the secondary partner has completed the task defined in the HOCommand, it uses the HOCommand Complete response message to alert the primary partner. If an HOCommand cannot be accepted or fails, this message shall be used to convey that information.

<u>HOVerify</u> — The primary transfer partner, believing all micro moves complete, shall check its port to ensure that the transfer object has been sent (or received) and that all mechanisms are in a safe position. Next, it shall send the HOVerify message to the secondary partner, asking that it perform the same check.

<u>HOVerify Response</u> — The affirmative response from the secondary partner confirms that the transfer was a success. This message may alternatively signify (through a data field) that the secondary partner does not consider the transfer to be complete. This message coincides with the transition for both partners from the macro level TRANSFERRING state to the ATOMIC TRANSFER COMPLETE state.

5.2.2 *Micro Level Messaging via Host* — As mentioned above, all three parts of the micro level of communications must be carried out in some form. If a direct link from equipment to equipment exists, they should occur via that means, whether using SECS–I, Parallel I/O, or another protocol. If no direct link exists, there is a means by which the host may relay micro level messages from one transfer partner to the other. This is illustrated in Figure 5.2.

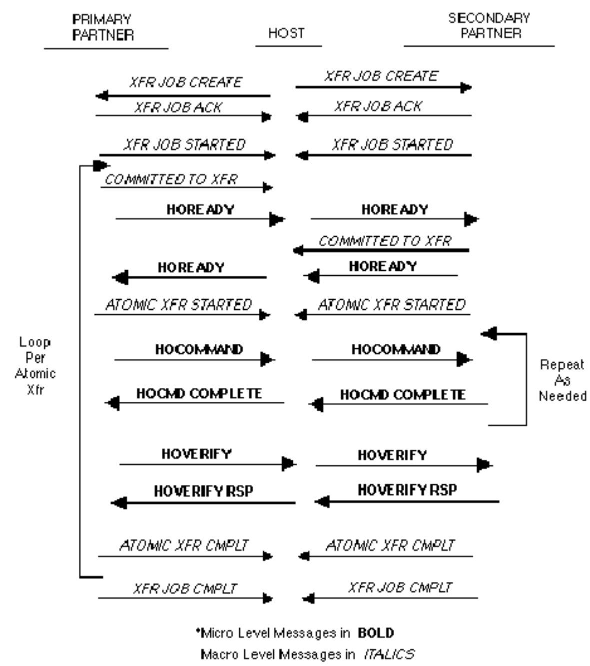

Figure 5.2
Micro Level Message Flow via Host

In this situation, the host may act as a surrogate of each equipment's transfer partner. A piece of equipment would send the same defined micro level message as before, but would deliver it to the host via the standard host link. The equipment would treat the host as its transfer partner, expecting the same response as if it were talking directly to its true transfer partner. The host is responsible for managing the relay of messages from one partner to the other as necessary.

The equipment shall provide the ability to pass micro level messages through the host. If a direct peer–to–peer link is available, the user shall be able to configure the path for the messages (directly to partner or through the standard host link).

5.3 *Extended Behavior* — This section discusses two micro level messages which may be exchanged between the transfer partners as a result of exceptional conditions.

HOCancelReady — Once a transfer partner has sent a HOReady message, it is committed to participate in a transfer. Under some circumstances, an equipment needs to withdraw from that commitment. The HOCancelReady message is used for this purpose.

The HOCancelReady shall be accepted by the transfer partner unless it has already sent the corresponding HOReady. In cases where both transfer partners have sent the HOReady message, the atomic transfer is considered to have begun and cannot be canceled. If the transfer partner receives an HOCancelReady, but has no record of receiving the original HOReady, it should accept the HOCancelReady.

HOHalt — The HOHalt message is used by a transfer partner in situations when the equipment or transfer object are endangered. The receiver of the HOHalt message shall cease all movement related to the atomic transfer immediately. Manual intervention is required before the halted partner may resume movement.

5.4 *Micro Level Services* — This section expands upon the messages defined in Section 5.2.1. It defines the parameters of the messages and discusses the possible values.

5.4.1 *Service List* — The following messages are exchanged between transfer partners during an atomic transfer.

Service Name	*Description*	*Confirmed*
HOReady	Each partner sends this message when it is ready to begin the transfer process.	No
HOCommand	Message sent by the primary transfer partner to cause the secondary partner to perform an activity in the transfer envelope. The response to this message indicates completion of the activity or error.	Yes
HOVerify	Message sent by the primary transfer partner informing the secondary partner that all activities should be complete and asking for confirmation.	Yes
HOCancelReady	Message sent to rescind a previous HOReady message.	Yes
HOHalt	Message sent to stop all action by the transfer partner. This message ends the transfer and requires manual intervention at the halted equipment.	Yes

5.4.2 *Service Detail* — The tables below define the parameters for each service. In some cases, parameters have additional detail which is defined in a following section. These parameters are marked with the "*" character.

The following codes are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" — Mandatory Parameter—must be given a valid value.

"C" — Conditional Parameter—may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of other parameter.

"U" — User-Defined Parameter.

"–" — Not Used.

"=" — (for Response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

The column labelled "Form" is used to indicate the type of data contained in a parameter. The forms used in this document are defined below.

Unsigned Integer — May take the value of any non–negative integer. Messaging protocol may impose a limit on the range of possible values.

Enumerated — The parameter may take on one of a limited set of possible values. These values are generally given textual names, but may have simpler representations in protocol (e.g., numeric values).

Boolean — The parameter may take on one of two possible values, equating to "True" and "False."

Text — A text string.

Structure — A complex structure which consists of a collection of values of one of the possible forms. The breakdown of all "Structure" parameters is provided within this document.

HOReady

An equipment indicates to its transfer partner a readiness to begin a specific atomic transfer.

Parameter	*REQ/IND*	*Description*	*Form*
EQName	M	Identifier (Name attribute) of the equipment sending this message.	Text
TRLink	M	Used by the transfer partners to assure that their communications relate to the same atomic transfer.	Unsigned integer
TRPort	M	Identifier of the port (on the equipment sending this message) to be used for the transfer.	Unsigned integer
TRObjName	C	Identifier of the object to be transferred.	Text
TRObjType	C	Type of transfer object, required if transfer might involve multiple types.	Enumerated
TRRole	M	Is the sender of this message the primary or secondary transfer partner.	Enumerated
TRPartner	C	Identifier (Name attribute) of the equipment expected to receive this message.	Text
TRPartnerPort	C	Material I/O port on the equipment which receives this message to be used for this atomic transfer.	Unsigned integer
TRDirection	M	Does the sender of this message expect to send or receive the transfer object.	Enumerated
TRType	M	Is the transfer to be passive or interactive?	Enumerated
TRLocation	C	Identifier of the material location (on the sender of this message) which will be the source (or destination) of the transfer object.	Unsigned integer

HOCommand

The primary transfer partner directs the secondary transfer partner to perform an action related to a specific atomic transfer.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRLink	M	M(=)	Identifier of the atomic transfer which related to this HOCommand.	Unsigned integer
HOCmdName*	M	-	Specific command to be executed.	Text
(List of) CmdParameter	C	-	Parameter(s) related to the specified HOCommand. (May be a list of 0.) See Section 4.4.2 for definition of CmdParameter.	Structure
HOStatus	-	M	Reports success or failure of the command and, if failure, supplies error detail.	Structure

HOStatus Detail

Parameter	*RSP/CONF*	*Description*	*Form*
HOAck	M	Did the activity succeed or fail, was the inquiry accepted or rejected. True is a positive result, False is negative.	Boolean
(List of) Status	C	Reports any errors found. (May be list of 0) See Section 4.4.2 for details of this structure.	Structure

HOVerify

The primary transfer partner indicates completion of the atomic transfer to the secondary partner and requests confirmation of a successful transfer.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRLink	M	M(=)	Identifier of the atomic transfer.	Unsigned integer
HOStatus	M	M	Reports the completion status of the atomic transfer from the standpoint of the sending transfer partner.	Structure

HOCancelReady

Having previously sent an HOReady message, a transfer partner determines that it is no longer ready to begin the transfer and sends the HOCancelReady message.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRLink	M	M(=)	Identifier of the atomic transfer.	Unsigned integer
HOCancelAck*	-	M	Acknowledge code for HOCancelReady.	Enumerated

HOHalt

This message may be sent by either transfer partner when the equipment or transfer object is endangered. It requires the receiver to cease all transfer-related movement immediately. Manual intervention is required before the halted partner may again be available for transfer.

Parameter	*REQ/IND*	*RSP/CONF*	*Description*	*Form*
TRLink	M	M(=)	Indentifier of the atomic transfer.	Unsigned integer
HOHaltAccept	-	M	True if the request is accepted. Request may be denied only if referenced atomic transfer does not exist.	Boolean

5.4.3 *Parameter Definitions* — This section gives further detail on certain parameters defined above. Parameters which are defined in Section 4.4 are not repeated here.

ErrorCode

HOCommand:

- Rejected/Unrecognized Command.
- Rejected/Parameter Error.
- Failed (Completed Unsuccessfully) — indicates that the activity was attemped, but failed; the mechanisms continue to be operational.
- Failed (Unsafe) — indicates that the equipment was left in an unrecoverable state at the end of the activity due to the failure of a mechanism or due to the risk of damage to the equipment or material. Manual intervention is required.

HOVerify:

- Sensor-Detected Obstable.
- Material Not Sent.
- Material Not Received.
- Material Lost.
- Hardware Failure.
- Handoff Canceled Externally (by host or operator).

HOCmdName — The set of micro commands is provided below as an example. The commands used are not limited to this set. However, adherence to a common set of commands will speed implementation of material transfer.

This particular example applies to a situation where the secondary partner is active and the primary partner is passive.

Cmd	*Description*
Pick	Commands the secondary partner to take all actions necesary to remove the transfer object from the primary partner's port.
Place	Commands the secondary partner to take all actions necesary to place the transfer object in the primary partner's port.
Extend	Commands the secondary partner to reach into the primary partner's port area in close proximity to the material location.
Acquire	Commands the secondary partner to acquire control of the material.
Release	Commands the secondary partner to release control of the material.
Retract	Commands the secondary partner to withdraw from the primary partner's port area.
Store	Commands the secondary partner to place the transfer object in its final location.
Retrieve	Commands the secondary partner to pick up the transfer object from its initial location.
MoveTo	Commands the secondary partner to move its transfer mechanism (e.g., robot gripper) to a specified position (given as a parameter).

The Pick command might actually be an equivalent of the sequence:

Extend, Acquire, Retract, Store.

The Place command might be an equivalent to the sequence:

Retrieve, Extend, Release, Retract.

HOCancelAck — Conveys the response to the HOCancelReady request. Possible values are:

0 — Accept Cancel.

1 — Atomic Transfer Unknown.

2 — Reject Cancel—Transfer Begun.

HOHaltAck — Conveys the response to the HOHalt request. Possible values are:

0 — Accept Halt.

1 — Atomic Transfer Unknown.

APPLICATION NOTES

A1-1 *Transfer-Related Mechanisms* — A transfer job interacts very closely with port-related hardware. This may include a variety of mechanisms such as port doors, cassette indexers, robot arms, carrier restraints, etc. The state models for the transfer job and atomic transfers shown above relate to this port hardware, but do not define hardware behavior directly. Therefore, an additional state model is needed for the port hardware.

A1-1.1 *Example Port State Model* — Figure A1-1 provides an example of a state model for a port. It is divided into three AND substates: MECHANISM, AVAILABILITY, and PAUSE. These substates represent the three most common areas of interest to the host.

Below, the states shown in Figure A1-1 are described, followed by a transition table. This is presented as an example. The actual model is implementation-dependent.

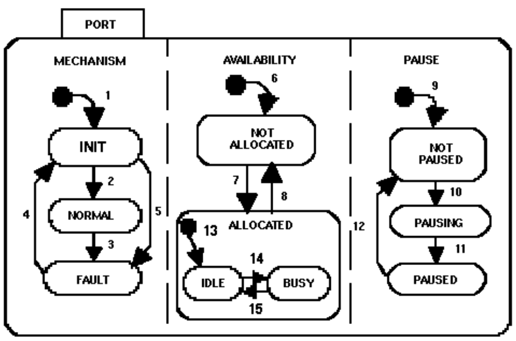

Figure A1-1
Example Port State Diagram

MECHANISM

This state pertains to the port's overall ability to function. It has three substates: INIT, NORMAL, and FAULT.

INIT

This is the default state upon powerup or reset of the port. It includes some unspecified operations to ensure that the port is ready to operate.

NORMAL

When in this substate, the port is in normal working order.

FAULT

In this substate, a problem has been detected with a port mechanism.

AVAILABILITY

This state pertains to the availability of the port to perform a function. This state has two substates: NOT ALLOCATED and ALLOCATED.

NOT ALLOCATED

In the NOT ALLOCATED state, neither the equipment nor the host has allocated the port. The port is waiting to be allocated to either a transfer job or to some process-related task. This is the default state upon equipment system startup.

ALLOCATED

In this state, the port is allocated to either the equipment (typically process-related) or to the host for a transfer job.

NOTE: If the port is allocated to an equipemnt function and the host does not wish to wait for the equipment to release the port, it must take some other action to force the port to become available. One possibility is a “Pause for Transfer” remote command that might be used during a processing cycle.

IDLE

Port is allocated to a task (e.g., processing or transfer job), but activity on the task has not yet begun.

PAUSE

This state pertains to the pausing of current port activity. Pausing of the port is different than pausing a transfer job which might be using the port.

NOT PAUSED

The port defaults to NOT PAUSED upon system startup. In this state, port activities are not hindered by the pause function.

PAUSING

In this state, the port has received a directive to pause and is in the process of bringing the current activity to a halt.

PAUSED

All port activity has ceased. The port is awaiting a directive to resume activity.

Table A1-1 describes the transitions for the example port state model. In the application-specific implementation, events should be defined for all significant occurences related to the model.

Table A1-1 Extended Atomic Transfer State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	(Undefined)	Entry into PORT Model.	INIT	None.	None.
2	INIT	Port mechanisms found to be functional.	NORMAL	None.	None.
3	NORMAL	A malfunction of the hardware occurs.	FAULT	None.	None.
4	FAULT	The malfunction is "fixed." This may be a manual re-initialization of the port.	INIT	None.	None.
5	INIT	A problem occurs during initialization.	FAULT	None.	None.
6	(Undefined)	Entry into PORT Model.	NOT ALLOCATED	None.	None.
7	NOT ALLOCATED	The port is allocated to transfer or process job.	ALLOCATED	None.	None.
8	ALLOCATED	Port is released from current job.	NOT ALLOCATED	None.	None.
9	(Undefined)	Entry into PORT Model.	NOT PAUSED	None.	None.
10	NOT PAUSED	Directive issued to pause port.	PAUSING	None.	None.
11	PAUSING	Port activity has ceased.	PAUSED	None.	None.
12	PAUSED	Directive issued to resume activity.	NOT PAUSED	None.	None.
13	(Undefined)	Entry into ALLOCATED state.	IDLE	None.	None.
14	IDLE	Task activity begins.	BUSY	None.	None.
15	BUSY	Task activity ends.	IDLE	None.	None.

A1-1.2 *Additional Related Mechanisms* — Many equipment material ports have additional related mechanisms that can aid or interfere with a transfer. These mechanisms can be represented as parallel (or orthogonal) states within the port state model. Most such state models will be simple two–state instances (e.g., open/closed, on/off).

In some circumstances, the host will have a need to be able to understand the status of these mechanisms and may wish to be informed of state changes. This is especially true if the host is to do error handling and preliminary diagnosis of problems. The host also may need some level of remote commands to manipulate these mechanisms. Some possible transfer-related mechanisms are discussed below.

<u>Port Material Sensors</u>: These sensors detect the presence or absence of material in a port. The change in this status is important, and an event should be provided to report change in this condition.

<u>Port Doors</u>: Some equipment closes the environment internal to the equipment, except during material transfer. The applicable states are normally open/closed.

<u>Port Elevator</u>: Port elevators have multiple states such as HOME, MOVING, SLOT 5 ACCESS, or interlocks such as BLOCKED BY INTERNAL TRANSFER ARM.

<u>Robot Arm</u>: The transfer arm may be in motion, may be holding material, etc.

<u>Carrier Restraints</u>: On some ports, carriers are clamped in place and cannot be removed unless the restraints are released. There would be a clamped/unclamped state model.

A1-2 *WIP Tracking* — WIP tracking refers to the ability of an entity (host or equipment) to keep accurate track of the material within its domain. Typically, the equipment is expected to track the material's location within its modules and subsystems, while the host may take a more global view, knowing at which equipment (or storage area) a specific transfer object resides.

The process of material movement crosses the boundary of the equipment domain. Therefore, there must be information exchanged between host and equipment about what material is being transferred and what the plans are for the material (e.g., when and how processed).

It is outside the scope of this standard to define WIP tracking capabilities, either at the host or equipment level. However, it is critical for the material movement function to supply enough information that WIP tracking is feasible. Specifically, the material movement messaging must identify the object being transferred. WIP references are kept at a minimum. For example, for a carrier containing wafers, the material movement process would need to know the carrier identifier, but need not be concerned with the specific lot contained within. It is also outside the scope of this standard to be concerned with the detailed contents or status (e.g., processed or not) of a transfer object. These are important issues that should be dealt with elsewhere.

A1-3 *Error Handling* — This section addresses some common problems that may occur during the transfer process. This is not intended to present hard and fast rules for error handling, but rather to raise potential issues and suggest possible solutions. Several primary error or interrupt types are covered. For state model representations of hardware faults, see Section A1-1.

NOTE: Transfer errors are not completely communicated between transfer partners. The host may be responsible for pausing or aborting (as needed) the activities of the partner or equipment with an error condition.

A1-3.1 *Macro Level Error Handling*

1. Transfer Specification Error

This would consist of an error in the data contained in the Transfer Job Create request. Some examples might include specification of a static port as an active transfer partner or the use of a non–existent port on the equipment. Such an error should result in rejection of the Transfer Job Create request.

2. Setup Error

It is during the setup for an atomic transfer that many prerequisites are typically checked. A setup error may be either a hardware or a transfer specification problem. Hardware problems might be such events as cassette elevator fault, door fails to open, etc. If a hardware problem occurs, the transfer job is paused and the hardware state model makes a transition to the FAULT state (see Section A1-1). When the problem is corrected, the host may resume the activity or stop the transfer job.

A transfer specification problem would typically relate to the presence or absence of material at specified locations. If there is a transfer specification problem found, a transition to the RESTORE state is made (transition #5) and the transfer job is terminated.

3. Restore Error

A restore error occurs when the port cannot be brought back to its desired physical condition for the NOT ALLOCATED state. This would be a failure of a hardware mechanism. The hardware should then transition to the hardware FAULT state (see Section A1-1). The “completeness” of the transfer job may not be hindered by problems in the restore activities. However, the next transfer job may be affected.

4. Transfer Error

Transfer errors may be of many types and of varying levels of severity. Any error that occurs must be reported to the host. If the error is caused by failure of a port mechanism, a transition to the hardware FAULT state should occur (see Section A1-1). The problem might also stem from a problem with the transfer specification or in the transfer recipe (i.e., specification is legal, but does not match that of the partner). If failure in the transfer hardware has occurred, the transfer job should transition to the PAUSED state and report it to the host. The host may choose to abort the transfer job, or correct the problem and resume the transfer job.

5. Timeouts

To ensure that all transfer problems are detected, the host should implement a process for timeout monitoring of transfer jobs. The timeout periods need only be very rough estimates of the actual times required for the transfer job (e.g., 2× or 3× actual). The host might choose to monitor individual atomic transfers if tighter tolerances are required. The goal is to ensure that problems are not left undetected over extended periods.

To determine the proper time to allow for a transfer job, the host would sum the estimated maximum times needed for the individual atomic transfers which make up the job[14] . The atomic transfer time estimates would typically be determined by experience, since they rely on the interactions of two different transfer partners. A doubling or tripling of the average observed transfer time would be a good estimate. In some cases, suppliers of dedicated transfer equipment may be able to supply reasonable estimates.

Transfer job timeout monitoring should begin with the receipt of the “Transfer Job Started” message and end with the “Transfer Job Complete” message (both via the TRJobAlert service). If the host is monitoring the atomic transfers, monitoring should begin at the “Atomic Transfer Started” event and end at the “Atomic Transfer Complete” event (both via the TRJobEvent service). The host must ensure that reporting of these events is enabled in this case.

If a transfer job exceeds the timeout period, the host may either pause the transfer job or attempt to end it with the stop command. The former may be preferred, since human intervention is required in either case and may enable a resume command to continue the transfer.

A1-3.2 *Micro Level Error Handling*

1. No Communication With Transfer Partner

If a transfer partner attempts to communicate with its transfer partner and finds that the communications link is not responding, it should inform the host via an event

14 This assumes that atomic transfers proceed sequentially. If they may proceed in parallel, the sequence for each port may be summed and the longest total chosen as the estimated time.

and continue to retry at intervals. Note that a disconnect may be normal in some cases where the link is only made when the transfer partners are in close proximity.

2. TRLink's Not Matched

If two transfer partners are attempting different handoffs using the same physical resources (locations, mechanisms, etc.), the host should be informed via an event. The partners shall continue to await an appropriate HOReady message—allowing the host to “fix” one or the other of the partners. If an equipment has no current transfer and it receives a HOReady message, it should hold that message until a transfer job is defined for it.

3. HOCommand Not Accepted

If the secondary transfer partner cannot accept a micro command from the primary partner, it should use the HOCommand Response message to inform the primary partner that the command was rejected. The primary partner may affect some recovery or inform the host that the transfer has failed.

4. HOCommand Failed in Execution

If the secondary transfer partner fails in the execution of an HOCommand, it should notify the primary partner of the problem. The primary partner may affect some recovery or inform the host that the transfer has failed.

5. Transfer Not Confirmed

If the secondary transfer partner sends a negative HOVerify Response message saying that the transfer object has not been properly transferred, the primary partner should not attempt recovery, but inform the host that the transfer has failed.

6. Timeout Awaiting Partner Readiness (HOReady)

Timeout Awaiting Micro Command Completion (HOCommand Response)

Timeout Awaiting Transfer Verify Response (HOVerify Response)

In some cases, action may be required if a transfer partner has been awaiting communication from its partner. The equipment should monitor timeout periods for each of the three cases. The factory user may need to customize the timeout periods for his/her factory. When a timeout occurs, the equipment should notify the host (via a TRJobEvent message) that the situation has occurred, reset the timer, and continue to await the partner. The host is responsible for taking any further action which is required (e.g., Stop or Pause command).

A1-4 *Practical Applications* — This section provides examples of practical applications of the material movement services as presented in this document. Four examples are provided below. Within these are presented some major variations expected in a factory situation. These are not exhaustive in scope, but the expectation is that reviewing these examples will help the reader understand how to apply these concepts to a real application. These examples are also not intended to represent a cohesive implementation strategy, but rather some alternatives that might be considered. AGVs are used in the examples below because they are familiar to most readers, not because they are favored over other transfer agents. To simplify the explanation, the examples below deal only with movement of cassettes.

A1-4.1 *Passive Transfer* — In this example, a transfer is to be performed between an AGV with robot arm and a piece of processing equipment. A cassette is to be picked up by the AGV for later delivery to another piece of equipment. The equipment has a cassette indexer and a port door, but no other port-related mechanism that would either aid or hinder transfer. The chosen transfer mechanism provides for the equipment to act as a passive transfer partner with no micro level communications required. This is called a passive transfer. The primary transfer partner is the AGV.

The setup for the equipment is to check to make sure that the correct material is in the specified port, drive the cassette elevator to the home position (if not already there), and open the port door. Note that the first two setup activities could have been designed to occur as a part of the micro level transfer if desired. The setup operations for the AGV are to ensure that its receiving port is empty and to drive to the transfer position in front of the designated equipment.

The transfer proceeds in the following steps:

1. The host sends a Transfer Job Create message to each transfer partner.
2. The partners each accept the transfer job.
3. The equipment both have the needed available resources so the transfer job immediately. Thus, Transfer Job Started messages are sent to the host by each.
4. Each partner in turn completes its setup activities for the atomic transfer, sends a “Committed To Transfer” event to the host, and then sends an HOReady message to its transfer partner (via the host).
5. Each partner sends the “Atomic Transfer Started” event to the host as soon as it determines that it has both sent and received an HOReady message for this handoff.

6. The AGV (as primary transfer partner) begins the transfer.
7. The AGV performs the transfer. Notice that no HOCommand messages are needed since this is a passive transfer.
8. The AGV sends an HOVerify message to the equipment via the host.
9. The equipment ensures that the cassette is no longer sensed in its port and then sends an HOVerify Response message (via the host) to the AGV, followed by an "Atomic Transfer Complete" event to the host.
10. Upon receipt of the HOVerify Response message, the AGV sends an "Atomic Transfer Complete" event to the host.
11. Each partner completes its RESTORE operations and then sends a Transfer Job Complete message to the host.

The transfer is now complete. The host may now direct the AGV to deliver the cassette to a new destination.

A1-4.2 *Active Transfer/Exchange of Cassettes* — This example addresses the situation where the factory control system needs to remove a processed lot from an equipment and immediately replace it with an unprocessed lot. The assumptions are that the processing of the lot on the equipment is nearing completion and that the AGV has already acquired the unprocessed lot that will next be placed on the equipment. Direct micro level communications exist between the AGV and the equipment. This will be an interactive transfer.

The setup operations for the equipment are opening the port door, driving the cassette indexer to the home position, and checking for the presence of the proper cassette. AGV setup is movement to the transfer location for that equipment. During the transfer, the equipment acts as the primary transfer partner, and will unclamp/clamp the cassette (clamps hold the cassette in the proper position). The AGV will interact with the equipment as the secondary transfer partner.

The transfer proceeds as follows:

1. The host sends Transfer Job Create requests to the equipment and to the AGV. The timing is chosen so that the time required for the AGV to travel to the equipment is approximately equal to the time left to complete processing of the lot to be transferred. The Transfer Job Create message to each contains two atomic transfers, the first dealing with the removal of the processed cassette from the equipment and the second dealing with the loading of the unprocessed cassette onto the equipment.
2. The AGV accepts the transfer job and begins the first atomic transfer immediately, sending a Transfer Job Started message to the host. Setup begins — the AGV begins traveling toward its transfer partner. The equipment accepts the transfer job and retains it for later execution.
3. When processing completes on the lot, the equipment begins the transfer job. It sends a Transfer Job Started message to the host and begins its setup operations for the first atomic transfer.
4. The AGV completes its setup activity and sends a "Committed To Transfer" event to the host. It also sends a HOReady message to the equipment.
5. The equipment completes its setup, then sends a "Committed to Transfer" event to the host and an HOReady message to the AGV.
6. Since the AGV had previously declared itself ready, the equipment sends an Atomic Transfer Started event to the host and starts the transfer.
7. The equipment begins by sending an HOCommand that results in the AGV reaching out and grasping the cassette.
8. Upon receiving the Command Complete message from the AGV, the equipment unclamps the cassette, allowing its removal.
9. The equipment sends an HOCommand that results in the AGV removing the cassette from the equipment. The material sent and material received events are sent to the host by the respective partners.
10. When the equipment receives the Command Complete message from the AGV, it considers the transfer to be complete. It sends the HOVerify message to the AGV.
11. The AGV sends the HOVerify Response message to the equipment.
12. Each of the transfer partners now determines that another atomic transfer is required in order to complete the transfer job.
13. Each transfer partner now transitions to the second atomic transfer. They each send "Atomic Transfer Complete" events.
14. Each transfer partner now begins the new setup phase. The AGV determines that it has already reached the transfer point and has the unprocessed cassette to be transferred. The equipment determines that the port is now empty, and that the door is open. This setup time was saved.

15. The second atomic transfer now proceeds in a similar fashion through steps 4–12 above. That done, since there are no further moves required, the restore stage begins, including “Atomic Transfer Complete” events to the host.

16. Once restore operations are complete, each sends a Transfer Job Complete message to the host. The transfer is now complete.

A1-4.3 *Sequential Moves* — In this example, the factory control system desires to move a cassette from equipment “A” to equipment “B” using a fixed robot stationed within reach of the two. Each piece of equipment has a static port and will act as passive transfer partners in all cases. The robot will act as the primary partner for all transfers. The host system must do the high-level planning of this move, determining that the lot to be transferred will be ready to go, that the robot is available, and that the receiving equipment is available to receive the cassette.

To accomplish the transfer, two atomic moves are required. First, the robot picks up the cassette at “A.” Second, the robot deposits the cassette on “B.” The gripper on the robot is considered its port in this case, since that is the point at which ownership of the cassette changes.

Since the step–by–step transfer details are similar to the first two examples, they will be omitted. However, a higher-level sequence will be given.

1. The host will send Transfer Job Create messages to “A,” “B,” and the robot. The robot will be given two sequential atomic moves to perform, the equipment one each. Note that the Transfer Job Create request to “B” could be delayed, if desired, until the completion of the first atomic move.

2. The first atomic transfer is performed: the robot removes the cassette from “A.” Note that no HOCommands are issued, since the secondary partner is passive.

3. The second atomic transfer is performed: the robot places the cassette on “B.”

4. Both “A,” “B,” and the robot deliver Transfer Job Complete messages to the host.

The transfer is complete.

An intelligent robot control system could combine the two atomic moves discussed above into a single robot program, achieving a more efficient transfer (e.g., no redundant movement during the transfer). In such a case, both “A” and “B” would need to be ready for transfer before the robot program was executed. The only limitation is that this combination would have to match the model and messaging discussed above.

A1-4.4 *Linked Lithography* — The final example is one where the micro level of material movement might be used without the macro level messaging described in this document. The linked lithography system described below is not patterned after any existing system and may not be the optimal implementation for such a system.

For this example, the challenge is to transfer wafers from a typical track system (following the coat/bake process) into a stepper for imaging, and then back to the track system for the develop process. In this example, the stepper acts as a slave to the track system, accepting wafers as they are given. The non–transfer-related communications will not be discussed.

In the wafer transfer process, the track takes on the macro level duties of the host. It is responsible for informing the stepper that a wafer is to be transferred, which wafer, and by what path and mechanism. It will initiate the transfer in a method analogous to the Transfer Job Create request. There is no transfer agent in this case. Either equipment might act as the primary transfer partner — it is irrelevant to this example.

The stepper and track will then exchange the normal micro communications. First, the HOReady messages will be sent. Next, the track will issue HOCommands to cause the wafer to be physically transferred. Finally, the HOVerify message transaction would occur. Meaningful events would be reported to the host as appropriate.

An alternative would be to design the system such that the track system tells the stepper system, in effect, “I'll be sending a series of wafers to you.” Since the HOReady message contains sufficient information to describe the transfer (assuming a specific transfer recipe is not required), no specifics about the individual transfers need be exchanged until the HOReady is sent. In such a scheme, the stepper would take the HOReady message as description of the specific transfer and respond with an HOReady to match.

A1-4.5 *Non–Compliant Transfer Partner* — There will be situations where only one of the transfer partners is compliant with this standard. It is reasonable to use this transfer methodology in some such cases, especially those involving passive transfer. The host would be responsible for emulating a compliant transfer partner on behalf of the non–compliant partner (for the benefit of the compliant partner). Examples of non–compliant transfer partners might include a WIP rack, a human transfer agent, an older process equipment, or any material handling systems that support other protocols.

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The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

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NOTE: The numbers in this index represent the section, table, and/or figure that contains the corresponding subject.

SEMI E32.1-0997
SECS-II SUPPORT FOR MATERIAL MOVEMENT

1 Introduction

This document contains the necessary information to implement the Material Movement Management standard using the SEMI E5 SECS-II communications protocol.

2 Service to Message Mapping

The table below lists each message service defined in the Material Movement standard with the SECS-II message which should be used to perform that service.

Service	*SECS-II Msg*	*Comments*
TRJobCreate	S4,F19[1]	
TRJobCreate Response	S4,F20	
TRJobCommand	S4,F21	
TRJobCommand Response	S4,F22	
TRJobAlert	S4,F23	
TRJobEvent	S6,F11[2]	Corresponding messages to enable reporting, create and link reports, etc. are also assumed.
GetAttribute	S1,F19[3]	
GetAttribute Response	S1,F20[3]	
HOReady	S4,F27	
HOCommand	S4,F29	
HOCommand Response	S4,F31	
HOVerify	S4,F33	
HOVerify Response	S4,F33	
HOCancelReady	S4,F35	
HOCancelReady Response	S4,F37	
HOHalt	S4,F39	
HOHalt Response	S4,F41	

[1] If the S4,F19 message is multi-block, it will require the S4,F25/F26 multi-block inquire/grant transaction.

[2] TRJobEvent is an unconfirmed service. While the required S6,F12 reply must be transferred by the protocol layer, there is no action required on the part of the host. Therefore, it shall be discarded rather than delivered to the application which employs this service.

[3] The GetAttributes request and response will be removed from E32 and E32.1 in 1998. This message transaction is replaced by GetAttr, S14F1/F2. See E39 and E39.1 for details.

3 Parameter to Data Item/Parameter Mapping

In the table below, each parameter used in the SEMI E32 messaging services is listed along with its corresponding SECS-II data item. In some cases, a parameter will correspond to a SECS-II list. These cases are noted.

SEMI E32 defines a number of message parameters as conditional. This means that under certain conditions, these parameters do not need to be included in the message. In SEMI E5, this is done by means of a zero length data item, or if the parameter is a list, a zero length list. Please refer to SEMI E5, “Zero Length Items and Lists,” Sections 6.2.1 and 6.3.1.

Parameter	*SECS-II Data Item*
AtomicSpec	List Structure
AttrData	ATTRDATA
AttributeID	ATTRID
CmdParameter	List Structure
CmdParmName	CPNAME
CmdParmValue	CPVAL
EQName	EQNAME
ErrorCode	ERRCODE
ErrorText	ERRTEXT
HOAck	HOACK
HOCancelAck	HOCANCELACK
HOCmdName	HOCMDNAME
HOHaltAck	HOHALTACK
HOStatus	List Structure
ObjectID	OBJID
ObjType	OBJTYPE
Status	List Structure
TRAck	TRACK
TRAtomicID	TRATOMICID
TRAutoStart	TRAUTOSTART
TRCmdName	TRCMDNAME
TRDirection	TRDIR
TREventData	List Structure (See S6,F11 in SEMI E5.)
TREventID	CEID
TRJobID	TRJOBID
TRJobMS	TRJOBMS
TRJobName	TRJOBNAME
TRLink	TRLINK
TRLocation	TRLOCATION
TRObjName	TROBJNAME
TRObjType	TROBJTYPE
TRPartner	TRPTNR
TRPartnerPort	TRPTPORT
TRPort	TRPORT
TRRecipe	TRRCP
TRRole	TRROLE
TRStatus	List Structure
TRType	TRTYPE

4 Collection Event List

The following collection events must be available for reporting from the equipment via S6,F11:

Committed To Transfer
Waiting for StartHandoff
Transfer Job Paused
Transfer Job Resumed
Atomic Transfer Started
Atomic Transfer Complete

Application Note — SECS-I Equipment-to-Equipment Link

The direct SECS-I link between equipment poses a small problem. That is, it is not clear which partner should be the “SECS-I host” and which the “SECS-I equipment.” As a general rule, if one partner is always the primary transfer partner, it should be configured as the SECS-I host. However, this is not a requirement, since in some cases the choice of which is the primary partner may depend upon the situation. Therefore, where SECS-I is used to link the transfer partners, each partner should be user-configurable as either “host” or “equipment.”

SEMI E36-0699
SEMICONDUCTOR EQUIPMENT MANUFACTURING INFORMATION TAGGING SPECIFICATION

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org February 1999; to be published June 1999. Originally published 1995; previous published revision February 1998.

This document replaces SEMI E36-0298 in its entirety.

NOTE: The Document Type Definitions, schemas, and documentation defined in other parts of Semiconductor Equipment Manufacturing Information Tagging may be used freely without permission or payment of royalties or other licensing charge, provided this source and/or its associated specifications are cited.

1 Purpose

The purpose of Semiconductor Equipment Manufacturing Information Tagging is to define a markup philosophy, a markup framework, and an information markup which is rich enough to facilitate:

- Electronic interchange and distribution of information;
- Quality hardcopy printing and screen display of information;
- Consistent high-precision online searching; and
- Reuse and repurposing of information for such applications as integrating source material into training material and online support applications.

The intent of this document is to create an information interchange specification, not an authoring specification or an electronic presentation specification. Semiconductor Equipment Manufacturing Information Tagging will define the markup necessary for exchanging documents electronically, for facilitating retrieval of information content, and for validating information interchanges.

2 Scope

2.1 *Information Scope* - Semiconductor Equipment Manufacturing Information Tagging is intended to cover the types of technical and commercial information typically needed to support the selection, installation, use, and maintenance of semiconductor manufacturing equipment.

The following list gives examples of information types within scope; this list is not exhaustive.

- *Operations Manuals/Guides* — typically used by equipment operators at customer sites to perform the tasks for which the equipment was designed.
- *Installation Manuals* — typically used by supplier and customer engineers to install the equipment at the customer site.
- *Maintenance Manuals* — typically used by trained maintenance technicians at customer sites to perform repair and upkeep of equipment.
- *Maintenance Schedules* — typically used by site coordinators and customer facility managers to schedule and document normal preventive maintenance.
- *Spares/Parts Lists* — typically used by on-site field service engineers and customers to maintain a sufficient stocking level to ensure prompt delivery of parts.
- *Repair/Troubleshooting Manuals* — typically used by equipment operators and qualified maintenance technicians to identify and correct equipment problems.
- *Release Notes* — typically used by operators, technicians and system administrators to identify changes in software configuration.
- *Training Manuals* — typically used by supplier training personnel and customers to train operators and maintenance technicians.

Additional information on potential use and re-use of these information types in electronic form can be found in the Auxiliary Information for this specification.

2.2 *Content of SEMI E36* - Semiconductor Equipment Manufacturing Information Tagging will be issued in three parts:

- this base document,
- associated information models such as SGML and XML Document Type Definitions (DTDs) and schema, and

- the documentation for these information models, including at least a comprehensive Tag Library.

Semiconductor Equipment Manufacturing Information Tagging does **not** include implementation advice, suggestions, or notes on how to implement the models described here. This material will be presented in the form of Auxiliary Information associated with Semiconductor Equipment Manufacturing Information Tagging.

Semiconductor Equipment Manufacturing Information Tagging by design does not include tutorials on SGML, XML, how to use the defined elements or modules, or how to create document content.

2.3 *SGML and XML* – Any documents marked up according to Semiconductor Equipment Manufacturing Information Tagging will be "valid" XML documents: that is, "well-formed" XML documents that have an associated document type declaration and that comply with the constraints expressed therein. Since valid XML documents are by definition type-valid SGML documents, such documents will be valid SGML documents as well.

Initially, information models will be maintained in both XML and SGML, with all changes made in parallel. SEMI will issue a dual set of models whenever a change is made, and both will always be (within the limits of their syntax) the same. Although parallel maintenance is unfortunate, it is intended to make it easier for members to create documents using current SGML or XML tools. As Web-SGML implementations and alternative XML schema syntax become more common, modules may be maintained in other syntactic forms.

2.4 *Examples of SEMI Content Specifications* - There are other SEMI standards and specifications that regulate the content of a document. Semiconductor Equipment Manufacturing Information Tagging is expressly not in conflict with any of them, since it specifies only how to identify the content present in the documents, and in some contexts, how to electronically structure the content. Semiconductor Equipment Manufacturing Information Tagging does not address what information is to be included. Examples of SEMI content-related or content guideline-related standards and specifications can be seen in section 7.

3 Referenced Documents

Semiconductor Equipment Manufacturing Information Tagging references the following information standards, which should be referred to in their entirety for full details:

3.1 *ISO Standards*[1]

International Standard for SGML; ISO-8879-1986 as modified by Amendment 1, of 1988

HyTime Standard ISO 10744 revision 2, which is referenced for hypertext linking

3.2 *Other references*[2]

The Extensible Markup Language (XML)V 1.0 Recommendation of the World Wide Web Consortium (W3C)

The draft W3C specifications for Extensible Linking Language (XLL).

4 Terminology

4.1 *Attribute* - An attribute is a markup construct that resides within the start tag of an element to provide additional information about the element. (Note: the start tag is the tag that is placed directly before the element in the datastream and determines where the element begins.)

4.2 *Conforming Authoring Application* - A conforming authoring application must be able to produce conforming documents. There is no requirement that all internal work in the application be performed in the markup described by Semiconductor Equipment Manufacturing Information Tagging, only that the end product, exported for interchange, must be a conforming document.

4.3 *Conforming Document* - A conforming document is one that meets the markup rules and specific information models defined in Semiconductor Equipment Manufacturing Information Tagging for the class of document. This specification comprises three parts: this base document, a set of information models, and the documentation for those models. A conforming document must conform to all three parts.

A conforming document created by one application must be interchangeable with a conforming application without significant information loss.

NOTE: Explicit rendering instructions such as font family and type size are not considered to be significant information.

4.4 *Conforming Element* - A conforming element is one that uses the names and markup rules defined in Semiconductor Equipment Manufacturing Information

[1] *ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genevè 20, Switzerland. http://www.iso.ch*

[2] *World Wide Web Consortium, Massachusetts Institute of Technology Laboratory for Computer Science, 545 Technology Square, Cambridge, MA 02139. http://www.w3.org*

Tagging for the class of element. A conforming element created by a conforming application must be interchangeable with another conforming application without information loss.

4.5 *Conforming Rendering Application* - Rendering (presentation) is the process and means by which the elements in a document shall be made visually or otherwise understandable to the end user, for example, printing a document on paper, browsing a series of elements on screen, or stating a series of elements through voice synthesis. A conforming rendering application must be able to print or display conforming documents without significant loss of information. The presentation should be consistent with the intent of the originating system.

A conforming rendering application may not impose structural requirements that are not required by the DTD or other document models as stated in the second part of Semiconductor Equipment Manufacturing Information Tagging. For example, a rendering engine may not require an element which is optional in the models or require an attribute that is implied. A rendering application may require that the rules in this Base Specification and those in the Tag Library are followed.

For example, if the DTDs say that an element is optional, a Rendering Application may not require that it be present. If the Tag Library says that the contents of an element must be some particular information, the Rendering Application may require that it be so. More specifically, if the <description> element is optional, a Rendering Application may not fail to process a document because it does not contain <description>s. If the Tag Library says that the contents of a "datechanged" attribute is a date in YYYYMMDD format, a Rendering Application may fail if the attribute does not contain a valid date.

4.6 *Document* - A logical assembly of elements, that, if correctly ordered, is a means of transmitting an internally consistent piece of information. A document is made up of one or more elements which must all be contained in one "root" element.

4.7 *Document Class* - A document class consists of all of the documents or information fragments that follow a single set of markup rules, including the same elements and element relationships. In general, a class of documents can be considered to be documents that are nearly the same in structure and have similar types of content. A document class is usually (but not necessarily) defined by a structural model (such as a DTD or Schema) that governs its existence.

4.8 *Document Exchange* - For SEMI E36, "document exchange" is synonymous with "document interchange" (see definition).

4.9 *Document Interchange* - Document interchange entails passing one or more elements, usually as a document, from one conforming system to one or more other systems (also known as "exchange").

4.10 *Document Model* - "Document model" is a term for a set of structural rules that describe the legal markup for a particular class of documents. DTDs and Schema are types of document models.

4.11 *Document Type Definition (DTD)* - A DTD is a document model or list of markup rules, which may be used in both SGML and XML. As specified in the SGML standard, ISO 8879, a DTD is:

> "Rules, determined by an application, that apply SGML to the markup of documents of a particular type. A document type definition includes a formal specification, expressed in a document type declaration, of the element types, element relationships and attributes and references that can be represented by markup. It thereby defines the vocabulary of the markup for which SGML defines the syntax." (ISO 8879 4.105)

4.12 *Element* - An element is one named, contiguous piece of information in the information stream. Usually the data within an element has a semantic or structural relationship as well, for example a person's surname, an error code, a pointer to external data, a paragraph, or a procedure that contains steps. In the previous version of this specification (i.e., in SEMI E36-95) an element is also referred to as an "information component."

An element is:

- A uniquely addressable unit of information within the document; and/or
- An identifier to an addressable unit of information outside the document.

4.13 *Markup* - For Semiconductor Equipment Manufacturing Information Tagging, markup is defined as additional data characters that are added to data to provide information about the data and make the data more useable. The markup described by Semiconductor Equipment Manufacturing Information Tagging is internal markup, that is, markup which resides in the same data stream as the data — in specific SGML and XML markup.

4.14 *Nonconforming Document* - A non-conforming document is one that does not use the markup properly or follow the markup rules defined in Semiconductor Equipment Manufacturing Information Tagging.

4.15 *SGML* - SGML is "Standard Generalized Markup Language." The Standard Generalized Markup Language is an International Organization for Standardization (ISO) standard. The ISO Reference Number is ISO 8879:1986(E). SGML is a meta-language for constructing markup. See also XML (Extensible Markup Language).

4.16 *Tag* - A tag is a string of characters delimited by rules set out in the SGML standard (and used in XML and HTML). Tags are placed in the datastream to indicate where an element begins and ends. In Semiconductor Equipment Manufacturing Information Tagging, tags match as closely as possible the names of the elements in English.

4.17 *XLL (Extensible Linking Language)* - When released, XLL is intended to be the syntax and semantics for both simple hypertext linking (as exemplified by HTML) and more complex linking, providing such functionality as multi-way links, multi-ended links, and addressing from an external document based on structure. A W3C Working Group is in the process of producing a draft specification, which uses many of the concepts from HyTime (Hypermedia/Time-based Document Representation Language ISO/IEC 10744) and the TEI (Text Encoding Initiative) extended pointers.

4.18 *XML (Extensible Markup Language)* - XML is a W3C Recommendation that describes a subset of SGML syntax and functionality intended for use on the World Wide Web. XML is, by design, simpler, less complex, and easier to implement than SGML. XML is also, by design, far less flexible than SGML because it includes only the most commonly implemented SGML features.

XML is a family of Recommendations that includes a linking specification (XLL); it may in the future include other specifications such as a stylesheet specification (XSL). The XLL linking specification will provide the syntax for hypertext links defined in Semiconductor Equipment Manufacturing Information Tagging. The XSL stylesheet language will be neither mandated nor prohibited in SEMI E36-98.

5 Design and Principles

5.1 *Information Markup* - For purposes of interchange, information will be marked-up according to the conventions established in Semiconductor Equipment Manufacturing Information Tagging. The defined markup will:

- Identify the start and end of elements, which may contain named information content or structural components;
- Provide information concerning the identified elements; and
- Specify connections among elements and between elements and external objects.

Applications will be able to utilize this markup to:

- Select, limit, and organize specific elements for reuse or interchange;
- Start and stop behavior, such as print formatting, complex screen display, and the actuation of programs;
- Limit retrieval (for increased precision);
- Generate navigation aids such as indexes and tables of contents; and
- Validate document structure or content.

5.2 *SGML Standard and XML Family of Recommendations* - The intent of Semiconductor Equipment Manufacturing Information Tagging is to define the rules and markup that can be used to create XML data (which is, by definition, SGML data) for maximum interchangeability and movement across both internets and intranets. Therefore all markup and rules will be designed to be fully conforming with the W3C XML Recommendation. It is also the intent to describe hypertext linking in conformance with the XLL (Extensible Linking Language), as much as it is known, and to migrate in the direction of that recommendation as the recommendation is finished.

Since the intent of Semiconductor Equipment Manufacturing Information Tagging is to create data that is both valid XML and type-valid SGML:

- The DTDs, which will be written in both SGML and XML syntax, will conform to the XML subset of SGML by not using features and syntax that XML prohibits such as exceptions and #CONREF attributes;
- Tagged data produced according to Semiconductor Equipment Manufacturing Information Tagging will be valid XML. Early implementers using SGML authoring or conversion tools should check with their tool suppliers to make sure those tools will work with their document without modification.

Names of elements, attributes, and entities will be used consistently within the SEMI E36 module set. While some elements may have different content models from module to module, and in fact that is the intent of the parameter entity framework, all name definitions and use will be consistent throughout the SEMI E36 DTD suite. This means that namespace issues, such as those addressed by the XML Namespace Recommendation (currently under development), are not relevant within the scope of SEMI E36. It is likely that mechanisms such as XML Namespaces will be used to incorporate parts of the SEMI E36 markup set in other applications; but this use is outside the scope of SEMI E36 itself.

5.3 *Specification for Interchange* - Semiconductor Equipment Manufacturing Information Tagging defines markup optimized for interchange, not for information development (authoring) nor for information presentation (rendering). Thus, some of the capabilities and functionality that might be desired for authoring or rendering will not be included in the markup rules, by design. For example, few elements may be required and the sequence of elements will not be tightly constrained.

It is anticipated that more specific authoring and rendering models may be developed by other parties as part of conforming applications. All conforming interchange, however, will explicitly follow the markup and structural rules defined in Semiconductor Equipment Manufacturing Information Tagging.

5.4 *General Modeling Principles*

- Document (information) models will be constructed that name the elements, describe the relationships among these elements, and impose certain markup or content constraints. The information markup will be controlled by these models.
- All models will be made available by SEMI and distributed and balloted as additional parts of Semiconductor Equipment Manufacturing Information Tagging. Models will be described in the second part of Semiconductor Equipment Manufacturing Information Tagging rather than included in the base document directly because the models are assumed to be dynamic documents that will grow and change as requirements alter. The data models and the Tag Library may be balloted separately without requiring a re-balloting of this part of the specification.
- The models will initially be in the form of SGML and XML Document Type Definitions (DTDs) and may later include other XML-defining schema.
- There will be no all-inclusive general information models; each DTD or other collection of rules will model specific elements or specific document types.
- Markup will be primarily designed according to the nature of the information being described; such considerations as data volume and ease of implementation will only be considered secondarily.
- DTDs will be constructed in a modular fashion, with content-related or structurally-related modules. The purpose of such modularization is to reuse existing information content models as much as possible. New element structures should be created only when new content is analyzed.

5.5 *Information Modeling*

5.5.1 *Types of Elements* - SGML and XML elements can identify many types of information. There are situations in which each of the following element types are appropriate, and many situations in which several could be used. In designing structures and tagging documents, elements should be designed using the following hierarchy of types, from most- to least-preferred. Only if the information cannot be satisfactorily identified using one type of element should those below it in the following list be considered.

- Content Elements — those that identify the information content, such as Warning, Procedural Step, Part Number, Installation Manual, or Bill of Materials.
- Structural Elements — those that identify the structural role of a part of a document, such as Title, Paragraph, or List Item.
- Pointer Elements — those that point to other locations, either in this document or another, such as Cross-reference, Footnote Reference, or URL.
- Format Elements — those that identify portions of a document that are to be formatted differently from surrounding text and for which there is no Content, Structural, or Pointing reason that they should be so formatted, for example a Bold element. Format elements are to be used as a last resort; use of a content, structure, or pointer element with a format-related attribute is preferable to use of a format element.

5.5.2 *Naming Elements* - Markup in the DTDs will be named consistently across contexts. That is, the same element name will be used for an element that can occur in many places with the same function, regardless of the location. For example, there is only one element for Title, not many separate elements for Section Title, Table Title, Figure Title, etc.

In XML, names are case-sensitive. In the interest of keeping compliant with XML, all names will be case-sensitive. (In SGML, names may not be case-sensitive since such names may be case-folded to upper case at any time.) All element tag names should be in lower case. Entity names and attribute names may be mixed case, lower case, or upper case to match common usage of the name involved. If there is no such consideration, lower case should be used. Attribute values should be in lower case unless there is a good reason to make them another case, such as a list of state or country codes which would naturally appear in upper case.

5.5.3 *Recursive Structures* - In cases where an element may contain one or more of the same elements within itself, there are several styles of modeling the solution:

- Use recursive structures. (In recursion, an element would be allowed to contain itself, thus a <section> could contain one or more <section>s, which could themselves contain <section>s, etc.);
- Create an explicit hierarchy by naming the top level and lower levels. (Thus a <section> could contain one or more <subsections>, which could themselves contain one or more <sub-subsections>, etc.); or
- Create an explicit hierarchy by numbering the top level as "1", and subsequent levels as "2", "3", etc. (Thus a <section1> could contain one or more <section2>s, which could themselves contain one or more <section3>s, etc.).

In such cases, recursion should be used to model an element because it is optimal for authoring, editing, and data reuse; in such an environment an editor can move a section from one level to another without needing to modify the tagging inside the section.

5.5.4 *Content Modeling* - To create SGML elements that are maximally re-useable and compatible with XML, there are several SGML modeling capabilities that are prohibited in SEMI E36:

- RCDATA and CDATA declared content (character data in which elements and entities cannot be recognized) are prohibited.
- The "AND" connector (which specifies that all the elements so connected are required but that order is irrelevant) is prohibited.
- Inclusions and Exclusions to content models are prohibited.
- Pernicious mixed element content is prohibited. This means that if an element model contains character data it must allow character data at any place in the model. In practice this means that any mixed content model groups should be repeatable "| " (or) groups.

In addition, the following rules also will apply:

- Each element must be declared separately;
- No inline comments or empty comments will be permitted; only full comment declarations may be used;
- The replacement text for external parameter entities must be well-formed, as per the XML specification declarations;
- The entity types CDATA, PI, and bracketed text are prohibited;
- No Marked Sections are allowed in the DTDs; and
- External entities must include both a SYSTEM and a PUBLIC identifier.

5.5.5 *Attributes* - The attribute list for each element must be declared separately. Attribute values must not contain references to external entities. If a Declared Value is not a specified list, only the following Declared Value keywords may be used:

- CDATA (character data);
- ID (a unique identifier for the element within its current document);
- IDREF and IDREFS (one or more pointer to the IDs of other elements within the same document);
- ENTITY or ENTITIES (the name of one or more defined entities); and
- NMTOKEN or NMTOKENS (one or more words that consist entirely of name characters).

On all attribute declarations, attribute values specified as defaults must be literals. Only the following Default Values keywords may be used:

- #REQUIRED (must be present);
- #IMPLIED (optional, may be implied by the application); and
- #FIXED (set, not able to be changed).

5.6 *Formatting from Element Context versus from Attributes* - The use of formatting attributes to indicate preferred rendition in display or print should be limited to situations in which no other mechanism is available. That is, if the desired formatting can be accomplished by use of the element name alone, or based on the context in which the element appears, no formatting attributes should be used. Elements should only carry formatting attributes such as "type-size" if there is no other mechanism to pass this information or if an author or editor, rather than the output system, must control the presentation directly. Formatting attributes, when used, should be optional and considered advisory by the rendering agent.

5.7 *Data Markup Rules* - To create SGML documents that are maximally re-useable and compatible with XML, the following restrictions are placed upon the tagged instances produced in accordance with Semiconductor Equipment Manufacturing Information Tagging:

- The characters “<” and “&” must always be escaped as “<” and “&” respectively.
- No Marked Sections will be allowed in data content.
- The replacement text of general text entities must be well-formed, for example, an element that starts within an entity must also end within it.
- All attributes should be present (even default attributes) and attribute values should be well-formed, that is with the name, equal sign, and quotation marks present.
- Processing Instructions are prohibited with the exception of the XML declaration, for example: <?XML version=″1.0″ RMD='INTERNAL'>.

6 How Semiconductor Equipment Manufacturing Information Tagging Should Be Used

6.1 *Conformance* - A conforming document is one that meets the markup rules defined for the document class in Semiconductor Equipment Manufacturing Information Tagging. A non-conforming document is one that does not use the markup properly or follow the markup rules defined in Semiconductor Equipment Manufacturing Information Tagging. A conforming document created by an application must be interchangeable with another conforming application without significant information loss. A conforming application may also deliver the markup rules (information models) for the document or information class being interchanged to another system.

Conforming applications are those that create, render, or work with conforming documents. Such applications may include browsers and online rendering software, print and composition engines, editors and authoring systems, search and retrieval engines, etc. In addition to strictly conforming applications, it is expected that many applications will accept conforming documents as input, converting them to the internal format of the software.

6.1.1 *Conforming Authoring Application* - A conforming authoring application must be able to produce conforming information. An application may state that it is conformant with Semiconductor Equipment Manufacturing Information Tagging if it has the ability to:

- Create and manipulate conforming documents;
- Create and manipulate one or more classes of conforming documents;
- Import conforming documents into the application and output matching conforming documents; or
- Turn non-conforming documents into conforming documents.

6.1.2 *Conforming Rendering Application* - There is no rendering specification stated or required by Semiconductor Equipment Manufacturing Information Tagging at this time. This specification does not define style conventions or endorse any particular language for the interchange of stylistic information. That said, a conforming rendering application is one that can render (print, display, pronounce, etc.) conforming documents without significant loss of information. The presentation should be consistent with the intent of the originating system, but need not be an exact, facsimile-reproduction match.

To call itself conforming, a rendering application must be able to take any conforming document, which is by definition legal according to this base specification and the models defined and explained in other parts of the specification, and render that document in some visual or non-visual fashion. A conforming rendering application may not impose additional requirements or constraints such as content requirements. For example, a rendering engine may not require the presence of an element that is optional in the models or require a more restrictive range of values for an attribute than the models state.

6.1.3 *Validation* - Documents tagged according to Semiconductor Equipment Manufacturing Information Tagging must parse cleanly according to their SGML or XML models and must follow the rules stated in this base document and the Tag Library and other documentation. Tagging validation must be accomplished through the use of validating SGML or XML parsers, in standalone form or as incorporated into other software packages. (Note: Validation of some of the rules described in this base document and the Tag Library documentation cannot be accomplished using only an XML or SGML parser. This does not mean that such rules can be ignored, merely that other validation techniques may be required.) SEMI E36 rules include both rules that can be checked with software and content rules that can only be verified intellectually; a conforming SEMI E36 document must conform to both types of rules.

6.2 *Maintenance of Semiconductor Equipment Manufacturing Information Tagging* - This base portion of the SEMI E36 specification is intended to be debated and balloted once and change little over time. Additional parts of the specification will contain the actual information models that describe the markup to be used. New information models may be proposed at any time. Such models will be distributed, discussed, and balloted individually or in small groups, in the form of one or more SEMI E36 modules, as they are created. Modules that are approved will be appended to Semiconductor Equipment Manufacturing Information Tagging. The documentation will be changed and balloted in parallel, to match any changes in the models.

6.2.1 *Module Library* - A growing module library containing all approved modules will be maintained, adding modules as additional subject areas and document types are defined. Once a module has been approved, it will be provided as part of Semiconductor Equipment Manufacturing Information Tagging. Place-holding modules may be introduced into the library that are designated as "Temporary", for use only until a formal analysis and balloting process can provide a more appropriate module. Initially modules will be XML and SGML DTDs and DTD fragments. As XML alternative modeling syntaxes such as schema become supported by software, these may be used to supplement SEMI E36 information models.

6.2.2 *Modules* - Each module will be given a unique short name (to be used as a file name), a version number, and a unique public identifier written according to the rules of ISO 8879 and incorporating the version number.

File names will be all lower case, constructed by concatenating the following, in order:

- A 3- to 8-character descriptive name;
- A hyphen;
- The file type as "xml" or "sgml";
- A period; and
- A 3-character descriptive extension that defines the type of file (such as "dec", "sgm", etc.) These extensions will be defined in the Tag Library.

Each module will contain:

- An initial comment which names the module, states the purpose of the modules, types the modules as Temporary or Implemented, and states how the module should be integrated with other modules;
- A growing change history comment that describes (in sedimentary order; that is, the most recent at the top) all modifications made to the model. Each item in the change history should be numbered, dated, provide a description of the change, give a brief rationale, and name the changing agent.
- Whatever syntax is employed, internal comments should be used throughout the module to name and describe the elements and provide information that may not be stated directly in the syntax used.

6.2.3 *Consolidated Tag Library* - A single, consolidated Tag Library will be maintained which will describe the elements, attributes, and entities defined in all the modules. Each description will contain sufficient detail to indicate the meaning and correct usage of the data markup. The library (or changes to the library) will be reissued whenever a module is added or modified in a way that affects any of the elements, attributes, or entities.

Modules should use elements (tags) that are already in the Tag Library wherever the definition of the element matches the need. If the definition of an existing tag does not meet the need, a new tag should be created.

A diagram of the structure of each element will be included in the Tag Library, except for elements that are empty, contain only character data, or contain a simple "or" group in which all contents may appear at any point in the model.

For each element, the Tag Library will contain:

- Element Title, consisting of its Tag and Name;
- Definition in clear, plain English, including description of intended use and application when appropriate;
- Remarks (if needed);
- Related Elements (if needed);
- For each Source, or module in which the element is defined:
    - Attributes Associated with the Element (if any);
    - The model of the Element in SGML syntax and narrative form;
    - Presentation information (if needed);
    - Formatted examples of the element (if needed);
    - Tagged examples of the elements (if needed); and
    - The Name of the Source, or module in which the element is defined.

For each Attribute, the Tag Library will contain:

- Attribute Title, consisting of the short form of the attribute which appears in the documents, and the attribute Name;
- Attribute usage, describing how that attribute is used;
- For each possible value of an attribute with a specified set of values, the meaning or implications of each value; and
- The default value of the attribute.

6.3 *Creation of More Specific Authoring or Rendering Models* - The DTDs and models described in Semiconductor Equipment Manufacturing Information Tagging will not be designed for optimal use in document creation. To create and display documents, data creators may wish to create more enforcing authoring models based on this markup. Such authoring models may:

- Require the presence of specific elements;
- Specify the sequence of elements; and/or
- Include additional elements for internal use (which would need to be removed before interchange). For example, such information might include elements for tracking the internal authoring and validation processes or for company-confidential information.

Similarly, it is likely that viewing, print rendition, search and retrieval, or other display applications will create display-only models based on Semiconductor Equipment Manufacturing Information Tagging. To load display tools, it is quite likely that the specified models will be transformed into a form that is optimized for the particular search and retrieval or display system. Such display models might:

- Resequence the data;
- Add additional markup such as "container" tags around structures to be considered one element for formatting purposes;
- Transform the form of some elements; or
- Remove parts of the information that are not relevant to a particular application.

7 Related Documents - SEMI Content Standards and Specifications

As described in section 2.4, the following list contains examples of SEMI content-related or content guideline-related standards and specifications.

SEMI C16 — Guide for Precision Reporting/Data Traceability

SEMI D9 — Definitions for Flat Panel Display Substrates

SEMI D13 — Terms and Definitions for FPD Color Filter Assemblies

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E35 — Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI G57 — Guideline for Standardization of Leadframe Terminology

SEMI M10 — Standard Nomenclature for Identification of Structures and Features Seen on Gallium Arsenide Wafers

SEMI P22 — Guidelines for Photomask Defect Classification and Size Definition

SEMI P29 — Guideline for Description of Characteristics Specific to Halftone/Attenuated Phase Shift Masks and Mask Blanks

SEMI P30 — Practice for Catalog Publication of Critical Dimension Measurement Scanning Electron Microscopes (CD-SEM)

SEMI S1 — Safety Guideline for Visual Hazard Alerts

SEMI S7 — Safety Guidelines for Environmental, Safety, and Health (ESH) Evaluation of Semiconductor Manufacturing Equipment

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

SEMI T6 — Procedure and Format for Reporting of Test Results by Electronic Data Interchange (EDI)

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E37-0702
HIGH-SPEED SECS MESSAGE SERVICES (HSMS) GENERIC SERVICES

1 Purpose

HSMS provides a means for independent manufacturers to produce implementations which can be connected and interoperate without requiring specific knowledge of one another.

HSMS is intended as an alternative to SEMI E4 (SECS-I) for applications where higher speed communication is needed or when a simple point-to-point topology is insufficient. SEMI E4 (SECS-I) can still be used in applications where these and other attributes of HSMS are not required.

HSMS is also intended as an alternative to SEMI E13 (SECS Message Services) for applications where TCP/IP is preferred over OSI.

It is intended that HSMS be supplemented by subsidiary standards which further specify details of its use or impose restrictions on its use in particular application domains.

2 Scope

High-Speed SECS Message Services (HSMS) defines a communication interface suitable for the exchange of messages between computers in a semiconductor factory.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communication Standard 1 — Message Transport (SECS-I)

SEMI E5 — SEMI Equipment Communication Standard 2 — Message Content (SECS-II)

3.2 *IETF Documents*[1]

IETF RFC 791 — Internet Protocol

IETF RFC 792 — Internet Control Message Protocol

IETF RFC 793 — Transmission Control Protocol

IETF RFC 1120 — Requirements for Internet Hosts - Communication Layers

IETF RFC 1340 — Assigned Numbers. Note: This RFC supersedes RFC 820.

3.3 *POSIX Document*[2]

IEEE POSIX P1003.12 — Protocol Independent Interfaces (PII)

4 Terminology

API — Application Program Interface. In the case of TCP/IP, a set of programming conventions used by an application program to prepare for or invoke TCP/IP capabilities.

communication failure — a failure in the communication link resulting from a transition to the NOT CONNECTED state from the SELECTED state. (See Section 9.)

confirmed service (HSMS) — an HSMS service requested by sending a message from the initiator to the responding entity which requires that completion of the service be indicated by a response message from the responding entity to the initiator.

connection — a logical linkage established on a TCP/IP LAN between two entities for the purposes of exchanging messages.

control message — an HSMS message used for the management of HSMS sessions between two entities.

data message — an HSMS message used for communication of application-specific data within an HSMS session. A Data Message can be a Primary Message or a Reply Message.

entity — an application program associated with an endpoint of a TCP/IP connection.

header — a 10-byte data element preceding every HSMS message.

initiator (HSMS) — the entity requesting an HSMS service. The initiator requests the service by sending an appropriate HSMS message.

IP Address — Internet Protocol Address. A logical address which uniquely identifies a particular attachment to a TCP/IP network.

local entity — relative to a particular end point of a connection, the local entity is that entity associated with that endpoint.

1 The IETF documents can be obtained from The Network Information Center, Network Solutions, 14700 Park Meadow Drive, Suite 200, Chantilly, VA 22021 USA

2 POSIX documents can be obtained from Institute of Electrical and Electronic Engineers (IEEE), 345 East 47th Street, New York, NY 10017 USA

local entity-specific — general qualifier to any procedure, option, issue, or other implementation matter which is not a subject of this standard and left to the discretion of the individual supplier.

message — a complete unit of communication in one direction. An HSMS Message consists of the Message Length, Message Header, and the Message Text. An HSMS Message can be a Data Message or a Control Message.

message length — a 4-byte unsigned integer field specifying the length of a message in bytes.

open transaction — a transaction in progress.

port — an endpoint of a TCP/IP connection whose complete network address is specified by an IP Address and TCP/IP Port number.

port number — (or TCP port number). The address of a port within an attachment to a TCP/IP network which can serve as an endpoint of a TCP/IP connection.

primary message — an HSMS Data Message with an odd numbered Function. Also, the first message of a data transaction.

published port — a TCP/IP IP Address and Port number associated with a particular entity (server) which that entity intends to use for receiving TCP/IP connection requests. An entity' s published port must be known by remote entities intending to initiate connections.

receiver — the HSMS Entity receiving a message.

remote entity — relative to a particular endpoint of a connection, the remote entity is the entity associated with the opposite endpoint of the connection.

reply — an HSMS Data Message with an even-numbered function. Also, the appropriate response to a Primary HSMS Data Message.

responding entity (HSMS) — the provider of an HSMS service. The responding entity receives a message from an initiator requesting the service. In the event of a confirmed service, the responding entity indicates completion of the requested service by sending an appropriate HSMS response message to the initiator of the request. In an unconfirmed service, the responding entity does not send a response message.

session — a relationship established between two entities for the purpose of exchanging HSMS messages.

session entity — an entity participating in an HSMS session.

session ID — a 16-bit unsigned integer which identifies a particular session between particular session entities.

stream (TCP/IP) — a sequence of bytes presented at one end of a TCP/IP connection for delivery to the other end. TCP/IP guarantees that the delivered sequence of bytes matches the presented stream. HSMS subdivides a stream into blocks of contiguous bytes - messages.

T3 — reply timeout in the HSMS protocol.

T5 — connect Separation Timeout in the HSMS protocol used to prevent excessive TCP/IP connect activity by providing a minimum time between the breaking, by an entity, of a TCP/IP connection or a failed attempt to establish one, and the attempt, by that same entity, to initiate a new TCP/IP connection.

T6 — control Timeout in the HSMS protocol which defines the maximum time an HSMS control transaction can remain open before a communications failure is considered to have occurred. A transaction is considered open from the time the initiator sends the required request message until the response message is received.

T7 — connection Idle Timeout in the HSMS protocol which defines the maximum amount of time which may transpire between the formation of a TCP/IP connection and the use of that connection for HSMS communications before a communications failure is considered to have occurred.

T8 — network Intercharacter Timeout in the HSMS protocol which defines the maximum amount of time which may transpire between the receipt of any two successive bytes of a complete HSMS message before a communications failure is considered to have occurred.

TCP/IP — Transmission Control Protocol/Internet Protocol. A method of communications which provides reliable, connection-oriented message exchange between computers within a network.

TLI — Transport Level Interface. One particular API provided by certain implementations of TCP/IP which provides a transport protocol and operating system independent definition of the use of any Transport Level protocol.

transaction — a Primary Message and its associated Reply message, if required. Also, an HSMS Control Message of the request (.req) type, and its response Control Message (.rsp), if required.

unconfirmed service (HSMS) — an HSMS service requested by sending a message from the initiator to the responding entity which requires no indication of completion from the responding entity.

5 HSMS Overview and State Diagram

High-Speed SECS Message Services (HSMS) defines a communication interface suitable for the exchange of messages between computers in a semiconductor factory using a TCP/IP environment. HSMS uses TCP/IP stream support, which provides reliable two way simultaneous transmision of streams of contiguous bytes. It can be used as a replacement for SECS-I communication as well as other more advanced communications environments.

The procedure for HSMS communications parallels the more familiar SECS-I communications it replaces. The following steps are followed for any communications (HSMS or otherwise):

1. Obtain a communications link between two entities. In SECS-I, this is the RS232 wire physically connecting host and equipment. In HSMS, the link is a TCP/IP connection obtained by the standard TCP/IP connect procedure. Note that the abstract term "entity" is used instead of "host" or "equipment." This is because, while HSMS is used for SECS-I replacement, it has more general applications as well. In a SECS-I replacement application, the "host" is an "entity" and the "equipment" is an "entity."

2. Establish the application protocol conventions to be used for exchanging data messages between two entities. For SECS-I, this step is implicit in the fact that semiconductor equipment is physically connected on the two ends of the wire: the protocol is SECS-II.

   In the case of HSMS, the communications link is a dynamically established TCP/IP connection on a physical link which may be shared with many other TCP/IP connections using protocols other than HSMS or connections using non TCP/IP protocols. HSMS adds a message exchange (called the Select procedure) which is used to confirm to both entities that the particular TCP/IP connection is to be used exlusively for HSMS communications.

3. Exchange Data. This is the normal intended purpose of the communications link. In both SECS-I and HSMS, the procedure is to exchange SECS-II encoded messages for the control of semiconductor equipment and/or processes. Data exchange normally continues until one or both of the entities are taken off-line for equipment-specific purposes, such as maintenance.

4. Formally end communications. In SECS-I, there is no formal requirement here; the equipment to be taken off-line stops communicating.

   In HSMS, a message exchange (either the "bilateral" Deselect procedure or the "unilateral" separate procedure) is used for both parties to confirm that the TCP/IP connection is no longer needed for HSMS communications.

5. Break the communications link. In SECS-I, this is done by physically unplugging the host or equipment from the communications cable, which only occurs during repair or physical reconfiguration of the factory network environment.

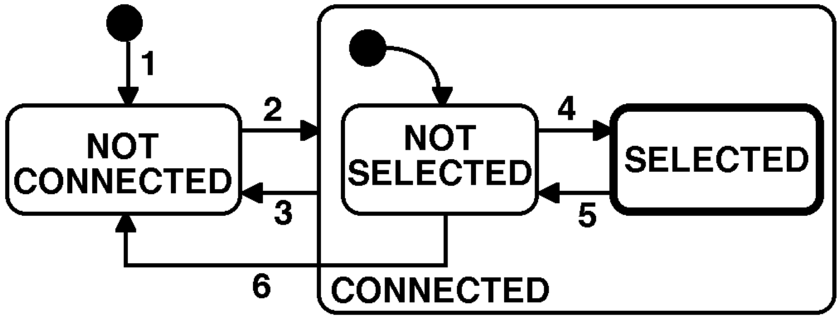
   In HSMS, since it uses the dynamic connection environment of TCP/IP, the TCP/IP connection is logically broken via a release or a disconnect procedure without any physical disconnect from the network medium.

Two additional procedures, of a diagnostic nature, are supported in HSMS, which are generally not required by a simple SECS-I link or a SECS-I direct replacement. These follow:

1. Linktest. This procedure provides a simple confirmation of connection integrity.

2. Reject. Because HSMS is intended to be extended to protocols other than just SECS-II (by means of subsidiary standards), it is possible that two entities can be connected (due to a configuration error) which use incompatible subsidiary standards. Also, during initial implementation, incorrect message types may be sent, or they may be sent out of order due to software bugs. The reject procedure is used to indicate such an occurrence.

5.1 *HSMS Connection State Diagram* — The HSMS state machine is illustrated in the diagram below. The behavior described in this diagram defines the basic requirements of HSMS: subsidiary standards may further extend these or other states.



5.2 *State Descriptions*

5.2.1 *NOT CONNECTED* — The entity is ready to listen for or initiate TCP/IP connections but either has not yet established any connections or all previously established TCP/IP connections have been terminated.

5.2.2 *CONNECTED* — A TCP/IP connection has been established. This state has two substates, NOT SELECTED and SELECTED.

5.2.2.1 *NOT SELECTED* — A substate of CONNECTED in which no HSMS session has been established or any previously established HSMS session has ended.

5.2.2.2 *SELECTED* — A substate of CONNECTED in which at least one HSMS session has been established. This is the normal "operating" state of HSMS: data messages may be exchanged in this state. It is highlighted by a heavy outline in the state diagram.

5.3 *State Transition Table*

Table 1

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comment*
1	...	Local entity-specific preparation for TCP/IP communication.	NOT CONNECTED	Local entity-specific	Action depends on connection procedure to be used: active or passive.
2	NOTCONNECTED	A TCP/IP connection is established for HSMS communication.	CONNECTED - NOT SELECTED	Local entity-specific	none
3	CONNECTED	Breaking of TCP connection.	NOT CONNECTED	Local entity-specific	See Section 6.4.
4	NOT SELECTED	Successful completion of HSMS Select Procedure.	SELECTED	Local entity-specific	HSMS communication is now fully established: data message exchange is permitted.
5	SELECTED	Successful completion of HSMS Deselect or Separate.	NOT SELECTED	Local entity-specific	This transition normally indicates the end of HSMS communication and so an entity would immediately proceed to break the TCP/IP connection (transition 3 above).
6	NOT SELECTED	T7 Connection Timeout.	NOT CORRECTED	Local entity-specific	per Section 9.2.2

6 Use of TCP/IP

6.1 *TCP/IP API* — The specification of a required TCP Application Program Interface (API) for use in implementations is outside the scope of HSMS. A given HSMS implementation may use any TCP/IP API — sockets, TLI (Transport Layer Interface), etc. — appropriate to the intended hardware and software platform, as long as it provides interoperable TCP/IP streams protocol on the network.

The appendix contains examples of the TCP/IP procedures referenced in this standard and sample scenarios using both the TLI (POSIX standard 1003.12) and the popular BSD socket model for TCP/IP communication.

6.2 *TCP/IP Network Addressing Conventions*

6.2.1 *IP Addresses* — Each physical TCP/IP connection to a given Local Area Network (LAN) must have a unique IP Address. IP Addresses must be assignable at installation time, and an HSMS implementation cannot select a fixed IP Address. A typical IP Address is 192.9.200.1.

IP imposes restrictions on these numbers which are outside the scope of the HSMS protocol. Consult Section 2.3 of RFC 791, Internet Protocol (IP) in Section 3.

6.2.2 *TCP Port Numbers* — A TCP Port Number can be considered as an extension of the IP Address.

HSMS implementations should allow configuring TCP Port to the full range of the TCP/IP implementation used. A typical TCP Port Number is 5000.

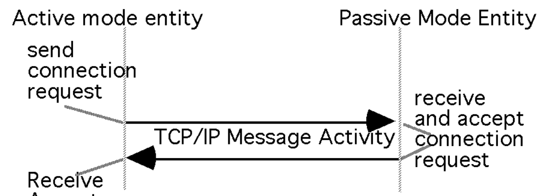
Conventions have been established for selecting TCP Port Numbers which are outside the scope of the HSMS protocol. Consult RFC 793, Transmission Control Protocol (TCP) in Section 3.

6.3 *Establishing a TCP/IP Connection*

6.3.1 *Connect Modes* — The procedures for establishing a TCP/IP connection are defined in RFC 793. However, not all the procedures defined by RFC 793 are supported by commonly available APIs. In particular, while RFC 793 permits both entities to initiate the connection simultaneously, this feature is rarely supported in available

APIs. Therefore, HSMS restricts an entity to one of the following modes:

- Passive Mode. The Passive mode is used when the local entity listens for and accepts a connect procedure initiated by the Remote Entity.
- Active Mode. The Active mode is used when the connect procedure is initiated by the Local Entity.



TCP/IP Connection Procedure Summary

The appendix provides an example of how an entity may operate alternately in the active and passive modes to achieve greater flexibility in establishing communications.

6.3.2 *Passive Mode Connect Procedure* — The procedure followed by the Passive Local Entity is defined in RFC 793. It is summarized as follows:

1. Obtain a connection endpoint and bind it to a published port.
2. Listen for an incoming connect request to the published port from a remote entity.
3. Upon receipt of a connect request, acknowledge it and indicate acceptance of the connection. At this point, the connect procedure has completed successfully, and the CONNECTED state is entered (Section 5).

These procedures are carried out through the API of the local entity' s implementation of TCP/IP. The appendices provide the API-specific procedures for the above steps using both TLI and BSD.

NOTE: A failure may occur during the above steps. The reason for failure may be local entity-specific or may be due to a lack of any connect request after a local entity-specific timeout. The action to be taken (for example: return to step 1 to retry) is a local entity-specific issue.

NOTE: See Section 9, Special Considerations, for issues relating to multiple connection requests to the same passive mode entity.

6.3.3 *Active Mode Connect Procedure* — The procedure followed by the Active Local Entity is defined in RFC 793. It is summarized as follows:

1. Obtain a connection endpoint.
2. Initiate a connection to the published port of a passive mode remote entity.
3. Wait for the receipt of the acknowledge and the acceptance of the connect request from the remote entity. Receipt of the acceptance from the remote

entity indicates successful completion of the connect procedure, and the CONNECTED state is entered (Section 5).

These procedures are carried out through the API of the local entity' s implementation of TCP/IP. The appendix provides the API-specific procedures for the above steps using both TLI and BSD.

NOTE: A failure may occur during the above steps. The reason for failure may be local entity-specific or may be due to a lack of any accept message after a local entity-specific timeout. The action to be taken is a local entity-specific issue. If, however, the local entity intends to retry the connection, it should do so subject to the T5 connect separation timeout (see "Special Considerations").

6.4 *Terminating a TCP/IP Connection* — Connection termination is the logical inverse of Connection establishment. From the Local Entity' s perspective, a TCP/IP connection may be broken at any time. However, HSMS only permits termination of the connection when the connection is in the NOT SELECTED substate of the CONNECTED state.

The procedures for termination of a connection are defined in RFC 793. Either entity may initiate termination of the connection. The NOT CONNECTED state is entered, indicating the end of HSMS communications. The appendix illustrates the procedures for both release and disconnect using the TLI and BSD APIs.

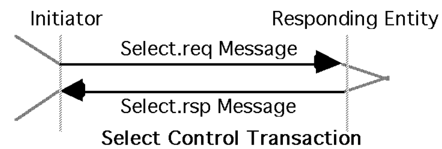
7 HSMS Message Exchange Procedures

HSMS defines the procedures for all message exchange between entities across the TCP/IP connection established according to the procedures in the previous section. As explained in the overview, once the connection is established, the two entities establish HSMS communications with the Select procedure. Then data messages may be exchanged in either direction at any time. When the entities wish to end HSMS communications, the Deselect or Separate procedure is used to end HSMS communications.

7.1 *Sending and Receiving HSMS Messages* — All HSMS procedures involve the exchange of HSMS messages. These messages are sent and received as TCP/IP streams using the previously established TCP/IP connection at standard priority. In particular, the use of "Urgent" data is not supported under HSMS (see RFC 793 for more information on send and receive procedures).

The appendix gives examples of sending and receiving HSMS messages using both TLI and BSD socket APIs.

7.2 *Select Procedure* — The Select procedure is used to establish HSMS communications on a TCP/IP connection using the Select.req and Select.rsp messages in a control transaction.



Although HSMS permits Select at any time in the CONNECTED state, subsidiary standards may further require the connection to be in the NOT SELECTED substate (see "Special Considerations").

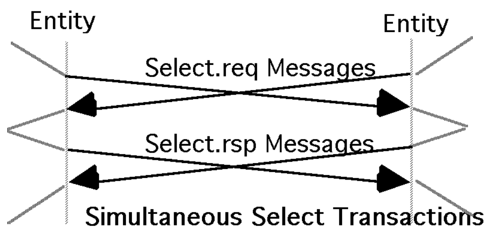
7.2.1 *Initiator Procedure* — The procedure followed by the initiator is as follows.

1. The initiator of the select procedure sends the Select.req message to the responding entity.
2. If the initiator receives a Select.rsp with a Select Status of 0, The HSMS Select procedure completes successfully and the SELECTED state is entered (see Section 5).
3. If the initiator receives a Select.rsp with a non-zero Select Status, the Select completes unsuccessfully (no state transitions).
4. If the T6 timeout expires in the initiator before receipt of a Select.rsp, it is considered a communications failure (see "Special Considerations").

7.2.2 *Responding Entity Procedure* — The procedure followed by the responding entity is as follows.

1. The responding entity receives the Select.req.
2. If the responding entity is able to accept the select, it transmits the Select.rsp with a Select Status of 0. The HSMS Select Procedure for the responding entity is successfully completed, and the SELECTED state is entered (see Section 5).
3. If the responding entity is unable to permit the select, it transmits the Select.rsp with a non-zero Select Status. The HSMS Select Procedure for the responding entity completes unsuccessfully (no state transitions).

7.2.3 *Simultaneous Select Procedures* — If the subsidiary standards do not restrict the use of the Select, it is possible that both entities simultaneously initiate Select Procedures with identical SessionID's. In such a case, each entity will accept the other entity' s select request by responding with a Select.rsp.

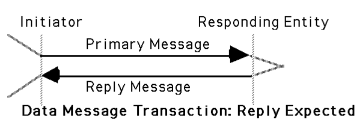


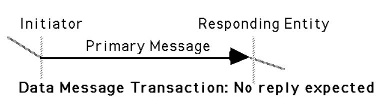
7.3 *Data Procedure* — HSMS data messages may be initiated by either entity as long as the connection is in the SELECTED state. Receipt of a data message when not in the SELECTED state will result in a reject procedure (see Section 7.7).

Data messages may be further defined as part of a data transaction as either a "Primary" or "Reply" data message. In a data transaction, the initiator of the transaction sends a primary message to the responding entity. If the Primary message indicates that a reply is expected, a Reply message is sent by the responding entity in response to the Primary.

The following types of Data Transactions are supported:

1. Primary Message with reply expected and the associated Reply Message.
2. Primary Message with no reply expected.

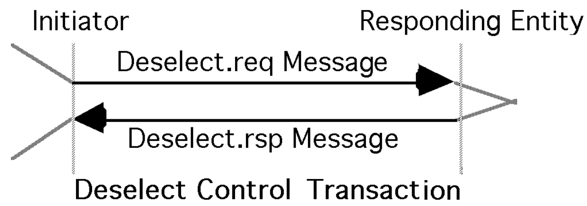




The specific procedures for these transactions are determined by the application layer and are subject to other standards (for example, E5 and E30 for GEM equipment using SECS-II encoded messages).

The applicable upper layer standard is identified by the message type. The type is determined from the specific format defined in Section 8. The normal type for HSMS messages is SECS-II text. Also refer to "Special Considerations" concerning the T3 Reply Timeout.

7.4 *Deselect Procedure* — The Deselect procedure is used to provide a graceful end to HSMS communication for an entity prior to breaking the TCP/IP connection. HSMS requires that the connection be in the SELECTED state. The procedure is as follows.



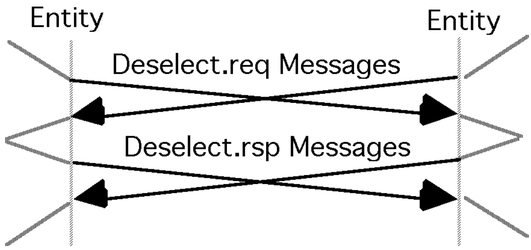
7.4.1 *Initiator Procedure*

1. The initiator of the Deselect procedure sends the Deselect.req message to the responding entity.
2. If the initiator receives a Deselect.rsp with a Deselect Status of 0, its Deselect procedure terminates successfully. The NOT SELECTED state is entered (see Section 5).
3. If the initiator receives a Deselect.rsp with a non-zero Deselect Status, its Deselect procedure terminates unsuccessfully. No state change occurs.
4. If the T6 timeout expires in the initiator before receipt of a Deselect.rsp, it is considered a communications failure (see "Special Considerations").

7.4.2 *Responding Entity Procedure*

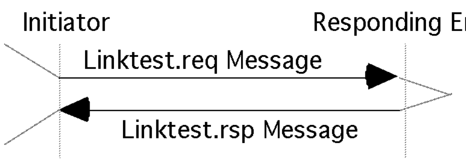
1. The responding entity receives the Deselect.req message.
2. If the responding entity is in the SELECTED state, and if it is able to permit the Deselect, it responds using the Deselect.rsp with a zero response code. The responding entity' s Deselect procedure completes successfully. The NOT SELECTED state is entered (see Section 5).
3. If the responding entity is unable to permit the Deselect, either because it is not in the SELECTED state or because local conditions do not permit the Deselect, it responds using the Deselect.rsp with a non-zero response code. The responding entity' s Deselect procedure terminates unsuccessfully. No state change occurs.

7.4.3 *Simultaneous Deselect Procedures* — If the subsidiary standards do not restrict the use of the Deselect, it is possible that both entities simultaneously initiate Deselect Procedures with identical SessionID's. In such a case, each entity will accept the other entity' s Deselect request by responding with the deselect.rsp.



Simultaneous Deselect Transactions

7.5 *Linktest Procedure* — The Linktest is used to determine the operational integrity of TCP/IP and HSMS communications. Its use is valid anytime in the CONNECTED state.



Linktest Control Transaction

7.5.1 *Initiator Procedure*

1. The initiator of the Linktest procedure sends the Linktest.req message to the responding entity.
2. If the initiator receives a Linktest.rsp within the T6 timeout, the Linktest is successfully completed.
3. If the T6 timeout expires in the initiator before receipt of a Linktest.rsp, it is considered a communications failure (see "Special Considerations").

7.5.2 *Responding Entity Procedure*

1. The responding entity receives the Linktest.req from the initiator.
2. The responding entity sends a Linktest.rsp.

7.6 *Separate Procedure* — The Separate procedure is used to abruptly terminate HSMS communication for an entity prior to breaking the TCP/IP Connection. HSMS requires that the connection be in the SELECTED state when using Separate. The responding entity does not send a response and is required to terminate communications regardless of its local state. The procedure is as follows.

Separate Control Transaction

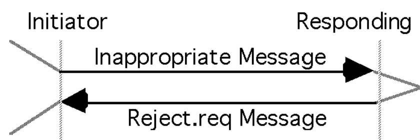
7.6.1 *Initiator Procedure*

1. The initiator of the select procedure sends the Separate.req message to the responding entity. The initiator' s Separate procedure completes successfully. The NOT SELECTED state is entered (see Section 5).

7.6.2 *Responding Entity Procedure*

1. The responding entity receives the Separate.req from the initiator.
2. If the responding entity is in the SELECTED state, its Separate procedure completes successfully.
3. If the responding entity is not in the SELECTED state, the Separate.req is ignored.

7.7 *Reject Procedure* — The Reject procedure is used in response to an otherwise valid HSMS message received in an inappropriate context. Supporting the reject procedure can provide useful diagnostic information during the development of a distributed application using HSMS. The procedure is as follows:



Reject Transaction

7.7.1 *Initiator (Sender of Inappropriate Message) Procedure*

1. The initiator of the inappropriate message, upon receiving the Reject.req, takes appropriate action (local entity-specific).

7.7.2 *Responding Entity Procedure*

1. The entity receiving the inappropriate message responds with a Reject.req message.

HSMS requires the reject procedure for the receipt of a data message in the NOT SELECTED state, or the receipt of a message whose SType or PType (see next section: Message Format) is not defined for the entity receiving the message. Subsidiary standards may define other conditions which require the Reject Procedure. In general, receipt of a reject message is an indication of an improperly configured system or a software programming error.

8 HSMS Message Format

This section defines the detailed format of the messages used by the procedures in the previous section.

8.1 *General Message Format*

8.1.1 *Byte Structure* — Within HSMS, a byte contains eight (8) bits. The bits in a byte are numbered from Bit 7 (most significant) to Bit 0 (least significant).

8.1.2 *Message Format* — An HSMS Message is transmitted as a single contiguous stream of bytes in the following order:

Table 2 HSMS Message Format

Number of Bytes	*Description*
4 Bytes	Message Length. MSB First. Specifies the number of bytes in the Message Header plus the Message Text.
10 Bytes	Message Header.
0–n Bytes	Message Text. Format is further specified by PType field of message header.

8.1.3 *Message Length* — Message Length is a four-byte unsigned integer value which specifies the length in bytes of the Message Header plus the Message Text. Message Length is transmitted most significant byte (MSB) first and least significant byte (LSB) last.

The minimum possible Message Length is 10 (Header only). The maximum possible Message Length is implementation-specific.

8.1.4 *Message Header* — The Message Header is a ten-byte field. The bytes in the header are numbered from byte 0 (first byte transmitted) to byte 9 (last byte transmitted). The format of the Message Header is as follows:

Table 3 HSMS Message Header

Bytes	*Description*
0–1	Session ID (Device ID)
2	Header Byte 2
3	Header Byte 3
4	PType
5	SType
6–9	System Bytes

The physical byte order is designed to correspond as closely as possible to the SECS-I header.

8.1.4.1 *Session ID* — Session ID is a 16-bit unsigned integer value, which occupies bytes 0 and 1 of the header (byte 0 is MSB, 1 is LSB). Its purpose is to provide an association by reference between control messages (particularly Select and Deselect) and subsequent data messages. It is the role of HSMS subsidiary standards to specify this association further.

8.1.4.2 *Header Byte 2* — This header byte is used in different ways for different HSMS messages. For Control Messages (see SType, below) it contains zero or a status code. For a Data Message whose PType (see below) = 0, it contains the W-Bit and SECS Stream. For a Data Message with PType not equal to 0, see "Special Considerations."

8.1.4.3 *Header Byte 3* — This header byte is used in different ways for different HSMS messages. For Control Messages, it contains zero or a status code. For a Data Message whose PType (see below) = 0, it contains the SECS Function. For a Data Message with PType not equal to 0, see "Special Considerations."

8.1.4.4 *PType* — PType (Presentation Type) is an 8-bit unsigned integer value which occupies byte 4 of the header. PType is intended as an enumerated type defining the presentation layer message type: how the Message Header and Message Text are encoded. Only PType = 0 is defined by HSMS to mean SECS-II message encoding. For non-zero PType values, see "Special Considerations."

Table 4 PType

Value	*Description*
0	SECS-II Encoding
1–127	Reserved for subsidiary standards
128–255	Reserved, not used

8.1.4.5 *SType* — SType (Session Type) is a one-byte unsigned integer value which occupies header byte 5.

SType is an enumerated type identifying whether this message is an HSMS Data Message (value = 0) or one of the HSMS Control Messages (other). Those values not explicitly defined in the table are addressed in "Special Considerations."

Table 5 SType

Value	*Description*
0	Data Message
1	Select.req
2	Select.rsp
3	Deselect.req
4	Deselect.rsp
5	Linktest.req
6	Linktest.rsp
7	Reject.req
8	(not used)
9	Separate.req
10	(not used)
11–127	Reserved for subsidiary standards
128–255	Reserved, not used

8.1.4.6 *System Bytes* — System Bytes is a four-byte field occupying header bytes 6-9. System Bytes is used to identify a transaction uniquely among the set of open transactions.

Uniqueness — The System Bytes of a Primary Data Message, Select.req, Deselect.req, or Linktest.req message must be unique from those of all other currently open transactions initiated from the same end of the connection. They must also be unique from those of the most recently completed transaction.

Reply Message — The System Bytes of a Reply Data Message must be the same as those of the corresponding Primary Message. The System Bytes of a Select.rsp, Deselect.rsp, or Linktest.rsp must be the same as those of the respective ".req" message.

8.2 *HSMS Message Formats by Type* — The specific interpretation of the header bytes in an HSMS message is dependent on the specific HSMS message type as defined by the value of the SType field. The complete set of messages defined is summarized in the table below, shown for PType = 0 (SECS-II message format).

Table 6 HSMS Message Format Summary

	Message Header						
Message Type	*Bytes 0-1 SessionID*	*Byte 2*	*Byte 3*	*Byte 4 PType*	*Byte 5 SType*	*Bytes 6–9 System Bytes*	*Message Text*
Data Message	*	W-bit and SECS Stream	SECS Function	0	0	Primary: UniqueReply: Same as primary	Text
Select.req	*	0	0	0	1	Unique	none
Select.rsp	Same as .req	0	Select Status	0	2	Same as .req	none
Deselect.req	*	0	0	0	3	Unique	none
Deselect.rsp	Same as .req	0	Deselect Status	0	4	Same as .req	none
Linktest.req	0xFFFF	0	0	0	5	Unique	none
Linktest.rsp	0xFFFF	0	0	0	6	Same as .req	none
Reject.req	same as message being rejected	PType or SType of message being rejected	Reason Code	0	7	Same as message being rejected	none
Separate.req	*	0	0	0	9	Unique	none

* Indicates further specification by subsidiary standards.

8.2.1 *SType=0: Data Message* — An HSMS message with SType = 0 is used by the HSMS Data procedure to send a Data message, either Primary or Reply. The message format is as follows:

HSMS Message Length is always 10 (the length of the header alone) or greater.

The HSMS Message Header is as follows:

Session ID — As described above. Specific value subject to subsidiary standards.

Header Byte 2 — For messages with PType value = 0 (SECS-II), header byte 2 is formatted as shown below.

7	6 0
W-Bit	Stream

The most significant bit (bit 7) of Header Byte 2 is the W-Bit. In a Primary Message, the W-Bit indicates whether the Primary Message expects a Reply message. A Primary Message which expects a Reply should set the W-Bit to 1. A Primary Message which does not expect a Reply should set the W-Bit to 0. A Reply Message should always set the W-Bit to 0. The low-order 7 bits (bits 6-0) of Header Byte 2 contain the SECS Stream for the message. The Stream is a 7-bit unsigned integer value, which identifies a major topic of the message, and its use is defined within SEMI E5 (SECS-II).

Header Byte 3 — For messages whose PType value=0, header Byte 3 contains the SECS Function for the message. The Function is an 8-bit unsigned integer value which identifies a minor topic of the message (within the Stream), and its use is defined within SEMI E5 (SECS-II). The least significant bit (bit 0) of the Function defines whether the Data Message is Primary or Reply; the value 1 indicates Primary and the value 0 indicates Reply.

PType — Set PType = 0 for SECS-II messages.

SType = 0

System Bytes — For PType=0 (SECS-II), the following definition applies. For a Primary Message, System Bytes contain a value uniquely identifying this transaction from all other open transactions initiated from the same end of the Connection. For a Reply Message, System Bytes contain the same value as the corresponding Primary Message.

The HSMS Message Text contains the text of the Data Message (if any), formatted as specified by the PType field. For PType = 0, the text will be formatted as SECS-II messages.

NOTE 4: Some Data Messages consist of header only, with no text.

8.2.2 *SType=1: Select.req* — An HSMS message with SType 1 is a “Select Request” Control Message, which is used by the initiator of the procedure for establishing HSMS communications. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID — As described above. Specific value subject to subsidiary standards.

Header Byte 2 = 0

Header Byte 3 = 0

PType = 0.

SType = 1

System Bytes — A unique value among open transactions.

8.2.3 *SType=2: Select.rsp* — An HSMS message with SType 2 is a “Select Response” Control Message, used as the response to a Select.req Control message in the procedure for establishing HSMS communications. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID — must be equal to the value of the session ID in the corresponding Select.req.

Header Byte 2 =0

Header Byte 3 — SelectStatus. A code of zero indicates success of the Select operation. A non-zero code indicates failure.

Table 7 SelectStatus

Value	*Description*
0	Communication Established. Select was successfully completed.
1	Communication Already Active. A previous select has already established communications to the entity being selected in this select.
2	Connection Not Ready. The Connection is not yet ready to accept select requests.
3	Connect Exhaust. The connection was accepted, but the entity is already servicing a separate TCP/IP connection and is unable to service more than one at any given time.

Value	*Description*
4–127	Reserved for subsidiary standard-specific reasons for select failure.
128–255	Reserved for local entity-specific reasons for select failure.

PType = 0

SType = 2

System Bytes — Equal to value of System Bytes in the corresponding Select.req.

8.2.4 *SType=3: Deselect.req* — An HSMS message with SType 3 is a "Deselect Request" Control Message, used by the initiator of the Select procedure for ending HSMS communication. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID — The SessionID must match the value of the SessionID of a previously sent Select.req to indicate the particular HSMS session that is ending. Subject to further specification by subsidiary standards.

Header Byte 2 = 0

Header Byte 3 = 0

PType = 0

SType = 3

System Bytes — A unique value among open transactions.

8.2.5 *SType=4: Deselect.rsp* — An HSMS message with SType 4 is a "Deselect Response" Control Message, used as the response to a Deselect.req Control message in the Deselect procedure for ending HSMS communications. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID — must equal the session ID in the corresponding Deselect.req

Header Byte 2 = 0

Header Byte 3 — DeselectStatus. A code of zero indicates success of the Deselect operation. A non-zero code indicates failure.

Table 8

Value	*Description*
0	Communication Ended. The Deselect completed successfully.
1	Communication Not Established. HSMS communications has not yet been established with a select, or has already been ended with a previous Deselect.
2	Communication Busy. The session is still in use by the responding entity and so it cannot yet relinquish it gracefully. In this case, if the original requester must terminate communications, the separate procedure should be used as a last resort.
3–127	Reserved for subsidiary standard-specific reasons for Deselect failure.
128–255	Reserved for local entity-specific reasons for Deselect failure.

PType = 0

SType = 4

System Bytes — Equal to System Bytes in corresponding Deselect.req.

8.2.6 *SType=5: Linktest.req* — An HSMS message with SType 5 is a "Linktest Request" Control Message. It is used to verify the integrity of the HSMS Connection, or as a periodic heartbeat. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID = 0xFFFF (in binary, all ones)

Header Byte 2 = 0

Header Byte 3 = 0

PType = 0

SType = 5

System Bytes — A unique value among open transactions.

8.2.7 *SType=6: Linktest.rsp* — An HSMS message with SType 6 is a "Linktest Response" Control Message, used as the response to a Linktest.req Control message in the Linktest Procedure. The message format is as follows:

Message Length is always 10 (Header only).

The HSMS Message Header is as follows:

SessionID = 0xFFFF (binary, all ones)

Header Byte 2 = 0

Header Byte 3 = 0

PType = 0

SType = 6

System Bytes — Equal to System Bytes in corresponding Linktest.req.

8.2.8 *SType=7: Reject.req* — An HSMS message with SType 7 is used in response to any valid HSMS message received which is not supported by the receiver of the message or which is not valid at the time. It is intended for dealing with attempts to use subsidiary standards or user-defined extensions which are not supported by the receiver (for example, SType equal to any value not defined in this standard). It must be used when an entity receives a control message which is a response (even numbered SType) for which there was no corresponding open transaction.

The HSMS Message Header is as follows:

SessionID — equal to the value of the Session ID in the message being rejected.

Header Byte 2 — For ReasonCode = PType Not Supported, equal to the PType in the message being rejected. Otherwise equal to the value of the SType in the message being rejected.

Header Byte 3 — reason code (always non-zero)

Table 9 ReasonCode

Value	*Description*
1	SType Not Supported. A message was received whose SType value not defined in the HSMS standard or the particular subsidiary standard(s) supported by the entity.
2	PType Not Supported. As above, but for PType.
3	Transaction Not Open. A Response control message was received when there was no outstanding request message which corresponded to it.
4	Entity Not Selected. A data message was received when not in the SELECTED state.
4–127	Reserved for subsidiary standard-specific reasons for reject.
128–255	Reserved for local entity-specific reasons for reject.

PType = 0

SType = 7

System Bytes — Equal to System Bytes in corresponding message being rejected.

8.2.9 *SType=9: Separate.req* — An HSMS message with SType = 9 is used to terminate HSMS communications immediately. With the exception of the SType value, it is identical to the Deselect.req message. Its purpose is to end HSMS communications immediately and without exception. No response is defined.

9 Special Considerations

9.1 *General Considerations*

9.1.1 *Communications Failures* — If a communications failure is detected, the entity should terminate the TCP/IP connection. Upon termination of the connection, the entity may, at this point, attempt to reestablish communications.

9.2 *TCP/IP Considerations*

9.2.1 *Connect Separation Time (T5)* — The connect procedures initiate some network activity. Frequent use of the active mode connect procedure to the IP Address and Port Number of an entity not yet ready to accept connections can be hostile to TCP/IP operations. The passive mode does not generate network activity and is not considered hostile to the network, although it may affect local application performance. An Entity initiating a connection in the active mode should limit its use of the connect procedure in a manner that is equivalent to the procedure described here.

After an active connect procedure terminates by any means (successfully or unsuccessfully), the Entity should not initiate another active connect procedure (for the same Remote Entity) until the T5 Connect Separation Time has elapsed. The separation of connect operations will be the sum of the T5 Connect Separation Time interval, plus the duration of the connect operation itself.

9.2.2 *NOT SELECTED Timeout (T7)* — Entry into the NOT SELECTED state is achieved either by state transition #2 (establishment of a TCP/IP connection). There is a time limit on how long an entity is required to remain in the NOT SELECTED state before either entering the SELECTED state or by returning to the NOT CONNECTED state.

Some entities, particularly those unable to accept more than a single TCP/IP connection, may be impaired in their operation by remaining in their NOT SELECTED state as they will be unavailable for communications with other entities. Such entities shall disconnect the TCP/IP connection (State Transition Event #3) if communication remains in the NOT SELECTED state for longer than the T7 timeout period.

9.2.3 *Network Intercharacter Timeout (T8)* — Because TCP/IP is a stream rather than a message protocol, it is possible that bytes which are all part of a single HSMS message may be transmitted in separate TCP/IP messages without any violation of the TCP/IP protocol. Since it is possible that these separate messages may be separated by a substantial period of time, the Network Intercharacter Timeout (T8) is defined.

T8 is similar in purpose to the SECS-I T1 timer except that the communications issues which necessitate T8 are not entirely in the control of the sender of the message. Therefore, it is defined only in terms of the receiver of the message. In particular, if after receipt of a partial message, the T8 timeout period expires prior to receipt of the complete message, the receiving entity shall consider such case as a communications failure, as defined above.

9.2.4 *Multiple Connection Requests Directed to a Single Published Port* — Once a passive entity has accepted a connection on its published port, TCP/IP permits (though does not require) the entity to listen for and accept additional connections directed to the same published port.

HSMS permits (though does not require) entities to operate in this manner. However, for the purposes of HSMS compliance, each connection so formed must exhibit the behavior defined in the HSMS state diagram as if it were completely independent of any other connection to the same published port.

9.2.4.1 *Rejection of Additional Connection Requests by a Passive Mode Entity* — A passive mode entity unable to service more than a single TCP/IP connection for HSMS communications will follow one of these three procedures with respect to additional connection requests.

a. Accept the connection, but always respond to any subsequent HSMS select procedures with the Communication Already Active response code. For the purpose of the HSMS State Diagram, the connect procedure terminates successfully (enters CONNECTED state), but HSMS communications are never established (remain in NOT SELECTED substate). This is the preferred option in that it can provide the most information to the remote entity as to why the connection is refused (see HSMS Select Procedure), but places an addition implementation requirement on the local entity.

b. Actively reject the connection request. This can be done in a TLI implementation using the t_snddis procedure. This will cause the connect procedure in the remote entity to terminate unsuccessfully. This option may not be available to all implementations because some API's, notably some implementations of BSD Sockets, do not provide for initiating an active reject. Note, however, that all TCP/IP implementations, including BSD Sockets, properly respond to an active reject from the remote entity.

c. Refuse to listen for or accept the connect request. No action is taken in the local entity: the remote entity's connect procedure will eventually time out. This option is permitted, but not recommended, as it can cause considerable delay on the part of the remote entity. However, it may be the only alternative available to implementations with network resource limitations.

The documentation of the passive local entity shall indicate which means it uses to refuse connections.

9.3 *HSMS-Specific Considerations*

9.3.1 *Control Transactions T6 Control Timeout* — A number of the control messages are part of procedures which require a message exchange or transaction: <xx>.req from the initiator of the control service, followed by an <xx>.rsp from the receiver of the <xx>.req in response to it. A control transaction is considered open from the time the <xx>.req request is sent until the time the <xx>.rsp is received.

The time a control transaction may remain open is subject to the T6 control transaction timeout. Upon initiation of a control transaction, the local entity should set a timer whose duration is equal to the T6 timeout value. If the transaction is properly closed prior to the expiration of the timer, the timer should be canceled. If the timer expires prior to the proper closing of the transaction, the transaction shall be considered closed by the initiator and considered an HSMS communications failure.

9.3.2 *Procedures and "Stateless" Transactions* — Most of the HSMS control procedures involve a transaction: the initiator sends a request message to the responding entity and waits for a response message. The responding entity receives the initiator' s request message and sends a reply.

Note that such transactions are "stateless" in the following sense: while the initiator of a transaction is waiting for a response, it may receive a message other than that response, and this message may be any message valid for the state the initiator was in at the time the original transaction was initiated. For example, the two entities may simultaneously initiate transactions. As a result, no states for "TRANSACTION OPEN" or "TRANSACTION NOT OPEN" are reflected in the HSMS state machine. The use of such state information in an implementation is strictly a local entity-specific issue.

9.3.3 *Alternative Message Types and Header Byte Values* — The HSMS standard does not completely define all possible enumerated values of either the PType or SType field. Further, Header bytes 2 and 3 have a format determined by the PType for messages whose SType is equal to 0, but is otherwise specified for all other SType values. The message text formatting is defined by the PType as well, but only for data messages.

Subsidiary standards must be consistent with this convention. In particular, for SType = 0, subsidiary standards defining PType values not equal to 0 may specify both the message text encoding and the interpretation of header bytes 2 and 3. For STypes not equal to 0 but otherwise specified in this standard, PType must = 0, and no message text may be transmitted. For STypes defined in subsidiary standards, the meaning of header bytes 2 and 3 may be specified on a per SType value basis, and these STypes may optionally define message text as long as the PType field is used in a manner consistent with the preceding paragraph.

9.4 *SECS-II Considerations* — The SECS-II standard (SEMI E5) makes certain references to SECS-I (SEMI E4). This section addresses issues specific to SECS-II when HSMS is used to transport SECS-II messages.

9.4.1 *Reply Matching* — When a Sender sends a Primary Message with W-Bit 1 (Reply Expected), the Sender should expect a Reply message whose header meets the following requirements.

The SessionID of the Reply must match the SessionID of the Primary Message.

The Stream of the Reply must match the Stream of the Primary Message.

The Function of the Reply must be one greater than the Function of the Primary Message, or else the Function of the Reply must be 0 (Function Zero Reply).

The System Bytes of the Reply must match the System Bytes of the Primary Message.

9.4.1.1 *T3 Reply Timeout* — The T3 reply timeout is a limit on the length of time that the HSMS message protocol is willing to wait for a Reply message.

After sending a Primary Message with W-bit 1 (Reply Expected), the sender must begin a reply timer, initialized to the T3 value. If the sender does not receive the Reply Message before the reply timer expires, then a T3 Timeout Error has occurred. The sender should close the transaction and no longer expect the Reply Message.

Each open transaction for which a Reply is expected requires a separate reply timer.

9.4.2 *Stream 9 Messages* — The SECS-II standard defines error messages S9F1, S9F3, S9F5, S9F7, S9F9, and S9F11, with message text containing the SECS-II Data Items MHEAD or SHEAD, which are defined to contain a 10-byte SECS-I block header.

When using SECS-II with HSMS, MHEAD and SHEAD should contain the ten bytes of the HSMS Message Header.

10 HSMS Documentation

An HSMS implementation is required to document the following information:

1. Method for setting protocol parameters (see Section 10.1).
2. Range allowed and resolution for each parameter.
3. The option used for refusing incoming connection requests if the implementation uses the passive mode for TCP/IP connection establishment.
4. Maximum message size which can be received.
5. Maximum expected size of messages sent.
6. Maximum number of supported concurrent open transactions.

10.1 *Parameter Setting* — Implementations of HSMS must provide for installation time setting of the following parameters. The range and resolution of all parameters must be at least as shown in the table. All parameters must be stored in such a manner that the settings will be retained if the power fails or if the system software is reloaded.

Table 10

Parameter Name	*Value Range*	*Resolution*	*Typical Value*	*Description*
T3 Reply Timeout	1-120 seconds	1 second	45 seconds	Reply timeout. Specifies maximum amount of time an entity expecting a reply message will wait for that reply.
T5 Connect Separation Timeout	1-240 seconds	1 second	10 seconds	Connection Separation Timeout. Specifies the amount of time which must elapse between successive attempts to connect to a given remote entity.
T6 Control Transaction Timeout	1-240 seconds	1 second	5 seconds	Control Transaction Timeout. Specifies the time which a control transaction may remain open before it is considered a communications failure.
T7 NOT SELECTED Timeout	1-240 seconds	1 second	10 seconds	Time which a TCP/IP connection can remain in NOT SELECTED state (i.e., no HSMS activity) before it is considered a communications failure.
T8 Network Intercharacter Timeout	1-120 seconds	1 second	5 seconds	Maximum time between successive bytes of a single HSMS message which may expire before it is considered a communications failure.
Connect Mode	PASSIVE, ACTIVE	—	—	Connect Mode. Specifies the logic this local entity will use during HSMS connection establishment.
Local Entity IP Address and Port number	determined by TCP/IP conventions	—	—	Required for any entity operating in PASSIVE mode. Determines the address on which the local entity will listen for incoming connection requests.
Remote Entity IP Address and Port Number	determined by TCP/IP conventions	—	—	Required for any entity operating in ACTIVE mode. Determines the address of the remote entity to which the local entity will attempt to connect.

NOTE: Parameter defaults shown above are for small networks (10 nodes or less). Settings may need to be adjusted for larger network configurations.

APPENDIX 1

NOTE: This appendix was approved as a part of SEMI E37 by full letter ballot procedure.

A1-1 TCP/IP Procedures Using TLI and BSD Socket Interfaces

A1-1.1 *Passive Mode Connect Procedure*

Table 1

Intended Action	*TLI Construct*	*BSD Construct*	*Comment*
Obtain a connection endpoint and bind it to a published port.	tep = t_open(...) t_bind(tep,...)	skt = socket(...) bind(skt,...)	BSD refers to a connection endpoint as a "socket." TLI refers to it as a TEP (transport end point).
Permit socket to listen for connections.	...	listen(skt...)	In TLI, the equivalent of BSD listen is not necessary.
Connect procedure: receive incoming connect request and accept it.	t_listen(tep,...) t_accept(tep,...)	accept(skt,...)	
Connect procedure: receive incoming connect request, but reject it.	t_listen(tep,...) t_snddis(tep,...)	...	The BSD API does not support originating a reject of a connect request, as receiving request and accepting it are a single operation.

A1-1.2 *Active Mode Connect Procedure*

Table 2

Intended Action	*TLI Construct*	*BSD Construct*	*Comment*
Obtain a connection endpoint.	tep = t_open(...) t_bind(tep,...)	skt = socket(...)	TLI requires bind to null address for active entity.
Connect procedure: send connect request and receive accept or reject from passive entity.	t_connect(tep,...) t_rcvconnect(tep,...)	connect(skt,...)	The BSD connect will correctly handle an active reject from the TLI-based remote entity.

A1-1.3 *Terminating the Connection*

Table 3

Intended Action	*TLI Construct*	*BSD Construct*	*Comment*
Release the connection and free connection endpoint.	t_sndrel(tep,..) t_close(tep)	close(skt)	The "gracefulness" of the BSD close is a function of the local implementation.
Disconnect and free the connection endpoint.	t_snddis(tep,..) t_close(tep)	shutdown(skt,2) close(skt)	Shutdown immediately disables further sends and receives if the second arg = 2.

A1-1.4 *Sending and Receiving HSMS Messages*

Table 4

Intended Action	*TLI Construct*	*BSD Construct*	*Comment*

Send an HSMS message	hdr->Len = length;
	t_snd(tep,hdr,14,0);
	t_snd(tep,Text,hdr->Len,0);
		hdr->Len = length;
		write(skt,hdr,14);
		write(skt,Text,hdr->Len);
			The procedure illustrates a "typical" implementation style in which the length bytes and header are combined into a single 14-byte item sent first, followed by the text. This is not to imply that combining everything is not permitted.

Receive and HSMS message	t_rcv(tep,hdr,14,...); t_rcv(tep,Text,hdr->Len,...);	read(skt,hdr,14); read(skt,Text,hdr->Len);	As above, but for receiving.

A1-2 HSMS Scenarios

The following scenarios are provided to illustrate the HSMS procedures as used for a typical complete session. The terminology, procedure names, and message names are further explained in the remainder of this document. Also note that either entity may initiate the HSMS Select procedure, the Deselect or Separate procedures, and HSMS Data Messages and Transactions. For convenience, the scenarios show the left-hand entity as the initiator of all transactions.

A1-2.1 *Begin HSMS Communication* — This scenario illustrates the TCP/IP connection procedure, an HSMS select procedure, and exchange of data messages. Note that the data message activity for TCP is for illustrative purposes only. In fact, the actual network activity can vary. For example, even if the data messages are sent as separate calls to t_snd (or write) as shown, the TCP/IP implementation may buffer the header and transmit it in a single packet with the text, or the text may be split into multiple packets.

Table 5

BSD API Calls	*TLI API Calls*	*Network Activity*	*TLI API Calls*	*BSD API Calls*
Prepare to initiate a connection request.			Prepare to receive a connection request.	
skt = socket(...);	tep = t_open(...); t_bind(tep, ...);		tep = t_open(...); t_bind(tep,...);	skt = socket(...);bind(skt,...); listen(skt,...);
Initiate a connection request and wait for response.			Receive a connection request, accept it, and send response.	
connect(skt,...);	t_connect(tep,...); t_rcvconnect(tep,...);	TCP/IP Connect Req Msg(s) → ← TCP/IP Accept Msg(s)	t_listen(tep,...);t_accept(tep,...);	accept(skt,...);
Initiate an HSMS Select procedure: send request and receive response.			Respond to HSMS select procedure: receive request and send response.	
write(skt,hdr,14); read(skt,hdr,14);	t_snd(tep,hdr,14,0); t_rcv(tep,hdr,14,...);	Select.req Message → ← Select.rsp Message	t_rcv(tep,hdr,14,...); t_snd(tep,hdr,14,0);	read(skt,hdr,14); write(skt,hdr,14);
Send an HSMS data message as length bytes and header, followed by Text.			Receive an HSMS data message as length bytes and header, followed by Text.	

hdr->Len = Length;
write(skt,hdr,14);
write(skt,Text,...);
	hdr->Len = Length;
	t_snd(tep,hdr,14,0);
	t_snd(tep,Text,...);
		HSMS Data Message (hdr) →
		HSMS Data Message (text) →
			t_rcv(tep,hdr,14,...);
			t_rcv(tep,Text,...);
				read(skt,hdr,14);read(skt,Text,...);

A1-2.2 *Ending Communicaiton Using Deselect* — This scenario illustrates ending an HSMS Session using the Deselect procedure to end the HSMS session.

BSD API Calls	*TLI API Calls*	*Network Activity*	*TLI API Calls*	*BSD API Calls*
Send the Deselct.req and receive Deselect.rsp.			Receive the Deselect.req and send the Deselect.rsp.	
write(skt,hdr,14); read(skt,hdr,14);	t_snd(tep,hdr,14,0); t_rcv(tep,hdr,14,...);	Deselect.req Message → ← Deselect.rsp Message	t_rcv(tep,hdr,14,...); t_snd(tep,hdr,14,0);	read(skt,hdr,14); write(skt,hdr,14);
Disconnect the TCP/IP Connection.			Respond to Disconnect of connection.	
shutdown(skt,2); close(skt);	t_snddis(tep; t_close(tep);	← TCP/IP Disconnect Msg(s) →	t_rcvdis(tep,...);	close(skt);

A1-3 HSMS Alternating Mode Connect Procedure

Some users have particular requirements which prevent them from determining which connect mode (active or passive) a given entity will use at any particular time. In such a case, a Local Entity alternately attempts the active mode and passive mode connect procedure until a connection is successfully established. Note that this requires that local entity provide a published port when in the passive phase. The general logic sequence at the Alternating Local Entity is as follows:

1. Attempt an active connect procedure as described in Section 6.3.3 using a timeout value for the t_rcvconnect greater than or equal to the connection separation timeout T5.

2. If the active connect procedure completes successfully, the alternating mode connect procedure completes successfully.

3. If the active connect procedure terminates unsuccessfully, attempt the passive connect procedure as described in 6.3.2 with the timeout for the t_listen greater than or equal to the connection separation timeout T5.

4. If the passive connect procedure completes successfully, the alternating mode connect procedure completes successfully as described in 6.3.2.

5. If the passive connect procedure terminates unsuccessfully, the local entity may either return to step 1 to continue the alternating mode procedure or terminate unsuccessfully. The number of times the above sequence of steps are repeated in attempting to form a connection is a local entity-specific issue.

A1-3.1 *Alternating Mode Cycle Time* — The Alternating Mode Cycle Time is the time between iterations of the Connect Procedure of an Alternating Mode entity. In the above procedure, this corresponds to the duration between the initiation of step 1 and completion of step 5 immediately prior to the reinitiation of step 1. This time is implementation-dependent.

In the case that two entities are both using the Alternating Mode Connect Procedure, it is desirable to ensure that they both have different alternating mode cycle times, to prevent the entities from attempting to connect in lock step: both in active mode, then both in passive mode. Adjusting the Alternating Mode Cycle Time can be readily achieved by adjustment of T5 so that the cycle time is different for the two entities:

A1-3.2 *HSMS Connect Combinations* — An entity configured as alternating between active and passive mode can connect with either an passive or active mode remote entity. The list below summarizes the combinations possible using the standard with this particular connections strategy.

1. An Entity "A" configured as ACTIVE can connect to an Entity "B" configured as PASSIVE or as ALTERNATING, and Entity A always establishes the Connection.

2. An Entity "A" configured as ALTERNATING can connect to an Entity "B" configured as PASSIVE, and Entity "A" always establishes the Connection.

3. An Entity "A" configured as ALTERNATING can connect to an Entity "B" configured as ALTERNATING, and either end can establish the Connection. In implementations which use multi-threaded connect logic, rather than the sequential logic described in this document, it may be possible that both ends of the HSMS connection attempt to connect at the same time. In this case, there can be two separate TCP/IP connections established, and it is necessary to establish a convention so that one connection is allowed to remain and the other is terminated.

4. It is not allowed to connect two Entities both configured as PASSIVE, or both configured as ACTIVE.

A1-4 Non-HSMS TCP/IP Protocols

For typical TCP/IP implementations, HSMS can co-exist with other TCP/IP based protocols on the same IP Address. This can be very useful. For example, a SECS-II message transaction could trigger an application to begin a TCP/IP FTP (File Transfer Protocol) sequence to transfer a large data file.

A1-5 Non-TCP/IP Protocols

The use of protocols other than TCP/IP on the same network as the HSMS entities is possible but beyond the scope of this standard. Typically, other protocols could be used, provided they have no impact on TCP/IP or HSMS entities on the network.

A1-6 Multiple LANs

The HSMS specification considers only a single TCP/IP LAN. Interconnecting multiple LANs is outside the scope of HSMS. However, since TCP/IP implementations typically support such configurations seamlessly through gateways, routers, and similar entities, it may be possible to establish an HSMS Connection across interconnected LAN's.

A1-7 TCP/IP Physical Layer

HSMS does not specify the physical layer of IP. Any physical layer supported by TCP/IP can be used. Most commonly, TCP/IP implementations use Ethernet (IEEE 802.3) as the physical layer. However, some TCP/IP implementations use other protocols (e.g., Token Bus, IEEE 802.4 and .5). To ensure interoperability within a given installation, it may be desirable to establish additional local standards for the physical layer.

A1-8 Well-Known TCP/IP Port Numbers

Some TCP/IP-based protocols specify a particular "Well Known" TCP Port Number, which is published and is not available for other protocols. HSMS does not specify a particular "Well Known" TCP Port Number, but instead requires that it be configurable. The IETF defines "Assigned Well Known Port Numbers" in RFC 1340.

A1-9 Delay between Disconnect and Re-Connect

Some TCP/IP systems exhibit problems with applications which terminate a connection and then quickly re-connect, when using identical TCP ports on both ends of the connection. When using such systems, it may be advisable to delay after disconnect before re-connecting. The delay time varies among TCP/IP implementations, but typically can be calculated as twice the "Maximum Segment Lifetime" or MSL. For example, most TCP/IP systems based on BSD (e.g., Sun, AIX) use a MSL of 30 seconds, so a delay of 60 seconds would be appropriate. If rapid connects are required, your application should use a different Port, if allowed by the Connect Mode you are using. In some TCP/IP systems, this problem does not occur.

A1-10 User-Defined Message Types

It is recognized that equipment suppliers may find it desirable to develop additional features not found in the base level HSMS or any defined subsidiary standards. This will be the case during the testing and development of any proposed new subsidiary standard. User-defined extensions through new message types are permissible as long as they are confined to intra-vendor communication interfaces: any inter-vendor communications interface which requires the use of such extensions is considered to be noncompliant with the HSMS standard.

If a supplier does deem it necessary to extend or otherwise go outside the standard, the use of "reserved, not used," values of PType and SType may simplify their implementation by permitting the reuse of the HSMS implementation rather than the implementation and use of a completely separate parallel standard. By remaining within the "reserved, not used," ranges for SType and PType, the implementor can be assured that future subsidiary standards which define new values for SType and/or PType will not conflict with user-defined extensions.

A1-11 Comparison of SECS-I and HSMS

The following table compares major features of SECS-I and HSMS.

Feature	*SECS-I*	*HSMS*
Communications Protocol Base	RS-232	TCP/IP
Physical Layer	25-pin connector and 4-wire serial cable	Physical layer not defined. HSMS allows any TCP/IP supported physical medium. Typical example is Ethernet (IEEE 802.3) and thin coax (10-BASE-2).
Communications Speed	Typically about 1000 bytes/second (assuming 9600 baud).	Typically 10 MBits/second (assuming typical Ethernet).
Connections	One physical RS-232 cable per SECS-I connection.	One physical network cable can support many HSMS Connections.
Message Format	Message text is SECS-II Data Items. Transmits a SECS-II message as a series of transmittal blocks each approximately 256 bytes in size. Each block has a one-byte block length, a ten-byte Block Header, text, and a two-byte Checksum.	Message Text is SECS-II Data Items. Transmits a SECS-II message as a TCP/IP byte stream. The message has a four-byte Message Length, a ten-byte Message Header, and text. The TCP/IP layer may impose blocking limits which depend on the physical layer used, but this blocking is transparent to the TCP/IP API and is outside the scope of HSMS.

Feature	*SECS-I*	*HSMS*
Header	Ten-byte header on each block of a message. Header bytes 4-5 contains E-Bit and Block Number.	One ten-byte Header for the entire message. Header bytes 4–5 contain PType and SType. Header bytes 2–3 are W-Bit, Stream, and Function when SType = 0 (Data Message). For SType not equal to 0 (Control Message), bytes 2–3 have other uses. No R-Bit.
Maximum message size	Limited to approximately 7.9 million bytes (32767 blocks times 244 text bytes per block).	Message size limited by 4-byte message length (approximately 4 GBytes). Local implementation of TCP/IP and HSMS may further limit this in practice.
Protocol Parameters (Common)	T3 Reply Timeout Device ID	T3 Reply Timeout Session ID (analogous to Device ID).
Protocol Parameters (SECS-I only)	Baud Rate T1 Inter-Character Timeout T2 Block Protocol Timeout T4 Inter-Block Timeout RTY Retry Count Host/Equipment	Not used in HSMS. Corresponding issues addressed by TCP/IP layers.
Protocol Parameters (HSMS Only)	Not needed by SECS-I.	IP Address and Port of Passive Entity. T5 Connect Separation Timeout. T6 Control Transaction Timeout. T7 NOT SELECTED Timeout. T8 Network Intercharacter Timeout.

SEMI E37.1-0702
HIGH-SPEED SECS MESSAGE SERVICE SINGLE SELECTED-SESSION MODE (HSMS-SS or HSMS-SSS)

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the Japan Information and Control Committee. Current edition approved by the Japan Regional Standards Committee on April 26, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1995; previoulsy published in 1996.

1 Purpose

1.1 HSMS-SS provides a means for independent manufacturers to produce implementations which can be connected without requiring specific knowledge of one another.

1.2 HSMS-SS is intended as an alternative to SEMI E4 (SECS-I) for applications where higher speed communication is needed.

1.3 HSMS-SS is intended as an alternative to SEMI E13 (SECS Message Services) for applications where TCP/IP is preferred over OSI as a communications basis.

2 Scope

2.1 High-Speed SECS Message Services Single-Session Mode (HSMS-SS) is a subsidiary standard to High-Speed SECS Message Services (HSMS) Generic Services.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Reference Standards

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

3.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communication Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communication Standard 2 Message Content (SECS-II)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

4 Terminology

4.1 *Definitions*

4.1.1 *device ID* — a 15-bit field in the message header used to identify a subentity within the equipment.

4.2 In addition, all definitions for HSMS Generic Services apply.

4.3 Note that the terms HSMS and HSMS generic services both refer to the HSMS Generic Services standard definition (SEMI E37).

5 HSMS-SS Overview and State Machine

5.1 This definition defines the HSMS-SS-specific use of HSMS Generic Services suitable for applications requiring a simple SECS-I replacement. The purpose of this standard is to explicitly limit the capabilities of the HSMS Generic Services to the minimum necessary for this type of application. Specifically, HSMS imposes the following limitations:

1. HSMS-SS eliminates the use of a number of HSMS procedures. Deselect is not to be used to end HSMS-SS communications (use Separate instead), and the Reject procedure is optional.
2. HSMS-SS limits certain other procedures such as Select to simplify operation for the specific case of SECS-I replacement.

5.2 The remainder of this document describes these limitations in more detail.

5.3 *HSMS-SS State Machine* — The HSMS-SS behavior and state machine differ from that specified in the HSMS Generic Services in the following ways:

1. The SelectionCounter defined in HSMS Generic Services is not required.
2. Various transitions are defined differently as illustrated in the HSMS-SS state machine illustrated below.

5.4 The HSMS-SS state machine is illustrated in the diagram below.

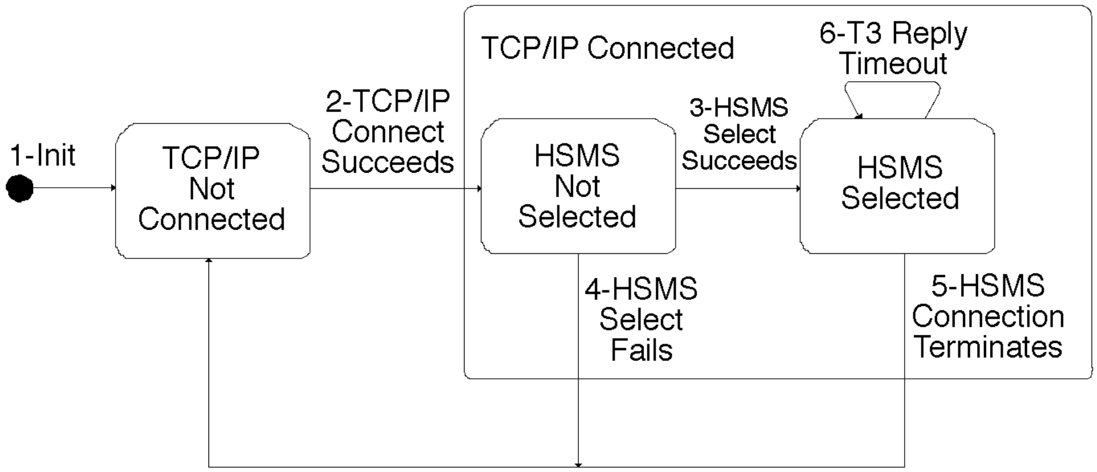


Figure 1

5.5 *State Transition Table for Passive Mode Connect*

Table 1 HSMS-SS Passive Mode Connect State Transitions

#	*Old State*	*New State*	*Trigger*	*Actions*
1	—	TCP/IP NOT CONNECTED	Initialization	
2	TCP/IP NOT CONNECTED	HSMS NOT SELECTED	TCP/IP Connect Succeeds: 1. TCP/IP “accept” succeeds.	Start T7 timeout.
3	HSMS NOT SELECTED	HSMS SELECTED	HSMS Select Succeeds: 1. Receive Select.req and decide to allow it.	1. Cancel T7 timeout; and 2. Send Select.rsp with zero SelectStatus.
4	HSMS NOT SELECTED	TCP/IP NOT CONNECTED	HSMS Select Fails: 1. T7 Timeout waiting for Select.req; or 2. Receive Select.req and decide to reject it and send Select.rsp with non-zero SelectStatus; or 3. Receive any HSMS message other than Select.req; or 4. Receive HSMS message length not equal to 10; or 5. Receive bad HSMS message header; or 6. T8 timeout waiting for TCP/IP; or 7. Other unrecoverable TCP/IP Error (entity-specific).	1. Close TCP/IP connection.

#	*Old State*	*New State*	*Trigger*	*Actions*
5	HSMS SELECTED	TCP/IP NOT CONNECTED	HSMS Connection Terminates: 1. Decide to terminate and send Separate.req; or 2. Receive Separate.req; or 3. T6 timeout waiting for Linktest.rsp; or 4. Receive HSMS message <10; or 5. Receive HSMS message length > maximum supported by entity; or 6. Receive bad HSMS message header; or 7. T8 timeout waiting for TCP/IP; or 8. Other uncorrectable TCP/IP Error (entity-specific).	1. Close TCP/IP connection.
6	HSMS SELECTED	HSMS SELECTED	T3 Timeout waiting for Data Reply Message.	1. Cancel the Data Transaction as appropriate (entity-specific) but do not terminate the TCP/IP connection; and 2. If entity is EQUIPMENT send SECS-II S9F9.

5.6 *State Transition Table for Active Mode Connect*

Table 2 HSMS-SS Active Mode Connect State Transitions

#	*Old State*	*New State*	*Trigger*	*Actions*
1	–	TCP/IP NOT CONNECTED	Initialization	
2	TCP/IP NOT CONNECTED	HSMS NOT SELECTED	TCP/IP Connect Succeeds: 1. Decide to connect.	1. TCP/IP Connect; and 2. Send Select.req; and 3. Start T6 timeout.
3	HSMS NOT SELECTED	HSMS SELECTED	HSMS Select Succeeds: 1. Receive Select.rsp with zero SelectStatus.	1. Cancel T6 timeout.
4	HSMS NOT SELECTED	TCP/IP NOT CONNECTED	HSMS Select Fails: 1. T6 Timeout waiting for Select.rsp; or 2. Receive Select.rsp with non-zero Select.Status; or 3. Receive any HSMS message other than Select.rsp; or 4. Receive HSMS message length not equal to 10; or 5. Receive bad HSMS message header; or 6. T8 timeout waiting for TCP/IP; or 7. Other unrecoverable TCP/IP Error (entity-specific).	1. Close TCP/IP connection; and 2. Start T5 Timeout.

#	*Old State*	*New State*	*Trigger*	*Actions*
5	HSMS SELECTED	TCP/IP NOT CONNECTED	HSMS Connection Terminates: 1. Decide to terminate and send Separate.req; or 2. Receive Separate.req; or 3. T6 timeout waiting for Linktest.rsp; or 4. Receive HSMS message length < 10; or 5. Receive HSMS message length > maximum supported by entity; or 6. Receive bad HSMS message header; or 7. T8 timeout waiting for TCP/IP; or 8. Other uncorrectable TCP/IP Error (entity-specific).	1. Close TCP/IP connection.
6	HSMS SELECTED	HSMS SELECTED	T3 Timeout waiting for Data Reply Message.	1. Cancel the Data Transaction as appropriate (entry-specific) but do not terminate the TCP/IP connection; and 2. If entity is EQUIPMENT, send SECS-II S9F9.

Table 3 When HSMS Transactions are Allowed

HSMS Transition	*Allowed in State(s)*	*Who Initiates Transaction?*
Select	HSMS Not Selected	Active Entity
Link Test	HSMS Selected	Either Entity
Data	HSMS Selected	Either Entity
Separate	HSMS Selected	Either Entity

6 HSMS-SS Use of TCP/IP

6.1 As defined in HSMS.

7 HSMS-SS Procedures

7.1 *Select Procedure* — The Select Procedure shall only be initiated by the entity establishing the TCP/IP connection in active mode. The Passive Mode Entity shall not initiate the Select Procedure.

7.1.1 The Select Procedure is only permitted in the NOT SELECTED state. It uses a SessionID value of 0xFFFF and implies that all device IDs are available for communication. Immediately following any Select Procedure which fails to complete successfully with a zero Select Status, each Entity must close the TCP/IP connection and transit to the NOT CONNECTED state.

7.2 *Data Procedure* — The Data Procedure is as defined in HSMS Generic Services. Note that any SessionID value that corresponds with a DeviceID supported by the Local Entity is valid as long as the Local Entity is in the SELECTED state.

7.3 *Deselect Procedure* — Deselect shall not be used in an HSMS-SS implementation. Communication is ended using the Separate Procedure.

7.4 *Linktest Procedure* — As defined by HSMS. Under HSMS-SS, the use of Linktest is strictly limited to the SELECTED state.

7.5 *Reject Procedure* — The Reject Procedure is optional in HSMS communications. Note, however, that any situation which would require the use of the Reject as described in HSMS Generic Services shall be treated as a communications failure in implementations not supporting reject. Specifically, the TCP/IP connection is immediately closed.

7.6 *Separate Procedure* — Separate shall always use SessionID 0xFFFF (binary, all ones). In HSMS-SS, the Separate.req is valid only in the TCP/IP CONNECTED state and its substates. After either initiating or receiving a Separate.req message, the entity shall immediately close the TCP/IP connection and transit to the TCP/IP NOT CONNECTED state.

7.7 *Communications Failures* — As defined by HSMS. Note that, in addition to the communications failures defined under HSMS, any violation of the restrictions defined in prior sections of this document are also to be treated as communication failures.

8 HSMS-SS Message Format

8.1 *Session ID* — In HSMS-SS Data Messages, the high-order bit of Session ID is zero, and the low-order 15 bits contain Device ID, a 15-bit unsigned integer value, which occupies the low-order 7 bits (bits 6-0) of byte 0 and all of byte 1 of the header. Device ID is a property of the equipment, and can be viewed as a logical identifier associated with a physical device or sub-entity within the equipment. The precise meaning of “device” or “sub-entity” is equipment-defined. A unit of equipment must have at least one Device ID. Equipment which contains several devices may define a unique Device ID for each device.

In HSMS-SS Control Messages, Session ID will always assume the special value 0xFFFF (all one bits).

8.2 *PType* — All HSMS-SS messages are PType 0 (SECS II encoded) as defined in HSMS.

8.3 *SType* — Only HSMS-defined STypes are permitted in HSMS-SS. User-defined SType messages are not permitted.

9 Special Considerations

9.1 *Multiblock Messages* — For each SECS-II message, the SECS-II standard defines whether that message should be transmitted in SECS-I as a single-block message or as a multiblock message. This distinction becomes unimportant with HSMS, which transmits all messages in the same fashion. However, to be compatible with older SECS-I applications, when an HSMS application sends a SECS-II message defined as single block, the HSMS Message Length should not exceed 254 bytes (10 byte header plus 244 text bytes).

10 HSMS-SS Documentation

10.1 An HSMS-SS implementation is required to document the following information in addition to the information required by HSMS.

1. The number of deviceIDs supported and their specific values.
2. Whether or not the implementation supports the normal or the restricted procedure for terminating communications.
3. The setting of the host vs. equipment parameter.

10.2 *Host vs. Equipment* — Many applications using SECS-II will need to designate one end of the communication link as “Equipment” and the other end as “Host.” HSMS-SS itself does not require configuring of “Host” and “Equipment,” but this parameter may be included in configuration where needed. HSMS can also be used in applications where the distinction between Host and Equipment is not used.

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E37.1 and is not intended to modify or supercede the official standard. Publication was authorized by full letter ballot. Determination of the suitability of the material is solely the responsiblity of the user.

R1-1

R1-1.1 An entity may have more than one session. If a unit of equipment can be divided into two or more logical sub-equipments, such as process chambers, or process resources, each of these may have separated session ID. If two or more physical sub-equipments are controlled by an equipment controller or communicated to through a TCP/IP network device, each sub-equipment may have a separate session ID. Such a session can be established once HSMS is selected. Each session ID corresponds to a device ID.

R1-1.2 If a unit of equipment has more than one sub-equipment or process resource (e.g. process modules) but the sub-equipment share a common resource (e.g. transfer subsystem), it is not recommended that each sub-equipment have an independent session to communicate with host. Even if the host requests an action to the shared subsystem with a session identifier specific for a sub-equipment, the shared subsystem may not always serve for the sub-equipment. Since the host expects the shared subsystem to perform the service for the sub-equipment, an error will occur if it is not possible to perform the service for the designated sub-equipment. See following figure.

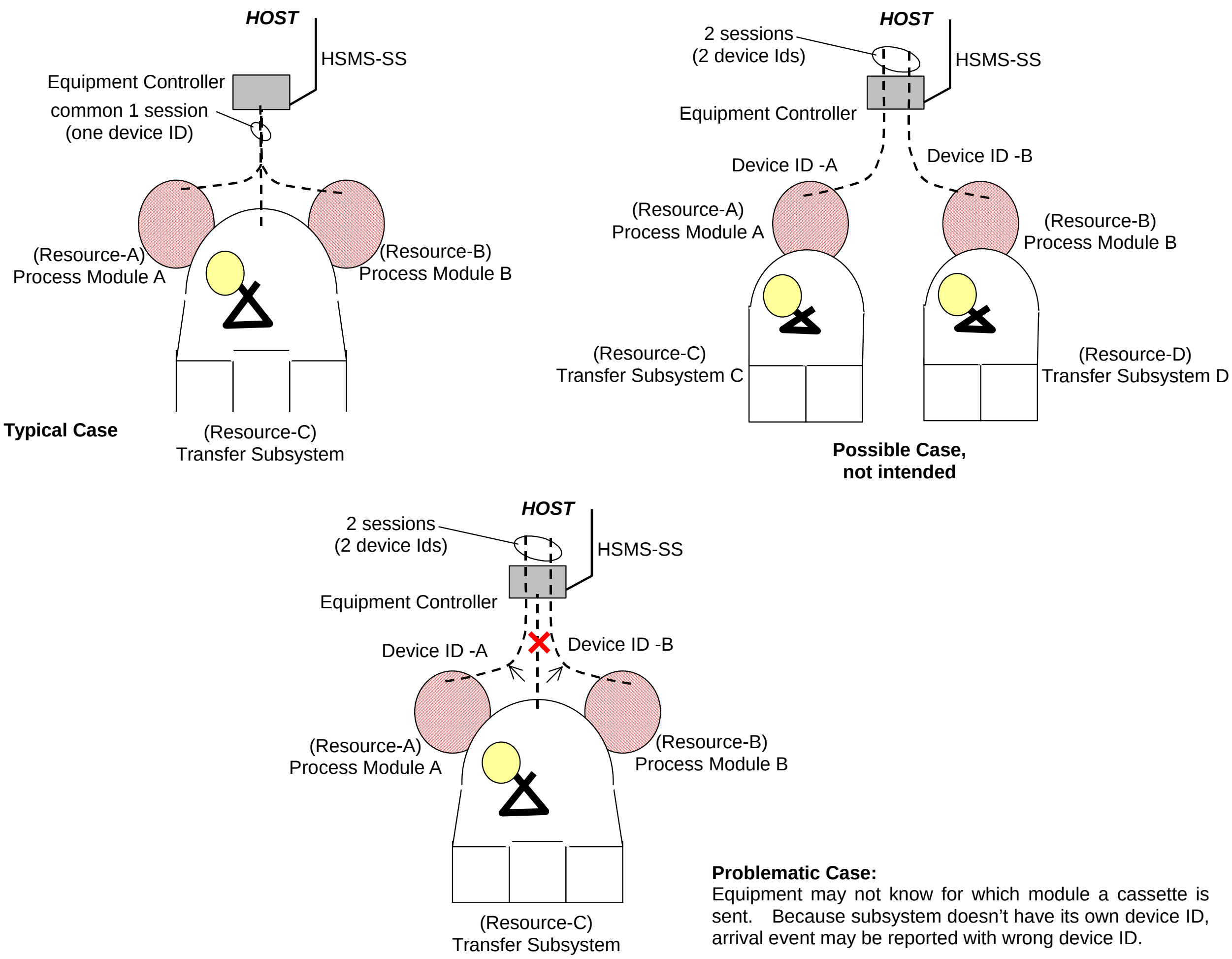


Figure R1-1

R1-2 Multiple HSMS Connections

R1-2.1 Typically, an Equipment will accept only one Host Connection.

R1-2.2 A Host may connect to several units of Equipment, so the Host may have several simultaneously active Connections (each to one Equipment).

R1-2.3 A Cell Controller (or similar entity) might have one Connection by which the Cell Controller appears as "Equipment" to the Factory Host Computer, as well as several Connections by which the Cell Controller appears as "Host" to Equipment.

R1-3 Equipment Support for Multiple Hosts

R1-3.1 HSMS requires Equipment to accept at least one active Connection, and does not require the equipment to support access by multiple concurrent Hosts. That is, if the Equipment has already accepted a Host Connection, but a Host (the same or a different Host) attempts a second Connection, the Equipment will immediately terminate that second Connection attempt.

R1-3.2 For specialized applications, an equipment could accept more than one Host Connection. Coordination of activity by multiple hosts is equipment-defined.

SEMI E37.2-95
HIGH-SPEED SECS MESSAGE SERVICES GENERAL SESSION (HSMS-GS)

1 Purpose

HSMS-GS is intended to support the needs of complex systems containing multiple independently accessible subsystems such as cluster tools or track systems. Specifically, procedures are defined to permit access to any individual subsystem or set of subsystems within any complex system.

2 Scope

High-Speed SECS Message Services General Session (HSMS-GS) is a subsidiary standard to High-Speed SECS Message Services (HSMS) Generic Services.

3 Applicable Documents

3.1 *SEMI Standards*

SEMI E37 — HSMS Generic Services

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transport (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

4 Selected Definitions

Selected Entity List — a list of session entities currently selected for communication on a given TCP/IP connection.

Selection Count — the number of sessions opened by an HSMS Select procedure and not yet ended by an HSMS Deselect or Separate procedure.

Session Entity — an individually selectable entity within an HSMS-GS system.

Session Entity ID — a 16-bit identifier for a Session-Entity.

SessionEntityList — a list of all available session entities within an HSMS-GS system and associated with a particular IP address and port number.

In addition, all definitions for HSMS Generic Services apply.

Note that the terms HSMS and HSMS Generic Services both refer to the HSMS Generic Services standard definition (SEMI E37).

5 HSMS-GS Overview and State Machine

HSMS-GS provides a set of definitions which permit the individual subentities (e.g., subsystems) of complex entities (e.g., systems) to be separately accessible during HSMS procedures. HSMS-GS defines no new procedures or message types beyond HSMS Generic Services to provide these services. It does, however, require extensions to the HSMS State machine, in the form of additional state transition definitions and additional state information, which are used by the extended state machine which must be maintained by an HSMS-GS implementation to support the extended state machine. The additional information consists of the following:

1. The Session Entity List

2. The Selected Entity List

3. The Selection Count

The Session Entity List consists of the set of all Session Entities having individual accessibility within the HSMS-GS entity. The scope of this list is normally the entire HSMS-GS entity. HSMS-GS, however, does not require this scope: the supplier may provide access to HSMS-GS entity through more than one well known port and provide a different Session Entity List for each.

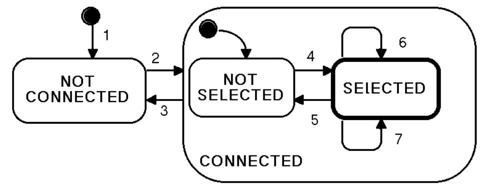
A Session Entity is any individually addressable subentity within the HSMS-GS entity: for example, a Session Entity may be an individual sub-device in a track system or cluster tool, or may be an individual service provider, such as a data server, within an entity. HSMS-GS only provides the conventions for identifying Session Entities. It places no restrictions on the individual supplier as to what constitues a SessionEntity: the supplier must determine what is the most appropriate for the particular implementation.

The Selected Entity List is the list of Session Entities actually selected for access on a given TCP/IP connection. When the TCP/IP connection is established (CONNECTED state entered), an empty Selected Entity List is created. Each time, the Select Procedure is used to select a Session Entity, its Session Entity ID is added to the Selected Entity List created for that TCP/IP connection. Each time the Session Entity is deselected via the Deselect or Separate procedures, its Session Entity ID is removed from the Selected Entity List. At any given time on any given TCP/IP connection endpoint, HSMS Data Messages will only be accepted by an entity if the SessionID of the Data Message is equal to any Session Entity ID in the Selected Entity List.

The Selection Count is simply the number of Session Entity IDs in the Selected Entity List. Its value affects the behavior of the state machine: the transition to NOT SELECTED from SELECT can only take place when the SELECTION COUNT is zero.

Note that the above lists and count are defined for the purpose of explaining state machine operation only. There is no requirement that any of the above lists and count be explicitly implemented.

5.1 *HSMS-GS State Machine* — The HSMS-GS state machine is the same as the HSMS Generic Services state machine with the addition of the two new state transitions (#6 and #7) and the use of the Selection Count in the other transitions as described in the state transition table below.



5.2 *State Descriptions* — The state descriptions are the same as HSMS Generic Services.

5.3 *State Transition Table* — The state transition table is almost identical with the state transition table for HSMS Generic Services. For convenience, however, the entire table is reproduced and extended here, not just those areas which differ from it.

Table 1

#	*Current State*	*Trigger*	*New State*	*Actions*	*Comment*
1	...	Local entity specific preparation for TCP/IP communication.	NOT CONNECTED	Local entity-specific.	Action depends on connection procedure to be used: active or passive.
2	NOT CONNECTED	A TCP/IP connection is established for HSMS communication.	CONNECTED - NOT SELECTED	Set Selection Count = 0 and create empty Selected Entity List.	none
3	CONNECTED	Breaking of TCP Connection.	NOT CONNECTED	Local entity-specific.	none
4	NOT SELECTED	Successful completion of HSMS Select Procedure.	SELECTED	Set Selection Count = 1 and add selected Session Entity to Selected Entity List.	none
5	SELECTED	Deselect or Separate procedure resulting in Selection Count = 0.	NOT SELECTED	Local entity-specific.	See transition 7 below.
6	SELECTED	Successful completion of HSMS Select Procedure when Selection Count > 0	SELECTED	Increment Selection Count and add selected Session Entity to Selected Entity List.	none
7	SELECTED	Successful completion of HSMS Deselect or Separate when Selection Count > 1.	SELECTED	Decrement Selection Count and remove selected Session Entity from Selected Entity List.	If this transition results in Selection Count = 0, immediately trigger state transition 5.

6 HSMS-GS Use of TCP/IP

6.1 There is no additional HSMS-GS specification for the use of TCP/IP beyond the above mentioned creation of the empty "Selected Entity List" upon entry into the CONNECTED state, NOT SELECTED substate.

7 HSMS-GS Specific Procedures

HSMS-GS provides further specification of the following procedures.

7.1 *Select Procedure* — The select procedure is permitted in both the NOT SELECTED state and the SELECTED state. The procedure for both the initiator and the responding entity is the same as HSMS Generic Services, with the following additional conditions:

1. If the responding entity contains no Session Entity in its Session Entity List whose ID matches the SessionID in the Select.req, a Select Status of No Such Entity is used in the Select.rsp.
2. If the responding entity is unable to provide access to the selected entity because it is usable on only a single TCP/IP connection at any one time and it is already in use on a different TCP/IP connection, a response code of Entity In Use is used in the Select.rsp.
3. If the responding entity finds the SessionID already in its Selected Entity List, a response code of Entity Selected is used in the Select.rsp.

The Select Status values referenced above are all defined in Section 8.

If none of the above is true, the Select completes successfully, and a Select Status of 0 is provided in the Select.rsp. Both entities will add the SessionID from the Select.req to the Selected Entity List.

7.2 *Data Procedure* — The Data Procedure is as defined in HSMS Generic Services. Note that the SessionID of any Data Message must match a SessionID in the SelectedEntityList. If a Data Message is received with a SessionID other than one from the Selected Entity List, a Reject.req message is sent in response by the receiving entity. The reason code will be Entity Not Selected.

7.3 *Deselect Procedure* — The Deselect procedure is restricted by the following conditions:

1. The SessionID must be in the Selected Entity List.
2. The corresponding SessionEntity is in a state which permits Deselect. This decision is local entity specific and not subject to the HSMS-GS.

If both of the above are true, then the Deselect can proceed. Assuming that the Deselect completes successfully, the SessionID is removed from the Selected Entity List, and the Selection Count is decremented. The transition to the NOT SELECTED state transpires only if the resulting Selection Count is equal to zero (i.e., an empty Selected Entity List).

7.4 *Linktest Procedure* — As defined by HSMS.

7.5 *Reject Procedure* — As defined by HSMS. Note, in particular, the use of Reject in response to certain data messages (above).

7.6 *Separate Procedure* — The Separate procedures and state transitions are subject to the same restrictions and conditions as the Deselect.

7.7 *Communications Failures* — As defined by HSMS. Note that any abrupt termination has the effect of deselecting all entities in the Selected Entity List.

8 HSMS-GS Message Format Issues

8.1 *Session ID* — In HSMS-GS Select, Data, Deselect, Reject, and Separate messages, the SessionID will equal the Session Entity ID of the target Session Entity which must equal the Session ID of a Session Entity contained in the Session Entity List. In the Linktest, it is 0xFFFF, as in HSMS.

8.2 *PType* — HSMS-GS messages are generally PType = 0 (SECS-II-encoded) as defined in HSMS. Although other PTypes are permitted, specific application domains may restrict the use of HSMS-GS to Ptype = 0.

8.3 *SType* — Only HSMS-defined STypes are permitted in HSMS-GS.

8.4 *Select/Deselect Status* — The following additional enumeration applies to the select/Deselect status in HSMS-GS:

Table 2 SelectStatus

Value	*Description*
4	No Such Entity — Session ID does not correspond to any Session Entity ID available at this connection.
5	Entity In Use (by another connection) — Session Entity corresponding to session ID is not sharable connections and is already selected by another connection.
6	Entity Selected (by current connection) — Session entity corresponding to Session ID is already selected on current connection.

9 Special Considerations

9.1 There are no special considerations above and beyond those described in HSMS Generic Services.

10 HSMS-GS Documentation

10.1 An HSMS-GS implementation is required to document the following information in addition to the information required by HSMS.

1. The Session Entity List — specifically the number of Session Entities available for HSMS-GS communication and the value of their particular Session Entity ID's.

RELATED INFORMATION 1 APPLICATION NOTES

NOTE: This related information is not an official part of SEMI E37.2 and is not intended to modify or supercede the official standard. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Supporting Both HSMS-GS and HSMS-SS Simultaneously

In certain applications, the equipment manufacturer may be faced with a requirement of providing both HSMS-GS and HSMS-SS communications interfaces. For example, a cluster tool may use HSMS-GS as the intra-tool communications and HSMS-SS as a GEM interface to the factory. However, implementing a communications facility that is simultaneously HSMS-SS- and HSMS-GS- compliant is straightforward.

Assuming that one has implemented an HSMS-GS, a simple test can be added to the first Select.req received by the equipment. If it is a Select for any particular SessionID, then operate as HSMS-GS. If its value is a -1, then copy the contents of the Session Entity List corresponding TCP/IP IP address and port number into the Selected Entity List. The Selection Counter would be set to a special value, such as -1, to indicate selection in this manner. The Separate would provide the reverse function. If the passive entity is implemented as an HSMS-SS node and the active entity is an implementation that supports both modes of operation, it must be explicitly configured to initiate the Select with a Session ID of -1 and must have a Session Entity List containing the Device IDs of all the available sub-devices within the passive mode entity.

In the local API for the case where the equipment must originate the select, a configuration parameter for the equipment could indicate which mode to use for a particular remote target.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E38-1296
CLUSTER TOOL MODULE COMMUNICATIONS (CTMC)

1 Purpose

1.1 Cluster tools fulfill a need for modularity and flexibility in semiconductor manufacturing equipment. This standard addresses the communications with and among modules within a cluster tool for automated control.

1.2 The module communications services defined here will enable standard interoperability of modules from independent suppliers. Together with other cluster tool standards, this is intended to result in the emergence of standards-compliant interoperable sub-systems. They should allow applications software to be developed which can assume the existence of these services and allow software products to be developed to offer them.

1.3 The adoption of the standards described will greatly reduce the effort required to integrate cluster tool components from independent suppliers. Compliance requires support of a minimal, but specific, set of standard services.

2 Scope

2.1 Cluster tool module communications address only communications with and among modules within a cluster tool and not the communications between the cluster tool and the factory. It is the modules and their interrelations which are modeled and not the cluster tool seen as a single equipment.

2.2 This standard does not specify cluster controller functionality (e.g., scheduling, human machine interface, cluster tool recipe editing, and management) but will enable development of standards in this area. The cluster controller is included only to the extent that it represents the entity or entities responsible for supervisory control of the modules in a cluster tool.

2.3 This standard identifies the communications services necessary to achieve automated control of independent transport, process, and cassette modules in a cluster tool. It defines the essential module architecture and the concepts and models on which the communications services are based.

2.4 The scope includes primary control services for material processing in process modules, material movement within the cluster tool, and material input/output with the factory. Support services also exist to enable recipe handling, resolution of exception conditions, event reporting, and data access.

2.5 A reliable communications environment is required for distributed control and is specified in supplementary standards.

2.6 This standard specifies the application of more general service standards as required within a cluster tool. This includes the limitations imposed by the cluster tool architecture and the fundamental functionality needed for compliance. The details of the general services, protocols, and communication environment elements are defined in the corresponding standards documents referenced.

2.7 This version of the standard is provisional because a number of the general services on which it relies are not yet standardized. The sections referring to these services have been omitted until they have become standards. These sections will be balloted separately with the corresponding general services and incorporated into this provisional standard.

2.8 The communication between the cluster tool as a single equipment and the factory is beyond the scope of cluster tool module communications standardized here and should follow the applicable SEMI standards (GEM, MMMS).

2.9 These standards place no restriction on where, within the cluster tool control architecture, this specific set of definitions is implemented. However, to have complete compliance to the standards in the area of the communications interface definitions, the entire layered structure as outlined in this document must be implemented.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E21 — Cluster Tool Module Interface: Mechanical Interface and Wafer Transport Standard

SEMI E22 — Cluster Tool Module Interface: Transport Module End Effector Exclusion Volume Standard

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E32 — Material Movement Management Standard

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

4 Terminology

4.1 The following terms are those that are appropriate for describing the overall structure of cluster tools. These terms, in addition to the more specific terms located in the individual service, protocol, and communications environment standards, complete the glossary of terms required.

4.1.1 *agent* — an intelligent system within a factory that provides one or more service resources and uses the services of other agents. A generalization of host, equipment, cell, cluster, cluster module, station controller, work station. Agents are associated with a physical system or a collection of physical systems, including computer platforms.

4.1.2 *alarm* — an alarm is related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed. [SEMI E30]

4.1.3 *atomic transfer* — the basic unit of movement. The transfer of a single material between two partners where only one change in ownership occurs.

4.1.4 *attached module* — any component of a cluster tool which mechanically attaches to the transport module at an interface flange. Specifically, the cassette, process, and docking modules are all attached modules. The attached module can be isolated from the transport module by an isolation valve controlled by the transport module. In addition, the attached module may also possess an additional isolation valve. The point of separation between the isolation valve on the transport module and the attached module is called the interface plane.

4.1.5 *am transfer job* — a material transfer job for an attached module specifying all criteria for receiving the material from, or sending the material to, a transport module.

4.1.6 *carrier (material)* — a device for the holding of material for various processing steps in semiconductor manufacturing. [SEMI E1]

4.1.7 *cassette module* — an attached module which provides the means of exchanging material between the intertool environment and the intratool environment of a particular cluster. There is no requirement that the material interface to the intertool environment with the use of cassettes.

4.1.8 *cm input/output transfer job* — a material transfer job for a cassette module, specifying all criteria for receiving the material from, or sending the material to, the factory.

4.1.9 *cluster controller* — the entity or entities responsible for supervisory control within a cluster tool, achieved through communicating with the various modules. The form of the cluster controller is not dictated. It may be a single platform, distributed, or incorporated with one or more modules.

4.1.10 *cluster tool* — an integrated, environmentally isolated, manufacturing system consisting of process, transport, and cassette modules mechanically linked together. There is no requirement that the modules come from the same supplier. [SEMI E21]

4.1.11 *decision authority* — an entity requiring to be notified of significant exception condition changes and which decides how to proceed to resolve abnormal situations related to recoverable error conditions. The decision authority may be represented by a supervisory controller interacting with an operator who may ultimately choose the recovery action.

4.1.12 *docking module* — a component for allowing the exchange, within a cluster tool, of material between multiple transport modules. The docking module presents an attached module interface to both transport modules and is modeled as a multi-port process module for intra-cluster tool communications.

4.1.13 *end effector* — a physical location attached to a transfer resource capable of holding material during an end-to-end material transfer.

4.1.14 *error condition* — an exception condition which is not an alarm and which may support recovery actions requested by a decision authority.

4.1.15 *exception condition* — a managed condition for reporting on and providing recovery from an abnormal situation in the equipment.

4.1.16 *factory* — entities outside the control domain of the cluster tool and from which material is received for processing and returned upon process completion. Also considered to be the intertool environment.

4.1.17 *factory transport resource* — n operator or a piece of equipment specialized in the transport of material from one equipment to another.

4.1.18 *form* — type of data representing information contained in an object attribute or service message parameter. The data types are detailed in Section 4.2.

4.1.19 *fundamental requirements* — the requirement for information and behavior that must be satisfied for compliance to a standard. Fundamental requirements apply to specific areas of application, objects, or services.

4.1.20 *handoff micro move* — an operation requested by an attached module and performed by a transport module to achieve all or part of a material handoff between them.

4.1.21 *interface flange* — the boundary plane separating an attached module and a single transport module.

4.1.22 *intertool environment* — defined relative to a particular cluster tool to be everywhere outside of the intratool environment.

4.1.23 *intertool material transfer job* — a transfer job in the cluster controller to receive material from, or send the material to, the factory. In automated transfer, it may be an element of a factory transfer job.

4.1.24 *intertool port resource* — a module resource associated with a particular cassette module which operates on behalf of the said module during material transfer between the cassette module and the intertool environment.

4.1.25 *intratool environment* — the entire environmentally isolated volume contained within a cluster tool.

4.1.26 *intratool port resource* — a module resource associated with a particular interface plane of a particular attached module which operates on behalf of the said module during material transfer between the transport module and the attached module.

4.1.27 *intratool material transfer job* — a transfer job in a cluster controller for transfer of material from one attached module to another through the linking transport module.

4.1.28 *isolation valve* — a mechanical component used at an interface plane to permit environmental isolation between the transport module and an attached module.

4.1.29 *material handoff* — the process by which material moves from the sending transfer partner to the receiving transfer partner.

4.1.30 *material location* — a physical position capable of holding a single material.

4.1.31 *material slot* — a material location in a carrier capable of holding a single material with an assigned identifier.

4.1.32 *module* — an independently operable unit that is part of a tool or system. [SEMI E21]

4.1.33 *module resource* — an entity which provides specific capabilities required of the module to be accessed or controlled externally. This includes the physical capability and the associated control and access management. It may contain material in one or more material locations.

4.1.34 *namespace* — a domain within which object identifiers are unique.

4.1.35 *port* — a point on the cluster at which a change of ownership of material occurs. A port is not itself a location but must have an associated location, such as an interface plane.

4.1.36 *process job* — a material processing job for a process module, specifying and tracking the processing to be applied to the material while in the module.

4.1.37 *process module* — an attached module which provides manufacturing value to material in a cluster tool.

4.1.38 *processing resource* — a module resource within a module which is independently capable of providing manufacturing value to material.

4.1.39 *protocol (communications)* — the message encoding used when transferring a message across some communication facility.

4.1.40 *recipe* — the pre-planned and reusable portion of the set of instructions, settings, and parameters under control of a processing agent that determines the processing environment seen by the material. Recipes may be subject to change between runs or processing cycles.

4.1.41 *recipe executor* — a component of a module that stores and executes recipes.

4.1.42 *recipe namespace* — a logical management domain with the responsibility for the storage and management of recipes. It ensures the uniqueness of recipe identifiers and provides services pertaining to recipes stored within that domain.

4.1.43 *recovery action* — an operation associated with an error condition with the aim of resolving the abnormal situation detected. It may supply information to the exception agent or request the exception agent to perform some activity.

4.1.44 *service* — the set of messages and definition of the behavior of a service provider that enables remote access to a particular functionality.

4.1.45 *service-provider* — the software control entity that is the provider of any of the related services.

4.1.46 *service-user* — the software control entity that is the user of any of the related services.

4.1.47 *transport module* — a module containing one or more transfer resources and a number of interface planes. It is capable of end-to-end transfer between any of the interface planes.

4.1.48 *tm transfer job* — a material transfer job for a transport module specifying all criteria for receiving the material from the source-attached module and sending the material to the destination module.

4.1.49 *transfer resource* — a module resource within a transport module independently capable of transferring material from one attached module to another.

4.2 *Data Type*

4.2.1 *form* — type of data: positive integer, unsigned integer, integer, enumerated, boolean, text, formatted text, structure, list, ordered list.

4.2.2 *positive integer* — may take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.2.3 *unsigned integer* — may take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

4.2.4 *integer* — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

4.2.5 *enumerated* — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.2.6 *boolean* — may assume one of two possible values, equating to TRUE or FALSE.

4.2.7 *text* — a text string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.2.8 *formatted text* — a text string with an imposed format. This could be by position, by use of special characters, or both.

4.2.9 *structure* — a complex structure consisting of a specific set of items, of possibly mixed data types, in a specified arrangement.

4.2.10 *list* — a set of one or more items that are all of the same form (one of the above forms).

4.2.11 *ordered list* — a list for which the order in which items appear is significant.

5 Conventions

5.1 *Harel State Model*

5.1.1 This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an Appendix of SEMI E30. The formal definition of this notation is presented in *Science of Computer Programming 8*, “Statecharts: A Visual Formalism for Complex Systems,” by D. Harel, 1987.

5.1.2 Transition tables are provided in conjunction with the state diagrams to describe explicitly the nature of each state transition. A transition contains columns for Transition #, Current State, Trigger, New State, Action(s). The “trigger” (column 3) for the transition occurs while in the “current” state. The “actions” (column 5) include a combination of (1) actions taken upon exit of the current state, (2) actions taken upon entry of the new state, and (3) actions taken which are most closely associated with the transition. No differentiation is made.

5.2 *OMT Object Information Model* — The object models are presented using the Object Modeling Technique developed by Rumbaugh, James, et al., in “Object-Oriented Modeling and Design,” Prentice Hall, Englewood Cliffs, NJ, ©1991. Overviews of this notation are provided in an appendix to SEMI E39.

5.3 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attibute Name	*Definition*	*Access*	*Rqmt*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	(see below)

The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that service-users have to the attribute.

A ‘Y’ or ‘N’ in the requirement (Rqmt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

The Form column is used to indicate the format of the attribute. (See Section 4.1 for definitions.)

6 Overview

The Cluster Tool Module Communications standard specifies the communications services necessary to achieve automated control within a cluster tool. It defines the essential cluster tool architecture and the concepts and models on which the communications services are based.

Cluster tools provide a means of grouping a number of independent process steps into a single equipment. The primary function of a cluster tool is material processing. Material enters the cluster tool, undergoes a number of sequential process steps which adds value to the material, and then exits.

From a mechanical viewpoint, Cluster Tool Module Interface standards-compliant equipment has a physical structure where process modules and cassette modules are attached in a standardized way to some form of transport module, a robotic material handler operating in an isolated environment. Cassette modules provide the input and output of material for the cluster tool, usually in cassettes.

This communications standard enables the distributed control of these cluster tools, and of other cluster tools and multi-resource equipment which can be decomposed into process, transport, and cassette modules, whether environmentally isolated or not. A basic assumption is made that the primary human-machine interfaces are not located at the individual modules.

Communication and control services are specified among service-users and service-providers within a cluster tool. The service-providers are the controlled processing, transfer, intratool port, and intertool port resources in the appropriate modules. The service-users are the application entities responsible for supervisory control and data acquisition within the cluster tool.

The services are fully defined in terms of the service-providers, and as such, do not dictate the architecture of the service-user(s). An example of cluster tool control architecture is shown in Figure 1, where the service-user is a single cluster controller platform providing internal scheduling, human-machine interface, and standardized communications interface to the factory.

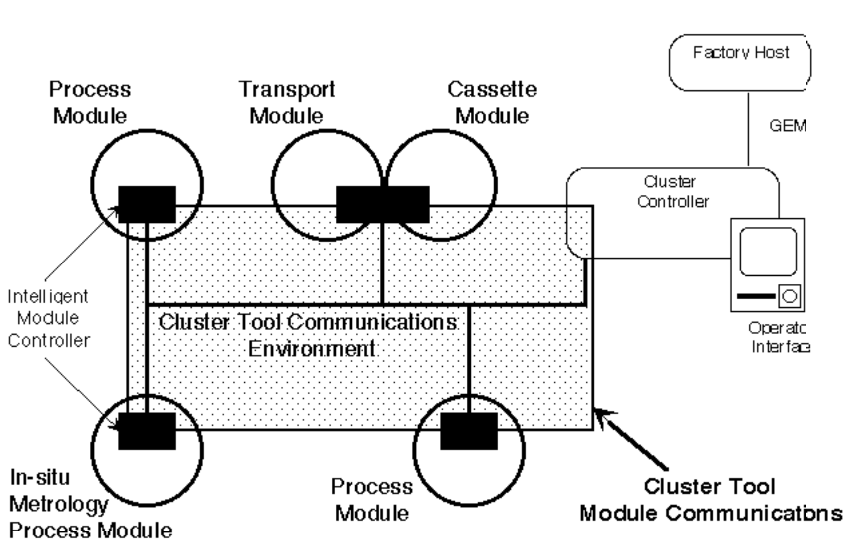

Figure 1
Example Cluster Control Architecture

The communication services include primary control services for material processing in process modules (processing management) and material movement within the cluster tool and material input/output with the factory (material movement management). The cluster controller, which is responsible for supervisory control within the cluster tool, is the service-user of these primary control services. The form of the cluster controller is not dictated. It may be a single platform, distributed, or incorporated with one or more modules.

Support services are also specified to enable resolution of exception conditions, recipe handling, event reporting and data access. The decision authority, which is responsible for making error recovery decisions, is the service-user for exception management. Appropriate agents are the designated service-users for the recipe management and event reporting support services. All service-users access data using the Object Services.

The communications services are defined independently of protocol in order to allow future standardization of alternative protocols without invalidating the services. Figure 2 shows the full communications stack needed for compliance, where the services are mapped to the communications environment, which is defined in supplementary standards.

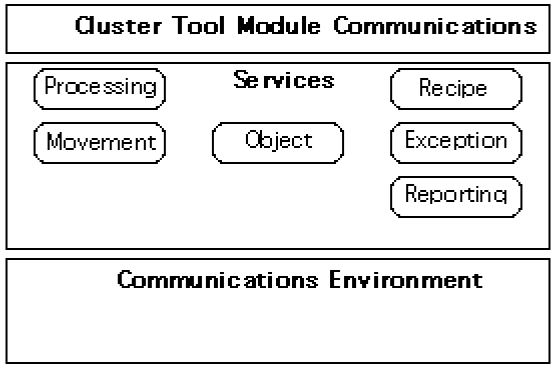

Figure 2
Cluster Tool Module Communications Standards

This standard describes the cluster tool model on which the communications are based. It then defines the application of each of the services required within a cluster tool. This includes limitations imposed by the cluster architecture as well as clear a statement of the fundamental requirements in order to minimize the implementation effort. Connection establishment and maintenance are defined together with the requirements of the communications environment. Communications environment is described in a subsection in order to allow additional options to be standardized in the future. The application notes include factory integration issues and an example scenario of standard communications for the lifecycle of a single material in a cluster tool.

6.1 *Compliance* — Cluster tool module communications compliance between entities in a cluster tool requires that all applicable exposed interfaces conform to the standards specified in this document.

The standardized interfaces are:

- Process module to Service-user (cluster controller)
- Transport module to Service-user (cluster controller)
- Cassette module to Service-user (cluster controller)
- Transport module to Cassette module
- Transport module to Process module

The exposed interfaces are those which result from a particular partition of the control entities in a cluster tool which are from independent suppliers. Three examples follow:

1. All modules independent, single cluster controller platform: Interfaces are required between the cluster controller and each module, and between the transport module and each process and each cassette module.
2. Material handler, process modules independent, single cluster controller platform: Interfaces are required between the cluster controller and each process module, between the cluster controller and each logical module in the material handler (transport and cassette modules), and between the material handler and each process module.
3. One independent process module integrating to a cluster tool control system: Interfaces are required between the cluster tool control system and the process module supporting the process module to cluster controller communications, and the process module to transport module communications.

For fundamental compliance, each exposed interface shall support the fundamental requirements of each of the service groups required by the entities communicating. The required service groups for each interface are detailed in Section 8.6, and the required services for each service group are detailed in Sections 8.1 to 8.6.

7 Concepts

The Cluster Tool architecture and requirements are modeled in order to extract only the entities necessary for robust automated control and monitoring communications within a cluster tool.

Figure 3 illustrates the major module domains and the primary relationships between them. Module resources and material domains are represented differently to others because they embody the physical entities acting and being acted upon respectively.

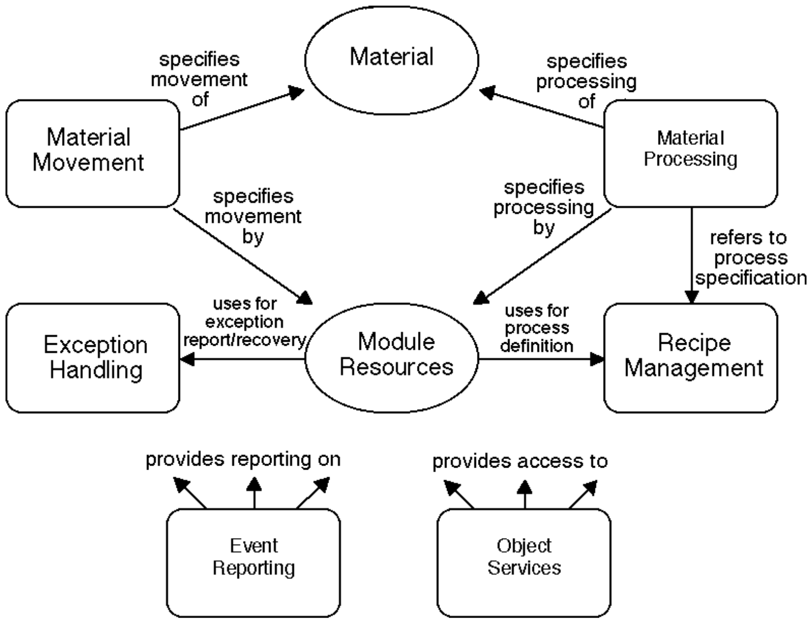

Figure 3
Cluster Tool Module Illustration

The domains illustrated are as follows:

Material — The material, or carrier of material, which is being received and processed in the cluster tool.

Material Processing — Specifies the required application of processing to material as defined by the assigned recipe, adding value to the material.

Material Movement — Includes exchange of material with the factory and material movement within the cluster, to get the material to the correct processing resource at the right time.

Module Resources — Perform and coordinate the processing and material movement activities.

Recipe Management — Provides the services to transfer recipes to be loaded as required for material processing, and manages recipe change control.

Exception Handling — Provides for interactive handling of exception conditions, including reporting and error recovery.

Event Reporting — Enables flexible event-based reporting of variable data as required by service-users.

Object Services — Provide services to obtain and modify standard object attribute data.

Each partition is presented in a subsection below with detailed information models.

The concepts are presented in this section using two types of formal models: OMT object information models describing entities and relationships, and Harel state models describing the behavioral characteristics of the cluster tool. The graphical representations of these models are described in Conventions, Section 5.

The events and actions which result from objects dynamically interacting form the basis for the communication requirements embodied in the standards. It is this mapping that specifies the communication services messages to be used.

The major requirement of the cluster tool control system is that it provide robust supervisory control with minimal overhead. Within a cluster tool there is a significant amount of parallel processing. In addition to concurrent processing in multiple independent process modules, each material processing requires the use of recipe management (to get the correct recipe with the correct material) and the use of material movement (to get the correct material to the correct processing resource at the right time).

The cluster controller maintains the overall mission of the system. Sub-missions are defined for, and responsibility given to, particular available module resources for execution. Once this responsibility is given, that module resource is fully in control, including direct communication with resources of other modules as required to attain the objective.

7.1 *Object Information Models* — The cluster tool objects relevant to distributed control in a number of models, each emphasizing a particular aspect of the system as partitioned (see Figure 4).

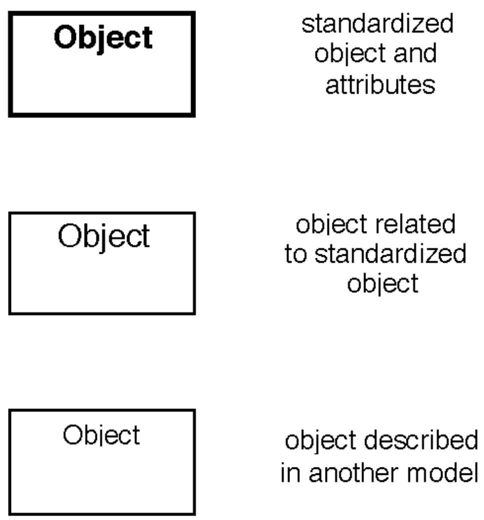

Figure 4
Object Designation

In addition to OMT conventions (see Section 5.2), each object in the information models has one of three designations: service objects with standardized attributes (thick border); other objects described in the sub-section (medium border); and objects described in other subsections but included to show significant relationships (thin border).

The models are process- and configuration-independent and do not dictate the internal architecture of the controlled modules beyond the physical requirements of cluster tools.

The first two models show major entities of the processing equipment and material being processed. Subsequent models are oriented towards one of the major functional domains.

7.1.1 *Cluster Tool Module Model* — The fundamental component of a cluster tool is the module. Figure 5 shows that there are three module types within a cluster tool:

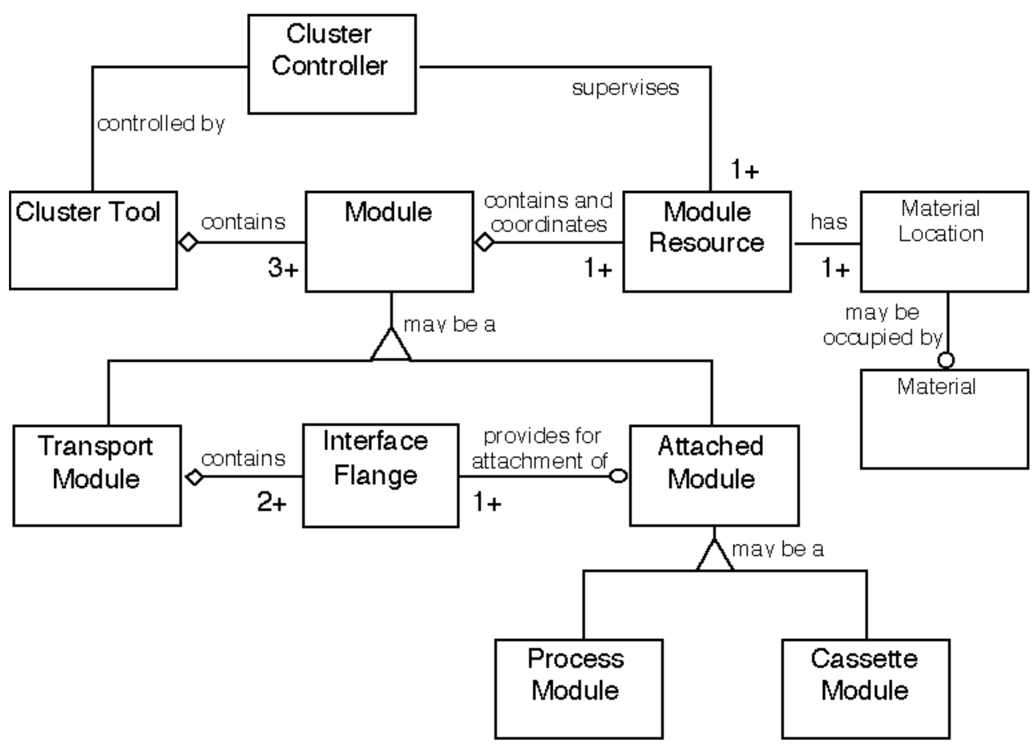

Figure 5
Cluster Tool Module Information Model

- process module (PM)— provides manufacturing value to material
- transport module (TM) — transfers material within cluster
- cassette module (CM) — exchanges material with factory

A cluster tool must contain one or more of each of these module types, as each performs a critical function in the cluster tool mission. Any module can contain processing resources.

Supervisory control within the cluster tool is the responsibility of the cluster controller. The cluster controller achieves this by supervising the various module resources using the standard communications services. It is the primary service-user in the cluster tool. The form of the cluster controller is not specified in this standard. It may be a single platform, distributed, or incorporated with one or more modules.

A module contains and coordinates a number of module resources dedicated to fulfilling a particular control function. Each module resource contains at least one material location, which may or may not contain material. Note that the location for material processing is defined separately from the location where the material is received or sent. This may be virtual if they are physically the same position, but they cannot be assumed to be so as this would exclude certain architectures.

The purpose of each type of module is described in detail below.

Cassette Module — The component of a cluster used to interface the cluster to the rest of the factory. It provides material input and output for the cluster. It makes only one material at a time available to the cluster transport (the intratool environment), regardless of how the material enters the cassette module from outside the cluster (the intertool environment). It is a specialization of attached module (AM).

Process Module — A process module is any component within a cluster which provides one or more steps of material processing for the cluster system. Material enters the process module through an interface flange, undergoes some transformation, and exits through the same or another interface flange. It is also a specialization of attached module (AM).

Transport Module — The transport module is responsible for transfer of material from one cluster-attached module to another. It consists of a robotic handler capable of exchanging material with each of the attached modules at the interface flanges. It can be a variety of physical topologies (radial or linear, for example). In SEMI standard cluster tools, the transport module has an interface isolation valve at each point of attachment to the attached modules. The transport module is responsible for managing constraints on the simultaneous opening of isolation valves as it relates to contamination of the transport module's environment by that of an attached module, as well as cross contamination between attached modules.

The attributes of modules and related objects in Figure 5 are not standardized as these objects are equipment and process-dependent.

7.1.2 *Material Model* — Material is received from the factory, in a carrier or singly, at an intertool port resource. They are transported within the cluster and processed by processing resources. Once processed, they are returned to the factory at the same, or another, intertool port resource.

The processing which is to be performed on material is determined from the process specification for that material.

The material model in Figure 6 establishes the relationships between the material and material locations. Two material types are of interest in cluster tool module communications, single material and carriers. Single material may be grouped in carriers. This is modeled by defining the material slot object, which is a type of material location. A carrier is made up of an ordered set of material slots. A single material occupies a material slot when in the carrier. In addition, a single material may be assigned a particular material slot which it does not yet occupy, indicating that it is to be received into that material slot when it arrives.

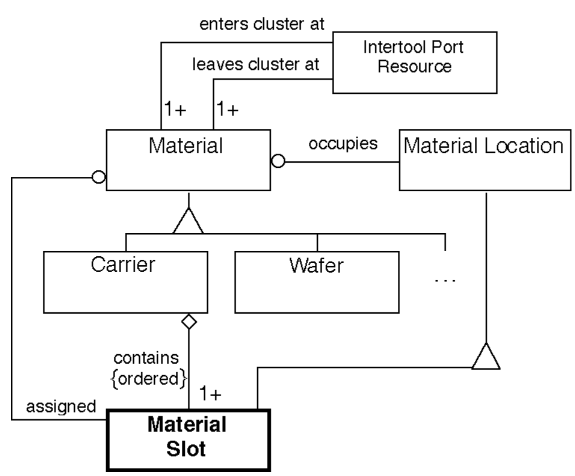

Figure 6
Material Information Model

Carriers may be cassettes used to transport single material in the factory and to input single material to the cluster tool, or they may be material boats in batch process modules.

The attributes of the material slot object are standardized to enable mapping of single material in carriers. Other objects in the diagram are not standardized. However, the identifier of the material, MaterialID, is an attribute of the material slot object.

Other materials (consumable gases and fluids, etc.) are present in the cluster tool, but outside the scope of these standards.

7.1.3 *Material Processing Model* — The material processing model in Figure 7 shows the use of the process job to direct the processing resource to apply the appropriate process, as specified by the recipe, to one or more materials in a process module. A processing resource in a process module has processing capabilities which are specified by corresponding recipes.

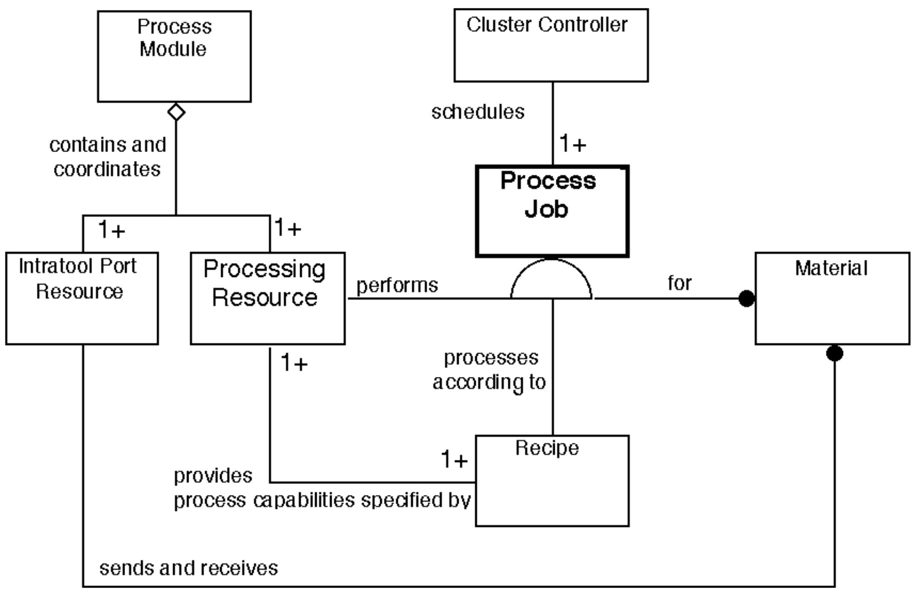

Figure 7
Material Processing Information Model

A process job can control multiple material only if identical processing is applied to all. Processing should begin and end simultaneously, synchronized with the arrival of the whole group of material.

The process job lifecycle extends beyond the active processing of the material. It exists from just before material arrival at the intratool port resource, through setup and processing, and until just after the material departure at the same, or another, intratool port resource. This allows for material-related pre-conditioning and post-conditioning of the processing resource before the material is received and after it is sent. As material input and output is controlled by the intratool port resource, it is the responsibility of the process module to ensure coordination of the intratool port and processing resources.

This is the model used to establish the Processing Management definition. There is no standardization beyond creation and control (starting, canceling, stopping, aborting, and pausing) of the high-level process job since the low-level control of process modules is application-dependent.

There is a component of scheduling embodied in this model. The material, recipes, and processing resources are scheduled by the cluster controller according to the process specification to a particular process module through the use of the process job. In order to perform the required processing, material is transferred to the processing resource, as directed by the cluster controller.

7.1.4 *Material Movement Models* — Material movement in a cluster tool includes all services required within the cluster tool to move material from the factory to a sequence of process modules in order to be processed and then back to the factory. Material is moved individually within a cluster tool and may be received from the factory in cassettes or individually.

The material movement model is divided into three parts as follows:

- intratool material movement defines the transfer of material between attached modules, with the transfer agent being a transport module.
- intertool material movement defines the exchange of carriers and single material with the factory at the cluster tool cassette module.
- carrier mapping defines presence and identifiers of single material contained in carriers.

These three models are used to establish the Material Movement Management definition within a cluster tool.

7.1.4.1 *Intratool Material Transfer* — The intratool material movement model is shown in Figure 8. An intratool material transfer is the movement of material from one attached module to another attached module through the linking transport module.

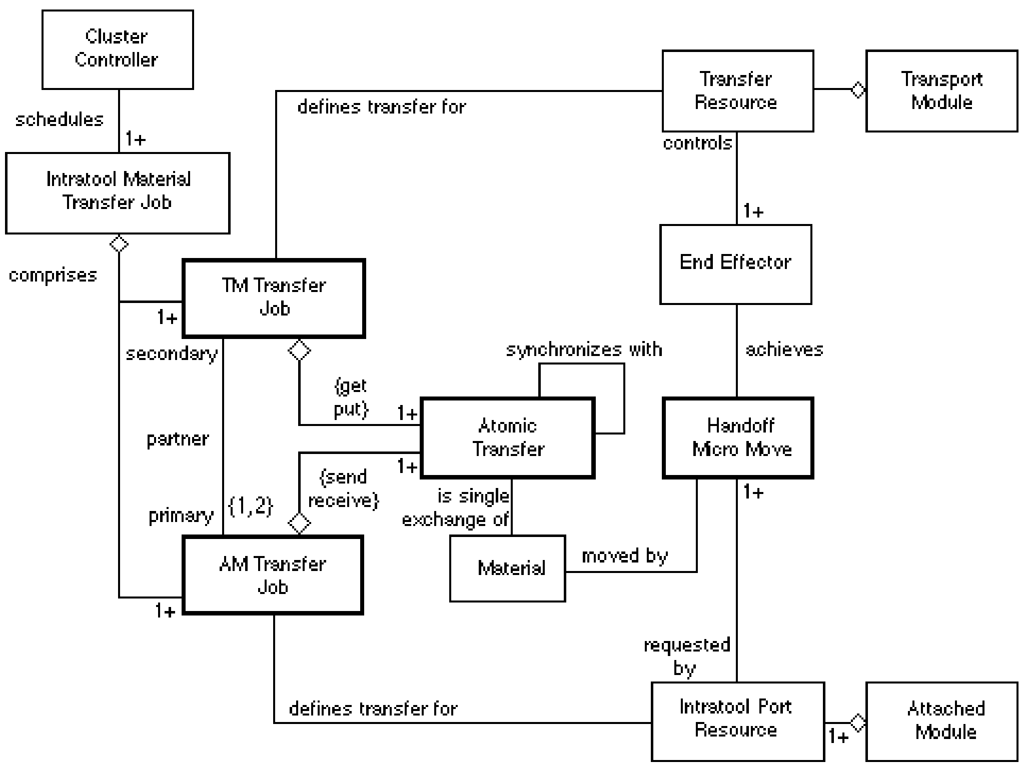

Figure 8
Intratool Material Movement Information Model

The cluster controller schedules an intratool material transfer job when intratool material transfer is required. This is achieved by TM and AM transfer jobs assigned to the appropriate module resource in each of the participating modules:

- to the transfer resource in the transport module to get the material from the source attached module and put it into the destination attached module.
- to the intratool port resource in the source attached module to send the material to the transport module.

- to the intratool port resource in the destination attached module to receive the material from the transport module.

Transfer jobs are made up of atomic transfers. An atomic transfer in one transfer partner synchronizes with the corresponding atomic transfer in the other partner to achieve the material transfer through handoff micro moves. In a cluster tool, the attached module is the primary partner, requesting the handoff micro moves, and the transport module is the secondary partner achieving those micro moves by controlling the end effector on which the material is transported.

The transport module is responsible for managing constraints on the simultaneous opening of isolation valves as it relates to contamination of the transport module's environment by that of an attached module, as well as cross contamination between modules. The attached module ensures that its environment will not contaminate the transport module before synchronizing for handoff. The rules for re-establishing isolation at verification are determined by the transport module.

7.1.4.2 *Intertool Material Transfer* — The cassette module performs material exchange with the factory. The material generally consists of cassettes with single material or empty cassettes, but may be individual single material. The intertool material movement model, shown in Figure 9, is similar to the intratool material movement model. An intertool material transfer is a transfer in the factory which includes the cluster tool as one of the transfer partners.

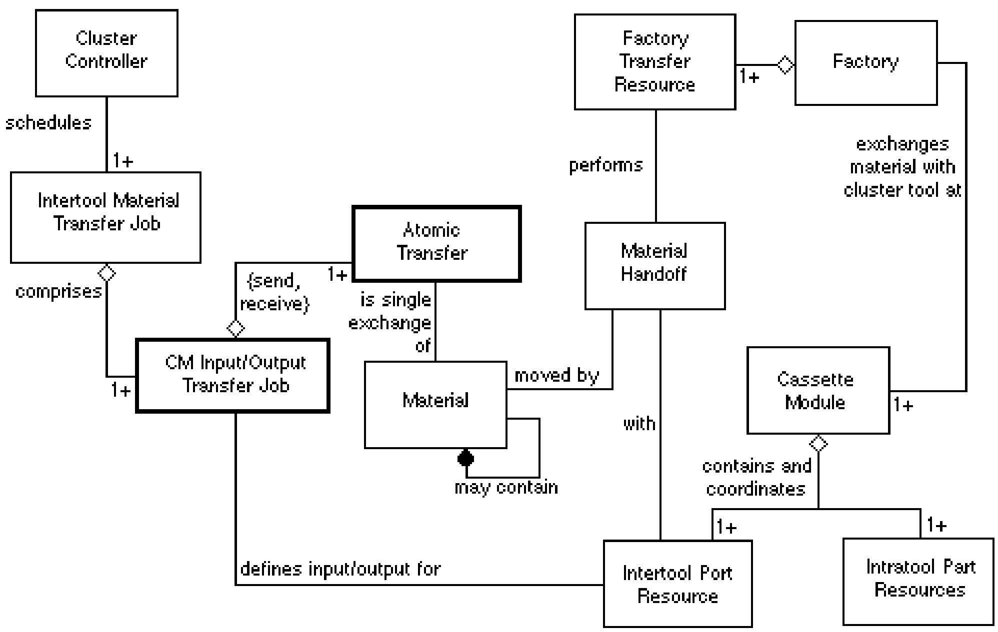

Figure 9
Intertool Material Movement Information Model

In the cluster tool, the cluster controller schedules an intertool material transfer job when material exchange with the factory is required. This job may be an element of a factory material transfer job in which the cluster tool is a partner.

The intertool material transfer job is achieved by a CM input/output transfer job assigned to the intertool port resource in the participating cassette module. It defines the material exchange with the factory for the cassette module. The CM input/output transfer job comprises an atomic transfer, which defines the roles in the material handoff.

In the cassette module, material transfer with the transport module is controlled by the intratool port resource. It is the responsibility of the cassette module to coordinate its intertool and intratool port resources.

The factory transfer resource may be an operator, SMIF, AGV, or other mechanism. Its definition, associated transfer jobs, and the handoff, are beyond the scope of this standard. Factory material movement may be achieved automatically using applicable SEMI standards.

7.1.4.3 *Carrier Mapping* — The final element of material movement in a cluster tool is the mapping of single material in a carrier. Once a cassette is received by the cluster tool, it is necessary to communicate the presence and identifiers of the material it contains. Batch process modules also require these carrier mapping services in order to define loading of the process carrier.

In carrier mapping, the carrier may be a cassette used to hold single material loaded at the cassette module from the factory, or a process carrier used to hold multiple material for batch processing. For the purposes of carrier mapping, these are equivalent, and the relationships are shown in the material model, Figure 6.

A carrier has an ordered set of material slots, a specialization of material location, each of which can hold a single material. The material slot of a carrier is only of interest when the carrier is in the cluster tool, so it is viewed as a location of the module which contains the carrier. In addition to occupancy, a single material may be assigned to a material slot, indicating, for example, the particular slot to which a single material is to be moved when available. Information on material presence and assignment of the material identifier may be detected in the module or determined by the cluster controller or a supervisory controller.

7.1.5 *Exception Model* — In an automated control system where the operator interface is remote from the module controller, it is necessary to have interactive exception handling for error recovery. In addition to exception reporting, a module requires input from a decision authority to resolve recoverable abnormal situations. These include exception conditions which extend beyond the module domain and those for which the module has insufficient information, such as in hardware failure.

The decision authority in a cluster tool is the cluster controller. It may interact with an operator to determine the appropriate recovery action to perform.

Figure 10 shows the exception model. Module resources detect appropriate exception conditions, which may be set or cleared. An abnormal situation is indicated by the corresponding exception condition being in the set state. A significant change in exception condition information generates an exception report to notify the decision authority. Both detection of the abnormal situation and its resolution generate exception reports. Reporting of each exception condition may be enabled and disabled independently in order to mask nuisance exceptions.

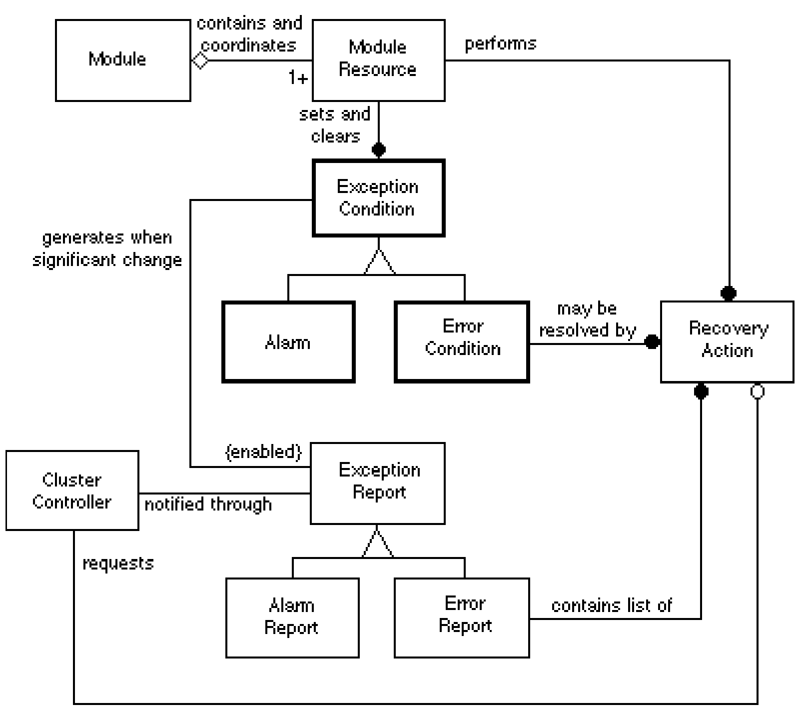

Figure 10
Exception Information Model

Error exception conditions may have associated recovery actions which can be performed by the module resource to attempt to recover from the abnormal situation. Alarm exception conditions cannot, by definition, be resolved using recovery actions.

A list of possible recovery actions is included in a posted error report. The decision authority can request one of the offered recovery actions to resolve the error condition. The selected recovery action is performed by the appropriate module resource and may result in clearing the error condition.

This model is used to establish the Exception Management definition.

7.1.6 *Recipe Management Model* — Recipe management in a module varies with the requirements of the application. Simple modules do not provide local recipe editing and don't require management of multiple logical domains (namespaces) and local recipe version control.

Figure 11 shows the full recipe management model for a sophisticated module.

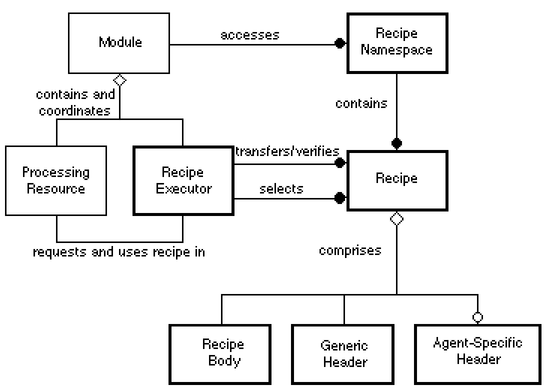

Figure 11
Recipe Management Information Model

Process recipes specify the actual parameters of the processing to be achieved. The module processing resource identifies, through the process job, the required recipe(s) to be loaded by the recipe executor in order to process a particular material.

The recipe executor accesses and selects recipes for execution. It uploads and downloads recipes from the cluster controller and is capable of verifying that a recipe is syntactically correct. The recipe executor also provides for a service-user to select a recipe to be loaded into the recipe execution area. The recipe is made up of a recipe body and may have headers if the module supports recipe namespace management.

The module accesses recipe namespaces where requested by service-users. A module which does not provide local editing and linking of recipes does not need recipe namespace management. Recipe namespace management requires management of recipe generic and agent (module) specific headers. For example, a process module could manage a recipe namespace containing its process and service recipes.

This model is used to establish the Recipe Management services requirements for cluster tool modules.

7.1.7 *Event Reporting Model*

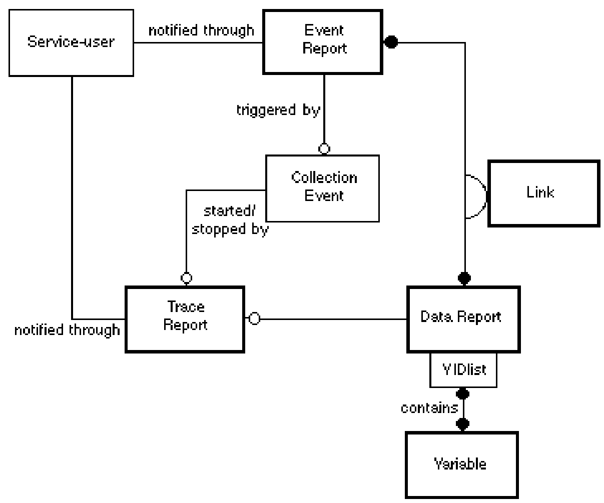

Figure 12
Event Reporting Information Model

Event reporting provides a dynamic and flexible means by which a service-user can receive notification of events and data relating to module resources.

The services-user can define and enable two types of reporting, event reporting and trace reporting. Both may convey data, the values of identified variables at the data collection time. The variable identifiers required to be reported are specified in the data report definition.

In event reporting, data reports are linked to event report definitions associated with each collection event type. On occurrence of the collection event, an event report message is generated according to the event report definition and the linked data report definitions. Reporting may be enabled and disabled for each collection event type. Data reports and links may be predefined or specified dynamically by the service user.

Trace reporting is time-based data reporting. Trace reporting is specified by the service-user dynamically as required. Collection events may initiate and terminate the tracing in order to link reporting to significant conditions, such as processing. The trace data is collected at a frequency specified by the service-user. Trace reports are generated according to the trace report definition and the associated data report definition.

Through associating the event report and trace report definition with the service-user, the model provides for the association of multiple service-users to a single service-provider. This allows for event reporting between modules where needed as well as the ability for direct connection of a data acquisition entity independent of the cluster controller.

7.2 *Cluster Tool Module Message Flow* — The appropriate objects in the information models in the previous section are grouped in the cluster tool module types. The communications with the essential objects are shown in the message flow diagrams in this section.

The diagrams show message flow between entities within an agent (in this case a module) and those outside the agent. Entities are rectangular boxes, and the agent is a rounded box. As emphasis is on the module and its services, only one agent is shown on each diagram. Outside entities in the cluster tool module communications domain appear within an agent on another diagram. The messaging is shown by arrows in each direction, with a brief label indicating the services requested or provided.

The communications are shown for the primary control of the process module (Figure 13), cassette module (Figure 14), and transport module (Figure 15). Note that the transport module transfer resource communicates with multiple process and cassette module intratool port resources.

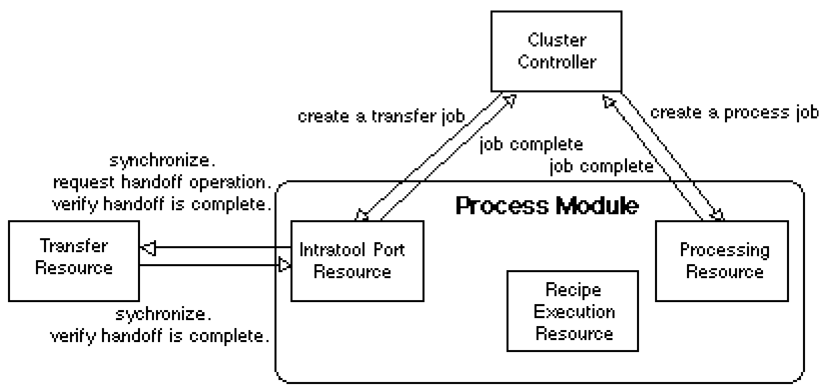

Figure 13
Process Module Primary Control Message Flow

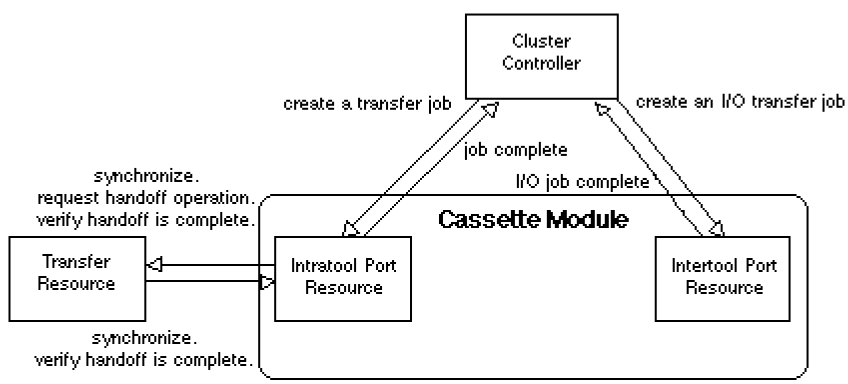

Figure 14
Cassette Module Primary Control Message Flow

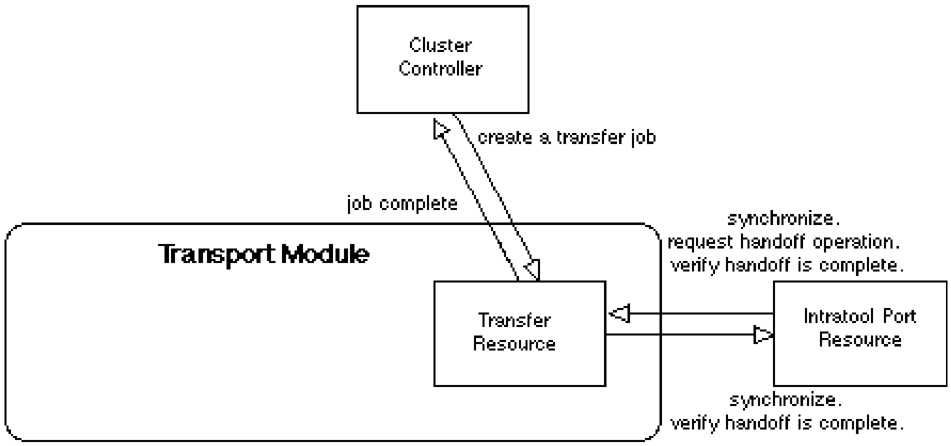

Figure 15
Transport Module Primary Control Message Flow

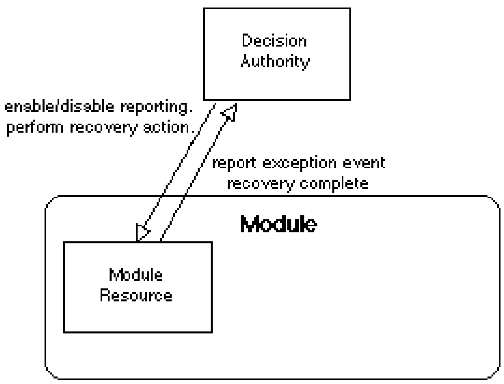

Figure 16
Module Exception Message Flow

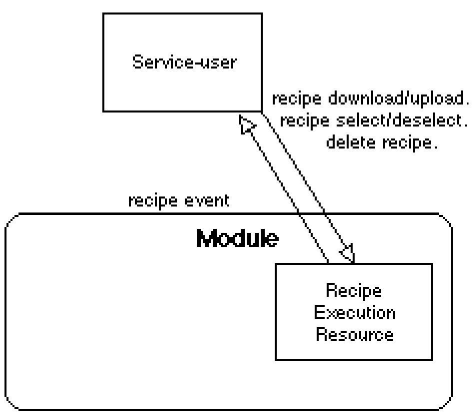

Figure 17
Module Recipe Message Flow

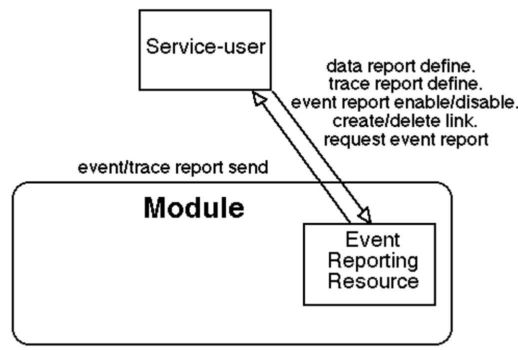

Figure 18
Module Event Reporting Message Flow

The communications for support functionality are shown for any module, as the services are common to all module types. The support functionality modeled includes exception handling (Figure 16), recipe management (Figure 17), and event reporting (Figure 18). A typical decision authority or service-user is the cluster controller.

7.3 *Cluster Tool Behavioral Model* — The process material is the fundamentally important object in a cluster tool and its lifecycle is the key component to establishing cohesiveness in the communication and controls standards.

The finite state model in Figure 19 presents the high-level behavior of a single material within the domain of the cluster tool. Bold transitions trace the normal lifecycle of the material and are described in the transition table, Table 1. Other transitions occur in exception situations and are not detailed here. The transition table actions indicate the primary control operations which are requested of the modules by the cluster controller.

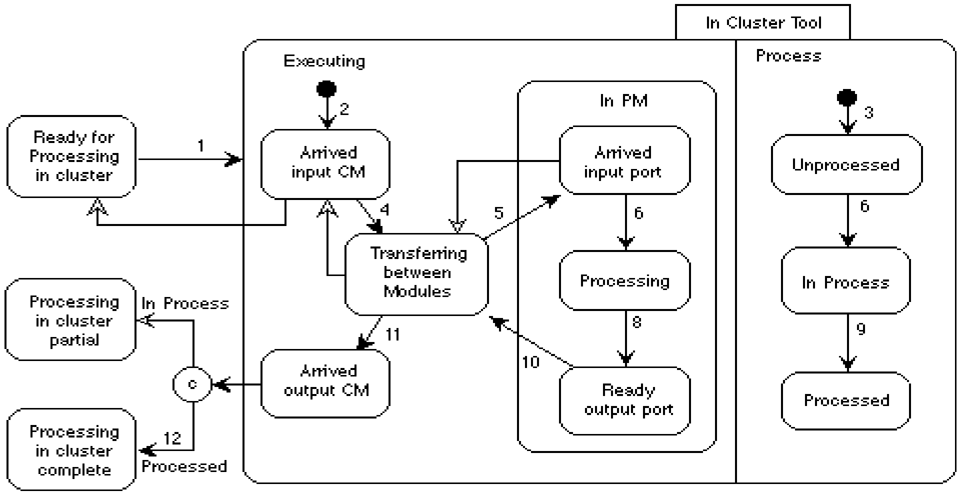

Figure 19
Cluster Tool Material State Model

When ready to be processed in the cluster tool, the material is presented and loaded at the input cassette module (intertool material transfer). It is usually contained with other single material in a cassette. The material process sub-state in the scope of this visit to the cluster tool is initially unprocessed. The material is then transferred to the first process module (intratool material transfer), ready for process. At this point, the material may be returned to the input cassette module and back to the factory, as the material has not been physically altered.

The material then begins processing in the process module according to the recipe for that process step (process job), and the process sub-state changes to in-process.

On successful completion of the process step, the material is then ready to be transferred to the next module (intratool material transfer). This may be another process module for the next process step or to the output cassette module if processing in the cluster tool is complete, in which case the process sub-state changes to processed. It is also possible that the next process step be performed in the same process module.

Table 1 Cluster Material State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1	Ready for Processing in cluster	Material being received at cluster CM.	In cluster tool	CM Input/Output Transfer Job. CM Carrier mapping.
2	Not in Cluster tool	Material being received at cluster CM.	Arrived input CM	
3	Not in Cluster tool	Material being received at cluster CM.	Unprocessed	
4	Arrived input CM	Initiate material transfer to PM.	Transferring between modules	Initiate PM Process Job. TM Transfer Job. Source AM Transfer Job (CM send). Dest. AM Transfer Job (PM receive).
5	Transferring between Modules	Material arrived in PM.	In PM/Arrived input port	
6	In PM/Arrived input port	Processing initiated on material.	In PM/Processing	PM Process the material.
7	Unprocessed	Processing initiated on material.	In Process	
8	In PM/Processing	PM processing complete.	In PM/Ready output port	
9	In Process	All required process steps in cluster completed.	Processed	
10	In PM/Ready output port	Initiate intratool material transfer.	Transferring between modules	Initiate next PM Process Job if material processing still required. TM Transfer Job. Source AM Transfer Job (send). Dest. AM Transfer Job (receive).

#	*Current State*	*Trigger*	*New State*	*Action(s)*
11	Transferring Between Modules	Arrived output CM.	Arrived output CM	CM Input/Output Transfer Job.
12	Arrived output CM	Transfer back to factory complete.	Processing in cluster complete	

The material is finally unloaded from the output cassette module to the factory (intertool material transfer). If all process steps in the cluster tool were completed and were successful, the processing in the cluster tool is complete; otherwise, processing in the cluster tool was only partially accomplished.

Detailed behavioral models are documented in the individual Cluster-Specific Services and in the standards which they reference. The Typical Operating Scenario in the application notes illustrates the behavioral characteristics of cluster tool control by showing the detailed messaging among modules and supervisory controller through the lifecycle of material as it enters the cluster, is processed, and then leaves the cluster.

7.4 *Cluster Tool Control Topology* — The natural decomposition of a cluster tool is into its modules. The module controller is the entity which performs internal control of a module and provides standard services. Module controllers provide certain application-specific functions (providers of services and user of services) and consist of hardware and software components that interact with the communications and control environment of the cluster tool.

Traditional definitions of controllers have implied certain PHYSICAL, hardware control topologies (such as distributed or centralized processors). These cluster tool standards specify the communications in terms of services-providers, enabling the module controllers to be based on LOGICAL control topologies.

The list of possible physical controllers which could be used to implement the logical services of the standards are listed below. It is emphasized, however, that the standard is not based on any constraint that each of these physical controllers be present in a cluster control system, but instead requires that the logical services (i.e., software functional components) be present somewhere in the cluster control system.

Possible Controllers:

- Cassette Module Controller
- Process Module Controller
- Transport Module Controller
- Cluster Controller

The logical control topology allows any combination of module controllers on a single control unit. Standard communication is not required among them. A common example is the grouping of transport module and cassette module control into a single material handler control unit as shown in Figure 1. For interface compliance, all communication between a logical module controller and remote controller or service-user must be compliant with the standard services.

8 Cluster Tool Module Services

The Cluster Tool control system elements, as represented in the object information, object communications, and behavioral models, require standard services in order to interface with one another.

The objects which are fully standardized (attributes, behavior, and operations) are only those essential to this communication, and the services are the interactions with these standard objects.

The services are grouped into the following functional areas:

- Object Services
- Processing Management
- Material Movement Management
- Exception Management
- Recipe Management
- Event Reporting
- Clock

The services of each of these groups are described in detail in this section. The services are defined in terms of services provided by independent SEMI standards, specifying their application and limitations with respect to the fundamental requirements of cluster tool module communications.

8.1 *Object Services* — All standardized service object attribute access across a cluster tool module communications interface is achieved using object services. Access may be to read attribute values of objects, to get a list of objects corresponding to certain criteria, and to set the values of writable attributes of objects. The message services provided to accomplish this are Get and Set.

The specific object types, relations, attributes, and access rules are defined in each specific services group.

The object services are defined in SEMI E39 (Object Services Standard: Concepts, Behavior, and Services). Cluster tool module communications require only the fundamental requirements of that standard except where stated in a specific services group below.

8.2 *Processing Management Services* — Processing management across a cluster tool module communications interface is achieved using the processing management services. These services provide the communications and behavior required of the processing resource by the material processing models through defining the process job object and its operations.

The processing management services follow SEMI E40 (Standard for Processing Management). Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of that document.

The process job creation is requested by the cluster controller using the PRJobCreate service. If the processing resource accepts the job, it performs the required processing to completion once the material arrives. The processing resource shall support the PRJobCommand Abort service, which ceases any processing and terminates the job. The processing resource reports process job milestones achieved to the cluster controller using the PRJobAlert service.

Process job object attributes required to be accessible through object services follow:

Attribute Name	*Description: Requirements*
ObjType	The object type: process job.
PRJobID	Identifier for the process job.
PRMtlType	MaterialType.
PRMtlNameList	Material identifier: single material only.
PRRecipeMethod	Recipe specification type: recipeID only.
RecID	Identifier of the recipe applied.
PRJobStateList	All concurrent substates of the process job.

Processing management messaging services required:

Message Name	*Description: Requirements*
PRJobCreate	Create process job: single material, recipe identifier only, auto-start.
PRJobCommand	Command on a process job: abort.
PRJobAlert	Notification: setup, processing, processing complete, complete.

Processing resource capabilities required, but not already specified above:

- Detect and report success or failure of a process job.
- Reject incomplete, invalid, and unsupported requests.

Processing resource capabilities permitted, but not to be required, by a service-user:

- Pre-conditioning and post-conditioning.
- Stop, Pause, and Resume of a process job.
- Manual process start.
- Process job queuing and queued job Cancel.
- Process tuning.
- Processing of material groups.
- Multiple concurrent process jobs.
- Multiple consecutive process jobs.
- Process job with no material.
- Notification of waiting for material and of process job state changes.

8.3 *Material Movement Services* — Each material movement in a cluster tool involves interaction among the cluster controller and all of the modules participating in the transfer. The communications interfaces and behavior resulting from the material movement models are defined for each association by the material movement services.

The material movement services are partitioned into intratool material movement services, intertool material movement services, and carrier mapping, as in the models.

The material movement services follow the Material Movement Management Standard [SEMI E32] and Object Services Standard: Concepts, Behavior, and Services [SEMI E39]. Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of those standards.

8.3.1 *Intratool Material Movement Services* — From the intratool material movement models, an intratool material transfer — the transfer of material from one attached module to another through a transport module — requires the following interactions:

1. The cluster controller decides that material is to be moved as the result of either arrival of material or the completion of some processing step on the material. It determines which material is to be

moved and the source and destination of that movement (cluster-application-specific). It requests all the modules involved to perform the appropriate TM or AM transfer job.

2. The source- and destination-attached modules inform the transport module that they are prepared to do their specific activities during the material transfer. The transport module informs the source- and destination-attached modules, each at the appropriate point in time, that it is synchronized for material handoff.

3. The detailed transactions required to handoff the material during the transfer are accomplished, first at the source and then at the destination.

These interactions may require a number of communications interfaces for intratool material transfer from the following:

- Cluster controller to transport module
  - transfer resource: TM transfer job source AM to destination AM
- Cluster controller to source-attached module
  - intratool port resource: AM transfer job send
- Cluster controller to destination-attached module
  - intratool port resource: AM transfer job receive
- Transport module to source-attached module
  - intratool port to transfer resource: handoff get
- Transport module to destination-attached module
  - intratool port to transfer resource: handoff put

The material movement services define the communications and behavior required of the attached module intratool port resource and the transport module transfer resource. They define the TM transfer job, TM atomic transfer, AM transfer job, and AM atomic transfer objects and their operations, as well as the handoff operations between the transfer resource and the intratool port resource.

Each interface is described below.

Cluster Controller to Transport Module Interface — The TM transfer job creation is requested by the cluster controller using the TRJobCreate service. If the transfer resource accepts the job, it performs the transfer of the material to completion, coordinating with the attached modules. The TM transfer job comprises two atomic transfers for the material, one to get (receive) it from the source-attached module and another to put (send) it to the destination-attached module.

The transfer resource shall support the TRJobCommand Abort service, which ceases any transfer activity and terminates the job. The transfer resource reports transfer job milestones achieved to the cluster controller using the TRJobAlert service.

The transfer resource coordinates material handoff with each attached module through the transport module/attached module interface, described below.

TM transfer job object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: transfer job.
TRJobID	Identifier for the transfer job.
(Ordered list of) TRAtomicID	Ordered list of identifiers for the atomic transfers in the transfer job: two atomic transfers for the material.
(List of)TRJobState	All concurrent substates of the transfer job.

TM atomic transfer object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: atomic transfer.
TRAtomicID	Identifier for the atomic transfer.
TRLink	Identifier to coordinate handoff.
TRObjType	Material Type.
TRObjName	Material identifier.
TRRole	Role in transfer control: secondary.
TRPartner	Identifies partner-attached module.
TRDirection	Handoff direction: receive from source AM, send to destination AM.
TRType	Active/passive in transfer: active.
(List of)TRAtomic-State	All concurrent substates of the atomic transfer.

Material movement messaging services required:

Message Name	*Description: Requirements*
TRJobCreate	Create transfer job: single material, source to destination AM, auto-start.
TRJobCommand	Command on transfer job: abort.
TRJobAlert	Notification: started, complete.

Transfer resource capabilities required, but not already specified above:

- Detect and report success or failure of a transfer job.

- Reject incomplete, invalid, and unsupported requests.

Transfer resource capabilities permitted, but not to be required, by a service-user:

- Stop, Pause, and Resume of a transfer job.
- Manual atomic transfer start.
- Transfer job queuing and queued job Cancel.
- Transferring of material groups.
- Multiple concurrent transfer jobs.
- Notification of transfer events.

Cluster Controller to Attached Module Interface — The AM transfer job creation is requested by the cluster controller using the TRJobCreate service. If the intratool port resource accepts the job, it coordinates with and directs the transport module to achieve the material handoff. The AM transfer job comprises an atomic transfer for material which is to receive it from, or send it to, the transport module.

The intratool port resource shall support the TRJobCommand Abort service, which ceases any transfer activity and terminates the job. The intratool port resource reports transfer job milestones achieved to the cluster controller using the TRJobAlert service.

The intratool port resource coordinates material handoff with the transport module through the transport module to attached module interface, described below.

AM transfer job object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: transfer job.
TRJobID	Identifier for the transfer job.
(Ordered list of) TRAtomicID	Ordered list of identifiers for the atomic transfers in the transfer job: one atomic transfer for each material.
(List of)TRJobState	All concurrent substates of the transfer job.

AM atomic transfer object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: atomic transfer.
TRAtomicID	Identifier for the atomic transfer.
TRLink	Identifier to coordinate handoff.
TRPort	AMPort through which transfer occurs.
TRObjType	Material type.
TRObjName	Material identifier.
TRRole	Role in transfer control: primary.
TRPartner	Identifies partner transport module.
TRDirection	Handoff direction: receive or send.
TRType	Active/passive in transfer.
(List of)TRAtomicState	All concurrent substates of the atomic transfer.

Note that TRLocation is not required to be supported as it is the responsibility of the attached module to determine the appropriate location to be used based on the material identifier.

Material movement messaging services required:

Message Name	*Description: Requirements*
TRJobCreate	Create transfer job: single material, send or receive, auto-start.
TRJobCommand	Command on transfer job: abort.
TRJobAlert	Notification: started, complete.

Transfer resource capabilities required, but not already specified above:

- Detect and report success or failure of a transfer job.
- Reject incomplete, invalid, and unsupported requests.

Transfer resource capabilities permitted, but not to be required, by a service-user:

- Stop, Pause, and Resume of a transfer job.
- Manual atomic transfer start.
- Transfer job queuing and queued job Cancel.
- Transferring of material groups.
- Multiple concurrent transfer jobs.
- Notification of transfer events.

Transport Module to Attached Module Interface — The control interface for the handoff of material between the end effector of a transport module and any attached module supports a sequence of three phases:

1. a synchronization phase that establishes that both the attached module intratool port resource and the transport module transfer resource are ready to handoff the material.
2. a physical handoff phase controlled by the intratool port resource.

3. a verification phase to determine that actual handoff took place. This action completes the handoff.

The transport module is responsible for managing constraints on the simultaneous opening of isolation valves as it relates to contamination of the transport module's environment by that of an attached module, as well as cross-contamination between modules. The attached module ensures that its environment will not contaminate the transport module before synchronizing. The rules for re-establishing isolation at verification are determined by the transport module.

The synchronization between the transfer resource and the intratool port resource is achieved by each, indicating readiness to transfer the material, using the HOReady service. Once both partners have received the HOReady, the intratool port resource directs the physical handoff. The intratool port resource commands the transfer resource using the defined HOCommand services. Once the physical handoff is complete, the intratool port resource requests verification using the HOVerify service.

The transfer resource and intratool port resource shall support the HOCancelReady service which cancels a previously sent HOReady while still in the synchronization phase. The transfer resource shall support the HOHalt service, which ceases any transfer activity and terminates the handoff.

Material movement messaging services required:

Message Name	*Description: Requirements*
HOReady	Synchronize with partner.
HOCommand	Command to the transport resource to perform an activity in the transfer envelope. Detailed below.
HOVerify	Verification of handoff completion with transfer resource.
HOCancelReady	Rescinds previous HOReady message.
HOHalt	Command to the partner to stop all action.

HOCommands to be supported by the transfer resource:

Command	*Description: Requirements*
Pick	Commands the transfer resource to take all actions necessary to remove the material from the intratool port.
Place	Commands the transfer resource to take all actions necessary to place the material in the intratool port.
Extend	Commands the transfer resource to reach into the intratool port to a predefined position at which the material can be accepted or released.
Retract	Commands the transfer resource to withdraw from the intratool port.

Where the robotic hardware does not provide for vertical motion, Pick and Place are not required to be supported.

Transfer partner capabilities required, but not already specified above:

- Detect and report success or failure of handoff commands.
- Detect and report success or failure of the handoff, through the verification.
- Reject incomplete, invalid, and unsupported requests.

Transfer resource capabilities permitted, but not to be required, by either partner:

- Multiple concurrent handoffs.
- Additional handoff commands.

8.3.2 *Intertool Material Movement Services* — Factory-to-cluster tool carrier or single material input/output management across a cluster tool module communications interface is achieved using the intertool material movement services. These services provide the communications and behavior required of the intertool port resource by the intertool material movement models through defining the CM input/output transfer job object and its operations.

This standard specifies only the required communication between the cluster controller and the cassette module and does not assume automated material movement in the factory. The CM input/output transfer job is compliant with SEMI E32 (Material Movement Management) and may be extended to support automated material movement in the factory.

The CM input/output transfer job creation is requested by the cluster controller using the TRJobCreate service. If the intertool port resource accepts the job, it coordinates with the operator or some entity to achieve the material handoff. The CM input/output transfer job comprises an atomic transfer for a cassette or single material which is to receive it from, or send it to, the factory.

The intertool port resource shall support the TRJobCommand Abort service, which ceases any transfer activity and terminates the job. The intertool port resource reports transfer job milestones achieved to the cluster controller using the TRJobAlert service.

CM input/output transfer job object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: transfer job.
TRJobID	Identifier for the transfer job.
(Ordered list of) TRAtomicID	Ordered list of identifiers for the atomic transfers in the transfer job: one atomic transfer for each material.
(List of)TRJobState	All concurrent substates of the transfer job.

Atomic transfer object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: atomic transfer.
TRAtomicID	Identifier for the atomic transfer.
TRLink	Identifier to coordinate handoff: none.
TRPort	CMPort through which transfer occurs.
TRObjType	Material Type: cassette or single material.
TRObjName	Material identifier.
TRRole	Role in transfer control: secondary.
TRPartner	Identifies partner if automated: none.
TRDirection	Handoff direction: receive or send.
TRType	Active/passive in transfer: passive.
(List of)TRAtomicState	All concurrent substates of the atomic transfer.

The requirements above indicate the settings if the transfer is to be manual, with the operator. The attributes TRLink, TRRole, TRPartner, and TRType are not significant in this situation. These become significant in automated material transfer.

Material movement messaging services required:

Message Name	*Description: Requirements*
TRJobCreate	Create transfer job: single material send or receive, auto-start.
TRJobCommand	Command on transfer job: abort.
TRJobAlert	Notification: started, complete.

Intertool port resource capabilities required, but not already specified above:

- Detect and report success or failure of a transfer job.
- Reject incomplete, invalid, and unsupported requests.

Intertool port resource capabilities permitted, but not to be required, by a service-user:

- Automated transfer of material within factory.
- Stop, Pause, and Resume of a transfer job.
- Manual atomic transfer start.
- Transfer job queuing and queued job Cancel.
- Transferring of material groups.
- Multiple concurrent transfer jobs.
- Notification of transfer events.

8.3.3 *Carrier Mapping Services* — Mapping of material in carriers across a cluster tool module communications interface is achieved using the carrier mapping services. These services provide the communications required of the appropriate module resources by the material models through defining the material slot object.

The carrier-mapping services are fully specified in terms of the material slot attributes accessed through the get and set services of SEMI E39 (Object Services Standard: Concepts, Behavior, and Services). Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of that standard.

The mapping information is only of interest to the cluster tool for a carrier contained in the module resource. The material slot objects are, therefore, associated with, and managed by, the module resource which uniquely identifies all of its material slots. The carrier-mapping services provide for communication of material slot information in both directions between the cluster controller and the module resource. The information communicated is material presence and material identification. Whether the material presence is detected by the module resource or determined by the cluster controller is application-specific. This is also the case for material identification.

A material slot may be assigned the identifier of material which is not yet occupying the material slot. This provides for determination by the cluster controller of which material slot the material is to be moved into when it arrives at the module.

Material slot object attributes required to be accessible through object services are detailed in Table 2.

Table 2 Material Slot Attributes

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	The object type.	Y	RO	Text: "MATERIALSLOT"
ObjID	Module unique identifier for the material slot.	Y	RO	Text: Unique with respect to the module.
MtlName	Identifier of the material occupying or assigned to the slot.	Y	RW	Text
OccState	Current state of the material slot.	Y	RW	Text: SlotUnknown SlotEmpty SlotOccupied SlotActive SlotDisabled

The material slot occupancy attribute indicates the presence of material as follows:

- SlotUnknown — the carrier is present and slot occupancy is not known, such as from when a carrier is loaded until the material is detected or the state is set by the cluster controller.
- SlotEmpty — no material in the slot.
- SlotOccupied — material is present in the slot.
- SlotActive — material is being removed from, or is arriving at, the slot.
- SlotDisabled — material slot unusable, such as when the carrier is not present.

Module resource capabilities required, but not already specified above:

- Reject incomplete, invalid, and unsupported requests.

Module resource capabilities permitted, but not to be required, by the cluster controller:

- Detection of the presence of material in a material slot.
- Detection of the identifier of material in a material slot.

Table 3 lock Attributes

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	The object type.	Y	RO	Text: "CLOCK"
ObjID	Module unique identifier for the clock.	Y	RO	Text: Unique with respect to the module. Services timestamp clock is "SERVICESCLOCK"
DateTime	Current time.	Y	RW	Text: yyyymmddhhmmsscc

8.4 *Exception Management Services* — Exception management across a cluster tool module communications interface is achieved using the exception management services. These services provide the communications and behavior required of the module resource by the exception models described in Section 7.1.5 through defining the exception condition object and its operations.

The exception management services follow SEMI Draft Document 2013C (SECS II Support for SEMI E41 (Exception Management Standard)). Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of that standard.

Exception conditions (alarms and error conditions) are created and managed by the module resource detecting the related abnormal situation. The module resource uses the EXPost service to report the occurrence of the abnormal situation or some significant change in exception condition information while the situation exists. EXCleared reports that the abnormal situation is no longer apparent or relevant. Reporting on an exception condition is enabled and disabled by setting its EXEnabled attribute.

The cluster controller may direct recovery of error conditions using the EXRecover service. The module resource performs the recovery action and reports its completion using the EXRecoveryComplete service. The module resource is only required to permit a single recovery action at a time on all set exception conditions, but may support multiple recovery actions. The module resource shall support the EXRecoveryAbort service, which ceases any activity and terminates the recovery action.

Exception condition object attributes required to be accessible through object services:

Attribute Name	*Description: Requirements*
ObjType	The object type: EXCEPTION.
EXID	Identifier for the exception condition.
EXType	Type of exception condition:alarm or error condition.
EXMessage	Text message describing the abnormal situation monitored.
EXEnabled	Indicates reporting to decision authority enabled/disabled.
EXRecActList	Possible recovery actions (none for alarms).
EXStateList	All concurrent substates of the exception.

Exception management messaging services required:

Message Name	*Description: Requirements*
EXPost	Notify/update on abnormal situation.
EXCleared	Notify resolution of abnormal situation.
EXRecover	Command to perform recovery action.
EXRecoveryComplete	Notify completion of recovery action.
EXRecoveryAbort	Command to abort a recovery action.

Reporting of all exception conditions is set to be enabled on establishment of an association, and those in the set state are posted.

Module resource capabilities required, but not already specified above:

- Reject incomplete, invalid, and unsupported requests.

Module resource capabilities permitted, but not to be required, by a service-user:

- Multiple concurrent recovery actions.
- Dynamic update of exception condition message and valid recovery actions.

8.5 *Recipe Management Services* — Recipe management across a cluster tool module communications interface is achieved using the recipe management services. These services provide the communications and behavior required of the module by the recipe models described in Section 7.1.6 of this document.

The recipe management services follow SEMI E42 (Recipe Management Standard). Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of a recipe executor, and optionally the recipe namespace management, as defined in that standard.

The module requiring recipe services contains a recipe executor that is capable of performing recipe download, verification, selection, deselection, and deletion as requested by the cluster controller. The module may also support recipe namespace services.

In certain configurations, the module may require recipe management services to be provided by the cluster controller, in order that it may request a selected recipe that is not stored locally. The module is the service-user in this case, and the cluster controller should support the necessary recipe namespace services.

The module coordinates the activities of the processing resource and the recipe executor to ensure the appropriate recipes are loaded into the execution area for material processing.

Recipe executor object attributes required to be accessible through object services:

Attribute Name	*Description*
ObjType	The object type: “RcpExec”
ObjID	Identifier for the recipe executor
DefaultNamespace	Namespace for all hardware-dependent recipes
RecipeSelectID	List of recipe identifiers for the currently selected recipe

Recipe management messaging services required:

Message Name	*Description: Requirements*
RMEDnldVer	Receive a recipe, optionally verify it, and put it into storage
RMEDelete	Delete a recipe from storage
RMESelect	Select recipes for execution
RMEDeselect	Deselect a recipe to prevent its execution
RMEComplete	Notify service-user of completion of an action

Modules that require more than one recipe class for an execution cycle shall support multi-part recipes. That is, the ability to select multiple recipes in a single process job request is not supported in processing management.

Recipe executor capabilities required and not already specified above:

- Reject incomplete, invalid, and unsupported requests

Recipe executor and module capabilities permitted by not to be required by a service-user:

- Support for variable parameters (attributes and select service),
- Support for multi-part recipes,
- Upload a recipe,
- Support recipe namespace services for local recipe management,
- Local editing.

8.6 *Event Reporting Services* — Event reporting services are to be supported in accordance with the models described in Section 7.1.7. Both event-based reporting and tracing are required. Support for user-defined reports is not required.

Event reporting for CTMC-compliant modules shall be based on services as described in SEMI E53.

8.6.1 The attributes defined in the following table shall be supported by CTMC compliant modules.

Attribute Name	*Description: Requirements*
ObjID	The identifier for Data Reports, Event Reports, and Trace Reports.
DataReportList	List of data report identifiers.
Enabled	A flag which controls generation of Event and Trace Reports.
SamplePeriod	Time delay between samples in a Trace report.
TotalSamples	Maximum number of samples to include in a Trace report.
GroupSize	Number of samples to include before sending a report to a service user.

8.6.2 Support for the following messages from SEMI E53 shall be provided.

Message Name	*Description: Requirements*
EventReportRequest	User can ask for a report to be generated and sent.
EventReportSend	Provider generates and sends report on an event.
DataReportCreate	Define attributes to be sampled for a report.
DataReportDelete	Delete report definitions
DataReportRequest	User requests sample and send of a report.
CollectionEventLink	Link data reports to a collection event.
CollectionEventUnlink	Unlink a data report
TraceReportCreate	Define a trace report
TraceReportDelete	Delete trace report definitions
TraceReportRequest	User requests a sample and send of a trace data.
TraceReportSend	Service provider sends a trace report to the user.
TraceReportReset	A trace reporting is set to its IDLE state.

8.6.3 Support for dynamic and user defined reports is optional. However, implementations which support these advanced capabilities, shall comply with the specifications of SEMI E53 and SEMI E39. SEMI E39 service messages shall use the optional object specifier arguments, such as EvtSrcSpec. Object services can then be used to interrogate objects for their reportable attributes.

8.7 *Clock Services* — The clock services provide for synchronization of the clocks on the modules with that of the cluster controller. These services provide the communications required of the appropriate module resources through defining the clock object.

The clock services are fully specified in terms of the clock attributes accessed through the get and set services of SEMI E39 (Object Services Standard: Concepts, Behavior, and Services). Cluster tool module communications require full compliance with the information, behavior, and messaging services of the fundamental requirements of that standard.

The clock object is uniquely identified for the module. Table 3 describes the attributes of the clock object. The identifier of the clock used for communications services is defined. The clock attribute Time is kept current and used to determine the value of the timestamp used in service messages. The module returns the current Time when it receives a get.

The clock time is synchronized by using the object set service on the Time attribute. On receipt of a set request, the module performs the operations necessary to set the clock to the value supplied, within its resolution, from which it shall continue immediately.

The DateTime attribute of the Clock object as used in Clock Services has a resolution in the range of seconds to centiseconds. If it is possible to specify the DateTime accurate to centiseconds, then centiseconds should be specified. If it is not possible to resolve time to less than a second, then centiseconds shall be reported as “00.” This requirement is for the reporting of the DateTime attribute of the Clock object in Clock Services only; other services may require greater resolution, in which case the Clock Services DateTime attribute resolution shall also be greater.

8.8 *Required Services* — Within a standards-compliant Cluster Tool, a number of services must be supported, at least to the fundamental requirements level. Due to the specialization of the modules in a Cluster Tool as detailed in the concepts section above, each module type only needs to support a subset of the service groups as shown in the message flow diagrams.

The services requirements for each module controller are described in this section. An example of use of services by a cluster controller is also given.

8.8.1 *Transport Module Controller*

- Material transfer functions for the end-to-end establishment of material movement within the cluster (supported through the Material Movement services). Material transfer is set up through a Transfer Job requested of the transport module by the service-user (e.g., cluster controller).
- Material Handoff between the process and cassette modules and the transport module (supported through the Material Movement services).
- Exception capabilities to post and manage exception conditions within the transport module (supported through the Exception Management services).
- Reporting of module variable data linked to events to the service-user (supported through the Event Reporting services).
- Access to standard objects of the specific services above as required by the service-user (supported through the Object services).

8.8.2 *Cassette Module Controller*

- Material I/O functions for the management of moving cassettes in and out of the cluster as well as for moving material between the cassette module and the transport module (supported through the Material Movement services). Material I/O is set up through a Transfer Job requested of the cassette module by the service-user (e.g., cluster controller).
- Material Handoff between the cassette module and the transport module (supported through the Material Movement services).
- Exception capabilities to post and manage exception conditions within the transport module (supported through the Exception Management services).
- Reporting of module variable data linked to events to the service-user (supported through the Event Reporting services).
- Access to standard objects of the specific services above as required by the service-user (supported through the Object services).

8.8.3 *Process Module Controller*

- Material processing functions (supported through the Processing Management services). Processing is specified through a Process job requested of the process module by the service-user (e.g., cluster controller).
- Recipe Management to verify and transfer recipes between the process module and the service-user (supported through the Processing Management services).
- Material I/O functions for the management of moving material in and out of the process module (supported through the Material Movement services). Material I/O is set up through a Transfer job requested of the process module by the service-user (e.g., cluster controller).
- Material Handoff between the process module and the transport module (supported through the Material Movement services).
- Exception capabilities to post and manage exception conditions within the transport module (supported through the Exception Management services).
- Reporting of module variable data linked to events to the service-user (supported through the Event Reporting services).
- Access to standard objects of the specific services above as required by the service-user (supported through the Object services).

8.8.4 *Example Cluster Controller*

- Scheduling and primary module control. Schedules Transfer and Process jobs in order to achieve the mission of the cluster tool, the processing of material.

- Recipe management for storage, archival, and editing of process module recipes (supported through the Recipe Management services).
- Human interfaces for the attached process, transport, and cassette modules (supported through the Event Reporting and Object Service definitions).
- Exception resolution services for making recovery decisions on exception conditions within the cluster (supported through the Exception Management services).

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as a part of SEMI E38 by full letter ballot procedure.

A1-1 Factory Integration

The Cluster Tool Module Communications (CTMC) Standard and its associated services define the interactions of the cluster modules and the cluster controller. The standard does not address the communications between the cluster and an external factory "host." The SEMI standard which addresses the equipment to host communications interface is SEMI E30 (GEM).

The purpose of this application note is to discuss the requirements and possible pitfalls of the factory host-cluster tool interface. The bulk of the text will address the use of the current (at this writing) version of GEM (SEMI E30). However, some consideration will be given to the possibility of direct access to the components of the cluster through the cluster communications environment.

A1-1.1 *Direct Access to Cluster Modules* — The CTMC was designed to allow for interoperability among the entities in a cluster. It is possible to add a new entity to the cluster and share in this interoperability. This means that a software application that is "plugged" into the cluster communication environment will have access to all of the cluster modules via the standard message set. In this way, a factory host computer can gain direct access to cluster modules, by-passing the cluster controller.

While direct access to the cluster modules has some advantages, intrusions into the cluster tool communications environment can have a profound effect on the system. Below are listed a few of the positive benefits direct access can bring, followed by some of the negatives of such an approach.

Positives:

- If the cluster controller does not have to act as the intermediary in transactions between module and host, it may be simplified.
- Direct access of the modules can be a more efficient means of obtaining information.
- The factory host would have the flexibility to perform scenarios which the cluster controller suppliers had not imagined.

Negatives:

- A new, unplanned load on the cluster network may have a negative impact on system performance. If the delivered system's network is highly loaded and has been tuned for that load, added pressure on the system may have unexpected results.
- Direct access of the cluster modules may have a negative impact on system performance. The cluster modules are performing the physical work for the cluster. If they become busy answering inquiries, it may detract from their speed of processing. For example, a simple query, such as temperature of chamber, may actually result in messaging to the sensor itself along the same real-time communication path used to open and close valves, ect.
- System integrity of the cluster tool may be at risk if an external entity (e.g., Factory Host) takes even minor control actions. A changed equipment constant may put the cluster controller out of synch with its module. An external command to perform an action may directly conflict with the cluster's current actions.
- The CTMC defines no access security to prevent undesirable actions on the part of external entities.

If there is to be this sort of direct communication with cluster modules, the implementer should exercise extreme caution in the design of the add-on application. It is recommended that no active control be attempted and that no changes to the system configuration be attempted (e.g., do not set attributes). If data is to be accessed, it is best done by asynchronous event based reporting, rather than by polling. Above all, it is recommended that any plans to access the cluster through the cluster communication environment be discussed thoroughly with the system supplier.

A1-1.2 *GEM Control of a Cluster Tool* — This section discusses the interactions between a cluster tool and factory host. The basis for that communication is assumed to be SEMI E30, the Generic Equipment Model.

GEM was designed relative to the prevalent class of equipment at that time: proprietary, single supplier, and limited to a single process run at a time. The advent of multi-chamber processing equipment and later of multi-supplier cluster tools has changed the general requirements set for the factory-equipment interface. In the future, GEM may evolve to meet these new requirements. Regardless, the point of this application note is to explore how best to apply the existing factory host communication standards to cluster-based equipment.

Below, each GEM capability will be addressed separately, followed by a look at capabilities which GEM does not cover. The capabilities are taken in roughly the order given by SEMI E30 (GEM) table of contents.

Communications State Model/Establish Communications — The Communications State Model is related to the ability to communicate. It is independent of the functionality offered by the equipment. There is no conflict with the cluster tool supporting this GEM capability.

Control State Model — The control state model assumes a single operator interface at the equipment. A cluster tool is expected to supply such an interface connected to the cluster controller.

However, there is a potential disconnect with attached modules which supply user interfaces. Since CTMC does not provide anything similar to the control state model at this time, the cluster controller has no control over access to these separate user interfaces, nor even any knowledge of what might be happening. In this situation, the cluster controller cannot guarantee compliance to the control state model.

To assure GEM compliance, it is recommended that a module request and receive closure of all control-related service connections before allowing use of its local operator interface in a control mode. This assumes the use of the communication environment as defined in SEMI E38.1.

Equipment Processing States — GEM specifies that there be a processing state model. The model given in the document is only an example, which shows the approximate depth needed and suggests a form. The example applies to the classic single chamber, single-process machine. Thus, it may not be directly applicable to a cluster tool. The cluster tool is required to provide a processing state model, but the form should match the cluster tool's function. The Plasma Etch Specific Equipment Model (document available from SEMI) suggested one way to model a multi-chamber, multi-process job machine.

Data Collection — Data collection is a combination of several different capabilities. Each will be discussed in turn.

There is also a high-level issue with data collection. GEM assumes a flat address space. That is, it assumes that the smallest granularity of object is “equipment.” The equipment has attributes. Some attributes are read-only (Status Variables). Some have read/write access (Equipment Constants). There are a few read-only attributes which are valid only at certain times (DVVALs).

Cluster tools do not fit this model well. The CTMC was based on a model which includes a hierarchy of objects which contain (or control) other objects. The CTMC requirements are a subset of that model and include a cluster controller (which does not have to be a single entity), attached modules, transport module, and specific objects associated with the services. Thus, to request information about the processing of a wafer in a process module, the attributes of the process job must be accessed. The chain then includes Cluster Controller->Process Module->Process Job->Job Attribute. It is quite a challenge to present this attribute as SVID #532678. And yet, this is what must be done.

The cluster controller should provide a flat name space from which to access critical module data. Object services with scopeing capabilities may also be supported through the host interface, but if used, this would be an extension to the host's GEM interface. The data collection categories below give more detail on the challenge and possible solutions.

Event Notification — Many of the events of interest to the host actually occur at the attached modules (e.g., “Etch step complete for wafer x”). The cluster controller is responsible for assigning each of these events a unique CEID. There are two challenges: (1) to assure uniqueness of events from duplicate modules, and (2) to provide a scheme whereby the host can determine the source of the event. Embedding a module number within the CEID is one solution which has been used to address both challenges. For instance, the highest order byte of a four-byte integer might contain the module ID.

Dynamic Event Report Configuration — The host must be able to attach the information of interest to the event notifications. The cluster controller is responsible for providing access to the attributes of the cluster modules. It is also responsible for assuring that the data contained in the event reports is representative of the state of the cluster at the time the event occurred.

There are three sources of data for the event reports.

1. Cluster Controller: Data which is local to the cluster controller may be accessed directly.
2. Module (not source of collection event): This data must be polled unless a data trace for the attributes of interest is in progress.
3. Module (source of collection event): This data tends to be most closely related to the event and thus the most time-critical. While polling and data trace may be used in this case, it is better to use the

CTMC Event Reporting Services to attach the data of interest directly to the module collection event.

Variable Data Collection/Status Data Collection — Again, the cluster must take measures to present a flat address space. See various discussions above.

Limits Monitoring — Clearly, most variables which would be of interest for limits monitoring reside in the cluster modules. The CTMC does not provide specific services for configurable limits monitoring. A module may provide for some limits checking via "limits" attributes of objects which may be set via object services. Notification of excursions beyond limits would be via exceptions and/or collection events. If this method is not available, the cluster controller would have to institute a data trace on the attribute of interest and then itself perform the limits checking activity. The time period of the trace would be crucial to assuring that short-term excursions are not missed.

Trace Data Collection — Trace data collection maps well from GEM to CTMC. In fact, the CTMC services in this area are a superset of the GEM functionality.

On-Line Identification — At first glance, this seems to be an easy requirement to meet. However, the model number and software revision included in the message are ambiguous on a cluster with separate model numbers for each module (and the cluster controller itself) and separate software releases running on each. The purpose of these data items is to allow the host to determine when the equipment has been changed in such a way that it may no longer be compatible with the host software. At a minimum, the data items should indicate a change to the cluster controller software (e.g., a new revision of the software, or a significant reconfiguration such as the addition of a new module).

Alarm Management — GEM alarm management is a subset of the functionality of the CTMC exception services. Any exception message from a module can, where desired, be translated into a GEM-compliant alarm message. The set of CTMC exceptions is a superset of GEM alarms. GEM alarms are of a serious nature and expect human intervention to be required. The CTMC extends this set to include problems which the controller may be able to solve, and provides for modules to suggest appropriate recovery actions.

Those CTMC exceptions which fall into the GEM alarm category should be passed on via the GEM Alarm capability. Exceptions which are not GEM alarms should be reported only as events.

Remote Control — Cluster tools need to be able to handle multiple tasks simultaneously. Most need to handle multiple lot or batch jobs at once. GEM's support for (process) job control is minimal. The implicit assumption in GEM is that only one job at a time will occur on a machine. It provides for a "START" command, collection events when the job is actually started and when it finishes, and also job control commands (e.g., PAUSE, RESUME, ABORT, STOP). What GEM lacks is differentiation of one job from another (e.g., a job ID).

However, the GEM remote command message does provide for parameters. A cluster tool may be able to implement a scheme which is similar to that defined by the Process Management Services. For instance, a "job ID" parameter may be included in all job-related messages. Thus, the equipment would set a job ID in the "Start" or the "PP-Select" message (whichever first refers to the job), and would then refer to that ID in any subsequent job control commands. The job ID could also be available as a data value in collection event reports. While it might be preferable to have the equipment assign the job ID, this scheme may be workable.

Equipment Constants — Again, the flat address space issue applies. (See the Data Collection section above.)

Process Program Management — The CTMC uses Recipe Management Services (RMS) to manage recipes internal to the cluster. GEM's processing services is a different mechanism. The two can be made to interact, but the combination is not ideal. It is possible for the cluster to translate a "recipe" to a "process program" for communication with the host. However, if a recipe is created or modified at the host and then downloaded, the editor at the host must be compatible with RMS concepts, and care must be taken to maintain the integrity of the RMS system.

Material Movement — GEM requires only collection events when material is received or sent. A cluster can easily satisfy this requirement.

Equipment Terminal Services, Error Messages, and Spooling — Equipment Terminal Services, Error Messages, and Spooling are in the domain of the cluster controller. Cluster modules do not provide these functions, nor do they contribute to the cluster controller's delivery of the services.

Clock — A key purpose of clock is to allow the host to determine ordering of events from an equipment. The cluster controller should ensure that this need is met. The cluster should attempt to report consistent time relative to its modules. Also, when the factory host sets the time on the cluster, the cluster controller should resynchronize the time on its modules. There should be no compatibility problems in this area.

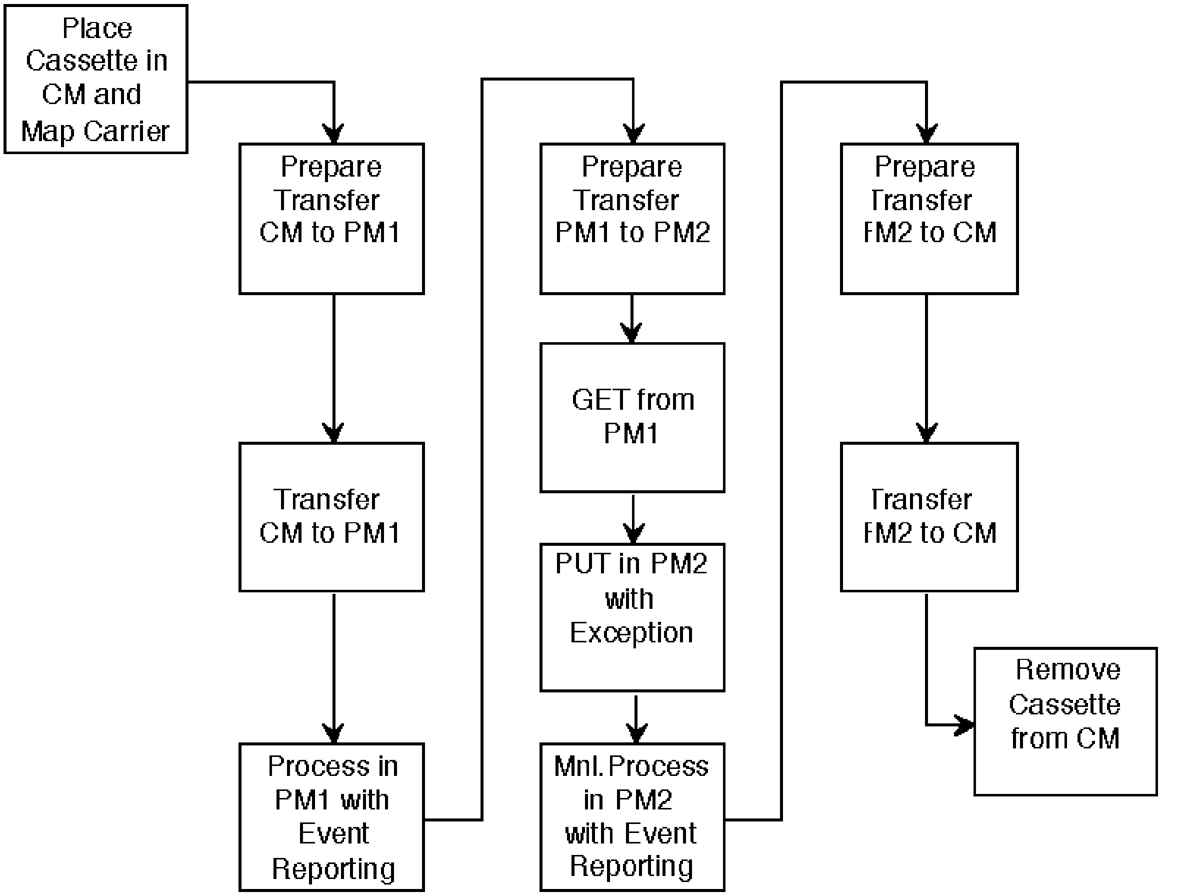

Figure 20
Typical Operating Scenario

A1-2 Typical Operating Scenario

The purpose of this section is to give an example of a typical operating scenario that will illustrate the various services being used to perform cluster tool control functionality. This operating scenario is **NOT** intended to be the only scenario to be implemented in a standards-compliant cluster. The intent is to provide guidance in navigating the various services standards. An exhaustive use of Object Services and Exception Management Services will not be done since these two areas tend to be very application-specific.

This scenario concentrates on the material processing, material movement aspects of the cluster-specific services.

The operating scenario shown in Figure 20 will be given in the form of a communication timing diagram with messages being sent between the various cluster tool components and will be indicated in the following manner:

ServiceGroup_ServiceName.Request or Response (Service Parameters)

Example: TRJobCreate.Req(...)

- TR is the service group that contains the service, the material movement services.
- JobCreate is the service being used to cause communication to take place between two cluster tool components. Specifically, this service is the material movement service that initiates the transfer of material between modules.
- Req indicates that the service is a Request.
- (...) indicates any other parameters that might be present with the service definition and will be service-dependent.

Definitions:

CC = Cluster Controller

CM = Cassette Module

TM = Transport Module

PM1 = Processing Module #1

PM2 = Processing Module #2

The general routing for the scenario is illustrated in the message sequence below:

1. A cassette of wafers arrives from the factory and is given to the cassette module.
2. A mapping of the wafers in the various slots of the cassette is determined for use inside the cluster.
3. A transfer job is initiated to move a wafer from the cassette to a process module (in this case PM1).
4. The cassette module is commanded to send the wafer to the transport module.
5. The PM1 is instructed to create the process job and to retrieve any pertinent recipe information in order to process the wafer.
6. The wafer is handed off between the cassette module and the transport module (Wafer GET operation).
7. The wafer is handed off between the transport module and PM1 (this is a Wafer PUT operation).
8. The wafer is processed in PM1.
9. A transfer job is initiated to the transport module to move a wafer from PM1 to PM2.
10. The PM1 is commanded to send the wafer to the transport module.
11. The PM2 is instructed to create the process job and to retrieve any pertinent recipe information in order to process the wafer.
12. The wafer is handed off between the PM1 and the transport module with a GET.
13. The wafer is handed off between the transport and PM2 with a PUT.
14. The wafer is processed in PM2 when manually started.
15. A transfer job is initiated to the transport module to move a wafer from PM2 back to the cassette module.
16. The PM2 is commanded to send the wafer to the transport module.
17. The cassette module is instructed to receive the wafer.
18. The wafer is handed off between PM2 and the transport module.
19. The wafer is handed off between the transport module and the cassette module.
20. The cassette module is instructed to send the cassette to the factory.

1. FACTORY TO CM CASSETTE HANDOFF

The cassette containing a single wafer in wafer slot 1 to be processed by the cluster tool is passed from the factory environment to the cluster tool.

At this point the user (human or host) will be prompted to place the cassette on the cassette module loading system. The cassette module is then informed to receive a cassette from the external environment.

```
CC                                      CM
>>-------------------------------------->>
TRJobCreate.Req(MID="Carrier1",Port=Port2
, Dir=Receive)
CC                                      CM
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob1,Status=OK)
```

The cassette module prepares to receive the cassette by such actions as loadlock venting, door opening, and then requesting handoff from the Factory.

```
CC                                      CM
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob1, TimeStamp)
```

The actual cassette transfer takes place, the cassette module takes such actions as door closing and loadlock pumping down to internal transfer pressures, and then reports completion of the material transfer.

```
CC                                      CM
<<--------------------------------------<<
TRJobComplete.Req(JobID=IOJob1,TimeStamp,
Status=OK))
```

2. WAFER MAPPING

The wafers in each of the cassette wafer slots are assigned a unique wafer ID. In this case, the wafer is identified as “Wafer1.” If there were more than one wafer, this process would be repeated until all the wafers had been given their appropriate identification that is used later when specific wafers are requested for transfer and processing.

```
CC                                      CM
>>-------------------------------------->>
Set.Req("WAFERSLOT",SlotID=1,MID=
"Wafer1")
CC                                     CM
<<-------------------------------------<<
Set.Rsp("WAFERSLOT",SlotID=1,Status=OK)
```

3. CC TO TM TRANSFER JOB SETUP

The CC informs the TM that a wafer transfer is required from the CM to PM1.

```
CC                                     TM
>>------------------------------------->>
TRJobCreate.Req(MID="Wafer1",TRSourceAmID
="CM",TRDestinationAmID="PM1")
```

The transport module assigns an identifier for this particular transfer job. This is important in an actual cluster implementation since multiple transfer jobs may be queued and active at any given time. The transfer job is then started by the transport module.

```
CC                                      TM
<←-------------------------------------<<
TRJobCreate.Rsp(JobID=TMJob1,Status=OK)
CC                                      TM
<<--------------------------------------<<
TRJobStarted.Req(JobID=TMJob1,TimeStamp)
```

4. CC TO CM SEND WAFER

The CC informs the CM that a wafer is to be transferred to the TM.

```
CC                                      CM
>>-------------------------------------->>
TRJobCreate.Req(MID="Wafer1",PortID=
"Port1",Dir=Send)
CC                                      CM
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob2,Status=OK)
```

When the cassette module is ready, it directly communicates with the cluster controller and the transport module to indicate its readiness for wafer handoff.

```
CC                                      CM
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob2, TimeStamp)
TM                                      CM
<<--------------------------------------<<
HOReady.Req(PortID="Port1",AmID="CM",
HODir=GET,MID="Wafer1")
```

5. CC TO PM1 PROCESSING JOB SETUP

The CC informs PM1 that a wafer will be delivered (which requires a TRJob to be created) and is to be processed (this requires that a process job be established). This involves creating the jobs and transferring the appropriate recipes to the process module as required. At some point in this process, the PM will inform the transport module that it is ready to receive the wafer with the issuing of the HOReady Request.

The CC informs PM1 that a wafer is to be transfered from the TM.

```
CC                                     PM1
>>-------------------------------------->>
TRJobCreate.Req(MID="Wafer1",Port="Port1"
, Dir=Receive)
CC                                     PM1
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob3,Status=OK)
```

When the process module is ready, it directly communicates with the cluster controller to indicate its readiness for wafer handoff.

```
CC                                      PM1
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob3, TimeStamp)
```

The process job is created on the process module.

```
CC                                      PM1
>>-------------------------------------->>
PRJobCreate.Req(RecID="PP1",MID="Wafer1")
CC                                      PM1
<<--------------------------------------<<
PRJobCreate.Rsp(JobID=PM1Job1,Status=OK)
CC                                      PM1
<<--------------------------------------<<
PRJobSetup.Req(JobID=PM1Job1)
```

The process module requests that all sections (headers and the body) of the recipe be downloaded.

```
CC                                        PM1
<<---------------------------------------<<
RCRequest.Req(RecID="PP1",RCTransfer=all)
CC                                        PM1
>>--------------------------------------->>
RCRequest.Rsp(RecID="PP1",Status=OK)
CC                                        PM1
>>--------------------------------------->>
RCSend.Req(RecID="PP1",<Headers & Body>)
CC                                        PM1
<<---------------------------------------<<
RCSend.Rsp(RecID="PP1",Status=OK)
```

The process module informs the transport module that it is ready to receive the material.

```
TM                                        PM1
<<---------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM1",HODir=P
UT,MID="Wafer1")
```

6. CM TO TM WAFER HANDOFF

The CM transfers the wafer to the TM through the handoff sequence, and the CM and TM will keep the cluster controller informed of its transfer progress.

The transport module informs the cassette module that it is proceeding with the "getting" of the wafer.

```
CM                                         TM
<<---------------------------------------<<
HOReady.Req(Port=Port1,AmID="CM",HODir=GE
T, MID="Wafer1")
```

The cassette module informs the transport module to use the PICK sequence to get the wafer.

```
CM                                         TM
>>--------------------------------------->>
HOPick.Req(Port=Port1,AmID="CM")
CM                                         TM
<<---------------------------------------<<
HOPick.Rsp(Port=Port1,AmID="CM",
Status=OK)
```

When the getting of the wafer has been successful, the cassette module informs the transport module with a verify sequence.

```
CM                                         TM
>>--------------------------------------->>
HOVerify.Req(Port=Port1,AmID="CM")
CM                                         TM
<<---------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="CM",
Status=OK)
```

The cassette module then informs the cluster controller of its current status.

```
CC                                         CM
<<---------------------------------------<<
TRJobComplete.Req(JobID=IOJob2,TimeStamp,
Status=OK)
```

7. TM TO PM1 WAFER HANDOFF

The TM now has possession of the wafer and is ready to proceed with the putting of the wafer into the process module. The TM and PM1 will inform the cluster controller of the progress of the transfer of material.

The TM informs the PM that it is proceeding with the putting of the wafer.

```
PM1                                        TM
<<---------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM1",HODir=P
UT,MID="Wafer1")
```

The process module informs the TM to use the PLACE scenario as the put operation.

```
PM1                                        TM
>>--------------------------------------->>
HOPlace.Req(Port=Port1,AmID="PM1")
PM1                                        TM
<<---------------------------------------<<
HOPlace.Rsp(Port=Port1,AmID="PM1",
Status=OK)
```

When the putting of the wafer has been successful, the PM informs the transport module with a verify sequence.

```
PM1                                    TM
>>------------------------------------>>
HOVerify.Req(Port=Port1,AmID="PM1")
PM1                                    TM
<<------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="PM1",
Status=OK)
CC                                    PM1
<<------------------------------------<<
TRJobComplete.Req(JobID=IOJob3,
TimeStamp)
```

The TM then informs the cluster controller that the putting phase of the transfer is complete and then that the requested transfer job is complete.

```
CC                                     TM
<<------------------------------------<<
TRJobComplete.Req(JobID=TMJob1,
TimeStamp,Status=OK)
```

8. PM1 JOB PROCESSING

The process module informs the cluster controller, now that is has received the material and having previously entered the setup state, that it is ready to initiate processing on the wafer. When actual processing is initiated, the PM informs the cluster controller of its current status.

```
CC                                    PM1
<<------------------------------------<<
PRJobProcessing.Req(JobID=PM1Job1,TimeSta
mp)
```

A data collection is enabled to allow parameters to be sent from the PM to the cluster controller while the wafer processing is taking place. A previously defined event is enabled and the report structure is established.

```
CC                                    PM1
>>------------------------------------>>
Set.Req(EREvent,EventID=Event1,
Enabled=TRUE)
CC                                    PM1
<<------------------------------------<<
Set.Rsp(EREvent,EventID=Event1,Status=OK)
```

Two variables for time and temperature will be reported based on Event1 occurring.

```
CC                                    PM1
<<------------------------------------<<
ERReport.Req(EventID=Event1,ReportID=Rpt1
, ValueList={time,temp})
```

When wafer processing is complete on the PM, the cluster controller is informed of the current status.

```
CC                                    PM1
<<------------------------------------<<
PRJobProcessingComplete.Req(JobID=PM1Job1
, TimeStamp,Status=OK)
```

Data collection is then disabled.

```
CC                                    PM1
>>------------------------------------>>
Set.Req(EREvent,EventID=Event1,
Enabled=FALSE)
CC                                    PM1
<<------------------------------------<<
Set.Rsp(EREvent,EventID=Event1,Status=OK)
```

9. PM1 to PM2 TRANSFER JOB SETUP

The CC informs the TM that a wafer transfer is required from the PM1 to PM2.

```
CC                                     TM
>>------------------------------------>>
TRJobCreate.Req(MID="Wafer1",
TRSourceAmID="PM1",
TRDestinationAmID="PM2")
```

The transport module assigns an identifier for this particular transfer job. The transfer job is then started by the transport module.

```
CC                                     TM
<<------------------------------------<<
TRJobCreate.Rsp(JobID=TMJob2,Status= OK)
CC                                     TM
<<------------------------------------<<
TRJobStarted.Req(JobID=TMJob2, TimeStamp)
```

10. CC TO PM1 SEND WAFER

The CC informs PM1 that a wafer is to be transferred to the TM.

```
CC                                    PM1
>>------------------------------------>>
TRJobCreate.Req(MID="Wafer1",Port=
"Port1", Dir=Send)
CC                                    PM1
<<------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob4,Status=OK)
CC                                    PM1
<<------------------------------------<<
TRJobStarted.Rsp(JobID=IOJob4, TimeStamp)
```

When the process module is ready, it directly communicates with the transport module to indicate its readiness for wafer handoff.

```
TM                                    PM1
<<------------------------------------<<
HOReady.Req(PortID="Port1",AmID="CM",
HODir=GET,MID="Wafer1")
```

11. CC TO PM2 PROCESSING JOB SETUP

The CC informs PM2 that a wafer will be delivered (requires a TRJob) and is to be processed (requires that a process job be established). This involves creating the jobs and transferring the appropriate recipes to the process module as required. At some point in this process, the PM will inform the transport module that it is ready to receive the wafer with the isssuing of the HOReady Request.

```
CC                                    PM2
>>------------------------------------>>
TRJobCreate.Req(MID="Wafer1",Port="Port1"
, Dir=Receive)
CC                                    PM2
<<------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob5,Status=OK)
CC                                    PM2
<<------------------------------------<<
TRJobStarted.Req(JobID=IOJob5, TimeStamp)
CC                                    PM2
>>------------------------------------>>
PRJobCreate.Req(RecID="PP2",MID="Wafer1",
ManualStart)
CC                                    PM2
<<------------------------------------<<
PRJobCreate.Rsp(JobID=PM2Job1,Status=OK)
CC                                    PM2
<<------------------------------------<<
PRJobSetup.Req(JobID=PM2Job1)
```

The process module requests that all sections (headers and the body) of the recipe be downloaded.

```
CC                                    PM2
<<------------------------------------<<
RCRequest.Req(RecID="PP2",RCTransfer=all)
CC                                    PM2
>>------------------------------------>>
RCRequest.Rsp(RecID="PP2",LinkedID=0,{Bod
y: "TEMP 250 TIME 40"})
CC                                    PM2
>>------------------------------------>>
RCSend.Req(RecID="PP1",<Headers & Body>)
CC                                    PM2
<<------------------------------------<<
RCSend.Rsp(RecID="PP1",Status=OK)
```

The process module then informs the transport module to proceed with the putting of the wafer.

```
TM                                    PM2
<<-------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM2",HODir=P
UT,MID="Wafer1")
```

12. PM1 TO TM WAFER HANDOFF

The PM1 transfers the wafer to the TM through the handoff sequence, and the TM will keep the cluster controller informed of its transfer progress. The transport module informs the process module that it is proceeding with the "getting" of the wafer.

```
PM                                     TM
<<-------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM1",HODir=G
ET,MID="Wafer1")
```

The process module informs the transport module to use the PICK sequence to get the wafer.

```
PM1                                    TM
>>------------------------------------->>
HOPick.Req(Port=Port1,AmID="PM1")
PM1                                    TM
<<-------------------------------------<<
HOPick.Rsp (Port=Port1,AmID="PM1",
Status=OK)
```

When the getting of the wafer has been successful, the process module informs the transport module with a verify sequence.

```
PM1                                    TM
>>------------------------------------->>
HOVerify.Req(Port=Port1,AmID="PM1")
PM1                                    TM
<<-------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="PM1",
Status=OK)
```

Process module #1 then informs the cluster controller of its current status.

```
CC                                    PM1
<<-------------------------------------<<
TRJobComplete.Req(JobID=IOJob4,TimeStamp,
Status=OK)
```

The cluster controller is informed that the processing job performed in PM1 is complete.

```
CC                                    PM1
<<-------------------------------------<<
PRJobComplete.Req(JobID=PM1Job1,
TimeStamp,Status=OK)
```

13. TM TO PM2 WAFER HANDOFF

The TM informs the cluster controller that it is proceeding with the transfer of the wafer. The TM informs the PM that it is proceeding with the putting of the wafer.

```
PM2                                    TM
<<-------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM2",HODir=P
UT,MID="Wafer1")
```

The process module informs the TM to use the EXTEND scenario as the put operation.

```
PM2                                    TM
>>------------------------------------->>
HOExtend.Req(Port=Port1,AmID="PM2")
PM2                                    TM
<<-------------------------------------<<
HOExtend.Rsp(Port=Port1,AmID="PM2",
Status=OK)
```

During this particular handoff, an exception is generated stating that the pins in the process module failed to come up and receive the wafer from the end effector. The cluster controller is given three recovery options to select from in attempting to resume operation in the presence of this exception.

```
CC                                    PM2
<<-------------------------------------<<
EXPost.Req(EXID=Error1, EXType=Error,
EXMessage="pins failed to raise",
EXRecoveryList=
{"Abort","Retry","Continue"}, TimeStamp)
```

The cluster controller selects the “continue” option.

```
CC                                     PM2
>>-------------------------------------->>
EXRecover.Req(EXID=Error1,
EXRecoverySelected= "Continue")
CC                                     PM2
<<--------------------------------------<<
EXRecover.Rsp(EXID=Error1, Status=OK)
CC                                     PM2
<<--------------------------------------<<
EXRecoveryComplete.Rsp(EXID=Error1,
Status=OK)
```

This action is successful, and the alarm (exception type) clears.

```
CC                                     PM2
<<--------------------------------------<<
EXCleared.Rsp(EXID=Error1,EXType=Error,
TimeStamp)
```

When the putting of the wafer is now successful, the PM commands the transport module to Retract.

```
PM2                                     TM
>>-------------------------------------->>
HORetract.Req(Port=Port1,AmID="PM2")
PM2                                     TM
<<--------------------------------------<<
HORetract.Rsp(Port=Port1,AmID="PM2",
Status=OK)
```

Upon successful completion of the handoff, a verify sequence is used to complete the transaction.

```
PM2                                     TM
>>-------------------------------------->>
HOVerify.Req(Port=Port1,AmID="PM2")
PM2                                     TM
<<--------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="PM2",
Status=OK)
CC                                     PM2
<<--------------------------------------<<
TRJobComplete.Req(JobID=IOJob5,TimeStamp,
Status=OK)
```

The TM then informs the cluster controller that the putting of material is complete and that the requested transfer job is complete.

```
CC                                      TM
<<--------------------------------------<<
TRJobComplete.Req(JobID=TMJob2,
TimeStamp,Status=OK)
```

The process module informs the cluster controller that now that is has received the material, it is ready to initiate processing on the wafer upon Start command.

```
CC                                     PM2
<<--------------------------------------<<
PRJobWaitingStart.Req(JobID=PM2Job1)
```

14. PM2 JOB PROCESSING

The cluster controller commands the PM to start processing the wafer.

```
CC                                     PM1
>>-------------------------------------->>
PRJobStart.Req(JobID=PM2Job1)
CC                                     PM1
<<--------------------------------------<<
PRJobStart.Rsp(JobID=PM2Job1,Status=OK)
```

When actual processing is initiated, the PM informs the cluster controller of its current status.

```
CC                                     PM2
<<--------------------------------------<<
PRJobProcessing.Req(JobID=PM2Job1,
TimeStamp)
```

A data collection is enabled to allow parameters to be sent from the PM to the cluster controller while the wafer processing is taking place. A previously defined event is enabled and the report structure is established.

```
CC                                     PM2
>>-------------------------------------->>
Set.Req(EREvent,EventID=Event1,
Enabled=TRUE)
CC                                     PM2
<<--------------------------------------<<
Set.Rsp(EREvent,EventID=Event1,Status=OK)
```

Two variables for time and temperature will be reported based on Event1 occurring.

```
CC                                     PM2
<<--------------------------------------<<
ERReport.Req(EventID=Event1,ReportID=Rpt1
, ValueList={time,temp})
```

When wafer processing is complete on the PM, the cluster controller is informed of the current status.

```
CC                                     PM2
<<--------------------------------------<<
PRJobProcessingComplete.Req(JobID=PM2Job1
, TimeStamp,Status=OK)
```

Data collection is then disabled.

```
CC                                      PM2
>>-------------------------------------->>
Set.Req(EREvent,EventID=Event1,
Enabled=FALSE)
CC                                      PM2
<<--------------------------------------<<
Set.Rsp(EREvent,EventID=Event1,Status=OK)
```

15. PM2 to CM TRANSFER JOB SETUP

The CC informs the TM that a wafer transfer is required from the PM2 to CM.

```
CC                                       TM
>>-------------------------------------->>
TRJobCreate.Req(MID="Wafer1",
TRSourceAmID="PM2",
TRDestinationAmID="CM")
```

The transport module assigns an identifier for this particular transfer job. The transfer job is then started by the transport module.

```
CC                                       TM
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=TMJob3,Status= OK)
CC                                       TM
<<--------------------------------------<<
TRJobStarted.Req(JobID=TMJob3, TimeStamp)
```

16. CC TO PM2 SEND WAFER

The CC informs the PM2 that a wafer is to be transferred to the TM.

```
CC                                      PM2
>>-------------------------------------->>
TRJobCreate.Req(MID="Wafer1",Port=
"Port1", Dir=Send))
CC                                      PM2
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob6,Status=OK)
CC                                      PM2
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob6, TimeStamp)
```

When the process module is ready, it directly communicates with the transport module to indicate its readiness for wafer handoff.

```
TM                                      PM2
<<--------------------------------------<<
HOReady.Req(PortID="Port1",AmID="PM2",
HODir=GET,MID="Wafer1")
```

17. CC TO CM RECEIVE WAFER

The CC informs the CM that a wafer is to be transfered from the TM.

```
CC                                       CM
>>-------------------------------------->>
TRJobCreate.Req(MID="Wafer1",Port=
"Port1", Dir=Receive)
CC                                      PM2
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob7,Status=OK)
CC                                      PM2
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob7, TimeStamp)
```

When the cassette module is ready, it directly communicates with the transport module to indicate its readiness for wafer handoff.

```
TM                                       CM
<<--------------------------------------<<
HOReady.Req(PortID="Port1",AmID="CM",
HODir=PUT,MID="Wafer1")
```

18. PM2 TO TM WAFER HANDOFF

The PM2 transfers the wafer to the TM through the handoff sequence, and the TM will keep the cluster controller informed of its transfer progress. The transport module informs the process module that it is proceeding with the “getting” of the wafer.

```
PM2                                      TM
<<--------------------------------------<<
HOReady.Req(Port=Port1,AmID="PM2",HODir=G
ET,MID="Wafer1")
```

The process module informs the TM to use the EXTEND scenario as the put operation.

```
PM2                                      TM
>>-------------------------------------->>
HOExtend.Req(Port=Port1,AmID="PM2")
PM2                                      TM
<<--------------------------------------<<
HOExtend.Rsp(Port=Port1,AmID="PM2",
Status=OK)
```

When the putting of the wafer is now successful, the PM commands the transport module to Retract.

```
PM2                                      TM
>>-------------------------------------->>
HORetract.Req(Port=Port1,AmID="PM2")
PM2                                      TM
<<--------------------------------------<<
HORetract.Rsp(Port=Port1,AmID="PM2",
Status=OK)
```

Upon successful completion of the handoff, a verify sequence is used to complete the transaction.

```
PM2                                      TM
>>-------------------------------------->>
HOVerify.Req(Port=Port1,AmID="PM2")
PM2                                      TM
<<--------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="PM2",
Status=OK)
CC                                      PM2
<<--------------------------------------<<
TRJobComplete.Req(JobID=IOJob6,
TimeStamp)
```

The cluster controller is informed that the processing job in PM2 is complete.

```
CC                                      PM2
<<--------------------------------------<<
PRJobComplete.Req(JobID=PM2Job1,
TimeStamp,Status=OK)
```

19. TM TO CM WAFER HANDOFF

The TM now has possession of the wafer and is ready to proceed with the putting of the wafer into the cassette module. First, the TM informs the cluster controller that it is proceeding with the transfer of the wafer to CM through the handoff sequence.

```
CM                                       TM
<<--------------------------------------<<
HOReady.Req(Port=Port1,AmID="CM",
HODir=PUT,MID="Wafer1")
```

The cassette module informs the transport module to use the PLACE sequence to put the wafer.

```
CM                                       TM
>>-------------------------------------->>
HOPlace.Req(Port=Port1,AmID="CM")
CM                                       TM
<<--------------------------------------<<
HOPlace.Rsp(Port=Port1,AmID="CM",
Status=OK)
```

When the putting of the wafer has been successful, the cassette module informs the transport module with a verify sequence.

```
CM                                       TM
>>-------------------------------------->>
HOVerify.Req(Port=Port1,AmID="CM")
CM                                       TM
<<--------------------------------------<<
HOVerify.Rsp(Port=Port1,AmID="CM",Status=
OK)
```

The cassette module then informs the cluster controller of its current status.

```
CC                                       CM
<<--------------------------------------<<
TRJobComplete.Req(JobID=IOJob7,
TimeStamp,Status=OK)
```

The TM then informs the cluster controller that the putting of material is finished and that the requested transfer job is complete.

```
CC                                       TM
<<--------------------------------------<<
TRJobComplete.Req(JobID=TMJob3,
TimeStamp,Status=OK)
```

20. CM TO FACTORY CASSETTE HANDOFF

The cassette is passed from the cluster tool to the factory environment.

```
CC                                       CM
>>-------------------------------------->>
TRJobCreate.Req(MID="Carrier1",
Port=Port2,Dir=Send)
CC                                       CM
<<--------------------------------------<<
TRJobCreate.Rsp(JobID=IOJob8,Status=OK)
CC                                       CM
<<--------------------------------------<<
TRJobStarted.Req(JobID=IOJob8, TimeStamp)
```

At this point, it is assumed that the cassette module performs actions such as loadlock venting, door opening, and initiating communication with the user (human or host) to perform the handoff to the factory. The cluster controller is informed of progress. When the transfer to the factory is complete, the cluster controller is informed.

```
CC                                     CM
<<-------------------------------------<<
TRJobComplete.Req(JobID=IOJob8,
TimeStamp,Status=OK)
```

SEMI E38.1-95
COMMUNICATIONS ENVIRONMENT HSMS/SECS-II FOR CLUSTER TOOL MODULE COMMUNICATIONS

1 Purpose

The purpose of this standard is to specify the communication environment for communication with and among modules in a cluster tool.

2 Scope

The scope of this standard is communication within a cluster tool as defined in the standard Cluster Tool Module Communication Standard (CTMC, SEMI E38). This standard specifies the transmission of SECS-II messages by HSMS (SEMI E37), HSMS-GS (SEMI E37.2), and Ethernet. Other methods of message communication are possible but beyond the scope of this standard.

This standard is intended to be one of possibly several supplements to the CTMC SEMI E38.

3 Referenced Documents

3.1 *SEMI Standards*[1]

The following SEMI standards are related to the Communications Environment standard:

SEMI E5 — SEMI Equipment Communication Standard 2 - Message Content (SECS -II).

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.2 — High-Speed SECS Message Services General Session (HSMS-GS)

3.2 *IEEE Standards*[2]

The following IEEE standard is related to the Communications Environment standard:

IEEE 802.3 — Carrier Sense Multiple Access with Collision Detection

4 Definitions

The following definitions are arranged in alphabetical order. Some are defined using terms defined elsewhere within this section. No definitions beyond this section and the referenced standards should be necessary for a basic understanding of these terms.

10 BASE 2 — a common physical medium for the transmission of Ethernet signals.

AUI (Attachment Unit Interface) — a specification of the connector, pins, and signals used to interface a computer to a MAU. Defined formally in IEEE 802.3.

Cluster Tool Environment — a collection of interconnected modules forming a cluster tool.

Communications Stack — a specification of successive layers of interfaces through which communication services are provided.

Ethernet — a method of transmitting signals. Ethernet is defined formally by IEEE 802.3

MAU (Medium Attachment Unit) — an adaptor from the AUI interface to a physical wire or medium such as 10 BASE 2. Defined formally in IEEE 802.3

Platform — a physical computer in a cluster tool that contains the Ethernet Interface or station as defined in IEEE 802.3. In a cluster tool, a platform may have one or more logical modules residing on it.

5 Required Sessions

In order to support the Services specified in the CTMC standard, there is an associated set of Protocol standards that specify a set of SECS-II messages to support these Services. This standard specifies the transmission of these SECS-II messages using HSMS sessions.

In order to communicate with a given logical module, a separate HSMS connection (TCP/IP connection) is required per logical module.

For correct operation of a cluster tool using these facilities, a set of standard sessions, given in Table 1, is required. Other sessions are possible, but are not required. In order to be compliant a module must not require further sessions in order to operate.

Table 1 Required Sessions

Client	*Server*	*Services*
Cluster Controller	Transport Module	Object Services, Material Movement, Exception Management, Event Reporting
Cluster Controller	Cassette Module	Object Services, Material Movement, Exception Management, Event Reporting

[1] Semiconductor Equipment & Materials International, 805 East Middlefield Road, Mountain View, CA 94043

[2] Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017

Client	*Server*	*Services*
Cluster Controller	Process Module	Object Services, Processing Management, Recipe Management, Material Movement, Exception Management, Event Reporting
Cassette Module	Transport Module	Object Services, Material Movement
Process Module	Transport Module	Object Services, Material Movement

6 Communication Stack Specification

There are many layers of software required in order to communicate using a facility such as HSMS. In order to interoperate, modules shall have identical or equivalent protocols at each layer on both sides of a physical connection.

HSMS does not specify a particular physical layer. In order to ensure interoperability between modules, of possibly different origin, a complete interoperable communication stack is required.

6.1 *SECS-II Messages* — The Cluster Tool Module Communications (CTMC) standard specifies a set of messaging services from applicable standards for use by a cluster tool module. Each service standard has a supplemental protocol standard which defines the SECS-II message support. This standard specifies a method for transporting these SECS-II messages. In order to be compliant with this standard, these SECS-II messages must be used. The detail of the SECS-II messages is found in SEMI E5. SECS-II message definitions refer to messages communicating between a host and equipment. With reference to implementing CTMC, the host is the service-user or cluster-controlling entity, and the equipment is the service-provider or cluster module entity.

6.2 *HSMS Messaging* — For the purposes of communication of SECS-II messages within the cluster tool communication environment, SEMI High-Speed SECS Message Service (HSMS) shall be used (SEMI E37).

CTMC defines a number of services. For inter-module, and service user-to-module communication, many services will be required simultaneously. As a result, the capabilities of the HSMS General Session (SEMI E37.2) are required and shall be used for communication of all services specified by the CTMC.

6.2.1 *IP Addresses, Port Numbers, and Session IDs* — HSMS defines the setting of IP Addresses, Port Numbers, and Session IDs. In order to uniquely specify a service, all three are required as configuration parameters. The actual numbers shall be within the allowed range and unique within their respective domains. Table 2 shows these parameters, what they define, and their respective domains.

Table 2 Configuration Parameters

Parameter	*Defines*	*Domain of Uniqueness*
IP Address	Platform	Network
Port Number	TCP/IP Connection	Platform
Session ID	CTMC Service	TCP/IP Connection

6.2.2 *Session ID's* — Each association required by CTMC (such as Processing, Material Movement, Exception, etc.) shall have a session within a connection. These Session ID's shall be documented by the service provider, and, if configurable, the method of configuration shall be documented.

The Session ID for a given service shall be defined and may be dictated by the service provider (at the server end of a connection).

In order to use a service, the service user (which is the client end of the connection) shall select the service by Session ID. Thus, the Session ID shall be configurable for the service user and the method of configuring shall be documented for each service user. Session IDs shall be as shown in Table 3.

Object services shall use Session ID 1; all other services shall use Session ID's from the range labeled "Available" in Table 3.

Table 3 Allowed Session ID's

Session ID	*Service*
0	Reserved
1	Object Services
2-63	Reserved (future)
64-65534	Available
65535 (OxFFFF)	Reserved (HSMS)

6.2.3 *Linktest* — The linktest procedure is an optional facility of HSMS. For the purposes of cluster tool communications, the linktest procedure as described in the HSMS standard shall be supported. On detection of a linktest timeout, a communication failure will be considered to have occurred, and higher communication layers shall be notified of this failure.

6.2.4 *Connection Mode* — HSMS provides for Active, Passive, and Alternating Connection Modes. For the purposes of establishing connections in a cluster tool, either Active or Passive shall be used. For each service provided, there is a service provider (server) and a service user (client). With respect to each service, the client shall connect in the Active mode and the server in the Passive mode. Table 1 specifies the client and server (and hence connection mode) of the required sessions.

In addition to establishing the connection, the client shall initiate the sessions with the Select message, as defined in HSMS. As a result, all sessions at the client end of a connection shall be service users and all sessions at the server end of the connection shall be service providers.

6.3 *Use of TCP/IP* — HSMS defines the use of TCP/IP for communication of messages. Other simultaneous uses of TCP/IP are possible but beyond the scope of this standard.

Within TCP, Port Numbers are used to uniquely identify the connection on a given platform. A port number may be any value between 0 and 65535, but TCP reserves port numbers starting at 0. Refer to HSMS and the references given in HSMS for the definition of the reserved port numbers.

Multiple logical modules may exist on a given platform. Each service for a logical module on a given platform must use a unique session within a connection. It is possible to configure a module so that each logical module uses a separate connection, but it is also possible for several logical modules to share a connection. Each service requires a unique connection for each external entity, but an external entity may, depending on the configuration, access the services of several logical modules on a platform, identifying them by unique session, except for Object Services. Object Services is always identified by Session ID 1.

Connection to a specific module shall be established using a non-reserved port number which is unique among modules on that platform. A given service may have several simultaneous connections.

6.3.1 *Setting Port Number* — The port numbers used for establishing HSMS connections shall be configurable for both the service user and service provider. This is because the port numbers may be used by some other software entity on the same platform. Port numbers shall be chosen that are not in the reserved range and do not conflict with any other software entity on the platform. The method of configuration of the port numbers shall be documented.

6.4 *Physical Layer* — HSMS allows for many different physical layers. In order for modules to interoperate, a single physical layer is required. This standard specifies Ethernet — as defined in the standard IEEE 802.3 — to be used for physical layer transmission of HSMS messages.

Other physical layers could be used, but the use of other such physical layers is not supported by this standard. It is anticipated that other related standards will be developed to support other physical layers. In such a case, only those modules compliant with the same standard would be interoperable.

6.5 *Media and Connectors* — With Ethernet, there is a choice of media used (twisted pair, coax, etc.). It is beyond the scope of this standard to specify the media used. The media is thus left to the configuration of a specific cluster tool and may depend on the available media used in the factory.

Most Ethernet interfaces provide a media-independent AUI interface. A transceiver is then used to access the physical media. In order to be compliant with this standard, a module shall provide an AUI interface. Many interfaces also provide a media-specific interface. This media specific interface may be used in the event that the cluster tool media is the same as the media specific interface.

7 Compliance

Compliance with this standard includes adherence to all stated requirements where implemented. In order to be compliant to this standard, an implementation shall:

1. use SECS-II messages as specified by CTMC document,
2. use SEMI E37 (HSMS) and SEMI E37.2 (HSMS-GS),
3. allow and document IP Address configuration,
4. allow and document Session ID configuration,
5. allow and document Port ID configuration,
6. use Ethernet as defined in IEEE 802.3,
7. provide an AUI connector.

Some Ethernet interfaces provide additional connectors (such as 10 BASE 2 or thinnet). These may be used in cases where this is the medium chosen, but for compliance, an AUI connector shall be provided.

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as a part of SEMI E38.1 by full letter ballot procedure.

A1-1 Example Configuration

The following example shows configuration of a cluster tool consisting of an existing process module with a new cluster controller and other modules.

The cluster consists of a Cluster Controller, two Process Modules (PM1, PM2), and a combined Transport/Cassette Module (TM/CM).

A1-1.1 *IP Addresses* — IP addresses are chosen so that they are unique to each platform on the network and consistent with the conventions used at the facility. For this example, the convention is to use 192.25.63.X for IP Addresses, where X is between 0 and 255. PM1 had an existing IP address of 192.25.63.122, which will not be changed. IP addresses starting at 205 are unused and thus available. Thus, the following IP addresses are chosen:

```
Cluster Controller       192.25.63.205
TM and CM                192.25.63.206
PM1                      192.25.63.122
PM2                      192.25.63.207
```

As part of the configuration, the IP Address of each module is identified as shown above, on all of the platforms. This configuration depends on the TCP/IP software used on the respective platforms.

A1-1.2 *Port Numbers* — TCP reserves port numbers below 1024 in RFC1340. There are no other TCP/IP programs on any of the platforms in the cluster using port number in the range 2000-10000, so the following port numbers are chosen:

```
2000 first TM
5000 first CM
8000 first PM
8001 second PM
```

The cluster controller is always a client and initiates the connections, so no port number assignment is required.

A1-1.3 *Session ID Assignment* — Before defining the Session ID's, recall that the following connections are required:

Client	**Server**
CC	TM
CC	CM
CC	PM1
CC	PM2
CM	TM
PM1	TM
PM2	TM

The Session ID's are arbitrary. PM1 already has ID's which are as follows:

PM1 IDs		
Clients		
Object Services	1	CC, TM
Processing Management	100	CC
Recipe Management	101	CC
Material Movement	102	CC, TM
Exception Management	103	CC
Event Reporting	104	CC

The other modules have not yet been set, so we choose to begin with ID 64.

The session IDs are established as follows:

PM2 Ids		
Clients		
Object Services	1	CC, TM
Processing Management	64	CC
Recipe Management	65	CC
Material Movement	66	CC, TM
Exception Management	67	CC
Event Reporting	68	CC

TM IDs		
Clients		
Object Services	1	CC
Material Movement	64	CC
Exception Management	65	CC
Event Reporting	66	CC

CM IDs		
Clients		
Object Services	1	CC, TM
Material Movement	64	CC, TM
Exception Management	65	CC
Event Reporting	66	CC

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E39-1101
OBJECT SERVICES STANDARD: CONCEPTS, BEHAVIOR, AND SERVICES

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the Japanese Information & Control Committee. Current edition approved by the North American Information and Control Committee on July 19 and August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995; previously published June 2000.

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APPENDIX 1

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SEMI E39-1101
OBJECT SERVICES STANDARD: CONCEPTS, BEHAVIOR, AND SERVICES

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the Japanese Information & Control Committee. Current edition approved by the North American Information and Control Committee on July 19 and August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995; previously published June 2000.

1 Purpose

1.1 The purpose of the Object Services Standard (OSS) is to provide general terminology, conventions, and notation for describing behavior and data in terms of objects and object attributes. In addition, it provides basic services for reading object attributes, setting their values, and for asking for an object's contents. This standard is intended to be referenced by other standards which define specific objects to reduce redundancy.

2 Scope

2.1 The scope of this standard is to provide concepts, behavior, and services common to a variety of public objects.

2.2 Object models are common to multiple standards. Object Services provide basic object-related definitions, and basic services for getting object attributes and setting attribute values, that can be used by all standards defining public objects. These services allow basic management of data based on objects.

2.3 The object services defined in this document may be included in the services provided by other standards. They may also be provided independently of such other standards.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ISO Standard*[1]

ISO 9595 — Common Management Information Service (CMIS)

3.2 *Other Standards*

James Rumbaugh, Michael Blaha, William Premerlani, Frederick Eddy, William Lorensen, *Object-Oriented Modeling and Design*, Englewood Cliffs, New Jersey: Prentice-Hall, 1991.

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Definitions

4.1 The following basic definitions are provided in a logical order.

4.2 *Requirements*

4.2.1 *fundamental compliance* — conformance to all fundamental requirements for an object or service resource.

4.2.2 *fundamental requirements* — the requirements for information and behavior that must be satisfied for compliance with a standard. Fundamental requirements apply to specific areas of application, objects, or services.

4.3 *Objects*

4.3.1 *object*[2] — an entity with a specific set of data and behaviors. Objects may be physical or conceptual.

4.3.2 *standardized object* — a object formally defined in SEMI standards and in compliance with the fundamental requirements of SEMI E39 (Object Services Standard: Concepts, Behavior, and Services).

4.3.3 *object model* — a static graphic model of objects to show structure — the identity of objects, their attributes and operations, and their relationships with one another.

4.3.4 *object type* — a formal classification of a group of similar objects. Synonym: *object class*. Examples: *equipment*, *wafer*, *carrier*.

4.3.5 *object instance* — an instance of an object type. An object type is like a template, while an object

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

2 The term "object" may refer to either an object class or an instance of a class.

instance is the actual object. Example: an actual and specific optical stepper installed in a particular fab is an instance of the type "Optical Stepper."

4.3.6 *object attribute (attribute)* — information concerning an object. Examples for object type "equipment": manufacturer, model, serial number.

4.3.6.1 Attributes are classified in various ways, according to their visibility (public/private), optionality, and access:

- *fundamental attribute* — an attribute that is required for fundamental compliance with a standard service.
- *optional attribute* — an attribute that is required only in support of one or more optional standard services.
- *private attribute* — an attribute that is used strictly for internal purposes and is unknown (invisible) through public services.
- *public attribute* — an attribute that is known (visible) and whose current value is provided as a service to other entities upon request.
- *read-only attribute (RO)* — may not be changed through public services.
- *read/write attribute (RW)* — may be changed through public services.

4.3.7 *attribute name* — the formal name of the attribute that is used to identify it. The names (and data types) of public attributes are included with the object's definition and are unique for that object.

4.3.8 *object identifier* — a set of one or more items of information, concerning a particular instance (instantiation) of an object of a given type, that together uniquely distinguish that instance from all other instances of that object within a defined scope. NOTE: An object may have more than one identifier. An identifier may be *simple* (consist of only one attribute) or *complex* (consist of more than one attribute). Example: The combination of equipment's manufacturer, model, and serial number serve as an identifier that uniquely identifies a specific installation.

4.3.9 *object handle* — a numeric or binary identifier assigned by an application for internal use. NOTE: A handle may also be available as a *public attribute* but cannot generally be guaranteed to be either persistent or unique outside of the current relationship between service user and service provider. The persistence of the handle is specified by the standard that defines the object.

4.3.10 *operation* — a function performed by, or inherent to, an object. Example: for equipment, "run," "stop," "abort."

4.3.11 *aggregation object* — an object that is composed (made up) of other objects. An aggregation may lose some degree of integrity if one of its components is missing.

4.3.12 *component object* — an object that is part of an aggregation.

4.3.13 *container object* — an object that is intended to hold other types of objects. The contents may or may not be ordered.

4.3.14 *contents* — an object that is in a container. Examples: a wafer in a cassette, a book in a library.

4.3.15 *owner object* — an object that is an aggregation, container, or supervisor of another object. The owner object is said to *own* the other object.

4.3.16 *owned object* — an object that is a component of, contained in, or supervised by, another object. The owned object is said to be *owned by* the other object.

4.3.16.1 An object may have multiple owners. For example, it may be a shared resource.

4.4 *Services*

4.4.1 *scope* — the specification of one or more objects that starts with a specific owner object and proceeds downward through a hierarchical sequence of "owns" relationships.

4.4.2 *service (or message service)* — represents a function offered to a user by a provider. A service consists of a sequence of service primitives, each described by a list of parameters. A service excludes definition of message structure and protocol.

4.4.2.1 A service may or may not be processed by the provider of the service. The invocation of some service may have to interact with other objects to fulfil its requirement completely; an exception will be raised if the service can not fulfill all its pre or post conditions. The object that provides the service may reject the service request or restrict the completion of the service to prevent an illegal action due to the equipment condition.

4.4.3 *notification service* — initiated by the service provider and sent to the service consumer/subscriber. No response is expected.[3]

4.4.3.1 Notifications consist of two service primitives — a message from the sender to the communications

3 This does not preclude the implementation of a response message in the message protocol.

facility and an indication to the receiver from the communications facility.

4.4.4 *request service* — initiated by the service consumer. Requests ask for data or for an activity (operation) from the provider. Requests expect a specific response message.

4.4.4.1 A request consists of a message that requires a response from the receiver. The primitives for a request are the same as those of the notification, while the response defines additional primitives called the *response* and the *confirmation*.

4.4.5 *service resource* — a logical group of one or more services within a specific area of functionality.

4.5 *Data Type*

4.5.1 *form* — type of data: positive integer, unsigned integer, integer, enumerated, boolean, text, formatted text, structure, list, ordered list.

4.5.2 *positive integer* — may take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.5.3 *unsigned integer* — may take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

4.5.4 *integer* — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

4.5.5 *floating point* — may take on any single (real) numeric value, positive or negative. Messaging protocol may impose a limit on the range of possible values.

4.5.6 *enumerated* — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.5.7 *boolean* — may take on one of two possible values, equating to TRUE or FALSE.

4.5.8 *text* — A text string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.5.9 *formatted text* — a text string with an imposed format. This could be by position, by use of special characters, or both.

4.5.10 *structure* — a complex structure consisting of a specific set of items, of possibly mixed data types, in a specified arrangement.

4.5.11 *list* — a set of one or more items that are all of the same form (one of the above forms).

4.5.12 *ordered list* — a list for which the order in which items appear is significant.

5 Conventions

- Defined terms are presented in boldface when introduced for the first time.
- Formally reserved text strings, such as attribute names, are underlined.

5.1 *OMT Object Information Model* — The object models are presented using the Object Modeling Technique (OMT) developed by Rumbaugh, James, et al, in *Object-Oriented Modeling and Design*, Prentice Hall, Englewood Cliffs, NJ, c1991.[4]

5.1.1 Overviews of this notation are provided in the Appendix. A brief discussion of terminology is also provided in the Appendix.

5.2 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
The formal text name of the attribute	Description of the information contained	RO or RW	Y or N	(See Section 4.4.)

5.2.1 The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that users of the service have to the attribute.

5.2.2 A "Y" or "N" in the Requirement (Reqt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

5.2.3 The Form column is used to indicate the format of the attribute. (See Section 4.4 for definitions.)

5.3 *Service Message Representation*

5.3.1 *Service Resource Definition* — A service resource definition table defines the specific set of messages for a given service group, as shown in the following table:

Message Service Name	*Type*	*Description*
Message name	N or R	The intent of the service.

5.3.1.1 Type can be either N = Notification or R = Request.

5.3.1.2 Notification type messages are initiated by the service provider, and the provider does not expect to get a response from the consumer/subscriber.

4 For a full description of the Object Modeling Technique, see Object-Oriented Modeling and Design, Rumbaugh, Blaha, Premerlani, Eddy and Lorenson, Prentice Hall, 1991.

5.3.1.3 Request messages are initiated by a service consumer or subscriber. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

5.3.2 *Service Parameter Dictionary* — A service parameter dictionary table defines the parameters for one or more services, as shown in the following table:

Parameter	*Form*	*Description*
Parameter X	Data type	A parameter called X is B in A.

5.3.2.1 A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding primitive.

5.3.2.2 The Form column is used to indicate the type of data contained in a parameter. (See Section 4.4 for definitions.)

5.3.2.3 The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the values it can assume, and any interrelationships with other parameters.

5.3.2.4 To prevent the definition of numerous parameters named "XxxList," this document adopts the convention of referring to the list as "(List of) Xxx." In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

5.3.3 *Service Message Definition* — A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Parameter X	(see below)	(see below)	A description of the service.

5.3.3.1 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request." The receiver terms this message the "Indication" or the request. The receiver may then send a "Response," which the original sender terms the "Confirmation."

5.3.3.2 The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

- "M" — *Mandatory Parameter* — must be given a valid value.
- "C" — *Conditional Parameter* — may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the values of other parameters.
- "U" — *User-Defined Parameter*
- "-" — The parameter is not used.
- "=" — (for response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

6 Background

6.1 During the development of proposals for several other service standards, it was discovered that they shared a common need for terminology and services related to objects. Originally each proposal included a service-specific message for getting the values of an object's attributes, and some also provided a service-specific message for setting these values.

6.1.1 The decision was made to eliminate this redundancy through provision of a standard to provide those definitions and services used by the other separate service standards.

7 Applicable Documents

SEMI Book of Standards, Equipment Automation/ Software Volumes 1 and 2[5]

ISO/TR 8509:1987,[6] Information Processing Systems, Open Systems Interconnection — Service Conventions

William Stallings, Networking Standards, *A Guide to OSI, ISDN, LAN, and MAN Standards*, Addison-Wesley Publishing Company

8 Basic Concepts and Behavior

8.1 This section defines the concepts and behavior that are common to public objects.

8.1.1 Object-oriented analysis is a widely accepted tool, both for applications that are implemented using

5 This set of documents may be obtained from SEMI, 3081 Zanker Road, San Jose, CA 95134.

6 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

object-oriented technologies and those using traditional technologies. Object information models provide a powerful method for describing relationships that can be intuitively understood.

8.1.2 For those unfamiliar with object-oriented terminology, a brief discussion of terms is provided in the Appendix.

8.2 *Object Attributes* — An *object attribute* is a data value that is held by all instances of a given object type. For communication purposes, public attributes are assigned a logical *name* that is unique for that object. An object's attributes may be individually referenced either by an enumerated numeric value or by a reserved *attribute name* that conforms to the use of text defined in Section 8.1.1.

8.2.1 An attribute that can be requested or referenced through formal public *services* is a *public attribute*. Other attributes may exist in specific implementations but are invisible through public services and are called *private attributes*.

8.2.2 Specific attributes may be designated as *fundamental* for a specific object. These shall be supported by all implementations that use or reference the specified object. Attributes that are not fundamental are *optional*.

8.2.3 *Use of Text* — Values defined as text, when given in ASCII, are subject to certain restrictions. This includes object attribute values, attribute names, and service parameters.

8.2.3.1 Text in ASCII is restricted to the characters between 20_{16} and $7E_{16}$, excluding the question mark "?", the asterisk "*", and the tilde "~".

8.2.3.2 The question mark and asterisk are reserved for use as "wild characters" in filters and searches, while the tilde is reserved to allow systems that cannot use spaces to convert spaces to tildes for internal use.

8.2.3.3 Text used in specific contexts may have additional restrictions.

8.2.3.4 Unless otherwise stated, case is not significant for purposes of comparison. However, case is used to improve readability and should be preserved whenever possible.

8.2.4 *Object Type* — An object always knows its type. For this reason, the attribute for object type, ObjType, is required for all public objects. ObjType is a text string containing the formal classification of an object. The text string shall conform to the convention defined in Section 8.1.1, with the additional restriction that the "greater than" symbol ">" and the colon ":" are also excluded. The text string shall not start or end with a space.

8.2.4.1 Object types (the values for ObjType) for standardized objects are reserved. Types reserved are specific to individual standards.

8.2.5 *Object Identifier* — Every instance of an object shall have one or more attributes that together uniquely distinguish that instance from all other instances of objects of the same object type. An object may have more than one identifier. The identifier(s) are defined as part of the object definition.

8.2.5.1 ObjID is a text-based fundamental attribute of all public objects and provides an attribute of a known form to serve as an identifier for an object of any type. The text string shall conform with the convention defined in Section 8.1.1 and with the additional restriction that the "greater than" symbol ">" and the colon ":" are also excluded. The text string shall not start or end with a space.

8.2.5.2 From the point of view of objects such as managers, aggregates, and containers that have responsibilities for other objects (see Sections 9.1 and 9.2) the combination of ObjType and ObjID for these other objects shall be unique. For example, if several process chambers have a single vacuum pump, each process chamber may have direct access to at most one ObjType:ObjID> combination of "Pump:Vacuum". However, the combination is not required to be unique across the different chambers. The host differentiates between the several vacuum pumps by their belonging to different aggregations.

8.2.5.3 The object definition for each object shall specify the particular identifier used for general access. For objects that normally use an identifier with a numeric value as an identifier (such as "handle," described below), the value of ObjID is a numeric text string set to the value of that attribute.

8.2.5.4 An object may also have other identifiers in addition to ObjID.

8.2.6 *Object Handle* — An object's *handle* is an attribute with a numeric value that is assigned by the application that created the object. The handle may be used for the object's identifier. It is generally intended for local use and may or may not be defined as a public attribute in the object's formal definition.

8.2.6.1 Where used, the handle may be guaranteed to be unique only within a specific context and within a single association between service-provider and service-user for a specific service resource. The handle may or may not be persistent beyond a certain context within that association or beyond it. Persistence of the handle is specified as part of the definition of the object and is beyond the scope of OSS.

8.3 *Object Definition* — An object definition includes an attribute definition table described in Section 5.3.

8.3.1 The object that is the super-type of all public objects is called the *top object*. The attributes and operations of the top object, shown in Figure 1, are fundamental requirements for all public objects. That is, all objects shall respond to the object attributes ObjType and text strings, and all public objects shall recognize and respond to the operations *get attributes* and *set attributes*.

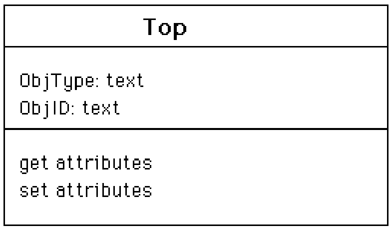

Figure 1
Top Object

8.3.2 Formal definition of an object shall include a table defining the object's public attributes. The Object Attribute Definition table for the top object is given in Table 1 below. It contains the two fundamental attributes required of all public objects.

Table 1 Top Object Attribute Definition

Name	*Definition*	*Access*	*Req*	*Form*
ObjType	The object type.	RO	Y	Text
ObjID	The object's identifier.	RO	Y	Text

8.3.3 Access refers to the ability to read and write the value of the attribute through OSS services. An object's type and identifier may not be changed through OSS services. However, it may be possible for the service user to assign a value for the object's identifier at the time the object (instance) is created. This depends on the object and the services provided.

9 Object Relationships

9.1 This section addresses relationships between objects that affect communications, either by restricting communications or through information concerning relationships.

9.2 *Object Hierarchy* — Certain objects may be specified as *aggregation objects* or as *container objects* when they are defined.

9.2.1 An aggregation object is composed of other objects called the *components* of the aggregation. This is illustrated in Figure 2. Components may be of one or more different types, or they may be of the same type.

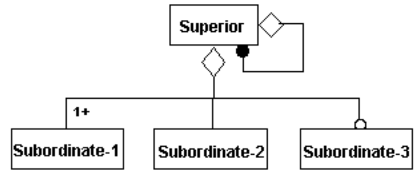

Figure 2
Aggregation with Two Component Types

9.2.2 Container objects *contain* other objects, of the same or different types, but are not made up of them.

9.2.3 Figure 3 shows two object types that are associated with a relationship called "contains." The solid circle indicates that Type-1 may contain zero or more objects of Type-2 type. An example of a common container type is a file directory.

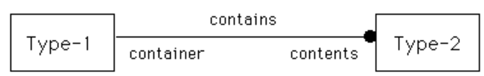

Figure 3
Container and Contents

9.2.4 An aggregation loses some degree of integrity if certain of its components are missing, while a container retains full integrity even if it has no contents. An automobile is an aggregation of many components, some of which are themselves aggregations. An automobile may also have contents (driver, passengers, belongings) which are removable and not considered as components. Other examples of container objects include lists, dictionaries, and libraries. A container that has no contents is said to be *empty*.

9.2.5 The aggregation or container is called the *superior object* and its components or contents are called *subordinate objects*.

9.2.6 In addition to the relationships of "is composed of" (roles: aggregate/component) and "contains" (roles: container/contents), the other hierarchical relationship that occurs naturally in factories and in control systems is that of "*supervises*" (roles: supervisor/supervised). This denotes a control relationship where the supervised object accepts part or all of its directions from the supervisor. The supervisor, in turn, has responsibilities that it delegates to the supervised. The supervisor typically will also have a relationship of "*is composed of*" or "*contains*" with its supervised subordinates.

9.3 *Scope and Ownership* — The hierarchical relationships of aggregations, containers, and supervisors may at times be required for pointing to a specific object. These relationships may be shown with a multi-level tree structure, as shown in Figure 4. Subordinate objects at one level may be the superior objects at the next lower level. The superior object at the highest level is called the *root* of the tree.

NOTE 2: Figure 4 is not drawn in OMT notation.

9.3.1 An *owner object* is an object that is an aggregate, container, or supervisor. An *owned object* is an object that is a component of, contained in, or supervised by, an owner object.

9.3.2 *Scope*[7] is the concept and method of pointing to a specific owned object through the use of sequence of hierarchical relationships. Scope allows any particular object (type or instance) within such a hierarchical tree to be fully specified by providing a unique path down this tree using a concatenation of object types and identifiers.

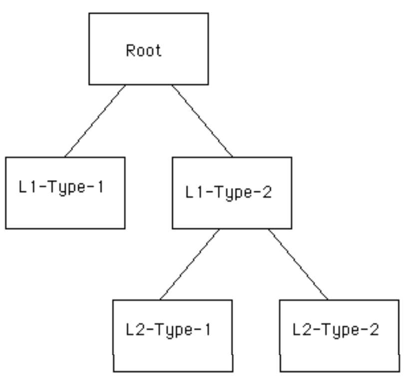

Figure 4
Example of Owner Hierarchy

9.3.3 This path is used to create an *object specifier* that is represented as a sequence of concatenated text strings of the form “type:id>”, which may be repeated as necessary to form the complete path. The character “>” is used to terminate the object type field, and the colon character “:” is used to terminate the identifier field. The object specifier uniquely identifies an object within the entire domain of objects and is able to extend the domain within which a search for an object would otherwise occur.

9.3.4 Formally, an object specifier is a formatted text string of the form:

“$type_1$:id_1>...$type_n$:id_n>”

where “$type_i$” and “id_i” represent the object type and object identifier, respectively, of the ith object instance in the sequence, and where the ith object is owned by the (i-1)th object and is the owner of the (i+1)th object.

9.3.5 Figure 5 shows an example of a typical set of hierarchical relationships in the factory. An application of scope might be through Cell AB, Cluster BB, Process Module (PM) CB, to Device DB. In this example, the object specifier for Device DB would be:

“FactoryHost:Hilda>Cell:AB>Cluster:BB>PM:CB>
Device:DB>”

9.3.6 It is generally not necessary to start with the root object. It is sufficient to start with an object that is owned by the communications partner. However, it is invalid to omit a level in the hierarchy that is between the starting object and the final object in the path.

9.3.7 Some systems may be able to guarantee the uniqueness of object identifiers for their owned objects. For example, equipment may be able to guarantee that all of its owned objects have unique identifiers regardless of type. In this case, an object’s identifier is sufficient to point to a specific object instance. Object type may be omitted without ambiguity, as it may be obtained as an attribute of the specified object. The form of the path then becomes "id_1>id_2>.id_n>". In the previous example, this might be "AB>BB>CB>DB>".

9.3.8 Object type may also be omitted in applications where it may be inferred without ambiguity within a particular context. A service that is dedicated to a specific object type X, for example, that is always owned only by another specific object type Y, may specify usage for object type X. Since object type may then be inferred from the context, object types X and Y need not be included in a specifier for an object of type X.

9.3.9 The terminator of the final identifier is optional. This allows a single object identifier to be used as a simple object specifier. As a result, however, it may be necessary to provide string delimiters to prevent premature termination of string parsing in the event an identifier contains one or more embedded spaces.

9.3.10 Scope can be applied to any set of hierarchical relationships, given a minimum set of requirements for public objects:

- an object always knows its own type (<u>ObjType</u>),
- an object always knows its own identifier(s) (including <u>ObjID</u>),
- an owner object knows the types of objects that are its components and/or contents, or that it otherwise

7 Scoping is used in material ISO 9595 (CMIS).

supervises, and is able to determine their identifiers (see GetType, Section 10.5),

- an owner object is able to determine the types and identifiers of its owned objects.

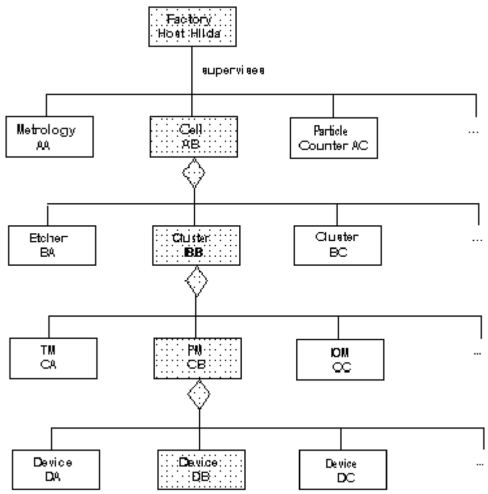

Figure 5
Hierarchical Relationships in the Factory

9.4 *Multiple Inheritance Hierarchy* — Multiple hierarchical inheritance may be required as an optional capability for pointing to a specific object that provides the same services from the inherited objects. Usually, inherited services are implemented by the domain object such that specifying "overrides" of attributes or services from inherited objects is not required. Sometimes the capability to override specified attributes and services from inherited object is necessary to resolve duplicated attribute names or services or to allow duplicated names in user extended objects.

9.4.1 If Andy an object TypeA inherits from object TypeB and TypeC and a service requestor is focusing services or attributes of the object TypeB rather than those with the same name in the object TypeC, the following text string form could specify the focused part of the object Andy:

```
TypeA@TypeB:Andy
```

9.4.2 If any names of service and/or attribute that TypeB provides are the same as those provided by TypeA or TypeC, then, the object Andy will have to be specified with the complete explanation from the supplier as how the object handles the exception and the differences from the original attribute or services. So, the above expression is the same as "TypeA:Andy" without notes to describe difference.

10 Additional Operations

10.1 This section defines operations that are common to many types of public objects but are not required for all types of public objects. These operations are not required for OSS compliance. However, they may be required for support of specific object types defined by other standards that use OSS services.

10.2 *Create and Delete* — Creation and deletion are optional services for object lifecycle management. Object definitions may specify conditions under which the services are supported. Objects may be created and/or deleted in other ways. For example, the creation and deletion of certain types of persistent objects may be outside of the scope of OSS services, while transient objects may be created and/or deleted automatically by their owners as the result of other activities.

10.2.1 *Create* — The create operation creates an instance of an object type.

10.2.1.1 Initial settings for one or more attributes may be specified by the service user. Initial settings may be required, prohibited, or optional, depending upon the specific object type. The ability to set attribute values through the create operation shall be clearly identified as part of the object definition for those objects supporting the create operation. For example, the ability to set the value of the object identifier ObjID may be required, optional, or prohibited, depending upon the type of object.

10.2.1.2 The object definition may also specify attributes of the new object instantiation that are returned to the service user by the service provider.

10.2.1.3 A request to create an object is invalid if it does not provide all required attribute settings, if it attempts to set prohibited attributes, or if it provides values invalid for a given attribute.

10.2.1.4 The definitions of certain objects may specify that the delete service only be provided to, or under the authority of, the service user that requested the original create operation. In this case, a private attribute (that is, an attribute not accessible through services defined in Section 11) named Delete Token shall return a unique integer as an attribute of the new object. This attribute is then used in a subsequent request to delete the object. The service user may delegate this token at its own discretion.

10.2.1.5 The create operation is invoked by the service Create sent to the owner that is to instantiate the specified object. In order for the Create service to be accepted if no owner for the object to be created is defined in the target entity or if it is physically outside of the domain of the entity; the object specifier shall define the owner as " " (an empty string). If the entity is just the equipment rather than a component of the equipment; the owner may be defined as“Equipment” even if no such object is defined.

10.2.2 *Delete* — The delete operation is the inverse of the create operation. Individual object types may restrict deletion based on well-defined set of criteria. For example, the definition of a type of container may specify that a container may only be deleted when it is empty.

10.2.2.1 If an object to be deleted requires the authority of the service user that invoked the original create operation, then the Delete Token attribute of the target object shall be provided by the user of the delete service.

10.2.2.2 A request to delete an object is invalid if it does not provide all required attribute settings or if it provides values invalid for a given attribute.

10.2.2.3 The delete operation is invoked by the service Delete sent to the object to be deleted.

10.3 *Attachment* — When an object receives a remote request for an operation, it may be unable to identify the requestor. At the same time, it may be necessary for an object to determine if certain messages were sent by its supervisor. This conflict is resolved by formalizing the relationship between a supervised object and its supervisor.

10.3.1 Attachment is a dynamic behavioral binding between two objects in a hierarchical relationship where it is important that the attached (supervised) object be able to differentiate certain service requests made by its supervisor from other requests. An attached object has exactly one supervisor, as illustrated in Figure 6.

10.3.2 An attached object may be detached from its current supervisor, or it may be reattached to a different supervisor. The latter operation is used when the previous supervisor has become damaged and is not intended as a general method for moving the object’s attachment, as the former supervisor is not notified of the change.

10.3.3 *Attach* — When sent to an unattached object, the attach operation creates a logical connection between the object and a supervisor. The object that is being attached creates a unique, private, non-zero numeric value, called an attach token. The attach token is treated as an attribute named AttachToken. It is a private attribute of the attached object, not visible through basic OSS services (see Section 11).

10.3.3.1 When an object is first created, it is unattached, and the value of its attach token is set to a default value of zero. An object is attached to another object as a formal relationship. The operation of attach generates the attach token, which is returned to the service user. The supervisor uses this token in subsequent critical service requests to identify itself to the attached object.

10.3.3.2 The attach operation also may accept settings for one or more attributes of the attached object, as defined for the attached object type. This allows the supervisor to provide values for attributes that are otherwise regarded as read-only values and cannot be set through the SetAttr service defined in Section 11. An example of an attribute value that it is often desirable to access in this way is the object specifier of the supervisor.

10.3.3.3 Requests to attach an object that attempt to set attributes shall be denied unless the attributes are among those accessible to the supervisor and all specified settings represent valid values of those attributes. The object type and identifier shall not be changed by the supervisor.

10.3.3.4 An attached object is owned by its supervisor.

10.3.3.5 The attach operation is invoked by the message service Attach by an intended supervisor. Requests to attach an already attached object shall be denied.

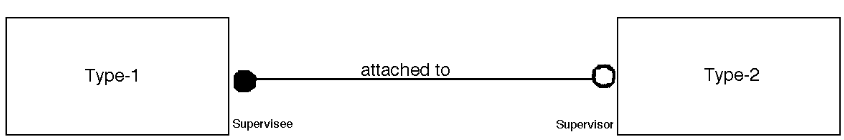

Figure 6
The Attachment Relationship

10.3.4 *Attach Set Attributes* — A supervisor may need the ability to set certain read-only attributes of one of its attached objects subsequent to the attach operation. The set attached attributes operation provides this capability to a supervisor of attached objects. The supervisor identifies itself by using the attach token for that object.

10.3.4.1 The definition of the attached object type may restrict the attributes that may be set by this operation. The attach set attributes operation shall be denied if the attributes or settings are invalid for this operation.

10.3.4.2 The attach set attributes operation is invoked by the message service AttachSetAttr sent by the object's supervisor and is otherwise invalid.

10.3.5 *Detach* — The detach operation breaks the logical connection between an attached object and its supervisor. The attach token is reset to zero, and the object becomes unattached.

10.3.5.1 The detach operation is invoked by the message service Detach sent by the object's supervisor and is otherwise invalid.

10.3.6 *Reattach* — The reattach operation is similiar to the attach operation, except that it is sent only to an attached object to change the logical connection from the attached object to a new supervisor. This operation is used to replace a damaged supervisor. Any existing connections to the old supervisor shall be closed. Note the reattach operation is vulnerable to misuse. Applications supporting the reattach operation may have additional requirements, such as notification sent to the previous supervisor, to provide a trace of misuse.

10.3.6.1 The reattach operation provides a unique attach token that has not been previously used by the attached object. This effectively disables its previous supervisor.

10.3.6.2 An attempt to reattach an object shall be denied unless the attributes and settings are valid for the operation.

10.3.6.3 The reattach operation is invoked with the message service Reattach sent to an attached object by the object's new supervisor and is otherwise invalid.

10.3.7 *Attach Supervised Object* — The attach supervised object operation is invoked by a service user to request a supervisor to attach to itself a valid target object. If the supervised object does not already exist or is not a valid target type for the supervisor, then the attached supervised object operation shall fail. The results of the operation are returned to the service user.

10.3.7.1 The attach supervised object operation is invoked with the service AttachSupervisedObject.

10.3.8 *Detach Supervised Object* — The detach supervised object operation is invoked by a service user to request a supervisor to detach from itself an attached object. The supervisor sends a detach request to the specified attached object. Regardless of any response from the specified supervised object, the supervisor shall consider it thereafter as unattached. This is required to allow a damaged attached object to be removed. This operation is successful except when the target object is not already attached to the supervisor.

10.3.8.1 The detach supervised object operation is invoked with the service DetachSupervisedObject.

11 Services and Scenarios

11.1 The services defined by OSS are contained in Table 2.

Table 2 Object Services

Message Service Name	*Type*	*Description*
GetAttr	R	Get values of specified attributes based on attribute filters.
SetAttr	R	Set values of specified attributes based on attribute filters.
GetAttrName	R	Set names of attributes of objects owned by the service provider.
GetType	R	Get types for objects owned by the service provider.

11.2 *Scope* — Scope is supported through the object specifier parameter. The object specifier provides a method for pointing to objects owned by the service provider that are otherwise not accessible to the service user. That is, the service provider may not provide direct services for, or to, that object. This can occur when an object for which the service provider offers services is an owner object, such as an aggregate or file directory, as described in Section 9. In some cases, the owned object may itself be remote from the service provider. For example, the owned object may be provided by a separate system.

11.2.1 The service provider may be an owner object with managerial responsibilities, and therefore it may prohibit direct access to one of its component or contained objects. In this case, requests concerning an owned object from a service consumer shall be directed to the owner object instead.

11.2.2 Object services use the *object specifier* for the owner of the target object(s). The construction of the object specifier is defined in Section 9.

11.2.3 Object type may be omitted from the object specifier where it may be otherwise determined without ambiguity. However, inclusion of type is always valid.

11.3 *Filtering* — An *attribute filter* is an optional set of one or more *attribute qualifications*. An *attribute qualification* is a boolean expression that makes a statement about the presence or values of attributes in a target object. It identifies an attribute, a *qualifying value* of that attribute, and a *qualifying relationship* that the value has to the target attribute. The attribute filter is a boolean that consists of the expression formed by an AND of the set of qualifications.

11.3.1 If the attribute is of text form, the qualifying value may be used as a *mask* with the embedded *wild characters* "?" (question mark) and "*" (asterisk). The character "?" may be used within the mask to represent "any single character" and may be repeated. The string "?????" represents any text string with a length of five characters.

11.3.2 The character "*" may be used in the mask to represent a variable-length string, including a null string. The string "*x" represents a string of any length that ends in "x"; the string "x*" represents any string that begins with "x".

11.3.3 When the character "*" is used by itself as the string "*", however, it represents any string of any non-zero length. It may also be repeated within a string, as in "*x*y*", which represents any string with embedded characters "x" and "y", such as "abxaby", "x_y", and "xy".

11.3.4 The comparison for text characters shall be case insensitive.

11.3.5 The qualifying value specifies a qualifying relationship, "R", between the value specified in the attribute qualification and the matching attribute of object instances. The qualifying value for the attribute is compared with the attribute of an instance of the target object to test the relationship.

11.3.6 If the qualifying value has the relationship "R" to the attribute of the target object, then the instance *qualifies* for the relationship and is included in the set of objects for which requested attributes are returned. For example, if the attribute name is "Length," qualifying value is the number 5, and the qualifying relationship is "is less than," then the Length attributes of all instances of the target object are tested. All instances with a "Length" attribute greater than 5 or equal to 5 qualify.

11.4 *Object Services Parameter Dictionary* — Table 3 defines all of the parameters, including the elements of complex parameters, used in object services.

Table 3 Object Services Parameter Dictionary

Parameter	*Definition*	*Form*
AttrData	The value of an attribute.	Varies with attribute. The form of an attribute's value is specified as part of the definition of an object type.
AttrFilter	Attribute filter.	Structure composed of AttrName, AttrData, AttrReln.
AttrName	The attribute's name.	Text. Varies with object type.
AttrReln	Qualifying relationship between the qualifying value and the matching attribute of object instances.	Enumerated: Equal To Not Equal To Less Than Less Than or Equal To Greater Than Greater Than or Equal To Present (specified attribute is present) Absent (specified attribute is absent) Contained (The qualifying value is in (i.e., equal to a member of) the set of the attribute's values.) Not Contained (If omitted, the relationship "Equal to" is assumed.)
AttrSetting	The name and value of an attribute.	Structure composed of AttrName and AttrData.
ErrorCode	Contains the code for the specific error found.	Enumerated: Unknown Object in Object Specifier Unknown Target Object Type Unknown Object Instance Unknown Attribute Name

		Read-Only Attribute — Access Denied
ErrorText	Text in support of the error code to provide additional information.	Text.
ObjAck	Acknowledgement code.	Unsigned integer. Possible values: Successful completion of request Error
ObjectAction	The name of an action to be performed on, or by, an object.	Text. Enumerated per individual object.
ObjectActionReportSatus	Status of receipt of an ObjectActionComplete-Notification.	Binary.
ObjectActionResult	List of return parameters, as name/value pairs, concerning the result.	List of ServiceParameters.
ObjectActionStatus	Status of action request.	Enumerated: Action was performed successfully. Action does not exist. Can not perform now – try later. Action will be performed and notification sent later. Action is prohibited. Target object unknown.
ObjectServiceList	Specified the services supported by a given object type.	Structure composed of ObjType, ServiceName
ObjID	Object identifier (ObjID).	Varies with object type.
ObjSetting	Attribute values for an object instance.	Structure composed of ObjID and (List of) AttrSetting.
ObjSpec	The object specifier, used to specify the owner of the target object.	Formatted text.
ObjStatus	Information concerning the success or failure of the operation.	Structure consisting of ObjAck and (List of) Status.
ObjType	Object type.	Object types are text strings reserved by individual standards. Object Services do not reserve object types.
OperationID	Identifies a specific request.	Unsigned Integer.
ServiceName	The name of a service or action to be performed on, or by, an object.	Text.
ServiceParameter	One or more arguments (parameters) providing additional information concerning the action requested.	Structure composed of ServiceParameterName and ServiceParameterValue.
ServiceParameterDef	A list of the parameter names that are supported for a specific service and object type.	A list of ServiceParameterName.
ServiceParameterName	Parameter name.	Text.
ServiceParameterValue	Parameter value.	Any. Varies depending on the parameter.
Status	Error information.	Structure composed of ErrorCode and ErrorText.

11.5 *Get and Set Attributes* — The GetAttr and SetAttr services are provided for reading and setting values of an object's attributes. They address attribute values of instances of objects. Figures 7 and 8 show the message flow for the GetAttr service.

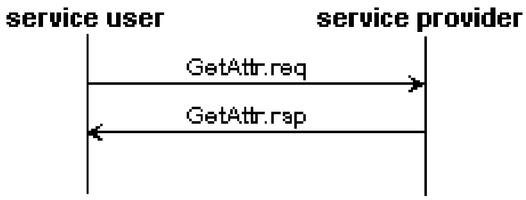

Figure 7
GetAttr Message Flow

Figure 8
SetAttr Message Flow

11.5.1 GetAttr and SetAttr allow access to attributes of objects that are owned by another object and are capable of addressing multiple levels of ownership (object hierarchy).

11.5.1.1 For example, GetAttr may be used as a "get directory" request to find the identifiers of all instances of one or more owned objects.

11.5.2 GetAttr and SetAttr may be used for objects that use a complex identifier, such as recipes with separate attributes for name and version.

11.5.3 GetAttr and SetAttr allow searching for those instances of an object that satisfy certain conditions through the specification of one or more qualifiers or filters. Only attributes of those instances of the desired object type that satisfy the conditions defined in the filters are returned by the service provider.

11.5.3.1 The filter is familiar to users of file services as a convenient way to obtain a partial directory of files, such as files with a date later than a specified date. This is particularly useful when the list of contents may be quite long.

11.5.4 The attribute value (all or a part of the list of ObjSetting) returned by the GetAttr service may be invalid if the acknowledge code of ObjStatus indicates a failure. In that case; the value(s) requested by the invocation of GetAttr service may be unknown, invalid or unavailable by any reason (e.g. corresponding hardware status, lack of privilege, mutual exclusion or other requirement not fulfilled by the application). Supplier shall document all conditions or timing requirements of any attributes if they are not always available.

11.5.5 The attribute value (all or a part of the list of ObjSetting) replied by the SetAttr service may be still unchanged if the acknowledge code of ObjStatus indicates a failure. In that case; the attribute value may be unchangeable, inhibited or blocked internally by any reason (e.g. corresponding hardware status, lack of privilege, mutual exclusion or other requirement not fulfilled by the application. The object providing the SetAttr service shall identify whether or not it is valid to change or set an attribute value. Supplier shall document all conditions and timing requirements of each attribute if they are not always allowed to be set.

11.5.6 *Object Specifier* — This parameter is used for specifying an owner object and may be omitted from the message. When included, it is a formatted text string that conforms to the description in Section 9. An object specifier is rejected by service providers that do not use owner or owned objects.

11.5.7 *Filter* — This is a optional list of qualifications to be applied to specifed attribute and may be omitted from the message. When included, the complete filter is formed by a logical AND of each attribute qualification in the list.

11.5.8 *Requested Attribute* — The final parameter in the GetAttr service gives the names of one or more attributes of interest. These are the attributes whose values shall be returned in the response, in the order requested.

11.5.9 *Settings* — In the SetAttr service, a list of one or more attribute name/value pairs is specified. This is the set of desired attribute values. SetAttr rejects any attempt to set a read-only attribute and returns information in Status, indicating the error and the attribute.

11.5.10 *ObjStatus* — This is a required parameter in the response message. It is a structure that consists of an acknowledge code and a list of status parameters. The acknowledge code is used to indicate errors that apply to the response as a whole. A status parameter is a structure consisting of a code indicating a specific error and accompanying text providing additional information. Text is often used to inform a person of the results of an operation.

11.5.11 Tables 4 and 5 define the parameters for the GetAttr and SetAttr services, respectively.

Table 4 GetAttr Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object.
ObjType	M	-	The type of the target object.
(List of) ObjID	C	-	The identifier of the target object. If present, identifiers are treated as a pre-filter of the form “ObjID = <identifier>”, where the individual identifiers are joined with logical OR’s.
(List of) AttrFilter	C	-	An attribute filter to be applied to the target object. If both AttrFilter and ObjID are omitted, attributes are requested for all instances of the target object type.
(List of) AttrName	C	-	The name of a desired attribute. If the name is “ObjType,” and if ObjType (above) is omitted, then the object type of all subordinate objects is requested. If omitted, then all public attributes of the target object are requested.
(List of) ObjSetting	-	M	Attributes that match the specified characteristics, per qualifying object instance. Setting value may not be valid if corresponding ObjStatus shows a failure.
ObjStatus	-	M	Information concerning the success or failure of the request.

Table 5 SetAttr Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object.
ObjType	M	-	The type of the target object.
(List of) ObjID	C	-	The identifier of the target object. If present, is treated as a primary filter of the form “ObjID = <identifier>”.
(List of) AttrSetting	M	-	An attribute’s name and desired value.
(List of) ObjSetting	-	M	The attributes’ resulting values. Requested setting value(s) may have not changed if corresponding ObjStatus shows a failure.
ObjStatus	-	M	Information concerning the success or failure of the request.

11.6 *GetType* — GetType is a service that is directed at object types rather than object instances. It is used to ask an owner object for the object types that it owns.

11.6.1 Figure 9 shows the message flow for the GetType service.

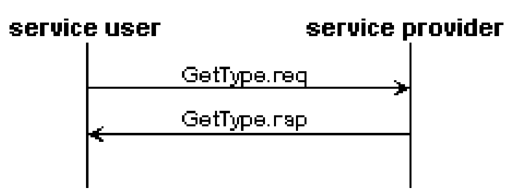

Figure 9
GetType Message Flow

11.6.2 Comments for the ObjSpec and ObjStatus parameters of GetAttr and SetAttr also apply to the parameters for the GetType service.

11.6.3 Table 6 defines the parameters for the GetType service.

Table 6 GetType Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object.
(List of)ObjType	-	M	The types of objects owned by the service provider.
ObjStatus	-	M	Information concerning the success or failure of the request.

11.7 *GetAttrName* — GetAttrName is a service that is directed at object types rather than object instances. It is used to ask for the names of the attributes of one or more objects owned by the service provider.

11.7.1 Figure 10 shows the message flow for the GetAttrName service.

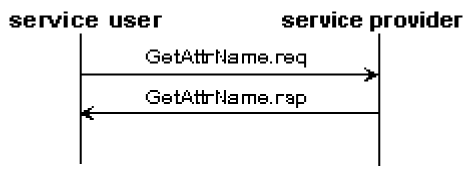

Figure 10
GetAttName Message Flow

11.7.2 Wild characters may be used in the object types requested.

11.7.3 Comments for the ObjSpec and ObjStatus parameters of GetAttr and SetAttr also apply to the parameters for the GetAttrName service.

11.7.4 Table 7 defines the parameters for the GetAttrName service.

Table 7 GetAttrName Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object.
(List of)ObjType	M	-	The type of the target object owned by the service provider. ObjType may use wild characters.
(List of)AttrName	-	M	The names of the attributes of each of the target object(s).
ObjStatus	-	M	Information concerning the success or failure of the request.

12 Additional Services

12.1 Additional services described in this section may have some restrictions when invoked. In some cases, services that are invoked may report a failure. For example: the owner of an object shall not delete the object during its lifecycle or while it is valid and required by another agent. Existence of an object may depend on preconditions, provided parameters, state of another object, corresponding operation, context of application, etc. Supplier shall document any restrictions or information regarding the validity of the additional services listed below.

12.1.1 This section defines the services required for additional operations defined in Section 10. These services are listed in Table 8.

Table 8 Additional Object Services

Message Service Name	*Type*	*Description*
Create	R	A request is made to create an object.
Delete	R	A request is made to delete an object.
Attach	R	A supervisor requests an object to attach itself to the supervisor.

AttachSetAttr	R	A supervisor requests to set one or more attributes of an attached object.
AttachSupervisedObject	R	A request is made to a supervisor to attach another object to the supervisor.
Detach	R	A supervisor requests an object to detach itself from the supervisor.
DetachSupervisedObject	R	A request is made to a supervisor to detach a specified attached object.
Reattach	R	A supervisor requests an object to reattach to itself to the new supervisor.
ObjectAction	R	A request for an object to perform an action.
ObjectActionCompletion	N	Notification that a delayed action has been completed, sucessfully or unsuccessfully.
GetServiceNames	R	A request to an object owner for a list of services supported by its owned objects.
GetServiceParameters	R	A request to an object for the service parameters supported for specified services.

12.2 *Object Services Parameter Dictionary* — Parameter definitions are provided in Section 11.1.

12.2.1 Table 9 defines the parameters used in services defined in Section 12, in addition to those parameters defined in Table 3.

Table 9 Additional Object Services Parameter Dictionary

Parameter	*Definition*	*Form*
AttachToken	Attach token provided by an object at the time it is attached or reattached.	Unsigned integer
TargetSpec	Object specifier of target object to attach or detach.	Formatted text for object specifier.

12.3 *Create* — The service user may request the service provider to create a new object and assign the value of one or more of its attributes. The request may be denied if an attempt is made to set attributes that are not allowed for that object type.

12.3.1 Parameters for Create are listed in Table 10.

Table 10 Create Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	M	In the request, the object specifier of agent providing the object create service. In the response, the object specifier of the new instance. NOTE: The values may be different in the request and the response. The parameter in the request may be “ ” (an empty string) if there is no object or the owner object is outside of the domain of the receiving entity. If the entity is the equipment itself rather than a component of equipment, the owner may be defined by “Equipment” even if no such object is defined.
ObjType	M	-	The object type to be created.
(list of) AttrSetting	C	C	Initial attribute settings. Conditions for inclusion of an attribute are object-specific in both request and response.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.4 *Delete* — The service user may request to delete an object.

12.4.1 Parameters for Delete are listed in Table 11.

Table 11 Delete Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	The object specifier of the object to be deleted.
(list of) AttrSetting	C	C	Conditions for inclusion of an attribute are object-specific both request and response.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.5 *Attach* — A service user may request an object to attach itself to the service user.

12.5.1 Parameters for Attach are listed in Table 12.

Table 12 Attach Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Specifier of server object to be attached.
AttachToken	-	M	Attach token. A value of zero shall be used if and only if the request to attach is denied.
(list of) AttrSetting	C	C	Settings for specific attributes. Object-dependent. Attributes in the list sent in the request and the response may be different.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.6 *AttachSetAttr* — A supervisor may request an attached object to set one or more attributes at any time while the object is attached.

12.6.1 Parameters for AttachSetAttr are listed in Table 13.

Table 13 AttachSetAttr Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Specifier of server object to be attached.
AttachToken	M	-	Attach token.
(list of) AttrSetting	C	C	Settings for specific attributes. Object-dependent. Attributes in the list sent in the request and the response may be different.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.7 *Detach* — The supervisor of an attached object may request the object to detach itself.

12.7.1 Parameters for Detach are listed in Table 14.

Table 14 Detach Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	The specifier of the attached object.
AttachToken	M	-	Attach token.
(list of) AttrSetting	C	C	Attribute settings. Object-dependent. Attributes in the list sent in the request and the response may be different.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.8 *Reattach* — An object may request an object attached to another supervisor to reattach to itself to the service user as its new supervisor.

12.8.1 Parameters for Reattach are listed in Table 15.

Table 15 Reattach Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Specifier of object to reattach.
AttachToken	-	M	Attach token. A value of zero shall be used if and only if the request to reattach is denied.
(list of) AttrSetting	C	C	Specific attribute settings. Object-dependent. Attributes in the list sent in the request and the response may be different.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.9 *AttachSupervisedObject* — A service user may request a supervisor to attach a specified object.

12.9.1 Parameters for AttachSupervisedObject are listed in Table 16.

Table 16 AttachSupervisedObject Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	The object specifier for the supervisor.
TargetSpec	M	-	The object specifier of the object to attach.
(list of) AttrSetting	C	C	Attribute settings. Object-dependent. May be omitted. Attributes in the list sent in the request and the response may be different.
ObjStatus	-	M	Information concerning the result of the requested operation.

12.10 *DetachSupervisedObject* — A service user may request a supervisor to detach a specified attached object.

12.10.1 Parameters for DetachSupervisedObject are listed in Table 17.

Table 17 DetachSupervisedObject Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	The object specifier of the supervisor.
TargetSpec	M	-	The object specifier of the object to be detached.
(list of) AttrSetting	C	C	Attribute settings. Object-dependent. May be omitted. Attributes in the list sent in the request and the response may be different.
ObjStatus	reserved	reserved	Information concerning the result of the requested operation.

12.11 *ObjectAction* — A service user may request a specific action to be performed by, or on, a particular object. The object specifier represents either the target object as its owner, depending upon the object and action.

12.11.1 Completion, either normal (successful) or abnormal, may be indicated in either of two ways. If the action can be completed in a very short time, then it should be completed before a response to the request is sent. If the action takes more time than would be normal for the response, or if the action must wait for one or more conditions to be fullfilled, then a response to the request indicating the action will be performed later and the notification sent of its completion. See Section 12.12 below.

12.11.2 Figure 11 illustrates the first case, where the action is completed before the response is sent. The value of ObjectActionStaus should be set to any value other than “Action will be performed and notification sent later”.

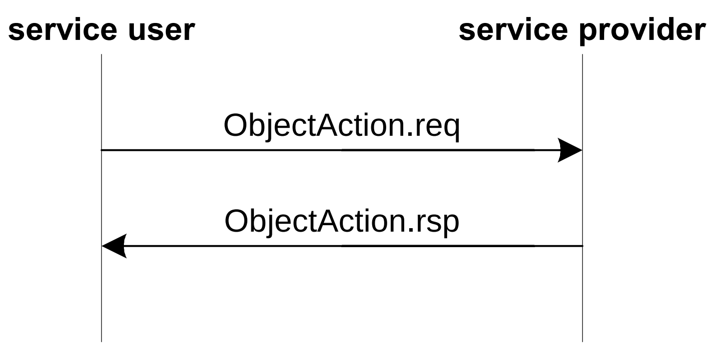

Figure 11
ObjectAction Request and Response

12.11.3 It is recommended that OperationID be always set to a unique non-zero value. However, if a value of zero is used, then the host should not send additional request until informed of the results of the outstanding request. Otherwise it may be ambiguous to which request an ObjectActionCompletion notification pertains. The definition of the target object type must include specification of the specific actions that it supports, together with the arguments that are required and the arguments that are optional for each action.

Table 18 ObjectAction Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
OperationID	M	M(=)	Operation identifier. Used where the service user may send multiple requests to link subsequent events to the original requests. May be zero otherwise.
ObjSpec	C	-	The object specifier of the target object or owner of the target object.
ObjectAction	M	-	Specific action requested.
(list of) ServiceParameter	C	C	A list of name/value pair arguments providing additional information about the request.
ObjectActionStatus	-	M	Information concerning the result of the requested action.
(list of) ObjectActionResult	-	C	List of return parameters, as name/value pairs, concerning the result.

12.12 *ObjectActionCompletion Notification* — This notification is sent to the requestor of an earlier action when the completion of that action occurred after the response to the request was sent.

12.12.1 Figure 12 illustrates the scenario where the notification message is sent. The value of ObjectActionStatus should be set to “Action will be performed and notification sent later”.

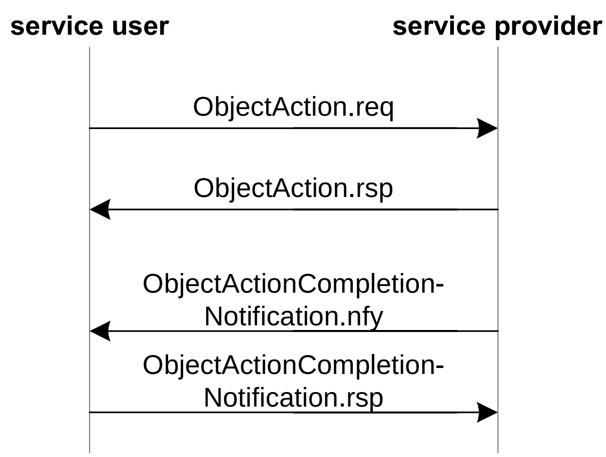

Figure 12
ObjectAction Request, Response, and Notification

Table 19 ObjectActionCompletion Notification

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
OperationID	M	-	Operation identifier. Set to the same value as in the original request.
(list of) ServiceParameter	M	-	A list of name/value pair arguments providing information about the status of the completion.
(list of) ObjectActionResult	C	-	List of return parameters, as name/value pairs, concerning the result.
ObjectActionReportStatus	-	M	Indicates whether the report has been received with no errors.

12.13 *GetServiceNames* — A service user may ask an object owner for a list of the services supported by its owned objects.

12.14 The definition of the target object type must include specification of the specific actions that it supports, together with the arguments that are required and the arguments that are optional for each action.

Table 20 GetServiceNames Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier of the owner object.
(list of) ObjType	M	M	A list of object type values
ObjStatus	-	M	Information concerning the result of the requested action.
(list of) ObjServiceList	-	M	List of structures of the form ObjType, (list of) service names.

12.15 *GetServiceParameters* — This message may be sent to an object to determine the service parameters that are used by that object for a set of different services that it supports.

Table 21 GetServiceParameters

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier of the owner object.
ObjType	M	-	The type of object referenced.
(list of) ServiceName	M	-	A list of service names.
ObjStatus	-	M	Information concerning the result of the requested action.
(list of) ServiceParameterDef	-	C	List of structures that contain a service name with a list of parameter names.

13 Applications

13.1 This section provides examples of applications of object services.

13.2 *Get All of an Object's Attributes* — In the most straight-forward case, GetAttr is used to get all of the current attribute values of a single target object known to the provider of the GetAttr service. The object specifier is omitted, and the object type is set to the type of the target object. To get all of the object’s attributes, both the attribute filter and the names of requested attributes are also omitted.

13.3 *Determine All Objects of a Specific Type and with Specific Characteristics* — To determine subordinate objects with specific characteristics, such as of type “Module” with an identifier *ObjID* starting with “ABC”, set object type to “Module”. In the attribute filter, set the attribute name to “ObjID”, set the attribute value to “ABC*”, and set the qualifying relationship to “is equal to” (or omit it).

13.4 *Determine Specific Attributes of a Specific Object Instance* — To determine the current value of certain attributes of a specific object, set the object type appropriately. Either set the list of ObjID to a list containing the one identifier of the target instance, or alternatively, in the attribute filter, set the attribute name to “ObjID”, set the attribute value to the identifier, and set the qualifying relationship to “is equal to” (or omit it).

13.5 *Determine Types of Subordinate Objects* — To determine all object types that are owned by another object, the GetType service is used with the single parameter of the object specifier of the owner. The service provider returns an error of “Unknown object type” if it has no types of owned objects.

13.6 *Determine Names of Attributes of Subordinate Objects* — To determine the names of the attributes of specific objects owned by the service provider, the GetAttrName service is used with two parameters: the object specifier of the owner and a list of the types of the target objects. The service provided returns an error of “Unknown object type” if it has no types of owned objects.

14 Requirements for Compliance

14.1 Object Services are common to all service resources that define public objects with operations for getting (reading) and setting (writing) attribute values and for getting object types and attribute names for objects. Object services provide common definitions for public objects and object services that may be incorporated into these service resources, thereby avoiding unnecessary duplication.

14.2 *Fundamental Requirements* — All objects compliant to any part of OSS shall be subtypes of the top object. That is, they shall inherit (provide) the *ObjType* and *ObjID* attributes as described in Section 8.2.

14.2.1 They shall provide documentation of their public attributes in the form of an Object Attribute Definition table as described in Section 5.3.

14.2.2 They shall also provide the services GetAttr and SetAttr as defined in Section 11.4. Support for an owner's object specifier and filter are not required for fundamental compliance with OSS. If the service user provides parameters for scope or filter in its request, they may be ignored by the service provider. However, they shall not cause errors in the response due to their presence.

14.3 *Additional Capabilities*

14.3.1 *Filters* — Support for attribute filters in GetAttr and SetAttr requests is an optional capability.

14.3.2 *Owner Objects* — All owner objects (aggregates, containers, and supervisors) shall support both scope and filters for the GetAttr and SetAttr services, as defined in Sections 9.2, 11.1, and 11.2.

14.3.2.1 In addition, they shall provide the service GetType as defined in Section 11.5, with support for wild characters in the specification of object types.

14.3.3 *Multiple Inheritance Hierarchy* — Inheriting objects shall identify inherited objects with an inheritance expression in the object specifier.

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI E39 and was approved by full letter ballot procedures on March 16 and April 21, 2000 by the Japanese Regional Standards Committee.

A1-1 Overview of Object Terminology

A1-1.1 This section provides an introduction to the basic terminology for object models.

A1-1.2 A *model* is an abstraction of a problem, a real-world phenomena, things, etc. for the purpose of understanding it. A model typically is a simplification that omits nonessential details. *Examples: architectural scale models, behavioral state models.*

A1-1.3 An *object* is an entity (concept, abstraction, or “real world” thing) with a particular behavior and with associated properties (information, or attributes). An *object type* (class) refers to a group of objects that have common (1) properties (but not specific values), (2) behavior, (3) relationships with other objects, and (4) semantics (public interfaces). The term “object” may be used either to refer to a type of object or to a particular instance of an object type.[8] The notation used for diagrams of objects used in this document is described in Section A1-2.

A1-1.4 An *object model* is a static graphic model of objects to show structure — the identity of objects, their attributes and operations, and their relationships with one another.

A1-1.5 An *instance* of an object is an instantiation of an object type. For example, a specific installation of equipment is an instance of the object type “Equipment.”

A1-1.6 Objects have items of associated information called *attributes*. For example, for an object “Equipment,” attributes of interest include the manufacturer, model, serial number, and a logical user-assigned name (nickname). Attributes used to uniquely identify a particular instance of an object type is called an identifier. An object may have more than one *identifier*. Also, a set of more than one attribute may be used as an identifier. In the example of “Equipment,” name could be used as an identifier, and the combination of manufacturer and serial number also could be an identifier.

A1-1.7 Objects have *operations* that may be applied to or by an object type. Operations are functions or transformations that are either performed by, or on, an object. Operations of interest to Object Services are “get (read) attributes,” “set (write) attributes,” and “get type.” A *service* provides a *service user* with an interface to the functionality of the operation.

A1-1.8 A high-level model may show a particular type of object with certain operations, while a more detailed model shows that a second type of object actually performs one or more of the operations on the first object. As an example, a model might show a process program object with the operation “delete,” to show that the “delete” operation is inherently associated with the process program. A more detailed model might show that a “process program manager” actually performs the operation of deleting a process program.

A1-1.9 A *method* is an implementation of an operation (e.g., the software code that performs the operation).

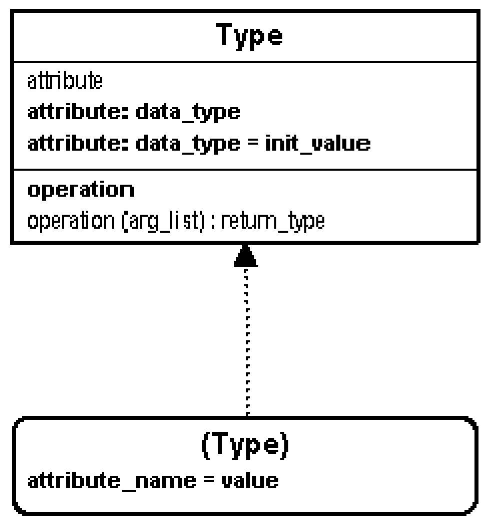

Figure A1-1
Object Type and Instance

8 The term “object” is used by some authors to only refer to instances and by other authors as a synonym for object type.

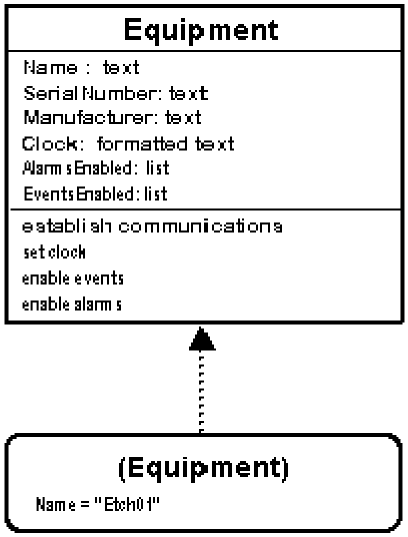

Figure A1-2
Example of Object Type and Instance

A1-2 Object Modeling Technique (OMT) Notation

A1-2.1 The material contained in this section is provided as a reference for auxiliary information.

A1-2.1.1 Object Modeling Technique (OMT) is a graphical notation for models of objects that is useful for analyzing a wide variety of problems, in all phases of software design and development, and in preparing documentation. OMT was developed by Rumbaugh, Blaha, et al., in *Object Modeling and Design*, Prentice Hall, Englewood Cliffs, NJ, ©1991. OMT has been adopted by different standards to describe requirements in terms of objects and relationships between objects. The purpose of this document is to provide a description of OMT notation as a reference for such SEMI standards and other SEMI documents.

A1-2.2 *Basic Notation* — Figure A1-1 illustrates notation for object type, showing object type, object attributes, object operations, object instance, and the relationship between an object type and instance. Figure A1-2 provides an example.

A1-2.2.1 Object *types* in OMT are shown as rectangles. The rectangle may be further subdivided into two or three parts. The object type always appears at the top. Object *attributes* are shown in a second part of the rectangle. *Operations* are shown in a third part of the rectangle. High-level models often omit the operations section and sometimes omit the attributes section.

A1-2.2.2 The *name* of an attribute may be followed by additional details, such as data type and initial value.

A1-2.2.3 *Instances* of objects are shown as rounded rectangles. The *instantiation* relationship is shown by a dotted arrow from an instance of an object type to the type.

A1-2-2.4 The example for an object type "Equipment" is shown in Figure A1-2; here "Etch01" is a specific real-world installation of type "Equipment."

A1-2.3 *Associations* — An association describes a set of potential bi-directional relationships between instances of objects. An association uses a formal structure and semantics.

A1-2.3.1 An association shows a specific multiplicity at both ends of the relationship. For example, a single factory manufacturing system may be associated with many equipment (one-to-many). Possible multiplicities of association types are shown in Figure A1-3.

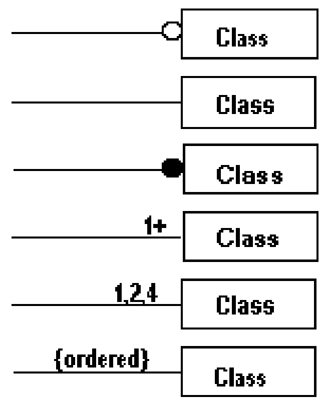

Figure A1-3
Multiplicities of Associations

A1-2.3.2 Figure A1-4 shows an example of a one-to-one relationship. The name of the association (using a verb) appears above the line connecting a pair of objects and describes the relationship that the object to the left (or above) has to the object to the right (or below).

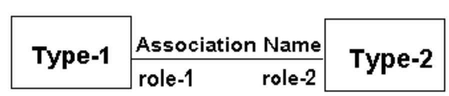

Figure A1-4
Association of Objects

A1-2.3.3 The name of the role of each object within the relationship may be placed beneath the line and near that object. Role names are nouns. In the example above, the roles might be "supervisor" and "subordinate." Role names are optional.

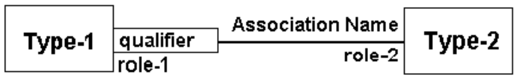

Figure A1-5
Qualified Association

A1-2.3.4 A *qualified association*, shown in Figure A1-5, uses a *qualifier* to reference an object. *Qualifiers* may be shown to specify the identifier used by one object to associate with instances of the other object. If Type-1 object is "Factory Host" and Type-2 object is "Equipment," a user-assigned "name" attribute may be used as a qualifier for the equipment.

A1-2.3.5 Figure A1-6 illustrates a *link object*, where link attributes are placed in an object box that is attached to the association with a loop. A *link object* may be used to show attributes that are dependent on the association between instances of one object type to instances of another type.

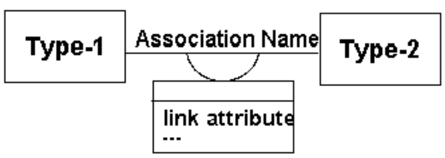

Figure A1-6
Link Object

A1-2.3.6 Figure A1-7 gives an example of a link object for the association "Authorized On" between an "Authorized User" and "Equipment."

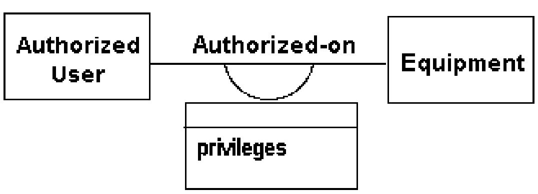

Figure A1-7
Example of a Link Object

A1-3 Generalization and Inheritance

A1-3.1 Figure A1-8 shows the concept of *generalization*. Generalization categorizes a set of object types and allows the abstraction of their common features into a supertype, with refinements of the *supertype* shown as *subtypes*. The subtype may be thought of as a specialization of the supertype. For example, "vehicle" is a supertype with many subtypes, including "aircraft," "automobile, "cart," and "robot."

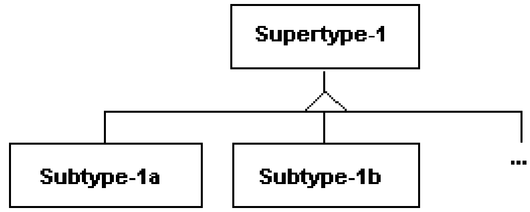

Figure A1-8
Non-Overlapping Subtypes

A1-3.1.1 An instance of a subtype is also an instance of its supertype. Attributes and operations of the supertype are inherited by all the subtypes. That is, the subtype has all of the same attributes and operations of the supertype, and in addition it adds attributes and operations of its own.

A1-3.1.2 The OMT notation for the generalization (supertype/subtype) relationship is shown by a solid triangle. White triangles indicate that the subtypes are *non-overlapping*; an instance of one subtype may not be an instance of another subtype.

A1-3.1.3 The method for a subtype of an object might be different from that of the supertype or from a different subtype, perhaps due to more specialized knowledge that allowed a more efficient implementation for the subtype. As an example, a Geometrical Figure object type might have the operation "draw." The methods for subtypes of "circle" and "rectangle" would differ, however.

A1-3.1.4 Figure A1-10 gives an example of an "agent" as a generalization of various types of active entities that might be found in a factory, and "equipment" as a generalization of specific kinds of equipment.

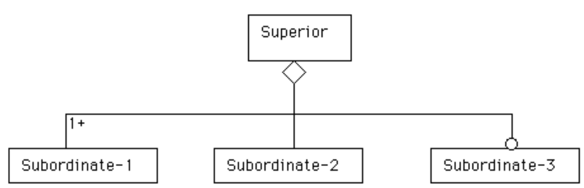

Figure A1-9
Aggregation with Two Component Types

A1-3.2 *Object Composition and Containment* — Figures A1-9 and A1-10 illustrate the diamond notation used to show aggregation. An aggregation object is also referred to as an assembly in object-oriented literature.

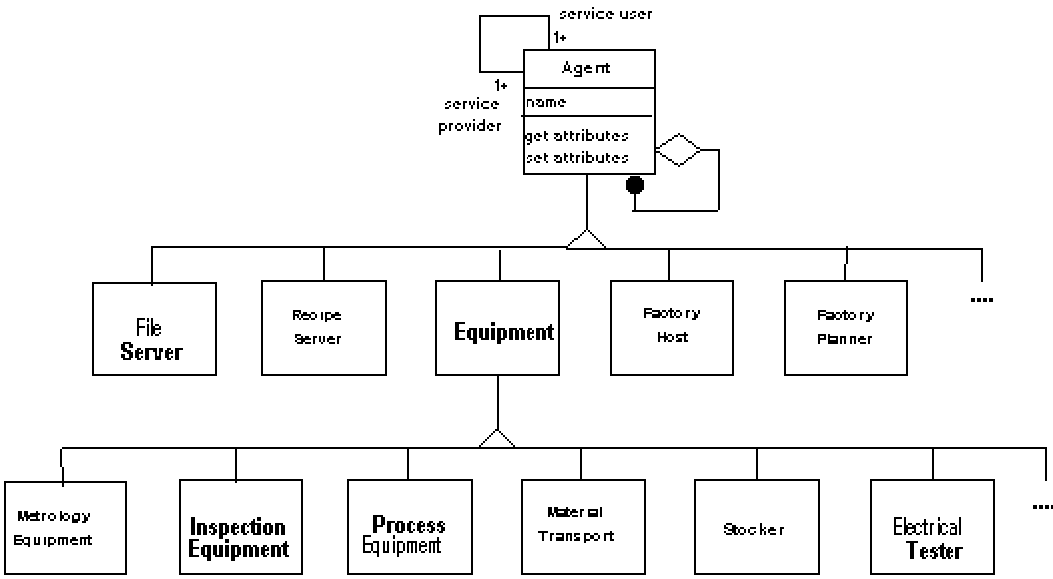

Figure A1-10
An Example of Generalization

A1-3.2.1 An aggregation object is composed of other objects called the *components* of the aggregation. Components may be of the same type as the aggregation (illustrated in Figure A1-10), or they may be of one or more different types.

A1-3.2.2 In Figure A1-9, the “Superior” object type is composed of one or more objects of type “Subordinate-1,” of exactly one component of object type “Subordinate-2,” and of zero or one objects of type “Subordinate-3.”

A1-3.2.3 In addition, an aggregate also may be optionally composed of other objects of the same type, as Figure A1-10 illustrates. The “agent” in this figure is a very general supertype of a factory system. Additional subtypes of agents, not shown in the figure, could include cells, clusters, and cluster modules. Cells, with equipment as components, and clusters, with modules as components, are examples of types of agents that are aggregates composed of other subtypes of agent.

SEMI E39.1-1101
SECS-II PROTOCOL FOR OBJECT SERVICES STANDARD (OSS)

This standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995; previously published December 1996.

1 Purpose

1.1 This document maps the services and data of the parent document to SECS-II streams and functions and data definitions.

2 Scope

2.1 This document applies to all implementations of Object Services that use the SECS-II message protocol (SEMI E5).

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Applicable Documents

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

4 Mapping of Object Services

4.1 Table 1 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations for the object services defined in OSS.

Table 1 Services Mapping Table

Message Name	*Stream, Function*	*SECS-II Name*
GetAttr.req	S14,F1	GetAttr Request
GetAttr.rsp	S14,F2	GetAttr Data
SetAttr.req	S14,F3	SetAttr Request
SetAttr.rsp	S14,F4	SetAttr Data
GetType.req	S14,F5	GetType Request
GetType.rsp	S14,F6	GetType Data
GetAttrName.req	S14,F7	GetAttrName Request
GetAttrName.rsp	S14,F8	GetAttrName Data
Create.req	S14,F9	Create Object Request
Create.rsp	S14,F10	Create Object Acknowledge
Delete.req	S14,F11	Delete Object Request
Delete.rsp	S14,F12	Delete Object Acknowledge
Attach.req	S14,F13	Object Attach Request
Attach.rsp	S14,F14	Object Attach Acknowledge
AttachSetAttr.req	S14,F15	Attached Object Action Request
AttachSetAttr.rsp	S14,F16	Attached Object Action Acknowledge
AttachSupervisedObject.req	S14,F17	Supervised Object Action Request
AttachSupervisedObject.rsp	S14,F18	Supervised Object Action Acknowledge
Detach.req	S14,F15	Attached Object Action Request
Detach.rsp	S14,F16	Attached Object Action Acknowledge
DetachSupervisedObject.req	S14,F17	Supervised Object Action Request
DetachSupervisedObject.rsp	S14,F18	Supervised Object Action Acknowledge
Reattach.req	S14,F13	Object Attach Request
Reattach.rsp	S14,F14	Object Attach Acknowledge

Message Name	*Stream, Function*	*SECS-II Name*
GetServiceNames.req	S14,F25	Get Service Name Request
GetServiceNames.rsp	S14,F26	Get Service Name Data
GetServiceParameters.req	S14,F27	Get Serivce Parameter Name Request
GetServiceParameters.rsp	S14,F28	Get Serivce Parameter Name Data
ObjectAction.req	S14,F19	Generic Service Request
ObjectAction.rsp	S14,F20	Generic Service Acknowledge
ObjectActionCompletion.nfy	S14,F21	Generic Service Completion Information
ObjectActionCompletion.rsp	S14,F22	Generic Service Completion Acknowledge

5 Service Parameter Mapping

5.1 Table 2 shows the mapping between message parameters defined by OSS and data items defined by SECS-II. For parameters specified in the definitions of an OSS service, either the parameters themselves, or individual elements of complex parameters, map to a specific data item.

Table 2 Service Parameters Item Mapping Table

Parameter Name	*SECS-II Data Item*
AttachToken	OBJTOKEN
AttrData	ATTRVAL
AttrName	ATTRID
AttrRein	ATTRRELN
ErrCode	ERRCODE
ErrText	ERRTEXT
ObjAck	OBJACK
ObjectAction	SVCNAME
ObjectActionReportStatus	DATAACK
ObjectActionStatus	SVCACK
ObjID	OBJID
ObjSpec	OBJSPEC
ObjType	OBJTYPE
OperationID	OPID
ServiceParameter	L,2 <SPNAME> <SPVAL>
ServiceParameterName	SPNAME
ServiceParameterValue	SPVAL
TargetSpec	TARGETSPEC

5.2 *SECS-II Data Items Without Corresponding SEMI E94 Parameters*

5.2.1 Table 3 contains the SECS-II data items that do not correspond to SEMI E39's service parameters.

Table 3 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
Used to satisfy SECS-II conventions for linking a multi-block inquiry with a subsequent multi-block message. Neither required nor specified by OSS.	DATAID
Used to inform receiver of total message length size for SECS-II multi-block conventions. Neither required nor specified by SEMI E39.	DATALENGTH
Used to satisfy SECS-II multi-block requirements. Neither required nor specified by OSS.	GRANT

6 Data Item Format Restrictions

ATTRID Format: 20

The ASCII version of ATTRID is restricted to the characters from 20_{16} through $7E_{16}$, excluding the following characters: the "greater than" symbol ">", the colon ":", the question mark "?", the asterisk "*", and the tilde "~". The space character (20_{16}) may not be used as the first or last character. Maximum length is 40 characters.

OBJTYPE Format: 20

The ASCII version of OBJTYPE is restricted to the characters from 20_{16} through $7E_{16}$, excluding the following characters: the "greater than" symbol ">", the colon ":", the question mark "?", the asterisk "*", and the tilde "~". The space character (20_{16}) may not be used as the first or last character. Maximum length is 40 characters.

OBJID Format: 20

The ASCII version of OBJID is restriced to the characters from 20_{16} through $7E_{16}$, excluding the following characters: the "greater than" symbol ">", the colon ":", the question mark "?", the asterisk "*", and the tilde "~". The space character (20_{16}) may not be used as the first or last characer. Maximum length is 80 characters.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E40-0702
STANDARD FOR PROCESSING MANAGEMENT

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1995; previously published November 2001.

1 Purpose

1.1 Automated management and command of material processing in equipment is a crucial aspect enabling factory automation. This standard addresses the communications needs within the semiconductor manufacturing environment with respect to the processing of material in an equipment.

1.2 This standard specifies the application of the appropriate processing to specified material received at the processing agent. It describes the concepts of material processing, the behavior of the equipment in relation to processing, and the messaging services which are needed to accomplish the task.

1.3 The communications services defined here enable standards-based interoperability of independent systems. They allow application software to be developed that can assume the existence of these services and allow software products to be developed which offer them.

1.4 Implementation of automated processing management will help eliminate misprocessing of material. The adoption of the standards described will greatly reduce the effort required to integrate compliant equipment components and reduce time to set up for processing. Compliance requires a minimal but specific set of standard services.

2 Scope

2.1 The scope of this standard is automated material processing based on discrete processing jobs. It provides the functionality required for process management for modules within a cluster tool. It may be applied to sub-systems of other multi-resource equipment, as well as to host control of many types of equipment.

2.2 This standard supports individual management of jobs for identical processing of material within a group and concurrent processing of independent groups. Where material contains other material (such as carriers containing wafers), processing may be specified in terms of either material type.

2.3 A simple tuning mechanism is provided for limited feedforward and feedback control between process steps. A method is defined for taking advantage of recipe variable parameters. This is not expected to satisfy all closed loop control requirements. Other mechanisms are anticipated with greater flexibility for late tuning and handling complex data.

2.4 This standard does not provide services for receiving material for processing, or disposing of it after processing is complete. Automation of material transfer is assumed to be provided through other services, such as those defined in applicable SEMI standards.

2.5 This standard presents a solution from the concepts and behavior down to the messaging services. It does not define the messaging protocol.

2.6 A messaging service includes the identification that a message shall be exchanged and a definition of the data which is contained in that message. It does not include information on the structure of the message, how the data is represented within the message, or how the message is exchanged. This additional information is contained within the message protocol.

2.7 The defined services may be applied to multiple protocols. Information on the mapping of processing management services to special protocols (e.g., SECS-II) are added as adjunct standards.

2.8 The services assume a communications environment in which a reliable connection has been established between the user of the services and the provider of the services. Establishing, maintaining, releasing a connection, and handling communication failures are beyond the scope of this standard.

2.9 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E53 — Event Reporting

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 The following definitions are arranged in alphabetical order. Some definitions use terms defined elsewhere within this section. No references beyond this section should be necessary for a basic understanding of these terms.

4.2 *Definitions*

4.2.1 *agent* — an intelligent system within a factory that provides one or more service resources and uses the services of other agents. A generalization of host, equipment, cell, cluster, cluster module, station controller, and work station. Agents are associated with a physical system or a collection of physical systems, including computer platforms.

4.2.2 *form* — type of data representing information contained in an object attribute or service message parameter.

4.2.3 *fundamental requirements* — the requirements for information and behavior that must be satisfied for compliance to a standard. Fundamental requirements apply to specific areas of application, objects, or services.

4.2.4 *post-conditioning* — activities performed by the processing resource after departure of the material being processed but related to the processing of that material (e.g., cleanup).

4.2.5 *pre-conditioning* — activities performed by the processing resource before arrival of the material being processed but related to the processing of that material.

4.2.6 *processing agent* — an intelligent system within a factory which is independently capable of providing manufacturing value added to material.

4.2.7 *processing resource* — an entity within a processing agent which provides the manufacturing value added to material.

4.2.8 *process job* — a material processing job for a processing resource specifying and tracking the processing to be applied to the material.

4.2.9 *recipe* — the pre-planned and reusable portion of the set of instructions, settings, and parameters under control of a processing resource that determines the processing environment seen by the material. Recipes may be subject to change between runs or processing cycles.

4.2.10 *recipe executor* — a component of a module that stores and executes recipes.

4.2.11 *recipe namespace* — a logical management domain with the responsibility for the storage and management of recipes. It ensures the uniqueness of recipe identifiers and provides services pertaining to recipes stored within that domain.

4.2.12 *service* — the set of messages and definition of the behavior of a service-provider that enables remote access to a particular functionality.

4.2.13 *service-provider* — the software control entity that is the provider of a particular functionality which may be accessible remotely.

4.2.14 *service-user* — the software control entity that is the user of any of the related services.

4.2.15 *supervisor* — an entity or entities having supervisory control responsibilities for one or more processing resource. It is the service-user of the processing management services.

4.2.16 *tuning* — specification of information which supplements the pre-defined recipe used to achieve the particular process goals.

4.3 *Data Type*

4.3.1 *boolean* — may take on one of two possible values, equating to TRUE or FALSE.

4.3.2 *enumerated* — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.3.3 *form* — type of data: positive integer, unsigned integer, integer, enumerated, boolean, text, formatted text, structure, list, ordered list.

4.3.4 *formatted text* — a text string with an imposed format. This could be by position, by use of special characters, or both.

4.3.5 *integer* — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

4.3.6 *list* — a set of one or more items that are all of the same form (one of the above forms).

4.3.7 *ordered list* — a list for which the order in which items appear is significant.

4.3.8 *positive integer* — may take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.3.9 *structure* — a complex structure consisting of a specific set of items, of possibly mixed data types, in a specified arrangement.

4.3.10 *text* — a text string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.3.11 *unsigned integer* — may take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

5 Conventions

5.1 *Harel State Model* — This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an appendix of SEMI E30. The formal definition of this notation is presented in *Science of Computer Programming 8*, “Statecharts: A Visual Formalism for Complex Systems,” by D. Harel, 1987.

5.1.1 The Harel notation does not include the concept of “creation” and “deletion” of state models to represent transient entities. The “job” described in this document is such an entity, where each new job created uses a copy of the same state model. In this document, an oval is used to denote the creation of an entity and also the deletion of that entity.

5.1.2 Transition tables are provided in conjunction with the state diagrams to describe explicitly the nature of each state transition. A transition contains columns for Transition #, Current State, Trigger, New State, Action(s). The “trigger” (column 3) for the transition occurs while in the “current” state. The “actions” (column 5) include a combination of (1) actions taken upon exit of the current state, (2) actions taken upon entry of the new state, and (3) actions taken which are most closely associated with the transition. No differentiation is made.

5.1.3 The state models included in this standard are a requirement for Processing Management compliance. A state model consists of a state model diagram, state definitions, and a state transition table. When using SEMI E30, E53 or similar style collection events, all state transitions in this standard, unless otherwise specified, shall correspond to collection events.

5.1.4 A state model represents the host’s view of the equipment, and does not necessarily describe the internal equipment operation. When using collection events, all Processing Management state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the Processing Management state models for transition to another state. In the case, the equipment makes the required transition without any additional actions in this situation.

5.2 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute Name	*Definition*	*Access*	*Requirement*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	(see below)

5.2.1 The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that service-users have to the attribute.

5.2.2 A ‘Y’ or ‘N’ in the requirement (Rqmt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

5.2.3 The Form column is used to indicate the format of the attribute. (See Section 4.1 for definitions.)

5.3 *Service Message Representation*

5.3.1 *Service Resource Definition* — A service resource definition table defines the specific set of messages for a given service group, as shown in the following table:

Message Service Name	*Type*	*Description*
Message Name	N or R	The intent of the service.

5.3.1.1 Type can be either N = Notification or R = Request.

5.3.1.2 Notification type messages are initiated by the service provider, and the provider does not expect to get a response from the consumer/subscriber.

5.3.1.3 Request messages are initiated by a service consumer or subscriber. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

5.3.2 *Service Parameter Dictionary* — A service parameter dictionary table defines the parameters used in a service, as shown in the following table:

Parameter	*Form*	*Description*
Parameter X	Data Type	A parameter called X is B in A.

5.3.2.1 A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding primitive.

5.3.2.2 The Form column is used to indicate the type of data contained in a parameter. (See Section 4.2 for definitions.)

5.3.2.3 The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the values it can take on, and any inter-relationships with other parameters.

5.3.2.4 To prevent the definition of numerous parameters named "XxxList," this document adopts the convention of referring to the list as "(List of) Xxx." In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

5.3.3 *Service Message Definition* — A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Cnf*	*Description*
Parameter X	(see below)	(see below)	A description of the service.

5.3.3.1 The columns labeled Req/Ind and Rsp/Cnf link the parameters to the direction of the message. The message sent by the initiator is called the "Request." The receiver terms this message the "Indication" or the request. The receiver may then send a "Response," which the original sender terms the "Confirmation."

5.3.3.2 The following codes appear in the Req/Ind and Rsp/Cnf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

M	**Mandatory Parameter** — Must be given a valid value.
C	**Conditional Parameter** — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.
U	**User-Defined Parameter**
-	The parameter is not used.
=	(for response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

6 Overview

6.1 Processing management is concerned with the processing of material by a processing resource. Its principle function is to ensure that material delivered to the processing resource is processed with the correct recipe. It defines the services needed by a supervisor (service-user) to initiate and track processing of a particular material. It also defines commands which affect the processing operation.

6.1.1 The processing resource is the entity which adds manufacturing value to the material. It may take several forms, including the processing element of a cluster tool process module or the entity managing processing for a complete stand-alone equipment. The processing agent is considered to be the provider of the processing services.

6.1.2 Process management allows for pre-conditioning before material arrival and post-conditioning after material departure. A simple tuning mechanism provides support for limited feedforward and feedback control. The tuning, applied at process initiation, sets recipe variable parameters.

6.1.3 The services are fully defined in terms of the functionality provided by the processing agent (service-provider) and, as such, do not dictate the architecture of the supervisor (service-user).

6.1.4 This standard describes the concepts and processing model on which the communications are based, followed by the detailed behavioral model used. It then describes the standard object attributes and message services in detail.

6.2 *Compliance* — Compliance to this standard includes adherence to all stated requirements in this document where implemented. Standard services are to be used where related functionality is required. This includes defined message services and state models.

6.2.1 Some capabilities are not required to be supported for compliance, such as queuing, multiple concurrent jobs, material groups, manual start, pause/ resume, and tuning. Required capabilities are indicated throughout the document and are also listed in the Fundamental Requirements section.

6.2.2 A processing agent shall provide the fundamental requirements, plus the set of optional services, appropriate to achieve effective processing management for the particular hardware architecture and automated processing requirements.

7 Concepts

7.1 *Material Processing Model* — Processing management ensures that the appropriate processing is applied to a particular material by a processing resource through the definition of a process job. The process job provides a widely applicable supervisory control capability for automated processing of material in equipment, irrespective of the particular process being used.

7.1.1 This standard assumes that, given the material and the recipe specification, the processing resource is capable of independently achieving the required processing objectives.

7.1.2 Processing management does not provide services for material movement, but the service-provider does need to coordinate its activities with regard to the receiving and sending of material, thereby maintaining system integrity.

7.2 *Process Job* — The process job is a dynamic object specified by the process supervisor (service-user) to effect material processing by the processing resource. The high-level job contains all the information required by the processing resource to achieve processing of the material, once it arrives, without further intervention by the supervisor.

7.2.1 The process job encompasses up to four sequential phases:

- processing resource pre-conditioning before material arrival,
- material and processing resource preparation for processing,
- material processing, and
- processing resource post-conditioning after material departure.

7.2.2 The material processing phase is the only phase in which the material is altered and is the only required phase.

7.2.3 This standard specifies services for the creation, control (pausing, aborting, etc.) and tracking of the process job. It does not define the low-level control of processing since this is application-dependent. The processing resource performing a process job is responsible for doing whatever is appropriate to achieve its processing objectives, as specified by the recipe and tuning parameters.

7.2.4 The material specified in a process job may be the actual single material elements to be processed or a container, such as in the case of a cassette of wafers.

7.2.5 The process job lifecycle may extend beyond the active processing of the material. It may exist from before material arrival, through setup and processing, and until after material departure. This allows for material processing-related pre-conditioning of the processing resource before the material is received and for processing resource post-conditioning (e.g., cleanup) after material is sent. Pre-conditioning and post-conditioning support is not a fundamental requirement.

7.2.6 The processing resource may provide process job queuing in order to offer flexibility in systems where work is pre-scheduled or the order of material arrival is unknown. Queuing is the acceptance of multiple process jobs in advance of performing the processing activities. Queuing is generally needed to support more complex systems requiring concurrent and consecutive jobs (see below). The jobs are listed in the queue in the order created. Execution order may be significant, such as consecutive jobs on the same material. Queuing is not a fundamental requirement.

7.3 *Relation to Material Movement* — Processing Management does not provide services for receiving material into the processing agent domain for processing or sending the material away after processing is complete.

7.3.1 Processing depends on the presence of the material, and material departure depends on process completion. There is also an interdependency requiring synchronization with material movement if processing resource pre-conditioning and post-conditioning are applied. The equipment is responsible for maintaining integrity between material transfer and processing.

7.3.2 Material movement management is outside the scope of this standard but may be achieved using applicable SEMI standards.

7.4 *Processing Description* — The description of the processing to be applied by the Process Job is crucial. The description may be supplied in the form of a Process Recipe (see SEMI E42) or a Process Program (see SEMI E30). This specification will define messages referencing only Process Recipes. Where there are special considerations for using Process Programs instead of a Process Recipe, they will be noted.

7.4.1 The process job includes a processing description (a recipe or process program) identifier that shall be unique within the domain of the processing agent. The type and content of the processing description must be appropriate for the processing resource and the type of material.

7.4.2 Creation and management of recipes and process programs is outside the scope of this standard.

7.5 *Process Tuning* — Feedforward and feedback control between process steps is becoming increasingly important for process tuning in stabilizing processes, such as those which lack in-situ metrology, and demand increasing yields (or performance). The process tuning requirements differ considerably with application, and there is little consensus on any particular method. It is not the intention of this standard to provide comprehensive support for process tuning, but rather to provide a simple mechanism which may be extended. Support for recipe tuning is not a fundamental requirement.

7.5.1 Processing management provides a mechanism for specification of the type of recipe method to be applied. Two methods are defined in the standard: RecipeID only, and RecipeID and Variables. User-defined methods may also be used, requiring all communicating entities to have a common understanding of the particular definition and application requirements.

7.5.2 The RecipeID only method accepts the identifier of the recipe to be applied but no additional tuning parameters. The application recipe body is not precluded from defining any application tuning, but there is no standardized support.

7.5.3 The RecipeID and Variables method provides a simple process tuning mechanism at process job creation to support limited run to run feedforward and feedback control. It defines the VariableTuning method, which supplies a list of variable names and values in the process job create. This sets variables defined in the recipe. Each variable name shall be one of the exposed variable definitions supported in recipe management, and its value shall fall within the range specified in the variable definition.

7.5.4 Recipe parameter names (RecipeVarName) shall be specified using the nomenclature defined for ‘Object Specification’ (ObjSpec) in SEMI E39 (Object Services Standard) within the scope of SEMI E40 (Note: see OBJSPEC in SEMI E5). This use of the ObjSpec nomenclature is required to unambiguously identify parameters within some complex recipes (e.g., cluster tool process recipes). If the specification of a recipe parameter is unambiguous, then the form of the ObjSpec may be simplified to just the parameter name. Using the ObjSpec nomenclature for SEMI E40 recipe parameter names requires an object model to describe equipment recipe structure.

7.5.5 Figure 1 shows an example of a typical set of cluster tool hierarchical recipe relationships. A processing parameter might be specified through Sequence Step AB, Process Recipe BB, Process Step CB, to Process Parameter DB. In this example, the object specifier for Process Parameter DB would be:

“Sequence:Erma>SequenceStep:AB>ProcessRecipe: BB>ProcessStep:CB>ProcessParameter:DB>”

or

“Erma>AB>BB>CB>DB>”

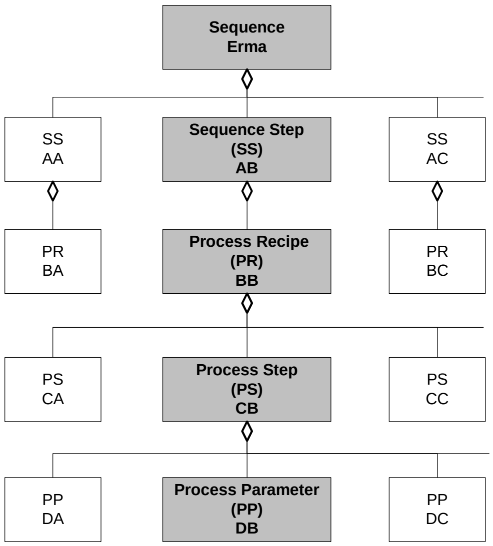

Figure 1
Cluster Tool Sequence Recipe Hierarchical Relationships

7.6 *Processing Material Groups* — Many equipment architectures require concurrent processing of groups of material. A single process job can control a group of material, with certain restrictions. All material in the group needs to be of the same type and processed identically. The processing of each material should be dependent on the arrival of the group. That is, the full material group shall be received by the equipment before processing begins and may not depart until all processing is complete. This ensures that the process job remains a simple logical control mechanism while maintaining robust control, good coordination with material movement, and effective material data tracking.

7.6.1 Two common examples of allowable material group processing are:

a) an equipment receiving a cassette of wafers to be processed identically. All the wafers in the group are received together, in the cassette. The processing of the wafers may or may not be simultaneous but can only proceed once the cassette has arrived. All wafer processing shall complete before the cassette may be removed. Note that this may alternatively be specified as a simple process job with the cassette as the material; and

b) a cluster tool batch process module processing wafers together. Wafers are received singly. Processing of the wafer group in the batch chamber begins when all the wafers specified in the process job have arrived. Wafers are sent after processing is complete.

7.7 *Concurrent Process Jobs* — Concurrent process jobs is the situation where multiple jobs are active (not queued) at the same time. A single process job is not always appropriate for concurrent processing of multiple material. In such cases, multiple concurrent jobs shall be supported by the processing resource. Support of concurrent process jobs is not a fundamental requirement.

7.7.1 An example of concurrent wafer processing which may not be achieved with a single process job is a carousel type cluster tool process module. The processing of a single wafer is not dependent on the arrival of the group. In this case, concurrent process jobs would be created, one for each wafer, even if they were to be processed identically. This allows effective control and tracking of the process jobs.

7.7.2 Processing management considers concurrent process jobs to be logically independent of one other. They are distinguished by unique job identifiers. Concurrent jobs may not apply to the same material because the processing resource may not have more than one active process job associated with a particular material.

7.7.3 There may be interdependencies between concurrent jobs due to resource availability and equipment hardware architecture.

7.8 *Consecutive Process Jobs* — Consecutive process jobs is a situation where multiple process jobs are applied to material while it is in the processing resource. The process jobs requested on the same material are maintained in the order received, and a subsequent job becomes active once the previous one has completed material processing.

7.8.1 A process job normally specifies all the processing to be applied to the material during a single visit to the processing resource. For example, a process job for a cluster tool would specify all the processing in the multiple sequential steps in the various process modules of the tool. Certain situations may require application of subsequent process jobs to material without it leaving the processing resource.

7.8.2 Processing management requires that a subsequent process job on the same material does not interrupt the previous process job processing. The previous process job terminates immediately once it completes active material processing, even though the material has not left the processing resource, and it is superceded by the subsequent job. The material becomes associated with the superceding process job. This allows sequential processing and maintains a single active association between material and process job.

7.9 *Process Job without Material* — This standard is primarily intended for the management of material processing. However, it permits application of a process job to a processing resource which contains no processing material. This may be used to achieve processing resource conditioning which is not related to a specific material.

7.9.1 The process job has the normal control characteristics, except that it has no dependency on material arrival and terminates at the end of active processing. Support of process jobs without material is not a fundamental requirement.

8 Behavior

8.1 This section provides a high-level definition of the communications between the supervisor and the processing resource needed to achieve material processing. It does not define the message detail, concentrating instead on the concepts. The message detail is addressed in Section 10, Messaging Services.

8.2 *Process Job Communications*

8.2.1 *Process Job Control Messaging* — The control message flow for normal operation is presented in Figure 1. The arrows represent significant information exchange.

8.2.1.1 A detailed description of each message used in normal operation follows.

8.2.1.2 *PR Job Create* — The supervisor requests that the processing resource perform the specified process job. This request may be acted upon immediately, or queued for later execution if the processing resource is busy or the order of material arrival unknown. If the processing resource does not support queuing or the queue is full, the request may be rejected. The request shall supply a process specification in which the supervisor supplies such information as:

- identification of the material to be processed,
- the recipe defining the processing, and
- whether processing will be started manually (optional, normal operation is automatic).

8.2.1.2.1 Upon receipt of the PR Job Create request and before acknowledging, the processing resource checks the process specifications to ensure that they are valid (i.e., that the specified parameters (recipe, material, manual start) are sufficient) and have legal values for the capabilities of the processing resource. Depending on its ability to queue jobs, it may also check such dynamic information as availability of the processing resource to receive the material or presence of correct material, etc., to determine whether to accept or reject.

8.2.1.2.2 The processing resource sets the process start attribute if automatic start is requested (normal operation).

8.2.1.3 *PR Job Create Acknowledge* — The processing resource informs the supervisor that the requested job is accepted or rejected, and if rejected, supplies error codes and textual reasons for the failure.

8.2.1.4 *PR Job Setup* — The processing resource reports that the process job is active and setting up for process. It may have been on the queue or have just been created. If the material is not already present, the processing resource performs any pre-conditioning required then awaits material arrival. Upon arrival of all the material, it prepares for processing and automatically initiates processing if the process start attribute is set.

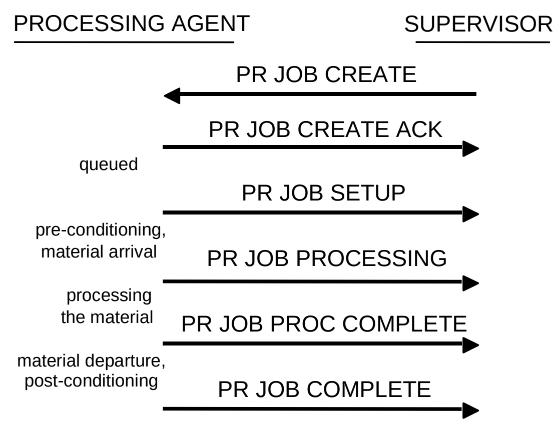

Figure 2
Process Job Message Flow

8.2.1.5 *PR Job Processing* — The processing resource reports that material processing has commenced.

8.2.1.6 *PR Job Processing Complete* — The processing resource reports that material processing is completed and that the material is available for removal.

8.2.1.7 *PR Job Complete* — The processing resource declares the process job to be complete once it has completed processing the material, the material has departed, and any required processing resource post-conditioning has completed. This message is also used when a process job ends abnormally. The message provides information on the success or failure of the processing and, if failed, supplies error codes and textual reasons for the failure.

8.2.2 *Process Job Informational Events* — There are process job related events which may be of significance to the service-user. These are designated as “collection events” and shall be available for event reporting. This section describes those collection events and shows how they fit into the chronology of a process job. These collection events, as specified by the PRJobEvent service, shall be implemented per definition of one of the following standards, SEMI E30, E40, E53 or similar style events, as required by the service-user. The equipment may also optionally implement the collection events per the remaining standards. However, the service-user shall only utilize one of the standards for collection event implementations. The selection mechanism by the service-user is equipment specific. For example, it may be part of an equipment power-on process or via an equipment specific equipment constant.

8.2.2.1 If SEMI E30, E53 or similar style collection events are used for PRJobEvent, the equipment must also implement events for the process job milestones as defined by the PRJobAlert service.

8.2.2.2 Collection event messages provide valuable information but are not strictly required to perform material processing. Therefore, it is expected that some message protocol implementations will provide a method by which the service-user may disable those events which are not needed in a particular implementation. For SEMI E40 style events, the activation for disabling the events is user specific. For SEMI E30, E53 or similar style events, the activation is as defined in those standards.

8.2.2.3 *PR Job Waiting for Material* — The processing resource reports that all required pre-conditioning has completed and that it cannot proceed until the process job material arrives. It is considered to be awaiting material arrival if it is not aware of activities in progress with the aim of receiving all or part of the material. This event may be generated only during process job setup. This event requires, at a minimum, PRJobID and Timestamp as its data.

8.2.2.4 *PR Job State Change* — The processing resource reports that it has changed state. All state transitions in the state model Figure 4 shall trigger this collection event. These events require, at a minimum, variables PRJobID, PRJobState, and TimeStamp (E30).

8.2.3 *Process Job Extended Messaging* — In this section, the extended messaging of Abort/Stop/Cancel, Pause/Resume and manual Start Process is added to the normal messaging described above. The only extended functionality required to be supported in processing management is Abort.

8.2.3.1 A detailed description of each message used in extended operation follows.

8.2.3.2 *PR Job Abort* — The supervisor may command the processing resource to abort a process job at any time. The goal of the abort command is to end the process job activities as quickly as possible. This includes halting all processing of material in progress, which may result in an unknown material condition. Abort is intended for use when serious problems are detected and further damage needs to be prevented. The abort command terminates the process job. In many cases, error recovery may be required before normal operation may continue and subsequent jobs can be executed. For processing equipment a part of the error recovery procedure may require the removal of substrates belonging to the aborted process job that still reside in the equipment. This is determined by the processing agent, which may use applicable service standards to handle the exception.

8.2.3.2.1 The abort command takes precedence over the stop, cancel, and pause commands. If the specified process job is queued, the abort command acts identically to a cancel command.

8.2.3.3 *PR Job Stop* — The supervisor may command the processing resource to stop a process job at any time. The stop command terminates the job in an orderly manner. The object of the stop command is to cease the current activity at the next safe, convenient point, preserving material integrity. In the situation of processing equipment, this convenient point may require that all related substrates are sent to their output destination. This implies that each material is either processed as specified in the recipe or not at all. As stop terminates the job, a new process job is needed to continue processing the material in the processing resource. If restart of the same job is needed, pause and resume should be used instead of stop. A new job is required if additional processing is needed after a job is stopped.

8.2.3.3.1 If the specified process job is queued, the stop command acts identically to a cancel command.

8.2.3.4 *PR Job Cancel* — The supervisor may cancel a process job which has not yet become active (e.g., a job which is queued). Cancel is used when the supervisor would like to remove a process job — to reschedule, for example — but does not want to affect process job activities already in-progress. A cancelled job is removed from the queue and ceases to exist. No physical action is associated with canceling a process job. If the specified process job is active, the processing resource shall reject this command.

8.2.3.5 *PR Job Pause* — The supervisor may issue a command to pause a process job at any time. A pause command shall cause the processing resource to continue to the first safe, continuable, pausing place and then cease activity. The activity may cease only at points that allow for resumption of the activity (see the resume command) such that material integrity is maintained and the processing goals are accomplished. Note that a paused process job may be aborted or stopped as an alternative to the resume command. In this case, the stop command may cause the equivalent of a resume in order to ensure material integrity (either fully processed or not processed at all) upon termination of the process job.

8.2.3.6 *PR Job Resume* — The resume command is used to continue a previously paused process job activity.

8.2.3.7 *PR Job Create* — The PR Job Create request as previously decribed is for normal automatic process job operation. If the process start attribute is not set, the processing resource waits for a manual start from the supervisor before processing the material. The control message flow for manual start is presented in Figure 3.

8.2.3.8 *PR Job Waiting for Start* — The processing resource is ready to process once the material has arrived and has been prepared for processing. The processing resource reports that it is ready to process and is waiting for start, if the process job PRProcessStart attribute is not set. The PRProcessStart attribute is not set if the job is defined to start manually and the start command has not yet been received. The WAITING FOR START state shall be a safe condition which maintains material integrity. If the process job is stopped or aborted while in this state, the material will not have been altered.

8.2.3.9 *PR Job Start Process* — The supervisor which has defined a process job to start manually issues a PR Job Start Process to allow processing of the material to proceed when the processing resource is ready. The start may be issued at any time after process job creation. On receiving the start command, the processing resource sets the process start attribute and starts processing if it is already in the WAITING FOR START state.

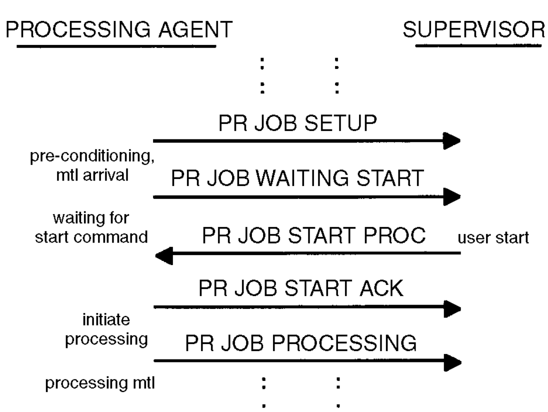

Figure 3
Manual Start Message Flow

8.2.3.10 *PR Job Start Acknowledge* — The processing resource responds to the supervisor that the requested start process is accepted or rejected and, if rejected, supplies errorcodes and textual reasons for failure.

8.3 *Process Job State Model* — The process job is a transient entity. It is created on request of the supervisor, executes, and then is deleted by the processing resource. The job usually spans the time period from shortly before material is physically delivered to the processing resource, through the processing, and until shortly after material is taken away.

8.3.1 *Process Job State Model Diagram* — Figure 4 shows the Process Job State Model diagram.

8.3.2 *Process Job State Descriptions* — The detailed state definitions follow.

8.3.2.1 *ABORTING (ACTIVE Substate)* — While the PR Job is in the ABORTING substate, the processing resource is performing an abort or an optional error recovery procedure. The abort procedure will cause immediate termination of the processing. It is the responsibility of the processing resource to cease physical activity as quickly as possible, having achieved a safe condition.

NOTE 2: For processing equipment the termination may have to be followed by an error recovery procedure with which remaining substrates can be brought to the output destination.

8.3.2.2 *ACTIVE* — ACTIVE is the parent state of all substates where the context of an active process job execution exists.

8.3.2.3 *EXECUTING (ACTIVE Substate)* — EXECUTING is the parent state of those substates that refer to the preparation and execution of a process job.

8.3.2.4 *SETTING UP (EXECUTING Substate)* — While the PR Job is in the SETTING UP substate, the processing resource performs pre-conditioning, awaits material arrival, and prepares for material processing. Pre-conditioning includes all operations in the processing resource, which are required by the recipe in advance of material arrival.

8.3.2.4.1 In cases where the material is already present, it is simply prepared for processing. If pre-conditioning (without material present) is required to achieve the processing goals specified by the recipe, the job fails and terminates.

8.3.2.5 *PAUSE (ACTIVE Substate)* — While the PR Job is in the PAUSE substate the processing resource is suspending or has suspended activity.

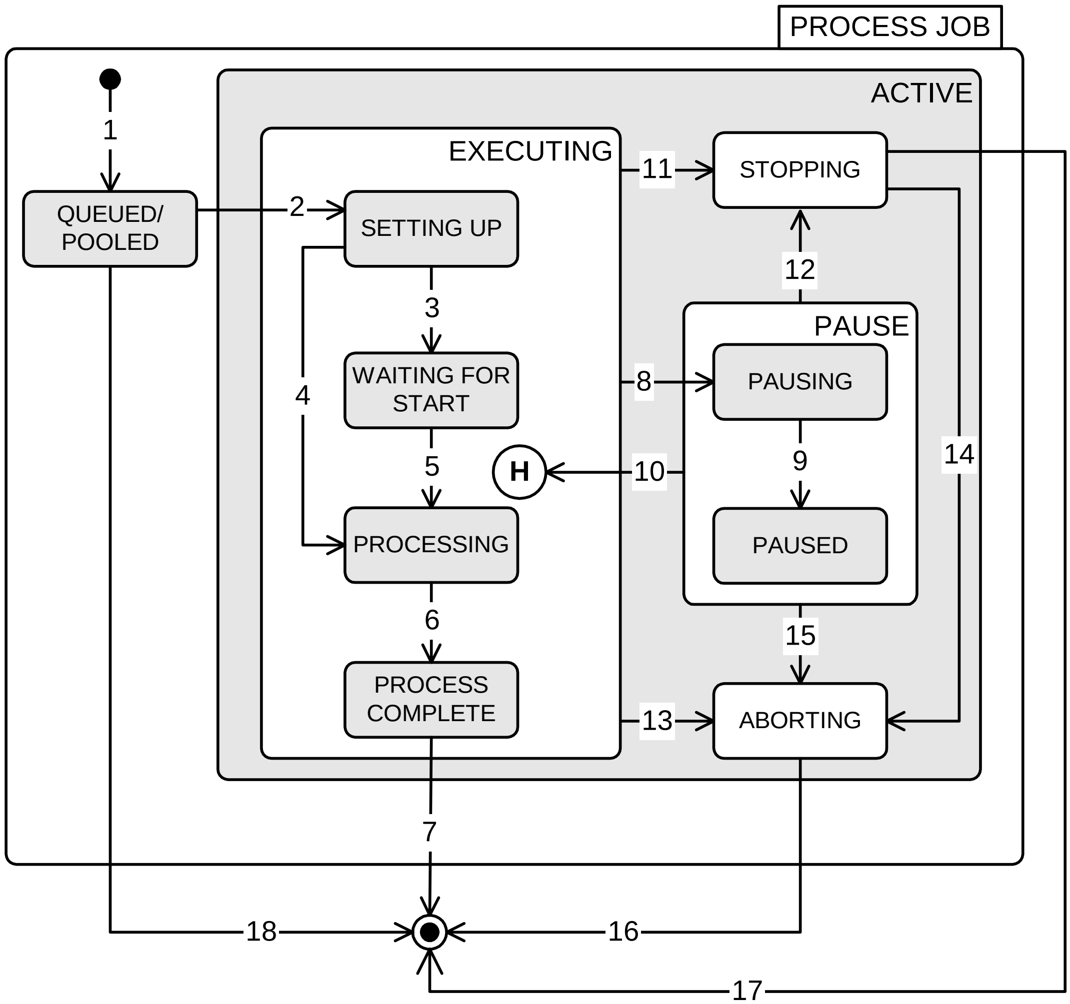

Figure 4
Process Job State Model

8.3.2.6 *PAUSED (PAUSE Substate)* — While the PR Job is in the PAUSED substate all processing resource activity has ceased. The PR Job is awaiting a RESUME (or STOP or ABORT) command.

8.3.2.7 *PAUSING (PAUSE Substate)* — While the PR Job is in the PAUSING substate, the processing resource continues to the first safe, continuable pausing place and then ceases activity. The activity may only cease at points that allow for resumption of the activity such that material integrity is maintained and the processing goals are accomplished.

8.3.2.8 *PROCESSING (EXECUTING Substate)* — While the PR Job is in the PROCESSING substate, the processing resource is doing the actual material processing using the equipment recipe(s) specified by the PR Job.

8.3.2.9 *PROCESS COMPLETE (EXECUTING Substate)* — While the PR Job is in the PROCESS COMPLETE substate the processing resource has completed processing all material specified by the PR Job. When all material removed from the processing resource, processing resource performs any required post-conditioning. Post-conditioning includes all operations in the processing resource after material departure, which are required by the recipe.

8.3.2.9.1 In cases where the process job is superseded by another process job on the same material and post-conditioning is not required, the first job terminates successfully while the material is still present. If post-conditioning is required, the second job may not supersede and remains on the queue.

8.3.2.10 *QUEUED/POOLED* — While the PR Job is in the QUEUED/POOLED substate, the process job has been accepted by the processing resource through a PR

Job Create/Acknowledge transaction (such as PRJobCreate, PRJobCreateEnh, PRJobDuplicateCreate, and PRJobMultiCreate) and is awaiting execution. One or more jobs may be in this state depending upon specific equipment capabilities. That is, if equipment does not support job queuing, then only one PR Job may be in this state at a time. If equipment does support job queuing, then the number of jobs that may be in this state must at least be equal to the number of load ports on the equipment. Advanced equipment job management capabilities require multiple jobs (greater than two) be in this state per load port.

8.3.2.10.1 The order that jobs become active is dependent upon whether the equipment supports job queuing and/or job pooling. Example methods for job activation include FIFO (first-in/first-out) order, material arrival order, and host ordering of jobs (provided by additional services). The equipment may support only one method of selecting jobs for activation, or more than one method allowing only one method to be used at a time or more than one method to be used at a time.

8.3.2.10.2 All process jobs pass through this state. If the processing resource supports queuing/pooling, jobs may remain in this state for prolonged periods. In any case, a process job remains queued/pooled until the material positions (of the processing resource) needed for the process are available or are already occupied by the material to be processed.

8.3.2.11 *STOPPING (ACTIVE Substate)* — While the PR Job is in the STOPPING substate, the processing resource is performing a stop procedure to terminate processing in an orderly manner. It is the responsibility of the processing resource to cease the current activity at the next safe, convenient point, preserving material integrity. For processing equipment this may require sending all related substrates to its output destination. This implies that each material is processed as specified in the recipe or not at all.

8.3.2.12 *WAITING FOR START (EXECUTING Substate)* — The substate WAITING FOR START is used only in manual start process jobs. It is entered once SETUP is complete and a PR Job Start Process has not yet been received by the processing resource. Manual start is defined by the supervisor in PR Job Create.

8.3.2.12.1 The job remains in this state, ready to process the material, until the PR Job Start Process is received or Abort or Stop terminates the job.

8.3.3 *Process Job State Transitions* — The detailed state definitions are defined in Table 1.

Table 1 Process Job State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1	(no state)	The processing resource accepts a Process Job create request.	QUEUED/ POOLED	1. The job is placed the job queue/pool. 2. Acknowledge the Process Job creation.
2	QUEUED/ POOLED	The processing resource has been allocated to the Process Job.	SETTING UP	1. The job is removed from the queue/pool. 2. PR Job Setup event is triggered. 3. All required resource preconditioning is performed. 4. When job material arrives all material preparation is performed.
3	SETTING UP	Job material is present AND the processing resource is ready to start the process job AND PRProcessStart attribute is not set.	WAITING FOR START	PR Job Waiting for Start event is triggered.
4	SETTING UP	Material is present and ready for processing. PRProcessStart attribute is set.	PROCESSING	1. PR Job Processing event is triggered. 2. Material is processed.
5	WAITING FOR START	Job Start directive	PROCESSING	1. PR Job Processing event is triggered. 2. Material is processed.

#	*Current State*	*Trigger*	*New State*	*Action(s)*
6	PROCESSING	Material processing completed.	PROCESS COMPLETE	1. PR Job Processing Complete event is triggered. 2. The processing resource performs all required resource post-conditioning. 3. Await material departure.
7	PROCESS COMPLETE	Job material departed the processing resource AND resource post-conditioning completed, OR superceded by another process job on the same material.	(no state)	1. PR Job Complete event is triggered. 2. The process job is deleted.
8	EXECUTING	The processing resource initiated a process pause action. (it received a PAUSE command or initiated an internal pause)	PAUSING	The processing resource pauses at the first convenient time.
9	PAUSING	The processing resource paused the job.	PAUSED	None.
10	PAUSE	The processing resource resumed the job.	EXECUTING	The processing resource resumes the activity that was paused.
11	EXECUTING	The processing resource initiated a process stop action. (it received a STOP command or initiated an internal stop)	STOPPING	The processing resource stops the current execution activity at the first convenient time.
12	PAUSE	The processing resource initiated a process stop action. (it received a STOP command or initiated an internal stop)	STOPPING	The processing resource stops the current execution activity at the first convenient time.
13	EXECUTING	The processing resource initiated a process abort action. (it received an ABORT command or initiated an internal abort)	ABORTING	The processing resource terminates the current execution activity immediately.
14	STOPPING	The processing resource initiated a process abort action. (it received an ABORT command or initiated an internal abort)	ABORTING	The processing resource terminates the current execution activity immediately.
15	PAUSE	The processing resource initiated a process abort action. (it received an ABORT command or initiated an internal abort)	ABORTING	The processing resource terminates the current execution activity immediately.
16	ABORTING	The processing resource abort procedure is complete and for some processing equipment the related substrates are moved out as part of the error recovery.	(no state)	1. PR Job Complete event is triggered. 2. The process job is deleted.
17	STOPPING	The processing resources stop procedure completed.	(no state)	1. PR Job Complete event is triggered. 2. The process job is deleted.
18	QUEUED/ POOLED	"CANCEL," "ABORT," or "STOP" command received.	(no state)	1. Remove the process job from the queue/pool 2. PR Job Complete event is triggered. 3. Delete the process job.

9 Object Definitions

9.1 Processing management defines one standard object, the Process Job.

9.2 *Process Job Object Definition* — The process job is a dynamic object created by the processing resource as requested by the supervisor. It tracks progress of the operations required and is deleted by the processing resource automatically upon completion. The process job is uniquely identified by the PRJobID attribute. The object attribute notation used in the table below is described in Conventions, Section 5.2.

9.2.1 The attributes in Table 2 shall be accessible using Object Services Standard (SEMI E39).

Table 2 Process Job Attributes

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjID	An identifier for the service user. It is set when the process job is created.	Y	RO	Text
ObjType	The object type.	Y	RO	Text: "PROCESSJOB"
PauseEvent	List of event identifiers that cause the equipment to automatically transition to the PAUSING/PAUSED states when one of the listed events is triggered.	N	RO	List of: EventID
PRJobState	A unique sub-state of the job according to the process job state model in Figure 4.			Enumerated: QUEUED/POOLED SETTING UP WAITING FOR START PROCESSING PROCESS COMPLETED EXECUTING PAUSING PAUSE STOPPING ABORTING
PRMtlNameList	List of identifiers of the material being processed.	Y	RO	List of: PRMtlName
PRMtlType	Identifies the type of material being processed.	Y	RO	Enumerated
PRProcessStart	Indicates that the processing resource start processing immediately when ready.	N	RO	Boolean: TRUE — Automatic start FALSE — Manual start
PRRecipeMethod	Indication of recipe specification type, whether using is applied and which method is used.	Y	RO	Enumerated: Recipe only Recipe with Variable Tuning
RecID	Identifier of the recipe applied.	Y	RO	Text
RecVariableList	List of variables supporting a recipe method.	N	RO	List of: RecipeVariable

9.2.2 A number of the ProcessJob attributes are composite data types. The constituent data is defined in Table 3.

Table 3 Attribute Data Definitions

Data Itentifier	*Description*	*Form*
PRMtlName	Textual identifier of the material being processed.	Text
RecipeVariable	Variables supporting a recipe method.	Structure composed of: RecipeVarName RecipeVarValue
RecipeVarName	The name of the recipe variable.	Text
RecipeVarValue	Value of the recipe variable.	Depends on variable

10 Messaging Services Detail

10.1 This section defines the messaging services required to implement the processing management concepts. The messages were introduced in Section 8.1. These services are independent of the messaging protocol used. They may be mapped to SECS-II (SEMI E5) or to other comparable protocols.

10.1.1 These messaging services define the messages to be used, the nature of the parameters contained within the messages, and data type of the parameters. Not defined here is the internal structure of the actual messages as transferred, including order of the parameters and how various data structures and data types are represented.

10.1.2 The service message notation used in the tables below is described in Conventions, Section 5.3.

10.2 *Service List* — The following messages are exchanged between host and equipment for the purpose of accomplishing processing management tasks.

Table 4 Service List

Message Name	*Type*	*Description*
PRGetAllJobs	R	Get a list of the jobs and their states for all jobs which have not completed.
PRGetSpace	R	Get the number of jobs which can currently be created on the resource.
PRJobAlert	N	Notification by the processing resource that the process job is setting up, processing, completed process, or that the job is completed.
PRJobCommand	R	Command which affects the process job.
PRJobCreate	R	Supervisor (service-user) request that a process job be performed.
PRJobCreateEnh	R	User request for job to be done. User assigns a unique job identifier.
PRJobDequeue	R	Removes (deletes) process job(s) from the queue.
PRJobDuplicateCreate	R	Create a set of similar process jobs. User assigns unique job identifiers.
PRJobEvent	N	Notification by the processing resource that a process-related event has occurred.
PRJobMultiCreate	R	Create several jobs which may be dissimilar. User assigns unique job identifiers.
PRJobSetRecipeVariable	R	User request for setting a new value to one of more recipe variable parameters.
PRJobSetStartMethod	R	Create a set of similar process jobs. User assigns unique job identifiers.
PRSetMtrlOrder	R	Request the service to use a specific methodology for processing order.

10.3 *Parameter Dictionary*

Table 5 Parameter Dictionary, Part 1

Parameter Name	*Definition*	*Form: Possible Values*
CmdParameter	Parameter supporting a command type.	Structure composed of: CmdParmName CmdParmValue
CmdParmName	The name of the parameter.	Text
CmdParmValue	Value of the parameter.	Varies per parameter
ErrorCode	Contains the code for the specific error found.	Enumerated: *PRJobCreate, PRJobCreateEnh, PRDuplicateCreate, PRJobMultiCreate:* • Parameters improperly specified • Insufficient parameters specified • Unsupported option requested • Busy (no queueing or queue full) *PRJobCreateEnh, PRDuplicateCreate, PRJobMultiCreate:* • Object identifier in use *PRJobCommand:* • Parameters improperly specified • Insufficient parameters specified • Unsupported option requested

Parameter Name	*Definition*	*Form: Possible Values*
		• Command not valid for current state *PRJobComplete:* • No material altered • Material partially processed • All material processed • Recipe specification related error • Failed during processing • Failed while not processing • Failed due to lack of material • Job aborted • Job stopped • Job cancelled
ErrorText	Text in support of the error code.	Text
PRAck	Indicates whether the activity was successful.	Boolean: TRUE — Successful FALSE — Unsuccessful
PRCmdName	Indicates which process job command to perform.	Text: ABORT STOP CANCEL PAUSE RESUME STARTPROCESS
PREventData	Data related to the specific event.	Varies per parameter reported
PREventID	Identifier of the specific event which occurred.	Enumerated: Unique collection event ID for Waiting for Material and Process Job State Change events.

Table 6 Parameter Dictionary, Part 2

Parameter Name	*Definition*	*Form: Possible Values*
PRJobID	The unique identifier for a process job. It can be accessed as the ObjID attribute of the process job. The host may provide this identifier to the processing resource. In this case, the host must guarantee uniqueness of job identifiers for all the process jobs in the PROCESS JOB STATE in the equipment.	Text.
PRJobList	List of process job identifiers and their states.	List of Structure PRJobID PRJobState
PRJobMilestone	Process job milestone.	Enumerated: PR Job Setup PR Job Processing PR Job Processing Complete PR Job Complete PR Job Waiting for Start
PRJobSpace	Used to indicate the number of jobs that can currently be created for the processing resource.	Integer

Parameter Name	*Definition*	*Form: Possible Values*
PRJobState	A unique state of the process job according to the process job state model.	Enumerated: QUEUED/POOLED SETTING UP WAITING FOR START PROCESSING PROCESS COMPLETE PAUSING PAUSED STOPPING ABORTING
PRMtlName	Textual identifier of the material being processed.	Text: Unique for each material with respect to the processing agent.
PRMtlType	Identifies the type of material being processed.	Enumerated.
PRMtrlOrder	Defines the order by which material in the process jobs material list will be processed.	Enumeration: ARRIVAL – process whichever material first arrives. OPTIMIZE – process in an order that maximizes throughput. LIST – follow the order in the list.
PRPauseEvent	Variable containing information which is transferred to the corresponding PRJob attribute. Shall conform to event identifiers as defined in either SEMI E30 or E53.	(list of) text
PRProcessStart	Indicates that the processing resource start processing immediately when ready.	Boolean: TRUE — Automatic Start FALSE — Manual Start
PRRecipe	Specification of the process job recipe.	Structure composed of: PRRecipeMethod RecID (List of) RecipeVariable
PRRecipeMethod	Indication of recipe specification type, whether tuning is applied and which method is used.	Enumerated: Recipe only Recipe with VariableTuning
PRStatus	Reports the acceptance or rejection of a requested operation.	Structure composed of: PRAck (List of) Status
RecID	Identifier of the recipe applied.	Text: Unique with respect to the processing agent.
RecipeVariable	Variables supporting a recipe method.	Structure composed of: RecipeVarName RecipeVarValue
RecipeVarName	The name of the recipe variable.	Text: Depends on recipe
RecipeVarValue	Value of the recipe variable.	Depends on variable
Status	Reports any errors found.	Structure composed of: ErrorCode ErrorText
Timestamp	Event date and time.	Text: yyyymmddhhmmsscc

10.4 *Service Detail* — The tables below define the parameters for each service. In some cases, parameters have additional detail which is defined in the parameter definition section.

10.4.1 *PRJobCreate*

Table 7 PRJobCreate Service Detail

PRJobCreate Service Detail Section

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobID	-	M	The processing agent assigns the unique identifier which is used in all subsequent process job communications.
PRMtIType	M	-	
(List of) PRMtIName	M	-	All material shall be of the same material type. This is an ordered list and indicates the order in which the process job should process the material, if it is single wafer processing equipment.
PRRecipe	M	-	
PRProcessStart	M	-	Indicates auto or manual start.
PRStatus	-	M	

PRRecipe Parameter Detail Section

PRRecipeMethod	M	-	
RecID	M	-	The process job recipe identifier shall be unique within the domain of the processing agent.
(List of) Recipe Variable	C	-	Parameters required depend on the recipe method selected.

PRStatus Parameter Detail Section

PRAck	-	M	Indication of acceptance to perform the job.
(List of) Status	-	C	Error information, required if PRAck is unsuccessful.

10.4.2 *PRJobCreateEnh*

Table 8 PRJobCreateEnh Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobID	M	M	User supplied Job ID. Must be unique among jobs known by the processing resource or else the resource shall reject the create request.
PRMtlType	M	-	May be NULL when no material is processed.
(List of) PRMtlName	M	-	An ordered list that associates a set materials with process conditions (process programs or recipes).
PRRecipe	M	-	This is a structure.
PRProcessStart	M	-	Indicates auto or manual start.
PRPauseEvent	M	-	If null, then processing will not be automatically paused.
PRStatus	-	M	Indicates success or failure.

10.4.3 *PRJobDuplicateCreate* — This service creates multiple process jobs. Each job will be identical (a duplicate) in terms of doing the same processing on all the material that must be identical. This means the same values of PRRecipe and PRProcessStart are applied to each job that is created by this service. Creates a series of process jobs useful for single wafer processing.

Table 9 PRJobDuplicateCreate Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
(List of) PRJobDupSpec	M	C	Ordered list of user supplied Job ID's and material. Structure: PRJobID PRMtlName
PRMtlType	M	-	Enumeration that Indicates type of material.
PRRecipe	M	-	This is a structure.
PRProcessStart	M	-	Indicates auto or manual start.
PRPauseEvent	M	-	If null, then processing will not be automatically paused.
(list of) PRJobID	-	C	Shall be used if PRJobSpec is not returned.
PRStatus	-	M	Indicates success or failure.

10.4.4 *PRJobMultiCreate* — This service creates multiple process jobs. Each job can be created uniquely.

Table 10 PRJobMultiCreate Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
(List of) PRJobMultiSpec	M	C	An ordered list of job specifications as follows: (list of) Structure: PRJobID PRRecipe PRProcessStart (List of) PRMtlName
PRMtlType	M	-	Enumeration that indicates type of material.
(list of) PRJobID	-	C	Shall be used if PRJobSpec is not returned.
PRStatus	-	M	Indicates success or failure.

10.4.5 *PRJobDequeue* — Remove one or more jobs from the queue. PRStatus shall indicate any jobs which could not be removed because they either did not exist or were in the PR JOB ACTIVE state.

Table 11 PRJobDequeue Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobList	M	-	(List of) PRJobID
PRStatus	-	M	Indicates success or failure.

10.4.6 *PRJobCommand* — All of the process job commands described in Section 8.2.3 are communicated using the PRJobCommand service. The commands are Abort, Stop, Cancel, Pause, Resume, and Start Process. This standard does not specify any required parameters. Abort is the only command which is required to be supported.

Table 12 PRJobCommand Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobID	M	-	Identifies the process job on which to perform the command.
PRCmdName	M	-	
(List of) CmdParameter	C	-	Dependent on the command selected.
PRStatus	-	M	

10.4.7 *PRJobAlert* — Notification of process job milestones achieved by the processing resource are communicated using the PRJobAlert service. Process job milestones, which are described in Section 8.2.1, are events which are important to the control and tracking of the process job. The milestones required to be supported are PR Job Setup, PR Job Processing, PR Job Processing Complete, and PR Job Complete. An additional milestone, PR Job Waiting for Start, is used with the manual start option.

Table 13 PRJobAlert Service Detail

Parameter	*Req/Ind*	*Comment*
Timestamp	M	
PRJobID	M	Identifies the process job on which the milestone has been reached.
PRJobMilestone	M	
PRStatus	M	

10.4.8 *PRJobEvent* — Process job informational event notification, which is described in Section 8.2.2, is communicated using the PRJobEvent service. These are defined for Waiting for Material and Process Job State Change events. Support for informational events is not required.

Table 14 PRJobEvent Service Detail

Parameter	*Req/Ind*	*Comment*
PREventID	M	
Timestamp	M	
PRJobID	M	Identifies the process job which generated the event.
PREventData	C	

10.4.9 *PRJobSetRecipeVariable* — Sends a request to change the settings for a list of recipe variable parameters. Implementation of this service is optional.

Table 15 PRJobSetRecipeVariable Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobID	M	-	
RecVariableList	M	-	(list of) RecipeVariable
PRStatus	-	M	Indicates success or failure. Failure is if a variable can't be set. A List of variables which could not be set is returned in the status.

10.4.10 *PRJobSetStartMethod* — Sends a request to change the start method for job(s). This request will fail if a specified job is not in the QUEUED/POOLED state. Implementation of this service is optional.

Table 16 PRJobSetStartMethod Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobList	M	-	(List of) PRJobID
PRProcessStart	M	-	Indicates auto or manual start.
PRStatus	-	M	Indicates success or failure.

10.4.11 *PRGetAllJobs* — This message shall return a list containing job identifiers and the associated states of those jobs for all jobs which have not completed.

Table 17 PRGetAllJobs Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobList	-	M	

10.4.12 *PRGetSpace* — This message shall return the remaining number of jobs that can be created for the processing resource.

Table 18 PRGetSpace Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRJobSpace	-	M	

10.4.13 *PRSetMtrlOrder* — Request the Processing Management Service to use a specific strategy for the order in which materials are processed.

Table 19 PRSetMtrlOrder Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
PRMtrlOrder	M	-	Sets the value for the strategy the service will use.
PRAck	-	M	Indicates success or failure.

10.5 *Mapping of Semantics to Syntax* — Table 20 provides the correspondence between the message semantics defined in Section 8.2 and the syntax as defined in Section 10.4. The use of '.req', '.rsp', or '.nfy' suffixes shows the direction of message flow. '.req' is a message request from the service user to the service provider. '.rsp' is a response message from the service provider to the service user. '.nfy' is a notification from the service provider to the service user.

Table 20 Correspondence of Message Semantics to Syntax

Parameter	*Comment*
PR Job Create	PRJobCreate.req
PR Job Create Acknowledge	PRJobCreate.rsp
PR Job Setup	PRJobAlert.nfy (PRJobMilestone=PR Job Setup)
PR Job Processing	PRJobAlert.nfy (PRJobMilestone=PR Job Processing)
PR Job Processing Complete	PRJobAlert.nfy (PRJobMilestone=PR Job ProcessingComplete)
PR Job Complete	PRJobAlert.nfy (PRJobMilestone=PR Job Complete)
PR Job Waiting for Material	PRJobEvent.nfy (PREventID=Waiting for Material)
PR Job State Changes	PRJobEvent.nfy (PREventID=Process Job State Change)
PR Job Abort	PRJobCommand.req (PRCmdName=ABORT)
PR Job Stop	PRJobCommand.req (PRCmdName=STOP)
PR Job Cancel	PRJobCommand.req (PRCmdName=CANCEL)
PR Job Pause	PRJobCommand.req (PRCmdName=PAUSE)
PR Job Resume	PRJobCommand.req (PRCmdName=RESUME)
PR Job Waiting for Start	PRJobAlert.nfy (PRJobMilestone=PR Job Waiting for Start)
PR Job Start Process	PRJobCommand.req (PRCmdName=STARTPROCESS)
PR Job Start Acknowledge	PRJobCommand.rsp (PRSatus.PRAck=TRUE)

11 Variable Data

11.1 The purpose of this section is to define the list of variable data requirements for Processing Management compliant equipment. Values of these variables are available to the host via collection event reports.

11.2 *Variable Data Definitions* — The identifier and all other attributes of the ProcessJob object shall be available for inclusion in event reports associated with it. The following attributes are most likely to be used: PRJobID, PRJobState, RecID, RecVariableList and PRMtlNameLIst.

12 Compliance

12.1 Processing management defines the standard services available to achieve job-based material processing in equipment. The capabilities supported allow flexible management of automated processing encompassing many process types. Only a subset of these capabilities may be needed for a particular implementation.

12.2 *Fundamental Requirements* — All processing agent implementations shall support the fundamental requirements. These have been indicated in the appropriate sections of the document and are listed together below:

- Create and execute a single process job to completion, given:
  - a single material of the appropriate type, uniquely identified.
  - a unique recipe identifier for which the corresponding recipe can be found.
- Report the process job milestones: Setup, Processing, Processing Complete, and Job Complete.
- Detect and report the success or failure of the process job, indicating complete, partial, or non-processing of the material.
- Support Abort of the process job at all times, immediately ceasing activity and terminating the process job.
- Maintain the data of required process job attributes indicated in Table 2.
- Reject requests with incomplete or invalid parameters.
- Reject requests for capabilities not supported.
- Implement the services and messages with the exception of those required for the Optional capabilities.

12.2.1 Satisfying fundamental requirements may not provide sufficient flexibility or performance for some equipment. In such cases, fundamental functionality should be supplemented by optional capabilities as appropriate to the needs of the system.

12.3 *Additional Capabilities* — Optional capabilities defined or enabled in this standard include:

- Processing resource pre-conditioning and post-conditioning.
- Stop, Pause, and Resume of a process job.
- Manual process start.
- Process job queuing and Cancel on a queued job.
- Process tuning.
- Processing of material groups.
- Multiple concurrent process jobs.
- Multiple consecutive process jobs in a single visit.
- Process job with no material.
- Notification of waiting for material and of process job state changes.
- Implement PRJobCreateEnh, PRJobMultiCreate, and PRJobDuplicateCreate.

12.3.1 The services are defined with mechanisms to reject unsupported services and options should they be requested. This improves robustness and enables sophisticated service-users to adjust their requests to the capabilities of the particular processing agent.

12.4 Table 21 provides a checklist for Processing Management (PM) compliance.

Table 21 PM Compliance Statement

Fundamental PM Requirements	*PM Section*	*Implemented*	*PM Compliant*
Single Process Job Execution	8.2	☐ Yes ☐ No	☐ Yes ☐ No
Process Job Milestones	8.2.1 (except 8.2.1.2,3)	☐ Yes ☐ No	☐ Yes ☐ No
Process Job Failure Indication	8.2.1.7	☐ Yes ☐ No	☐ Yes ☐ No
Abort Command	8.2.3.2	☐ Yes ☐ No	☐ Yes ☐ No
Process Job Object Implementation	8.3, 9	☐ Yes ☐ No	☐ Yes ☐ No
Reject Invalid/Incomplete Parameters	8.2.1.2.1	☐ Yes ☐ No	☐ Yes ☐ No
Reject Unsupported Capabilities	11.2	☐ Yes ☐ No	☐ Yes ☐ No
Services Implementation (not per Additional)	10	☐ Yes ☐ No	☐ Yes ☐ No
Additional PM Capabilities	*PM Section*	*Implemented*	*PM Compliant*
Resource Pre/Post-conditioning		☐ Yes ☐ No	☐ Yes ☐ No
Stop, Pause and Resume Commands	8.2.3.3,4,5	☐ Yes ☐ No	☐ Yes ☐ No
Manual Process Start	8.2.3.9	☐ Yes ☐ No	☐ Yes ☐ No
Process Job Queuing	8.3	☐ Yes ☐ No	☐ Yes ☐ No
Process Tuning	7.5, 10.4.9	☐ Yes ☐ No	☐ Yes ☐ No
Processing of Material Groups	7.6	☐ Yes ☐ No	☐ Yes ☐ No
Multiple Concurrent Process Jobs	7.7	☐ Yes ☐ No	☐ Yes ☐ No
Multiple Consecutive Process Jobs	7.8	☐ Yes ☐ No	☐ Yes ☐ No
Process Job with No Material	7.9	☐ Yes ☐ No	☐ Yes ☐ No
Event Notification	8.2.2	☐ Yes ☐ No	☐ Yes ☐ No
Enhanced Job Creation	10.4.2	☐ Yes ☐ No	☐ Yes ☐ No
Multiple Job Creation	10.4.3	☐ Yes ☐ No	☐ Yes ☐ No
Duplicate Job Creation	10.4.4	☐ Yes ☐ No	☐ Yes ☐ No

SEMI E40.1-1101
SECS-II SUPPORT FOR PROCESSING MANAGEMENT STANDARD

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1996; previously published July 2001.

1 Purpose

1.1 This document maps the services and data of SEMI E40 to SECS-II streams and functions and data definitions.

2 Scope

2.1 This is the standard way to implement the Processing Management, which provides remote control of wafer processing, using the SECS-II message protocol.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E40 — Standard for Processing Management

4 Terminology

4.1 None.

5 Mapping of Processing Services

Table 1 Processing Management Messages Mapping

Service Message Name	*Stream, Function*	*SECS-II Name*
PRJobCreate request	S16F3,F4	Process Job Create Request/Acknowledge
PrJobCommand request	S16F5,F6	Process Job Command Request/Acknowledge
PRJobAlert notify	If E30 style events: S6F11,F12 If E40 style alerts: S16F7,F8 If E53 style events: S6F11,F12 S6F13,F14	If E30 style events: Event Report Send/Acknowledge If E40 style alerts: Process Job Alert Notify/Confirm If E53 style events: Event Report Send/Acknowledge Annotated Event Report Send/Ack
PRJobEvent notify	If E30 style events: S6F11,F12 If E40 style events: S16F9,F10 If E53 style events: S6F11,F12 S6F13,F14	If E30 style events: Event Report Send/Acknowledge If E40 style events: Process Job Event Notify/Confirm If E53 style events: Event Report Send/Acknowledge Annotated Event Report Send/Ack
PRSetMtrlOrder request	S16F29,30	Process Job Set Material Order
PRJobCreateEnh	S16F11/F12	PRJobCreateEnh
PRJobDuplicate-Create	S16F13/F14	PRJobDuplicateCreate
PRJobMultiCreate	S16F15/F16	PRJobMultiCreate
PRJobDequeue	S16F17/F18	PRJobDequeue
PRGetAllJobs	S16F19/F20	PRGetAllJobs
PRGetSpace	S16F21/F22	PRGetSpace
PRJobSetRecipe-Variable	S16F23/F24	PRJobSetRecipeVariable
PRJobSetStart-Method	S16F25/F26	PRJobSetStartMethod

6 Mapping of Processing Parameter

Table 2 Data Item Mapping

Service Parameter	*SECS-II Data Item*
PrJobID	PRJOBID
PRMtlType	MF
PRMtlName	MID
PRAck	ACKA
PRRecipeMethod	PRRECIPEMETHOD
RecID	RCPSPEC
RecipeVarName	RCPPARNM
RecipeVarValue	RCPPARVAL
PRProcessStart	PRPROCESSSTART
PRCmdName	PRCMDNAME
PRJobMilestone	If E30 style events: CEID If E40 style alerts: PRJOBMILESTONE If E53 style events: CEID
PRJobState	PRSTATE
Timestamp	TIMESTAMP
PREventID	If E30 style events: CEID If E40 style events: PREVENTID If E53 style events: CEID
CmdParmName	CPNAME
CmdParmVal	CPVAL
PRMtrlOrder	PRMTRLORDER
ErrorCode	ERRCODE
ErrorText	ERRTEXT
PREventData	V (SV, ECV, DVVAL)
PRJobSpace	PRJOBSPACE
PRPauseEvent	PRPAUSEEVENT

7 Variable Data Item Mapping

7.1 This section shows the specific SECS-II data classes, and formats needed for SECS-II implementations of SEMI E40 variable data. According to SEMI E40 section 11, all ProcessJob object attributes are to be available as variables for Process Job state transition events. These variables will be of SEMI E5 data item DVVAL.

8 Implementation Details

8.1 *Use of Object Services* — Several capabilities of the Processing Management Services are accessed through the Object Services Standard. Whan a Process Job has been created, (PRJOBID is valid), then its attributes can be read and written using the Object Services GetAttr and SetAttr messages.

8.1.1 E39 Object Services shall be used for access to ProcessJob attributes. The GetAttr service may be used for all ProcessJob attributes and the SetAttr service may be used on only those attributes whose Access is set to RW.

8.2 *Multi-Block Messages* — Processing Management Services is protocol independent and therefore, makes no mention of SECS-II multi-block access and grant messages. When these Service use the SECS-II protocol, then S16F3,F5 shall be preceded by an S16F1/S16F2 access request/grant message exchange when the message will be multi-block.

9 SECS-II Attribute Definitions

9.1 *Process Job Object SECS-II Attributes Definitions* — The following are the SECS-II structure definitions for the E40 ProcessJob object.

Table 3 Process Job SECS-II Attribute Definitions

Attribute Name	*Attribute Data Form: SECS-II Structure*
"ObjID"	<PRJOBID> (Conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.)
"ObjType"	"ProcessJob"
"PauseEvent"	L,n n=number of collection events 1. <CEID$_1$> … n. <CEID$_n$> CEID restricted to format U()
"PRJobState"	<PRSTATE> PRJobState PRSTATE enumerated as follows: 51 (U1) Enumerations: 0 – QUEUED/POOLED 1 – SETTING UP 2 – WAITING FOR START 3 – PROCESSING 4 – PROCESS COMPLETE 5 – (Reserved) 6 – PAUSING 7 – PAUSED 8 – STOPPING 9 – ABORTING
"PRMtlNameList"	When MF = 13 (0x0d) (carriers) L,n n=number of carriers 1. L,2 1. <CARRIERID$_1$> 2. L,j j=number of slots 1. <SLOTID$_1$> : j. <SLOTID$_j$> : n. L,2 1. <CARRIERID$_n$> 2. L,k k=number of slots 1. <SLOTID$_1$> : k. <SLOTID$_k$> When MF = 14 (0x0e) (substrate) L,n n=number of material (substrate) 1. <MID$_1$> substrate ID … n. <MID$_n$> MID restricted to format A
"PRMtlType"	<MF> MF restricted to format B **MF Value** **Description** 13 (0x0d) carriers (e.g. FOUP, SMIF pod, cassette) 14 (0x0e) substrate (e.g. wafer, mask, flat panel) other not valid for E40 material

Attribute Name	*Attribute Data Form: SECS-II Structure*
"PRProcessStart"	<PRPROCESSSTART>
"PRRecipeMethod"	<PRRECIPEMETHOD>
"RecID"	<RCPSPEC>
"RecVariableList"	L,n n=number of recipe variables 1. L,2 1. <RCPPARNM$_1$> 2. <RCPPARVAL$_1$> … n. L,2 1. <RCPPARNM$_n$> 2. <RCPPARVAL$_n$>

SEMI E41-95
EXCEPTION MANAGEMENT (EM) STANDARD

1 Purpose

1.1 Interactive exception handling enhances the error recovery ability while maintaining automated control in the factory. This standard addresses the communications needs within the semiconductor manufacturing environment with respect to equipment exception handling.

1.2 This standard specifies capabilities to be provided by the exception agent for effective reporting and interaction with respect to abnormal situations in the equipment. It describes the *concept* of exception management, the *behavior* of the equipment in relation to interactive exception handling, and the *messaging services* which are needed to provide the functionality.

1.3 The communications services defined here will enable standards-based interoperability of independent systems. They shall allow application software to be developed which can assume the existence of these services and allow software products to be developed which offer them.

1.4 Implementation of automated exception management will help reduce error recovery time and avoid changing from automatic to manual equipment control in many situations. The adoption of the standards described will greatly reduce the effort required to integrate compliant equipment components. Compliance requires a specific set of standard services.

2 Scope

2.1 The current scope of this standard is interactive exception handling within a cluster tool.

2.2 While the functionality provided may be applied to other multi-resource equipment, it may not provide the flexibility required for automated management and command by the factory of all types of equipment. It is anticipated that this standard will be extended to accommodate management of exceptions in other types of multi-resource equipment and by the factory of all types of equipment.

2.3 This standard supports exception condition reporting, including alarms, by an exception agent to a decision authority. The exception agent also has the ability to enable and disable reporting on each exception condition.

2.4 Interactive exception handling is supported through selection by the decision authority of recovery actions in certain situations. The recovery actions are performed by the exception agent with the goal of resolving the abnormal situation and allowing normal equipment operation to continue.

2.5 This standard presents a solution from the concepts and behavior down to the messaging services. It does not define the messaging protocol.

2.6 A messaging service includes the identification that a message shall be exchanged and definition of the data which is contained in that message. It does not include information on the structure of the message, how the data is represented within the message, or how the message is exchanged. This additional information is contained within the *message protocol*.

2.7 The defined services may be applied to multiple protocols. Information on the mapping of exception management services to special protocols (e.g., SECS-II) are added as adjunct standards.

2.8 The services assume a communications environment in which a reliable connection has been established between the user of the services and the provider of the services. Establishing, maintaining, releasing a connection, and handling communication failures is beyond the scope of this standard.

3 Referenced Standards

3.1 *SEMI Standards*

3.2 The following SEMI[1] standard is related to the Exception Management standard:

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

4 Definitions

The following definitions are arranged in alphabetical order. Some are defined using terms defined elsewhere within this section. No references beyond this section should be necessary for a basic understanding of these terms.

agent — an intelligent system within a factory that provides one or more service resources and uses the services of other agents. A generalization of host, equipment, cell, cluster, cluster module, station controller, work station. Agents are associated with a physical system or a collection of physical systems, including computer platforms.

1 These documents can be obtained from Semiconductor Equipment and Materials International, 3081 Zanker Road, San Jose, CA 95134, 408.943.6900.

alarm — an alarm is related to any abnormal situation of the equipment that may endanger people, equipment, or material being processed.

clearing — exception agent to decision authority reporting that an abnormal situation related to an exception condition is no longer apparent or relevant.

decision authority — an entity requiring to be notified of significant exception condition changes and which decides how to proceed to resolve abnormal situations related to recoverable error conditions. The decision authority may be represented by a supervisory controller interacting with an operator who may ultimately choose the recovery action.

error condition — an exception condition which is not an alarm and which may support recovery actions requested by a decision authority.

exception agent — the entity which manages access to and reporting of information on abnormal situations in equipment. It achieves this by defining exception conditions, each related to a significant abnormal situation. It may provide services for a decision authority to direct the recovery from certain situations.

exception condition — a condition managed by an exception agent for reporting on and recovery from an abnormal situation in the equipment.

form — type of data representing information contained in an object attribute or service message parameter. The data types are detailed in Section 4.1.

fundamental requirements — the requirements for information and behavior that must be satisfied for compliance with a standard. Fundamental requirements apply to specific areas of application, objects, or services.

posting — all exception agent to decision authority reporting associated with an exception condition while the related abnormal situation is apparent and relevant.

recovery action — an operation associated with an error condition with the aim of resolving the abnormal situation detected. It may supply information to the exception agent or request the exception agent to perform some activity.

service — the set of messages and definition of the behavior of a service provider that enables remote access to a particular functionality.

service-provider — the software control entity that is the provider of any of the related services.

service-user — the software control entity that is the user of any of the related services.

4.1 *Data Type*

form — type of data: positive integer, unsigned integer, integer, enumerated, boolean, text, formatted text, structure, list, ordered list.

positive integer — may take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

unsigned integer — may take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

integer — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

enumerated — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

boolean — may take on one of two possible values, equating to TRUE or FALSE.

text — a text string. Messaging protocol may impose restrictions, such as length or ASCII representation.

formatted text — a text string with an imposed format. This could be by position, by use of special characters, or both.

structure — a complex structure consisting of a specific set of items, of possibly mixed data types, in a specified arrangement.

list — a set of one or more items that are all of the same form (one of the above forms).

ordered list — a list for which the order in which items appear is significant.

5 Conventions

5.1 *Harel State Model* — This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an Appendix of SEMI E30. The formal definition of this notation is presented in Science of Computer Programming 8, “Statecharts: A Visual Formalism for Complex Systems,” by D. Harel, 1987.

Transition tables are provided in conjunction with the state diagrams to describe explicitly the nature of each state transition. A transition contains columns for Transition #, Current State, Trigger, New State, Action(s). The “trigger” (column 3) for the transition occurs while in the “current” state. The “actions” (column 5) include a combination of (1) actions taken upon exit of the current state, (2) actions taken upon entry of the new state, and (3) actions taken which are most closely associated with the transition. No differentiation is made.

5.2 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
The formal text name of the attribute	Description of the information contained	RO or RW	Y or N	(see below)

The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that service-users have to the attribute.

A 'Y' or 'N' in the requirement (Rqmt) column indicates whether or not this attribute must be supported in order to meet fundamental compliance for the service.

The Form column is used to indicates the format of the attribute. (See Section 4.1 for definitions.)

5.3 *Service Message Representation*

5.3.1 *Service Resource Definition* — A service resource definition table defines the specific set of messages for a given service group, as shown in the following table:

Message Service Name	*Type*	*Description*
Message Name	N or R	The intent of the service.

Type can be either N = Notification or R = Request.

Notification type messages are initiated by the service provider, and the provider does not expect to get a response from the consumer/subscriber.

Request messages are initiated by a service consumer or subscriber. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

5.3.2 *Service Parameter Dictionary* — A service parameter dictionary table defines the parameters used in a service, as shown in the following table:

Parameter	*Form*	*Description*
Parameter X	Data type	A parameter called X is B in A.

A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding primitive.

The Form column is used to indicate the type of data contained in a parameter. (See Section 4.1 for definitions.)

The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the values it can assume, and any interrelationships with other parameters.

To prevent the definition of numerous parameters named "XxxList," this document adopts the convention of referring to the list as "(List of) Xxx." In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

5.3.3 *Service Message Definition* — A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Cnf*	*Description*
Parameter X	(see below)	(see below)	A description of the service.

The columns labeled Req/Ind and Rsp/Cnf link the parameters to the direction of the message. The message sent by the initiator is called the "Request." The receiver terms this message the "Indication" or the request. The receiver may then send a "Response," which the original sender terms the "Confirmation."

The following codes appear in the Req/Ind and Rsp/Cnf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" — *Mandatory parameter* — must be given a valid value.

"C" — *Conditional parameter* — may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of another parameter.

"U" — *User-defined parameter*.

"-" — The parameter is not used.

"=" — (for Response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

6 Overview

Exception management is concerned with the interactive handling of equipment exception conditions. This standard defines the services provided by which abnormal situations are reported by an exception agent (service-provider) to a decision authority (service-user). In the case of recoverable situations, services are provided for a decision authority to choose how to proceed to resolve the abnormal situation.

The exception agent is the equipment entity which manages access to and reporting of information on abnormal situations. It achieves this by defining exception conditions, each related to a significant abnormal situation. All services are defined in terms of these exception conditions.

Exception management allows for the decision authority to direct the resolution of an abnormal situation. The decision authority selects a recovery action to be performed to resolve the situation from among the options supplied with the exception condition. The exception agent performs the requested recovery action, which may or may not resolve the situation.

The services are fully defined in terms of the functionality provided by the exception agent (service-provider) and as such do not dictate the architecture of the decision authority (service-user).

This standard describes the concepts and exception condition model on which the communications are based, followed by the detailed behavioral model used. It then describes the standard object attributes and message services in detail.

6.1 *Compliance* — Compliance with this standard includes adherence to all stated requirements in this document where implemented. This includes defined message services and state models.

There are two levels of compliance defined. The first is alarm reporting support. The second extends support to include interactive handling of recoverable exception conditions. Required capabilities are listed in Fundamental Requirements, Section 10.4.

7 Concepts

7.1 *Exception Management Model* — The exception management model describes the mechanism for interactive handling of equipment exception conditions.

An exception condition is a condition monitored in equipment by an exception agent (service-provider) for detecting an abnormal situation. Exception conditions are limited in this standard to those accessible by a remote decision authority (service-user).

An exception condition is persistent, existing whether or not the abnormal situation currently exists. The abnormal situation is indicated by the exception condition state becoming SET. An exception agent is an entity which manages remote decision authority access to any number of exception conditions. Each exception condition is identified by a name which is unique for the exception agent.

A decision authority is a remote entity requiring to be notified of exception condition information and which decides appropriate actions to take to resolve abnormal situations. The decision authority may be represented by a supervisory controller interacting with an operator who may ultimately choose the recovery action.

The exception agent notifies the decision authority on detection of an abnormal situation related to an exception condition (i.e., state is SET) and again when it is no longer apparent. It also provides access to exception condition attribute data and for the execution of recovery actions requested by the decision authority.

Exception management defines two types of exception conditions: alarms and error conditions.

An alarm is related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed. Alarms do not provide for decision authority involvement in the resolution of the abnormal situation.

An error condition is related to any abnormal situation detected which is made accessible to a decision authority. An error condition may supply a list of possible recovery actions from which the decision authority can select to attempt to resolve the abnormal situation, thereby resulting in the error condition state becoming CLEARED.

Being persistent, exception condition attributes may be queried at any time, and reporting of changes, such as state SET/CLEARED, can be disabled by the decision authority.

7.2 *Posting and Clearing* — Significant changes in an exception condition are reported to the decision authority if enabled. The major significant events are the transitioning of the exception condition state to SET or CLEARED, which indicate that the abnormal situation has been detected or is no longer apparent, respectively.

All significant information is sent when reporting that the exception condition state is SET. This includes the unique identifier, type, a message describing the abnormal situation, time and a list of possible recovery actions where appropriate. It is important to keep the decision authority updated on exception condition information while the abnormal situation exists, especially with respect to valid recovery actions. All changes in the list of possible recovery actions are reported to the decision authority while the exception condition state is SET.

The term posting is used to describe all reporting the transition to the SET state and while an exception condition state is SET.

Clearing is the reporting of the occurrence of an exception condition state transition to CLEARED. Note that the exception agent, not the decision authority, transitions the state to CLEARED. Any acknowledgment at the decision authority of exception condition posting (e.g., by the operator) is not relevant to the exception agent.

Exception condition changes while its state is CLEARED are not reported to the decision authority.

7.3 *Enable/Disable Reporting* — The decision authority may enable and disable posting and clearing for a particular exception condition by setting and resetting its enabled attribute, respectively. Reporting on an exception condition is enabled by default.

Note that the exception condition itself is not being enabled or disabled, but the reporting of its state is being enabled or disabled.

Posting of an exception condition shall occur upon being enabled if the exception condition state is SET.

7.4 *Recovery Actions* — Recovery actions provide a mechanism for a decision authority to assist in resolving an abnormal situation detected in the equipment. This is generally needed to resolve failure or conflict where information is required beyond the capabilities of the system. By supplying options related to each error condition, error recovery is directed to the problem area.

One or more recovery actions may be associated with an error condition. A recovery action is any operation with the aim of resolving the abnormal situation detected. It may supply information to the exception agent or request it to perform some activity.

A recovery action may be requested by the decision authority only when the error condition state is SET. Only recovery actions currently valid for the error condition are accepted by the exception agent.

The list of valid recovery actions is supplied in the posting of an error condition. Changes in this list are notified by re-posting. A decision authority may request any of the supplied recovery actions to be performed and is notified of acceptance to perform the recovery and, some time later, its completion. No more than one recovery action may be in progress on a particular error condition and it may be aborted by the decision authority at any time.

A recovery action does not directly change the error condition state to CLEARED. It performs activities or provides information with the object of removing the abnormal situation which in turn changes the state to CLEARED. A recovery action may continue after the state has transitioned to CLEARED, until the activity initiated has completed. A recovery action is rejected if received when the error condition state is CLEARED.

Since the exception agent must maintain system integrity by ensuring that incompatible operations are not performed concurrently, it may reject any recovery action requested.

8 Behavior

This section provides a high-level definition of the communications between the decision authority and the exception agent used in exception management. It does not define the message detail, concentrating on the concepts. The message detail is addressed in the Messaging Services section.

8.1 *Exception Condition Communication*

8.1.1 *Exception Report Messaging* — The message flow for exception reporting is shown in Figure 1. The arrows represent significant information exchange.

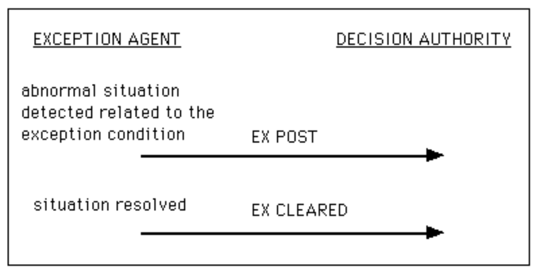

Figure 1
Exception Reporting Message Flow

A detailed description of each message used in exception reporting follows:

EX Post — The exception agent has detected an abnormal situation which is monitored by an exception condition. It changes the exception condition state attribute to SET. The exception agent notifies the decision authority using the EX Post notification, supplying the following information:

- identification of the exception condition,
- type of exception,
- time,
- a message explaining the abnormal situation,
- a list of possible recovery actions (where available with error conditions).

EX Post is re-sent every time the message or recovery action information changes as long as the exception condition state remains SET.

The EX Post notification is not sent if reporting on the exception condition is disabled, that is, if the enabled attribute is false. The EX Post notification is sent when an exception condition becomes enabled if the exception condition state is SET.

Upon receipt of the EX Post, the decision authority has the information needed to take the appropriate action. This may include requesting the exception agent to perform one of the supplied recovery actions.

EX Cleared — The abnormal situation detected by the exception agent is no longer apparent or relevant. The exception agent changes the exception condition state attribute to CLEARED. It notifies the decision authority using the EX Cleared notification, supplying the following information:

- identification of the exception condition,
- type of exception,
- time,
- a message.

The EX Cleared message is not sent if reporting on the exception condition is disabled. That is, the enabled attribute is false.

Upon receipt of the EX Cleared, the decision authority knows that the abnormal situation related to the exception condition is no longer apparent or relevant.

8.1.2 *Recovery Action Messaging* — In this section, the extended messaging of the recovery action is added to the reporting messaging described above. Recovery actions are not available for alarms. The message flow for recovery actions is shown in Figure 2.

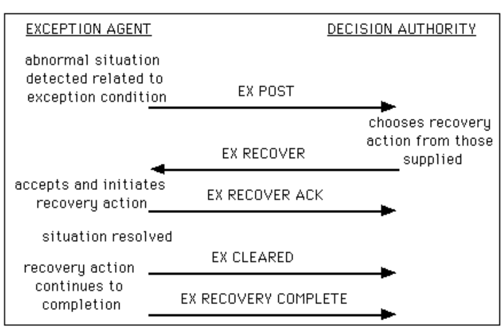

Figure 2
Recovery Action Message Flow

A detailed description of each message used in recovery actions follows:

EX Recover — The decision authority requests that the exception agent perform a recovery action. The particular recovery action selected is identified in the EX Recover request together with the related exception condition identifier. It shall be one of the recovery actions supplied for the exception condition in the EX Post notification.

Upon receipt of the EX Recover request and before acknowledging, the exception agent checks that the specified recovery action is currently valid. The request shall be accepted and initiated immediately or rejected by the exception agent.

The exception agent rejects a recovery action request if there is already a recovery action in progress on that exception condition.

EX Recover Acknowledge — The exception agent responds to the decision authority that the requested recovery action is accepted or rejected, and if rejected, supplies text reasons for failure.

Acceptance of a recovery action indicates that the exception agent has initiated the operation. The operation continues to completion without further intervention by the decision authority. The recovery action may or may not result in the exception condition state changing to CLEARED and the recovery action may continue after the state becomes CLEARED.

The exception agent may reject a requested recovery action for a number of reasons, including:

- unknown recovery for the exception condition,
- recovery currently invalid,
- busy with recovery for this exception condition,
- currently unable to perform the recovery (e.g., other conflicting activity or failure).

EX Recovery Complete — The exception agent declares the recovery action to be complete once it has completed the associated operation. This message is also used when a recovery action ends abnormally. The message indicates whether the operation completed normally and, if not, supplies text reasons for the failure.

Note that normal completion of a recovery action does not indicate that the abnormal situation has been resolved. That is indicated by the EX Cleared notification.

EX Recovery Abort — The decision authority may command the exception agent to abort a recovery action at any time. The goal of the abort command is to end the recovery action activities as quickly as possible. The abort command terminates the recovery action.

8.2 *Exception Condition State Model* — The behavior required for exception management is fully specified by the exception agent (service-provider) behavior. This is described by the exception agent exception condition state model. All required decision authority (service-user) behavior is inferred by this model.

Message flow diagrams presented in the previous section are useful to show simple situations. The exception condition state model presented in this section provides the information necessary to extrapolate the message flow diagrams for all situations within the scope of this standard.

The exception condition provides for exception agent reporting on an abnormal situation in the equipment and management of a recovery action requested by the decision authority to resolve the situation. Recovery is requested in the context of a particular exception condition so the recovery action behavior forms a part of the exception condition behavior.

Figure 3 shows the state diagram for an exception condition. The Harel state model notation used is described in Conventions, Section 5.1. The corresponding state transition table is shown in Table 1 on the following page.

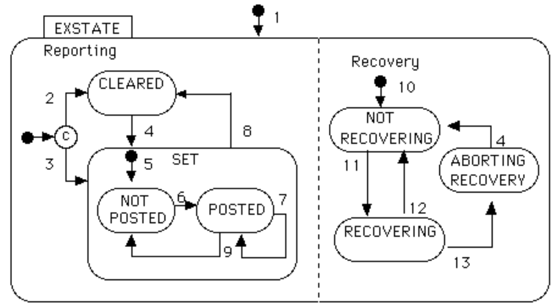

Figure 3
Exception Condition State Model

The detailed state definitions follow:

EXSTATE — When created by the exception agent, an exception condition enters the EXSTATE. It is in this state as long as it is in existence, irrespective of association to the decision authority. The exception condition has two concurrent subsets, which together fully describe its state. These subsets are Reporting and Recovery.

The exception condition initializes to the SET state if the abnormal situation related to the exception condition is apparent and relevant; otherwise, it initializes to the CLEARED state.

Reporting — Reporting is one concurrent subset of EXSTATE. It includes the substates describing whether the abnormal situation related to the exception condition is apparent and relevant, and whether the latest information on the situation has been reported.

Table 1 Exception Condition Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1	not EXSTATE	The exception agent creates the exception condition.	EXSTATE	
2	not EXSTATE	Initial creation and the abnormal situation is either not apparent or irrelevant.	CLEARED	
3	not EXSTATE	Initial creation and the abnormal situation is both apparent and relevant.	SET	
4	CLEARED	The abnormal situation is detected.	SET	
5	not SET	Default entry into SET state.	NOT POSTED	
6	NOT POSTED	Reporting enabled.	POSTED	Send “EX Post” message.
7	POSTED	Change in the list of possible recovery actions.	POSTED	Send “EX Post” message.
8	SET	The abnormal situation is either no longer apparent or has become irrelevant.	CLEARED	Send “EX Cleared” message.

9	POSTED	Reporting disabled.	NOT POSTED	
10	not EXSTATE	Default entry into recovery concurrent state at initial exception condition creation.	NOTRECOVERING	
11	NOTRECOVERING	“EXRecover” message received while in the SET state and accepted.	RECOVERING	Initiate requested recovery action and execute to completion.
12	RECOVERING	Recovery action completed.	NOTRECOVERING	Send “EX Recovery Complete” message.
13	RECOVERING	“EXRecoveryAbort” message received.	ABORTING-RECOVERY	Perform the abort procedure to terminate the recovery action in progress.
14	ABORTING-RECOVERY	Abort procedure is complete.	NOTRECOVERING	Send “EX Recovery Complete” message.

CLEARED — The abnormal situation related to the exception condition is either not apparent or not relevant.

SET — The abnormal situation related to the exception condition is apparent and relevant.

The exception agent should generate a collection event each time an exception condition transitions from CLEARED to SET and another from SET to CLEARED.

NOT POSTED — The latest information on the detected abnormal situation has not yet been reported by the exception agent. This may be transient on entering the SET state or may be because reporting is disabled. NOT POSTED is the default state when entering the SET state.

POSTED — The latest information on the detected abnormal situation has been reported by the exception agent to the decision authority.

Recovery — Recovery is one concurrent subset of EXSTATE. It includes the substates describing the behavior in relation to exception condition recovery actions.

NOTRECOVERING — In the NOTRECOVERING substate, there is no recovery action in progress directly related to the exception condition. NOTRECOVERING is the default state when an exception condition is initially created.

Recovery actions may only be initiated when the exception condition is in the SET state.

RECOVERING — A recovery action related to the exception condition is in progress when in the RECOVERING state.

ABORTINGRECOVERY — In the ABORTINGRECOVERY substate, the abort procedure is performed to immediately terminate the recovery action. It is the responsibility of the exception agent to cease physical activity as quickly as possible, having achieved a safe condition.

9 Object Definitions

Exception management defines one standard object, the Exception Condition.

9.1 *Exception Condition Object Definition* — The exception condition is a persistent object created by the exception agent. It provides the decision authority with reporting on, access to, and the possibility to direct resolution of an abnormal situation detected. It also tracks progress of a requested recovery action. The exception condition is uniquely identified by the EXID attribute.

The object attribute notation used in Table 2 is described in Conventions, Section 5.2.

Table 2 Exception Condition Attributes

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	The object type.	Y	RO	Text: “EXCEPTION”
ObjID	Exception agent unique identifier for the exception condition.	Y	RO	Text: Unique with respect to the exception agent.

EXType	Identifies the type of exception condition.	Y	RO	Enumerated: AlarmError
EXMessage	Text message describing the abnormal situation monitored.	Y	RO	Text
EXEnabled	Indicates that reporting to the decision authority on the exception condition is enabled.	Y	RW	Boolean: TRUE – Enabled FALSE - Disabled
EXRecActList	List of possible recovery actions.	N	RO	List of: Text
EXStateList	All concurrent sub-states of the exception condition according to the state model in Figure 3.	Y	RO	List of: Text
EXRecoveryAction	Recovery action which may be requested to resolve the abnormal situation.	N	RO	Text
EXState	A unique sub-state of the exception condition according to the state model in Figure 3.	Y	RO	Text: EXSTATE/CLEARED EXSTATE/SET/NOTPOSTED EXSTATE/SET/POSTED EXSTATE/NOTRECOVERING EXSTATE/RECOVERING EXSTATE/ABORTINGRECOVERY

10 Messaging Services Detail

This section defines the messaging services required to implement the exception management concepts. The messages were introduced in Section 8.1. These services are independent of the messaging protocol used. They may be mapped to SECS-II (SEMI-E5) or to other comparable protocols.

These messaging services define the messages to be used, the nature of the parameters contained within the messages, and data type of the parameters. Not defined here is the internal structure of the actual messages as transferred, including order of the parameters and how various data structures and data types are represented.

The service message notation used in the tables below is described in Conventions, Section 5.3.

10.1 *Service List* — The messages shown in Table 3 are exchanged between service-provider and service-user for the purpose of accomplishing exception management tasks.

Table 3 Service List

Message Name	*Type*	*Description*
EXPost	N	Notification by the exception agent that the abnormal situation related to the exception condition has been detected or significant information has changed while the situation exists.
EXCleared	N	Notification by the exception agent that the abnormal situation related to the exception condition is no longer apparent or relevant.
EXRecover	R	Decision authority request that a particular recovery action be performed.
EXRecoveryComplete	N	Notification by the exception agent that a recovery action has completed.
EXRecoveryAbort	R	Decision authority request that a recovery action be terminated immediately.

10.2 *Parameter Dictionary*

Table 4 Parameter Dictionary

Parameter Name	*Definition*	*Form: Possible Values*
ErrorCode	Contains the code for the specific error found.	Enumerated: EXRecover: Parameters improperly specified Insufficient parameters specified Recovery action currently invalid Busy with another recovery Currently unable to perform the recovery EXRecoveryAbort: Parameters improperly specified Insufficient parameters specified No active recovery action EXRecoveryComplete: FailedRecovery aborted
ErrorText	Text in support of the error code.	Text
EXAck	Indicates whether the request was successful or the activity completed normally.	Boolean: TRUE – Successful FALSE – Unsuccessful
EXID	Persistent exception condition identifier.	Text: Unique with respect to the exception agent.
EXMessage	Message describing the situation related to an exception condition.	Text
EXRecovery	Identifies a recovery action associated with an exception condition.	Text
EXRecoveryStatus	Reports the acceptance or rejection of a requested recovery action and whether completion was normal.	Structure composed of: EXAck (List of) Status
EXType	Identifies the type of exception condition.	Enumerated: Alarm Error
Status	Reports any errors found.	Structure composed of: ErrorCode ErrorText
Timestamp	Event date and time.	Text yyyymmddhhmmsscc

10.3 *Service Detail* — Tables 5 through 9 define the parameters for each service. Parameters have additional detail which is defined in the parameter dictionary, Table 4.

10.3.1 *EXPost* — Detection of abnormal situations by the exception agent is communicated using the EXPost service, as described in Section 8.1. This notification is also used to communicate any significant changes in exception condition information while its state is SET.

Table 5 EXPost Service Detail

Parameter	*Req/Ind*	*Comment*
Timestamp	M	
EXID	M	Identifies the exception condition which has detected the abnormal situation.
EXType	M	
EXMessage	M	
(List of) EXRecovery	C	List of possible recovery actions. Not available for alarms.

10.3.2 *EXCleared* — Notification that an abnormal situation is no longer apparent or relevant, as is described in Section 8.1, is communicated using the EXCleared service.

Table 6 EXCleared Service Detail

Parameter	*Req/Ind*	*Comment*
Timestamp	M	
EXID	M	Identifies the exception condition which has detected the abnormal situation.
EXType	M	
EXMessage	M	

10.3.3 *EXRecover* — Recovery action requests, described in Section 8.1, are communicated using the EXRecover service. The recovery action services are not available for alarms.

Table 7 EXRecover Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
EXID	M	-	Identifies the exception condition on which to perform the recovery action.
EXRecovery	M	-	The particular recovery action being requested.
EXRecoveryStatus	-	M	

10.3.4 *EXRecoveryComplete* — Notification of recovery action completion by the exception agent is communicated using the EXRecoveryComplete service. Recovery action completion, which is described in Section 8.1, is not directly linked to clearing the exception condition state, and successful completion indicates only that the operation performed completed normally.

Table 8 EXRecoveryComplete Service Detail

Parameter	*Req/Ind*	*Comment*
Timestamp	M	
EXID	M	Identifies the exception condition on which the recovery action was performed.
EXRecoveryStatus	M	

10.3.5 *EXRecoveryAbort* — Recovery action abort, described in Section 8.1 is communicated using the EXRecoveryAbort service.

Table 9 EXRecoveryAbort Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
EXID	M	-	Identifies the exception condition on which the recovery action is being performed.
EXRecoveryStatus	-	M	

10.4 *Fundamental Requirements* — Exception management defines the standard services available to achieve exception condition-based exception handling and error recovery in equipment.

All exception agent implementations shall support the fundamental requirements. This standard provides for two aspects of fundamental requirements: exception reporting and interactive exception handling. It is possible to support only exception reporting in systems which do not require interactive exception handling. Interactive exception handling requires that exception reporting be supported.

10.4.1 *Exception Reporting* — The fundamental requirements of the exception agent for exception reporting are based on maintaining the decision authority updated on the exception conditions it is interested in. These are listed below.

- Detect and report the occurrence of significant abnormal situations by setting the related exception condition, and posting it if reporting is enabled.

- Detect and report that an abnormal situation is no longer apparent or relevant by clearing the related exception condition and reporting it if enabled.
- Provide for enabling and disabling reporting on each exception condition.
- Maintain the data of exception condition attributes indicated in Table 2.
- Reject requests for capabilities not supported (such as recovery actions).

10.4.2 *Interactive Exception Handling* — The fundamental requirements of the exception agent for interactive exception handling extend the exception reporting to allow the decision authority to request recovery actions to be performed to resolve abnormal situations. These are listed below.

- Support all exception reporting fundamental requirements specified above.
- Supply a list of valid recovery actions for an exception condition when posting.
- Execute a requested recovery action for an exception condition if the requested recovery action is currently valid. The exception agent may support only a single recovery action to be in progress at a time and reject all other recovery action requests for other exception conditions while it is busy.
- Report the completion of the recovery action.
- Support Abort of the recovery action at all times, immediately ceasing recovery activity and terminating the recovery action.
- Reject requests with incomplete or invalid parameters.
- Reject requests for capabilities not supported.

Optional capabilities defined or enabled in this standard include the following:

- Support for multiple concurrent recovery actions. The standard allows only one recovery action in progress for each exception condition.
- Adjust the exception condition message and the valid recovery action list as appropriate during the error recovery, and post the changes if reporting is enabled.

The services are defined with mechanisms to reject unsupported services and options should they be requested. This improves robustness and enables sophisticated service-users to adjust its requests to the capabilities of the particular exception agent.

SEMI E41.1-0996
SECS-II SUPPORT FOR EXCEPTION MANAGEMENT STANDARD

1 Purpose

This document maps the services and data of its prime document, SEMI E41, to SECS-II streams and functions and data definitions.

2 Scope

This is the standard way to implement the Exception Management Standard, which provides remote control communication of exceptions and recovery, using the SECS-II message format.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E41 — Exception Management (EM) Standard

4 Terminology

None.

5 Mapping of Exception Management Messages

Table 1 Exception Management Messages SECS-II Mapping

Service Message Name	*Stream, Function*	*SECS-II Name*
EXPost Notify	S5F9,F10	Exception Post Notify/Confirm
EXCleared Notify	S5F11,F12	Exception Clear Notify/Confirm
EXRecover Request	S5F13,F14	Exception Recover Request/Acknowledge
EXRecoveryComplete Notify	S5F15,F16	Exception Recovery Complete Notify/Confirm
EXRecoveryAbort Request	S5F17,F18	Exception Recovery Abort Request/Acknowledge

6 Exception Parameters Mapping

Table 2 Exceptions Data Item Mapping

Parameter	*SECS-II Data Item*
ErrorCode	ERRCODE
ErrorText	ERRTEXT
EXAck	ACKA
EXEnabled	EXENABLED
EXID	EXID
EXMessage	EXMESSAGE
EXRecovery	EXRECVRA
EXState	EXSTATE
EXType	EXTYPE
Timestamp	TIMESTAMP

7 Implementation Details

7.1 Several capabilities of the Exception Management Services (EMS) are accessed through the Object Services Standard. The Exception Objects are persistent. An Object Services compliant implementation of EMS will allow access to all the attributes specified in the SEMI E5 Object definition table for an Exception Object.

All implementations shall use Object Service's GetAttr and SetAttr to access:

EXENABLED

EXSTATE

NOTE 1: EXSTATE is read-only.

SEMI E42-0299E
RECIPE MANAGEMENT STANDARD: CONCEPTS, BEHAVIOR, AND MESSAGE SERVICES

E This standard was editorially modified in September 1999 to conform to its non-provisional status. Changes were made to Section 1.2.

CONTENTS

NOTES

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SEMI E42-0299[E]
RECIPE MANAGEMENT STANDARD: CONCEPTS, BEHAVIOR, AND MESSAGE SERVICES

[E] This standard was editorially modified in September 1999 to conform to its non-provisional status. Changes were made to Section 1.2.

1 Introduction

This standard defines the concepts required for management of recipes, the operations or behavior provided by the Recipe Management Standard (RMS), and the messages through which services are provided through an interface between the provider and the user of these services.

1.1 *Purpose* — The purpose of this standard is twofold:

- *To enable applications software to be developed that can assume the existence of standard concepts, behaviors, and message services that collectively form Recipe Management and that take advantage of them.*
- *To enable software to be developed to offer the Recipe Management capabilities.*

1.2 *Scope* — This is a standard that defines concepts, behavior, and services to support the integration of automated recipe management within a semiconductor factory. These services are applicable to a variety of relationships, including both traditional **host/equipment** and cluster tool controller/attached module communications and control.

The standard provides a set of communications services which allows such systems to transfer and manage recipes to ensure the correct processing of material within semiconductor manufacturing *equipment* and systems. RMS also requires compliance to SEMI E39 (Object Services Standard (OSS): Concepts, Behavior, and Services) for completeness.

This document describes several different hierarchical relationships: supervisory agents and their supervised agents, recipes and their subrecipes, and recipe classes and their subclasses. Such hierarchical relationships provide a natural organizational and classification structure that is reflected in many different kinds of systems, such as telephone switching systems and directory trees. It is the intent of this standard to support logical hierarchical relationships rather than to require that strict hierarchical relationships be implemented in systems architecture.

RMS places no restriction on where the set of defined services is implemented.

1.3 *Referenced Documents*

1.3.1 *Semiconductor Equipment and Materials International (SEMI)*[1]

1.3.1.1 *SEMI Equipment Automation/Hardware Volume*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

1.3.1.2 *SEMI Equipment Automation/Software 2 Volume*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E53 — Event Reporting

1.3.2 *Other References*

James Rumbaugh, Michael Blaha, William Premerlani, Frederick Eddy, William Lorensen, *Object-Oriented Modeling and Design*, Englewood Cliffs, New Jersey: Prentice-Hall, 1991.

D. Harel, *Statecharts: A Visual Formalism for Complex Systems,* Science of Computer Programming 8, 1987.

1.4 *Definitions* — Basic definitions for objects, services, and form are provided in SEMI E39, Sections 4.1 through 4.4. This section provides additional definitions.

Definitions in Section 1.4.3 are specific to RMS.

1.4.1 *Services*

service provider — An application (a component of an *agent*) responsible for providing services to the service user.

service user — (service consumer) An application that uses the services provided.

1 Semiconductor Equipment and Materials International (SEMI), 805 East Middlefield Road, Mountain View, CA 94043, 650.964.5111, FAX 650.967.5375

1.4.2 *Form*

binary — A string of bit values (zeroes and ones), with a format that is either left unspecified or specified by bit position, with the most significant bit first. The total length of the string is a multiple of eight. Messaging protocol may impose restrictions on length.

1.4.3 *Recipe Management* — This section introduces basic terminology used in RMS. Entries are in alphabetical order. Additional definitions and specifications are provided in later sections.

agent — An intelligent system within a factory that provides one or more service resources and uses the services of other agents. This is a generalization that includes host, equipment, cell, cluster, cluster module, station controller, and work station. *Agents* are associated with a physical system or a collection of physical systems, such as computer platforms.

authorized user — A user who can be identified to an *agent* as having the level of authority required for a particular activity, such as *certifying* a recipe for that equipment.

collection event — A detectable occurrence of interest to a service user.

component agent — A subordinate *agent* that provides services to a *supervisory* agent.

download — An operation that transfers a recipe (down) to an execution storage area.

edit — An operation which creates a new recipe body or changes the body of an existing recipe.

editor — A service which allows a *user* to edit a recipe. *Editors* are not specified in RMS.

equipment[2] — An *agent* with associated hardware that provides, at a minimum, recipe **execution** services.

event — A detectable occurrence significant to an object.

execution (recipe execution) — The process of reading the recipe contents and implementing its instructions, process parameters, or other information required for its own processing.

executing agent — An *agent* that provides *recipe execution* capabilities.

execution area — The storage location of the recipe(s) currently *selected* (ready) for *execution*.

host — A *supervisory agent* that represents the factory to its subordinates.

logical recipe — A recipe with a particular set of *attributes* and a particular *body,* considered independently from its physical location. A *logical recipe* may have multiple instances or copies.

name — A text-based *attribute* of an object that may be used as all or part of its *identifier*.

namespace — In general, a domain within which object identifiers are unique. In RMS, the term *namespace* is used as a synonym for *recipe namespace*, unless otherwise stated.

operator — The user who interacts locally with *agent* through the *agent's* interface.

recipe — The pre-planned and reusable portion of the set of instructions, *settings*, and parameters under control of an *agent* that determines the processing environment seen by the manufactured object and that may be subject to change between runs or processing cycles.

recipe class — A formal grouping of recipes with a common language syntax and functionality.

recipe executor — The component of an *executing agent* that executes recipes.

recipe namespace — A logical management domain with the responsibility for the storage and management of recipes, the ensurance of the uniqueness of recipe **identifiers** within that domain, and the provision of services pertaining to recipes stored within that domain.

recipe parameter — A control value that affects the *agent's* process.

select — The act of preparing a recipe for execution.

setting — A static value accessible to the *user*, through one or more methods, that is used by equipment to control its process. *Settings* include, but are not limited to, setpoint values. *Settings* typically may be specified within a recipe.

storage area — An area where objects and data are stored.

subordinate agent — An *agent* that is a component of, or managed by, another *agent*.

supervisory agent — An *agent* with supervisory responsibilities for one or more subordinate *agents*.

timestamp — The notation of the date and time of the occurrence of an event.

upload — An operation that transfers a recipe (up) from an execution storage area.

user — A person interacting with an *agent* directly through the *agent's* human interface or indirectly through the *agent's supervisor*.

---

2 The term "equipment" is restricted in RMS to "intelligent equipment."

validate — The action of checking recipe contents to ensure that parameter type and range are valid for the equipment configuration prior to execution. [Note that *validation* and *verification* are used in different ways.]

variable parameter — A formally defined variable (*setting*) defined in the body of a recipe permitting the actual value to be supplied externally.

verify — The operation of reading a recipe's contents to ensure that it is syntactically correct and identifying elements that must be made public.

version — Part of a recipe's *identifier* that is used to show its heritage.

1.5 *Conventions* — The following conventions are used in this document:

- *To highlight terms specific to RMS (excluding terms defined in Sections 1.4.1 through 1.4.3 that are common to multiple standards), a defined term appears in* **boldface** *wherever it first appears and wherever it is defined. This alerts the reader to those terms with specific meanings. Except for terms that are very common, such as recipe, host, and equipment, defined terms otherwise are in* italics *wherever they appear.*
- *Terms related to objects and object services are in conformance with SEMI E39 (Object Services Standard: Concepts, Behavior, and Services). A brief discussion of objects is provided in the Appendix of that document.*
- *Attribute names are underlined.*
- *Attributes called "names" in RMS are generally intended to be used for the ObjID attribute of a* standardized object.
- *To prevent the definition of numerous message parameters named "XxxList," this document adopts the convention of referring to the list as "(List of) Xxx". In this case, the definition of the parameter Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type.*

For attributes that are lists, this convention is not followed, as the entire attribute, as a list, must be assigned a specific name.

1.5.1 *Text String Restrictions* — Text strings used in attribute names, attribute values, or message parameters, are subject to the restrictions defined by OSS: Text in ASCII is restricted to the characters between 20_{16} and $7D_{16}$, excluding the question mark "?" ($3F_{16}$), the asterisk "*" ($2A_{16}$), and the tilde "~" ($7E_{16}$). Text strings used as, or within, the object identifier ObjID are additionally restricted to exclude the "greater than" symbol ">" ($2E_{16}$) and the colon character ":" ($3A_{16}$) to conform with OSS requirements.

1.5.2 *Harel State Model* — This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an Appendix of SEMI E30. The formal definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems," by D. Harel, 1987.

This document also adopts the extension of Harel notation to show the deletion of an object as used by Rumbaugh, et al. (see Section 1.5.2.1).

1.5.3 *Objects — Standardized objects* defined by RMS conform to the requirements of SEMI E39 (Object Services Standard: Concepts, Behavior, and Services). RMS adopts the convention of showing *standardized objects* as drawn with a heavy line in object models. *Non-standardized objects* are used to illustrate concepts and relationships but are not formally defined and cannot be accessed through Object Services. A list of *standardized objects* defined by RMS is included in Related Information 1.

1.5.3.1 *OMT Object Information Model* — The object models are presented using the Object Modeling Technique, developed by Rumbaugh et al., in *Object-Oriented Modeling and Design,* Prentice-Hall, Englewood Cliffs, NJ, 1991. Overviews of this notation are provided in an appendix of SEMI E39 (Object Services Standard: Concepts, Behavior, and Services).

1.5.3.2 *Object Attribute Representation* — The object information models for *standardized* objects will be supported by an **attribute definition** table with the following column headings:

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	(see below)

The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that users of the service have to the attribute.

A 'Y' or 'N' in the Requirement (Rqmt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

The Form column is used to indicate the format of the attribute. (See Section 1.4 for definitions.)

1.5.4 *Service Message Representation*

Service Resource Definition

A **service definition table** defines the specific set of messages for a given *service resource*, as shown in the following table:

Message Service Name	*Type*	*Description*
Message name	N or R	The intent of the service.

Type can be either N = Notification or R = Request.

Notification type messages are initiated by the service provider, and the provider does not expect to get a response from the user.

Request messages are initiated by a service user. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

Service Parameter Dictionary

A **service parameter dictionary** table defines the parameters for one or more services, as shown in the following table:

Parameter	*Form*	*Description*
Parameter X	Data type	A parameter called X is B in A.

A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding primitive.

The Form column is used to indicate the type of data contained in a parameter. (See Section 1.4 for definitions.)

The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the values it can take on, and any interrelationships with other parameters.

To prevent the definition of numerous parameters named "XxxList", this document adopts the convention of referring to the list as "(List of)Xxx". In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element, unless zero elements are specifically allowed.

Service Message Definition

A **service message definition** table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Parameter X	(see below)	(see below)	A description of the service.

The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request". When receiver terms this message the "Indication" or the "Request", the receiver may then send a "Response", which the original sender terms the "Confirmation".

The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" — **Mandatory parameter** — must be given a valid value.

"C" — **Conditional parameter** — may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.

"U" — **User-defined parameter**.

"-" — The parameter is not used.

"=" — (for Response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

1.6 *Requirements* — Requirements for recipe management are varied. For example, there is a fundamental need to retain information about each recipe, to provide that information upon request, and to transfer it with the recipe so that it remains available. There is a need to classify recipes, to reuse them, and to share them with multiple installations of *equipment*. The need for sharing recipes introduces a new requirement for safeguarding the relationship between a recipe's **identifier** and its contents, to be able to protect a recipe from unauthorized changes, and to ensure that the *identifier* for a recipe that is used by multiple *equipment* is in fact the same recipe.

The requirements for managing recipes in a factory are given in tabular form in Table 1.1, which presents them according to their functional areas and the specific issues involved. Table R1-1, in Related Information, shows the specific concepts defined in RMS to address each of these requirements.

Table 1.1 Requirements

Functional Areas	*Issue*	*Requirements*
Management of Recipes	Identification	Uniquely store, identify, and select recipes in a system.
		Easy and clear identification of a recipe.
	Multiple Access	Share recipes among *equipment*.
		Enable synchronized change of shared recipes among *equipment*.
	History and Traceability	Capture the history of recipe usage.
		Capture the history of recipe changes.
	Life Cycle Management	Manage approval of recipes for process development and production.
Operations	Protection	Protect recipes from unexpected changes.
		Protect recipes from mistakes in operations.
	Portability	Create, edit, and change recipes outside the *equipment* which execute them.
	Reusability	Change recipes for a specific piece of *equipment*.
		Use recipes developed on one piece of *equipment* for other *equipment*.
		Share recipes among the same kind of *equipment* by adjusting for individual differences.
Execution	Safety	Do not execute recipes that are not syntactically correct.
		Execute the specified (selected) recipes without errors.
		Protect recipes being executed from inadvertent change caused by other activities.
	Flexibility	Change a recipe's **parameters** during or between runs in a systematic way.
System Operation	System Node Operation	Dynamically connect and disconnect *equipment* to/from the communications network.
	Stand-Alone Operation	Execute recipes with no communications link.
		Create and change recipes with no communications link.
		Manage recipes moved between *equipment* or from off-line storage through removable media.
		Enable smooth integration of stand-alone *equipment* into on-line factory systems.

1.7 *Document Structure* — Figure 1.1 depicts the domain of the Recipe Management Standard as consisting of Purpose, Concepts, Behavior, and Message Services. This also reflects an underlying structure of the document.

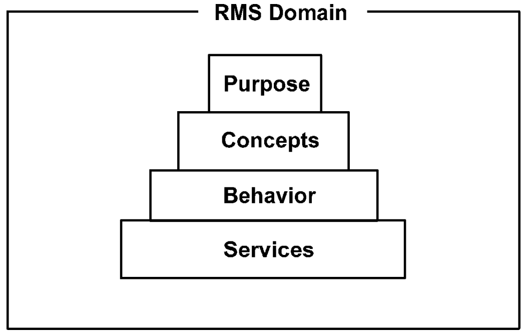

Figure 1.1
Recipe Management Domain

Purpose provides the motivation for Recipe Management capabilities and is addressed in Section 1.6. Concepts provide a detailed introduction to the *standardized objects* of RMS, their attributes, and their relationships with other objects. Behavior describes the operations that are performed by, or on, these objects. Finally, message services define the messages and their parameters independently of the protocol in which they are implemented. Both concepts and behavior represent an "inside view" of an RMS application, while services provide an interface from an external view.

- *Section 1: the formal introduction to RMS.*
- *Section 2: an overview of the major objects of RMS and their relationships, to provide a general context for the technical detail that follows.*
- *Sections 3-6: concepts for recipes, recipe namespace, distributed recipe namespace, and recipe executor.*
- *Section 7: the concept of the* agent *and of* service resources*, to provide a more complete context for RMS implementations.*
- *Sections 8-11: behavior (operations) for recipe management, namespace management, distributed recipe namespace management, and the* recipe executor.
- *Sections 12-14: definitions of message services for the* recipe namespace, distributed recipe namespace, *and* recipe executor ***service resources****.*
- *Section 15: RMS compliance.*
- *Section 16: a glossary of terms, provided as a convenient reference.*
- *Related Information: provides background information on the requirements behind RMS and examples of applications.*

1.8 *Applicable Documents*

ISO/TR 8509:1987, Information Processing Systems, Open Systems Interconnection — Service Conventions.

2 Overview of RMS

This section provides an introduction to, and overview of, the major objects of RMS.

2.1 *Recipe Management Models* — To provide a clearer understanding of the major entities or areas of functionality specified by RMS, they are portrayed as objects in RMS models, using OMT notation.

Relationship lines in the object-based models do not represent a direct communication link between objects, but rather the knowledge and association that one object has with respect to another.

The models do not indicate the relative location of two objects.

2.2 *Major Objects in RMS* — Recipe Management is concerned with the major areas of functionality illustrated in Figure 2.1: recipes[3], **recipe namespaces** providing persistent recipe storage, **recipe namespace managers** that provide management of the *namespace* and access to its recipes, and the **recipe executor** that executes recipes.

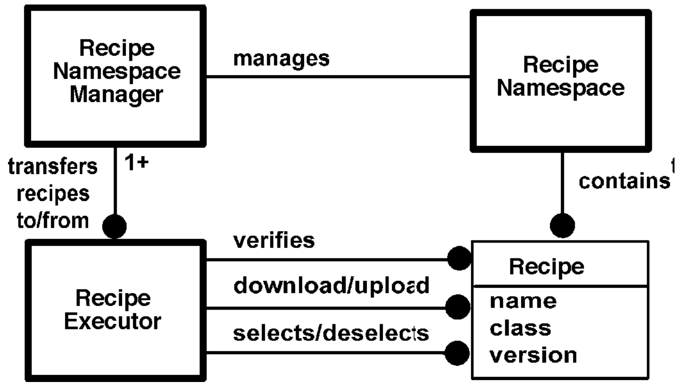

Figure 2.1
Major Objects of RMS

2.2.1 *Recipes* — Recipes provide a flexible, manipulatable, and re-usable form for users to select sequencing and settings to effect a particular result. Equipment uses recipes in a variety of ways to control the processing environment, sometimes using several types of recipes together. Recipes may also be used for maintenance activities, such as calibration or cleaning.

Recipes can be modified and copied from one environment to another. Their inherent flexibility as a form also becomes an endless source of problems unless they can be managed. Misprocessing, unintentionally running the wrong recipe for a given product, is prohibitively expensive for factories.

RMS defines a recipe as an object with attributes — information about the recipe — as well as content. It is the attributes of the recipe that allow true management of recipes, throughout their lifecycles, to occur.

2.2.2 *Recipe Namespace* — A *recipe namespace* in RMS is analogous to a smart file directory. The *namespace* provides long-term recipe storage capability.

Basic operations are part of the *namespace* specification. For example, recipes can be copied from one *namespace* to another, copied within a *namespace*, renamed, created, updated, and deleted. They can be downloaded to, and uploaded from, an application called a *recipe executor*. Several recipes can be *linked* together to form a set.

The *namespace* also can serve as a recipe pool that can be shared by a group of equipment of a common type. The *distributed recipe namespace* is a *namespace* able to utilize and manage recipe storage provided by such an equipment group.

2.2.3 *Recipe Namespace Manager* — The *recipe namespace* itself is passive, a container for recipes. The **recipe namespace manager (manager)** provides the dynamic element that manages the *namespace*. The *manager* represents the interface for the *namespace* to the external world and the internal decision authority within the *namespace*.

---

3 The recipe object in Figure 2.1 is not itself a standardized object. However, two recipe subtypes defined in Section 3 are standardized objects.

2.2.4 *Recipe Executor* — The **recipe executor (executor)** is the component of an *agent* that understands the contents of a recipe and is able to **verify** their syntactical correctness and to **validate** that it can be executed under the current configuration. It **executes** a recipe by reading its contents and applying them appropriately in order to achieve a desired result.

The *recipe executor* also may provide additional limited storage capability, but it is restricted from modifying existing recipes, except under special conditions, to prevent unexpected and/or unwanted change.

2.3 *Agent* — As used in RMS, an **agent** is a system, or subsystem, in a factory, that has a physical aspect. It consists of one or more applications that provide and/or use *service resources*, such as a *recipe namespace manager* and/or a *recipe executor*, as illustrated in Figure 2.2.

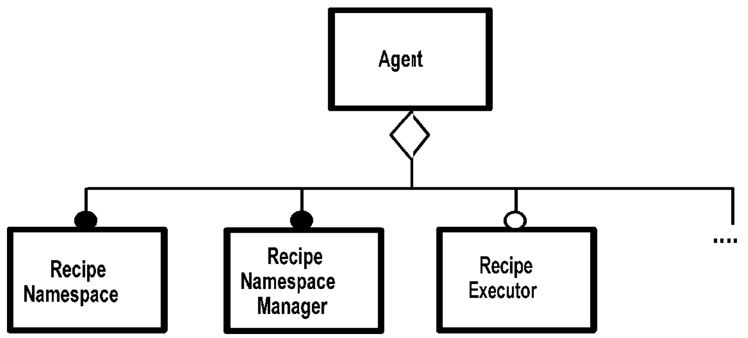

Figure 2.2
An Example of an Agent and Component Applications

Agent is a generalization that covers traditional *equipment*, supervisory or aggregate systems such as stations, cells, and clusters, and intelligent subsystems within *equipment*, such as process modules within a cluster. Other types of *agents* may also be implemented, such as those dedicated to *recipe namespace management*.

An *agent* that provides a *recipe executor* is called an **executing agent**. **Equipment** is an *executing agent* with associated hardware to which the recipe applies and which it uses to do work.

2.4 *Implementations* — RMS can be implemented on different platforms within a factory. A host controller may only provide *recipe namespace management*, while a diskless cluster module may provide only *recipe execution*. Traditional *equipment* capable of operating in stand-alone mode is required to provide a *recipe namespace* that is available on powerup as well as a *recipe executor* component. Additional examples of implementations of RMS are provided in Related Information 1.

RMS defines the services provided through an external interface. Communications between or within applications that are internal to an *agent* are not covered by RMS, so long as the attributes and operations comply with RMS requirements.

3 Recipes

This section describes the concepts concerning recipes.

3.1 *Motivations* — Definitions of recipe structure, attributes, and operations address the following issues:

- *maintenance of recipe attributes for management and traceability,*
- *provision of a standard method for transferring attributes separately, as well as with the recipe body,*
- *reduction or elimination of the need for dedicated recipe editors,*
- *support for applications requiring multiple recipe types, such as formats or language syntaxes,*
- *run-to-run control,*

- *support for sorting by factory approval and* ***certification levels****,*
- *the ability to tune a generic recipe for a specific installation of agent as well as the same agent over time, and*
- *the ability to share recipes across* executing agents *supporting the same recipe syntax or language(s).*

3.2 *Basic Concepts* — There are two types of recipes addressed by RMS, the **managed recipe** that is stored in a *recipe namespace* and the **execution recipe** that is stored in **recipe execution storage**. This section describes the basic concepts concerning both types of recipes.

3.2.1 *Types of Recipes* — There are three types of recipe objects shown in Figure 3.1. Most of Recipe Management is concerned with the management of recipes stored in a ***recipe namespace***. These recipes are called **managed recipes**. Recipes are also stored by the *recipe executor* in the **recipe execution storage**, and these are called **execution recipes**.

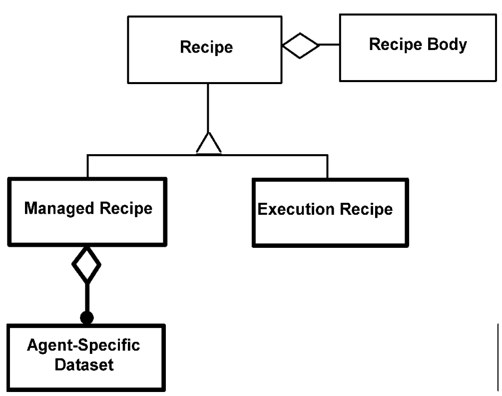

Figure 3.1

Recipe Types

The recipe supertype is an abstract type that shows the common elements and attributes of the *managed recipe* and the *execution recipe* and their differences. The recipe supertype is not itself intended to be implemented. That is, recipe object types formally defined in RMS are either *managed recipes* or *execution recipes*. As indicated by the light lines, the supertype is not a *standardized object*.

3.2.2 *Recipe Structure* — Both the *managed* and the *execution* recipe have a **body**[4] and a set of attributes. The *body* (contents) of the recipe contains the data used by the *recipe executor* for its execution process. The *body* is also not a *standardized object* and may not be accessed through Object Services.

Figure 3.2 illustrates all of the attributes defined by RMS that are common to both the *managed recipe* and the *execution recipe*. Not all of these attributes are required for a minimum implementation of RMS. The rules for setting the values of certain attributes, however, are different for the *managed recipe* and the *execution recipe*.

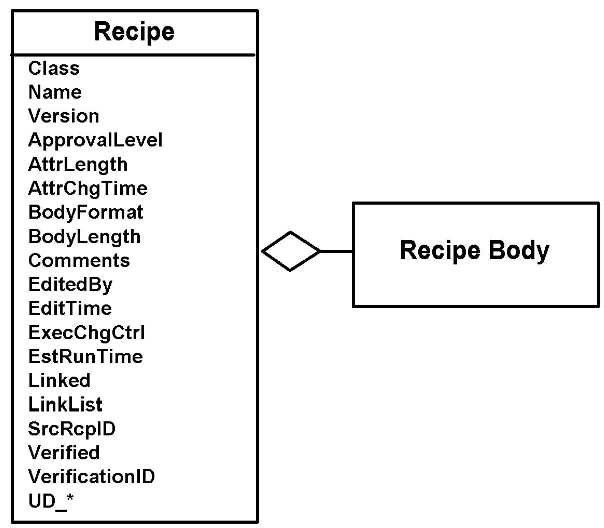

Figure 3.2

Recipe Supertype

The **identification attributes**, those attributes used for purposes of identification, are discussed in Section 3.3. The other attributes are discussed in later sections specific to each recipe type.

The *managed recipe* also may maintain a set of attributes that are specific to a single *executing agent*. The **agent-specific** attributes are technically attributes of the association between the recipe and the *executing agent*. In RMS, however, these attributes are treated as attributes of a component of the recipe called the **agent-specific dataset**, in order to allow them to be managed within the *namespace* along with the other attributes of the recipe. *Agent-specific* attributes allow the recipe to be personalized for particular *executing agents* (i.e., particular *recipe executors*).

4 The recipe's body corresponds to a "process program" in SEMI E5 and SEMI E30.

Because the *managed* recipe may be applied to multiple *agents*, it may have multiple *agent-specific datasets*. When a *recipe* is downloaded from a *recipe namespace* to a *recipe executor*, the *managed recipe* is transformed into an *execution recipe* by taking the *agent-specific* attributes of the *agent-specific dataset* for that *agent* (its *recipe executor*) and merging them into the attributes of the *execution recipe*.

Methods of storing a recipe or the components of a recipe are not dictated by RMS. However, the association between a recipe's *body* and its attributes shall be carefully maintained.

3.2.2.1 *Recipe Body* — The recipe **body** contains the reusable instructions, *settings*, *parameters*, and other data that the *recipe executor* reads to *execute* the recipe and control its operation.

A recipe *body* may be in one of two basic forms: **source** (text) or **object**. The purpose of the *source form* is to encourage the use of human-readable and human-editable text. The *object form* supports the types intended only to be read and applied by machines and other automated systems, such as those produced by vision systems or CAD programs, as well as proprietary formats created and used by the *recipe executor*.

3.2.2.1.1 *Source Form* — Recipes that are created and modified by a form of editor should be available in *source form*. The **source form** of a recipe *body* is equivalent to a text file, such as ASCII or JIS-8, that can be created, read, printed, or modified with any "standard" text editor[5]. The *executing agent* is not required to supply such a text editor, but its *recipe executor* should be able both to read and write recipes in *source form*. Editing is not covered by RMS.

The *source form* of a recipe may be copied from one *namespace* to another *namespace* and from a *namespace* to a *recipe executor's recipe execution storage*, and all *recipe executors* with access to a given *namespace* are assumed to use the same recipe language and the same functionality.

Two restrictions are placed on the interpretation of the text transferred between agents:

- *In ASCII, the valid characters are from space* (20_{16}) *through "~"* ($7D_{16}$)*, plus the tab* (09_{16})*, linefeed* ($0A_{16}$)*, carriage return* ($0D_{16}$)*, and form feed* ($0C_{16}$) *characters. The space and tab are considered as* ***horizontal whitespace*** *characters, and the carriage return and form feed characters are considered* ***vertical whitespace*** *characters. The line-feed character is used to define the end of a line of text (eol).*

- *The meaning of a recipe should not depend on embedded control characters, or specific* whitespace *characters, or the existence of* whitespace *at the end of a line.* Horizontal whitespace *characters should be treated alike for purposes of interpretation, as should* vertical whitespace *characters. All other characters, aside from those specified here, are discouraged and, if found, should be removed from the text prior to transfer.*

In general, the recipe language and syntax used within a recipe *body* are beyond the scope of recipe management. However, to reduce arbitrary variability for the *user*, the following "rules" are recommended:

- *Case is not significant for the purpose of comparison or meaning but should be retained as encountered, since it is often used to enhance readability. For example, the tokens alarmlevel, ALARMLEVEL, and AlarmLevel should all have the same meaning.*

- *Comments may be included in the text and are ignored in recipe interpretation. Two types of comments are defined: comments that begin with the character pair "//" continue to the end of the line, while comments that begin with the character pair "/*" are terminated only by the character pair "*/". A comment of the second type is terminated by the first character pair "*/" that follows. Comments may not be nested. Nested comments are not honored and may generate a syntax error.*

- *The minimum line consists of a single line-feed character.*

In addition, recipe languages that support **external references** to other recipes should use the text form defined for the recipe *identifier* (Section 3.2.3.4) and for the recipe **specifier** (Section 3.2.4.1.2).

The supplier of the *recipe executor* shall provide documentation that formally defines each recipe language that the *agent* supports. Two forms are required, one for the *user*, who must be able to write correct recipes, and one that covers both the syntactical and lexical structures of the language using a formal descriptive protocol such as the Backus-Naur Form (BNF). The second form of documentation allows parsers to be built that are capable of pre-checking a recipe for syntactic and lexical correctness prior to downloading it. Pre-checking improves efficiency and

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5 The intent is not to specify the text editor, but rather to allow a user to modify text on the basis of clear guidelines and restrictions that may apply. Source form recipes are highly desirable to reduce the proliferation of, and need for, proprietary editors that are dedicated and language-specific.

performance by reducing the demand for recipe checking by the *recipe executor*.

The final responsibility for determining the correctness of a recipe shall belong to the *recipe executor*.

3.2.2.1.2 *Object Form* — Recipes that cannot be translated into a meaningful *source form* include datasets derived from vision systems or mechanical systems through a special hardware-dependent "teach" operation. Such recipes may remain in a proprietary *object form* and may or may not be applicable to other *recipe executors* because of their hardware dependencies.

For greater efficiency, *recipe executors* may rewrite (e.g., **tokenize**) a *source* recipe to generate a proprietary *object form* of the recipe. This is called the **derived object form**, to distinguish it from *object form* recipes that never exist in *source form*. The *agent's* manufacturer may choose to make this form available for transfer as well. From the point of view of the *supervisor*, the *body* of a recipe that is in *object form* is an unstructured binary vector or string. In general, it cannot be edited on a *supervisor*, and the *source form* of the recipe is still required. *Derived object form* recipes that cannot be used by multiple *recipe executors* should not be stored in *recipe namespaces* that are shared.

Where both the *source form* and the *derived object form* exist, the *identifier* for the *object form* of the recipe shall be different from that of the *source form* in some recognizable way. The supplier of the *recipe executor* shall provide a documented method for distinguishing one from the other within the *identifier*. This method must be such that the relationship of the *derived object form* recipe from the original source recipe is obvious to the user. (See Section 3.2.3.4 for examples.) An attribute of the recipe, SrcRcpID, is provided to retain the relationship between the *source form* recipe and the *derived object form* recipe.

3.2.3 *Recipe Identification* — The ability to properly and unambiguously identify a recipe is critical to both recipe management and processing. It is also important for the user that identification be logical. RMS defines three elements used to uniquely identify a recipe within any *recipe namespace*. These three elements are the recipe's **class**, **name**, and version. Each element is expressed as a text string, and they are concatenated together to form the **recipe identifier** (see Section 3.2.3.4).

3.2.3.1 *Recipe Name* — The **recipe name** is a user-defined text string that may be used to encode the technology, layer, manufacturing area, and other characteristics. The *recipe name* alone is not necessarily unique within either a given class or a given *namespace*.

The *recipe name* is subject to the conventions for text as defined in Section 1.5.1.

3.2.3.2 *Recipe Class* — A **recipe class** is a formal grouping of recipes that have a common syntax. A class may contain **subclasses** where the recipes within the *subclasses* operate in different environments or have different syntaxes from the parent *class* and/or from one another. A *subclass* is itself a *class* and may contain further *subclasses*.

The overall model for recipes is a set of *class* hierarchies or "*class* trees" defined by the supplier of the *recipe executor*. The major *classes* of recipes are the **PROCESS** *class*, the **SERVICE** *class*, and possibly other *agent-specific classes*. These are called **primary classes**. A **primary class** is a *class* that is not a *subclass* of another *class*.

The PROCESS *class* is a required *primary class* and is composed of recipes whose primary purpose is to increase the manufactured value of the production material[6].

The SERVICE class is an optional *primary class* used for recipes whose purpose is to maintain, prepare, calibrate, or test the operation of *equipment*. Typical *subclasses* of the SERVICE *class* might be CALIBRATION and CLEANING. SERVICE recipes that use the same recipe language as normal process recipes are not required to be placed into a separate *primary* class. The SERVICE class allows separation and use of a different syntax for special non-process purposes.

Other *primary classes* that do not fit the PROCESS or SERVICE may be provided by the supplier of the *recipe executor*. Such additional *classes*, and their function, shall be documented.

Recipes that are not in the PROCESS *class* or one of its *subclasses* shall not be used for production purposes. However, recipes within the PROCESS class may be used for purposes other than production.

Figures 3.3 and 3.4 show examples of object models of possible *classes* and *subclasses* for a wire-bonder and for a furnace with an automatic boat-loader subsystem.

6 Material handling systems, wafer metrology, wafer measurement, wafer inspection systems, as well as process equipment which directly changes the characteristics of the material, increase the value of the material in some way.

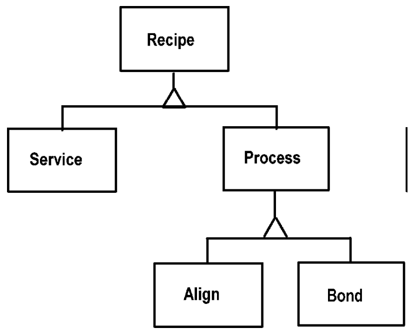

Figure 3.3

Wire-Bonder Recipe Classes

The text form of a recipe *class* shall conform to the convention for text (Section 1.5.1). Within the text form of a recipe *identifier*, a class is delimited on both ends by the forward slash character "/". The complete *class* specification within recipe *identifier* is formed by the concatenation of *classes* and *subclasses*, starting with the *primary class* and ending with the particular *class* of the recipe in question:

"/PRIMARY CLASS/SUBCLASS$_1$/SUBCLASS$_2$/…".

For example, a recipe named DryOx, version 4, within the NORMAL CYCLE *class* in Figure 3.4., has an *identifier* of

"/PROCESS/FURNACE/DIFFUSION/NORMAL CYCLE/DryOx;4".

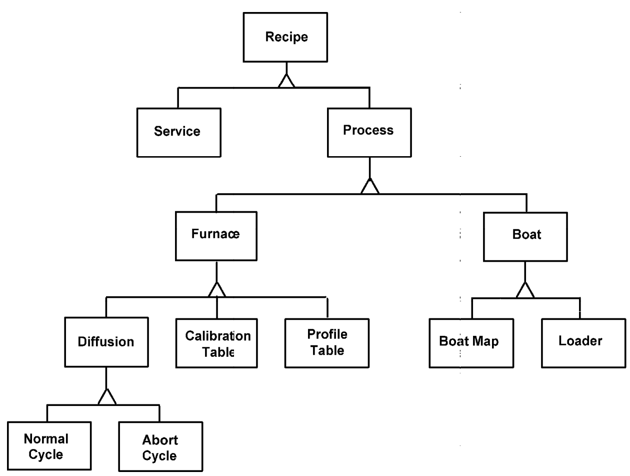

Figure 3.4

Recipe Classes for Furnace

The complete *class* specification, which always starts with the *primary class*, shall always be accepted. If *class names* within a *namespace* are all unique, however, the *service* provider may also accept a *class* designator consisting of a single *class*. The *identifier* in the example above then becomes

"/NORMAL CYCLE/DryOx;4".

3.2.3.3 *Version* — A recipe may evolve over time and exist in several versions. This allows the user to retain a recipe *name* over multiple versions and show the recipe's heritage. Different versions are identified by the **version** portion of the recipe's *identifier*. NOTE: More than one version of a recipe may be in use for production at the same time, not only within the factory, but also within a single equipment.

A **version** is a text string consisting of at least one character. A new *version* is either generated automatically by the *recipe namespace* or is assigned by the *user*. A *user* may assign any combination of text characters and punctuation marks to the *version*, except for:

- *the characters prohibited by the convention for text usage and the object identifier (Section 1.5.1),*
- *whitespace characters.*

It is recommended, but not required, that only upper case be used.

Numeric versions (**version numbers**) consist only of the digits "0" through "9" and one decimal point character "." and can be translated to a pure number. To avoid confusion and multiple *versions* with the same numeric value, *numeric versions* are further restricted as follows:

- *whole numbers (with no decimal point) may not start with a zero "0" followed by another digit, and*
- *decimal numbers (with a decimal point) may not start or end with the decimal point or end with a zero following the decimal point.*

For example, *version numbers* "09", "1.", ".5", and "1.670" are prohibited. The proper forms with the same numeric values are "9", "1", "0.5", and "1.67". The *user* may assign a *version* of "0" but not of "00".

Versions that are assigned automatically have additional restrictions:

- *They shall be* numeric versions*, excluding the decimal point and with a minimum value of "1".*
- Versions *shall be assigned incrementally. When assigning a* version *for a recipe with a given* class *and* name*, if no other recipe exists within the* namespace *with that* class *and* name*, then a* version *of "1" is assigned. Otherwise, the highest* existing version *already in use for that* class *and* name *is determined, and the new* version *is assigned a value equal to that value plus 1. For example, if the highest* version *in use has a numeric value of 5, then the next* version *assigned would be "6". To compare* two versions*, they are converted to upper-case and compared character by character.*

3.2.3.4 *Recipe Identifiers* — The **recipe identifier** is formed from the concatenation of the recipe's *class*, *name*, and *version*, in that order:

"/$CLASS_1$/$CLASS_2$/…/$CLASS_n$/NAME;VERSION"

where $CLASS_1$ is a *primary class* and $CLASS_{i+1}$ is a *subclass* of $CLASS_i$. The recipe *name* follows *class*. *Name* and *version* are always separated by a semicolon ";" ($3B_{16}$).

Where $CLASS_n$ is a unique class name, the form becomes

"/CLASS/NAME;VERSION".

The recipe *identifier* is used for the OSS-required attribute ObjID and shall conform to restrictions imposed on ObjID (see SEMI E39). The total length of ObjID may have additional restrictions imposed by the protocol.

NOTE: There is no necessary relationship between a recipe's *identifier* or *name* and any file name(s) under which the *body* and attributes may be stored internally. The recipe *identifier* is a logical reference to the recipe that is independent of specific platforms and implementations. In particular, file services provided by operating systems may have naming restrictions, such as length, that are incompatible with the requirements of RMS. A recipe may be stored internally in different ways, such as in a single flat file, a set of related files, or a database. Actual storage methods shall be invisible to RMS.

Where suppliers supporting recipes in *source form* also rewrite them, as discussed in Section 3.2.2.1.2, a method based on the recipe *identifier* (ObjID) is required to both distinguish between the two *forms* and to recognize the relationship between the original *source form* recipe and the derived *object form* recipe. The method may use any of the three elements of the *identifier* for this purpose. For example, recipes in *object form* may be placed in a separate *subclass* called "/OBJ/", or a suffix such as ".obj" might be appended to the user-defined *name* of the original recipe.

3.2.3.4.1 *Default Recipe Identifiers* — It is always possible to reference a recipe by specifying its *full identifier* (*class*, *name*, and *version number*). In certain cases, described in Section 3.2.4.1.1, it may also be necessary to specify the *namespace* of a recipe. However, it is not always necessary to specify all components of the *identifier*. Specifically, *class* and/or *version* may be omitted when a recipe is *selected* for execution and within an *external reference*. *Namespace* is not normally specified. Rules define default values for *namespace* and *class*, and there are rules for determining the appropriate *version*.

The recipe *name* must always be specified.

For *external references* within a recipe, the default *class* is the *class* of the recipe making the reference. The proper *class* is determined when the recipe is *linked* (see Section 3.2.4.1.3).

Where a recipe *version* is unspecified, the recipe of that *class* and *name* having the highest *approval level* will be used. Where several recipes are found with the same *approval level*, the one with the highest *version* will be used. Where the *version* is unspecified in an *external reference*, the correct *version* is determined when a **linked recipe set** is built by the **link** operation.

For references with *managed recipes*, if no *namespace* is specified, the default is *namespace* of the referring recipe.

3.2.4 *Advanced Recipe Capabilities*

3.2.4.1 *Multi-Part Recipes* — Use of multi-part recipes is often dictated by the *recipe executor*, which may require a set of recipes of different *classes* for its process. In addition, support for multi-part recipes can be helpful for the user, in particular where recipes are otherwise long. The recipe language may define use of subrecipes analogous to that of subroutines in ordinary programming languages. This enables better re-use where a high degree of similarity exists between different recipes.

Where recipes of more than one *class* are required, it is convenient to allow one recipe to reference another. A recipe in the PROCESS *class*, for example, may refer to recipes in other *classes* to ensure that an entire set of recipes is *executed* together.

It is also convenient to allow one recipe to reference other recipes within the same *class*, where a substantial set of instructions and/or *settings* are common to a variety of other recipes.

A reference within the *body* of one recipe to a different recipe is called an **external reference.** The exact syntax in which this is done is determined by the recipe language used. An *external reference* may also specify values for *variable parameters* defined in the referenced recipe or in one of its *subrecipes*.

3.2.4.1.1 *Subrecipes* — When one recipe references another recipe, both recipes are required for *execution*. The starting recipe is called the **main** recipe.

Subrecipes are those recipes that are referenced by the *main* recipe, or by another *subrecipe* of the main recipe. A recipe that references other recipes is a **parent** recipe to the referenced *subrecipes*. A parent recipe is not necessarily a *main* recipe. A main recipe must not be referenced by any of its *subrecipes*.

External references to recipes within the same *namespace* may or may not be explicit. That is, references to the current *class* (i.e., the *class* of the recipe being *verified*) may be implicit, and *versions* may be left to the rules for determining the default *version* at *link-time*.

A recipe may also reference recipes in another *namespace*. This occurs either when a recipe is to be **delegated** or when a recipe in a *namespace* accessed by multiple *agents* must reference a hardware-dependent or other *agent-specific* recipe kept in a **default namespace**. The *default namespace* of a *recipe executor* is always referenced within a recipe as the namespace named "Default". This name is interpreted by the *recipe executor* at execution time, based on its attribute DefaultNamespace (see Section 6.3).

When specified in a text string within a recipe with the subrecipe's *identifier*, the *identifier* is preceded by the value of the *namespace's* identifier, followed by a greater-than symbol ">". This is called the **recipe specifier**. For a recipe ETCH version 5 in a *namespace* named "NS-MOM", this would be specified as

“NS-MOM>/PROCESS/ETCH;5”.

According to the rules of OSS, object type may be omitted when it may be otherwise determined. In RMS, determination is made according to order.

3.2.4.1.2 *Delegated Recipes* — A recipe may reference recipes in another *namespace* that are to be executed by a *component agent* and are termed **delegated recipes**. Although referenced by another recipe, *delegated recipes* are not considered as *subrecipes* of the *parent* (referencing) recipe as they are to be *executed* by a difference *agent* and are themselves required to be a *main* recipe. A reference to a *delegated recipe* is the equivalent to an automated "select" and "start" sequence of commands from the *supervisor*. As such, they are generally subject to the constraints of a *select* operation.

Delegated recipes may or may not require the *name* of the *executing agent* (*recipe executor*), depending on the rules of the particular implementation. For example, a *supervisor* may be able to determine the appropriate *executing agent* at run-time, based on the *namespace* specified. However, the ability to specify a particular *executing agent* is important to the user, as process results may be sensitive to a particular equipment installation. Therefore, recipe languages that support delegation shall allow specification of the particular *executing agent* to be used. The text format of the full **recipe specifier** in this case is:

"Agent-Name>Namespace-Name>CLASS/Name;Version".

The required order of *identifiers* within the *specifier* is: agent, *namespace*, recipe.

3.2.4.1.3 *Linked Recipe Sets* — Where one recipe references another, a set of recipes to be executed together is formed by starting at the *main* recipe and collecting the *external references* to identify all the members of the set. This set is called a **linked recipe set**, and the operation of collecting the references is the **link** operation.

3.2.4.2 *Variable Parameters* — **Variable parameters** are variables that can be assigned values from outside the recipe itself. *Variable parameters* allow recipes to use variables rather than constants for such actions as setting temperature setpoints, time delay intervals, and data-set names. This capability greatly extends the re-usability of a recipe.

A *parameter* first is formally **defined** within a recipe body and given a unique **parameter name**, a **parameter initial value** (default value) for use when the recipe is *selected* for execution, unless overridden. Where applicable, the *definition* also includes a **parameter restriction** that represents one or more conditions that any *value* assigned to that *parameter* is required to satisfy to be valid.

The syntax for *parameter definitions* in recipe *bodies* remains unspecified, so long as it conforms to the syntax of the recipe language and contains the required elements. Other restrictions concerning the use of *variable parameters* may be imposed by the *recipe executor's* supplier through the specification of the recipe language.

The **parameter domain** is the set of all possible values of a given *form* (see Section 1.4.3) that fulfill the conditions of the **parameter restriction** (if any).

The form need not be included in the *parameter definition* declared within the recipe *body*, but rather may be derived by the *recipe executor* during the *verification* process from the way in which the *parameter* is applied within the recipe. If temperature is maintained internally as an unsigned integer, for example, those *parameters* that are used in the recipe to assign temperature setpoints and ranges would typically be required by the supplier of the *executing agent* to represent unsigned integers as well. The supplier shall document the forms and valid *domains* for each of the *parameters* that may be used as a *variable parameter*.

NOTE: The *parameter's value* may be changed from its *initial* (default) *value* within the text of a recipe, and it may also be set as an "argument" passed to a *subrecipe*. These capabilities are a function of the recipe language and are beyond the scope of RMS.

Two categories of *parameters* are defined: **numeric** and **non-numeric**.

3.2.4.2.1 *Numeric Parameters* — *Numeric parameters* include all *parameters* that can take on *any numeric value* for its *format type* between a **parameter low limit** and **parameter high limit**.

The *parameter restriction* for a *numeric parameter* in any of the attributes that store *parameter definitions* shall be a text string that conforms to one of the following:

- *"(a,b)└┘UNITS" the* domain *of numbers x such that* $a<x<b$
- *"(a,)└┘UNITS" the* domain *of numbers x such that* $a<x<+\infty$
- *"(,b)└┘UNITS" the* domain *of numbers x such that* $-\infty<x<b$
- *"UNITS" the* domain *of numbers x such that* $-\infty<x<+\infty$.

where:

1. a and b are *numeric values* formed from the digits "0" through "9", the plus and minus signs "+" and "-", the period ".", and the letters "E" or "e" for floating point numbers,
2. └┘ represents optional *whitespace*, and
3. UNITS is a valid case-sensitive string conforming to the Units of Measure Identifiers (see SEMI E5, Section 9).

For example, both of the following strings are valid: "(500,2000)└┘degC" and "(0,100)".

To include equality, parentheses are replaced by the square brace "[" and/or "]" on the left or right end, respectively. For example, "[a,b)" represents the domain of numbers x such that $a \le x < b$.

To specify units only, with no restriction on range, the *low limit* may be set to $-\infty$ and the *high limit* to $+\infty$. However, the *low* and *high* limit shall not exceed absolute minimum and maximum limits set for that *parameter* by the *recipe executor's* supplier.

Numeric parameters with no *parameter restriction* are pure numbers (with no units) with a domain of $(-\infty,\infty)$.

A *numeric parameter* shall have a *format type* of one of the following:

- *text string of a length of no more than 80 characters,*
- *signed or unsigned integer of an even length,*
- *floating point number of an even length.*

Text strings are restricted to the character set defined above to represent the *low* and *high limits* of the *domain* and shall convert to a *numeric value* within that *domain*.

3.2.4.2.2 *Non-Numeric Parameters* — A **non-numeric parameter** is any parameter other than a *numeric parameter*, including *parameters* whose *domains* are sets of discrete numbers that cannot be represented by a single mathematical interval, and strings that represent names. *Non-numeric values* may or may not place restrictions on the replacement *value*. A *parameter* that contains the name of a wafer map, for example, cannot be easily restricted by a general rule[7], whereas a *parameter* that contains a string identifying thermocouple type can be restricted to one of a defined, unordered set of valid strings. Restrictions for *non-numeric parameters* might also consist of, or include, logical expressions that shall evaluate to TRUE before a value may be used.

If a recipe language has been defined for the corresponding *class* of recipes, the syntax for the *restriction* is taken directly from the formal *definition* of that *parameter* within the body of a *source form* recipe (and therefore conforms to the specification for that recipe language). Otherwise, the restriction is expressed in a syntax defined by the *recipe executor's* supplier specifically for *parameter* attributes.

For example, the *parameter* for a furnace recipe may specify which set of PID *values* should be used, where sets A-F exist on the *equipment*. The automatic *restriction* on the *value* for such a parameter, as specified by the *recipe executor's* supplier, might be "{A,B,C,D,E,F}" with the default for the *value* specified as the character "C" with a *format type* of "ASCII string of length 1".

In another example, a *restriction* might be that the *value* be taken from the enumerated set

"{cassette, lot , batch }".

3.2.4.2.3 *Agent-Specific Parameters* — In order to "tune" a recipe so that it produces the same result on all *recipe executors* of the same type, it may be necessary to provide a different *initial value* for the *parameter* or a different *parameter restriction* for individual *executing agents*. A special editing facility may be provided by the *recipe manager* to allow the original *value* and/or *restriction* of a *parameter* to be modified for a specific *executing agent*.

NOTE: *Agent-specific parameter definitions* replace the corresponding original *definitions* in the recipe that is *downloaded* to the *recipe executor*. At run-time, they are superseded by *parameter values* specified for the *recipe executor's select* operation.

3.2.5 *Attributes* — The name of an attribute is a text string required to be unique for its object. The names of the attributes defined in this document are reserved for their standard use.

Identification attributes are those used to identify the object in OSS. These attributes are available through OSS, but in RMS, services are handled separately from the other attributes and are not transferred in parameters for "recipe attributes".

Attributes other than *identification* attributes and **mandatory** attributes discussed below always have a defined **default value**. Attributes with a *default value* not otherwise specified are considered to have a **null value** corresponding to their form as their *default value*. The *null value* for a text string is a zero-length string. The *null value* for a numeric form is zero. The *null value* for a boolean form is FALSE. The null value for an empty list or structure is an empty (zero-length) list. The manner of representing *null values* is left to the protocol.

An attribute is **cleared** or **reset** by setting its value to the *default value*.

Mandatory attributes are attributes that are required to always have a *non-default value*.

Certain attributes are **required**, including all *mandatory attributes*. A **required** attribute is one that shall be supported with a *non-default value*. For example, the BodyFormat attribute is *required*. This means that *object form* recipes (for which BodyFormat has a *non-default value*) shall be supported by a *namespace*.

Any attribute defined in this standard shall only be modified according to the rules specified for that attribute.

Attributes of the *managed recipe* and the *execution recipe* may be accessed through Object Services. However, only certain of the attributes may be set through Object Services.

For purposes of OSS, all attributes defined in RMS shall be *recognized*. That is, a response to a GetAttr service request that references any attribute of an object defined in RMS for that object shall not return an "invalid attribute" error. If the attribute is not supported by the application, then it shall show the value of that attribute as having the null value appropriate for its form, and it shall deny attempts to set its value through the SetAttr service.

7 Typically, the validity of parameters which are unrestricted names can only be established at run-time.

3.2.5.1 *Descriptors* — Two types of *mandatory* attributes of particular importance are the **timestamp** and **length** attributes. These are provided for the *body*, for each *agent-specific dataset*, and for the set of attributes of the recipe object itself, including the *timestamp* and length attributes of the *body*.

A **descriptor** contains the *length* and *timestamp* attributes (in that order) of one or more of the aspects of a recipe: its attributes, its *body*, or an *agent-specific dataset*. *Descriptors* are used to compare two recipes stored in different *namespaces* or in a *namespace* and in the *recipe execution area* of a *recipe executor*.

NOTE: Provision of a real-time clock or other device capable of counting time in centiseconds greatly improves the value of the *timestamps* for this comparison.

3.3 *Full and Minimal Recipe Models* — Figure 3.5 contains an object model for the *managed* and *execution* recipes supporting all of the standard *attributes* defined in RMS. *Non-identifier* attributes are shown in alphabetical order. Many of these attributes are not required for minimal applications. Minimal models for the *managed* and *execution* recipes are shown in Sections 3.4.2.3 and 3.5.2, respectively.

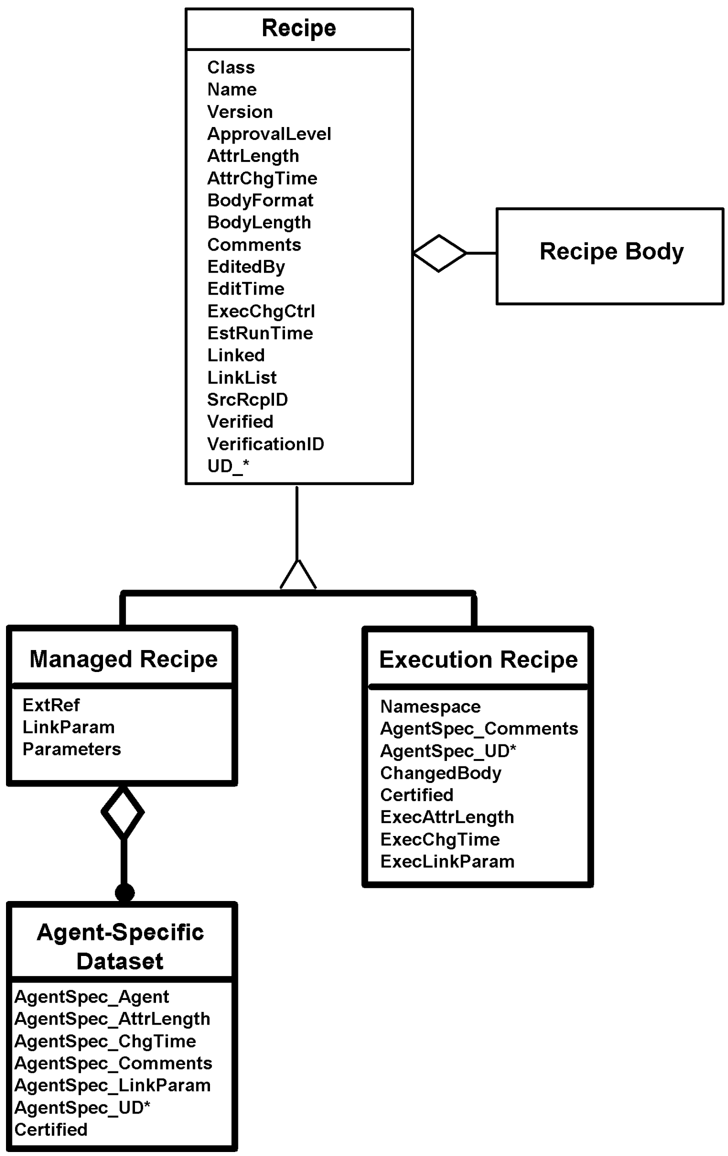

Figure 3.5
Full Recipe Object Model

3.4 *Managed Recipes* — This section defines the *managed recipe* and its attributes.

3.4.1 *Generic Attributes* — For clarity, the attributes of the *managed recipe* are sometimes called **generic** attributes to distinguish them from *agent-specific* attributes or attributes of the *execution recipe*.

Attributes that are not specifically defined in this standard may be defined by an application or by the user. Attributes that are defined by a *namespace* or by a *recipe executor* for its own use shall be changed only by rules specified and documented by the originator of the attribute.

To prevent conflict between non-standard attribute names and names which may become standard in the future, non-standard attribute names shall start with the prefix "UD_" (the two characters "U" and "D" followed by the underline character). It is the responsibility of the originator to provide unique attribute names. When using other RMS services, non-standard attributes shall follow all standard attributes.

It is desirable that a method be provided for the user to define new attributes.

3.4.1.1 *Timestamp Attributes* — **Timestamp** information (date and time of the last change) is important to recipe management. *Timestamp* attributes are maintained by the *recipe namespace* and may not be changed otherwise.

A **timestamp** attribute shall always contain the date and time that the particular aspect of the recipe was last changed. This attribute is a text string of the form "yyyymmddhhmmsscc" for the year yyyy, the month mm, the day dd, the hour hh, the minutes mm, the seconds ss, and the centiseconds cc.

The *timestamp* of the *body* is called EditTime and is set when a recipe is first **created** and updated whenever the *body* is modified in any way.

Because a recipe's attributes may be changed without changing the body, both the recipe's *generic* attributes and each set of *agent-specific* attributes themselves each have a *timestamp* attribute. For the *generic* attributes, the *timestamp* attribute is called AttrChgTime. The set of *agent-specific* attributes (of an *agent-specific dataset*) has its own *timestamp* attribute, called AgentSpec_ChgTime.

3.4.1.2 *Length Attributes* — There are three **length attributes**, one which contains the length of body, one that contains the length of the *generic* attributes, and one that contains the length of the *agent-specific* attributes. *Length* attributes are calculated without regard to either protocol overhead or storage overhead, such as proprietary formats used for internal storage that may change from one implementation to another. This preserves the length across different conventions used for recipe storage and different communications protocol.

The *length attribute* of the *body*, BodyLength, contains the length of the *body* in bytes. The *length* of the *body* is calculated as the number of bytes it will require when transferred, excluding any overhead, such as that which might be required for protocol format information.

The length of an individual attribute is calculated as the sum of the lengths of the attribute name and the attribute value.

The length of a set of attributes shall be calculated as the sum of the lengths of the individual attributes that are set to a *non-default value* at the time the calculation is performed, including the *length attribute* itself. All attributes set to their *default value*, at the time the *length* is calculated, are excluded from the calculation. This is because only the attributes with a *non-default* value are transferred when a recipe is moved into or out of a *namespace*. It also results in a more significant change to value of the *length* attribute when an attribute is set to a non-default value.

3.4.1.3 *Descriptors* — The *descriptors* of the *managed recipe* are the **body descriptor** (BodyLength and EditTime), the *generic* **attribute descriptor** (AttrLength and AttrChgTime), and the *agent-specific descriptor* (AgentSpec_AttrLength and AgentSpec_ChgTime). The **recipe descriptor** for a *managed recipe* consists of the *attribute descriptor*, the *body descriptor* (in that order), followed by *descriptors* of any existing *agent-specific datasets*.

3.4.2 *Managed Recipe Object Attribute Definitions* — This section provides the formal definitions for the recipe's *generic* attributes. For Object Services, a recipe is considered as the owner of its *components*, any *agent-specific datasets*. The *body* may not be accessed through Object Services.

Attributes in Tables 3.1 and 3.2 are presented in the following order:

- identification *attributes, including object type and identifier, appearing above the heavy line in Tables 3.1 and 3.2,*
- mandatory *attributes and the other required attributes, in the order in which they are to appear when a recipe is transferred,*
- *optional attributes in alphabetical order, and*
- *non-standard attributes, which are transferred last.*

When transferring a recipe with RMS services, *identification* attributes are not included in the list of attributes, and required attributes are sent, in order, before optional attributes. *Non-mandatory* attributes having their *default value* are not transferred, since their absence indicates their value, but they are always available through Object Services. Order of optional attributes is not dictated.

3.4.2.1 *Generic Attribute Definitions* — Table 3.1 provides the formal definition of the *generic* attributes of the *managed recipe*.

Table 3.1 Managed Recipe Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
Identification Attributes				
ObjType	The object type.	RO	Y	Text: "MRcp"
ObjID	An identifier derived from Class, Name, and Version. No part of a recipe's identifier shall be changed except through *renaming*.	RO	Y	Formatted text.
Name	A logical name assigned by the user when the recipe is *created* or *renamed*.	RO	Y	Text.
Class	The recipe's class (e.g., "/PROCESS/" or "/PROCESS/LOADER/").	RO	Y	Formatted text: "CLASS/CLASS/../CLASS/"
Version	The version of the recipe.	RO	Y	Text.
Mandatory Attributes				
AttrLength	The total length of the *generic* attributes, in bytes. *Mandatory*.	RO	Y	Unsigned integer.
AttrChgTime	Timestamp of the last change to a *generic* attribute. *Mandatory*.	RO	Y	Formatted text.
BodyLength	Length of the recipe's body, in bytes. *Mandatory*.	RO	Y	Unsigned integer.
EditTime	Timestamp of when the *body* was *created* or last *updated*. *Mandatory*.	RO	Y	Formatted text. *Timestamp* format.
Required Attributes				
BodyFormat	Indicates the form and format of the recipe's *body*. *Default* is zero.	RO	Y	Enumerated unsigned integer: 0 = *source*, 1 = *object*, > 1 reserved.
Verified	Indicates whether the recipe's body is syntactically correct. Reset when the recipe is *created* or *updated*. Default is FALSE.	RO	Y	Boolean.
Linked	Indicates whether the recipe is linked. Reset when the recipe is *originated*, *verified*, or *unlinked*. Default is FALSE.	RO	Y	Boolean.
Optional Attributes				
ApprovalLevel	Indicates the level of approval assigned by an *authorized user*. Default is zero. Reset when the recipe is *originated* or *linked*. For a *linked* recipe, may not be higher than any of its *subrecipes*.	RW	N	Unsigned integer.
Comments	User comments.	RW	N	Text. Maximum length is 80 characters.
EditedBy	The name of the person who last edited the recipe.	RO	N	Text. Maximum length is 40 characters.
EstRunTime	The nominal or estimated execution (run) time of the recipe, in seconds. Reset when the recipe is *created* or *updated*. Set when the recipe is *verified*. May be	RW	N	Unsigned integer.

Attribute Name	Definition	Access	Rqmt	Form
	recalculated to total time for a main recipe when *linked*. Used for scheduling purposes. Algorithm for calculation shall be documented. Default is 0.			
ExecChgCtrl	Specifies change control requirements for recipe. (See Section 6.5.)	RW	N	Binary. Bitwise (MSB = 8**). 1 - The recipe body may be changed, 2 - Change notification is required, 3 - Recipe may be selected after change, 4 - Most recent parameter settings shall be saved.
ExtRef	A list of all recipe *specifiers* as referenced within the recipe. Explicit *versions* not required. Reset when the recipe is *created*, *updated*, and *verified*.	RO	N	List of formatted text.
LinkList	A complete list of recipe *specifiers* found in the ExtRef attribute of a *main* recipe and all of its *sub-recipes*, with duplicates removed and all *versions* explicitly determined. Set for the *main* recipe when linked. Reset when the recipe is *originated* or *verified*. Required for multi-part recipe support.	RO	N	List of formatted text.
LinkParam	A list of all variable parameter definitions contained in the Parameters attribute of a *main* recipe and all of its *subrecipes*, with duplicates removed. Reset when the recipe is *created*, *updated*, or *verified*. Set when the recipe is *linked*. Required for *variable parameter* support.	RO	N	Structure composed of parameter name, initial value, and restrictions.
Parameters	A list of variable parameter definitions contained in the recipe. Reset when the recipe is *created*, *updated*, and *verified*. Set when the recipe is *verified*. Required only for *variable parameter* support.	RO	N	Structure composed of parameter name, initial value, and restrictions.
SrcRcpID	*Identifier* of the *source form* recipe from which a *derived object form* recipe is derived. Value determined by the *verifier* of the recipe. Required only for support of *derived object form* recipes.	RO	N	Formatted text.
VerificationID	Identification code set by the *verifier* of the recipe. May be used to determine out-of-date formats that need to be *reverified*.	RO	N	Text. Maximum length is 40 characters.
UD_*	Non-standard attribute defined by supplier or *user*. Asterisk indicates the part of the attribute name that is provided in this definition. Shall be preserved exactly except by the entity that defined it.	RO	N	Varies with definition. Text form is limited to 80 characters.

** NOTE: SEMI E4 and E5 number bits 1–8, where Bit 8 = MSB (most significant bit).

3.4.2.2 *Agent-Specific Attribute Definitions* — The names of user-defined attributes shall start with the prefix "AgentSpec_UD_" and shall be preserved without modification from transferred recipes. These attributes follow all standard attributes when transferred.

An *agent-specific dataset* exists only if an *agent-specific* attribute other than the *timestamp* and *attribute-length attributes* of the *dataset* itself have been set.

Table 3.2 defines the attributes of the *agent-specific dataset object*.

Table 3.2 Agent-Specific Dataset Object Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "MRcpASDS"
ObjID	The object's identifier. Contains the value in AgentSpec_Agent.	RO	Y	Text.
AgentSpec_Agent	The name of the *executing agent* to which the other attributes in the *dataset* apply. *Mandatory*.	RO	Y	Text.
AgentSpec_AttrLength	The length of the *agent-specific* attributes, in bytes. *Mandatory*.	RO	Y	Unsigned integer.
AgentSpec_ChgTime	Timestamp of when an *agent-specific* attribute was last changed. *Mandatory*.	RO	Y	Formatted text.
AgentSpec_Comments	Comments specific to the *agent* entered by the author.	RW	N	Text. Maximum length is 80 characters.
AgentSpec_LinkParam	A list of *variable parameter definitions* modified from the list in LinkParam. Valid only for a *linked main* recipe. *Parameter name* and form may not be changed.	RO	N	List of Structure composed parameter name, value, and restrictions.
Certified	The certification-level for the specific *agent*, assigned by an *authorized user*. Reset when AgentSpec_LinkParam is modified. Required for *certification* support.	RW	N	Unsigned integer.
AgentSpec_UD_*	Non-standard attribute defined by the supplier or user. Asterisk indicates the part of the attribute name that is provided in this definition. Must be preserved exactly except by the defining entity.	RO	N	Varies with definition. Text form is limited to 80 characters.

3.4.2.3 *Minimal Managed Recipe* — The minimal model for a *managed recipe* is shown in Figure 3.6. Only required attributes are supported in this model. This model can only be used for single-part recipes in the dedicated *namespace,* such as the *default namespace* required for stand-alone *equipment*. There are no *agent-specific datasets*.

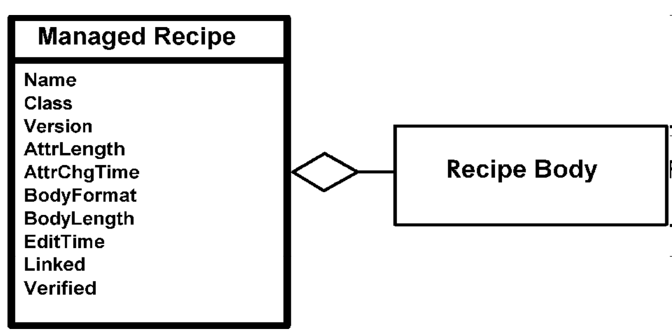

Figure 3.6
Object Model for Minimal *Managed* Recipe

3.5 *Execution Recipes* — The type of recipe handled by a *recipe executor* is called an *execution recipe*. This type of recipe has attributes and a *body* but does not have an *agent-specific dataset*. Most of the *generic* attributes of the *managed recipe*, and certain of the *agent-specific* attributes, are also attributes of the *execution recipe*, while in other cases, a *generic* attribute and an *agent-specific* attribute are merged and placed in a new *execution recipe* attribute.

A *managed recipe* is converted to an *execution recipe* when the recipe is *downloaded* to the *recipe executor*, and correspondingly, an *execution recipe* is converted to a *managed recipe* when *uploaded* from the *recipe executor*.

The *execution recipe* is defined in detail in Section 6.3.

4 Recipe Namespace

This section defines the basic conceptual model for the **recipe namespace**, a logical domain for recipe storage and management, within which the *identifier* of a recipe is guaranteed to be unique. The model in the current section is applicable to implementations with centralized storage. Section 5 defines an extension of the basic model for a distributed recipe namespace.

In general, the term "namespace" refers to a domain of unique *identifiers*. The issue of *namespace* boundaries exists for all object types, particularly in a distributed environment, and is not unique to recipes. However, within the context of RMS, **namespace** is used as a synonym for *recipe namespace*.

4.1 *Motivations* — A recipe's *identifier* may not be unique across different *namespaces* or throughout a factory. (That is, a given identifier may be used by internally different recipes except within a single *namespace*.) A primary role of a *namespace* is to define an area within which the uniqueness of any given recipe *identifier* may be guaranteed.

The requirements for Recipe Management that are addressed in this section include:

- *to define the boundaries of specific areas where recipes may be uniquely identified, stored, and retrieved,*
- *to define the* attributes *and operations for the management domain of recipes, including recipe protection and recipe operations,*
- *to allow control of removable media,*
- *to allow stand-alone* equipment *to* execute *recipes,*
- *to facilitate smooth integration of stand-alone* equipment *into on-line factory systems,*
- *to allow integrated* equipment *to continue to execute recipes when communications have been lost, and*
- *to provide the basis for the* **distributed** *model in Section 5, which allows a* supervisor *to use and manage the storage capacity of its* subordinate agents.

4.2 *Namespace Model* — The *namespace* model serves two major purposes. First, it provides a common set of management rules. Second, it allows a set of recipes to be shared among a group of *executing agents* that have a common process type, common functionality, and a common recipe language.

Figure 4.1 shows the basic *namespace* model with four objects: the recipe, the *namespace* itself, a *namespace* component called **recipe namespace segment**, and a **recipe namespace manager**.

The **recipe namespace manager** (or **manager**) represents the interface for the *namespace* to the external world and the internal decision authority within the *namespace*. All services for the *namespace* and its recipes are provided by the *manager*. The *namespace* itself is passive. While it has important *attributes*, the *namespace* has no operations, and it provides no services.

The **recipe namespace segment** (or **segment**) represents both the internal storage element and the actual manipulation of recipes within the *namespace*, under the supervision of the *manager*. In the basic model, it also provides no public services. The relationship between the *segment* and the *manager* in this model is presumed to be internal to an application.

Figure 4.1 represents a *namespace* with centralized storage. However, it can easily be extended to the **distributed recipe namespace**, which may have multiple *segments*, each provided by a different external *agent*. For that case, the *manager* and *segment* must provide public services for one another.

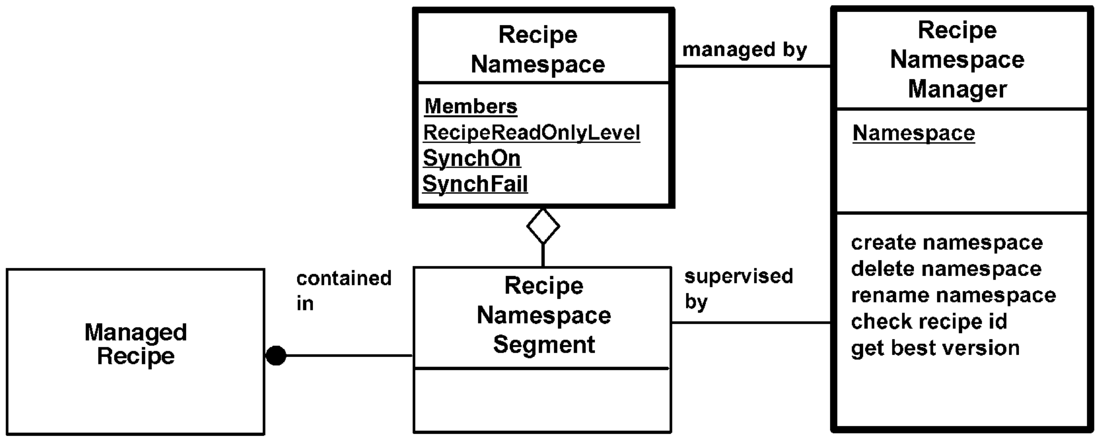

Figure 4.1

Recipe Namespace Model

All operations performed on a recipe through Recipe Management *services* are performed within the *namespace* by, or under the supervision of, the **namespace manager**, with two exceptions. A *namespace manager* is not required to understand the syntax of the recipe languages. For this reason, recipe **editing** (modifying a recipe's *body*) is not part of the *namespace* definition, and *verification* shall be provided by a **recipe executor** of an appropriate *executing agent* (see Section 6). These two activities require an in-depth understanding of the particular recipe languages used. Their separation from the other activities allows generic *namespace* capabilities to be provided.

4.3 *Namespace Specifications* — The combination of the *recipe namespace*, its *segment* component, and its *manager* provides storage, retrieval, and management of recipes conforming to RMS.

A *namespace manager* is responsible for maintaining the integrity of the *namespace*, the integrity of the recipes within the *namespace*, and the integrity of the recipe *identifiers*. It understands the rules regarding recipes, their *attributes*, and their components, and it is responsible for enforcing those rules. It will not allow a *read-only* recipe to be changed or deleted, for example. Therefore, it will not accept a recipe with an *identifier* already used by a *read-only* recipe.

A *namespace* has no restrictions on the **read access** of a recipe as a whole or of its *attributes*, nor is it concerned with the uses to which they might be put outside the *namespace*. The ability for multiple *agents* to share the same recipes is determined solely by the ability of the *agents* to access the same *namespace*. Issues of security and authentication are beyond the scope of RMS.

The term *recipe namespace*, or *namespace*, is used inclusively to refer to those *attributes*, operations, and other requirements common to both the *namespace* described in this section and to its *distributed* subtype. The term **centralized namespace** is used in references to an instance (implementation) of the basic model and to clarify statements that do not apply to instances of the *distributed* subtype.

A *centralized namespace* is analogous to a single directory of files, where duplicate file names are not allowed. It may exist in several different configurations that are incidental to *namespace* requirements.

It is possible to provide a *namespace* that uses removable media for its physical storage. Recipes may then be transferred to and from this *namespace* to any other *namespace*.

In no case shall it be possible to transfer recipes into a *namespace* except according to the requirements for *namespace management*. For example, a *read-only* recipe may not be replaced.

The *centralized namespace* may be applied several ways. An *agent* with *execution* capabilities that may be operated in stand-alone mode shall provide itself with a *centralized namespace* to be used when operating in stand-alone mode. Other *agents*, such as diskless process modules in a cluster, may expect to rely upon the *namespace* capabilities provided by the cluster *supervisor*.

4.4 *Member Agents* — A *namespace* that contains recipes used by multiple *agents* is called **shared**. Otherwise, it is called **dedicated** or **non-shared**. Figure 4.2 illustrates two *dedicated namespaces*, one provided by an etcher and one by its host. This terminology is introduced for clarification and descriptive purposes only.

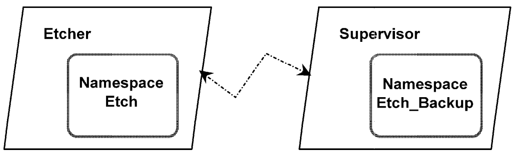

Figure 4.2

Host Backup of Equipment Namespace

The Members attribute of the *namespace* contains the names (object identifiers) of the *agents* that use the recipes in the *namespace*, and these *agents* are called **member agents** (**members**) of the *namespace*. The *namespace manager* uses this information as it may require assistance from a *member agent* to *verify* a recipe.

If the Members attribute of the *namespace* contains multiple *agent* names, then the *namespace* is *shared*. Otherwise, it may be *non-shared* or not yet completely set up. If it is empty (null), the *namespace* has not been completely set up and is not fully functional, as certain operations, including recipe *verification*, require it to have content.

4.5 *Illustrations* — This section provides illustrations of several possible configurations of a *centralized namespace*.

Figure 4.2 illustrates an etcher that has its own local *namespace* and that communicates with its *supervisor* over an RS-232 line. The *supervisor* in this example maintains a separate *namespace*, providing backup for recipes of particular significance.

Figure 4.3 illustrates a *supervisor* with four diskless subordinates. In this configuration, the *supervisor* provides recipes for all four subordinates from a *centralized namespace*.

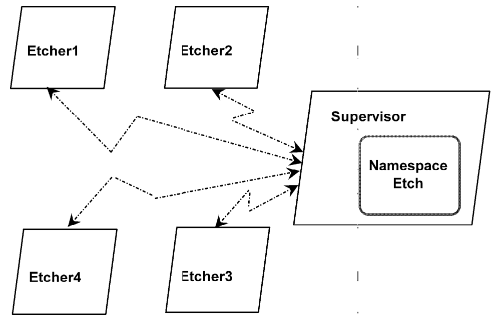

Figure 4.3

Namespace Provided by Supervisor

Figure 4.4 illustrates four *executing agents* on a common network with a *supervisory agent* and a sixth *agent* providing a *centralized namespace*. Each *executing agent* is able to access the *namespace* independently of the *supervisor*.

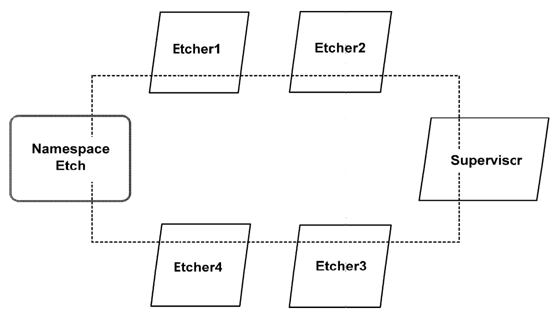

Figure 4.4

Shared Network Access

Figures 4.3 and 4.4 both represent examples of *shared centralized namespaces*.

4.6 *Attribute Definition Tables* — Table 4.1 defines the attributes of the recipe namespace.

Table 4.1 Recipe Namespace Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNS"
ObjID	The *name* of the *namespace*.	RO	Y	Text. A name of "Default" is prohibited.
RecipeReadOnly-Level	The level of *approval* at which recipes are *read-only*.	RW	Y	Unsigned integer.
Members	The *names* of *agents* capable of *verifying* and *executing* the recipes in the *namespace*.	RW	Y	List of *agent names* (identifiers).
SynchOn	Level of synchronization (see Section 9.5). Required if synchronization is supported.	RW	N	Unsigned integer: Either 0 = Disabled, or any combination (sum) of: 1 = changes in body 2 = new *execution recipe* 8 = changes in *last value* 16 = new *derived object form execution recipe*
SynchFail	Specifiers for *execution recipes* for which an attempt to *synchronize* failed. Required if *synchronization* is supported.	RW	N	List of formatted text.

Table 4.2 defines the attributes of the *recipe namespace manager* objects. The *name (identifier)* of the *manager* is not generally of interest, as the *namespace specifier* is more commonly used. However, it is important for the *manager* to be accessible through Object Services.

Table 4.2 Recipe Namespace Manager Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNS_Mgr"
ObjID	The *manager's* name.	RO	Y	Text.
NamespaceName	The *name* of the *namespace* managed.	RO	Y	Text.

5 Distributed Recipe Namespace

A **distributed recipe namespace** is a *recipe namespace* that utilizes the storage capacity of multiple *agents* for recipe storage. Recipes are stored in special **recipe namespace segments** provided by the different *agents*. These *segments* are **distributed recipe namespace segments** and are supervised by the **distributed recipe namespace manager**.

This section defines the different objects that together provide the *distributed recipe namespace* capability: the *distributed recipe namespace*, the *distributed recipe namespace manager,* the *distributed recipe namespace segment*, and the **distributed recipe namespace recorder**. Detailed descriptions of operations are contained in Section 10.

Throughout this document, the acronym **DRNS** refers to the term "distributed recipe namespace" and is used primarily to differentiate a *DRNS* subtype object from its supertype.

5.1 *Motivations* — The *distributed recipe namespace* capability provides a method for using the storage capacity of multiple *agents*, as illustrated in Figure 5.1. This reduces the storage requirements of a centralized factory system, improves performance by allowing recipes to be used by those *agents*, and provides a centralized management of the *namespace* to ensure that the uniqueness of the recipe *identifier* is properly maintained.

Figure 5.1 illustrates a *distributed recipe namespace* with four *segments*, each provided by a different *agent*, and each *agent* also having a local *namespace*.

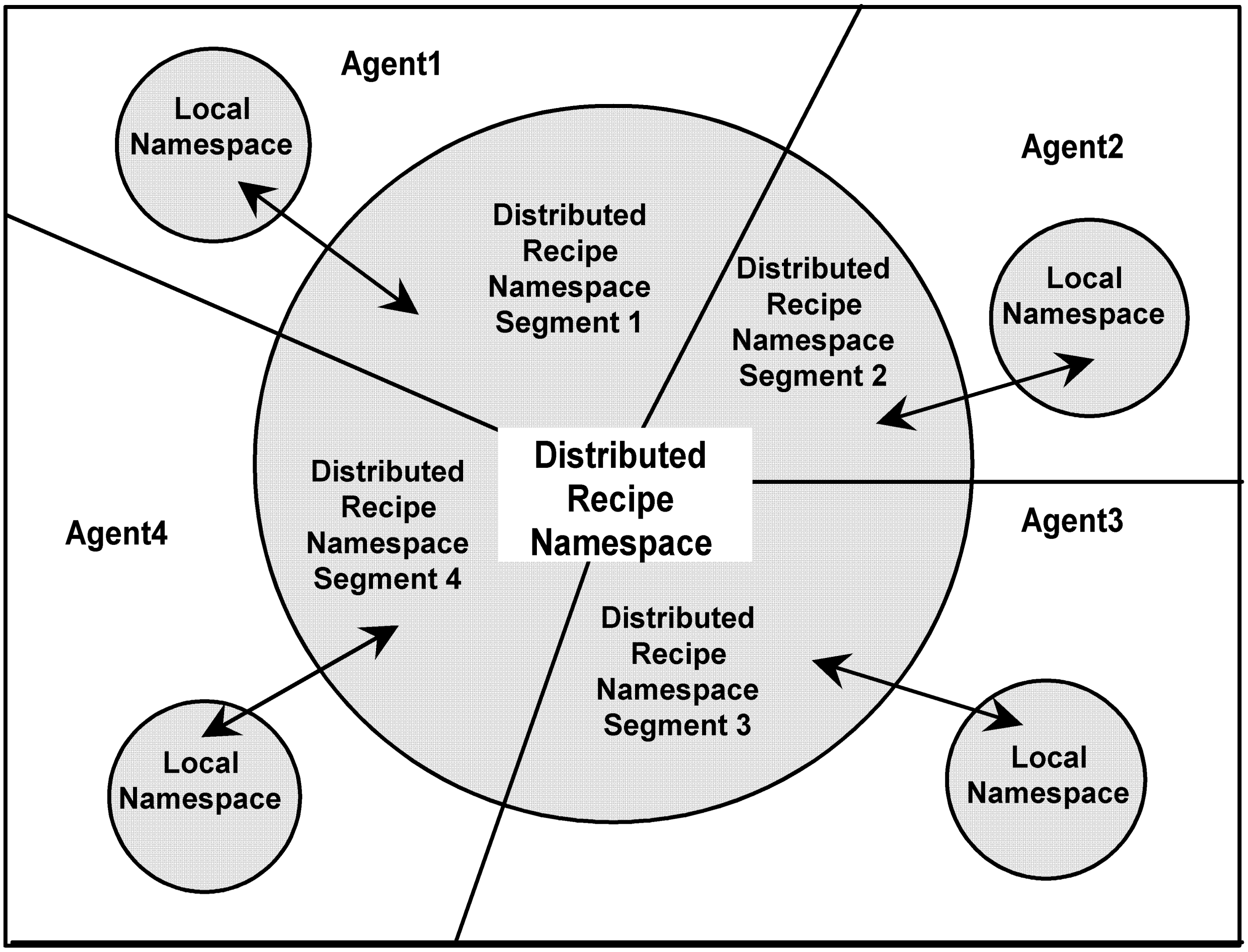

Figure 5.1
Illustration of Agents, Segments, and Local Namespaces

5.2 *Overview* — The *DRNS* object model (Figure 5.2) is a specialization of the model introduced in Section 4. The *distributed recipe namespace*, the *DRNS* segment, and the *DRNS* manager are subtypes of the *recipe namespace*, the *recipe namespace segment*, and the *recipe namespace manager* respectively. Each inherits the *attributes* and *operations* of its corresponding *supertype*. Only those attributes and operations that are specific to the *DRNS* types are shown in object representations.

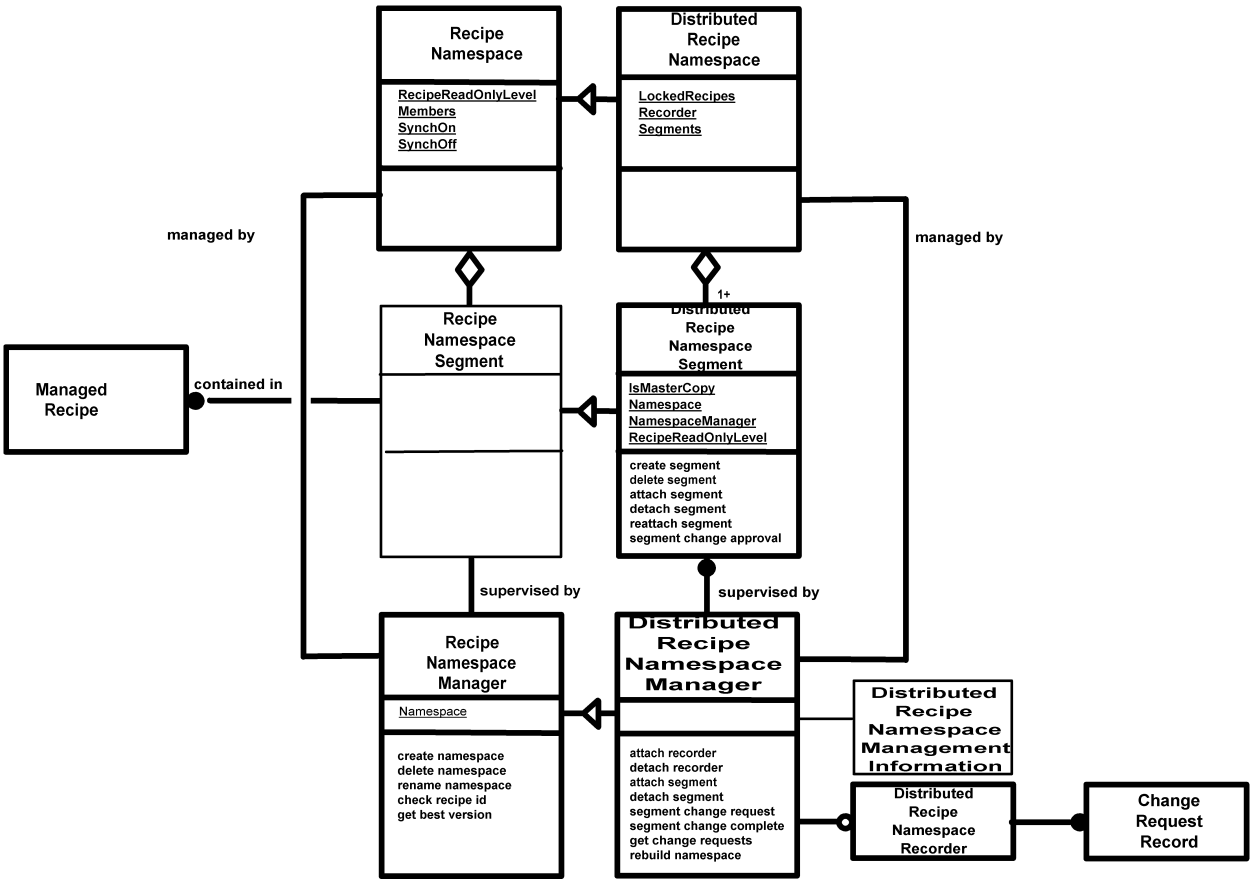

Figure 5.2

Distributed Recipe Namespace Model

The *namespace* supertype has exactly one *segment* of storage. Where storage is *centralized*, the *segment* is internal and private to the *namespace*. However, in the case of the *distributed recipe namespace*, there may be multiple *DRNS segments*, each provided by a separate *agent*. For this reason, the *DRNS segment* is a *standardized object*.

The *distributed recipe namespace* separates the management of recipes within a specific recipe storage area from the management of the entire *namespace*. The management of individual recipes within a specific storage area is delegated to the *distributed recipe namespace segment*. The *distributed recipe namespace manager* manages the various *segments* and the *namespace* itself. The *manager* is responsible for knowing the *identifiers* of all recipes stored in the entire *namespace*. It requires a knowledge of the structure of the recipe's *identifier* and the significance of the *version* in differentiating between recipes of the same name and different *versions*.

The *DRNS recorder* provides a backup facility for information required to automate the rebuilding of a *distributed recipe namespace*. It is external to the *DRNS namespace* and to its *DRNS manager*.

5.3 *Distributed Recipe Namespace Issues* — This section introduces issues that are applied to more than one object within the *distributed recipe namespace* capability.

5.3.1 *Object Services* — Attachment is a relationship between a managed object and its manager that is defined in OSS (SEMI E39). One object may be attached, detached, and reattached to a manager. When attached, the managed object is able to recognize that certain critical services have been requested by its manager. The *segment* and *recorder* objects shall comply with requirements for the operations and services defined in SEMI E39 (OSS) to attach, detach, and reattach to and from a *DRNS manager*. They shall also allow their *manager* to modify specified attributes that are otherwise read-only.

The ability to create and delete a *segment* or *recorder* is optional.

The *authorized user* may request a *DRNS manager* to attach or detach a specified *segment* or *recorder*.

5.3.2 *Logical Recipe* — A **logical recipe** is defined as a recipe with a specific *body* and a specific set of *generic attribute values*. Every *managed* recipe stored is an instance of a *logical recipe*.

In a *distributed recipe namespace*, it is normal for instances (copies) of a given *logical recipe* to exist in more than one *DRNS segment* at any time. In other words, multiple duplicate copies of a recipe with the same *identifier* may co-exist within the *distributed recipe namespace*. To retain the integrity of the *namespace*, this can be allowed if, and only if, each copy of a recipe with a given *identifier* is an instance of the same *logical recipe*. It is the responsibility of the *DRNS manager* to ensure this logical identity is maintained.

Agent-specific datasets are not included in the definition of the *logical recipe* because multiple *agent-specific datasets* may exist independently of one another, and only the *dataset* specific to the *agent* providing the *DRNS segment* is normally kept in that *segment*.

5.3.3 *Change Requests* — A **change request** occurs whenever a *user*, an external application, or an attached *DRNS segment* requests the *DRNS manager* to make, or permit, any change in a recipe. Information concerning *change requests* is kept in the form of logical **change request records**. Once a *change request* is made, a *change request record* is created and maintained until the change has been either completed or discarded. Because the information represented by *change request records* is publicly available, they provide a degree of diagnostic capability.

The *change request record* is not a formal or standardized object, but it represents the information that is available through services.

Change management is the most critical issue of the *DRNS* capability and is discussed in detail in different sections below.

5.4 *Distributed Recipe Namespace Segment* — The **distributed recipe namespace segment** (Figure 5.3) is responsible for all of the activities that directly manipulate recipes, including storage, retrieval, deletion, and operations that change a recipe's *attributes* or *body*. This requires a micro-level knowledge of the recipe's *identifier*, its structure, the inter-relationships between the various recipe *attributes*, how the recipe is stored, and how it is transferred. It also includes a macro-level knowledge of all of the *identifiers* of the recipes that it has stored. The *DRNS segment* shall ensure that only one recipe with a given *identifier* exists within that *DRNS segment*. The contents of an unattached *DRNS segment* shall be *read-only*.

A *DRNS segment* and its storage are provided by an *agent*, which could be equipment, an independent "recipe server", or other factory systems.

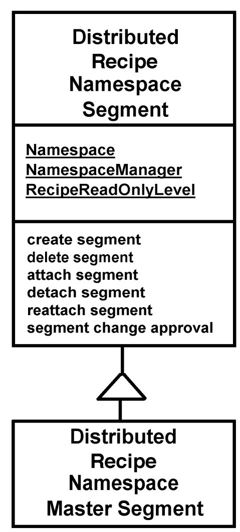

Figure 5.3

Distributed Recipe Namespace Segment

5.4.1 *Master and Dedicated Segments* — A **master segment** is a specialization of a *DRNS segment* that is capable of storing multiple *agent-specific datasets* per recipe. *Master segments* are not dedicated to a single equipment and are used to store a **full copy** (including all existing *agent-specific datasets*) of all *logical* recipes within the *namespace*. It is required that every *distributed recipe namespace manager* be capable of supporting at least one attached *master segment*. Additional *master segments* may be desirable for further backup protection.

The term **dedicated segment** is used to refer to *segments* that are not *master segments*. *Dedicated segments* store at most one *agent-specific dataset* per recipe. Because a *DRNS segment* provided by equipment would not expect to keep *agent-specific datasets* for other *equipment*, equipment normally does not provide *master segment* capability.

Master and *dedicated* segments have the same attributes and support the same message services, but they respond differently to *agent-specific datasets* and are used for different purposes. A *master segment* requires approval prior to changing an *agent-specific dataset*.

5.4.2 *Change Restrictions* — The *DRNS segment* may provide access to recipes within its storage to the other *components* of the *agent* providing the storage. However, neither the generic attributes nor the body of recipes stored by the *segment* shall be changed except with the explicit approval of the *distributed recipe namespace manager*.

Dedicated DRNS segments that are attached to a *DRNS manager* may change the contents of an *agent-specific dataset* without first asking permission. However, they are required to notify the *manager* of any change as soon as it occurs.

The attribute RecipeReadOnlyLevel is set by the *DRNS manager* to the value of the corresponding *namespace* RecipeReadOnlyLevel attribute when the *segment* is first attached and whenever the *namespace* attribute is changed. This attribute has the same function as the *namespace* attribute and allows the *segment* to prohibit changes based on a recipe's *approval level* as defined in Section 8.2.5. For example, the *segment* shall deny requests to *modify a write-protected* recipe.

The *DRNS segment* is prohibited from changing its contents whenever it is unattached. However, recipes and recipe *attributes* may be read at any time by other entities, including other *components* of the owner *agent*.

Any changes to a logical recipe stored by the *DRNS segment* shall first be approved by the *DRNS manager* before the change is made. This includes any changes to the body or to any generic attribute. This is required for two reasons. First, two different *DRNS segments* may attempt to change a recipe at the same time, and this activity must be coordinated. Second, to protect the integrity of the recipe *identifier* where multiple instances of a recipe exist, the *distributed recipe namespace* is required to ensure that all such instances have been updated appropriately with that change before other changes to the same recipe are allowed.

NOTE: The prohibition against unauthorized change does not preclude the saving of such changes external to the *DRNS segment* while waiting for authorization. However, changes made by other *DRNS segments*, subsequent to such changes and prior to authorization, may invalidate these changes.

Communications between the different *components* of an *agent* that do not require or use the formal *services* defined by RMS are considered as proprietary to the *agent* and are neither covered nor excluded by RMS, subject to the above restrictions against change.

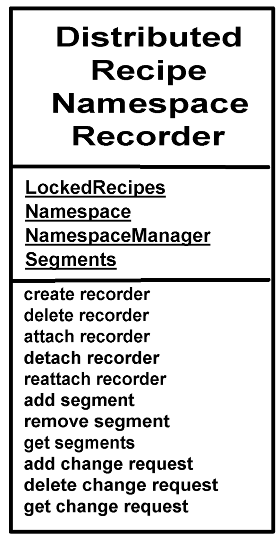

Figure 5.4

Distributed Recipe Namespace Recorder

5.5 *Distributed Recipe Namespace Recorder* — The **distributed recipe namespace recorder** provides a method of externally storing and retrieving information critical to automated rebuilding of a damaged *distributed recipe namespace*. It contains two types of information: a list of the *DRNS segments* that are attached to the *DRNS manager* and the current *change request record* in process per recipe.

A *DRNS recorder* may be attached and detached from a *DRNS manager*, and reattached to that *manager*. Information that it contains is available to anyone but may only be changed by its *manager*.

The *DRNS recorder* is able to store the *DRNS* **segment specifiers** (the *object specifiers*) of the attached *DRNS segments* in its Segments attribute. This information allows a *distributed recipe namespace* to be automatically rebuilt in the event that the *namespace*, or the *DRNS manager*, is damaged and its information becomes lost or unavailable.

The *DRNS recorder* is also used to store the current *change request* per recipe, to delete a *change request*, and to return the set of *change requests* for one or more recipes. The attribute LockedRecipes provides a list of *identifiers* for recipes with *change requests*.

The *DRNS manager* shall use the services of a *DRNS recorder* when one is attached to the *namespace* by a service user. However, use (attachment) of a *recorder* is optional for the user. The *DRNS recorder* is provided for remote storage of critical information and is not intended as a general source of information for the user. It is not able to provide *inactive change request* information.

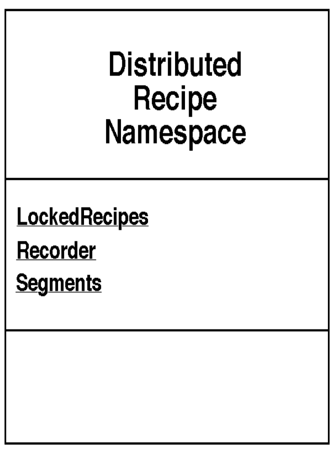

Figure 5.5

Distributed Recipe Namespace

5.6 *Distributed Recipe Namespace Management Information* — The *DRNS* **management information** object is private and proprietary to the *DRNS manager*. It is included in Figure 5.2 as an emphasis on the importance of the information that a *DRNS manager* requires for management. This includes, but is not limited to, the recipe *identifiers* stored in each attached *segment* and all existing *change request records*.

The *DRNS manager* is required to know the contents of all of its attached *segments* at all times. It shall be able to uniquely identify each instance of a recipe within the *distributed recipe namespace*. It is responsible for tracking the current status of each instance of a logical recipe within the *distributed recipe namespace* when a change to a recipe within one *segment* is being updated to other *segments*. The *DRNS management information* is important for these purposes.

5.7 *Distributed Recipe Namespace* — The *distributed recipe namespace* has three additional attributes, as shown in Figure 5.5, that are read-only, set by the *DRNS manager*. The attribute Segments contains a list of the *object specifiers* of the *DRNS segments* currently attached. The attribute Recorder contains the object specifier of an assigned *DRNS recorder*. The attribute LockedRecipes contains a list of recipe *identifiers* of recipes with existing *change request records*.

5.8 *Distributed Recipe Namespace Manager* — The *distributed recipe namespace manager* (Figure 5.6) is responsible for ensuring that the *distributed recipe namespace* and *DRNS segments* operate together and for maintaining *namespace* integrity as a whole. It is required to know the identities of its attached *DRNS recorder* and *DRNS segments* and the contents (*recipe identifiers*) of each attached *DRNS segment* at all times.

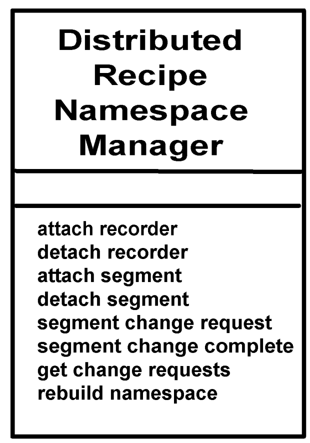

Figure 5.6

Distributed Recipe Namespace Manager

The current attachments of the *DRNS manager* are maintained in the *DRNS namespace* attributes Recorder and Segments and through the services of the *DRNS recorder* described in Section 5.5. Whenever a *DRNS segment* is attached, the *DRNS manager* shall add the *segment specifier* to the *namespace* attribute Segments and to the current list maintained by the *DRNS recorder*. Whenever a *DRNS segment* is detached, the *DRNS manager* shall remove its *specifier* from the Segments attribute and from the *DRNS recorder's* list.

The *DRNS manager* is able to know which recipes are stored in each *DRNS segment* through use of Object Services provided for or by the individual *DRNS segments*. It shall maintain the integrity of the *namespace* through ensuring that an *identifier* of any recipe stored within the *namespace* represents exactly one *logical recipe*. This is achievable because the *manager* must give explicit approval of any change of *logical recipes* (generic attributes or body) stored by the *DRNS segments*.

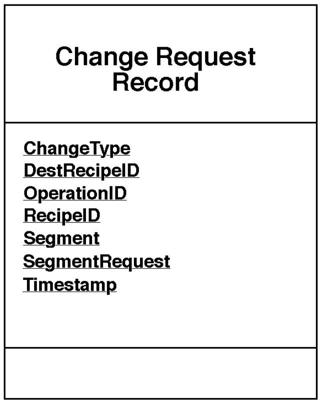

Figure 5.7

Change Request Record

5.8.1 *Change Management* — A *change request* occurs whenever a *user* or an attached *segment* requests the *distributed recipe namespace manager* to make, or permit, a specific type of change. A change request record (Figure 5.7) contains information about who requested what type of change. This allows later diagnostics when necessary.

A *change request record* is created for a recipe whenever an attached *DRNS segment* requests a change and is deleted when the requested change has been completed or discarded. A *change request* is either **inactive** or **active**. Once a *change request* is made, it is considered as inactive until the change has been approved by the *DRNS manager*. Once approved, it is considered as **active**.

The *change request record* is not a standardized object and is not accessed directly through public services. However, the information represented by the *change request record* shall be available, upon request, from the *DRNS manager* for all *inactive* and *active change requests*. For this reason, it is convenient to model the *change request record* as an object.

A recipe for which a *change request* exists is called **locked**. Otherwise, it is **unlocked**.

The *DRNS manager* is responsible for ensuring that only one *change request* per recipe is *active* at any time. The results of each approved *change request* shall be updated appropriately to each of the other *DRNS segments* with a copy of the same *logical recipe* before a subsequent change to the recipe is approved.

5.9 *Building a Distributed Recipe Namespace* — A *distributed recipe namespace* is built up in several stages. The *distributed recipe namespace* and its associated *DRNS manager* are created separately in the first stage. The individual *DRNS segments* are first *created* and then attached to the *DRNS manager*. At least one *DRNS segment* must be attached to the *DRNS manager* before it can accept recipes, as the *distributed recipe namespace* has no other means of storage. Figure 5.8 illustrates the attachment relationship.

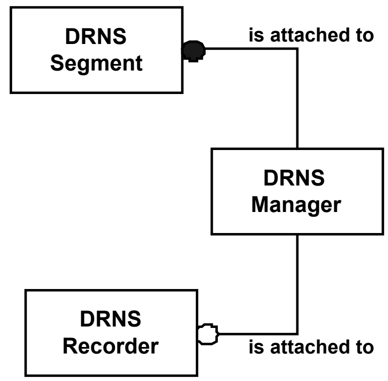

Figure 5.8

The Attachment Relationship

The attached *DRNS segments* may later be detached from the *namespace* and then either attached again to the same *namespace* or to a different *namespace* without affecting the recipes stored within the *DRNS segment*.

NOTE: When a *DRNS segment* with existing recipes is detached and then attached to a different *namespace*, its recipe *identifiers* fall within the domain of the new *namespace*. This may require some recipes to be *renamed* before the attach process is complete.

5.10 *Rebuilding a Damaged Distributed Recipe Namespace* — A *distributed recipe namespace*, or its *manager*, may become damaged or unavailable. If a *DRNS recorder* was attached to the *damaged* name-space, then rebuilding the *namespace* can be automated.

A new *distributed recipe namespace* and new *DRNS manager* are created, assigning the old *namespace* name as the object identifier ObjID for the new *namespace*. The new *DRNS manager* should be assigned a different *identifier*, however, as a security measure. The *user* may then request the new *DRNS manager* to rebuild the *namespace* with the old *DRNS recorder*. A *namespace* may also be rebuilt without a *recorder* if the list of *segment specifiers* can be provided by the user. However, the user is not expected to provide the information retained through *change request records*.

5.11 *Object Attribute Definition Tables* — This section contains the formal attribute definitions for the *distributed recipe namespace* capability. Except for the *object identifier* attributes, attributes are listed alphabetically.

Objects that are subtypes of objects introduced in Section 4 inherit the attributes of the supertype objects. These attributes are not repeated in this section.

5.11.1 *Distributed Recipe Namespace Segment Attribute Definition* — Table 5.1 defines the attributes required for a *distributed recipe namespace segment*, and Table 5.2 defines the attributes of the subtype *master segment*.

Table 5.1 Distributed Recipe Namespace Segment Attribute Definition

Attribute Name	*Description*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNSDSegment"
ObjID	The object name (identifier).	RO	Y	Text.
Namespace	The name (ObjID) of the *namespace* to which the *segment* belongs. May be set by the manager.	RO	Y	Text.
NamespaceManager	Identifies the *distributed recipe namespace manager*. May be set by the manager.	RO	Y	Text.
RecipeReadOnlyLevel	Used to track the corresponding attribute of the *namespace* to which the *segment* belongs. May be set by the manager.	RO	Y	Unsigned integer.

Table 5.2 Distributed Recipe Namespace Master Segment Attribute Definition

Attribute Name	*Description*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNSDMaster"
ObjID	The object name (identifier).	RO	Y	Text.

5.11.2 *Distributed Recipe Namespace Recorder Attribute Definition* — Table 5.3 defines the attributes required for a *distributed recipe namespace recorder*.

Table 5.3 Distributed Recipe Namespace Recorder Attribute Definition

Attribute Name	*Description*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNSDRecorder"
ObjID	Text.	RO	Y	Text.
LockedRecipes	List of *identifiers* of recipes with existing *change request records*.	RO	Y	List of formatted text.
Namespace	Identifies the *namespace* to which the recorder is attached. May be set by the manager.	RO	Y	Text.
NamespaceManager	Identifies the *distributed recipe namespace manager*. May be set by the manager.	RO	Y	Text.
Segments	List of *specifiers* of currently attached *segments*.	RO	Y	List of formatted text.

5.11.3 *Distributed Recipe Namespace Attribute Definition* — Table 5.4 defines the attributes required for a distributed recipe namespace.

Table 5.4 Distributed Recipe Namespace Attribute Definition

Attribute Name	*Description*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RNSD"
ObjID	Text.	RO	Y	Text.
LockedRecipes	A list of *identifiers* of all recipes with existing *change request records*.	RO	Y	List of formatted text.
Recorder	The *recorder specifier* of the attached *distributed recipe namespace recorder*.	RO	Y	Text.
Segments	A list of *specifiers* of the *distributed namespace segments* attached to the *namespace*.	RO	Y	List of formatted text.

5.11.4 *Distributed Recipe Namespace Manager Attribute Definition* — Table 5.5 defines the attributes required for a *distributed recipe namespace manager*.

Table 5.5 Distributed Recipe Namespace Manager Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = “RNS_MgrD”
ObjID	The *manager's* name.	RO	Y	Text.

6 Recipe Executor

This section describes the basic concepts for the *recipe executor* and the *execution recipe* that it stores.

The **recipe executor** is the component of an *executing agent* that reads and comprehends the contents of a recipe (its *body*) and puts into effect its instructions, settings, and/or other data. The object model of the *recipe executor* is shown in Figure 6.1.

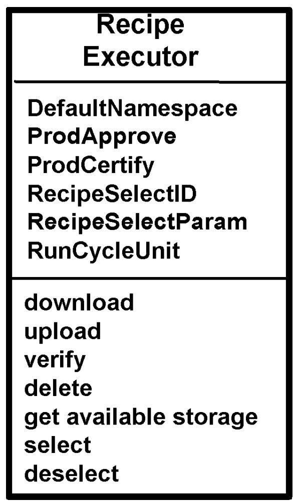

Figure 6.1
Recipe Executor

The *recipe executor* is able to temporarily store recipes for execution purposes, and it may also be able to store *execution recipes* for later execution.

The execution process is beyond the scope of RMS.

6.1 *Motivations* — Specification of the *recipe executor* and the *execution recipe* that it stores is necessary to complete the management of recipes in the factory. The *recipe executor* provides limited storage for recipes and minimum capability to manage them. The storage provided is intended to be temporary only.

Some *recipe executors* have the ability to purposefully change a recipe's body or create new recipes. To ensure that *execution* recipes remain synchronized with the *managed* recipes in a *recipe namespace*, additional rules are required for such cases.

The requirements for RMS that are addressed by the *recipe executor* include the following:

- *The ability to create, edit, and change recipes outside the* executing agents *that execute them,*
- *The ability for* executing agents *to use recipes developed externally,*
- *The ability to share recipes among equipment of the same type,*
- *Protection of stored* execution recipes *and of currently* selected *recipes from unexpected or unauthorized change,*

- *Execution of recipes without errors, including errors detected during* verification *and* ***validation*** *errors caused by improper settings or parameters or incompatibility with the current configuration,*

- *The ability to change a recipe's* parameters *between runs in a systematic way without changing the recipe itself,*

- *The ability to dynamically connect and disconnect the* executing agent *from the communications environment, and*

- *The ability of standalone equipment to execute recipes without a communications link.*

6.2 *Description* — The *recipe executor* is able to receive a downloaded *execution recipe* and temporarily store it. The *executor* can *verify* the recipe *body* (Section 11.2.2) both at the time of the download and after the recipe has been stored. It is able to store at least as many recipes as it requires for a single process cycle, which is determined by its own requirements.

Recipes stored by the *recipe executor* may be downloaded from more than one *namespace*. To prevent ambiguity or conflict between recipe *identifiers* from different *namespaces*, the name of the namespace from which the recipe was originally downloaded is retained in the *identifier* of the *execution recipe*.

The *recipe executor* **selects** one or more specified recipes by *validating* them and preparing them for execution. This may include moving the recipes into a separate **recipe execution area** to create an **executable copy** recipe. The *executable copy* recipe, if it exists separately, shall be protected from inadvertent change caused by other activities, such as downloading a new recipe. The *executable copy* recipe is not otherwise addressed by RMS. If a separate *copy* is *selected*, the stored *execution recipe* shall be protected from change. Protection from change and permission to change are discussed in Section 6.6.

Validation of a recipe consists of checking the values of its settings and variable parameters against existing supplier-defined and/or user-defined restrictions, and ensuring the recipe, or the *linked recipe set*, is valid for the current configuration of the *executor* (e.g. equipment or attached module).

Additionally, the *recipe executor* is able to calculate the amount of available storage, to delete recipes from its storage to make room for new recipes, to **de-select** recipes by preventing them from being re-executed without another explicit *select*, to **rename** an *execution recipe*, and to provide requested information about itself and its stored *execution recipes*, in conformance with OSS.[8]

The *recipe executor* may wish to rewrite *source form* recipes into a proprietary *derived object form* that is more efficient for execution or storage purposes. Where this type of recipe is to be stored for re-use, a new *identifier* is required for the *object form*, as described in Section 3.2.2.1.2. *Derived object form* recipes are discussed in detail in Section 11.2.2.1.

6.3 *The Execution Recipe* — An *execution recipe* is a type of recipe, as shown in Section 3, Figure 3.5. The *recipe executor* stores recipes as *execution* recipes. *Execution* recipes are created in one of two ways: they are either **downloaded** from a *recipe namespace*, or they are **created** by the *recipe executor*.

6.3.1 *Comparison of Managed and Execution Recipes* — An *execution recipe* differs from a *managed recipe* in two ways: its attributes and its lack of *agent-specific datasets*.

The differences in attributes between a *managed recipe* and an *execution recipe* consist of:

- *The addition of* <u>*Namespace*</u> *as an* identification *attribute of the* execution recipe*,*

- *The intermediate parameters,* <u>*ExtRef*</u> *and* <u>*Parameters*</u>*, of a* verified managed *recipe, required for the* namespace link *operation, are not used by the* recipe executor *and are not retained in the* execution recipe*,*

- *The attributes* <u>*LinkParam*</u> *and* <u>*AgentSpec LinkParam*</u> *of the* managed recipe *are merged into the single attribute* <u>*ExecLinkParam*</u>*,*

- *The attributes of the remaining* agent-specific dataset *are absorbed into the attributes of the* execution *recipe, and*

- *The addition of the attribute* length <u>*ExecAttrLength*</u> *and attribute* timestamp <u>*ExecAttrChgTime*</u> *attributes, and*

- *The additional attribute* <u>*ChangedBody*</u>*, which is required for* execution recipes *where the* recipe executor *is capable of changing the recipe* body *or of creating new recipes and is not otherwise used.*

The conversion of a *managed recipe* to and from an *execution recipe* is the responsibility of the *namespace manager* and is discussed in Sections 9.4.8 and 9.4.9.

Most of these differences are invisible for an *unverified* recipe or minimal recipe implementations. For an

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unverified recipe, all of the above attributes are *cleared* to their *default value* and are not transferred with the recipe. Attributes needed for multi-part recipes and *variable parameters* are not required for minimal implementations. Figure 6.2 provides a model of the minimal implementation of an *execution recipe* to meet RMS requirements.

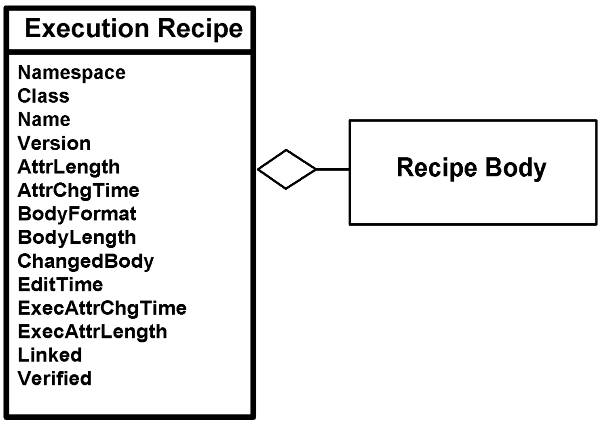

Figure 6.2

Object Model for Minimal *Execution* Recipe

6.3.2 *Downloaded Recipes* — To *download* a recipe from a *namespace*, the *namespace manager* is responsible for first converting the attributes of the specified *managed recipe* into those of the *execution recipe*. The *recipe executor* stores the downloaded recipe as an *execution* recipe. The body of the recipe is unchanged by the download operation and may be in *source form* or *object form*, including the *derived object form*. (See Section 11.2.2.1.)

The *namespace manager* may optionally request that the recipe being downloaded replace any pre-existing recipe with the same *identifier*. Otherwise, if such a recipe exists, the download request is denied.

Upon request, the *recipe executor* shall *verify* a recipe that it has previously stored and return to the requestor the information required for recipe management.

Attributes of the *execution* recipe that have the same attribute *name* as either a *generic* attribute or an *agent-specific* attribute of the *managed recipe* are not changed except in specific cases.

The attributes giving the *timestamp* and *length* of the attributes of the *execution recipe* are different from those of the *managed recipe*. This allows the *generic* and *body descriptors* of a *managed recipe* to be compared with the corresponding attributes of an *execution recipe* for traceability. The *timestamp* of the *execution recipe's* attributes is ExecChgTime, and the *length* of its attributes is ExecAttrLength. These are calculated by the *recipe executor* at the time the *execution recipe* is stored and updated whenever other attributes of the recipe change.

6.3.3 *Execution Recipe Identifier* — The *identifier* of an *execution recipe*, in addition to the recipe *name, class,* and *version* of the *managed* recipe, also contains the name of the **originating namespace**. The **originating namespace** is the namespace from which the recipe was originally downloaded. For recipes newly created within the storage of the *recipe executor*, this is the namespace to which the recipe will be *uploaded*.

The full *identifier* of an *execution recipe* is identical to that used within recipes to indicate the recipe is external to that of the referencing recipe (see Section 3.2.4.1.1) and has the form:

"Namespace Name>/CLASS/.../CLASS/name; version".

6.3.4 *Execution Recipe Descriptor* — The *descriptors* of the *execution recipe* consist of the *execution attribute descriptor* (ExecAttrLength and Exec-AttrChgTime), the *generic attribute descriptor* (AttrLength and AttrChgTime), and the *body descriptor* (BodyLength and EditTime). The **execution recipe descriptor** consists of the *execution attribute descriptor*, the *generic attribute descriptor*, and the *body descriptor*, in that order.

6.3.5 *Execution Recipe Attribute Definitions* — Table 6.1 provides the formal definition of the attributes of the *execution recipe*. Attributes in Table 6.1 are classified as identification attributes, mandatory and other required attributes, optional attributes, and non-standard attributes. Identification attributes are not used in RMS services as "recipe attributes" and are used solely to specify one or more execution recipes. Support for all required attributes is necessary for RMS compliance. Support for the remaining attributes is not required.

The *execution* recipe's attribute *length* and *timestamp* attributes are transferred first when a recipe **attribute section** (Section 14.1) is **uploaded**.

Attributes that are described as "preserved" are maintained without change from a *downloaded* recipe. For recipes that are first created by the *recipe executor*, such as hardware-specific recipes, they are set to their appropriate values. Default values have been added for attributes that cannot be determined.

Attributes in Table 6.1 are presented in the following order:

- *Identification attributes, including object type and identifier, the first six listed in the table,*

- *Mandatory attributes and the other required attributes, in the order in which they are to appear when a recipe is transferred.*
- *Optional attributes in alphabetical order, and*
- *Non-standard attributes, transferred last.*

Default values for *non-mandatory* attributes are shown in the last column. Null values (indicated by "NULL") are dependent upon the particular form (see Section 3.2.5).

Table 6.1 Execution Recipe Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*	*Default Value*
Identification Attributes					
ObjType	The object type.	RO	Y	Text: "ERcp"	"ERcp"
ObjID	An identifier derived from Namespace, Class, Name, and Version	RO	Y	Formatted text.	-
Namespace	The name of the *originating namespace.*	RO	Y	Text.	NULL
Name	A logical name assigned by the user when the recipe is *created*.	RO	Y	Text.	-
Class	The recipe's class (e.g., "/PROCESS/" or "/PROCESS/LOADER/").	RO	Y	Formatted text: "CLASS/CLASS/../ CLASS/"	-
Version	The version of the recipe.	RO	Y	Text.	-
Mandatory Attributes					
ExecAttrLength	The *length attribute* for the attributes of the *execution recipe*. Calculated when the recipe is *downloaded* and whenever an attribute changes.	RO	Y	List of formatted text.	-
ExecChgTime	The *timestamp* of a change to the attributes of the *execution recipe*.	RO	Y	Formatted text, *timestamp* format.	-
AttrLength	Preserved.	RO	Y	Unsigned integer.	0
AttrChgTime	Preserved.	RO	Y	Formatted text.	NULL
Required Attributes					
BodyLength	Preserved unless recipe is modified. Length of the recipe's body, in bytes.	RO	Y	Unsigned integer.	-
EditTime	Preserved unless recipe is modified. *Timestamp* of when the *body* was *created* or modified.	RO	Y	Formatted text. *Timestamp* format.	-
BodyFormat	Indicates the form and format of the recipe's *body.*	RO	Y	Enumerated unsigned integer: 0 = *source*, 1 = *object*, > 1 reserved.	0
Verified	Indicates whether the recipe's body is syntactically correct.	RO	Y	Boolean.	FALSE
Linked	Indicates whether the recipe is *linked*.	RO	Y	Boolean.	FALSE
ChangedBody	Set to TRUE if the recipe body has changed without a subsequent upload to the originating namespace. NOTE: This attribute is never uploaded to a namespace. Required only if recipe can be changed or created.	RO	Y	Boolean.	FALSE

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*	*Default Value*
ExecChgCtrl	Preserved. Specifies change control requirements for recipe.	RO	Y	Binary. Bitwise (MSB=8): 1 - The recipe body may be changed, 2 – Change notification required, 4 - Recipe may be selected after change, 8 - Most recent parameter setting shall be saved.	0
Optional Attributes					
AgentSpecComments	Copied from the original *agent-specific* attribute when downloaded. Set by the user.	RO	N	Text. Maximum length is 80 characters.	-
ApprovalLevel	Indicates the level of approval assigned by an *authorized user*.	RW	N	Unsigned integer.	0
Certified	Preserved from the *agent-specific* attribute as downloaded. May be used as control for production-worthy recipes.	RO	N	Unsigned integer.	0
Comments	User comments. Preserved from the *generic* attribute as downloaded.	RO	N	Text. Maximum length is 80 characters.	-
EditedBy	Preserved unless recipe is modified. The name of the person or *executing agent* who last modified the recipe.	RO	N	Text. Maximum length is 80 characters.	-
EstRunTime	The nominal or estimated execution (run) time of the recipe, in seconds. Used for scheduling purposes. Preserved from the *generic* attribute as downloaded.	RO	N	Unsigned integer.	0
ExecLinkParam	Preserved unless *last value* is changed (Section 6.6.4). Contains the list of *parameter definitions*, including any *agent-specific* modifications. Required for *variable parameter* support.	RO	N	Structure composed of parameter name, initial value, and restrictions.	NULL
LinkList	Preserved. A complete list of recipe *specifiers* for a *linked recipe set*. Required for multipart recipe support.	RO	N	List of formatted text.	NULL
SrcRcpID	For a *derived object form* recipe, contains the recipe *identifier* of the original *source form* recipe. Required only for *derived object form* recipes.	RO	N	Formatted text.	NULL
VerificationID	Identifier code used by the *verifier* of the recipe. May be used to determine out-of-date formats that need to be *reverified*.	RO	N	Text. Maximum length is 40 characters.	NULL
Non-Standard Attributes					
AgentSpec- UD *	Preserved from the original *agent-specific* attributes as downloaded.	RO	N	Defined by supplier or user. Text limited to 80 characters.	-

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*	*Default Value*
UD *	Non-standard attribute defined by supplier or *user*. Asterisk indicates the part of the attribute name that is provided in this definition. Shall be preserved exactly, except by the entity that defined it.	RO	N	Varies with definition. Text form is limited to 80 characters.	-

6.4 *Default Namespace* — The **default namespace** is a *dedicated centralized namespace* (see Section 4.4) that is used for all *agent-specific* recipes. A *recipe executor* that uses *agent-specific* recipes, such as thermocouple calibration tables, shall be provided with a *namespace* for such recipes. *Equipment* that may be operated in a stand-alone mode, and that requires *agent-specific* recipes, shall also provide a local *namespace* to be used for this purpose. A single *namespace* shall be used to satisfy both requirements.

The *recipe executor* shall provide a user-settable *attribute* DefaultNamespace that contains the name of the *default namespace*. The *default namespace* shall be available on power-up for stand-alone operation. For *executing agents* intended to operate only in a *supervised* configuration, such as cluster process modules, the *default namespace* may be provided by the *supervisor*.

A recipe in a *default namespace* is referenced within a recipe *body* by specifying a *namespace* named "Default". This allows controlled specification by *namespace* role for hardware-specific recipes.

6.5 *Recipe Storage* — Discussion of types of storage used by the *recipe executor* is provided to clarify terminology.

Storage is generally assumed to consume space in some form, and the amount of space available for recipes is assumed to be finite, so that adding recipes reduces the amount of space available and deleting recipes increases the amount of space available. These assumptions are based on current technologies and are not requirements.

The *recipe executor* may have one or more types of storage area for recipes, shown in Figure 6.3. The storage area used for the current process cycle is called the **recipe execution area**. This is the minimum storage capacity required. *Executable copy* recipes in the *recipe execution area* may or may not be transformed for execution purposes but shall retain the attributes of the *execution recipe*. The *recipe execution area* shall be protected from all inadvertent and unintentional change, including change resulting from transferring a recipe to or from a *recipe namespace* or from *editing* a recipe.

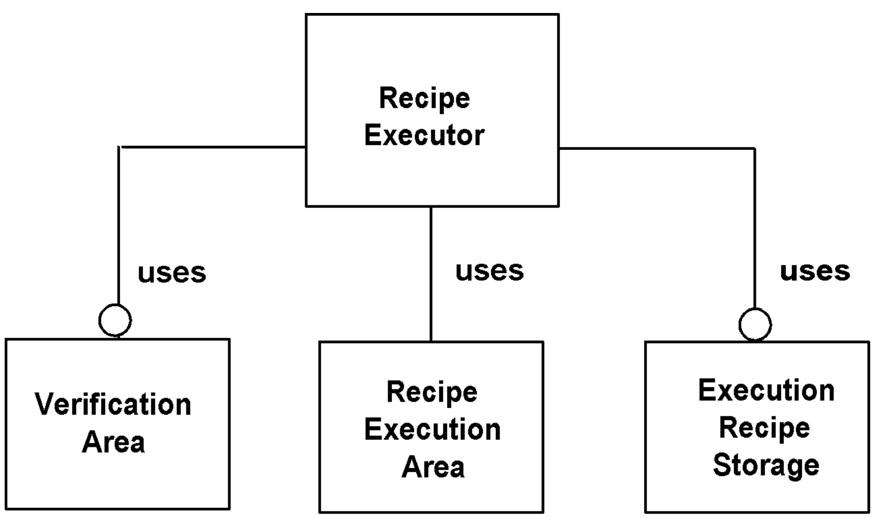

Figure 6.3

Object Model for Recipe Executor

Extra storage area, for additional recipes that are not currently *selected*, when provided, is called the **execution recipe storage**.

A separate intermediate area for temporary storage of *unverified* downloaded recipes may also be provided. This area is the **verification area**. The separation of this area provides protection for the *executable copy* recipes and the *execution recipes*. Recipes that fail *verification*, or that have been requested to be discarded without storage after *verification*, may be removed from this area more easily when it is separate.

A recipe temporarily placed in a *verification area* shall be immediately either discarded or else moved to *execution recipe storage* following a successful *verification*.

The term **stored recipes** in this section refers to recipes in *execution recipe storage*.

The storage areas of the *recipe executor* may or may not be volatile. The *verification area*, *recipe execution area*, and the *execution recipe storage* are not required to be physically separate, so long as recipes in each logical area are protected from change caused by activities in the other areas.

6.6 *Change Control* — Storage provided by the *recipe executor* is intended as temporary, and only minimum management capability is required, such as the ability to rename or delete recipes.

Some *recipe executors* may choose to provide additional capabilities, such as the ability to *create* new recipes, to *edit* existing recipes, to build a compressed *derived object form* recipe, to modify existing recipes through the execution process itself, and/or to save the **last value** used for *variable parameter settings*. Certain restrictions apply to these activities. Each different capability provided for creating and changing recipes shall be explicitly documented by the supplier.

In general, change is controlled by the *user* through the attribute ExecChgCtrl. ExecChgCtrl specified four separate types of control related to change, including permission to subsequently *select* or *re-select* a changed recipe and a requirement that the *originating recipe* be notified of all protected changes to the recipe.

The *recipe executor* is prohibited from setting the Linked attribute of any recipe to TRUE.

The *recipe executor* is responsible for ensuring the uniqueness of the *identifiers* of the recipes that it stores.

Detailed requirements governing the creation of new recipes and the changes protected by ExecChgCtrl are defined in Section 11.

6.6.1 *Recipe Creation* — Certain *recipe executors* may be able to *create* recipes. This capability is allowed to cover the hardware-dependent recipes and the provision of editing services. Mechanisms for creating and changing recipes are beyond the scope of RMS. *Change notification* is required for all newly *created* recipes.

6.6.2 *Recipe Compression* — A *source form* recipe may be *compressed* to obtain a *derived object form* recipe, described in Section 3.2.2.1.2. This is not considered as a *newly created* recipe, as the *source form* and *derived object form* recipes achieve the identical process results. For this reason, most of the attributes of the *source form* recipe, including the Linked and ExecChgCtrl attributes, are passed to the *derived object form*. A *change notification* requirement for the *source form* recipe extends to the *derived object form* as well, including notification when the *derived object form* is built. Requirements for the *derived object form* recipe are defined in detail in Section 11.2.2.1.

6.6.3 *Changes to Stored Recipes* — The *recipe executors* may be able to **change** *an existing recipe by changing its body*. Certain hardware-dependent recipes may sometimes be *changed* by, or as a result of, the execution process itself. Recipes also may be *changed* through an **editing** activity, including interactive “teach” and automated “self-teach” operations provided by some systems. Except where expressly granted permission to change an existing recipe through the ExecChgCtrl attribute, the bodies of all recipes in storage shall be *protected from change*. This is not the same as the *write-protection* of the *namespace* in that *execution recipes* may be *deleted* and *renamed* by an *authorized user* and by the manager of the *originating namespace*.

Depending upon the value of the ExecChgCtrl attribute of the recipe, permission to **change** the *execution recipe* (stored in the *execution recipe storage*) is granted or denied in advance and allows case-by-case granularity. Unless explicitly granted permission, a *changed* recipe may not be subsequently *selected* or *re-selected*.

Purposeful change during the *execution* process for hardware-dependent recipes is included in the ExecChgCtrl attribute permission to change the recipe body. For example, furnaces may be able to update a “profile recipe” during a normal process cycle. Recipes changed purposefully by the execution process are assumed to represent the best, most up-to-date, and most valid version of a hardware-dependent *class* of recipe. Suppliers of *recipe executors* with this capability shall provide complete documentation of the *class* of recipe changed and the circumstances under which it is changed.

The ExecChgCtrl attribute of a recipe may require that the *originating namespace* be notified of change. **Change notification** consists of a *notification message* sent to the *originating namespace* that alerts the *namespace manager* that a recipe has been changed or *originated*. Where *change notification* is required through ExecChgCtrl, the *namespace manager* is responsible for subsequently uploading the recipe, assigning it a new *identifier* if necessary, and requesting the renaming of the *execution recipe* as necessary to remain *synchronized*.

6.6.4 *Last Value* — Some *recipe executors* may also want to save the **last value** set by the user for each *variable parameter* and use it as the new *initial value* of that *parameter* when the same recipe is rerun.

This is useful when internal conditions drift in a consistent manner over time, the parameters are occasionally modified to compensate for such drift, and the last *setting* used is, therefore, a better "default" than the one specified in the recipe itself.

Permission to save the *last value* may be expressly granted by the user in the recipe attribute ExecChgCtrl.

Care should be taken to prevent unintentional modifications.

6.7 *Production* — Equipment utilizations states are defined by SEMI E10 (Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)). These states include the PRODUCTIVE and STANDBY states used by the factory for normal production work. The attributes ProdApprove and ProdCertify are defined as required only for equipment supporting states defined in this document.

To ensure that only recipes authorized for production are executed while the *executing agent* is in the PRODUCTIVE state, or are *selected* while in the STANDBY state, the *authorized user* may set the values of the attributes ProdApprove and/or ProdCertify to non-zero values. Non-zero values in ProdApprove or ProdCertify represent minimums for a recipe's ApprovalLevel and Certified attributes, respectively.

The *recipe executor* is responsible for comparing the corresponding recipe attributes ApprovalLevel and Certified. When a recipe is *selected* for execution (implicitly or explicitly) while either of the PRODUCTIVE or STANDBY states is active, the value of ApprovalLevel is required to be equal to or greater than the value in ProdApprove, and the value in Certified is required to be equal to or greater than the value in ProdCertify. Otherwise, the *select* shall fail.

6.8 *Recipe Executor Attributes* — The *recipe executor* is owned by the *agent* that provides a *recipe execution resource*. The *recipe executor* in turn owns the recipes that it has stored. It shall support Object Services for its owned object types and for itself.

Table 6.2 defines the *attributes* of the *recipe executor* in alphabetical order.

Table 6.2 Recipe Executor Attribute Definition

Attribute Name	*Definition*	*Access*	*Rqmt*	*Form*
ObjType	The object type.	RO	Y	Text = "RcpExec"
ObjID	Text.	RO	Y	Text.
DefaultNamespace	The name of an *executing agent's namespace* used for all hardware-dependent and other *agent-specific* recipes.	RW	Y	Text.
ProdApprove	The minimum value of a recipe's *approval level* accepted during productive and standby states. Required for SEMI E10 support only.	RW	N	Unsigned integer.
ProdCertify	The minimum value of a recipe's *certification level* accepted during productive and standby states. Required for SEMI E10 support only.	RW	N	Unsigned integer.
RunCycleUnit	The process unit on which the calculation of the estimated value of the recipe *generic attribute* EstRunTime is based.	RO	N	Case-sensitive formatted text composed of a unit of measure and an optional numeric suffix. Compliant with SEMI E5, Section 9.
RecipeSelectID	A list of recipe *identifiers* for the currently selected recipes.	RO	Y	List of formatted text.
RecipeSelect-Parameters	A list of all *parameter definitions* in effect for the i^{th} recipe *identifier* in RecipeSelectID. The maximum value for i is determined by the equipment supplier as the maximum number of recipes which may be *selected* at the same time. Required if variable parameters are supported.	RO	N	List of structures composed of parameter name, parameter value, parameter restriction.

7 Agents

This section describes the *agent* and **resources** as they are used in Recipe Management. The concept of *agent* is introduced to cover the different types of RMS implementations and to provide a context for the other specific object types introduced in RMS.

7.1 *Definitions* — A **resource** is an owned entity that has an active role in factory operations. A factory has many different kinds of *resources*. Some *resources*, such as valves, may be primarily physical. A software application is a type of *resource* not generally considered as physical. The factory itself is a *resource* for the corporation.

An **agent** is a system in a factory — a type of *resource* that includes both hardware and software components, at least some of which are also *resources*. Intelligent equipment that provides recipe namespace capability, for example, would be an *agent* with a recipe namespace *resource*, as well as a computer platform, operating system, and electro-mechanical components, some or all of which represent other types of *resources*. An *agent* may be a component of another *agent*, and it may also contain other *agents* as components. For example, a cluster module is a component of a cluster and may itself contain intelligent subsystems as components.

Agents may, in some cases, share certain *resources* with other *agents*. An example is a docking station that connects two clusters.

Services defined by RMS may be provided at various levels within the factory. The generic term *agent* may be applied at any of these levels as appropriate. Typical *agents* that use and provide Recipe Management services include *equipment*, clusters, cluster modules, cells, and independent *recipe namespace* servers[9] . The term *agent* applies equally well to each of these.

A **service resource** is a set of services within a particular area of specialization. *Service* resources of interest to RMS are the **recipe namespace resource**, the **recipe execution resource**, and the Object Services Resource. The *service resource* object, illustrated in Figure 7.1, allows a group of message services defined by a service standard (such as RMS) to be represented by a single object, one of the subtypes of the *service resource*. However, this concept is introduced for clarification only. The *service resource* object is not a *standardized object*.

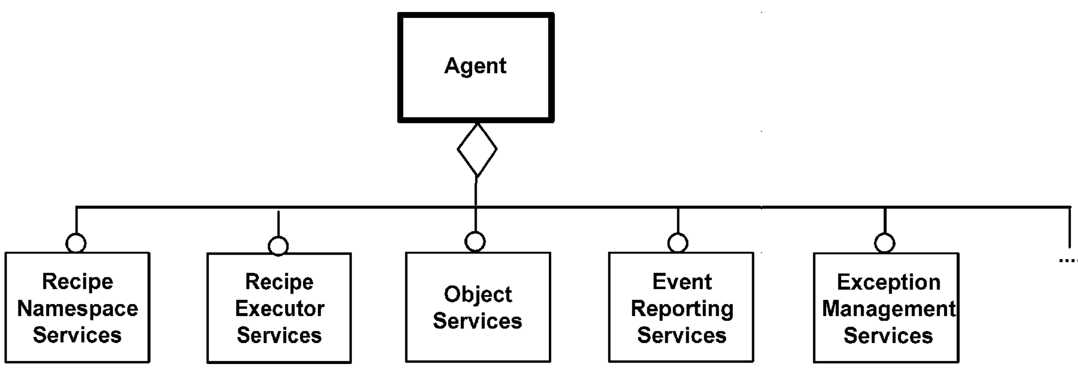

Figure 7.1
Examples of Service Resource Subtypes

An **agent** is introduced as a *standardized object* that provides one or more *service resources*. Figure 7.1 shows an example of an *agent* composed of different *service resources*. Also, an *agent* may *supervise subordinate agents* or be *supervised by a superior agent*, each of which in turn will possess their own *service resources*.

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9 A recipe namespace server is an agent whose primary function is to provide recipe namespace capabilities.

Agents interact with one another collaboratively and/or hierarchically, through the *service resources* that they provide, to perform work in the factory.

7.2 *RMS Resources* — The service resources defined by RMS are the **recipe namespace resource** and the **recipe execution resource**.

A *recipe namespace resource* consists of the set of message services defined in Section 12, corresponding to the *namespace* operations defined in Sections 8 and 9. All services required for operations designated as required are *fundamental* and shall be provided for an RMS-compliant *recipe namespace resource*.

A **recipe execution resource** consists of the set of messages defined in Section 14 corresponding to the *recipe executor* operations defined in Section 11. All services required for operations designated as required are *fundamental* and shall be provided for an RMS-compliant *recipe execution resource*.

7.3 *Agent Attributes* — Table 7.1 defines the *public attributes* of *agents* that are required for recipe management.

Table 7.1 Agent Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqt*	*Form*
ObjType	Agent object type.	RO	Y	Text: "Agent"
ObjID	The agent's name, assigned by an *authorized user.*	RO	Y	Text.

8 Recipe Management Operations

There are two important kinds of operations involving recipes within a *namespace*. Those that change a recipe's attributes or body are called **recipe management** operations. Those that affect the set of recipe *identifiers* within a *namespace* are part of **recipe namespace management** operations. A few operations qualify as both *recipe management* and *namespace management* and are discussed in their different aspects under both topics.

A third type of operation is informational only and requires reading but not changing recipe attributes. Operations of this type that require knowledge of the attributes of the *namespace* or of more than one recipe are discussed in Section 9.

This section describes **recipe management** operations.

Requests for *recipe operations* are always directed to the *namespace* where the recipe is stored. *Recipe management* operations are delegated by the *namespace manager* to the *namespace segment*, which is considered as the **recipe manager**. This is invisible for a *centralized namespace* and explicit for a *distributed recipe namespace*.

Operations may be invoked by the *operator* or through *namespace* services defined in Section 12. In many cases, service scenarios consist of a single message request from the service user and a corresponding response from the *namespace manager*. This case is illustrated in Section 12.2, Figure 12.1. Operations requiring additional messages are discussed in Section 8.2.

The service user is responsible for proper authorization of the user prior to requesting an operation that is restricted to authorized users through RMS services.

8.1 *Recipe Lifecycle* — A typical production recipe goes through various stages in its development within a *namespace*. These stages are shown below in a typical order through their associated operations. The attributes concerning the body are provided by the initiator of the operation.

create — The **create** operation enters a recipe *body* into the *namespace*.

Editing is expected, but not required, to be performed outside the *namespace.* Where provided by the *manager*, the same requirements concerning *creating* or *updating* a recipe are to be followed.

update — A recipe is **updated** when a body (typically, a modification of the original body) is entered into the *namespace* to replace the *body* of an existing recipe that is not **write-protected**. The attributes concerning the body are provided by the initiator of the operation.

verify — The **verify** operation is used to build a recipe. Checks for semantic correctness may also be performed at this time but are not required. The recipe *body* is read and checked for syntactical correctness, and all *external references* and *variable parameter definitions* are collected. The *verification* operation may be delegated to a *recipe executor*, which returns the required information.

write-protect — At some point during its development, an *authorized user* needs to be able to prevent the accidental deletion or modification of a recipe and requests to have it be **write-protected**. A **write-protected (read-only)** recipe may not be *updated*, **renamed, deleted, unlinked,** or **relinked**.

link — The **link** operation is used to signify that the recipe is ready for *execution*. If the recipe has *external references*, *linking* also builds a *linked recipe set* by collecting the *external references* and *variable parameter definitions* and saving them for quick access in the *main* recipe's attributes. *Linking* resolves all *identifiers* explicitly for recipes that are within the *namespace*.

unlink — At times it may be desirable to undo the *link* operation. The **unlink** operation *clears* those attributes set by the last *link* operation. A *write-protected* recipe may not be *unlinked*.

approve — The factory uses the recipe's *approval level* to indicate the level of its authorization. For example, *approval levels* of 1, 2, and 3 may indicate "write-protected," "authorized for engineering," and "authorized for production," respectively.

modify variable parameters — The *variable parameter definitions* of a *linked* recipe may be adjusted for a specific *executing agent* to achieve the desired result. For example, a *generic* parameter for time may be incremented repeatedly for a specific furnace until it goes out of range, which indicates that it needs to be cleaned. If the recipe did not previously have an *agent-specific dataset* for this *agent*, this operation causes one to be created.

certify — An *authorized user* (typically by the process engineer who developed the recipe) assigns it a **certification-level** to indicate that it achieves the desired result on a specific *executing agent*. The factory may require certain **certification levels** for production.

de-certify — the *certification level* of the recipe is reset to zero.

unprotect — Before a recipe can be *updated, deleted, renamed, re-linked,* or *unlinked*, the recipe must be *unprotected*.

delete — **Deleting** a recipe causes it to be removed from the *namespace*.

8.2 *Description of Operations* — Operations that require additional messages are of two types: operations that may be performed on more than one recipe (such as **certify recipe**) and operations that may require interactions with a *recipe executor* to complete (**verify recipe**). The scenario for *verify recipe* is shown in Section 9.4.7.

The remaining operations that require additional messages are invoked with the *namespace* service RMNAction, where multiple recipes are specified for the operation. Operations such as these may require more time to complete. The initial response to the message service request only indicates the intent to perform the operation. In this case, the scenario is illustrated by Figure 8.1 and Figure 12.2, Section 12.2. The *namespace manager* performs the operation for each recipe, in the order specified, and upon the completion of each operation, sends the notification message RMNComplete with the results for that operation. (See Sections 12.15 and 12.17 for additional details.)

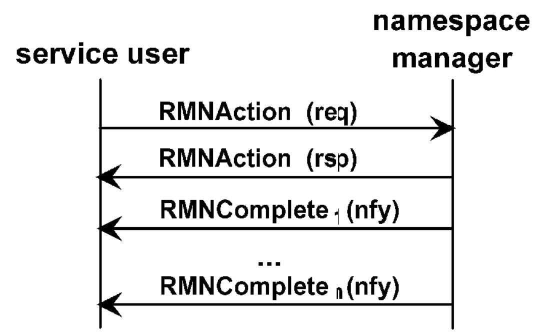

Figure 8.1

Message Flow with Completion Notification

Recipe management operations are categorized into three types: **recipe origination, recipe building,** and **recipe authorization**.

Recipe origination includes those operations that create or modify an entire recipe. **Recipe building** includes the *verification, link, unlink,* and *modify variable parameter* operations. **Recipe authorization** includes the *write-protect,* **unprotect, approve,** and **certify** operations.

Except for those operations that only provide information, *recipe management* operations change the state of the recipe. Section 8.3 contains the complete state model, and a table of transitions is given in Table 3.1. Substates of this model are provided for illustration in sections defining the operations that affect these substates.

8.2.1 *General Requirements* — The *generic length* and *timestamp* attributes AttrLength and AttrChgTime shall be updated whenever any other *generic* attribute changes value.

An *agent-specific dataset* for a specific *agent* exists only when a non-required attribute is given a *non-default value*, such as whenever a recipe is *certified* for a given *agent*. If the non-required attributes are all *cleared*, the *agent-specific dataset* is **removed** and no longer exists. Otherwise, the *agent-specific length* and *timestamp* attributes for an *agent-specific dataset* shall be updated whenever one of its attributes changes value.

8.2.2 *Recipe Origination* — A recipe may be originated by the *create recipe* operation and by the *copy recipe* operation. The *copy recipe* operation creates a duplicate of an original recipe and assigns it a new *identifier*. All of the attributes of the original are copied directly. These operations are included in *Namespace Management* in Section 9.4.1.

8.2.2.1 *Create Recipe* — A recipe is **created** when a recipe *body* is first entered into a *namespace* and assigned a new *identifier*. The recipe's *mandatory attributes* are set. All other *attributes* take on their default values. The values for the *attributes* BodyLength, *EditTime*, and EditedBy are required to be provided by the initiator of the *create* operation. The attribute BodyFormat is also provided at this time if it is not in source form (i.e., if BodyFormat has a *non-default* value).

A newly *created* recipe has an active state model (Figure 8.7). The recipe is in the UNVERIFIED, UNLINKED, UNAPPROVED, UNPROTECTED, and UNCERTIFIED states.

The *create recipe* operation is invoked with the RMNCreate service.

8.2.2.2 *Update Recipe* — The **update** operation is identical to that of *create* except that an *unprotected* recipe with the specified *identifier* already exists, and the new *body* replaces the existing *body*. Attributes concerning the *body* are provided by the initiator of the request, as for the *create* operation. All *non-mandatory attributes* are *cleared* (reset to their *default values*). Any existing *agent-specific datasets* are discarded.

The *update recipe* operation is invoked with the RMNUpdate service.

8.2.3 *Recipe Building* — Building a recipe is a two-step process. First the recipe is *verified* and then *linked*.

8.2.3.1 *Verify Recipe* — The **verify operation** is the only time it is necessary to parse the contents of the recipe *body* until the recipe is *executed*. The primary purpose of this process is to ensure that the syntactical and lexical structure of the *body* is correct. One or more checks for semantic correctness may also be performed as part of the *verification* operation, but this is not required.

Actual *verification* is performed by a member agent's **recipe executor** at the request of a *namespace manager*. For this reason, this operation is also discussed under *namespace management* in Section 9.4.7.

Recipes may be stored in a *namespace* in an incomplete or unfinished form. For recipes in *source form*, the *verification* procedure shall be performed only at the request of the *user*. It shall not be performed automatically.

There are four attributes affected by the *verification* operation: Verified, EstRunTime, ExtRef, and Parameters.

The boolean *generic attribute* Verified is used to indicate the recipe's state with respect to this procedure. Verified is *cleared* when a recipe is first created and whenever it is updated. Verified is set TRUE only when the recipe passes the *verification* by a *recipe executor*. A recipe is considered to be **verified** if, and only if, the Verified *attribute* is TRUE. Figure 8.2 illustrates the recipe's VERIFICATION state. For a description of the transitions, see Table 8.1 in Section 8.3.

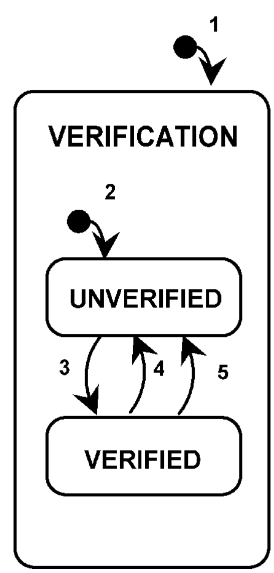

Figure 8.2
Verification State Model

The values for the attributes EstRunTime, ExtRef, Parameters, and VerificationID are returned (where set) by the *recipe executor* when the *verification* has been successful. If the operation is unsuccessful, they shall be *cleared*.

ExtRef contains a list of all *external references* found within the *body* of the recipe by the *recipe executor*. These references may be explicit or implicit, leaving the *class* and/or *version* unspecified.

The *verify recipe* operation is invoked with the RMNAction service.

8.2.3.2 *Link Recipe* — The **link operation** is a required *operation* that may be requested at any time by the *operator* or *supervisor*. Successful completion of the *link operation* indicates that the recipe is ready for *execution*. For single-part recipes without *variable parameters*, *linking* consists only of *setting* the *generic attribute* Linked to TRUE. Figure 8.3 illustrates the LINKAGE state of the recipe. For a description of the transitions, see Table 8.1 in Section 8.3.

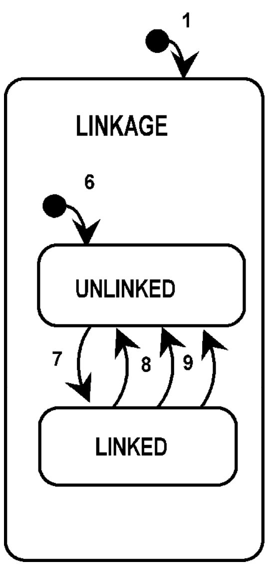

Figure 8.3
Link State Model

For multi-part recipes, this *operation* also collects *external references* and *variable parameter definitions* into the LinkList and LinkParam attributes, to be used by the *recipe executor* at run-time.

External references contained within multi-part recipes are not required to specify the *class* of the *subrecipe* when the *class* is the same as that of the *parent* recipe. Where *class* is omitted in a recipe *identifier* in the ExtRef attribute, the *link* operation is responsible for adding the *class* of the *parent recipe* in the *identifier* added to the LinkList parameter, as the *parent/child* relationship cannot be derived from the final contents of LinkList.

External references are assumed to refer to recipes within the same *namespace* and are not required to give explicit *versions* unless they specify a different *namespace*. This ensures that the *user* will be able to *link* together the "best choice" *subrecipes*. The exact value of *versions* of such references is determined only at the time the *main* recipe is *linked*.

The **link** operation is performed on a *main* recipe. That is, it only modifies *attributes* of the *main* recipe. It resolves all *external references* within that recipe and within any of its *subrecipes* according to well-defined rules for determining default *versions* at the time of the *link*. At the same time, *variable parameter definitions* are collected. The resulting explicit references are placed in the LinkList *attribute*, *variable parameter definitions* are placed in LinkParam, the ApprovalLevel attribute is *cleared*, the Linked attribute is set to TRUE, and the *main* recipe is then said to be **linked**.

Subrecipes are not affected by this operation. *Subrecipes* of a *main* recipe have no knowledge of parents or of linkages. As a result, it is possible to *delete* or change a *subrecipe* with an unintended detrimental impact on a *linked recipe set*. Factory policy may designate certain levels of *approval* to mean "this recipe is used by (*linked* into) one or more *protected* recipes."

For multi-part recipes, *linking* starts at the *main recipe* and works through all chains of referenced *subrecipes* to determine the complete set of *identifiers* that will comprise the recipe as a whole. The *link* operation is a mechanical procedure that may be performed at any time.

Successful *linking* implies that all referenced *subrecipes* have been located and parsed for further references until all references are exhausted. The *link* operation shall fail when any recipe or *subrecipe* within the namespace either is *unverified* or cannot be located.

If the same *parameter name* is used to *define* a *parameter* in more than one recipe of a set of recipes that are *linked* together, the *name* shall represent the same *parameter* and have the same *parameter definition* in all recipes in the set, to avoid ambiguity. *Parameters* with the same *parameter name* and differing *definitions* shall cause, at a minimum, a warning to the user when the *link operation* completes.

For purposes of comparison of results, the order of references in LinkList and LinkParam at the completion of the *link* operation shall conform to the results when the following sequence is used:

1. Copy the contents of ExtRef from the *main* recipe to LinkList, resolving *class* and *version* to each recipe *identifier* as needed. For support of *variable parameters*, also copy the contents of

Parameters to LinkParam. If ExtRef is *empty*, then LinkList is also *empty* and the parsing process is complete.

2. If LinkList is not *empty*, begin with the first reference in LinkList as the **link target reference**.
3. If the *link target reference* lies within the same *namespace*, resolve the *class* and *version* if necessary. (Note: the referenced recipe must be already present within the *namespace* at the time the *link* is performed, or else the *link* fails.) If the *link target reference* specifies a different *namespace*, go to Step (6) — the *link* operation of this chain terminates (without error) without an attempt to locate the actual recipe or its ExtRef *attribute*. If the recipe is located, then it is called the **link target recipe**.
4. Determine the contents of the Verified attribute of the *link target recipe*. If Verified is FALSE, the *link* operation fails immediately.
5. Determine the contents of the ExtRef *attribute* of the *link target recipe*. Remove any references that duplicate those already contained in LinkList, resolve *class* and *version* as needed, and append the result to LinkList. If *variable parameters* are supported, also determine the contents of Parameters in the *link target recipe*, remove *parameters* already defined in LinkParam, and append the result to LinkParam.
6. Set the *link target reference* to the next reference in LinkList and repeat steps (3) through (6) until all references in LinkList have been processed.

For recipes with no *external references*, the LinkList list will be *empty*. Similarly, for recipes with no *variable parameters*, the LinkParam list will be empty.

The effect of allowing incomplete recipe *versions* to be specified within a recipe *body*, and determined only when the *main* recipe is *linked*, means that a *linked recipe set* (the set of recipes *linked* together) produced on one occasion may not be the same as those produced on a different occasion. Therefore, it is necessary to protect the contents of the LinkList *attribute* from inadvertent change.

For this reason, the *link* operation cannot be performed on a *read-only* recipe with the Linked *attribute* already set from a previous *link*. Any attempt to *link* an already *linked read-only* recipe either shall be denied or a new copy of that recipe shall be generated with a new *identifier*, which may then be automatically *approved* and *linked*.

The *link recipe* operation is invoked with the RMNAction service.

8.2.3.3 *Unlink Recipe* — A *linked* recipe that is not *write-protected* may also be *unlinked*. The *unlink* operation *clears* the *generic attributes* Linked, LinkList, and LinkParam. If the recipe has *agent-specific datasets*, the attributes Certified and AgentSpec_LinkParam are *cleared*. If no other non-required *agent-specific* attributes have a *non-default value*, the *agent-specific dataset* is removed.

The *unlink recipe* operation is invoked with the RMNAction service.

8.2.3.4 *Modify Variable Parameters* — The recipe *attributes* Parameters, LinkParam, and AgentSpec_LinkParam each consist of a list of **parameter definitions**. Each *parameter definition* contains the *parameter name, parameter initial value,* and the *parameter restriction* (if any) specified for that *parameter* by a formal definition within the recipe body.

In order to "tune" a recipe so that it produces the same result on all *executing agents* of the same type, it may be necessary to provide a different *initial value* or a different *parameter restriction* for one or more *parameters* for individual *executing agents*. The *agent-specific* attribute AgentSpec_LinkParam is used to provide this capability.

AgentSpec_LinkParam is an optional *agent-specific attribute* that contains a list of alternate *parameter definitions* for one or more of the *variable parameters* included in the *definitions* in the *generic attribute* LinkParam of a *linked* recipe. A special editing facility may be provided to allow an *authorized user* to **add**, **delete**, or **modify** *parameter definitions* to AgentSpec_LinkParam.

Parameter definitions initially are added individually to AgentSpec_LinkParam by copying the *definition* for that *parameter* from LinkParam. The *initial value* or *restriction* then may be modified by the user, subject to the absolute restrictions, such as minima and maxima, imposed by the *executing agent's* supplier. The *initial value* may be changed to any value within the *parameter domain*.

Any modification of the *restriction* shall cause the *certification level* to be *cleared* in the Certified *attribute*. This is required because of the potential impact on fab operations of a change in the *restriction*.

The UNITS in the *restriction* of a *numeric parameter* may be modified within constraints imposed by the use of the *parameter* and the *executing agent's* supplier. For example, a two-byte unsigned integer named WaitTime that is used to set a variable time delay period may permit units of either “min” (minutes) or “s” (seconds). It is desirable, but not required, that suppliers of *executing agents* support different options for specifications of UNITS. The possible options for each potential *variable parameter* shall be documented by the supplier.

The **modify variable parameter** operation consists of **adding**, **deleting**, or **modifying** a specific *parameter definition* to a list of *definitions* in AgentSpec_LinkParam for a specific *agent*.

A *definition* is **added** when it is copied directly from the LinkParam *attribute* to the AgentSpec_ LinkParam *attribute* without modification. A *definition* shall only be *added* if there is currently no *definition* for a *parameter* with the same *parameter name* in the AgentSpec_LinkParam *attribute*.

A *definition* is **deleted** when it is completely removed from the list of *definitions* in AgentSpec_ LinkParam.

A *definition* is **modified** when the *value* or *restriction* of an existing *definition* is replaced in AgentSpec_LinkParam.

The *modify variable parameters* operation is invoked with the RMNVarPar service.

8.2.4 *Recipe Authorization* — Recipe authorization operations include those that allow an *authorized user* to change the value in the *generic* attribute Approval-Level or the *agent-specific* attribute Certified.

The *de-certify* operation is invoked with the service RMNAction.

8.2.4.1 *Approve Recipe* — Recipe management provides two different methods of controlling how a recipe is applied: through the *generic* attribute ApprovalLevel and through the *agent-specific* attribute Certified. The recipe's **approval level** (the value contained in ApprovalLevel) is also used to protect it from change.

A recipe goes through different stages during its lifecycle. After a recipe has been initially created, it will typically go through a dynamic period while it is tested and adjusted until it produces the desired results.

ApprovalLevel is an unsigned integer used to designate the different stages in a recipe's life cycle. It is set to zero (its *default value*) whenever a recipe is *created*, *updated*, or *linked*.

The **approval** operation allows an *authorized user* to set ApprovalLevel to a non-zero value. Otherwise, it may not be set externally.

A recipe is said to be **approved** whenever Approval-Level is non-zero. An example of a factory's implementation of *approval levels* is given in the appendix, Section 8.3. Figure 8.4 illustrates the recipe's APPROVAL state. For a description of the transitions, see Table 8.1 in Section 8.3.

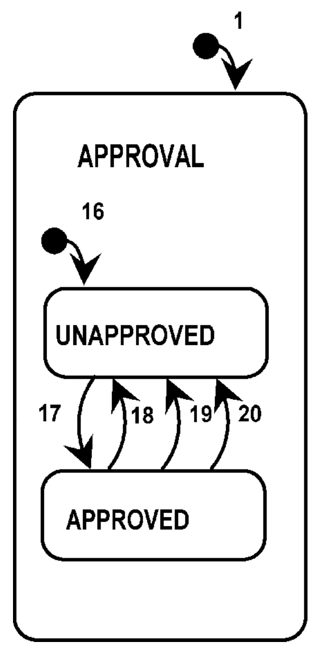

Figure 8.4
Approval State Model

A *subrecipe* may be *approved* independently from any recipes which reference it.

A *linked* recipe may not be *approved* to a level higher than the lowest *approval level* of any of its *subrecipes*. Therefore, all *subrecipes* referenced in the *attribute* LinkList of a *linked* recipe must be located prior to granting an *approval level* other than zero. The ApprovalLevel *attribute* of the *subrecipes* must be increased to a value equal to, or greater than, the required *level* by an *authorized user* before the higher *approval level* of the *linked recipe* is accepted.

The restriction on the *approval level* of the *linked* recipe requires the *user* to purposefully change the *approval level* in order to protect the entire *linked recipe set* as a unit from unexpected change, as it is by the *main recipe identifier* that the recipe as a whole will be known. It should be noted that *approval* of a *linked* recipe is not the same as approval of the individual parts, as a *subrecipe* which is appropriate in one recipe may be inappropriate in another.

The *approve recipe* operation is invoked with the RMNAction service.

8.2.4.2 *Certify* — The **certify** operation sets the value of Certified for a specific *executing agent* to a non-zero value specified by an *authorized user*. This operation affects no other attributes (except the *length* and *timestamp* attributes of the affected *agent-specific dataset*).

A recipe may be syntactically and procedurally correct but, due to the differences between different installations of *agents* with access to a *namespace*, may give different results on these different installations. Recipe **certification** signifies that a *linked* recipe produces the desired results on a specific installation.

A recipe is considered **certified** for *agent* if the **certification-level** contained in the *agent-specific attribute* Certified is non-zero. Otherwise, the recipe is *uncertified*. A *certified* recipe is *de-certified* when the *certification-level* is set to zero.

A recipe may be *certified* and *de-certified* only by an *authorized user*. Figure 8.6 illustrates the recipe's CERTIFICATION states. For a description of the transitions, see Table 8.1 in Section 8.3.

Recipes with *variable parameters* may be *certified* for specific *values* and *restrictions* of some of these variables. If so, such values are stored in the AgentSpec_LinkParam *attribute*.

Only recipes with the Linked *attribute* set to TRUE may be *certified*.

The *certify recipe* operation is invoked with the RMNAction service.

8.2.4.3 *De-certify* — The **de-certify** operation clears the Certified attribute for a specific *agent* at the request of an *authorized user*.

A recipe may need to be *de-certified* after major maintenance has been performed and later *re-certified* only after testing its results.

8.2.5 *Recipe Protection* — The *namespace* attribute RecipeReadOnlyLevel is used as a threshold to govern the level of approval required for individual recipes to be protected. A recipe is **protected** when the value in its ApprovalLevel attribute is equal to, or greater than, RecipeReadOnlyLevel. All recipes are protected whenever the namespace's RecipeReadOnlyLevel attribute is equal to zero. Figure 8.5 illustrates the recipe's PROTECTION states. For a description of the transitions, see Table 8.1 in Section 8.3.

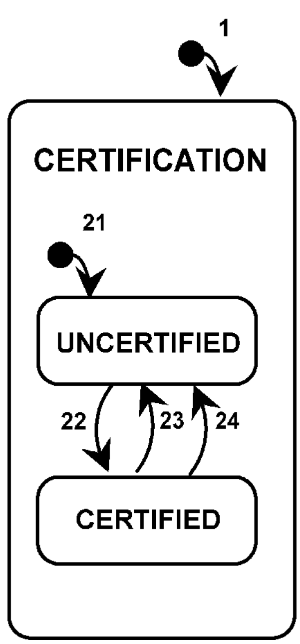

Figure 8.6
Certification State Model

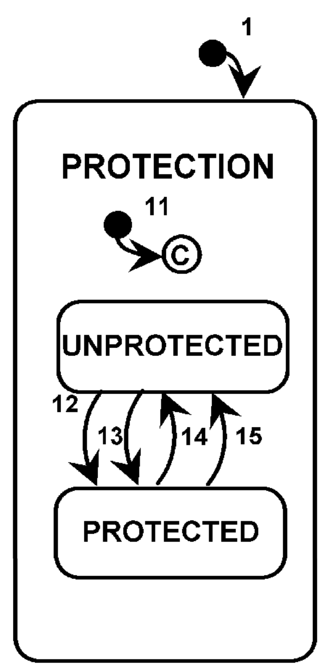

Figure 8.5
Protection State Model

If the value of RecipeReadOnlyLevel is n, then recipes with *approval levels* greater than, or equal to, n are ***read-only***. The body of a *read-only* recipe may not be changed in any way, including by over-writing or deleting. The *identifier* of a *read-only* recipe may not be renamed. A *linked* recipe that is *read-only* may not be *re-linked*.

The *recipe protect* operation sets the value of ApprovalLevel to the value in RecipeRead OnlyLevel. For *linked* recipes with *subrecipes*, the operation is denied if the resulting *approval level* for the main recipe would be higher than any *subrecipe*, as described in Section 8.2.4.

If the value in RecipeReadOnlyLevel is zero, all recipes within the *namespace* are automatically *write-protected*, regardless of the support for the ApprovalLevel *attribute*.

The *protect recipe* operation is invoked with the RMNAction service.

8.2.6 *Unprotect* — The *read-only* status of a recipe may be changed either by changing its *approval level* to a value less than the value of RecipeReadOnlyLevel or by increasing the value in RecipeReadOnlyLevel.

NOTE: If RecipeReadOnlyLevel is zero, all recipes are write-protected regardless of the value in approval-level.

A protected recipe may be changed to **unprotected** at the request of an *authorized user*. This operation *clears* the ApprovalLevel attribute.

The unprotect recipe operation is invoked with the RMNAction service.

8.2.7 *Informational Operations* — Object Services are used to request the current value of one or more recipe attributes and to set one or more values. Certain *attributes* have **restricted access** and may not be set through RMS *services*. These *attributes* are identified as "RO" (read-only) in Tables 3.1 and 3.2 in the column labeled "Access" in Section 3.4.2. When attributes identified as "RW" (read-write) are set through Object Services, the appropriate attribute *length* and *timestamp* attributes shall be updated appropriately.

In addition to Object Services, the **get descriptors** operation provides important information.

8.2.7.1 *Get Recipe Descriptors* — The **get recipe descriptor** operation returns the *descriptor* of a specified recipe: *the generic descriptor*, the *body descriptor*, and the *agent-specific descriptors* of any existing *agent-specific datasets*.

A *recipe descriptor* may be used to determine if two or more recipes are identical or which is most recent.

The *get recipe descriptors* operation is invoked with the RMNGetDescriptor service.

8.3 *Recipe State Model* — An existing recipe has different states of interest to RMS. These are shown in Figure 8.7. The Recipe Available State Model in Figure 8.7 combines the separate models for VERIFICATION, APPROVAL, PROTECTION, LINKAGE, and CERTIFICATION as AND substates of RECIPE AVAILABLE.

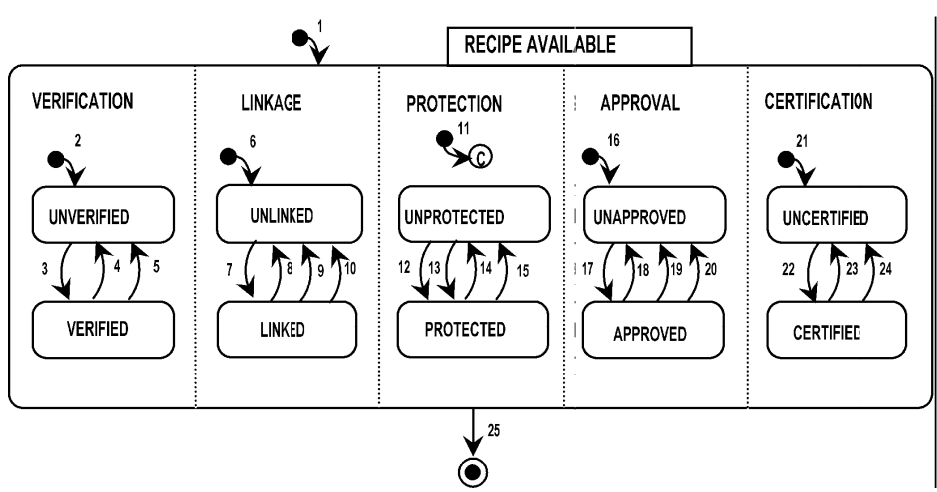

Figure 8.7
Recipe Available State Model

These states have been discussed in previous sections and are associated with one or more of the recipe's *attributes*, as follows:

VERICATION: Verified,

APPROVAL: ApprovalLevel,

PROTECTION: the interaction of ApprovalLevel and the *namespace attribute* RecipeReadOnlyLevel,

LINKAGE: Linked, and

CERTIFICATION: Certified.

The table of transitions is given in Table 8.1.

Table 8.1 Table of Transitions

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	(entry to Recipe Available)	Recipe is created.	Recipe Available.	Initialize generic attributes.	None.
2	(default entry to VERIFICATION)	Recipe is created.	UNVERIFIED	Verified reset.	Newly created recipe is unverified.
3	UNVERIFIED	Requested verification operation is successful.	VERIFIED	Set Verified to TRUE.	Verification is performed by the recipe executor.
4	VERIFIED	Requested verification operation, on previously verified recipe, fails.	UNVERIFIED	Reset Verified.	Verification is performed by the recipe executor.
5	VERIFIED	Recipe is updated.	UNVERIFIED	Reset Verified.	Updated recipe must be *re-verified*.
6	(default entry to LINKAGE)	Recipe is created.	UNLINKED	Reset Linked, LinkList, and LinkParam.	Newly created recipe is *unlinked*.
7	UNLINKED	*Authorized user* requested *link* operation is successful.	LINKED	Set Linked to TRUE. Set LinkList and LinkParam.	Single-part recipes set Linked only.
8	LINKED	Recipe is *updated*.	UNLINKED	Reset Linked, LinkList, and LinkParam.	Single-part recipes set Linked only.
9	LINKED	Recipe is *re-verified*.	UNLINKED	Reset Linked, LinkList, and LinkParam.	Single-part recipes set Linked only.
10	LINKED	*Authorized user requests the* unlink operation.	UNLINKED	Reset Linked, LinkList, and LinkParam.	Single-part recipes set Linked only.
11	(default entry to PROTECTION)	Recipe is created.	If RecipeRead-OnlyLevel is zero, new state is PROTECTED. Otherwise, it is UNPROTECTED.	None.	All recipes are *read only* when RecipeReadOnlyLevel is zero.
12	UNPROTECTED	*Authorized user* request to *protect* the recipe.	PROTECTED	Set ApprovalLevel to the value in RecipeReadOnly-Level.	Recipe is *protected* when *approval level* = RecipeReadOnlyLevel.
13	UNPROTECTED	Authorized user sets RecipeReadOnlyLevel to	PROTECTED	None.	Recipe is *protected* when *approval level* greater than

		value greater than or equal to *approval level*.			or equal to RecipeReadOnlyLevel.
14	PROTECTED	*Authorized user* sets *approval level* to a value less than RecipeReadOnlyLevel.	UNPROTECTED	None.	Recipe is *unprotected* when *approval level* less than RecipeReadOnlyLevel.
15	PROTECTED	*Authorized user* sets RecipeReadOnlyLevel to a value greater than *approval level*.	UNPROTECTED	None.	Recipe is *unprotected* when *approval level* less than RecipeReadOnlyLevel.
16	(default entry to APPROVAL)	Recipe is created.	UNAPPROVED	Reset ApprovalLevel.	Newly created recipe is *unapproved*.
17	UNAPPROVED	*Authorized user* sets non-zero *approval level*.	APPROVED	Set ApprovalLevel as specified by the user.	User assigns *approval level* to a specific value.
18	APPROVED	*Authorized user* sets *approval level* to *zero*.	UNAPPROVED	Reset ApprovalLevel.	User assigns a zero value as *approval level*.
19	APPROVED	Recipe is *linked*.	UNAPPROVED	Reset ApprovalLevel.	User is required to specifically approve a *newly linked recipe set*.
20	APPROVED	Recipe is *updated*.	UNAPPROVED	Reset ApprovalLevel.	A modified recipe is *unapproved*.
21	(default entry to CERTIFICATION)	Recipe is *created*.	UNCERTIFIED	None.	Newly created recipe has no *agent-specific attributes*.
22	UNCERTIFIED	*Authorized user* assigned non-zero *certification level*.	CERTIFIED	Create *agent-specific dataset* if necessary. Set Certified to specified value.	User assigns *certification level*.
23	CERTIFIED	*Authorized user* assigned zero *certification level*.	UNCERTIFIED	Reset Certified.	*Agent-specific dataset* not required if there are no *agent-specific attributes*.
24	CERTIFIED	*Authorized user* changes *agent-specific variable parameter restrictions*.	UNCERTIFIED	Reset Certified.	A change in restrictions affects performance of recipe.
25	CERTIFIED	*Recipe* is *unlinked*.	UNCERTIFIED	Reset Certified attribute.	Agent-specific dataset not required if there are no agent-specific attributes.
26	RECIPE AVAILABLE	Authorized user deletes unprotected recipe.	(Undefined recipe no longer exists.)	Storage occupied by recipe becomes available.	None.

8.4 *Table of Operations* — Table 8.2 lists the *recipe management* operations in the order presented in this section. The column labelled "Rqmt" is used to indicate those operations that are required for *fundamental compliance* to RMS.

Table 8.2 Recipe Management Operations

Operation	*Description*	*Rqmt*
create recipe*	A new recipe body is entered into the namespace.	Y
update recipe*	The body of an existing recipe is replaced.	Y
verify recipe	Check the syntax or format of a recipe body for correctness.	Y
link recipe	A *main* recipe is *linked*.	Y
unlink recipe	An *unprotected linked* recipe is *unlinked*.	N
modify variable parameters	A *linked* recipe's parameter definitions are modified within an *agent-specific dataset*.	N
approve recipe	Set the recipe's *approval level* to a non-zero value.	N

protect recipe	Set the recipe's *approval level* to the value in RecipeReadOnlyLevel.	N
unprotect recipe	Set the recipe's *approval level* to zero.	N
certify recipe	A linked recipe's certification level is set to a non-zero value.	N
decertify recipe	A linked recipe's certification level is set to zero.	N
get recipe descriptor	A recipe's descriptor is requested.	Y

*This operation is also covered under Namespace Management Operations.

9 Namespace Management Operations

Namespace management operations include operations that affect the *namespace* itself in some way and those operations that provide information about the *namespace* or its *manager*, or that require knowledge about more than one recipe.

Namespace operations defined in RMS are presented in groups of similar functionality:

- *operations on the* namespace *(create, delete, and rename* namespace*),*
- *operations that provide information about the* namespace *or its recipes (get available storage, check recipe status, and get best version), and*
- *operations on recipes that affect the set of recipe identifiers within the* namespace *and/or moving a recipe as a whole (create, delete, store, retrieve, copy, and rename recipe),*
- *operations that always require interactions with a* recipe executor *(*verify*, download, and upload recipe).*

Namespace management operations may be invoked through *namespace* services defined in Section 12. In most cases, service scenarios consist of a single message request from the service user and a corresponding response from the *namespace manager*. This case is illustrated in Section 12.1.

Scenarios are shown only for operations that require additional messages. These operations are one of two types: operations that may be performed on more than one recipe (such as **delete recipe**) and operations that require interactions with a *recipe executor* to complete.

Operations such as these may require more time to complete. The initial response to the message service request only indicates the intent to perform the operation. The *namespace manager* informs the service user of the completion of each individual operation by sending the notification message RMNComplete. (See Section 12.1 for more detail.)

9.1 *Applications of Object Services* — A *manager* shall comply with SEMI E39 (Object Services Standard (OSS): Concepts, Behavior, and Services) specifications for *fundamental requirements* and with the requirements for Filters and Owner Objects.

9.1.1 *Object Specifiers* — The "owns/owned by" relationship is used by OSS to define the object specifier used for scope. Recipes within a *namespace* are *owned* by the *namespace* in which they reside. The *namespace* in turn is owned by its *manager*. The *agent* that provides the storage and services for a *centralized namespace* owns both the *manager* and the *namespace*.

An object specifier has the form of:

$$\text{“}\text{type}_1 : \text{id}_1\text{>}\ldots\text{type}_n : \text{id}_n\text{>”}$$

where "type_i" and "id_i" represent the object type and object identifier, respectively, of the ith object instance in the sequence, and where each object is owned by the preceding object in the sequence and is the owner of the succeeding object.

A **namespace specifier** is an object specifier applied to *namespaces*. A **recipe specifier** is an object specifier applied to recipes.

Object types in the object specifier may be omitted where they may be otherwise determined. For the *recipe specifier*, when omitted, they are determined by their relative positions, with the recipe identifier in the final position, preceded by a *namespace identifier*. Additional *identifiers* preceding that of the *namespace* are those of *agents*.

An example of a *namespace specifier* for a namespace "NS-MOM" owned by an *agent* "Etch01" would be "Agent:Etch01>RNS:NS-MOM>" or (where object types can be otherwise determined) "Etch01>NS-MOM". A recipe specifier for recipe "/PROCESS/ ABC;5" stored in NS-MOM would be "Agent: Etch01>RNS:NS-MOM>/PROCESS/ABC; 5>".

Where the *manager* is to be used instead of the *namespace*, the object type of the *manager* must be included.

A recipe in a *namespace* also owns its components. An *agent-specific attribute* is accessed through the recipe owner.

9.1.2 *Required Object Services* — A *manager* shall support operations for Get Attributes and Set Attributes for the *attributes* of the *namespace*, the recipes within the *namespace*, and the *manager* itself. For a *shared namespace*, access to different *agent-specific datasets* shall be supported.

When a recipe's *attributes* are changed through the Set Attributes operation, the appropriate attribute *timestamp* and *length attributes* shall be updated as well.

A *manager* shall support the Get Type and Get Attribute Name operations for the object types of *namespace*, recipe, recipe *components*, and *manager*.

9.2 *Namespace Operations* — This section describes operations that are performed on a *namespace*.

9.2.1 *Create Namespace* — The **create namespace** operation is used to define a *namespace* and assign a *name* to be used as its *identifier* ObjID. The *name* is assigned only by an *authorized* user, except that a *name* of "Default" is prohibited. Once *created*, the *namespace* shall be ready to accept recipes.

This is an optional capability that is not required if the *owner agent* that provides the *namespace* capabilities also provides an installed *default namespace* (see Section 6) that cannot be deleted. In this case, a means of recreating the *namespace* shall be provided in the event the *namespace* becomes damaged.

The *create namespace* operation is invoked with the message service RMNCreateNS.

9.2.2 *Delete Namespace* — The **delete namespace** operation is the inverse of the *create namespace* operation. A *namespace* that is not *empty* may not be *deleted*. It is recommended that the *default namespace* of a *recipe executor* should not be *deleted*. This is an optional capability required only if the *create namespace* operation is supported.

The *delete namespace* operation is invoked by the message service RMNDeleteNS.

9.2.3 *Rename Namespace* — The **rename namespace** operation allows an *authorized user* to change the *identifier* of the *namespace*. It is recommended that the *default namespace* of a *recipe executor* should not be renamed. This is an optional capability required only if the *create namespace* operation is supported.

The *rename namespace* is invoked by the message service RMNRenameNS.

9.3 *Namespace Informational Operations*

9.3.1 *Get Available Storage* — The **get available storage** operation is used to determine the size of the remaining recipe storage capacity, in bytes. The value returned shall exclude any overhead requirements for storage of one *generic* recipe. That is, it shall be assumed that sufficient storage exists for a single recipe with a combined *generic attribute length* and *body length* less than or equal to the returned value, and ignoring possible space requirements for additional *agent-specific datasets*. This is a required operation.

The *get available storage* operation is invoked by the message service RMNSpaceInquire.

9.3.2 *Check Recipe Status* — The **check recipe status** operation checks a recipe *identifier* and returns the status for existence and *read-only* (PROTECTED or UNPROTECTED state). It also returns the next available *numeric version*. This is a required operation.

This operation may be used to determine if a given recipe *identifier* will be accepted prior to sending it to the *namespace* and to obtain an available version if the original *identifier* is used for a *read-only* recipe.

The *check recipe status* operation is invoked by the message service RMNRecStatInquire.

9.3.3 *Get Best Version* — The **get best version** operation checks for the best *default version* of a recipe with a specified *class* and *name* and for an optional specific *member agent*. If a *member agent* is specified, then in addition to the rules for selection of a default version defined in Section 3.2.3.4.1, the *version* with the highest *certification level* for that *agent* is selected. This is a required operation.

The *get best version* operation is invoked by the message service RMNVersionInquire.

9.4 *Namespace Recipe Operations* — This section describes the recipe operations that affect the set of recipe *identifiers* within the *namespace* and/or involve moving an entire recipe.

9.4.1 *Create Recipe* — A recipe is created through the **create recipe** operation when a *namespace* is sent a recipe with an *identifier*, *body*, *body descriptor*, and the *attributes* BodyFormat and EditedBy only. This operation sets the attributes AttrLength and AttrChgTime and *clears* the remaining *generic attributes*.

This capability allows a recipe body that has been created off-line to be stored in a *namespace*. It is required of any *namespace* intended for use other than as a *default namespace* for hardware-specific recipes only[10].

The *create recipe* operation is invoked by the message service RMNCreate.

9.4.2 *Delete Recipe* — The **delete recipe** operation has the effect of deleting a recipe from the *namespace*. Complete physical erasure of the recipe is not required, but the recipe is no longer considered to be stored in the *namespace*, is no longer accessible, and the storage space that it used is freed.

A *read-only* recipe may not be *deleted*.

The *delete recipe* operation is invoked by the message service RMNAction. More than one recipe may be specified by the service user. Figure 9.1 illustrates the flow of messages in this case. The *namespace manager* responds to the initial request with an intent to comply before performing any deletions. As each deletion is completed, the *manager* notifies the service user of the results using RMNComplete.

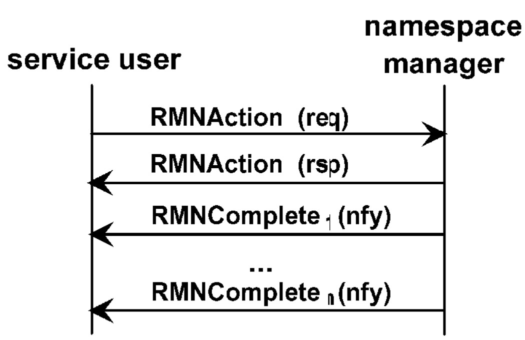

Figure 9.1

Delete Recipe Scenario

9.4.3 *Store Recipe* — The **store recipe** operation is used to store a complete recipe, including its *body, generic attributes*, and one or *more agent-specific datasets*, in a *namespace*. Note: methods of storing recipes are not specified by RMS.

Storage shall be denied if the specified recipe *identifier* is already used by an existing *read-only* recipe or if there is insufficient storage available for the recipe. Otherwise, the recipe shall be accepted into the *namespace*.

The *store recipe* operation is invoked by the message service RMNStore.

9.4.4 *Retrieve Recipe* — The **retrieve recipe** request specifies the *identifier* of a recipe. If the recipe exists within the *namespace*, the *namespace manager* returns the requested recipe. Otherwise, it shall deny the request. This is a required operation.

It is also possible to *retrieve* a recipe's *generic attributes* set to a *non-default value* and/or one or more of its *agent-specific datasets* without *retrieving* its *body*.

The retrieve recipe operation is invoked by the message service RMNRetrieve.

9.4.5 *Copy Recipe* — The copy recipe operation causes a new copy of a recipe, with a different *identifier* from the original recipe, to be created within the *namespace*. If the *identifier* for the new *copy* is already in use by a pre-existing *read-only* recipe, the namespace shall deny the request.

The *copy recipe* operation is invoked by the message service RMNCopy.

9.4.6 *Rename Recipe* — The rename recipe operation causes a recipe to be assigned a new *identifier* within the *namespace*. If the new *identifier* is already in use by a pre-existing *read-only* recipe, the namespace shall deny the request. In this case, it may suggest a new *version* according to the rules in Section 3.2.3.3.

The *rename recipe* operation is invoked by the message service RMNRename.

9.4.7 *Verify Recipe* — A *manager* is not required to understand the syntax or semantics of the recipe language of a *source* recipe or to understand the internal format of an *object form* recipe. To *verify* a recipe, the *manager* may require the services of a *recipe executor*, described in Section 6. In this case, the *manager* shall request *verification* from the *recipe executor* of one of the *agents* listed in its Members attribute and shall return the resulting status and error information to the initial requestor. (See Section 11 for more detail.) This is a required operation.

10 In the case of the default namespace dedicated to hardware-specific recipes, the recipes may always be created initially by the recipe executor and uploaded to namespace.

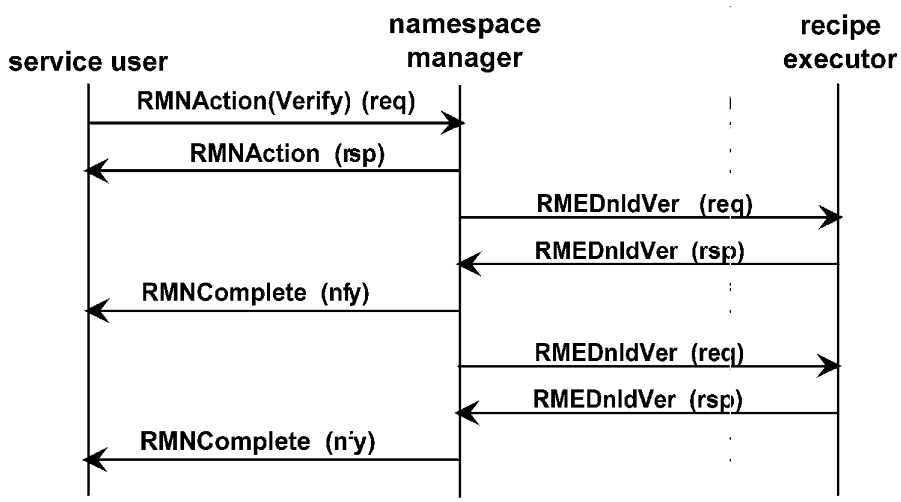

Figure 9.2
Verify Scenario

The *verify recipe* operation is invoked by the message service RMNAction. Figure 9.2 shows a typical sequence of the message flow when the *verify* operation is requested for multiple recipes. The *namespace manager* responds to the service request RMNAction (Verify) with an intent to perform the requested operations. Each recipe specified in the request is downloaded to a *recipe executor* of an *agent* listed in the *namespace* attribute Members. (Note: where the *namespace manager* and *recipe executor* are provided by the same *agent*, formal RMS services are not required for communications between the two.) In this example, the *recipe executor* responds to the *namespace manager* with an intent to comply, *verifies* the recipe, and returns the information required for the completion of the *verify* operation as described in Section 8.2.3.1. The *namespace manager*, in turn, returns the final status of the operation for that recipe in the notification message RMNComplete.

The *recipe executor* provides two operations for performing verifications, "download and verify" and "verify". The former operation does not typically *re-verify* already *verified* recipes. See Sections 11.2.1 and 11.2.2 for detail.

The *verify recipe* operation is invoked by the message service RMNAction.

9.4.8 *Download Recipe* — The **download recipe** operation causes the *namespace manager* to download a recipe to the *recipe executor* of a specified *agent* (see Section 11.2.1). This operation differs from the verify operation, which results in a download to an unspecified recipe executor if the *namespace manager* is not able to perform the verification without help.

The *namespace manager* is responsible for converting the form of a *managed recipe* to that of an *execution recipe* for downloading. This is accomplished through the following steps:

1. If the recipe is not *verified*, then no conversion is performed. The attributes ExecAttrLength and ExecAttrChgTime are set and maintained only by the *recipe executor*. These attributes are not sent with the downloaded recipe.

2. The *generic* attributes ExtRef and Parameters of the *verified* recipe are not sent with the downloaded recipe.

3. If an *agent-specific dataset* exists that corresponds to the destination *recipe executor*, and if the *agent-specific* attributes AgentSpec Comments and Certified are non-empty, they are included in the attributes of the downloaded recipe.

4. The *execution recipe* attribute ExecLinkParam combines the contents of the *generic* attribute LinkParam and the *agent-specific* attribute AgentSpec LinkParam. If an *agent-specific dataset* exists that corresponds to the destination *recipe executor*, and if there are *variable parameter initial values* and *restrictions* in the *agent-specific* attribute AgentSpec LinkParam, then they replace their corresponding elements in the *generic attribute* LinkParam, and the results are placed in the ExecLinkParam attribute of the downloaded recipe.

The *download recipe* operation is invoked by the message service RMNAction.

9.4.9 *Upload Recipe* — The **upload recipe** operation causes the *manager* to upload a recipe from the *recipe executor* of a specified *agent* (see Section 11.2.3). This operation is the equivalent of a *namespace-initiated recipe create* (if the specified recipe *identifier* does not already exist in the *namespace*) or a recipe update.

The *upload* operation allows recipes that have been *created* or modified by the *recipe executor* to be placed under management in a *namespace*. Such recipes are always *unlinked*.

In addition, it is possible to upload previously downloaded recipes. However, due to the differences in the attributes, certain intermediate information available in a *managed recipe*, such as ExtRef and Parameters, must be re-created for the uploaded recipe by requesting the *recipe executor* to *verify* the recipe and send the results.

In the case of the *derived object form* recipe, where the original source recipe identified in the SrcRcpID attribute (common to both recipe types) exists within the *namespace*, most of the attributes of the *derived object form* recipe are identified to those of the original. The exceptions are the attributes AttrLength, AttrChgTime, BodyLength, BodyFormat, and EditTime, which are all set by the *recipe executor* at the time the *derived object form* recipe is derived.

The *namespace manager* is responsible for converting the uploaded *execution recipe* to a *managed recipe* for storage in the *namespace*. This is accomplished through the following steps:

1. If the recipe is not *verified*, then no conversion is performed. The attributes ExecAttrLength and *ExecAttrChgTime*, if uploaded, are discarded.

2. The *generic* attributes ExtRef and Parameters of the *verified* recipe are not sent with the uploaded recipe. They must be obtained separately through the *verify*.

3. If an *agent-specific dataset* exists that corresponds to the destination *recipe executor*, then if the *execution recipe* attributes AgentSpec Comments and Certified are non-empty, they are placed in the corresponding attributes of an *agent-specific dataset* for that *recipe executor*. If necessary, an *agent-specific dataset* is created.

4. Any *variable parameter initial values* and *restrictions* in the *execution recipe* attribute AgentSpec-LinkParam replace their corresponding elements in the corresponding *agent-specific attribute* (if the *dataset* for that *agent* exists) in the uploaded recipe. If it can be determined that the contents of AgentSpec LinkParam are not different from those of the *generic* attribute LinkParam (as in the case of a *derived object form* recipe), then AgentSpec LinkParam should be discarded. If necessary, an *agent-specific dataset* is created for the appropriate *agent*.

The *upload recipe* operation is invoked by the message service RMNAction.

9.5 *Synchronization* — In addition to the explicit operations that are invoked through specific message services, the *recipe namespace manager* may provide the optional capability of **sychronization** of the *managed recipes* with *execution recipes* stored by the *recipe executors* of its *member agents*. This section describes the *synchronization* capability.

The ExecChgCtrl attribute of a recipe is used to specify types of permitted changes in *execution recipes*. The *recipe executor* is permitted to change the recipe body or to save the last settings used for *variable parameters* in the ExecLinkParam attribute of the *execution recipe* only when expressly granted permission in ExecChgCtrl.

ExecChgCtrl may also require the *recipe executor* to send a **change notification** message to the recipe's **originating namespace**. The **originating namespace** is either the *namespace* from which the recipe was *downloaded* or to which a new recipe will be *uploaded*. *Change notification* applies to both the explicitly permitted changes (modification and saving the *last value*) and to a *derived object form recipe* built from a *source form recipe*. *Change notification* informs the *namespace* that a change of interest to the *namespace* has occurred.

Namespaces with *synchronization* capability provide two additional attributes, SynchOn and SynchFail. The first allows the user to disable *synchronization* or to select the types of synchronization desired, and the second records *execution recipe specifiers* of recipes for which *synchronization failed*.

Synchronization for a new or changed recipe, or a new recipe *form*, consists of *uploading* the *execution recipe* for which a *change notification* has been received and, when necessary to protect a *read-only* recipe, assigning it a new *version number* and requesting the *recipe executor* to rename the corresponding *execution recipe*. Note that the *recipe executor* is required to deny attempts to rename a currently *selected execution recipe*.

The *recipe executor* saves the *last value* of a *variable parameter* in the *execution recipe* attribute Exec-LinkParam. **Synchronization** for a new *last value* consists of getting the value of this attribute from the *recipe executor* and updating the AgentSpec LinkParam attribute of the *agent-specific dataset* for the *recipe executor's agent*. Note that attributes of a recipe may change without affecting the *version number*.

Synchronization may fail either through failure to properly *upload* an *execution recipe*, through failure to properly retrieve the value of the *execution recipe's* ExecLinkParam attribute, or through failure to successfully rename the recipe stored by the *recipe executor*. The attribute SynchFail contains a list of *recipe specifiers* of the *execution recipes* for which *synchronization* was attempted but failed to be successfully completed. A *recipe specifier* shall be deleted from SynchFail if a later attempt at the failed operation for that recipe is successful. The *authorized user* may also remove one or all *recipe specifiers* from this attribute.

The attribute SynchOn is set by the user to indicate the types of changes for which *synchronization* shall be performed. SynchOn may be set to specify *synchronization* for changes to the body, changes to the *last value*, creation of a new recipe, building a new *derived object form* recipe from a *source form*, or any combination of these settings. A value of zero disables *synchronization*.

SynchOn is an unsigned integer. Possible values are either 0 (disabled) or any combination (sum) of one or more of the following decimal values:

0 = synchronization disabled

1 = changes in body

2 = new *execution recipes*

8 = changes in the *last value* of one or more *variable parameters* (i.e., to the ExecParam attribute of the *execution recipe*)

16 = new *derived object form execution recipes*

NOTE: Where possible, the values of SynchOn and ExecChgCtrl address the same change issues. For this reason, a value of 4 is not used, and a new value of 16 is added.

9.6 *Table of Operations* — Table 9.1 lists all the operations defined for *namespace management*.

The column labeled "Rqmt" is used to indicate those operations that are required for *fundamental compliance* to RMS as a *recipe namespace resource*.

Table 9.1 Namespace Operations

Operation	*Description*	*Rqmt*
create namespace	A new *namespace* is created and assigned an identifier.	N
delete namespace	A *namespace* is deleted.	N
rename namespace	The *namespace identifier* is re-assigned.	N
get available storage	Determine the amount of recipe storage available.	Y
check recipe status	Determine the existence and *read-only* status of a recipe, and obtain the next numeric *version*.	Y
get best version	Determine the default version for a given recipe class and *name* and for an optional *agent*.	Y
create recipe	A new recipe body is entered into the namespace.	Y
delete recipe	A recipe's identifier is removed from the *namespace.*	Y
store recipe	A recipe is stored in a namespace.	Y
retrieve recipe	A recipe is sent from the namespace.	Y
copy recipe	A new recipe is originated as a copy of an existing recipe.	N
rename recipe	A recipe is assigned a new identifier.	N
verify recipe	Check the syntax or format of a recipe body for correctness.	Y
download recipe	A recipe is downloaded to a specified agent's *recipe executor.*	Y
upload recipe	A recipe is created or updated by uploading a recipe *body* from a specified agent's *recipe executor*.	N

9.7 *Namespace Events* — A user of recipe namespace services is potentially interested in any change that occurs to or within a namespace that was not initiated by the user itself. Two such events are defined: Recipe Namespace Change and Recipe Change. A Recipe Namespace Change event occurs when a namespace is created, deleted, or renamed, or when a recipe is created, deleted, copied, or renamed. A Recipe Change event occurs whenever the body or any of the attributes, including *agent-specific attributes*, of an existing recipe is changed.

The selection of events to be reported, and the mechanisms for reporting these events, are defined in SEMI E53 (Event Reporting).

10 Distributed Recipe Namespace Management Operations

This section defines the operations required for the *distributed recipe namespace* capability. Operations are defined for the *DRNS segment*, the *DRNS recorder*, and the *DRNS manager*, in that order. Support for the *distributed recipe namespace capability* is not required for RMS compliance.

10.1 *Distributed Recipe Namespace Segment Operations* — This section defines the operations that shall be supported by the *distributed recipe namespace segment*.

10.1.1 *Object Services* — The *DRNS segment* is considered to own the recipes that it stores.

The **segment specifier** is the object specifier for a *DRNS segment* and has the form "type1:id1>...>type2:id2". An attached *DRNS segment* is owned by the *agent* providing the *DRNS segment* capabilities, by the *distributed recipe namespace* of which it is a component, and by the *DRNS manager* to which it is attached, and shall be accessible by any of these three paths. An unattached *DRNS segment* is owned by the providing *agent*.

An example of a *segment specifier* for a *DRNS segment* named ABC_Etch_Seg, a component of a *namespace* named WetEtchA provided by an *agent* named WetEtch003, is

"Agent:WetEtch003>RNSD:WetEtchA>RNSDSegment:ABC_Etch_Seg".

For a *master segment* Alpha provided by *agent* RecipeServer, this becomes

"Agent:RecipeServer>RNSD:WetEtchA>RNSDMaster:Alpha."

NOTE: The form of the specifier used for *DRNS segments* and *DRNS recorders* will vary. For example, to specify a *segment* to be attached to a *DRNS manager*, the specifier must include the object type and identifier for the *agent* providing the *segment* capability. Once the *segment* is attached, it may be specified through the *namespace* hierarchy, as in the example above.

10.1.1.1 *Attribute Read/Write* — The *DRNS segment* shall support the get attributes operation for itself and all recipes that it has stored.

It shall support the set attributes operation for its recipes only according to the restrictions against change defined in Section 5.4.2 and within Section 10.1.

If requested to change *read/write* attributes, it shall request and receive permission to change attributes prior to making such change.

A request to change either several *generic* attributes at the same time, or several *agent-specific* attributes for a specific *agent-specific dataset* at the same time, is considered for approval purposes as one change. However, changes to both *generic* and *agent-specific* attributes shall not be included in one change request or change.

10.1.1.2 *Create and Delete Operations* — The *segment* may support both the create object and delete objects pair of operations. The *authorized user* who invokes the create object operation shall assign a name to be used as its *name* ObjID. The *name* "Default" is prohibited. Once *created*, the *segment* shall be attached to a specific *manager* before it is permitted to accept recipes.

The create and delete operations are optional if the *owner agent* that provides the *distributed recipe namespace segment* capabilities provides an installed *distributed recipe namespace segment* that cannot be deleted. In this case, a means of recreating the *segment* shall be provided in the event the *segment* becomes damaged. If one of these two operations is supported, both are required.

The attributes Namespace, NamespaceManager, and RecipeReadOnlyLevel shall be set to null values at the time the *segment* is *created*.

A *segment* that is attached or that contains recipes (is not **empty**) shall not be *deleted*.

10.1.1.3 *Object Attachment Operations* — The *segment* shall support the operations to attach and reattach to a *DRNS manager*, and also the operations invoked by its *manager* to detach itself from a *DRNS namespace manager*. It shall also support the attach set attributes operation. Certain RMS operations shall be accepted only when received from its *manager*, as indicated below.

All requests for changes to recipes within the *segment* shall be sent to the *DRNS manager* to which it is attached.

The *manager* shall set the *segment* attributes Namespace, NamespaceManager, and RecipeRead-OnlyLevel when attaching or reattaching a *segment*. It may change these attributes for an attached *segment* at any time.

The detach operation breaks the logical connection between the *segment* and its *manager*. The *segment* becomes unattached, and the values of Namespace, NamespaceManager, and RecipeReadOnlyLevel are set to a null value. All recipes and recipe attributes are considered as *read-only* during the time the *segment* is unattached.

The reattach object operation is used in rebuilding a *distributed recipe namespace*. This operation sets the value of the attribute NamespaceManager to the name of the new *manager*. The *segment* returns a new token value to the *manager*.

The request to reattach itself serves to inform the *segment* that any of its *pending change requests* not previously approved have now been forgotten. The *segment* should either discard the request or resubmit it to its new *manager*.

10.1.2 *Segment Recipe Management Operations* — Within a *distributed recipe namespace* environment, all recipe management operations (Section 8) and namespace recipe operations (Section 9.4) are performed by the *DRNS segment*. The *DRNS segment* shall support all operations defined in these sections.

Operations defined in Section 9.4 that involve a *recipe executor*, such as *download* and *upload*, shall be performed only with a *recipe executor* that is either owned by the *agent* providing the *DRNS segment* capability or is owned by a component within the internal hierarchy of that *agent*. For example, a *DRNS segment* provided by a cluster tool may *download* to a *recipe executor* owned by a cluster module but not to equipment external to the cluster.

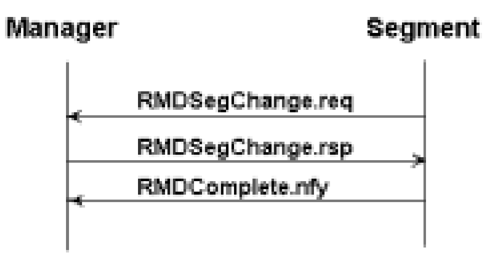

Figure 10.1

Segment-Initiated Change Request Message Flow

10.1.2.1 *Requirements for Approval* — Operations that change a recipe in any way shall be denied unless the *DRNS segment* is attached to a *DRNS manager*. All changes to logical recipes within a *DRNS segment* shall be approved by the *DRNS manager* before the changes are made to the recipe stored within the *DRNS segment*.

Changes to *agent-specific datasets* stored by attached *dedicated segments* are pre-approved. This is possible since, at most, one *dedicated segment* has an *agent-specific dataset* for a specific *agent* for any given recipe. However, the *segment* shall notify its *manager* immediately after any such change by sending the RMDNotify notification, which shall include the attribute AgentSpec_Agent, to identify the *agent-specific dataset*, as well as all *agent-specific* attributes that changed, regardless of whether they have been reset to their default value or set to a non-default value. (Otherwise, the entire *agent-specific dataset* would be required.)

A *master segment*, however, is prohibited from changing an *agent-specific dataset* without explicit permission from the *manager*.

Requests for changes that are made with RMS services defined in Section 12 may be sent from any service user, including the *DRNS manager*. The *DRNS segment* may reject requests for invalid changes, such as a request to modify a *read-only* recipe. Otherwise, the *DRNS segment* shall request approval from its *DRNS manager* for each change (Section 10.3.5). The *manager* responds by either approving, denying, or putting the request on hold.

NOTE: Service requests sent directly to a *DRNS segment* may not, in some circumstances, be fulfilled.

If the *change request* is denied, then the change is prohibited immediately. If it is put on hold, the *segment* shall retain the information necessary to effect the desired change at a later time.

If the *change request* is approved, the *DRNS segment* shall proceed with the change and shall notify its *DRNS manager* when the change is completed, either normally or abnormally, through sending the notification RMDComplete with the results, as illustrated in Figure 10.1.

The *DRNS manager* will put a *change request* on hold when another *change request* exists for the same recipe and the recipe is *locked*. In this case, the *DRNS manager* responds to the *segment's change request* with an *operation identifier* that the *manager* uses later when sending a **segment change approval** request.

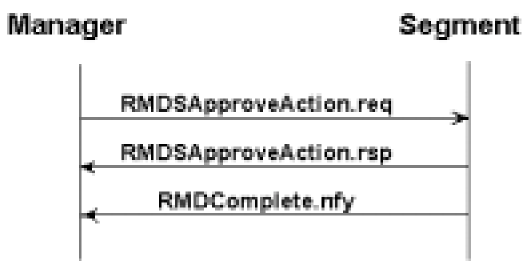

Figure 10.2

Message Flow for Manager Approval of Change Request

10.1.2.2 *Segment Change Approval* — The *DRNS segment* may receive a **segment change approval** request for an action that the *DRNS segment* had earlier requested. This informs the *DRNS segment* that an earlier *change request* made by the *DRNS segment* has now been approved for immediate action or has been completely denied.

The *segment* shall respond in one of three ways:

— It may reject the approval due to changes in circumstances since the original request was made (Figure 10.2(a).

— It may first fulfill the change request and then respond that the change request has now been completed, either successfully or unsuccessfully (Figure 10.2(a).

— It may first respond that it accepts the change request and then attempt to complete the change. When change request has been completed, normally or abnormally, the *segment* shall notify the *manager* of the results with the RMDComplete notification service (Figure 10.2(b).

Rejection of *segment change approval* shall be used when the change is no longer desired. For example, a *DRNS segment* "S" may request to *link* a *write-protected* recipe, and the *manager* responds that the request is on hold. Before the *segment* receives approval for that change, the same *logical recipe* is *linked* by a different attached *DRNS segment*, and the results are updated to each *DRNS segment* having a copy of the *logical recipe*, including *segment* "S". In this case, the recipe may not be relinked.[11]

The *segment change approval* operation is invoked by the message service RMDSApproveAction by the *segment's DRNS manager* and is otherwise invalid.

10.1.2.3 *Scenario of a Segment Change Request* — A typical scenario is illustrated in Table 10.3.

In this scenario, a local operator wants to change the generic attribute EditedBy. The *segment* requests approval for a generic attributes change. However, an *active change request* exists for this recipe.

11 Both the DRNS manager and the DRNS segment are responsible for compliance to RMS namespace requirements

Table 10.3 Typical Change Request Scenario

Manager	*Segment*
	Receives request for attribute change from local operator. Requests change from manager.
	<- RMDChangeRequest.req
Manager already has an active change request to link that recipe and answers that the request is on hold:	
RMDChangeRequest.rsp ->	
The active change request completes. The manager updates the change to the segment:	
RMNStore.req ->	
	The segment responds that it will make the change and notify the requestor when done.
	<- RMNStore.rsp
	The segment requests approval to make the second change:
	<- RMDChangeRequest.req
The manager approves the second request immediately:	
RMDChangeRequest.rsp ->	
	The segment stores the generic attributes sent by its manager.
	<- RMDComplete.nfy
	The segment notifies the requestor of the second change (in this case, its manager) that the change is complete.
	<- RMNComplete.nfy
When all other segments are similarly updated, the manager now approves the segment's earlier request to change generic attributes:	
RMDSApproveAction.req ->	
	The segment makes the approved change to <u>EditedBy</u> and then responds:
	<- RMDSApproveAction.rsp
	The segment sends notification to the operator making request for first change.
	change:
	<- RMNComplete.nfy
The manager requests the new set of generic attributes:	
RMNRetrieve.req ->	
	The segment sends the generic attributes to any requestor:
	<- RMNRetrieve.rsp

10.2 *Distributed Recipe Namespace Recorder* — This section defines the operations supported by the *distributed recipe namespace recorder*.

10.2.1 *Object Services* — The *recorder specifier* is the object specifier of the *recorder*. A *recorder* is owned by the *agent* providing the *DRNS recorder* capabilities. When attached to a *DRNS manager*, it is also owned by that *manager*. An example of the object specifier for a *recorder* named Recorder182 provided by *agent* RecorderServer is

"Agent:RecorderServer>RNSDRecorder:Recorder182>".

10.2.1.1 *Attribute Read/Write* — The *DRNS distributed recipe namespace recorder* shall support the get attributes operation for its attributes. It shall deny attempts to set its attributes through the set attributes service.

10.2.1.2 *Object Create and Delete Operations* — The *recorder* may support both the create object and delete object pair of operations. The *authorized user* who invokes the create object operation shall assign a name to be used as its *name* ObjID. The *name* "Default" is prohibited.

Once *created*, the *recorder* shall be attached to a specific *manager* before it is ready to accept data. Once *created*, the *recorder* shall set its attributes other than ObjID to null or empty values.

The create and delete operations are not required if the *owner agent* that provides the *distributed recipe namespace recorder* capabilities provides an installed *distributed recipe namespace recorder* that cannot be deleted. In this case, a means of recreating the *recorder* shall be provided in the event the *recorder* becomes damaged. If either of these two operations is supported, both are required.

10.2.1.3 *Object Attachment Operations* — The *recorder* shall support the operations to attach and reattach to a *DRNS manager*, and the detach and attach set attributes when invoked by the *DRNS manager* to which it is attached.

The *recorder* attributes Namespace and Namespace-Manager are set by the attach and reattach operations.

The detach operation breaks the logical connection of the *recorder* to the *namespace* and *managers* by setting the *recorder* attributes Namespace and Namespace-Manager to *null values*.

NOTE: In the event that a *distributed recipe namespace* becomes damaged, its *recorder* should be left attached so that it may later be reattached to a new *manager*.

The reattach operation is used in rebuilding a *distributed recipe namespace*.

10.2.2 *Add Segment Record* — The **add segment record** operation adds a given *segment* (its *object specifier*) to the *DRNS recorder's* internal list of *DRNS segments*. A request to *add* a *DRNS segment* that is already in the list shall be denied.

The *add segment record* operation is invoked by the service RMDRAddSegRecord.

10.2.3 *Delete Segment Record* — The **delete segment record** operation deletes a given *segment specifier* from the *DRNS recorder's* internal list of *DRNS segments*. A request to *delete* a *segment* not in the current list shall be denied.

The *delete segment record* operation is invoked by the service RMDRDelSegRecord.

10.2.4 *Add Change Request Record* — The **add change request record** operation adds a *change request record* to the *DRNS recorder*. The *DRNS recorder* keeps, at most, one *change request record* per recipe at any time. This is intended to represent a change currently approved and *active* for that recipe. If the *DRNS recorder* already has a *change request record* for the specified recipe, the information in the new *change request* replaces the previous information.

The contents of the *change request record* are defined in Section 10.3.7.4.

The *add change request record* operation is invoked by the service RMDRAddChgRecord.

10.2.5 *Delete Change Request Record* — The **delete change request record** operation removes a *change request record* for a specified recipe.

The *delete change request record* operation is invoked by the service RMDRDelChgRecord.

10.2.6 *Get Change Request Record* — The **get change request record** operation returns the current *change request record* for a specified recipe or assigned *segment*.

The *get change request record* operation is invoked by the service RMDRGetChgRecord and is available to any service user.

10.3 *Distributed Recipe Namespace Management Operations* — Operations defined in Sections 8 and 9 shall be supported by the *DRNS manager*. This section defines the additional operations provided by the *DRNS manager*. Operations defined in Sections 8 and 9.4 are delegated by the *DRNS manager* to an attached *DRNS segment*.

10.3.1 *Object Services* — The *DRNS manager* is considered to own the *DRNS segments* and any *DRNS recorder* currently attached to the *distributed recipe namespace*. In addition to the object services required in Section 9, the *DRNS manager* shall support the get type and get attribute name operations for its attached objects. The *DRNS manager* shall support object services directed to any of its attached objects and to recipes stored by specific *DRNS segments*.

The *DRNS manager* is considered to own the recipes that are owned through delegation by any of its attached *DRNS segments*. The Get Attributes and Set Attributes operations for a recipe may be directed to the *distributed recipe namespace*.

The object specifier for an object owned by a *DRNS manager* is formed by concatenating the object type and identifier for either the *manager* or the *namespace*, followed by the object type and identifier of each owned object in the ownership hierarchy. An example of the object specifier for a recipe XYZ;3 stored by *DRNS segment* ABC_Etch_Seg within the *distributed recipe namespace* WetEtch003 would be:

"RNSD:WetEtch003>RNSDSegment:ABC_Etch_Seg>MRcp:XYZ;3"

If an *agent* or a *DRNS segment* is specified, then the *DRNS manager* shall delegate the operation to the that *segment*. Otherwise, the operation shall be delegated to a *master segment*.

A request to set one or more *read-write* attributes of a recipe is treated by the *DRNS manager* as a *change request*.

10.3.2 *Delete Distributed Recipe Namespace* — A *distributed recipe namespace* with attachments may not be deleted.

The *delete distributed recipe namespace* operation is invoked by the service RMNDeleteNS defined in Section 9.2.2.

10.3.3 *Attach and Detach Supervised Objects* — This section defines the support required for the *authorized user* to request a *DRNS manager* to attach or detach one or more *segments* or a *recorder*. The operations and services are defined in detail in SEMI E39 (OSS).

10.3.3.1 *Attach Supervised Object* — The **attach supervised object** operation is invoked by an *authorized user* to request the *DRNS manager* to attach a specified *unattached segment* or *recorder*.

When a request to attach a supervised object is accepted, the *DRNS manager* sends an attach or detach request to the specified object.

The *DRNS manager* shall have the capability of managing at least one attached *dedicated* and one attached *master segment* at a time. At most, one *recorder* shall be attached to a *DRNS manager* at any given time.

Once attached, the *segment* or *recorder* becomes a formal part of the *namespace* and is owned by the *manager*.

When adding attachments to a *DRNS manager*, the *recorder* should be added first, so that it may be used to record the *segments* as they are subsequently attached. When the *distributed recipe namespace manager* receives a request to attach a *segment*, it sends that request to the specified *segment*. If the operation is successful, and if a *recorder* is attached, the *manager* requests the *distributed recipe namespace recorder* to record the *segment specifier* (the object specifier for the segment). If the *agent* providing the *segment* is not already in the *namespace* attribute Members, it is added at this time.

The operation of attaching a *recorder* shall set the *distributed recipe namespace* attribute Recorder to the value of the *recorder's* attribute ObjID. The operation of attaching a *segment* shall add the *segment specifier* to the Segments attribute of the *distributed recipe namespace*.

When a *recorder* is attached, all subsequent operations that attach and detach *segments* shall update the *recorder* through its operations to add and remove a record of the *segment*.

Specifiers used in the *namespace* attributes Recorder and Segments, and *segment* specifiers stored in the *DRNS recorder*, shall use the form including the specifier for the *agent* providing the capability for the *recorder* or *segment*. This is required for identification outside the scope of the current *namespace*. For example, if it later becomes necessary to rebuild the *distributed recipe namespace*, then the *segment* must be located through its *agent* owner rather than through the *namespace*.

10.3.3.2 *Detach Supervised Object* — An attached *segment* or *recorder* may be detached at any time. The *manager* forwards the request to the specified object. When a *segment* is detached, if a *recorder* is attached, then the *manager* requests the *recorder* to remove the *segment* that is being detached.

The user may request a *DRNS manager* to detach an attached *recorder* or *segment* at any time. When a *recorder* is detached, the *distributed recipe namespace* attribute Recorder shall be set to a null value. When a *segment* is detached, its *specifier* is removed from any attached *recorder* and from the Segments attribute of the *distributed recipe namespace*.

10.3.4 *Change Request Management* — A *change request* occurs whenever the *DRNS manager* receives any request, from any source, to change a recipe or the contents of the *distributed recipe namespace* as a whole. This includes requests to change the recipe *identifier*, a *generic attribute*, an *agent-specific attribute*, or the body of an existing recipe. It also includes all changes that affect the set of *recipe identifiers* within the *distributed recipe namespace*.

Requests for changes may come from a source that is either internal or external to the *namespace*.

10.3.4.1 *External Change Requests* — The *DRNS manager* may receive a request, through recipe management services, to change a recipe, or to change the *namespace* (for example, to *store* a new recipe or *delete* an existing one), from an entity other than an attached *DRNS segment*. If the change involves a specified *agent* (for example, *verify* or *upload* requests), then the *DRNS manager* shall delegate the operation to the *DRNS segment* provided by that *agent*. Otherwise, operations are preferably delegated to a *DRNS master segment*.

10.3.4.2 *Internal Change Requests* — A *change request* may be initiated by a specific attached *segment*. For example, a local operator may want to change the *generic* attribute EditedBy (illustrated in Figure 10.3) or to rename a recipe. The *DRNS segment* then requests its *DRNS manager* for approval to make the specific type of change desired. The *DRNS manager*, upon receipt of the request, shall create a *change request record* (Section 10.3.4.4) for the recipe(s), specifying the *DRNS segment* that initiated the request, the type of change requested, and noting that the change was *segment*-initiated.

10.3.4.3 *Allowable Change Requests* — A *change request* may not be allowable. For example, a change to a *write-protected* recipe or a change to introduce a recipe *identifier* already in use may be denied immediately. If the change is allowed, then a *change request record* shall be created in non-volatile memory for each allowed *change request*.

Any operation that creates or changes a recipe body, a recipe attribute, or a recipe identifier, requires explicit *manager* approval. This includes the following operations: create, delete, modify (body), copy (new *identifier*), rename (new *identifier*), protect, verify, link, unlink, certify, de-certify, change read-write *generic attribute*, and change read-write *agent-specific attribute*.

The following requirements shall apply:

— A request to *create* a new recipe, or *copy* an existing recipe, with a specified *identifier* shall be granted only if that *identifier* is not in use for a *write-protected* recipe within the *namespace* as a whole (that is, no attached *DRNS segment* has a *write-protected* recipe using that *identifier*).

— A request from a *DRNS segment* to rename a recipe shall be granted only if no other *segment* has that recipe and the new *identifier* is not otherwise in use.

— A request from a *dedicated segment* to delete a recipe shall be denied only if the recipe is *write-protected*.

10.3.4.4 *Change Request Record Definition* — A **change request record**, as shown in Figure 5.7, consists of the following information:

— The *recipe identifier* (RecipeID),

— a *destination recipe identifier* (DestRecipeID) (used for copy and rename only, and otherwise null),

— the *segment specifier*, (Segment), of the *DRNS segment* that has requested a change or to which the change operation is or will be delegated,

— the specific type of change requested (ChangeType),

— a timestamp of when the request was received (Timestamp),

— an **operation identifier** (OperationID), an integer delegated by the *DRNS manager* that uniquely identifies a given *change request* within the *distributed recipe namespace* at large,

— a boolean (SegmentRequest) used to differentiate requests by attached *segments* from other requests (the *manager* responds differently in the two cases).

All of the above information, with the exception of the *segment specifier*, shall be determined at the time the *change request record* is created. In the case of externally initiated requests, delegation of a *segment specifier* may be postponed until the *change request* is **selected**.

The *operation identifier* is used to identify a specific change request by both the *namespace* and the delegated *DRNS segment*. It is passed to the *DRNS segment* when granting permission to make the requested change (Section 10.3.5) and when sending *segment change approval* to a *DRNS segment* (Section 10.1.2.2) for a previous *change request* made while the recipe was *locked*. It shall also be used for recipe management services defined in Section 12 that use an *operation identifier* (parameter RMOpID).

For *change requests* initiated by an attached *segment*, the boolean SegmentRequest is set to TRUE. Otherwise, it is FALSE.

The *change request record* shall be deleted when the requested change operation has been completed, whether successfully or unsuccessfully.

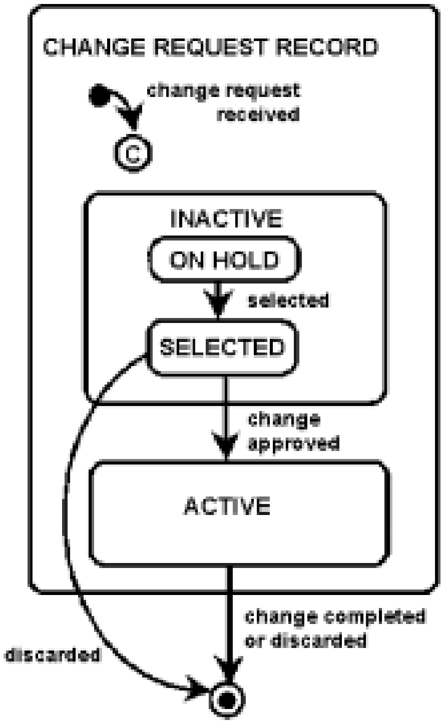

Figure 10.3

Change Request Record State Model

10.3.4.5 *Change Request Lifecycle* — This section describes the states of a *change request.*

A *change request* is received and examined. It is determined either to be allowed or not allowed.

If the requested change is allowed, then a *change request record* is created for the specified recipe by saving the information required. The *change request* is now INACTIVE and ON HOLD (see Figure 10.1). The *operations identifier* is set to a unique unsigned integer. If the change was initiated externally, a *segment* may or may not be designated until the *change request* is selected for approval. The remaining information is filled at this time. The *change request record* is placed in a queue for that recipe in non-volatile memory.

The *change request* remains **on hold** until the *DRNS manager* selects it as the next change and it becomes **selected**. If a *segment* has not already been designated, then one is determined at this time. The *selected* recipe may be discarded after evaluation due to changes in circumstances since it was originally put *on hold*. Otherwise, the *change request* becomes **active**, and the *change request record* is added to any attached *DRNS recorder*. The *manager* is ready to begin its negotiations with the designated *segment* or to approve a *segment*-initiated *change request* already in progress, at this point.

These stages may occur in rapid succession if the request is initiated by a *segment* and the recipe was not *locked*.

Selection occurs in one of two ways: either a *change request* is received when the specified recipe is *unlocked (Section 10.3.4.5)*, or else a currently *active change request* completes, and a new *change request* is *selected* from the queue of *change request records on hold* for that recipe. Rules for selection may vary and are beyond the scope of RMS. For example, rules could be sequence-oriented (first-in, first-out), or they might consider the types of operations specified. For example, requests for *verification* might be given precedence over requests to *link*.

When a *selected change request* becomes *active*, the *manager* adds the *change request record* to any attached *recorder* and begins negotiations with the delegated *segment*.

If the *change request* was *segment*-initiated (Section 10.3.5), the *segment change request* is approved. The *DRNS manager* shall initiate a *segment change approval* to the *DRNS segment* (Section 10.1.2.2).

There are three possible scenarios for the negotiations with the *segment*: an externally initiated request, an internally initiated request from a *segment* when the recipe specified was *unlocked*, and an internally initiated request from a *segment* when the recipe specified was *locked*. These three types of scenarios are illustrated in Table 10.5. NOTE: In both of the first two cases, the *segment* sends a request to make a change with RMDChangeRequest.req. However, in the first case, the initiation of that *change request* was external, and the *segment's* request is its required response to any change request that it receives.

Table 10.5 Active Change Request Negotiations

Manager	*Segment*
Externally Initiated Change Request	
An externally initiated change request becomes active. The manager requests the delegated segment to make the change:	
RMNAction.req ->	
	The segment responds that it will make the change and notify the requestor when done.
	<- RMNAction.rsp
	The segment requests approval to make the change:
	<- RMDChangeRequest.req
The manager approves the request immediately:	
RMDChangeRequest.rsp ->	
	The segment completes the change and notifies its manager:
	<- RMDComplete.nfy
	The segment notifies the requestor of the change (in this case, its manager) that the change is complete.
	<- RMNComplete.nfy
Segment-Initiated Change Request for Unlocked Recipe	
	The segment requests approval to make the change:
	<- RMDChangeRequest.req
The manager approves the request immediately:	
RMDChangeRequest.rsp ->	
	The segment completes the change and notifies its manager:
	<- RMDComplete.nfy
	The segment notifies the requestor of the change (in this case, its manager) that the change is complete.
	<- RMNComplete.nfy
	The segment notifies the initial requestor of the change that the change is complete:
	RMNComplete.nfy ->
Segment-Initiated Change Request for Locked Recipe	
	The segment requests approval to make a change: <- RMDChangeRequest.req
The manager puts the change request on hold:	
RMDChangeRequest.rsp ->	
The change request later becomes active. The manager now approves the segment's earlier request to change generic attributes:	
RMDSApproveAction.req ->	
	The segment responds that it intends to make the change:
	<- RMDSApproveAction.rsp
	The segment completes the change and notifies its manager:
	<- RMDComplete.nfy
	The segment notifies the initial requestor of the change that the change is complete:
	RMNComplete.nfy ->

10.3.4.6 *Change Request Completion* — The *DRNS manager* is informed of the completion of an approved change either immediately or through a later notification using the RMDComplete service.

There are two circumstances when a *DRNS segment* notifies its *manager* that it has completed an approved change, illustrated by Figures 10.1 and 10.2 (b) for the services RMDSegChange and RMDSApproveAction respectively.

Figure 10.2 (a) illustrates the case where the *manager* approves an earlier change request and the *segment* makes the change before responding. In this case, RMDComplete is not sent. However, if the *segment* responds before actually making the change, then it is required to send the notification RMDComplete when done.

When a requested change has been completed by the delegated *segment*, it notifies its *manager* by sending the notification RMDComplete as shown in Figures 10.1 and 10.2 (b). The type of change and results of the change operation dictate how the change shall be updated to the other attached *DRNS segments* of the *namespace*. After all affected *DRNS segments* have been properly updated, then the *change request record* corresponding to the completed change shall be removed from the queue. If there are still *inactive change requests*, the next *request* is selected and then made *active*.

All other *DRNS segments* with the same logical recipe shall be updated as appropriate. A change in *agent-specific datasets* only shall be updated to *master segments*. A change to attributes only shall cause only the attributes of other instances of that recipe to be updated. If the *logical recipe* was changed, then all *segments* having a copy of that *logical recipe* shall be updated.

When all necessary updates have been performed, the *DRNS manager* shall discard the *change request record*. It shall either request its *DRNS recorder* to remove the *change request* for that change or to add the next *change request* to be approved. Then the *DRNS manager* shall select another *inactive change request*. If no further *change requests* exist for that recipe, the *DRNS manager* shall remove the last *change request* from any attached *DRNS recorder*.

10.3.4.7 *Change Management Example* — As an example of change management, if an *operator* at Equipment A wants to *link* Recipe R;3 within the *distributed recipe namespace* D, the resulting changes to the recipe's *generic header* must be passed to all other attached *DRNS segments* within the *namespace* that contain Recipe R;3 before any other change is approved.

In this example, if a request from *segment* A to *link* Recipe R;3 is received by the *manager*, and no *inactive* requests exist, and if Recipe R;3 is not already both *linked* and *write-protected*, and if the request is to be approved, the *DRNS manager* creates a *change request record* for that recipe, which *locks* the recipe. The *DRNS manager* approves the request and denies subsequent requests until the approved change has been made and other *segments* with an *instance* of that recipe have been updated appropriately.

10.3.5 *Segment Change Request* — The **segment change request** operation is a request made by an attached *DRNS segment* to approve a specific type of change. The *DRNS manager* shall respond by either approving the request, denying it, or putting it on hold. When putting the requested change on hold, the *DRNS manager* shall return the *operation identifier* delegated in the corresponding *change request record*.

The *segment change request* operation is invoked with the service RMDSegChange sent by an attached *DRNS segment*.

10.3.6 *Segment Action Complete* — A *DRNS segment* that has requested and received permission to change a recipe shall notify the *DRNS manager* when the action is complete, whether normally or abnormally. Also, when the *manager* approves an earlier request made by a *segment*, and the *segment* makes the change after responding to the approval, the *segment* shall also notify its *manager* of the completion of the change. The notification allows the *DRNS manager* to request the updated recipe and send it to other *segments* as appropriate.

The *segment action complete* operation is invoked with the service RMDComplete, sent by an *attached segment*.

10.3.7 *Segment Notification* — A *dedicated segment* shall notify its *manager* of any change to an *agent-specific dataset*. These changes are pre-approved. They are not preceded by formal requests for change and do not generate change request records. Upon receiving notification of such a change, the *DRNS manager* shall update all *master segments* with the new *agent-specific dataset* values. An example of this case is illustrated in Table 10.6.

The *segment notification* operation is invoked with the service RMDNotify, sent by an attached *segment*.

Table 10.6 Notification of Change to an Agent-Specific Dataset

Manager	*Segment*
	Receives request from local operator to certify recipe.
	Local operator certifies recipe for this agent.
	The segment stores the generic attribute sent by its manager.
	<- RMDComplete.nfy
	The segment notifies its manager that the change has been made.
	<- RMNComplete.nfy
The manager requests the new set of agent-specific attributes:	
RMNRetrieve.req ->	
	The segment sends the generic attributes to any requestor:
	<- RMNRetrieve.rsp
The manager updates all master segments with the new agent-specific attributes for that agent and recipe.	

10.3.8 *Get Change Requests* — The **get change requests** operation returns a list of *active* and *inactive change requests* (in that order) for a *locked* recipe. If the recipe is not *locked*, an empty list is returned. Otherwise, where the *active change request* record is returned first in the list, followed by any *pending change requests*.

The *get change requests* operation is invoked with the service RMDGetChangeRequests.

10.3.9 *Rebuild Distributed Recipe Namespace* — The **rebuild distributed recipe namespace** operation is used to rebuild a previous *namespace* by *reattaching* all of its *attachments* to a different *namespace*.

The *DRNS manager* must first get a list of *DRNS segments* to be used. This list may be provided by either the service user or by a *DRNS recorder* specified by the service user. It then **reattaches** the *DRNS recorder* (where specified) and each of the specified *DRNS segments*. The reattach operation alerts the reattached object that the communication linkages to its *DRNS manager* may have changed and that its *inactive change requests* have been lost.

Next, the *DRNS manager* obtains the list of recipe *identifiers* stored by each *DRNS segment*. Finally, when a *DRNS recorder* has been provided, the *DRNS manager* completes the *rebuild* operation by checking the *DRNS recorder* for any *change request record* in progress at the time the original *namespace* was lost. The *DRNS manager* shall determine if the change was completed (through comparisons of recipe *descriptors*) and, if so, shall update the other *segments* as if it had just received a *segment change completion* notification.

Note that only the currently *active change request record* is retained. Other *inactive change requests* made while a recipe was *locked* have been lost with the original *DRNS manager*.

Note also the potential exists for *agent-specific datasets* stored by *dedicated segments* to be more recent than the corresponding *datasets* stored by *master segments*.

The *rebuild distributed recipe namespace* operation is invoked with the service RMDRebuild.

10.4 *Tables of Operations* — This section provides the operations defined for each object within the *distributed recipe namespace* capability. An additional column for the object authorized to invoke the operation is provided for tables in this section.

10.4.1 *Segment Operations Table* — Table 10.1 lists all the operations defined for *DRNS segment*.

Table 10.1 Distributed Recipe Namespace Segment Operations

Operation	*Invoked by*	*Description*	*Reqd*
Segment change approval	The *manager* of the attached *distributed recipe namespace segment.*	A change to a recipe requested earlier by a segment is now permitted.	Y

10.4.2 *Recorder Operations Table* — Table 10.2 lists all the operations defined *for distributed recipe namespace recorder*.

Table 10.2 Distributed Recipe Namespace Recorder Operations

Operation	*Invoked by*	*Description*	*Reqd*
add segment record	the *recorder's manager*	A *segment specifier* is added to the current list.	Y
delete segment record	the *recorder's manager*	A *segment specifier* is removed from the current list.	Y
add change request record	the *recorder's manager*	A currently active *change request record* is added for a specified recipe.	Y
delete change request record	the *recorder's manager*	An existing *change request record* is removed for a specified recipe.	Y
get change request records	any	The *change request records* for one or more recipes are requested.	Y

10.4.3 *Manager Operations Table* — Table 10.3 lists all the operations defined *for distributed recipe namespace manager*.

Table 10.3 Distributed Recipe Namespace Manager Operations

Operation	*Invoked by*	*Description*	*Reqd*
segment change request	an attached *segment*	A *segment* requests approval for a specified type of change on a specified recipe.	Y
segment change complete	an attached *segment*	A *segment's* notification that an approved change has been completed, either normally or abnormally.	Y
segment notification	an attached *dedicated segment*	A *dedicated segment's* notification that an *agent-specific dataset* has been changed.	Y
get change requests	any	A request for the list of existing change requests for a specified recipe.	Y
rebuild distributed namespace	an *authorized user*	A *manager* is requested to rebuild a *distributed recipe namespace* using a specified *recorder*.	Y

11 Recipe Executor Operations

The operations of the *recipe executor* defined by RMS are: **download and verify, verify, upload, rename, get available storage, delete, select, deselect,** and **change notification.** In addition, the *recipe executor* shall provide object services as described in Section 11.1.

Recipe executor operations may be invoked by an operator or through *recipe executor* services defined in Section 14. In most cases, service scenarios consist of a single message request from the service user and a corresponding response from the *recipe executor*. This case is illustrated in Section 14.1.

Scenarios are shown only for operations that differ from this typical case. For example, some operations may require more time to complete, such as *recipe verification* and the *select* operation that may be performed on more than one recipe and may require interactions with a *recipe namespace* to complete. In this case, the initial response to the message service request may only indicate the intent to perform the operation. The *recipe executor* informs the service user of the completion of each individual operation by sending the notification message RMEComplete.

In addition, in restricted circumstances, the *recipe executor* is required to inform a *namespace* that a recipe body originally downloaded from that *namespace* has been changed.

11.1 *Object Services Operations* — A *recipe executor* shall comply with Object Services Standard specifications for *fundamental requirements* and with the requirements for Owner Objects. Support for Filtering is optional.

A *recipe executor* owns the *execution recipes* that it stores, and it is *owned by* the *agent* that provides *recipe executor*. The owner relationships are used by Object Services to define a *recipe specifier*.

The *recipe executor* shall support operations for Get Attributes and Set Attributes for its own attributes. It shall support the operation of Get Attributes for the execution recipe. (Note that all attributes of the execution recipe are read-only and may not be set through the interface. It shall support the Get Type and Get Attribute Name operations for the object types of *recipe executor* and *execution recipe*.

11.1.1 *Execution Recipe Specifier* — The object specifier for an *execution recipe* includes the object type and *identifier* of the recipe executor, followed by the identifier of the recipe, including its *originating namespace*. For example, to specify an *execution recipe* "NS-MOM>PROCESS/ABC;5>" that is stored by a *recipe executor* named "RE-Etch" owned by "Agent-:Etch01", the object specifier would be

"Agent:Etch01>RcpExec:RE-Etch>NS-MOM>PROCESS/ABC;5>".

11.2 *Description of Operations* — This section describes the operations of the *recipe executor*.

11.2.1 *Recipe Download and Verify* — A recipe is **downloaded** when it is transferred (sent) to the *recipe executor*. *Downloaded* recipes that do not have the <u>Verified</u> attribute set to TRUE shall be immediately *verified*. Otherwise, it is not necessary to *re-verify* a recipe. Any *verification* errors shall be reported to the initiator of the *download* operation.

For further discussion of the *verification* operation, see Section 11.2.2.

Normally, if the *identifier* of the recipe *(namespace name, recipe class, recipe name, and version number)* is already assigned to an *execution recipe* already existing in storage, the *download* is refused. However, the initiator of the download operation may optionally request a **forced overwrite** of any such pre-existing recipe. In this case, if the existing recipe is not currently *selected*, the new recipe replaces the older one. A request to *delete or overwrite* a currently *selected* recipe shall be denied.

The body of a recipe currently being edited shall be protected from inadvertent change or overwriting by a recipe with the same identifier that is downloaded during this time. If the downloaded recipe is accepted (stored), the equipment shall require the operator either to save the edited recipe to a new (unused) identifier or to discard it.

The *download and verify recipe* operation is invoked with the RMEDnldVer service.

11.2.2 *Recipe Verify* — This is a required operation that *verifies* a specified *execution recipe*.

Verification requires reading the recipe's body. For a *source form* recipe, the *verification* operation checks the contents of the recipe for syntactical correctness. If supported, the *recipe executor* may also include one or more checks for semantic correctness as part of its *verification* operation. For recipes in *object form*, *verification* checks the format of the contents to achieve the same effect.

A *verified* recipe merely indicates that it is technically correct and can be executed. It does not indicate that it can be properly executed for the current hardware configuration. Checking to ensure a recipe will execute properly is called **validation** and shall only be performed at the time recipes are *selected* for execution.

A recipe that has syntactical or format errors fails the *verification* process. Information concerning errors shall be reported to the initiator of the *verification* process. This information is required for the user to be able to make appropriate corrections.

Information returned to the *namespace manager* at the conclusion of the *verification* process includes:

- *All* external references*, required for the <u>ExtRef</u> attribute of the* managed *recipe,*
- *All* variable parameter definitions*, required for the <u>Parameters</u> attribute of the* managed *recipe,*
- *The estimated or nominal time of the recipe, in seconds, used for the <u>EstRunTime</u> attribute of the* managed recipe *(optional).*

These items are not returned if the recipe fails *verification*. In this case, the *recipe executor* shall provide sufficient information to the user for identification of the type of error and where within the *body* it occurred, for at least the first error encountered.

The *external references* that are returned shall always include the *name* of the recipe referenced, and any referenced *namespace*, in the proper form for a *recipe identifier*. If the *external reference* specifies a *namespace* other than "Default" (Section 6.4), the *version* is required to be fully specified for *verification* to be successful. Otherwise, *version* shall be left exactly as specified in the *body*. Omission of version allows "the best version" to be determined by the *namespace* at a later stage.

The *verify* operation is invoked explicitly with the RMEVerify service. It may also be performed as part of the *download and verify* operation as discussed in Section 11.2.1.

11.2.2.1 *Derived Object Form Recipes* — For downloaded recipes that are to be stored, the *recipe executor* may wish to re-write or compress a *source form* recipe into a *derived object form* recipe (Section 3.2.2.1.2) as part of the *verification* process. (The rewritten form may be of any format and is typically **not** a form of "machine-executable code".)

Where downloaded recipes are converted to a *derived object* form prior to storage, a method of re-converting to *source form* is required. Note that the capability to retain user comments is desirable, but not required, where this process is adopted.

The new *derived object form* recipe inherits the attributes of the *source form* recipe with the following exceptions:

- *The* class *or* name *of the* object form *shall be changed in a systematic and documented manner that both makes clear the* object form *derivative and its heritage from the* source form *original. For example, the object form may add an extension to the* name *of the original recipe.*
- *The* BodyFormat *attribute shall be changed to reflect the* object form.
- *The attributes* ExecLength*,* ExecChgTime*,* BodyLength*, and* EditTime *shall be updated.*

If the attribute ExecChgCtrl requires the *originating namespace* to be notified of changes, then this request applies to the creation of the *derived object form recipe*, and the ChangedBody attribute is set to TRUE until the recipe has been *uploaded* successfully by the *namespace manager*.

The *source form recipe* from which the *derived object form* was obtained should not be deleted automatically.

11.2.2.2 *Verification ID* — The attribute VerificationID is used for *derived object form* recipes and is provided for the *recipe executor* **identification code**. This is a text string containing a unique and persistent "signature" or identifier for the *recipe executor*. This is used to detect *derived object form* recipes that were derived by earlier software versions of the *recipe executor*, or by versions used by other *agents*, that may have obtained different results.

The *identifier* of the *source form* recipe of the *derived object form* recipe is stored in the attribute SrcRcpID of the *derived object form* recipe.

11.2.3 *Recipe Upload* — **Recipe upload** is the operation that returns an *execution* recipe from the *recipe executor's* storage to the service user. It is required for *recipe executors* that are able to *originate* or modify recipes. *Recipe upload* allows recipes to be managed in a *recipe namespace.*

The *upload recipe* operation is invoked with the RMEUpload service.

11.2.4 *Recipe Rename* — The **recipe rename** operation causes a recipe to be assigned a new *identifier*. If the new *identifier* is already in use by a pre-existing *execution recipe*, or if the recipe to be *renamed* is currently *selected*, the request shall be denied. This is a required operation.

This service is provided to maintain synchronization between *execution recipes* and the *managed recipes* within an *originating namespace*.

The *rename recipe* operation is invoked by the message service RMERename.

11.2.5 *Get Available Storage* — The **get available storage** operation is used to determine the size of the remaining recipe storage capacity, in bytes. The value returned shall exclude any overhead requirements for storage of one *execution recipe*. That is, it shall be assumed that sufficient storage exists for a single recipe with a combined *attribute length* and *body length* less than or equal to the returned value. This is a required operation.

The *get available storage* operation is invoked by the message service RMESpaceInquire.

11.2.6 *Recipe Delete* — The **recipe delete** operation removes one or more recipes from the *execution recipe storage*. Any reusable (rewritable) storage used by a *deleted* recipe shall be made available for other recipes, and the *deleted* recipe shall be unavailable for all subsequent operations. This is useful to release storage for new recipes. This is a required operation.

Recipes stored in non-reusable storage that cannot be physically deleted shall be made unavailable for subsequent *selection*.

If the *recipe executor* does not have *execution recipe storage* (that is, if its sole storage is the *recipe execution area*), then the *delete* operation shall completely remove the specified recipes from the *recipe execution area*.

The *delete recipe* operation is invoked with the RMEDelete service. A request to *delete* a currently *selected* recipe shall be denied.

11.2.7 *Recipe Selection* — Recipe **selection** is the process of locating, *validating*, and preparing a recipe for execution within the *execution area*. Recipe *selection* is a required *operation* of the *recipe executor* that allows specification of initial (default) values of any *variable parameters* defined by the recipe. Initial parameter values specified at this time shall override the corresponding values contained in the ExecLinkParam attribute.

It shall be possible to explicitly specify a recipe for execution. It may also be possible to implicitly *select* a recipe, including initial *variable parameter* values, through other operations, such as within a higher-order "process job". Services for implicit methods and for starting execution itself are beyond the scope of RMS.

If the recipe class is omitted when specifying a recipe for *selection*, then the class "/PROCESS/" shall be assumed.

The request for *recipe selection* specifies one or more recipes to be *selected.* If a recipe cannot be located in the *recipe executor's* recipe storage area, then the *recipe executor* may optionally attempt to locate and *retrieve* it from the *originating namespace* specified.

Only a *linked* recipe (with the Linked attribute set to TRUE) may be specified by the service user. An attempt to *select* an *unlinked* recipe shall be denied. *Subrecipes* that are part of a *linked recipe set* are required only to be *verified* but not *linked*.

The *selection* process completes abnormally whenever an error is detected, including the failure to locate a specified recipe or to successfully store it, invalid parameter settings, an attempt to *select* an *unverified* recipe, and other *validation* errors.

The *select recipe* operation is invoked with the RMESelect service.

11.2.7.1 *Multiple Selection* — *Executing agents* that support *subclasses* of the PROCESS *class* shall provide at least one of two methods for the *selection* of multiple recipes: (1) they may either allow, or require, that a request for recipe *selection* explicitly specify a recipe from each of certain *subclasses*, and/or (2) they may either allow, or require, specification of required *subclasses* within a *linked* set of multi-part recipes. Such additional permissions and restrictions shall be included in the recipe management documentation.

For *executing agents* that support multi-part recipes (such as described in method 2 above), the *recipe executor* is responsible for *validating*, as a set, the *main* recipe and all its *subrecipes* listed in the LinkList attribute of the *main* recipe as a condition of execution.

If the *namespace* is specified as "Default", the *default namespace* is used. The *name* of this *namespace* is the value in the *recipe executor* attribute DefaultNamespace (see Section 6.4 and 6.7).

All recipes in the *linked recipe set* are considered to be *selected* if the *select* operation is successful.

11.2.7.2 *Validation* — **Validation** consists of type and range-checking of recipe settings and parameters, and of confirmation that the recipe is valid for the current hardware configuration. *Validation* shall occur as part of the process of *selection*. For *recipe executors* that require several different *classes* of recipe, *validation* may depend on the recipes that are *selected* as a set.

For example, a diffusion furnace may have a *class* of recipe that is used for the current gas configuration to map gases to valves. The furnace's normal process recipe that uses names of gases can only be *validated* in combination with the gas configuration table *selected* at the same time.

11.2.7.3 *Delegation* — If *delegated* recipes are specified in LinkList, it is the responsibility of the *recipe executor* to ensure that the designated recipe is accessible to the *recipe executor* of the *component agent* at the time it is *selected*. Otherwise, the *select* request shall be denied.

11.2.7.4 *Variable Parameters* — For recipes with *variable parameters*, new *initial values* for some or all of its *parameters* may be specified as part of the *selection* as a *parameter name* and *parameter initial value* pair. *Parameter values* specified as part of the *selection* take precedence over those *initial values* defined in the ExecLinkParam attribute. However, *parameter restrictions* may not be changed when *selecting* a recipe.

All *parameter values* that are set either prior to, or during[12], the execution of a recipe shall satisfy the conditions of the *parameter restriction.* If a *parameter restriction* is given in the ExecLinkParam attribute, then that *restriction* is used for all occurrences of the *parameter*.

11.2.7.5 *Message Scenarios* — There are two possible message flows between the *recipe executor* and the service user for the *select* service.

If the *recipe executor* is able to locate the recipes in its local storage, to *validate* them as a set, and to ready

12 RMS neither defines, nor prohibits, methods for changing parameter values during the execution process.

them for execution in a timely manner, then it may indicate the results of the *select* operation in the response message, as illustrated in Figure 11.1.

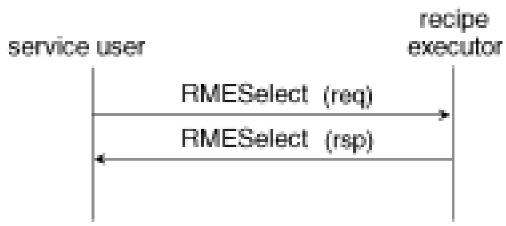

Figure 11.1

RMESelect Message Flow

Alternatively, the *recipe executor* may anticipate that the process of *selection* will require more time. In this case, it may send a response indicating the intent to perform the operation as soon as possible, prior to starting the operation. The notification message RMEComplete is sent when all specified recipes are *selected* or when a *selection* failure occurs. Exactly one notification message is sent, as illustrated in Figure 11.2.

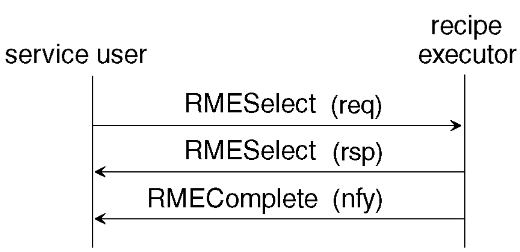

Figure 11.2

RMESelect with RMEComplete Notification

If all recipes are located and in local storage, the recipes are *validated* as a set.

11.2.7.6 *Selected Recipes* — Once a recipe and its associated *subrecipes* have been *selected*, they shall be fully protected from inadvertent (unintentional) change, including change through download, overwrite, deletion, and renaming operations.

The *recipe executor* attribute RecipeSelectID shall be set to the list of currently *selected* recipes, including all *main* recipes specified in the *select* request and all *subrecipes* within a *linked recipe set.*

The attribute RecipeSelectParam shall be set to the list of all *variable parameter definitions* currently in effect following *selection* and prior to the start of actual recipe execution.

11.2.7.6.1 *Select Errors* — If the *recipe executor* is unable to locate a recipe specified for *selection* in its storage, it is responsible for obtaining the recipe from the designated *namespace* included in the *recipe specifier*.

Possible errors resulting from the *select* operation include:

- *Failure to specify recipes from each of the* subclasses *that it requires,*
- *Failure to validate a recipe,*
- *Failure to locate a recipe in a specified* namespace*,*
- *Failure to locate a recipe, and*
- *An attempt by the user to* select *an* unlinked *recipe.*

The *select recipe* operation is invoked with the RMESelect service.

11.2.8 *Recipe Deselection* — A *selected* recipe is **deselected** by making it unavailable for execution for the next (subsequent) processing cycle, deleting its *identifier* from the RecipeSelectID attribute, and deleting its *parameter definitions* from RecipeSelectParam attribute. This is a required operation.

Only a *main* recipe that is currently *selected* may be specified for *deselection*. *Deselecting* a main recipe shall result in the simultaneous *deselection* of all of its *subrecipes.*

If a recipe is *deselected* during execution, this shall have no effect until the current process cycle has completed.

The *recipe executor* may have additional restrictions concerning *deselection*.

The *deselect recipe* operation is invoked with the RMEDeselect service.

11.2.9 *Get Execution Recipe Descriptor* — The **get execution recipe descriptors** operation returns the *descriptors* of a specified *execution* recipe: the *execution attribute descriptor*, the *generic attribute descriptor*, and the *body descriptor*, in that order. This is a required operation.

The *execution recipe descriptor* may be used to compare two *execution* recipes or a *managed* recipe and an *execution* recipe.

The *get execution recipe descriptor* operation is invoked with the RMEGetDescriptor service.

11.2.10 *Change Control* — It is important to the user to be able to control change for execution recipes. In addition, it may be important to store recipes that were *originated* by the *recipe executor* in the managed environment of a *recipe namespace.* The recipe attribute ExecChgCtrl is used to accomplish both purposes.

The ExecChgCtl attribute allows the user to control the modification of an existing *execution recipe* and its subsequent use. ExecChgCtrl is a binary value that specifies permission for behavior related to changes. ExecChgCtrl uses bit settings to indicate permission in order to facilitate the different possible combinations. Values given below are in decimal:

1 = permission to change the body of the *execution recipe*

2 = requirement to notify the *originating namespace* of permitted changes

4 = permission to select (including *re-selection* of an already *selected* recipe) a changed recipe

8 = permission to save the *last values* of *variable parameters* in the ExecParam attribute

11.2.10.1 *Changing Existing Recipes* — Whenever the body is changed, the attributes ExecAttrLength, ExecChgTime, BodyLength, and EditTime shall be updated. The attribute ChangedBody shall be set to TRUE and remain set until the recipe is uploaded successfully to the *originating recipe namespace.* The ChangedBody attribute is *reset* when the upload request is received. It is not included in the uploaded attributes. Note that the attributes ExecAttrLength and ExecChgTime are not kept in the *managed* recipe stored in the *namespace*, and that the attributes AttrLength and AttrChgTime are not maintained by the *recipe executor* and are recalculated for the *managed recipe* when stored.

If the ExecChgCtrl attribute permits both change and subsequent selection or *re-selection* (as for a currently *selected* recipe changed by the execution process itself), then the recipe's Linked attribute is not affected. Otherwise, if change is permitted but subsequent *selection* is not permitted, then the Linked attribute of the *main* recipe shall be *cleared* (set to FALSE) to prevent any subsequent *selection*, and the recipe shall be automatically *de-selected* at the end of any current processing cycle. It shall not be available for *selection* until it has been *uploaded*, *re-linked*, and *downloaded* again, with its changes, by the *originating namespace*.

11.2.10.2 *Creating New Recipes* — A new *execution recipe* may be *created* by various mechanisms. Such mechanisms are beyond the scope of RMS. However, all such recipes shall be assigned an *identifier* that is not already in use by an *execution recipe.* It is not required that an *originating namespace* be assigned immediately in all cases. However, it must be provided before the recipe can be *uploaded* and placed in the management system. New *identifiers* assigned automatically by the *recipe executor* shall use the next available *numeric version*, in conformance with Section 3.2.3.3.

A newly *created* recipe may not be executed. Its ChangedBody attribute shall be set to TRUE, and BodyFormat shall be set TRUE for non-text recipes. The attribute ExecChgCtrl shall be set to a value of 3 (1 plus 2) or higher. Other *non-mandatory* attributes shall be set to their default value. Since the Linked attribute is set to FALSE, the new recipe may not be *executed* as a *main* recipe. New recipes must be *uploaded* to a designated *originating namespace* for management purposes and subsequently *downloaded* after they have been *linked*.

11.2.10.3 *Building Derived Form Recipes* — A new recipe, with a new identifier, is also originated if recipe executor builds a *derived object form recipe* from an existing *source form recipe*. Requirements for the *derived object form recipe* are defined in Section 11.2.2.1.

The *manager* of the *originating namespace* shall be notified when a *derived object form* recipe is built from a *source form recipe* where ExecChgCtrl requires notification of change for the original *source form* recipe.

11.2.10.4 *Saving Last Value* — Saving the most recent settings specified by the user in the attribute ExecLink-Param is a protected activity requiring explicit permission in ExecChgCtrl. A *change notification* requirement in ExecChgCtrl applies to the change of this attribute.

Parameter values in ExecLinkParam are overridden by any parameter settings specified by the user at the time a recipe is *selected*. In this case, the last value of each parameter is stored in the appropriate *parameter definition* in the ExecLinkParam *attribute.* If *change notification* is specified, the *originating namespace* shall be notified of this change. The attributes ExecLength and ExecChgTime shall be updated whenever this change is made. The *body* of the recipe in *execution recipe storage* shall not be changed for this purpose.

11.2.10.5 *Change Notification* — If ExecChgCtrl requires that the *originating namespace* be notified of changes, the notification service RMEChange is sent to the specified *namespace* indicating the type of change that has occurred.

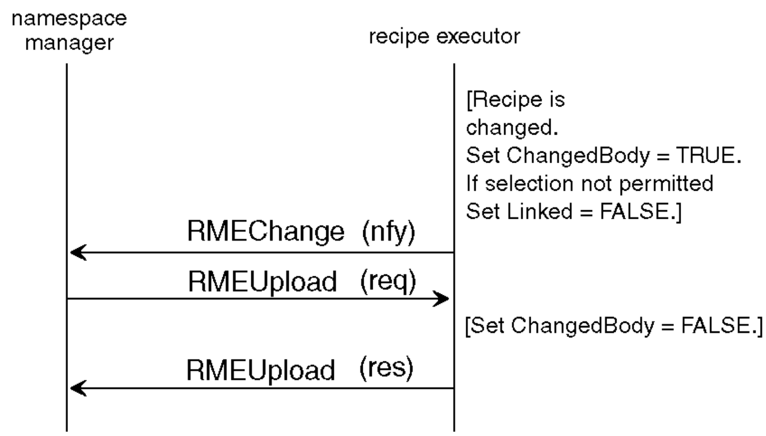

Figure 11.3
RMEChange Message Flow

The *recipe executor* may or may not have direct communication links with the *namespace* itself. However, in this case, the necessary links may be assumed to exist with the *supervisor* or other *owner* of the *recipe executor*, or it would not be possible for recipes to be *downloaded* in the first place.

The *originating namespace*, on receipt of a change notification, is responsible for uploading the changed recipe and for *synchronizing* through the service RMERename any change in *identifier* that might result from changing a *write-protected* recipe.

11.3 *Table of Operations* — Table 11.1 lists all the operations defined for recipes and *namespaces*.

The column labeled "Rqmt" indicates those operations that are required for *fundamental compliance* to the RMS *recipe execution resource.*

Table 11.1 Recipe Executor Operations

Operation	*Description*	*Rqmt*
Recipe download and verify	Transfer *execution recipe* to local storage. If the recipe is *unverified*, then *verify* it at this time.	Y
Recipe verify	*Verify* a stored *execution recipe.*	Y
Recipe unload	Transfer a recipe from local storage. Required if the execution process modifies an executed recipe or if the *recipe executor* is able to *create* recipes.	N
Recipe rename	Change the recipe's *identifier.*	Y
Get available storage	Calculate the amount of storage available for a single *execution recipe*, exclusive of formatting overhead.	Y
Recipe delete	Delete a recipe from local storage.	Y
Recipe select	*Select* recipes for execution.	Y
Recipe deselect	*Deselect* one or more recipes.	Y
Get recipe descriptor	Get the *descriptors* of a specified *execution recipe.*	Y
Change notification	Inform the *originating recipe* that a recipe has been *originated* or changed. Required if the *recipe executor* is able to make a change protected by ExecChgCtrl or to originate a recipe.	N

11.4 *Recipe Executor Events* — The *recipe executor* shall provide the Recipe Select and Recipe Deselect events. *Recipe executors* that are capable of *originating* a new *execution recipe* shall provide the New Execution Recipe event. *Recipe executors* that are capable of *changing* the body of an existing recipe shall provide an Execution Recipe Change Event. These events allow *service users* other than the *originating namespace* to receive notification whenever a new recipe is created or an existing recipe body is modified.

12 Recipe Namespace Services

This section defines *recipe management* and *namespace* services (see Table 12.1), which begin with a prefix of RMN. RMS services used by *distributed recipe namespaces* and by the *recipe executor* are defined in later sections.

Recipe management and *recipe namespace services* request that an operation be performed on a recipe within a *namespace* or on a *namespace*.

Recipe management operations that change recipe attributes are invoked with the RMNAction or RMNVarPar requests.

Certain activities that require extended time to complete may indicate the intent to comply in the response message and then provide confirmation with the RMNComplete message at the completion of each individual operation specified.

Table 12.1 Recipe Namespace Services

Message Service Name	*Type*	*Description*
RMNCreateNS	R	Create a new *namespace*.
RMNDeleteNS	R	Delete a *namespace*.
RMNRenameNS	R	Rename a *namespace* (assign a new *identifier*).
RMNSpaceInquire	R	Determine the available space for recipe storage.
RMNRcpStatInquire	R	Determine a recipe's *read-only* status.
RMNVersionInquire	R	Determine the best version of a recipe.
RMNCreate	R	Initialize new recipe with the specified body.
RMNUpdate	R	Transfer new recipe body.
RMNStore	R	Store a recipe.
RMNRetrieve	R	Retrieve a recipe and give to the requestor.
RMNCopy	R	*Copy* a recipe to a new recipe (originated).
RMNRename	R	*Rename* a recipe.
RMNAction	R	Perform an operation on a recipe (verify, link, unlink, …)
RMNVarPar	N	Modify *agent-specific variable parameter definition*.
RMNGetDescriptor	R	Get recipe *descriptors*.
RMNComplete	N	Notification that a requested action has completed.

12.1 *Recipe Management Message Parameter Dictionary* — Table 12.2 contains the definitions for message parameters, and their components, used by *namespace* services.

For purposes of transferring a recipe with its components, it is regarded as having three types of **sections**: a *section* containing the *generic* attributes, a *section* consisting of the *body*, and a *section* containing the attributes of the *agent-specific dataset*. The *generic section* is always transferred first, and the attributes AttrLength, AttrTimestamp, BodyLength, and EditTime are always sent first, in that order. This allows the length information to be immediately determined by the receiver. *Agent-specific dataset* sections are sent last, since the number of *agent-specific datasets* will vary.

Descriptors are also regarded as consisting of *sections* for the *generic descriptor*, the body *descriptor*, and zero or more *agent-specific descriptors*.

Each start of each *section* is identified with a text string reserved for that *section type*.

Table 12.2 Recipe Management Parameter Dictionary

Parameter	*Definition*	*Form*
AgentSpec_Desc	*Agent-specific dataset* descriptor.	Structure composed of AgentSpec_DescName, AgentSpec_DescLength, AgentSpec_DescTimestamp.
AgentSpec_DescName	Identifies start of *agent-specific dataset descriptor*.	Text = "ASDesc".
AgentSpec_DescLength	Value of AgentSpec_AttrLength.	Unsigned integer.
AgentSpec_DescTimestamp	Value of AgentSpec_AttrChgTime attribute.	Timestamp format: "YYYYMMDDHHMMSSCC".
AgentSpec_Section	A message section for an *agent-specific* dataset.	(List of) structures composed of AgentSpec_SectionName, AgentSpec_SectionData
AgentSpec_SectionData	*Agent-specific* attribute name/value pairs.	(List of) AttrSetting
AgentSpec_SectionName	Identifies start of *agent-specific* dataset.	Text = "ASDS".
AttrData	Value of attribute.	Varies with attribute.
AttrName	Name of attribute.	Text.
AttrSetting	Attribute name/value pair.	Structure composed of AttrName, AttrData.
BodyData	The recipe body contents.	Varies.
BodyDesc	Body descriptor section.	Structure composed of BodyDescName, BodyDescLength, BodyDescTimestamp.
BodyDescLength	Value of BodyLength *attribute*.	Unsigned integer.
BodyDescName	Identifies start of *body descriptor*.	Text = "BodyDesc".
BodyDescTimestamp	Value of EditTime *attribute*.	Timestamp format: "YYYYMMDDHHMMSSCC".
BodySection	The recipe *body* section.	Structure composed of BodySectionName, BodyData.
BodySectionName	Value of BodyName attribute.	Text = "Body".
ErrorCode	Contains the code for the specific error found.	Enumerated: unknown object type in specifier unknown object identifier in specifier unknown attribute name invalid attribute value access denied syntax error recipe not found verification error validation error agent not found
ErrorText	Text in support of the error code to provide additional information.	Text.
GenAttrSection	The *generic* attribute *section*.	Structure composed of GenAttrSectionName and (List of) AttrSettings for *generic* attributes.
GenAttrSectionName	Value of Gen_AttrName *attribute*.	Text ="Generic".
GenDesc	*Generic* attribute descriptor.	Structure composed of GenDescName, GenDescLength, and GenDescTimeStamp.
GenDescLength	Value of AttrLength *attribute*.	Unsigned integer.
GenDescName	Identifies start of *generic section*.	Text ="GenDesc".
GenDescTimestamp	Value of AttrChgTime attribute.	Timestamp format: "YYYYMMDDHHMMSSCC".
LinkID	In response or completion message, has the value of RMOpID in the request. Otherwise, set to zero if, and only if, no further completion messages will be sent.	Unsigned integer.
NSAck	Acknowledge code.	Enumerated: requested operation completed without errors

		requested operation completed with errors requested operation will be performed and notifications of results will be sent
NSStatus	Information concerning the outcome of the requested operations.	Structure composed of NSAck and Status.
RcpClass	Recipe *class*.	Formatted text.
RcpName	Recipe name.	Text.
RcpVersion	Recipe version.	Text.
RMAction	Identifies action performed on recipe.	Enumerated: *delete* *protect* *verify* *link* *unlink* *certify* *de-certify* *download* *upload*
RMAgent	Agent name (identifier).	Text.
RMChangeStatus	Indicates new status of recipe.	Enumerated: *no change* *created (new identifier)* *updated (modified)* *deleted* *copied (new identifier)* *renamed (new identifier)* *verified* *linked* *unlinked* *certified* *de-certified*
RMDestRcpID	Identifier of destination recipe.	Formatted text.
RMDesc	Recipe descriptor (timestamp and length attributes).	Structure composed of GenAttrDesc, BodyDesc, and (list of) AgentSpec_Desc
RMNewNS	New *namespace* name.	Text.
RMSpace	Amount of space available in *namespace*.	Unsigned integer.
RMNSSpec	Target *namespace specifier*.	Formatted text for object specifier.
RMOpID	Operation ID assigned by the service user in a request.	Unsigned integer.
RMParam	Parameter definition.	Structure composed of RMParamName, RMParamSetting, and RMParamRule.
RMParamName	Parameter name.	Text.
RMParamRule	Parameter definition restriction.	Formatted text.
RMParamSetting	The initial value to use for that parameter at execution time.	Varies with parameter definition and recipe language.
RMRcpID	Recipe identifier.	Formatted text.
RMRcpSpec	Target *recipe specifier*.	Formatted text for object specifier.
RMRcpStat	The status of a recipe.	Enumerated: Does not exist Unprotected Protected
RMSectionsCode	Indicates which recipe sections are requested.	Enumerated: All *generic attributes* and the body *Generic* attributes *Generic* and body *Agent-specific dataset* only All *agent-specific datasets*
RMSectionsRequested	Specification of recipe sections requested.	Structure composed of RMSectionsCode and

		RMAgent.
RMSectionsSent	Recipe attributes, recipe body, and attributes of *agent-specific* section(s).	Structure composed of GenAttrSection, BodySection, and (List of) AgentSpec_Section.
Status	Error Information.	Structure composed of ErrorCode and ErrorText.

12.2 *Message Flow* — The flow of messages defined in RMS, between the service user and the service provider, are of two types. The first type, illustrated in Figure 12.1, applies to most namespace operations. A request message is sent from the service user, and the *namespace manager* returns a response message containing the appropriate information.

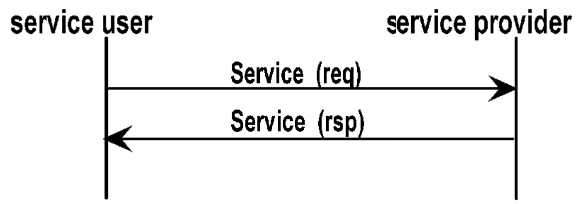

Figure 12.1

Basic Message Flow

The second type of message flow, illustrated in Figure 12.2, is used for messages that specify an operation to be performed that may require more time for completion than is allowed between a request and a response. In this case, the response to the request indicates an intent to complete the operation rather than actual completion. The operation is then performed on each of the specified recipes in turn, until each operation has completed, either successfully or with errors. Any errors that occurred are reported in the completion message.

The second type of message flow may be used for notifying the service user of RMNAction that individual operations on recipes have been completed. The first type of message flow is used for all other *namespace* services.

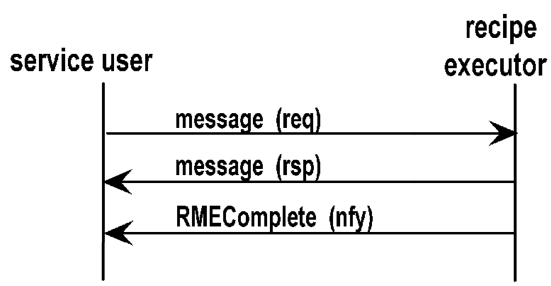

Figure 12.2

Message Flow with Completion Notification

The second type of message flow may be used for notifying the service user of RMNAction that individual operations on recipes have been completed. The first type of message flow is used for all other namespace services.

12.3 *RMNCreateNS* — The service user may request to *create* a new *namespace* and assign it a name (*identifier*). The request shall be denied if the *owner agent* already has a *namespace* with the new name.

The parameters for RMNCreateNS are listed in Table 12.3.

Table 12.3 RMNCreateNS

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
NSStatus	-	M	Information concerning the result of the requested operation.

12.4 *RMNDeleteNS* — The service user may request to delete a *namespace*. If the *namespace* contains recipes, the request shall be denied.

The parameters for RMNDeleteNS are listed in Table 12.4.

Table 12.4 RMNDeleteNS

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
NSStatus	-	M	Information concerning the result of the requested operation.

12.5 *RMNRenameNS* — The service user may request to rename a *namespace*. The request shall be denied if the owner agent already has a *namespace* with the new name.

The parameters for RMNRenameNS are listed in Table 12.5.

Table 12.5 RMNRenameNS Service

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
RMNewNS	M	M(=)	New *namespace* name *(identifier)*.
NSStatus	-	M	Information concerning the result of the requested operation.

12.6 *RMNSpaceInquire* — The service user may request the amount of space available for recipes.

The parameters for RMNSpaceInquire are listed in Table 12.6.

Table 12.6 RMNSpaceInquire

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
RMSpace	-	M	Amount of space available in target *namespace*.
NSStatus	-	M	Information concerning the result of the requested operation.

12.7 *RMNRcpStatInquire* — The service user may request the current write-protection status of a recipe and the next available numeric version for a recipe of the same class and name.

The parameters for RMNRcpStatInquire are listed in Table 12.7.

Table 12.7 RMNRcpStatInquire

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
RMRcpStat	-	M	Status of recipe.
RcpVersion	-	C	Next available numeric version. Required, except with the specified recipe does not exist.
NSStatus	-	M	Information concerning the result of the requested operation.

12.8 *RMNVersionInquire* — The service user may request the best version (highest) for a recipe with given qualifiers of *class*, *name*, and (optionally) *agent*.

The parameters for RMNVersionInquire are listed in Table 12.8.

Table 12.8 RMNVersionInquire

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
RcpClass	M	-	Qualifying recipe *class*.
RcpName	M	-	Qualifying recipe *name*.
RMAgent	C	C(=)	Certified agent. If omitted, agent qualification is not considered. If included, only recipes for which the *agent* is *certified* qualify.
RcpVersion	-	C	The best available *version* of the recipe. Omitted if no qualifying recipe is found.
NSStatus	-	M	Information concerning the result of the requested operation.

12.9 *RMNCreate* — A service user may request to initialize a new recipe in a namespace with a body created elsewhere. The requestor is required to supply the *attributes* of the recipe *body*. If the requested recipe *identifier* is used by a *read-only* recipe, the request shall be denied.

The parameters for RMNCreate are listed in Table 12.9.

12.10 *RMNUpdate* — The service user requests to replace an existing recipe *body* in a namespace with an *updated* body. If the requested recipe *identifier* is used by a *read-only* recipe, the request shall be denied.

The parameters for RMNUpdate are listed in Table 12.9.

Table 12.9 RMNCreate and RMNUpdate

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMRcpSpec	M	-	Recipe specifier.
(List of) AttrSetting	M	-	List of recipe attributes required for create/update.
BodySection	M	-	Recipe body.
NSStatus	-	M	Information concerning the result of the requested operation.

12.11 *RMNStore* — The service user may request to store a recipe in a *namespace*. If the recipe *identifier* is already in use by a *read-only* recipe in the *namespace,* or if the *namespace* has insufficient space for storing the recipe, request shall be denied.

The parameters for RMNRetrieve are listed in Table 12.10.

Table 12.10 RMNStore

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMRcpSpec	M	-	The *recipe specifier.*
RMSectionsCode	M	-	Indicates which sections sent.
RMSectionsSent	M	-	Contents of all sections to be sent.
NSStatus	-	M	Information concerning the result of the requested operation.

12.12 *RMNRetrieve* — The service user may request to receive a recipe in its entirety (including all *agent-specific datasets*), the *generic* attributes with or without the *body* but without *agent-specific* datasets, a particular *agent-specific dataset*, or all *agent-specific datasets*.

The parameters for RMNRetrieve are listed in Table 12.11.

Table 12.11 RMNRetrieve

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMRcpSpec	M	-	The *recipe specifier.*
RMSectionsRequested	M	-	Indicates which sections are requested.
RMSectionsSent	-	M	Contents of all sections to be sent.
NSStatus	-	M	Information concerning the result of the requested operation.

12.13 *RMNCopy* — The service user may request to copy a recipe in a *namespace* to another recipe within the same *namespace*. If a *read-only* recipe with the specified Destination ID exists, an Access Denied error shall be returned.

The parameters for RMNCopy are listed in Table 12.12.

12.14 *RMNRename* — The service user may request to rename a recipe in a *namespace* if the recipe is not *write-protected.* If the recipe is *write-protected*, then an Access Denied error shall be returned.

The parameters for RMNRename are listed in Table 12.12.

Table 12.12 RMNCopy, RMNRename

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMRcpSpec	M	-	*Specifier* of the recipe to be copied or renamed (source).
RMDestRcpID	M	-	The identifier for the recipe to be originated (destination).
NSStatus	-	M	Information concerning the result of the requested operation.

12.15 *RMNAction* — RMNAction is used to request the performance of one of the following actions (operations) on one or more recipes: delete, protect, verify, link, unlink, certify, de-certify, download to a specified *agent*, and upload from a specified *agent*. Where more than one recipe is specified, operations shall be performed on each recipe in the requested order.

If performance of the requested action is likely to take more time to complete than is normally allowed between a request message and the corresponding response, then the *namespace manager* should respond with an intent to comply at the earliest opportunity before it begins the requested operation. Immediately following the completion of the operation on each of the specified recipes, the *manager* shall send a notification message RMNComplete to the service requestor, providing the results of that operation together with information concerning any errors causing abnormal completion of the operation. Error information is important for diagnosis and correction of problems. Figure 12.2 in Section 12.2 shows an example of the message flow for the download operation performed on two recipes.

The parameter LinkID is set to a zero value in the response if the operations have been completed and no notifications will be sent. Otherwise, it is set to a non-zero value, and the value set in the parameter RMOpID shall be retained for use in RMNComplete.

The parameters for RMNAction are listed in Table 12.14.

Table 12.14 RMNAction

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
RMAction	M	M(=)	Action.
RMOpID	C	C(=)	Operation ID, used where multiple confirmations may occur. May be null or omitted where the service initiator does not request a new service until all confirmations for the outstanding service have been received.
(List of) RMRcpID	M	-	Identifier of the target recipe.
RMAgent	C	C(=)	Omitted, except for certify, de-certify, download, upload.
RMLinkID	-	M	LinkID is set to zero if, and only if, no further completion messages will be required.
NSStatus	-	M	Information concerning the result of the requested operation.

12.16 *RMNVarPar* — The service user may request to set *agent-specific variable parameter definitions*. NOTE: Modification of the *parameter restrictions* in a *variable parameter definition* shall reset the Certified *attribute* for that *agent*.

The parameters for RMNVarPar are listed in Table 12.15.

Table 12.15 RMNVarPar

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMRcpSpec	M	-	*Specifier* of the target recipe.
RMAgent	M	-	Agent name (identifier).
(List of) RMParam	M	-	Variable parameter definition.
NSStatus	-	M	Information concerning the result of the requested operation.

12.17 *RMNGetDescriptor* — The service user may request the descriptors of one or more recipes.

The parameters for RMNGetDescriptor are listed in Table 12.13.

Table 12.13 RMNGetDescriptor

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMNSSpec	M	-	Target *namespace specifier*.
(List of) RMRcpID	M	-	Identifier of the target recipe.
(List of) RMDesc	-	M	Requested *recipe descriptor(s)* in the same order as requested.
NSStatus	-	M	Information concerning the result of the requested operation.

12.18 *RMNComplete* — The service provider notifies the service user that an action requested by the service user has completed.

The parameter RMOpID is retained from the initial request message RMNAction.

The parameter LinkID is set to a non-zero value for all notifications except the notification of completion of the last operation performed. A zero value indicates that no further notifications will be sent.

The parameters for RMNComplete are listed in Table 12.16.

Table 12.16 RMNComplete

Parameter	*Req/ Ind*	*Rsp/ Conf*	*Description*
RMOpID	C(=)	-	Operation ID, used where multiple completion messages may occur, corresponding to the value in the original request. May be null or omitted where the service initiator does not request a new service until all confirmations for the outstanding service have been received.
RMLinkID	M	-	LinkID is set to zero if, and only if, no further completion messages will be required.
RMRcpSpec	-	C	*Specifier* of the changed recipe. Indicates *namespace* and recipe *identifiers*.
RMChange Status	M	-	State of the changed recipe.
(List of) AttrSettings	C	-	Attributes of particular interest to the result. Varies with action.
NSStatus	M	-	Information conerning the result of the requested operation.

13 Distributed Recipe Namespace Services

This section defines the new message services required for implementation of *distributed recipe namespace* services. Table 13.1 lists the messages, the type of each message (request or notification), and provides a brief description.

Table 13.1 Distributed Recipe Namespace Services

Message Service Name	*Type*	*Description*
DRNS Segment Services		
RMDSApproveAction	R	A *segment's manager* approves an earlier *change request*.
DRNS Recorder Services		
RMDRAddSegRecord	R	A *manager* requests a *recorder* to add a *segment specifier* to its Segments attribute.
RMDRDelSegRecord	R	A *manager* requests a *recorder* to delete a *segment specifier* from its Segments attribute.
RMDRAddChgRecord	R	A *manager* requests a *recorder* to add a *change request record* for a specified recipe.
RMDRDelChgRecord	R	A *manager* requests a *recorder* to delete a *change request record* for a specified recipe.
RMDRGetChgRecord	R	A *service user* requests *change request* for a recipe or segment.
DRNS Manager Services		
RMDComplete	N	An attached *segment* notifies its *manager* that an approved change has been completed.
RMDNotify	N	An attached *dedicated segment* notifies its *manager* that an *agent-specific dataset* has been changed.
RMDGetChgRequest	R	A request is made for *change request* information for a recipe.
RMDSegChange	R	An attached *segment* requests approval for a specified type of change to a recipe.
RMDRebuild	R	A request is made for a new *manager* to rebuild an existing *distributed namespace*.

13.1 *Distributed Recipe Namespace Message Parameter Dictionary* — This section defines, in alphabetical order, the parameters that are used in *distributed recipe namespace* services and are not already defined in Table 12.2 in Section 12.

Table 13.2 contains the definitions for message parameters.

Table 13.2 Distribute Recipe Namespace Parameter Dictionary

Parameter	*Definition*	*Form*
AttrData	Value of attribute.	Varies with attribute.
AttrName	Name of attribute.	Text.
AttrSetting	Attribute name/value.	Structure composed of AttrName, AttrData.
Attach Token	Attach token provided by an object at the time it is attached or reattached and used by the manager as identification.	Unsigned integer.
ChgRequest	The information provided in a change request.	Structure composed of: RMRcpID, DestRcpID, RMSegSpec, RMChgType, RMOpID, RMTimestamp, RMRequestor
NSAck	Acknowledge code.	Enumerated: no request for this action exists requested operation completed without errors requested operation completed with errors requested operation will be performed and notification of results will be sent

NSStatus	Information concerning the outcome of the requested operation.	Structure composed of NSAck and Status.
ObjID	Object identifier.	Text.
ObjSpec	Object specifier.	Formatted text for object specifier.
ObjType	Object type.	Text.
RMChgType	Type of change requested.	Enumerated: create update delete copy rename verify link unlink certify de-certify change generic attributes(s) change agent-specific attribute(s) store
RMManagerSpec	Object specifier for a *DRNS manager*.	Formatted text.
RMOpID	Operation ID assigned by the *distributed recipe namespace manager*.	Unsigned integer.
RMPermit	Approval for a requested change.	Enumerated: change request approved change request denied change request on hold
RMRcpID	Recipe identifier.	Formatted text.
RMRecorderSpec	Recorder specifier.	Formatted text for object specifier.
RMRequestor	Indicates if the initiator of a change request was an *attached segment* (TRUE) or an external user (FALSE).	Boolean.
RMSegSpec	Segment specifier.	Formatted text for object specifier.
RMTimestamp	Date and time a *change request* was first received.	Timestamp format: "YYYYMDDhhmmsscc".
TargetSpec	Object specifier of target object.	Formatted text for object specifier.

13.2 *Distributed Recipe Namespace Segment Services*

13.2.1 *RMDSApproveAction* — A *distributed recipe namespace manager* may approve or deny a *change request* that the *segment* requested at an earlier time.

Parameters for RMDSApproveAction are listed in Table 13.3.

Table 13.3 RMDSApproveAction Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMSegSpec	M	-	The segment specifier.
Attach Token	M	-	Segment attach token.
RMPermit	M	-	Approval is granted or denied by the *manager*.
RMOpID	M	-	An *operation identifier* assigned by the *manager* for the change.
RMRcpID	M	-	The *identifier* of the recipe for which a change was requested.
RMChgType	M	-	The type of change requested.
NSStatus	-	M	Information concerning the result of the requested operation.

13.3 *Distributed Recipe Namespace Recorder Services*

13.3.1 *RMDRAddSegRecord* — A *recorder's manager* may request the *recorder* to add a *segment record*. Parameters for RMDRAddSegRecord are listed in Table 13.4.

Table 13.4 RMDRAddSegRecord Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRecorderSpec	M	-	The *recorder specifier*.
RMSegSpec	M	-	The *specifier* of the *segment* to add.
Attach Token	M	-	The recorder's attach token.
NSStatus	-	M	Information concerning the result of the requested operation.

13.3.2 *RMDRDelSegRecord* — A *recorder's manager* may request the *recorder* to delete a *segment record*. Parameters for RMDRDelSegRecord are listed in Table 13.5.

Table 13.5 RMDRDelSegRecord Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRecorderSpec	M	-	The *recorder specifier*.
RMSegSpec	M	-	The *specifier* of the *segment* to add.
Attach Token	M	-	The recorder's attach token.
NSStatus	-	M	Information concerning the result of the requested operation.

13.3.3 *RMDRAddChgRecord* — A *recorder's manager* may request the *recorder* to add a *change request record*. Parameters for RMDRAddChgRecord are listed in Table 13.6.

Table 13.6 RMDRAddChgRecord Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRecorderSpec	M	-	The *recorder specifier*.
ChgRequest	M	-	Change request record.
Attach Token	M	-	The recorder's attach token.
NSStatus	-	M	Information concerning the result of the requested operation.

13.3.4 *RMDRDelChgRecord* — A *recorder's manager* may request the *recorder* to delete a *change request record*. Parameters for RMDRDelChgRecord are listed in Table 13.7.

13.7 RMDRDelChgRecord Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRecorderSpec	M	-	The *recorder specifier*.
RMRcpID	M	-	The *identifier* of the recipe to be changed.
Attach Token	M	-	The recorder's attach token.
NSStatus	-	M	Information concerning the result of the requested operation.

13.3.5 *RMDRGetChgRecord* — A service user may request an attached *recorder* to return the current *change request record(s)* for a recipe or an attached *DRNS segment*.

Parameters for RMDRGetChgRecord are listed in Table 13.8.

Table 13.8 RMDRGetChgRecord Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRecorderSpec	M	-	Recorder specifier.
TargetSpec	M	-	Recipe identifier or segment specifier.
Attach Token	M	-	The recorder's attach token.
(list of) ChangeRequest	-	C	List of change request information. Omitted if no change requests exist for specified recipe/segment.
NSStatus	-	M	Information concerning the result of the requested operation.

13.4 *Distributed Recipe Namespace Manager Services*

13.4.1 *RMDComplete* — An attached *segment* notifies its *manager* when it has completed an approved change to a recipe.

The parameter RMOpID is retained from the initial request message RMNAction.

The parameter LinkID is set to a non-zero value for all notifications except the notification of completion of the last operation performed. A zero value indicates that no further notifications will be sent.

Parameters for RMDComplete are listed in Table 13.9.

Table 13.9 RMDComplete

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMOpID	C(=)	-	Operation ID, used where multiple completion messages may occur, corresponding to the value in the original request. May be null or omitted where the service initiator does not request a new service until all confirmations for the outstanding service have been received.
RMLinkID	M	-	LinkID is set to zero if, and only if, no further completion messages will be required.
RMRcpSpec	M	-	*Specifier* of the changed recipe. Indicates *namespace* and recipe *identifiers*.
RMChangeStatus	M	-	State of the changed recipe.
(List of) AttrSettings	C	-	Attributes of particular interest to the result. Varies with action.
NSStatus	-	C	Information concerning the result of the requested operation.

13.4.2 *RMDNotify* — An attached *dedicated segment* notifies its *manager* that it has changed an *agent-specific dataset* and provides the attribute AgentSpec_Agent and all updated attributes.

Parameters for RMDNotify are listed in Table 13.10.

Table 13.10 RMDNotify

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRcpSpec	M	-	*Specifier* of the changed recipe. Indicates *namespace* and recipe *identifiers*.
RMChangeStatus	M	-	State of the changed recipe.
(List of) AttrSettings	C	-	Changed *agent-specific attributes*.
NSStatus	-	C	Information concerning the result of the requested operation.

13.4.3 *RMDSegChange* — An *attached segment* may request its *manager*'s approval to make a change. The recipe specifier RMRcpSpec shall include the requesting *segment's* object type and name to identify the requestor and the specific instance of the logical recipe to be changed first.

Parameters for RMDSegChange are listed in Table 13.11.

Table 13.11 RMDSegChangeService

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMRcpSpec	M		Recipe specifier.
RMDestRcpID	C		Destination recipe identifier (copy/rename only).
RMChgType	M	M	Type of change requested.
RMPermit		M	Grants or denies permission.
RMOpID		M	A non-zero value returned when the change is completed.

13.4.4 *RMDGetChangeRequests* — A service user may request that all existing *change requests* for a recipe be returned. The first item returned is the *active change request*.

Parameters for RMDGetChangeRequests are listed in Table 13.12.

Table 13.12 RMDGetChangeRequests Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMNSSpec	M	-	The object specifier of the *distributed recipe namespace*.
RMRcdID	M	-	The *recipe specifier*.
(list of) ChangeRequest	C	-	Omitted if no *change requests* exist for the specified recipe.
NSStatus	-	M	Information concerning the result of the requested operation.

13.4.5 *RMDRebuild* — A service user may request a *distributed namespace manager* to rebuild a *distributed namespace*.

Parameters for RMDRebuild are listed in Table 13.13.

Table 13.13 RMDRebuild Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RMManagerSpec	M	-	The object specifier of the new *distributed namespace manager*.
RMNSSpec	M	-	The specifier of the *distributed namespace*.
RMRecorderSpec	C	-	The *recorder specifier*. Omitted only if list of segments provided.
(list of) RMSegSpec	C	-	List of specifiers of attached *segments*. Omitted if *recorder specifier* provided.
NSStatus	-	M	Information concerning the result of the requested operation.

14 Recipe Executor Services

This section defines *recipe executor services*. *Recipe executor services* request that an operation be performed by the *recipe executor* and begin with the prefix RME.

Certain activities that may require extended time to complete shall provide confirmation with the RMEComplete message at the completion of each individual operation specified.

Table 14.1 Recipe Executor Services

Message Service Name	*Type*	*Description*
RMEDnldVer	R	Receive a recipe, verify it, and put it into storage.
RMEVerify	R	Verify one or more recipes.
RMEUpload	R	Retrieve a recipe from storage.
RMERename	R	Change a recipe's *identifier*.
RMESpaceInquire	R	Determine the available space for recipe storage.
RMEDelete	R	Delete a recipe from storage.
RMESelect	R	*Select* recipes for execution.
RMEDeselect	R	*Deselect* a recipe to prevent its execution.
RMEGetDescriptor	R	Get recipe descriptor.
RMEChange	N	Notification that a permitted change has occurred.
RMEComplete	N	Notification that a requested action is complete.

14.1 *Recipe Executor Message Parameter Dictionary* — For purposes of transferring a recipe, it is regarded as having two types of *sections:* an *attribute section* containing the recipe's attributes, and a **body section** consisting of the *body*. The *attribute section* is always transferred first, and the attributes ExecAttrLength, ExecAttrChgTime, AttrLength, AttrTimestamp, BodyLength, and EditTime are always sent first, in that order. This allows the length information to be immediately determined by the receiver.

Descriptors are also regarded as consisting of *sections* for the *attribute descriptor*, the *generic attribute descriptor*, and the *body descriptor*.

Each start of each *section* is identified with a text string reserved for that *section type*.

Table 14.2 contains the definitions for message parameters.

Table 14.2 Recipe Executor Parameter Dictionary

Parameter	*Definition*	*Form*
AttrName	Name of attribute.	Text.
AttrData	Value of attribute.	Varies with attitude.
AttrSetting	Attribute name/value pair.	Structure composed of AttrName, AttrData.
BodyData	The recipe *body* contents.	Varies.
BodyDesc	*Body descriptor.*	Structure composed of BodyDescName, BodyDescLength, BodyDescTimestamp.
BodyDescLength	Value of BodyLength.	Unsigned integer.
BodyDescName	Identifies the start of the *body descriptor*.	Text ="BodyDesc".
BodyDescTimestamp	Value of EditTime.	Timestamp format: "YYYYMMDDhhmmsscc".
BodySection	The recipe *body section.*	Structure composed of BodySectionName, BodyData.
BodySectionName	Identifies the start of the *body section.*	Text ="Body".
ErrorCode	Contains the code for the specific error found.	Enumerated: unknown object type unknown object identifier unknown attribute name unknown attribute value access denied recipe not found syntax error validation error verification error recipe select error: unlinked recipe recipe approval level too low recipe certification level too low
ErrorText	Text in support of the error code to provide additional information.	Text.
GenDesc	*Generic attribute* descriptor.	Structure composed of GenDescName, GenDescLength, and GenDescTimestamp.
GenDescLength	Value of AttrLength.	Unsigned integer.
GenDescName	Identifies start of *generic descriptor.*	Text ="GenDesc".
GenDescTimestamp	Value of AttrChgTime.	Timestamp format: "YYYYMMDDhhmmsscc".
LinkID	In response or completion message, has the value of REOplD in the request, or is set to zero if, and only if, no further completion messages will be sent.	Unsigned integer.
RcpDerivedID	Identifier of derived object form recipe.	Structure composed of text "DerivedID" and REDerivedID.
RcpEstRunTime	EstRunTime attribute.	Structure composed of text "EstRunTime" and REEstRunTime.
RcpExtRef	ExtRef attribute of *managed* recipe.	Structure composed of text "ExtRef" and (list of) REExtRef.

Parameter	*Definition*	*Form*
RcpParameters	Parameters attribute of *managed* recipe.	Structure composed of text "Parameters" and (list of) REParam.
RcpVerificationID	VerificationID attribute of a *verified* recipe.	Structure composed of text "VerificationID" and REVerID.
REAck	Acknowledge code.	Enumerated: unknown object type unknown object identifier unknown attribute name invalid attribute value access denied recipe not found invalid parameter settings
REAttrDesc	The descriptor of the *execution* recipe attributes.	Structure composed of REAttrDescName, REAttrDescLength, REAttrDescTimestamp.
REAttrDescLength	The value of ExecAttrLength.	Unsigned integer.
REAttrDescName	Identifies the start of the *attribute descriptor*.	Text ="REAttrDesc".
REAttrDescTimestamp	Value of ExecAttrChgTime.	Timestamp format: "YYYYMMDDmmhhsscc".
REAttrSection	Recipe attributes section.	Structure composed of REAttrSectionName and REAttrSectionData.
REAttrSectionData	Recipe attributes name/value pairs.	(List of) AttrSetting.
REAttrSectionName	Identifies recipe attribute section.	Text ="Attributes".
REChangeStatus	Indicates new status of recipe.	Enumerated: stored deleted selected de-selected created changed body updated last value derived object form
REDerivedID	The *identifier* of a *derived form recipe.*	Formatted text.
REDesc	*Descriptor* of the *execution* recipe.	Structure composed of REAttrDesc, GenDesc, and BodyDesc.
REEstRunTime	Estimated run time of recipe, in seconds. Value of EstRunTime attribute.	Unsigned integer.
REExRef	A reference to an external recipe, in the form of a *recipe specifier.*	Formatted text.
REDestRcpID	The new *identifier* of a renamed recipe.	Formatted text.
REOpID	Operation ID assigned by the service user in a request.	Unsigned integer.
REOWCode	Indicates a forced overwrite of any pre-existing recipe of the same *identifier.*	Boolean: If FALSE or omitted, a pre-existing recipe with the same identifier is not overwritten and will cause a download error. If TRUE, any pre-existing recipe with the same *identifier* is effectively overwritten.
REParam	Parameter definition.	Structure composed of REParamName, REParamSetting, and REParamRule.
REParamName	Parameter name.	Text.
REParamSetting	The *initial value* to use for a parameter at execution time.	Varies with parameter definition and recipe language.
RERcpID	Recipe *identifier*.	Formatted text.
RERcpSpec	Recipe specifier[a].	Formatted text.

Parameter	*Definition*	*Form*
RERecipe	*Execution* recipe.	Structure composed of REAttrSection, BodySection.
RESelect	Recipe specifier with option parameter setting.	(List of) Structure composed of RERcpSpec and (list of) RESelectParam.
RESelectParam	*Variable parameter name* and *initial value*.	Structure composed of REParamName and REParamSetting.
RESpace	Amount of available storage, in bytes.	Unsigned integer.
RESpec	The specifier of the *recipe executor.*	Formatted text.
REStatus	Information regarding the success or failure of the request.	Structure composed of REAck and (List of) Status.
REVerData	Information concerning a successfully *verified* recipe.	Structure composed of RcpExtRef, RcpParameters, RcpEstRunTime (optional), RcpVerificationID (optional), and (where applicable) RcpDerivedID.
REVerID	Contents of VerificationID attribute.	Text.
Status	Error information.	Structure composed of Error Code and ErrorText.

a. A recipe specifier may reference a recipe that is in a namespace and not in the recipe executor's storage.

14.2 *Message Flow* — The flow of messages defined in RMS, between the service user and the service provider, are of three types. The first type, illustrated in Figure 14.1, is the most common and applies to all *recipe executor* operations except for cases of RMEDnldVer, RMEVerify, and RMESelect. A request message is sent from the service user, and the *recipe executor* returns a response message containing the appropriate information. All activities that occur as a result of the request are completed before the response message is sent.

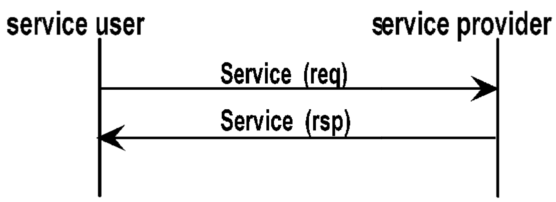

Figure 14.1

Basic Message Flow

The second type of message flow, illustrated in Figure 14.2, is used for messages that specify an operation to be performed that may require more time for completion than is allowed between a request and a response. In this case, the response to the request indicates an intent to complete the operation rather than actual completion. The operation is then performed on each of the specified recipes in turn, until each operation has completed, either successfully or with errors. Any errors that occurred are reported in the completion message.

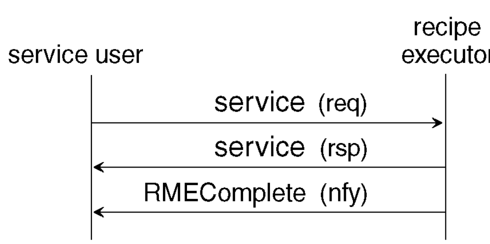

Figure 14.2

Message Flow with Completion Notification

The second type of message flow may be used for notifying the service user of RMEDnldVer, RMEVerify, and RMESelect that individual operations on recipes have been completed.

A third type of message flow consists of a single notification message, shown in Figure 11.3, sent by the *recipe executor* to inform the *originating namespace* of a new or changed *execution* recipe. (See Section 11.2.10.)

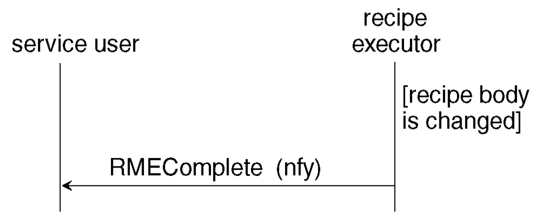

Figure 14.3
Change Notification Message Flow

14.3 *RMEDnldVer* — The service user may request the *recipe executor* to download and *verify* an *execution* recipe. All *unverified* downloaded recipes are *verified* automatically. The service user may optionally specify a *forced overwrite* of any pre-existing *unselected* recipe with the same *identifier.* A currently *selected* recipe shall not be overwritten. If forced *overwrite* is not specified and a recipe with the same *identifier* is already in storage, the request to *download* is denied and the recipe is discarded.

If the *recipe executor* performs a *verification* of the *downloaded* recipe, and if the *verification* is successful, then it shall return the information provided by the conditional parameters.

Parameters for RMEDnldVer are listed in Table 14.3.

Table 14.3 RMEDnldVer Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RERcpSpec	M	-	Destination *specifier* of the *execution* recipe.
REOWCode	M	-	Indicates if a forced overwrite is requested.
RERecipe	M	-	The *execution* recipe.
REVerData	-	C	Information concerning the successfully *verified* recipe. Omitted if recipe has no external references or fails *verification.*
REStatus	-	M	Information concerning the results of the operation.

14.4 *RMEVerify* — The service user may request the *recipe executor* to *verify* an *execution* recipe. If the *verification* is successful, then it shall return the information provided by the conditional parameters.

Parameters for RMEVerify are listed in Table 14.4.

Table 14.4 RMEVerify Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	*Specifier* of the target recipe executor.
(List of) RERcpID	M	-	*Identifier* of the recipe.
REOpID	C	C(=)	Operation ID, used where multiple confirmations may occur. May be null or omitted where the service initiator does not request a new service, until all confirmations for the outstanding service have been received.
LinkID	-	M	LinkID is set to zero if, and only if, no further completion messages will be required.
(List of) REVerData	-	C	Information concerning the successfully *verified* recipe. Omitted if recipe has no external references or fails *verification.*
REStatus	-	M	Information concerning the results of the operation.

14.5 *RMEUpload* — RMEUpload retrieves a recipe from local storage and sends it to the service user.

Parameters for RMEUpload are listed in Table 14.5.

Table 14.5 RMEUpload Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RERcpSpec	M	M(=)	Specifier.
RERecipe	-	M	The *execution* recipe.
REStatus	-	M	Information concerning the results of the operation.

14.6 *RMERename* — RMERename changes the *identifier* of an *execution recipe* through changing one or more of its *identification* attributes. If the new *identifier* is already in use by an *execution recipe*, or if the recipe is currently *selected*, permission to rename the recipe shall be denied.

Parameters for RMERename are listed in Table 14.6.

Table 14.6 RMERename Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RERcpSpec	M	-	*Specifier* of the *execution* recipe.
REDestRcpID	M	M(=)	The new recipe *identifier*.
REStatus	-	M	Information concerning the results of the operation.

14.7 *RMESpaceInquire* — The service user may request the amount of space available for recipes. The parameters for RMESpaceInquire are listed in Table 14.7.

Table 14.7 RMESpaceInquire

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	Target *recipe executor specifier*.
RESpace	-	M	Amount of space available in target *namespace*.
REStatus	-	M	Information concerning the results of the requested operation.

14.8 *RMEDelete* — RMEDelete removes one or more recipes from local storage and frees any reusable storage area for new recipes. If the recipe is currently *selected*, permission to delete the recipe shall be denied.

Parameters for RMEDelete are listed in Table 14.8.

Table 14.8 RMEDelete Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	*Specifier* of the recipe executor.
(List of) RERcpID	M	C	Identifier of the recipe to be deleted. Response returns identifiers of successfully deleted recipe(s) only.
REStatus	-	M	Information concerning the results of the operation.

14.9 *RMESelect* — The service user may specify one or more recipes to be *selected* for *execution*. RMESelect is the only service of the *recipe executor* that allows the service user to specify more than one recipe in a single request.

Parameters for RMESelect are listed in Table 14.9.

Table 14.9 RMESelect Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	*Specifier* of the recipe executor.
(List of) RESelect	M	-	Recipe *specifiers* with (optionally) one or more associated parameter names/values per recipe.
REOpID	C	C(=)	Operation ID, used where multiple confirmations may occur. May be null or omitted where the service initiator does not request a new service, until all confirmations for the outstanding service have been received.
LinkID	-	M	LinkID is set to zero if, and only if, no further completion messages will be required.
REStatus	-	M	Indicates the results of the operation.

14.10 *RMEDeselect* — The service user may deselect a recipe to prevent its *re-execution*.

Parameters for RMEDeselect are listed in Table 14.10.

Table 14.10 RMEDeselect Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	*Specifier* of the recipe executor.
(List of) RERcpID	M	-	Identifier of the recipe.
REStatus	-	M	Information concerning the results of the operation.

14.11 *RMEGetDescriptor* — The service user may request the descriptors of one or more recipes.

Parameters for RMEGetDescriptor are listed in Table 14.11.

Table 14.11 RMEGetDescriptor

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RESpec	M	-	*Specifier* of the recipe executor.
(List of) RERcpID	M	-	Identifier of the recipe.
(List of) REDesc	-	M	Requested *recipe descriptor(s)* in the same order as requested.
REStatus	-	M	Information concerning the results of the operation.

14.12 *RMEChange* — The service provider informs an *originating namespace* that a permitted change has occurred.

Parameters for RMEChange are listed in Table 14.12.

Table 14.12 RMEChange Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
REOpID	C	-	Operation ID, used where multiple completion messages may occur, corresponding to the value in the original request. May be null or omitted where the service initiator does not request a new service using REOpID, until the confirmation for the outstanding service has been received.
RERcpID	M	-	*Identifier* of the recipe of interest. Equivalent to *specifier* of corresponding *managed recipe*.
REChangeStatus	M	-	State of the changed recipe.
(List of) AttrSettings	C	-	Attributes of particular interest to the result. Varies with action.
REStatus	M	-	Information concerning the results of the operation.

14.13 *RMEComplete* — The service provider notifies the service user that an action requested by the service user has completed.

Parameters for RMEComplete are listed in Table 14.13.

Table 14.13 RMEComplete Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
REOpID	C	-	Operation ID, used where multiple completion messages may occur, corresponding to the value in the original request. May be null or omitted where the service initiator does not request a new service using REOpID, until the confirmation for the outstanding service has been received.
RERcpID	M	-	*Identifier* of the recipe of interest. Equivalent to *specifier* of corresponding *managed recipe*.
REChangeStatus	M	-	State of the changed recipe.
(List of) AttrSettings	C	-	Attributes of particular interest to the result. Varies with action.
REStatus	M	-	Information concerning the results of the operation.

15 Recipe Management Compliance

This section gives a centralized reference location for compliance for RMS objects. It provides references to other sections of the standard where detailed requirements are located. This section also defines standard terminology and documentation related to RMS compliance that can be used by *agent* suppliers and device manufacturers to describe compliance with this standard.

Each object defined by RMS has both *fundamental requirements* and *additional capabilities*. *Fundamental requirements* shall be met by all instances of an RMS-compliant object as specified in cited sections. Additional capabilities consist of those features that are optional. However, for RMS compliance, where features providing the same or similar capabilities are implemented, they shall be implemented according to RMS specifications.

Except where one or more subsections are specifically excluded, section references include all subsections of the referenced section.

The following table format is used in this section to specify fundamental and additional (optional) capabilities. Fundamental capabilities have a "Y" in the column labeled "Fund." Otherwise, the capability is optional.

Capability	*Reference*	*Fundamental*
Name of capability	Sections in SEMI E42	Y or N

15.1 *Areas of Compliance* — There are seven areas of RMS compliance, as follows:

a. Managed Recipe

b. Recipe Namespace Management

c. Distributed Recipe Namespace Management

e. Distributed Recipe Namespace Recorder

d. Distributed Recipe Namespace Segment

f. Execution Recipe

g. Recipe Executor

15.2 *Managed Recipe* — This section defines RMS compliance for the *managed recipe*.

A *managed recipe* has attributes, a body, and is capable of supporting at least one agent-specific dataset. An RMS-compliant *managed recipe* reflects its compliance (a) through its attributes and (b) through its structure when it is transferred.

In some cases, a capability is represented by a single attribute. In other case, support of an additional capability requires several attributes that are required as a set.

Table 15.1 describes the requirements for compliance to the *managed recipe*.

Table 15.1 Section References for Managed Recipe Capabilities

Capability	*Reference*	*Fundamental*
Recipe identifier (class, name, version)	3.2.3	Y
/PROCESS/ recipe class	3.2.3.2	Y
Mandatory and required generic attributes	3.2.5, 3.4.1, 3.4.2	Y
Mandatory and required agent-specific dataset attributes	3.4.2.2	Y
Recipe State Model	8.3, Table 8.1	Y
/PROCESS/ recipe subclass(es)	3.2.3.2	N
Non-process recipe class(es)	3.2.3.2	N
Multi-part recipe (ExtRef, LinkList)	3.2.3.1, 3.4.2.1	N
Variable parameters (Parameters, LinkParam)	3.2.4.2, 3.4.2.1	N
Approval level (ApprovalLevel)	3.4.2.1, 3.4.2.1	N
Certification Certified	3.4.2.1	N
Source Form recipe body	3.2.2.1.1	N*
Object Form recipe body	3.2.2.1.2	N*

* At least one of the two forms is required.

15.3 *Managed Recipe Compliance Table* — Table 15.2 provides a statement of compliance for the *managed recipe*.

Table 15.2 Recipe Namespace Management Compliance Table

Manual Recipe Compliance Table		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Recipe identifier (class, name, version)	❒ Yes ❒ No	❒ Yes[1] ❒ No
/PROCESS/ recipe class	❒ Yes ❒ No	
Mandatory and required generic attributes	❒ Yes ❒ No	
Mandatory and required agent-specific dataset attributes	❒ Yes ❒ No	
Recipe State Model	❒ Yes ❒ No	
Additional Capabilities	*Implemented*	*RMS Compliant*[2]
/PROCESS/ recipe subclass(es)	❒ Yes ❒ No	❒ Yes ❒ No
Non-process recipe class(es)	❒ Yes ❒ No	❒ Yes ❒ No
Multi-part recipe (ExtRef, LinkList)	❒ Yes ❒ No	❒ Yes ❒ No
Variable parameters (Parameters, LinkParam)	❒ Yes ❒ No	❒ Yes ❒ No
Approval level (ApprovalLevel)	❒ Yes ❒ No	❒ Yes ❒ No
Agent-specific dataset mandatory and required attributes	❒ Yes ❒ No	❒ Yes ❒ No
Certification Certified	❒ Yes ❒ No	❒ Yes ❒ No
Source Form recipe body	❒ Yes ❒ No	❒ Yes ❒ No
Object Form recipe body	❒ Yes ❒ No	❒ Yes ❒ No

[1] Do not mark YES unless all fundamental RMS requirements are implemented.

[2] Additional capabilities may not be marked RMS compliant unless all fundamental RMS requirements are implemented.

15.4 *Recipe Namespace Management* — Recipe Namespace Management requires compliance to specifications for the *managed recipe*, the *recipe namespace*, and the *recipe namespace manager*.

15.4.1 *Recipe Namespace* — This section defines RMS compliance for the *recipe namespace* object. A *recipe namespace* exhibits RMS compliance through its attributes and access to managed recipes.

NOTE: Operations and services are performed by the *recipe manager*.

Table 15.3 describes the requirements for compliance to the *recipe namespace*.

Table 15.3 Section References for Recipe Namespace Capabilities

Capability	*Reference*	*Fundamental*
Fundamental compliance to *managed recipe*	15.2, Table 15.2	Y
Basic requirements	4.3, 4.4, 4.6, 8.2.1	Y

15.4.2 *Recipe Namespace Manager* — Table 15.4 describes RMS compliance for the *recipe namespace manager*.

Table 15.4 Section References for Recipe Namespace Manager Capabilities

Capability	*Reference*	*Fundamental*
Basic requirements	4.3, 4.6 (Table 4.2), 8.2.1	Y
OSS services	9.1, 9.1.1–9.1.2	Y
Create recipe (RMNCreate)	8.2.2, 8.2.2.1, 9.4.1, 12.9	Y
Update recipe (RMNUpdate)	8.2.2.2, 9.4.2, 12.10	Y
Verify recipe (RMNAction)	8.2.3.1, 9.4.7, 12.15	Y
Link recipe (RMNAction)	8.2.3.2, 12.15	Y
Get recipe descriptor (RMNGetDescriptor)	8.2.7.1, 12.17	Y
Get available space (RMNSpaceInquire)	9.3.1, 12.6	Y
Check recipe status (RMNRcpStatInquire)	9.3.2, 12.7	Y
Get best version (RMNVersionInquire)	9.3.3, 12.8	Y
Store recipe (RMNStore)	9.4.3, 12.11	Y
Download *execution* recipe (RMNAction)	6.3.2, 9.4.8, 12.15	Y
Retrieve recipe (RMNRetrieve)	9.4.4, 12.12	Y
Recipe Namespace Change Event	9.6	Y
Action complete notification (RMNComplete)	12.18	Y
Upload *execution* recipe (RMNAction)	9.4.9, 12.15	N
Unlink recipe (RMNAction)	8.2.3.3, 12.15	N
Approve recipe (RMNAction)	8.2.4.1, 12.15	N
Protect recipe (RMNAction)	8.2.5, 12.15	N
Unprotect recipe (RMNAction)	8.2.6, 12.15	N
Certify recipe (RMNAction)	8.2.4.2, 8.2.7, 12.15	N
Decertify recipe (RMNAction)	8.2.8, 12.15	N
Create namespace (RMNCreate)	9.2.1, 12.3	N
Delete namespace (RMNDeleteNS)	9.2.2, 12.4	N
Rename namespace (RMNRename)	9.2.3, 9.4.6, 12.5	N
Copy recipe (RMNCopy)	9.4.5, 12.13	N
Upload recipe (RMNAction)	9.4.9, 12.15	N
Modify recipe variable parameters (RMNVarPar)	8.2.3.4, 12.16	N
Recipe synchronization	9.5	N

15.4.3 *Recipe Namespace Management Compliance Table* — Table 15.5 provides a statement of compliance for recipe namespace management.

Table 15.5 Recipe Namespace Management Compliance Table

RMS Recipe Namespace Management	*Compliance Statement*	
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Managed Recipe Object	❐ Yes ❐ No	
Recipe Namespace Object	❐ Yes ❐ No	❐ Yes[3]
Recipe Namespace Manager Object Basic Requirements	❐ Yes ❐ No	
OSS Services	❐ Yes ❐ No	❐ No
Create Recipe	❐ Yes ❐ No	
Update Recipe	❐ Yes ❐ No	
Verify Recipe	❐ Yes ❐ No	
Link Recipe	❐ Yes ❐ No	
Get Recipe Descriptor	❐ Yes ❐ No	
Get Available Space	❐ Yes ❐ No	
Check Recipe Status	❐ Yes ❐ No	
Get Best Version	❐ Yes ❐ No	
Store Recipe	❐ Yes ❐ No	
Download Recipe	❐ Yes ❐ No	
Retrieve Recipe	❐ Yes ❐ No	
Recipe Namespace Change Event	❐ Yes ❐ No	
Action Complete Notification	❐ Yes ❐ No	
Additional Capabilities	*Implemented*	*RMS Compliant[4]*
Upload Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Unlink Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Approve Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Protect Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Unprotect Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Certify Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Decertify Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Delete Namespace	❐ Yes ❐ No	❐ Yes ❐ No
Rename Namespace	❐ Yes ❐ No	❐ Yes ❐ No
Copy Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Upload Recipe	❐ Yes ❐ No	❐ Yes ❐ No
Modify Recipe Variable Parameters	❐ Yes ❐ No	❐ Yes ❐ No
Recipe Synchronization	❐ Yes ❐ No	❐ Yes ❐ No

3 Do not mark YES unless all fundamental RMS requirements are implemented.

4 Additional capabilities may not be marked RMS compliant unless all fundamental RMS requirements are implemented.

15.5 *Compliance for Distributed Recipe Namespace Management* — Compliance for distributed recipe management requires compliance to the following objects:

- *managed recipe*
- *recipe namespace*
- *distributed recipe namespace*
- *recipe namespace manager*
- *distributed recipe namespace manager*

15.5.1 *Distributed Recipe Namespace* — Table 15.6 describes the requirements for compliance for the *distributed recipe namespace*.

Table 15.6 Section References for Distributed Recipe Namespace Capabilities

Capability	*Reference*	*Fundamental*
Recipe namespace fundamental requirements	15.x, Table 15.x	Y
Basic requirements	5.11.3, Table 5.4	Y
OSS services	5.3.1, 10.1, 10.1.1.1–10.1.1.3	Y
Logical recipes	5.3.2	Y

15.5.2 *Distributed Recipe Namespace Manager* — Table 15.7 describes the requirements for compliance to the *distributed recipe namespace manager*.

Table 15.7 Section References for Distributed Recipe Namespace Manager Capabilities

Capability	*Reference*	*Fundamental*
Recipe namespace manager	15.x, Table 15.x	Y
Basic requirements	5.8, 5.8.1, 5.11.4, 10.3	Y
OSS services	10.3.1	
Attachment and detachment	10.3.3 (all)	Y
Attached segment read-only level	5.4.2	Y
Delete *distributed namespace*		Y
Change request management	10.3.4 (all)	Y
Segment change request (RMDSegChange)	10.3.5, 13.4.3	Y
Segment action complete (RMDComplete)	10.3.6?, 13.4.1	Y
Segment action complete (RMDNotify)	10.3.6?, 13.4.2	Y
Get change request (RMDGetChangeRequest)	10.3.8, 13.4.4	Y
Rebuild *distributed recipe namespace* (RMDRebuild)	5.10, 10.3.9, 13.4.5	Y

15.5.3 *Distributed Recipe Namespace Management Compliance Table* — Table 15.8 provides a statement of compliance for *distributed recipe namespace* management.

Table 15.8 Distributed Recipe Namespace Management Compliance Table

RMS Compliance Statement		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Managed Recipe Object	❐ Yes ❐ No	❐ Yes[5] ❐ No
Recipe Namespace Object	❐ Yes ❐ No	
Recipe Namespace Manager Object	❐ Yes ❐ No	
Distributed Recipe Namespace Object	❐ Yes ❐ No	
Distributed Recipe Namespace Manager Basic Requirements	❐ Yes ❐ No	
OSS services	❐ Yes ❐ No	
Attachment and detachment	❐ Yes ❐ No	
Attached segment read-only level	❐ Yes ❐ No	
Delete *distributed namespace*	❐ Yes ❐ No	
Change request management	❐ Yes ❐ No	
Segment change request	❐ Yes ❐ No	
Segment action complete	❐ Yes ❐ No	
Segment action complete	❐ Yes ❐ No	
Get change request	❐ Yes ❐ No	
Rebuild *distributed recipe namespace*	❐ Yes ❐ No	

[5] Do not mark YES unless all fundamental RMS requirements are implemented.

15.6 *Distributed Recipe Namespace Segment* — Table 15.9 describes the requirements for compliance to the distributed recipe namespace segment.

Table 15.9 Section References for Distributed Recipe Namespace Segment Capabilities

Capability	*Reference*	*Fundamental*
Fundamental compliance to *managed recipe*	15.2	
Basic requirements	5.4, 5.11.1 (Table 5.1), 10.1.2	Y
OSS services	5.3.1	Y
Change management	5.4.2, 5.9, 10.1.2.1	Y
Segment change approval (RMDSApproveAction)	10.1.2.2, 13.2.1	Y
Master segment	5.4.1, Table 5.2	N

15.6.1 *Distributed Recipe Namespace Segment Compliance Table* — Table 15.10 provides a statement of compliance for the distributed recipe namespace segment.

Table 15.10 Distributed Recipe Namespace Segment Compliance Table

RMS Compliance Statement		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Managed Recipe	❒ Yes ❒ No	❒ Yes[6] ❒ No
Basic Requirements	❒ Yes ❒ No	
OSS Services	❒ Yes ❒ No	
Change Management	❒ Yes ❒ No	
Segment Change Approval	❒ Yes ❒ No	
Additional Capabilities	*Implemented*	*RMS Compliant*[7]
Master Segment	❒ Yes ❒ No	❒ Yes ❒ No

[6] Do not mark YES unless all fundamental RMS requirements are implemented.

[7] Additional capabilities may not be marked RMS compliant unless all fundamental RMS requirements are implemented.

15.7 *Distributed Recipe Namespace Recorder* — Table 15.11 describes the requirements for compliance to the distributed recipe namespace recorder.

Table 15.11 Section References for Distributed Recipe Namespace Recorder Capabilities

Capability	*Reference*	*Fundamental*
Basic requirements	5.5, 5.11.2, Table 5.3	Y
OSS services	5.3.1, 10.2.1.1–10.2.1.3	Y
Add segment record (RMDRAddSegRecord)	10.2.2, 13.3.1	Y
Delete segment record (RMDRDelSegRecord)	10.2.3, 13.3.2	Y
Add change request record (RMDRAddChgRecord)	10.2.4, 13.3.3	Y
Delete change request record (RMDRDelChgRecord)	10.2.5, 13.3.4	Y
Get change request record (RMDRGetChgRecord)	10.2.6, 13.3.5	Y

15.7.1 *Distributed Recipe Namespace Recorder Compliance Table* — Table 15.12 provides a statement of compliance for the *distributed recipe namespace recorder*.

Table 15.12 Distributed Recipe Namespace Recorder Compliance Table

RMS Compliance Statement		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Basic Requirements	❒ Yes ❒ No	❒ Yes[8] ❒ No
OSS Services	❒ Yes ❒ No	
Add Segment Record	❒ Yes ❒ No	
Delete Segment Record	❒ Yes ❒ No	
Add Change Request Record	❒ Yes ❒ No	
Delete Change Request Record	❒ Yes ❒ No	
Get Change Request Record	❒ Yes ❒ No	

[8] Do not mark YES unless all fundamental RMS requirements are implemented.

15.8 *Execution Recipe Compliance* — This section defines RMS compliance for the execution recipe. An *execution recipe* exhibits RMS compliance (1) through its attributes and (2) through its structure when transferred.

Table 15.13 describes the requirements for compliance to the *execution recipe*.

Table 15.13 Section References for Execution Recipe Capabilities

Capability	*Reference*	*Fundamental*
Mandatory and required attributes	Table 6.1	Y
Recipe identifier (namespace, class, name, version)	6.3.3	Y
Preservation of designated downloaded attributes	6.3.5	Y
Change management (ChangedBody) (required if *recipe executor* can change recipes)	6.3.1, Table 6.1	Y
Recipe modification EditedBy	Table 6.1	N
Variable parameters (ExecLinkParam)	Table 6.1	N
Multi-part recipe (LinkList)	Table 6.1	N
Recipe compression (SrcRcpID)	Table 6.1	N
Verification signature (VerificationID)	Table 6.1, 11.2.2.2	N

15.8.1 *Execution Recipe Compliance Table* — Table 15.14 provides a statement of compliance for the *execution recipe*.

Table 15.14 Execution Recipe Compliance Table

RMS Compliance Statement		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Mandatory and required attributes	❒ Yes ❒ No	
Recipe identifier (namespace, class, name, version)	❒ Yes ❒ No	❒ Yes[9]
Preservation of designated downloaded attributes	❒ Yes ❒ No	
Change management	❒ Yes ❒ No	❒ No
Additional Capabilities	*Implemented*	*RMS Compliant*[10]
Recipe Modification	❒ Yes ❒ No	❒ Yes ❒ No
Variable Parameters	❒ Yes ❒ No	❒ Yes ❒ No
Multi-Part Recipe	❒ Yes ❒ No	❒ Yes ❒ No
Recipe Compression	❒ Yes ❒ No	❒ Yes ❒ No
Verification Signature	❒ Yes ❒ No	❒ Yes ❒ No

9 Do not mark YES unless all fundamental RMS requirements are implemented.

10 Additional capabilities may not be marked RMS compliant unless all fundamental RMS requirements are implemented.

15.9 *Recipe Executor* — Table 15.15 describes requirements for compliance for the *recipe executor*. The *recipe executor* exhibits RMS compliance through its attributes, behavior, and services.

Table 15.15 Section References for Recipe Executor Capabilities

Capability	*Reference*	*Fundamental*
Fundamental compliance to *execution recipe*	15.x	Y
OSS services for *execution recipe* attributes	11.1	Y
OSS services for *recipe executor* attributes	11.1	Y
Unique recipe identifier	6.6	Y
Protection of *recipe execution area*	6.5	Y
Change control	6.6, 11.2.10, 11.2.10.5	Y
Recipe download and vertify (RMEDnLdVer)	11.2.1, 14.3	Y
Recipe verify (RMEVerify)	11.2.2, 14.4	Y
Recipe rename (RMERename)	11.2.4, 14.6	Y
Get available storage (RMESpaceInquire)	11.2.5, 14.7	Y
Recipe delete (RMEDelete)	11.2.6, 14.8	Y
Recipe select (RMESelect)	11.2.7, 11.2.7.1, 11.2.7.6, 11.2.7.6.1, 14.9	Y
Recipe de-select	11.2.8, 14.10	Y
Recipe validation	11.2.7.2	Y
Variable parameters	11.2.7.4	Y
Recipe upload (RMEUpload)	11.2.3, 14.5	Y
Get recipe descriptor	11.2.9, 14.11	Y
Action completion notification	14.12	Y
Recipe delegation	11.2.7.3	N
Recipe creation	6.6.1, 11.2.10.2, 11.4	N
Recipe compression	6.6.2, 11.2.2.1, 11.2.10.3, 11.4	N
Recipe modification	6.6.3, 11.2.10.1, 11.4	N
Save last values	6.6.4, 11.2.10.4	N
SEMI E10 Productive state minimum approval (ProdApprove)	6.7, Table 6.2	N
SEMI E10 Productive state minimum certification (ProdCertify)	6.7, Table 6.2	N
Cycle units (RunCycleUnit)	Table 6.2	N
Variable parameters (RecipeSelectParameters)	Table 6.2	N
Change notification (RMEChange)	14.12	N

15.9.1 *Recipe Executor Compliance Table* — Table 15.16 provides a statement of compliance for the *recipe executor*.

Table 15.16 RMS Compliance Statement

RMS Compliance Statement		
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
RMS Compliant Execution Recipe	❒ Yes ❒ No	❒ Yes[11] ❒ No
Basic Requirements	❒ Yes ❒ No	
OSS Services for Execution Recipe	❒ Yes ❒ No	
OSS Services for Recipe Executor	❒ Yes ❒ No	
Unique Recipe Identifier	❒ Yes ❒ No	
Protection of Recipe Execution Area	❒ Yes ❒ No	
Change Control	❒ Yes ❒ No	
Recipe Download and Verify	❒ Yes ❒ No	
Fundamental RMS Requirements	*Implemented*	*RMS Compliant*
Recipe Verify	❒ Yes ❒ No	
Recipe Rename	❒ Yes ❒ No	
Get Available Storage	❒ Yes ❒ No	
Recipe Delete	❒ Yes ❒ No	
Recipe Select	❒ Yes ❒ No	
Recipe De-Select	❒ Yes ❒ No	
Recipe Validation	❒ Yes ❒ No	
Variable Parameters	❒ Yes ❒ No	
Recipe Upload	❒ Yes ❒ No	
Get Recipe Descriptors	❒ Yes ❒ No	
Action Complete Notification	❒ Yes ❒ No	
Additional Capabilities	*Implemented*	*RMS Compliant*[12]
Recipe Delegation	❒ Yes ❒ No	❒ Yes ❒ No
Recipe Creation	❒ Yes ❒ No	❒ Yes ❒ No
Recipe Compression	❒ Yes ❒ No	❒ Yes ❒ No
Recipe Modification	❒ Yes ❒ No	❒ Yes ❒ No
Save Last Values	❒ Yes ❒ No	❒ Yes ❒ No
SEMI E10 Productive State Minimum Approval	❒ Yes ❒ No	❒ Yes ❒ No
SEMI E10 Productive State Minimum Certification	❒ Yes ❒ No	❒ Yes ❒ No
Cycle Units	❒ Yes ❒ No	❒ Yes ❒ No
Change Notification	❒ Yes ❒ No	❒ Yes ❒ No

[11] Do not mark YES unless all fundamental RMS requirements are implemented.

[12] Additional capabilities may not be marked RMS compliant unless all fundamental RMS requirements are implemented.

16 Glossary of Terms

The list of terms in this section is intended only as a guide. Formal definitions are provided in the main body of the document.

agent — A type of *resource* system in a factory that includes both hardware and software components, at least some of which are also *resources*.

Examples of *agents* include recipe namespace servers, cells, stations, clusters, attached cluster modules, equipment, and smart equipment subsystems. *Agents* are associated with a physical system or a collection of physical systems, including computer platforms.

agent-specific attribute — A recipe attribute that applies only to a specific agent.

agent-specific parameter — A *variable parameter* that has been "tuned" for a specific *agent* by modifying its original initial value and/or restrictions and placing the result in the *agent-specific attribute* AgentSpecific LinkParam.

agent-specific recipe — A recipe stored in the *default namespace* of a specific *agent*.

agent-specific dataset — The recipe component containing the set of agent-specific attributes that have been set for that recipe for a specific *agent*.

approve — The operation that sets a recipe's ApprovalLevel attribute to a non-zero value.

approved — A recipe is *approved* whenever its ApprovalLevel attribute is non-zero.

approval level — (1) Used to reflect different degrees of recipe development and qualification; (2) The value of the attribute ApprovalLevel.

attribute — Information concerning an *object* that may be used either for internal or external purposes.

attribute length — The length of an individual attribute, calculated as the sum of the lengths of the *attribute name* and the *attribute value*, exclusive of formatting information.

attribute length attribute — An attribute that contains the sum of the lengths of the attributes. A *managed recipe, agent-specific dataset,* and *execution recipe* each have their own *attribute length* attribute.

attribute timestamp attribute — The *timestamp* of the last change to any of a recipe's attributes.

authorized user — A user who is able to identify him or herself to the host or equipment as having the level of authority required for a particular activity, such as *certifying* a recipe for that equipment.

body — See *recipe body*.

centralized namespace — A *recipe namespace* that is not distributed.

certification-level — The value of the attribute Certified.

certified — (1) Factory-level approval that a recipe produces the expected results on a particular instance of equipment; (2) A recipe for which the Certified attribute is defined and given a non-zero value for a specific *agent*.

certify — The operation of changing the *certification-level* of a recipe for an installation of equipment.

class — See *recipe class*.

clear — An attribute is *cleared* (reset) by setting its value to its *default value*.

component agent — A subordinate *agent* that provides services to a *supervisory agent*.

copy — Originate a recipe by the internal operation of duplicating a recipe and assigning a new *identifier*.

create — The operation of entering a recipe *body* into a *namespace* and assigning it a new (unused) *identifier*.

de-certify — The operation of *clearing* the *certification level* (Certified attribute) for a specific *agent*.

dedicated namespace — A *recipe namespace* with exactly one *member*.

default namespace — A *dedicated, centralized namespace* that is used by standalone equipment and/or for hardware-specific *(agent-specific)* recipes.

default value — A pre-defined value. All non-mandatory recipe attributes are assigned a *default value* as part of their definition. An attribute set to its *default value* may be omitted when a recipe is transferred.

delegate — An *agent's supervisor* **delegates** a recipe that is *executed* by its component *agent*. The *delegating agent* is responsible for ensuring that the *component* has access to a current copy of the recipe and that the recipe is *selected*, started, and *deselected* at the proper time.

delete — A recipe is *deleted* by removing its *identifier*, preventing further access, and freeing its storage.

derived object form — An *object form* of a recipe that is based upon a recipe in *source form* and that represents a more efficient format for execution purposes. Typically, but not by definition, this is a "tokenized" form and requires less storage.

descriptor — (1) The *length* and *timestamp* attributes of a recipe's attributes or of one of its components; (2) The set of all of the individual *descriptors* of a recipe.

deselect — The operation that **prevents a selected** recipe from subsequent execution without its first being *selected* again.

distributed recipe namespace — A namespace that is capable of using *namespace segments* provided by multiple *agents*.

download — To send a recipe to the *recipe executor*.

edit — An operation which *creates* a new recipe *body* or changes the *body* of an existing recipe.

editor — A service which allows a *user* to *create* or modify the contents of the recipe *body*. *Editors* are not defined by RMS and are generally considered as external to a *namespace*.

eol — The ASCII line-feed character ($0A_{16}$) signifying the end of a line of text.

empty — An attribute with a *binary*, list, or text format with no content.

end of line character — See *eol*.

equipment — An *agent* with associated hardware that provides, at a minimum, *recipe execution* services.

event — A detectable occurrence of interest to a *service user*.

exception — An irregular event that indicates some abnormal or unacceptable condition that requires attention but does not constitute a safety hazard. Within RMS, *exceptions* indicate the abnormal completion of an *operation*.

execute — An *agent* **executes** a recipe by reading the recipe contents and implementing its instructions, process parameters, or other information required for its own processing.

executing agent — The *agent* that is capable of *executing* a specific recipe.

execution area — The storage location of the recipe(s) currently *selected* (ready) for *execution*.

executable copy — A selected recipe, or “copy” of a selected recipe, which is in the *execution area*.

execution recipe — The subtype of recipe that is stored by the *recipe executor*.

execution recipe descriptor — Consists of the *execution attribute description*, the *generic attribute description*, and the *body descriptor*, in that order.

execution recipe storage — Storage for recipes provided by the *recipe executor* for recipes that are not currently *selected*.

external reference — (1) The reference which a recipe makes to another recipe; (2) The list of *subrecipes* referenced by a *parent* recipe.

forced overwrite — The replacement of an existing *execution recipe* with a *downloaded* recipe with the same *identifier*.

fundamental requirements — The requirements for information and behavior that must be satisfied for compliance to the Recipe Management Standard. *Fundamental requirements* apply to specific areas of application or objects.

generic attribute — A recipe *attribute* that applies to all *agents* capable of *executing* a specific recipe.

get available storage — The operation that calculates the amount of remaining recipe storage capacity, in bytes, exceeding overhead requirements.

header length — The sum of the lengths of the *attributes* the *header* contains at the time the calculation is performed.

host — A *supervisory agent* that represents the factory to its subordinates.

identification attribute — An attribute that is used to identify a specific object and that is not included in a recipe section when a recipe is transferred.

identification code — A text string containing a unique and persistent “signature” for the *recipe executor* that last performed verification on a recipe.

identifier — One or more attributes of an object that uniquely identify it within a specific context.

last value — The setting for a *variable parameter* specified by the *user* when the recipe was last *selected* for execution.

link — The operation performed on a main recipe that collects and resolves external references, and collects variable parameter definitions, for that recipe and all referenced recipes.

linked recipe set — The set of recipes identified by the *link* operation and specified by the attribute LinkList.

logical recipe — A recipe with a particular set of attributes and a particular *body* considered independently from its physical location. A *logical recipe* may have multiple instances or copies.

main recipe — (1) The recipe, within a set of one or more recipes to be *linked* together, which is not a *subrecipe*; (2) The starting recipe or “entry point” for a set of recipes.

managed recipe — A recipe that is stored with a *recipe namespace*.

mandatory attribute — A required attribute that always exists and has a *non-default value*.

modify variable parameters — An operation that modifies the *variable parameter definitions* applied to a specific agent.

name — A text-based attribute of an object that may be used as all or part of an identifier. Certain restrictions on its characters exist. (See SEMI E39.)

namespace — A domain within which object identifiers are unique. Also see *recipe namespace*.

namespace specifier — An object specifier applied to a *recipe namespace*.

non-numeric parameter — Any *variable parameter* that is not a *numeric parameter*.

non-shared namespace — A *recipe namespace* that has at most one *member*.

notification service — A *service* that does not expect a response.

numeric parameter — Any *variable parameters* that can take on any *numeric value* for their *format type*, between a *parameter low limit* and a *parameter high limit*. These *limits* shall not exceed absolute minimum and maximum limits set for that *parameter* by the *agent's* supplier.

numeric version — See *version number*.

object form — (1) Any recipe not in text form; (2) The *body* of a recipe which has been compressed from the *source form*. (See also the generic attribute BodyFormat.)

object specifier — A logical pointer to a remote object. See SEMI E39 (OSS).

operator — The user who interacts locally with *agent* through the *agent's* human interface.

originate — Any operation which produces a new recipe *identifier*, including *copying, renaming, creating, editing* a *read-only* recipe, and *downloading* a new version.

originating namespace — The *recipe namespace* from which an *execution recipe* was originally *downloaded* and/or to which it is to be *uploaded*.

parameter — A control value that affects the *agent's* process. Also see *variable parameter*.

parameter definition — A formal declaration of a *variable parameter* that specifies the *parameter's name*, *initial value*, and *restrictions*.

parameter domain — The set of all possible values for a given *form* that fulfill the conditions of the *parameter restriction* (if any).

parameter restriction — A required part of a *parameter definition* specifying one or more conditions that any *value* assigned to that *parameter* is required to satisfy to be valid.

parent recipe — Any recipe with *external references* to *subrecipes*.

primary class — A recipe *class* which is not a *subclass* of another *class*.

PROCESS class — The required *primary class* for all recipes used for the *agent's* normal process.

protect — The operation of changing the *approval level* of an individual recipe to that of the RecipeRead-OnlyLevel attribute of the *recipe namespace*.

read-only recipe — A recipe that is *protected*. A recipe with an *approval-level* greater than, or equal to, the value of the *namespace* attribute RecipeRead-OnlyLevel cannot be changed by *updating, deleting, renaming, unlinking,* or *re-linking*.

recipe — (1) The pre-planned and reusable portion of the set of instructions, *settings,* and parameters under control of the *agent* that determine the processing environment seen by the manufactured object and that may be subject to change between runs or processing cycles; (2) The aggregation composed of a *generic header*, zero or more *agent-specific headers*, and a recipe body.

recipe attribute — Structured information concerning a recipe within the recipe *header*.

recipe body — The contents of the recipe containing the data used for execution purposes.

recipe class — A formal grouping of recipes with a common language syntax and functionality.

managed recipe descriptor — Consists of the *generic attribute descriptor* and the *body descriptor*, followed by *descriptors* for any *agent-specific* datasets.

recipe execution area — Storage used for currently *selected* recipes (i.e., for the current process cycle).

recipe executor — The component of an *executing agent* responsible for understanding and *verifying* the syntax and semantics of a recipe, for *validating* it, and for *executing* it.

recipe identifier — Consists of the recipe's *class, name,* and *version*.

recipe name — A user-defined text string used in the recipe *identifier*. The *name* corresponds to PPID in Stream 7 implementations.

recipe namespace — A logical management domain for (1) the storage and management of recipes, and (2) the insurance of the uniqueness of recipe *identifiers* within that domain.

recipe namespace manager (manager) — The component of an *agent* that manages the *recipe namespace* and that represents the interface for the *namespace* to the external world.

recipe namespace segment (segment) — The component of a *namespace* that represents the internal storage and actual manipulation of recipes.

recipe section — A partition of the recipe for purposes of transferring it through an RMS service. All recipes have a section containing the *generic* attributes and a section containing the body. Some recipes also have a section containing the *agent-specific* attributes.

recipe specifier — An object specifier applied to a recipe.

recipe storage area — A storage area for recipes.

rename — The operation of assigning a new *identifier* to a recipe or to a *recipe namespace*.

request service — A *service* that requires a response.

SERVICE class — An optional *primary class* used for recipes whose purpose is to maintain, prepare, calibrate, or test the operation of *equipment*.

reset — See *clear*.

resource — An owned entity that has an active role in factory operations.

select — The act of preparing a recipe, or a linked recipe set, for execution. This includes confirmation that all specified *subrecipes* are available, that the attributes of the *main* recipe and all its referenced *recipes* meet *execution* requirements, that the recipes are *validated* as a set, and that all other steps that may be necessary for the proper *execution* of the recipe have been performed.

service — A **service** (or **message service**) represents a function offered to a user by a provider. A *service* is one of two types: a *request* or a *notification*.

service resource — A set of services within a particular area of specialization, such as a *recipe namespace resource* or a *recipe execution resource*.

setting — A static value accessible to the *user*, through one or more methods, that is used by *agent* to control its process. *Settings* include, but are not limited to, setpoint values. *Settings* typically may be specified within a recipe.

shared namespace — A *namespace* with more than one *member*.

source form — A recipe *body* which consists of one or more lines of text and which conforms to a formally defined recipe language.

storage area — An area where objects and data are stored. See also *recipe storage area*.

stored recipe attribute — An attribute of a recipe, a *recipe header*, or a *recipe body*, that is stored as a name/value pair within a recipe *header* whenever the recipe is transferred.

subclass — A *class* of recipes within a larger *class*.

subrecipe — Any recipe which is referenced by another recipe within the same *namespace*.

supervisory agent — An *agent* with supervisory responsibilities for one or more subordinate *agents*. Examples include a *host* manufacturing system and a cluster controller.

timestamp — (1) The notation of the date and time of the occurrence of an event; (2) An attribute of a *recipe header* or *recipe body* that contains the date and time the particular section was last changed. This attribute is a text string of the form "yyyymmddhhmmsscc" for the year yyyy, the month mm, the day dd, the hour hh, the minutes mm, and the seconds ss.

unlink — An operation that *clears* all attributes set by a *link* operation.

unprotect — An operation that resets a recipe's ApprovalLevel attribute. (Set it to zero.)

update — The operation of replacing the *body* of an existing recipe.

upload — To transfer a recipe body from the *recipe executor*.

user — A person interacting with an *agent* directly through the *agent's* human interface or indirectly through the *agent's supervisor*.

validate — The action of checking a recipe to ensure that the recipe and its parameters' type and range are valid for the *agent's* configuration at the time the recipe is *selected* for execution. [A recipe may be syntactically correct and yet may contain statements that cannot be executed under all configurations of the *agent*.]

variable parameter — A formally defined variable *(setting)* defined in the body of a recipe (1) With a specified default value, boundaries or conditions for replacement values, and (where applicable) units, and which is placed in the Parameters attribute of the recipe when it is *verified*; (2) Permitting the actual value to be supplied externally by a parent recipe, or at the time the recipe is selected for execution by the *supervisor* or the *operator*.

verification area — Optional temporary storage provided for unverified downloaded recipes.

verify — The operation of (1) ensuring that a recipe is syntactically correct, and (2) identifying *variable parameters* and *external references*.

version — A text string that is part of a recipe's *identifier*.

version number — A version consisting only of the digits “0” through “9” and one decimal point character “.” that can be translated to a pure number. Only whole numbers (with no decimal point) and numbers with a decimal point that do not begin or end with a “0” may be used.

whitespace — In ASCII, the space (20_{16}), tab (9_{16}), carriage return ($0D_{16}$), and form feed ($0C_{16}$) characters.

write-protect — See *protect*.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E42 and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information provided as background or examples of possible application and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

R1-1 RMS Standardized Objects

The *standardized objects* defined by RMS are shown in Table R1-1.

Table R1-1 Standardized Objects

Object Type	*ObjType*	*Section Reference*
Managed Recipe	MRcp	3.4.2.1
Agent-Specific Dataset	MRcpASDS	3.4.2.2
Execution Recipe	ERcp	3.5.4
Recipe Namespace	RNS	4.6
Recipe Namespace Manager	RNS_Mgr	4.6
Recipe Executor	RcpExec	6.8
Agent	Agent	7.3

R1-2 RMS Requirements/Concepts Map

Table R1-2 provides the specific RMS concepts that address each of the requirements from Table 2.1.

Table R1-2 RMS Requirements/Concepts Map

Requirement	*Concept*
Uniquely store, identify, and select recipes in a system.	Namespace
Share recipes among different agents.	
Synchronize the change of shared recipes among agents.	
Share recipes among different installations of the same type of *equipment* by adjusting individual differences.	
Ability to execute recipes with or without a communication link.	Default Namespace
Ability to change recipes managed by another agent when the communication link has failed or before it is established.	
Formal differentiation of, and recognition of, recipes of different types.	Recipe Class
Allow a recipe name to retain its base identity across a series of modifications.	Version Number
Allow shared recipes to be adjusted for individual pieces of *equipment*.	Variable Parameters
Allow a recipe's parameters to be adjusted within specified limits without requiring the recipe body to be changed.	
Support feedback/feed forward control.	
Ensure the recipe is syntactically correct.	Verification
Manage the approval level of specific recipes with respect to process development and production-worthiness.	Approval
Allow management of equipment qualified for specific recipes.	Certification
Change the recipe while it is running.	Protection of execution area from inadvertent change

R1-3 Background

The material in this section provides a context for the Recipe Management Standard and is intended for background information only.

In a complex environment, *equipment* and *host* become relative terms indicating roles of two independent *agents* with respect to each other. In general, both *equipment* and *host* may provide services to one another, and some services may be provided by both. In certain cases, one may provide services to its partner that the other does not. With respect to recipes, *equipment* refers to the recipe's executor, whereas *host* represents a *supervisory agent* who may *delegate* recipes which will be executed by the *equipment*.

For clusters, cells, and local-area stations, where a mid-level controller communicates both to lower-level *components* and to a higher level factory system, that controller may alternately take the role of *host* to its *components* and of *equipment* to the factory system.

Where role is significant, the terms *equipment* and *host* are used in this section to indicate the relationship of the two *agents* to one another.

R1-3.1 *Traceability* — A main management objective in both a Development Fab and a Production Fab is traceability of manufacturing conditions to the final device characteristics. This traceability is required in a Development Fab to support the analysis and characterization of the process under development. Certain customers of a Production Fab require this traceability in order to do business. Even without such a customer requirement, traceability is important for process control and postmortem analysis of unexpected device characteristics.

The recipe is the primary specification of manufacturing conditions to the *equipment*; therefore, the management of recipes is critical to this traceability.

R1-3.2 *Recipe Life Cycle* — The lifetime of a recipe in a Fab typically has several phases, as illustrated in Figure R1-1. While being developed, it may contain errors, or it may not produce the desired results. The recipe may be edited several times during its initial development. At some point, the recipe enters the test phase, where it will be executed and its results evaluated. A check for syntax correctness occurs at or before the time the equipment prepares it for execution. Still further changes may be made to fine-tune the process to achieve a particular result. During this process, it is still desirable to be able to protect it from inadvertent change or deletion. Finally, the recipe is ready for production and goes through a series of signoffs which constitutes a formal authorization procedure. In many factories, only recipes which have been approved as production-worthy may be used in production runs.

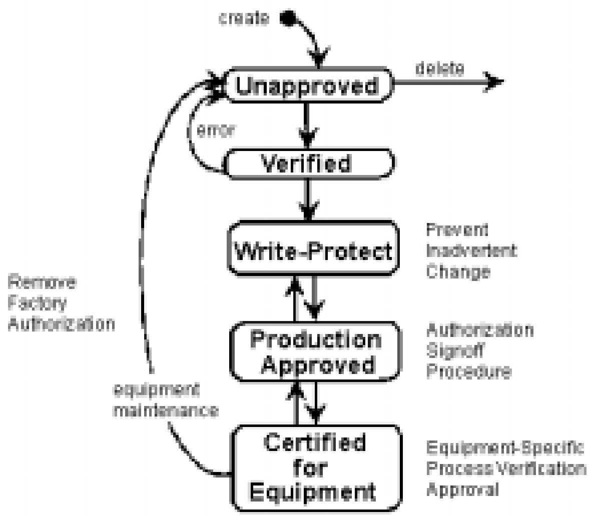

Figure R1-1
Typical Recipe Life Cycle

Also, because results may vary between different installations of *equipment*, an additional level of authorization may be required that certifies individual *equipment* for a given approved recipe.

A factory change control system must accommodate different levels of protection for recipes in different phases of their life cycle. To accomplish this, *equipment* must recognize and support the different requirements for each phase.

R1-3.3 *Recipe Editing* — Traditionally, recipes are developed on the *equipment* that runs them. Besides requiring time on the target machine (a potentially scarce and expensive resource), this requires the person defining the recipe to be inside a clean area. A potential solution is for *equipment* manufacturers to provide versions of their dedicated recipe editors that can be integrated into the factory manufacturing systems. Aside from the difficulty of the *equipment* manufacturer supporting the variety of platforms currently in use internationally, even in a distributed factory environment, a proliferation of different dedicated recipe editors required for the different types of *equipment* is not considered a good solution.

A better solution is to permit editing external to the cleanroom and then to transmit the completed recipe to the *equipment* for verification. This can be achieved by providing a text form of the *equipment* manufacturer's recipe language which can be created and modified with any standard text editor. This may not be possible with some types of recipes (e.g., pattern recognition programs for vision systems), but this restriction may be removed when the technology advances.

Editing on the *equipment* may still be desirable, particularly in a Development Fab. When the *equipment* permits a recipe to be changed, the *equipment* must provide reporting mechanisms that inform the *host* of changes and allow the *host's* change control system to operate.

R1-3.4 *Recipe Sharing* — A Fab may have several installation of the same type of equipment (equipment with the same functionality and the same recipe language). Therefore, where possible, the same recipe should be able to be shared between different equipment of this same type.

R1-3.5 *Protection and Process Control* — The primary goal of process control is to ensure that the final result of the manufacturing process does not change over time. This may be accomplished by both feedback and feedforward methods. These methods modify the settings used in the process. This requires two capabilities that seem to be in conflict:

- The definition of the process settings (the recipe) should not change.
- The process settings should change to counter the drift inherent in real processes.

The first capability is particularly important in a Production Fab. Most Fab policies prohibit processes from changing after they have been approved for production. This is easy to build into a change control system on the *host*. However, if the *equipment* allows local editing, then it must also enforce this policy.

Wholesale changes in a recipe are never necessary for the second purpose. Usually only a few parameter values are modified in small increments to effect control of the process. A well-defined process specifies the parameters that vary and their range of variation. For any given recipe, it must be possible for the *host* to specify different values of such parameters for each piece of *equipment* so that the recipe may be "tuned" for that *equipment* to produce uniform results. In addition, the process control *agent*, on the *equipment* or the *host*, may need the ability to calculate the parameter value changes for each run and to inform the *equipment* of the new values. Mechanisms are provided to support such interactions.

R1-3.6 *Recipe Selection* — Typical operation of *equipment* requires an *operator* or the *host* to initially *select* the recipe to be run. Recipe *selection* may be specified implicitly within the definition of a higher order "process job". In either case, the specification of a recipe is accomplished by referring to its recipe *identifier* (i.e., the *identifier* used by the change control system) and, where needed to resolve ambiguity, its location. Once *selected*, a recipe is initiated by an appropriate start command, which may be explicitly given by the *operator* or *host* or implicitly given by the *equipment* when executing a higher order process job. Repeated runs of the same recipe may be accomplished via subsequent start commands without the necessity of formal recipe re-selection.

R1-4 Example of a Factory Implementation of Approval Levels

A factory might implement different levels of approval by regulating the following levels of recipe *approval* on the equipment:

```
   Approval Level                                  FACTORY POLICY

   Level 0                                         "Unapproved"
   Level 1                                         "In Test"
   Level 2                                         "Non-Production"
   Level 3                                         "Ready for Release"
   Level 4                                         "Released for Production"
with
   RecipeReadOnlyLevel = 2                         Level 2 = read-only
```

R1-5 Examples of Variable Parameters

The recipe *body* may have statements that allow parameters to be changed within fixed limits. For example, recipe BAKE;2.3 may contain statements such as:

```
   Parameter BakeTime of TIME                      default = 200 seconds
                                                   minimum = 100 seconds
                                                   maximum = 300 seconds;
  or
   TIME BakeTime • (200,100,300,"s")                  /* default,min,max,units */
```

that define the process parameter "BakeTime", its *initial value* and *restrictions*. The BAKE;2.3 recipe may use the BakeTime *parameter* in further internal statements to determine the length of time a wafer is processed, such as:

```
      wait for TIME BakeTime;
```

This parameter may then be set by a *parent* recipe as in Example (1) below or from the EqpSpec_PARAM *attribute* (see 5.3.1.4) or with a "Select Recipe" command from the *host* or *operator*.

For example, a recipe "BAKE;2.3" may *define* a *variable* "BakeTime", while a recipe "RAMP;1,0" may *define* a *variable* "RampSetPoint". A *parent* recipe "XYZ" might contain *external references* in the text of the *source form* such as:

```
(1)    RUN RAMP;1                               // use default for RampSetPoint
       RUN BAKE;2.3 with BakeTime=10            // bake for 10 seconds
```

or

```
(2)    set RampSetPoint to 500;                 /* ramp up to 500 degC */
       do RAMP(RampSetPoint);
       set Baketime to 120;                     /* 120 sec (2 min.) bake */
       do BAKE;2.3(BakeTime);
```

or

```
(3)    RAMP(RampSetPoint:=500)
       BAKE;2.3(BakeTime:=Time_A)               /* 1st bake time may vary */
       RAMP(RampSetPoint:=650)
       BAKE;2.3(BakeTime:=Time_B)               /* 2nd bake time may vary*/
       RAMP(RampSetPoint:=800)
       BAKE;2.3(BakeTime:=Time_B+50)            /* 2nd bake plus 50 sec */
```

where "Time_A" and "Time_B" were both formally defined within XYZ.

In example (1), no *initial* value is specified for RampSetPoint. In this case, when the *main* recipe is selected, the *initial value* specified either in EqpSpec_LinkParam or in Gen_LinkParam (that is the same as the *definition* in RAMP;2.3) is used. However, in this example, the *parameter* BakeTime is assigned a value by the *parent* recipe, and this supersedes any *value* from a recipe *attribute* or a "Select Recipe" command from the *host* or *operator*. In the example given, BakeTime is assigned a value outside of the declared *domain*. This should create an error when the recipe is *verified*.

Examples (2) and (3) illustrate how *subrecipes* RAMP and BAKE may be referenced multiple times by a *parent* recipe, and the *parent* may provide different *values* with each reference (Example 2) or may *define* new *parameters* to use with different *references* (Example 3).

In the above examples, PARAMETERS (set when each individual recipe is *verified*) and Gen_LinkParam (set when XYZ is *linked*) will contain *parameter definitions* as follows:

Recipe	PARAMETERS	n_LinkParam
XYZ;0.8	Time_A	Time_A
	Time_B	Time_B
		RampSetPoint
		BakeTime
RAMP;1.0	RampSetPoint	undefined for *unlinked* recipe
BAKE;2.3	BakeTime	undefined for *unlinked* recipe

R1-6 Applications of Object Services

Object Services are defined in SEMI E39 (Object Services Standard (OSS): Concepts, Behavior, and Services). This section provides a description of how these services may be applied for RMS.

R1-6.1 *Scope* — Scope may be used to specify the *namespace* of interest. It may also be used to specify a *namespace* or *recipe execution resource* belonging to a *component agent* of the service provider. For example, scope allows a factory host to ask a cluster tool for the attributes of a cluster module.

Scope may be used to point to one of several namespaces supported by an agent.

R1-6.2 *Filter* — A filter may be used when asking a *namespace* for a list of recipe *identifiers* to limit the number of *identifiers* returned. For example, the service user may ask a *namespace* for a list of recipe *identifiers* that were edited by “Tom” (Attribute name = “EditedBy”, Attribute value = “Tom”, Attribute Relation = “is equal to”) and that are *linked* (Attribute name = “Linked”, Attribute value = “TRUE”, Attribute Relation = “is equal to”).

R1-6.3 *Complex Attributes* — Object Services do not provide a way to change individual elements in an attribute with a structure or list form. To add, delete, or modify items in a list or structure, it is necessary to first get the current attribute value for the object of interest using the GetAttr service, to make the desired changes externally to the value, and then to write the new value using the SetAttr service.

R1-7 Examples of RMS Application

Figure R1-2 illustrates possible interactions between a *namespace* and *namespace manager* implemented on a factory system, a diskless equipment with a *recipe executor*, and an *operator*.

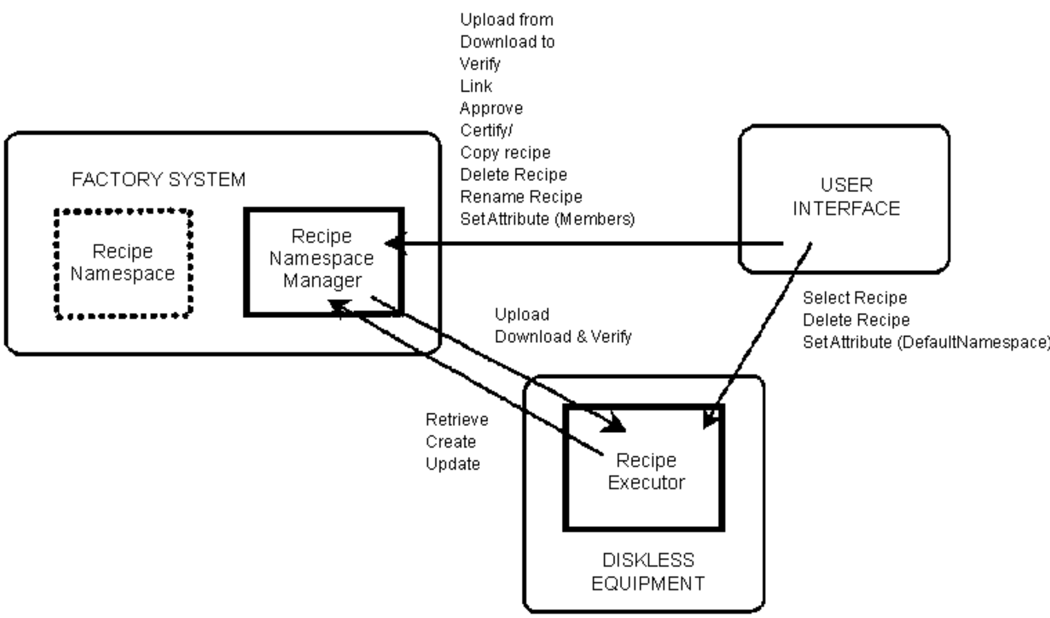

Figure R1-2
Example of RMS Applications

Other examples would be similar. Interactions are primarily with external service users of *namespace* and *recipe execution* capabilities, and between *namespace managers* and *recipe executors*.

Namespaces do not interact with one another. To copy a recipe from one *namespace* to another, an intermediary is required. This is not covered by RMS.

SEMI E42.1-0997
STANDARD FOR SECS-II PROTOCOL FOR RECIPE MANAGEMENT STANDARD (RMS)

1 Purpose

1.1 This document maps the services and data of the parent document to SECS-II streams and functions and data definitions.

2 Scope

2.1 This document applies to all implementations of Recipe Management that use the SECS-II message protocol (SEMI E5).

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

4 Terminology

None.

5 Service Mapping

5.1 Table 1 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the services defined in RMS.

5.2 Request and notification messages are mapped to primary (odd-numbered) SECS-II functions and response messages are mapped to secondary (even-numbered) SECS-II functions.

5.3 In several cases, a common set of parameters allows more than one RMS services to be mapped to a single stream and function, with an additional SECS-II data item used to differentiate between the two services. RMNCreateNS and RMNDeleteNS both map to S15,F3/F4, RMNCreate and RMNUpdate both map to S15,F13/14, and RMNCopy and RMNRename both map to S15,F19/20.

5.4 In addition, the notification messages RMNComplete, RMEComplete, RMEChange, RMDComplete, and RMDNotify all map to S6,F25/F26.

Table 1 Services Mapping Table

Message Name	*Stream, Function*	*SECS-II Name*
RMNCreateNS	S15,F3/F4	Recipe Namespace Action Request/Acknowledge
RMNDeleteNS	S15,F3/F4	Recipe Namespace Action Request/Acknowledge
RMNRenameNS	S15,F5/F6	Recipe Namespace Rename Request/Acknowledge
RMNSpaceInquire	S15,F7/F8	Recipe Space Request/Data
RMNRcpStatInquire	S15,F9/F10	Recipe Status Request/Data
RMNVersionInquire	S15,F11/F12	Recipe Version Request/Data
RMNCreate	S15,F13/F14	Recipe Create Request/Acknowledge
RMNUpdate	S15,F13/F14	Recipe Create Request/Acknowledge
RMNStore	S15,F15/F16	Recipe Store Request/Acknowledge
RMNRetrieve	S15,F17/F18	Recipe Retrieve Request/Data
RMNCopy	S15,F19/F20	Recipe Rename Request/Acknowledge
RMNRename	S15,F19/F20	Recipe Rename Request/Acknowledge
RMNAction	S15,F21/F22	Recipe Action Request/Acknowledge
RMNGetDescriptor	S15,F23/F24	Recipe Descriptor Request/Data
RMNVarPar	S15,F25/F26	Recipe Parameter Update Request/Acknowledge
RMNComplete	S6,F25	Notification Report Send
RMEDnldVer	S15,F27/F28	Recipe Download
RMEVerify	S15,F29/F30	Recipe Verify
RMEUpload	S15,F31/F32	Recipe Upload
RMESpaceInquire	S15,F7/F8	Recipe Space Request/Data
RMERename	S15,F19/F20	Recipe Rename Request/Acknowledge

Message Name	*Stream, Function*	*SECS-II Name*
RMEDelete	S15,F35/F36	Recipe Delete Request/Acknowledge
RMESelect	S15,F33/F34	Recipe Select Request/Acknowledge
RMEDeselect	S15,F35/F36	Recipe Deselect Request/Acknowledge
RMEGetDescriptor	S15,F23/F24	Recipe Descriptor Request/Data
RMNAction	S15,F21/F22	Recipe Action Request/Acknowledge
RMEChange	S6,F25	Notification Report Send
RMEComplete	S6,F25	Notification Report Send
RMDSApproveAction	S15,F37/F38	DRNS Segment Approve Action Request/Acknowledge
RMDRAdd SegRecord	S15,F39/F40	DRNS Recorder Segment Request/Acknowledge
RMDRDelSegRecord	S15,F39/F40	DRNS Recorder Segment Request/Acknowledge
RMDRAddChgRecord	S15,F41/F42	DRNS Recorder Modify Request/Acknowledge
RMDRDelChgRecord	S15,F41/F42	DRNS Recorder Modify Request/Acknowledge
RMDRGetChgRecord	S15,F43/F44	DRNS Get Change Request/Data
RMDGetChgRequest	S15,F43/F44	DRNS Get Change Request/Data
RMDSegChange	S15,F45/F46	DRNS Manager Segment Change Approval Request/Grant
RMDRebuild	S15,F47/F48	DRNS Manager Rebuild Request/Acknowledge
RMDComplete	S6,F25/F26	Notification Report Send
RMDNotify	S6,F25/F26	Notification Report Send

6 Service Parameter Mapping

6.1 Table 2 shows the mapping between message parameters defined by RMS and data items defined by SECS-II. For parameters specified in the definitions of an RMS service, either the parameters themselves, or individual elements of complex parameters, map to a specific data item.

Table 2 Service Parameters Item Mapping Table

Parameter Name	*SECS-II Data Item*
RMSectionsCode	RCPSECCODE
AgentSpec_DescLength	RCPDESCLTH
AgentSpec_DescName	RCPDESCNM = “ASDesc”
AgentSpec_DescTimestamp	RCPDESCTIME
AgentSpec_SectionName	RCPSECNM = “ASDS”
AttrData	RCPDESCLTH
AttrName	ATTRID
BodyData	RCPBODY
BodyDescLength	RCPDESCLTH
BodyDescName	RCPDESCNM = “BodyDesc”
BodyDescTimestamp	RCPDESCTIME
BodySectionName	RCPSECNM = “Body”
ErrorCode	ERRCODE
ErrorText	ERRTEXT
GenAttrSectionName	RCPSECNM = “Generic”
GenDescLength	RCPDESCLTH
GenDescTimestamp	RCPDESCTIME
LinkID	LINKID
NSAck	RMACK
RcpClass	RCPCLASS
RcpName	RCPNAME
RcpVersion	RCPVERS

Parameter Name	*SECS-II Data Item*
RMAction	RCPCMD
RMAgent	AGENT
RMChangeStatus	RMCHGSTAT
RMDestRecID	RCPNEWID
RMNewNS	RMNEWNS
RMNSSpec	RMNSSPEC
RMOpID	OPID
RMParamName	RCPPARNM
RMParamRule	RCPPARRULE
RMParamSetting	RCPPARVAL
RMRcpID	RCPID
RMRcpSpec	RCPSPEC
RMRcpStat	RCPSTAT
RMSectionsCode	RCPSECCODE
RMSpace	RMSPACE
RcpDerivedID	RCPID
REAck	RMACK
REAttrDescLength	RCPDESCLTH
REAttrDescName	RCPDESCNM = “REAttrDesc”
REAttrDescTimestamp	RCPDESCTIME
REAtrSectionName	RCPSECNM = “Attribute”
REChangeStatus	CHGCODE
REDerivedID	RCPID
REDestRcpID	RCPNEWID
REOpID	OPID
REWOCode	REOWCODE
REParamName	PARAMNAME
REParamSetting	PARAMVALUE
RERcpID	RCPID
RERcpSpec	RCPSPEC
RESpace	RMSPACE
RESpec	RESPEC
AttachToken	OBJTOKEN
RMChgType	RMCHGTYPE
RMManagerSpec	OBJSPEC
RMPermit	RMGRNT
RMRecorderSpec	OBJSPEC (S15,F43) and RMRECSPEC otherwise
RMRequestor	RMREQUESTOR
RMSegSpec	RMSEGSPEC
RMTimestamp	TIMESTAMP
TargetSpec	TARGETSPEC

6.2 There are also several data items that are used in the SECS-II messages which do not map to specific services parameters. Services with the same set of parameters are mapped to the same SECS-II message by adding an additional data item to differentiate between the services. In addition, SECS-II restrictions require multi-block primary messages to be preceded by a multi-block inquire/grant transaction defined within the same stream. For RMS messages, this requirement is satisfied with the S15,F1 and F2 messages. Data items defined for these two messages have no counterpart in RMS service parameters.

6.3 Table 3 contains the SECS-II data items that have no corresponding RMS service parameter:

Table 3 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
Used to satisfy SECS-II conventions for linking a multi-block inquiry with a subsequent multi-block message.	DATAID
Used for the name of any *non-identifier* recipe attribute.	RCPATTRID
Used for the value of any *non-identifier* recipe attribute.	RCPATTRDATA
Used by S15,F19 to differentiate between RMNCopy and RMNRename services.	RCPRENAME
Used to satisfy SECS-II multi-block requirements.	RMGRNT
Used by S15,F3 to differentiate between RMNCreateNS and RMNDeleteNS services. Used by S15,F39 to differentiate between RMDRAddSegRecord and RMDRDelSegRecord. Used by S15,F41 to differentiate between RMDRAddChgRecord and RMDRDelChgRecord.	RMNSCMD
Used to satisfy SECS-II multi-block requirements. Neither required nor specified by RMS.	RMDATASIZE
Used by S15,F13 to differentiate between RMNCreate and RMNUpdate services.	RCPUPDT
Used by S15,F35 to differentiate between RMEDelete and RMEDeselect services.	RCPDEL
Used by S15,Fy to differentiate between A and B services.	RCPDEL

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E42.1 and is not intended to modify or supercede the official standard. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 RMS-Compliant Equipment with a Stream 7 Host

Semiconductor manufacturers with legacy systems, capable of communicating using Stream 7 messages only, may still take advantage of many of the Recipe Management concepts when used with equipment that is Recipe Management-compliant. This section contains guidelines and examples for maintaining recipe attributes within the body of a Stream 7 process program.

R1-1.1 *Recipe Identifier* — Both the process program identifier PPID and the object identifier, including the recipe identifier, have a maximum length of 80 characters. Recipe class, name, and version number may be encoded into the data item PPID using the format required for the recipe identifier.

"/$CLASS_1$/$CLASS_2$/.../$CLASS_n$/NAME;VERSION"

It is recommended that recipe class names be unique, allowing use of the form

"/CLASS/NAME;VERSION"

to ensure the length conforms to the maximum allowed in SECS-II.

R1-1.2 *Recipe Sections* — All sections of the recipe are transferred together as the data item PPBODY. This allows all non-default values of recipe attributes to be preserved when a recipe is uploaded to the host and later downloaded back to equipment.

There are two potential methods for formatting PPBODY. If the recipe body is a text file, it is recommended that all attribute values are translated into text, including numeric and boolean values, with boolean values represented by the strings ".T." or ".F.". The second recommended method, applicable to both source and object forms, uses the structure of one of the SECS-II messages containing the managed recipe, as illustrated in Figure 1, or of an execution recipe. A cluster tool supporting shared *namespaces*, for example, might require multiple agent-specific data sets, while single-process equipment types would not.

R1-1.2.1 *Structuring PPBODY Using Text* — For purposes of transfer, recipes are regarded as composed of sections: The generic section, the body section, and zero or more agent-specific data-set sections (RMS, Section 12.1). This convention should also be maintained within PPBODY. The SECS-II messages used to transfer recipes (Stream 15, Functions 15 and 18) transfer the data-set sections last, because they are variable in number and are not always present. However, in a text format within PPBODY, it is generally easier to put all attributes before the body.

Since RMS uses the end-of-line character for source form recipes, this convention is recommended to separate the logical components of the sections containing attributes as well. A few reserved keywords are sufficient as tags to identify significant components: SECTION, ATTRIBUTE, LIST, PARAMNAME, PARAMSETTING, and PARAMRULE are recommended for consistency. Keywords are in uppercase for visual impact and are not delimited except for use of whitespace and the line-feed character ($0A_{16}$) used as the end-of-line (eol) character.

Whitespace is used to separate fields within a line. The symbol ⎵ is used here to represent whitespace, which is used both as a delimiter to separate fields within a line and also for optional visual effect.

Each section begins with a section declaration of the form

SECTION⎵"text"(eol)

where text is a section name, one of "Generic", "ASDS", "Body". Two sections are separated with two eol characters together. The eol convention within the body section, however, must conform to the recipe language specifications provided by the equipment manufacturer.

Each attribute begins with

ATTRIBUTE⎵AttributeName

followed by the attribute value, which may be a single item, a list of single items, or a list of complex items, such as variable parameters. If a list, the keyword LIST precedes the values, each item in the list terminated with either a comma or, for the last item, the eol character.

This becomes

ATTRIBUTE␣AttributeName␣ “text”(eol)   (single-value attributes)

or

ATTRIBUTE␣AttributeName␣LIST␣“text”, ␣“text”,...(eol)

for attributes consisting of lists of single items (e.g., LinkList or ExtRef).

If the keyword LIST if followed by eol, this indicates a list of complex items. The eol character, in this case, also is used to terminate the individual items in the high-order list. An attribute consisting of a list of complex items should identify the individual fields of each complex item. Those attributes containing variable parameters (e.g., Parameters) are of the form

ATTRIBUTE␣AttributeName␣LIST(eol)

␣PARAMNAME␣“text”, ␣PARAMSETTING␣“text”, ␣PARAMRULE␣“text”(eol)
␣PARAMNAME␣“text”, ␣PARAMSETTING␣“text”, ␣PARAMRULE␣“text”(eol)

...

␣PARAMNAME␣“text”, ␣PARAMSETTING␣“text”, ␣PARAMRULE␣“text”(eol)

Each individual field within a complex attribute value is delimited with the quotation mark (“) character. The eol character is used to terminate a section declaration, an attribute declaration, and a complex item within an attribute.

The recipe body is preceded with

SECTION “Body”(eol)

followed by the recipe body in the form normally used by the equipment.

In comparison of the two suggested formats, the advantage of the text form described in this section is that the attributes are human-readable and printable and therefore the user is able to modify those attributes that are not designated as read-only with a standard text editor.

The advantage of the SECS-II form (Figure 1) is that the equipment is more easily able to support a host that is only capable of using Stream 7.

R1-2 RMS-Compliant Recipe Management with Stream 7 Equipment

For RMS-Compliant Recipe Management applications dealing with legacy Stream 7 equipment, the situation is more restricted. While an RMS-compliant equipment may preserve attributes by bundling them inside the PPBODY of a process program, this option is not available when the situation is reversed because the equipment determines the permissible format(s) within the recipe. Therefore, all attributes of the recipe must be completely maintained by the host. The host in this situation may provide a recipe namespace that is dedicated either to an individual equipment installation, to a group of equipment capable of sharing the same process programs, or both.

If the equipment is compliant to Process Program Management as defined in SEMI E30 (GEM), then it will provide a collection event when the process program is created, changed, or deleted. Hosts that provide a dedicated recipe namespace for non-RMS equipment are able to use this event to trigger a process program upload and update the corresponding recipe.

Most Stream 7 equipment use only a single type of process program. This defaults to the recipe class PROCESS. The equipment is unaware of the internal fields used by the recipe identifier. If it preserves the contents of PPID and does not impose its own restrictions, it may be desirable to use the format of the recipe identifier, in particular the version component. This would allow version control at the host.

Some equipment maintains more than one type of process program and may distinguish between the different types either through providing additional Stream 7 messages, through naming conventions such as a ".ext" extension, through program length, or other devices.

Downloading a process program in Stream 7 is equivalent to both the operation of "sending" a recipe to a different namespace (at the equipment) and to downloading a recipe to the recipe executor for execution.

R1-2.1 *Structuring PPBODY Using SECS-II Message Format* — The second method of sending attributes within PPBODY is to use a SECS-II message structure that is used to send and receive recipes. Figure 1 illustrates using the structure of a managed recipe form S15,F13 and F16.

Note that cluster tools may provide full recipe namespace capabilities for its modules, including shared namespaces for modules of a specific type. In this case, a cluster recipe may contain multiple agent-specific datasets (m > 1). Other equipment may be able to use the structure for the *execution recipe*.

```
L,q                                    (q = 1,2,3)
  1. L,r                               (r = 0 or 2)
       1. <RCPSECNM>
       2. L,g                          (g = # generic attributes)
            1. L,2
                 1. <RCPATTRID1>
                 2. <RCPATTRDATA1>
            .
            .
            a. L,2
                 1. <RCPATTRIDg>
                 2. <RCPATTRDATAg>
  2. <RCPBODY>
  3. L,m                               (m = # agent-specific datasets)
       1. L,2
            1. <RCPSECNM1>
            2. L,b
                 1. L,2
                      1. <RCPATTRID11>
                      2. <RCPATTRDATA11>
                 .
                 .
                 b. L,2
                      1. <RCPATTRID1b>
                      2. <RCPATTRDATA1b>
       .
       .
       m. L,2
            1. <RCPSECNMm>
            2. L,c
                 1. L,2
                      1. <RCPATTRIDm1>
                      2. <RCPATTRDATAm1>
                 .
                 .
                 c. L,2
                      1. <RCPATTRIDmc>
                      2. <RCPATTRDATAmc>
```

Figure 1
SECS-II Format for PPBODY

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E53-1296
EVENT REPORTING

1 Purpose

Access to process data in equipment is crucial for effective process monitoring and control in a semiconductor manufacturing facility. This standard addresses the communication needs of semiconductor equipment and other factory objects, such as cell controllers or recipe servers, with respect to the timely collection and reporting of such data.

The purpose of this standard is to provide a general purpose set of event reporting services that may be offered by equipment suppliers. This document may be referenced, in whole or in part, by other standards addressing higher level application domains.

The communications services defined here will enable standards based inter-operability of independent systems. They shall allow application software to be developed which can assume the existence of these services and allow software products to be developed which offer them.

2 Scope

This standard is applicable to any stand-alone equipment, cluster module, cluster tool, or cell of automation in a factory. As such it addresses event reporting at all levels in the factory and equipment control hierarchy.

This standard requires significant communication and computational resources and is therefore not applicable at or below the level of I/O distribution (e.g., sensor bus) within the equipment.

This standard covers the reporting of data periodically and/or in response to events. Reports may also be requested on demand.

This standard presents a solution from the concepts and behavior down to the messaging services. It does not define the messaging protocol.

A messaging service includes the identification that a message shall be exchanged and definition of the data which is contained in that message. It does not include information on the structure of the message, how the data is represented within the message, or how the message is exchanged. This additional information is contained with the message protocol. The defined services may be applied to multiple protocols. Information on the mapping of these services to special protocols (e.g., SECS II) are added as adjunct standards.

The services assume a communications environment in which a reliable connection has been established between the user and the provider of the services. Establishing, maintaining, and releasing a connection is beyond the scope of this standard.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS II)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E38 — Cluster Tool Module Communications (CTMC)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E40 — Standard for Processing Management

4 Terminology

4.1 The following definitions are arranged in alphabetical order. Some terms are defined using terms defined elsewhere within this section. Other terms may be defined within SEMI's Compilation of Terms.

4.1.1 *attribute* — a data item associated with an object. An attribute may be referenced by zero or more data reports.

4.1.2 *behavior* — the manner in which something functions; how an object acts and reacts, in terms of its state changes and message passing.

4.1.3 *collection event* — an event that may be used to initiate the collection and reporting of data. A collection event may trigger an event report. A collection event may also start or stop one or more trace reports.

4.1.4 *data report* — a data report is a list of attribute names for a single object. Data reports may be pre-defined by a factory object or defined dynamically by the service user.

4.1.5 *default object* — the object assumed when no object specifier is supplied.

4.1.6 *event* — represents the occurrence of a change in the condition of a system (e.g., lot complete, temperature over range).

4.1.7 *event report* — a class of objects that has information related to an event and can be linked to user defined data reports and can send messages containing this information to a service user.

4.1.8 *factory object* — any identifiable object within the factory information and control architecture. Examples include equipment, a cluster process module, a cell controller, a recipe namespace server.

4.1.9 *object* — defined in the Object Services (SEMI E39).

4.1.10 *object specifier* — defined in the Object Services (SEMI E39).

4.1.11 *services* — a set of closely related messages.

4.1.12 *service provider* — a service provider is an application responsible for providing services to service users.

NOTE 1: There may be one or more service users concurrently accessing a single service provider. It is the responsibility of the service provider to provide its services transparently to each service user.

4.1.13 *service user* — a service user is any application that uses the services.

4.1.14 *trace report* — a class of objects which provides to a service user a means for collecting periodic readings of selected attributes of a system.

4.2 *Data Types*

4.2.1 *form* — type of data: float, positive integer, unsigned integer, integer, enumerated, boolean, text, formatted text, structure, list, ordered list.

4.2.2 *float* — a number represented by a mantissa and an exponent. It is used to represent numeric data which is continuous in value.

4.2.3 *positive integer* — May take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.2.4 *unsigned integer* — May take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

4.2.5 *integer* — May take the value of any negative or unsigned number. Messaging protocol may impose a limit on the range of possible values.

4.2.6 *enumerated* — May take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.2.7 *boolean* — May take on one of two possible values; TRUE or FALSE.

4.2.8 *Text* — A text string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.2.9 *formatted text* — a text string with an imposed format. This could be by position, by use of special characters, or both.

4.2.10 *structure* — a complex structure consisting of a specific set of items, of possibly mixed data types, in a specific arrangement.

4.2.11 *list* — set of one or more items that are all of the same form (one of the above forms).

4.2.12 *ordered list* — s list for which the order in which the items appear is significant.

5 Conventions

5.1 *Harel State Model* — This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an appendix of SEMI E30. The formal definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems," by D. Harel, 1987.

Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition contains columns for transition #, current state, trigger, new state, action(s). The "trigger" (column 3) for the transition occurs while in the "current" state. The "actions" (column 5) include a combination of; 1) actions taken upon exit of the current state, 2) actions taken upon entry of the new state, and 3) actions taken which are most closely associated with the transition. No differentiation is made.

5.2 *OMT Object Information Model* — The object models are presented using the Object Modeling Technique developed by Rumbaugh, James, et al, in "Object-Oriented Modeling and Design," Prentice Hall, Englewood Cliffs, NJ, ©1991. Overviews of this notation are provided in an appendix of the Object Services SEMI E39.

5.3 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute	*Definition*	*Rqmt*	*Access*	*Form*
The formal text name of the attribute	Description of the information contained	Y or N	RO or RW	(see below)

The access column uses RO (read only) or RW (read and write) to indicate the access that users of object services have to the attribute.

A ‘Y’ or ‘N’ in the requirement (rqmt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

The form column is used to indicates the format of the attribute. See Section 4.2 for definitions.

5.4 *Service Message Representation*

5.4.1 *Service Resource Definition* — The service resource definition table defines the specific set of messages for a given service group, as shown in the following table:

Service	*Type*	*Description*
Message name	N or R	The intent of the service

Type can be either notification (N) or request (R). Notification messages are initiated by the service provider. No response is expected. Request messages are initiated by the service user. Request messages ask for data or for an operation to be performed. Request messages expect a specific response (no presumption on the message content).

5.4.2 *Service Parameter Dictionary* — Each parameter should relate to either attributes from the object model or events of the dynamic model (Harel State Chart). All parameters to the services are listed in a single table or dictionary. The column headings for this parameter dictionary are as follows:

Parameter	*Description*	*Form*
Parameter X	Data type	A parameter

A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and the contents of the parameter.

The description column describes the meaning of the parameter and interrelationships with other parameters.

The form column is used to indicate the type of data contained in the parameter (see Section 4.2 for definitions) and the possible values it may take on.

To prevent definition of numerous parameters named “XxxList,” this document adopts the convention of referring to the list as “(list of) Xxx.” In this case, the definition of the parameter “Xxx” will be given, not of the list. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

5.4.3 *Service Message Definition* — There is a table for each service showing the parameter detail. The column headings for the service detail are as follows:

Parameter	*Req/ Ind*	*Rsp/ Cnf*	*Comment*
Parameter X	(see below)	(see below)	A description of the service

The columns labeled req/ind and rsp/cnf link the parameters to the direction of the message. The message sent by the initiator is called the “request” (req). The receiver terms the message the “indication” (ind). The receiver may then send a “response” (rsp), which the original sender terms the “confirmation” (cnf).

The request (req/ind) and response (rsp/cnf) entries can take on the following values:

“M”	**Mandatory parameter** — Must be given a valid value.
“C”	**Conditional parameter** — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of another parameter.
“U”	**User-defined parameter**
“-”	The parameter is not used.
“=”	The entries M and C in the response can be modified with (=) to indicate that the value in the response must match the request.

6 Overview

Event reporting provides a dynamic and flexible means by which the service user can receive notification of events and data relating to objects defined here and in other SEMI standards.

Figure 1 illustrates a simple event reporting situation.

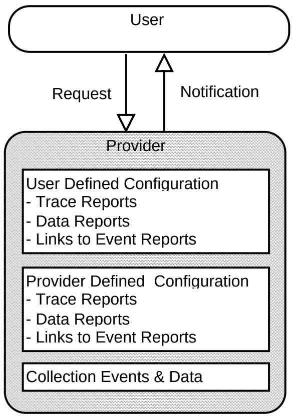

Figure 1
Simple Event Reporting

Event and variable identifiers may be defined by another standard with which equipment or an object complies. In either case, the definitions must be included in the documentation from the supplier.

The service user may define and access data reports using the event reporting request services. Data reports are sampled and sent by the service provider using the event reporting notification services.

Data reports may be pre-defined by the supplier. Such reports cannot be deleted and their report identifiers may not be used for dynamically created reports.

6.1 *Multiple Service Users* — In a more complex situation, several service users may require simultaneous access to the event reporting services (ERS). In this case, the service provider manages data report definitions independently for each service user as shown in Figure 2. A copy of each pre-defined report is made for each service user. Support for more than one simultaneous service user is optional.

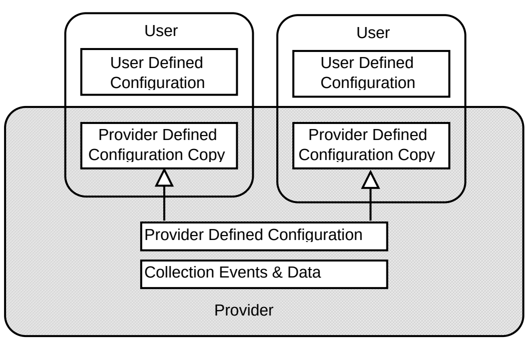

Figure 2
Multiple Service Users

6.2 *Using Object Services* — An event reporting service user can create reports dynamically by accessing attribute information using the object services (see SEMI E39) when they are provided (see Figure 3).

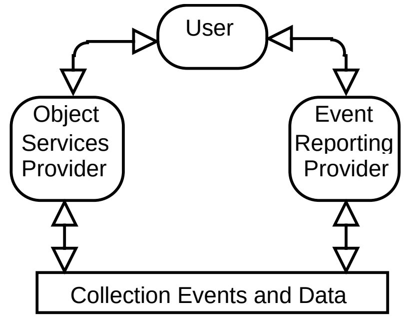

Figure 3
Using Object Services

7 Concepts

7.1 *Objects and Identifiers* — Much of the discussion and specification for event reporting services relies on an understanding of object technology and modeling techniques. The use of object technology for ERS implementations is not required. Further, it is not required that ERS implementations be compliant to the Object Services Standard (OSS). This standard does specifiy mechanisms by which ERS can take advantage of OSS when those services are provided.

Events are associated with an object and data is stored in object attributes. To uniquely identify an event or an attribute the object to which it relates must first be identified.

An object may be a physical entity such as stand-alone process equipment, a cluster tool or a cluster module. An object may be an abstraction such as a recipe, a process job or a transfer job. An object may be defined by the equipment supplier, or by a standard with which the equipment complies. An example of a cluster tool, containing process modules, is used in this section as the service provider. This example is for illustration purposes only. The same concepts apply for all factory objects as defined above.

Objects may be part of an object hierarchy or contained in other objects. The default object is the object which provides the service connection. In the case for batch processing equipment which is compliant to GEM, SEMI E30, the connection to the host is provided by the equipment and the equipment is the default object. Also, a cluster controller would be the default object of equipment containing process modules. However, from the point of view of the cluster controller, each connection to the service providers in each connected module would be the default object. For example, the processing management service of PM:ETCH would be a default object for that module connection. But, the cluster controller would have differernt default objects on each of its other service connections.

An object specifier, (see SEMI E39), identifies an object within the scope of the service provider. An object specifier consists of one or more object type and object instance identifier pairs. For example, “PM:ETCH>” might be the object specifier of a process module (type=PM, identifier=ETCH) within a cluster tool. If the object specifier is omitted, then the default object is assumed.

Objects are considered local to the service provider even if they exist on a remote module. That means the service provider is responsible for detecting events and accessing data from those objects in a timely manner, by whatever means, to provide the specified services.

Equipment which implements OSS-compliant event reporting services allows the service user to reference equipment components by an object specifier; for example, “PM:ETCH>MFC:CCL4.”

7.2 *Event Report Object Model* — Figure 4 shows the objects, attributes (variables), and relationships involved in event reporting. The notation used is defined in Section 5. The diagram illustrates the relationships between the service’s messages and attributes (variables). The objects and their attributes are defined Section 8. Only the trace, data report, collection event, and data source objects’ attributes and behaviors are standardized in that section. Note that this model presents a view of event reporting services from the perspective a single user. It is optional for the service provider to support simultaneous access from multiple service users. But for that option the provider shall present this view to each user independently.

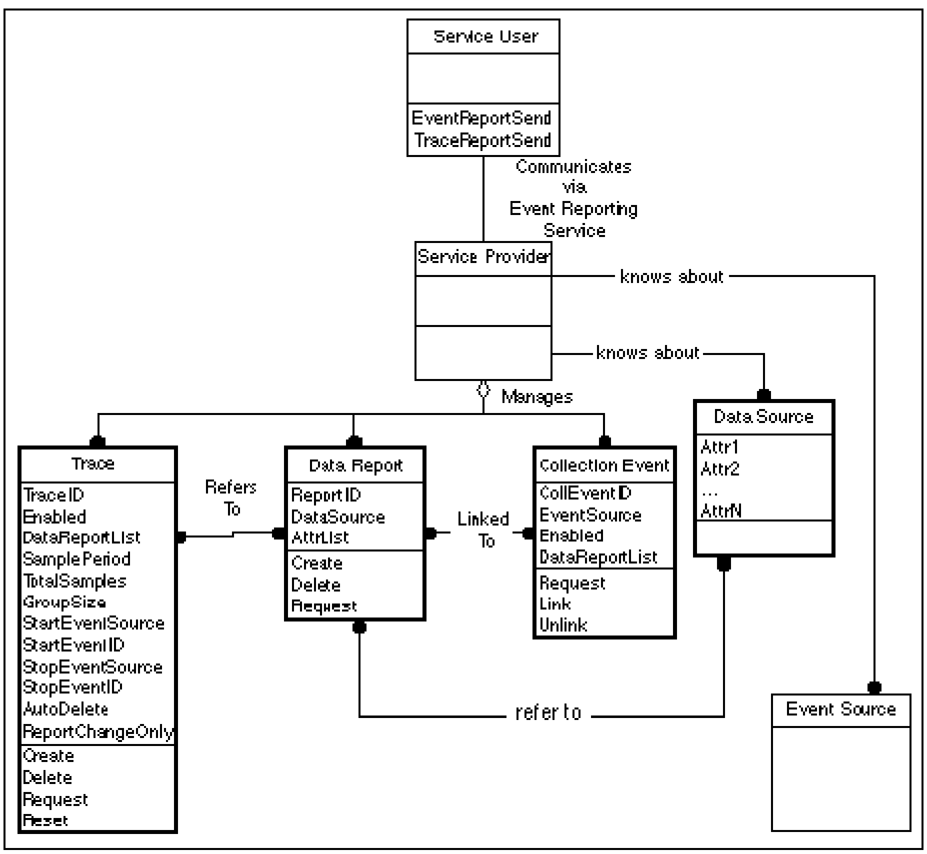

Figure 4
Event Report Object Model

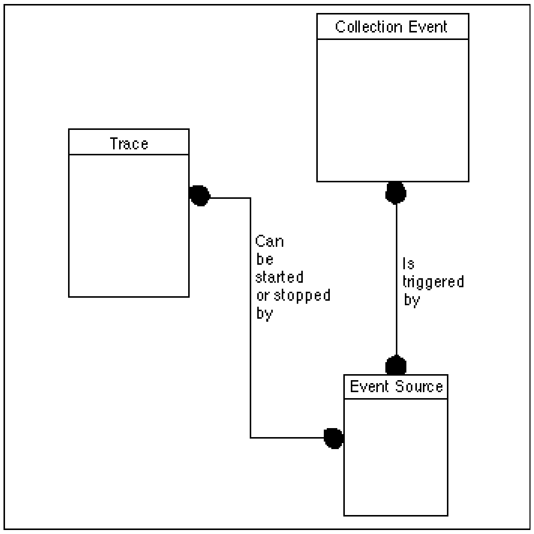

Figure 5
Trace Object Information Model

7.2.1 *Service Provider Object* — The service provider is responsible for compiling report samples according to each service user setup. It detects collection events, provides trace timing and accesses the value of data source object attributes (variables) in order to compile the data reports. ERS does not specify the attributes or behavior of this object. It is included in the event report object model to provide context for other objects within ERS.

7.2.2 *Service User Object* — The service user is responsible for configuring its own event reporting setup and receives reports from the service provider according to that setup. ERS does not specify the attributes or behavior of this object. It is included in the event report object model to provide context for other objects within ERS. However, the service user object shall be able to receive the event report send and trace report send messages from the service provider.

7.2.3 *Collection Event Object* — This object type or class is responsible to provide all the collection event identifiers for which event reports can be generated. Other factory services and objects may provide event notification messages which are important in the context of a service or functionality that they provide. But, in general, these notifications do not provide mechanisms to report information beyond their domain boundaries. For example, Processing Management, SEMI E40, includes an event notification for process complete (PRJobAlert (Milestone)). In order to collect data associated with this event, it must be "known" to the collection event object type. When it is "known" by the collection event object, then event reports can be generated using data or attributes from the data sources which are "known" by the event reporting service provider. A data source could provide information on process chamber pressure and temperature, which are attributes or variables important to the process but which are not known to the processing management service.

7.2.4 *Event and Data Source Objects* — The use of the event source and data source objects provides extensive capability to access the attributes of objects in a distributed environment. Where the event services provider has a domain which extends over multiple resources, such as a cell controller for a furnace bay or a cluster tool controller, these objects provide an unambiguous mechanism for addressing the data that the service user wishes to access.

The event and data source objects are to the event reporting services what directory object is in a file system of a computer's operating system. They should be thought of as containers of information which provide pointers (or names) of objects that are the actual sources of events or data.

The event source object is not directly accessible to the service user. Knowledge of events and event sources can be accumulated by interrogation of the collection event object using OSS.

Collection event identifiers shall be determined by either of two possible methods. One, the equipment supplier may define and supply with the equipment a list of collection event IDs (identifiers). Two, the equipment's collection event object can be interrogated with object services requests for collection event sources and identifiers. For example, using the second method, one could use object services to ask the collection event object for a list of collection event sources, which might include objects such as "PM:Etch>MFC:CCL4" or "TM>Aligner." Then using OSS, the collection event object can be queried for events associated with these sources. For the MFC a list of events might include "preslow," "overlimit," "valvemax," etc..

7.2.5 *Data Report Object* — A data report defines the variables (or attributes) of a specific object (data source) which are to be sampled. Data reports are either pre-defined or defined dynamically by the service user. A data report sample is a set of data containing the values of the variables defined for the data report. To sample a data report means that the current values of the variables at their data source object should be recorded. Data reports may be sampled and sent either with an event report and/or with a trace report. The service user may request:

- To sample an individual data report.
- Create a data report.

- Delete a data report.

7.2.6 *Event Report* — Event reports may be sent as messages to the service user whenever the associated collection event occurs. The collection event object is the source of the event report message. Event reporting is initially disabled. If the data to be sent with an event report has more than one data source, then there must be at least one data report for each data source to be included in the event report link definition. The service user may request:

- Event reporting to be enabled.
- Event reporting to be disabled.
- One or more data reports to be to linked (included in) the event report.

7.2.7 *Trace Report* — Trace reports are messages which are sent to the service user periodically. The trace report will contain the value(s) of the data item(s) specified in the data report(s) referred to by the trace object which is the source of the trace report.

The trace object contains the description of what to include in the trace report and trace objects are either pre-defined or defined dynamically by the service user. The service user may request:

- Trace reporting to be enabled.
- Trace reporting to be disabled.
- One or more trace reports to be reset at any time to their initial state.
- One or more trace reports to be deleted at any time.

When the enabled attribute of the trace object is set, then trace reporting may be started or in response to a start event. When the trace reporting starts, the sample count is reset to zero. A trace report may be stopped when a certain number of samples have been reported or when a stop event occurs.

The service user may specify a trace object to be automatically deleted once it has been stopped by whichever mechanism. Otherwise, the trace reporting simply stops. If no start event is defined, then the trace is restarted immediately. Otherwise, the next start event will restart the trace. Disabling or deleting a trace report stops reporting immediately.

7.3 *Scenarios* — The communications involved in event reporting are introduced below in the form of some representative scenarios. The full behavior and message set are covered in Sections 8.2 and 8.3 respectively.

7.3.1 *Event Reporting* — Figure 6 shows a scenario in which a data report is created by the service user and linked to an event report. Event reporting is then enabled. Subsequently, an event report is sent with the data reports attached whenever the collection event occurs. The service user then disables event reporting, preventing subsequent collection events from triggering the report. Data reports and links to event reports may be pre-defined by the equipment in which case the DataReportCreate and LinkCreate messages are omitted.

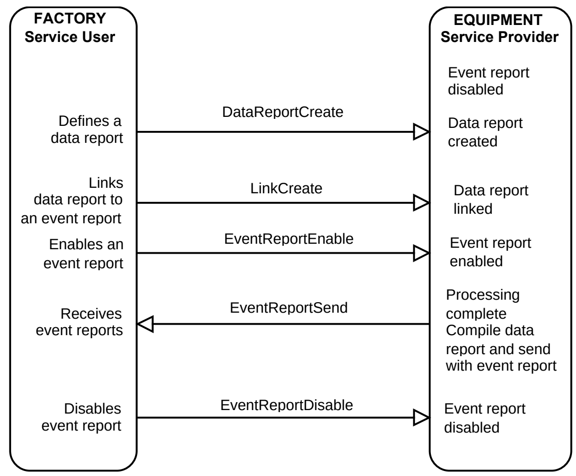

Figure 6
Event Reporting Scenario

7.3.2 *Trace Reporting* — Figure 7 shows a scenario in which a trace object is created with enabled and AutoDelete both set to TRUE. Since the trace object is enabled and there is no start event defined the data reports assigned to the trace object are sampled and sent immediately as a trace report message. The trace object timer is started and the sample counter set to zero. Each time the sample period elapses thereafter, a new trace report is sent, and the sample counter incremented. When the sample counter reaches the total samples parameter, then the trace report is automatically deleted.

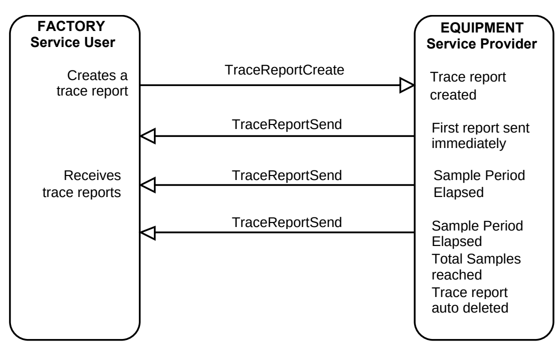

Figure 7
Trace Reporting Scenario

7.3.3 *Trace Reporting with Event Control* — Figure 8 shows a scenario in which a trace object is created with enabled and AutoDelete both set to FALSE. There is also a start event (ProcessingStarted) and a stop event (ProcessingComplete) defined. When the start event occurs, the data reports assigned to the trace are sampled and sent, the trace timer is started and the sample counter set to zero. Each time the sample period elapses thereafter, a report is sent and the sample counter incremented. Since a total samples parameter was not specified, the trace report stops only when the stop event occurs. Once the stop event has occurred, the service user disables the trace report preventing it from restarting when the next start event occurs.

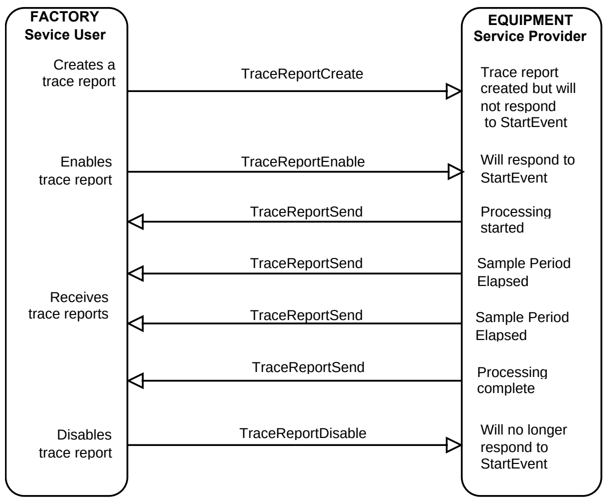

Figure 8
Trace Reporting with Event Control

8 Specification

8.1 *Object Definitions*

8.1.1 *Collection Event Object* — A collection event object generates an event report each time it is triggered by a collection event from an event source. An event report contains the data samples from zero or more data reports to which it is linked by the collection event object.

Table 1 Collection Event Object Attribute Definitions

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	Specification of the Object Type of "Collection Event."	Y	RO	Text = "COLLEVENT"
ObjID	Object Identifier, within the scope of the event source object, for the Collection Event which is the trigger for the generation of an event report.	Y	RO	Text
EventSource	The object specifier which is the source of the event, see Section 7.1 and SEMI E39 (Object Services Standard).	N	RO	Formatted Text
DataReportList	Ordered list of data report object identifiers (text) to be sampled and sent with the event report.	Y	RO	List
Enabled	If this flag is cleared or false, then event reports will not be generated and sent when the associated Collection Event is detected.	Y	RW	Boolean

8.1.2 *Data Report Object* — The data report is part of the event reporting setup. It references zero or more attributes of a data source object and may be linked to zero or more event reports or trace reports.

Table 2 Data Report Object Attribute Definitions

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	Specification of the Object Type of "Data Report."	Y	RO	Text="DATARPT"
ObjID	The object identifier of a pre-defined data report or one defined dynamically by the service user. ReportIDs are unique for eachservice user.	Y	RO	Text
DataSource	The object specifier of the object which has the attributes to be reported, see Section 7.1.	N	RO	Formatted Text
AttrList	An ordered list of attribute names from the Data Source object which will be sampled for inclusion in the data report.	Y	RW	List

8.1.3 *Trace Object* — The trace object generates trace reports based on the settings of its attributes. Trace object activities may be started and stopped by a collection event and may refer to one or more data reports.

Table 3 Trace Report Object Attribute Definitions

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	Specification of the Object Type.	Y	RO	Text="TRACE"
ObjID	The identifier of a Trace Object. Trace reports contain this parameter to be used for reference purposes.	Y	RO	Text
Enabled	If this flag is cleared or false, then trace reports will not be generated and sent.	Y	RW	Boolean
DataReportList	Ordered list of data report object identifiers (text) to be sampled and sent with trace report.	Y	RO	List
SamplePeriod	The time delay between samples in seconds. Resolution may be in fractions of a second and should be specified by the service provider. The resolution available may also vary depending on the Data Source.	Y	RO	Float
TotalSamples	The number of samples to be taken before trace reporting stops automatically.	N	RO	Positive Integer
GroupSize	The number of samples taken before the report is sent to the service user.	N	RO	Positive Integer
StartEventSource	The object specifier of the object which is the source of the event which starts the trace reporting.	N	RO	Formatted Text
StartEventID	The event within the event source object which starts the trace reporting.	N	RO	Text
StopEventSource	The object specifier of the object which is the source of the event which stops the trace reporting.	N	RO	Formatted Text
StopEventID	The event within the event source object which stops the trace reporting.	N	RO	Text
AutoDelete	Specifies if trace report automatically deletes itself when its reporting cycle is complete.	N	RO	Boolean
ReportChangeOnly	If TRUE, then only those data reports linked to the trace report which have changed since the last sample will be sent with the trace report. Otherwise, all data reports will be sent with the trace report.	N	RO	Boolean

8.1.4 *Data Source Object* — The data source is an entity, accessible to the service provider, which contains data (attributes) that may be of interest to the service user. The event reporting service can be composed of one or more data sources. In the case of only one data source, the use of its identifier in messages can be dropped. In this case, the data source is the default object. The attributes of a data source may be referenced by zero or more data reports.

Table 4 Data Source Object Attribute Definitions

Attribute Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjType	The specification of the name for object type of "Data Source."	N	RO	Text = "DATASRC"
ObjID	The identifier of a Data Source Object. (This identifier is used in the object specifier when defining Data Report.)	N	RO	Text
AttrList	A list of the data source object attribute names. Names from this list may be used when defining a data report.	Y	RO	List

8.1.5 *Event Source Object* — This object represents components within a system that generate collection events. The service provider supplies mechanisms such that the when collection events are generated by the event source, then the collection event object, if enabled, will be triggered to generate an event report. ERS does not specify the attributes or behavior of the event source object. It is included in the event report object model to provide context for other objects within ERS.

8.2 *Object Behaviors* — This section specifies the behavior of the three objects in the information model which have standardized behaviors. The message detail for the service is addressed in a later section. Message flow diagrams presented in the previous section are useful to show simple situations. The data report, event report and trace report state models presented in this section provide the information necessary to extrapolate the message flow diagrams for all situations within the scope of this standard.

8.2.1 *Event Reporting State Models* — The behavior required for event reporting is fully specified by the service provider state model. All required service user behavior is inferred by this model.

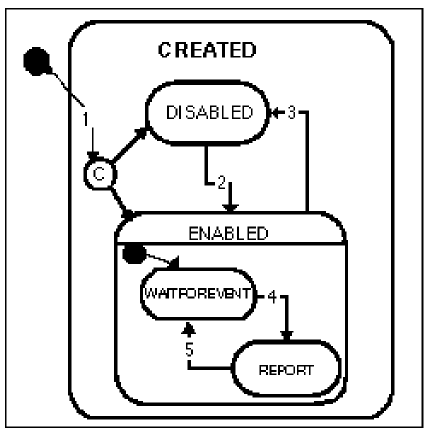

Figure 9
Collection Event Object State Diagram

Figure 9 shows the state diagram for a collection event object. The Harel State Model Notation used is described in Section 5.

Table 5 Collection Event Object State Definitions

State	*Definition*
CREATED	Each collection event is associated with a unique Collection Event ID.
ENABLED	The Service User will be notified by the sending of an event report when the collection event occurs.
DISABLED	Event reports will not be sent to the Service User.
WAITFOREVENT	The object is waiting for its associated Collection Event to occur.
REPORT	Send an Event Report to a Service User, sample Data Reports which have been linked.
notExist	User view of Collection Event Objects prior to connection (establishment of communications).

Table 6 Event Report Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1		Service user establishes connection.	CREATED and ENABLED or DISABLED	A Collection Event Object is created on behalf of the service user for every collection event. The event reporting Enable attribute setting is conditional. It may get its value from stored configuration information.
2	DISABLED	Enable attribute set to TRUE	ENABLED	Event reporting is enabled for a specific collection event.
3	ENABLED	Enable attribute set to FALSE	DISABLED	Event reporting is disabled for a specific collection event.
4	WAITFOREVENT	Collection Event occurs	REPORT	Sample linked data reports. Send event report with linked data reports.
5	REPORT	Reporting Complete	WAITFOREVENT	The object waits for the collection event.

8.2.2 *Data Report Object State Model* — Each data report shall follow the transitions as specified in Figure 10. Multiple instances of data report are managed by the event services. There are two basic types of data reports; pre-defined and user defined.

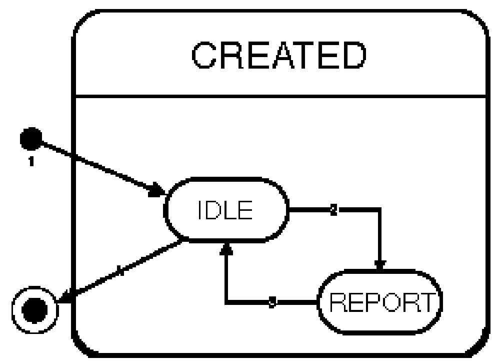

Figure 10
Data Report Object State Chart

Table 7 Data Report Object State Definitions

State	*Definition*
notExist	The state from which the service provider creates reports. NOTE: Some reports may be predefined, that is, they are not created by a user request.
IDLE	Reports are sampled and generated only when requested from an external source such as the Trace or Event Report object or the Service User directly.
CREATED	This is the super-state of Idle and Report. Variables and/or attributes to be sampled are defined.
REPORT	The variables or attributes specified in the Data Report Object are sampled and then sent to the report requestor.

Table 8 Data Report State Transition

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1		CreateRequest	CREATED and IDLE	New ReportID is defined. Wait for an actionable event.
2	IDLE	ReportRequest	REPORT	Sample data in report definition
3	REPORT	SamplingComplete	IDLE	Send data to report requestor
4	IDLE	DeleteRequest and not pre-defined	notExists	ReportID is no longer valid

8.2.3 *Trace Object State Model* — Figure 11 shows the state diagram for a trace object. The Harel State Model Notation used is described Section 5. The state transition table is shown in Table 10.

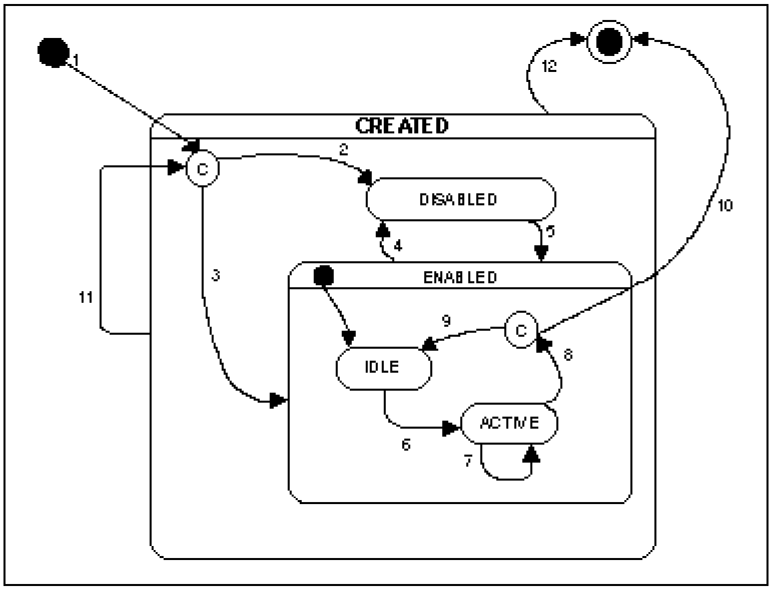

Figure 11
Trace Object State Diagram

Table 9 Trace Object State Definitions

State	*Definition*
CREATED	The Trace Object is created and ready to be accessed.
DISABLED	Trace report is created but will not be sampled or sent.
ENABLED	Trace object may begin generation of trace reports. See sub-states IDLE and ACTIVE.
IDLE	Trace reports are not being generated.
ACTIVE	The trace reports are being generated and sent periodically.

Table 10 Trace Report Transition Table

#	*Current State*	*Trigger*	*New State*	*Action(s)*
1	(deleted)	Trace Object Create	(condition)	A Trace Object is created with Report ID, Enabled, Group Size, Total Samples, Sample Period, Start Event, Stop Event, and Auto Delete parameters.
2	(condition)	Enabled was initially FALSE.	DISABLED	Trace reporting is disabled.
3	(condition)	Enabled was initially TRUE.	ENABLED	Trace reporting is enabled.
4	ENABLED	Trace Report Disable	DISABLED	Trace reporting is disabled.
5	DISABLED	Trace Report Enable	ENABLED	Trace reporting is enabled.
6	IDLE	Start Event is not defined or Start Event is defined and occurs.	ACTIVE	Sample Data Reports and send. Start sample timer. Reset sample counter. Reset group counter. Wait for sample timer to elapse.
7	ACTIVE	Sample period elapses.	ACTIVE	Sample data reports into a trace report. If group sample counter equals group size, then send the trace report and reset group counter. Then prepare to generate the next trace report. Start sample time and wait for it to elapse.

#	*Current State*	*Trigger*	*New State*	*Action(s)*
8	ACTIVE	Stop Event is defined and occurs or… Total Samples > 0 and sample counter equals Total Samples.	(condition)	Sample data reports into a trace report. Send the trace report.
9	(condition)	Auto Delete is FALSE	IDLE	(none)
10	(condition)	Auto Delete is TRUE	(deleted)	Delete Trace Report Object.
11	CREATED	Event Report Reset	(condition)	Reset Trace Report Object state back to initial state when it was first created.
12	CREATED	Event Report Delete	(deleted)	Delete Trace Report Object.

8.3 *Messaging Services Detail* — This section specifies the messages required to implement the event reporting service. The messages were introduced in Section 7.3.1. These services are independent of the messaging protocol used.

The specification includes a list of required messages, the definition of the parameters contained within the messages, and data type of the parameters. Not defined here is the internal structure of the actual messages as transferred, including order of the parameters and how various data structures and data types are represented.

The service message notation used in the tables below is described in the Conventions, Section 5.4.

8.3.1 *Service List*

Table 11 Event Reporting Services

Service	*Type*	*Description*
Event Report Request	R	Requests the specified event report, and the data reports linked to it, to be sampled and returned to the service user.
Event Report Send	N	Notifies the service user of the occurrence of an event with a time stamp indicating when the event occurred. Any data reports linked to the event report are sampled and attached to the event report sent to the service user.
Data Report Create	R	Creates a data report which defines a set of attributes of an object to be reported.
Data Report Delete	R	Deletes one or more data report definitions.
Data Report Request	R	Requests the specified data report to be sampled and returned to the service user.
Collection Event Link	R	Request a Collection Event Object to link a Data Report. All Data Reports linked to an enabled Collection Event Object are sampled and sent with the event report when the collection event occurs.
Collection Event Unlink	R	Unlinks one or more Data Reports from the Collection Event Object.
Trace Report Create	R	Creates a trace report which defines the sample period, group size, start and stop events, auto delete, report change only, and the initial state (enabled or disabled).
Trace Report Delete	R	Deletes one or more trace report definitions.
Trace Report Request	R	Requests that the data reports assigned to the trace report be sampled and returned to the service user.
Trace Report Send	N	Notifies the service user of trace report samples taken. Group size samples are taken before the service user is notified. After notifying the service user, the group counter is reset to zero. A trace report sample is taken either when the start event occurs or the sample period elapses.
Trace Report Reset	R	Resets one or more trace reports back to their initial state when created regardless of the current state of the trace report. All reports may be reset at once providing a simple way to re-establish the event reporting setup after modifications have been made.

8.3.2 *Use Object Services* — Attributes of the standardized objects listed in Table 12: SEMI E39 shall be accessed by using the GetAttr and SetAttr messages as defined in SEMI E39.

Table 12 SEMI E39 Access

Object	*Attribute*	*Comment*
Collection Event	Enabled	When set to TRUE, a Collection Event Report will be sampled and sent when the Collection Event occurs. When FALSE, Collection Event Reports are not sampled and sent.
Trace	Enabled	When set to TRUE, a Trace Report will be sampled and as described by the Trace Report definition. When FALSE, Trace Reports are not sampled and sent.
Data Source	AttrList	Use GetAttr to get the names of the attributes of a data source. These names can be used in the Data Report Create message.
Data Report	AttrList	Use GetAttr and SetAttr to change the variables included in a data reportdefinition.

8.3.3 *Parameter Dictionary*

Table 13 Event Reporting Parameters

Parameter	*Definition*	*Form*
EvtSrcSpec	The object specifier of the Event Source Object.	Formatted text
CollEventID	References the Object Identifier of the collection event, within the scope of the event source object, that triggers an event report to be sent.	Text
Enabled	Specifies whether an Event or Trace Report is enabled.	Boolean: TRUE – Successful FASLE – Unsuccessful
DatSrcSpec	The object specifier of the data source object.	Formatted text
(list of) AttrName	An ordered list of attribute names from the data source object which specify the samples to be included in a data report. Maximum must be documented by supplier.	Text
ReportID	References the Object Identifier of a data report, either pre-defined by the service provider or specified by the service user.	Text
TraceID	References the Object Identifier of a trace report specified by the service user.	Text
(list of) ReportID	A list of data reports to be linked to a trace. Maximum must be documented by supplier.	Text
SamplePeriod	The time delay between samples. Minimum and maximum must be documented by supplier.	Float
TotalSamples	The number of samples to be taken before trace data reporting stops automatically.	Positive Integer
GroupSize	The number of trace report samples made before the report is sent to the service user. Maximum group size must be documented by supplier.	Positive Integer
StartEvtSrcSpec	The object which is the source of the event which starts the trace reporting.	Text
StartEventID	The Collection Event Object Identifier within the event source object which starts the trace reporting.	Text
StopEvtSrcSpec	The object which is the source of the event which stops the trace reporting.	Text
StopEventID	The Collection Event Object Identifier within the event source object which stops the trace reporting.	Text
AutoDelete	Specifies if trace report automatically deletes itself when its reporting cycle is complete.	Boolean: TRUE – Successful FASLE – Unsuccessful
ReportChangeOnly	If TRUE, then only data reports linked to the trace report which have changed since the last sample will be sent with the trace report. Otherwise, all data reports will be sent with the trace report.	Boolean: TRUE – Successful FASLE – Unsuccessful

Parameter	*Definition*	*Form*
(list of) DataReportSample	A list of data reports. Each data report sample contains the values of the variables specified in the data report at the time at which the sample was taken (see TimeStamp).	Structure
(list of) TraceReportSample	Trace report data. Each trace report contains a set of data report samples taken at a single point in time. This parameter is used when several trace report samples are made before notifying the service user (see Group Size).	Structure
ERAck	Indicates whether the activity was successful.	Boolean: TRUE – Successful FALSE - Unsuccessful
ErrorCode	Identifies errors that may arise.	Enumerated: Unknown event Unknown attribute Unknown data report Duplicate Report ID Data report not linked Unknown trace report Duplicate Trace ID Cannot delete predefined Too many data reports Sample period out of range Group size too large text
ErrorText	Text in support of Error code.	Text
ERStatus	Reports the acceptance or rejection of a requested operation.	Structure Composed of: ERAck (list of) Status
Status	Reports any errors found.	Structure Composed of: ErrorCode ErrorText

Table 14 Data Report Sample Parameter Detail

Parameter	*Definition*	*Form*
ReportID	Unique identifier of a data report.	Text
TimeStamp	Records time at which report sample values were recorded.	Formatted text: YYYMMDDhhmmsscc
(list of) AttributeValue	An ordered list of attribute values that match the (list of) AttrName in the data report.	(depends on attribute)

Table 15 Trace Report Sample Parameter Detail

Parameter	*Definition*	*Form*
(list of) DataReportSample	Samples of data reports assigned to the trace report.	Structure

8.3.4 *Service Detail*

8.3.4.1 *Event Report Request* — When the event object receives this message, it immediately generates and sends an event report to the service user.

Table 16 Event Report Request Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
EvtSrcSpec	C	C(=)	Source object for requested event report. If omitted, then the default object is assumed.
CollEventID	M	M(=)	Identifies requested Event Report. If not recognized, then the error code “unknown event” is returned.
TimeStamp	-	C	Time at which request was received. Parameter is omitted if Event ID is not recognized.
(list of)DataReportSample	-	C	Samples of data reports linked to the event. Parameter is omitted if Event ID is not recognized.
ERStatus	-	C	Possible errors: Unknown event

8.3.4.2 *Event Report Send* — This is a notification message to the service user. It contains the event report for the collection event which has triggered this action.

Table 17 Event Report Send Service Detail

Parameter	*Req/Ind*	*Comment*
EvtSrcSpec	C	Source object for event report to be sent. If omitted, then the default object is assumed.
CollEventID	M	Event Report being sent.
TimeStamp	M	Time at which Collection Event occurred.
(list of)DataReportSample	M	Samples of data reports linked to the event. An empty list can be sent by the service prvider when there are no data reports linked to the Collection Event.

8.3.4.3 *Data Report Create*

Table 18 Data Report Create Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
DatSrcSpec	C	-	Source object for data report to be created. If omitted, then the default object is assumed.
AttrList	M	-	Attributes of data source object to be included in data report. If an AttrName is not recognized, then the error code “unknown attribute” is returned.
ReportID	C	M(=)	If ReportID is not specified in the request, then the provider will return a unique ID to the user. If the user specifies ReportID, then the user must be responsible for making it unique, otherwise, the ReportID already identifies a Data Report, then that Report definition will be overwritten.
ErrorCode	-	C	Possible errors: Unknown Data Source Unknown Attribute

8.3.4.4 *Data Report Delete*

Table 19 Data Report Delete Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
(list of) Report ID	C	C	Identifies data report(s) to be deleted. If data report ispre-defined, then the error code “Cannot delete pre-defined” is returned. If a ReportID is not recognized, then the error code “unknown data report” is returned. If parameter is omitted in the request, then all data reports are deleted. In all cases, the (list of) ReportID that are deleted, if any, is returned in the response.
ERStatus	-	C	ERAck is set to FALSE if any requested ReportID cannot be deleted. ErrorCodes: Unknown data report Cannot delete predefined ErrorText shall be set to the ReportID of reports which could not be deleted.

8.3.4.5 *Data Report Request* — Message asking the service provider to sample the data report and send the resulting report.

Table 20 Data Report Request Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
ReportID	M	C(=)	Identifies requested Data Report to sample. If Report ID is not recognized then the error code “unknown data report” is returned. Parameter is omitted in the response when the ReportID is recognized by the service provider.
DataReportSample	-		Parameter is omitted if ReportID is not recognized.
ERAck	-	C	In the case where no Data Report can be returned then this value is returned set to FALSE. This informs the service requestor that the message was received but that for some reason, the report could not be sampled. The most likely reason is the ReportID was not recognized.

8.3.4.6 *Collection Event Link*

Table 21 Collection Event Link Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
EvtSrcSpec	C	C(=)	Source object for event report to be linked. If omitted, then the default object is assumed.
CollEventID	M	M(=)	Identifies Collection Event Object to be linked. If CollEventID is not recognized, then the error code “unknown event” is returned. This error takes precedence over other errors.
(list of) ReportID	M	-	Identifies Data Report(s) to be linked to an Event Report for this Collection Event Object. If ReportID is not recognized, then the error code “unknown data report” is returned.
ERStatus	-	C	ERAck is set to FALSE if any ReportID cannot be linked. ErrorCodes: Unknown event Unknown data report ErrorText shall be set to the ReportID of reports which could not be linked.

8.3.4.7 *Collection Event Unlink*

Table 22 Collection Event Unlink Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
EvtSrcSpec	C	C(=)	Source object for event report to be unlinked. If omitted, then the default object is assumed.
CollEventID	M	M(=)	Identifies Collection Event to be unlinked. If the ID is not recognized, then the error code “unknown event” is returned. This error takes precedence over other errors.
(list of) ReportID	M	-	Identifies data report to be unlinked. If link is pre-defined, then the error code “Cannot delete predefined” is returned. If ReportID is not recognized, then the error code “unknown data report” is returned. If data report is not linked to the specified event, then the error code “data report not linked” is returned.
ERStatus	-	C	ERAck is set to FALSE if any ReportID cannot be unlinked. ErrorCodes: Unknown event Unknown data report Data report not linked Cannot delete predefined ErrorText shall be set to the ReportID of reports which could not be unlinked.

8.3.4.8 *Trace Create*

Table 23 Trace Report Create Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
TraceID	C	M(=)	Identifier of Trace Object to be created. The service user can be responsible for the uniqueness of the Trace ID. If duplicate ID is used, then the current Trace Object definition overwritten. If omitted in the request, then the Service Provider will generate a unique identifer.
Enabled	M	-	If TRUE, then the initial state of trace report is enabled and will start reporting when the next Start Event occurs, if one is defined, or immediately otherwise.
(list of) ReportID	M	-	Data reports to be linked to trace report.
SamplePeriod	M	-	A Sample Period outside the range supported by the service provider will return the error code “Sample period out of range.”
TotalSamples	C	-	If this is equal to zero or is omitted, then the trace reporting will continue until it is stopped by some other means (i.e., by Stop Event, by Trace Report Disable or by Trace Report Delete).
GroupSize	C	-	If this is omitted, then every sample is immediately reported.
StartEvtSrcSpec	C	-	The object which is the source of the event which starts the trace reporting. If omitted, then the default object is assumed.
StartEventID	C	-	The event within the event source object which starts the trace reporting. If this is omitted, then trace reporting begins as soon as it is enabled.
StopEvtSrcSpec	C	-	The object which is the source of the event which stops the trace reporting. If omitted, then the default is assumed.
StopEventID	C	-	The event within the event source object which stops the trace reporting. If this is omitted, then trace reporting must be stopped by some other means (i.e., by Total Samples, or by Trace Report Delete).
AutoDelete	C	-	If this is omitted, then AutoDelete is assumed to be TRUE.
ReportChangeOnly	C	-	If this is omitted, then ReportChangeOnly is assumed to be FALSE.
ErrorCode	-	C	Possible errors: Duplicate trace ID Too many data reports Sample period out or range Group size too large Unknown event

8.3.4.9 *Trace Delete*

Table 24 Trace Report Delete Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
(list of) Trace ID	C	C	Identifies Trace Object(s) to be deleted. If a Trace Object ispre-defined, then the error code "Cannot delete predefined" is returned. If a TraceID is not recognized, then the error code "unknown trace report" is returned. If parameter is omitted in the request, then all trace reports are deleted. In all cases, the (list of) Trace ID that are deleted, is returned in the response.
ERStatus	-	C	ERAck is set to false if any requested TraceID cannot be deleted. ErrorCodes: Unknown trace report Cannot delete predefined ErrorText shall be set to the TraceID of reports which could not be deleted.

8.3.4.10 *Trace Report Request* — Request the data reports specified by the trace object ID be sampled and sent to the service user.

Table 25 Trace Report Request Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
TraceID	M	M(=)	Identifies requested trace report.
TimeStamp	-	C	Time at which request was serviced and data report samples taken. Parameter is omitted if Trace ID is not recognized.
(list of) DataReportSample	-	C	Samples of data reports assigned to the trace report. Parameter is omitted if Trace ID is not recognized.
ERAck	-	C	If the Data Report Samples cannot be sent, then this item shall be returned with its Boolean value set to false. The most likely cause of this would be that the TraceID was undefined.

8.3.4.11 *Trace Report Send* — The notification message sent by the service provider to the service user when the trace object has prepared a trace report according to its definition.

Table 26 Trace Report Send Service Detail

Parameter	*Req/Ind*	*Comment*
TraceID	M	Identifies trace report.
(list of) TraceReportSample	M	Number of samples in list is determined by Group Size parameter in TraceReportCreate.

8.3.4.12 *Trace Report Reset*

Table 27 Trace Report Reset Service Detail

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
(list of) TraceID	C	M	Identifies trace report(s) to be reset. If a Trace ID is not recognized, then the error code "unknown trace report" is returned. If parameter is omitted in the request, then all trace reports are reset. In all cases, the (list of) TraceID that are reset is returned in the response.
ERStatus	-	C	ERAck is set to false if any requested TraceID cannot be reset. ErrorCodes: Unknown trace report ErrorText shall be set to the TraceID of reports which could not be reset.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E53.1-1296
SECS-II SUPPORT FOR EVENT REPORTING STANDARD

1 Purpose

This document maps the services and data of its prime document, SEMI E53, to SECS-II streams and functions and data definitions.

2 Scope

This is the standard way to implement the Event Reporting, which provides event-based reporting using the SECS-II message format.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E53 — Event Reporting

4 Terminology

None.

5 Mapping of Event Reporting Messages

Table 1 Event Messages Mapping

Service Message Name	*Stream, Function*	*SECS-II Name*
Event Report Send	S6F11,F12,F13,F14	Event Report Send/Acknowledge Annotated Event Report Send/ Acknowledge
Event Report Request	S6F15,F16	Event Report Request/Data
Data Report Request	S6F19,F20	Individual Report Request/Data
Collection Event Link Request	S17F9,F10	Collection Event Link Request/Acknowledge
Collection Event Unlink Request	S17F11,F12	Collection Event Unlink Request/Acknowledge
Data Report Create	S17F1,F2	Data Report Create Request/Acknowledge
Data Report Delete Request	S17F3,F4	Data Report Delete Request/Acknowledge
Trace Create Request	S17F5,F6	Trace Create Request/Acknowledge
Trace Delete Request	S17F7,F8	Trace Delete Request/Acknowledge
Trace Report Send	S6F27,F28	Trace Report Send/ Acknowledge
Trace Report Reset Request	S17F13,F14	Trace Report Reset Request/Acknowledge
Trace Report Request	S6F29,F30	Trace Report Request/Data

6 Event Parameters Mapping

Table 2 Event Service Parameter Mapping

Parameter	*SECS-II Data Item or Object Attribute*
ErrorCode	ERRORCODE
ErrorText	ERRTEXT
ReportID	RPTID
DataSrcSpec	DATASRC
CollEventID	CEID
EvtSrcSpec	EVNTSRC
Enabled	CEED

Parameter	*SECS-II Data Item or Object Attribute*
(list of) AttrName	(list of) VID
ReportChangeOnly	RPTOC
TraceID	TRID
SamplePeriod	TRSPER
TotalSamples	TOTSMP
GroupSize	REPGSZ
StartEventID	CEID
StopEventID	CEID
AutoDelete	TRAUTOD

7 Implementation Details

Many of the messages of the Event Reporting Standard are implemented with currently defined SECS-II messages. Certain restrictions must be applied to their usage. These restrictions are specified in this section.

7.1 To be OSS-compliant, the following data items must use the format 20 specification:

RPTID

CEID

TRID

VID

The format of the ASCII strings shall conform to the Object identifier specifications in the Object Services Standards, document SEMI E39 and SEMI E39.1.

7.2 Each Data Report sample, whether stand alone or as part of an Event or Trace report, will report TIMESTAMP as the first item in its list of report variables and/or object attributes. This means for reports defined by the service user, the user should define TIMESTAMP as the first VID in the report definition. Further, all of the service provider's predefined reports shall deliver the value of TIMESTAMP in the first V.

7.3 Serveral capabilities of the Event Reporting Standard are accessed through the Object Services Standard. When an instance of a report (Report, Event, or Trace) object has been created, then its attributes can be read and written using the Object Service's GetAttr and SetAttr messages.

7.3.1 Object Services shall be used to set RPTOC and to get CHGND.

7.3.2 Object Services shall be used to set or clear CEED.

7.3.3 EVNTSRC shall be provided in supplier documentation or as a list of Event Sources obtained by using Object Services to interrogate the Collection Event Object, COLLEVENT, with the GetAttrName request message.

7.4 Event Reporting Services is protocol independent and therefore, makes no mention of SECS-II multi-block access and grant messages. When the Event Reporting Services use the SECS-II protocol, then S6F11,F13 shall be preceded by S6F5 if a report will be multi-block. Trace Report Send, S6F27 shall also use the multi-block access/grant transaction if the report will be multi-block.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E54-0997
SENSOR/ACTUATOR NETWORK STANDARD

NOTE: The document that was previously designated as SEMI E54 (Standard for Sensor/Actuator Network Common Device Model) has been redesignated as SEMI E54.1. Because the Sensor/Actuator Network Standard is the parent document, it has been designated as SEMI E54.

1 Purpose

1.1 This specification provides the structure of SEMI's Sensor/Actuator Network (SAN) standard. It provides the definition for interoperability with respect to SEMI SAN standard-compliant Sensor/Actuator devices.

2 Scope

2.1 This standard specifies how devices interoperate on a network as part of the control system for equipment.

2.2 This specification, which is the root of the SAN standard, defines the relationships of each of the other specifications that are components of the SEMI SAN standard.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

3.2 *Other Documents*

ISO 7498[1] — Basic Reference Model for Open Systems Interconnection (OSI)

James Rumbaugh, Michael Blaha, William Premerlani, Frederic Eddy, William Lorensen, *Object-Oriented Modeling and Design*, Englewood Cliffs, New Jersey: Prentice-Hall, 1991.

4 Terminology

4.1 *Abbreviations & Acronyms*

4.1.1 *API* — Applications Programming Interface

4.1.2 *CDM — Common Device Model.* The root object application model for devices on the sensor bus.

4.1.3 *DM* — DeviceManager. An object specified in SEMI E54.1 (Standard for Sensor/Actuator Network Common Device Model).

4.1.4 *IDL* — Interface Definition Language. A programming language-independent notation for specifying interfaces.

4.1.5 *ISO* — International Organization for Standardization.

4.1.6 *NCS* — Network Communication Standard. Provides the specification for mapping the CDM and SDM to specific network technologies. These standards will be incorporated as parts of the SEMI SAN standard.

4.1.7 *OEM* — Original Equipment Manufacturer. They are usually the control system developer, but in any case they are almost always responsible for the control system.

4.1.8 *OMT* — Object Modeling Technique. A methodology developed by James Rumbaugh, et al. for using objects to model systems.

4.1.9 *OSI* — Open System Interconnection. A seven-layer model for communications developed by ISO.

4.1.10 *OSS* — Object Services Standard. SEMI E39.

4.1.11 *SAN* — Sensor/Actuator Network. It is frequently used to reference this standard.

4.1.12 *SDM* — Specific Device Model. This is an application model for a specific type of sensor, actuator, or entity.

1 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland. Available in the US from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

4.2 *Definitions*

4.2.1 *application* — for software, this is a working series of computer instructions that provide end user services.

4.2.2 *applications model* — a formal description of the software elements and interactions that perform an end user task.

4.2.3 *entity* — in software engineering, this is something that is recognizable as distinct and particular from the other things that make up a software system or program.

4.2.4 *interface* — in information modeling, it is the boundary between two entities from which information will flow.

4.2.5 *user layer* — in communications, this is a set software function connected to the communication protocol's top layer, usually called the applications layer, from the user's application environment. It typically allows the user application to be protocol-independent.

5 Overview

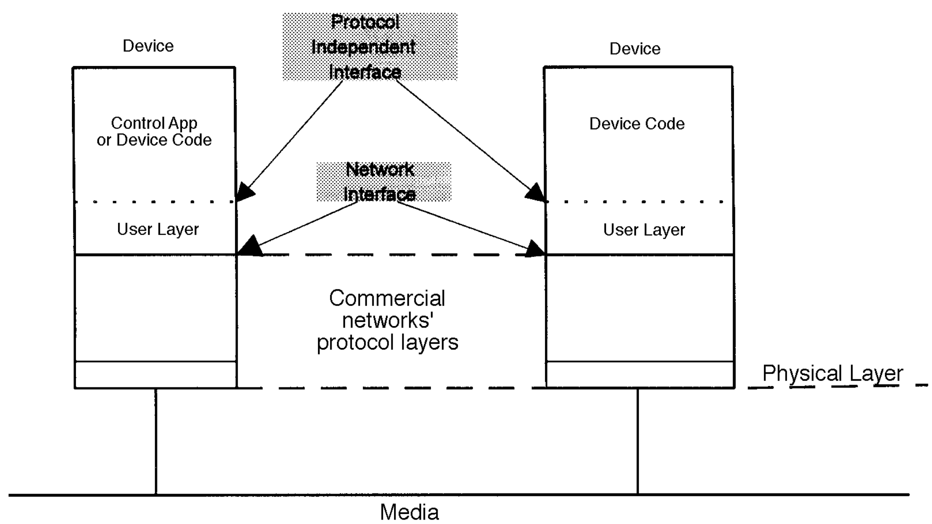

Figure 1
SEMI SAN Protocol Layers

5.1 Referring to Figure 1, the SAN standards specify a complete communications solution covering all the layers of the OSI reference model. The CDM and SDM together specify a protocol-independent set of application services, attributes, and behavior for a device that must be supported by the user layer as shown in Figure 1. An NCS completes the specification of the user layer by specifying a mapping to a network technology's interface. The NCS must specify its capabilities referenced against the ISO OSI Reference Model. An NCS may utilize an open or commercial solution. In any case, the NCS will provide references to those solution's specifications.

5.2 Generally, the functionality of a software layer is embodied by the definition of the services it provides. Its services are the set of messages it generates and to which it responds, and its subsequent behavior upon receipt of any particular message. The CDM and an SDM provide a complete user layer specification in a platform and language-neutral form (dotted line in Figure 1). The goal being to provide device interoperability at the applications level. The NCS will guarantee interoperability at the network level (i.e., across a single type of network). The SAN standard does not require implementation of the top interface to the user layer, as specified by the CDM and an SDM. The CDM and an SDM provide the information needed to develop an NCS, which defines the interface requirement between the user layer and a specific network technologies communication layer (the solid line labeled as Network Interface). This means that the SAN standard allows user applications, whether from the device or the controller side implementation viewpoint, to interact directly with a network technologies interface.

5.3 *Network Technology Supplier View* of *the SAN Standard*

5.3.1 The CDM and an SDM together specify the messages, behavior, and attributes of a device type that will be visible over the network. In Figure 1, this is the area above the line that indicates the protocol-independent interface. Network suppliers will map this information to the top layer of their protocol. They do this by helping to develop and extend their NCS.

5.3.2 Most network suppliers have an application layer already defined for their protocol. In that case, the user layer as specified in a SEMI SAN NCS is quite thin. In fact, it is just a simple mapping of SDM interface to messages and data (attributes) provided by the network. Thus, an NCS (one for each supported network) specifies a user layer that sits on top of the network supplier's protocol.

5.4 *Device Supplier View of the SAN Standard*

5.4.1 Device suppliers are not required to implement designs illustrated in the specific device model (SDM) specifications. The designs are presented using an object-modeling notation as a means to clearly specify the devices interface. An SDM provides a model of a device, it is not a design for the device. Device suppliers are not expected to provide an object-oriented implementation. However, in order to ensure that a device interface responds as expected, it is necessary for the device supplier to not only provide the support for the services and attributes specified, but to ensure that the code that is implemented on the device behaves as specified by the applications model for a specific device type.

5.5 *Equipment Supplier View of the SAN Standard*

5.5.1 The OEM's have the largest task in adopting the SAN standard. They have to implement applications that use the interfaces defined for the many devices that make up the typical equipment control system. They have to be familiar with the interfaces of a large number of the SDMs. On the other hand, they will become insulated from the inner workings of many devices, and from the code that they used to write to support those inner workings. In many cases, they may have to implement more than one Network Communication Standard.

5.5.2 During early adoption, OEM's may look to the SAN to act as a replacement for memory mapped discrete wired IO. With this type of adoption, the OEM will not lessen his burden of control code.

5.5.3 As Sensor Bus becomes more broadly adopted, OEM's may take advantage of the distributed processing capability offered by intelligent devices to reduce the complexity of their control software.

5.6 *The SAN Standard Structure*

5.6.1 A SAN employs devices from numerous suppliers. The SEMI SAN standard provides a framework to ensure interoperability of these devices within a network. The standard enables device suppliers and equipment control system developers to achieve that end. The SAN standard comprises five specifications.

5.6.2 The first specification is this document, which is the root document and specifies the connection between the other documents of the standard. It also specifies the construction for each of the other documents.

5.6.3 The next specification is the Common Device Model Specification. Each device on the SAN must comply with this specification.

5.6.4 The third specification defines the templates for creating ballots for specific device models and additions to the NCS.

5.6.5 The fourth specification is Specific Device Models standard. These standards contain models for various types of sensors, actuators, and entities. For instance, a model of a mass flow controller, a manometer, and a thermocouple will be specified.

5.6.6 The fifth type of specification is the Network Communication Standards. Each network technology has its own standard as an ancillary specification to the SAN standard.

5.6.7 Applications notes may accompany a number of the standards documents and are intended to guide implementors in the application of the standard.

6 Concepts

6.1 *Minimal device* — The SAN specifications allow simple and complex devices to be built compliant to the standard. This is done by specifying a minimum of required attributes, services, and behaviors in an SDM. The SDMs may also provide optional service definitions that must be followed if extended capabilities are to be built into a device. Devices that do not implement the extended capabilities must respond to extended service or access requests with an appropriate response code rather than failing to respond or issuing an exception or alarm message.

6.2 Many of the SAN NCS specifications rely on commercial technology. A significant number of network technologies are available off-the-shelf. The standards do not prescribe a choice. Once a technology described in an NCS is chosen, the NCS specifies how it is to be applied. The SAN standard is easily extensible for future technologies.

6.3 A device supplier must be able to use the standard to describe a device with little or no ambiguity for the device users. For the user, this means that he can select a device with confidence and that it can be easily integrated with his control system. The user must understand the electrical interface, the capabilities, and messages which a device supports based on the supplier's description of how this standard is supported by the device.

7 Requirements

7.1 *Organization of the SAN Specifications* — Figures 2 and 3 are intended to assist in understanding the document relationships that are specified in the following subsections. In these figures, all specifications that are standards are drawn as rounded rectangles. In Figure 3, the shadowed rectangles indicate the standards that contain requirements for implementing devices that are compliant to this standard.

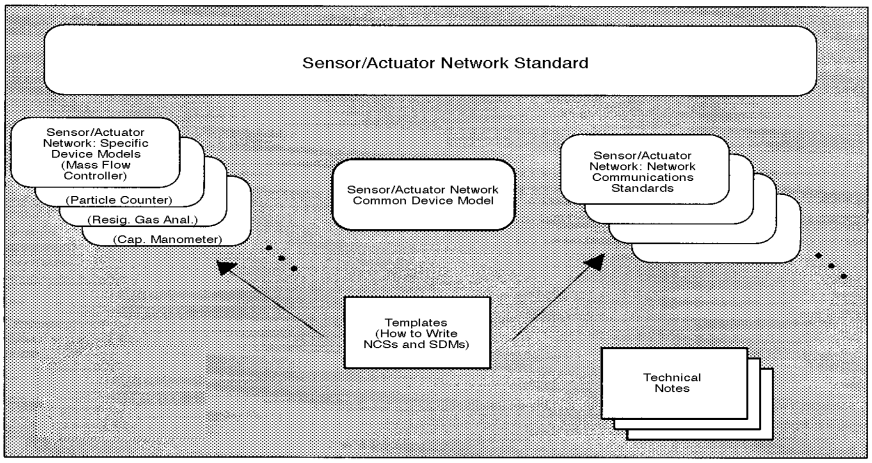

Figure 2
Organization of SAN Specification

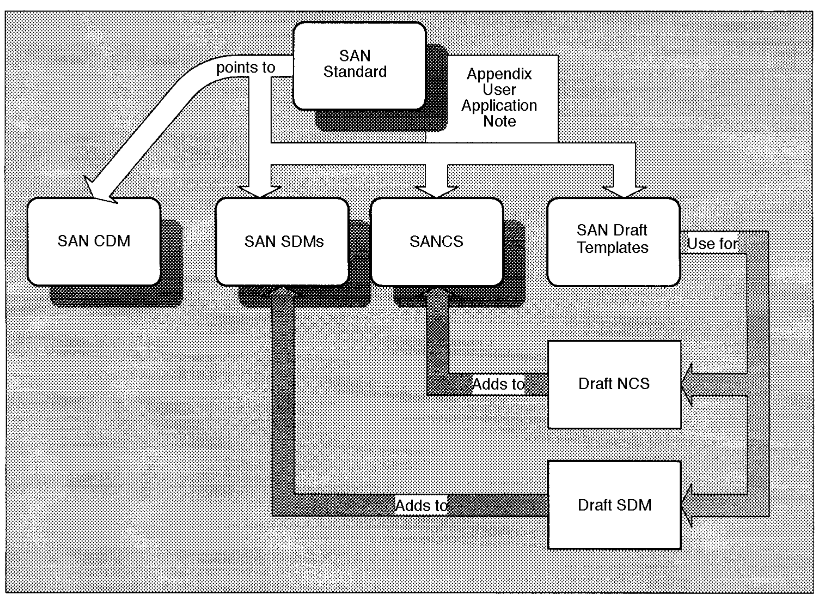

Figure 3
SAN Standard Relationships

7.1.1 The CDM specification is the first ancillary document of the SAN suite.

7.1.2 A second ancillary specification to the SAN standard provides templates that are guides to adding specific device models and network communication mappings to the SAN standard.

7.1.3 Specifications for specific device models for all types of devices are included as additional ancillary specifications of the SEMI SAN standard. Specific device models are added in the order they are developed and passed SEMI's ballot procedure.

7.1.4 Each network technology's user layer specification is included as an ancillary standard (see Figure 3). These *Network Communication Standards (NCS)* provide the mapping for each of the approved specific device models. Therefore, each NCS is also a specification that grows over time. As new device models are developed and approved, a mapping of the model to a network technology is added to a NCS.

7.1.5 *Auxiliary Information* — Auxiliary information may be included with the standard in the form of appendices or technical notes. Generally, this information is not balloted, but is included as provided by the SEMI Standards Program regulations. Auxiliary information shall always be noted as such when it accompanies a specification or ballot.

7.2 *Interoperability*

7.2.1 *At the Applications Level* — The SDMs are used to derive the definitions for attributes, services, and behavior that are unique to each device type. A model may discuss relationships internal to a device to provide additional meaning to the services and attributes that can be manipulated over the network. Applications written to these models can operate a device independent of the network on which they communicate. The models shall assure that devices of different types can operate cooperatively at the applications level.

7.2.2 *Below the User Layer* — The various SANCS specifications describe the method by which a device communicates over a specific network such that it can meet the requirements of its type. All devices described within an NCS shall operate cooperatively on that specific network technology below the user layer.

7.2.3 The SEMI SAN standard does not address methods for internet-working below the applications layer, as described herein. An application entity may connect to more than one network. This could be typical of the application entities on the equipment controller. While the SAN standard allows that application entities could exist at any network node, it requires no mechanism for a message that begins on one network to be routed to another network.

7.3 *SEMI SAN Compliance* — To fully describe the characteristics of a network capable device, its compliance shall be specified by reference to the SAN ancillary standards. Thus, a device indicates both its type and network technology for its SDM and a NCS.

7.3.1 For a device to be compliant to the SAN standard, it shall implement all of the required attributes, behavior, and services as described in the SAN CDM.

7.3.2 *Type or Applications Model Specification* — The SDM of a device (which is its type, e.g., MFC or thermocouple) shall be denoted by SEMI E54.y, where "y" indicates the SDM ancillary standard.

7.3.3 Network Communication Specification Communication (protocol) compliance specification of a device is denoted by SEMI E54.x, where "x" is the network communications ancillary specification.

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: The material contained in these Application Notes is not an official part of SEMI E54 and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information included as reference material for implementers of the standard. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of this material for any particular purpose is solely the responsibility of the user.

R1-1 Implementing a SAN Standard-Compliant Device

This Related Information section describes how the SAN standard is used by a device supplier who wishes to offer SEMI SAN-compliant devices to the market.

R1-1.1 While the SAN standard may appear overwhelming on first viewing, it is actually built from independent components. It is not necessary to understand or 'know' the entire standard. It can be dealt with in small pieces. For device suppliers, only the pieces that deal with their particular device type need to be considered. The specifications to implement a specific device are typically less than thirty pages of text. The standard is structured such that it is extensible while providing the ability to specify a device by reference to the standard.

R1-1.2 *Synopsis of Device Operation* — All devices on a SAN have a similar operational profile. That profile is specified in SEMI E54.1 (Standard for Sensor/Actuator Network Common Device Model) and in the Common Device Model support section of each NCS.

Table R-1 explains where to find specifications for various device operations.

Table R-1

Operation	*Spec.*
Power applied	CDM
Enable SAC	CDM
Enable DM	CDM
Enable Communications	NCS
Establish Communication	NCS
Send Events	CDM
Receive messages/answer	CDM
Send messages/accept	CDM

R1-1.3 *Device Type* — Each type of device is specified in the SDM specifications. One SDM is devoted to each device type. An SDM is always a specialization of the CDM. The SDM provides services, behavior, and attributes that are in addition to those specified in the CDM. For example, the SDM of a manometer might specify attributes for current pressure and alarm bands. It might have services needed for performing calibration.

R1-1.4 *Network Technology* — How a network technology is used by the SAN standard is specified in an NCS. The NCS for a technology provides a mapping of the CDM and SDM of a device type to a specific network protocol.

R1-1.4.1 It is only necessary for a device to support an NCS and the section for its type within that NCS. The NCS provides all that is needed to ensure that a device can communicate and interoperate across a given network technology. The point is that from the other side of the wire, the network-independent interface is not visible. That interface is implied by the behavior of the network interface.

R1-1.5 *Network Independence* — Device suppliers have the option of supplying an interface at the protocol-independent applications layer, as indicated in Figure 1. While this requires more implementation work for the device supplier, it speeds the integration of sensors and actuators for the OEM.

R1-1.5.1 In this case, it is still necessary for the device to support the NCS to ensure that their device will interoperate with other devices on the network.

R1-1.5.2 To supply this option, a device supplier would provide a device driver-like interface (software) to the OEM.

R1-1.5.3 Devices that supply a protocol-independent API that is compliant to the SEMI SAN standard provide advantages to both device and control system suppliers. The device supplier can assure that his device receives syntactically correct messages at his network interface layer. Control applications written to the protocol-independent interfaces have the advantage that they would not have to be rewritten in order to change to another network. To achieve this, device suppliers would have to ship software, in the form of 'device drivers', that would be installed on the control supplier's platform.

NOTE: Standards for these 'device drivers' may be developed at a later time as they do not currently exist. However, most operating systems used by control systems suppliers support installable device drivers.

R1-1.6 *Recommendations on Optional and Extended Device Capabilities* — It is expected that device suppliers would not compete based on their network interface. Devices traditionally compete based on cost, service, stability, reliability, accuracy and repeatability, and relevant dynamic attributes. From a network perspective, all devices have these common characteristics: periodic reporting, polled reporting, asynchronous event reporting, calibration, health, and diagnostic reporting. Access and control over the common characteristics should be implemented based on the SAN standard. Access and control of the competitive characteristics of devices may be implemented with supplier-specific interface extensions. However, the device supplier is strongly cautioned in the use of these extensions. Heavy use of extensions could be a serious competitive disadvantage unless the supplier is the clear winner in all the competitive characteristics. A locked door could lock one in, it could also lock one out. Device suppliers will usually find that their extensions can be implemented using the optional features of the CDM and SDM.

NOTE: Network interfaces could be a competitive factor during the early technology adoption phase.

R1-1.7 *The Controller Side Usage of the SAN Standard* — The control system supplier (in many cases this is the OEM) evolves a different view of SEMI's SAN standard. They are not as concerned with the network technology as with utilizing the applications capabilities as specified by the CDM and SDMs. It is strongly recommended that control applications not be network aware. This may produce some operating overhead, but for most applications, this is a good trade-off to gain flexibility provided by a protocol-independent interface. Many network devices may be supplied without any user layer (device driver) application side software. For these devices, the control system supplier would have to do some system's programming to provide a device driver for the application interface. Over time, it is likely that most devices will be delivered with a device driver. (Similar to the way printers are sold with Windows (TM) device drivers. This is what allows Windows applications to use a printer of the end users choosing.)

R1-1.7.1 The standards as of 1996 do not provide all the specifications needed to uniquely define how device drivers would be installed in the controller side of the API. This may become a future area of standardization, if OEMs decide to invest in the standard's development time.

R1-1.8 *Device Intelligence* — This varies considerably between device types and between devices of the same type. SEMI SAN specifications attempt to allow a range of intelligence to devices without forcing them to be 'highly' intelligent. To this end, the applications models specify a required minimum set of capabilities that must be supported for a device. Optional capabilities generally require more intelligent device operation. Devices that are not capable of supporting these extended capabilities provide a "not implemented" indication if access to those capabilities is requested.

R1-1.8.1 The following subsections describe device capabilities in order of increasing intelligence. A device's I/O direction is defined relative to the control application entity. Therefore, a sensor is an input, even though from the sensor's point of view it supplies output values.

R1-1.8.2 Polled input is the simplest sensor device requirement. All sensing devices should meet this requirement. In this mode of operation, a device only reports its value(s) when requested. This mode potentially provides the biggest burden on network bandwidth. However, it is the capability level that is most compatible with current control system architectures.

R1-1.8.3 Strobed output is the simplest actuator device requirement. All actuating devices should meet this requirement. This device only changes to a new state at the time of receipt of a specific message to do so.

R1-1.8.4 Periodic input is the capability to program the input device so that it sends its value(s) on a scheduled or periodic basis. Network bandwidth burden is reduced because it is not required to send a request each time an update for the input value is needed.

R1-1.8.4.1 This is also very compatible with current control architectures.

R1-1.8.5 Asynchronous input provides a capability for a sensing device to supply its value(s) when an event is detected. These events are usually programmed into the device. Examples of programmable events include threshold crossing of a value, value rate of change, measurement complete.

R1-1.8.5.1 Devices with this capability can significantly reduce network bandwidth burden, because they only need the network when some event has occurred. Equipment control architectures developed before 1990 may not be able to utilize this type of capability.

R1-1.8.6 Programmed output provides the capability for actuating devices to follow a programmable sequence of operations. For instance, an analog output could be given a ramp profile to follow as it moves between set points.

R1-1.8.6.1 This is another capability which can greatly reduce network bandwidth requirements. But, it is also a capability that 1990 vintage and earlier control systems may not be able to utilize easily.

R1-1.8.7 Devices with distributed processing capabilities are able to support features such as monitoring their health, providing diagnostics, and programmable preprocessing of data.

R1-1.8.7.1 These capabilities can have an impact on network burden, but more importantly may improve equipment reliability and maintainability. Again, this is a capability that is not readily utilized by control architectures developed prior to 1990.

R1-1.8.8 Devices with distributed control capabilities are capable of being programmed to create peer relationships with other devices on the network. Within these relationships, it is possible for one or more of the peers to control or regulate a subsystem within the equipment. For instance, a butterfly valve and manometer with these capabilities could be programmed to hold a particular pressure.

RELATED INFORMATION 2
INDEX FOR SENSOR/ACTUATOR STANDARDS

NOTE: This related information is not an official part of SEMI E54 and is not intended to modify or supercede the official standard. After approval of this document, publication of this Related Information was authorized by the committee chairs solely to aid in identifying the relationships between the current Sensor Bus standards and documents in process. Determination of the suitability of the material is solely the responsibility of the user.

R2-1 Scope

The table below is based on Figure 1 in SEMI E54.1, and is intended to show the relationships between standards that are currently published, as well as describe documents in process in SEMI Standards that, if approved, will be added to SEMI E54.

There are five categories:

Main Document
Templates
Specific Device Model
Common Device Model
Network Communication Standards

Standard titles with a designation number are published documents, and descriptors without designation numbers are documents in process.

Table 1 Sensor/Actuator Network (SAN) Standards

<table>
<tr><td colspan="3">SEMI E54, Sensor/Actuator Network (SAN) Standard</td></tr>
<tr><td colspan="3">Templates (How to Write Network Communications Standards (NCS) and Specific Device Models (SDM))</td></tr>
<tr><th>Specific Device Models</th><th>Common Device Models</th><th>Network Communications Standards</th></tr>
<tr><td rowspan="3">Mass Flow Controller SDM</td><td rowspan="3">SEMI E54.1, Standard for Sensor/Actuator Network Common Device Model</td><td>SEMI E54.4, Standard for SAN Communications for DeviceNet</td></tr>
<tr><td>SEMI E54.5, Standard for SAN Communications for the Smart Distributed System (SDS)</td></tr>
<tr><td>SEMI E54.6, Standard for SAN Communications for LONWorks</td></tr>
</table>

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E54.1-1000
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMON DEVICE MODEL

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on July 14, 2000. Initially available at www.semi.org August 2000; to be published October 2000. Originally published in 1996; previously published February 1999.

NOTE: This document was previously designated SEMI E54. Because this document is part of a suite of documents, its designation has been reassigned for ease of reference.

1 Purpose

This standard defines a model comprised of device objects which are common to all devices on a semiconductor equipment sensor/actuator communications network.

2 Scope

2.1 This document describes common device structure and behavior (i.e., the minimum data structure and behavior all devices must support to operate on the network). These devices may range from simple sensors and actuators through hosts, masters, or controllers.

2.2 The model specified in this document is used in conjunction with a sensor/actuator network specific device model which describes the data structure and behavior characteristic of the specific device. Together, these two models are sufficient to completely describe a device as it appears from the network interface.

2.3 This standard, together with a sensor/actuator network interoperability guideline, a sensor/actuator network communication specification, and one or more specific device model specifications, form a complete interoperability specification. The sensor/actuator network document architecture is shown in Figure 1.

2.4 To comply with this standard, a device must implement and support instances of the objects, object attributes, object services, and object behaviors identified in this document, unless explicitly stated otherwise.

3 Limitations

3.1 This standard is a companion to a suite of sensor/actuator network communication network specifications. Therefore, using portions of this standard that relate to network communications necessarily requires an understanding of the associated network specification.

3.2 As this document is a standard for a *common* device model, it does not contain any information (e.g., object, attribute, services, or behavioral descriptions) that relates to a specific device or device type.

3.3 While the standards depicted in Figure 1 are sufficient to completely describe a device as it appears from the network, they do not fully describe behavior of the device which is not visible from the network. Some of the behavior detail within standard objects is intentionally left to the manufacturer to define. This allows flexibility for product differentiation and creates room for technology evolution. Manufacturer-specific objects may be defined by the manufacturer as appropriate, but are by definition outside the scope of this standard.

3.4 This standard is compatible, but not compliant, with SEMI E39. This means that although this standard does not require compliance with SEMI E39, it is extensible such that implementations may be developed that are fully compliant with both standards. Note that the concepts and terminology of this standard are compatible with those of SEMI E39. However, SEMI E39 has specific requirements that are intended for higher level applications and thus are not applied to the Common Device Model.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

4.2 *Other Documents*

ISO 7498[1] — Basic Reference Model for Open Systems Interconnection

David Harel, "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8, 1987

James Rumbaugh, Michael Blaha, William Premerlani, Frederic Eddy, William Lorensen, Object-Oriented Modeling and Design, Englewood Cliffs, New Jersey: Prentice-Hall, 1991

1 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland. Available in the US from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY10036.

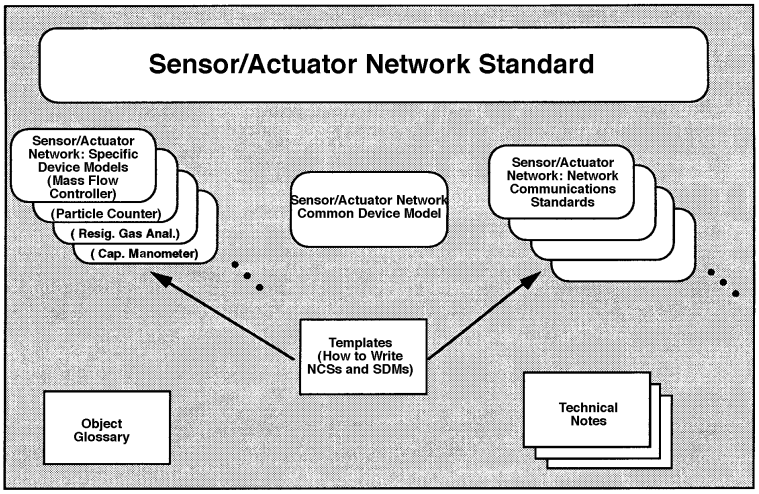

Figure 1
Sensor/Actuator Network-Related Documents

5 Terminology

Terminology may be reproduced here which is defined in other SEMI documents.

5.1 *Device Component Terminology*

5.1.1 *attribute* — Externally visible information concerning an object.

5.1.2 *behavior* — A specification of how an object acts. Actions result from different events the object detects, such as receiving service request, detecting internal faults, or elapsing timers.

5.1.3 *class* — A specific type or classification of objects.

5.1.4 *device* — A tangible thing consisting of: (1) at least one sensor and/or actuator and/or controller, (2) a communications controller which supports a single point of access to a network as specified in this document, and (3) interconnection and management hardware and software that provides for the consolidation of (1) and (2) into a system that has the capability to comply with the specification detailed in this document. Examples of devices are given in Figure 2.

5.1.5 *device model* — An abstraction of a device for the purpose of understanding it before building it or using it.

5.1.6 *embedded object* — An embedded object is similar in functionality or purpose to the object in which it is embedded, or supports the functionality of the object in which it is embedded. The embedding construct is utilized solely for purposes of documentation structure and understanding. As such, it does not imply any direct relationship, inheritance, similarity in structure, or connectivity in addressing scheme between the embedded object and the object in which it is embedded.

5.1.7 *instance* — A specific and real occurrence of an object.

5.1.8 *manufacturer* — In the context of this document, this refers to the manufacturer of the device.

5.1.9 *object* — An entity with a specific set of data and behaviors. Objects may be physical or conceptual. An object may be described in terms of its attributes, services it provides, and behavior it exhibits.

5.1.10 *service* — A function offered or supported by an object. A service consists of a sequence of service primitives, each described by a list of parameters. A service excludes definition of message structure and protocol.

5.1.11 *state diagram* — A means of representing state transitions, where the boxes represent states and the arrows represent transitions between states.

5.2 *Data Type Terminology* — Unless otherwise noted, data type terminology defined in SEMI E39 will be used in this document. The following terminology will also be used:

5.2.1 *Boolean (BOOL)* — A binary bit representing 0 and 1 corresponding to FALSE and TRUE or DISABLE and ENABLE respectively.

5.2.2 *byte* — A string of eight adjacent bits, interpreted as a unit and often representing a character.

5.2.3 *character* — A text symbol, letter, digit, or mark used to represent, control, or organize information that is one byte in length.

5.2.4 *character string* — A text string.

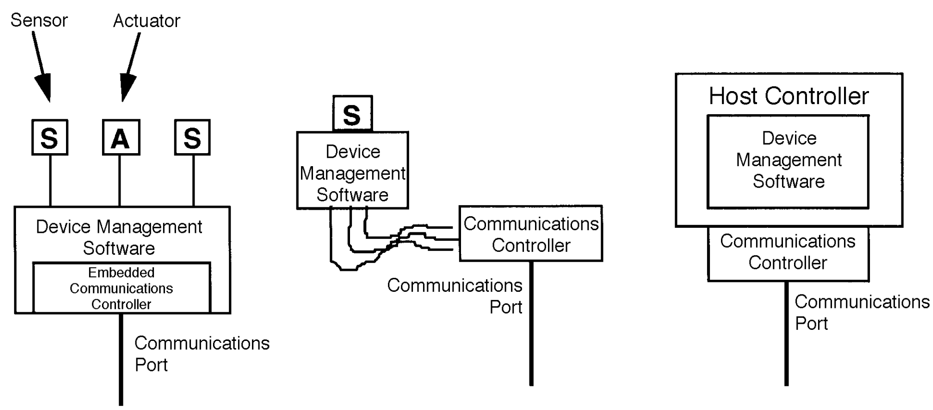

Figure 2
Examples of Devices

5.2.5 *data type* — An unsigned short integer formatted as an enumerated byte to specify attribute data format. The intended use of this attribute type is in cases where an attribute, or set of attributes, may be defined, allowing for more than one level of support (e.g., INT or REAL). The following values are defined:

0=INT

1=REAL

2=USINT

3=SINT

4=DINT

5=LINT

6=UINT

7=UDINT

8=ULINT

9=LREAL

10–99=reserved for CDM

100–199=reserved for SDMs

200–255=manufacturer-specified

5.2.6 *data units* — An unsigned integer enumerated to specify attribute data units. The intended use of this attribute type is in cases where an attribute, or set of attributes, may be defined, allowing for more than one unit's context. The values are defined in Appendix 1 of this document.

5.2.7 *date* — A data structure of four bytes used to represent a calendar date. Table 1 defines the format of the date data type.

Table 1 Date Format

Data #	*Description*	*Range*
0–1	Year	Unsigned Integer < 65,536
2	Month	Unsigned Integer (range of 1 to 12)
3	Day	Unsigned Integer (range of 1 to 31)

5.2.8 *Double Integer (DINT)* — An integer, four bytes long, in the range -2^{31} to $2^{31}-1$.

5.2.9 *enumerated byte* — A byte with assigned meaning to the values 0 through 255. May take on one of a limited set of possible values.

5.2.10 *full scale range* — The defined 100% value of an attribute in its assigned units. This value is not necessarily the maximum value for the attribute. As an example, the indicated flow attribute value may attain 120% of the full scale range.

5.2.11 *Last Valid Value (LVV)* — The most recent value successfully assigned to an attribute.

5.2.12 *Long Integer (LINT)* — An integer, eight bytes long, in the range -2^{63} to $2^{63}-1$.

5.2.13 *Long Real (LREAL)* — A double floating point number, 8 bytes long, as defined by IEEE 754.

5.2.14 *nibble* — A string of four adjacent binary bits.

5.2.15 *null character* — A byte with a value of zero.

5.2.16 *Real (REAL)* — A floating point number, 4 bytes long, as defined by IEEE 754.

5.2.17 *Short Integer (SINT)* — An integer, one byte long, in the range -128 to 127.

5.2.18 *Signed Integer (INT)* — An integer, 2 bytes long, in the range -32768 to 32767.

5.2.19 *text string* — A string of one byte characters.

5.2.20 *Unsigned Double Integer (UDINT)* — An unsigned integer, four bytes long, in the range 0 to 2^{32}-1.

5.2.21 *Unsigned Integer (UINT)* — An integer, 2 bytes long, in the range 0 to 65535.

5.2.22 *Unsigned Long Integer (ULINT)* — An unsigned integer, eight bytes long, in the range 0 to 2^{64}-1.

5.2.23 *Unsigned Short Integer (USINT)* — An integer, 1 byte long, in the range 0 to 255.

6 Conventions

6.1 *Harel State Model* — This document uses the Harel State Chart notation to describe the dynamic behavior of the objects defined. An overview of this notation is presented in an appendix of SEMI E30. The formal definition of this notation is presented in *Science of Computer Programming 8*, "Statecharts: A Visual Formalism for Complex Systems," by D. Harel, 1987.

Transition tables (referred to in this document as "state transition matrices") are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. Each transition table contains columns for Transition #, Current State, Trigger, New State, Action(s). The "trigger" (column 3) for the transition occurs while in the "current" state. The "actions" (column 5) include a combination of: 1) actions taken upon exit of the current state, 2) actions taken upon entry of the new state, and 3) actions taken which are most closely associated with the transition. No differentiation is made.

6.2 *OMT Object Information Model* — The object models are presented using the Object Modeling Technique developed by Rumbaugh, James, et al, in "Object-Oriented Modeling and Design," Prentice Hall, Englewood Cliffs, NJ, ©1991. Overviews of this notation are provided in an appendix of SEMI E39.

6.3 *Object Attribute Representation* — The object information models for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute	*Definition*	*Access*	*Rqmt*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	(see below)

The access column uses RO (Read Only) or RW (Read and Write) to indicate the access that users of Object Services have to the attribute. Note that, in this document, the access column is used only to indicate user access via the network; no indication is made as to local access as this level of specification is considered to be implementation-specific. Thus, in the context of this document, a RW attribute is a network-settable attribute (i.e., an attribute whose value can be altered from the network), while a RO attribute is a non-network-settable attribute.

A 'Y' or 'N' in the requirement (Rqmt) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

The Form column is used to indicate the format of the attribute.

6.4 *Service Message Representation*

6.4.1 *Service Resource Definition* — The service resource definition table defines the specific set of messages for a given service group, as shown in the following table:

Service	*Type*	*Description*
Message name	N or R	The intent of the service.

Type can be either Notification (N) or Request (R). Notification messages are initiated by the service provider. No response is expected. Request messages are initiated by the service user. Request messages ask for data or for an operation to be performed. Request messages expect a specific response (no presumption on the message content).

6.4.2 *Service Parameter Dictionary* — Each parameter should relate to either attributes from the object model or events of the dynamic model (Harel State Chart). All parameters to the services are listed in a single table or dictionary. The column headings for this parameter dictionary are as follows:

Parameter	*Form*	*Description*
Parameter X	Data type	A parameter

A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and the contents of the parameter.

The form column is used to indicate the type of data contained in the parameter and the possible values it may take on.

The description column describes the meaning of the parameter and interrelationships with other parameters.

6.4.2.1 *Service Message Definition* — There is a table showing the parameter detail for each service in which parameters are explicitly specified. The column headings for the service detail are as follows:

Parameter	*Req/Ind*	*Rsp/Cnf*	*Description*
Parameter X	(see below)	(see below)	A description of the service.

The columns labeled Req/Ind and Rsp/Cnf link the parameters to the direction of the message. The message sent by the initiator is called the "Request" (Req). The receiver terms the message the "Indication" (Ind). The receiver may then send a "Response" (Rsp), which the original sender terms the "Confirmation" (Cnf).

The request (Req/Ind) and response (Rsp/Cnf) entries can take on the following values:

"M" **Mandatory parameter** — Must be given a valid value.

"C" **Conditional parameter** — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of another parameter.

"U" **User-defined parameter**

"-" The parameter is not used.

"=" The entries M and C in the response can be modified with (=) to indicate that the value in the response must match the request.

7 Device High Level Structure

The high level object view of a device aggregation is shown in Figure 3. A device is depicted as consisting of a sensor/actuator/controller (SAC) object, a device manager (DM) object, and at least one active element object (i.e., sensor or actuator or controller object). Each of these objects by definition has attributes, services, and behavior. Note that the "Device" object is depicted in Figure 3 only for purposes of illustrating a high level view of the device and its component objects; in the context of this document, the "Device" object is not addressable, does not have addressable attributes or accessible services, and has no behavior defined.

This document defines in detail only the DM object. The SAC, Sensor, Actuator, and Controller objects are defined here only in terms of characteristics common to all devices. A complete definition of a SAC object includes an appropriate sensor/actuator network specific device model. This companion model could also complete the definition of sensor, actuator, and controller objects as appropriate to specify a device model.

7.1 *General Requirements* — Objects are defined in terms of their object name and instance identifier. Identifiers for all objects described in this document are summarized in Table 2. Note that these identifiers may be used for remote interrogation of an object instance via the sensor/actuator network (see appropriate sensor/actuator communications specification). Also note that, in Table 2, many of the objects specified in this document have exactly one instantiation per device.

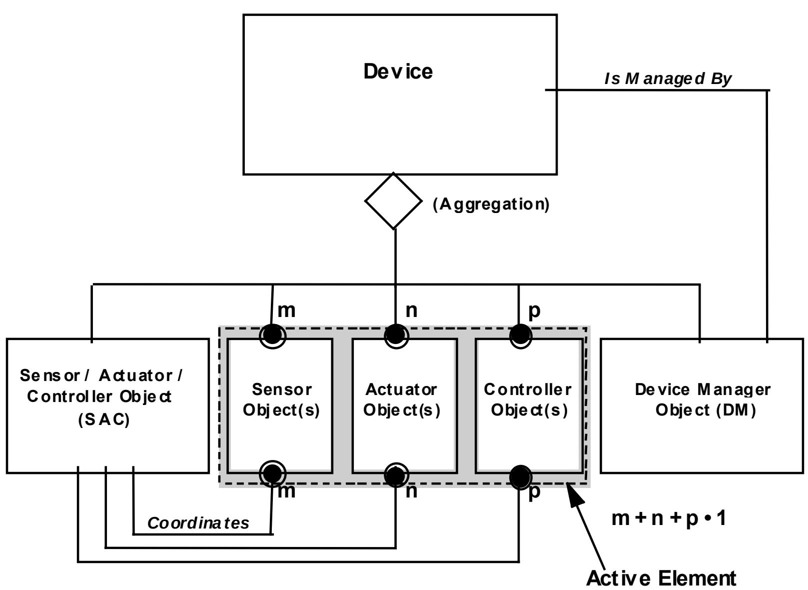

Figure 3
High Level Object View of a Device

Table 2 Device Objects and Identifiers

Object Name	*Object Identifier (tag)*	*Support Required in a Device*	*Comment*
Sensor/Actuator/Controller	SacI0*	Yes	Only one instance per device allowed.
Sensor	SenIn**	No	Zero or more instances per device allowed.***
Actuator	ActIn**	No	Zero or more instances per device allowed.***
Controller	CntIn**	No	Zero or more instances per device allowed.***
Device Manager	DmI0*	Yes	Only one instance per device allowed.

* Only one object instance per device; identifier uses “I0” to specify “instance zero.”

** “In” is used to indicate the instance number of the object; “n” is a non-negative integer.

*** The specification of the number of sensor, actuator, and/or controller object instances allowed per device may be further constrained by the appropriate sensor/actuator network specification.

The objects described in this document collectively define a device’s capabilities, including how it has been configured for network interoperability. The information in the attributes of these object instances must be accessible over the network and stored at the device.

Character strings described in this document have a prescribed maximum length. If the contents of the string are shorter than the prescribed length, the string must be terminated with the null character: a byte whose value is 00h. Note that this specification of null termination does not indicate that a sensor/actuator network protocol implementation communicating a character string over a network must send the null termination; the presentation of character string data over a network is sensor/actuator network communication protocol-specific.

7.2 *Sensor/Actuator/Controller (SAC) Object* — The SAC object is the device component responsible for coordinating the interaction of the device with the sensory/actuation/control environment. A view of the SAC object is shown in Figure 4. The SAC object coordinates operation of one or more sensor, actuator, and/or control object instances that collectively form the sensory/actuation/control portion of the device, so as to enable desired device behavior. For example, it could coordinate the operation of the device sensor, actuator, and/or control elements to enable device level data reporting or actuation, alarming detection and servicing, status reporting, device self-testing, device shutdown, etc. The number of sensor, actuator, and/or controller object instances allowed per device may be specified by the appropriate sensor/actuator network specific device model. An operating device shall contain exactly one instance of a SAC object.

The SAC object has embedded in it other objects that address specific tasks associated with coordinating the interaction of the device with the sensor/actuation/control environment. These objects are listed in Table 3. Note that although only one instance of the SAC object is allowed per device, a device can have multiple instances of embedded objects. These objects are described in Section 7.2.4.

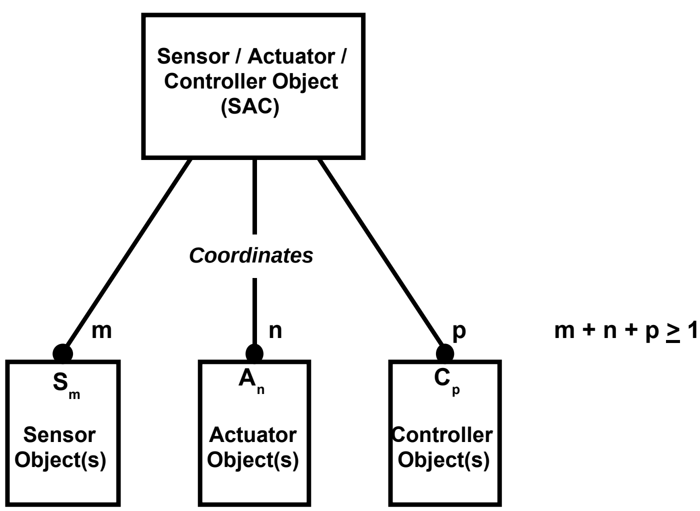

Figure 4
Detailed View of the Sensor/Actuator/Controller Object

Table 3 Objects Embedded in SAC Object and Identifiers

Object Name	*Object Identifier (tag)*	*Support Required in a Device*	*Comment*
Assembly	AsmIn*	No	Zero or more instances per device allowed.**
Local Link	LnkIn*	No	Zero or more instances per device allowed.**

* "In" is used to indicate the instance number of the object; "n" is a non-negative integer.

** The specification of the number of Assembly or Local Link object instances allowed per device may be further constrained by the appropriate sensor/actuator network specification.

7.2.1 *SAC Object Attributes* — All required and "common optional" SAC object attributes are listed in Table 4. Note that many of the attributes are in text "human-readable" forms. Information provided in this table includes, for each attribute: (1) an attribute identifier tag; (2) an indication of user access (via the network) to the attribute, (i.e., an indication of whether the attribute is network-settable); and (3) an attribute type. Required attributes must be supported in all SAC object instantiations. Optional attributes may or may not be supported; a further specification of the requirement of support for these optional attributes can be found in Section 7.2.3 and in an appropriate sensor/actuator network specific device model specification.

Table 4 SAC Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Last Calibration Date	SacA1	RW	No	date
Next Calibration Date	SacA2	RW	No	date
Expiration Timer	SacA3	RW	No	signed integer
Expiration Warning Enable	SacA4	RW	No*	Boolean
Run Hours	SacA5	R	No	unsigned integer
Reserved	SacA7-SacA64	—	—	Reserved for future expansion.

* The Expiration Warning Enable attribute is required if the Expiration Timer attribute is supported.

7.2.1.1 *Last Calibration Date* (Optional) — An attribute which identifies the date the device was last calibrated. The attribute is formatted as a date defined in Section 5.2.

7.2.1.2 *Next Calibration Date* (Optional) — An attribute which identifies the date the device is scheduled for the next calibration. The attribute is formatted as a date defined in Section 5.2.

7.2.1.3 *Expiration Timer* (Optional) — An attribute which identifies the number of run hours remaining until the next recommended calibration. The attribute is an unsigned integer with a resolution of 1 hour.

7.2.1.4 *Expiration Warning Enable* (Optional) — An attribute which specifies whether the calibration expiration timer will set a specific warning status bit in the exception status attribute of the DM object instance (specifically the "calibration expiration" exception bit — see Section 7.3.1.14).

The expiration warning enable attribute is Boolean and can take on one of the following values:

0 = Disable

1 = Enable

7.2.1.5 *Run Hours* (Optional) — An attribute which identifies the number of hours that the device has been powered ON. The attribute is an unsigned integer with a resolution of 1 hour.

7.2.1.6 *Initial and Default Values* — The initial and default values for relevant SAC attributes are given in Table 5:

Table 5 SAC Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Last Calibration Date	LVV	0,0,0*	
Next Calibration Date	LVV	0,0,0	
Expiration Timer	LVV	0	
Expiration Warning Enable	LVV	0	
Run Hours	LVV	0	

* Corresponding to year, month, and day; see Section 5.2.

7.2.2 *SAC Object Services* — All SAC object instances must provide the services listed in Table 6 (the SAC object is the "service provider" of these services). SAC services are identified with a service identifier of the form "SacSn", where "n" is a positive decimal number. SAC service identifiers SacS1 through SacS3 are used by this common device model standard. SAC service identifiers SacS4 through SacS32 are reserved.

Table 6 SAC Services

Service	*Service Identifier*	*Required*	*Type*	*Description*
Reset	SacS1	Yes	R	Used to place object in INITIALIZING state.
Abort	SacS2	Yes	R	Used to place object in ABORT state.
Recover	SacS3	Yes	R	Used to move object from ABORT state to RECOVERING state.
Get Attribute	SacS4	Yes	R	Used to read object attribute.
Set Attribute	SacS5	Yes	R	Used to modify object attribute.
Operate	SacS6	Yes	R	Used to move object to the OPERATING state from INITIALIZING or RECOVERING state.
Restore Default	SacS7	No	R	Used to restore object attributes to their default values.
Publish Attribute	SacS8	No	N	Used to proactively report an object attribute value.
	<SacS32	–	–	Reserved for future extensions of the CDM.

7.2.2.1 *Reset (Service Identifier: SacS1)* — Used to place the SAC object in its INITIALIZED state. The description of this state is device-specific. There are no parameters specified for this service.

7.2.2.2 *Abort (Service Identifier: SacS2)* — Used to place the SAC object in its ABORT state. The description of this state is device-specific. There are no parameters specified for this service.

7.2.2.3 *Recover (Service Identifier: SacS3)* — Used to move the SAC object from an ABORT state to its RECOVERED state. The description of this state is device-specific. There are no parameters specified for this service.

Additional services and/or service parameters may be provided by a SAC object that are device-specific and/or implementation-specific. These services may be Notification or Request type services (see Section 6.4.1). A complete definition of additional services and service parameters that are device-specific may be found in an appropriate sensor/actuator network specific device model specification.

7.2.2.4 *Get Attribute* — This service is used to read the value of an object instance attribute over the network. Table 7 describes the parameters specified for this service.

Table 7 SAC Object Get Attribute Parameter Definition

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Attribute ID	M	C	Network-Specific	Attribute Identifier of the attribute whose value is being requested.
Attribute Value	–	M	Context-Specific	Value of the attribute requested.

7.2.2.5 *Set Attribute* — This service is used to modify the value of an object instance attribute over the network which has been identified as modifiable. Table 8 describes the parameters specified for this service.

Table 8 SAC Object Set Attribute Parameter Definition

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Attribute ID	M	C	Network-Specific	Attribute Identifier of the attribute whose value is being modified.
Attribute Value	M	C	Context-Specific	Value of the attribute to modify.

7.2.2.6 *Operate* — This service is used to move the object instance to the OPERATING state from the INITIALIZING or RECOVERING state There are no parameters specified for this service. Operate requests are issued to all S, A, and C objects.

7.2.2.7 *Restore Default* (Optional) — This service is used to restore attributes of this object instance to their default values. Table 9 describes the parameters specified for this service. For Restore Default Conditions = 2, a Restore Default Condition = 1 request is issued to all S, A, and C objects.

Table 9 SAC Object Restore Default Parameter Definition

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Restore Conditions	M	C	byte, enumerated	0 = Restore specific attribute of this object 1 = Restore this object 2 = Restore all objects of this device
Attribute ID	C	C	Network-Specific	Attribute ID of the attribute whose value is being restored. This parameter is only used for Restore Conditions = 0.

7.2.2.8 *Publish Attribute* (Optional) — Used to proactively communicate a SAC object attribute. Table 10 describes parameters specified for this service.

Table 10 SAC Publish Attribute Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf**	*Description*
Attribute ID	M	–	Attribute Identifier of the attribute whose value is being reported.
Attribute Value	M	–	Value of attribute being reported.

*The utilization of a service response message and its format is outside the scope of this document.

7.2.3 *SAC Instance Behavior* — SAC object instance behavior that is common to all devices is illustrated in Figure 5. Associated states and state transitions are described in Tables 11 and 12. The following also applies to SAC object behavior:

A SAC object service may be requested internally by the SAC object.

Upon SAC object instantiation or upon receipt of a reset request, the SAC responds by entering or staying in its INITIALIZED state.

Upon receipt of an abort request, the SAC object responds by entering or staying in its ABORT state.

Upon receipt of a recover request, the SAC object responds by transitioning to its RECOVERED state if and only if it is currently in its ABORT state. Otherwise, it responds with an error indication.

Additional behavior may be exhibited by a SAC object that is device-specific. A complete definition of this additional SAC object behavior may be found in an appropriate sensor/actuator network specific device model specification.

All SAC services have the same behavior associated with invalid service requests unless otherwise indicated. Common service error responses are listed in Appendix 2.

If a Set Attribute request is received over the network for an attribute that is not network-settable, or if the value in the SetAttribute request is beyond the specified range allowed for the value of the specified attribute, the attribute value is not changed and an error service response is generated.

When the SAC object instance is INITIALIZED, all attributes are set to their appropriate initial values (as indicated in their associated object instance attribute descriptions). Initial values could correspond to those retrieved from the device's non-volatile memory and reflect, in large part, the values set in a previous NORMAL OPERATING state.

Additionally, whenever the SAC object instance enters the INITIALIZED state, it must issue a Reset service request to all Sensor, Actuator, and Controller object instances. Each object instance must then respond with a Pass or Fail response indication upon completion of its respective INITIALIZING application process. The SAC object instance must coordinate these responses in order to determine whether the device is qualified to enter the OPERATING state. If qualified, an Execute service request is issued to the DM object instance. If not qualified, an exception condition is reported to the DM object instance (see Section 7.3).

When the SAC object instance is recovering from an ABORT state, all attributes are set to their appropriate values (as determined by the associated object instance recovering application process defined by the manufacturer). Additionally, the SAC object instance must issue a Recover service request to all Sensor, Actuator, and Controller object instances. Each object instance must then respond with a Pass or Fail response indication upon completion of its respective recovering application process. The SAC object instance must coordinate these responses in order to determine whether the device is qualified to enter the OPERATING state. If qualified, an Execute service request is issued to the DM object instance. If not qualified, an exception condition is reported to the DM object instance.

The SAC object optionally includes an Expiration Timer attribute. The value of this attribute is decremented at a rate described by the "ExpirationTimer" attribute format definition. Whenever the "ExpirationTimer" attribute is less than or equal to zero, a warning exception condition exists and is reported to the DM object instance (utilizing the PublishAttribute service) provided the "ExpirationWarningEnable" attribute is set to Enable. When the "ExpirationWarningEnable" attribute is set to Disable, the "ExpirationTimer" attribute continues to decrement; however, a warning exception condition will not be reported to the DM object instance.

The "ExpirationTimer" attribute will continue to be decremented to values less than zero. Therefore, a negative number indicates an elapsed time past expiration. When this attribute reaches its most negative value, it maintains this value and no longer decrements.

The "ExpirationTimer" is also maintained by the object while in the ABORT state. In the RECOVERING state, the current status of the device is evaluated and any exception conditions that exist are reported to the DM object instance.

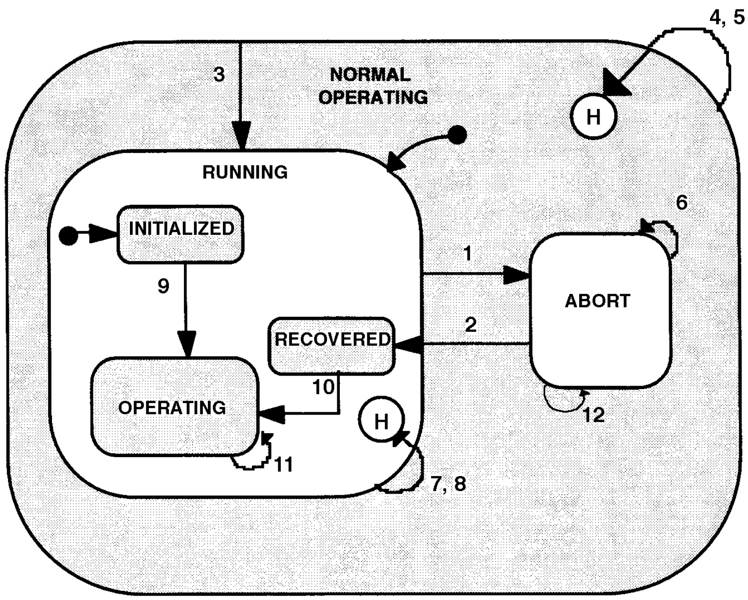

Figure 5
SAC Object Instance Behavior*

NOTE: Only generic behavior is indicated in this chart. A complete state chart necessarily requires the inclusion of device-specific behavior.

* Transitions 4 through 8, 11, and 12 are recursive (i.e., the New State is the same as the Current State (including all nested sub-states)).

Table 11 SAC Object Instance Behavior State Description

State	*Description*
NORMAL OPERATING	Object instance exists. Object services can be processed.
RUNNING	This is the entry sub-state to NORMAL OPERATING. Object instance is not in its ABORT state.
INITIALIZED	This is the entry sub-state to NORMAL OPERATING and RUNNING. Object instance exists and has been initialized. All attributes set to appropriate initial values (as indicated in an appropriate sensor/actuator network specific device model specification).
RECOVERED	Object instance is in an abort recovered state.
OPERATING	This represents the entire collection of sub-states within RUNNING except INITIALIZED and RECOVERED. The further delineation of this sub-state and transition into this sub-state is outside the scope of this document.
ABORT	Object instance is in an aborted state; a detailed description of this state is outside the scope of this document.

Table 12 SAC Object Instance Behavior State Transition Matrix*, **

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	RUNNING	Abort request.	ABORT	Abort. Abort response.	ABORT state is device-specific.
2	ABORT	Recover request.	RECOVERED	Recover. Recover response.	RECOVERED state is device-specific.
3	NORMAL OPERATING	Reset request.	RUNNING	Reset. Reset response.	Valid for all sub-states of NORMAL OPERATING. Move to RUNNING/INITIALIZED.
4	NORMAL OPERATING	Invalid service request.	NORMAL OPERATING	Error response.	Valid for all substates of NORMAL OPERATING.

5	NORMAL OPERATING	GetAttribute, SetAttribute, or RestoreDefault request.	NORMAL OPERATING	Get or Set appropriate attribute or restore defaults.	Valid for all substrates of NORMAL OPERATING.
6	ABORT	Abort request, Operate request.	ABORT	Error response.	Invalid request in this state.
7	RUNNING	Recover request.	RUNNING	Error response.	Recover service can only be invoked while in ABORT state.
8	RUNNING	PublishAttribute.	RUNNING	Attribute identified by attribute ID in PublishAttribute service is published.	Notification service.
9	INITIALIZED	Operate request or Device-specific.	OPERATING	Device-specific.	Behavior associated with this transition may be further specified in an appropriate sensor/actuator network specific device model specification.
10	RECOVERED	Operate request or Device-specific.	OPERATING	Device-specific.	Behavior associated with this transition may be further specified in an appropriate sensor/actuator network specific device model specification.
11	OPERATING	Operate request.	OPERATING	Error response.	Invalid request in OPERATING state.
12	ABORT	PublishAttribute.	ABORT	None.	Attributes cannot be published while in ABORT state.

* Transitions 4 through 8, 11, and 12 are recursive (i.e., the New State is the same as the Current State (including all nested sub-states)).

** Note: Only generic behavior is indicated in this table.

7.2.4 *Objects Embedded in SAC Object* — The object types that are embedded in the SAC object are listed in Table 3. The structure and behavior of instances of these object types are detailed in the remainder of this section.

7.2.4.1 *Assembly Object* — Assembly object instances may be used to provide a mechanism for grouping more than one attribute from one or more object instances in a device into a single data structure for communication over the network.

7.2.4.1.1 *Assembly Object Attributes* — All required and "common optional" Assembly object attributes are listed in Table 13.

Table 13 Assembly Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Data	AsmA1	Context-Specific	Yes	Context-Specific

7.2.4.1.1.1 *Data* — An attribute which contains the assembled data. The structure of this data is context-specific.

7.2.4.1.2 *Assembly Object Services* — The Assembly object instance provides two services: GetAttribute and SetAttribute.

7.2.4.1.2.1 *Get Attribute* — This service is used to read the value of an object instance attribute over the network. Table 14 describes the parameters specified for this service.

Table 14 Assembly Object Get Attribute Parameter Definition

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Attribute ID	M	C	Network-Specific	Attribute Identifier of the attribute whose value is being requested.
Attribute Value	—	M	Context-Specific	Value of the attribute requested.

7.2.4.1.2.2 *Set Attribute* — This service is used to modify the value of an object instance attribute over the network which has been identified as modifiable. Table 15 describes the parameters specified for this service.

Table 15 Assembly Object Set Attribute Parameter Definition

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Attribute ID	M	C, =	Network-Specific	Attribute Identifier of attribute whose value is to be modified. Inclusion of Attribute in Rsp/Conf. is optional.
Attribute Value	M	C	Context-Specific	Value to which the attribute is to be modified. Inclusion of Attribute in Rsp/Conf. is optional. Conditions under which the value may differ from that supplied in the associated Req/Ind. message (e.g., negative response) are not defined in this document.

Additional services and/or service parameters may be provided by an Assembly object instance that are device-specific and/or implementation-specific. These services may be Notification or Request type services (see Section 6.4.1). A complete definition of additional services and service parameters that are device-specific may be found in an appropriate sensor/actuator network specific device model specification.

7.2.4.1.3 *Assembly Object Behavior* — The behavior exhibited by the Assembly object instance is in support of the GetAttribute and SetAttribute services. That is, when a GetAttribute service request is received for the attribute "Data", the response contains the "Data" attribute value. Similarly, when a SetAttribute service request is received for the attribute "Data", the value of "Data" is modified, if indeed the attribute is modifiable, and a successful service response is returned; otherwise, a service not successful is returned.

7.2.4.2 *Local Link Object* — Local Link object instances may be used to "link" an attribute of one object instance to an attribute of another object instance.

7.2.4.2.1 *Local Link Object Attributes* — All required and "common optional" Local Link object attributes are listed in Table 16.

Table 16 Local Link Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Source Object Class	LnkA1	Context-Specific	N	Context-Specific
Source Object Instance	LnkA2	Context-Specific	N	Context-Specific
Source Object Attribute	LnkA3	Context-Specific	Y	Context-Specific
Destination Object Class	LnkA4	Context-Specific	N	Context-Specific
Destination Object Instance	LnkA5	Context-Specific	N	Context-Specific
Destination Object Attribute	LnkA6	Context-Specific	Y	Context-Specific
Commit	LnkA7	Context-Specific	N	Boolean

7.2.4.2.1.1 *Source Object Class* — Where applicable, the class of the object instance from which the source attribute is to be linked.

7.2.4.2.1.2 *Source Object Instance* — The instance number of the object from which the source attribute is to be linked.

7.2.4.2.1.3 *Source Object Attribute* — The attribute ID of the source attribute to be linked.

7.2.4.2.1.4 *Destination Object Class* — Where applicable, the class of the object instance to which the destination attribute is to be linked.

7.2.4.2.1.5 *Destination Object Instance* — The instance number of the object to which the destination attribute is to be linked.

7.2.4.2.1.6 *Destination Object Attribute* — The attribute ID of the destination attribute to be linked.

7.2.4.2.1.7 *Commit* — An attribute that indicates whether the Link object will perform the link function (the link function is described in Section 7.2.4.2.3). When this attribute is FALSE, the object cannot perform the link function.

7.2.4.2.2 *Local Link Object Services* — There are no common Local Link object services specified. Services and service parameters may be provided by a Local Link object instance that are device-specific and/or implementation-specific. These services may be Notification or Request type services (see Section 6.4.1). A complete definition of additional services and service parameters that are device-specific may be found in an appropriate sensor/actuator network specific device model specification.

7.2.4.2.3 *Local Link Object Behavior* — Local Link object instance behavior common to all instances is as follows. When instantiated, this object performs the link function. That is, it first uses the GetAttribute service capability of the source object instance identified by the Source Object Instance and (possibly) Source Object Class attributes to retrieve the attribute value of the attribute identified by the Source Object Attribute. If the Commit attribute value is TRUE, the object then uses the SetAttribute service capability of the destination object instance identified by the Destination Object Instance and (possibly) Destination Object Class attributes to set the attribute value of the attribute identified by Destination Object Attribute to the (retrieved) value of Source Object Attribute. The object shall also perform the link function any time the Commit attribute value transitions to TRUE. The object shall not write to the destination object instance whenever the value of the Commit attribute is set to FALSE. Issues such as frequency of this link update behavior (while the Commit attribute is set to TRUE, or when the Commit attribute does not exist), type matching of Source and Destination attributes, etc., are beyond the scope of this document.

7.3 *Device Manager (DM) Object* — The DM object is the device component responsible for managing and consolidating the device operation. The DM object houses information about the device (e.g., serial number, device type) so that the device may be uniquely identified remotely via a sensor/actuator network. The DM object is also responsible for providing details of the device status. As such, the responsibility of the DM object includes managing the reporting of exceptions to normal processing as alarms or warnings. Note that it is outside the scope of this document to specify the detailed conditions which initiate alarms and warnings. Exception handling that is common to all devices on the network is described here. This behavior and structure may be extended to handle exceptions which are specific to certain devices or are proprietary to individual manufacturers. Extensions for specific devices would be described in a sensor/actuator network specific device model for those devices.

A device shall contain exactly one instantiation of a DM object.

7.3.1 *DM Object Attributes* — All required and "common optional" DM object attributes are listed in Table 17. Note that many of the attributes are in text "human-readable" forms. Information provided in this table includes, for each attribute: (1) an attribute identifier tag; (2) an indication of user "write" access (via the network) to the attribute, (i.e., an indication of whether the attribute is network-settable); and (3) an attribute type and maximum length. (Note that in many cases it may be desirable to limit the length of these attributes.) Required attributes must be supported in all DM object instantiations. Optional attributes may or may not be supported; a further specification of the requirement of support for these optional attributes can be found in Section 7.3.3 and in an appropriate sensor/actuator network specific device model specification. DM attributes are identified with an attribute identifier of the form "DmAn" where "n" is a positive decimal number. DM attribute identifiers DmA1 through DmA14 are used in this common device model standard. DM attribute identifier numbers DmA15 through DmA64 are reserved.

Table 17 Device Manager Instance Attributes*

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Device Type	DmA1	RO	Y	Text, 8 characters maximum
Standard Revision Level	DmA2	RO	Y	Text, 10 characters maximum
Device Manufacturer Identifier	DmA3	RO	Y	Text, 20 characters maximum
Manufacturer Model Number	DmA4	RO	Y	Text, 20 characters maximum
Software or Firmware Revision Level	DmA5	RO	Y	Text, 8 characters maximum
Hardware Revision Level	DmA6	RO	Y	Text, 8 characters maximum
Serial Number (optional)	DmA7	RO	N	Text, 30 characters maximum
Device Configuration (optional)	DmA8	RO	N	Text, 50 characters maximum
Device Status	DmA9	RO	Y	unsigned integer, enumerated, see text
Reporting Mode	DmA10	RW	Y	Formatted byte, see text
Exception Status Report Interval (optional)	DmA11	RW	N	unsigned integer, < 65,536

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Exception Status	DmA12	RO	Y	Formatted byte, see text
Exception Detail Alarm (optional)	DmA13	—	N	Structure of
Common Exception Detail	—	—	—	Structure of
Size	—	RO	—	unsigned integer, < 256
Detail	—	RO	—	Ordered list of bytes, see text
Device Exception Detail	—	—	—	Structure of
Size	—	RO	—	unsigned integer, < 256
Detail	—	RO	—	Ordered list of bytes, see text
Manufacturer Exception Detail	—	—	—	Structure of
Size	—	RO	—	unsigned integer, < 256
Detail	—	RO	—	Ordered list of bytes, see text
Exception Detail Warning (Optional)	DmA14	***	N	Structure of***
Visual Indicator	DmA15	RW	N	Byte, enumerated
Alarm Enable	DmA16	RW	N	Boolean
Warning Enable	DmA17	RW	N	Boolean
Exception Detail Type	DmA18	RW	N	Byte, enumerated
Exception Detail Alarm Queue	DmA19	R	N	Ordered list of type Exception Detail Alarm.
Exception Detail Warning Queue	DmA20	R	N	Ordered list of type Exception Detail Warning.
Date and Time	DmA21	RW	N	See Section 7.3.1.23
Date and Time Type	DmA22	RW	N	Enumerated USINT
Reserved for CDM	< DmA32	—	—	Reserved for future CDM DM attribute definitions.

* A “Definition” column is not included. For attribute definitions, see text.

** A value of 00 indicates that this timer is disabled.

*** Same as Exception Detail Alarm.

7.3.1.1 *Device Type* — An attribute which identifies the type of the device on the sensor/actuator network. It is formatted as a text string with a maximum length of 8 characters. The exact content may be defined in an appropriate sensor/actuator network specific device model specification. For example, “MFC” = mass flow controller, “CDG” = capacitance diaphragm gauge.

7.3.1.2 *Standard Revision Level* — An attribute which identifies the most recent version of the sensor/actuator network specific device model to which the device adheres. It is formatted as a text string with a maximum length of 9 characters as “ENNNNNNYY,” where “E” is a constant defined by SEMI, “NNNNNN” is the number of the standard, and “YY” is the last two digits of the year in which the standard/revision was published. If there is no relevant standard or the device is not compliant to the standard, then “NNNNNN” is zero length and “YY” is set to “00” (thus, the attribute is set to “E00”).

7.3.1.3 *Device Manufacturer Identifier* — An attribute which designates the manufacturer of the device. Each manufacturer is responsible for defining this variable for their products in a way which will be unique to that manufacturer and which must be the same for all devices they provide. Formatted as a text string with a maximum length of 20 characters, it will usually be the company name, as in “Acme Instrument Co.”

7.3.1.4 *Manufacturer Model Number* — An attribute which designates the basic model identification number, defined by the manufacturer. It is formatted as a text string with a maximum length of 20 characters.

7.3.1.5 *Device Software or Firmware Revision Level* — An attribute which designates the version of microprocessor code which is contained in the device, defined by the manufacturer. It is formatted as a text string with a maximum length of 5 characters.

7.3.1.6 *Hardware Revision Level* — An attribute which designates the version of the device, excluding the microprocessor code, defined by the manufacturer. It is formatted as a text string with a maximum length of 5 characters.

7.3.1.7 *Serial Number (optional)* — An attribute which designates the number defined and assigned by the manufacturer that uniquely identifies each individual device produced. It is formatted as a text string with a maximum length of 30 characters.

7.3.1.8 *Device Configuration (optional)* — An attribute which designates a manufacturer-defined device configuration (beyond model number). It is formatted as a text string with a maximum length of 50 characters.

7.3.1.9 *Device Status* — An attribute which designates the state of the DM object. The attribute (unsigned integer) values and corresponding object states specified by this attribute are enumerated in Table 18.

Table 18 Device Status Attribute Values

Attribute Value	*DM Object State*
0	Unknown
1	INITIALIZED/SELF TESTING
2	IDLE
3	SELF TEST EXCEPTION
4	EXECUTING
5	ABORT FROM IDLE OR EXECUTING
6	ABORT FROM INITIALIZED/SELF TESTING OR SELF TEST EXCEPTION
7 – 255	Reserved

This attribute is set and updated internally by the DM object as part of the object behavior associated with transition between the various states (see Section 7.3.3 and Figure 6).

7.3.1.10 *Reporting Mode* — A network-settable attribute defined as a single byte containing two nibbles: A low nibble (bits 0 – 3) and a high nibble (bits 4 – 7). The high nibble contains the value for alarm conditions. The low nibble contains the value for warning conditions. The value assigned to each nibble indicates how the alarm/warning status variable is to be reported. The possible attribute values and corresponding reporting modes specified by this attribute are enumerated in Table 19.

Table 19 Reporting Mode Attribute Values for Alarms and Warnings

Reporting Mode	*Attribute High Nibble Value (Alarm)*	*Attribute Low Nibble Value (Warning)*
Request	0	0
RequestLatched (optional)	1	1
EventTriggeredOn (optional)	2	2
EventTriggeredOn/Off (optional)	3	3
TimeTriggered (optional)	4	4
EventOnOrTimeTriggered (optional)	5	5
EventOn/OffOrTimeTriggered (optional)	6	6

The behavior of the DM object associated with this attribute and each of these reporting modes is described in Section 7.3.3.

7.3.1.11 *Exception Status Report Interval (optional)* — A network-settable attribute which specifies the time interval for periodic exception status reporting (when a time-triggered reporting mode is indicated, see definition of Reporting Mode attribute and Section 7.3.3). It is formatted as an unsigned integer whose least significant bit corresponds to a value of 1/100 second. The requirement to store this attribute in non-volatile memory (so that the value upon “power-up” is the last value active) is device-specific. Note that a value of 0.00 indicates that this timer, and thus time-triggered exception reporting, is not enabled (see also Section 7.3.3).

7.3.1.12 *Exception Status* — A single-byte attribute whose value indicates the status of the alarms and warnings for the device (see Table 19). This indication may be provided in one of two methods: Basic or Expanded. In the Basic method, bit seven of the Exception Status attribute is set to zero; all exceptions are reported exclusively through communication of this Exception Status attribute. The format of bits zero through six in this mode is device-specific; the format may be further specified in an appropriate sensor/actuator network specific device model specification; if it is not specified, then the format of bits zero through six is equivalent to that specified in the expanded mode. In the Expanded method, bit seven of Exception Status attribute is set to one; exceptions are reported through the communication of this Exception Status attribute, formatted as specified in Table 20, and exception detail attributes as indicated by the Exception Status attribute.

Table 20 Exception Status Attribute Value*

	Exception Status Bit Map, Bit 7 set to 0	*Exception Status Bit Map, Bit 7 set to 1*
bit	*Function*	*Function*
0	Device-Specific	ALARM/device-common**
1	See sensor/actuator network specific device model for further specification	ALARM/device-specific
2		ALARM/manufacturer-specific
3		reserved
4		WARNING/device-common**
5		WARNING/device-specific
6		WARNING/manufacturer-specific
7	0 == Basic Method	1 == Expanded Method

* Behavior associated with the reporting of exception status attribute values is described in Section 7.3.3.

** The alarm or warning is not specific to the device type or device type manufacturer.

7.3.1.13 *Exception Detail Alarm and Exception Detail Warning (optional)* — Attributes that relate the detailed status of the alarms or warnings associated with the device. Each attribute is a structure containing three members; these three members respectively relate the detailed status of exceptions that are device-common (i.e., not device-specific), device-specific but not manufacturer-specific, and manufacturer-specific. Each of the three structure members is defined as a structure containing an ordered list (i.e., array) of bytes of length SIZE, and an unsigned integer whose value is SIZE. Each of the bytes in each array has a specific mapping. This mapping is formatted as 8 bits representing 8 independent conditions, whereas a value of 1 indicates that the condition is set (or present), and a value of 0 indicates that the condition is cleared (or not present). Note that if a device does not support an exception detail, the corresponding bit is never set. The bitmaps for alarms and warnings in the corresponding attributes are structured in parallel so that a condition may have either alarm or warning set, depending on severity. If a condition inherently cannot be both alarm and warning, then the parallel bit position corresponding to the other state will remain “0.”

The existence of an exception detail variable structure is dependent on the value of the Exception Status Attribute; the existence of an exception detail variable structure is only required if bit seven of the Exception Status attribute is set to 1 (indicating Expanded mode reporting) and the bit (among bits zero through six) of the Exception Status attribute corresponding to the particular exception type is also set to 1 (see Table 20).

7.3.1.14 *Common Exception Detail (optional)* — This structure relates exception conditions (i.e., alarms or warnings) which are common to all devices on the network. The Detail element of the structure is an ordered list (i.e., array) of bytes of length [SIZE] which is the value of the structure element Size. For each byte in the Detail field, all bits which are not identified are reserved for future standardization. The first byte in this attribute is CommonExceptionDetail[0]. Additional exception details, if provided, are named CommonExceptionDetail[1], CommonException Detail[SIZE]. The specific exception associated with each of the bitmaps is given in Table 21. The criteria details for each exception condition are outside the scope of this document.

Table 21 Common Exception Detail Attribute Value

	*Common Exception Detail**
bit	*Detail[0]*
0	internal diagnostic exception
1	microprocessor exception
2	EPROM exception
3	EEPROM exception
4	RAM exception
5	communications exception
6	internal real-time exception
7	calibration expiration

	*Common Exception Detail**
bit	*Detail[1]*
0	power supply overcurrent
1	reserved power supply
2	power supply output voltage
3	power supply input voltage
4	routine maintenance due
5	notify manufacturer
6	reset exception
7	reserved

* Note that if a device does not support an exception detail, the corresponding bit is never set.

7.3.1.15 *Device Exception Detail (optional)* — This structure, similar in form to Common Exception Detail, relates exception conditions which are specific to individual devices on the network and are defined in their respective device model documents. The Detail element of the structure is an ordered list (i.e., array) of bytes of length [SIZE] which is the value of the structure element size. For a detailed description of this attribute, consult the appropriate specific device model documentation.

7.3.1.16 *Manufacturer Exception Detail (optional)* — This structure, similar in form to Common Exception Detail, relates exception conditions which are specific to the manufacturers of individual devices on the network and are defined by them in their product documentation. The Detail element of the structure is an ordered list (i.e., array) of bytes of length [SIZE] which is the value of the structure element size. For a detailed description of this attribute, consult the appropriate specific device manufacturer documentation.

Additional attributes may be supported by a DM object that are device-specific. A complete definition of any additional attributes may be found in an appropriate sensor/actuator network specific device model specification.

7.3.1.17 *VisualIndicator* (Optional) — An attribute which defines the behavior of a visual indicator allowing the device to be visually located. This attribute is an enumerated byte that can take on one of the following values:

0 = Visual Indicator OFF

1 = Visual Indicator ON

2–63 = Reserved

64–255 = Manufacturer-Specified

For values visual indicator OFF and visual indicator ON, the visual indicator is defined to be a Light Emitting Diode (LED). When the value is visual indicator ON, the device is expected to flash the LED at a frequency of approximately 0.5 to 1.5 Hz at a duty cycle of approximately 30 to 70 percent. The location and labeling of the LED are manufacturer-specified.

7.3.1.18 *AlarmEnable* (Optional) — An attribute which defines whether or not the object will report alarms (as indicated by the ReportingMode, ExceptionStatus, ExceptionDetailType, and ExceptionDetailAlarm attributes). When this attribute is set to TRUE, then alarming is enabled. When this attribute is set to FALSE, all DM exception attributes are set and maintained at values that indicate a no alarm state. Thus bits 0 through 2 of the ExceptionStatus attribute are set and maintained at zero, and any ExceptionDetailAlarm attribute bytes are set and maintained at a value of zero.

7.3.1.19 *WarningEnable* (Optional) — An attribute which defines whether or not the object will report warnings (as indicated by the ReportingMode, ExceptionStatus, ExceptionDetailType, and ExceptionDetailWarning attributes). When this attribute is set to TRUE, then warning exception reporting is enabled. If this attribute is set to FALSE, all DM exception attributes are set and maintained at values that indicate a no warning state. Thus, bits 4 through 6 of the ExceptionStatus attribute are set and maintained at zero, and any ExceptionDetailWarning attribute bytes are set and maintained at a value of zero.

7.3.1.20 *ExceptionDetailType* (Optional) — An attribute consisting of two enumerated nibbles that designate the method of alarm and warning detail reporting respectively that is supported. The possible attribute values and corresponding reporting mode support indications are enumerated in Table 22. Note that if this attribute is not supported, the reporting mode is either zero (basic) or one (expanded) as indicated in bit seven of the ExceptionStatus attribute.

Table 22 ExceptionDetailType Attribute Values for Alarm and Warning Reporting Methods

Reporting Method	*Attribute High Nibble Value (Alarm)*	*Attribute Low Nibble Value (Warning)*
Basic	0	0
Expanded	1	1
Queued	2	2
Reserved for Future Extension of CDM	3 – 15	3 – 15

7.3.1.21 *ExceptionDetailAlarmQueue* (Optional) — An attribute consisting of an ordered list of alarm events; the data structure of the individual alarm events (i.e., queue elements) is determined by the values of the ExceptionStatus attribute; if bit 7 of the ExceptionStatus attribute indicates a Basic Mode reporting data format then each queue element is of the same data type as ExceptionStatus; if bit 7 of the ExceptionStatus attribute indicates an Expanded Mode reporting data format then each queue element is of the same data type as ExceptionDetail (Alarm/Warning). The behavior of this queue in storing and reporting alarms is described in Section 7.3.3.

7.3.1.22 *ExceptionDetailWarningQueue* (Optional) — An attribute consisting of an ordered list of warning events; the data structure is determined as described in Section 7.3.1.21. The behavior of this queue in storing and reporting warnings is described in Section 7.3.3.

7.3.1.23 *Date and Time* — A structure that relates the current time as perceived by the device. The form of the structure depends on the value of the *Data and Time Type* attribute as follows:

Date and Time Type	*Date and Time Structure*	*Semantics*
0 [default]	Struct of: UDINT UINT	{*Standard Time and Date*} (6 Bytes) Number of milliseconds since midnight Number of days since 01 January, 1972
1	Struct of: UDINT UINT INT	{*Standard Time and Date with Offset*} (8 Bytes) Number of milliseconds since midnight Number of days since 01 January, 1972 Number of minutes displacement from the Greenwich Meridian
2	Struct of: LINT	{*Universal Time Coordinated* (UTC)} (8 Bytes) Number of 100 nanoseconds since 15 October, 1582, 00:00:00
3	Struct of: LINT INT	{*UTC with Time Displacement Factor*} (10 Bytes) Number of 100 nanoseconds since 15 October, 1582, 00:00:00 Number of minutes displacement from the Greenwich Meridian
4 - 63	Reserved	
64 - 127	Specific Device Model definitions as required	
128 - 255	Manufacturer specified as required	

7.3.1.23.1 If the *Date and Time Type* attribute is not supported, the default value of zero (0) is assumed.

7.3.1.23.2 The *Standard Time and Date* (Type 0) uses 32 bits to represent the number of milliseconds since midnight followed by 16 bits to represent the number of days since 01 January, 1972. The reference for this format is either Greenwich Mean Time or Local Time as defined by the user. This format has a range of 01 January, 1972 to 06 June, 2151.

7.3.1.23.3 The *Standard Time and Date with Offset* (Type 1) uses the above format followed by 16 bits to represent the number of minutes displacement from the Greenwich Meridian. Meridians to the East are positive, while those to the West are negative.

7.3.1.23.4 The *Universal Time Coordinated* (UTC) (Type 2) is based on the format used by the WWV radio station of NIST. It uses 64 bits to represent the number of 100 nanoseconds since 15 October, 1582, 00:00:00. The reference for this format is always Greenwich Mean Time. This format has an approximate range of BC 27,000 to AD 30,000.

7.3.1.23.5 The *UTC with Time Displacement Factor* (TDF) (Type 3) uses the above format followed by 16 bits to represent the number of minutes displacement from the Greenwich Meridian. Meridians to the East are positive, while those to the West are negative.

7.3.2 *DM Object Services* — All DM object instances must provide the services listed in Table 23. (The DM object is the "service provider" of these services.) Note that all of these services are Request services, with the exception of the PublishAttribute service (which is a notification service). DM services are identified with a service identifier of the form "DmSn", where "n" is a positive decimal number. Dm service identifiers DmS1 through DmS8 are used by this common device model standard. DM service identifiers DmS9 through DmS32 are reserved. Service parameters that are specified in this standard are summarized in Table 24.

Table 23 DM Object Service Resource Definition

Service	*Service Identifier*	*Required*	*Type*	*Description*
Reset	DmS1	Y	R	Used to place object in INITIALIZED state.
Abort	DmS2	Y	R	Used to place object in ABORT state.
Recover	DmS3	Y	R	Used to move object from ABORT state to RECOVERED state.
GetAttribute	DmS4	Y	R	Used to read object attribute.
SetAttribute	DmS5	Y	R	Used to modify object attribute.
Execute	DmS6	Y	R	Used to move object from IDLE state to EXECUTING state.
PerformDiagnostics	DmS7	Y	R	Used to instruct object to perform diagnostic test.
PublishAttribute	DmS8	N	N	Used to proactively report exception status attribute.
Lock	DmS9	N	R	Used to restrict access to READ only attributes.
Unlock	DmS10	N	R	Used to make READ only attributes modifiable.
Get Exception Queue	DmS11	N	R	Used to retrieve all, or a specified number of, exception events from the front of the ExceptionDetailAlarm/WarningQueue.
Clear Exception Queue	DmS12	N	R	Used to clear all exception events from the ExceptionDetail Alarm or WarningQueue.
Reserved by CDM	DmS13 – DmS32	—	—	Reserved for CDM expansion.

Table 24 DM Object Service Parameter Dictionary

Parameter	*Form*	*Description*
AttributeID	Enumerated	DM object attribute identifier (see Table 17)
AttributeValue	Context-specific (see Table 17)	Value of DM object attribute.
TestID	Non-negative integer, < 256	Type and possibly detail of diagnostic test to be performed.

A detailed description of these services follows.

7.3.2.1 *Reset (Service Identifier: DmS1)* — Used to place the DM object in its INITIALIZED state. There are no parameters specified for this service.

7.3.2.2 *Abort (Service Identifier: DmS2)* — Used to place the DM object in its ABORT state. There are no parameters specified for this service.

7.3.2.3 *Recover (Service Identifier: DmS3)* — Used to move the DM object from its ABORT state to a recovered state (which is the IDLE state for this object). There are no parameters specified for this service.

7.3.2.4 *GetAttribute (Service Identifier: DmS4)* — Used to read a DM object attribute.

GetAttribute Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
AttributeID	M	C**, =	Attribute Identifier of attribute whose value is being requested. Inclusion of attribute in Rsp/Conf. is optional.
AttributeValue	—	M	Value of attribute requested.

* See Section 6.4.3 for a further description of terminology used in this table.

** The determination of whether Attribute ID is supplied in the service response/confirm is outside the scope of this document.

7.3.2.5 *SetAttribute (Service Identifier: DmS5)* — Used to modify a DM object attribute.

Set_Attribute Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
AttributeID	M	C, =	Attribute Identifier of attribute whose value is to be modified. Inclusion of Attribute in Rsp/Conf. is optional.
AttributeValue	M	C	Value to which the attribute is to be modified. Inclusion of Attribute in Rsp/Conf. is optional. Conditions under which the value may differ from that supplied in the associated Req/Ind. message (e.g., negative response) are not defined in this document.

* See Section 6.4.3 for a further description of terminology used in this table.

7.3.2.6 *Execute (Service Identifier: DmS6)* — Used to move the DM object from its IDLE state to its EXECUTING state. Note that this service may be internally generated by the DM object. There are no parameters specified for this service.

7.3.2.7 *PerformDiagnostics (Service Identifier: DmS7)* — Used to instruct the DM object to perform a diagnostic test. A diagnostic test is either of type “common” or “device-dependent.” “Common” diagnostic tests could include: RAM, EPROM, non-volatile memory, and communications. The structure of “common” type diagnostic tests is implementation-specific. All detail of “device-dependent” diagnostics is outside the scope of this document. The following table describes parameters specified for this service.

Perform_Diagnostics Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
TestID	M	C, =	Indicates the type and possibly detail of the test to be performed.

* See Section 6.4.3 for a further description of terminology used in this table.

Additional services and/or service parameters that are device-specific and/or implementation-specific may be provided by a DM object. These services may be Notification or Request type services (see Section 6.4.1). A complete definition of additional services and service parameters that are device-specific may be found in an appropriate sensor/actuator network specific device model specification.

7.3.2.8 *PublishAttribute (Optional — Service Identifier: DmS8)* — Used to proactively communicate a DM object attribute. The following table describes parameters specified for this service.

PublishAttribute Service Message Definition Table*

Parameter	*Ind*	*Description*
AttributeID	M	Attribute Identifier of attribute whose value is being reported.
AttributeValue	M	Value of attribute being reported.

* The utilization of a service response message and its format is outside the scope of this document.

7.3.2.9 *Lock* (Optional) — This service is used to restrict network access to all READ only attributes of all objects of this device. This service guarantees that the READ only attributes of this device are not modified over the network. There are no parameters specified for this service.

7.3.2.10 *Unlock* (Optional) — This service is used to make READ only attributes of objects of this device modifiable over the network. Not only is support of this object optional, but the degree to which it is supported is also specified by the manufacturer (i.e., only some attributes may become "unlocked"). Table 25 describes the parameters specified for this service.

Table 25 DM Object Unlock Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
Password Key	C	C	Manufacturer-Specific	Password may be specified to restrict access or to provide a manufacturer-specified security scheme.

7.3.2.11 *GetExceptionQueue* (Optional) — This service is used to read all or portions of the AlarmQueue and WarningQueue elements. Table 26 describes the parameters specified for this service.

Table 26 DM Object GetExceptionQueue Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
ExceptionType	M	C**, =	Byte, enumerated0 = Alarm1 = Warning	Used to indicate which exception queue is being queried.
ElementNumb	M	M	unsigned integer < 65,536	Used to indicate the number of Exception queue events to be returned with the service response. A zero value implies that all elements in the queue should be returned.
ExceptionList	—	M	List of elements; element data type. Dependent on the Reporting Mode (Basic or Expanded — See Sections 7.3.1.12, 7.3.1.19, 7.3.1.20, and 7.3.3).	An array of exception queue events of size ElemNumb returned with the response.
Clear	M	C	Boolean	Used to indicate whether or not the exceptions are to be removed from the exception queue upon reporting.

7.3.2.12 *ClearExceptionQueue* (Optional) — This service is used to clear all elements out of either the AlarmQueue or WarningQueue. Table 27 describes the parameters specified for this service. If the ExceptionType attribute is set to 0, 1, or 2 with the service request, the Alarm, Warning, or both queues respectively are cleared completely of their members.

Table 27 DM Object Clear ExceptionQueue Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Form*	*Description*
ExceptionType	M	C**, =	Byte, enumerated 0 = Alarm 1 = Warning 2 = Both	Used to indicate which exception queue(s) is/are to be cleared.

7.3.3 *DM Object Behavior* — The DM object behavior is illustrated in Figure 6 and in Tables 28 and 29.

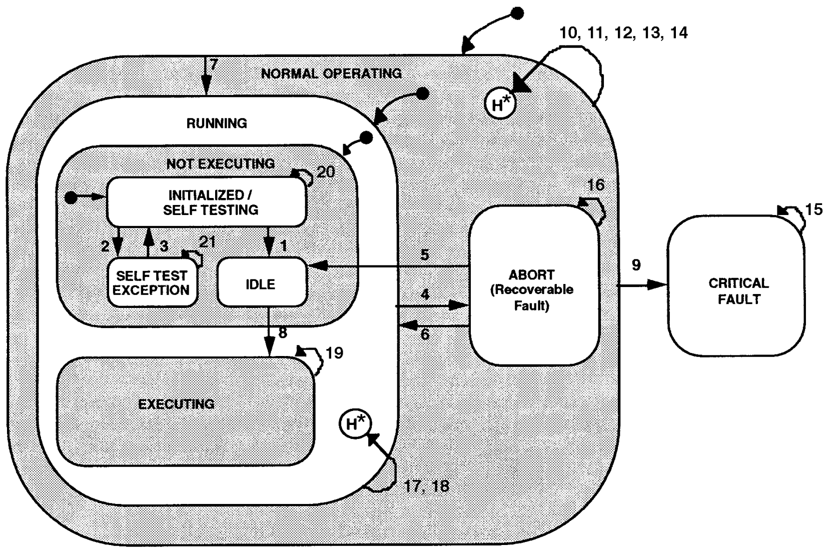

Figure 6
DM Object Instance Behavior*

*Transitions 10 through 21 are recursive (i.e., the New State is the same as the Current State (including all nested sub-states)).

Table 28 DM Instance Behavior State Description

State	*Description*
NORMAL OPERATING	Object instance exists. Object services can be processed.
RUNNING	This is the entry sub-state to NORMAL OPERATING. Object instance is not in an aborted state. Object is capable of reporting attribute values, including exceptions.
NOT EXECUTING	Device is not executing (e.g., it is not performing its device-specific function). A detailed description of this state is outside the scope of this document.
	This state may be further specified in an appropriate sensor/actuator network specific device model specification.
EXECUTING	Device is executing (e.g., it is performing its device-specific function). A detailed description of this state is outside the scope of this document.
	This state may be further specified in an appropriate sensor/actuator network specific device model specification.
INITIALIZED/SELF TESTING	This is the entry sub-state to NORMAL OPERATING and RUNNING.
	Object instance exists and has been initialized; all attributes have appropriate initial values(as indicated herein and in an appropriate sensor/actuator network specific device model specification).
	Device is performing device-specific and device type-specific tests to determine if it is qualified to be running.
	Note that as this is a sub-state of RUNNING, object is not initialized unless it is capable of reporting attribute values, including exceptions.
SELF TEST EXCEPTION	Object has detected an exception condition during self testing. The details of the exception are stored in the appropriate attribute values of the DM object.
IDLE	Object and device have been initialized and have successfully completed self testing.
ABORT	Object instance is in an aborted state; a detailed description of this state is outside the scope of this document. The object will not initiate communication over the network while in this state.
CRITICAL FAULT	The object (and device) are in a fault state from which there is no recovery. Object services cannot be processed. The conditions required for exit from a critical fault are outside the scope of this document.

Table 29 DM Instance Behavior State Transition Matrix*

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	INITIALIZED/ SELF TESTING	DM Object determines internally that the device is initialized and self test passed.	IDLE	Set Device Status attribute to appropriate value.	Device is in an idle state.
2	INITIALIZED/ SELF TESTING	One or more exceptions reported as a result of device testing.	SELF TEST EXCEPTION	Report exceptions through appropriate attribute settings in DM object. Set Device Status attribute to appropriate value.	Conditions resulting in the reporting of a self test exception are device-specific.
3	SELF TEST EXCEPTION	Exception condition cleared.	INITIALIZED/ SELF TESTING	Set Device Status attribute to appropriate value. Initiate self testing procedure from beginning.	Enter RUNNING/NOT EXECUTING/INITIALIZ ED/SELF TESTING.
4	RUNNING	Abort request.	ABORT	Abort response. Set Device Status attribute to appropriate value.	Abort request may be generated internally (e.g., as a result of Self Test catastrophic failure).
5	ABORT	Recover request; Device Status attribute value == ABORT FROM IDLE OREXECUTING.	IDLE	Recover response. Set Device Status attribute to appropriate value.	Enter IDLE state.
6	ABORT	Recover request; Device Status attribute value == ABORT FROM INITIALIZED/ SELF TESTING OR SELF TEST EXCEPTION.	INITIALIZED/S ELF TESTING	Recover response. Initiate self testing procedure from beginning. Set Device Status attribute to appropriate value.	Enter RUNNING/NOT EXECUTING/ INITIALIZED/SELF TESTING.
7	NORMAL OPERATING	Reset request.	RUNNING	Reset response. DM Object is initialized. Set Device Status attribute to appropriate value.	Valid for all sub-states of NORMAL OPERATING. Move to RUNNING/NOT EXECUTING/ INITIALIZED/SELF TESTING.
8	IDLE	Execute service request (this service request may be internally generated).	EXECUTING	Execute response. Set Device Status attribute to appropriate value.	Device is now executing.
9	NORMAL OPERATING	Critical Fault detected.	CRITICAL FAULT	The object (and device) is in a fault state from which there is no recovery. Object services generally cannot be processed.	The mechanism for exit from a critical fault is device-specific.
10	NORMAL OPERATING	GetAttribute or Set Attribute request.	NORMAL OPERATING	Get or Set Attribute appropriate response.	Valid for all sub-states of NORMAL OPERATING.
11	NORMAL OPERATING	PerformDiagnostics request.	NORMAL OPERATING	PerformDiagnostics response. Diagnostic is performed if possible. Exceptions are set within DM object as necessary.	Conditions which are deemed exceptions are device-specific.
12	NORMAL OPERATING	Lock or Unlock request.	NORMAL OPERATING	Adjust write access to READ only attributes of all device objects as appropriate. Lock or Unlock service response.	The mechanism for exit from a critical fault is device-specific.
13	NORMAL OPERATING	GetExceptionQueue or Clear Exception Queue request.	NORMAL OPERATING	GetExceptionQueue response with appropriate exception queue data. Clear appropriate	Valid for all substates of NORMAL OPERATING.

				exception queue and send service response.	
14	NORMAL OPERATING	Invalid service request.	NORMAL OPERATING	Error response to appropriate request.	Valid for all sub-states of NORMAL OPERATING.
15	CRITICAL FAULT	Any service request.	CRITICAL FAULT	none	Object services generally cannot be processed.
16	ABORT	Abort or Execute request.	ABORT	Error response.	Not valid requests in this state.
17	RUNNING	Recover request.	RUNNING	Error response.	Recover request only valid while in ABORT state.
18	RUNNING	Internally generated PublishAttribute Notification Service.	RUNNING	Attribute Identified by Attribute ID in PublishAttribute Service is Published.	Notification only occurs if specific conditions are met (see Section 7.3.3).
19	EXECUTING	Execute Request.	EXECUTING	Error response.	Not a valid request in this state.
20	INITIALIZED/ SELF TESTING	Execute service request.	INITIALIZED/ SELF TESTING	Error response.	Not a valid request in this state.
21	SELF TEST EXCEPTION	Execute service request.	SELF TEST EXCEPTION	Error response.	Not a valid request in this state.

* Transitions 10 through 21 are recursive (i.e., the New State is the same as the Current State (including all nested sub-states)).

The following also applies to DM behavior:

A DM instance service may be requested internally by the DM object.

If a SetAttribute request is received over the network for an attribute that is not network-settable, the attribute value is not changed and an error service response is generated.

When processing an Abort, Recover, or Reset service request, the DM object issues a corresponding Abort, Recover, or Reset service request to the SAC object.

While in the Abort state, the DM object will not initiate communications over the network (e.g., it will not initiate communication of exceptions over the network). It may, however, communicate over the network in response to service requests.

All DM services have the same behavior associated with invalid service requests unless otherwise indicated. Common service error responses are listed in Appendix 2.

The following identifies additional behavior associated with specific values of DM object attributes:

The Device Status attribute value indicates the state of the DM object (see Table 18). It is updated on appropriate state transitions within the DM object (see Table 29). Attribute values 1 through 6 represent valid states. A value of zero indicates that the DM state is unknown; conditions under which a zero value may occur are outside the scope of this document.

The Reporting Mode attribute determines five different conditions under which alarms and warnings are reported through communication of the Exception Status attribute (see Table 19). Both warnings and alarms have separate values within Reporting Mode. This allows alarms to be reported more aggressively than warnings because alarms are presumably more time-critical. The behavior associated with the five Reporting Mode conditions which are used for both alarms and warnings is described in the following paragraphs. Optionality indicates that the mode may or may not be supported; this optionality may be further specified in a sensor/actuator network specific device model and/or device manufacturer specification.

_ *Request* — When a bit in the status attribute transitions from cleared to set, the device will not report until requested. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail attribute are cleared. In this mode, a device may go in and out of an exception condition without ever reporting the condition because there has been no request. The device must always respond to a request for exception conditions, regardless of Reporting Mode state.

_ Optional *RequestLatched* — When a bit in the status attribute transitions from cleared to set, the device will not report until requested. When the exception condition no longer exists, the exception status bit and the specific bit in the exception detail attribute are not cleared until they have been requested and reported. This mode guarantees that a brief occurrence of an exception condition will always be reported, barring an unrecoverable communications error. Within each exception variable, active bits will be cleared as they are reported.

_ Optional *EventTriggeredOn* — When a bit in the status attribute transitions from cleared to set, the device will automatically report the exception status attribute. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail variable are cleared.

_ Optional *EventTriggeredOn/Off* — When a bit in the status attribute transitions from cleared to set, the device will automatically report the exception status attribute. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail attribute are cleared, and the device will again automatically report the exception status attribute.

_ Optional *TimeTriggered* — If this mode is supported, the Exception Status Timer attribute value indicates the time interval for periodic status reporting. When the indicated time period expires, the device will automatically report the exception status attribute. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail attribute are cleared.

_ Optional *EventOnOrTimeTriggered* — This is a logical "or" of EventTriggeredOn mode and TimeTriggered mode. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail attribute are cleared.

_ Optional *EventOn/OffOrTimeTriggered* — This is a logical "or" of EventTriggeredOn/Off mode and Time-Triggered mode. When the exception condition no longer exists, both the exception status bit and the specific bit in the exception detail attribute are cleared.

The Reporting Mode attribute value defaults to zero upon object initialization (i.e., request mode), unless otherwise specified in an appropriate sensor/actuator network specific device model specification.

The Reporting Mode attribute is defined as network-settable; however, it is only settable to (valid) values corresponding to supported reporting modes (see Table 19, appropriate sensor/actuator network specific device model specification, and device manufacturer specification). Note that at least one reporting mode, Request, must be supported. If an attempt is made, via a Set_Attribute service request, to set the Reporting Mode attribute to an invalid value, an error service response is returned.

All exceptions are communicated through reporting the values of the Exception Status and, conditionally, the Exception Detail Alarm and Exception Detail Warning attributes. An Exception Detail attribute may only be reported if both bit 7 and the corresponding exception bit of the Exception Status variable are set to 1.

If the Reporting Mode attribute indicates a reporting mode of TimeTriggered, EventOnOrTimeTriggered, or EventOn/OffOrTimeTriggered, the time interval for reporting is the value of the Exception Status Report Interval attribute. Time zero is defined as the time at which the Reporting Mode attribute is last modified utilizing the SetAttribute service. The first report is generated at time zero (not after the first time interval). If this value of the Exception Status Report Interval attribute is zero, then time triggered exception reporting is disabled.

If the Reporting Mode attribute indicates a reporting mode of EventOnOrTimeTriggered, or EventOn/OffOrTimeTriggered, the reporting associated with the occurrence of the appropriate event and the reporting associated with the report interval are independent (e.g., the occurrence of reporting due to an event does not impact the timing associated with reporting according to a specified time interval).

The Exception Status Report Interval attribute value defaults to 0.0 seconds upon object initialization, unless otherwise specified in an appropriate sensor/actuator network specific device model specification.

Additional behavior may be provided by a DM object that is device-specific. A complete definition of this additional behavior may be found in an appropriate sensor/actuator network specific device model specification.

The PublishAttribute service would be used for automatic reporting of the DM object exception status attribute when (1) an exception exists, (2) an automatic reporting mode is indicated by the Reporting Mode attribute (see Section 7.3.1), and (3) the indicated reporting mode is supported by the device (in its current state).

Behavior associated with the AlarmEnable and WarningEnable attributes is as follows. If the alarm/warning attribute is TRUE or if the attribute is not supported, alarm/warning reporting behavior as described elsewhere in this section is not impacted by this attribute. If the alarm/warning attribute is set to FALSE, all alarm/warning DM exception attributes are set and maintained at values that indicate a no alarm state. Thus, bits 0 through 2 of the ExceptionStatus attribute (alarms) or bits 4 through 6 (warnings) are set and maintained at zero, and any ExceptionDetail Alarm/Warning attribute bytes are set and maintained at a value of zero. When the Alarm/WarningEnable is toggled to TRUE, the device immediately determines its alarm/warning state, updates the appropriate DM attributes as necessary, and reports any alarms/warnings according to the mode defined by the ReportingMode attribute.

Behavior associated with the (Alarm and Warning) Exception Queues (see Sections 7.3.1.21 and 7.3.1.22), if supported, is as follows: Upon device initialization (start-up) or reset, both exception queues are cleared. The data type of queue elements is determined by the value of bit 7 of the status attribute (as explained in Section 7.3.1.21). As alarm events are issued to the DM object, the appropriate exception parameters are set (ExceptionStatus and ExceptionDetailAlarm/Warning) and the events are also logged onto the appropriate Alarm or Warning Exception Queue on a first-in, first-out basis. Any alarm or warning clear events are also logged onto these queues in the same manner; these events are logged in the same data format as the exception, but with the data value indicating that the exception no longer exists. The maximum number of elements that are retained by the queue is application-specific. Once the maximum queue length is reached, new exception events depose the oldest exception event from the queue in a first-in, first-out fashion (similar to a shift register). The GetExceptionQueue service may be used to retrieve any number or all exception events from either (alarm or warning exception) queue. If the value of the Clear attribute is TRUE, retrieved events are deposed from the queue; otherwise, they are left in the queue.

Behavior associated with the optional “Date and Time” attribute is as follows. This attribute indicates the current date and time as perceived by the device whenever it is reported. The resolution of the “Time of Day” reported shall be milliseconds unless the “Date and Time Type” attribute is supported and it indicates a resolution other than milliseconds.

7.4 *Sensor, Actuator, and Controller Objects* — The Sensor (S), Actuator (A), and Controller (C) objects are the model components that model the high level sensory, actuation, and/or control element capabilities of the device as viewed from the network. Although the structure and behavior of these elements can vary widely from device to device, there are common aspects of structure and behavior that can be identified. Specifically, there are structure and behavior characteristics common to all active elements (i.e., all S, A, and C objects), common to all elements of an element type (i.e., all S objects, A objects, or C objects), or common to all elements of an element sub-type (e.g., all analog input sensor objects). This commonality of structure and behavior among these object types is depicted in the class generalization hierarchy of Figure 7. With this generalization hierarchy in place, objects inherit structure and behavior from their parent object classes, thus reducing the level of redundancy in description. For example, object instances of the Sensor-AI class inherit (i.e., also have) the attributes, services, and behavior of the Sensor and Active Element parent classes.

Note that the only classes from which accessible object instances can be created in this hierarchy exist at the lowest level (i.e., Sensor-AI, Sensor-BI, Actuator-AO, Actuator-BO, and Controller objects). Also note that the object identifiers for these object instances are designated as indicated in Table 1 (e.g., a Sensor-AI object instance has an Object Identifier of SenI’n’, where ‘n’ is the instance number of the sensor object for the device).

In the following sub-sections, the attributes, services, and behavior at each level of the active element class generalization hierarchy are identified and defined. Note that the specific device model would complete the definition of each sensor, actuator, and controller element of a specific device type through definition of additional structure and behavior for the S, A, and C object instances that collectively realize the sensory/ actuation/control capability portion of the device model.

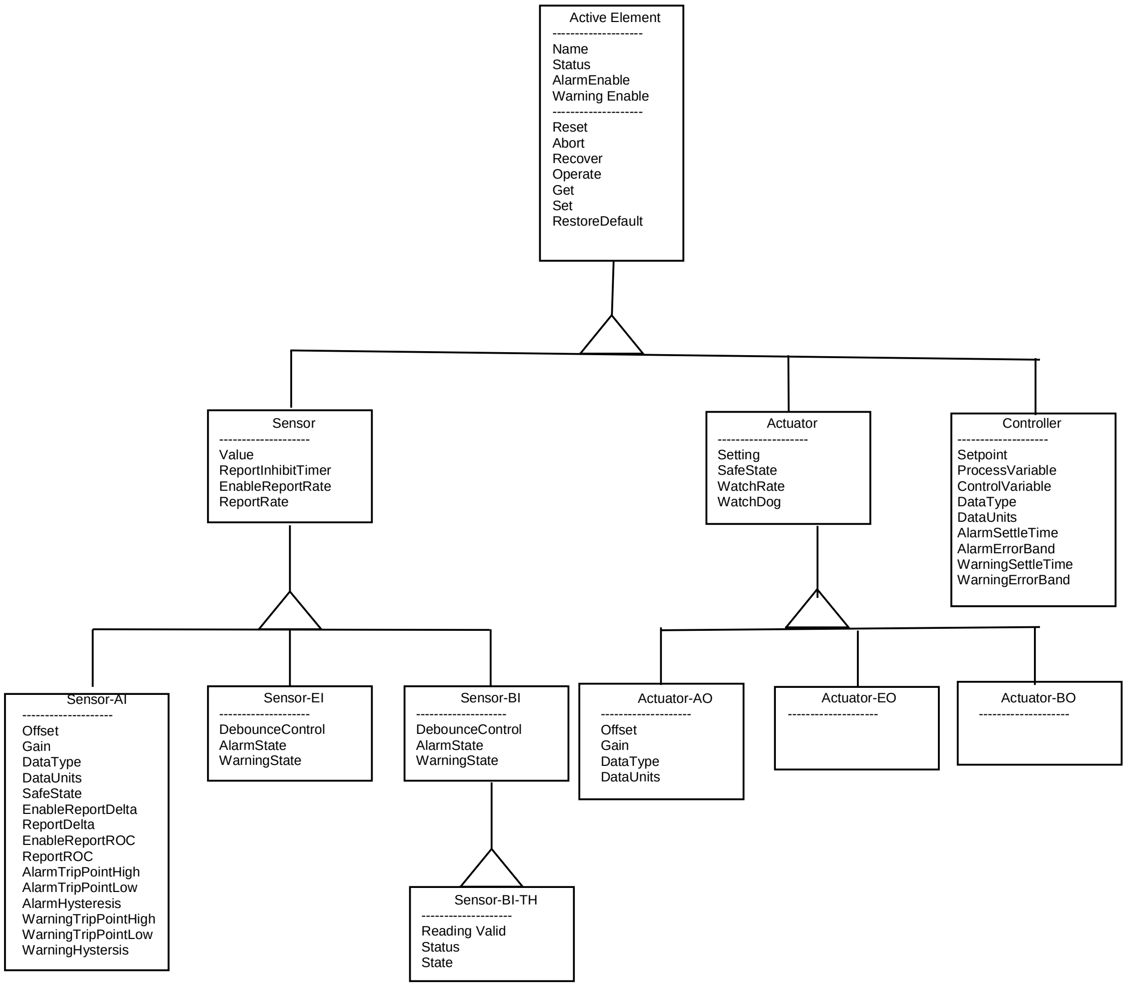

Figure 7
Active Element Class Generalization Hierarchy

7.4.1 *Active Element (AE) Class* — The AE class at the top of the active element generalization hierarchy contains structure and behavior common to all active element instances in a device.

7.4.1.1 *Active Element Class Attributes* — All required and "common optional" AE class attributes are listed in Table 30 and described below. For an explanation of the table format, see Section 7.3.1.

Table 30 AE Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Name	nA1**	RO	N	Text, 16 characters maximum
Status	nA2	RO	Y	Context-specific
AlarmEnable	nA3	RW	N	Boolean
WarningEnable	nA4***	RW	N	Boolean

* A "Definition" column is not included. For attribute definitions, see text.

** Where 'n' is the type of the object instance to which the particular attribute is associated (e.g., Sai, Sbi, Aao, Ado, or C), see Sections 7.4.4 through 7.4.8.

*** ID's nA5 through nA15 are reserved for future AE class attribute definition.

7.4.1.1.1 *Name* — A label used to identify the active element associated with the object instance.

7.4.1.1.2 *Status* — An indication of the state of the active element associated with the object instance. The form and interpretation of the value of this attribute is context-specific.

7.4.1.1.3 *AlarmEnable* — An attribute which specifies whether alarm exception conditions of the active element associated with the object instance are to be reported. Reporting is enabled if this variable is set to TRUE. The method of reporting is beyond the scope of this document.

7.4.1.1.4 *WarningEnable* — An attribute which specifies whether warning exception conditions of the active element associated with the object instance are to be reported. Reporting is enabled if this variable is set to TRUE. The method of reporting is beyond the scope of this document.

7.4.1.2 *Active Element Class Services* — All Active Element common services are listed in Table 31 (the specific AE object is the "service provider" of these services). Note that all of these services are Request services. Service parameters that are specified in this standard are summarized in Table 32.

Table 31 AE Class Service Resource Definition

Service	*Service ID*	*Type*	*Description*
Reset	nS1*	R	Used to place object in INITIALIZED state.
Abort	nS2	R	Used to place object in ABORT state.
Recover	nS3	R	Used to move object from ABORT state to RECOVERED state.
Operate	nS4	R	Used to move object to the operating state from INITIALIZING, or RECOVERING state.
GetAttribute	nS5	R	Used to read object attribute.
SetAttribute	nS6	R	Used to modify object attribute.
RestoreDefault	nS7**	R	Used to restore object attributes to their default values.

* Where 'n' is the type of the object instance to which the particular service is associated (e.g., Sai, Sbi, Aao, Ado, or C), see Sections 7.4.4 through 7.4.8.

** ID's nS8 through nS15 are reserved for future AE class service definition.

Table 32 AE Class Service Parameter Dictionary

Parameter	*Form*	*Description*
AttributeID	Positive Integer	Object instance Attribute Identifier.
AttributeValue	Context-specific	Value of object instance attribute.
RestoreConditions	Byte enumerated	Level of restore requested.

A detailed description of these services follows:

7.4.1.2.1 *Reset* — Used to place the object instance in its INITIALIZED state. There are no parameters specified for this service.

7.4.1.2.2 *Abort* — Used to place the object instance in its ABORT state. There are no parameters specified for this service.

7.4.1.2.3 *Recover* — Used to move the object instance from its ABORT state to a RECOVERED state. There are no parameters specified for this service.

7.4.1.2.4 *Operate* — Used to move the object instance to the OPERATING state from the INITIALIZING or RECOVERING state. There are no parameters specified for this service.

7.4.1.2.5 *GetAttribute* — Used to read a value of an object instance attribute over the network. The following table describes the parameters specified for this service.

GetAttribute Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Form*	*Description*
AttributeID	M	C**, =	Network-Specific	Attribute Identifier of attribute whose value is being requested. Inclusion of attribute in Rsp/Conf. is optional.
AttributeValue	-	M	Context-Specific	Value of attribute requested.

* See Section 6.4.3 for further description of terminology used in this table.

** The determination of whether Attribute ID is supplied in the service response/confirm is outside the scope of this document.

7.4.1.2.6 *SetAttribute* — Used to modify the value of an object instance attribute over the network which has been identified as modifiable. The following table describes the parameters specified for this service.

SetAttribute Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Form*	*Description*
AttributeID	M	C, =	Network-Specific	Attribute Identifier of attribute whose value is to be modified. Inclusion of Attribute in Rsp/Conf. is optional.
AttributeValue	M	C	Context-Specific	Value to which the attribute is to be modified. Inclusion of Attribute in Rsp/Conf. is optional. Conditions under which the value may differ from that supplied in the associated Req/Ind. message (e.g., negative response) are not defined in this document.

* See Section 6.4.3 for further description of terminology used in this table.

7.4.1.2.7 *RestoreDefault* — Used to restore attributes of this object instance to their default values. The following table describes the parameters specified for this service.

RestoreDefault Service Message Definition Table*

Parameter	*Req/Ind*	*Rsp/Conf*	*Form*	*Description*
Restore Conditions	M	C	byte, enumerated	0 = Restore specific attribute of this object 1 = Restore all attributes of this object 2 – 63 = Reserved 64 – 255 = Application-Defined
AttributeID	C	C	Network-Specific	Attribute ID of the attribute whose value is being restored.

* See Section 6.4.3 for further description of terminology used in this table.

7.4.1.3 *Active Element Class Behavior* — The AE class behavior is illustrated in Figure 8. Associated states and state transitions are described in Tables 33 and 34. The following also applies to AE class behavior:

An AE class service may be requested internally by the AE object instance.

Note that the behavior associated with the Reset, Abort, Recover, Operate, and Restore Default services differs from the SAC object instance behavior in that no service requests are necessarily issued to any other object instances.

Upon instantiation or upon receipt of a reset request, an AE object instance responds by entering or staying in its INITIALIZED state.

The object INITIALIZING application process is described as follows: When a request to initialize is received (e.g., through a Reset service request), all object instance attributes are restored to their initial value; the interpretation of these values and how they are stored/retrieved is beyond the scope of this document. The object performs any manufacturer-specified self tests and diagnostics to determine if it is qualified to enter the OPERATING state. Upon completion of these tests, the appropriate Pass or Fail service response is reported to the requesting object instance. The content, format, and protocol of this service response are specified by the network for requests made over the network.

Upon receipt of an abort request, an AE object instance responds by entering or staying in its ABORT state.

Upon receipt of a recover request, an AE object instance responds by transitioning to its RECOVERED state if, and only if, it is currently in its ABORT state. Otherwise, it responds with an error indication.

The object RECOVERING application process is described as follows: Upon receipt of a Recover service request, the object performs any manufacturer-specified self tests and diagnostics to determine if it is qualified to enter the OPERATING state.

Upon completion, the appropriate Pass or Fail service response is reported to the requesting object instance. The content, format, and protocol of this service response are specified by the network for requests made over the network.

The AlarmEnable attribute determines whether or not alarms are reported through the ExceptionStatus and ExceptionDetail attributes of the DM object (see Section 7.3). If the AlarmEnable attribute is set to the enabled state, then any alarm is reported to the DM object instance upon its occurrence. The WarningEnable attribute works analogously with respect to reporting a warning.

Additional behavior may be exhibited by an AE object instance that is defined elsewhere in its class generalization hierarchy, or is device-specific. A complete definition of AE object type instance behavior includes the appropriate sensor/actuator network specific device model specification.

Behavior associated with receipt of an invalid service request identified in this document applies to all services required for this class. Unless otherwise specified (e.g., in an appropriate sensor/actuator network specific device model specification), behavior associated with the receipt of an invalid service request for additional services defined (elsewhere) for this class shall be the same as that for required services.

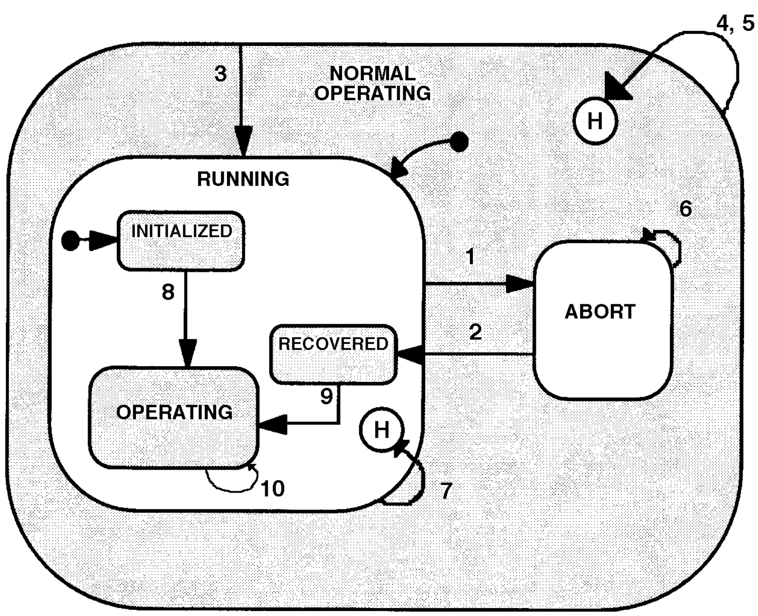

Figure 8
AE Class Behavior

NOTE: Only generic behavior is indicated in this chart. A complete state chart necessarily requires the inclusion of device-specific behavior.

Table 33 AE Class Behavior State Description

State	*Description*
NORMAL OPERATING	Object instance exists. Object services can be processed.
RUNNING	This is the entry sub-state to NORMAL OPERATING. Object instance is not in its ABORT state.
INITIALIZED	This is the entry sub-state to NORMAL OPERATING and RUNNING. Object instance exists and has been initialized. All attributes set to appropriate initial values (as indicated in an appropriate sensor/actuator network specific device model specification).
RECOVERED	Object instance is in an abort recovered state.
OPERATING	This represents the entire collection of sub-states within RUNNING except INITIALIZED and RECOVERED. The further delineation of this sub-state and transition into this sub-state is outside the scope of this document.
ABORT	Object instance is in an aborted state and is not running any application process; a detailed description of this state is outside the scope of this document.

Table 34 AE Class Behavior State Transition Matrix*

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	RUNNING	Abort request.	ABORT	Abort. Abort response.	ABORT state is device-specific.
2	ABORT	Recover request.	RECOVERED	Recover. Recover response.	RECOVERED state is device-specific.
3	NORMAL OPERATING	Reset request.	RUNNING	Reset. Reset response.	Valid for all sub-states of NORMAL OPERATING. Move to RUNNING/ INITIALIZED.
4	NORMAL OPERATING	GetAttribute, SetAttribute, RestoreDefault.	NORMAL OPERATING	Get Attribute, Set Attribute, Restore Defaults. Appropriate Response.	Valid for all sub-states of NORMAL OPERATING.
5	NORMAL OPERATING	Invalid service request.	NORMAL OPERATING	Error response.	Valid for all substates of NORMAL OPERATING.
6	ABORT	Abort request, Operate request.	ABORT	Error response.	Invalid request in this state.
7	RUNNING	Recover request.	RUNNING	Error response.	Recover service can only be invoked while in ABORT state.
8	INITIALIZING	Operate request.	OPERATING	Device-specific.	Behavior associated with this transition may be further specified in an appropriate sensor/ actuator network specific device model specification.
9	RECOVERED	Operate request.	OPERATING	Device-specific.	Behavior associated with this transition may be further specified in an appropriate sensor/actuator network specific device model.
10	OPERATING	Operate request.	OPERATING	Operate response.	Object remains in the OPERATING state. Additional behavior associated with this transition may befurther specified in an appropriate sensor/actuator network specific device model.

* NOTE: Only generic behavior is indicated in this table.

7.4.2 *Sensor (S) Class* — The S class at the second level of the active element generalization hierarchy contains structure and behavior common to all sensing element instances in a device.

7.4.2.1 *Sensor Class Attributes* — All required and "common optional" S class attributes are listed in Table 35 and described below. For an explanation of the table format, see Section 7.3.1. Note that the S class also inherits all AE class attributes.

Table 35 S Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Value	nA16**	RO	Y	Context-Specific
ReportInhibitTimer	nA17	RW	N	Context-Specific
EnableReportRate	nA18	RW	N	Boolean
ReportRate	nA19***	RW	N	Context-Specific

* A "Definition" column is not included. For attribute definitions, see text.

** Where 'n' is the type of the object instance to which the particular attribute is associated (e.g., Sai or Sbi), see Sections 7.4.4 through 7.4.8.

*** ID's nA20 through nA63 are reserved for future S class attribute definition.

7.4.2.1.1 *Value* — The value of the sensor (associated with the object instance) that is to be conveyed. The form and content of this attribute is context-specific.

7.4.2.1.2 *ReportInhibitTimer* — An attribute which is used to identify the absolute minimal time interval (i.e., maximum rate) for reporting the attribute "Value"; expressed in seconds. A value of zero indicates that there is no minimal time interval.

7.4.2.1.3 *EnableReportRate* — An attribute which enables the reporting of the attribute "Value" based on the "ReportingRate" attribute value; a value of TRUE signifies that the reporting at the "ReportingRate" is enabled.

7.4.2.1.4 *ReportRate* — An attribute which defines the time interval at which the attribute "Value" will be reported; expressed in seconds.

7.4.2.2 *Sensor Class Service*s — No S class common services are defined. Note that the S class inherits all AE class services.

7.4.2.3 *Sensor Class Behavior* — The following applies to S class behavior:

Some form of measurement or other sensory activity is made by the active sensory element. This measurement is converted into the appropriate data and becomes the value of the "Value" attribute. The method of conversion is beyond the scope of this document.

No other S class common behavior is defined. Note that the S class inherits all AE class-defined behavior.

7.4.3 *Actuator (A) Class* — The A class at the second level of the active element generalization hierarchy contains structure and behavior common to all actuator element instances in a device.

7.4.3.1 *Actuator Class Attributes* — All required and "common optional" A class attributes are listed in Table 36 and described below. For an explanation of the table format, see Section 7.3.1. Note that the A class also inherits all AE class attributes.

Table 36 A Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Setting	nA16**	RW	Y	Context-Specific
SafeState	nA17	RW	N	Context-Specific
WatchRate	nA18	RW	N	Unsigned Integer < 65,536
WatchDog	nA19***	RW	N	Boolean

* A "Definition" column is not included. For attribute definitions, see text.

** Where 'n' is the type of the object instance to which the particular attribute is associated (e.g., Aao or Ado), see Sections 7.4.4 through 7.4.8.

*** ID's nA20 through nA63 are reserved for future A class attribute definition.

7.4.3.1.1 *Setting* — Specifies the value that is to be actuated by the actuator associated with the object instance. The form and content of this attribute is context-specific.

7.4.3.1.2 *SafeState* — Specifies the state in which the actuator will be placed for ABORT and INITIALIZING states. Unless otherwise specified, this attribute is a Boolean type corresponding to Zero (or "no output") or One (or "full output").

7.4.3.1.3 *WatchRate* — Specifies the rate at which the "Setting" attribute is to be refreshed (i.e., set externally). If the "Setting" attribute is not refreshed at this rate, it reverts to its default value; expressed in (integer/100) hertz.

7.4.3.1.4 *WatchDog* — Enables or disables the capability of setting the "Setting" attribute to its default value due to a refresh rate lower than specified by the "WatchRate" attribute value; a value of TRUE signifies that the WatchRate functionality is enabled.

7.4.3.2 *Actuator Class Services* — No A class common services are defined. Note that the A class inherits all AE class services.

7.4.3.3 *Actuator Class Behavior* — The following applies to A class behavior:

Some form of actuation activity is made by the active actuation element. The value of the "Setting" attribute is converted into the appropriate signal to cause the desired actuation.

A class-defined behavior associated with the "WatchRate" and "WatchDog" attributes is defined in Section 7.4.3.1 (above). No other A class common behavior is defined. Note that the A class inherits all AE class-defined behavior.

7.4.4 *Controller (C) Class* — The C class at the second level of the active element generalization hierarchy contains structure and behavior common to all controller element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device type (see Figure 7), object instances can be created as instances of this class type.

7.4.4.1 *Controller Class Attributes* — All required and "common optional" C class attributes are listed in Table 37 and described below. For an explanation of the table format, see Section 7.3.1. Note that the C class also inherits all AE class attributes.

Table 37 C Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Setpoint	CA16	RW	Y	Context-Specific
ProcessVariable	CA17	RW	N	Context-Specific
ControlVariable	CA18	RW	N	Context-Specific
DataType	CA19	RW	N	Context-Specific
AlarmSettleTime	CA21	RW	N	Context-Specific
AlarmErrorBand	CA22	RW	N	Context-Specific
WarningSettleTime	CA24	RW	N	Context-Specific
WarningErrorBand	CA25	RW	N	Context-Specific

* A "Definition" column is not included. For attribute definitions, see text.

** ID's CA27 through CA63 are reserved for future C class attribute definition.

7.4.4.1.1 *Setpoint* — This attribute specifies the value to which the Process Variable will be controlled via the Control Variable. This is one of the inputs of a classic single-stage closed-loop controller. The setpoint attribute value is expressed in units identified by the "DataUnits" attribute.

7.4.4.1.2 *ProcessVariable* — This attribute value is the measurement of the process being controlled. This is one of the inputs of a classic single-stage closed-loop controller.

7.4.4.1.3 *ControlVariable* — This attribute value is the control signal being sent to the process controlling element. This is the output of a classic single-stage closed-loop controller.

7.4.4.1.4 *DataType* — An attribute which defines the format of the data associated with "Value" attribute (inherited) of the object instance.

7.4.4.1.5 *DataUnits* — An attribute which defines the current units associated with "Value" attribute (inherited) of the object instance.

7.4.4.1.6 *AlarmSettleTime* — An attribute which specifies a time used in the determination of a Controller object instance alarm exception condition. This value is expressed in units of seconds. The minimum allowable value for this attribute is specified by the manufacturer. An out-of-range error will result from an attempt to set this attribute to a value lower than that specified as the minimum allowable.

7.4.4.1.7 *AlarmErrorBand* — An attribute which specifies an amount by which the process variable may not equal the setpoint used in the determination of a Controller object instance alarm exception condition. This value is expressed in units identified by the "DataUnits" attribute and in a format specified by the "DataType" attribute.

7.4.4.1.8 *WarningSettleTime* — An attribute which specifies a time used in the determination of a Controller object instance warning exception condition. This value is expressed in units of seconds. The minimum allowable value for this attribute is specified by the manufacturer. An out-of-range error will result from an attempt to set this attribute to a value lower than that specified as the minimum allowable.

7.4.4.1.9 *WarningErrorBand* — An attribute which specifies an amount by which the process variable may not equal the setpoint used in the determination of a Controller object instance warning exception condition. This value is expressed in units identified by the "DataUnits" attribute and in a format specified by the "DataType" attribute.

7.4.4.2 *Controller Class Services* — No C class common services are defined. Note that the C class inherits all AE class services.

7.4.4.3 *Controller Class Behavior* — The following applies to C class behavior:

The controller element uses the value of the Process-Variable and Setpoint attributes and determines the error signal. It then adjusts the ControlVariable attribute value as necessary and appropriate to minimize this error signal. The method of, and conditions for, adjustment are beyond the scope of this document.

Note that the C class inherits all AE class-defined behavior.

7.4.5 *Sensor-Analog Input (SAI) Class* — The SAI class at the third level of the active element generalization hierarchy contains structure and behavior common to all analog input sensor element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device element type (see Figure 7), object instances can be created as instances of this class type.

7.4.5.1 *Sensor-Analog Input Class Attributes* — All required and "common optional" SAI class attributes are listed in Table 38 and described below. For an explanation of the table format, see Section 7.3.1. Note that the SAI class also inherits all AE and S class attributes.

Table 38 SAI Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Offset	SaiA64	RW	N	Context-Specific
Gain	SaiA65	RW	N	Context-Specific
DataType	SaiA66	RW	N	Context-Specific
DataUnits	SaiA67	RW	N	Context-Specific
SafeState	SaiA68	RW	N	Enumerated Byte
EnableReportDelta	SaiA69	RW	N	Boolean
ReportDelta	SaiA70	RW	N	Context-Specific
EnableReportROC	SaiA71	RW	N	Boolean
ReportROC	SaiA72	RW	N	Context-Specific
AlarmTripPointHigh	SaiA73	RW	N	Context-Specific
AlarmTripPointLow	SaiA74	RW	N	Context-Specific
AlarmHystersis	SaiA75	RW	N	Context-Specific
WarningTripPointHigh	SaiA76	RW	N	Context-Specific
WarningTripPointLow	SaiA77	RW	N	Context-Specific
WarningHystersis	SaiA78**	RW	N	Context-Specific

* A "Definition" column is not included. For attribute definitions, see text.

** ID's SaiA78 through SaiA127 are reserved for future Sai class attribute definition.

7.4.5.1.1 *Offset* — An attribute which specifies the amount of offset correction being applied to derive the value of the “Value” attribute (inherited) of the object instance. It is expressed in terms of the units specified by the “DataUnits” attribute.

7.4.5.1.2 *Gain* — An attribute which is used to define the range of the “Value” attribute (inherited) of the object instance. The method of conveying this range with this attribute is beyond the scope of this document.

7.4.5.1.3 *DataType* — An attribute which defines the format of the data associated with “Value” attribute (inherited) of the object instance.

7.4.5.1.4 *DataUnits* — An attribute which defines the current units associated with “Value” attribute (inherited) of the object instance.

7.4.5.1.5 *SafeState* — An attribute which defines the Value (inherited attribute) to be reported by the object instance when it is in a non-OPERATING state. The enumeration of the SafeState attribute is given in Table 39.

Table 39 SafeState Attribute Values

Attribute Value	*DM Object State*
0	Zero
1	Full-Scale
2	LVV
3	Undefined
4 – 63	Reserved
64 – 255	Open

7.4.5.1.6 *EnableReportDelta* — An attribute which enables the reporting of the attribute “Value” based on the “ReportDelta” attribute value (see below); a value of TRUE signifies that reporting using the “ReportDelta” method is enabled.

7.4.5.1.7 *ReportDelta* — The value of this attribute indicates the amount by which the sensor value (indicated by the “Value” attribute (inherited)) must change before it is published. When the value of the EnableReportDelta attribute indicates that this method of reporting is “enabled”, and when the value of the “Value” attribute changes by an amount in excess of the amount indicated by the ReportDelta attribute value, the object will publish the Value attribute.

7.4.5.1.8 *EnableReportROC* — The Enable ReportROC (rate of change) attribute enables the reporting of the attribute “Value” based on the “ReportROC” attribute value (see below); a value of TRUE signifies that reporting using the rate of change method is enabled.

7.4.5.1.9 *ReportROC* — The value of this attribute indicates the rate by which the sensor value (indicated by the “Value” attribute (inherited)) must change before it is published. The attribute value context is DataUnits/Time; the specific context of DataUnits is defined in the DataUnits attribute, while the unit of Time is context-specific. When the value of the EnableReportDelta attribute indicates that this method of reporting is “enabled”, and when the value of the “Value” attribute changes at a rate in excess of the amount indicated by the ReportDelta attribute value, the object will publish the Value attribute.

7.4.5.1.10 *AlarmTripPointHigh* — An attribute which specifies the value above which the object instance “Value” attribute (inherited) value must be to generate an alarm status indication. The behavior associated with the generation of an alarm status indication (beyond that described in Section 7.4.1.3) is beyond the scope of this document.

7.4.5.1.11 *AlarmTripPointLow* — An attribute which specifies the value below which the object instance “Value” attribute (inherited) value must be to generate an alarm status indication. The behavior associated with the generation of an alarm status indication (beyond that described in Section 7.4.1.3) is beyond the scope of this document.

7.4.5.1.12 *AlarmHysteresis* — An attribute which specifies the amount of hysteresis to be applied in the clearing of an alarm condition. For example: a Trip Point High value of 100 with a hysteresis value of 2 will result in an exception condition being set when the Value attribute exceeds 100 in the positive direction and cleared when the Value attribute exceeds 98 in the negative direction. Similarly, a Trip Point Low value of 100 with a hysteresis value of 2 will result in an exception condition being set when the Value attribute exceeds 100 in the negative direction and cleared when the Value attribute exceeds 102 in the positive direction. The behavior associated with the generation and clearing of exception conditions is beyond the scope of this document.

7.4.5.1.13 *WarningTripPointHigh* — An attribute which specifies the value above which the object instance “Value” attribute (inherited) value must be to generate a warning status indication. The behavior associated with the generation of a warning status indication is beyond the scope of this document.

7.4.5.1.14 *WarningTripPointLow* — An attribute which specifies the value below which the object instance “Value” attribute (inherited) value must be to generate a warning status indication. The behavior associated with the generation of a warning status indication is beyond the scope of this document.

7.4.5.1.15 *WarningHysteresis* — An attribute which specifies the amount of hysteresis to be applied in the clearing of an alarm condition (see Section 7.4.5.1.12). The behavior associated with the generation and clearing of exception conditions is beyond the scope of this document.

7.4.5.2 *Sensor-Analog Input Class Services* — No SAI class common services are defined. Note that the SAI class inherits all AE and S class services.

7.4.5.3 *Sensor-Analog Input Class Behavior* — No SAI class common behavior is defined. Note that the SAI class inherits all AE and S class-defined behavior.

7.4.6 *Sensor-Binary Input (SBI) Class* — The SBI class at the third level of the active element generalization hierarchy contains structure and behavior common to all binary input sensor element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device element type (see Figure 7), object instances can be created as instances of this class type.

7.4.6.1 *Sensor-Binary Input Class Attributes* — All required and "common optional" SBI class attributes are listed in Table 40 and described below. For an explanation of the table format, see Section 7.3.1. Note that the SBI class also inherits all AE and S class attributes.

Table 40 SBI Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
DebounceControl	SbiA64	RW	N	Context-specific
AlarmState	SbiA65	RW	N	Boolean
WarningState	SbiA66**	RW	N	Boolean

* A "Definition" column is not included. For attribute definitions, see text.

** ID's Sbi67 through SbiA127 are reserved for future Sbi class attribute definition.

7.4.6.1.1 *DebounceControl* — This attribute is used to control sensitivity to 'false' transitions. The method of utilization of this attribute for debounce control is application-specific.

7.4.6.1.2 *AlarmState* — The value of the Value attribute (i.e., TRUE or FALSE) that will cause an alarm condition.

7.4.6.1.3 *WarningState* — The value of the Value attribute (i.e., TRUE or FALSE) that will cause a warning condition.

7.4.6.2 *Sensor-Binary Input Class Services* — No SBI class common services are defined. Note that the SBI class inherits all AE and S class services.

7.4.6.3 *Sensor-Binary Input Class Behavior* — No SBI class common behavior is defined. Note that the SBI class inherits all AE and S class-defined behavior.

7.4.6.4 *Sensor-Enumerated Input Class Services* — No SEI class common services are defined. Note that the SEI class inherits all AE and S class services.

7.4.6.5 *Sensor-Enumerated Input Class Attributes* — All required and "common optional" SEI class attributes are listed in Table 41 and described below. For an explanation of the table format, see Section 7.3.1. Note that the SEI class also inherits all AE and S class attributes.

Table 41 SEI Class Attributes*

Attribute Name	*Attribute Identifier*	*Access Network*	*Rqmt*	*Form*
DebounceControl	SeiA64	RW	N	Context-Specific
AlarmState	SeiA65	RW	N	Enumerated
WarningState	SeiA66	RW	N	Enumerated

* A "Definition" column is not included. For attribute definitions, see text.

7.4.6.5.1 *DebounceControl* — This attribute is used to control sensitivity to 'false' transitions. The method of utilization of this attribute for debounce control is application-specific.

7.4.6.5.2 *AlarmState* — The value of the Value attribute that will cause an alarm condition.

7.4.6.5.3 *WarningState* — The value of the Value attribute that will cause a warning condition.

7.4.7 *Actuator-Analog Output (AAO) Class* — The AAO class at the third level of the active element generalization hierarchy contains structure and behavior common to all analog output actuator element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device element type (see Figure 7), object instances can be created as instances of this class type.

7.4.7.1 *Actuator-Analog Output Class Attributes* — All required and "common optional" AAO class attributes are listed in Table 42 and described below. For an explanation of the table format, see Section 7.3.1. Note that the AAO class also inherits all AE and A class attributes.

Table 42 AAO Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Offset	AaoA64	RW	N	Context-specific
Gain	AaoA65	RW	N	Context-specific
DataType	AaoA66	RW	N	Context-specific
DataUnits	AaoA67**	RW	N	Context-specific

* A "Definition" column is not included. For attribute definitions, see text.

** ID's AaoA68 through AaoA127 are reserved for future Aao class attribute definition.

7.4.7.1.1 *Offset* — An attribute which specifies the amount of offset correction being applied to derive the value of the "Value" attribute (inherited) of the object instance. It is expressed in terms of the units specified by the "DataUnits" attribute.

7.4.7.1.2 *Gain* — An attribute which is used to define the range of the "Value" attribute (inherited) of the object instance. The method of conveying this range with this attribute is beyond the scope of this document.

7.4.7.1.3 *DataType* — An attribute which defines the format of the data associated with "Value" attribute (inherited) of the object instance.

7.4.7.1.4 *DataUnits* — An attribute which defines the current units associated with "Value" attribute (inherited) of the object instance.

7.4.7.2 *Actuator-Analog Output Class Services* — No AAO class common services are defined. Note that the AAO class inherits all AE and A class services.

7.4.7.3 *Actuator-Analog Output Class Behavior* — No AAO class common behavior is defined. Note that the AAO class inherits all AE and A class-defined behavior.

7.4.8 *Actuator-Binary Output (ABO) Class* — The ABO class at the third level of the active element generalization hierarchy contains structure and behavior common to all binary output actuator element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device element type (see Figure 7), object instances can be created as instances of this class type.

7.4.8.1 *Actuator-Binary Output Class Attributes* — No ABO class common attributes are defined. Note that the ABO class inherits all AE and A class attributes.

7.4.8.2 *Actuator-Binary Output Class Services* — No ABO class common services are defined. Note that the ABO class inherits all AE and A class services.

7.4.8.3 *Actuator-Binary Output Class Behavior* — No ABO class common behavior is defined. Note that the ABO class inherits all AE and A class-defined behavior.

7.4.9 *Actuator-Enumerated Output (AEO) Class* — The AEO class at the third level of the active element generalization hierarchy contains structure and behavior common to all Enumerated output actuator element instances in a device. Note that, as discussed in Section 7.4, since this is the lowest level of class description in the generalization hierarchy for this device element type (see Figure 7), object instances can be created as instances of this class type.

7.4.9.1 *Actuator-Enumerated Output Class Attributes* — No AEO class common attributes are defined. Note that the AEO class inherits all AE and A class attributes.

7.4.9.2 *Actuator-Enumerated Output Class Services* — No AEO class common services are defined. Note that the AEO class inherits all AE and A class services.

7.4.9.3 *Actuator-Enumerated Output Class Behavior* — No AEO class common behavior is defined. Note that the AEO class inherits all AE and A class-defined behavior.

7.4.10 *Sensor-Binary Input-Threshold (SBITH) Class* — The SBITH class at the fourth level of the active element generalization hierarchy contains structure and behavior common to all binary input threshold sensor element instances in a device.

7.4.10.1 *Sensor-Binary Input Threshold Class Attributes* — All required and "common optional" SBITH class attributes are listed in Table 43 and described below. For an explanation of the table format see Section 7.3.1. Note that the SBITH class also inherits all AE, S, an SBI class attributes.

Table 43 SBITH Class Attributes*

Attribute Name	*Attribute Identifier*	*Access (Network)*	*Rqmt*	*Form*
Reading Valid	SbithA64	R	N	Enumerated, Byte
State	SbithA65	R	N	Enumerated, Byte
Status	SbithA66	R	N	Enumerated, Byte

* A "Definition" column is not included. For attribute definitions, see text.

** ID's Sbith67 through Sbith127 are reserved for future Sbith class attribute definition.

7.4.10.1.1 *Reading Valid* — This attribute is used to specify the validity of the "*Value*" attribute of the SBITH object. The method of utilization of this attribute is application specific.

7.4.10.1.2 *State* — This attribute is used to record the current state of the SBITH object. The method of utilization of this attribute is application specific.

7.4.10.1.3 *Status* — This attribute is used to record the current active reporting status of the SBITH object. The method of utilization of this attribute is application specific.

7.4.10.2 *Sensor-Binary Input-Threshold Class Services* — No SBITH class common services are defined. Note that the SBITH class inherits all AE, S, and SBI class services.

7.4.10.3 *Sensor-Binary Input-Threshold Class Behavior* — No SBITH class common behavior is defined. Note that the SBITH class inherits all AE, S, and SBI class behavior.

APPENDIX 1
DATA UNIT ENUMERATION

NOTE: This appendix was approved as an official part of SEMI E54.1 by full letter ballot procedure.

The Data Units data type term is defined in Section 5.2. The following is a partial enumeration of that data type; further enumeration may be provided in an application-specific context.

Table A1-1 General

Data Units	*Description*
0	Counts
1	Counts per Second
2	Counts per Millisecond
3	Counts per Microsecond
4	Counts per Minute
5	Counts per Hour
6	Counts per Day
7	Percent
8–191	Reserved
192–255	Open

Group 1 — Time and Frequency (256–511)

Table A1-2 Time and Frequency

Data Units	*Description*
256	Seconds
257	Milliseconds
258	Microseconds
259	Minutes
260	Hours
261	Days
262	Hertz
263	KiloHertz
264	MegaHertz
265	GigaHertz
266–447	Reserved
448–511	Open

Group 2 — Temperature (512–767)

Table A1-3 Temperature

Data Units	*Description*
512	Centigrade/Celsius
513	Fahrenheit
514	Kelvin
515–703	Reserved
704–767	Open

Group 3 — Pressure (768–1023)

Table A1-4 Pressure

Data Units	*Description*
768	PSI
769	Torr
770	MilliTorr
771	mm Hg (0°C)
772	inches Hg (0°C)
773	cm H_2O (25°C)
774	inches H_2O (25°C)
775	Bar
776	MilliBar
777	Pascal
778	KiloPascal
779	Atmosphere
780–959	Reserved
960–1023	Open

Group 4 — Flow (1024–1279)

Table A1-5 Flow

Data Units	*Description*
1024	SCCM
1025	SLM
1026	CFM
1027	Pa-m^3/s
1028–1215	Reserved
1216–1279	Open

Group 5 — Electrical (1280–1535)

Table A1-6 Electrical

Data Units	*Description*
1280	Volts
1281	MilliVolts
1282	MicroVolts
1283	NanoVolts
1284	PicoVolts
1285	FemtoVolts
1286	KiloVolts
1287	MegaVolts
1288	GigaVolts
1290	Amps
1291	MilliAmps

1292	MicroAmps
1293	NanoAmps
1294	PicoAmps
1295	FemtoAmps
1296	KiloAmps
1297	MegaAmps
1298	GigaAmps
1300	Ohms
1301	MilliOhms
1302	MicroOhms
1303	NanoOhms
1304	PicoOhms
1305	FemtoOhms
1306	KiloOhms
1307	MegaOhms
1308	GigaOhms
1310	Farads
1311	MilliFarads
1312	MicroFarads
1313	NanoFarads
1314	PicoFarads
1315	FemtoFarads
1320	Henries
1321	MilliHenries
1322	MicroHenries
1323	NanoHenries
1324	PicoHenries
1325	FemtoHenries
1326–1471	Reserved
1472–1535	Open

APPENDIX 2
ERROR RESPONSES

NOTE: This appendix was approved as an official part of SEMI E54.1 by full letter ballot procedure.

The following is a listing of common service error responses. The details of presentation of these responses over the network (such as response codes) are network-specific and, thus, are not part of this document. Also, note that there may be additional service error responses delineated in the appropriate SDM specification or manufacturer specification.

A2-1 Error Responses

A2-1.1 *Resource Unavailable* — Resources needed for the object to perform the requested service are unavailable.

A2-1.2 *Service Not Supported* — The requested service is not implemented or is not defined for this Object Class/Instance.

A2-1.3 *Invalid Attribute Value* — Invalid attribute data detected.

A2-1.4 *Already in Requested Mode/State* — The object is already in the mode/state being requested by the service.

A2-1.5 *Object State Conflict* — The object cannot perform the requested service in its current mode/state.

A2-1.6 *Attribute Not Settable* — A request to modify a non-modifiable attribute was received.

A2-1.7 *Device State Conflict* — The device's current mode/state prohibits the execution of the requested service.

A2-1.8 *Service Parameter Data Not Complete* — Not enough data supplied with the service request.

A2-1.9 *Attribute Not Supported* — The attribute specified in the request is not supported.

A2-1.10 *Too Much Data for Service Parameters* — The service supplied more data than was expected.

A2-1.11 *Object Does Not Exist* — The object specified does not exist in the device.

A2-1.12 *Vendor-Specific Error* — Vendor-specific error.

A2-1.13 *Invalid Service Parameter* — A parameter associated with the request was invalid.

SEMI E54.2-0698
GUIDE FOR WRITING SENSOR/ACTUATOR NETWORK (SAN) STANDARD BALLOTS

1 Purpose

1.1 This guide recommends the method, form, and content for adding specific device models and associated Sensor Actuator Network Communications Standard (SANCS) extensions to the SEMI Sensor Actuator Network (SAN) standard. This guide facilitates consistency of these ballots, leading to better consistency and clarity of the resulting specifications and to easier development of SAN standard-conformant devices that achieve a high level of interoperability.

2 Scope

2.1 This guide provides written templates for ballots that will add either a specific device model (SDM), an SANCS ancillary standard, or SANCS extensions to support an SDM to the SEMI SAN standards. The guide provides directions for using the templates.

2.2 Physical devices will not be compliant with this guide; they will be compliant to standards which are spawned from the templates specified herein.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

SEMI E54.3 — Standard for Sensor/Actuator Network Specific Device Model for Mass Flow Device

4 Terminology

4.1 Acronyms

4.1.1 *A* — Actuator (a CDM class definition)

4.1.2 *AE* — Active Element (a CDM class definition)

4.1.3 *C* — Controller (a CDM class definition)

4.1.4 *CDM* — (SEMI) Common Device Model

4.1.5 *DM* — Device Manager (a CDM class definition)

4.1.6 *ISO-OSI* — International Organization for Standardization - Open Systems Interconnect (model)

4.1.7 *NCS* — Network Communications Standard

4.1.8 *OMT* — Object Modeling Technique

4.1.9 *S* — Sensor (A CDM object)

4.1.10 *SAC* — Sensor/Actuator/Controller (a CDM class definition)

4.1.11 *SAN* — Sensor/Actuator Network (or Sensor Bus)

4.1.12 *SANCS* — Sensor/Actuator Network Communications Standard, frequently abbreviated to NCS

4.1.13 *SDM* — (SEMI) Specific Device Model

4.2 *Definitions*

4.2.1 *connection oriented* — a situation between communicating objects wherein they are connected in a mode analogous to a two-way phone conversation.

4.2.2 *specific device model (SDM)* — a model used to specify each type of device, such as a Mass Flow Controller or Thermocouple.

5 Background

The SEMI sensor bus (SAN) communications model consists of three components: a CDM, an SDM, and an SANCS (NCS). The following subsections provide a brief description of the specifications which define these components:

5.1 *Network Communications Standard Specification* — An NCS specification is required for each network technology. Each one consists of two major parts:

5.1.1 *Part 1, Enabling Protocol and CDM Object Presentation* — This part of an SANCS specification should achieve the following goals:

- provide an ISO-OSI layered specification of the protocol, specifying the protocol requirements at each layer,
- specify the object oriented communication environment, including object representation and addressing, attributes and services addressing, etc.,
- specify how CDM objects are represented and addressed to/from the network, and

- specify how AE class and subclass objects, defined in the CDM and the SDMs, are represented and addressed to/from the network.

5.1.2 *Part 2, Enabling Specific Device Models* — This part provides a mapping of SDM objects for the SANCS specification. There should be a section for each SDM which identifies specific objects that must be supported to enable the SDM and how the SDM structure fits into the protocol application layer foundation.

5.2 *Common Device Model* — Each device's functions on a network should comply with the specifications of the Common Device Model, SEMI E54.1. Three types or classes of objects may be combined to create models of real devices. The types are Active Element (AE) and its subclasses, Sensor/Actuator Controller (SAC) and its embedded objects, and the Device Manager (DM).

NOTE: The CDM specifies the relationship between these objects. It specifies some of the structure and behavior for the DM and SAC objects. The subclasses of the AE object provide capabilities which are useful to most devices.

5.3 *Specific Device Model*

5.3.1 Specific Device Models are defined in the SEMI SAN SDM (SEMI E54.3). Each SDM is added as a separate new section (similar to the way a new section is added to SEMI E5 when a new stream is added).

5.3.2 The Specific Device Models (SDM's) should be a specialization of the CDM and may extend the attributes, services, and behavior of any of the Sensor, Actuator, or Controller (subclasses of the AE class) objects of which they are made. SDM's may add to the attributes, services, and behavior of the SAC object.

6 Ballot Preparation

6.1 *The Cover Letter* — All ballots are submitted with a cover letter. The cover letter sets the context for the ballot. The Ballot Cover Letter Template provides guidance to prepare the cover letter.

6.2 *Specific Device Model Ballots* — A ballot to add an ancillary specification for a new SDM should be prepared as defined in the template in the section titled Template for SDM Ballot Proposals.

SEMI E39 is the basis for the tables and figures called out in the template. Refer to SEMI E39 for clarifications on using and defining object models. General instructions for using the template are contained in the subsections of this section. Specific instructions are included within the templates.

6.2.1 Device application models should be presented using Rumbaugh's Object Modeling Technology notation for information models. (See SEMI E39 for details on using object notation for defining standards.)

6.2.2 The behavior of objects should be defined using Harel State charts, state definition tables, and state transition tables. A discussion of the notation may be found in Appendix A.5 of SEMI E30. An alternative table, Object Behavior State Transition Matrix, may be used in place of the more traditional (State) Transition Table. Cells in the Transition Matrix indicate the transition action which is taken for an event for any of the states in which it can be detected. This can be particularly useful for describing the variation in device response depending on a sub-state when the parent state detects an event.

6.2.3 The set of tables which define the device's interfaces are the only testable parts of the specification for the application models. The interface for each device model should be defined in a series of tables, as follows:

6.2.3.1 *Attribute Tables* — For each object defined as an element of a device, a table which defines its network visible attributes should be specified. Each attribute is named and tagged. Its network access type (read only or read/write) and storage class (volatile, non-volatile, or constant) are also specified. The table should also indicate which attributes have standardized values and which are device supplier reserved. The definition or description of an attribute can either be included in the table or else should immediately follow the table. The "Required" column indicates if the attribute must be supported for a device to be SDM-compliant. Use the letter "Y" to indicate yes and the letter "N" to indicate no. The form field is used to indicate the data type of the attribute, such as integer, floating point, array of characters, etc. Actual format of these data types is network-dependent.

6.2.3.2 *Optional Service Parameter Table* — If this table is included in the specification of an SDM, the parameters, which are used by the device's services, are defined in it, including the data type and length.

6.2.3.3 *Service Definition Table* — Each service and its parameters are defined in a table. If the optional parameter table is not used in the SDM specification, then the form field should be included in the service definition table.

6.3 *SANCS Ballots* — A ballot to add an ancillary specification for a new SANCS should be prepared as defined by the template in the section titled Template for Part 1 of an SANCS Ancillary Standard.

When a new SDM is added to the SAN standard, an update to Part 2 of the ancillary SANCS specifications is needed. A ballot should be prepared as defined in the template in the section titled Template for an SANCS ballot to support an SDM.

The nature of the Template for an SANCS ballot to support an SDM is that it adds SDM information to only one SANCS specification at a time. Additions and changes to support each new SDM are balloted separately for each SANCS specification.

6.3.1 *Coordination with Industry User Groups* — Most of the network technologies are supported by an industry user group or association. These groups are responsible for the assignment (i.e., mapping) of identifiers to the variables or attributes, parameters, and messages/services that will be managed by their protocol. When the SEMI SAN standards require new identifiers, they should be requested from the appropriate industry group.

6.3.1.1 *Technical Notes* — SEMI will make technical notes available, for each protocol supported by the SEMI SAN standards, that list the protocol's identifiers.

6.4 *Template Conventions*

6.4.1 Instructions or text that is meant to be replaced with ballot-specific information are included within the templates in italics. Non-italicized text and tables are intended to be included in the ballot as depicted in the template.

6.4.2 Section, figure, and table numbers specified using letters are meant to indicate structure and format. Specific numbers should be generated by the ballot author. Ballots which require adding to or modifying existing SAN standards will be edited by SEMI for consistency with the existing standard where necessary.

7 Ballot Cover Letter Template

Each ballot is accompanied by a cover letter which includes the following sections:

7.1 *Proposal* — Provide a brief description, typically one or two sentences, of the content of the ballot proposal.

7.2 *Background* — In 1–3 paragraphs, give the readers the background they need to understand the content and value of the proposed standard.

7.3 *Impact* — Use one or two paragraphs to describe how this standard affects the SEMI community.

7.4 *Ballot Description* — Describe the form of the ballot proposal. Use one or two paragraphs.

Note that SDM ballots are additions to the SEMI SAN SDM Specification (SEMI E54.3). This is a parent document which already has sections for overall purpose, scope, terminology, conventions, etc. for SDMs. Each individual SDM ballot should include only device-specific purpose, scope, and terminology. Items that are used in multiple SDMs should be balloted as updates to the SEMI E54.3 parent document.

8 Template for SDM Ballot Proposals

SEMI Document Number

Title

1 Purpose

Describe the purpose of the document. This is typically to provide a network-independent application model for the specific device - NamedDevice.

2 Scope

Describe the scope of the document.

3 Referenced Documents

List documents referenced from within this specification.

4 Terminology

Define terms used within this document. This is only for terms that are used within this document and not defined elsewhere (in the SEMI E54.3 parent document or other referenced documents).

5 NamedDevice High Level Structure

5.1 *General Description* — Describe what this device does, how it is used, etc.

5.1.1 *NamedDevice Description* — Provide a description of NamedDevice, including information model(s) in figure(s) that use a Rumbaugh OMT (see SEMI E39 Appendix A1-2) diagram.

NOTE 3: The device may actually consist of multiple devices (e.g., Mass Flow Device includes a Controller device and a Meter device), in which case multiple sections should be created - one per device.

5.1.x *General Requirements*

5.1.x.1 *Device Objects* — All objects are defined in terms of their object name and instance identifier. Identifiers for all objects described in this document are summarized in Table m.

Table m NamedDevice Device Objects

Referenced Document Section	*Object Name*	*Object Identifier*	*Minimum Instances*	*Maximum Instances*

All parameters used by the device's services can be summarized using the table (Table n). This is optional, as the parameters are further defined in association with specific objects (see 5.x.2).

Table n Parameter Definition Table

Parameter Name	*Data Type*	*Tag*	*Description*

For each Object in Table m, a section (5.x) is created as below, beginning with 5.2.

5.x *Name1 Object*

5.x.1 *Name1 Object Attributes* — Provide the object attribute information using the table (Table o) below.

Table o Object Name1 Attributes

Attribute Name	*Definition**	*Attribute Identifier*	*Network Access*	*Form*	*Storage Class*	*Required*

* The definition column can be omitted if the definitions immediately follow the table. The definitions can be provided as subsections.

Where appropriate, provide initial and default values for object attributes. This can be done as a table.

5.x.2 *Name1 Object Services* — Describe the services provided by this object using the following table (Table p) to list the services:

Table p Object Name1 Services

Service	*Service Identifier*	*Type*	*Description*

Provide a detailed description of each service, including a definition of the parameters for the service. The parameters can be defined using the following table (Table q) format:

Table q Service1 Service Parameter Definitions

Parameter	*Request/Indication*	*Response/Confirmation*	*Data Type**	*Description*

* This column can be removed if there is an overall parameter definition table (Table n) included in the specification.

5.x.3 *Name1 Object Behavior* — Describe the object states and sub-states as needed with a Harel State Diagram(s):

Figure

Harel State Diagram

Provide a state definition table as given in Table r. More than one state table could be added if a device is sufficiently complex. Put in any text needed to explain object states.

Table r Name1 Object Behavior State Descriptions

State Name	*Description*

Describe the state transitions using a table as given in Tables s or t. More than one table could be needed.

Table s Name1 Object Behavior State Transition Table

Event or Transition #	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comments*

Table t Name1 Object Behavior State Transition Matrix

Event Number	*State 1*	*State 2*	*State 3*	
			Sub A	*Sub B*
1				
2				
3				
4				

9 Template for Part 1 of an SANCS Ancillary Standard

The body of the ballot should then contain the following sections:

1 Purpose

This section contains wording describing the purpose with customization for the specific protocol. A "Background and Motivation" subsection could be included to generally describe the protocol.

2 Scope

This section contains wording describing the scope with customization for the specific protocol.

3 Limitations

This section contains wording describing the limitations customized for the specific protocol. Any limitations of CDM or SDMs support, due to the protocol, should be identified.

4 Referenced Documents

This section contains wording describing the referenced documents with additional references to protocol specification documentation and any support documentation as required for complete specification of the protocol (two subsections). A clearly defined mechanism is specified for obtaining any documentation that is not publicly available or available from SEMI.

5 Terminology

The various protocols and the CDM invariably use different terminology. A mapping is made between the CDM terminology and the terminology used in discussing the protocol. For example, a CDM Service implementation may be defined as an Action in the NCS. This terminology mapping is explicitly covered completely in the "Terminology" section. A mapping table is desirable that contains a column listing of the CDM terms in the same order as defined in the CDM document, mapped to terminology used in the NCS document. This NCS terminology and any additional terminology is defined in a subsection (e.g., Section 5.2).

6 Communication Protocol High Level Structure

A basic description of the protocol is provided in Section 6. The main purpose of Section 6 is to give the reader a general understanding of what will be specifically presented in the remainder of the subsections in Section 6.

The rest of the subsections in Section 6 should be devoted to describing the communications standard in terms of the OSI seven-layer model (one subsection for each layer) and any network management services.

Each of the OSI seven layers should be addressed and specified either directly or through reference; for each:

- If an OSI layer is not supported/defined, this is stated explicitly.
- Choices among protocol options are made, specified, and explained where appropriate. A complete summary of protocol choices specified and protocol options allowed should be summarized in a subsection of this section of the specification.

The Physical layer is specified either directly or through reference (signaling, bus arbitration, baud rate, transceivers, cabling, connectors, etc.).

The Data link layer is specified either directly or through reference (packet/frame specification and node addressing).

The Network layer is optional.

The Transport layer elements are specified either directly or through reference; message segmentation and reassembling should be supported as no message length limits are indicated in CDM or SDM's. This support should be provided as a transport layer service. Note that this functionality may alternatively be provided at the application layer by protocols unable to support it at the transport layer; if this is the case, it is explicitly stated in the description of transport layer support. Connection support would be specified here as appropriate.

The Session layer is optional.

The Presentation layer is optional.

The Application layer is specified. The document defines (explicitly or through reference) how objects are structured, identified, and addressed. Thus, it should also define how object attributes are addressed and how object request and notify services are addressed and communicated. This section also defines the application object to object communication mechanism which should include or reference a communication state model. This communication model should clearly indicate whether or not the protocol is connection oriented.

Network Management Services may be defined in a separate subsection.

7 Required Object Types

This section identifies specific objects that must be supported to enable the CDM. The document should identify how the CDM structure (Objects and relations) fits into the protocol application layer foundation. Any identifiable protocol object hierarchy should be introduced here. Specifically, the following are defined:

- The implementation of all CDM objects (DM, SAC, AE, and all subclasses) defined to the extent that these objects are defined in CDM documentation.
- Specific addressing/referencing for CDM objects (attributes, services, etc.) defined as necessary so as to specify access to CDM objects as required by the CDM standard specification. Attributes and services are further specified as necessary so that the protocol required to access specific attributes and services is fully defined. For example, a CDM service may be defined as a “new” SANCS service or mapped to an existing SANCS service (if an appropriate candidate has already been defined in the protocol specification).
- Any limitations among CDM object options are identified.
- Any additional capabilities required of, or optional for, CDM objects (e.g., attributes, services, and/or behavior) are identified.
- Any additional required objects (e.g., network management object) identified and their interaction with the CDM objects (e.g., connection management object) should be specified.

8 Protocol Compliance

This section should specify a method or reference for testing protocol compliance. It should contain in subsection 8.1 a “protocol specification sheet” that lists all protocol options that have been specified in the document or must be resolved by the user in order to achieve interoperability.

10 Template for an SANCS Ballot to Support an SDM

Section 1 Table of Contents

Request that the table of contents for the SANCS be updated to contain a pointer to the paragraphs which specify the SDM mappings which are being added by the ballot.

Section 2 <SDM> Object Mapping

Each of the subsections within this section should identify specific objects that must be supported to enable the SDM and should identify how the SDM structure (objects and relations) fits into the protocol application layer foundation.

Specifically, the following issues are addressed:

Terminology

- A mapping is made between the SDM terminology and the terminology used in discussing the protocol. This is explicitly covered in a “Terminology” section. A mapping table is desirable that contains a column listing of the SDM terms in the same order as defined in the CDM document, mapped to terminology used by the network technology.

Required Object Types

- Address implementation of all SDM objects to the extent that they are defined in SDM documentation.

- Identify and map the specific addressing/referencing for SDM object attributes, services, and parameters to the protocol. Note that, for example, this may be achieved by fully specifying a SDM service as a “new” NCS service or by mapping the service to an existing NCS service.

Protocol Compliance

- Provide methods or references (in addition to those identified in the section titled Template for Part 1 of an SANCS Ancillary Standard, Section 8) for testing protocol compliance of the SDM.

SEMI E54.3-0698
SPECIFICATION FOR SENSOR/ACTUATOR NETWORK SPECIFIC DEVICE MODEL FOR MASS FLOW DEVICE

1 Purpose

1.1 This specification is part of a suite of standards which specify the implementation of SEMI standards for the Sensor/Actuator Network. The specific purpose of this specification is to describe a network-independent application model comprised of device objects which are common to all Mass Flow Devices on a semiconductor equipment Sensor/Actuator communications network.

2 Scope

2.1 This specification specifically addresses the minimum attributes, services, and behavior a Mass Flow Controller (MFC) and Mass Flow Meter (MFM) device must support to be interoperable on the Sensor/Actuator Network.

2.2 This specification is intended to ensure a high-degree of device interoperability on the Sensor/Actuator Network, while still allowing flexibility for product differentiation and technology evolution.

2.3 The model specified in this specification is used in conjunction with the Sensor/Actuator Network Common Device Model (CDM) to completely describe the MFC or MFM as it appears from the network interface.

2.4 This specification, together with the Sensor/Actuator Network Standard, the Sensor/Actuator Network Common Device Model, and a Sensor/Actuator Network Communication Specification, form a complete interoperability specification for the MFC and MFM.

2.5 To comply with this specification, a device must implement and support, at a minimum, the required attributes, services, and behavior identified in these documents. Support for **optional** attributes, services, and behavior are not required to be compliant to this specification. Optional attributes, services, and behavior are specified in these documents to promote further device interoperability as features evolve and are adopted by more manufacturers. If optional attributes, services, and behavior are implemented for this device, they must be implemented as identified in this document.

3 Limitations

3.1 This specification is a companion to a suite of specifications which together make up the Sensor/Actuator Network Communication standard. Therefore, using portions of this specification that relate to network communications necessarily requires an understanding of the associated network specification.

3.2 As this document is a specification for the Mass Flow Device Model, it does not contain any definition of objects, attributes, services, or behavioral descriptions that are already defined in the Sensor/Actuator Network Common Device Model (CDM). Additional attributes, attribute assignments, services, and/or service parameters that are Mass Flow Device-specific and/or implementation-specific are contained in this specification.

3.3 While this specification is sufficient to completely describe the MFC or MFM as it appears from the network, it does not fully describe behavior of the MFC or MFM which is not visible from the network. This allows flexibility in implementation techniques and product differentiation between manufacturers. Manufacturer-specific objects may be defined by the manufacturer, but are, by definition, outside the scope of this standard.

3.4 This specification is compatible, but not compliant, with SEMI E39. This means that although this specification does not require compliance with SEMI E39, it is extensible such that implementations may be developed that are fully compliant with both standards. Note that the concepts and terminology of this specification are compatible with those of SEMI E39. However, SEMI E39 has specific requirements that are intended for higher level applications and, thus, are not applied to the Mass Flow Device Model.

3.5 Operation over the entire range specified for an attribute within a specific object instance is not a requisite for compliance with this specification.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E12 — Standard for Standard Pressure, Temperature, Density, and Flow Units Used in Mass Flow Meters and Mass Flow Controllers

SEMI E18 — Guideline for Temperature Specifications of the Mass Flow Controller

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E52 — Practice for Referencing Gases Used in Digital Mass Flow Controllers

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

4.2 *IEEE Document*[1]

IEEE 754 — Floating Point Definition

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Terminology Defined in Standard for Sensor/Actuator Network Common Device Model (SEMI E54.1)*

5.1.1 Attribute

5.1.2 Behavior

5.1.3 Byte

5.1.4 Character

5.1.5 Device

5.1.6 Device Manager (DM) Object

5.1.7 Device Model

5.1.8 Instance

5.1.9 Nibble

5.1.10 Object

5.1.11 S, A, and C Objects

5.1.12 Sensor Actuator Controller (SAC) Object

5.1.13 Service

5.1.14 State Diagram

5.2 *Definitions*

5.2.1 *boolean (BOOL)* — a binary bit representing 0 and 1 corresponding to FALSE and TRUE or DISABLE and ENABLE respectively.

5.2.2 *common device model (CDM)* — refers to Sensor/Actuator Network Common Device Model (SEMI E54.1).

5.2.3 *data type* — an unsigned short integer formatted as an enumerated byte to specify attribute data format. The intended use of this attribute type is in cases where an attribute, or set of attributes, may be defined, allowing for more than one level of support (e.g., INT or REAL). The following values are defined:

0 = INT

1 = REAL

2 = USINT

3 = SINT

4 = DINT

5 = LINT

6 = UINT

7 = UDINT

8 = ULINT

9 = LREAL

10–99 = reserved for CDM

100–199 = reserved for SDMs

200–255 = manufacturer-specified

5.2.4 *data units* — an unsigned integer formatted as an enumerated byte to specify attribute data units. The intended use of this attribute type is in cases where an attribute, or set of attributes, may be defined, allowing for more than one unit's context. The values are defined in an appendix of this document.

5.2.5 *date* — a data structure of four bytes used to represent a calendar date. Table 1 defines the format of the date data type.

Table 1 Date Format

Data #	*Description*	*Range*
0–1	Year	Unsigned Integer
2	Month	Unsigned Short Integer(range of 1 to 12)
3	Day	Unsigned Short Integer(range of 1 to 31)

5.2.6 *double integer (DINT)* — an integer, four bytes long, in the range -2^{31} to $2^{31} - 1$.

5.2.7 *enumerated byte* — a byte with assigned meaning to the values 0 through 255. May take on one of a limited set of possible values.

5.2.8 *full scale range* — the defined 100% value of an attribute in its assigned units. This value is not necessarily the maximum value for the attribute. As an example, the *indicated flow* attribute value may attain 120% of the full scale range.

1 Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017

5.2.9 *gas calibration* — a reference to a set of parameters or methods which are used to calibrate or correct the device for a particular gas type, range, and units.

5.2.10 *gas standard number* — a number that references a gas type. The number and its referenced gas type are defined in SEMI E52.

5.2.11 *gas standard symbol* — a text symbol that references a gas type. The symbol and its referenced gas type are defined in SEMI E52.

5.2.12 *last valid value (LVV)* — the most recent value successfully assigned to an attribute.

5.2.13 *long integer (LINT)* — an integer, eight bytes long, in the range -2^{63} to $2^{63}-1$.

5.2.14 *long real (LREAL)* — a double floating point number, eight bytes long, as defined in IEEE 754.

5.2.15 *manufacturer* — in the context of this document, this refers to the manufacturer of the device.

5.2.16 *mass flow controller (MFC)* — a self-contained device, consisting of a mass flow transducer, control valve, and control and signal-processing electronics, commonly used in the semiconductor industry to measure and regulate the mass flow of gas.

5.2.17 *mass flow device (MFD)* — a device which is either a mass flow controller or mass flow meter.

5.2.18 *mass flow meter (MFM)* — a self-contained device, consisting of a mass flow transducer and signal-processing electronics, commonly used in the semiconductor industry to measure the mass flow of gas.

5.2.19 *null character* — a byte with a value of zero.

5.2.20 *programmed gas calibration* — a reference to a particular gas type, range, and units for which the device is currently calibrated.

5.2.21 real (REAL) — a floating point number, four bytes long, as defined by IEEE 754.

5.2.22 *short integer (SINT)* — an integer, one byte long, in the range -128 to 127.

5.2.23 *signed integer (INT)* — an integer, two bytes long, in the range -32768 to 32767.

5.2.24 *text string* — a string of one-byte characters. See Section 5.1 for a definition of a character.

5.2.25 *unsigned integer (UINT)* — an integer, two bytes long, in the range 0 to 65535.

5.2.26 *unsigned short integer (USINT)* — an integer, one byte long, in the range 0 to 255.

6 Requirements

6.1 In order to implement this standard in a Mass Flow Device, it is necessary to also implement SEMI E54.1 and one of the Sensor/Actuator Network Communication standards. See Section 2 for more information on a complete interoperability standard.

7 Conventions

7.1 This document embraces the Harel State Chart notation, the transition table definition format, the object attribute representation formats, service message definition formats, and behavior definition formats as specified in SEMI E54.1.

7.2 Figure 1 describes the convention for object representation used throughout this specification.

```
OBJECT NAME
-------------------------
Attributes

-------------------------
Services
```

Figure 1
Object Representation

8 Device High Level Structure

8.1 *General Description* — The high level object view of a Mass Flow Meter (MFM) device and a Mass Flow Controller (MFC) Device is shown in Figure 2.

Note that the "MFM" and the "MFC" objects are depicted in Figure 2 only for the purposes of illustrating a high level view of the device and its component objects. In the context of this document, these objects are not addressable, do not have addressable attributes, do not have accessible services, nor do they exhibit any defined behavior. These objects are only included in the figures to aid in the visualization of the device.

This document defines in detail all of the component objects unique to the MFC and the MFM devices. References, rather than definitions, are included for the DM, the SAC, and other objects defined in SEMI E54.1.

Many of the objects defined in this document inherit properties from other objects. The properties inherited include attribute, service, and behavior definitions. These other objects are specified here or in SEMI E54.1.

This document provides for future extensions, as well as manufacturer-specific enhancements, by reserving object attribute identifiers and object service identifiers. Specifically, all object definitions in this document specify or reserve the first 64 attribute identifiers (A1 through A64) and the first 64 service identifiers (S1 through S64), allowing manufacturers to specify identifiers beyond these ranges. Additionally, byte-enumerated attributes are specified or reserved from 0 to 63, allowing manufacturers to specify enumerations beyond this range (64 to 255).

8.1.1 *Mass Flow Meter (MFM) Device Description* — A Mass Flow Meter device profile is composed of the component objects and object relationships shown in Figure 2.

8.1.2 *Mass Flow Controller (MFC) Device Description* — A Mass Flow Controller device profile is composed of (1) all of the component objects and object relationships of the Mass Flow Meter Device in addition to (2) the component objects and object relationships as shown in Figure 2.

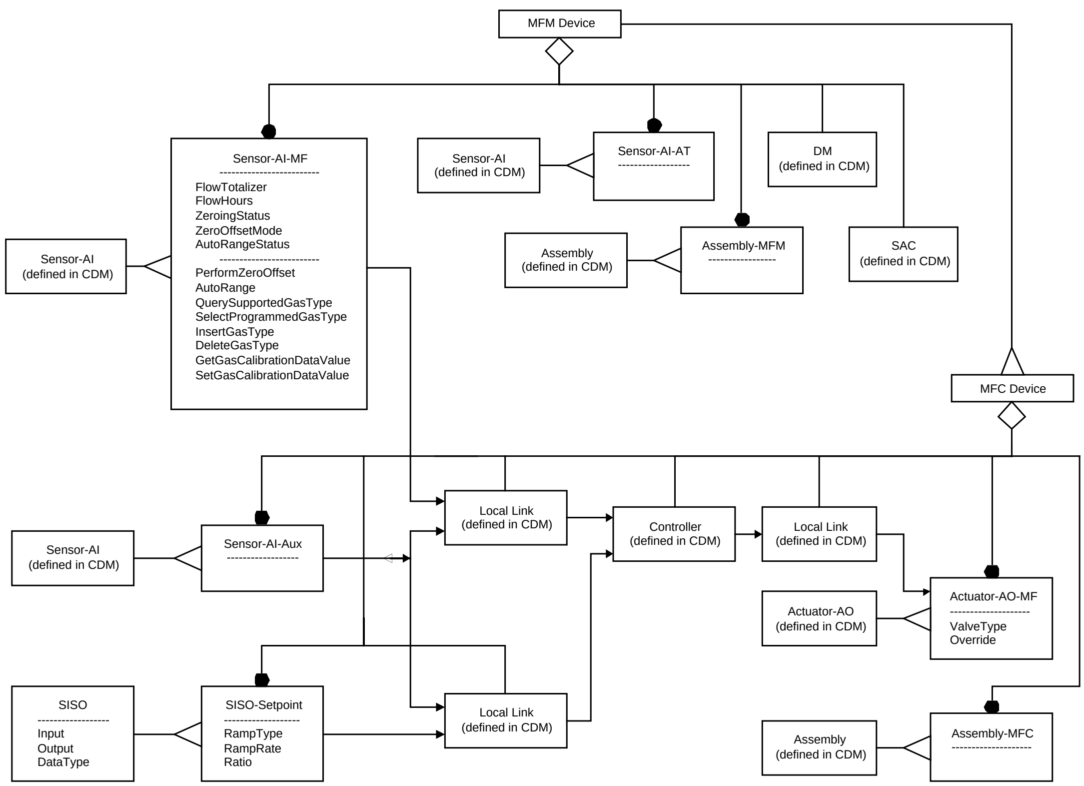

Figure 2
Mass Flow Meter Device and Mass Flow Controller Device High Level Structure

8.1.3 *General Requirements*

8.1.3.1 *Device Objects* — All objects are defined in terms of their object name and instance identifier. Identifiers for all objects described in this document are summarized in Table 2.

Table 2 Mass Flow Device Objects

Referenced Document Section	*Object Name*	*Object Identifier*	*MFC Minimum Instances*	*MFM Minimum Instances*	*Maximum Instances*
8.2	Device Manager (DM)	MFD1	1	1	1
8.3	Sensor Actuator Controller (SAC)	MFD2	1	1	1
8.4	Sensor-AI-MF	MFD3	1	1	Manufacturer-Specified
8.5	Sensor-AI-AT	MFD4	0	0	Manufacturer-Specified
8.6	Assembly-MFM	MFD5	0	0	1
8.7	Sensor-AI-Aux	MFD6	0	0	Manufacturer-Specified
8.8	Actuator-AO-MF	MFD7	1	0	Manufacturer-Specified
8.9	Controller	MFD8	1	0	1
8.10	Local Link	MFD9	2	0	Manufacturer-Specified
8.11	SISO	MFD10	0	0	Manufacturer-Specified
8.12	SISO-Setpoint	MFD11	0	0	Manufacturer-Specified
8.13	Assembly-MFC	MFD12	0	0	Manufacturer-Specified
—	Reserved	MFD13–MFD64	–	–	—
—	Manufacturer-Specified	> MFD64	–	–	—

8.1.3.2 *Object Services* — Not all object services listed in this document can necessarily be requested over the network. They are included in this document because their behavior may generate network activity.

8.1.3.3 *Object Behavior* — For all service requests received over the network that are unsupported by the object, or contain a parameter value which is beyond the supported range, or which is otherwise invalid, a network-specific service error response is generated as specified in SEMI E54.1.

8.2 *Device Manager Object (DM)*

8.2.1 The Device Manager object instance is the device component responsible for managing and consolidating the device operation as specified in SEMI E54.1. The following sections specify the components of the DM object that are not specified in the Common Device Model.

8.2.2 *Device Manager Object Attributes* — Required and optional DM object instance attributes are listed in Table 3.

Table 3 DM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Device Type	A1	R	Yes	Refer to CDM (SEMI E54.1).
Exception Detail Alarm	A13	R	No	Refer to CDM (SEMI E54.1).
Exception Detail Warning	A14	R	No	Refer to CDM (SEMI E54.1).
Reserved	A33–A64	—	—	Reserved for SDM future expansion.
Manufacturer-Specified	> A64	—	—	Manufacturer-Specific attributes

8.2.2.1 *Device Type* — An attribute which uniquely identifies the type of the device on the network. The device type attribute is assigned as follows:

Mass Flow Controller Device = “MFC”

Mass Flow Meter Device = “MFM”

8.2.2.2 *Exception Detail Alarm (Optional)* — An attribute which identifies the detailed alarm status of the device. Table 4 defines the bit assignments associated with the alarm exception detail.

Table 4 Exception Detail Alarm Bit Assignments

Bit	*Device-Specific Alarm [0]*
0	Reserved
1	Indicated Flow High
2	Indicated Flow Low
3	Flow Controller
4	Flow Valve Actuator
5	Reserved
6	Reserved
7	Reserved

8.2.2.3 *Exception Detail Warning (Optional)* — An attribute which identifies the detailed warning status of the device. Table 5 defines the bit assignments associated with the warning exception detail.

Table 5 Exception Detail Warning Bit Assignments

Bit	*Device-Specific Warning [0]*
0	Reserved
1	Indicated Flow High
2	Indicated Flow Low
3	Flow Controller
4	Flow Valve Actuator
5	Reserved
6	Reserved
7	Reserved

8.2.2.4 *Initial and Default Values*

Table 6 DM Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Device Type	MFC, MFM	MFC, MFM	MFM = Mass Flow Meter Device MFC = Mass Flow Controller Device
Exception Detail Alarm	0	0	
Exception Detail Warning	0	0	

8.3 *Sensor Actuator Controller Object (SAC)* — The Sensor Actuator Controller object instance is the device component responsible for coordinating the interaction of the mass flow device with the sensory/actuation/control environment as specified in SEMI E54.1.

8.4 *Sensor-AI-MF Object* — The Sensor-AI-MF object inherits the attributes, services, and behavior of the Sensor-AI as defined in SEMI E54.1. The Sensor-AI-MF object instance is the device component responsible for retrieving a reading from a physical flow sensor, optionally correcting the reading with a manufacturer-specified algorithm, or algorithms, then making the value available to feed the Controller object instance via a Local Link object instance.

8.4.1 *Sensor-AI-MF Object Attributes*

Table 7 Sensor-AI-MF Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Flow Totalizer	A1	RW	No	REAL
Flow Hours	A2	R	No	ULINT
Zero Offset Mode	A5	RW	No	Enumerated Byte
Zeroing Status	A6	R	No	Enumerated Byte
Autorange Status	A7	R	No	Enumerated Byte
Reserved	A8–A64	—	—	Reserved for future expansion
Manufacturer-Specified	> A64	—	—	Manufacturer-Specific attributes

8.4.1.1 *Flow Totalizer (Optional)* — An attribute that maintains the volume of gas in standard cubic centimeters (SCC) that has flowed through the device since the last time the flow *totalizer* attribute value was set to zero.

8.4.1.2 *Flow Hours (Optional)* — An attribute which identifies the number of hours that the device has been flowing gas since the last time the *flow hours* attribute value was set to zero, as specified by the manufacturer. The attribute is an unsigned long integer with a resolution of 1 hour.

8.4.1.3 *Zero Offset Mode (Optional)* — An attribute which specifies the zero offset formula to be applied to produce the value attribute. This attribute is an enumerated byte that can take on one of the following values:

0 = Disable
1 = Enable Application of Formula
2 = Enable Automatic Zeroing
3–63 = Reserved
64–255 = Manufacturer-Specified

8.4.1.4 *Zeroing Status (Optional)* — An attribute which specifies whether the object is in the ZEROING substate. This attribute is an enumerated byte that can take on one of the following values:

0 = Not Zeroing
1 = Zeroing

8.4.1.5 *Autorange Status (Optional)* — An attribute which specifies whether the object is in the AUTORANGING sub-state. This attribute is an enumerated byte that can take on one of the following values:

0 = Not Autoranging
1 = Autoranging

8.4.1.6 *Initial and Default Values*

Table 8 Sensor-AI-MF Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Flow Totalizer	LVV	0	
Flow Hours	LVV	0	
Zero Offset Mode	LVV	Disable	
Zeroing Status	Not Zeroing	Not Zeroing	
Autorange Status	LVV	Not Autoranging	

8.4.2 *Sensor-AI-MF Object Services* — The services provided by the Sensor-AI-MF object instance are defined in SEMI E54.1. The Sensor-AI-MF object supports the additional services listed below.

All Gas Correction services are optional. Gas correction may be handled within the device as a pre-assigned gas calibration or may not be implemented at all. If these services are available, it is manufacturer-specific as to whether the device supports references to *gas standard number*, *gas standard symbol*, or both. It is strongly recommended that, if a device supports only one method of referencing gas types, it should be *gas standard number*.

A device may support any of these services, in whole or in part, as specified by the manufacturer. A manufacturer may specify a subset of the service parameter values which is supported. The following table lists the services supported by the Sensor-AI-MF object instance:

Table 9 Sensor-AI-MF Object Services

Service	*Service Identifier*	*Type*	*Description*
Perform Zero Offset	S1	R	Used to instruct the object to perform an automatic zeroing operation.
Query-Supported Gas Types	S2	R	Used to query the device to determine whether a specific gas calibration is supported.
Selected Programmed Gas Type	S3	R	Used to select the gas type and associated data to be used as the current programmed gas calibration.
Insert Gas Type	S4	R	Used to add a gas type to the list of available gas types.
Delete Gas Type	S5	R	Used to remove a gas type from the list of available gas types.
Get Gas Calibration Data Value	S6	R	Used to request the value of a specific gas calibration data value.
Set Gas Calibration Data Value	S7	R	Used to set the value of a specific gas calibration data value.
Autorange	S8	R	Used to enter the AUTORANGING state.
Reserved	S9–S64	—	Reserved for future expansion.
Manufacturer-Specified	> S64	—	Manufacturer-Specific services

8.4.2.1 *Perform Zero Offset (Optional)* — This service is used to instruct the Sensor-AI-MF object instance to perform a one-time automatic zeroing operation on the device or to reset the *offset* attribute value to zero. This service causes the automatic zeroing of the Sensor-AI-MF object instance *value* attribute by modifying the value of the *offset* attribute in order to yield a value of zero for the *value* attribute. Table 10 describes the parameters specified for this service.

Table 10 Perform Zero Service Parameter Definitions

Parameter	*Request/Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Command	M	—	Byte	Enumerated Byte: 0 = Set offset attribute to zero 1 = Calculate offset 2 = Cancel Zeroing 3–63 = Reserved 64–255 = Manufacturer-Specified

8.4.2.2 *Query-Supported Gas Types Service (Optional)* — This service is used to query the device to determine whether a specific gas type, range, and units is supported. Supported, in this context, implies that the device contains suitable gas calibration correction data or methods to correct the flow measurement for the specified gas type, range, and units. The query can be made by referencing either *gas standard number* or *gas standard symbol* (see Section 5 for a definition of “gas standard number” and “gas standard symbol”). The entire list of supported gas standard numbers or gas standard symbols (with ranges and units) can also be requested. The following table describes the parameters specified for this service:

Table 11 Query-Supported Gas Types Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Query Type	M	—	Byte	0 = specific gas type 1 = all currently supported gas calibrations 2 = currently programmed gas calibration
Gas Standard Number	C*	—	Unsigned Integer	0 = use standard gas symbol field n = gas standard number
Gas Standard Symbol	C*	—	Text String	null character = not specified text string = gas standard symbol
Full Scale Range	C*	—	Real	0 = not specified n = full scale range
Units	C*	—	UINT	Indication of the units associated with the full scale range.
Valid Flag	—	M	Byte	0 = Not Valid 1 = Valid
Size of List	—	M	Unsigned Integer	Number of gas calibrations in the list.
List of Gas Calibrations	—	M	Array of Structures	The list of gas calibrations.

* Parameter is Mandatory for Query Type = 0.

8.4.2.2.1 *Query Type* — This parameter is used to specify the type of service response. It is an enumerated byte that can take on the following values:

0 = specific gas type
1 = all currently supported gas calibrations
2 = currently programmed gas calibration
3–63 = Reserved
64–255 = Manufacturer-Specified

8.4.2.2.2 *Gas Standard Number* — This parameter is used to specify a gas standard number, for which device support is being queried. A value of “0” indicates that the following parameter “gas standard symbol” is used instead to reference the gas type.

8.4.2.2.3 *Gas Standard Symbol* — This parameter is used to specify a gas standard symbol, for which device support is being queried. If the gas standard number parameter has a value that is not zero, then this parameter will have the value of null character.

8.4.2.2.4 *Full Scale Range* — This parameter is used to specify the full scale range, for which device support is being queried. See Section 5 for a definition of “full scale range.” A value of “0” queries the device to return the entire list of full scale ranges for the specified gas type.

8.4.2.2.5 *Units* — This parameter is used to specify the units associated with the full scale range specified in the service request. Its values are defined in SEMI E54.1. The supported list includes:

SCCM
SLM
Percent
Volts
Millivolts
Counts

8.4.2.2.6 *Valid Flag* — The first parameter of a Query-Supported Gas Type service response is a byte that indicates whether the requested gas type, range, and units are supported. If an entire list was requested, and at least one gas calibration exists, this byte will have the value of “Valid.”

8.4.2.2.7 *Size of List* — This parameter is an unsigned integer that specifies the number of gas calibrations in the list that follows.

8.4.2.2.8 *List of Gas Calibrations* — This attribute is an array of structures that identifies the gas calibrations supported in the device. The format of the structure is *gas standard number*, *gas standard symbol* (zero if not supported), *full scale range*, and *units*.

8.4.2.3 *Select Programmed Gas Type Service (Optional)* — This service is used to select the gas type, range, and units of the programmed gas calibration to be used by the device (see Section 5 for a definition of "programmed gas calibration"). The following table describes the parameters specified for this service:

Table 12 Select Programmed Gas Type Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Gas Standard Number	M	—	UINT	0 = use gas standard symbol field n = gas standard number
Gas Standard Symbol	M	—	Text String	null character = not specified text string = gas standard symbol
Range Select Mode	M	—	Byte	0 = select highest full scale range 1 = use full scale range and units specified 2 = use full scale range and units greater than or equal to specified
Full Scale Range	C*	—	REAL	Full scale range of which the select references.
Units	C*	—	UINT	Indication of the units associated with the full scale range.

* Parameter is Mandatory for Range Select Mode = 1 and 2.

8.4.2.3.1 *Gas Standard Number* — This parameter is used to specify a gas standard number, for which device support is being queried. A value of "0" indicates that the following parameter "gas standard symbol" is used instead to reference the gas type.

8.4.2.3.2 *Gas Standard Symbol* — This parameter is used to specify a gas standard symbol, for which device support is being queried. If the gas standard number parameter has a value that is not zero, then this parameter will have the value of null character.

8.4.2.3.3 *Range Select Mode* — This parameter is used to specify the mode by which the programmed gas is selected. It is an enumerated byte that can take on the following values:

0 = Select highest full scale range
1 = Use full scale range and units specified
2 = Use full scale range and units greater than or equal to specified
3–63 = Reserved
64–255 = Manufacturer-Specified

8.4.2.3.4 *Full Scale Range* — This parameter is used to specify the full scale range to be selected as the current programmed gas calibration full scale range.

8.4.2.3.5 *Units* — This parameter specifies the units associated with the full scale range to be set as the current programmed gas calibration being used by the device. If the Full Scale Range parameter has the value "0," this parameter is not included in the request. Its values are defined in Section 8.4.2.2.

8.4.2.4 *Insert Gas Type Service (Optional)* — This service is used to add a gas calibration to the list of supported gas calibrations. This service will typically be invoked while calibrating the device, since it has not specified what, if any, gas calibration data or methods will be set as the new gas calibration. The Set Gas Calibration Data Value service will generally be required to set the gas calibration data or methods after invoking this service. The following table describes the parameters specified for this service:

Table 13 Insert Gas Type Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Gas Standard Number	M	—	UINT	0 = use gas standard symbol field n = gas standard number
Gas Standard Symbol	M	—	Text String	null character = not specified text string = gas standard symbol
Full Scale Range	M	—	REAL	n = full scale range
Units	M	—	UINT	Indication of the units associated with the full scale range.

8.4.2.4.1 *Gas Standard Number* — This parameter is used to specify a gas standard number, for which a gas calibration is to be added. A value of "0" indicates that the following parameter "gas standard symbol" is used instead to reference the gas type.

8.4.2.4.2 *Gas Standard Symbol* — This parameter is used to specify a gas standard symbol for which a gas calibration is to be added.

8.4.2.4.3 *Full Scale Range* — This parameter is used to specify the full scale range for which a gas calibration is to be added. See Section 5 for a definition of full scale range.

8.4.2.4.4 *Units* — This parameter is used to specify the units associated with the full scale range specified in the service request. Its values are defined in Section 8.4.2.2.

8.4.2.5 *Delete Gas Type Service (Optional)* — This service is used to remove a gas calibration from the list of supported gas calibrations. The gas calibration data or method used by the device, if the current programmed gas type is deleted, is manufacturer-specified. The following table describes the parameters specified for this service:

Table 14 Delete Gas Type Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Gas Standard Number	M	—	UINT	0 = use gas standard symbol field n = gas standard number
Gas Standard Symbol	M	—	Text String	null character = not specified text string = gas standard symbol
Full Scale Range	M	—	REAL	n = full scale range
Units	M	—	UINT	Indication of the units associated with the full scale range.

8.4.2.5.1 *Gas Standard Number* — This parameter is used to specify a gas standard number for which a gas calibration is to be deleted. A value of "0" indicates that the following parameter "gas standard symbol" is used instead to reference the gas type.

8.4.2.5.2 *Gas Standard Symbol* — This parameter is used to specify a gas standard symbol for which a gas calibration is to be deleted.

8.4.2.5.3 *Full Scale Range* — This parameter is used to specify the full scale range for which a gas calibration is to be deleted. See Section 5 for a definition of "full scale range."

8.4.2.5.4 *Units* — This parameter is used to specify the units associated with the full scale range specified in the service request. Its values are defined in Section 8.4.2.2.

8.4.2.6 *Get Gas Calibration Data Value Service (Optional)* — This service is used to retrieve the values associated with a gas calibration. The mechanism for referencing a data value involves specifying the gas type and full scale range (a default is provided to specify the programmed gas calibration currently in use by the device), followed by an index value which is used to specify the particular data value that is being requested. The following table describes the parameters specified for this service:

Table 15 Get Calibration Data Value Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Gas Standard Number	M	—	INT	-1 = current programmed gas calibration 0 = use gas standard symbol field n = gas standard number
Gas Standard Symbol	M	—	Text String	null character = not specified text string = gas standard symbol
Full Scale Range	M	—	REAL	0 = not specified n = full scale range
Units	M	—	UINT	Indication of the units associated with the full scale range.
Data Index	M	—	Byte	The identifier of the particular gas calibration datum within the list of data values.
Size of List	—	M	Byte	This parameter specifies the number of values returned in the list.
Zero	—	C	REAL	zero offset
Span	—	C	REAL	span multiplier
Calibration Date	—	C	Date	The date of calibration for a particular gas type and full scale range.
Calibration Gas Standard Number	—	C	UINT	The gas standard number representing the gas used to calibrate the device.
Calibration Temperature	—	C	REAL	The standard temperature of calibration conditions.
Calibration Pressure	—	C	REAL	The standard pressure of the calibration conditions.
Manufacturer-Specified Parameters	—	C	Manufacturer-Specific	

8.4.2.6.1 *Gas Standard Number* — This parameter is used to specify a gas standard number for which a gas calibration data value is being requested. Two special values are allowed: A value of "0" indicates that the following parameter "gas standard symbol" is used instead to reference the gas type. A value of "-1" indicates that the current programmed gas calibration is requested.

8.4.2.6.2 *Gas Standard Symbol* — This parameter is used to specify a gas standard symbol for which a gas calibration data value is being requested. If the *gas standard number* parameter has a value that is not "0," then this parameter is set to the null character.

8.4.2.6.3 *Full Scale Range* — This parameter is used to specify the full scale range for which a gas calibration data value is being requested. If the *gas standard number* parameter has a value that is "-1," then this parameter is set to zero.

8.4.2.6.4 *Units* — This parameter specifies the units associated with the *full scale range parameter*. Its values are defined in Section 8.4.2.2. If the *gas standard number* parameter has a value that is "-1," then this parameter is set to 0.

8.4.2.6.5 *Data Index* — This parameter is used to specify the index of the value being requested. It is an enumerated byte that can take on the values listed in the following table:

Table 16 Gas Calibration Data Value Matrix

Data Value Name	*Data Index*	*Access Network*	*Required*	*Form*
All	0	—	No	
Zero	1	RW	No	REAL
Span	2	RW	No	REAL
Calibration Date	3	R	No	Date
Calibration Gas Standard Number	4	R	No	UINT
Calibration Temperature	5	R	No	REAL
Calibration Pressure	6	R	No	REAL
Reserved	7–63	—	—	
Manufacturer-Specified	64–255	—	—	

Table 17 Gas Calibration Data Initial and Default Values

Data Value Name	*Data Index*	*Initial Value*	*Default Value*	*Comment*
Zero	1	LVV	0	
Span	2	LVV	1	
Calibration Date	3	LVV	0, 0, 0	
Calibration Gas Standard Number	4	LVV	Manufacturer-Specific	
Calibration Temperature	5	LVV	0.0	Defined by SEMI E12 as 0.0°C. Other industries may specify a different value.
Calibration Pressure	6	LVV	101.32	Defined by SEMI E12 as 101.32 kPa. Other industries may specify a different value.
Reserved	7–63	—	—	
Manufacturer-Specified	64–255	—	—	

8.4.2.6.5.1 *All* — This value for the data index parameter requests the list of all data values associated with a gas calibration. The returned parameter values are ordered by index as defined in Table 15. The size of the list returned is manufacturer-specified, since it includes the Manufacturer-Specific values.

8.4.2.6.5.2 *Size of List* — This parameter is used to specify the number of parameters returned in the response list.

8.4.2.6.5.3 *Zero* — This value is used in conjunction with the span value to correct the flow measurement. It is expressed in terms of the units parameter.

8.4.2.6.5.4 *Span* — This value is used in conjunction with the zero value to correct the flow measurement. It is a dimensionless value.

8.4.2.6.5.5 *Calibration Date* — This value identifies the date the device was last calibrated for the specified gas type and full scale range.

8.4.2.6.5.6 *Calibration Gas Standard Number* — This value identifies the gas type used when the device was calibrated for the referenced gas type and full scale range. It may be the same gas as gas type, a surrogate gas, nitrogen, or some other gas.

8.4.2.6.5.7 *Calibration Temperature* — This value identifies the Standard Temperature with respect to calibration conditions. The units for this value are degrees Centigrade.

8.4.2.6.5.8 *Calibration Pressure* — This value identifies the Standard Pressure with respect to calibration conditions. The units for this value are KiloPascal.

8.4.2.7 *Set Gas Calibration Data Value Service (Optional)* — This service is used to set the values associated with a gas calibration. The mechanism for referencing a data value involves specifying the gas type and full scale range (a default is provided to specify the programmed gas calibration currently in use by the device), followed by an index value which is used to specify the particular data value associated with the referenced gas calibration that is being set. The specific value to be set is the last parameter passed in the service request. The following table describes the parameters specified for this service:

Table 18 Set Calibration Data Value Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Gas Standard Number	M	—	INT	-1 = current programmed gas calibration 0 = use gas standard symbol field n = gas standard number
Gas Standard Symbol	M	—	Text String	null character = not specified text string = gas standard symbol
Full Scale Range	M	—	REAL	0 = not specified n = full scale range
Units	M	—	UINT	Indication of the units associated with the full scale range.
Data Index	M	—	Byte	The identifier of the particular gas calibration datum within the list of data values.
Size of List	M	—	Byte	This parameter specifies the number of values in the list that follows.
Zero	C	—	REAL	zero offset
Span	C	—	REAL	span multiplier
Calibration Date	C	—	Date	The date of calibration for a particular gas type and full scale range.
Calibration Gas Standard Number	C	—	UINT	The gas standard number representing the gas used to calibrate the device.
Calibration Temperature	C	—	REAL	The standard temperature of calibration conditions.
Calibration Pressure	C	—	REAL	The standard pressure of the calibration conditions.
Manufacturer-Specified Parameters	C	—	Manufacturer-Specific	

For a description of these parameters, see the preceding section.

8.4.2.8 *Autorange Service (Optional)* — This service is used to instruct the Sensor-AI-MF object instance to enter the AUTORANGING state from the NOT AUTORANGING state or to enter the NOT AUTORANGING state from the AUTORANGING state. The following table describes the parameters specified for this service:

Table 19 Autorange Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Command	M	—	Byte	Enumerated Byte: 0 = enter NOT AUTORANGING state 1 = enter AUTORANGING state 2–63 = Reserved 64–255 = Manufacturer-Specified

8.4.3 *Sensor-AI-MF Object Behavior* — The behavior exhibited by the Sensor-AI-MF object instance is inherited from the Sensor-AI object defined in SEMI E54.1. Additional specific behavior associated with the Sensor-AI-MF object is defined below.

8.4.3.1 *Sensor-AI-MF OPERATING Application Process* — A reading is retrieved from a physical flow sensor. This reading may be corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the offset and gain formula to generate the *value* attribute as referenced in SEMI E54.1.

For Gas Correction, the value retrieved is corrected with a manufacturer-specified algorithm using the correction values, parameters, coefficients, or methods for the programmed gas calibration.

8.4.3.2 *Sensor-AI-MF OPERATING Application Process–Flow Totalizer* — The value of the *flow totalizer* attribute is incremented at a rate of once every cubic centimeter of gas flow. Whenever the *flow totalizer* attribute reaches its maximum allowed value, it no longer is incremented and remains at the maximum value.

8.4.3.3 *Sensor-AI-MF OPERATING Application Process–Flow Hours* — The value of the *flow hours* attribute is incremented at a rate of once every hour. Whenever the *flow hours* attribute reaches its maximum allowed value, it no longer is incremented and remains at the maximum value.

8.4.3.4 *Sensor-AI-MF ZEROING Application Process* — The Zeroing application process is described as follows: Certain manufacturer-specified service requests may be sent to other objects. The value of *offset* is set such that *value* is nulled to zero. The Sensor-AI-MF object instance determines, using a manufacturer-specified method, when a Zeroing application process is completed.

If a Perform Zero Offset: Command = 2 (cancel) service request is received while in the ZEROING state, the original value of the *offset* attribute is restored, and the process is considered Failed. If a Perform Zero Offset: Command = 0 (set offset attribute to zero) service request is received while in the ZEROING state, the *offset* attribute is set to zero, and the process is considered Failed. If a Perform Zero Offset: Command = 1 (calculate offset) service request is received while in the ZEROING state, the process is simply restarted.

Upon completion, the appropriate Pass or Fail service response is reported to the requesting object instance, and an internal Operate service request to this object is generated.

The Sensor-AI-MF object instance supports the additional behavior sub-states (defined in Figure 3) within the OPERATING state. Table 20 defines the additional sub-states, and Table 21 defines the additional state transitions specified for this object.

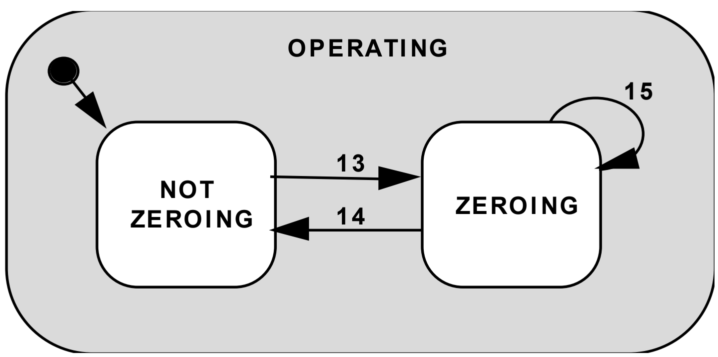

Figure 3
Sensor-AI-MF Object Behavior Additional Sub-States

Table 20 Sensor-AI-MF Object Behavior State Descriptions

State	*Description*
NOT ZEROING	The Sensor-AI-MF object instance is running the Sensor-AI-MF OPERATING application process.
ZEROING	The Sensor-AI-MF object instance is running the Sensor-AI-MF OPERATING application process. Additionally, the Sensor-AI-MF object instance is running the Sensor-AI-MF ZEROING application process.

Table 21 Sensor AI-MF Object Behavior State Transition Matrix

#	*Current State*	*Trigger*	*New State*	*Action*	*Comments*
4	NORMAL OPERATING	Get Attribute, Set Attribute, Restore Defaults request, Perform Zero Offset request (command ≠ 1)	NORMAL OPERATING	Get Attribute, Set Attribute, Restore Defaults appropriate response	Valid for all sub-states of NORMAL OPERATING.
13	NOT ZEROING	Perform Zero Offset request (command = 1)	ZEROING	Run the ZEROING application process. Set *zeroing status* to Zeroing.	
14	ZEROING	Operate request or Perform Zero Offset request (command ≠ 1)	NOT ZEROING	Resume the OPERATING application process. Set *zeroing status* to Not Zeroing. Report appropriate service response.	The mechanism for reporting is network-specific.
15	ZEROING	Perform Zero Offset request (command = 1)	ZEROING	Restart the ZEROING application process.	

8.4.3.5 *Sensor-AI-MF AUTORANGING Application Process* — The Sensor-AI-MF object instance supports the additional behavior sub-states (defined in Figure 4) within the OPERATING state. Table 22 defines the additional sub-states, and Table 23 defines the additional state transitions specified for this object.

The object instance is automatically selecting gas calibrations based on a manufacturer's specified method. This method may include a determination based on the value of the *value* attribute and/or on the value of the *setpoint value* attribute.

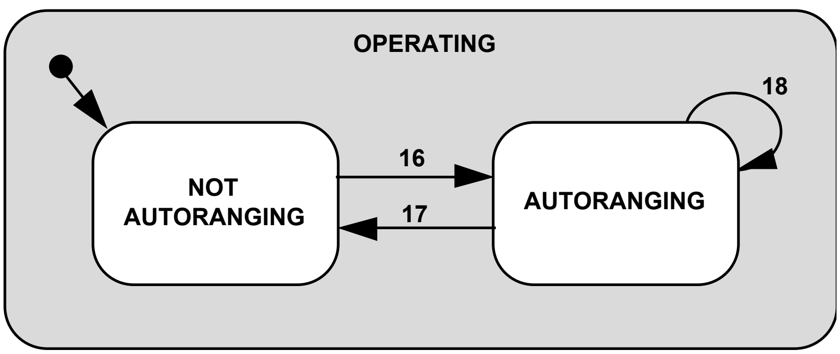

Figure 4
Sensor-AI-MF Object Behavior Additional Sub-States

Table 22 Sensor-AI-MF Object Behavior State Descriptions

State	*Description*
NOT AUTORANGING	The Sensor-AI-MF object instance is running the Sensor-AI-MF OPERATING application process.
AUTORANGING	The Sensor-AI-MF object instance is running the Sensor-AI-MF OPERATING application process. Additionally, the Sensor-AI-MF object instance is running the Sensor-AI-MF AUTORANGING application process (defined above).

Table 23 Sensor-AI-MF Object Behavior State Transition Matrix

#	*Current State*	*Trigger*	*New State*	*Action*	*Comments*
4	NORMAL OPERATING	Get Attribute, Set Attribute, Restore Defaults request, Autorange request (command = 0)	NORMAL OPERATING	Get Attribute, Set Attribute, Restore Defaults appropriate response	Valid for all sub-states of NORMAL OPERATING.
16	NOT AUTORANGING	Autorange request Command = 1	AUTORANGING	Run AUTORANGING application process. Set *Autoranging status* to Autoranging.	
17	AUTORANGING	Autorange request Command = 0	NOT AUTORANGING	Halt the Autoranging application process. Set *Autoranging status* to Not Autoranging.	
18	AUTORANGING	Autorange request Command = 1	AUTORANGING		No change.

8.5 *Sensor-AI-AT Object* — The Sensor-AI-AT object is an Ambient Temperature object instance which inherits attributes, services, and behavior from the Sensor-AI object as defined in SEMI E54.1. The Sensor-AI-AT object instance is the device component responsible for retrieving a reading from a physical temperature sensor and making the value available to the network.

8.5.1 *Sensor-AI-AT Object Attributes* — The inherited *value* attribute represents the ambient temperature measurement. There are no additional attributes defined for this object in this document.

8.5.2 *Sensor-AI-AT Object Services* — There are no additional services defined for this object in this document.

8.5.3 *Sensor-AI-AT Object Behavior* — The behavior exhibited by the Sensor-AI-AT object instance is defined in SEM E54.1. Additional specific behavior associated with the Sensor-AI-AT object is defined below.

8.5.3.1 *Sensor-AI-AT OPERATING Application Process* — A reading is retrieved from a physical temperature sensor. This reading may be corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the offset and gain formula to generate the *value* attribute as referenced in SEMI E54.1.

8.6 *Assembly-MFM Object* — The Assembly-MFM object inherits attributes, services, and behavior from the Assembly object. The Assembly object instance is the device component which provides a mechanism of grouping more than one attribute from one or more object instances into a single data structure for access over the network.

8.6.1 *Assembly-MFM Object Attributes*

Table 24 Assembly-MFM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Data	A1	R	Yes	Structure as defined below.

8.6.1.1 *Data* — An attribute with the following list of attributes within its structure:

Table 25 Assembly-MFM Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	MFD3	A4	Sensor-AI-MF Value

8.7 *Sensor-AI-Aux Object* — The Sensor-AI-Aux object is an Auxiliary Input object instance which inherits attributes, services, and behavior from the Sensor-AI object as defined in SEMI E54.1. The Sensor-AI-Aux object instance is the device component responsible for retrieving a reading from a physical analog input and making the value available to the network.

8.7.1 *Sensor-AI-Aux Object Attributes* — The attributes provided by the Sensor-AI-Aux object instance are defined in SEMI E54.1. The *value* attribute represents the analog input measurement.

8.7.2 *Sensor-AI-Aux Object Services* — The services provided by the Sensor-AI object instance are defined in SEMI E54.1.

8.7.3 *Sensor-AI-Aux Object Behavior* — The behavior exhibited by the Sensor-AI-Aux object instance is defined in SEMI E54.1. Additional specific behavior associated with the Sensor-AI-Aux object is defined below.

8.7.3.1 *Sensor-AI-Aux OPERATING Application Process* — A reading is retrieved from a physical analog input. This reading may be corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the offset and gain formula to generate the *value* attribute as referenced in SEMI E54.1.

8.8 *Actuator-AO-MF Object* — The Actuator-AO-MF object instance inherits from the Actuator-AO object attributes, services, and behavior as defined in SEMI E54.1. The Actuator-AO-MF object instance is the component responsible for driving the physical mass flow control valve of the device. Override attributes are available to produce valve drives which either fully close or fully open the valve, irrespective of the value of the *setting* attribute.

8.8.1 *Actuator-AO-MF Object Attributes*

Table 26 Actuator-AO-MF Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Valve Type	A1	R	No	Enumerated Byte
Override	A2	RW	No	Enumerated Byte
Reserved	A3–A64	—	—	Reserved for future expansion.
Manufacturer-Specified	> A64	—	—	Manufacturer-Specific attributes.

8.8.1.1 *Valve Type (Optional)* — An attribute which specifies the type of valve present in the device. This attribute is an enumerated byte that can take on one of the following values:

0 = Solenoid

1 = Voice Coil

2 = Piezo Electric

3 = Thermal

4–63 = Reserved

64–255 = Manufacturer-Specified

8.8.1.2 *Override (Optional)* — An attribute which specifies an override to the controlled valve position derived from the Controller object instance. This attribute is an enumerated byte that can take on one of the following values:

0 = Normal — Normal control mode

1 = Flow Off — Valve Closed

2 = Purge — Valve Open

3 = Power Off — Valve to unpowered state

4–63 = Reserved

64–255 = Manufacturer-Specified

8.8.1.3 *Initial and Default Values*

Table 27 Actuator-AO-MF Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Valve Type	Default Value	Manufacturer-Specific	
Override	LVV	Normal	

8.8.2 *Actuator-AO-MF Object Services* — There are no additional services defined for this object in this document.

8.8.3 *Actuator-AO-MF Object Behavior* — The behavior exhibited by the Actuator-AO-MF object instance is defined in SEMI E54.1. The specific behavior associated with the Actuator-AO-MF object is defined below.

8.8.3.1 *Actuator-AO-MF OPERATING Application Process–Override* — The *override* attribute determines whether the position of the physical flow control valve will be overridden and, if so, to what position it will be driven. Otherwise, the physical flow control valve is driven by the converted signal derived from the Controller object instance.

8.9 *Controller Object* — The Controller object definition is provided in SEMI E54.1. This object instance is the device component which provides the closed-loop control of mass flow. There are no additional attributes, services, or behavior defined for this object in this document.

8.9.1 *Controller Object Attributes* — The following attribute table is provided to enhance the C Class Attribute table and provides a specific attribute "Form" definition.

Table 28 C Class Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Alarm Settling Time	CA21	RW	N	Real
Warning Settling Time	CA24	RW	N	Real

8.10 *Local Link Object* — The Local Link object is defined in SEMI E54.1. This object instance is the device component which provides a mechanism of linking two attributes within the device. There are no additional attributes, services, or behavior defined for this object in this document.

8.11 *SISO Object* — The SISO object provides a Single Input, Single Output function. At this level, only the input and output attributes are defined. An instance of this object makes no sense, because there is no transfer function defined, but rather, the attributes, services, and behavior of this object are inherited by the next level down (e.g., SISO-Setpoint Object).

8.11.1 *SISO Object Attributes*

Table 29 SISO Function Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Input	A1	RW	Yes	Data Type
Output	A2	R	Yes	Data Type
Data Type	A3	R	No	USINT
Reserved	A4–A32	—	—	For future revisions to this object.
Reserved	A33–A64			For next level object.
Manufacturer-Specified	> A64	—	—	For manufacturer specification.

8.11.1.1 *Input* — An attribute which specifies the input value, or independent variable, for the transfer function. The data type is specified by the *data type* attribute.

8.11.1.2 *Output* — An attribute whose value is the output, or dependent variable, of the transfer function. The data type is specified by the *data type* attribute.

8.11.1.3 *Data Type* — An attribute which specifies the data type of the *input* attribute and the *output* attribute. The format and values of this attribute are defined in SEMI E54.1.

8.11.1.4 *Initial and Default Values*

Table 30 SISO Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Input	LVV	0	
Output	LVV	manufacturer-specified	
Data Type	LVV	manufacturer-specified	

8.11.2 *SISO Object Behavior* — The only behavior defined at this level is that of a continuously operating transfer function: The Output attribute value is calculated as a function of the Input attribute value. The specific transfer function is defined by lower level objects which inherit from this object.

Output = F(Input)

where: F is the function specified

8.12 *SISO-Setpoint Object* — The SISO-Setpoint Object inherits from the SISO object. The definitions added by the SISO-Setpoint object include the behavior associated with the transfer function.

8.12.1 *SISO-Setpoint Object Attributes*

Table 31 SISO-Setpoint Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Ramp Type	A33	RW	No	USINT
Ramp Rate	A34	RW	No	Data Type
Ratio	A35	RW	No	REAL
Reserved	A36–A64	—	—	Reserved for future expansion.

8.12.1.1 *Ramp Type (Optional)* — An attribute which specifies a mechanism by which the *output* attribute is ramped to the current value of the *input* attribute.

0 = Disable

1 = Time in seconds

2 = Amount per second

3–63 = Reserved

64–255 = Manufacturer-specified

8.12.1.2 *Ramp Rate (Optional)* — An attribute specified to define the ramp rate at which the SISO-Setpoint object instance tracks towards the current *input* value. The ramp rate specifies how quickly the *output* is ramped from the previous *output* value to the current *input* value. This attribute is expressed in terms of seconds or amount of change per second.

8.12.1.3 *Ratio (Optional)* — An attribute which specifies the ratio multiplier to be applied to the *input* attribute value prior to the application of the ramp transfer function.

8.12.1.4 *Initial and Default Values*

Table 32 SISO-Setpoint Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Ramp Type	LVV	Disable	
Ramp Rate	LVV	0	
Ratio	LVV	1.0	

8.12.2 *SISO-Setpoint Object Behavior* — The general behavior exhibited by the SISO-Setpoint object instance is defined in SEMI E54.1. The specific behavior associated with this object is defined below.

8.12.2.1 *SISO-Setpoint OPERATING Application Process–Ramp* — The *ramp type* and *ramp rate* attributes determine the conditions under which the value of the *output* attribute is calculated and modified by this application process. The *ramp rate* attribute is defined to express the rate at which the *output* attribute is ramped to the value of the *input* attribute based on the value of the *ramp type* attribute. Table 33 describes the behavior of the SISO-Setpoint object instance based on the value of the *ramp type* attribute.

Table 33 SISO-Setpoint Object Behavior - Ramp

Ramp Type Value	*SISO-Setpoint Object Instance Behavior*
Disabled	Achieve a new output value in one step.
Time in Seconds	Achieve a new output value in the time interval specified by the *ramp rate* attribute.
Amount per Second	Achieve a new output value in the amount per second increments specified by the *ramp rate* attribute.

8.12.2.2 *SISO-Setpoint OPERATING Application Process–Ratio* — Prior to the application of the Ramp calculation, a multiplier is applied to the value of the *input* attribute. The value of the *ratio* attribute is multiplied to the value of the *input* attribute, and the result becomes the value which is used in the ramp calculation.

The combined formula for the SISO-Setpoint object is as follows:

Output = F(x)

where: F is the function as defined by ramp type above

and: x = (ratio)(input)

8.13 *Assembly-MFC Object* — The Assembly-MFC object inherits attributes, services, and behavior from the Assembly object. The Assembly object instance is the device component which provides a mechanism of grouping more than one attribute from one or more object instances into a single data structure for communication over the network.

8.13.1 *Assembly-MFC Object Attributes*

Table 34 Assembly-MFC Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Data	A1	R	Yes	Structure as defined below.

8.13.1.1 *Data* — An attribute with the following list of attributes within its structure:

Table 35 Assembly-MFC Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	MFD8	A1	Controller Status
3	MFD3	A4	Sensor-AI-MF Value
4	MFD8	A4	Controller Setpoint
5	MFD8	A6	Controller Control Variable

SEMI E54.4-0997
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR DEVICENET

NOTE: This document was previously designated SEMI E59. Because this document is part of a suite of documents, its designation has been reassigned for ease of reference. Please note that the technical content of this document is unchanged from the 0697 version.

1 Purpose

This standard defines a communication specification based on the DeviceNet protocol to enable communications between intelligent devices on a sensor/actuator network (SAN) that operate according to SEMI- specified device models (common and device specific) in a semiconductor manufacturing tool.

1.1 *Background and Motivation* — DeviceNet provides for networking between simple industrial devices (e.g., sensors and actuators) and higher level devices such as controllers. DeviceNet provides:

- A solution to low-level device networking
- Access to intelligence present in low-level devices
- Master/Slave and Peer-to-Peer capabilities

DeviceNet is based on the Controller Area Network (CAN) technology. CAN defines a Media Access Control (MAC) methodology and physical signaling characteristics. DeviceNet wraps a communication model and protocol as well as a complete Physical Layer definition around CAN to provide a complete network definition.

This document enables communications between intelligent devices on a SEMI-compliant SAN by providing a presentation mapping of common and specific device network visible structure and behavior to a DeviceNet network.

2 Scope

2.1 This document specifies the protocol and services that compliant intelligent devices must support to interchange information over this semiconductor equipment sensor/actuator network.

2.2 This document specifies the utilization of the DeviceNet protocol to present externally visible device structure and behavior, specified in the Common Device Model (CDM) and appropriate Specific Device Models (SDM's), on a DeviceNet network.

2.3 This document is used in conjunction with a SEMI standard SAN Common Device Model specification and one or more SEMI standard-specific device model specifications (e.g., for a mass flow controller). Together, they describe the externally visible data structure and behavior of devices using the DeviceNet networking capability in a SEMI-compliant SAN system.

2.4 This standard, together with a sensor/actuator network interoperability guideline, the sensor/actuator network common device model, one or more sensor/actuator network specific device model documents, and the DeviceNet specifications, form a complete interoperability standard. The general sensor/actuator network document architecture is shown in the Sensor/Actuator Network Common Device Model document in Figure 1.

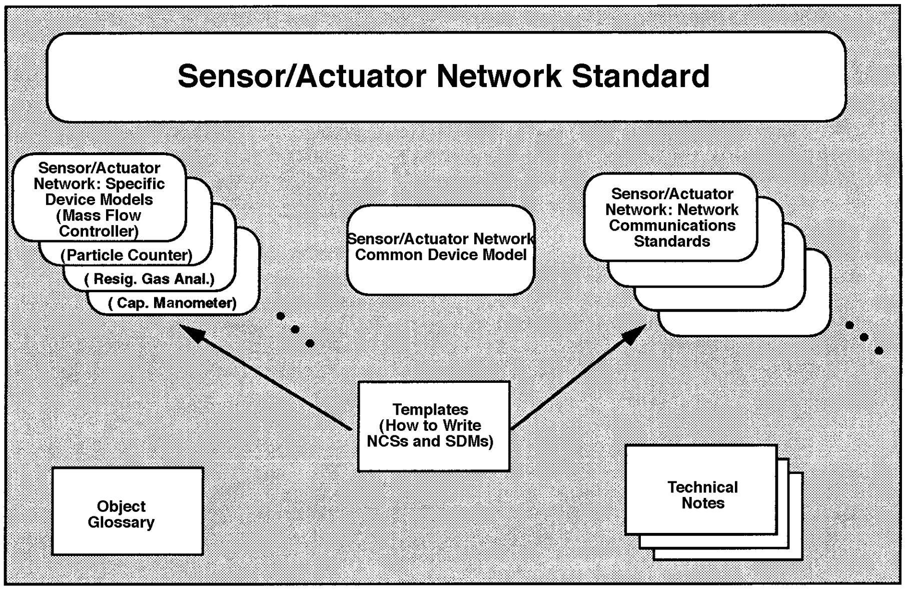

Figure 1
Sensor/Actuator Network Related Documents

2.5 *Document Structure* — The DeviceNet network communication standard complies with the SEMI SAN NCS template document structure; this structure is shown in Figure 2. The standard document is composed of two main parts. The first part (Sections 1 through 8) specifies the SAN enabling protocol as well as the presentation (i.e., mapping) of CDM object structure and behavior onto the network (referred to as the "CDM mapping"). The second part (Section 9) specifies the presentation (i.e., mapping) of SDM object structure and behavior onto the network for each SEMI-specified SDM (referred to as the "SDM mapping").

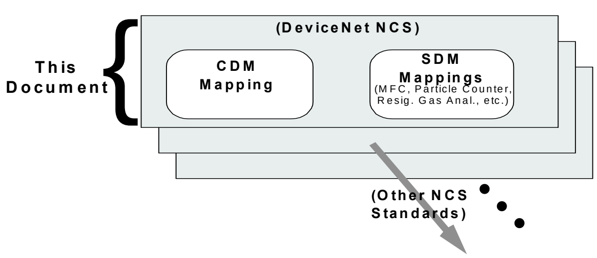

Figure 2
DeviceNet NCS Document Structure

2.6 *Adding SDM Mappings* — SDM mappings added to part two of this document are considered document additions and are balloted as such. An SDM mapping may only be balloted for addition to this document if the corresponding SEMI SDM has been standardized or is in the process of being balloted for standardization.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on DeviceNet and is a companion document to the DeviceNet specification; thus, a complete specification of this standard necessarily includes the DeviceNet specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by DeviceNet. In order to avoid document consistency problems, information in the DeviceNet specification that relates to this standard is not repeated in this document. This document is limited to describing enhancements or limitations to the DeviceNet specification that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the DeviceNet protocol conformance testing specification. Conformance testing shall also include enhancements and limitations to the DeviceNet specification required by this standard.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

4.2 *ISO Standards*[1]

ISO 7498 — Basic Reference Model for Open Systems Interconnection

ISO 11898 — Road Vehicles — Interchange of Digital Information — Controller Area Network (CAN) for High-Speed Communications

4.3 *Other Documents*

DeviceNet Specification — Volume I Release 1.3, Volume II Release 1.3 (includes DeviceNet Statement of Compliance)

Controller Area Network Specification — Version 2, R. Bosch GmbH, + Postfach 50 D-7000, Stuttgart 1, Germany, 1991

5 Terminology

Terminology that is common to all of the documents in this SAN standard may also be defined in the Sensor Actuator Network Standard. Terminology may be reproduced here which is defined in other SEMI documents.

5.1 *Acronyms*

5.1.1 *CAN* — Controller area network

5.1.2 *CDM* — Common device model

5.1.3 *DM* — Device manager (object)

5.1.4 *DN* — DeviceNet

5.1.5 *NCS* — Network communication standard

5.1.6 *OSI* — Open systems interconnect

5.1.7 *OSS* — Object services standard

5.1.8 *SAC* — Sensor, actuator, controller (object)

5.1.9 *SAN* — Sensor/actuator network

5.1.10 *SDM* — Specific device model

5.2 *Device Component Definitions* — As this standard defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in the CDM document. Table 1 provides a mapping of fundamental terminology of the CDM document into this document and the DeviceNet specification. Note that Column 2 contains an equal sign "=" if the definition is used exactly as specified in the CDM specification.

Table 1 Mapping of CDM to NCS Terminology

CDM Term	*NCS Equivalent*	*DeviceNet Equivalent*
Device	=	=
Device Model	=	=
Object	=, Class	=, Class
Instance	=	=
Attribute	=	=
Behavior	=	=
Service	=	=
State Diagram	=	=
Byte	=	=
Nibble	=	=
Character String	=	=

5.3 *DeviceNet Specific Definitions*

5.3.1 *class* — a set of objects that all represent the same kind of system component. A class is a generalization of an object. All objects in a class are identical in form and behavior, but may contain different attribute values.

5.3.2 *controller area network (CAN)* — a protocol developed by the Bosch corporation for automotive in-vehicle networking. The CAN specification specifies OSI reference model layers 1 and 2, specifically the physical signaling and media access/data link protocols.

5.3.3 *device profile* — a DeviceNet specification for a device that contains an object model for the device type, the I/O data format for the device type, and the configuration data and the public interface(s) to that data.

5.3.4 *explicit message connections* — connections over a DeviceNet network that provide generic, multi-purpose communication paths between two devices. These connections often are referred to as just messaging connections. Explicit messages provide the typical request/response - oriented network communications.

5.3.5 *input/output connections* — connections over a DeviceNet network that provide dedicated, special-purpose communication paths between a producing application and one or more consuming applications. Application-specific I/O data moves through these ports.

1 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland

6 Communication Protocol High Level Structure

The DeviceNet protocol is loosely based on a three-layer architecture. These layers constitute a collapsed form of the OSI seven-layer architecture, mapping into the physical, data link, and application layers of the Reference Model; however, DeviceNet provides additional functionality (such as connection support) commonly attributed to other OSI layers. The high level protocol architecture is shown in Figure 3.

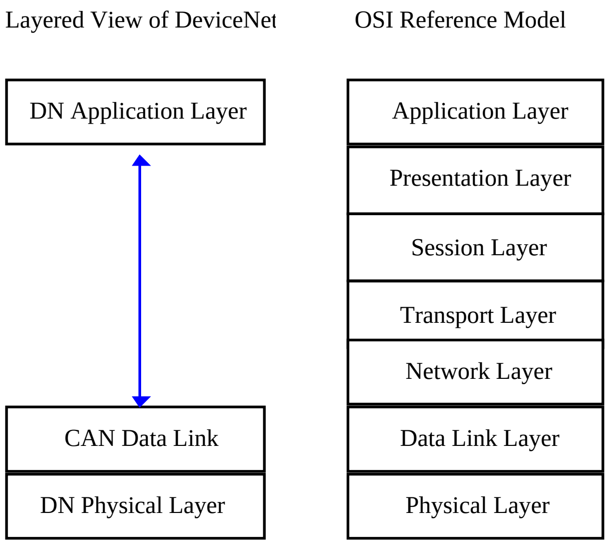

Figure 3
Layered View of DeviceNet

Note that Figure 3 represents a conceptual view of the device architecture. Conforming implementations must implement the services defined in this specification at each layer and must appear (from the network) to have implemented this architecture; however, an internal modular partitioning is not required. Implementations may sacrifice modularity in order to achieve high performance.

The DeviceNet physical layer is fully specified in Volume 1 of the DN Specification. Features of this layer include Trunkline - dropline configuration, simultaneous support for both network-powered and self-powered devices, and selectable data rates including at least 125k, 250k, and 500k baud. At the data link layer, the CAN specification defines a carrier sense multiple access mechanism for media access control that avoids collisions and sends frames reliably. The application layer is specified in Volumes 1 and 2 of the DN Specification and provides for the definition of DeviceNet applications as a collection of addressable objects. Two basic categories of objects exist: Communication Objects and Application Objects. Communication Objects manage and provide for the runtime exchange of messages across DeviceNet. Application Objects implement product-specific features and/or provide a logical interface to product-specific information of devices on a DeviceNet network.

In the remainder of this section, the protocol structure is described in more detail in terms of the OSI seven layer reference model, the object model environment, and network management specifications.

6.1 *Physical Layer* — The device shall comply with the DeviceNet physical layer specification (contained in Volume 1 of the DeviceNet specification). This includes physical signaling (levels and baud rates - detailed in the CAN specification), transceivers, node isolation, media topology, cable specifications, network connectors and taps, and power considerations (load limits, system tolerances, and power supply options).

6.1.1 *Physical Layer Enhancements* — This standard supports the following physical layer enhancement to the DeviceNet specifications:

> The transmission media, including both trunk cable and drop cable, shall be DeviceNet Thin Cable. Specifications on this cable and its utilization in DeviceNet systems (e.g., maximum trunk and drop lengths) are included in the DeviceNet specification.

6.2 *Data Link Layer* — The device shall comply with the DeviceNet Data Link Layer Specifications (i.e., Controller Area Network Specification: Version 2). This includes the media access control mechanism and the logical link control mechanism. Addressing is currently limited to 11 bits.

6.3 *Network Layer* — There is no distinct network layer.

6.4 *Transport Layer* — There is no distinct transport layer. Some of the functionality of this layer is implemented in the Application Layer. Specific functions include: segmentation/reassembly for full message delivery and the establishment of node-to-node connections.

6.5 *Session Layer* — There is no distinct session layer.

6.6 *Presentation Layer* — There is no distinct presentation layer. Data types and data presentation in DeviceNet messages are specified as part of the DeviceNet object definitions and object attribute and service communication protocol.

6.7 *Application Layer* — The device shall comply with the DeviceNet application layer specification for defining and addressing objects, including their attributes and services, and enabling specified network behavior. The device shall comply with the object model specifications provided in the DeviceNet specification. In addition, the device shall comply with the object specifications defined in Section 7 of this document.

6.7.1 *Object Models* — The DeviceNet protocol provides an object-oriented specification for creating, defining, and addressing objects explicitly, including their attributes and services (i.e., explicit messaging), and creating, defining, and communicating object attribute assemblies in an application-dependent format (i.e., input/output messaging). The device shall comply with the object model specifications provided in the DeviceNet documentation. In addition, the device shall comply with the object specifications defined in Section 7 of this document.

6.8 *Network Management* — The device shall comply with the DeviceNet network management specifications (e.g., physical layer bit rate, duplicate MAC ID detection, master-slave, and peer-to-peer network management). No (additional) network management functions are specified in this document.

7 Required Object Types

The DeviceNet specification identifies and describes objects (i.e., classes) that must exist in all DeviceNet-compliant devices. The Common Device Model specification additionally identifies two objects (namely the Device Manager (DM) and Sensor Actuator Controller (SAC) objects) that must exist in all SEMI-compliant SAN devices. The required object types for a SEMI-compliant SAN device, using the network communication specification described herein, necessarily comprise the union of the above to requirements.

A list of required and optional object types is given in Table 2. Note that the Sensor, Acutator, and Controller object types are not required and are indicated as optional in the CDM specification. These objects are aggregated together to form a SEMI- and DN-compliant device, as shown in Figure 4.

Table 2 Required Object Types

Object	*DN Class #**	*CDM Tag ***	*Required by DN **	*Required by CDM ***	*Required by NCS*
Identity	01	N.A.***	Yes	No	Yes
MR	02	N.A.	Yes	No	Yes
DN	03	N.A.	Yes	No	Yes
DM	64	DmI0	No	Yes	Yes
SAC	66	SACI0	No	Yes	Yes
Sensor	****	SenIn	No	No	No
Actuator	****	ActIn	No	No	No
Controller	****	CntIn	No	No	No
(Other)	****	N.A.	No	No	No

* See DeviceNet specification for further information; values are hexadecimal.

** See CDM specification for further information.

*** Not applicable.

**** Application-dependent.

An embodiment of a specific device type represented as an aggregation of the object types listed in Table 2, that is compliant with both the CDM specification and the DN specification, is a candidate for a SEMI SDM as well as a DN Device Profile. Conversely, all SEMI SDM's and DN Device profiles specified for operation over a SEMI-compliant DN network must be an aggregation of the object types listed in Table 2 and be compliant with both the CDM specification and the DN specification.

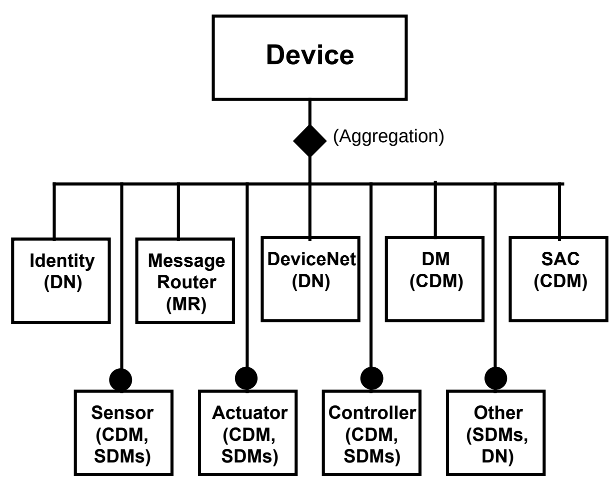

Figure 4
Aggregation of a Compliant Device

In the following sections, the presentation to the network of object addressing, object attributes, and object services for each of the object types listed in Table 2 and Figure 4 is described in detail.

7.1 *Identity Object* — This object provides identification of, and general information about, the device. The Identity Object must be present in all DeviceNet products. As specified by DeviceNet, each DeviceNet product shall support one (and only one) Identity object per physical connection to the DeviceNet communication link. Presentation of object identity, attributes, and services to the network for this object is described in the DeviceNet specification. Compliance with the DeviceNet specification shall constitute compliance with this NCS for the Identity Object.

7.2 *Message Router (MR) Object* — The MR Object provides a messaging connection point through which a service of any object class or instance residing in the physical device may be addressed. The MR object must be present in all DeviceNet products. As specified by DeviceNet, each DeviceNet product shall support one (and only one) Message Router object per physical connection to the DeviceNet communication link. Presentation of object identity, attributes, and services to the network for this object is described in the DeviceNet specification. Compliance with the DeviceNet specification shall constitute compliance with this NCS for the MR Object.

7.3 *DeviceNet (DN) Object* — The DN Object provides the configuration and status of a DeviceNet port. As specified by DeviceNet, each DeviceNet product shall support one (and only one) DN object per physical connection to the DeviceNet communication link. Presentation of object identity, attributes, and services to the network for this object is described in the DeviceNet specification. Compliance with the DeviceNet specification shall constitute compliance with this NCS for the DN Object.

7.4 *Device Manager (DM) Object* — The DM object is the device component responsible for managing and consolidating the device operation. Each device must support one (and only one) DM object. The DM object, as well as its common required and optional attributes, services, and behavior, is described in the CDM standard. The presentation of object attributes and services to the DN network shall be as indicated in Table 3.

Table 3 Network Presentation of DM Object Attributes and Services

Device Manager Object - - Object ID == 64			
Attributes			
ID *	**Name**		**CDM Tag**
31 **	Device Type		DmA1
32	Standard Revision Level		DmA2
33	Device Manufacturer Identifier		DmA3
34	Manufacturer Model Number		DmA4
35	Software or Firmware Revision Level		DmA5
36	Hardware Revision Level		DmA6
37	Serial Number (optional)		DmA7
38	Device Configuration (optional)		DmA8
39	Device Status		DmA9
3A	Reporting Mode		DmA10
3B	Exception Status Timer (optional)		DmA11
3C	Exception Status		DmA12
3D	Exception Detail Alarm (optional)		DmA13
3E	Exception Detail Warning (optional)		DmA14
Services			
ID *	**Name (SEMI)**	**Name (DN)**	**CDM Tag**
05	Reset	Reset	DmS1
4D ***	Abort	Abort ***	DmS2
4E ***	Recover	Recover***	DmS3
0E	Get_Attribute	Get_Attribute_Single	DmS4
10	Set_Attribute	Set_Attribute_Single	DmS5
4B	Execute	Execute ***	DmS6
4C	Perform_Diagnostics	Perform_Diagnostics ***	DmS7

* DN Attribute/Service Identifier. Values are hexadecimal.

** ID's are assigned beginning with 31 hexadecimal to avoid confusion with similiar variables defined for the DN Object Instance (see DN documentation).

*** These services will be detailed in later revisions of the DeviceNet specification. ID value assignments for Abort and Recover services may be changed to reflect the fact that these are deemed DeviceNet Common Services rather than Object Class Specific Services.

Note that the format of DM object attributes is detailed in the CDM document; the presentation of DM object attributes to the DN network is detailed in Table 3 and the DN specification; the format of DM object services is detailed in the CDM document and the DN specification; and the presentation of the DM object services is detailed in Table 3 and the DN specification.

7.4.1 *Device Manager (DM) Object: Alternate Format* — In Section 7.3, the presentation of the DM object structure and behavior is achieved through a distinct, addressable object. In applications where memory limitations are of primary concern, the DM object may be emulated as an extension of the Identity Object (see Section 7.1 and DeviceNet documentation). In this emulation, the presentation of DM object attributes and services shall be as indicated in Table 3 (above), except that the Object ID shall be the ID of the Identity Object (i.e., 01). Additionally, the behavior specified for the DM object (in the CDM standard) shall be incorporated into the Identity Object. Note that this emulation is an alternate format for DM object structure and behavior presentation; unless otherwise indicated (e.g., in the appropriate SDM specification or SDM mapping (see Section 9)), the DM object structure and behavior shall be presented as a distinct object (as detailed in the CDM and Table 3).

7.5 *Sensor, Actuator, Controller (SAC) Object* — The SAC object is the device component responsible for coordinating the interaction of the device with the sensory/actuation/control environment. Each device must support one (and only one) SAC object. The SAC object, as well as its common required and optional attributes, services, and behavior, is described in the CDM standard. The presentation of object attributes and services to the DN network shall be as indicated in Table 4.

Table 4 Network Presentation of SAC Object Attributes and Services

Sensor, Actuator, Controller Object - - Object ID == 66			
Attributes			
ID*	**Name**		**CDM Tag**
	None Defined		
Services			
ID*	**Name (SEMI)**	**Name (DN)**	**CDM Tag**
05	Reset	Reset	SacS1
4D ***	Abort	Abort***	SacS2
4E***	Recover	Recover***	SacS3

* DN Attribute/Service Identifier. Values are hexadecimal.
*** These services will be detailed in later revisions of the DeviceNet specification. ID value assignments for Abort and Recover services may be changed to reflect the fact that these are deemed DeviceNet Common Services rather than Object Class Specific Services.

Note that the format of SAC object attributes is detailed in the CDM document; the presentation of SAC object attributes to the DN network is detailed in Table 3 and the DN specification; the format of SAC object services is detailed in the CDM document and the DN specification; and the presentation of the SAC object services is detailed in Table 3 and the DN specification.

7.6 *Sensor Object, Acutator Object, Controller Object, and Other Object Types* — These object types are used collectively to model the type-specific structure and behavior of the device. The requirement and number of each of these object types in a device model is device type-specific. Further, the attributes, services, and behavior associated with each of these object classes and instances in a device is also device type-specific, but must be compliant with both SEMI and DN specifications. The specification of these object types for a specific device type can be found in the appropriate SDM. The method of presentation of object structure and behavior to the DN network for objects defined for, and associated with, a specific device type can be found in Section 9 of this document.

8 Protocol Compliance

A method of testing protocol compliance is required to verify implementation conformance to the standard. The test plan includes tests for duplicate address resolution, mandatory objects, etc.

The compliance test suite for this protocol necessarily includes the DeviceNet protocol compliance specification and test suite. Additional compliance specification required for compliance to this NCS is provided as a set of Protocol Specification Sheets.

Any enhancements to DeviceNet presented in this document must be accepted by the Open DeviceNet Vendors Association (ODVA) and incorporated into the DeviceNet Specification before they can be implemented as a DeviceNet product.

8.1 *Protocol Specification Sheets* — Compliance to this NCS necessarily requires adherence to a set of protocol specification sheets. These sheets are included as Appendix 1 of this document. Note that these sheets provide statements of compliance for general device data, physical conformance data, communications data, required object implementation (see also Section 7 or this document), and optional object implementation. Note also that these specification sheets must conform with DeviceNet specifications for “Statement of Compliance” forms. Finally note that additional specification sheets shall be completed as necessary to specify compliance with objects defined in SDM’s and SDM mappings (see Section 9).

9 Specific Device Model Mappings

This section provides for the mapping of network-visible specific device structure and behavior, specified in a SEMI standard SDM specification, to the DN network. Each subsection is devoted to a single SDM specification (e.g., 9.1: Mass Flow Controller). Additional SDM mappings are added as sub-sections to this NCS specfication according to SEMI guidelines and the guidelines of the SEMI SAN Interoperability standard.

APPENDIX 1
PROTOCOL SPECIFICATION SHEETS

NOTE A1-1: This appendix is not an official part of SEMI E54.4 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user. This appendix contains a set of protocol specification sheets. Compliance to this NCS necessarily requires adherence to this set of protocol specification sheets (see Section 8.1).

The protocol specification set of sheets contains the following components:

- A General Device Data/Physical ConformanceData/ DeviceNet Communication Data statement of compliance. (Form F_1, 1 page.)
- DeviceNet required object implementation statements of compliance (for Identity, Message Router, and DeviceNet objects, see Section 7). (Forms F_2 through F_5, 4 pages.)
- NCS - DeviceNet required object implementation statements of compliance (for Device Manager and Sensor/Actuator/Controller objects, see Section 7). (Form F_6, 2 pages.)
- Open object- and vendor- specific implementation templates (for utilization by SDMs, vendors, etc.). (Forms F_6 through F_7, 2 pages.)

Note that these protocol specification sheets are aligned with DeviceNet specifications for “Statement of Compliance” documentation, available with the DeviceNet specification from ODVA. Detailed instructions on completing these forms are in this “Statement of Compliance” documentation. The set of protocol specification sheets begins on the following page.

DeviceNet **Statement of Compliance**

Complete this form using the definitions previously outlined.

			Fill in the blank or X the appropriate box
General Device Data	Conforms to DeviceNet Specification	Volume I - Release	_____________________
		Volume II - Release	_____________________
	Vendor Name		_____________________
	Device Profile Name		_____________________
	Product Catalog Number		_____________________
	Product Revision		_____________________
DeviceNet Physical Conformance Data	Network Power Consumption (Max)		_______A @ 11V dc (worst case)
	Connector Style	Open-Hardwired ❑	Sealed-Mini ❑
		Open-Pluggable ❑	Sealed-Micro ❑
	Isolated Physical Layer	Yes ❑	
		No ❑	
	LEDs Supported	Module ❑	Combo Mod/Net ❑
		Network ❑	I/O ❑
		DIP Switch ❑	Software-Settable ❑
		Other____	
	Default MAC ID	_____________________	
	Communication Rate Setting	DIP Switch ❑	Software-Settable ❑
		Other____	
	Communication Rates Supported	125k bit/s ❑	500k bit/s ❑
		250k bit/s ❑	
DeviceNet Communication Data	❑ Predefined Master/Slave Connection Set	Group 2 Client ❑	Group 2 Only Client ❑
		Group 2 Server ❑	Group 2 Only Server ❑
	❑ Dynamic Connections Supported (UCMM)	Group 1 ❑	Group 3 ❑
		Group 2 ❑	
	Fragmented Explicit	Yes ❑	
	Messaging Implemented	No ❑	
		If yes, Transmission Time Out______________________ms	
		Typical Target Address	Class___________________
			Instance_________________
			Attribute_________________

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.

X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 1

DeviceNet		Statement of Compliance				
DeviceNet Required Object Implementation		**Identity Object 0x01**				
	Object Class	**ID**	**Description**	**Get**	**Set**	**Value Limits**
	Attributes Open	1	Revision	❑	❑	___________________
		2	Max instance	❑	❑	___________________
	❑ None Supported	6	Max ID of class attributes	❑	❑	___________________
		7	Max ID of instance attributes	❑	❑	___________________
		DeviceNet Services		**Parameter Options**		
	Services	❑	Get_Attribute_All	____________________________		
		❑	Reset	____________________________		
	❑ None Supported	❑	Get_Attribute_Single	____________________________		
		❑	Find_Next_Object_Instance	____________________________		
	Object Instance	**ID**	**Description**	**Get**	**Set**	**Value Limits**
	Attributes Open	1	Vendor	❑	❑	___________________
		2	Product type	❑	❑	___________________
	❑ None Supported	3	Product code	❑	❑	___________________
		4	Revision	❑	❑	___________________
		5	Status	❑	❑	___________________
		6	Serial number	❑	❑	___________________
		7	Product name	❑	❑	___________________ ___________________
		8	State	❑	❑	___________________
		DeviceNet Services		**Parameter Options**		
	Services	❑ Reset		____________________________		
		❑ Get_Attribute_All		____________________________		
	❑ None Supported					
	Vendor-Specific Additions	If yes, fill out the Vendor-Specific		Yes	❑	
		Additions form on page F_7.		No	❑	

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.

X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 2

DeviceNet		Statement of Compliance				
DeviceNet		**Message Router Object 0x02**				
Required Object Implementation	**Object Class**		**ID Description**		**Get Set Value Limits**	
	Attributes	Open	1	Revision	❑ ❑	___________________
			4	Optional attribute list	❑ ❑	___________________
	❑ None Supported		5	Optional service list	❑ ❑	___________________
			6	Max ID of class attributes	❑ ❑	___________________
			7	Max ID of instance attributes	❑ ❑	___________________
			DeviceNet Services		**Parameter Options**	
	Services		❑	Get_Attribute_all	____________________________	
			❑	Get_Attribute_Single	____________________________	
	❑ None Supported					
	Object Instance		**ID Description**		**Get Set Value Limits**	
	Attributes	Open	1	Object list	❑ ❑	___________________
			2	Maximum connections supported	❑ ❑	___________________
	❑ None Supported		3	Number of active connections	❑ ❑	___________________
			4	Active connections list	❑ ❑	___________________
			DeviceNet Services		**Parameter Options**	
	Services		❑	Get_Attribute_All	____________________________	
			❑	Get_Attribute_Single	____________________________	
	❑ None Supported					
	Vendor-Specific Additions		If yes, fill out the Vendor-Specific		Yes ❑	
			Additions form on page F_7.		No ❑	

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.
X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 3

DeviceNet		Statement of Compliance		
DeviceNet Required Object Implementation		**DeviceNet Object 0x03**		
	Object Class	**ID Description**		**Get Set Value Limits**
	Attributes Open	1	Revision	❑ ❑ ___________________
	❑ None Supported			
		DeviceNet Services		**Parameter Options**
	Services	❑	Get_Attribute_Single	____________________________
	❑ None Supported			
	Object Instance	**ID Description**		**Get Set Value Limits**
	Attributes Open	1	MAC ID	❑ ❑ ___________________
		2	Baud rate	❑ ❑ ___________________
	❑ None Supported	3	BOI	❑ ❑ ___________________
		4	Bus-off counter	❑ ❑ ___________________
		5	Allocation information	❑ ❑ ___________________
		6	MAC ID switch changed	❑ ❑ ___________________
		7	Baud rate switch changed	❑ ❑ ___________________
		8	MAC ID switch value	❑ ❑ ___________________
		9	Baud rate switch value	❑ ❑ ___________________
		DeviceNet Services		**Parameter Options**
	Services	❑	Get_Attribute_Single	____________________________
		❑	Set_Attribute_Single	____________________________
	❑ None Supported	❑	Allocate M/S connection set	____________________________
		❑	Release M/S connection set	____________________________
	Vendor-Specific Additions	If yes, fill out Vendor-Specific		Yes ❑
		Additions form on page F_7.		No ❑

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.
X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 4

DeviceNet	Statement of Compliance		
DeviceNet Required Object Implementation	**Connection Object 0x05**		
	Object Class	**ID Description**	**Get Set Value Limits**
	Attributes Open ❑ None Supported	1 Revision	❑ ❑ ____________________
		DeviceNet Services	**Parameter Options**
	Services ❑None Supported	❑ Reset ❑ Create ❑ Delete ❑ Get_Attribute_Single ❑ Find_Next_Object_Instance	____________________ ____________________ ____________________ ____________________ ____________________
	Total Active Connections Possible	________________________________ __________	
	Object Instance	**Section**	**Information Max**
	The Object Instance section must be completed for each combination of Instance type, Production trigger, Transport type, and Transport class supported	Instance type	Explicit Message ❑ _______ Polled I/O ❑ _______ Bit Strobed I/O ❑ _______ Dynamic I/O ❑ _______
		Production trigger	Cyclic ❑ _______ Change of State ❑ _______ Application Trig. ❑ _______
		Transport type	Server ❑ _______ Client ❑ _______
		Transport class	0 ❑ _______ 2 ❑ _______ 3 ❑ _______
		ID Description	**Get Set Value Limits**
	Attributes Open	1 State	❑ ❑ _______
		2 Instance type	❑ ❑ _______
		3 Transport class trigger	❑ ❑ _______
		4 Produced connection ID	❑ ❑ _______
		5 Consumed connection ID	❑ ❑ _______
		6 Initial comm. characteristics	❑ ❑ _______
		7 Produced connection size	❑ ❑ _______
		8 Consumed connection size	❑ ❑ _______
		9 Expected packet rate	❑ ❑ _______
		12 Watchdog time-out action	❑ ❑ _______
		13 Produced connection path length	❑ ❑ _______
		14 Produced connection path	❑ ❑ _______
		15 Consumed connection path length	❑ ❑ _______
		16 Consumed connection path	❑ ❑ _______
		DeviceNet Services	**Parameter Options**
	Services	❑ Reset ❑ Delete ❑ Apply_Attributes ❑ Get_Attribute_Single ❑ Set_Attribute_Single	____________________ ____________________ ____________________ ____________________ ____________________
	Vendor-Specific Additions	If yes, fill out the Vendor-Specific Additions form on page F_7.	Yes ❑ No ❑

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.

X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 5

DeviceNet	**OBJECT NAME** Device Manager		**OBJECT ID** 64	
Open Object Implementation	**Object Class**	**ID Description**	**Get Set**	**Value Limits**
	Attributes Open	_____ ______________	❑ ❑	________________
		DeviceNet Services	**Parameter Options**	
	Services	____________________	____________________	
	Object Instance	**ID Description**	**Get Set**	**Value Limits**
	Attributes Open	31 Device Type	❑ ❑	________________
		32 Standard Revision Level	❑ ❑	________________
		33 Device Manufacturer ID	❑ ❑	________________
		34 Manufacturer Model Number	❑ ❑	________________
		35 Soft/Firmware Rev. Level	❑ ❑	________________
		36 Hardware Revision Level	❑ ❑	________________
		37 Serial Number	❑ ❑	________________
		38 Device Configuration	❑ ❑	________________
		39 Device Status	❑ ❑	________________
		3A Reporting Mode	❑ ❑	________________
		3B Exception Status Timer	❑ ❑	________________
		3C Exception Status	❑ ❑	________________
		3D Exception Detail Alarm	❑ ❑	________________
		3E Exception Detail Warning	❑ ❑	________________
		DeviceNet Services	**Parameter Options**	
	Services	❑ Reset	____________________	
		❑ Abort	____________________	
		❑ Recover	____________________	
		❑ Get_Attribute_Single	____________________	
		❑ Set_Attribute_Single	____________________	
		❑ Execute	____________________	
		❑ Perform Diagnostics	____________________	
	Meaning of Zero Length I/O Data Production________________________________			
	Vendor-Specific Additions	If yes, fill out the Vendor-Specific	Yes ❑	
		Additions form on page F_7.	No ❑	

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.
X Set to indicate that attribute value is written by the use of Set_Attribute_Single service.

F_ 6

DeviceNet	OBJECT NAME Sensor Actuator Controller		OBJECT ID 66	
Open Object Implementation	**Object Class**		**ID Description**	**Get Set Value Limits**
	Attributes	Open	_____ ____________________	❑ ❑ ____________________
			_____ ____________________	❑ ❑ ____________________
			_____ ____________________	❑ ❑ ____________________
			DeviceNet Services	**Parameter Options**
	Services		______________________________	______________________________
			______________________________	______________________________
			______________________________	______________________________
	Object Instance		**ID Description**	**Get Set Value Limits**
	Attributes	Open	______________________________	❑ ❑ ____________________
			______________________________	❑ ❑ ____________________
			______________________________	❑ ❑ ____________________
			DeviceNet Services	**Parameter Options**
	Services		❑ Reset	______________________________
			❑ Abort	______________________________
			❑ Recover	______________________________
			❑ Get_Attribute_Single	______________________________
			❑ Set_Attribute_Single	______________________________
			______________________________	______________________________
			______________________________	______________________________
			______________________________	______________________________
	Meaning of Zero Length I/O Data Production______________________________			
	Vendor-Specific Additions		If yes, fill out the Vendor-Specific	Yes ❑
			Additions form on page F_7.	No ❑

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.

X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 7

DeviceNet	OBJECT NAME______________________________		OBJECT ID_______________
Open Object Implementation	**Object Class**	**ID Description**	**Get Set Value Limits**
	Attributes Open	_____ __________________	❑ ❑ _________________
		_____ __________________	❑ ❑ _________________
		_____ __________________	❑ ❑ _________________
		DeviceNet Services	**Parameter Options**
	Service	____________________________	____________________________
		____________________________	____________________________
		____________________________	____________________________
	Object Instance	**ID Description**	**Get Set Value Limits**
	Attributes Open	1 ________________________	❑ ❑ _________________
		2 ________________________	❑ ❑ _________________
		3 ________________________	❑ ❑ _________________
		DeviceNet Services	**Parameter Options**
	Services	____________________________	____________________________
		____________________________	____________________________
		____________________________	____________________________
	Meaning of Zero Length I/O Data Production______________________________		
	Vendor-SpecificAdditions	If yes, fill out the Vendor-Specific	Yes ❑
		Additions form on page F_7.	No ❑

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.
X Set indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 8

	❑ Extension to Open Object ❑ Vendor-Specific Object		
Vendor	**OBJECT NAME**______________________________		**OBJECT ID**__________
Specific Object Implementation	**Object Class**	**ID Description**	**Get Set Value Limits**
	Attributes	_____ ____________________	❑ ❑ ____________________
		_____ ____________________	❑ ❑ ____________________
		_____ ____________________	❑ ❑ ____________________
		Code (Hex) Service Description	**Parameter Type/Options**
	Services	__________ ________________	____________________________
		__________ ________________	____________________________
		__________ ________________	____________________________
	Object Instance	**ID Description**	**Get Set Type/Value Limits**
	Attributes	_____ ____________________	❑ ❑ ____________________
		_____ ____________________	❑ ❑ ____________________
		_____ ____________________	❑ ❑ ____________________
		Code (Hex) Service Description	**Parameter Type/Options**
	Services	__________ ________________	____________________________
		__________ ________________	____________________________
		__________ ________________	____________________________
	Meaning of Zero Length I/O Data Production______________________________		

X Get to indicate that attribute value is returned by the use of Get_Attribute_Single service.

X Set to indicate that attribute value is written to by the use of Set_Attribute_Single service.

F_ 9

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E54.5-0997
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR THE SMART DISTRIBUTED SYSTEM (SDS)

NOTE: This document was previously designated SEMI E60. Because this document is part of a suite of documents, its designation has been reassigned for ease of reference. Please note that the technical content of this document is unchanged from the 0697 version.

1 Purpose

This standard defines a communication protocol based on the Smart Distributed System (SDS) to enable communications between intelligent devices on a sensor/actuator network (SAN) to be used in semiconductor manufacturing equipment.

1.1 *Background and Motivation* — SDS provides interconnection of smart control devices such as sensors, actuators, and controllers in a fast-response time, low-cost network for industrial use. SDS enables multiple devices to share a single bus, thereby significantly reducing the point-to-point wiring between controllers, sensors, and actuators. The SDS system is based on CAN, the controller area network used in the automotive industry and defined by Bosch.

2 Scope

This document specifies a SAN communications standard based on the Smart Distributed System (SDS) specification that is in compliance with the SEMI SAN Common Device Model specification.

2.1 This document specifies the protocol and services that compliant intelligent devices must support to interchange information over this semiconductor equipment sensor/actuator network.

2.2 This document is used in conjunction with a SEMI standard SAN Common Device Model specification and one or more SEMI standard specific device model specifications (e.g., for a mass flow controller). Together, the model documents describe the data structure and behavior that are characteristic of the various devices on the network. This SAN communications standard identifies the protocol for the interaction with such a device over the network to make the data structures and behavior available to other devices.

2.3 This standard, together with a sensor/actuator network interoperability guideline, the sensor/actuator network common device model, one or more sensor/actuator network specific device model documents, and the SDS specifications, form a complete interoperability standard. The general sensor/actuator network document architecture is shown in the Sensor/Actuator Network Common Device Model document in Figure 1.

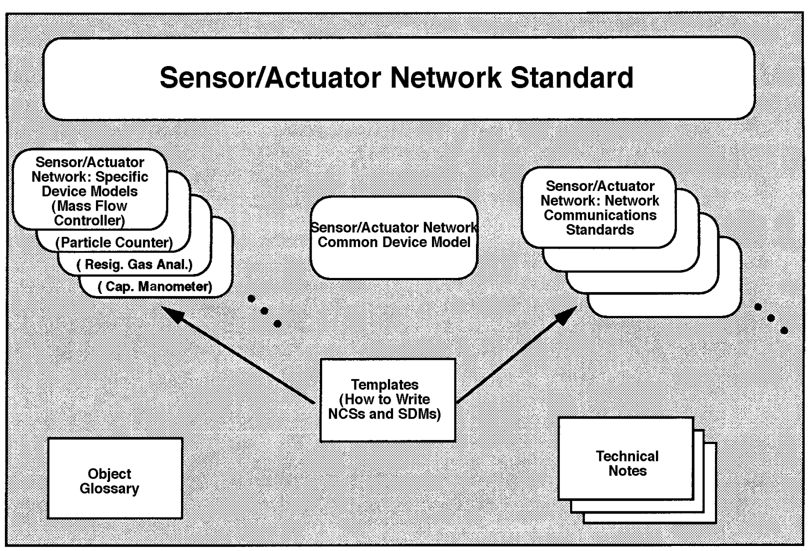

Figure 1
Sensor/Actuator Network Related Documents

The SDS Network communications standard document structure is shown in Figure 2. This standard specifies the mapping of the SAN common device model onto the SDS-specific network. In addition, the document will include mappings to specific device models (e.g., the mass flow controller). The latter mappings will be included in this document as the specific device models are defined.

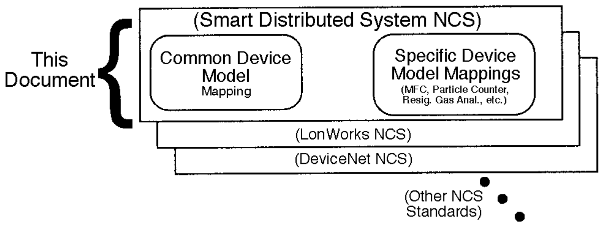

Figure 2
SDS Network Communications Standard Document Structure

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on SDS and is a companion document to the SDS specification; thus, a complete specification of this standard necessarily includes the SDS specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by SDS. In order to avoid document consistency problems, information in the SDS specification that relates to this standard is not repeated in this document. This document is limited to describing enhancements or limitations to the SDS specification that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the SDS protocol conformance testing specification. Conformance testing shall also include enhancements and limitations to the SDS specification required by this standard.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

4.2 *ISO Standards*[1]

ISO 7498 — Basic Reference Model for Open Systems Interconnection

ISO 11898 — Road Vehicles — Interchange of Digital Information — Controller Area Network (CAN) for High-Speed Communications

4.3 *Other Documents*

Doc 84-08420-1 (GS 052 103) — SMART DISTRIBUTED SYSTEM Application Layer Protocol Specification, Honeywell MICRO SWITCH, February 15, 1995

Doc 84-08421-A (GS 052 104) — SDS Physical Layer Specification, Honeywell MICRO SWITCH, December 15, 1994

Doc 85-08453-0 (GS 052 107) — SMART DISTRIBUTED SYSTEM Component Model Specification, Honeywell MICRO SWITCH, January 29, 1995

Doc GS 052 108 Issue 1 — SMART DISTRIBUTED SYSTEM Conformance Test Procedure Specification, Honeywell MICRO SWITCH, January 2, 1995

Controller Area Network Specification: Version 2, R. Bosch GmbH, + Postfach 50 D-7000, Stuttgart 1, Germany, 1991

5 Terminology

Terminology that is common to all of the documents in this SAN series may also be defined in the *Sensor Actuator Network Interoperability Guideline.* Terminology may be reproduced here which is defined in other SEMI documents.

5.1 *Device Component Definitions* — This standard is based on the concepts developed in the Sensor Actuator Network Common Device Model (SEMI E54) document and makes use of the following terms defined in it:

a) device

b) device model

c) object

d) instance

e) attribute

f) behavior

g) service

---

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h) state diagram

i) byte

j) nibble

k) character string

5.2 *SDS-Specific Definitions* — In addition to the above terms, the following terms are defined for SDS networks.

5.2.1 *actions* — operations that a client may request an Embedded Object to perform. The action typically modifies the state of the device. Actions are more powerful than writing to an attribute, in that multiple input arguments may be provided as part of an action request. Also, results of the action are typically returned. Actions, like attributes, have identifiers that are specific to the type of the object. However, these identifiers are independent from attribute or event identifiers. The "request" services specified in SEMI E54 are implemented as SDS actions.

5.2.2 *controller area network (CAN)* — a protocol developed by the Bosch corporation for automotive in-vehicle networking. The CAN specification specifies OSI reference model layers 1 and 2, specifically the physical signaling and media access/data link protocols.

5.2.3 *embedded objects* — each SDS Logical Device contains at least one, and at most 32, Embedded Objects. An SDS Embedded Object is an abstraction representing an addressable entity "embedded" within a Logical Device having specific application-related interface characteristics. These characteristics include a defined set of attributes, actions, and events that are specific to the Embedded Object. Combinations of these Embedded Objects provide a mechanism for describing an arbitrary sensor/actuator network device. The behaviors required by SEMI E54 are specified as part of the definition of attributes, actions, and events.

5.2.4 *events* — Are used by objects to asynchronously report the occurrence of events within an Embedded Object. Event definitions specify the event reports that a specific Embedded Object type may emit. Events also have type-specific identifiers. Event definitions include: a text string defining the semantics of the event, an event identifier numerical value and textual name, and a syntax definition. The "notification" services specified in SEMI E54 are implemented as SDS events.

5.2.5 *logical device* — It is possible to have one or more independent Logical Devices within the Physical Component. This provides the illusion of multiple devices on the network that actually are implemented on the same physical hardware. Logical Devices are distinguished within the Physical Component using unique SDS bus addresses. The Logical Device defines a separately addressable entity within a Physical Component that has an independent interface definition.

5.2.6 *physical component* — An SDS Physical Component is an abstraction representing a single physical package of hardware and software that is connected to the network. This is equivalent to the CDM SEMI E54 definition for "device." The Physical Component contains one or more Logical Devices.

Table 1 provides a mapping of SEMI E54 definitions to SDS-specific definitions. Column 2 contains an equal sign "=" if the definition is used exactly as specified in SEMI E54. Otherwise, the appropriate SDS-specific term(s) are identified.

Table 1 Mapping of Terms Between SEMI E54 and SDS

SEMI E54 Term	*SDS Term*
Device	=
Device Model	Physical Component
Object	Embedded Object
Instance	=
Attribute	=
Behavior	Set of Attribute/Action/Event definitions
Service	Actions for Request Services and Events for Notification Services
State Diagram	=
Byte	=
Nibble	=
Character String	=

6 Communication Protocol High Level Structure

The SDS protocol is based on a three-layer architecture. These layers constitute a collapsed form of the OSI seven-layer architecture, mapping into the physical, datalink, and application layers of the Open Systems Interconnection Reference Model. The high level protocol architecture is shown in Figure 3.

Note that Figure 3 represents a conceptual view of the device architecture. Conforming implementations must implement the services defined in this specification at each layer and must appear (from the network) to have implemented this architecture; however, an internal modular partitioning is not required. Implementations may sacrifice modularity in order to achieve high performance.

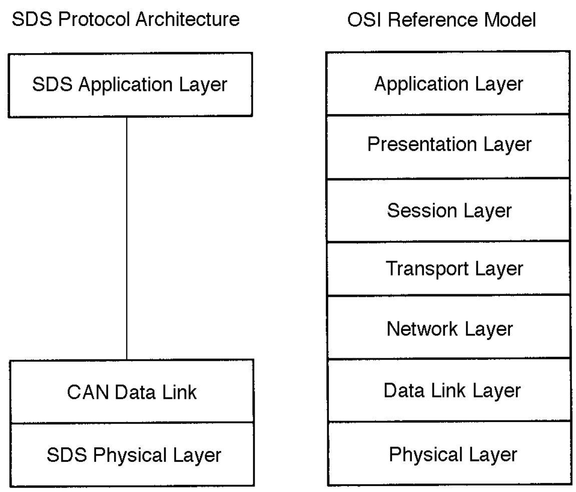

Figure 3
Protocol Architecture

SDS uses a three-layer protocol stack consisting of the physical, datalink, and application layers. The SDS physical layer uses two twisted pair to deliver power and data to smart devices at speeds ranging from 125 Kbps to 1 Mbps and distances up to 500 meters. At the data link layer, the CAN specification defines a carrier sense multiple access mechanism for media access control that avoids collisions and sends frames reliably. The application layer supports a concise set of services to set and get attributes of objects, to invoke operations on objects, and to report notifications from objects. These services are optimized for high performance in discrete control applications (e.g., 3 byte messages convey digital I/O state changes). In addition, a set of pre-defined and extensible component objects flexibly specifies all network-visible application level device capabilities.

6.1 *Physical Layer* — The device shall comply with the SDS physical layer specifications. These include physical signaling (levels and baud rates - detailed in the CAN specification), transceivers, node isolation, media topology, cable specifications, network connectors and taps, and power considerations (load limits, system tolerances, and power supply options).

6.2 *Data Link Layer* — The device shall comply with the SDS Data Link Layer Specifications (i.e., Controller Area Network Specification: Version 2). These include the media access control mechanism and the logical link control mechanism. Frame formats, interframe spacing, and error signaling shall comply with the CAN specifications. CAN frame identifiers shall be 11 bits in length.

6.3 *Network Layer* — There is no distinct network layer. A future extension of the SDS SEMI SAN protocol will support inter network messaging.

6.4 *Transport Layer* — There is no distinct transport layer. Specific functionality of this layer is implemented in the Application Layer. Functions include: segmentation and reassembly for large message delivery.

6.5 *Session Layer* — There is no distinct session layer.

6.6 *Presentation Layer* — There is no distinct presentation layer. Data types are specified as part of the SDS object definitions.

6.7 *Application Layer* — The device shall comply with the SDS application layer specification. This includes application object to application object communication mechanisms.

6.7.1 *Object Models* — The SDS protocol provides an object-oriented specification for defining and addressing objects, including their attributes, actions, and events. The device shall comply with the object model specifications provided in the SDS Component Model Specification. In addition, the device shall comply with the object specifications defined in Section 7 of this document.

6.8 *Network Management* — The device shall comply with the SDS system and network management specifications.

7 Required Object Types

The Common Device Model specification identifies the objects that must be supported in SEMI SAN-compliant devices. These objects are specified in Table 1 of SEMI E54 and include the following:

a) Device Manager (DM)

b) Sensor/Actuator/Controller (SAC)

c) Sensor (S_i)

d) Actuator (A_i)

e) Controller (C_i).

As specified in SEMI E54, a conforming device must support the DM, the SAC, and one or more of the remaining object types.

This section specifies the implementation of these required and optional objects in the SDS object model. SDS object types are defined for the DM and SAC objects. Sensor, actuator, or controller objects may be implemented using existing standard SDS object types, or new types may be specified, depending on the specific device model needs.

7.1 *Embedded Object Type Hierarchy* — SDS classifies Embedded Objects into specific object types (classes), and these types are organized into a class inheritance hierarchy. (For more information on classification and inheritance, see SEMI E39 -- Object Services Standard). Each SDS object type specifies the details of an object's attributes, actions, and events. The Embedded Object (an instance of a type) is a network-addressable entity within a logical device. The classification identifies common characteristics and enables reuse of object definitions. The top two levels of that hierarchy are shown in Figure 4 below.

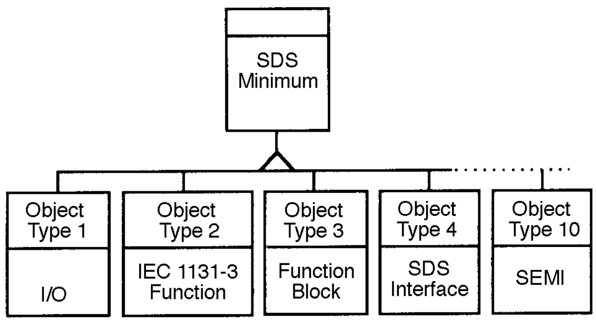

Figure 4
Top Levels of the SDS Embedded Object Type Hierarchy

The SDS object types are specified in detail in the SDS Component Modeling Specification. There are four primary Embedded Object types in the SDS type hierarchy. These include: I/O, IEC 1131-3 Function Object, Function Block, and SDS Interface. In addition, a new SEMI object type has been defined for use in developing classes necessary for SEMI SAN-compliant networks. Each of these object types is derived from a common type called SDS Minimum, which defines the minimum characteristics that are common to all SDS Embedded Objects.

All SDS object types inherit from the SDS Minimum object type, which provides the fundamental characteristics of an SDS device. The other top level SDS object types shown in Figure 4 are summarized below.

I/O Object (Type 1) — Defines the general characteristics of objects used for process I/O type functions. Subtypes of this type specify input and output objects with either analog or digital process variables. These may be used in SAN devices as the sensor or actuator objects.

IEC 1131-3 Function Object (Type 2) — Defines standard IEC 1131-3 Function Objects such as counters, timers, type conversion, bit-wise operations, character strings, etc.

Function Block Object (Type 3) — Collections of function objects that have a specific set of inputs and outputs (e.g., a predefined control algorithm). These may be used in the SAN devices as the controller objects.

SDS Interface Object (Type 4) — Models, network interfaces, gateways, etc.

SEMI Object (object Type 10) — Implement the additional object types necessary for SEMI SAN-compliant networks.

7.1.1 *SEMI Objects* — To implement SEMI-specific object types, the SDS object type hierarchy is augmented with type number 10 - SEMI object. This type, and the types derived from it, specify the new functionality necessary to implement this SEMI standard. Object type 10 is defined to include the common required attributes, services, and behaviors as described in the SAN Common Device Model standard SEMI E54. This definition is in terms of SDS Attributes, Actions, and Events.

In addition, there are derived types: types 10.1 implementing the SAC object and 10.2 implementing the Device Manager (DM) object (Figure 5). Object instances of these types are required in the Common Device Model document SEMI E54.

Each object type inheriting from the SEMI Object type 10 (e.g., 10.1 SAC object) automatically includes the features of the SEMI Object. Thus, both the SAC and the DM object have the reset, abort, and recover actions that are defined for the SEMI Object type 10. (See Section 7.2.) The Device Manager type augments the SEMI Object to provide the required characteristics over and above those specified in type 10 and SDS minimum.

As specific device models are defined, the SAC object type will be refined to be specific to that device. These object types are indicated in Figure 5 as object types SDM-1, SDM-2, etc. (examples include: Mass Flow Controller, Particle Counter, and Capacitance Manometer SAC objects). These object types have (at least) the set of attributes, actions, and events inherited from SDS Minimum, the SEMI Object type, and the SAC object type. Additionally, each SDM-n may have other, unique attributes, actions, and events which implement the desired behavior of a specific device SAC object.

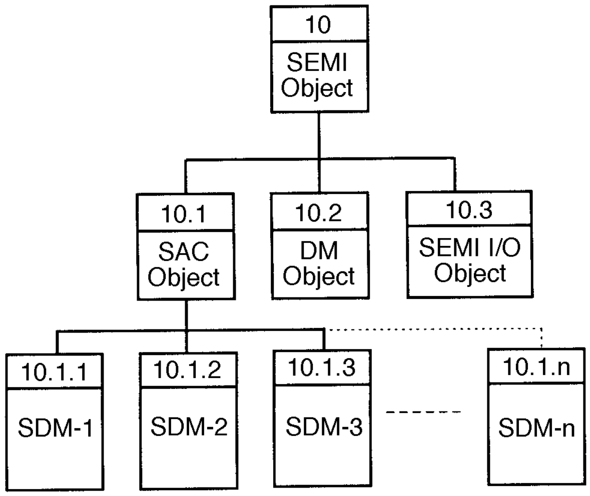

Figure 5
Second and Third Levels of the SEMI Object Type Hierarchy

The optional sensor and actuator objects described in the SEMI E54 specification may be instances of existing SDS object types (e.g., of type I/O object in Figure 4). In cases where a desired object type is not available under SDS object type 1, new I/O object types may be defined as sub-types of object type 10.3 SEMI I/O object.

7.1.2 *Example SEMI Device* — For clarification purposes, an example SEMI device is shown in Figure 6 (using Rumbaugh notation). It consists of three (or more) objects, including a DM, SAC, and binary input object. This is a complete and fully functional SEMI SAN-compliant digital input device.

In Figure 6, the Device is assigned an SDS address (e.g., 125), and each object is assigned an object instance number. The device address may be changed during installation. Each SDS message contains a device address and an object instance number.

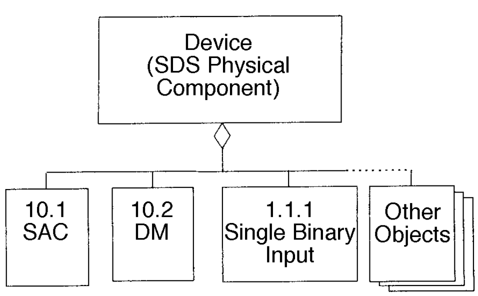

Figure 6
Example Device with Multiple Objects

7.2 *SEMI Object Type 10 Definition* — Table 2 formally specifies the SEMI Object (type 10). The three sections in this table specify SDS identifiers to code the required attributes, actions, or events. The first column is the SDS identifier number, the unique identifier used in SDS messaging. The second column is the SEMI E54-specified name associated with the ID#. The third column identifies the associated tag name (identifier) used in SEMI E54.

Table 2 SEMI Object Common Level Model(Object Type 10)

Type 10 SEMI Object Common Structure and Behavior		
Attributes		
ID	Name	SEMI E54 tag
	None defined.	
80–144	SEMI Reserved Attribute IDs	Reserve
Actions		
ID	Name	SEMI E54 tag
80	Reset	SacS1/DmS1
81	Abort	SacS2/DmS1
82	Recover	SacS3/DmS3
83–95	SEMI Reserved Action IDs	Reserve
Events		
ID	Name	SEMI E54 tag
	None defined.	
80–95	SEMI Reserved Event IDs	Reserve

There are no attributes that are currently identified in SEMI E54 that are common to all SEMI objects. As a result, there are no attributes defined in the table. However, 64 attribute IDs have been reserved for use in other sub-types derived from type 10 in this document and in future revisions of this document.

SEMI E54 defines three service requests (reset, abort, and recover) that are common to the Device Manager and the SAC objects. These service requests are implemented as specific SDS Actions. Each service is mapped to a designated SDS action in Table 2. The actions are identified as ID# 80, 81, and 82 respectively. Additional action identifiers are reserved for use in sub-types of this type and for future use.

Not explicitly shown as Actions are the SEMI E54 Get and Set Attribute services. The equivalent behavior is provided by the SDS Read and Write Attribute services that are implicit for every attribute.

The execution of a service request may cause a change in the object's state variable. When a device receives an SDS action message indicating a service request, the object transitions to the appropriate state, after which an SDS response message is transmitted to the service requester indicating the response to the request. For example, the SAC Object Instance Behavior State Transition Matrix in Table 4 of the SEMI E54 document defines the valid SAC state transitions.

Service Notifications (as defined in SEMI E54) are implemented with specific SDS event messages which are specified in the third part of the table. The SEMI object (type 10) has no events defined at this time. Additional event identifiers are reserved for use in sub-types of this type and for future use.

7.3 *Implementation of Sensor/Actuator/Controller Object Type (SAC)* — A single instance of a SAC object type is required in each SAN device. The actual object type used will typically be derived from the SAC object type rather than this exact type. The derived type will have added services and attributes that are device-specific (according to a Specific Device Model specification). The generic SAC type is, nevertheless, defined as a semantic type definition (sensor actuator controller object). The features of the SAC object include service requests (for Reset, Abort, Recover, etc.) that are mapped to SDS Action functions. Since these have been defined in the super type (object type 10), they are not re-defined here.

7.3.1 *SDS Object Model for Sensor/Actuator/Controller Object Type (SAC)* — The SDS object model for the SAC object type (Table 3) needs only to include the appropriate mapping for SAC-specific attributes and behavior (i.e., augmenting the SEMI Object Common Level - Table 8-1). The SAC Object Model contains no attributes, actions, or events beyond those specified in its super type (type 10).

An implementor of a specific device will normally derive a new SAC object type and add new attributes, actions, or events as necessary (i.e., 10.1.1 MFC SAC Object). Object type 10.1 is, in essence, a semantic grouping only—for a group of device-specific SAC object types implementing specific behavior.

The default object identifier that should be used for the SAC object in an SDS device is 1. The actual object identifier used may be reassigned by the implementor. The identifier may be determined on line via reading the object type attributes from all objects on the device.

Table 3 SAC Object Model (Object Type 10.1)

Type 10.1 Sensor/Actuator/Controller Object Model		
Attributes		
ID	Name	SEMI E54 tag
	None defined.	
Actions		
ID	Name	SEMI E54 tag
	None defined.	
Events		
ID	Name	SEMI E54 tag
	None defined.	

7.4 *Implementation of Device Manager Object Type (DM)* — A single instance of this type is required on each device.

7.4.1 *SDS Object Model for Device Manager Object Type (DM)* — The SDS object model for the DM object type includes the appropriate mapping for DM-specific attributes and behavior to SDS-specific identifiers (Table 4).

Table 4 DM Object Model (Object Type 10.2)

Type 10.2 Device Manager (DM) Object Model		
Attributes		
ID Name		SEMI E54 tag
81	Device Type	DmA1
82	Standard Revision Level	DmA2
83	Device Manufacturer Identifier	DmA3
84	Manufacturer Model Number	DmA4
85	Software or Firmware Revision Level	DmA5
86	Hardware Revision Level	DmA6
87	Serial Number (optional)	DmA7
88	Device Configuration (optional)	DmA8
89	Device Status	DmA9
90	Reporting Mode	DmA10
91	Exception Status Timer (optional)	DmA11
92	Exception Status	DmA12
93	Exception Detail Alarm (optional)	DmA13
94	Exception Detail Warning (optional)	DmA14
Actions		
ID	Name	SEMI E54 tag
83	Execute	DmS6
84	PerformDiagnostics	DmS7
Events		
ID	Name	SEMI E54 tag
81	Publish Attribute	DmS8

The DM Object Model maps exactly to the specification for the DM in SEMI E54. Refer to that document for detailed descriptions for the attributes, actions, and events defined in Table 4. The SEMI E54 tag column indicates the identifier used in SEMI E54.

The default object identifier that should be used for the DM object in an SDS device is 2. The actual object identifier used may be reassigned by the implementer.

7.5 *Implementation of Sensor Object Type (S_i)* — Zero or more instances of this object type are permitted on each device.

Sensor object types are already defined within the SDS object hierarchy (e.g., Object Type 1 - I/O Device). Implementation of a device which is compliant with this type results in compliance with this standard.

If the existing sensor object types defined in the SDS specifications do not meet the requirements of the application, new SEMI-specific types may be defined deriving from type 10.3. If new types are required that are generic (i.e., not specific to SEMI), they should be derived from type 1 - I/O Device.

7.6 *Implementation of Actuator Object Type (A_i)* — Zero or more instances of this object type are permitted on each device.

Actuator object types are already defined within the SDS object hierarchy (e.g., Object Type 1 - I/O Device). Implementation of a device which is compliant with this type results in compliance with this standard.

If the existing actuator object types defined in the SDS specifications do not meet the requirements of the application, new SEMI-specific object types may be defined deriving from type 10.3. If new types are required that are generic (i.e., not specific to SEMI), they should be derived from type 1 - I/O Device.

7.7 *Implementation of Controller Object Type (C_i)* — Zero or more instances of this object type are permitted on each device.

Specific controller object types are defined within the SDS object hierarchy (e.g., Object type 3 - Function Block Object). Implementation of a device which is compliant with these types results in compliance with this standard.

If the controller types defined in the SDS specifications do not meet the requirements of the application, new SEMI-specific object types may be defined deriving from type 10. If new types are required that are generic (i.e., not specific to SEMI), they should be derived from type 3 - Function Block Object.

8 Protocol Compliance

A method of testing protocol compliance is required to verify conformance to this standard. The device must satisfy the SDS protocol conformance requirements as documented in the SDS specifications. The SDS partners group provides a conformance verification test procedure service to its members. When this SEMI Sensor/Actuator Network standard is incorporated into the SDS Partners specification set, this service may be used to verify compliance with the SEMI guidelines.

8.1 *Compliance Statement* — Addendum A includes a compliance statement form that should be completed by device implementors for compliance verification.

9 Specific Device Model Mappings

9.1 *Device Model for Mass Flow Controller* — This model will be specified after the MFC-specific device model (SDM) standard is complete.

9.2 *Device Model for Capacitance Manometer* — This model will be specified after the capacitance manometer SDM standard is complete.

9.3 *Device Model for Particle Counter* — This model will be specified after the particle counter SDM standdard is complete.

9.4 *Device Model for Residual Gas Analyzer* — This model will be specified after the residual gas analyzer SDM is defined.

APPENDIX 1
STATEMENT OF COMPLIANCE

NOTE: This appendix was approved as an official part of SEMI E54.5 by full letter ballot procedure.

This form is used to specify conformance options with respect to the SDS and common device model SEMI E54 specifications.

		Fill in the blank or the appropriate box. ❑ ❑			
General Device Data	Conforms to Smart Distributed System Specification:	Release ___________			
	Vendor Name	___________________			
	Vendor Partner ID#	___________________			
	Catalog Listing	___________________			
	Object Type	___________________			
	Software Version	___________________			
Smart Distributed System Physical Conformance Data	Network Power Consumption			___________mA @ 18 VDC	
	Connector Style	Open-Hardwired	❑	Sealed-Mini	❑
		Open-Pluggable	❑	Sealed-Micro	❑
		9 Pin	❑		
	Isolated Physical Layer	Yes		No	❑
		Opto	❑		
		Transformer	❑		
	Default Device Address	___________			
	Communication Data Rates Supported	125K bits/s	❑	500K bits/s	❑
		250k bits/s	❑	1M bits/s	❑
Smart Distributed System Logical Device & Object Data	Device Type	Master	❑		
		Slave	❑		
		Peer-to-Peer	❑		
	Number of Logical Devices	Default = 1			
	Object Class(es) on Logical Device #0	Minimum = 1			
		Object #0 ___________			
		Object #1 ___________			
		Object #2 ___________			
		Object #3 ___________			
		...			
		Object #31 __________			

If there are additional logical devices, they should be documented as above.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E54.6-0997
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR LONWORKS

NOTE: This document was previously designated SEMI E61. Because this document is part of a suite of documents, its designation has been reassigned for ease of reference. Please note that the technical content of this document is unchanged from the 0697 version.

1 Purpose

This standard defines a communication specification based on the LonWorks technology specification to enable communications between intelligent devices on a sensor/actuator network (SAN) that operate according to SEMI-specified device models (common and device specific) in a semiconductor manufacturing tool.

This document specifies a mapping of the SEMI common device model (CDM) onto LonWorks technology using the *LonMark Interoperability Guidelines* established for LonWorks devices. The LonMark Interoperability Association may incorporate into the Interoperability Guidelines any enhancements presented in this document.

1.1 *Background and Motivation* — The LonWorks communications system provides interconnection of smart control devices such as sensors, actuators, and controllers in a fast-response time, low-cost network for industrial use. LonWorks enables multiple devices to share a single network, thereby significantly reducing the point-to-point wiring between controllers, sensors, and actuators. The LonWorks network communications standard (NCS) is based on the seven-layer LonTalk Protocol, implemented by the Neuron Chip, a physical layer transceiver, and an optional host processor. The LonTalk Protocol was developed by Echelon and may be freely licensed for implementation on any hardware platform. The SEMI NCS for LonWorks is based on the LonMark interoperability guidelines, which provide a framework for interoperable use of the LonTalk Protocol at layers 1-6, as well as at the application layer. Where the LonMark interoperability guidelines do not provide the functionality required by the SEMI CDM, the guidelines are extended with SEMI-specific requirements.

2 Scope

This document specifies a SAN communications standard, based on the LonWorks specification, that enables communication with SAN devices configured according to the SEMI SAN Common Device Model and appropriate Specific Device Model (SDM) specifications.

2.1 This document specifies the use of LonWorks technology for services that compliant intelligent devices must support in order to exchange information over this semiconductor equipment sensor/actuator network.

2.2 This document specifies the utilization of LonWorks technology to present externally visible device structure and behavior, specified in the CDM and appropriate SDMs, on a LonWorks network.

2.3 This document is used in conjunction with a SEMI standard SAN Common Device Model specification and one or more SEMI standard Specific Device Model specifications (e.g., for a mass flow controller). Together, the model documents describe the externally visible data structures and behavior of devices using LonWorks technology in a SEMI-compliant SAN system.

2.4 This standard, together with a sensor/actuator network interoperability guideline, the sensor/actuator network common device model, one or more sensor/ actuator network specific device model documents, the LonTalk protocol specification, and the LonMark interoperability guidelines, specifies requirements for SEMI SAN implementations based on LonWorks technology. The general sensor/actuator network document architecture is shown in the Sensor/Actuator Network Common Device Model document in Figure 1.

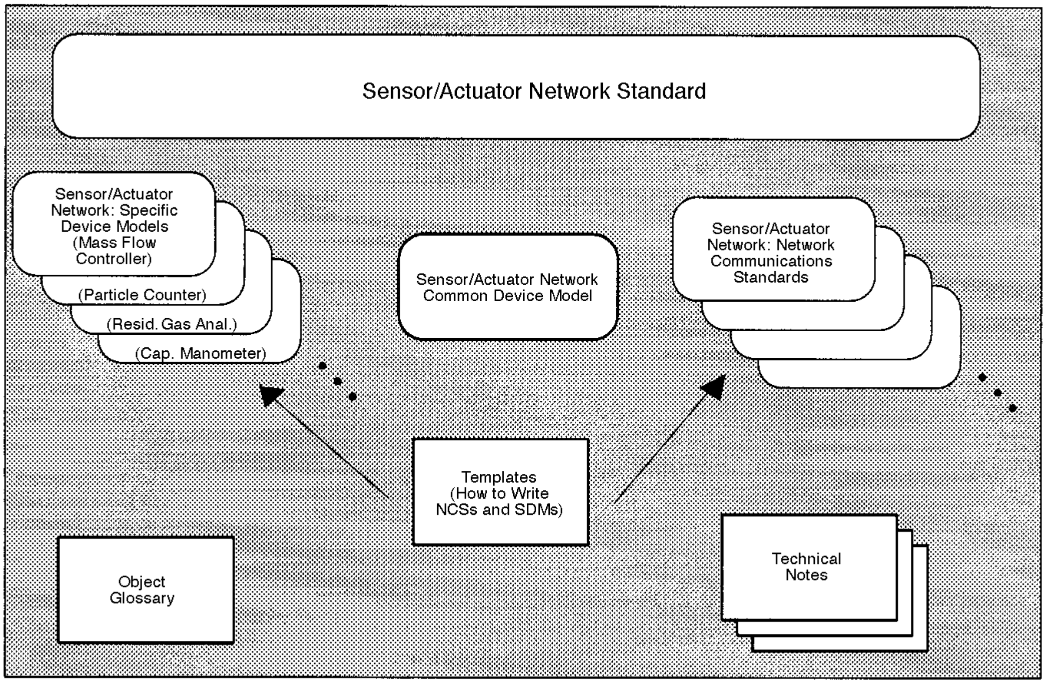

Figure 1
Sensor/Actuator Network Related Documents

2.5 *Document Structure* — The LonWorks network communications standard complies with the SEMI SAN NCS template document structure; this structure is shown in Figure 2. The standard document is composed of two main parts. The first part (Sections 1 through 8) specifies the SAN-enabling protocol as well as the presentation (i.e., mapping) of CDM object structure and behavior onto the network (referred to as the "CDM mapping"). The second part (Section 9) specifies the presentation (i.e., mapping) of SDM object structure and behavior onto the network for each SEMI-specified SDM (referred to as the "SDM mapping"). Device-type-specific items, such as connector deviations (see Section 6.1), may also be noted in Section 9.

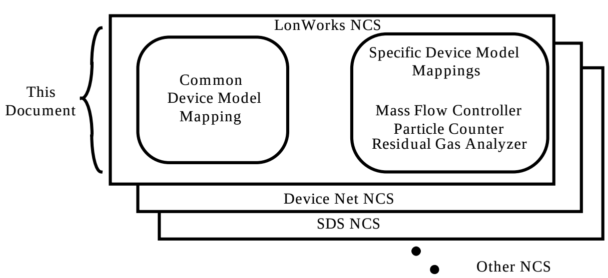

Figure 2
LonWorks Network Communications Standard Document Structure

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on LonWorks and is a companion document to the LonWorks protocol specification; thus, a complete specification of this standard necessarily includes the LonWorks specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by the *LonMark Interoperability Guidelines*. In order to avoid document consistency problems, information in the LonWorks technology standard that relates to this standard is not repeated in this document. This document is limited to describing enhancements or limitations of LonWorks technology and the LonMark interoperability guidelines that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the applicable LonMark interoperability conformance testing specification. Conformance testing shall include enhancements to the LonMark guidelines required by this standard.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

4.2 *ISO Standard*[1]

ISO 7498 — Basic Reference Model for Open Systems Interconnection

4.3 *Other Documents*

LonTalk Protocol Specification, Echelon Corporation, 4015 Miranda Avenue, Palo Alto, CA 94304 USA

LonMark Layers 1–6 Interoperability Guidelines, Echelon Corporation

LonMark Application Layer Interoperability Guidelines, Echelon Corporation

Neuron Chip Data Book, Echelon Corporation

Neuron C Programmer's Guide, Echelon Corporation

Standard Network Variable Type Master List and Programmer's Guide, Echelon Corporation

Standard Configuration Parameter Type Master List and Programmer's Guide, Echelon Corporation

5 Terminology

Terminology that is common to all of the documents in this SAN series may also be defined in the *Sensor Actuator Network Standard*. Terminology may be reproduced here which is defined in other SEMI documents.

5.1 *Acronyms*

5.1.1 *CDM* — Common device model

5.1.2 *DM* — DeviceManager

5.1.3 *DS* — Device status

5.1.4 *NCS* — Network communications standard

5.1.5 *NV* — Network variable

5.1.6 *OSI* — Open systems interconnect

5.1.7 *OSS* — Object services standard

5.1.8 *SAC* — Sensor, actuator, controller object

1 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland

5.1.9 *SAN* — Sensor/actuator network

5.1.10 *SCPT* — Standard configuration parameter type

5.1.11 *SDM* — Specific device model

5.1.12 *SNVT* — Standard network variable type

5.2 *Device Component Definitions* — As this standard defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in the CDM document. Table 1 provides a mapping of fundamental terminology of the CDM document into this document and the LonWorks definitions. The symbol "=" indicates that the definition is used exactly as specified on the CDM specification.

In the following sections, additional clarification of some of these terms is provided in the context of the LonWorks protocol.

Table 1 Mapping of CDM to NCS Terminology

CDM Term	*NCS Equivalent*	*LonWorks Equivalent*
Device	=	Device or node
Device Model	=	Functional profile
Object	=	LonMark object type
Instance	=	LonMark object instance
Attribute	=	Network variable or configuration property
Behavior	=	=
Service	=	Network variable function or application message
State Diagram	=	=
Byte	=	=
Nibble	=	=
Character String	=	String of ASCII characters or string of international characters

5.2.1 *attribute* — Attributes are either input network variables, output network variables, or configuration properties. Input and output network variables may be read and/or written by the device itself, and all attributes may be polled over the network. Additionally, input network variables and configuration properties may be updated over the network, and the receipt of such an update causes an event to be propagated to the device's application layer. This corresponds to a RW (Read and Write) attribute of the object owning the network variable. Output network variables may not be updated over the network. This corresponds to a RO (Read Only) attribute of the object owning the network variable. When the device itself updates one of its output network variables, the value of that variable may be propagated over the network to destination address(es) determined at installation time. Finally, configuration properties are attributes typically stored in non-volatile memory and preserved across device resets and power cycles.

5.2.2 *behavior* — Generic object behavior is specified by the *LonMark Application Layer Interoperability Guidelines*. Additional object-specific behavior is specified by means of functional profiles.

5.2.3 *device* — A device (or node) consists of one network transceiver which implements the physical layer of the LonTalk Protocol, one Neuron Chip with associated firmware which implements the other layers of the LonTalk Protocol, and input/output hardware implementing the physical interface of the device to external sensor and/or actuator hardware. A LonWorks device may optionally contain a host processor and associated software or firmware which implements the application layer of the LonTalk Protocol.

5.2.4 *device model* — The device model comprises several elements which fully describe the external interface of the device for an interoperable network. The interface is made of the following pieces: a Device Manager (DM) object; a Sensor/Actuator/Controller (SAC) object; LonMark objects such as sensors, actuators, and controllers; individual network variables; and configuration properties.

5.2.5 *instance* — Real devices may have zero or more instances of each of the defined LonMark objects and functional profiles. Object instances are identified by means of an instance number within the device.

5.2.6 *object* — LonMark objects are defined as a set of one or more network variable inputs and/or outputs, implemented as Standard Network Variable Types, and a set of configuration properties, implemented as Standard Configuration Property Types. LonMark objects form the basis of interoperability at the application layer. The LonMark objects describe standard formats for how information is input to, and output from, a device, and shared with other devices on the network.

5.2.7 *service* — Request services are represented by LonTalk messages delivered to the device application. Notification services are represented by LonTalk messages originated by the device application.

5.2.8 *state diagram* — In a LonWorks device, state is represented by the collection of values of local and network variables of the application program. Transitions between states are the result of external events (such as the receipt of a network variable update, or other I/O event), or internal events (such as the expiration of a timer).

5.3 *LonWorks-Specific Definitions* — In addition to the standard data type definitions for bit, nibble, byte, and character, the LonTalk Protocol defines a set of standard data representations for use as attribute values.

5.3.1 *binding* — Network variables on the same or different devices may be associated together by means of a network management service known as binding. Binding is permitted only if all the network variables in the set are of the same data type. The values of network variables that are bound together are propagated over the network by the LonTalk protocol. Table 2 shows the permitted combinations for updating and polling of network variables.

Table 2 Updating and Polling of Network Variables

Network Variable Class	*Update from Network*	*Update from Device*	*Poll from Network*	*Poll from Device*
Input	Yes	Yes	Yes	Yes[2]
Output	No	Yes[1]	Yes	No
Config'n	Yes	No	Yes	Yes[2]

NOTES:

1. When the device updates one of its own output network variables, input network variables that are bound to this output network variable receive an update from the network.

2. When the device polls one of its own input or configuration network variables, output network variables that are bound to this input or configuration network variable receive a poll from the network.

5.3.2 *configuration properties* — These are attributes of a LonMark object that are used to configure the application-specific behavior of the object, such as sensor gain and offset, linearization table, and sample rate. These attributes are typically updated when the device is installed, configured, or calibrated, and are stored in non-volatile memory.

5.3.3 *functional profile* — A functional profile is a set of one or more LonMark objects, together with semantic definitions relating the behavior of the object(s) to the network variable values. The collection of functional profiles and LonMark objects in a device corresponds to the device-specific model for that device. Each type of functional profile is identified by a type number which is allocated when the profile is standardized.

5.3.4 *network variable* — This is a network-visible data attribute of a device, with a well-defined data type. Network variables are either input variables, output variables, or configuration variables. The value of a network variable may be updated either by the device itself, or over the network by some other device. This corresponds to a SetAttribute operation. The value of a network variable may be polled over the network by some other device, or retrieved by the device itself. This corresponds to a GetAttribute operation.

5.3.5 *object instance* — A device's external interface documentation specifies the type identifiers of the LonMark object instances contained within the device. Each instance is allocated an index number based on the order of the declaration of the instance in the device's external interface documentation. This documentation may be uploaded from the device, and completely specifies the functional profiles and LonMark objects contained within the device, as well as the network variables and configuration properties contained within each of the functional profiles.

5.3.6 *object type* — An object type is the definition of the attributes and behaviors of an abstract entity. Each type of LonMark object is identified by a type number which is allocated when the object type is standardized. A specific device type consists of instantiations of one or more of these object types. The term *LonMark object* is loosely used to refer to either a LonMark object type or to a specific instance of a LonMark object type. The attributes of a LonMark object are implemented as a collection of network variables of SNVT types and configuration properties of SCPT types.

5.3.7 *standard configuration parameter types* — These data types, also known as SCPTs, provide a data type definition and a semantic behavior for the configuration properties of LonMark objects. A list of all available SCPTs and details of their definitions is provided in the *SCPT Master List and Programmer's Guide*.

5.3.8 *standard network variable types* — These data types, also known as SNVTs, facilitate interoperability by providing a well-defined interface for communication between devices made by different manufacturers. A device may be installed in a network, and logically connected to other devices via network variables, as long as the data types match. A list of all available SNVTs and details of their definitions is provided in the *SNVT Master List and Programmer's Guide*.

6 Communication Protocol High Level Structure

The LonTalk Protocol is based on a seven-layer architecture. At each layer, there is a description of the services provided within that layer. The high level protocol architecture is shown in Figure 3.

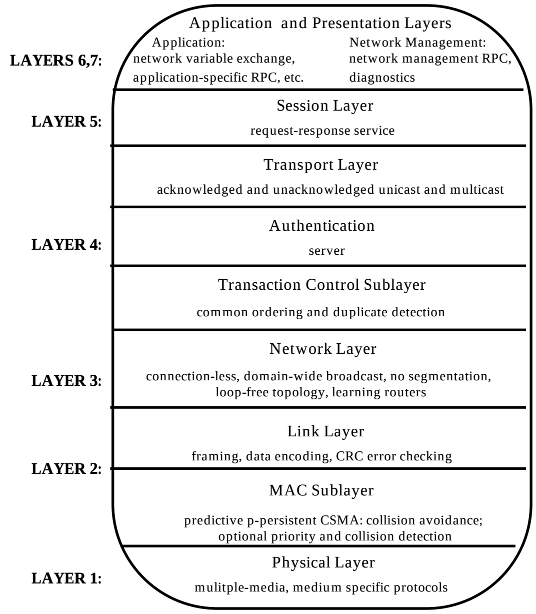

Figure 3
Layered View of the LonTalk Protocol

Note that Figure 3 represents a conceptual view of the device architecture. Implementations typically use the Neuron Chip and its associated firmware, which provide a conforming implementation of layers 2 through 6. The *LonMark Interoperability Guidelines* specify the protocol options to be used, most specifically at the physical layer (network transceivers) and at the application layer (object model).

6.1 *Physical Layer* — The device shall employ one of the LonMark-approved physical channels as specified in the *LonMark Layers 1–6 Interoperability Guidelines*. LonWorks-based SEMI SAN-compliant devices shall use, by default, a two-pin screw-terminal open pluggable connector (Weidmüller-Klippon SL2, Phoenix Combicon, or equivalent) for the network connection. The default connector specification may be overridden for specific device types if special requirements apply; any such overrides shall be noted in Section 9 of this document. This connection is polarity-insensitive. The requirements of semiconductor equipment may be met by one of the twisted pair channel specifications listed below.

6.1.1 *TP/XF-1250 Twisted Pair* — This twisted-pair channel operates at a bit rate of 1,250kbps and supports a bus topology using transformer-coupled transceivers.

6.1.2 *TP/FT-10 Twisted Pair* — This twisted-pair channel operates at a bit rate of 78kbps and supports both free topology and bus topology wiring, as well as optional link power.

The *LonMark Layers 1-6 Interoperability Guidelines* provide specific details of the characteristics of these transceivers. This document also provides specifications of wiring types and interconnection topologies to be used for guaranteed device interoperability. Note that the LonTalk Protocol supports heterogeneous networks. Devices with dissimilar transceivers may be interconnected and communicate via routers or repeaters. Similarly, routers and repeaters may be used to extend a physical channel beyond the device count, wire length, or other physical limitations imposed by the chosen transceiver.

Multiple physical layer protocols and data encoding methods are used in the LonTalk Protocol. Differential Manchester encoding is used on twisted pair physical layers.

6.2 *Link Layer* — The device shall comply with the LonTalk protocol link layer specification. This layer includes the media access control sublayer. For a number of reasons, including simplicity and compatibility with the multicast protocol, the LonTalk protocol supports a simple connectionless service. Its functions are limited to framing, frame encoding, and error detection, with no error recovery by retransmission.

6.2.1 *Media Access Control Sublayer* — In order to deal with a variety of media in the potential absence of collision detection, the MAC (Media Access Control) sublayer employs a collision avoidance algorithm called Predictive *p*-persistent CSMA (Carrier Sense, Multiple Access).

6.3 *Network Layer* — The device shall comply with the LonTalk protocol network layer specification. This layer handles packet delivery within a single domain, with no provisions for inter-domain communication. The network service is connection-less, unacknowledged, and supports neither segmentation nor re-assembly of messages. The routing algorithms employed by the network layer to learn the topology assume a tree-like network topology; routers with configured tables may operate on topologies with physical loops, as long as the communication paths are logically tree-like. In this configuration, a packet may never appear more than once at the router on the side on which the packet originated. The unicast routing algorithm uses learning for minimal overhead and no additional routing traffic. Use of configured routing tables is supported for both unicast and multicast addresses.

6.4 *Transport Layer* — The device shall comply with the LonTalk protocol transport layer specification. The heart of the protocol hierarchy is the Transport and Session layers. A common Transaction Control sublayer handles transaction ordering and duplicate detection for both layers. The transport layer is connectionless and provides reliable message delivery to both single and multiple destinations. Authentication of the message sender's identity is provided as an optional feature. The authentication server requires only the Transaction Control sublayer to accomplish its function. The transport and session layer messages may be authenticated using all of the LonTalk addressing modes other than broadcast. The transport layer supports end-to-end acknowledged service and an unacknowledged/ repeated service.

6.5 *Session Layer* — The device shall comply with the LonTalk protocol session layer specification. This layer implements a simple Request-Response mechanism for access to remote servers. This mechanism provides a platform upon which application-specific remote procedure calls can be built. The LonTalk network management protocol, for example, is dependent on the Request-Response mechanism in the Session layer, even though it accesses the protocol via the application layer interface.

6.6 *Presentation Layer* — The device shall comply with the LonTalk protocol presentation layer specification. The Presentation layer and the Application layer taken together form the foundation of interoperability for LonTalk devices. The application layer provides all the usual services for sending and receiving messages, but it also contains the concept of network variables. The presentation layer provides information in the Application Protocol Data Unit (APDU) header for how the APDU is to be interpreted for network variable updates. This application-independent interpretation of the data allows data to be shared among devices without prior arrangement. With agreement on which network variables are to be used for sensors, actuators, etc., intelligent components from different manufacturers may work together without prior knowledge of each other's characteristics.

6.7 *Application Layer* — At the application layer, interoperability between LonWorks-based devices is facilitated through the use of LonMark objects and Standard Network Variable Types (SNVTs). LonMark objects build upon network variables and provide a concise application layer interface that incorporates semantic meaning for specific device functions. LonMark objects not only define which SNVTs to use to convey data, but also provide semantic meaning about the information being communicated. To aid in the specification of specific device models with well-defined functional behavior, collections of objects with defined relations can be aggregated and referenced as functional profiles. The Application Layer also includes the LonTalk file transfer protocol, which provides segmentation and reassembly of arbitrary length files of data. This service may be used to get and set object attributes that exceed the network variable size limit of 31 bytes.

6.7.1 *Object Models* — The LonTalk Protocol provides an object-oriented specification for defining and addressing network variables and configuration properties, which are the representation of object attributes and events. The device shall comply with the object model specifications defined in Section 7 of this document.

6.7.2 *LonMark Object Structure* — The *LonMark Application Layer Interoperability Guidelines* define a number of object types. Each object type has a set of mandatory network variables, a set of optional network variables, a set of configuration properties (both mandatory and optional), and a manufacturer-defined section, which may be used for non-interoperable extensions to the object. This is illustrated in Figure 4. This notation is defined in the *LonMark Application Layer Interoperability Guidelines*.

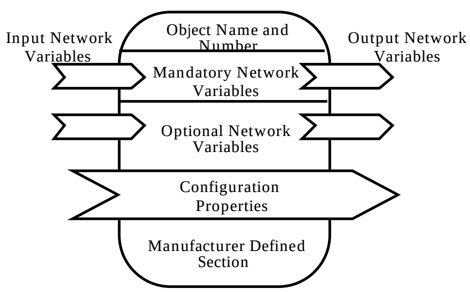

Figure 4
LonMark Object Structure[2]

The *LonMark Application Layer Interoperability Guidelines* provide for the definition of new Standard Network Variable Types, LonMark Object Types, and Functional Profiles. In the mapping of the SEMI CDM to the LonMark object structure in Section 7, extensions to the current SNVT list and Interoperability Guidelines are marked with an asterisk (*). Object type numbers are specified by the guidelines; a device may consist of one instance of a node object type, and one or more instances of LonMark object types, which are assigned sequential instance numbers starting from one.

6.8 *Network Management* — The LonTalk Protocol defines a complete network management and diagnostic protocol for LonWorks devices. This protocol is a layer above the Session layer (request/response service) and provides mechanisms for application downloading, device address assignment, distribution of destination addresses for implicit messaging, router configuration, and device-level diagnostics. The *LonMark Application Layer Interoperability Guidelines* define a device management layer for LonMark objects.

7 Required Object Types

The *LonMark Application Layer Interoperability Guidelines* describe sensor, actuator, and controller objects. A specific device may be implemented using these objects or functional profiles based on these objects. The Common Device Model specification additionally identifies two objects (namely the Device Manager (DM) and Sensor Actuator Controller (SAC) objects) that must exist in all SEMI-compliant SAN devices.

7.1 *Service Requests* — Common Device Model service requests are implemented as LonTalk foreign frame messages delivered to the application using the LonTalk request/response protocol. The transaction layer protocol ensures that response messages are correlated with the original request message. Tables 3 and 4 show the LonTalk APDU format for the Request/Indication message, and for the Response/Confirmation message respectively.

2 Diagram notation, the arrow-like symbol used in Figure 4 is defined in the LonMark Application Layer Interoperability Guidelines.

Table 3 SEMI SAN Request Message APDU Format

Field Name	*Size (bits)*	*Value*
Message Code	8	4D (hex). Indicates a SEMI SAN-compliant foreign frame message.
Object ID	16	Destination object's ID number. Based on the order of the declaration of the instance in the device's external interface documentation string.
Service Code	8	Defines the service being requested.
Request Parameters	optional	Service-specific request parameters.

Table 4 SEMI SAN Response Message APDU Format

Field Name	*Size (bits)*	*Value*
Message Code	8	Zero indicates successful execution of the requested service. Non-zero indicates failure. Values are request-specific.
Response Parameters	optional	Service-specific result parameters.

7.2 *Object Attributes* — The GetAttribute and SetAttribute service requests may also be implemented as network variable fetch, poll, and update requests addressed to the network variable corresponding to the specified attribute. This is appropriate when application-layer service responses are not required. A GetAttribute service request may be addressed directly to any network variable as a LonTalk request message, using the LonTalk protocol network management NV fetch mechanism. A GetAttribute service request may also be addressed to an output network variable as a LonTalk NV poll message, using the NV selection mechanism. A SetAttribute service request may be addressed to an input network variable as a LonTalk NV update message, using the NV selection mechanism. The confirmation of a SetAttribute (network variable update) is provided by the acknowledged service of the LonTalk protocol transport layer.

Each network variable in a LonMark object is identified by means of a self-documentation string stored in the device's memory. This string contains the object id of the object to which this variable belongs, and the sequence number of the network variable within its enclosing object. For the LonWorks NCS, this sequence number is identical to the numerical sequence number specified by the CDM tag.

Example: Suppose that the Device Manager object instance is declared as the second object instance in the device. It would, therefore, have object id 1. The Device Manager attribute Standard Revision Level has the tag DmA2. The self-documentation string for this network variable is, therefore, specified as "@1| 2."

The Publish notification service is implicit when an output network variable is updated. The device propagates the value of the output network variable (equivalent to a read-only attribute) to any input network variable(s) to which it may be bound.

The LonTalk protocol only supports propagation of output network variables. In CDM terminology, this means that only read-only attributes may be published. If a specific device model requires publication of a read/write attribute, an output network variable whose value mirrors the value of the input (read/write) network variable may be introduced to the object definition.

7.3 *Sensor/Actuator/Controller Object (*)* — The SEMI CDM SAC object coordinates the functionality of Sensor, Actuator, and Controller objects in the device. A new object type is defined, which forms part of the LonMark Functional Profile for SEMI SAN-compliant devices based on LonWorks. Table 5 summarizes the services implemented by the SAC object.

Table 5 SAC Object Services

Service Name	*CDM Tag*	*Service Code*
Reset	SacS1	1
Abort	SacS2	2
Recover	SacS3	3

7.4 *Device Manager Object (*)* — The SEMI CDM Device Manager Object combines attributes of device self-documentation with an exception reporting mechanism. A new object type is, therefore, defined with the following mandatory network variables and behaviors. This object type forms part of the LonMark Functional Profile for SEMI SAN-compliant devices based on LonWorks. Table 6 summarizes the network variables that implement the attributes of the Device Manager object.

Table 6 Device Manager Object Network Variables

Name	*Storage Class*	*CDM Tag*	*Standard NV DataType*
Device Type	const	DmA1	SNVT_str_asc or SNVT_str_int
Standard Rev. Level	const	DmA2	SNVT_str_asc or SNVT_str_int
Device Mfgr. Identifier	const	DmA3	SNVT_str_asc or SNVT_str_int
Mfr. Model Number	const	DmA4	SNVT_str_asc or SNVT_str_int
S/W or F/W Rev. Level	const	DmA5	SNVT_str_asc or SNVT_str_int
Hardware Rev. Level	const	DmA6	SNVT_str_asc or SNVT_str_int
Serial Number	const	DmA7	SNVT_str_asc or SNVT_str_int
Device Config'n	const	DmA8	SNVT_str_asc or SNVT_str_int
Device Status	output	DmA9	SNVT_dev_status
Reporting Mode	config	DmA10	SCPT_rept_mode
Exception Status Rept Interval	config	DmA11	SCPT_exc_sts_t
Exception Status	output	DmA12	SNVT_exc_status
Exception Detail Alarm	output	DmA13	SNVT_exc_detail
Exception Detail Warning	output	DmA14	SNVT_exc_detail

7.4.1 *Device Manager Object Requests* — Table 7 summarizes the services implemented by the Device Manager object.

Table7 Device Manager Object Request Services

Service Name	*CDM Tag*	*Service Code*	*Request Parameters*	*Result Parameters*
Reset	DmS1	1		
Abort	DmS2	2		
Recover	DmS3	3		
GetAttribute#	DmS4	4	Attribute ID##	Attribute Value
SetAttribute###	DmS5	5	Attribute ID##, Attribute Value	
Execute	DmS6	6		
Perform Diagnostics	DmS7	7	Test ID####	

\# The GetAttribute service may also be implemented as a network variable poll.
The attribute ID is the numerical sequence number specified by the CDM tag for the attribute. This is the same as the LonMark member ID of the network variable in its owning object.
The SetAttribute service may also be implemented as a network variable update.
The Test ID parameter will be the first parameter in the Perform Diagnostics Request Parameters field.

The Publish (DmS8) notification service for the Device Manager exception status is implemented when the device updates the output network variable of type SNVT_exc_status. This causes the value of this network variable to be propagated across the network to other network variable(s) to which it may be bound. The implementation of the Device Manager object updates this output network variable according to the conditions specified by the Reporting Mode and Exception Status Reporting Interval configuration properties of the object.

7.4.2 *Device Manager Object Constant Output Network Variables* — Table 6 lists the constant output network variables of the Device Manager object. The type of each of these network variables is either SNVT_str_asc, a Standard Network Variable Type that can represent from 0 to 30 ASCII characters, or SNVT_str_int, a Standard Network Variable Type that can represent from 0 to 14 international 16-bit characters.

7.4.3 *Device Manager Object Configuration Properties* — The DM object has two configuration properties to control exception reporting as shown in Table 6. These parameters are of Standard Configuration Parameter Types (SCPTs).

The type SCPT_rept_mode(*) contains two four-bit fields specifying the reporting method for alarms and warning conditions. For example, in Neuron C, the application programming language used on the Neuron Chip, the declaration of SCPT_rept_mode is as follows:

```
typedef enum {
   REP_REQUEST                  = 0,
   REP_REQ_LATCHED              = 1,
   REP_EVT_TRIGD_ON             = 2,
   REP_EVT_TRIGD_ONOFF          = 3,
   REP_TIME_TRIGD               = 4,
   REP_EVT_ON_TIME_TRIGD        = 5,
   REP_EVT_ONOFF_TIME_TRIGD     = 6,
} rept_mode_t;
typedef struct {
   rept_mode_t alarm_rept_mode :4;
   rept_mode_t warn_rept_mode  :4;
} SCPT_rept_mode;
```

The type SCPT_exc_sts_t(*) is a 16-bit value representing times from 0.00 to 655.35 seconds, with a resolution of 0.01 seconds. This parameter is optional. The default reporting mode is REP_REQUEST.

7.4.4 *Device Manager Object Output Network Variables* — The Device Manager object has four output network variables as shown in Table 6. The data type SNVT_dev_status is an enumeration, corresponding to the device status attribute defined in Table 6 of the CDM. The values of this type are defined in Table 8.

Table 8 Device Status Enumeration Values

Value	*Enumeration Tag*
0	DS_UNKNOWN
1	DS_INIT_SELFTEST
2	DS_IDLE
3	DS_SELFTEST_EXCPT
4	DS_EXECUTING
5	DS_ABORT_1
6	DS_ABORT_2

The value DS_ABORT_1 corresponds to the *Abort from Idle* or *Executing* state, and the value DS_ABORT_2 corresponds to the *Abort from Initialized/Self Testing or Self Test Exception* state of the DM object.

The type SNVT_exc_status(*) is a union of two structures, depending on whether expanded or basic exception reporting mode is used. For example, in Neuron C, the declaration of SNVT_exc_status is as follows:

```
typedef union {
 struct {
  int  excpt_method : 1; //set to 0
  int  dev_spec     : 7;
} basic_method;
 struct {
  int  excpt_method  : 1; //set to 1
  int  warn_mfr_spec : 1;
  int  warn_dev_spec : 1;
  int  warn_dev_comn : 1;
  int  resvd         : 1;
  int  alrm_mfr_spec : 1;
  int  alrm_dev_spec : 1;
  int  alrm_dev_comn : 1;
 } expanded_method;
} SNVT_exc_status;
```

The type SNVT_exc_detail(*) is a sequence of three structures containing arrays. The LonWorks Network Communication Standard limits the size of each of these arrays to 9 bytes, so that the type fits within the network variable size limit of 31 bytes. For example, in Neuron C, the declaration of SNVT_exc_detail is as follows:

```
typedef struct {
   u_char comn_exc_size;
   int    resvd1          : 1;
   int    real_time       : 1;
   int    communic        : 1;
   int    RAM             : 1;
   int    EEPROM          : 1;
   int    EPROM           : 1;
   int    microproc       : 1;
   int    diagnostic      : 1;
/*--------------------------*/
   int    resvd2          : 1;
   int    reset           : 1;
   int    notify_mfr      : 1;
   int    maintenance     : 1;
   int    power_inputV    : 1;
   int    power_outptV    : 1;
   int    power_resvd     : 1;
   int    power_overC     : 1;
   u_char comn_exc_dtl[7];
/*--------------------------*/
   u_char dev_exc_size;
   u_char dev_exc_dtl[9];
/*--------------------------*/
   u_char mfr_exc_size;
   u_char mfr_exc_dtl[9];
} SNVT_exc_detail;
```

7.5 *Sensor, Actuator, and Controller Objects* — These objects are necessarily specific to the Specific Device Models. The *LonMark Application Layer Interoperability Guidelines* provide a framework for defining LonMark objects, together with specifications of generic sensor and actuator objects. Specific Device Models may employ these objects, and/or may define their own objects and Standard Network Variable Types for device-specific requirements. As long as the LonMark object definition guidelines are followed, these device-specific objects may be proposed to the LonMark Interoperability Association for incorporation within the LonMark guidelines.

8 Protocol Compliance

A method of testing protocol compliance is required to verify implementation conformance to the standard. By virtue of the fact that the intermediate layers of the LonTalk protocol are implemented in commercially available silicon, compliance verification is needed only at the physical and application layers. The LonMark Interoperability Association provides a compliance verification service to its members. When the SEMI Sensor/Actuator Network standard is incorporated into the LonMark guidelines, this service may be used to verify compliance with the SEMI guidelines.

8.1 *Interoperability Guidelines Checklist*

Applicant Name	
Product Name	
Standard Program ID	
Manufacturer ID	
Device Class	
Device Subclass	
Model Number	
Comm. Transceiver	
Standard Xcvr Type	
Network Connector	
Neuron Chip Clock Rate	
Oscillator Accuracy	
Network Buffer Size	
Receive Transactions	
SAC Object	
Mandatory NVs	
Optional NVs	
Configuration Properties	
Device Manager Object	
Mandatory NVs	
Optional NVs	
Configuration Properties	
Functional Profiles	
Mandatory NVs	
Optional NVs	
Configuration Properties	

9 Specific Device Type Information

9.1 This section provides for the mapping of network-visible specific device structure and behavior, specified in a SEMI standard SDM specification, to the LonWorks network. Each subsection is devoted to a single SDM specification (e.g., Section 9.1: Mass Flow Controller). Additional SDM mappings are added as subsections to this NCS specification according to SEMI guidelines and the guidelines of the SEMI SAN Interoperability standard. Device-type-specific items, such as overrides to the standard connector, may also be noted in these subsections.

SEMI E54.7-0999
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMUNICATION FOR SERIPLEX

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on July 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 This standard defines a communication specification based on the Seriplex protocol to enable communications between intelligent devices on a sensor/actuator network (SAN) that operate according to SEMI specified device models (common and device specific) in a semiconductor manufacturing tool.

1.2 *Background and Motivation*

1.2.1 Seriplex is a component level network which provides a simple, inexpensive, fast, and deterministic means of exchanging data among control level industrial devices (e.g., sensors and actuators) and higher level devices such as controllers. Seriplex provides:

- A solution to low-level device networking
- Access to intelligence present in low-level devices
- Networking between higher level controllers
- Master/Slave and Peer-to-Peer capabilities

1.2.2 Seriplex specifies a communication model and protocol as well as a complete Physical Layer definition.

1.2.3 This document enables communications between intelligent devices on a SEMI compliant SAN by providing a presentation mapping of common and specific device network visible structure and behavior to a Seriplex network.

2 Scope

2.1 This document specifies the protocol and services that compliant intelligent devices must support to exchange information over this semiconductor equipment sensor/actuator network.

2.2 This document specifies the utilization of the Seriplex protocol to present externally visible device structure and behavior, specified in the Common Device Model (CDM) and appropriate Specific Device Models (SDMs), on a Seriplex network.

2.3 This document is used in conjunction with a SEMI standard SAN Common Device Model specification, one or more SEMI standard Specific Device Model (SDM) specifications (e.g. for a mass flow controller) and the Seriplex Standard Specification. Together, they describe the Seriplex protocol, the externally visible data structures and behaviors of devices utilizing the Seriplex networking capability in a SEMI compliant SAN system.

2.4 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicablity of regulatory limitations prior to use.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on Seriplex and is a companion document to the Seriplex standard specification; thus a complete specification of this standard necessarily includes the Seriplex standard specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by Seriplex. In order to avoid document consistency problems, information in the Seriplex standard specification that relates to this standard is not repeated in this document. This document is limited to describing enhancements or limitations to the Seriplex standard specification that are imposed by this standard.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

SEMI E54.3 — Specification for Sensor/Actuator Network Specific Device Model for Mass Flow Device

4.2 *Other Documents*

Bulletin No. 8310PD9603 — Seriplex Standard Specification: August 1997, Technology Organization, Inc. Raleigh, NC, USA. [1]

ISO 7498 — Basic Reference Model for Open Systems Interconnection[2]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 Terminology that is common to all of the documents in this SAN standard may also be defined in the Sensor/Actuator Network Standard. Terminology may be reproduced here which is defined in other SEMI documents.

5.2 *Abbreviations and Acronyms*

CDM — Common Device Model

DM — Device Manager (object)

NCS — Network Communication Standard

OSI — Open Systems Interconnect

OSS — Object Services Standard

SAC — Sensor, Actuator, Controller (Object)

SAN — Sensor/Actuator Network

SDM — Specific Device Model

STO — Seriplex Technology Organization

VDC — Volts, Direct Current

5.3 *Device Component Definitions*

5.3.1 As this standard defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in the SEMI E54.1 CDM document. Table 1 provides a mapping of fundamental terminology of the CDM document into this document and the Seriplex standard specification. Note that Column 2 contains an equal sign '=' if the definition is used exactly as specified in the CDM specification.

Table 1 Mapping of CDM to NCS Terminology

CDM Term	*NCS Equivalent*	*Seriplex Equivalent*
Device	=	=
Device Model	=	=
Object	=, Class	=, Class
Instance	=	=
Attribute	=	=
Behavior	=	=
Service	=	=
State Diagram	=	=
Byte	=	=
Nibble	=	=
Character String	=	=

5.4 *Seriplex Specific Definitions*

class — a set of objects that all represent the same kind of system component. A class is a general-ization of an object. All objects in a class are identical in form and behavior, but may contain different attri-bute values.

master/slave mode — communication over a Seriplex network that provides exclusive control of data by a "master" or "host" device. All bus input data is reported exclusively to the host, and the host has exclusive control over the states of all bus output signals, with all bus I/O devices acting as 'slaves". Master/Slave mode provides the typical request/ response oriented network communications.

peer-to-peer mode — communication over a Seriplex network that provides sharing of bus input and output data directly among devices. This mode allows dedicated or broadcast data to be shared between a producing application and one or more consuming applications. Application specific I/O data moves though these devices.

seriplex — an open protocol maintained by the Seriplex Technology Organization (STO) as a standard means of interconnection for simple field devices. The Seriplex standard specification specifies OSI reference model layers 1, 2, 4 and 7 specifically the physical signaling, the media access/data link protocols, the transport capability of end-to-end transmission of data, and the application layer.

6 Communication Protocol High Level Structure

6.1 The Seriplex protocol is loosely based on a four-layer architecture. These layers constitute a collapsed form of the OSI seven layer architecture, mapping into the physical, data link, transport and application layers

1 Seriplex Technology Organization, P.O. Box 27446, Raleigh, NC 27611, www.seriplex.org
2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

of the Reference Model. The high level protocol architecture is shown in Figure 1.

6.1.1 Note that Figure 1 represents a conceptual view of the device architecture. Conforming implementations must implement the services defined in this specification at each layer and must appear (from the network) to have implemented this architecture, however an internal modular partitioning is not required. Implementations may sacrifice modularity in order to achieve high performance.

6.1.2 The Seriplex physical layer is fully specified in the Seriplex Standard Specification. There are guideline specified for the topology of the bus cable, length of bus cable and number of bus nodes within the system. Typical configurations include: Daisy Chain, Trunk/Dropline, Tree, Loop, Star and Combinations of the above. Reference guidelines are specified for the cable length and node limits determined by a system's Clock rate and total data line capacity within a system. Bus Power Supply provides power for the Seriplex bus itself – that is, for the Seriplex bus communication circuitry within each bus device. The bus power supply normally provides a 24 VDC source for the bus. In general, the bus supply does not provide power to monitoring and control devices.

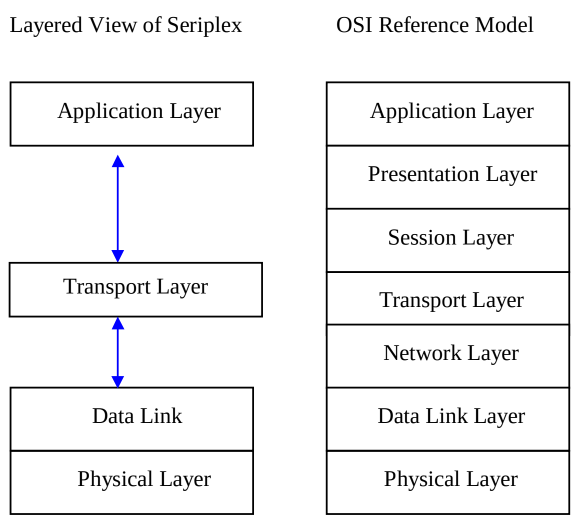

Figure 1
Layered View of Seriplex

6.1.3 At the data link layer, the Seriplex standard messaging specification defines a carrier sense multiple access mechanism for media access control that supports non-destructive collision resolution and sends frames reliably.

6.1.4 The application layer is specified in the Seriplex standard specification and provides for the definition of Seriplex applications as a collection of addressable objects. A subset of these objects may be addressed over the network (as defined by the implementation).

6.1.5 In the remainder of this section the protocol structure is described in more detail in terms of the OSI seven layer reference model, the object model environment and network management specifications.

6.2 *Physical Layer* — The device shall comply with the Seriplex physical layer specification (contained in Seriplex standard specification). This includes physical signaling (levels and data rates), transceivers, node isolation, media topology, cable specifications, network connectors and taps, and power considerations (load limits, system tolerances, and power supply options).

6.3 *Data Link Layer* — The device shall comply with the Seriplex standard specification for the Data Link Layer. This includes the media access control mechanism and the logical link control mechanism. Addressing is currently limited to 8 bits of source address and 8 bits of destination address. Bitwise arbitration is used to gain access to the network in cases where multiple nodes contend for the same message bandwidth.

6.4 *Network Layer* — There is no distinct network layer.

6.5 *Transport (Messaging) Layer* — The device shall comply with the Seriplex standard specification for the Messaging Layer. The messaging layer provides transparent transfer of data between objects in application-entities. Some of the functionality, of this layer is implemented in the Application Layer. Specific functions include: segmentation/re-assembly (fragmentation) for full message delivery.

6.6 *Session Layer* — There is no distinct session layer.

6.7 *Presentation Layer* — There is no distinct presentation layer. Object addressing and data presentation in Seriplex messages are specified as part of the Seriplex object definitions and object attribute and service communication protocol.

6.8 *Application Layer* — The device shall comply with the Seriplex application layer specification for defining and addressing objects, including their attributes and services, and enabling specified network behavior. The device shall comply with the object messaging and object model specifications included in the Seriplex standard specification. In addition the device shall comply with the object specifications defined in Section 7 of this document.

6.8.1 *Object Models* — The Seriplex protocol has been enhanced to provide an object-oriented specification for creating, defining and addressing objects explicitly, including their attributes and services, and creating, defining and communicating object attributes in an application dependent format. The device shall comply with the object messaging and object model specifications included in the Seriplex standard specification documentation. In addition the device shall comply with the object specifications defined in Section 7 of this document.

6.8.2 *Alternate Method for the Communication Transmission of Attributes* — In order to take advantage of the Seriplex network's speed and deterministic characteristics, the Seriplex Standard Specification details a mechanism of transmitting data over the network by assigning, in advance, a sequence of serial frames to be used collectively to deliver specific sensor and/or actuator attribute data. This mechanism can be utilized as an alternative to the object messaging specification of the Seriplex Standard Specification to implement the behavior associated with the GetAttribute and SetAttribute services detailed in Section 7. This mechanism may be used to provide an efficient and optimum implementation of data transmission over the network.

6.9 *Network Management* — The device shall comply with the Seriplex network management specifications detailed in the Seriplex Standard Specification (e.g., physical layer bit rate, master/slave and peer-to-peer network management, etc.). No (additional) network management functions are specified in this document.

7 Required Object Types

7.1 At this time, the Seriplex Standard Specification does not require any specific objects to exist in a Seriplex device in order to be a compliant Seriplex device. The Seriplex Standard Specification will be extended to identify and describe objects (i.e. classes) that must exist in devices that are to be interoperable and interchangeable on a Seriplex SEMI compliant SAN network.

7.1.1 The Common Device Model specification identifies two objects (namely the Device Manager (DM) and Sensor Actuator Controller (SAC) objects) that must exist in all SEMI compliant SAN devices. The required object types for a SEMI compliant SAN device utilizing the network communication specification described herein, necessarily comprises the union of the above two requirements.

7.1.2 A list of required and optional object types is given in Table 2. Additional objects that are specified in a particular SDM are given identifiers in that SDM specification; Seriplex specific presentation information for these identifiers is given in Section 9 of this document.

7.1.3 An embodiment of a specific device type, represented as an aggregation of the object types listed in Table 2, that is compliant with both the CDM specification and the Seriplex specification, is a candidate for a SEMI SDM as well as a Seriplex device definition. Conversely, all SEMI SDM's and Seriplex device definitions specified for operation over a SEMI compliant Seriplex network must be an aggregation of the object types listed in Table 2, and be compliant with both the CDM specification and the Seriplex standard specification.

7.1.4 In the following sections the presentation to the network of object addressing, object attributes, and object services for each of the object types listed in Table 2 is described in detail. Refer to the CDM standard to determine if the object instance attribute and service is specified as required or optional. Unless otherwise noted, all attributes and services described are instance level attributes (as opposed to class level attributes). A class level attribute and service is accessed as instance number zero.

7.1.5 Note that the formats of object attributes and services are detailed in the CDM document; the presentation of object attributes and services to the Seriplex network is detailed in the tables contained in the following sub-sections and in the Seriplex standard specification.

7.2 *Device Manager (DM) Object* — The DM object is the device component responsible for managing and consolidating the device operation. Each device must support one (and only one) DM object. The DM object as well as its common required and optional attributes, services and behavior are described in the CDM standard. The presentation of object instance attributes and services to the Seriplex network shall be as indicated in Table 3.

7.2.1 Note that the formats of DM object attributes are detailed in the CDM document; the presentation of DM object attributes to the Seriplex network is detailed in Table 3 and the Seriplex standard specification; the format of DM object services is detailed in the CDM document and the Seriplex standard specification; and the presentation of the DM object services is detailed in Table 3 and the Seriplex standard specification.

Table 2 Required and Optional Object Types

Object Name	*Seriplex Class ID/Instance ID (See Note 1)*	*CDM Tag (See Note 2)*	*Required by Seriplex (See Note 1)*	*Required by CDM (See Note 2)*	*Required by NCS*
Device Manager	1/1	DmI0	No	Yes	Yes
Sensor/ Actuator/ Controller	2/1	SacI0	No	Yes	Yes
Assembly	3/1 through i	Asm	No	No	No
Local Link	4/1 through j	Lnk	No	No	No
Sensor – AI	33/1 through k	Sai	No	No	No
Sensor – EI	34/1 through l	Sei	No	No	No
Sensor – BI	35/1 through m	Sbi	No	No	No
Actuator – AO	36/1 through n	Aao	No	No	No
Actuator – EO	37/1 through o	Aeo	No	No	No
Actuator – BO	38/1 through p	Abo	No	No	No
Controller	39/1 through q	Ca	No	No	No
Application Objects	129 through x/ 1 through r	(See Note 3)	No	No	No

NOTE 1: See Seriplex specification for further information; values are decimal; ‘i’, ‘j’, ‘k’, ‘l’, ‘m’, ‘n’, ‘o’, ‘p’, ‘q’ and ‘r’ represent arbitrary numbers (greater than or equal to 1) indicating that more than one instance may be supported. ‘x’ is a number greater than or equal to 129 indicating that one or more application object classes may be supported.

NOTE 2: See CDM specification for further information.

NOTE 3: Application Dependent objects as specified in SDM.

Table 3 DM Object Instance Attributes and Services

Device Manager Object (DM) Class ID = 01, Instance ID = 01		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Device Type	DmA1
02	Standard Revision Level	DmA2
03	Device Manufacturer Identifier	DmA3
04	Manufacturer Model Number	DmA4
05	Software or Firmware Revision Level	DmA5
06	Hardware Revision Level	DmA6
07	Serial Number	DmA7
08	Device Configuration	DmA8
09	Device Status	DmA9
12	Exception Status	DmA12
13	Exception Detail Alarm	DmA13
14	Exception Detail Warning	DmA14
15	Visual Indicator	DmA15
16	Alarm Enable	DmA16
17	Warning Enable	DmA17
18	Exception Detail Type	DmA18
19	Exception Detail Alarm Queue	DmA19
20	Exception Detail Warning Queue	DmA20
Services		
ID	*Service Name*	*CDM Tag*
01	Reset	DmS1
03	Abort	DmS2
05	Recover	DmS3
07	Get Attribute	DmS4
09	Set Attribute	DmS5
11	Execute	DmS6
13	Perform Diagnostics	DmS7
15	Publish Attribute	DmS8
17	Lock	DmS9
19	Unlock	DmS10
21	Get Exception Queue	DmS11
23	Clear Exception Queue	DmS12

7.3 *Sensor, Actuator, Controller (SAC) Object* — The SAC object is the device component responsible for coordinating the interaction of the device with the sensory/actuation/control environment. Each device must support one (and only one) SAC object. The SAC object as well as its common required and optional attributes, services and behavior are described in the CDM standard. The presentation of object instance attributes and services to the Seriplex network shall be as indicated in Table 4.

Table 4 SAC Object Instance Attributes and Services

Sensor, Actuator, Controller Object (SAC) Class ID = 02, Instance ID = 01		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Last Calibration Date	SacA1
02	Next Calibration Date	SacA2
03	Expiration Timer	SacA3
04	Expiration Warning Enable	SacA4
05	Run Hours	SacA5
Services		
ID	*Service Name*	*CDM Tag*
01	Reset	SacS1
03	Abort	SacS2
05	Recover	SacS3
07	Get Attribute	SacA4
09	Set Attribute	SacA5
25	Operate	SacA6
27	Restore Default	SacA7
29	Publish Attribute	SacA8

7.3.1 Note that the format of SAC object attributes is detailed in the CDM document; the presentation of SAC object attributes to the Seriplex network is detailed in Table 3 and the Seriplex standard specification; the format of SAC object services is detailed in the CDM document and the Seriplex standard specification; and the presentation of the SAC object services is detailed in Table 3 and the Seriplex standard specification.

7.4 *Assembly Object (Asm)* — The Assembly (Asm) object instances may be used to provide for grouping more than one attribute from one or more object instances is a device into a single data structure for communication over the Seriplex network. The presentation of object instance attributes and services shall be as indicated in Table 5.

Table 5 Assembly Object Instance Attributes and Services

ASSEMBLY Object (Asm) *Class ID == 03, Instance ID = 01 through i*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Data	AsmA1
Services		
ID	*Service Name*	*CDM Tag*
07	Get Attribute	AsmS4
09	Set Attribute	AsmS5

7.5 *Local Link Object (Lnk)* — The Local Link (Lnk) object instances may be used to ‘link” an attribute of one object instance to an attribute of another object instance. The presentation of object instance attributes and services are as indicated in Table 6.

Table 6 Local Link Object Instance Attributes and Services

Local Link Object (Asm) *Class ID = 04, Instance ID = 01 through j*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Source Object Class	LnkA1
02	Source Object Instance	LnkA2
03	Source Object Attribute	LnkA3
04	Destination Object Class	LnkA4
05	Destination Object Instance	LnkA5
06	Destination Object Attribute	LnkA6
07	Commit	LnkA7
Services		
ID	*Service Name*	*CDM Tag*
--	No services defined	--

7.6 *Sensor-AI Object (Sai)* — The presentation of the Sensor Analog Input (Sensor-AI) object instance attributes and services are as indicated in Table 7.

Table 7 Sensor-AI Object Instance Attributes and Services

Sensor-AI *Class ID = 33, Instance ID = 01 through k*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SaiA1
02	Status	SaiA2
03	Alarm Enable	SaiA3
04	Warning Enable	SaiA5
16	Value	Sai16
17	ReportInhibitTimer	Sai17
18	EnableReportRate	Sai18
19	ReportRate	Sai19
64	Offset	Sai64
65	Gain	Sai65
66	DataType	Sai66
67	DataUnits	Sai67
68	SafeState	Sai68
69	EnableReportDelta	Sai69
70	ReportDelta	Sai70
71	EnableReportROC	Sai71
72	AlarmTripPointHigh	Sai72
73	AlarmTrippointLow	Sai73
74	AlarmHysteresis	Sai74
75	WarningTripPointHigh	Sai75
76	WarningTripPointLow	Sai76
77	WarningHysteresis	Sai77
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SaiS1
03	Abort	SaiS2
05	Recover	SaiS3
25	Operate	SaiS4
07	GetAttribute	SaiS5
09	SetAttribute	SaiS6
27	RestoreDefault	SaiS7

7.7 *Sensor-EI Object (Sei)* — The presentation of the Sensor Enumerated Input (Sensor-EI) object instance attributes and services are as indicated in Table 8.

Table 8 Sensor-EI Object Instance Attributes and Services

Sensor-EI *Class ID = 34, Instance = 01 through l*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SeiA1
02	Status	SeiA2
03	Alarm Enable	SeiA3
04	Warning Enable	SeiA5
16	Value	Sei16
17	ReportInhibitTimer	Sei17
18	EnableReportRate	Sei18
19	ReportRate	Sei19
64	DebounceControl	Sei64
65	AlarmStatus	Sei65
66	WarningStatus	Sei66
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SeiS1
03	Abort	SeiS2
05	Recover	SeiS3
25	Operate	SeiS4
07	GetAttribute	SeiS5
09	SetAttribute	SeiS6
27	RestoreDefault	SeiS7

7.8 *Sensor-BI Object (Sbi)* — The presentation of the Sensor Binary Input (Sensor-BI) object instance attributes and services are as indicated in Table 9.

Table 9 Sensor-BI Object Instance Attributes and Services

Sensor-BI *Class ID = 35, Instance ID = 01 through m*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SbiA1
02	Status	SbiA2
03	Alarm Enable	SbiA3
04	Warning Enable	SbiA5
16	Value	Sbi16
17	ReportInhibitTimer	Sbi17
18	EnableReportRate	Sbi18
19	ReportRate	Sbi19
64	DebounceControl	Sbi64
65	AlarmStatus	Sbi65
66	WarningStatus	Sbi66
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SbiS1
03	Abort	SbiS2
05	Recover	SbiS3
25	Operate	SbiS4
07	GetAttribute	SbiS5
09	SetAttribute	SbiS6
27	RestoreDefault	SbiS7

7.9 *Actuator-AO Object (Aao)* — The presentation of the Actuator Analog Output (Actuator-AO) object instance attributes and services are as indicated in Table 10.

Table 10 Actuator-AO Object Instance Attributes and Services

Actuator-AO *Class ID = 36, Instance = 01 through n*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AaoA1
02	Status	AaoA2
03	Alarm Enable	AaoA3
04	Warning Enable	AaoA5
16	Setting	Aao16
17	SafeState	Aao17
18	WatchRate	Aao18
19	Watchdog	Aao19
64	Offset	Aao64
65	Gain	Aao65
66	DataType	Aao66
67	DataUnits	Aao67
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AaoS1
03	Abort	AaoS2
05	Recover	AaoS3
25	Operate	AaoS4
07	GetAttribute	AaoS5
09	SetAttribute	AaoS6
27	RestoreDefault	AaoS7

7.10 *Actuator-EO Object (Aeo)* — The presentation of the Actuator Enumerated Output (Actuator-EO) object instance attributes and services are as indicated in Table 11.

Table 11 Actuator-EO Object Instance Attributes and Services

Actuator-EO Class ID = 37, Instance ID = 01 through o		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AeoA1
02	Status	AeoA2
03	Alarm Enable	AeoA3
04	Warning Enable	AeoA5
16	Setting	Aeo16
17	SafeState	Aeo17
18	WatchRate	Aeo18
19	Watchdog	Aeo19
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AeoS1
03	Abort	AeoS2
05	Recover	AeoS3
25	Operate	AeoS4
07	GetAttribute	AeoS5
09	SetAttribute	AeoS6
27	RestoreDefault	AeoS7

7.11 *Actuator-BO Object (Abo)* — The presentation of the Actuator Binary Output (Actuator-BO) object instance attributes and services are as indicated in Table 12.

Table 12 Actuator-BO Object Instance Attributes and Services

Actuator-BO Class ID = 38, Instance ID = 01 through p		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AboA1
02	Status	AboA2
03	Alarm Enable	AboA3
04	Warning Enable	AboA5
16	Setting	Abo16
17	SafeState	Abo17
18	WatchRate	Abo18
19	Watchdog	Abo19
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AboS1
03	Abort	AboS2
05	Recover	AboS3
25	Operate	AboS4
07	GetAttribute	AboS5
09	SetAttribute	AboS6
27	RestoreDefault	AboS7

7.12 *Controller Object (CA)* — The presentation of the Controller (CA) object instance attributes and services are as indicated in Table 13.

Table 13 Controller-CA Object Instance Attributes and Services

Controller Class ID = 39, Instance ID = 01 through q		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	CAA1
02	Status	CAA2
03	Alarm Enable	CAA3
04	Warning Enable	CAA4
16	Setpoint	CAA16
17	ProcessVariable	CAA17
18	ControlVariable	CAA18
19	DataType	CAA19
64	DataUnits	CAA20
65	AlarmSettleTime	CAA21
66	AlarmErrorBand	CAA22
67	WarningSettleTime	CAA23
68	WarningErrorBand	CAA24
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	CAS1
03	Abort	CAS2
05	Recover	CAS3
25	Operate	CAS4
07	GetAttribute	CAS5
09	SetAttribute	CAS6
27	RestoreDefault	CAS7

8 Protocol Compliance

8.1 A method of testing protocol compliance is required to verify implementation conformance to the standard. The Seriplex Technology Organization (STO)[3] has established a mechanism for self certification of devices on a Seriplex network. This certification includes procedures and reporting mechanisms to demonstrate conformance testing and interoperability testing of devices.

9 Specific Device Model Mappings

9.1 This section provides for the mapping of network visible specific device structure and behavior, specified in a SEMI standard SDM specification, to the Seriplex network. Each subsection is devoted to a single SDM specification. Additional SDM mappings are added as sub-sections to this NCS specification according to SEMI guidelines and the guidelines of the SEMI SAN Interoperability standard.

9.2 *Specific Device Model For Mass Flow Device*

9.2.1 This section details the network mapping required to support the Specific Device Model For Mass Flow Devices. Table 14 summarizes the Mass Flow Device Object types. Subsequent tables 15 to 24 details the attributes and services associated with each Mass Flow Device object type.

Table 14 Mass Flow Device Object Types

SDM Object Identifier	*Object Name*	*Seriplex Class ID*
MFD1 (DM)	Device Manager	1
MFD2 (SAC)	Sensor Actuator Controller	2
MFD3	Sensor-AI-MF	129
MFD4	Sensor-AI-AT	130
MFD5	Assembly-MFM	131
MFD6	Sensor-AI-Aux	132
MFD7	Actuator-AO-MF	133
MFD8	Controller	39
MFD9	Local Link	4
MFD10	SISO	134
MFD11	SISO-Setpoint	135
MFD12	Assembly-MFC	136

9.3 *Sensor-AI-MF* — The presentation of the Sensor Analog Input Mass Flow (Sensor-AI-MF) object instance attributes and services are as indicated in Table 15.

Table 15 Sensor-AI-MF Object Instance Attributes and Services

Sensor-AI-MF Class ID = 129, Instance ID = 1 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Flow Totalizer	A1
129	Flow Hours	A2
130	Zero Offset Mode	A5
131	Zeroing Status	A6
132	Autorange Status	A7
Services		
ID	*Service Name*	*SDM Tag*
129	Perform Zero Offset	S1
131	Query-Supported Gas Types	S2
133	Selected Programmed Gas Type	S3
135	Insert Gas Type	S4
137	Delete Gas Type	S5
139	Get Gas Calibration Data Value	S6
141	Set Gas Calibration Data Value	S7
143	Autorange	S8

9.4 *Sensor-AI-AT* — The presentation of the Sensor Analog Input Ambient Temperature (Sensor-AI-AT) object instance attributes and services are as indicated in Table 16.

Table 16 Sensor-AI-AT Object Instance Attributes and Services

Sensor-AI-AT Class ID = 130, Instance = 01 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.5 *Assembly-MFM* The presentation of the Assembly Mass Flow Meter (Assembly-MFM) object instance attributes and services are as indicated in Table 17.

3 Seriplex Technology Organization, P.O. Box 27446, Raleigh, NC 27611, www.seriplex.org

Table 17 Assembly-MFM Object Instance Attributes and Services

Assembly-MFM Class ID = 131, Instance ID = 01 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.6 *Sensor-AI-Aux*— The presentation of the Sensor Analog Input Auxiliary (Sensor-AI-Aux) object instance attributes and services are as indicated in Table 18.

Table 18 Sensor-AI-Aux Object Instance Attributes and Services

Sensor-AI-Aux Class ID = 132, Instance ID = 01 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.7 *Actuator-AO-MF* — The presentation of the Actuator Analog Output Mass Flow (Actuator-AO-MF) object instance attributes and services are as indicated in Table 19.

Table 19 Actuator-AO-MF Object Instance Attributes and Services

Actuator-AO – MF Class ID = 133, Instance ID = 01 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Valve Type	A1
129	Override	A2
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.8 *Controller* — The presentation of the Controller (Ca) object instance attributes and services are as indicated in Table 20.

Table 20 Controller Object Instance Attributes and Services

Controller Class ID = 39, Instance ID = 01 through q		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Alarm Settling Time	CaA21
129	Warning Settling Time	CaA24
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.9 *Local Link* — The presentation of the Local Link (Lnk) object instance attributes and services are as indicated in Table 21.

Table 21 Local Link Object Instance Attributes and Services

Local Link Class ID = 4, Instance ID = 01 through j		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.10 *SISO* — The presentation of the Single Input Single Output (SISO) object instance attributes and services are as indicated in Table 22.

Table 22 SISO Object Instance Attributes and Services

SISO Class ID = 134, Instance = 01		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Input	A1
129	Output	A2
130	Data Type	A3
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.11 *SISO-Setpoint* — The presentation of the Single Input Single Output Setpoint (SISO-Setpoint) object instance attributes and services are as indicated in Table 23.

Table 23 SISO-Setpoint Object Instance Attributes and Services

SISO-Setpoint *Class ID = 135, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
161	Ramp Type	A33
162	Ramp Rate	A34
163	Ratio	A35
Services		
ID	*Service Name*	*SDM Tag*
---	No additional services defined	--

9.12 *Assembly-MFC* — The presentation of the Assembly Mass Flow Controller (Assembly-MFC) object instance attributes and services are as indicated in Table 24.

Table 24 Assembly-MFC Object Instance Attributes and Services

Assembly-MFC *Class ID = 136, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

SEMI E54.8-0999
STANDARD FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR PROFIBUS-DP

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 This specification is part of the SEMI Sensor/Actuator Network (SAN) suite of standards and defines a specific communications protocol based on the PROFIBUS-DP standard. This Network Communication Standard (NCS) taken together with the SEMI Sensor/Actuator Network standard suite and the PROFIBUS standard completely and unambiguously defines an open standard providing an industry specific solution to off-the-shelf interoperability of networked devices in semiconductor manufacturing equipment.

1.2 PROFIBUS is a vendor independent, open fieldbus standard for a wide range of applications in manufacturing, process and building automation. Vendor independence and openness are guaranteed by the European standard for PROFIBUS, EN 50 170. PROFIBUS-DP is one version of PROFIBUS which is optimized for high speed and inexpensive connectivity between automation control systems and distributed I/O at the device level.

2 Scope

2.1 This document specifies a SAN communications standard based on the PROFIBUS-DP specification that is in compliance with SEMI E54.1. As such, it specifies the protocol, services, and behavior that compliant intelligent devices must support in order to interchange information over this SAN in a method compatible with SEMI E39.

2.2 In conjunction with a SEMI standard SAN Common Device Model (CDM) specification and one or more SEMI standard Specific Device Model (SDM) specifications (e.g., for a mass flow controller), this Network Communication Standard (NCS) with the related PROFIBUS-DP standard describe the data structures, interactions, and behavior that are characteristic of the various devices on the network. This composite model forms a complete interoperability standard for communications among intelligent sensors, actuators, and controllers in semiconductor manufacturing equipment.

2.3 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicablity of regulatory limitations prior to use.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on PROFIBUS-DP and is a companion document to the PROFIBUS-DP specification, including, by reference, the PROFIBUS-DPV1 standard; thus, a complete specification of this standard necessarily includes the PROFIBUS-DP specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 The specifications within are strictly enhancements that provide additional capabilities over and above those currently required by PROFIBUS-DP. Included throughout this document, primarily in Section 6, is information paraphrased from the PROFIBUS-DP specifications such as: protocol structure, capabilities, options, and limitations. This information is provided here for reference only and is not intended to provide specification definitions. In all such areas, refer to the PROFIBUS-DP specification documents for information. This document is limited to describing enhancements or limitations to the PROFIBUS-DP specification that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the PROFIBUS-DP protocol conformance testing specification. Conformance testing shall also include enhancements and limitations to the PROFIBUS-DP specification required by this standard.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

SEMI E54.3 — Specification for Sensor/Actuator Network Specific Device Model for Mass Flow Device

4.2 *ISO Standard*[1]

ISO 7498 OSI — Basic Reference Model for Open Systems Interconnection

4.3 *Other Standard*

EN 50 170 Volume 2 — DIN 19245 Part 1 to 4 — PROFIBUS Standard[23]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Acronyms*

CDM — Common Device Model

CSRD — Cyclic Send and Request Data

DDLM — Direct Data Link Mapper

DP — Decentralized Periphery

DPM1 — DP-Master Class 1

DPM2 — DP-Master Class 2

DPV1 — DP Extensions Version 1

DSAP — Destination SAP

FDL — Fieldbus Data Link

FMA1/2 — Fieldbus Management for Layers 1 and 2

NCS — Network Communication Standard

OSI — Basic Reference Model for Open Systems Interconnection (ISO 7498)

PDU — Protocol Data Unit

PHY — Physical Layer

SAN — Sensor/Actuator Network

SAP — Service Access Point

SDA — Send Data with Acknowledge

SDM — Specific Device Model

SDN — Send Data with No acknowledge

SRD — Send and Request Data with reply

SSAP — Source SAP

UI — User Interface

5.2 *Terminology Defined in Sensor/Actuator Network Common Device Model (SEMI E54.1)*

attribute

behavior

byte

common device model

device

Device Manager (DM) Object

device model

instance

network communication standard

object

Sensor, Actuator and Controller (SAC) Object

service

specific device model

state diagram

5.3 *Terminology Defined in PROFIBUS*

Device Data Base — an electronic file that provides a clear and comprehensive description of the characteristics of a device type in a precisely defined format. Also called a GSD File.

Device Profile — a Device Data Base Sheet, which specifies the characteristic features of a device, and a GSD File.

Direct Data Link Mapper — a protocol layer that provides an interface to the User Interface Layer by translating service requests and responses between the User Interface Layer and the Fieldbus Data Link.

DP-Master Class 1 (DPM1) — a device that polls its assigned DP-Slave devices and handles user data exchange.

DP-Master Class 2 (DPM2) — a device that interacts as a configuration or diagnostic tool; usually a programming device.

DP-Slave — a device that is configured, managed, and polled by Master devices; a DP-Slave initiates no unsolicited communications.

Fieldbus Data Link — the PROFIBUS-DP model for the OSI Layer 2 definition.

GSD File — see Device Data Base

Service Access Point — an addressable location in a device for the directing of service requests.

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1 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland

2 Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, PROFIBUS Trade Organization, 5010 East Shea Blvd., Scottsdale, AZ 85254, USA

3 The original Profibus standard was the DIN standard listed, in March 1996, the DIN standard became the EN standard listed.

Send Data with No acknowledge — a service request that sends data with no reply.

Send and Request Data with reply — a service request that sends data followed by a reply by the receiving device.

Slave Diagnostics — a method of retrieving a specifically formatted Data Structure that represents the diagnostic status of a DP-Slave.

5.4 *Terminology Defined in This Document*

DP Service Protocol — a messaging specification for the request of, and response to, services for the PROFIBUS-DP NCS using the PROFIBUS-DP standard.

DPV1 Service Protocol — a messaging specification for the request of, and response to, services for the PROFIBUS-DP NCS using the PROFIBUS-DPV1 standard.

6 Communication Protocol High Level Structure

6.1 In a typical remote I/O configuration, single master architectures are used to optimize response times. In lower speed applications, multi-master architectures are also possible. PROFIBUS-DP uses the polling principle for communication (Master-Slave method).

6.1.1 Message transfer is organized in cycles. A message cycle mainly consists of a request-frame followed by a corresponding acknowledge/response-frame of the addressed station. An exception to this is the global-control function for synchronization and coordination of several remote I/O stations.

6.1.2 A brief description of the PROFIBUS-DP protocol as it relates to the ISO 7498 OSI model follows in the sections below. For protocol efficiency, PROFIBUS-DP does not define layers 3 to 7. However, since the OSI model specifies Layer 7 as the interface between the Application Process and the communication stack, it is appropriate to discuss several aspects of the PROFIBUS-DP standard at this level. These include: the Direct Data Link Mapper, the User Interface, the Service Access Point, the Device Profile, and the Device Data Base.

NOTE 2: The information contained in this section is for reference only. It in no way represents specifications for PROFIBUS-DP. See related documentation for these specifications.

6.2 *Physical Layer — Layer 1*

6.2.1 There are currently two options specified for the Physical Layer (PHY): RS-485 and Optical. See the PROFIBUS-DP standard for more information about these options.

6.3 *Data Link Layer — Layer 2*

6.3.1 *Data Transfer*

6.3.1.1 The Data Link Layer or Fieldbus Data Link (FDL) provides the functions for sending and receiving data over the network. Protocol Data Units (PDU) are packaged, delivered, and checked. Acknowledgements, responses, retries, and timeouts are used to guard against Line Protocol Errors (e.g., frame, overrun, and parity) and Transmission Protocol Errors (e.g., start and end delimiters, frame check, frame length, and response times).

6.3.1.2 A PDU is restricted to 246 bytes. Preferably, the PDU size should not exceed 32 bytes for optimum performance. In addition to the PDU, a transmission frame of variable length will contain 8 bytes of overhead; one of fixed length (8 bytes) will contain 6 bytes of overhead. Various acknowledgement and response frames are also defined.

6.3.1.3 To better understand the FDL, a summary of FDL data transfer services is given by the following list:

- Send Data with Acknowledge (SDA),
- Send Data with No Acknowledge (SDN),
- Send and Request Data with Reply (SRD), and
- Cyclic Send and Request Data with Reply (CSRD).

6.3.2 *Bus Management*

6.3.2.1 The Fieldbus Management for Layers 1 and 2 is provided by the FMA1/2 component. The FMA1/2 acts as a mediator between the local FMA1/2 user and layers 1 and 2. Requests from the FMA1/2 user, modified as required, are transferred to the FDL and PHY control, and acknowledged with a confirmation to the local FMA1/2 user. The FMA1/2 immediately receives indications from the FDL and PHY if status changes have occurred within the layers, which then leads to an FMA1/2 user indication.

6.4 *Application Layer — Layer 7*

6.4.1 As stated above, PROFIBUS-DP does not define Layer 7. The following components may be considered part of, or above, Layer 7.

6.4.2 *Direct Data Link Mapper (DDLM)*

6.4.2.1 The DDLM performs the interpretation of service requests from, and responses to, the User Interface (UI). The DDLM offers a well defined, easy interface between the UI and the FDL. Table 1 is included to demonstrate the basic structure of the

PROFIBUS-DP DDLM. For speed and efficiency, the PROFIBUS-DP protocol defines the Service Access Point (SAP). These are included in the transmission protocol to direct messages within the device for fast dedicated processing. Defined are Destination SAP (DSAP) and Source SAP (SSAP).

6.4.3 *User Interface (UI)*

6.4.3.1 The UI provides the user with access to functionality of the PROFIBUS-DP protocol. There is one UI definition for DPM1 devices and one for DPM2 devices. To better understand the UI, a summary of application functions follows:

6.4.3.2 *DPM1 and DPM2 UI — Master-Slave Application Functions*

- Read Diagnostic Information of DP-Slaves
- Cyclic User Data Exchange
- Parameterization and Configuration Checking
- Submit Control Commands

6.4.3.3 *DPM2 UI — Master-Slave Application Functions*

- Read Configuration of a DP-Slave
- Read Input/Output Values
- Address Assignment to DP-Slaves

Table 1 DDLM Primitive Functions

DDLM Function	*Description*	*SSAP*	*DSAP*	*FDL SRV*
Master-Slave				
DDLM_Data_Exchange	Exchanges I/O Data	NIL	NIL	SRD
DDLM_Check_Cfg	Sends Configuration to DP-Slave for verification.	62	62	SRD
DDLM_Set_Prm	Sends Parametric Data to DP-Slave.	62	61	SRD
DDLM_Slave_Diag	Retrieves the Diagnostic Data Structure from a DP-Slave.	62	60	SRD
DDLM_Get_Cfg	Retrieves the Configuration Data Structure from a DP-Slave.	62	59	SRD
DDLM_Global_Control	Controls the Operational and Synchronization Modes of DP-Slaves.	62	58	SDN
DPM2-Slave				
DDLM_RD_Outp	Retrieves the Status of the Outputs of the DP-Slave.	62	57	SRD
DDLM_RD_Inp	Retrieves the Values of the Inputs of the DP-Slave.	62	56	SRD
DDLM_Set_Slave_Add	Sets the Node Address of a DP-Slave.	62	55	SRD
Master-Master				
DDLM_xxx	Various Services for Master-Master Communications	54	54	SRD
DDLM_Act_Para_Brct	Accept and Activate the most recent Download of Parameters.	54	54	SDN
Master-Slave — Extended Communications				
DDLM_Read	Acyclic Read of DP-Slave Data	62	51	SRD
DDLM_Write	Acyclic Write of DP-Slave Data	62	51	SRD
DPM2-Slave — Connection Configuration				
DDLM_xxx	Various Services for Control and Management of the MSAC_C2 Connection	50	40–48	

6.4.3.4 *DPM2 UI — Master-Master Application Functions*

- Read DP-Master Class 1 Diagnostic Information of the Associated DP-Slaves
- Upload and Download of Parameters
- Activate Bus Parameters
- Activate and Deactivate DP-Slaves
- Select Operating Mode of a DP-Master Class 1

6.4.4 *Service Access Point (SAP)*

6.4.4.1 The Service Access Point provides standard access addressing for messages. The FDL message frame includes fields for Source and Destination SAP. By directing a message to a particular Destination SAP, its context is immediately known. This provides a fast and interoperable environment for device messaging.

6.4.5 *Device Profile/Device Data Base*

6.4.5.1 PROFIBUS devices have different performance characteristics. Features differ in regard to available functionality (i.e., number of I/O signals and diagnostic messages) or possible bus parameters such as baud rate and time monitoring. These parameters vary individually for each device type and vendor. These parameters are usually documented in the technical manual. To achieve simple plug-and-play configuration of PROFIBUS, the characteristic features are specified in an electronic data sheet called a Device Data Base file or GSD file.

6.4.5.2 The GSD Files provide a clear and comprehensive description of the characteristics of a device type in a precisely defined format. These are prepared individually by the vendor for each type of device and made available to the user in the form of a Device Data Base Sheet and a GSD File. The device data base file is divided into three parts: General Specifications, Master Related Specifications, and Slave Related Specifications.

6.4.5.3 These GSD Files are maintained and managed by the PROFIBUS Trade Organization.

6.5 *Network Management*

6.5.1 The PROFIBUS-DP system is managed through several phases of operation. A Master device must have knowledge of the Device Profile for each of the Slave devices it will connect. The Device Data Base Files serve this purpose. Upon initialization, a Master will control a DP-Slave through three operational modes: Parameterization, Configuration, and I/O Data Exchange. In any operational mode, a Master may interrogate a DP-Slave for its Diagnostic information.

6.5.2 In the sections that follow, these operation modes are mapped to related SAN CDM behavior states.

7 Required Object Types

7.1 This section describes a general mapping of the SEMI SAN Object Model to the PROFIBUS-DP environment. Component definitions are clarified and the mapping of Attributes, Services, and Behaviors are specified.

7.2 *Object Model*

7.2.1 The Object Model defined in the CDM is represented in the PROFIBUS NCS. Specifically, the DM and SAC objects are mapped.

7.2.2 The Application Objects associated with the SDM standards are mapped in PROFIBUS-DP Device Data Base documents as defined above in the Device Profile/Device Data Base section. Section 9 specifies the mapping of SDM Objects in PROFIBUS-DP.

7.3 *Component Mapping Summary*

7.3.1 Table 2 provides a summary of the components of the CDM object model as they relate to the components of PROFIBUS-DP.

Table 2 Component Mapping Summary

SEMI SAN			*PROFIBUS-DP*	
Definition	*Object*	*Component*	*Device*	*Component*
Attributes	DM	Identification and related device attributes	Remote	Device Data Base
	DM	Status and Exception	Slave	Diagnostics
	Active Element	Input/Output	Master/Slave	I/O Data Exchange
	DM & Active Element	Configuration	Slave	Configuration

SEMI SAN			PROFIBUS-DP	
Definition	*Object*	*Component*	*Device*	*Component*
Services	All	Get_Attribute and Set_Attribute	Master/Slave	Service Request
	DM & SAC	Reset	Slave	Service Request Master_Unlock
	DM & SAC	Operate and Recover	Slave	Service Request Send Parameter Data Check Configuration
	DM & SAC	Abort	Slave	Service Request Clear_Data
Behavior States	DM & SAC	Initialized/Self Testing	Slave	Wait_Prm
	DM & SAC	Idle	Slave	Wait_Cfg
	DM & SAC	Executing	Slave	Data_Exch
	DM & SAC	Self Test Exception and Critical Fault	Slave	Diag.Station_Not_Ready
	DM & SAC	Abort	Slave	Device Clear

7.4 *Objects*

7.4.1 The required objects of the CDM are identified here. Additional objects that are contained in the SDM are given identifiers in the Device Profile. Section 9 specifies additional mapping information.

7.4.2 Table 3 lists the Object Identifiers specified for use in protocol messages.

Table 3 Object Identifiers

Object ID	*Object*
0	Invalid
1	DM Object
2	SAC Object
3–n	Application Objects as specified in Section 9.

7.5 *Attributes*

7.5.1 All attributes are accessible via Get_Attribute and Set_Attribute services defined in the sections below. Additionally, attributes are accessible via different PROFIBUS-DP defined methods which are mapped in this document based on attribute type.

7.5.1.1 The attributes of the DM object are divided into three types: Identification, Status, and Configuration. Identification attributes are communicated with the Device Data Base. Status attributes are communicated using the DP-Slave Diagnostic method. Configuration attributes are communicated using the Configuration method.

7.5.1.2 The attributes of Application objects are divided into two types: Input/Output and Configuration. Input/Output attributes are communicated using the I/O Data Exchange method. Configuration attributes are communicated using the Configuration method.

7.5.1.3 See Table 5 for a list of DM attributes and their related alternative access methods.

7.5.2 *PROFIBUS-DP Device Data Base*

7.5.2.1 The specification of the Device Data Base (or GSD file) for a given SDM is beyond the scope of this document. The PROFIBUS Trade Organization is responsible for the management of these files.

7.5.2.2 Table 5 lists which attributes of the CDM are mapped to the GSD file.

7.5.2.3 *PROFIBUS-DP Slave Diagnostics*

7.5.2.3.1 The two attributes of the DM object listed in Table 5 that are identified with an alternative access method of slave diagnostics are mapped into the PROFIBUS-DP Slave Diagnostics as specified in this section. See the PROFIBUS-DP standard for a description of the DP Slave Diagnostics.

7.5.2.3.2 These two attributes, each a single byte in length, are mapped into the Slave Diagnostic data structure. Additional diagnostic data may be included as specified by PROFIBUS-DP.

7.5.2.3.3 In response to a DDLM_Slave_Diag request, the device responds with its Diag_Data. Specifically, Table 4 shows the mapping that applies to the Device Related Diagnostic Block.

Table 4 Device Related Diagnostic Block Format

Byte	*Definition*	*Value*
0	Length	3
1	Octet 1	Device Status
2	Octet 2	Exception Status

7.5.3 *PROFIBUS-DP I/O Data Exchange*

7.5.3.1 Input/Output attributes of the Application objects are communicated using the I/O Data Exchange method of PROFIBUS-DP. This method is described in the PROFIBUS-DP standard. A list of which attributes are accessible with this method is included in the PROFIBUS Device Profile for a given device type.

7.5.4 *PROFIBUS-DP Configuration*

7.5.4.1 Configuration attributes of the DM object and Application objects are communicated using the Configuration method of PROFIBUS-DP. This method is described in the PROFIBUS-DP standard. A list of which Application object attributes are accessible with this method is included in the PROFIBUS Device Profile for a given device type.

7.5.4.2 *Attribute Identifiers*

7.5.4.2.1 Every object specified in the CDM and SDMs uses tags to identify its attributes. These tags are formatted with letters (identifying the object) followed by an upper case “A”, followed by a numerical identifier. The Attribute ID used in the PROFIBUS-DP NCS is simply the numerical portion of these tags.

7.5.4.2.2 The PROFIBUS attribute ID is used to identify attributes for access via PROFIBUS-DP message requests, which are explained in later sections.

7.5.4.2.3 Table 5 shows the attributes defined in the SEMI CDM with the respectively mapped ID numbers. Also shown is the alternative PROFIBUS-DP access method.

7.6 *Services*

7.6.1 PROFIBUS-DP specifies standard mechanisms for the communication of data over the network. These mechanisms are used to communicate attributes specified in the device model of a DP-Slave device. The attributes of the DM that are accessible with this method are identified in Table 5.

7.6.2 Additionally, PROFIBUS-DP specifies standard methods for the control of devices over the network. These mechanisms are used to control the basic operational states associated with a DP-Slave device. These standard mechanisms and methods are identified in this document but specified in the PROFIBUS-DP standard.

Table 5 DM Object Attribute Identifiers

SEMI CDM Attribute ID	*PROFIBUS Attribute ID*	*Attribute*	*Alternative Access Method*
DmA1	1	Device Type	Device Data Base
DmA2	2	Standard Revision Level	Device Data Base
DmA3	3	Device Manufacturer Identifier	Device Data Base
DmA4	4	Manufacturer Model Number	Device Data Base
DmA5	5	Software or Firmware Revision Level	Device Data Base
DmA6	6	Hardware Revision Level	Device Data Base
DmA7	7	Serial Number	Device Data Base
DmA8	8	Device Configuration	Device Data Base
DmA9	9	Device Status	Slave Diagnostics
DmA12	12	Exception Status	Slave Diagnostics
DmA13	13	Exception Detail Alarm	N/A
DmA14	14	Exception Detail Warning	N/A
DmA15	15	Visual Indicator	N/A
DmA16	16	Alarm Enable	Configuration
DmA17	17	Warning Enable	Configuration

7.6.3 *Service Requests*

7.6.3.1 There are two methods defined in this standard that allow service requests to be delivered to DP-Slave devices.

7.6.3.2 The PROFIBUS-DPV1 method can be used by devices with Extended Data Communications capabilities as defined by the PROFIBUS-DPV1 specification. The specification for communication of these service requests is defined in the following sections.

7.6.3.3 The PROFIBUS-DP method is used by devices without Extended Data Communications capabilities. Support of the PROFIBUS-DP method requires specific definitions for I/O Data Exchange data. These definitions are described in the following sections.

7.6.3.4 *DPV1 Service Request*

7.6.3.4.1 For systems utilizing the Extended Data Communication capabilities, additional services may be requested over the network using the Extended Data Communications together with the DPV1 Service Request Protocol specified in this section.

7.6.3.4.2 The Extended Data Communication definition describes a method of establishing connections between a DPM1 and DP-Slaves via the Supplemental Service Access Point — SAP 51.

7.6.3.4.3 *DPV1 Service Request Protocol*

7.6.3.4.3.1 All service request messages, except Get-Attribute and Set_Attribute, are sent to a DP-Slave using the DDLM_Write function of PROFIBUS-DPV1. The responses to these message requests are specified by PROFIBUS-DPV1.

7.6.3.4.3.2 The DPV1 Service Request message is formatted (as defined by PROFIBUS-DPV1) with the following Protocol Fields defined:

Slot = Object ID
Index = 0

7.6.3.4.3.3 Table 6 shows the Data Fields defined by this standard for the Extended Data Communications.

Table 6 Data Field of DPV1 Service Request Protocol

Byte	*Description*
0	Service Request ID
1–n	Service Parameters

NOTE 1: Service ID 4 (Get_Attribute) and Service ID 5 (Set_Attribute) are invalid for this protocol. The following two sections specify the protocol for these service requests.

7.6.3.4.4 *DPV1 Set_Attribute Protocol*

7.6.3.4.4.1 The DPV1 Service Request message for the Set-Attribute is sent to a DP-Slave device using the DDLM_Write function of PROFIBUS-DPV1. It is formatted with the following protocol fields defined:

Slot = Object ID
Index = Attribute ID
Data Field = Attribute Value

7.6.3.4.4.2 The Slot and Index limit is 255 and data is limited to 244 bytes. Therefore, the Device Models of the PROFIBUS-DP devices defined here are limited to 255 Objects, each with no more than 255 attributes, each no larger than 244 bytes.

7.6.3.4.5 *DPV1 Get_Attribute Protocol*

7.6.3.4.5.1 The DPV1 Service Request message for the Get-Attribute is sent to a DP-Slave device using the DDLM_Read function of PROFIBUS-DPV1. It is formatted with the following protocol fields defined:

Slot = Object ID
Index = Attribute ID

7.6.3.4.5.2 The Slot and Index limits are as defined above for Set_Attribute. The response to this request is the attribute value.

7.6.3.5 *DP Service Request*

7.6.3.5.1 Beyond that which is specified by PROFIBUS-DP, additional services may be requested over the network using the I/O Data Exchange method definition together with the DP Service Protocol specified in this section. Additionally, specified in this standard is a DP Service Response Protocol.

7.6.3.5.2 A DP-Slave device must identify support for the DP Service protocol in its GSD File. Support is enabled during the configuration of the DP-Slave device. In this mode of I/O Data Exchange, each data packet delivered to the DP-Slave device is formatted per the DP Service Request protocol and each data packet received from the DP-Slave device is formatted per the DP Service Response protocol.

7.6.3.5.3 The I/O Data Exchange data length must be specified for the longest message (MAX). That is, the DP-Slave device output data length must be set to accommodate the longest request message; and the input data must be set for the longest response message.

7.6.3.5.4 The SDM may specify services in addition to what is specified in the CDM. However, for reference, support of the services of the CDM requires a maximum request message length of three bytes plus the maximum data value length associated with the Set_Attribute.

7.6.3.5.5 In the same context, support of the services of the CDM requires a maximum response message length of one byte plus the maximum data value length associated with the Get_Attribute.

7.6.3.5.6 *DP Service Request Protocol* — The output data communicated to a DP-Slave device configured for DP Services is formatted as specified in Table 7.

Table 7 Data I/O Data Field for DP Service Request Protocol

Byte	*Description*
0	Object ID
1	Service ID
2 through n	Service Parameters
(n+1) through Max	Zero

7.6.3.6 *DP Service Response*

7.6.3.6.1 The response to a service request may or may not contain data based upon the type of request. However, all service responses contain a Response Code.

7.6.3.6.2 A Response Code of Zero indicates a successful service completion. A non-zero Response Code indicates an error. An error is identified via the DP-Slave diagnostics.

7.6.3.6.3 *DP Service Response Protocol* — The input data communicated from a DP-Slave device configured for DP Services is formatted as specified in Table 8.

Table 8 Data I/O Data Field for DP Service Response Protocol

Byte	*Description*
0	Response Code
1 through n	Data
(n+1) through Max	Zero

7.6.3.7 *Service Identifiers* — The required services of the CDM are identified here. Additional services that are contained in the SDM are given identifiers in the Device Profile. Table 9 specifies the required services and ID numbers.

Table 9 Service Identifiers

Service ID	*Service*
0	Invalid
1	Reset
2	Abort
3	Recover
4	Get Attribute
5	Set Attribute
6	Execute
7	Perform Diagnostics

7.6.4 *Specified Services*

7.6.4.1 The following sections define the details associated with each of the services required by the CDM.

7.6.4.2 *Reset*

7.6.4.2.1 The Reset Request specifies no parameters.

7.6.4.2.2 In addition to an explicit Reset Service Request, PROFIBUS-DP specifies others methods whereby a DP-Slave device can be reset. The following sections describe methods by which a DP-Slave will execute a reset.

7.6.4.2.3 *Startup* — During the startup phase, a DP-Master locks the DP-Slave for protection. A DP-Master can also unlock a DP-Slave which causes a Reset to the DP-Slave.

7.6.4.2.4 *Incorrect Configuration* — If a DP-Master delivers an incorrect set of data for parameterization or for configuration to a DP-Slave, it will automatically reset that DP-Slave.

7.6.4.2.5 *Watchdog* — A DP-Slave will automatically reset upon the expiration of its watchdog timer. During the startup phase, a DP-Master sends a Watchdog Time to the DP-Slave. This time must be longer than the Buscycle time for the DP-Slave to operate properly. A DP-Master can also send a Watchdog Time to a DP-Slave during normal operation. Therefore, a DP-Master could affect a reset by intentionally sending a Watchdog Time that is shorter than the Buscycle time.

7.6.4.3 *Abort* — The Abort Service Request specifies no parameters.

7.6.4.4 *Recover* — The Recover Service Request specifies no parameters.

7.6.4.5 *Get Attribute* — As defined above, in the section on attributes there are several methods used to retrieve the value of an attribute: Device Data Base, DP-Slave Diagnostic, I/O Data Exchange, and explicit use of the Get Attribute Service request.

7.6.4.6 *Set Attribute* — As defined above, there are several methods used to set the value of an attribute: Configuration, I/O Data Exchange, and explicit use of the Set Attribute Service request.

7.6.4.7 *Execute* — The Execute Service Request specifies no parameters.

7.6.4.8 *Perform Diagnostics* — The Perform Diagnostic Request specifies one parameter: Test ID. The Test ID parameter is one byte in length, as specified in the CDM.

7.7 *Behavior*

7.7.1 The behavior of PROFIBUS-DP devices is broken down by device type. A DP-Master device controls the operational modes of its assigned DP-Slave devices and polls them using a cyclic communication scheme. This cyclic communication is used to set outputs, read inputs and check the status of DP-Slaves. DP-Slave devices implement the CDM and one or more SDM standards in addition to the DP-Slave standards for behavior.

7.7.2 *DP-Master*

7.7.2.1 A DPM1 device can be controlled either locally or via the network by the configuration Device. A DPM1 device has three main states as described in Table 10:

Table 10 DPM1 Behavior States

State	*Description*
Stop	No data transmission between the DPM1 and DP-Slaves occurs.
Clear	The DPM1 reads input information from the DP-Slaves and holds the outputs in fail-safe status.
Operate	The DPM1 is in the data transfer phase. In a cyclic communication scheme, inputs of the DP-Slaves are read and output information is written to the DP-Slaves.

7.7.3 *DP-Slave*

7.7.3.1 The DM object shares a unique relationship with the DP-Slave device. State Transitions associated with the DP-Slave device cause analogous transitions in the DM Object. However, Transitions associated with the DM object may, or may not, cause transitions in the DP-Slave device.

7.7.3.2 There are essentially four states associated with a DP-Slave device. These states are mapped to the states of the CDM DM Model. Any change of state in one context (i.e., DM object or DP-Slave) causes the corresponding change of state in the other context. This mechanism is achieved via implicit service requests automatically generated within the device to affect the correlated change of state.

7.7.3.3 Table 11 defines the correlation of DP-Slave states to DM object states. Table 12 shows the reverse correlation of DM object states to DP-Slave states.

Table 11 DP-Slave Behavior States Effect on DM Object

DP-Slave State	*Resulting DM State*
Wait_Prm	Initialized/Self Testing
Wait_Cfg	Idle
Data_Exch	Executing
Device_Clear	Abort

Table 12 DM Object Behavior States Effect on DP-Slave

DM State	*Resulting DP-Slave State*
Initialized/Self Testing	Wait_Prm
Idle	Diag.Station_Not_Ready
Executing	Data_Exch
Self Test Exception	Diag.Station_Not_Ready
Critical Fault	Diag.Station_Not_Ready
Abort	Device_Clear

8 Protocol Compliance

8.1 PROFIBBUS International has established a qualified certification system, with test laboratories in Europe and USA, which includes conformance testing and interoperability testing. Certified products are listed with their certificate number in the PROFIBUS Electronic Product Guide.

8.2 GSD files of all PROFIBUS-DP devices that are tested for their conformity to the PROFIBUS standard are available in the GSD library on the World Wide Web Server of the PROFIBUS User Organization at http://www.PROFIBUS.com.

9 Specific Device Model Mappings

9.1 Every type of device must have an identifier number. Vendors must apply for an identifier number from the PROFIBUS User Organization for every Device Type. In order to receive a valid identifier number, a Device Profile must be submitted in the form of a GSD File and Device Data Base Sheet.

9.1.1 The Device Profile must specify the identifiers for Objects, Attributes and Services for CDM and SDM components, including data formats and bit mappings for specified parameters, as represented in this document.

9.1.2 The following sections specify mappings for Sensor Actuator Network Specific Device Models.

9.2 *Mass Flow Device*

9.2.1 Reference SEMI E54.3 for a complete specification of the SDM for Mass Flow Devices. Accordingly, the following mapping rules apply to the identification tags for the Objects, Attributes and Services of this model.

9.2.2 *Objects*

9.2.2.1 Consistent with SEMI E54.3 and Section 7.4 above, the DM and SAC objects are identified as Object 1 and Object 2, respectively.

9.2.2.2 Notice that references for the Local Link Objects are not included; the existence of these objects are implied by behavior and not explicitly included. Therefore, these objects are not accessible from the network and the Sensor-AI-Aux Object is not supported. Also, Assembly Objects are defined in the Device Profile as required.

9.2.2.3 Table 13 shows the mapping of the SDM Object Instances specified in SEMI E54.3 Instance numbers are listed under the heading Instance in the table and the PROFIBUS Object ID is listed under ID in the table.

Table 13 MFD Object Identifiers

SDM Object Name	*SDM Object ID*	*Instance*	*ID*
Sensor-AI-MF	MFD3	1	3
Actuator-AO-MF	MFD7	1	4
Controller	MFD8	1	5
SISO-Setpoint	MFD11	1	6
Sensor-AI-AT	MFD4	1	7

NOTE 1: Additional objects may be defined by the manufacturer in the Device Profile for a given device.

9.2.3 *Attributes*

9.2.3.1 The mapping of Attribute Tags and Identifiers is defined in Section 7.5.4.2 for the CDM. The same method applies here for the SDM.

9.2.4 *Services*

9.2.4.1 The mapping of Service Tags and Identifiers is defined in Section 7.6.3.7 for the CDM. The same method applies here for the SDM.

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SEMI E54.9-1000
SPECIFICATION FOR SENSOR/ACTUATOR NETWORK COMMUNICATION FOR MODBUS/TCP OVER TCP/IP

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on July 14, 2000. Initially available at www.semi.org September 2000; to be published October 2000. Originally published February 2000.

1 Purpose

1.1 This standard defines a communication specification based on the Modbus/TCP protocol over a Transmission Control Protocol/Internet Protocol (TCP/IP) network to enable communications between intelligent devices on a sensor/actuator network (SAN) that operate according to SEMI specified device models (common and device specific) in a semiconductor manufacturing tool.

1.2 *Background and Motivation*

1.2.1 Modbus/TCP over TCP/IP is a component level network which provides a simple, inexpensive, and fast means of exchanging data among control level industrial devices (e.g., sensors and actuators) and higher level devices such as controllers. Modbus/TCP over TCP/IP provides:

- A solution to low-level device networking,
- Access to intelligence present in low-level devices,
- Networking between higher level controllers, and
- Master/Slave and Peer-to-Peer communication capabilities.

1.2.2 Modbus/TCP specifies a communication model and protocol. The Physical, Data Link, and Network Layer definitions are defined by the network in which the Modbus/TCP protocol is embedded such as TCP/IP Ethernet.

1.2.3 This document enables communications between intelligent devices on a SEMI compliant SAN by providing a presentation mapping of common and specific device network visible structure and behavior to Modbus/TCP over a TCP/IP network.

2 Scope

2.1 This document specifies the protocol and services that compliant intelligent devices must support to exchange information over this semiconductor equipment sensor/actuator network.

2.2 This document specifies the utilization of the Modbus/TCP protocol to present externally visible device structure and behavior, specified in the Common Device Model (CDM) and appropriate Specific Device Models (SDMs), for the Modbus/TCP protocol over a TCP/IP network.

2.3 This document is used in conjunction with a SEMI standard SAN Common Device Model specification, one or more SEMI standard Specific Device Model (SDM) specifications (e.g., for a mass flow device), the Modicon Modbus Protocol Reference Guide and the Open Modbus/TCP Specification. Together, they describe the Modbus/TCP protocol, the externally visible data structures and behaviors of devices utilizing the Modbus/TCP networking capability in a SEMI compliant SAN system.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on Modbus/TCP over a TCP/IP network and is a companion document to the Open Modbus/TCP Specification; thus a complete specification of this standard necessarily includes the Modbus/TCP and Modbus protocol specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by Modbus/TCP. In order to avoid document consistency problems, information in the Modbus/TCP standard specifications that relate to this standard is not repeated in this document. This document is limited to describing enhancements or limitations to the Modbus/TCP standard specifications that are imposed by this standard.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services (OSS)

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

SEMI E54.3 — Specification for Sensor/Actuator Network Specific Device Model for Mass Flow Device

4.2 *Other Standards*

IEEE 802.3 — Telecommunication and Information Exchange between System Local and Metropolitan Networks Specific Requirement Part 3: Carrier Sense Multiple Access CSMA/CD Method and Physical Layer Specification, 1998[1]

IP RFC 791 — Reference for data transmission[2]

ISO 7498 — Basic Reference Model for Open Systems Interconnection[3]

PI-MBUS-300 Rev. E — Modicon Modbus Protocol Reference Guide, March 1993[4]

Specification — Open Modbus/TCP Specification Version 1.0 March 29, 1999[4]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 Terminology that is common to all of the documents in this SAN standard may also be defined in the Sensor/Actuator Network standard. Terminology may be reproduced here which is defined in other SEMI standards.

5.2 *Abbreviations and Acronyms*

5.2.1 *CDM* — Common Device Model

5.2.2 *DM* — Device Manager (object)

5.2.3 *IP* — Internet Protocol

5.2.4 *NCS* — Network Communication Standard

5.2.5 *OSI* — Open Systems Interconnect

5.2.6 *OSS* — Object Services Standard

5.2.7 *SAC* — Sensor, Actuator, Controller (Object)

5.2.8 *SAN* — Sensor/Actuator Network

5.2.9 *SDM* — Specific Device Model

5.2.10 *TCP* — Transmission Control Protocol

5.3 *Device Component Definitions*

5.3.1 As this standard defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in SEMI E54.1. Table 1 provides a mapping of fundamental terminology of the CDM document into this document and the Modbus/TCP standard specifications.

NOTE 2: Column 2 contains an equal sign "=" if the definition is used exactly as specified in the CDM specification.

Table 1 Mapping of CDM to NCS Terminology

CDM Term	*NCS Equivalent*	*Modbus/TCP Equivalent*
Device	=	=
Device Model	=	=
Object	=, Class, Instance	=, Class, Instance
Instance	=	=
Attribute	=	=
Behavior	=	=
Service	=	=
State Diagram	=	=
Byte	=	=
Nibble	=	=
Character String	=	=

5.4 *Modbus/TCP Specific Definitions*

5.4.1 *class* — a set of objects that represent the same kind of system component. A class is a generalization of an object. All objects in a class are identical in form and behavior, but may contain different attribute values as well as additional attributes and services. Refer to SEMI E39 for further definition.

5.4.2 *master/slave* — communication over a Modbus network, which is referred to as "client/server", that provides exclusive control of data by a "master" or "host" device acting as a "client". All network input data is reported exclusively to the host when requested by the host, and the host has exclusive control over the states of all network output signals of all nodes acting as it's "slaves" or "servers". Master/Slave communication provides the typical request/response oriented network communications.

5.4.3 *modbus/TCP* — an open protocol established at The University of Michigan's Electronics Manufacturing Laboratory as a standard means of interconnection for simple field devices. The Modbus/TCP over TCP/IP standard specifies OSI reference model layers 1, 2, 3, 4 and 7 specifically the physical signaling, the media access/data link protocols, internetworking capability, the transport capability of end-to-end transmission of data, and the application layer.

1 IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016 U.S.A. tel: 212 419 7900 fax: 212 752 4929. http://www.ieee.org/
2 http://src.doc.ic.ac.uk/computing/internet/rfc/rfc791.txt
3 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland
4 http://www.modicon.com/openmbus/standards/standards.htm

5.4.4 *peer-to-peer* — on Modbus/TCP over TCP/IP networks, messages formatted according to the Modbus/TCP protocol are embedded into the TCP packet structure that is used on the TCP/IP network. The Modbus protocol over TCP/IP supports the asynchronous or unsolicited bi-directional transmission of data between nodes. This type of communication is referred to as peer-to-peer.

6 Communication Protocol High Level Structure

6.1 The Modbus/TCP protocol over TCP/IP is loosely based on a five-layer architecture. These layers constitute a collapsed form of the OSI seven layer architecture, mapping into the physical, data link, network, transport, and application layers of the Reference Model. This section has been formatted to be aligned with the Basic Reference Model for OSI. The high-level protocol architecture is shown in Figure 1.

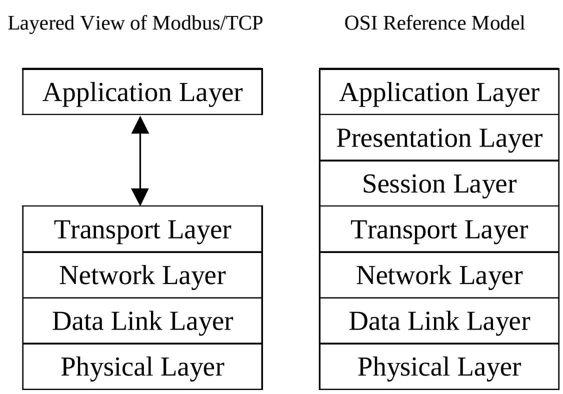

Figure 1
Layered View of Modbus/TCP Over TCP/IP

NOTE 3: Figure 1 represents a conceptual view of the communication device architecture. Conforming implementations must implement the services defined in this specification at each layer and must appear (from the network) to have implemented this architecture, however, an internal modular partitioning is not required. Implementations may sacrifice modularity in order to achieve high performance.

6.1.1 The application layer is specified in the Modicon Modbus Protocol Reference Guide and provides for the definition of Modbus applications as a collection of addressable objects. A subset of these objects may be addressed over the network (as defined by the implementation).

6.1.2 In the remainder of this section the protocol structure is described in more detail in terms of the OSI seven layer reference model, the object model environment and network management specifications.

6.2 *Physical Layer* — The device shall comply with a physical layer specification identified in the Modbus/TCP specification. The recommended and default Modbus/TCP physical layer is IEEE 802.3. If an accepted physical layer specification other than IEEE 802.3 is being used, this must be clearly specified in product literature. Physical layer specification includes physical signaling (levels and data rates), transceivers, node isolation, media topology, cable specifications, network connectors and taps, and power considerations (load limits, system tolerances, and power supply options).

6.3 *Data Link Layer* — The device shall comply with a data link layer specification of the Modbus/TCP specification. The recommended and default Modbus/TCP data link layer is IEEE 802.3. If an accepted data link layer specification other than IEEE 802.3 is being used, this must be clearly specified in product literature. Data link layer specification includes the media access control mechanism and the logical link control mechanism.

6.4 *Network Layer* — The device shall comply with a network layer specification of the Modbus/TCP specification. This specification is the IP or Internet Protocol as defined in the Modbus/TCP standard specification. The network layer specification includes network routing and internetworking.

6.5 *Transport (Messaging) Layer* — The device shall comply with the Modbus/TCP standard specification for the Transport Layer. This specification is the Transmission Control Protocol as defined in the Modbus/TCP standard specification. The transport layer provides transparent transfer of data between objects in application-entities. Some of the functionality of this layer is implemented in the Application Layer. Specific functions include: object data segmentation/re-assembly (fragmentation) for full message delivery.

6.6 *Session Layer* — There is no distinct session layer.

6.7 *Presentation Layer* — There is no distinct presentation layer. Object addressing and data presentation in Modbus messages are specified as part of the Modbus object definitions and object attribute and service communication protocol. Data byte transmission ordering is defined in IP RFC 791, Appendix B.

6.8 *Application Layer* — The device shall comply with the Modbus/TCP application layer specification for defining and addressing objects, including their attributes and services, and enabling specified network behavior. The device shall comply with the object messaging and object model specifications included in the Modbus/TCP standard specifications. In addition, the device shall comply with the object specifications defined in Section 7 of this document.

6.8.1 *Object Models* — The Modbus/TCP protocol has been enhanced to provide an object-oriented specification for creating, defining, and addressing objects explicitly, including their attributes and services, and creating, defining, and communicating object attributes in an application dependent format. The device shall comply with the object messaging and object model specifications included in the Modbus/TCP standard specification documentation. In addition, the device shall comply with the object specifications defined in Section 7 of this document.

6.9 *Network Management* — The device shall comply with the Modbus/TCP and TCP/IP network management specifications detailed in the Modbus/TCP Standard Specifications (e.g., physical layer bit rate, master/slave and peer-to-peer network management, etc.). No (additional) network management functions are speci fied in this document.

7 Required and Optional Object Types

7.1 At this time, the Modbus/TCP standard specifications do not require any specific objects to exist in a Modbus/TCP device in order to be a compliant Modbus/TCP device. The Modbus/TCP standard specifications will be extended to identify and describe objects (i.e., classes) that must exist in devices that are to be interoperable and interchangeable on a Modbus/TCP SEMI compliant SAN network.

7.1.1 The Common Device Model (CDM) specification identifies two objects (namely the Device Manager (DM) and Sensor Actuator Controller (SAC) objects) that must exist in all SEMI compliant SAN devices.

7.1.2 The required object types for a SEMI compliant SAN device utilizing the network communication specification described herein, necessarily comprises, at minimum, the union of the Modbus/TCP object type requirements and the CDM specification requirements.

7.1.3 A list of required and optional object types is given in Table 2. Additional objects that are specified in a particular SDM are given identifiers in that SDM specification. Modbus specific presentation information for these identifiers is given in Section 9 of this document.

Table 2 Required and Optional Object Types

Object Name	*Modbus Class ID/Instance ID (See Note 1)*	*CDM Tag (See Note 2)*	*Required by Modbus (See Note 1)*	*Required by CDM (See Note 2)*	*Required by NCS*
Device Manager	1/1	DmI0	No	Yes	Yes
Sensor/Actuator/ Controller	2/1	SacI0	No	Yes	Yes
Assembly	3/1 through i	Asm	No	No	No
Local Link	4/1 through j	Lnk	No	No	No
Sensor – AI	33/1 through k	Sai	No	No	No
Sensor – EI	34/1 through l	Sei	No	No	No
Sensor – BI	35/1 through m	Sbi	No	No	No
Actuator – AO	36/1 through n	Aao	No	No	No
Actuator – EO	37/1 through o	Aeo	No	No	No
Actuator – BO	38/1 through p	Abo	No	No	No
Controller	39/1 through q	Ca	No	No	No
Application Objects	129 through x/ 1 through r	(See Note 3)	No	No	No

NOTE 1: See Modbus specification for further information; values are decimal: “i”, “j”, “k”, “l”, “m”, “n”, “o”, “p”, “q” and “r” represent arbitrary numbers (greater than or equal to 1) indicating that more than one instance may be supported. “x” is a number greater than or equal to 129 indicating that one or more application object classes may be supported.

NOTE 2: See CDM specification for further information.

NOTE 3: Application Dependent objects as specified in SDM.

7.1.4 An embodiment of a specific device type represented as an aggregation of the object types listed in Table 2 that is compliant with both the CDM specification and the Modbus/TCP specification, is a candidate for a SEMI SDM as well as a Modbus/TCP device definition. Conversely, all SEMI SDM's and Modbus/TCP device definitions specified for operation over a SEMI compliant Modbus/TCP network must be an aggregation of the object types listed in Table 2, and be compliant with both the CDM specification and the Modbus/TCP standard specifications.

7.1.5 In the following sections the presentation to the network of object addressing, object attributes, and object services for each of the object types listed in Table 2 is described in detail. Refer to the CDM standard to determine if the object instance attribute and service is specified as required or optional. Unless otherwise noted, all attributes and services described are instance level attributes (as opposed to class level attributes). A class level attribute and service is accessed as instance number zero.

NOTE 4: The formats of object attributes and services are detailed in the CDM document; the presentation of object attributes and services to the Modbus/TCP over a TCP/IP network is detailed in the tables contained in the following sub-sections and in the Modbus/TCP standard specifications.

7.2 *Device Manager (DM) Object* — The DM object instance is the device component responsible for managing and consolidating the device operation. Each device must support one (and only one) DM object. The DM object as well as its common required and optional attributes, services and behavior are described in the CDM standard. The presentation of object instance attributes and services to the Modbus/TCP network shall be as indicated in Table 3. Note that all service ID values identified refer to the ID of the request or notification component of that service. Corresponding reply components to request/reply services shall have a service ID value equal to the request component ID plus one.

Table 3 DM Object Instance Attributes and Services

Device Manager Object (DM) Class ID = 01, Instance ID = 01		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Device Type	DmA1
02	Standard Revision Level	DmA2
03	Device Manufacturer Identifier	DmA3
04	Manufacturer Model Number	DmA4
05	Software or Firmware Revision Level	DmA5
06	Hardware Revision Level	DmA6
07	Serial Number	DmA7
08	Device Configuration	DmA8
09	Device Status	DmA9
12	Exception Status	DmA12
13	Exception Detail Alarm	DmA13
14	Exception Detail Warning	DmA14
15	Visual Indicator	DmA15
16	Alarm Enable	DmA16
17	Warning Enable	DmA17
18	Exception Detail Type	DmA18
19	Exception Detail Alarm Queue	DmA19
20	Exception Detail Warning Queue	DmA20
Services		
ID	*Service Name*	*CDM Tag*
01	Reset	DmS1
03	Abort	DmS2
05	Recover	DmS3
07	Get Attribute	DmS4
09	Set Attribute	DmS5
11	Execute	DmS6
13	Perform Diagnostics	DmS7
15	Publish Attribute	DmS8
17	Lock	DmS9
19	Unlock	DmS10
21	Get Exception Queue	DmS11
23	Clear Exception Queue	DmS12

7.3 *Sensor, Actuator, Controller (SAC) Object* — The SAC object instance is the device component responsible for coordinating the interaction of the device with the sensory/actuation/control environment. Each device must support one (and only one) SAC object instance. The SAC object instance as well as its common required and optional attributes, services, and behavior are described in the CDM standard. The presentation of object instance attributes and services to the Modbus/TCP network shall be as indicated in Table 4.

Table 4 SAC Object Instance Attributes and Services

Sensor, Actuator, Controller Object (SAC) *Class ID = 02, Instance ID = 01*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Last Calibration Date	SacA1
02	Next Calibration Date	SacA2
03	Expiration Timer	SacA3
04	Expiration Warning Enable	SacA4
05	Run Hours	SacA5
Services		
ID	*Service Name*	*CDM Tag*
01	Reset	SacS1
03	Abort	SacS2
05	Recover	SacS3
07	Get Attribute	SacA4
09	Set Attribute	SacA5
25	Operate	SacA6
27	Restore Default	SacA7
29	Publish Attribute	SacA8

7.4 *Assembly Object (Asm)* — The Assembly (Asm) object instances may be used to provide for grouping more than one attribute from one or more object instances in a device into a single data structure for communication over the Modbus/TCP network. The presentation of object instance attributes and services shall be as indicated in Table 5.

Table 5 Assembly Object Instance Attributes and Services

ASSEMBLY Object (Asm) *Class ID == 03, Instance ID = 01 through i*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Data	AsmA1
Services		
ID	*Service Name*	*CDM Tag*
07	Get Attribute	AsmS4
09	Set Attribute	AsmS5

7.5 *Local Link Object (Lnk)* — The Local Link (Lnk) object instances may be used to "link" an attribute of one object instance to an attribute of another object instance. Refer to the CDM for further explanation and use of this object. The presentation of object instance attributes and services are as indicated in Table 6.

Table 6 Local Link Object Instance Attributes and Services

Local Link Object (Asm) *Class ID = 04, Instance ID = 01 through j*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Source Object Class	LnkA1
02	Source Object Instance	LnkA2
03	Source Object Attribute	LnkA3
04	Destination Object Class	LnkA4
05	Destination Object Instance	LnkA5
06	Destination Object Attribute	LnkA6
07	Commit	LnkA7
Services		
ID	*Service Name*	*CDM Tag*
--	No services defined.	--

7.6 *Sensor-AI Object (Sai)* — The presentation of the Sensor Analog Input (Sensor-AI) object instance attributes and services are as indicated in Table 7.

Table 7 Sensor-AI Object Instance Attributes and Services

Sensor-AI *Class ID = 33, Instance ID = 01 through k*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SaiA1
02	Status	SaiA2
03	Alarm Enable	SaiA3
04	Warning Enable	SaiA5
16	Value	Sai16
17	ReportInhibitTimer	Sai17
18	EnableReportRate	Sai18
19	ReportRate	Sai19
64	Offset	Sai64
65	Gain	Sai65
66	DataType	Sai66
67	DataUnits	Sai67
68	SafeState	Sai68
69	EnableReportDelta	Sai69
70	ReportDelta	Sai70
71	EnableReportROC	Sai71
72	ReportROC	Sai72
73	AlarmTripPointHigh	Sai73
74	AlarmTripPointLow	Sai74
75	AlarmHysteresis	Sai75
76	WarningTripPointHigh	Sai76
77	WarningTripPointLow	Sai77

78	WarningHysteresis	Sai78
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SaiS1
03	Abort	SaiS2
05	Recover	SaiS3
25	Operate	SaiS4
07	GetAttribute	SaiS5
09	SetAttribute	SaiS6
27	RestoreDefault	SaiS7

7.7 *Sensor-EI Object (Sei)* — The presentation of the Sensor Enumerated Input (Sensor-EI) object instance attributes and services are as indicated in Table 8.

Table 8 Sensor-EI Object Instance Attributes and Services

Sensor-EI Class ID = 34, Instance = 01 through l		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SeiA1
02	Status	SeiA2
03	Alarm Enable	SeiA3
04	Warning Enable	SeiA5
16	Value	Sei16
17	ReportInhibitTimer	Sei17
18	EnableReportRate	Sei18
19	ReportRate	Sei19
64	DebounceControl	Sei64
65	AlarmStatus	Sei65
66	WarningStatus	Sei66
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SeiS1
03	Abort	SeiS2
05	Recover	SeiS3
25	Operate	SeiS4
07	GetAttribute	SeiS5
09	SetAttribute	SeiS6
27	RestoreDefault	SeiS7

7.8 *Sensor-BI Object (Sbi)* — The presentation of the Sensor Binary Input (Sensor-BI) object instance attributes and services are as indicated in Table 9.

Table 9 Sensor-BI Object Instance Attributes and Services

Sensor-BI Class ID = 35, Instance ID = 01 through m		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	SbiA1
02	Status	SbiA2
03	Alarm Enable	SbiA3
04	Warning Enable	SbiA5
16	Value	Sbi16
17	ReportInhibitTimer	Sbi17
18	EnableReportRate	Sbi18
19	ReportRate	Sbi19
64	DebounceControl	Sbi64
65	AlarmStatus	Sbi65
66	WarningStatus	Sbi66
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	SbiS1
03	Abort	SbiS2
05	Recover	SbiS3
25	Operate	SbiS4
07	GetAttribute	SbiS5
09	SetAttribute	SbiS6
27	RestoreDefault	SbiS7

7.9 *Actuator-AO Object (Aao)* — The presentation of the Actuator Analog Output (Actuator-AO) object instance attributes and services are as indicated in Table 10.

Table 10 Actuator-AO Object Instance Attributes and Services

Actuator-AO Class ID = 36, Instance = 01 through n		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AaoA1
02	Status	AaoA2
03	Alarm Enable	AaoA3
04	Warning Enable	AaoA5
16	Setting	Aao16
17	SafeState	Aao17
18	WatchRate	Aao18
19	Watchdog	Aao19
64	Offset	Aao64
65	Gain	Aao65

66	DataType	Aao66
67	DataUnits	Aao67
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AaoS1
03	Abort	AaoS2
05	Recover	AaoS3
25	Operate	AaoS4
07	GetAttribute	AaoS5
09	SetAttribute	AaoS6
27	RestoreDefault	AaoS7

7.10 *Actuator-EO Object (Aeo)* — The presentation of the Actuator Enumerated Output (Actuator-EO) object instance attributes and services are as indicated in Table 11.

Table 11 Actuator-EO Object Instance Attributes and Services

Actuator-EO *Class ID = 37, Instance ID = 01 through o*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AeoA1
02	Status	AeoA2
03	Alarm Enable	AeoA3
04	Warning Enable	AeoA5
16	Setting	Aeo16
17	SafeState	Aeo17
18	WatchRate	Aeo18
19	Watchdog	Aeo19
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AeoS1
03	Abort	AeoS2
05	Recover	AeoS3
25	Operate	AeoS4
07	GetAttribute	AeoS5
09	SetAttribute	AeoS6
27	RestoreDefault	AeoS7

7.11 *Actuator-BO Object (Abo)* — The presentation of the Actuator Binary Output (Actuator-BO) object instance attributes and services are as indicated in Table 12.

Table 12 Actuator-BO Object Instance Attributes and Services

Actuator-BO *Class ID = 38, Instance ID = 01 through p*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	AboA1
02	Status	AboA2
03	Alarm Enable	AboA3
04	Warning Enable	AboA5
16	Setting	Abo16
17	SafeState	Abo17
18	WatchRate	Abo18
19	Watchdog	Abo19
Services		
ID	*Service Name*	*SDM Tag*
01	Reset	AboS1
03	Abort	AboS2
05	Recover	AboS3
25	Operate	AboS4
07	GetAttribute	AboS5
09	SetAttribute	AboS6
27	RestoreDefault	AboS7

7.12 *Controller Object (CA)* — The presentation of the Controller (CA) object instance attributes and services are as indicated in Table 13.

Table 13 Controller-CA Instance Object Attributes and Services

Controller *Class ID = 39, Instance ID = 01 through q*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
01	Name	CAA1
02	Status	CAA2
03	Alarm Enable	CAA3
04	Warning Enable	CAA4
16	Setpoint	CAA16
17	ProcessVariable	CAA17
18	ControlVariable	CAA18
19	DataType	CAA19
64	DataUnits	CAA20
65	AlarmSettleTime	CAA21
66	AlarmErrorBand	CAA22
67	WarningSettleTime	CAA23
68	WarningErrorBand	CAA24
Services		
ID	*Service Name*	*SDM Tag*

01	Reset	CAS1
03	Abort	CAS2
05	Recover	CAS3
25	Operate	CAS4
07	GetAttribute	CAS5
09	SetAttribute	CAS6
27	RestoreDefault	CAS7

8 Protocol Compliance

8.1 A method of testing protocol compliance is required to verify implementation conformance to the standard. An independent compliance testing laboratory has been established at The University of Michigan's Electronics Manufacturing Laboratory for the testing of Modbus/TCP over TCP/IP solutions. This laboratory utilizes an established, documented and freely available mechanism for compliance certification of devices on a Modbus/TCP over a TCP/IP network. This certification includes procedures and reporting mechanisms to demonstrate conformance and interoperability of Modbus/TCP devices. Information on the conformance testing laboratory can be found on the World Wide Web.[5] Additional information on certification procedures can also be found on the World Wide Web.[6]

9 Specific Device Model Mappings

9.1 This section provides for the mapping of network visible specific device structure and behavior, specified in a SEMI SDM specification, to the Modbus/TCP network. Each subsection is devoted to a single Specific Device Model (SDM) specification. Additional SDM mappings are added as sub-sections to this NCS specification according to SEMI guidelines and the guidelines SEMI E54. Unless otherwise noted, all attributes and services described are instance level attributes (as opposed to class level attributes).

NOTE 5: The formats of object instance attributes and services are detailed in the associated SDM specification; the presentation of object attributes and services to the Modbus/TCP over a TCP/IP network is detailed in the tables contained in the following sub-sections and in the Modbus/TCP standard specifications.

NOTE 6: Relationships between object classes, including inheritance is defined in the associated SDM specification and the CDM specification.

9.1.1 The instance identifier of 1 through r, assigned to an object type, refers to the possibility of multiple instantiations of the object type. Refer to Table 2 of this document and the CDM document for a further explanation of object instance identifier assignments.

9.2 *Specific Device Model for Mass Flow Device* — These sections detail the network mapping required to support the Specific Device Model for Mass Flow Devices. Table 14 summarizes the Mass Flow Device Object types. Subsequent Tables 15 to 24 detail the instance attributes and services associated with each Mass Flow Device object type.

Table 14 Mass Flow Device Object Types

SDM Object Identifier	*Object Name*	*Modbus Class ID*
MFD1 (DM)	Device Manager	1
MFD2 (SAC)	Sensor Actuator Controller	2
MFD3	Sensor-AI-MF	129
MFD4	Sensor-AI-AT	130
MFD5	Assembly-MFM	131
MFD6	Sensor-AI-Aux	132
MFD7	Actuator-AO-MF	133
MFD8	Controller	39
MFD9	Local Link	4
MFD10	SISO	134
MFD11	SISO-Setpoint	135
MFD12	Assembly-MFC	136

9.2.1 *Sensor-AI-MF* — The presentation of the Sensor Analog Input Mass Flow (Sensor-AI-MF) object instance attributes and services are as indicated in Table 15.

Table 15 Sensor-AI-MF Object Instance Attributes and Services

Sensor-AI-MF Class ID = 129, Instance ID = 1 through r		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Flow Totalizer	A1
129	Flow Hours	A2
130	Zero Offset Mode	A5
131	Zeroing Status	A6
132	Autorange Status	A7
Services		
ID	*Service Name*	*SDM Tag*
129	Perform Zero Offset	S1
131	Query-Supported Gas Types	S2
133	Selected Programmed Gas Type	S3
135	Insert Gas Type	S4
137	Delete Gas Type	S5
139	Get Gas Calibration Data Value	S6
141	Set Gas Calibration Data Value	S7
143	Autorange	S8

5 http://www.eecs.umich.edu/~sbus
6 http://www.modicon.com/openmbus

9.2.2 *Sensor-AI-AT* — The presentation of the Sensor Analog Input Ambient Temperature (Sensor-AI-AT) object instance attributes and services are as indicated in Table 16.

Table 16 Sensor-AI-AT Object Instance Attributes and Services

Sensor-AI-AT *Class ID = 130, Instance = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined.	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.3 *Assembly-MFM* — The presentation of the Assembly Mass Flow Meter (Assembly-MFM) object instance attributes and services are as indicated in Table 17.

Table 17 Assembly-MFM Object Instance Attributes and Services

Assembly-MFM *Class ID = 131, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined.	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.4 *Sensor-AI-Aux* — The presentation of the Sensor Analog Input Auxiliary (Sensor-AI-Aux) object instance attributes and services are as indicated in Table 18.

Table 18 Sensor-AI-Aux Object Instance Attributes and Services

Sensor-AI-Aux *Class ID = 132, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined.	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.5 *Actuator-AO-MF* — The presentation of the Actuator Analog Output Mass Flow (Actuator-AO-MF) object instance attributes and services are as indicated in Table 19.

Table 19 Actuator-AO-MF Object Instance Attributes and Services

Actuator-AO – MF *Class ID = 133, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Valve Type	A1
129	Override	A2
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.6 *Controller* — The presentation of the extended Controller (Ca) object instance attributes and services are as indicated in Table 20.

Table 20 Controller Object Instance Attributes and Services

Controller *Class ID = 39, Instance ID = 01 through q*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Alarm Settling Time	CaA21
129	Warning Settling Time	CaA24
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.7 *Local Link* — The presentation of the extended Local Link (Lnk) object instance attributes and services are as indicated in Table 21.

Table 21 Local Link Object Instance Attributes and Services

Local Link *Class ID = 4, Instance ID = 01 through j*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined.	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.8 *SISO* — The presentation of the Single Input Single Output (SISO) object instance attributes and services are as indicated in Table 22.

Table 22 SISO Object Instance Attributes and Services

SISO *Class ID = 134, Instance = 01*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Input	A1
129	Output	A2
130	Data Type	A3
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.2.9 *SISO-Setpoint* — The presentation of the Single Input Single Output Setpoint (SISO-Setpoint) object instance attributes and services are as indicated in Table 23.

Table 23 SISO-Setpoint Object Instance Attributes and Services

SISO-Setpoint *Class ID = 135, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
161	Ramp Type	A33
162	Ramp Rate	A34
163	Ratio	A35
Services		
ID	*Service Name*	*SDM Tag*
---	No additional services defined.	--

9.2.10 *Assembly-MFC* — The presentation of the Assembly Mass Flow Controller (Assembly-MFC) object instance attributes and services are as indicated in Table 24.

Table 24 Assembly-MFC Object Instance Attributes and Services

Assembly-MFC *Class ID = 136, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined.	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined.	--

9.3 *Specific Device Model For In-Situ Particle Monitor Device* — These sections detail the network mapping required to support the Specific Device Model for In-Situ Particle Monitor (ISPM) Devices. Table 25 summarizes the In-Situ Particle Monitor Device Object types. Subsequent tables 26 to 40 details the attributes and services associated with each In-Situ Particle Monitor Device object type.

Table 25 In-Situ Particle Monitor Device Object Types

SDM Object Identifier	*Object Name*	*Modbus Class ID*
ISPMD1 (DM)	Device Manager	1
ISPMD2 (SAC)	Sensor Actuator Controller	2
ISPMD3	Sensor-AI-LCS	137
ISPMD4	Sensor-AI-SLS	138
ISPMD5	Sensor-AI-MNS	139
ISPM16	Sensor-AI-Counter	140
ISPMD17	Assembly-ISPM#1	141
ISPMD18	Assembly-ISPM#2	142
ISPMD19	Assembly-ISPM#3	143
ISPMD20	Assembly-ISPM#4	144
ISPMD21	Assembly-ISPM#5	145
ISPMD22	Assembly-ISPM#6	146
ISPMD23	Assembly-ISPM#7	147
ISPMD24	Assembly-ISPM#8	148
ISPMD25	Assembly-ISPM#9	149

9.3.1 *Device Manager (DM)* — The presentation of the extended ISPM Device Manager (DM) object attributes and services are as indicated in Table 26.

Table 26 DM Object Instance Attributes and Services

Device Manager Object (DM) *Class ID = 01, Instance ID = 01*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
128	Gain	DmA33
129	Filter Bandwidth	DmA34
130	Tool State	DmA35
131	Laser Status	DmA36
132	Flow Path	DmA37
133	Volume	DmA38
134	Volume Units	DmA39
135	Leak Status	DmA40
136	Time Stamp	DmA41
Services		
ID	*Service Name*	*CDM Tag*
33	Laser On	DmS1
35	Laser Off	DmS2

9.3.2 *Sensor Actuator Controller (SAC)* — The presentation of the extended ISPM Sensor Actuator Controller (SAC) object attributes and services are as indicated in Table 27.

Table 27 SAC Object Instance Attributes and Services

Sensor, Actuator, Controller Object (SAC) *Class ID = 02, Instance ID = 01*		
Attributes		
ID	*Attribute Name*	*CDM Tag*
65	Number of Bins	SacA65
66	Count Mode	SacA66
67	Duration	SacA67
Services		
ID	*Service Name*	*CDM Tag*
33	Clear Counts	SacS33

9.3.3 *Sensor-AI-LCS* — The presentation of the Sensor Analog Input Laser Current Sensor (Sensor-AI-LCS) object attributes and services are as indicated in Table 28.

Table 28 Sensor-AI-LCS Object Instance Attributes and Services

Sensor-AI-LCS *Class ID = 137, Instance ID = 1 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Reading Valid	LcsA1
129	Full Scale	LcsA2
130	Alarm Settling Time	LcsA3
131	Warning Settling Time	LcsA4
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.4 *Sensor-AI-SLS* — The presentation of the Sensor Analog Input Stray Light Sensor (Sensor-AI-SLS) object attributes and services are as indicated in Table 29.

Table 29 Sensor-AI-SLS Object Instance Attributes and Services

Sensor-AI-SLS *Class ID = 138, Instance ID = 1 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Reading Valid	SlsA1
129	Full Scale	SlsA2
130	Alarm Settling Time	SlsA3
131	Warning Settling Time	SlsA4
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.5 *Sensor-AI-MNS* — The presentation of the Sensor Analog Input Medium Noise Sensor (Sensor-AI-MNS) object attributes and services are as indicated in Table 30.

Table 30 Sensor-AI-MNS Object Instance Attributes and Services

Sensor-AI-MNS *Class ID = 139, Instance ID = 1 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Reading Valid	MnsA1
129	Full Scale	MnsA2
130	Alarm Settling Time	MnsA3
131	Warning Settling Time	MnsA4
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.6 *Sensor-AI-Counter* — The presentation of the Sensor Analog Input Counter (Sensor-AI-Counter) object attributes and services are as indicated in Table 31.

Table 31 Sensor-AI-Counter Object Instance Attributes and Services

Sensor-AI-Counter *Class ID = 140, Instance ID = 1 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
128	Reading Valid	CounterA1
129	Full Scale	CounterA2
130	Alarm Settling Time	CounterA3
131	Warning Settling Time	CounterA4
132	Upper Size	CounterA5
133	Lower Size	CounterA6
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.7 *Assembly-ISPM#1* — The presentation of the Assembly #1 In-Situ Particle Monitor (Assembly-ISPM#1) object attributes and services are as indicated in Table 32.

Table 32 Assembly-ISPM#1 Object Instance Attributes and Services

Assembly-ISPM#1 *Class ID = 141, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.8 *Assembly-ISPM#2* — The presentation of the Assembly #2 In-Situ Particle Monitor (Assembly-ISPM#2) object attributes and services are as indicated in Table 33.

Table 33 Assembly-ISPM#2 Object Instance Attributes and Services

Assembly-ISPM#2 *Class ID = 142, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.9 *Assembly-ISPM#3* — The presentation of the Assembly #3 In-Situ Particle Monitor (Assembly-ISPM#3) object attributes and services are as indicated in Table 34.

Table 34 Assembly-ISPM#3 Object Instance Attributes and Services

Assembly-ISPM#3 *Class ID = 143, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.10 *Assembly-ISPM#4* — The presentation of the Assembly #4 In-Situ Particle Monitor (Assembly-ISPM#4) object attributes and services are as indicated in Table 35.

Table 35 Assembly-ISPM#4 Object Instance Attributes and Services

Assembly-ISPM#4 *Class ID = 144, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.11 *Assembly-ISPM#5* — The presentation of the Assembly #5 In-Situ Particle Monitor (Assembly-ISPM#5) object attributes and services are as indicated in Table 36.

Table 36 Assembly-ISPM#5 Object Instance Attributes and Services

Assembly-ISPM#5 *Class ID = 145, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.12 *Assembly-ISPM#6* — The presentation of the Assembly #6 In-Situ Particle Monitor (Assembly-ISPM#6) object attributes and services are as indicated in Table 37.

Table 37 Assembly-ISPM#6 Object Instance Attributes and Services

Assembly-ISPM#6 *Class ID = 146, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.13 *Assembly-ISPM#7* — The presentation of the Assembly #7 In-Situ Particle Monitor (Assembly-ISPM#4) object attributes and services are as indicated in Table 38.

Table 38 Assembly-ISPM#7 Object Instance Attributes and Services

Assembly-ISPM#7 *Class ID = 147, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.14 *Assembly-ISPM#8* — The presentation of the Assembly #8 In-Situ Particle Monitor (Assembly-ISPM#8) object attributes and services are as indicated in Table 39.

Table 39 Assembly-ISPM#8 Object Instance Attributes and Services

Assembly-ISPM#8 *Class ID = 148, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

9.3.15 *Assembly-ISPM#9* — The presentation of the Assembly #9 In-Situ Particle Monitor (Assembly-ISPM#9) object attributes and services are as indicated in Table 40.

Table 40 Assembly-ISPM#9 Object Instance Attributes and Services

Assembly-ISPM#9 *Class ID = 149, Instance ID = 01 through r*		
Attributes		
ID	*Attribute Name*	*SDM Tag*
--	No additional attributes defined	--
Services		
ID	*Service Name*	*SDM Tag*
--	No additional services defined	--

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SEMI E54.10-0600
SPECIFICATION FOR SENSOR/ACTUATOR NETWORK SPECIFIC DEVICE MODEL FOR AN IN-SITU PARTICLE MONITOR DEVICE

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org May 2000; to be published June 2000.

1 Purpose

1.1 This specification is part of a suite of standards that specify the implementation of SEMI standards for the Sensor/Actuator Network. The specific purpose of this specification is to describe a network independent application model comprised of device objects that are common to all In-Situ Particle Monitor Devices on a semiconductor equipment Sensor/Actuator communications network.

2 Scope

2.1 An In-Situ Particle Monitor (ISPM) is a device that measures and counts particles. These devices classify by size and count, particles in the environment (gaseous, liquid, or vacuum) utilizing a technique such as detecting light from a sample region of the environment's space. These counts are accumulated in bins and then reported. The number of bins varies by vendor and model.

2.2 This specification specifically addresses the minimum attributes, services, and behavior an In-Situ Particle Monitor (ISPM) device must support to be interoperable on the Sensor/Actuator Network.

2.3 This specification is intended to ensure a high-degree of device interoperability on the Sensor/Actuator Network, while still allowing flexibility for product differentiation and technology evolution.

2.4 The model specified in this specification is used in conjunction with SEMI E54.1 (Standard for Sensor/Actuator Network Common Device Model (CDM)) to completely describe the ISPM as it appears from the network interface.

2.5 This specification, together with SEMI E54, SEMI E54.1, and one of the Sensor/Actuator Network Communication Specifications, form a complete interoperability specification for the ISPM.

2.6 To comply with this specification, a device must implement and support, at a minimum, the required attributes, services, and behavior identified in these documents. Support for optional attributes, services, and behavior is not required to be compliant to this specification. Optional attributes, services, and behavior are specified in these documents to promote further device interoperability as features evolve and are adopted by more manufacturers. If optional attributes, services, and behavior are implemented for this device they must be implemented as identified in this document.

2.7 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification is a companion to a suite of specifications that together make up the Sensor/Actuator Network Communication standard. Therefore, using portions of this specification that relate to network communications necessarily requires an understanding of the associated network specification.

3.2 As this document is a specification for the In-Situ Particle Monitor Device Model, it does not contain any definition of objects, attributes, services, or behavioral descriptions that are already defined in SEMI E54.1. Additional attributes, attribute assignments, services, and/or service parameters that are ISPM Device specific and/or implementation specific are contained in this specification.

3.3 While this specification is sufficient to completely describe the ISPM as it appears from the network, it does not fully describe behavior of the ISPM which is not visible from the network. This allows flexibility in implementation techniques and product differentiation between manufacturers. Manufacturer specific objects may be defined by the manufacturer but are, by definition, outside the scope of this standard.

3.4 This specification is compatible, but not compliant with SEMI E39. This means that although this specification does not require compliance with SEMI E39, it is extensible such that implementations may be developed that are fully compliant with both standards. Note that the concepts and terminology of this specification are compatible with those of SEMI E39. However, SEMI E39 has specific requirements that are intended for higher level applications and thus are not applied to the In-Situ Particle Monitor Device Model.

3.5 Operation over the entire range specified for an attribute within a specific object is not a requisite for compliance with this specification.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *LCS* — an ISPM sensor named the Laser Current Sensor.

5.1.2 *MNS* — an ISPM sensor named the Median Noise Sensor.

5.1.3 *SLS* — an ISPM sensor named the Stray Light Sensor.

5.2 *Terminology Defined in This Document*

5.2.1 *In-Situ Particle Monitor (ISPM)* — a self-contained device, consisting of a laser that generates light, a light detector, counters, diagnostics and control and signal-processing electronics, commonly used in the semiconductor industry to measure and count particles in a specific area.

5.3 This document inherits the terminology defined by SEMI E54.1 [3].

5.3.1 *Attribute*

5.3.2 *Behavior*

5.3.3 *Boolean*

5.3.4 *Byte*

5.3.5 *Character*

5.3.6 *Common Device Model (CDM)*

5.3.7 *Data Type*

5.3.8 *Data Units*

5.3.9 *Device*

5.3.10 *Device Manager (DM) Object*

5.3.11 *Device Model*

5.3.12 *Double Integer (DINT)*

5.3.13 *Enumerated Byte*

5.3.14 *Full Scale Range*

5.3.15 *Instance*

5.3.16 *Last Valid Value (LVV)*

5.3.17 *Long Integer (LINT)*

5.3.18 *Long Real (LREAL)*

5.3.19 *Manufacturer*

5.3.20 *Nibble*

5.3.21 *Null Character*

5.3.22 *Object*

5.3.23 *Real (REAL)*

5.3.24 *S, A, and C Objects*

5.3.25 *Sensor Actuator Controller (SAC) Object*

5.3.26 *Service*

5.3.27 *Short Integer (SINT)*

5.3.28 *Signed Integer (INT)*

5.3.29 *State Diagram*

5.3.30 *Test String*

5.3.31 *Unsigned Double Integer (UDINT)*

5.3.32 *Unsigned Double Long Integer (UDLINT)*

5.3.33 *Unsigned Integer (UINT)*

5.3.34 *Unsigned Long Integer (ULINT)*

5.3.35 *Unsigned Short Integer (USINT)*

6 Requirements and Specifications

6.1 In order to implement this standard in an In-Situ Particle Monitor Device, it is necessary to also implement SEMI E54.1 and one of the Sensor/Actuator Network Communication Standards [2]. See Section 1.1 for more information on a complete interoperability standard.

6.2 This specification also requires the implementation of a Date_And_Time data structure used to represent the current device Date and Time. Table 1 defines the format of the Date_And_Time data type.

Table 1 Date_And_Time Format

Data Item	*Description*	*Range*
1	Number of milli-seconds since midnight	Unsigned Double Integer (UDINT)
2	Number of days since	Unsigned Integer

Data Item	Description	Range
	1/1/72	(UINT)

7 Conventions

7.1 This document embraces the conventions and notations stated in Section 6 of SEMI E54.1 [3].

8 Device High Level Structure

8.1 *General Description*

8.1.1 The high-level object view of an In-Situ Particle Monitor (ISPM) Device is shown in Figure 1.

8.1.2 Note that the "ISPM" device object is depicted in Figure 1 only for the purposes of illustrating a high level view of the device and its component objects. In the context of this document, this object is not addressable, does not have addressable attributes, does not have accessible services, and does not exhibit any defined behavior.

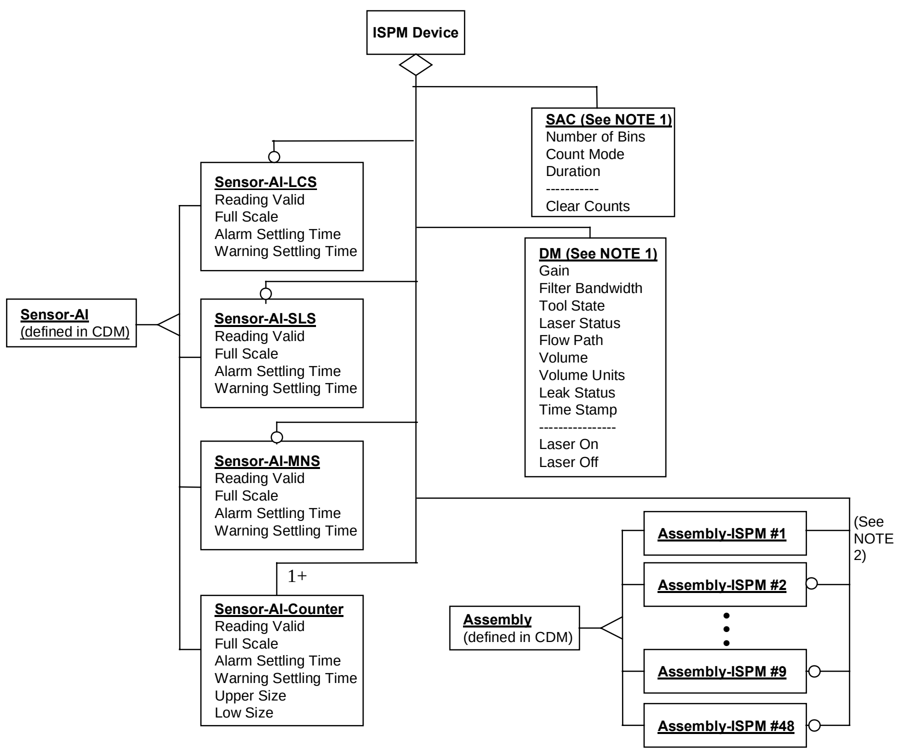
8.1.3 In the remainder of this section, this document defines in detail all of the component objects unique to the ISPM device. References, rather than definitions, are included for the DM, the SAC, and other objects defined in SEMI E54.1 [3].

8.1.4 Many of the objects defined in this document inherit properties from other objects. The properties inherited include attribute, services, and behavior definitions. These other objects are specified here or in SEMI E54.1 [3].

8.1.5 This document provides for future extensions as well as manufacturer specific enhancements by reserving object attribute identifiers and object service identifiers. Specifically, all object definitions in this document specify or reserve the first 64 attribute identifiers (A1 through A64) and the first 64 service identifiers (S1 through S64) allowing manufacturers to specify identifiers beyond these ranges. Additionally, byte enumerated attributes are specified or reserved from 0 to 63 allowing manufacturers to specify an enumeration beyond this range (64 to 255).

8.1.6 *In-Situ Particle Monitor (ISPM) Device Description*

8.1.6.1 An In-Situ particle Monitor device profile is composed of the component objects and object relationships shown in Figure 1.



NOTE 1: The DM and SAC are taken from the CDM. Additional attributes and services are added to support the ISPM device.

NOTE 2: Assembly-ISPM #1 and Assembly-ISPM #6 objects are required. Other Assembly-ISPM objects are optional.

Figure 1
In-Situ Particle Monitor Device High Level Structure

8.1.7 *General Requirements*

8.1.7.1 *Device Objects* — All objects are defined in terms of their object name and Class/Object identifier. Identifiers for all objects described in this document are summarized in Table 2.

Table 2 In-Situ Particle Monitor Device Objects

Referenced Document Section	*Object Name*	*Class/Object Identifier*	*Minimum #*	*Maximum #*
8.2	Device Manager (DM)	ISPMD1	1	1
8.3	Sensor Actuator Controller (SAC)	ISPMD2	1	1
8.5	Sensor-AI-LCS	ISPMD3	0	1
8.6	Sensor-AI-SLS	ISPMD4	0	1
8.7	Sensor-AI-MNS	ISPMD5	0	1
8.8	Sensor-AI-Counter	ISPMD16	1	1024
8.9	Assembly-ISPM#1	ISPMD17	1	1
8.9	Assembly-ISPM#2	ISPMD18	0	1
8.9	Assembly-ISPM#3	ISPMD19	0	1
8.9	Assembly-ISPM#4	ISPMD20	0	1
8.9	Assembly-ISPM#5	ISPMD21	0	1
8.9	Assembly-ISPM#6	ISPMD22	1	1
8.9	Assembly-ISPM#7	ISPMD23	0	1
8.9	Assembly-ISPM#8	ISPMD24	0	1
8.9	Assembly-ISPM#9	ISPMD25	0	1
8.9	Assembly-ISPM#48	ISPMD64	0	1
—	Reserved	ISPM26–ISPM63	—	—
—	Manufacturer Specified	> ISPM64	—	—

8.1.7.2 *Object Services* — Not all object services listed in this document can necessarily be requested over the network. They are included in this document because their behavior may generate network activity.

8.1.7.3 *Object Behavior* — For all service requests received over the network that are not supported by the object, or contain a parameter value which is beyond the supported range, or which is otherwise invalid, a network specific service error response is generated.

8.2 *Device Manager Object (DM)* — The Device Manager object is the device component responsible for managing and consolidating the device operation as specified in SEMI E54.1 [3]. The following sections specify the components of the DM object that are not specified in SEMI E54.1 or require further definition than specified in SEMI E54.1.

8.2.1 *Device Manager Object Attributes* — Required and optional DM object attributes are listed in Table 3.

Table 3 DM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Device Type	A1	R	Yes	refer to CDM [1]
Exception Detail Alarm	A13	R	No	refer to CDM [1]
Exception Detail Warning	A14	R	No	refer to CDM [1]
Gain	A33	RW *	No	REAL
Filter Bandwidth	A34	RW *	No	REAL
Tool State	A35	R	No	USINT, enumerated
Laser Status	A36	R	Yes	USINT, enumerated
Flow Path	A37	RW	No	USINT
Volume	A38	R	No	REAL
Volume Units	A39	R	No	Byte, enumerated

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Leak Status	A40	R	No	Byte, enumerated
Time Stamp	A41	RW	No	Date_And_Time
Reserved	A42–A64	—	—	Reserved for SDM future expansion
Manufacturer Specified	> A64	—	—	Manufacturer Specific attributes

NOTE 1: "*" Indicates that the specific attribute is nonvolatile. Nonvolatile requires that the current attribute value be maintained through a component power cycle.

8.2.1.1 *Device Type* — An attribute that uniquely identifies the type of the device on the network. The device type attribute is assigned as follows:

In-Situ Particle Monitor Device = "ISPM"

8.2.1.2 *Exception Detail Alarm (Optional)* — An attribute which identifies the detailed alarm status of the device. Table 4 defines the bit assignments associated with the alarm exception detail.

Table 4 Exception Detail Alarm Bit Assignments

Bit	*Device Specific Alarm[0]*
0	Reserved
1	Interlock
2	Sensor Not Detected
3	Leak Detected
4	Reserved
5	Sensor Type Changed
6	Reserved
7	Reserved

Bit	*Device Specific Alarm[1]*
0	High Laser Current
1	High Stray Light
2	High Median Noise
3	High Calibration
4	High Fill Rate
5	High Flow Rate
6	Reserved
7	Reserved

Bit	*Device Specific Alarm[2]*
0	Low Laser Current
1	Low Stray Light
2	Low Median Noise
3	Low Calibration
4	Low Fill Rate
5	Low Flow Rate
6	Reserved
7	Reserved

8.2.1.3 *Exception Detail Warning (Optional)* — An attribute which identifies the detailed warning status of the device. Table 5 defines the bit assignments associated with the warning exception detail.

Table 5 Exception Detail Warning Bit Assignments

Bit	*Device Specific Warning[0]*
0	Reserved
1	0
2	0
3	0
4	Reserved
5	0
6	Reserved
7	Reserved

Bit	*Device Specific Warning[1]*
0	High Laser Current
1	High Stray Light
2	High Median Noise
3	High Calibration
4	High Fill Rate
5	High Flow Rate
6	Reserved
7	Reserved

Bit	*Device Specific Warning[2]*
0	Low Laser Current
1	Low Stray Light
2	Low Median Noise
3	Low Calibration
4	Low Fill Rate
5	Low Flow Rate
6	Reserved
7	Reserved

8.2.1.4 *Manufacturer Exception Detail Size (Optional)* — An attribute that specifies the number of exception detail bytes included in the alarm or warning details.

8.2.1.5 *Gain (Optional)* — An attribute that specifies the Gain value of the amplifier for the photodiode signal. The factory configured out-of-box value is determined by the manufacturer based on the sensor type.

8.2.1.6 *Filter Bandwidth (Optional)* — An attribute that determines the bandwidth in kilohertz of the amplifier for the photodiode signal. The factory configured out-of-box value is determined by the manufacturer based on the sensor type.

8.2.1.7 *Tool State (Optional)* — An attribute that identifies the current state of the tool that is utilizing the counter. In many cases, the ISPM device can detect and report the Tool State; this variable is utilized for this type of reporting. This attribute is enumerated and is specified by the manufacturer.

8.2.1.8 *Laser Status* — An attribute that records the current status of the laser. This attribute is enumerated. The possible enumeration and the requirement for support are as follows:

0 = LASER OFF (required)
1 = LASER TURNING ON (optional)
2 = LASER ON BUT NOT STABLE (optional)
3 = LASER ON AND STABLE (required)
4 = LASER INTERLOCKED (optional)
5 = SENSOR MISSING (required)
6–63 = Reserved
64–255 = Manufacturer Specified (optional)

8.2.1.9 *Flow Path (Optional)* — An attribute that identifies the current flow path (from multiple sources) being utilized. The source may be modified by a Host at anytime. Changing the "Flow path" attribute connects the ISPM device to a different source. When changing sources, data is not valid for a time interval whose length is a function of the distance to the source.

8.2.1.10 *Volume (Optional)* — An attribute that maintains the sample volume. This attribute is used primarily by liquid particle counters utilizing a sampling technique in a small container to extrapolate the particle count in the volume of interest. The value of this attribute is the size of the small container.

8.2.1.11 *Volume Units (Optional)* — An attribute that specifies the unit for the "Volume" attribute. This attribute is enumerated and can take on one of the following values: milliliters or gallons. (See Appendix 1 of SEMI E54.1 for assigned values.)

8.2.1.12 *Leak Status (Optional)* — An attribute that indicates which one of the potential leak locations is actually leaking. This attribute is enumerated and is specified by the manufacturer. The enumerated value corresponds to a specific leak location.

8.2.1.13 *Time Stamp (Optional)* — An attribute that records the time when the last counting event completed.

8.2.1.14 *Duration (Optional)* — An attribute that defines the interval of time during which the particle counts are collected and put into the bin assemblies.

8.2.1.15 *Initial and Default Values*

Table 6 DM Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Device Type	ISPM	ISPM	ISPM = In-Situ Particle Monitor Device
Exception Detail Alarm	0	0	
Exception Detail Warning	0	0	
Laser Status	0	0	Laser Off

8.2.2 *Device Manager Object Services* — The services provided by the Device Manager object are defined in SEMI E54.1 [1]. The Device Manager object supports the additional services listed below.

Table 7 Device Manager Object Services

Service	*Service Identifier*	*Type*	*Description*
Laser On	S1	R	Used to prompt the device to take the laser from the LASER OFF state to LASER ON AND STABLE state as defined by the Laser Status attribute.
Laser Off	S2	R	Used to prompt the device to take the laser immediately to the LASER OFF state as defined by the Laser Status attribute.
Reserved	S3–S64	—	Reserved for future expansion
Manufacturer Specified	> S64	—	Manufacturer Specific services

8.2.2.1 *Laser On (Optional)* — This service is used to prompt the device to take the laser from the LASER OFF state through supported laser states 1 and/or 2, to state 3, as defined by the Laser Status attribute. If the laser turns on successfully, a "success" response code is returned. If the sensor is missing or interlocked off, a "object state conflict" error response is returned and the laser remains in the appropriate state.

8.2.2.2 *Laser Off (Optional)* — This service is used to prompt the device to take the laser to the LASER OFF state immediately. If the laser turns off successfully, a "success" response is returned. If the sensor is in an interlocked state, a "object state conflict" error response is returned and the laser remains in the interlocked off state.

8.2.3 *Device Manager Object Behavior* — The behavior exhibited by the Device Manager object is defined in SEMI E54.1 [1]. Additional behavior is detailed below.

8.2.3.1 *Device Manager EXECUTING State Behavior* — Required sub-states within the EXECUTING state, descriptions of these substates, and a transition matrix associated with these sub-states are given in Figure 2, Table 8, and Table 9 respectively.

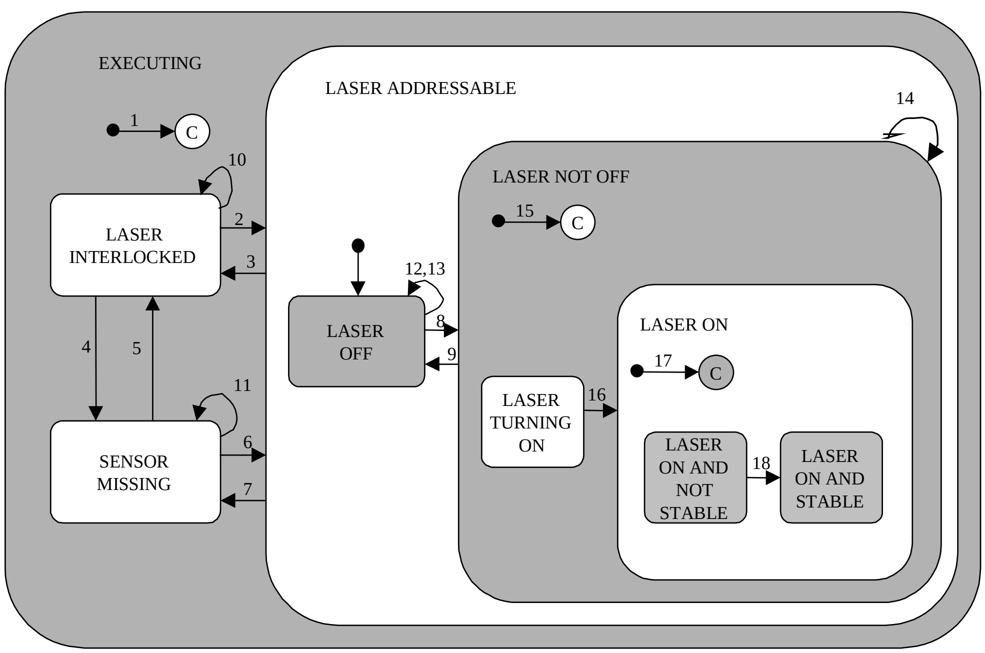


Figure 2
Device Manager Object Behavior Within the EXECUTING State

Table 8 Device Manager Behavior EXECUTING Sub-State Description

State	*Description*
EXECUTING	Laser is in one of the following enumerated states as indicated in the Laser Status Device Manager attribute: LASER INTERLOCKED (optional), LASER MISSING (optional), or LASER OFF. Device will respond to Laser On and Laser Off services as appropriate to move between sub-states within the EXECUTING and LASER ADDRESSABLE states.
LASER ADDRESSABLE	Laser is in one of the following enumerated states as indicated in the Laser Status Device Manager attribute: LASER OFF, LASER ON AND STABLE, LASER TURNING ON (optional), or LASER ON BUT NOT STABLE (optional). Device will respond to Laser On and Laser Off services as appropriate to move between sub-states within the LASER ADDRESSABLE state.
LASER OFF	This is the entry sub-state to LASER ADDRESSABLE; Laser is Off; Laser Status Device Manager attribute is in the enumerated state: LASER OFF. Device is not performing the “counting” process. (See NOTE 1.)
LASER ON AND STABLE	Sub-state of LASER ADDRESSABLE; device is “counting” (See NOTE 1); Laser Status Device Manager attribute is the enumerated state: LASER ON AND STABLE. Laser is performing the “counting” process.
LASER INTERLOCKED	Laser is Interlocked off; Laser Status Device Manager attribute is in the enumerated state: LASER INTERLOCKED. Device is not performing the “counting” process. (See NOTE 1.) Sensor may or may not be missing. Device cannot move to the LASER ADDRESSABLE or SENSOR MISSING states until the interlock is removed.
SENSOR MISSING	Laser sensor is missing; Laser Status Device Manager attribute is in the enumerated state: SENSOR MISSING. Device is not performing the “counting” process. (See NOTE 1.) Device cannot move to the LASER ADDRESSABLE state until the sensor is replaced.
LASER NOT OFF	Laser is in one of the enumerated states as indicated in the Laser Status Device Manager attribute: LASER TURNING ON (optional), LASER ON AND NOT STABLE (optional), or LASER ON AND STABLE. Device will respond to Laser Off service as appropriate to move between sub-states within the LASER ADDRESSABLE state.
LASER TURNING ON	An optional sub-state of LASER NOT OFF. This is a conditional entry sub-state to LASER NOT OFF. Device is preparing to turn on. Device is not performing the “counting” process. (See NOTE 1.)
LASER ON	Laser is in one of the enumerated states as indicated in the Laser Status Device Manager attribute: LASER ON AND NOT STABLE (optional) or LASER ON AND STABLE. Device will respond to Laser Off service as appropriate to move between sub-states within the LASER ADDRESSABLE state.
LASER ON AND NOT STABLE	Sub-state of LASER ON; device is not “counting” (See NOTE 1); Laser Status Device Manager attribute is the enumerated state: LASER ON AND NOT STABLE. Laser is not performing the “counting” process.

NOTE 1: The “counting” process is defined in Section 8.8.3.1.

Table 9 Device Manager Behavior EXECUTING Sub-State Transition Matrix (See NOTE 1.)

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Entry into EXECUTING	Device detects interlock condition, and availability and state of laser.	Conditional: LASER ADDRESSABLE/ LASER OFF or LASER INTERLOCKED or SENSOR MISSING	If the sensor is in an interlocked or missing condition then state is LASER INTERLOCKED. If laser interlock and or laser missing is not supported then state is LASER OFF. Set Laser Status attribute to appropriate value.	Entry state depends on availability of laser and physical laser interlock setting on device.
2	LASER INTERLOCKED	Device detects removal of interlock condition	LASER MISSING	Set Laser Status attribute to	Device moves to LASER OFF state.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
		and determines that sensor is not missing.		appropriate value.	
3	LASER ADDRESSABLE	Device detects that it has been set to a laser interlock condition.	LASER INTERLOCKED	Set Laser Status attribute to appropriate value.	Valid for all sub-states of LASER ADDRESSABLE.
4	LASER INTERLOCKED	Device detects removal of interlock condition and determines that sensor is missing.	SENSOR MISSING	Set Laser Status attribute to appropriate value.	
5	SENSOR MISSING	Device detects that it has been set to a laser interlock condition.	LASER INTERLOCKED	Set Laser Status attribute to appropriate value.	
6	SENSOR MISSING	Device detects replacement of sensor.	LASER ADDRESSABLE/ LASER OFF	Set Laser Status attribute to appropriate value.	Device moves to LASER OFF.
7	LASER ADDRESSABLE/ LASER OFF	Device detects that sensor is missing.	SENSOR MISSING	Set Laser Status attribute to appropriate value.	
8	LASER OFF	Laser On request	LASER ON AND STABLE	Take the object from the LASER OFF state through optional laser states LASER TURNING ON and LASER ON BUT NOT STABLE to the required LASER ON AND STABLE state, turning on the laser and stabilizing it respectively. Set the Laser Status attribute to the appropriate values throughout the transition. Issue Laser On response and begin the “counting” process. (See NOTE 2.)	LASER TURNING ON and “LASER ON BUT NOT STABLE” are optional intermediate states between LASER OFF and LASER ON AND STABLE. Laser must not be missing or in an interlocked off state. Service response is not issued until transition to LASER ON AND STABLE is completed.
9	LASER ON AND STABLE	Laser Off request	LASER OFF	Stop the “counting” process. (See NOTE 2.) Turn the laser off. Issue Laser Off response.	
10	LASER INTERLOCKED	Laser Off request or Laser On request	LASER INTERLOCKED	Error response	Object cannot move from this state until interlock is turned off.
11	SENSOR MISSING	Laser Off request or Laser On request	SENSOR MISSING	Error response	Object cannot move to LASER ADDRESSABLE state until sensor is replaced.
12	LASER OFF	Laser Off request	LASER OFF	Error response	Laser is already off.
13	LASER OFF	Laser On request	LASER OFF	Device attempts to take the laser from the “Laser Off” state through optional laser	Behavior associated with determining that laser will not turn on properly or

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
				state "Laser Turning On" and to required state "Laser On But Not Stable". Set the Laser Status attribute to the appropriate values throughout the transition attempt. Laser either won't turn on properly or won't stabilize. Turn laser back off and generate Error response.	won't stabilize is manufacturer specific.
14	LASER ON		LASER ON AND STABLE	Error response	Laser is attempting to turn on.
15	Entry into LASER NOT OFF	Laser On request	Conditional: LASER NOT OFF/LASER TURNING ON or LASER ON/LASER ON AND NOT STABLE or LASER ON AND STABLE	Set Laser Status attribute to appropriate value.	Entry state depends on device support for optional states LASER TURNING ON and LASER ON / LASER ON AND NOT STABLE or LASER ON AND STABLE
16	LASER TURNING ON	Device detects that the laser is on.	LASER ON/LASER ON AND NOT STABLE or LASER ON AND STABLE	Set Laser Status attribute to appropriate value.	Behavior associated with determining that laser is in the process of turning on and is manufacturer specific.
17	Entry into LASER ON	Laser On request	Conditional: LASER ON/LASER ON AND NOT STABLE or LASER ON AND STABLE	Set Laser Status attribute to appropriate value.	Entry state depends on device support for optional states LASER ON AND NOT STABLE or LASER ON AND STABLE.
18	LASER ON AND NOT STABLE	Device determines that the laser is stable.	LASER ON AND STABLE	Set Laser Status attribute to appropriate value.	Laser is on. Behavior associated with determining that laser will turn on properly or won't stabilize is manufacturer specific.

NOTE 1: Note that this matrix augments the Device Manager Behavior State Transition Matrix as defined in SEMI E54.1 [3]. All transitions are in addition to those specified in SEMI E54.1.

NOTE 2: The "counting" process is defined in Section 8.8.3.1.

8.3 *Sensor Actuator Controller Object (SAC)* — The Sensor Actuator Controller object is the device component responsible for coordinating the interaction of the ISPM device with the sensory/actuation/control environment as specified in SEMI E54.1 [3]. The following sections specify the components of the SAC object that are not specified in the Common Device model or require further definition than specified in the CDM.

8.3.1 *Sensor Actuator Controller Object Attributes* — The attributes provided by the Sensor Actuator Controller object are defined in SEMI E54.1 [3]. Table 10 contains the additional attributes required for the Sensor Actuator Controller object.

Table 10 SAC Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Number of Bins	SacA65	R*	Yes	UINT
Count Mode	SacA66	RW*	Yes	Enumerated, USINT
Duration	SacA67	R	No	REAL

NOTE 1: "*" Indicates that the specific attribute is nonvolatile. Nonvolatile requires that the current attribute value be maintained through a component power cycle.

8.3.1.1 *Number of Bins* — An attribute that specifies the number of counters in the device. This value represents the number of Sensor-AI-Counter objects in the device.

8.3.1.2 *Count Mode* — An attribute that specifies whether all count object values are cleared (to zero) when read. This attribute is an enumerated USINT that can take on one of the following values:

0 = The particle counter count is not affected by reading the count.
1 = The particle counter count is cleared to zero when the count ("value" attribute of the Counter object) is read or reported through a service request to or from an Assembly-ISPM object that contains that count.
2 = The particle counter count is cleared to zero when the count ("value" attribute of the Counter object) is read or reported (regardless of the connection) through a service request to or from either an Assembly-ISPM object that contains that count ("value" attribute), or the Counter object that contains the count.
3–63 = Reserved
64–255 = Manufacturer Specified

8.3.1.3 *Duration (Optional)* — An attribute that defines the interval of time during which the particle counts (value of *Value* object attribute) are collected and put into the bin assemblies.

8.3.1.4 *Initial and Default Values*

Table 11 SAC Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Number of Bins	Manufacturer Specified	Manufacturer Specified	
Count Mode	LVV	0	Do not clear particle counter value.
Duration	Manufacturer Specified	Manufacturer Specified	

8.3.2 *Sensor Actuator Controller Object Services* — The services provided by the Sensor Actuator Controller object are defined in SEMI E54.1 [1]. Table 12 contains the additional services required for the Sensor Actuator Controller object.

Table 12 SAC Object Services

Service	*Service Identifier*	*Type*	*Description*
Clear Counts	S33	R	Used to clear the "Value" attribute of all Sensor-AI-Counter sensor objects.
Reserved	S34–S64	—	Reserved for future expansion
Manufacturer Specified	> S64	—	Manufacturer Specific services

8.3.2.1 *Clear Counts (Optional)* — This service is used to instruct all of the Sensor-AI-Counter object to perform a one-time clear of their respective Sensor-AI-Counter "*Value*" attributes by setting the value to zero. There are no parameters required for this service.

8.3.3 *Sensor Actuator Controller Object Behavior*

8.3.3.1 The behavior exhibited by the Sensor Actuator Controller object is defined in SEMI E54.1 [3]. Additional behavior is detailed below.

8.3.3.2 The "*Value*" attribute is cleared (to zero) in each ISPM counter sensor object, after being read, if the "*Count Mode*" attribute has a value of 1. It may also be cleared by a "Clear Counts" service of the SAC object or the "Reset" service issued to the S-Analog Sensor class.

8.4 *Sensor-AI Object* — The Sensor-AI object is the device component responsible for coordinating the behavior common to all analog input sensor elements in the ISPM device as specified in SEMI E54.1 [3].

8.4.1 *Sensor-AI Object Attributes* — The attributes provided by the Sensor-AI object are defined in SEMI E54.1 [1]. There are no additional attributes required for the Sensor-AI object.

8.4.2 *Sensor-AI Object Services* — The services provided by the Sensor-AI object are defined in SEMI E54.1 [3]. There are no additional services required for the Sensor-AI object.

8.4.3 *Sensor-AI Object Behavior* — The behavior exhibited by the Sensor-AI object is defined in SEMI E54.1 [3]. There is no additional behavior required for the Sensor-AI object.

8.5 *Sensor-AI-LCS Object* — The Sensor-AI-LCS (Laser Current Sensor) object inherits the attributes, services, and behavior of the Sensor-AI as defined in SEMI E54.1 [3]. The Sensor-AI-LCS is the device component responsible for retrieving a reading from a physical laser current sensor, optionally correcting the reading with a manufacturer specified algorithm, or algorithms, then making the value available through the "*Value*" attribute.

8.5.1 *Sensor-AI-LCS Object Attributes* — The attributes provided by the Sensor-AI object are defined in SEMI E54.1 [3]. The Sensor-AI object attribute content and its attribute extensions to support the Sensor-AI-LCS object are listed in Table 13.

Table 13 Sensor-AI and Sensor-AI-LCS Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Value	SaiA16	R	Yes	UINT
Gain	SaiA65	R	Yes	REAL
Data Type	SaiA66	R	Yes	USINT
Data Units	SaiA67	R	Yes	Enumerated, UINT milliAmps only value supported
Reading Valid	LcsA1	R	Yes	Enumerated, Byte
Full Scale	LcsA2	R	Yes	UINT
Alarm Settling Time	LcsA3	R	Yes	UINT
Warning Settling Time	LcsA4	R	Yes	UINT
Reserved	LcsA5–LcsA64	—	—	Reserved for future expansion.
Manufacturer Specified	> LcsA64	—	—	Manufacturer Specific attributes

8.5.1.1 *Value* — The attribute that maintains the laser current sensor value. This value is always read as milliAmps.

8.5.1.2 *Gain* — The attribute that specifies the gain of the laser current measuring circuit.

8.5.1.3 *Data Type* — The attribute which defines the format of the data associated with the "value" attribute.

8.5.1.4 *Data Units* — The attribute which specifies the units for the "*Value*" attribute. This attribute is an enumerated UINT that can take only one value:

MilliAmps (as assigned in Appendix 1 of SEMI E54.1).

8.5.1.5 *Reading Valid* — An attribute which specifies whether the "*Value*" attribute contains a valid value. This attribute is an enumerated byte that can take on one of the following values:

0 = Invalid, or
1 = Valid.

8.5.1.6 *Full Scale* — An attribute which specifies the maximum value allowed for the "*Value*" attribute.

8.5.1.7 *Alarm Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before an alarm is generated.

8.5.1.8 *Warning Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before a warning is generated.

8.5.1.9 *Initial and Default Values*

Table 14 Sensor-AI and Sensor-AI-LCS Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Value	0	0	
Gain	LVV	1.0	
Data Type	LVV	UINT	
Data Units	LVV	MilliAmps	See Appendix 1 of SEMI E54.1.
Reading Valid	0	0	Invalid
Full Scale	LVV	0XFFFF	
Alarm Settling Time	LVV	1000	Milliseconds
Warning Settling Time	LVV	1000	Milliseconds

8.5.2 *Sensor-AI-LCS Object Services* — The services provided by the Sensor-AI-LCS are inherited from the Sensor-AI object defined in SEMI E54.1 [3]. There are no additional services required for the Sensor AI-LCS object.

8.5.3 *Sensor-AI-LCS Object Behavior* — The behavior exhibited by the Sensor-AI-LCS object is inherited from the Sensor-AI object defined in SEMI E54.1 [3]. Additional specific behavior associated with the Sensor-AI-LCS object is defined below.

8.5.3.1 *Sensor-AI-LCS OPERATING Application Process* — A reading is retrieved from a physical laser current sensor. This reading may be corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the gain formula to generate the *value* attribute as referenced in SEMI E54.1 [3]. This process is executed only when the Device Manager Object is in the EXECUTING state as defined in the Common Device Model. When not in the EXECUTING state, the value of the "*Reading Valid*" attribute shall be set to "Invalid". When in one of the sub-states of the EXECUTING state, the validity of the "*Value*" attribute shall be manufacturer specific.

8.6 *Sensor-AI-SLS Object* — The Sensor-AI-SLS (Stray Light Sensor) object inherits the attributes, services, and behavior of the Sensor-AI as defined in SEMI E54.1 [3]. The Sensor-AI-SLS is the device component responsible for retrieving a reading from a physical stray light sensor, optionally correcting the reading with a manufacturer specified algorithm, or algorithms, then making the value available through the "*Value*" attribute.

8.6.1 *Sensor-AI-SLS Object Attributes* — The attributes provided by the Sensor-AI object are defined in SEMI E54.1 [3]. The Sensor-AI object attribute content and its attribute extensions to support the Sensor-AI-SLS object is listed in Table 15.

Table 15 Sensor-AI and Sensor-AI-SLS Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Value	SaiA16	R	Yes	UINT
Gain	SaiA65	R	Yes	REAL
Data Type	SaiA66	R	Yes	USINT
Data Units	SaiA67	R	Yes	Enumerated, UINT milliVolts only value supported
Reading Valid	SlsA1	R	Yes	Enumerated, Byte

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Full Scale	SlsA2	R	Yes	UINT
Alarm Settling Time	SlsA3	R	Yes	UINT
Warning Settling Time	SlsA4	R	Yes	UINT
Reserved	SlsA5–SlsA64	—	—	Reserved for future expansion.
Manufacturer Specified	> SlsA64	—	—	Manufacturer Specific attributes

8.6.1.1 *Value* — The attribute that maintains the stray light sensor value. This value is always read as milliVolts.

8.6.1.2 *Gain* — The attribute that specifies the gain between the photodiode (or some other light detection source) and the stray light reading.

8.6.1.3 *Data Type* — The attribute which defines the format of the data associated with the "value" attribute.

8.6.1.4 *Data Units* — The attribute which specifies the units for the "*Value*" attribute. This attribute is an enumerated UINT and can take only one value:

MilliVolts (as assigned in Appendix 1 of SEMI E54.1).

8.6.1.5 *Reading Valid* — An attribute which specifies whether the "*Value*" attribute contains a valid value. This attribute is an enumerated byte that can take on one of the following values:

0 = Invalid, or
1 = Valid.

8.6.1.6 *Full Scale* — An attribute which specifies the maximum value allowed for the "*Value*" attribute.

8.6.1.7 *Alarm Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before an alarm is generated.

8.6.1.8 *Warning Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before a warning is generated.

8.6.1.9 *Initial and Default Values*

Table 16 Sensor-AI and Sensor-AI-SLS Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Value	0	0	
Gain	LVV	1.0	
Data Type	LVV	UINT	
Data Units	LVV	MilliVolts	See Appendix 1 of SEMI E54.1.
Reading Valid	0	0	Invalid
Full Scale	LVV	0XFFFF	
Alarm Settling Time	LVV	1000	Milliseconds
Warning Settling Time	LVV	1000	Milliseconds

8.6.2 *Sensor-AI-SLS Object Services* — The services provided by the Sensor-AI-SLS object are inherited from the Sensor-AI object defined in SEMI E54.1 [3]. There are no additional services required for the Sensor AI-SLS object.

8.6.3 *Sensor-AI-SLS Object Behavior* — The behavior exhibited by the Sensor-AI-SLS object is inherited from the Sensor-AI object defined in SEMI E54.1 [3]. Additional specific behavior associated with the Sensor-AI-SLS object is defined below.

8.6.3.1 *Sensor-AI-SLS OPERATING Application Process* — A reading is retrieved from a physical stray light sensor. This reading may be corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the gain formula to generate the *value* attribute as referenced in SEMI E54.1 [3]. This process is executed only when the Device Manager Object is in the EXECUTING state as defined in the Common Device Model. When not in the EXECUTING state, the value of the "*Reading Valid*" attribute shall be set to "Invalid". When in one of the sub-states of the EXECUTING state, the validity of the "*Value*" attribute shall be manufacturer specific.

8.7 *Sensor-AI-MNS Object* — The Sensor-AI-MNS (Median Noise Sensor) object inherits the attributes, services, and behavior of the Sensor-AI as defined in SEMI E54.1 [3]. The Sensor-AI-MNS is the device component responsible for retrieving a reading from a physical median noise sensor, optionally correcting the reading with a manufacturer specified algorithm, or algorithms, then making the value available through the "*Value*" attribute.

8.7.1 *Sensor-AI-MNS Object Attributes* — The attributes provided by the Sensor-AI object are defined in SEMI E54.1 [3]. The Sensor-AI object attribute content and its attribute extensions to support the Sensor-AI-MNS object is listed in Table 17.

Table 17 Sensor-AI and Sensor-AI-MNS Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Value	SaiA16	R	Yes	UINT
Gain	SaiA65	R	Yes	REAL
Data Type	SaiA66	R	Yes	USINT
Data Units	SaiA67	R	Yes	Enumerated, UINT milliVolts only value supported
Reading Valid	MnsA1	R	Yes	Enumerated, Byte
Full Scale	MnsA2	R	Yes	UINT
Alarm Settling Time	MnsA3	R	Yes	UINT
Warning Settling Time	MnsA4	R	Yes	UINT
Reserved	MnsA5–MnsA64	—	—	Reserved for future expansion.
Manufacturer Specified	> MnsA64	—	—	Manufacturer Specific attributes

8.7.1.1 *Value* — The attribute that maintains the median noise sensor value. This is the noise level at the output of the sensor amplifier. The value is calculated by taking the median value of the last manufacturer specific number of rolling samples of the sensor amplifier output. This value is always read as milliVolts.

8.7.1.2 *Gain* — The attribute that specifies the gain of the median noise measuring circuit.

8.7.1.3 *Data Type* — The attribute which defines the format of the data associated with the "value" attribute.

8.7.1.4 *Data Units* — The attribute which specifies the units for the "*Value*" attribute. This attribute is an enumerated UINT and can take only one value:

MilliVolts (as assigned in Appendix 1 of SEMI E54.1).

8.7.1.5 *Reading Valid* — An attribute which specifies whether the "*Value*" attribute contains a valid value. This attribute is an enumerated byte that can take on one of the following values:

0 = Invalid, or
1 = Valid.

8.7.1.6 *Full Scale* — An attribute which specifies the maximum value allowed for the "*Value*" attribute.

8.7.1.7 *Alarm Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before an alarm is generated.

8.7.1.8 *Warning Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before a warning is generated.

8.7.1.9 *Initial and Default Values*

Table 18 Sensor-AI and Sensor-AI-MNS Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Value	0	0	
Gain	LVV	1.0	
Data Type	LVV	UINT	
Data Units	LVV	MilliVolts	See Appendix 1 of SEMI E54.1.
Reading Valid	0	0	Invalid
Full Scale	LVV	0XFFFF	
Alarm Settling Time	LVV	1000	Milliseconds
Warning Settling Time	LVV	1000	Milliseconds

8.7.2 *Sensor-AI-MNS Object Services* — The services provided by the Sensor-AI-MNS object are inherited from the Sensor-AI object defined in SEMI E54.1 [3]. There are no additional services required for the Sensor AI-MNS object.

8.7.3 *Sensor-AI-MNS Object Behavior* — The behavior exhibited by the Sensor-AI-MNS object is inherited from the Sensor-AI object defined in SEMI E54.1 [3]. Additional specific behavior associated with the Sensor-AI-MNS object is defined below.

8.7.3.1 *Sensor-AI-MNS OPERATING Application Process* — A reading is retrieved from the physical median noise sensor. This reading is maintained in a rolling count of manufacturer specified samples and then the median value of the manufacturer specified samples is calculated. This median reading becomes the input to the gain formula to generate the *value* attribute as referenced in SEMI E54.1 [3]. This process is executed only when the Device Manager Object is in the EXECUTING state as defined in SEMI E54.1. When not in the EXECUTING state, the value of the "*Reading Valid*" attribute shall be set to "Invalid". When in one of the sub-states of the EXECUTING state, the validity of the "*Value*" attribute shall be manufacturer specific.

8.8 *Sensor-AI-Counter Object* — The Sensor-AI-Counter object inherits the attributes, services, and behavior of the Sensor-AI as defined in SEMI E54.1 [3]. The Sensor-AI-Counter is the device component responsible for maintaining a count of the number of particles deposited in each bin and then making the value available through the "*Value*" attribute.

8.8.1 *Sensor-AI-Counter Object Attributes* — The attributes provided by the Sensor-AI object are defined in SEMI E54.1 [3]. The Sensor-AI object attribute content and its attribute extensions to support the Sensor-AI-Counter object is listed in Table 19.

Table 19 Sensor-AI and Sensor-AI-Counter Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Value	SaiA16	R	Yes	UDINT
Data Type	SaiA66	R	Yes	USINT
Data Units	SaiA67	R	Yes	Enumerated, UINT
Reading Valid	CounterA1	R	Yes	Enumerated, Byte
Full Scale	CounterA2	R	Yes	UDINT
Alarm Settling Time	CounterA3	R	Yes	UINT
Warning Settling Time	CounterA4	R	Yes	UINT
Upper Size	CounterA5	RW (See NOTE 1.)	Yes	REAL
Lower Size	CounterA6	RW (See NOTE 1.)	Yes	REAL
Reserved	CounterA7–CounterA64	—	—	Reserved for future expansion.
Manufacturer Specified	> CounterA64	—	—	Manufacturer Specific attributes

NOTE 1: Consult the manufacturer's specification for specific "Write" capabilities of this attribute.

8.8.1.1 *Value* — The attribute that maintains the particle count in the bin.

8.8.1.2 *Data Type* — The attribute that defines the format of the data associated with the "*Value*" attribute.

8.8.1.3 *Data Units* — The attribute which specifies the units for the "*Value*" attribute. This attribute is an enumerated UINT that can take on one of the following values: raw counts, count per second, counts per milliliter, and counts per gallon. (See Appendix 1 of SEMI E54.1.)

8.8.1.4 *Reading Valid* — An attribute which specifies whether the "*Value*" attribute contains a valid value. This attribute is an enumerated byte that can take on one of the following values:

0 = Invalid, or
1 = Valid.

8.8.1.5 *Full Scale* — An attribute which specifies the maximum value allowed for the "*Value*" attribute.

8.8.1.6 *Alarm Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before an alarm is generated.

8.8.1.7 *Warning Settling Time* — An attribute which specifies the maximum time in milliseconds that the "*Value*" attribute may take to stabilize before a warning is generated.

8.8.1.8 *Upper Size* — An attribute which specifies the upper bound of the particle size, in microns, included in the bin counts.

8.8.1.9 *Lower Size* — An attribute which specifies the lower bound of particle size, in microns, included in the bin counts.

8.8.1.10 *Initial and Default Values*

Table 20 Sensor-AI and Sensor-AI-Counter Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Value	0	0	
Data Type	LVV	UDINT	
Data Units	LVV	0	Raw counts
Reading Valid	0	0	Invalid
Full Scale	LVV	0XFFFFFFFF	
Alarm Settling Time	LVV	1000	Milliseconds
Warning Settling Time	LVV	1000	Milliseconds
Upper Size	LVV	Manufacturer Specified	Manufacturer Specific
Lower Size	LVV	Manufacturer Specified	Manufacturer Specific

8.8.2 *Sensor-AI-Counter Object Services* — The services provided by the Sensor-AI-Counter object are defined in SEMI E54.1 [1]. There are no additional services required for the Sensor AI-Counter object.

8.8.3 *Sensor-AI-Counter Object Behavior* — The behavior exhibited by the Sensor-AI-Counter object is inherited from the Sensor-AI object defined in SEMI E54.1. Additional specific behavior associated with the Sensor-AI-Counter object is defined below.

8.8.3.1 *Sensor-AI-Counter OPERATING Application Process*

8.8.3.1.1 A reading is retrieved from the physical median noise sensor. This reading is filtered through an analysis of a manufacturer specified number of samples. The *value* attribute is set to this processed reading. This process is called "counting" and is executed only when the Device Manager Object is in the EXECUTING state as defined in the Common Device Model.

8.8.3.1.2 Whenever an Interlock alarm, Sensor Not Detected alarm, Leak Detected alarm, and Sensor Type Change alarm is active the ISPM device shall stop "counting" until the alarm clears (see Section 8.2).

8.8.3.1.3 The ISPM is a device that measures and counts particles. As part of counting, particles are classified by size and count and accumulated in bins over time intervals then reported. The number of bins varies by vendor and device model.

8.8.3.1.4 The *value* attributes for all Sensor-AI-Counter objects, shall be held at zero unless the device laser is on and stable (i.e., Laser Status attribute of Device Manager Object has a value indicating "LASER ON AND STABLE"). The *value* attribute of any Sensor-AI-Counter object may be cleared (to zero) in a counter sensor after being read; the conditions under which this clearing behavior occurs may be further specified in the associated Network Communication Standard or by the manufacturer. The *value* shall also be cleared (to zero) by a valid "Clear Counts" service from the SAC object or the "Reset" service issued to the Sensor AI Class Object.

8.8.3.1.5 When attempting to set the "Upper Size" attribute to a value above the capability of the sensor, or to a value equal to or below the current "Lower Size" attribute value, an error response shall be generated indicating an invalid operation has been attempted. Similarly, an attempt to set the "Lower Size" attribute to a value below the capability of the sensor, or to a value equal to or above the current "Upper Size" attribute value, an error response shall be generated indicating an invalid operation has been attempted.

8.9 *Assembly-ISPM Objects* — Assembly-ISPM objects inherit attributes, services, and behavior from the Assembly object. The Assembly object is the device component which provides a mechanism of grouping more than one attribute from one or more objects into a single data structure for communication over the network.

8.9.1 Table 21 identifies the Assembly-ISPM objects defined for the ISPM device.

Table 21 Assembly List

Object	*Access Network*	*Required*	*Form*
Assembly-ISPM#1	R	Yes	Status and Counters (Counters ≤ 1024); Default Assembly
Assembly-ISPM#2	R	No	Status, Count and Counters (Counters ≤ 1024)
Assembly-ISPM#3	R	No	Status Diagnostics, and Counters (Counters ≤ 1024)
Assembly-ISPM#4	R	No	Status, Tool State, Time Stamp, Duration, and Counters (Counters ≤ 1024)
Assembly-ISPM#5	R	No	Status, Tool State, Time Stamp, Duration, Diagnostics, and Counters (Counters ≤ 1024)
Assembly-ISPM#6	R	Yes	Status
Assembly-ISPM#7	R	No	Exception Detail Alarm
Assembly-ISPM#8	R	No	Exception Detail Warning
Assembly-ISPM#9	R	No	Exception Detail Alarm and Exception Detail Warning
Assembly-ISPM#40	RW	No	Device Configuration

8.9.2 *Assembly-ISPM Objects Attributes* — Table 22 provides a list of attributes common to all Assembly-ISPM object types.

Table 22 Assembly-ISPM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Data (See NOTE 1.)	A1	RW	Yes	Structure as defined below

NOTE 1: Inherited from the Assembly object as shown in Figure 1.

8.9.2.1 *Data Attribute Format for Assembly-ISPM Objects* — The Data attribute of all Assembly-ISPM objects is a structured attribute containing an ordered list of attributes within its structure. In the following tables (23 through 31), the structure of the Data attribute for each of the Assembly-ISPM object types is defined.

Table 23 Assembly-ISPM #1 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #1 Value
3	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #2 Value
.	ISPMD16	SaiA16	Sensor-AI-Counter #3 to Sensor-AI-Counter-ISPM #N-1 Value
N≤1024 (See NOTE 1.)	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #N Value

NOTE 1: "N" is the value of the Sensor-AI-Counter object attribute "Number of Bins". Note also that the number of bins reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 24 Assembly-ISPM #2 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	ISPMD2	SacA65	SAC Number of Bins
3	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #1 Value
4	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #2 Value
.	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #3 to Sensor-AI-Counter-ISPM #N-1 Value
N≤1024 (See NOTE 1.)	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #N Value

NOTE 1: "N" is the value of the Sensor-AI-Counter object attribute "Number of Bins". Note also that the number of bins reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 25 Assembly-ISPM #3 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	ISPMD3	SaiA16	Sensor-AI-LCS Value (Laser Current Diagnostic)
3	ISPMD4	SaiA16	Sensor-AI-SLS Value (Stray Light Diagnostic)
4	ISPMD5	SaiA16	Sensor-AI-MNS Value (Median Noise Diagnostic)
5	–	–	Reserved (2 bytes)
6	ISPMD2	SacA65	SAC Number of Bins
7	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #1 Value
8	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #2 Value
.	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #3 to Sensor-AI-Counter-ISPM #N-1 Value

Data Index	Source Object ID	Source Attribute ID	Description
N ≤ 1024 (See NOTE 1.)	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #N Value

NOTE 1: “N” is the value of the Sensor-AI-Counter object attribute “Number of Bins”. Note also that the number of bins reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 26 Assembly-ISPM #4 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	DM1	A35	Device Manager Tool State
3	DM1	A41	Device Manager Time Stamp
4	ISPMD2	SacA67	SAC Duration
6	ISPMD2	SacA65	Sensor-AI-Counter Number of Bins
7	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #1 Value
8	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #2 Value
.	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #3 to Sensor-AI-Counter-ISPM #N-1 Value
N ≤ 1024 (See NOTE 1.)	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #N Value

NOTE 1: “N” is the value of the Sensor-AI-Counter object attribute “Number of Bins”. Note also that the number of bins reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 27 Assembly-ISPM #5 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	DM1	A12	Device Manager Exception Status
2	DM1	A35	Device Manager Tool State
3	DM1	A41	Device Manager Time Stamp
4	ISPMD2	SacA67	SAC Duration
5	ISPMD3	SaiA16	Sensor-AI-LCS Value (Laser Current Diagnostic)
6	ISPMD4	SaiA16	Sensor-AI-SLS Value (Stray Light Diagnostic)
7	ISPMD5	SaiA16	Sensor-AI-MNS Value (Median Noise Diagnostic)
8	–	–	Reserved (2 bytes)
9	ISPMD2	SacA65	SAC Number of Bins
10	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #1 Value
11	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #2 Value

Data Index	Source Object ID	Source Attribute ID	Description
.	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #3 to Sensor-AI-Counter-ISPM #N-1 Value
N ≤ 1024*	ISPMD16	SaiA16	Sensor-AI-Counter-ISPM #N Value

NOTE 1: "N" is the value of the Sensor-AI-Counter object attribute "Number of Bins". Note also that the number of bins reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 28 Assembly-ISPM #6 Object Data List

Data Index	Source Object ID	Source Attribute ID	Description
1	DM1	A12	Device Manager Exception Status

Table 29 Assembly-ISPM #7 Object Data List

Data Index	Source Object ID	Source Attribute ID	Description
1	DM1	A12	Device Manager Exception Status
2	DM1	A13	Device Manager Exception Detail Alarm

Table 30 Assembly-ISPM #8 Object Data List

Data Index	Source Object ID	Source Attribute ID	Description
1	DM1	A12	Device Manager Exception Status
2	DM1	A14	Device Manager Exception Detail Warning

Table 31 Assembly-ISPM #9 Object Data List

Data Index	Source Object ID	Source Attribute ID	Description
1	DM1	A12	Device Manager Exception Status
2	DM1	A13	Device Manager Exception Detail Alarm
3	DM1	A14	Device Manager Exception Detail Warning

Table 32 Assembly-ISPM #40 Object Data List

Data Index	Source Object ID	Source Attribute ID	Description
1	DM1	A33	Device Manager Gain
2	DM1	A13	Device Manager Filter Bandwidth
3	ISPMD2	SacA65	SAC Number of Bins
4	ISPMD3	SaiA73	Sensor-AI-LCS Alarm Trip Point High (See NOTE 1.)
5	ISPMD3	SaiA76	Sensor-AI-LCS

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
			Warning Trip Point High (See NOTE 1.)
6	ISPMD3	SaiA74	Sensor-AI-LCS Alarm Trip Point Low (See NOTE 1.)
7	ISPMD3	SaiA77	Sensor-AI-LCS Warning Trip Point Low (See NOTE 1.)
8	ISPMD4	SaiA73	Sensor-AI-SLS Alarm Trip Point High (See NOTE 1.)
9	ISPMD4	SaiA76	Sensor-AI-SLS Warning Trip Point High (See NOTE 1.)
10	ISPMD4	SaiA74	Sensor-AI-SLS Alarm Trip Point Low (See NOTE 1.)
11	ISPMD4	SaiA77	Sensor-AI-SLS Warning Trip Point Low (See NOTE 1.)
12	ISPMD5	SaiA73	Sensor-AI-MNS Alarm Trip Point High (See NOTE 1.)
13	ISPMD5	SaiA76	Sensor-AI-MNS Warning Trip Point High (See NOTE 1.)
14	ISPMD5	SaiA74	Sensor-AI-MNS Alarm Trip Point Low (See NOTE 1.)
15	ISPMD5	SaiA77	Sensor-AI-MNS Warning Trip Point Low (See NOTE 1.)

NOTE 1: Objects to which these attributes are linked are optional. If the associated object is not supported in the ISPM device, the data field for the associated attribute in this assembly is set to zero and should be interpreted as having no meaning.

SEMI E54.11-0301
SPECIFIC DEVICE MODEL FOR ENDPOINT DEVICES

This specific device model was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org January 2001; to be published March 2001.

1 Purpose

1.1 This specification is part of a suite of standards that specify the implementation of SEMI standards for the Sensor/Actuator Network. The specific purpose of this specification is to describe a network independent application model comprised of device objects that are common to all Endpoint Devices on a semiconductor equipment Sensor/Actuator communication network.

2 Scope

2.1 An Endpoint device (EPD) is a device that measures and monitors process characteristics to determine when a specific threshold or event has been obtained usually to signal the completion of a process or process step. These endpoint devices are, but not limited to, devices that may classify a process endpoint by determining the size and count of particles in the process environment, detecting and determining optical light from a sample region of the environment's space, or determining motor current of an equipment component.

2.2 This specification specifically addresses the minimum attributes, services and behavior an Endpoint (EPD) device must support to be interoperable on the Sensor/Actuator Network.

2.3 This specification is intended to ensure a high-degree of device interoperability on the Sensor/Actuator Network, while still allowing flexibility for product differentiation and technology evolution.

2.4 The model specified in this specification is used in conjunction with the Sensor/Actuator Network Common Device Model (CDM) to completely describe the Endpoint device (EPD) as it appears from the network interface.

2.5 This specification, together with the Sensor/Actuator Network Standard, the Sensor/Actuator Network Common Device Model, and a Sensor/Actuator Network Communication Specification, form a complete interoperability specification for the EPD.

2.6 To comply with this specification, a device must implement and support, at a minimum, the required attributes, services, and behavior identified in these documents. Support for optional attributes, services and behavior is not required to be compliant to this specification. Optional attributes, services, and behavior are specified in these documents to promote further device interoperability as features evolve and are adopted by more manufacturers. If optional attributes, services, and behavior are implemented for this device they must be implemented as identified in this document.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use

3 Limitations

3.1 This specification is a companion to a suite of specifications that together make up the Sensor/Actuator Network Communication standard. Therefore, using portions of this specification that relate to network communications necessarily requires an understanding of the associated network specification.

3.2 As this document is a specification for the Endpoint Device Model, it does not contain any definition of objects, attributes, services, or behavioral descriptions that are already defined in the Sensor/Actuator Network Common Device Model (CDM). Additional attributes, attribute assignments, services and/or service parameters that are Endpoint Device specific and/or implementation specific are contained in this specification.

3.3 While this specification is sufficient to completely describe the EPD as it appears from the network, it does not fully describe behavior of a specific endpoint device type which is not visible from the network. This allows flexibility in implementation techniques and product differentiation between manufacturers. Manufacturer specific objects may be defined by the manufacturer but are, by definition, outside the scope of this standard.

3.4 This specification is compatible, but not compliant with SEMI E39. This means that although this specification does not require compliance with SEMI E39, it is extensible such that implementations may be developed that are fully compliant with both standards. Note that the concepts and terminology of this specification are compatible with those of SEMI E39.

However, SEMI E39 has specific requirements that are intended for higher level applications and thus are not applied to the Endpoint Device Model.

3.5 Operation over the entire range specified for an attribute within a specific object is not a requisite for compliance with this specification.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.1— Standard for Sensor/Actuator Network Common Device Model

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *EP* — an EPD sensor named Endpoint.

5.2 *Definitions*

5.2.1 *Endpoint Device (EPD)* — a self-contained device, consisting of device specific signal-processing electronics, which is capable of monitoring and measuring the occurrence of a process endpoint.

5.2.2 *Endpoint Detection Event* — consists of the device operation of monitoring, measuring, analyzing, waiting, and reporting endpoint.

5.3 This document inherits the terminology defined by SEMI E54.1

5.3.1 *Attribute*

5.3.2 *Behavior*

5.3.3 *Boolean (BOOL)*

5.3.4 *Byte*

5.3.5 *Character*

5.3.6 *Common Device Model (CDM)*

5.3.7 *Data Type*

5.3.8 *Data Units*

5.3.9 *Device*

5.3.10 *Device Manager (DM) Object*

5.3.11 *Device Model*

5.3.12 *Double Integer (DINT)*

5.3.13 *Enumerated Byte*

5.3.14 *Full Scale Range*

5.3.15 *Instance*

5.3.16 *Last Valid Value (LVV)*

5.3.17 *Long Integer (LINT)*

5.3.18 *Long Real (LREAL)*

5.3.19 *Manufacturer*

5.3.20 *Nibble*

5.3.21 *Null Character*

5.3.22 *Object*

5.3.23 *Real (REAL)*

5.3.24 *S, A, and C Objects*

5.3.25 *Sensor Actuator Controller (SAC) Object*

5.3.26 *Service*

5.3.27 *Signed Integer (INT)*

5.3.28 *Short Integer (SINT)*

5.3.29 *State Diagram*

5.3.30 *Test String*

5.3.31 *Unsigned Double Integer (UDINT)*

5.3.32 *Unsigned Double Long Integer (UDLINT)*

5.3.33 *Unsigned Integer (UINT)*

5.3.34 *Unsigned Long Integer (ULINT)*

5.3.35 *Unsigned Short Integer (USINT)*

6 Requirements and Specifications

6.1 In order to implement this standard in an Endpoint Device, it is necessary to also implement SEMI E54.1 and one of the Sensor/Actuator Network Communication Standards (SEMI E54.4–E54.9). See Section 3 for more information on a complete interoperability standard.

6.2 This specification also requires the implementation of a Date_And_Time data structure used to represent the current device Date and Time. Table 1 defines the format of the Date_And_Time data type.

Table 1 Date_And_Time Format

Data Item	*Description*	*Range*
1	Number of milliseconds since midnight	Unsigned Double Integer (UDINT)
2	Number of days since 1/1/72	Unsigned Integer (UINT)

7 Conventions

7.1 This document embraces the conventions and notations stated in section 6 of SEMI E54.1.

8 Device High Level Structure

8.1 *General Description*

8.1.1 The high-level object view of an Endpoint Device (EPD) profile is shown in Figure 1.

8.1.2 Note that the profile for an "EPD Device" object is depicted in Figure 1 only for the purposes of illustrating a high level view of the device and its component objects. In the context of this document, this object is not addressable, does not have addressable attributes, does not have accessible services and, does not exhibit any defined behavior.

8.1.3 In the remainder of this section, this document defines in detail the component objects unique to the EPD device. References, rather than definitions, are included for the DM, the SAC and other objects defined in SEMI E54.1.

8.1.4 Many of the objects defined in this document inherit properties from other objects. The properties inherited include attribute, service and behavior definitions. These other objects are specified here or in SEMI E54.1.

8.1.5 This document provides for future extensions as well as manufacturer specific enhancements by reserving object attribute identifiers and object service identifiers. Specifically all object definitions in this document specify or reserve the first 64 attribute identifiers (A1 through A64) and the first 64 service identifiers (S1 through S64) allowing manufacturers to specify identifiers beyond these ranges. Additionally, byte enumerated attributes are specified or reserved from 0 to 63 allowing manufacturers to specify an enumeration beyond this range (64 to 255).

8.1.6 *Endpoint Device (EPD) Description* — An Endpoint device profile is composed of the component objects and object relationships shown in Figure 1.

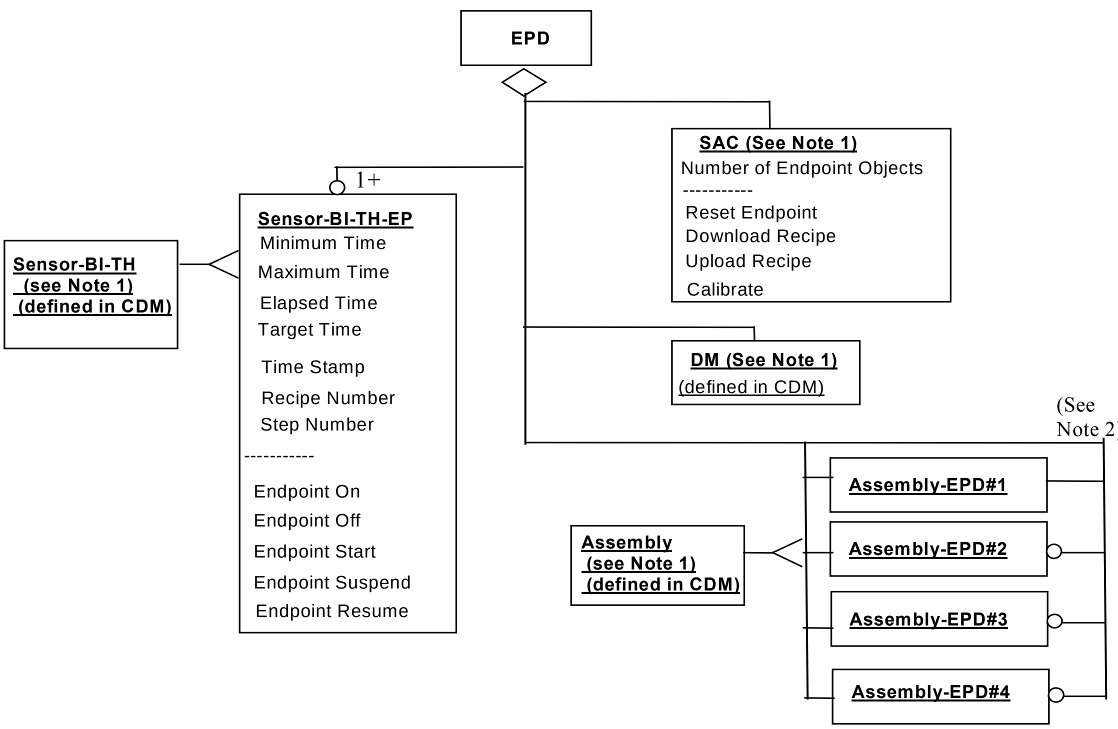


Figure 1
Endpoint Device High Level Structure

NOTE 1: The Sensor-BI-TH, DM, SAC, and Assembly are defined in the CDM. Additional attributes and services are added to support the EPD.

NOTE 2: Assembly-EPD #1 object is required. Other Assembly-EPD objects are optional.

8.1.7 *General Requirements*

8.1.7.1 *Device Objects* — All objects are defined in terms of their object name and Class/Object identifier. Identifiers for all objects described in this document are summarized in Table 2.

Table 2 Endpoint Device Objects

Referenced Document Section	*Object Name*	*Class/Object Identifier*	*Minimum #*	*Maximum #*
8.2	Device Manager (DM)	EPD1	1	1
8.3	Sensor Actuator Controller (SAC)	EPD2	1	1
8.5	Sensor-BI-TH-EP	EPD3	1	1024
8.6	Assembly-EPD#1	EPD4	1	1
8.6	Assembly-EPD#2	EPD5	0	1
8.6	Assembly-EPD#3	EPD6	0	1
8.6	Assembly-EPD#4	EPD7	0	1
—	Reserved	EPD7 – EPD63	-	—
—	Manufacturer Specified	> EPD64	-	—

8.1.7.2 *Object Services* — Not all object services listed in this document can necessarily be requested over the network. They are included in this document because their behavior may generate network activity.

8.1.7.3 *Object Behavior* — A network specific service error response is generated for all service requests received over the network that are not supported by the object, or contain a parameter value which is beyond the supported range, or which is otherwise invalid.

8.2 *Device Manager Object (DM)* — The Device Manager object is the device component responsible for managing and consolidating the device operation as specified in SEMI E54.1. The following sections specify the components of the DM object that are not specified in the Common Device Model or require further definition than specified in SEMI E54.1.

8.2.1 *Device Manager Object Attributes* — Required and optional DM object attributes are listed in Table 3.

Table 3 DM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Device Type	A1	R	Yes	Refer to SEMI E54.1.
Exception Detail Alarm	A13	R	No	Refer to SEMI E54.1.
Exception Detail Warning	A14	R	No	Refer to SEMI E54.1.
Reserved	A33-A64	—	—	Reserved for SDM future expansion
Manufacturer Specified	> A64	—	—	Manufacturer Specific attributes

8.2.1.1 *Device Type* — An attribute that uniquely identifies the type of the device on the network. The device type attribute is assigned as follows:

Endpoint Device = “EPD”

NOTE 2: If the “Endpoint Device” functionality is implemented by another Sensor/Actuator Network Specific Device Model, the ‘*Device Type*’ attribute value may be specified by the manufacturer to identify the other Specific Device Model.

8.2.1.2 *Exception Detail Alarm (Optional)* — An attribute that identifies the detailed alarm status of the device. Table 4 defines the bit assignments associated with the alarm exception detail.

Table 4 Exception Detail Alarm Bit Assignments

Bit	*Device Specific Alarm[0]*
0	Unexpected Conditions Detected
1	Reserved
2	Sensor Not Detected
3	Reserved
4	Reserved
5	Reserved
6	Reserved
7	Endpoint Failure

8.2.1.3 *Exception Detail Warning (Optional)* — An attribute that identifies the detailed warning status of the device. Table 5 defines the bit assignments associated with the warning exception detail.

Table 5 Exception Detail Warning Bit Assignments

Bit	*Device Specific Warning[0]*
0	Unexpected Conditions Detected
1	Reserved
2	0
3	Reserved
4	Reserved
5	Reserved
6	Reserved
7	Endpoint Warning

8.2.1.4 *Manufacturer Exception Detail Size (Optional)* — An attribute that specifies the number of exception detail bytes included in the alarm or warning details.

8.2.1.5 *Initial and Default Values*

Table 6 DM Object Attribute Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Device Type	EPD	EPD	EPD = Endpoint Device
Exception Detail Alarm	0	0	
Exception Detail Warning	0	0	

8.2.2 *Device Manager Object Services* — The services provided by the Device Manager object are defined in SEMI E54.1. There are no additional services required for the Device Manager object.

8.2.3 *Device Manager Object Behavior* — The behavior exhibited by the Device Manager object is defined in SEMI E54.1. There is no additional behavior specified for the Device Manager object.

8.3 *Sensor Actuator Controller Object (SAC)* — The Sensor Actuator Controller object is the device component responsible for coordinating the interaction of the EPD device with the sensory/actuation/control environment as specified in SEMI E54.1. The following sections specify the components of the SAC object that are not specified in the Common Device Model or require further definition than specified in the Common Device Model.

8.3.1 *Sensor Actuator Controller Object Attributes* — The attributes provided by the Sensor Actuator Controller object are defined in SEMI E54.1. Table 7 contains the additional attributes required for the Sensor Actuator Controller object.

Table 7 SAC Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Number of Endpoint Objects	SacA65	R	No	UINT

8.3.1.1 *Number of Endpoint Objects* — An attribute that specifies the number of endpoint objects in the device. This value represents the number of Sensor-BI-TH-EP objects in the device. If this attribute is not supported then the default value of 1 Endpoint object is supported.

8.3.1.2 *Initial and Default Values*

Table 8 SAC Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Number of Endpoint Objects	Manufacturer Specified	Manufacturer Specified	There must be at least one Endpoint object.

8.3.2 *Sensor Actuator Controller Object Services* — The services provided by the Sensor Actuator Controller object are defined in SEMI E54.1. Table 9 contains the additional services required for the Sensor Actuator Controller object.

Table 9 SAC Object Services

Service	*Service Identifier*	*Type*	*Description*
Reset Endpoint	S33	R	Used to 'Reset' all of the Sensor-BI-TH-EP sensor objects.
Download Recipe	S34	R	Used to download the Sensor-BI-TH-EP sensor objects with manufacturer specific recipe data.
Upload Recipe	S35	R	Used to upload, from the device, manufacturer specific recipe data.
Calibrate	S36	R	Used to execute a device manufacture specific calibration procedure.
Reserved	S37–S64	—	Reserved for future expansion
Manufacturer Specified	> S64	—	Manufacturer Specific services

8.3.2.1 *Reset Endpoint (Optional)* — This service is used to instruct all of the Sensor-BI-TH-EP objects to perform a 'Reset' of their endpoint monitoring and measuring events. A one-time reset of their respective Sensor-BI-TH-EP attributes is performed. There are no parameters required for this service.

8.3.2.2 *Download Recipe (Optional)* — This service is used to set the recipe parameters associated with the endpoint sensor or a specific Sensor-BI-TH-EP object. The format and type of data comprising recipe data and the mechanism implemented to interrupt recipe data and distribute its contents to the appropriate Sensor-BI-TH-EP object is manufacturer specific. The parameter 'Recipe Data' may be a formatted data structure or a list of individual data items. The following table describes the parameters specified for this service.

Table 10 Download Recipe Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Recipe Data #1	M	U	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #2	M	U	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #3 through Recipe Data #N-1	M	U	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #N	M	U	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.

8.3.2.3 *Upload Recipe (Optional)* — This service is used to read the recipe parameters associated with the endpoint sensor or a specific Sensor-BI-TH-EP object. The format and type of data comprising recipe data and the mechanism implemented to assemble recipe data to be read is manufacturer specific. The parameter 'Recipe Data' may be a formatted data structure or a list of individual data items. The following table describes the parameters specified for this service.

Table 11 Upload Recipe Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Recipe Data #1	M	M	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #2	M	M	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #3 through Recipe Data #N-1	M	M	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Recipe Data #N	M	M	Manufacturer Specific	The recipe parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.

8.3.2.4 *Calibrate (Optional)* — This service is used to set the calibration parameters associated with the endpoint sensor or a specific Sensor-BI-TH-EP object. The format and type of data comprising calibration data and the mechanism implemented to interrupt calibration data and execute a calibration algorithm is manufacturer specific. The parameter 'Calibration Data' may be a formatted data structure or a list of individual data items. The following table describes the parameters specified for this service.

Table 12 Calibration Service Parameter Definitions

Parameter	*Request/ Indication*	*Response/ Confirmation*	*Data Type*	*Description*
Calibration Data #1	C	C	Manufacturer Specific	The calibration parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Calibration Data #2	C	C	Manufacturer Specific	The calibration parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Calibration Data #3 through Calibration Data #N-1	C	C	Manufacturer Specific	The Calibration parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.
Calibration Data #N	C	C	Manufacturer Specific	The calibration parameter format is manufacturer specific. The implementation behavior required to support this service is also manufacturer specific.

8.3.3 *Sensor Actuator Controller Object Behavior*

8.3.3.1 The behavior exhibited by the Sensor Actuator Controller object is defined in SEMI E54.1. Additional behavior is detailed below.

8.3.3.2 The *"Reset Endpoint"* service will issue an "Endpoint Restart" object service to each Sensor-BI-TH-EP sensor object.

8.4 *Sensor-BI-TH Object* — The Sensor-BI object is the device component responsible for coordinating the behavior common to all Boolean input threshold sensor elements in the EPD device as specified in SEMI E54.1.

8.4.1 *Sensor-BI-TH Object Attributes* — The attributes provided by the Sensor-BI-TH object are defined in SEMI E54.1. There are no additional attributes required for the Sensor-BI-TH object.

8.4.2 *Sensor-BI-TH Object Services* — The services provided by the Sensor-BI-TH object are defined in SEMI E54.1. There are no additional services required for the Sensor-BI-TH object.

8.4.3 *Sensor-BI-TH Object Behavior* — The behavior exhibited by the Sensor-BI-TH object is defined in SEMI E54.1. There is no additional behavior required for the Sensor-BI-TH object.

8.5 *Sensor-BI-TH-EP Object* — The Sensor-BI-TH-EP (Endpoint) object inherits the attributes, services, and behavior of the Sensor-BI-TH as defined in SEMI E54.1. The Sensor-BI-TH-EP is the device component responsible for retrieving a reading, or readings, from the device specific signal-processing sensors, optionally processing the readings with a manufacturer specified algorithm, or algorithms, and then making the endpoint result available through the "*Value*" attribute.

8.5.1 *Sensor-BI-TH-EP Object Attributes* — The attributes provided by the Sensor-BI-TH object are defined in SEMI E54.1. The Sensor-BI-TH object attribute content and its attribute extensions to support the Sensor-BI-TH-EP object are listed in the table below.

Table 13 Sensor-BI, Sensor-BI-TH, and Sensor-BI-TH-EP Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Value	SbithepA16	R	Yes	BOOL
Reading Valid	SbithA64	R	Yes	BOOL
State	SbithA65	R	No	Enumerated, Byte
Status	SbithA66	R	No	Enumerated, Byte
Minimum Time	EpA1	RW*	No	UDINT
Maximum Time	EpA2	RW*	No	UDINT
Target Time	EpA3	RW*	No	UDINT
Elapsed Time	EpA4	R	No	UDINT
Time Stamp	EpA5	R	No	Date_And_Time
Recipe Identifier	EpA6	RW*	No	Text String
Step Identifier	EpA7	RW*	No	Text String
Reserved	EpA8 –EpA64	—	—	Reserved for future expansion
Manufacturer Specified	> EpA64	—	—	Manufacturer Specific attributes

NOTE 1: "*" Indicates that the specific attribute is nonvolatile. Nonvolatile requires that the current attribute value be maintained through a component power cycle.

8.5.1.1 *Value* — The attribute that maintains the current endpoint event result. The value of the *'Value'* attribute is read as a Boolean (True or False) endpoint detection event result.

8.5.1.2 *Reading Valid* — An attribute which specifies whether the "*Value*" attribute contains a valid value. This attribute is Boolean that can take on one of the following values:

0 = INVALID
1 = VALID

NOTE 3: The 'Reading Valid' attribute is identified as an optional attribute of the SBITH object class but is identified as a required attribute for the SBITHEP object class.

8.5.1.3 *State* — An attribute that records the current state of the endpoint object. This attribute is an enumerated byte. The possible enumeration and the requirement for support are as follows:

0 = ENDPOINT OFF (required)
1 = ENDPOINT IN PROCESS (required)
2 = ENDPOINT IDLE (optional)
3 = ENDPOINT SUSPENDED (optional)
4 = ENDPOINT FAILURE (optional)

5-63 = Reserved
64-255 = Manufacturer Specified (optional)

8.5.1.4 *Status* — An attribute which specifies whether endpoint detection event reporting is active based upon the services 'Endpoint On', 'Endpoint Start', and 'Endpoint Off or On'. This attribute is an enumerated byte that can take on one of the following values:

0 = Endpoint Off
1 = Endpoint On

8.5.1.5 *Minimum Time* — An attribute that specifies the minimum time in milliseconds for an endpoint detection event. No attempt to report an endpoint detection event will take place until the minimum time specified has expired.

8.5.1.6 *Maximum Time* — An attribute that specifies the maximum time in milliseconds for an Endpoint detection event before an alarm is reported.

8.5.1.7 *Target Time* — An attribute that specifies the expected time in milliseconds for an Endpoint detection event.

8.5.1.8 *Elapsed Time* — An attribute that specifies in milliseconds the amount of time that has elapsed since the beginning of the current endpoint detection event. This attribute will behave as a count up timer that is frozen when the endpoint event is detected.

8.5.1.9 *Time Stamp* — An attribute that specifies the time when the endpoint detection event completed.

8.5.1.10 *Recipe Identifier* — An attribute that specifies a manufacturer specific endpoint algorithm or algorithms to be utilized to determine the current endpoint detection event. The interpretation of this attribute is manufacturer specific.

8.5.1.11 *Step Identifier* — An attribute that specifies a process recipe step that is associated with the current endpoint detection recipe and/or event. The interpretation of this attribute is manufacturer specific.

8.5.1.12 *Initial and Default Values*

Table 14 Sensor-BI and Sensor-BI-EP Object Attributes Initial and Default Values

Attribute	*Initial Value*	*Default Value*	*Comment*
Value	FALSE	FALSE	
Reading Valid	0	0	Invalid Reading
State	LVV	0	ENDPOINT OFF
Status	0	Endpoint Off	
Minimum Time	LVV	0	Milliseconds
Maximum Time	LVV	0	Milliseconds
Target Time	LVV	0	Milliseconds
Elapsed Time	LVV	0	Milliseconds
Time Stamp	LVV	Manufacture Specified	Date_And_Time
Recipe Identifier	LVV	Manufacture Specified	
Step Identifier	LVV	Manufacturer Specified	

8.5.2 *Sensor-BI-EP Object Services* — The services provided by the Sensor-BI-EP are inherited from the Sensor-BI object defined in SEMI E54.1. The Sensor-BI-EP object supports the additional services listed in Table 15 below.

Table 15 Sensor-BI-EP Object Services

Service	*Service Identifier*	*Type*	*Description*
Endpoint On	S1	R	Used to prompt the endpoint object to go from the ENDPOINT OFF state to ENDPOINT ON/ENDPOINT IDLE state as defined by the State and Status attribute.
Endpoint Off	S2	R	Used to prompt the endpoint object to go immediately to the ENDPOINT OFF state as defined by the State and Status attribute. All endpoint detection processes are aborted and all active timers are stopped.
Endpoint Start	S3	R	Used to prompt the endpoint object to go from the ENDPOINT OFF or ENDPOINT IDLE (optional) state to the ENDPOINT IN PROCESS state and begin the endpoint detection event process.
Endpoint Suspend	S4	R	Used to prompt the endpoint object to go to the ENDPOINT SUSPENDED state from the ENDPOINT IN PROCESS state. All endpoint detection event processes and active timers are suspended.
Endpoint Resume	S5	R	Used to prompt the endpoint object to go from the ENDPOINT SUSPENDED state to the ENDPOINT IN PROCESS state. All endpoint detection event processes and active timers resume from where they were suspended.
Reserved	S6–S64	—	Reserved for future expansion
Manufacturer Specified	> S64	—	Manufacturer Specific services

8.5.2.1 *Endpoint On (Required)* — This service is used to prompt the endpoint object to go from the ENDPOINT OFF state to the ENDPOINT ON / ENDPOINT IDLE state as defined by the State attribute. If the device does not support the ENDPOINT IDLE state then the endpoint object goes immediately to the ENDPOINT ON / ENDPOINT IN PROCESS state. If the State attribute is already set to ENDPOINT IDLE or ENDPOINT IN PROCESS, the endpoint object is set to the appropriate state. If the device turns on successfully, a “success” response is returned. If the device fails to turn on properly, a “fail” response is returned and the endpoint object remains in the appropriate state.

8.5.2.2 *Endpoint Off (Required)* — This service is used to prompt the endpoint object to go immediately to the ENDPOINT OFF state from the ENDPOINT ON state as defined by the State attribute. All endpoint detection event processes are aborted and all active timers are stopped. If the state attribute is already set to ENDPOINT OFF, the endpoint object remains in the appropriate state. If the device turns off successfully, a “success” response is returned. If the device fails to turn off properly, a “fail” response is returned and the endpoint object remains in the current state.

8.5.2.3 *Endpoint Start (Optional)* — This service is used to prompt the endpoint object to go from the ENDPOINT OFF or ENDPOINT IDLE state to the ENDPOINT IN PROCESS state and begin the endpoint detection event process with the initial endpoint attribute parameter values. If the State attribute is not currently in the ENDPOINT OFF or ENDPOINT IDLE state, an “object state conflict” error response is returned and the endpoint event remains in the appropriate state.

8.5.2.4 *Endpoint Suspend (Optional)* — This service is used to prompt the endpoint object to go from the ENDPOINT IN PROCESS state to the ENDPOINT SUSPENDED state and suspend the endpoint detection event process. All active timers are suspended and held at their current values. If the State attribute is not currently in the ENDPOINT IN PROCESS state, an “object state conflict” error response is returned and the endpoint object remains in the appropriate state. The Endpoint Suspend service is conditional on the Endpoint Resume service being supported.

8.5.2.5 *Endpoint Resume (Optional)* — This service is used to prompt the endpoint object to go from the ENDPOINT SUSPENDED state to the ENDPOINT IN PROCESS state and resume the endpoint detection event process. The process resumes using the endpoint attribute parameter values and timer readings that were saved when the endpoint was suspended by the Endpoint Suspend service request. If the Endpoint Resume service is issued while the State attribute is not in the ENDPOINT SUSPENDED state, an “object state conflict” error response is returned and the endpoint event remains in its existing state. The Endpoint Resume service is conditional on the Endpoint Suspend service being supported.

8.5.3 *Sensor-BI-TH-EP Object Behavior* — The behavior exhibited by the Sensor-BI-TH-EP object is inherited from the Sensor-BI-TH object defined in SEMI E54.1. Additional specific behavior associated with the Sensor-BI-TH-EP object is defined below.

8.5.3.1 *Sensor-BI-EP OPERATING Application Process* — When in the ENDPOINT ON / ENDPOINT IN PROCESS state, the '*Value'* attribute is set to FALSE and the '*Reading Value'* attribute is set to VALID. *A* reading, or readings, may be retrieved from the device physical signal processing electronics. This reading may be filtered, analyzed, and corrected with a manufacturer-specified algorithm. This corrected reading becomes the input to the endpoint formula to generate the 'V*alue'* attribute as referenced in SEMI E54.1. This process is called "endpoint detection" and is executed only when the Sensor-BI-TH-EP object is in the OPERATING state as defined in SEMI E54.1. When an Endpoint event is detected, the '*Value'* attribute is set to TRUE and the '*Reading Valid'* attribute is VALID. When not in the OPERATING state, the value of the '*Reading Valid*' attribute shall be set to INVALID. When in one of the sub-states of the OPERATING state, the validity of the '*Value*' attribute shall be manufacturer specific. Required sub-states within the OPERATING state, descriptions of these sub-states, and a transition matrix associated with these sub-states are given in Figure 2, Table 16 and Table 17 respectively.

8.5.3.1.1 Whenever a 'Sensor Not Detected' alarm, 'Endpoint Failure' alarm or 'Unexpected Conditions Detected' alarm is active, the EPD device shall turn off the endpoint detection event process and hold the device in the ENDPOINT OFF state until the alarm clears (see Section 8.2).

8.5.3.1.2 A device can concurrently monitor and report many endpoint detection events. The number of endpoint detection events varies by vendor and device model.

8.5.3.1.3 The 'Value' attributes for all Sensor-BI-TH-EP objects shall be held at 'FALSE' until a valid endpoint detection event is determined. An endpoint detection event is initiated when the endpoint service request 'Endpoint Start' or Endpoint On (if the state ENDPOINT ON / ENDPOINT IDLE is not supported) is received and the endpoint object can successfully transition to the ENDPOINT ON / ENDPOINT IN PROCESS state.

8.5.3.1.4 When attempting to set the "Minimum Time", "Maximum Time", and "Target Time" attribute to a value above the capability of the endpoint detection event an error response shall be generated indicating an invalid operation has been attempted.

8.5.3.1.5 When attempting to set the "Recipe Identifier" or "Step Identifier" attribute to an identifier outside the range of the endpoint detection event an error response shall be generated indicating an invalid operation has been attempted.

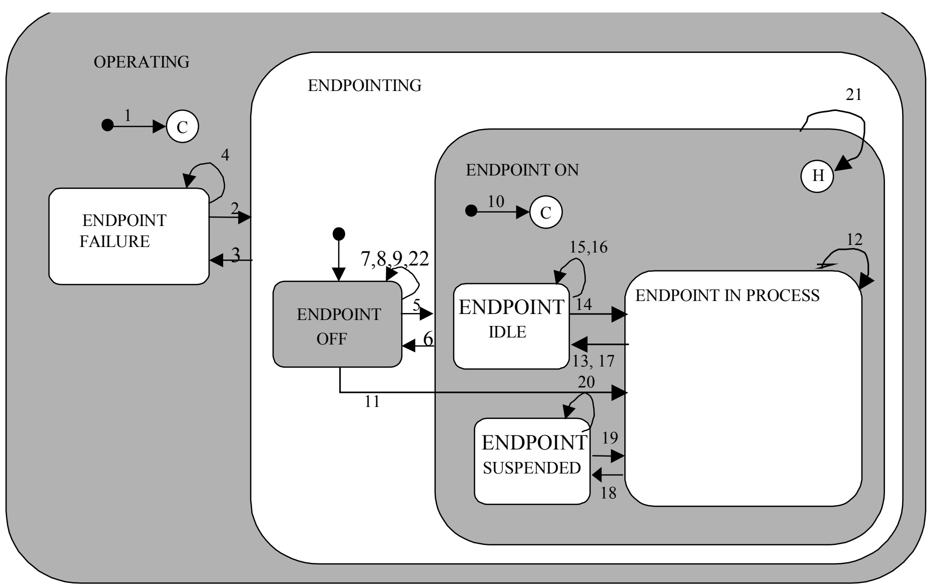


Figure 2
Sensor-BI-TH-EP Object Behavior Within the Operating State

Table 16 Sensor-BI-TH-EP Behavior OPERATING Sub-state Description

State	*Description*
OPERATING	Endpoint is in one of the following enumerated states as indicated in the Sensor-BI-TH-EP State attribute: ENDPOINT FAILURE (optional), ENDPOINT OFF, ENDPOINT IDLE (optional), ENDPOINT IN PROCESS, or ENDPOINT SUSPENDED (optional). Endpoint will respond to Endpoint On and Endpoint Off services as appropriate to move between sub-states within the ENDPOINTING and ENDPOINT ON states.
ENDPOINTING	Endpoint is in one of the following enumerated states as indicated in the Sensor-BI-TH-EP State attribute: ENDPOINT OFF, ENDPOINT IDLE, ENDPOINT SUSPENDED, and ENDPOINT IN PROCESS. Endpoint will respond to Endpoint On, Endpoint Off, Endpoint Start, Endpoint Suspend, and Endpoint Resume services as appropriate to move between sub-states within the ENDPOINTING state.
ENDPOINT OFF	This is a sub-state to ENDPOINTING; Endpoint Off is the status of the Sensor-BI-TH-EP Status attribute and ENDPOINT OFF is the enumerated state of the Sensor-BI-TH-EP State attribute. Endpoint object is **NOT** performing the “endpoint” detection event process. The endpoint object may be downloaded with new recipe parameters when in this state.
ENDPOINT ON	This is a sub-state of ENDPOINTING; Endpoint On is the status of the Sensor-BI-TH-EP Status attribute and ENDPOINT IDLE, ENDPOINT SUSPENDED or ENDPOINT IN PROCESS is the enumerated state of the Sensor-BI-TH-EP State attribute. Endpoint object may not be performing the “endpoint” detection event process.
ENDPOINT IDLE	This is a sub-state to ENDPOINT ON. Endpoint On is the status of the SENSOR-BI-TH-EP Status attribute and ENDPOINT IDLE is the enumerated state of the Sensor-BI-TH-EP State attribute. Endpoint object is not performing the “endpoint” detection event process. The endpoint object may be downloaded with new recipe parameters.
ENDPOINT IN PROCESS	This is a sub-state to ENDPOINT ON. Endpoint On is the status of the Sensor-BI-TH-EP Status attribute and ENDPOINT IN PROCESS is the enumerated state of the Sensor-BI-TH-EP State attribute. Endpoint object is performing the “endpoint” detection event process. The endpoint object may not be downloaded with new recipe parameters when in this state.
ENDPOINT SUSPENDED	This is a sub-state to ENDPOINT ON; Endpoint On is the status of the Sensor-BI-TH-EP Status attribute and ENDPOINT SUSPENDED is the enumerated state of the Sensor-BI-TH-EP State attribute. Endpoint object is **NOT** performing the “endpoint” detection event process. The endpoint object may not be downloaded with new recipe parameters when in this state.
ENDPOINT FAILURE	Endpoint electronics failure; Sensor-BI-TH-EP State attribute is in the enumerated state: ENDPOINT FAILURE. Endpoint is not performing the “endpoint” detection event process. Endpoint cannot move to the ENDPOINTING state until the electronics are repaired or replaced. A Perform Diagnostics or Reset service request to the Device Manager object may be sent to validate that the failure has been cleared. The endpoint object may not be downloaded with new recipe parameters when in this state.

Table 17 Sensor-BI-TH-EP Behavior EXECUTING Sub-state Transition Matrix*

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Entry into OPERATING	Power Up	Conditional: ENDPOINTING or ENDPOINT FAILURE (optional)	If the endpoint electronics are in a failure condition than State is ENDPOINT FAILURE (optional) or ENDPOINTING. If endpoint failure checking is not supported the state is ENDPOINTING / ENDPOINT OFF. Set Status attribute to appropriate value.	Entry state depends on availability of endpoint electronics checking.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
2	ENDPOINT FAILURE	Perform Diagnostics or Reset service request received and device determines that the failure no longer exists or the Endpoint device detects replacement of electronics that caused the failure	ENDPOINTING / ENDPOINT OFF	Set Status attribute to appropriate value.	Endpoint moves to ENDPOINT OFF state.
3	ENDPOINTING	Endpoint device detects an endpoint electronics failure	Conditional: ENDPOINT FAILURE or ENDPOINTING / EDNDPOINT OFF	Set State attribute to appropriate value.	The setting of the Status attribute is manufacturer specific.
4	ENDPOINT FAILURE	Endpoint Off, Endpoint On, Endpoint Start, Endpoint Resume, Endpoint Suspend, Download Recipe, Upload Recipe, and Calibrate request	ENDPOINT FAILURE	Error response	Object cannot move to ENDPOINTING / ENDPOINT OFF state until the electronics are repaired.
5	ENDPOINT OFF	Endpoint On request	Conditional: ENDPOINT ON / ENDPOINT IDLE or ENDPOINT ON / ENDPOINT IN PROCESS	If ENDPOINT IDLE supported: Take the object from the ENDPOINT OFF state to the ENDPOINT IDLE state and wait for an Endpoint Start request. Recipe parameter downloads are allowed. If ENDPOINT IDLE is not supported: Take the object from the ENDPOINT OFF state immediately to the ENDPOINT IN PROCESS state and begin the endpoint detection event process. Set the Status attribute to the appropriate values throughout the transition. Issue an Endpoint On response.	ENDPOINT IDLE is an optional intermediate state between ENDPOINT OFF and ENDPOINT IN PROCESS. Endpoint electronics must not be in failure. Service response is not issued until transition to ENDPOINT IDLE or ENDPOINT IN PROCESS is completed.
6	ENDPOINT ON	Endpoint Off request	ENDPOINT OFF	Stop the “endpoint” detection event process. Issue an Endpoint Off response.	This results in the same state transition as when a valid Abort service request is issued to the device.
7	ENDPOINT OFF	Endpoint Off request	ENDPOINT OFF	Error response	Endpoint is already off.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
8	ENDPOINT OFF	Endpoint Suspend, or Endpoint Resume request	ENDPOINT OFF	Error response	Endpoint event process remains off.
9	ENDPOINT OFF	Endpoint On or Endpoint Start request. Endpoint is unable to turn on properly.	ENDPOINT OFF	Endpoint attempts to take the object from the ENDPOINT OFF state to an ENDPOINT ON state. Endpoint won't turn on properly. Turn "endpoint" detection event process back off and generate an Error response.	Behavior associated with determining that the endpoint will not turn on properly is manufacturer specific.
10	Entry into ENDPOINT ON	None	Entry state for ENDPOINT ON state. Conditional: ENDPOINT ON / ENDPOINT IDLE or ENDPOINT ON / ENDPOINT IN PROCESS	ENDPOINT IDLE state entered if supported; otherwise ENDPOINT IN PROCESS state entered	Entry depends on endpoint electronics functioning properly.
11	ENDPOINT OFF	Endpoint Start request	ENDPOINT ON / ENDPOINT IN PROCESS	Go immediately to the ENDPOINT ON / ENDPOINT IN PROCESS state and begin the endpoint detection event process. Issue an Endpoint Start response	Behavior associated with determining that the endpoint will not turn on properly is manufacturer specific.
12	ENDPOINT IN PROCESS	Endpoint On, Endpoint Start, Endpoint Resume, Download Recipe, Upload Recipe	ENDPOINT IN PROCESS	Error response	Endpoint is already in process.
13	ENDPOINT IN PROCESS	Endpoint detection completed and idle state supported	ENDPOINT IDLE	Endpoint event detected. Endpoint event reported.	
14	ENDPOINT IDLE	Endpoint Start Request	ENDPOINT IN PROCESS	Endpoint event detection process is started. Issue an Endpoint Started success response.	
15	ENDPOINT IDLE	Download Recipe, and Upload Recipe Request	ENDPOINT IDLE	Valid recipes are Downloaded or Uploaded and a services response is generated.	
16	ENDPOINT IDLE	Endpoint Suspend and Endpoint Resume request	ENDPOINT IDLE	Error response	Endpoint is not in process so it can not be suspended.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
17	ENDPOINT IN PROCESS	Endpoint detection failed	Conditional: ENDPOINTING ON / ENDPOINT IDLE or ENDPOINTING / ENDPOINT OFF	Endpoint event not detected within the allotted endpoint active timers. Endpoint event failure reported.	
18	ENDPOINT IN PROCESS	Endpoint Suspend request and service supported	ENDPOINT SUSPENDED	Take the object from the ENDPOINT IN PROCESS state to ENDPOINT SUSPENDED state, turning off the endpoint event process. All active endpoint timers are held at their current values. Set the Status attribute to the appropriate value. Issue an Endpoint Suspended response and stop the “endpoint” detection process.	Endpoint event process is temporally suspended. All timers are suspended.
19	ENDPOINT SUSPENDED	Endpoint Resume request	ENDPOINT IN PROCESS	Take the object from ENDPOINT SUSPENDED state to ENDPOINT IN PROCESS. Begin the “endpoint” detection event process form the point it was suspended. All active endpoint timers are reinstated to their last held values. Issue an Endpoint Resume response.	Endpoint event process is resumed from the point it was suspended.
20	ENDPOINT SUSPENDED	Endpoint On, Endpoint Start, Endpoint Suspend , Download Recipe, Upload Recipe request	ENDPOINT SUSPENDED	Error response	Endpoint event process remains suspended.
21	ENDPOINT ON	Endpoint On, Endpoint Start, Endpoint Resume, Download Recipe, and Upload Recipe request	ENDPOINT ON	Error response	Endpoint detection event process remains on and continues endpoint process from its current attribute settings.
22	ENDPOINT OFF	Download Recipe or Upload Recipe request	ENDPOINT OFF	Valid recipes are Downloaded or Uploaded and a services response is generated.	

8.6 *Assembly-EP Objects* — Assembly-EP objects inherit attributes, services, and behavior from the Assembly object. The Assembly object is the device component that provides a mechanism of grouping more than one attribute from one or more objects into a single data structure for communication over the network.

Table 18 identifies the Assembly-EP objects defined for the EPD device.

Table 18 Assembly List

Object	*Access Network*	*Required*	*Form*
Assembly-EPD#1	R	Yes	Status; Default Assembly
Assembly-EPD#2	R	No	Value, Reading Valid
Assembly-EPD#3	R	No	Status, Number of Endpoint Objects and Value (Values ≤ 1024)
Assembly-EPD#4	R	No	Status, Exception Detail Alarm and Exception Detail Warning

8.6.1 *Assembly-EP Objects Attributes* — Table 19 provides a list of attributes common to all Assembly-EP object types.

Table 19 Assembly-EP Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Data (See NOTE 1.)	A1	RW	Yes	Structure as defined below.

NOTE 1: Inherited from the Assembly object as shown in Figure 1.

8.6.1.1 *Data Attribute Format for Assembly-EP Objects* — The Data attribute of all Assembly-EP objects is a structured attribute containing an ordered list of attributes within its structure. In the following tables (20 through 23), the structure of the Data attribute for each of the Assembly-EP object types is defined.

Table 20 Assembly-EPD #1 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	EPD1	A12	Device Manager Exception Status

Table 21 Assembly-EPD #2 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	EPD3	SbithepA16	Sensor-BI-TH-EP #1 Value Reading Valid

Table 22 Assembly-EPD #3 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	EPD1	A12	Device Manager Exception Status
2	EPD2	SacA65	SAC Number of Endpoint Objects
3	EPD3	SbithepA16	Sensor-BI-TH-EP #1 Value
4	EPD3	SbithepA16	Sensor-BI-TH-EP #2 Value
.	EPD3	SbithepA16	Sensor-BI-YH-EP #3 to Sensor-BI-TH-EP #N-1 Value
N ≤ 1024 (See NOTE 1.)	EPD3	SbithepA16	Sensor-BI-TH-EP #N Value

NOTE 1: 'N' is the value of the Sensor-BI-EP object attribute "Number of Endpointing Objects". Note also that the number of endpoints reported in an assembly is fixed throughout the life of the device, and is specified by the manufacturer.

Table 23 Assembly-EPD #4 Object Data List

Data Index	*Source Object ID*	*Source Attribute ID*	*Description*
1	EPD1	A12	Device Manager Exception Status
2	EPD1	A13	Device Manager Exception Detail Alarm
3	EPD1	A14	Device Manager Exception Detail Warning

SEMI E54.12-0701^E
SPECIFICATION FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR CC-LINK

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Global Information and Control Committee. Current edition approved by the North American Information and Control Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001.

E This standard was editorially modified in September 2001 to correct a typographical error and the omission of a required disclaimer. Section 2.3 was added and changes were made to Section 7.6.2.6.

1 Purpose

1.1 This specification is part of the SEMI Sensor/Actuator Network (SAN) suite of standards and defines a specific communications protocol based on the CC-Link standard. This Network Communication Standard (NCS) taken together with the SEMI Sensor/Actuator Network standard suite and the CC-Link standard completely and unambiguously defines an open standard providing an industry specific solution to off-the-shelf interoperability of networked devices in semiconductor manufacturing equipment.

1.2 CC-Link is a vendor independent, open device level network standard. Vendor independence and openness are guaranteed by the CC-Link Partner Association.

2 Scope

2.1 This document specifies a SAN communications standard based on the CC-Link specification that is in compliance with SEMI E54.1. As such, it specifies the protocol, services and behavior that compliant intelligent devices must support in order to interchange information over this SAN in a method compatible with SEMI E39.

2.2 In conjunction with a SEMI standard SAN Common Device Model (CDM) specification and one or more SEMI standard Specific Device Model (SDM) specifications (e.g., for a mass flow controller), this Network Communication Standard (NCS) with the related CC-Link standard describe the data structures, interactions and behavior that are characteristic of the various devices on the network. This composite model forms a complete interoperability standard for communications among intelligent sensors, actuators and controllers in semiconductor manufacturing equipment.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on CC-Link; thus, a complete specification of this standard necessarily includes the CC-Link specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 The specifications within are strictly enhancements that provide additional capabilities over and above those currently required by CC-Link. Included throughout this document, primarily in Section 6, is information paraphrased from the CC-Link specifications — such as: protocol structure, capabilities, options and limitations. This information is provided here for reference only and is not intended to provide specification definitions. In all such areas, refer to the CC-Link specification documents for information. This document is limited to describing enhancements or limitations to the CC-Link specification that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the CC-Link protocol conformance testing specification. Conformance testing shall also include enhancements and limitations to the CC-Link specification required by this standard.

4 Referenced Standards

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.1 *SEMI Standards*

SEMI E39 — Object Services Standard: Concepts, Behavior and Services

SEMI E54.1 — Sensor/Actuator Network Common Device Model

SEMI E54.3 — Specification for Sensor/Actuator Network Specific Device Model for Mass Flow Device

4.2 *ISO*[1] *Standards*

7498 OSI — Basic Reference Model for Open Systems Interconnection

4.3 *CC-Link Partner Association*[2]

CC-Link Specification, Version 1.11 (or later)

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CDM* — Common Device Model

5.1.2 *NCS* — Network Communication Standard

5.1.3 *OSI* — Basic Reference Model for Open Systems Interconnection (ISO 7498)

5.1.4 *SAN* — Sensor/Actuator Network

5.1.5 *SDM* — Specific Device Model

5.2 *Definitions from Sensor/Actuator Network Common Device Model (SEMI E54.1)*

5.2.1 *Attribute*

5.2.2 *Behavior*

5.2.3 *Byte*

5.2.4 *Common Device Model*

5.2.5 *Device*

5.2.6 *Device Manager (DM) Object*

5.2.7 *Device Model*

5.2.8 *Instance*

5.2.9 *Network Communication Standard*

5.2.10 *Object*

5.2.11 *Sensor, Actuator and Controller (SAC) Object*

5.2.12 *Service*

5.2.13 *Specific Device Model*

5.2.14 *State Diagram*

5.3 *Definitions*

5.3.1 *broadcast polling method* — polling to each station and the data communication are executed by the same packet, and the data is transmitted to all of the stations in this method.

5.3.2 *cyclic transmission* — function to transmit the data from master station to all stations periodically, then for each station to transmit the response data to master station.

5.3.3 *intelligent device station* — station which can send cyclic transmission and transient transmission to master station.

5.3.4 *local station* — station which can send cyclic transmission and transient transmission to master station and other local stations.

5.3.5 *master station* — station that controls all stations on CC-Link. One (and only one) master station per system is required.

5.3.6 *profiles* — Application Object Model specifications.

5.3.7 *remote device station* — station that handles bit data and word data.

5.3.8 *remote I/O station* — station that handles only bit data.

5.3.9 *remote station* — generic name of remote I/O station and remote device station.

5.3.10 *slave station* — generic name of station other than master station.

5.3.11 *station* — equipment which can be connected with CC-Link and is assigned a station number of 0–64.

5.3.12 *transient transmission* — function to transmit the non-periodic data generated in master station, local station, and intelligent device station.

6 Communication Protocol High Level Structure

6.1 Message transfer is organized in cycles. A message cycle mainly consists of a request-frame followed by a corresponding acknowledge/response-frame of the addressed station.

6.2 A brief description of the CC-Link protocol as it relates to the ISO 7498 OSI model follows in the sections below. For protocol efficiency, CC-Link does not define layers 3 to 6.

NOTE 2: The information contained in this section is for reference only. It in no way represents specifications for CC-Link. See related documentation for these specifications.

6.3 *Physical Layer - Layer 1* — the Physical Layer conforms to the EIA RS-485 standard. See the CC-Link standard for more information.

6.4 *Data Link Layer - Layer 2* — the Data Link Layer conforms to the HDLC standard. See the CC-Link standard for more information.

6.5 *Application Layer - Layer 7* — the Application Layer defines services and protocols for Network

1 ISO - International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland

2 CC-Link Partner Association - <www.cc-link.org>

Management, Cyclic Transmission and Non-Cyclic Transmission (or Transient Transmission). Also, Application Object Models are specified as "Profiles". See the CC-Link standard for more information.

6.6 Version 1.11 of the CC-Link Standard introduces two methods for request/response messaging.

6.7 Devices that support the CC-Link Transient Transmission capability, use this method, together with a messaging protocol to transmit Service Requests and Responses.

6.8 Devices that do not support the Transient Transmission capability, use the Cyclic Transmission method. A protocol is defined for changing the context of the cyclic data from I/O to a messaging protocol for Service Requests and Responses.

6.9 See the CC-Link standard for more information.

7 Required Object Types

7.1 This section describes a general mapping of the SEMI SAN Object Model to the CC-Link environment. Component definitions are clarified and the mapping of Attributes, Services and Behaviors are specified.

7.2 *Object Model* — The Object Model defined in the CDM is represented in the CC-Link NCS. Specifically, the DM and SAC objects are mapped.

7.2.1 Section 9 specifies the mapping of SDM Objects in CC-Link.

7.3 *Objects* — The required objects of the CDM are identified here. Additional objects that are contained in the SDM are given identifiers in the Device Profile. Section 9 specifies additional mapping information.

7.3.1 Table 1 lists the Object Identifiers specified for use in protocol messages.

Table 1 Object Identifiers

Object ID	*Object*
0	Invalid
1	DM Object
2	SAC Object
3–n	Application Objects as specified in Section 9

7.4 *Attributes* — All attributes are accessible via Get_Attribute and Set_Attribute services defined in the sections below.

7.4.1 *Attribute Identifiers* — Every object specified in the CDM and SDMs uses tags to identify its attributes. These tags are formatted with letters (identifying the object) followed by an upper case "A", followed by a numerical identifier. The Attribute ID used in the CC-Link NCS is simply the numerical portion of these tags.

7.5 See Table 2 for a list of DM attributes.

Table 2 DM Object Attribute Identifiers

SEMI CDM Attribute ID	*CC-Link Attribute ID*	*Attribute*
DmA1	1	Device Type
DmA2	2	Standard Revision Level
DmA3	3	Device Manufacturer Identifier
DmA4	4	Manufacturer Model Number
DmA5	5	Software or Firmware Revision Level
DmA6	6	Hardware Revision Level
DmA7	7	Serial Number
DmA8	8	Device Configuration
DmA9	9	Device Status
DmA12	12	Exception Status
DmA13	13	Exception Detail Alarm
DmA14	14	Exception Detail Warning
DmA15	15	Visual Indicator
DmA16	16	Alarm Enable
DmA17	17	Warning Enable

7.6 *Services*

7.6.1 *Service Identifiers* — The required services of the CDM are identified here. Additional services that are contained in the SDM are given identifiers in the Device Profile. Table 3 specifies the required services and ID numbers.

Table 3 Service Identifiers

Service ID	*Service*
0	Invalid
1	Reset
2	Abort
3	Recover
4	Get Attribute
5	Set Attribute
6	Execute
7	Perform Diagnostics

7.6.2 *Specified Services* — The following sections define the details associated with each of the services required by the CDM.

7.6.2.1 *Reset* — The Reset Request specifies no parameters. In addition to an explicit Reset Service Request, CC-Link specifies others methods whereby a Slave device can be reset.

7.6.2.2 *Abort* — The Abort Service Request specifies no parameters.

7.6.2.3 *Recover* — The Recover Service Request specifies no parameters.

7.6.2.4 *Get Attribute* — The Get Attribute Request specifies two parameters: the Object ID and the Attribute ID. Each are currently defined in the range 1–255. Both are expandable to 65,535.

7.6.2.5 *Set Attribute* — The Set Attribute Request specifies three parameters: the Object ID, the Attribute ID and the Attribute Value to set. The Object ID and the Attribute ID are defined the same as for the Set Attribute Service. The length of the Attribute Value is based on the specification of the attribute.

7.6.2.6 *Execute* — The Execute Service Request specifies no parameters.

7.6.2.7 *Perform Diagnostics* — The Perform Diagnostic Request specifies one parameter: Test ID. The Test ID parameter is one byte in length.

8 Protocol Compliance

8.1 The CC-Link Partner Association has established a qualified certification system, with test laboratories in Japan that include conformance testing and interoperability testing.

9 Specific Device Model Mappings

9.1 The following sections specify mappings for Sensor Actuator Network Specific Device Models.

9.2 *Mass Flow Device* — Reference SEMI E54.3 for a complete specification of the SDM for Mass Flow Devices. Accordingly, the following mapping rules apply to the identification tags for the Objects, Attributes and Services of this model.

9.2.1 *Objects* — Consistent with SEMI E54.3 and Section 7.3 above, the DM and SAC objects are identified as Object 1 and Object 2, respectively.

9.2.1.1 Table 4 shows the mapping of the SDM Object Instances specified in SEMI E54.3 (Instance numbers are listed under heading Inst. in the table) and the CC-Link Object ID (listed under ID in the table).

Table 4 MFD Object Identifiers

SDM Object Name	*SDM Object ID*	*Inst.*	*ID*
Sensor-AI-MF	MFD3	1	3
Actuator-AO-MF	MFD7	1	4
Controller	MFD8	1	5
SISO-Setpoint	MFD11	1	6
Sensor-AI-AT	MFD4	1	7

9.2.1.2 Additional objects may be defined by the manufacturer in the Device Profile for a given device.

9.2.2 *Attributes* — The mapping of Attribute Tags and Identifiers is defined in Section 7.4.1 for the CDM. The same method applies here for the SDM.

9.2.3 *Services* — The mapping of Service Tags and Identifiers is defined in Section 7.6.1 for the CDM. The same method applies here for the SDM.

9.3 *In-Situ Particle Monitor* — Reference SEMI E54.10 for a complete specification of the SDM for In-Situ Particle Monitor Devices. Accordingly, the following mapping rules apply to the identification tags for the Objects, Attributes and Services of this model.

9.3.1 *Objects* — Consistent with SEMI E54.10 and Section 7.3 above, the DM and SAC objects are identified as Object 1 and Object 2, respectively.

9.3.1.1 Table 5 shows the mapping of the SDM Object Instances specified in SEMI E54.3 (Instance numbers are listed under heading Inst. in the table) and the CC-Link Object ID (listed under ID in the table).

Table 5 ISPM Object Identifiers

SDM Object Name	*SDM Object ID*	*Inst.*	*ID*
Sensor-AI-LCS	ISPMD3	1	3
Sensor-AI-SLS	ISPMD4	1	4
Sensor-AI-MNS	ISPMD5	1	5
Assembly-ISPM#1	ISPMD17	1	6
Assembly-ISPM#2	ISPMD18	1	7
Assembly-ISPM#3	ISPMD19	1	8
Assembly-ISPM#4	ISPMD20	1	9
Assembly-ISPM#5	ISPMD21	1	10
Assembly-ISPM#6	ISPMD22	1	11
Assembly-ISPM#7	ISPMD23	1	12
Assembly-ISPM#8	ISPMD24	1	13
Assembly-ISPM#9	ISPMD25	1	14
Assembly-ISPM#40	ISPMD64	1	15
Sensor-AI-Counter	ISPMD16	1	16
Sensor-AI-Counter	ISPMD16	n	15 + n
Sensor-AI-Counter	ISPMD16	1024	1039

9.3.1.2 Additional objects may be defined by the manufacturer in the Device Profile for a given device.

9.3.2 *Attributes* — The mapping of Attribute Tags and Identifiers is defined in Section 7.4.1 for the CDM. The same method applies here for the SDM.

9.3.3 *Services* — The mapping of Service Tags and Identifiers is defined in Section 7.6.1 for the CDM. The same method applies here for the SDM.

SEMI E58-0301
AUTOMATED RELIABILITY, AVAILABILITY, AND MAINTAINABILITY STANDARD (ARAMS): CONCEPTS, BEHAVIOR, AND SERVICES

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on October 19, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published June 1997.

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AUTOMATED RELIABILITY, AVAILABILITY, AND MAINTAINABILITY STANDARD (ARAMS): CONCEPTS, BEHAVIOR, AND SERVICES

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1 Purpose

1.1 This document provides standards for implementing and collecting SEMI E10 state changes at the equipment level per SEMI E10.

1.1.1 SEMI E10 defines various terms and equipment states but was not written specifically for application by automated equipment. This document is intended to provide a consistent interpretation of these equipment states through formal state model methodology.

1.1.2 ARAMS defines concepts, behavior, and message services to support the integration of automated systems within a semiconductor factory.

1.2 *Background and Motivations* — To implement the integration of SEMI E10 states on automated equipment, integration of definitions and requirements must be detailed and precise to ensure interpretations are consistent across equipment suppliers. This provides an opportunity to automatically retain information at the equipment itself.

1.2.1 Both equipment supplier and equipment user benefit from the automation of SEMI E10 data collection at the equipment through application of a consistent state model.

1.2.2 SEMI E10 defines specific states but does not address transitions between states. The ARAMS standard specifies the triggers for state transitions made by automated equipment. Extensions to SEMI E10 described in this document apply to decisions made by automated equipment only.

2 Scope

2.1 This standard is applicable to the following relationships: traditional host/equipment, operator/equipment, and cluster tool controller/attached module. The scope of this document is to define standards which facilitate equipment-level capture and communication of SEMI E10 related data. Specifically, this document provides the following:

- An equipment state model that defines the rules for equipment state changes,
- A set of standard equipment codes for representing substates of the six basic equipment states defined in SEMI E10,
- Definition of equipment-generated data,
- Concepts and messages required to exchange information, and
- Requirements for fundamental compliance to ARAMS
- Additional optional specifications.

2.2 This standard is intended as a supplement to SEMI E10 to be used for equipment support of SEMI E10. Formal definitions of all terms common to both documents are provided solely by SEMI E10.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E38 — Cluster Tool Module Communications (CTMC)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E41 — Exception Management (EM) Standard

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

SEMI E53 — Event Reporting

3.2 *Other Document*

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," *Science of Computer Programming 8* (1987) 231–274

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Acronyms* — The following acronyms are used in this document.

4.1.1 *ARAMS* — Automated Reliability, Availability, and Maintainability Standard, as defined by this document.

4.1.2 *CTMC* — Cluster Tool Module Communications [SEMI E38].

4.1.3 *EMS* — Exception Management Standard [SEMI E41].

4.1.4 *ERS* — Event Reporting Standard [SEMI E53].

4.1.5 *GEM* — Generic Equipment Model [SEMI E30].

4.1.6 *OSS* — Object Services Standard [SEMI E39].

4.1.7 *RAM* — Reliability, Availability, and Maintainability.

4.2 *General Terms* — The following definitions for general terms are used in this document. References are given in brackets.

4.2.1 *alarm* — Related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed [SEMI E30, SEMI E41].

4.2.2 *collection event* — An event (or grouping of related events) on the equipment that is considered to be significant to the host [SEMI E30].

NOTE 2: A state transition in a formal state model always represents a collection event unless explicitly stated otherwise.

4.2.3 *equipment production criteria* — The set of conditions and operating specifications that must be satisfied for the equipment to consider itself as performing its intended function. This includes basic requirements for information, material to process, and the absence of any detectable exception conditions (e.g., no alarms). It also includes criteria specific to the equipment model, such as a required level for vacuum pressure and availability of consumables and support tools required for its process.

4.2.4 *event* — A detectable occurrence significant to the equipment.

NOTE 3: Within the context of ARAMS, an event may be detected by either the equipment or the user.

4.2.5 *event report* — A message the equipment sends to the host on the occurrence of a collection event.

4.2.6 *exception* — An alarm or error that is reported to the user and that may or may not be recoverable.

4.2.7 *fault* — An exception.

4.2.8 *host* — The intelligent system that communicates with the equipment, acts as a supervisory agent, and represents the factory and the user to the equipment.

4.2.9 *intended function* — A manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment and measurement functions for metrology equipment as well as process functions such as physical vapor deposition and wire bonding. Complex equipment may have more than one intended function.

4.2.10 *interrupt (interruption)* — A failure [SEMI E10].

4.2.11 *operator* — Any person who communicates locally with the equipment through the equipment's control panel.

4.2.12 *state* — A static set of conditions and associated behavior. While all of its conditions are met, the state is current (active). Behavior within a given state includes the response to various stimuli.

NOTE 4: Within the scope of this document, the term "state" generally refers to one of the six equipment states defined by SEMI E10 and used in the ARAMS State Model: productive, standby, engineering, scheduled downtime, unscheduled downtime, and non-scheduled time.

4.2.13 *state model* — A collection of states and state transitions that combine to describe the behavior of a system. This model includes a definition of the conditions that delineate a state, the activities possible within a state, the events that trigger transitions to other states, and the process of transitioning between states.

4.2.14 *state transition* — A change from one state to another state.

4.2.15 *standby condition* — Any condition during manufacturing time when the equipment's production criteria are not satisfied, and it is fault free and otherwise able to perform its intended function.

4.2.16 *substate* — A refinement of a state.

NOTE 5: States may be subdivided into substates to facilitate more concise definition of behavior. Thus, a hierarchy is defined whereby any state may be a substate of some parent state and in turn be the parent of its own substates [SEMI E30, Appendix].

4.2.17 *superstate* — The parent state of two or more states.

4.2.18 *symptom* — A user-detected event (e.g., smoke observed).

4.2.19 *timestamp* — The notation of the date and time of the occurrence of an event [SEMI E42].

4.2.20 *timestamp format* — A text string of the form "YYYYMMDDhhmmsscc", where:

YYYY = year (e.g., 1995)

MM = month (01–12)

DD = day (01–31)

hh = hour (00–23)

mm = minute (00–59)

ss = second (00–59)

cc = centisecond (00–99)

4.2.21 *trigger* — An event that causes a change in the state of the equipment. Examples are changes in sensor readings, alarms, messages received from the host, and operator commands.

4.2.22 *user* — Any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment's viewpoint, both the operator and the host represent the user.

4.3 *data types* — The following terms are used to represent valid types of data.

4.3.1 *form* — Type of data: positive integer, unsigned integer, integer, floating point (float) enumerated, Boolean, text, formatted text, structure, list, ordered list.

4.3.2 *positive integer* — May take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.3.3 *unsigned integer* — May take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

4.3.4 *integer* — May take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

4.3.5 *floating point (float)* — May take on any single (real) numeric value, positive or negative. Messaging protocol may impose a limit on the range of possible values.

4.3.6 *enumerated* — May take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.3.7 *boolean* — May take on one of two possible values, equating to TRUE and FALSE.

4.3.8 *text* — A character string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.3.9 *formatted text* — A character string with an imposed format. This could be by position, by use of special characters, or both.

4.3.10 *structure* — A specific set of items, of possibly mixed data types, in a specified arrangement.

4.3.11 *list* — A set of one or more items that are all of the same form (one of the above forms).

4.3.12 *ordered list* — A set of items in specific sequence.

5 Basic Requirements

5.1 An ARAMS-compliant implementation requires provision of certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and provision of an internal time-and-date clock. These requirements may be satisfied through compliance to one of the following sets of requirements:

- The Generic Equipment Model (GEM):
  - Clock Services
  - Event Notification
  - Status Data Collection
  - Equipment Constants
  - Alarm Management
- The following set of standards:
  - Object Services Standard
  - Clock Services, Cluster Tool Module Communications
  - Event Reporting Standard
  - Exception Management Standard

5.2 The developer is expected to be familiar with the appropriate documents before attempting to implement ARAMS (see Section 16.1).

6 Conventions

This document follows the conventions for state model methodology and service definitions used by the SEMI standards referenced in Section 3.

6.1 *State Model Methodology* — This document uses the state model methodology in SEMI E30 to describe the behavior of equipment. A state model has three elements: definitions of each state and substate, a diagram of the states and the transitions between states, and a state transition table. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an appendix of SEMI

E30. The formal definition of this notation is presented in *Science of Computer Programming 8*, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.

6.1.1 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A **transition table** contains columns for Transition #, Current State, Trigger, New State, Action(s), and Comment. The "trigger" (column 3) for the transition occurs while in the "current" state. The "actions" (column 5) includes a combination of 1) actions taken upon exit of the current state, 2) actions taken upon entry of the new state, and 3) actions taken which are most closely associated with the transition. No differentiation is made between these cases.

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
Transition #					

6.2 *Object Attribute Representation* — The object information models for standardized objects will be supported by an **attribute definition table** with the following column headings:

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
The formal text name of the attribute.	Description of the information contained.	RO or RW	Y or N	(see below)

6.2.1 The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that users of the service have to the attribute.

6.2.2 A 'Y' or 'N' in the Required (Reqd) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

6.2.3 The Form column is used to indicate the format of the attribute (see Section 4 for definitions).

6.3 *Service Message Representation*

6.3.1 *Service Resource Definition* — A **service definition table** defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*
Message name	N or R	The intent of the service

6.3.1.1 Type can be either N = Notification or R = Request.

6.3.1.2 Notification type messages are initiated by the service provider and the provider does not expect to get a response from the service user (consumer/subscriber).

6.3.1.3 Request messages are initiated by a service user. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.3.2 *Service Parameter Dictionary* — A **service parameter dictionary table** defines the parameters for one or more services, as shown in the following table:

Parameter	*Description*	*Form*
Parameter X	A parameter called X is B in A.	Data type.

6.3.2.1 A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding parameter.

6.3.2.2 The Form column is used to indicate the type of data contained in a parameter (see Section 4 for definitions).

6.3.2.3 The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the allowed values, and any interrelationships with other parameters.

6.3.2.4 To prevent the definition of numerous parameters named "XxxList", this document adopts the convention of referring to the list as "(List of) Xxx". In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type.

6.3.2.5 Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

6.3.3 *Service Message Definition* — A **service message definition table** defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Parameter X	(see below)	(see below)	A description of the parameter.

6.3.3.1 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication". The receiver may then send a "Response", which the original sender terms the "Confirmation".

6.3.3.2 The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" - *Mandatory parameter* — Must be given a valid value.

"C" - *Conditional parameter* — May be defined in some circumstances and undefined in others. Whether a value is given may be a completely optional or may depend on the value of other parameters.

"U" - *User-defined parameter*

"-" — The parameter is not used.

"=" — (For response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7 Overview

7.1 This section provides an overview of how ARAMS will be applied and the capabilities that ARAMS defines.

7.2 Systems that are used to track equipment performance should be based on SEMI E10's definitions of the six basic equipment states. The tracking systems typically rely on factory personnel to manually enter SEMI E10 state changes. Individual factories may have further company-specific and/or facilities-specific refinements of the states. For example, the basic equipment state may be "unscheduled downtime" with a refinement of "waiting for parts". In addition to entering a state change, the operator (who may be the production operator, a process engineer, an equipment engineer, or a supplier field service engineer) may select from a pre-defined set of behaviors (symptoms) that prompted the change of state, such as "smoke observed".

7.3 Specifications provided by ARAMS are intended to support the integration of equipment systems with factory tracking systems. For this purpose, equipment needs to be cognizant of the ARAMS states and substates, must know its current state, and must follow common rules for determining if equipment-initiated transitions can be made. In addition, the user needs to be able to interact with the tracking system at either the host system's console or the equipment's operator console. This requires that the operator be able to enter certain information at the equipment's console: a new state or substate request, and specific observed behavior that prompted the request. The host system is then notified that a change in state has occurred.

7.4 Integrated systems are able to provide more accurate data for those state changes than the equipment alone is able to detect. While the user is still required to initiate state changes for other conditions, this can be accomplished either directly at the equipment's console or remotely at the host tracking system terminal.

7.5 Exchange of information is accomplished through standardization of the meaning and form of data and the specification of the message services for the exchange. ARAMS provides generic definitions for the common substates described in SEMI E10. ARAMS also defines two tables and the message services required for the equipment and host to exchange tables. The first table contains a set of ARAMS substate definitions (an ARAMS code identifying the substate) and a corresponding description. The second table defines a set of symptoms with a numeric symptom identifier and a corresponding description.

7.6 While the above discussion assumes that the equipment is interacting with host systems, the ARAMS state model only requires interactions with a "user", which might be either a local operator or a host system.

8 State Models

8.1 This section defines the formal state model for ARAMS, called the ARAMS State Model, which is required for ARAMS compliance. To clarify the relationships between this state model and the equipment's operations, it introduces a second state model, called the General Equipment Operations Model, which is used for purposes of illustration. The General Equipment Operations Model is assumed to exist in some form but is not required for ARAMS compliance.

8.1.1 This document follows the convention of using upper-case to denote the formal names of states. Informal references may use lower case. For example, the ARAMS states SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME may be referred to as downtime states.

8.1.2 Detailed requirements for equipment behavior are provided in Section 16.

NOTE 6: Although the equipment is unable to detect a condition of no power, it is able to detect when the INITIALIZING state has been entered and is able to differentiate between a hard reset (Transition 6) and a soft re-boot (Transition 5).

8.2 *SEMI E10 Equipment States* — Figure 1 contains a diagram of SEMI E10 equipment states using the Harel notation. SEMI E10 divides total time into six basic states: PRODUCTIVE, ENGINEERING, STANDBY, SCHEDULED DOWNTIME, UNSCHEDULED DOWNTIME, and NON-SCHEDULED TIME. These six states are shown in Figure 1 with solid lines.

8.2.1 OPERATIONS TIME, UPTIME, DOWNTIME, and MANUFACTURING TIME are derived by grouping states defined in SEMI E10 and are useful for classification purposes, but formally they are not considered as SEMI E10 equipment states. Time in these groupings can be derived by summing the time in their corresponding states, based on Figure 1.

NOTE 7: Figure 1 uses shadings to show derived states. It is not intended as a formal state model.

8.2.2 MANUFACTURING TIME includes time spent in PRODUCTIVE and STANDBY. UPTIME includes the time spent in MANUFACTURING TIME and ENGINEERING. DOWNTIME includes the time spent in SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME.

8.2.3 In SEMI E10, precise rules governing state transitions are not required. The ARAMS model, in contrast, is intended to be used by automated equipment capable of detecting internal conditions. Conditions for each valid state transition are defined, both those initiated by equipment and those determined by interactions between the user and the equipment.

8.3 *ARAMS State Model Definition* — This section contains the formal definition of the ARAMS State Model, consisting of three parts:

- A diagram of the ARAMS State Model (Figure 2), using Harel notation,
- a description of each state and the behavior of the equipment within that state, and
- a table of transitions (Table 1) showing the previous state before the transition, the trigger for the transition, the new state after the transition, a description of any actions to be taken upon entry, and comments concerning the new state.

8.3.1 *ARAMS State Model Diagram* — Figure 2 contains the diagram of the ARAMS State Model.

8.3.2 *Descriptions of ARAMS States* — This section provides brief descriptions of the basic states for model completeness.

NOTE 8: These are informal descriptions included for the completeness of the ARAMS State Model. They do not replace the formal definitions in SEMI E10.

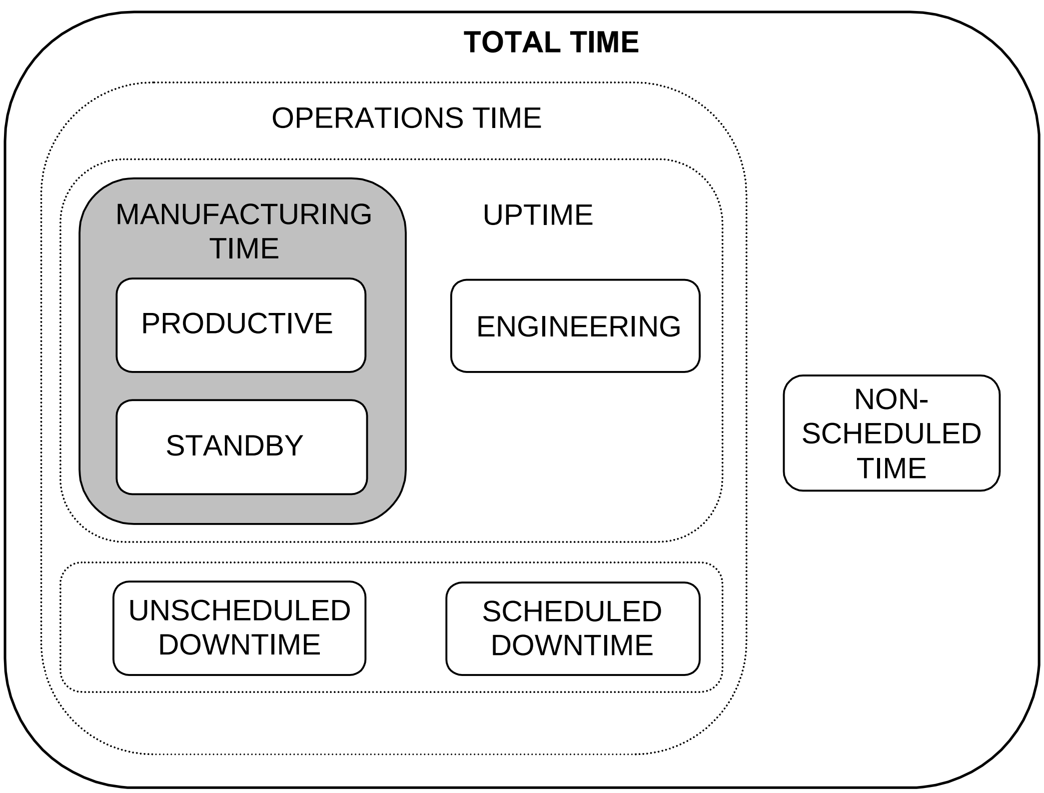


Figure 1
SEMI E10 Equipment States in Harel Notation

8.3.2.1 *TOTAL TIME* — The TOTAL TIME state includes 100% of real time; the sum of the time in the six basic SEMI E10 states, including time when the equipment is powered down. PRODUCTIVE, STANDBY, and ENGINEERING are called *uptime*, and SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME are called *downtime*.

8.3.2.2 *MANUFACTURING* — The ARAMS State Model includes MANUFACTURING as a user-selectable superstate of PRODUCTIVE and STANDBY. When the user selects MANUFACTURING, the equipment automatically transitions to either PRODUCTIVE or STANDBY, depending upon its internal status at the time.

8.3.2.2.1 Equipment is fault-free during MANUFACTURING.

NOTE 9: MANUFACTURING is not a SEMI E10 equipment state.

8.3.2.3 *PRODUCTIVE* — The PRODUCTIVE state covers the time spent by the equipment in performing its intended function. This also includes time spent loading and unloading product. PRODUCTIVE is an uptime manufacturing state.

8.3.2.3.1 The equipment is in PRODUCTIVE when, and only when, it is in MANUFACTURING, its equipment production criteria are satisfied, and it is busy performing its intended function.

NOTE 10: Although by definition, the equipment is only considered to be "performing its intended function" in the PRODUCTIVE state, equipment processing cycles may occur in any of the basic SEMI E10 states except STANDBY.

8.3.2.4 *STANDBY* — The STANDBY state is an uptime manufacturing state that covers the time the equipment is waiting to enter the PRODUCTIVE state.

8.3.2.4.1 The equipment enters this state automatically from the PRODUCTIVE state whenever it is in the MANUFACTURING superstate and the requirements for PRODUCTIVE do not apply. This includes periods during which it detects a normal standby condition, such as no work, no operator, etc. During STANDBY, the equipment monitors conditions for PRODUCTIVE. When all requirements for PRODUCTIVE are satisfied, then it transitions automatically to PRODUCTIVE.

8.3.2.5 *ENGINEERING* — The ENGINEERING state is an uptime state that is selected by the user for process and equipment engineering purposes, such as process development or characterization.

8.3.2.5.1 Because the equipment may be pushed deliberately outside of its normal operating conditions, faults that may occur in the ENGINEERING state do not trigger equipment-initiated transitions to UNSCHEDULED DOWNTIME. The equipment may also be powered off while in ENGINEERING.

8.3.2.6 *UNSCHEDULED DOWNTIME* — The UNSCHEDULED DOWNTIME state is used for unplanned downtime activities, such as maintenance, setups, conversions, change of consumables, factory-related problems, etc.

8.3.2.6.1 Any transition from PRODUCTIVE to UNSCHEDULED DOWNTIME, whether equipment or user initiated, counts as a SEMI E10 failure. In some cases, where the equipment has detected an alarm condition and has transitioned to UNSCHEDULED DOWNTIME, the equipment is able to recover and return to PRODUCTIVE.

8.3.2.7 *SCHEDULED DOWNTIME* — The SCHEDULED DOWNTIME state is used for planned downtime activities, such as preventive maintenance, setups, conversions, change of consumables, factory-related events, etc.

8.3.2.8 *NON-SCHEDULED TIME* — The NON-SCHEDULED TIME state is used to account for time outside of the normal factory production schedule. This includes time when the factory itself is not operating and time when the equipment is being used for purposes other than production, engineering, or maintenance. Examples of such time include unworked shifts, holidays, plant shutdowns, installation, and off-line (outside of normal factory operations) training of personnel.

8.3.3 *ARAMS Substates* — Each of the six basic ARAMS states have refinements defined in SEMI E10. These refinements are captured by the ARAMS Substate Codes in Section 9. The host requests an ARAMS state change by specifying an ARAMS Substate Code directly, while the operator selects a state and substate combination, through the human interface, that results in an ARAMS Substate Code. The equipment then determines the appropriate ARAMS state/substate based on this code.

8.3.4 *State Transitions* — The user may ask the equipment to go to any ARAMS state at any time by specifying a new ARAMS Substate Code (see Section 9) or by specifying a code of "0000" to request a change to the MANUFACTURING superstate.

NOTE 11: A user-initiated ARAMS state change is not intended to initiate a change in the equipment's operation. For example, if the operator puts the equipment in UNSCHEDULED DOWNTIME while the equipment is completing a process cycle of material, the equipment shall complete its normal cycle. If the operator intends to abort the process, then the process must be specifically aborted.

8.3.4.1 Table 1 defines the triggers for each transition shown in Figure 2.

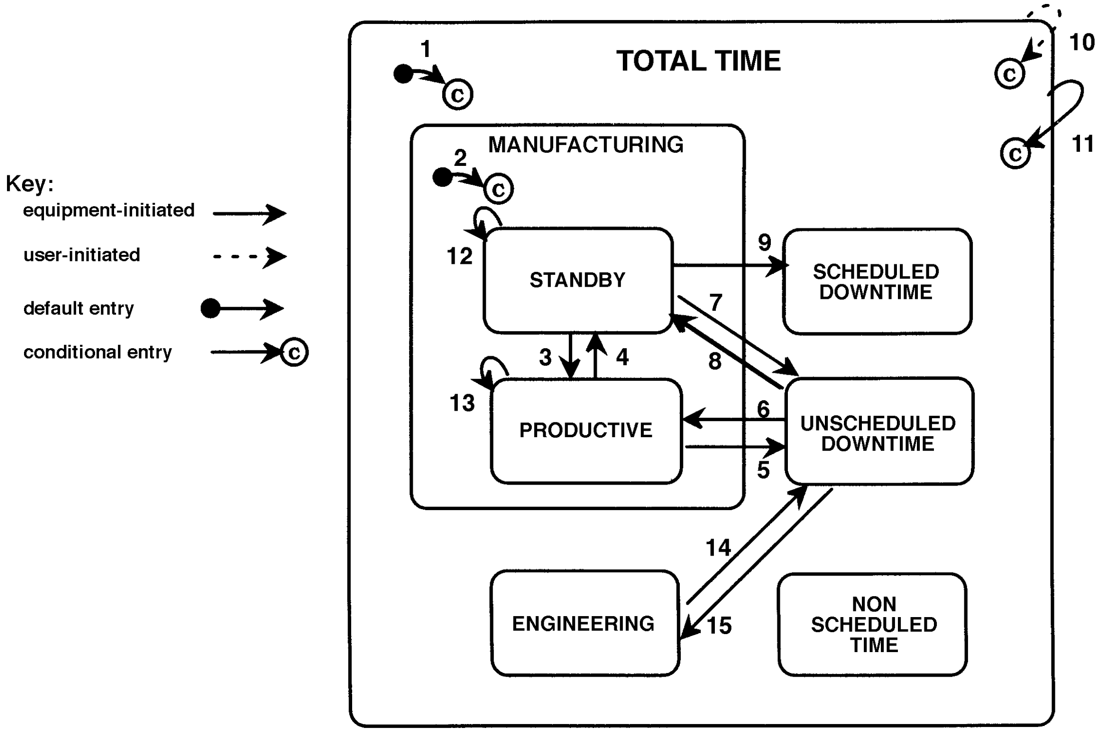


Figure 2
ARAMS State Model

Table 1 Transitions for ARAMS State Model

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	(Either undeterminable or any state except PRODUCTIVE or STANDBY)	Powerup/reset	Depends upon the state in which Transition 11 occurred (see Section 8.5.2).	None	Entry state is dependent upon previous state (see NOTE 1) where this can be determined. May not generate an event report.
2	(any state)	User selects a manufacturing state.	PRODUCTIVE or STANDBY, depending upon the status of the equipment.	Determine the new ARAMS state/substate.	Equipment determines if production criteria are satisfied. If not, it transitions to STANDBY. No event report is generated.
3	STANDBY	Equipment detects that all its production criteria are satisfied.	PRODUCTIVE	Set ARAMSState to value in PrdState (Section 11.2).	May begin or resume processing.
4	PRODUCTIVE	Equipment detects a standby condition.	STANDBY	Monitor all production criteria.	Equipment may detect a standby condition at any time.
5	PRODUCTIVE	Equipment detects an exception.	UNSCHEDULED DOWNTIME	Increment InterruptionPrd (Section 11.5).	Alarm or exception report generated by same trigger.

#	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
6	UNSCHEDULED DOWNTIME	All fault conditions have been cleared.	PRODUCTIVE	Resume processing	Transition 6 can only follow Transition 5. Automatic recovery without operator direction may be disabled by the user. (See NOTE 2.) May resume processing. Process should be recoverable without degradation.
7	STANDBY	Equipment detects fault condition.	UNSCHEDULED DOWNTIME	None	Alarm or exception report generated by same trigger.
8	UNSCHEDULED DOWNTIME	All fault conditions have been cleared.	STANDBY	Monitor all production criteria.	Transition 8 can only follow Transition 7 and may be disabled by the user. (See NOTE 3.)
9	STANDBY	A monitored parameter has reached a pre-defined limit.	SCHEDULED DOWNTIME	None	Preventive maintenance may require reset of the monitored parameter.
10	(Any ARAMS state/substate)	User selects a new ARAMS Substate Code.	(Based on state/substate selected by user)	Depends upon state/substate selected.	The user may select a new ARAMS state or substate at any time.
11	(Any of the six basic states)	Powerdown	UNSCHEDULED DOWNTIME, SCHEDULED DOWNTIME, or NON-SCHEDULED TIME.	None	On powerup, the equipment assumes this transition has occurred. This state transition does not represent a collection event.
12	STANDBY	Equipment detects a change in standby conditions.	STANDBY	None	Transitions 12 and 13 are optional and may be disabled by the user. (See NOTE 4.)
13	PRODUCTIVE	Equipment detects a change in productive conditions.	PRODUCTIVE	None	Transitions 12 and 13 are optional and may be disabled by the user. (See NOTE 4.)
14	ENGINEERING	Equipment detects a fault condition.	UNSCHEDULED DOWNTIME	None	Transitions 14 and 15 may be disabled by the user. (See NOTE 5.)
15	UNSCHEDULED DOWNTIME	All fault conditions have been cleared.	ENGINEERING	None	Transition 14 shall only follow Transition 15. (See NOTE 6.)

NOTE 1: See the variable ARAMSState in Section 11.2.4.

NOTE 2: See PrdRecovery variable in Section 11.4.5.

NOTE 3: See SbyRecovery variable in Section 11.4.6.

NOTE 4: See SubstateSelect variable in Section 11.4.7.

NOTE 5: See EngInterrupt variable in Section 11.4.1.

NOTE 6: EngRecovery variable in Section 11.4.2 required for automatic recovery.

8.4 *General Equipment Operations Model* — The equipment has various state models that it maintains in addition to the ARAMS State Model. The state model presented in this section (Figure 3) is provided as a high-level example of one such model to clarify the relationship between ARAMS and the equipment's operations. For purposes of ARAMS, it is referred to as the General Equipment Operations Model.

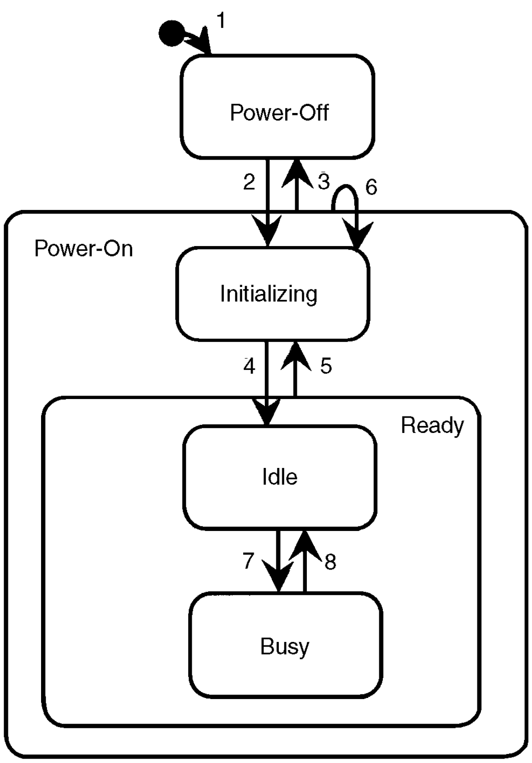


Figure 3
Example of General Equipment Operations Model

8.4.1 ARAMS assumes that a similar model, either formal or implicit, exists, although it may differ in detail depending upon the equipment type and the application. Formal implementation of the General Equipment Operations Model is not required for ARAMS compliance.

8.4.1.1 The states of the General Equipment Operations Model are not SEMI E10 states or substates.

NOTE 12: To minimize confusion between references to states and events, the events of losing power and recovering power are termed *powerdown* and *powerup* respectively.

8.4.2 *State Definitions* — The General Equipment Operations Model uses the following states:

8.4.2.1 *POWER-OFF* — The equipment has no power and is unable to function. While this state is only valid from a view external to the equipment, it is required to cover all periods of time to match the ARAMS model.

8.4.2.2 *POWER-ON* — The POWER-ON state includes all the functions of the equipment. It has two substates, INITIALIZING and READY.

8.4.2.3 *INITIALIZING* — When equipment is first powered on or recovers from a reset, it must initialize its hardware and software subsystems and components, including its different internal state models. This process takes time, which is represented by the INITIALIZING state.

8.4.2.4 *READY* — When all initializations are complete, the equipment enters the READY state and is able to interact with the user. The READY state has two substates, IDLE and BUSY.

8.4.2.5 *IDLE* — In the IDLE state, the equipment is inactive and able to accept a command for automatic processing or manual operations.

NOTE 13: IDLE is not the same as the SEMI E10 STANDBY state. (See Section 8.5.3.)

8.4.2.6 *BUSY* — In the BUSY state, the equipment is active. BUSY includes all operations of the equipment.

NOTE 14: BUSY is not the same as the SEMI E10 PRODUCTION state. (See Section 8.5.3.)

8.4.3 *General Equipment Operations Model Table of Transitions* — Table 2 defines the triggers for each transition shown in Figure 3. The second column, labeled Table 1, shows the corresponding transition in the ARAMS state model.

Table 2 Table of Transitions for General Equipment Operations Model

#	*Table 1*	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	None	(undefined)	Equipment is installed.	POWER-OFF	None	New equipment
2	None	POWER-OFF	Power is turned on (powerup).	INITIALIZING	Begin system initialization.	Initialization of hardware and software.
3	11	POWER-ON	Power is turned off (powerdown).	POWER-OFF	None	Equipment does not function.

#	*Table 1*	*Current State*	*Trigger*	*New State*	*Action(s)*	*Comment*
4	1	INITIALIZING	System initialization is complete.	IDLE	Begin normal internal activities. Wait for input.	Normal. Equipment is able to interact with the user.
5	11	READY(any substate)	Internal error, or soft re-boot by request.	INITIALIZING	Re-initialize system.	This is treated in the same way as Transition 2.
6	1	(any substate of) POWER-ON	System reset.	INITIALIZING	Re-initialize system.	A reset is done through hardware.
7	Conditional	IDLE	Equipment receives instructions to perform an automated or manual function.	BUSY (See NOTE 1.)	Perform the requested function.	Equipment may be capable of performing multiple functions while in BUSY.
8	Continued Conditional	BUSY (See NOTE 1.)	The equipment has completed all requested functions.	IDLE	Wait for new instructions.	Equipment may be capable of performing non-hardware-related functions in IDLE.

NOTE 1: The PROCESSING ACTIVE state of the Processing State Model example in SEMI E30 would be a substate of BUSY. Other substates may exist for maintenance and diagnostics.

8.5 *State Model Relationships* — Figure 4 shows the ARAMS State Model and the General Equipment Operations Model as both simultaneously active. Certain relationships exist between the two models.

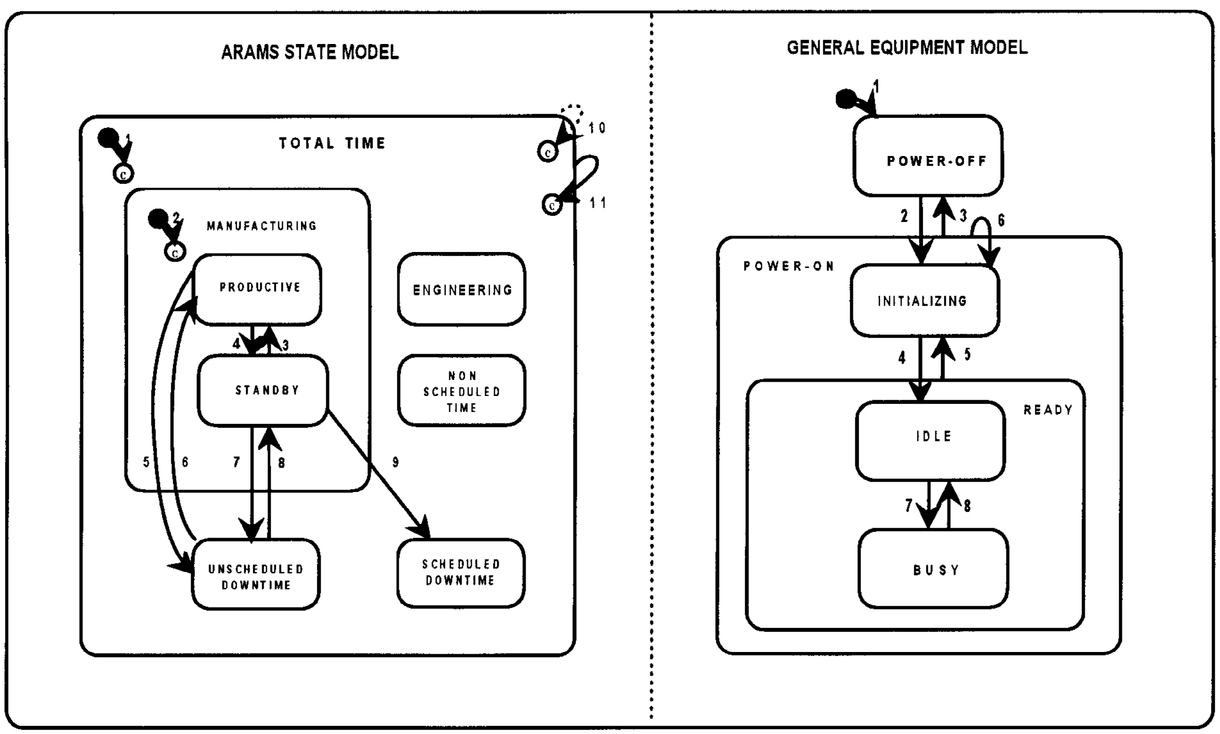


Figure 4
ARAMS State Model and General Equipment Operations Model

8.5.1 Both models cover all time, twenty-four hours each day. The ARAMS State Model describes how the equipment is used in the factory. The General Equipment Operations Model describes the equipment's activities, including the time when it has no power and is completely inactive.

8.5.1.1 The General Equipment Operations Model is provided to clarify two specific areas of relationship:

- The transitions related to powerup (#2), powerdown (#3), soft re-boot (#5), and reset (#6).
- The IDLE and BUSY activity states.

8.5.1.2 The term "reset" is used in this document to collectively represent both the soft re-boot and the hardware reset where no powerdown occurs.

8.5.1.3 Requirements related to powerup, powerdown, re-boot, and reset are specified in Section 16.

NOTE 15: Although the equipment is unable to detect a condition of no power, it is able to detect when the INITIALIZING state has been entered and is able to differentiate between a hard reset (Transition 6) and a soft re-boot (Transition 5).

8.5.2 *IDLE and BUSY* — By definition, the equipment is not in the IDLE state and in the PRODUCTIVE state at the same time, and it is not intended to be in the BUSY state while in STANDBY. The PRODUCTIVE and STANDBY states correspond to implicit substates of the BUSY and IDLE states only for the time the equipment is within the MANUFACTURING superstate — that is, it is scheduled for manufacturing (non-engineering factory operations) and is in a condition to perform its intended function.

8.5.2.1 Occasional exceptions may occur due to improper timing of a user request to change to a manufacturing state before the equipment completes a non-processing activity started in another state. For example, the equipment may be performing an automatic calibration during routine maintenance in a downtime state. In this case, the equipment determines that its production criteria are not satisfied and shall transition to STANDBY, as it is busy performing a function other than its intended function.

8.5.3 *Non-Manufacturing States* — The equipment may be in any of the POWER-OFF, INITIALIZING, IDLE, or BUSY states in the General Equipment Operations Model while in any of the non-manufacturing states: ENGINEERING, UNSCHEDULED DOWNTIME, SCHEDULED DOWNTIME, or NON-SCHEDULED TIME. For example, it may be powered off while being installed (NON-SCHEDULED TIME) or repaired (SCHEDULED or UNSCHEDULED DOWNTIME). It may be required to perform its normal processing cycle (its intended function) in ENGINEERING, NON-SCHEDULED TIME or in a downtime state.

9 ARAMS Substate Codes

9.1 This section defines the format for ARAMS Substate Codes and a set of reserved values for generic substates based on the descriptions in SEMI E10. The format is defined specifically to allow further resolution of the six basic SEMI E10 equipment states by both the factory and equipment supplier.

9.1.1 An ARAMS Substate Code consists of four ordered alphanumeric text characters, where the first two characters are reserved digits. The first character indicates the primary ARAMS state as follows:

1. PRODUCTIVE
2. STANDBY
3. ENGINEERING
4. SCHEDULED DOWNTIME
5. UNSCHEDULED DOWNTIME
6. NON-SCHEDULED TIME

9.1.2 The second character of the code, if non-zero, indicates a substate of the primary state. A zero in the second position indicates no substate has been selected. This may also be referred to as a substate of "default".

9.1.3 Codes of the form "n000" indicate no substates of a basic state have been selected. This is the "default code" for that basic state. For example, a code of "1000" indicates the PRODUCTIVE state with no substates.

9.1.4 Descriptive formatted text is defined to correspond to each ARAMS code. The first three characters of this text represent the basic state. If the next character is a forward slash "/", then subsequent text represents a substate of the basic state.

9.2 *Reserved Codes* — States and substates referenced by the reserved text in this section are based on SEMI E10 specifications. For further definition of terminology, see SEMI E10.

9.2.1 The following ARAMS Substate Codes, and the corresponding descriptive text strings for the English language (delimited by quotes), are reserved. Descriptive text with a substate of "Reserved" indicates the corresponding code is reserved for future expansion by this standard.

9.2.2 In the future, text strings in other languages may also be reserved. Equipment supporting other languages shall provide a method for the user to define alternative text strings. This provides the consistency, across different equipment, that is important to the user.

PRODUCTIVE

1000 “PRD” (default productive code)

1100 “PRD/Regular production”

1200 “PRD/Work for third parties”

1300 “PRD/Rework”

1400 “PRD/Engineering runs”

1500 “PRD/Reserved*”

1600 “PRD/Reserved”

1700 “PRD/Reserved”

1800 “PRD/Reserved”

1900 “PRD/Reserved”

STANDBY

2000 “SBY” (default standby code)

2100 “SBY/No operator”

2200 “SBY/No product”

2300 “SBY/No support tool”*

2400 “SBY/Associated cluster module down”

2500 “SBY/No host”

2600 “SBY/Reserved”

2700 “SBY/Reserved”

2800 “SBY/Reserved”

2900 “SBY/Reserved”

* NOTE: A support tool is a mechanical device used by, but not part of, the equipment. This includes cassettes, probe cards, etc.

ENGINEERING

3000 “ENG” (default engineering code)

3100 “ENG/Process experiments”

3200 “ENG/Equipment experiments”

3300 “ENG/Reserved”

3400 “ENG/Reserved”

3500 “ENG/Reserved”

3600 “ENG/Reserved”

3700 “ENG/Reserved”

3800 “ENG/Reserved”

3900 “ENG/Reserved”

SCHEDULED DOWNTIME

4000 “SDT” (default scheduled downtime code)

4100 “SDT/User maintenance delay”

4200 “SDT/Supplier maintenance delay”

4300 “SDT/Preventive maintenance”

4400 “SDT/Change of consumables”

4500 “SDT/Setup”

4600 “SDT/Production test”

4700 “SDT/Facilities-related”

4800 “SDT/Reserved”

4900 “SDT/Reserved”

UNSCHEDULED DOWNTIME

5000 “UDT” (default unscheduled downtime code)

5100 “UDT/User maintenance delay”

5200 “UDT/Supplier maintenance delay”

5300 “UDT/Repair”

5400 “UDT/Out-of-spec input material”

5500 “UDT/Change of consumables”

5600 “UDT/Facilities-related”

5700 “UDT/Reserved”

5800 “UDT/Reserved”

5900 “UDT/Reserved”

NON-SCHEDULED TIME

6000 “NST” (default non-scheduled downtime code)

6100 “NST/Unworked shifts”

6200 “NST/Equipment installation”

6300 “NST/Equipment modifications” (modify, rebuild, upgrade)

6400 “NST/Off-line training”

6500 “NST/Shutdown/startup”

6600 “NST/Reserved”

6700 “NST/Reserved”

6800 “NST/Reserved”

6900 “NST/Reserved”

9.3 *Additional Codes* — Additional codes may be defined by both the user and supplier, subject to the following constraints:

- The new code defines a refinement of a primary ARAMS state, as defined in Section 9, through use of the characters in the third and fourth positions.
- Alphabetic characters are permitted in the third and fourth positions. For purposes of sorting, these characters are assumed to be case-sensitive. All characters other than alphanumeric are prohibited.
- The third character is used to differentiate between codes defined by the user (factory) and those defined by the equipment supplier. If the third character is a digit, then the code is user defined. Otherwise, the code is supplier-defined. The user is free to assign values between "01" and "9z" as the third and fourth characters, while the supplier may assign values between "A0" and "zz".

* NOTE: Additional reserved codes may be added to Section 9.2 in the future.

9.3.1 Code definitions are exchanged as ARAMS Substate Tables, described in Section 10.3.

9.4 *Valid ARAMS Substate Code* — A valid ARAMS Substate Code is defined as any code with four alphanumeric characters where the first character is a digit between 1 and 6 and the second character is a digit between 0 and 9.

9.5 *Manufacturing Code* — A user request for the equipment to go to manufacturing specifies a special code of "0000". The code "0000" is not itself an ARAMS Substate Code and shall not be used as a code representing the current ARAMS state/substate in the variable ARAMSState.

10 ARAMS Tables

10.1 The information in this section is not required unless the equipment supports one or both of the two **ARAMS Tables** defined in Sections 10.3 and 10.4 respectively.

10.1.1 ARAMS defines two sets of data that are to be exchanged between equipment and host. These sets of data are transferred as "tables". A table is a vehicle for exchanging information and is independent of actual storage mechanisms.

10.1.2 This section introduces the concept and definitions of a generic table and defines the two specific types of tables required by ARAMS, the ARAMS Substate Table, and the ARAMS Symptom Table.

10.2 *Definition of Tables* — A table represents a general way of exchanging sets of data arranged in a tabular format. A table consists of one or more ordered sets of data, called rows, where the format and interpretation of each element of data within a row depends upon its relative position within the row, called column. Tables are transferred by providing:

- An ordered list of predefined text strings, called column headers, that identify the data element at the corresponding column position within each row,
- one or more rows of data, where each row is an ordered set of individual data elements, presented in the order specified by the column headers, and
- a set of information (attributes) about the table as a whole.

10.2.1 *Table Types and Identifiers* — Each instance of a table has a formally defined table type and a table identifier. This allows definition of general-purpose services for exchanging tables. It also allows multiple instances of a specific type of table to be referenced. OSS-compliant applications consider a table as a type of object, and a table type as a specialization of a table.

10.2.1.1 The table type definition includes specification of a reserved text string that begins with the string "Table". Table services (Section 15) and OSS services (SEMI E39) use the reserved text string as the ObjType attribute of the table object. The general table definition does not specify requirements for assigning identifiers to individual tables.

10.2.1.2 The table identifier is a text string that conforms to the requirements for an object identifier (ObjID) as specified in SEMI E39, which prohibits specific characters in ASCII. The identifier is used to identify a specific instance of a given table type and shall be unique for all tables of a given type.

10.2.1.3 A column in a table refers to all data elements at a given position across all rows of the table. Column headers are pre-defined text strings that identify the individual elements used and their relative order within each row.

10.2.2 *Table Row Definition* — A formal table type requires definition of the individual data elements within a row of the table and the specification of the column header. This information is provided in Table 3.

Table 3 Definition for Table Row Format

Column Header	*Data Element Definition*	*Form*
Text string for column position.	Definition of data element at the corresponding column position.	Valid form for data element.

10.2.2.1 The order of elements within a row shall be invariant for a given table instance and shall strictly conform to the order in which column headers are presented. The length of any given row (the number of elements within the row) may not exceed the number of defined positions (columns). Partial rows that omit elements at the end of the row are permitted by the general definition, so long as they retain the meaning of the column positions included. That is, if a complete row consists of n columns, then an individual row may consist of the first m elements, for $m \leq n$.

10.2.2.2 The first element (first column position) of a row must contain a value that is unique for all rows within a specific table instance. This value may be used as a key to identify a specific row within the table and therefore shall be a single item (e.g., not a list or structure) and may not be a floating point number. Other elements within the row may be simple lists or simple structures that do not themselves contain embedded (nested) lists or structures.

10.2.3 *Table Attributes* — It is also important to be able to exchange information about the table itself. In addition to the definition of data elements and columns, tables also have predefined attributes. The general table definition specifies three attributes: the number of columns, the number of rows, and the size of the table exclusive of formatting used for storing or transferring the table. (See Section 13.2.)

10.2.4 *Additional Requirements* — Specific table types may have additional requirements and restrictions.

10.2.4.1 ARAMS tables, defined in Sections 10.3 and 10.4, have additional requirements as follows:

- Tables shall be stored in non-volatile memory and shall be capable of subsequent modifications.
- Elements within a row shall follow the order specified in the table definitions.
- All rows shall consist of the full number of columns specified. Partial rows are prohibited.

10.2.4.2 A table is considered structurally valid if it conforms to the requirements in this section and to the row format defined for its specific type. A structurally valid table may or may not have correct content — that is, the values within any given row may or may not meet other requirements or expectations.

10.2.4.3 ARAMS tables are provided only for use by the operator and the associated data sent to the host. Equipment shall not reject a user-defined table that is structurally valid for its table type because of its contents. Equipment shall not use the contents of tables to validate ARAMS Substate Codes or symptom information provided by the host.

10.2.4.4 Certain errors in the contents may cause the tables to not work properly in some way. For example, if a row identifier is used more than once, then the equipment may fail to find any but the first occurrence. However, the user shall accept responsibilities for any errors in the contents of ARAMS tables.

10.3 *ARAMS Substate Table* — The ARAMS Substate Table provides extensions to the generic substate definitions contained in Section 9.

10.3.1 Each row in an ARAMS Substate Table consists of a four-character ARAMS Substate Code as the first element of the row, and a corresponding text string containing a brief description of the state as the second element. Table 4 defines the ARAMS Substate Table row format.

Table 4 ARAMS Substate Table Row Definition

Column Header	*Data Element Definition*	*Form*
"Code"	ARAMS Substate Code.	Four-character text string.
"Text"	Brief description of ARAMS Substate Code.	Formatted text, Sections 9.1, 9.2.

10.3.2 The descriptive text is displayed as a prompt or selection item for the operator when selecting a new ARAMS state. The description selected is placed in the variable ARAMSText and the corresponding ARAMS Substate Code is placed in the variable ARAMSState as the new ARAMS state (see Section 11.2).

10.3.3 Extensions to ARAMS codes may be defined by either the user or supplier according to the rules in Section 9.3. The ARAMS Substate Table provides a formal method for each to obtain the codes and text defined by the other. The table's identifier provides a method for differentiating between the three sets of information (generic definitions, user-defined definitions, and supplier-defined definitions) when necessary to remove ambiguity in communications. The user at all times shall be able to select an ARAMS state or substate based on the combination of the three sources of definitions.

10.3.4 An ARAMS Substate Table has a table type of "TableARAMSCode". The row format is defined in Table 4.

10.4 *ARAMS Symptom Table* — The user may define an optional table of common human-observable symptoms called the ARAMS Symptom Table, with a table type of "TableARAMSSymptom". The row of this table is defined in Table 5 below.

Table 5 ARAMS Symptom Table Row Definition

Column Header	*Data Element Definition*	*Form*
"ID"	Identifier of ARAMS symptom.	Unsigned integer.
"Indicator"	First one to four characters of ARAMS code to which symptom may be applied.	Formatted text. 1 to 4 characters. (See Sections 9.2–9.3.)
"Text"	Brief description of ARAMS symptom.	Text. Maximum length is 80 characters.

10.4.1 Each table row consists of three items: a symptom identifier, an ARAMS substate indicator, and a text string describing the symptom.

10.4.2 The symptom identifier and text are analogous to the equipment's alarm or exception identifier and corresponding text description. The identifier and text should each be unique. A symptom identifier with a value of zero is reserved to indicate "no symptom".

10.4.3 The substate indicator consists of the first one to four characters of an ARAMS Substate Code and indicates the ARAMS state or state/substate where the symptom is to be applied. For example, a symptom that is to be applied whenever the user requests a change to the UNSCHEDULED DOWNTIME state, including any of its substates, is assigned an indicator of "5". A symptom that is to be applied in any case of "UDT/change of consumable" would use an indicator of "55" as the first two digits of the corresponding ARAMS code.

10.4.4 Whenever the operator requests a change in the ARAMS state or substate, the operator shall be presented with the text descriptions from the appropriate Symptom Table. The text description of the selection is placed in the status variable SymptomText, and the corresponding identifier is placed in SymptomID.

11 ARAMS Data

11.1 This section defines the data requirements for ARAMS. This includes requirements for retaining data across a powerdown or reset. Data retention requirements are classified for each item of ARAMS data in one of the following ways:

Class 1 — A "soft" value that is reset to a default value as part of system initialization (e.g., DowntimeAlarm)

Class 2 — A "hard" value that never changes (e.g., "EqpSerialNum")

Class 3 — A "firm" value that changes infrequently and is to be retained in non-volatile memory (e.g., "EqpName")

Class 4 — A "dynamic" value that is retained in non-volatile memory and changes whenever an ARAMS state transition occurs.

Class 5 — A "very dynamic" value that may change rapidly and is important to retain but does not require absolute accuracy (e.g., CycleCtr for high throughput equipment). Current values shall be saved in non-volatile memory periodically at least once per minute.

11.1.1 Except where otherwise specified, data is assumed to be Class 1.

11.1.2 Variables within each section are presented in alphabetical order.

11.2 *Status Information* — Status data is information that is maintained by equipment and in general cannot be changed by the host. This section defines specific elements of status data that the user is able to read upon request and that may be included in event report messages to the host.

11.2.1 A mechanism shall be provided for the user to read these values.

11.2.2 All date/time values are text strings with a timestamp format (see Section 4).

NOTE 16: The timestamp format is not a requirement for clock precision.

NOTE 17: Subsequent references to subsections of 11.2 below are using the original numbers.

11.2.3 *ARAMSInfo* — Additional information set or cleared by the equipment at the time an ARAMS state transition occurs. Optional. Form: text. 0–80 characters.

11.2.4 *ARAMSState* — The ARAMS Substate Code corresponding to the ARAMS state/substate that became active following the most recent ARAMS state transition. When an ARAMS state transition occurs, ARAMSState is the specific code representing the new ARAMS state/substate. It shall be retained as Class 4 data. The value of "0000" is prohibited. Form: formatted alphanumeric text. 4 characters.

11.2.5 *ARAMSText* — The descriptive text corresponding to the code in ARAMSState. Form: text. 5–80 characters.

11.2.6 *Clock* — Contains the current value of the date and time at the equipment. When included in an event report, Clock represents the timestamp for the occurrence of the event. Clock may represent the current value of a real-time date/time clock available upon demand. Form: formatted text.

11.2.7 *CycleCtr* — The number of cycles (equipment cycles) during the lifetime of the equipment (not resettable). It shall be retained as Class 5 data. Form: unsigned integer.

NOTE 18: See SEMI E10 for a formal definition of cycle.

11.2.8 *DowntimeAlarm* — Identifier of the most recent alarm or exception triggering an equipment-initiated transition to SCHEDULED DOWNTIME or UNSCHEDULED DOWNTIME from the PRODUCTIVE or STANDBY states. This value is reset to zero for all other ARAMS state transitions to indicate "no associated alarm/exception". Form: unsigned integer.

11.2.9 *DowntimeAlarmText* — Text associated with DowntimeAlarm. This value is cleared (set to a zero-length string) for all ARAMS state transitions except the transition to SCHEDULED DOWNTIME or UNSCHEDULED DOWNTIME from the PRODUCTIVE or STANDBY states. Form: text. 0–80 characters.

11.2.10 *DowntimeData* — Text associated with transitions to, or within, the SCHEDULED or UNSCHEDULED DOWNTIME states. For transitions following powerup/reset (see Section 8.5.2), the value in DowntimeData shall be set to "Power Loss". This value is reset to a zero length (empty) string for other ARAMS state transitions. When associated with equipment initiated transitions, this may be used to carry fault information (e.g., the component serial number of a repaired component, as defined by the equipment supplied). When associated with operator-initiated transitions, it may consist of comments entered at the equipment's control panel. Form: text. 0–256 characters.

11.2.11 *LastPowerdown* — Contains a date/time timestamp that estimates the time when the last loss of power or reset occurred (Transition 11), based on the value in PowerdownTime on powerup. It shall be retained as Class 3 data. Form: formatted text.

11.2.12 *PowerdownTime* — Contains a date/time timestamp used as an estimate for the timestamp for loss of power or reset and used for reports associated with ARAMS state Transition 11. It shall be retained as Class 5 data. Form: formatted text.

11.2.13 *PrdState* — The ARAMS code corresponding to the last user-specified ARAMS Substate Code for PRODUCTIVE. Used as the default substate for PRODUCTIVE. Initialized to "1000" at Transition 1. Form: formatted alphanumeric text. 4 characters.

11.2.14 *PrevARAMSState* — The ARAMS code corresponding to the ARAMS state/substate that was active immediately preceding the most recent ARAMS state transition. This value is useful for resynchronization after a period of inability to communicate. It shall be retained as Class 4 data. Form: formatted alphanumeric text. 4 characters.

11.2.15 *SymptomID* — A numeric identifier of a symptom selected by the user when requesting the equipment to change states. A value of zero is equivalent to a selection of "no symptom". Form: unsigned integer.

11.2.16 *SymptomText* — The descriptive text for the symptom selected by the user when requesting the equipment to change states. A zero-length string corresponds to a selection of "no symptom". Form: text. 0–80 characters.

11.3 *Constant Data* — Equipment shall provide and maintain the following values as class 2 data. These values are set by the equipment manufacturer and shall not be changeable by the user. These data elements are required for equipment with formally defined components that are also ARAMS compliant, such as clustertools. This data is used for event reports, to identify the original source of the event.

11.3.1 *EqpModel* — A text string containing the equipment model. Form: 1–80 characters.

11.3.2 *EqpSerialNum* — A text string containing the product serial number assigned by the supplier. Form: 1–80 characters.

11.4 *User-Configurable Data* — The data elements in this section shall be settable by both the operator and the host. They shall be retained as Class 3 data.

11.4.1 *EngInterrupt (optional)* — A Boolean value that enables (TRUE) or disables (FALSE) equipment-initiated transitions from ENGINEERING to UNSCHEDULED DOWNTIME (Transition 14 in Figure 2) when a fault condition is detected. This variable is required if EngRecovery is supported. Form: Boolean.

11.4.2 *EngRecovery (optional)* — A Boolean value that enables (TRUE) or disables (FALSE) automatic recovery returning to ENGINEERING from UNSCHEDULED DOWNTIME (Transition 15 in Figure 2) following an equipment-detected fault that has spontaneously cleared. Form: Boolean.

11.4.3 *EqpName (required)* — A text string representing the user-assigned logical name of the equipment. Form: 1–80 characters.

NOTE 19: For OSS-compliant equipment, this corresponds to the ObjID attribute of the object "Agent", "PM", "CM", or "TM" in other standards.

11.4.4 *PowerupState (optional)* — A text character indicating the powerup (default entry) state when a powerdown occurs during manufacturing time. May be either "2" for STANDBY or "5" for UNSCHEDULED DOWNTIME.

11.4.5 *PrdRecovery (optional)* — A boolean value that enables (TRUE) or disables (FALSE) the equipment-initiated return to PRODUCTIVE (Transition 6 in Figure 2) following an equipment-detected fault that has cleared without operator intervention. Form: boolean.

11.4.6 *SbyRecovery (optional)* — A boolean value that enables (TRUE) or disables (FALSE) the equipment-initiated return to STANDBY (Transition 8 in Figure 2) following an equipment-detected fault that has cleared. Form: boolean.

11.4.7 *SubstateSelect (optional)* — A Boolean value that enables (TRUE) or disables (FALSE) equipment-initiated selection of substates of STANDBY and PRODUCTIVE (including Transitions 12 and 13). Form: Boolean.

11.5 *Accumulators* — This section defines a set of optional accumulators that either count time in one of the six basic SEMI E10 states or count interruptions occurring in the PRODUCTIVE state. It shall be possible for both the operator and host to (1) adjust the values in the individual accumulators, and (2) reset all seven values to zero simultaneously. Operator and host assume responsibility for the edited values and their accuracy. Equipment shall not impose restrictions on the modified values.

11.5.1 In addition, two timestamps are required for support of the accumulators. These timestamps shall not be changed by the user.

11.5.1.1 Where accumulators are supported, the variables defined in this section shall be supported as a set as Class 4 data.

11.5.1.2 The time accumulators are reported in minutes with an accuracy of ± one minute. Internal representations of the accumulators in smaller units may be required for short processes.

11.5.2 *ARAMSAccumReset* — The timestamp of when the following seven accumulators were last reset to zero. Form: formatted numeric text.

11.5.3 *ARAMSTimestamp* — The timestamp of the most recent ARAMS state change to the state identified in ARAMSState. This value is updated whenever a transition to a new ARAMS state occurs and is used in conjunction with PowerdownTime to update the accumulators following a powerup or reset. Form: formatted numeric text.

11.5.4 *EngTime* — Time in ENGINEERING.

11.5.5 *InterruptionPrd* — The number of transitions to UNSCHEDULED DOWNTIME from PRODUCTIVE.

NOTE 20: This includes the equipment-initiated Transition 5, a user-initiated transition covered by Transition 10, and the powerdown Transition 11, when occurring from PRODUCTIVE.

11.5.6 *InterruptionTotal* — The total number of transitions to UNSCHEDULED DOWNTIME from any state. This includes equipment-initiated transitions and user-initiated transitions.

11.5.7 *NSTime* — Time in NON-SCHEDULED TIME.

11.5.8 *PrdTime* — Time in PRODUCTIVE.

11.5.9 *SbyTime* — Time in STANDBY.

11.5.10 *SDTime* — Time in SCHEDULED DOWNTIME.

11.5.11 *UDTime* — Time in UNSCHEDULED DOWNTIME.

12 Events and Pre-Defined Event Reports

12.1 Each transition in the ARAMS State Model, with the exception of Transitions 2 and 11, represents a unique collection event that shall be reportable to the host. A generic collection event ARAMS State Change shall be provided that corresponds to any ARAMS state change. This allows greater efficiency for common data to be placed in a single report.

12.2 The equipment shall support one of the two following requirements:

- The capability of allowing the host to define reports associated with each ARAMS state change event, or
- A set of pre-defined (default) event reports for the ARAMS State Change Event, equipment-initiated transitions to UNSCHEDULED DOWNTIME (Transitions 5 and 7, and Transition 1 as appropriate), and user-initiated transitions to UNSCHEDULED DOWNTIME.

12.3 The pre-defined reports, defined below, are labeled “A”, “B”, and “C”, for ease of reference only. Report “A” represents the information required for every ARAMS State Change Event. Implementations of these reports shall provide, at a minimum, the updated values of the indicated variables.

Report “A”

ARAMS State Change Event

EqpModel

EqpSerialNum

EqpName

Clock

ARAMSState

PrevARAMSState

Report “B”

Equipment-Initiated Transitions to UNSCHEDULED DOWNTIME Event

DowntimeAlarm

DowntimeAlarmText

DowntimeData

Report “C”

User-Initiated Transition

SymptomID

SymptomText

DowntimeData

13 Object Services Compliance

This section provides information required for equipment that is OSS-compliant. OSS compliance is not required for ARAMS compliance.

13.1 *Equipment Object* — ARAMS-compliant equipment (equipment subsystems) that are compliant to OSS (SEMI E39) and that provide an object representing the equipment (equipment subsystems) shall include as attributes of that object the attributes listed in Table 6.

13.1.1 The data element Clock may be represented by a Clock object. In this case, Clock is not an attribute of the Equipment object but is a component of the Equipment object and is accessible through OSS services.

13.1.2 Table 6 defines the variables specified in earlier sections as object attributes conformant with the requirements of OSS. The column labeled “Access” indicates whether the attribute is read-only (RO) or read-write (RW), and the column labeled “Reqd” indicates if the attribute is required for ARAMS compliance.

Table 6 ARAMS Object Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ARAMSAccumReset	Timestamp for when time-in-state accumulators were last reset to zero. Required if accumulators are supported.	RO	N	Formatted numeric text: timestamp format.
ARAMSInfo	Additional information set by the equipment at the time of an ARAMS state transition.	RO	N	Text. 0–80 characters.
ARAMSState	Code corresponding to currently selected ARAMS state/substate.	RO	Y	Formatted alphanumeric text. 4 characters.
ARAMSText	Descriptive text corresponding to code in ARAMSState.	RO	Y	Text. 5–80 characters.

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ARAMSTimestamp	Timestamp of last ARAMS state change.	RO	N	Formatted numeric text: timestamp format.
Clock (See NOTE 1.)	Current time and date.	RW	Y	Formatted numeric text: timestamp format.
CycleCtr	Non-resettable counter of equipment run cycles.	RO	Y	Unsigned integer.
DowntimeAlarm	Identifier of last alarm or exception triggering an equipment-initiated transition to a downtime state and/or substate.	RO	Y	Text. Conforms to ObjID.
DowntimeAlarmText	Text associated with DowntimeAlarm.	RO	Y	Text. 0–80 characters.
DowntimeData	Equipment-defined text associated with transitions to downtime state and/or substate.	RO	Y	Text. 0–256 characters.
EngInterrupt	Enables (TRUE) or disables (FALSE) an equipment-initiated transition from ENGINEERING to UNSCHEDULED DOWNTIME. Required in EngRecovery is supported.	RW	N	Boolean.
EngRecovery	Enables (TRUE) or disables (FALSE) automatic recovery from UNSCHEDULED DOWNTIME to ENGINEERING.	RW	N	Boolean.
EngTime	Accumulated minutes in the ENGINEERING state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.
EqpModel	The equipment model.	RO	Y	Text. 1–80 characters.
EqpSerialNum	Equipment serial number.	RO	Y	Text. 1–80 characters.
InterruptionPrd	Counts number of transitions from PRODUCTIVE to UNSCHEDULED DOWNTIME. Required if accumulators are supported.	RW	N	Unsigned integer.
InterruptionTotal	Counts total number of transitions to UNSCHEDULED DOWNTIME. Required if accumulators are supported.	RW	N	Unsigned integer.
LastPowerdown	Estimate of last powerdown time.	RO	Y	Formatted numeric text: timestamp format.
NSTime	Accumulated minutes in NON-SCHEDULED TIME state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.
PowerdownTime	Estimate of powerdown time.	RO	Y	Formatted numeric text: timestamp format.
PowerupState	Indicates the powerdown state when powerdown occurs during manufacturing time.	RW	N	Text digit: “2” = standby, “5” =unscheduled downtime.
PrdRecovery	Enables (TRUE) or disables (FALSE) the equipment-initiated return to PRODUCTIVE from UNSCHEDULED DOWNTIME. Required for support of automatic equipment-initiated recovery.	RW	N	Boolean.
PrdState	The last ARAMS code specified by the user for PRODUCTIVE.	RO	Y	Formatted alphanumeric text. 4 characters.
PrdTime	Accumulated minutes in PRODUCTIVE state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.
PrevARAMSState	ARAMS Substate Code corresponding to state prior to last state transition.	RO	Y	Formatted alphanumeric text. 4 characters.
SDTime	Accumulated minutes in SCHEDULED DOWNTIME state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.
SbyRecovery	Enables or disables the equipment-initiated return to STANDBY from UNSCHEDULED DOWNTIME. Required for support of automatic equipment-initiated recovery.	RW	N	Boolean.
SbyTime	Accumulated minutes in STANDBY state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.

Attribute Name	Definition	Access	Reqd	Form
SubstateSelect	Enables (TRUE) or disables (FALSE) equipment-initiated selection of substates in PRODUCTIVE and STANDBY.	RW	N	Boolean.
SymptomID	The identifier of a symptom selected by the user when requesting a state change.	RO	Y	Text. Conforms to ObjID.
SymptomText	The descriptive text of the symptom selected by the user when requesting a state change.	RO	Y	Text. 0–80 characters.
UDTime	Accumulated minutes in UNSCHEDULED DOWNTIME state/substate. Required if accumulators are supported.	RW	N	Unsigned integer.

NOTE 1: The Clock attribute may be replaced by a Clock object having a DateTime attribute, as defined in SEMI E38.

13.2 *Table Objects* — Table 7 defines the attributes of a generic table. This is an abstract type of object that is not itself directly implemented. Specific table types, which require definitions of their row formats (Section 10.2), are subtypes of the generic table supertype and inherit all of the attributes of the supertype (see SEMI E39, Appendix).

Table 7 Table Object Attribute Definition

Attribute Name	Definition	Access	Reqd	Form
ObjType	The object type.	RO	Y	Text = “Table”.
ObjID	The object’s identifier.	RO	Y	Text. 1–80 characters.
NumCols	Number of columns.	RO	Y	Unsigned integer.
NumRows	Number of rows.	RO	Y	Unsigned integer.
DataLength	Total number of bytes required to store the table elements, exclusive of any formatting required for storage or transfer.	RO	Y	Unsigned integer.

13.3 Different applications may define additional table attributes for specific table types. The subtypes defined by ARAMS (Sections 10.3 and 10.4) are “TableARAMSCode” and “TableARAMSSymptom” and have no additional attributes.

14 Human Interface Requirements

This section provides a central location for requirements affecting the human interface. It specifies the functions that shall be available to the operator through the equipment’s console (human interface), where the equipment provides such an interface. Applications that do not otherwise provide such an interface (e.g., cluster modules) are exempted from these requirements.

14.1 *Data Access* — All supported data elements defined in Section 11 shall be accessible to the operator. Specifically, the operator shall be able to view all ARAMS data provided by the equipment and shall be able to modify the values of all data defined in Section 11.4.

14.1.1 Where the accumulators defined in Section 11.5 are supported, the operator shall be able to change their individual values, with the exception of ARAMSAccumReset, and to reset the entire set together.

14.2 *Selection of an ARAMS State/Substate* — The operator shall be able to select any of the standard ARAMS states and substates defined in Section 9.2, exclusive of those definitions with a “Reserved” substate that are reserved for future standards. The operator shall also be able to select MANUFACTURING.

14.2.1 Where ARAMS Substate Tables are provided with user-defined or supplier-defined extensions, these extensions shall also be available to the operator for selecting a change in the current ARAMS state and /or substate.

14.2.2 When selecting a SCHEDULED DOWNTIME or UNSCHEDULED DOWNTIME state/substate, the operator shall be able to enter a comment to be stored in DowntimeData (Section 11.2.10).

14.3 *User-Defined ARAMS Symptom Tables* — Where ARAMS Symptom Tables are supported, the descriptive text for symptoms provided within existing ARAMS Symptom Tables shall be presented to the operator for selection, according to the specifications in Section 10.4, at the time the operator selects an ARAMS State (Section 14.3). The operator is not required to select a symptom. If the operator selects a symptom, the symptom identifier is stored in the variable SymptomID and the descriptive text is stored in SymptomText.

14.4 *Table Access* — Where the equipment supports one or both types of tables specified by ARAMS (Sections 10.3 and 10.4), the operator shall have full access to entries within those tables that are user-defined. The operator shall be able to enter (define), modify, and delete user-defined entries within ARAMS table. The operator shall not be able to change or delete the generic ARAMS Substate Codes defined in Section 9 or supplier extensions to those generic codes.

14.4.1 The operator shall be able to read the contents of all existing ARAMS tables.

14.5 *Color Codes* — The use of color associated with the display of ARAMS state information is optional. To ensure consistency for the user, the following color schemes shall be applied for all cases where color is associated with an ARAMS state.

Uptime states

PRODUCTIVE: green

STANDBY: yellow

ENGINEERING: blue

Downtime states

SCHEDULED DOWNTIME: light red

UNSCHEDULED DOWNTIME: red

Other

NON-SCHEDULED TIME: grey

14.5.1 This scheme provides a visual grouping.

NOTE 21: The colors used for the two downtime states should be both clearly related and readily distinguishable, such as pink and bright red.

15 Services

15.1 This section formally defines the message services specifically required to support ARAMS functionality.

15.1.1 Formal definition has three parts:

- A list of the services defined (Table 8),
- a common parameter dictionary defining all of the parameters of these services (Table 9), and
- a dictionary of the individual services that defines the parameters used by each service.

15.1.2 Services that are used by ARAMS, but are not specific to ARAMS, are defined by other standards and are referenced in Section 3.

15.1.3 Both the equipment and the host provide the services TableSend and TableRequest, and both may use the services provided by the other. The service ARAMSStateChange is provided by equipment only.

15.1.4 Table 8 lists the ARAMS services. There are two types of services:

- An initial message and response between the service user and the service provider.
- A notification message from the service provider to the service user that does not require a response.

15.1.5 The column in Table 8 that is called “Type” is used to indicate whether the service consists of a request/response message pair (R) or a single notification message (N).

Table 8 ARAMS Services

Message Service Name	*Type*	*Description*
TableSend	R	Used by the service user to send or delete a table.
TableRequest	R	A request to receive a table.
ResetAccumulators	R	A request to reset the set of accumulators.
ARAMSStateChange	R	Request to go to a specified ARAMS state/substate.

15.1.6 Figure 5 shows the message flow for each of the above ARAMS services.

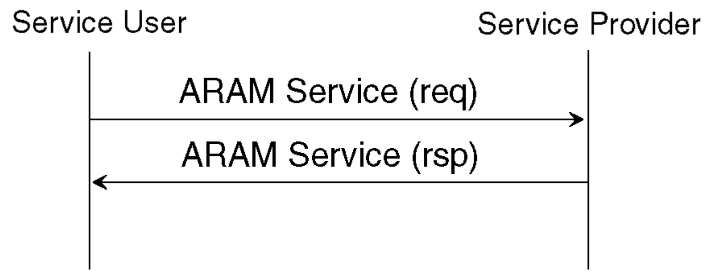


Figure 5
ARAM Service Message Flow

15.2 *Services Parameter Dictionary* — Table 9 defines all of the parameters, including the elements of complex parameters, used in ARAMS message services. Parameters are listed in alphabetical order.

15.2.1 The "Form" column in Table 9 indicates the data type for the parameter. A list of the standard data types for "Form" is included in Section 4.3.

Table 9 ARAMS Services Parameter Dictionary

Parameter	*Definition*	*Form*
ARAMSCode	ARAMS state/substate code.	Alphanumeric text with fixed length of four characters.
AttrData	The value of an attribute.	Varies with attribute.
AttrName	The attribute's name.	Text. Varies with object type.
ColHdr	Column header.	Text. 1–20 characters.
ErrorCode	Contains the code for the specific error found.	Enumerated.
ErrorText	Text in support of the error code to provide additional information.	Text.
ObjSpec	The object specifier, used to specify the owner of the target object.	Formatted text.
RequestStatus	The result of the request to change to a new ARAMS state/substate.	Enumerated: 0 = Acknowledge, action has been effected. 2 = Cannot perform now. 3 = Invalid parameter 4 = Acknowledge, action will be performed with completion signaled later by an event. 6 = Object unknown.
Status	Error information.	Structure consisting of ErrorCode and ErrorText.
SymptomID	The numeric symptom identifier.	Unsigned integer.
SymptomText	Descriptive text for symptom.	Text. 0–80 characters.
TableAck	Indicates the success (=T) or failure (=F) of the operation.	Boolean.
TableAttr	A table attribute other than object (table) type or object (table) identifier. (See NOTE 1.)	Structure consisting of AttrName and AttrData.
TableCmd	Instructions concerning the table transfer.	Enumerated: Entire table Add new rows Append new columns Replace existing rows Replace existing columns
TableElem	One of the basic elements of a table.	Varies with table type and (column) position within the row.

Parameter	Definition	Form
TableID	Table identifier.	Text. 1–80 characters.
TableRow	A row of the table in terms of its elements TableElem.	Structure, consisting of different table elements, following the order of the column headers.
TableStatus	Information concerning the success or failure of the operation.	Structure consisting of TableAck and (List of) Status.
TableType	Type of table.	Text = "TableARAMSCode" or "TableARAMSSymptom".

NOTE 1: ARAMS tables use only the general table attributes: number of rows, number of columns, and table length.

15.3 *TableSend* — The TableSend service is used to transfer or delete a table.

15.3.1 Table 10 defines the parameters for the TableSend service. A table that is not structurally valid shall be rejected and discarded.

Table 10 TableSend Service

Parameter	Req/Ind	Rsp/Conf	Description
ObjSpec	C	-	The object specifier, used to specify the owner of the target object. When omitted, the receiver of the message is intended.
TableType	M	M	Signifies the type of table to be sent.
TableID	C	C(=)	Table identifier. Required for table type TableARAMSSymptom.
TableCmd	M	-	Instructions about the table being transferred.
TableAttr (list of)	M	-	The table's attributes.
ColHdr (list of)	M	-	Table column headers.
TableRow (list of)	C	-	Table contents, organized by rows. Rows may or may not be ordered, depending on the definition for a specific table type. Must be omitted when deleting a table.
TableStatus	-	M	Information concerning the success or failure of the request.

15.4 *TableRequest* — The TableRequest service is used to request the service provider to send a table. A table that is not structurally valid shall be discarded.

15.4.1 Table 11 defines the parameters for the TableRequest service.

Table 11 TableRequest Service

Parameter	Req/Ind	Rsp/Conf	Description
ObjSpec	C	-	The object specifier, used to specify the owner of the target object. When omitted, the receiver of the message is intended.
TableType	M	M	Signifies the type of table to be sent.
TableID	C	C(=)	Table identifier. Required for table type TableARAMSSymptom.
TableCmd	M	-	Instructions about the table being transferred.
TableElem (list of)	C	-	Row identifiers of requested rows. If omitted, entire table is requested.
TableAttr (list of)	-	M	Table attributes.
ColHdr (list of)	-	M	Table column headers. Omitted only if table for specified type and identifier does not exist.
TableRow (list of)	-	M	Table rows. Omitted only if table for specified type and identifier does not exist.
TableStatus	-	M	Information concerning the success or failure of the request.

15.5 *ARAMSStateChange* — The ARAMSStateChange service is sent to the service provider to request a change to a new ARAMS state/substate.

15.5.1 Table 12 defines the parameters for the ARAMSStateChange service.

Table 12 ARAMSStateChange Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object. When omitted, the receiver of the message is intended.
ARAMSCode	M	-	New ARAMS state/substate requested.
SymptomID	C	-	ARAMS Symptom ID. Optional.
SymptomText	C	-	Symptom description. Optional.
RequestStatus	-	M	Information concerning the success or failure of the request.

15.6 *ResetAccumulators* — The ResetAccumulators service is sent to the service provider to request that the set of accumulators defined in Section 11.5 be reset.

15.6.1 Table 13 defines the parameters for the ResetAccumulators service.

Table 13 ResetAccumulators Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	C	-	The object specifier, used to specify the owner of the target object. When omitted, the receiver of the message is intended.
RequestStatus	-	M	Information concerning the success or failure of the request.

16 ARAMS Behavioral Requirements

This section specifies the behavior required for ARAMS compliance.

16.1 *ARAMS State Transitions* — ARAMS compliance requires that the equipment be capable of Transitions 1 through 11 in Table 1, with the exception of Transition 9. Transitions 12 and higher are optional.

16.1.1 Transition 9 is required only of equipment that puts itself in a preventive maintenance mode based on one or more internally monitored parameters, such as a cycle counter. Transition 9 specifies that such a transition takes place from STANDBY to SCHEDULED DOWNTIME only. For equipment without this feature, Transition 9 never occurs.

16.1.2 The equipment is required to provide the capability to report to the host each time a state transition occurs and to include data related to that transition in these reports. Transition data included in these reports allows the factory to calculate the amounts of time spent in the different states.

16.1.3 At all transitions except Transition 10, when a manufacturing state is specified, and Transition 11, the current value of ARAMSState is stored in PrevARAMSState and the ARAMS Substate Code specified is then stored in ARAMSState. A user selection of a specific manufacturing state is discussed in Section 16.5 below.

16.1.4 For all equipment-initiated transitions, except as specified in Sections 16.5 and 16.6, the equipment shall use an ARAMS Substate Code representing the default for that state and shall not select a substate.

16.1.5 DowntimeAlarm and DowntimeAlarmText are set only for equipment-initiated transitions to SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME. For all other transitions, these variables are cleared.

16.1.6 If the equipment supports ARAMS accumulators (Section 11.5), then the time spent in the previous state is calculated and the appropriate accumulator is updated at this time.

16.2 *Powerup Entry* — The ARAMS State Model becomes active during or after initialization following a powerup or reset when Transition 1 occurs. The state entered at Transition 1 (the default entry state) depends upon the ARAMS state that was last active before the powerdown or reset occurred. This is determined by the ARAMS Substate Code stored in ARAMSState (Section 11.2.4). If this value is not a valid ARAMS Substate Code as defined in Section 9.4, then the default entry state is NON-SCHEDULED TIME.

16.2.1 At Transition 1, if the value in Powerdown-Time does not represent a valid date and time, it shall be set to a string of all zeroes. The value stored in PowerdownTime is then stored in LastPowerdown to preserve the estimate of the timestamp of the last powerdown or reset. PowerdownTime is next set to the current date and time, and periodic updating of Class 5 variables is enabled.

16.2.2 Normal communications to both operator and host are unavailable from powerdown to a point within or following system initialization. It is recommended that initializations affecting communications with the host precede initialization of the ARAMS State Model, to allow an event report to be sent to the host on Transition 1. It is highly desirable to the host to receive an event report for Transition 1. However, it is not required for ARAMS compliance.

16.2.3 Transition 11 never generates an event report.

16.3 *Powerup and Powerdown States* — The ARAMS state entered at Transition 1 is the default or powerup entry state for the ARAMS State Model. The powerdown state is the state that was active at Transition 11 and is determined by the value stored in ARAMSState at the time of Transition 1.

16.3.1 If the value in ARAMSState indicates any non-manufacturing state (ENGINEERING, SCHEDULED DOWNTIME, UNSCHEDULED DOWNTIME, or NON-SCHEDULED TIME), it is regarded by the factory as continuing in that state both during the time it is powered off and at Transition 1. The powerup entry state is the same as the powerdown state.

16.3.1.1 If the equipment is in PRODUCTIVE or STANDBY and is powered off, it is regarded by the factory as in UNSCHEDULED DOWNTIME from the time of the powerdown, through any subsequent powerup, and until it is specifically put into a different state by the user. The ARAMS powerup entry state either is UNSCHEDULED DOWNTIME or is determined by an optional variable PowerupState (Section 11.4.2) to be either UNSCHEDULED DOWNTIME or STANDBY.

16.3.1.2 If the ARAMS state prior to powerdown cannot be determined (e.g., if it has never been set or is invalid), the state entered after powerup is NON-SCHEDULED TIME.

16.3.1.3 Time-in-state calculations for the powerdown state assume that any transition to a new state occurs at the time of powerdown, re-boot, or reset.

16.3.2 *PowerupState* — PowerupState, where supported, shall be configurable by the user to specify either UNSCHEDULED DOWNTIME or STANDBY as the powerup entry state after a powerdown has occurred from PRODUCTIVE or STANDBY. The impact of loss of power has different effects on different types of equipment. An entry state of STANDBY allows those types of equipment that do not have safety or setup concerns to be powered off and on and returned to manufacturing. PowerupState contains a text character of either "2" (STANDBY) or "5" (UNSCHEDULED DOWNTIME) and has an initial default value of "5". If the value in PowerupState is neither "2" nor "5", then it shall be set to "5".

16.4 *User-Initiated State Change Requests* — The user may request an ARAMS state change at any time. The host requests a state change through the ARAMS message ARAMSStateChange (Section 15.5), specifying an ARAMS Substate Code or the special manufacturing code "0000". The operator uses the human interface to request a state change, and this shall result in the specification of a valid ARAMS Substate Code (Section 9.4) or of the manufacturing code.

16.4.1 The equipment shall deny the request if the specified code is not valid or if the user specifies a code for manufacturing when any exception condition exists that would prevent the equipment from performing its intended function.* Otherwise, Transition 10 occurs, regardless of whether the new ARAMS Substate Code is the same or different from the value in ARAMSState representing the current state.

* NOTE: See SEMI E10 definitions.

16.4.2 If the user specifies a manufacturing state, and the equipment accepts the state change request, then Transition 10 occurs and is immediately followed by Transition 2. Transition 2 always occurs in conjunction with Transition 10 and does not generate a report separately from Transition 10. It is regarded as an extension of Transition 10 where the equipment determines the specific state/substate based on its internal status at the time.

16.4.3 At Transition 2, the equipment determines the new state as either PRODUCTIVE or STANDBY, based on its internal condition at the time. It is prohibited from transitioning to PRODUCTIVE unless its productive criteria have been met and it is busy performing its intended function. The current value of ARAMSState is moved to PrevARAMSState, and the ARAMS Substate Code for the new state is placed in ARAMSState. The event report associated with Transition 10 shall be generated after the equipment has determined the new state at Transition 2 and updated the appropriate variables.

16.4.4 The user may optionally specify a symptom identifier and text, which are saved in the variables SymptomID and SymptomText (Section 11.2). If not provided, SymptomID is set to zero and SymptomText is set to a zero-length text string. The equipment does not otherwise set these values.

16.4.5 The user also may optionally enter comments that are stored in DowntimeData when selecting a transition to UNSCHEDULED DOWNTIME from a manufacturing state. Otherwise, DowntimeData is set to a zero-length text string.

16.5 *Production and Standby Substates* — Transitions 2, 3, and 4 are made automatically by the equipment. User requests to change to PRODUCTIVE or STANDBY are accepted as methods of setting the current substate of PRODUCTIVE or STANDBY. However, within the MANUFACTURING superstate, the equipment is responsible for determining when its production criteria are satisfied.

16.5.1 Unless the equipment has information as specified in this section concerning the appropriate substate of PRODUCTIVE or STANDBY, then the equipment shall select the appropriate default ARAMS Substate Code ("1000" or "2000", defined in Section 9.2).

16.5.2 To provide substate refinements important to the user, the equipment shall remember the last ARAMS Substate Code specified by the user for the PRODUCTIVE state at Transition 10 and use this as a default PRODUCTIVE substate value PrdState (Section 11.2) until a new value is specified. This value shall be used for the new (current) ARAMS state/substate information in the variable ARAMSState whenever the equipment transitions to PRODUCTIVE.

16.5.3 The equipment normally uses the default code for all transitions to STANDBY ("2000"). However, when the user specifies an ARAMS Substate Code for STANDBY with a substate, this value is to be used at the next following transition to STANDBY at Transition 2 (if the equipment then transitions to STANDBY) or at the subsequent occurrence of Transition 4 (if the equipment transitioned to PRODUCTIVE at Transition 2).

16.5.4 This value is discarded (or reset to "2000") after a single use or upon any other transition that intervenes between the Transition 10 where it is specified and the time it is applied. This includes intervening occurrences of a new Transition 10 as well as of Transitions 11, 1, and others.

16.5.5 It is not important that the equipment provide the user access to this value except when it is stored in ARAMSState.

16.6 *Equipment-Selected Substates* — Equipment may provide an optional capability to select substates of PRODUCTIVE and STANDBY. In this case, the equipment shall provide a user-configurable variable SubstateSelect that enables and disables this capability (Section 11.4.7).

16.6.1 Substate selection by the equipment is subject to the requirements specified in Section 16.5. If the user has selected a substate of PRODUCTIVE or STANDBY, the equipment is restricted to that substate or extensions of that substate. Note that a user-selected substate of STANDBY is applied at most once.

16.6.2 The capability of selecting substates includes the ability to select a new substate of the current state. Transistions 12 and 13 shall be used for this purpose.

16.6.3 When transitioning to STANDBY, normally at the completion of a process cycle, multiple standby conditions may exist. For example, the equipment may need both material and instructions from the host. In general, a substate code of 2200 (SBY/No product) shall take precedence over 2100 (SBY/No operator) and 2500 (SBY/No host).

16.6.4 If the standby condition represented by the currently selected substate clears, then the equipment shall either select a new substate of STANDBY (Transition 12) or transition from STANDBY (Transition 3).

16.6.5 Additional rules for determining substates may be specific to a type of equipment and may be specified by standards defining the capabilities for that type of equipment.

16.6.6 The equipment supplier shall document the prioritization of standby conditions used by the equipment and of the basis for selecting substates of PRODUCTIVE.

16.7 *Equipment-Detected Exceptions* — The equipment may detect exceptions in any ARAMS state. However, only those exceptions that occur during an uptime state are of interest to the host.

16.7.1 Transitions 5 and 7 indicate the equipment detects a fault condition and transitions to UNSCHEDULED DOWNTIME from STANDBY and PRODUCTIVE respectively. Transitions 6 and 8 are provided to allow the equipment to return to its prior state and are discussed in the following section.

16.7.2 When the equipment detects an exception condition during PRODUCTIVE or STANDBY, so that it is unable to perform its intended function, it shall immediately transition to UNSCHEDULED DOWN-TIME. The identifier of the associated alarm is stored in DowntimeAlarm, and any description text associated with that alarm is stored in DowntimeAlarmText. The equipment supplier may provide additional descriptive text that would be useful in diagnostics or analysis in DowntimeData. In the case of the failure of a component, attributes of that component (e.g., serial number, installation date, lifetime cycles) is desirable.

16.7.3 If the equipment detects an exception condition in non-uptime states, it shall not initiate a state change. Exceptions occur for many reasons in non-manufacturing states. For example, the equipment may be improperly or incompletely installed, or it may be deliberately pushed past its limits.

16.7.4 *Fault Detection in ENGINEERING* — The equipment may also provide optional capability of transitioning to UNSCHEDULED DOWNTIME from ENGINEERING (Transition 12) when it detects an exception. Alarm-related variables in this case are handled in the same way as described above.

16.7.5 The user shall be able to enable and disable this capability with the user-configurable variable EngInterrupt (Section 11.4.1).

16.8 *Equipment-Initiated Recovery* — Equipment-initiated transitions 6, 8, and 13 from UNSCHEDULED DOWNTIME are provided to allow equipment to recover from an equipment-detected fault when the operator intervenes, corrects the fault, and indicates the process can be recovered. For Transition 6 to occur, the equipment shall be able to resume processing without degradation of the process or the material. The equipment is responsible for ensuring the safety of persons, material, and for the equipment itself.

16.8.1 Transition 13 is required if Transition 12 is supported and is prohibited otherwise.

16.8.2 *Automatic Recovery* — Equipment may also provide optional capabilities to recover automatically from transient faults that clear spontaneously. Automatic recovery at Transitions 6, 8, and 13 shall be separately enabled and disabled using the user-configurable variables PrdRecovery (Transition 6), SbyRecovery (Transition 8), and EngRecovery (Transition 13). Equipment is otherwise prohibited from using Transitions 6, 8, or 13 to recover without explicit operator approval.

16.8.2.1 Automatic recovery to manufacturing and automatic recovery to ENGINEERING are regarded as two separate capabilities.

16.8.2.2 If EngInterrupt (Section 11.4.1) is not supported or is disabled, then Transition 13 is prohibited.

17 Requirements for Compliance

This section summarizes the requirements for compliance to ARAMS that are defined in this document.

17.1 *Fundamental Requirements* — Compliance to ARAMS requires certain capabilities that are defined by other standards.

17.1.1 *Event Notification* — A standard method for notifying the host that an event of interest has occurred and for providing specific information related to the event.

17.1.2 *Clock Services* — Provision of a real-time date/time clock with methods for setting and reading the clock from the host.

17.1.3 *Read-Only Data Access* — A standard method for the host to obtain the current values of selected status variables and constants specified in Sections 11.2 and 11.3.

17.1.4 *User-Configurable Data Access* — A standard method for the host to change the values of selected variables defined in Sections 11.4 and 11.5.

17.1.5 *Alarm/Exception Management* — A standard method for notifying the host of abnormal events and/or conditions.

17.1.5.1 In addition to the requirements defined in other standards, the following, defined by ARAMS, are required for compliance to ARAMS:

17.1.6 *ARAMS State Model* — Conformance to the behavior of the ARAMS state model defined in Section 8.3.

17.1.7 *ARAMS State Transition Notification* — Using standard event report mechanisms (above), the host shall be notified of all state transitions as described in Sections 12 and 16.1.

17.1.8 *ARAMS Substate Codes* — Support for ARAMS Substate Code formats, used for equipment variables and service parameters defined in Section 9.

17.1.9 *ARAMS Status Data* — Support for all status variables defined in Section 11.2.

17.1.10 *ARAMS Constant Data* — Support for all data constants and for the user-configurable variable EqpName defined in Sections 11.3 and 11.4.

17.1.11 *ARAMS Event Report Data* — Support for the requirements of Section 12 requires either the provision of pre-defined event reports or provision of the Dynamic Event Report Configuration capability that allows the host to dynamically modify the equipment event reporting setup and define the content of reports for each event.

17.1.12 *Host State Change Request* — Support for the ARAMSStateChange service, defined in Sections 15.1, 15.2, and 15.5.

17.1.13 *Estimation of Powerdown Time* — Provision of a method for maintaining PowerdownTime as an estimate of the time of powerdown to an accuracy within ± one minute.

17.1.14 *ARAMS Behavioral Requirements* — Conformance to all requirements in Section 16 except those identified as optional or requiring optional variables.

17.1.14.1 Table 14 lists the requirements for fundamental compliance to ARAMS and the section references to ARAMS or (where applicable) the standards where these capabilities are defined. These requirements shall all be satisfied for equipment to be termed ARAMS-compliant.

Table 14 Fundamental ARAMS Requirements

Requirement	*Reference*
Event Notification	GEM 4.2.1.1 or ERS
Clock Services	GEM 4.10 or CTMC 8.7
Read-Only Data Access	GEM 4.2.2 or OSS 12.1
User-Configurable Data Access	GEM 4.5 or OSS 12.1
Alarm/Exception Management	GEM 4.3 or EMS
ARAMS State Model	ARAMS 8.3
ARAMS State TransitionNotification	ARAMS 12, 16.1
ARAMS Substate Codes	ARAMS 9
ARAMS Status Data	ARAMS 11.2
ARAMS Constant Data	ARAMS 11.3, 11.4
ARAMS Event Report Data	ARAMS 12, GEM 4.2.1.1, GEM 4.2.1.2.
Host State Change Request	ARAMS 15.1, 15.2, 15.5
Estimation of Powerdown Time	ARAMS 16.2
ARAMS Behavioral Requirements	ARAMS 16 (all except 16.3.2, 16.7.4, 16.8.2)

17.2 *Additional Capabilities* — The following capabilities are not required for fundamental compliance to ARAMS. They are recommended for equipment that provide a local operator interface and are not expected from equipment such as individual process modules of a cluster tool.

17.2.1 *User-Configurable Powerup State* — Provision of the user-programmable variable PowerupState, which allows the user to select either STANDBY or UNSCHEDULED DOWNTIME as the powerup state following powerdowns that occurred during STANDBY. (See Section 16.3.2.)

17.2.2 *User-Configurable Fault Recovery to Manufacturing* — Provision of user-programmable variables, PrdRecovery and SbyRecovery, that allows the user to enable or disable automatic equipment-initiated recovery from faults that clear without user intervention. (See Section 16.7.4.)

17.2.3 *Accumulator Data* — Support for the variables defined in Section 11.5, together with access to this data by the operator (Section 14.1) and the host, with support for the ResetAccumulators service. (See Sections 11.5 and 15.6.)

17.2.4 *User-Generated ARAMS Substate Table(s)* — The ability to accept one or more sets of user-generated ARAMS Substate Codes, as defined in ARAMS Substate Tables, that may be selected by the user in a request to change to a new state or substate. This includes support of the TableSend and TableRequest services and methods for operator access. (See Sections 10.3, 14.2, and 15.3.)

17.2.5 *Equipment-Generated ARAMS Substate Table(s)* — Provision of a set of equipment-defined ARAMS Substate Codes that can be selected by the user in a request to change to a new ARAMS state or substate. This includes support of the TableRequest service. (See Sections 10.3 and 15.4.)

17.2.6 *User-Generated Symptom Table(s)* — The ability to accept one or more user-defined ARAMS Symptom Table, allows the operator to select a symptom when requesting a transition to a new ARAMS state, and the associated data. This includes support for the TableRequest service and methods for operator access. (See Sections 10.4, 14.3, and 15.3.)

17.2.7 *Human Interface Requirements* — Operator access to ARAMS tables as defined in Sections 14.2 through 14.4. Where color is used, conformance to color code in Section 14.5.

17.2.8 *Equipment-Selected Substates* — Support for the user-configurable variable SubstateSelect (Section 11.4.5) allowing the user to enable and disable the capability to select substates of PRODUCTIVE and STANDBY. Documentation of the prioritization of substate selection. (See Section 16.6).

17.2.9 *User-Configurable Fault Detection in ENGINEERING* — Support for Transitions 12 and 13 (Section 16.7.4) and the user-configurable variable EngInterrupt (Section 11.4.1) allowing the user to enable and disable Transitions 12 and 13.

17.2.10 *User-Configurable Fault Recovery to ENGINEERING* — Support for automatic recovery (Transition 13, Sections 16.8.1 and 16.8.2) and the user-configurable variable EngRecovery (Section 11.4.2) allowing the user to enable and disable automatic recovery in Transition 13.

17.2.10.1 Table 15 provides the section references for additional ARAMS capabilities.

Table 15 Section References for Additional ARAMS Capabilities

Capability	*Section Reference*
User-Configurable Powerup State	ARAMS 11.4.4, 16.3.2
User-Configurable Fault Recovery	ARAMS 11.4.2, 11.4.5, 11.4.6, 16.8.2
Accumulator Data	ARAMS 11.5, 15.5
User-Generated ARAMS Substate Table(s)	ARAMS 10.1, 10.2, 10.3, 14.3, 15.3
Equipment-Generated ARAMS Substate Table(s)	ARAMS 10.1, 10.2, 10.3, 15.4
User-Generated ARAMS Symptom Table(s)	ARAMS 10.1, 10.2, 10.4, 14.3, 14.4, 15.3
Human Interface Requirements	ARAMS 14.2, 14.3, 14.4, 14.5
Equipment-Selected Substates	ARAMS 11.4.7, 16.6
User-Configurable Fault Detection in ENGINEERING	ARAMS 11.4.1, 16.7, 16.7.4
User-Configurable Fault Recovery to ENGINEERING	ARAMS 11.4.2, 16.8
Human Interface Requirements	ARAMS 14, 14.1, 14.2.

17.2.11 *Human Interface Requirements* — Operator access to ARAMS data and state change, defined in Sections 14, 14.1, and 14.2.

17.3 *Requirements for Compliance* — Table 16 provides a checklist for ARAMS compliance.

Table 16 ARAMS Compliance Statement

Fundamental ARAMS Requirements	*Implemented*	*ARAMS Compliant (See NOTE 1.)*
Event Notification	❑ Yes ❑ No	❑ Yes ❑ No
Clock Services	❑ Yes ❑ No	❑ Yes ❑ No
Read-Only Data Access	❑ Yes ❑ No	❑ Yes ❑ No
User-Configurable Data Access	❑ Yes ❑ No	❑ Yes ❑ No
Alarm/Exception Management	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS State Model	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS State Transition Notification	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS Substate Codes	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS Status Data	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS Constant Data	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS Event Report Data	❑ Yes ❑ No	❑ Yes ❑ No
Host State Change Request	❑ Yes ❑ No	❑ Yes ❑ No
Estimation of Powerdown Time	❑ Yes ❑ No	❑ Yes ❑ No
ARAMS Behavioral Requirements	❑ Yes ❑ No	❑ Yes ❑ No
Additional Capabilities	*Implemented*	*ARAMS Compliant (See NOTE 2.)*
User-Configurable Powerup State	❑ Yes ❑ No	❑ Yes ❑ No
User-Configurable Fault Recovery to Manufacturing	❑ Yes ❑ No	❑ Yes ❑ No
Accumulator Data	❑ Yes ❑ No	❑ Yes ❑ No
User-Generated ARAMS Substate Table(s)	❑ Yes ❑ No	❑ Yes ❑ No
Equipment-Generated ARAMS Substate Table(s)	❑ Yes ❑ No	❑ Yes ❑ No
User-Generated ARAMS Symptom Table(s)	❑ Yes ❑ No	❑ Yes ❑ No
Equipment-Selected Substates	❑ Yes ❑ No	❑ Yes ❑ No
User-Configurable Fault Detection in ENGINEERING	❑ Yes ❑ No	❑ Yes ❑ No
User-Configurable Fault Recovery to ENGINEERING	❑ Yes ❑ No	❑ Yes ❑ No
Human Interface Requirements	❑ Yes ❑ No	❑ Yes ❑ No

NOTE 1: Do not mark YES unless all fundamental ARAMS requirements are implemented.

NOTE 2: Additional capabilities may not be marked ARAMS-compliant unless all fundamental ARAMS requirements are implemented.

18 ARAMS States for Multi-Module Equipment

18.1 The preceding sections define how ARAMS is to be supported by simple equipment. Simple equipment includes equipment with at most one process chamber, and a single process capability, where individual modules are not treated separately from the equipment.

NOTE 22: Process capability, in this context, refers to the factory's manufacturing process. Equipment with more than one process capability may be used in different ways at different steps, typically through different process recipes. Such equipment may be "available" for one process but not for another. This type of complexity is neither addressed nor affected by SEMI E10 or by ARAMS.

18.2 This section addresses the application of ARAMS to complex equipment, including modular equipment where individual modules may be in different ARAMS states/substates. Complex equipment includes cluster tools and any other type of equipment that is organized into separate subsystems that can be addressed individually. In this case, it is advantageous for each module or subsystem to be given its own ARAMS state model. In addition, the overall equipment system itself has an ARAMS state model. This situation is illustrated in Figure 6.

18.3 The complexities of possible interactions between ARAMS states of the individual modules and the ARAMS state of the cluster tool as a whole are beyond the scope of this document. The following approach is recommended:

- Each module complies to fundamental requirements for the ARAMS state model, data variables, and message services.
- The integrated cluster tool complies to requirements for the ARAMS state model, data variables, and message services.
- The set of all the ARAMS models above are simultaneously active, as represented in Figure 6.
- The relationships between the ARAMS state for the cluster tool and the ARAMS states for the individual modules are user-configurable wherever possible. (Certain relationships between the cluster and critical modules, such as central wafer handler or central load lock, may not be configurable: e.g., if the critical module is down, the cluster is down.)

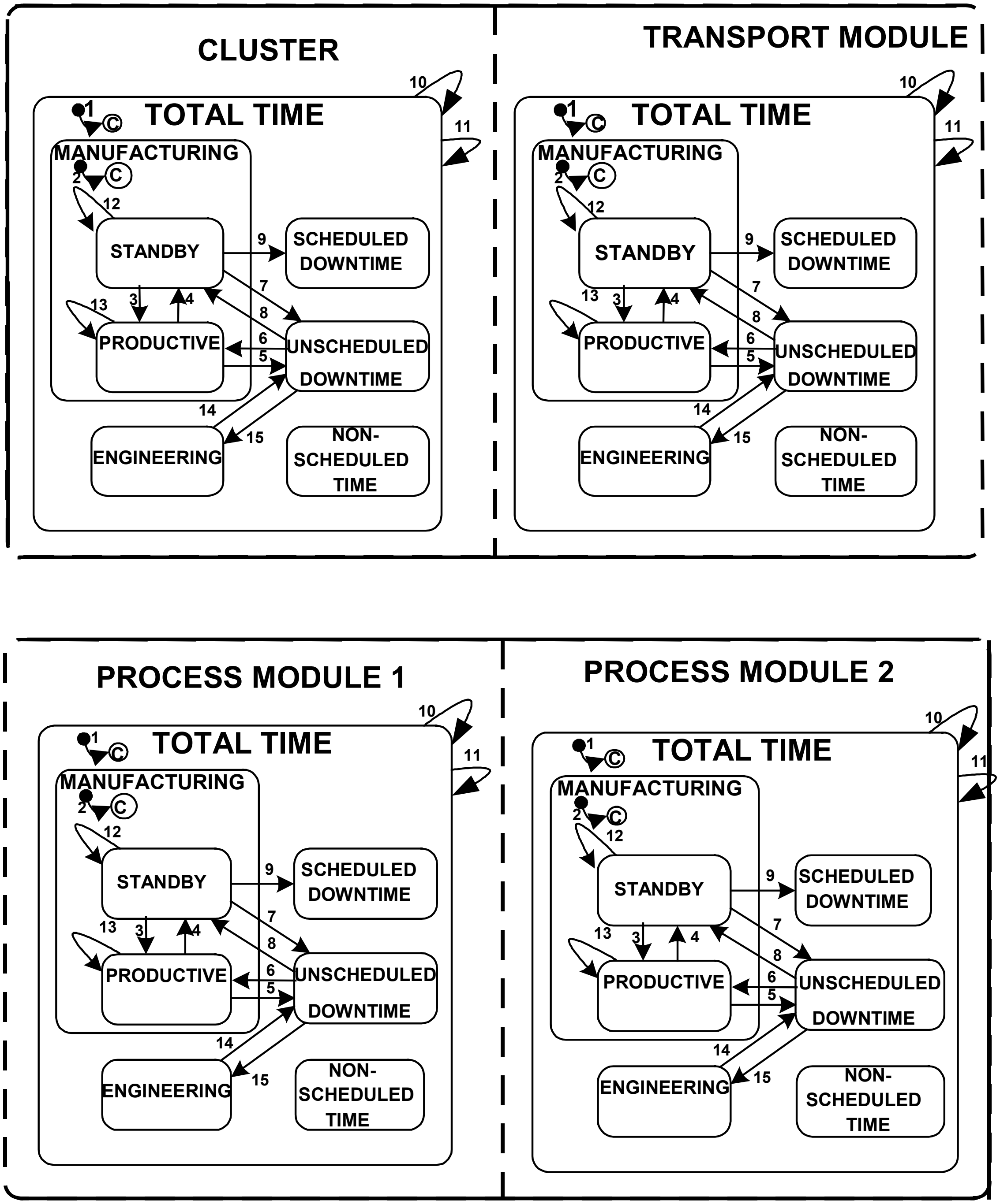


Figure 6
ARAMS Model for Cluster

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E58 and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information provided as background or examples of possible application and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

This section describes different applications of ARAMS, including an example of a method for estimating the time of powerdown as well as various scenarios.

R1-1 Estimating Powerdown Time

R1-1.1 This section describes a method for estimating the time at which a loss of power, reset, or re-boot occurs. Estimation of this time, allows the accumulation of time-in-state for the previous ARAMS state to be maintained.

R1-1.1.1 The equipment maintains a date/time value, PowerdownTime, that is used to estimate the time when a loss of power occurred (see Section 11.2.12). In this example, the equipment provides an additional user-configurable variable, UpdatePeriod, that defines the number of seconds in an update period. UpdatePeriod is used to set an interval timer. PowerdownTime is updated with the current date and time at the end of each timed interval.

R1-1.1.2 Whenever the equipment enters the initialization state, whether through powerup, reset, or re-boot, it uses the value found in PowerdownTime as the estimate of when the powerdown occurred. If a state change occurs as the result of a powerdown, then the time that has elapsed since the point of powerdown is used to update the appropriate time-in-state accumulator for the previous ARAMS state.

R1-1.1.3 For an example of the sequence of events and actions following a powerup, see Section R1-2.

R1-1.1.4 Figure R1-1 provides a simple logic flowchart as an illustration of the update process.

R1-1.2 *UpdatePeriod* — The length of the time interval, in seconds, for updating PowerdownTime. Form: positive integer.

R1-2 Powerup Scenario

R1-2.1 This scenario is analogous to a timing diagram. It illustrates the actions that occur at different times in sequence, showing the effect of a powerdown that occurs while the equipment was in the PRODUCTIVE state. In this example, accumulators defined in Section 11.5 are supported. UpdatePeriod is defined in the prior section and is set to a value of 30 seconds.

R1-2.2 In this example, the equipment received instructions for processing prior to the start of the timing and waited briefly for the material to arrive. Timing shown in this example begins when it receives the expected material and transitions from STANDBY to PRODUCTIVE at time = t_0. After a sequence of its normal periodic updates ($t_i = t_{i-1}$ + UpdatePeriod) of the estimated time of powerdown, it loses power while still in the PRODUCTIVE state. Following powerup, it determines the new ARAMS state, sets the required variables, and reports the state change to the host.

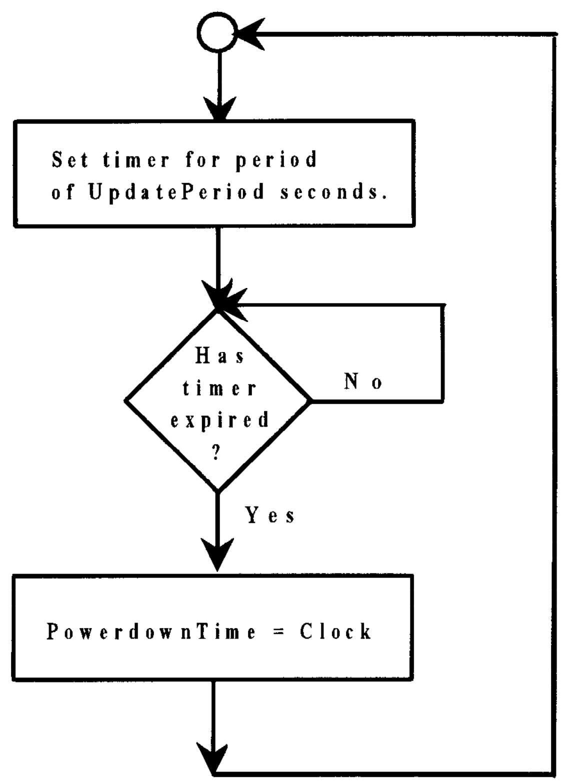


Figure R1-1
Periodic Update Logic

R1-2.3 The notation "=" indicates the value of a variable, while ":=" is used to indicate the act of setting a variable to a specific value. The notation "←" is used to indicate a message sent from equipment to host, and the notation "→" is used to indicate a message sent from the host to equipment.

Table R1-1 Powerup Scenario

Time	*Action*	*Comment*
	ARAMSState = “2000” ARAMSTimestamp = t_{-1} PrdState = “1100”	Initial conditions prior to t = t_0: Equipment is in STANDBY PRODUCTION substate is “regular”
t_0	ARAMSTimestamp:= Clock PrevARAMSState:= ARAMSState ARAMSState:= PrdState	Requirements for PRODUCTIVE are satisfied. Equipment transitions automatically.
$t_1 = t_0 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
$t_2 = t_1 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
$t_3 = t_2 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
$t_4 = t_3 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
$t_5 = t_4 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
$t_6 = t_5 + 30$	PowerdownTime:= Clock	Periodic update of estimated powerdown time.
t_7		Powerdown
t_8	LastPowerdown:= PowerdownTime PowerdownTime:= Clock Elapsed time before powerdown = LastPowerdown – ARAMSTimestamp ($t_6 - t_0$) ARAMSTimestamp:= LastPowerdown (t_6) PrevARAMSState:= ARAMSState (“1100”) ARAMSState:= “5000” (“UDT”) PrdTime:= PrdTime + elapsed time ($t_6 - t_0$)	Powerup: Transition 1 Equipment system initialization ARAMS housekeeping Transition complete.
t_9	← ARAMS State Change Event Report “A” ← ARAMS Transition Event Report “B”	Equipment sends event notification to host.

R1-3 Equipment-Initiated Transition

R1-3.1 This scenario illustrates the events and activities that occur as the result of an equipment-initiated transition from PRODUCTIVE to UNSCHEDULED DOWNTIME, for equipment supporting the accumulators in Section 11.4.

Table R1-2 Equipment-Initiated Transition

Comment	*Host*	*Equipment*	*Comment*
		ARAMSState = “1100” (“PRD/Regular Production”)	Initial conditions.
			Equipment detects mechanical fault in wafer handler.
			Equipment suspends processing, transitions to UNSCHEDULED DOWNTIME, and notifies user.
		Elapsed time: = Clock – ARAMS ARAMSTimestamp:= Clock PrevARAMSState:= ARAMSState (“1100”) ARAMSState:= “5000” (“UDT”) DowntimeAlarm:= alarm/exception identifier DowntimeAlarmText := alarm/exception description DowntimeData:= additional information Prdtime:= Prdtime + elapsed time	

		← ARAMS State Change Event (Report "A")	
		← ARAMS Transition Event (Report "B")	

R1-4 Operator-Initiated Transition

R1-4.1 This scenario illustrates the events and activities that occur as the result of an operator-initiated transition from PRODUCTIVE to UNSCHEDULED DOWNTIME.

Table R1-3 Operator-Initiated Transition

Comment	*Host*	*Equipment*	*Comment*
		ARAMSState = "1100" ("PRD/Regular Production")	Initial conditions.
			Operator aborts process. Equipment halts processing.
		PrevARAMSState:=ARAMSState ("1100") ARAMSState:= "5000" ARAMSTimestamp:= Clock SymptomID:= corresponding symptom identifier. SymptomText:= corresponding symptom description.	Operator selects new ARAMS state of UNSCHEDULED DOWNTIME ("5000"). Operator selects description of a symptom.
		Elapsed time:= Clock – ARAMSTimestamp ARAMSTimestamp:= Clock ARAMSState:= "5000" ("UDT") DowntimeAlarm:= alarm/exception identifier DowntimeAlarmText:= alarm/exception description DowntimeData:= additional information PrdTime:= PrdTime + elapsed time	
		← ARAMS State Change Event (Report "A")	
		← ARAMS Transition Event (Report "C")	

R1-5 Host-Initiated Transition

R1-5.1 This scenario illustrates the events and activities that occur as the result of a host-initiated transition from its current substate of STANDBY to a different substate of STANDBY.

Table R1-4 Host-Initiated Transition

Comment	*Host*	*Equipment*	*Comment*
		ARAMSState = "2800" ("SBY/No host")	Initial conditions.
Host sends new ARAMS substate code.	ARAMSStateChange.req → (ARAMSCode = "2400")		
		Elapsed time:= Clock Ð ARAMSTimestamp PrevARAMSState:= ARAMSState ("2800") ARAMSState:= "2400" ("SBY")	NOTE – ARAMSTimestamp is unchanged.
		← ARAMSStateChange.rsp	Equipment acknowledges the new state change.
		← ARAMS State Change Event (Report "A") ← ARAMS Transition Event (Report "C")	Equipment notifies host of ARAMS state change.

RELATED INFORMATION 2

NOTE: This related information is not an official part of SEMI E58 and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information provided as background or examples of possible application and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

This section discusses issues that may arise through implementations of ARAMS.

R2-1 User-Initiated Transitions to UNSCHEDULED DOWNTIME

R2-1.1 Although substates of UNSCHEDULED DOWNTIME include (unplanned) change of consumables, out-of-spec input material, and facilities-related downtime, transitions to UNSCHEDULED DOWNTIME are generally regarded as resulting from an equipment fault. Operators have sometimes been known to log the equipment into UNSCHEDULED DOWNTIME as a way of freeing time, even though the equipment is operating completely within specifications.

R2-1.2 The equipment may use the status (read-only) ARAMSInfo to record information, such as Operator ID, that could be used in its defense.

R2-1.3 Additionally, equipment is encouraged to maintain an internal log of events. While the host may or may not request ARAMSInfo in an event report, the equipment's log could be used to record the information and would be accessible to field service personnel for analysis. Recording information such as the date, day of week, time of day, identifier of the operator (where known) could be an effective protection against abuse.

SEMI E58.1-0697
SECS-II PROTOCOL FOR AUTOMATED RELIABILITY, AVAILABILITY, AND MAINTAINABILITY STANDARD (ARAMS): CONCEPTS, BEHAVIOR, AND SERVICES

1 Purpose

This document maps the services and data of the Automated Reliability, Availability, and Maintainability Standard (ARAMS) to SECS-II streams and functions and data definitions.

2 Scope

This document applies to all implementations of ARAMS that use the SECS-II message protocol (SEMI E5).

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E58 — Automated Reliability, Availability and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

4 Services Mapping

Table 1 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the services defined in ARAMS.

The ARAMSStateChange service may be mapped either to S2,F41/F42 or to S2,F49/F50 or both. The equipment supplier is required to document the mapping used.

Table 1 Services Mapping Table

Message Name	*Stream, Function*	*SECS-II Message Name*
ARAMSStateChange	S2,F41/F42 S2,F49/F50	Host Command Send/Acknowledge Enhanced Remote Command/Acknowledge
ResetAccumulators	S2,F41/F42 S2,F49/F50	Host Command Send/Acknowledge Enhanced Remote Command/Acknowledge
TableSend	S13,F13/F14	Table Data Send/Acknowledge
TableRequest	S13,F15/F16	Table Data Request/Table Data

5 Service Parameter Mappin g

Table 2 shows the mapping between service parameters defined by ARAMS and the data items defined by SEMI E5. An additional mapping for the ARAMSStateChange and ResetAccumulators services is shown in Table 4 below.

Table 2 Service Parameter Mapping Table

Parameter Name	*SECS-II Data Item*
AttrData	ATTRDATA
AttrName	ATTRID
ColHdr	COLHDR
ErrorCode	ERRCODE
ErrorText	ERRTEXT
ObjSpec	OBJSPEC
RequestStatus	HCACK
TableAck	TBLACK
TableCmd	TBLCMD
TableElem	TBLELT
TableID	TBLID
TableType	TBLTYP

Table 3 shows the data items in SECS-II messages that do not have a corresponding service parameter.

Table 3 Additional Data Item Requirement Table

Function	*SECS-II Data Item*
Used to satisfy SECS-II conventions for linking a multi block inquiry with subsequent multilock message.	DATAID
Used by S2F41 and S2F49 to indicate the ARAMSStateChange Service.	RCMD="ARAMSStateChange"
Used by S2F41 and S2F49 to indicate the ResetAccumulators Service.	RCMD="ResetAccumulators"

NOTE: The text strings specified in Table 3 for RCMD shall be recognized by the equipment, whether the equipment is or is not case-sensitive.

Table 4 provides the parameter mapping for the ARAMSStateChange and the S2,F41 and S2,F49 messages.

Table 4 Service Parameter Mapping (S2F41 and S2F49)

Parameter Name	*CPNAME*	*CPVAL/CEPVAL (Form)*
ARAMSCode	"ARAMSCode"	Text, 4 characters
ObjSpec	"ObjSpec"	Text. Conforms to data item OBJSPEC. NOTE: in S2,F49, ObjSpec maps directly to the data item OBJSPEC.
SymptomID	"SympID"	Unsigned integer
SymptomText	"SympText"	Text, 0–80 characters

NOTE: The text strings specified in Table 4 for CPNAME shall be recognized by the equipment, whether the equipment is or is not case-sensitive.

SEMI E81-0600
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK DOMAIN ARCHITECTURE

This provisional specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org April 1999; to be published June 2000. Originally published June 1999.

1 Purpose

1.1 This document is an overview of the structure and contents of a suite of documents representing an application framework for the Computer Integrated Manufacturing (CIM) systems as used in semiconductor factories. A framework is a software infrastructure that creates a common environment for integrating applications and sharing information in a given domain. The purpose of this framework is to establish an industry standard architecture for complex manufacturing systems, leading to an open, multisupplier CIM system environment. The framework described in this specification is called the CIM Framework.

2 Scope

2.1 The intent of this document is to describe the Manufacturing Execution Systems (MES) domain that is the subject of the CIM Framework and to provide a reference for concepts that are common to the set of documents that specify the CIM Framework. The *Provisional Specification for CIM Framework Domain Architecture* defines the structure, relationships and interworkings of the components that together comprise the CIM Framework. This architecture defines the partitioning of the CIM Framework components and the responsibilities of each of those components. It also specifies the common abstractions for manufacturing jobs, material, and factory resources that are used consistently throughout the CIM Framework as unifying themes.

2.2 The CIM Framework Domain Architecture does not address the dependencies on computing technologies needed to implement these components. These aspects apply more to the realization of the components as software artifacts than to their functionality in terms of semiconductor manufacturing concepts. The technical aspects of the CIM Framework architecture are captured in a separate document, SEMI E96, Guide for CIM Framework Technical Architecture.

2.3 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The CIM Framework Specification must continue to evolve to meet the needs of a competitive and vital industry. The content of this framework represents a significant amount of real development experience from a number of commercial software suppliers and their customers. These specifications reflect the product architectures of those companies, as well as the requirements of their customers.

3.2 As a SEMI Provisional Standard, the Specification for CIM Framework Domain Architecture has specific deficiencies that must be addressed before it may be upgraded to full SEMI Standard status. These deficiencies are:

- Ensuring consistency with the details of subsequent related specifications that are based on this domain architecture.
- Evolving from coarse-grained component partitions to fine-grained components that provide substitutability of smaller components.
- Expanding interfaces to include build-time configuration functions.
- Providing fully validated models using the standard Unified Modeling Language (UML) notation.
- Aligning the CIM Framework representation of equipment and interfaces for interactions with equipment automation software with emerging standards in areas such as Object-Based Equipment Model (OBEM) and Automated Material Handling Systems (AMHS).
- Modifying the CIM Framework use of the “in” parameter mode and operation return value to include also the “out” and “inout” modes to better accommodate implementations based on Microsoft DCOM and IDL enhancements for pass-by-value of objects.

- Adjusting the functional partitioning of the Domain Architecture to reflect the final positioning of sub-components in the anticipated revisions of the other CIM Framework specifications.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E32 — Material Movement Management (MMM)

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E86 — Provisional Specification for CIM Framework Factory Labor Component

SEMI E93 — Provisional Specification for CIM Framework Advanced Process Control Component

SEMI E96 — Guide for CIM Framework Technical Architecture

SEMI E97 — Provisional Specification for CIM Framework Global Declarations and Abstract Interfaces

SEMI E102 — Provisional Specification for CIM Framework Material Transport and Storage Component

4.2 *OMG Documents*[1]

CORBA — Common Object Request Broker Architecture, Version 2.3.1 (OMG Document formal/99-10-07).

MfgDTF — Manufacturing Domain Task Force Roadmap, Version 3.1 (OMG Document mfg/98-06-11).

OMA — Object Management Architecture Guide, Version 3.0 (OMG Document ab/97-05-05).

UML — UML Notation Guide, Version 1.1 (OMG Document ad/97-08-05).

Workflow — Joint Workflow RFP Revised Submission (OMG Document bom/98-06-07).

1 Object Management Group, 492 Old Connecticut Path, Framingham, MA 01701, USA

4.3 *SEMATECH Documents*[2]

CIMArch — Computer Integrated Manufacturing (CIM) Framework Architecture Concepts, Principles, and Guidelines, Version 1.0 (SEMATECH-Technology Transfer #97103379A-ENG).

CIMFW — Computer Integrated Manufacturing (CIM) Application Framework 2.0 (SEMATECH Technology Transfer #93061697J-ENG).

4.4 *Other References*

ALBUS — J.S. Albus and A.M. Meystel, *A reference model architecture for design and implementation of intelligent control in large and complex systems*, International Journal of Intelligent Control and Systems vol. 1, no.1 p.15–30, World Scientific: Singapore, March 1996.[3]

ANSI — ANSI Standard ANSI/ISA-S88.01-1995, Batch Control Part 1: Models and Terminology[4]

COM+ — http://www.microsoft.com/msj/1197/complus.htm; http://www.microsoft.com/com/[5]

DCOM — http://www.microsoft.com/windows/downloads/bin/nts/dcom_architecture.exe. [5]

JAVA — http://www.javasoft.com.[6]

WfMC — http://www.wfmc.org.[7]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling System

5.1.2 *APC* — Advanced Process Control

5.1.3 *APCFI* — Advanced Process Control Framework Initiative

5.1.4 *API* — Application Programming Interface

5.1.5 *CIM* — Computer Integrated Manufacturing

5.1.6 *MES* — Manufacturing Execution System

2 SEMATECH, 2706 Montopolis Dr., Austin, TX 78741, USA

3 World Scientific Publishing Co., 1060 Main St., River Edge, NJ 07661, USA

4 American National Standards Institute, 11 West 42nd St., New York, NY 10036, USA

5 Microsoft, 10500 NE 8th St., Ste. 1300, Bellevue, WA 98004, USA

6 Sun Microsystems Inc., 901 San Antonio Road, Palo Alto, CA 94303, USA

7 Workflow Management Coalition Office, 2 Crown Walk, Winchester, Hampshire, S022 5XE, United Kingdom

5.1.7 *MMMS* — Material Movement Management Services (SEMI)

5.1.8 *OBEM* — Object Based Equipment Model

5.1.9 *OMA* — Object Management Architecture

5.1.10 *PFC* — Process Flow Context

5.1.11 *PFI* — Process Flow Iterator

5.1.12 *RFP* — Request for Proposal

5.1.13 *RMS* — Recipe Management System

5.1.14 *UI* — User Interface

5.1.15 *WIP* — Work In Process

5.2 *Definitions*

5.2.1 *abstract interface* — an interface defined outside any component that generalizes common features of the CIM Framework. The abstract interfaces are intended for use in multiple components via interface inheritance mechanisms.

5.2.2 *application* — 1. One or more programs consisting of a collection of interoperating objects which provide domain specific functionality to an end user or other applications. 2. Functionality provided by one or more programs consisting of a collection of interoperating objects.

5.2.3 *application framework* — a framework that constitutes an application or a set of applications for a domain area.

5.2.4 *application interface* — the interface provided by an application or application program.

5.2.5 *application object* — an object implementing an application interface.

5.2.6 *architecture* — the structure of the components of a program/system, their interrelationships, and principles and guidelines governing their design and evolution over time.

5.2.7 *attribute* — an identifiable association between an object and a value. An attribute may have functions to set and retrieve its value.

5.2.8 *behavior* — the effects of performing a requested service including its results.

5.2.9 *binding* — a specific choice of platform technologies and other implementation-specific criteria.

5.2.10 *class* — the shared common structure and common behavior of a set of objects. Class often implies an implementation of the common structure and behavior while interface represents a specification of those common features.

5.2.11 *client* — an object that uses the services of another object by operating upon it or referencing its state.

5.2.12 *collection* — an object containing references to (collections of) other objects with services for managing them and providing access to them as a related group of objects.

5.2.13 *component* — a reusable package of encapsulated objects and/or other components with well-specified interfaces. The component is the element of standardization and substitutability in the CIM Framework.

5.2.14 *Computer Integrated Manufacturing (CIM)* — an approach that leverages the information handling capability of computers to manage manufacturing information and support or automate the execution of manufacturing operations.

5.2.15 *conformance* — adherence to a standard or specification in the implementation of a product, process, or service.

5.2.16 *conformance requirement* — identification in the specification of behavior and/or capabilities required by an implementation for it to conform to that specification.

5.2.17 *conforming implementation* — an implementation that satisfies all relevant specified conformance requirements.

5.2.18 *distributed system* — an integrated collection of several processing and memory components whose distribution is transparent to the user so that the system appears to be local.

5.2.19 *domain interface* — an interface specific to an application subject area.

5.2.20 *domain object* — an object implementing a domain interface.

5.2.21 *events* — an asynchronous message denoting the occurrence of some incident of importance. For example, state change or new object created.

5.2.22 *event channel* — the intermediate object that forwards published events to interested subscribers.

5.2.23 *exception* — an infrastructure mechanism used to notify a calling client of an operation that an unusual condition occurred in carrying out the operation.

5.2.24 *extensibility* — the ability to extend or specialize existing components and add new object classes or components while preserving architectural integrity and component conformance to standards.

5.2.25 *framework* — a collection of classes or components that provide a set of services and functionality for a particular domain.

5.2.26 *implementation* — the internal view of a class, object or module, including any non-public behavior. The specific code and functionality that implements an interface.

5.2.27 *infrastructure* — the services, facilities, and communications mechanisms that support the collaboration between and lifecycle of distributed objects.

5.2.28 *inheritance* — a relationship among classes wherein one class (a subclass) shares the structure or behavior defined in one or more other classes (superclass). A subclass typically specializes its superclasses by augmenting or redefining existing structure and behavior.

5.2.29 *instance* — a software entity that has state, behavior and identity. The terms instance and object are interchangeable. An object is an instance of an interface if it provides the operations, signatures and semantics specified by that interface. An object is an instance of an implementation if its behavior is provided by that implementation.

5.2.30 *interface* — the external view of a class, object, or module that emphasizes its abstraction while hiding its structure and internal behavior. An interface definition ideally includes the semantics.

5.2.31 *interface inheritance* — the construction of an interface by incremental modification of other interfaces (see implementation inheritance). The CIM Framework specifies interface inheritance but not implementation inheritance.

5.2.32 *interoperability* — the ability for two applications or the parts of an application to cooperate. In the CIM Framework, interoperability requires that application components be able to share data, invoke each others' behavior (services), exchange events, and publish service exceptions.

5.2.33 *job* — some system level operation whose execution may be requested by an entity whose responsibility it is to manage jobs. The job concept is analogous to operations performed on the "factory floor" in a physical factory. There, operators are requested to perform operations (jobs) requested by their managing supervisors or some other managing source. A job often spans a significant amount of time and multiple resources within the system. In the CIM Framework, the job construct is intended for specialization to enable specific job supervisors and jobs to provide system solutions.

5.2.34 *lifecycle* — the life of an object, including creation, deletion, copy, and equivalence.

5.2.35 *method* — an operation upon an object defined as part of the declaration of a class. In general, the terms message, method and operation can be used interchangeably. Technically, a method is defined within a class and an operation is defined within the IDL. An operation is implemented by a method.

5.2.36 *object* — an identifiable encapsulated entity that implements one or more services that can be requested by a client. An instance of a class.

5.2.37 *object services* — interfaces for general services that are likely to be used in any program based on distributed objects.

5.2.38 *Object Management Group (OMG)* — an international consortium dedicated to the development of open specifications for distributed, heterogeneous, object-oriented systems.

5.2.39 *operation* — an operation is an entity, identified by an operation identifier that denotes a service that can be requested. An operation has a signature that describes the legitimate values of request parameters and returned results, including any exceptions.

5.2.40 *persistent object* — an object that can survive the process or thread that created it. A persistent object exists until it is explicitly deleted.

5.2.41 *process definition* — information characterizing manufacturing processes including an estimate for the time a process resource will be engaged in the process; process resource settings; and the process capabilities required for the process.

5.2.42 *process flow* — the part of a product specification that defines the sequence of process steps for the manufacturing of a specific product. The data structure for representing a process flow is the directed graph; specifically, a tree structure. The nodes of the tree are called process flow nodes (see below). Services are required to navigate the process flow.

5.2.43 *process flow context* — navigational information pertaining to a product's progress as it traverses its context process flow.

5.2.44 *process step* — the smallest unit of processing activity that can be defined in a process flow. One or more process steps are sequenced to define an operation set.

5.2.45 *recipe* — the pre-planned and reusable portion of the set of instructions, settings and parameters that determine how a job is to be performed. For example, recipes are used to describe Process Steps and are typically contained within a Product Specification.

They determine the processing environment seen by a manufactured product (e.g., wafer). Processing recipes may be subject to change between product runs or processing cycles.

5.2.46 *sub-component* — a component that is fully contained within a larger component. The interfaces of the sub-component may be exposed or hidden by the encapsulating component.

5.2.47 *substitutability* — the ability to replace a given component from one supplier with a functionally equivalent component from another supplier without impacting the other components or its clients in the system.

5.2.48 *type* — a declaration that describes the common properties and behavior for a collection of objects. Types classify objects according to a common interface; classes classify objects according to a common implementation.

6 Overview

6.1 This section provides background information that will help readers get the most from the content of this specification.

6.2 *Intended Audience*

6.2.1 The framework specification is intended to address the needs of the following CIM technologists:

- Technical CIM managers.
- System architects and engineers.
- Application developers and integrators.
- Standards developers.

6.2.2 These groups may be found in a variety of organizations, including semiconductor manufacturers, software product suppliers, system integrators, equipment suppliers, standards organizations, universities, national laboratories, and other research organizations.

6.2.3 *Technical CIM Managers*

6.2.3.1 Technical CIM managers are responsible for managing the development, delivery, and integration of complex manufacturing software applications. They can use the CIM Framework specification to plan and organize the development activities and guide component testing and validation. Moreover, those who buy some of their software from external sources can use it as a purchasing guide when discussing system architecture and integration requirements with potential suppliers.

6.2.4 *System Architects and Engineers*

6.2.4.1 System architects and engineers are responsible for overall system design, including selection of industry standards for computing and communications infrastructure, software development processes, product roadmaps, and related topics. They can make extensive use of the CIM Framework as a starting point for many of their activities, including the

- partitioning and allocation of application functions to specific modules,
- definition of the boundary between the distributed system infrastructure and the rest of the system, and
- specification of open interfaces between the portions of the system they are designing and the external environment.

6.2.4.2 They can also use the CIM Framework specifications to define a strategic system roadmap for migration to an open, distributed system environment.

6.2.5 *Application Developers and Integrators*

6.2.5.1 Application developers and integrators must produce, install, and support software applications for semiconductor manufacturing. The CIM Framework specification, in conjunction with a specific framework "binding" (i.e., target computer system hardware and software technologies), represents a set of detailed design requirements for the application developer. At a minimum, the CIM Framework defines the scope and boundaries of the essential standard components of a manufacturing execution system, and can be used principally as an interface specification. The object models can also be used in the internal design of new applications and/or legacy integration "wrappers," accelerating the development process even further. Finally, the specification can form the basis for creating an independent set of tests necessary to verify conformance.

6.2.6 *Standards Developers*

6.2.6.1 Developers of CIM software standards are responsible for specifying the public interfaces and shared information models that allow the many software products found in a modern semiconductor factory to work together. They can use the CIM Framework as an open source of information for establishing precise definitions for the many items in a factory that must be represented in multiple suppliers' products, including

- standards for partitioning and communicating with complex equipment,
- product and raw material attributes and relationships,

- process definitions and routings,
- equipment data sampling schemes and storage schema,
- personnel qualifications,
- and many others.

6.3 *CIM Framework Foundational Concepts*

6.3.1 This section provides an explanation of the basic concepts of framework, component, and sub-component as used in the CIM Framework Domain Architecture.

6.3.2 *Framework*

6.3.2.1 A framework is a software infrastructure that provides a common environment for the development and integration of applications and sharing of information in a given problem domain. The CIM Framework is a particular type of framework based on an object-oriented model of semiconductor wafer manufacturing. It specifies manufacturing objects and object interaction protocols that enable building semiconductor CIM applications from a framework of compatible, substitutable application components.

6.3.2.2 The heart of the framework is a set of semiconductor manufacturing abstractions (e.g., Wafer, Specification, Machine) and services (e.g., get wafer location, set specification parameter, get machine utilization) that are typically embodied in applications (e.g., material management, specification management, machine control). The implementations of these abstractions are delivered on distributed computer platforms (e.g., workstations, servers) which use standard software system technologies (e.g., communications, database, and user interface). The current CIM Framework is specifically targeted at manufacturing information management and control for both the planning and operational phases of semiconductor wafer fabrication.

6.3.3 *Component Architecture*

6.3.3.1 The CIM Framework specifies software functions that are common across MES applications and serve to integrate those MES applications into a coherent system. The CIM Framework software architecture is based on components. Components are software building blocks—"chunks" of functionality that make up software applications. By specifying standard interfaces and behavior of common MES components, manufacturers can assemble systems from components from multiple suppliers and they can evolve those systems by extending the common components and by substituting old components with improved components that implement the same interfaces and behavior in improved and extended ways. The CIM Framework defines a manufacturing execution system architecture whose components can be assembled in many ways and driven by many business processes and operational policies.

6.3.3.2 Figure 1 shows the CIM Framework architecture as a layered system, with the CIM Framework covering the middle layer of that system. Figure 2 details the layers, showing the components and their interaction and extension. The following subsections provide an introduction to the CIM Framework architecture.

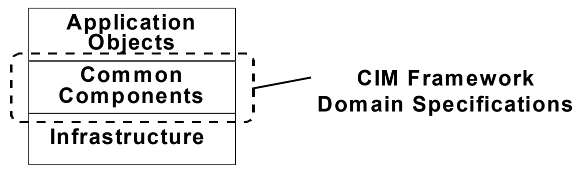


Figure 1
CIM Framework Layering

6.3.3.3 *Infrastructure*

6.3.3.3.1 The infrastructure provides the distributed computing environment for the application. These services include operating system, communications, data storage, user interface, event distribution, exception management, etc. The CIM Framework assumes infrastructure services and facilities defined by the Object Management Group®'s (OMG) Object Management Architecture (OMA) or by the Microsoft® DCOM and COM+ architecture and it can be mapped to other infrastructures such as those for Java™. SEMI E96 addresses the infrastructure layer.

6.3.3.4 *Common Components*

6.3.3.4.1 Common components are the functional entities common across MES applications. For example, material tracking, machine management, and scheduling applications all need a common, shareable concept of wafer groups (lots), machines, and process recipes. The common components provide a shared model for these entities, enabling quicker development and integration of material tracking, machine management, scheduling and other applications. They specify the data and behavior of these components required for interoperability between the applications.

6.3.3.5 *Application Objects*

6.3.3.5.1 The application objects provide the application functionality beyond the common components. These application objects provide application-specific data and behavior (such as the specific scheduling algorithms or the specific recipe management functions), building on the common component data and behavior that allows the application to interoperate with other applications. The application objects also define the business process workflows, business logic and user interfaces for the applications. They provide functionality that is often product- or site-specific. This functionality should not be included in an industry-wide standard for common components. Rather, it should be accommodated through the extendibility and reuse mechanisms of the common components.

6.3.3.6 *Component Granularity and Incremental Standard Conformance*

6.3.3.6.1 The CIM Framework components are the smallest elements of standardization of functional interface and behavior. The CIM Framework specifies relatively fine-grained components (in terms of their functional scope) as in the SEMATECH CIM Framework Specification Version 2.0 [CIMFW]. These components are larger than objects (their specification is in terms of an object model with typically three to five objects) but more fine-grained than traditional MES applications. However, the initial SEMI CIM Framework standards also identify components that are more coarse-grained, aligning with current MES product boundaries. These coarse-grained components contain fine-grained sub-components in their specifications, as in Figure 3 (typically two to four sub-components per coarse-grained component).

6.3.3.6.2 The coarse-grained components encapsulate the detail of the internal objects, relationships and sub-components by selectively exposing, hiding or abstracting some object methods and relationships. The coarse-grained components are specified with the detail of the sub-component and object interfaces and behavior, but standard conformance is in two levels; first-level conformance is to the interfaces of the coarse-grained components (not requiring exposure of the encapsulated detail), and second-level conformance is to the detail of the sub-components.

6.4 *CIM Framework Functional Scope*

6.4.1 The term Manufacturing Execution System (MES) represents an abstraction for a *collection* of software implementations. While there are examples of implementations that provide significant coverage of MES functionality, the industry trend is toward supplier focus on areas of core competency. In many cases this will result in a supplier offering for a subset of the MES domain, or a partitioned offering of separable products by a single source. Large, more monolithic implementations are gradually evolving toward this model of component packaging for smaller implementations. Ideally, MES scoping should correspond to natural boundaries that have emerged in representative products that border the “In MES”/“Outside MES” dividing line. It is that capability within MES scope that will be provided by the CIM Framework.

6.4.2 The following list identifies some criteria that may be used to help scope MES within the larger context of manufacturing enterprise systems often called Computer Integrated Manufacturing.

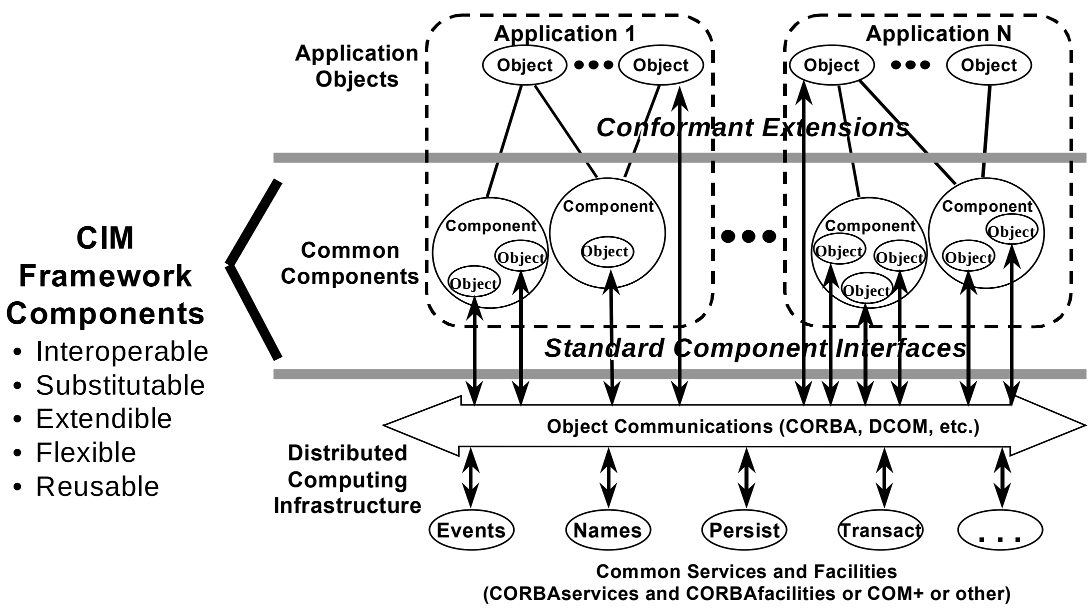


Figure 2
CIM Framework Component Architecture

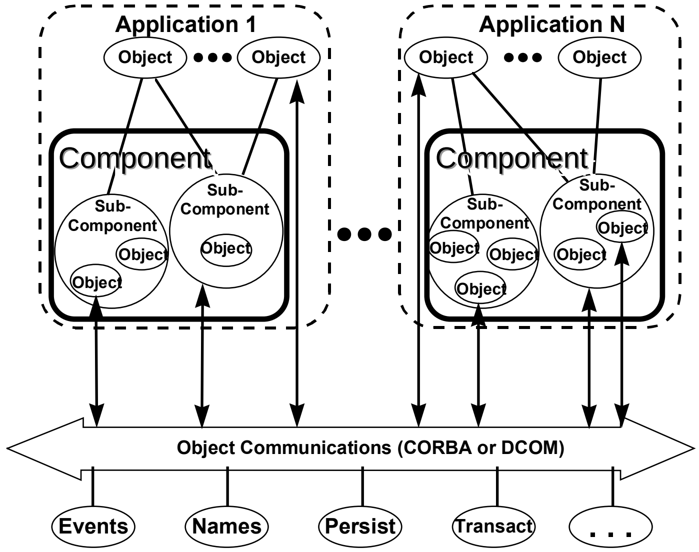


Figure 3
Components and Sub-Components

6.4.3 Thus, a component is "In MES" scope and within the CIM Framework scope, if

- it provides a job abstraction to manage work currently in progress across the manufacturing facility,
- it represents the convergence of product and process specifications, material, and manufacturing resources through execution of production jobs,
- it provides facility level planning and scheduling of manufacturing production activities,
- it provides access to historical data and reporting of occurrences that changed the state of the products, the production facility or its resources,
- it allows coordinated actions to control factory resources,
- it allows abstraction representations of production facilities and their resources,
- it enables automated update of manufacturing parameters (settings) through data collection and analysis of manufacturing processes, and
- it supports quality management through capture of key metrics (e.g., yield, throughput, cycle-time and utilization).

6.4.4 A component is "Outside MES" scope, thus outside CIM Framework scope, if

- it controls or manipulates the internal state or operation of a piece of manufacturing equipment,
- it deals with the business interactions between the manufacturing enterprise and external enterprises such as customers or suppliers,
- it manipulates the product or process definition with a focus on product design rather than execution of the manufacturing process,
- it focuses on the creation and manipulation of what-if models of factory or product state,
- it isn't directly concerned with transforming material from an initial (raw or partially completed) state to a more valuable product, and
- it is primarily used in support of laboratory analysis that is not directly integrated into the manufacturing process (e.g., off-line metrology).

6.4.5 Examples applying the MES definition and scoping criteria might be derived from the following high-level interactions.

6.4.5.1 *"In MES" Scope*

- A product request for production of goods (partial or finished) is offered to one facility which responds with a delivery commitment.

- A production job is created, along with a grouping structure for the target product.
- A production job is split into subjobs and maybe merged again.
- A production job is rerouted to a different resource due to specific circumstances.
- A production job is assigned to a set of resources, allocated required material, and dispatched for execution.
- A change in state of product, resources or material resulting in a change to delivery commitments is reported.
- A change to a manufacturing process results in alteration of the execution of a production job.
- A production job is assigned to specific set of manufacturing machines due to their machine resource capabilities.
- A value for a process specification is changed due to gathered values of a influencing quality control process.
- Material is made available for use or is moved to a new physical location within the facility.
- Material is exchanged between different positional containers due to e.g., contamination control (cleaning of a positional container).
- A manufacturing machine is taken down for maintenance and becomes unavailable for job execution.
- A resource of a multiple resource machine is taken down and becomes unavailable, but not the whole machine.

6.4.5.2 *"Outside MES" Scope*

- A product is defined and engineered for production — Product and Process Engineering.
- A facility is qualified to produce a given product — Release for Production.
- An order is released for production — represented as a demand from Order Management System.
- A consumable is running out of stock — an order is released for delivery to the facility — Enterprise Resource Tracking.
- The facilities (or series of facilities) capable of producing the needed product are analyzed and the demand is matched with available supply (including capacity for future production) — Enterprise Planning System.
- A piece of manufacturing equipment obtains a recipe and enacts a manufacturing process on material — Equipment Automation.
- Material movement equipment controls the transport of material to a specified destination — Equipment Automation.
- Modeling data representing a hypothetical change in factory state is manipulated and analyzed to determine the effects of the changes — Modeling and Simulation.
- Material is packed for transport from the front-end facility to the back-end facility and a carrier is notified of shipping order — Transportation Logistics.
- A customer order is divided into two product requests involving two facilities to meet the requested delivery date — Release for Production.
- The layout of equipment locations within the factory is modified to accommodate a new tool — Factory Design.

6.4.6 Multiple levels of packaging framework functionality are supported by the specification so that a variety of applications from multiple suppliers with potentially intersecting capabilities can be accommodated. This means that, given a specific framework binding to a set of computer and software system technologies, an application can be instantiated and executed in this environment and will register itself as a set of well-known objects that provide a core set of framework specified services.

6.4.7 The CIM Framework specification defines a set of functional components designed to work together to form an integrated manufacturing system. The CIM Framework components cover the functionality of Manufacturing Execution Systems (MES). MES is a factory-wide function that drives material processing on equipment to produce products, and it manages all the resources to accomplish this.

6.4.8 Figure 4 shows the functional scope of the CIM Framework. The left-hand side represents engineering aspects of manufacturing systems, such as configuration, while the right-hand side indicates where MES falls within manufacturing operations. The CIM Framework covers operations of manufacturing execution to a larger degree and configuration to a lesser degree.

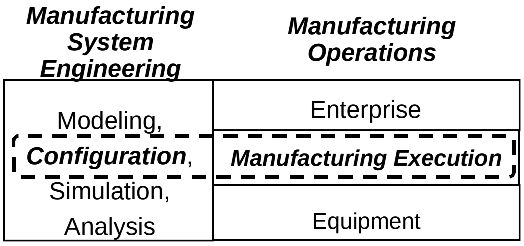


Figure 4
Boundaries of the CIM Framework: Manufacturing Execution

6.4.9 The CIM Framework specifies the MES functional responsibilities for semiconductor wafer fabrication. It does not include responsibilities for semiconductor packaging, assembly and test, but it was designed to accommodate extensions into this phase of semiconductor manufacturing.

6.4.10 Using the definition of component as found in Section 6.3.3, the components of the CIM Framework provide the following functionality found within MES configuration and execution:

- Product Management: manages product material and material groups.
- Durables Management: manages durable materials such as reticles and material carriers.
- Consumables Management: manages consumable materials such as gases and chemicals.
- Specification: manages product specifications and process flows.
- Factory Operations: drives efficient use of factory resources to manufacture products while meeting overall factory objectives.
- Scheduling: supports factory operations and other functions to optimize use of resources in manufacturing products and meeting factory objectives.
- Equipment Tracking and Maintenance: tracks equipment state and usage and manages equipment maintenance.
- Production Machine: manages execution of manufacturing process steps on process and metrology equipment.
- Recipe Management: provides factory-wide management and use of processing recipes.
- Advanced Process Control: executes run-to-run process control and fault detection strategies.
- Material Transport and Storage: moves and stores material.
- Factory Labor: manages labor resources and qualifications.
- Factory Services: provides support functions common across components, such as access security, document management/change control, and history storage and retrieval.

6.4.11 Section 7 lists the functional responsibilities of each of these components by MES configuration (called build-time) and execution (called run-time). The separation of the CIM Framework into components reflects anticipated boundaries of MES products, enabling integration of products from multiple suppliers into a coherent, integrated MES.

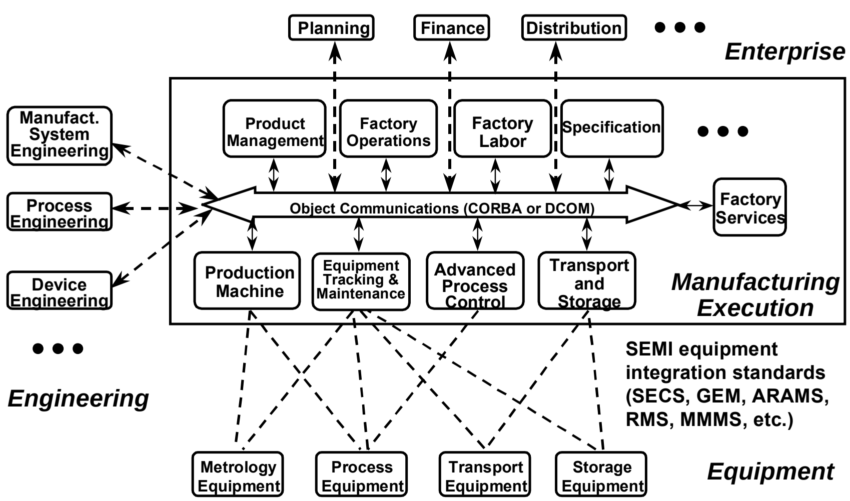


Figure 5
MES Component Integration

6.4.12 As Figure 5 shows, the CIM Framework specifies MES interfaces enabling integration between MES components, that is integration within the MES. The CIM Framework does not directly address integration between the MES and external functions. External functions, such as enterprise functions and engineering functions, can interact with the MES using the CIM Framework-specified intra-MES interfaces and communications mechanisms. Interaction between MES functions and manufacturing equipment can use existing SEMI equipment integration standards such as SECS II (SEMI E5), GEM (SEMI E30), ARAMS (SEMI E58), RMS (SEMI E42), and MMMS (SEMI E32). Equipment can also implement CIM Framework components such as Production Machine and Equipment Tracking and Maintenance within the equipment, integrating with the MES (the equipment host) through CIM Framework component interfaces.

6.4.13 The Object Management Group's Manufacturing Domain Task Force is adopting standards for Enterprise, MES, Machine Control and Engineering applications (MfgDTF). Other related activity within the OMG includes its efforts regarding workflow (Workflow) and component architectures. SEMI tracks these through a liaison with the OMG.

6.4.14 The CIM Framework focuses on the common software functions that serve to integrate MES. It specifies components for factory resources, materials, specifications and factory control, and it establishes a functional and technical architecture so the components can be assembled to meet many functional needs and driven by company-specific business process, workflows and operation rules. The CIM Framework enables, but does not define, workflow and business logic to drive component behavior, nor does it define user interfaces (including decision support and reporting). Workflow, business logic and user interface are considered use-specific and thus outside an industry consensus standard. In addition, the CIM Framework specifies application interfaces to the MES functions, but does not specify the implementation of those functions.

6.4.15 *What Is in the CIM Framework Specification*

6.4.15.1 This section provides additional information about the CIM Framework suite of documents. A brief description of each document is given below.

6.4.15.2 *Specification for CIM Framework Domain Architecture (this document)*

- Contains introductory information and an overview of the CIM Framework specifications.
- Specifies the functional partitioning and functional responsibilities of CIM Framework components.
- Specifies common architecture patterns that functionally integrate CIM Framework components.
- Provides graphical and textual specification notation conventions for all CIM Framework components.
- Provides citations for related specifications or documents referenced within the CIM Framework.

6.4.15.3 *SEMI E96, Guide for CIM Framework Technical Architecture*

- documents the CIM Framework component interoperability architecture based on distributed computing standards including OMG CORBA® and Microsoft DCOM.

6.4.15.4 Additional documents detail the CIM Framework specifications. The document structure will reflect the functional partitioning of the domain architecture. Except for reorganization, the details will remain substantially the same as contained within the CIM Framework Blue Ballots with some requested extensions. The structure of these documents has been influenced by SEMATECH's CIM Framework Specification [CIMFW]. These companion documents represent the actual specification; whereas this document serves primarily as their introduction.

7 Requirements

7.1 This section specifies the functional requirements of CIM Framework components. It establishes a functional partitioning of CIM Framework components and it defines functional architectures for resource tracking and maintenance and for factory control. It also establishes the graphical and textual notations required to specify the CIM Framework components. The list below is a short overview of this section.

- Global and Abstract Definitions Group
- Factory Services Group
- Product Management Component
- Durables Management Component
- Consumables Management Component
- Specification Component
- Factory Operations Component
- Scheduling Component
- Equipment Tracking and Maintenance Component
- Production Machine Component
- Recipe Management Component

- Advanced Process Control Component
- Material Transport and Storage Component
- Factory Labor Component

7.2 *Functional Partitioning*

7.2.1 This section overviews the functional responsibilities of the CIM Framework domain components. Details of the responsibilities are specified in the individual CIM Framework domain component specifications.

7.2.2 The domain component responsibilities cover two types of functions:

- Build-time, or configuration aspect of manufacturing systems engineering in Figure 4, which defines and configures the specific entities in the component, such as the specific machines and their state models or the wafer carriers and their initial locations.
- Run-time, or the execution aspect of manufacturing operations in Figure 4, which executes the component behaviors, maintains inter-component relationships, maintains component state and history and provides run-time access to component state and behavior.

7.2.3 The initial CIM Framework domain standards do not address the build-time functions of the components. These will be added as the standards move from provisional status to full standards. However, this functional partitioning section does identify build-time responsibilities, permitting these build-time functions to be properly allocated to the correct component as the CIM Framework evolves.

7.2.4 The components partition CIM Framework functionality. The components are designed to be exclusive: no functionality exists in more than one component. The only exception is that there are some cross-system functions that are used, specialized or implemented by most or all of the other components. These cross-component domain functions are in separate groups, called Global and Abstract Definitions Group and Factory Services Group.

7.2.5 The list of responsibilities for a complete MES solution is far more than the responsibilities of the CIM Framework components. The CIM Framework focuses on those functions that serve to integrate applications. Suppliers and users will provide functional responsibilities in addition to the standard responsibilities. The CIM Framework component responsibilities are also limited by focusing the scope of the CIM Framework on the run-time needs for wafer fabrication MES but to not cover the full scope of CIM solutions for the full semiconductor manufacturing process.

7.2.6 Sections 7.2.7 through 7.2.20 present the responsibilities for each of the CIM Framework components and the groups. Example terminology specific to semiconductor manufacturing is provided for clarity. It does not preclude application specialization for other industries.

7.2.7 *Responsibilities of Global and Abstract Definitions Group*

7.2.7.1 The Global and Abstract Definitions group (defined in SEMI E97) specifies the definitions of abstract data types and abstract interfaces used throughout the CIM Framework. These specifications are separated into a distinct group to enable them to be specified once and then logically included or inherited wherever they are subsequently needed.

7.2.7.2 *Global Definition Responsibilities*

- Provide type definitions for common data structures to ensure consistent representation. These items include data types for common concepts such as coordinates, priorities, timestamps, and sequences of basic data types.
- Provide type definitions for representations of historical occurrences.
- Provide definitions for common exceptions used consistently throughout the CIM Framework.

7.2.7.3 *Abstract Interface Responsibilities*

- Material architecture: the functions common to identifying, grouping, moving, locating and tracking material in the factory. The architecture is specialized for product material, durables and consumables. See Section 7.3.2.
- Factory resource architecture: the functions common to defining, organizing, tracking usage of and maintaining factory resources including equipment, sensors, durables, and people. See Section 7.3.3.
- Job architecture: the functions common to creating, executing and managing work in the factory. The job architecture is specialized for material processing jobs, material transport jobs, resource maintenance jobs and factory jobs that drive product material through their process flows. See Section 7.3.4.

7.2.8 *Responsibilities of Factory Services Group*

7.2.8.1 The Factory Services group (which is not actually a component) specifies domain facilities to support all domain components. The components can separately implement these facilities for their own use, they can share a common facility across components, or use a combination of separate and shared implementations.

7.2.8.2 *Services in Factory Services Group*

- Document management and version management: functions common to creating, storing, retrieving, and changing (under change control and version management) documents such as process recipes, process flow specifications, and maintenance specifications.
- Event broker: support for components to publish, subscribe to and filter events.
- Access security control: support for components to limit access of system functions to authorized users and applications.
- Component management: functions for CIM Framework component registration, start-up, shutdown, etc.
- History: supports the ability of factory objects to configure and maintain histories (time-based sequences of data and events) and to support access to those histories.
- Data collection: the functions common to data collectors, including equipment, sensors, and manual data entry.

7.2.9 *Responsibilities of Product Management Component*

7.2.9.1 The Product Management component captures the state of all product material (work in progress). For wafer fabrication, this includes wafer and die-level tracking to support multiple products on a single wafer and to track known-good-die through wafer probe. The component also tracks engineering wafers and test wafers, even though they may not become “product.” The component implements the common material architecture functions so product material can be identified, grouped (product groups, lots, process groups, transport groups), moved and located in the factory.

7.2.9.2 *Build-time Responsibilities of Product Management Component*

- Configure inventory regions.
- Configure product tracking histories, including what data to store and data archival mechanisms.

7.2.9.3 *Run-time Responsibilities of Product Management Component*

- Record and support access to current and historical product information, including:
  - Where material is (and has been) in its process flow.

    NOTE 2: The decision to advance material along its process flow is in the Factory Operations component.
  - Product state (processing, on hold, scrapped, etc.).
  - Material type (product, engineering, filler, etc.).
  - User-defined product information.
  - Genealogy, batching, allocation to product requests, the number of times reworked, etc.
  - Historical information on what equipment processed the material, when, with what process flow specification, recipe and durables, and by what operator.
  - Relations and history to related information in other components, including material location, material container, process flow specification, inventory region, process run data, recipe, etc.
- Notify other components of material information changes.
- Support creation, maintenance and historical recording of product groups and relationships among product groups (such as lots, transport groups and process batches) including splits and joins (and resulting product genealogy), experiments (planned future splits and processing changes), hold, rework, etc.

  NOTE 3: The decision to split, join, batch, move, rework, etc. is a responsibility outside of the Product Management component. Product Management records the results of the decisions.
- Record and support access to material location at multiple levels of detail: an area, a specific machine, a specific load port on a machine, a specific zone in a stocker, a specific wafer slot in a carrier, or a specific wafer coordinate of a die.
  - Including reference to material containers (cassettes, pods, etc.) holding the product (the containers are managed by the Durables Management component).

    NOTE 4: Material location is served by the Product Management component and the Material Transport and Storage component. The Material Transport and Storage component is responsible for physically moving material and recording its location, and the

Product Management component is responsible for keeping its material location consistent with Material Transport and Storage material location information.

- Account for and track material loss.
- Support inventory regions: monitor, report and capture history of material movement through physical and logical regions of the factory.

7.2.10 *Responsibilities of Durables Management Component*

7.2.10.1 The Durables Management component manages the durable resources used in wafer manufacturing, including material containers (cassettes, SMIF pods, etc.), reticles, fixtures, test probes, etc. The component implements the generic resource tracking and maintenance architecture specialized for durables. The component also implements the common material architecture behavior so durables can be identified, grouped and located in the factory.

7.2.10.2 *Build-time Responsibilities of Durables Management Component*

- Define the specific durables in the factory (the inventory of carriers, reticles, etc.).
- Define inventory regions that track the use and movement of various durable types in a factory (for example, the reticles assigned to and existing in a lithography bay).
- Define relationships between durables and the process steps that use them.
- Define maintenance tasks for durables and what triggers them.

7.2.10.3 *Run-time Responsibilities of Durables Management Component*

- Track durable attributes (location, usage, contamination exposure, etc.) and state (available, not available, in use, etc.).
- Maintain relations between durables and other CIM Framework objects (such as product material contained in a wafer carrier, the reticles in a reticle carrier, the process step a reticle is used for, etc.).

  NOTE 5: The Material Transport and Storage component has some responsibility for managing material containers, such as to move and allocate empty pods, gas purge and clean pods, etc.

- Maintain, report and record history of durable attributes, state and relations.
- Support assignment of durables to factory jobs (e.g. supporting the scheduling of a reticle for use in a production machine job) and monitor and record job progress (from the perspective of the durable's role).
- Monitor durable maintenance triggers (such as excessive exposure to contaminants) and recommend durable maintenance jobs.
- Execute triggered durable maintenance jobs.
  - Change durable capabilities.
  - Execute durable maintenance jobs (pod cleaning, reticle inspection and repair, etc.) and report job progress.
  - Record durable maintenance triggers and job results in resource maintenance histories.
- Collect and report durable utilization and effectiveness measures.

7.2.11 *Responsibilities of Consumables Management Component*

7.2.11.1 The Consumables Management component manages consumable materials, including gases, chemicals, etc. The component implements the generic resource tracking and maintenance architecture to track consumable usage and quality (e.g., expired resist) and to enable maintenance based on replenishment levels and quality expiration. The component also implements the common material architecture behavior so consumables can be identified, grouped and located in the factory.

7.2.11.2 *Build-time Responsibilities of Consumables Management Component*

- Define the specific consumables in the factory (the types of gases, chemicals, etc.).
- Define inventory regions that track the use and movement of consumable types in a factory (for example, the equipment fed by a common gas bottle and feeders).
- Define relationships between consumable types and the process steps that use them.
- Define maintenance tasks and triggers for testing the quality of and replacing consumables.

7.2.11.3 *Run-time Responsibilities of Consumables Management Component*

- Track consumable attributes and state (supplier's lot number, quantity available, usage rate, expiration date, etc.).
- Maintain relations between consumables and other CIM Framework objects (the product groups a particular consumable was used on, the equipment fed by a common gas bottle, etc.).

- Maintain, report and record history of consumable attributes, state and relations.
- Support assignment of consumables to factory jobs (e.g., the scheduling of a gas feed pressure for use in a production machine job) and monitor and record job progress (from the perspective of the consumable's role).
- Monitor consumable maintenance triggers (quality checks and replenishment levels) and recommend consumable maintenance jobs.
- Execute triggered consumable maintenance jobs.
- Change consumable capabilities.
- Execute consumable maintenance jobs and report job progress.
- Record consumable maintenance triggers and job results in resource maintenance histories.
- Collect and report consumable utilization and effectiveness measures.

7.2.12 *Responsibilities of Specification Component*

7.2.12.1 The Specification component supports definition and use of process specifications, product specifications and bill of materials. Process specifications define process flows (the process steps to manufacture a product, along with supporting material movement, advance process control, equipment maintenance and other tasks). Product specifications relate product types to the process flows to build them.

7.2.12.2 The CIM Framework does not specify a fully-detailed representation of process flows. At run-time, it views a specification as a current operation (the Process Flow Context) and a view of potential next steps (the Process Flow Iterator). Although a complete MES solution must build and provide process flow details, the CIM Framework standard does not require this detail for component integration.

7.2.12.3 Recipes, process capabilities, maintenance specifications, document management and version control services are the responsibilities of other components. The Specification component references and uses these services.

7.2.12.4 *Build-time Responsibilities of Specification Component*

- Build process operation specifications.
  - Specify a processing step as a relationship between a combination of recipes, data collection plans, advanced process control strategies, process capabilities, processing constraints (timing dependencies, contamination constraints, qualified machines, etc.), operator qualifications, durables, consumables and other elements.

    NOTE 6: At run-time, a process operation specification is fully bound to create a process operation (a specific machine is selected, recipe parameters are set, specific support resources are named, etc.).
- Build manufacturing process flows.
  - Specify a process flow as a combination of material processing steps, material movement tasks, equipment qualification and maintenance tasks and other tasks.

    NOTE 7: Process flows are primarily a combination process operation specifications, but the process flow should allow inclusion of explicit steps for material movement, metrology, equipment calibration, etc.
  - Define process flow traversal logic (rework decisions, metrology sampling decisions, alternate path decisions, parallel assembly routes, etc.).
    - preconditions for beginning a step.
    - postconditions for completing a step.
    - logic to enable selecting appropriate next steps.
  - Support recursive (nested) composition of simple process flows (partial flows or mini-flows) into complex process flows.
- Support a library of configurable, reusable process operation specifications and process flows.
- Build product specifications.
  - The process flow to build the product.
  - Product-specific run-time parameters.
    - Reticle and other required resources.
    - Quality/metrology sampling plans.
    - Required manufacturing technologies.

      NOTE 8: This is not a full product specification. It is only those elements needed to select and initialize the manufacturing process.
- Define and maintain relationships between process flow specifications and product specifications which use them.
- Use document and version management for specification change control.

7.2.12.5 *Run-time Responsibilities of Specification Component*

- Create a fully-bound process operation from a process operation specification.
- Create a Process Flow Context (PFC) from a product specification (create the initial process flow for a product).

  NOTE 9: The PFC is the "pointer" marking the current step in a process flow.

- Transition the PFC from the current process operation to the next process operation in the flow (move along the process flow).

  NOTE 10: The decision to move is the responsibility of other components. The Specification component records the decision.

- Create a PFC from an existing PFC (for example, to support splitting of a product group).
- Create a Process Flow Iterator (PFI) from a product specification (create an initial process flow iterator for a product).

  NOTE 11: The PFI is a process flow navigation aid to look ahead or look behind at steps in a process flow without actually incrementing the PFC. This allows scheduling and other functions to determine what steps are possible and to use processing history in determining what steps to take next.

- Create a PFI from an existing PFI (for example, to support evaluating among alternatives).
- Use the PFI to traverse forward and backward through a process flow.
  - Using the results of executing process flow traversal logic (the factory job control or process job control does the actual execution of traversal logic to decide among alternate paths).
- Provide query support for the contents and relationships of process operation specifications and process operations.
- Maintain relationships of active process flows to the factory jobs, production machine jobs, and transport jobs that are implementing the process flow.
- Maintain relationships of active process flows (process flow contexts) to product groups (e.g. process groups, transport groups, etc.) and product group histories for recording the results of executing process flow steps.
- Maintain relationships of process flow specifications to process capabilities and process resources.
- Support effectivity changes to process flows and process operation specifications (if the process flow version changes for the current product group on the flow, be responsive to those changes).

7.2.13 *Responsibilities of Factory Operations Component*

7.2.13.1 The Factory Operations component provides support for maximizing factory effectiveness through efficient use of factory resources to satisfy product demand and planned objectives. Examples of overall factory effectiveness measures are on-time delivery, profit margin, profit rate, cost per wafer, yield, overall equipment effectiveness, cycle time, etc. The Factory Operations component also provides the interface to the enterprise planning systems to commit the factory to fulfill product requests and to communicate factory capacity and production capability to enterprise planning. The product requests also provide a placeholder for order information (such as quantity, due date, priority, etc.) and are part of the link to material tracking at the enterprise level. Given the factory-wide scope of Factory Operations, this component owns the overall factory resource model of machines, areas, inventory regions, etc.

7.2.13.2 Factory Operations may not have exclusive responsibility for maximizing all factory objectives. The Production Machine component maximizes the use of process resources (chambers, internal storage, production batching, etc.), the Material Transport and Storage component maximizes the use of transport and storage resources (transport vehicles, transport paths, storage locations, etc.), the Equipment Tracking and Maintenance component maximizes equipment availability and capability, etc. The business logic and decision-making methods may be distributed to improve overall enterprise effectiveness (Enterprise functions), overall factory effectiveness (Factory Operations functions) and overall equipment effectiveness (Production Machine, Material Transport and Storage and other functions). The CIM Framework provides flexibility, enabling the spectrum from centralized, enterprise-wide or factory-wide operations to distributed, resource-focused operations with coordination to achieve factory-wide effectiveness. The CIM Framework Job Architecture is critical to enabling this flexibility (see Section 7.3.4).

7.2.13.3 *Build-time Responsibilities of Factory Operations Component*

- Define the factory model of resources (machines, people, durables, etc.), areas (bays, lines, cells, etc.), and inventory regions (see Section 7.3.3 for a description of the factory model of resources).

- Define the (initial or nominal) capabilities of the factory and area resources, including factory capacity, area capacity and process capability (detailed capabilities of the machines, people, etc. are the responsibility of other components).

7.2.13.4 *Run-time Responsibilities of Factory Operations Component*

- Dynamically receive product requests (from the enterprise or internally) and map them to product work-in-progress and planned material release (lot starts).
  - Associate material to a process flow (in the Specification component) for the product.
  - Consolidate product demand in the factory.
  - Request Factory Jobs or modify existing Factory Jobs to drive material through its process flows, in response to product requests.
    - New Factory Jobs for new material release,
    - Modify existing Factory Jobs (and associated material model and assigned process flow) for assigning new or modified product requests to material in process.
  - Set or modify product material quantity and due date(s) and other scheduling support information (such as priority and planned profit margin).
- Execute Factory Jobs to drive material through its process flow, using scheduling and dispatching services of the Scheduling component and requesting work from Production Machine, Material Transport and Storage, Equipment Tracking and Maintenance, and Factory Labor components.
  - Based on factory state (material process state, material due date and priority, material location, equipment state, equipment process capability, operator availability and qualification, etc.) and where the material is in its process flow, request and track Production machine jobs, transport jobs, maintenance jobs and other jobs that implement and enable the process steps in the process flow.
  - Based on success, failure or partial failure of production machine jobs and transport jobs, and based on metrology results and other information, determine the next activities for material and factory resources. This may include splitting or joining product groups, scrapping material, downgrading or changing the product type of material, and other actions responsive to job performance and resource availability. Once split, scrap and other decisions are made, Factory Operations may use scheduling utilities to select the next activities for the material and resources.
- Record and report factory job status and decisions in factory job histories.
- Report status and progress on enterprise product requests.
- Manage assignment of human resources to other factory resources.

7.2.14 *Responsibilities of Scheduling Component*

7.2.14.1 The Scheduling component supports Factory Operations, Material Movement, Production Machine and other components by ordering, in time, jobs that process material on equipment, move material, maintain equipment, etc. The scheduler uses knowledge of product demand, equipment and material state, process flows, throughput bottlenecks, operational policy and constraints, and other information to recommend jobs that maximize effective utilization of factory resources to satisfy product demand and planned objectives.

7.2.14.2 The CIM Framework specifies a dispatching function to support Factory Operations. Dispatching provides an answer to questions of the form, "What is next for this material or resource?" The answer may be based on any number of current or future constraints and objectives, but the dispatcher does not typically define a sequence of jobs projected into the future. Scheduling functions in the Scheduling component provide this future job sequencing function. Separate scheduler and dispatcher utilities can also provide resource-focused utilities, such as scheduling of process resources within a production machine or scheduling of material transport and storage resources and internal material movements within the factory-wide material transport and storage system.

7.2.14.3 *Build-time Responsibilities of Scheduling Component*

- Configure scheduling and dispatching decision mechanisms (for example, define scheduling goals and constraints, rules for resolving conflicting constraints, etc.).

7.2.14.4 *Run-time Responsibilities of Scheduling Component*

- Monitor resource and material state and apply scheduling and dispatching decision mechanisms to recommend the next task (dispatching) or a sequence of tasks (scheduling) for factory resources.

7.2.15 *Responsibilities of Equipment Tracking and Maintenance Component*

7.2.15.1 The Equipment Tracking and Maintenance component implements the Factory Resource architecture (see Section 7.3.3) specialized for production equipment (process and metrology tools and material handling and storage equipment).

7.2.15.2 Note that the machine is the software representation of physical equipment and should reflect the state of that equipment. The functionality can be implemented within the equipment, within the MES, or in a separate system such as a cell controller, station controller or equipment integration solution.

7.2.15.3 *Build-time Responsibilities of Equipment Tracking and Maintenance Component*

- Configure production machines as a combination of, or relationship to, process resources (such as process chambers) and support resources (loadports, add-on sensors, internal material buffers and transport, etc.).
- Configure material handling resources as a combination of transport machines and storage machines and relations to support resources (loadports, add-on sensors such as automatic material identification, etc.).
- Configure equipment state models compatible with SEMI E10 (at the machine level and/or at the machine resource level).
- Configure (initial or nominal) production machine capabilities.
- Configure the (initial) recipe namespaces that production machines use and manage.
- Configure the (initial) material locations that material transport equipment is able to reach and the locations it is authorized to reach.
- Define equipment maintenance tasks and what triggers them.
  - Tasks: repair, calibration, qualification, etc.
  - Triggers: failures, usage, elapsed time, need by another related maintenance task, etc.
- Use document management and version control for maintenance specification change control.

7.2.15.4 *Run-time Responsibilities of Equipment Tracking and Maintenance Component*

- Track the equipment state and update the machine state, accordingly.
  - Keep the machine state model current.
  - Report and record equipment and machine state changes, alarms and events in machine history.
  - Support query of machine state and history.
  - Update machine and machine resource process capabilities to reflect machine state and capability and machine assigned capabilities.
- Drive the equipment to a requested state.
- Collect and report machine performance according to SEMI E58 and other utilization and effectiveness measures.
- Monitor equipment maintenance triggers.
- Execute and monitor triggered maintenance jobs.
  - Update equipment state and resource capability (before and after maintenance).
  - Recommend maintenance jobs for scheduling.
  - Execute maintenance jobs and report job progress.
  - Record maintenance triggered and maintenance job results in equipment maintenance history.
- Manage the relationships between production machines that have specific process capabilities and process flows that need specific process capabilities.
- Manage the material locations that material transport equipment is capable of reaching and is authorized to reach.

7.2.16 *Responsibilities of Production Machine Component*

7.2.16.1 The Production Machine component supports execution of production machine jobs on process equipment and interaction with material handling equipment for material input/output at the machine. The functionality can be implemented within the equipment and/or in a separate system such as a cell controller, station controller or equipment integration solution.

7.2.16.2 *Build-time Responsibilities of Production Machine Component*

7.2.16.2.1 Note that the configuration of the machine is the responsibility of the Equipment Tracking and Maintenance component.

7.2.16.3 *Run-time Responsibilities of Production Machine Component*

- Initiate and execute production machine jobs to perform specific process operations (and recipes) on specific material (process groups). Here are the steps to initiating and executing production machine jobs:

  1) Validate the production machine job: compatibility and availability of the material in the process group, process capability of the equipment, proper machine state, valid and available recipe or process specification, necessary operator skills, etc.

  2) Equipment setup: recipe download and select, launch advanced process control (APC) calculation, make operator and APC-recommended adjustments, configure equipment and sensors according to data collection plans.

  3) Initiate processing.

  4) Monitor process operation:

    - Collect process run data from equipment, add-on sensors and operator entry according to data collection plans.
    - per machine and per process resource.
    - Store in process run histories.
    - Event management: capture, interpret, record and respond to equipment events, fault detection events and other process anomalies.
    - Monitor equipment operation and state (from the equipment tracking and maintenance component) as another source of information on process operation.
    - Generate MES-level (machine) events and alarms.
    - Track material within machine and record with process run histories and product histories.

  5) Complete processing.

    - Execute post-processing tasks for the process operation.
    - Generate job completed events and invoke "inform job completed" method on job requestor.

- Sequence steps between machines and machine resources (for that sequence logic that is not covered by embedded equipment control).
- Implement recipe control and recipe agent functionality as defined in SEMI E42 - Recipe Management Standard. Integrate with factory-level recipe namespace functionality in the CIM Framework Recipe Management component.
- Job accountability: account for and report material yield loss in material management component and equipment productivity loss in equipment tracking component.
- Interact with Material Transport and Storage component and loadport for material hand-off handshake protocols.
- Manage and monitor equipment when idle.

7.2.17 *Responsibilities of Recipe Management Component*

7.2.17.1 The Recipe Management component provides a capability for applying machine recipes across the factory. Recipes for multiple machines of the same process capability using the same recipe syntax are managed by specializing the recipes based on specific machine settings. The Production Machine component is responsible for merging the recipe with machine-specific data and run-time data (such as Advanced Process Control component recommendations for recipe settings) into an executable recipe and for downloading it to the equipment or selecting and modifying it in the equipment. The Recipe Management component also works with Recipe Executors and Recipe Agents (terminology from SEMI E42) implemented in the Production Machine component, in the equipment, or elsewhere.

7.2.17.2 *Build-time Responsibilities of Recipe Management Component*

- Build process recipes.
  - Generic.
  - Specific to a machine type (same process capability and recipe syntax).
  - Including identification of variable parameters in recipe.
  - Use document management and version control for change management and effectivity.
- Define, configure and initialize recipe namespaces.

  NOTE 12: Including this responsibility under "build time" does not imply that all recipes are built at MES system build time. Recipes may be built after the MES system is running.

7.2.17.3 *Run-time Responsibilities of Recipe Management Component*

- Work with Production Machine component and other recipe controllers to select, download and modify recipes.
- Implement resource effectivity control (manage when and to what material and machines to apply recipe changes).

7.2.18 *Responsibilities of Advanced Process Control Component*

7.2.18.1 The Advanced Process Control component (defined in SEMI E93) supports the Production Machine component execution of production machine jobs by optimizing machine-specific settings for the current material and machine state to achieve desired process effects. It also detects faults in processing and recommends an appropriate response to the Production Machine component. Advanced Process Control strategies can include statistical process control, model-based process control, multi-variate analysis, trace analysis, fault pattern matching, or any other appropriate mechanism. The internal design of the Advanced Process Control component allows integrating different types of analysis and computation mechanisms and their execution environments into a single control strategy.

7.2.18.2 *Build-time Responsibilities of Advanced Process Control Component*

- Define control strategies and associated sensor processing algorithms, fault detection algorithms and optimal process control algorithms.
- Define real-time control data structures to support control algorithms.
- Define data collection plans to acquire control data.
- Define control strategy selection logic.

7.2.18.3 *Run-time Responsibilities of Advanced Process Control Component*

- Select a control strategy and associated sensor processing and analysis algorithms to optimize processing and detect faults.
- Launch, coordinate and monitor the execution of data collection plans and control processing and analysis algorithms.
- Apply algorithm results to recommend process settings and detected fault response actions (recipe adjustment, equipment shutdown, maintenance, rework, etc.).
- Update control data with algorithm results.
- Update control data with equipment and product material data (current equipment state, material state, process operation, etc.).
- Record and report control strategy and algorithm results and recommendations in process run histories.

7.2.19 *Responsibilities of Material Transport and Storage Component*

7.2.19.1 The Material Transport and Storage component (defined in SEMI E102) supports active and manual material movement and active and passive material storage (active storage: stockers, smart racks, equipment buffers; passive storage: tables, racks). It executes Transport Jobs and interacts with the Production Machine components for material handoff to and from process equipment. The component tracks and reports on material location and material movement history. The equipment configuration, tracking and maintenance functions are the responsibility of the Equipment Tracking and Maintenance component. For complicated interbay and intrabay material transport and storage, there may be multiple instances of the component -- one for each material movement area -- that cooperate to provide factory-wide material movement functions.

7.2.19.2 *Build-time Responsibilities of Material Transport and Storage Component*

7.2.19.2.1 Note that configuration of the material transport and storage equipment and its capabilities is the responsibility of the Equipment Tracking and Maintenance component.

7.2.19.3 *Run-time Responsibilities of Material Transport and Storage Component*

- Support scheduling of material movement and processing by predicting time for material delivery to specific locations.
- Execute and monitor transport jobs to move material groups (transport groups) to specific locations.
    - Validate that the job can be done: the material is available, the destination is reachable and has available storage or loadport capacity, there are sufficient material movement resources (cars, storage space, etc.) to implement the job.
    - Implement the job by scheduling and enacting actions on internal material movement and storage resources (cars, turntables, stocker shelves, etc.).
    - Collect and record data on transport job execution and history.

- Capture, record, interpret and respond to equipment events and fault detection.
- Generate MES-level job status events and material location change events.

- Record and report on material locations and material movement histories for material in the system.
- Interact with Production Machine component and loadport for material hand-off handshake protocols.

7.2.20 *Responsibilities of Factory Labor Component*

7.2.20.1 The Factory Labor component (defined in SEMI E86) implements the generic Factory Resource architecture (see Section 7.3.3) applied to factory personnel resources. It represents personnel, their capabilities (skills) and skill maintenance (training), and their assignment to other factory resources (to machines and areas) and jobs. The Factory Labor component integrates with access security services (in the Factory Services group) to associate personnel with roles, identity authentication (e.g. system login passwords) and access authorization.

7.2.20.2 *Build-time Responsibilities of Factory Labor Component*

- Configure the Person resource model.
  - Each Person's name, identification, department, role, etc.
  - Each Person's initial skills and authorization to perform jobs and access data.
  - Each Person's initial assignment to other factory resources (such as specific machines or factory areas).
  - Each Person's medical qualifications.
- Define skill maintenance tasks and what triggers them.

7.2.20.3 *Run-time Responsibilities of Factory Labor Component*

- Track and report the Person skills, authorization and assignments and record these in Person histories.
- Support assignment of Persons to factory jobs and monitor and record job progress (from the perspective of the Person's role).
- Monitor skill maintenance triggers (such as expired skill certification) and recommend skill maintenance jobs.
- Execute triggered skill maintenance jobs.
  - Change Person capabilities (before and after training).
  - Execute and monitor skill maintenance jobs (training, certification testing) and report job progress.
  - Record skill maintenance triggers and job results in person skill maintenance histories.
- Collect and report person and skill performance (utilization and effectiveness).
- Maintain relationships between persons and system security for identity authentication and authorization.

7.3 *Common Architectural Patterns*

7.3.1 This section documents architecture patterns that serve to functionally integrate CIM Framework components. The material architecture defines functionality common to Product Management, Durables Management and Consumables Management components. The factory resource architecture defines relationships and common functionality of factory resources. The job architecture defines a factory-wide model of controlling factory operations.

7.3.2 *Material Architecture*

7.3.2.1 The Product Management, Durables Management and Consumables Management components all share a common architecture for identifying, grouping and locating materials. Figure 6 illustrates the common material interface architecture.

7.3.2.2 Material has an identification, history, location, inventory region and associations to material containers that may contain it. Material can also be in multiple material groups that physically (same location or carrier) or logically (same lot, same process batch, same product family, etc.) associate material. Specializations of material include products, durables and consumables. Specializations of material groups include product groups, lots, process groups and transport groups.

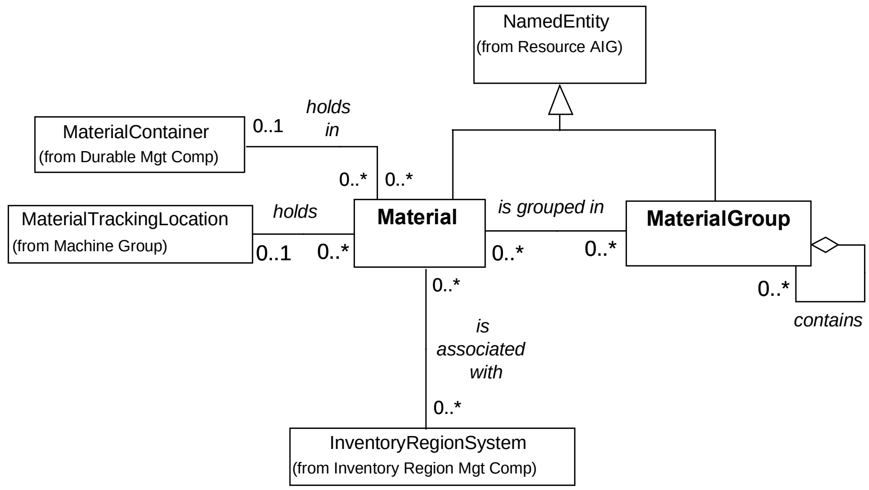


Figure 6
Material Interface Architecture

7.3.3 *Factory Resource Architecture*

7.3.3.1 Factory resources, such as machines, people and reticles, are the entities that participate in transforming material into products. The CIM Framework defines an overall domain architecture for factory resources that supports

- resource tracking and maintenance (resource usage counters, maintenance procedures, etc.),
- hierarchical organization (e.g., a factory is organized into areas which group machines and people),
- composition of resources (e.g., a machine is composed of chambers, load ports and sensors), and
- an object-oriented type structure (transport machines and production machines are types of machines; machines, ports, durables and people are support resources, etc.).

7.3.3.2 This section defines the CIM Framework resource architecture.

7.3.3.3 *Factory Resource Hierarchy*

7.3.3.3.1 A factory is usually viewed as a hierarchy of resources organized in groups, as in Figure 7. Each level or portion of the hierarchy has an associated task scope.

- An enterprise often includes multiple factories. The task of the enterprise is to deliver products to customers.
- A factory is made up of areas and bays with interbay material handling systems. The task of the factory is to manufacture product in response to product requests.
- Areas or bays are made up of processing and metrology equipment with intrabay material handling systems. The task of the areas or bays is to perform a group of process operations on groups of materials, move material to the processing equipment, and perform maintenance and other supporting tasks. For a simple factory, the area level is optional. For a complex factory, there may be multiple area levels, with areas made up of sub-areas.
- Complex processing equipment (such as a cluster tool) is made up of processing chambers and internal material handling and storage resources. The task of the processing equipment is to perform a process or metrology step or a closely related group of steps on a material lot or process group. The task of the processing resource in the processing equipment (such as a chamber in a cluster tool) is to perform a single process step on a single wafer or on a collection of wafers in a process resource group.
- Material handling and transport systems are made up of interconnected stockers, tracks, conveyers, robotic handlers and other material storage and movement equipment. The task of the material handling systems is to store and move materials in transport groups.

- Manufacturing operators and other factory personnel are important resources to facilitate and supervise material processing and handling, preventive maintenance, and in some cases, perform manufacturing steps such as moving material or performing a visual inspection.
- Other factory resources include durables (reticles, cassettes, pods, etc.) and consumables (gases, utilities, etc.).
- The information model in Figure 8 shows the CIM Framework Resource Composition Architecture. The interfaces in the box labeled Resource Abstract Interface Group define the generic resource architecture. In general, resources can be composed of other resources. In particular, at the factory and area levels, Factory can be composed of Areas and an Area can be composed of other Areas. Areas group Support Resources, such as machines and persons. This is not a strict composition so that support resources can be in more than one Area grouping. At the machine level, Machine Resources are composed of other Machine Resources, in general. In particular, Production Machines are composed of Process Resources.

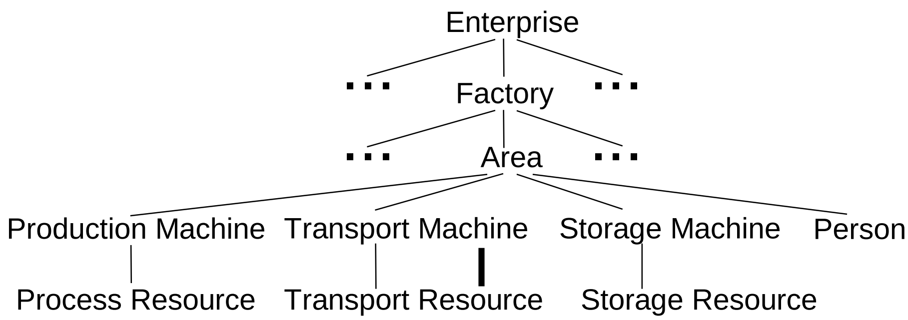


Figure 7
Factory Resource Hierarchy Model

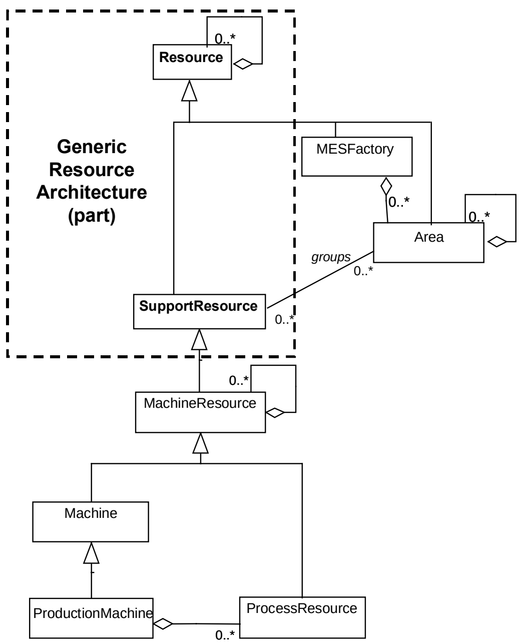


Figure 8
Resource Composition Architecture

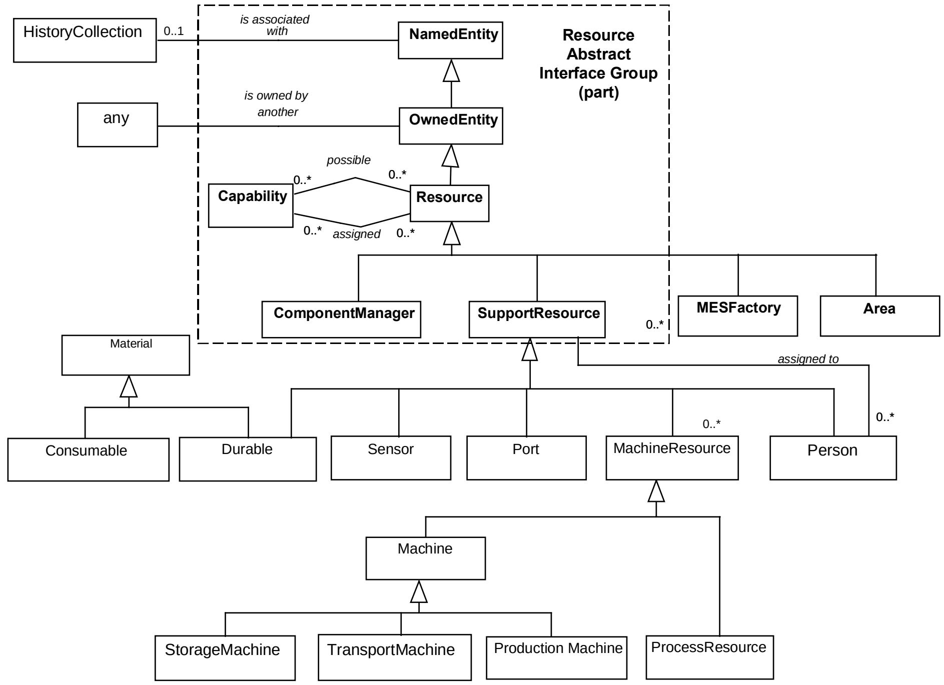


Figure 9
Resource Type Architecture

7.3.3.3.2 Figure 9 shows the CIM Framework Resource Type Architecture. Specializations of these interfaces, such as Machine Resource and Durable, provide component-specific details that extend the generic resource architecture. The functions added at each level of type specialization are discussed next.

7.3.3.3.3 *Named Entity*

7.3.3.3.3.1 The CIM Framework Named Entity interface provides for names and histories to be associated with any CIM Framework entity, including resources.

7.3.3.3.4 *Owned Entity*

7.3.3.3.4.1 The Owned Entity interface provides for resources to be organized into hierarchies.

7.3.3.3.5 *Resource*

7.3.3.3.5.1 The Resource interface provides for

- composition of subresources into complex resources,
- representing resource capabilities (such as capacity or process capability) (See Section 7.3.3),
- a simple state model (available, not available) and services to startup and shutdown the resource, and
- modeling of resource levels as in Figure 7 and Figure 8.

7.3.3.3.5.2 Each Resource has an attribute called resourceLevel to support the factory resource composition hierarchy of Figure 8. The CIM Framework defines the following resource levels: Factory (called MESFactory so as not to be confused with the OMA's object Factory type), Area, Machine and Machine Resource. The Area level is optional, or it may have multiple levels (such as an area called LithoBay with sub-areas called Zone1 and Zone2). Other levels can be defined. The resourceLevel concept, combined with the Named Entity and Owned Entity, also provide a name scoping facility.

7.3.3.3.6 *Support Resource*

7.3.3.3.6.1 The Support Resource interface provides services for reserving resources (to support scheduling, for example) and to track resource utilization and effectiveness and associate maintenance tasks with resources (see Figure 10 and Section 7.3.3.5). The support resources include machine resources, material load ports, sensors, durables and people.

7.3.3.3.7 *Machine Resource*

7.3.3.3.7.1 The Machine Resource interface provides attributes for machine description, serial number, model number, vendor, software version, etc. The interface extends resource composition to provide machine resources as composites of machine (sub)resources and specialized process resources with associated process capabilities. The Machine Resource interface also extends the resource state model to include the states and substates of SEMI E10 and SEMI E58. Specific subtypes of Machine Resource and Machine are possible. The CIM Framework defines the subtypes for Production Machine and Process Resource. Additional subtypes to support Transport Machine and Storage Machine interfaces are also possible if there are additional attributes or behaviors required that Machine and Machine Resource interfaces do not already provide.

7.3.3.3.8 *Port, Sensor, Durable, Consumable, Person, etc.*

7.3.3.3.8.1 The other support resource subtypes provide additional, resource-specific, attributes and behavior. Note that durables are also subtypes of Material so they can be moved and tracked as material. Consumables are not currently considered as resources, but a given implementation of the CIM Framework could have consumables be support resources to track their consumption and replenish them as regular maintenance. Persons are considered support resources to schedule them and associate them with machines and other resources and to have associated "maintenance" schedules for training and certification.

7.3.3.4 *Resource Capabilities*

7.3.3.4.1 Resources have associated capabilities, as Figure 9 shows. Factory operations and scheduling use capabilities to identify resources with the capability to perform a specific task. A CIM Framework capability is represented as a text string, providing flexibility to define types of capabilities appropriate for a variety of resources. For example, an MESFactory resource may have capabilities defined in terms of its capacity and the product families it can produce, and a Process Resource may have capabilities that define its C_{pk} process capability and its throughput.

7.3.3.4.2 The Capability interface maintains a list of Resources which have that specific capability, and the associated Resource interface maintains a list of its overall possible capabilities and the subset of possible capabilities that resource is assigned to perform.

7.3.3.4.3 The Capability interface is specialized for Process Capabilities associated with Process Resources. This provides an association to the Process Operation Specifications a Process Resource can perform and the Process Durables and the person Skills needed to support the Process Capability. Other Resources can specialize the Capability interface.

7.3.3.5 *Resource Tracking and Maintenance*

7.3.3.5.1 Support Resources have an associated resource tracking and maintenance management function, as Figure 10 shows. A Resource Tracking Supervisor for a Resource monitors and records resource usage and status and creates Maintenance Jobs according to Maintenance Specifications. Factory Operations, with the aid of a scheduler or dispatcher, assigns Persons and other support resources defined in the Maintenance Specification and initiates Maintenance Job execution. The Resource Tracking Supervisor then supervises Maintenance Job execution. The Maintenance Job and Resource Tracking Supervisor specialize the Job/Job Supervisor pair as Section 7.3.4.6 describes. The Resource Tracking Supervisor also records appropriate history, such as maintenance logs and resource utilization and state, in the Named History Collection for the Resource (inherited from Named Entity). Resource type-specific specializations of the resource tracking and maintenance interfaces are possible.

7.3.4 *Job Architecture*

7.3.4.1 This section describes the job management and control architecture of the CIM Framework. It defines a hierarchical job supervision and control structure that manages factory-level jobs (create product material to fill enterprise product requests) and implements these factory-level jobs by creating and managing machine-level process jobs and transport jobs, coordinated with maintenance jobs and other support jobs. The job control architecture defines and manages relationships between manufacturing resources (process equipment, transport equipment, people), material groups (lots, product groups, process groups, transport groups) and specifications (product specifications, process flows and recipes). This is the central functional architecture which integrates the CIM Framework components into a coherent manufacturing execution system architecture. The concepts are derived from existing standards and related standards efforts [ANSI], [ALBUS], [OMA], [WfMC].

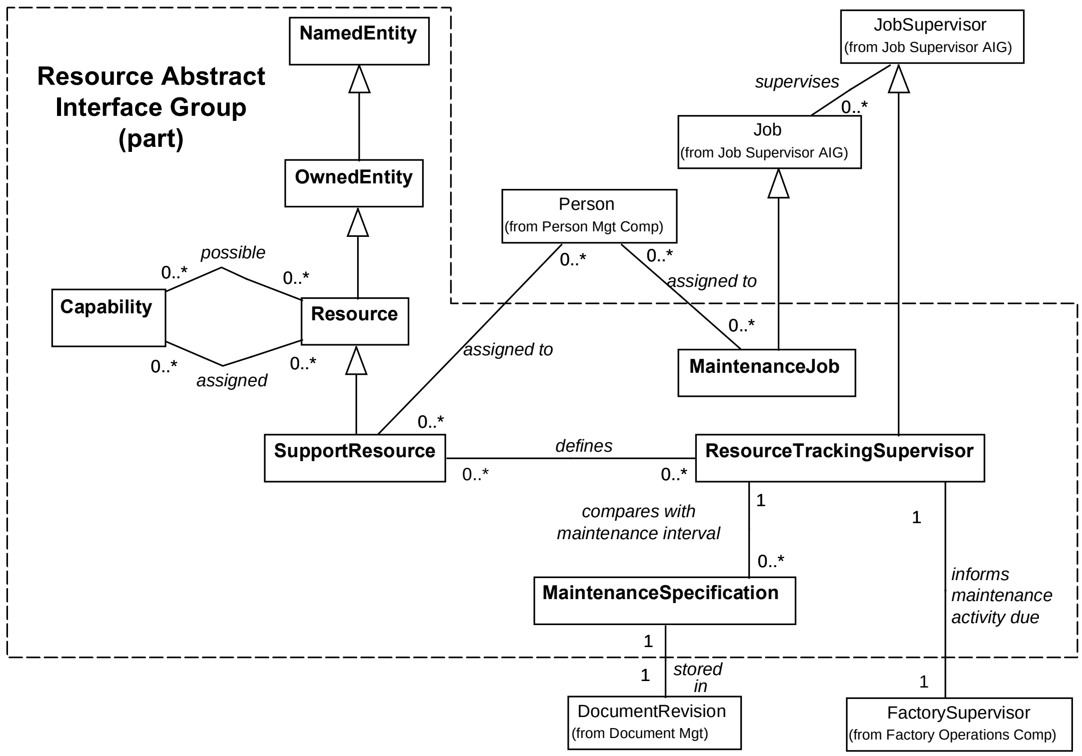


Figure 10
Resource Tracking and Maintenance Architecture

7.3.4.2 *Job Architecture Concepts*

7.3.4.2.1 A job represents a unit of work requested of and performed (or facilitated) by a factory entity that results in some change to the overall factory state. There are several important aspects of a job within the CIM Framework:

- A job typically takes a non-zero time to perform and has a non-zero chance of refusal or failure.
- A job may encapsulate a decomposition into a combination of jobs/tasks/activities.
- There is a notion of higher-level jobs and lower-level jobs. Coordination of lower-level jobs are delegated to other job supervisors to ensure that the higher-level job is completed.
- There is a job requestor.

7.3.4.2.2 The CIM Framework specifies a number of structures for job control. The complexity and variability of the factory requires some organizational structure and separation of manufacturing tasks. Breaking up a complex task into a coordinated interoperation of simpler tasks enables practical solutions to complex problems (the principle of "divide and conquer"). This results in a key organizational structure based on the factory resource hierarchy of Figure 7 and Figure 8 , with the separation of tasks summarized in Section 7.3.3.3. The job control architecture defines how tasks are assigned and coordinated across the hierarchy of factory resources.

7.3.4.2.3 Another key job structure is the relationship between manufacturing tasks and the material and resources used to carry out the task. For example, Factory Operations is responsible for efficiently allocating machine resources with the required processing capability to the material work-in-progress to drive the material through its process flow. A job is a combination of a requested task and the material and resources needed to execute that task (see Figure 13). The relationship between task, material and resource, combined with a hierarchical job structure (based on a hierarchical resource structure) results in complex relationships between tasks, material, and resources at multiple levels.

7.3.4.2.4 Given the complexity, scope and variability (chance of failure or partial success) of jobs, the CIM Framework separates job control into explicit functions.

It does not bury job control into material management functions for driving process flows, nor does it bury job control into machine management functions for driving process operations. The CIM Framework makes job control explicit, providing an architectural structure to attach decision support logic (such as scheduling utilities), business processes (workflow) and business rules that enforce operational policy. Further, the CIM Framework distributes and coordinates job control among factory jobs, production machine jobs, transport jobs, and maintenance jobs. This allows job control to manage "local" complexity while coordinating factory-wide operations toward "global" objectives.

7.3.4.3 *Hierarchical Task Structure*

7.3.4.3.1 At the lowest level of the factory hierarchy (the resource level in Figure 7), the tasks are single process or metrology operations or material movements. Through a complex, context-dependent combination of single tasks, products are manufactured and delivered to customers. This complex combination of single tasks is a task structure as shown in Figure 11. In manufacturing operations, these structures are pre-defined as task procedures, work flows, process specifications, etc. To accommodate manufacturing variability and exceptions, though, the structures must also be adjusted and modified as they are executed. For example, as factory operations selects specific machine resources to perform process steps, it may insert machine-dependent setup tasks and operation sequences, it may modify step specifications (recipes) with machine-dependents settings, or it may insert transport steps to get the material to the machine.

7.3.4.3.2 Notice in Figure 11 that tasks of a higher level are decomposed into combinations of tasks for lower level resources. Each manufacturing resource has a thread of tasks that must be coordinated with the tasks of other resources. The higher level task is completed when the combination of lower level tasks is completed. Figure 11 illustrates this with the coordination of material movement and processing operations and with the coordination of operations within the processing equipment. Resource maintenance, advanced process control calculations and other tasks must also be coordinated with material processing, inspection and movement tasks. The role of job control is to decompose, coordinate, monitor, adjust, and report on this hierarchical structure of tasks.

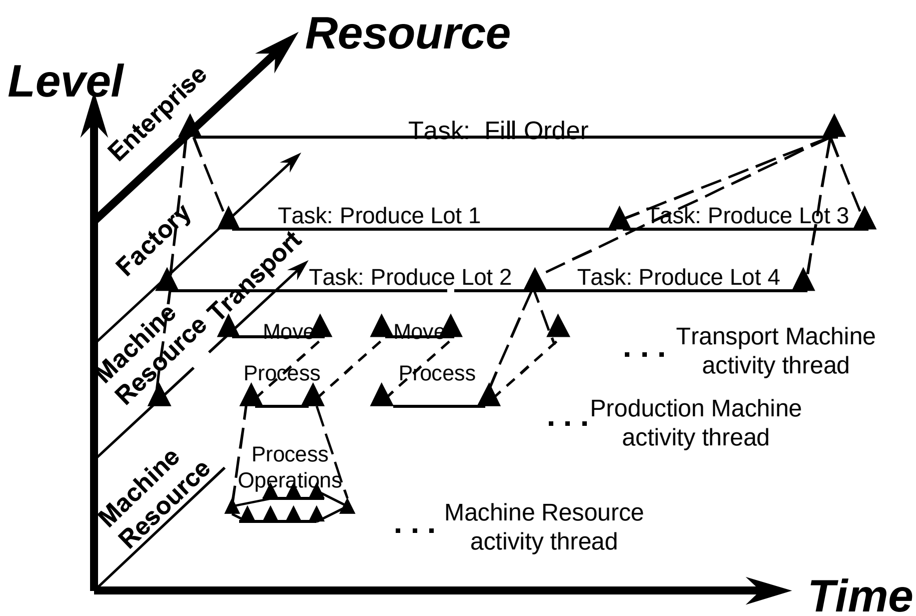


Figure 11
Hierarchical Task Structure

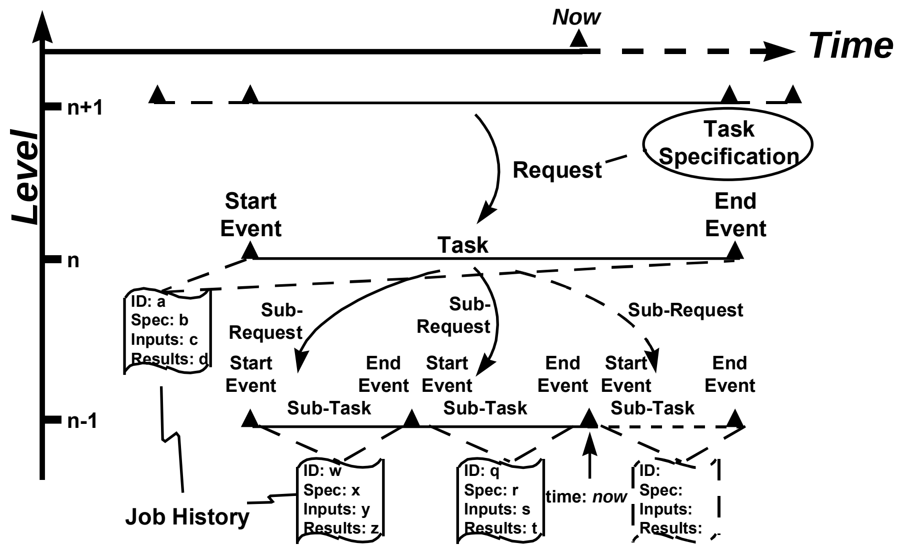


Figure 12
Elements of a Hierarchical Task

7.3.4.4 *Elements of a Task*

7.3.4.4.1 The Hierarchical Task Structure of Figure 11 defines the requirements for a multi-level task model. Figure 12 shows the elements of a hierarchical task, indicating some of the additional data for an overall job control structure. A task is requested from a superior level. Along with the request is a task specification, which is often a template or procedure for how to carry out the task, including a combination of subtasks and monitor and adjustment checkpoints along the way.

7.3.4.4.2 As each task is started, completed, modified or aborted, the job control for the task publishes appropriate events or other notifications. The task endpoints illustrated in Figure 12 as triangles represent factory states or some specific aspect of a factory state. When a task is completed, the factory state is changed in the specified way. For example, after a wafer deposition task, the product state is changed, with a layer of oxide deposited on all the wafers in a lot. When a movement task is completed, the product location state is changed to the load port for a machine to perform the next process operation. These intended factory states often have side effects on other factory states. For example, after a process operation, the equipment state changes to reflect its utilization, consumables consumption, etc. Job control achieves orderly, coordinated, efficient changes to factory state that result in products, that is, that efficiently turn raw wafers into product wafers.

7.3.4.4.3 As the job control executes the task, task results are collected in a job history that includes a job identifier, the (modified) specification used, and recorded inputs and results. Higher level job results could be a roll-up, an abstraction, or simply pointers to lower level job results.

7.3.4.5 *Job Structure*

7.3.4.5.1 A job is a relationship between all the elements necessary to perform a task with specific control functionality to carry out the task in light of manufacturing variability. A job implements a specified task on specified material using specific resources. The job structure of Figure 13 is the relationship mechanism for controlling and changing factory material and resource states and recording job results in associated job histories. That is, the job instantiates and manages the relationships in the structure of Figure 13.

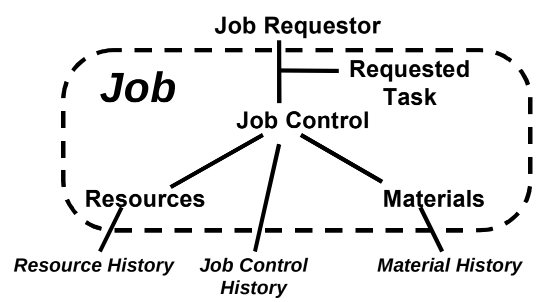


Figure 13
Job Structure

7.3.4.6 *Jobs and Job Supervisors*

7.3.4.6.1 Jobs are transient entities. They are created to perform a task and go away when the task is complete. A job supervisor is the persistent object that responds to job requests by creating jobs. Figure 14 shows an information model for the generic Job Supervision architecture.

7.3.4.6.2 There is a corresponding job supervisor which specializes the generic job supervisor; a Factory Job Supervisor manages Factory Jobs; an Area Job Supervisor manages Area Jobs; and a Production Machine Job Supervisor manages Production Machine Jobs. There is also a Maintenance Job Supervisor and an Advance Process Control job supervisor (the Control Execution Manager in the Advanced Process Control component).

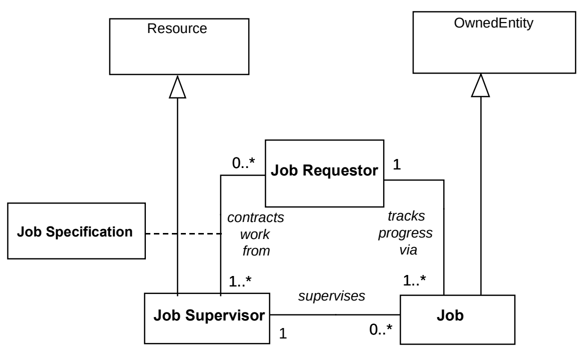


Figure 14
Job Requestors, Job Supervisors, and Jobs

7.3.4.6.3 The entities in Figure 14 are as follows:

- Job.
    - A unit of work that takes time and may fail.
    - Has state (see Figure 15).
- Job Supervisor.
    - Receives requests for work, facilitates creation of a job for the task and returns a reference to that job to the requestor.
    - Manages all jobs within the component that implements it.
- Job Requestor.
    - Requests work.
    - Receives job progress through interface methods (informJobStarted, informJobCompleted, informJobTerminated) and published events.
- Job Specification.
    - Job description (process flow, recipe, transport destination, maintenance spec, etc.).
    - Priority and deadline.

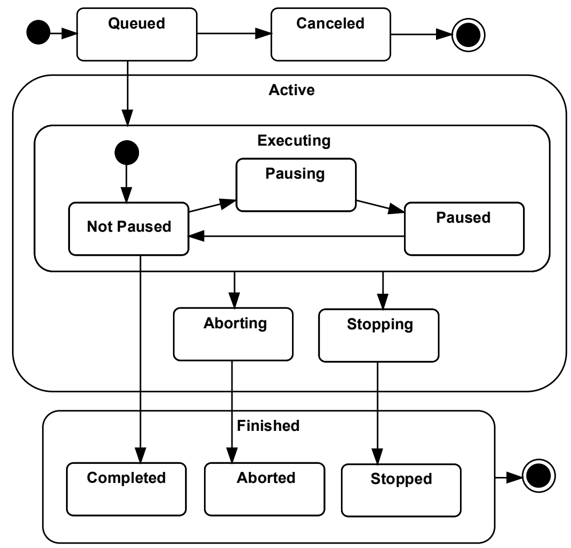


Figure 15
Job State Model (CIMFW)

7.3.4.7 *Job Supervision Design Principles*

7.3.4.7.1 Jobs and Job Supervision are encapsulated within a component. Their interaction and the division of responsibility between them is hidden. At any level, the requestor of activity will request work of a Job Supervisor and receive in return the handle to a Job which represents this work. This requestor will not have visibility to how the Job Supervisor performs the work beyond what is specified in the original activity specification and what is reported later as data. Not visible or accessible are the Job Supervisor's internal and lower-level activity requests (and resulting jobs).

7.3.4.7.2 A job requestor does not micromanage the job. Instead, the job requestor creates a specification of the work to be done and hands it to the Job Supervisor when requesting the work. Once the work request is accepted, the Job Supervisor's component controls the execution of that job within the limitations of the job specification and its business rules. The only exceptions are coarse commands such as job abort or pause. The responsibility of the Job Supervisor and Job is to perform the activity and report back to the requestor on the success or failure of the effort.

7.3.4.7.3 There is no predefined limitation on the facilities within the factory that may be used to satisfy a job request. However, a Job Supervisor may be configured to be limited to specific factory resources that it can call on to perform work.

7.3.4.7.4 The job requestor has an interface so the Job/Job Supervisor can report overall job progress. The Job Requestor interface includes the methods requesting that it be notified that a job has started, completed, or been terminated. The requestor or other components can subscribe to job state change events and other events for a more detailed job status.

7.3.4.7.5 The Job Supervisor interface provides high level information about the jobs it is currently managing. The details of any specific job are provided by the Job itself, not the Job Supervisor. From the Job Supervisor, the Job Requestor is able to

- request activity,
- locate jobs that meet certain criteria,
- request lists of all jobs being performed, and
- control all the jobs as a group (e.g. "abort all jobs"), but not individually (not "abort job X"— this would be a responsibility of the Job interface).

NOTE 13: Much thought should be given to the use of these "all jobs" commands since they can cause a great deal of harm if not designed and used properly.

7.3.4.7.6 The Job interface is the sole source of all public information about a job. It also provides all specific control of the job (pause, abort, etc.).

7.3.4.8 *Hierarchical Job Structure*

7.3.4.8.1 The factory and task hierarchy of Figure 11 and Figure 12 results in a multi-level (hierarchical) job control structure, with a given Job/Job Supervisor requesting work through other (sub)Jobs. As Figure 16 illustrates, higher level job controllers specify and request work from any number of lower level job controllers and monitor job progress through status and external feedback. At the lowest level, job control results in directly manipulating equipment actuators based on real-time sensor feedback. (Note, this lowest level of job control is outside the MES scope of the CIM Framework—it is within the scope of the equipment control.) The job request, status, and feedback information are all candidates for storage in job history.

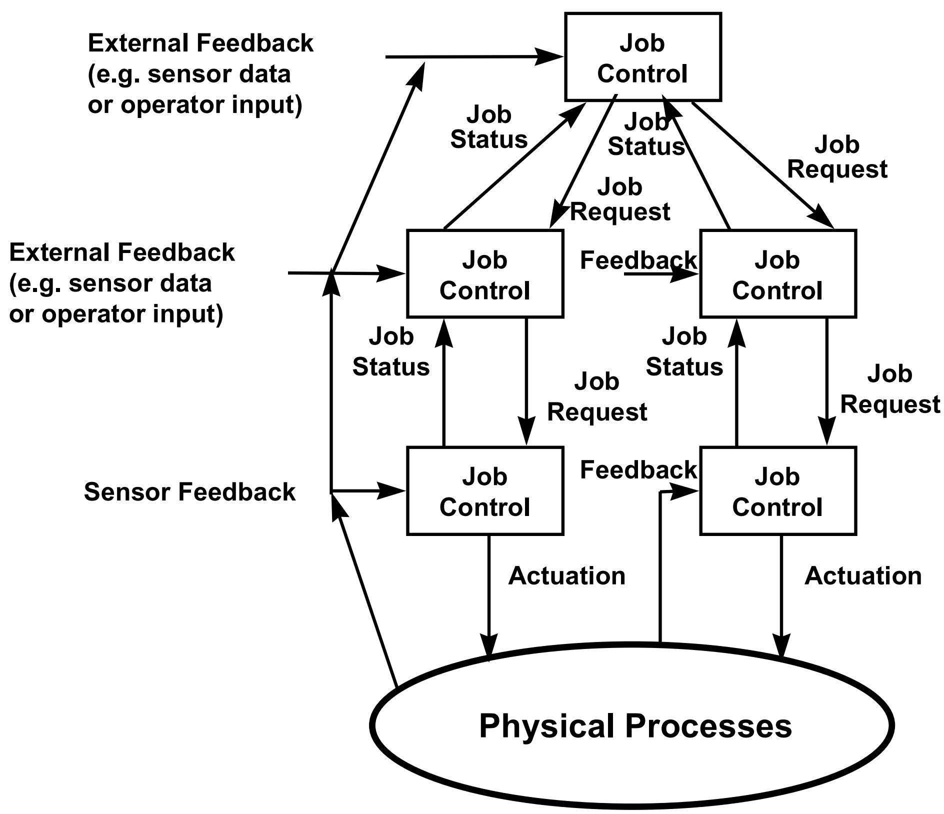


Figure 16
Hierarchical Job Control

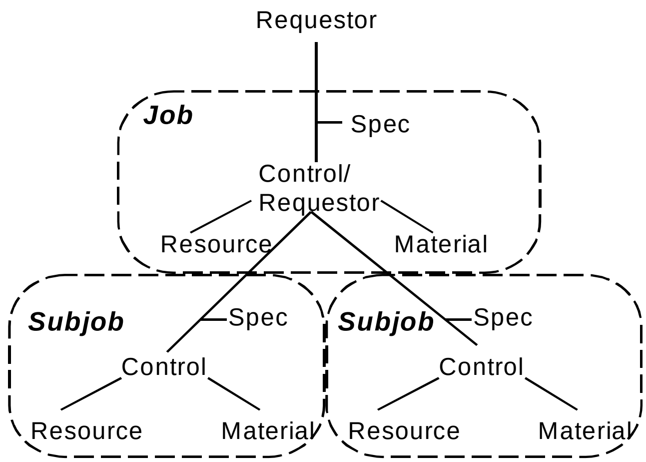


Figure 17
Hierarchical Job Control Pattern

7.3.4.8.2 Placing the job structure template of Figure 13 into the job control hierarchy of Figure 16 results in the hierarchical job control pattern of Figure 17.

7.3.4.8.3 At each level, the job control

- Receives job requests with associated job specifications,
- Decomposes the job into subjobs,
- Defines resource relations between the job and subjob (e.g., selects and schedules resources for subjobs within the scope of the job supervisor, such as machines assigned to an area or process chambers in a production machine),
- Defines material relations between the job and subjob (e.g. how lots are assigned to transport groups and process groups, including decisions on batching, splits, joins, etc.),
- Requests the subjobs and provides associated subjob specifications,
- Monitors subjob progress,
- Reports job progress to the job requestor and other interested functions,
- Records job history.

7.3.4.9 *CIM Framework Job Structure Summary*

7.3.4.9.1 Figure 18 shows the job hierarchy pattern applied to the material movement resources of Figure 7. Figure 19 shows the pattern of Figure 17 applied to the material processing resources of Figure 7 (branching to multiple lower-level resources is not shown). Figure 20 summarizes how the CIM Framework components come together into an integrated manufacturing execution system.

- The product material hierarchy and genealogy is modeled in the Product Management components of the CIM Framework Specification.
- The task specification hierarchy is modeled in the Specification Definition and Recipe Management components.
- The resource hierarchy is modeled in the Factory Operations (for Factory and Area levels), Equipment Tracking and Maintenance, Durables and Consumables Management, and Factory Labor components.
- The control hierarchy is modeled in the Factory Operations (Factory Jobs), Production Machine (Production Machine Jobs), Material Transport and Storage (Transport Jobs), and the maintenance job supervision aspects of the various Resource Tracking and Maintenance specializations (Maintenance Jobs).

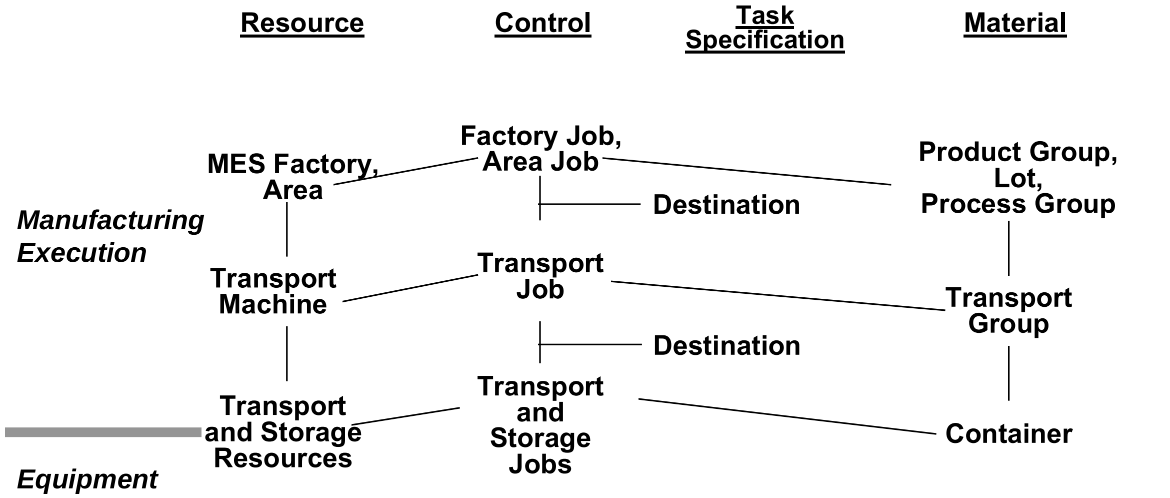


Figure 18
Hierarchical Job Control - Material Transport Aspects

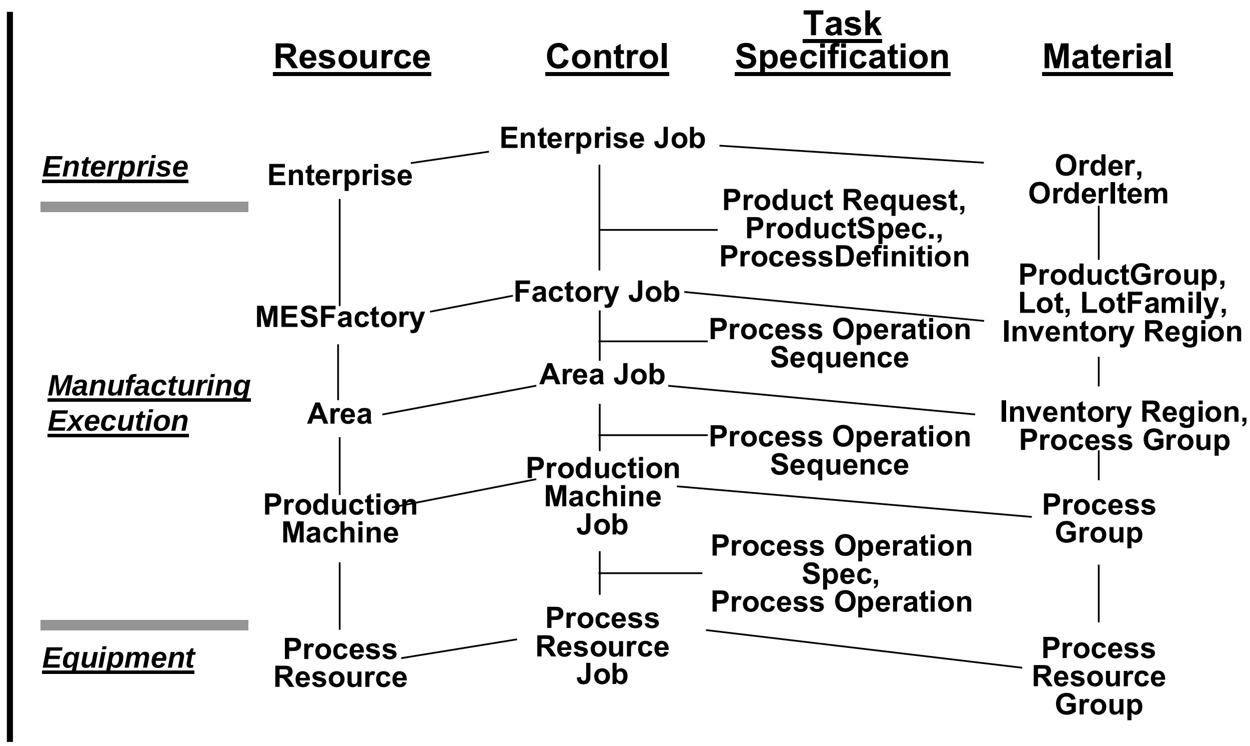


Figure 19
Hierarchical Job Control - Material Processing Aspects

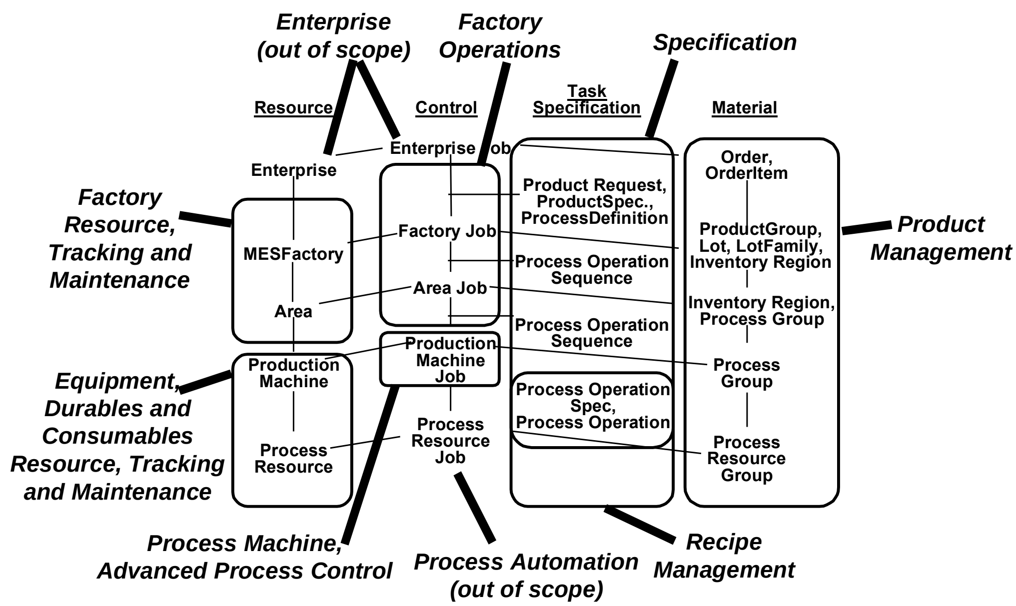


Figure 20
Integrated Hierarchical Job Control

7.3.4.9.2 As Section 7.3.3.3 describes, each of these job control views shows a job supervision function that performs the tasks for each level of the factory resource hierarchy.

7.3.4.9.2.1 Factory Job Supervision: Factory Operations satisfies enterprise product requests. It releases material and creates Factory Jobs which drive material work-in-progress through its process flow. The Factory Job Executor requests, schedules, monitors and coordinates supporting jobs: production machine jobs, transport jobs, maintenance jobs, etc.

7.3.4.9.2.2 Area Job Supervision: This optional level serves Factory Operations and is responsible for multiple machine activities (areas may map to bays, cell controllers, linked lithography, etc.). This level is not required, but is available for organizing large factories. Area job supervision could support factories that have a factory within a factory model with separate but integrated operations management for separate units of manufacturing capacity. It could also support factories transitioning from legacy systems, with parts of the factory under a CIM Framework-conformant MES and other parts under a legacy MES that is fronted or wrapped by a CIM Framework conformant Area Job Supervisor component. Another example could be a factory that provides a pseudo-cluster cell controller to group stand-alone process equipment into an integrated workcell that behaves like a cluster tool. The CIM Framework does not specify separate Area Job Supervision interfaces. These functions are met by the Production Machine Job interfaces with no change—the same interface serves both functional roles. Areas typically receive a sequence of process jobs as a request (implemented by requesting lower-level process jobs and material transport jobs), whereas simple machines usually receive a single process job (implemented through direct interaction with process equipment).

7.3.4.9.2.3 Machine Job Supervision: This level lies within the CIM Framework Production Machine component. It accepts activities that apply to a single Machine. It delegates work directly to the physical equipment, either through some equipment interface driver or directly through the GEM/SECS interface.

7.3.4.9.2.4 Transport Job Supervision: This level lies within the Material Transport and Storage component. It takes requests to move material from one location to another. While the CIM Framework provides for layers of Transport Job Supervisors in a complex interbay and intrabay material handling system, today's typical installation has a single material handling system controller (a single Transport Job Supervisor). Complex production machines with internal material handling and storage may also be Transport Job Supervisors.

7.3.4.9.2.5 Maintenance Job Supervision: Maintenance is a preventive (scheduled) or reactive (repair on failure) activity on specific resources (machines, durables, etc.) using labor resources and materials. Maintenance job progress is reported and tracked and maintenance job history is stored. The generic Resource Tracking and Maintenance component defines the overall maintenance job supervision functions (see Section 7.3.3.5), and the various resource types implement these functions in the Equipment Tracking and Maintenance, Durables Management, Consumables Management, and Factory Labor components.

7.3.4.9.2.6 Advanced Process Control (APC): APC includes lengthy calculation activities that may not succeed and which impact the performance of other jobs. For example, an algorithm may not converge, a sensor may emit bad data, or process recipes and job specifications may be modified. The CIM Framework APC component leverages the overall job architecture, where control strategies and scripts are the job specifications, sensor analysis and control execution environments are scheduled resources, and the state of process specifications (machine settings, modified process flows) are the result of APC job execution.

7.3.4.9.2.7 Enterprise and Process Resource: The job control hierarchy of Figure 19 provides interfaces to the enterprise at the top level and the equipment at the bottom level. The enterprise level is the requestor of work for the factory. Enterprise control is outside the MES functional scope of the CIM Framework. The equipment level is also outside the scope of control of the CIM Framework. It is usually implemented by process controllers embedded in or piggyback on equipment. The equipment level is modeled for the MES to allow process data to be collected and organized for specific equipment resources such as a specific chamber in a cluster tool.

7.3.4.10 *Job History*

7.3.4.10.1 Any entity can have an associated CIM Framework History. The CIM Framework defines some specific named histories, as Figure 21 illustrates. Product-oriented data is captured in production history associated with the material hierarchy and is used, for example, for material traceability and defect analysis. Process-oriented data is captured in process history associated with the job supervision hierarchy and is used, for example, for run-to-run process control. Equipment and other resource-oriented data is captured in resource history associated with the resource hierarchy and is used, for example, for preventive maintenance and warranty tracking.

7.3.4.10.2 As jobs are executed (and possibly broken down into sub-tasks as shown in Figure 12), their results are captured as various types of histories. For example, an Area Job's history may be captured within an InventoryRegionHistory. A Resource Level Job's history may be captured within an E10PerformanceHistory or within a ResourceMaintenanceLogHistory.

7.3.4.11 *Task Specification and Workflow*

7.3.4.11.1 The specification of a task takes various forms. For Factory Jobs, the specification is the process flow defining the process steps to transform material into products. For Production Machine Jobs, the specification is the specific steps in the process flow that this production machine is to perform, along with process recipes. For Transport Jobs, the specification defines the destination location for the material transport group. For maintenance jobs, the specification defines the specific maintenance tasks for the resource. For advanced process control jobs, the specification defines a script that includes the sensor processing and algorithm steps of a control strategy.

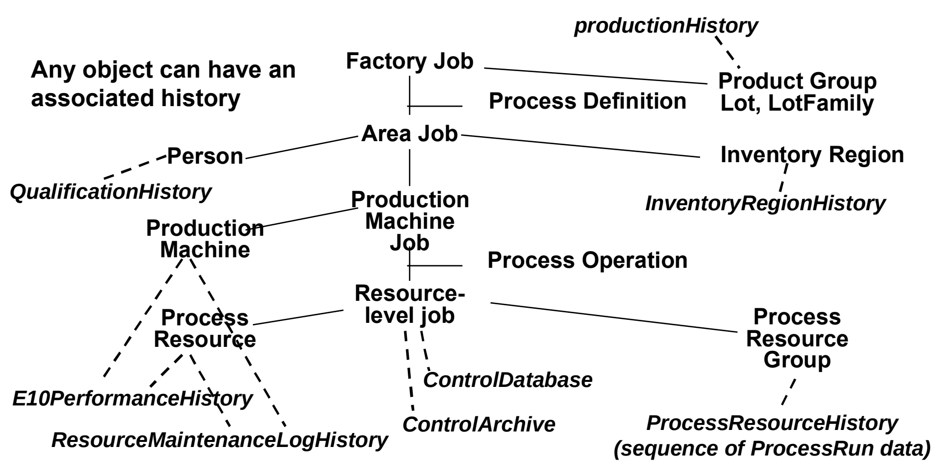


Figure 21
History Structure

7.3.4.11.2 In general, each task specification is a definition of a business process and a task workflow to carry out that business process. There is a diversity of information that could appear in a business process, including associated operational business rules and constraints, workflow traversal logic, and data structures for tasks, recipes, steps, etc. There is not industry consensus on representing these generic task specification details. For each specific job type, the CIM Framework defines some specification structure, but leaves room for suppliers and users to define additional data and behavior and to leverage workflow engines and evolving workflow standards [Workflow, WfMC].

7.4 *Specification Conventions*

7.4.1 This section provides an overview of the notations required to express the CIM Framework specifications. These notations provide the representational formalisms for all CIM Framework specifications. This section is a reference rather than a tutorial. Hence, those unfamiliar with these topics are strongly encouraged to consult the materials listed in the references for a more thorough explanation.

7.4.2 CIM systems requirements and the architectural principles upon which the CIM Framework was founded were derived through use of industry standards, practices reported in the literature, and other state-of-the-art information. The requirements of the CIM Framework are specified using a combination of graphical and textual notations. Where applicable, methods were employed and notations applied that were supported by the automation of computer-aided software engineering tools.

7.4.3 *Model Specification and Graphical Notation Usage*

7.4.3.1 This section briefly describes the graphical notations used to specify the semantics of the framework, including the following:

- Component Relationship Model.
- Component Information Model.
- Component Interaction Diagram.
- State Model.

7.4.3.2 *Component Relationship Model*

7.4.3.2.1 The Component Relationship Model was developed specifically for the framework specification as a mechanism to show relationships among framework components. It shows the logical combination of components and the relationships among the component parts. Figure 22 depicts the Component Relationship Model.

7.4.3.2.2 This model is based on the Unified Modeling Language (UML) Class Diagram [UML] with added stereotypes to represent the components. The UML Association concept is abstracted to represent the high-level relationships between components of the framework.

7.4.3.3 *Component Information Model*

7.4.3.3.1 The Component Information Model shows the specified CIM Framework interfaces along with the relationships between those interfaces. This model is based on the UML Class Diagram [UML] with the stereotype «Interface» to indicate that the classes are interfaces rather than implementation artifacts. This model shows generalization as applied to interface inheritance, aggregation of interfaces, and the use of an Association Class to represent data associated with an association between two interfaces. The associations also capture specific semantics of the relationship, including multiplicity and optionality as shown in Figure 23.

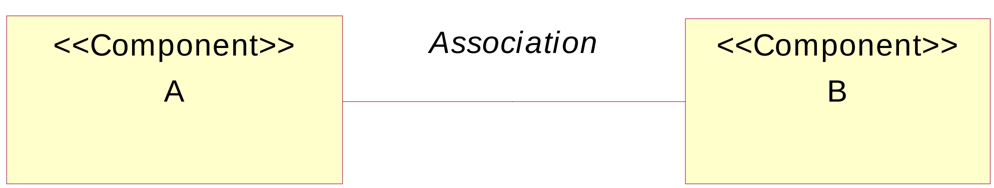


Figure 22
Component Relationship Model

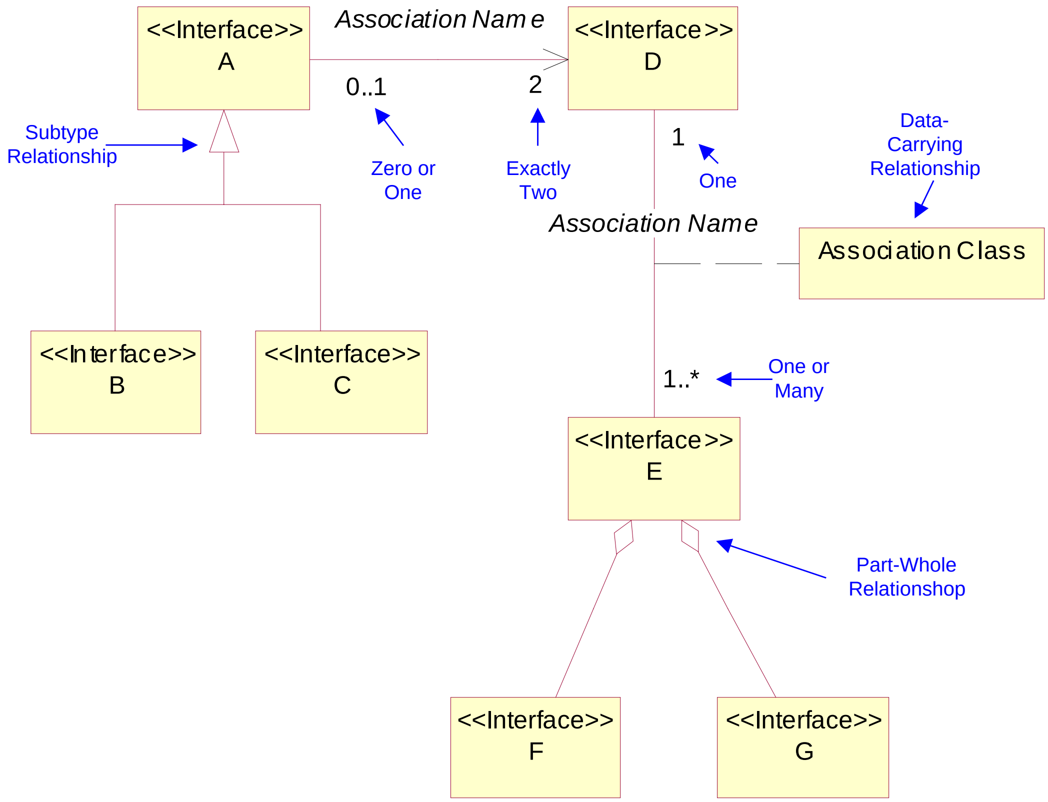


Figure 23
Information Model Example

7.4.3.4 *Component Interaction Model*

7.4.3.4.1 The Component Interaction Model expresses framework dynamics by describing the sequence of collaborations between objects supporting CIM Framework interfaces. This model is represented using the UML Sequence Diagram [UML]. The vertical lines each represent an object that conforms to a role specified by a CIM Framework interface. This is called a “lifeline.” The connecting arrows represent messages that flow between these objects and the data they convey. Each message must map to a defined operation on the interface of the message recipient. The example shown in Figure 24 of a Sequence Diagram models a portion of the interaction between a bank customer and an Automated Teller Machine (ATM).

7.4.3.5 *State Model*

7.4.3.5.1 The State Model shows behavior associated with CIM Framework interfaces as changes in state that result from specific events. The required behavior for an interface is conveyed through UML State Diagrams [UML] and textual tables that offer supporting details. Under this notation which is based on Harel Statecharts, states may be divided into substates, thereby forming a hierarchy of states. Substates must be one of two types, termed AND substates (representing concurrency) and exclusive OR substates (representing a finer breakdown of a parent state).

7.4.3.5.2 Object State Tables provide supplementary (to the State Diagram) state information including descriptive state definitions, state query mechanisms, the triggers effecting state transition, and the actions resulting from state transitions.

7.4.3.5.3 *Object State Definitions and Query Table*

7.4.3.5.3.1 The Object State Definition and Query Table provide supplementary information to the State Diagram.

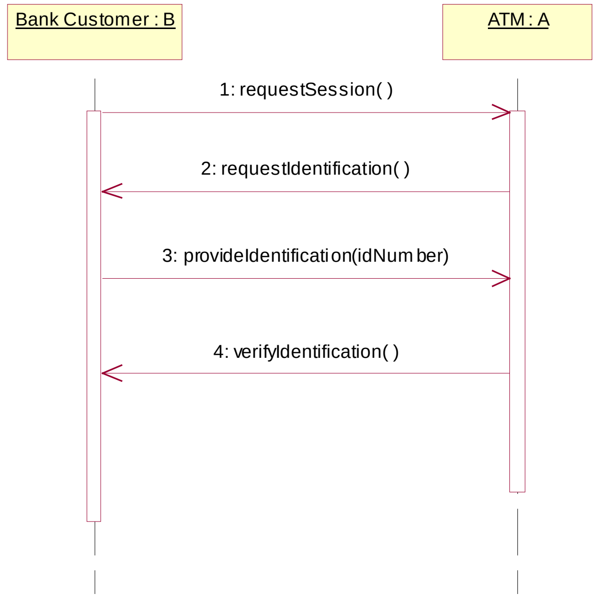


Figure 24
Component Interaction Model Example

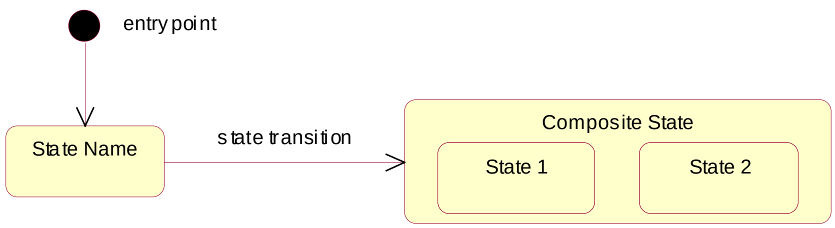


Figure 25
State Diagram

7.4.3.5.3.2 Table 1 provides a detailed description of each object state and identifies the query mechanism for determining if the object is in that state. Given the example provided in this section, an entry in the State Definitions and Query Table would appear as shown.

7.4.3.5.4 *Object State Transition Tables*

7.4.3.5.4.1 Another supplement to the state model is the Object State Transition Table (Table 2).

7.4.3.5.4.2 It lists the transition from the state diagram identified by the starting and ending states, and the event that causes the transition between these states.

7.4.3.5.4.3 Within the CIM Framework specification, only those triggers and state changes relevant to external interfacing are shown to help define how an external entity (in this case a driver) interoperates with an object (in this example an automobile).

7.4.3.5.4.4 While this table defines triggers for state transitions, there is no guarantee that the transition will take place in response to the trigger. In the above example, if the car is out of gas the engine will not go to the running state; if the light is burned out, it will not transition to the on state; depressing the accelerator pedal when the auto is in the off state will have no effect, etc. In the CIM Framework, object state can be queried to ensure successful transitioning in response to a triggering message. Events are also used in some cases to inform the client of a transition or change of state.

Table 1 Object State Definitions and Query Table Example

State	*Definition*	*Query for State Via*
ENGINE RUNNING	In this state, the automobile's engine is running.	boolean isEngineRunning ( ); sent to instance of Automobile. Returns true.

Table 2 Object State Transition Table Example

Current State	*Trigger*	*New State*	*Action*
ENGINE STOPPED	turn ignition key to right	ENGINE RUNNING	tachometer indicates positive RPM
ENGINE RUNNING	turn ignition key to left	ENGINE STOPPED	tachometer indicates zero RPM
LIGHTS OFF	turn light switch on	LIGHTS ON	driving at night is enabled
LIGHTS ON	turn light switch off	LIGHTS OFF	driving at night disabled

7.4.4 *Textual Specification Language*

7.4.4.1 The textual notations used to specify the framework in this specification, include the following:

- Interface Definition Language (IDL).
- Interface Definition Format.

7.4.4.2 *Interface Definition Language (IDL)*

7.4.4.2.1 Specifications of CIM Framework components are composed mainly of interfaces. The specifics of each interface, while also represented in the UML-based Component Information Model, are rigorously specified using OMG IDL. The IDL for CIM Framework interfaces shall be complete and consistent as verified by automated IDL compilers. The IDL portion of SEMI specifications will be available in a text file format to facilitate such validation and use with IDL compiler technologies.

7.4.4.2.2 This explanation of IDL is addressed to its use as a rigorous specification tool. The considerations of mapping the specifications to an implementation infrastructure are addressed in SEMI E96.

7.4.4.2.3 *Common Object Broker Architecture (CORBA)* [CORBA][CIMArch] defines the architecture which enables and regulates interoperability between objects and applications across heterogeneous languages and computer boundaries. In all Object Management Group (OMG) specifications, services are defined as object interfaces expressed in the OMG's *IDL*. *CORBA* standards define *IDL* and its mapping to implementation languages (for example, *C*, *C++*, *Smalltalk*, and *Java*).

7.4.4.2.4 *IDL* is a compilable language that describes the operations that are specified for an interface. The notation is independent of the language in which the methods that implement an interface's operations are written. This goal is achieved by mapping between the *IDL* syntax and whatever language is used to implement client and server objects. Because *IDL* is designed purely for interface specification, it omits the flow control and operator constructs of an implementation language. Object classes can implement an interface differently as long as their behavior conforms to the interface specification.

7.4.4.2.5 *IDL* obeys the same lexical rules as *C*, while introducing a number of keywords specific to a distributed system. As *IDL* is mapped to object-oriented languages, new constructs will appear. A brief discourse on some of the keywords and concepts used in this specification follows. In the examples, words in italics are user supplied, others are *IDL*-defined keywords.

7.4.4.3 *Interface Specification Format*

7.4.4.3.1 The OMG defines an object's interface as "a listing of the operations and attributes that an object provides. This includes the signatures of the operations, and the types of the attributes. An interface specification ideally includes the semantics as well" [OMA]. The CIM Framework Specification builds upon this definition to provide additional semantic information for an interface. These semantics are captured in an interface description. This section describes the format of an interface. Each description of an interface follows this format. The format includes the following:

- Name — The capitalized noun following the word "Interface:"
- Inherited Interface — The capitalized noun after the words "Inherited Interface:"
- Description — A definition of the interface giving its form and function.

- Exceptions — An IDL specification for reporting user-defined, framework-related error conditions.
- Published Events — The name of the event structure that must be placed on an event channel. The event structure identifies the event through a subject field. The subject is composed of the component and interface issuing the event and data describing the event, and filterable and non-filterable information. Events are defined at the interface level; neither posting services nor subscribers are identified. Thus, events are not tied to specific services and may be the result of an internal (to the component) computation.
- Provided Services — A list of publicly available services provided by this interface. In other words, a list of non-private, named operations. Each is given by a description in comment form (i.e., /*....*/) followed by its representation in the IDL syntax.
- Contracted Services — A table of framework services provided by other interfaces that are being used by public and/or private services in this interface. These methods must be available in order for the documented interface to provide its described services. Changes to contracted services may result in changes to the behavior of the interface making use of these services.
- State Model — See Section 7.4.3.5 for details.

7.4.4.3.2 If no Provided Services are defined for a particular category, then “No public interfaces” will appear after the category identifier. If no Exceptions, Published Events, Contracted Services, or Dynamic Model are provided, then the word “None” will appear. State Transition Tables occur only in conjunction with Dynamic Models.

7.4.4.4 *Interface Specification Example*

7.4.4.4.1 Table 3 provides a complete illustration of *IDL* and CIM Framework interface specification format usage within this specification. Words in italics are user-supplied, others are either *IDL* or CIM Framework-defined keywords.

8 Conformance to CIM Framework Domain Specifications

8.1 The objective of the CIM Framework is to speed the creation, use and improvement of a manufacturing execution system for a semiconductor wafer fabrication factory by enabling the integration of disparate components into a cohesive system. The CIM Framework achieves this objective by specifying a domain model for MES components. MES component suppliers use the specification to help establish the boundaries and interfaces of their components. Component customers first use the specification to assess the capabilities of individual components and then to facilitate the integration of components into a working system.

8.2 The CIM Framework increases the value of the MES components by enhancing their qualities of interoperability, substitutability and extensibility.

- Interoperability is the ability of components to work together through compatible interfaces.
- Substitutability implies the option to swap one component with another because they support the same interfaces.
- Extensibility means the planned capability to add functionality to a component, again by leveraging the support for predefined interface specifications.

8.3 Given both the scope and objectives of the CIM Framework, conformance to the Framework can not be reduced to a simple “yes or no” proposition. Rather, component customers must assess component conformance on a case-by-case basis. Potential buyers assess conformance in terms of how well a component supplier demonstrates use of the CIM Framework specification to enable rapid component integration.

8.4 With this background, here then are factors for consumers to consider in assessing MES components and for suppliers to comprehend when building components. These factors form the basis for communication between buyers and sellers of components regarding conformance to the CIM Framework specifications.

Table 3 Interface Specification Example

/* Comments are set between slashes and asterisks */

Interface: *FrameworkObject2*

Inherited Interface: *FrameworkObject1*

Description: The example defines the interface for *FrameworkObject2*, which inherits from *FrameworkObject1*.

Exceptions:

/* The following portrays the syntax used to describe exceptions for this interface. *ObjectType* and *instanceName* specify an object instance (supplementary information) returned with the exception. */

```
exception ExceptionName { ObjectType instanceName };
```

Published Events: *NamedEvent*

Provided Services:

/* The following defines the read/write methods for AttributeName1. */

```
ObjectType getAttributeName1 ( );
void setAttributeName1 (in ObjectType parameterName);
```

/* The following defines a method for readonly *AttributeName2* */

```
ObjectType getAttributeName2 ( );
```

/* The following says operationName1 is a local operation returning an object of the class ObjectTypeReturned. */

```
ObjectTypeReturned operationName1 ( );
```

/* The following says *operationName2* is a local operation returning an object of the class *ObjectTypeReturned* with an argument *instanceName* of the object type *ObjectType*. In addition, there is an operation-specific exception, *E*, that may be raised by this operation. */

```
ObjectTypeReturned operationName2 (in ObjectType instanceName)
          raises (E);
```

The type definitions follow the following format:

/* Type Declarations: */

/* The following specifies (types) the *ObjectType* for the named *datatype*. */

```
typedef ObjectType datatype ;
```

/* The following specifies a sequence (collection) of *ObjectType* for *ObjectTypeSequence*. */

typedef sequence<*ObjectType*> *ObjectTypeSequence* ;

- **CIM Framework component packaging:** Component suppliers must explain how their component is packaged relative to the corresponding CIM Framework component(s). Note, however, that suppliers may choose to provide multiple CIM Framework components as an integrated package. In this case the complete package can be assessed relative to the combination of services provided by the combined set of CIM Framework components. Obviously, a consumer must also assess the benefits of the integrated component relative to the reduction in the ability to substitute components within the integrated package.
- **CIM Framework objects and interfaces:** Component suppliers must describe how their objects and methods support the CIM Framework component interfaces. This includes describing the object methods available in comparison to the interfaces specified in the CIM Framework. Note that this interface specification question encompasses specific operations, the operations' arguments, the exceptions returned, and the events published.
- **Object behavior:** Component suppliers must document object behavior so component consumers can understand the purpose and consequences of specific methods. The CIM Framework specifies behavioral semantics for components using a variety of representations such as state models, information models showing relationships, interaction models, and text-based

comments. Component suppliers need to explain how their objects conform to the CIM Framework behavioral semantics.

8.5 As these factors indicate, assessing the CIM Framework conformance of supplied components takes more than just verifying the existence of specific objects and methods. The key issue is whether a component supplier provides both the software and its associated conformance information needed to enable the use and integration of the component.

9 Related Documents

9.1 The following documents describe programs, standards, and guidelines used in the development of the CIM Framework specification.

9.1.1 *SEMATECH Documents*

Advanced Process Control Framework Initiative (APCFI) 1.0,6/27/97 (SEMATECH - Technology Transfer #97063300A-ENG):CIM Framework Enhanced Machine Component Communications Driver (MCCD) Final Report (SEMATECH - Technology Transfer #97073323A-TR).

C++ Reference Implementation for the Computer Integrated Manufacturing (CIM) Application Framework: Release 2, 1/4/96 (SEMATECH - Technology Transfer #95082944B-ENG).

Computer Integrated Manufacturing (CIM) Application Framework Validation Project: Lessons Learned During the Automation Software Systems Project (SEMATECH - Technology Transfer #94102568A-ENG).

Computer Integrated Manufacturing (CIM) Development Manual 1.1 - Volumes 1 and 2 (SEMATECH - Technology Transfer #91120794B-ENG).

Computer Integrated Manufacturing (CIM) Framework Member Validation Project (FMVP): Phase II Final Report (SEMATECH - Technology Transfer #96013061A-TR).

Evolution of WorkStream for Preventive, Predictive Maintenance (PM) at SEMATECH (SEMATECH - Technology Transfer #95092966A-TR).

Real-Time Dispatcher (RTD) Computer Integrated Manufacturing (CIM) Framework Conformance and Integration Studies (SEMATECH - Technology Transfer #96023088A-ENG).

Results of the AutoSimulations and TI/WORKS Integration Feasibility Study (SEMATECH - Technology Transfer #95092981A-ENG).

SEMATECH Workbench for Integrated Modeling (SWIM) Enhanced Prototype Functional Specification 5.0, 12/2/93 (SEMATECH - Technology Transfer #93112072A-ENG).

Semiconductor Generic Manufacturing Model. (SEMATECH - Technology Transfer #91090704A-ENG).

Semiconductor Generic Manufacturing Requirements Specification (SEMATECH - Technology Transfer #91090703A-ENG).

Strategic Cell Controller (SCC) Program Repository Contents Guide 1.1 SEMATECH Factory Integration Technologies (FIT) Project (SEMATECH - Technology Transfer #93091827B-XFR).

Strategic Computer Integrated Manufacturing (CIM) Computing Environment Specifications. (SEMATECH - Technology Transfer #92010916A-ENG)

Technical Summary of CIM Framework-Based Integration of ASI Real-Time Dispatcher and IBM Legacy Systems (SEMATECH - Technology Transfer #96093180A-TR).

SEMI E82-0302
SPECIFICATION FOR INTERBAY/INTRABAY AMHS SEM (IBSEM)

This standard was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on October 14 and November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published September 1999; previously published November 2001.

This document replaces SEMI E30.4 in its entirety.

1 Purpose

1.1 This standard establishes a Specific Equipment Model (SEM) for interbay and intrabay AMHS transport equipment (IBSEM). The model consists of equipment characteristics and behaviors that are to be implemented in addition to the SEMI E30 fundamental requirements and selected additional capabilities. The intent of this standard is to facilitate the integration of IBSEM equipment into an automated (e.g., semiconductor fabrication and flat panel display) factory. This document accomplishes this by defining an operational model for IBSEM equipment as viewed by a factory automation controller (Host). This definition provides a standard host interface and equipment operational behavior (e.g., control, state models, data reports, and reporting levels). Several topics require additional activity that are within the scope of this standard: traffic management characteristics (queuing), parallel interface for carrier transfer (SEMI E23), transport system controller architecture, and delivery of the transfer unit.

2 Scope

2.1 The scope of this standard is limited to the usage and description of interbay and intrabay AMHS transport equipment (OHT, OHS, RGT, AGT, DWC) as perceived by a SEMI Equipment Communications Standard 2 (SECS-II) host that complies with the GEM model (as specified in Section 13). It defines the view of the equipment through the SECS communication link. It does not define the internal operation of the equipment. It includes a specific transfer command state model and transport system controller state model as the basis for all equipment of this class.

2.2 This document assumes that the GEM fundamental requirements and selected additional capabilities (as specified in Section 13) have been implemented on the IBSEM equipment. It expands the GEM standard requirements and capabilities in the areas of state models (TSC, transfer command, vehicle and carrier state models), collection events, alarm documentation, remote commands, data item variables, and material movement.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 *Evaluation of SEMI E32 (MMM)*

3.1.1 The concepts defined in SEMI E32 were analyzed and included where applicable to the IBSEM, but the GEM model was used as the basis for IBSEM requirements definition.

3.2 *Interbay and Intrabay AMHS Transport Equipment Types*

3.2.1 This standard is targeted at the different types of 300 mm and interbay and intrabay AMHS transport equipment. The term *IBSEM equipment* refers to all types of transport equipment. The equipment types have fundamental mechanical differences:

3.2.1.1 *Overhead Hoist Transport (OHT)* — An overhead rail guided transport system positioned for vertical access to SEMI E15.1 compliant ports.

3.2.1.2 *Over Head Shuttle (OHS)* — An overhead rail guided transport system (monorail) positioned for access to stocker automated interbay input and output ports. The OHS vehicle may or may not contain a transfer agent.

3.2.1.3 *Rail Guided Transport (RGT)* — A ground-based rail guided transport system positioned for access to SEMI E15.1 compliant ports.

3.2.1.4 *Automated Guided Transport (AGT)* — A ground-based transport system with automated guidance (i.e., no rail guidance). Automated guidance system allows vehicles to access SEMI E15.1 compliant ports.

3.2.1.5 *Direct WIP Conveyer (DWC)* — An overhead transport system, based on direct WIP roller conveyers. No vehicles are used for point to point delivery. The conveyers are positioned for vertical access to SEMI E15.1 ports.

3.2.2 Transport vehicles may contain zero or more internal buffers for carrier transport. If mechanically feasible, the transport system may acquire or deposit carriers simultaneously. If transported in a safe manner, carrier transport may occur while occupying the acquire/deposit transfer port(s) of the transport vehicle (e.g., a single position hoist vehicle). In the context of this standard, a "vehicle" on a DWC is defined as a single carrier in the transport system.

3.3 *Physical Layout Limitations*

3.3.1 The equipment controlled by a single TSC must allow for a carrier to be transported from any given source port to any destination port via a single transfer command without the assistance of an external device (manual or automated). In other words, if a source port and a destination port are controlled by a TSC, there must not exist a physical or logical barrier that prevents a carrier from being moved between the two ports. This assumes that the type of carrier (FOUP, Reticle Pod, etc.) is permitted at the source and destination ports.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E32 — Material Movement Management (MMM)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

4.2 *Other References*

Harel, D., "Statecharts: A Visual Formalism for Complex Systems," Science of Computer Programming 8 (1987) 231-274.[1]

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGT* — Automated Guided Transport

5.1.2 *AMHS* — Automated Material Handling System

5.1.3 *DWC* — Direct WIP Conveyor

5.1.4 *FOUP* — Front Opening Unified Pod

5.1.5 *GEM* — Generic Equipment Model

5.1.6 *ITS* — Interbay or Intrabay Transport System

5.1.7 *OHS* — Over Head Shuttle

5.1.8 *OHT* — Overhead Hoist Transport

5.1.9 *PGV* — Person Guided Vehicle

5.1.10 *RGT* — Rail Guided Transport

5.1.11 *TCP/IP* — Transmission Communication Protocol/ Internet Protocol

5.1.12 *TSC* — Transport System Controller

5.2 *Definitions*

5.2.1 *active vehicle* — a vehicle in the transport system that contains a robot or other transfer agent for providing the acquiring (loading) and depositing (unloading) actions.

5.2.2 *buffer* — a set of one or more locations for holding carriers at the production equipment.

5.2.3 *carrier* — a container with one or more fixed positions for holding substrates. Examples of carriers include FOUPs and open cassettes.

5.2.4 *FOUP* — a closed carrier for holding wafers.

5.2.5 *host* — the factory computer system, or an intermediate system, that represents the factory and the user to the equipment. Refers to the system that controls or supervises the Transport System Controller (TSC) throughout this document.

5.2.6 *internal buffer* — locations within the equipment to store carriers. These locations exclude load ports.

5.2.7 *load port* — the interface location on the equipment where carriers are delivered.

5.2.8 *open cassette* — an open structure that holds one or more wafers.

5.2.9 *passive vehicle* — a vehicle in the transport system that does not contain a robot or other transfer agent for providing the acquiring (loading) and depositing (unloading) actions. The vehicle simply contains a position(s) to carry the transfer unit. The loading and unloading action must be accomplished at the load or unload port by a different system (e.g., stocker port robot).

5.2.10 *process equipment* — equipment used to make semiconductor devices. This excludes metrology and material handling equipment.

5.2.11 *production equipment* — equipment used to produce semiconductor devices, including wafer sorting, process, and metrology equipment and excluding material handling equipment.

5.2.12 *transfer port* — point on the transport system at which a change of equipment ownership of the carrier occurs.

5.2.13 *transfer unit* — the element of movement (assemblage of carriers) of the ITS that consists of a maximum num-ber of carriers allowed in a specific transfer command:

- AA is the maximum number of carriers allowed for acquire at the transfer source.
- BB is the maximum number of carriers allowed for deposit at the transfer destination.
- CC is the maximum number of carriers allowed for transfer in one transport vehicle.
- The maximum size of the transfer unit is the minimum of AA, BB, and CC.

5.2.14 *Transport System* — a transport system dedicated to one or more bays in the factory and responsible for transferring carriers to production equipment, from production equipment, from production equipment to production equipment or from stocker to stocker. TS consists of the physical units of the system (e.g., vehicles, nodes, docking stations), the low-level unit controllers, and a system-level controller. TS excludes factory floor storage systems (stockers), but includes any short-term storage integral to the system, such as storage locations within an overhead track system that are accessible only to units of the particular TS.

5.2.15 *Transport System Controller* — interbay or intrabay Transport System Controller that communicates with the Factory Host and represents the system as the equipment.

5.2.16 *Transport System Equipment* — an individual transport system viewed as a single piece of equipment, with distributed components and distributed control. The TS controller communicates with the host using HSMS and GEM and represents the system as an equipment. The factory may require more than one type of transport system.

5.2.17 *transport unit* — a physical component of a transport system, such as a vehicle, node, or docking unit.

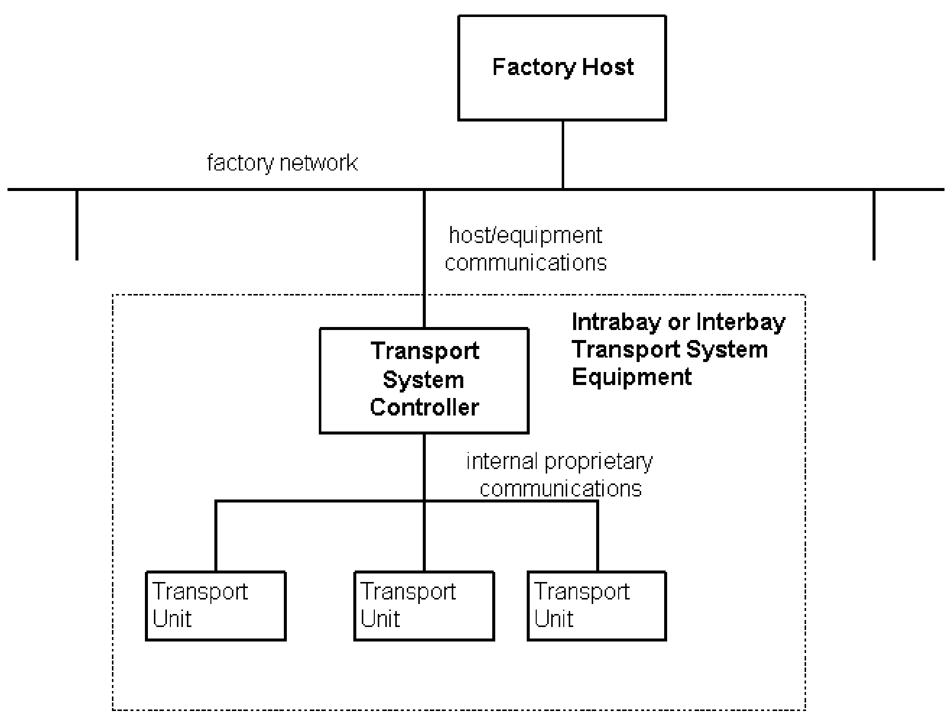


Figure 1
Example of Transport System Equipment

6 Communication Requirements

6.1 It is required that any IBSEM compliant equipment follow the Communications State Model in SEMI E30. In addition, IBSEM compliant equipment shall support either the High-speed SECS Message Services Single-Session Mode (SEMI E37 and SEMI E37.1, HSMS and HSMS-SS) communication standard or SEMI Equipment Communications Standard 1 Message Transfer (SEMI E4, SECS-I) communication standard.

7 State Models

7.1 *State Model Requirements*

7.1.1 The state models included in this standard are a requirement for IBSEM equipment. This standard requires implementation of all SEMI E30 state models (such as control, communication, on-line/off-line, etc. according to the GEM capabilities required per Section 13). A state model consists of a state model diagram, state definitions, and a state transition table. All state transitions in this standard, unless otherwise specified, shall correspond to collection events.

7.1.2 A state model is the host's view of the equipment, and does not necessarily describe the internal equipment operation. All IBSEM state model transitions shall be mapped sequentially into the appropriate internal equipment events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the IBSEM state model for transition to another state. The equipment makes the required transition without any additional actions in this situation.

7.1.3 Some equipment may need to include additional substates other than those in this standard. Additional substates may be added, but shall not change the IBSEM defined state transitions. All expected transitions between IBSEM states shall occur.

7.2 *TSC State Model*

7.2.1 *TSC State Model Requirements*

7.2.1.1 The purpose of the Transport System state model is to provide information to the host regarding the overall status of the Transport System. The TSC state model is valid when the SEMI E30 (GEM) state is ON-LINE. The TSC state model is **not** valid when the SEMI E30 (GEM) state is OFF-LINE. Since a transport system may consist of many components (e.g., vehicle, robot arm, ID reader, etc.), it may be possible to continue ON-LINE operation when the operation mode of some transport components (as viewed by the TSC) is a manual state. The details of what happens when individual components of the transport system enter a manual state are specific to the IBSEM equipment supplier. When the SEMI E30 Control state changes from OFF-LINE to ON-LINE, the TSC State Model is started from the TSC INIT state.

7.2.2 *TSC State Model*

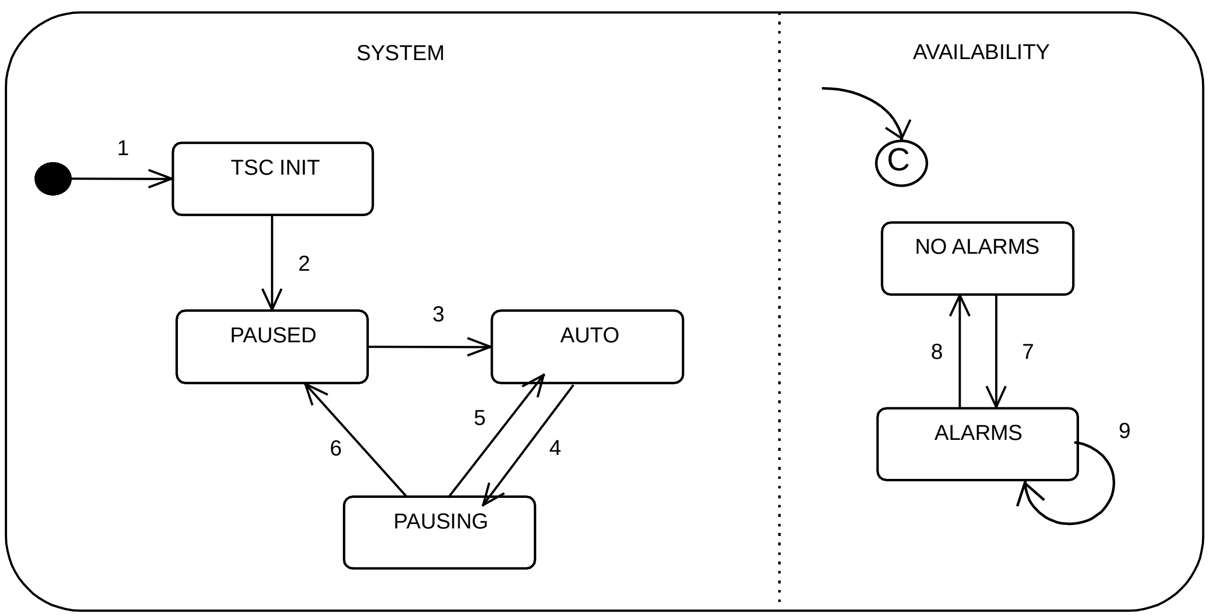


Figure 2
Generic IBSEM TSC State Model Diagram

7.2.3 *TSC State Definitions*

7.2.3.1 *TSC INIT* — TSC initialization of TS components is occurring. This is a non-operational state. No commands from the host will be processed or queued. The system will not move out of this state if there are vehicles actively loading or unloading carriers at ports. These vehicles must be manually or automatically recovered before moving on to the next state.

7.2.3.2 *PAUSING* — A system PAUSE command has been received and is being processed. All vehicles that are currently loading or unloading will continue until the load/unload is complete. Vehicles that are currently moving may continue to move but they must not begin a load or unload. TRANSFER commands are accepted and queued. All status requests will be processed. The RESUME command will also be processed.

7.2.3.3 *PAUSED* — No vehicles are in the process of loading or unloading a carrier at a port, but vehicles may still be moving. TRANSFER commands are accepted and queued.s All status requests will be processed. The RESUME command will also be processed.

7.2.3.4 *AUTO* — System is in the normal operational state. Commands are actively processed.

7.2.3.5 *NO ALARMS* — There are no alarms present in the system.

7.2.3.6 *ALARMS* — There are one or more alarms present in the system, but the TSC is still capable of normal processing since several components may remain unaffected by the alarm situation.

7.2.4 *TSC State Transition Table*

Table 1 TSC State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	None	TSC Initiation	TSC INIT	S6F11 TSCAutoInitiated	System runs through its startup sequence.
2	TSC INIT	System started up successfully. All loads and unloads are complete.	PAUSED	S6F11 TSCPaused	System ready
3	PAUSED	TSC is resumed.	AUTO	S6F11 TSCAutoCompleted	System will now perform all commands.
4	AUTO	TSC is requested to pause.	PAUSING	S6F11 TSCPauseInitiated	Vehicles that are stopped stay stopped. Vehicles that are moving stop at the next logical point without proceeding.
5	PAUSING	TSC is resumed.	AUTO	S6F11 TSCAutoCompleted	System will now perform all commands.
6	PAUSING	All carrier loads and unloads are completed. No new acquires or deposits will occur. Outstanding acquires and deposits will complete.	PAUSED	S6F11 TSCPauseCompleted	System will accept and queue new commands but will not execute them.
7	NO ALARMS	Alarm Set	ALARMS	S6F11 AlarmSet	System can process normally for transport components that are unaffected by the alarm.
8	ALARMS	Last remaining alarm cleared.	NO ALARMS	S6F11 AlarmCleared	
9	ALARMS	Alarm Set	ALARMS	S6F11 AlarmSet	Alarm occurs when there is already an outstanding alarm.

7.3 *TRANSFER Command State Model*

7.3.1 *TRANSFER Command State Model Requirements*

7.3.1.1 The TRANSFER command state model serves as the SEMI E30 Processing State Model. The purpose of the TRANSFER command state model is to provide information to the host regarding the control of the TRANSFER command. The TRANSFER command allows the host to manage interbay or intrabay delivery and scheduling. The control of each TRANSFER command must independently support the TRANSFER command state model.

7.3.2 *TRANSFER Command State Model Diagram*

7.3.2.1 The TRANSFER command state model is detailed for IBSEM equipment in Figure 3.

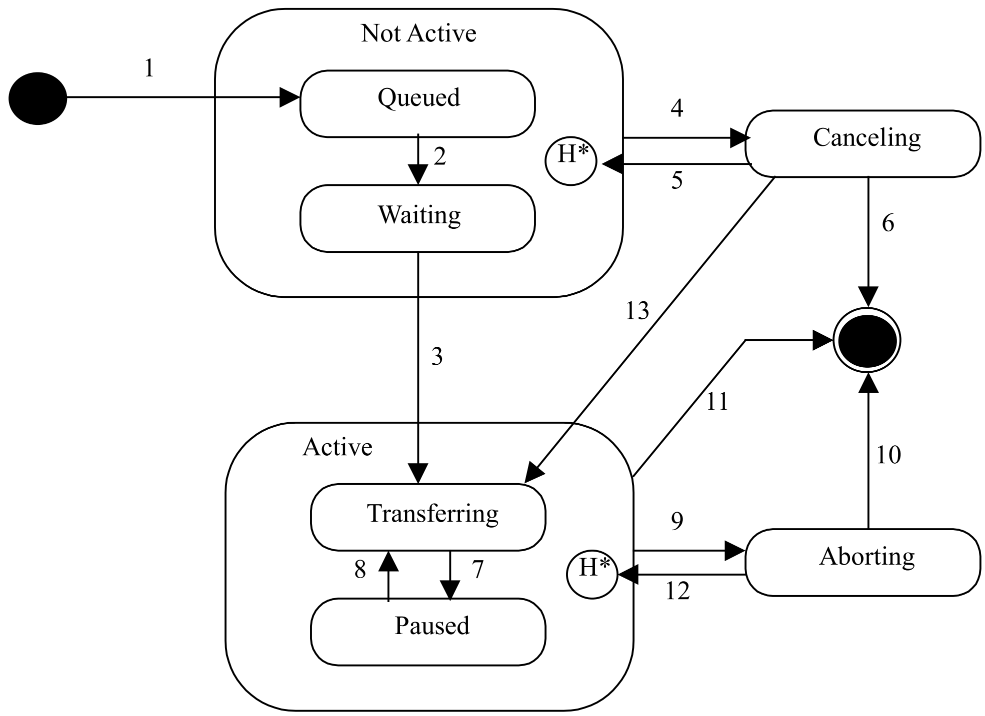


Figure 3
Generic IBSEM TRANSFER Command State Model Diagram

7.3.3 *TRANSFER Command State Definitions*

7.3.3.1 *NOT ACTIVE* — The transfer unit is not involved in the physical aspect of the TRANSFER command. It is denoted by the time spanned by the queuing of the TRANSFER command to the moment just prior to the acquire of the first carrier in the transfer unit.

7.3.3.2 *QUEUED (NOT ACTIVE sub-state)* — TSC has acknowledged and queued the TRANSFER command. TRANSFER command has not been initiated.

7.3.3.3 *WAITING (NOT ACTIVE sub-state)* — TRANSFER command has been initiated. A vehicle is on its way to the source location to acquire the transfer unit.

7.3.3.4 *ACTIVE* — The transfer unit is involved in the physical aspect of the TRANSFER command. It is denoted by the time spanned by the acquire of the first carrier in the transfer unit to the deposit of the last carrier in the transfer unit.

7.3.3.5 *TRANSFERRING (ACTIVE sub-state)* — The transfer command is actively being executed by the transport equipment.

7.3.3.6 *PAUSED (ACTIVE sub-state)* — The transfer command is not actively being executed by the transport equipment.

7.3.3.7 *CANCELING* — The TRANSFER command cancel procedure is being performed to terminate a transfer command which never entered the ACTIVE state (either QUEUED or WAITING). This state is entered via a CANCEL remote command. An unsuccessful transfer command completion will ultimately result.

7.3.3.8 *ABORTING* — The TRANSFER command abort procedure is being performed to terminate a transfer command which has entered the ACTIVE state. This state can only be entered via an ABORT remote command. An unsuccessful transfer command completion will ultimately result from this state.

7.3.4 *TRANSFER Command State Transition Table*

Table 2 Transfer Command State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	None	The Host generated TRANSFER command is successfully acknowledged by the TSC.	QUEUED		
2	QUEUED	The TRANSFER command has been initiated by the TSC.	WAITING	S6F11 Transfer-Initiated	Transport vehicle is dispatched to acquire the transfer unit.
3	WAITING	The acquire of the first carrier of the transfer unit begins.	TRANSFERRING	S6F11 Transferring	
4	NOT ACTIVE	Host issued cancel for the TRANSFER command is accepted by the TSC.	CANCELING	S6F11 TransferCancel-Initiated	A CANCEL remote command was issued to terminate a TRANSFER command that has not entered the physical aspect of the command.
5	CANCELING	Transport system is unable to cancel the TRANSFER command.	Previous NOT ACTIVE sub-state	S6F11 TransferCancel-Failed	The ability of the equipment to successfully complete a cancel of the TRANSFER command is specific to the IBSEM equipment supplier.
6	CANCELING	The cancel procedure for the TRANSFER command has completed by the transport system and TSC.	None	S6F11 TransferCancel-Completed	The transfer unit will still be situated at the transfer source location. The carriers in the transfer unit may now be included in a future transfer (either AMHS or PGV based).
7	TRANSFERRING	The TSC pauses execution of the TRANSFER command due to an anomaly condition.	PAUSED	S6F11 TransferPaused	It is an important distinction to make that the TRANSFER command is paused even though the vehicle may not be.
8	PAUSED	The TSC resumes execution of the TRANSFER command since the anomaly condition has been cleared.	TRANSFERRING	S6F11 Transfer-Resumed	

Tran-sition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
9	ACTIVE	Host initiates an abort of a TRANSFER command.	ABORTING	S6F11 TransferAbort-Initiated	An ABORT remote command was issued to terminate a TRANSFER command.
10	ABORTING	The abort procedure for the TRANSFER command has completed by the transport system and TSC.	None	S6F11 TransferAbort-Completed	Transfer unit could be located at any location or port located along the path of the ACTIVE transfer. The location of the carrier(s) associated with the aborted transfer command must be legal SourcePort(s) for issuing a new TRANSFER command.
11	ACTIVE	The TRANSFER command has completed by the transport system and TSC (either successfully or unsuccessfully).	None	S6F11 TransferCompleted sent to Host with appropriate ResultCode ResultCode = 0 if successful ResultCode Not = 0 if unsuccessful	Carrier(s) could be located at any location or port located along the path of the transfer if the TRANSFER command completed unsuccessfully. The location of the carrier(s) associated with an unsuccessful transfer command must be legal SourcePort(s) for a new TRANSFER command.
12	ABORTING	Transport system is physically unable to abort the TRANSFER command.	Previous ACTIVE sub-state	S6F11 TransferAbort-Failed	The ability of the equipment to successfully complete an ABORT of the TRANSFER command is specific to the IBSEM equipment supplier.
13	CANCELING	Transport system is unable to cancel the TRANSFER command because the transfer is now ACTIVE.	TRANSFERRING	S6F11 Transferring	The ability of the equipment to successfully complete a cancel of the TRANSFER command is specific to the IBSEM equipment supplier.

7.4 *Vehicle State Model*

7.4.1 *Vehicle State Model Requirements*

7.4.1.1 The purpose of the vehicle state model is to provide information to the host for use of transport vehicle information and metric tracking (i.e., the Host will not control vehicles). Each vehicle must individually comply with the vehicle state model. Implementation of this state model, along with associated events and variables, is not a requirement for Transport Systems which do not have vehicles. An example of such a Transport System is a DWC. The Host should not be dependent on any events from the vehicle state model.

7.4.2 *Vehicle State Model*

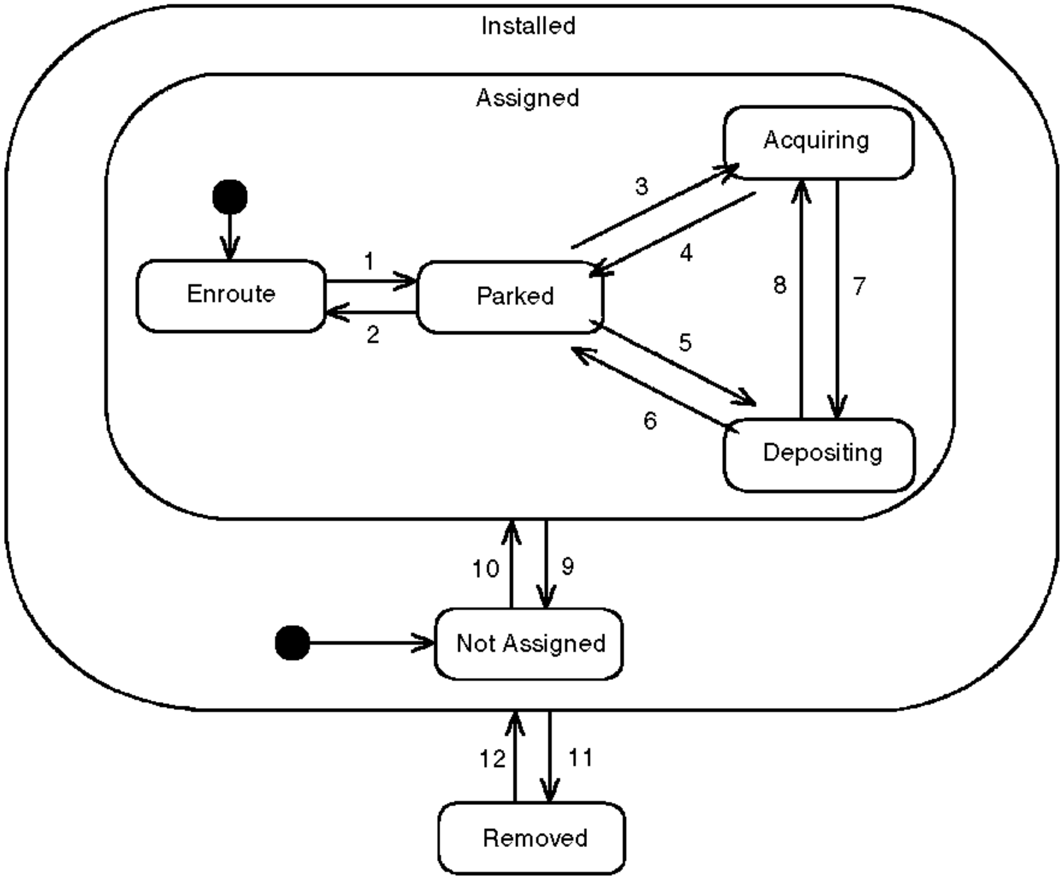


Figure 4
Generic IBSEM Vehicle State Model Diagram

7.4.3 *Vehicle State Definitions*

7.4.3.1 *INSTALLED* — The vehicle is available or being used for TRANSFER commands. All enabled collection events and alarms will be sent to the Host for vehicles in this state.

7.4.3.2 *REMOVED* — The vehicle is not available for Host initiated TRANSFER commands. No collection events or alarms will be sent to the Host for vehicles in this state.

7.4.3.3 *ASSIGNED (INSTALLED sub-state)* — Vehicle is allocated to a TRANSFER command.

7.4.3.4 *NOT ASSIGNED (INSTALLED sub-state)* — Vehicle is not allocated to a TRANSFER command. The vehicle may contain a carrier as the result of a command being aborted.

7.4.3.5 *ENROUTE (ASSIGNED sub-state)* — The vehicle is on its way to a transfer port. This is the default entry into the ASSIGNED state since it must be entered for the host to track vehicle metrics completely and adequately.

7.4.3.6 *PARKED (ASSIGNED sub-state)* — This state occurs when the vehicle is in the following conditions:

- After the arrival of the vehicle is completed and before the action of the transfer agent is started.
- After the action of the transfer agent has completed and before the departure of the vehicle.
- After continuous actions of the transfer agent (e.g., acquire/acquire and deposit/deposit) are completed.

7.4.3.7 *ACQUIRING (ASSIGNED sub-state)* — The vehicle is currently involved in carrier acquire (one or more carriers possible depending on vehicle limitations).

7.4.3.8 *DEPOSITING (ASSIGNED sub-state)* — The vehicle is currently involved in carrier deposit (one or more carriers possible depending on vehicle limitations).

7.4.4 *Vehicle State Transition Table*

Table 3 Vehicle State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
1	ENROUTE	Vehicle arrives at a transfer port associated with an ACTIVE transfer command.	PARKED	S6F11 VehicleArrived	
2	PARKED	Vehicle departs a transfer port associated with an ACTIVE transfer command.	ENROUTE	S6F11 VehicleDeparted	
3	PARKED	The carrier handoff parallel I/O starts for the vehicle to acquire (load) the transfer unit.	ACQUIRING	S6F11 VehicleAcquire-Started	If the vehicle is a passive type then the acquire occurs by the robot on the other equipment loading the transfer unit to the vehicle.
4	ACQUIRING	The carrier handoff parallel I/O completes for the vehicle to acquire (unload) the transfer unit.	PARKED	S6F11 VehicleAcquire-Completed	
5	PARKED	The carrier handoff parallel I/O starts for the vehicle to deposit (unload) the transfer unit.	DEPOSITING	S6F11 VehicleDeposit-Started	If the vehicle is a passive type then the deposit occurs by the robot on the other equipment unloading the transfer unit from the vehicle.
6	DEPOSITING	The carrier handoff parallel I/O completes for the vehicle to deposit (unload) the transfer unit.	PARKED	S6F11 VehicleDeposit-Completed	
7	ACQUIRING	The carrier handoff parallel I/O completes for the vehicle to acquire (load) the transfer unit and starts for the vehicle to deposit (unload) the carrier.	DEPOSITING	S6F11 VehicleDeposit-Started	Carrier Replace See scenario for an example.
8	DEPOSITING	The carrier handoff parallel I/O completes for the vehicle to deposit (unload) the transfer unit and starts for the vehicle to acquire (load) the carrier.	ACQUIRING	S6F11 VehicleAcquire-Started	Carrier Replace See scenario for an example.
9	ASSIGNED	Vehicle is no longer being utilized for the specified command.	NOT ASSIGNED	S6F11 Vehicle-Unassigned	This could be the result of the command being completed or aborted. It could also be the result of the TSC scheduling algorithms assigning this vehicle to another command and/or another vehicle being assigned to this command.
10	NOT ASSIGNED	Vehicle is allocated to a TRANSFER command.	ASSIGNED	S6F11 VehicleAssigned	
11	INSTALLED	Vehicle is removed from use of transfer commands.	REMOVED	S6F11 VehicleRemoved	

Tran-sition #	Previous State	Trigger	New State	Actions	Comment
12	REMOVED	Vehicle is installed for use of transfer commands.	INSTALLED	S6F11 VehicleInstalled	

7.5 *IBSEM Carrier State Model*

7.5.1 *IBSEM Carrier State Model Requirements*

7.5.1.1 The purpose of the carrier state model is to provide information to the host regarding carrier tracking (the Host will not control carriers). Each carrier must comply with the carrier state model.

7.5.2 *IBSEM Carrier State Model*

Figure 5
Generic IBSEM Carrier State Model Diagram

7.5.3 *Carrier State Definitions*

7.5.3.1 *INSTALLED* — A TSC database entry exists for the carrier.

7.5.4 *Carrier State Transition Table*

Table 4 Carrier State Transition Table

Transition #	Previous State	Trigger	New State	Actions	Comments
1	None	A TSC database entry is created for the carrier.	INSTALLED	S6F11 CarrierInstalled	
2	INSTALLED	A TSC database entry is removed for the carrier.	None	S6F11 CarrierRemoved	

7.6 *Port Transfer State Model*

7.6.1 *Port Transfer State Model Requirements*

7.6.1.1 The purpose of the port transfer state model is to provided information to the host for the use in accessing ports. This may permit the host and stocker to utilize ports that are in service while avoiding the use of ports that are not in service.

7.6.2 *Port Transfer State Model*

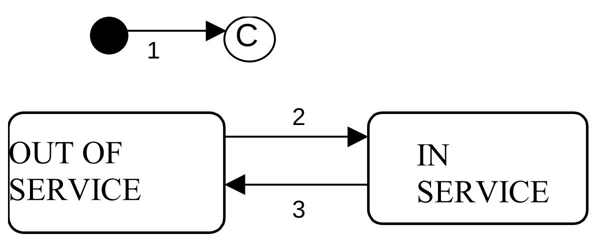


Figure 6
Port State Model Diagram

7.6.3 *Port Transfer State Definitions*

7.6.3.1 *OUT OF SERVICE* — Transfer to/from this port is disabled and the port should not be used in any Transfer command issued by the host. If a command is issued by the host which uses this port, it will not be rejected simply because the port is in this state.

7.6.3.2 *IN SERVICE* — Transfer to/from this port is enabled.

7.6.4 *Port Transfer State Transition Table*

Table 5 Port Transfer State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Action*	*Comments*
1	None	System reset.	OUT OF SERVICE Or IN SERVICE	S6F11 PortOutOfService Or S6F11 PortInService	The new state is based on the current status of the port or the state prior to system reset.
2	OUT OF SERVICE	The equipment has determined that the port can be utilized for transfers.	IN SERVICE	S6F11 PortInService	
3	IN SERVICE	The equipment has determined that the port should not be used for transfers.	OUT OF SERVICE	S6F11 PortOutOfService	This could be the result of an alarm condition.

8 Collection Event List

8.1 This section identifies data collection events and defines (Stream 6) suggested associated variable data items. The host can use the report definition scenario defined in SEMI E30 to define reports at IBSEM defined levels. The intent of this section is to demonstrate that certain suggested data is available at specific events.

8.2 *Requirements*

8.2.1 This standard requires all collection events listed in the SEMI E30 standard (according to the GEM capabilities required per Section 13).

8.3 *Collection Event Table*

Table 6 Collection Event Table (State Transition Based)

Collection Event Name	*From State*	*To State*	*Required DVVAL's*
TSC STATE TRANSITION EVENTS			
AlarmCleared	ALARMS	NO ALARMS	CommandID VehicleInfo
AlarmSet	NO ALARMS ALARMS	ALARMS ALARMS	CommandID VehicleInfo
TSCAutoCompleted	PAUSED PAUSING	AUTO AUTO	N/A
TSCAutoInitiated	None	TSC INIT	N/A
TSCPauseCompleted	PAUSING	PAUSED	N/A
TSCPaused	TSC INIT	PAUSED	N/A
TSCPauseInitiated	AUTO	PAUSING	N/A
TRANSFER COMMAND STATE TRANSITION EVENTS			
TransferAbortCompleted	ABORTING	None	CommandID TransferCompleteInfo
TransferAbortFailed	ABORTING	ACTIVE (History)	CommandID
TransferAbortInitiated	ACTIVE	ABORTING	CommandID
TransferCancelCompleted	CANCELING	None	CommandID
TransferCancelFailed	CANCELING	NOT ACTIVE (History)	CommandID
TransferCancelInitiated	NOT ACTIVE	CANCELING	CommandID
TransferCompleted	ACTIVE	None	CommandInfo TransferCompleteInfo ResultCode
TransferInitiated	QUEUED	WAITING	CommandID

Collection Event Name	*From State*	*To State*	*Required DVVAL's*
TransferPaused	TRANSFERRING	PAUSED	CommandID
TransferResumed	PAUSED	TRANSFERRING	CommandID
Transferring	WAITING CANCELING	TRANSFERRING TRANSFERRING	CommandID
VEHICLE STATE TRANSITION EVENTS			
VehicleArrived	ENROUTE	PARKED	VehicleID TransferPortList
VehicleAcquireStarted	PARKED DEPOSITING	ACQUIRING ACQUIRING	VehicleID TransferPort CarrierID (If Multi-position vehicles) TransferPortList CarrierIDList
VehicleAcquireCompleted	ACQUIRING	PARKED	VehicleID TransferPort CarrierID (If Multi-position vehicles) TransferPortList CarrierIDList
VehicleAssigned	NOT ASSIGNED	ASSIGNED	VehicleID CommandID
VehicleDeparted	PARKED	ENROUTE	VehicleID TransferPortList
VehicleDepositStarted	PARKED ACQUIRING	DEPOSITING DEPOSITING	VehicleID TransferPort CarrierID (If Multi-position vehicles) TransferPortList CarrierIDList
VehicleDepositCompleted	DEPOSITING	PARKED	VehicleID TransferPort CarrierID (If Multi-position vehicles) TransferPortList CarrierIDList
VehicleInstalled	REMOVED	INSTALLED	VehicleID
VehicleRemoved	INSTALLED	REMOVED	VehicleID
VehicleUnassigned	ASSIGNED	NOT ASSIGNED	VehicleID CommandID
CARRIER STATE TRANSITION EVENTS			
CarrierInstalled	None	INSTALLED	VehicleID CarrierID CarrierLoc CommandID
CarrierRemoved	INSTALLED	None	VehicleID CarrierID CarrierLoc CommandID
PORT TRANSFER STATE TRANSITION EVENTS			
PortInService	None OUT OF SERVICE	IN SERVICE	PortID
PortOutOfService	None IN SERVICE	OUT OF SERVICE	PortID

8.4 *Non-Transition Collection Event Table*

Table 7 Non-Transition Collection Event Table

Collection Event Name	*Event Description*	*Required DVVALs*
OperatorInitiatedAction	The operator initiated an action from the Stocker Controller. The related State Transition Events defined in Table 6 shall be required after this "OperatorInitiatedAction" event.	CommandID CommandType CarrierID SourcePort DestPort Priority

9 Variable Data Items

9.1 The purpose of this section is to define the list of variable data item requirements for IBSEM equipment. Values of these variables will be available to the host via collection event reports and host status queries.

9.2 *Requirements*

- All variable data items defined in GEM and data item restrictions defined in SEMI E30 are required on IBSEM equipment (according to the GEM capabilities required per Section 13).
- All variable data items in the IBSEM Variable Data Item Dictionary for specific equipment classifications are required for IBSEM equipment. The data item restrictions are also required.
- Some SV's in the Variable Data Item Dictionary are referenced by an "i" subscript (e.g., $CarrierID_i$). The "i" subscript denotes a specific instance of the SV. This is necessary since there is usually more than one instance of such an SV active in the system at the same time (e.g., if there are 20 carriers active at the same time then "i" could range from 1 to 20 for $CarrierID_i$). Variable Data Items containing the "i" subscript should not have Variable ID's assigned to them.

9.2.1 Variable data items are documented in the IBSEM Variable Data Item Dictionary using the following format:

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*

Where:

Variable Name: A unique name for the variable data item.

Type: CV – meaning common variables, variables that are general to all vehicles.
CSV – meaning configuration specific variables.

Description: If class is DVVAL, then the description shall contain a statement of when data is valid in terms of IBSEM events.

Class: The data type of the item.

Format: < SECS Message Language (SML) mnemonic > acceptable formats are SEMI E5 lists, ASCII, floating point, unsigned integer or signed integer. A description of "ANY", indicates that only the above formats are acceptable and is left to the supplier to decide.

Comments: Any additional information pertinent to the variable name.

9.3 *Variable Data Item Types*

9.3.1 *Equipment Constants (ECV)* — The value can be changed by the host using S2F15. The operator may have the ability to change some or all of the values. The value of an equipment constant may be queried at any time by the host using the S2F13/14 transaction or Stream 6 reports.

9.3.2 *Status Variables (SV)* — The values are valid at all times. A SV may not be changed by the host or operator, but may be changed by the equipment. A host or operator command may change an equipment status thus changing a SV. The value of status variables may be queried by the host at any time using the S1F3/4 or Stream 6 reports.

9.3.3 *Data Variables (DVVAL)* — These are variables which are valid upon the occurrence of a specific collection event, and may or may not be valid at other times depending upon the equipment. An attempt to read a variable data item when it's invalid will not result in an error, but the data reported may not have relevant meaning.

9.3.4 *Variable Data (V)* — This is a class of variable data which includes all the previously defined types of variables.

9.4 *Variable Data Item Dictionary*

Table 8 Variable Data Item Dictionary

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
ActiveCarriers	CV	List current status of all carrier information in the TSC database.	SV	L,n 1. <CarrierInfo$_1$> . . n. <CarrierInfo$_n$>	
ActiveTransfers	CV	List current status of all ACTIVE TRANSFER commands.	SV	L,n 1. <TransferCommand$_1$> . . n. <TransferCommand$_n$>	
ActiveVehicles	CV	List current status of all vehicles available or being used for TRANSFER commands.	SV	L,n 1. <VehicleInfo$_1$> . . n. <VehicleInfo$_n$>	
CarrierID	CV	ID of the carrier being moved.	DVVAL	A[1–64]	If an Id is created by the equipment (not obtained via an id reader, the host interface, or the user interface) it must be of the following format: UNKNOWNEqpNameSeq Where: UNKNOWN are the exact characters "UNKNOWN" EqpName is the value of the EqpName ECV (truncated if required) Seq is a unique sequence identifier determined by the vendor.
CarrierID$_i$	CV	ID of the i^{th} carrier.	SV	A[1–64]	See comment for CarrierID.
CarrierIDList	CV	The Ids of the Carriers being moved.	DVVAL	L,n 1.<CarrierID$_1$> . . n.<CarrierID$_n$>	'n' is the number of carriers being simultaneously transferred.
CarrierInfo	CV	All database information associated with a particular carrier generating an event.	DVVAL	L,3 1. <CarrierID> 2. <VehicleID> 3. <CarrierLoc>	

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
$CarrierInfo_i$	CV	All database information associated with the i^{th} carrier.	SV	L,3 1. <$CarrierID_i$> 2. <$VehicleID_i$> 3. <$CarrierLoc_i$>	
CarrierLoc	CSV	Unique location of the carrier within ITS as reported by the TSC.	DVVAL	A[1–64]	For multiple position vehicles, the "CarrierLoc" must be unique for each position on the vehicle and must be distinct from a location on any other vehicle.
$CarrierLoc_i$	CSV	Unique Location of the ith carrier within ITS as reported by the TSC.	SV	A[1–64]	
CommandName	CV	Host command issued to controller.	DVVAL	A[1–20]	
CommandID	CV	Remote Command ID Command ID generated by TSC.	DVVAL	A[1–64]	Used to subsequently refer to a specified remote command (e.g., to cancel a remote command). If a command is generated by the Transport System Controller using Non-Transition Collection Event "OperatorInitiatedAction", the commandId must begin with the string 'MANUAL' followed by any arbitrary sequence identifier.
$CommandID_i$	CV	The i^{th} Remote Command ID. The i^{th} Command ID generated by TSC.	SV	A[1–64]	Used to subsequently refer to a specified remote command (e.g., to cancel a remote command).
CommandInfo	CV	Command information associated with a particular transfer command.	DVVAL	L,3 1. <CommandID> 2. <Priority> 3. <Replace>	
$CommandInfo_i$	CV	Command information associated with the i^{th} transfer command.	SV	L,3 1. <$CommandID_i$> 2. <$Priority_i$> 3. <$Replace_i$>	
CommandType	CV	The type of Command being initiated	DVVAL	A[1-20]	Valid Values are 'TRANSFER' 'CANCEL' 'ABORT'
CurrentPortStates	CV	Current State of all the ports	SV	L,n 1. <$PortInfo_1$> . . n. <$PortInfo_n$>	
DestPort	CV	Destination port unique identifier	DVVAL	A[1–64]	Must be the name of the port not the corresponding transport system node name or number.

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
DestPort$_i$	CV	The i[th] Destination port unique identifier	SV	A[1–64]	Must be the name of the port not the corresponding transport system node name or number.
EnhancedCarriers	CV	List Current status of all carrier information in the TSC database. This includes all carriers for which there are Transfer commands.	SV	L,n 1. <EnhancedCarrierInfo$_1$> . . n. <EnhancedCarrierInfo$_n$>	
EnhancedCarrier-Info$_i$	CV	All database information associated with a particular carrier.	SV	L,4 1. <CarrierID$_i$> 2. <VehicleID$_i$> 3. <CarrierLoc$_i$> 4. <InstallTime$_i$>	
EnhancedTransfers	CV	List current status of ALL transfer commands.	SV	L,n 1. <EnhancedTransferCommand$_1$> . . n. <EnhancedTransferCommand$_n$>	
EnhancedTransfer Command$_i$	CV	Information associated with a particular Transfer command.	SV	L,3 1. <CommandInfo$_i$> 2. <TransferState$_i$> 3. L,n 1. <TransferInfo$_1$> . n. <TransferInfo$_n$>	
EnhancedVehicles	CV	List current status of all vehicles available or being used for TRANSFER commands.	SV	L,n 1. <EnhancedVehicle$_1$-Info> . . n.<EnhancedVehicle-Info$_n$>	
EnhancedVehicle-Info$_i$	CV	Information associated with a particular vehicle.	SV	L,3 1. <VehicleID> 2. <VehicleState> 3. <VehicleLocation>	
EqpName	CV	Unique ID of the TSC	ECV	A[1–80]	Like a device name
InstallTime$_i$	CV	Time the carrier was created in the TSC database.	SV	TIME (A16)	yyyymmddhhmmsscc
PortID	CV	ID of the port	DVVAL	A[1–64]	
PortID$_i$	CV	ID of the port	SV	A[1–64]	
PortInfo$_i$	CV	Port information associated with a particular port.	SV	L,2 1. <PortID$_i$> 2. <PortTransferState$_i$>	
PortTransferState$_i$	CV	Port Transfer State	SV	U2	1 – OutOfService 2 – InService

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
Priority	CV	Remote command priority	DVVAL	U2	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.
$Priority_i$	CV	The i^{th} Remote command priority	SV	U2	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.
Replace	CV	Flag to denote if a transfer command involves a carrier replace at the DestPort.	DVVAL	U2	0 = OFF > 0 = ON
$Replace_i$	CV	The i^{th} flag used to denote if a transfer command involves a carrier replace at the DestPort.	SV	U2	0 = OFF > 0 = ON
ResultCode	CV	Result Code of a transport system command. Associated with the command completion event.	DVVAL	U2 Successful = 0 Unsuccessful ≠ 0 ResultCode's that must be implemented are: Canceled Aborted	Values of ResultCode will correspond to meaningful completion results (0 always signifies normal successful completion).
SourcePort	CV	Source port unique identifier	DVVAL	A[1–64]	Must be the name of the port not the corresponding transport system node name or number.
$SourcePort_i$	CV	The i^{th} Source port unique identifier	SV	A[1–64]	Must be the name of the port not the corresponding transport system node name or number.
SpecVersion	CV	Version of SEMI E82 to which the equipment is compliant.	SV	A[0–20]	Example values are: E82-0999, E82-0301. If the equipment is not compliant, a zero length value may be specified.
TransferCommand	CV	Information associated with a particular TRANSFER command.	DVVAL	L,n 1. <CommandInfo> 2. <$TransferInfo_1$> . . . n. <$TransferInfo_m$>	m ≤ Number of carriers in the Transfer Unit
$TransferCommand_i$	CV	Information associated with the i^{th} TRANSFER command.	SV	L,2 1. <$CommandInfo_i$> 2. L, m 1. <$TransferInfo_1$> . . . m. <$TransferInfo_m$>	m = Number of carriers in the Transfer Unit

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
TransferComplete-Info	CV	Carrier information associated with a transfer.	DVVAL	L,n 1.<L,2 1. <TransferInfo$_1$> 2. <CarrierLoc$_1$(*1)> : : n.<L,2> 1. <TransferInfo$_n$> 2. <CarrierLoc$_n$(*1)>	N : size of Transfer Unit
TransferInfo	CV	Carrier information associated with a particular transfer command.	DVVAL	L,3 1. <CarrierID> 2. <SourcePort> 3. <DestPort>	
TransferInfo$_i$	CV	Carrier information associated with the ith transfer command.	SV	L,3 1. <CarrierID$_i$> 2. <SourcePort$_i$> 3. <DestPort$_i$>	
TransferPort	CV	Transfer Port unique identifier	DVVAL	A[1–64]	Must be the name of the port where the transfer is taking place, not the corresponding transport system node name or number.
TransferPortList	CV	Transfer Port information associated with a particular vehicle arrival or departure event.	DVVAL	L,n 1. <TransferPort$_1$> 2. <TransferPort$_2$> . . . n. <TransferPort$_n$>	n > 1 for simultaneous transfers
TransferState$_i$	CV	State of Transfer Command	SV	U2	1. Queued 2. Transferring 3. Paused 4. Canceling 5. Aborting 6. Waiting
TSCState	CV	TSC State (SYSTEM)	SV	U2	1 = SC Init 2 = Paused 3 = Auto 4 = Pausing
VehicleID	CV	Unique identification of a vehicle associated with an event.	DVVAL	A[1–32]	
VehicleID$_i$	CV	Unique identification of the ith vehicle.	SV	A[1–32]	
VehicleInfo	CV	Information associated with a particular vehicle.	DVVAL	L,2 1. <VehicleID> 2. <VehicleState>	

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comment*
$VehicleInfo_i$	CV	Information associated with the ith vehicle.	SV	L,2 1. <$VehicleID_i$> 2. <$VehicleState_i$>	
VehicleLocation	CV	Location of the Vehicle	DVVAL	A[0-64]	The vehicle's port location. The data is only valid if the vehicle is Parked, Acquiring, or Depositing.
$VehicleLocation_i$	CV	Location of the Vehicle	SV	A[0-64]	The vehicle's port location. The data is only valid of the vehicle is Parked, Acquiring, or Depositiong.
VehicleState	CV	The state of the vehicle	DVVAL	U2	1 = Removed 2 = Not Assigned 3 = Enroute 4 = Parked 5 = Acquiring 6 = Depositing
$VehicleState_i$	CV	The state of the ith vehicle	SV	U2	See VehicleState above.

(*1) Current location (port or vehicle id) of the carrier is reported in 'CarrierLoc'. This may be used as a source port in a following transfer command.

10 Alarm List

10.1 Since each model of IBSEM equipment differs in configuration, it is not practical to provide an exhaustive list of all possible alarms. Instead, the IBSEM is requiring the two tables provided as described in SEMI E30 (Document Section). Alarm List Table which is intended to provide for equipment configuration specific alarms and Alarm ID, Alarm Set/Cleared Event Table. Any alarm that is displayed locally at the equipment, if enabled, is required to be sent to the host. To be compliant, Tables 9 and 10 must be completed by the supplier, documenting all alarms.

10.2 *Alarm List Table*

10.2.1 The alarm list table contains examples of alarms that pertain to various configuration aspects of equipment. These examples are intended to illustrate that alarms pertain to situations in which there exists a potential for exceeding physical safety limits associated with people, equipment, and material being transported as per the SEMI E30 definition of an alarm. See SEMI E30 for further reference. The supplier is responsible for supplying documentation associated with these alarm definitions. Each alarm will have an associated alarm text (ALTX) and alarm identifier (ALID). Table 9 contains example alarm list information that is intended to be augmented when the IBSEM equipment supplier documents its interface. Examples highlighted by (*) are required by IBSEM.

Table 9 Alarm List Table

Equipment Cfg.	*Alarm Text*	*ALID*	*Danger*		*Affected*		
			Potential	*Imminant*	*Operator*	*Equipment*	*Material*
OHT, OHS, RGT, AGT, and DWC	vehicle obstruction* (exceeded timeout)		X			X	
	transport system equipment failure*		X			X	X
	Carrier Handoff Parallel I/O failure*		X		X	X	X
	database error*		X			X	

10.3 *Alarm ID, Alarm Set/Cleared Event Table*

10.3.1 The Alarm ID, Alarm Set/Cleared Event table documents the association of each ALID to a set and cleared event as required by SEMI E30. See SEMI E30 for further reference. The supplier is responsible for supplying documentation associated with these alarm definitions. Each alarm will have associated alarm set and cleared collection event identifiers ($CEID_{set}$ and $CEID_{clear}$). Table 10 contains example alarm event information that is intended to be replaced when the IBSEM equipment supplier documents its interface.

Table 10 Alarm ID, Alarm Set/Cleared Event Table

Alarm ID (ALID)	*Alarm SET Event ($CEID_{set}$)*	*Alarm CLEARED Event ($CEID_{cleared}$)*

11 Remote Commands

11.1 The purpose of this section is to identify remote commands, command parameters, and valid commands versus states pertinent to the SEM. All remote commands identified in this section follow the format of the S2,F41 Host Command Send SECS-II message except for the TRANSFER command which follows the S2,F49 Enhanced Remote Command Send SECS-II message.

11.2 *Requirements*

- The equipment shall support the SEMI E30 (according to the GEM capabilities required per Section 13) required remote commands.
- All the remote commands defined by IBSEM are required to be implemented as specified.
- The alphanumeric strings defined by IBSEM for RCMD and CPNAME are required.
- A completed table must be generated where an “X” is placed in the table for each state that a given command is valid.
- If additional remote commands are supported then a “remote commands versus valid states” matrix must be generated for these additional commands.
- For additional commands, a table must be generated similar to the remote command descriptions summary.

11.3 *Remote Commands Description*

11.3.1.1 *ABORT* — This command terminates the activity of a specific TRANSFER command based on CommandID while the command is in the ACTIVE state. This command may not be accepted due to mechanical issues if the vehicle is in a specific condition (e.g., depositing a carrier). The exact conditions surrounding when the ABORT command is not accepted by the TSC must be documented by the IBSEM equipment supplier.

11.3.1.2 *CANCEL* — This command terminates the activity of a specific TRANSFER command based on CommandID while the command is in either the QUEUED or WAITING state. This command must always be accepted by the TSC when in the QUEUED or WAITING state.

11.3.1.3 *PAUSE* — This command puts the TSC in the PAUSING state.

11.3.1.4 *RESUME* — This command puts the TSC in the AUTO state.

11.3.1.5 *TRANSFER* — This is a SECS-II Enhanced Remote Command instead of a SECS-II Host Command Send (S2,F49 instead of S2,F41). See the examples in Related Information 1 for details.

11.3.1.5.1 This command is used to perform the entire transfer command for the carrier(s) to be transferred between transfer ports. The execution of this command will include allocation of a vehicle, acquiring the carrier(s), moving the carrier(s) to the destination port(s), depositing the carrier(s), and returning the vehicle for other use. The number of carriers in the TRANSFER command is less than or equal to the number of carriers in the transfer unit (see Section 5.2 for definition of the transfer unit). It is recommended that the Carrier already be at the SOURCEPORT upon the issue of the TRANSFER command, otherwise, it is possible that the TRANSFER command can fail on "empty acquire" when no carrier is present on the SOURCEPORT when the acquire is started.

11.3.2 *Remote Commands and Associated Host Command Parameters*

11.3.2.1 This table describes the allowable command parameters (CPNAME) for each remote command (RCMD). Equipment shall support all parameters. The column marked Req/Opt, specifies which parameters are required to be sent by the host and which parameters may be optionally sent by the host.

Table 11 Allowable Command Parameters

Remote Command	*Parameters*		
	Cpname	*Req/opt*	*Comment*
ABORT	"COMMANDID"	R	Must specify the commandID that was used for the TRANSFER command that is being ABORT'ed.
CANCEL	"COMMANDID"	R	Must specify the commandID that was used for the TRANSFER command that is being CANCEL'ed.
PAUSE	None	NA	Once received by the TSC, the TSC will queue any TRANSFER commands until the TSC receives and successfully executes the RESUME command. Once in the AUTO state the TSC will process the TRANSFER commands in its queue.
RESUME	None	N/A	Returns the PAUSEd TSC to the AUTO state.
TRANSFER	"COMMANDINFO" "TRANSFERINFO"*	R R	* TRANSFER commands are allowed a maximum of |transfer unit| TRANSFERINFO's.

11.3.3 *Host Command Parameters Name and Values*

Table 12 Host Command Parameters CPNAMES

Cpname	*Parameter Value*		
	Description	*Range*	*Format*
CARRIERID	ID of the carrier being moved.		A[1–64]
COMMANDID	Unique command identifier created by the Host.		A[1–64]
COMMANDINFO	L,3 COMMANDID PRIORITY REPLACE		L,3
DESTPORT	Destination port unique identifier.		A[1–64]
PRIORITY	Remote command priority	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.	U2
REPLACE	Flag to denote a TRANSFER replace carrier. Replace a carrier already on the port with the one on the vehicle.	0 is OFF > 0 is ON	U2
SOURCEPORT	Source port unique identifier.		A[1–64]
TRANSFERINFO	L,3 CARRIERID SOURCEPORT DESTPORT		L,3

11.3.4 *Remote Commands versus TSC and TRANSFER Command States*

11.3.4.1 The following table indicates TSC and TRANSFER Command States where the remote commands are allowed. This is indicated with a “X” mark. Remote commands act independently of other state models (e.g., Vehicle States and Carrier States are independent from the IBSEM remote commands). “N/A” (Not Applicable) means that States and Remote Commands have no direct relationship.

Table 13 Remote Commands versus TSC and TRANSFER Command States

	COMMAND				
	TRANSFER	RESUME	PAUSE	CANCEL	ABORT
TSC STATE					
AUTO	X		X	X	X
ALARMS	X	X	X	X	X
NO ALARMS	X	X	X	X	X
INIT					
PAUSED	X	X		X	X
PAUSING	X	X		X	X
TRANSFER COMMAND STATE					
QUEUED	N/A	N/A	N/A	X	
WAITING	N/A	N/A	N/A	X	
ACTIVE (PAUSED or TRANS.)	N/A	N/A	N/A		X
ABORTING	N/A	N/A	N/A		
CANCELING	N/A	N/A	N/A		

12 Scenarios

12.1 The following scenarios represent Application Notes. In the scenarios, all unique Remote Command ID's must initially be created and sent by the Host. Subsequent event reports sent from the equipment referring to the status of a particular remote command must return the applicable CommandID. All collection events identified in Table 6 are assumed to be enabled (per the SEMI E30 definition/scenario) throughout the following scenarios. Variable data specified in the Host commands has been chosen arbitrarily for the purpose of demonstrating message structure/content. The Collection Event Report definitions contained in the scenarios are examples that could be defined by the Host.

12.2 *Normal Transport*

12.2.1 *Single Carrier Transfer — Transfer Unit Size is Equal to 1 Carrier*

12.2.1.1 A carrier is transported from a source port to a destination port.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	Carrier 123456 is sitting at PORTXX prepared for a TRANSFER command.			
2.	Enhanced Remote Command (ERC) **TRANSFER** • COMMANDID = "111111" • PRIORITY = 5 • REPLACE = 0 • TRANSFERINFO$_1$ - L,3 1. CARRIERID = "123456" 2. SOURCEPORT = "PORTXX" 3. DESTPORT = "PORTYY"	S2,F49->		
3.			<-S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			<-S6,F11	Event Report Send (ERS) TransferInitiated • CommandID = "111111"
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) VehicleAssigned • VehicleID = "CARXX" /* Actual VehicleID used for the transfer may be different due to TSC scheduling optimizations */ CommandID = "111111"
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "CARXX" • TransferPortList - L,1 1. TransferPort = "PORTXX"
9.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
10.			<-S6,F11	Event Report Send (ERS) Transferring • CommandID = “111111”
11.	Event Report Acknowledge (ERA)	S6,F12->		
12.			<-S6,F11	Event Report Send (ERS) VehicleAcquireStarted • VehicleID = “CARXX” • TransferPort = “PORTXX” • CarrierID = “123456”
13.	Event Report Acknowledge (ERA)	S6,F12->		
14.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = “CARXX” • CarrierID = “123456” • CarrierLoc = “LOC1”
15.	Event Report Acknowledge (ERA)	S6,F12->		
16.			<-S6,F11	Event Report Send (ERS) VehicleAcquireCompleted • VehicleID = “CARXX” • TransferPort = “PORTXX” • CarrierID = “123456”
17.	Event Report Acknowledge (ERA)	S6,F12->		
18.			<-S6,F11	Event Report Send (ERS) VehicleDeparted • VehicleID = “CARXX” • TransferPortList - L,1 1. TransferPort = “PORTXX”
19.	Event Report Acknowledge (ERA)	S6,F12->		
20.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = “CARXX” • TransferPortList - L,1 1. TransferPort = “PORTYY”
21.	Event Report Acknowledge (ERA)	S6,F12->		
22.			<-S6,F11	Event Report Send (ERS) VehicleDepositStarted • VehicleID = “CARXX” • TransferPort = “PORTYY” • CarrierID = “123456”
23.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
24.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "CARXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
25.	Event Report Acknowledge (ERA)	S6,F12->		
26.			<-S6,F11	Event Report Send (ERS) VehicleDeposit-Completed • VehicleID = "CARXX" • TransferPort = "PORTYY" • CarrierID = "123456"
27.	Event Report Acknowledge (ERA)	S6,F12->		
28.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = "CARXX" • CommandID = "111111"
29.	Event Report Acknowledge (ERA)	S6,F12->		
30.			<-S6,F11	Event Report Send (ERS) TransferCompleted • CommandName = "TRANSFER" • CommandID = "111111" • Priority = 5 • Replace = 0 • ResultCode = 0 • CarrierLoc = "PORTYY" • $TransferInfo_1$ - L,3 1. CarrierID = "123456" 2. SourcePort = "PORTXX" 3. DestPort = "PORTYY"
31.	Event Report Acknowledge (ERA)	S6,F12->		

12.2.2 *Simultaneous Multiple Carrier Transfer — Transfer Unit Size is Equal to 2 Carriers*

12.2.2.1 Two carriers are transported from 2 source ports (e.g., L-Shaped stocker output ports) to 2 destination ports (e.g., process equipment ports). The transport vehicle is capable of acquiring and depositing 2 carriers at the same time (e.g., forking type vehicle). It is assumed that the source and destination ports must be the same equipment.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	Both carriers are prepared for a TRANSFER command at the source ports.			

STEP	COMMENTS	HOST	TSC	COMMENTS
2.	Enhanced Remote Command (ERC) • TRANSFER • COMMANDID = "111111" • PRIORITY = 5 • REPLACE = 0 • TRANSFERINFO$_1$ – L,3 1. CARRIERID = "123456" 2. SOURCEPORT = "PORTX1" 3. DESTPORT = "PORTY1" • TRANSFERINFO$_2$ – L,3 4. CARRIERID = "654321" 5. SOURCEPORT = "PORTX2" 6. DESTPORT = "PORTY2"	S2,F49->		
3.			<-S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			<-S6,F11	Event Report Send (ERS) TransferInitiated • CommandID = "111111"
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) VehicleAssigned • VehicleID = "AGVXX" • CommandID = "111111"
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "AGVXX" • TransferPortList – L,2 1. TransferPort$_1$ = "PORTX1" 2. TransferPort$_2$ = "PORTX2"
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.			<-S6,F11	Event Report Send (ERS) Transferring • CommandID = "111111"
11.	Event Report Acknowledge (ERA)	S6,F12->		
12.			<-S6,F11	Event Report Send (ERS) VehicleAcquireStarted • VehicleID = "AGVXX"
13.	Event Report Acknowledge (ERA)	S6,F12->		
14.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = "AGVXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
15.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
16.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = "AGVXX" • CarrierID = "654321" • CarrierLoc = "LOC2"
17.	Event Report Acknowledge (ERA)	S6,F12->		
18.			<-S6,F11	Event Report Send (ERS) VehicleAcquireCompleted • VehicleID = "AGVXX"
19.	Event Report Acknowledge (ERA)	S6,F12->		
20.			<-S6,F11	Event Report Send (ERS) VehicleDeparted • VehicleID = "AGVXX" • TransferPortList – L,2 1. $TransferPort_1$ = "PORTX1" 2. $TransferPort_2$ = "PORTX2"
21.	Event Report Acknowledge (ERA)	S6,F12->		
22.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "AGVXX" • TransferPortList – L,2 1. $TransferPort_1$ = "PORTY1" 2. $TransferPort_2$ = "PORTY2"
23.	Event Report Acknowledge (ERA)	S6,F12->		
24.			<-S6,F11	Event Report Send (ERS) VehicleDepositStarted • VehicleID = "AGVXX"
25.	Event Report Acknowledge (ERA)	S6,F12->		
26.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "AGVXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
27.	Event Report Acknowledge (ERA)	S6,F12->		
28.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "AGVXX" • CarrierID = "654321" • CarrierLoc = "LOC2"
29.	Event Report Acknowledge (ERA)	S6,F12->		
30.			<-S6,F11	Event Report Send (ERS) VehicleDeposit-Completed VehicleID = "AGVXX"

STEP	COMMENTS	HOST	TSC	COMMENTS
31.	Event Report Acknowledge (ERA)	S6,F12->		
32.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = “AGVXX” • CommandID = “111111”
33.	Event Report Acknowledge (ERA)	S6,F12->		
34.			<-S6,F11	Event Report Send (ERS) TransferCompleted (Complete parameters) • CommandName = “TRANSFER” • CommandID = “111111” • Priority = 5 • Replace = 0 • ResultCode = 0 • $CarrierLoc_1$ = “PORTY1” • $TransferInfo_1$ – L,3 1. CarrierID = “123456” 2. SourcePort = “PORTX1” 3. DestPort = “PORTY1” • $CarrierLoc_2$ = “PORTY2” • $TransferInfo_2$ – L,3 4. CarrierID = “654321” 5. SourcePort = “PORTX2” 6. DestPort = “PORTY2”
35.	Event Report Acknowledge (ERA)	S6,F12->		

12.2.3 *Continuous Multiple Carrier Transfer – Transfer Unit Size is Equal to 2 Carriers*

12.2.3.1 Two carriers are transported from a single source port to a single destination port. This scenario is used to demonstrate how the TSC would handle a continuous load/unload request. It also shows the sequence of events associated with the continuous case. It is assumed that the source and destination ports must be the same equipment.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	The carriers are prepared for a TRANSFER command. They are sitting sequentially at the single pickup point source output. 123456 is at the vehicle accessible source port for the first acquire of two. 654321 is sitting right behind it, and it will be shuttled out after 123456 is acquired by the vehicle. The vehicle will then acquire 654321 once in position. The depositing order depends on the IBSEM supplier’s functional specification.			

STEP	COMMENTS	HOST	TSC	COMMENTS
2.	Enhanced Remote Command(ERC) **TRANSFER** • COMMANDID = "111111" • PRIORITY = 5 • REPLACE = 0 • TRANSFERINFO$_1$ – L,3 1. CARRIERID = "123456" 2. SOURCEPORT = "PORTXX" 3. DESTPORT = "PORTYY" • TRANSFERINFO$_2$ – L,3 4. CARRIERID = "654321" 5. SOURCEPORT = "PORTXX" 6. DESTPORT = "PORTYY"	S2,F49->		
3.			<-S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			<-S6,F11	Event Report Send (ERS) TransferInitiated • CommandID = "111111"
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) VehicleAssigned • VehicleID = "RGVXX" • CommandID = "111111"
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "RGVXX" • TransferPortList – L,1 1. TransferPort = "PORTXX"
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.			<-S6,F11	Event Report Send (ERS) Transferring • CommandID = "111111"
11.	Event Report Acknowledge (ERA)	S6,F12->		
12.			<-S6,F11	Event Report Send (ERS) VehicleAcquireStarted • VehicleID = "RGVXX"
13.	Event Report Acknowledge (ERA)	S6,F12->		
14.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = "RGVXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
15.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
16.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = "RGVXX" • CarrierID = "654321" • CarrierLoc = "LOC2"
17.	Event Report Acknowledge (ERA)	S6,F12->		
18.			<-S6,F11	Event Report Send (ERS) VehicleAcquireCompleted • VehicleID = "RGVXX"
19.	Event Report Acknowledge (ERA)	S6,F12->		
20.			<-S6,F11	Event Report Send (ERS) VehicleDeparted • VehicleID = "RGVXX" • TransferPortList – L,1 1. TransferPort = "PORTXX"
21.	Event Report Acknowledge (ERA)	S6,F12->		
22.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "RGVXX" • TransferPortList – L,1 1. TransferPort = "PORTYY"
23.	Event Report Acknowledge (ERA)	S6,F12->		
24.			<-S6,F11	Event Report Send (ERS) VehicleDepositStarted • VehicleID = "RGVXX"
25.	Event Report Acknowledge (ERA)	S6,F12->		
26.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "RGVXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
27.	Event Report Acknowledge (ERA)	S6,F12->		
28.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "RGVXX" • CarrierID = "654321" • CarrierLoc = "LOC2"
29.	Event Report Acknowledge (ERA)	S6,F12->		
30.			<-S6,F11	Event Report Send (ERS) VehicleDeposit-Completed • VehicleID = "RGVXX"
31.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
32.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = “RGVXX” • CommandID = “111111”
33.	Event Report Acknowledge (ERA)	S6,F12->		
34.			<-S6,F11	Event Report Send (ERS) TransferCompleted (Complete parameters) • CommandName = “TRANSFER” • CommandID = “111111” • Priority = 5 • Replace = 0 • ResultCode = 0 • CarrierLoc$_1$ = “PORTYY” • TransferInfo$_1$ – L,3 1. CarrierID = “123456” 2. SourcePort = “PORTXX” 3. DestPort = “PORTYY” • CarrierLoc$_2$ = “PORTYY” • TransferInfo$_2$ – L,3 4. CarrierID = “654321” 5. SourcePort = “PORTXX” 6. DestPort = “PORTYY”
35.	Event Report Acknowledge (ERA)	S6,F12->		

12.2.4 *Carriers Replace*

12.2.4.1 One carrier is transported from the source port (e.g., stocker output port) to the destination port (e.g., process equipment port-1) and the other carrier is transported from the same port (process equipment port-1) to the destination ports (e.g., stocker input port) by the same vehicle. The transport vehicle is capable of acquiring and depositing these two carriers sequentially. This function is used for the depressuring process equipment with door, because the door opening time should be shorten for this type of equipment.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	Both carriers are prepared for a TRANSFER command at the source ports.			

STEP	COMMENTS	HOST	TSC	COMMENTS
2.	Enhanced Remote Command (ERC) TRANSFER • COMMANDID = “111111” • PRIORITY = 5 • REPLACE = 1 • TRANSFERINFO$_1$ – L,3 1. CARRIERID = “123456” 2. SOURCEPORT = “PORTX1” 3. DESTPORT = “PORTY1” • TRANSFERINFO$_2$ – L,3 4. CARRIERID = “654321” 5. SOURCEPORT = “PORTY1” 6. DESTPORT = “PORTZ1”	S2,F49->		
3.			<-S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			<-S6,F11	Event Report Send (ERS) TransferInitiated • CommandID = “111111”
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) VehicleAssigned • VehicleID = “AGVXX” • CommandID = “111111”
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = “AGVXX” • TransferPortList – L,1 1. TransferPort$_1$ = “PORTX1”
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.			<-S6,F11	Event Report Send (ERS) Transferring • CommandID = “111111”
11.	Event Report Acknowledge (ERA)	S6,F12->		
12.			<-S6,F11	Event Report Send (ERS) VehicleAcquireStarted • VehicleID = “AGVXX”
13.	Event Report Acknowledge (ERA)	S6,F12->		
14.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = “AGVXX” • CarrierID = “123456” • CarrierLoc = “LOC1”
15.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
16.			<-S6,F11	Event Report Send (ERS) VehicleAcquireCompleted • VehicleID = "AGVXX"
17.	Event Report Acknowledge (ERA)	S6,F12->		
18.			<-S6,F11	Event Report Send (ERS) VehicleDeparted • VehicleID = "AGVXX" • TransferPortList – L,1 1. $TransferPort_1$ = "PORTX1"
19.	Event Report Acknowledge (ERA)	S6,F12->		
20.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = "AGVXX" • TransferPortList – L,1 1. $TransferPort_1$ = "PORTY1"
21.	Event Report Acknowledge (ERA)	S6,F12->		
22.			<-S6,F11	Event Report Send (ERS) VehicleAcquireStarted • VehicleID = "AGVXX"
23.	Event Report Acknowledge (ERA)	S6,F12->		
24.			<-S6,F11	Event Report Send (ERS) CarrierInstalled • VehicleID = "AGVXX" • CarrierID = "654321" • CarrierLoc = "LOC2"
25.	Event Report Acknowledge (ERA)	S6,F12->		
26.			<-S6,F11	Event Report Send (ERS) VehicleDepositStarted • VehicleID = "AGVXX"
27.	Event Report Acknowledge (ERA)	S6,F12->		
28.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = "AGVXX" • CarrierID = "123456" • CarrierLoc = "LOC1"
29.	Event Report Acknowledge (ERA)	S6,F12->		
30.			<-S6,F11	Event Report Send (ERS) VehicleDepositCompleted • VehicleID = "AGVXX"
31.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
32.			<-S6,F11	Event Report Send (ERS) VehicleDeparted • VehicleID = “AGVXX” • TransferPortList – L,1 1. $TransferPort_1$ = “PORTY1”
33.	Event Report Acknowledge (ERA)	S6,F12->		
34.			<-S6,F11	Event Report Send (ERS) VehicleArrived • VehicleID = “AGVXX” • TransferPortList – L,1 1. $TransferPort_1$ = “PORTZ1”
35.	Event Report Acknowledge (ERA)	S6,F12->		
36.			<-S6,F11	Event Report Send (ERS) VehicleDepositStarted • VehicleID = “AGVXX”
37.	Event Report Acknowledge (ERA)	S6,F12->		
38.			<-S6,F11	Event Report Send (ERS) CarrierRemoved • VehicleID = “AGVXX” • CarrierID = “654321” • CarrierLoc = “LOC2”
39.	Event Report Acknowledge (ERA)	S6,F12->		
40.			<-S6,F11	Event Report Send (ERS) VehicleDepositCompleted • VehicleID = “AGVXX”
41.	Event Report Acknowledge (ERA)	S6,F12->		
42.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = “AGVXX” • CommandID = “111111”
43.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
44.			<-S6,F11	Event Report Send (ERS) TransferCompleted (Complete parameters) • CommandName = "TRANSFER" • CommandID = "111111" • Priority = 5 • Replace = 1 • ResultCode = 0 • CarrierLoc_1 = "PORTY1" • TransferInfo_1 – L,3 1. CarrierID = "123456" 2. SourcePort = "PORTX1" 3. DestPort = "PORTY1" • CarrierLoc_2 = "PORTZ1" • TransferInfo_2 – L,3 4. CarrierID = "654321" 5. SourcePort = "PORTY1" 6. DestPort = "PORTZ1"
45.	Event Report Acknowledge (ERA)	S6,F12->		

12.3 *Anomaly Transport*

12.3.1 *Host-Initiated CANCEL of a TRANSFER Command*

12.3.1.1 The Host wishes to terminate a previously issued TRANSFER command. This could be done so that the Host could issue another TRANSFER command with new command parameter values or so that a PGV could transfer the carriers. A Host initiated ABORT scenario would be similar to this scenario except that the remote command would be ABORT instead of CANCEL and the states when it is accepted by the TSC are different.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	The Host desires to CANCEL a particular TRANSFER command that it had previously issued to the TSC. Outstanding TRANSFER command has CommandId = "111111"			
2.	Host Command Send (HCS) **CANCEL** • COMMANDID = "111111" The COMMANDID must match that of the TRANSFER command that is being CANCEL'ed	S2,F41->		
3.			<-S2,F42	Host Command Acknowledge (HCA) This is the point where the TSC would reject the CANCEL command if not in the QUEUED or WAITING state.
4.			<-S6,F11	Event Report Send (ERS) TransferCancelInitiated • CommandID = "111111"
5.	Event Report Acknowledge (ERA)	S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
6.			<-S6,F11	Event Report Send (ERS) TransferCancelCompleted • CommandID = "111111"
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = "CARXX" • CommandID = "111111"
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.	The host may now initiate another TRANSFER command for the carrier(s) from the TRANSFER command that was canceled or allow a PGV to deliver the carriers. If there were multiple carriers in the CANCEL'ed TRANSFER then the Host may elect to issue one TRANSFER command for all carriers or individual TRANSFER commands for each carrier. The SOURCEPORT in the resulting TRANSFER command(s) will be the same as when the original TRANSFER was issued since the carriers have not moved.			

12.3.2 *Host-Initiated Override of a TRANSFER Command*

12.3.2.1 The Host wishes to override the destination of a previously issued TRANSFER command after the command has entered the ACTIVE state. This could be done so that the Host could issue another TRANSFER command with a new destination.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	The Host desires to ABORT a particular TRANSFER command that it had previously issued to the TSC. The outstanding TRANSFER command has CommandID = "111111"			
2.	Host Command Send(HCS) **ABORT** • COMMANDID = "111111" The COMMANDID must match that of the TRANSFER command that is being ABORT'ed	S2,F41->		

STEP	COMMENTS	HOST	TSC	COMMENTS
3.			<-S2,F42	Host Command Acknowledge (HCA) This is the point where the TSC would reject the ABORT command if it is not possible for the transport system to abort the ACTIVE TRANSFER command.
4.			<-S6,F11	Event Report Send (ERS) TransferAbortInitiated • CommandID = “111111”
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) TransferAbort-Completed • CommandID = “111111” • CarrierLoc = “LOC1” • TransferInfo
7.	Event Report Acknowledge (ERA)	S6,F12->		
8.			<-S6,F11	Event Report Send (ERS) VehicleUnassigned • VehicleID = “CARXX” • CommandID = “111111”
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.	The host will now initiate another TRANSFER command for the carrier(s) from the TRANSFER command that was aborted.			
11.	Enhanced Remote Command(ERC) **TRANSFER** • COMMANDID = “111112” • PRIORITY = 5 • REPLACE = 0 • TRANSFERINFO$_1$ - L,3 1. CARRIERID = “123456” 2. SOURCEPORT = The current location of the carrier as sent from the TSC to the Host in the TransferCompleted for the failed TRANSFER command(an example is a port on a vehicle). The Host does not have to know the difference of whether the carrier is still on the car or not to send another TRANSFER command. 3. DESTPORT = “PORTYY”	S2,F49->		
12.			<-S2,F50	Enhanced Remote Command Acknowledge (ERCA)
13.	Scenario will now follow 12.1.1			

12.3.3 *Unsuccessful Completion of a TRANSFER Command*

12.3.3.1 The TSC must unsuccessfully complete a previously issued TRANSFER command due to an unrecoverable transport system error. Although this scenario follows the GEM defined scenario for Alarm handling, it was included to define the specifics of an IBSEM alarm and subsequent unsuccessful TRANSFER command completion. The abort of TRANSFER command should be performed by host as described in Section 12.2.2.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.			<-S5,F1	Alarm Report Send (ARS) Alarm Set Unrecoverable Transport System Error • ALID • ALTX
2.	Alarm Report Acknowledge (ARA)	S5,F2->		
3.			<-S6,F11	Event Report Send (ERS) TransferPaused • CommandID
4.	Event Report Acknowledge (ERA)	S6,F12->		
5.			<-S6,F11	Event Report Send (ERS) AlarmSet • All VID’s necessary to fully describe the nature of the unrecoverable error must be sent to the Host in this event.
6.	Event Report Acknowledge (ERA)	S6,F12->		
7.	Human intervention is necessary to clear the unrecoverable error.			
8.	Note that the ResultCode is crucial for the Host to determine that the TRANSFER command has completed unsuccessfully. It is equally important that the current locations of all carriers is sent to the Host in the unsuccessful completion event.		<-S6,F11	Event Report Send (ERS) TransferCompleted • CommandName = “TRANSFER” • CommandID = “111111” • Priority • Replace • ResultCode = Error /*NonZero*/ • CarrierLoc = “LOC1” • TransferInfo
9.	Event Report Acknowledge (ERA)	S6,F12->		
10.			<-S5,F1	Alarm Report Send (ARS) Alarm Cleared Unrecoverable Transport System Error • ALID • ALTX
11.	Alarm Report Acknowledge (ARA)	S5,F2->		

STEP	COMMENTS	HOST	TSC	COMMENTS
12.			<-S6,F11	Event Report Send (ERS) AlarmCleared • All VID's necessary to fully describe the nature of the unrecoverable error must be sent to the Host in this event.
13.	Event Report Acknowledge (ERA)	S6,F12->		
14.	The host may now initiate another TRANSFER command for the carrier(s) from the TRANSFER command that was completed unsuccessfully. If there were multiple carriers in the unsuccessful TRANSFER then the Host may elect to issue one TRANSFER command for all carriers or individual TRANSFER commands for each carrier. The SOURCEPORT in the resulting TRANSFER command(s) may be an internal vehicle location or any other location along the path of the TRANSFER command.			

12.3.4 *Connection or Reconnection between TSC and Host*

12.3.4.1 The Factory Host System crashes (or loses communication with the TSC for a time exceeding all time-outs and retries) and must re-synchronize with the TSC in lieu of several events completing while the communication link between the two was down.

STEP	COMMENTS	HOST	TSC	COMMENTS
1.	Communication session between host and TSC (re)established. Host establishes communication with the TSC per the GEM standard scenario (e.g., S1F13, etc).			
2.	Host Command Send (HCS) **PAUSE**	S2,F41->		
3.			<-S2,F42	Host Command Acknowledge (HCA)
4.			<-S6,F11	Event Report Send (ERS) TSCPauseInitiated
5.	Event Report Acknowledge (ERA)	S6,F12->		
6.			<-S6,F11	Event Report Send (ERS) TSCPauseCompleted • CommandName = "PAUSE" • ResultCode = 0
7.		S6,F12->		

STEP	COMMENTS	HOST	TSC	COMMENTS
8.	Selected Equipment Status Request (SSR) • ActiveCarriers • ActiveVehicles • ActiveTransfers	S1,F3->		HOST asks for carrier and vehicle information
9.			<-S1,F4	Selected Equipment Status Data (SSD) • CarrierInfo - L,3 . . (one CarrierInfo for each carrier) . • VehicleInfo - L,2 . . (one VehicleInfo for each vehicle) . • TransferCommand - L,n . . (one TransferCommand for each . Active TRANSFER command)
10.	The HOST updates it's model of the system with the information from the vehicle and carrier status data.			
11.	Host Command Send (HCS) **RESUME**	S2,F41->		HOST enables the system to continue operations.
12.			<-S2,F42	Host Command Acknowledge (HCA)
13.			<-S6,F11	Event Report Send (ERS) TSCAutoCompleted
14.	Event Report Acknowledge (ERA)	S6,F12->		
15.				System continues processing all commands that were in process or queued before/during the Host crash or communication loss/initialization. System will also now process new commands.

13 GEM Capabilities

13.1 The purpose of this section is to specify any SEMI E30 additional capabilities that are required to be supported by this class of equipment.

13.2 *Requirement*

13.2.1 This standard requires that the SEMI E30 fundamental requirements and additional capabilities have been implemented on the IBSEM equipment with the exception of Trace Data Collection, Remote Control, Process Program Management, and Limits Monitoring and Spooling. The TRANSFER Command State Model will serve as the Equipment Processing State Model specified in SEMI E30. If these capabilities are implemented, they will be implemented as required by SEMI E30. The SEMI E30 additional capabilities required by IBSEM are:

- Establish Communications
- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Equipment Constants
- Material Movement
- Equipment Terminal Services
- Clock
- Control (host-initiated)

RELATED INFORMATION 1
IBSEM UNIQUE CAPABILITIES

NOTE: This related information is not an official part of SEMI E82, but was approved for publication by full letter ballot procedures on April 15, 1999.

R1-1 Transfer Command Message Examples (SML Format)

R1-1.1 Variable data values specified in the following TRANSFER commands have been chosen arbitrarily for the purpose of demonstrating message structure/content.

R1-1.2 *Transfer Command Message Example for a Single Carrier Transfer*

```
S2,F49
<L [4]
    <U2     0>                                  /* DATAID */
    <A[0]   ‘’>                                 /* OBJSPEC */
    <A[8]   ‘TRANSFER’>                         /* RCMD */
    <L [2]
        <L [2]
            <A[11]  ‘COMMANDINFO’>              /* CPNAME1 */
            <L[3]
                <L[2]
                    <A[9]   ‘COMMANDID’>        /* CPNAME */
                    <A[6]   ‘111111’>           /* CPVAL */
                >
                <L[2]
                    <A[8]   ‘PRIORITY’>         /* CPNAME */
                    <U2     5>                  /* CPVAL */
                >
                <L[2]
                    <A[7]   ‘REPLACE’>          /* CPNAME */
                    <U2     0>                  /* CPVAL */
                >
            >
        >
        <L [2]
            <A[12]  ‘TRANSFERINFO’>             /* CPNAME2 */
            <L[3]
                <L[2]
                    <A[9]   ‘CARRIERID’>        /* CPNAME */
                    <A[6]   ‘123456’>           /* CPVAL */
```

```
                    >
                    <L[2]
                         <A[10]  'SOURCEPORT'>          /* CPNAME */
                         <A[6]   'PORTXX'>              /* CPVAL */
                    >
                    <L[2]
                         <A[8]   'DESTPORT'>            /* CPNAME */
                         <A[6]   'PORTYY'>              /* CPVAL */
                    >
               >
          >
     >
>
```

R1-1.2 *Transfer Command Message Example for a Double Carrier Transfer*

```
S2,F49
<L [4]
     <U2     0>                                         /* DATAID */
     <A[0]   ''>                                        /* OBJSPEC */
     <A[8]   'TRANSFER'>                                /* RCMD */
     <L [3]
          <L [2]
               <A[11]  'COMMANDINFO'>                   /* CPNAME1 */
               <L[3]
                    <L[2]
                         <A[9]   'COMMANDID'>           /* CPNAME */
                         <A[6]   '111111'>              /* CPVAL */
                    >
                    <L[2]
                         <A[8]   'PRIORITY'>            /* CPNAME */
                         <U2     5>                     /* CPVAL */
                    >
                    <L[2]
                         <A[7]   'REPLACE'>             /* CPNAME */
                         <U2     0>                     /* CPVAL */
                    >
               >
```

```
            >
            <L [2]
                <A[12]  'TRANSFERINFO'>                     /* CPNAME2 */
                <L[3]
                    <L[2]
                        <A[9]   'CARRIERID'>                /* CPNAME */
                        <A[6]   '123456'>                   /* CPVAL */
                    >
                    <L[2]
                        <A[10]  'SOURCEPORT'>               /* CPNAME */
                        <A[6]   'PORTX1'>                   /* CPVAL */
                    >
                    <L[2]
                        <A[8]   'DESTPORT'>                 /* CPNAME */
                        <A[6]   'PORTY1'>                   /* CPVAL */
                    >
                >
            >
            <L [2]
                <A[12]  'TRANSFERINFO'>                     /* CPNAME2 */
                <L[3]
                    <L[2]
                        <A[9]   'CARRIERID'>                /* CPNAME */
                        <A[6]   '654321'>                   /* CPVAL */
                    >
                    <L[2]
                        <A[10]  'SOURCEPORT'>               /* CPNAME */
                        <A[6]   'PORTX2'>                   /* CPVAL */
                    >
                    <L[2]
                        <A[8]   'DESTPORT'>                 /* CPNAME */
                        <A[6]   'PORTY2'>                   /* CPVAL */
                    >
                >
            >
        >
    >
```

R1-2 Parallel Interface for Carrier Transfer - SEMI E23 Required Transfer

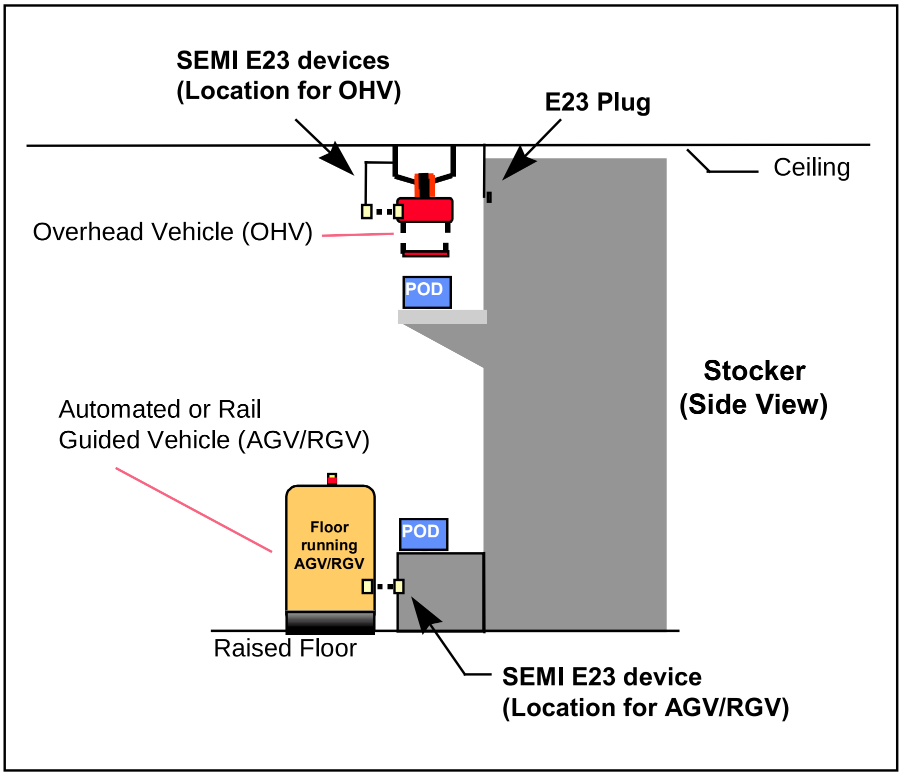


Figure R1-1
SEMI E23 Example Diagram for OHV/AGV/RGV

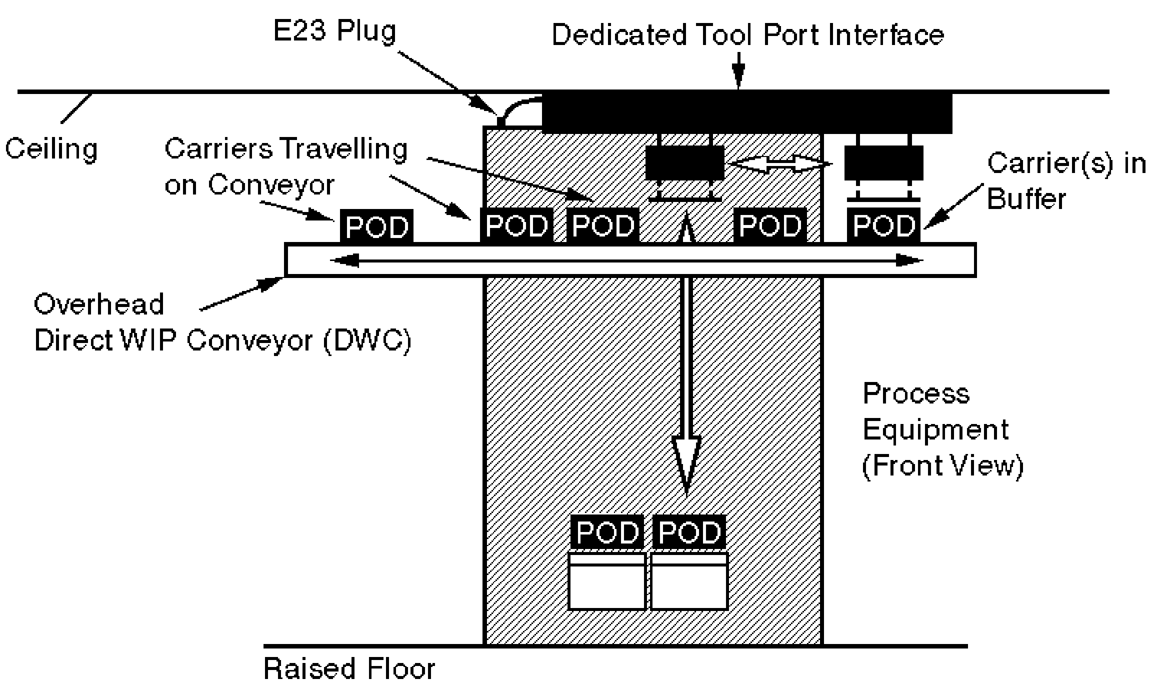


Figure R1-2
SEMI E23 Example Diagram for DWC

R1-3 Hardware Architecture

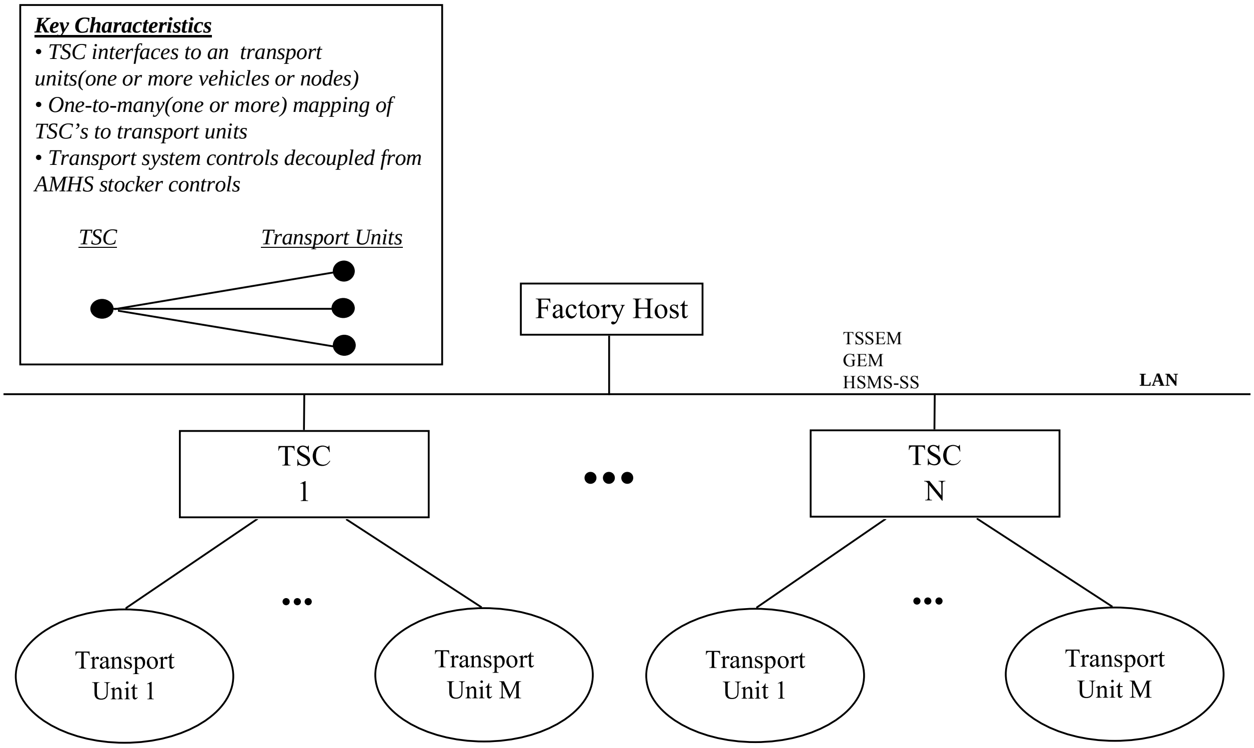


Figure R1-3
Configurable Centralized TSC Architecture (Logical View)

R1-4 Traffic Management Characteristics

R1-4.1 At a minimum, the TSC must offer Priority-based First-In-First-Out (FIFO) queuing of TRANSFER commands. In other words, all TRANSFER commands which have yet to be processed by the transport system must be serviced in the order in which they are received by the TSC based on the priority given in the host command. The minimum priority levels required to be available on IBSEM equipment are “Normal” and “High.” “Normal” and “High” priorities will be denoted by U2 compatible numbers as per the definition of the priority in the Variable Data and Remote Command sections of this document. Other options may be implemented, but to be an IBSEM equipment it must at a minimum have the ability to be configured to perform Priority-based FIFO queuing of TRANSFER commands. Additionally, the command priorities are to be utilized during execution of the commands to the following level: any “High” priority command will cause all other commands that are not “High” priority to be usurped. That is to say that all other commands will modify the execution steps to allow the “High” priority commands to be completed in the minimal elapsed time possible. Multiple “High” priority commands will act upon each other according to the same rules as “Normal” commands act on each other.

The following TRANSFER commands are received by the TSC in top to bottom order:

TRANSFER Command	Priority
1	Normal
2	Normal
3	High
4	Normal
5	High

Corresponding TSC processing queue for outstanding TRANSFER commands :

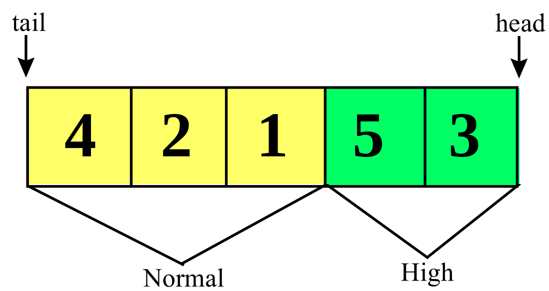


Figure R1-4
TSC Priority-based FIFO TRANSFER Command Processing Example

R1-4.2 The TSC must manage the vehicles so that TRANSFER requests are queued for later service if all vehicles are currently utilized.

R1-5 Transport System Handling and Delivery of the Transfer Unit

R1-5.1 A transfer unit must always be delivered by the same vehicle simultaneously. A transfer unit cannot be split between multiple vehicles.

RELATED INFORMATION 2
REQUIREMENTS FOR COMPLIANCE

NOTE: This related information is not an official part of SEMI E82, but was approved for publication by full letter ballot procedures on April 15, 1999.

Table R2-1 provides a checklist for IBSEM compliance.

R2-1 IBSEM Compliance Statement

Table R2-1 IBSEM Compliance Statement

Fundamental IBSEM Requirements	*Implemented*	*IBSEM Compliant*
TSC State Model	☐ Yes ☐ No	☐ Yes ☐ No
Transfer Command State Model	☐ Yes ☐ No	☐ Yes ☐ No
Vehicle State Model *(optional, see Section 7.4)*	☐ Yes ☐ No	☐ Yes ☐ No
Carrier State Model	☐ Yes ☐ No	☐ Yes ☐ No
Collection Event List	☐ Yes ☐ No	☐ Yes ☐ No
Collection Event Data Availability	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data Items	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data Availability	☐ Yes ☐ No	☐ Yes ☐ No
Alarm List	☐ Yes ☐ No	☐ Yes ☐ No
Remote Command List	☐ Yes ☐ No	☐ Yes ☐ No
Remote Command Parameters	☐ Yes ☐ No	☐ Yes ☐ No
Remote Command Mapping	☐ Yes ☐ No	☐ Yes ☐ No
Transfer Command Format	☐ Yes ☐ No	☐ Yes ☐ No
System Architecture	☐ Yes ☐ No	☐ Yes ☐ No
Traffic Management Characteristics	☐ Yes ☐ No	☐ Yes ☐ No
Delivery of the Transfer Unit	☐ Yes ☐ No	☐ Yes ☐ No

SEMI E86-0200
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK FACTORY LABOR COMPONENT

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on October 21, 1999. Initially available at www.semi.org January 2000; to be published February 2000. Originally published September 1999.

1 Purpose

1.1 The Factory Labor Component provides the capability to support the qualification and management of available, qualified human resources for manufacturing operations.

1.2 The technical content of this ballot addresses the portion of the CIM Framework domain specified in SEMI E81, Provisional Specification for CIM Framework Domain Architecture, concerned with management of the availability of qualified factory personnel. This specification provides the interfaces required by Manufacturing Execution Systems to:

- Configure the Person resource model.
  - Each Person's name (or appropriate alias), identification, department, role, etc. There may be cases where identifying information should not be used to associate a person with the required factory labor records.
  - Each Person's initial skills and authorization to perform jobs and access data.
  - Each Person's initial assignment to other factory resources (such as specific machines or factory areas).
  - Each Person's medical qualifications.
- Define skill maintenance tasks and what triggers them.
- Track and report the Person's skills, authorization, and assignments and record these in the Person's histories.
- Support assignment of Persons to factory jobs and monitor and record job progress (from the perspective of the Person's role).
- Monitor skill maintenance triggers (such as expired skill certification) and recommend skill maintenance jobs.
- Execute triggered skill maintenance jobs.
  - Change Person capabilities (before and after training).
  - Execute and monitor skill maintenance jobs (training, certification testing) and report job progress.
  - Record skill maintenance triggers and job results in Person's skill maintenance histories.
- Collect and report Person and skill performance (utilization and effectiveness).
- Maintain relationships between Persons and system security for identity authentication and authorization.

2 Scope

2.1 Specifically, this component provides the services to:

- Manage the assignment of qualified and available labor resources for factory operations.
- Manage the training and medical requirements for factory operations.
- Support the maintenance of personnel information (full name, employee number, department, shift assignment, machines qualified to operate, course and medical examination records).
- Support the maintenance of personnel skill qualification histories (courses and medical examinations successfully completed) of factory personnel.

2.2 The Factory Labor Component is divided into two subcomponents:

- Person Management, which tracks, logs, and maintains availability and task assignment for factory operations personnel within the manufacturing facility. Also provides support for the management of personnel information, training, and medical qualifications.
- Skill Management, which provides support for the management of training and medical requirements for factory operations.

2.3 Figure 1 depicts the relationships between these two components and their interaction with other CIM Framework components defined in the Section 7.2 Functional Partitioning of SEMI E81, Provisional

Specification for CIM Framework Domain Architecture.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification is designated as provisional due to known areas that need to be completed. The following items summarize the deficiencies of the provisional specification to be addressed before a subsequent ballot to upgrade it to full standard status.

3.2 *Provisional Status*

3.2.1 The following items need to be completed before conducting a subsequent ballot to upgrade the Factory Labor Component to full standard status.

- Define skill maintenance tasks and what triggers them.
- Monitor skill maintenance triggers (such as expired skill certification) and recommend skill maintenance jobs.
- Maintain relationships between persons and system security for identity authentication and authorization.

3.2.2 It is anticipated that a future document defining the Resource Abstract Interface will satisfy the first two items.

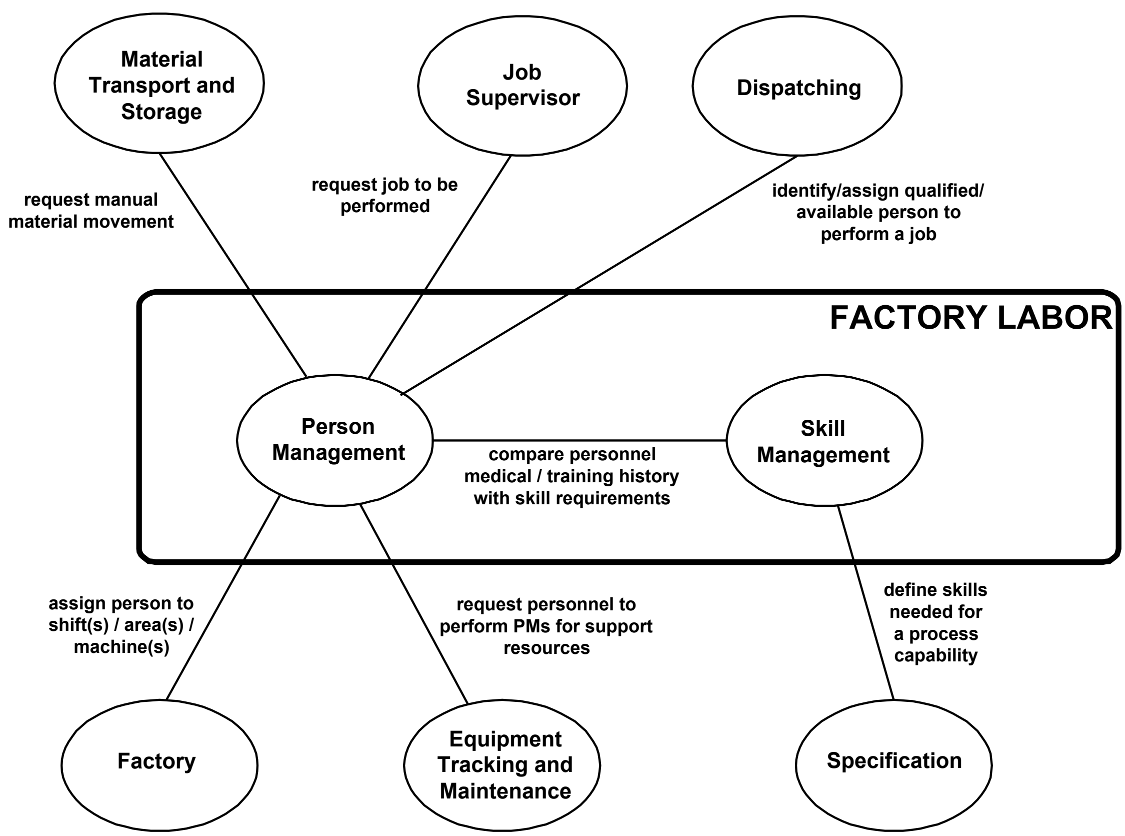


Figure 1
Factory Labor Component Relationships

4 Referenced Standards

4.1 *SEMI Standard*

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

4.2 *ISO/IEC Standard*[1]

ISO/IEC 14750 (also ITU-T Recommendation X.920) — Information Technology – Open Distributed Processing – Interface Definition Language

4.3 *OMG Standard*[2]

UML Notation Guide, Version 1.1, document number ad/97-08-05

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *person* — personnel performing manufacturing operations within a factory.

5.2 *person responsibility* — the concept of "responsibility" implies that factory personnel are authorized to perform, operate or access a specific factory object (but it does not imply ownership).

5.3 *skill* — skill is an attribute of factory personnel denoting that they are qualified to assist a process resource or job in the performance of a process capability or some other factory operation.

5.4 *skill qualification* — a skill qualification indicates that factory personnel meet a requirement (or all requirements) necessary to perform some factory operation.

5.5 *skill requirement* — a skill requirement is the training or medical examination(s) required to achieve a specific skill.

6 Requirements

6.1 The following sections provide the specification of interfaces that comprise the Factory Labor Component. The model notation used is the Unified Modeling Language (UML). UML is documented in the UML Notation Guide. The details of each interface are supplied using standard IT-ODP-IDL. Conformant implementations of the Factory Labor Component shall provide support for all elements of the IDL specifications and the semantics provided in the UML models. Conformant implementations are not constrained to any specific implementation approach, provided that a mapping is provided to the IDL specification.

6.2 *External Interfaces, Global Type Definitions, Global Exceptions and Events*

6.2.1 The following interfaces (external to this component), global type definitions, global exceptions, and events are required to support the Factory Labor component specification.

6.2.2 *Abstract and Base Interfaces*

6.2.2.1 Base interfaces provide a suite of interfaces that are used throughout the CIM Framework Specification. The Abstract Interfaces provide a hierarchy of abstract interfaces that are used as "Inherited Interfaces" in the rest of the framework. These interfaces are expected to be specialized in a specific implementation.

6.2.2.2 This section identifies base and abstract interfaces required by the Factory Labor component specification.

```
interface NamedEntity {
};

interface OwnedEntity : NamedEntity {
};
```

1 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

2 Object Management Group, Inc., Framingham Corporate Center, 492 Old Connecticut Path, Framingham, MA 01701, 1.508.820.4300, [*http://www.omg.org/cgi-bin/doclist.pl*](http://www.omg.org/cgi-bin/doclist.pl)

```
interface Resource : OwnedEntity {
};

interface ComponentManager : Resource {
};

interface Job {
} ;
```

6.2.3 *Other CIM Framework Interfaces*

6.2.3.1 This section identifies interfaces within other CIM Framework components that are needed to satisfy relationships with the Factory Labor component.

```
interface HistoryCollection { // from Factory Services
} ;

interface History { // from Factory Services
} ;

interface MESFactory { // from Factory Management
} ;
```

6.2.4 *Global Type Definitions*

6.2.4.1 The CIM Framework uses IT-ODP-IDL *typedefs* in two ways:

- To define aliases for compound object types (*structs*), which can then be used in IDL specifications and
- To define aliases for basic object types, but with additional implied semantics. (e.g., the *units* typedef defines a *string*, whose contents conform to definitions found in SEMI E5).

6.2.4.2 This section identifies the global type definitions required by the Factory Labor component specification.

```
typedef sequence<string> stringSequence ;

typedef struct HistoryEvent_body {
        string subject ;
} HistoryEvent ;

struct ulonglong {
        unsigned long low ;
        unsigned long high ;
} ;

typedef ulonglong TimeT ;

typedef TimeT TimeStamp ;

struct IntervalT {
        TimeT lower_bound ;
        TimeT upper_bound ;
} ;
```

```
typedef IntervalT TimeWindow ;

typedef struct Shift_Structure {
        string name ;
        // ...
} Shift ;

typedef struct PersonResponsibilitystruct {
        string responsibilityCategory ;
        any responsibility ;
} PersonResponsibility;

typedef sequence<ProcessCapability> ProcessCapabilitySequence ;
typedef stringSequence CategorySequence ;
typedef sequence<HistoryEvent> HistoryEventSequence ;
typedef sequence<Job> JobSequence ;
typedef sequence<Machine> MachineSequence ;
typedef sequence<Person> PersonSequence ;
typedef sequence<QualificationData> QualificationDataSequence ;
typedef sequence<Resource> ResourceSequence ;
typedef sequence<SkillRequirement> RequirementSequence ;
typedef sequence<PersonResponsibility> ResponsibilitySequence ;
typedef sequence<Skill> SkillSequence ;

typedef string PropertyName;
struct Property
    {
    PropertyName property_name;
    any property_value;
    };
typedef sequence<Property> Properties;
```

6.2.5 *Global Exception Declarations*

6.2.5.1 An exception is an infrastructure mechanism used to notify a calling client of an operation that an unusual condition occurred in carrying out the operation. This section identifies the global exception declarations required by the Factory Labor component specification.

```
exception FrameworkErrorSignal {
        unsigned long errorCode ;
        any errorInformation ;
} ;

exception InvalidStateTransitionSignal {
} ;

exception SetValueOutOfRangeSignal {
} ;
```

6.2.6 *Events*

6.2.6.1 An event is an asynchronous message denoting the occurrence of some incident of importance. For example, state change or new object created. This section identifies the events defined by the Factory Labor component specification. Note that “//” or “/* ....*/” infers a comment.

```
/* Person lifecycle event definition. */
const string PersonLifecycleSubject =
        "/PersonManagement/PersonManager/PersonLifecycle" ;
typedef struct PersonLifecycleFilters_Structure {
        Property        name;           // “Name”, aPerson’s name
        Property        lifecycleEvent; // “LifecycleEvent”, LifecycleState
} PersonLifecycleFilters;
typedef struct PersonLifecycleEvent_Structure {
        string                          eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonLifecycleFilters          eventFilterData;
        Properties                      eventNews;
        Person                          aPerson;
                        // Except when “Delete” where value will be nil
} PersonLifecycleEvent;

/* Person capacity changed event definition. */
const string PersonCapacityChangedSubject =
        "/PersonManagement/Person/CapabilityChanged" ;
typedef struct PersonCapacityChangedFilters_Structure {
        Property        name;           // “Name”, aPerson’s name
} PersonCapacityChangedFilters;
typedef struct PersonCapacityChangedEvent_Structure {
        string                          eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonCapacityChangedFilters    eventFilterData;
        Properties                      eventNews;
        Person                          aPerson;
} PersonCapacityChangedEvent;

/* Person state changed event definition. */
const string PersonStateChangedSubject = "/PersonManagement/Person/StateChanged";
enum PersonState {PersonDefined, PersonOffShift, PersonOnShift,
PersonAvailableForWork, PersonNotAvailableForWork, PersonUnassignedToMachines,
PersonAssignedToJobs, PersonAssignedToMachines, PersonAvailableForMoreAssignments,
PersonAssignmentAtCapacityExceeded, PersonIdleWithJob, PersonBusyWithJob };
typedef struct PersonStateChangedFilters_Structure {
        Property        name;           // “Name”, aPerson’s name
        Property        formerState;    // “FormerState”, PersonState
        Property        newState;       // “NewState”, PersonState
} PersonStateChangedFilters;
typedef struct PersonStateChangedEvent_Structure {
        string                          eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonStateChangedFilters       eventFilterData;
        Properties                      eventNews;
        Person                          aPerson;
} PersonStateChangedEvent;

/* Person shift worked changed event definition. */
const string PersonShiftChangedSubject = "/PersonManagement/Person/ShiftChanged";
typedef struct PersonShiftChangedFilters_Structure {
        Property        name;           // “Name”, aPerson’s name
        Property        fromShift;      // “FromShift”, former shift
```

```
        Property        toShift;        // "ToShift", new shift
} PersonShiftChangedFilters;
typedef struct PersonShiftChangedEvent_Structure {
        string                          eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonShiftChangedFilters       eventFilterData;
        Properties                      eventNews;
        Person                          aPerson;
} PersonShiftChangedEvent;
```

6.3 *Person Management Component*

6.3.1 This component defines factory personnel (Person interface) to a CIM system. Persons are viewed as resources in the manufacturing environment, are assigned to a factory area, and own a detailed training and medical examination history (which qualifies them to perform a skill or set of skills). For example, there may be a requirement that an operator periodically completes specific training or medical testing. Qualifications would include verification that required training had occurred within the specified time limit. The associated skill would identify the process capability enabled for this person through that qualification. At any given time, a Person may be assigned to one or more factory jobs associated with other factory resources or operations.

6.3.2 The Component Information Model for Person Management is shown in Figure 2.

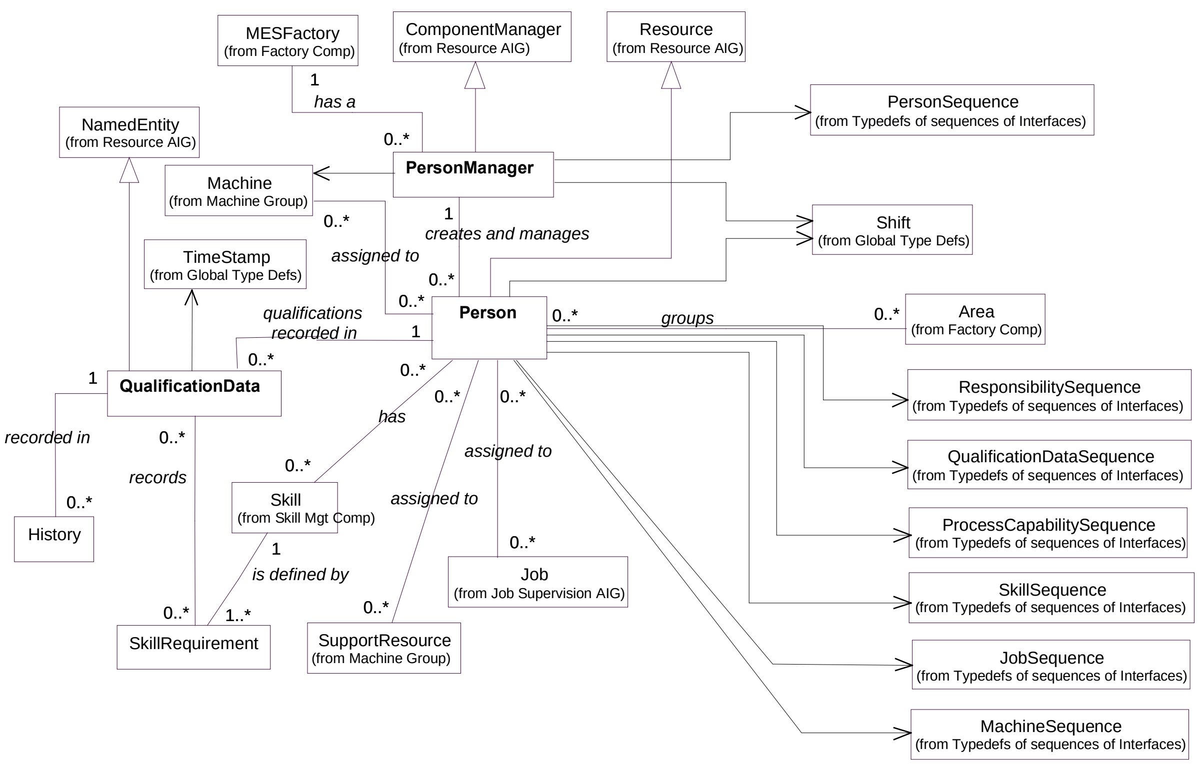


Figure 2
Person Management Component Information Model

6.3.3 *PersonManager Interface*

Interface: PersonManager

Inherited Interface: ComponentManager

Description: This is the interface between the Person Management Component and the rest of the CIM environment. The PersonManager creates instances of Persons within the factory and manages those Persons (shift, job assignment and status information). There are no limitations to the number of PersonManagers within a factory.

Exceptions:

/* This signal is raised with attempted creation of Person through the use of a Person identifier that already exists. */

```
exception PersonDuplicateSignal {string identificationNumber;};
```

/* This signal is raised when a retrieval operation fails because the Person specified by the argument could not be located. */

```
exception PersonNotFoundSignal {string identificationNumber;};
```

/* This signal is raised when a removal operation fails because the Person specified by the argument is not assigned to the PersonManager. */

```
exception PersonNotAssigned { Person unknownPerson;};
exception PersonRemovalFailedSignal { };
```

Published Events:

```
PersonLifecycleEvent
```

Provided Services:

/* Create an instance of Person with a unique identifier and add to the list managed by PersonManager. */

```
Person createPersonWithIdentifier (in string identificationNumber)
        raises (FrameworkErrorSignal, PersonDuplicateSignal);
```

/* Delete the Person identified by the argument from the list managed by PersonManager. */

```
void removePerson (in Person aPerson)
        raises (FrameworkErrorSignal, PersonRemovalFailedSignal,
                PersonNotAssignedSignal);
```

/* Return a set of Persons managed by the PersonManager. */

```
PersonSequence allPersons ( ) raises (FrameworkErrorSignal);
```

/* Search for an instance of Person using its unique identifier. Raises an exception if the Person is not found. */

```
Person findByIdentifier (in string identificationNumber)
        raises (FrameworkErrorSignal, PersonNotFoundSignal);
```

/* Return a set of all Persons logged on to the specified shift. */

```
PersonSequence allOnShiftPersons (in shift aShift) raises (FrameworkErrorSignal);
```

/* Return a set of all Persons available for work. */

```
PersonSequence allAvailableForWorkPersons ( ) raises (FrameworkErrorSignal);
```

/* Return a set of all Persons not available for work. */

```
PersonSequence allNotAvailableForWorkPersons ( ) raises (FrameworkErrorSignal);
```

/***** Manage Person / Machine relationship. *****/

/* Return a set of Persons qualified to operate a process or material handling machine. The Person is qualified to operate the machine if the machine is noted in the Person's skill list or if a comparison of the person's course and medical exam histories satisfy the requirements defined within the Skill Management Component for the noted machine. This method does not check the availability of the person to actually perform a task. */

```
PersonSequence allPersonsWithSkill (in Skill aSkill) raises (FrameworkErrorSignal);
```

/* Return a set of Persons available ("on duty" on the current shift) to operate the specified machine. This service assumes that a Person is qualified to operate the machine. */

```
PersonSequence allPersonsAvailableForMachine (in Machine aMachine)
        raises (FrameworkErrorSignal);
```

/* Return a set of all Persons currently assigned to the specified machine. */

```
PersonSequence allPersonsAssignedToMachine (in Machine aMachine)
        raises (FrameworkErrorSignal);
```

/* Return a set of all Persons currently assigned to machines. */

```
PersonSequence allAssignedToMachinesPersons ( ) raises (FrameworkErrorSignal);
```

/***** Manage Person/Job relationship. *****/

/* Return a set of Persons qualified to perform a process or material handling job. The Person is qualified for the job if the job qualification is noted in the person's skill list or if a comparison of the person's course and medical exam histories satisfy the requirements defined within the Skill Management Component for the noted job. This method does not check the availability of the person to actually perform a task. */

```
PersonSequence allPersonsQualifiedForJob (in Job aJob)
        raises (FrameworkErrorSignal);
```

/* Return a set of Persons available ("on duty" on the current shift) to perform a process or material movement job. This service assumes that a Person is qualified to perform the job. */

```
PersonSequence allPersonsAvailableForJob (in Job aJob)
        raises (FrameworkErrorSignal);
```

/* Return a set of Persons currently assigned to the specified job. */

```
PersonSequence allPersonsAssignedToJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Return a set of all Persons currently assigned to jobs. */

```
PersonSequence allAssignedToJobsPersons ( ) raises (FrameworkErrorSignal);
```

Contracted Services: None.

Dynamic Model: Same as inherited interface (Component Manager).

6.3.4 *Person Interface*

Interface: Person

Inherited Interface: Resource

Description: This interface represents factory personnel. As currently defined, Person refers specifically to operating personnel within the manufacturing facility. Instances of this interface hold the following information pertaining to these individuals: employee information (full name, identification number, department, shift assignment); training and medical certification; and factory operations (e.g., operate a machine, perform a process) qualified to perform.

Exceptions:

/* This signal is raised when an addition operation fails because the Qualification specified by the argument already exists. */

```
exception QualificationDuplicateSignal {
        QualificationData qualificationInformation;};
```

/* This signal is raised when a removal operation fails because the Qualification specified by the argument could not be located. */

```
exception QualificationNotAssignedSignal {string identificationNumber;};
```

/* This signal is raised when a retrieval operation fails because the Qualification specified by the argument could not be located. */

```
exception QualificationNotFoundSignal {string identificationNumber;};
```

/* This signal is raised when an addition operation fails because the Responsibility specified by the argument already exists. */

```
exception ResponsibilityDuplicateSignal {any responsibility ;
        string responsibilityCategory;};
```

/* This signal is raised when an operation fails because the Responsibility category specified by the argument could not be located. */

```
exception ResponsibilityCategoryNotFoundSignal {
        string responsibilityCategory;};
exception ResponsibilityCategoryRemovalFailedSignal { };
```

/* This signal is raised when a removal operation fails because the Responsibility specified by the argument could not be located. */

```
exception ResponsibilityRemovalFailedSignal {
        any responsibility;
        string responsibilityCategory;};
```

/* This signal is raised when an addition operation fails because the skill specified by the argument already exists. */

```
exception SkillDuplicateSignal {Skill aSkill;};
```

/* This signal is raised when a removal operation fails because the skill specified by the argument could not be located. */

```
exception SkillRemovalFailedSignal {Skill aSkill;};
exception SkillNotAssignedSignal {Skill aSkill;};
```

Published Events:

/* This event is posted when a Person's capacity to do work has changed. This includes assignment to/deassignment from machines and jobs. It also includes changing the number of jobs and/or machines to which a Person may be assigned. */

```
        PersonCapacityChangedEvent
```

/* This event is posted when a Person's availability has changed. This includes logging on/off a shift, leaving/returning to a work station, or capacity exceeded. */

```
        PersonStateChangedEvent
```

/* This event is posted when a Person has been reassigned to a different shift. */

```
        PersonShiftChangedEvent
```

Provided Services:

/* Set and get the Person's department. */

```
void setDepartment (in string department)
        raises (SetValueOutOfRange, FrameworkErrorSignal);
string getDepartment ( ) raises (FrameworkErrorSignal);
```

/* Set and get the Person's name. */

```
void setFullname (in string fullname)
         raises (SetValueOutOfRange, FrameworkErrorSignal);
string getFullname ( ) raises (FrameworkErrorSignal);
```

/* Set and get the Person's identification number. */

```
void setIdentificationNumber (in string idNumber)
         raises (SetValueOutOfRange, FrameworkErrorSignal);
string getIdentificationNumber ( ) raises (FrameworkErrorSignal);
```

/* Set and get the maximum number of jobs to which a Person can be assigned simultaneously. */

```
void setMaximumAssignedJobs (in long maximumJobs)
         raises (SetValueOutOfRange, FrameworkErrorSignal);
long getMaximumAssignedJobs ( ) raises (FrameworkErrorSignal);
```

/* Set and get the maximum number of machines to which a Person can be assigned simultaneously. */

```
void setMaximumAssignedMachines (in long maximumMachine)
        raises (SetValueOutOfRange, FrameworkErrorSignal);
long getMaximumAssignedMachines ( ) raises (FrameworkErrorSignal);
```

/* Set and get the Person's shift assignment. */

```
void setShift (in shift aShift) raises (SetValueOutOfRange, FrameworkErrorSignal);
shift getShift ( ) raises (FrameworkErrorSignal);
```

/* Add an object within the factory to a Person's responsibility category. The concept of "responsibility" implies that a Person is authorized to perform, operate or access the factory object. It does not imply ownership. The first argument represents the responsibility (object within the factory) which is associated with a responsibility category, while the second argument is the category. If the specified category does not exist, it is created. The service returns the added factory object. For example, add a machine to the Person's "maintenance responsibilities" category. Another example: add a change notice to a Person's "signoff responsibility" category. */

```
any addResponsibility_toCategory (in any responsibility,
        in string responsibilityCategory)
        raises (FrameworkErrorSignal, ResponsibilityDuplicateSignal,
                ResponsibilityCategoryNotFoundSignal );
```

/* Remove an object within the factory from a Person's responsibility category. If the specified category, or responsibility does not exist, then an exception is raised. */

```
void removeResponsibility_fromCategory (in any responsibility,
        in string responsibilityCategory)
        raises (FrameworkErrorSignal, ResponsibilityRemovalFailedSignal,
                ResponsibilityCategoryRemovalFailedSignal);
```

/* Return the responsibilities (objects within a factory) which are assigned to a Person's responsibility category. For example, return all of the specifications in the category "specification management." A dictionary of key/value pairs is returned that represents these responsibility associations. The key is the "responsibility category name" while the value is the set of factory objects associated with that category. */

```
ResponsibilitySequence responsibilities ( ) raises (FrameworkErrorSignal);
```

/* Add the skill (qualification to operate a specific machine) to the Person's list of skills. Skills may be assigned or obtained through the completion of specified course (s) and medical examination (s). This service does not detail specific course and medical examination requirements. */

```
void addSkill (in Skill aSkill)
        raises (FrameworkErrorSignal, SkillDuplicateSignal);
```

/* Remove the skill from the Person's list of skills. */

```
void removeSkill (in Skill aSkill)
        raises (FrameworkErrorSignal, SkillRemovalFailedSignal,
                SkillNotFoundSignal);
```

/* Retrieve the set of skills for which this Person is qualified. */

```
SkillSequence skills ( ) raises (FrameworkErrorSignal);
```

/* Add the specified qualification (training course or medical examination) data to the training or medical history of a Person. */

```
void addQualification (in QualificationData qualificationInformation)
        raises (FrameworkErrorSignal, QualificationDuplicateSignal);
```

/* Remove the specified qualification data from the training or medical history of a Person. */

```
void removeQualification (in QualificationData qualificationInformation)
        raises (FrameworkErrorSignal, QualificationNotAssignedSignal);
```

/* Retrieve all information relative to a Person's particular qualification by performing a search using its unique identifier. */

```
QualificationData findQualificationByIdentifier (in string identifier)
        raises (FrameworkErrorSignal, QualificationNotFoundSignal);
```

/* Retrieve the set of qualifications attained by this Person. */

```
QualificationDataSequence qualifications ( ) raises (FrameworkErrorSignal);
```

/* Return the sequence of process capabilities that this Person is qualified to perform. */

```
ProcessCapabilitySequence processCapabilities ( ) raises (FrameworkErrorSignal);
```

/***** The following services provide basic state control and query. *****/

/* Denote that this person has logged on to the current shift and is AVAILABLE. */

```
void makeOnShift ( )
```

/* Denote that this person has logged off of the current shift and is NOT AVAILABLE. */

```
void makeOffShift ( )
```

/* Denote that this Person is at a workstation and available for work. It is required that the Person has logged on to the current shift. Assignment to machine (s) and/or job (s) may or may not have occurred. */

```
void makeAtWorkStation ( )
       raises (FrameworkErrorSignal, InvalidStateTransitionSignal );
```

/* Denote that this Person is not immediately available at a work station and cannot perform work. An example of this condition is an operator taking a personal break during a shift. */

```
void makeNotAtWorkStation ( )
       raises (FrameworkErrorSignal, InvalidStateTransitionSignal );
```

/* Return a boolean denoting whether or not a Person is logged on to the current shift. */

```
boolean isOnShift ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is available for work. */

```
boolean isAvailableForWork ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is at their work station. */

```
boolean isAtWorkStation ( ) raises (FrameworkErrorSignal);
```

/* Determine if a Person is qualified to perform a process or material handling job for a specific machine (has a specific skill.) The Person is qualified to operate the machine if the machine is noted in the Person's skill list, or if a comparison of the Person's course and medical exam histories satisfy the requirements defined within the Skill Management Component for the noted machine. This service does not check the availability of the Person to actually perform a task. */

```
boolean hasSkill (in Skill aSkill) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is qualified for any machine. */

```
boolean hasSkills ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is available for the specified machine. */

```
boolean isAvailableForMachine (in Machine aMachine) raises (FrameworkErrorSignal);
```

/* Assign Person to a machine. A Person may be assigned to more than one machine at a time.*/

```
void assignToMachine (in Machine aMachine) raises (FrameworkErrorSignal);
```

/* Terminates personnel assignment to a machine. */

```
void deassignFromMachine (in Machine aMachine) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is assigned to the specified machine. */

```
boolean isAssignedToMachine (in Machine aMachine) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is assigned to any machine. */

```
boolean isAssignedToMachines ( ) raises (FrameworkErrorSignal);
```

/* Retrieve the set of machines to which a Person is assigned. */

```
MachineSequence assignedMachines ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is available to be assigned to more machines. */

```
boolean isAvailableForMoreMachineAssignments ( ) raises (FrameworkErrorSignal);
```

/***** The following services support job assignment. *****/

/* Return a boolean denoting whether or not a Person is qualified for the specified job. */

```
boolean isQualifiedForJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is qualified for any job. */

```
boolean isQualifiedForJobs ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is available for the specified job. */

```
boolean isAvailableForJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Assigns a Person to a job. A Person may be allocated to more than one job at a time. */

```
void assignToJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Terminates personnel assignment to a job. */

```
void deassignFromJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is assigned to the specified job. */

```
boolean isAssignedToJob (in Job aJob) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is assigned to any jobs. */

```
boolean isAssignedToJobs ( ) raises (FrameworkErrorSignal);
```

/* Retrieve the set of jobs to which a Person is assigned. */

```
JobSequence assignedJobs ( ) raises (FrameworkErrorSignal);
```

/* Return a boolean denoting whether or not a Person is available for more jobs. */

```
boolean isAvailableForMoreJobAssignments ( ) raises (FrameworkErrorSignal);
```

Contracted Services: None.

Dynamic Model:

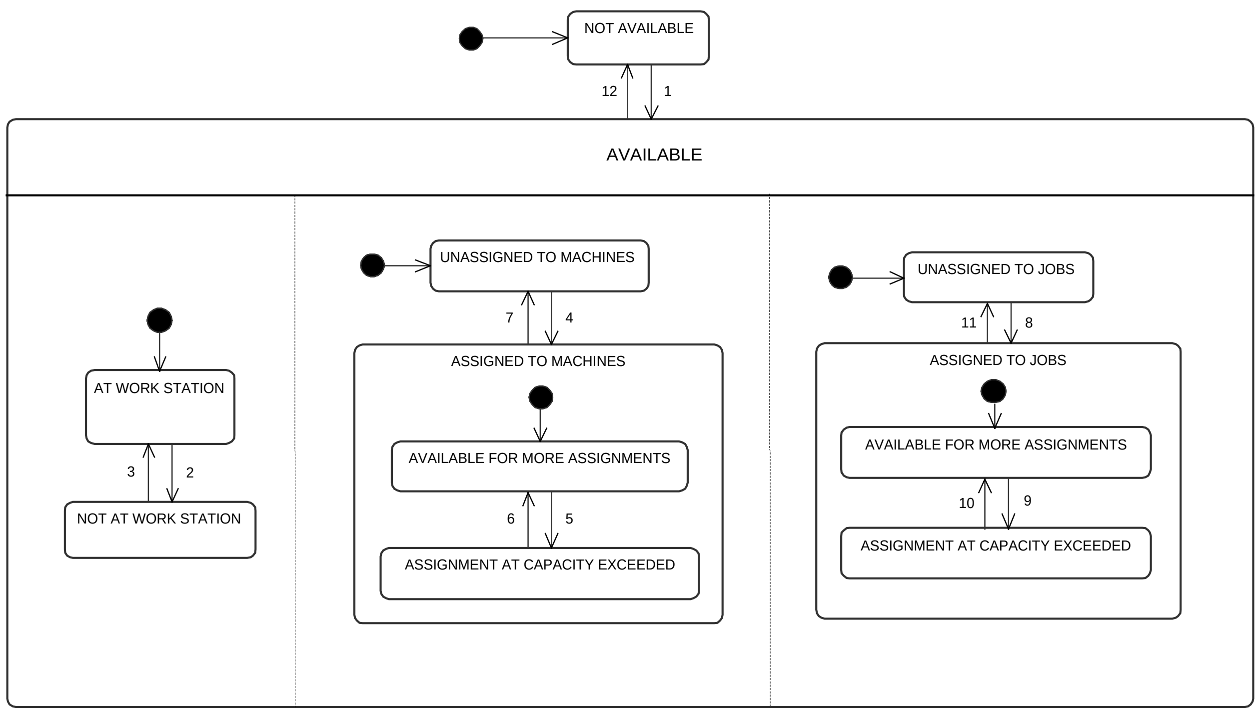


Figure 3
Person Dynamic Model

6.3.4.1 Object State Tables

Table 1 Person State Definitions and Query

State	*Definition*	*Query for State via*
NOT AVAILABLE	In this state, a Person is not clocked on to shift and cannot perform work.	boolean isOnShift ( ) sent to instance of Person returns FALSE. Person **NOT** included in set returned by PersonManager services. PersonSequence allOnShiftPersons (in Shift aShift) or allAvailableForWorkPersons ( ).
AVAILABLE	In this superstate, a Person is clocked on to a shift and is ready to perform work.	boolean isOnShift ( ) sent to instance of Person returns TRUE. Person included in set returned by PersonManager services PersonSequence allOnShiftPersons (in Shift aShift) or PersonSequence allAvailableForWorkPersons ( ).
AT WORK STATION	A Person is available to perform some manufacturing task; that is, the Person is physically present at his or her work site.	boolean isAtWorkStation ( ) sent to instance of Person returns TRUE.
NOT AT WORK STATION	A Person is not available to perform any manufacturing task; that is, the Person is physically absent from his or her work site.	boolean isAtWorkStation ( ) sent to instance of Person returns FALSE.
UNASSIGNED TO MACHINES	In this state, a Person has not been assigned to any machines. A Person may or may not be assigned to a job(s).	boolean isAssignedToMachines ( ) or boolean isAssignedToMachine (in Machine aMachine) [for all Machines] sent to instance of Person returns FALSE. Person **NOT** included in set returned by PersonManager services PersonSequence allPersonsAssignedToMachine (in Machine aMachine) [for all Machines] or PersonSequence allAssignedToMachinesPersons ( ). Empty set returned by Person service MachineSequence assignedMachines ( );
ASSIGNED TO MACHINES	In this parent state, a Person has been assigned to one or more machines.	boolean isAssignedToMachines ( ) or boolean isAssignedToMachine (in Machine aMachine) sent to instance of Person returns TRUE. Person included in set returned by PersonManager services PersonSequence allPersonsAssignedToMachine (in Machine aMachine) or PersonSequence allAssignedToMachinesPersons ( ). Non-empty set returned by Person service MachineSequence assignedMachines ( );
AVAILABLE FOR MORE ASSIGNMENTS	In this substate, a Person is available for assignments to more machines.	boolean isAvailableForMoreMachineAssignments ( ) sent to instance of Person returns TRUE.
ASSIGNMENT AT CAPACITY EXCEEDED	In this substate, a Person can no longer be assigned to another machine; that is, they are AT CAPACITY with regard to machine assignment.	boolean isAvailableForMoreMachineAssignments ( ) sent to instance of Person returns FALSE.

State	*Definition*	*Query for State via*
UNASSIGNED TO JOBS	In this state a Person has not been assigned to any jobs. A Person may or may not be assigned to job(s).	boolean isAssignedToJobs ( ) or boolean isAssignedToJob (in Job aJob) [for all Jobs] sent to instance of Person returns FALSE. Person **NOT** included in set returned by PersonManager services PersonSequence allPersonsAssignedToJob (in Job aJob) [for all Jobs] or PersonSequence allAssignedToJobsPersons ( ). Empty set returned by Person service JobSequence assignedJobs( );
ASSIGNED TO JOBS	In this parent state, a Person has been assigned to one or more job(s).	boolean isAssignedToJobs ( ) or boolean isAssignedToJob (in Job aJob) sent to instance of Person returns TRUE. Person included in set returned by PersonManager services PersonSequence allPersonsAssignedToJob (in Job aJob) or PersonSequence allAssignedToJobsPersons ( ). Non-empty set returned by Person service JobSequence assignedJobs ( );
AVAILABLE FOR MORE ASSIGNMENTS	In this substate, a Person is available for assignments to more jobs.	boolean isAvailableForMoreJobAssignments ( ) sent to instance of Person returns TRUE. Person included in set returned by PersonManager service PersonSequence allPersonsAvailableForJob (in Job aJob).
ASSIGNMENT AT CAPACITY EXCEEDED	In this substate, a Person can no longer be assigned to another job; that is, they are AT CAPACITY with regard to job assignment.	boolean isAvailableForMoreJobAssignments ( ) sent to instance of Person returns FALSE. Person not included in set returned by PersonManager service PersonSequence allPersonsAvailableForJob (in Job aJob).

Table 2 Person State Transitions

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
	non-existent	createPersonWithIdentifier (in string identificationNumber); sent to an instance of PersonManager.	NOT AVAILABLE		
1	NOT AVAILABLE	makeOnShift( ); sent to instance of Person.	AVAILABLE	PersonShiftChanged event posted by instance of Person. PersonStateChanged event posted by instance of Person.	Person logged on to shift. Person is assumed to be initially available for work (at work station) and not assigned to machines or jobs.
2	AT WORK STATION	makeNotAtWorkStation ( ); sent to instance of Person.	NOT AT WORK STATION	PersonStateChanged event posted by instance of Person.	Typically used for situation where Person is not physically present at work site (e.g., on a break). Person is still assigned to machine(s) and/or job(s). Person may be busy with a job.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
3	NOT AT WORK STATION	makeAtWorkStation ( ); sent to instance of Person.	AT WORK STATION	PersonStateChanged event posted by instance of Person.	Person is physically present at work site.
4	UNASSIGNED TO MACHINES	assignToMachine (...); sent to instance of Person.	ASSIGNED TO MACHINES	PersonCapacityChanged event posted by instance of Person.	Person assigned to a machine. For example, a Scheduling Component might assign an operator to a machine.
5	AVAILABLE FOR MORE ASSIGNMENTS	Sending assignToMachine (...); to instance of Person increments number of machine assignments to AT CAPACITY level.	ASSIGNMENT AT CAPACITY EXCEEDED	PersonStateChanged event posted by instance of Person.	
6	ASSIGNMENT AT CAPACITY EXCEEDED	Sending deassignFromMachine (...); to instance of Person decrements number of machine assignments below AT CAPACITY level.	AVAILABLE FOR MORE ASSIGNMENTS	PersonStateChanged event posted by instance of Person.	
7	ASSIGNED TO MACHINES	Sending deassignFromMachine (...); decrements number of machine assignments to nil.	UNASSIGNED TO MACHINES	PersonCapacityChanged event posted by instance of Person.	Person not assigned to any machines.
8	UNASSIGNED TO JOBS	assignToJob (...); sent to instance of Person.	ASSIGNED TO JOBS	PersonCapacityChanged event posted by instance of Person.	Person assigned to job. Allocates a Person to a manufacturing task. A Person may be allocated to more than one task at a time.
9	AVAILABLE FOR MORE ASSIGNMENTS	Sending assignToJob (...); to instance of Person increments number of job assignments to AT CAPACITY level.	ASSIGNMENT AT CAPACITY EXCEEDED	PersonStateChanged event posted by instance of Person.	
10	ASSIGNMENT AT CAPACITY EXCEEDED	Sending deassignFromJob (...); to instance of Person decrements number of job assignments below AT CAPACITY level.	AVAILABLE FOR MORE ASSIGNMENTS	PersonStateChanged event posted by instance of Person.	
11	ASSIGNED TO JOBS	Sending deassignFromJob (...) decrements number of job assignments to nil.	UNASSIGNED TO JOBS	PersonCapacityChanged event posted by instance of Person.	Person not assigned to any jobs.
12	AVAILABLE	makeOffShift ( ); sent to instance of Person.	NOT AVAILABLE	PersonShiftChanged event posted by instance of Person. PersonStateChanged event posted by instance of Person.	Person logged off of shift.

6.3.5 *QualificationData Interface*

Interface:	QualificationData
Inherited Interface:	NamedEntity
Description:	This interface represents the record of training and medical examinations taken by factory personnel. Successful completion of training and medical examinations qualifies personnel for a factory operation (a skill). It is anticipated that a Factory Labor application will specialize and instantiate this interface to maintain the training and medical examination histories of factory personnel. For example, CourseQualificationData and MedicalQualificationData sub-interfaces could be defined. These sub-interfaces would exhibit most of the interesting behavior for this interface. For instance, each sub-interface could be compared with a corresponding sub-interface of the Skill Management Component interface SkillRequirement to determine certification (qualification for a skill). The attribute QualificationHistory indicates that either a specific course or a medical examination was taken; information regarding the date and time the Person tested for the qualification (when testing for a course or a medical examination occurred); and the results of that test or examination.
Exceptions:	None.
Published Events:	None.

Provided Services:

/* Set and get the qualification descriptor (an abbreviated string which serves as a "short-hand" notation for identifying the course or examination; e.g., a course number.) */

```
void setQualificationDesignator (in string designator)
        raises (FrameworkErrorSignal);
string getQualificationDesignator ( ) raises (FrameworkErrorSignal);
```

/* Set and get the history for a qualification event. Historical information indicates that either a specific course or a medical examination was taken; information regarding the date and time the Person tested for the qualification (when testing for a course or a medical examination occurred); and the results of that test or examination. */

```
void setQualificationHistory (in History qualificationHistory)
        raises (FrameworkErrorSignal);
History getQualificationHistory ( ) raises (FrameworkErrorSignal);
```

/* Return the date and time of qualification (when certification was made.) */

```
TimeStamp certificationDate ( ) raises (FrameworkErrorSignal);
```

Contracted Services: None.

Dynamic Model: None.

6.4 *Skill Management Component*

6.4.1 This component supports the management of the skill or skill set required to qualify personnel for a factory operation. Specifically, the skills required in order that personnel can assist a process resource or job in the performance of a process capability. Support is provided through association of skill requirements (training and medical examinations which must be completed) with a specific skill or skill set. Some personnel management aspect of the factory (e.g., training department) will interface with this component to define the training interface and medical examination roadmaps to achieve certification for factory operations.

6.4.2 The Skill Management Component Information Model is shown in Figure 4.

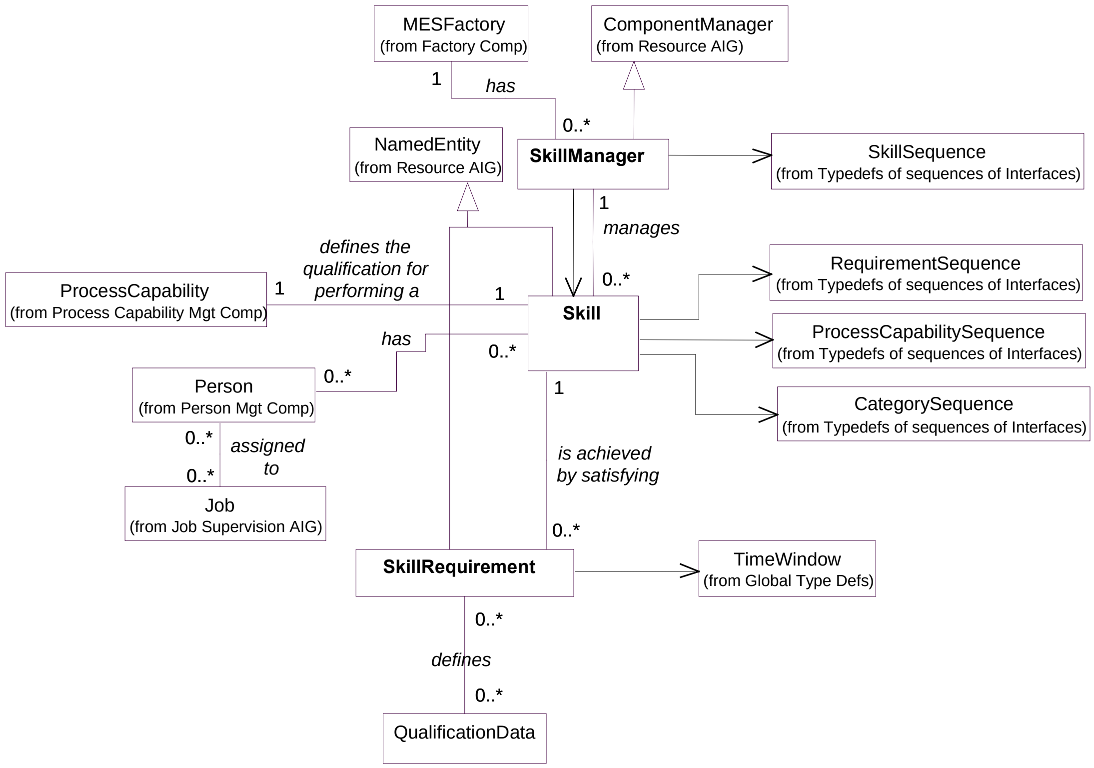


Figure 4
Skill Management Component Information Model

6.4.3 *SkillManager Interface*

Interface: SkillManager

Inherited Interface: ComponentManager

Description: This is the interface between the Skill Management Component and the rest of the CIM environment. This interface manages the skills or skill sets that personnel must possess before they are permitted to operate factory equipment. There are no limitations to the number of SkillManagers within a factory.

It is anticipated that a Factory Labor application would maintain the appropriate order (if required) of the qualifications related to a specific skill.

Exceptions:

/* This signal is raised with attempted creation of a duplicated Skill name. */

```
exception SkillDuplicateSignal {string skillName;};
```

/* This signal is raised when a removal operation fails because the Skill specified by the argument could not be located. */

```
exception SkillNotAssignedSignal {string skillName;};
exception SkillRemovalFailedSignal {string skillName;};
```

/* This signal is raised when a retrieval operation fails because the Skill specified by the argument could not be found. */

```
exception SkillNotFoundSignal {string skillName;};
```

Published Events: None.

Provided Services:

/* Create an instance of Skill and add to the list managed by this SkillManager. */

```
Skill createSkillNamed (in string skillName)
        raises (FrameworkErrorSignal, SkillDuplicateSignal);
```

/* Delete a specific skill from the list managed by this SkillManager. */

```
void removeSkillNamed (in string skillName)
        raises (FrameworkErrorSignal, SkillNotAssignedSignal,
                 SkillRemovalFailedSignal);
```

/* List the skills managed by this SkillManager. */

```
SkillSequence skills ( ) raises (FrameworkErrorSignal);
```

/* Search for an instance of Skill using its name. Raises an exception if the Skill is not found. */

```
Skill findSkillNamed (in string skillName)
        raises (FrameworkErrorSignal, SkillNotFoundSignal );
```

Contracted Services: None.

Dynamic Model: Same as inherited interface.

6.4.4 *Skill Interface*

Interface: Skill

Inherited Interface: NamedEntity

Description: This interface describes the specific Skill or set of Skills required to be held by personnel pursuant to performing factory operations. Specifically, a Skill is required in order that a Person can assist a process resource or job in the performance of a process capability. Each Skill is associated with one or more medical examination and/or training course requirements. A Skill may be associated with one or more process capabilities.

A Skill may represent a singular entity, it may categorize other Skills, or it might be categorized with other Skills. It is anticipated that a Factory Labor training application would maintain the appropriate order (if required) of a set of Skills.

Exceptions:

/* This signal is raised when a definition operation fails because the SkillRequirement specified already exists. */

```
exception SkillRequirementDuplicateSignal {string requirementName;};
```

/* This signal is raised when a removal operation fails because the SkillRequirement specified by the argument could not be located. */

```
exception SkillRequirementRemovalFailedSignal {SkillRequirement aRequirement;};
exception SkillRequirementNotFoundSignal {SkillRequirement aRequirement;};
```

/* This signal is raised when a retrieval operation fails because the SkillRequirement specified by the argument could not be located. */

```
exception SkillRequirementNotFoundSignal {string requirementName;};
```

Published Events: None.

Provided Services:

/* Get and set the Skill categories to which this Skill is associated. */

```
void setSkillCategories (in CategorySequence Categories)
        raises (FrameworkErrorSignal);
CategorySequence getSkillCategories ( ) raises (FrameworkErrorSignal);
```

/* Define a training course or medical examination necessary for obtaining an instance of Skill. */

```
SkillRequirement createSkillRequirementNamed (in string requirementName)
        raises (FrameworkErrorSignal, SkillRequirementDuplicateSignal);
```

/* Delete a training course or medical examination required for an instance of Skill. */

```
void removeSkillRequirement (in SkillRequirement aRequirement)
        raises (FrameworkErrorSignal, SkillRequirementRemovalFailedSignal,
                SkillRequirementNotFoundSignal);
```

/* Search for an instance of SkillRequirement using its name. Exception if the SkillRequirement is not found. */

```
SkillRequirement findSkillRequirementNamed (in string requirementName)
        raises (FrameworkErrorSignal, SkillRequirementNotFoundSignal);
```

/* Return the set of ProcessCapabilities to which this Skill is associated. */

```
ProcessCapabilitySequence processCapabilities ( ) raises (FrameworkErrorSignal);
```

/* List the training course or medical examination requirements that must be completed in order to be qualified for an instance of Skill. */

```
RequirementSequence requirements ( ) raises (FrameworkErrorSignal);
```

Contracted Services: None.

Dynamic Model: None.

6.4.5 *SkillRequirement Interface*

Interface: SkillRequirement

Inherited Interface: NamedEntity

Description: This interface defines training and medical examinations required to achieve a specific skill. The collection of these requirements associated with a specific skill constitutes the “roadmap” for acquiring the skill.

It is anticipated that a Factory Labor training application will specialize and instantiate this interface to maintain the training and medical examination requirements for skills. For example, CourseSkillRequirement and MedicalSkillRequirement sub-interface could be defined.

Exceptions: None.

Published Events: None.

Provided Services:

/* Set and get the complete description of this requirement. The requirement is either a training course which must be successfully completed or a medical examination that must be taken and passed. */

```
void setDescription (in string description) raises (FrameworkErrorSignal);
string getDescription ( ) raises (FrameworkErrorSignal);
```

/* Set and get the requirement descriptor. (An abbreviated string which serves as a “short-hand” notation for identifying a training course or examination; e.g., “OPS-ORIENT-1.”) */

```
void setDesignator (in string designator) raises (FrameworkErrorSignal);
string getDesignator ( ) raises (FrameworkErrorSignal);
```

/* Set and get the required training course grade which must be received or medical examination result which must be achieved for the requirement. */

```
void setRequiredResult (in string result) raises (FrameworkErrorSignal);
string getRequiredResult ( ) raises (FrameworkErrorSignal);
```

/* Return the information pertaining to the period of time in which this requirement is in effect. The information includes a starting time and a duration, from which expiration date can be computed. */

```
TimeWindow effectivity ( ) raises (FrameworkErrorSignal);
```

Contracted Services: None.

Dynamic Model: None.

APPENDIX 1
COMPLETE IDL FOR FACTORY LABOR

NOTE: The material in this appendix is an official part of SEMI E86 and was approved by full letter ballot procedures on April 15, 1999.

```
// CIM Framework References

// ********** Forward references **********

interface Job ;
interface Machine ;
interface Person ;
interface ProcessCapability ;
interface QualificationData ;
interface Resource ;
interface SkillRequirement ;
interface Skill ;

// ********** Global Type Definitions **********

typedef struct HistoryEvent_body {
        string subject ;
} HistoryEvent ;

struct ulonglong {
        unsigned long low ;
        unsigned long high ;
} ;

typedef ulonglong TimeT ;

typedef TimeT TimeStamp ;

struct IntervalT {
        TimeT lower_bound ;
        TimeT upper_bound ;
} ;

typedef IntervalT TimeWindow ;

typedef struct Shift_Structure {
        string name ;
        // ...
} Shift ;

typedef struct PersonResponsibilitystruct {
        string responsibilityCategory ;
        any responsibility ;
} PersonResponsibility;

typedef string PropertyName;
```

```
struct Property
    {
    PropertyName property_name;
    any property_value;
    };
typedef sequence<Property> Properties;

// ---------- Exceptions  ----------

exception FrameworkErrorSignal {
        unsigned long errorCode ;
        any errorInformation ;
} ;

exception InvalidStateTransitionSignal {
} ;

exception SetValueOutOfRangeSignal {
} ;

// ---------- Sequences  ----------

typedef sequence<ProcessCapability> ProcessCapabilitySequence ;
typedef stringSequence CategorySequence ;
typedef sequence<HistoryEvent> HistoryEventSequence ;
typedef sequence<Job> JobSequence ;
typedef sequence<Machine> MachineSequence ;
typedef sequence<Person> PersonSequence ;
typedef sequence<QualificationData> QualificationDataSequence ;
typedef sequence<Resource> ResourceSequence ;
typedef sequence<SkillRequirement> RequirementSequence ;
typedef sequence<PersonResponsibility> ResponsibilitySequence ;
typedef sequence<Skill> SkillSequence ;
typedef sequence<string> stringSequence ;

// ********** Base Interfaces **********

interface Job {
} ;

// ********** Factory Services **********

interface HistoryCollection {
} ;

interface History {
} ;

// ********** Factory Management **********

interface MESFactory {
} ;
```

```
// ********** Abstract Interfaces **********

interface NamedEntity {
        void setName (in string name) raises (FrameworkErrorSignal);
        string getName ( ) raises (FrameworkErrorSignal);
        boolean isNamed (in string testName) raises (FrameworkErrorSignal);
        HistoryEventSequence getHistoryEvents ( ) raises (FrameworkErrorSignal);
        HistoryCollection getHistoryCollection ( ) raises (FrameworkErrorSignal);
};

interface OwnedEntity : NamedEntity {
        void setOwner (in any owner) raises (FrameworkErrorSignal);
        any getOwner ( ) raises (FrameworkErrorSignal);
};

interface Resource : OwnedEntity {
        void startUp ( ) raises (FrameworkErrorSignal);
        void shutdownNormal ( ) raises (FrameworkErrorSignal);
        void shutdownImmediate ( ) raises (FrameworkErrorSignal);
        string resourceLevel ( ) raises (FrameworkErrorSignal);
        string nameQualifiedTo (in string resourceLevel)
                raises (FrameworkErrorSignal);
        ResourceSequence subresources ( ) raises (FrameworkErrorSignal);
        boolean isAvailable ( );
        boolean isNotAvailable ( );
};

interface ComponentManager : Resource {
        void makeRegistered (in MESFactory aFactory)
                raises (FrameworkErrorSignal,InvalidStateTransitionSignal);
        void makeNotRegistered (in MESFactory aFactory)
                raises (FrameworkErrorSignal,InvalidStateTransitionSignal);
        void makeStartingUp ( )
                raises (FrameworkErrorSignal,InvalidStateTransitionSignal);
        void makeShuttingDown ( )
                raises (FrameworkErrorSignal,InvalidStateTransitionSignal);
        void makeStopped ( )
                raises (FrameworkErrorSignal,InvalidStateTransitionSignal);
        boolean isStopped ( ) raises (FrameworkErrorSignal);
        boolean isStartingUp ( ) raises (FrameworkErrorSignal);
        boolean isShuttingDown ( ) raises (FrameworkErrorSignal);
        boolean isNotRegistered ( ) raises (FrameworkErrorSignal);
        boolean isRegistered ( ) raises (FrameworkErrorSignal);
};
```

// Person Management Component

```
module PersonManagement {

// --------------------------  PersonManager  --------------------------

interface PersonManager : ComponentManager {
```

```
exception PersonDuplicateSignal {string identificationNumber;};
exception PersonNotFoundSignal {string identificationNumber;};
exception PersonNotAssignedSignal {Person unknownPerson;};
exception PersonRemovalFailedSignal { };

const string PersonLifecycleSubject =
"/PersonManagement/PersonManager/PersonLifecycle" ;
typedef struct PersonLifecycleFilters_Structure {
        Property        name;           // "Name", aPerson's name
        Property        lifecycleEvent; // "LifecycleEvent", LifecycleState
} PersonLifecycleFilters;
typedef struct PersonLifecycleEvent_Structure {
        string                  eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonLifecycleFilters          eventFilterData;
        Properties                      eventNews;
        Person                  aPerson;
                // Except when "Delete" where value will be nil
} PersonLifecycleEvent;

const string PersonCapacityChangedSubject =
"/PersonManagement/Person/CapabilityChanged" ;
typedef struct PersonCapacityChangedFilters_Structure {
        Property        name;           // "Name", aPerson's name
} PersonCapacityChangedFilters;
typedef struct PersonCapacityChangedEvent_Structure {
        string                  eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonCapacityChangedFilters    eventFilterData;
        Properties                      eventNews;
        Person                  aPerson;
} PersonCapacityChangedEvent;

const string PersonStateChangedSubject =
        "/PersonManagement/Person/StateChanged";
enum PersonState {PersonDefined, PersonOffShift, PersonOnShift,
PersonAvailableForWork, PersonNotAvailableForWork, PersonUnassignedToMachines,
PersonAssignedToJobs, PersonAssignedToMachines,
PersonAvailableForMoreAssignments, PersonAssignmentAtCapacityExceeded,
PersonIdleWithJob, PersonBusyWithJob };
typedef struct PersonStateChangedFilters_Structure {
        Property        name;           // "Name", aPerson's name
        Property        formerState;    // "FormerState", PersonState
        Property        newState;       // "NewState", PersonState
} PersonStateChangedFilters;
typedef struct PersonStateChangedEvent_Structure {
        string                  eventSubject;
        TimeStamp                       eventTimeStamp;
        PersonStateChangedFilters       eventFilterData;
        Properties                      eventNews;
        Person                  aPerson;
} PersonStateChangedEvent;

const string PersonShiftChangedSubject =
```

```
            "/PersonManagement/Person/ShiftChanged";
        typedef struct PersonShiftChangedFilters_Structure {
                Property        name;           // "Name", aPerson's name
                Property        fromShift;      // "FromShift", former shift
                Property        toShift;        // "ToShift", new shift
        } PersonShiftChangedFilters;
        typedef struct PersonShiftChangedEvent_Structure {
                string                  eventSubject;
                TimeStamp                       eventTimeStamp;
                PersonShiftChangedFilters       eventFilterData;
                Properties                      eventNews;
                Person                  aPerson;
        } PersonShiftChangedEvent;

        Person createPersonWithIdentifier (in string identificationNumber)
                raises (FrameworkErrorSignal, PersonDuplicateSignal);
        void removePerson (in Person aPerson)
                raises (FrameworkErrorSignal,PersonRemovalFailedSignal,
                PersonNotAssignedSignal);
        PersonSequence allPersons ( ) raises (FrameworkErrorSignal);
        Person findByIdentifier (in string identificationNumber)
                raises (FrameworkErrorSignal, PersonNotFoundSignal);
        PersonSequence allOnShiftPersons (in Shift aShift)
                raises (FrameworkErrorSignal);
        PersonSequence allAvailableForWorkPersons ( )
                raises (FrameworkErrorSignal);
        PersonSequence allNotAvailableForWorkPersons ( )
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsWithSkill (in Skill aSkill)
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsAvailableForMachine (in Machine aMachine)
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsAssignedToMachine (in Machine aMachine)
                raises (FrameworkErrorSignal);
        PersonSequence allAssignedToMachinesPersons ( )
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsQualifiedForJob (in Job aJob)
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsAvailableForJob (in Job aJob)
                raises (FrameworkErrorSignal);
        PersonSequence allPersonsAssignedToJob (in Job aJob)
                raises (FrameworkErrorSignal);
        PersonSequence allAssignedToJobsPersons ( )
                raises (FrameworkErrorSignal);

}; // end PersonManager

// --------------------------  Person  --------------------------

interface Person : Resource {

        exception QualificationDuplicateSignal {
                QualificationData qualificationInformation;};
```

```
exception QualificationNotAssignedSignal {string identificationNumber;};
exception QualificationNotFoundSignal {string identificationNumber;};
exception ResponsibilityDuplicateSignal {any responsibility ;
        string responsibilityCategory;};
exception ResponsibilityCategoryNotFoundSignal {
        string responsibilityCategory;};
exception ResponsibilityCategoryRemovalFailedSignal { };
exception ResponsibilityRemovalFailedSignal {
        any responsibility;
        string responsibilityCategory;};
exception SkillDuplicateSignal {Skill aSkill;};
exception SkillRemovalFailedSignal {Skill aSkill;};
exception SkillNotAssignedSignal {Skill aSkill;};
exception SkillNotFoundSignal {Skill aSkill;};

void setDepartment (in string department)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
string getDepartment ( ) raises (FrameworkErrorSignal);
void setFullname (in string fullname)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
string getFullname ( ) raises (FrameworkErrorSignal);
void setIdentificationNumber (in string idNumber)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
string getIdentificationNumber ( ) raises (FrameworkErrorSignal);
void setMaximumAssignedJobs (in long maximumJobs)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
long getMaximumAssignedJobs ( ) raises (FrameworkErrorSignal);
void setMaximumAssignedMachines (in long maximumMachine)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
long getMaximumAssignedMachines ( ) raises (FrameworkErrorSignal);
void setShift (in Shift aShift)
        raises (SetValueOutOfRangeSignal, FrameworkErrorSignal);
Shift getShift ( ) raises (FrameworkErrorSignal);

any addResponsibility_toCategory (in any responsibility,
in string responsibilityCategory)
        raises (FrameworkErrorSignal, ResponsibilityDuplicateSignal,
                ResponsibilityCategoryNotFoundSignal );

void removeResponsibility_fromCategory (in any responsibility,
in string responsibilityCategory)
        raises (FrameworkErrorSignal, ResponsibilityRemovalFailedSignal,
                ResponsibilityCategoryRemovalFailedSignal);

ResponsibilitySequence responsibilities ( ) raises (FrameworkErrorSignal);
void addSkill (in Skill aSkill)
        raises (FrameworkErrorSignal, SkillDuplicateSignal);
void removeSkill (in Skill aSkill)
        raises (FrameworkErrorSignal, SkillRemovalFailedSignal,
        SkillNotFoundSignal);
SkillSequence skills ( ) raises (FrameworkErrorSignal);
void addQualification (in QualificationData qualificationInformation)
        raises (FrameworkErrorSignal, QualificationDuplicateSignal);
```

```
        void removeQualification (in QualificationData qualificationInformation)
                raises (FrameworkErrorSignal, QualificationNotAssignedSignal);
        QualificationData findQualificationByIdentifier (in string identifier)
                raises (FrameworkErrorSignal, QualificationNotFoundSignal);
        QualificationDataSequence qualifications ( )
                raises (FrameworkErrorSignal);
        ProcessCapabilitySequence processCapabilities ( )
                raises (FrameworkErrorSignal);
        void makeOnShift ( ) raises (FrameworkErrorSignal);
        void makeOffShift ( ) raises (FrameworkErrorSignal);
        void makeAtWorkStation ( )
                raises (FrameworkErrorSignal, InvalidStateTransitionSignal );
        void makeNotAtWorkStation ( )
                raises (FrameworkErrorSignal, InvalidStateTransitionSignal );
        boolean isOnShift ( ) raises (FrameworkErrorSignal);
        boolean isAvailableForWork ( ) raises (FrameworkErrorSignal);
        boolean isAtWorkStation ( ) raises (FrameworkErrorSignal);
        boolean hasSkill (in Skill aSkill) raises (FrameworkErrorSignal);
        boolean hasSkills ( ) raises (FrameworkErrorSignal);
        boolean isAvailableForMachine (in Machine aMachine)
                raises (FrameworkErrorSignal);
        void assignToMachine (in Machine aMachine) raises (FrameworkErrorSignal);
        void deassignFromMachine (in Machine aMachine)
                raises (FrameworkErrorSignal);
        boolean isAssignedToMachine (in Machine aMachine)
                raises (FrameworkErrorSignal);
        boolean isAssignedToMachines ( ) raises (FrameworkErrorSignal);
        MachineSequence assignedMachines ( ) raises (FrameworkErrorSignal);
        boolean isAvailableForMoreMachineAssignments ( )
                raises (FrameworkErrorSignal);
        boolean isQualifiedForJob (in Job aJob) raises (FrameworkErrorSignal);
        boolean isQualifiedForJobs ( ) raises (FrameworkErrorSignal);
        boolean isAvailableForJob (in Job aJob) raises (FrameworkErrorSignal);
        void assignToJob (in Job aJob) raises (FrameworkErrorSignal);
        void deassignFromJob (in Job aJob) raises (FrameworkErrorSignal);
        boolean isAssignedToJob (in Job aJob) raises (FrameworkErrorSignal);
        boolean isAssignedToJobs ( ) raises (FrameworkErrorSignal);
        JobSequence assignedJobs ( ) raises (FrameworkErrorSignal);
        boolean isAvailableForMoreJobAssignments ( )
                raises (FrameworkErrorSignal);

}; // end Person

// --------------------------  QualificationData  --------------------------

interface QualificationData : NamedEntity {

        void setQualificationDesignator (in string designator)
                raises (FrameworkErrorSignal);
        string getQualificationDesignator ( ) raises (FrameworkErrorSignal);
        void setQualificationHistory (in History qualificationHistory)
                raises (FrameworkErrorSignal);
        History getQualificationHistory( ) raises (FrameworkErrorSignal);
```

```
        TimeStamp certificationDate ( ) raises (FrameworkErrorSignal);

}; // end QualificationData

}; // end PersonManagement
```

// Skill Management Component

```
module SkillManagement {

// -------------------------  SkillManager  -------------------------

interface SkillManager : ComponentManager {

        exception SkillDuplicateSignal {string skillName;};
        exception SkillNotAssignedSignal {string skillName;};
        exception SkillRemovalFailedSignal {string skillName;};
        exception SkillNotFoundSignal {string skillName;};

        Skill createSkillNamed (in string skillName)
                raises (FrameworkErrorSignal, SkillDuplicateSignal);
        void removeSkillNamed (in string skillName)
                raises (FrameworkErrorSignal, SkillNotAssignedSignal,
                SkillRemovalFailedSignal);
        SkillSequence skills ( ) raises (FrameworkErrorSignal);
        Skill findSkillNamed (in string skillName)
                raises (FrameworkErrorSignal, SkillNotFoundSignal );

}; // end SkillManager

// -------------------------  Skill  -------------------------

interface Skill : NamedEntity {

        exception SkillRequirementDuplicateSignal {string requirementName;};
        exception SkillRequirementRemovalFailedSignal
                {SkillRequirement aRequirement;};
        exception SkillRequirementNotFoundSignal {string requirementName;};

        void setSkillCategories (in CategorySequence Categories)
                raises (FrameworkErrorSignal);
        CategorySequence getSkillCategories ( ) raises (FrameworkErrorSignal);
        SkillRequirement createSkillRequirementNamed (in string requirementName)
                raises (FrameworkErrorSignal, SkillRequirementDuplicateSignal);
        void removeSkillRequirement (in SkillRequirement aRequirement)
                raises (FrameworkErrorSignal, SkillRequirementRemovalFailedSignal,
                SkillRequirementNotFoundSignal);
        SkillRequirement findSkillRequirementNamed (in string requirementName)
                raises (FrameworkErrorSignal, SkillRequirementNotFoundSignal);
        ProcessCapabilitySequence processCapabilities ( )
                raises (FrameworkErrorSignal);
        RequirementSequence requirements ( ) raises (FrameworkErrorSignal);
```

```
}; // end Skill

// -------------------------  SkillRequirement  -------------------------

interface SkillRequirement : NamedEntity {

        void setDescription (in string description) raises (FrameworkErrorSignal);
        string getDescription ( ) raises (FrameworkErrorSignal);
        void setDesignator (in string designator) raises (FrameworkErrorSignal);
        string getDesignator ( ) raises (FrameworkErrorSignal);
        void setRequiredResult (in string result) raises (FrameworkErrorSignal);
        string getRequiredResult ( ) raises (FrameworkErrorSignal);
        TimeWindow effectivity ( ) raises (FrameworkErrorSignal);

}; // end SkillRequirement

}; // end SkillManagement
```

SEMI E87-0702
SPECIFICATION FOR CARRIER MANAGEMENT (CMS)

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published September 1999; previously published March 2002.

1 Purpose

1.1 This document provides a standardized behavior for host view communication with production equipment during the coordination, execution, and completion of automated and manual carrier transfers to and from the equipment and, if it exists, its internal buffer space.

2 Scope

2.1 This is a standard that covers host and equipment communication for SEMI E15.1 300 mm load ports.

2.2 The scope of this document is to define standards that facilitate the host's knowledge and role in automated and manual carrier transfers, as well as internal buffer equipment carrier transfers. Specifically, this document provides state models and scenarios that define the host interaction with the equipment for the following:

- Carrier transfer between AMHS vehicles and production equipment load ports.
- Carrier transfers to/from production equipment internal buffer space.
- Equipment and load port access mode switching.
- Carrier to load port association.
- CarrierID verification and Carrier slot map verification.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard applies to semiconductor equipment with SEMI E15.1 compliant load ports. It may also be applied to other manufacturing equipment that supports automated carrier transfers, and/or contains an internal buffer. This standard is intended to be used for production equipment. It may or may not be applied to other types of equipment. Also, stocker load ports are not addressed by this standard.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concept, Behavior, and Services

SEMI E41 — Exception Management (EM) Standard

SEMI E53 — Event Reporting

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

SEMI E90 — Specification for Substrate Tracking

SEMI E99 — Carrier ID Read/Write Functional Standard

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGT* — Automated Guided Transport

5.1.2 *AGV*— Automated Guided Vehicle

5.1.3 *AMHS* — Automated Material Handling System

5.1.4 *FIMS* — Front-Opening Interface Mechanical Standard

5.1.5 *FOUP* — Front Opening Unified Pod

5.1.6 *GEM* — Generic Equipment Model

5.1.7 *OHT* — Overhead Hoist Transport

5.1.8 *PGV* — Person Guided Vehicle

5.1.9 *PIO* — Parallel Input/Output Interface

5.1.10 *RGT* — Rail Guided Transport

5.1.11 *RGV* — Rail Guided Vehicle

5.2 *Definitions*

5.2.1 *Automated Material Handling System* — an automated system to store and transport materials within the factory.

5.2.2 *automation* — the degree to which activities of machines or production systems are self-acting. In this standard automation provides methods that will reduce the amount of operator intervention required.

5.2.3 *buffer* — a set of one or more locations for holding carriers at/inside the production equipment.

5.2.4 *carrier* — a container, such as a FOUP or open cassette, with one or more positions for holding substrates.

5.2.5 *CarrierID* — a readable and unique identifier for the carrier.

5.2.6 *CarrierID read* — the process of the equipment reading the CarrierID from the carrier.

5.2.7 *carrier ID tag (tag, ID tag)* — a physical device for storing Carrier ID and other information. There are two basic types of tags, read-only tags and read/write tags. [SEMI E99]

5.2.8 *Collection Event* — a collection event is an event (or grouping of related events) on the equipment that is considered to be significant to the host.

5.2.9 *docked position* — the position where the carrier is ready for substrate extraction or insertion.

5.2.10 *FIMS port* — the substrate access port where the FOUP is opened and closed.

5.2.11 *fixed buffer equipment* — production equipment that has only fixed load ports and no internal buffer for carrier storage. Substrates are loaded and unloaded directly from the carrier at the load port for processing.

5.2.12 *host* — the factory computer system or an intermediate system that represents the factory and the user to the equipment.

5.2.13 *internal buffer* — a set of locations within the equipment to store carriers. These locations exclude load ports.

5.2.14 *internal buffer equipment* — equipment that uses an internal buffer.

5.2.15 *load* — the operation of placing a carrier on a load port.

5.2.16 *load port* — the interface location on the equipment where carriers are loaded and unloaded.

5.2.17 *object instantiation* — the act of storing of information related to a physical or logical entity so that it can be recalled on demand based on its public identifier.

5.2.18 *on-line equipment* — equipment that is connected to, and able to communicate fully with, the host.

5.2.19 *process equipment* — equipment used to produce product, such as semiconductor devices. This excludes metrology and material handling equipment.

5.2.20 *production equipment* — equipment used to produce product, such as semiconductor devices, including substrate sorting, process, and metrology equipment and excluding material handling equipment.

5.2.21 *properties* — a set of name value pairs assigned to an object or used in a service message to include additional information about the object (i.e., carrier, port, etc.).

5.2.22 *re-initialization* — a process where production equipment is either powered off then on or when some kind of hardware or software reset is initiated to cause the equipment to reset and possibly reload its software. On production equipment that contains some kind of mass storage device this can also be called a “reboot”.

5.2.23 *read position* — any position on a load port or in an internal buffer from which the tag on a carrier can be read.

NOTE 2: This position may vary on any particular equipment depending on the read technology selected by the end user. Some technology/load ports may allow the carrier to be moved during reading. Equipment may have more than one read position.

5.2.24 *single communication connection* — exactly one physical connection using exactly one logical session and a standard set of messages.

5.2.25 *slot map* — the information that relates which slots in a carrier hold substrates, both correctly and incorrectly.

5.2.26 *slot map read* — the process of the equipment reading the slot map for substrate position and placement within the carrier.

5.2.27 *standard message set* — messages conforming to standard message specifications.

5.2.28 *substrate* — material held within a carrier. This can be product, or durables such as reticles.

5.2.29 *substrate port* — the carrier location from which substrates are accessed by the equipment.

5.2.30 *transfer unit* — maximum number of carriers allowed in a specific transfer service:

- AA is the maximum number of carriers allowed for acquisition at the transfer source.

- BB is the maximum number of carriers allowed for deposit at the transfer destination.
- CC is the maximum number of carriers allowed for transfer in one transport vehicle.

The transfer unit is the minimum of AA, BB, and CC.

5.2.31 *undocked* — the status of a carrier on a load port or in an internal buffer that is not at the docked position.

5.2.32 *unload* — the operation of removing a carrier from a load port.

5.2.33 *write position* — any position on a load port or in an internal buffer from which the tag on a carrier can be written to. This position may vary on any particular equipment depending on the write technology selected by the end user. Some technology/load ports may allow the carrier to be moved during writing. The read position and the write position may or may not be the same position.

6 Requirements

6.1 Carrier Management Standard (CMS) compliant equipment is required to provide certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and equipment control. These requirements shall be satisfied through compliance to the following sets of standards:

6.2 Generic Equipment Model Standard (GEM) SEMI E30

- Event Notification
- Status Data Collection
- Equipment Constants
- Alarm Management
- Equipment Control

6.3 Object-Based Standards

- Object Services Standard (SEMI E39)
- Event Reporting (SEMI E53)
- Exception Management (SEMI E41)

7 Conventions

7.1 *Objects*

7.1.1 Whenever the equipment is required to know about specific kinds of entities, and required to manage information concerning these entities, it is useful to treat these entities as objects that comply with the basic requirements of SEMI E39 Object Services Standard (OSS). This is especially true whenever there are a large number of objects of a given type or when the entities are transient rather than permanent. In both cases, it is difficult to describe a general way for the host and equipment to specify which particular entity is referenced and to get information related only to a specific one out of many.

7.1.2 By defining these entities as objects that comply with OSS, it is only necessary for the host to specify the type of object and its specific identifier in order to inquire about one or more properties of the specific entity of interest.

7.1.3 *Object Properties*

7.1.3.1 A property (attribute) is information about an individual object that is presented as a name/value pair. The name is a formally reserved text string that represents the property, and the value is the current setting for that property.

7.1.3.2 Properties shall be accessible to the host via the service GetAttr and SetAttr for the Carrier and Carrier Location objects. Using SEMI E39 Object Services Standard, for example, it is possible to:

- get the list of IDs for the current carriers at the equipment, and
- get the specified properties for one or more individual carriers.

7.1.4 *Rules for Object Properties*

- Attributes with RO access can not be changed using SetAttr service as defined in OSS.
- Attributes with RW access can be changed using SetAttr service as defined in OSS.
- Additional attributes may be specified by the user or the equipment supplier by using an attribute name starting with “UD” (User Defined). Care should be taken to ensure the name of the attribute is unique.

7.1.5 *Object Attribute Table*

7.1.5.1 The object attribute table is used to list all the attributes related to the defined object as shown below the access is defined as Read only (RO) or Read/Write (RW). The REQD column is used to specify whether the attribute is required for implementation. Finally, the Form column is used to specify the format of that particular attribute.

Table 1 Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text = "Carrier"

7.2 *State Model Methodology*

7.2.1 A state model has three elements: definitions of each state and sub-state, a diagram of the states and the transitions between states, and a state transition table. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an Appendix of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.[1]

7.2.2 *State Model Requirements*

The state models included in this standard are a requirement for CMS compliance. A state model consists of a state model diagram, state definitions, and a state transition table. All state transitions in this standard, unless otherwise specified, shall correspond to collection events. More explicitly, there must be a unique collection event for each state transition.

7.2.2.1

7.2.2.2 Equipment must maintain state models for each of the required state models as defined in this document. Equipment shall maintain individual and unique state models for each logical entity instantiated or physical entity in the equipment that has state models associated with it. The event identifier reported during a particular state transition change for each of these state models shall be shared for all associated state models but unique for each transition. For example, if the equipment has two load ports and the load port state model defines 10 transitions, there must be exactly 10 event identifiers for each load port transfer state model but not 10 for each physical load port. The information identifying the physical entity or logical entity undergoing the transition will be contained within the associated event report.

7.2.2.3 A state model represents the host' s view of the equipment, and does not necessarily describe the internal equipment operation. All CMS state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the CMS state model for transition to another state. In this case, the equipment makes the required transition without any additional actions in this situation.

7.2.2.4 Some equipment may need to include additional sub-states other than those in this standard. Additional sub-states may be added, but shall not change the CMS defined state transitions. All expected transitions between CMS states shall occur.

7.2.2.5 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

- Actions taken upon exit of the previous state.
- Actions taken upon entry of the new state.

---

1 Elsevier Science, P. O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

- Actions taken which are most closely associated with the transition.

7.2.2.6 When a state model is defined with multiple AND sub-states, the equipment may report all state entry events with only one collection event. When conditional paths are defined in the state model, it is not necessary to report any state transition(s) until a terminal state is reached at which time each transition used to reach that state is reported.

Table 2 State Transition Table

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

7.3 *Services*

7.3.1 Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message that does not require a response.

7.3.2 *Service Message Description*

7.3.2.1 A service message description table defines the parameters used in a service, as shown in the following table:

Table 3 Service Message Description Table

Service Name	*Type*	*Description*

Type can be either "N" = Notification or "R" = Request & Response.

7.3.2.2 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

7.3.3 *Service Message Parameter Definition*

7.3.3.1 A service parameter dictionary table defines the description, range, and type for parameters used by services, as shown in the following table:

Table 4 Service Message Parameter Definition Table

Parameter Name	*Form*	*Description*

A row is provided in the table for each parameter used on a service.

7.3.4 *Service Message Definition*

7.3.4.1 A service message description table defines the parameters used in a service message. It also describes each message and its cause/effect to the equipment. The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message.

Service Parameter	*Req/Ind*	*Resp/Conf*	*Description*

7.3.4.2 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication". The receiver may then send a "Response", which the original sender terms the "Confirmation".

7.3.4.3 The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M"	Mandatory Parameter – must be given a valid value.
"C"	Conditional Parameter – may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the values of other parameters.
"U"	User-Defined Parameter.
"-"	The parameter is not used.
"="	(for response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7.4 *Alarm Requirements Definition*

7.4.1 An alarm requirements definition table defines the specific set of alarms required by CMS. The table is divided up by equipment configuration, and then by alarm. The danger and affected columns are marked with "X" characters to show each alarm and its possible impact to operators, equipment, and material. The table format is shown in the following example:

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
Configuration 1	Alarm 1	X		X	X	X
	Alarm 2		X			X
Configuration 2	Alarm 3	X		X	X	
	Alarm 4	X			X	X

8 Overview

8.1 CMS defines the behavior, data, and services required for equipment supporting automated carrier transfer. This document provides a standard interface for host/equipment communications regarding the transfer of carriers. The standardized carrier transfer host interface includes not only transfers to and from the external load ports, but also transfers to and from the internal buffer positions on internal buffer type equipment.

8.2 *Single Connection Requirement*

8.2.1 The expectation of the production equipment supplier is that this standard be implemented in conjunction with the GEM interface to their production equipment and without the use of a separate communication connection.

9 Load Port

9.1 A load port (port) is used by the factory to load and unload carriers to and from production equipment. A load port may be used as an input load port, an output load port, or as an input/output load port, depending upon equipment type, configuration and/or factory practices. This classification may be fixed or it may be programmable by the user. A load port is generally designed to handle one specific carrier type, such as substrate cassettes, leadframe magazines, SMIF pods, or FOUPs.

9.2 *Load Port Numbering*

9.2.1 The load port number shall be assigned incrementally from the bottom left to bottom right, then top left to top right when facing the front of the equipment. The load port numbering requirement is to provide a common reference base to external entities, such as humans.

9.3 *Carrier Slot Numbering*

9.3.1 The slot numbers for a carrier shall be assigned incrementally from the bottom, starting with "1."

9.4 *Load Port Resource Sharing*

9.4.1 A model of a load port must account for any mechanical assemblies that are either active during carrier transfer or are capable of interacting with the transfer. The load port is responsible for such mechanisms when the load port is in the TRANSFER READY state. If these mechanisms are shared with other load ports, then the sharing must be coordinated.

9.5 *Load Port Transfer State Model*

9.5.1 The purpose of the Load Port Transfer State Model is to define the host view of a carrier transfer, which includes the host interactions with the equipment necessary to transfer carriers to and from equipment load ports. Each load port on the equipment shall maintain an independent instance of this state model.

9.5.2 *Load Port Transfer State Model Diagram*

9.5.2.1 Figure 1 is the diagram for the Load Port Transfer State Model.

9.5.3 *Load Port Transfer State Definitions*

9.5.3.1 LOAD PORT TRANSFER — The super state for the IN SERVICE and OUT OF SERVICE states.

9.5.3.2 OUT OF SERVICE — Transfer to/from this load port is disabled. A transition to IN SERVICE is required to continue using this load port for transfers.

9.5.3.3 IN SERVICE — Transfer to/from this load port is enabled. A transition to OUT OF SERVICE disables the load port for transfer use.

9.5.3.4 TRANSFER READY — A sub-state of IN SERVICE. The load port is available for carrier transfer. The transfer can either be manual or automated, and can be a load or an unload. This state contains two sub-states, which are used depending on whether or not a carrier is present on the load port (READY TO LOAD and READY TO UNLOAD).

9.5.3.5 READY TO LOAD — A sub-state of TRANSFER READY. When transitioning to the TRANSFER READY state, if a carrier is not present on the specified load port, this is the active sub-state. In this state, the load port is available to be loaded with an external carrier, or with a carrier that is currently located inside the equipment (i.e. internal buffer).

9.5.3.6 READY TO UNLOAD — A sub-state of TRANSFER READY. When transitioning to the TRANSFER READY state, if a carrier is present on the specified load port, this is the active sub-state. In this state, the load port is available for unloading of a carrier from the loadport to material handling equipment. When the load port is being used by the equipment, the state shall transition to TRANSFER BLOCKED.

9.5.3.7 TRANSFER BLOCKED — The carrier transfer state is neither READY TO LOAD nor READY TO UNLOAD. Because of load port related activity being performed, transfer is not available to/from this load port at this time.

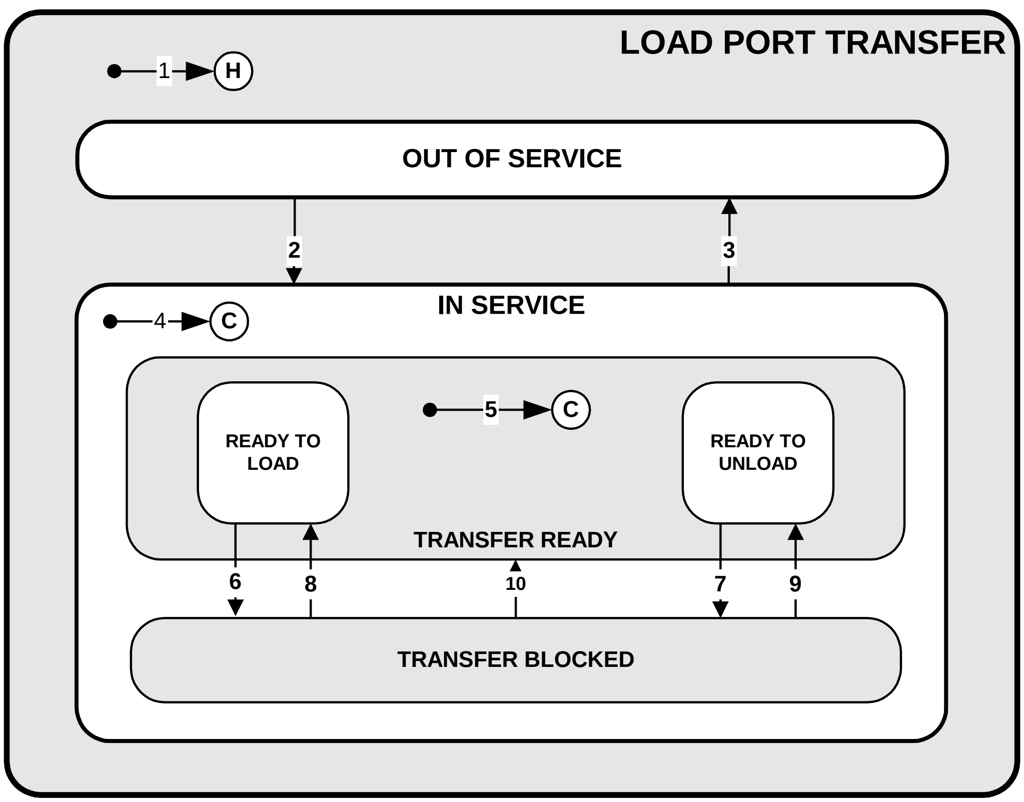


Figure 1
Load Port Transfer State Model Diagram

9.5.4 *Load Port Transfer State Transition Table*

Table 5 Load Port Transfer State Transition Definition

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	OUT OF SERVICE or IN SERVICE (History)		This transition is based on what the current transfer status was prior to system reset. Data required to be available for this event report: PortID PortTransferState
2	OUT OF SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE.	IN SERVICE		Load port is now usable for transfer. Data required to be available for this event report: PortID PortTransferState
3	IN SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of OUT OF SERVICE.	OUT OF SERVICE		Load port is now rendered unusable for transfer. Attempted usage of the load port for carrier transfer after the state transition results in an alarm. Data required to be available for this event report: PortID PortTransferState
4	IN SERVICE	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization.	TRANSFER READY or TRANSFER BLOCKED		This is the default entry into IN SERVICE. The state is TRANSFER BLOCKED if the carrier, or load port, is not available for carrier transfer. Otherwise, the state is TRANSFER READY. Data required to be available for this event report: PortID PortTransferState
5	TRANSFER READY	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization. *Failed Transfer:* If a transfer fails, this transition is activated by transition #10.	READY TO LOAD or READY TO UNLOAD		When entering the TRANSFER READY state, if a carrier is present, the sub-state is READY TO UNLOAD, else the sub-state is READY TO LOAD. If the state is READY TO LOAD, data required to be available for this event report: PortID If the state is READY TO UNLOAD, data required to be available for this event report: PortID CarrierID PortTransferState

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
6	READY TO LOAD	*Manual*: The equipment recognizes the logical indication of the start of a manual load transfer. This trigger is configurable by the user, examples are included in table 8. *Automated*: The PIO load transfer is beginning and the PIO "READY" signal is activated (see SEMI E84). *Internal Buffer:* A CarrierOut service has started for this load port.	TRANSFER BLOCKED		When a CarrierOut service is queued and the equipment load port is currently in the TRANSFER BLOCKED state, the equipment shall keep the load port in the TRANSFER BLOCKED state. Data required to be available for this event report: PortID PortTransferState
7	READY TO UNLOAD	*Manual*: The equipment recognizes the logical indication of the start of a manual unload transfer. This trigger is configurable by the user, examples are included in table 8. *Automated*: The PIO unload transfer is beginning and the PIO "READY" signal is activated (see SEMI E84). *Internal Buffer:* A CarrierIn service has started for this load port. *By CarrierReCreate Service:* A CarrierReCreate service command has been issued by host or operator on a carrier currently in the 'CarrierComplete' or 'Carrier Stopped' state.	TRANSFER BLOCKED		When a CarrierOut service is queued and the equipment load port is currently in the TRANSFER BLOCKED state, the equipment shall keep the load port in the TRANSFER BLOCKED state. Data required to be available for this event report: PortID PortTransferState
8	TRANSFER BLOCKED	*Manual:* The carrier unload transfer has completed, and the load port is now empty and ready for load transfer. This is indicated when two conditions are met, the presence signal indicates that no carrier is present and the operator has logically indicated that the transfer is complete. *Automated:* The PIO unload transfer ends with the PIO "COMPT" signal (see SEMI E84). *Internal Buffer:* The carrier has finished its move from the load port into the internal buffer, and no CarrierOut services are queued for this load port.	READY TO LOAD		A carrier can now be loaded onto the load port from either an external entity, or by the equipment's internal material handling resource. Data required to be available for this event report: PortID PortTransferState

Num	Previous State	Trigger	New State	Actions	Comments
9	TRANSFER BLOCKED	*Manual:* Processing for substrates contained within the carrier has completed, or a CancelCarrier/ CancelCarrierAtPort service has been issued, and the carrier has returned to the load/unload position on the load port. *Automated:* Processing for the substrates belonging to the carrier has completed, or a CancelCarrier/CancelCarrier-AtPort service has been received, and the carrier has returned to the load/unload position. *Internal Buffer:* A carrier has completed its move from the internal buffer to the load port.	READY TO UNLOAD		The carrier on the load port can now be unloaded from the load port to an external entity. Data required to be available for this event report: PortID CarrierID PortTransferState
10	TRANSFER BLOCKED	The transfer was unsuccessful, and the carrier was not loaded or unloaded.	TRANSFER READY		The sub-state of TRANSFER READY which is decided by transition #5. Data required to be available for this event report: PortID PortTransferState

10 Carrier Object

10.1 Information about a carrier is encapsulated as an object. This allows the host to exchange information with the equipment about one or more specific carriers using services defined in SEMI E39, Object Services Standard. A carrier has properties (attributes) that are defined in Table 6, Carrier Attribute Definition.

10.2 *Object Instantiation*

10.2.1 The carrier object is a software representation of the carrier in the equipment. Under normal circumstances this object is instantiated by the equipment when the host uses the Bind or Carrier Notification service or when the equipment successfully reads the carrierID from the carrier. A carrier object is instantiated by carrierID read only if there are no currently existing objects with the carrierID just read. A carrier object can also be instantiated by either the ProceedWithCarrier or CancelCarrier Services on an NOT ASSOCIATED port. (This implies a failed carrierID read event.) The ContentMap attribute will be an empty list (a list of zero) when the instantiation is done by CarrierID read. The SlotMap attribute should be a list consisting of all slots enumerated as “UNDEFINED” when the carrier object is instantiated by CarrierID read.

10.2.2 From the host point of view, an object is instantiated if the host is able to query the equipment about that object, it' s current state, and other attributes. Once instantiated, the object is considered destroyed (no longer instantiated) if the response to such queries is “unknown object”.

10.2.3 Summary of carrier object instantiation:

1. Bind or Carrier Notification or CarrierReCreate (with PropertiesList) service;
2. CarrierID read with no currently existing carrier objects having the carrierID just read; and
3. ProceedWithCarrier or CancelCarrier Service on an NOT ASSOCIATED port with a carrier.

10.2.4 *Carrier Object Identifier (ObjID)*

10.2.4.1 The purpose of an Object Identifier is to allow references to an object within the system. The object identifier is created when an object is instantiated and should be unchanged or persistent until the end of the object lifecycle. The Object Identifier shall be unique at the equipment during lifecycle of the object. The Carrier ID is the Carrier Object Identifier. The equipment is responsible for ensuring uniqueness of the Carrier ID prior to instantiation by the bind service.

10.2.5 *Carrier Object Destruction*

10.2.5.1 Normally, the Carrier Object reaches the end of its lifecycle when the carrier is unloaded from the equipment. Abnormally, the Carrier Object reaches the end of it’s lifecycle when a CancelBind or CancelCarrierNotification service is executed prior to the carrier being loaded, or when an equipment based carrier verification fails following carrier instantiation by the bind service.

10.2.5.2 Summary of carrier object destruction:

1. A carrier is unloaded from the equipment;
2. A CancelBind or CancelCarrierNotification service is received; and
3. An equipment based CarrierID verification fails after a carrier object was previously instantiated with a "Bind" service (Equipment initiated CancelBind).
4. The host or operator has issued a CarrierReCreate service.

10.3 *Carrier Attribute Definitions*

10.3.1 The following table contains the attributes that are of importance to the host and/or the equipment in order to manage the history and the reports about the carrier object.

10.3.2 *REQD Column*

10.3.2.1 All attributes in the following table are required to be associated with the carrier object and are always maintained and updated by the equipment (for example, if the equipment has a waferID reader, the equipment can determine the ContentMap).

10.3.3 *ACCESS Column*

10.3.3.1 Even though a value may be marked as RO (read only), the initial value for the attribute may be provided by the host when attached to either the Bind or ProceedWithCarrier services.

10.3.4 *Carrier Attribute Definition Table*

Table 6 Carrier Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
Capacity	Maximum number of substrates a carrier can hold.	RO	Y	Positive integer.
CarrierIDStatus	Current state of the carrier ID verification.	RO	Y	Enumerated: ID NOT READ, [ID] WAITING FOR HOST, ID VERIFICATION OK, ID VERIFICATION FAILED.
CarrierAccessingStatus	The current accessing state of the carrier by the equipment. The current substate of the CarrierAccessingStatus state model.	RO	Y	Enumerated: NOT ACCESSED, IN ACCESS, CARRIER COMPLETE, CARRIER STOPPED
ContentMap	Ordered list of lot and substrate identifiers corresponding to slot 1,2,3,…n	RO	Y	Ordered list of n structures, where n is equal to the value of "Capacity" above, and each structure consists of a LotID and SubstrateID. List of Structure LotID SubstrateID When no Lot ID is provided by the host, the LotID value should be null. When a slot has no substrate or the host does not know substrate identifier, the LotID and SubstrateID value should be null.
LocationID	Identifier of current location.	RO	Y	Text 1 to 80 characters.
ObjType	Object type.	RO	Y	Text 1 to 40 characters equal to "Carrier".
ObjID	Object identifier.	RO	Y	Text 1 to 80 characters equal to the CarrierID.

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
SlotMap	Ordered list of slot status as provided by the host and corresponding to slot 1,2,3‥n until a successful slot map read, then as read by the equipment.	RO	Y	Ordered list of n, where n is equal to the value of “Capacity” above, each value in the list is enumerated Enumerated Enumerated: UNDEFINED, EMPTY, NOT EMPTY, CORRECTLY OCCUPIED, CROSS SLOTTED, DOUBLESLOTTED. (NOT EMPTY provided for equipment that cannot detect incorrectly slotted substrates)
SlotMapStatus	Current state of slot map verification.	RO	Y	Enumerated: SLOT MAP NOT READ, [SLOT] WAITING FOR HOST, SLOT MAP VERIFICATION OK, SLOT MAP VERIFICATION FAILED.
SubstrateCount	The number of substrates currently in the carrier.	RO	Y	Non negative integer less than or equal to the Capacity.
Usage	The type of material contained in the carrier (i.e., TEST, DUMMY, PRODUCT, FILLER, etc.).	RO	Y	Text as defined by the Equipment.

NOTE 1: NOT EMPTY is included to indicate presence for equipment that is only able to detect substrate presence but not correct positioning of the substrate slot. For equipment that can detect incorrect positioning such as cross-slotted or double slotted, NOT EMPTY may not be applicable.

10.3.5 *Rules for Carrier Attributes*

- The equipment shall change object attributes, Capacity, ContentMap, SlotMap, Substrate count and Usage, provided by the host. All other attributes, such as LocationID, shall be set and maintained by the equipment.
- The attributes, Capacity, ContentMap, Substrate count and Usage, shall be provided with Bind, CarrierNotification, or ProceedWithCarrier service before or when SlotMap is provided.
- The SlotMap shall be provided with Bind, CarrierNotification, or ProceedWithCarrier to verify CarrierID, when the SlotMap verification is equipment based. And it shall not be provided when the SlotMap verification is host based.
- Carrier properties may be provided before the carrier arrives as part of the Bind service and should be retained until either a CancelBind service is received or the carrier is removed.
- Carrier properties may also be provided by the ProceedWithCarrier service. The carrier properties that are provided by the ProceedWithCarrier service may differ based whether or not the object is instantiated by the service.
- Carrier properties that are required shall be actively updated by the equipment.

10.3.6 *Carrier Location*

10.3.6.1 A carrier location, signified by LocationID, is used for tracking carriers as they move through the equipment. A carrier location is any physical area that is capable of holding a carrier. It is not intended to represent entire mechanisms, which may have a variety of other properties of interest, but only that portion where a Carrier may rest.

10.3.7 *Carrier Location Examples*

10.3.7.1 Carrier Locations include load port locations, substrate port locations, internal buffer locations, as well as grippers, conveyors, and elevators that are used internally for moving the carrier from one fixed location to another.

10.4 *Carrier Location Naming*

10.4.1 Carrier locations shall be assigned a unique name. Information about the carrier location can be obtained by querying the CarrierObject for the LocationID or by asking the equipment for the CarrierLocation-Matrix. The text form of the LocationID shall be descriptive of the location. For example, LocationID form for load port load/unload location might be “LPn”, where “n” equal is equal to the load port number (the load port number is determined through the numbering rule in Section 9.1). The LocationID form for the FIMS port location might be “FIMSn”. The LocationID form for a buffer location might be “BUFn”.

10.5 *Load Port Carrier Locations*

10.5.1 For fixed buffer equipment configured to handle FOUPs, a Load Port has two different Carrier Locations. One represents the place where a Carrier is delivered and picked up, while the other represents the place where the Carrier is docked and can be opened.

10.6 *Carriers Between Locations*

10.6.1 When the carrier is traveling from one location to another, the location attribute remains equal to the source location until the carrier movement is complete and the carrier is resting at the new carrier location (the destination location).

10.6.2 *Usage*

10.6.2.1 The Usage parameter indicates the type of substrate the carrier contains. All Usage values are equipment specific values. Some internal buffer equipment manages carriers by establishing logical partitions. This type of equipment shall use the Usage parameter to determine which logical partition where the carrier is held.

10.6.3 *SubstrateCount*

10.6.3.1 The SubstrateCount parameter can be sent to the equipment by the host in either the Bind service or the ProceedWithCarrier service. However the equipment shall update this parameter based on the results of the read slot map operation. Furthermore, the equipment shall update the parameter based on it's own actions of adding and removing a substrate to and from a carrier. If the equipment does not know the value of SubstrateCount prior to instantiation, the equipment shall instantiate the carrier object with the value of null for SubstrateCount.

10.6.4 *Lot information for ContentMap*

10.6.4.1 Lot is defined in SEMI E90 as a group of one or more substrates of the same type. It is organized external to the equipment. The Lot ID is the identifier of this group. If the equipment is informed of the Lot ID to which a substrate belongs, the equipment must maintain this information.

10.6.5 *Carrier Accessing Status*

10.6.5.1 The CarrierAccessingStatus is used by the host to know whether or not the carrier owned by the equipment can be moved out. If the carrier is within the internal buffer equipment, this status may be used by the host to issue CarrierOut service.

10.7 *Carrier State Model*

10.7.1 The purpose of the Carrier State Model is to define the host's view of a carrier. The equipment shall maintain a separate and independent state model for each carrier in/at the equipment.

10.7.2 *Carrier State Model Diagram*

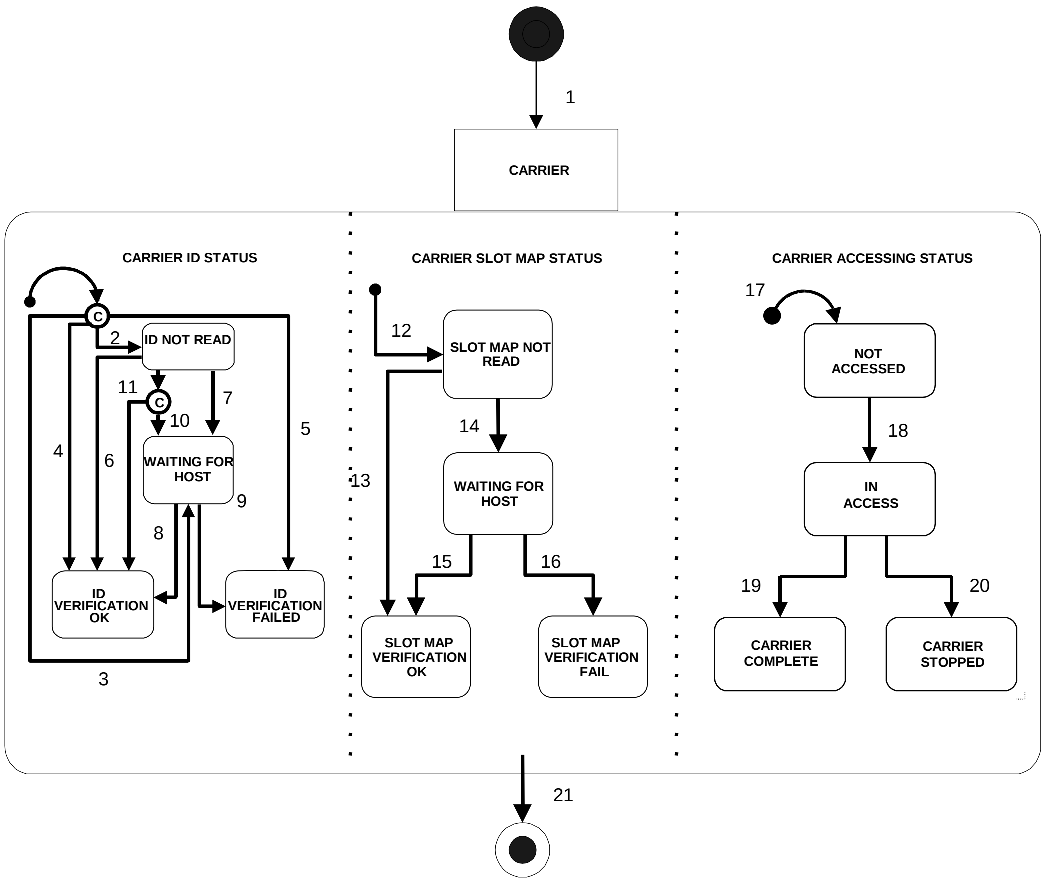


Figure 2
Carrier State Model Diagram

10.7.3 *Carrier State Definitions*

10.7.3.1 *CARRIER* — The CARRIER state has three ANDed (orthogonal) states: CARRIER ID STATUS, CARRIER SLOT MAP STATUS and CARRIER ACCESSING STATUS.

10.7.3.2 *CARRIER ACCESSING STATUS* — This is a substate of CARRIER and indicates the current accessing status of the carrier. It has four substates, NOT ACCESSED, IN ACCESS, CARRIER COMPLETE, and CARRIER STOPPED. The initial default entry substate is NOT ACCESSED.

10.7.3.2.1 *NOT ACCESSED* — This is a substate of CARRIER ACCESSING STATUS and is active when access by the equipment to the carrier has not been started. The carrier can be moved out.

10.7.3.2.2 *IN ACCESS* — This is a substate of CARRIER ACCESSING STATUS and is active when access by the equipment to the carrier has been started but has not been finished, and the carrier should not be moved out.

10.7.3.2.3 *CARRIER COMPLETE* — This is a substate of CARRIER ACCESSING STATUS and is active when the access by the equipment to the carrier has been finished, and the carrier should be moved out. This is a final state.

10.7.3.2.4 *CARRIER STOPPED* — This is a substate of CARRIER ACCESSING STATUS and is active when the access by the equipment to the carrier has been stopped abnormally, and the carrier should be moved out. This is a final state.

10.7.3.3 *CARRIER ID STATUS* — This is a substate of CARRIER and indicates the current status of the carrier with respect to its identifier. It has four substates, ID NOT READ, WAITING FOR HOST, ID VERIFICATION FAILED, ID VERIFICATION OK. The initial substate is conditional based on information the equipment has about the carrier. When the carrierID is provided by the Bind or the Carrier Notification service, the carrier object shall be instantiated in the ID NOT READ substate. When the carrierID is provided by the carrier ID reader, the carrier shall be instantiated in the WAITING FOR HOST substate. When the Carrier is instantiated by the ProceedWithCarrier service, the carrier shall be instantiated in the ID VERIFICATION OK substate. Finally when the carrier is instantiated by the CancelCarrier service, the carrier will be instantiated in the ID VERIFICATION FAILED substate.

10.7.3.3.1 *ID NOT READ* — This is a substate of CARRIER ID STATUS. This state is active whenever the CarrierID has not been read by the equipment.

10.7.3.3.2 *ID VERIFICATION FAILED* — This is a substate of CARRIER ID STATUS and is active when the carrierID has failed verification by the host following the CancelCarrier service. This is a final state.

10.7.3.3.3 *ID VERIFICATION OK* — This is a substate of CARRIER ID STATUS and is active as soon as the CarrierID has been accepted. The ID is determined to be accepted by either successful verification by the equipment or the host, or by bypassing ID read because a carrier ID reader is not available and the BypassReadID variable is set to true. This is a final state.

10.7.3.3.4 *WAITING FOR HOST* — This is a substate of CARRIER ID STATUS and is active during the period of time when the carrierID has been read by the equipment successfully or unsuccessfully and has not yet been verified by the host.

10.7.3.4 *CARRIER SLOT MAP STATUS* — This is a substate of CARRIER and indicates the current status of the carrier with respect to its slot map. It has four substates, SLOT MAP NOT READ, WAITING FOR HOST, SLOT MAP VERIFICATION FAILED, SLOT MAP VERIFICATION OK. The initial default entry sub-state is SLOT MAP NOT READ.

10.7.3.4.1 *SLOT MAP NOT READ* — This is a substate of CARRIER SLOT MAP STATUS and is the default entry state. It is active when the Carrier is first loaded at the equipment until the Slot Map has been read successfully by the equipment at the Substrate Port.

10.7.3.4.2 *SLOT MAP VERIFICATION FAIL* — This is a substate of CARRIER SLOT MAP STATUS and is active when the Slot Map has been read by the equipment and has failed verification by the host. This is a final state.

10.7.3.4.3 *SLOT MAP VERIFICATION OK* — This is a substate of CARRIER SLOT MAP STATUS and is active as soon as the slot map has been verified. This is a final state.

10.7.3.4.4 *WAITING FOR HOST* — This is a substate of CARRIER SLOT MAP STATUS and is active when the equipment is waiting for input from the host.

10.7.4 *Carrier State Transition Table*

10.7.4.1 Table 7 indicates the triggers and the expected behavior of the instantiated carrier object.

Table 7 Carrier State Transition Definition

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
1	(no state)	A carrier is instantiated.	CARRIER	None.	No event is required for this transition
2	(no state)	*Normal:* A Bind or Carrier Notification service is received.	ID NOT READ	None.	Data required to be available for this event report: CarrierID CarrierIDStatus
3	(no state)	*Normal:* A carrierID not currently existing at the equipment is successfully read. *Abnormal:* A carrierID is read successfully but an equipment based verification failed.	WAITING FOR HOST	None.	Data required to be available for this event report: CarrierID PortID CarrierIDStatus Normally, this transition will happen after a successful ID read if a bind service has not been issued (host based verification) or abnormally if a bind service is followed by a successful ID read and an unsuccessful equipment based verification.

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
4	(no state)	*ID Read fail*: A ProceedWithCarrier service is received.	ID VERIFICATION OK	A carrier is instantiated having the carrierID provided by the Proceed WithCarrier service.	Data required to be available for this event report: CarrierID CarrierIDStatus This transition can happen only if a bind service has not been received.
5	(no state)	*ID Read fail:* A CancelCarrier service is received.	ID VERIFICATION FAIL	A carrier is instantiated having the carrierID provided by the Cancel Carrier service.	Data required to be available for this event report: CarrierID CarrierIDStatus This transition can happen only if a bind service has not been received.
6	ID NOT READ	Carrier ID is read successfully and the equipment has verified the carrierID successfully.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
7	ID NOT READ	Carrier ID is read unsuccessfully.	WAITING FOR HOST	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
8	WAITING FOR HOST	A ProceedWithCarrier service is received.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
9	WAITING FOR HOST	A Cancel Carrier Service is received.	ID VERIFICATION FAIL	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
10	ID NOT READ	BypassReadID variable is set to FALSE, and a carrier is received when the id reader is not in service or not installed.	WAITING FOR HOST	Wait for ProceedWith-Carrier.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
11	ID NOT READ	BypassReadID variable is set to TRUE, and a carrier is received when the id reader is not in service or not installed.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
12	(no state)	A carrier is instantiated.	SLOT MAP NOT READ	None.	No event is required for this transition.

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
13	SLOT MAP NOT READ	Slot Map is read and verified successfully by the equipment.	SLOT MAP VERIFICATION OK	None.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID CarrierAccessingStatus SlotMapStatus
14	SLOT MAP NOT READ	*Normal host based verification:* Slot Map is read successfully and the equipment is waiting for host verification. *Equipment based verification fail:* Slot Map is read successfully but equipment based verification has failed. *Slot map read fail:* Slot Map cannot be read. *Abnormal substrate position within the carrier:* The Slot Map read has indicated an abnormal substrate position.	WAITING FOR HOST	Save new slot map in the SlotMap attribute.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID SlotMap (if valid) Reason SlotMapStatus
15	WAITING FOR HOST	A ProceedWithCarrier service is received.	SLOT MAP VERIFICATION OK	Proceed with the Carrier as instructed.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID SlotMapStatus
16	WAITING FOR HOST	A CancelCarrier service is received.	SLOT MAP VERIFICATION FAIL	Prepare the Carrier for Unload.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID CarrierAccessingStatus SlotMapStatus
17	(no state)	A carrier object is instantiated.	NOT ACCESSED	None.	No event is required for this transition
18	NOT ACCESSED	The equipment starts accessing the carrier.	IN ACCESS	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus
19	IN ACCESS	The equipment finishes accessing the carrier normally.	CARRIER COMPLETE	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus
20	IN ACCESS	The equipment finishes accessing the carrier abnormally.	CARRIER STOPPED	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus

#	Previous State	Trigger	New State	Actions	Comment
21	CARRIER	*Normal:* The carrier is unloaded from the equipment. *Abnormal by service:* CancelBind or CancelCarrierNotification service is received prior to the carrier load. *Abnormal by equipment:* An equipment based verification fails and the equipment performs a self-initiated CancelBind service.	(no state)	The equipment destroys the instance of this carrier object.	Data required to be available for this event report: CarrierID

NOTE 1: Only one collection event report is required when entering the Carrier State Model (instantiating a carrier object). This event report shall include the entry state of the all the substates of Carrier State Model, (including CARRIER ID STATUS substate and the CARRIER SLOT MAP STATUS substate).

10.7.5 *Slot Map Read Details*

10.7.5.1 The Slot Map shall be read on all production equipment prior to removal of substrates from the carrier.

10.7.6 *Carrier Read Failure* — A carrier read failure occurs when the carrier ID reader is present, in service, and reports that it is unable to read the ID of a carrier. This represents a transient random failure rather than a steady condition.

10.7.7 *Bypass Read ID* — A carrier ID reader may be unavailable: either out of service, not installed, or otherwise malfunctioning and unable to execute a read operation. This represents a steady condition that often is known in advance. The equipment shall provide a user-configurable variable BypassReadID that the user is able to set to specify the action to take when a carrier is received to an ASSOCIATED loadport. In this case, the carrier object is instantiated in the ID NOT READ state, and when the carrier is received, the state model transitions to either WAITING FOR HOST or ID VERIFICATION OK, depending upon whether BypassReadID is FALSE (the default value) or TRUE. When TRUE, then the Carrier ID received in the Bind is used automatically. Otherwise, the carrier transitions to WAITING FOR HOST and waits for the host to send a ProceedWithCarrier. The ID used will be the ID included with the ProceedWithCarrier.

11 Access Mode

11.1 *Access Mode State Model*

11.1.1 The Access Mode State Model defines the host view of equipment access mode, as well as the host interactions with the equipment necessary to switch the access mode. Each Load Port has its own Access Mode State Model. There are two access mode states: MANUAL and AUTO. These are defined in Section 11.3.3.

11.1.2 The access mode for a load port may be switched at anytime by the host or the operator, except when the Load Port Reservation State Model for that Load Port is in the RESERVED state or during carrier transfer. Carrier transfer boundaries, for determining when access mode may be changed, are designated by Table 8, Carrier Transfer Boundaries.

Table 8 Carrier Transfer Boundaries

Transfer Type	*Transfer Method*	*Starting Boundary*	*Ending Boundary*
LOAD	MANUAL	This starting boundary is specified by the user. Known examples of the starting boundary include but are not limited to; the presence sensor detecting a carrier, a load port door opening, input to the equipment by the operator through a switch at the load port or the equipment console.	This ending boundary is specified by the user. Known examples of the ending boundary include but are not limited to; a preset configurable time following presence and placement sensor detecting a carrier, a load port door closing, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.
	AUTO	The PIO signal "READY" is active for load. See SEMI E84.	PIO signals a transfer complete signal "COMPT". See SEMI E84.
UNLOAD	MANUAL	This starting boundary is specified by the user. Examples of the starting boundary include but are not limited to presence and placement sensor no longer detecting a carrier, a load port door opening, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.	This ending boundary is specified by the user. Examples of the ending boundary include but are not limited to a preset configurable time following presence and placement sensor no longer detecting a carrier, a load port door closing, or input to the equipment by the operator through a switch at the load port or the equipment console, or a service message.
	AUTO	The PIO signal "READY" is active for unload. See SEMI E84.	PIO signals a transfer complete signal "COMPT". See SEMI E84.

11.2 *Manual Carrier Transfer Confirmation Trigger*

11.2.1 For a manual transfer completion confirmation, the production equipment supplier must implement a software or hardware mechanism for an operator to inform the equipment that the carrier transfer is complete.

11.3 *Access Mode Initial Value*

11.3.1 Also, when equipment re-initialization occurs, the access mode(s) must be remembered, and used as the initial value when initializing. Since the access mode is remembered through re-initializations, the initial value that is used the very first time the software is ever loaded is not important. The equipment supplier is free to set this default value.

11.3.2 *Access Mode State Model Diagram*

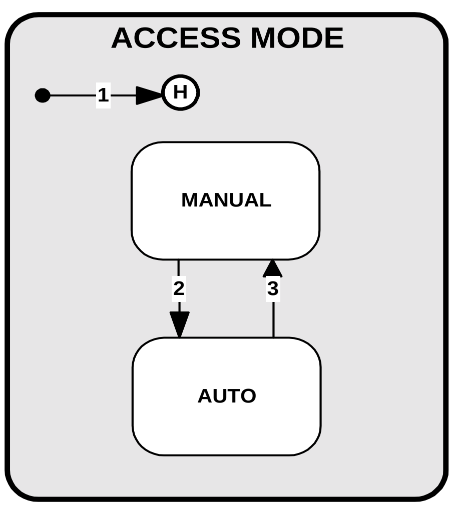


Figure 3
Access Mode State Model Diagram

11.3.3 *Access Mode State Definitions*

11.3.3.1 ACCESS MODE — The parent state for the MANUAL and AUTO sub-states.

11.3.3.2 MANUAL — A sub-state of ACCESS MODE. When the production equipment or specified load port is in this mode, only manual (non-AMHS) carrier transfers are allowed. The production equipment shall have the capability of generating an alarm if an automated (AMHS) delivery is attempted.

11.3.3.3 AUTO — A sub-state of ACCESS MODE. When the production equipment or specified load ports are in this mode, only automated (AMHS) carrier transfers are allowed. The production equipment shall have the capability of generating an alarm if a manual delivery is attempted.

11.3.4 *Access Mode State Transition Table*

11.3.4.1 Table 9 defines the transitions for the Access Mode State Model.

Table 9 Access Mode State Transition Definitions

#	*Previous State*	*Trigger*	*New state*	*Actions*	*Comments*
1	(no state)	System restart.	MANUAL or AUTO (History)	The access mode returns to the mode it was previous to the system reset.	Data required to be available for this event report: PortID AccessMode
2	MANUAL	The host or operator has executed a ChangeAccess service with the value of AUTO. This trigger can happen at anytime, except during a carrier transfer.	AUTO		Manual deliveries are not allowed after this state transition. The operator may also trigger this transaction from the production equipment console. Data required to be available for this event report: PortID AccessMode
3	AUTO	The host or operator has executed a ChangeAccess service with the value of MANUAL. This trigger can happen at anytime, except during carrier transfer.	MANUAL		The operator may also trigger this transaction from the production equipment console or a manual switch at the load port. Automated transfers are not allowed after this state transition. Data required to be available for this event report: PortID AccessMode

12 Reservation State Model

12.1 The purpose of the Reservation State Model is to define the host view of future activity at a specific load port.

12.1.1 The Reservation State Model, the ReserveAtPort service and CancelReserveAtPort enable the following items:

1. They enable the host to inform the equipment of a future carrier delivery without specifying the carrier ID and at the same time allow host based verification. (Equipment based verification is enabled via the Load Port/Carrier Association State Model, the Bind service, and the Carrier Notification service detailed in Sections 13, 15.4.2 and 15.4.11 of SEMI E87.)
2. They enable the equipment to send a state change event to the host if the operator (either local or remote) informs the equipment of a future carrier delivery to a port without specifying the carrier ID. Thus the host knows that the operator expects to use that port for something the host did not request for AMHS based delivery.
3. They enable internal buffer equipment to inform the host that it is physically initiating a carrier out operation (this carrier has a known or specified ID) and that no AMHS delivery should be scheduled.

4. The Bind and CancelBind services also trigger changes in the Load Port Reservation State Model. If the Load Port Reservation state model is in the NOT RESERVED state, the Bind service triggers a transition to the RESERVED state. If the Load Port Reservation is in the RESERVED State, the CancelBind service triggers a transition to NOT RESERVED.

12.1.2 For internal buffers equipment, the Reservation State Model, the ReserveAtPort service, the CancelReserveAtPort service, and all other associated functionality is necessary for fundamental compliance to this standard.

12.1.3 For fixed buffer equipment, the Reservation State Model, the ReserveAtPort service, the CancelReserveAtPort service, and all other associated functionality is a user option and not necessary for fundamental compliance.

12.1.4 For equipment implementing the reservation state model, the equipment shall provide a load port reservation state model for each load port.

12.2 *Reservation Visible Signal*

12.2.1 When a port reservation has taken place, the equipment shall display a visible signal indicating that the designated load port is in the Reserved State. Examples of visible signals for the associated load port are: Blinking LEDs, flags, color indicators, or other methods that allow easy recognition that the load port is reserved; proximity to or location on the load port is recommended. The visible signal shall remain present as long as the load port state remains RESERVED. When the state changes to NOT RESERVED the visible indicator shall cease. This capability is not required for fundamental compliance to CMS.

12.3 *Reservation State Model Diagram*

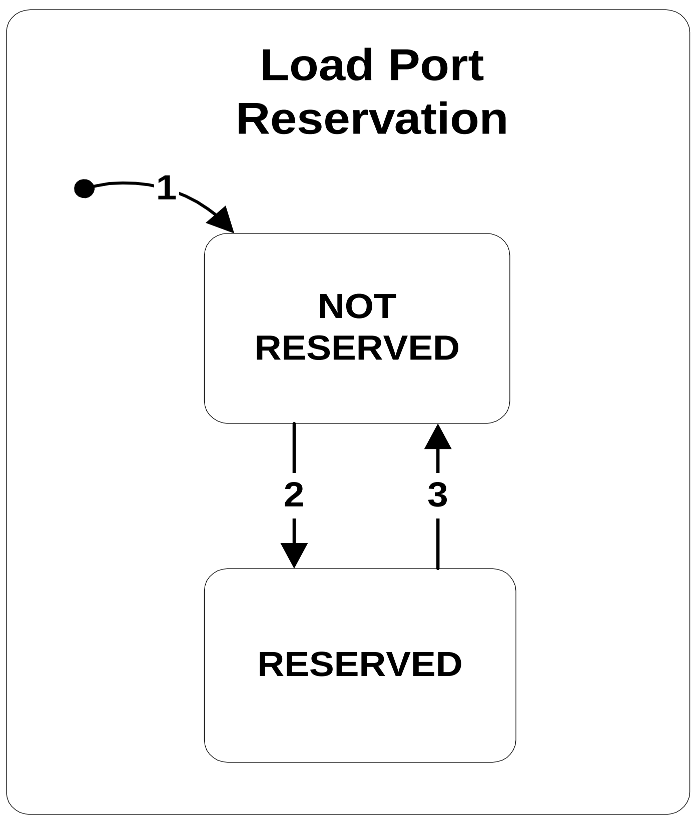


Figure 4
Reservation State Model Diagram

12.4 *Load Port Reservation State Definitions*

12.4.1 LOAD PORT RESERVATION — The super state of the substates NOT RESERVED and RESERVED.

12.4.2 NOT RESERVED — A substate of LOAD PORT RESERVATION, this state is active when there is no reservation existing at the load port.

12.4.3 RESERVED — A substate of LOADPORT RESERVATION, this state is active when there is a reservation for future activity at the load port. When in this state, the access mode for a load port may not be changed.

12.5 *Load Port Reservation State Transition Table*

Table 10 Load Port Reservation State Transition Table

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	NOT RESERVED		No event report is required for this transition.
2	NOT RESERVED	*Service:* If reserved by service, the host or operator sends a ReserveAtPort or a Bind service to the production equipment. *CarrierOut:* This happens when the equipment physically initiates a CarrierOut operation.	RESERVED	If the user has configured the equipment to use the reservation visible signal indicator, it is activated for this load port.	Data required to be available for this event report: PortID LoadPortReservation-State CarrierID may be included when a carrier out or a bind service triggers this transition.
3	RESERVED	*Service:* If a reservation is cancelled by service, the host or operator sends a CancelBind or a CancelReservationAtPort. *Carrier arrival:* A carrier arrives at the reserved port.	NOT RESERVED	If the user has configured the equipment to use the reservation visible signal, the indicator is deactivated for this load port.	Data required to be available for this event report: PortID LoadPortReservation-State

12.6 *Relation of Reservation to Association*

12.6.1 The following figure indicates the relationship of Association to Reservation.

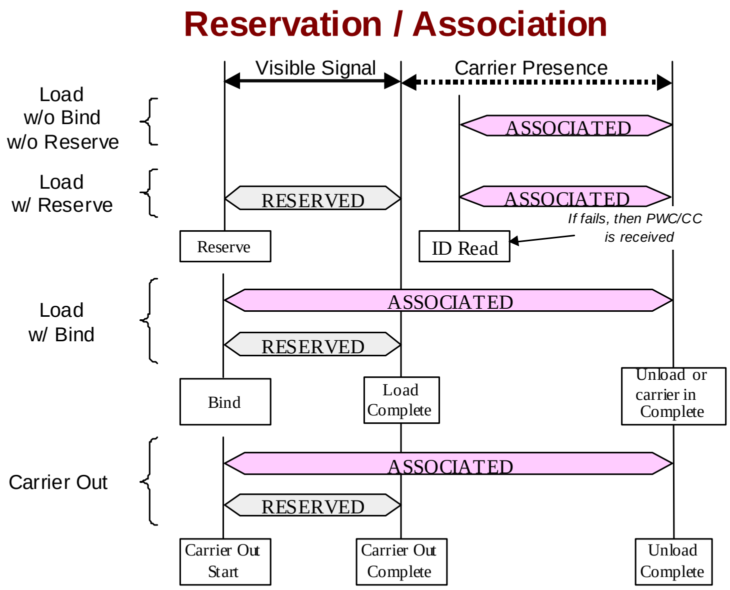


Figure 5
Relation of Reservation to Association

13 Load Port/Carrier Association State Model

13.1 The purpose of the Carrier Association State Model is to define the host view of carrier to load port association of the production equipment, as well as the host interactions with the production equipment necessary to associate a carrier to load port, and to perform equipment based carrier verification. Each load port shall maintain an independent instance of the Carrier Association State Model. Each instance of this state model must not influence the state of the same state model for a different load port.

13.1.1 This state model provides the ability to perform carrierID verification with two different methods. If the CarrierID is provided before the equipment reads the CarrierID, the CarrierID that becomes associated with the load port can be used later for equipment based carrier verification. If the association happens by CarrierID read (not by a service execution), then the production equipment shall report the CarrierID information in a data collection event.

13.2 *Load Port/Carrier Association State Model Diagram*

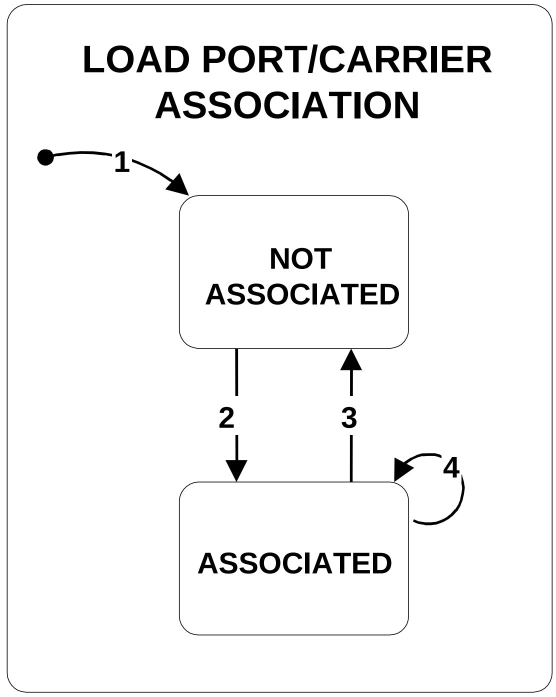


Figure 6
Load Port/Carrier Association State Model Diagram

13.2.1 *Load Port/Carrier Association State Definitions*

13.2.1.1 LOAD PORT/CARRIER ASSOCIATION — The parent state of the NOT ASSOCIATED and ASSOCIATED sub-states.

13.2.1.2 NOT ASSOCIATED — A sub-state of LOAD PORT/CARRIER ASSOCIATION. There is no carrier association present for this load port.

13.2.1.3 ASSOCIATED — A sub-state of LOAD PORT/CARRIER ASSOCIATION. A CarrierID has been associated with this load port. The load port is not available for a new carrier association.

13.2.2 *Load Port/Carrier Association State Transition Table*

13.2.2.1 Table 11 defines the transitions of the Load Port/Carrier Association State Model.

Table 11 Load Port/Carrier Association State Transition Definitions

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	NOT ASSOCIATED		No event report is required for this transition
2	NOT ASSOCIATED	*Service Normal:* If associated by service in the noraml situation, the host sends a Bind service to the production equipment when the port is unoccupied. *Service Abnormal:* If associated with a service in an abnormal situation, the host sends a ProceedWithCarrierService to the production equipment when the load port is ocuupied. *CarrierID Read:* If associated by a CarrierID read, the production equipment creates the association at the time the CarrierID read is performed. *Known Carrier:* A carrier already known to the production equipment is being loaded onto the load port. This happens when the CarrierOut service is initiated.	ASSOCIATED		Once the CarrierID to load port association is complete, the load port is not available for association until the state returns to NOT ASSOCIATED again. Data required to be available for this event report: PortID CarrierID PortAssociationState
3	ASSOCIATED	*Service:* If cancellation of a load port association is required; then, this can be accomplished by sending a CancelBind service to the production equipment before the carrier arrives to the loadport or before a transfer sequence has started. *Carrier Unload:* An association cancellation may also be performed by removing the carrier from the load port or by the production equipment moving a carrier to an internal buffer position.	NOT ASSOCIATED		A carrier unload, may happen before or after processing occurs. The load port is available for another association once the carrier is removed. Data required to be available for this event report: PortID PortAssociationState

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
4	ASSOCIATED	Production equipment based carrier verification fails, and the carrier assumes the ID value from the carrier that is on the load port. *Internal buffer:* A carrier is unloaded and a queued CarrierOut service starts.	ASSOCIATED	The existing carrierID that was associated by a Bind service is unassociated by the production equipment and the new carrierID is now associated to the Load Port. The production equipment shall delay further action until receiving either a CancelCarrier or a ProceedWithCarrier command from the host.	This transition only occurs when the Bind command has been used. Data required to be available for this event report: PortID CarrierID PortAssociateState

14 Verification

14.1 Verification is the operation of comparing an actual value with an expected value. Verification may be performed by either the host or the equipment, depending upon whether the host is using the Bind service or not.

14.1.1 If the host provides the expected value before the actual value is obtained by the production equipment, then the production equipment shall perform the verification.

14.1.2 If the host does not provide the expected value, using the Bind service, before the actual value is read, then the production equipment shall provide to the host, the information necessary for host based verification.

14.1.3 There are two values that are defined by Carrier Management that require verification: Carrier ID and Carrier Slot Map.

14.2 *CarrierID Verification*

14.2.1 Table 12 defines the methods for verifying the Carrier ID.

Table 12 Carrier ID Verification Methods

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Carrier Is Loaded*	*Host Actions after Load*
Production Equipment Based	*Bind Service:* The host executes the Bind service to associate a load port and a CarrierID.	*Bind Service:* The production equipment reads the Carrier ID from the carrier, compares it to the CarrierID supplied with the Bind service.	
		Verification Passed: Transition 6 of the Carrier State Model occurs. The production equipment proceeds with processing.	*Verification Passed:* None.
		Verification Failed: The equipment initiates by itself a CancelBind and destroys the carrier created with the “Bind” service and instantiates a new carrier with the newly read CarrierID. The carrier shall not be opened or moved to an internal buffer in the production equipment until and unless the ProceedWithCarrier service is received from the host.	*Verification Failed:* The host uses either the CancelCarrier service to force the carrier to the unload position, or indicates to the production equipment that it may proceed with the unexpected carrier, by sending the ProceedWithCarrier service. In both cases the carrierID specified in the service is equal to the one

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Carrier Is Loaded*	*Host Actions after Load*
			determined by the carrierID read.
	Carrier Notification Service: The host executes the CarrierNotification service to inform the equipment of the future arrival of a carrier to an unspecified port.	*Carrier Notification Service:* The production equipment reads the Carrier ID from the carrier, compares it to the CarrierID supplied with a CarrierNotification service.	
		Verification Passed: Transition 6 of the Carrier State Model occurs. The production equipment proceeds with processing.	*Verification Passed:* None.
		Verification Failed: Not Applicable; because there is no association between a load port and a carrier, equipment based verification failure is not possible. If a carrier that has not been instantiated arrives at a load port, the equipment shall consider this as host based verification.	*Verification Failed:* Not Applicable, because there is no association between a load port and a carrier, equipment based verification failed is not possible. If a carrier that has not been instantiated arrives at a load port, the equipment shall consider this as host based verification." The host will respond with either a ProceedWithCarrier or a CancelCarrier Service. (See Host Based verification method).
Host Based	None required, the host may issue a ReserveAtPort service.	The production equipment reads the CarrierID and reports it to the host in an event report. Following carrierID read the equipment initiates Transition 3 of the Carrier State Model and a carrier object with the carrierID equal to the one determined by the carrierID read is instantiated. The carrier shall not be opened or moved to an internal buffer in the production equipment until and unless the ProceedWithCarrier service is received from the host.	*Verification Passed:* The host sends a ProceedWithCarrier service indicating the verification passed.
			Verification Failed: The host uses the CancelCarrier or CancelCarrierAtPort service to force the carrier to the unload position.

14.3 *Slot Map Verification*

14.3.1 Table 13 defines the methods for verification of the Carrier Slot Map. Some user's factory operations may not require strict management of the slot map. In this case the user may use the host based verification method.

Table 13 Slot Map Verification Methods

Verification Method Desired	*Host Actions Before Verification*	*Equipment Action When Carrier is Loaded*	*Host Actions After Load*
Production Equipment Based	The host provides a Slot Map with the Bind service or	The production equipment checks the carrier slot map and compares it to the slot	*Verification Passed:* None, the production equipment proceeds with the carrier. *Verification Failed:* If the host decides to cancel

Verification Method Desired	*Host Actions Before Verification*	*Equipment Action When Carrier is Loaded*	*Host Actions After Load*
	the ProceedWithCarrier service.	map supplied by the host. Either transition 13 or 14 of the Carrier State Model occurs.	processing, the host issues the CancelCarrier service. If the host decides to continue processing, the host issues the ProceedWithCarrier service.
Host Based	None.	The production equipment checks the carrier slot map and reports it to the host in an event report. The host has the responsibility for verifying the slot map.	*Verification Passed:* The host sends a ProceedWithCarrier indicating the verification passed. *Verification Failed:* If the host decides to cancel processing, the host issues the CancelCarrier service. If the host decides to continue processing, the host issues the ProceedWithCarrier service.

14.4 This table clarifies the relation of the reservation and verification to the related services.

Table 14 Reservation and Verification Relation to Service

	Reser-vation	*CarrierID Verification*	*Carrier SlotMap Verification*	*Service Used*	*Information Provided with Service*		
					Port ID	*Carrier ID*	*Carrier SlotMap*
1	Yes	Equipment based	Equipment based	Bind	Yes	Yes	Yes
2	Yes	Equipment based	Host based	Bind	Yes	Yes	No
3	Yes	Host based	Host based	ReserveAtPort	Yes	No	No
				ProceedWithCarrier (following ID read and host verification)	No	Yes	No
4	Yes	Host based	Equipment based	ReserveAtPort	Yes	No	No
				ProceedWithCarrier to provide slotmap (following ID read and host verification)	No	Yes	Yes
5	No	Equipment based	Equipment based	CarrierNotification	No	Yes	Yes
6	No	Equipment based	Host based	CarrierNotification	No	Yes	No
7	No	Host based	Equipment based	ProceedWithCarrier to provide slotmap (following ID read and host verification)	No	Yes	Yes
8	No	Host based	Host based	ProceedWithCarrier (following ID read and host verification)	No	Yes	No

15 Carrier Release Control

15.1 For both fixed buffer and internal buffer equipment, where Carrier Read/Write technology is used, the carrier must remain at the write position where the tag may be accurately written on until the Host has completed all of its read and write operations. For this purpose, a variable that affects the equipment releasing a carrier is defined.

15.2 *Carrier Hold Trigger* — Both fixed buffer equipment and internal buffer equipment shall allow the user to select a trigger to release the carrier when reading/writing is complete. Carrier release does not mean the equipment must move the carrier from the location it currently occupies, only that it is permissible to do so.

15.2.1 *CarrierHold Trigger set to Host Release* — If the Carrier Hold trigger is set to Host Release, both fixed buffer and internal buffer equipment shall hold the carrier at the write position until the CarrierRelease service is received.

15.2.2 *CarrierHold Trigger set to Equipment Release* — If the Carrier Hold trigger is set to Equipment Release, the equipment shall release the carrier based on the Carrier Object state model transition to CARRIER COMPLETE or CARRIER STOPPED.

15.3 For fixed load port equipment in AUTO access mode, it may be desirable to leave a completed carrier clamped, locked, or at the docked position until the AMHS arrives to pick it up. This reduces the chance that an operator may remove it. For this purpose, a variable that affects UnClamp Control is provided to allow the user to select the desired behavior. When the equipment finishes with a carrier, the Carrier State transitions from ACCESSING to CARRIER COMPLETE (normal) or CARRIER STOPPED (abnormal) and the equipment sends either the CarrierComplete event (normal) or the CarrierStopped event (abnormal). If the carrier has a door, the door shall be closed by this point.

15.4 Fixed buffer equipment shall allow the user to select a trigger to unclamp the carrier based on AMHS arrival at the equipment. If the access mode is MANUAL, the unclamp control trigger has no effect.

15.4.1 *UnclampControl trigger set to CARRIERCOMPLETE/CARRIERSTOPPED Triggered Unclamp* — The equipment automatically unclamps the carrier when the Carrier Status transitions to CARRIERCOMPLETE or CARRIERSTOPPED.

15.4.2 *UnclampControl trigger set to AMHS Triggered Unclamp* — The equipment behavior depends upon the Load Port Access State. If the Loadport Access State is AUTO, the carrier remains clamped, locked, or at the docked position (it will remain at the docked position only if that is the only position on which the carrier can be clamped) until AMHS has arrived. The AMHS arrives and begins a PIO unload sequence. The carrier must be at or moved to the pickup position and any additional clamp mechanisms must be released by the appropriate point of the sequence.

NOTE 3: It may be necessary to adjust timeouts for the AMHS to allow a few more seconds to move the carrier into the pickup position.

16 Services

16.1 The purpose of this section is to define the message services required to support CMS functionality.

16.1.1 This message service definition has four parts:

- A service description table.
- A service parameter table.
- A service parameter value table that specifies the type and range of the parameters.
- A service state mapping table that defines the states in which each service is valid.

16.2 *Service Message Description*

16.2.1 There are two types of services:

- An initial message and response between the service user and the service provider.
- A notification message from the service provider to the service user that does not require a response.

16.2.2 The "TYPE" column in the following table is used to indicate whether the service consists of a request/response message pair, "R", or a single notification message, "N".

Table 15 Service Message Description

Service Name	*Type*	*Description*
Bind	R	This service shall associate a CarrierID to a load port and shall cause the load port to transition to the RESERVED state..
CancelAllCarrierOut	R	This service shall cause all CarrierOut services to be removed from the queue.
CancelBind	R	This service cancels a CarrierID to load port association and shall cause the load port to transition to the NOT RESERVED state.
CancelCarrier	R	This service shall Cancel the current carrier related action, and the production equipment shall return the carrier to the unload position of the load port, or an internal buffer position, depending on the carrier's position in the production equipment.
CancelCarrierAtPort	R	This service shall Cancel the current carrier related action, and the production equipment shall return the carrier to the unload position of the load port.
CancelCarrierNotification	R	This service shall cause the equipment to destroy a carrier object instantiated through a prior CarrierNotification.
CancelCarrierOut	R	This service shall cause a specified CarrierOut service to be removed from the queue by the production equipment.
CancelReservationAtPort	R	This service shall cause the equipment to remove the reservation at the specified Port and to deactivate the visible signal.
CarrierIn	R	This service shall cause a carrier to be moved from a load port to an internal buffer location. Used in anomaly situations.
CarrierNotification	R	This service shall cause the equipment to instantiate a carrier object.
CarrierOut	R	This service shall cause a carrier to be moved from the internal buffer to a load port. This service can be queued by the production equipment.

Service Name	*Type*	*Description*
CarrierReCreate	R	This service shall cause the carrier object (and consequently, associated state models of the object) specified by the service to be recreated. This service shall be accepted only if the carrier accessing state is “Carrier Complete” or “Carrier Stopped” and the load port is in the “Ready to Unload” state.
CarrierRelease	R	Release the carrier from Carrier Hold
CarrierTagReadData	R	Read data from carrier ID tag.
CarrierTagWriteData	R	Write data to the carrier ID tag.
ChangeAccess	R	This service shall change the access mode of the specified Ports at the production equipment. If the service parameters include more than one load port and one of the load ports cannot be changed for any reason, the service request shall be rejected entirely. This means the Access mode shall not be changed for any load ports.
ChangeServiceStatus	R	This service shall change the transfer status of a specified load port at the production equipment.
ProceedWithCarrier	R	This service shall instruct the production equipment to proceed with using the specified carrier.
ReserveAtPort	R	This service shall cause the equipment to reserve the specified Port and activate a visible signal. This service is a Transfer boundary.

16.3 *Service Message Parameter Definition*

16.3.1 The following is a list of required parameters used in conjunction with service messages.

Table 16 Service Message Parameter Definition

Parameter Name	*Form*	*Description*
AccessMode	Enumerated AUTO, MANUAL.	The desired access mode of the ports specified.
AttributeData	Could be several different data types.	The data value associated with AttributeID.
AttributeID	Text 1 to 40 characters.	Identifier of the object attribute in the PropertiesList.
CarrierID	Text Conforms to ObjID as defined in SEMI E39.	Identifier of a carrier.
CMAcknowledge	Enumerated: • Acknowledge, command has been performed • Invalid command • Cannot perform now • Invalid data or argument • Acknowledge, request will be performed with completion signaled later by an event • Rejected, invalid state	Acknowledgement of request. Some services are commanding a certain task to be performed. This task is only completed if the expected end-condition is reached or has failed. A number of services only have effect on a ‘logical’ level (e.g. Bind, CancelReservationAtPort). Those services in general can be acknowledged right away after having performed the task. Other services that include triggering of physical movements (e.g. CarrierOut, CancelCarrier) most likely will be interpreted as “request action to be initiated” rather than “do action”. The equipment will reply in those cases the command “is going to be performed”. This alleviates transaction timeouts for these services that may take a long time to perform. It is however up to the supplier to decide if this is applicable. The completion of the task initiated by the services commanding some task to be performed (either acknowledged or going to be performed) must result in either a state transition or other action that generates a collection event upon normal / abnormal completion.
CMStatus	A structure consisting of CMAcknowledge and Status	Return information for a service.

Parameter Name	*Form*	*Description*
Data	Text	User data.
DataSeg	Protocol-specific.	Indicates specific section of data to read or write.
DataSize	Unsigned integer	Indicates the number of bytes of data to read or write.
ErrorCode	Enumerated: *Valid for all services listed below* Unsupported option [service] requested Command not valid for current state Insufficient parameters specified Parameters improperly specified *Bind* Load port does not exist Load port already in use Object identifier in use, Duplicate CarrierID Invalid attribute value Unknown attribute name *CancelAllCarrierOut* (none) *CancelBind* Load port does not exist Unknown object instance – Unknown CarrierID *CancelCarrier* Load port does not exist Unknown object instance – Unknown CarrierID Missing Carrier *CancelCarrierAtPort* Load port does not exist *CancelCarrierNotification* Unknown object instance – Unknown CarrierID *CancelCarrierOut* Unknown object instance – Unknown CarrierID *CancelReservationAtPort* Load port does not exist *CarrierIn* Unknown object instance – Unknown CarrierID *CarrierNotification* Object identifier in use, Duplicate CarrierID Invalid attribute value Unknown attribute name *CarrierOut* Load port does not exist Unknown object instance – Unknown CarrierID *CarrierReCreate* Unknown object instance – Unkown CarrierID Invalid attribute value Unknown attribute name Command not valid for current state *ChangeAccess* Load port does not exist *ChangeServiceStatus* Load port does not exist *ProceedWithCarrier* Load port does not exist Unknown object instance – Unknown CarrierID Invalid attribute value Unknown attribute name	Contains the code for the specific error found.

Parameter Name	*Form*	*Description*
	ReserveAtPort Load port does not exist Load port already in use	
ErrorText	Text	Text in support of the error code.
PortID	Integer 1 to n.	ID number of a load port. The PortID number should be the same as the load port number.
PortList	List 1 to n items.	List of n items $PortID_1$ . . n $PortID_n$
PropertiesList	List 1 to n name/value pairs.	List of n items 1. $AttributeID_1$ $AttributeData_1$ . . n. $AttributeID_n$ $AttributeData_n$
ServiceStatus	Enumerated: IN SERVICE, or OUT OF SERVICE.	The desired transfer service status of the specified list of load ports.
Status	A list of ErrorCode/ErrorText pairs.	Reports any errors found.

16.3.2 The "Acknowledge, request will be performed with completion signaled by a later event" response to a service, may apply to services listed in the table below. If this does apply, the supplier must document the event that signals completion. Any service not included in Table 17 shall respond with "Acknowledge, command has been performed."

16.3.2.1 Events that may signal completion are listed in Table 17.

Table 17 Deferred Completion Events

Service	*Events that may signal completion*
CarrierOut	CarrierLocation Changed Event Load Port State Change Event (transition 9)
CarrierIn	CarrierLocation Change Event Load Port State Change Event (transition 8)
CancelCarrier	CarrierLocation Changed Event Load Port State Change Event (transition 9)
CancelCarrierAtPort	CarrierLocation Changed Event Load Port State Change Event (transition 9)
ChangeService	LoadPortTransferState Change Event (transition 2 and 3)

16.4 *Service Message Definitions*

16.4.1 The following tables specify the allowable/required parameters for each service. The column marked "REQ/IND" specifies which parameters are required to be supported for CMS compliance (see Section 7.3.4.3).

16.4.2 *Bind*

16.4.2.1 The Bind service is used to associate a CarrierID with a load port. The Bind can contain a PropertiesList of carrier object attributes that are supplied by the host. A carrier object is instantiated when this service is used successfully. The Bind service will be rejected if the carrier specified has already been instantiated through the Bind or CarrierNotification service, or a carrierID read. The Bind service also triggers a transition in the Load Port Reservation state model from NOT RESERVED to RESERVED.

Table 18 Bind Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The PortID where a carrier is expected.
CarrierID	M	—	The expected CarrierID.
PropertiesList	C	—	A list of name value pairs providing attributes for the carrier object being instantiated with the Bind service.
CMStatus	—	M	Information concerning the result of the service.

16.4.3 *CancelAllCarrierOut*

16.4.3.1 The CancelAllCarrierOut service is sent to internal buffer production equipment to cancel all CarrierOut services in queue.

Table 19 CancelAllCarrierOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CMStatus	—	M	Information concerning the result of the service.

16.4.4 *CancelBind*

16.4.4.1 The CancelBind request is used to cancel the association between a port and a Carrier ID. The carrier object is destroyed when this service is used successfully. The CancelBind service also triggers a transition in the Load Port Reservation state model from RESERVED to NOT RESERVED.

Table 20 CancelBind Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	C	—	The PortID for which to cancel the load port to carrier association. Either PortID or CarrierID must be specified.
CarrierID	C	—	The CarrierID for which to cancel the load port to carrier association. Either PortID or CarrierID must be specified.
CMStatus	—	M	Information concerning the result of the service.

16.4.5 *CancelCarrier*

16.4.5.1 The CancelCarrier request is used to stop a carrier. If the carrier is at a load port, then it shall be returned to the load/unload location of the load port and made ready for unload. If the carrier is at an internal location the carrier will return to an internal buffer location. A subsequent CarrierOut request is required for the production equipment to move the carrier to the external load port. The production equipment shall reject this service if issued after substrates have been removed for processing.

Table 21 CancelCarrier Service Parameters

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	The carrierID to cancel.
CMStatus	—	M	Information concerning the result of the service.
PortID	C	—	The PortID where the carrier object is located. This parameter is not required if the carrier object has been previously instantiated.

16.4.6 *CancelCarrierAtPort*

16.4.6.1 CancelCarrierAtPort is used to abort any carrier at a designated port. This service can be used when the carrierID of the carrier at the designated port is unknown.

Table 22 CancelCarrierAtPort Service Parameters

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	Any carrier that exist on the load port specified shall be made ready for unloading.
CMStatus	—	M	Information concerning the result of the service.

16.4.7 *CancelCarrierNotification*

16.4.7.1 The CancelCarrierNotification is used by the host to request the equipment cancel a previous CarrierNotification service. This service shall cause the equipment to destroy the carrier object specified.

Table 23 CancelCarrierNotification Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	The CarrierID of the carrier object to destroy.
CMStatus	—	M	Information concerning the result of the service.

16.4.8 *CancelCarrierOut*

16.4.8.1 The CancelCarrierOut service is sent to internal buffer production equipment to cancel a queued CarrierOut.

Table 24 CancelCarrierOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	CarrierID for the CarrierOut service that is being cancelled.
CMStatus	—	M	Information concerning the result of the service.

16.4.9 *CancelReservationAtPort*

16.4.9.1 The CancelReservationAtPort service is sent by the host to cancel a reservation at the load port. The load port will enter the UNRESERVED State after receiving this service.   A Port reserved by the physical initiation of a carrier out operation may not be cancelled by this service.

Table 25 CancelReservationAtPort Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The Port ID to reserve
CMStatus	—	M	Information concerning the result of the service.

16.4.10 *CarrierIn*

16.4.10.1 The CarrierIn service is only used to request the internal buffer equipment internalize a carrier that has been moved to the load port via a previous CarrierOut service. When using host based verification, the production equipment shall move the carrier in to the internal buffer for the first time after receiving the ProceedWithCarrier request. If the CarrierIn service is received by the production equipment without previously having received a CarrierOut service for the carrier, the service will be refused.

Table 26 CarrierIn Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	The CarrierID for the carrier to internalize.
CMStatus	—	M	Information concerning the result of the service.

16.4.11 *CarrierNotification*

16.4.11.1 The Carrier Notification service is used by the host to inform the equipment that a Carrier with the ID specified will be arriving at the equipment. The load port is not specified; therefore no carrier to load port association takes place. A carrier object with the ObjID equal to the carrierID specified in the service is instantiated. "The CarrierNotification service will be rejected if the carrier specified has already been instantiated through the Bind or CarrierNotification service, or a carrierID read.

Table 27 CarrierNotification Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	The CarrierID of the carrier object to instantiate.
PropertiesList	C		The PropertiesList of the carrier to instantiate.
CMStatus	—	M	Information concerning the result of the service.

16.4.12 *CarrierOut*

16.4.12.1 The CarrierOut service is sent to internal buffer production equipment, to request that the equipment move the specified carrier to a load port, as soon as the carrier is completed. When the CarrierOut service is started, the destination load port state becomes TRANSFER BLOCKED, and the load port's association state becomes ASSOCIATED.

16.4.12.2 *CarrierOut Queuing*

16.4.12.2.1 This service request can be queued by the production equipment. The production equipment is required to support a queue of n size, where n is equal to the sum of the number of internal buffer locations and the number of internal FIMS ports. The order of the queue is FIFO for each load port. If the load port is not specified in service request, the equipment chooses which load port queue to place the CarrierOut service. The queued service does not take effect until the current substrate handling action is complete (i.e., filling, emptying of the carrier) and the load port is in the NOT ASSOCIATED state. When a CarrierOut service is queued and the production equipment load port is currently in the TRANSFER BLOCKED state, the production equipment shall keep the load port in the TRANSFER BLOCKED state. Then, after the port is cleared, the CarrierOut service shall begin.

Table 28 CarrierOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	—	CarrierID for the carrier to be moved out.
PortID	C	—	If omitted, the production equipment shall select an appropriate port at the time the carrier is ready to be moved.
CMStatus	—	M	Information concerning the result of the service.

16.4.13 *CarrierRelease*

16.4.13.1 CarrierRelease request is used to tell the equipment that the carrier is ready to be moved away from the read or write position. Equipment shall deny the request if LocationID and CarrierID are mismatched.

Table 29 CarrierRelease Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the carrier. Either LocationID or CarrierID must be used.
CarrierID	C	—	The CarrierID of the carrier. Either LocationID or CarrierID must be used.
CMStatus	—	M	Information concerning the result of the service.

16.4.14 CarrierReCreate

16.4.14.1 CarrierReCreate request is used to re-create the carrier object specified by the service. This will allow a repeated introduction of the same carrier on the loadport. After the service is issued, the equipment shall treat the carrier occupying the respective loadport identically to one that was physically removed and replaced, deleting the original carrier and then re-instantiating it. If no PropertiesList is provided with the service, then the host verification scenarios for re-instantiating the carrier object shall be followed. For example, the carrier ID would be re-read (at which point Carrier State transition #3, (no state) to Waiting for Host occurs) and subsequently verified by host, followed by slot map re-read and verification by host. Alternatively, if PropertiesList is provided with this service, then the equipment shall follow the equipment based verification steps. For example, the carrier object is re-instantiated with the CarrierID (and possibly content/slot map) information provided within the CarrierReCreate Service. In this equipment based verification scenario, the equipment is responsible for verifying the contents of the carrier against the received information. If the equipment supports other SEMI standards (i.e.- SEMI E40/E90/E94), then from the perspective of those standards, when CarrierReCreate service is received, the scenario would resemble that of a carrier being removed and a new carrier placed. The service shall be accepted only if the current carrier Accessing Status is either “Carrier Complete” or “Carrier Stopped” and the load port is in the “Ready to Unload” state.

Table 30 CarrierReCreate Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CarrierID	M	-	Carrier ID for the carrier object the service is to be performed upon
PropertiesList	C	-	If sent by the host, then equipment based verification scenario. If not, then host based verification scenario.
CMStatus	-	M	Information concerning the result of the service

16.4.15 *CarrierTagReadData*

16.4.15.1 CarrierTagReadData is used to request a block of data from the carrier ID tag. Equipment shall deny the request if LocationID and CarrierID are mismatched.

Table 31 CarrierTagReadData Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the carrier. Either LocationID or CarrierID must be used.
CarrierID	C	—	The CarrierID of the carrier. Either LocationID or CarrierID must be used.
DataSeg	C	—	Indicates a specific section of data.
DataSize	C	—	Indicates the number of bytes to read.
Data	—	C	Data from the carrier ID tag. May be NULL if no data exists for the given section.
CMStatus	—	M	Information concerning the result of the service.

16.4.16 *CarrierTagWriteData*

16.4.16.1 CarrierTagWriteData is used to request that a block of data be written to the carrier ID tag. Equipment shall deny the request if LocationID and CarrierID are mismatched.

Table 32 CarrierTagWriteData Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the carrier. Either LocationID or CarrierID must be used.
CarrierID	C	—	The CarrierID of the carrier. Either LocationID or CarrierID must be used.
DataSeg	C	—	Indicates a specific section of data.
DataSize	C	—	Indicates the number of bytes to read.

Parameter Name	Req/Ind	Rsp/Conf	Description
Data	M	—	Data from the carrier ID tag. May be NULL if no data exists for the given section.
CMStatus	—	M	Information concerning the result of the service.

16.4.17 *ChangeAccess*

16.4.17.1 The ChangeAccess message requests a change of access mode for the load ports specified in the PortList.

Table 33 ChangeAccess Service Parameter Definitions

Parameter Name	Req/Ind	Rsp/Conf	Description
AccessMode	M	—	The new desired access mode.
PortList	M	—	The list of ports to use the new access mode.
CMStatus	—	M	Information concerning the result of the service.

16.4.18 *ChangeServiceStatus*

16.4.18.1 The ChangeServiceStatus service is used to request the production equipment change a load port service state.

Table 34 ChangeServiceStatus Parameter Definitions

Parameter Name	Req/Ind	Rsp/Conf	Description
PortID	M	—	PortID to designate the new service status.
ServiceStatus	M	—	The new service state.
CMStatus	—	M	Information concerning the result of the service.

16.4.19 *ProceedWithCarrier*

16.4.19.1 The ProceedWithCarrier service is sent by the host to indicate that the carrier operations may continue. When using host based verification it is used by the host to indicate to the production equipment that the verification of Carrier ID and/or the Carrier Slot Map is correct. For successful production equipment based verification the production equipment shall not require this message before proceeding with the carrier. For failed production equipment based verification the production equipment shall require either a CancelCarrier or ProceedWithCarrier service.

16.4.19.2 Using Table 34, for the Host based CarrierID verification case, the ProceedWithCarrier service sent by the host after the first carrier ID read is referred to as ProceedWithCarrier #1, the ProceedWithCarrier service sent after slot map read is referred to as ProceedWithCarrier #2.

Table 35 ProceedWithCarrier Service Parameter Definitions

Parameter Name	Req/Ind	Rsp/Conf	Description
PortID	C	—	The PortID for which processing may proceed.
CarrierID	M	—	The CarrierID for which processing may proceed.
PropertiesList	C	—	A list of name value pairs providing attributes for the carrier object.
CMStatus	—	M	Information concerning the result of the service.

16.4.20 *ReserveAtPort*

16.4.20.1 The ReserveAtPort service is sent by the host to indicate future activity at the load port. This allows for reserving the port but doing host based ID verification. The load port will enter the RESERVED State after receiving this service. The equipment shall move a carrier to a reserved load port.

Table 36 ReserveAtPort Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The Port ID to reserve
CMStatus	—	M	Information concerning the result of the service.

17 Carrier Tag Read/Write

17.1 Some technologies allow data to be stored on a carrier ID tag where it can be subsequently read and/or modified. In this case, it is the host that specifies when this data is written and read, because the equipment has no knowledge of the contents of the data. The read operations shall be performed only when the carrier is at the read position. The write operations shall be performed only when the carrier is at the write position. NOTE: The read and write positions may be the same position. The host shall be able to both read and write whenever CarrierHold switch is set to Host Release and the carrier is at the respective read or write position. Once the host has completed all of its read and write operations for that carrier, then the host sends the CarrierRelease request to the equipment. In all cases, the CarrierAccessingStatus state shall be set to either CARRIER COMPLETE or CARRIER STOPPED before the carrier may be undocked. The CarrierRelease service informs the equipment that carrier read or carrier write is complete. For internal buffer equipment the CarrierRelease service shall allow the equipment to move the carrier away from the read or write position.

NOTE 4: The CarrierRelease service has a different purpose from the CarrierOut service. The intent of the CarrierOut service request is to move the carrier to a loadport, while the intent of the CarrierRelease service request is to inform equipment that it may move the carrier away from the read or write position. Therefore, CarrierOut may also be used with the CarrierRelease command. If CarrierHold is Host Release, then the carrier shall be kept at the write position until an CarrierRelease service request is received, regardless of when a CarrierOut is sent. If CarrierHold is set to Equipment Release, then the CarrierRelease request has no effect.

18 Additional Events

18.1 This section identifies data collection events that are not related to State transitions for variable data items. The intent of this section is to ensure certain data is available for specific events that are not related to state transitions, not to define all the additional collection events for CMS. Also, all state transitions in CMS state models are required to have associated event reports.

18.2 *Buffer Capacity Changed Event*

18.2.1 An event shall be generated whenever Buffer Capacity changes. This applies to all internal buffers and internal buffer partitions.

18.2.2 Data required to be available for this event report:

- BufferPartitionInfo.

18.3 *Carrier Approaching Complete Event*

18.3.1 In some cases, for carrier transfer efficiency, the host needs to know carrier completion timing a little faster than actual. For example:

- If the equipment is internal buffer type, QTAT carriers need to be moved out directly from internal FIMS to a load port to shorten moving out time.
- If the equipment uses non-product carriers, such as dummy, they need to be changed before it becomes not reusable to prevent stopping the equipment operation.
- If the equipment uses non-product carriers, such as test, reject, they need to be changed before it becomes empty or full to prevent stopping the equipment operation.

18.3.2 This event shall be generated when the access by the equipment to the carrier is approaching complete. How the timing of the event is determined shall be configurable.

18.3.3 Detailed definition of the event timing depends upon the type of usage of the carrier. Some examples of event timing for different types of usage are shown below.

18.3.3.1 *PRODUCT* — When remaining time until the carrier starts moving from internal FIMS to internal buffer reaches the configurable variable time (internal buffer equipment only).

18.3.3.2 *DUMMY* — When remaining times until substrates of the carrier becomes not reusable reaches the configurable variable times.

18.3.3.3 *TEST* — When remaining substrates until the carrier becomes empty reaches the configurable variable number.

18.3.3.4 *REJECT* — When remaining slots until the carrier becomes full reaches the configurable variable number.

18.3.4 Suppliers shall document the interpretation and the configurable variable(s) in the equipment specification document.

18.3.5 Data required to be available for this event report:

- CarrierID

18.4 *Carrier Clamped Event*

18.4.1 An event shall be generated whenever a carrier is clamped. Clamped means the load port has engaged a device that would inhibit removal or movement of the carrier by any entity external to the load port. Some load ports may include more than one clamping device. This event should be generated only when the first clamping is engaged. This applies to all load ports.

18.4.2 There is no standard for when load ports clamp a carrier. Therefore the IC makers host systems and personnel will need some signal from the equipment to know if a carrier is clamped. This event provides that signal. This applies to all load ports that provide clamping. If a load ports does not clamp the carrier no event is required.

18.4.3 Data required to be available for this event report:

- Port ID,
- Carrier ID (if available), and
- Location ID.

18.5 *Carrier Closed Event*

18.5.1 If the carrier is equipped with a door, an event shall be generated when a carrier door has been closed.

18.5.2 Data required to be available for this event report:

- CarrierID,
- LocationID, and
- PortID (if valid).

18.6 *Carrier Location Change Event*

18.6.1 An event shall be generated whenever a carrier has changed location. This applies to both load ports, substrate ports, and internal buffer locations.

18.6.2 Data required to be available for this event report:

- CarrierID,
- LocationID (new destination location), and
- CarrierLocationMatrix.

18.7 *Carrier Opened Event*

18.7.1 If the carrier is equipped with a door, an event shall be generated when a carrier door has been opened.

18.7.2 Data required to be available for this event report:

- CarrierID,
- LocationID, and
- PortID (if valid).

18.8 *Carrier Unclamped Event*

18.8.1 An event shall be generated whenever a carrier is unclamped. Unclamped means that the load port has disengaged any devices that would inhibit removal or movement of the carrier by any entity external to the load port. Some load ports may include more than one clamping device. This event should be generated only when all clamping or locking devices are disengaged.

18.8.2 There is no standard for when load ports unclamp a carrier. Therefore the IC makers host systems and personnel will need some signal from the equipment to know if a carrier is unclamped. This event provides that signal. This applies to all load ports that provide clamping and unclamping. If a load ports does not clamp and unclamp the carrier no event is required.

18.8.3 Data required to be available for this event report:

- Port ID,
- Carrier ID (if available), and
- Location ID.

18.9 *CarrierID Read Fail Event*

18.9.1 An event shall be generated when the equipment attempts to read a carrierID and fails at a port in the NOT ASSOCIATED STATE.

18.9.2 Data required to be available for this event report:

- PortID

18.10 *ID Reader Available Event*

18.10.1 An event shall be generated whenever an id reader becomes available. This applies to all load ports.

18.10.2 Data required to be available for this event report:

- Port ID

18.11 *ID Reader Unavailable Event*

18.11.1 An event shall be generated whenever an id reader becomes unavailable for any reason. This applies to all load ports.

18.11.2 Data required to be available for this event report:

- Port ID

19 Variable Data

19.1 The purpose of this section is to define the list of variable data requirements for CMS equipment. Values of these variables are available to the host via collection event reports and host status queries. Some of the data items listed are valid for internal buffer production equipment only, and are marked as such.

19.2 *Variable Data Definitions*

19.2.1 The following table defines variable data that shall be provided by the production equipment. Also, for the objects defined by Carrier Management, the identifier of that object and all of the attributes of that object shall be available for inclusion in event reports associated with that object. Subscripted variables are used either as items within a list or to differentiate data representing different entities. Subscripted variables are always valid.

Table 37 Variable Data Definitions

Variable Name	*Description*	*Type*	*Access*	*Comment*
AccessMode	The access mode of the loadport.	Enumerated: MANUAL, AUTO	RO	
$AccessMode_i$	The access mode for the i^{th} load port.	Enumerated: MANUAL, AUTO	RO	
AvailPartitionCapacity	The current available buffer capacity for a logical partition inside internal buffer equipment (PartitionCapacity - # of carriers in partition).	Non-negative integer	RO	Only applicable to internal buffer production equipment.
AvailPartition-$Capacity_i$	The AvailPartitionCapacity for the i^{th} PartitionID within the internal buffer.	Non-negative integer	RO	Only applicable to internal buffer production equipment.
BufferCapacityList	The current PartitionType, AvailPartitionCapacity, and PartitionCapacity for all logical buffer partitions.	List of n groups of items 1. $BufferPartitionInfo_1$ . . n. $BufferPartitionInfo_n$	RO	Only applicable to internal buffer production equipment.
BufferPartitionInfo	The related information for a logical buffer partition.	Structure of 5 items PartitionID PartitionType AvailPartitionCapacity PartitionCapacity UnallocatedPartition-Capacity	RO	Only applicable to internal buffer production equipment.
$BufferPartitionInfo_i$	The related information for the i^{th} buffer partition.	Structure of 5 items $PartitionID_i$ $PartitionType_i$ $AvailPartitionCapacity_i$ $PartitionCapacity_i$ UnallocatedPartition-$Capacity_i$	RO	Only applicable to internal buffer production equipment.
BypassReadID	Enables or disables automatic ID acceptance when the carrier ID reader is unavailable.	Boolean.	RW	If TRUE, the ID provided with Bind is used automatically.

Variable Name	*Description*	*Type*	*Access*	*Comment*
CarrierAccessing-Status	The state of the carrier accessing status.	Enumerated: NOT ACCESSED, IN ACCESS, CARRIER COMPLETE, CARRIER STOPPED	RO	
CarrierID	The ID of the carrier.	Text	RO	
$CarrierID_i$	The CarrierID at the i^{th} locationID.	Text	RO	
CarrierIDStatus	State of the carrier ID status.	Enumerated: ID NOT READ, [ID]WAITING FOR HOST, ID VERIFICATION OK, ID VERIFICATION FAILED	RO	
CarrierLocationMatrix	A list all the carriers at/in the equipment. Both internal to the equipment, and on equipment load ports.	List of n pairs of items 1. $LocationID_1$ $CarrierID_1$ . . n. $LocationID_n$ $CarrierID_n$	RO	The $CarrierID_i$ shall be null if there is no carrier at the $locationID_i$. If a carrier is at $LocationID_i$, but the $CarrierID_i$ is not known, the value of $CarrierID_i$ shall be "UNKNOWN".
LocationID	The ID of a carrier location.	Text	RO	Carrier locations are any location at/in the production equipment where a carrier may rest.
$LocationID_i$	The LocationID of the i^{th} carrier location.	Text	RO	Carrier locations are any location at/in the production equipment where a carrier may rest.
LoadPortReservation-State	The reservation state of a Load Port.	Enumerated: NOT RESERVED, RESERVED	RO	
LoadPortReservation-$State_I$	The reservation state of the i^{th} Load Port.	Enumerated: NOT RESERVED, RESERVED	RO	
LoadPortReservation-StateList	The current reservation state of all the load ports.	A list of n items 1. $LoadPortReservationState_1$ . . n.$LoadPortReservationState_n$	RO	This can be used to resynchronize the host.
PartitionCapacity	The total PartitionCapacity for a logical internal buffer partition.	Non-negative integer	RO	Only applicable to internal buffer production equipment.
$PartitionCapacity_i$	The PartitionCapacity for the i^{th} PartitionID of the internal buffer.	Non-negative integer	RO	Only applicable to internal buffer production equipment.
PartitionID	The ID of a logical internal buffer partition.	Text	RO	Used to identify separate material types in an internal buffer.
$PartitionID_i$	The ID of the i^{th} logical partition of the internal buffer.	Text	RO	Used to identify separate material types in an internal buffer.

Variable Name	*Description*	*Type*	*Access*	*Comment*
PartitionType	The type of a logical partition within an internal buffer.	Text	RO	Only applicable to internal buffer production equipment. Some examples of logical buffer PartitionType are Product, Dummy, Substrate, and Seed.
PartitionType_i	The PartitionType corresponding with the i^{th} PartitionID.	Text	RO	Only applicable to internal buffer production equipment. Some examples of logical buffer PartitionType are Product, Dummy, Substrate, and Seed.
PortAssociationState	The association state of a load port.	Enumerated: ASSOCIATED, NOT ASSOCIATED	RO	
$\text{PortAssociationState}_i$	The association state of the i^{th} load port.	Enumerated: ASSOCIATED, NOT ASSOCIATED	RO	
PortAssociationState-List	The current association state for all load ports.	A list of n items 1. $\text{PortAssociationState}_1$ . . n. $\text{PortAssociationState}_n$	RO	This can be used to re-synchronize the host.
PortID	ID of a load port.	Positive integer	RO	
PortID_i	ID of the load port where the carrier transfer is taking place. One PortID exists for each load port.	Positive integer	RO	
PortStateInfo	The PortAssociationState combined with the PortTransferState.	List of 2 items PortAssociationState PortTransferState	RO	A combination of both port states.
PortStateInfo_i	The PortAssociationState combined with the PortTransferState for the i^{th} load port.	List of 2 items $\text{PortAssociationState}_i$ $\text{PortTransferState}_i$	RO	A combination of both port states.
PortStateInfoList	List of PortStateInfo for all load ports.	List of n items 1. PortStateInfo_1 . . n PortStateInfo_n	RO	A list of all the port states for all the ports.
PortTransferState	The current transfer state of a load port.	Enumerated: OUT OF SERVICE, TRANSFER BLOCKED, READY TO LOAD, READY TO UNLOAD	RO	Super states are not included, only sub states.
$\text{PortTransferState}_i$	The current transfer state of the i^{th} load port.	Enumerated: OUT OF SERVICE, TRANSFER BLOCKED, READY TO LOAD, READY TO UNLOAD	RO	Super states are not included, only sub states.
PortTransferStateList	The current Load Port Transfer State for all load ports.	A list of n items 1. $\text{PortTransferState}_1$ . . n. $\text{PortTransferState}_n$	RO	This can be used to re-synchronize the host.

Variable Name	*Description*	*Type*	*Access*	*Comment*
Reason	The reason for transition 14, SLOT MAP NOT READ to WAITING FOR HOST	Enumerated: VERIFICATION NEEDED, VERIFICATION BY EQUIPMENT UNSUCCESSFUL, READ FAIL, IMPROPER SUBSTRATE POSITION	RO	Information to aid host in deciding appropriate action.
SlotMapStatus	State of the carrier slot map status.	Enumerated: SLOT MAP NOT READ, [SLOT]WAITING FOR HOST, SLOT MAP VERIFICATION OK, SLOT MAP VERIFICATION FAILED	RO	
UnAllocatedPartition-Capacity	The current unallocated capacity for a logical partition inside internal buffer equipment, (PartitionCapacity - # of carriers in partition - # of carriers allocated for the partition (via reception of a Bind, CarrierIn, Carrier-Notification, ReserveAtPort, or ProceedWithCarrier service)). Any carriers allocated for a partition will be de-allocated if the corresponding Cancel service is received (for example Bind-CancelBind, CarrierNotification – CancelCarrierNotification, ReserveAtPort – CancelReservationAtPort, ProceedWithCarrier – CancelCarrier).	Non-negative integer	RO	Only applicable to internal buffer equipment.
UnAllocatedPartition-$Capacity_i$	The UnallocatedPartition-Capacity for the i^{th} Partition ID within the internal buffer	Non-negative integer	RO	Only applicable to internal buffer equipment.

20 Alarms

20.1 This section includes specific alarms that are required to be implemented by CMS compliant equipment.

20.2 *Alarm List Table*

20.2.1 Table 37 is a listing of required alarms for both fixed buffer and internal buffer equipment. This list is only a subset of the carrier transfer alarms. There may be more carrier transfer related alarms that are not listed here.

Table 38 Alarm List

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
Fixed & Internal Buffer Equipment	PIO Failure	X		X	X	X

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
	Access Mode Violation	X		X	X	X
	Carrier Verification Failure	X				X
	Slot Map Read Failed	X		X	X	X
	Slot Map Verification Failed	X			X	X
	Attempt To Use Out Of Service Load Port	X			X	X
	Carrier Presence Error	X		X	X	X
	Carrier Placement Error	X		X	X	X
	Carrier Dock/UnDock Failure	X			X	X
	Carrier Open/Close Failure	X			X	X
Fixed and Internal Buffer	Duplicate CarrierID	X				X
Internal Buffer Equipment Only	Internal Buffer Carrier Move Failure	X			X	X
Fixed & Internal Buffer Equipment	Carrier Removal Error	X		X	X	X

20.3 *Duplicate CarrierID*

20.3.1 If the equipment receives a carrier with a CarrierID that is the same as that of another carrier present at the equipment, the following rules shall apply:

1. The second carrier with a CarrierID shall not be processed.
2. If processing on the first carrier with the CarrierID has not begun, it should not be processed.
3. If processing on the first carrier has begun a Duplicate Carrier ID In Process event shall be issued to notify the host.

21 Requirements for Compliance

21.1 Table 38 provides a checklist for CMS compliance.

Table 39 CMS Compliance Statement

Fundamental CMS Requirements	*CMS Section*	*Implemented*	*CMS Compliant*
Load Port Numbering	9.1	☐ Yes ☐ No	☐ Yes ☐ No
Carrier Slot Numbering	9.2	☐ Yes ☐ No	☐ Yes ☐ No
Load Port Transfer State Model	9.3–9.4.3	☐ Yes ☐ No	☐ Yes ☐ No
Carrier Object Implementation	10	☐ Yes ☐ No	☐ Yes ☐ No
Load Port Reservation State Model (internal buffer equipment)	12	☐ Yes ☐ No	☐ Yes ☐ No
Load Port/Carrier Association State Model	13	☐ Yes ☐ No	☐ Yes ☐ No
CarrierID Verification Support	14.2	☐ Yes ☐ No	☐ Yes ☐ No
Slot Map Verification Support	14.3	☐ Yes ☐ No	☐ Yes ☐ No
Services Implementation	16	☐ Yes ☐ No	☐ Yes ☐ No
Additional Events Implementation	18	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data Definitions	19	☐ Yes ☐ No	☐ Yes ☐ No
Alarms Implementation	20	☐ Yes ☐ No	☐ Yes ☐ No
Additional CMS Capabilities	*CMS Section*	*Implemented*	*CMS Compliant*
Load Port Reservation State Model (fixed buffer equipment)	12	☐ Yes ☐ No	☐ Yes ☐ No
Reservation Visible Signal	12.2	☐ Yes ☐ No	☐ Yes ☐ No

RELATED INFORMATION 1
CARRIER OBJECT ID

NOTE: This related information is not an official part of SEMI E87, but was approved for publication by full letter ballot procedures on December 15, 1999.

R1-1 Carrier Object ID

R1-1.1 The Carrier Object ID is derived as stated in the Table R1-1 Carrier ID derivation.

Table R1-1 CarrierID Derivation

	Method of Original Instantiation	*CarrierID Read*	*ID Verifi-cation*	*Following Actions*	*CarrierID =*	*Parameter Required by Service*
1	Bind	Success-ful	Successful and equipment based	Production equipment continues with the carrier.	CarrierID in Bind service.	*Bind:* CarrierID, PortID, and PropertiesList
2	Bind	Success-ful	Fails	The carrier object instantiated via the Bind message is destroyed and a new carrier object with the carrierID equal to the one determined by the carrierID is instantiated. ProceedWithCarrier service is received.	CarrierID provided by the CarrierID read.	*ProceedWith-Carrier:* CarrierID, PropertiesList
3	Bind	Success-ful	Fails	The carrier object instantiated via the Bind message is destroyed and a new carrier object with the carrierID equal to the one determined by the carrierID is instantiated. CancelCarrier service is received.	CarrierID provided by the CarrierID read.	*CancelCarrier*: CarrierID
4	Bind	Fails	NA	ProceedWithCarrier service is received and the carrierID matches the carrierID provided by the Bind service.	CarrierID provided by the Bind service.	*ProceedWith-Carrier*: CarrierID
5	Bind	Fails	NA	CancelCarrier service is received and the carrierID matches the carrierID provided by the Bind service.	CarrierID provided by the Bind service.	*CancelCarrier*: CarrierID
6	Carrier-Notification	Success-ful	Successful and equipment based	Production equipment continues with the carrier.	CarrierID in Carrier-Notification.	*Carrier-Notification:* CarrierID and PropertiesList
7	Carrier ID read	Success-ful	Successful and Host based	ProceedWithCarrier service is received and the carrierID matches the carrierID read by the production equipment.	CarrierID read by production equipment.	*ProceedWith-Carrier*: CarrierID and PropertiesList, PortID may be included.
8	CarrierID read	Success-ful	Fails and Host based	A CancelCarrier service is received and the carrierID matches the carrierID read by the production equipment.	CarrierID read by production equipment.	*CancelCarrier*: CarrierID

	Method of Original Instantiation	*CarrierID Read*	*ID Verifi-cation*	*Following Actions*	*CarrierID =*	*Parameter Required by Service*
9	The method of original instantiation is defined following the carrierID read fail and is described in column titled following actions.	Fails	NA	A ProceedWithCarrier service is received and the carrierID is provided in the service.	CarrierID provided by the Proceed-WithCarrier service.	*ProceedWith-Carrier* : CarrierID, PortID, PropertiesList
10	The method of original instantiation is defined following the carrierID read fail and is described in the column titled *Following Actions*.			A CancelCarrier service is received and the carrierID is the one provided by the CancelCarrier.	CarrierID provided by the Cancel-Carrier service.	*CancelCarrier*: CarrierID, PortID

R1-2 Scenarios

R1-2.1 The scenarios listed here are not a requirement of this standard. They are provided to aid in the understanding of the document. These scenarios are not an exhaustive set of all possible scenarios. The scenarios presented are typical or common scenarios encountered when using this standard.

R1-2.2 *Normal Roundtrip 1*

R1-2.2.1 Assumptions: Fixed buffer production equipment, FOUP, Host based verification

R1-2.2.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-2 Normal Roundtrip 1

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Loading transfer starts.	H<-E	TransferBlocked	TB			
2	Loading transfer completes.						
3	CarrierID is read.	H<-E	WaitingForHost		A	WFH	SNR
4	CarrierID is verified by host, and result is OK.						
5	Host commands to proceed.	H->E	ProceedWithCarrier			IVO	
6	Carrier is docked.						
7	Slot map is read.	H<-E	WaitingForHost				WFH
8	Slot map is verified by host, and result is OK.						
9	Host commands to proceed.	H->E	ProceedWithCarrier				SVO
10	Process starts.						
11	Process completes.						
12	Carrier is undocked.	H<-E	ReadyToUnload	RTU			
13	Unloading transfer starts.	H<-E	TransferBlocked	TB			
14	Unloading transfer completes.	H<-E	ReadyToLoad	RTL	NA	(T)	(T)

R1-2.3 *Normal Roundtrip 2*

R1-2.3.1 Assumptions: Fixed buffer production equipment, FOUP, Production equipment based verification, Bind Service received

R1-2.3.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-3 Normal Roundtrip 2

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E	Bind		R	A	INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.							
5	CarrierID is verified by production equipment, and result is OK.	H<-E	IDVerificationOK				IVO	
6	Carrier is docked.							
7	Slot map is read.							
8	Slot map is verified by production equipment, and result is OK.	H<-E	SlotMapVerificationOK					SVO
9	Process starts.							
10	Process completes.							
11	Carrier is undocked.	H<-E	ReadyToUnload	RTU				
12	Unloading transfer starts.	H<-E	TransferBlocked	TB				
13	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.4 *Normal Roundtrip 3*

R1-2.4.1 Internal buffer production equipment, FOUP, Host based verification

R1-2.4.2 Indicated states: LTS = Load Port Transfer State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status, LCAS = Load Port/Carrier Association State

Table R1-4 Normal Roundtrip 3

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Loading transfer starts.	H<-E	TransferBlocked	TB			
2	Loading transfer completes.						
3	CarrierID is read.	H<-E	WaitingForHost		A	WFH	SNR
4	CarrierID is verified by host, and result is OK.						
5	Host commands to proceed.	H->E	ProceedWithCarrier			IVO	
6	Carrier-in starts.	H<-E	BufferCapacityChange				
7	Carrier-in completes.			RTL	NA		
8	Process starts.						
9	Slot map is read at FIMS port.	H<-E	WaitingForHost				WFH
10	Slot map is verified by host, and result is OK.						
11	Host commands to proceed.	H->E	ProceedWithCarrier				SVO
12	Process completes.						
13	Carrier completes.	H<-E	CarrierComplete				
14	Host commands to carrier-out.	H->E	CarrierOut		A		
15	Carrier-out starts.	H<-E	TransferBlocked	TB			
16	Carrier-out completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU			
17	Unloading transfer starts.	H<-E	TransferBlocked	TB			
18	Unloading transfer completes.	H<-E	ReadyToLoad	RTL	NA	(T)	(T)

R1-2.5 *Normal Roundtrip 4*

R1-2.5.1 Internal buffer production equipment, FOUP, Production equipment based verification, Bind service received

R1-2.5.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-5 Normal Roundtrip 4

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E	Bind		R	A	INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.							
5	CarrierID is verified by equipment, and result is OK.	H<-E	IDVerificationOK				IVO	
6	Carrier-in starts.	H<-E	BufferCapacityChange					
7	Carrier-in completes.			RTL		NA		
8	Process starts.							
9	Slot map is read at FIMS port.							
10	Slot map is verified by equipment, and result is OK.	H<-E	SlotMapVerificationOK					SVO
11	Process completes.							
12	Carrier completes.	H<-E	CarrierComplete					
13	Host commands to carrier-out.	H->E	CarrierOut					
14	Carrier-out starts.	H<-E	TransferBlocked	TB	R	A		
15	Carrier-out completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR			
16	Unloading transfer starts.	H<-E	TransferBlocked	TB				
17	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.6 *Normal Roundtrip 5*

R1-2.6.1 Assumptions: Fixed buffer production equipment, FOUP, Production equipment based verification, Carrier Notification service received

R1-2.6.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-6 Normal Roundtrip 5

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Equipment is notified of future Carrier arrival.	H->E	CarrierNotification				INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.							
4	CarrierID is read.					A		
5	CarrierID is verified by production equipment, and result is OK.	H<-E	IDVerificationOK				IVO	
6	Carrier is docked.							
7	Slot map is read.							
8	Slot map is verified by production equipment, and result is OK.	H<-E	SlotMapVerificationOK					SVO
9	Process starts.							
10	Process completes.							
11	Carrier is undocked.	H<-E	ReadyToUnload	RTU				
12	Unloading transfer starts.	H<-E	TransferBlocked	TB				
13	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.7 *Normal Roundtrip 6*

R1-2.7.1 Internal buffer production equipment, FOUP, Production equipment based verification, CarrierNotification service received

R1-2.7.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-7 Normal Roundtrip 6

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port notified of future carrier arrival.	H->E	CarrierNotification				INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.							
4	CarrierID is read.					A		
5	CarrierID is verified by equipment, and result is OK.	H<-E	IDVerificationOK				IVO	
6	Carrier-in starts.	H<-E	BufferCapacityChange					
7	Carrier-in completes.			RTL		NA		
8	Process starts.							
9	Slot map is read at FIMS port.							
10	Slot map is verified by equipment, and result is OK.	H<-E	SlotMapVerificationOK					SVO
11	Process completes.							
12	Carrier completes.	H<-E	CarrierComplete					
13	Host commands to carrier-out.	H->E	CarrierOut					
14	Carrier-out starts.	H<-E	TransferBlocked	TB	R	A		
15	Carrier-out completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR			
16	Unloading transfer starts.	H<-E	TransferBlocked	TB				
17	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.8 *Normal Roundtrip 7*

R1-2.8.1 Assumptions: Fixed buffer production equipment, FOUP, Host based verification, ReserveAtPort service received

R1-2.8.2 Indicated states: LTS = Load Port Transfer State, LRS= Load Port Reserve State, LCAS = Load Port/Carrier State Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-8 Normal Roundtrip 7

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Reserve a port for future activity.	H->E	ReserveAtPort		R			
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.	H<-E	WaitingForHost			A	WFH	SNR
5	CarrierID is verified by host, and result is OK.							
6	Host commands to proceed.	H->E	ProceedWithCarrier				IVO	
7	Carrier is docked.							
8	Slot map is read.	H<-E	WaitingForHost					WFH
9	Slot map is verified by host, and result is OK.							
10	Host commands to proceed.	H->E	ProceedWithCarrier					SVO
11	Process starts.							
12	Process completes.							
13	Carrier is undocked.	H<-E	ReadyToUnload	RTU				
14	Unloading transfer starts.	H<-E	TransferBlocked	TB				
15	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.9 *Normal Roundtrip 8*

R1-2.9.1 Internal buffer production equipment, FOUP, Host based verification, ReserveAtPort service received

R1-2.9.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status, CPS = Carrier Processing Status

Table R1-9 Normal Roundtrip 8

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Reserve Port for future activity.	H->E	ReserveAtPort		R			
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.	H<-E	WaitingForHost			A	WFH	SNR
5	CarrierID is verified by host, and result is OK.							
6	Host commands to proceed.	H->E	ProceedWithCarrier				IVO	
7	Carrier-in starts.	H<-E	BufferCapacityChange					
8	Carrier-in completes.			RTL		NA		
9	Process starts.							
10	Slot map is read at FIMS port.	H<-E	WaitingForHost					WFH
11	Slot map is verified by host, and result is OK.							
12	Host commands to proceed.	H->E	ProceedWithCarrier					SVO
13	Process completes.							
14	Carrier completes.	H<-E	CarrierComplete					
15	Host commands to carrier-out.	H->E	CarrierOut			A		
16	Carrier-out starts.	H<-E	TransferBlocked	TB	R			
17	Carrier-out completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR			
18	Unloading transfer starts.	H<-E	TransferBlocked	TB				
19	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA	(T)	(T)

R1-2.10 *Abnormal CarrierID Verification 1*

R1-2.10.1 Host based verification, CancelCarrier

R1-2.10.2 Indicated states: LTS = Load Port Transfer State, LAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-10 Abnormal CarrierID Verification 1

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Loading transfer starts.	H<-E	TransferBlocked	TB			
2	Loading transfer completes.						
3	CarrierID is read.	H<-E	WaitingForHost		A	WFH	SNR
4	CarrierID is verified by host, and result is Failed.						
5	Host commands to return.	H->E	CancelCarrier			IVF	
6	Carrier is made ready to unload.	H<-E	ReadyToUnload	RTU			

R1-2.11 *Abnormal CarrierID Verification 2*

R1-2.11.1 Production equipment based verification, Bind service received, CancelCarrier

R1-2.11.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-11 Abnormal CarrierID Verification 2

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E	Bind		R	A	INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.							
5	CarrierID is verified by production equipment, and result is Failed. The carrier object created by the Bind service is destroyed. A carrier object with the id determined by read is created.	H<-E	WaitingForHost				(T) / WFH	(T) / SNR
5	Host commands to return.	H->E	CancelCarrier				IVF	
6	Carrier is made ready to unload.	H<-E	ReadyToUnload	RTU				

R1-2.12 *Abnormal CarrierID Verification 3*

R1-2.12.1 Production equipment based verification, Bind Service received, ProceedWithCarrier

R1-2.12.2 Production equipment based verification, ProceedWithCarrier

R1-2.12.3 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-12 Abnormal CarrierID Verification 3

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E	Bind		R	A	INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.							
5	CarrierID is verified by production equipment, and result is Failed.	H<-E	WaitingForHost				(T) / WFH	(T) / SNR
6	Host commands to proceed.	H->E	ProceedWithCarrier				IVO	
7	(Go to next step.)							

R1-2.13 *Abnormal Slot Map Verification 1*

R1-2.13.1 Fixed buffer production equipment, FOUP, Host based verification, CancelCarrier

R1-2.13.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-13 Abnormal Slot Map Verification 1

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Loading transfer starts.	H<-E	TransferBlocked	TB				
2	Loading transfer completes.							
3	CarrierID is read.	H<-E	WaitingForHost			A	WFH	SNR
4	CarrierID is verified by host, and result is OK.							
5	Host commands to proceed.	H->E	ProceedWithCarrier				IVO	
6	Carrier is docked.							
7	Slot map is read.	H<-E	WaitingForHost					WFH
8	Slot map is verified by host, and result is Failed.							
9	Host commands to return.	H->E	CancelCarrier					SVF
10	Carrier is made ready to unload.		ReadyToUnload	RTU				

R1-2.14 *Abnormal Slot Map Verification 2*

R1-2.14.1 Internal buffer production equipment, FOUP, Production equipment based verification, CancelCarrier

R1-2.14.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-14 Abnormal Slot Map Verification 2

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E	Bind		R	A	INR	SNR
2	Loading transfer starts.	H<-E	TransferBlocked	TB				
3	Loading transfer completes.				NR			
4	CarrierID is read.							
5	CarrierID is verified by equipment, and result is OK.	H<-E	IDVerificationOK				IVO	
6	Carrier-in starts.	H<-E	BufferCapacityChange					
7	Carrier-in completes.			RTL		NA		
8	Process starts.							
9	Slot map is read at FIMS port.							
10	Slot map is verified by production equipment, and result is Failed.	H<-E	WaitingForHost					WFH
11	Host commands to return.	H->E	CancelCarrier					SVF
12	Carrier returns to internal buffer.							

R1-2.15 *Carrier-Out Queuing*

R1-2.15.1 Internal buffer equipment

R1-2.15.2 Initial condition: Two more carriers are within the production equipment

R1-2.15.3 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State

R1-15 Carrier-Out Queuing

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*
0	Initial condition.			RTL	NR	NA
1	Host commands to carrier-out #1.	H->E	CarrierOut			
2	Carrier-out #1 starts.	H<-E	TransferBlocked	TB	R	A
3	Host commands to carrier-out #2 (Queued).	H->E	CarrierOut			
4	Carrier-out #1 completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR	
5	Unloading transfer #1 starts.	H<-E	TransferBlocked	TB		
6	Unloading transfer #1 completes.					
7	Carrier-out #2 starts.				R	
8	Carrier-out #2 completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR	
9	Unloading transfer #2 starts.	H<-E	TransferBlocked	TB		
10	Unloading transfer #2 completes.	H<-E	ReadyToLoad	RTL		NA

R1-2.16 *Carrier-Out Dequeuing (Cancellation)*

R1-2.16.1 Internal buffer production equipment

R1-2.16.2 Initial condition: One more carrier-out services are queued, One carrier-out service is active

R1-2.16.3 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State

Table R1-16 Carrier-Out Dequeuing (Cancellation)

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*
0	Initial condition.			TB	R	A
1	Host commands to cancel all carrier-out services from queue.	H->E	CancelAllCarrierOut			
2	All carrier-out services are canceled from queue.					
3	Current carrier-out service completes.	H<-E H<-E	ReadyToUnload BufferCapacityChange	RTU	NR	
4	Unloading transfer starts.	H<-E	TransferBlocked	TB		
5	Unloading transfer completes.	H<-E	ReadyToLoad	RTL		NA

R1-2.17 *Carrier Association Cancellation*

R1-2.17.1 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-17 Carrier Association Cancellation

#	*Comment*	*Dir*	*Message*	*LTS*	*LRS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	(T)	(T)
1	Load port is associated with specified carrierID, and reserved for loading.	H->E H<-E	Bind Associated		R	A	INR	SNR
2	Host decides to cancel current carrier delivery.							
3	Host commands to cancel association.	H->E H<-E	CancelBind NotAssociated		NR	NA	(T)	(T)

R1-2.18 *Access Mode Change*

R1-2.18.1 Initial condition: Access mode = AUTO

R1-2.18.2 Indicated states: AMS = Access Mode State

Table R1-18 Access Mode Change

#	*Comment*	*Dir*	*Message*	*AMS*
0	Initial condition.			A
1	Host commands to change access mode to MANUAL.	H->E	ChangeAccess	M
2	Access mode is changed to MANUAL.	H<-E	Manual	

R1-2.19 *Load Port Service Status Change*

R1-2.19.1 Initial condition: Load port service status = IN SERVICE

R1-2.19.2 Indicated states: LTS = Load Port Transfer State

Table R1-19 Load Port Service Status Change

#	*Comment*	*Dir*	*Message*	*LTS*
0	Initial condition.			IS
1	Host commands to change service status to OUT OF SERVICE.	H->E	ChangeServiceStatus	OS
2	Service status is changed to OUT OF SERVICE.	H<-E	OutofService	

R1-2.201 *Correct Carrier Delivery to Wrong Port 1 Scenario*

R1-2.20.1 Assumptions: Fixed Load Port Equipment based verification

R1-2.20.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-20 Correct Carrier Delivery to Wrong Port 1 Scenario

#	*Comment*	*Dir*	*Message*	*LTS1*	*LRS2*	*LCAS 3*	*LTS2*	*LRS2*	*LCAS 2*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NR	NA	RTL	NR	NA	(T)	(T)
1	Load port 1 is associated with specified carrierID, and reserved for loading.	H->E H<-E	Bind (lp1) LP1 Associated		R	A				INR	SNR
2	Transfer starts at load port 2	H<-E	LP2 TRANSFER BLOCKED				TB				
3	Transfer Completes at load port2.	H<-E	Transfer Complete								
4	CarrierID read at load port 2 Equipment based verification indicates the carrier is at the correct equipment.	H<-E H<-E H<-E	LP1 NOT ASSOCIATED LP2 ASSOCIATED IV0		NR	NA			A	WFH	

R1-2.21 *Correct Carrier Delivery to Wrong Port 2 Scenario*

R1-2.21.1 Assumptions: Fixed Load Port Equipment based verification

R1-21.2 Indicated states: LTS = Load Port Transfer State, LRS = Load Port Reservation State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-21 Correct Carrier Delivery to Wrong Port 2 Scenario

#	*Comment*	*Dir*	*Message*	*LTS1*	*LRS2*	*LCAS 3*	*LTS2*	*LRS2*	*LCAS 2*	*CIDS A*	*CSMS A*	*CIDS B*	*CSMS B*
0	Initial condition.			RTL	NR	NA	RTL	NR	NA	(T)	(T)	(T)	(T)
1	Load port 1 is associated with specified carrierID A, and reserved for loading.	H->E H<-E	Bind (CA, LP1) Lp1 Associated		R	A				INR	SNR		
2	Load port 2 is associated with specified carrierID B, and reserved for loading.	H->E H<-E	Bind (CB, LP2) Lp2 Associated					R	A			INR	SNR
2	Carrier A Transfer starts at load port 2	H<-E	LP2 TRANSFER BLOCKED				TB						
3	Transfer Completes at load port2.	H<-E	Transfer Complete					NR					
4	CarrierID read at load port 2, Equipment based verification indicates that a correct carrier was delivered to the wrong load port.	H<-E H<-E H<-E	LP1 NOT ASSOCI-ATED Carrier B object destroyed Alarm LP2 verification failed		NR	NA				WFH		(T)	(T)
5	Host oks processing.	H->	ProceedWith Carrier							IVO			

R1-2.22 *CarrierID Read Fail Scenario 1*

R1-2.22.1 Assumptions: Fixed buffer Equipment, Equipment based Verification, Bind service has been received

R1-2.22.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-22 CarrierID Read Fail Scenario 1

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	A	INR	SNR
1	Carrier Arrives.	E>H	Transfer Blocked	TB	A	INR	SNR
2	ID read attempt fails.	E>H	State change to Waiting For Host	TB	A	WFH	SNR
3	Decision to continue is made.						
4	Host sends ProceedWithCarrier service.	H>E E>H	ProceedWithCarrier State change to Id Verification OK	TB	A	IVO	SNR

R1-2.23 *CarrierID Read Fail Scenario 2*

R1-2.23.1 Assumptions: Fixed buffer Equipment, Equipment based Verification, Bind service has been received

R1-2.23.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-23 CarrierID Read Fail Scenario 2

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	A	INR	SNR
1	Carrier Arrives.	E>H	Transfer Blocked	TB			
2	ID read attempt fails.	E>H	State change to Waiting For Host	TB		WFH	
3	Decision to stop is made.						
4	Host sends CancelCarrier service.	H>E E>H	CancelCarrier State change to Id Verification Failed	TB		IVF	

R1-2.24 *CarrierID Read Fail Scenario 3*

R1-2.24.1 Assumptions: Fixed buffer Equipment, Host based Verification,

R1-2.24.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-24 CarrierID Read Fail Scenario 3

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Carrier Arrives.	E>H	Transfer Blocked	TB			
2	ID read attempt fails.	E>H	ID read fail event				
3	Decision to continue is made.	H>E					
4	Host sends ProceedWithCarrier service.	H>E E>H E>H	ProceedWithCarrier State change to Id Verification OK State change to Load Port Associated		A	IVO	SNR

R1-2.25 *CarrierID Read Fail Scenario 4*

R1-2.25.1 Assumptions: Fixed buffer Equipment, Host based Verification,

R1-2.25.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

Table R1-25 CarrierID Read Fail Scenario 4

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Carrier Arrives.	E>H	Transfer Blocked	TB			
2	ID read attempt fails.	E>H	ID read fail event				
3	Decision to stop is made.	H>E					
4	Host sends CancelCarrier.	H>E E>H E>H	CancelCarrier State change to Id Verification Failed State change to Load Port Associated		A	IVF	SNR

R1-2.26 *CarrierID Read Fail Scenario 5*

R1-2.26.1 Assumptions: Fixed buffer Equipment, Host based Verification,

R1-2.26.2 Indicated states: LTS = Load Port Transfer State, LCAS = Load Port/Carrier Association State, CIDS = Carrier ID Status, CSMS = Carrier Slot Map Status

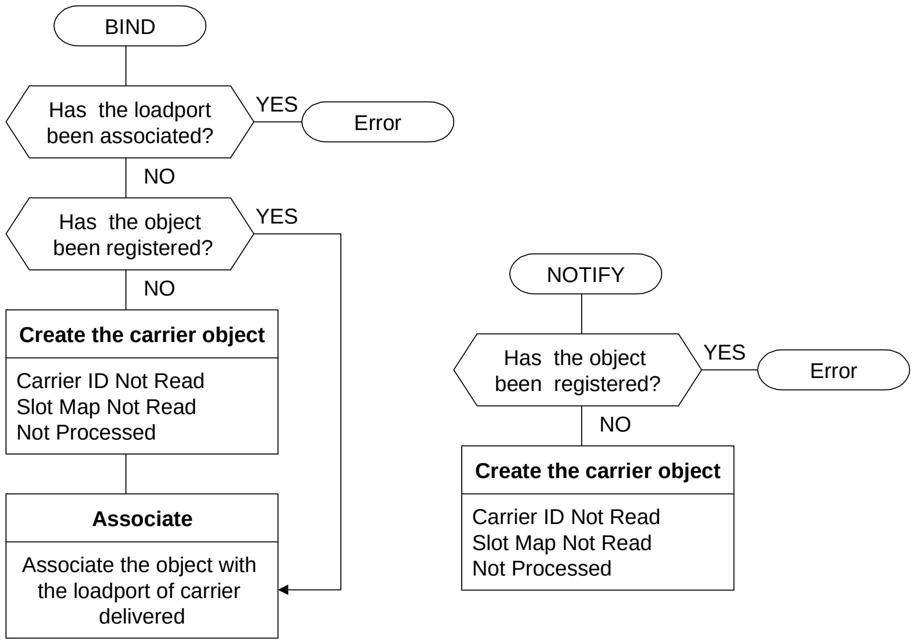
Table R1-26 CarrierID Read Fail Scenario 5

#	*Comment*	*Dir*	*Message*	*LTS*	*LCAS*	*CIDS*	*CSMS*
0	Initial condition.			RTL	NA	(T)	(T)
1	Carrier Arrives.	E>H	Transfer Blocked	TB			
2	ID read attempt fails.	E>H	ID read fail event				
3	Decision to stop is made.	H>E					
4	Host sends CancelCarrierAtPort.	H>E	CancelCarrierAtPort				

R1-3 Example Equipment Logic for Carrier Delivery

R1-3.1 To summarize the CMS carrier object behavior, following flow-charts are provided. The charts show the example of an equipment logic for the CMS definitions.

R1-3.2 *Bind and Notify*



R1-3.2.1 *Bind Service Request From the Host*

R1-3.2.1.1 Verify no object has been associated with designated loadport. If it is associated the Bind service shall be failed.

R1-3.2.1.2 Verify no object having the same ID specified in Bind service has been registered.

R1-3.2.1.2.1 If it is registered, the Bind service shall associate the object that is already registered with the designated loadport.

R1-3.2.1.2.2 If it is not registered, then create the object and associate it to the loadport. The initial states of the object are Carrier ID Not Read, Carrier Slot Map Not Read, Carrier Not Processed and Associated to the loadport.

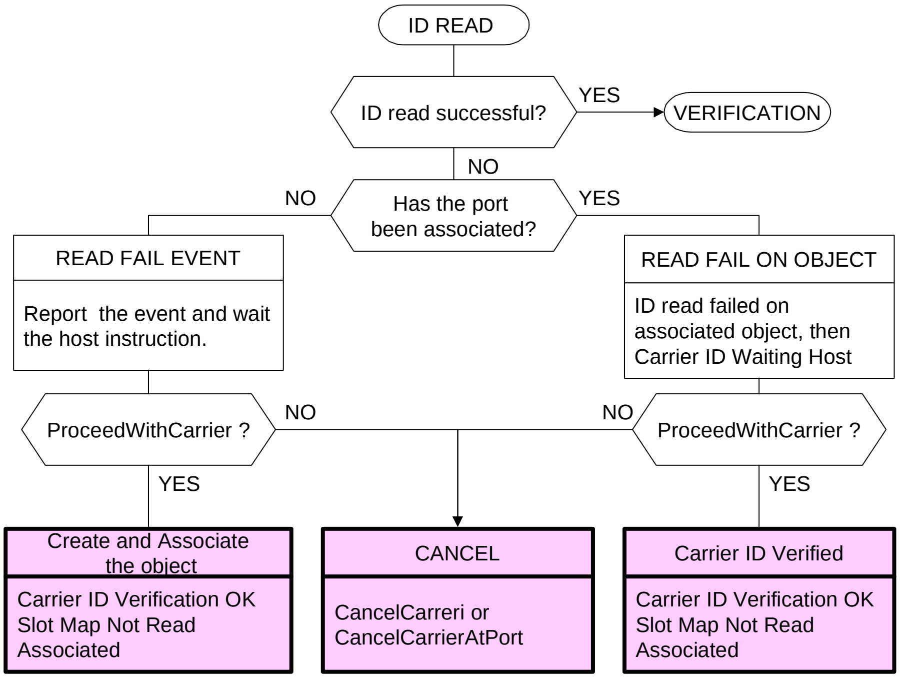
R1-3.2.2 Notify service request from the host

R1-3.2.2.1 Verify no object having the same ID specified in Notify service has been registered.

R1-3.2.2.1.1 If it is registered, the Notify service shall be failed.

R1-3.2.2.1.2 If it is not registered, then create the carrier object. The initial states of the object are Carrier ID Not Read, Carrier Slot Map Not Read, Carrier Not Processed and Not Associated.

R1-3.3 *Carrier ID Read*



R1-3.3.1 *Carrier ID Read Event*

R1-3.3.1.1 If carrier ID has been read successfully then ID DETERMINATION (ID DET) is executed.

R1-3.3.1.2 If carrier ID has been failed to be read and the port is not associated with any object;

R1-3.3.1.2.1 Report the host the event to inform Carrier ID read fail when the loadport has no Bind.

R1-3.3.1.2.2 If the host requests ProceedWithCarrier service, then create the object and associate it with the loadport. Carrier ID state shall be changed to Carrier ID Verification OK.

R1-3.3.1.2.3 If the host requests CancelCarrierservice, then create the object and associate it with the loadport. Carrier ID state shall be changed to Carrier ID Verification Fail. Take the carrier to Ready to Unload.

R1-3.3.1.2.4 If the host requests CancelCarrierAtPort service, no objet is created. Take the carrier to Ready to Unload.

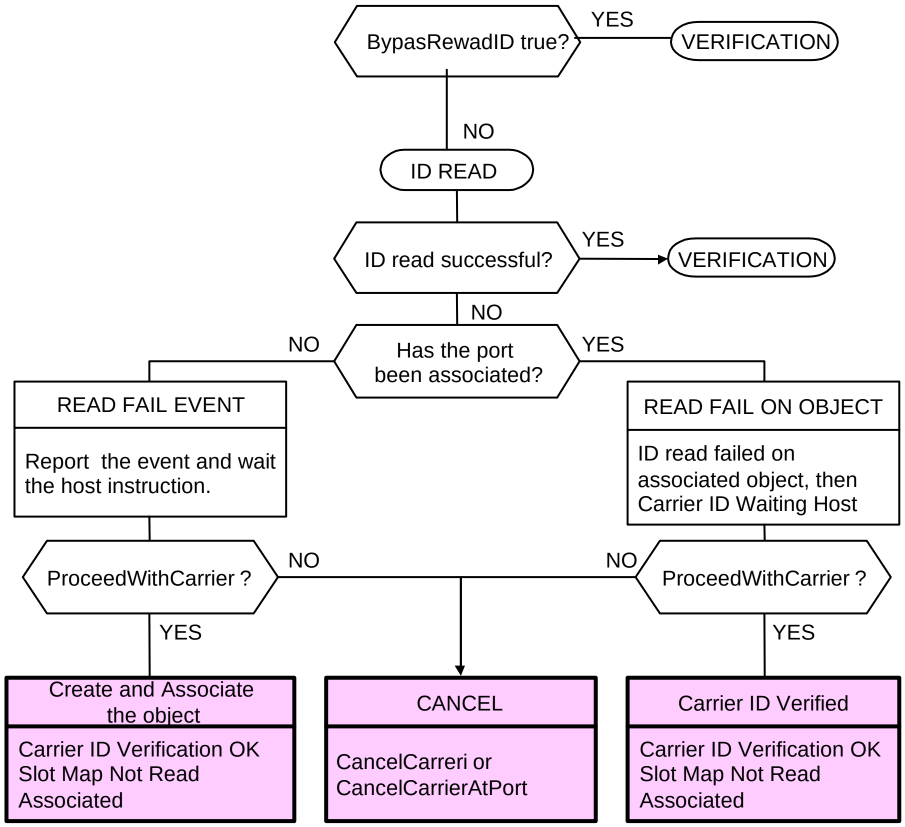
R1-3.3.1.3 If carrier ID has been failed to be read and the port is associated with any object;

R1-3.3.1.3.1 Change the Carrier ID status of the associated object to Waiting for Host. The event shall be reported to indicate carrier ID read for associated object has been failed.

R1-3.3.1.3.2 If the host requests ProceedWithCarrier service, then change the Carrie ID status of the associated object to Carrier ID Verification OK.

R1-3.3.1.3.3 If the host requests CancelCarrier service, then change the Carrie ID status of the associated object to Carrier ID Verification Fail. Take the carrier to Ready to Unload.

R1-3.4 *BypassReadID*



R1-3.4.1 *BypassReadID*

R1-3.4.1.1 If Bind has been received, then decision should be made if ID read is necessary.

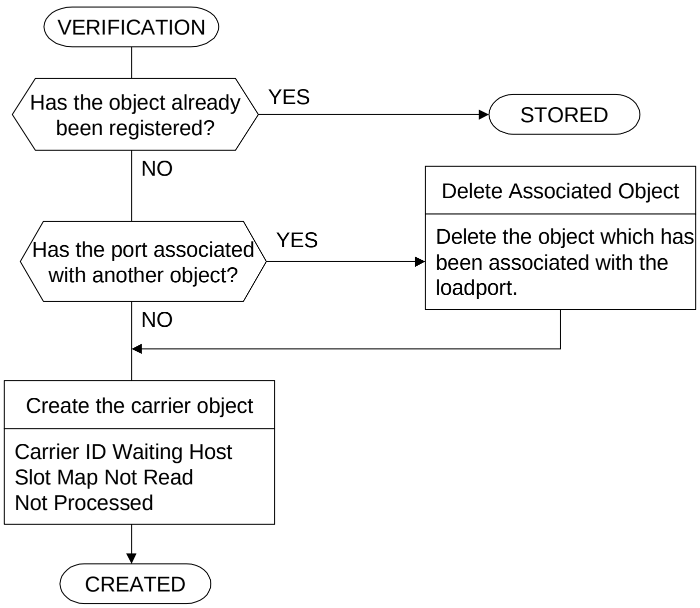
R1-3.4.1.2 If BypassReadID is equal to True

R1-3.4.1.2.1 No ID read is required and carrier object enters ID Verification OK state

R1-3.4.1.3 If BypassReadID is equal to False

R1-3.4.1.3.1 ID Read is required

R1-3.5 *Carrier Object Verification*



R1-3.5.1 If the object having the ID read from the carrier has been registered, then STORED object logic shall be executed.

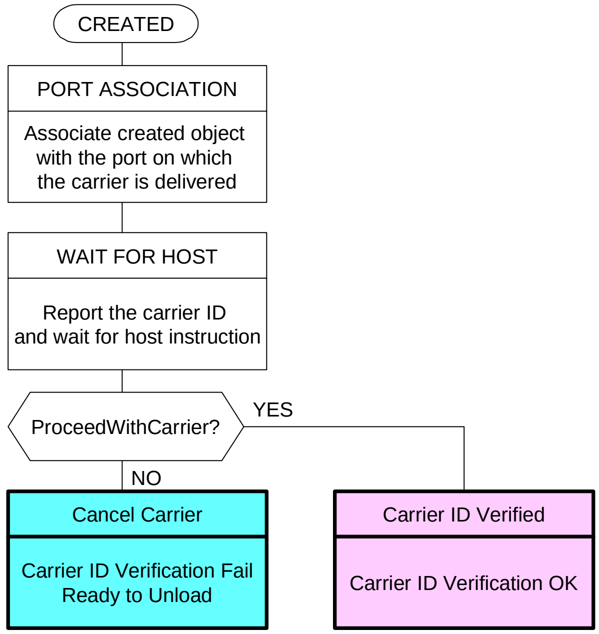
R1-3.5.2 If no object having the ID read from the carrier has been registered;

R1-3.5.2.1 Create the object.

R1-3.5.2.2 If an object has been associated with the loadport on which the carrier is delivered, the event means the carrier delivered is not expected by the associated object. That is Carrier ID verification fail. Then, delete the asoociated object.

R1-3.5.2.3 CREATED logic shall be executed.

R1-3.6 *CREATED*



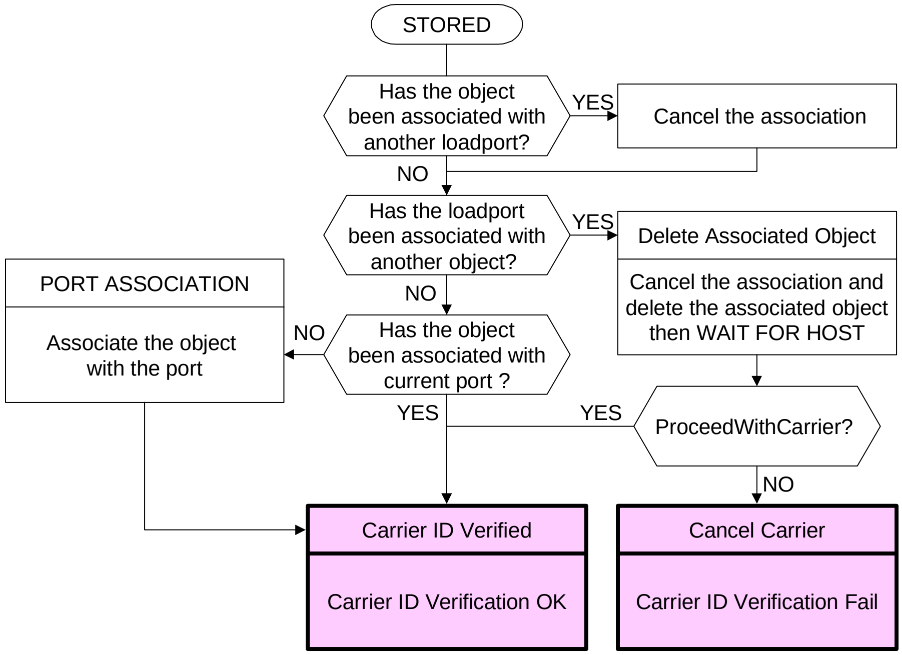
R1-3.6.1 Associate the object just created with the loadport on which the carrier is delivered.

R1-3.6.2 Report the carrier ID and wait for host instruction.

R1-3.6.3 If the host requests ProceedWithCarrier service, change the Carrier ID Status to Carrier ID Verification OK.

R1-3.6.4 If the host requests CancelCarrier service, change the Carrier ID Status to Carrier ID Verification Fail. The carrier shall be taken to Ready to Unload.

R1-3.7 *STORED*



R1-3.7.1 If the object has been already associated with the loadport other than the carrier is delivered;

R1-3.7.1.1 This is the case for misloading to a wrong loadport.

R1-3.7.1.2 Cancel the association.

R1-3.7.2 And If the loadport on which the carrier has been delivered is associated to another object, then delete the object associated with the port on which the carrier is delivered.

R1-3.7.2.1 This is the case for equipment base ID VERIFICATION FAIL.

R1-3.7.2.2 Associate the object with the loadport on which the carrier has been delivered.

R1-3.7.2.3 Then enter WAITING FOR HOST.

R1-3.7.2.4 If ProceedWithCarrier is given, then the carrier is verified.

R1-3.7.2.5 If CancelCarrier is given, then the carrier verification is failed.

R1-3.7.3 If the object has been associated with the loadport on which the carrier is delivered, the carrier is verified. Change the Carrier ID status to Carrier ID Verified.

R1-3.7.4 If no object has been associated with the loadport on which the carrier is delivered, associate the object with the loadport. This is the case for associating object created by Notify.

SEMI E87.1-0702
PROVISIONAL SPECIFICATION FOR SECS-II PROTOCOL FOR CARRIER MANAGEMENT (CMS)

This provisional specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on April 30 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published February 2000; previously published March 2002.

1 Purpose

1.1 This document maps the services and data of SEMI E87 to SECS-II streams and functions, and data definitions.

2 Scope

2.1 This is a provisional specification covering equipment supporting automated access to load ports from the host point-of-view. The provisional status is required because of the immaturity of implementations of integrated equipment with AMHS, and additional specifications may yet be defined. Also, further exception handling and error recovery scenarios need to be defined.

2.2 This document applies to all implementations of SEMI E87 that use the SECS-II message protocol (SEMI E5). Compliance to this standard requires compliance to both SEMI E87 and SEMI E5.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification applies to semiconductor equipment with SEMI E15.1 compliant load ports. It may also be applied to other manufacturing equipment that supports automated carrier transfer and or contains an internal buffer.

3.2 This is a provisional specification. The following areas must be completed before the provisional status is removed:

1) Any additional services, or changes to existing services, in Carrier Management must be mapped to SECS-II messages.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI 15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E87 — Specification for Carrier Management (CMS)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Services Mapping

5.1 This section shows the specific SECS-II streams and functions that shall be used for SECS-II implementation of the services defined in SEMI E87, as well as the parameter mapping for data attached to services.

5.2 *Services Message Mapping*

5.2.1 Table 1 defines the relationships between SEMI E87 services and SECS-II messages.

Table 1 Services Message Mapping Table

Service Name	*Stream, Function*	*SECS-II Message Name*
Bind	S3,F17/18	Carrier Action Request/Acknowledge
CancelBind	S3,F17/18	Carrier Action Request/Acknowledge
CancelAllCarrierOut	S3,F19/20	Cancel All Carrier Out Request/Acknowledge
CancelCarrier	S3,F17/18	Carrier Action Request/Acknowledge
CancelCarrierAtPort	S3,F17/18	Carrier Action Request/Acknowledge
CancelCarrierNotification	S3,F17/18	Carrier Action Request/Acknowledge
CancelCarrierOut	S3,F17/18	Carrier Action Request/Acknowledge
CancelReservationAtPort	S3,F25/26	Port Action Request/Acknowledge
CarrierIn	S3,F17/18	Carrier Action Request/Acknowledge
CarrierNotification	S3,F17/18	Carrier Action Request/Acknowledge
CarrierOut	S3,F17/18	Carrier Action Request/Acknowledge
CarrierReCreate	S3,F17/18	CarrierReCreate Rquest/Acknowledge
CarrierRelease	S3,F17/18	Carrier Action Request/Acknowledge
CarrierTagReadData	S3,F29/30	Carrier Tag Read Data Request/Acknowledge
CarrierTagWriteData	S3,F31/32	Carrier Tag Write Data Request/Acknowledge
ChangeAccess	S3,F27/28	ChangeAccess
ChangeServiceStatus	S3,F25/26	Port Action Request/Acknowledge
ProceedWithCarrier	S3,F17/18	Carrier Action Request/Acknowledge
ReserveAtPort	S3,F25/26	Port Action Request/Acknowledge

5.3 *Services Parameter Mapping*

5.3.1 Table 2 maps the SEMI E87 service parameters to SECS-II Data Items.

NOTE 2: Use of parameters not specified for a given message in SEMI E87 is prohibited. SECS-II data items not used for a given message shall be sent as zero-length items.

Table 2 Service Parameters to SECS-II Data Items Mapping

Parameter Name	*Range*	*SECS-II Data Item*
AccessMode	Enumerated: MANUAL, AUTO	PORTACCESS
AttributeData	Any	CATTRDATA
AttributeID	Text format restrictions per SEMI E39.1, Section 6.	CATTRID
CarrierID	1 to 80 characters	CARRIERID
CMAcknowledge	Enumerated	CAACK
CMStatus	Structure	L,2 1. <CAACK> 2. Status
Data	ASCII (20)	DATA
DataLength	Integer (Un or Sn)	DATALENGTH
DataSeg	ASCII (20)	DATASEG
ErrorCode	Enumerated	ERRCODE
ErrorText	1 to 80 characters	ERRTEXT
LocationID	ASCII (20)	LOCID
PropertiesList	Non-identifier properties	L,n 1. L,2 1. <CATTRID$_1$> 2. <CATTRDATA$_1$>

Parameter Name	*Range*	*SECS-II Data Item*
		. . n. L,2 1.< CATTRID $_n$> 2. <CATTRDATA $_n$>
PortID	U1 (1–255)	PTN
ServiceStatus	Enumerated: IN SERVICE, OUT OF SERVICE	U1 0 = OUT OF SERVICE 1 = IN SERVICE
Status	n errors	L,n 1. L,2 1. <ERRCODE$_1$> 2. < ERRTEXT $_1$> . . n. 1.< ERRCODE $_n$> 2. <ERRTEXT $_n$>

5.4 *SECS-II Data Items Without Corresponding SEMI E87 Parameters*

5.4.1 Table 3 contains the SECS-II data items that do not correspond to SEMI E87's service parameter.

Table 3 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
Used by S3,F17 to differentiate between Bind, CancelCarrierOut, CancelCarrierAtPort, CancelBind, CarrierIn, ProceedWithCarrier, CancelCarrierNotification CarrierNotification services, and CarrierReCreate.	CARRIERACTION
Used to satisfy SECS-II conventions for linking a multi-block inquiry with a subsequent multi-block message. Neither required nor specified by CMS.	DATAID
Used to inform receiver of total message length size for SECS-II multi-block conventions. May also be used to indicate the length of a section of data being transmitted to or from a carrier tag.	DATALENGTH
Used to satisfy SECS-II multi-block requirements. Neither required nor specified by SEMI E87.	GRANT
Used by S3,F25 to differentiate between port related, CancelReservationAtPort, and ReserveAtPort services.	PORTACTION
Used by S3F27 to specify desired Port Access Mode.	ACCESSMODE

6 Variable Data Item Mapping

6.1 This section shows the specific SECS-II data classes, and formats needed for SECS-II implementations of SEMI E87 variable data items.

Table 4 Variable Data Item Mapping Table

Variable Name	*Class*	*Format*
AccessMode	DVVAL	51 (U1) Enumerated: 0 = MANUAL 1 = AUTO
AccessMode$_i$	SV	51 (U1) Enumerated: 0 = MANUAL 1 = AUTO
AvailPartitionCapacity	DVVAL	51
AvailPartitionCapacity$_i$	SV	51
BufferCapacityList	SV	L,n 1. <BufferPartitionInfo$_1$> . . n. <BufferPartitionInfo$_n$>
BufferPartitionInfo	DVVAL	L,4 1. <PartitionID> 2. <PartitionType> 3. <AvailPartitionCapacity> 4. <PartitionCapacity>
BufferPartitionInfo$_i$	SV	L,4 1. <PartitionID$_i$> 2. <PartitionType$_i$> 3. <AvailPartitionCapacity$_i$> 4. <PartitionCapacity$_i$>
CarrierAccessingStatus	DVVAL	51 (U1) Enumerated as: 0 = NOT ACCESSED 1 = IN ACCESS 2 = CARRIER COMPLETE 3 = CARRIER STOPPED
CarrierID	DVVAL	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
CarrierID$_i$	SV	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
CarrierIDStatus	DVVAL	51 (U1) Enumerated as: 0 = ID NOT READ 1 = [ID] WAITING FOR HOST 2 = ID VERIFICATION OK 3 = ID VERIFICATION FAILED

Variable Name	*Class*	*Format*
CarrierLocationMatrix	SV	L,n 1. L,2 1. <LocationID$_1$> 2. <CarrierID$_1$> . . n. L,2 1. <LocationID$_n$> 2. <CarrierID$_n$>
LoadPortReservationState	DVVAL	51 (U1) Enumerated as: 0 = NOT RESERVEED 1 = RESERVED
LoadPortReservationState$_I$	SV	51 (U1) Enumerated as: 0 = NOT RESERVED 1 = RESERVED
LoadPortReservationStateList	SV	L,n 1.<LoadPortReservationState$_1$> . . n.<LoadPortReservationState$_N$>
LocationID	DVVAL	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
LocationID$_i$	SV	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
PartitionCapacity	DVVAL	51
PartitionCapacity$_i$	SV	51
PartitionID	DVVAL	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
PartitionID$_i$	SV	A[1-80] (Conforms to restrictions of ObjID as specified in SEMI E39.1, Section 6.)
PartitionType	DVVAL	A[1-64]
PartitionType$_i$	SV	A[1-64]
PortAssociationState	DVVAL	51 (U1) Enumerated as: 0 = NOT ASSOCIATED 1 = ASSOCIATED
PortAssociationState$_i$	SV	51 (U1) Enumerated as: 0 = NOT ASSOCIATED 1 = ASSOCIATED
PortAssociationStateList	SV	L,n 1. <PortAssociationState$_1$> . . n. <PortAssociationState$_n$>
PortID	DVVAL	51
PortID$_i$	SV	51
PortStateInfo	DVVAL	L,2 1. <PortAssociationState> 2. <PortTransferState>

Variable Name	*Class*	*Format*
PortStateInfo$_i$	SV	L,2 1. <PortAssociationState$_i$> 2. <PortTransferState$_i$>
PortStateInfoList	SV	L,n 1. <PortStateInfo$_1$> . n. <PortStateInfo$_n$>
PortTransferState	DVVAL	51 (U1) Enumerated as: 0 = OUT OF SERVICE 1 = TRANSFER BLOCKED 2 = READY TO LOAD 3 = READY TO UNLOAD
PortTransferState$_i$	SV	51 (U1) Enumerated as: 0 = OUT OF SERVICE 1 = TRANSFER BLOCKED 2 = READY TO LOAD 3 = READY TO UNLOAD
PortTransferStateList	SV	L,n 1. <PortTransferState$_1$> . . n. <PortTransferState$_n$>
Reason	DVVAL	51 (U1) Enumerated as: 0 = VERIFICATION NEEDED 1 = VERIFICATION BY EQUIPMENT UNSUCCESSFUL 2 = READ FAIL 3 = IMPROPER SUBSTRATE POSITION
SlotMapStatus	DVVAL	51 (U1) Enumerated as: 0 = SLOT MAP NOT READ 1 = [SLOT] WAITING FOR HOST 2 = SLOT MAP VERIFICATION OK 3 = SLOT MAP VERIFICATION FAILED
SlotMap	DVVAL	L, n n= capacity (1...25) 1. Enumerated 2. Enumerated 3. . . n Each as 51 (U1) Enumerated as: 0 = UNDEFINED 1 = EMPTY 2 = NOT EMPTY 3 = CORRECTLY OCCUPIED 4 = DOUBLE SLOTTED 5 = CROSS SLOTTED
UnAllocatedPartitionCapacity	DVVAL	51
UnAllocatedPartitionCapacity$_i$	SV	51

7 SECS-II Attribute Definitions

7.1 *Carrier Object SECS-II Attributes Definitions*

7.1.1 The following are the SECS-II structure definitions for the E87 Carrier Object.

Table 5 Carrier Object Attribute Definitions

Attribute Name	*Attribute Data Form: SECS-II Structure*
"ObjType"	1. "Carrier"
"ObjID"	1. <CARRIERID> (Conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.)
"Capacity"	51 (U1) Capacity Capacity Range: 1..25 Capacity Examples: 1, 13, 25
"CarrierAccessingStatus"	51 (U1) CarrierAccessingStatus CarrierAccessingStatus enumerated per Variable CarrierAccessingStatus
"CarrierIDStatus"	51 (U1) CarrierIDStatus CarrierIDStatus enumerated per Variable CarrierIDStatus
"ContentMap"	L, n n=Capacity 1. L,2 1. 20 (A) LotID 2. 20 (A) SubstID … n. L,2 1. 20 (A) LotID 2. 20 (A) SubstID SubstID conform to the restrictions of ObjID as specified in SEMI E39.1, Section 6.
"LocationID"	20 (A) LocationID LocationID conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.
"SlotMap"	L, n n=Capacity 1. 51 (U1) enumerated … n. 51 (U1) enumerated enumerated per variable SlotMap
"SlotMapStatus"	51 (U1) SlotMapStatus SlotMapStatus enumerated per Variable SlotMapStatus.
"SubstrateCount"	51 (U1) SubstrateCount SubstrateCount Range: 0..25 SubstrateCount Examples: 1, 3, 21, 25
"Usage"	20 (A) Usage Usage is equipment defined, examples: "TEST", "DUMMY", "PRODUCT"

SEMI E88-0702
SPECIFICATION FOR AMHS STORAGE SEM (STOCKER SEM)

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published September 1999; previously published March 2002.

1 Purpose

1.1 This standard establishes a Specific Equipment Model (SEM) for AMHS storage equipment (Stocker SEM). The model consists of equipment characteristics and behaviors that are to be implemented in addition to the SEMI E30 fundamental requirements and selected additional capabilities. The intent of this standard is to facilitate the integration of Stocker SEM equipment into an automated (e.g., semiconductor fabrication and flat panel display) factory. This document accomplishes this by defining an operational model for Stocker SEM equipment as viewed by a factory automation controller (Host). This definition provides a standard host interface and equipment operational behavior (e.g., control, state models, and data reports). Several topics require additional activity that are within the scope of this standard: queuing, parallel interface for carrier transfer (SEMI E23), stocker controller architecture, and scheduling and transport of the transfer unit.

2 Scope

2.1 The scope of this standard is limited to the usage and description of AMHS storage equipment (Stockers) as perceived by a SEMI Equipment Communications Standard 2 (SECS-II) host that complies with the GEM model (as specified in Section 13). It defines the view of the equipment through the SECS communication link. It does not define the internal operation of the equipment. It includes a specific transfer command state model and stocker controller state model as the basis for all equipment of this class.

2.2 This document assumes that the GEM fundamental requirements and selected additional capabilities (as specified in Section 13) have been implemented on the Stocker SEM equipment. It expands the GEM standard requirements and capabilities in the areas of state models (stocker controller, transfer command, carrier and stocker crane state models), collection events, alarm documentation, remote commands, data item variables, and material movement.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 *SEMI Standards Alignment*

3.1.1 The GEM (SEMI E30) model was used as the basis for Stocker SEM requirements definition in alignment with existing AMHS SEM Specifications.

3.2 *AMHS Storage Equipment Description*

3.2.1 This standard is targeted at the different types/configurations of 300 mm AMHS storage equipment. The term Stocker SEM equipment refers to all the types of AMHS storage equipment. The equipment types may have fundamental mechanical differences.

3.2.2 *Stocker (configuration)*

3.2.2.1 Generally an AMHS automated storage and retrieval device used to provide temporary storage of carriers. The device is not required to provide temporary storage of carriers when used as a device to connect multiple IBSEM devices or as a lifter (Floor to Floor Transport). Additionally, any number of physical interfaces may exist to connect the stocker with external devices such as: Interbay and/or Intrabay Transport Systems, Process Equipment, other StockerSEM devices, Operator ports, etc.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E37.1 — High-Speed SECS Message Services Single-Session Mode (HSMS-SS)

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

4.2 *Other References*

Harel, D., “Statecharts: A Visual Formalism for Complex Systems,” Science of Computer Programming 8 (1987) 231-274.[1]

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling System

5.1.2 *BP* — Buffer Port

5.1.3 *FOUP* — Front Opening Unified Pod

5.1.4 *GEM* — Generic Equipment Model

5.1.5 *IBSEM* — InterBay/IntraBay Specific Equipment Model

5.1.6 *ITS* — Interbay or Intrabay Transport System

5.1.7 *LP* — Loading Port

5.1.8 *OP* — Output Port

5.1.9 *PGV* — Person Guided Vehicle

5.1.10 *SC* — Stocker Controller

5.1.11 *TCP/IP* — Transmission Control Protocol/Internet Protocol

5.1.12 *TSC* — Transport System Controller

5.2 *Definitions*

5.2.1 *Automated Material Handling System* — an automated system to store and transport materials within the factory.

5.2.2 *automation* — the capability of managing material and data within the factory.

5.2.3 *bidirectional load port* — a load port used for loading and unloading carriers.

5.2.4 *buffer* — a set of one or more locations for holding carriers at the production equipment.

5.2.5 *buffer port* — special buffer port location on a stocker output shuttle. Contains carrier presence sensors so that the host can be notified when a carrier is situated at this position.

5.2.6 *carrier* — a container with one or more fixed positions for holding substrates. Examples of carriers include FOUPs and open cassettes.

5.2.7 *carrier ID* — a readable and unique identifier for the carrier.

5.2.8 *FOUP*—a closed carrier for holding wafers.

5.2.9 *host* — the factory computer system, or an intermediate system, that represents the factory and the user to the equipment. Refers system that controls or supervises the Stocker Controller (SC) throughout this document.

5.2.10 *independent port* — a load port on the stocker that is dedicated to input or output. It is considered that the carriers can only be transferred in one direction.

5.2.11 *interbay transport system* — a transport system used to move work-in-process between stockers in different parts of the factory.

5.2.12 *Intrabay Transport System* — a transport system dedicated to one or more bays in the factory and responsible for transferring carriers to and from production equipment. ITS consists of the physical units of the system (e.g., vehicles, nodes, docking stations), the low-level unit controllers, and a system-level controller. ITS excludes factory floor storage systems (stockers), but includes any short-term storage integral to the system, such as storage locations within an overhead track system that are accessible only to units of the particular ITS.

5.2.13 *load port* — the interface location on the equipment where carriers are transferred.

5.2.14 *loading port* — user or vehicle accessible port location on a stocker output shuttle. Contains carrier presence sensors so that the host can be notified when a carrier is situated at this position.

5.2.15 *output port* — stocker crane accessible port location on a stocker output shuttle. Contains carrier presence sensors so that the host can be notified when a carrier is situated at this position.

5.2.16 *process equipment* — equipment used to make semiconductor devices. This excludes metrology and material handling equipment.

5.2.17 *production equipment* — equipment used to produce semiconductor devices, including wafer sorting, process, and metrology equipment and excluding material handling equipment.

5.2.18 *Stocker Controller* — stocker Equipment Controller that communicates with the host and represents the system as the equipment.

5.2.19 *stocker crane* — stocker transfer agent specialized for the movement of carriers between shelves and input and output port locations.

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

5.2.20 *stocker equipment* — an individual stocker viewed as a single piece of equipment, with distributed components and distributed control, as illustrated in Figure 1. The stocker controller communicates with the host using HSMS and GEM and represents the system as an equipment. The factory may require more than one type of stocker.

5.2.20.1 Communications with transport system equipment may require a low-level handshake with a transport unit directly involved in the transfer of material (such as a vehicle or a docking station on an overhead track).

5.2.20.2 Communications between the various stocker units and controllers are proprietary to the supplier.

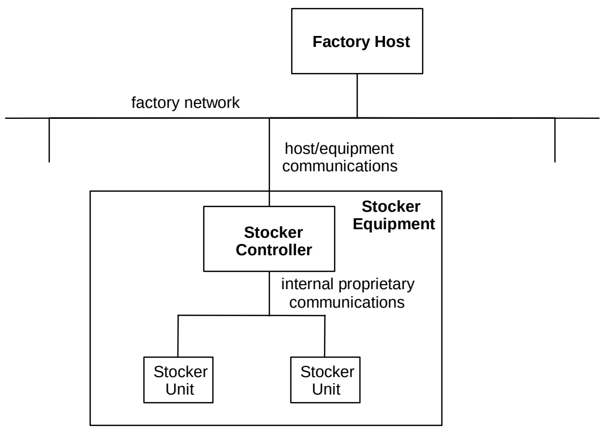


Figure 1
Example of Stocker Equipment

5.2.21 *stocker shelf* — locations within the stocker equipment to store carriers. These locations exclude load ports.

5.2.22 *stocker unit* — a physical component of the stocker system, such as a stocker crane, ID reader, wafer sensor, shuttle port, etc.

5.2.23 *swapping port* — a load port on the stocker capable of handling single load and unload of carriers or simultaneous replace of carriers.

5.2.24 *transfer agent* — a component of equipment specialized to the movement of transfer objects from place to place within a factory. May be of different types with widely-differing characteristics. Examples are fixed-arm robots, robot arms on fixed tracks, overhead gantries or even systems containing a heterogeneous collection of other transfer agents. Humans may also act as transfer agents.

5.2.25 *transfer completed port* — the destination port specified in a transfer command.

5.2.26 *transfer port* — point on the transport system at which a change of equipment ownership of the carrier occurs.

5.2.27 *transfer unit* — the element of movement (assemblage of carriers) of the ITS that consists of a maximum number of carriers allowed in a specific transfer command:

- AA is the maximum number of carriers allowed for acquire at the transfer source.
- BB is the maximum number of carriers allowed for deposit at the transfer destination.
- CC is the maximum number of carriers allowed for transfer in one transport vehicle.

5.2.27.1 The maximum size of the transfer unit is the minimum of AA, BB, and CC.

5.2.27.2 For purposes of the Stocker SEM, the transfer unit is limited to one carrier.

5.2.28 *transport system* — the component of AMHS that moves material from one part of the factory to another.

5.2.29 *transport unit* — a physical component of a transport system, such as a vehicle, node, or docking unit.

5.2.30 *zone* — a logical assignment referencing a set of one or more locations. A stocker can have several logical zone assignments. For example, a specific stocker may have 2 zones defined as LEFT_ZONE and RIGHT_ZONE. The assignment of zones is specific to the Stocker SEM equipment supplier and it may be desirable for the supplier to remain flexible in the assignment of zones so that it could be configured to meet the specific requirements of different users. A specific zone may only contain shelf locations or ports, but not both.

6 Overview and Assumptions

NOTE 2: This section has been included as background information to help clarify requirements.

6.1 *Destination Control (to Shelf or to Output Port)*

6.1.1 The destination is controlled by Host when the carrier is input to the stocker (i.e., the carrier enters the stocker domain). The destination of the transfer command is required. It would be invalid for the Host to issue a transfer command to the SC without including a valid destination.

6.1.2 *Output to the Interbay Output Port*

6.1.2.1 The destination for a transfer command to move a carrier to an interbay output port must be a loading port. It is the responsibility of the Host to ensure that sufficient capacity exists in the destination stocker when delivering from a source stocker to a destination stocker (i.e., an interbay move). For example, it would be the responsibility of the Host to check the remaining capacity of the destination stocker prior to issuing the transfer command to send the carrier to the interbay output port of the source stocker.

6.1.3 *Output to the Intrabay Output Port*

6.1.3.1 The destination for a transfer command to move a carrier to an intrabay output port must be a loading port.

6.1.4 *Store to the Stocker Shelf*

6.1.4.1 The specific stocker shelf location is to be controlled by the Stocker Controller (SC). The Host does not specify a shelf ID in a transfer command. The Host sends the name of a zone as the destination in the transfer command

6.1.4.2 The carrier is stored to a stocker shelf temporarily when the Host requested output port destination is occupied. This is the responsibility of the Stocker Controller. The carrier count of the stocker is incremented due to this temporary storage (i.e., the current capacity decreases).

6.2 *Quantity Control in the Stocker (Capacity Planning)*

6.2.1 The number of carriers in the stocker is controlled by the Host. A list of carrier database entries in the specified stocker's SC database will be available to the Host upon request via a remote command.

6.3 *Number of Stocker Cranes*

6.3.1 No Limitation. Host does not control the stocker crane directly.

6.4 *Port Type*

6.4.1 The independent input port and the independent output port are required for the Stocker SEM. The swapping type is considered as an independent port.

6.5 *Plural Sets of Input/Output Ports*

6.5.1 Plural sets of Input/Output ports connected to the interbay or intrabay transport system must be considered. (This would be considered a Multi-loop type interface connection to the stocker.) Examples of plural sets of interfaces are as follows:

- Main Loop/Sub Loop,
- Right-handed rotation/Left-handed rotation, and
- Double Track (i.e., Stacked Track).

6.6 *Carrier ID Reader*

- Manual Input Port: Carrier ID Reader is mandatory.
- Automated Input Port: Carrier ID Reader is a customer option.
- Carrier ID Reader at any output port: Carrier ID Reader is a customer option.

6.6.1 The intrabay automated input port is sometimes used as the manual Input Port. If one port is used for both an automated and a manual, the Carrier ID Reader is mandatory for this port. If there is a Carrier ID Reader, the scenario for a stocker transfer without a Carrier ID Reader is not applicable.

6.7 *Tag*

6.7.1 Same assumptions as Carrier ID Reader.

6.8 *Carrier Exchanger/Gas Purger*

6.8.1 Out of scope of Stocker SEM.

6.9 *Robot Arm in the Passive Type Stocker*

6.9.1 No assumption is made regarding the passive type stocker.

6.10 *Empty or Not Empty Carriers*

6.10.1 No assumption is made regarding empty and not empty carriers.

6.11 *Monitor/Dummy*

6.11.1 No assumption.

6.12 *Operation Mode*

6.12.1 No assumption.

6.13 *Transfer Completed Port*

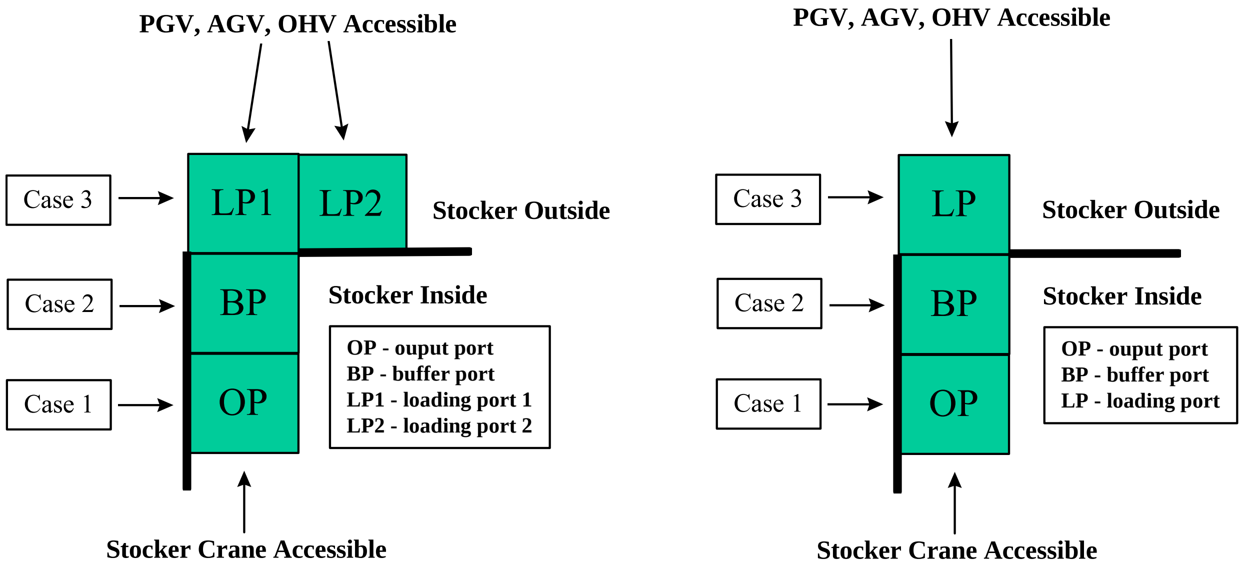


Figure 2
Output Shuttle Examples: L-Shaped Shuttle on Left, I-Shaped Shuttle on Right

6.13.1 The Transfer Completed Port is always the LoadingPort (LP) specified in the transfer command. If the end user desires that the Host issue a transfer to the TSC prior to the carrier arriving at the LP, the states defined in the Stocker Carrier State Model may be utilized.

7 Communication Requirements

7.1 It is required that any Stocker SEM compliant equipment follow the Communications State Model in SEMI E30. In addition, Stocker SEM compliant equipment shall support either SEMI E37 and SEMI E37.1 or SEMI E4.

8 State Models

8.1 *State Model Requirements*

8.1.1 The state models included in this standard are a requirement for Stocker SEM equipment. This standard requires implementation of all SEMI E30 state models (such as control, communication, on-line/off-line, etc. according to the GEM capabilities required per Section 13). A state model consists of a state model diagram, state definitions, and a state transition table. All state transitions in this standard, unless otherwise specified, shall correspond to collection events.

8.1.2 A state model is the host's view of the equipment, and does not necessarily describe the internal equipment operation. All Stocker SEM state model transitions shall be mapped sequentially into the appropriate internal equipment events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the Stocker SEM state model for transition to another state. The equipment makes the required transition without any additional actions in this situation.

8.1.3 Some equipment may need to include additional substates other than those in this standard. Additional substates may be added, but shall not change the Stocker SEM defined state transitions. All expected transitions between Stocker SEM states shall occur.

8.2 *SC State Model*

8.2.1 *SC State Model Requirements*

8.2.1.1 The purpose of the SC state model is to provide information to the host regarding the overall status of the stocker system. The SC state model is valid when the SEMI E30 (GEM) state is ON-LINE. The SC state model is **not** valid when the SEMI E30 (GEM) state is OFF-LINE. Since a stocker may consist of many components (e.g., stocker crane, conveyor, ID reader, etc.), it may be possible to continue ON-LINE operation when the operation mode of some stocker components (as viewed by the SC) is a manual state. The details of what happens when individual components of the stocker enter a manual state are specific to the Stocker SEM equipment supplier. When the SEMI E30 Control state changes from OFF-LINE to ON-LINE, the SC State Model is started from the SC INIT state.

8.2.2 *SC State Model*

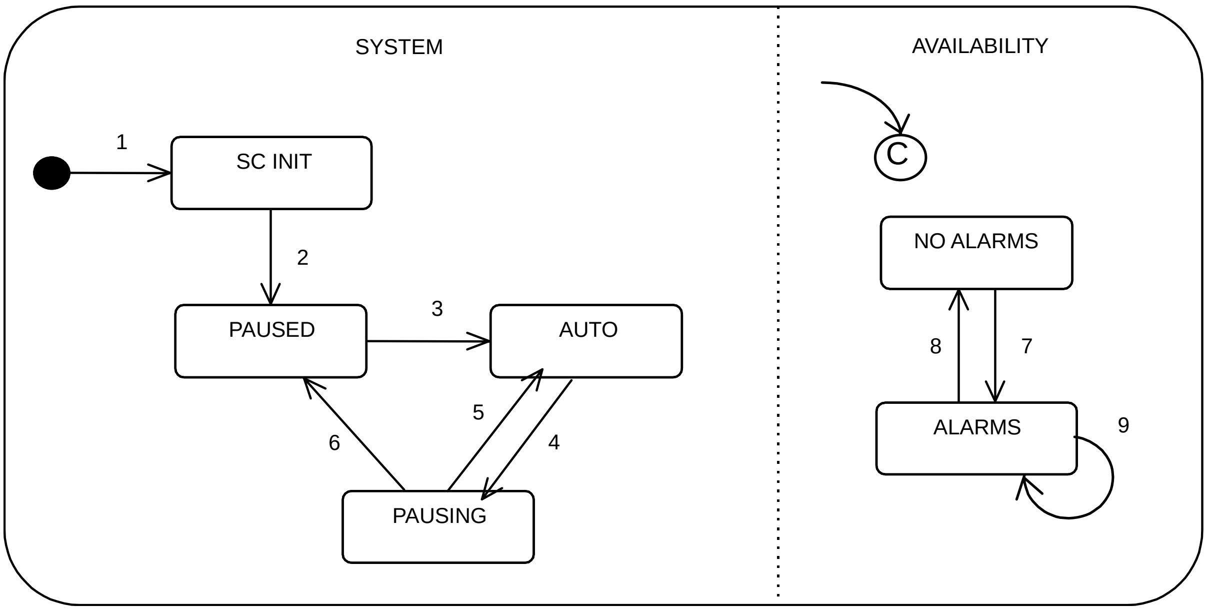


Figure 3
Generic Stocker SEM SC State Model Diagram

8.2.3 *SC State Definitions*

8.2.3.1 SC INIT — SC initialization of stocker components is occurring. This is a non-operational state. No commands from the host will be acknowledged, queued or processed. The system will not move out of this state if there are carriers moving on any of the stocker units controlled by the SC. Such devices must be manually or automatically recovered before transitioning to the next state.

8.2.3.2 PAUSING — A system PAUSE command has been received and is being processed. All carriers that are currently moving will continue until complete. Carriers that are currently moving may continue to move but they must not begin another movement. TRANSFER commands are accepted and queued. All status requests will be processed. The RESUME, INSTALL, REMOVE, and LOCATE commands will also be processed.

8.2.3.3 PAUSED — No carriers are in the process of moving on any of the stocker units controlled by the SC. TRANSFER commands are accepted and queued. All status requests will be processed. The RESUME, INSTALL, REMOVE, and LOCATE commands will also be processed.

8.2.3.4 AUTO — Stocker is in the normal operational state. Commands are actively processed.

8.2.3.5 NO ALARMS — There are no alarms present in the system.

8.2.3.6 ALARMS — There are one or more alarms present in the system.

8.2.4 *SC State Transition Table*

Table 1 SC State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	none	SC Initiation	SC INIT	S6F11 SCAutoInitiated	System runs through its startup sequence.
2	SC INIT	System started up successfully. All carrier movement stopped.	PAUSED	S6F11 SCPaused	System ready.
3	PAUSED	RESUME command	AUTO	S6F11 SCAutoCompleted	System will now execute remote commands.
4	AUTO	PAUSE command	PAUSING	S6F11 SCPauseInitiated	Carriers that are not moving remain there. Carriers that are moving must stop at the next logical stopping point.
5	PAUSING	All carrier movement has completed.	PAUSED	S6F11 SCPauseCompleted	System will accept and queue new commands but will not execute them. No new movement will occur. Outstanding moves/commands will remain NOT ACTIVE.
6	PAUSING	RESUME command	AUTO	S6F11 SCAutoCompleted	System will now execute remote commands.
7	NO ALARMS	Alarm Set	ALARMS	S6F11 AlarmSet	
8	ALARMS	All Alarms cleared.	NO ALARMS	S6F11 AlarmCleared	
9	ALARMS	Alarm Set	ALARMS	S6F11 AlarmSet	Alarm occurs when there is already an outstanding alarm.

8.3 *TRANSFER Command State Model*

8.3.1 *TRANSFER Command State Model Requirements*

8.3.1.1 The TRANSFER command state model serves as the SEMI E30 Processing State Model. The purpose of the TRANSFER command state model is to provide information to the host regarding the control of the TRANSFER command. The TRANSFER command allows the host to manage carrier movement and scheduling. The control of each TRANSFER command must independently support the TRANSFER command state model.

8.3.2 *TRANSFER Command State Model Diagram*

8.3.2.1 The TRANSFER command state model is detailed for Stocker SEM equipment in Figure 4.

8.3.3 *TRANSFER Command State Definitions*

8.3.3.1 QUEUED — SC has acknowledged and queued the TRANSFER command. TRANSFER command has not been initiated.

8.3.3.2 ACTIVE — The carrier is involved in the physical aspect of the TRANSFER command. It is denoted by the time spanned by command initiation to command completion.

8.3.3.3 TRANSFERRING (ACTIVE sub-state) — The transfer command is actively being executed by the stocker.

8.3.3.4 PAUSED (ACTIVE sub-state) — The Transfer command is not actively being executed by the stocker. This may be due to an internal equipment error that does not immediately terminate the Transfer command unsuccessfully. This would allow the Host or Operator the opportunity to retry the transfer.

8.3.3.5 CANCELING — The TRANSFER command cancel procedure is being performed to terminate a transfer command which never entered the ACTIVE state (currently QUEUED). This state is entered via a CANCEL remote command.

8.3.3.6 ABORTING — The TRANSFER command abort procedure is being performed to terminate a transfer command which has entered the ACTIVE state. This state can only be entered via an ABORT remote command. An unsuccessful transfer command completion will ultimately result from this state.

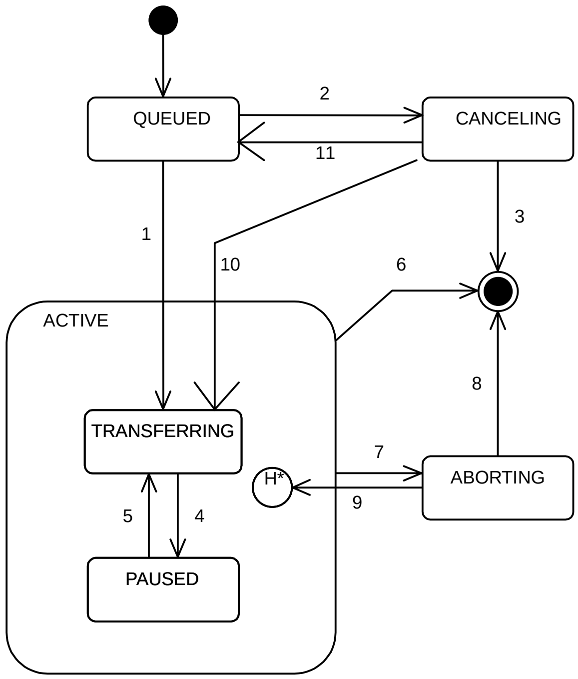


Figure 4
Generic Stocker SEM TRANSFER Command State Model Diagram

8.3.4 *TRANSFER Command State Transition Table*

Table 2 Transfer Command State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	QUEUED	The TRANSFER command has been initiated by the SC.	TRANSFER-RING	S6F11 TransferInitiated	
2	QUEUED	Host sends CANCEL command for a specified TRANSFER command to SC.	CANCELING	S6F11 TransferCancel-Initiated	TRANSFER command is to be removed from the TRANSFER command queue.
3	CANCELING	The cancel procedure for the TRANSFER command has completed by the stocker and the SC.	None	S6F11 TransferCancel-Completed	The carrier will still be situated at the transfer source location. The carrier may now be included in a future transfer.
4	TRANSFER-RING	The SC pauses execution of the TRANSFER command due to an anomaly condition.	PAUSED	S6F11 TransferPaused for a specific CommandID	It is an important distinction to make that the TRANSFER command is paused and not just the transfer agent. The Stocker Controller state will be ALARM.

Tran-sition #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
5	PAUSED	The SC resumes execution of the TRANSFER command since the anomaly condition has been cleared.	TRANSFER-RING	S6F11 TransferResumed for a specific CommandID	If this was the only remaining stocker alarm, the Stocker Controller state will transition to NO ALARMS.
6	ACTIVE	The TRANSFER command has completed by the stocker and SC (either successfully or unsuccessfully).	None	S6F11 TransferComplete d sent to Host with appropriate ResultCode ResultCode = 0 if successful ResultCode is nonzero if unsuccessful	Carrier(s) could be located at any location or port located along the path of the transfer, if the TRANSFER command completed unsuccessfully. **Supplier Option** — The location of the carrier(s) associated with an unsuccessful transfer command must be a legal SourcePort for a new TRANSFER command.
7	ACTIVE	Host sends ABORT command for a specified TRANSFER command to SC.	ABORTING	S6F11 TransferAbort-Initiated	
8	ABORTING	The abort procedure for the TRANSFER command has completed by the stocker and SC.	None	S6F11 TransferAbort-Completed	Carrier could be located at any location or port located along the path of the ACTIVE transfer. **Supplier Option** — The location of the carrier associated with the aborted transfer command must be a legal SourcePort for issuing a new TRANSFER command.
9	ABORTING	TRANSFER command cannot be aborted.	ACTIVE	S6F11 TransferAbort-Failed	TRANSFER command could not be aborted due to the physical state of the equipment. Such conditions must be documented by the Stocker SEM equipment Supplier.
10	CANCELING	Transport system is unable to cancel the TRANSFER command because the transfer is now ACTIVE.	TRANSFER-RING	S6F11 TransferInitiated	
11	CANCELING	Transport system is unable to cancel the TRANSFER command and it is still queued.	QUEUED	S6F11 TransferCancel-Failed	

8.4 *Stocker Carrier State Model*

8.4.1 *Stocker Carrier State Model Requirements*

8.4.1.1 The purpose of the stocker carrier state model is to provide information to the host regarding carrier tracking (the Host will not control carriers) while the carrier is in the domain of the stocker. The carrier is in the domain of the stocker when it is in storage or transport internal to the stocker or on a stocker interface port (manual, interbay, or intrabay). The equipment shall track each carrier in compliance with the Stocker Carrier State Model.

8.4.2 *Stocker Carrier State Model*

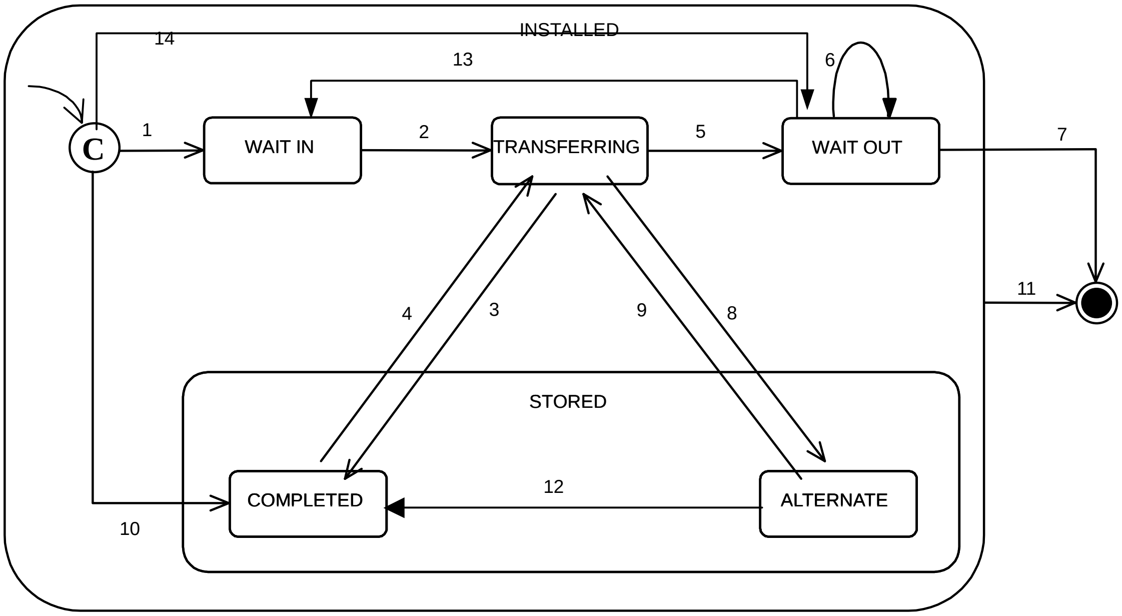


Figure 5
Generic Stocker SEM Carrier State Model Diagram

8.4.3 *Stocker Carrier State Definitions*

8.4.3.1 INSTALLED — Carrier in stocker database.

8.4.3.2 WAIT IN (INSTALLED sub-state) — Carrier at an internal input location in the stocker ready to be moved to a storage or output location.

8.4.3.3 WAIT OUT (INSTALLED sub-state) — Carrier is at an Output, Buffer, or Loading Port.

8.4.3.4 TRANSFERRING (INSTALLED sub-state) — Carrier moving between locations in the stocker.

8.4.3.5 STORED (INSTALLED sub-state) — Carrier is sitting at a storage location.

8.4.3.6 COMPLETED (STORED sub-state) — The carrier is stored at a shelf location as a result of completing a transfer for which this shelf represents the destination of the transfer command.

8.4.3.7 ALTERNATE (STORED sub-state) — The carrier is temporarily stored at a shelf location. The transfer command completion is pending until the destination becomes available.

8.4.4 *Stocker Carrier State Transition Table*

Table 3 Stocker Carrier State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Action*	*Comments*
1	none	Carrier is registered into stocker.	WAIT IN	S6F11 CarrierWaitIn	
2	WAIT IN	Stocker is executing a TRANSFER command for the carrier.	TRANSFER-RING	S6F11 Carrier-Transferring	

Transition #	*Previous State*	*Trigger*	*New State*	*Action*	*Comments*
3	TRANSFER-RING	Completion of a TRANSFER command with a DEST of internal stocker storage.	COMPLETED	S6F11 CarrierStored	Carrier is at an internal storage destination.
4	COMPLETED	Stocker is executing a TRANSFER command for the carrier.	TRANSFER-RING	S6F11 Carrier-Transferring	
5	TRANSFER-RING	Carrier has arrived at the output port.	WAIT OUT	S6F11 CarrierWaitOut	
6	WAIT OUT	Carrier has advanced (automatically) on a port beyond the output port.	WAIT OUT	S6F11 CarrierWaitOut	
7	WAIT OUT	Carrier is removed from the stocker domain (removed from the output LP).	None	S6F11 CarrierRemoved	
8	TRANSFER-RING	The destination of the move command is occupied.	ALTERNATE	S6F11 CarrierStoredAlt	SC is waiting for the Destination to become available.
9	ALTERNATE	The port becomes available and transfer command is first in queue.	TRANSFER-RING	S6F11 CarrierResumed	Carrier continues with move to the Destination.
10	None	Carrier entry is created or modified in the SC database.	COMPLETED	S6F11 CarrierInstall-Completed	Could be due to an INSTALL remote command.
11	INSTALLED	Carrier entry is removed from the SC database.	None	S6F11 CarrierRemove-Completed	Could be due to a REMOVE remote command.
12	ALTERNATE	Transfer command is Aborted	COMPLETED	S6F11 CarrierStored	
13	WAIT OUT	Carrier on a bi-directional port is ready to be moved to a storage or output location.	WAIT IN	S6F11 CarrierWaitIn	Examples of a trigger could be the operator pressing a button or the host issuing a transfer command for the carrier.
14	None	The result of ID read at an output port that did not match the expected ID.	WAITOUT	S6F11 CarrierInstall-Completed	

8.5 *Stocker Crane State Model*

8.5.1 *Stocker Crane State Model Requirements*

8.5.1.1 The purpose of the stocker crane state model is to provide information to the host for use of stocker crane information and metric tracking (i.e., the Host will not control the stocker crane). If it is possible for the stocker to continue operation while the stocker crane is not operational then the Stocker Crane State Model will retain its current state and the SC State Model will be ALARM. When the stocker crane becomes operational again, the state of the Stocker Crane State Model will transition to the new state. Whether it is possible to continue operation while the stocker crane is not operational is specific to the stocker SEM equipment supplier. If a single stocker contains multiple stocker cranes, each stocker crane must comply with the stocker crane state model. The Host should not be dependent on any events from the stocker crane state model.

8.5.2 *Stocker Crane State Model*

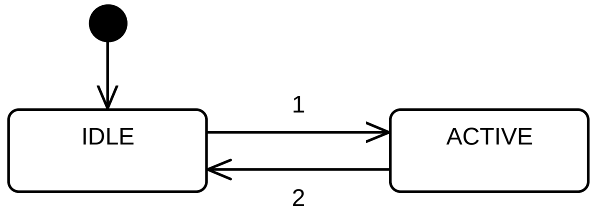


Figure 6
Generic Stocker SEM Stocker Crane State Model Diagram

8.5.3 *Stocker Crane State Definitions*

8.5.3.1 IDLE — The stocker crane is not performing Host or SC initiated work.

8.5.3.2 ACTIVE — The stocker crane is busy performing Host or SC initiated work.

8.5.4 *Stocker Crane State Transition Table*

Table 4 Stocker Crane State Transition Table

Transi-tion #	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	IDLE	Crane is requested to perform host or SC initiated work.	ACTIVE	S6F11 CraneActive	
2	ACTIVE	Crane completes host or SC initiated work.	IDLE	S6F11 CraneIdle	

8.6 *Port Transfer State Model*

8.6.1 *Port Transfer State Model Requirements*

8.6.1.1 The purpose of the port state model is to provided information to the host for the use in accessing ports. This may permit the host and stocker to utilize ports that are in service while avoiding the use of ports that are not in service.

8.6.2 *Port Transfer State Model*

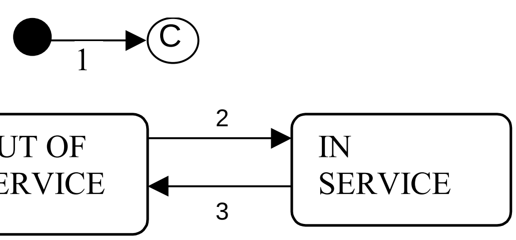


Figure 7
Port State Model Diagram

8.6.3 *Port Transfer State Definitions*

8.6.3.1 OUT OF SERVICE — Transfer to/from this port is disabled and the port should not be used in any Transfer command issued by the host. If a command is issued by the host which uses this port, it will not be rejected simply because the port is in this state.

8.6.3.2 IN SERVICE — Transfer to/from this port is enabled.

8.6.3.3 *Port Transfer State Transition Table*

Table 5 Port Transfer State Transition Table

Transition #	*Previous State*	*Trigger*	*New State*	*Action*	*Comments*
1	None	System reset.	OUT OF SERVICE Or IN SERVICE	S6F11 PortOutOfService Or S6F11 PortInService	The new state is based on the current status of the port or the state prior to system reset.
2	OUT OF SERVICE	The equipment has determined that the port can be utilized for transfers.	IN SERVICE	S6F11 PortInService	
3	IN SERVICE	The equipment has determined that the port should not be used for transfers.	OUT OF SERVICE	S6F11 PortOutOfService	This could be the result of an alarm condition.

9 Collection Event List

9.1 This section identifies data collection events and defines (Stream 6) reporting levels for variable data items. The host can use the report definition scenario defined in SEMI E30 to define reports at Stocker SEM defined levels. The intent of this section is to demonstrate that certain suggested data is available at specific events. The collection events are grouped according to whether or not they are associated with a state change (according to the state models defined within this document).

9.2 *Requirements*

9.2.1 This standard requires all collection events listed in the SEMI E30 standard (according to the GEM capabilities required per Section 14). There are cases where specific collection event names are designated for GEM defined collection events. Such collection event names are denoted by “Y” in the GEM column.

9.3 *State Transition Collection Event Table*

Table 6 State Transition Collection Event Table

Collection Event Name	*From State*	*To State*	*Required DVVAL’s*	*GEM*
SC STATE TRANSITION EVENTS				
AlarmCleared	ALARMS	NO ALARMS	CommandID ErrorID StockerUnitInfo	Y
AlarmSet	NO ALARMS ALARMS	ALARMS ALARMS	CommandID ErrorID StockerUnitInfo RecoveryOptions	Y
SCAutoCompleted	PAUSED PAUSING	AUTO AUTO	N/A	N
SCAutoInitiated	None	SC INIT	N/A	N
SCPauseCompleted	PAUSING	PAUSED	N/A	N
SCPaused	SC INIT	PAUSED	N/A	N
SCPauseInitiated	AUTO	PAUSING	N/A	N
TransferAbortCompleted	ABORTING	None	CommandID CarrierID CarrierLoc CarrierZoneName	N

Collection Event Name	*From State*	*To State*	*Required DVVAL's*	*GEM*
TRANSFER COMMAND STATE TRANSITION EVENTS				
TransferAbortFailed	ABORTING	ACTIVE	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferAbortInitiated	ACTIVE	ABORTING	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferCancelCompleted	CANCELING	None	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferCancelFailed	CANCELING	QUEUED	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferCancelInitiated	QUEUED	CANCELING	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferCompleted	ACTIVE	None This event will occur when the carrier arrives at the transfer completed port. The TRANSFER command DEST is an LP if transferring to an output of the stocker.	CommandID CarrierID CarrierLoc ResultCode CarrierZoneName	N
TransferInitiated	QUEUED CANCELING	TRANSFERRING TRANSFERRING	CommandID CarrierID CarrierLoc CarrierZoneName Dest	N
TransferPaused	TRANSFERRING	PAUSED	CommandID CarrierID CarrierLoc CarrierZoneName	N
TransferResumed	PAUSED	TRANSFERRING	CommandID CarrierID CarrierLoc CarrierZoneName	N
STOCKER CARRIER STATE TRANSITION EVENTS				
CarrierInstallCompleted	None	COMPLETED	CarrierID CarrierLoc CarrierZoneName	N
CarrierRemoveCompleted	INSTALLED	None	CarrierID CarrierLoc CarrierZoneName	N
CarrierRemoved	WAIT OUT	None	CarrierID HandoffType	N

Collection Event Name	*From State*	*To State*	*Required DVVAL's*	*GEM*
CarrierResumed	ALTERNATE	TRANSFERRING	CommandID CarrierID CarrierLoc CarrierZoneName Dest	N
CarrierStored	TRANSFERRING	COMPLETED	CarrierID CarrierLoc CarrierZoneName	N
CarrierStoredAlt	TRANSFERRING	ALTERNATE	CommandID CarrierID CarrierLoc CarrierZoneName Dest	N
CarrierTransferring	WAIT IN COMPLETED	TRANSFERRING TRANSFERRING	CarrierID CarrierLoc CarrierZoneName	N
CarrierWaitIn	None	WAIT IN	CarrierID CarrierLoc CarrierZoneName	N
CarrierWaitOut	TRANSFERRING WAIT OUT	WAIT OUT WAIT OUT	CarrierID CarrierLoc CarrierZoneName PortType	N
ZoneCapacityChange	Any State or None	Any State or None	ZoneData	N
STOCKER CRANE STATE TRANSITION EVENTS				
CraneActive	IDLE	ACTIVE	CommandID StockerCraneID	N
CraneIdle	ACTIVE	IDLE	CommandID StockerCraneID	N
PORT TRANSFER STATE TRANSITION EVENTS				
PortInService	None OUT OF SERVICE	IN SERVICE	PortID	
PortOutOfService	None IN SERVICE	OUT OF SERVICE	PortID	

9.4 *Non-Transition Collection Event Table*

Table 7 Non-Transition Collection Event Table

Collection Event Name	*Event Description*	*Required DVVAL's or Reports*
CarrierIDRead	A carrier identification has been performed by the stocker system. It was deemed unnecessary to represent this simple event with a state model. This event is always sent to the Host immediately following the actual ID read by the stocker.	CarrierID CarrierLoc IDReadStatus
CarrierLocateCompleted	A LOCATE remote command has completed.	CarrierLocations
IDReadError	All carriers related to an ID error situation have been dispositioned. This event occurs automatically when the stocker places the carrier that experienced the ID error to the pickup port (See Section 13.3.3).	CarrierID CarrierLoc IDReadStatus

Collection Event Name	*Event Description*	*Required DVVAL's or Reports*
OperatorInitiatedAction	The operator initiated an action from the Stocker Controller.	CommandID CommandType CarrierID Source Dest Priority

10 Variable Data Items

10.1 The purpose of this section is to define the list of variable data item requirements for Stocker SEM equipment. Values of these variables will be available to the host via collection event reports and host status queries.

10.2 *Requirements*

- All variable data items and data item restrictions defined in SEMI E30 are required on Stocker SEM equipment (according to the GEM capabilities required per Section 13).
- All variable data items in the Stocker SEM Variable Data Item Dictionary for specific equipment classifications are required for Stocker SEM equipment. The data item restrictions are also required.
- Some SV's in the Variable Data Item Dictionary are referenced by an "i" subscript (e.g., $CarrierID_i$). The "i" subscript denotes a specific instance of the SV. This is necessary since there is usually more than one instance of such an SV active in the system at the same time (e.g., if there are 20 carriers active at the same time then "i" could range from 1 to 20 for $CarrierID_i$). Variable Data Items containing the "i" subscript should not have Variable ID's assigned to them.

10.2.1 Variable data items are documented in the Stocker SEM Variable Data Item Dictionary using the following format:

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*

Where:

Variable Name: A unique name for the variable data item.

Type: CV – meaning common variables, variables that are general to all vehicles.

CSV – meaning configuration specific variables.

Description: If class is DVVAL, then the description shall contain a statement of when data is valid in terms of Stocker SEM events.

Class: The data type of the item.

Format: <SECS Message Language (SML) mnemonic>acceptable formats are SEMI E5 lists, ASCII, floating point, unsigned integer or signed integer. A description of "ANY", indicates that only the above formats are acceptable and is left to the supplier to decide.

Comments: Any additional information pertinent to the variable name.

10.3 *Variable Data Item Types*

10.3.1 *Equipment Constants (ECV)* — The value can be changed by the host using S2F15. The operator may have the ability to change some or all of the values. The value of an equipment constant may be queried at any time by the host using the S2F13/14 transaction or Stream 6 reports.

10.3.2 *Status Variables (SV)* — The values are valid at all times. A SV may not be changed by the host or operator, but may be changed by the equipment. A host or operator command may change an equipment status thus changing a SV. The value of status variables may be queried by the host at any time using the S1F3/4 or Stream 6 reports.

10.3.3 *Data Variables (DVVAL)* — These are variables which are valid upon the occurrence of a specific collection event, and may or may not be valid at other times depending upon the equipment. An attempt to read a variable data item when it's invalid will not result in an error, but the data reported may not have relevant meaning.

10.3.4 *Variable Data (V)* — This is a class of variable data which includes all the previously defined types of variables.

10.4 *Variable Data Item Dictionary*

Table 8 Variable Data Item Dictionary

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
ActiveCarriers	CV	List current status of all carrier information in the SC database.	SV	L,n 1. <$CarrierInfo_1$> . . n. <$CarrierInfo_n$>	
ActiveTransfers	CV	List current status of all ACTIVE TRANSFER commands.	SV	L,n 1. <$TransferCommand_1$> . . n. <$TransferCommand_n$>	
ActiveZones	CV	List current status associated with all zones being used by the SC.	SV	L,n 1. <$ZoneData_1$> . . n. <$ZoneData_n$>	
CarrierID	CV	Unique ID of the carrier.	DVVAL	A[1–64]	If an Id is created by the equipment (not obtained via an id reader, the host interface, or the user interface) it must be of the following format: UNKNOWNEqpNameSeq Where: UNKNOWN are the exact characters “UNKNOWN” EqpName is the value of the EqpName ECV (truncated if required) Seq is a unique sequence identifier determined by the vendor.
$CarrierID_i$	CV	Unique ID of the carrier.	SV	A[1–64]	See comment for CarrierID.
CarrierInfo	CV	All database information associated with a particular carrier.	DVVAL	L,2 1. <CarrierID> 2. <CarrierLoc>	
$CarrierInfo_i$	CV	All database information associated with a particular carrier.	SV	L,2 1. <$CarrierID_i$> 2. <$CarrierLoc_i$>	
CarrierLoc	CV	Unique location of the carrier within the stocker as reported by the SC.	DVVAL	A[1–64]	It is important to note that this is the unique location within the stocker (i.e., 2 carriers cannot be stored at the same CarrierLoc, but 2 carriers can be stored at the same ZoneName).

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
CarrierLoc$_i$	CV	Unique location of the carrier within the stocker as reported by the SC.	SV	A[1–64]	It is important to note that this is the unique location within the stocker (i.e., 2 carriers cannot be stored at the same CarrierLoc, but 2 carriers can be stored at the same ZoneName).
CarrierLocationInfo$_i$	CV	Carrier Location Information	DVVAL	L,3 1. <CarrierID$_i$> 2. <CarrierLoc$_i$> 3. <CarrierZoneName$_i$>	
CarrierLocations	CV	Carrier Location Information for the 'LOCATE' host command	DVVAL	L,n 1. <CarrierLocationInfo$_1$> . . n. < CarrierLocationInfo$_n$ >	'n' number of carriers
CarrierState$_i$	CV	The Carrier State	SV	U2	1 = Wait In 2 = Transferring 3 = Completed 4 = Alternate 5 = Wait Out
CarrierZoneName	CV	The name of the zone associated with the carrier's current location.	DVVAL	A[0–64]	A location may not be associated with a particular zone. This would be the case if ports are not assigned to a zone.
CarrierZoneName$_i$	CV	The name of the zone associated with the carrier's current location.	SV	A[0–64]	A location may not be associated with a particular zone. This would be the case if ports are not assigned to a zone.
CommandName	CV	Name of Host issued remote command.	DVVAL	A[1–20]	
CommandID	CV	Remote Command ID	DVVAL	A[1–64]	Used to subsequently refer to a specified remote command (e.g., to cancel a remote command). If a command is generated by the Stocker Controller, the commandid must begin with the string 'MANUAL' followed by any arbitrary sequence identifier.
CommandID$_i$	CV	Remote Command ID	SV	A[1–64]	Used to subsequently refer to a specified remote command (e.g., to cancel a remote command).
CommandInfo	CV	Command information associated with a particular transfer command.	DVVAL	L,2 1. <CommandID> 2. <Priority>	
CommandInfo$_i$	CV	Command information associated with a particular transfer command.	SV	L,2 1. <CommandID$_i$> 2. <Priority$_i$>	
CommandType	CV	The type of Command being initiated	DVVAL	A[1–20]	Valid Values are 'TRANSFER' 'CANCEL' 'ABORT'

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
CurrentPortStates	CV	Current State of all the ports	SV	L,n 1. <$PortInfo_1$> . . n. <$PortInfo_n$>	
Dest	CV	Destination location identifier.	DVVAL	A[1–64]	Can either be a CarrierLoc or a ZoneName.
$Dest_i$	CV	Destination location identifier.	SV	A[1–64]	Can either be a CarrierLoc or a ZoneName.
EmptyCarrier	CV	Flag which denotes whether the carrier is empty or not empty.	DVVAL	U2	Empty = 0 Not Empty = 1
EnhancedCarriers	CV	List Current status of all carrier information in the SC database.	SV	L,n 1. <$EnhancedCarrierInfo_1$> . . n. <$EnhancedCarrierInfo_n$>	
$EnhancedCarrierInfo_i$	CV	All database information associated with a particular carrier.	SV	L,5 1. <$CarrierID_i$> 2. <$CarrierLoc_i$> 3. <$CarrierZoneName_i$> 4. <$InstallTime_i$> 5. <$CarrierState_i$>	
EnhancedTransfers	CV	List current status of all transfer commands.	SV	L,n 1. <$EnhancedTransferCommand_1$> . . n. <$EnhancedTransferCommand_n$>	
EnhancedTransfer-$Command_i$	CV	Information associated with a particular Transfer command.	SV	L,3 1. <$TransferState_i$> 2. <$CommandInfo_i$> 3. <$TransferInfo_i$>	
EnhancedActive-Zones	CV	List current status associated with all zoned being used by the SC.	SV	L,n 1. <$EnhancedZoneData_1$> . n. <$EnhancedZoneData_n$>	
$EnhancedZoneData_i$	CV	Information associated with a particular zone.	SV	L,4 1. <$ZoneName_i$> 2. <$ZoneCapacity_i$> 3. <$ZoneSize_i$> 4. <$ZoneType_i$>	
EqpName	CV	Unique ID of the SC	ECV	A[1–32]	

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
ErrorID	CV	Unique ID of an error	DVVAL	A[1–64]	Used to subsequently refer to a specified stocker error (e.g., to RETRY a stocker operation). The following values are required: "DestOcuupied" – Double Store "SourceEmpty" – Empty Retrieve Other values may be used as required.
HandoffType	CV	Denotes the type of handoff that occurred at the equipment ownership transfer point (e.g., from loading port to vehicle).	DVVAL	U2	MANUAL = 1 means that no handoff handshake occurs (e.g., PGV handoff). AUTOMATED = 2 means that a handshake occurs (e.g., SEMI E84).
IDReadDuplicate-Option	CV	Indicates manner in which Duplicate ID reads must be processed.	ECV	U1	0=Reject 1=HostControlled See Carrier ID Error Scenarios (Table 14) for detailed information.
IDReadFailureOption	CV	Indicates manner in which IDRead Failures must be processed.	ECV	U1	0=Reject 1=HostControlled See Carrier ID Error Scenarios (Table 14) for detailed information.
IDReadMismatch-Option	CV	Indicated manner in which Mismatch ID reads must be processed	ECV	U1	0=Reject 1=HostControlled See Carrier ID error Scenarios (Table 14) for detailed information.
IDReadStatus	CV	Result Code of an ID read event.	DVVAL	U2	Success = 0 Failure = 1 Duplicate = 2 Mismatch = 3
$InstallTime_i$	CV	Time the carrier was created in the SC database.	SV	TIME (A16)	yyyymmddhhmmsscc
PortID	CV	ID of the port	DVVAL	A[1–64]	
$PortID_i$	CV	ID of the port	SV	A[1–64]	
$PortInfo_i$	CV	Port information associated with a particular port.	SV	L,2 1. <$PortID_i$> 2. <$PortTransferState_i$>	
$PortTransferState_i$	CV	Port Transfer State	SV	U2	1 – OutOfService 2 – InService
PortType	CV	Definition of the type of port associated with the carrier's current location.	DVVAL	A[1–32]	"OP" = output port "BP" = buffer port "LP" = loading port
Priority	CV	Remote command priority	DVVAL	U2	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
$Priority_i$	CV	Remote command priority	SV	U2	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.
RecoveryOptions (Supplier Option)	CV	List of options that the Host may use to try to recover a specific stocker error.	DVVAL	A[1–64] blank RETRY ABORT	This variable will enumerate the possible Host command responses to the error associated with the event. If blank, Host cannot do anything.
ResultCode	CV	Result Code of a stocker system command. Associated with the command completion event.	DVVAL	U2	Values of ResultCode will correspond to meaningful completion results (0 always signifies normal successful completion). The following Result Codes are required: 0=Success 1=Other Error 2=Shelf Zone is FULL 3=Duplicate ID 4=Mismatch ID
SCState	CV	SC State (SYSTEM)	SV	U2	1 = SC Init 2 = Paused 3 = Auto 4 = Pausing
Source	CV	Source location unique identifier.	DVVAL	A[1–64]	
$Source_i$	CV	Source location unique identifier.	SV	A[1–64]	
SpecVersion	CV	Version of SEMI E88 to which the equipment is compliant.	SV	A[0–20]	Example values are: E88-0999, E88-0301. If the equipment is not compliant, a zero length value may be specified.
StockerCraneID	CV	The id of the stocker crane	DVVAL	A[1–64]	Generally only used when there are multiple cranes in a stocker.
StockerUnitID	CV	Unique identification of a stocker unit (e.g., port, transfer agent, etc.).	DVVAL	A[1–32]	
$StockerUnitID_i$	CV	Unique identification of a stocker unit (e.g., port, transfer agent, etc.).	SV	A[1–32]	
StockerUnitInfo	CV	Information associated with a particular stocker unit.	DVVAL	L,2 1. <StockerUnitID> 2. <StockerUnitState>	
$StockerUnitInfo_i$	CV	Information associated with a particular stocker unit.	SV	L,2 1. <$StockerUnitID_i$> 2. <$StockerUnitState_i$>	
StockerUnitState	CV	The state of the stocker unit.	DVVAL	U2	The State of the component will be specific to the stocker configuration.
$StockerUnitState_i$	CV	The state of the stocker unit.	SV	U2	The State of the component will be specific to the stocker configuration.

Variable Name	*Type*	*Description*	*Class*	*Format*	*Comments*
TransferCommand	CV	Information associated with a particular TRANSFER command.	DVVAL	L,2 1. <CommandInfo> 2. <TransferInfo>	
TransferCommand_i	CV	Information associated with a particular TRANSFER command.	SV	L,n 1. <CommandInfo_i> 2. <TransferInfo_i>	
TransferInfo	CV	Carrier information associated with a particular transfer command.	DVVAL	L,3 1. <CarrierID> 2. <CarrierLoc> 3. <Dest>	
TransferInfo_i	CV	Carrier information associated with a particular transfer command.	SV	L,3 1. <CarrierID_i> 2. <CarrierLoc_i> 3. <Dest_i>	
TransferState	CV	State of Transfer Command	SV	U2	1. Queued 2. Transferring 3. Paused 4. Canceling 5. Aborting
ZoneCapacity	CV	Available capacity (in carriers) of a particular zone.	DVVAL	U2	Example: If a stocker zone can store 100 carriers and 25 of the locations are currently occupied, then the ZoneCapacity is 75.
ZoneCapacity_i	CV	Available capacity (in carriers) of a particular zone.	SV	U2	Example: If a stocker zone can store 100 carriers and 25 of the locations are currently occupied, then the ZoneCapacity is 75.
ZoneData	CV	Information associated with a particular zone.	DVVAL	L,2 1. <ZoneName> 2. <ZoneCapacity>	
ZoneData_i	CV	Information associated with a particular zone.	SV	L,2 1. <ZoneName_i> 2. <ZoneCapacity_i>	
ZoneName	CV	Alphanumeric name of a particular zone.	DVVAL	A[1–64]	
ZoneName_i	CV	Alphanumeric name of a particular zone.	SV	A[1–64]	
ZoneSize_i	CV	Size (in carriers) of a particular zone.	SV	U2	The physical size of the zone.
ZoneType_i	CV	Type of the Zone	SV	U2	1: Shelf 2: Port 3: Other

11 Alarm List

11.1 Since each model of Stocker SEM equipment differs in configuration, it is not practical to provide an exhaustive list of all possible alarms. Instead, the Stocker SEM is requiring the two tables provided as described in SEMI E30 (Section 8.4). Alarm List Table which is intended to provide for equipment configuration specific alarms and Alarm ID, Alarm Set/Cleared Event Table. Any alarm that is displayed locally at the equipment, if enabled, is required to be sent to the host. To be compliant, Tables 9 and 10 must be completed by the supplier, documenting all alarms.

11.2 *Alarm List Table*

11.2.1 The alarm list table contains examples of alarms that pertain to various configuration aspects of equipment. These examples are intended to illustrate that alarms pertain to situations in which there exists a potential for exceeding physical safety limits associated with people, equipment, and material being transported as per the SEMI E30 definition of an alarm. See SEMI E30 for further reference. The supplier is responsible for supplying documentation associated with these alarm definitions. Each alarm will have an associated alarm text (ALTX) and alarm identifier (ALID). Table 9 contains an example of alarm list information that is intended to be augmented when the Stocker SEM equipment supplier documents their interface. Examples highlighted by (*) are required by Stocker SEM.

Table 9 Alarm List Table

Equipment Cfg.	*Alarm Text*	*ALID*	*Danger*		*Affected*		
			Potential	*Imminent*	*Operator*	*Equipment*	*Material*
Stocker	stocker unit error*		X			X	X
	handoff error*		X		X	X	X
	database error*		X			X	

11.3 *Alarm ID, Alarm Set/Cleared Event Table*

11.3.1 The Alarm ID, Alarm Set/Cleared Event table documents the association of each ALID to a set and cleared event as required by SEMI E30. See SEMI E30 for further reference. The supplier is responsible for supplying documentation associated with these alarm definitions. Each alarm will have associated alarm set and cleared collection event identifiers ($CEID_{set}$ and $CEID_{clear}$).

Table 10 Alarm ID, Alarm Set/Cleared Event Table

Alarm ID (ALID)	*Alarm SET Event ($CEID_{set}$)*	*Alarm CLEARED Event ($CEID_{cleared}$)*

12 Remote Commands

12.1 The purpose of this section is to identify remote commands, command parameters, and valid commands versus states pertinent to the Stocker SEM.

12.2 *A. Requirements*

- The equipment shall support the SEMI E30 (according to the GEM capabilities required per Section 13) required remote commands.
- All the remote commands defined by Stocker SEM are required to be implemented as specified.
- The alphanumeric strings defined by Stocker SEM for RCMD and CPNAME are required.
- A completed table must be generated where an “X” is placed in the table for each state that a given command is valid.
- If additional remote commands are supported then a “remote commands versus valid states” matrix must be generated for these additional commands.
- For additional commands, a table must be generated similar to the remote command descriptions summary.

12.3 *Remote Commands Description*

12.3.1 ABORT — This command terminates the activity of a specific TRANSFER command based on CommandID while the command is in the ACTIVE state. This command might not be accepted due to mechanical issues if the stocker is in a specific con-dition (e.g., moving a carrier). The exact conditions surrounding when the ABORT command is not ac-cepted by the SC must be documented by the Stocker SEM equipment supplier.

12.3.2 CANCEL — This command terminates the activity of a specific TRANSFER command based on CommandID while the command is in the QUEUED state. This command must always be accepted by the SC when in the QUEUED state.

12.3.3 INSTALL — This is used to update the SC database by adding a specified CarrierID record to a specified CarrierLoc. If the CarrierID specified by the Host is already in the SC database then the additional fields will be updated based on the information contained in this command.

12.3.4 LOCATE — This command is used by the Host to query the SC for database carrier information.

12.3.5 PAUSE — This command puts the SC in the PAUSING state.

12.3.6 REMOVE — This is used to update the SC database by deleting a specified carrier. This command would be used for database recovery.

12.3.7 RESUME — This command puts the SC in the AUTO state.

12.3.8 RETRY (Supplier Option) — This command may be used by the Host when an error is encountered by the stocker. The Host would use this command to allow the stocker to retry the movement which gener-ated the error condition.

12.3.9 TRANSFER — This is a SECS-II Enhanced Remote Command instead of a SECS-II Host Command Send (S2,F49 instead of S2,F41). See the examples in Section 15.1 for details.

12.3.10 This command is used to perform the entire transfer command for the carrier to be transferred between stocker locations. The execution of this com-mand will include allocation of resources, acquiring the carrier, moving the carrier to the destination, queuing the carrier at an alternate destination (if needed), depositing the carrier, and returning the resources for other use. The number of carriers in the TRANSFER command is always equal to one (i.e., the size of the transfer unit is always equal to one carrier).

12.3.11 *Remote Commands and Associated Host Command Parameters*

12.3.11.1 This table describes the allowable command parameters (CPNAME) for each remote command (RCMD). Equipment shall support all parameters. The column marked Req/Opt, specifies which parameters are required to be sent by the host and which parameters may be optionally sent by the host.

Table 11 Allowable Command Parameters

Remote Command	*Parameters*		
	Cpname	*Req/Opt*	*Comment*
ABORT	"COMMANDID"	R	Must specify the commandID that was used for the TRANSFER command that is being ABORT'ed.
CANCEL	"COMMANDID"	R	Must specify the commandID that was used for the TRANSFER command that is being CANCEL'ed.
INSTALL	"CARRIERID" "CARRIERLOC"	R R	

Remote Command	*Parameters*		
	Cpname	*Req/Opt*	*Comment*
LOCATE	"CARRIERID" or "ZONENAME" or "CARRIERLOC"	O	SC will check its database and return the carrier information to the Host with a single 'CarrierLocateCompleted' event for all relevant carriers. If the Host issues the LOCATE command with CARRIERID then SC returns information associated with the carrier specified by the Host. If the Host issues the LOCATE command with ZONENAME or CARRIERLOC, all carrier information in the specified area (ZONENAME or CARRIERLOC) will be returned. If the Host issues the LOCATE command without a Cpname, all carrier information in the SC database will be returned.
PAUSE	None	N/A	Once received by the SC, the SC will queue any TRANSFER commands until the SC receives and successfully executes the RESUME command. Once in the AUTO state the SC will process the TRANSFER commands in its queue.
REMOVE	"CARRIERID"	R	
RESUME	None	N/A	Returns the PAUSEd TSC to the AUTO state.
RETRY Supplier Option	"ERRORID"	R	Since more than one error can occur for the same TRANSFER command, an ERRORID must be used to identify the ERRORID to apply the RETRY to.
TRANSFER	"COMMANDINFO" "TRANSFERINFO"	R R	

12.3.12 *Host Command Parameters Name and Values*

Table 12 Host Command Parameters CPNAMES

Cpname	*Parameter Value*		
	Description	*Range*	*Format*
CARRIERID	Unique ID of the carrier.		A[1–64]
CARRIERLOC	Unique carrier location within the stocker.		A[1–64]
COMMANDID	Unique command identifier created by the Host.		A[1–64]
COMMANDINFO	L,2 COMMANDID PRIORITY		L,2
DEST	Destination location identifier	Must be a valid ZoneName. Must be a loading port for a move to an output shuttle (DEST = LP).	A[1–64]
ERRORID	Unique error identifier created by the stocker.		A[1–64]
PRIORITY	Remote command priority	0 is not valid. 1 is the LOWEST priority, 99 is the highest priority.	U2
SOURCE	Unique source location identifier	Stocker Robot/Crane is a valid SOURCE (Supplier Option).	A[1–64]
TRANSFERINFO	L,3 CARRIERID SOURCE DEST	SOURCE may intentionally be left blank by the Host. If this is true, the stocker must determine the carrier's current location by checking its database for the specified CARRIERID.	L,3

12.3.13 *Remote Commands versus SC, Transfer Command and Stocker Carrier States*

12.3.13.1 The following table indicates SC, TRANSFER Command and Stocker Carrier States where the remote commands are allowed. This is indicated with a “X” mark. Remote commands act independently of other state models (e.g., Stocker Crane States are independent from the Stocker SEM remote commands). “NA” (Not Applicable) means that States and Remote Commands have no direct relationship.

Table 13 Remote Commands versus SC and TRANSFER Command States

	COMMAND								
	TRANSFER	*RETRY*	*RESUME*	*REMOVE*	*PAUSE*	*LOCATE*	*INSTALL*	*CANCEL*	*ABORT*
SC STATE									
AUTO	X	X		X	X	X	X	X	X
ALARMS	X	X	X	X	X	X	X	X	X
SC INIT									
NO ALARMS	X		X	X	X	X	X	X	X
PAUSED	X	X	X	X		X	X	X	X
PAUSING	X	X	X	X		X	X	X	X
TRANSFER COMMAND STATE									
ACTIVE (PAUSED)	NA	X	NA		NA	X			X
ACTIVE (QUEUED AT ALT.)	NA		NA		NA	X			X
ACTIVE (TRANSFERRING)	NA		NA		NA	X			X
ABORTING	NA		NA		NA	X			
CANCELING	NA		NA		NA	X			
QUEUED	NA		NA		NA	X		X	
STOCKER CARRIER STATE									
STORED (ALTERNATE)		NA	NA		NA	X		NA	X
STORED (COMPLETED)	X	NA	NA	X	NA	X	X	NA	
TRANSFERRING		NA	NA		NA	X		NA	NA
WAIT IN	X	NA	NA	X	NA	X	X	NA	NA
WAIT OUT		NA	NA	X	NA	X	X	NA	NA

12.4 *Remote Command Relies*

12.4.1 For a TRANSFER remote command the HCACK in the reply message must return an error 6 (No such Object Exists) if the SOURCE is not specified and the CARRIERID is not in the SC database.

13 Scenarios

13.1 The scenarios that follow represent Application Notes. In the scenarios, all unique Remote CommandID’s must initially be created and sent by the Host. Subsequent event reports sent from the equipment referring to the status of a particular remote command must return the applicable CommandID. All collection events identified in Table 6 are assumed to be enabled (per the SEMI E30 definition/scenario) throughout the following scenarios. Variable data specified in the Host commands has been chosen arbitrarily for the purpose of demonstrating message structure/content. The Collection Event Report definitions contained in the scenarios are examples that could be defined by the host.

13.2 *Normal Operation*

13.2.1 *Carrier Transfer from an Input to a Storage Location (No ID Reader at Input Port)*

13.2.1.1 The carrier is transferred from a stocker input port to a storage location. The SC inserts the carrier into the database based on the CarrierID sent by the Host in the TRANSFER command. This is the scenario when the stocker does not have a carrier ID reader at the input port. A good example of this would be for a interbay transport input port.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 enters the domain of the stocker			
2.	Since there is no ID reader, the SC can choose any arbitrary CarrierID to internally track the carrier; However, the SC must send the empty string as the CarrierID to the Host so that the Host can distinguish this condition. It is the Host responsibility to recognize that the empty string "" for the CarrierID denotes that a carrier ID reader does not exist at this input port.		←S6,F11	Event Report Send (ERS) CarrierWaitIn · CarrierID = "" /* Empty String */ · CarrierLoc · CarrierZoneName
3.	Event Report Acknowledge (ERA)	S6,F12→		
4.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.	Enhanced Remote Command (ERC) **TRANSFER** · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID = "123456" 2. SOURCE = blank 3. DEST = "STORAGE"	S2,F49→		In this scenario SOURCE is the name of an input port position and DEST is the ZoneName STORAGE which is a SC selected shelf. Both CARRIERID and SOURCE must be included to do an automatic install of the carrier into the SC database.
7.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
8.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID = · CarrierID = "12345" · CarrierLoc = · CarrierZoneName = · Dest = "STORAGE"
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = "12345" · CarrierLoc · CarrierZoneName
11.	Event Report Acknowledge (ERA)	S6,F12→		
12.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
13.	Event Report Acknowledge (ERA)	S6,F12→		
14.			←S6,F11	Event Report Send (ERS) CraneActive
15.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
16.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID · CarrierID = "12345" · CarrierLoc · ResultCode = 0 · CarrierZoneName
17.	Event Report Acknowledge (ERA)	S6,F12→		
18.			←S6,F11	Event Report Send (ERS) CarrierStored · CarrierID · CarrierLoc = "112" · CarrierZoneName
19.	Event Report Acknowledge (ERA)	S6,F12→		
20.			←S6,F11	Event Report Send (ERS) CraneIdle
21.	Event Report Acknowledge (ERA)	S6,F12→		

13.2.2 *Carrier Transfer from an Input to a Storage Location (ID Reader at Input Port)*

13.2.2.1 The carrier is transferred from a stocker input port to a storage location. The carrier is automatically inserted into the SC database by the SC based on the carrier ID read which occurs on the stocker input port.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 enters the domain of the stocker			
2.			←S6,F11	Event Report Send (ERS) CarrierIDRead · CarrierID = "123456" · CarrierLoc = SOURCE · IDReadStatus = 0
3.	Event Report Acknowledge (ERA)	S6,F12→		
4.			←S6,F11	Event Report Send (ERS) CarrierWaitIn · CarrierID = "123456" · CarrierLoc = SOURCE
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
7.	Event Report Acknowledge (ERA)	S6,F12→		
8.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID = "123456" 2. SOURCE 3. DEST = "STORAGE"	S2,F49→		In this scenario SOURCE is the name of a input port position and DEST is the ZoneName STORAGE which is a SC selected shelf. SOURCE is optional since the SC knows where the CARRIERID is located.
9.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
10.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID · CarrierID = "123456" · CarrierLoc · CarrierZoneName · Dest = "STORAGE"
11.	Event Report Acknowledge (ERA)	S6,F12→		
12.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = "123456" · CarrierLoc · CarrierZoneName

STEP	COMMENTS	HOST	SC	COMMENTS
13.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
14.			←S6,F11	Event Report Send (ERS) CraneActive
15.	Event Report Acknowledge (ERA)	S6,F12→		
16.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID · CarrierID = "123456" · CarrierLoc · ResultCode = "0" · CarrierZoneName
17.	Event Report Acknowledge (ERA)	S6,F12→		
18.			←S6,F11	Event Report Send (ERS) CarrierStored · CarrierID · CarrierLoc = "112" · CarrierZoneName
19.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
20.			←S6,F11	Event Report Send (ERS) CraneIdle
21.	Event Report Acknowledge (ERA)	S6,F12→		

13.2.3 *Carrier Transfer to an Automated Stocker Output Port*

13.2.3.1 The carrier is transferred from a stocker location (storage location or input port) to an output port where it is then automatically transferred (Carrier Handoff) to an automated vehicle such as an OHV or AGV.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID 2. SOURCE 3. DEST = "LP1"	S2,F49→		In this scenario SOURCE is the name of a CarrierLoc or ZoneName and DEST is the name of a loading port. Either CARRIERID or SOURCE is optional.
2.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
3.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID · CarrierID · CarrierLoc · CarrierZoneName · Dest = "LP1"
4.	Event Report Acknowledge (ERA)	S6,F12→		
5.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID · CarrierLoc · CarrierZoneName
6.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
7.			←S6,F11	Event Report Send (ERS) CraneActive
8.	Event Report Acknowledge (ERA)	S6,F12→		
9.			←S6,F11	Event Report Send (ERS) CraneIdle
10.	Event Report Acknowledge (ERA)	S6,F12→		
11.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID · CarrierID · CarrierLoc · ResultCode = "0" · CarrierZoneName
12.	Event Report Acknowledge (ERA)	S6,F12→		
13.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID · CarrierLoc = "LP1" · CarrierZoneName · PortType = "LP"
14.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
15.	Carrier leaves the domain of the stocker as it is acquired by the transport vehicle.			
16.			←S6,F11	Event Report Send (ERS) CarrierRemoved · CarrierID · HandoffType = AUTOMATED
17.	Event Report Acknowledge (ERA)	S6,F12→		
18.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
19.	Event Report Acknowledge (ERA)	S6,F12→		

13.2.4 *Carrier Transfer to a Stocker Output Port Requiring Intermediate Storage*

13.2.4.1 The carrier is requested by the Host to be transferred from a stocker input port (with an ID reader) to a manual output port but requires intermediate storage due to the destination output port being fully occupied with carriers.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 is sitting at the stocker crane accessible input port position.			
2.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID 2. SOURCE 3. DEST = "LP"	S2,F49→		In this scenario SOURCE is the name of an input port position and DEST is the name of a loading port. Either CARRIERID or SOURCE is optional.
3.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)

STEP	COMMENTS	HOST	SC	COMMENTS
4.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID · CarrierID · CarrierLoc · CarrierZoneName · Dest = "LP"
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID · CarrierLoc · CarrierZoneName
7.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
8.			←S6,F11	Event Report Send (ERS) CraneActive
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.			←S6,F11	Event Report Send (ERS) CraneIdle
11.	Event Report Acknowledge (ERA)	S6,F12→		
12.			←S6,F11	Event Report Send (ERS) CarrierStoredAlt · CommandID · CarrierID · CarrierLoc = "132" · Dest = "LP" · CarrierZoneName
13.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
14.			←S6,F11	Event Report Send (ERS) CarrierResumed · CommandID · CarrierID · CarrierLoc = "132" · Dest = "LP" · CarrierZoneName
15.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
16.			←S6,F11	Event Report Send (ERS) CraneActive
17.	Event Report Acknowledge (ERA)	S6,F12→		
18.			←S6,F11	Event Report Send (ERS) CraneIdle
19.	Event Report Acknowledge (ERA)	S6,F12→		
20.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID · CarrierID · CarrierLoc · ResultCode = "0" · CarrierZoneName
21.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
22.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID · CarrierLoc = "LP" · CarrierZoneName · PortType = "LP"
23.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
24.	Carrier leaves the domain of the stocker as it is acquired manually by a PGV.			
25.			←S6,F11	Event Report Send (ERS) CarrierRemoved · CarrierID · HandoffType = MANUAL
26.	Event Report Acknowledge (ERA)	S6,F12→		
27.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
28.	Event Report Acknowledge (ERA)	S6,F12→		

13.2.5 *Carrier Transfer to an Automated Stocker Output with Multiple Loading Ports*

13.2.5.1 Three carriers are requested to the stocker output. The output shuttle consists of multiple carrier positions including the stocker crane set down port (OP – location 03) and two AGV accessible port locations (LP's – locations 05 and 06). The port shuttle also has a BP (location 04) that is the location reached by a carrier before reaching the LP positions. The BP is configured to be the transfer completed port for this scenario. The Host sends the three Transfer commands to the stocker and they are queued. The first two Transfer commands send carriers to LP locations 05 and 06 respectively. These carriers are to be loaded by the same AGV. The third carrier is also requested to LP 05. Each carrier is transferred to the OP where it then automatically travels forward on the shuttle toward the BP and LP's (see figure in Section 6.16). The first two carriers arrive at the LP's. The vehicle removes the two carriers from the LP's. The third carrier then shuttles forward to the LP location 05.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID = '060658' · PRIORITY = '20' · TRANSFERINFO 1. CARRIERID = '11111' 2. SOURCE 3. DEST = '06'	S2,F49→		In this scenario SOURCE is the name of a CarrierLoc or ZoneName and DEST is the name of a "loading port." Either CARRIERID or SOURCE may be empty.
2.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
3.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID = '060658' · CarrierID = '11111' · CarrierLoc · CarrierZoneName · Dest = '06'
4.	Event Report Acknowledge (ERA)	S6,F12→		
5.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = '11111' · CarrierLoc · CarrierZoneName
6.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange

STEP	COMMENTS	HOST	SC	COMMENTS
	Event Report Acknowledge (ERA)	S6,F12→		
7.			←S6,F11	Event Report Send (ERS) CraneActive
8.	Event Report Acknowledge (ERA)	S6,F12→		
9.	The Host issues the other two commands for carriers '22222' and '33333.' These commands are queued by the stocker because it is active performing the command for carrier '11111.'			
10.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID = '101883' · PRIORITY = '21' · TRANSFERINFO 1. CARRIERID = '22222' 2. SOURCE 3. DEST = '05'	S2,F49→		In this scenario SOURCE is the name of a CarrierLoc or ZoneName and DEST is the name of an "loading port." Either CARRIERID or SOURCE may be empty.
11.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
12.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID = '012155' · PRIORITY = '30' · TRANSFERINFO 1. CARRIERID = '33333' 2. SOURCE 3. DEST = '05'	S2,F49→		In this scenario SOURCE is the name of a CarrierLoc or ZoneName and DEST is the name of an output port. Either CARRIERID or SOURCE may be empty.
13.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
16.	The first carrier is set down by the stocker on the output port.			
17.			←S6,F11	Event Report Send (ERS) CraneIdle
18.	Event Report Acknowledge (ERA)	S6,F12→		
19.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '11111' · CarrierLoc = "03" · CarrierZoneName · PortType = "OP"
20.	Event Report Acknowledge (ERA)	S6,F12→		
21.	Now that carrier '11111' has left the "stocker set down" position of the output port, the stocker initiates the next highest priority queued command.			
22.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID = '012155' · CarrierID = '33333' · CarrierLoc · CarrierZoneName · Dest = '05'
23.	Event Report Acknowledge (ERA)	S6,F12→		
24.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = '33333' · CarrierLoc · CarrierZoneName
25.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
26.			←S6,F11	Event Report Send (ERS) CraneActive
27.	Event Report Acknowledge (ERA)	S6,F12→		
28.	Carrier ‘11111’ arrives at the buffer port.			
29.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = ‘11111’ · CarrierLoc = ‘04’ · PortType = ‘BP’ · CarrierZoneName
30.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
31.	Carrier ‘11111’ arrives at the first vehicle loading port.			
32.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = ‘11111’ · CarrierLoc = ‘05’ · PortType = ‘LP’ · CarrierZoneName
33.	Event Report Acknowledge (ERA)	S6,F12→		
34.	Carrier ‘11111’ can cycle forward one more port so it does.			
35.	Carrier ‘11111’ arrives at the vehicle loading “end” port (‘06’).			
36.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID = ‘060658’ · ResultCode = 0 · CarrierID = ‘11111’ · CarrierLoc = ‘06’ · CarrierZoneName
37.	Event Report Acknowledge (ERA)	S6,F12→		
38.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = ‘11111’ · CarrierLoc = ‘06’ · PortType = ‘LP’ · CarrierZoneName
39.	Event Report Acknowledge (ERA)	S6,F12→		
40.	The stocker sets down carrier ‘33333’ on the output port.			
41.			←S6,F11	Event Report Send (ERS) CraneIdle
42.	Event Report Acknowledge (ERA)	S6,F12→		
43.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = ‘33333’ · CarrierLoc = “03” · CarrierZoneName · PortType = “OP”
44.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
45.	Now the stocker can initiate the next transfer command.			
46.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID = '101883' · CarrierID = '22222' · CarrierLoc · CarrierZoneName · Dest '05'
47.	Event Report Acknowledge (ERA)	S6,F12→		
48.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = '22222' · CarrierLoc · CarrierZoneName
49.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
50.			←S6,F11	Event Report Send (ERS) CraneActive
51.	Event Report Acknowledge (ERA)	S6,F12→		
52.	Carrier '33333' arrives at the buffer port.			
53.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '33333' · CarrierLoc = '04' · PortType = 'BP' · CarrierZoneName
54.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
55.	At this point, the CarrierWaitOut at BP event could be optionally used as an advanced notification to the Host to go ahead and request a vehicle to come and pick up carriers '11111' and '33333'.			
56.	Carrier '33333' arrives at the first vehicle loading port (its destination).			
57.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID = '012155' · ResultCode = 0 · CarrierID = '33333' · CarrierLoc = '05' · CarrierZoneName
58.	Event Report Acknowledge (ERA)	S6,F12→		
59.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '33333' · CarrierLoc = '05' · PortType = 'LP' · CarrierZoneName
60.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
61.	Now carriers '11111' and '33333' are on the two vehicle loading port locations of the output port.			
62.			←S6,F11	Event Report Send (ERS) CraneIdle
63.	Event Report Acknowledge (ERA)	S6,F12→		
64.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '22222' · CarrierLoc = "03" · CarrierZoneName · PortType = "OP"
65.	Event Report Acknowledge (ERA)	S6,F12→		
66.	Carrier '22222' arrives at the buffer port.			
67.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '22222' · CarrierLoc = '04' · PortType = 'BP' · CarrierZoneName
68.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
69.	The vehicle arrives and removes the two carriers from the output port. The carriers leave the domain of the stocker.			
70.			←S6,F11	Event Report Send (ERS) CarrierRemoved · CarrierID = '33333' · HandoffType = AUTOMATED
71.			←S6,F11	Event Report Send (ERS) CarrierRemoved · CarrierID = '11111' · HandoffType = AUTOMATED
72.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
73.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
74.	The third carrier is now able to 'cycle forward' on the output port to a vehicle loading port.			
75.			←S6,F11	Event Report Send (ERS) TransferCompleted · CommandID = '101883' · ResultCode = 0 · CarrierID = '22222' · CarrierLoc = '05' · CarrierZoneName
76.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
77.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = '22222' · CarrierLoc = '05' · PortType = 'LP' · CarrierZoneName
78.	Event Report Acknowledge (ERA)	S6,F12→		
79.	No carrier is occupying the '06' port location, however because the requested destination for '22222' was '05' the carrier does not cycle forward on the output conveyor. The carrier waits at location '05' for its vehicle.			

13.2.6 *Database Operations (Install, Remove, Locate, and Update a Carrier Record)*

STEP	COMMENTS	HOST	SC	COMMENTS
1.	The host desires to insert a SC database entry for carrier 123456 at stocker storage location 123			
2.	Host Command Send (HCS) INSTALL · CARRIERID = "123456" · CARRIERLOC = "123"	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) CarrierInstallCompleted · CarrierID = "123456" · CarrierLoc = "123" · CarrierZoneName
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
7.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
1.	The host desires to remove the SC database entry for carrier 123456 from the SC database.			
2.	Host Command Send (HCS) REMOVE · CARRIERID = "123456"	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) CarrierRemoveCompleted · CarrierID · CarrierLoc · CarrierZoneName
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
7.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
1.	The host desires to perform a database lookup(locate) for carrier 123456.			

STEP	COMMENTS	HOST	SC	COMMENTS
2.	Host Command Send (HCS) LOCATE · CARRIERID = “123456” The host could set CARRIERID blank if it wanted the SC to return all carriers it has in its database.	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) CarrierLocateCompleted · CarrierID = “123456” · CarrierLoc = “123” · CarrierZoneName = “Zone1”
5.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
1.	The host desires to update the SC database location of carrier 123456(currently thought to be at stocker storage location 123).			
2.	Host Command Send (HCS) INSTALL · CARRIERID = “123456” · CARRIERLOC = “456”	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) CarrierInstallCompleted · CarrierID = “123456” · CarrierLoc = “456” · CarrierZoneName The existing database entry for carrier 123456 is updated with the new CarrierLoc information.
5.	Event Report Acknowledge (ERA)	S6,F12→		

13.3 *Anomaly Operation*

13.3.1 *Source Location Empty during Transfer – Empty Retrieve*

13.3.1.1 The Host issues a TRANSFER command to the SC to transfer a carrier from an input port to a storage location. When the stocker attempts to pick up the carrier at the input port, it finds that the source location is empty.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 is sitting at the stocker crane accessible input port position.			
2.	Enhanced Remote Command (ERC) **TRANSFER** · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID = “123456” 2. SOURCE 3. DEST = “STORAGE”	S2,F49→		In this scenario SOURCE is the name of a input port position and DEST is the ZoneName STORAGE which is a SC selected shelf. SOURCE is optional since the SC knows where the CARRIERID is located.
3.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)

STEP	COMMENTS	HOST	SC	COMMENTS
4.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID · CarrierID = ‘123456’ · CarrierLoc · CarrierZoneName · Dest = ‘STORAGE’
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) CarrierTransferring
7.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
8.			←S6,F11	Event Report Send (ERS) CraneActive
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.				The stocker attempts to pick the carrier but finds the position to be empty.
11.			←S5,F1	Alarm Report Send (ARS) · ALCD(Alarm Set) · ALID · ALTX
12.	Alarm Report Acknowledge (ARA) · ACKC5	S5,F2→		
13.			←S6,F11	Event Report Send (ERS) AlarmSetEvent · CommandID · ErrorID = SourceEmpty · StockerDeviceInfo · RecoveryOptions =RETRY, ABORT
14.	Event Report Acknowledge (ERA)	S6,F12→		
15.	The Host may choose to disposition the error as follows: 1. Retry the TRANSFER · The stocker attempts to pick the carrier from the input port again			

13.3.1.2 The Host issues a TRANSFER command to the SC to transfer a carrier from a shelf to an output port. When the stocker attempts to pick up the carrier at the shelf, it finds that the source location is empty.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 is logically sitting at a shelf location.			
2.	Enhanced Remote Command (ERC) **TRANSFER** · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID = “123456” 2. SOURCE 3. DEST = “LP1”	S2,F49→		.
3.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			←S6,F11	Event Report Send (ERS) TransferInitiated
5.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
6.			←S6,F11	Event Report Send (ERS) CarrierTransferring
7.	Event Report Acknowledge (ERA)	S6,F12→		
8.			←S6,F11	Event Report Send (ERS) CraneActive
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.				The stocker attempts to pick the carrier but finds the position to be empty.
11.			←S5,F1	Alarm Report Send (ARS) · ALCD(Alarm Set) · ALID · ALTX
12.	Alarm Report Acknowledge (ARA) · ACKC5	S5,F2→		
13.			←S6,F11	Event Report Send (ERS) AlarmSetEvent · CommandID · ErrorID = SourceEmpty · StockerDeviceInfo · RecoveryOptions =RETRY, ABORT
14.	Event Report Acknowledge (ERA)	S6,F12→		
15.	The Host may choose to disposition the error as follows: 1. Retry the TRANSFER · The stocker attempts to pick the carrier from the shelf again			
16.	The Host may choose to disposition the error as follows: 1. Abort the TRANSFER			The carrier is deleted from the SC database and a CarrierRemoveCompleted event is generated as well as a TransferAbortCompleted event and a ZoneCapacityChange event.

13.3.2 *Dest Location Full during Transfer – Double Store*

13.3.2.1 The Host issues a TRANSFER command to the SC to transfer a carrier from an input port to a storage location. When the stocker attempts to place the carrier to the storage location, it finds that the location is occupied.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Carrier 123456 is sitting at the stocker crane accessible input port position.			
2.	Enhanced Remote Command (ERC) TRANSFER · COMMANDID · PRIORITY · TRANSFERINFO 1. CARRIERID = “123456” 2. SOURCE 3. DEST = “STORAGE”	S2,F49→		In this scenario SOURCE is the name of a input port position and DEST is the ZoneName STORAGE which is a SC selected shelf. SOURCE is optional since the SC knows where the CARRIERID is located.
3.			←S2,F50	Enhanced Remote Command Acknowledge (ERCA)
4.			←S6,F11	Event Report Send (ERS) TransferInitiated · CommandID · CarrierID = ‘123456’ · CarrierLoc · CarrierZoneName · Dest = ‘STORAGE’

STEP	COMMENTS	HOST	SC	COMMENTS
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = '123456' · CarrierLoc · CarrierZoneName
7.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
8.			←S6,F11	Event Report Send (ERS) CraneActive
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.				The stocker attempts to place the carrier to the storage location but finds the location to be full.
11.			←S5,F1	Alarm Report Send (ARS) · ALCD(Alarm Set) · ALID · ALTX
12.	Alarm Report Acknowledge (ARA) · ACKC5	S5,F2→		
13.			←S6,F11	Event Report Send (ERS) AlarmSetEvent · CommandID · ErrorID = DestOccupied · StockerDeviceInfo · RecoveryOptions = RETRY, ABORT /* Supplier Option */
14.	Event Report Acknowledge (ERA)	S6,F12→		
15.	Supplier Option The Host may choose to disposition the error as follows: 1. Retry the TRANSFER · The stocker attempts to place the carrier to the dest location again			This is a Supplier Option to implement this Host initiated recovery method.
16.	If the ABORT command is issued by the Host, an unkown carrier is created in the SC database at the physical location responsible for the error. This generates a CarrierInstalledCompleted event for the newly created carrier. The newly created carrier is NOT automatically sent to the LP of the manual output port. The host can issue a new TRANSFER command for the carrier currently on the crane as well as the recently created unkown carrier.			

STEP	COMMENTS	HOST	SC	COMMENTS
17.	If the operator indicates, via the stocker console (supplier option), that the SC should select another shelf location, an unknown carrier is created in the SC database at the physical location responsible for the error. This generates a CarrierInstalledCompleted event for the newly created carrier. The newly created carrier is NOT automatically sent to the LP of the manual output port. The host can issue a new Transfer command for the recently created unknown carrier. The original transfer command for the carrier on the crane completes with success at the other shelf location.			

13.3.3 *Carrier ID Errors*

13.3.3.1 A carrier ID error occurred. See table below for possible Carrier ID errors and resolutions.

Table 14 Carrier ID Error Scenarios at Stocker Ports

ID Error	*Error Description*	*Input Port Action*	*Intrabay Output Port Action**
Failure	ID read fails Examples of reasons for failure are: · Bad bar code reader · Bad bar code label · Obstruction of bar code read · Other	If IDReadFailureOption is 'Reject' Option 1 1. CarrierIDRead event sent 2. Carrier automatically sent to LP of manual output port 3. IDReadError event sent when carrier arrives at LP of manual output port Option 2 - manual input port only 1. CarrierIDRead event sent 2. Stocker automatically sends carrier back to operator accessible location of input port(if necessary) 3. IDReadError event sent Person picks up carrier from input port with the PGV If IDReadFailureOption is 'HostControlled' 1. CarrierIDread event sent 2. CarrierWaitIn event sent with unkown carrier ID 3. Host issues Transfer Command	1. CarrierIDRead event sent 2. Carrier automatically sent to LP of this output port 3. IDReadError event sent when carrier arrives at LP of this output port

ID Error	*Error Description*	*Input Port Action*	*Intrabay Output Port Action**
Duplicate	The carrier ID read results in an ID that matches another entry already in the SC database at a different physical location. Example at Input – Carrier 123 read at ID reader, but there is already a database entry for a carrier with CarrierID 123. Example at Output - Carrier 456 requested to ID reader but CarrierIDRead result is 123, but there is already a database entry for a carrier with CarrierID 123. DuplicateIDs are a subset of unkownIDs with the following format: UNKNOWNDUP-oldid-Seq. Where Seq is a unique sequence identifier.	1. CarrierIDRead event sent for 123 2. If existing carrier 123 has a TransferCommand, send TransferCompleted with 'Duplicate ID' ResultCode. 3. SC automatically Deletes carrier 123 from SC database and sends CarrierRemovedCompleted. 4. SC automatically creates an DuplicateID carrier at shelf location and sends CarrierInstallCompleted event. 5. CarrierWaitIn event for 123 at the port. If IDReadDuplicateOption is 'Reject' EITHER Option 1 6a. Carrier 123 automatically sent to LP of manual output port. 7a. IDReadError event sent for 123 when carrier arrives at LP of manual output port 8a. Host or manual maintenance required to disposition the carrier that SC thought was 123 that is now a Duplicate. OR Option 2 – manual input port only 6b. Stocker automatically sends carrier back to operator accessible location of input port(if necessary) 7b. IDReadError event sent 8b. Person picks up carrier from input port with the PGV 9b. Host or manual maintenance required to disposition the carrier that SC thought was 123 that is now a Duplicate. If IDReadDuplicateOption is 'HostControlled' 6c. Host responsible for sending appropriate Transfer Commands for both carriers.	If IfReadDuplicateOption is 'Reject' or 'HostControlled' and carrier's previous location is a shelf 1. CarrierWaitOut event for 456 2. CarrierIDRead 123 event sent 3. If carrier ID has a TransferCommand, send TransferCompleted with 'Duplicate ID' ResultCode. 4. SC automatically deletes carrier 123 from SC database and sends CarrierRemoveCompleted event. 5. SC automaically creates a DuplicateID carrier at shelf location and sends CarrierInstallCompleted event. 6. SC automatically deletes carrier 456 from SC database and sends CarrierRemoveCompleted event. 7. TransferCompleted for 456 with duplicate ID ResultCode. 8. SC automatically creates an carrier123 at the port location and sends CarrierInstallCompleted event. 9. Carrier continues to LP of this output port. (CarrierWaitOut for 123 at each position) 10. IDReadError event sent when carrier arrives at the LP of this output port 11. Host or manual maintenance required to disposition the carrier that SC thought was 123 (now a duplicate). Note: The TransferCompleted events may come anywhere from step 3 to step 8.

ID Error	*Error Description*	*Input Port Action*	*Intrabay Output Port Action**
Mismatch	The carrier ID read results in an ID that does not match any entries in the SC database. Example - Carrier 456 requested to ID reader but CarrierIDRead result is 123, but there is no SC database entry for a carrier with CarrierID 123.		1. CarrierWaitOut event for 456 2. CarrierIDRead 123 event sent 3. TransferComplete for 456 with mismatch error. 4. SC automatically deletes carrier 456 from SC database and send CarrierRemoveCompleted event. 5. SC automatically creates carrier 123 at the port and sends CarrierInstallCompleted event 6. Carrier continues to LP of this output port. (CarrierWaitOut for 123 at each position) 7. IDReadError event sent when carrier arrives at the LP of this output port. Note: Optionally step 3 may come after step 4 or 5.

13.3.3.2 The following scenario represents a carrier ID *failure* at the stocker *input port* with *option 1* implemented.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	The SC assigns an arbitrary CarrierID based on the failure. An example of such an arbitrary CarrierID would be “FAILURE001” Note: IDReadStatus = 1 means that a Carrier ID Read failure occurred.		←S6,F11	Event Report Send (ERS) CarrierIDRead · CarrierID = “FAILURE001” · PortID · IDReadStatus = 1
2.	Event Report Acknowledge (ERA)	S6,F12→		
3.			←S6,F11	Event Report Send (ERS) CarrierWaitIn · CarrierID = “FAILURE001” · CarrierLoc = SOURCE · CarrierZoneName
4.	Event Report Acknowledge (ERA)	S6,F12→		
5.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
6.	Event Report Acknowledge (ERA)	S6,F12→		
7.	No TRANSFER command issued by Host since recovery is automatic.			
8.			←S6,F11	Event Report Send (ERS) CarrierTransferring · CarrierID = “FAILURE001” · CarrierLoc · CarrierZoneName
9.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
10.			←S6,F11	Event Report Send (ERS) CraneActive
11.	Event Report Acknowledge (ERA)	S6,F12→		

STEP	COMMENTS	HOST	SC	COMMENTS
12.			←S6,F11	Event Report Send (ERS) CraneIdle
13.	Event Report Acknowledge (ERA)	S6,F12→		
14.			←S6,F11	Event Report Send (ERS) CarrierWaitOut · CarrierID = "FAILURE001" · CarrierLoc = "LP1" · PortType = "LP" · CarrierZoneName
15.	Event Report Acknowledge (ERA)	S6,F12→		
			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
	Event Report Acknowledge (ERA)	S6,F12→		
16.			←S6,F11	Event Report Send (ERS) IDReadError · CarrierID = "FAILURE001" · CarrierLoc · IDReadStatus = 1
17.	Event Report Acknowledge (ERA)	S6,F12→		
18.	Carrier leaves the domain of the stocker as it is acquired by a person(PGV)		←S6,F11	Event Report Send (ERS) CarrierRemoved · CarrierID · HandoffType = MANUAL
19.	Event Report Acknowledge (ERA)	S6,F12→		
20.			←S6,F11	Event Report Send (ERS) ZoneCapacityChange
21.	Event Report Acknowledge (ERA)	S6,F12→		

13.3.4 *Host Initiated CANCEL of a TRANSFER Command*

13.3.4.1 The Host wishes to cancel a previously issued transfer command. The assumption is that the carrier is currently sitting on a stocker shelf and has not been picked up by the stocker crane.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Assumption is that a TRANSFER command(CommandID = 111111) is in the QUEUED state.			
2.	Host Command Send (HCS) CANCEL · CARRIERID = "111111"	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) TransferCancelInitiated · CommandID = "111111" · CarrierID = "123456" · CarrierLoc = "STORAGE" · CarrierZoneName
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) TransferCancelCompleted · CommandID = "111111" · CarrierID = "123456" · CarrierLoc = "STORAGE" · CarrierZoneName
7.	Event Report Acknowledge (ERA)	S6,F12→		
8.	Event Report Acknowledge (ERA)	S6,F12→		

13.3.5 *Host Initiated ABORT of a TRANSFER Command*

13.3.5.1 The Host wishes to abort a previously issued transfer command. The assumption is that the carrier is currently in the ALTERNATE substate of STORED.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Assumption is that a TRANSFER command (CommandID = 111111) is in the ACTIVE state.			
2.	Host Command Send (HCS) ABORT · CARRIERID = "111111"	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.				The stocker must abort the transfer command if the carrier was in the ALTERNATE sub-state. Other INSTALL stocker carrier states may cause ABORT command rejection. The latter scenario is supplier specific.
5.			←S6,F11	Event Report Send (ERS) TransferAbortInitiated · CommandID = "111111" · CarrierID = "123456" · CarrierLoc = "STOCKER CRANE" · CarrierZoneName
6.	Event Report Acknowledge (ERA)	S6,F12→		
7.			←S6,F11	Event Report Send (ERS) TransferAbortCompleted · CommandID = "111111" · CarrierID = "123456" · CarrierLoc = "STOCKER CRANE" · CarrierZoneName
8.	Event Report Acknowledge (ERA)	S6,F12→		
9.	Event Report Acknowledge (ERA)	S6,F12→		
10.	Two options may be available for recovery: 1. Manual Recovery 2. Host Initiated Recovery The host would have to issue a TRANSFER command to dispose of the carrier on the stocker crane end-effector for the crane to be utilized for future transfers. This is a Supplier Option			

13.3.6 *Connection or Reconnection between SC and Host*

13.3.6.1 The Host System crashes (or loses communication with the SC for a time exceeding all time-outs and retries) and must re-synchronize with the SC with the possibility of several events completing while the communication link was lost.

STEP	COMMENTS	HOST	SC	COMMENTS
1.	Communication session between host and SC (re)established. Host establishes communication with the SC per the GEM standard scenario (e.g., S1F13, etc).			

STEP	COMMENTS	HOST	SC	COMMENTS
2.	Host Command Send (HCS) PAUSE	S2,F41→		
3.			←S2,F42	Host Command Acknowledge (HCA)
4.			←S6,F11	Event Report Send (ERS) SCPauseInitiated
5.	Event Report Acknowledge (ERA)	S6,F12→		
6.			←S6,F11	Event Report Send (ERS) SCPauseCompleted
7.		S6,F12→		
8.	Selected Equipment Status Request (SSR) ActiveCarriers ActiveZones ActiveTransfers	S1,F3→		HOST asks for carrier, zone and transfer command information
9.			←S1,F4	Selected Equipment Status Data (SSD) · ActiveCarriers . . (one CarrierInfo for each carrier) . · ActiveZones . . (one ZoneData for each zone) . · ActiveTransfers . . (one TransferCommand for each . Active TRANSFER command)
10.	The HOST updates it's model of the system with the information from the status data.			
11.	Host Command Send (HCS) RESUME	S2,F41→		HOST enables the system to continue operations.
12.			←S2,F42	Host Command Acknowledge (HCA)
13.			←S6,F11	Event Report Send (ERS) SCAutoInitiated
14.	Event Report Acknowledge (ERA)	S6,F12→		
15.			←S6,F11	Event Report Send (ERS) SCAutoCompleted
16.	Event Report Acknowledge (ERA)	S6,F12→		
17.				System continues processing all commands that were in process or queued before/during the Host crash or communication loss/initialization. System will also now process new commands.

14 GEM Capabilities

14.1 The purpose of this section is to specify any SEMI E30 additional capabilities that are required to be supported by this class of equipment.

14.2 *Requirement*

14.2.1 This standard requires that the SEMI E30 fundamental requirements and additional capabilities have been implemented on the Stocker SEM equipment with the exception of Trace Data Collection, Process Program Management, Remote Control, Limits Monitoring and Spooling. If these capabilities are implemented, they will be implemented as required by the SEMI E30 document. The Stocker SEM Transfer Command State Model serves as the SEMI E30 Processing State Model. The SEMI E30 additional capabilities required by Stocker SEM are:

- Establish Communications
- Dynamic Event Report Configuration
- Variable Data Collection
- Status Data Collection
- Alarm Management
- Equipment Constants
- Material Movement
- Equipment Terminal Services
- Clock
- Control (host-initiated)

RELATED INFORMATION 1
STOCKER SEM UNIQUE CAPABILITIES

NOTE: This related information is not an official part of SEMI E88, but was approved for publication by full letter ballot procedures.

R1-1 *Transfer Command Message Example (SML Format)*

R1-1.1 Variable data values specified in the following example TRANSFER command have been chosen arbitrarily for the purpose of demonstrating message structure/content.

```
S2,F49
<L [4]
      <U2    0>                                               /* DATAID */
      <A[0]  ‘’>                                              /* OBJSPEC */
      <A[8]  ‘TRANSFER’>                                      /* RCMD */
      <L [2]
            <L [2]
                  <A[11] ‘COMMANDINFO’>                       /* CPNAME1 */
                  <L[2]
                        <L[2]
                              <A[9]  ‘COMMANDID’> /* CPNAME */
                              <A[6]  ‘111111’>          /* CPVAL */
                        >
                        <L[2]
                              <A[8]  ‘PRIORITY’>        /* CPNAME */
                              <U2    5>                 /* CPVAL */
                        >
                  >
            >
            <L [2]
                  <A[12] ‘TRANSFERINFO’>                      /* CPNAME2 */
                  <L[3]
                        <L[2]
                              <A[9]  ‘CARRIERID’>       /* CPNAME */
                              <A[6]  ‘123456’>          /* CPVAL */
                        >
                        <L[2]
                              <A[6]  ‘SOURCE’>          /* CPNAME */
                              <A[0]  ‘’>                /* CPVAL */
                        >
                        <L[2]
                              <A[4]  ‘DEST’>            /* CPNAME */
                              <A[5]  ‘SHELF’>           /* CPVAL */
                        >
                  >
```

>

>

>

R1-2 *Parallel Interface for Carrier Handoff*

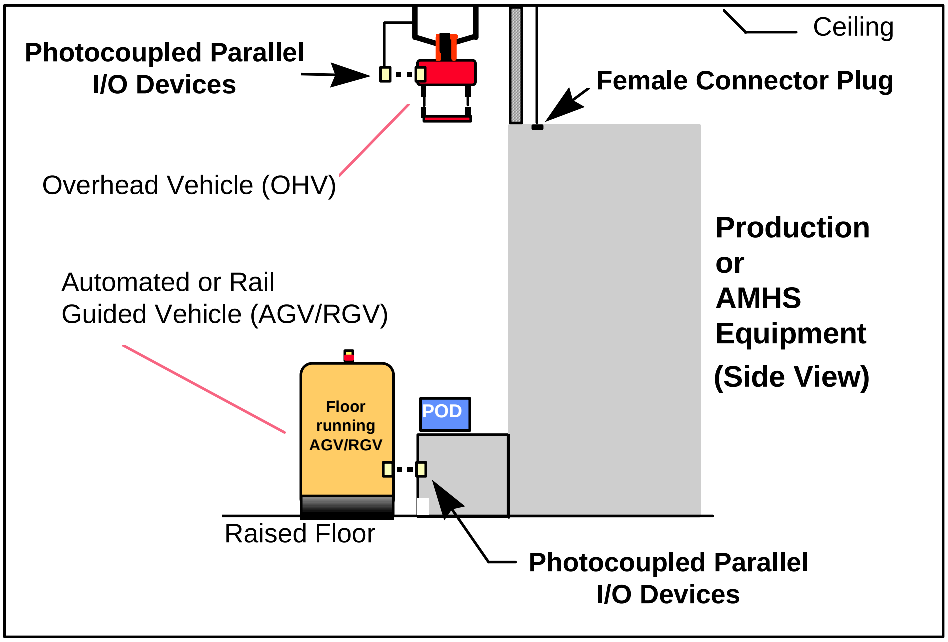


Figure R1-1
Carrier Handoff Example Diagram for OHV/AGV/RGV

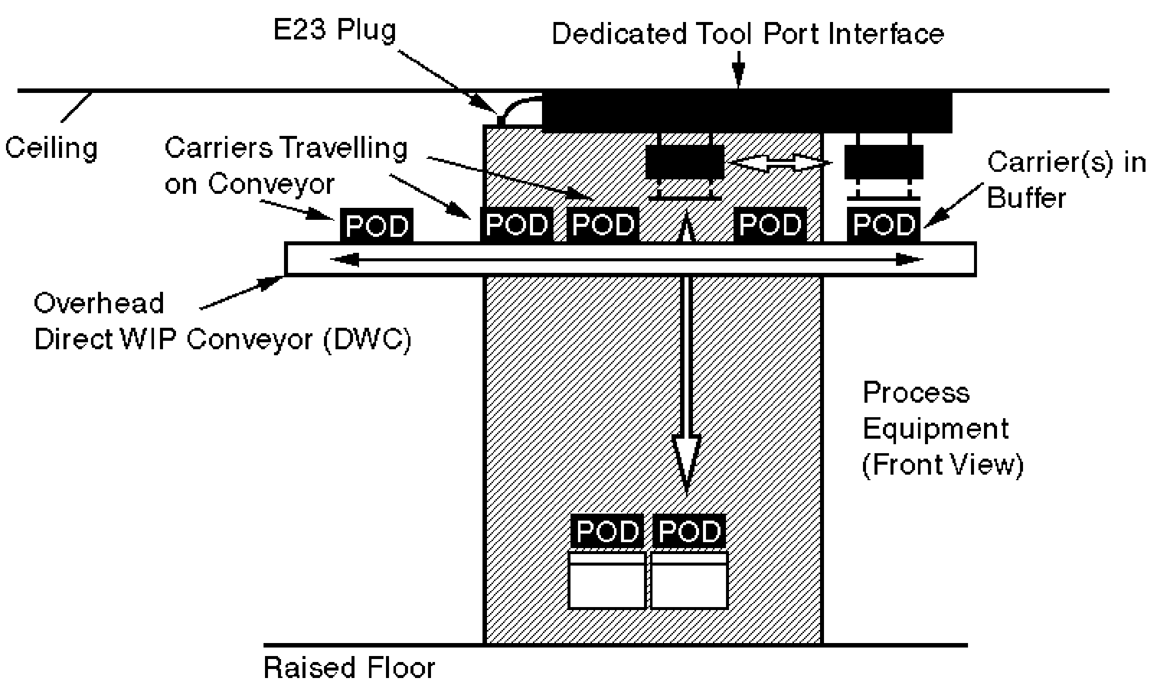


Figure R1-2
Carrier Handoff Example Diagram for DWC

R1-3 *Hardware Architecture*

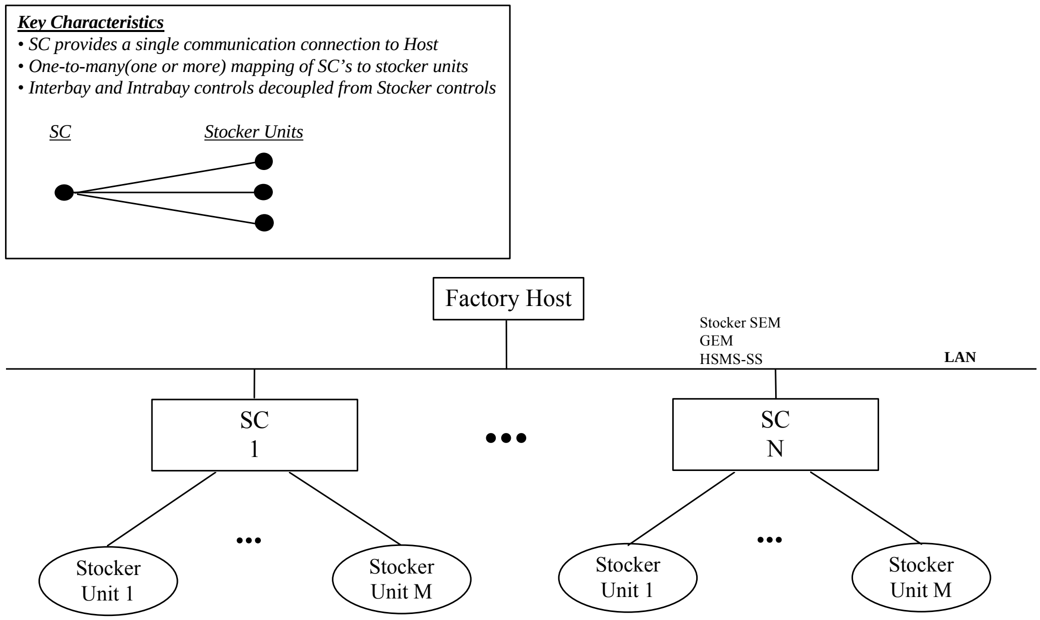


Figure R1-3
SC Architecture (Logical View)

R1-4 *Stocker Command Scheduling Characteristics*

R1-4.1 At a minimum, the SC must offer Priority-based First-In-First-Out (FIFO) queuing of TRANSFER commands. In other words, all TRANSFER commands which have yet to be processed by the SC must be serviced in the order in which they are received by the SC based on the priority given in the host command. The minimum priority levels required to be available on Stocker SEM equipment are “Normal” and “High” (refer to Figure R1-4 for an example). “Normal” and “High” priorities will be denoted by U2 compatible numbers as per the definition of the priority in the Variable Data and Remote Command sections of this document. Other options may be implemented, but to be a Stocker SEM equipment it must at a minimum have the ability to be configured to perform Priority-based FIFO queuing of TRANSFER commands. Additionally, the command priorities are to be utilized during execution of the commands to the following level: any “High” priority command will cause all other commands that are not “High” priority to be usurped. That is to say that all other commands will modify the execution steps to allow the “High” priority commands to be completed in the minimal elapsed time possible. Multiple “High” priority commands will act upon each other according to the same rules as “Normal” commands act on each other.

The following TRANSFER commands are received by the SC in top to bottom order:

TRANSFER Command	Priority
1	Normal
2	Normal
3	High
4	Normal
5	High

Corresponding SC processing queue for outstanding TRANSFER commands :

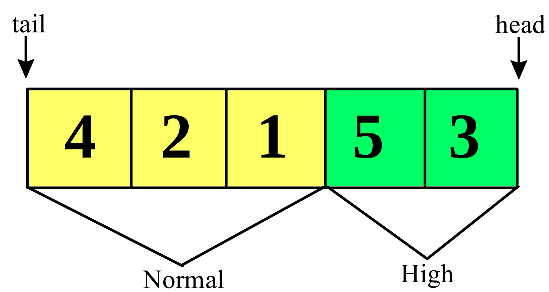


Figure R1-4
SC Priority-Based FIFO TRANSFER Command Processing Example

R1-4.2 The SC must manage the resources so that TRANSFER requests are queued for later service if all resources are currently utilized.

RELATED INFORMATION 2
REQUIREMENTS FOR COMPLIANCE

NOTE: This related information is not an official part of SEMI E88, but was approved for publication by full letter ballot procedures.

Table R2-1 provides a checklist for Stocker SEM compliance.

R2-1 *Stocker SEM Compliance Statement*

Table R2-1 Stocker SEM Compliance Statement

Fundamental Stocker SEM Requirements	*Implemented*	*Stocker SEM Compliant*
SC State Model	□ Yes □ No	□ Yes □ No
Transfer Command State Model	□ Yes □ No	□ Yes □ No
Stocker Crane State Model *(optional, see section 8.5)*	□ Yes □ No	□ Yes □ No
Stocker Carrier State Model	□ Yes □ No	□ Yes □ No
Collection Event List	□ Yes □ No	□ Yes □ No
Collection Event Data Availability	□ Yes □ No	□ Yes □ No
Variable Data Items	□ Yes □ No	□ Yes □ No
Variable Data Availability	□ Yes □ No	□ Yes □ No
Alarm List	□ Yes □ No	□ Yes □ No
Remote Command List	□ Yes □ No	□ Yes □ No
Remote Command Parameters	□ Yes □ No	□ Yes □ No
Remote Command Mapping	□ Yes □ No	□ Yes □ No
Transfer Command Format	□ Yes □ No	□ Yes □ No
System Architecture	□ Yes □ No	□ Yes □ No
Stocker Command Scheduling Characteristics	□ Yes □ No	□ Yes □ No

SEMI E90-0702
SPECIFICATION FOR SUBSTRATE TRACKING

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published September 1999; previously published March 2002.

1 Purpose

1.1 The purpose of this standard is to provide the standard services of equipment to track substrates (manufactured product) in manufacturing equipment. This standard defines the concepts and behaviors for the information management of substrates, as well as the messages/services.

2 Scope

2.1 Essentially, information about substrates must be managed by the factory system, while the equipment is required to provide the services for the substrate information management. This standard addresses the requirement for the equipment services to manage information of substrates that reside in the equipment.

2.2 The scope of this standard is to define the information services of equipment that can be requested by the user. To clarify required services, the concepts and behaviors of the substrate and the substrate location are defined.

2.3 This standard is applicable to any manufacturing equipment that handles substrates. To implement these services, the equipment and factory system must be integrated by means of a communication link.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard assumes that the substrate(s) to be managed has been resident in the equipment and has been given a substrate identifier.

3.2 The service for a substrate is valid while the substrate is registered in the equipment. That is, the service is available from the moment that the substrate is registered into the equipment and, to the moment that the substrate is removed from the equipment.

3.3 This standard is only for information services. It does not address any mechanism to read or write information from/to the substrate.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E53 — Event Reporting

SEMI E87 — Specification for Carrier Management (CMS)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Definitions*

5.1.1 *carrier ID* — the name to identify a specific substrate carrier.

5.1.2 *carrier slot* — physical location capable of holding a substrate within cassette type carrier.

5.1.3 *carrier slot map* — the registry of substrates to the substrate carrier slots.

5.1.4 *carrier substrate location* — a substrate location within a substrate carrier capable of holding a substrate.

5.1.5 *default substrate ID (default ID)* — the substrate ID assigned to the substrate when no substrate ID information is given by the user but the carrier ID for the source carrier is known. The default ID is the combined text of the source carrier ID and the slot number.

5.1.6 *equipment substrate location* — a substrate location on a equipment resource.

5.1.7 *location ID* — the name of a material location.

5.1.8 *lot* — a group of one or more substrates of the same type. A lot must be organized by the user. The group may be referred to for tracking of substrates in the factory.

5.1.9 *material location* — an identifiable place within the equipment or carrier where material can be held.

5.1.10 *register* — an operation that adds the substrate object to the equipment's database. This operation is performed automatically when the equipment receives both a carrier and information from the host about the contents of the carrier. The operation is also performed automatically when the equipment detects the substrate ID.

5.1.11 *remove* — the operation that removes a substrate from the equipment.

5.1.12 *service* — represents a function offered to a user by a provider. A service consists of a sequence of service primitives, each described by a list of parameters.

5.1.13 *substrate* — the basic unit of material on which work is performed to create a product. Examples include wafers, die, plates used for masks, flat panels, circuit boards, and leadframes.

5.1.14 *substrate carrier* — a carrier to hold substrates to be transferred to/from the equipment. A substrate carrier has one or more position to hold substrates (carrier substrate location).

5.1.15 *substrate history* — ordered set of information about the locations visited by the substrate.

5.1.16 *substrate ID* — identifier of a substrate.

5.1.17 *substrate location* — a material location which is capable of holding a substrate. For example, but not limited to, process modules, transfer subsystems, wafer chucks, robot end effecter, and carrier slots.

5.1.18 *substrate type* — represents the type of the substrate, such as wafers, CDs, flat panels, or masks.

5.2 *Data Type*

5.2.1 *Boolean* — may take on one of two possible values, equating to TRUE or FALSE.

5.2.2 *enumerated* — may take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type except floating point.

5.2.3 *floating point* — may take on any single numeric value, positive or negative. Messaging protocol may impose a limit on the range of possible values.

5.2.4 *form* — type of data: positive integer, unsigned integer, integer, floating point, enumerative, Boolean, text, formatted text, structure, list, and ordered list.

5.2.5 *formatted text* — text with an imposed format. This could be by position, by use of special characters, or both.

5.2.6 *integer* — may take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

5.2.7 *list* — a set of one or more items that are all of the same form (one of the above forms).

5.2.8 *ordered list* — a list for which the order in which items appear is significant.

5.2.9 *positive integer* — may take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

5.2.10 *structure* — a complex set of information consisting of specific sets of items of possibly mixed data types, in a specified arrangement.

5.2.11 *text* — a text string. The message protocol restricts its length or ASCII representation. Messaging protocol may impose restrictions, such as length or ASCII representation.

5.2.12 *unsigned integer* — may take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

6 Convention

6.1 *Harel State Model*

6.1.1 This document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in “Statecharts: A Visual Formalism for Complex Systems” written by D. Harel in Science of Computer Programming 8, 1987.[1]

6.1.2 A transition table is used with the state chart for clearly describing the character of each state transition. The table contains the folllowing: a transition number, current state, trigger, new state, and operation in transition.

6.1.3 The state models included in this standard are a requirement for Substrate Tracking compliance. A state model consists of a state model diagram, state definitions, and a state transition table. When using collection events, all state transitions in this standard, unless otherwise specified, shall correspond to collection events.

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

6.1.4 A state model represents the host's view of the equipment and does not necessarily describe the internal equipment operation. When using collection events, all Substrate Tracking state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the Substrate Tracking state models for transition to another state. In this case, the equipment makes the required transition without any additional actions.

6.2 *OMT Object Information Model*

6.2.1 The object models are represented using the Object Modeling Technique (OMT) developed by Rumbaugh, James, et al, in Object Oriented Modeling Design, Prentice Hall, Englewood Cliffs, NJ, 1991.[2]

6.2.2 An overview of this notation is provided in the Appendix 1 of SEMI E39.

6.3 *Object Attributes Representation*

6.3.1 The object information model for standardized objects will be supported by an attribute definition table with the following column headings:

Attribute Name	*Definition*	*Access*	*Reqmt*	*Format*
The formal text name of the attributes.	Description of information contained.	RO or RW	Y or N	Refer to the description below.

6.3.1.1 The Access column uses RO (read only) or RW (read/write) to indicate the access that a service user has to the attribute.

6.3.1.2 A "Y" or "N" in the Requirement (Reqmt) column indicates if this attribute must be supported in order to meet the fundamental requirement for the service.

6.3.1.3 The Format column is used for showing the data type of the attribute. (See Section 5.2.)

6.4 *Service Message Representation*

6.4.1 *Service Resource Definition* — A service resource definition table defines the specific sets of messages for a service group, as shown in the following table:

Message Service Name	*Type*	*Description*
Message name	N or R	Purpose of the service

6.4.1.1 Type can be either N = Notification or R = Request. Notification type messages are initiated by a service provider and the provider does not expect to get the response from the service user or requester.

6.4.1.2 Request messages are initiated by a service user or requester. The Request message asks for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message context).

6.4.2 *Service Parameter Dictionary* — A service parameter dictionary table defines the parameters for one or more services, as shown in the following table:

Parameter	*Form*	*Description*
Parameter X	Data type	The parameter called X is B in A.

6.4.2.1 A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing form and contents of the corresponding primitive.

6.4.2.2 The Form column is used to indicate the type of data contained in a parameter. (See Section 5.2 for definitions.)

2 Prentice Hall, Inc., Upper Saddle River, NJ 07458, http://www.prenhall.com/divisions/ecs/cscat.html

6.4.2.3 The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the values it can assume, and any interrelationships with other parameters.

6.4.2.4 To prevent the definition of numerous parameters named "XxxList", this document adopts the convention of referring to the list as "(List of) Xxxx". In this case, the definition of the variable Xxx will be given, not of the list. The term "list" indicates a collection (or set) of zero or more items of the same data type. Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

6.4.3 *Service Message Definition* — A service message definition table defines the parameter used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
Parameter X	see below	see below	A description of the service.

6.4.3.1 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication". The receiver may then send a "Response", which the original sender terms the "Confirmation".

6.4.3.2 The following codes appear in the Req/Ind and Rsp/Conf columns, and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M" — Mandatory Parameter – must be given a valid value.

"C" — Conditional Parameter – may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the values of other parameters.

"U" — User-Defined Parameter

"-" — The parameter is not used.

"="— (for response only) Indicates that the value of this parameter in the response shall match the value in the primary (if defined).

7 Overview

7.1 *Purpose of Substrate Tracking*

7.1.1 Substrate tracking consists of two kinds of capabilities, as described below:

7.1.2 *Substrate Location Tracking* — Substrate Location Tracking provides the capability to determine the current location of substrates in the equipment. The indication of the substrate location will help the user to understand the environment to which the substrate is exposed in the equipment.

7.1.3 *Substrate History Record* — Substrate History Record provides the capability to read the history of substrates in the equipment. The user can inquire about the history of a particular substrate or substrate location. A history includes the series of locations that the substrate has visited in the equipment.

7.1.4 *Substrate Process Tracking* — Substrate Process Tracking provides the capability of tracking current substrate processing state. For example, the user may determine whether a substrate is processed or not by requesting its state when the process has been completed abnormally. The user may use the state transitions to trigger wafer level data collection.

7.2 *View of Substrate Tracking*

7.2.1 Figure 1 shows the view of Substrate Tracking using the OMT representation. It is assumed that substrates are available before usage of the services. Substrate carriers may or may not be used to load the substrates to the equipment. Substrates are loaded into the equipment and travel through substrate locations. The equipment must maintain all information necessary to track substrates in the equipment.

7.3 *Substrate Location*

7.3.1 A substrate location is a discrete position that can hold a substrate in the equipment. This document will not define where the substrate location exists. Substrate locations shall be determined by the design of equipment and the applications. For example, to track the order of process chambers that is applied to a substrate process in a multi-chamber equipment, it is appropriate to designate process chambers for substrate locations. All substrate locations shall be documented by the equipment supplier.

7.3.2 Figure 2 shows the concept of the substrate location using OMT representation. This figure is provided to clarify the definition of locations.

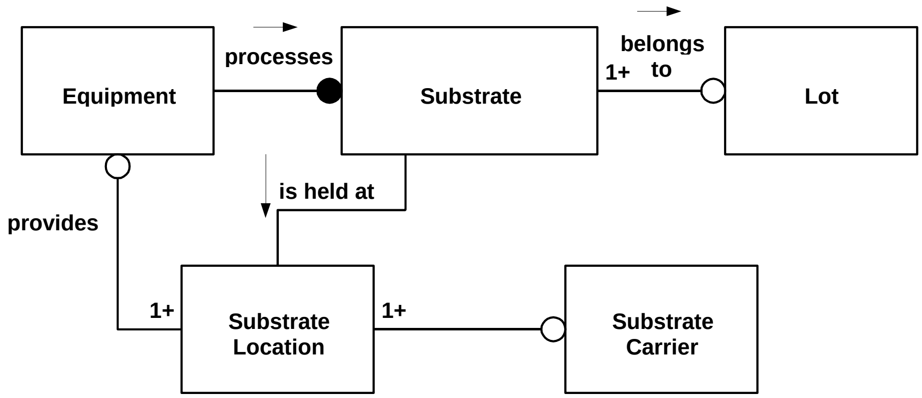


Figure 1
Overview of Substrate Tracking

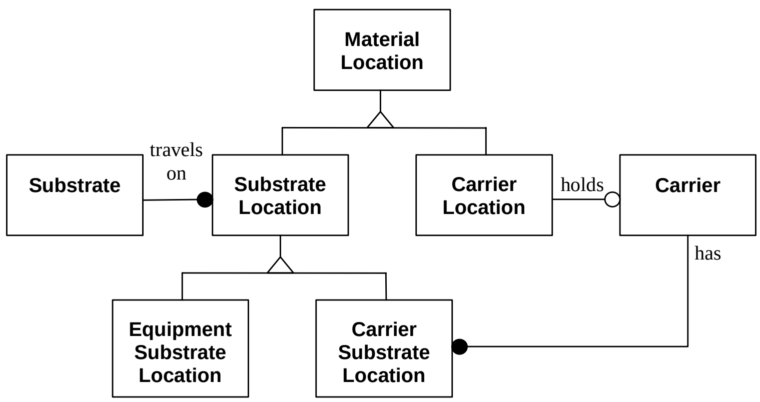


Figure 2
Concept of Substrate Location

7.3.3 Material Location is classified into Substrate Location and Carrier Location. A Carrier Location may hold a carrier and a Substrate Location may hold a substrate.

7.3.4 Substrate Location is classified into Equipment Substrate Location and Carrier Substrate Location. Carrier has Carrier Substrate Locations. A Carrier Substrate Location is the location which can hold a substrate in a carrier. An Equipment Substrate Location is the location which can hold a substrate on the equipment resource.

7.3.5 Substrate travels on substrate locations.

7.4 *Identification of Substrate*

7.4.1 Substrate shall be identified by substrate ID. There are options for assigning substrate ID to a substrate.

- When a carrier is used for loading substrates and the carrier is given its carrier ID, substrate IDs can be obtained by utilizing the carrier ID and carrier substrate location. This standard will define the requirement for the substrate ID assignment to the substrates in a carrier.
- Substrate ID may be read from the substrate directly by a substrate ID reader. The substrate ID read from the substrate can be used for the identification.

- Substrate ID may be assigned by the user (i.e., host or operator). The substrate ID can be used for the identification. This standard will define the service for registering substrates.

7.4.2 The recommendation of a particular option for assigning substrate IDs is not within the scope of this standard. It must be selected based on the equipment design and applications.

8 Substrate Tracking Requirement

8.1 Compliance to Substrate Tracking Service (STS) requires that an implementation also provide certain capabilities that are defined in other standards.

- STS requires compliance to SEMI E39 (OSS) for Substrate objects. The attributes of these objects may be accessed through use of the GetAttr and SetAttr services.
- STS requires an event reporting capability. This capability may be satisfied by the Event Reporting capability in SEMI E30 (GEM) or by SEMI E53 (ERS).

8.2 STS compliant equipment must implement capabilities defined in the following sections of this document:

- Section 9, Substrate Object Definition,
- Section 10, Substrate Location Object Definition,
- Section 11, Substrate Tracking Services, and
- Section 12, Variable Data, if SEMI E53 is not implemented.

8.3 Suppliers shall document the method by which the equipment identifies individual substrates. If the equipment has implemented a substrate ID reading capability, then the equipment shall provide the capability to assign the ID read from the substrate to the substrate object. Otherwise, the equipment shall provide the capability to assign substrate ID to the substrate object by the information provided by the host with the source carrier, either in ContentMap, where provided (see SEMI E87), or the default substrate ID. The default substrate ID shall be represented in text as the carrier ID, a period ".", and a two-digit slot number combined, as in "carrier ID" + "." + "slot number". For example, if CarrierID = "xyz" and SlotNumber = 5, then the substrate ID would be "xyz.05".

8.4 All state transitions defined for the two state models specified in this document must be reportable via discrete collection events as defined in Section 6.1, Harel State Model. The two state models are the Substrate Object State Model (Figure 3) and the Substrate Location State Model (Figure 4).

8.4.1 The following data is required to be available, at a minimum, for the Substrate Object State Model transition collection events:

- SubstID or SubstIDList
- SubstState or SubstStateList
- SubstProcState or SubstProcStateList
- SubstLocID or SubstLocIDList

An equipment may support both SubstID and SubstIDList, but depending on equipment type, one or the other must be supported in the following manner: Fixed buffer equipment must, at a minimum, support the SubstID variable, whereas internal buffer equipment must, at a minimum, support the SubstIDList variable. SubstID is valid at collection events triggered by discrete state model transitions, whereas SubstIDList is valid at collection events triggered by a group of related state model transitions.

8.4.2 The following data is required to be available, at a minimum, for the Substrate Location State Model transition collection events:

- SubstLocID or SubstLocIDList
- SubstLocState or SubstLocStateList
- SubstID or SubstIDList

An equipment may support both SubstLocID and SubstLocIDList, but depending on equipment type, one or the other must be supported in the following manner: Fixed buffer equipment must, at a minimum, support the SubstLocID variable, whereas internal buffer equipment must, at a minimum, support the SubstLocIDList variable. SubstLocID is valid at collection events triggered by discrete state model transitions, whereas SubstLocIDList is valid at collection events triggered by a group of related state model transitions.

8.5 The minimum data required to be valid at each state model transition event is defined in Table 10, Variable Data Definitions for Substrate, of this document. The host may assign other variables, as applicable, from other equipment variable data items.

8.6 Each Substrate Object instantiated on the equipment must maintain an independent instance of the Substrate Object State Model. When discrete and unrelated state transitions occur for Substrate Object models, each shall trigger a separate collection event. However, when related state transitions occur for a group of Substrate Object models (such as with internal buffer equipment material transfers), each model does not trigger a separate collection event. Instead, a single collection event shall be triggered (for all related Substrate Objects in the group). The data items defined in Table 10 are required to be valid for collection events triggered by discrete state model transitions as well as those triggered by a group of related state model transitions, with one exception. SubstID must be valid for collection events triggered by discrete state transitions, but SubstIDList must be valid for collection events triggered by a group of related state transitions. The value of SubstIDList shall be the list of SubstID data items that identify the Substrate Objects related by the collection event.

8.7 Each Substrate Location Object instantiated on the equipment must maintain an independent instance of the appropriate state Substrate Location Object Model. Each Substrate Location Object shall trigger a separate collection event for each state transition. The data items defined in Table 10 are required to be valid for collection events triggered by each state model transition.

9 Substrate Object Definition

9.1 A substrate is a base upon which a product unit is built in the manufacturing equipment. Wafers and flat panel displays are examples of substrates. A substrate may be associated with a lot, which the factory uses for tracking purposes.

9.1.1 The substrate object shall be created when the substrate is registered by the equipment. There are two possible ways of registering the substrate.

(1) The substrate is registered by the equipment when the information for the carrier containing the substrate is registered. The information required to create a substrate object must be provided with the carrier. However, the specification of carrier management services is outside the scope of this standard. Substrate Tracking implementations shall be consistent with the Carrier Management standard. For instance, if the Carrier Management standard specifies the method of identifying the substrates in a carrier, then Substrate Tracking shall recognize those identifiers.

(2) The substrate is registered when the substrate is transferred directly (not in a carrier) to the equipment by the Create service defined in SEMI E39 to inform the equipment of this event.

9.2 *Substrate Object State Model*

9.2.1 A substrate has both a state indicating where it is located and a state indicating the progress of processing. These states are represented by the SUBSTRATE TRANSPORT and the SUBSTRATE PROCESSING states, which are concurrent substates of the SUBSTRATE State Model shown in Figure 3.

9.3 *Substrate Object State Definitions*

9.3.1 ABORTED — The process has been aborted during the processing. The substrate will require special treatment.

9.3.2 AT DESTINATION — The substrate has been placed at its designated destination substrate location. The substrate may have been placed at a carrier substrate location when the carrier is used to unload the substrate from the equipment, or at an equipment substrate location when the substrate is to be removed by itself from the equipment.

9.3.3 AT SOURCE — The state which the substrate is originally received. The substrate is held at carrier substrate location when a carrier is used to supply the substrate.

9.3.4 AT WORK — The substrate has been taken from the original substrate location or destination substrate location, and is traveling on intermediate equipment substrate locations. The substrate has been taken out of the carrier and placed into the equipment when a carrier is used to supply the substrate.

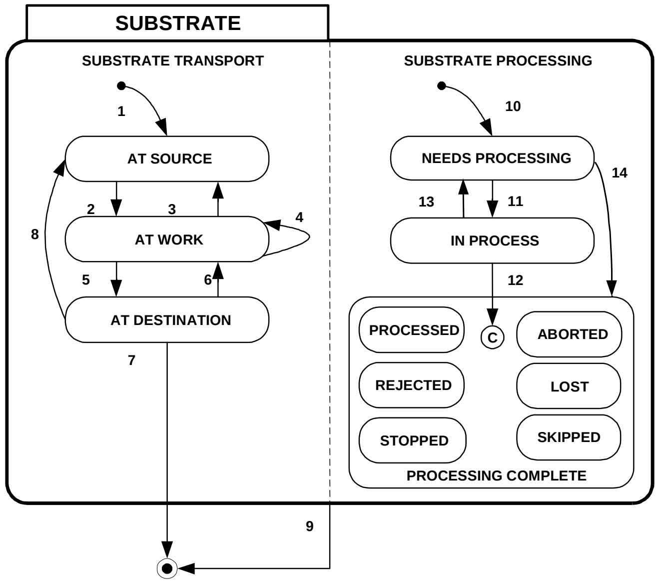


Figure 3
Substrate Object State Model

9.3.5 IN PROCESS — The processing for the substrate has begun and not completed. The processing is effecting on that substrate. The nature of the process depends upon the substate usage.

9.3.6 LOST — The terminal state when the substrate has been broken and/or removed from the equipment by an external entity and it no longer exists at the equipment.

9.3.7 NEEDS PROCESSING — Processing requirements exist that have not yet been fulfilled. This is the default entry state when the substrate is originally received. In some cases, the substrate may return to this state while it waits for additional processing to be performed.

9.3.8 PROCESSED — All substrate processing has successfully completed. No further processing will be performed by the equipment.

9.3.9 PROCESSING COMPLETE — The superstate of PROCESSED, ABORTED, REJECTED, LOST, STOPPED, SKIPPED which the substrate has completed the processing.

9.3.10 REJECTED — The state which the substrate has been processed completely; however, the result of the processing may have a problem. The substrate will require special treatment. This substate is not required for equipment that is unable to identify rejected substrates.

9.3.11 SKIPPED — As directed by an operator or a host, the substrate was not processed.

9.3.12 STOPPED — The process has been stopped during the processing. The substrate will require special treatment.

9.3.13 SUBSTRATE — The superstate of the SUBSTRATE TRANSPORT and SUBSTRATE PROCESSING. SUBSTRATE TRANSPORT and SUBSTRATE PROCESSING are concurrent substates. The state is created when the substrate is initially registered to the equipment, and deleted when the substrate is removed from the equipment.

9.3.14 SUBSTRATE PROCESSING — The superstate of NEEDS PROCESSING, IN PROCESS, PROCESSING COMPLETE which represents the processing state of the substrate.

9.3.15 SUBSTRATE TRANSPORT — The superstate of the AT SOURCE, AT WORK, AT DESTINATION which represents the transport state of the substrate within the equipment.

9.4 *Substrate State Transition*

Table 1 Substrate State Model Transition Table

No.	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	no state	The substrate is registered.	AT SOURCE		
2	AT SOURCE	The substrate is taken from the source substrate location and placed into the equipment.	AT WORK	Update substrate location history.	Substrate tracking through the equipment substrate locations begin.
3	AT WORK	The substrate has moved to the source substrate location.	AT SOURCE	Update substrate location history.	This transition is not required for compliance to this standard.
4	AT WORK	The substrate has moved out from current equipment substrate location towards a new equipment substrate location.	AT WORK	Update substrate location history.	The substrate has moved between equipment substrate locations. This transition is not required for compliance to this standard. This transition is not required if the equipment only provides a single Equipment Substrate Location.
5	AT WORK	The substrate is moved to the destination substrate location.	AT DESTINATION	Update substrate location history.	
6	AT DESTINATION	The substrate is taken from the destination substrate location and placed into the equipment.	AT WORK	Update substrate location history.	This transition is not required for compliance to this standard.
7	AT DESTINATION	The substrate is removed from the equipment by a normal transfer sequence.	(Extinction)	The substrate object is deleted in the equipment.	
8	AT DESTINATION	The user informs or the equipment detects that the substrate is AT SOURCE.	AT SOURCE	Update substrate location history.	This transition is not required for compliance to this standard.
9	Any SUBSTRATE substate	The equipment detects or is informed by the user that a substrate has been removed.	(Extinction)	The substrate object is deleted in the equipment.	The removal may be detected by the equipment or in-formed by the user. This transition would not occur during normal wafer movement. So if transition 7 occurs, there is no need to report a transition 9.
10	no state	The substrate object is created.	NEEDS PROCESSING		
11	NEEDS PROCESSING	The processing to the substrate starts.	IN PROCESS		
12	IN PROCESS	The processing to the substrate completes.	PROCESSING COMPLETE	One of the substates PROCESSED, ABORTED, STOPPED, REJECTED, LOST, SKIPPED is determined.	
13	IN PROCESS	The substrate is requested to be processed again.	NEEDS PROCESSING		This transition is not required for compliance to this standard.
14	NEED PROCESSING	The substrate has been removed from the equipment by an external agent or it is physically missing (LOST) or the substrate has been not processed (SKIPPED).	PROCESSING COMPLETE	One of the substrates LOST, SKIPPED, is determined.	

9.5 *Substrate Object Attribute Definition*

9.5.1 Table 2 defines attributes for substrate objects. These attributes can be accessed by using GetAttr and SetAttr messages as defined in SEMI E39 (OSS).

Table 2 Substrate Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqmt*	*Format*
LotID	Identifier of the lot associated with the substrate by the user.	RW	N	Text
MaterialStatus	Current status of the substrate that represents criteria of the processing quality. The criteria is equipment design dependent.	RO	N	Enumerated: equipment dependent
ObjID	Object Identifier	RO	Y	Text equal to the Substrate ID
ObjType	Object type	RO	Y	Text = "Substrate"
SubstDestination	Identifier of the substrate location on which the substrate shall be finally restored. When a carrier is used for restoring the substrate, the value shall be the concatenation of carrier identifier (carrier ID) string and a numeric string representing the substrate position in the carrier to represent the carrier and position of the substrate restored.	RO	Y	Text If empty string, then same as source substrate location
SubstHistory	History of locations visited.	RO	Y	List of structures consisting of SubstLocID, TimeIn, TimeOut
SubstLocID	Identifier for current equipment substrate location.	RO	Y	Text
SubstProcState	Processing state of the substrate. "NEEDS PROCESSING": initial value to indicate that processing in the equpment is required and has not started. "IN PROCESS": processing has started. "PROCESSED": processing has completed normally. "ABORTED": processing has terminated abnormally. "STOPPED": processing has terminated at completion of certain processing step. "REJECTED": the substrate has been identified as needing special treatment. "LOST": the substrate has been removed from the equipment by an external agent or it is physically missing. "SKIPPED": the substrate was not processed.	RO	N	Enumerated: NEEDS PROCESSING IN PROCESS PROCESSED ABORTED STOPPED REJECTED LOST SKIPPED
SubstSource	Identifier of the substrate location on which the substrate has been initially registered. When a carrier is used for registering the substrate, the value shall be the concatenation of carrier identifier (carrier ID) string and a numeric string representing the substrate position in the carrier to represent the carrier and position of the substrate registered.	RO	Y	Text
SubstState	Transport state of the substrate.	RO	Y	Enumerated: AT SOURCE AT WORK AT DESTINATION
SubstType	The type of the substrate. It includes wafers, flat panels, CD's or masks.	RW	N	Enumerated: WAFER FLAT PANEL CD MASK

Attribute Name	Definition	Access	Reqmt	Format
SubstUsage	How the substrate is used, such as “product”, “test”, “filler” and “cleaning”.	RW	N	Enumerated: PRODUCT TEST FILLER CLEANING

9.5.2 SubstHistory attribute is a composite data type. The constitute data is defined in Table 3.

Table 3 Attribute Data Definition

Data Identifier	Description	Form
SubstLocID	Equipment substrate location on which the substrate has visited. Must be copied from SubstLocID of which the substrate has visited.	Text
TimeIn	Actual arrival time of the substrate on the substrate location.	The format of the timestamp defined by the protocol for implementation.
TimeOut	Actual departure time of the substrate from the substrate location.	The format of the timestamp defined by the protocol for implementation.

10 Substrate Location Object Definition

10.1 A Substrate Location Object (SLO) provides a model for identifying substrate locations. Each SLO on an equipment is assigned a substrate location ID to uniquely identify it. The assignment shall be docu-mented by the equipment supplier. There are two types of substrate locations: carrier substrate location, which is the location or position (e.g., slot) in the carrier, and equipment substrate location, which is on the equip-ment resource. The equipment substrate location is a persistent object, while the carrier substrate locations are dynamic objects that shall be created or deleted by the placement or removal of carriers on the equipment.

10.1.1 Source substrate locations and Destination substrate locations are the points at which substrates transfer to/from the equipment’s internal substrate locations (often locations at which processing occurs). A carrier substrate location is the Source or Destination substrate location when a carrier is used to transfer the substrate. An equipment substrate location can be the Source or Destination substrate location when the substrate is transferred directly (without a carrier).

10.2 *Substrate Location State Model*

Figure 4 shows the dynamic behavior of the substrate location using the Harel state chart representation.

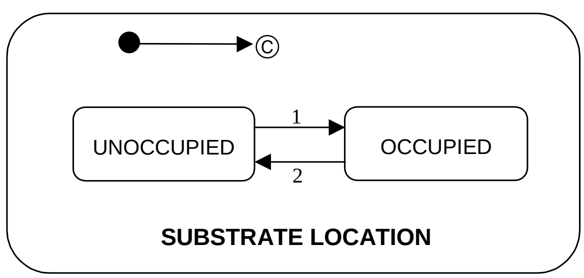


Figure 4
Dynamic Behavior Model of Substrate Location

10.3 *Substrate Location State Definitions*

10.3.1 SUBSTRATE LOCATION — the superstate of UNOCCUPIED and OCCUPIED.

10.3.2 UNOCCUPIED — the state in which the substrate location does not hold or have a substrate.

10.3.3 OCCUPIED — the state in which the substrate location holds a substrate.

10.4 *Substrate Location State Transition*

Table 4 Substrate Location State Model Transition Table

No.	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	UNOCCUPIED	Substrate moves onto the substrate location.	OCCUPIED	None.	
2	OCCUPIED	Substrate moves off the location.	UNOCCUPIED	Update substrate tracking history.	

10.5 *Substrate Location Object Attributes*

10.5.1 Table 5 defines attributes for substrate location objects. These attributes can be accessed by using GetAttr and SetAttr messages as defined in SEMI E39 (OSS).

Table 5 Substrate Location Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqmt*	*Format*
ObjID	Object Identifier	RO	Y	Text equal to the Substrate Location ID
ObjType	Object type	RO	Y	Text = "SubstLoc"
SubstID	Substrate Identifier relevant to the location	RO	Y	Text
SubstLocState	Substrate Location state	RO	Y	Enumerated: UNOCCUPIED, OCCUPIED

11 Substrate Tracking Services

11.1 *Creating and Deleting Substrate Objects*

11.1.1 Substrates may be registered at the equipment through the Create service defined in SEMI E39. Table 6 defines the attribute settings that may be initialized through this service.

11.1.2 In general, it depends on the application whether or not attributes are initialized by the user of the create service. In some situation, it may be necessary to match the new substrate with a location, for example, while in other situations it would be unnecessary. Each application must specify its own requirements.

11.1.3 ObjType is a required argument of the Create service and should not be reset by including it as an attribute setting. In the table, M indicates Mandatory, O indicates Optional, and R specifies Restricted (shall be ignored if used).

Table 6 Substrate Attributes Settable through Create

Substrate Attribute Name	*Use as AttrSetting in Create Service*
LotID	O
MaterialStatus	O
ObjID	M
ObjType	R
SubstDestination	O
SubstHistory	O
SubstLocID	O
SubstProcState	O
SubstSource	O

11.1.4 Use of attribute settings for the Delete service are optional and specific to the application.

11.2 Table 7 defines services required for substrate tracking. These services must be supported with substrate object.

Table 7 Substrate Tracking Service Message Definition Table

Message Service Name	*Type*	*Description*
Change substrate state	R	Request to change substrate state. This message can be used to inform the equipment that external intervention has occurred and the state of the substrate (SubstState) must be corrected. For example, changing from AT DESTINATION state to AT SOURCE state.

11.3 *Substrate Tracking Service Parameter Dictionary*

Table 8 Substrate Tracking Service Parameter

Dictionary Parameter	*Form*	*Description*
ErrorCode	Enumerated	Contains the code for the specific error found.
ErrorText	Text	Text in support of the error code.
STAcknowledge	Enumerated	Acknowledge of request
Status	A list of ErrorCode/ErrorText pairs	Report any errors found
STStatus	A structure consisting of STAcknowledge and Status	Return information for a service.
SubstID	Text	Identifier of a substrate.
SubstLocID	Text	Identifier of substrate location.
SubProcState	Enumerated	Processing State of a substrate.
SubstState	Enumerated	Transport State of a substrate

Table 9 Change Substrate State Message Pararmeter Table

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
(list of) SubstID	M	=	
(list of) SubstState	C (See NOTE 1.)	-	The order of SubstStates corresponds to the order of SubstID list.
(list of) SubstProcState	C (See NOTE 1.)	-	The order of SubstStates corresponds to the order of SubstID list.
Status	-	M	Information about the results.

12 Variable Data

12.1 The host may inquire about any data related to specific substrates at any time by using the OSS service GetAttr. However, in order for the host to be able to specify the data of interest for building event reports, it must be possible for the host to indicate any of the attributes of the specific instance of substrate associated with an event. To satisfy this need, implementations of STS that are not compliant with SEMI E53 are required to provide variables defined in Table 10.

12.1.1 Variables are presented in alphabetical order.

Table 10 Variable Data Definitions for Substrate

Variable Name	*Description*	*Access*	*Form*	*Comment*
LotID	A tracking ID for the substrate associated with the last event.	RO	Text	
SubstDestination	Destination Carrier Substrate Location for the substrate associated with the last event.	RO	Text	If empty string, then same as source carrier position.
SubstHistory	List of history of locations visited for the substrate associated with the last event.	RO	List of structures consisting of Location ID, Time In, and Time Out.	

Variable Name	*Description*	*Access*	*Form*	*Comment*
SubstID	Identifier of substrate associated with last event.	RO	Text	
SubstIDList	A list of substrate identifiers related by the same Substrate Object State Model or Substrate Location Object State Model state transition that triggered a collection event with which this variable was associated.	RO	Ordered list of SubstID	When a group of substrates have a related state model transition, only one collection event is triggered.
SubstLocID	Identifier for equipment substrate location associated with the last event.	RO	Text	
$SubstLocID_i$	Identifier of the ith equipment substrate location.	RO	Text	
SubstLocIDList	A list of substrate location identifiers related by the same Substrate Object State Model or Substrate Location Object State Model state transition that triggered a collection event with which this variable was associated.	RO	Ordered list of SubstLocID	When a group of substrates have a related state model transition, only one collection event is triggered.
SubstLocState	State of substrate location associated with the last event.	RO	Enumerated: OCCUPIED UNOCCUPIED	
$SubstLocState_i$	State of ith equipment substrate location.	RO	Enumerated: OCCUPIED UNOCCUPIED	
SubstLocStateList	A list of substrate location states related by the same Substrate Location Object State Model state transition that triggered a collection event with which this variable was associated.	RO	Ordered list of SubstLocState	When a group of substrates have a related state model transition, only one collection event is triggered.
$SubstrLocSubstrID_i$	Substrate ID of the substrate at the ith equipment substrate location, when occupied.	RO	Text	
SubstMtrlStatus	Processing quality criteria associated with the last event.	RO	Enumerated (equipment specific)	
SubstProcState	Processing state of the substrate associated with the last event.	RO	Enumerated: NEEDS PROCESSING IN PROCESS PROCESSED ABORTED STOPPED REJECTED	May not be implemented when the equipment does not have capability of process.
SubstProcStateList	A list of substrate process states related by the same Substrate Object State Model state transition that triggered a collection event with which this variable was associated.	RO	Ordered list of SubstProcState	When a group of substrates have a related state model transition, only one collection event is triggered.
SubstSource	Source Carrier Substrate Location for the substrate associated with the last event.	RO	Text	
SubstState	The current state of the substrate associated with the last event.	RO	Enumerated: AT SOURCE AT WORK AT DESTINATION	

Variable Name	*Description*	*Access*	*Form*	*Comment*
SubstStateList	A list of substrate states related by the same Substrate Object State Model state transition that triggered a collection event with which this variable was associated.	RO	Ordered list of SubstState	When a group of substrates have a related state model transition, only one collection event is triggered.
SubstType	Substrate subtype for the substrate associated with the last event.	RO	Enumerated: wafer, disc, flat panel, reticle	SEMI E5, Section 9.2 contains a dictionary of units.
SubstUsage	Description of the substrate associated with the last event.	RO	Enumerated: PRODUCT TEST FILLER CLEANING	Indicates how the substrate is used.

13 Requirements for Compliance

13.1 Table 11 provides a checklist for Substrate Tracking (STS) compliance.

Table 11 STS Compliance Statement

Fundamental STS Requirements	*STS Section*	*Implemented*	*STS Compliant*
Subtrate Tracking	8 (except 8.4)	☐ Yes ☐ No	☐ Yes ☐ No
Substrate Object and State Model	9	☐ Yes ☐ No	☐ Yes ☐ No
Substrate Location Object and State Model	10	☐ Yes ☐ No	☐ Yes ☐ No
Service Message Implementation	11	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data	12	☐ Yes ☐ No	☐ Yes ☐ No
Events	8.4	☐ Yes ☐ No	☐ Yes ☐ No
Additional STS Capabilities	*STS Section*	*Implemented*	*STS Compliant*
None			

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E90. This related information was approved for publication by full letter ballot procedures on January 14, 2000.

R1-1 Substrate State Model Implementation

R1-1.1 The Substrate Object State Model defined in Section 9.1 is a generic representation of the substrate object state model that includes standard transitions for various equipment types.

R1-1.2 Some equipment may not be able to implement all of the transitions defined in this model. For example, the transition from AT WORK to AT SOURCE (Transition Number 3) represents the case where the substrate returns to the original (source) location, typically for further processing. If the equipment is unable to implement this return, then the transition would never occur, and it should be omitted from the implemented state model.

R1-1.3 The state model shall be implemented based on the definition of the state model; however, substates and transitions that cannot occur for a particular equipment design may be omitted where the model allows.

R1-2 Example of Substrate Object State Model for Simple Equipment

R1-2.1 This section shows an example of Substrate Object State Model for simple equipment. (See Figure R1-1.)

R1-2.2 The equipment transports the substrate only in a forward direction, so that the Substrate Transport Substate takes straight forward transitions from AT SOURCE to AT WORK and then to AT DESTINATION. For example, the wirebonder removes leadframes from a magazine and carries them on a transport mechanism but is unable to return them to the magazine.

R1-2.3 Also, the equipment processes the substrate only in forward steps so that the Substrate Processing Substate takes straight forward transitions from NEED PROCESSING to IN PROCESS and then to PROCESSING COMPLETE. The REJECTED state is not applied to this equipment.

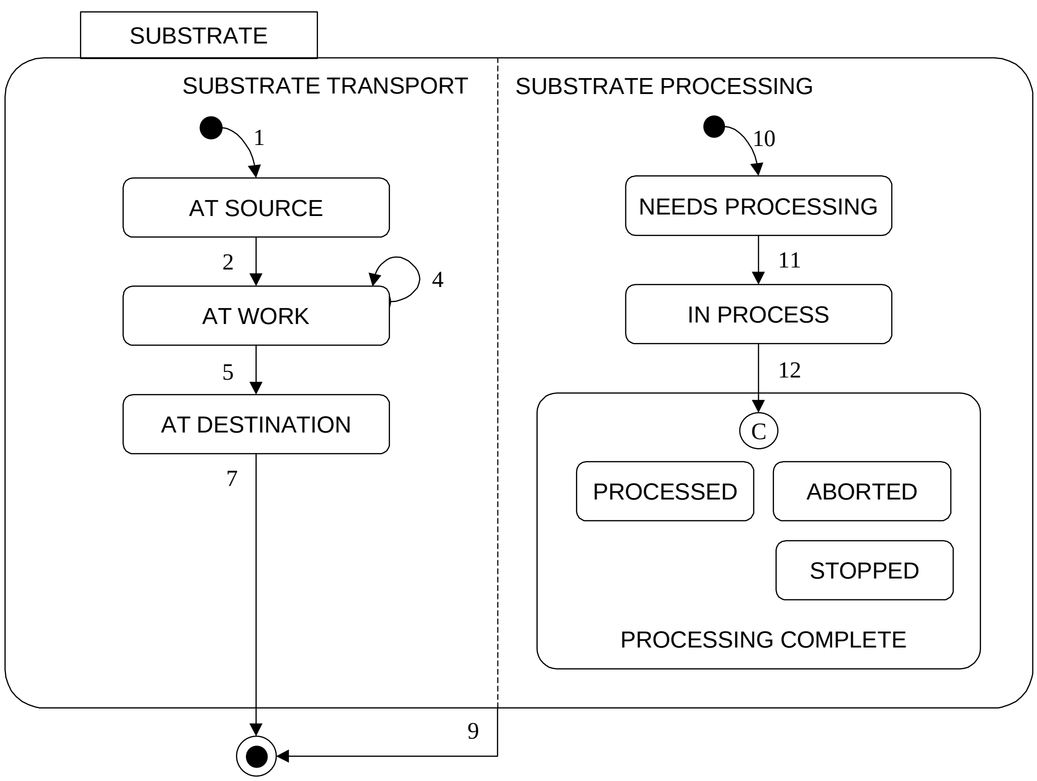


Figure R1-1
Substrate State Model for Simple Equipment

SEMI E90.1-0702
PROVISIONAL SPECIFICATION FOR SECS-II PROTOCOL SUBSTRATE TRACKING

This provisional specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published March 2001, previously published July 2001.

1 Purpose

1.1 This document maps the services and data of SEMI E90 to SECS-II streams and functions, and data definitions.

2 Scope

2.1 This is a specification covering equipment supporting automated substrate tracking.

2.2 This document applies to all implementations of SEMI E90 that use the SECS-II message protocol (SEMI E5). Compliance to this standard requires compliance to both SEMI E90 and SEMI E5.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.4 This standard is provisional. To have the provisional status removed, the following must be completed:

- Table 1, Services Message Mapping Table
- Table 3, Services Parameters to SECS-II Data Items Mapping

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E53 — Event Reporting

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Mapping

4.1 This section shows the specific SECS-II streams and functions that shall be used for SECS-II implementation of the services defined in SEMI E90, as well as the parameter mapping for data attached to services.

4.2 *Message Mapping*

4.2.1 *Services Message Mapping* — Table 1 defines the relationships between SEMI E90 services and SECS-II messages.

4.2.2 *Event Message Mapping* — Table 2 defines the relationships between SEMI E90 collection events and SECS-II messages.

Table 1 Services Message Mapping Table

Service Name	*Stream, Function*	*SECS-II Message Name*
change substrate state	(not yet defined)	(not yet defined)
register substrate	S14,F9/10	Create Object Request/Acknowledge (E39.1)
remove substrate	S14,F11/12	Delete Object Request/Acknowledge (E39.1)

Table 2 Event Message Mapping Table

Event Name	*Stream, Function*	*SECS-II Message Name*
All state model transitions	If SEMI E30 style events: S6F11/12 If SEMI E53 style events: S6F11/12 S6F13/14	If SEMI E30 style events: Event Report Send/Acknowledge If SEMI E53 style events: Event Report Send/Acknowledge Annotated Event Report Send/Ack

4.3 *Parameter Mapping* — Table 3 defines the relationships between SEMI E90 service parameters and SECS-II data definitions.

Table 3 Service Parameters to SECS-II Data Items Mapping

Parameter Name	*Range*	*SECS-II Data Item*
ErrorCode	Enumerated	ERRCODE
ErrorText	1 to 80 characters	ERRTEXT
STAcknowledge	0 if success; 1 if error (Conforms to ObjAck in SEMI E39.1)	OBJACK
Status	List of error information	L,n n=number of errors 1. L,2 1. <ErrorCode$_1$> 2. <ErrorText$_1$> . . n. L,2 1. <ErrorCode$_n$> 2. <ErrorText$_n$>
STStatus	STAcknowledge and Status	L,2 1. <STAcknowledge> 2. <Status>
SubstID	1–80 characters (Conforms to ObjID in SEMI E39.1)	OBJID
SubstIDList (ordered list of)	List of Substrate ID' s	L,n n=number of substrate identifiers 1. <SubstID$_1$> . . n. <SubstID$_n$>
SubstLocID	1–80 characters (Conforms to ObjID in SEMI E39.1)	OBJID
SubstLocIDList (ordered list of)	List of Substrate Location ID's corresponding to the SubstIDList (ordered list of).	L,n n=number of substrate identifiers in SubstIDList (ordered list of) 1. <SubstLocID$_1$> . . n. <SubstLocID $_n$>
SubstProcState	Enumerated per Variable SubstProcState.	U1
SubstProcStateList (ordered list of)	List of Substrate Processing States corresponding to the SubstIDList (ordered list of).	L,n n=number of substrate identifiers in SubstIDList (ordered list of) 1. <SubstProcState$_1$> . . n. <SubstProcState $_n$>
SubstState	Enumerated per Variable SubstState	U1
SubstStateList (ordered list of)	List of Substrate Transport States corresponding to the SubstIDList (ordered list of).	L,n n=number of substrate identifers in SubstIDList (ordered list of) 1. <SubstState$_1$> . . n. <SubstState $_n$>

4.4 *SECS-II Data Items without Corresponding SEMI E90 Parameters* — Table 4 contains the SECS-II data items that do not correspond to SEMI E90's service parameter.

Table 4 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
" TimeIn" from SubstHistory variable data definition	TIMESTAMP
" TimeOut" from SubstHistory variable data definition	TIMESTAMP

5 Variable Data Item Mapping

5.1 Table 5 shows the specific SECS-II data classes, and formats needed for SECS-II implementations of SEMI E90 variable data items.

Table 5 Variable Data Item Mapping

Variable Name	*Class*	*Format*
LotID	DVVAL	A[1..80]
SubstDestination	DVVAL	A[1..80] (Conforms to ObjID in SEMI E39.1)
SubstHistory	DVVAL	L,n n=number of substrate locations visited by the substrate 1. L,3 1. <SubstLocID$_1$> 2. <TimeIn$_1$> 3. <TimeOut$_1$> . . n. L,3 1. <SubstLocID$_n$> 2. <TimeIn$_n$> 3. <TimeOut$_n$>
SubstID	DVVAL	A[1..80] (Conforms to ObjID in SEMI E39.1)
SubstLocID	DVVAL	A[1..80] (Conforms to ObjID in SEMI E39.1)
SubstLocID$_i$	SV	A[1..80] (Conforms to ObjID in E39.1)
SubstLocState	DVVAL	51 (U1) Enumerated as: 0 – UNOCCUPIED 1 – OCCUPIED
SubstLocState$_i$	SV	51 (U1) Enumerated as: 0 – UNOCCUPIED 1 – OCCUPIED
SubstLocSubstrID$_i$	SV	A[1..80] (Conforms to ObjID in E39.1)
SubstMtrlStatus	DVVAL	U1 (equipment dependent enumeration)
SubstProcState	DVVAL	51 (U1) Enumerated as: 0 – NEEDS PROCESSING 1 – IN PROCESS 2 – PROCESSED 3 – ABORTED 4 – STOPPED 5 – REJECTED 6 – LOST
SubstSource	DVVAL	A[1..80] (Conforms to ObjID in SEMI E39.1)

Variable Name	*Class*	*Format*
SubstState	DVVAL	51 (U1) Enumerated as: 0 – AT SOURCE 1 – AT WORK 2 – AT DESTINATION
SubstType	DVVAL	51 (U1) Enumerated as: 0 – WAFER 1 – FLAT PANEL 2 – CD 3 – MASK
SubstUsage	DVVAL	51 (U1) Enumerated as: 0 – PRODUCT 1 – TEST 2 – FILLER 3 – CLEANING

6 SECS-II Attribute Definitions

6.1 *Substrate Object SECS-II Attributes Definitions* — The following are the SECS-II structure definitions for the E90 Substrate Object.

Table 6 Substrate Object SECS-II Attribute Definitions

Attribute Name	*Attribute Date Form: SECS-II Structure*
"ObjType"	"Substrate"
"ObjID"	<OBJID> SubstID (Conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.)
"LotID"	20 (A) LotID
"MaterialStatus"	51 (U1) MaterialStatus MaterialStatus is an equipment specific enumerated value
"SubstDestination"	<OBJID> SubstLocID
"SubstHistory"	L,n n=number of substrate locations visited by the substrate 1. L,3 1. <OBJID$_1$> SubstLocID$_1$ 2. <TIMESTAMP$_1$> TimeIn$_1$ 3. <TIMESTAMP$_1$> TimeOut$_1$ . . n. L,3 1. <OBJID$_n$> SubstLocID$_n$ 2. <TIMESTAMP$_n$> TimeIn$_n$ 3. <TIMESTAMP$_n$> TimeOut$_n$
"SubstLocID"	<OBJID> SubstLocID
"SubstProcState"	51 (U1) SubstProcState SubstProcState enumerated per Variable SubstProcState.
"SubstSource"	<OBJID> SubstLocID
"SubstState"	51 (U1) SubstState SubstState enumerated per Variable SubstState.
"SubstType"	51 (U1) SubstType SubstType enumerated per Variable SubstType.

Attribute Name	*Attribute Date Form: SECS-II Structure*
“SubstUsage”	51 (U1) SubstUsage SubstUsage enumerated per Variable SubstUsage.

6.2 *Substrate Location Object SECS-II Attributes Definitions* — The following are the SECS-II structure definitions for the E90 Substrate Location Object.

Table 7 Substrate Location Object Attribute Definitions

Attribute Name	*Attribute Data Form: SECS-II Structure*
“ObjType”	“SubstLoc”
“ObjID”	<OBJID> SubstLocID (Conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.)
“SubstID”	<OBJID> SubstID
“SubstLocState”	51 (U1) SubstLocState SubstLocState enumerated per Variable SubstLocState.

SEMI E91-0600
SPECIFICATION FOR PROBER SPECIFIC EQUIPMENT MODEL (PSEM)

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the Japanese Communications Committee. Current edition approved by the Japanese Regional Standards Committee on January 14, 2000. Initially available at www.semi.org March 2000; to be published June 2000. Originally published September 1999.

1 Purpose

1.1 This document establishes a Specific Equipment Model for prober equipment (PSEM). The PSEM consists of equipment characteristics and behaviors that apply to this class of equipment and are required to be implemented in addition to the fundamental requirements and additional capabilities specified in SEMI E30 (GEM). The intent of this document is to facilitate the integration of prober equipment into an automated semiconductor factory. This document accomplishes this by defining an operational model for prober equipment as viewed by a factory automation controller. This definition provides a standard host interface and equipment operational behavior.

2 Scope

2.1 The scope of this document is limited to the definition of prober equipment behavior as perceived by a Semiconductor Equipment Communications Standard (SECS-II) (SEMI E5) host that complies with GEM. The document defines the view of the equipment through the SECS communications link, but does not define the internal operation of the equipment. It includes a specific processing state model as the basis for the behavior of all equipment of this class.

2.2 This document requires that the GEM fundamental requirements and applicable additional capabilities have been implemented on the prober equipment. This document expands GEM Standard requirements and capabilities in the areas of the processing state model, collection events, remote commands, data item variables and process program management, and adds Prober Job state model to GEM Standard requirements and capabilities. This document does not include the definition of the treatment of Multiple Stage.

2.3 This document applies to the class of prober equipment in which the wafer is unloaded from the same slot in the same carrier which loaded the wafer after processing.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M21 — Specification for Assigning Addresses to Rectangular Elements in a Cartesian Array

3.2 *Other Documents*

Harel, D., "Statechart: A Visual Formalism for Complex Systems", Science of Computer Programming 8 (1987) 231-274.[1]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *alignment* — a procedure in which a coordinate system is established on a substrate.

4.2 *bin* — categorized data of die as a result of measurement.

4.3 *cassette* — a physical object containing one or more substrate locations (see slot). For example, a SEMI standard cassette is a carrier with 25 substrate slot locations.

4.4 *die* — 1. A field sub-unit. 2. An area of substrate that contains the device being manufactured.

4.5 *execution area* — the area from which a current copy of the process program instructions are executed.

4.6 *inker* — a resource of the prober. The electromechanical units to put ink mark on die.

4.7 *instruction data* — the Result Data to refer on the inspection process.

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

4.8 *job* — a lot, processed with a single process program on PSEM equipment.

4.9 *load* — move material to the probing or marking location from the cassette.

4.10 *lot* — a group of one or more substrates of the same type (e.g., wafers, masks, CDs).

4.11 *map* — a list of coordinate positions of die on a substrate. MAP is defined in accordance with SEMI M21 in this document.

4.12 *map data* — the categorized data of die as a result of measurement associated with coordinates. Map data also have an information that identifies origin die.

4.13 *marking* — the process of the prober that making an ink mark on a die using the inker.

4.14 *material* — 1. The basic unit of process, physically a cassette or some cassettes. 2. A lot.

4.15 *measurement* — making a test, contacting the probe card and the die. The tester sends to the prober a categorized data as a result of test.

4.16 *probe card* — the electromechanical interface necessary to enable temporary electrical contact between the substrate to be tested and the tester resource. May consist of multiple components.

4.17 *re-inspection* — a process where the same substrate is tested again by using the inspected map data.

4.18 *slot* — a physical location within a cassette capable of containing a substrate. (Also referred to as a carrier location).

4.19 *state* — 1. A static set of conditions. If the conditions are met, the state is current (SEMI E30). 2. A state reacts predictably to specific stimuli.

4.20 *substrate* — 1. The basic unit of material, processed by PSEM equipment such as wafers.

4.21 *testing equipment* — an equipment class generally consisting of integrated mechanisms and controls for performing electrical tests of packaged devices and or wafer die during the manufacturing process.

4.22 *unload* — remove materials to the cassette slots from the probing or marking location.

4.23 *wafer end* — the end of measuring process of a wafer.

5 State Model

5.1 The purpose is to define the equipment-specific processing state model and Prober Job state models necessary to portray the expected operational states of the equipment to enable host tracking and control in place of a local operator.

5.1.1 The processing state models in this document are required for implementing an PSEM-compliant prober, in addition to the required state models in SEMI E30. A state model consists of a state model diagram, state definitions, and a state transitions' table. A state model represents the host's view of the prober, but not necessarily the actual prober operations. All PSEM state model transitions shall be mapped sequentially into the actual equipment events that satisfy the requirements of those transitions. In certain implementations, the prober may enter a state and has already satisfied all of the conditions required by the PSEM state model for transition to another state. In this situation, the prober makes the required transition without any additional actions.

5.1.1.1 Various symbols used in a state diagram are described in Figure 1.

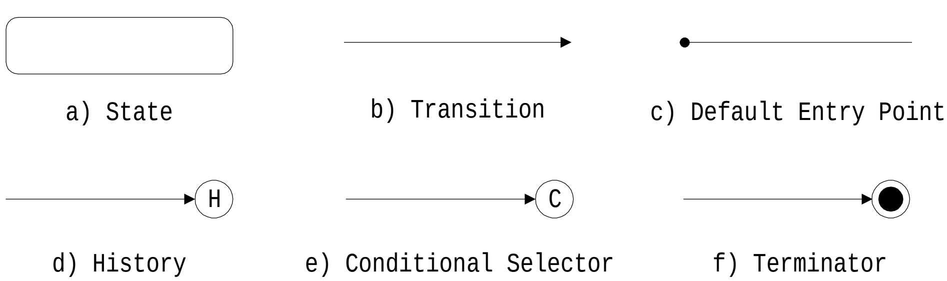


Figure 1
Various Symbols Used in a State Diagram

5.1.2 Some equipment may need to include additional states. However, any additional states must not change the PSEM-defined state transitions. All expected transitions between PSEM states must occur.

5.2 *PSEM Processing State Model*

5.2.1 *Purpose*

5.2.1.1 The purpose of the PSEM Processing State Model is to make an accurate model for the behavior of the PSEM prober from Processing State Model defined in SEMI E30.

5.2.2 *PSEM Processing State Model Diagram*

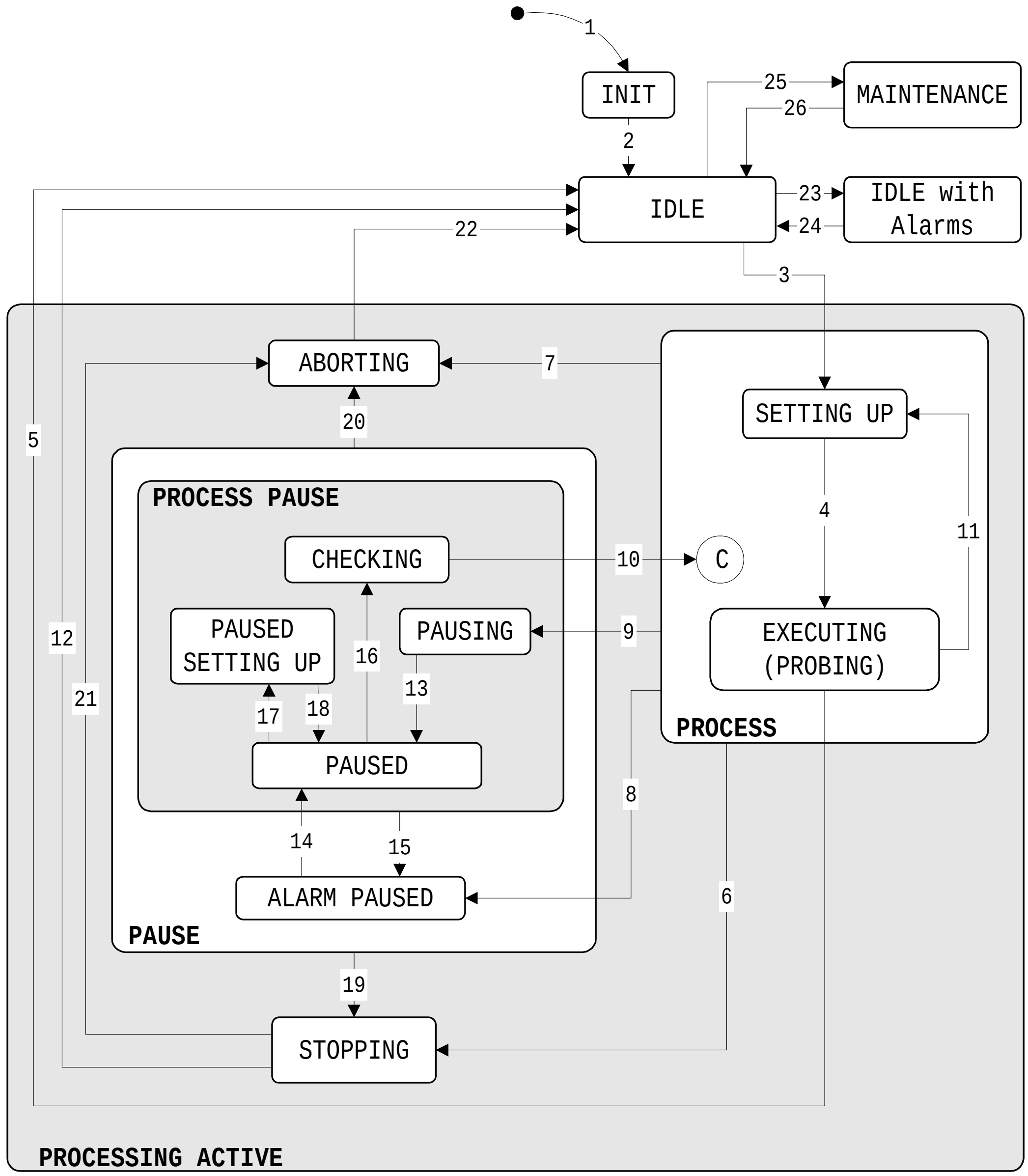


Figure 2
PSEM Processing State Model Diagram

5.2.3 *Description of Prober Processing States*

5.2.3.1 *ABORTING (PROCESSING ACTIVE Sub-state)* — The prober has received ABORT command. All activities are suspended. The prober is taking an appropriate action to ensure possible safe state for the prober itself and materials. Wafer data or lot data may be unavailable.

5.2.3.2 *ALARM PAUSED (PAUSE Sub-state)* — An alarm has occurred in PROCESS or PROCESS PAUSE state. The prober is waiting for the alarm to be cleared.

5.2.3.3 *CHECKING (PROCESS PAUSE Sub-state)* — The prober verifies that a process program update performed is valid. This is a procedure same with that taken in SETTING UP state before the prober is ready to transit to READY state. Upon completion of verification, an event will be created if the verification is successfully ended. A transition is made to the process state, based on the process model condition table.

5.2.3.4 *EXECUTING (PROCESS Sub-state)* — The prober is processing material automatically and can continue to do so without external intervention. This state may include interaction with the host or operator.

5.2.3.5 *IDLE* — The prober is waiting for an instruction. IDLE is free of ALARMS and error conditions.

5.2.3.6 *IDLE with ALARMS* — An alarm has occurred in the IDLE state and the prober is waiting for all alarms to be cleared.

5.2.3.7 *INIT* — Prober is in the course of initialization.

5.2.3.8 *MAINTENANCE*

5.2.3.8.1 The operator's instruction has disabled production by the prober.

5.2.3.8.2 Maintenance and inspection of the prober are executed in this state.

5.2.3.9 *PAUSE (PROCESSING ACTIVE Sub-state)* — PROCESS state is interrupted when the processing can be paused. An action to ensure safety of the prober is taken. The prober waits for a command (RESUME, STOP or ABORT) or the alarm to be cleared.

5.2.3.10 *PAUSED (PROCESS PAUSE Sub-state)* — In this state an operator can correct an error as far as the current process program selection is not affected. PROCESS state is suspended and the prober waits for a command (RESUME, STOP or ABORT). In this state, the operator is allowed to correct an error conditions that does not affect the current process program selected. One of such corrective actions that can be taken by the operator is manual alignment of the wafer in process.

5.2.3.11 *PAUSED SETTING UP (PROCESS PAUSE Sub-state)* — When PROCESS state is suspended, the prober is made to perform simple set-up operations. Probe card replacing work and inker replacing work are included in those operations.

5.2.3.12 *PAUSING (PROCESS PAUSE Sub-state)* — PROCESS state is interrupted when the processing can be paused. The prober cannot transit to PAUSED state until safe state is ensured.

5.2.3.13 *PROCESS (PROCESSING ACTIVE Sub-state)* — This state is the parent of those sub-states that refer to the preparation and execution of a process program.

5.2.3.14 *PROCESS PAUSE (PAUSE Sub-state)* — The prober is free of alarm conditions in the PAUSE state.

5.2.3.15 *PROCESSING ACTIVE* — The state in which the prober is processing materials.

5.2.3.16 *SETTING UP (PROCESS Sub-state)* — The prober is trying to satisfy requirements to be able to start processing. This is the state under which the prober has already received a process program and materials to be processed, then has received START command from the host or the operator and is making preparation for the processing according to the process program.

5.2.3.17 *STOPPING (PROCESSING ACTIVE Sub-state)* — The prober has received STOP command and sets up for the stop. All necessary cleanup is completed within this state with regard to material, data, control system, etc. Data is preserved. Any error condition is cleared before exiting from this state.

5.2.4 *PSEM Processing State Transition Table*

Table 1 Processing State Transition Table

No.	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Undefined	After turning the power on, the operator has commanded the prober to perform initialization.	INIT	The prober executes initialization.	None
2	INIT	Initialization of all probers completes without an alarm or error.	IDLE	The prober is waiting for a command by the host or the operator.	None
3	IDLE	Prober Job has been created, and the prober has already received a process program and materials, then has received START command from the host or the operator.	SETTING UP	The prober is set up according to the process program.	None
4	SETTING UP	All set-up performance has completed.	EXECUTING	The prober executes wafer transfer and measuring.	None
5	EXECUTING	Material processing completes.	IDLE	None	None
6	PROCESS	The prober received STOP command.	STOPPING	The prober completes the current wafer or the current die under EXECUTING state and unloads it in accordance with the setting of ECV "StopUnit".	The prober starts clearing data. Whether or not unloading is executed after the completion of the current wafer or the current die depends on the specification.
7	PROCESS	The prober received ABORT command from operator, host or self generated.	ABORTING	The prober is placed in a safe state.	Wafer data or lot data may be invalid or not available.
8	PROCESS	An alarm occurs.	ALARM PAUSED	PROCESS activity is suspended, the prober is waiting for all alarms to be cleared, STOP or ABORT command.	ALARM PAUSED is PAUSE sub-state.
9	PROCESS	The prober received PAUSE command from the host or the operator.	PAUSING	PROCESS state is suspended when the processing can be stopped. All operations required to put the prober in safe condition are performed.	PAUSING is PROCESS PAUSE sub-state.
10	CHECKING	Parameter checking ends normally.	Previous PROCESS state.	Processing re-starts from the previously suspended state.	None

No.	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
11	EXECUTING	Processing of the last wafer of a current lot completed. The prober has received START command for next lot.	SETTING UP	None	None
12	STOPPING	The prober completes clearing of data and no alarm remains.	IDLE	None	None
13	PAUSING	The prober stopped the processing of the current wafer which was in EXECUTING state at a possible stop breakpoint and attained a safe state.	PAUSED	The prober is waiting for command (RESUME, STOP or ABORT).	None
14	ALARM PAUSED	Alarm is cleared.	PAUSED	The prober is waiting for command (RESUME, STOP or ABORT).	None
15	PROCESS PAUSE	An alarm occurs in the prober.	ALARM PAUSED	The prober is waiting for all alarms to be cleared, STOP or ABORT command.	None
16	PAUSED	RESUME command was received.	CHECKING	Verification of process program parameters.	Before continuing processing, the host or operator is required to issue RESUME command.
17	PAUSED	The operator instructed a state transition.	PAUSED SETTING UP	Probe card replacement or inker replacement is carried out by operator's instruction.	None
18	PAUSED SETTING UP	The operator instructed a state transition.	PAUSED	None	None
19	PAUSE	The prober received STOP command.	STOPPING	The prober starts clearing data.	Data is saved and valid.
20	PAUSE	The prober received ABORT command.	ABORTING	If possible, unsafe condition is reset.	Wafer data or lot data may be invalid or not available.
21	STOPPING	The prober received ABORT command.	ABORTING	If possible, unsafe condition is reset.	Wafer data or lot data may be invalid or not available.
22	ABORTING	An abort performance has completed.	IDLE	None	Only a state transition to IDLE is permitted.
23	IDLE	An alarm occurs.	IDLE with ALARMS	The prober is waiting for all alarms to be cleared.	None
24	IDLE with ALARMS	All alarms were cleared.	IDLE	None	The IDLE state is free of alarms.
25	IDLE	The operator instructed a state transition.	MAINTEN-ANCE	None	Maintenance and inspection of the prober modules and creation, change and deletion of process programs are possible.
26	MAINTEN-ANCE	The operator instructed a state transition.	IDLE	None	None

5.2.5 *The Process Model Condition Table*

5.2.5.1 Undermentioned Table 2 is an explanation of the transition condition of transition No. 10 in PSEM Processing State Model diagram.

Table 2 The Process Model Condition Table

Conditions	*Next State*
The check approves that the process program is changed.	SETTING UP
The check approves that the process program is **not** changed.	
The previous state was SETTING UP.	SETTING UP
The previous state was EXECUTING.	EXECUTING

5.3 *Prober Job State Model*

5.3.1 *Purpose*

5.3.1.1 The Prober Job state model is defined for the purpose of keeping track of its processing state of the material to be processed by the prober in every material. The host can give instructions on how to process which material by creating Prober Job to the equipment. Prober Job is created by the JOB CREATE command. Prober Job state exists in each Prober Job. It occurs upon creation of Prober Job and is deleted upon its completion. The host can control progress of material processing which is requested to the equipment according to an event report accompanied by progress of Prober Job.

5.3.2 *Prober Job State Model Diagram*

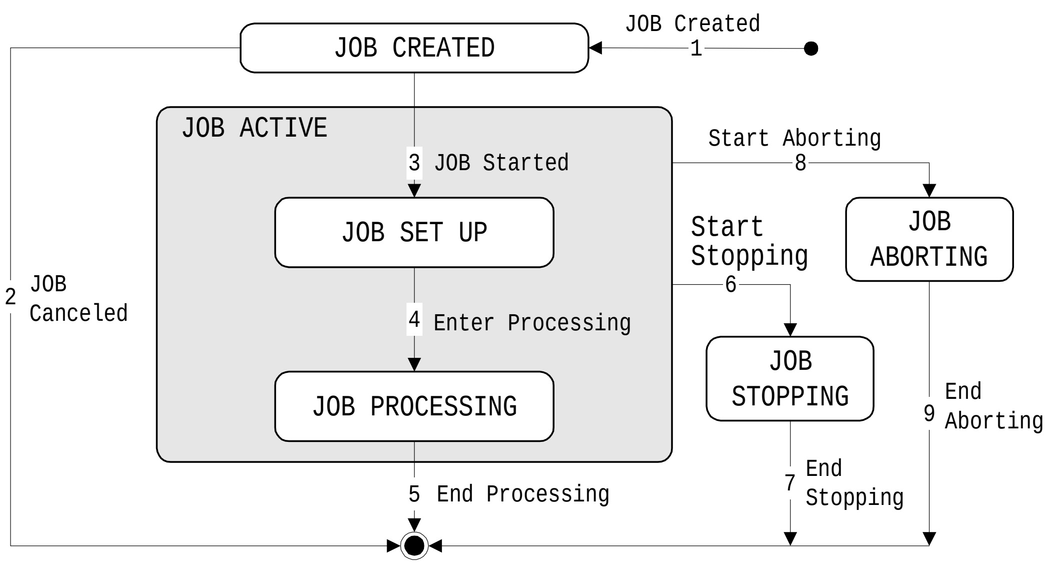


Figure 3
Prober Job State Model Diagram

5.3.3 *Description of Prober Job State*

5.3.3.1 *JOB CREATED* — State where Prober Job is created to the equipment Prober Job has not processed yet. It has nothing to do with whether material reached the equipment or not.

5.3.3.2 *JOB ACTIVE* — State where normal Prober Job processing operation is performed It consists of two sub-states.

5.3.3.3 *JOB SET UP (JOB ACTIVE Sub-state)* — State that waits for condition to be ready for processing such as Equipment preparation.

5.3.3.4 *JOB PROCESSING (JOB ACTIVE Sub-state)* — State where this processing is performed.

5.3.3.5 *JOB STOPPING* — State where attempts are made to stop Prober Job.

5.3.3.6 *JOB ABORTING* — State where attempts are made to abort Prober Job.

5.3.4 *Prober Job State Transition Table*

Table 3 Prober Job State Transition Table

No.	*Current State*	*Trigger*	*New State*	*Action*	*Comments*
1	Undefined	JOB_CREATE command was received from host or the Job Create operation was instructed by operator when Processing State is neither INIT nor MAINTENANCE state.	JOB CREATED	Create Prober Job.	None.
2	JOB CREATED	JOB_CANCEL command from host or operator.	Undefined	Cancel Prober Job.	None.
3	JOB CREATED	START command from host or the Start operation was instructed by operator.	JOB SET UP	Prepare for processing of Prober Job and wait for processing to be possible.	None.
4	JOB SET UP	Prober Job processing conditions were established.	JOB PROCESSING	Start processing of the main unit.	None.
5	JOB PROCESSING	Processing of Prober Job was normally completed.	Undefined	Delete Prober Job.	None.
6	JOB ACTIVE	STOP command was received from host or the stop operation was instructed by operator.	JOB STOPPING	Start stop processing.	A trigger may be caused by error detection of the equipment itself as well as by instruction from outside.
7	JOB STOPPING	The stop operation was completed.	Undefined	Delete Prober Job.	None.
8	JOB ACTIVE	ABORT command was received from host of the Abort operation was instructed by operator.	JOB ABORTING	Start abort processing.	A trigger may be caused by error detection of the equipment itself as well as by instruction from outside.
9	JOB ABORTING	Abort processing was completed.	Undefined	Delete Prober Job.	None.

6 Collection Event List

6.1 *Requirements*

6.1.1 All GEM-required Events are required by the PSEM. Since Processing State Model is required by the PSEM, all state transitions are required Events.

6.1.2 All GEM-required Events associated with the GEM Control, Communications, Alarm, and Spooling State Models are required. This section of the PSEM lists only those collection events that are not associated with a change of state or those requiring specific data variables (DVVALs) or Reports defined in the PSEM.

6.2 *Collection Event Tables*

6.2.1 Table 4 shows events and reports required for the PSEM process state transition. Table 5 shows events and reports required for the Prober Job state transition. Table 6 shows other collection events.

Table 4 Collection Events Required by Process State Transition

Transition	*Transition No.*	*Current State*	*New State*	*Typical Variable Data*
Start INIT	1	Undefined	INIT	Previous Process State
Into IDLE	2	INIT	IDLE	
	5	EXECUTING		
	12	STOPPING		
	22	ABORTING		
	24	IDLE with ALARMS		
	26	MAINTENANCE		
Into IDLE with ALARMS	23	IDLE	IDLE with ALARMS	
Into MAINTENANCE	25	IDLE	MAINTENANCE	
Start SETTING UP	3	IDLE	SETTING UP	
	11	EXECUTING		
	10	CHECKING		
Start EXECUTING	4	SETTING UP	EXECUTING	
	10	CHECKING		
Start PAUSING	9	SETTING UP	PAUSING	
	9	EXECUTING		
Into PAUSED	13	PAUSING	PAUSED	
	18	PAUSED SETTING UP		
	14	ALARM PAUSED		
Start CHECKING	16	PAUSED	CHECKING	
Into PAUSED SETTING UP	17	PAUSED	PAUSED SETTING UP	
Into ALARM PAUSED	8	SETTING UP	ALARM PAUSED	
	8	EXECUTING		
	15	CHECKING		
	15	PAUSING		
	15	PAUSED SETTING UP		
	15	PAUSED		
Start STOPPING	6	SETTING UP	STOPPING	
	6	EXECUTING		
	19	CHECKING		
	19	PAUSING		
	19	PAUSED SETTING UP		
	19	PAUSED		
	19	ALARM PAUSED		
Start ABORTING	7	SETTING UP	ABORTING	
	7	EXECUTING		
	20	CHECKING		
	20	PAUSING		
	20	PAUSED SETTING UP		
	20	PAUSED		
	20	ALARM PAUSED		
	21	STOPPING		

Table 5 Collection Events Required by Prober Job State Transition

Transition	*Current State*	*New State*	*Typical Variable Data*
JOB Created	Undefined	JOB CREATED	EventJobID
JOB Canceled	JOB CREATED	Undefined	
JOB Started	JOB CREATED	JOB SET UP	
Enter Processing	JOB SET UP	JOB PROCESSING	
End Processing	JOB PROCESSING	Undefined	
Start Aborting	JOB SET UP, JOB PROCESSING	JOB ABORTING	
End Aborting	JOB ABORTING	Undefined	
Start Stopping	JOB SET UP, JOB PROCESSING	JOB STOPPING	
End Stopping	JOB STOPPING	Undefined	

Table 6 Other Collection Events

Event Name	*Contents*	*Typical Variable Data*
Wafer Start	Wafer processing was started.	WaferStartJobID, WaferStartWaferID
Wafer End	Wafer processing was completed.	WaferEndJobID, WaferEndWaferID
Ready to Receive Previous Data	Waits for reception of instructed data for wafer.	WaitPreDataJobID, WaitPreDataWaferID

7 Data Item Variables

7.1 The purpose of this section is to define the list of data item variables required by the PSEM. Values of these variables will be available to the host through collection event reports and host status queries.

7.2 *Requirements*

7.2.1 All generic variable data items defined in GEM are required by all PSEM equipment. Any supplier-defined variables shall be documented in the same format used by this document. The following minimum information is required:

<variable name> Class: <ECV, SV, or DVVAL>

Format: <SML>

Description: <if class=DVVAL, description must contain statement of when data is valid>.

<If format = ASCII then a length is required. It is assumed to be left-justified unless otherwise noted. >

7.3 *Data Types*

7.3.1 Equipment Constants (ECVs) can be changed by the host using S2F15. The operator may be able to change some values, but the equipment does not change the values on its own. The value of an equipment constant may be queried by the host at any time, using the S2F13/14 transaction. They reside in non-volatile memory of the equipment. Equipment constants remain in effect until they are overwritten either by manual entry or by a NEW EQUIPMENT CONSTANT SEND. Equipment constants have various uses in PSEM, including the following:

- Equipment offsets that match the performance of several pieces of equipment that would otherwise perform differently due to inherent manufacturing differences. Examples are home values and motion axis scaling factors.
- Setting the configuration of the equipment to allow for different material specifications, equipment options, material flows, frequency of automatic functions, etc. Examples are yield check frequency.
- Managing optional machine features. Examples are constants that tell the system whether optional features such as automated media stackers are present and control the configuration and function of these optional subsystems when they are present.

7.3.2 Status Variables (SVs) are valid at all times. A SV may not be changed by the host but may be changed by the equipment or operator. The value of status variables may be queried by the host at anytime using the S1,F3/4 or S6,F19/20 transactions. DVVALs are variables that are valid only upon the occurrence of specific collection events. An attempt to read a data variable at the wrong time will not generate an error, but the data reported may not have relevant meaning.

7.4 *Data Item Variable Table*

Table 7 Data Item Variable Table

Variable Name	*Description*	*Class*	*Format*	*Comments*
StopUnit	Constant which specifies separation of stop operation in probing.	ECV	U1	0=Unit of Die 1=Unit of Wafer 2=Unit of Cassette 3=Unit of Lot
EventJobID	Prober Job ID which occurs Prober Job state transition.	DVVAL	A[30]	Valid when Prober Job state transition occurs.
EventJobState	Current state of Prober Job whose state changed.	DVVAL	U2	Valid in event of Prober Job state transition.
ResultData	Processing result in unit of one wafer.	DVVAL	L[n]	Valid only in wafer end event.

8 Process Program Management

8.1 PSEM explains how to specify a process program for the prober and the process program control between the host and prober.

8.2 *Process Program Requirements*

8.2.1 The PSEM requires that the GEM capability of process program management be fully supported for this class of prober.

8.3 *Process Program*

8.3.1 The process program of the prober consists of the main process program and two or more sub process programs that are referred to by the main process program.

Table 8 Kinds and Descriptions of Process Programs

Kind	*Description*
Product type master record	Master process program for processing.
Sub-parameter record	Sub-process program for processing. Various kinds of parameter records that consist main process program for processing.

8.3.2 These process programs are controlled by the prober with grouped into different categories according to application purposes and structures. The prober defines PPID with "structure class name/class name/process program record name." The number of PPID digits is defined by an equipment supplier. If the number of the digits is less than a default value, left-justify and fill in space after PPID. Do not use space at some midpoint in PPID. At present, the prober practically uses the structure class name and class name as shown in the table given below.

Table 9 How to Operate Class Name and Structural Class Name

Classification	*Operation*	*Remarks*
Structural class name	Class name indicating major classification of process program record.	Defined by supplier.
Class name	Class name indicating attribute of process program record.	Defined by supplier.

8.4 *Master Process Program Record*

8.4.1 The master process program record is a plain text (ASCII) record like below:

DEVICE:xxxxxxxx

WAFER_SIZE:xx

DIE_SIZE:xxxxxx,xxxxxx

....

PARAM_RECORD00:structure class name/class name/process program record name

....

PARAM_RECORDnn:structure class name/class name/process program record name

8.4.1.1 Each line has a structure:

TAG + ":" + parameter(s) + line terminator

8.4.1.2 The line terminator is some of CR+LF (0x0d0a), CR (0x0d), LF (0x0a).

8.4.1.3 Specific parameters of equipment supplier may be put between "HOT_CHUCK_TOLE" and "PARAM_FILE00".

Table 10 Tag Parameters in Master Process Program

Tag	*Description*	*Format*	*Unit*
PRODID	Product name (i.e., Device type)	A[1,24]	-
WAFER_SIZE	Wafer size	A[1,3]	mm
DIE_SIZE_X	Die size X	A[1,6]	micron
DIE_SIZE_Y	Die size Y	A[1,6]	micron
MULTI_DIE	Multi probing number	A[1,3]	-
REFERENCE_DIE_COORD_X	Reference die coordinator X	A[1,4]	-
REFERENCE_DIE_COORD_Y	Reference die coordinator Y	A[1,4]	-
OVER_DRIVE	Over drive value	A[1,4]	micron
FLAT_ANGLE	Flat orientation	A[1,3]	degree
FLAT_TYPE	FLAT or NOTCH	A[1,5]	-
HOT_CHUCK	Flag of hot chuck usage	A[2,3] “ON” or “OFF”	-
HOT_CHUCK_TEMP	Hot chuck temperature	A[1,4]	Celsius
HOT_CHUCK_TOLE	Hot chuck tolerance	A[1,3]	Celsius
PARAM_RECORDnn	Sub-parameter record nn	A[ ]	-

9 Map Data

9.1 This section defines handling of map data in the PSEM equipment. The contents of map data are not defined here. The specification in this section is provisional. This will be revised in the near future.

9.2 *Use of Map Data*

9.2.1 Map data is divided into two groups: result data which is reported to the host when processing of each wafer is completed and instruction data which is instructed by the host in a unit of wafer at the time of re-inspection or marking.

9.3 *Structure of Map Data*

9.3.1 The map data has a list structure and the result data is defined by class <DVVAL> and the instruction data is defined by <CEPVAL>.

9.3.1.1 Example:

<ResultData>

L,n

1. <Data$_1$>

```
:
n. <Datan>
```

9.4 *Uploading (Reporting) Result Data*

9.4.1 Result Data is reported by S6,F11 upon completion of the inspection in each wafer.

9.4.1.1 Example:

```
L,3
  1. <DATAID>
  2. <CEID>:Wafer End
  3. L,a
       1. L,2
            1. <RPTID1>
            2. L,7
                 1. <LOTID>
                 2. <PROCID>
                 3. <IDTYP>
                 4. <MID>
                 5. <ROWCOLCT>
                 6. <REFDIEPOS>
                 7. <ResultData>
       :
       a. L,2
            1. <RPTIDa>
            2. L,b
                 1. <LOC>
                 2. <PRODID>
                 3. <WAFSIZE>
                 4. <FLATTYPE>
                 5. <FLATANGL>
                 6. <REFDIECOORD>
                 7. <BINLIST>
                 :
                 b. <Vb>
```

9.5 *Downloading Instruction Data*

9.5.1 If the past inspection result is required in processing a wafer, the equipment obtains instructed data from the host in the following procedure.

Comment	*Host*		*Equipment*	*Comment*
				Transfer a wafer. The equipment is ready to receive previous result data for a wafer concerned.
		←	S6,F11	“Waiting Previous Data (wait for reception of previous result data)” event report.
Check event.	S6,F12	→		
Instruction data download (PRE-DATA_DOWNLOAD)	S2,F49	→		
		←	S2,F50	Reception response. The processing is performed based on instruction data.

9.5.2 An example of Waiting Previous Data event report S6,F11 in the procedure above is shown below:

9.5.2.1 Example:

S6,F11
    L,3
        1. <DATAID>
        2. <CEID> :Waiting Previous Data
        3. L,2
            1. <RPTID1>
            2. L,4
                1. <LOTID> :Prober Job ID
                2. <PROCID>
                3. <MID>
                4. <IDTYP>

9.5.3 An example of remote command S2,F49 used in the procedure above is shown below.

9.5.3.1 Example:

S2,F49
    L,4
        1. <DATAID>
        2. <OBJSPEC> :a null length item.
        3. < RCMD> :“PRE-DATA_DOWNLOAD”
        2. L,n
            1. L,2
                1. <CPNAME$_1$>
                2. <CEPVAL$_1$>
            :
            n. L,2
                1. <CPNAME$_n$> :PreviousResultData
                2. L,b
                    1. <CPVAL$_{n1}$>
                    :
                    b. <CPVAL$_{nb}$>

9.6 *Map Data Item Variable Table*

Table 11 Map Data Item Variable Table

Variable Name	*Description*	*Format*	*Comments*
LOTID	Lot ID (Prober Job ID)	A[30]	
PROCID	Process ID	A[20]	
LOC	Cassette location	U1	
PRODID	Product name (i.e., Device type)	A[24]	
SLOTNO	Slot position in the cassette	A[2]	MID
WAFERNO	Wafer number	A[2]	MID
WAFERID	Wafer ID	A[32]	MID
IDTYP	ID type to recognize a wafer.	A[8]	“SLOTNO” or “WAFERNO” or “WAFERID”
WAFSIZE	Wafer size	A[3]	Unit is mm
FLAT	Flat or Notch	A[5]	“FLAT” or “NOTCH”
FLATANGLE	Flat angle	A[3]	Range from “000” to “359”. Unit is degree.
ROW	Row count	U2	
COLUMN	Column count	U2	

DIESIZE_X	Die Size X	A[1,6]	Unit is micron
DIESIZE_Y	Die Size X	A[1,6]	Unit is micron
REFDIECOORD_X	X coordinator of reference die	A[1,4]	
REFDIECOORD_Y	Y coordinator of reference die	A[1,4]	
REFDIEPOS_X	X address of reference die from wafer center	I4	Unit is micron
REFDIEPOS_Y	Y address of reference die from wafer center	I4	Unit is micron
BINLIST	Bin value array containing pass/fail information.	B[n]	
ResultData	Result data	B[m]	

NOTE 1: One of these three OPT items needs to be specified.

9.6.1 The data structure of ResultData is selectable with soft-switch as below:

(i) X,Y,BIN,...,X,Y,BIN

(ii) X,Y,N,BIN,BIN,...,BIN

(iii) BIN,BIN,...,BIN

9.6.2 The BIN data is a binary array and defined by an equipment supplier. For example, BIN data may include an attribute of die (skip, on-wafer, etc.), pass or fail information and bin code.

9.7 *Data Item Variable Table*

Table12 Data Item Variable Table

Variable Name	*Description*	*Class*	*Format*	*Comments*
BinType	Constant which specifies the kind of the data structure of ResultData.	ECV	U1	0= X, Y, BIN, ..., X, Y, BIN 1= X, Y, N, BIN, BIN, ..., BIN 2= BIN, BIN, ..., BIN

10 Remote Commands

10.1 The purpose of this section is to identify remote commands, command parameters, and valid commands versus states in the processing state models. The specification in this section is provisional. This will be revised in the near future.

10.2 *Requirements*

10.2.1 The prober must support the GEM-required remote commands. (Some of the GEM required remote commands are restated here to define PSEM specific requirements.)

10.2.2 All the remote commands defined by PSEM are required.

10.2.3 The alphanumeric strings defined by PSEM for remote commands (RMCD) and command parameter (CPNAME) are required.

10.2.4 If additional remote commands are supported, then the “Remote Command Versus Valid States” matrix must be generated for these additional commands. Place an “X” in the table for each state in which a given command is valid.

10.3 *Remote Commands Descriptions*

10.3.1 *ABORT* — This command terminates the current processing. ABORT makes no guarantee about completion of the current process.

10.3.2 *JOB_CANCEL* — Instruct to delete Prober Job before starting processing.

10.3.3 *JOB_CREATE* — Instruct to create Prober Job in batch processing unit (usually, unit of one cassette). This allows management data for batch processing unit to be instructed to the prober.

10.3.4 *PRE-DATA_DOWNLOAD* — Downloads previous result data which instructs the details of processing for a wafer.

10.3.5 *ONLINE-LOCAL* — Change the control state from On-Line Remote to On-Line Local.

10.3.6 *ONLINE-REMOTE* — Change the control state from On-Line Local to On-Line Remote.

10.3.7 *PAUSE* — Instructs the equipment to pause the processing. This command puts the prober into PAUSING state when the current operation is completed.

10.3.8 *PP-SELECT* — This command instructs the prober to copy the indicated Process Program from non-volatile storage to the prober's Process Program execution area.

10.3.9 *RESUME* — Instructs the equipment in pause to resume operation. This command makes the equipment resume the processing from a point where the processing PAUSED.

10.3.10 *START* — Instructs to start Prober Job.

10.3.11 *STOP* — Instructs the equipment to stop the processing. This command completes the current processing unit, stops the equipment in safe state, and puts the equipment back to IDLE state. STOP has an intention of causing a normal completion after the current unit is completed. Also, whether the processing unit is die or wafer can be specified by the equipment constant Stop Unit.

10.4 *Parameter Related to Remote Command*

Table 13 Description of Remote Command

Command Name	*Command Parameter*			
	Name	*OPT/REQ*	*Description*	*Format*
ABORT			No parameter.	
JOB_CANCEL	ProberJobID	REQ.	ID of deleted Prober Job	A[30]
JOB_CREATE	ProberJobID	REQ.	ID of created Prober Job (Used as lot ID.)	A[30]
	LOC	REQ.	Location number of the cassette in which processed wafers are placed.	B
	PRODID	OPT	Product name i.e., Device type	A[24]
	PPID	OPT	Product type master record name. Unless otherwise specified, use the current PPID.	A[]
	NO-OF-WAFER	OPT	Number of wafers held in the cassette (regardless of whether the wafers are subject to processing or not).	A[20]
	SLOT-ORD	OPT	Specify the wafer pick-up order from the cassette.	BOOL
	SLOT-INFO	OPT	Set a wafer ID and whether a wafer is subject to processing or not. Example: L[25,26] 1. L[2] 1. A[1,28] ; wafer ID 2. B ; whether a wafer is subject to processing or not. : n. L[2] 1. A[1,28] ; wafer ID 2. B ; whether a wafer is subject to processing or not. (Notes) n = 25 or 26	L[25,26]

Command Name	Command Parameter			
	Name	*OPT/REQ*	*Description*	*Format*
PRE-DATA_DOWNLOAD	ProberJobID	REQ.	Prober Job ID	A[30]
	PROCID	REQ.	Process ID	A[20]
	LOC	OPT	Port number of the cassette in which wafers to be processed are placed.	B
	PRODID	OPT	Product name (i.e., Device type)	A[24]
	SLOTNO	OPT (See NOTE 1.)	Slot number in which the wafer is held.	A[2]
	WAFERNO	OPT (See NOTE 1.)	Wafer number set by the host or operator.	A[2]
	WAFERID	OPT (See NOTE 1.)	Wafer ID read by OCR.	A[28]
	IDTYP	REQ.	ID type to recognize a wafer.	A[8]
	WAFSIZE	OPT	Wafer size	A[3]
	FLAT	OPT	Flat or Notch	A[5]
	FLATANGLE	OPT	Flat angle	A[3]
	ROW	REQ.	Row count	U2
	COLUMN	REQ.	Column count	U2
	DIESIZE_X	OPT	X die size	A[6]
	DIESIZE_Y	OPT	Y die size	A[6]
	REFDIECOORD_X	REQ.	X coordinator of reference die	A[4]
	REFDIECOORD_Y	REQ.	Y coordinator of reference die	A[4]
	REFDIEPOS_X	REQ.	X address of reference die from wafer center	I4
	REFDIEPOS_Y	REQ.	Y address of reference die from wafer center	I4
	BINLIST	OPT	Bin value array containing pass/fail information.	B[n]
	PreviousResultData	REQ.	Previous result data information	L[n]
ONLINE-LOCAL			No parameter	
ONLINE-REMOTE			No parameter	
PAUSE			No parameter	
PP-SELECT	PPID	REQ.	Product type master record name.	A[]
RESUME	Resume-Die	OPT	Specify which die to restart the processing (e.g., last die, current die, next die).	B
START	ProberJobID	REQ.	ID of Prober Job to be started.	A[30]
STOP			No parameter	

NOTE 1: At least one of <SLOTNO>, <WAFERNO>, and <WAFERID> need to be set.

10.5 *Remote Commands and PSEM Process Model Mapping*

10.5.1 Each remote command either can or cannot be executed depending on a state other than the control state.

10.5.2 The following table shows remote commands and the relationship between process state to be operated by these commands and Prober Job state.

Table 14 Remote Command vs. Process State/Prober Job State

	Command Name										
	STOP	START	RESUME	PP-SELECT	PAUSE	ONLINE-REMOTE	ONLINE-LOCAL	PRE-DATA_DOWNLOAD (See NOTE 3.)	JOB_CREATE	JOB_CANCEL	ABORT
PROCESSING STATE											
INIT											
IDLE				X (See NOTE 1.)		X (See NOTE 2.)	X (See NOTE 2.)				
IDLE with ALARMS											
MAINTENANCE											
PROCESSING ACTIVE											
...PROCESS											
......SETTING UP	X				X						X
......EXECUTING	X				X						X
...PAUSE											
......PROCESS PAUSE											
.........PAUSING	X										X
.........PAUSED	X		X								X
.........CHECKING	X										X
.........PAUSED SETTING UP	X										X
......ALARM PAUSED	X										X
...STOPPING											X
...ABORTING											
Prober Job STATE											
Undefined				X (See NOTE 1.)		X (See NOTE 2.)	X (See NOTE 2.)		X		
JOB CREATED		X								X	
JOB ACTIVE											
...JOB SET UP								X (See NOTE 3.)			
...JOB PROCESSING								X (See NOTE 3.)			(X)
JOB STOPPING											
JOB ABORTING											

NOTE 1: Both IDLE and Undefined need hold true for PP-SELECT.

NOTE 2: Both IDLE and Undefined need hold true for ONLINE-REMOTE and ONLINE-LOCAL.

NOTE 3: PRE-DATA_DOWNLOAD is valid when Ready to Receive Previous Data event is reported.

10.6 *Restriction on the Operator by Control States*

10.6.1 For the remote commands, the operator of the prober or the host is restricted by the control states of the equipment.

Table 15 Table of Restrictions on the Operator by Control States

Remote Commands	*Operator*		*Host*	
	LOCAL	*REMOTE*	*LOCAL*	*REMOTE*
JOB_CREATE	O	X	O	O
PP-SELECT	O	X	O	O
PRE-DATA _DOWNLOAD	X	X	O	O
JOB_CANCEL	O	X	O	O
START	O	X	X	O
PAUSE	O	O	X	O
RESUME	O	O	X	O
STOP	O	O	X	O
ABORT	O	O	X	O
ONLINE-LOCAL	X	O	X	O
ONLINE-REMOTE	O	X	O	X

O: Operation is allowed.
X: Operation is prohibited.

11 Scenario

11.1 The purpose of this section is to document a typical PSEM specified operation scenario.

11.2 *From Power-On to Online Remote*

11.2.1 A typical scenario of transition from equipment power-on to online remote is shown below.

Comment	*Host*		*Equipment*	*Comment*
				(Equipment power-on)
				(Equipment initialization operation)
		←	S1,F13	Communication establishment request
Communication establishment request confirmation	S1,F14	→		
				(Press the online transition switch.)
		←	S1,F1	Are You There Request
Online data	S1,F2	→		
				(Online transition is completed.)
		←	S6,F11	Send ONLINE-REMOTE transition event report
Confirm event report	S6,F12	→		
		←	S6,F11	Send IDLE transition event report
Confirm event report S6,F12	S6,F12	→		

11.3 *1 Lot Processing in Online Remote*

11.3.1 A typical scenario from 1 lot processing instruction to processing completion in online remote is shown below.

Comment	*Host*		*Equipment*	*Comment*
				ONLINE-REMOTE IDLE
Send JOB_CREATE command	S2,F49	→		
		←	S2,F50	Confirm host command
		←	S6,F11	Send Prober Job Created event report
Confirm event report	S6,F12	→		
				(Carry in cassette)
		←	S6,F11	Send material carry-in event report
Confirm event report	S6,F12	→		
Send START command	S2,F49	→		
		←	S2,F50	Confirm host command
		←	S6,F11	Send Prober Job Started event report
Confirm event report	S6,F12	→		
		←	S6,F11	Send SETTING UP transition event report
Confirm event report	S6,F12	→		
				(Equipment setup is started.)
				(Equipment setup is completed.)
		←	S6,F11	Send Enter Processing event report
Confirm event report	S6,F12	→		
		←	S6,F11	Send EXECUTING transition event report
Confirm event report	S6,F12	→		
				[DO] "wafer count times"
				(Wafer load is completed.)
				[IF]
				Is Instruction data required?
				[THEN]
		←	S6,F11	Send Waiting Previous Data event report
Confirm event report	S6,F12	→		
Send PRE-DATA_DOWNLOAD command	S2,F49	→		
		←	S2,F50	Confirm host command
				[END_IF]
				(Wafer processing is started.)
				(Wafer processing is completed.)
		←	S6,F11	Send wafer end event report (Result Data)
Confirm event report	S6,F12	→		
				(Wafer unload is completed.)
				[END_DO]
		←	S6,F11	Send End Processing event report
Confirm event report	S6,F12	→		
		←	S6,F11	Send IDLE transition event report
Confirm event report	S6,F12	→		
				(Carry out cassette)
		←	S6,F11	Send material carry-out event report
Confirm event report	S6,F12	→		

NOTE 1: Each event report send order in Prober Job Started and SETTING UP transition, Enter Processing and EXECUTING transition, and End Processing and IDLE transition may be inverted.

12 GEM Addition Request

12.1 The purpose of this section is to specify all GEM addition requests which are required to support the equipment of this class.

12.2 *Requirements*

12.2.1 GEM addition requests required of PSEM are as shown below:

- Establish Communications,
- Dynamic Event Report Configuration,
- Variable Data Collection,
- Status Data Collection,
- Alarm Management,
- Remote Control,
- Equipment Constants,
- Process Program Management,
- Equipment Terminal Services,
- Clock,
- Spooling, and
- Control (host-initiated).

SEMI E93-0200
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK ADVANCED PROCESS CONTROL COMPONENT

This provisional specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on October 21, 1999. Initially available at www.semi.org January 2000; to be published February 2000. Originally published September 1999.

1 Purpose

1.1 The Advanced Process Control (APC) component supports the Process Machine component's execution of process machine jobs by optimizing machine-specific settings for the current material and machine state to achieve desired process effects. It may also detect faults in processing and recommend an appropriate response to the Process Machine component. An APC component may include statistical process control, model-based process control, multi-variate analysis, trace analysis, fault pattern matching, or other analysis techniques.

1.2 The Advanced Process Control component specification does not constrain implementation approaches. However, subcomponents are defined to enable integration with different types of analysis and computation mechanisms, specifically those provided in other software systems. The subcomponents are defined principally along boundaries expected to align with products addressing process control in the factory. The number of subcomponents offered by suppliers may vary, with some suppliers supporting all of the subcomponent interfaces and others focusing on a specific subset of subcomponents. These subcomponent boundaries provide the customer with added flexibility to integrate and use multiple suppliers' products.

1.3 This specification provides the interfaces required by Manufacturing Execution Systems to:

- Define control data structures to support control algorithms.
- Launch, coordinate, and monitor the execution of control processing and analysis algorithms.

2 Scope

2.1 The technical content of this ballot addresses the portion of the CIM Framework domain concerned with Advanced Process Control (APC). Compliant implementations are free to use other components defined in the CIM Framework via their standard interfaces. They are also free to use components that are not defined by the CIM Framework standards as long as they don't conflict with the standard. The specific details of these interactions are implementation level choices. The key elements of the APC Component shown here are:

2.1.1 *APC Control Execution Component* — The component that executes control strategies.

2.1.2 *Algorithm Execution Interface Group* — The group of interfaces that abstracts external computation facilities which perform processing or calculations. The execution model abstracts an Algorithm, representing a computation, and an Algorithm Executor, responsible for performing the computation.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The CIM Framework Advanced Process Control Component is at the supervisory level, meaning this is a MES specification, not a specification for tool-level, real-time control. For example, the proposed interfaces support a control granularity no finer than wafer-to-wafer adjustments. The interfaces support APC applications such as fault detection and classification, run-to-run feedback, and feed-forward control spanning one or more process tools. The interfaces are very high-level such that a factory CIM system can communicate with a tool or set of tools providing process control while remaining unaware of the details of how that control is carried out.

3.2 *Provisional Status*

3.2.1 This specification is designated as provisional due to known areas that need to be completed. The following items summarize the deficiencies of the provisional specification to be addressed before a subsequent ballot to upgrade it to full standard status.

3.2.2 *Dependence on Global Declarations and Abstract Interfaces* — Components of this document depend on global declarations and on abstract interfaces for material, resource, and job concepts. Work is currently underway to standardize these declarations and interfaces.

3.2.3 This specification will require alignment with future specifications from SEMI expected to specify standards for data collection.

3.2.4 This specification will require a standard service for document management that provides operations for the manipulation of versioned documents containing stored forms of APC objects. This service is anticipated as part of a future CIM Framework ballot. When a document management specification is adopted by SEMI, the APC Component can be enhanced to use the standard document management interfaces.

3.2.5 This specification will require additional operations for interactions with a component for MES-level access to data collection plans. Interfaces for manipulating data collection plans are anticipated as part of a future CIM Framework ballot. When they are adopted by SEMI, this specification can be enhanced to use those standard data collection plan interfaces.

3.2.6 This specification will require additional operations for interactions with a component to manage the flow of data from the sources where the data is collected to the data sinks where that data is used. These data flow interfaces are anticipated as part of a future CIM Framework ballot. When they are adopted by SEMI, this specification can be enhanced to use those standard data flow interfaces.

3.2.7 Parts of this specification will require additional declarations of the specific property names and value datatypes for arguments that include name-value pairs.

3.2.8 The events identified in Section 6.1 require more detailed specification to identify the event subject strings, filterable data, and event news contents.

3.2.9 The Algorithm Execution interfaces will require alignment with future architecture extensions for CIM Framework services that are provided without full component management lifecycle support.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

4.2 *Other Standards*

ISO/IEC International Standard 14750 (also ITU-T Recommendation X.920): Information Technology – Open Distributed Processing – Interface Definition Language[1]

UML Notation Guide, Version 1.1, document number ad/97-08-05, Object Management Group[2]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Advanced Process Control (APC)* — the manufacturing discipline for applying control strategies employing analysis and computation mechanisms to recommend optimized machine settings and detect faults in processing.

5.2 *control strategy* — a sequence of actions performed in response to a factory event to achieve an Advanced Process Control objective of process optimization or fault detection. Control Strategies are implementation specific.

6 Requirements

6.1 The following sections provide the interface design and description of the interfaces that comprise the APC Component. The model notation used is the Unified Modeling Language (UML). UML is documented in the *UML Notation Guide*. The details of each interface are supplied using standard IT-ODP-IDL. Conformant implementations of the APC Component or the Algorithm Execution interfaces shall provide support for all elements of the IDL specifications and the semantics provided in the UML models. Conformant implementations are not constrained to any specific implementation approach, provided that a mapping to the IDL specification is documented.

6.1.1 Figure 1 shows the Advanced Process Control Control Execution component and the Algorithm Interface Group in the context of other CIM Framework components. The Process Machine component will be the primary client of APC services, requesting APC results as part of process setup and monitoring. The Data Collection Plan and Dataflow components provide mechanisms to specify APC data collection needs and to supply collected information to APC. APC can be a client of other CIM Framework components, such as Product Management and Specification Management for modifying APC behavior based on prior and planned subsequent processing for the process material.

1 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

2 UML Notation Guide v1.1 is available to the general public at http://www.omg.org/cgi-bin/doclist.pl, +1.508.820.4300, Object Management Group, Inc., Framingham Corporate Center, 492 Old Connecticut Path, Framingham, MA 01701.

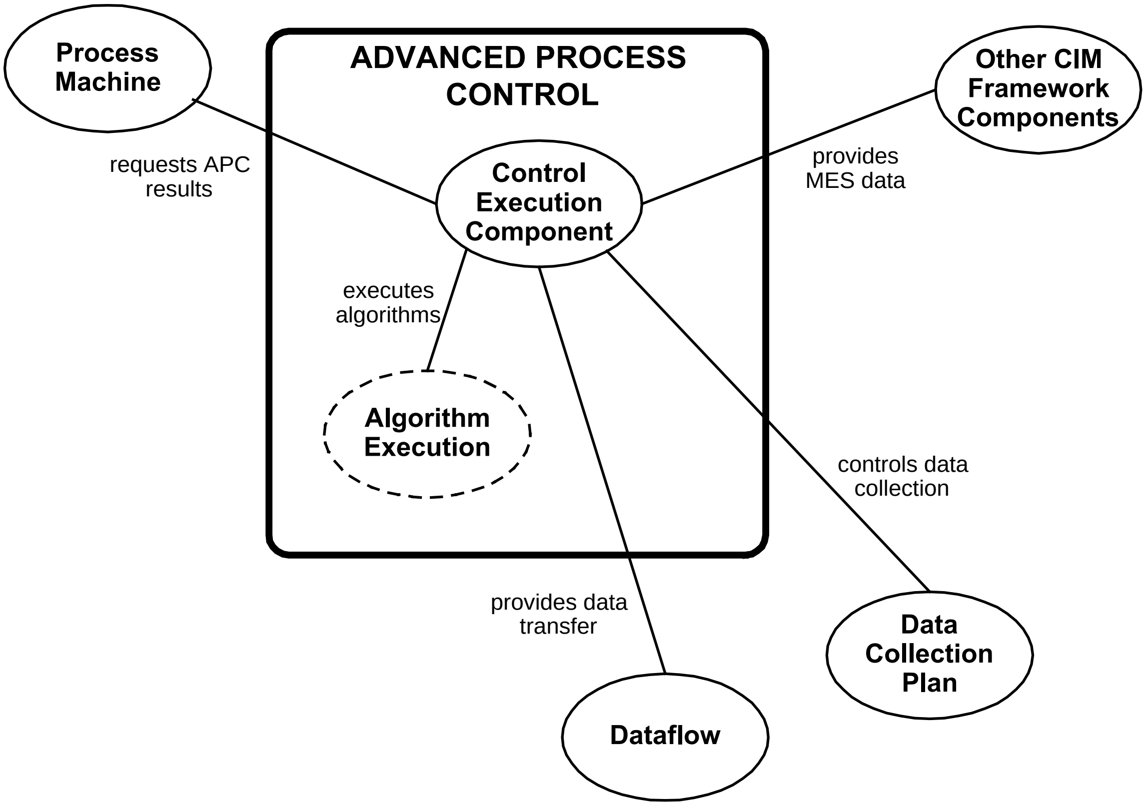


Figure 1
Advanced Process Control Component Context

6.1.2 The Algorithm Execution interface group is shown in dotted lines to indicate that the Algorithm Execution interface group is not a *component*, but rather a collection of interfaces that can be used in the specification of other components.

6.2 *APC Control Execution Component*

6.2.1 This component contains the main interfaces used to invoke APC functionality and the objects that describe and direct process control. Through the control component a client such as another MES component can request APC actions and receive results based on the execution of the APC action.

6.2.2 The APC Control Execution Component uses the CIM Framework job architecture, which is characterized by a JobSupervisor that handles requests to run Jobs. In the APC's Control Execution Component, Jobs typically return results. Results are represented by the Results type defined in the Job Architecture.

6.2.3 The major concepts defined by the APC Control Execution Component derive the following interfaces:

6.2.3.1 *ControlExecutionManager* — The interface used to initiate APC actions. A typical use would be by a process machine as part of its setup for a process job. The ControlExecutionManager creates and implicitly starts ControlStrategyJobs.

6.2.3.2 *ControlStrategyJob* — A unit of work performed by the APC Control Execution Component. The ControlStrategyJob performs some or all of the actions that make up an APC control strategy. The ControlStrategyJob is central to the APC Control Execution Component. It logically orchestrates interaction with other framework services such as AlgorithmExecutors. Dependencies on other interfaces, such as Algorithm Execution or access to process data, are implementation defined.

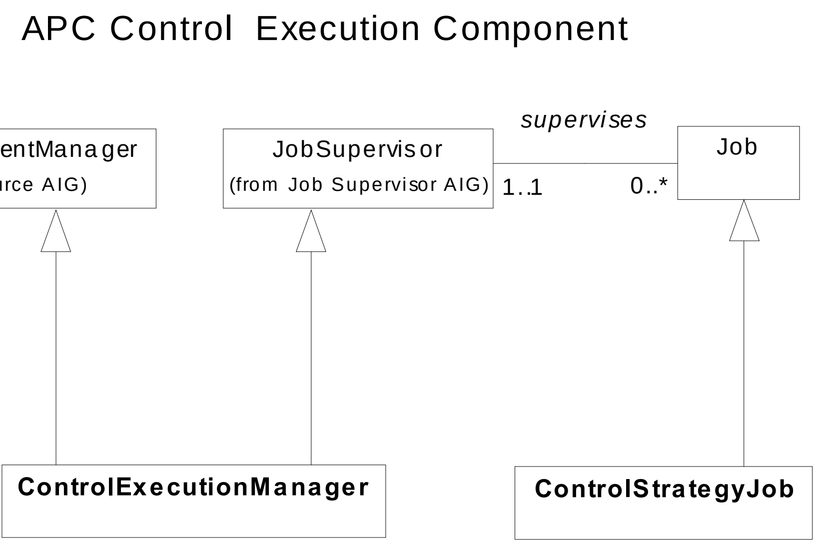


Figure 2
APC Control Execution Information Model

6.2.4 The following subsections define the interfaces for the APC Control Execution Component.

6.2.5 *ControlExecutionManager Interface*

Module:	APCControlExecution
Interface:	ControlExecutionManager
Inherited Interface:	AbstractIF::JobSupervisor, FactoryOperations::ComponentManager

```
interface ControlExecutionManager : AbstractIF::JobSupervisor,
        FactoryOperations::ComponentManager {
```

Description:	The ControlExecutionManager creates and manages ControlStrategyJobs. The behavior of the Control Execution Manager is specified by the inherited operations from JobSupervisor and Component Manager. Calls to the inherited requestJob and runJob operations from JobSupervisor shall include the value “ControlStrategyJob” for the JobType property of the JobSpecification.
Type Declarations:	None.
Exceptions:	None.
Published Events:	None.
Provided Services:	None.
Contracted Services:	None.
Dynamic Model:	None.

```
}; // ControlExecutionManager
```

6.2.6 *ControlStrategyJob Interface*

Module:	APCControlExecution
Interface:	ControlStrategyJob
Inherited Interface:	AbstractIF::Job

```
interface ControlStrategyJob : AbstractIF::Job {
```

Description: The ControlStrategyJob executes control actions such as settings, calculations, fault detection, or data collection. It is a “Job,” executing whatever actions are specified by a control strategy.

A ControlStrategyJob may return results which are accessed with the inherited operation getJobResults or through a ControlStrategyJobStatusEvent that contains the results.

Exceptions: None.

Published Events: This section describes the intent of the APC events and the data that should be provided in the APC events. Specific declaration of these events will be added in a future revision of this standard.

Information specified for an event is not required. The events will be flexible and allow additional fields to be added. An implementation may choose to provide more or less information for these events.

ControlStrategyJobStatusEvent

The ControlStrategyJobStatusEvent is issued by ControlStrategyJobs (refer to definition in Section 6.2) to indicate a change in job status. The event would contain a reference to the ControlStrategyJob that initiated the event so that clients can query the Job for additional information as well as an indication of the type of status change that occurred. The status change could indicate the availability of results, in which case the event would contain the Job results. The status change could indicate a change in Job state, in which case the event would contain an indication of the Job state change.

ApplicationEvent

An ApplicationEvent is an Event published by a ControlStrategyJob to indicate an important milestone or status during the execution of the control strategy. ApplicationEvents can be used to indicate the detection of a fault or provide other kinds of notification. ApplicationEvents provide a mechanism to convey application information that goes beyond the specifics of the ControlStrategyJob state changes.

Provided Services: None.

Contracted Services: None.

Dynamic Model: None.

```
}; // ControlStrategyJob
```

6.3 *Algorithm Execution Interface Group*

6.3.1 The Algorithm Execution Interface Group provides interfaces that encapsulate interaction with computational services. Typically these services are to provide an APC compliant interface to a non-APC compliant computational service. The Algorithm Execution Interface Group defines a synchronous “call/return” style interaction for an Algorithm. The requestor of the algorithm execution calls the interface and waits for the completion of the calculation and the return of the results. This interaction pattern is the most common form of interaction between an APC application and an Algorithm. Support for other forms could be vendor defined or added in future revisions of this standard.

6.3.2 Within the Algorithm Service the following concepts are defined:

6.3.2.1 *AlgorithmExecutor* — A wrapper for an external computation engine. The AlgorithmExecutor creates AlgorithmJobs to perform calculations within the computation engine.

6.3.2.2 *AlgorithmJob* — Responsible for translating the specifications defined within an Algorithm into a form that is usable by the wrapped application.

6.3.2.3 *Algorithm* — A specification of actions that is interpreted by an AlgorithmJob. An Algorithm has a collection of AlgorithmContents that define the algorithm.

6.3.2.4 *AlgorithmContents* — AlgorithmContents are specific attributes of an Algorithm. AlgorithmContents can be such things as a command script to be dynamically interpreted by an application, configuration values used for calculations, and capabilities required from the AlgorithmExecutor in order to execute the Algorithm.

6.3.3 Executing an Algorithm requires two operations. The first is to create an AlgorithmJob with the AlgorithmExecutor. The client supplies the Algorithm. Once the AlgorithmJob is created it is assumed to be initialized and ready to run. *AlgorithmJob.execute* causes the Algorithm to be interpreted with the results of the calculations being returned.

6.3.4 The AlgorithmExecutor is isolated from the APC Component to allow suppliers of Algorithm products to build custom versions to enable their products for framework applications. In a typical APC scenario the ControlStrategyJob would be a client of the AlgorithmExecutor. ControlStrategyJobs would invoke AlgorithmExecutors, passing them Algorithms.

6.3.5 This specification requires any implementation of a conformant Algorithm to support an AlgorithmExecutor interface. The AlgorithmExecutor interface would be implemented by an external component that provides the operations enabling the execution of an Algorithm.

6.3.6 Specification of the AlgorithmContents, management of Algorithms and AlgorithmContents and how clients locate AlgorithmExecutors is vendor defined. This specification intends that Algorithms and AlgorithmContents be managed through separate document management and version control components as they become available.

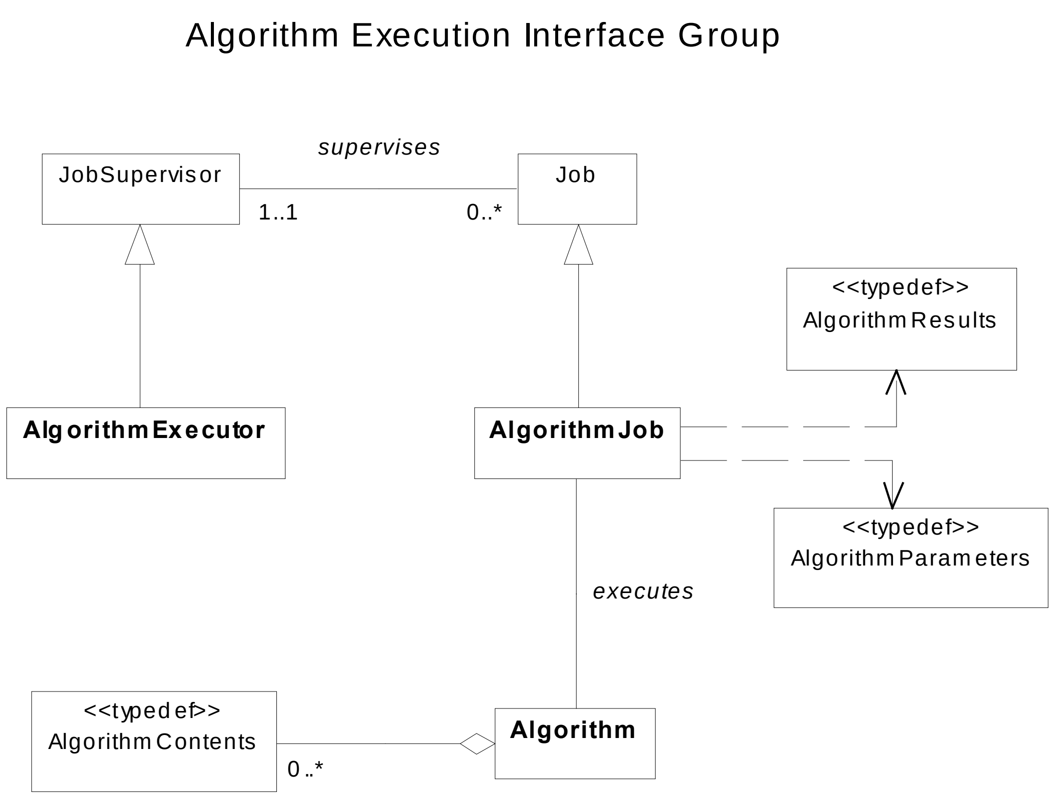


Figure 3
Algorithm Execution Information Model

6.3.7 *APCAlgorithm Declarations*

Module: APCAlgorithm

Description: These declarations are used by the Algorithm Execution Interfaces.

Declarations:

/* Data values returned by an Algorithm */

```
typedef any AlgorithmResults ;
```

/* Data values input to an Algorithm */

```
typedef any AlgorithmParameters ;
```

/* An attribute of the Algorithm. Could represent an algorithm source, compiled algorithm, etc. */

```
typedef any AlgorithmContents ;

typedef Global::Properties AlgorithmContentsSequence ;
```

/* A specification of the AlgorithmContents Type. */

```
typedef string AlgorithmContentsType;
```

/* Indicates the Algorithm did not contain content with the type */

```
exception NoContentForTypeSignal {
        string errorMessage;
        AlgorithmContentsType aType; } ;

typedef sequence <Algorithm> AlgorithmSequence;
```

6.3.8 *AlgorithmExecutor Interface*

Module: APCAlgorithm

Interface: AlgorithmExecutor

Inherited Interface: AbstractIF::JobSupervisor

```
interface AlgorithmExecutor : AbstractIF::JobSupervisor {
```

Description: The AlgorithmExecutor provides execution environments for application Algorithms. Execution of the Algorithm is performed by the AlgorithmJob. The behavior of the AlgorithmExecutor is specified by the inherited operations from JobSupervisor. Calls to the inherited requestJob and runJob operations from JobSupervisor shall include the value "AlgorithmJob" for the JobType property of the JobSepecification.

AlgorithmExecutor::requestAlgorithmJob provides the same functionality as AlgorithmExecutor::requestJob except requestAlgorithmJob returns a Job with a type of AlgorithmJob and requestJob returns a Job with the type AbstractIF::Job.

Exceptions: None.

Published Events: None.

Provided Services:

/* Creates a new AlgorithmJob to execute the Algorithm

A Job Property with the tag "Algorithm" and a value with type Algorithm is required.

A Job Property with the tag "Parameters" and a value AlgorithmParameters is optional.

*/

```
AlgorithmJob requestAlgorithmJob (
        in Global::Properties aJobSpecification,
        in AbstractIF::JobRequestor aJobRequestor)
        raises (Global::FrameworkErrorSignal,
        AbstractIF::JobSuperviso::JobRejectedSignal);
```

/* Creates an AlgorithmJob and performs execute. The Job is managed internal to the AlgorithmExecutor.

A Job Property with the tag "Algorithm" and a value with type Algorithm is required.

A Job Property with the tag "Parameters" and a value AlgorithmParameters is optional. If Parameters are provided, the AlgorithmJob execute operation is performed on behalf of the client. No explicit call to execute is required in this case.

*/

```
AlgorithmResults runAlgorithmJob (
        in Global::Properties aJobSpecification )
        raises (UnableToExecuteSignal,
        Global::FrameworkErrorSignal,
        AbstractIF::JobSupervisor::JobRejectedSignal );
```

Contracted Services: None.

Dynamic Model: None.

```
}; // AlgorithmExecutor
```

6.3.9 *AlgorithmJob Interface*

Module: APCAlgorithm

Interface: AlgorithmJob

Inherited Interface: AbstractIF::Job

```
interface AlgorithmJob : AbstractIF::Job {
```

Description: The AlgorithmJob is responsible for execution of an Algorithm. The AlgorithmJob is initiated by an AlgorithmExecutor. The behavior of the AlgorithmJob is specified by the inherited operations from Job along with the operation defined below.

Exceptions: None.

Published Events: None.

Provided Services:

/* Executes the Algorithm and returns the result. Note: successful return from "execute" does not imply that the Job has completed. Execute is a valid operation whenever the Job is in the EXECUTING state. */

```
AlgorithmResults execute (
        in AlgorithmParameters parameters )
        raises (UnableToExecuteSignal,
        Global::FrameworkErrorSignal );
```

Contracted Services: None.

Dynamic Model: None.

```
}; // AlgorithmJob
```

6.3.10 *Algorithm Interface*

Module: APCAlgorithm

Interface: Algorithm

Inherited Interface: None.

```
interface Algorithm {
```

Description: The Algorithm encapsulates the code instructions or settings to perform a specific control calculation as specified by a specific algorithm. The Algorithm is used to incorporate algorithms developed on third-party platforms into the CIM environment for use in process control applications.

Contents of the Algorithm are defined according to the specific implementation. The format is designed to give ControlStrategies a flexible way to interact with a wide range of external applications while maintaining a simple interface.

As an example, an Algorithm could define an AlgorithmContentsType of “Data File” with a value of a string. A second AlgorithmContentsType could be “long parameter” with a value of a numeric long.

Exceptions: None.

Published Events: None.

Provided Services:

/* Returns a copy of the Algorithm “contents” (executable algorithm, source algorithm, etc.). */

```
AlgorithmContentsSequence getAllContents ()
        raises (Global::FrameworkErrorSignal);
```

/* Retrieves the “content” with the given contents type. */

```
AlgorithmContents getContentByType (
        in AlgorithmContentsType aAlgorithmContentType)
        raises (Global::FrameworkErrorSignal,
        NoContentForTypeSignal);
```

Contracted Services: None.

Dynamic Model: None.

```
}; // Algorithm
```

APPENDIX 1
COMPLETE IDL LISTING

NOTE: The material in this appendix is an official part of SEMI E93 and was approved by full letter ballot procedures on July 15, 1999.

```
module CIMFW {

#include <Global.idl>

#include <AbstractIF.idl>

#include <FactoryOperations.idl>

#ifndef _APC_CONTROL_EXECUTION_

#define _APC_CONTROL_EXECUTION_

    module APCControlExecution {

        interface ControlExecutionManager : AbstractIF::JobSupervisor,
        FactoryOperations::ComponentManager {

        }; // ControlExecutionManager

        interface ControlStrategyJob : AbstractIF::Job {

        }; // ControlStrategyJob

    }; // module APCControlExecution

#endif // _APC_CONTROL_EXECUTION_


#ifndef _APC_ALGORITHM_

#define _APC_ALGORITHM_

    module APCAlgorithm {

        interface Algorithm;

        interface AlgorithmJob;

            exception UnableToExecuteSignal {
                string errorMessage; } ;

            typedef any AlgorithmResults ;

            typedef any AlgorithmParameters ;

            typedef any AlgorithmContents ;

            typedef Global::Properties AlgorithmContentsSequence ;

            typedef string AlgorithmContentsType;

            exception NoContentForTypeSignal {
                string errorMessage;AlgorithmContentsType aType; } ;

            typedef sequence <Algorithm> AlgorithmSequence;
```

```
        interface Algorithm {

        AlgorithmContentsSequence getAllContents ()

                raises (Global::FrameworkErrorSignal);

            AlgorithmContents getContentByType (
                in AlgorithmContentsType aAlgorithmContentType)
                raises (Global::FrameworkErrorSignal,
                NoContentForTypeSignal);

        }; // Algorithm

        interface AlgorithmExecutor : AbstractIF::JobSupervisor {

            AlgorithmJob requestAlgorithmJob (
                in Global::Properties aJobSpecification,
                in AbstractIF::JobRequestor aJobRequestor)
                raises (Global::FrameworkErrorSignal,
                AbstractIF::JobSupervisor::JobRejectedSignal);

            AlgorithmResults runAlgorithmJob (
                in Global::Properties aJobSpecification )
                raises (UnableToExecuteSignal,
                Global::FrameworkErrorSignal,
                AbstractIF::JobSupervisor::JobRejectedSignal );

        }; // AlgorithmExecutor

        interface AlgorithmJob : AbstractIF::Job {

            AlgorithmResults execute (
                in AlgorithmParameters parameters )
                raises (UnableToExecuteSignal,
                Global::FrameworkErrorSignal );

        }; // AlgorithmJob

    }; // module APCAlgorithm

#endif // _APC_ALGORITHM_

}; // module CIMFW
```

SEMI E94-0702
PROVISIONAL SPECIFICATION FOR CONTROL JOB MANAGEMENT

This provisional specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on March 17, 2002. Initially available at www.semi.org June 2002, to be published July 2002. Originally published February 2000; previously published March 2002.

1 Purpose

1.1 This specification describes equipment provided services to the factory that supports a high level of factory automation. These services provide capabilities for the host to coordinate processing and disposition of materials on production equipment.

2 Scope

2.1 This specification may be applied to equipment that is compliant to SEMI E30 (GEM). However, it is also intended that this standard will be useful for future generation equipment interfaces that supercede SEMI E30, such as SEMI E53.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard presents a model of the ControlJob. The model delineates the services (messages) and behavior of the ControlJob. The model is protocol independent. Thus, an ancillary standard must be selected in order to provide a complete implementation.

3.2 This standard should not be applied to non-production equipment, such as, material transport systems or facilities (environmental) controllers.

3.3 *Provisional Status*

3.3.1 For this standard specification to be complete (removal of provisional status) the following areas need to be completed:

1) ControlJob to assure equivalent processing regardless of module used in multi-module equipment.

2) Complete specification of relationship to Carrier Management.

3) Standardized support for the parallel execution of ControlJobs.

4) Support for processing materials on equipment that have batch sizes that are not either multi-carrier or on which the carrier substrate location count is not an integer multiple of the batch size.

5) Possible linkages between ControlJob, material, and substrate tracking.

6) Complete work on the model for the control job queue. Additional functions and attributes for manipulating the job queue may be added.

3.4 This specification applies to equipment for which the atomic unit of material is the same for all input and output carriers on the equipment. It may not apply to equipment which would perform operations such as slicing or assembly that would require or result in different input and output material objects. This specification may not apply to equipment or equipment configurations where the equipment does not handle carriers, as in the case of a stepper or scanner in a linked photolithography cell.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E40 — Standard for Processing Management

SEMI E53 — Event Reporting

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Definitions*

5.1.1 *control job* — defines a unit of work on equipment for one or more carriers. The work is described by a set of one or more process jobs to be applied to the material contained in the carriers.

5.1.2 *de-queue* — the act of removing an item from a queue. The de-queue implies nothing about the status of the item after removal.

5.1.3 *equipment* — the intelligent system that communicates with the host.

5.1.4 *host* — the intelligent system that communicates with the equipment.

5.1.5 *life cycle* — the processes and activities of something from its beginning (creation) to its ending.

5.1.6 *multi-module equipment* — equipment that has more than one distinct processing resource (e.g., chamber).

5.1.7 *production equipment* — equipment that measures or adds value to the product.

5.1.8 *protocol independent* — for software, this means that the message descriptions are independent of delivery mechanisms.

5.1.9 *set-up* — a description of the current process capability of an equipment.

5.1.10 *substrate* — basic unit of material on which work is performed to create a product. Examples include wafers, lead frames, CD's, die, flat panel displays, circuit boards, and disks.

5.1.11 *substrate port* — the carrier location from which substrates are accessed by the equipment.

5.1.12 *uni-carrier* — term for an equipment mode of operation in which all material is returned to the source carrier after processing.

5.1.13 *user start* — activities that are initiated on a system by another system or operator.

6 Conventions

6.1 *Object Models*

6.1.1 This standard uses object models to specify the control job interface.

6.1.2 *Object Services Standard*

6.1.2.1 This document conforms to the conventions established by SEMI E39.

6.1.3 *Formal Name of an Object*

6.1.3.1 The text capitalizes formal object name references, similar to the way capitalization is normally used when discussing entities. When describing something in the general (like cities) lower case is used, but when a specific entity is of interest (New York City), then first letters are capitalized.

6.2 *State Model Methodology*

6.2.1 This document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in "State Charts: A Visual Formalism for Complex Systems" written by D. Harel in Science of Computer Programming 8, 1987. [1]

6.2.2 The Harel convention does not have the concept of state models of "creation" and "extinction" for expressing a temporary entity. The "job" described in this document is such an entity, and a copy of the same state model is used for an independent job newly created. In this document, a circle with a black circle inside is used for expressing extinction of an entity. A filled, black circle denotes the entry to the state model (the entity creation).

6.2.3 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

1) Actions taken upon exit of the previous state.

2) Actions taken upon entry of the new state.

3) Actions taken which are most closely associated with the transition.

6.2.3.1 No differentiation is made between these cases.

6.2.4 The state models included in this standard are a requirement for Control Job Management compliance. A state model consists of a state model diagram, state definitions, and a state transition table. When using collection events, all state transitions in this standard, unless otherwise specified, shall correspond to collection events.

6.2.5 A state model represents the host's view of the equipment, and does not necessarily describe the internal equipment operation. When using collection events, all Control Job Management state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the Control Job Management state models for transition to another state. In the case, the equipment makes the required transition without any additional actions in this situation.

1 Elsevier Science, P.O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.htt

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

6.3 *Service Message Representation*

6.3.1 Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message, that does not require a response.

6.3.2 *Service Definition*

6.3.2.1 A service definition table defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*

6.3.2.2 Type can be either "N" = Notification or "R" = Request & Response.

6.3.2.3 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.3.3 *Service Parameter Dictionary*

6.3.3.1 A service parameter dictionary table defines the description, format and its possible value for parameters used by services, as shown in the following table:

Parameter Name	*Description*	*Format: Possible Value*

6.3.3.2 A row is provided in the table for each parameter of a service.

6.3.4 *Service Message Definition*

6.3.4.1 A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Res/Cnf*	*Comment*

6.3.4.2 The columns labeled REQ/IND and RSP/CNF link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication" or the request. The receiver may then send a "Response" which the original sender terms the " Confirmation".

6.3.4.3 The following codes appear in the REQ/IND and RSP/CNF columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

M	Mandatory Parameter — Must be given a valid value.
C	Conditional Parameter — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.
U	User-Defined Parameter.
-	The parameter is not used.
=	(For response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7 Overview

7.1 This section provides an overview of the control job functionality. It does not contain the specifications which define that functionality.

7.1.1 Control jobs provide a supervisory level of control for process jobs on material processing equipment. They can be used to reduce the amount of host level interaction required for material processing. A factory host is provided with methods for instructing the equipment to provide only significant factory level events, such as, a carrier complete. The ControlJob also supplies methods for the disposition of material after processing.

7.2 *User Requirements*

7.2.1 To handle the complexity required for manufacturing, equipment must support the ability to coordinate its processing services with the factory's needs. The ControlJob provides the services that the factory needs to accomplish this coordination. The requirements that the ControlJob satisfies include: (1) a method by which the equipment coordinates related work, for instance, all process jobs associated with a carrier, and (2) a method by which the equipment can be informed of material destination after processing. The ControlJob is not a type of process job. It is not responsible for the coordination of the processing resource and the material to be processed.

7.2.2 *Initiate and Monitor Process Jobs*

7.2.2.1 ControlJobs are queued. ProcessJobs are not queued by equipment that supports control jobs, rather they are pooled waiting to be scheduled by their respective ControlJob. The ControlJob specifies the order for process jobs. The equipment follows that order as the equipment's resources become available (and when material is available).

7.3 *Supplier Requirements*

7.3.1 *Management of Process Materials*

7.3.1.1 Suppliers need to implement an operational model for managing material and processing in a manner consistent with factory expectations. For instance, the equipment must know when it is finished with a carrier so that it can either allow or signal the factory for the removal of the carrier. This standard provides mechanisms to meet this requirement. While the model implies some implementation it is only the external events that are required by this standard.

7.3.2 *Control Job Events*

7.3.2.1 Control jobs supply information to host systems as either responses to request messages or as events which are sent to the host. Typically the equipment can implement the event mechanisms either in GEM (SEMI E30) or the Event Reporting standard (SEMI E53).

7.3.2.2 All state transitions defined for state models in this document must be able to be reported by separate collection events as defined in section 6.2, State Model Methodology. The state model is the Control Job State Model (Figure 2). The data required for each state model transition event is defined per the following. This data is the minimum required per event. The host may assign other variable, as applicable, from Section 13, Variable Data, of this document, or from other equipment variable data.

7.3.2.3 The following data is required to be available for the Control Job State Model transition collection events:

CtrlJobID

7.4 *Operational Descriptions*

7.4.1 The ProcessJob as referenced in the specification of the control job model is the SEMI E40 process job. Within a ProcessJob the material processing order is managed by the equipment. For some equipment types, the user may be able to configure the material processing order. If available, this feature shall be fully documented by the supplier (see SEMI E40).

7.4.2 To support a simpler interface for single substrate processing, it is suggested to use the PRJobMultiCreate (see SEMI E40) service.

7.4.3 The use of control jobs restricts some SEMI E40 functionality. In particular, the equipment's queue management functionality for process jobs is superseded by the job order as defined in the control job.

7.4.4 The relationship between control jobs and process jobs varies by equipment type. The equipment supplier should document this relationship. In general aborting or stopping a process job does not stop or abort the control job. Equipment is responsible to disposition material correctly depending on how a process job ends. In the case of equipment types that always have a one to one relationship between a control job and a process job it may be convenient for a process job abort or stop to automatically abort the respective control job. In the same sense, if a control job specifies more than one process job, it may be convenient for an abort or stop of all process jobs to automatically abort or stop the respective control job.

8 ControlJob Object Model

8.1 This specification only standardizes the ControlJob object's interface. The other objects provide a context for the ControlJob interface. Since only the interface is standardized, it is not a requirement for equipment to implement a control job object, it is only required that the equipment provide an external interface that provides the services and behavior defined for the ControlJob.

8.2 *Material to Job Linkage*

8.2.1 The equipment has relationships with many other components not illustrated in Figure 1. In partic-ular, from its knowledge based on substrate and carrier tracking capabilities, the equipment shall connect the process job material list to the materials in the carriers that it has. It is the responsibility of the factory host to make sure that the description or identifiers of material contained in carriers can be mapped to the material identifiers in the process job definition.

8.3 *Control Jobs and Carriers*

8.3.1 A control job may specify work for several carriers. The supplier shall document the behavior of the equipment in the case where a carrier is specified for use in more than one control job.

8.4 *Attribute Definitions*

8.4.1 The attributes in Table 1 shall be accessible using the Object Services standard (SEMI E39). Object services is a set of messages which may be required of any service provider which is modeled by objects. An object model for a service provides a consistent naming convention for exchanging information between the service provider and user. Object services implementations shall be consistent with the service's object and state models. For instance, if an attribute can only be modified in a certain state, then a request to set that attribute when the model is in the wrong state shall be rejected (fail). ControlJob Attributes shall be modifiable if and only if the ControlJob is not in either the EXECUTING or COMPLETED states by using OSS to change them (see Section 14.3.1).

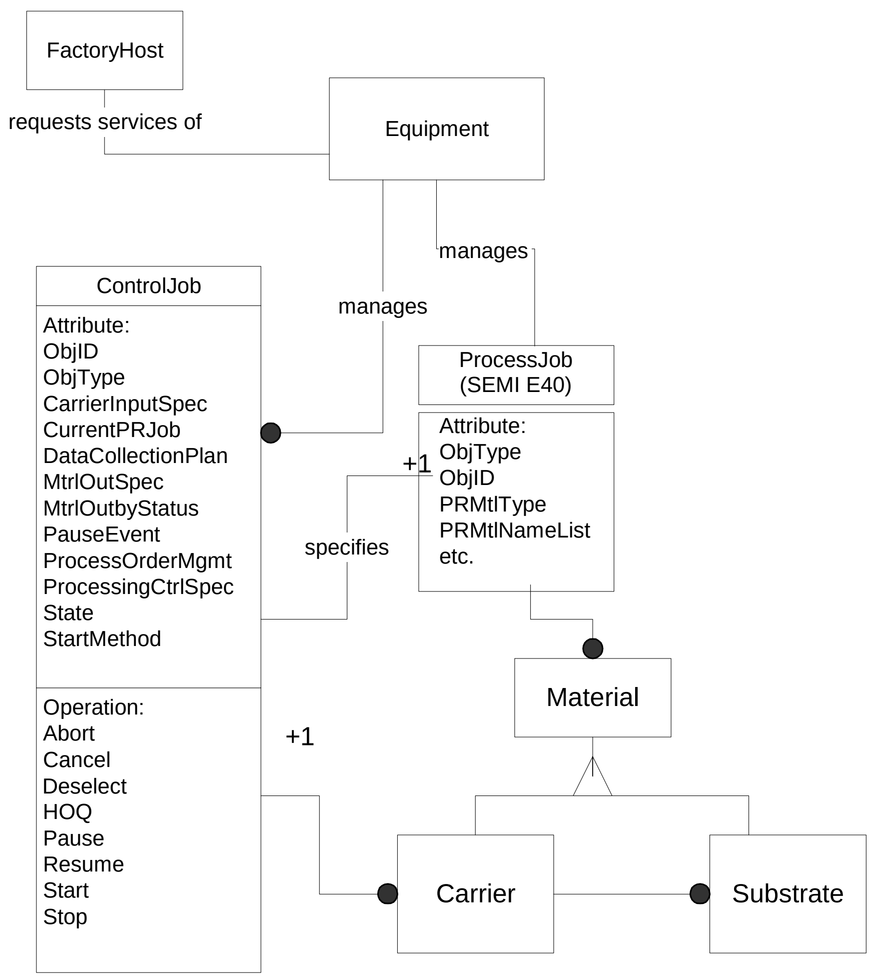


Figure 1
ControlJob Object Model

Table 1 ControlJob Attributes

Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjID	Host defined identifier of the control job.	Y	RO	Text
ObjType	Object type	Y	RO	Text = 'ControlJob'
CurrentPRJob	Holds the identifiers of any process job in the active state (i.e., in the Executing, Stopping, Aborting or Pause states).	Y	RO	(list of) PRJobID (see SEMI E40)
DataCollectionPlan	Identifier for a data collection plan to be used during execution of the control job.	N	RW	Text
CarrierInputSpec	A list of carrierID for material that will be used by the ControlJob. An empty list is allowed.	Y	RW	(list of) CarrierID
MtrlOutSpec	Maps material from source to destination after processing. For uni-carrier operation, the list shall be empty. The list shall also be empty, if CarrierInputSpec is an empty list.	Y	RW	List of Structure: SourceMap DestinationMap
MtrlOutByStatus	List structure which maps locations or Carriers where processed material will be placed based on material status.	N	RW	List of structure: MaterialStatus DestinationMap
PauseEvent	Identifier of a list of events on which the Control Job shall PAUSE.	N	RW	(list of) EventID
ProcessingCtrlSpec	A list of structures that defines the process jobs and rules for running each that will be run within this ControlJob.	Y	RW	(list of) Structure: PRJobID ControlRule OutputRule
ProcessOrderMgmt	Define the method for the order in which process jobs are initiated.	Y	RW	Enumeration: LIST ARRIVAL OPTIMIZE
StartMethod	A logical flag that determines if the ControlJob can start automatically. A user start may come through either the host connection or the operator console.	Y	RO	Boolean: TRUE – Auto FALSE – UserStart
State	The current state of the ControlJob.	Y	RO	Enumerated: per State Model

8.4.2 A number of the ControlJob attributes are composite data types. The constituent data is defined in Table 2.

Table 2 Attribute Data Definitions

Data Identifier	*Description*	*Form*
CarrierID	The identifier of a carrier that is the source or destination for substrates.	Text
ControlRule	Provides additional job control functionality. It is equipment type dependent. It may be used to modify processing based on processing results. Use of this attribute is not required for equipment, which does not support it. Suppliers shall document the use of this attribute when supported.	(list of) Structure: RuleName RuleValue
Destination	The identifier of a substrate location at which material can be placed. (Identifier should conform to standards for substrate tracking.)	Text
DestinationMap	Describes carrier positions into which finished material will be placed. If the list of carrier positions is empty, then follow sequential order of source.	Structure: CarrierID List of SubstrateLocation

Data Identifier	*Description*	*Form*
MaterialStatus	ControlJob processing assigns this value to finished material. The association of MaterialStatus to Destination enables ControlJob processing to put material at the desired destination.	Equipment dependent enumeration
OutputRule	Defines the MaterialStatus (such as Good, Reject, Aborted, Monitor, etc.) based on results of the process job.	Equipment dependent
PRJobID	A process job identifier as defined by SEMI E40. Host must supply same name in the ProcessingCtrlSpec as when it requested creation of process job. NOTE: SEMI E40 process jobs link material to a recipe.	See SEMI E40.
Rule Value	The value used by the equipment for execution of a control rule.	Equipment dependent
RuleName	Identifier of a control rule.	Text
SourceMap	Describes the locations from which material is taken for processing. If the list of location is empty, then assume the default of ascending order.	Structure: CarrierID List of SubstrateLocation
SubstrateLocation	A substrate position at a source and a destination. A carrier is an example of a multi-location destination. For a wafer carrier the SubstrateLocation is a slot number.	Numeric

8.4.3 *ControlRule*

8.4.3.1 For equipment that supports this attribute (field), the host sets this in order to achieve better host processing control capabilities. For example, the host may have previously measured characteristics of the material to be processed. A standard recipe is used based on the product and process step, but based on the measured characteristics, the application of the recipe is biased by the specified rule and the value that is passed to the rule (RuleValue). However, use of ControlRule should not be considered to be limited to only this type of application.

8.4.4 *DataCollectionPlan*

8.4.4.1 The DataCollectionPlan is a name given by the host to associate data collection activities to a specific control job. In general, it provides a way for the equipment to then inform and coordinate with the host to receive data collection requests. A DataCollectionPlan is generic and will be applied to many control jobs. The variable itself, DataCollectionPlan, will hold no significance for the equipment. It is simply a label the equipment reports back when requested by the host. Normally, the host upon receiving the ControlJob START event would include DataCollectionPlan as a data variable to be reported. The host then knows that the time is appropriate to set up various trace reports and event reports on the equipment. Potentially, all jobs that specify the same product type and process capability could specify the same DataCollectionPlan.

8.4.5 *OutputRule*

8.4.5.1 This attribute can only be supported by equipment that has some means to determine the status of material that it has processed. For equipment with that ability, the rule will usually take the form of a list of name value pairs. The names will be material status and the values will be measurement thresholds that correspond to the status category (such as, Good, Reject, Rework, etc.). Substrate (material) status changes should be recorded in substrate histories created by the equipment.

8.4.5.2 Equipment which also supports the MtrlOutbyStatus shall use the status determined by the OutputRule to place substrates at the Destination associated with MaterialStatus.

8.4.6 *PauseEvent*

8.4.6.1 For equipment which can support it, this attribute contains a list of equipment events, specified by the host, at which the host expects the equipment to PAUSE the ControlJob. Equipment suppliers shall document any events that can be used for the pausing of control jobs. Pausing a control job causes it to stop initiating process jobs. The host might use this to stop processing after one or more process jobs has started in order to await results before processing the rest of the material in the control job.

8.4.7 *ProcessOrderMgmt*

8.4.7.1 This is an enumerated attribute that defines the order in which processing will occur. This standard defines three enumerations. For some equipment other enumerations may be possible. If they are the supplier shall document them.

8.4.7.2 LIST

8.4.7.2.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated in the order of the list in ProcessingCtrlSpec.

8.4.7.3 ARRIVAL

8.4.7.3.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated as the material for the job arrives. Any jobs that do not require material will be initiated first.

8.4.7.4 OPTIMIZE

8.4.7.4.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated in an order to be determined by internal equipment algorithms, that optimize the throughput of material in the equipment.

9 Control Job State Model – Behavior

9.1 The following state chart defines the behavior of the ControlJob.

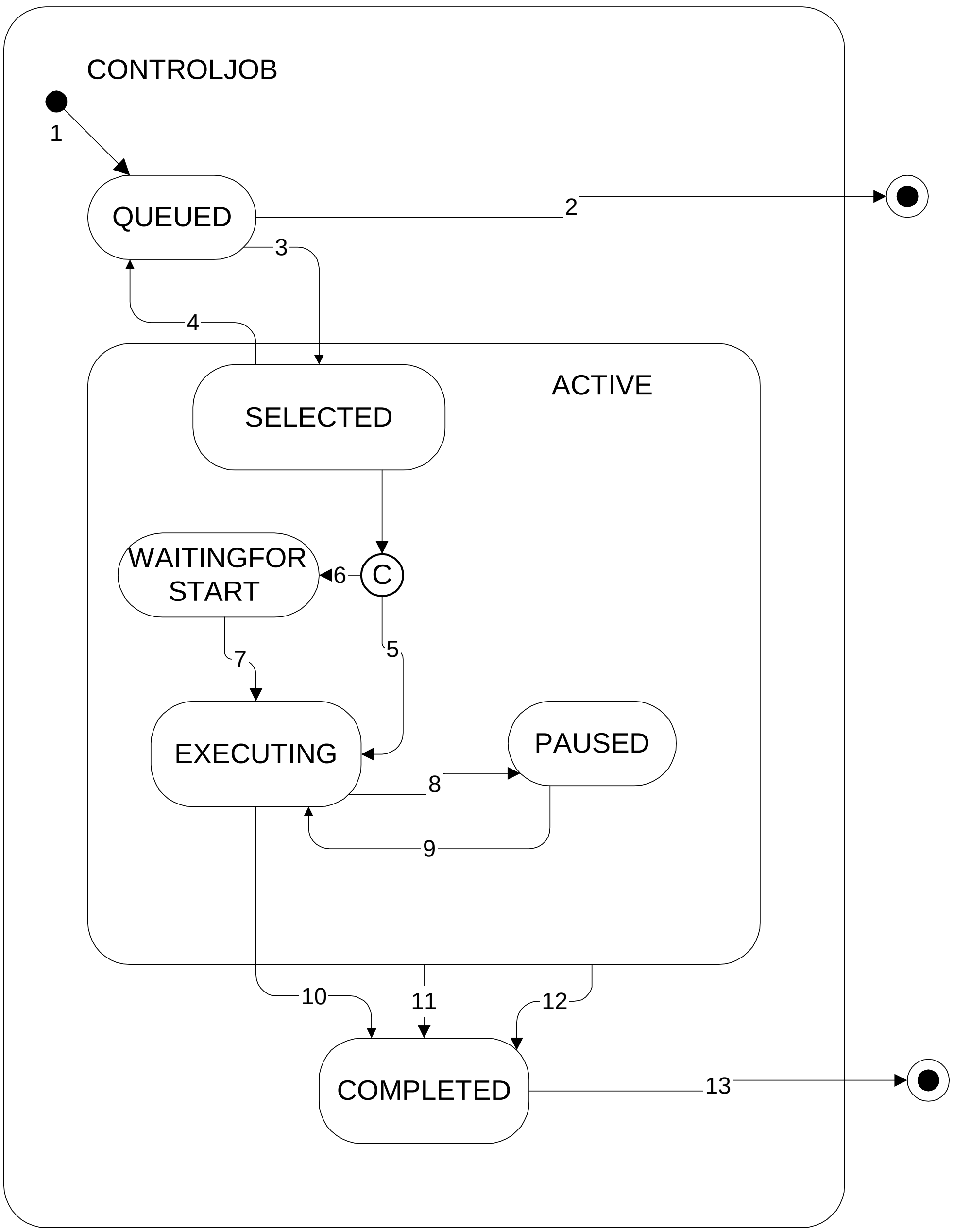


Figure 2
Control Job State Model

9.2 *State Definitions*

9.2.1 QUEUED — A ControlJob is queued after its creation or de-selection. A newly created ControlJob is placed at the tail of the queue.

9.2.2 SELECTED — In this state, the ControlJob does not initiate process jobs specified in it and therefore pre-defined (based on recipe variable parameters) process conditions can be modified. The processing resource is reserved (not available for any other jobs) by the ControlJob in the SELECTED state. If materials, required by the ControlJob, for processing have not arrived at the equipment, the ControlJob will stay in this state until materials arrive. If the ControlJob or the first process job in the ControlJob does not require material, this state is exited immediately. A SELECTED ControlJob can be de-selected if specified materials have not arrived.

9.2.3 WAITING FOR START — The ControlJob is waiting to receive a start command manually or remotely from the host. The ControlJob transitions to this state only if the StartMethod is set to FALSE (UserStart) and materials have arrived.

9.2.4 EXECUTING — In this state, each process job in the ProcessingCtrlSpec is initiated in order, based on the value of the ControlJob's ProcessOrderMgmt attribute as required resources become available and material for the job has been verified. Process jobs that have been initiated but that are WAITINGFORSTART or PAUSED shall block the availability of the resources that they require (see SEMI E40).

NOTE 2: Process jobs that have blocked available resources shall cause the ControlJob to stop initiating subsequent process jobs that use those resources.

9.2.5 PAUSED — When the ControlJob is paused it shall not commence the initiation of any more Process jobs. In this state, Process jobs that have not entered the "PROCESSING" state can be modified. Various attributes of the ControlJob can also be modified. This is equipment specific and shall be documented by the equipment supplier.

9.2.6 COMPLETED — A control job enters this state once all of its process jobs have been completed, stopped or aborted.

Table 3 ControlJob State Transition Table

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(No state)	Receive "Create" command from host or operator through operator console.	QUEUED	Create ControlJob and put it at the tail of a control job queue.	If job queue is full, "Create" request is rejected.
2	QUEUED	Receive "Cancel", "Abort", or "Stop" command from host or operator through operator console.	(No state)	De-queue and terminate the job. Send a "ControlJob Canceled" event to the host.	If other control jobs are waiting behind the canceled job in the queue, they are shifted forward to fill in the gap after the de-queuing of the canceled control job.
3	QUEUED	The processing resource has capacity to begin work on the next ControlJob.	SELECTED	Select and de-queue the job at the head of the queue. Send a "Selected" event to the host.	Materials are not necessarily at the equipment.
4	SELECTED	Receive "De-select" command from host or operator through operator console and materials for the control job have not arrived yet.	QUEUED	De-selected job moves to the head of the job queue and the job that was at the head becomes the SELECTED job.	The command shall be rejected if the resources for the job at the head of queue are not available. See the Queue Model.

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
5	SELECTED	Material for the first process job arrives or in the case where the first (or only) process job does not require material, this transition shall be taken as soon as the processing resource for that process job becomes available. "StartMethod" attribute in the ControlJob is set for Auto.	EXECUTING	Send "Execution began" event to the host.	Process jobs associated with a carrier will not initiate until the identifier and substrate slot map for the carrier have been verified. Process jobs that don't use material can be initiated immediately.
6	SELECTED	Same as for transition 5 except that the "StartMethod" attribute in the control job is set for user start.	WAITING FORSTART	Send a "JobWaiting for Start" event to host and/or operator.	
7	WAITING FORSTART	User START command received.	EXECUTING	Same as for transition 5.	Same as for transition 5.
8	EXECUTING	Received "Pause" message from host or operator through operator console or a ControlJob. PauseEvent has occurred.	PAUSED	Send a "Paused" event to the host.	Process jobs which have not started can be modified in this state.
9	PAUSED	Receive "Resume" message from host or operator through operator console.	EXECUTING	Commence initiating process jobs. Send a "Resumed" event to the host.	
10	EXECUTING	All the ProcessJobs specified for the ControlJob have completed.	COMPLETED	Send a "Complete" event to the host.	It may include post processing completion.
11	ACTIVE	Receive "CJStop" message from host or operator through operator console or all the process jobs under the ControlJob have been stopped and material processing is stopped.	COMPLETED	Send a "Stopped" event to the host.	
12	ACTIVE	Receive "CJAbort" command from host or operator through operator console or all the process jobs under the ControlJob have been aborted and material processing is aborted.	COMPLETED	Send "Aborted" message to the host.	
13	COMPLETED	The ControlJob is deleted.	(No state)		Equipment should perform this function automatically for COMPLETED jobs.

10 Control Job Queue Model

10.1 The Queuing mechanism for control jobs will generally operate under FIFO (First in- First Out) constraints. The commands used to monitor queue status and prevent deadlock conditions are specified here.

10.2 *Queue Integrity*

10.2.1 To maintain queue integrity, only one operation shall be performed at any given time (e.g., the "Create" request shall be rejected by the equipment if the CJHOQ service is being processed). The Queue is defined to be "locked" while it is performing an operation (and refusing any further operation until completion of the current operation).

10.3 *Head of Queue Service*

10.3.1 The Head of Queue service (CJHOQ) shall operate under the following rules:

1) All control jobs positioned between the specified control job and the head of the queue (including the job currently positioned at the head) will be moved back one position. The specified control job will then be moved into the head of queue position.

2) When the CJHOQ command is invoked, the queue will be "locked" to maintain integrity.

3) In the case where only one control job exists in the queue, the command will perform no action on the queue.

10.4 *DeadLocks*

10.4.1 The Head of Queue service (CJHOQ) requests a specific control job to be set as the next control job to be run. In order to prevent deadlock when the job at Head of Queue and the job in the SELECTED state are both awaiting material delivery, the CJHOQ command may be used to move a different job to the head of the queue position. The potential dead lock is then broken by issuing the DE-SELECT service request.

10.5 *Utilization of Queue for Control Job Priority Management*

10.5.1 Similar to Deadlock, certain cases may arise where a job at the head of the queue cannot be selected due to a lack of processing resources. In this case, DE-SELECT command shall be rejected and consequently a series of DE-SELECT and CJHOQ commands may be issued in an attempt to find a job which can transition to SELECTED state.

10.5.2 To force a "hot job" to be the next job run, it could be necessary to send the CJStop message to the SELECTED job. This case only happens when the job at the head of the queue (the hot job) does not yet have resources available.

NOTE 3: Most equipment where this is possible can support parallel execution of Control Jobs. Management of the queue(s) in this case is currently beyond the scope of this standard.

10.6 *Space in the Queue*

10.6.1 The QueueAvailableSpace variable data item is used to query the number of control job openings within the queue. The QueueAvailableSpace shall function according to the following rules:

1) This variable can only be guaranteed valid when no other operations are being performed simultaneously on the queue. For example, don't request this variable while a Create control job command is being processed by the equipment.

2) This variable shall be incremented whenever a control job in the queue is de-queued. That is, when a "Cancel", "Abort", or "Stop" command has been received and completed while the control job is queued. It should also be incremented when the SELECTED state is entered by a control job. However, if this transition occurs as a result of the "Deselect" command (at least one job in queue, and a control job in the SELECTED state), no change should be made to the variable value.

3) This variable should be decremented whenever a control job joins the queue. That is, when a "Create" command is received and accepted. It should also be decremented if a "Deselect" command is issued on a control job in the SELECTED state and no other jobs currently reside in the queue.

4) The equipment should reject the "Create" command when this variable is equal to zero.

10.7 *Getting a List of Queued Jobs*

10.7.1 The QueuedCJobs Variable Data Item is used to query the names of the control jobs currently residing in the queue. It lists items starting at the head of the queue.

10.7.2 The QueuedCJobs Variable Data Item shall function according to the following rules:

1) This variable can only be guaranteed valid when no other operations are being performed simultaneously on the queue.

2) This variable list will be modified whenever a successful "Create" command is received. Additionally, "Cancel", "Abort", and "Stop" commands issued on control jobs residing in the queue will modify this variable list. Any use of the "Deselect" command will also modify the variable list.

11 Properties for Carriers

11.1 Compliance to Control Job Management requires that the equipment track the status of individual carriers. In particular, the factory needs to know the status of carriers with respect to control jobs. Carriers may have various properties that are beyond the scope of this standard. However, there are specific properties that are needed for Control Jobs.

11.2 *Carrier Verification*

11.2.1 The equipment needs to know when a carrier has been verified as proper. Only process jobs associated with the carrier that has been verified shall be initiated by a control job. Depending on the equipment's capabilities, verification may include verification by an equipment read of the carrier's ID (identification) and the reading of the substrate (e.g., wafer) slot map. The ControlJob determines if the carrier is verified by checking the carrier's attributes that indicate the level to which a carrier has been verified. This section is reserved for further specification of this requirement.

11.3 *Carrier Completion for Control Jobs*

11.3.1 A carrier that has been loaded onto the equipment may go through three stages: first, it is in the "not accessed" stage until it is accessed by a control job. When the carrier is at the substrate port and unloading of the substrates within the carrier begins, the carrier enters the "in access" stage. Once it enters this stage, it remains in this stage until all material has been returned to the carrier, no active control job exists that is using it and no control jobs in the queue exist that reference it. The equipment shall provide a property of the carrier that shows the current stage of all carriers. The equipment shall provide a "CarrierComplete" or "CarrierStopped" event for each change in stage. The event when the carrier enters the "in access" stage informs the host that the carrier may not be removed from the equipment. The event when the carrier enters the "completed" stage informs the host that the carrier may be removed.

12 Requirements - Service Definitions

12.1 *Service Definitions*

Table 4 Service Definitions Table

Message Service Name	*Type*	*Description*
CJStart	R	To start a ControlJob.
CJPause	R	To request a ControlJob to pause.
CJResume	R	To request a PAUSED ControlJob to go to the EXECUTING state.
CJCancel	R	To request a ControlJob to be removed from the queue.
CJDeselect	R	To request a ControlJob to be deselected; it will no longer be the next job to run.
CJStop	R	To request a ControlJob to stop. Used to discontinue a job without risk to the material.
CJAbort	R	To request a ControlJob to abort. Used to discontinue a job on equipment that may be malfunctioning. Material is at risk when this command is issued.
CJHOQ	R	To request a particular ControlJob to be set as the next control job to be SELECT'ed.

12.2 *Parameter Definitions*

Table 5 Parameter Definitions Table

Parameter Name	*Description*	*Format: Possible Value*
ACKcode	To return indication of result of service call.	Enumeration: SUCCESS, FAILURE
Action	See Section 12.2.1	Enumeration: SAVEJOBS REMOVEJOBS
CtrlJobID	ObjID (object identifier) of a control job.	Text
ErrorCode	Contains the code for the specific error found.	Enumerated (ACKcode must equal FAILURE): *All services:* • Unknown object instance • Parameters improperly specified • Insufficient parameters specified *CJStart:* • Command not valid for current state *CJPause:* • Command not valid for current state *CJResume:* • Command not valid for current state *CJCancel:*

Parameter Name	Description	Format: Possible Value
		• Job cancelled • Command not valid for current state *CJDeselect:* • Command not valid for current state • Busy (when queue empty or resources for HOQ job would not be available) *CJStop:* • Job stopped *CJAbort:* • Job aborted *CJHOQ:* • Command not valid for current state
ErrorInfo	The parameter may be null or excluded on a SUCCESS.	(List of) ErrorCode ErrorText
ErrorText	Description of the error.	Text
Status	Information returned by service provider which indicates the result of the service call.	Structure: ACKcode ErrorInfo

12.2.1 *Action Parameter* — The Control Job services CJCancel, CJStop, and CJAbort can all cause Process Jobs to be terminated, as specified in SEMI E40. In these Control Job services, the parameter "Action" specifies the disposition of the Process Job objects for the terminated Process Jobs. "Action" specifies one of the following enumerated values: SAVEJOBS and REMOVEJOBS. This Action parameter only affects Process Jobs that are in the QUEUED/POOLED state.

12.3 *Message Details*

12.3.1 This section specifies parameter usage by the service messages.

12.3.2 *Creating ControlJobs* — ControlJobs shall be created by using the OSS (SEMI E39) Object Create message. The following table defines the use of the AttrSetting arguments to the Object Create service. Note: ObjType is a required argument of Object Create and therefore should not be reset by including it as an AttrSetting argument. In the table M indicates mandatory, O indicates optional, and R specifies restricted (shall be ignored if used).

12.3.3 The process jobs specified for a control job must exist prior to calling this message. If a process job does not exist, the Create service shall fail and the ObjStatus shall return a list of any PRJob identifiers that were not present. The Create request shall be rejected if the ControlJob queue is full. Newly created control jobs will be put at the end of the queue.

Table 6 SetAttr Arguments Table

Control Job Attribute Name	*Use as AttrSetting of Create Service*
ObjID	M
ObjType	R
CurrentPRJob	R
DataCollectionPlan	O
CarrierInputSpec	M
MtrlOutSpec	M
MtrlOutbyStatus	O
PauseEvent	O
ProcessingCtrlSpec	M

Control Job Attribute Name	*Use as AttrSetting of Create Service*
ProcessOrderMgmt	M
StartMethod	M
State	R

12.3.4 *CJStart* — Starts jobs that require a user start. The host sends this command only to a Control Job from which it has received a WAITINGFORSTART event.

Table 7 CJStart Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Status	-	M	Success or failure

12.3.5 *CJPause* — The ControlJob shall stop initiating process jobs. Process jobs in the EXECUTING state are not affected by this command.

Table 8 CJ Pause Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Status	-	M	Success or failure

12.3.6 *CJResume* — The ControlJob shall resume initiating process jobs.

Table 9 CJResume Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Status	-	M	Success or failure

12.3.7 *CJCancel* — Used to remove a ControlJob from the Queue. The command shall only succeed for jobs in the QUEUED state.

Table 10 CJCancel Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Action	M	-	
Status	-	M	Success or failure

12.3.8 *CJDeselect* — Shall only succeed for jobs in the SELECTED state. Deselected jobs must trade places with the job that is currently at the head of the queue. If the job at the head of the queue cannot transition to the SELECTED state, then the deselect request shall be rejected. See the section on Control Job Queue Model for information on breaking possible deadlocks.

Table 11 CJDeselect Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Status	-	M	Success or failure

12.3.9 *CJStop* — Stops the ControlJob from initiating any more process jobs. Equipment should issue a STOP command to all running process jobs. When the currently running process jobs have stopped, the ControlJob will send a complete event with a status code indicating the ControlJob has stopped. ControlJobStop shall only succeed on a job in the ACTIVE or QUEUED states. When CJStop is issued in the QUEUED state, its affect will be identical to that of CJCancel.

Table 12 CJStop Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Action	M	-	
Status	-	M	Success or failure

12.3.10 *CJAbort* — Stops the control job from initiating any more process jobs. The currently running process jobs are sent the Abort command by the equipment. When the equipment has detected the successful ABORT of currently running process jobs, the ControlJob shall send a complete event with a status code indicating the job was aborted. ControlJobAbort shall only succeed on a job in the ACTIVE or QUEUED states. When CJAbort is issued in the QUEUED state, its affect will be identical to that of CJCancel. The equipment due to a serious alarm situation (operator risk) may internally generate this command.

Table 13 CJAbort Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Action	M	-	
Status	-	M	Success or failure

12.3.11 *CJHOQ* — The other jobs in the queue are pushed back (rest of queue order remains unchanged).

Table 14 CJHOQ Service Parameter Definitions Table

Parameter	*Req/Ind*	*Rsp/Cnf*	*Comment*
CtrlJobID	M	M	Indicate which job
Status	-	M	Success or failure

13 Variable Data

13.1 For objects defined by Control Job Management, the identifiers of the objects and all of the attributes of the objects shall be available for inclusion in event reports associated with those objects. The following attribute is the most likely to be used: CtrlJobID.

13.2 The following table provides the definition of additional Variable Data that equipment shall support for Control Job Management.

Table 15 Variable Data Definitions Table

Variable Name	*Description*	*Type*	*Access*	*Comment*
CtrlJobID	Control job identifier, available to be used in control job related event reports.	Text	RO	
QueuedCJobs	This is an ordered list of control jobs currently in the Queue. The first job in the list is the job at the head of the Queue.	(list of) Text	RO	Each list item is a control job identifier.
QueueAvailableSpace	Indicates number of jobs which the Queue can accept.	Numeric	RO	This value cannot be negative. When it is zero it indicates that the queue is full.

Variable Name	Description	Type	Access	Comment
SetUpName	Host sets this to define the operational condition of the equipment.	Text	RW	If the equipment is manipulated locally, it should set this variable to "unknown", otherwise it returns the value set by the host (when requested).

14 Additional Requirements

14.1 *Serial Execution of Control Jobs*

14.1.1 Control jobs are initiated in sequential order by the equipment. The order is based on the queue. A ControlJob shall not issue a complete event (message) until all substrates have been placed in destination carriers. However, in many cases equipment must support multiple control jobs running at once; in order to support the factory requirement for equipment productivity. This will be particularly true for multi-module equipment. The next ControlJob in the queue shall start as soon as possible after processing has begun for the last ProcessJob in the previous ControlJob's processing control specification.

14.2 *Parallel Execution of Control Job*

14.2.1 Some equipment may be able to support parallel execution of control jobs. The supplier must fully document this behavior and any additional services needed to manage it.

14.3 *Modifying Control Jobs*

14.3.1 Control jobs shall be modifiable if and only if they are not in either the EXECUTING or COMPLETED states. Jobs shall be modified by using OSS to change their attributes. Modifications shall be rejected if the equipment is in the wrong state or requested value changes are out of range.

14.4 *Set-up, Pre- and Post-Conditioning*

14.4.1 Whenever equipment has completed some processing work, with or without material, the equipment can be considered to be "set-up" for a certain process capability. Information about the equipment's set-up is important to the factory in determining the best material routing. The SetupName variable defined in this standard is set by the host after host directed processing or changes to equipment constants. If the equipment is used for processing while off-line or not under host command, the value of the variable shall be set to "unknown". It shall also be set to "unknown" immediately after any changes to equipment constants.

14.5 *Event Relationships*

14.5.1 This section is reserved for specification of the relationship between process job events and control job events.

14.5.2 PRJob Paused

14.5.3 PRJob Aborted or Stopped

15 Compliance

15.1 Implementations compliant to this standard shall implement all the messages as specified in Section 12. All mandatory parameters must be supported. The supplier shall document support for any of the optional parameters. Any additional parameters and messages shall be fully documented by the supplier. Additional messages shall be used to support additional functionality and not as a replacement for any of messages specified herein.

15.2 Table 16 provides a checklist for Control Job Mangement (CJM) compliance.

Table 16 CJM Compliance Statement

Fundamental CJM Requirements	*CJM Section*	*Implemented*	*CJM Compliant*
Control Job Object	8	☐ Yes ☐ No	☐ Yes ☐ No
Control Job State Model	9	☐ Yes ☐ No	☐ Yes ☐ No
Control Job Queue Model	10	☐ Yes ☐ No	☐ Yes ☐ No
Carrier Properties	11	☐ Yes ☐ No	☐ Yes ☐ No
Service Message Implementation	12	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data	13	☐ Yes ☐ No	☐ Yes ☐ No
Events	7.3.2	☐ Yes ☐ No	☐ Yes ☐ No
Additional Requirements	14	☐ Yes ☐ No	☐ Yes ☐ No
Additional CJM Capabilities	*CJM Section*	*Implemented*	*CJM Compliant*
none			

RELATED INFORMATION 1
APPLICATION NOTES

NOTE: The material contained in these Applications Notes is not an official part of SEMI E94 and is not intended to modify or supersede the official standard. Rather, these notes are auxiliary information describing possible methods for implementing the protocol described by the standard and are included as reference material. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

Service messages are presented with a "C" language style of application interface. For illustrative purposes values for variables may be included using the "=" in the argument list. If not used the optional arguments are not shown. Service names (e.g., PRJob) are prefixed to function name. The scenarios assume processing is for wafers. The services used in these scenarios are PRJob for Processing Management, ControlJob for Control Job Management, and CMS for Carrier Management Services.

R1-1 ControlJob for a Batch Processing Tool

R1-1.1 Tool processes the contents of a single carrier as a batch. This example demonstrates the simplicity of using control jobs for a simple situation. Wafer order is maintained, and material is returned to the source carrier.

#	*Comment*	*Dir*	*Message*	*CJS*	*PJS*
1	Create the process job.	H->E	PRJobCreateEnh (PRJobID=prj01_04, Mtrl = CS001, RecID=ILD3)	No state	No state
2		H<-E	PRJobCreateAck (PRJobID, PRJobStatus)		In POOL
3	Request a control job. Material out specification maintains wafer order from source carrier to destination carrier.	H->E	ControlJobCreate (CtrlJobID=cjf01_01, ProcessingCtrlSpec= (prj01_04, null,null), MtrlOutSpec=(CSA01,null,null), MaterialIn= CS001, StartMethod=AUTO)		
4	Request accepted.	H<-E	ControlJobCreateAck (CtrlJobID=cjf01_01, JobStatus)	QUEUED	
5	No CJ in selected state so the newly created job immediately transitions.	H<-E	Event (CJSELECTED, CtrlJobID=cjf01_01)	SELECTED	
6	A carrier for the selected control job arrives.	H<-E	Event (CARRIERIDREAD, CID=CS001)		
7	The equipment recognizes it and starts execution of the ControlJob.	H<-E	Event (ControlJobStart, cjf01_01)	EXECUTING	
8	ControlJob starts the ProcessJob; begins loading wafers to the processing boat.	H<-E	Event (PRJOBSETUP, prj01_01)		ACTIVE/ SETUP
9	Material processing starts after all material is in the processing boat.	H<-E	Event (PRJOBPROCESSING, prj01_04)		ACTIVE/ PROCESSING
10	Equipment begins to return material to the source carrier (= destination carrier).	H<-E	Event (PROCESSINGCOMPLETE, PRJob=prj01_04)		ACTIVE/ PROCESSING COMPLETE
11	Carrier is filled with wafers.	H<-E	Event (CarrierComplete=CS001)		
12	Host wants to get it.	H->E	Rcommand (CarrierOut=CS001)		

#	Comment	Dir	Message	CJS	PJS
13	Equipment indicates carrier can now be picked up.	H<-E	Event (ReadytoUnload, CarrierID=CS001, PortID)		
14		H<-E	Event (PRJOBCOMPLETE, PRJob=prj01_01,)		No state
15	Jobs may complete before the carrier is picked up.	H<-E	Event (ControlJobCompleted=cjf01_01, status=OK)	COMPLETE	

R1-2 ControlJob for a Single Wafer Processing Tool

R1-2.1 Will be added later.

R1-3 ControlJob for Single Wafer Processing with Recipe Variable Parameters

R1-3.1 Will be added later.

R1-4 Error Recovery of Batch Tool ControlJob, Carrier Slot Map Failure

R1-4.1 Will be added later.

R1-5 Carrier Swap During Processing

R1-5.1 Multiple carriers are loaded to a batch processing tool that has buffering, after carriers are emptied, they are removed and new empty carriers are loaded. In this example, it requires four carriers for a batch.

CJS = Control Job State, PJS = Process Job State

#	Comment	Dir	Message	CJS	PJS
1	Create the process job.	H->E	PRJobCreateEnh (PRJobID=prj01_01, Mtrl = CSA01,CSA02, CSA03, CSA04, RecID=ILD1)	No state	No state
2		H<-E	PRJobCreateAck (PRJobID, PRJobStatus)		In POOL
3	Request a control job. Material out specification maintains wafer order from source carrier to destination carrier.	H->E	ControlJobCreate (CtrlJobID=cjf01_01, ProcessingCtrlSpec= (prj01_01, null,null), ProcessOrderMgmt = ARRIVAL, MtrlOutSpec=(((CSA01,null),(CSB01, null)), ((CSA02, null), (CSB02,null)), ((CSA03, null), (CSB03,null)), ((CSA04, null), (CSB04,null))), MaterialIn= (CSA01,CSA02, CSA03, CSA04), StartMethod=AUTO)		
4	Request accepted.	H<-E	ControlJobCreateAck (CtrlJobID=cjf01_01, JobStatus)	QUEUED	
5	No CJ in selected state so the newly created job immediately transitions.	H<-E	Event (CJSELECTED, CtrlJobID=cjf01_01)	SELECTED	
6	A carrier for the selected control job arrives.	H<-E	Event (CARRIERIDREAD, CID=CSA01)		
7	The equipment recognizes it and starts execution of the ControlJob.	H<-E	Event (ControlJobStart, cjf01_01)	EXECUTING	

#	Comment	Dir	Message	CJS	PJS
8	ControlJob starts the ProcessJob; begins loading wafers to the processing boat.	H<-E	Event (PRJOBSETUP, prj01_01)		ACTIVE/SETUP
9		H<-E	Event (CarrierEmpty,CSA01)		
10	The next carrier arrives.	H<-E	Event (CARRIERIDREAD, CSA02)		
11		H->E	Rcommand (CarrierOut=CSA01)		
	As carriers are emptied they are removed.		Steps 9 through 11 are repeated 3 more times		
12	Material processing starts after all material is in the processing boat.	H<-E	Event (PRJOBPROCESSING, prj01_01)		ACTIVE/ PROCESSING
13	Output carriers begin to arrive.	H<-E	Event (CARRIERIDREAD, CID=CSB01)		
	Until all output carriers arrive.		Step 13 is repeated 3 more times		
14	Equipment begins to load output carriers.	H<-E	Event (PROCESSINGCOMPLETE, PRJob=prj01_01)		ACTIVE/ PROCESSING COMPLETE
15	First output carrier is filled with wafers.	H<-E	Event (CarrierComplete=CSB04)		
16	Host wants to get it.	H->E	Rcommand (CarrierOut=CSB04)		
17	Gets rest of carriers.		Steps 15 and 16 are repeated 3 more times		
18		H<-E	Event (PRJOBCOMPLETE, PRJob=prj01_01,)		No state
19		H<-E	Event (ControlJobCompleted=cjf01_01, status=OK)	COMPLETE	

R1-6 Using Cleaning Wafers

R1-6.1 For this scenario we assume a single wafer processing tool, such as an RIE. The tool has three fixed load ports; two for product material, one for cleaning material. A cleaning wafer is run before the 1st and 13th wafer of each carrier of product wafers. Show the load and unload of the cleaning wafers and the running of the ControlJob for processing material. Note that control jobs do not provide functionality for dispositioning collateral material consumed during processing (the cleaning wafers). The equipment is responsible for providing mechanisms to determine when this collateral material has been consumed (should be replaced).

Step #	Comment	Dir	Message	CJS	PJS
1	Remove the previously spent wafers.	H<-E	Event (ReadytoUnload, PortID=Cleaning, CarrierID=CC01)	No state	No state
2	After host picks up the spent wafers, the equipment is ready to load.	H<-E	Event (ReadytoLoad, PortID=Cleaning)		
3	Delivered material is identified.	H<-E	Event (CarrierIDRead, CarrierID=CC02)		
4	Host directs carrier to be moved to the wafer access position.	H->E	CMSProceedwithCarrier (CarrierID=CC02)		
5	Create a job to run a cleaning wafer.	H->E	PRJobCreate (PRJobID=prj01_01, Mtrl = ACleanWafer, RecID=CleaningProcess)		

Step #	*Comment*	*Dir*	*Message*	*CJS*	*PJS*
6		H<-E	PRJobCreateAck (PRJobID, PRJobStatus)		In POOL
7	Create the jobs for the first 12 wafers in the carrier (PW1-12).	H->E	PRJobDuplicateCreate (PRJobSpecList = (prj01_02, PW1), (prj01_03, PW2), ..(prj01_13, PW12), RecID = P64ME5, Start=AUTO, MtrlType=WAFER)		
8		H<-E	PRJobCreateAck (PRJobIDList, PRJobStatus)		In POOL
9	Another cleaning wafer	H->E	PRJobCreate (PRJobID=prj01_14, Mtrl = ACleanWafer, RecID=CleaningProcess)		
10		H<-E	PRJobCreateAck (PRJobID, PRJobStatus)		In POOL
11	The rest of the product wafers	H->E	PRJobDuplicateCreate (PRJobSpecList = (prj01_15, PW13), (prj01_16, PW14), ..(prj01_27, PW25), RecID = P64ME5, Start=AUTO, MtrlType=WAFER)		
12		H<-E	PRJobCreateAck (PRJobIDList, PRJobStatus)		In POOL
13	Now the control job	H->E	CtrlJobCreate (CtrlJobID=cj01_01, ProcessingCtrlSpecList = (prj01_01, null, null), (prj01_02, null, null), ..(prj01_27, null, null), CarrierInputSpec = CP01, Start = AUTO, ProcessOrderMgmt = LIST, MtrlOutSpec = (CP01, null, CP01,null)		
14		H<-E	CtrlJobCreateAck (ID = cj01_01, Status=OK)	QUEUED -> SELECTED	
15		H<-E	Event (ReadytoLoad, PortID = P1)		
16		H<-E	Event (CarrierIDRead, CarrierID=CP01)		
17		H->E	CMSProceedwithCarrier (CP01)		
18		H<-E	Event (CtrlJobStart = cj01_01)	EXECUTING	
	Host might not even have these sent.		Lots of PRJob Start and End Events		
19		H<-E	Event (CtrlJobComplete = cj01_01)	COMPLETED	
20		H<-E	Event (ReadytoUnload, CarrierID = CP01)		

SEMI E94.1-1101
SPECIFICATION FOR SECS-II PROTOCOL FOR CONTROL JOB MANAGEMENT (CJM)

This provisional specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001, to be published November 2001.

1 Purpose

1.1 This document maps the services and data of SEMI E94 to SECS-II streams and functions and data definitions.

2 Scope

2.1 This is a specification covering equipment supporting automated control job management.

2.2 This document applies to all implementations of SEMI E94 that use the SECS-II message protocol (SEMI E5). Compliance to this standard requires compliance to both SEMI E94 and SEMI E5.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification applies to semiconductor equipment that also use SEMI E40 Process Jobs.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E40 — Standard for Processing Management (PJM)

SEMI E53 — Event Reporting (ER)

SEMI E94— Provisional Specification for Control Job Management (CJM)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Mapping

5.1 This section shows the specific SECS-II streams and functions that shall be used for SECS-II implementation of the services defined in SEMI E94, as well as the parameter mapping for data attached to services.

5.2 *Message Mapping*

5.2.1 *Services Message Mapping*

5.2.1.1 Table 1 defines the relationships between SEMI E94 services and SECS-II messages.

Table 1 Services Message Mapping Table

Service Name	*Stream, Function*	*SECS-II Message Name*
Create Object	S14,F9/10	Create Object Request/Acknowledge (SEMI E39.1)
CJAbort	S16,F27/28	Control Job Command Request/Acknowledge
CJCancel	S16,F27/28	Control Job Command Request/Acknowledge
CJDeselect	S16,F27/28	Control Job Command Request/Acknowledge
CJHOQ	S16,F27/28	Control Job Command Request/Acknowledge
CJPause	S16,F27/28	Control Job Command Request/Acknowledge
CJResume	S16,F27/28	Control Job Command Request/Acknowledge
CJStart	S16,F27/28	Control Job Command Request/Acknowledge
CJStop	S16,F27/28	Control Job Command Request/Acknowledge

5.2.2 *Event Message Mapping*

5.2.2.1 Table 2 defines the relationships between SEMI E94 collection events and SECS-II messages.

Table 2 Event Message Mapping Table

Event Name	*Stream, Function*	*SECS-II Message Name*
All state model transitions	If SEMI E30 style events: S6,F11/12 If SEMI E53 style events: S6,F11/12 S6,F13/14	If SEMI E30 style events: Event Report Send/Acknowledge If SEM E53 style events: Event Report Send/Acknowledge Annotated Event Report Send/Ack

5.2.3 *Parameter Mapping*

5.2.3.1 Table 3 defines the relationships between SEMI E94 service parameters and SECS-II data definitions.

Table 3 Parameter to SECS-II Data Items Mapping

Parameter Name	*Range*	*SECS-II Data Item*
ACKcode	TRUE, FALSE	ACKA
Action	SAVEJOBS, REMOVEJOBS	CPVAL (U1) 0 = SAVEJOBS. This command does not destroy the Process Jobs specified by this Control Job. 1 = REMOVEJOBS. This command destroys all Process Jobs specified by this Control Job.
CtrlJobID	1–80 characters (Conforms to ObjID in SEMI E39.1, Section 6.)	OBJID
ErrorCode	Enumerated	ERRCODE
ErrorInfo	Error	L,2 1. ErrorCode 2. ErrorText
ErrorText	1–80 characters	ERRTEXT
Status	Acknowledgement and error	L,2 1. ACKcode 2. ErrorInfo

5.2.4 *SECS-II Data Items without Corresponding SEMI E94 Parameters*

5.2.4.1 Table 4 contains the SECS-II data items that do not correspond to SEMI E94's service parameter.

Table 4 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
Used to identify control job commands.	CTLJOBCMD
Used to satisfy SECS-II conventions for linking a multi block inquiry with subsequent multi block message.	DATAID

5.2.5 *Variable Data Item Mapping*

5.2.5.1 Table 5 shows the specific SECS-II data classes, and formats needed for SECS-II implementations of SEMI E94 variable data items.

Table 5 Variable Data Item Mapping

Variable Name	*Class*	*Format*
CtrlJobID	DVVAL	<OBJID>
QueueAvailableSpace	SV	5() (U1, U2, U4, U8)
QueuedCJobs	SV	L,n n = number of queued control jobs 1. <CtrlJobID$_1$> … n. <CtrlJobID$_n$>
SetUpName	ECV	20 (A[1..80]) Zero length string is used by the equipment to indicate “unknown”.

6 SECS-II Attribute Definitions

6.1 *ControlJob Object SECS-II Attributes Definitions*

6.1.1 The following are the SECS-II structure definitions for the E94 ControlJob Object.

Table 6 ControlJob Object Attribute Definitions

Attribute Name	*Attribute Data Form: SECS-II Structure*
“ObjType”	20 (A) “ControlJob”
“ObjID”	<OBJID> CtrlJobID (Conforms to the restrictions of ObjID as specified in SEMI E39.1, Section 6.)
“CarrierInputSpec”	L,n n = number of input carriers 1. <CARRIERID$_1$> … n. <CARRIERID$_n$>
“CurrentPRJob”	L,n n = number of process jobs 1. <PRJOBID$_1$> … n. <PRJOBID$_n$>
“DataCollectionPlan”	20 (A) DataCollectionPlan

Attribute Name	*Attribute Data Form: SECS-II Structure*
"MtrlOutByStatus"	L,n n = number of status dispositions 1. L,2 1. 51 (U1) MaterialStatus$_1$ 2. L,2 DestinationMap$_1$ 1. <CARRIERID$_{1,1}$> 2. L,m m = number of slots 1. <SLOTID$_1$> … m. <SLOTID$_m$> … n. L,2 1. 51 (U1) MaterialStatus$_n$ 2. L,2 DestinationMap$_n$ 1. <CARRIERID$_{n,1}$> 2. L,m m = number of slots 1. <SLOTID$_1$> … m. <SLOTID$_m$> If m = 0, the substrates may be placed by the equipment in any available slot.
"MtrlOutSpec"	L,p p = number of mapping source/destination pairs 1. L,2 1. L,2 SourceMap$_1$ 1. <CARRIERID$_{1,1}$> 2. L,m m = number of slots 1. <SLOTID$_1$> … m. <SLOTID$_m$> 2. L,2 DestinationMap$_1$ 1. <CARRIERID$_{1,2}$> 2. L,m m = number of slots 1. <SLOTID$_1$> … m. <SLOTID$_m$> … p. L,2 1. L,2 SourceMap$_p$ 1. <CARRIERID$_{p,1}$> 2. L,n n = number of slots 1. <SLOTID$_1$> … n. <SLOTID$_n$> 2. L,2 DestinationMap$_p$ 1. <CARRIERID$_{p,2}$> 2. L,n n = number of slots 1. <SLOTID$_1$> … n. <SLOTID$_n$>

Attribute Name	*Attribute Data Form: SECS-II Structure*
"PauseEvent"	L,n n = number of collection events 1. <CEID$_1$> … n. <CEID$_n$>
"ProcessingCtrlSpec"	L,p p = number of process jobs assigned to control job 1. L,3 1. <PRJOBID$_1$> 2. L,m ControlRule$_1$ 1. L,2 1. 20 (A) RuleName$_1$ 2. (Any format) RuleValue$_1$ … m. L,2 1. 20 (A) RuleName$_m$ 2. (Any format) RuleValue$_m$ 3. L,n OutputRule$_1$ 1. L,2 1. 51 (U1) MaterialStatus$_1$ 2. (Any format) OutputRuleValue$_1$ … n. L,2 1. 51 (U1) MaterialStatus$_n$ 2. (Any format) OutputRuleValue$_n$ … p. L,3 1. <PRJOBID$_p$> 2. L,m ControlRule$_p$ 1. L,2 1. 20 (A) RuleName$_1$ 2. (Any format) RuleValue$_1$ … m. L,2 1. 20 (A) RuleName$_m$ 2. (Any format) RuleValue$_m$ 3. L,n OutputRule$_p$ 1. L,2 1. 51 (U1) MaterialStatus$_1$ 2. (Any format) OutputRuleValue$_1$ … n. L,2 1. 51 (U1) MaterialStatus$_n$ 2. (Any format) OutputRuleValue$_n$ ControlRule 1) m = 0 indicates no ControlRule specified 2) RuleName and RuleValue are equipment specific OutputRule 1) n = 0 indicates no OutputRule specified 2) There is no defined OutputRuleValue. The content and format of OutputRuleValue is equipment dependent per SEMI E94 intent.

Attribute Name	*Attribute Data Form: SECS-II Structure*
"ProcessOrderMgmt"	51 (U1) ProcessOrderMgmt ProcessOrderMgmt is enumerated as follows: 1 = ARRIVAL 2 = OPTIMIZE 3 = LIST
"StartMethod"	11 (BOOLEAN) StartMethod StartMethod is as follows: TRUE – Auto FALSE – UserStart
"State"	51 (U1) State State is enumerated as follows: 0 = QUEUED 1 = SELECTED 2 = WAITINGFORSTART 3 = EXECUTING 4 = PAUSED 5 = COMPLETED

SEMI E95-1101
SPECIFICATION FOR HUMAN INTERFACE FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published February 2000.

1 Purpose

1.1 This standard addresses the area of processing content with the direct intention of developing common software standards, so that problems involving operator training, operation specifications, and efficient development can be resolved more easily.

1.2 This standard is written to be "tool-neutral" without reference to, or reliance on, specific capabilities of platforms or operating systems. Neither is it intended that choices of software tools or detailed implementation strategies be dictated.

1.3 Note that all figures in this standard are schematic, are not drawn to scale, and unless otherwise specified, are not intended to provide implementation details about number of buttons, button sizes, panel sizes, etc.

2 Scope

2.1 This standard specification applies to manufacturing equipment used in the production of semiconductors.

2.2 This standard may be applicable to other areas such as the manufacture of flat panel displays, but specific application to these areas is outside the scope of this document.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

None.

4 Terminology

4.1 *condition* — a property of a displayed object or value (textual or numeric) that visually indicates, if applicable, whether the current state of an object or the current value violates the defined bounds of normal operational states or parameters, whether that violation is categorized as a minor exception (a caution) or a severe exception (an alarm), and provides no visual indication if no exception has occurred.

4.2 *display objects* — user interface elements displayed on the screen, such as function selection buttons, keyboard input buttons, graphics representing the equipment, etc.

4.3 *functional area* — a grouping of one or more views presenting information and control capabilities to the user.

4.4 *icon* — an icon (diagrammatic image) is a bitmap or other image used in GUI environments such as windowing systems to show different types of objects, improve operability, and help the user better understand the functionality underlying buttons.

4.5 *navigation model* — the navigation model determines how a user interacts with a system to access functionality and information.

4.6 *salience* — a salience is a solid (or textured), colored border shown around a display object to indicate an alarm, caution, or other condition, or to draw the user's attention to the display object.

5 Requirements

5.1 Each of the following sections is designated with one of the following labels:

5.1.1 Sections designated:

Description	provide background information and set the context for subsequent specifications;
Mandatory	provide a specification of a requirement which shall both be present and implemented as specified;
Conditional	provide a specification of a requirement which shall be implemented as specified if such a feature is implemented on the tool;
Recommended	provide a recommended capability and implementation of that capability, but neither their presence nor their implementation is required.

5.2 *Basic Display Objects* Description

5.2.1 This section specifies the general appearance and behavior of basic display objects used throughout the interface, including buttons, saliences, and dialog boxes. It is intended that the use of other types of display objects (choose lists, data display and data entry fields, scroll-bars, etc.) is specifically allowed, and their use is at the discretion of the implementers.

5.2.1.1 There are two types of display objects; selectable and non-selectable. Some are selectable by the user to initiate or execute an action. Non-selectable graphics and user interface elements (such as pipes and text field labels, respectively) are read only, and no action is initiated or executed.

5.2.2 *Buttons*

5.2.2.1 *Button Size* Mandatory

5.2.2.1.1 When a touchscreen device is used, button sizes must be large enough to ensure selection on the targeted display.

5.2.2.2 *Button Dimensions* Recommended

5.2.2.2.1 It is recommended that buttons shall have a minimum dimension of approximately 1.5 cm on the shortest side. If a smaller size is used, the space between buttons must be increased to avoid selection errors. For installations where a keyboard and a mouse, light pen or other pointing device is available, button sizes in the navigation panel and the command panel may be made somewhat smaller (approximately 1–1.25 cm), and the size of the information panel increased proportionally.

5.2.2.3 *Button Behavior* Mandatory

5.2.2.3.1 One type of button behavior is momentary; that is, user selection of a button causes a brief display of the down (selected) state of the button, followed immediately by a display of the up (unselected) state. The other button behavior is two-state; the button remains in the down state after user selection. User re-selection of the button, and/or selection of another button, and/or selection of another display object restores the display of the up state. In some cases, the software will control the display of the down state or restore the up state, without direct user interaction.

5.2.2.3.2 For 2-D buttons, the down state shall be indicated by hatching, cross-hatching, or otherwise texturing the button in such a manner that does not obscure the button label.

5.2.2.4 *Button Text* Mandatory

5.2.2.4.1 Text for all button labels shall have the first letter of words capitalized unless it is an article or preposition not occurring at the beginning or end of the label, or unless the word's conventional usage is not capitalized. Button labels that are all capital letters are harder to read than mixed case labels. Additionally, text in all capitals appears larger, and the user may attach more importance to the button than necessary simply because the label is visually distracting.

5.2.3 *Saliences* Conditional

5.2.3.1 Saliences, colored, textured, or both shall be displayed around buttons and other display objects to indicate their condition, which may include caution, alarm, user attention required or requested, processing, unfinished task notification, and other conditions.

5.2.3.2 A salience is displayed to draw the user's attention to a display object when its condition is *not* normal or OK (in this case, the absence of a displayed salience shall indicate a normal or OK condition), or when the salience provides information that benefits the user in the performance of tasks or the monitoring of equipment functions and operations.

5.2.3.3 A salience shall not hide the display object it surrounds. Saliences shall not be used to indicate the state (open, closed, on, off, etc.) of display objects.

5.2.3.4 On color displays, alarm saliences shall appear bright red, caution saliences shall appear bright yellow, and processing and unfinished task saliences shall appear medium blue. User attention required or requested saliences, (for example, "Ready to Load," or "Ready to Unload") shall appear medium green.

5.2.4 *Dialog Boxes* Description

5.2.4.1 Dialog boxes are secondary windows used to display supplemental information, solicit information from the user, or report errors.

5.2.4.2 Dialog boxes are used to provide additional information to the user; to display detailed information not shown on the information panel for controlling the system, and to display detailed information for monitoring system operation.

5.2.5 *Dialog Boxes* Mandatory

5.2.5.1 Dialog boxes (which are always temporary) are displayed in response to some action initiated by the user. When displayed, a dialog box shall overlay a portion of the information panel, and shall not obscure the title panel. If invoked by user selection of a display object on the information or command panels, all the display objects on those two panels shall be disabled until the dialog box is dismissed. The title and navigation panels remain enabled. At the explicit request of the user, the dialog box is dismissed, and the underlying information is refreshed.

5.2.5.2 Dialog boxes contain a title bar at the top, a display (free use) area, and one or more dialog box window control buttons arranged horizontally at the bottom. The title bar text reflects the command or the nature of the event that invoked the dialog box. Dialog box window control buttons are centered on the width of the dialog box, with any other buttons (Apply, Log-out, etc.) right-aligned and visually separated from the window control buttons. If the underlying operating system will not allow this alignment, then it is allowed that other alignments may be used, but only if the alignment is consistent across all dialog boxes.

5.2.5.2.1 User selection of a dialog box control button controls the dismissal of the dialog box and, when applicable, controls whether the user accepts or rejects information or choices displayed, or desires no action be performed.

5.2.5.2.1.1 An "OK" dialog box control button, when selected by the user, indicates acceptance of any choices or user inputs made, if any, and causes the dismissal of the dialog box. If no choices or user inputs were made, selecting this button indicates acceptance of any default values displayed. If user choices or inputs are required, this button shall be disabled until the choices or inputs are made.

5.2.5.2.1.2 A "Cancel" dialog box control button, when selected by the user, indicates no action should be taken, causes the dismissal of the dialog box, and returns the user to the state that existed prior to the invocation of the dialog box.

5.2.5.2.1.3 A "Yes" dialog box control button is displayed when the dialog box message is in the form of a question. User selection indicates a positive response to the question asked and causes the dismissal of the dialog box.

5.2.5.2.1.4 A "No" dialog box control button is displayed when the dialog box message is in the form of a question. User selection indicates no action should be taken, causes the dismissal of the dialog box, and returns the user to the state that existed prior to the invocation of the dialog box.

5.2.5.2.1.5 A "Close" dialog box control button is displayed (often as the only dialog box control button) when the dialog box message contains only information and does not require the user to make or accept choices, and shall be used instead of an "OK" dialog box control button in this case. The "Close" dialog box control button shall also be used instead of a "Cancel" dialog box control button when the user cannot be returned to the state that existed prior to the invocation of the dialog box. User selection indicates no action should be taken and causes the dismissal of the dialog box.

5.2.5.2.1.6 An "Apply" dialog box control button, when selected by the user, indicates acceptance of any choices or user inputs made, if any, but does not dismiss the dialog box. This button shall be disabled until one or more user choices or inputs are made. After user selection of this button, it shall be disabled until additional choices or user inputs are made, if any.

5.2.5.3 Dialog boxes may not be resized or moved, but may display a button equivalent to the Cancel button in the title bar.

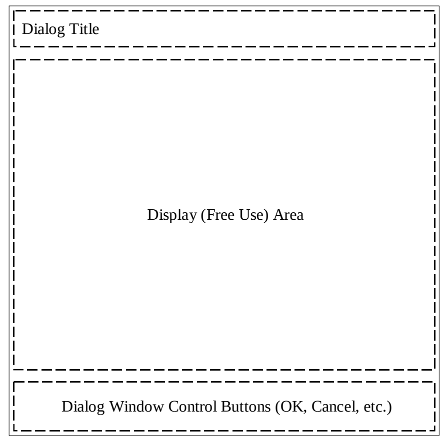


Figure 1
Dialog Box

5.2.5.4 Dialog boxes are classified into the following three types:

- Information dialog box
- Data input/selection dialog box
- Message dialog box

5.2.5.5 To be compliant with this specification, at least one of these dialog box types shall be supported.

5.2.6 *Information Dialog Box* — *Conditional*

5.2.6.1 This dialog box type is used to provide additional information to the user about some display object or topic addressed by the information panel. User selection of a display object on the information panel invokes an information dialog box, if appropriate for the display object selected. The window control button to dismiss the dialog box shall be the Close button. Use of an OK button in this case is not allowed.

5.2.6.2 Implementation of this dialog box type shall be conditional on the equipment having the capability of providing the required information.

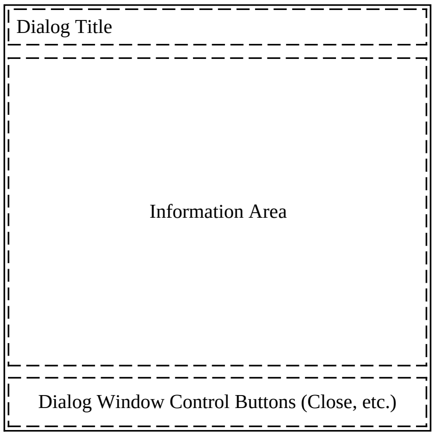


Figure 2
Information Dialog Box

5.2.7 *Input/Selection Dialog Box* Conditional

5.2.7.1 This dialog box type is used to request data input or selection from the user. If no keyboard or keypad is available, and the user must input characters, an on-screen representation ("mimic") of one or both shall be displayed as part of the dialog box. The window control buttons are the OK and Cancel buttons.

5.2.7.2 Implementation of this dialog box type shall be conditional on the presence of display objects that allow user input or selection.

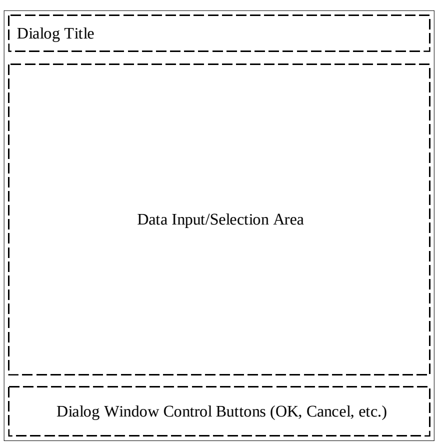


Figure 3
Data Input/Selection Dialog Box

5.2.8 *Message Dialog Box* Conditional

5.2.8.1 This dialog box type is used to provide a message to the user (including the reporting of errors) or to request confirmation of a user initiated action. The message text is located to the right of the icon. It is recommended that icons from the underlying operating system be used to represent the message type as follows:

- Information in the form of a simple message
- Progress, informing the user of an ongoing process
- Attention, alerting the user of possible danger, or inability to execute a command, or requesting confirmation (either as a statement or as a question)
- Error, informing the user of danger or inability to execute a command (if effect is severe)

5.2.8.2 Note that most style guides no longer recommend the use of a question mark icon when the message is phrased as a question, as its meaning could be ambiguous in some cases. The attention icon should be used instead.

5.2.8.3 The first two message types use the Close window control button. The second two use OK and Cancel, or Yes and No (and sometimes Cancel) if the message is phrased as a question. It is recommended that buttons or other display objects that would cause an error message be disabled in those circumstances.

5.2.8.4 Implementation of this dialog box type shall be conditional on the equipment having the capability of providing the required information.

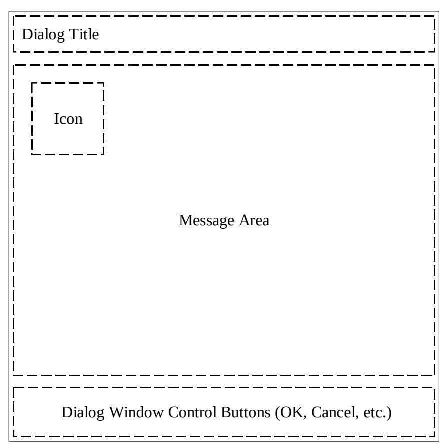


Figure 4
Message Dialog Box

5.3 *Basic Network Navigation Model* Mandatory

5.3.1 This standard specifies a simple navigation model designed specifically to minimize the number of actions and the amount of time required of the user.

5.3.2 The basic network navigation model is capable of displaying a number of views within a single level of hierarchy. The user does not have to traverse up and down menu or view "trees" when exercising control and monitoring tasks. As shown in the figure below, the basic navigation model is a network, supporting horizontal (lateral) transfer, at any time, between any of the functional areas in the interface. The basic network navigation model does not support more than one view in any functional area. Expansion of detail for views is typically implemented using dialog boxes.

5.3.3 Note that the diagram is schematic; it shows that user selection of a functional area shall display its associated information panel. Only one information panel shall be displayed at any time.

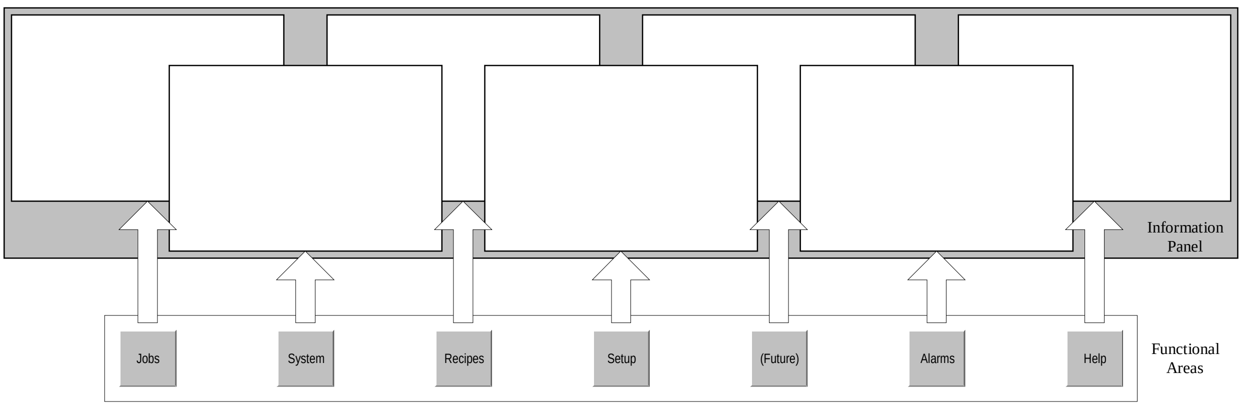


Figure 5
Basic Network Navigational Model

5.3.4 *Network Navigation Model with Sub-navigation* Conditional

5.3.4.1 While maintaining the same basic structure, this navigation model supports multiple views within functional areas on the network. If any functional area has more than one view, all functional areas in the interface shall consistently use one of the two view sub-navigation methods described below. Lateral transfer between any of the views within a functional area is supported either by providing a single row of tabs which may be selected to change views (Figure 6), or by providing view sub-navigation buttons (Figure 7) in a separate screen area dedicated solely to sub-navigation. Expansion of detail for each of these views is typically implemented using dialog boxes.

5.3.4.2 The grouping of tasks within functional areas reflects the natural flow of information, events, and tasks in a way that is familiar to the user and that directly supports the attainment of successful process and equipment performance goals. Functional areas are user task oriented, collecting together logically related monitoring and control functions, reducing the need to navigate between views.

5.3.4.3 Note that the diagrams are schematic; they show that user selection of a functional area shall display its associated information panel. Only one information panel shall be displayed at any time. Similarly, user selection of a tab or sub-navigation button displays only one of the views available at any time.

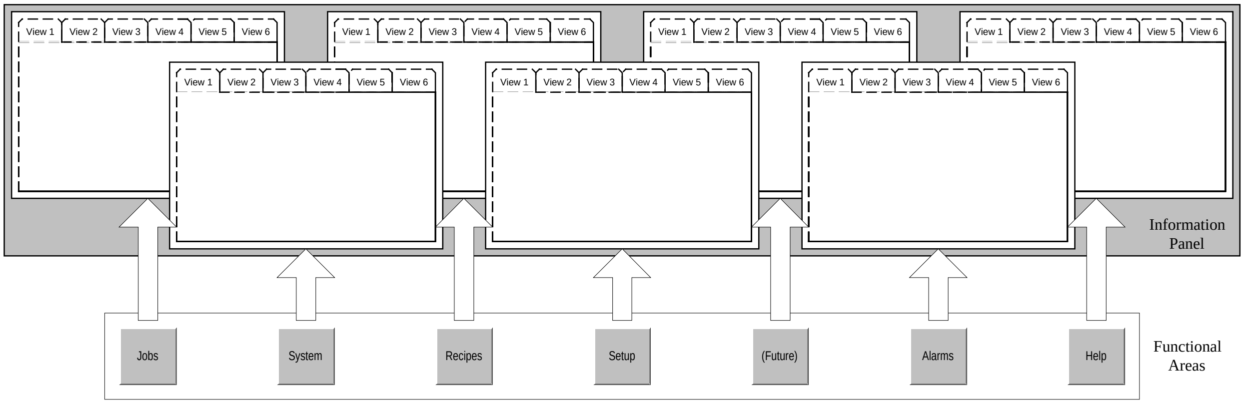


Figure 6
Network Navigation Model — Tab Sub-navigation

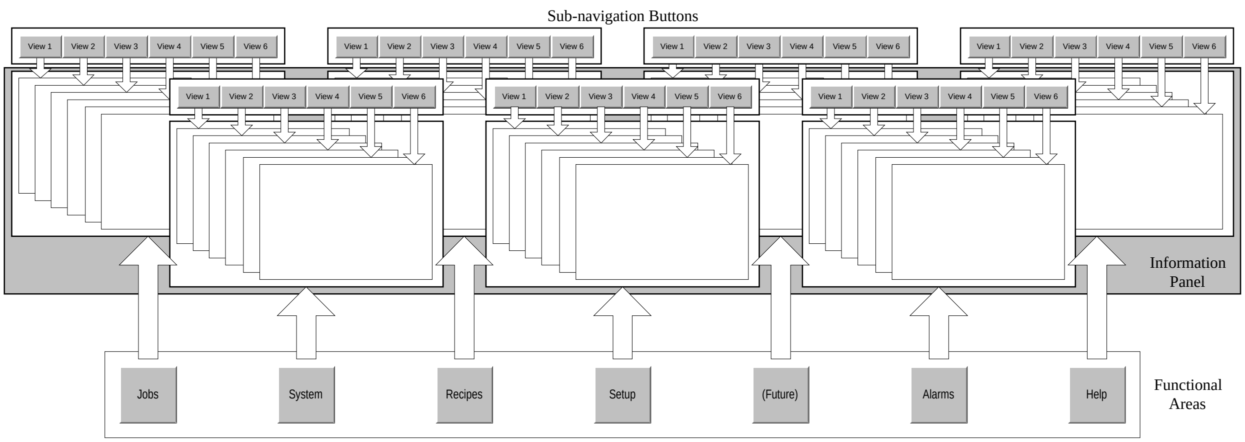


Figure 7
Network Navigation Model — Button Sub-navigation

5.3.5 *Display Layout* *Description*

5.3.5.1 The display layout is designed for ease of use with touchscreen input devices and does not require a keyboard or other pointing device. By dividing the screen into rectangular panels, provision is made to accommodate the display and input of information organized by the tasks users must accomplish in managing and monitoring processing, maintaining and repairing the equipment, and other relevant work.

5.3.6 *Basic Layout* *Mandatory*

5.3.6.1 The basic layout shall contain four panels as shown and oriented in Figure 8. At a minimum, the interface shall support the orientation of the command panel on the right-hand side, unless the enhanced layout (Section 5.3.7) is implemented.

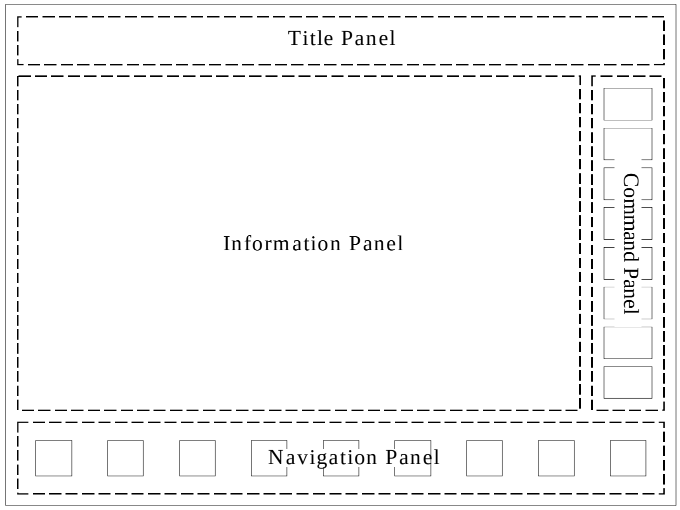


Figure 8
Basic Layout

5.3.6.2 All the panels are tiled edge to edge to create the display, and only the relative position of the panels is specified in this standard. Panels may or may not display a visible border. For an interface that is the primary display (typically, but not always at the front of equipment), an outer window frame allowing window resizing, closing, or positioning shall not be shown or enabled. This is to prevent the user from mistakenly “losing” the window, which may result in a dangerous condition. If desired, a logged-in user with sufficient privileges may be allowed to resize, but not minimize or close, the primary display window. Secondary instances of the interface (e.g., displayed at a maintenance node or displayed at a remote node) may show and enable the outer window frame.

5.3.7 *Enhanced Layout* *Recommended*

5.3.7.1 It is strongly recommended that left-handed users be allowed to change the location of the command panel to the left-hand side (see Figure 9(b)) to avoid obscuring the screen when reaching with their left hand to make selections on the command panel when it is located on the right-hand side of the screen.

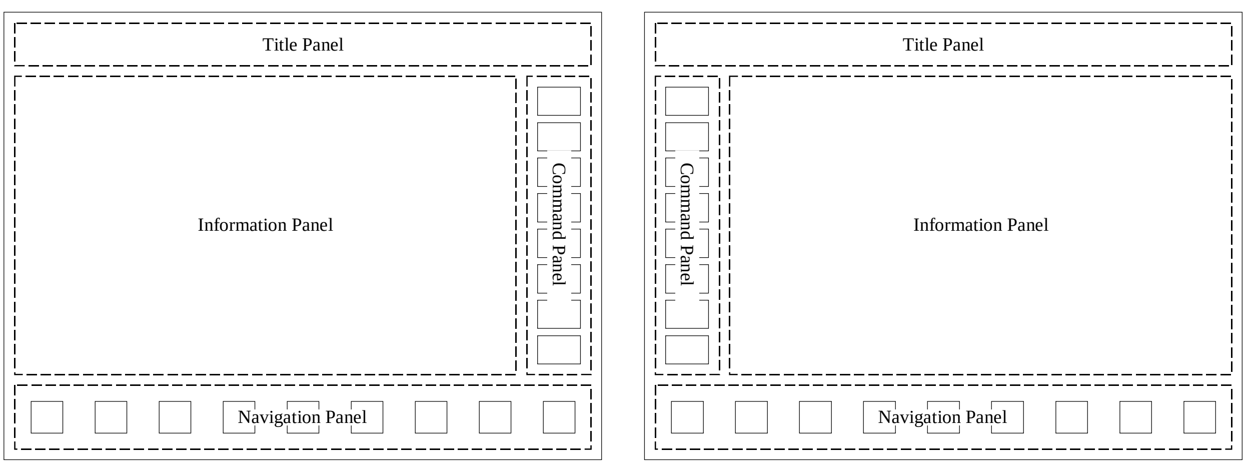


Figure 9
Enhanced Layout – Right and Left Command Panel Orientation

5.3.8 *Title Panel* — *Description*

5.3.8.1 The title panel is a horizontal area above the information and command panels, at the top of the interface window. It is always displayed and contains the host communications status display (if host communications is supported), date/time display, Login/Logout button (if security is supported), message display area, and the name of the current view. It may optionally contain a corporate identifier or logo, a display of critical parameters, an audible alarm silencing button, orientation graphics, a light tower representation, and other items that should always be displayed to ensure effective operation.

5.3.9 *Title Panel Basic Information* — *Mandatory*

5.3.9.1 Shown below is the title panel with the mandatory display objects. The relative positions shown, with the top portion of the title panel containing the date/time display at the left, the current view name to its right, and with the message area below the top portion, are mandatory.

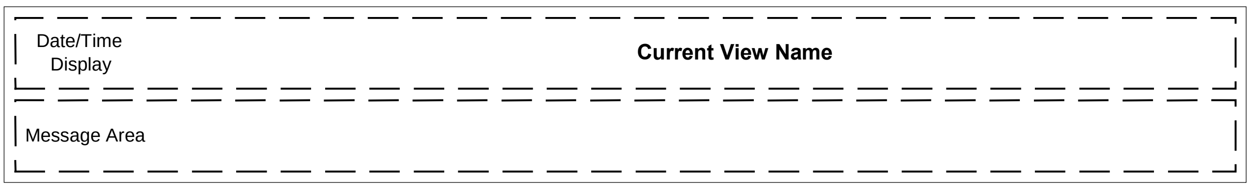


Figure 10
Title Panel

5.3.10 *Title Panel with Conditional Information* — *Conditional*

5.3.10.1 Shown below is the title panel with the mandatory display objects, plus the conditional host communications status display and the conditional Login/Logout button. The relative positions shown, with the host communications status display left-most, and the Login/Logout button at the upper right, are mandatory.

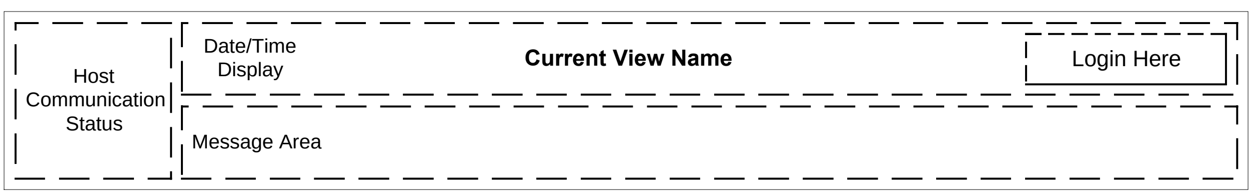


Figure 11
Title Panel

5.3.10.2 *Title Panel Host Communications Status* — *Conditional*

5.3.10.2.1 If the equipment supports host communication then status information shall be included in the title panel. Information such as communications status (i.e., whether communications is active), communications state (i.e., connected, disconnected, etc.), and whether the equipment is in a local or remote mode may be displayed here. The display of specific information is dependent on the host communication protocol which may impose additional specific requirements on what is displayed.

5.3.10.3 *Title Panel Login/Logout Button* — *Conditional*

5.3.10.3.1 The Login/Logout button label reads “Login Here” until a user is logged in, then displays a user identifier until the user logs out. User selection of the Login/Logout button invokes a dialog box where the user may enter a user identifier and password, or, if already logged in, may select a button to log out. If required by the implementation, when this dialog box is displayed, all other functions in the interface window may be disabled, including the navigation panel.

5.3.11 *Title Panel with Additional Information* | *Recommended*

5.3.11.1 Shown below is an example of a layout for the title panel incorporating some recommended display objects and their relative positions.

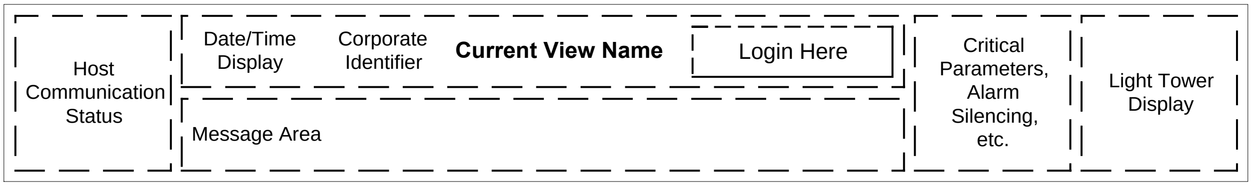


Figure 12
Title Panel with Some Additional Display Objects

5.3.11.2 *Title Panel Alarms Button* | *Recommended*

5.3.11.2.1 Although not recommended for new designs, the title panel may also contain an Alarms button that allows the user to respond to cautions and severe alarms. In this case, the Alarms navigation button in the navigation panel shall be omitted, and any alarms accessed through a title panel Alarms button shall be displayed in a dialog box, not as an information panel and its command panel.

5.4 *Navigation Panel* | *Mandatory*

5.4.1 Navigation buttons shall have a text label. In addition, they may also include an icon to graphically represent their function. When no icon is present, the button label shall be centered on the button. If an icon is present, the label shall be centered below the icon. Navigation buttons are arranged horizontally along the bottom of the display, in the navigation panel, which shall always be present.

5.4.2 *Required Navigation Functions* | *Mandatory*

5.4.2.1 At a minimum, the user shall always be able to immediately access and respond to alarm and caution notifications, even when a dialog box is displayed on the current view. Dialog boxes shall not obscure the navigation panel. Additionally, the user shall always be able to immediately access other parts of the interface if such access is required to ensure the safe operation of the equipment. Only when prohibited by the operating system or other implementation limitations such that a displayed dialog box cannot be maintained during, or redisplayed after navigation, it is allowed that such access may be accomplished by displaying another dialog box that completely covers the originally displayed dialog box. When the overlaying dialog box is dismissed, the underlying dialog box is redisplayed, in the same state it was in prior to the invocation of the overlying dialog box (i.e., given the stated prohibition or limitations, it is not mandatory that access be provided through navigation using the navigation panel). Immediate access shall mean that the user shall not have to dismiss or otherwise interact with any displayed dialog box in order to perform the required access. When the user navigates back or otherwise returns from the required access, the last selected view shall be displayed, along with any dialog box that was displayed, in the same state it was in. If no dialog box was displayed, the last selected view shall be displayed.

5.4.2.2 An allowed exception is a login and/or logout dialog box or screen if an implementation requires modal operation while logging in or out.

5.4.3 *Conditional Navigation Functions* | *Conditional*

5.4.3.1 Except when absolutely prevented by the operating system or implementation limitations, the navigation panel shall always be available for user selection, even when a dialog box is displayed on the current view. This makes it possible for the user to directly and immediately access any functional area from anywhere within the user interface. Immediate access shall mean that the user shall not have to dismiss or otherwise interact with any displayed dialog box in order to perform the required access. When the user navigates back to a functional area, the last selected view is displayed, along with any dialog box that was displayed, in the same state it was in.

5.4.3.2 An allowed exception is a login and/or logout dialog box or screen if an implementation requires modal operation while logging in or out.

5.4.4 *Navigation Panel Layout* Mandatory

5.4.4.1 The figure below shows the navigation panel, with three buttons labeled "(Future)" indicating the positions where buttons may be placed if required by the specific implementation of the interface, or as a result of modifications or enhancements in future releases of the software. It is recommended that the navigation panel contain no more than ten buttons.

5.4.4.2 The navigation buttons shall be sequenced from left to right in descending order of expected frequency of use. The most frequently selected navigation button shall be left-most within the navigation panel; and the least frequently selected button shall be right-most.

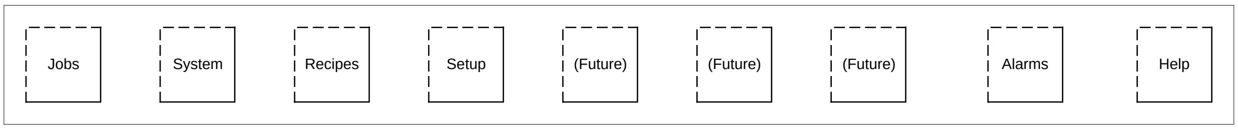


Figure 13
Navigation Panel

5.4.5 *Navigation Panel Alarm and Help Buttons* Conditional

5.4.5.1 The two exceptions to the above ordering are the Alarms and Help navigation buttons, which, when they are supported in an implementation, shall be the next to right-most and right-most buttons, respectively. This placement ensures that the position of these buttons shall remain unchanged, even if subsequent interface modifications or enhancements require additional buttons. The Alarm button shall be placed so that the spacing between it and adjacent buttons is larger than the spacing between other buttons, to allow its selection quickly, and without error.

5.4.6 *Navigation Button Labels* Conditional

5.4.6.1 For each functional area, there is a corresponding navigation button identified by a text label (mandatory) and icon (recommended) identifying the functionality and information provided. The table below shows text labels (conditional) for the navigation buttons, a description of each functional area, and some recommended alternative labels.

Table 1 Functional Areas

Navigation Button Label	*Description*	*Alternate Labels*
Jobs	Operations related to product processing, including any pre- and post-production equipment setup	Lot Operations, Operation, Operations, Processing, Main, Run
System	Equipment status, manual move, maintenance, service, calibration, & other engineering-level functions	Overview, Service, Status, System Status, Maintenance
Recipes	Recipe management, including creation, editing, storing, etc.	None
Datalog	Data histories, event logs, SPC functions (If supported)	History, Analysis, Logs, Data
Setup	User account administration, host communications control, user preferences, parameters, hardware configuration/options, light tower programming, etc.	Configuration, Options
Alarms	Alarm and caution summary to acknowledge and clear posted alarms, current event log	None (see Section 5.4.5)
Help	Help files on operations, procedures, and the interface	None (see Section 5.4.5)

5.4.6.2 The top to bottom ordering of the table reflects the left to right ordering of navigation buttons. Also allowed, but not recommended for new designs, is a left to right ordering of: System, Jobs, Equipment Setup, Recipes, History, Maintenance, and Configuration. The alternative labels specified in the table may be applied to this ordering also. Additional buttons, if required for a particular implementation, shall be added between the Setup and Alarm button positions.

5.4.7 *Navigation Panel Saliences* Conditional

5.4.7.1 Only one navigation button at a time shall display a pressed appearance. Additionally, navigation buttons shall display colored salience coding for a number of purposes: 1, to indicate the user is viewing a functional area (medium blue salience); 2, to indicate an unfinished task (typically an open dialog box) in a functional area not currently displayed (medium blue salience); and 3, to inform the user that there are new or unacknowledged cautions or alarms (saturated yellow or saturated red salience, respectively). The caution and alarm saliences are displayed on the Alarms navigation button only. As an example, if the user has opened a dialog box in the Jobs functional area, and then selects the Recipes navigation button, the Recipes button shall display a pressed (down) appearance *and* a medium blue salience, and the Jobs button shall display an unpressed (up) appearance *and* a medium blue salience (Figure 14). This reminds the user that there is an open dialog box in the Jobs functional area. More than one navigation button may display the unfinished task salience.

5.4.7.2 The Jobs button may also display a medium green salience (not shown) to notify the user that the equipment is “Ready to Load,” “Ready to Unload,” “Ready to Run,” or is in a similar state such that the user’s attention is requested in the Jobs functional area. This is useful when the user has navigated to another functional area of the interface. If there is an unfinished task, its medium blue salience shall remain displayed, even if the user’s attention is requested.

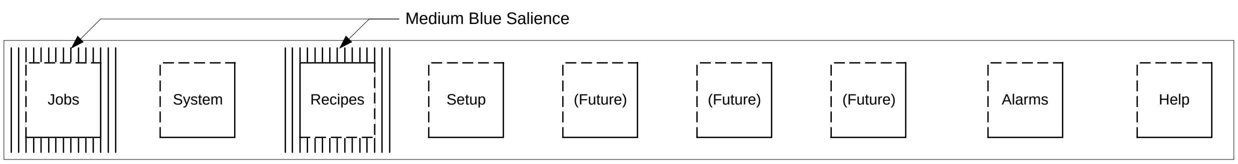


Figure 14
Navigation Button Saliences

5.4.7.3 The Alarm navigation button, in addition to the medium blue salience, displays a saturated (bright) yellow salience when there are new or unacknowledged cautions, or displays a saturated red salience when there are new or unacknowledged alarms. Only the severest level is displayed. That is, when there are both cautions and alarms, the red alarm salience shall be displayed. When there are no alarms and only cautions, the caution salience shall be displayed. The figures below show the same situation as Figure 14, with Figure 15 showing a caution salience, and Figure 16 showing an alarm salience. If there are no cautions or alarms, the Alarm button displays a medium blue salience if the user is viewing the Alarms functional area, or if there is an unfinished task and another functional area is being viewed. If a caution or alarm occurs, the medium blue salience is replaced with the appropriate salience, and is only re-displayed when all cautions and alarms have been acknowledged or cleared.

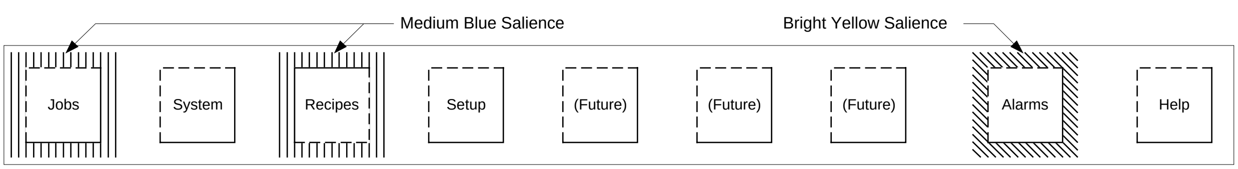


Figure 15
Warning Salience

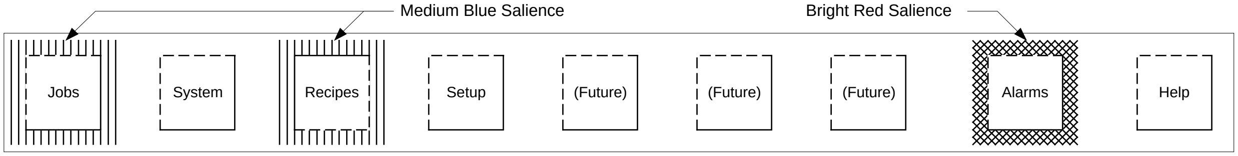


Figure 16
Alarm Salience

5.4.8 *Sub-navigation* *Conditional*

5.4.8.1 When sub-navigation is supported it shall be by a single row of tabs or buttons in a sub-navigation panel as shown below.

5.4.8.2 *Sub-navigation Layout A — Tabs*

5.4.8.2.1 Shown below are two orientations of the layout (right-hand and left-hand command panels), with sub-navigation using tabs. This is the preferred method for new designs where more than one view per functional area is needed. User selection of a tab brings the tab to the front, displays its information and command panel, and allows the user access to its display objects. Use of tabs in each functional area must be consistent throughout the interface, even if there is only one view in a functional area, and thus, one tab.

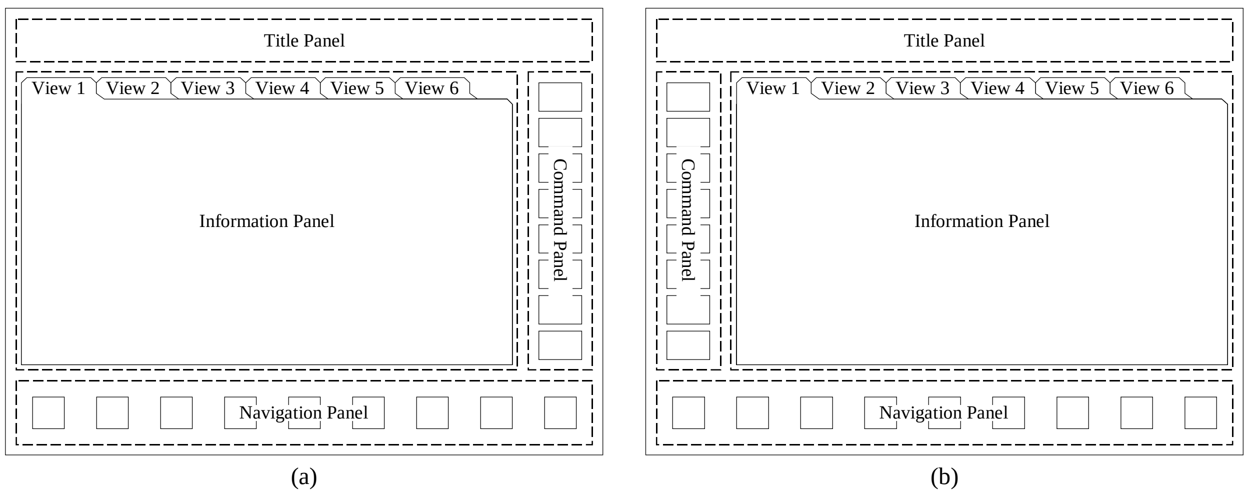
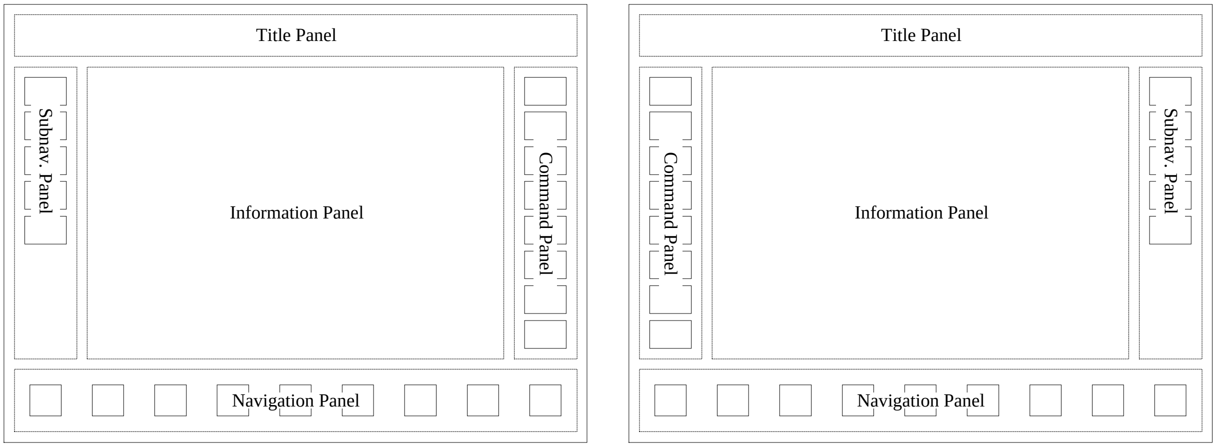


Figure 17
View Sub-navigation Using Tabs

5.4.8.3 *Sub-navigation Layout B — Sub-navigation Panel With Buttons*

5.4.8.3.1 Shown below are two orientations of the layout, with sub-navigation using view selection buttons in a sub-navigation panel. The figure shows one possible relative location for a sub-navigation panel, but is not intended to restrict implementation. Other arrangements are allowed. However, if a sub-navigation panel is used, its size and location in each functional area must be consistent throughout the interface, even if there is only one view in a functional area, and thus, no buttons in the panel.



(a) (b)

Figure 18
View Sub-navigation Using Buttons in Separate Panel

5.4.8.3.2 It is important in the layout to separate sub-navigation methods from the global commands in the command panel. This limits the number of buttons needed in the command panel; and reduces or eliminates the need for multiple columns of buttons, which would alter the information panel display aspect ratio. If an information panel has a different aspect ratio than the others, its contents may appear to "jump" sideways when navigating, distracting the user. The separation of sub-navigation from commands accomplishes two important objectives; a) users do not become confused trying to differentiate sub-navigation from commands, and b) the aspect ratio of the information panel display is consistent for all views across all functional areas.

5.5 *Information Panel* Mandatory

5.5.1 The information panel displays a view or views of the information and graphics for each functional area. Graphics and other display objects are placed in this panel to achieve the control and monitoring capabilities required. If necessary, multiple views of information may be displayed within a functional area, one at a time, in the information panel.

5.5.2 When any functional areas have more than one view, the user must be able to switch between those views while remaining within the context of the current functional area. The ways the user may select among multiple views presented in this standard are called sub-navigation methods to distinguish them from user navigation between functional areas using the navigation panel.

5.6 *Command Panel* Mandatory

5.6.1 The command panel is a vertical column of command buttons located to the right of the information panel (to the left if switched to accommodate left-handed users). Only buttons for common or global commands related to the current view displayed in the information panel shall be located in the command panel. If there are no common commands for an information panel, the command panel shall have no buttons. Each view in a functional area shall have its own command panel. To limit the number of command buttons needed in each command panel, user selection of a different view shall display that view and its associated command panel, with commands that apply only to the selected view. A command panel may be used for more than one view if it is suitable for that purpose. Command buttons or other display objects that have a more limited scope shall be located in the information panel. Restricting locally-acting commands and functions to the information panel makes clear to the user that only general, global commands are located in the command panel. Buttons for navigation (i.e., that invoke the display of another view in the information panel) shall not be located in the command panel. It is recommended that multiple columns of buttons in the command panel be avoided.

6 Compliance Statement

6.1 In order to be compliant with this specification, the documentation accompanying an equipment shall include a Human Computer Interface (HCI) Compliance Statement that accurately indicates compliance with the individual requirements defined in this document. Requirements and recommended capabilities are defined in Table 2.

6.2 In order to be compliant with HCI, equipment must meet all requirements in each of three categories, as follows:

6.2.1 Mandatory: In order to be compliant with this standard, all of the mandatory requirements shall be both implemented and compliant as defined in this specification.

6.2.2 Conditional: In order to be compliant with this standard, each conditional requirement shall either be implemented as defined in this specification or shall both not be implemented in the user interface and not be supported in some other way by the equipment. (i.e., no conditional capability which is present on the equipment shall be implemented in a manner other than as defined in this specification).

6.2.3 Recommended: Implementation of these features is at the discretion of the implementers. The only requirement for compliance with this specification for these capabilities is that they be accurately documented in the compliance statement for the equipment.

6.3 Each requirement/capability shall be marked "Yes" under "Implemented" if the equipment includes a feature which provides equivalent functionality as that defined in this specification even if that feature appears in a different form. Otherwise it shall be marked "No".

6.4 Each requirement/capability shall be marked "Yes" under "HCI Compliant" if the equipment includes a feature which conforms to all aspects of the requirement or recommended capability as defined in this specification. Otherwise it shall be marked "No".

Table 2 HCI Compliance Statement

HCI Compliance Statement			
Mandatory Requirements	*Reference*	*Implemented*	*HCI Compliant*
Button Size	5.2.2.1	Yes No	Yes No
Button Behavior	5.2.2.3	Yes No	Yes No
Button Text	5.2.2.4	Yes No	Yes No
Dialog Boxes	5.2.5	Yes No	Yes No
Basic Network Navigation Model	5.3	Yes No	Yes No
Basic Layout	5.3.6	Yes No	Yes No
Title Panel Basic Information	5.3.9	Yes No	Yes No
Navigation Panel	5.4	Yes No	Yes No
Required Navigation Panel Functions	5.4.2	Yes No	Yes No
Navigation Panel Layout	5.4.4	Yes No	Yes No
Information Panel	5.5	Yes No	Yes No
Command Panel	5.6	Yes No	Yes No
Conditional Requirements	*Reference*	*Implemented*	*HCI Compliant*
Saliences	5.2.3	Yes No	Yes No
Information Dialog Boxes	5.2.6	Yes No	Yes No
Input/Selection Dialog Box	5.2.7	Yes No	Yes No
Message Dialog Box	5.2.8	Yes No	Yes No
Network Navigation Model with Sub-navigation	5.3.4	Yes No	Yes No
Title Panel with Conditional Information	5.3.10	Yes No	Yes No
Title Panel Host Communications Status	5.3.10.2	Yes No	Yes No
Title Panel Login/Logout Button	5.3.10.3	Yes No	Yes No
Conditional Navigation Panel Functions	5.4.3	Yes No	Yes No
Navigation Panel Alarm & Help Buttons	5.4.5	Yes No	Yes No
Navigation Button Labels	5.4.6	Yes No	Yes No
Navigation Panel Saliences	5.4.7	Yes No	Yes No
Sub-navigation	5.4.8	Yes No	Yes No
Recommended Capabilities	*Reference*	*Implemented*	*HCI Compliant*
Button Dimensions	5.2.2.2	Yes No	Yes No
Enhanced Layout	5.3.7	Yes No	Yes No
Title Panel with Additional Information	5.3.11	Yes No	Yes No
Title Panel Alarms Button	5.3.11.2	Yes No	Yes No

7 Related Documents

7.1 *SEMATECH Documents*[1]

Computer Integrated Manufacturing (CIM) Application Framework Specification

SCC User-Interface Style Guide

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI E96-1101
GUIDE FOR CIM FRAMEWORK TECHNICAL ARCHITECTURE

This guide was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the European Regional Standards Committee on June 11, 2001, and by the North American Regional Standards Committee on July 19, 2001. Initially available at www.semi.org August 2001; to be published November 2001. Originally published February 2000. This document replaces PR5-0699 in its entirety.

1 Purpose

1.1 This guide describes technical architecture choices that enable application components to cooperate in a Computer Integrated Manufacturing (CIM) environment and reduce the effort required to integrate those components into a working solution. The CIM Framework technical architecture guide builds on publicly available specifications for distributed object computing. It defines manufacturing production systems requirements for the technical infrastructure needed for improved component interoperability, substitutability, and extensibility. It provides guidance for specifying components and addresses options for using an underlying distributed object communication infrastructure.

1.2 This guide provides guidance for the technical foundation of the SEMI Computer Integrated Manufacturing (CIM) Framework standards. It discusses a component-based architecture using object-oriented and framework technology that helps implementers achieve component interoperability and substitutability, application extensibility, and reuse. It establishes the role of distributed object communications infrastructure in providing necessary support for the framework technology. Specification methods for mapping a CIM Framework specification to alternative infrastructure technologies are also addressed by this technical architecture. However, these mappings are not intended to be prescriptive. Further work may be required to define additional mappings to emerging technologies. Many implementation issues that should be resolved for a particular software implementation are outside the scope of this guide.

1.3 Adhering to this guide for technical architecture alone does not provide interoperability between applications. While the technical architecture provides a foundation for interoperability, it is limited by the following factors:

- Multiple infrastructure implementation choices are possible, and interoperability across these environments is not guaranteed.
- The technical architecture intentionally limits its scope to only the most fundamental infrastructure requirements, leaving additional technical issues for future guide upgrades or for implementers' discretion.
- Conformance to a specification for CIM Framework Domain Architecture is also required for interoperability of domain components.
- More complete semantics (including behavioral constraints and collaboration patterns) for components are needed to ensure consistent interactions among components developed by separate suppliers.

1.4 A guide for technical architecture is a necessary, but not a sufficient, basis to achieve the goals of the CIM Framework specifications. It does not mandate specific solutions to address the identified technical requirements because there are multiple implementation choices that meet these requirements. Rather, the technical architecture identifies those crucial technical requirements that should be considered by both CIM software suppliers and consumers. The proposed standard identifies the technical capabilities implementations should provide, but leaves the implementation options open. It is the responsibility of suppliers to provide and explain an implementation of each capability, and the responsibility of consumers to assess particular implementations for use in their factories.

1.5 This guide provides guidance on the technical tradeoffs for services provided by the distributed computing infrastructure for the purpose of supporting and enabling the domain specifications of CIM Framework components. These areas are:

- *Distributed Object Communication* — Provides the basic services to enable implementations supporting the CIM Framework interfaces to transparently locate other, possibly distributed implementations and exchange messages requesting standard CIM Framework operations. Interface Definition Language provides a formal specification of the CIM Framework interfaces that can be automatically transformed into conformant implementations ready for integration and interoperation.
- *Exception Declarations* — Identify the form and structure of return messages that inform requestors that a requested operation resulted in an anticipated, but abnormal outcome.

- *Event Specification* — Establishes the delivery mechanism, identification conventions, and data structures for reporting the occurrence of anticipated state changes to CIM Framework objects.
- *Distributed Transactions* — Define mechanisms needed to coordinate the start, completion or rollback of units-of-work that cross CIM Framework component boundaries.
- *Component Manager Support* — Identifies the component-level operations needed to create, locate, or remove instances of objects (and manage collections of those objects) that support the CIM Framework specified interfaces.

2 Scope

2.1 *Intended Audience*

2.1.1 This document is intended for developers of components and applications, and integrators of MES systems that adhere to the CIM Framework specifications. It is also intended for system architects who contribute to the evolution of the CIM Framework architecture and guides based on implementation experience. A guide for technical architecture is focused on the software technologies that support the architectural goals for the CIM Framework rather than on the manufacturing domain concepts that the CIM Framework encompasses. The technical architecture perspective complements SEMI E81.

2.2 *Architectural Issues Not Covered*

2.2.1 A number of architectural issues are not covered within this document because they are beyond the scope of the CIM Framework standards and are not expected to come within the scope of the standards as they are revised. They are itemized here because a product architecture layered on the CIM Framework Technical Architecture should address these additional architecture issues. In these cases, other more general specifications emerging in the infrastructure technology areas are expected to provide these needed standards. The CIM Framework domain specifications do not require specific conformance in these areas to support component specifications.

2.2.2 *Persistence*

2.2.2.1 Persistence refers to the ability of an object to maintain a nonvolatile copy of its current state such that the object could recreate the state during a future initialization. There are various operations for object persistence, and problems can occur if objects with cross-references do not coordinate their persistence strategies and mechanisms. The CIM Framework excludes persistence as an implementation mechanism.

2.2.3 *System Performance*

2.2.3.1 System performance is highly dependent on the selection of hardware and software platforms for system execution. Tests should be performed to verify adequate system performance and scalability for the anticipated operating environment. Performance tuning mechanisms or measurement tools are excluded from the CIM Framework specifications as an implementation dependent mechanism.

2.2.4 *Data Replication*

2.2.4.1 Data replication is a technique used to provide additional fault tolerance or improve system performance in certain situations. The CIM Framework excludes specification of replication strategies as an implementation dependent mechanism.

2.2.5 *Change Management*

2.2.5.1 Change management is the ability to introduce and control changes to the system configuration. The CIM Framework encompasses change management in the domain context of document control, but the CIM Framework excludes the broader treatment of change management for the MES software configuration itself.

2.2.6 *Externalization*

2.2.6.1 Externalization can be used to provide a form of persistence or to transfer object state between disjoint implementations. The ability of an object to externalize its data and state supports recovery of data and state for objects that terminated from memory. The CIM Framework excludes externalization as an implementation dependent mechanism.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The CIM Framework should continue to evolve to meet the needs of a competitive and vital industry. The content of this framework represents a significant amount of real development experience from a number of commercial software suppliers and their customers. These specifications reflect the product architectures of those companies, as well as the requirements of their customers. This evolution process should continue as more products based on the CIM Framework are developed.

3.1.1 This guide acknowledges the following deficiencies that should be addressed in future revisions. These deficiencies are identified in the following sections.

3.2 *Mapping to Alternate Distributed Computing Infrastructures*

3.2.1 The CIM Framework provides a specification for MES software components, specified in terms of generalized manufacturing production systems requirements, that may be implemented using a variety of technical infrastructure foundations. While the intent of this guide is to provide both rigor in specification and flexibility to make infrastructure implementation choices, these goals often conflict. The use of mapping techniques complicates the task of integrating applications across technology boundaries.

3.2.2 While it is anticipated that a conformant implementation using either CORBA®[1] or the Microsoft®[2] Distributed Component Object Model (DCOM) is feasible by mapping the specifications to the implementation, it is recognized that cross-infrastructure integration is significantly more difficult (for example, merging transaction models). The mapping described here offers more diverse implementation choices, but it does not guarantee that all of those chosen technologies easily work together in a single heterogeneous implementation.

3.2.3 Although the DCOM mapping provides a straightforward transform from the OMG® Interface Definition Language (IDL)™[3] specifications for static invocation, the Microsoft OLE Automation interfaces may be required for dynamic invocation. There appears to be greater risk in being able to successfully map the CIM Framework to the OLE Automation interfaces. The requirement for dynamic invocation should be evaluated with this in mind.

3.2.4 Another issue with DCOM mapping concerns exceptions. DCOM returns exceptions using its return value HRESULT. Many CIM Framework operations already use return values and would not be able to return a HRESULT without restructuring the return mechanism for the operation results.

3.2.5 Finally, there has not yet been a detailed analysis of the CIM Framework interfaces to verify that they can be successfully mapped using the CORBA Interworking Architecture.[4] This is especially true of the OLE Automation mapping resolution.

1 CORBA is a registered trademark of Object Management Group, Inc. in the United States and other countries.

2 Microsoft is a registered trademark of Microsoft Corporation, Inc. in the United States and other countries.

3 OMG Interface Definition Language (IDL) is a trademark of Object Management Group, Inc. in the United States and other countries.

4 Object Management Group. The Common Object Request Broker: Architecture and Specification, Revision 2.2, Object Management Group, 492 Old Connecticut Path, Framingham, MA: Object Management Group, 1998.

3.3 *Business Rules*

3.3.1 The management of factory objects requires the use of a set of business rules; that is, procedures representing common business practices that should be applied under a given set of circumstances in response to some factory event. For instance, “Do not assign a process job to a machine which is scheduled for maintenance within 24 hours.” Factory systems implementations typically specify business rules as event-driven ECA (event-condition-action) or ECAA (event-condition-action-alternative action) rules. For example:

- *event* — request to edit a process specification;
- *condition* — invalid user access privilege;
- *action* — deny access;
- (*alternative action* — deny access and report breach of security).

3.3.2 Business rules can also be embodied in the sequencing logic of sequential process definitions. In this case the business rules define the criteria for making sequencing decisions that effect the flow of work through the factory.

3.3.3 Business rules are intended to be addressed in future revisions of this guide.

3.4 *Security and Access Control*

3.4.1 The management of sensitive information regarding business processes and product specifications requires that MES implementations (especially distributed systems) provide some level of security and access control services. Typically, such services:

- identify and authenticate any factory object seeking sensitive information,
- permit access to information or operations based upon identity and privilege,
- provide security-related audit trails,
- provide secure communications (not susceptible to being intercepted nor malicious or inadvertent modification), and
- administer an enterprise’s security policy.

3.4.2 Security and access control is intended to be addressed in future revisions of this guide.

3.5 *Internationalization*

3.5.1 Specifications that deal with issues related to internationalization are emerging from several sources, including the OMG. This guide should encompass the need and ability to incorporate internationalization features into the CIM Framework specifications.

3.5.2 Internationalization are intended to be addressed in future revisions of this guide.

3.6 *Object Properties*

3.6.1 Object properties refers to a technique that allows additional attributes (data) to be dynamically associated with an object without changing the interfaces of the objects to which the properties are attached. This can be used as a convenient dynamic extensibility mechanism that may be considered in future CIM Framework specifications.

3.6.2 Object properties are intended to be addressed in future revisions of this guide.

3.7 *Object Collections and Queries*

3.7.1 Object collections and queries allow flexible access to aggregate data for a group of objects. This capability may be a candidate to replace the limited operations for collections found in the component manager interface.

3.7.2 Object collections and queries are intended to be addressed in future revisions of this guide.

4 Referenced Standard

4.1 *SEMI Standard*

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ACID* — Atomicity Consistency Isolation Durability

5.1.2 *CIM* — Computer Integrated Manufacturing

5.1.3 *ECA* — Event-Condition-Action (rule)

5.1.4 *ECAA* — Event-Condition-Action-Alternative Action (rule)

5.1.5 *ENS* — Event Notification System

5.1.6 *ERP* — Enterprise Resource Planning

5.1.7 *GUI* — Graphical User Interface

5.1.8 *MES* — Manufacturing Execution System

5.1.9 *ODL* — Object Definition Language

5.1.10 *OMA* — Object Management Architecture

5.1.11 *OTS* — Object Transaction Service

5.2 *Definitions*

5.2.1 *application* — 1. one or more programs consisting of a collection of interoperating objects which provide domain specific functionality to an end user or other applications. 2. functionality provided by one or more programs consisting of a collection of interoperating objects.

5.2.2 *application interface* — the interface provided by an application or application program.

5.2.3 *application object* — an object implementing an application interface.

5.2.4 *architecture* — the structure of the components of a program/system, their interrelationships, and principles and guidelines governing their design and evolution over time.

5.2.5 *attribute* — an identifiable association between an object and a value. An attribute may have functions to set and retrieve its value.

5.2.6 *behavior* — the effects of performing a requested service, including its results (e.g., changes in the state of an object).

5.2.7 *binding* — a specific choice of platform technologies and other implementation-specific criteria.

5.2.8 *class* — the shared common structure and common behavior of a set of object implementations.

5.2.9 *client* — an object that uses the services of another object by sending messages to it or referencing its state.

5.2.10 *collection* — an object containing references to (collections of) other objects with services for managing them and providing access to them as a related group of objects.

5.2.11 *component* — a reusable package of encapsulated objects and/or other components with well-specified, published interfaces. The component is the element of standardization and substitutability for the CIM Framework.

5.2.12 *Computer Integrated Manufacturing* — an approach that leverages the information handling capability of computers to manage manufacturing information and support or automate the execution of manufacturing operations.

5.2.13 *conformance* — adherence to a standard or specification in the implementation of a product, process, or service.

5.2.14 *conformance requirement* — identification in the specification of behavior and/or capabilities required by an implementation for it to conform to that specification.

5.2.15 *conforming implementation* — an implementation that satisfies all relevant specified conformance requirements.

5.2.16 *event* — an asynchronous message denoting the occurrence of some incident of importance. For example, state change or new object created.

5.2.17 *event channel* — the intermediate object that forwards published events to interested subscribers.

5.2.18 *exception* — an infrastructure mechanism used to notify a calling client of an operation that an unusual condition occurred in carrying out the operation.

5.2.19 *extensibility* — the ability to extend or specialize existing components and add new object classes or components while preserving architectural integrity and component conformance to standards.

5.2.20 *framework* — a collection of classes or components that provide a set of interoperable services and functionality for a particular domain.

5.2.21 *implementation* — the internal view of a class, object or module, including any non-public behavior. The specific code and functionality that implements an interface.

5.2.22 *implementation conformance statement* — a statement made by the supplier of an implementation or system claiming to conform to one or more specifications and stating which capabilities have been implemented. It specifically includes the relevant optional capabilities and limits.

5.2.23 *infrastructure* — the services, facilities, and communications mechanisms that support the collaboration between and lifecycle of distributed objects.

5.2.24 *inheritance* — the ability to derive new classes, types or interfaces from existing classes, types or interfaces. For example, a derived class ("subclass") inherits the instance variables and methods of the base class ("superclass") and may add new instance variables and methods. In the CIM Framework, inheritance applies to interfaces and their specification of operations rather than implementations of classes.

5.2.25 *instance* — a software entity that has state, behavior and identity. The terms instance and object are interchangeable. An object is an instance of an interface if it provides the operations, signatures, and semantics specified by that interface. An object is an instance of an implementation if its behavior is provided by that implementation.

5.2.26 *interface* — the external view of a class, object, or module that emphasizes its abstraction while hiding its structure and internal behavior. An interface definition ideally includes the semantics of attributes and operations.

5.2.27 *interoperability* — the ability for two applications or the parts of an application to cooperate. In the CIM Framework, interoperability requires that application components be able to support specified relationships, share data, invoke each others' behavior (operations), return exceptions, and exchange events.

5.2.28 *lifecycle* — the life of an object, including creation, deletion, copy, and equivalence.

5.2.29 *message* — in object oriented systems a message is the means by which a client object invokes the behavior specified by an operation of a server object.

5.2.30 *message bus* — a software infrastructure that provides distributed communication between objects in component implementations. It can refer to an Object Request Broker, Microsoft DCOM, Java Remote Method Invocation or other infrastructure for conveying messages between objects.

5.2.31 *name-value pair* — a data structure that associates a name with an arbitrary value, typically used as an extensibility mechanism for conveying information by name-based retrieval.

5.2.32 *namespace* — a namespace is a bounded collection of names with a constraint to ensure that each name is unique within the collection.

5.2.33 *object* — a software entity that has state, behavior, and identity. The terms instance and object are interchangeable. An object is an instance of an interface if it provides the operations, signatures, and semantics specified by that interface. An object is an instance of an implementation if its behavior is provided by that implementation.

5.2.34 *object services* — interfaces for general services that are likely to be used in any program based on distributed objects.

5.2.35 *operation* — an operation is a specification entity, identified by an operation identifier, that denotes a service that can be requested. An operation has a signature that describes the legitimate values of request parameters and returned results, including any exceptions.

5.2.36 *persistent object* — an object that can survive the process or thread that created it.

5.2.37 *productive entity* — productive entity is an abstraction of a physical unit, which is involved in any way in a production process (e.g. production or supporting equipment). A productive entity has its own internal logic and provides a software interface to access this logic

5.2.38 *query* — a message sent to a server (e.g. the productive entity) by a client interested in some information from the server (state of the productive entity). A query may or may not have arguments and it always has an answer. The semantics of a query is that some information from the server is returned, but the query cannot effect any change to the state of the server.

5.2.39 *service* — a function provided by a service provider that is performed through an operation specified by the provider.

5.2.40 *service provider, server* — an object providing services to other objects as specified by its published operations.

5.2.41 *signature* — a signature is the name, parameters, return values, and exceptions for a specific operation.

5.2.42 *substitutability* — the ability to replace a given component from one supplier with a functionally equivalent component from another supplier without impacting the other components or its clients in the system.

5.2.43 *trader service* — a collection of names with associated properties of features for each name and methods for manipulating and inspection that collection.

5.2.44 *type* — a declaration that describes the common properties and behavior for a collection of objects. Types classify objects according to a common interface; classes classify objects according to a common implementation.

6 Technical Architecture Guidance

6.1 The computing infrastructure provides the distributed computing environment for CIM Framework applications. This infrastructure includes the operating system, networking and communications, data storage and access, user interface and presentation services, event distribution, systems management, and many other elements. Of these many infrastructure elements, a guide for technical architecture specifies a small subset of key services that need to be standardized in order to facilitate and streamline system integration between conformant CIM Framework implementations.

6.2 The CIM Framework relies on publicly available specifications to define the use of infrastructure services wherever such published specifications exist. The largest single source for openly defined specifications for distributed object services is the Object Management Architecture.[5] Reference to this guide does not imply that CIM Framework conformant implementations should implement the referenced services. The implementations that realize these infrastructure technologies are outside the scope of this guide. The technology choices made by implementers should be kept transparent to the CIM Framework to the greatest extent possible.

6.3 *Distributed Object Communication*

6.3.1 The CIM Framework documents assume the use of software infrastructure to provide distributed communication between objects in an implementation. The acronym ORB was originated by the OMG to describe its distributed object communication infrastructure, but is sometimes used in a more general sense. In this document ORB is used only to refer to the OMG specified technology and the more general term "message bus" is used for the diverse class of distributed communication mechanisms for communication between objects. The message bus is used to allow objects to make requests and receive responses from other objects. An object can communicate through the message bus with objects that are local or remote. Location transparency allows the object to remain ignorant of the actual location of the object with which it communicates.

6.3.2 A primary criterion for a message bus implementation is its ability to deliver all messages specified by the interfaces of the CIM Framework components. To accomplish this, the message bus should provide the ability to support or map a specified interface, including its inherited features, data types, operations, object references, and exceptions to and from runtime marshaled transport formats.

6.3.3 Alternate message bus implementation technologies are supported by the CIM Framework by mapping the OMG IDL for the CIM Framework interfaces into a specific message bus implementation. The Common Object Request Broker: Architecture and Specification[4] contains sections that define this mapping from CORBA to COM and from CORBA to OLE Automation. These sections, called the "Interworking Architecture," cover detailed rules for mapping OMG IDL, types, and exceptions to compatible interfaces in COM and OLE Automation.

6.3.4 From a high level perspective, the DCOM and CORBA message buses are comparable. The DCOM capabilities are roughly equivalent to those of an ORB. However, with a lower level analysis, differences show up in data types, inheritance, object identity, and the handling of exceptions. The CORBA Interworking

5 Object Management Group. The Object Management Architecture Guide, Revision 3.0, John Wiley and Sons, New York NY, 1995.

Architecture[4] (Chapter 15, "Interworking Architecture," Chapter 16, "Mapping COM to CORBA," and Chapter 17, "Mapping OLE Automation to CORBA") defines mapping approaches covering:

Interface Mapping,

Interface Composition Mapping, and

Identity Mapping.

6.3.5 These areas should be addressed in order to provide a mapping between the OMG IDL used to specify CIM Framework interfaces and the message bus used for implementation. If the mapping is not specific (i.e., can occur in multiple ways) then two implementations may not necessarily be able to communicate even if they use the same message bus type. Although the CORBA Interworking Architecture is specific to Microsoft technologies, it could provide the foundation for future interworking mappings.

6.3.6 The current CIM Framework interfaces are specified in OMG IDL. The interfaces can be directly compiled and used with any of the available ORB implementations on the market.

6.3.7 The only way to provide such a direct solution using Microsoft DCOM would be to create additional CIM Framework interface specifications in DCOM MIDL and/or OLE Automation ODL. This would allow direct support for message bus functionality using DCOM. For example, the CIM Framework memory management requirement of "in" for parameter passing (see Section 6.3.15) would be directly supported by MIDL and DCOM but since the CORBA exception model is significantly richer than the DCOM exception model, mapping CORBA exceptions to COM would require an additional protocol to be defined for DCOM.

6.3.8 The CORBA Interworking Architecture supports mapping the current CIM Framework interfaces defined in OMG IDL to DCOM MIDL or OLE Automation ODL. This mapping is detailed enough that the mapping should always provide the same MIDL/ODL solution. Even though the current scope does not include interoperability between implementations on DCOM and CORBA (see Section 3.2), the issue of mapping the interface is still the same. This would also provide a step towards true interoperability using CORBA/ DCOM bridge products that are beginning to become available.

6.3.9 Microsoft also provides an extension called OLE Automation. These interfaces are described in Object Definition Language (ODL). The OLE interfaces can be invoked dynamically by a client with no compile-time interface knowledge. The OLE data types are a subset of the types supported in DCOM, and there is no support for user-defined constructed types. The mapping solution differs for the DCOM and the OLE Automation. OLE Automation does not provide as clean a mapping from OMG IDL as DCOM does. This limitation may not allow some of the interfaces to translate completely to an OLE Automation implementation. Thus, component suppliers using an OLE Automation implementation should explain impact on interfaces that were not fully supported due to the Automation restrictions.

6.3.10 The CORBA Interworking Architecture covers mapping issues for the major areas of concern for the CIM Framework. The areas of primary importance are the Interface mapping, Interface composition mapping, Identity mapping, and Exception mapping. The CORBA Interworking Architecture gives detailed mappings for each of these areas and deals with the DCOM and OLE Automation mappings separately. The following five subsections summarize these mapping issues.

6.3.11 *Interface Mapping*

6.3.11.1 The OMG IDL primitives, constructed data types, and object references map closely to DCOM. The inherited CORBA interfaces may be represented as multiple DCOM interfaces. The CORBA attributes may be mapped to get and set operations in DCOM interfaces.

6.3.11.2 The OMG IDL primitives map to OLE primitives except for special cases. The OLE interfaces do not support constructed data types and should be mapped to specially constructed interfaces. CORBA object references map to OLE Automation interface pointers. There are difficulties in mapping CORBA multiple inheritance to OLE Automation interfaces documented in the CORBA specification.[4] CORBA attributes may be mapped to get and set operations in OLE Automation interfaces.

6.3.12 *Aspects* — The total behavior of a piece of a productive entity in a factory can be viewed as the union of distinct behaviors. Each such isolated behavior (or functional area) is called an aspect of the productive entity.

6.3.12.1 There is great variety in productive entity behavior. There are generic aspects that are shared by all or most productive entities (such as recipe management or process state model or material tracking) and there are aspects that are specific to one productive entity type or to a particular productive entity model. The behavior of each productive entity is the union of the particular aspects of that productive entity.

6.3.12.2 Saying that two pieces of productive entities have a certain aspect does not necessarily mean that they behave absolutely the same way. There are two ways by which behavioral variation within an aspect can be modeled: Parameters and Variants.

6.3.13 *Parameterized Aspects* — An aspect can have parameters. Differences in productive entities behavior are modeled by assigning different values to the parameters. For example if a physical structure aspect of the productive entity specifies that the productive entity has a material buffer, the number of material units (buffer size) that can be placed on the buffer is a possible parameter. The number of buffers the productive entity has can be another parameter.

6.3.14 *Variants* — While parameterization is a very powerful tool, there are variations in behavior that cannot be simply modeled as different parameter values. In this case one can use variants. An aspect is said to have variants if there are some different behaviors related to the same aspect. For example the process control aspect can have a discrete variant and a continuous variant. In the discrete variant the productive entity processes discrete units of material (like the material within a magazine or a single wafer carrier), while in the continuous variant the productive entity processes continuously as long as there is material to be processed.

6.3.14.1 Differences between productive entities are best modeled as parameters when possible in order to avoid an explosion of the number of variants, while at the same time trying to maintain the clarity of the model.

6.3.14.2 A complete specification of the behavior of a piece of productive entity should specify variants for these aspects that have them.

6.3.15 Where do aspects and variants come from? — They leverage on previous work done by the industry. GEM (Generic Equipment Model, SEMI E30) is a primary source for identifying generic aspects. Various SEMs (Specific Equipment Models) are a source for specific aspects and very likely for variants. Other SEMI standards like SEMI E-40 (Standard For Processing Management) cover other aspects neglected by GEM.

6.3.16 *Specifying Productive Entity Interfaces in a Factory* — In order to specify the interface of a productive entity it is necessary first to identify the aspects (or variants of these aspects) supported by the productive entity, then to specify the interfaces associated with each aspect. The productive entity interface specification is then the sum of the interface specifications for all participating aspects.

6.3.16.1 The interface of an aspect (or variants of these aspects) is the sum of its Queries, Commands, Event Notifications and Service Requests and thus the problem of defining productive entity interface is reduced to the problem of defining the interfaces of individual aspects (or variants of these aspects).

6.3.17 *Architecture* — The productive entity in a factory is viewed as a composition of its aspects. The total productive entity behavior is therefore represented by the sum of all its aspects representing these behaviors. Each aspect specifies a specific behavior of productive entity and provides an interface for incoming messages (queries and commands).

6.3.17.1 An aspect has a name. The productive entity can answer a reference to one of its aspects given the aspect name:

```
AspectInterface aspectNamed(in string
aspectName);
```

6.3.17.2 An AspectInterface is a virtual interface that represents a generic aspect. All aspect interfaces inherit from the generic AspectInterface. When an aspect has variants, the aspect interface itself is virtual, and all its variant interfaces inherit from it.

6.3.17.3 Additionally the productive entity answers a list of the names of all its aspects:

```
StringList allAspectNames();
```

6.3.17.4 The usual scenario for a client is to acquire a reference to the productive entity. It then acquires references to the productive entity aspects of interest by querying the productive entity. The client then invokes methods on the aspect interfaces as required.

6.3.17.5 The client only needs to acquire aspect interfaces once when it first establishes communication with the productive entity. From then on it caches the productive entity interface as well as the references to the productive entity aspects for further use. The procedure of acquiring references needs to be repeated only in case the references become invalid (due to productive entity restart for example).

6.3.18 *How To Add A New Aspect* — The definition of an aspect follows the following aspect definition pattern. It includes the following items:

6.3.18.1 *Aspect Name* — Each aspect has a name that identifies it.

6.3.18.2 *Aspect Description* — The aspect description explains the productive entity behavior covered by the aspect. If the aspect has been derived from an existing standard, the description includes a reference to this standard. It explains the concepts and the used terminology, adds state models and state transition diagrams if required, and explains the interactions between the productive entity and the factory elements related to the aspect. If the interactions require certain sequences of messages, they are also described (as use cases or interaction diagrams).

6.3.18.3 The description also includes all the side effects and exceptions that can occur as a result of the interactions related to the aspect.

6.3.18.4 If the aspect has any relation or effects related to other aspects, they are also described here.

6.3.19 *Variants* — If the aspect has variants, each variant is named and described.

6.3.19.1 *IDL* — Usually the IDL will include a special module for the aspect. The module includes data type definitions specific to the aspect and usually a single interface that provides the various queries and commands of the aspect. An aspect that has variants has an interface per variant. The interfaces for the variants can be inherited from a common (abstract) aspect interface.

6.3.19.1.1 An aspect that deals with service requests should also include an IDL definition for the server that provides the services. Which is to be done in a separate module.

6.3.19.2 *Aspect Definition Example* — Here the Control State Aspect has been chosen as an example for aspect definition.

6.3.19.2.1 *Aspect Name* — Control State

6.3.19.2.2 *Aspect Description* — The definition of the Control State Aspect is based on Generic Equipment Model (GEM) SEMI standard E30.

NOTE 2: The state diagram presented here is simpler than the one in SEMI E30, since the internal sub-states are irrelevant to the productive entity interface, and the concept of HOST OFFLNE is obsolete in a distributed factory environment

6.3.19.2.2.1 The control state model defines the level of cooperation between the productive entity and the factory. It also specifies how the operator interacts in the different levels of factory control.

6.3.19.2.2.2 The control state model provides the factory with three levels of control over the productive entity:

6.3.19.2.3 *OFFLINE* — In the OFFLINE state, operation of the productive entity is done by the operator. In the OFFLINE state the productive entity accepts a query to find out the current control state and the command to change its control state, but rejects all other queries or commands (raising the rejected exception). While in the OFFLINE state the productive entity produces no events and no service requests.

6.3.19.2.4 *LOCAL* — In the LOCAL state the productive entity is operated by the operator.

6.3.19.2.4.1 In the LOCAL state the productive entity answers all queries from the factory and allows the factory to execute a limited set of commands. The commands that are prohibited are those that cause movement or directly affect the process. The productive entity sends events and asks for services from the factory.

6.3.19.2.5 *REMOTE* — In the REMOTE state the productive entity is controlled by the factory. The factory has full access to all the necessary commands to operate the productive entity through the full process cycle in an automated manner. The degree of automation can vary from productive entity to productive entity and from factory to factory. Generally operators are required to intervene in setup operations, operator assist situations, etc. Therefore when in REMOTE state, even though theoretically fully under control of the factory, the productive entity should not restrict the operator from executing essential operations such as selecting a recipe, pausing or resuming the process, operator assists, material movement to/from the productive entity, initiating recipe download and other productive entity specific commands on a command by command basis as needed. At the very least the operator should be able to change the control state, actuate an emergency stop and interrupt processing (stop, abort or pause).

6.3.19.2.6 The following diagram depicts the productive entity Control State model.

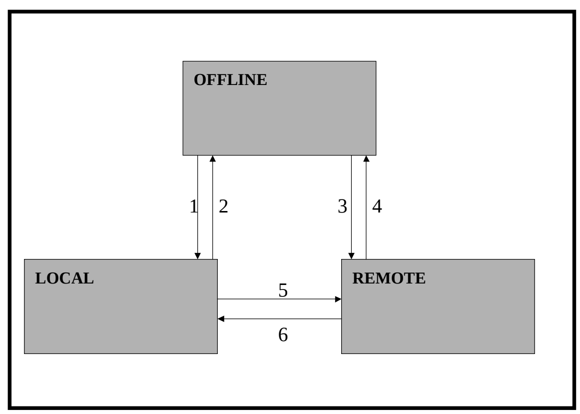

Figure 1

6.3.19.2.7 As can be seen from the diagram, transition from any state is allowed to the two others. The aspect provides the factory methods for querying the current state, for initiating a transition to any of the states, and for events when state transitions occur.

Variants : None

IDL

```
 module ControlStateModule {
   // Type Definitions
   enum ControlState {OFFLINE, LOCAL,
   REMOTE);

        interface ControlState {
         // Queries
         ControlState getControlState()
       raises (EqBasicTypesModule::
       CommunicationFailure);

         // Commands
      void changeControlStateToOffline()
       raises (EqBasicTypesModule::
       CommunicationFailure);
      void changeControlStateToLocal()
       raises (EqBasicTypesModule::
       CommunicationFailure);
      void changeControlStateToRemote()
       raises (EqBasicTypesModule::
       CommunicationFailure);
        };
};
```

6.3.19.2.8 The control state aspect can post the following events:

```
ControlStateChangedToLocal
ControlStateChangedToRemote
controlStateChangedToOffline
```

6.3.20 *Interface Composition Mapping*

6.3.20.1 The DCOM interfaces do not support multiple inheritance. When multiple inheritance is used to extend functionality, the mapping is not very difficult. When multiple inheritance is used to “mix in” orthogonal behavior the mapping is more difficult. The CIM Framework interfaces that only use single inheritance provide the most reliable mapping. Interfaces that use multiple inheritance should follow the detailed mapping rules and ordering provided in the CORBA Interworking Architecture.

6.3.20.2 OLE Automation also has problems directly supporting the multiple inheritance of CORBA. The CORBA Interworking Architecture[4] provides detailed mapping rules for making the conversion where multiple inheritance is used.

6.3.21 *Identity Mapping*

6.3.21.1 CORBA and DCOM/OLE Automation have different notions of what object identity means. CORBA defines an object as a combination of the state and a set of operations that explicitly define the instance. An object reference is defined as a name that reliably and consistently denotes an instantiated object. A CORBA object exists until it is destroyed; its lifecycle is controlled by the server.

6.3.21.2 DCOM does not provide the same mechanism for identifying a particular object. DCOM objects are usually created when used and their state does not persist as an object instance. DCOM objects exist while they are referenced; their lifecycle is controlled by the client. This is true of OLE Automation objects as well.

6.3.21.3 The CORBA Interworking Architecture provides mapping solutions for managing the object lifecycle. The lifecycle issues should be minimized with the CIM Framework use of component managers to control object lifecycles. The implementation of DCOM lifecycle mapping should be encapsulated in the component manager.

6.3.22 *Naming*

6.3.22.1 As a mechanism to support initialization between collaborating components, the name of each component manager should be registered in a publicly available *namespace* along with the object reference for the component manager. The same name may be reused unambiguously as long as all occurrences belong to distinct namespaces. Other objects should be able to obtain a handle (object reference) to each component manager by utilizing the namespace through the operations of a naming service. A *trader* service may also be used to perform lookup of component managers and other objects based on well documented search criteria. Additional objects may also be registered in the namespace or trader as appropriate. The component manager serves as the namespace for the objects it manages, providing object references for named objects. Implementations should provide documentation on how to obtain available object references in either the namespace or the trader.

6.3.23 *Memory Management*

6.3.23.1 ORB implementations’ memory allocation and deallocation services should handle all three types of OMG IDL parameter passing:

- *in* — Memory is caller-allocated and read-only. The caller is responsible for memory deallocation.
- *out* — Memory deallocation depends on the specific usage of the argument.
- *inout* — Memory allocation and deallocation depend on the specific usage of the argument.

6.3.23.2 The CIM Framework uses only the *in* parameter passing mechanism. Within operations that have had objects passed by reference, any modification of the object occurs by using the *in* parameter as a reference. Supplier provided extensions to the CIM Framework that use either the *out* or *inout* parameter passing mechanism should document the caller and callee responsibilities with respect to memory allocation and deallocation.

6.3.24 *Use of OMG IDL Module Packaging Constructs*

6.3.24.1 All IDL statements included as part of the specification of SEMI E81 should be contained within one or more CIM Framework defined modules.

6.3.24.2 *CIMFW Module Conventions*

6.3.24.2.1 Each CIM Framework sub-document that specifies IDL declarations should provide a full listing of the IDL statements in a compilable IDL file. This file may be presented as an appendix to the specification prior to final adoption and preparation for distribution with the standard. The IDL file should include module statements to enclose all IDL declarations for that specification.

6.3.24.2.2 IDL files (or appendices) should begin with a comment identifying the correct name of the file that contains the enclosed IDL specification. The following hypothetical example illustrates the form of this comment.

```
//File: CIMFactoryLabor.idl
//Part of the CIM Framework for the
Factory Labor Component
```

6.3.24.2.3 Every IDL appendix should contain the following statement identifying the top-level module that contains all CIM Framework declarations.

```
module CIMFW{

      ...

};
```

6.3.24.3 *Lower Level Modules within the CIM Framework Module*

6.3.24.3.1 The CIM Framework module should enclose second level modules that further package each partition of the CIM Framework specification as defined in SEMI E81. All IDL declarations should thus be scoped, first, to the CIM Framework, and second, to the specific component of the framework. The following example illustrates the positioning of elements of the Factory Labor component within a component module.

```
module CIMFW{

      module FactoryLabor{

            typedef ..., etc.

      };

};
```

6.3.24.3.2 Subsequent decomposition of CIM Framework specifications into a third level of module containment may be necessary in some places, but should be avoided where possible to keep fully qualified names from getting to an unworkable length.

6.3.24.4 *Conventions for CIM Framework Dependencies*

6.3.24.4.1 Each CIM Framework IDL file should include explicit statements identifying any other files in the CIM Framework specification set that contain modules that are referenced. These statements should be in the form of `#include` statements. In order to avoid circular references among related modules, a specification may need to partition a module into more than one file and include parts of the module at different points in the referencing file. This structure of IDL files is dependent on the specific implementation and which parts of the CIM Framework it implements and may be adjusted as needed to achieve successful compiles. The IDL files distributed with the standard should suggest a file structure to achieve a successful compile, but should not indicate that the file structure is specified as a part of the standard. The following example illustrates an include statement.

```
#include <CIMGlobal.idl>

module CIMFW{ ...
```

6.3.24.4.2 All references to elements of separate modules will then need to be fully qualified with the module scoping. For example, to reference a type defined in the CIMGlobal module, the reference should take a form similar to the following hypothetical example:

```
#include <CIMGlobal.idl>

module CIMFW{

      module FactoryLabor{ ...

            Global::MachineSequence
assignedMachines ( )

                  raises
(Global::FrameworkErrorSignal);

      };

};
```

6.3.24.4.3 Fully qualified names may also be automatically generated if the target programming language compiler supports the "namespace" concepts. For example, the C++ standard uses namespace and Java uses package to support namespaces.

6.3.24.5 *Guard Statements*

6.3.24.5.1 To avoid the possibility of the same CIM Framework file being included more than once and thus causing multiple definition errors, each module should be preceded by the following type of guard statement.

```
#ifndef _CIM_FACTORY_LABOR_IDL_

#define _CIM_FACTORY_LABOR_IDL_

module ...

};

#endif // _CIM_FACTORY_LABOR_IDL_
```

6.3.24.5.2 The guard name should be designated by the string that begins and ends with an underscore and includes an all caps version of the filename with embedded underscores to separate the parts of the name. The guard statement should be documented for each module.

6.3.24.6 *Naming Modules and IDL Files*

6.3.24.6.1 All Module names for CIM Framework specifications are scoped within the CIMFW module and need not use redundant prefixing of the name with CIMFW. The names should be derived as closely as possible from the name of the CIM Framework specification they represent.

6.3.24.6.2 All Names should be composed of one or more words, abbreviations or acronyms concatenated together with capital letters used as delimiters between parts.

6.3.24.6.3 Names should be kept as short as possible while still providing understandable semantic associations for the subject module.

6.3.24.6.4 IDL File names should be based on the second level module contained within the CIMFW module.

6.4 *Exception Declarations*

6.4.1 Exceptions provide an alternative return mechanism for operations. When performing a normal return, control is returned to the point of invocation and the provided return values and output parameters are valid. Abnormal operation results raise an exception, which causes control to return to the defined exception handler and breaks the flow of control. Any data defined as part of the exception and provided by the called operation is valid and available to the exception handler. When an exception is raised, normal output parameters defined in the operation signature are not valid and are not available in the exception handler.

6.4.2 Exceptions are not communicated as an operation return code. An exception signifies that the post-conditions for successful operation completion have not been satisfied. If, on the other hand, the operation merely needs to communicate which one of multiple post-conditions were met, then the operation should provide this information in a return code or return structure as part of the normal operation completion.

6.4.3 Exception declarations in OMG IDL follow a *C* struct-like data structure with the keyword *exception* taking the place of *struct*. It contains attributes that can be used to pass information about an exception condition to a service requester. An exception is declared with an identifier (*ExceptionNameSignal*, the exception name), which is accessible as a value when the exception is raised, allowing the client to determine which exception has been received. Data values associated with the exception, if declared, are accessible to the client. The keyword *raises* is used in the operation definition to specify that a user-defined exception may be raised (or thrown in implementation terminology). The CIM Framework specifications assume that an operation may raise a CORBA-defined standard system exception, thus these exceptions are not specified.

6.4.4 The following conventions are used when defining exceptions:

Exceptions are not reserved for system or programming errors or failures, but should be included for any abnormal application behavior in the called service. This is consistent with CORBA usage of exceptions for application errors.

Exception descriptions are shown as OMG IDL comments similar to descriptions for services.

Return values should, if necessary, be implemented as fields in the exception definition.

All state transition services (e.g., *makeXXX* services) should include the *InvalidStateTransition-Signal* exception in their list of raised exceptions.

Services that perform a “find” or “lookup” function raise an appropriate *<ObjectType> NotFound-Signal* exception: a null return value is not an appropriate response. However, services that return a collection of objects do not raise an exception but simply return an empty collection.

Services that perform “add” functions raise a *<ObjectType>DuplicateSignal* exception for the case where the object to be added is already in the target collection or logical set. The exception includes a field containing a reference to the currently existing object.

Services that perform “remove” functions raise a *<ObjectType>NotAssignedSignal* exception for the case when the given object is not in the collection it was to be removed from or *<ObjectType> RemovalFailedSignal* exception if the object could not be removed.

Boolean query services should rarely raise an exception unless conditions are such that neither a true or false return value can be determined.

6.4.5 User-defined exceptions can be defined for any operation specified in IDL. Only user-defined exceptions that are defined and listed in the *raises* clause of an operation should be thrown. Interface-defined or other standard system exceptions may be thrown without using a *raises* clause on an operation. The data contained in the user exception should help the caller interpret and deal with the exception. Specific data can be defined for each user exception. Any additional information that assists in debugging situations should be sent to a tracing or logging facility.

6.4.6 Operations should throw standard system exceptions when an error condition clearly matches the defined exception. This ability should be used judiciously as the receiver of the exception may not be able to distinguish between a system-thrown or user-thrown exception. If a system exception does not clearly fit the situation at hand, then a user exception should be defined. Use of user-defined exceptions is part of the binding that should be considered for interoperability and substitutability.

6.4.7 The mapping defined for exceptions should support both the system exceptions and user exceptions. The CORBA model uses the concept of exceptions being raised to report error information. There should be exception specific data associated with the exception. The DCOM model provides error information by returning an HRESULT type. There is no facility for returning user-defined exception data.

6.4.8 The CORBA Interworking Architecture provides a mapping for the CORBA System Exceptions to the DCOM HRESULT values. The additional exception information for User Exceptions can be returned in an exception structure and added as another parameter to methods that include the *raises* keyword. The OLE Automation mapping provides for the use of a Pseudo-Automation Interface called a pseudo-exception. This is included in the interface as an additional out parameter.

6.4.9 The mapping of exceptions from CORBA to DCOM is very complex and requires an added parameter on many of the interfaces. The complete mapping rules are defined in the CORBA Interworking Architecture.

6.5 *Event Specification*

6.5.1 This guide uses a publish/subscribe model of events. Published events are sent to subscribers of the event in an asynchronous manner. The identity and quantity of subscribers are not known by the publisher of an event. The publisher is also known as the "supplier" and the subscriber known as the "consumer" of the event. Although the receipt of an event can alter the flow of control in the consumer, they should typically be used primarily as an information broadcast mechanism. Direct operation requests to another object should be used when affecting changes to critical flow of control to ensure message receipt by the intended recipient.

6.5.2 This guide suggests the use of an event delivery mechanism called "event channels." Event channels can provide a coarse grain filtering capability for events. Consumers can subscribe to a specific event channel in order to receive a particular event type. The event broker specification of this guide extends this event channel capability by adding features for locating event channel, registering for event delivery, and filtering the events of interest to minimize performance penalties when large numbers of events are present.

6.5.3 This guide supports creating, posting, and subscribing to events. It also provides the mechanisms to support subject-based addressing. When a consumer subscribes to events for a particular subject, it should be notified whenever an event for the subject is posted by any supplier.

6.5.4 The event delivery requirements are summarized as follows:

Suppliers do not know who the consumers of news events are; therefore, suppliers do not need to get a "handle" for them.

No response or answer is sent back from the consumer(s) to the supplier once the post is completed.

Message delivery is based entirely on message context (subject).

6.5.5 *Event Content*

6.5.5.1 The specification of event content should have two parts: a header and a body. The header should consist of information of a general nature regarding the event, such as the name of its subject (a subject string used for identification); an aging factor (for determining event effectiveness and may be site specific); priority; and any filtering information relevant to event delivery at a general level. The event body should contain: the actual event message; the original time of the event; and data relevant to filtering by the consumer of the event. The body should also contain any information required by the consumer not used in the filtering process (called "News"). The body should be extended with object references as required to facilitate communication with any objects associated with the event.

6.5.5.2 The event header is constructed by the supplier of the event and is used by an Event Notification System (ENS) to route the event to any consumer registering interest in the event. Note that the structure of the header may be specific to a particular ENS. The body of the event is constructed by the event supplier and is intended for use by the event consumer. Consumers of events express interest in an event type by passing the subject name and associated filter data along to the ENS. The ENS returns an original connection, called an event channel, to the consumer.

6.5.5.3 Name-value pairs are one mechanism that should be used to define data either in the header or body. Specific information within the body varies according to event type; issues such as allocation are implementation dependent.

6.5.6 *Subject String*

6.5.6.1 The event subject string should be defined as a multi-level hierarchy to assist in event classification and filtering. The levels designate the CIM Framework issuing the event component, the issuing interface within that component, and the event type. Each level should be delimited by a special character (e.g., a forward slash: "/"). An example of this syntax is */RecipeManagement/MachineRecipe/ParameterChanged*.

6.5.7 *Filter Data and News*

6.5.7.1 Filter data are attribute names, values, and operators that are specified by the consumer and are used by the filter subsystem to further qualify an event. News consists of additional attributes and values that are received by the consumer but not used in the filtering process and thus are not specified by the consumer. The consumer specifies the attributes, values, and operators upon which the event data is filtered. The actual filtering is performed after the supplier sends an event but prior to the consumer receiving the event. The filterable data should be well known and standardized. News may be used by the consumer to further filter the event, but the attributes and values are not standardized. Additionally, news may be used to convey the identity of the object generating the event to any consumer of the event.

6.5.7.2 An Event Broker is required to support subscription to an event channel that has the specified subject and supports filtering. The actual filtering mechanism is an implementation dependency. Filter data is passed to the Event Broker by the consumer to qualify the particular events that the consumer is interested in receiving. The filter data specifies filterable items in which the consumer is interested plus operators and operands to perform the filtering. The filtering sub-system should use the filter data to ensure that a specific event is passed to the consumer. The interface is *simple* and does not try to construct advanced logic to build the filter. The results of the filtering are *anded* together, such that the passed event should meet all of the filter criteria. The need to specify logical operators (e.g., "or") on the filter criteria or the use of query languages should be evaluated. Extensions to the filter structures would be required to support these additional capabilities.

NOTE 2: The location of the filtering subsystem is an implementation detail.

6.6 *Distributed Transactions*

6.6.1 Many operations defined in the CIM Framework are related to one another in complex ways that require multiple operations to be treated as a single unit of work. For example, grouping operations are combined with the ability to make an explicit decision to commit the aggregation of changes, or to abort all of the operations and return to the prior state. These grouping of operations are consistent with the familiar concept of a transaction (most commonly encountered in the context of database management systems). CIM Framework objects should be capable of participating in transactions as described below. However, the choice of how an object participates is implementation specific. For example, the implementer chooses the implementation technology and whether a change in object state is recoverable (that is, whether a change in state can be rolled back).

6.6.2 A transaction is a contract between two or more objects to perform some action based upon one or more requests in some context and having the ACID properties as follows:[6]

- Atomicity — State changes are atomic; either all happen or none happen. These changes include database changes, messages and events.
- Consistency — A correct transformation of state. Actions taken as a group do not violate any of the integrity constraints associated with the state.
- Isolation — Even though transactions execute concurrently, it appears to each transaction T that others executed either before T or after T, but not both.
- Durability — Once a transaction completes successfully (commits), its changes to state survive failures.

6.6.3 For example, consider a lot that starts processing in a piece of equipment. The states of the lot and the

6 J. Gray, Transaction Processing Concepts and Techniques, Morgan Kaufmann Publishers/Harcourt Brace and Co., 6277 Sea Harbor Dr., Orlando, FL, 1993.

equipment should change in order to accurately track the state of the factory. Coordinating the lot and equipment state changes as a transaction guarantees that factory state can be recovered accurately.

6.6.4 Transactions are created by a user of a service (the client) requesting an operation from a provider of a service (the server). To maintain the ACID properties of a transaction, the server should be able to return to the state prior to the request for the operation in the event of a failure. In this sense, the server should be recoverable. Failures are either software or hardware events that prevent the completion of the transaction. The server is a recoverable server if it is able to maintain the ACID properties when faced with a failure.

6.6.5 Transactions should be designed in a manner such that they do not span a period of interaction with an external entity such as a person using a GUI or a piece of equipment. Waiting for the response from an external entity can result in locks being held for multiple seconds, minutes, or longer. This can adversely affect other transactions by causing time-outs or deadlocks. These types of transactions can usually be split into multiple serially executed transactions with some small amount of extra revalidation of current states at succeeding transactions.

6.6.6 Coordinating the completion of transactions may involve multiple servers and may entail either committing the successfully completed transaction or rolling back the unsuccessful transaction. This activity imposes additional overhead on a system. Suppliers and consumers should assess the impact of transactions on system performance during component design and selection of transactional events.

6.6.7 Transactions may cause physical effects in the manufacturing system that cannot simply be rolled back in accordance with the ACID properties. Application and system designers should include ways to modify the logical view of the system to match the physical reality of the manufacturing floor if such a mismatch occurs.

6.6.8 Transactions can create CIM Framework events as state changes occur. As the transaction may not be committed at the point of event creation, the event should not be visible outside the transaction until the final commit point. The details of performing this task are implementation dependent. For example, the event announcing the completion of a lot at a processing step should not be published until the processing step completion transaction is committed. Otherwise, the event could be published, but the transaction subsequently rolled back, creating a system inconsistency.

6.6.9 Transactions should be able to be *nested*, thus providing the ability to define transactions within other transactions. These sub-transactions can generate additional sub-transactions, thus forming a hierarchy of transactions. In the spirit of maintaining the ACID properties, each sub-transaction can issue a commit or rollback for its piece of work. The results of the sub-transaction are only available to the parent transaction. The sub-transactions commit becomes permanent only after it issues a local commit and all ancestors commit. If the parent transaction does a rollback, all descendent transactions are rolled back regardless of any local commits.

6.6.10 There are two types of transactions widely supported for distributed object infrastructures. The OMA support for transactions is described in the OMG's Object Transaction Service (OTS). Microsoft provides support for transactions with its Microsoft Transaction Server (MTS) product. The OTS closely aligns with other standards such as The Open Group *Distributed Transaction Processing (DTP)* model.[7] Using industry standard protocols as a base, the OTS supports interfacing with products from the major database suppliers. Using the provided OTS interfaces and information about The Open Group standards, non-ORB supplied database interfaces could be developed to allow for interoperability with other cooperating transaction services. MTS also supports transactions with major database suppliers through use of The Open Group XA interface. Using the MTS Software Developer Kit, transaction support can be extended to other resources.

6.6.11 Combining heterogeneous components based on a combination of OTS and MTS is not straightfor-ward. Although both rely on the XA interface for dis-tributed transaction coordination, they are not designed to operate with each other. Both OTS and MTS hide the details of transactions from users. This makes either solution very convenient, but makes linking them together more difficult. For example, suppose a CORBA-based component adhering to OTS should interact with an MTS-based component. The scenario calls for the CORBA based component to use the XA interface to work with the MTS provided transaction coordinator (see Gray[8] for additional information on distributed transactions). However, in hiding XA complexity, OTS also hides the ability to readily specify the transaction coordinator (OTS does this behind the scenes). CIM Framework component developers and consumers should determine the relative need for distributed transactions spanning OTS and MTS against the additional complexity of developing a XA-based mechanism for combined OTS and MTS transactions.

7 The Open Group, Distributed TP: The XA+ Specification, Version 2, The Open Group, 11 Cambridge Center, Cambridge MA, 1994.

6.6.12 The ACID properties provided by either OTS or MTS may be used for CIM Framework transactions. Many implementation details are supplier specific; however, the major architectural principles have been described above.

6.7 *Component Management*

6.7.1 A component refers to a collection of related interfaces that form a coherent subsystem. Components may have a component manager to assist in the tracking and management of the instantiated interfaces (objects). The objects that are managed by a component manager are called managed objects.

6.7.2 *Component Level Interface*

6.7.2.1 Component managers provide services such as reporting on the collection of instances they manage and creating object instances. The component manager provides the following:

Object references to managed objects.

Collective queries for some aspect (usually a state) across all the objects it manages.

Services for:

Creating a managed object and returning a reference to it, or receiving an object reference to a newly created object. The component manager then "registers" the object reference.

Removing managed objects.

Finding managed objects.

6.7.3 *Component Manager Classification*

6.7.3.1 Component Managers are classified by their allowable number of instances.

6.7.3.2 *Unique Component Managers*

6.7.3.2.1 A unique component manager describes a component manager for which there is only one running instance in an MES implementation. Unique component managers are used when a single point of factory level control or focus is required. An example use of this pattern might be an interface within a Dispatcher component called DispatchingManager. This might be a unique component manager because multiple dispatching systems on the factory floor could create problems with work scheduling.

6.7.3.3 *Non-Unique Component Managers*

6.7.3.3.1 A non-unique component manager describes a component manager for which multiple instances may be running in an installed MES system. The component manager instances are derived from the same code base, but have separate instance data for each running instance. Non-unique component managers should be registered with the factory with some selection criteria in order for a requester to be able to obtain a handle to the correct instance. An example use of this pattern is the scenario in which several ProductManagers are employed within a production system.

6.8 *Architecture For Service Requests*

6.8.1 Services are implemented by a factory object that is the service provider. The productive entity in a factory invokes the service methods on that factory object.

6.8.1.1 For example, a recipe server could offer the following interface:

```
interface RecipeManagementServer {
     // upload a recipe
     void acceptRecipe(
          in string recipeName,
          in Recipe recipe);
     // download a recipe
     Recipe provideRecipe(in string
     recipeName);
};
```

6.8.1.2 The problem with service requests is that they require a flow from the productive entity to the factory object that provides the service. This kind of reverse flow contradicts the principle of layered architecture by which the productive entity is supposed to be a more primitive entity, unaware of factory objects, their locations and their structures. The trading service addresses this problem.

6.8.2 *Trading Service*

6.8.2.1 *Using Trading Service*

6.8.2.1.1 A trading helps clients to locate services. An object that must locate a service must know how to access the trading service.

6.8.2.1.2 A trading service relies on the description of the service itself, rather than any attribute relating to the server that provides the service (such as the name of the server). It must be able to describe the service it requires. The trading server locates a server that fulfills the required service profile.

NOTE 3: The trading service described here is based on the CORBA COS Trading Object Service, implementations of which are available from vendors of CORBA environments. The solution however does not require the full generality of the COS Trading Object Service, and can be viewed as a strict subset of the latter.

6.8.2.2 *The Trading Concept*

6.8.2.2.1 A trading scenario is based on a server that exports a service to a trader. The client then imports the service from the trader, receiving a reference to the server on which it can invoke the service.

6.8.2.2.2 This is depicted in the following diagram:

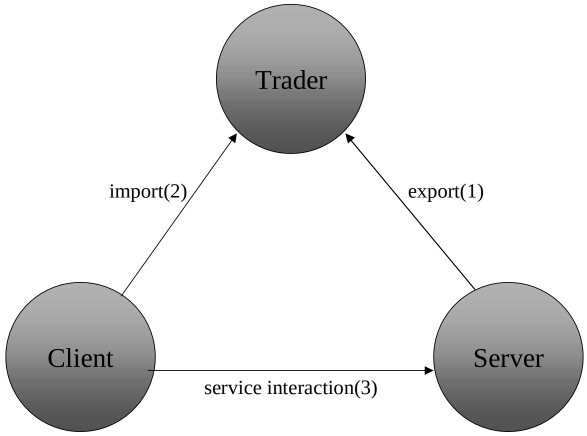

Figure 2

6.8.2.2.3 The diagram suggests that the server exports its service to the trader. In practice any object aware of the server and its provided services could assume this job. For example, a factory configuration object could be responsible for exporting all services to the trader.

6.8.2.3 *Trading Service Models*

6.8.2.3.1 The trader has to implement two interfaces:

- The Register interface allows other objects to register export service offers to the trader.

  NOTE 4: This interface is used e.g. by the service provider to inform the trader about the services the service provider offers.

- The Lookup interface allows other objects to lookup the trader for a required service.

  NOTE 5: This interface is used by e.g. the productive entity to find a service provider for a specific service.

6.8.2.4 *Export Use Cases*

6.8.2.4.1 The trader offers an interface named Register, that allows a server to register its services with the trader.

6.8.2.4.2 The IDL definitions given below are for illustrative purposes. They are extracted from the COS Trading Object Service specification [OMG]. For clarity, not all services are included here.

6.8.2.4.3 *Exporting a Service*

6.8.2.4.4 To export a service, the server uses:

```
OfferId export (
     in Object reference,
     in ServiceTypeName type,
     in PropertySeq properties
);
```

6.8.2.4.5 The server passes a reference to itself, and describes its offer by passing in a service type name and a list of properties of the service. The trader answers an offer id, through which the server can further manipulate its offer.

6.8.2.4.6 Factory service offers are described as follows:

6.8.2.4.6.1 *Service Type Name*

6.8.2.4.6.2 The type is a string naming the service itself. We are yet to agree upon the services supported by this specification. The following are obvious candidates:

- Recipe Service
- Wafer Map Service
- Fixtures Service[8]

6.8.2.4.6.3 *Properties*

6.8.2.4.6.3.1 Properties are used to characterize and specialize the service. A property is a name/value pair, where the name is a string naming the property, and the value specifies the property value offered by the server. The constraint language defined by the COS Trading Object Service [OMG] limits the type of values to the basic data types (such as numbers, chars, booleans and strings) and sequences of these.

6.8.2.4.6.3.2 The following properties are to be used for registering factory services:

- “Serviced Productive entities” — The value of this property is a list of the ids of the productive entities serviced by this server. This allows multiple servers of the same type to be installed, and partition the productive entity service among the available servers. Note that it does not require the server to know the productive entities it serves, since the server registration can be done by a factory configuration service.
- “Serviced Areas” — The value of this property is a string collection naming the factory areas serviced by the server. This property is another means of partitioning the service among multiple servers. The area could be a name of a cell controller if cellular manufacturing is practiced, or the name of any organizational unit implemented by the factory, and known to the factory configuration service.

6.8.2.4.7 *Withdrawing a Service*

6.8.2.4.7.1 To withdraw a registered service, the server (or the configuration service) uses:

```
void withdraw (
     in OfferId Id);
```

8 In back end fixtures is a generic name for durables and consumable materials

6.8.2.4.8 *Querying a Registered Service*

6.8.2.4.8.1 A server may query the trader the details of a registered service by passing in the offer id.

```
Struct OfferInfo {
     Object  reference;
     ServiceTYpeName  type;
     PropertySeq  properties;
};
OfferInfo describe (
     in OfferId  id);
```

6.8.2.4.9 *Modifying a Registered Service*

6.8.2.4.9.1 The server may modify the properties of a registered service. It may add new properties, delete existing properties, or modify the value of existing properties. This is done using the following method:

```
void modify (
     in OfferId  id,
     in PropertyNameSeq  del_list,
     in PropertySeq  modify_list
);
```

6.8.2.4.9.2 The properties named in the del_list are deleted. Properties in the modify_list that do not exist are added. Properties in the modify_list that exist, receive a new value.

6.8.2.4.9.3 The modify method can be used to support changes in the factory configuration, such as new productive entity being added or deleted, a productive entity being migrated from one cell to another, a new load balancing policy for the servers installed, etc.

6.8.2.5 *Import Use Cases*

6.8.2.5.1 *Importing a Service* — The trader offers an interface named Lookup that clients can use in order to locate a service:

```
void query (
in ServiceTypeName  type,
     in Constraint  constr,
     in Preference  pref,
     in PolicySeq  policies,
     in SpecifiedProps  desired_props,
     in unsigned long  how_many,
     out OfferSeq  offers,
     out OfferIterator  offer_itr,
     out PolicyNameSeq  limits_applied
);
```

6.8.2.5.1.1 The Query in Parameters — The “in” parameters are used by the client to specify the service it needs and the policies for searching it.

- The “type” parameter is key to the central purpose of trading. It specifies the name of the service type the client is interested in.
- The “constraint” guides the trader on how to select a server based on its registered properties. It is a string that describes the selection in some given constraint language. The typical constraints will select a server for a specific productive entity or for the area the productive entity belongs to. Both possibilities use the “in” operator for testing the inclusion of an element in a set. Some examples follow:

```
“DieAttachXYZ in ServicedProductive-
Entities”
“Cell22 in ServicedAreas”
```

6.8.2.5.1.2 “Preferences” specify how should a server be selected in case the query results in more than one answer. It is suggested that this parameter be ignored, which means that the default of first is always used.

6.8.2.5.1.3 The “policies” parameter guides the trader on how to choose a policy for performing the search. Search policies are a rather complicated issue, which can be ignored in the Simple Trader case.

6.8.2.5.1.4 The “desired_props” parameter instructs the trader which properties are to be returned as part of the answer (it does not affect the selection itself). This does not make much sense with the limited set of properties which has been defined, and can also be ignored (use none as the parameter value).

6.8.2.5.1.5 The “how_many” parameter is another way to restrict the number of answers. It is proposed that 1 always be used as the value of this parameter.

NOTE 6: Should areas be used as the selection criteria, the equipment must be aware of its area within the factory. This should be supported through the productive entity “Configuration” aspect.

6.8.2.5.1.6 *The Query out Parameters*

6.8.2.5.1.6.1 The query returns the selected servers in one of two forms: a collection of services or a reference to an iterator through which the returned servers can be obtained. The second method is designed for queries that may return a large number of offers. One can always assume that results are returned within the first out parameter (out OfferSeq offers*)*, namely a sequence of offers. Furthermore, having specified 1 as the value of the “how_many” parameter, it is ensured that the answered sequence contains at most one element.

6.8.2.6 *Locating the Trading Service*

6.8.2.6.1 The productive entity locates the services it requires using a trading service.

6.8.2.6.2 A client can obtain a reference to the trading service by invoking the following method on the ORB:

```
Object resolve_initial_references (
     in ObjectId identifier)^
     raises (InvalidName);
```

Where:

the reserved name “TradingService” is passed as the identifier.

6.8.2.7 *A Usage Scenario Example*

6.8.2.7.1 Here is an example of a usage scenario.

6.8.2.7.2 In common factory practice, cellular manufacturing has a factory configuration service responsible (among other things) for exporting the factory services to the trading service. The following are some typical use cases:

1. The factory configuration service registers a wafer map server to server two cells named CellA and CellB.

   The factory configuration service obtains an initial reference to the trading service from the ORB:

   ```
   trader =
        orb.resolve_initial_refer
        ences("TradingService");
   The trader answers its Register
   interface:
        traderRegistry =
        trader.register_if();
   ```

   The factory configuration service builds properties as a single-itemed sequence of containing one name/value pair whose name is "ServicedAreas" and whose value is a sequence of the cell names { "CellA", , CellB"} . It then uses the Register interface of the Trading Service to register the service offer:

   ```
   traderRegistry.export(
        waferMapServer,"Wafer Map
        Service", properties);
   ```

2. The configuration manager informs a Die Attach equipment that it belongs to CellA.

   ```
   ProductiveEntities.setArea("CellA");
   ```

3. The Die Attach needs a wafer map.

   It obtains an initial reference to the trading service from the ORB:

   ```
   trader =
        orb.resolve_initial_refer
        ences("TradingService");
   ```

   The trader answers its Lookup interface:

   ```
   traderLookup = trader.lookup_if();
   ```

   The productive entity looks up the trading service for the wafer map service:

   ```
   traderLookup.query(
        "Wafer Map Service",
        "CellA in ServicedAreas",
        pref, policies, desired_props,
        1, preference, offers,
        offers_itr, limits_applied);
   ```

   The wafer map server is returned as the first element of the offers sequence. The productive entity may keep the reference to the wafer map server for future use.

4. The Die Attach can now invoke the service on the wafer map server:

   ```
   waferMapServer.getWaferMap(…);
   ```

7 Technical Architecture Conformance

7.1 Conformance is defined as "adherence to a standard or specification in the implementation of a product, process, or service." A conforming implementation should have an associated implementation conformance statement that details the capabilities that have been implemented. While recognizing that the CIM Framework is, by definition, not a complete specification of a MES, a guide for technical architecture defines conformance for each of its major requirements as follows.

7.2 *Distributed Object Communications Conformance*

7.2.1 The CIM Framework object model is based on the ability to issue service requests to a component object and to subscribe to events published by the component object. Component suppliers should explain how these two forms of communications are accomplished so consumers can assess the ease and feasibility of integrating a component into the factory MES. Example terminology specific to semiconductor manufacturing is provided for clarity. It does not preclude application specialization for other industries.

7.3 *Exception Conformance*

7.3.1 Alerting operation requesters of abnormal outcomes is essential for robust implementations. Component suppliers should explain how their implementations support raising specified system and user-defined exceptions.

7.4 *Event Specification Conformance*

7.4.1 Notification of asynchronous occurrences is a cornerstone of distributed event-driven application domains such as MES. Suppliers should explain how their components support event delivery, including the registration of event suppliers, event consumers and the provision for Event Broker features for event filtering.

7.5 *Distributed Transaction Conformance*

7.5.1 Ensuring consistent state changes among components is a key concern in the integration of a factory MES. Component suppliers should explain how their components support transactional units of work.

7.6 *Component Management Conformance*

7.6.1 Component suppliers should explain how object instances are managed. This includes how the object is identified, constructed, accessed, and destroyed (or flattened in the case of a persistent object). It also includes mechanisms for query or lookup of specific managed object instances.

7.7 *General Rules for CIM Framework Conformance*

7.7.1 The following rules define the general expectations for technical conformance to any CIM Framework specification. Suppliers should provide documentation explaining any deviations from these general rules.

- All CIM Framework-defined operations for an interface should be supported.
- All exceptions and events for an interface should be supported.
- A component should use component manager interfaces for object instance creation and registration where these operations are specified.
- A component implementation should support all interfaces specified for that component.
- An application may not add states and transitions to the defined dynamic models that have external interfacing ramifications. The application may still further subdivide the states.
- A component implementation should explain how it supports substitutability. For example, it may support different degrees of substitutability between the following levels:
  - Strict — An application that supplies a CIM Framework component should be reconfigurable so it can use another supplier's implementation of that component. The application's interactions with the component are restricted to CIM Framework defined interfaces.
  - Weak — An application may use extended, pro-prietary, or private interfaces of a component. When the another supplier's implementation is substituted for an installed component, any components using the extended, proprietary, or private interfaces need to be reassessed and possibly modified. The use of the CIM Frame-work-defined interfaces does not change.

SEMI E97-0200A
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK GLOBAL DECLARATIONS AND ABSTRACT INTERFACES

This provisional specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on October 21 and December 15, 1999. Initially available at www.semi.org January 2000; to be published February 2000.

NOTE: This document was published twice during the February 2000 (0200) publishing cycle.

1 Purpose

1.1 This document defines the global declarations used by all other components of the CIM Framework and also specifies the common architecture patterns that serve to functionally integrate CIM Framework components. The material architecture defines functionality common to product management, durables management and consumables management components. The factory resource architecture defines relationships and common functionality of a variety of factory resources. The job architecture defines a factory-wide model for controlling factory jobs that drive a variety of manufacturing tasks. These specifications are separated into a distinct group to enable them to be specified once and then logically included or inherited wherever they are subsequently needed.

2 Scope

2.1 This specification provides the common interfaces required by Manufacturing Execution Systems to:

- Provide type definitions for common data structures to ensure consistent representation. These items include data types for common concepts such as coordinates, priorities, timestamps, and sequences of basic data types.
- Provide definitions for common exceptions used consistently throughout the CIM Framework.
- Provide the material architecture interfaces common to identifying, grouping, moving, locating and tracking material in the factory.
- Provide the factory resource architecture interfaces common to defining, organizing, tracking usage of and maintaining factory resources including equipment, sensors, durables, and people.
- Provide the job architecture interfaces common to creating, executing and managing work in the factory. The job architecture is specialized for material processing jobs, material transport jobs, resource maintenance jobs and factory jobs that drive product material through their process flows.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 *Provisional Status*

3.1.1 This specification is designated as provisional due to known areas that need to be completed. The following items summarize the deficiencies of the provisional specification to be addressed before a subsequent ballot to upgrade it to full standard status.

3.1.2 The specification uses the IDL typedef “any” in several places. While this usage provides flexibility, it can have the effect of reducing interoperability due to differences in interpretation of the value provided by separate implementations that interact through a standard interface. The “any” typedefs should be replaced with explicit data types prior to upgrade from Provisional to full Standard status.

3.1.3 The definition of interfaces for retrieval of history associated with CIM Framework objects may need to be added to abstract interfaces in this document after the complete specification for the history facility within the CIM Framework Factory Services Component.

3.1.4 The specification of CIM Framework states reported through published state change events is currently based on a type definition for an enumeration of state values. There may be alternate representations for states that are better able to capture the semantics of nested and parallel states. The state representation used for the CIM Framework will be reviewed and possibly changed before upgrade to full standard status.

3.1.5 The Resource model defined in SEMI E81 includes several extensions that are not yet included in this specification. These extensions include composition of resources from other resources, capabilities associated with resources, and associations with tracking and maintenance functions for resources.

These extensions will be addressed before upgrade to full standard status.

3.1.6 The interfaces specified for MESFactory, Area, and ComponentManager are included in the E81 responsibilities for the Factory Component within Factory Operations. These interfaces will need to be moved to that component when it is considered in a future ballot.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

4.2 *Other Standards*

UML Notation Guide, Version 1.1, document number ad/97-08-05, Object Management Group[1]

ISO/IEC International Standard 14750 (also ITU-T Recommendation X.920) — Information Technology – Open Distributed Processing – Interface Definition Language [2]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *abstract interface* — an interface specified only for inheritance rather than for implementation in order to standardize common features shared by all specializations of the interface.

6 Requirements

6.1 *Global Type Definitions*

6.1.1 This section describes data type definitions and exceptions that are global in nature. By "global" it is meant that they are designed to be used by any component within the CIM Framework. This specification does not address how they are implemented within a CIM Framework conformant application; that level of detail is within the realm of the development effort.

6.1.2 Global type definitions are specified as IDL declarations which may be referenced by any CIM Framework interface. The CIM Framework uses the keyword *typedef* to define aliases for basic object types, but with additional implied semantics. (e.g., the *units* typedef defines a *string*, whose contents conform to definitions found in SEMI E5). The keyword *struct* begins the type declaration for record structures composed of a collection of named and typed values. The third form of type definition is an enumerated type beginning with the reserved word *enum*. Enumerated types are used to declare a list of tokens that can be used as values of that type. Enumerated types are mainly used to denote the states of an object for communication in CIM Framework events. Finally, collections of values are declared with the keyword *sequence*. This kind of type definition may or may not imply significance to the ordering of the members in the sequence. Where no ordering constraint is mentioned, the elements of the *sequence* are not assumed to be in any meaningful order.

NOTE 2: In the following definitions, "//" or "/* .... */" delimits a comment.

NOTE TO THE READER: The comments in the following sections (described in NOTE 2, above) appear to immediately precede, rather than follow, the items they discuss. — SEMI Staff

6.1.3 All CIM Framework specifications will be declared within the context of the CIMFW module which spans all of the components of the CIM Framework. Within the CIMFW module, the global type definitions will be declared within a second-level module called Global.

1 UML Notation Guide v1.1 is available to the general public at http://www.omg.org/cgi-bin/doclist.pl, +1-508-820 4300, Object Management Group, Inc. , Framingham Corporate Center, 492 Old Connecticut Path, Framingham, MA 01701.

2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

Module: Global

```
typedef string Identifier;

typedef unsigned long Flags;

struct NamedValue {
        Identifier name;
        any argument;
        long len;
        Flags arg_modes;
};

typedef NamedValue NameValue;

typedef sequence <NamedValue> NameValueSequence;

typedef string PropertyName;

struct Property {
        PropertyName property_name;
        any property_value;
};

typedef sequence <Property> Properties;
```

/* This type definition represents units for factory parameters, measurements. etc., and conforms to the SEMI E5 standard for representation of units. In that standard, the string contains a code representing a value of the units. For example, "ns" would mean nano-seconds; "A" for ampere; and "wfr" for wafer. */

```
typedef string Unit;

typedef string Units;
```

/* This type definition represents a sequence of *string* values. */

```
typedef sequence <string> StringSequence;
```

/* This type definition represents a sequence of *any* values. */

```
typedef sequence <any> AnySequence;
```

/* This type definition represents a sequence of *long* values. */

```
typedef sequence <long> LongSequence;
```

/* This enumerated type identifies event priorities and is used in each event definition. */

```
enum PriorityOfEvent {
        Low,
        Medium,
        High,
        Alarm };
```

/* This enumerated type identifies the lifecycle states that an object may go through. It is used in event notifications of state changes. */

```
enum LifecycleState {
        Undefined,
        Created,
        Deleted,
        Moved,
        Copied };
```

/* This enumerated type identifies the states of objects that can be reserved (Lot, Durable and Machine). It is used in event notifications of state changes. */

```
enum ReservationState {
        UndefinedReservationState,
        Reserved,
        UnReserved };
```

/* This enumerated type represents the SEMI E10 states for Machines and Support Resources. It is used in event notifications of state changes. */

```
enum E10State {
        E10Productive,
        E10Standby,
        E10Engineering,
        E10ScheduledDowntime,
        E10UnscheduledDowntime,
        E10NonscheduledTime };
```

/* *TimeT* is a *ulonglong* value (64 bits) that represents the number of 100 nanosecond increments that have passed since a base time (October 15, 1582 at 00:00, the Universal Time Representation which refers to time in Greenwich Mean Time). The specification for *TimeT* is: */

```
struct ulonglong {
        unsigned long low;
        unsigned long high;
};
```

```
typedef ulonglong TimeT;
```

/* *TimeStamp* is mapped to the data type of *TimeT.* */

```
typedef TimeT TimeStamp;
```

```
typedef sequence <TimeStamp> TimeStampSequence;
```

/* The notion of a specific interval of time denoting a start time and an end time is represented as a struct called *IntervalT.* */

```
struct IntervalT {
        TimeT lower_bound ;
        TimeT upper_bound ;
};
```

/* *TimeWindow* is mapped to the data type *IntervalT.* */

```
typedef IntervalT TimeWindow;
```

/* Duration is mapped to the datatype TimeT. */

```
typedef TimeT Duration;
```

/* This structure is for the representation of a single schedule instance. It should be noted that “EndTime” should never proceed “StartTime.” */

```
struct ResourceSchedule {
        TimeStamp plannedStartTime;
        TimeStamp plannedEndTime;
        TimeStamp actualStartTime;
        TimeStamp actualEndTime;
};
```

/* The definition of a sequence of ResourceSchedules. This sequence is ordered in increasing time order and that order must be maintained in any manipulation of the sequence. */

```
typedef sequence <ResourceSchedule> ResourceScheduleSequence;
```

6.2 *Global Exception Declarations*

6.2.1 This section describes the standard CIM Framework exceptions that may be thrown by operations in any component.

Module: Global

/* This signal is raised when a lookup or find fails. */

```
exception NotFoundSignal { string errorMessage; };
```

/* This signal is raised when an add fails because an object already exists with the given identifier. Interfaces may also define and raise a <ObjectType>DuplicateSignal. */

```
exception DuplicateIdentifierSignal {
        string errorMessage;
        string duplicateIdentifier; };
```

/*This signal is raised when an invalid state transition request is made of an object. */

```
exception InvalidStateTransitionSignal {
        string errorMessage; };
```

/*This signal is raised when a "set" attribute contains a value out of range. */

```
exception SetValueOutOfRangeSignal {
        string errorMessage; };
```

/* This signal is raised when an incorrect TimePeriod is used. */

```
exception TimePeriodInvalidSignal {
        string errorMessage; };
```

/* This signal is raised when a Property name is not valid. */

```
exception InvalidPropertyNameSignal {};
```

/* This signal is raised when a a Property with this name is not defined. */

```
exception PropertyNotFoundSignal {};
```

/* This signal is raised when a Property is not supported. */

```
exception UnsupportedPropertySignal {};
```

/* This signal is raised when a Property is read-only and cannot be set. */

```
exception ReadOnlyPropertySignal {};
```

/* This signal is raised when no other defined signal matches the error condition. */

```
exception FrameworkErrorSignal {
        string errorMessage;
        unsigned long errorCode;
        any errorInformation; };
```

/* Definition of fields for FrameworkErrorSignal:

errorMessage	is a text field representing a description of the circumstances of the exception for use by developers in debugging the exception.
errorCode	is a numeric field representing the code for the given exception.
errorInformation	is any further debugging information related to the circumstances of the exception.

The errorCode has certain reserved values that are defined and standardized in the CIM Framework.

- 0000–0999 reserved for the CIM Framework.
- 1000–1999 reserved for extensions to the CIM Framework.
- 2000–2999 reserved for specializations of CIM Framework interfaces.
- 3000–maximum reserved for implementers. /*

/* This errorCode should be used for any operation where the supplier has chosen to not provide implementation, but needs to communicate to the user that nothing has happened as a result of this operation invocation. */

```
const unsigned long NOT_IMPLEMENTED = 0;
```

/* This errorCode should be used for any operation where the supplier assumes a specialization will implement this operation. If this exception is received, the user will realize that an interface has not been properly specialized. */

```
const unsigned long IMPLEMENTED_BY_SUBCLASS = 1;
```

/* This errorCode should be used for any operation where an unknown exception has been caught by the implementation and, rather than crashing, the implementation can map the “unknown” exception into this known exception. This probably does not aid in program debugging but does prevent program crashing. */

```
const unsigned long UNKNOWN_EXCEPTION = 2;
```

/* This errorCode should be used for any invocation where some unknown error has occurred that left the server object in an ambiguous state. */

```
const unsigned long COMPLETION_UNKNOWN = 3;
```

6.3 *Abstract Interface Type Definitions*

6.3.1 *Referenced Declarations*

6.3.1.1 The following declarations are not part of this specification, but are required for reference by Abstract Interface elements. These referenced declarations are defined in separate documents but are noted here as dependencies that appear in IDL compilations.

Module:	EquipmentTracking
Interface:	Machine

```
module EquipmentTracking {

interface Machine {}; // Stub

typedef sequence <Machine> MachineSequence;

exception MachineDuplicateSignal { };
```

```
exception MachineNotAssignedSignal { };

exception MachineRemovalFailedSignal { };

}; // module EquipmentTracking
```

Module: Labor

Interface: Person

```
module Labor {

interface Person {}; // Stub

typedef sequence <Person> PersonSequence;

exception PersonDuplicateSignal { };

exception PersonNotAssignedSignal { };

exception PersonRemovalFailedSignal { };

}; // module Labor
```

6.3.2 *Abstract Interface Declarations*

Module: AbstractIF

/* The following IDL interfaces will be fully defined in the sections below. They are declared here as forward references to support the sequence typedefs. */

```
interface Resource;

interface Material;

interface MaterialGroup;

interface JobSupervisor;

interface Job;

interface JobRequestor;
```

/* Type definitions for sequences of interfaces instances. */

```
typedef sequence <Resource> ResourceSequence;

typedef sequence <Material> MaterialSequence;

typedef sequence <MaterialGroup> MaterialGroupSequence;

typedef sequence <Job> JobSequence;

typedef sequence <JobSupervisor> JobSupervisorSequence;
```

6.4 *Resource Abstract Interface Group*

6.4.1 The Resource Abstract Interface Group provides a set of abstractions that are globally useful. Figure 1 is the Information Model for the Resource Abstract Interface Group.

Resource Abstract Interface Group

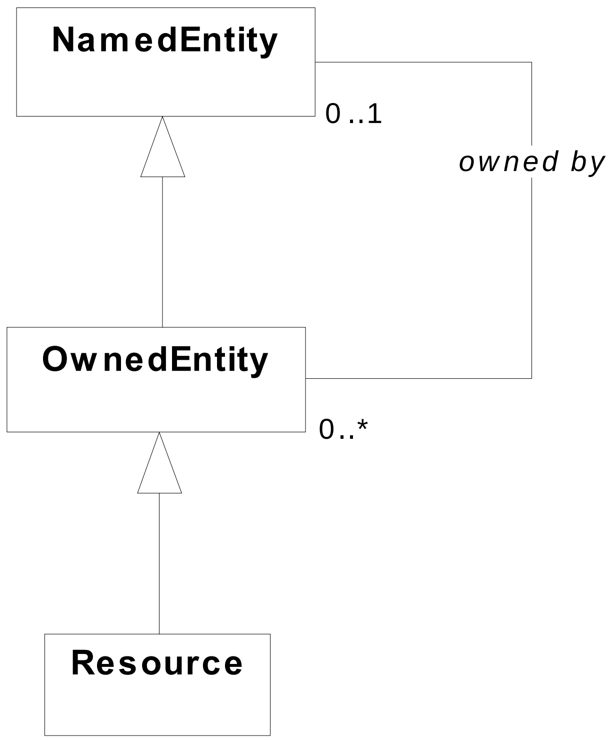

Figure 1
Resource Abstract Interface Group Information Model

6.4.1.1 All CIM Framework interfaces will inherit from one of the interfaces shown in Figure 1. NamedEntity provides the most basic naming functions. An OwnedEntity is a NamedEntity with functions supporting the concept of ownership. A Resource is an OwnedEntity which also takes an active role in product manufacturing.

6.4.2 *Named Entity Interface*

Module:	AbstractIF
Interface:	NamedEntity
Inherited Interface:	Implementation-dependent.
Description:	The abstract interface NamedEntity provides the concept of a named item. This allows for comparison and conversion of names via a standard object.
Exceptions:	None.
Published Events:	None.
Provided Services:	

```
interface NamedEntity {
```

/* Set and get the name. The NamedEntity interface does not specify scoping of names or enforce uniqueness of names. This could allow distinct instances of a NamedEntity to use the same string as a name. */

```
void setName (in string name)
        raises (Global::FrameworkErrorSignal);

string getName ( )
        raises (Global::FrameworkErrorSignal);
```

/* Tests the equality of the name with the name provided as an argument. */

```
boolean isNamed (in string testName)
        raises (Global::FrameworkErrorSignal);

}; // NamedEntity
```

Contracted Services: None.

Dynamic Model: None.

6.4.3 *Owned Entity Interface*

6.4.3.1 The concept of ownership in the CIM Framework relates to the hierarchical structure that may be defined where one object "owns" another object. This should not be confused with the business concept of ownership relating to an item's value as an asset.

Module: AbstractIF

Interface: OwnedEntity

Inherited Interface: NamedEntity

Description: The abstract interface OwnedEntity provides for the concept of an "owned" entity. There may be only one "owner" for each instance of an OwnedEntity. The OwnedEntity is able to communicate with the owner to request services, or forward information of interest. To build a "parts of" hierarchy, a series of ownerships can be established.

Exceptions: None.

Published Events: None.

Provided Services:

```
interface OwnedEntity : NamedEntity {
```

/* Set and get owner. */

```
void setOwner (in NamedEntity owner)
        raises (Global::FrameworkErrorSignal);

NamedEntity getOwner ( )
        raises (Global::FrameworkErrorSignal);

}; // OwnedEntity
```

Contracted Services: None.

Dynamic Model: None.

6.4.4 *Resource Interface*

Module: AbstractIF

Interface: Resource

Inherited Interface: OwnedEntity

Description: Resource is an abstract inherited interface for any entity in the factory that takes an active role in advancing a product along its manufacturing life cycle (adds value). This includes the factory itself, personnel, production, planning and scheduling resources, and all of the machines used for processing, transporting, and storing materials. Resource provides a common set of services for monitoring and control. Resource uses the NamedEntity and OwnedEntity characteristics together to allow for the building of resource hierarchies.

There must be a clear division between the state of the Resource and the condition of the physical entity which the Resource represents. For instance, a Machine is a resource, but the fact that it is “Out of Service” may not mean the physical equipment is shutdown on the shop floor. In fact, the equipment may be operating in manual mode. The Resource state represents the availability of the Resource object to accept work for the factory system.

Exceptions: None.

Published Events: None.

Provided Services:

```
interface Resource : OwnedEntity {
```

/* Perform the startup activities for this Resource. Should be implemented by Resource specializations. */

```
void startUp ( )
        raises (Global::FrameworkErrorSignal);
```

/* Perform normal shutdown activities for this Resource. Normal is defined as allowing the Resource to complete any current activities and “gracefully” shutdown. */

```
void shutdownNormal ( )
        raises (Global::FrameworkErrorSignal);
```

/* Perform immediate shutdown activities for this Resource. Immediate is defined as aborting or terminating any current activities and stopping activity as soon as possible. This should be implemented by Resource specializations. */

```
void shutdownImmediate ( )
        raises (Global::FrameworkErrorSignal);
```

/* Respond with the receiver’s level in the Resource hierarchy. Resource specifies that each different type of Resource provide a “resourceLevel” identifier.

```
string resourceLevel ( )
        raises (Global::FrameworkErrorSignal);
```

/* The following service provides name scoping for Resources. Resource name scoping makes use of the notion of “Resource level” and the ownership hierarchy. For example, unique identification of MachineResources within a Machine is possible, but to identify them outside the Machine additional information about their ownership will be required.

Thus: nameQualifiedTo (“Machine”) sent to the ProcessResource named “Chamber” answers

“TestMachine>Chamber”.

If the Machine was owned by a Factory named “TestFactory”, then:

nameQualifiedTo (“Factory”) sent to the ProcessResource answers

“TestFactory>TestMachine>Chamber”

where the ProcessResource has now been uniquely identified for the given Factory.

There is no limit to the number of levels that may be addressed this way. Based on the implementations of nameQualifiedTo (string); a name need not always be concatenated, if a particular Resource level is not applicable to identification. */

```
string nameQualifiedTo (in string resourceLevel)
        raises (Global::FrameworkErrorSignal);
```

/* Returns the set of subordinate Resources for a given Resource. */

```
ResourceSequence subResources ( )
        raises (Global::FrameworkErrorSignal);
```

/* Answer if the resource is in service. In service means the resource is functional and ready to accept and perform its normal tasks. Derivatives of Resource are expected to expand this state (e.g., add sub-interfaces) that explicitly deal with such additional issues as capacity, "normal" work versus maintenance, etc. */

```
boolean isInService ( );
```

/* Answer if the resource is out of service. Out of service means the resource is unable to accept or begin new tasks. Previously begun tasks may continue in some cases. */

```
boolean isOutOfService ( );
```

```
}; // Resource
```

Contracted Services: None.

Dynamic Model:

Implementations of Resource may extend the state model by providing additional sub-states that are wholly contained within a state defined here. Extending the state model by the addition of state transitions is also an option for subtypes of Resource.

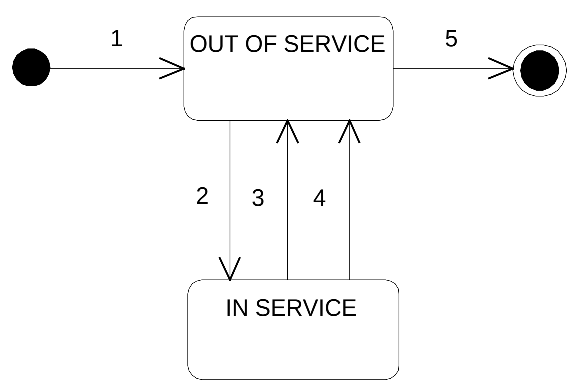

Figure 2
Resource Dynamic Model

Table 1 Resource State Definitions and Query Table

State	*Definition*	*Query for State via*
IN SERVICE	Resource is capable of interacting with other resources with its full service interface.	boolean isInService ( ); sent to the instance of Resource returns TRUE.
OUT OF SERVICE	Resource is not able to provide services	boolean isOutOfService ( ); sent to the instance of Resource returns TRUE.

Table 2 Resource State Transitions

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Non Existent	Object creation.	OUT OF SERVICE	None.	Default entry.
2	OUT OF SERVICE	startUp ( ) or object initialization.	IN SERVICE	Initiate Resource and subresources.	startUp() service initiates the trigger.
3	IN SERVICE	shutdownNormal ( ).	OUT OF SERVICE	Complete current execution of resources normally.	shutdownNormal() service initiates the trigger.
4	IN SERVICE	shutdownImmediate ( ). Take resource out of service.	OUT OF SERVICE	Stop execution of resource immediately.	shutdownImmediate() service initiates the trigger.
5	OUT OF SERVICE	Resource removed.	Non Existent	None.	

6.5 *Material Abstract Interface Group*

6.5.1 The CIM Framework uses a common architecture for identifying, grouping and locating materials. Any material has an identification, history, location, and associations to any material containers that contain it. Material can also be in multiple material groups that physically (same location or carrier) or logically (same lot, same process batch, same product family, etc.) associate material. Specializations of material include products, durables and consumables. Specializations of material groups include product groups, lots, and process groups.

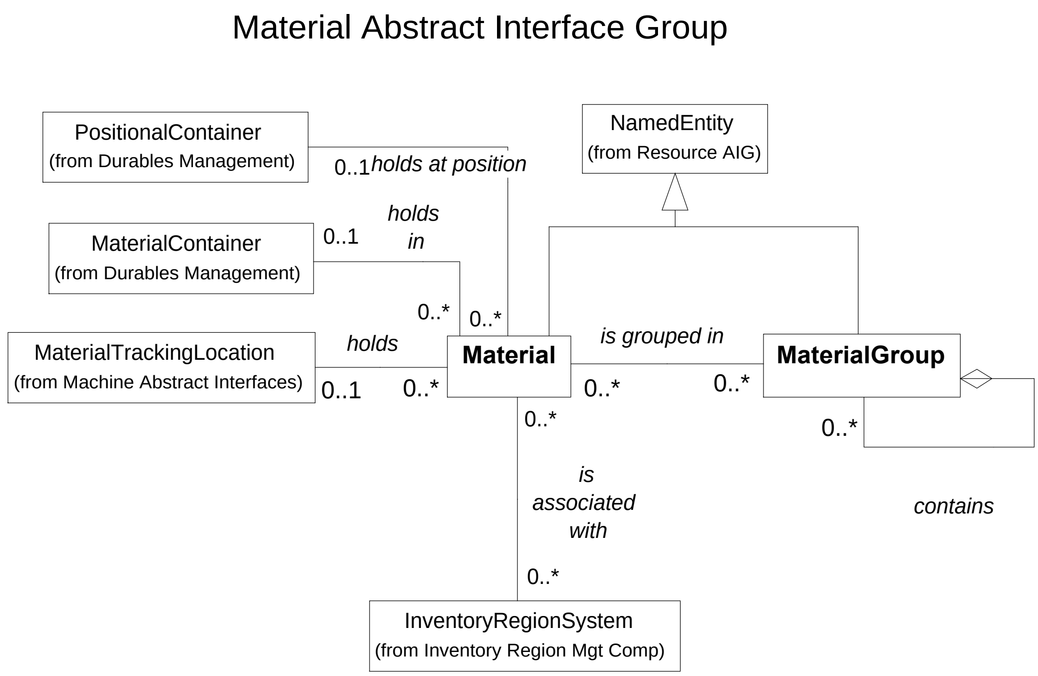

Figure 3
Material Abstract Interface Group Information Model

6.5.2 *Material Interface*

Module:	AbstractIF
Interface:	Material
Inherited Interface:	NamedEntity
Description:	Material is an abstract interface for physical items or substances that are required as inputs to the manufacturing process. This includes the product itself, consumables and durables used in the manufacturing process. It does not include the resources used to transform material into product.
Exceptions:	None.
Published Events:	None.
Provided Services:	

```
interface Material : NamedEntity {
```

/* Set and get the identifier for this material. The identifier is unique within the extent of all material for an MES Factory. */

```
string getIdentifier ( )
        raises (Global::FrameworkErrorSignal);

void setIdentifier (in string identifier)
        raises (Global::FrameworkErrorSignal,
        Global::DuplicateIdentifierSignal);
```

/* Returns the material groups of which the receiver is a member. */

```
MaterialGroupSequence materialGroups ( )
        raises (Global::FrameworkErrorSignal);
```

/* Answers whether the receiver is a member of the material group indicated by the argument. */

```
boolean isMemberOf (in MaterialGroup aMaterialGroup)
        raises (Global::FrameworkErrorSignal);
```

```
}; // Material
```

Dynamic Model: None.

6.5.3 *Material Group Interface*

Module: AbstractIF

Interface: MaterialGroup

Inherited Interface: NamedEntity

Description: MaterialGroup is the abstract interface for any aggregation of Material.

```
interface MaterialGroup : NamedEntity {
```

Exceptions:

/* Signals an attempt to add Material to the MaterialGroup that is already in the group. */

```
exception DuplicateMaterialSignal {Material aMaterial;};
```

/* Signals an attempt to add a MaterialGroup to a MaterialGroup that is already in the group. */

```
exception DuplicateMaterialGroupSignal {Material aMaterialGroup;};
```

/* Signals an attempt to remove Material that wasn't found in this MaterialGroup. */

```
exception MaterialRemovalFailedSignal {Material aMaterial;};
```

/* Signals an attempt to remove a MaterialGroup that wasn't found in this MaterialGroup. */

```
exception MaterialGroupRemovalFailedSignal {MaterialGroup aMaterialGroup;};
```

Published Events: None.

Provided Services:

/* Set and get the unique identifier for this group. */

```
string getIdentifier ( )
        raises (Global::FrameworkErrorSignal);

void setIdentifier (in string identifier)
        raises (Global::FrameworkErrorSignal,
        Global::DuplicateIdentifierSignal);
```

/* Adds the argument MaterialSequence to the collection of Matrial held by the receiver. */

```
void addMaterials (in MaterialSequence aMaterialSequence)
        raises (Global::FrameworkErrorSignal,
        DuplicateMaterialSignal);
```

/* Adds the argument Material to the collection of Material held by the receiver. */

```
void addMaterial (in Material aMaterial)
        raises (Global::FrameworkErrorSignal,
        DuplicateMaterialSignal);
```

/* Removes the Material indicated from the MaterialGroup. Throws the exception if not found. */

```
void removeMaterial (in Material aMaterial)
        raises (Global::FrameworkErrorSignal,
        MaterialRemovalFailedSignal,
        Global::NotFoundSignal);
```

/* Remove and return all Material from the MaterialGroup. */

```
MaterialSequence removeAllMaterials ( )
        raises (Global::FrameworkErrorSignal);
```

/* Add the argument MaterialGroup to this MaterialGroup. */

```
void addMaterialGroup (in MaterialGroup aMaterialGroup)
        raises (Global::FrameworkErrorSignal,
        DuplicateMaterialGroupSignal);
```

/* Removes the argument MaterialGroup from this MaterialGroup. */

```
void removeMaterialGroup (in MaterialGroup aMaterialGroup)
        raises (Global::FrameworkErrorSignal,
        MaterialGroupRemovalFailedSignal,
        Global::NotFoundSignal);
```

/* Remove and return all MaterialGroups from this MaterialGroup. */

```
MaterialGroupSequence removeAllMaterialGroups ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns the collection of material in this MaterialGroup. */

```
MaterialSequence allMaterials ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns all the MaterialGroups in this MaterialGroup. */

```
MaterialGroupSequence allMaterialGroups ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns the count of the items in the MaterialGroup. */

```
long count ( )
        raises (Global::FrameworkErrorSignal);

}; // MaterialGroup
```

Dynamic Model: None.

6.6 *Job Supervision Abstract Interface Group*

6.6.1 The Job Supervision Abstract Interface Group provides the abstractions common to creating, executing and managing a “job,” where a job can be defined as some system level operation which may be requested from the JobSupervisor. The job often spans a significant amount of time and multiple resources within the system. It is intended for specialization to provide specific job supervisors and jobs to provide system solutions.

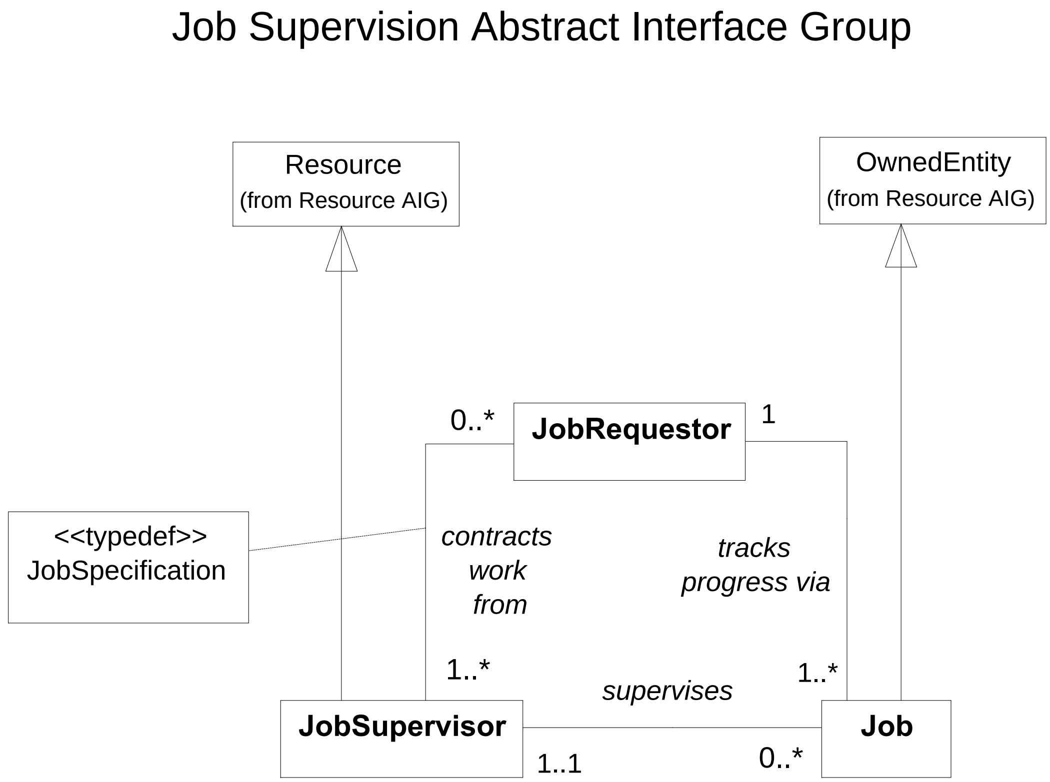

Figure 4
Job Supervision Abstract Interface Group Information Model

6.6.1.1 The basic Job Supervision Abstract Interface Group does not interact with other components, except to the extent that other components instantiate its interfaces. Figure 4 shows how the interfaces of Job Supervision relate to one another.

6.6.1.2 A Job Specification is a sequence of properties containing the parameters required to sufficiently define the work to be done. This sequence is passed by the JobRequestor to the JobSupervisor in the Job request message. See the JobSupervisor interface for more details.

6.6.1.3 JobSupervision levels are hierarchical. One level may accept a Job and delegate portions of that Job to lower levels. Jobs, however, are not purely hierarchical. A Job accepted by one JobSupervisor may be broken down, along with other Jobs of that component and reconstituted as needed to optimize the activities of the factory.

6.6.1.4 For example, a ProductRequest may ask for 15 wafers of a particular product. The ProductRequestManager may delegate a LotJob to Factory Operations with a Lot containing those 15 wafers and 10 more from a different ProductRequest. In the factory, this Lot may be split up and processed in smaller groups at various stages or, as scrap reduces the wafer count, combined with another small lot to create a more optimal process group. The Job Supervision implementation is allowed great latitude to optimize performance. Its only requirement is to fulfill the specification of the Job.

6.6.2 *JobSupervisor Interface*

Module:	AbstractIF
Interface:	JobSupervisor
Inherited Interface:	Resource

Description: The JobSupervisor manages all the Jobs being performed by the component which implements it. It receives the requests for work, facilitates the creation of a Job for the task and returns (a reference to) that Job.

A JobSupervisor will have a well defined domain which it can call on to perform work. These may be CIM Framework Resources if it delegates the work, or internal resources if it performs the work itself. Only activity requests which can be accomplished within the domain of a JobSupervisor should be issued to/accepted by that JobSupervisor.

Jobs, as subtypes of NamedEntity, are named by the JobSupervisor in such a way that their name attribute may be used to query for the Job. Jobs from different JobSupervisors may have the same name.

The definition of the work to be performed is the JobSpecification, a sequence of name/value pairs (see “Properties” definition). Specializations of Job Supervision may require certain properties in the JobSpecification. Some commonly useful properties are defined in the following table. When possible, specializations should reuse these definitions. Specializations should also document the allowable and mandatory properties that are supported. See Job definition for more information.

```
interface JobSupervisor : Resource {
```

Type Definitions:

/* Type for returning results of Job execution. */

```
typedef Global::NameValueSequence Results;
```

JobSpecification Properties:

Name	*Value Type*	*Description*
“JobType”	string	The kind of Job to run. This is useful when a JobSupervisor can initiate more than one type of Job. String values reserved for this property are: ProductRequestJobType, LotJobType, AreaJobType, ProcessMachineJobType, TransportJobType, PMJobType, ControlStrategyJobType, AlgorithmJobType.
“Priority”	long	Integer value, ranges from 1 to 99, where 1 is the highest priority and 99 is the lowest.
“Deadline”	TimeStamp	The Job is expected to be completed no later than the specified value of the Deadline.

Exceptions:

/* Requested Job was rejected. */

```
exception JobRejectedSignal {
        string errorMessage; };
```

/* Requested Job was not found */

```
exception JobNotFoundSignal {
        string errorMessage;
        string missingJobName; };
```

Published Events:

/* Provide lifecycle event for tracking */

```
const string JobLifecycleSubject =
        "/JobSupervision/JobSupervisor/JobLifecycle";
```

/* The use of “name” here (and in all other events) indicates the string value for the name or identifier of the Job to which the event refers. Since filtering does not support object reference comparisons, the filtering must be on the “name” of the object. */

```
struct JobLifecycleFilters {
        Global::Property name;
        Global::Property lifecycle;
};
```

JobLifecycleFilters Properties:

Name	*Value Type*	*Description*
“Name”	string	The name of the Job.
“Lifecycle”	Global::LifecycleState	New lifecycle state.

```
struct JobLifecycleEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobLifecycleFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob; // on Delete, aJob is nil
};
```

Provided Services:

/* Request that work be done according to the referred specification. A Job which represents the work is returned for future reference. The post-condition for this operation is the specified Job successfully created. */

```
Job requestJob (
        in Global::Properties aJobSpecification,
        in JobRequestor aJobRequestor)
        raises (Global::FrameworkErrorSignal,
        JobRejectedSignal);
```

/* Request that work be done according to the Job specification. This operation blocks until the Job completes. Results generated by the Job are returned. The post-condition for this operation is a successful execution of the specified Job. This interface offers a lightweight alternative to ***requestJob*** that does not require that requestors support the JobRequestor interfaces (e.g., informJobStateChange operation). A Job may or may not be created by runJob, but if created, the Job may be accessed with the Job query operations of JobSupervisor. */

```
Results runJob (
        in Global::Properties aJobSpecification)
        raises (Global::FrameworkErrorSignal,
        JobRejectedSignal);
```

/* Ask whether the Job specified by the JobSpecification would be accepted for current or future (queued) processing if a requestJob or runJob message were issued now. */

```
boolean canPerform (in Properties aJobSpecification)
        raises (Global::FrameworkErrorSignal);
```

/* Command to begin the pausing of all Jobs of this JobSupervisor which can be paused (e.g. Jobs that have not reached the Finished state). */

```
void pauseAllJobs ()
        raises (Global::FrameworkErrorSignal);
```

/* Command to “resume” all Jobs of this JobSupervisor which are currently Paused. */

```
void resumeAllJobs ()
        raises (Global::FrameworkErrorSignal);
```

/* This command aborts all the Jobs under the control of the JobSupervisor immediately, without regard to the impact of abruptly halting the Job. This service should be used with great caution. It may result in irrevocable change to factory or material state. */

```
void abortAllJobs ()
        raises (Global::FrameworkErrorSignal);
```

/* This command stops all Jobs under control of the JobSupervisor, as quickly as possible. Stopping Jobs should not result in damage to the factory or material being processed. */

```
void stopAllJobs ()
        raises (Global::FrameworkErrorSignal);
```

/* This service removes a Job which is in the terminated state. If required, persistent information about the Job may be captured in a history entry. Jobs may also be removed based on other archiving rules. */

```
void removeFinishedJob (in Job aJob)
        raises (Global::FrameworkErrorSignal);
```

/* Find a Job by name. A Job is a NamedEntity */

```
Job findJobNamed (in string jobName)
        raises (Global::FrameworkErrorSignal,
        JobNotFoundSignal);
```

/* Find a queued Job by name. */

```
Job findQueuedJobNamed (in string jobName)
        raises (Global::FrameworkErrorSignal,
        JobNotFoundSignal);
```

/* Find an active Job by name. */

```
Job findActiveJobNamed (in string jobName)
        raises (Global::FrameworkErrorSignal,
        JobNotFoundSignal);
```

/* Find a canceled Job by name. */

```
Job findCanceledJobNamed (in string jobName)
        raises (Global::FrameworkErrorSignal,
        JobNotFoundSignal);
```

/* Find a finished Job by name. */

```
Job findFinishedJobNamed (in string jobName)
        raises (Global::FrameworkErrorSignal,
        JobNotFoundSignal);
```

/* Return all the specified Jobs. The JobSequence may be empty. */

```
JobSequence allJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allQueuedJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allCanceledJobs ( )
        raises (Global::FrameworkErrorSignal);
```

```
JobSequence allActiveJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allExecutingJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allPausingJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allPausedJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allStoppingJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allAbortingJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allFinishedJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allStoppedJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allAbortedJobs ( )
        raises (Global::FrameworkErrorSignal);

JobSequence allCompletedJobs ( )
        raises (Global::FrameworkErrorSignal);

}; // JobSupervisor
```

Contracted Services: None.

Dynamic Model: Inherited.

6.6.3 *Job Interface*

Module: AbstractIF

Interface: Job

Inherited Interface: OwnedEntity

Description: The Job interface represents a unit of work requested of an associated JobSupervisor and performed (or facilitated) by a factory entity. A Job generally results in some change of the overall factory state. How the entities that supply the Job and JobSupervisor interfaces actually perform the work (or delegation of work) is an implementation decision. A Job is expected (but not required) to take a non-zero time to perform and have a non-zero chance of refusal or failure. A Job may encapsulate a decomposition into a sequence of jobs/tasks/activities which are delegated to lower level job supervisors. The Job exists during the execution timeframe. The more persistent record of the Job should be maintained in a history entry.

```
interface Job : OwnedEntity {
```

Exceptions:

Published Events:

/* Any time the Job's state changes. */

```
const string JobStateChangedSubject =
        "/JobSupervision/Job/StateChanged";
```

/* This enumerated type identifies the states of Jobs. It is used in event notifications of state changes. */

```
enum JobState {
        JobUndefined,
        JobCreated,
        JobQueued,
        JobActive,
        JobExecuting,
        JobNotPaused,
        JobPausing,
        JobPaused,
        JobNotStopping,
        JobStopping,
        JobNotAborting,
        JobAborting,
        JobFinished,
        JobCanceled,
        JobCompleted,
        JobStopped,
        JobAborted };

struct JobStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
};
```

JobStateChangedFilters Properties:

Name	*Value Type*	*Description*
"Name"	string	The name of the Job.
"PreviousState"	string	Previous state preceding the most recent change.
"NewState"	RegistrationState	New state following the most recent change.

```
struct JobStateChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobStateChangedFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob;
};
```

/* If the Job cannot be completed by the specified deadline, a JobDeadlineCannotBeMetEvent should be sent as early as possible, not necessarily after the deadline has passed. */

```
const string JobDeadlineCannotBeMetSubject =
        "/JobSupervision/Job/DeadlineCannotBeMet";

struct JobDeadlineCannotBeMetFilters {
        Global::Property name;
        Global::Property deadline;
};
```

JobDeadlineCannotBeMetFilters Properties:

Name	*Value Type*	*Description*
"Name"	string	The name of the Job.
"Deadline"	Global::TimeStamp	Value of the Deadline that cannot be met.

```
struct JobDeadlineCannotBeMetEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobDeadlineCannotBeMetFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob;
};
```

/* This event is posted when a Job's deadline date has changed. */

```
const string JobDeadlineChangedSubject =
        "/JobSupervision/Job/DeadlineChanged";

struct JobDeadlineChangedFilters {
        Global::Property name;
        Global::Property previousDeadline;
        Global::Property newDeadline;
};
```

JobDeadlineChangedFilters Properties:

Name	*Value Type*	*Description*
"Name"	string	The name of the Job.
"PreviousDeadline"	Global::TimeStamp	Previous Deadline.
"NewDeadline"	Global::TimeStamp	New Deadline.

```
struct JobDeadlineChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobDeadlineChangedFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob;
};
```

Exceptions: None.

Provided Services:

/* Ask the Job for its JobRequestor. */

```
JobRequestor getJobRequestor ()
        raises (Global::FrameworkErrorSignal);
```

/* Get a named Job property from its Job Specification. */

```
Global::Property getJobProperty (
        in Global::PropertyName aPropertyName)
        raises (Global::FrameworkErrorSignal,
        Global::InvalidPropertyNameSignal,
        Global::PropertyNotFoundSignal);
```

/* Set a named Job property in its Job Specification. */

```
void setJobProperty (
        in Global::Property aProperty)
        raises (Global::FrameworkErrorSignal,
        Global::SetValueOutOfRangeSignal,
        Global::InvalidPropertyNameSignal,
        Global::UnsupportedPropertySignal,
        Global::ReadOnlyPropertySignal);
```

/* Indicates whether results are available for this Job. Each specialization may determine what constitutes results. */

```
boolean areJobResultsAvailable()
        raises( Global::FrameworkErrorSignal );
```

/* Retrieve the latest results. Each implementation determines what constitutes relevant results. This may be used for returning current results for complex Jobs. */

```
JobSupervisor::Results getJobResults()
        raises( Global::FrameworkErrorSignal );
```

/* Begin the process to pause the Job at the next safe opportunity. Results in the transition to Pausing state and eventually Paused state. */

```
void makePaused ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Request Job resume activity from the previous Pause. Results in the transition to the executing state. */

```
void makeExecuting ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Request to cancel the Job. This operation is only valid if the Job is in the Queued state (e.g. the Job cannot be canceled once it is Active). This operation results in the transition to the Canceled state. */

```
void makeCanceled ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Begin the process to stop the Job. This is an orderly termination and should never cause irreparable problems (e.g. should not stop etching a wafer in mid-cycle). This operation results in the transition to the Stopping state and eventually the Stopped state. */

```
void makeStopped ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Begin the process to abort the Job. Caution should be used with this operation. Aborting a Job requires immediate termination of the Job and could result in irrecoverable change to factory or material state. This operation results in the transition to the Aborting state and eventually the Aborted state. */

```
void makeAborted ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Determine whether the Job is in state indicated. */

```
boolean isAborting ( )
        raises (Global::FrameworkErrorSignal);

boolean isAborted ( )
        raises (Global::FrameworkErrorSignal);
```

```
boolean isActive ( )
        raises (Global::FrameworkErrorSignal);

boolean isCanceled ( )
        raises (Global::FrameworkErrorSignal);

boolean isCompleted ( )
        raises (Global::FrameworkErrorSignal);

boolean isExecuting ( )
        raises (Global::FrameworkErrorSignal);

boolean isFinished ( )
        raises (Global::FrameworkErrorSignal);

boolean isPausing ( )
        raises (Global::FrameworkErrorSignal);

boolean isPaused ( )
        raises (Global::FrameworkErrorSignal);

boolean isQueued ( )
        raises (Global::FrameworkErrorSignal);

boolean isStopping ( )
        raises (Global::FrameworkErrorSignal);

boolean isStopped ( )
        raises (Global::FrameworkErrorSignal);
```

/* Return the estimated time remaining until Job completion. The quality of this estimate is dependent both on the specific Job derivative and on the implementation. If the Job is Finished or Canceled, a zero Duration will be returned. */

```
Duration timeRemaining ( )
        raises (Global::FrameworkErrorSignal);

}; // Job
```

Contracted Services:

Interface	*Component*	*Service*
JobRequestor	JobSupervision	informJobStateChange

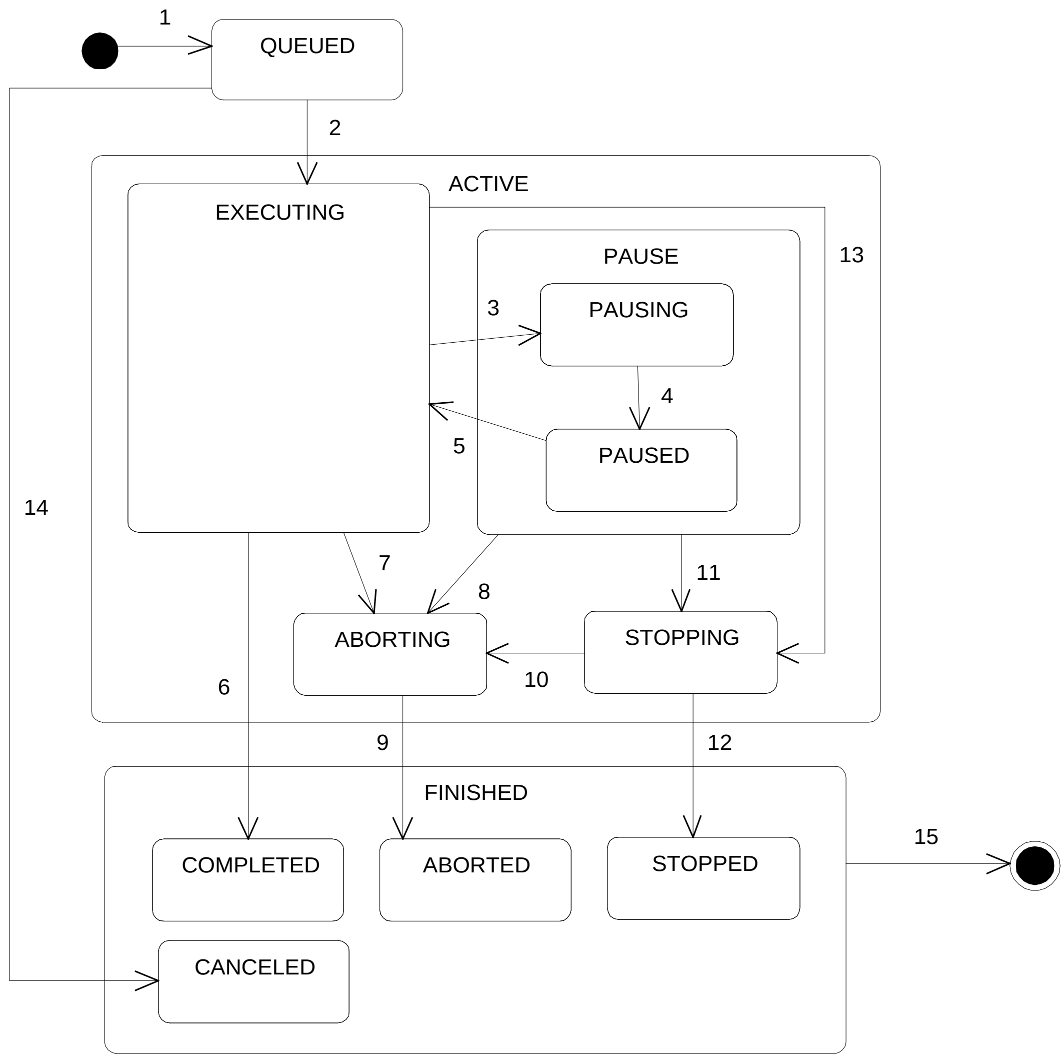

Figure 5
Job Dynamic Model

6.6.3.1 For implementations (e.g., Job derivatives), the Executing state is expected to be extended by partitioning it into at least two "orthogonal" states. One would hold the Pause states. The other would contain the implementation behavior of Executing.

Object State Tables:

Table 3 Job State Definitions and Query Table

State	*Definition*	*Query for State via*
ABORTED	In this state the Job has aborted execution. This is a substate of Finished.	boolean isAborted(); sent to an instance of Job; returns TRUE JobSequence allFinishedJobs (); sent to instance of JobSupervisor will provide some indication.
ABORTING	ABORTING represents an immediate termination of the Job and activities not completed before the aborting will be terminated. After ABORTING, execution is not intended to continue.	boolean isAborting(); sent to an instance of Job; returns TRUE
ACTIVE	This is a parent state representing that the Job is ACTIVE for the JobSupervisor; i.e., the current status of the Job is tracked by the JobSupervisor when the Job is in the ACTIVE state.	boolean isActive(); sent to an instance of Job; returns TRUE. JobSequence allActiveJobs (); or Job findActiveJobNamed (in string jobName); sent to instance of JobSupervisor.
CANCELED	In this state the Job has been removed from the Queue and will never become Active. This is a substate of Finished.	boolean isCanceled(); sent to an instance of Job; returns TRUE
COMPLETED	This state represents that the Job has successfully completed execution. This is a substate of Finished.	boolean isCompleted(); sent to an instance of Job; returns TRUE. Job findCompletedJobNamed (in string jobName); sent to instance of JobSupervisor JobSequence allFinishedJobs (); sent to instance of JobSupervisor will provide some indication.
EXECUTING	This state represents that the Job is EXECUTING. Specializations of Job will normally develop substates representing the specialized Job execution behavior.	boolean isExecuting(); sent to an instance of Job; returns TRUE.
PAUSE	Parent state of PAUSING, PAUSED	None.
PAUSED	In this state the Job has paused execution.	boolean isPaused(); sent to an instance of Job; returns TRUE.
PAUSING	In this state the Job is being paused by the executor of the Job. Execution is intended to continue.	boolean isPausing(); sent to an instance of Job; returns TRUE.
QUEUED	In this state the Job is waiting to become active.	boolean isQueued(); sent to an instance of Job; returns TRUE. JobSequence allQueuedJobs (); or Job findQueuedJobNamed (in string jobName); sent to instance of JobSupervisor.
STOPPED	In this state the Job has stopped execution. This is a substate of Finished.	boolean isStopped(); sent to an instance of Job; returns TRUE. JobSequence allFinishedManagedJobs (); sent to instance of JobSupervisor will provide some indication.
STOPPING	In this state the Job is being stopped. Execution is not intended to continue. STOPPING represents an ordered termination of the Job Activities. Job Activities not completed before stopping may or may not be performed, depending on the implementation.	boolean isStopping(); sent to an instance of Job; returns TRUE.
FINISHED	This is a parent state representing that the Job has finished execution, through either successful execution, abort, or stop. This is the superstate of Completed, Aborted, Stopped, and Canceled.	boolean isFinished(); sent to an instance of Job; returns TRUE. JobSequence allFinishedJobs (); sent to instance of JobSupervisor.

Table 4 Job State Transitions

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Non Existent	Job creation.	QUEUED	JobStateChanged Event published by the instance of Job	None.
2	QUEUED	Internal to component.	EXECUTING	JobStateChanged Event published by the instance of Job	Job has started.
3	EXECUTING	void makePaused ( ); sent to the Job; or void PauseAllJobs ( ); sent to an instance of JobSupervisor.	PAUSING	JobStateChanged Event published by the instance of Job	Job has been told to pause.
4	PAUSING	Internal to component	PAUSED	JobStateChanged Event published by the instance of Job	Job has completed PAUSING activities. Wait for resume.
5	PAUSED	void makeExecuting ( ); sent to the Job or void resumeAllJobs (); sent to an instance of JobSupervisor.	EXECUTING	JobStateChanged Event published by the instance of Job	Restart EXECUTING from the point PAUSED at.
6	EXECUTING	Internal to component	COMPLETED	Execution of the Job was successful or completed normally.	None.
7	EXECUTING	void makeAborted ( ); sent the Job or void abortAllJobs ( ); sent to the JobSupervisor.	ABORTING	Execution of the Job stops immediately. Product or Job will be unfinished.	None.
8	PAUSE	void makeAborted ( ); sent the Job or void abortAllJobs ( ); sent to the JobSupervisor.	ABORTING	Active Job is aborted immediately.	None.
9	ABORTING	Internal to component	ABORTED	JobStateChanged Event published by the instance of Job	Job has completed aborting activities.
10	STOPPING	void makeAborted ( ); sent the Job or void abortAllJobs ( ); sent to the JobSupervisor.	ABORTING	JobStateChanged Event published by the instance of Job	None.
11	PAUSE	void makeStopped( ); sent to the Job or void stopAllJobs( ); sent to the JobSupervisor.	STOPPING	JobStateChanged Event published by the instance of Job	None.
12	STOPPING	Internal to component	STOPPED	JobStateChanged Event published by the instance of Job	Job has completed stopping activities.
13	EXECUTING	void makeStopped( ); sent to the Job or void stopAllJobs( ); sent to the JobSupervisor.	STOPPING	JobStateChanged Event published by the instance of Job	None.
14	QUEUED	void makeCanceled( ); sent to the Job.	CANCELED	JobStateChanged Event published by the instance of Job	Job has been canceled before starting execution. It cannot be restarted.
15	FINISHED	void removeFinished-Job (in Job aJob); sent to an instance of JobSupervisor.	Non Existent	JobStateChanged Event published by the instance of Job	Job has been removed from the finished queue.

6.6.4 *JobRequestor Interface*

Module: AbstractIF

Interface: JobRequestor

Inherited Interface: Implementation Dependent

Description: In order to request work of a JobSupervisor using the requestJob operation, a component must implement the JobRequestor interface. This is a companion interface to JobSupervisor. The JobRequestor may also subscribe to the state change events of the Job, if more detail is required.

```
interface JobRequestor {
```

Exceptions: None.

Published Events: None.

Provided Services:

/* The Job has transitioned to a new state. Required for transition to Executing from Queued and for any transition to a Finished sub-state. This operation is in addition to the required JobStateChangedEvent notifications. */

```
void informJobStateChange (
        in Job aJob,
        in Job::JobState previousState,
        in Job::JobState newState)
        raises (Global::FrameworkErrorSignal);

}; // JobRequestor
```

Contracted Services: None.

Dynamic Model: None.

Scenario:

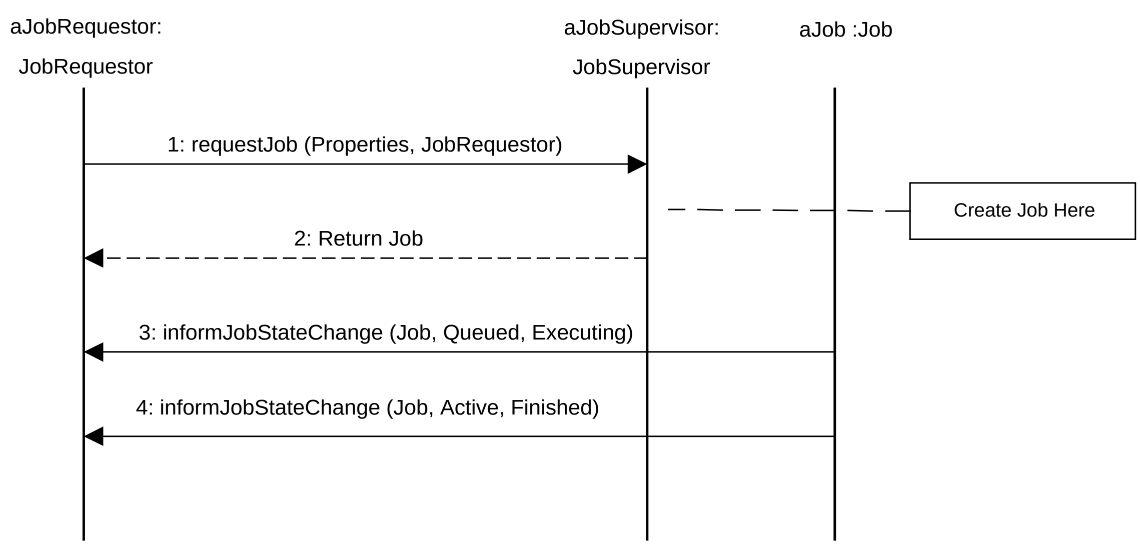

Figure 6
Job Supervision Scenario

6.6.4.1 Figure 6 shows the most basic of scenarios for Job Supervision interactions. It proceeds in this fashion:

6.6.4.1.1 The JobRequestor populates a JobSpecification then requests a Job according to that specification.

6.6.4.1.2 In response to the Job request, the JobSupervisor facilitates the creation of a Job to represent the task. A handle to the Job is returned to the JobRequestor (assuming the Job request is accepted).

6.6.4.1.3 The Job Supervision component (e.g. in the form of the Job) informs the JobRequestor when the Job begins.

6.6.4.1.4 The Job Supervision component (e.g. in the form of the Job) informs the JobRequestor when the Job has completed (assuming successful completion). It also issues events for each state change (not shown in the scenario diagram).

6.7 *Factory Component*

6.7.1 The Factory interfaces provide configuration services to specify the existence and connectivity of factory resources that constitute a factory. This includes area configuration and the registration of CIM system components, and the ability to dynamically configure a factory to enforce business policy.

6.7.1.1 These interfaces are included here to satisfy dependencies and meet needs of other CIM Framework Components. These interfaces will be moved to the Factory Operations Component in a subsequent revision ballot.

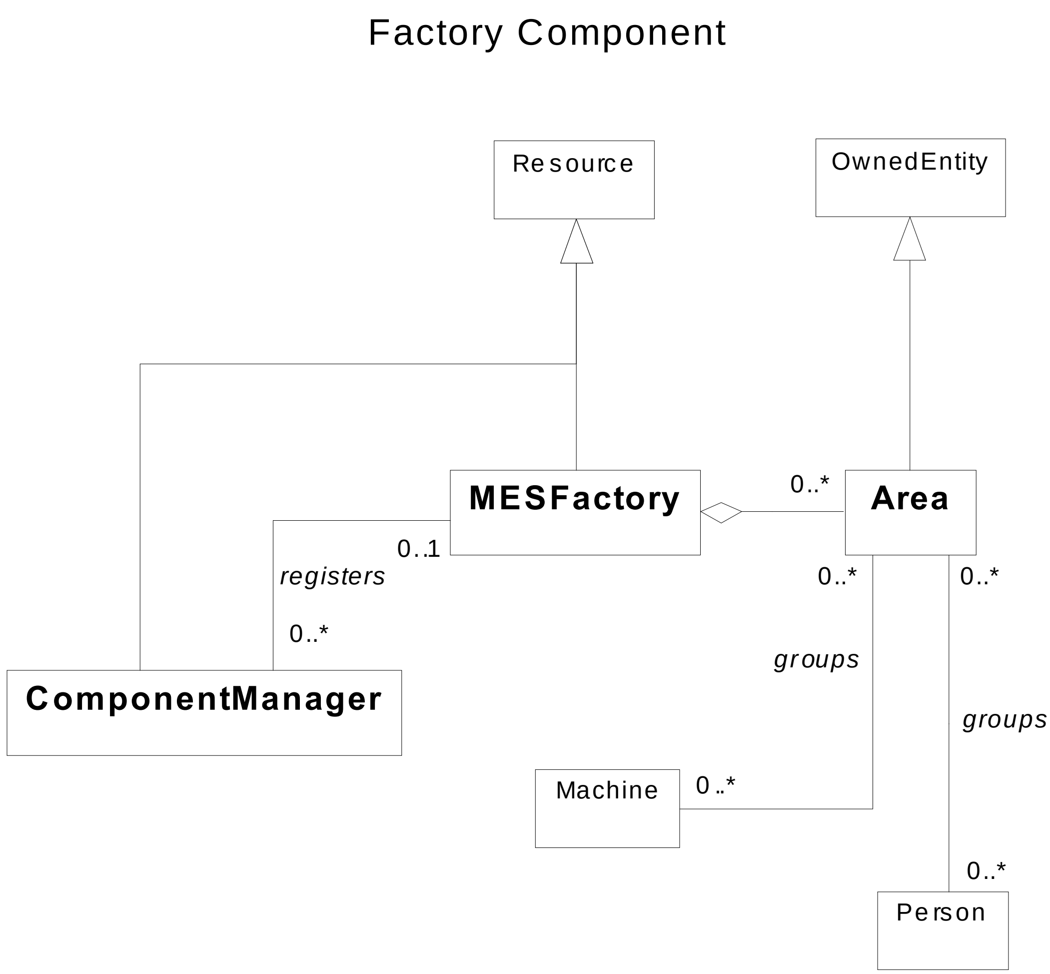

Figure 7
Factory Component Information Model

6.7.2 *Factory Declarations*

6.7.2.1 The following declarations are used by the interfaces of the Factory Component.

```
interface ComponentManager;

interface Area;

typedef sequence <ComponentManager> ComponentManagerSequence;

typedef sequence <Area> AreaSequence;

exception AreaNotFoundSignal {Area requestedArea;};

exception AreaDuplicateSignal { };

exception AreaNotAssignedSignal { };

exception AreaRemovalFailedSignal { };
```

6.7.3 *MESFactory Interface*

Module:	FactoryOperations
Interface:	MESFactory
Inherited Interface:	AbstractIF::Resource
Description:	The MESFactory interface represents one particular factory. This instance is a composite object referring to the objects that represent factory resources, particularly CIM system components. The factory instance provides overall startup and shutdown capability.

```
interface MESFactory : AbstractIF::Resource {
```

Exceptions: None.

Published Events:

/* MES Factory state change event definition. */

```
const string MESFactoryStateChangedSubject = "/Factory/MESFactory/StateChanged";
```

/* This enumerated type identifies the states of the MES Factory. It is used in event notifications of state changes. */

```
enum MESFactoryState {
        FactoryUndefined,
        FactoryStartingUp,
        FactoryOperating,
        FactoryGoingToStandby,
        FactoryStandby,
        FactoryShuttingDownImmediately,
        FactoryShuttingDownNormally,
        FactoryOff };

struct MESFactoryStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
};
```

MESFactoryStateChangedFilters Properties:

Name	*Value Type*	*Description*
"MESFactoryName"	string	The name of the MES Factory.
"PreviousState"	MESFactoryState	Previous state preceding the most recent change.
"NewState"	MESFactoryState	New state following the most recent change.

```
struct MESFactoryStateChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        MESFactoryStateChangedFilters eventFilterData;
        Global::Properties eventNews;
        MESFactory aMESFactory;
};
```

/* Registration of Component Manager has changed */

```
const string ComponentManagerRegistrationChangedSubject =
"/Factory/MESFctory/ComponentManagerRegistrationChanged";
```

/* This enumerated type identifies the states of Component Manager registration. It is used in event notifications of state changes. */

```
enum RegistrationState {
        RegistrationUndefined,
        Registered,
        NotRegistered };

struct RegistrationChangedFilters {
        Global::Property MESFactoryName;
        Global::Property componentManagerName;
        Global::Property newState;
};
```

RegistrationChangedFilters Properties:

Name	*Value Type*	*Description*
"MESFactoryName"	string	The name of the MES Factory.
"ComponentManagerName"	string	The name of the Component Manager.
"NewState"	RegistrationState	New state following the most recent change.

```
struct ComponentManagerRegistrationChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        RegistrationChangedFilters eventFilterData;
        Global::Properties eventNews;
        MESFactory aMESFactory;
        ComponentManager aComponentManager;
};
```

Provided Services:

/* Add an area to the receiver. Returns the area. */

```
Area addArea (in Area anArea)
        raises (AreaDuplicateSignal,
        Global::FrameworkErrorSignal);
```

/* Remove an area from the receiver. Returns the area removed. */

```
Area removeArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaRemovalFailedSignal,
        AreaNotAssignedSignal);
```

/* Returns the factory areas */

```
AreaSequence allAreas ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns collections of various factory resources. */

```
EquipmentTracking::MachineSequence allMachines ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns a collection of the component managers for the factory. */

```
ComponentManagerSequence allComponentManagers ( )
        raises (Global::FrameworkErrorSignal);
```

/* A component informs the factory that it has completed startup. */

```
void informComponentManagerIsOperating (in ComponentManager aComponentManager)
        raises (Global::FrameworkErrorSignal);
```

/* A component informs the factory that it has completed shutdown. */

```
void informComponentManagerIsStopped (in ComponentManager aComponentManager)
        raises (Global::FrameworkErrorSignal);
```

/* Factory is requested to go to STARTING UP state. Note MESFactory inherits from the Resource interface and is started up using the operations defined in that interface. During the startup and shutdown the factory delegates appropriate requests to all registered components. */

```
void makeStartingUp ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Factory is requested to specified state. */

```
void makeOperating ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

void makeStandby ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

void makeShuttingDownNormaly ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

void makeShuttingDownImmediately ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

void makeOff ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Answer whether the factory is in the state indicated */

```
boolean isOutOfService ( )
        raises (Global::FrameworkErrorSignal);

boolean isOff ( )
        raises (Global::FrameworkErrorSignal);

boolean isStartingUp ( )
        raises (Global::FrameworkErrorSignal);

boolean isInService ( )
        raises (Global::FrameworkErrorSignal);

boolean isOperating ( )
        raises (Global::FrameworkErrorSignal);

boolean isShuttingDownNormaly ( )
        raises (Global::FrameworkErrorSignal);

boolean isShuttingDownImmediately ( )
        raises (Global::FrameworkErrorSignal);

boolean isGoingToStandby ( )
        raises (Global::FrameworkErrorSignal);

boolean isStandby ( )
        raises (Global::FrameworkErrorSignal);

}; // MESFactory
```

Contracted Services: None.

Dynamic Model:

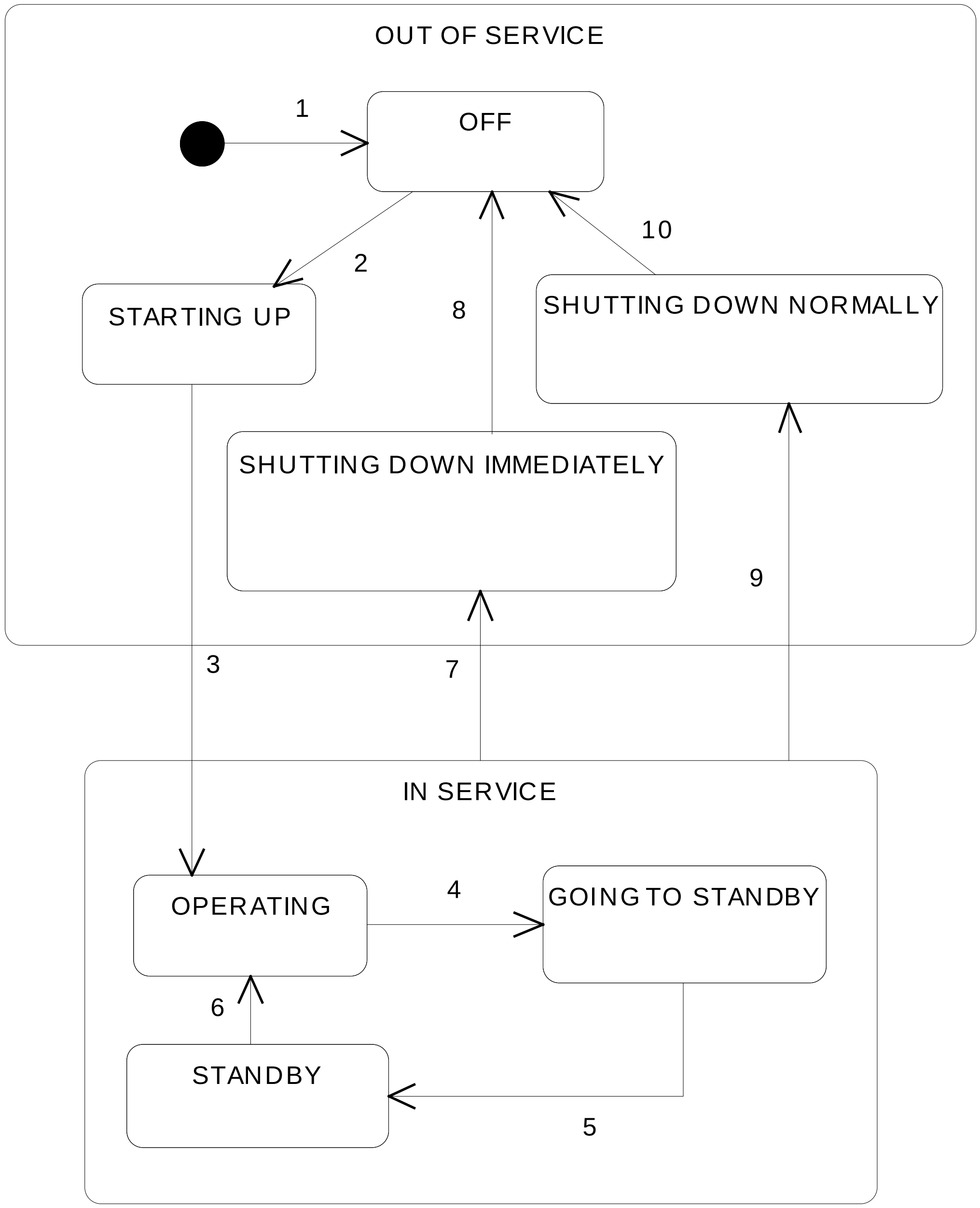

Figure 8
MESFactory Dynamic Model

Table 5 MESFactory State Definitions and Query Table

State	*Definition*	*Query for State via*
OUT OF SERVICE	A superstate, inherited from Resource, encompassing the next four substate definitions.	boolean isOutOfService ( ); sent to the instance of MESFactory returns FALSE.
OFF	In this state the MESFactory has a building, machines and other resources. No CIM activities should be allowed. ComponentManagers should not be registered yet.	boolean isOff ( ); sent to the instance of MESFactory returns TRUE.
STARTING UP	In this state the MESFactory has requested startup sequences for all resources.	boolean isStartingUp ( ); sent to the instance of MESFactory returns TRUE.
SHUTTING DOWN NORMALY	In this state MESFactory resources and material are brought to a safe state in preparation for terminating in an orderly fashion.	boolean isShuttingDownNormaly ( ); sent to the instance of MESFactory returns TRUE.
SHUTTING DOWN IMMEDIATELY	In this state the MESFactory is shutting down without regard for the safe state of material or potential product and data loss. All processes are terminated immediately.	boolean isShuttingDownImmediately ( ); sent to the instance of MESFactory returns TRUE.
IN SERVICE	A superstate, inherited from Resource, encompassing the next three substate definitions.	boolean isInService ( ); sent to the instance of MESFactory returns TRUE.
OPERATING	In this state the MESFactory is able to process product. Applications are prepared to support factory operations to process product.	boolean isOperating ( ); sent to the instance of MESFactory returns TRUE.
GOING TO STANDBY	In this state the MESFactory is performing sequences to make the transition to STANDBY. It brings all product and equipment to a safe stopping place.	boolean isGoingToStandby ( ); sent to the instance of MESFactory returns TRUE.
STANDBY	STANDBY means nearly available for immediate use. In this state the MESFactory is idle and available; applications are able to respond to a subset of selected messages.	boolean isStandby ( ); sent to the instance of MESFactory returns TRUE.

Table 6 MESFactory State Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	non-existent	No CIM Framework trigger necessary	OFF	Building(s), machines and other resources are added after this transition.	The MESFactory object instance is unique in the Framework. It is the only object that must be created by the implementation.
2	OFF	void makeStartingUp ( ); sent to the instance of MESFactory.	STARTING UP		Startup sequence performed, including delegated messages to component managers. Resource inherited interface also defines startup.
3	STARTING UP	void makeOperating ( ); sent to the instance of MESFactory.	OPERATING	MESFactory is operating event published by the instance of MESFactory.	Relevant registered components inform the factory when they have completed startup prior to startup being complete.

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
4	OPERATING	void makeStandby ( ); sent to the instance of MESFactory.	GOING TO STANDBY		MESFactory is requested to go to STANDBY state.
5	GOING TO STANDBY	completion of Standby transition by MESFactory.	STANDBY	MESFactory is in STANDBY state event published by the instance of MESFactory.	All component managers, machines and material are idle and in a safe state.
6	STANDBY	void makeOperating ( ); sent to MESFactory	OPERATING	void startup ( ); sent to an instance of Component-Manager.	Since standby means nearly available for immediate use, this startup transition should be minimal.
7	IN SERVICE	void makeShuttingDown Immediately ( ); sent to the instance of MESFactory.	SHUTTING DOWN IMMEDI-ATELY	void shutdownImmediate ( ); sent to all instances of registered Component Managers.	As an action, messages delegated to component managers. The Resource inherited interface also implements shutdownImmediate
8	SHUTTING DOWN IMMEDI-ATELY	void makeOff (); sent to the instance of MESFactory.	OFF	void informComponent ManagerIsStopped (in ComponentManager aComponentManager); sent to the instance of MESFactory by the Component Managers. MESFactory is off event published by the instance of MESFactory.	The MESFactory polls the ComponentManagers and Resources for completion of shutdown before the MESFactory state transitions to OFF.
9	IN SERVICE	void makeShuttingDown Normally ( ); sent to the instance of MESFactory.	SHUTTING DOWN	void shutdown Normal ( ); sent to all instances of registered Component-Managers.	As an action, messages delegated to component managers.
10	SHUTTING DOWN NORMALLY	void makeOff ( ); sent to the instance of MESFactory.	OFF	void informComponent ManagerIsStopped (in ComponentManager aComponentManager); sent to the instance of MESFactory by the Component Managers. MESFactory is off event published by the instance of MESFactory.	The MESFactory polls the ComponentManagers and Resources for completion of shutdown before the MESFactory state transitions to OFF.

6.7.4 *Area Interface*

Module:	FactoryOperations
Interface:	Area
Inherited Interface:	OwnedEntity
Description:	Area is the interface corresponding to a physical or logical grouping of factory resources (the complement of machines and/or personnel assigned to it). Area may represent a singular entity or it may represent a collection of other Areas. For example, an Area may represent an entire facility for maintenance purposes, or an Area may represent a processing area such as a “bay” which is comprised of “zones.”

The association between an Area and its composite Areas may be hierarchical or there may simply be a collection of peer Areas without any explicit or implicit relationship.

Area may or may not be an optional construct, depending on such issues as security.

```
interface Area {
```

Exceptions: None.

Published Events:

/* Area configuration changed event definition. */

```
const string AreaConfigurationChangedSubject =
"/Factory/Area/AreaConfigurationChanged";
```

/* This enumerated type identifies the types of configuration changes for Areas. It is used in event notifications of state changes. */

```
enum AreaChangeType {
        MachinesChanged,
        PersonsChanged,
        SubAreaChanged };

struct AreaConfigurationChangedFilters {
        Global::Property name;
        Global::Property changeType;
};
```

AreaConfigurationChangedFilters Properties:

Name	*Value Type*	*Description*
"Name"	string	The name of the Area.
"ChangeType"	AreaChangeType	The type of change to the Area.

```
struct AreaConfigurationChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        AreaConfigurationChangedFilters eventFilterData;
        Global::Properties eventNews;
        Area anArea;
};
```

Provided Services:

/* Answer the Area to which this Area is associated. If no membership has been established, nil is returned. */

```
Area getSuperArea ( )
        raises (Global::FrameworkErrorSignal);
```

/* Get the unique identifier for the Area. */

```
string getAreaIdentifier ( )
        raises (Global::FrameworkErrorSignal);
```

/* Adds a machine to the receiver. Returns the machine added. */

```
EquipmentTracking::Machine addMachine (in EquipmentTracking::Machine aMachine)
        raises (Global::FrameworkErrorSignal,
        EquipmentTracking::MachineDuplicateSignal);
```

/* Create an association between an Area and the Area to which it belongs. The service will add the Area indicated by the argument to the receiver's set of subareas. The service will also update the superarea for the argument. The service returns the argument. */

```
Area addSubArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaDuplicateSignal);
```

/* Adds a person to the receiver. Returns the person added. */

```
Labor::Person addPerson (in Labor::Person aPerson)
        raises (Global::FrameworkErrorSignal,
        Labor::PersonDuplicateSignal);
```

/* Remove the association between an Area and the Area to which it belongs. The service will remove the Area indicated by the argument from the receiver's set of subareas. The service will also nullify membership (ownership) for the argument. */

```
void removeSubArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaNotAssignedSignal,
        AreaRemovalFailedSignal);
```

/* Removes a machine from the receiver. */

```
void removeMachine (in EquipmentTracking::Machine aMachine)
        raises (Global::FrameworkErrorSignal,
        EquipmentTracking::MachineNotAssignedSignal,
        EquipmentTracking::MachineRemovalFailedSignal);
```

/* Removes a person from the receiver. */

```
void removePerson (in Labor::Person aPerson)
        raises (Global::FrameworkErrorSignal,
        Labor::PersonNotAssignedSignal,
        Labor::PersonRemovalFailedSignal);
```

/* Set the unique identifier for the Area. */

```
void setAreaIdentifier (in string identifier)
        raises (Global::FrameworkErrorSignal,
        Global::DuplicateIdentifierSignal);
```

/* Returns the set of subareas associated with this Area, that is, the Areas "contained" within this higher-level Area. If no membership has been established, an empty set is returned. */

```
AreaSequence allSubAreas ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns the receiver's set of process machines. */

```
EquipmentTracking::MachineSequence allMachines ( )
        raises (Global::FrameworkErrorSignal);
```

/* Returns the receiver's set of persons */

```
Labor::PersonSequence allPersons ( )
        raises (Global::FrameworkErrorSignal);
```

```
}; // Area
```

Contracted Services: None.

Dynamic Model: None.

6.7.5 *Component Manager Interface*

Module: FactoryOperations

Interface: ComponentManager

Inherited Interface: Resource

Description: The ComponentManager is an abstract interface that supports the registration and control (enabling/disabling) of a component's interface and for managing the resources in its domain.

Exceptions: None.

Published Events:

```
interface ComponentManager : Resource {
```

/* Component Manager state has changed */

```
const string ComponentManagerStateChangedSubject =
"/Factory/ComponentManager/ComponentManagerStateChanged";
```

/* This enumerated type identifies the states of Component Managers. It is used in event notifications of state changes. */

```
enum ComponentManagerState {
        ComponentManagerUndefined,
        ComponentManagerStopped,
        ComponentManagerStartingUp,
        ComponentManagerShuttingDown };

struct ComponentManagerStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
};
```

ComponentManagerStateChangedFilters Properties:

Name	*Value Type*	*Description*
"Name"	string	The name of the ComponentManager.
"PreviousState"	ComponentManagerState	Previous state prior to the most recent transition.
"NewState"	ComponentManagerState	New state following the most recent transition.

```
struct ComponentManagerStateChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        ComponentManagerStateChangedFilters eventFilterData;
        Global::Properties eventNews;
        ComponentManager aComponentManager;
};
```

Provided Services:

/* This operation causes the component to do its portion of the registration interchange with the factory indicated by the argument. */

```
void makeRegistered (in MESFactory aFactory)
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* This operation causes the component to remove its registration from the factory. */

```
void makeNotRegistered (in MESFactory aFactory)
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* This operation causes a registered component to perform its startup sequence. Each manager gets itself to the point where it is capable of interacting with other components. When it is ready to support all services defined in the interface, the component manager tells the factory that component startup is complete. */

```
void makeStartingUp ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* This operation causes the component to perform its shutdown sequence and then enter the state STOPPED. During shutting down activities, time is allotted to bringing the resources of a component to a safe stopping condition. The component manager tells the factory that component shutdown is complete. */

```
void makeShuttingDown ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* This operation causes the component to go into the state STOPPED without regard to data loss or the stopping condition of resources or material. There is no communication with the factory. */

```
void makeStopped ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* This operation causes a registered component to go into the state IN SERVICE from the state STOPPED. */

```
void makeInService ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);
```

/* Answer whether the status of the component is that indicated. */

```
boolean isStopped ( )
        raises (Global::FrameworkErrorSignal);

boolean isStartingUp ( )
        raises (Global::FrameworkErrorSignal);

boolean isShuttingDown ( )
        raises (Global::FrameworkErrorSignal);

boolean isNotRegistered ( )
        raises (Global::FrameworkErrorSignal);

boolean isRegistered ( )
        raises (Global::FrameworkErrorSignal);

}; // ComponentManager
```

Contracted Services: None.

Dynamic Model:

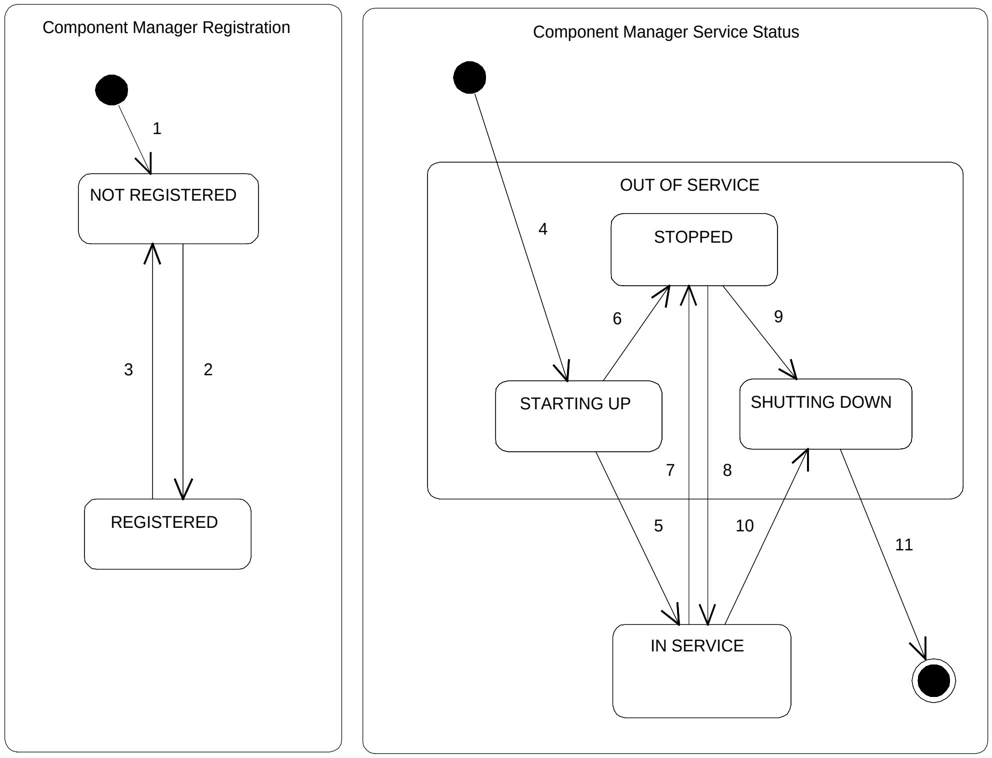

Figure 9
Component Manager Dynamic Model

Table 7 ComponentManager State Definitions and Query Table

State	*Definition*	*Query for State via*
NOT REGISTERED	Component is not registered with a factory and is not connected to the system.	boolean isNotRegistered ( ); sent to the instance of ComponentManager returns TRUE.
REGISTERED	Component is registered with a factory and is connected to the system.	boolean isRegistered ( ); sent to the instance of ComponentManager returns TRUE.
STOPPED	Component is not able to provide services.	boolean isStopped ( ); sent to the instance of ComponentManager returns TRUE.
STARTING UP	Component is performing a startup sequence.	boolean isStartingUp ( ); sent to the instance of ComponentManager returns TRUE.
IN SERVICE	Component is capable of interacting with other components.	boolean isInService ( ); sent to the instance of ComponentManager returns TRUE.
SHUTTING DOWN	Component is performing shutdown sequence.	boolean isShuttingDown ( ); sent to the instance of ComponentManager returns TRUE.
OUT OF SERVICE	Component is not able to provide services.	None.

Table 8 ComponentManager State Transitions

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	Non Existent	No CIM Framework trigger necessary.	NOT REGISTERED	Instance creation is done by the specialization.	ComponentManager is an abstract inherited interface designed to provide common behavior for specializations.
2	NOT REGISTERED	makeRegistered() sent to the instance of ComponentManager.	REGISTERED	Component manager registers with a Factory instance via Trader.	None.
3	REGISTERED	makeNotRegistered() sent to the instance of ComponentManager.	NOT REGISTERED	Component manager removes registration from the Factory via Trader.	None.
4	Unknown	makeStartingUp() sent to the instance of ComponentManager.	STARTING UP	Component manager is requested to startup.	Implementation can use startup() or makeStartingUp() services.
5	STARTING UP	Internal to component.	IN SERVICE	Report to Factory that Component is able to provide services, via events.	Component manager has finished its startup sequence.
6	STARTING UP	Internal to component.	STOPPED	None.	Component Manager could not complete startup procedure and is stopped for further corrective action.
7	IN SERVICE	makeStopped() sent to the instance of Component Manager.	STOPPED	Component will also go out of service.	ComponentManager is stopped and it may be resumed as needed.
8	STOPPED	makeInService() sent to the instance of Component Manager.	IN SERVICE	Component Manager has resumed operations and is in service for execution.	None.
9	STOPPED	makeShuttingDown() sent to the instance of ComponentManager.	SHUTTING DOWN	As an action it reports to the Factory that resources and material are brought to a safe state.	The component manager receives “shutdown normal” message.
10	IN SERVICE	makeShuttingDown() sent to the instance of ComponentManager.	SHUTTING DOWN	As an action it reports to the Factory that resources and material are brought to a safe state.	The component manager receives “shutdown normal” message.
11	SHUTTING DOWN	makeNotRegistered() sent to the instance of Component Manager.	Non Existent	The Component Manager is unregistered.	None.

APPENDIX 1
FULL IDL SPECIFICATION

NOTE: The material in this appendix is an official part of SEMI E97 and was approved by full letter ballot procedures on October 21 and December 15, 1999 by the North American Regional Standards Committee.

```
module CIMFW {
#ifndef _CIMFW_GLOBAL_
#define _CIMFW_GLOBAL_

    module Global {

            typedef string Identifier;

            typedef unsigned long Flags;

            struct NamedValue{
                Identifier name;
                any argument;
                long len;
                Flags arg_modes;
            };

            typedef NamedValue NameValue;

            typedef sequence <NamedValue> NameValueSequence;

            typedef string PropertyName;

            struct Property{
                PropertyName Property_name;
                any Property_value;
            };

            typedef sequence <Property> Properties;

            typedef sequence <string> StringSequence;

            typedef string Unit;

            typedef string Units;

            typedef sequence <any> anySequence;

            typedef sequence <long> longSequence;

            enum PriorityOfEvent { Low,
                Medium,
                High,
                Alarm };

            enum LifecycleState { Undefined,
                Created,
                Deleted,
                Moved,
                Copied };

            enum ReservationState { UndefinedReservationState,
                Reserved,
                UnReserved };

            enum E10State { E10Productive,
                E10Standby,
                E10Engineering,
                E10ScheduledDowntime,
                E10UnscheduledDowntime,
                E10NonscheduledTime };
```

```
        struct ulonglong
            {unsigned long low ;
             unsigned long high ;
        } ;

        typedef ulonglong TimeT ;

        typedef TimeT TimeStamp;

        typedef sequence <TimeStamp> TimeStampSequence;

        struct IntervalT {
            TimeT lower_bound;
            TimeT upper_bound;
        };

        typedef IntervalT TimeWindow;

        typedef TimeT Duration;

        struct ResourceSchedule {
            TimeStamp plannedStartTime;
            TimeStamp plannedEndTime;
            TimeStamp actualStartTime;
            TimeStamp actualEndTime;
        };

        typedef sequence <ResourceSchedule> ResourceScheduleSequence;

        exception NotFoundSignal { string errorMessage; };

        exception DuplicateIdentifierSignal {
            string errorMessage;
            string duplicateIdentifier; };

        exception InvalidStateTransitionSignal {
            string errorMessage; };

        exception SetValueOutOfRangeSignal {
            string errorMessage; };

        exception TimePeriodInvalidSignal {
            string errorMessage; };

        exception InvalidPropertyNameSignal {};

        exception PropertyNotFoundSignal {};

        exception UnsupportedPropertySignal {};

        exception ReadOnlyPropertySignal {};

        exception FrameworkErrorSignal {
            string errorMessage;
            unsigned long errorCode;
            any errorInformation;};

        const unsigned long NOT_IMPLEMENTED = 0;

        const unsigned long IMPLEMENTED_BY_SUBCLASS = 1;

        const unsigned long UNKNOWN_EXCEPTION = 2;

        const unsigned long COMPLETION_UNKNOWN = 3;

    }; // module Global
#endif // _CIMFW_GLOBAL_

    module EquipmentTracking {

        interface Machine {}; // Stub
```

```
            typedef sequence <Machine> MachineSequence;

            exception MachineDuplicateSignal { };

            exception MachineNotAssignedSignal { };

            exception MachineRemovalFailedSignal { };

    }; // module EquipmentTracking

    module Labor {

        interface Person {}; // Stub

            typedef sequence <Person> PersonSequence;

            exception PersonDuplicateSignal { };

            exception PersonNotAssignedSignal { };

            exception PersonRemovalFailedSignal { };

    }; // module Labor

#ifndef _CIMFW_ABSTRACT_IF_
#define _CIMFW_ABSTRACT_IF_

    module AbstractIF {

        interface Resource;

        interface Material;

        interface MaterialGroup;

        interface JobSupervisor;

        interface Job;

        interface JobRequestor;

            typedef sequence <Resource> ResourceSequence;

            typedef sequence <Material> MaterialSequence;

            typedef sequence <MaterialGroup> MaterialGroupSequence;

            typedef sequence <Job> JobSequence;

            typedef sequence <JobSupervisor> JobSupervisorSequence;

        interface NamedEntity {

            void setName (in string name)
                raises (Global::FrameworkErrorSignal);

            string getName ( )
                raises (Global::FrameworkErrorSignal);

            boolean isNamed (in string testName)
                raises (Global::FrameworkErrorSignal);

        }; // NamedEntity

        interface OwnedEntity : NamedEntity {

            void setOwner (in NamedEntity owner)
                raises (Global::FrameworkErrorSignal);

            NamedEntity getOwner ( )
```

```
            raises (Global::FrameworkErrorSignal);

    }; // OwnedEntity

    interface Resource : OwnedEntity {

        typedef sequence <Resource> ResourceSequence;

        void startUp ( )
            raises (Global::FrameworkErrorSignal);

        void shutdownNormal ( )
            raises (Global::FrameworkErrorSignal);

        void shutdownImmediate ( )
            raises (Global::FrameworkErrorSignal);

        string resourceLevel ( )

            raises (Global::FrameworkErrorSignal);

        string nameQualifiedTo (in string resourceLevel)
            raises (Global::FrameworkErrorSignal);

        ResourceSequence subresources ( )
            raises (Global::FrameworkErrorSignal);

        boolean isInService ( );

        boolean isOutOfService ( );

    }; // Resource

    interface Material : NamedEntity {

        string getIdentifier ( )
            raises (Global::FrameworkErrorSignal);

        void setIdentifier (in string identifier)
            raises (Global::FrameworkErrorSignal,
            Global::DuplicateIdentifierSignal);

        MaterialGroupSequence materialGroups ( )
            raises (Global::FrameworkErrorSignal);

        boolean isMemberOf (in MaterialGroup aMaterialGroup)
            raises (Global::FrameworkErrorSignal);

    }; // Material

    interface MaterialGroup : NamedEntity {

        exception DuplicateMaterialSignal {Material aMaterial;};

        exception DuplicateMaterialGroupSignal {Material
        aMaterialGroup;};

        exception MaterialRemovalFailedSignal {Material aMaterial;};

        exception MaterialGroupRemovalFailedSignal {
            MaterialGroup  aMaterialGroup;};

        string getIdentifier ( )
            raises (Global::FrameworkErrorSignal);

        void setIdentifier (in string identifier)
            raises (Global::FrameworkErrorSignal,
            Global::DuplicateIdentifierSignal);

        void addMaterials (in MaterialSequence aMaterialSequence)
            raises  (Global::FrameworkErrorSignal,
```

```
        DuplicateMaterialSignal);

    void addMaterial (in Material aMaterial)
        raises (Global::FrameworkErrorSignal,
        DuplicateMaterialSignal);

    void removeMaterial (in Material aMaterial)
        raises  (Global::FrameworkErrorSignal,
        MaterialRemovalFailedSignal,
        Global::NotFoundSignal);

    MaterialSequence removeAllMaterials ( )
        raises (Global::FrameworkErrorSignal);

    void addMaterialGroup (in MaterialGroup aMaterialGroup)
        raises (Global::FrameworkErrorSignal,
        DuplicateMaterialGroupSignal);

    void removeMaterialGroup (in MaterialGroup aMaterialGroup)
        raises (Global::FrameworkErrorSignal,
        MaterialGroupRemovalFailedSignal,
        Global::NotFoundSignal);

    MaterialSequence allMaterials ( )
        raises (Global::FrameworkErrorSignal);

    MaterialGroupSequence allMaterialGroups ( )
        raises (Global::FrameworkErrorSignal);

    long size ( )
        raises  (Global::FrameworkErrorSignal);

}; // MaterialGroup

interface JobSupervisor : Resource {

    typedef Global::NameValueSequence Results;

    exception JobRejectedSignal { string errorMessage; };

    exception JobNotFoundSignal {
        string errorMessage;
        string missingJobName; };

    const string JobLifecycleSubject
    =”/JobSupervision/JobSupervisor/JobLifecycle”;

    struct JobLifecycleFilters {
        Global::Property name;
        Global::Property lifecycle;
    };

    struct JobLifecycleEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobLifecycleFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob; // on Delete, aJob is nil
    };

    Job requestJob (
        in Global::Properties aJobSpecification,
        in JobRequestor aJobRequestor)
        raises (Global::FrameworkErrorSignal,
        JobRejectedSignal);

    Results runJob (
        in Global::Properties aJobSpecification)
        raises (Global::FrameworkErrorSignal,
        JobRejectedSignal);
```

```
boolean canPerform (
    in Global::Properties aJobSpecification)
    raises (Global::FrameworkErrorSignal);

void pauseAllJobs ()
    raises (Global::FrameworkErrorSignal);

void resumeAllJobs ()
    raises (Global::FrameworkErrorSignal);

void abortAllJobs ()
    raises (Global::FrameworkErrorSignal);

void stopAllJobs ()
    raises (Global::FrameworkErrorSignal);

void removeFinishedJob (in Job aJob)
    raises (Global::FrameworkErrorSignal);

Job findJobNamed (in string jobName)
    raises (Global::FrameworkErrorSignal,
    JobNotFoundSignal);

Job findQueuedJobNamed (in string jobName)

    raises (Global::FrameworkErrorSignal,
    JobNotFoundSignal);

Job findActiveJobNamed (in string jobName)
    raises (Global::FrameworkErrorSignal,
    JobNotFoundSignal);

Job findCancelledJobNamed (in string jobName)
    raises (Global::FrameworkErrorSignal,
    JobNotFoundSignal);

Job findFinishedJobNamed (in string jobName)
    raises (Global::FrameworkErrorSignal,
    JobNotFoundSignal);

JobSequence allJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allQueuedJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allCanceledJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allActiveJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allExecutingJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allPausingJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allPausedJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allStoppingJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allAbortingJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allFinishedJobs ( )
    raises (Global::FrameworkErrorSignal);

JobSequence allStoppedJobs ( )
```

```
        raises (Global::FrameworkErrorSignal);

    JobSequence allAbortedJobs ( )
        raises (Global::FrameworkErrorSignal);

    JobSequence allCompletedJobs ( )
        raises (Global::FrameworkErrorSignal);

}; // JobSupervisor

interface Job : OwnedEntity {

    const string JobStateChangedSubject =
    "/JobSupervision/Job/StateChanged";

    enum JobState {
        JobUndefined,
        JobCreated,
        JobQueued,
        JobActive,
        JobExecuting,
        JobNotPaused,
        JobPausing,
        JobPaused,
        JobNotStopping,
        JobStopping,

        JobNotAborting,
        JobAborting,
        JobFinished,
        JobCanceled,
        JobCompleted,
        JobStopped,
        JobAborted };

    struct JobStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
    };

    struct JobStateChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobStateChangedFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob;
    };

    const string JobDeadlineCannotBeMetSubject =
        "/JobSupervision/Job/DeadlineCannotBeMet";

    struct JobDeadlineCannotBeMetFilters {
        Global::Property name;
        Global::Property deadline;
    };

    struct JobDeadlineCannotBeMetEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        JobDeadlineCannotBeMetFilters eventFilterData;
        Global::Properties eventNews;
        Job aJob;
    };

    const string JobDeadlineChangedSubject =
        "/JobSupervision/Job/DeadlineChanged";

    struct JobDeadlineChangedFilters {
        Global::Property name;
        Global::Property previousDeadline;
```

```
    Global::Property newDeadline;
};

struct JobDeadlineChangedEvent {
    string eventSubject;
    Global::TimeStamp eventTimeStamp;
    JobDeadlineChangedFilters eventFilterData;
    Global::Properties eventNews;
    Job aJob;
};

exception InvalidPropertyNameSignal {};

exception PropertyNotFoundSignal {};

exception UnsupportedPropertySignal {};

exception ReadOnlyPropertySignal {};

JobRequestor getJobRequestor ()
    raises (Global::FrameworkErrorSignal);

Global::Property getJobProperty (
    in Global::PropertyName aPropertyName)

    raises (Global::FrameworkErrorSignal,
    InvalidPropertyNameSignal,
    PropertyNotFoundSignal);

void setJobProperty (
    in Global::Property aProperty)
    raises (Global::FrameworkErrorSignal,
    Global::SetValueOutOfRangeSignal,
    InvalidPropertyNameSignal,
    UnsupportedPropertySignal,
    ReadOnlyPropertySignal);

boolean areJobResultsAvailable()
    raises( Global::FrameworkErrorSignal);

JobSupervisor::Results getJobResults()
    raises( Global::FrameworkErrorSignal);

void makePaused ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

void makeExecuting ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

void makeCanceled ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

void makeStopped ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

void makeInService ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

void makeAborted ( )
    raises (Global::FrameworkErrorSignal,
    Global::InvalidStateTransitionSignal);

boolean isAborting ( )
    raises (Global::FrameworkErrorSignal);

boolean isAborted ( )
```

```
                raises (Global::FrameworkErrorSignal);

            boolean isActive ( )
                raises (Global::FrameworkErrorSignal);

            boolean isCanceled ( )
                raises (Global::FrameworkErrorSignal);

            boolean isCompleted ( )
                raises (Global::FrameworkErrorSignal);

            boolean isExecuting ( )
                raises (Global::FrameworkErrorSignal);

            boolean isFinished ( )
                raises (Global::FrameworkErrorSignal);

            boolean isPausing ( )
                raises (Global::FrameworkErrorSignal);

            boolean isPaused ( )
                raises (Global::FrameworkErrorSignal);

            boolean isQueued ( )
                raises (Global::FrameworkErrorSignal);

            boolean isStopping ( )
                raises (Global::FrameworkErrorSignal);

            boolean isStopped ( )
                raises (Global::FrameworkErrorSignal);

            Global::Duration timeRemaining ( )

                raises (Global::FrameworkErrorSignal);

        }; // Job

        interface JobRequestor {

            void informJobStateChange (
                in Job aJob,
                in Job::JobState oldState,
                in Job::JobState newState)
                raises (Global::FrameworkErrorSignal);

        }; // JobRequestor

    }; // module AbstractIF

#endif // _CIMFW_ABSTRACT_IF_
#ifndef _CIMFW_FACTORY_OPERATIONS_
#define _CIMFW_FACTORY_OPERATIONS_

    module FactoryOperations {

        interface ComponentManager;

        interface Area;

            typedef sequence <ComponentManager> ComponentManagerSequence;

            typedef sequence <Area> AreaSequence;

            exception AreaNotFoundSignal {Area requestedArea;};

            exception AreaDuplicateSignal { };

            exception AreaNotAssignedSignal { };

            exception AreaRemovalFailedSignal { };
```

```
interface MESFactory : AbstractIF::Resource {

    const string MESFactoryStateChangedSubject =
    "/Factory/MESFactory/StateChanged";

    enum MESFactoryState { FactoryUndefined,
        FactoryStartingUp,
        FactoryOperating,
        FactoryGoingToStandby,
        FactoryStandby,
        FactoryShuttingDownImmediately,
        FactoryShuttingDownNormally,
        FactoryOff };

    struct MESFactoryStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
    };

    struct MESFactoryStateChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        MESFactoryStateChangedFilters eventFilterData;
        Global::Properties eventNews;
        MESFactory aMESFactory;

    };

    struct RegistrationChangedFilters {
        Global::Property MESFactoryName;
        Global::Property componentManagerName;
        Global::Property newState;
    };

    struct ComponentManagerRegistrationChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        RegistrationChangedFilters eventFilterData;
        Global::Properties eventNews;
        MESFactory aMESFactory;
        ComponentManager aComponentManager;
    };

    Area addArea (in Area anArea)
        raises (AreaDuplicateSignal,
        Global::FrameworkErrorSignal);

    Area removeArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaRemovalFailedSignal,
        AreaNotAssignedSignal);

    AreaSequence allAreas ( )
        raises (Global::FrameworkErrorSignal);

    EquipmentTracking::MachineSequence allMachines ( )
        raises (Global::FrameworkErrorSignal);

    ComponentManagerSequence allComponentManagers ( )
        raises (Global::FrameworkErrorSignal);

    void informComponentManagerIsOperating (in ComponentManager
    aComponentManager)
        raises (Global::FrameworkErrorSignal);

    void informComponentManagerIsStopped (in ComponentManager
    aComponentManager)
        raises (Global::FrameworkErrorSignal);
```

```
    void makeStartingUp ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    void makeOperating ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    void makeStandby ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    void makeShuttingDownNormaly ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    void makeShuttingDownImmediately ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    void makeOff ( )
        raises (Global::FrameworkErrorSignal,
        Global::InvalidStateTransitionSignal);

    boolean isOff ( )
        raises (Global::FrameworkErrorSignal);

    boolean isStartingUp ( )

        raises (Global::FrameworkErrorSignal);

    boolean isOperating ( )
        raises (Global::FrameworkErrorSignal);

    boolean isShuttingDownNormaly ( )
        raises (Global::FrameworkErrorSignal);

    boolean isShuttingDownImmediately ( )
        raises (Global::FrameworkErrorSignal);

    boolean isGoingToStandby ( )
        raises (Global::FrameworkErrorSignal);

    boolean isStandby ( )
        raises (Global::FrameworkErrorSignal);

}; // MESFactory

interface Area : AbstractIF::OwnedEntity {

    const string AreaConfigurationChangedSubject =
    "/Factory/Area/AreaConfigurationChanged";

    enum AreaChangeType {
        MachinesChanged,
        PersonsChanged,
        SubAreaChanged };

    struct AreaConfigurationChangedFilters {
        Global::Property name;
        Global::Property changeType;
    };

    struct AreaConfigurationChangedEvent {
        string eventSubject;
        Global::TimeStamp eventTimeStamp;
        AreaConfigurationChangedFilters eventFilterData;
        Global::Properties eventNews;
        Area anArea;
    };
```

```
    Area getSuperArea ( )
        raises (Global::FrameworkErrorSignal);

    string getAreaIdentifier ( )
        raises (Global::FrameworkErrorSignal);

    Area addSubArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaDuplicateSignal);

    void removeSubArea (in Area anArea)
        raises (Global::FrameworkErrorSignal,
        AreaNotAssignedSignal,
        AreaRemovalFailedSignal);

    void setAreaIdentifier (in string identifier)
        raises (Global::FrameworkErrorSignal,
        Global::DuplicateIdentifierSignal);

    AreaSequence subAreas ( )
        raises (Global::FrameworkErrorSignal);

    EquipmentTracking::Machine addMachine (in
    EquipmentTracking::Machine aMachine)

        raises (Global::FrameworkErrorSignal,
        EquipmentTracking::MachineDuplicateSignal);

    void removeMachine (
        in EquipmentTracking::Machine aMachine)
        raises (Global::FrameworkErrorSignal,
        EquipmentTracking::MachineNotAssignedSignal,
        EquipmentTracking::MachineRemovalFailedSignal);

    Labor::Person addPerson (
        in Labor::Person aPerson)
        raises (Global::FrameworkErrorSignal,
        Labor::PersonDuplicateSignal);

    void removePerson (
        in Labor::Person aPerson)
        raises (Global::FrameworkErrorSignal,
        Labor::PersonNotAssignedSignal,
        Labor::PersonRemovalFailedSignal);

    EquipmentTracking::MachineSequence machines ( )
        raises (Global::FrameworkErrorSignal);

    Labor::PersonSequence persons ( )
        raises (Global::FrameworkErrorSignal);

}; // Area

interface ComponentManager : AbstractIF::Resource {

    const string ComponentManagerStateChangedSubject =
    "/FactoryOperations/ComponentManager/ComponentManagerStateChang
    ed";

    enum ComponentManagerState { ComponentManagerUndefined,
        ComponentManagerStopped,
        ComponentManagerStartingUp,
        ComponentManagerShuttingDown};

    struct ComponentManagerStateChangedFilters {
        Global::Property name;
        Global::Property previousState;
        Global::Property newState;
    };

    struct ComponentManagerStateChangedEvent {
```

```
            string eventSubject;
            Global::TimeStamp eventTimeStamp;
            ComponentManagerStateChangedFilters eventFilterData;
            Global::Properties eventNews;
            ComponentManager aComponentManager;
        };

        const string ComponentManagerRegistrationChangedSubject =
        "/Factory/ComponentManager/ComponentManagerRegistrationChanged"
        ;

        enum RegistrationState {
            RegistrationUndefined,
            Registered,
            NotRegistered };

        void makeRegistered (in MESFactory aFactory)
            raises (Global::FrameworkErrorSignal,
            Global::InvalidStateTransitionSignal);

        void makeNotRegistered (in MESFactory aFactory)
            raises (Global::FrameworkErrorSignal,
            Global::InvalidStateTransitionSignal);

        void makeStartingUp ( )
            raises (Global::FrameworkErrorSignal,
            Global::InvalidStateTransitionSignal);

        void makeShuttingDown ( )
            raises (Global::FrameworkErrorSignal,
            Global::InvalidStateTransitionSignal);

        void makeStopped ( )
            raises (Global::FrameworkErrorSignal,
            Global::InvalidStateTransitionSignal);

        boolean isStopped ( )
            raises (Global::FrameworkErrorSignal);

        boolean isStartingUp ( )
            raises (Global::FrameworkErrorSignal);

        boolean isShuttingDown ( )
            raises (Global::FrameworkErrorSignal);

        boolean isNotRegistered ( )
            raises (Global::FrameworkErrorSignal);

        boolean isRegistered ( )
            raises (Global::FrameworkErrorSignal);

    }; // ComponentManager

  }; // module FactoryOperations
#endif // _CIMFW_FACTORY_OPERATIONS_

}; // module CIMFW
```

SEMI E98-0302
PROVISIONAL STANDARD FOR THE OBJECT- BASED EQUIPMENT MODEL (OBEM)

This provisional standard was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published February 2000; previously published November 2001.

1 Purpose

1.1 Purposes of the Object-Based Equipment Model include the following:

- Define a standard model for interfacing to multi-process equipment and other complex equipment.
- Define standard equipment components so that communications can "discuss" component-related issues.
- Provide an equipment model that can be easily integrated with SEMI E81 CIM Framework systems by connecting an OBEM-compliant equipment to a Machine object.

1.2 The purpose of the Object-Based Equipment Model (OBEM) standard is to provide definitions, services, and behavior, as seen through communications with the factory, for the common types of physical and logical objects of which equipment is typically composed, including the equipment itself. The definition of standardized objects allows the equipment to describe its makeup to the factory and provides the factory visibility into the equipment.

2 Scope

2.1 This is a provisional standard that defines concepts, behavior, and services to support the integration of production equipment within a semiconductor factory. The scope of this standard includes all semiconductor manufacturing equipment that provides an interface to the factory host systems. Some services may not be applicable to some material handling systems.

2.2 Sections that must be completed in order for the provisional status of OBEM to be removed include the following:

1. Section 11.2 — Access Management
2. Section 14 — OBEM Compliance

2.3 Detail standards will also be added in the future to specify OBEM mappings to different protocols such as SECS-II, CORBA IDL, and DCOM.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is not intended to define the attributes, behavior, or services of systems that are aggregates of equipment, such as cells.

3.2 The decomposition of equipment into different objects is chosen by the equipment supplier to map the physical equipment to the characteristics of the objects defined by this standard.

3.3 Object-oriented technology is not required for implementations of OBEM. However, object-oriented implementations should be compatible with OBEM.

4 Referenced Standards

4.1 This section lists documents referenced by this standard.

4.2 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E40 — Standard for Processing Management

SEMI E41 — Exception Management (EM) Standard

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

SEMI E53 — Event Reporting

SEMI E54 — Sensor/Actuator Network Standard

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

SEMI E87 — Provisional Specification for Carrier Management (CMS)

SEMI E90 — Specification for Substrate Tracking

SEMI E94 — Provisional Specification for Control Job Management

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGV* — Automated Guided Vehicle

5.1.2 *AMHS* — Automated Material Handling System

5.1.3 *APC* — Advanced Process Control

5.1.4 *ARAMS* — Automated Reliability, Availability, and Maintainability Standard (SEMI E58)

5.1.5 *CIM* — Computer Integrated Manufacturing

5.1.6 *CJM* — Control Job Management

5.1.7 *CMS* — Carrier Management Standard

5.1.8 *FDC* — Fault Detection Control

5.1.9 *FIMS* — Front-Opening Interface Mechanical Standard (reference SEMI E62)

5.1.10 *FOUP* — Front-Opening Unified Pod

5.1.11 *FPD* — Flat Panel Display

5.1.12 *OBEM* — Object-Based Equipment Model

5.1.13 *OSS* — Object Services Standard (SEMI E39)

5.1.14 *PGV* — Personal Guided Vehicle

5.1.15 *R2R* — Run-to-Run Control

5.1.16 *RMS* — Recipe Management Standard (SEMI E42)

5.1.17 *SMIF* — Standard Mechanical Interface (SEMI E19)

5.1.18 *STS* — Specification for Substrate Tracking

5.2 *Definitions*

5.2.1 *abstract object type* — an object supertype that is not instantiated directly but only through one of its subtypes.

5.2.2 *actuator* — an analog or digital output device that is used to affect changes in the physical environment. Examples of actuators include mass flow controllers (MFCs) and open/closed valves.

5.2.3 *advanced process control (APC)* — techniques covering both feedforward and feedback control and automated fault detection, applied both by the equipment (in situ) and by the factory (ex situ).

5.2.4 *Automated Material Handling System (AMHS)* — a factory system used to transport and store carriers. AMHS has two major types of components: an automated transport system and one or more storage systems (stockers).

5.2.5 *automated transport system* — the component of AMHS used to transport carriers between stockers and/or production equipment.

5.2.6 *carrier* — a container with one or more fixed positions at which material may be held.

NOTE 2: Positions within a carrier may be considered as material locations owned by the carrier.

5.2.7 *clock* — a device that is used to provide real-time date and time information.

5.2.8 *container* — a durable that is used to hold other material, including other containers, for transport, storage, or shipping. Types of containers include carriers and boxes.

5.2.9 *dry run (mechanical dry run)* — a complete equipment cycle that allows the material handling and software capabilities of the equipment to be exercised without requiring full facilities hookups and without changing the physical state of the wafer. Environmental control subsystem (e.g., vacuum, nitrogen purge, particle detection) should not be affected by a dry run, and process consumables are not used.

5.2.10 *durable* — a type of material used to facilitate manufacturing but not normally consumed in the process that is removable, reusable, and trackable. Examples include containers, reticles, and pellicles.

5.2.11 *environmental subsystem* — a subsystem of equipment with the purpose of monitoring or maintaining one or more specific environmental conditions or used to handle product or durables. Environmental subsystems include vacuum systems, particle detection systems, and nitrogen purge systems.

5.2.12 *equipment* — equipment (manufacturing equipment) performs one or more of the following manufacturing functions in the factory: material process, material transport, or material storage. Equipment is made up of various parts: modules, subsystems and sensors/actuators. Equipment has at least one carrier port. Equipment communicates with the factory.

5.2.13 *equipment element* — a component of the equipment that behaves as a unit, performs work, and may or may not contain lower-level components.

5.2.14 *equipment module (module)* — a major component of equipment that contains at least one material location and performs some task on material. Equipment modules may be aggregates of equipment subsystems, i/o devices, and other modules.

5.2.15 *fault detection* — analysis of data for early detection of process faults before yield loss becomes significant.

5.2.16 *Front-Opening Unified Pod (FOUP)* — a front-opening pod with an integrated (non-removable) cassette.

5.2.17 *implementation* — the internal view of a type, class, or instance, including any non-public properties and behavior. The specific code and functionality that implements an interface. (See SEMI E81.)

5.2.18 *interface* — the external view of an object type, class, or object that defines its public properties and services without regard to the internal structure and internal behavior. (See also SEMI E81.)

5.2.19 *interface inheritance* — the construction of an interface by incremental modification of other interfaces (see implementation inheritance). (See SEMI E81.) OBEM specifies interface inheritance but not implementation inheritance.

5.2.20 *I/O device* — a general term for any type of sensor or actuator or aggregation of sensor and/or actuator.

5.2.21 *linked equipment* — two or more equipment that are physically and logically connected and function as a single installation of equipment. In this case, the individual component equipment are modeled as high-level modules of the linked equipment.

5.2.22 *load port* — The physical interface provided for the exchange of carriers with an agent of the factory (operator or automated material handling system). (Reference SEMI E15.)

5.2.23 *Manufacturing Execution System (MES)* — the factory system responsible for managing the manufacturing process, including logistics and process flow.

5.2.24 *material* — (1) any material used in, or required by, the manufacturing process. Material is classified as consumable, durable, or product. (2) an abstraction of the various types of things used during manufacturing, such as wafers, carriers, and chemicals, which require some management.

5.2.25 *material location* — a reference to a place within the equipment or an equipment component that can hold material, such as the top surface of an indexer or substrate chuck or the end effector of a substrate handler.

5.2.26 *measured value* — a value representing a measurement, with a numerical value, measurement units, and a valid range.

5.2.27 *measurement equipment* — equipment whose intended function is to measure or inspect the product and to report results. Measurement of the product is the factory's means of gaining feedback on the manufacturing process.

5.2.28 *Object-Based Equipment Model* — a model of equipment, its components, behaviors, attributes, and services, as defined by this document.

5.2.29 *object type* — a declaration (specification) that describes the common properties and behavior for a collection of objects. Types classify objects according to a common interface; classes classify objects according to a common implementation. (See also SEMI E39 and E81.)

5.2.30 *object specifier* — designates a logical path pointing to a specific instance of an object through a hierarchy of owners. See SEMI E39.

5.2.31 *Personal Guided Vehicle (PGV)* — a manually guided and operated vehicle capable of placing and removing carriers to and from a carrier port.

5.2.32 *pod* — as used in this document, a container providing environmental control, such as a SMIF or FIMS pod[1].

5.2.33 *production equipment* — process equipment and measurement equipment.

5.2.34 *process durable* — a specialized durable used by process equipment and specified by the user as part of the process, such as a reticle or burin-in board.

5.2.35 *process equipment* — equipment whose intended function is to process product, adding value to the product.

5.2.36 *product* — (1) from the equipment's perspective, product is a synonym for substrate, and includes

1 The term "pod" was originally defined as a bottom-opening pod with a SMIF interface.

non-product substrates such as test substrates and send-ahead substrates; (2) from the factory perspective, product is the material being processed and produced by the factory.

5.2.37 *run-to-run control* — techniques for varying settings in one run based on analysis of either incoming product (feed-forward) or product from an earlier run.

5.2.38 *sensor* — a component that responds to changes in the physical environment and provides an analog or digital input value.

5.2.39 *sensor/actuator device* — a device consisting of one or more sensors and/or actuators on the physical tool. See SEMI E54 for a precise definition of "sensor or actuator" and for a description of the internal structure of an sensor/actuator network Common Device Model definition.

5.2.40 *setup* — 1. (verb) the performance of one or more steps that puts the equipment into a known state in which it is ready to perform a specific process; 2. (noun) the state of the equipment once it has been setup.

5.2.41 *standardized object* — an object that is formally defined and compliant to SEMI E39, Object Services Standard (reference SEMI E42).

5.2.42 *storage equipment (stocker)* — equipment whose intended function is primarily to provide storage, either short-term or long-term, for carriers.

5.2.43 *subassembly* — a component of equipment that provides some limited functionality.

5.2.44 *substrate* — basic unit of material on which work is performed to create a product. Examples include wafers, die, plates used for masks, flat panels, circuit boards, and leadframes.

5.2.45 *subsystem* — a subsystem is an intelligent aggregate that behaves as a unit. A subsystem is made up of sensors and/or actuators and may contain mechanical assemblies. Subsystems may be shared by multiple modules.

5.2.46 *subtype* — an object type that is based on (derived from) another type and adds some specialization or overrides some properties or services. The type from which the subtype is derived is the supertype. For additional detail, see SEMI E39, Object Services Standard.

5.2.47 *supertype* — an object type which is used as a basis from which specializations are derived. The derived types are called subtypes. For additional detail, see SEMI E39.

5.2.48 *transport equipment* — equipment whose intended function is primarily to move material from one location in the factory to another location. Transport equipment may also provide short-term storage for material. (See also AMHS.)

5.2.49 *virtual sensor (synthetic sensor, derived sensor)* — one or more calculated measured values that are based on one or more sensor readings. This may include results based on neural nets, statistical analysis, etc. or may be based on a single sensor value.

5.2.50 *work* — a group of one or more substrates that undergo processing in a factory. Something that may be work in one kind of factory, such as reticles and leadframes, may have a different role in other types of factories. Work includes, but is not limited to, material intended as product. For example, it may include product substrates, test substrates, and filler substrates.

5.2.50.1 From the point of view of the equipment, work is either new (processing has not started), completed (all intended processing has been performed, terminated, or aborted, including rejected and resorted work, and no further processing is to be done) or incomplete (work in progress, on hold).

6 Conventions

6.1 This section defines the conventions followed by this document.

6.2 *Object Conventions* — This document conforms to the conventions for objects established by SEMI E39, including object diagrams, object terminology, and requirements for standardized objects. Accordingly, notation is based on Object Modeling Technique (OMT) as described in Object Oriented Modeling Design.[2]

6.2.1 *Formal Name of an Object* — The text capitalizes formal object name references. Similar to the way capitalization is normally used when discussing entities. When describing something in the general (like cities) lower case is used, but when a specific entity is of interest (New York City), then first letters are capitalized.

6.2.2 *Components of Complex Attributes* — The names of object attributes defined in tables are left-justified. The individual elements of complex attributes are right-justified in order of appearance below the complex attribute.

2 Rumbaugh, James, et al, Object Oriented Modeling Design, Prentice Hall, Englewood Cliffs, NJ, c1991.

6.2.3 *Names of OBEM Objects* — The names of abstract object types start with the word “Abstract” and are not intended to be directly implemented. All other objects defined in OBEM are concrete types that may be directly implemented.

6.3 *State Model Conventions*

6.3.1 This document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in “State charts: A Visual Formalism for Complex Systems”[3].

6.3.2 The Harel convention has not the concept of state models of “creation” and “extinction” for expressing a temporary entity. The “job” described in this document is such an entity, and a copy of the same state model is used for an independent job newly created. In this document, a circle with a black circle inside is used for expressing extinction of an entity. A filled black circle denotes the entry to the state model (the entity creation).

6.3.3 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The “trigger” (column 3) for the transition occurs while in the “previous” state. The “actions” (column 5) includes a combination of:

1. Actions taken upon exit of the previous state.
2. Actions taken upon entry of the new state.
3. Actions taken which are most closely associated with the transition.

6.3.3.1 No differentiation is made between these cases.

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

6.4 *Service Message Representation* — Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message, that does not require a response.

6.4.1 *Service Definition*

6.4.1.1 A service definition table defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*

6.4.1.2 Type can be either “N” = Notification or “R” = Request & Response.

6.4.1.3 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.4.2 *Service Parameter Dictionary*

6.4.2.1 A service parameter dictionary table defines the description, format and its possible value for parameters used by services, as shown in the following table:

Parameter Name	*Description*	*Format: Possible Value*

6.4.2.2 A row is provided in the table for each parameter of a service.

3 D. Harel, “State charts: A Visual Formalism for Complex Systems”, Science of Computer Programming 8, 1987.

6.4.3 *Service Message Definition*

6.4.3.1 A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Res/Cnf*	*Comment*

6.4.3.2 The columns labeled REQ/IND and RSP/CNF link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication" or the request. The receiver may then send a "Response" which the original sender terms the "Confirmation".

6.4.3.3 The following codes appear in the REQ/IND and RSP/CNF columns and are used in the definition of the parameters (eg., how each parameter is used in each direction):

M	Mandatory Parameter — Must be given a valid value.
C	Conditional Parameter — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.
U	User-Defined Parameter.
-	The parameter is not used.
=	(For response only.) Indicates that the value of this parameter in the response must match that in the primary (if defined).

6.5 *OBEM Standard Structure*

6.5.1 The remaining part of this document is organized as follows:

6.5.1.1 Section 7 contains background information to provide a context for the Object-Based Equipment Model.

6.5.1.2 Sections 8 provides an overview of two major views of the equipment: the functional view and the internal composition view.

6.5.1.3 Section 9 introduces the OBEM object model: the interface inheritance hierarchy and the rules of aggregation that together form the foundation of the OBEM model of equipment.

6.5.1.4 Section 11 defines the requirements for the component objects within the equipment interface hierarchy: and other related objects of significance not defined elsewhere.

6.5.1.5 Section 12 defines the message services used in OBEM that are not defined in other standards.

6.5.1.6 Section 13 defines the services that are required of the user (factory system, remote access, and operator).

6.5.1.7 Section 14 specifies the minimum requirements and optional capabilities for compliance to the OBEM standard.

6.5.1.8 Section 15 provides scenarios showing typical message flows during operation.

6.5.2 Additional sections are provided as related information: examples and additional material that are not part of the standard itself. These include models for linked litho, 300 mm equipment, the relationship of OBEM and the CIM Framework, and representations of date and time.

7 Background

7.1 Both modern manufacturing processes and modern manufacturing equipment are increasingly complex. A single installation of equipment may have hundreds or thousands of sensors and actuators. In order to manage this complexity, better methods of referencing the internal components of equipment are needed. Use of the object paradigm provides a means for the equipment to describe its internal composition to the factory in a natural way.

7.2 Definition of standardized objects allows the factory to be specific about its requirements and its need for information.

7.3 *Computer Manufacturing Integration Business Goals*

7.3.1 The intent of this section is to provide a context for, and insight into, those requirements of industries such as semiconductor and flat panel display (FPD) manufacturing businesses that affect the object-based equipment model.

7.3.2 The primary purpose of computer integrated manufacturing (CIM) technologies is to improve factory productivity.[4] Other inter-related secondary CIM business goals are listed below.

- Maximize product yields (line/mechanical yield).
- Maximize device yields (electrical/functional yield).
- Maximize total factory product substrate throughput.
- Increase individual equipment product substrate throughput.
- Reduce product variability.
- Reduce process variability.
- Optimize ability to center processes in a “sweet spot”.
- Reduce the use of non-product substrates.
- Reduced time to utilization for equipment (i.e., the time to install, qualify, characterize and ramp production).
- Increase the usability, accuracy, and reliability of data used for metrics.
- These business goals can be met by addressing certain concrete objectives, which are listed below.

7.4 *OBEM Functional Objectives*

7.4.1 OBEM will standardize specific functional capabilities to be implemented on semiconductor/FPD and other manufacturing equipment, providing a hierarchical view of equipment for effective factory integration.

7.4.2 The OBEM functional objectives are as follows:

- Manage material into and through the equipment.
- Manage the association of the process instructions with the material.
- Report data associated with the equipment, the process, and the material.
- Facilitate equipment performance monitoring.

7.4.3 These OBEM functional objectives, individually and collectively, can be shown to directly address the overall business goals:

7.4.4 The Object Based Model objective directly affects the ability to implement most of the other objectives, especially in the case of highly modular equipment.

7.4.5 Equipment performance monitoring has the effect of improving product variability, device yield and can reduce the need for non-product test substrates. It can also provide a means of targeting a specific process window to improve device characteristics such as speed.

7.4.6 Management of the association of process instructions with the material can reduce scrap due to misprocessing, thus improving product yield. The material management objectives impact on the throughput of individual equipment and the total factory throughput.

7.5 *Relevant Factory Environment* — Equipment must support a variety of different factory environments. This is necessary because factory business practices and factory configurations vary not only from company to company but also from one facility within a company to another. Items will be added to this section as their relevance becomes apparent.

7.5.1 *Material Handling Systems* — Material may be loaded and unloaded manually by a fab technician or it may be loaded and unloaded using semi-automated and automated transport systems. Types of systems include:

- Automated Guided Vehicles (AGV),
- Personal Guided Vehicles (PGV),
- Overhead Transport Systems (OTS), including Overhead Hoist Transport (OHT), and
- Fixed Arm Robots.

7.5.2 *Containers* — Containers may be open (e.g., cassettes) or closed (pods, including reticle pods). Pods may be bottom-opening (SMIF), with a removable cassette, or front-opening (FIMS), which may have either a removable cassette or an integrated (non-removable) cassette (FOUP).

7.5.3 *Factory Interface* — The equipment must be able to support different levels of automation, including:

4 For a more detailed discussion and list, see the Guidance and Guideline documents at http://www.sematech.org/public/docubase/abstract/tech-30.htm

- stand-alone (with no connection to the factory systems),
- fully on-line and operated locally (by the operator),
- fully on-line and operated remotely (by the factory systems), and
- fully on-line and able to support and coordinate interactions from multiple factory users and systems at the same time.

8 Equipment Overview

8.1 The Object-Based Equipment Model defines the objects that are generic components of equipment as well as the object representing the equipment itself. OBEM does not dictate the makeup of equipment. Through support of OBEM, the equipment is able to describe its own makeup to the factory. However, OBEM does require certain visibility and access to those parts of the equipment that control and/or monitor the environment or the location of the product.

8.2 Two view areas are of importance: the functional view of the equipment and the internal composition view of the equipment.

8.3 *Functional View of Equipment* — From a functional view, equipment is internally composed of logical subsystems with different areas of responsibility that are at different levels within a control hierarchy, as illustrated in Figure 1. There are three general levels. Equipment Control is at the highest level, both responsible for, and representing, the equipment as an integrated whole. The middle level provides management of specific areas, while the lowest level of functionality has specific time-critical responsibilities and handles all direct interaction with the equipment's I/O (sensors and actuators). The third level is below the factory level of visibility and is discussed here for completeness.

NOTE 3: This is not intended to represent the design of an actual implementation.

8.3.1 The functional areas are discussed below in alphabetical order.

8.3.2 *Access Management* — Access Management is responsible for communications with the factory, including factory computers, local and remote operators, third party systems, and alternate users (desktop access by process engineers, maintenance personnel, supplier remote diagnostics, etc.) Communications with the local operator include input devices (such as keyboards, wands, buttons, and optical character readers) and display devices (console, light pole, and LCD panel) as well as interpretation of operator requests.

8.3.3 *Communications Link* — Communications Link is responsible for low-level communications, including establishing a connection with a communications partner, sending messages, and receiving messages.

8.3.4 *Date/Time Management* — Date/Time Management is responsible for maintaining an accurate date and time-of-day, and for providing current date/time information to the rest of the system. This may include maintenance of regular time-based scheduling.

8.3.5 *Environment Control* — Environment Control is responsible for maintaining the internal environment according to the equipment's specifications. While Process Control is specific to a process and recipe, other monitoring activities may be required regardless of whether the equipment is processing or idle. Such activities include monitoring for particles, humidity, or temperature.

8.3.6 *Equipment Control* — Equipment Control is the supervisory level with overall high-level control. Equipment Control represents the entire equipment as an integrated whole to the factory and represents the decision-making authority within the equipment.

8.3.7 *Event Management* — Events continually occur in all equipment states. A variety of these events are of interest to the factory, including those events that generate a change of state in any standardized object. The factory requires notification when selected events occur, and in many cases, requires reports of the values of specified information at the time that the event occurred. Event Management is responsible for tracking those events and the reports associated with those events.

8.3.8 *Exception Management* — Exception Management is responsible for determining the proper response to an action or operation that the equipment was unable to perform which raised an exception condition. It prompts notification to all affected components, including internal components and currently connected users. In some cases, the proper action may have to be resolved by the user. Exception Management is a high level activity that is in addition to underlying hardware and software interlocks.

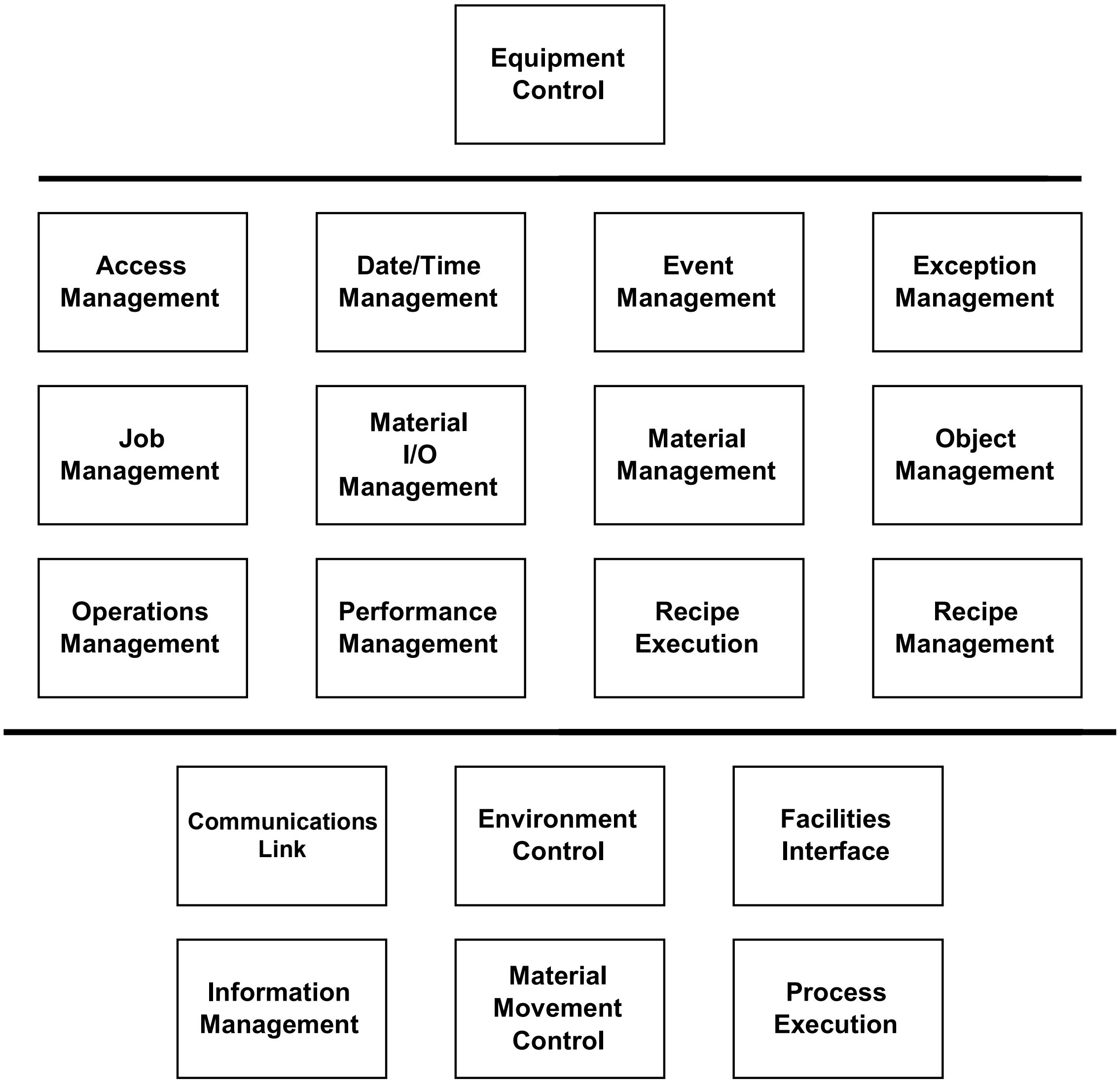

Figure 1
Functional View of Equipment

8.3.9 *Facilities Interface* — The Facilities Interface is responsible for managing the physical interfaces (hookups) to the factory. This includes bulk fill, continuous chemical services, factory vacuum, factory exhaust, and the electrical environment of the equipment.

8.3.10 *Information Management* — Information Management is responsible for the information and data stored by the equipment, including information required for the user as well as various internal event and data logs.

8.3.11 *Job Management* — Job Management is responsible for all jobs, including process jobs, job queues, and job execution.

8.3.12 *Material I/O Management* — The Material Input/Output (I/O) Management is responsible for loading and unloading material to and from the factory. This includes the AMHS interface (parallel I/O), pod interface, carrier management, and carrier-related services such as reading, writing, and slot mapping (identifying unoccupied, correctly occupied, and incorrectly occupied slots in a carrier).

8.3.13 *Material Management* — Material Management is responsible for tracking all material, including carriers, product, and consumables, within or used by the equipment. This includes providing historical information required for product history.

8.3.14 *Material Movement Control* — Material Movement Control consists of low-level control of internal subsystems, subassemblies, and i/o devices used in moving material within the equipment, such as robots, location sensors, proximity sensors, motors, centering and alignment systems, and material identifier readers.

8.3.15 *Object Management*

8.3.15.1 Object Management consists of management of OBEM objects, their attributes, and internal communications. It includes all elements of configuration definition, both fixed and user-configurable, that pertain to the equipment. Configuration settings consist of those attributes that affect the global behavior of the equipment and are generally static and change only on request. They are in effect at all times regardless of the current recipe(s) and/or processing states. They control activities that maintain the environment when “not processing”.

8.3.15.2 Configuration settings shall be retained in non-volatile storage. Some elements of configuration may be distributed. For example, individual process chambers may have their own configuration elements.

8.3.15.3 Elements of configuration management include:

- configuration of individual physical chambers, and
- configuration of individual logical objects.

8.3.16 *Operations Management* — Operations Management is responsible for the overall operation of the equipment in all operational modes: automatic, semi-automatic, and manual.

8.3.17 *Performance Management* — Performance Management is responsible for managing information and operations related to the performance of the equipment and equipment modules. This includes oversight for manual mode operations performed when the equipment and equipment modules are out of service. For implementations of ARAMS, this also includes ARAMS state changes and data as well as oversight for manual mode operations performed during downtime and non-scheduled time.

8.3.18 *Process Execution* — Process Execution covers those fixed algorithms and procedures that are not reachable or changeable by the user. This includes any embedded control and sequence algorithms not contained in recipes. It consists of low-level control of subsystems, sensors, and actuators not covered by Material Management Control, such as, chemical control (valves, exhaust), motion control (rotational, acceleration, positional) and the control of the environment during processing of the product (temperature, etc.). It also includes product environment control and any fixed embedded fault detection classification, and/or fixed low-level in-situ run-to-run control for advanced process control.

8.3.19 *Recipe Execution*

8.3.19.1 A recipe represents the pre-planned and reusable set of instructions, algorithms, and settings that are used by process execution to control process, including variable in situ process control algorithms. Recipes are created by the user, and in some cases by the equipment as well. Recipes may be of a variety of types, such as flow sequence, metrology, models, abort, and load maps, as well as etch, clean, etc.

8.3.19.2 Recipe Execution is responsible for the proper and safe execution of recipes, including loading the recipe into the execution area, verification of the recipe, validation of recipes (ensuring the recipe does not conflict with the current equipment configuration), and initiation of process execution based on recipe instructions (SEMI E42).

8.3.20 *Recipe Management* — Recipe Management consists of the management of stored recipes. This is differentiated from short-term storage of recipes and the selection and execution of recipes performed by Recipe Execution (SEMI E42). Recipes are classified (organized) according to their primary application function: process, environment, service (maintenance), etc.

8.4 *Relationships with Other Standards*

8.4.1 Only those functional areas in the middle in Figure 1 are of interest to the host. The top level of Equipment Control represents all of the functionality below it, while the functional areas at the bottom are considered to be low level and proprietary to the equipment supplier.

8.4.2 Table 1 shows those functional areas that are defined by OBEM and those that are defined by other SEMI standards. In some cases, OBEM may extend or limit the functionality defined elsewhere.

Table 1 Functional Area Definition

Functional Area	*Where Defined*	*Comments*
Access Management	SEMI E98 (OBEM)	Defines different kinds of user control.
Date/Time Management	SEMI E98 (OBEM)	Addresses timestamp, date/time synchronization.
Event Management	SEMI E53 (ERS)	SEMI E53 may be required for SECS-II implementations.
Exception Management	SEMI E41 (EMS)	Required for reporting alarms and exceptions.
Material I/O Management	SEMI E87 (CMS)	Required for Carrier Management.
Material Management	SEMI E90 (STS)	Required for Substrate Tracking.
Object Management	SEMI E39 (OSS)	Required
Operations Management	SEMI E98 (OBEM)	Overall coordination.
Performance Management	SEMI E58 (ARAMS)	Optional for EquipmentModule and Equipment. Not used for lower level components.
Job Management	SEMI E40 (PM), SEMI E94 (CJM)	Process Managment and Control Job Management
Recipe Execution	SEMI E42 (RMS)	Required for processing by EquipmentModule.
Recipe Management	SEMI E42 (RMS)	Required for long-term storage by Equipment.

8.5 *Internal Composition View of the Equipment* — The physical makeup of equipment is of interest to the factory, particularly for equipment that is complex, multi-module, and/or multi-process. Productivity and maintenance tracking, for example, requires that the factory be able to specify individual subsystems and/or modules for maintenance activities, where it is possible to do so without removing the entire equipment from manufacturing scheduling. For example, one or more baths in a wet bench may be down for maintenance even though the wet bench itself continues to process.

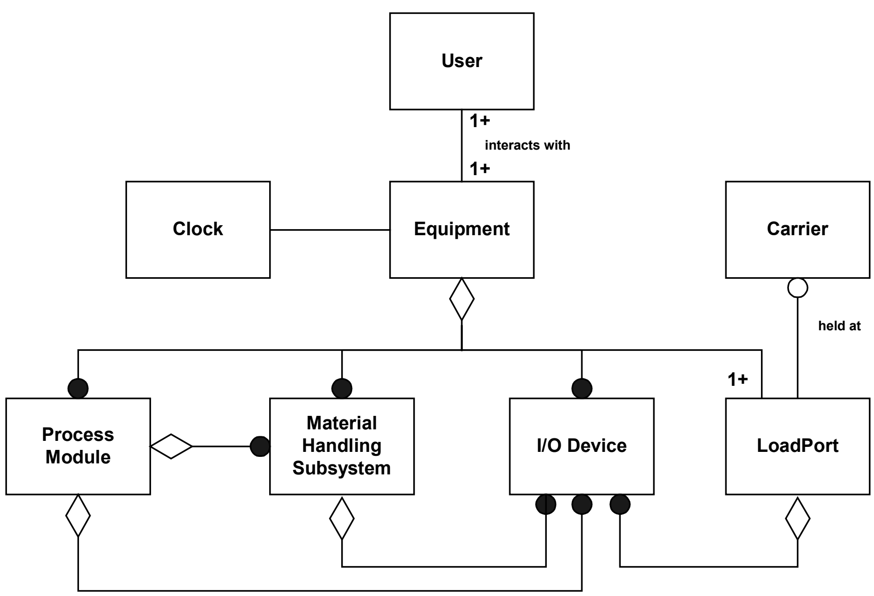

Figure 2
An Example of Equipment Internal Composition

9 OBEM Object Model

9.1 OBEM defines generic component objects of Equipment, and the Equipment object itself. Equipment is made up of elements (units or parts) of different levels of intelligence and complexity, such as modules, subsystems, and I/O devices. Each of these elements may itself be made up of several smaller elements, some of which may also be intelligent, and this allows the complexity of the equipment to be distributed to smaller functional units. Many of these elements may be of interest to the factory. In particular, process modules, which are intelligent and may be independently operable, are very interesting to the factory, since these are the units where the product is actually processed. The factory requires processing modules to be highly visible and individually addressable and to support certain of the same remote commands that are required of the equipment. Other elements of interest include subsystems for material handling, alignment, and measurement.

9.2 The equipment is responsible for all communications at all times, including messages directed to a specific part of the equipment. Service requests directed to components of the equipment shall be managed by the equipment to ensure equipment integrity.

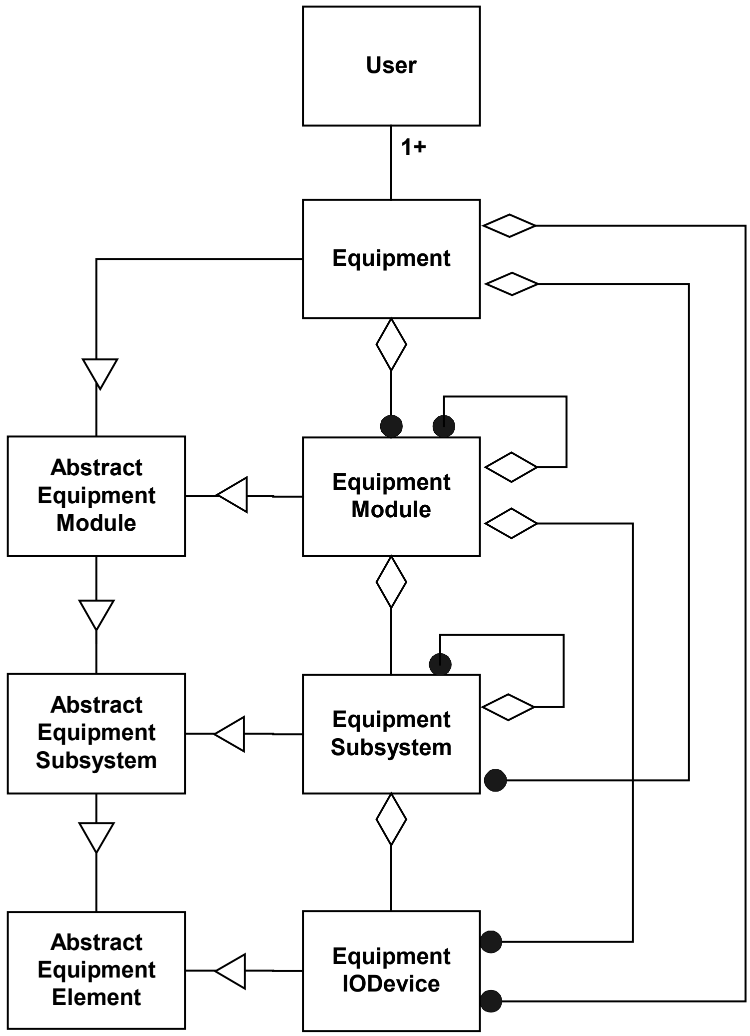

Figure 3
Equipment Object Model

9.3 In Figure 3, two hierarchies are shown. On the left is an inverted interface inheritance hierarchy, and on the right the concrete subtypes where rules of aggretation are shown. The interface inheritance shows the objects that define the attributes, state models, and services of the subtype objects as viewed externally. These are presented upside down from the usual presentation so that they may be directly related to the aggregation hierarchy on the right. In both cases, the simpler objects are below the more complex objects.

9.4 Those object types starting with the word "Abstract" are abstract objects not intended to be implemented directly. Their purpose is solely to define the inherited attributes, state models, and services for those objects used to build an OBEM model of equipment. The remaining objects shown in Figure 3 are concrete objects. All rules of aggregation are defined for concrete objects only.

9.5 *OBEM Object Requirements* — By definition, subtypes of objects inherit the properties (attributes, services, and relationships) of their supertypes. In some cases, properties of the subtype may be further specialized.

9.5.1 *Object Services Requirements* — All objects formally defined by this standard shall be compliant to the fundamental requirements of SEMI E39 (OSS). All OBEM-defined objects that are aggregates, containers, or managers of other objects shall comply with the additional OSS requirements for object owners. According to OSS, an owner is any aggregate, container, or manager of one or more other objects. An owner is required to respond to queries about the types of objects that it owns. Owners have additional responsibilities, as specified in OSS.

9.5.2 *Object Non-volatility*

9.5.2.1 All objects defined by OBEM shall be persistent. The individual object persists across powerdown and powerup conditions, and all current values of static attributes (attributes that do not change dynamically indicating the object's status) shall be maintained and restored upon powerup. It may be important to maintain other critical values as well, depending upon the object and the implementation. When the equipment is powdered on or reset[5], all state models are restored. Following initialization, the object is considered to be operational. Figure 4 shows this convention for a generic OBEM object. However, since the state model can not be accessed by the user until the object is operational, the default entry state for a specific state model is considered to be within the Operational state.

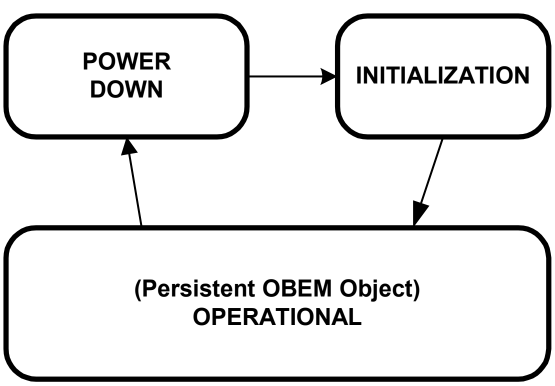

Figure 4
Persistence of OBEM Objects

5 For a more detailed discussion of powerdown, reset, and soft reset, see SEMI E58.

9.5.2.2 POWERDOWN and INITIALIZATION are common to all OBEM objects. Therefore, they are not specific to any object and are not generally shown. When operational, the OBEM object is capable of maintaining state information. From the user view, an instantiation of an OBEM object shall follow the behavior or state model as shown in Figure 4. The equipment representation, which consists of an aggregation of OBEM objects, shall also reflect the state model shown here.

9.5.2.3 The equipment is responsible for managing the exchange of any of its component parts, including parts exchanged during powerdown. This may be accomplished through use of intelligent components that are able to identify themselves or through the user interface.

9.5.3 *Shared Resources* — When two (or more) objects cooperate in using the services provided by a third object, then the third object should not be modeled as a component of either of the first two objects. If the two cooperating objects have a common owner, either logical or physical, then the shared resource object should belong to the common owner.

9.5.4 *Object Factory Communications* — OBEM objects other than the Equipment object are neither required nor expected to communicate directly with the factory. Factory communications are handled by the Equipment instantiation.

9.5.5 *Object Event Reporting*

9.5.5.1 Event reporting allows a user to receive notification of events together with related data of interest. OBEM compliance requires that the equipment provide a standard mechanism for reporting events of interest to the user, together with the current values of user-selectable data.

9.5.5.2 All transitions in state models are of interest to the user and reportable unless otherwise stated in the state model definition.

9.6 *OBEM Interface Inheritance Hierarchy*

9.6.1 An interface inheritance hierarchy begins with a simple interface at the highest (most abstract) level, and lower levels within the hierarchy represent added functionality (specialization). A subtype of an object inherits the attributes, behavior, relationships, and services of the supertype and adds to and/or modifies (overrides) them.

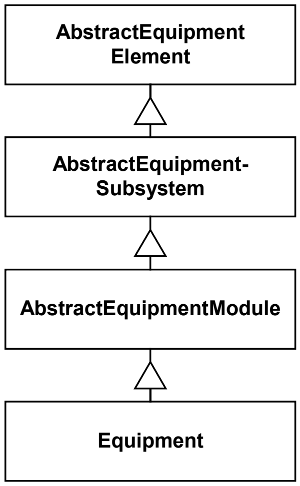

Figure 5
Object Interface Hierarchy Concept

9.6.1.1 The physical view shown in Figure 2 is concerned with the relationships between different objects. In that view, the equipment is at the highest level and owns (is responsible for) the lower level objects of which it is made up. A process chamber is considered to be at a higher level than subsystems such as substrate handlers.

9.6.1.2 From the view of the object interface hierarchy, this order is reversed, with AbstractEquipmentElement appearing at the top level as shown in Figure 5. From the view of an object interface — the interface to an object — the higher the level, the more simple the interface. This is because of inheritance, where the "child" object inherits all of the attributes, behavior, and services of the "parent" object and at the same time adds some degree of specialization that will be reflected in either additional attributes, behavior, or services, or in restrictions on the more general object.

9.6.1.3 All objects represent the view as seen by the factory, not the internal view of equipment control. From this view, the information and services required for an equipment part such as a pod door opener is relatively simple. The view of a module such as a process chamber is more complex but contains all the elements of the view provided for the simpler part (functional description, immutable id, etc.). The view of the equipment is the most complex and includes all of the attributes and services of the equipment element, equipment subsystem, equipment module, and the equipment itself.

9.6.1.4 The object model of equipment presented to the factory is based on SEMI E39 (OSS). OSS services allow the factory to "discover" the actual physical makeup and aggregation hierarchy of the physical view of equipment illustrated in Figures 2 and 3.

9.6.1.5 Each object is defined in terms of its requirements, attributes, behavior (state models), and the services that it is required to support. The equipment owns all of the objects that it is made of and is responsible for providing the required behavior.

9.6.1.6 All objects in OBEM inherit the attributes and services defined for the Top Object as specified in the Object Service Standard (OSS). This allows the factory to use object services to request the equipment to describe its physical view by reporting which objects that it owns.

9.6.1.7 Note that equipment support for an OBEM interface to the factory does not imply or require direct access from the factory to any equipment element.

10 OBEM Object Definitions

10.1 OBEM objects are defined in this section.

10.2 *AbstractEquipmentElement Object* — The supertype object of the interface hierarchy is AbstractEquipmentElement, which is an abstraction of any equipment component that can perform work. AbstractEquipmentElement is an abstract type that is not implemented directly. There are two subtypes of AbstractEquipmentElement: AbstractEquipmentSub-system, and EquipmentIODevice. AbstractEquipment-Element is an abstract type, so that implementations are of one of the subtypes.

10.2.1 *AbstractEquipmentElement Requirements*

10.2.1.1 *Object Exception Management*

10.2.1.1.1 SEMI E41 defines a model for Exception Conditions. An Exception Condition may be either an Alarm Condition or an Error Condition. Error Conditions may, in some cases, have a set of associated Recovery Actions that can be performed by the AbstractEquipmentElement to attempt to recover from the abnormal situation.

10.2.1.1.2 An OBEM object shall comply with the fundamental requirements of SEMI E41, Section 10.4. Exception Condition objects shall be provided in conformance with SEMI E41 and shall be accessible through services defined in SEMI E39. The AbstractEquipmentElement owns all exceptions that it generates. Therefore, it shall report all of its Exception Condition objects through OSS services.

10.2.2 *AbstractEquipmentElement Subtypes* — The AbstractEquipmentElement has two subtypes, the EquipmentIODevice and the AbstractEquipment-Subsystem.

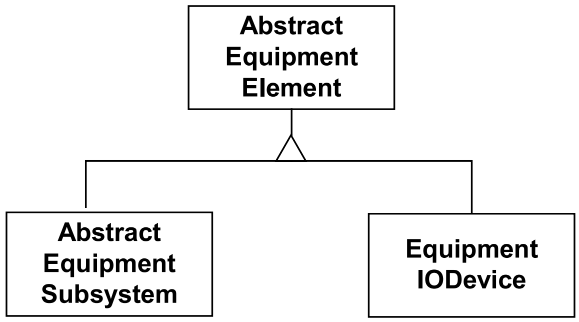

Figure 6
AbstractEquipmentElement Object Types

10.2.3 *AbstractEquipmentElement State Model*

10.2.3.1 The AbstractEquipmentElement is either IN SERVICE (available for work) or OUT OF SERVICE (unavailable for work). In some cases, the user may be able to set the AbstractEquipmentElement's operational state.

10.2.3.2 The state diagram for the AbstractEquipmentElement state model is shown in Figure 7.

10.2.3.3 The AbstractEquipmentElement shall be fault-free whenever it is in the IN SERVICE state.

10.2.3.4 An AbstractEquipmentElement in the OUT OF SERVICE state shall not be used by the equipment or the user for normal manufacturing purposes (while the Equipment or containing EquipmentModule is in the ARAMS superstate of MANUFACTURING).

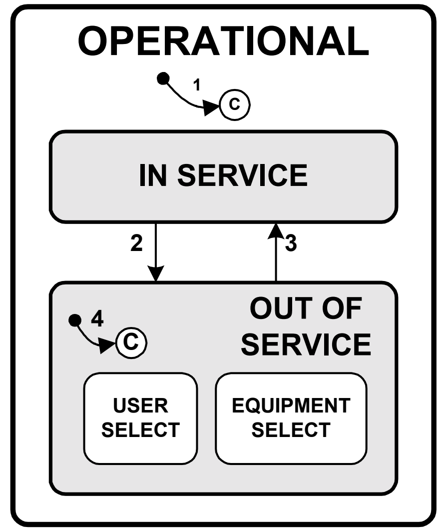

Figure 7
AbstractEquipmentElement State Model

10.2.3.5 The user may or may not be allowed to put a certain subtype of AbstractEquipmentElement out of service, depending upon the equipment design. This is optional for the equipment. In general, the user requires the ability to put major components into and out of service but does not require this for lower level components. In many cases, a component can not operate without some or all of its component elements.

10.2.3.6 Substates of OUT OF SERVICE are not required unless the user is able to put the AbstractEquipmentElement out of service. However, if a user places an AbstractEquipmentElement out of service, only a user shall be able to return it back in service. The substates are then required to retain the source of the out of service selection through the substates USER SELECT and EQUIPMENT SELECT.

10.2.3.7 *State Model Definitions* — Table 2 defines the states of the AbstractEquipmentElement object.

Table 2 AbstractEquipmentElement State Definitions

State Name	*Superstate*	*Definition*	*Comment*
IN SERVICE	OPERATIONAL	The AbstractEquipmentElement is error-free and may be used for work.	None
OUT OF SERVICE	OPERATIONAL	The AbstractEquipmentElement has one or more exceptions and/or has been made unavailable by the equipment or User.	None
USER SELECT	OUT OF SERVICE	The user requested the Abstract-Equipment-Element be put out of service.	Stays out of service until the user returns it to service. This substate may be omitted for low level elements.
EQUIPMENT SELECT	OUT OF SERVICE	The equipment determined that the AbstractEquipmentElement should be placed out of service.	Stays out of service until the equipment determines it is able to operate properly. This substate may be omitted for low level elements.

10.2.3.8 *State Transition Table* — Table 3 defines the state transitions of the AbstractEquipmentElement object.

Table 3 AbstractEquipmentElement State Transitions

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	INITIALIZATION	Initialization is complete.	Depends upon previous state and current condition	None	If the user made the element unavailable, it shall remain unavailable. If the element has a fault, it shall be made unavailable by the equipment.
2	IN SERVICE	The user has placed the element OUT OF SERVICE by the user or the equipment.	OUT OF SERVICE	None	The equipment should put the element out of service whenever a fault condition exists at the element.
3	OUT OF SERVICE	The element has been returned to service by the entity that placed it out of service. All exceptions and any user restriction have cleared.	IN SERVICE	None	The original out of service condition has cleared. The element may be used for work.
4	IN SERVICE or INITIALIZING	Default entry into OUT OF SERVICE	USER SELECT or EQUIPMENT SELECT	None	

10.2.4 *AbstractEquipmentElement Object* — Figure 8 represents the AbstractEquipmentElement object.

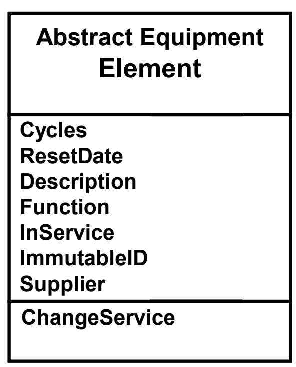

Figure 8
AbstractEquipmentElement Object Type

10.2.5 *AbstractEquipmentElement Attributes* — Table 4 defines the attributes of the AbstractEquipmentElement.

Table 4 AbstractEquipmentElement Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="EqpElement"
ObjID	Object identifier	RO	Y	Text
Cycles	Number of cycles (or hours) since installation or last reset.	RO	Y	Unsigned long integer
ResetDate	Date cycles set to zero.	RO	Y	Text
Description	User-definable text	RW	Y	Text
Function	Describes function of object (e.g., substrate-chuck, apply/develop track).	RO	Y	Text
Supplier	Name of manufacturer or provider	RO	Y	Text
ImmutableID	An unchangeable identifier such as serial number.	RO	Y	Text
InService	Available for work.	RO	Y	Boolean

10.2.6 *AbstractEquipmentElement Services* — The user may be allowed to change the operational state of specific AbstractEquipmentElement objects that are of significance for preventive maintenance. This is particularly desirable for those subsystems for which preventive maintenance may be performed while the equipment is still assigned to manufacturing operations.

10.2.6.1 *ChangeService*

10.2.6.1.1 The user may request that an element currently in the IN SERVICE state be placed in the OUT OF SERVICE\ USER SELECT state. This request shall not affect any current activity for which the element is being used. However, an element in the OUT OF SERVICE state shall not be used for any new activities.

10.2.6.1.2 The user may request that an element currently in the OUT OF SERVICE/USER SELECT state be placed back into the IN SERVICE state.

10.3 *EquipmentIODevice Object*

10.3.1 An EquipmentIODevice object is a specialization of AbstractEquipmentElement used to represent the sensors, actuators, and intelligent sensor/actuator devices that provide most of the process data sought by manufacturing engineering. Individual I/O points are represented by individual Observables contained within the EquipmentIODevice object.

10.3.2 Observables are not formalized as standardized objects, as indicated by the thin line in Figure 9. The EquipmentIODevice may represent a single I/O point, an aggregation of I/O points, or a virtual sensor providing composite data.

10.3.3 Table 5 defines the attributes of the EquipmentIODevice. Attributes are in alphabetical order, with the exception of the Observables$_i$ attribute, which is placed at the end with its structure members for clarity.

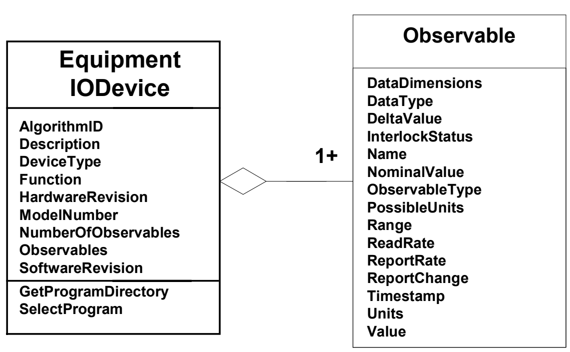

Figure 9
EquipmentIODevice and Observable Object Types

Table 5 EquipmentIODevice Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text = "EqpIODevice"
ObjID	Object identifier	RO	Y	Text
AlgorithmID	Identifier of any algorithm used to produce the set of observable values.	RO or RW	Y	Text
HardwareRevision	Revision level for hardware.	RO	Y	Text. 1–5 characters.
ModelNumber	Manufacturer model number.	RO	Y	Text. 1–20 characters.
Numberof-Observables	The number of data items provided	RO	Y	Integer
SoftwareRevision	Revision level for s/w or firmware	RO	Y	Text. 1–5 characters.
$Observables_I$	Information about the ith item of observable data values.	RO	Y	Structure comprised of Name, Value, Units, and Range, and Timestamp as follows.
Name	The name of the data, sensor, or actuator.	RO	Y	Text
DataDimension	Used for arrays to indicate the number and length of "rows" of data.	RO	N. Required for arrays.	List of unsigned integers.
Datatype	The form of the data.	RO	Y	Enumerated.
DeltaValue	Amount of change from the target for reporting. Zero value indicates it is not used.	RW	N	As indicated by Datatype.
InterlockStatus	Status of current interlock.	RO	N. Required for Actuator types.	Enumerated: None, Off, On
NominalValue	Target used for reporting change of DeltaValue.	RW	N	Numeric text string. If empty, is not used.
ObservableType	Type of Observable.	RO	Y	Enumerated
Possible Units	List of possible units	RO	N	List of text
Range	Valid interval or set of possible discrete values.	RO	Y	Text
ReadRate	Interval between sequential reads, in seconds.	RO	Y	Floating point
ReportChange	A user-settable switch to enable or disable reporting.	RW	N	Boolean. Set TRUE when enabled.
ReportRate	Interval between sequential reports, in seconds.	RW	N	Floating point. Zero indicates no time-based reporting.
Timestamp	The date and time when the value was last read or set.	RO	Y	Numeric. Specific form to be resolved.
Units	Units of measurement	RO or RW	Y if value is scalar.	Text. Conforms to units specified in SEMI E5 (SECS-II) Units of Measurement Identifiers.
Value	Current value.	RO	Y	Single item or array of numeric, or text
DeviceType	Defines the type of device (e.g., "MFC", "OES", FTIR", "CDG", etc.)	RO	Y	Text 1–8 characters

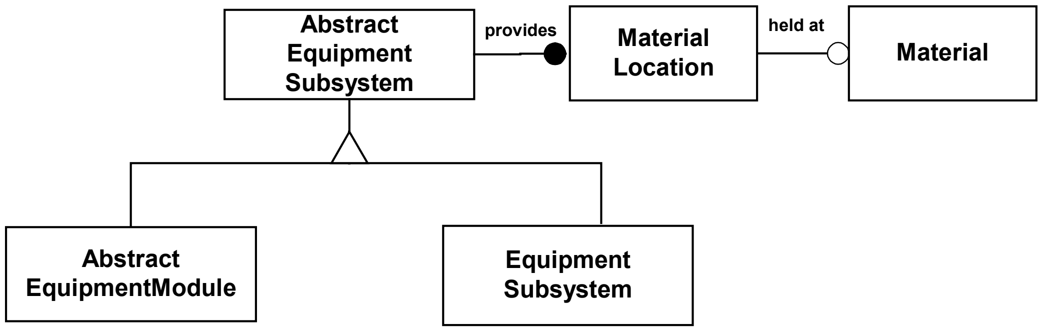

Figure 10
AbstractEquipmentSubsystem Subtypes

10.4 *AbstractEquipmentSubsystem Object*

10.4.1 The AbstractEquipmentSubsystem is a subtype of AbstractEquipmentElement and inherits all of its attributes and services. It may have associated MaterialLocations to hold Material. AbstractEquipmentSubsystem represents all subsystem and subassembly components of which the equipment is made up. The AbstractEquipmentSubsystem may or may not be capable of holding material and may or may not have recipe execution capability.

10.4.2 Figure 10 shows the relationships of the EquipmentSubsystem.

10.4.3 *Material Object*

10.4.3.1 An AbstractEquipmentSubsystem may or may not be able to hold material. Those that are able to hold material owns any material that it holds at any given point in time. They are expected to know the type of material that they hold, whether material is present, and the identifier of the material. In some cases, the AbstractEquipmentSubsystem may be able to hold multiple units of material or more than one type of material.

10.4.3.2 There are three major subtypes of material objects: consumables, durables, and substrates, where the major subtypes of durables are carriers and process durables.

10.4.3.3 Consumable materials, such as chemicals, are used up (as opposed to worn out) during the manufacturing process.

10.4.3.4 Durable material has a significant lifetime and is not part of the equipment (is removable). It includes material that some equipment may require to operate. The subtype of durable of common interest to almost all equipment is carrier. A carrier is a durable used to hold substrates. Process durables are of special interest to a limited subset of equipment. A process durable is an identifiable durable that is specified for a certain process step and recipe. For example, reticles are identified by product id and the mask level where used, and they are also identified by serial number. The factory is very interested in the management and tracking of process durables.

10.4.3.5 Product is typically a Substrate. In the semiconductor industry, Substrates include Wafer, Die, and Leadframe. Reticles are considered a Substrate by some equipment. In the semiconductor industry, reticles are considered as a process durable rather than a product. Specific reticles are specified in recipes for expose tools and modules. In other industries, substrates include flat panel (for flat panel displays) and discs (for hard disk drives).

10.4.3.6 Material objects are not formally defined in OBEM. Carrier objects are defined in SEMI E87 (CMS) and substrate objects are defined in SEMI E90 (STS).

10.4.4 *Material Locations*

10.4.4.1 A material location is a place that is capable of holding material.

10.4.4.2 A MaterialLocation is an abstraction used to facilitate the tracking of material without regard to the physical component associated with the tracking location. For example, a substrate chuck is a subsystem and can hold a single substrate on its surface. The entire subsystem consists of a stage that may or may not be able to move. It may use vacuum to hold the substrate in place, and it may have additional mechanisms and sensors. The MaterialLocation only represents the surface of the chuck. For this reason, the EquipmentSubsystem is said to *provide* a MaterialLocation rather than to be made up of MaterialLocations through aggregation.

10.4.4.3 This relationship is illustrated in Figure 11.

10.4.4.4 The MaterialLocation object is an abstract type. Figure 11 shows the subtypes of MaterialLocations of interest to OBEM.

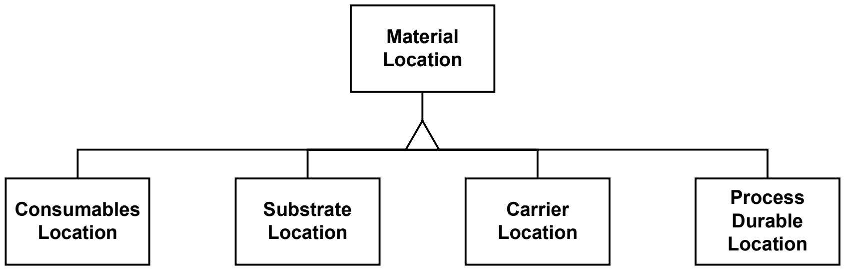

Figure 11
MaterialLocation Subtypes

10.4.4.5 *MaterialLocation Object* — Figure 12 shows the attributes of the MaterialLocation that are defined in Table 6. Every subtype of MaterialLocation shall have, at a minimum, attributes showing its current state and the ID of any material present.

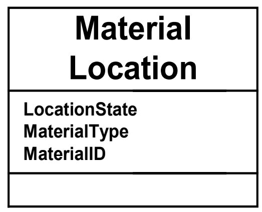

Figure 12
MaterialLocation Object Type

Table 6 MaterialLocation Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="MatlLoc"
ObjID	Object identifier	RO	Y	Text
LocationState	Current state.	RO	Y	Enumerated: Occupied Unoccupied
MaterialType	Type of material held.	RO	Y	Enumerated: One of, or a subtype of, the following Consumable Carrier Substrate ProcessDurable
MaterialID	Identifier of any material that occupies the location.	RO	Y	Text. "Unknown" if identifier is not known. Null (empty) string if location is unoccupied.

10.4.4.6 *CarrierLocation Object* — The CarrierLocation attribute LocationState may allow an additional enumeration Not Aligned, as shown in Table 7.

Table 7 CarrierLocation Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="CarrierLoc"
ObjID	Object identifier	RO	Y	Text
LocationState	Current state.	RO	Y	Enumerated: Occupied Unoccupied Not aligned

10.4.4.7 *SubstrateLocation Object* — The SubstrateLocation object is defined in SEMI E90 (STS). STS defines SubstID as an attribute of SubstrateLocation. Note this is identical to MaterialID in the general case for MaterialLocation.

10.4.5 *AbstractEquipmentSubsystem Requirements*

10.4.5.1 AbstractEquipmentSubsystems may or may not be able to hold material.

10.4.5.2 The AbstractEquipmentSubsystem owns all of the MaterialLocations that it provides or that are provided by one of its components. Similarly, it owns all of the Material at those MaterialLocations.

10.4.6 *AbstractEquipmentSubsystem Type* — Figure 13 shows the diagram for the AbstractEquipmentSubsystem object.

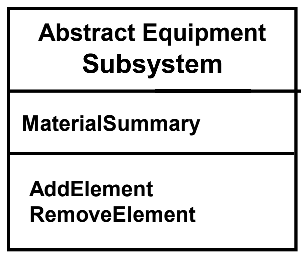

Figure 13
AbstractEquipmentSubsystem Object Type

10.4.7 *AbstractEquipmentSubsystem Attributes*

10.4.7.1 Table 8 defines the attributes of the AbstractEquipmentSubsystem.

Table 8 AbstractEquipmentSubsystem Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="AbstractEqpSubsystem"
ObjID	Object identifier	RO	Y	Text
MaterialSummary	List of specifications of material capacity and current status for each type of material.	RO	N	List of structure composed of MaterialType, MaterialCapacity, and MaterialCount.

10.4.7.2 Table 9 defines individual elements of AbstractEquipmentSubsystem attributes.

Table 9 Definition of Elements of MaterialSummary Attribute

Element Name	*Definition*	*Access*	*Reqd*	*Form*
MaterialCapacity	Number of units of material that can be held at one time.	RO	Y	Unsigned integer.
MaterialCount	Current number of units of material present.	RO	Y	Unsigned integer.
MaterialType	Specifies the type of material held.	RO	Y	Text. Conforms to SEMI E5.

10.4.8 *AbstractEquipmentSubsystem Services*

10.4.8.1 *Add Element*

10.4.8.1.1 The user may be able to instruct the equipment to add a specific type of AbstractEquipmentElement. The supplier may restrict this service to specific AbstractEquipmentElement subtypes, both in destination (the AbstractEquipmentElement accepting the addition) and in the added element. This is an optional service.

10.4.8.1.2 A typical kind of AbstractEquipmentElement that the user may want to add is an "add-on sensor", a SensorActuatorDevice on a Sensor/Actuator Network. If the Equipment knows the properties, it is possible for it to read an added I/O device and to reference it within recipes.

10.4.8.2 *Remove Element* — The user may instruct the equipment to remove an AbstractEquipmentElement that was added earlier. This service is required wherever the Add Element service is supported.

10.4.9 *EquipmentSubsystem Object*

10.4.9.1 The EquipmentSubsystem is a concrete subtype of AbstractEquipmentSubsystem. It inherits all of the attributes, state models, and services of the AbstractEquipmentSubsystem and in addition defines the rules for aggregation. These rules are illustrated in Figure 14.

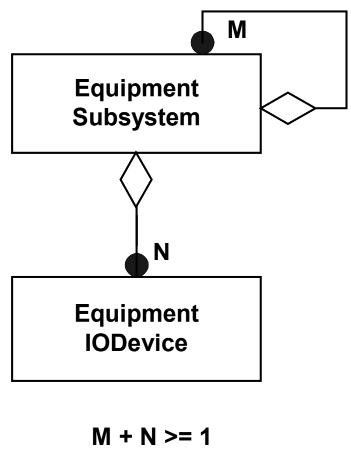

Figure 14
EquipmentSubsystem Aggregation

10.4.9.2 As shown in Figure 14, the EquipmentSubsystem may be made up of other, smaller EquipmentSubsystems and/or EquipmentIODevices. It is required to have at least one of these two components.

Table 10 EquipmentSubsystem Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text = "EqpSubsystem"
ObjID	Object identifier	RO	Y	Text.

10.5 *AbstractEquipmentModule Object*

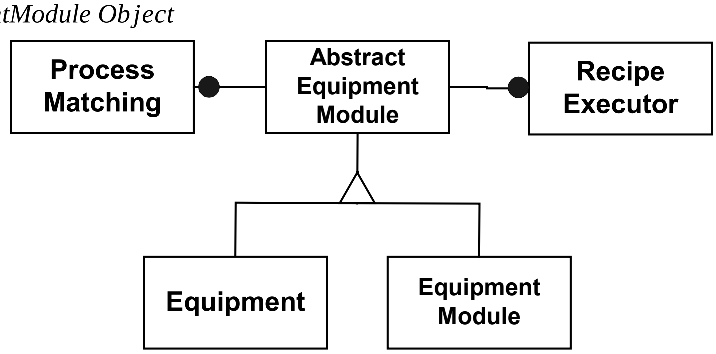

Figure 15
AbstractEquipmentModule Types

10.5.1 As shown in Figure 15, an *AbstractEquipment-Module* is a type of AbstractEquipmentSubsystem that represents a higher level of complexity and is of greater importance to the factory. It is mainly intended to represent process modules but may be used for other major intelligent subsystems capable of supporting the requirements for the AbstractEquipmentModule. It may be possible in some cases for the physical module to operate independently from the equipment.

10.5.2 The AbstractEquipmentModule has two subtypes, Equipment and EquipmentModule.

10.5.3 *ProcessMatching*

10.5.3.1 ProcessMatching provides one or more mechanisms for managing process differences between two or more identically configured subsystems of the same type to ensure that a generic recipe run on both subsystems will achieve the same process result. ProcessMatching may be either internal or external or both.

10.5.3.2 An example of an external method would be through provision of a ProcessMatching object that allows a user to manipulate offsets to process parameters. This can be done through setting parameter offsets for each subsystem so that, within specified constraints, all subsystems of the same type give the same process results. More sophisticated systems may use algorithms to determine process offsets based on mathematical models and module history.

10.5.3.3 As a simple example of process matching, three different individual hotplates may be matched for the temperature range 225–275°C by modifying their temperature offset by 1°C, 1.75°C, and –2.1°C respectively. This approach is illustrated in Figure 16.

10.5.3.4 The equipment supplier is responsible for determining the set of parameters to which offsets may be applied as well as the range of values that are valid.

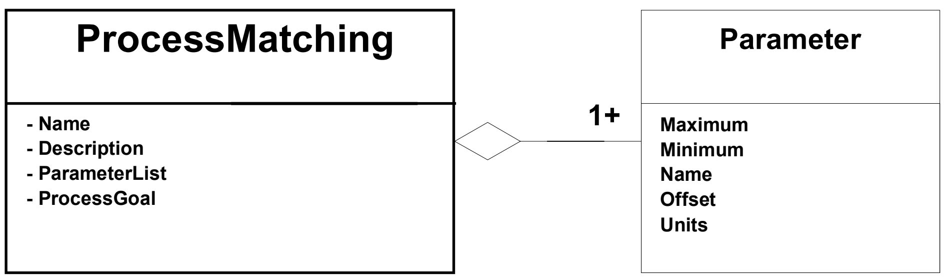

Figure 16
ProcessMatching and Parameter Objects

10.5.3.5 These parameters may be the same as those referenced within recipes for Recipe Variable Parameters.[6] In this case, Recipe Variable Parameters are given as setpoints that can be based on characteristics of the incoming substrate and are hardware independent, while Parameters used in Process-Matching are relative (applied to an existing setpoint) and are used to compensate for hardware differences. Support of both Recipe Variable Parameters and ProcessMatching parameters allows the user to compensate for hardware-specific differences separately from product-specific differences. The number of cycles since the last preventive maintenance performed on a process module affects its performance in a certain way, while the effect of too thin a film on the wafer will affect requirements in a different way.

10.5.3.6 The ProcessMatching object here is shown as an example. This is not a standardized object.

10.5.3.7 Internal methods of process matching may use other techniques, such as special types of recipes.

10.5.4 *AbstractEquipmentModule Requirements*

10.5.4.1 The AbstractEquipmentModule inherits the attributes, state models, and services of both the AbstractEquipmentElement and the AbstractEquipmentSubsystem. As a type of AbstractEquipmentSubsystem, the AbstractEquipmentModule is also able to hold one or more units of material.

10.5.4.2 The AbstractEquipmentModule represents major subsystems, such as process chambers. It supports basic operational commands: start, stop, pause, resume, and abort.

10.5.4.3 *ARAMS*

10.5.4.3.1 When implementing SEMI E58, the AbstractEquipmentModule shall provide compliance except as qualified in this section. The AbstractEquipmentModule is the smallest component of equipment for which SEMI E58 (ARAMS) states should be maintained.

10.5.4.3.2 An AbstractEquipmentModule that can not be powered off separately from Equipment is not required to provide its own powerdown estimate or time of last powerdown.

10.5.4.3.3 Otherwise, an AbstractEquipmentModule implementing SEMI E58 shall comply with the requirements of Section 13, Object Services Compliance, in SEMI E58, including all of the attributes defined in Table 6, ARAMS Object Attribute Definitions in that document. These attributes are not repeated in OBEM. The user may change the ARAMS state. In some cases, a change in the ARAMS state of a module may cause an ARAMS state change for the equipment. The supplier shall document any relationships between the ARAMS state of the Equipment and the ARAMS states of its modules.

10.5.4.4 *AbstractEquipmentModule Service States* — For implementations of ARAMS, to be consistent with SEMI E10, the AbstractEquip-mentModule is IN SERVICE whenever it is in an uptime state. Otherwise, it is OUT OF SERVICE, as it can not be scheduled for manufacturing. To change the service state of an AbstractEquipmentModule, the user must change its SEMI E10 (RAM) state. Note that the service state of some modules will affect the service state of Equipment as well.

10.5.4.5 *Clock* — For modules able to operate independently of the equipment (e.g., modules with a dedicated CPU), AbstractEquipmentModules are required to have individual clocks. It is the responsibility of the Equipment to synchronize multiple internal clocks.

10.5.4.6 *Process Type*

10.5.4.6.1 An AbstractEquipmentModule has a Process Type that indicates its primary functionality as one of the following: Process, Measurement, Transport, or Storage. This is represented as a text string that may specialized further as needed.

10.5.4.6.2 The AbstractEquipmentModule has one or more ProcessCapabilities. ProcessType and ProcessCapability are used for high-level and detailed process characterization. The user may add and remove ProcessCapability descriptions through operations Add Process Capability and Remove Process Capability.

10.5.4.7 *Process Matching*

10.5.4.7.1 All AbstractEquipmentModules supporting Recipe Execution shall provide one or more methods for process matching.

10.5.4.7.2 ProcessMatching allows the AbstractEquipmentModule to be tuned for a specific set of conditions in order to achieve the same results as other AbstractEquipmentModules with the same process capability.

10.5.4.8 *Process Setup*

10.5.4.8.1 AbstractEquipmentModules capable of performing different processes may need to be reconfigured following one process before a process of a different type can be executed. Examples of setup requirements include: a new reticle for a stepper, a source change for an ion implanter, or a significant change in temperature for a furnace.

6 Variable Parameters are defined in SEMI E42.

10.5.4.8.2 Both process recipes and service recipes may be associated with specific setups.

10.5.4.8.3 Recipes of the class "/SETUP/" may be used to put the AbstractEquipmentModule into a specific state. The user uses the name of the setup for scheduling work. This is captured in the attribute ProcessSetup.

10.5.4.9 *Recipes*

10.5.4.9.1 An AbstractEquipmentModule may provide recipe execution services and the ability to accept, store, verify, select, and run Execution Recipes (SEMI E42). This ability is required for AbstractEquipment-Modules with a ProcessType of "Process" or "Measure-ment". Where provided, recipes and recipe execution shall comply with the fundamental requirements for the Execution Recipe and Recipe Executor as specified in SEMI E42 (RMS).

10.5.4.9.2 Some equipment performs its process in three stages, which can be characterized as preamble, main process, and postamble, where the preamble is preparation for the stable part of the process, and the postamble takes care of the transition from the stable part of the process until it is ready to unload the material. In a furnace, for example, the preamble could include both the period where it is ramping to attain the setpoint temperature and the gas flow setpoints. A fourth stage is sometimes defined to handle abnormal terminations.

10.5.4.9.3 From a recipe standpoint, these different stages can be represented as different sections of a single recipe or as separate recipes linked to a main recipe.

10.5.4.10 *Mechanical Dry Run*

10.5.4.10.1 The AbstractEquipmentModule shall support the capability to do a mechanical dry run. This allows the material handling subsystems and software functions to be exercised and tested without requiring full process hookups and without using process consumables. Typically this is done through a specially designated recipe that allows time settings and does not use settings for temperature, gases, plasmas, water, etc. In some cases, it may require a recipe of a special class, such as "/DRYRUN/". Environmental subsystems such as vacuum, nitrogen purge, particle detection subsystems, etc. must be allowed to function normally during a mechanical dry run.

10.5.4.10.2 Dry runs shall be prohibited during the ARAMS Manufacturing state.

10.5.4.10.3 Certain types of tools may need to modify the definition of the mechanical dry run to address special issues in a way that still satisfies the objectives. Equipment documentation shall specify the method used to satisfy this requirement.

10.5.5 *AbstractEquipmentModule State Model*

10.5.5.1 The AbstractEquipmentModule inherits the Operational State Model of the AbstractEquipment-Subsystem. In addition to the concurrent substates of SERVICE, the AbstractEquipmentModule adds the BEHAVIOR state. Figure 17 shows the Operational State Model with its two concurrent substates.

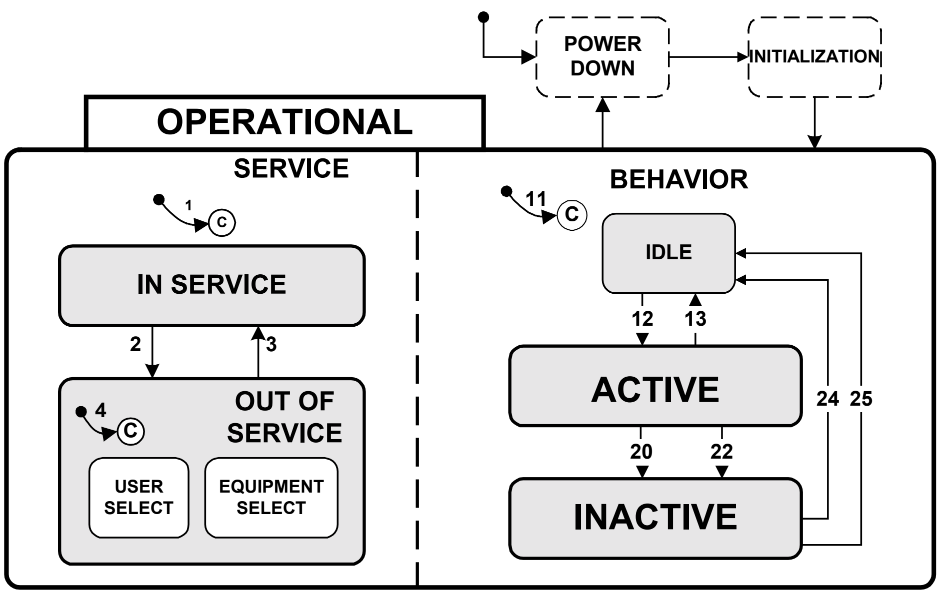

Figure 17
AbstractEquipmentModule Operational State Model

10.5.5.2 Additional details of the BEHAVIOR state are shown in Figure 18.

10.5.5.3 In addition to the states shown above, the AbstractEquipmentModule has an ARAMS state model, defined in SEMI E58. The diagram for the ARAMS state model for modules is shown in Figure 6 in that document.

10.5.5.4 *AbstractEquipmentModule Behavior State*

10.5.5.4.1 The details of the BEHAVIOR state are shown in Table 11. POWERDOWN and INITIALIZING states are included in the table to simplify comparisons with the ARAMS State Model and the Operational State Model defined in SEMI E58. State models are initialized during the INITIALIZATION state. Communications shall be initialized before the ARAMS state model is initialized in order to allow reporting of power down events.

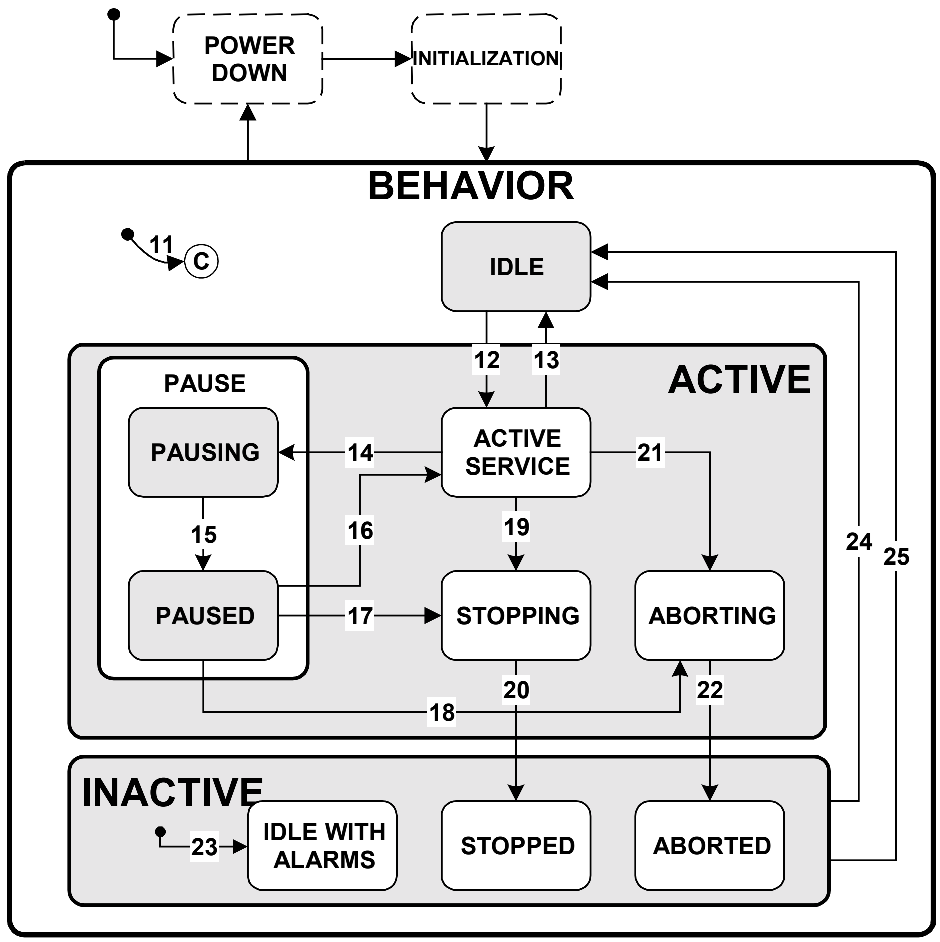

Figure 18
Behavior State

10.5.5.4.2 Table 11 defines the substates of the BEHAVIOR state.

Table 11 AbstractEquipmentModule Behavior State Definitions

State Name	*Superstate*	*Definition*
POWERDOWN	None	The AbstractEquipmentModule is powered off.
INITIALIZING	None	The AbstractEquipmentModule system, including hardware and software, is being initialized. It is not ready to accept instructions.
IDLE	IN SERVICE	The AbstractEquipmentModule is fault free and able to accept instructions to perform a manual or automated procedure that may change its physical state.

State Name	*Superstate*	*Definition*
ACTIVE	IN SERVICE	The AbstractEquipmentModule is performing activities that change its physical state.
ACTIVE SERVICE	ACTIVE	While assigned to manufacturing, the AbstractEquipmentModule may only perform its normal process.
PAUSE	ACTIVE	The AbstractEquipmentModule has received instructions to pause its activity.
PAUSING	PAUSE	The AbstractEquipmentModule is in the process of putting itself into a safe state.
PAUSED	PAUSE	The AbstractEquipmentModule is in a safe state.
STOPPING	ACTIVE	The AbstractEquipmentModule has begun the stop operation.
ABORTING	ACTIVE	The AbstractEquipmentModule has started the abort operation.
INACTIVE	IN SERVICE	The AbstractEquipmentModule has completed its stop or abort operation.
IDLE WITH ALARMS	INACTIVE	The AbstractEquipmentModule is idle but has a fault condition.
STOPPED	INACTIVE	The AbstractEquipmentModule has completed the stop operation.
ABORTED	INACTIVE	The AbstractEquipmentModule has completed the abort operation.

10.5.5.5 *AbstractEquipment Module State Transition Table* — Table 12 defines the state transitions for the AbstractEquipmentModule Operations state model.

Table 12 AbstractEquipmentModule Behavior State Transitions

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
11	Any	State model is initialized.	depends on previous state and current condition	None	See Section 9.5.2.2.
12	IDLE	An activity changing the physical state of the module is started.	ACTIVE SERVICE	None	Substates of ACTIVE SERVICE are module dependent.
13	ACTIVE SERVICE	All activities changing the physical state are completed without fault.	IDLE	None	IDLE is fault-free.
14	ACTIVE SERVICE	The module received instructions to pause its activity.	PAUSING	None	The module is responsible for reaching a safe state.
15	PAUSING	All activity is paused.	PAUSED	None	
16	PAUSED	The module has received instructions to resume its activity.	ACTIVE SERVICE	None	
17	PAUSED	The module has received instructions to stop its activity.	STOPPING	None	The module is responsible for reaching a safe state.
18	PAUSED	The module has received instructions to abort its activity.	ABORTING	None	
19	ACTIVE SERVICE	The module has received instructions to stop its activity.	STOPPING	None	
20	STOPPING	The Stop operation has completed and all material started has been returned to its proper destination.	STOPPED	None	
21	ACTIVE SERVICE	The module has received instructions to abort its activity.	ABORTING	None	The module is responsible for reaching a safe state.
22	ABORTING	Completion of aborting activity.	ABORTED	None	
23	Any	Default entry into INACTIVE	IDLE WITH ALARMS	None	One or more exceptions detected during initialization.
24	INACTIVE	The module received instructions to return to IDLE.	IDLE	None	IDLE is fault-free.
25	INACTIVE	The module returns to IDLE automatically.	IDLE	None	IDLE is fault-free.

10.5.6 *AbstractEquipmentModule Attributes*

10.5.6.1 The AbstractEquipmentModule Object is shown in Figure 19.

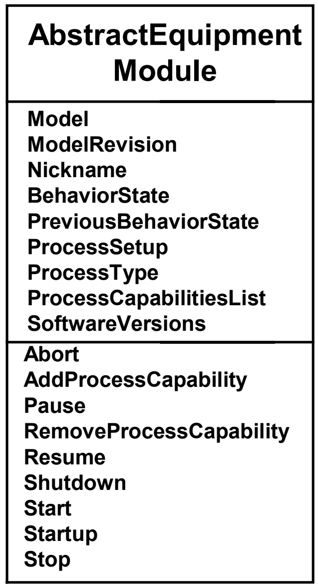

Figure 19
AbstractEquipmentModule Object Type

10.5.6.2 Attributes of the AbstractEquipmentModule are defined in Table 13.

Table 13 AbstractEquipmentModule Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="AbstractEquipmentModule"
ObjID	Object identifier	RO	Y	Text
Nickname	User-assigned name	RW	Y	Text
Model	Model designator	RO	Y	Text
ModelRevision	Model Revision	RO	Y	Text
BehaviorState	Current substate of BEHAVIOR	RO	Y	Enumerated
ProcessType	Characterization of processes for user	RW	Y	Text
ProcessCapabilityList	One or more specific process capabilities	RO	Y	List of text
PreviousBehaviorState	The previous operations state	RO	Y	Enumerated
ProcessSetup	Name of current setup.	RW	Y	Text
SoftwareVersions	The set of software versions installed	RO	Y	Ordered list of text
Units	Type of material held	RO	Y	Text

NOTE 1: Required if the AbstractEquipmentModule provides recipe execution services.

10.5.7 *AbstractEquipmentModule Services* — The AbstractEquipmentModule has one or more automated activities, including its normal process (its intended function). The user shall be able to start, stop, abort, and resume the activities of the module.

NOTE 4: Changing the operational state of an individual AbstractEquipmentModule within a multi-process Equipment during automatic processing will affect both upstream and downstream operations. The Equipment is responsible for determining the impact on other AbstractEquipmentModules.

NOTE 5: Directly changing the operational state of the AbstractEquipmentModule is not the same as changing the state of a job or as changing the operational state of the Equipment. The equipment supplier shall document the relationships between the operational state of the Equipment, the AbstractEquipmentModule, and the different job types that it supports.

10.5.7.1 *Abort*

10.5.7.1.1 On receipt of an Abort request from the user, the module shall stop all of its current activity as soon as it is safe to do so. It should remove any material in process within the module whenever possible to do so safely.

10.5.7.1.2 A module may also self-abort when it detects a dangerous condition.

10.5.7.1.3 In the Behavior State Model, the module shall transition from ACTIVE SERVICE to ABORTING when an abort occurs. When all activity has ceased other than normal background activities for environmental control, the module transitions to ABORTED. The module shall not start a new activity until it is instructed to do so by the user or the user instructs it to return to IDLE.

10.5.7.2 *Add Process Capability* — ProcessCapabilityList is an attribute of the equipment module and consists of a list of text strings representing process capabilities that are meaningful to the user. Individual capabilities are added by the factory to recognize the type of processes the equipment module may be able to run.

10.5.7.3 *Pause*

10.5.7.3.1 On receipt of a Pause request from the user, the module shall suspend its activity at the next logical point in the process from which it will be able to resume activities at a later time and which will prevent unintended change to the product. It shall not accept new work while it is in this state.

10.5.7.3.2 In many cases, to avoid unintended change to the product, the AbstractEquipmentModule should wait until the current product has been removed and then pause, preventing new product from entering.

10.5.7.4 *Remove Process Capability* — This allows the factory to remove from the ProcessCapabilityList a capability that is no longer required or one that can not be performed by the equipment due to environment or actual physical changes in the equipment.

10.5.7.5 *Resume* — When a Resume request is received during a PAUSE state, the module shall resume its activity from the point where it was paused.

10.5.7.6 *Shutdown* — The Shutdown request is used to put an AbstractEquipmentModule in a state where it is safe to turn off its power and remove it from the equipment. The specific operations shall be documented by the supplier.

10.5.7.7 *Start*

10.5.7.7.1 Some activities may require specific Start instructions.

10.5.7.7.2 The user may issue a Start Activity request to a specific AbstractEquipmentModule.

10.5.7.8 *Startup* — The Startup request is used when an AbstractEquipmentModule has been shutdown. The specific activities that result shall be documented by the supplier.

10.5.7.9 *Stop*

10.5.7.9.1 On receipt of a Stop request from the user, the module shall stop its current activity in an orderly fashion as soon as it is safe to do so, with all product material returned as would be expected had the activity completed normally.

10.5.7.9.2 In the Behavior State Model, the module shall transition from ACTIVE SERVICE to STOPPING when a stop operation begins. When all activity has ceased other than normal background activities for environmental control, the module transitions to STOPPED. The module shall not start a new activity until it is instructed to do so by the user.

10.5.8 *EquipmentModule Object* — The EquipmentModule is a type of AbstractEquipmentModule and inherits all of its attributes, state models, relations, and services. As shown in Figure 20, the EquipmentModule may be an aggregate of EquipmentIODevice, EquipmentSubsystem, and other EquipmentModule objects.

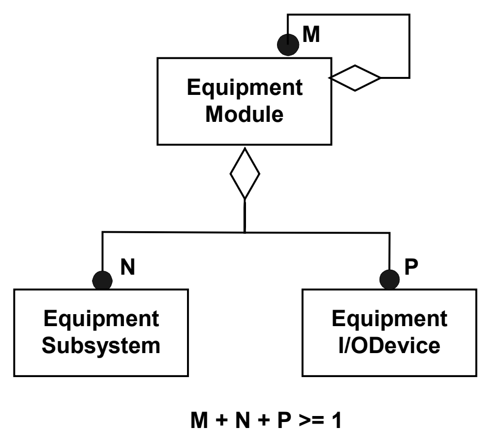

Figure 20
EquipmentModule Aggregation

10.6 *Equipment Object*

10.6.1 The Equipment is a type of AbstractEquipmentModule and supports all of the attributes, state models, and services defined for the AbstractEquipmentModule.

10.6.2 Equipment is an aggregation of EquipmentModules, EquipmentSubsystems, and EquipmentIODevices objects and owns all the objects of which it is made. Figure 21 shows the relationships of the Equipment.

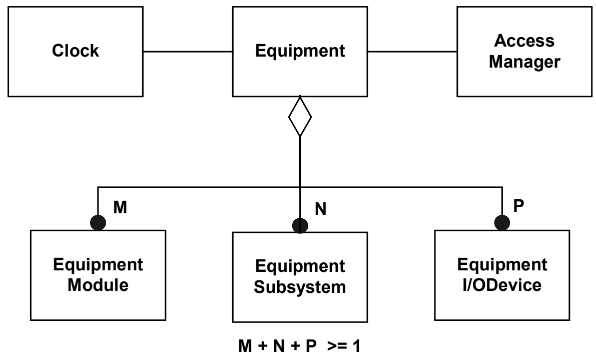

Figure 21
Equipment Object Relationships

10.6.3 *Equipment Requirements* — All equipment shall satisfy the following requirements:

- The Equipment provides the interface to the factory and shall not be made up of other Equipment.
- Equipment is the root object within the equipment hierarchy.
- Equipment may not be a component of any other AbstractEquipmentElement or any of its subtypes.
- Equipment may be made up of any standardized objects except for other Equipment objects.
- Equipment is required to have a Clock.
- Equipment is required to have at least one CarrierPort. Exceptions to this requirement may be made for testers and for exposure equipment in a linked litho cell that have separate communications with the factory systems.
- Equipment is responsible for (owns) all of its components

10.6.4 *Clock Object*

10.6.4.1 Clock represents current real-time date and time of day information. This information may be provided by a physical real-time clock or by other methods of calculating time. The Clock is used to timestamp data and events.

10.6.4.2 Requirements include:

- The user shall be able to read the current date and time at any time.
- Equipment shall be capable of using both factory network time services and user interface services to set current date and time.
- Clock resolution shall be 0.01 seconds or smaller.
- Date shall maintain a four-digit year.

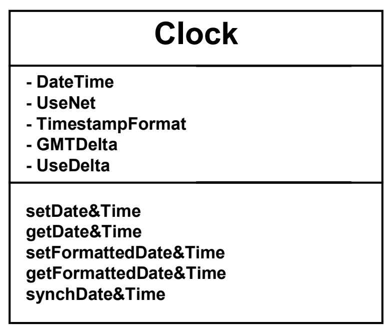

Figure 22
Clock Object

10.6.4.3 All calculations based on, or related to, date and time shall be fault-free in both the twentieth and twenty-first centuries.

10.6.4.4 Table 14 defines the attributes of Clock.

Table 14 Clock Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text = “Clock”
ObjID	Object identifier	RO	Y	Text
DateTime	Current date and time	RO	Y	Protocol specific
UseNet	Enable/disable network time synchronization	RW	Y	Boolean
TimestampFormat	Date and time format used to timestamp events	RW	Y	Enumerated
GMTDelta	Difference, in minutes, between the current time and Greenwich Mean Time (GMT)	RO	Y	Integer
UseDelta	Enable/disable showing current GMTDelta on timestamps	RW	Y	Boolean

10.6.4.5 *Network Time*

10.6.4.5.1 It shall be possible to set current date and time by using time services provided by the network in the factory. Use of network time allows the different systems within the factory to remain closely synchronized with a high degree of accuracy, and it relieves the factory host from explicitly setting the equipment's clock. The attribute UseNet allows the user to enable and disable use of network time services.

10.6.4.5.2 When enabled, the equipment shall be responsible for ensuring that any change in time does not result in discontinuities in date/timestamp reporting. For example, if the time changes in the middle of a process, applying the time change to current process events can cause later events to appear earlier than previous events, or they can give the appearance of large pause in activities during processing. Both of these cases can cause time-based analysis of data to give wrong results and must be prevented.

10.6.4.6 *Timestamp Data*

10.6.4.6.1 Date/time information is used by the factory for a variety of purposes, including analysis of historical data. Typically a factory keeps local time. GMTDelta, the offset between local time and Greenwich Mean Time, is provided to allow time values to be compared outside of the local time zone. GMTDelta may also be added to the timestamp to clarify time data when local time changes within a process.

10.6.4.6.2 The attribute TimestampFormat allows the user to select the format used for timestamping events. Possible formats include: formatted time, a text string of the form YYYYMMDDhhmmsscc, long signed integer, and floating point.

10.6.5 *Equipment Attributes*

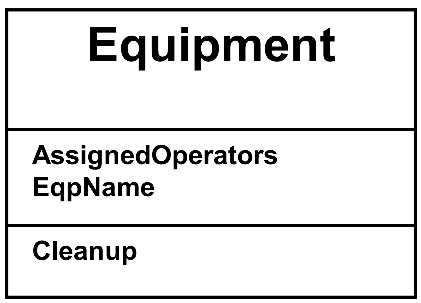

Figure 23
Equipment Object

10.6.5.1 Table 15 defines the attributes of the Equipment object, as shown in Figure 23.

Table 15 Equipment Attribute Definitions

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text="Equipment"
ObjID	Object identifier	RO	Y	Text
AssignedOperators	Currently assigned operators.	RO	Y	List of text
Nickname	User-assigned name.	RW	Y	Text

10.6.6 *Equipment Services*

10.6.6.1 Basic operational commands may be directed to an EquipmentModule, the Equipment as a whole, or to an individual Process Job.

10.6.6.2 For multi-module or multi-process Equipment, the effect of an operational command varies depending upon the level of the target object and the configuration of the Equipment. Given the number of Process Jobs that are defined during the course of a work shift and their temporary nature; it is unlikely that an operator will differentiate easily between one Process Job and another. Whereas they will be able to more quickly identify an individual module or the Equipment when time is a critical factor.

10.6.6.3 *Operational Services*

10.6.6.3.1 *Abort* — The user may direct the Equipment to abort its operations at any time. The Equipment shall stop all activity as soon as possible while maintaining the safety of the product, the Equipment itself, and people. Product is not returned to the carriers.

10.6.6.3.2 *Cleanup* — When product is left in the Equipment following an abort operation, it may be necessary to request the Equipment to return all substrates to their carriers.

10.6.6.3.3 *Pause* — The user may request the Equipment to pause its operations. The Equipment is responsible for determining the appropriate points within its process where it is safe to temporarily stop. As with the Stop command above, the multi-module Equipment may direct individual EquipmentModules to Pause one at a time.

10.6.6.3.4 *Resume* — This command directs the Equipment to resume normal operations from the PAUSED state.

10.6.6.3.5 *Start* — The Start command directs the Equipment to begin an activity that is already setup and ready. Its use is not intended for automatic processing by Equipment providing Process Job capabilities.

10.6.6.3.6 *Stop* — The user may direct the Equipment to stop activity at any time. The Equipment shall be responsible for ensuring that all of its components stop their activities in an orderly fashion at the first opportunity. Processing shall be completed for all work in process (e.g., substrates that have already been removed from their input carrier), but no processing shall be started for remaining work.

For Equipment with multiple EquipmentModules performing individual process steps in a sequence of steps, a Stop command to the Equipment is equivalent to issuing a Stop command to the first EquipmentModule in the sequence, followed by subsequent Stop commands to each EquipmentModule once it has accepted the substrate last started.

10.6.6.4 *Time Services* — This section describes the services provided by the clock.

10.6.6.4.1 *Request Date and Time* — The user shall be able to read the equipment's current date and time as a numeric value.

10.6.6.4.2 *Set Date and Time*

10.6.6.4.2.1 If UseNet is disabled, the user shall be able to set the current date and time as a numeric value. Note that this method does not generally give good synchronization results.

10.6.6.4.2.2 Set Date and Time shall not cause a discontinuity in timestamps for data associated with an individual substrate in process.

10.6.6.4.3 *Request Formatted Date and Time* — The user shall be able to read the equipment's current date and time as a formatted text string.

10.6.6.4.4 *Set Formatted Date and Time* — If UseNet is disabled, the user shall be able to set the current date and time as a formatted text string. Note that this method does not generally give good synchronization results.

10.6.6.4.5 *Synchronize Date and Time* — The user may request the equipment to synchronize date and time from the network as soon as it can do so without disrupting the timestamp series for any work in process.

11 OBEM Equipment Functional Requirements

11.1 The functional areas of the equipment are described in the Functional View in Section 8.3. Section 11 defines the requirements for each of these functional areas. These are requirements at the level of the Equipment object, in addition to those specified in Section 10.

11.2 *Access Management*

11.2.1 Access Management is responsible for all communications with the user, including local operators, factory systems, and remote users. As illustrated in Figure 24, the equipment may be required to support multiple users, with at least one connection to the factory and at least one interface to the local operator. Where automation is used for material handling, more than one human interface will be required.

11.2.2 Objects shown in Figure 24 are not standardized objects. Further work is required to determine requirements for standardized objects to support access management.

11.2.3 *Arbitration* — This section is reserved.

11.2.4 *Authorization* — This section is reserved.

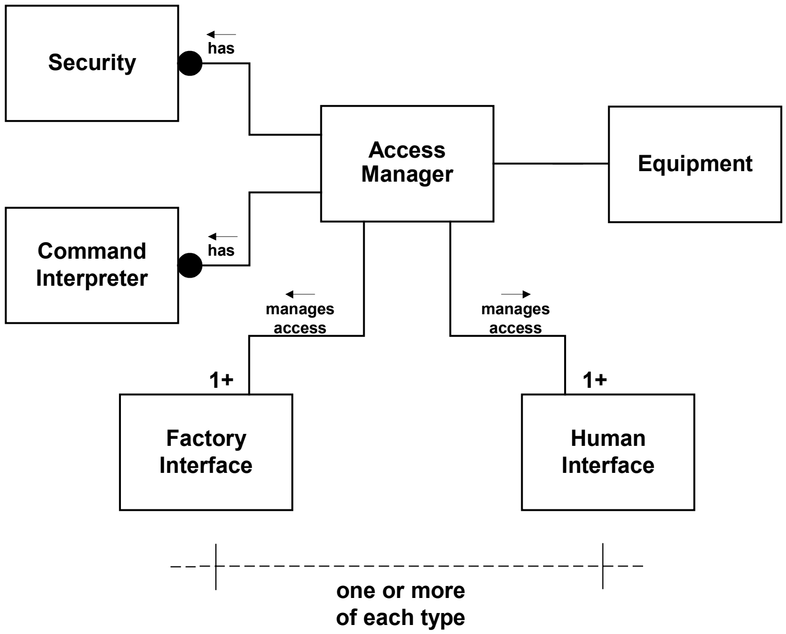

Figure 24
Access Management Model

11.2.5 *Multiple Operator Interfaces*

11.2.5.1 The equipment shall support a minimum of two user interfaces, one that is dedicated to factory system communications and one that is dedicated for local operations.

11.2.5.2 Equipment may support additional interfaces as well. Equipment handling large wafers (300 mm diameter or more) may be required to provide a second operator interface away from the traditional interface at the front. The factory may require separate connections for direct communications with AMHS and/or advanced process control. The equipment supplier's customer service may need remote access for diagnostics.

11.2.6 *Remote Dial-in* — This section is reserved for requirements for remote dial-in using a modem.

11.2.7 *Access Attributes* — Table 16 defines the attributes of the Access Object.

Table 16 Access Session Configuration Data

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
Authorization	Level of authorization specifies user access.	RO	Y	Equipment-specific
FDControl	User may detect a probable fault and instruct that no new work be started.	RO	Y	Boolean
FormatCode	Indicates the code used for interpretation of text.	RW	Y	Enumerated
Language	Indicates the preferred language for text.	RW	Y	Enumerated
Recipe Access	The user may request recipe upload, download, and other recipe-access requests.	RW	Y	Enumerated
R2Rcontrol	User may issue instructions for run-to-run control.	RO	Y	Boolean
MaterialControl	User may issue instructions related to loading and unloading carriers.	RO	Y	Boolean
OperationsControl	User may issue operational instructions.	RO	Y	Boolean
UserID	Identification of the user	RO	Y	Text

11.3 *Date/Time Management* — Equipment shall have an OBEM-compliant Clock with sufficient resolution to differentiate the order in which events occur. (See Section 12.)

11.3.1 *Timestamp Data* — Date/time information is used by the factory for a variety of purposes, including analysis of historical data. Should time change significantly during processing, the assumed ordering of events can be affected so that later events appear earlier, large unexplained gaps can appear in a sequence of events, or data can seem to appear from the past. For these reasons, any change in current time shall not be applied to material in the middle of a process.

11.3.2 *Date/Time Values* — Date and Time information shall be expressed as a numeric value.

11.3.3 *Local Time Change* — Where local time changes automatically, the equipment is responsible for maintaining the correct difference between local time and Greenwich Mean Time (GMT) in the Clock attribute GMTDelta.

11.3.4 *Optional Timestamp Format* — The equipment shall provide an option for the user to include the value of GMTDelta as an additional field in timestamps. The user may enable and disable use of GMTDelta by setting and clearing the Boolean Clock attribute UseDelta.

11.4 *Equipment Control* — Control is divided into several areas: Fault Detection Control, Run to Run Control, Material-Control, and Operational Control. Control of each of these four areas shall be assigned to exactly one user at any point in time. However, that user may be the same for one or more of these areas.

11.4.1 *Advanced Process Control (APC)* — Two categories of APC are described herein: run-to-run control (between lots, carriers, or substrates), and fault-detection control. Support for APC may be required at the EquipmentModule level.

11.4.2 *Run-to-Run Control (R2R)* — The factory may dedicate a separate session for Run-to-Run Control. Run-to-run control consists of adjusting Variable Parameter settings of Process Recipes within a process job.

11.4.3 *Fault Detection Control (FDC)*

11.4.3.1 Fault detection is able to detect a probable fault before it can be detected by SPC, equipment failure, or product failure. The user may provide fault detection through analysis of process data in conjunction with data from external sensors.

11.4.3.2 A separate dedicated session may be used for fault detection control because of its need for large amounts of data. FDC may instruct the Equipment to put itself into a downtime state as soon as it completes work currently in process.

11.5 *Event Management* — Equipment shall provide standard mechanisms for notifying the user of events of interest to the user, together with any data the user has associated with specific events.

11.6 *Exception Management* — The equipment shall comply with SEMI E41 (EMS).

11.7 *Job Management* — This section is reserved for requirements related to specifications for managing jobs. Jobs are defined by SEMI E94 Control Job Management and by SEMI E40 Process Management.

11.8 *Material I/O Management* — Material I/O Management allows the user to request services related to management of the carrier ports and internal buffers required for managing the movement of product through the factory (material logistics). Equipment shall comply with the fundamental requirements of SEMI E87 (CMS).

11.9 *Material Management*

11.9.1 Material Management is responsible for all material present at the equipment from the time it is loaded from the factory until it is unloaded. This includes tracking of all material that is identifiable.

11.9.2 The location of all material that is mobile, such as product, shall be known at all times. The factory may inquire about what material is currently present and where (at what MaterialLocation) that material is placed.

11.9.3 Consumables that are not mobile; such as gold wire on a wire-bonder, may be identified by lot number. The equipment may be required to store current lot numbers for non-mobile material when that information is provided by the factory.

11.9.4 Equipment shall comply with the fundamental requirements for SEMI E90 (STS).

11.10 *Operational Control* — The user with Operation Control may issue operational commands related to starting, stopping, process job management, and recipe access, including upload, download, and recipe selection.

11.11 *Object Management*

11.11.1 This section is reserved for requirements concerning data and information.

11.11.2 Object Management is responsible for providing all data and information required by the factory through Object Services.

11.12 *Performance Management* — As a type of AbstractEquipmentModule, the equipment shall con-form to the Operational State Model defined in Section 10.5.5 and compliance to SEMI E58 (ARAMS).

11.13 *Operations Management* — This section specifies the requirements related to operations, including processing.

11.14 *Recipe Execution* — As a type of EquipmentModule, Equipment providing temporary recipe storage and recipe execution capabilities shall comply to the fundamental requirements for the Execution Recipe and Recipe Executor as specified in SEMI E42.

11.15 *Recipe Management* — Equipment providing long-term storage of recipes shall comply with the fundamental requirements for the Managed Recipe and either the Recipe Namespace with its Recipe Namespace Manager, or the Distributed Recipe Namespace Segment, for all recipes stored, as specified in SEMI E42.

12 OBEM Service Definitions

12.1 This section defines the content of service messages specified in this document and provided by OBEM objects. The services are described in previous sections. This section details the parameters for each message.

12.2 Table 17 lists the services defined in this section. Services of Type "R" are asynchronous requests that require a response. Services of Type N are notifications and do not require a response.

12.3 OBEM compliant equipment is required to understand all service requests. However, if the service is not marked as required, then support for the service itself (the operations) is optional for the equipment, and a response of "request denied" may be returned.

12.4 Services are listed in alphabetical order.

Table 17 List of Services

Operation	*Description*	*Type*	*Reqd*
Abort	Directs an object to immediately stop all activity as soon as it is safe to do so.	R	Y
AddElement	Add a type of AbstractEquipmentElement.	R	N
AddProcessCapability	Add a process capability.	R	Y
ChangeService	Set an AbstractEquipmentElement in service or out of service.	R	N
Cleanup	Directs Equipment to return all substrates to their carriers.	R	N
GetDateTime	Returns the current date and time.	R	Y
GetProgramDirectory	Returns the list of identifiers of Sensor Programs stored by the specified Sensor/ActuatorDevice.	R	N
Pause	Directs an object to temporarily stop its activity as soon as it is at a point where it is safe to the process to do so.	R	Y
RemoveProcessCapability	Remove a process capability from the list.	R	Y
RemoveElement	Remove an element added by the user.	R	Y
Resume	Directs a paused object to resume its activity.	R	Y
SelectProgram	Provides an EquipmentIODevice Program identifier to be selected and executed.	R	N
SetDateTime	Provides current date and time for setting the equipment Clock.	R	Y
Shutdown	Prepare for powerdown.	R	N
Start	Directs an object to begin an activity that has been set up.	R	N
Startup	Prepare for standby for processing.	R	N
Stop	Directs an object to stop an activity in progress by completing work already started and not beginning new work.	R	Y

12.5 *Service Parameter Definitions* — Table 18 defines the parameters for OBEM services.

Table 18 Service Parameter Definitions

Parameter	*Definition*	*Form*
DateTime	Date and time setting.	To be resolved.
DeviceProgramID	Identifier for EquipmentIODevice program.	Integer
ErrorCode	Contains the code for the specific error found.	Enumerated
ErrorText	Text in support of the error code.	Text

Parameter	*Definition*	*Form*
ObjSpec	Object specifier of target object. An empty string implies Equipment is the target.	Formatted text. See SEMI E39 for restrictions.
ProcessCapability	User-defined description	Text
Property	An attribute name and value.	Structure of attribute name, attribute value
RequestAcknowledge	Acknowledgement of request.	Enumerated: Request performed Cannot perform now Invalid request Already in requested state Will perform when able and report results when complete
RequestStatus	Result of request	Structure consisting of RequestAcknowledge and Status
Service	New substate of SERVICE	Enumerated: IN SERVICE, OUT OF SERVICE
Status	Reports any errors found.	List of ErrorCode, ErrorText pairs

12.6 *Abort* — Table 19 defines the Abort service. The Abort request may be directed to the Equipment or to an EquiipmentModule.

Table 19 Abort Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for EquipmentModule.
RequestStatus	-	M	Result status

12.7 *AddProcessCapability* — Table 20 defines the service to add a ProcessCapability. This request may be directed to the Equipment or to an EquipmentModule.

Table 20 AddProcessCapability Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M		Object specifier for owner of capability
ProcessCapability	M	-	User description of a process objective.
RequestStatus	-	M	Result status

12.8 *AddElement* — Table 21 defines the service to add an AbstractEquipmentElement. This request may be directed to the Equipment or to an EquipmentModule. Properties needed for the AbstractEquipmentElement must be included in the list of properties.

Table 21 AddElement Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for new owner
(list of) Property	M	-	Properties of new element
RequestStatus	-	M	Result status

12.9 *Cleanup* — This service directs the equipment to return all substrates that have been removed from their carriers to their appropriate destinations. Table 22 defines the Cleanup service.

Table 22 Cleanup Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RequestStatus	-	M	Result status

12.10 *GetDateTime* — Table 23 defines the GetDateTime service.

Table 23 GetDateTime Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
DateTime	-	M	Date and time.
RequestStatus	-	M	Result status

12.11 *ChangeService* — Table 24 defines the ChangeService service. This service requests that the target object be placed either in service or out of service. The user shall only be allowed to place an object back into service if it was originally put out of service by a user.

Table 24 ChangeService Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target
Service	M	-	New substate for SERVICE.
RequestStatus	-	M	Result status

12.12 *Pause* — Table 25 defines the Pause service.

Table 25 Pause Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target object.
RequestStatus	-	M	Result status

12.13 *RemoveProcessCapability* — Table 26 defines the service to remove a process capability from the ProcessCapabilityList.

Table 26 RemoveProcessCapability Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target object.
ProcessCapability	M	-	Capability to be removed
RequestStatus	-	M	Result status

12.14 *RemoveElement* — Table 27 defines the service to remove an element previously added by a user.

Table 27 RemoveElement Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for element to be removed
RequestStatus	-	M	Result status

12.15 *Resume* — Table 28 defines the service for starting an activity at a designated EquipmentModule or at the Equipment.

Table 28 ResumeService Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target object.
RequestStatus	-	M	Result status

12.16 *SelectProgram* — Table 29 defines the service to select a program for an EquipmentIODevice.

Table 29 SelectProgram Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target object.
DeviceProgramID	M	-	Text
RequestStatus	-	M	Result status

12.17 *SetDateTime* — Table 30 defines the service for setting the equipment's date and time.

Table 30 SetDateTime Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
DateTime	M	-	Date and time
RequestStatus	-	M	Result status

12.18 *Shutdown* — Table 31 defines the service to shut down the equipment or one of its modules.

Table 31 Shutdown Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target
RequestStatus	-	M	Result status

12.19 *Start* — Table 32 defines the service for starting an activity at a designated EquipmentModule or at the Equipment.

Table 32 Start Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for EquipmentModule or Equipment.
RequestStatus	-	M	Result status

12.20 *Startup* — Table 33 defines the service to start up the equipment or one of its modules.

Table 33 Shutdown Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for target
RequestStatus	-	M	Result status

12.21 *Stop* — Table 34 defines the service for stopping an activity at the equipment or one of its modules.

Table 34 Stop Service Definition

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
ObjSpec	M	-	Object specifier for EquipmentModule or Equipment.
RequestStatus	-	M	Result status

12.22 *SynchDate&Time* — The SynchDate&Time service instructs the equipment to synchronize date and time with the network at its next opportunity to do so at a time where a timestamp series for work in process will not be compromised by a change in date or time. This service is defined in Table 35.

Table 35 SynchDate&Time Service

Parameter	*Req/Ind*	*Rsp/Conf*	*Description*
RequestStatus	-	M	Result status

13 Services Provided by Factory Systems

13.1 This section describes the services provided by the factory system. These are messages sent by the equipment to the factory system.

13.2 *Date and Time Request* — The equipment may request the current date and time from the factory system. This message service is identical to the GetDateTime service defined in Section 12.6 and Table 23.

13.3 *Event Notification* — The factory system will receive standard event notifications from the equipment. Event notifications used will depend upon the protocol used.

13.4 *Alarm and Error Notifications* — The factory system will receive notifications of errors and alarms. Errors may be recoverable. Equipment shall comply to SEMI E41.

14 OBEM Compliance

NOTE 6: Section must be completed in order for the provisional status of OBEM to be removed.

15 Scenarios

NOTE 7: Section must be completed in order for the provisional status of OBEM to be removed.

15.1 This section contains scenarios showing typical interactions between factory and equipment, including interactions defined by other standards.

RELATED INFORMATION 1
MODELS

NOTE: This related information is not an official part of SEMI E98. This is Related Information for the provisional specification and is not intended to modify or supersede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

This section provides examples of equipment models to clarify the standard.

R1-1 Linked Litho Model

R1-1.1 This section describes the application of OBEM objects to a linked litho as illustrated in Figure R1-1.

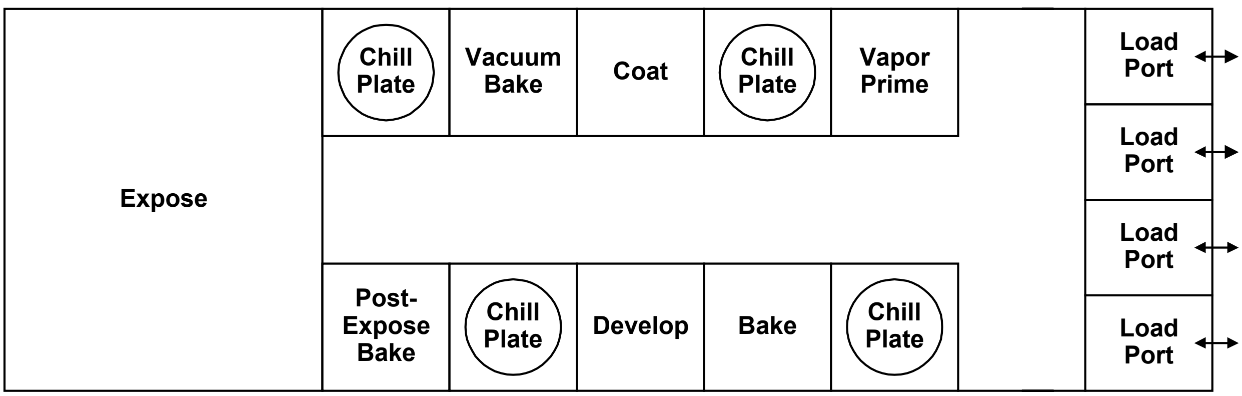

Figure R1-1
Illustration of Linked Litho

R1-1.2 A linked litho is an aggregate created by physically connecting an apply/develop track to a lithography equipment. Work enters through the track where it goes through a set of initial processing steps. Individual substrates are passed to the lithography equipment where they are exposed and returned to another part of the track, where they complete another set of processing steps. Both the track and the lithography equipment are capable of acting independently. However, in the linked-litho configuration, they must perform together as a single system and are treated as a single Equipment by the factory.

R1-1.3 *Apply/Develop Track Equipment*

R1-1.3.1 Before considering the object model for a linked litho, it is helpful to examine the model for an apply/develop track as a type of stand-alone equipment. This is illustrated in Figure R1-2.

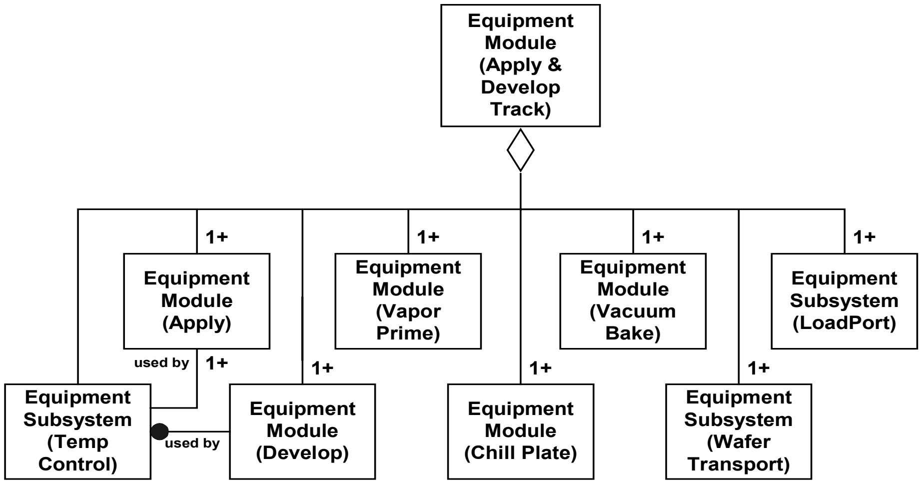

Figure R1-2
Apply and Develop Track Equipment

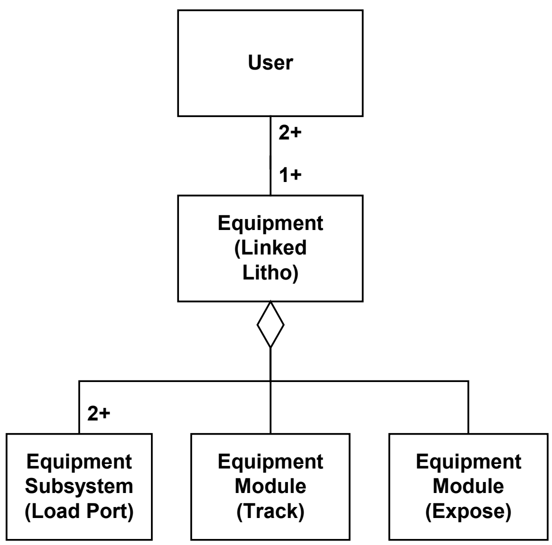

Figure R1-3
Object Model for Linked Litho Equipment

R1-1.4 *Combined Linked Litho*

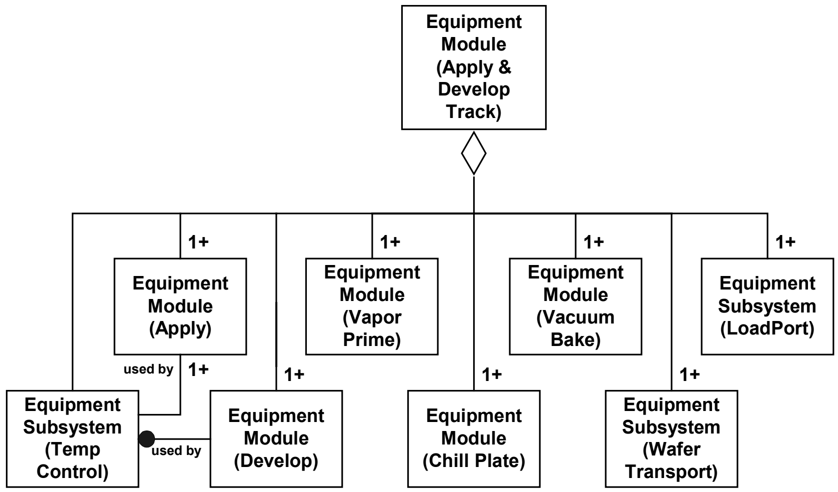

Figure R1-4
Linked Litho Track Module

R1-1.4.1 The Linked Litho Equipment has two major EquipmentModules, the track module and the expose module in this model. The track, in turn, is composed of various types of Sub-modules, such as the Vapor Prime module, the Spin module, and so forth.

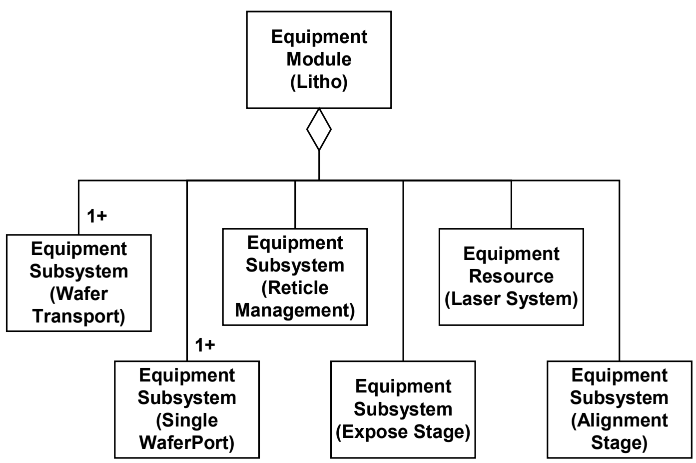

Figure R1-5
Linked Litho Expose Module Object Model

R1-1.4.2 Figure R1-6 shows the makeup of another track module. This process may be extended as many times as is required by the particular installation.

R1-2 300 mm Equipment

R1-2.1 Because of the size and the weight of wafers with a diameter of 300 mm or greater, a 25-wafer cassette is too heavy for repetitive lifting by people. 300 mm factories must be able to integrate automated material handling systems and production equipment. To achieve this, equipment loadports must be standardized for access by different material handling technologies such as overhead tracks and rail-guided vehicles in addition to personal-guided vehicles (PGVs) used by operators.

R1-2.2 In addition to issues regarding access, users require that equipment be capable of continuous processing. To meet this requirement, certain types of equipment need to provide intermediate storage for carriers to prevent starvation, running out of work before new work is delivered.

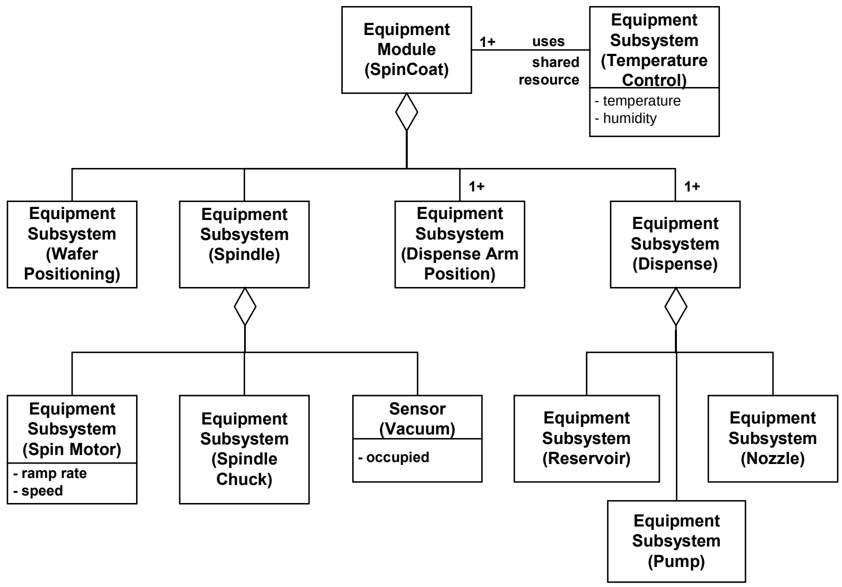

Figure R1-6
Spin/Coat Track Module Object Model

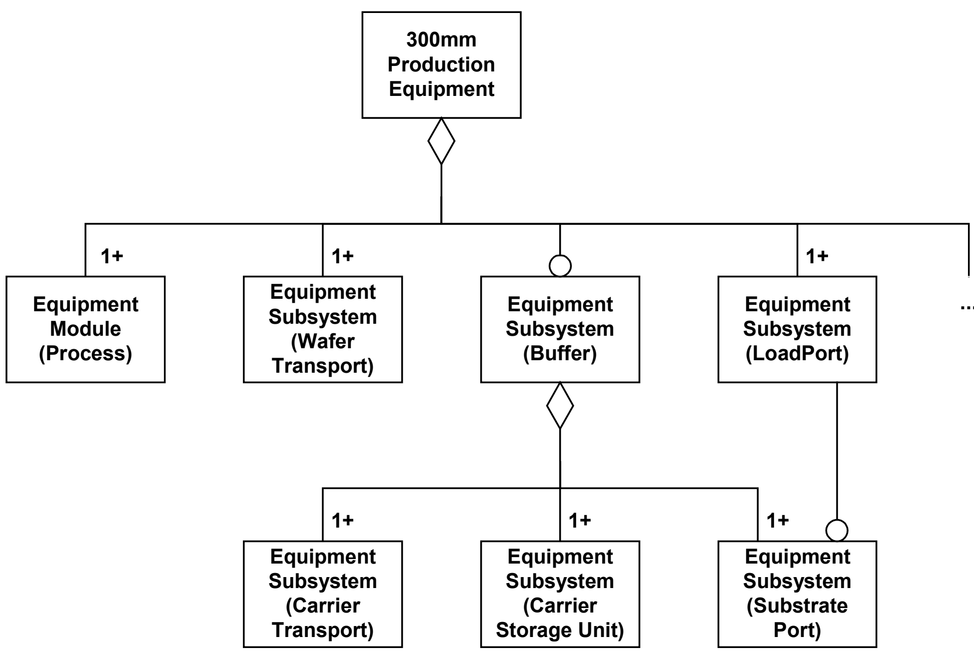

Figure R1-7
Example of Object Model for 300 mm Equipment

R1-2.3 The term “Equipment Front End Module” (EFEM) refers to the aggregation shown in Figure R1-8 consisting of all the components handling carriers, i.e., the loadport and buffer subsystems. An EFEM would not typically provide ARAMS capability and therefore would be considered as an EquipmentSubsystem and not considered as an OBEM EquipmentModule.

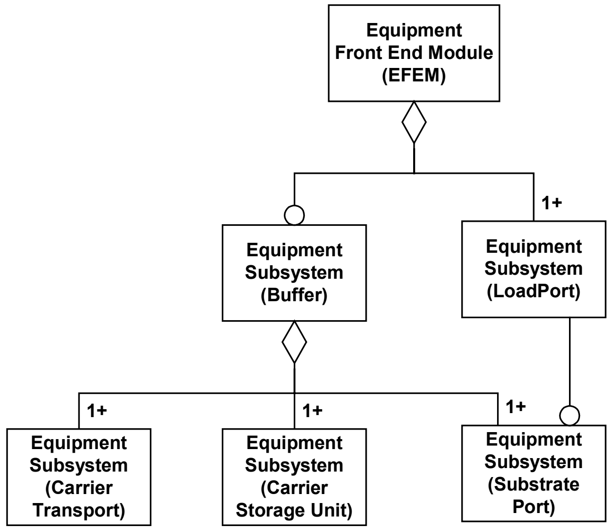

Figure R1-8
Equipment Front End Module (EFEM)

RELATED INFORMATION 2
RELATIONSHIP TO THE CIM FRAMEWORK

NOTE: This related information is not an official part of SEMI E98. This is Related Information for the provisional specification and is not intended to modify or supersede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

This section discusses the relationship of OBEM and the OBEM objects to the objects defined in SEMI E81. It uses terms both from the CIM Framework and from OBEM. It is not part of the OBEM standard.

Additional documentation should be provided in this section as the CIM Framework develops.

R2-1 Equipment and Machine

R2-1.1 The interface to Equipment defined in OBEM is provided for the physical equipment on the manufacturing floor. From time to time, the Equipment will be powered off for maintenance and at these times is unable to communicate. In contrast, the Machine object, defined in the CIM Framework, is part of the manufacturing execution system and is always available, even when the Equipment is powered off or otherwise unable to communicate.

R2-1.2 The Machine provides a generic interface for factory logistics and is able to provide some services without relying on the Equipment itself. The Machine is responsible for communications with the Equipment and for representing the Equipment to the Factory and representing the Factory to the Equipment.

R2-2 EquipmentModule and MachineResource

R2-2.1 The EquipmentModule defined in OBEM corresponds to the MachineResource interface defined in the CIM Framework. The MachineResource is a type of Resource and therefore can respond to requests to start up and shut down. These services are provided for the EquipmentModule but not for its supertypes.

R2-3 Location Tracking

R2-3.1 The CIM Framework defines an interface for a MaterialTrackingLocation. The MaterialTrackingLocation differs from the OBEM MaterialLocation. MaterialLocations represent places within the equipment itself where carriers and substrates can be placed, including wafer chucks, carrier slots, and robot end effectors. A MaterialTrackingLocation, in contrast, is at a higher level of granularity and provides the ability to locate material associated with a Machine. MaterialTrackingLocation does not track material locations down to the level of specific places within the equipment.

RELATED INFORMATION 3
ADDITIONAL DATA

NOTE: This related information is not an official part of SEMI E98. This is Related Information for the provisional specification and is not intended to modify or supersede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

This section provides examples of equipment models to clarify the standard.

This section contains additional information that is not part of the standard.

R3-1 Representations of Date and Time

R3-1.1 This section discusses several date and time representations, and provides background information in support of the OBEM adoption of an IEEE floating point representation of date and time values.

R3-1.2 In this section, the term "date value" means an encoding of a date and time value, such as 12/25/1997 11:04:56.

R3-1.3 *ASCII Digit Representation*

R3-1.3.1 The standard date and time format in SECS communication is the ASCII representation "YYYYMMDDhhmmsscc". In this representation, date and time are represented as a fixed length sequence of ASCII digit characters, grouped into fields as indicated.

Advantages	*Disadvantages*
Very simple conversion to display format.	Date computations difficult. For example, adding two date values is not a trivial operation.
Simple to extract date and time from date value.	Many digit sequences are not valid date values.
	The format does not lend itself to expressions of time intervals. The representation of "ten minutes" might be "00000000001000", but the job of adding this interval to a date value is not simple.
	The resolution of the representation is fixed at seconds.

R3-1.4 *Long Signed Integer Representation*

R3-1.4.1 UNIX represents date and time as the number of ticks since Epoch. Typically the time interval of a tick is one second. Date values are expressed as the number of ticks since a certain instant, called the Epoch.

R3-1.4.2 There are 31,536,000 seconds in a 365 day year. If stored as a four byte signed integer, with ticks in seconds, this representation will overflow after approximately 68 years. Eight byte integers provide sufficient range for dates spanning human history many times. Unfortunately, eight byte integers are inconvenient on many computer platforms.

Advantages	*Disadvantages*
All bit sequences are valid date values.	Difficult to separate date and time from date value.
Intervals are simple to express.	Eight byte representation required for sufficient range, but inconvenient on many computer platforms.
Date value arithmetic is simple.	No simple way to convert date value to display format.
	The resolution of the representation is fixed at the tick value, typically seconds.

R3-1.5 *Floating Point Representation*

R3-1.5.1 This representation is used in many applications. It represents date values as floating point numbers, with units of days past 12/30/1899. It is very similar to the "Ticks since the Epoch" representation, except that the tick values are days.

R3-1.5.2 This representation has the advantages of the "Tick since Epoch" representation for date value arithmetic. Second, the separation of the date and time from a date value is simple. The date is the whole value, the time is the fractional value. Third, the minimum time resolution is very small, and is not fixed by the representation.

R3-1.5.3 The following calculation is used to determine roughly the minimum time resolution that can be expressed:

R3-1.5.4 The IEEE 8 byte floating point representation uses an excess 128 notation. This means 7 bits of exponent and one bit of sign. This leaves 7 bytes of significant. On November 18, 1997 the day number is 35752. This is hex 8BA8, and requires two bytes. This leaves 5 bytes of significant to represent the fractional day, or the time portion of the date value. These 5 bytes of significant contain 40 bits, and can represent values to 2^40, or one part in 1,099,511,627,776. There are 86,400 seconds in one day, so this representation is accurate to approximately 7.86E-08 seconds, or about 1/10 of a microsecond. In about a hundred years the day number will have doubled, and this resolution will have shrunk by a factor of 2. For practical purposes the resolution is no worse than one microsecond resolution.

Advantages	*Disadvantages*
All legal float values are valid date values.	Minimum resolution changes over time.
Simple to separate date and time from a date value.	No simple way to convert date value to display format (but simpler than the "Tick since the Epoch" representation).
Intervals are simple to express.	
Date value arithmetic is simple.	
The eight byte floating point representation used is supported on most computer platforms.	
The time resolution is not implied by the representation, but is valid to very small intervals.	

R3-1.6 *Examples*

11/18/1997	35752
11/18/97 1:03:13 PM	35752.543912037
One second	1.15740740740741E-05
One day	1
One microsecond	1.15740740740741E-11
1/1/1000	-328716
12/30/1899	0

RELATED INFORMATION 4
OBEM EQUIPMENTIODEVICE AND SENSOR/ACTUATOR NETWORK COMMON DEVICE MODEL

NOTE: This related information is not an official part of SEMI E98 and was derived from work developed in the Object-Based Model Task Force in North America, and the Sunsor/Actuator Bus subcommittee. This related information was approved for publication by full letter ballot on April 30, 2001.

R4-1 Relationship between OBEM EquipmentIODevice and Sensor/Actuator Network Common Device Model

R4-1.1 This section describes the relationship between the EquipmentIODevice defined in Section 10.3 and the Common Device Model defined in SEMI E54.1 Standard for Sensor/Actuator Network Common Device Model.

R4-1.2 SEMI E54.1 defines in detail the internal structure of a sensor/actuator device on an E54-compliant sensor/actuator network. That is, it defines the possible internal components of such a device and the relationships between these components. To ensure proper behavior, it was necessary to give sufficient guidance to implementers using an E54 network communication protocol. E54.1 defines sensor (input) objects, actuator (output) objects, controller objects, a sensor/actuator controller object (SAC), and a device manager object (DM) as individual components of a sensor/actuator device aggregation as components of an aggregate Common Device Model (CDM). The device aggregation must have at least one sensor or actuator or controller (combined) and exactly one SAC and one DM. In addition, the CDM defines additional classes to further classify components, such as the ActiveElement, Sensor, and Sensor-Analog Input classes, which should be considered. Some attributes of the EquipmentIODevice Observables only apply to elements of certain classes.

R4-1.3 E54.1 does not define the CDM, which is the aggregation of these elements, as an object in its own right,. Such an aggregation might have the sum of all of the attributes of its components.

R4-1.4 OBEM defines a high-level device, the EquipmentIODevice, that is of interest to factory system applications such as Advanced Process Control (APC) and Fault Detection Classification (FDC). These systems are seldom interested in all of the low-level details. Actual raw data as read directly by an analog sensor may not be desired but rather a calculated value that has been converted into some specified units, such as degrees Celsius. OBEM can support either.

R4-1.5 Some of the attributes of the EquipmentIODevice are maintained only by the equipment. Most of the attributes must come directly from the attributes read from the CDM components for E54.1 compliant devices. The following sections suggest a way to relate attributes of the EquipmentIODevice and attributes of the elements from the CDM in a consistent manner.

R4-1.6 Each individual sensor or actuator or controller element within the CDM corresponds to one Observable in the EquipmentIOElement model. Observables were not made into formal objects, as they could be, but rather are included as one set of data within the EquipmentIODevice. Each EquipmentIODevice may have multiple sets of Observables data.

R4-1.7 Table R4-1 lists all of the attributes of an EquipmentIODevice, including those it inherits from the AbstractEquipmentElement (marked with asterisks) and shows the object and attribute in the General Device Model hierarchy to which it corresponds, where a correspondence exists.

R4-1.7.1 The “em dash” character “—”is used where no correspondence exists.

R4-1.7.2 This table is intended for equipment implementers of E98 and not for the suppliers of E54-compliant devices.

Table R4-1 Relationships between EquipmentIOElement and Generic Device Model

EquipmentIODevice Attribute Name	*Generic Device Model Object Name*	*Corresponding Attribute Name*
ObjType	—	—
ObjID	—	—
AlgorithmID	—	—
Cycles* (units may be time)	SAC	Run Hours (SacA5)
Description*	—	—
DeviceType	Device Manager	Device Type (DmA1)
Function*	—	—
HardwareRevision	Device Manager	Hardware Revision Level (DmA6)
ImmutableID*	DeviceManager	Serial Number (optional) (DmA7)
InService*	—	—
ModelNumber	Device Manager	Manufacturer Model Number (DmA4)
NumberofObservables	—	—
SoftwareRevision	Device Manager	Software or Firmware Revision Level (DmA5)
Supplier*	Device Manager	Device Manufacturer Identifier (DmA3)
Observable$_I$		
DataDimension	Sensor-Analog Input Class element	—
Datatype	Sensor-Analog Input Class or Actuator-Analog Output Class or Controller Class element	Datatype SaiA66or AaoA66 or Controller CA19 (translated for host as necessary to conform to SECS-II format types (10,11,20, etc.)
DeltaValue	Sensor of Sensor-Analog Input Class element	ReportDelta (SaiA70)
InterlockStatus	—	—
Name	Sensor or Actuator or Controller	Text strings “SenIn” or “ActIn” or “CntIn” where n represents the instance number of the corresponding device object (Table 2, E54.1)
NominalValue	—	—
ObservableType	—	—
Possible Units	—	—
Range	—	—
ReadRate	—	—
ReportChange	Sensor-Analog Input Class element	EnableReportROC SaiA71
ReportRate	Sensor-Analog Input Class element	ReportROC SaiA72
Timestamp	Device Manager	Date and Time (DmA21)
Units	Sensor-Analog Input or Actuator-Analog Output Class element	DataUnits (SaiA67 or Aao67)
Value	Sensor or Actuator or Controller	Value or Setting (nA16) or Setpoint (CA16)

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SEMI E98.1-0302
PROVISIONAL SPECIFICATION FOR SECS-II PROTOCOL FOR THE OBJECT-BASED EQUIPMENT MODEL

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002.

1 Purpose

1.1 This document maps the services and data of SEMI E98 Object-Based Equipment Model (OBEM) to SECS-II streams and functions and data definitions.

2 Scope

2.1 This document applies to all implementations of OBEM that use the SECS-II message protocol (SEMI E5).

2.2 This specification is provisional. To remove the provisional status, the SECS-II format for the attributes of the remaining object defined in OBEM must be included in Section 6:

- EquipmentIODevice

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Documents

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E98 — Provisional Standard for the Object-Based Equipment Model (OBEM)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Services Mapping

4.1 Table 1 shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the services defined in OBEM.

Table 1 Services Mapping Table

Message Name	*Stream, Function*	*SECS-II Message Name*
Abort	S14,F19/ 20	Generic Service Request/Acknowledge
AddElement	S14,F19/ 20	Generic Service Request/Acknowledge
AddProcessCapability	S14,F19/ 20	Generic Service Request/Acknowledge
ChangeService	S14,F19/ 20	Generic Service Request/Acknowledge
Cleanup	S14,F19/ 20	Generic Service Request/Acknowledge
GetDateTime	S14,F19/ 20	Generic Service Request/Acknowledge
GetProgramDirectory	S14,F19/ 20	Generic Service Request/Acknowledge
Pause	S14,F19/ 20	Generic Service Request/Acknowledge
RemoveProcessCapability	S14,F19/ 20	Generic Service Request/Acknowledge
RemoveElement	S14,F19/ 20	Generic Service Request/Acknowledge
Resume	S14,F19/ 20	Generic Service Request/Acknowledge
SelectProgram	S14,F19/ 20	Generic Service Request/Acknowledge
SetDateTime	S14,F19/ 20	Generic Service Request/Acknowledge
Shutdown	S14,F19/ 20	Generic Service Request/Acknowledge
Start	S14,F19/ 20	Generic Service Request/Acknowledge
Startup	S14,F19/ 20	Generic Service Request/Acknowledge
Stop	S14,F19/ 20	Generic Service Request/Acknowledge

5 Service Parameter Mapping

5.1 Table 2 shows the mapping between service parameters defined by OBEM and the data items defined by SEMI E5. All OBEM messages map to Stream 14 Functions 19 and 20. The data item SVCNAME is the text string representation of the service name found in Table 1 and should be assumed as case-sensitive. The name of each parameter is the text string representation of the parameter name as it appears in Table 2. The SECS-II Data Item Reference, where different from SPVAL, provides additional information and restrictions for the value.

Table 2 Service Parameter Mapping Table

Parameter Name (SPNAME)	*Parameter Range (SPVAL)*	*SECS-II Data Item Reference*	*SECS-II Format*
"DateTime"	A valid date and time.	SPVAL	20,34,30
"DeviceProgramID"	0–65,535	SPVAL	51,52
"ErrorCode"	Enumerated as defined in SEMI E5 or by supplier.	ERRCODE	5()
"ErrorText"	1–80 characters	ERRTEXT	20
"ObjSpec"	0–80 characters	OBJSPEC	20
"ProcessCapability"	1–80 characters	SPVAL	20
"Property"	See Table 4.	SPVAL	—
"RequestAcknowledge"	Enumerated: 0 = Request performed 1 = Invalid request 2 = Can not perform now 4 = Will perform when able and report results when complete.	SVCACK	10
"Service"	Enumerated: 0 = OUT OF SERVICE 1 = IN SERVICE	SPVAL	51
"Status"	See Table 4.		

5.2 Table 3 shows the data items in SECS II messages that do not have a corresponding service parameter.

Table 3 Additional Data Item Requirement Table

Function	*SECS-II Data Item*
Used to satisfy SECS-II conventions for linking a multi-block inquiry with subsequent multi-block message.	DATAID
Name of OBEM service. Enumerated: "Abort" "Add Element" "AddProcessCapability" "ChangeService" "Cleanup" "GetDateTime" "GetProgramDirectory" "Pause" "RemoveProcessCapability" "RemoveElement" "Resume" "SelectProgram" "SetDateTime" "Shutdown" "Start" "Startup" "Stop"	SVCNAME

Function	*SECS-II Data Item*
A unique number generated by the service requestor to identify a specific operation and connect it to a later completion confirmation.	OPID

NOTE 1: The text strings specified in Table 3 for SVCNAME shall be recognized by the equipment as vaild, whether the equipment is or is not case-sensitive.

5.3 Table 4 provides the parameter mapping for OBEM parameters not specified in Tables 2 or 3.

Table 4 Mapping for Elements of Service Parameters

Parameter Name	*Mapping*	*SPVAL Format*
Property	Each property is an attribute name/value pair for some object indicated in ObjSpec. Each attribute name maps directly to SPNAME, and each attribute value maps directly to SPVAL.	The format of SPVAL is dictated by the format used for the specific attribute.
Status	Each ErrorCode/ErrorText pair maps directly to an SPNAME/SPVAL name pair:	--
ErrorCode	SPNAME = "ErrorCode"	52. Enumerated per ERRORCODE. Implementers may add documented values above 63 as needed.
ErrorText	SPNAME = "ErrorText"	20. I-80 characters. May not be blank.

6 Object Attribute Form

6.1 Section 6 defines the SECS-II form of the attributes of objects defined in OBEM, presented in alphabetical order. Note that attribute names in this section indicate the literal text string that shall be accepted in string comparisons for attribute names in Stream 14 messages.

6.1.1 By convention, all tables include ObjID as well as ObjType as the two attributes required by SEMI E39.

6.2 *AbstractEquipmentElement*

6.2.1 Table 5 specifies the attributes of the AbstractEquipmentElement.

Table 5 AbstractEquipmentElement Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"Cycles"	0+.	54
"Description"		20
"Function"		20
"ImmutableID"		20
"InService "	Enumerated: 0 = OUT OF SERVICE 1 = IN SERVICE	51
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
"ObjType"	"EqpElement"	20
"ResetDate"	Conforms to DateTime attribute of Clock	20,30,34
"Supplier"		20

6.3 *AbstractEquipmentModule*

6.3.1 Table 6 specifies the elements of the AbstractEquipmentModule object.

Table 6 AbstractEquipmentModule Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"BehaviorState"	Enumerated: 0 = IDLE 1 = ACTIVE SERVICE 2 = PAUSING 3 = PAUSED 4 = STOPPING 5 = STOPPED 6 = ABORTING 7 = ABORTED 8 = IDLE WITH ALARMS	
"Model"		20
"ModelRevision"		20
"Nickname"		20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
"ObjType"	0 or more	20
"ProcessType"		20
"ProcessCapabilityList"		0
"ProcessSetup"		20
"PreviousBehaviorState"	Enumerated: 0 = IDLE 1 = ACTIVE SERVICE 2 = PAUSING 3 = PAUSED 4 = STOPPING 5 = STOPPED 6 = ABORTING 7 = ABORTED 8 = IDLE WITH ALARMS	51
"SoftwareVersions"		0
"Units"	Conforms to SEMI E5, Section 9.	20

6.4 *AbstractEquipmentSubsystem*

6.4.1 Table 7 specifies the attributes of the AbstractEquipmentSubsystem.

Table 7 AbstractEquipmentSubsystem Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"AbstractEqpSubsystem"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
"MaterialSummary"	Ordered list. See Table 8 for detail.	0

6.4.2 Table 8 specifies the elements of the MaterialSummary attribute.

Table 8 MaterialSummary Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"MaterialCapacity"	0 or more	5()
"MaterialCount"	0 ≤ MaterialCount ≤ Material-Capacity	5()
"MaterialType"	Conforms to SEMI E5, Section 9.	20

6.5 *CarrierLocation Object*

6.5.1 Note that the CarrierLocation inherits the attributes of the MaterialLocation.

6.5.2 Table 9 specifies the additional attributes of the CarrierLocation object. See Table 13.

Table 9 CarrierLocation Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"CarrierLoc"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
LocationState	Enumerated: 0 = Unoccupied 1 = Occupied 2 = Not Aligned	51

6.6 *Clock*

6.6.1 Table 10 specifies the attributes of the Clock object.

Table 10 Clock Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"Clock"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
"DateTime"	As specified by TimestampFormat.	20,30,34
"UseNet"	FALSE = DISABLED TRUE = ENABLED	11
"TimestampFormat"	Enumerated: (see SEMI E54.1, Section 7.3.1.23) 0 = Text "yyyymmddhhmmsscc" 1 = Univeral Time Coordinated 2 = Standard Time and Date	51
"GMTDelta"	-32,768 to +32767 (minutes) *actual value in use at locale	32
"UseDelta"	Boolean: TRUE = use GMDelta FALSE= do not use GMDelta	11

6.7 *Equipment*

6.7.1 Table 11 specifies the attributes of the Equipment object.

Table 11 Equipment Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"Equipment"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
"AssignedOperators"	List.	0
"Nickname"	Any.	20

6.8 *EquipmentSubsystem*

6.8.1 Table 12 specifies the attributes of the AbstractEquipmentSubsystem object.

Table 12 EquipmentSubsystem Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"EqpSubsystem"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20

6.9 *Material Location*

6.9.1 Table 13 specifies the attributes of the AbstractEquipmentSubsystem object.

Table 13 MaterialLocation Object Attribute Specification

Attribute Name	*Range/Value*	*SECS-II Format*
"ObjType"	"MatlLoc"	20
"ObjID"	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20
LocationState	Enumerated: 0 = Unoccupied 1 = Occupied	51
MaterialType	Conforms to SEMI E5, Section 9.	20
MaterialID	Conforms to OBJID restrictions in SEMI E39.1, Section 6.	20

SEMI E102-0600
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK MATERIAL TRANSPORT AND STORAGE COMPONENT

This provisional specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the Japanese Information and Control Committee. Current edition approved by the Japanese Regional Standards Committee on March 14, 2000 and by the North American Regional Standards Committee on March 2, 2000. Initially available at www.semi.org March 2000; to be published June 2000.

1 Purpose

1.1 Wafer fabrication factories will require the baseline capabilities of stocker storage and interbay transport. In addition to these baseline capabilities, intrabay transport will be added as a result of ergonomic and safety requirements brought about by the increased size and weight of 300 mm wafer carriers. These stocker, interbay transport, and intrabay transport systems will be required to be fully integrated with each other and the factory Manufacturing Execution System (MES) in order to realize the full vision of cost effective automated material transport to and from production equipment.

1.2 A baseline requirement of Automated Material Handling System (AMHS) equipment is efficient integration with the factory MES. Therefore, the purpose of this specification is to enable cost effective integration of interoperable AMHS systems, as illustrated in Figure 1. Manufacturers require a SEMI standard which specifies the visible behavior of the AMHS Integration system and its interface to the factory MES. The purpose of this standard is to specify these interfaces and the interactions between MES and AMHS systems as a part of the CIM Framework. While the term AMHS is commonly used to refer to a wide range of equipment and systems that support automated material handling, the CIM Framework specifies a software component called “Material Transport and Storage Component (MTSC)” which represents the standard interface of the MES to the complete suite of AMHS capabilities.

2 Scope

2.1 This specification provides the common interfaces required by Manufacturing Execution Systems for runtime interactions between the factory (as represented by other CIM Framework components) and the Material Tracking and Storage Component. Some interfaces supporting configuration and tracking of the material transport and storage equipment are the responsibility of the Equipment Tracking and Maintenance component of the CIM Framework. These interfaces are complementary to the interfaces of Transport Machines and Storage Machines presented in this specification.

2.2 The responsibilities of the Material Transport and Storage Component include interfaces that

- Support scheduling of material transport and processing by predicting time for material delivery to specific locations. NOTE: The interfaces for delivery time prediction are deferred as one of the deficiencies noted in this provisional specification.
- Execute and monitor transport jobs to move material to specific locations.
  - Validate that the job can be done: the material is available, the destination is reachable and has available storage or loadport capacity, and there are sufficient material movement resources (cars, storage space, etc.) to implement the job.
  - Request operations from AMHS equipment controllers to enact internal material movement and storage actions. Implementations of the Material Transport and Storage Component will use lower level standards such as IBSEM and StockerSEM for communication with equipment that performs the physical movement and storage actions.
  - Collect and record data on transport job execution and history.
  - Capture, record, interpret, and respond to equipment events and fault detection.
  - Generate MES-level job status events and material location change events.
- Record and report on material locations and material transport histories for material in the system.
- Interact with machine and port interfaces for material hand-off handshake protocols.

2.3 Automated Material Handling Systems (AMHS’s) are an important part of any semiconductor factory and have, typically, been implemented and integrated with a

Manufacturing Execution System (MES) as a separate logical software entity. An AMHS is made up of the AMHS Framework, the system controllers for AMHS equipment (the software) and the transport and storage machines (the hardware). In keeping with this tradition, the CIM Framework views the AMHS as a "black box" where the interface into that system is visible, but the inner workings and control of that system is the responsibility of the AMHS supplier and not in the domain of the MES. The CIM Framework specifies the Material Transport and Storage Component (MTSC) as the MES level interface to AMHS capabilities.

2.4 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

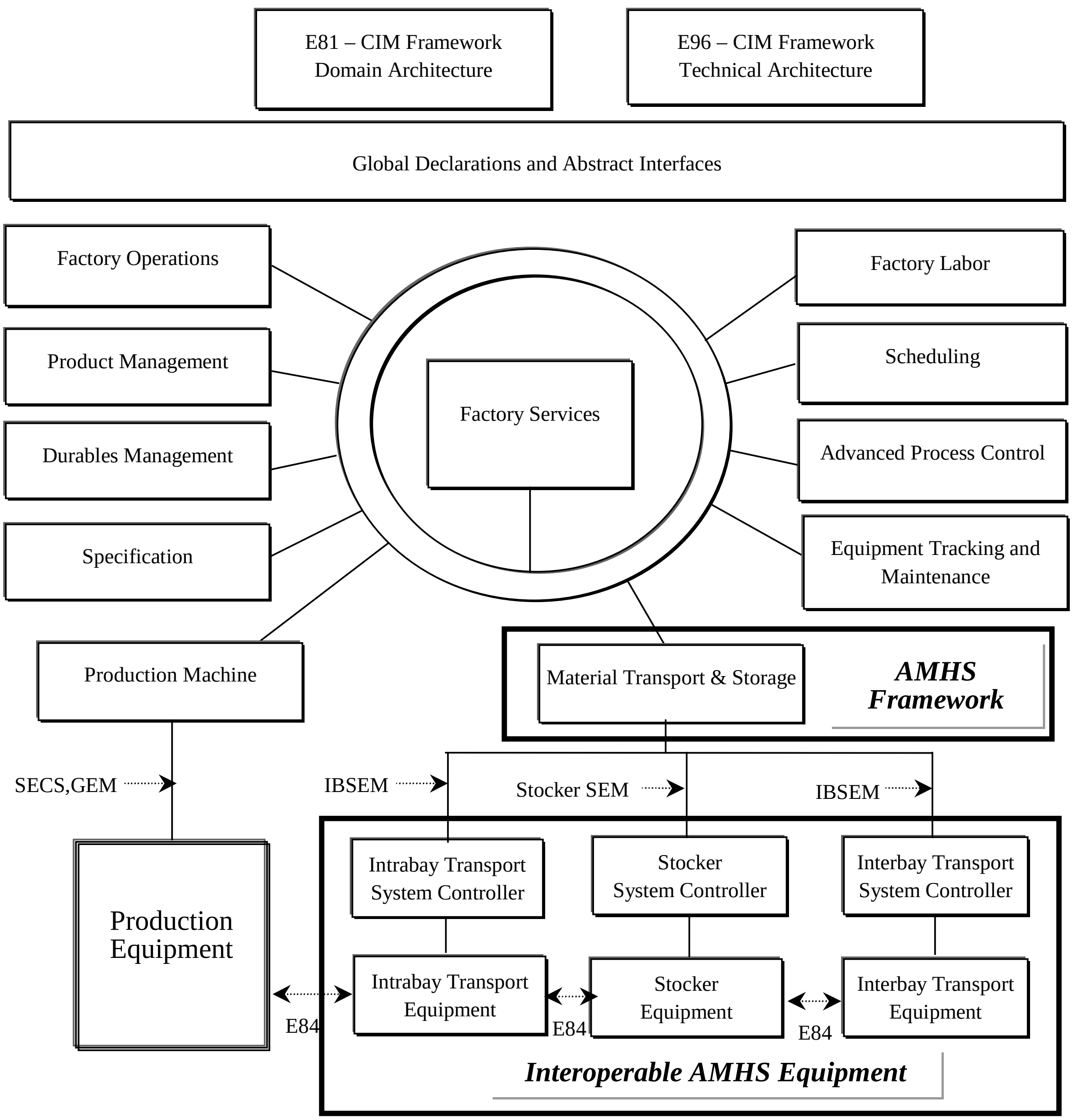

Figure 1
AMHS Environment

3 Limitations

3.1 The Material Transport and Storage Component provides AMHS Framework level interfaces to interoperable AMHS Equipment. This level of material transport is factory level movement, i.e., the transport of product and durables between machines, areas or material tracking locations. The Material Tracking and Storage Component does not provide interfaces that make material movement within machines visible.

3.2 *Provisional Status* — This specification is designated as provisional due to known areas that need to be completed. The following items summarize the deficiencies of the provisional specification to be addressed before a subsequent ballot to upgrade it to full standard status.

3.2.1 *Dependence on Global Declarations and Abstract Interfaces* — Components of this document reference global declarations and specialize abstract interfaces for material, resource and job concepts. The provisional specification for these declarations and interfaces was balloted and recommended by the SEMI Information and Control Committee in July, 1999. When this specification is published a revision will be undertaken to clearly define the relationship of this specification to those common elements of the CIM Framework.

3.2.2 *Dependence on Durables Management Component* — The Material Transport and Storage Component depends upon interfaces specified as part of the Durables Management Component of the CIM Framework. This document includes only the required interfaces from Durables Management. Those interfaces, found in Section 6.2.3, will be removed from this document when the Durables Management Component of the CIM Framework is adopted in a future ballot.

3.2.3 *Dependence on Machine Abstract Interface Group* — The Material Transport and Storage Component depends upon interfaces specified as part of the Machine Abstract Interface Group (Machine AIG) of the CIM Framework. This document includes only the required interfaces from the Machine AIG. Those interfaces, found in Section 6.2.4, will be removed from this document when the Machine AIG of the CIM Framework is adopted in a future ballot.

3.2.4 *Dependence on Factory Operations Component* — The Material Transport and Storage Component depends upon interfaces specified as part of the Factory Operations Component of the CIM Framework. This document includes only the required interfaces from the Factory Operations Component. Those interfaces, found in Section 6.2.5, will be removed from this document when the Factory Operations Component of the CIM Framework is adopted in a future ballot.

3.2.5 *Deterministic Prediction of Transport Time* — The responsibility for providing estimates of predicted transport time of future TransportJobs in a deterministic way is beyond the scope of the Provisional Specification. This capability may be offered in future upgrades of this specification based on added experience with such predictions. It may be found that heuristic methods for transport time prediction are the most practical way to provide such estimates.

4 Referenced Standards

4.1 *SEMI Documents*

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

4.2 *Other Documents*

ISO/IEC International Standard 14750 (also ITU-T Recommendation X.920): Information Technology – Open Distributed Processing – Interface Definition Language[1]

UML Notation Guide, Version 1.1, document number ad/97-08-05, Object Management Group[2]

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — Automated Material Handling System

5.1.2 *MTSC* — Material Transport and Storage Component

6 Requirements

6.1 The following sections specify the interfaces that comprise the Material Transport and Storage Component of the CIM Framework. Additionally, the subsets of interfaces from Durables Management, Machine Abstract Interface Group, and Factory Operations required to support Material Transport and Storage are included here pending future ballots that will address the full scope of these other specifications.

6.1.1 Figure 2 illustrates the context of the Material Transport and Storage Component within the CIM Framework. The Factory Operation component requests the transport of material by the Material Transport Manager which provides services for creation

1 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

2 UML Notation Guide v1.1 is available to the general public at http://www.omg.org/cgi-bin/doclist.pl, +1-508-820 4300, Object Management Group, Inc. , Framingham Corporate Center, 492 Old Connecticut Path, Framingham, MA 01701.

of Transport Jobs. The Material Transport and Storage Component uses services provided by the Machine AIG to access interfaces of Machines and Ports that serve as the source or destination of Transport Jobs. The MES Factory defines areas within a factory which represent groups of machines. Finally, Durables Management provides the services needed to manage the material containers that are moved.

6.1.2 Figure 3 shows the Material Transport and Storage Component information model, including the inherited interfaces and the associations between interfaces. These interfaces are fully defined in Sections 6.3 and 6.4. The interfaces associated with the Material Transport and Storage are as follows:

1. TransportJobSupervisor – abstract interface,
2. MaterialTransportManager,
3. MaterialTransportController, and
4. TransportJob.

6.2 *Required Subsets of Future CIM Framework Specifications*

6.2.1 This specification depends on interfaces from Durables Management Component, the Machine Abstract Interface Group and the Factory Operations Component that will eventually be contained in future CIM Framework component specifications. They are included with this document to support a complete specification for AMHS support within the CIM Framework. When these items are balloted as separate documents, they will be removed from this specification and referenced in their full form.

6.2.2 Figure 4 illustrates the dependencies of the Material Transport and Storage Component.

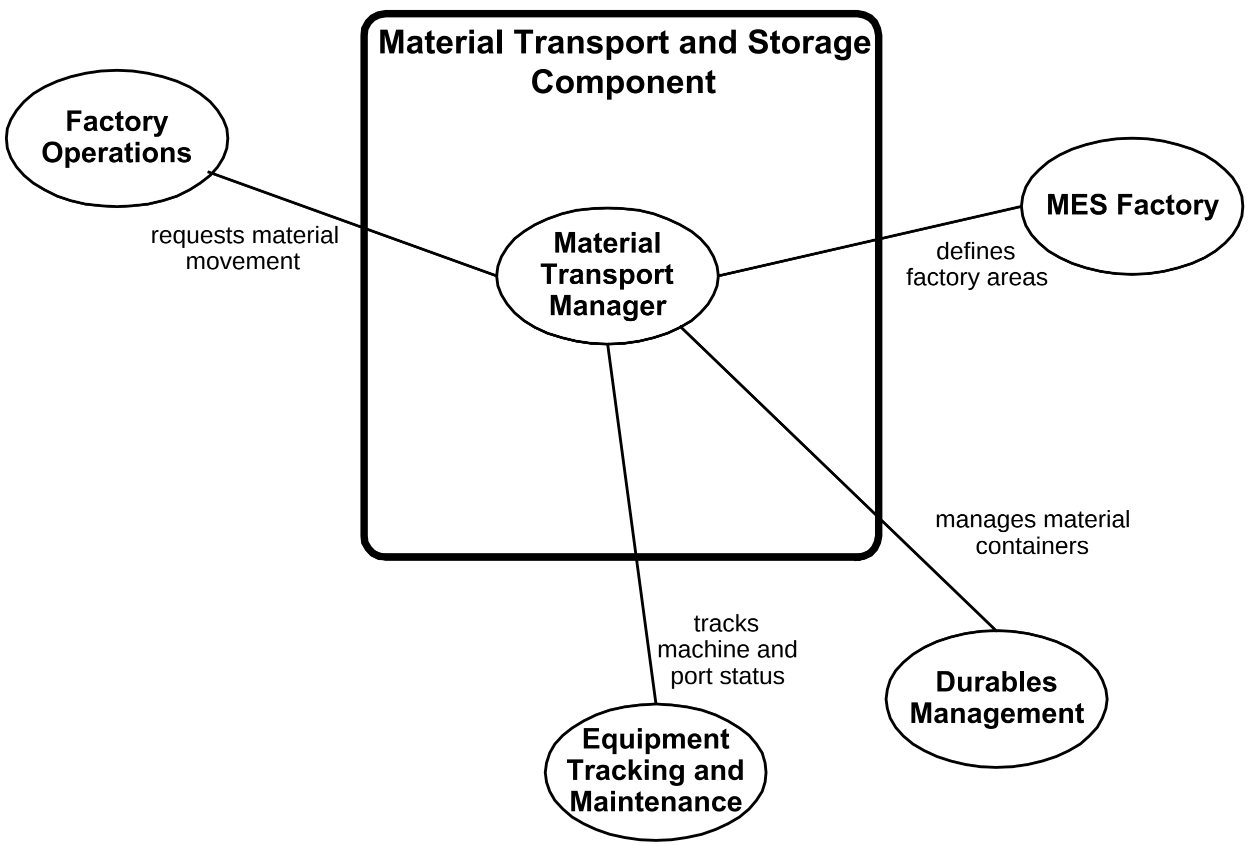

Figure 2
Material Transport and Storage Component Context

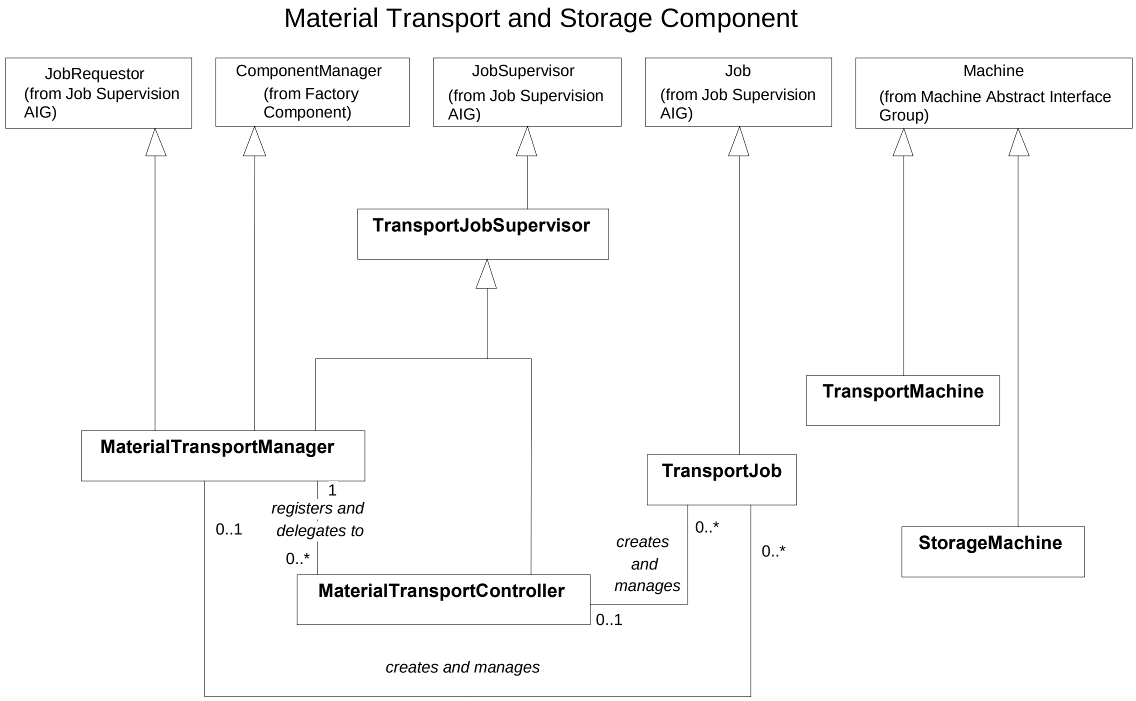

Figure 3
Material Transport and Storage Information Model

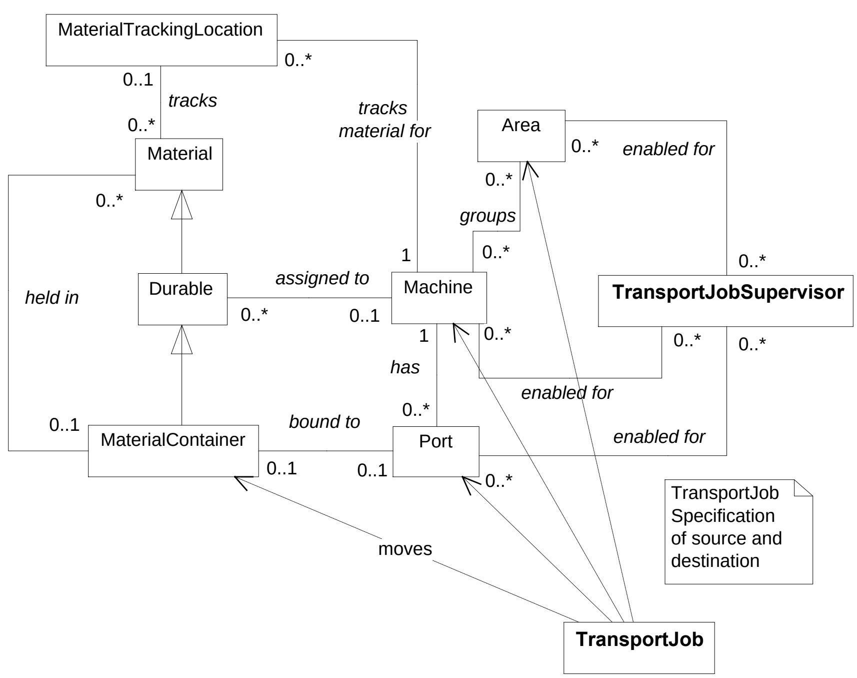

Figure 4
Material Transport and Storage Dependencies

6.2.3 *Durables Management Component (subset)* — This section includes only those interfaces and specific operations from the Durables Management Component that are referenced within this component specification. These interfaces are provided here for the referential integrity of this specification and are not included as part of this component. Further, this is not intended to be a comprehensive treatment of the required interfaces, but only the subset needed here for reference prior to the full specification of Durables Management being adopted through a subsequent ballot. When that occurs, this specification can be updated by a follow-on ballot to reference the interfaces directly rather than replicate them here.

6.2.3.1 *Durable Interface (subset)*

Module:	DurablesManagement
Interface:	Durable
Inherited Interface:	Material

```
interface Durable : AbstractIF::Material {
```

Description: The Durable interface represents any Material in the Factory used to facilitate manufacturing but not normally consumed in the process. It is capable of relocation within the Factory and requires dynamic tracking. This includes containers used to transport the Material, fixtures (attachments for holding material in a fixed position), and tools (such as reticles, load boards, workholders) used by equipment or personnel in the manufacturing process. Grouping of Durables (such as all reticles that are usable for a given process) can be achieved by creating MaterialGroups for the specific categorizations required.

Exceptions:

Published Events:

/* Notifies subscribers of a change in the MaterialTrackingLocation that is tracking the Durable. */

```
DurableLocationChangedEvent
```

Provided Services:

/* Set and get the location of the durable. If the MaterialTrackingLocation is set to NULL, the durable is not in any MaterialTrackingLocation and may be under manual control within the factory. */

```
void setMaterialTrackingLocation (
      in MachineAIG::MaterialTrackingLocation
            aMaterialTrackingLocation)
      raises (Global::FrameworkErrorSignal,
            MachineAIG::MaterialTrackingLocation::MaterialTrackingLocationFullSignal);

MachineAIG::MaterialTrackingLocation getMaterialTrackingLocation ( )
      raises (Global::FrameworkErrorSignal);
```

/* Set and get the Unit that determines which MaterialTrackingLocation this Durable will be tracked through for a given Machine. The Unit is a string value that maps to the Unit attribute of the MaterialTrackingLocation. */

```
void setUnit(
      in string aUnit)
      raises (Global::FrameworkErrorSignal,
            MachineAIG:: MaterialTrackingLocation::InvalidUnitSignal);

string getUnit( )
      raises (Global::FrameworkErrorSignal);

}; // Durable
```

Dynamic Model: None

6.2.3.2 *MaterialContainer Interface (subset)*

Module: DurablesManagement

Interface: MaterialContainer

Inherited Interface: Durable

```
interface MaterialContainer : Durable {
```

Description: A MaterialContainer interface represents any receptacle for holding Material for transport, processing or storage. Examples of MaterialContainers are shipping boxes, tubes, standard mechanical interface (SMIF) pods, etc.

Exceptions: None.

Published Events:

/* Notifies subscribers of a state change in the MaterialContainer. */

MaterialContainerStateChangeEvent

Provided Services:

/* The following operations are provided to trigger MaterialContainer state transitions. */

```
void makeManualControl ( )
     raises (Global::FrameworkErrorSignal,
          Global::InvalidStateTransitionSignal);

void makeStored ( )
     raises (Global::FrameworkErrorSignal,
          Global::InvalidStateTransitionSignal);

void makeInTransit ( )
     raises (Global::FrameworkErrorSignal,
          Global::InvalidStateTransitionSignal);

void makeProcessing ( )
     raises (Global::FrameworkErrorSignal,
          Global::InvalidStateTransitionSignal);

}; // MaterialContainer

typedef sequence <MaterialContainer> MaterialContainerSequence;
```

Dynamic Model:

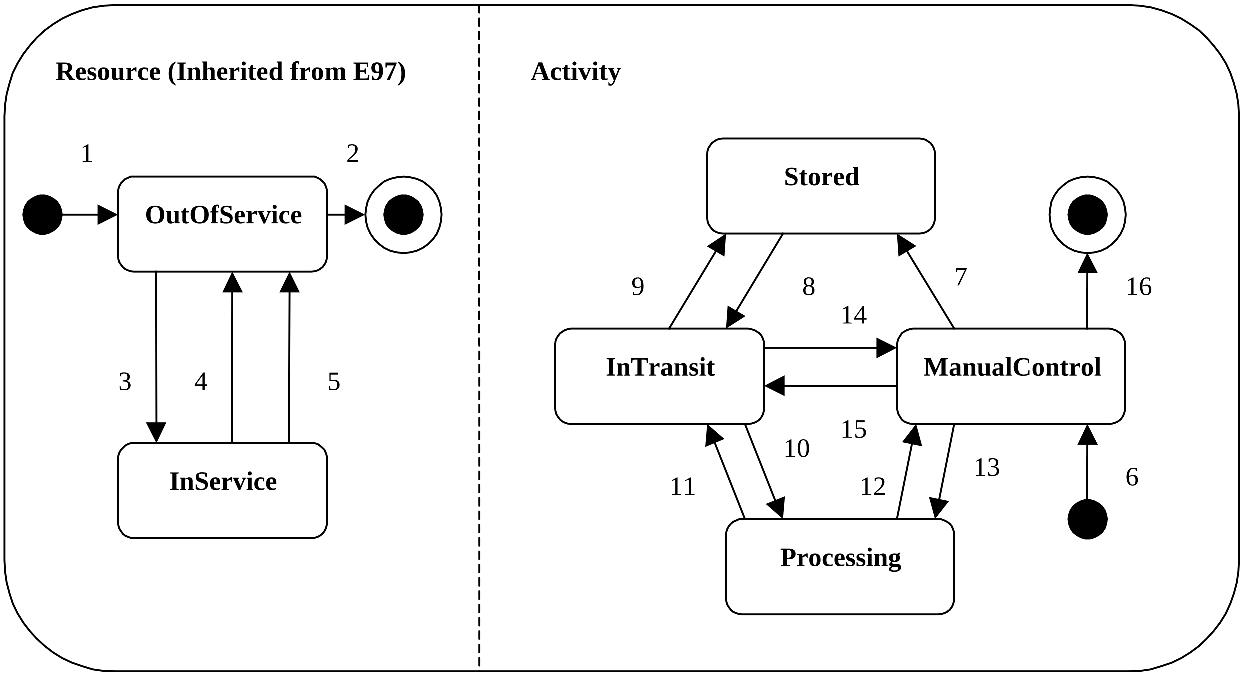

Figure 5
MaterialContainer Dynamic Model

Table 1 MaterialContainer State Definitions

State	*State Definition*	*Example*
InService	Inherited from Resource State Model	
OutOfService	Inherited from Resource State Model	
InTransit	Container is en route as the subject of a Transport Job.	Container is on an OHT transport vehicle.
Stored	Container is stored in a Storage Machine and not subject to a Transport Job.	Container is on a stocker shelf.
ManualControl	Container is outside of the control of the Material Transport and Storage Component.	Container is on a PGV.
Processing	Container is at process equipment.	Container is on a lithography tool.

Table 2 MaterialContainer State Transitions

#	*Current State*	*Trigger*	*Next State*	*Action*	*Comment*
1–5	NOTE: Transitions 1–5 are defined in the dynamic model inherited from Resource.				
6	N/A	makeManual Control()	ManualControl	MaterialContainer instance is created.	Initial state
7	ManualControl	makeStored()	Stored	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container is placed on input port of a Storage Machine without a TransportJob assigned to it.
8	Stored	makeInTransit()	InTransit	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has started to move. TransportJob state transitions to Executing.
9	InTransit	makeStored()	Stored	DurableLocation ChangedEvent Published	Container stored. TransportJob state

#	*Current State*	*Trigger*	*Next State*	*Action*	*Comment*
				by the instance of MaterialContainer	transitions to Completed.
10	InTransit	makeProcessing()	Processing	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has reached destination at process equipment. TransportJob state transitions to Completed.
11	Processing	makeInTransit()	InTransit	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has left process equipment. TransportJob state transitions to Executing.
12	Processing	makeManual Control()	ManualControl	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has left control of process equipment (not via TransportJob).
13	ManualControl	makeProcessing()	Processing	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has entered control of process equipment (not via TransportJob).
14	InTransit	makeManual Control()	ManualControl	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has left the control of the TransportJob via a manual output port. TransportJob state transitions to Aborted.
15	ManualControl	makeInTransit()	InTransit	DurableLocation ChangedEvent Published by the instance of MaterialContainer	Container has entered the AMHS via a manual input port. TransportJob state transitions to Executing.
16	ManualControl	none	N/A	none	MaterialContainer instance has been removed.

6.2.4 *Machine Abstract Interface Group (subset)*

This section includes only those interfaces and specific operations from the Machine Abstract Interface Group that are referenced within this component specification. These interfaces are provided here for referential integrity of this specification and are not intended to remain as part of this component. Further, this is not intended to be a comprehensive treatment of the required interfaces, but only the subset needed for reference until the full specification is adopted through a subsequent ballot. When that occurs, this specification can be updated to reference the interfaces directly rather than replicate them here.

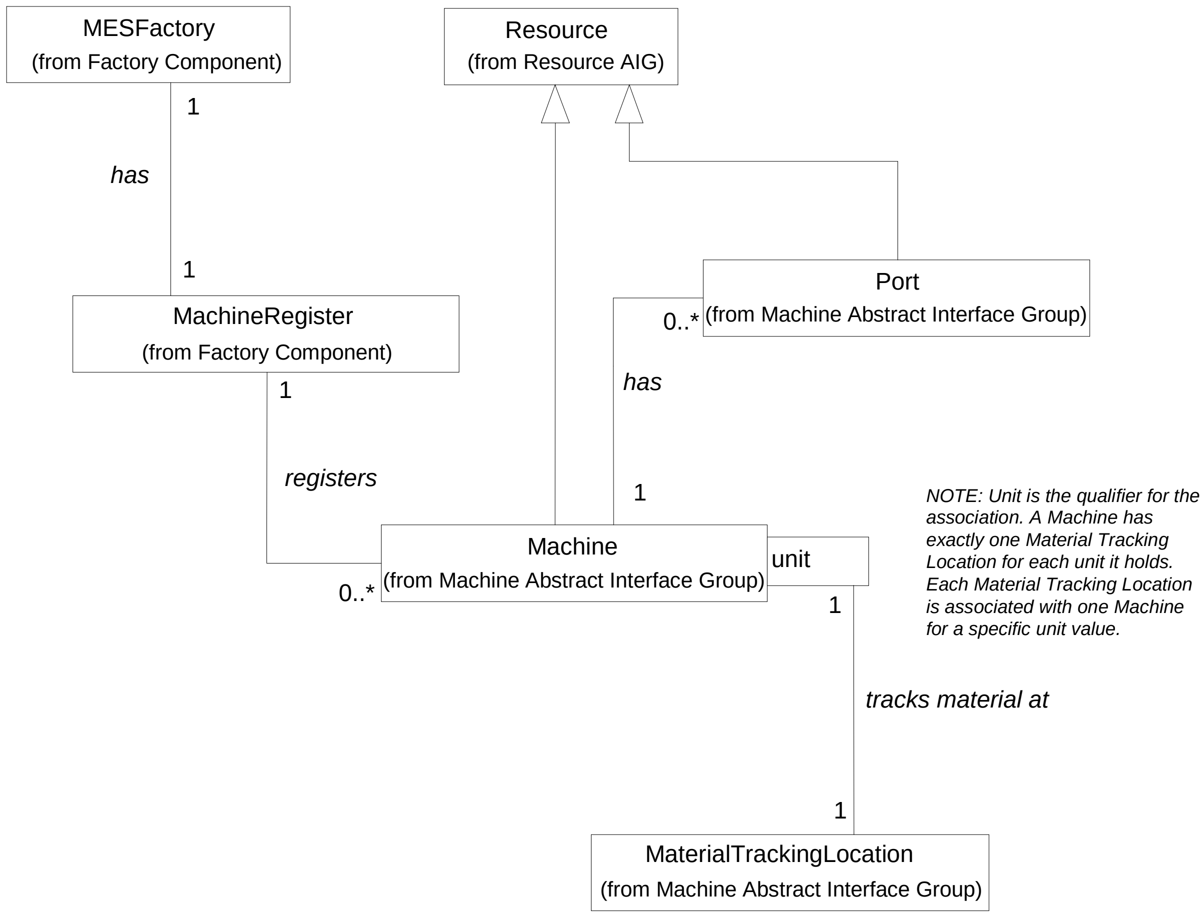

Figure 6
Machine Abstract Interface Group (subset) Information Model

6.2.4.1 *Machine Interface (subset)*

Module: MachineAIG

Interface: Machine

Inherited Interface: Resource

```
interface Machine : AbstractIF::Resource {
```

Description: This abstract interface representing the concept of a piece of equipment in the factory. A Machine establishes the identity of the physical equipment existing in the factory for reference within an MES context. The Machine also maintains one MaterialTrackingLocation for each Unit defined to classify the Material processed, used, or stored by the Machine.

Type Definitions:

```
typedef sequence <Machine> MachineSequence;

typedef sequence <MaterialTrackingLocation> MaterialTrackingLocationSequence;
```

```
typedef sequence <Port> PortSequence;

enum MachineType {
      FixedBufferProductionMachine,
      InternalBufferProductionMachine,
      StorageMachine,
      TransportMachine };
```

Exceptions:

/* Port indicated for receiving material was invalid. */

```
exception InvalidPortSignal { };
```

/* Material specified for unloading was invalid. */

```
exception InvalidMaterialSignal { };
```

Published Events:

/* An E10 State change has occurred in the Machine that the Factory needs to know. */

MachineResourceE10StateChangedEvent

Provided Services:

/* Set the MachineType for this machine. */

```
void setMachineType (
      in MachineType aMachineType )
      raises (Global::FrameworkErrorSignal);
```

/* Return the MachineType for this machine. */

```
MachineType getMachineType ( )
      raises (Global::FrameworkErrorSignal);
```

/* Set up a MaterialTrackingLocation for this Machine to track a particular material Unit characterizing its contents. A Machine may have more than one MaterialTrackingLocation as long as each is tracking a different Unit. The value of Unit is used with corresponding attributes of the material to allocate the tracked material to the correct MaterialTrackingLocation for a Machine. */

```
void setMaterialTrackingLocation (
      in MaterialTrackingLocation aMaterialTrackingLocation,
      in string aUnitToTrack)
      raises (Global::FrameworkErrorSignal);
```

/* Get all MaterialTrackingLocations for this Machine. There is one and only one MaterialTrackingLocation per Unit used in the Machine. */

```
MaterialTrackingLocationSequence getAllMaterialTrackingLocations ( )
      raises (Global::FrameworkErrorSignal);
```

/* Get the MaterialTrackingLocation for the Unit specified. */

```
MaterialTrackingLocation getMaterialTrackingLocation (
      in string aUnit)
      raises (Global::FrameworkErrorSignal);
```

/* Request a Machine to reserve a port to load material. This may involve communication between the Port and the Machine Objects, but these need not be public (or may involve communication between the Machine and the Equipment). If requestedPort parameter left null, machine chooses the requestedPort. Returns Null if Machine cannot or refuses to comply. */

```
Port reservePortForTransferTo (
     in DurablesManagement::MaterialContainer aContainer,
     in Port requestedPort )
     raises (Global::FrameworkErrorSignal,
          InvalidPortSignal);
```

/* Request a Machine to reserve a port to load two or more MaterialContainers. All MaterialContainers in the sequence must be loaded before the Machine can accept another port reservation request. The MaterialContainers specified in the MaterialContainerSequence may be loaded in any order. If requestedPort parameter left null, machine chooses the requestedPort. Returns Null if Machine cannot or refuses to comply. */

```
Port reservePortForBatchTransferTo (
     in DurablesManagement::MaterialContainerSequence aContainerGroup,
     in Port requestedPort )
     raises (Global::FrameworkErrorSignal,
          InvalidPortSignal);
```

/* Request a Machine to cancel a reservation previously established for a transfer to a port. */

```
void cancelPortReservationForTransferTo (
     in DurablesManagement::MaterialContainer aContainer,
     in Port requestedPort )
     raises (Global::FrameworkErrorSignal,
          InvalidPortSignal);
```

/* Inform a Machine that a transfer to or from a port has been completed. This may involve communication between the Port and the Machine Objects, but these need not be public (or may involve communication between the Machine and the Equipment). */

```
void transferComplete (in DurablesManagement::MaterialContainer aContainer,
     in Port reservedPort )
     raises (Global::FrameworkErrorSignal,
          InvalidPortSignal);
```

/* Request a Machine to prepare to unload material. Returns the Port on which the material will be unloaded or Null if the Machine cannot or refuses to comply. */

```
Port containerOut (
     in DurablesManagement::MaterialContainer aContainer,
     in Port requestedPort )
     raises (Global::FrameworkErrorSignal,
          InvalidMaterialSignal);
```

/* Returns a list of all Ports for the machine. */

```
PortSequence allPorts ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns the list of all Areas that this Machine is in. */

```
AreaSequence allAreas( )
     raises (Global::FrameworkErrorSignal);

}; // Machine
```

6.2.4.2 *MaterialTrackingLocation Interface*

Module: MachineAIG

Interface: MaterialTrackingLocation

Inherited Interface: OwnedEntity

```
interface MaterialTrackingLocation : AbstractIF::OwnedEntity {
```

Description: A MaterialTrackingLocation is a place where Material may be held. The "type" of the location is based on the classification Unit of Material that the location can hold (e.g., locations to hold wafers have a "Wafer" Unit and can only hold this Material type). Each machine has one MaterialTrackingLocation for each material Unit. The MaterialTrackingLocation also maintains a capacity.

Exceptions:

/* Material specified in the call is not a valid Material for this MaterialTrackingLocation. */

```
exception InvalidMaterialSignal { };
```

/* Intent to assign more Material to the MaterialTrackingLocation failed because it is full. */

```
exception MaterialTrackingLocationFullSignal { };
```

/* Unit value is not valid for the MaterialTrackingLocation. */

```
exception InvalidUnitSignal { };
```

Published Events:

/* A Material Tracking Location has reached its capacity. */

MaterialTrackingLocationFullEvent

/* A Material Tracking Location that was previously Full now has available capacity. */

MaterialTrackingLocationNotFullEvent

Provided Services:

/* Return the Material at the MaterialTrackingLocation, return nil if the location is empty. */

```
AbstractIF::MaterialSequence allMaterialHeld ( )
     raises (Global::FrameworkErrorSignal);
```

/* Get and set the unique identifier for the MaterialTrackingLocation. */

```
string getIdentifier ( )
     raises (Global::FrameworkErrorSignal);

void setIdentifier (
     in string identifier)
     raises (Global::FrameworkErrorSignal,
          Global::SetValueOutOfRangeSignal,
          Global::DuplicateIdentifierSignal);
```

/* Return the Machine that holds this MaterialTrackingLocation. */

```
Machine getMachine ( )
     raises (Global::FrameworkErrorSignal);
```

/* Set the material Unit that can be held in the MaterialTrackingLocation. Example: If the MaterialTrackingLocation is to hold wafers, the Unit could be "wafer". If it was a particular size of Wafer the Unit could be "200mmWafer." */

```
void setUnit (
      in string aUnit)
      raises (Global::FrameworkErrorSignal,
            InvalidUnitSignal);
```

/* Get the Unit for the MaterialTrackingLocation. */

```
string getUnit ( )
      raises (Global::FrameworkErrorSignal);
```

/* Add a Material to the MaterialTrackingLocation. */

```
void addMaterialToTrack (
      in AbstractIF::Material aMaterial )
      raises (Global::FrameworkErrorSignal,
            InvalidMaterialSignal,
            MaterialTrackingLocationFullSignal);
```

/* Remove a Material from the MaterialTrackingLocation. */

```
void removeMaterial (
      in AbstractIF::Material aMaterial )
      raises (Global::FrameworkErrorSignal,
            InvalidMaterialSignal);
```

/* Reserve capacity of the MaterialTrackingLocation. If accepted, this portion of the MaterialTrackingLocation's capacity will be kept for the designated material. If the capacity is reserved the operation returns True. */

```
boolean reserveCapacity (
      in AbstractIF::Material capacityToReserve)
      raises (InvalidUnitSignal,
            InvalidMaterialSignal,
            MaterialTrackingLocationFullSignal,
            Global::FrameworkErrorSignal);
```

/* Release reserved capacity of the MaterialTrackingLocation. If accepted, this portion of the MaterialTrackingLocation's capacity will be released for use by other material. */

```
boolean releaseCapacity (
      in AbstractIF::Material capacityToRelease)
      raises (Global::FrameworkErrorSignal);
```

/* Get and set the Maximum Capacity for the MaterialTrackingLocation. */

```
void setMaximumCapacity (
      in long maximum)
      raises (Global::FrameworkErrorSignal,
            Global::SetValueOutOfRangeSignal);

long getMaximumCapacity ( )
      raises (Global::FrameworkErrorSignal);
```

/* Get the Available Capacity for the MaterialTrackingLocation. Available Capacity is the difference between Maximum Capacity and the count of the sequence returned by AllMaterialHeld. */

```
long getAvailableCapacity ( )
      raises (Global::FrameworkErrorSignal);
```

/* Get the Reserved Capacity for the MaterialTrackingLocation. Reserved Capacity is the portion of the AvailableCapacity that has been set aside for known material that has not yet arrived. */

```
long getReservedCapacity ( )
     raises (Global::FrameworkErrorSignal);
```

/* This is a query for the availability status of the MaterialTrackingLocation. Available means the MaterialTrackingLocation has available capacity in which more material could go. */

```
boolean hasAvailableCapacity ( )
     raises (Global::FrameworkErrorSignal);

}; // MaterialTrackingLocation
```

6.2.4.3 *Port Interface (subset)*

Module:	MachineAIG
Interface:	Port
Inherited Interface:	Resource

```
interface Port : AbstractIF::Resource {
```

Description:	The Port represents the point at which a “change of ownership” occurs during a material transfer. Each Port has at least one associated Machine and the Port may be thought of as an “access point” to the Machine.
Exceptions:	None.
Events:	None.

Provided Services:

/* Returns the machine to which this port belongs. */

```
Machine getMachine ( )
     raises (Global::FrameworkErrorSignal);

}; // Port
```

6.2.5 *Factory Operations Component (subset)* — This section includes only those interfaces and specific operations from the Factory Component that are referenced within this component specification. These interfaces are provided here for referential integrity of this specification and are not intended to remain as part of this component. Further, this is not intended to be a comprehensive treatment of the required interfaces, but only the subset needed for reference until the full specification is adopted through a subsequent ballot for the full Factory Operations component. When that occurs, this specification can be updated to reference the interfaces directly rather than replicate them here.

6.2.5.1 *MachineRegister Interface*

Module:	FactoryOperations
Interface:	MachineRegister
Inherited Interface:	Resource

```
interface MachineRegister : AbstractIF::Resource {
```

Description:	The MachineRegister maintains a list of known machines for the factory and supplies related information on demand. There is only one MachineRegister per factory. NOTE: this interface may eventually be replaced by the trader service.

Exceptions:

/* An attempt was made to locate an unknown Machine. */

```
exception MachineNotFoundSignal {string machineName;};
```

```
exception MachineRemovalFailedSignal { };
```

Published Events:

/* Event indicating that a Machine has been added or removed from the Factory. */

MachineListChangedEvent

Provided Services:

/* Add a Machine to the set of machine(s) managed by the MachineRegister. */

```
void addMachine (in Machine aMachine)
     raises (Global::FrameworkErrorSignal);
```

/* Remove a Machine from the set of machine(s) managed by the MachineRegister. */

```
void removeMachine (in Machine aMachine)
     raises (Global::FrameworkErrorSignal,
          MachineRemovalFailedSignal);
```

/* Return a sequence of all machines managed by the MachineRegister. */

```
MachineSequence allMachines ( )
     raises (Global::FrameworkErrorSignal);
```

/* Return the Machine corresponding to the given name. */

```
Machine findMachineNamed (in string identifier)
     raises (Global::FrameworkErrorSignal,
          MachineNotFoundSignal) ;
```

Contracted Services: None.

Dynamic Model: None.

```
}; // MachineRegister
```

6.3 *Material Transport Abstract Interfaces* — The Material Transport Abstract Interfaces are defined to perform material transport at the factory level. The TransportJobSupervisor interface must be specialized by the users of the Material Transport Manager Interface. These interfaces provide a way to track the job through the factory.

6.3.1 *TransportJobSupervisor Interface*

Module: MaterialTransport

Interface: TransportJobSupervisor

Inherited Interface: JobSupervisor

```
interface TransportJobSupervisor : AbstractIF::JobSupervisor {
```

Description: TransportJobSupervisor is an abstract interface which provides the operations needed by clients to request, track, and control material transport within the domain of the specific TransportJobSupervisor. Any entity which is responsible for moving material will inherit and implement TransportJobSupervisor.

Type Definitions:

```
typedef sequence <Global::Properties> JobSpecSequence;
```

Exceptions:

```
exception UnsupportedDestinationTypeSignal { };
```

Published Events: None.

Provided Services:

The Creation of TransportJobs is accomplished by use of the requestJob operation from the inherited JobSupervisor interface. The “JobType” property specified in the inherited interface should be set to “TransportJobType” for all TransportJob requests. The additional Job Specification properties required for the creation of Transport jobs are defined in Table 3. The types of machines specified in the TransportJob are AMHS Storage Machines, Fixed Buffer Production Equipment, or Internal Buffer Production Equipment. Each machine type represents a separate case used in defining the Job Specification for a Transport Job, and these cases are also defined in Table 3.

For transportJobs, the inherited ABORTING and ABORTED states may not always result in an immediate termination of the job and associated activities. For example, transportJobs may involve autonomous transport equipment that operate without persistent communication links to the TransportJob and TransportJobSupervisor objects. In these cases there may be a time delay before the results of a transportJob makeAborted request can be enacted to allow the transport equipment to reach a known location. In other cases a movement activity must reach a stable condition before it can be interrupted. The location of the MaterialContainer associated with the aborted TransportJob is the nearest location where movement can be safely and reliably interrupted.

By contrast, if a transportJob is transitioned to the inherited STOPPING state, the location of the MaterialContainer associated with the stopped TransportJob must be a legal Source for issuing a new TransportJob.

Table 3 Additional Required Properties for Transport Jobs

Name	*Value Type*	*Description*
“Container”	MaterialContainer	Container being transported.
“SourceMachine”	Machine	The source production machine for the transport job. AMHS Storage Equipment: SourceMachine is Optional. Fixed Buffer Production Equipment: SourceMachine is Required. Internal Buffer Production Equipment: SourceMachine is Required.
“SourcePort”	Port	The source production machine port for the transport job. AMHS Storage Equipment: SourcePort is Optional. Fixed Buffer Production Equipment: SourcePort is Required. Internal Buffer Production Equipment: SourcePort is optional. Port may be obtained dynamically with the containerOut operation or it may be predefined in the TransportJob specification.
“DestinationArea”	Area	The destination area for the transport job. DestinationArea shall contain only StorageMachines. The implementation shall determine the specific machine to which the MaterialContainer is delivered. AMHS Storage Equipment: DestinationArea is optional. Fixed Buffer Production Equipment: DestinationArea is not allowed. Internal Buffer Production Equipment: DestinationArea is not allowed.
“DestinationMachine”	Machine	The destination machine for the transport job. AMHS Storage Equipment: DestinationMachine is required if DestinationArea is not specified. Fixed Buffer Production Equipment: DestinationMachine is required. Internal Buffer Production Equipment: DestinationMachine is required.

Name	Value Type	Description
"DestinationPort"	Port	The destination port for the transport job. AMHS Storage Equipment: DestinationPort is required for Manual output port destinations. Fixed Buffer Production Equipment: DestinationPort is required. Internal Buffer Production Equipment: DestinationPort is NULL.

/* The requestBatchTransportJob operation will provide two or more job specifications for transport jobs that share a dependency on completion. All job specifications must have the same priority. In the normal case, the TransportJobSupervisor will create simple transport jobs for each job specification and return the jobs as a sequence. Subsequently, if one of the simple jobs cannot complete, the other subordinate jobs must be reassessed by the JobRequestor to determine the appropriate corrective action. In this case, the TransportJobSupervisor will notify the JobRequestor of the job failure with the informJobTerminated message and pause the other jobs of the batch-job to allow the JobRequestor to determine its response. Implementations may implement the TransportJobSupervisor with more complex default actions in response to a partial failure of a batch-transport-job, but these more complex scenarios are not part of the standard behavior for this operation. */

```
AbstractIF::JobSequence requestBatchTransportJob (
     in JobSpecSequence jobSpecs,
     in AbstractIF::JobRequestor aJobRequestor)
     raises (Global::FrameworkErrorSignal,
          AbstractIF::JobSupervisor::JobRejectedSignal);
```

Contracted Services: None

Dynamic Model: None

```
}; // TransportJobSupervisor
```

6.4 *Material Transport and Storage Component*

6.4.1 This component is concerned only with factory-wide material transport and not the movement of material within a piece of equipment. Also note that material can be either product, durables, or consumables. The CIM Framework recognizes the potential for multiple AMHS's within a single factory (e.g., one supplier of interbay movement and another supplier of intrabay movement). The MES, however, wants to only have to issue a move request ("move this material from here to there") without regard to whether that transport spans one or more AMHS's. Therefore, the component supporting material transport requires a single entry point for initiating material transport which will be through the Material Transport Manager (MTM).

6.4.2 The Material Transport Manager must be able manage transport jobs carried out by many different AMHS's. To accomplish this, a separate interface for a Material Transport Controller (MTC) is specified. In the simplest implementations, a single MTM may manage all TransportJobs directly. In this case no separate Material Transport Controller implementation is needed. If there is a need for delegation to one or more Material Transport Controllers, the Material Transport Manager can register any conformant MTC implementation which supports the specified interface. The low-level interaction of the material movement controllers with the physical equipment (transport machines, storage machines and ports) is encapsulated within the scope of this component. Note that the component manager does not provide lifecycle services for its managed material movement controllers, but instead uses the registration interfaces.

6.4.3 *MaterialTransportManager Interface*

Module: MaterialTransport

Interface: MaterialTransportManager

Inherited Interface: ComponentManager, TransportJobSupervisor, JobRequestor

```
interface MaterialTransportManager : FactoryOperations::ComponentManager,
     TransportJobSupervisor, AbstractIF::JobRequestor {
```

Description: A MaterialTransportManager (MTM) operates on requests to move material in the factory. It returns a TransportJob to the requestor, allowing the requestor to track the status and progress of the move. The MTM may perform these TransportJobs by breaking them into separate tasks to be performed by MaterialTransportControllers (MTC). If TransportJobs are decomposed, the MaterialTransportManager then tracks the MTC TransportJobs to fulfill its commitment.

Exceptions:

```
exception MaterialTransportControllerNotRegisteredSignal { };
```

Published Events: None.

Provided Services:

/* Add a MaterialTransportController to the collection of MaterialTransportControllers which the MaterialTransportManager can use to carry out jobs. */

```
void registerMaterialTransportController (
     in MaterialTransportController aMaterialTransportController)
     raises (Global::FrameworkErrorSignal);
```

/* Remove a MaterialTransportController from the list of resources available to the MaterialTransportManager. No new jobs will be issued but existing jobs will be unaffected. */

```
void unregisterMaterialTransportController (
     in MaterialTransportController aMaterialTransportController)
     raises (Global::FrameworkErrorSignal,
          MaterialTransportControllerNotRegisteredSignal);
```

/* Return a list of all MaterialTransportControllers managed by the MaterialTransportManager. */

```
MaterialTransportControllerSequence allMaterialTransportControllers ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns a list of all material in the material transport system. */

```
AbstractIF::MaterialSequence allMaterial ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns a list of all material in transit in the material transport system. */

```
AbstractIF::MaterialSequence allMaterialInTransit ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns a list of all material in storage in the material transport system. */

```
AbstractIF::MaterialSequence allMaterialInStorage ( )
     raises (Global::FrameworkErrorSignal);
```

Contracted Services: None

Dynamic Model: None

```
}; // MaterialTransportManager
```

6.4.4 *MaterialTransportController Interface*

Module: MaterialTransport

Interface: MaterialTransportController

Inherited Interface: TransportJobSupervisor

```
interface MaterialTransportController : TransportJobSupervisor {
```

Description: A MaterialTransportController accepts transport job requests, schedules them, and executes them in order to move material around the factory or a part of the factory.

Exceptions: None.

Published Events: None.

Provided Services:

```
typedef sequence <MaterialTransportController> MaterialTransportControllerSequence;
```

/* Returns a list of all material in the domain of this material transport controller. */

```
AbstractIF::MaterialSequence allMaterial ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns a list of all material in transit in the domain of this material transport controller. */

```
AbstractIF::MaterialSequence allMaterialInTransit ( )
     raises (Global::FrameworkErrorSignal);
```

/* Returns a list of all material in storage in the domain of this material transport controller. */

```
AbstractIF::MaterialSequence allMaterialInStorage ( )
     raises (Global::FrameworkErrorSignal);
```

Contracted Services: None

Dynamic Model: None

```
}; // MaterialTransportController
```

6.4.5 *TransportJob Interface*

Module: MaterialTransport

Interface: TransportJob

Inherited Interface: Job

```
interface TransportJob : AbstractIF::Job {
```

Description: This type of Job performs a specific transport of material. The ongoing status of the move can be monitored by subscribing to the appropriate Job events.

Exceptions:

```
exception TimeUndeterminableSignal { };
```

Published Events: Same as Job

Provided Services:

/* Determine if the move can be completed by the specified time. */

```
boolean canCompleteBy (
     in Global::TimeStamp whenNeeded)
     raises (Global::FrameworkErrorSignal,
          TimeUndeterminableSignal);
```

/* Estimate how long this job will take once it begins. */

```
Global::Duration transportTime ( )
     raises (Global::FrameworkErrorSignal,
          TimeUndeterminableSignal);
```

Contracted Services: None

Dynamic Model: None

```
}; // TransportJob
```

6.4.6 *TransportMachine Interface*

Module: MaterialTransport

Interface: TransportMachine

Inherited Interface: Machine

```
interface TransportMachine : MachineAIG::Machine {
```

Description: This concrete specialization of Machine represents the equipment used to transport material within the factory. Implementations of the Material Transport and Storage Component would provide implementations supporting this interface for each TransportMachine registered with the factory.

Exceptions: None

Published Events: Same as Machine

Provided Services: None

Contracted Services: None

Dynamic Model: None

```
}; // TransportMachine
```

6.4.7 *StorageMachine Interface*

Module: MaterialTransport

Interface: StorageMachine

Inherited Interface: Machine

```
interface StorageMachine : MachineAIG::Machine {
```

Description: This concrete specialization of Machine represents the equipment used to store material within the factory. Implementations of the Material Transport and Storage Component would provide implementations supporting this interface for each StorageMachine registered with the factory.

Exceptions: None

Published Events:

*/ Notifies subscribers that a MaterialContainer arrived on a manual input port may require further action (e.g., creation of a TransportJob or transfer to a particular logical partition). */

```
const string MaterialContainerArrivedAtManualInputPortSubject =
      "/MaterialTransport/StorageMachine/MaterialContainerArrivedAtManualInputPort";

struct MaterialContainerArrivedAtManualInputPortFilters {
      Global::Property Port;
      Global::Property MaterialContainer;
};
```

Table 4 MaterialContainerArrivedAtManualInputPortFilters Properties:

Name	*Value Type*	*Description*
"Port"	MachineAIG::Port	The port where the MaterialContainer was placed.
"MaterialContainer"	DurablesManagement::Material Container	The carrier that arrived at the manual input port.

```
struct MaterialContainerArrivedAtManualInputPortEvent {
     string eventSubject;
     Global::TimeStamp eventTimeStamp;
     MaterialContainerArrivedAtManualInputPortFilters eventFilterData;
     Global::Properties eventNews;
     StorageMachine aMachine
};
```

Provided Services: None

Contracted Services: None

Dynamic Model: None

```
}; // StorageMachine
```

APPENDIX 1
COMPLETE LISTING OF MATERIAL TRANSPORT IDL

NOTE: The material in this appendix is an official part of SEMI E10# and was approved by full letter ballot procedures on January 14, 2000 by the Japanese Regional Standards Committee.

```
module CIMFW {

#include <Global.idl>

#include <FactoryLabor.idl>

#include <AbstractIF.idl>

#include <FactoryOperations.idl>

module MachineAIG {

      interface Machine;

      interface MaterialTrackingLocation;

      interface Port;

      typedef sequence <Machine> MachineSequence;

      exception MachineDuplicateSignal { };

      exception MachineNotAssignedSignal { };

      exception MachineRemovalFailedSignal { };

      exception MaterialTrackingLocationFullSignal { };

      interface Machine : AbstractIF::Resource {

            typedef sequence <Machine> MachineSequence;

            typedef sequence <MaterialTrackingLocation>
            MaterialTrackingLocationSequence;

            typedef sequence <Port> PortSequence;

            enum MachineType {
                  FixedBufferProductionMachine,
                  InternalBufferProductionMachine,
                  StorageMachine,
                  TransportMachine };

            exception InvalidPortSignal { };

            exception InvalidMaterialSignal { };

            void setMachineType (
                  in MachineType aMachineType )
                  raises (Global::FrameworkErrorSignal);

            MachineType getMachineType ( )
                  raises (Global::FrameworkErrorSignal);
```

```
        void setMaterialTrackingLocation (
             in MaterialTrackingLocation aMaterialTrackingLocation,
             in string aUnitToTrack)
             raises (Global::FrameworkErrorSignal);

        MaterialTrackingLocationSequence getAllMaterialTrackingLocations ( )
             raises (Global::FrameworkErrorSignal);

        MaterialTrackingLocation getMaterialTrackingLocation (
             in string aUnit)
             raises (Global::FrameworkErrorSignal);

        Port reservePortForTransferTo (
             in DurablesManagement::MaterialContainer aContainer,
             in Port requestedPort )
             raises (Global::FrameworkErrorSignal,
                  InvalidPortSignal);

        Port reservePortForBatchTransferTo (
             in DurablesManagement::MaterialContainerSequence aContainerGroup,
             in Port requestedPort )
             raises (Global::FrameworkErrorSignal,
                  InvalidPortSignal);

        void cancelPortReservationForTransferTo (
             in DurablesManagement::MaterialContainer aContainer,
             in Port requestedPort )
             raises (Global::FrameworkErrorSignal,
                  InvalidPortSignal);

        void transferComplete (in DurablesManagement::MaterialContainer aContainer,
             in Port reservedPort )
             raises (Global::FrameworkErrorSignal,
                  InvalidPortSignal);

        Port containerOut (
             in DurablesManagement::MaterialContainer aContainer,
             in Port requestedPort )
             raises (Global::FrameworkErrorSignal,
                  InvalidMaterialSignal);

        PortSequence allPorts ( )
             raises (Global::FrameworkErrorSignal);

        FactoryOperations::AreaSequence allAreas( )
             raises (Global::FrameworkErrorSignal);

   }; // Machine

   interface MaterialTrackingLocation : AbstractIF::OwnedEntity {

        exception InvalidMaterialSignal { };

        exception MaterialTrackingLocationFullSignal { };

        exception InvalidUnitSignal { };

        AbstractIF::MaterialSequence allMaterialHeld ( )
             raises (Global::FrameworkErrorSignal);
```

```
    string getIdentifier ( )
        raises (Global::FrameworkErrorSignal);

    void setIdentifier (
        in string identifier)
        raises (Global::FrameworkErrorSignal,
            Global::SetValueOutOfRangeSignal,
            Global::DuplicateIdentifierSignal);

    Machine getMachine ( )
        raises (Global::FrameworkErrorSignal);

    void setUnit (
        in string aUnit)
        raises(Global::FrameworkErrorSignal,
        InvalidUnitSignal);

    string getUnit ( )
        raises (Global::FrameworkErrorSignal);

    void addMaterialToTrack (
        in AbstractIF::Material aMaterial )
        raises (Global::FrameworkErrorSignal,
            InvalidMaterialSignal,
            MaterialTrackingLocationFullSignal);

    void removeMaterial (
        in AbstractIF::Material aMaterial )
        raises (Global::FrameworkErrorSignal,
            InvalidMaterialSignal);

    boolean reserveCapacity (
        in AbstractIF::Material capacityToReserve)
        raises (InvalidUnitSignal,
            InvalidMaterialSignal,
            MachineAIG::MaterialTrackingLocationFullSignal,
            Global::FrameworkErrorSignal);

    boolean releaseCapacity (
        in AbstractIF::Material capacityToRelease)
        raises (Global::FrameworkErrorSignal);

    void setMaximumCapacity (
        in long maximum)
        raises (Global::FrameworkErrorSignal,
            Global::SetValueOutOfRangeSignal);

    long getMaximumCapacity ( )
        raises (Global::FrameworkErrorSignal);

    long getAvailableCapacity ( )
        raises (Global::FrameworkErrorSignal);

    long getReservedCapacity ( )
        raises (Global::FrameworkErrorSignal);

    boolean hasAvailableCapacity ( )
        raises (Global::FrameworkErrorSignal);

}; // MaterialTrackingLocation
```

```
    interface Port : AbstractIF::Resource {

        MachineAIG::Machine getMachine ( )
            raises (Global::FrameworkErrorSignal);

    }; // Port

}; // module MachineAIG

module DurablesManagement {

    interface Durable : AbstractIF::Material {

        void setMaterialTrackingLocation (
            in MachineAIG::MaterialTrackingLocation aMaterialTrackingLocation)
            raises (Global::FrameworkErrorSignal,
                MachineAIG::
        MaterialTrackingLocation::MaterialTrackingLocationFullSignal);

        MachineAIG::MaterialTrackingLocation getMaterialTrackingLocation ( )
            raises (Global::FrameworkErrorSignal);

        void setUnit(
            in string aUnit)
            raises (Global::FrameworkErrorSignal,
                MachineAIG::MaterialTrackingLocation::InvalidUnitSignal);

        string getUnit( )
            raises (Global::FrameworkErrorSignal);

    }; // Durable

    interface MaterialContainer : Durable {

        void makeManualControl ( )
            raises (Global::FrameworkErrorSignal,
                Global::InvalidStateTransitionSignal);

        void makeStored ( )
            raises (Global::FrameworkErrorSignal,
                Global::InvalidStateTransitionSignal);

        void makeInTransit ( )
            raises (Global::FrameworkErrorSignal,
                Global::InvalidStateTransitionSignal);

        void makeProcessing ( )
            raises (Global::FrameworkErrorSignal,
                Global::InvalidStateTransitionSignal);

    }; // MaterialContainer

    typedef sequence <MaterialContainer> MaterialContainerSequence;

}; // module DurablesManagement {

#ifndef _CIMFW_MATERIAL_TRANSPORT_

#define _CIMFW_MATERIAL_TRANSPORT_
```

```
module MaterialTransport {

      interface MaterialTransportController;

      typedef sequence <MaterialTransportController>
      MaterialTransportControllerSequence;

      interface TransportJobSupervisor : AbstractIF::JobSupervisor {

            typedef sequence <Global::Properties> JobSpecSequence;

            exception UnsupportedDestinationTypeSignal { };

            AbstractIF::JobSequence requestBatchTransportJob (
                  in JobSpecSequence jobSpecs,
                  in AbstractIF::JobRequestor aJobRequestor)
                  raises (Global::FrameworkErrorSignal,
                        AbstractIF::JobSupervisor::JobRejectedSignal);

      }; // TransportJobSupervisor

      interface MaterialTransportManager : FactoryOperations::ComponentManager,
            TransportJobSupervisor, AbstractIF::JobRequestor {

            exception MaterialTransportControllerNotRegisteredSignal { };

            void registerMaterialTransportController (
                  in MaterialTransportController aMaterialTransportController)
                  raises (Global::FrameworkErrorSignal);

            void unregisterMaterialTransportController (
                  in MaterialTransportController aMaterialTransportController)
                  raises (Global::FrameworkErrorSignal,
                        MaterialTransportControllerNotRegisteredSignal);

            MaterialTransportControllerSequence allMaterialTransportControllers ( )
                  raises (Global::FrameworkErrorSignal);

            AbstractIF::MaterialSequence allMaterial ( )
                  raises (Global::FrameworkErrorSignal);

            AbstractIF::MaterialSequence allMaterialInTransit ( )
                  raises (Global::FrameworkErrorSignal);

            AbstractIF::MaterialSequence allMaterialInStorage ( )
                  raises (Global::FrameworkErrorSignal);

      }; // MaterialTransportManager

      interface MaterialTransportController : TransportJobSupervisor {

            AbstractIF::MaterialSequence allMaterial ( )
                  raises (Global::FrameworkErrorSignal);

            AbstractIF::MaterialSequence allMaterialInTransit ( )
                  raises (Global::FrameworkErrorSignal);

            AbstractIF::MaterialSequence allMaterialInStorage ( )
                  raises (Global::FrameworkErrorSignal);
```

```
    }; // MaterialTransportController

    interface TransportJob : AbstractIF::Job {

        exception TimeUndeterminableSignal { };

        boolean canCompleteBy (
            in Global::TimeStamp whenNeeded)
            raises (Global::FrameworkErrorSignal,
                TimeUndeterminableSignal);

        Global::Duration transportTime ( )
            raises (Global::FrameworkErrorSignal,
                TimeUndeterminableSignal);

    }; // TransportJob

    interface TransportMachine : MachineAIG::Machine {

    }; // TransportMachine

    interface StorageMachine : MachineAIG::Machine {

        const string MaterialContainerArrivedAtManualInputPortSubject =
            "/MaterialTransport/StorageMachine/
            MaterialContainerArrivedAtManualInputPort";

        struct MaterialContainerArrivedAtManualInputPortFilters {
            Global::Property Port;
            Global::Property MaterialContainer;
        };

        struct MaterialContainerArrivedAtManualInputPortEvent {
            string eventSubject;
            Global::TimeStamp eventTimeStamp;
            MaterialContainerArrivedAtManualInputPortFilters eventFilterData;
            Global::Properties eventNews;
            StorageMachine aMachine
        };

    }; // StorageMachine

}; // module MaterialTransport

#endif // _CIMFW_MATERIAL_TRANSPORT_

}; // module CIMFW
```

RELATED INFORMATION 1
SCENARIOS FOR MATERIAL TRANSPORT AND STORAGE

NOTE: This related information is not an official part of SEMI E10# and was derived from the work of the I300I/J300E AMHS workgroup accomplished during development of the proposed standard. This related information is included with the Material Transport and Storage Component specification to aid the readers in understanding the intent and use of the standard. This related information was approved for publication by full letter ballot procedures on January 14, 2000.

R1-1 Introduction

R1-1.1 *Scenario Assumptions* — These scenarios show possible implementations of the SEMI standard. The information shown here is intended to be a guide rather than describe rigid implementation rules. Some of the message sequences and implied functionality included in these scenarios will vary across different implementations.

R1-1.2 *Scenario Configuration* — There are thirteen scenarios included in this section. The first and last scenarios show all interactions at an individual interface level. For simplicity, the remaining scenarios show interactions abstracted up to the Component level. Background information related to the scenarios is shown in Figure R1-1. Table R1-1 outlines the thirteen scenario case conditions.

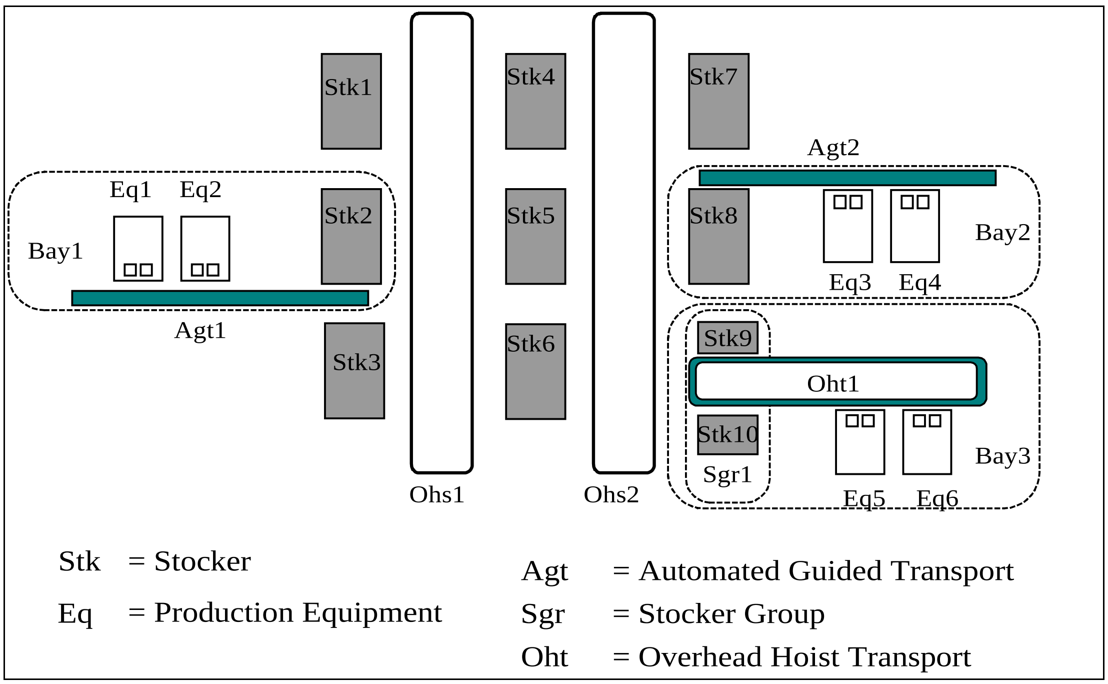

Figure R1-1
Scenario System Layout Configuration

Table R-1 Material Transport and Storage Scenario Definitions

Case	*Source*	*Destination*	*Batch Size*	*Route/Condition*	*Comments*
1	Stk4	Stk9 Manual Output Port	1 Carrier	Stk4>Ohs2>Stk9	Interactions at an individual interface level.
2	Eq1	Stk7	1 Carrier	Eq1>Agt1>Stk2>Ohs1>Stk(Relay)>Ohs2>Stk7 Stk(Relay) priority = Stk4, Stk5, Stk6	Base Scenario: Delivery from Production Equipment to Stocker.
3	Stk7	Eq3	2 Carriers	Stk7>Ohs2>Stk8>Agt2>Eq3 Eq3 batch size = 2 Carrier Ohs2 batch size = 1 Carrier Agt2 batch size = 2 Carrier	Base Scenario: Batch delivery from Stocker to Production Equipment.
4	Eq1	Stk7	1 Carrier	Eq1>Agt1>Stk2>Ohs1>Stk (Relay)>Ohs2>Stk8 (Temp)>Stk7 Stk(Relay) priority = Stk4, Stk5, Stk6 Stk4 Status = Down Stk7 logical partition = Full	Includes AMHS equipment (Storage Device) monitoring and stocker logical partition overflow control.
5	Stk6	Stk4	1 Carrier	Operator>Stk6	Manual Carrier Input handling.
6	Stk4	Stk9	1 Carrier	Stk4>Ohs2>Stk9 - Ohs2 Status = Down	Includes AMHS equipment (transport device) monitoring.
7	Stk7	Eq6	4 Carriers	Stk7>Ohs2>Sgr1>Oht1>Eq6 Eq6 has internal buffer, batch size = 4 carriers Ohs2 batch size = 1 carrier, Oht1 batch size = 1 carrier	Base scenario: Batch delivery to internal buffer equipment.
8	Stk5	Eq5	1 Carrier	Stk5>Ohs2>Sgr1>Oht1>Eq5 Macro command is aborted with carrier on Ohs2.	Includes abort job handling.
9	Stk5	Eq5	1 Carrier	Stk5>Ohs2>Sgr1>Oht1>Eq5 Macro command is modified to final destination Sgr1.	Includes modify job handling.
10	-	-	-	Startup - Material Transport and Storage Component is registered and starts up.	Base scenario: MTSC startup.
11	Stk6	Stk4	1 Carrier	Stk6>Ohs2>Stk4 - Operator removes carrier while on Ohs2.	Includes handling of manual interruption of delivery.
12	Eq3	Eq5	1 Carrier	Eq3>Agt2>Stk8>Ohs2>Sgr1>Oht1>Eq5	Base scenario: tool-to-tool delivery.
13	Stk4	Stk9	1 Carrier	Stk4>Ohs2>Stk9	Interactions at an individual interface level (including capacity reservation).

R1-2 Scenarios

R1-2.1 *Scenario One — Interactions at the Interface Level*

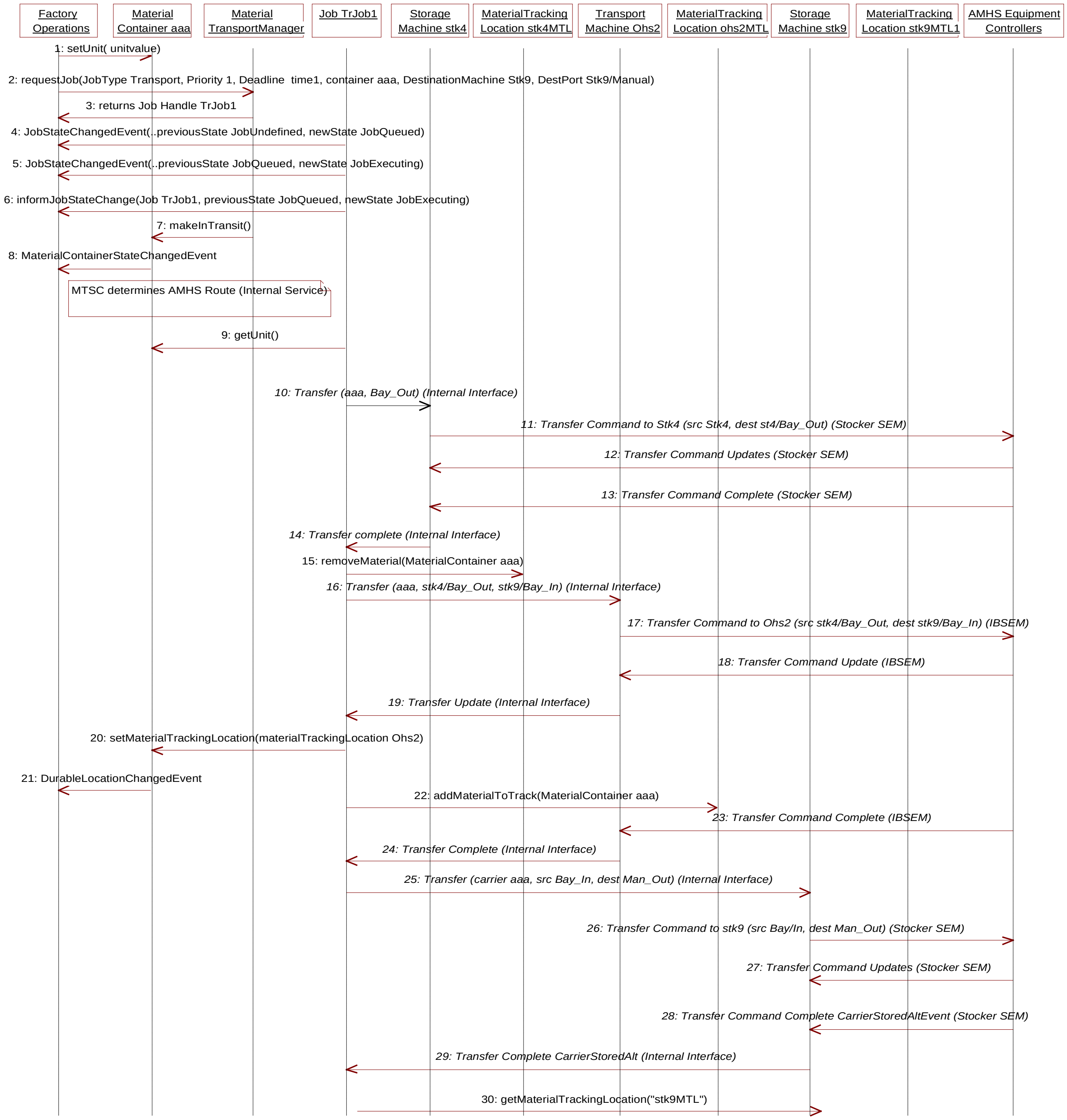

Figure R1-2
Scenario Case 1

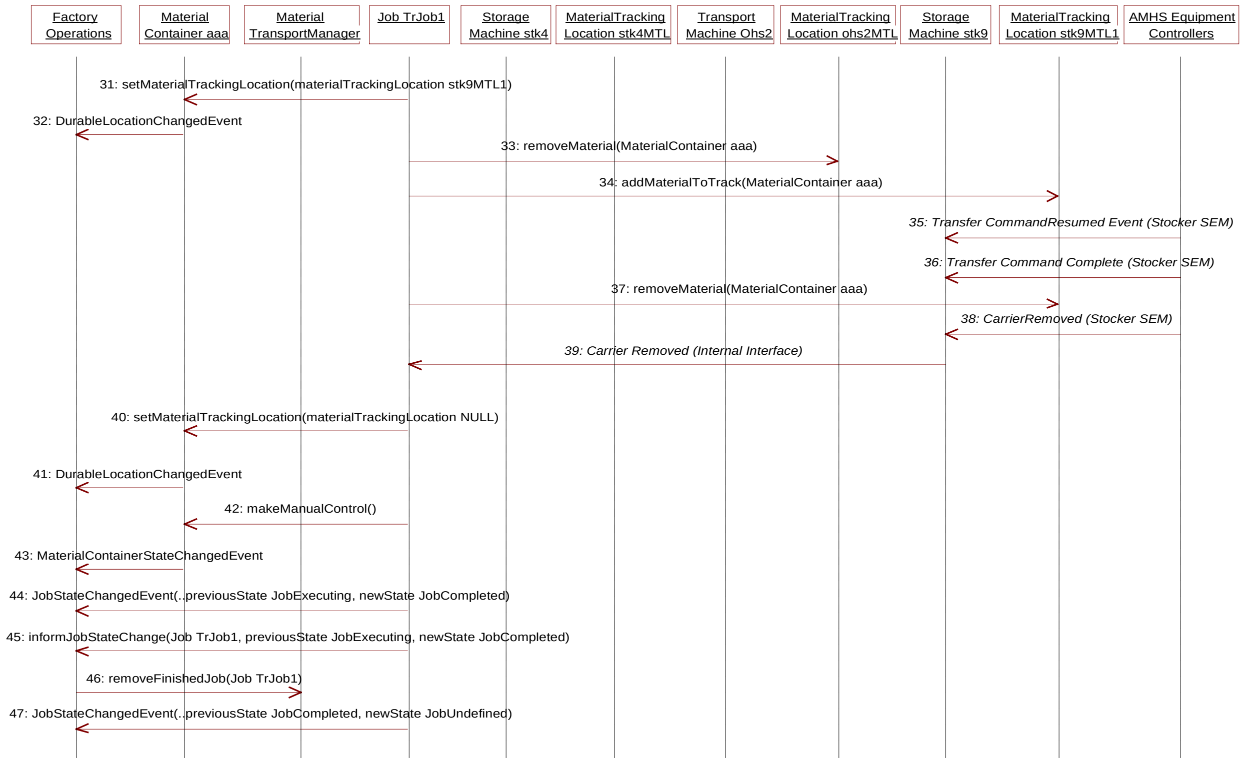

Figure R1-3
Scenario Case 1 (continued)

R1-2.2 *Scenario Two — Base Scenario for Delivery from Production Equipment to Stocker*

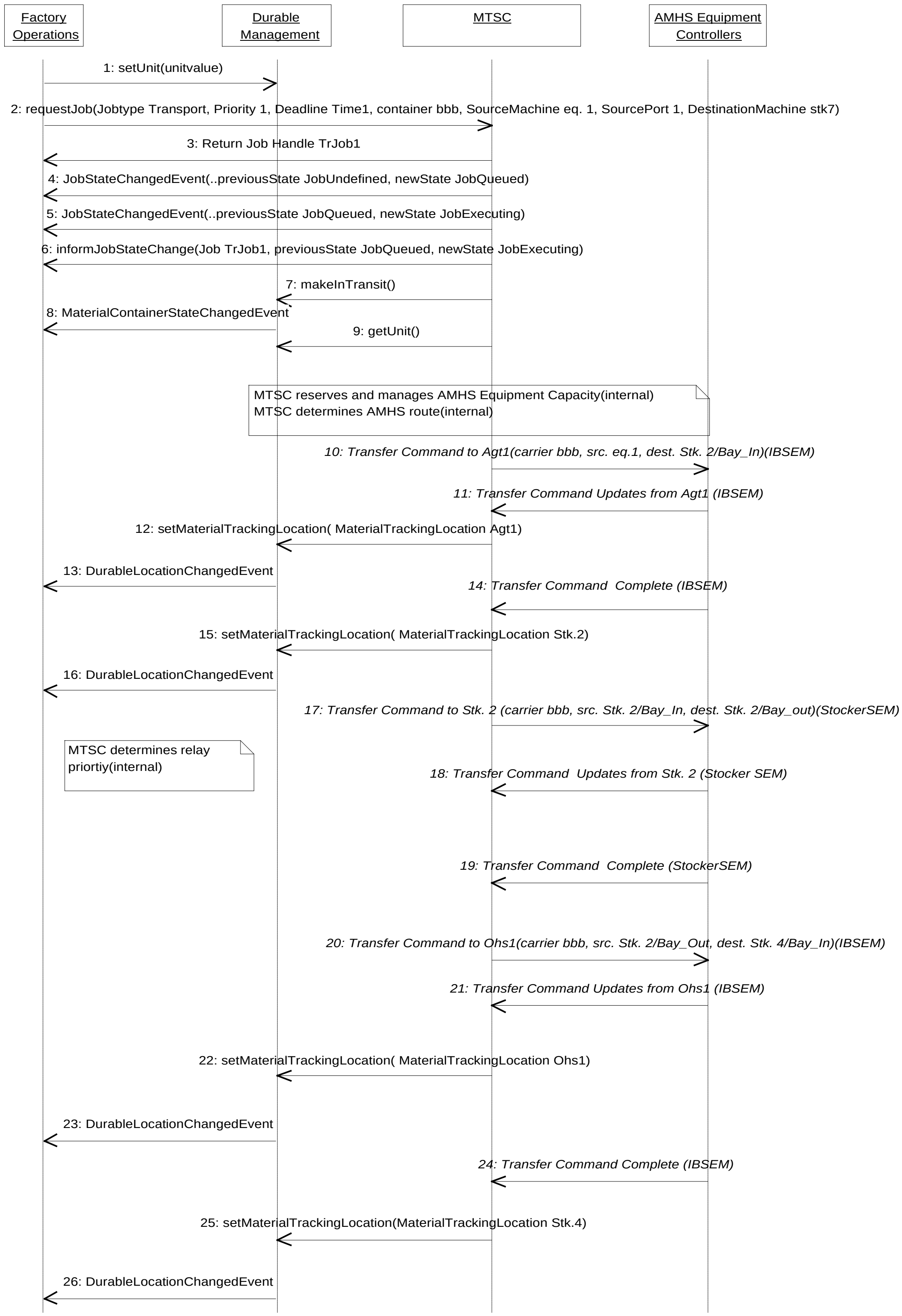

Figure R1-4
Scenario Case 2

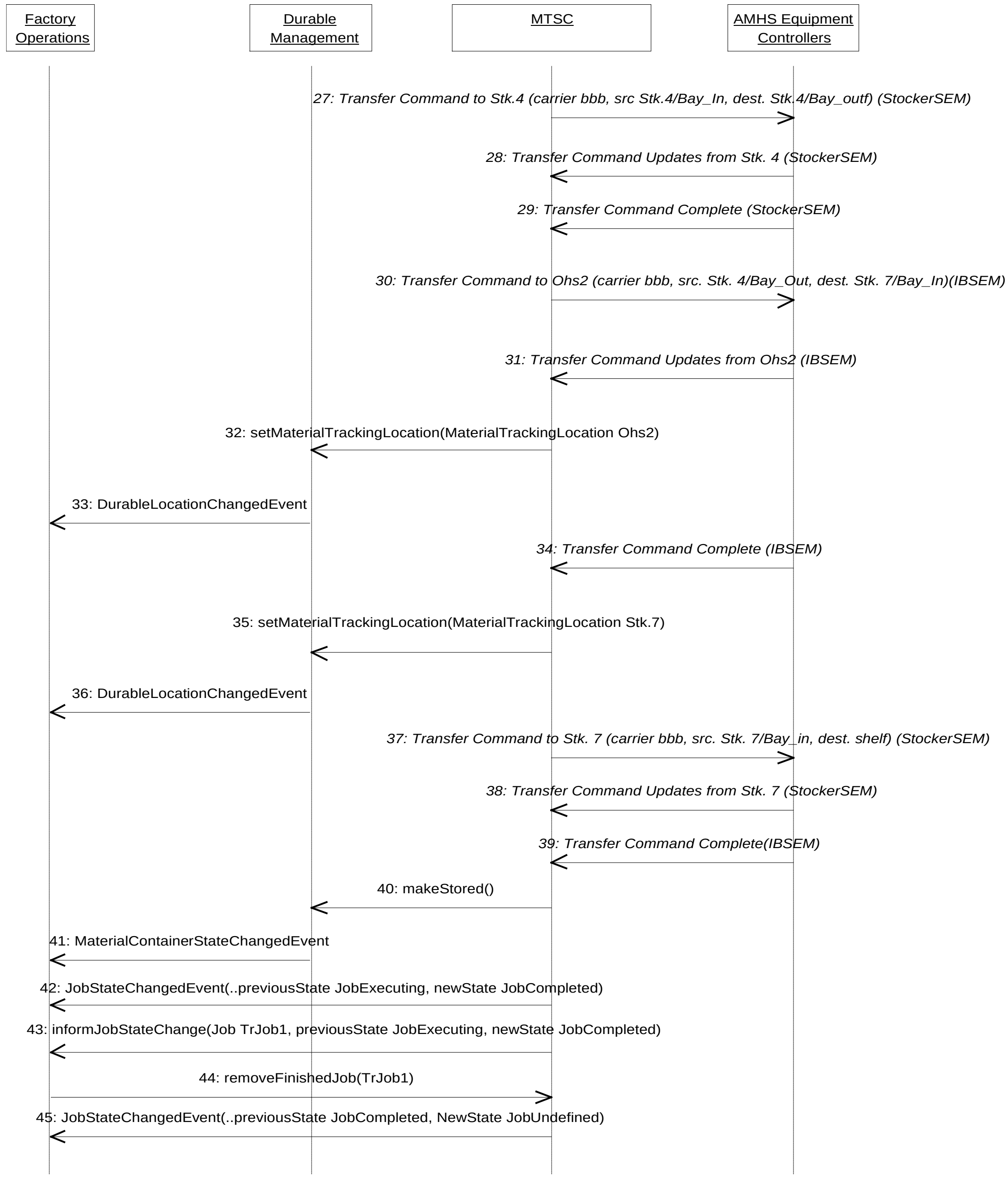

Figure R1-5
Scenario Case 2 (continued)

R1-2.3 *Scenario Three — Base Scenario for Batch Delivery from Stocker to Production Equipment*

Figure R1-6
Scenario Case 3

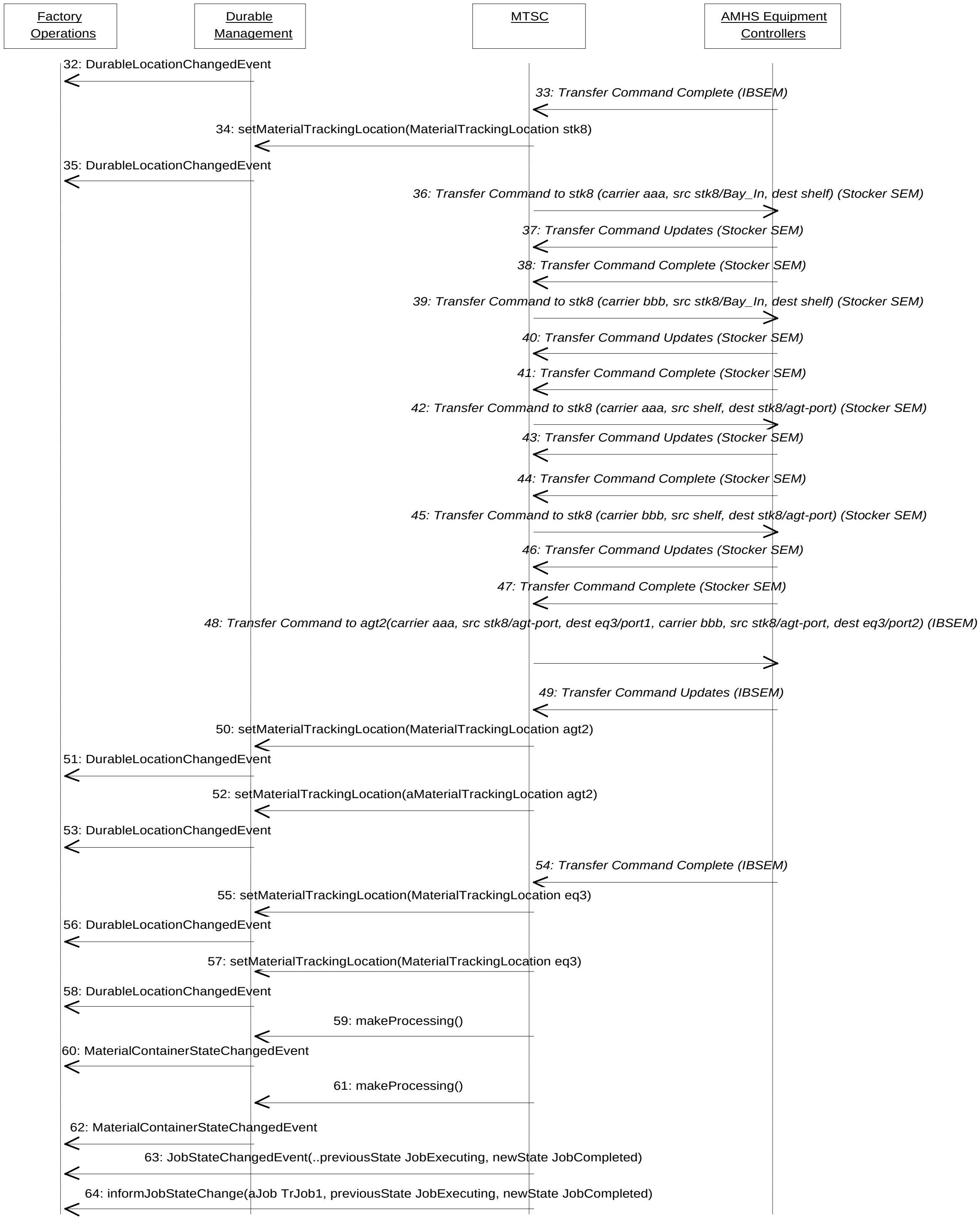

Figure R1-7
Scenario Case 3 (continued)

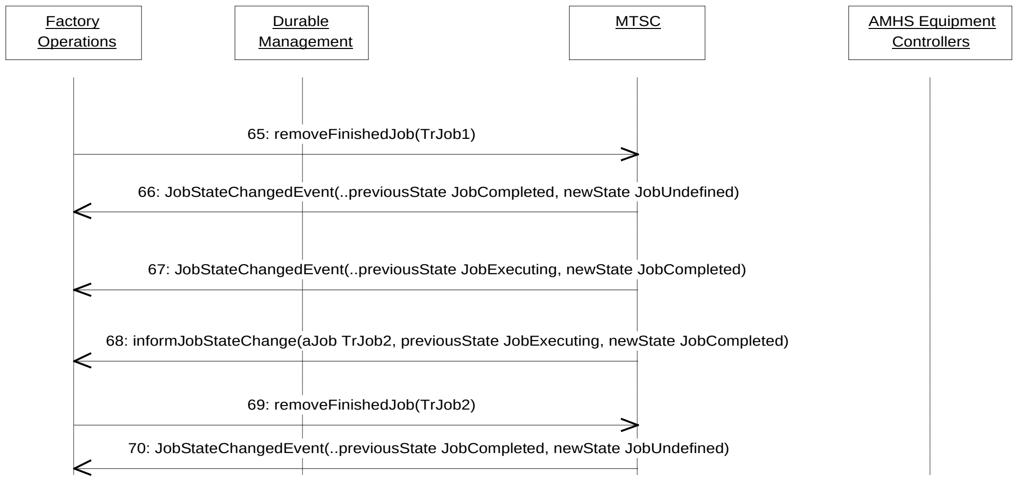

Figure R1-8
Scenario Case 3 (continued)

R1-2.4 *Scenario 4 — Equipment Monitoring and Logical Partition Overflow Control*

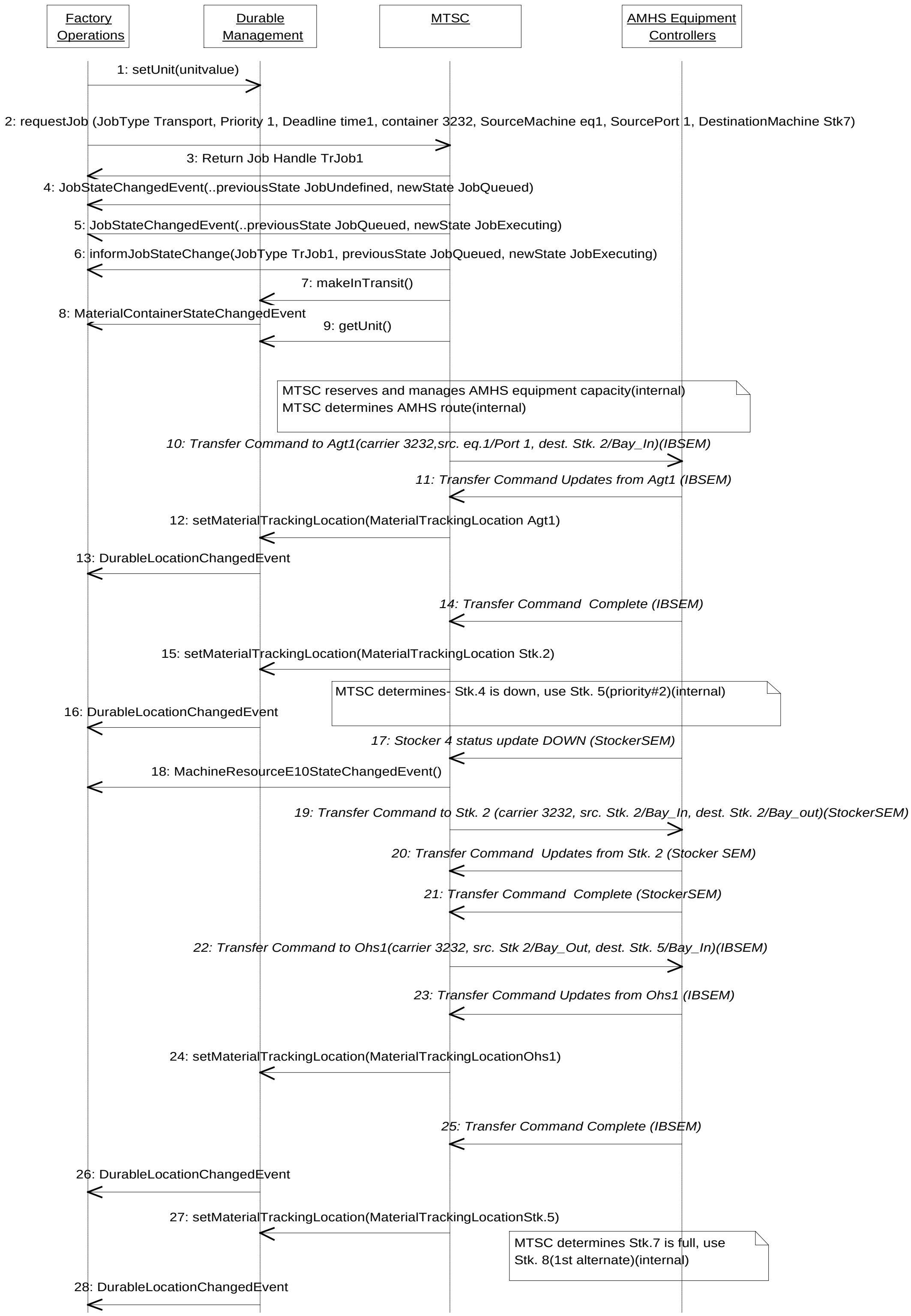

Figure R1-9
Scenario Case 4

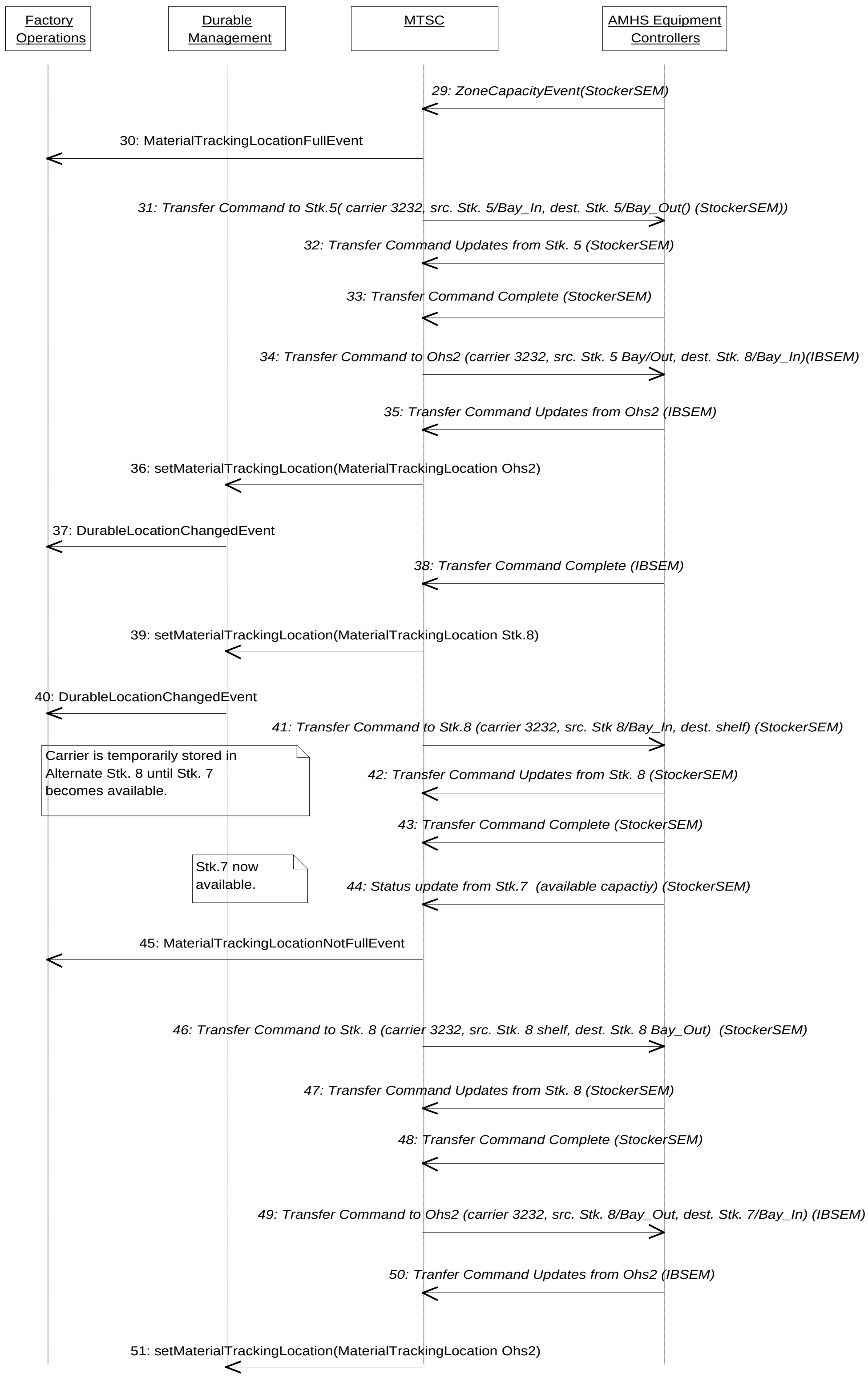

Figure R1-10
Scenario Case 4 (continued)

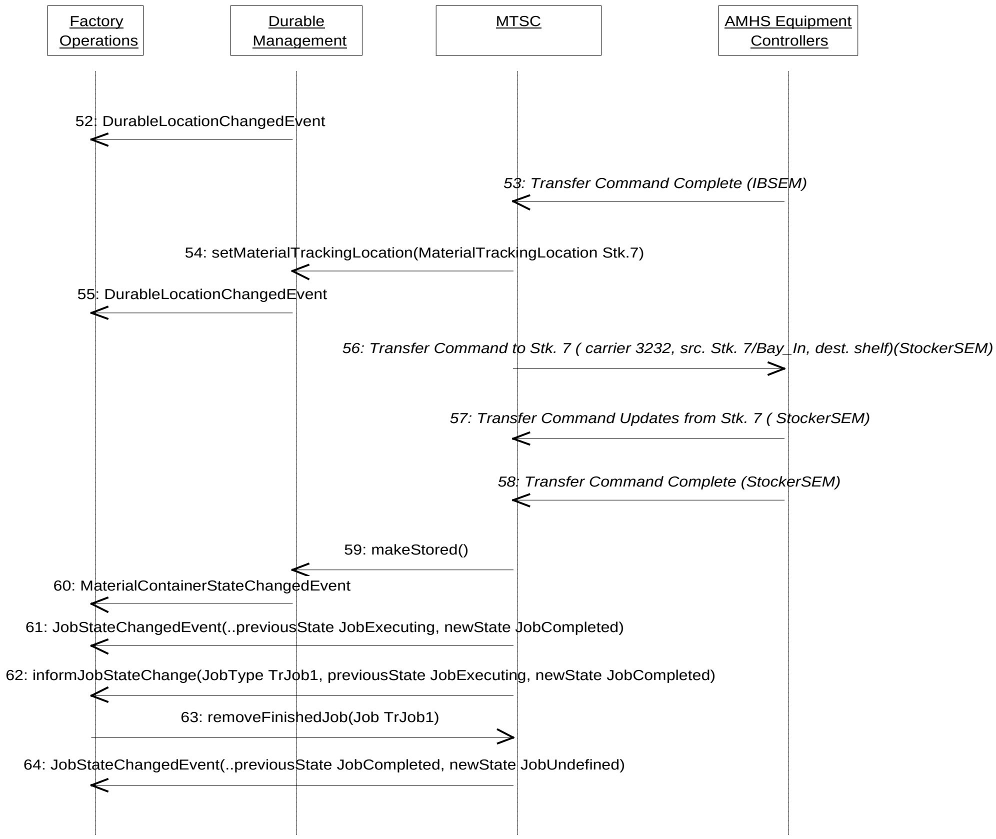

Figure R1-11
Scenario Case 4 (continued)

R1-2.5 *Scenario Five — Manual Carrier Input and Handling*

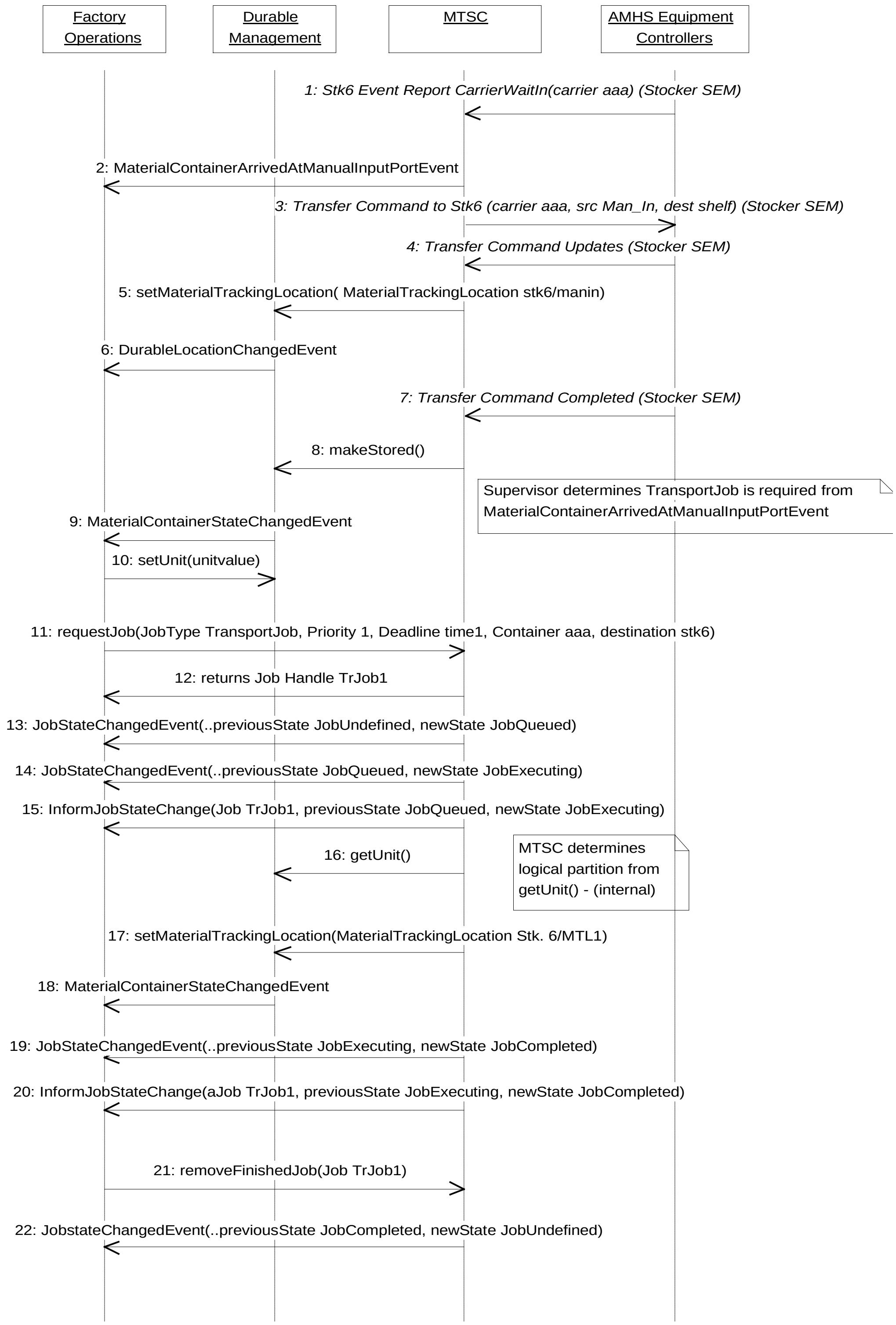

Figure R1-12
Scenario Case 5

R1-2.6 *Scenario Six — AMHS Equipment Monitoring*

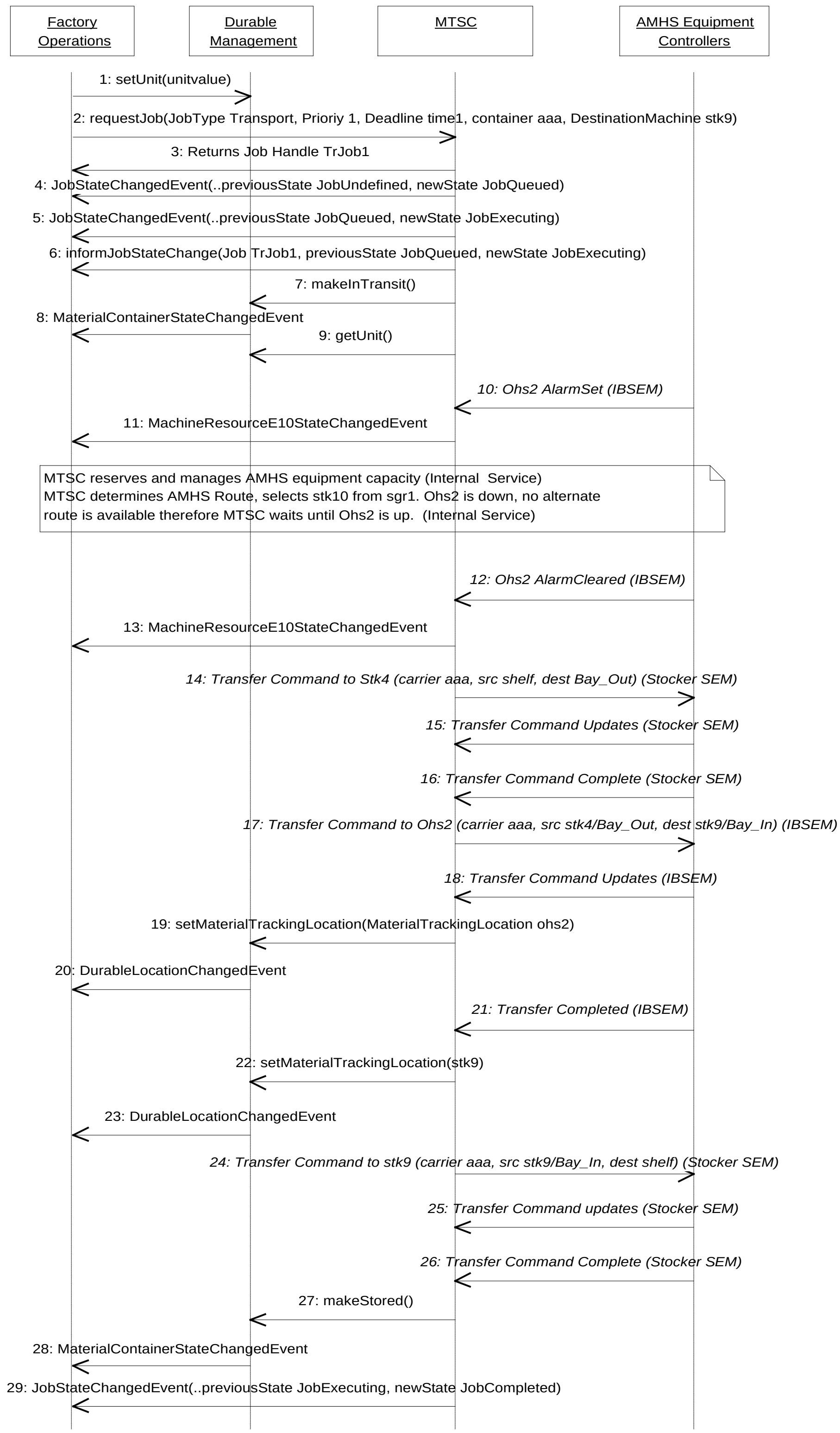

Figure R1-13
Scenario Case 6

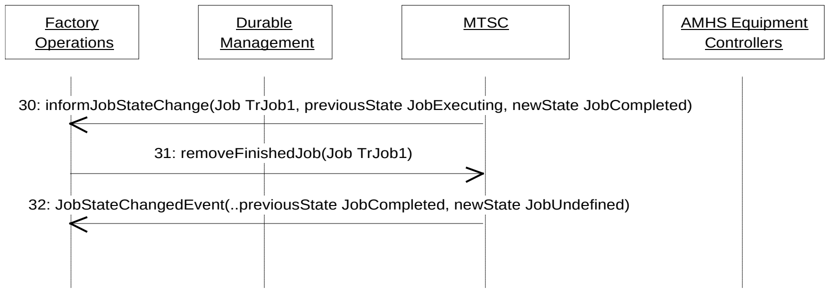

Figure R1-14
Scenario Case 6 (continued)

R1-2.7 *Scenario 7 — Batch Delivery to Internal Buffer Equipment*

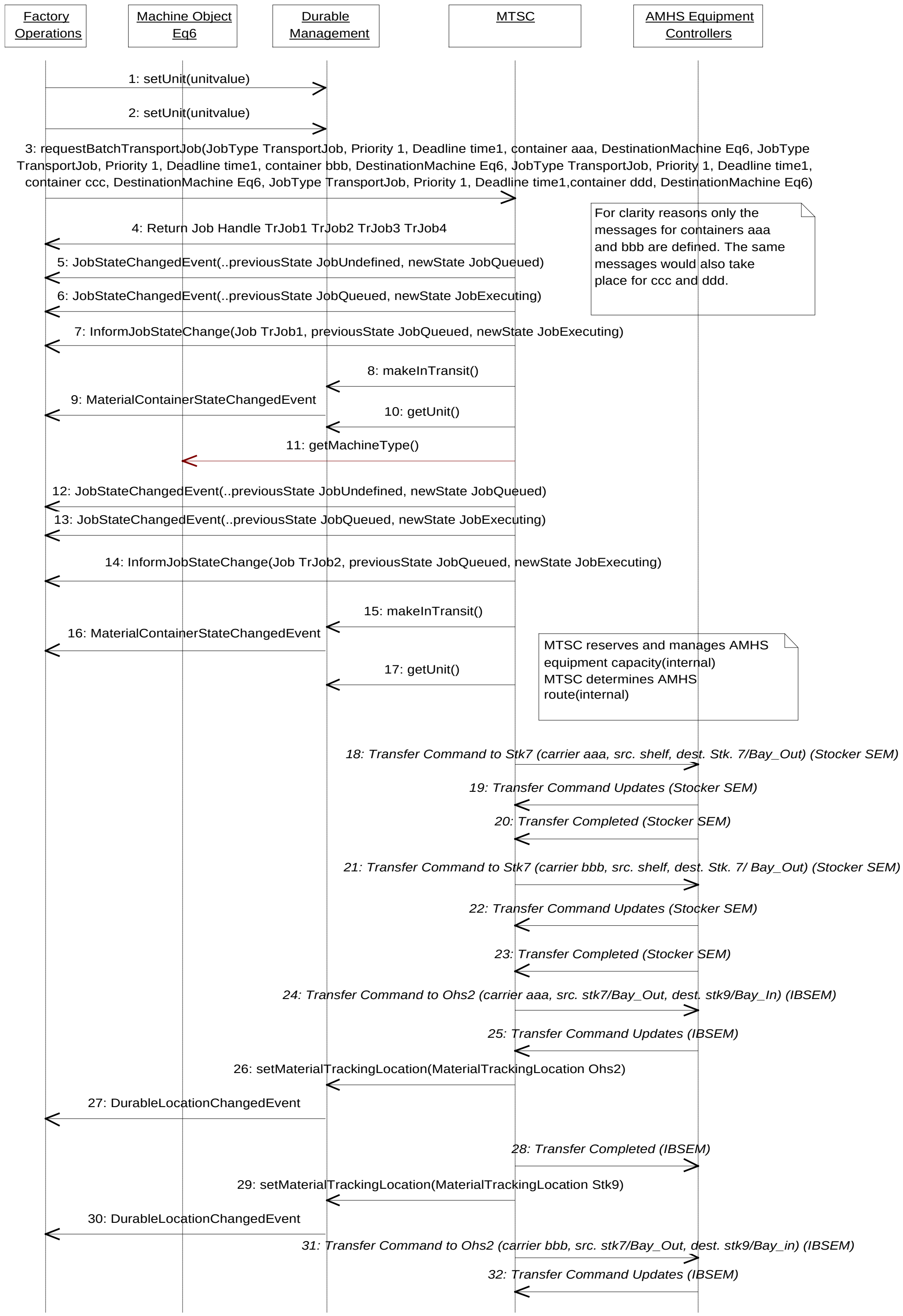

Figure R1-15
Scenario Case 7

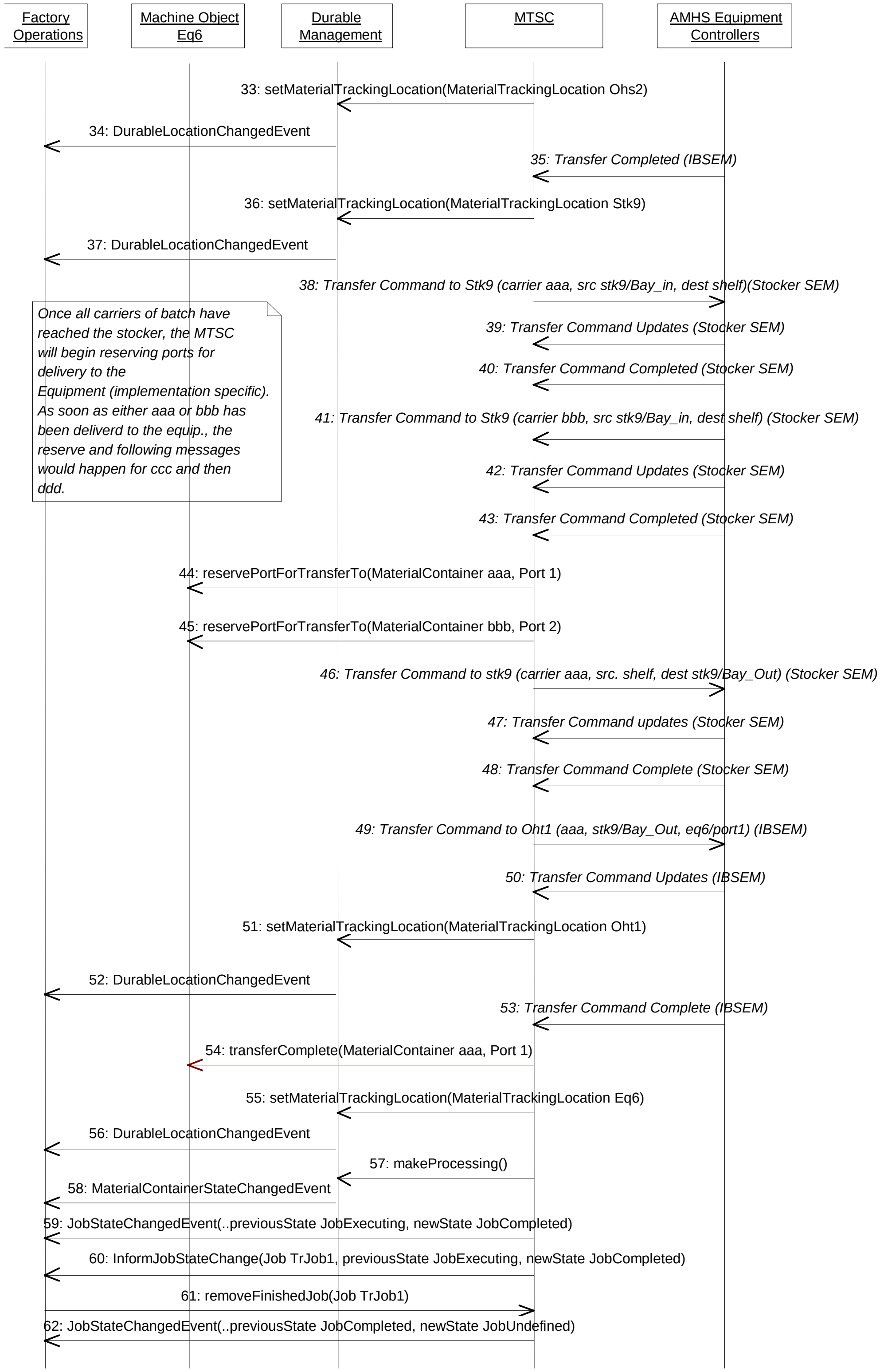

Figure R1-16
Scenario Case 7 (continued)

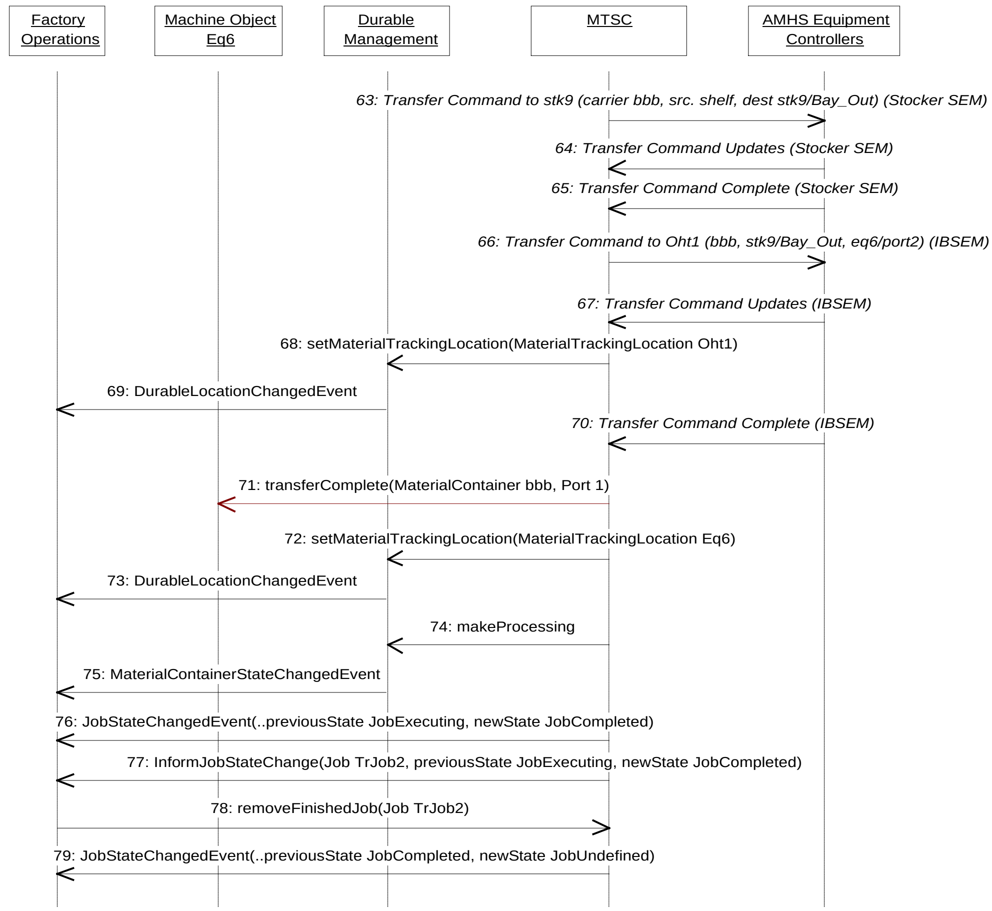

Figure R1-17
Scenario Case 7 (continued)

R1-2.8 *Scenario Eight — Abort Job Handling*

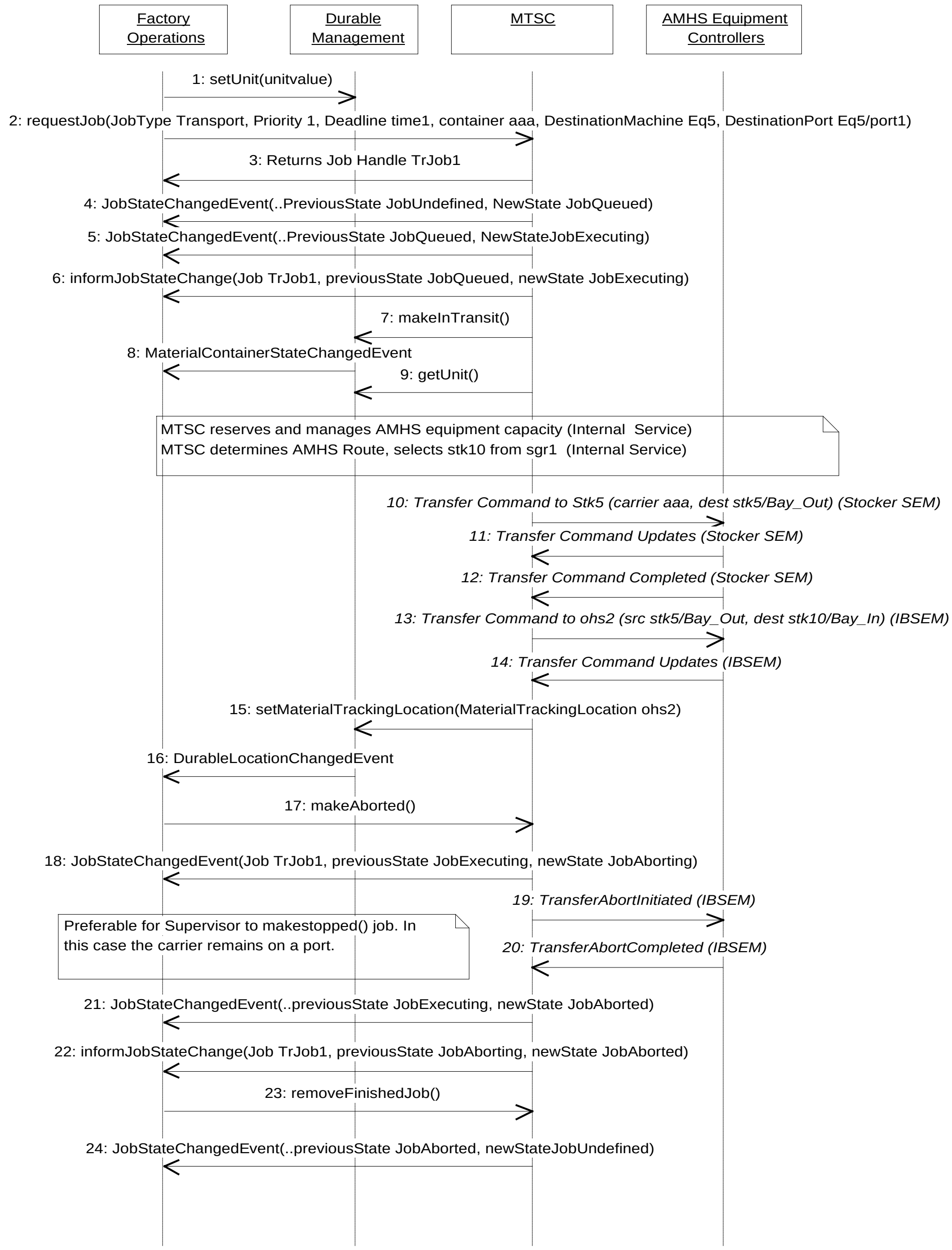

Figure R1-18
Scenario Case 8

R1-2.9 *Scenario Nine — Modify Job Handling*

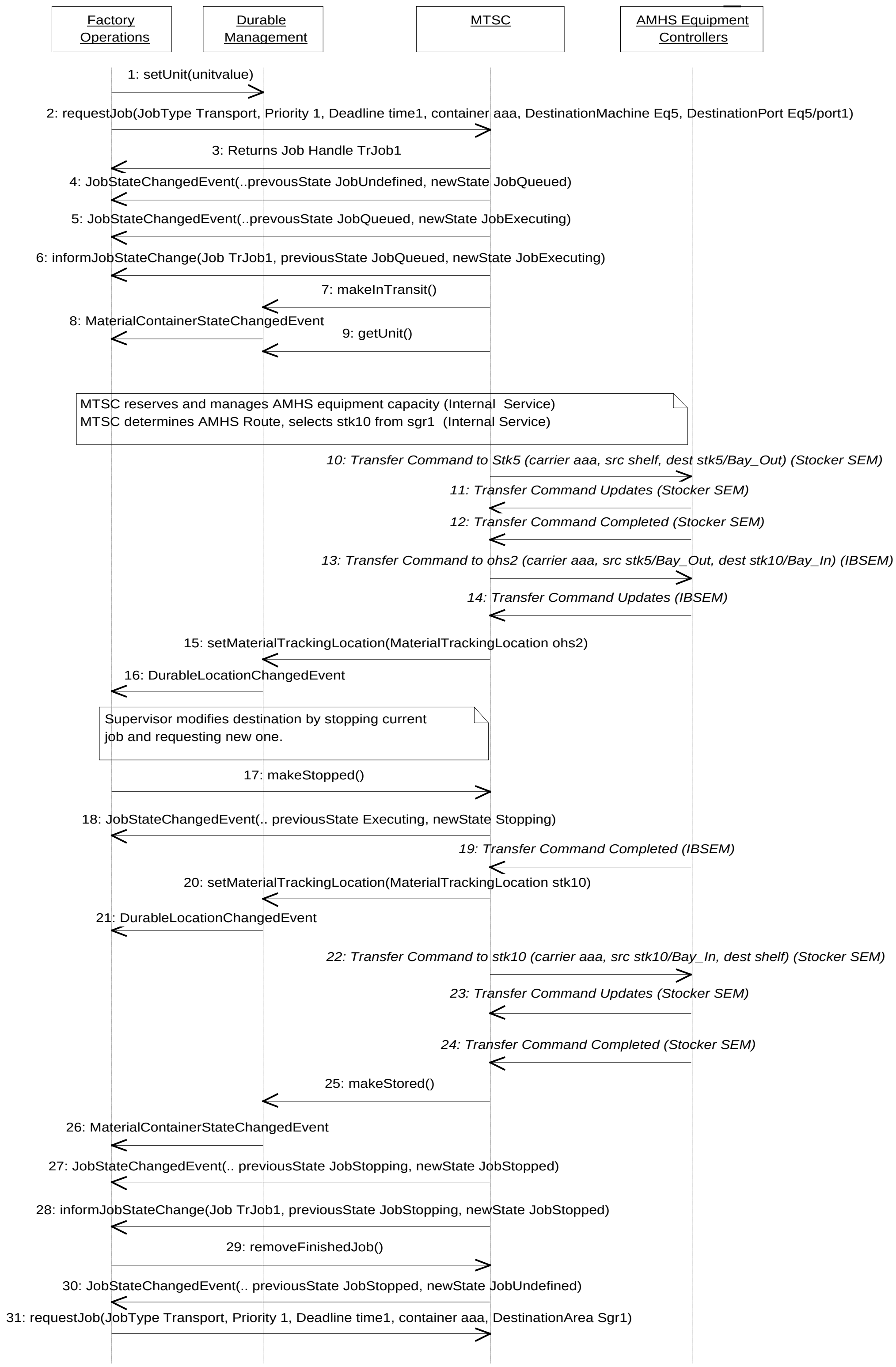

Figure R1-19
Scenario Case 9

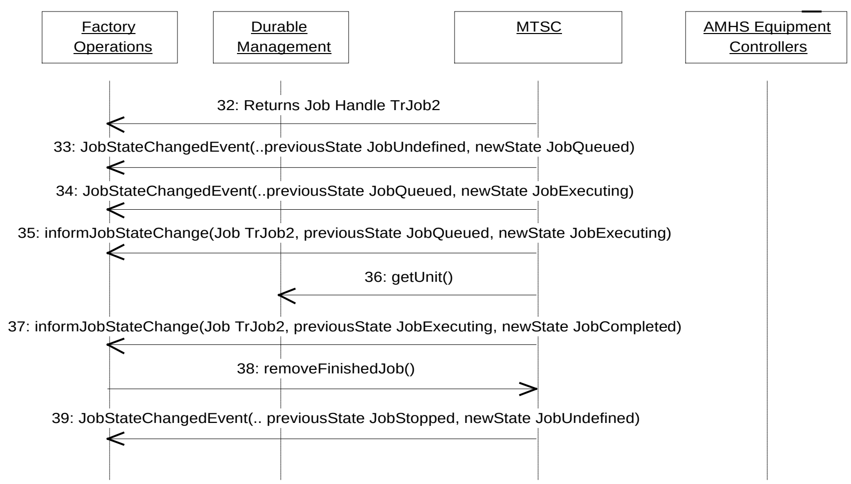

Figure R1-20
Scenario Case 9 (continued)

R1-2.10 *Scenario Ten — Material Transport and Storage Component Startup*

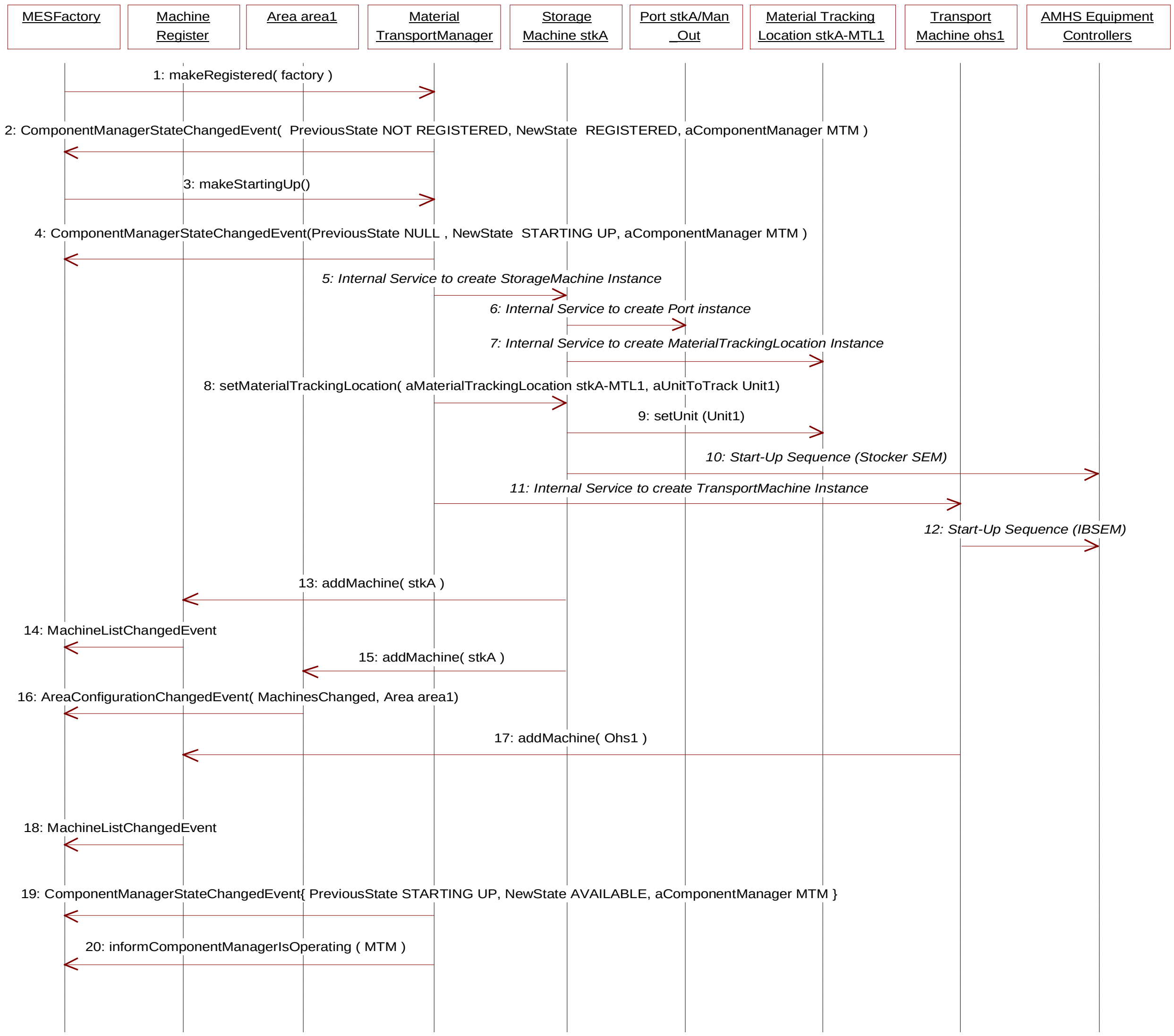

Figure R1-21
Scenario Case 10

R1-2.11 *Scenario Eleven — Manual Interruption of Delivery*

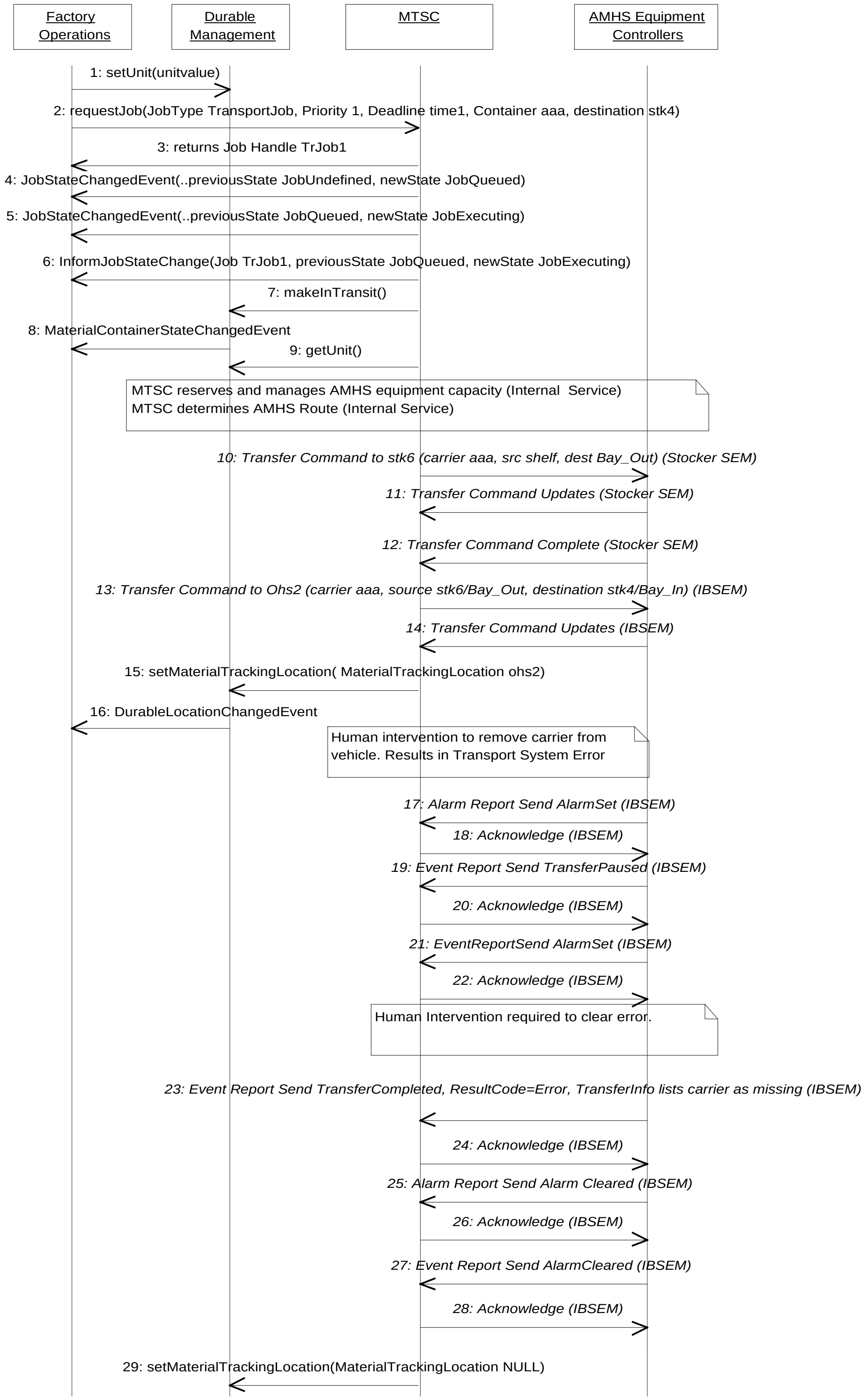

Figure R1-22
Scenario Case 11

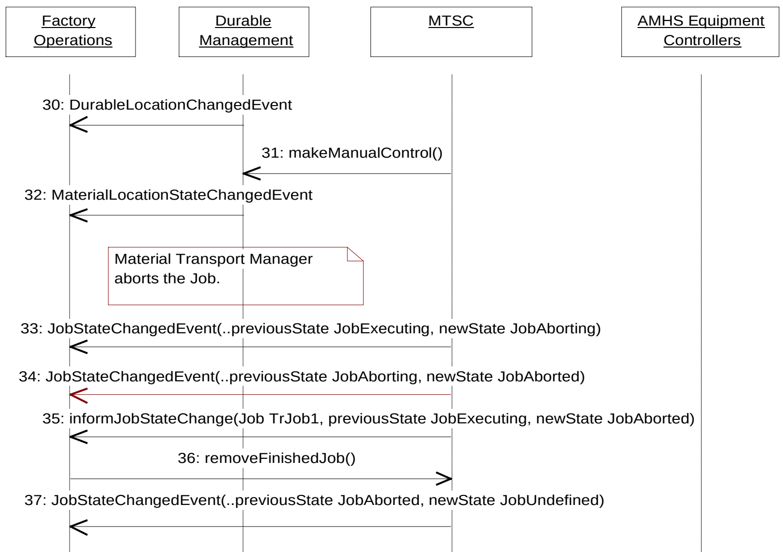

Figure R1-23
Scenario Case 11 (continued)

R1-2.12 *Scenario 12 — Tool to Tool Delivery*

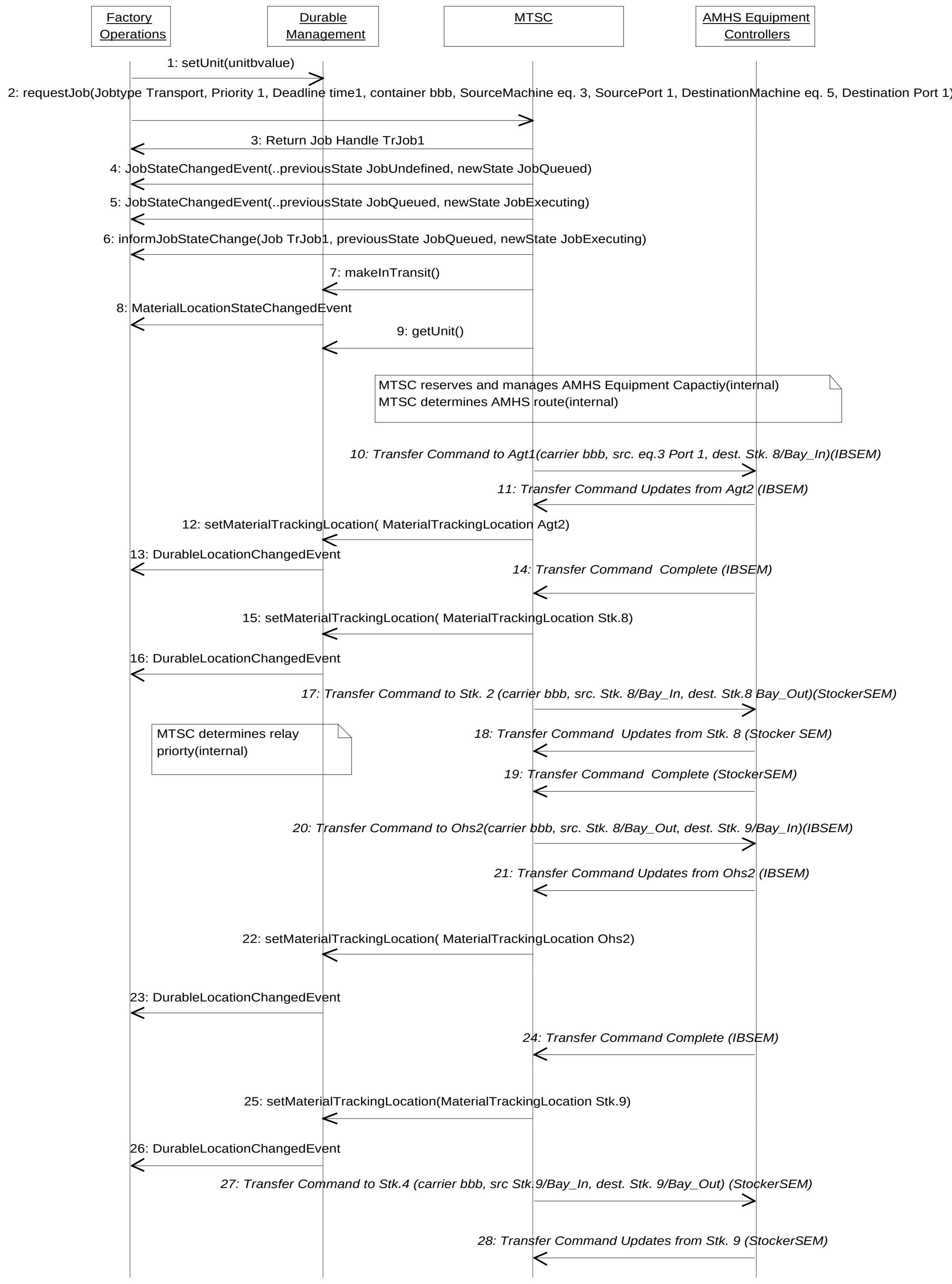

Figure R1-24
Scenario Case 12

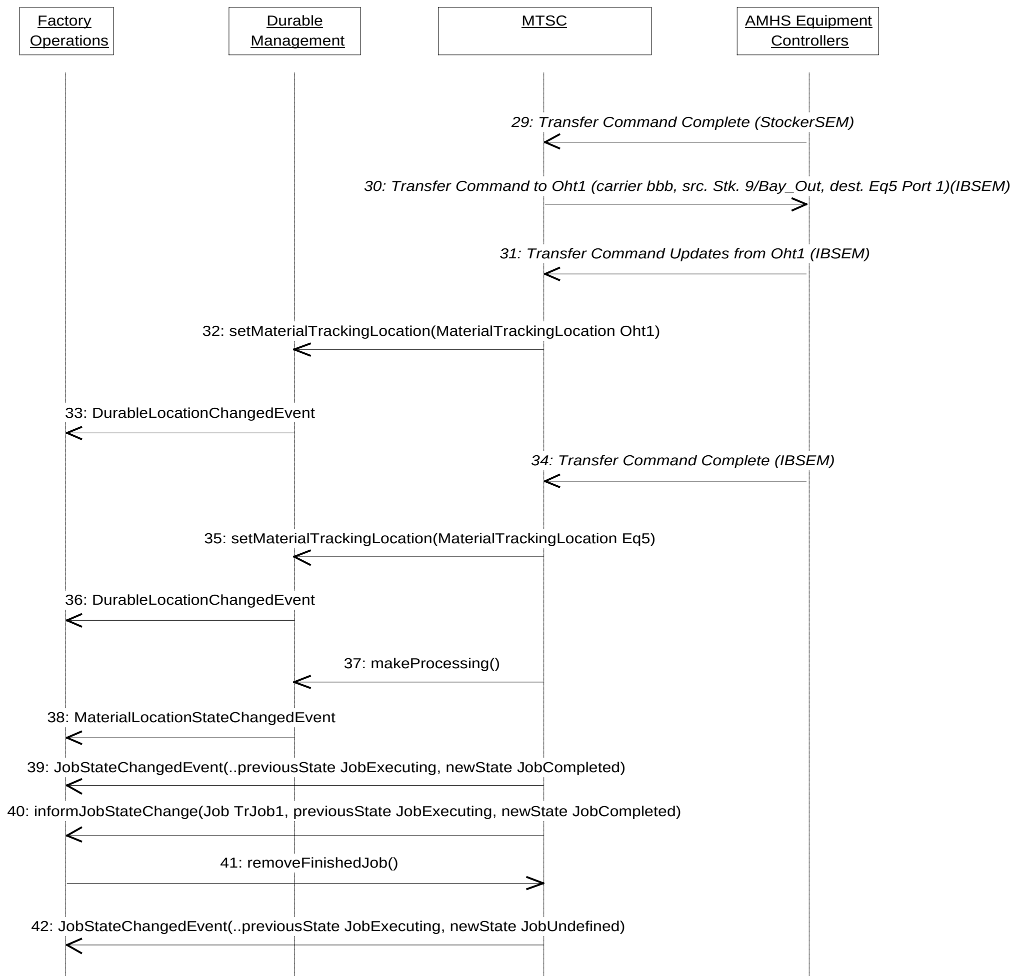

Figure R1-25
Scenario Case 12 (continued)

R1-2.13 *Scenario 13 — Interactions at an Individual Interface Level (including capacity reservation)*

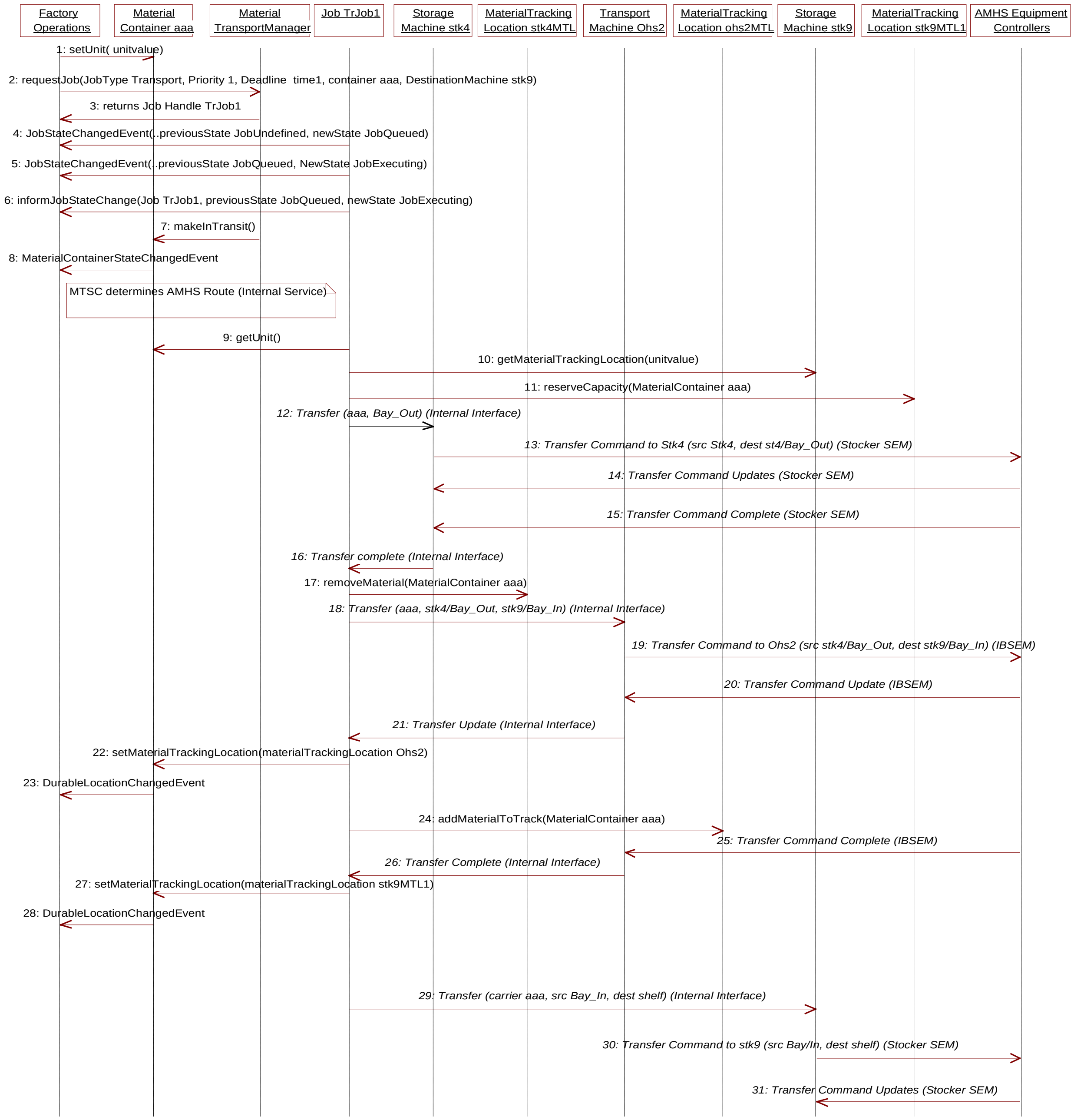

Figure R1-26
Scenario Case 13

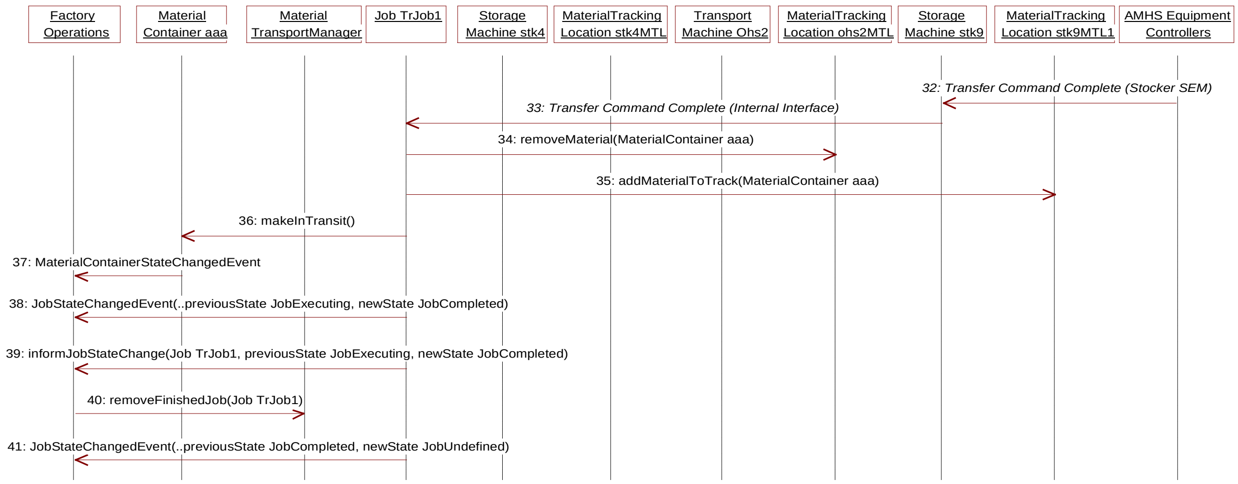

Figure R1-27
Scenario Case 13 (continued)

RELATED INFORMATION 2
LOGICAL PARTITION STORAGE

NOTE: This related information is not an official part of SEMI E10# and was derived from the work of the I300I/J300E AMHS workgroup accomplished during development of the proposed standard. This related information is included with the Material Transport and Storage Component specification to aid the readers in understanding the intent and use of the standard. This related information was approved for publication by full letter ballot procedures on January 14, 2000.

R2-1 The concept of Stocker storage via logical partitions has been implemented through the use of the MaterialTrackingLocation concept and interfaces. In the example below, the correlation between Durables and MaterialTrackingLocations are each object's unit attribute. First, the Factory Supervisor sets the Durable unit to a particular value based on user specifications. The MTSC then maps the Durable Unit to the appropriate MaterialTrackingLocation unit for the destination Storage Machine in order to determine the appropriate logical partition for that particular durable. It is not required that the Durable unit and MaterialTrackingLocation unit be identical in order for a mapping to occur, the MTSC may implement mapping logic in order to obtain various relationships between Durable units and MaterialTrackingLocation units.

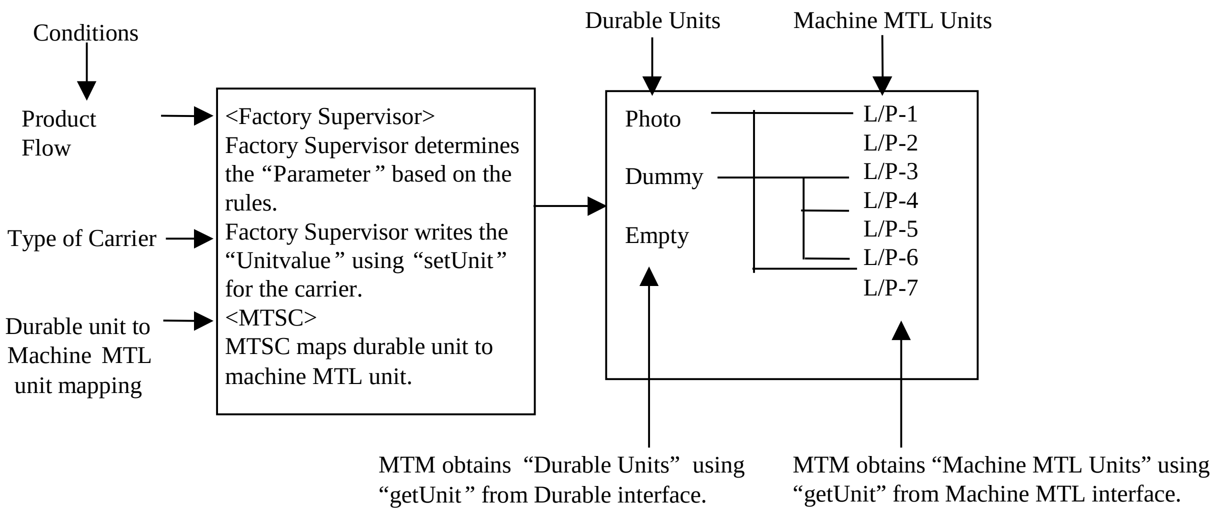

Figure R2-1
Storage in Logical Partitions

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SEMI E105-0701
PROVISIONAL SPECIFICATION FOR CIM FRAMEWORK SCHEDULING COMPONENT

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the Japanese Regional Standards Committee on February 1, 2001. Initially available at www.semi.org April 2001; to be published July 2001. Originally published October 2000.

1 Purpose

1.1 The Scheduling Component supports Factory Operations, Material Transport and Storage, Production Machine, and Equipment Tracking and Maintenance components by ordering, in time, jobs that process material on equipment, move material, and maintain equipment. The scheduler uses knowledge of product demand, equipment and material state, process flows, throughput bottlenecks, operational policy and constraints, and other information to recommend jobs that maximize effective utilization of factory resources to satisfy product demand and planned objectives.

1.2 Increased control over operations requires an active Scheduling Component that can respond to factory events and changes in state and dynamically adjust the schedules for material processing, material transport and equipment maintenance. The Scheduling Component can react to inventory levels of material in the factory to adjust priorities to minimize queue sizes and ensure that use of bottleneck equipment is optimized to keep WIP inventory levels at desired levels.

1.3 The Scheduling Component can minimize turn around time (TAT) by coordinating material transport (for substrates and durables) with processing to reduce equipment idle time. The Scheduling Component can sequence activities to minimize setup time. It can also respond to scheduled and unscheduled equipment down-time to minimize impact on turn around time. In addition to minimizing overall TAT, it can react to the priorities for urgent lots to move them through the process flow in the minimum possible time while adjusting the schedules of lower-priority lots that are impacted.

2 Scope

2.1 The primary run-time responsibilities of the Scheduling Component are to monitor resource and material state and apply scheduling and dispatching decision mechanisms to identify the next activity (dispatching) or sequence of activities (scheduling) for factory resources. The Scheduling Component includes an interface that supports both scheduling and dispatching. Figure 1 illustrates the interactions between the Scheduling Component and other components of the CIM Framework. This illustration does not reflect all of the many inputs to the Scheduling Component that are required to provide it with the current status of the factory resources.

2.2 As described in this standard, the Scheduling Component produces activity option and activity forecast lists. These lists are produced by combining the factory model and status information from other components with scheduling policies in the Scheduling Component. For example, the Scheduling Component combines data from the Specification Component on how products are made with status data from the Equipment and Product Management Components to give activity options for a machine.

2.3 The Factory Operations Component uses the Scheduling Component services to orchestrate the management of machines and production of lots. For example, when a tool becomes available, Factory Operations uses the Activity Options list to select the next lot to process on the tool. Factory Operations then works with other components to execute the production job for the lot on the machine. Executing the production job changes the state of lot and tool in other components. These status changes are then used by the Scheduling Component when it produces new activity lists.

2.4 The Scheduling Manager supports Factory Operations by providing an answer to questions like, “What is next for this material or resource?” The answer may be based on evaluation of current or future constraints and objectives. Although the dispatcher's output takes the form of a decision for the next activity for the target resource, the interface may also support manual scenarios by providing a list of prioritized activities from which the decision is selected.

2.5 The Scheduling Manager interface also provides forecasts of future activities projected to occur after the next activity. By simulating anticipated future activity sequencing and execution timing the scheduler can generate forecasts that predict future responses from the dispatcher for subsequent requests. These forecasts are subject to change as factory conditions change, but they offer the best current projection of future activity decisions.

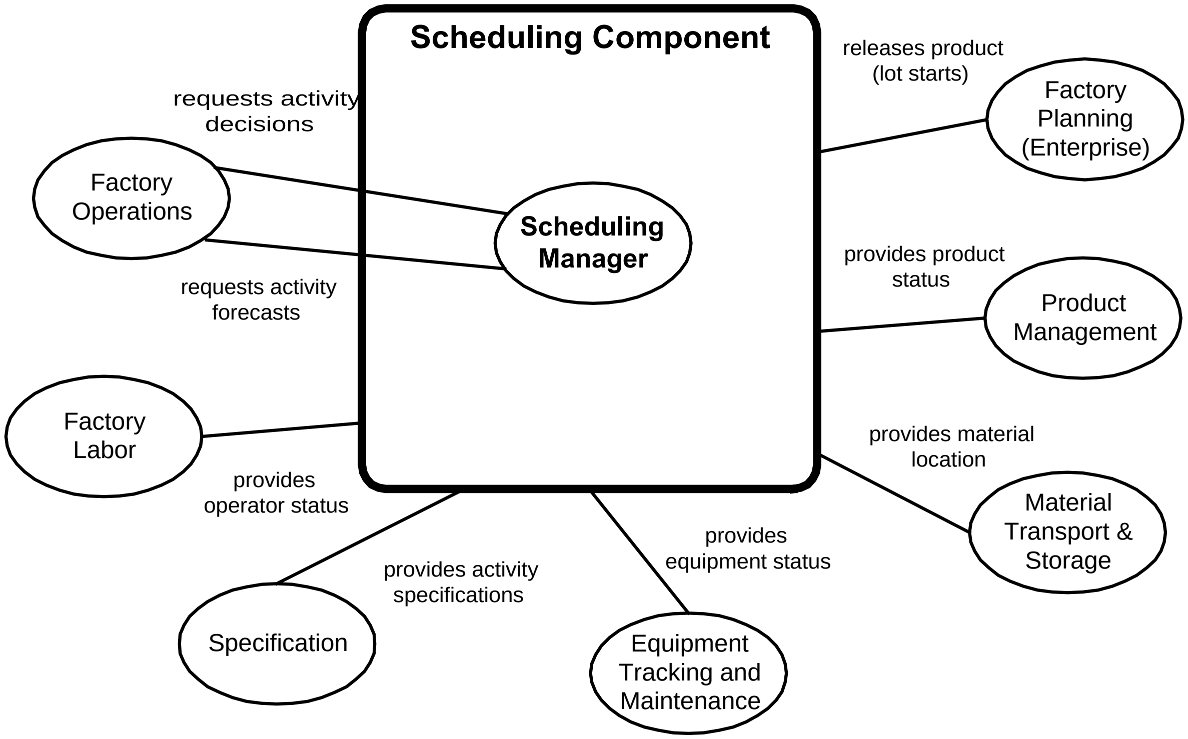


Figure 1
Scheduling Component Interactions

2.6 This specification does not describe the definition of the policies used by the Scheduling Component to produce activity lists. This is left to component implementors.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 *Provisional Status* — This specification is designated as provisional due to known areas that need to be completed. The following items summarize the deficiencies of the provisional specification to be addressed before a subsequent ballot to upgrade it to full standard status.

3.1.1 *Dependence on Factory Operations Component* — The Scheduling Component provides specifications of activities that are executed by the Factory Operations Component in the form of production jobs, transport jobs and maintenance jobs. The specification of Factory Operations may require changes to the activity specification properties of the Scheduling Component. When the Specification for CIM Framework Factory Operations Component is complete, this dependency can be resolved.

3.1.2 *Specification of Event Subscriptions* — The Scheduling Component maintains a current status of the factory resources and material by receiving event notifications of occurrences that indicate changes in other components. Events are specified with the component responsible for publishing the event notifications. Until all of the required event formats are defined as part of the publishing component specification, the inputs to the Scheduling Component will be defined only in general terms. When event specifications are complete, these event subscriptions can be specified.

3.1.3 *Initialization* — The Scheduling Component does not currently provide interfaces that allow the representation of factory conditions to be initialized for the start-up of dispatching and scheduling. The addition of initialization interfaces will be added or deemed out of scope prior to upgrade to full standard status.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E81 — Provisional Specification for CIM Framework Domain Architecture

SEMI E97 — Provisional Specification for CIM Framework Global Declarations and Abstract Interfaces

SEMI E102 — Provisional Specification for CIM Framework Material Transport and Storage Component

4.2 *Other Documents*

UML Notation Guide, Version 1.1, document number ad/97-08-05, Object Management Group.[1]

ISO/IEC International Standard 14750 (also ITU-T Recommendation X.920): Information Technology – Open Distributed Processing – Interface Definition Language [2]

5 Terminology

5.1 *Definitions*

5.1.1 *activity* — work performed as part of the manufacturing operations of a factory. Activities may be specified formally by a predefined type of job specification (for example, Production Job, Transport Job or PM Job), or they may be represented by identifying the minimal set of resources and material needed to allow subsequent completion of the job specification. An activity is the result of dispatching or scheduling.

5.1.2 *dispatching* — generation of a decision or option for the next activity involving a particular factory resource or material. The dispatch result is determined by evaluating the current state of the factory, the priorities and requirements for the activities, and the relationship of the activities to one another. Dispatching returns only the immediately applicable part of a schedule.

5.1.3 *factory planning* — recommendation of lot starts for a particular production facility over an extended period of time. The factory plan is determined by predicting future changes in factory state and available capacity as lots progress through production. This prediction is used to determine the optimum sequence of lot starts to best achieve the production goals of the facility. Factory planning is typically the responsibility of enterprise systems.

5.1.4 *scheduling* — generation of a forecast of future time sequenced activities involving factory resources or material. The schedule is based on the current state of the factory, the priorities and requirements for the activities, the relationship of the activities to one another and knowledge of factory level goals and capacity. Scheduling covers activities projected to occur over a longer future time interval than dispatching.

6 Requirements

6.1 *Scheduling Component* — The Scheduling Component provides a single interface called the SchedulingManager with operations for both dispatching and scheduling.

6.1.1 Any resource or material within the factory may have a next activity defined for it. The SchedulingManager interface is responsible for identifying activities that answer questions such as:

- What's next for this Machine?
- Where next for this Lot?
- What's next for this Operator?

6.1.2 The SchedulingManager interface is also responsible for generating a time-sequenced forecast of future activities for a resource or for material within the factory. This forecast is based on projections from the current factory state and may be updated as actual activities are dispatched and executed.

6.1.3 The Scheduling Component Information Model is shown in Figure 2.

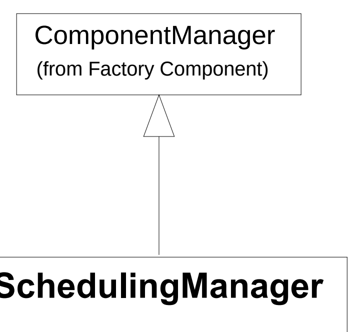


Figure 2
Dispatching Component Information Model

1 UML Notation Guide v1.1 is available to the general public at http://www.omg.org/cgi-bin/doclist.pl, +1-508-820 4300, Object Management Group, Inc. , Framingham Corporate Center, 492 Old Connecticut Path, Framingham, MA 01701.

2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

6.1.4 *Scheduling Component Declarations*

/* The ActivityType enumerated value will determine which kind of activity is represented and the appropriate properties present in the activitySpec. */

```
enum ActivityType {
     ProductionActivity,
     TransportActivity,
     MaintenanceActivity,
     DoNothing };
```

/* ActivityOption represents a single activity that is eligible to be dispatched for execution. The prioritySequenceNumber represents the priority ordering of a list of ActivityOptions in the case where a manual process includes selection of one ActivityOption from the list. The deadline is a timestamp that is used to convey start time constraints for activities. It may also be used in a DoNothing activity to specify the timeout for a retry of the dispatch request. */

```
struct ActivityOption {
     ActivityType activityType;
     short prioritySequenceNumber;
     Global::TimeStamp deadline;
     AbstractIF::ResourceSequence resources;
     AbstractIF::MaterialGroupSequence materialGroups;
     DurablesManagement::DurableSequence durables;
     Global::Properties activitySpec;
}; // ActivityOption
```

/* ActivityForecast represents a single Activity that may be dispatched and executed in the future. An ActivityForecast includes information that is equivalent to an ActivityOption, but with added start and finish time projections. The timeSequenceNumber represents the time ordering of activities consistent with the projectedStart and projectedFinish. */

```
struct ActivityForecast {
     ActivityType activityType;
     short timeSequenceNumber;
     AbstractIF::ResourceSequence resources;
     AbstractIF::MaterialGroupSequence materialGroups;
     DurablesManagement::DurableSequence durables;
     Global::TimeStamp projectedStart;
     Global::TimeStamp projectedFinish;
     Global::Properties activitySpec;
}; // ActivityForecast
```

/* An ActivityList contains one or more ActivityOptions for a Resource, MaterialGroup or Durable which are all eligible for immediate execution. A list of one ActivityOption represents a decision from the SchedulingComponent. A list of more than one ActivityOption represents recommendations from the SchedulingComponent which require some external interaction for a decision to be reached. */

```
typedef sequence <ActivityOption> ActivityList;
```

/* A ForecastList contains one or more ActivityForecasts for a Resource or MaterialGroup which are not yet dispatched for execution. */

```
typedef sequence <ActivityForecast> ForecastList;
```

6.1.5 *Use of ActivitySpec Properties*— The ActivitySpec part of the ActivityOption and ActivityForecast are provided to allow implementations to extend the specifications of activities for specific implementations. The names and value types of properties included in these ActivitySpec structure are not part of the standard.

6.1.6 *SchedulingManager Interface*

Module: Scheduling

Interface: SchedulingManager

Inherited Interface: ComponentManager

```
interface SchedulingManager : FactoryOperations::ComponentManager {
```

Description: The SchedulingManager provides the concrete interfaces that support the registration and control of the Scheduling Component and enable access to the Dispatcher and Scheduler interfaces.

Exceptions:

/* An attempt was made to request an activity for a resource that is not found within the factory data available to this SchedulingManager. */

```
exception ResourceNotFound {
      AbstractIF::Resource requestedObject;};
```

/* An attempt was made to request an activity for a material group that is not found within the factory data available to this SchedulingManager. */

```
exception MaterialGroupNotFound {
      AbstractIF::MaterialGroup requestedObject;};
```

/* An attempt was made to request an activity for a durable that is not found within the factory data available to this SchedulingManager. */

```
exception DurableNotFound {
      DurablesManagement::Durable requestedObject;};
```

Published Events:.

/* The ActivityListAvailable event is published by the Scheduling Component to notify event subscribers that a new ActivityList containing changes is available. The generation of ActivityListAvailable events is controlled as an implementation specific configuration choice. */

ActivityListAvailable

/* The ForecastListAvailable event is published by the Scheduling Component to notify event subscribers that a new Forecast is available. ForecastList generation is potentially a compute-intensive operation which may benefit from event notification when an updated forecast is available. The generation of ForecastListAvailable events is controlled as an implementation specific configuration choice. */

ForecastListAvailable

Provided Services:

/* Return an activity list for this resource. The activity list will contain the number of existing activities requested in listCount in maximum. If “listCount” is blank, the activity list shall contain all existing activities. A decision will be represented by an activity list with only one activity option. The ActivityOptions returned by this operation may be ProductionActivity, MaintenanceActivity or DoNothing ActivityTypes. Although Resources are typically immobile (such a Equipment), some Resources may also be subject to TransportActivities. */

```
ActivityList whatNextForResourceByCount (
       in AbstractIF::Resource aResource)
       in short listCount)
       raises (Global::FrameworkErrorSignal,
                    ResourceNotFound);
```

/* Return an activity list for this material group. The activity list will contain the number of existing activities requested in listCount in maximum. If “listCount” is blank, the activity list shall contain all existing activities. A decision will be represented by an activity list with only one activity option. The ActivityOptions returned by this operation may be ProductionActivity, TransportActivity or DoNothing ActivityTypes. */

```
ActivityList whatNextForMaterialGroupByCount (
     in AbstractIF::MaterialGroup aMaterialGroup,
     in short listCount)
     raises (Global::FrameworkErrorSignal,
          MaterialGroupNotFound);
```

/* Return an activity list for this durable. The activity list will contain the number of existing activities requested in listCount in maximum. If “listCount” is blank, the activity list shall contain all existing activities. A decision will be represented by an activity list with only one activity option. The ActivityOptions returned by this operation may be ProductionActivity, MaintenanceActivity, TransportActivity or DoNothing ActivityTypes. */

```
ActivityList whatNextForDurableByCount (
       in DurablesManagement::Durable aDurable)
       in short listCount)
       raises (Global::FrameworkErrorSignal,
            DurableNotFound);
```

/* Return an activity list containing the next TransportActivity for this material group. A decision will be represented by an activity list with only one activity option. The ActivityOptions returned by this operation may be TransportActivity or DoNothing ActivityTypes. This operation is defined to support a factory operating with a “push” model that pushes material to the next storage or production machine. */

```
ActivityList whereNextForMaterialGroup (in AbstractIF::MaterialGroup aMaterialGroup)
     raises (Global::FrameworkErrorSignal,
          MaterialGroupNotFound);
```

/* Return an activity list containing the next TransportActivity for this durable. A decision will be represented by an activity list with only one activity option. The ActivityOptions returned by this operation may be TransportActivity or DoNothing ActivityTypes. This operation is defined to support a factory operating with a “push” model that pushes material to the next storage or production machine. */

```
ActivityList whereNextForDurable (in DurablesManagement::Durable aDurable)
     raises (Global::FrameworkErrorSignal,
          DurableNotFound);
```

/* Return a forecast list containing future activities for this resource. The forecast list will contain all activities projected to start before the lookAheadTime, but which have not yet been started. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForResourceByTime (
     in AbstractIF::Resource aResource,
     in Global::TimeStamp lookAheadTime)
     raises (Global::FrameworkErrorSignal,
          ResourceNotFound);
```

/* Return a forecast list containing future activities for this material group. The forecast list will contain all activities projected to start before the lookAheadTime, but which have not yet been started. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForMaterialGroupByTime (
     in AbstractIF::MaterialGroup aMaterialGroup,
     in Global::TimeStamp lookAheadTime)
     raises (Global::FrameworkErrorSignal,
          MaterialGroupNotFound);
```

/* Return a forecast list containing future activities for this durable. The forecast list will contain all activities projected to start before the lookAheadTime, but which have not yet been started. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForDurableByTime (
      in DurablesManagement::Durable aDurable,
      in Global::TimeStamp lookAheadTime)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);
```

/* Return a forecast list containing future activities for this resource. The forecast list will contain the number of upcoming activities requested in lookAheadCount. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForResourceByCount (
      in AbstractIF::Resource aResource,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            ResourceNotFound);
```

/* Return a forecast list containing future activities for this material group. The forecast list will contain the number of upcoming activities requested in lookAheadCount. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForMaterialGroupByCount (
      in AbstractIF::MaterialGroup aMaterialGroup,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            MaterialGroupNotFound);
```

/* Return a forecast list containing future activities for this durable. The forecast list will contain the number of upcoming activities requested in lookAheadCount. The forecast list may include a mix of different activity types. */

```
ForecastList forecastForDurableByCount (
      in DurablesManagement::Durable aDurable,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);
```

Contracted Services: None.

Dynamic Model: Inherited from ComponentManager.

```
}; // SchedulingManager
```

APPENDIX 1
COMPLETE LISTING OF SCHEDULING COMPONENT IDL

NOTE: The material in this appendix is an official part of SEMI E105 and was approved by full letter ballot procedures on August 28, 2000 by North American Regional Standards Committee.

```
module CIMFW {

#include <Global.idl>
#include <AbstractIF.idl>
#include <FactoryOperations.idl>
#include <DurablesManagement.idl>
#ifndef _CIMFW_SCHEDULING_
#define _CIMFW_SCHEDULING_

module Scheduling {

     enum ActivityType {
          ProductionActivity,
          TransportActivity,
          MaintenanceActivity,
          DoNothing };

     struct ActivityOption {
          ActivityType activityType;
          short prioritySequenceNumber;
          Global::TimeStamp deadline;
          AbstractIF::ResourceSequence resources;
          AbstractIF::MaterialGroupSequence materialGroups;
          DurablesManagement::DurableSequence durables;
          Global::Properties activitySpec;
     }; // ActivityOption

     struct ActivityForecast {
          ActivityType activityType;
          short timeSequenceNumber;
          AbstractIF::ResourceSequence resources;
          AbstractIF::MaterialGroupSequence materialGroups;
          DurablesManagement::DurableSequence durables;
          Global::TimeStamp projectedStart;
          Global::TimeStamp projectedFinish;
          Global::Properties activitySpec;
     }; // ActivityForecast

     typedef sequence <ActivityOption> ActivityList;

     typedef sequence <ActivityForecast> ForecastList;

interface SchedulingManager : FactoryOperations::ComponentManager {

     exception ResourceNotFound {
          AbstractIF::Resource requestedObject;};

     exception MaterialGroupNotFound {
          AbstractIF::MaterialGroup requestedObject;};

     exception DurableNotFound {
          DurablesManagement::Durable requestedObject;};
```

```
ActivityList whatNextForResourceByCount (
      in AbstractIF::Resource aResource)
      in short listCount)
      raises (Global::FrameworkErrorSignal,
            ResourceNotFound);

ActivityList whatNextForMaterialGroupByCount (
      in AbstractIF::MaterialGroup aMaterialGroup,
      in short listCount)
      raises (Global::FrameworkErrorSignal,
            MaterialGroupNotFound);

ActivityList whatNextForDurableByCount (
      in DurablesManagement::Durable aDurable)
      in short listCount)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);

ActivityList whereNextForMaterialGroup (in AbstractIF::MaterialGroup aMaterialGroup)
      raises (Global::FrameworkErrorSignal,
            MaterialGroupNotFound);

ActivityList whereNextForDurable (in DurablesManagement::Durable aDurable)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);

ForecastList forecastForResourceByTime (
      in AbstractIF::Resource aResource,
      in Global::TimeStamp lookAheadTime)
      raises (Global::FrameworkErrorSignal,
            ResourceNotFound);

ForecastList forecastForMaterialGroupByTime (
      in AbstractIF::MaterialGroup aMaterialGroup,
      in Global::TimeStamp lookAheadTime)
      raises (Global::FrameworkErrorSignal,
            MaterialGroupNotFound);

ForecastList forecastForDurableByTime (
      in DurablesManagement::Durable aDurable,
      in Global::TimeStamp lookAheadTime)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);

ForecastList forecastForResourceByCount (
      in AbstractIF::Resource aResource,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            ResourceNotFound);

ForecastList forecastForMaterialGroupByCount (
      in AbstractIF::MaterialGroup aMaterialGroup,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            MaterialGroupNotFound);

ForecastList forecastForDurableByCount (
      in DurablesManagement::Durable aDurable,
      in short lookAheadCount)
      raises (Global::FrameworkErrorSignal,
            DurableNotFound);

}; // SchedulingManager
}; // module Scheduling
```

```
#endif // _CIMFW_SCHEDULING_
}; // mdoule CIMFW
```

RELATED INFORMATION 1
IMPLEMENTATION GUIDANCE FOR INPUT OF FACTORY STATE INFORMATION TO THE SCHEDULING COMPONENT

NOTE: This related information is not an official part of SEMI E105. This related information was approved for publication by full letter ballot procedures on August 28, 2000.

NOTE: This related information is included with the Scheduling Component specification to aid the readers in understanding the intent and use of the standard.

R1-1 The Scheduling Component has two types of interfaces:

A. Scheduling and Dispatching Service Interface - this is the interface for services provided by the Scheduling Component in response to requests from the Factory Operations Component or some other client. It also includes interfaces to support asynchronous actions for an active scheduler or dispatcher which provides the same information content on an event driven basis rather than requiring a client request.

This is included within the scope of the current standard.

B. Scheduling and Dispatching Factory Input Interface - this is the interface used by other components to provide updated information on factory state used by the Scheduling Component in making scheduling and dispatching decisions. The updates are typically provided by other CIM Framework components to the Scheduling Component asynchronously.

This is NOT included within the scope of the current standard.

R1-2 The goal for CIM Framework standards is to eventually standardize both of these types of interface. However, at this time there are two major issues that prevent inclusion of the Factory Input Interface to the Scheduling Component.

1. There is inadequate consensus on the technical maturity of the currently available asynchronous input mechanisms. While the CIM Framework specifies events for delivery via an Event Broker mechanism, it is not assumed that the quality of service for events will include guaranteed delivery and performance adequate for keeping a Scheduling Component current with real-time factory state changes. For a more complete discussion of the CIM Framework technical architecture issues, see SEMI E96.

2. Some key components of the CIM Framework needed to provide factory state to the Scheduling Component have not yet been approved as SEMI standards.

R1-3 The following approach is suggested as a possible way to address Scheduling Component Input in the future:

1. Identify the most important inputs required by the Scheduling Component in a follow-on ballot for the Scheduling Component to be used during the interim period until the full component specifications containing those events are approved as SEMI standards.

2. Suppliers who implement the Scheduling Component should take advantage of existing standard interfaces defined in adopted CIM framework standards and use this experience as expert input on future updates to this standard.

3. Encourage technical studies to provide added understanding of the tradeoffs and limitations that impact standardization of this interface in the future.

RELATED INFORMATION 2
SCENARIOS FOR SCHEDULING AND DISPATCHING.

NOTE: This related information is not an official part of SEMI E105. This related information was approved for publication by full letter ballot procedures on August 28, 2000.

These scenarios show possible implementations of the SEMI Scheduling Component. The information shown here is intended to be a guide rather than describe prescriptive implementation rules. Some of the message sequences and implied functionality included in these scenarios will vary across different implementations.

This section focuses primarily on the interface between the Scheduling Component and factory operations component. The messaging between the lower level components is for informational purposes, and may not actually reflect what is developed in the future when standards for those components have been completed.

R2-1 *Scenario 1* — Simulator Based Scheduler/Dispatcher, Stocker is Not Managed by Scheduling Component

R2-1.1 Lot 1 is scheduled for equipment 2 at 10:00. Lot is held in stocker until ready to start on equipment 2. Factory operations makes the carrier delivery decisions.

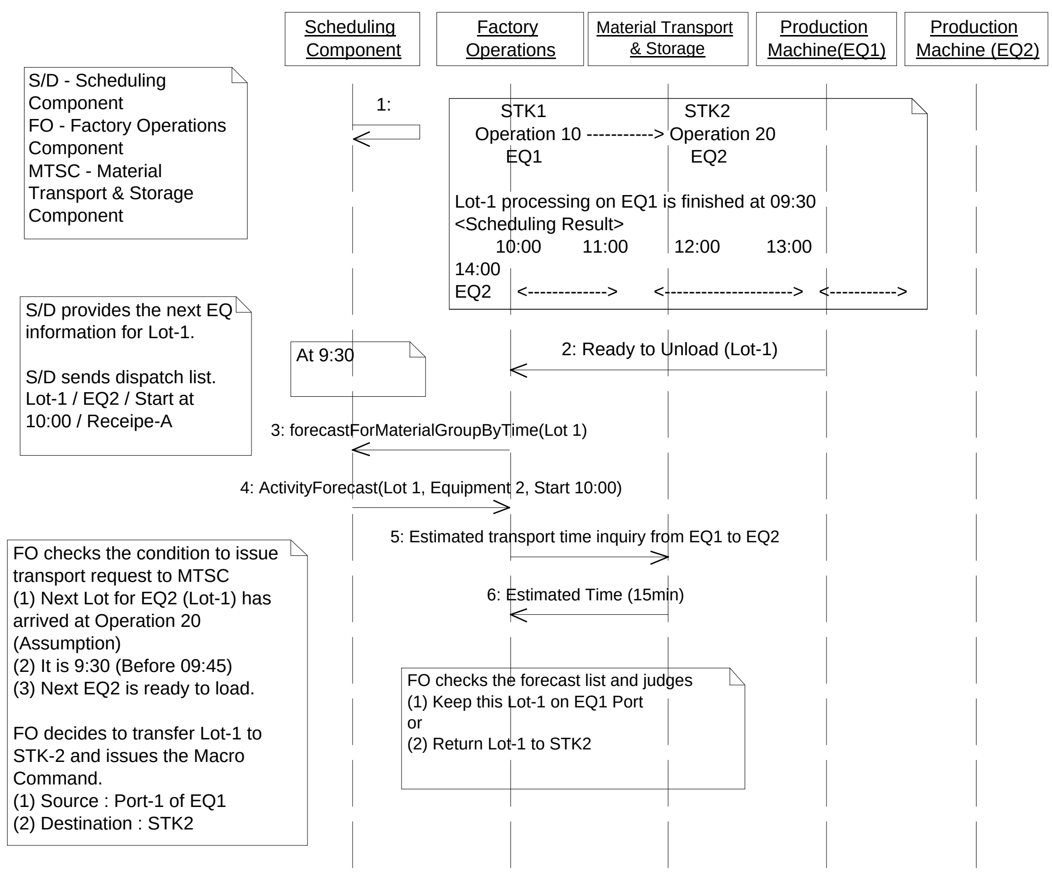


Figure R2-1
Scenario Case 1

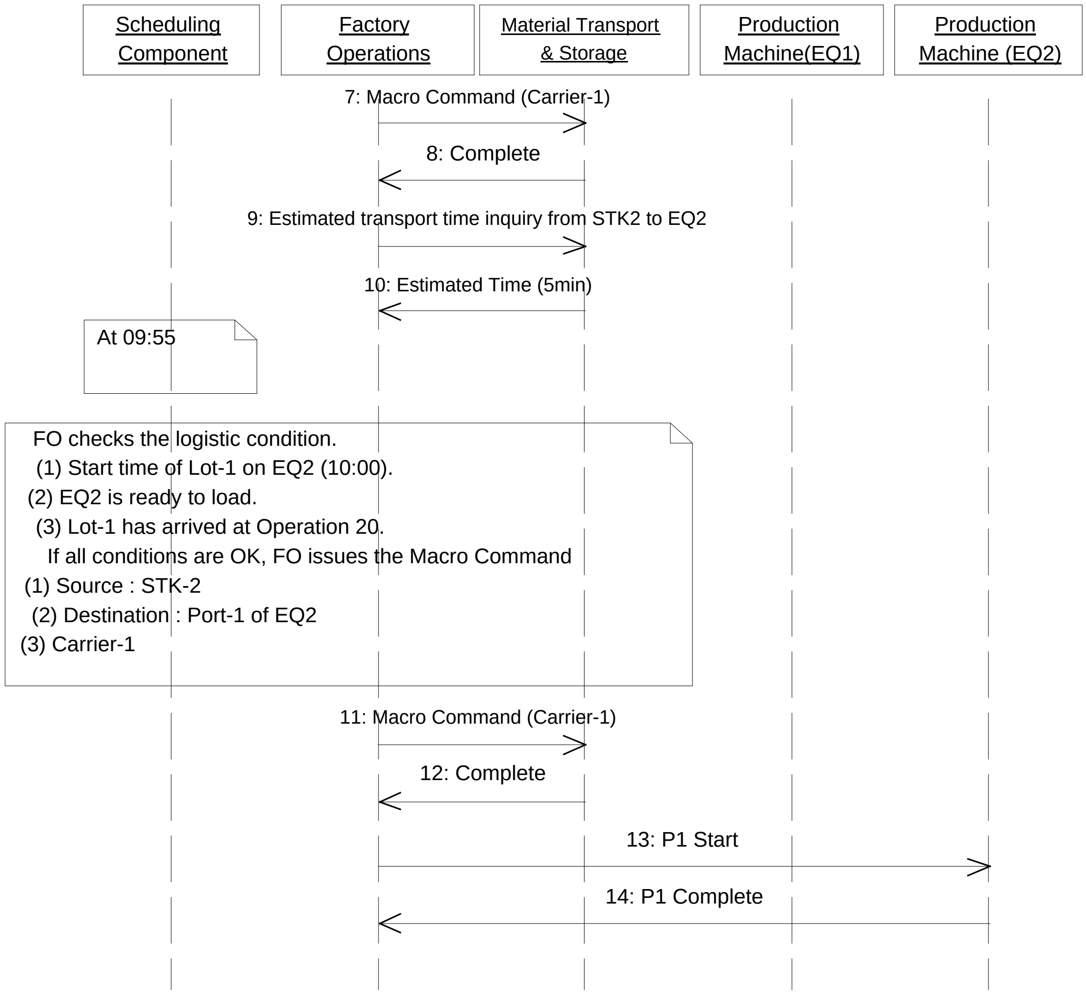


Figure R2-2
Scenario Case 1 Continued

R2-2 *Scenario 2* — Simulator Based Scheduler/Dispatcher, Stocker is Not Managed by Scheduling Component

R2-2.1 Lot 1 is scheduled for equipment 2. Lot is transported directly from Eqp1 to Eqp 2. Factory Operations makes the carrier delivery decisions.

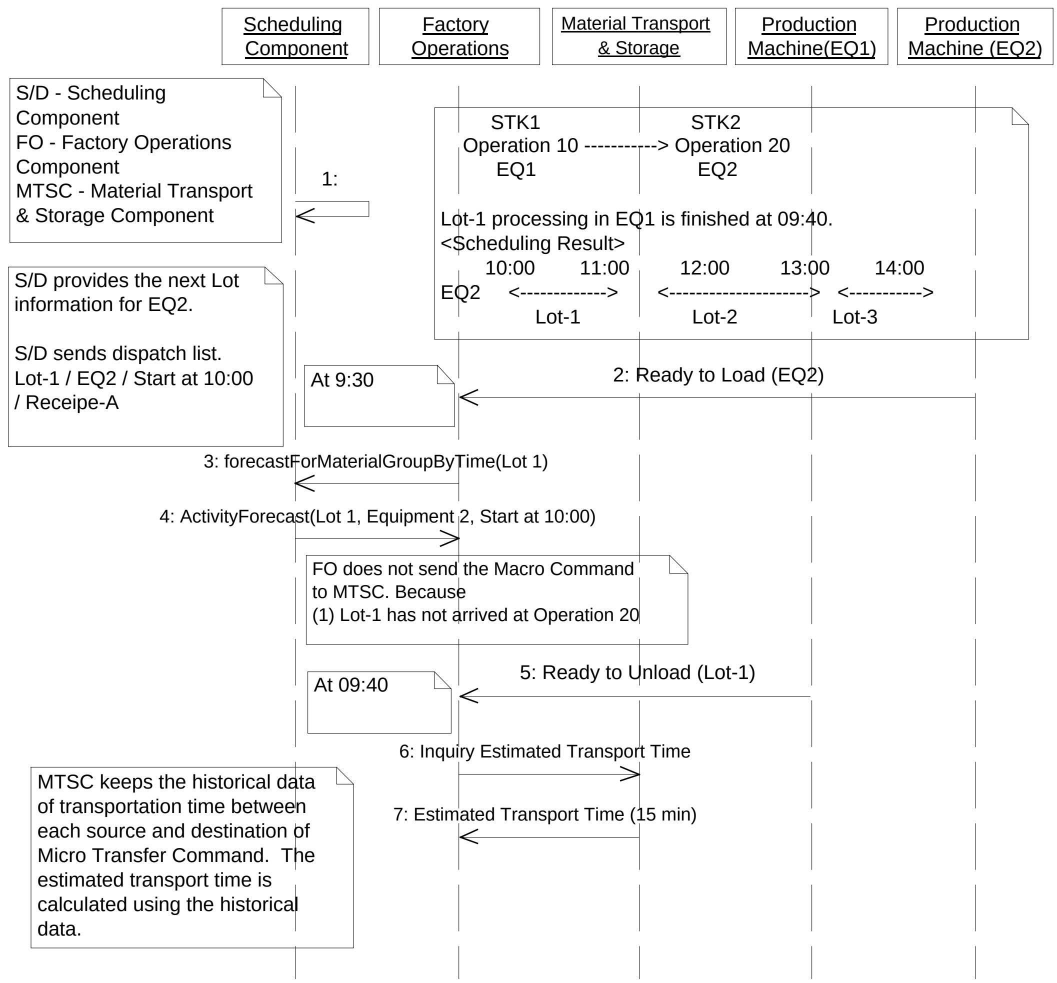


Figure R2-3
Scenario Case 2

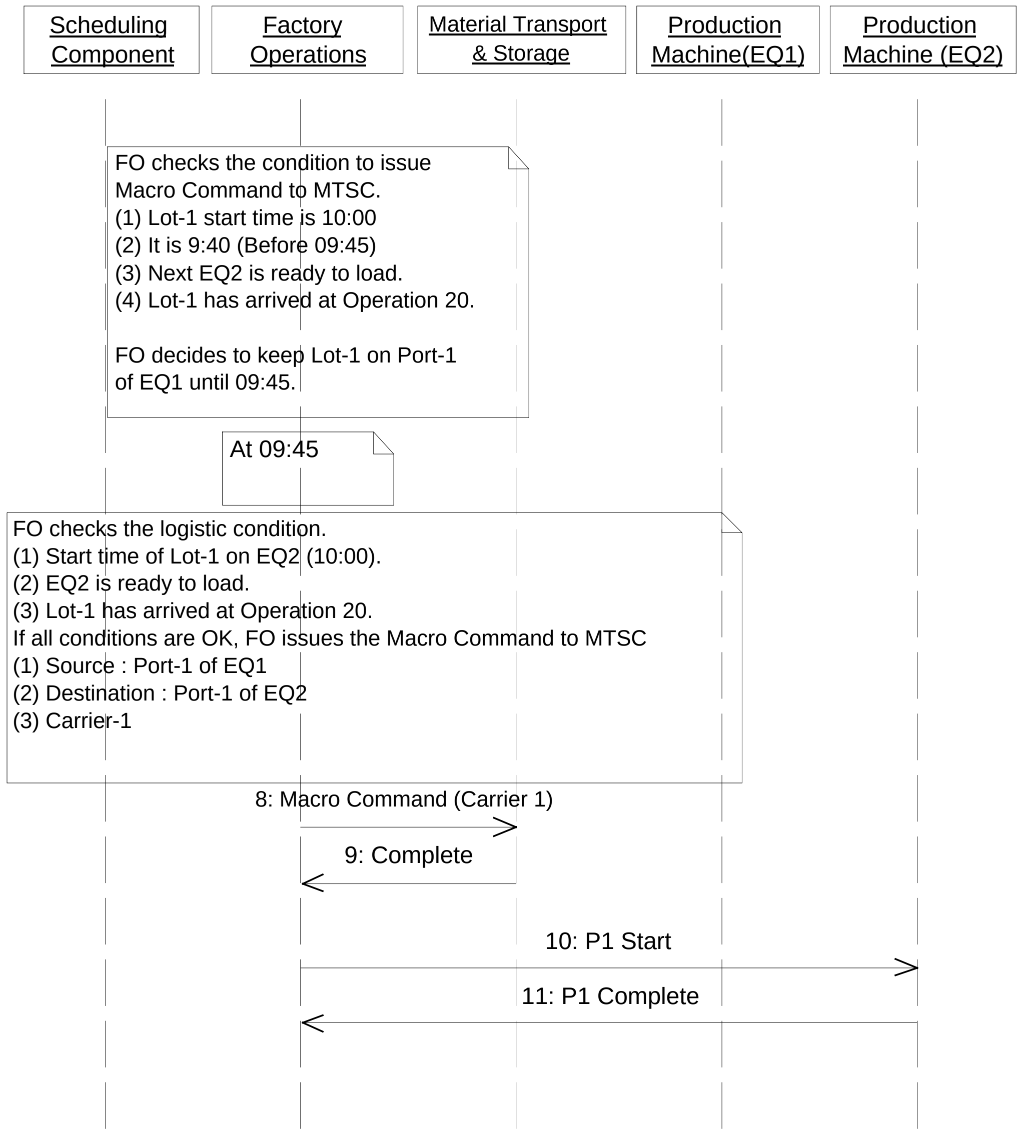
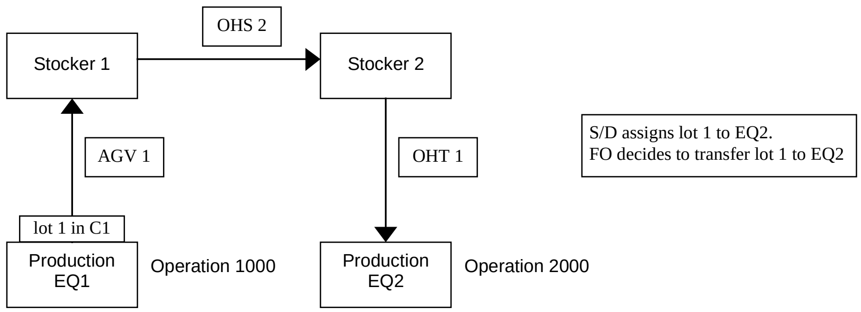
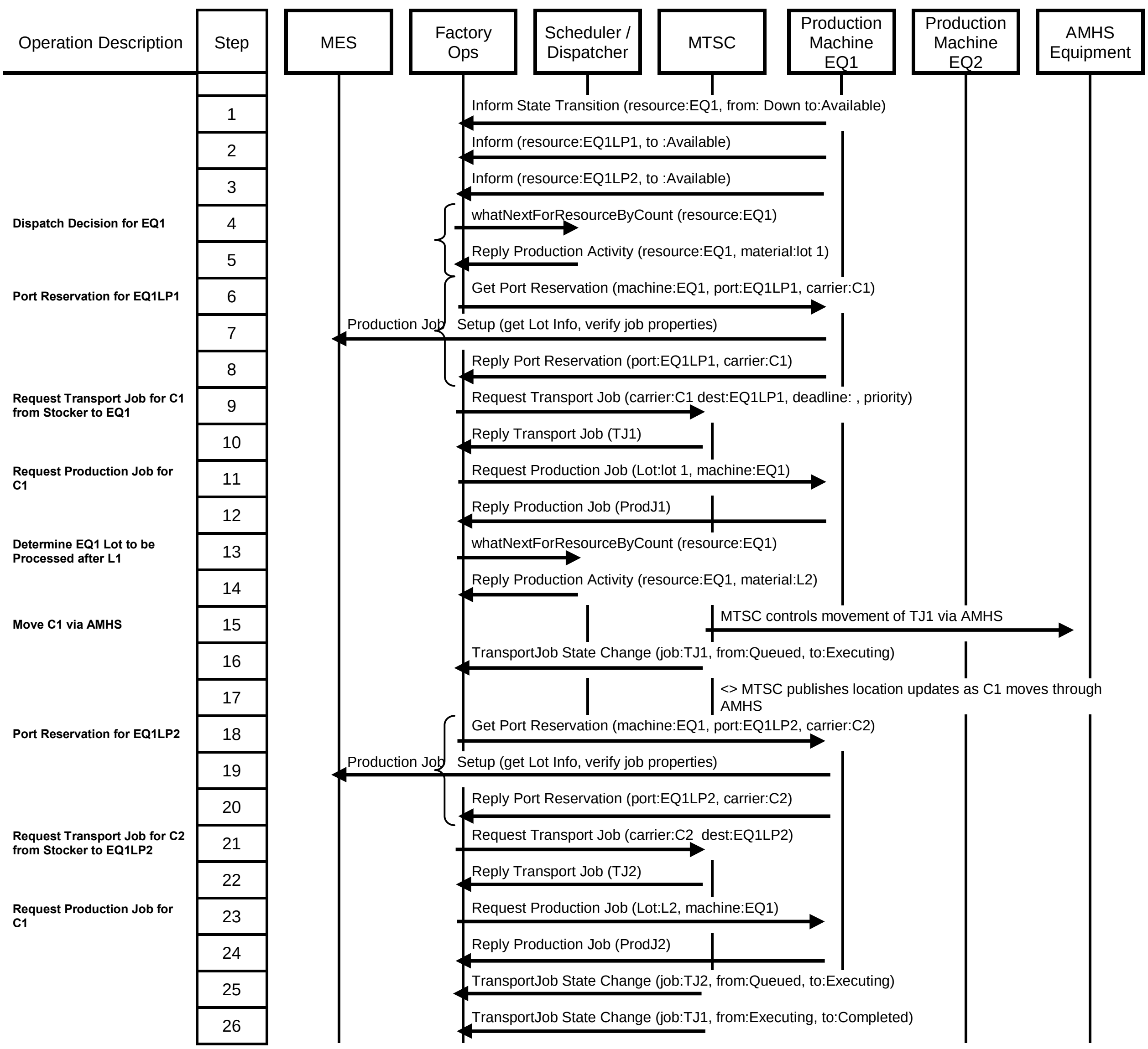


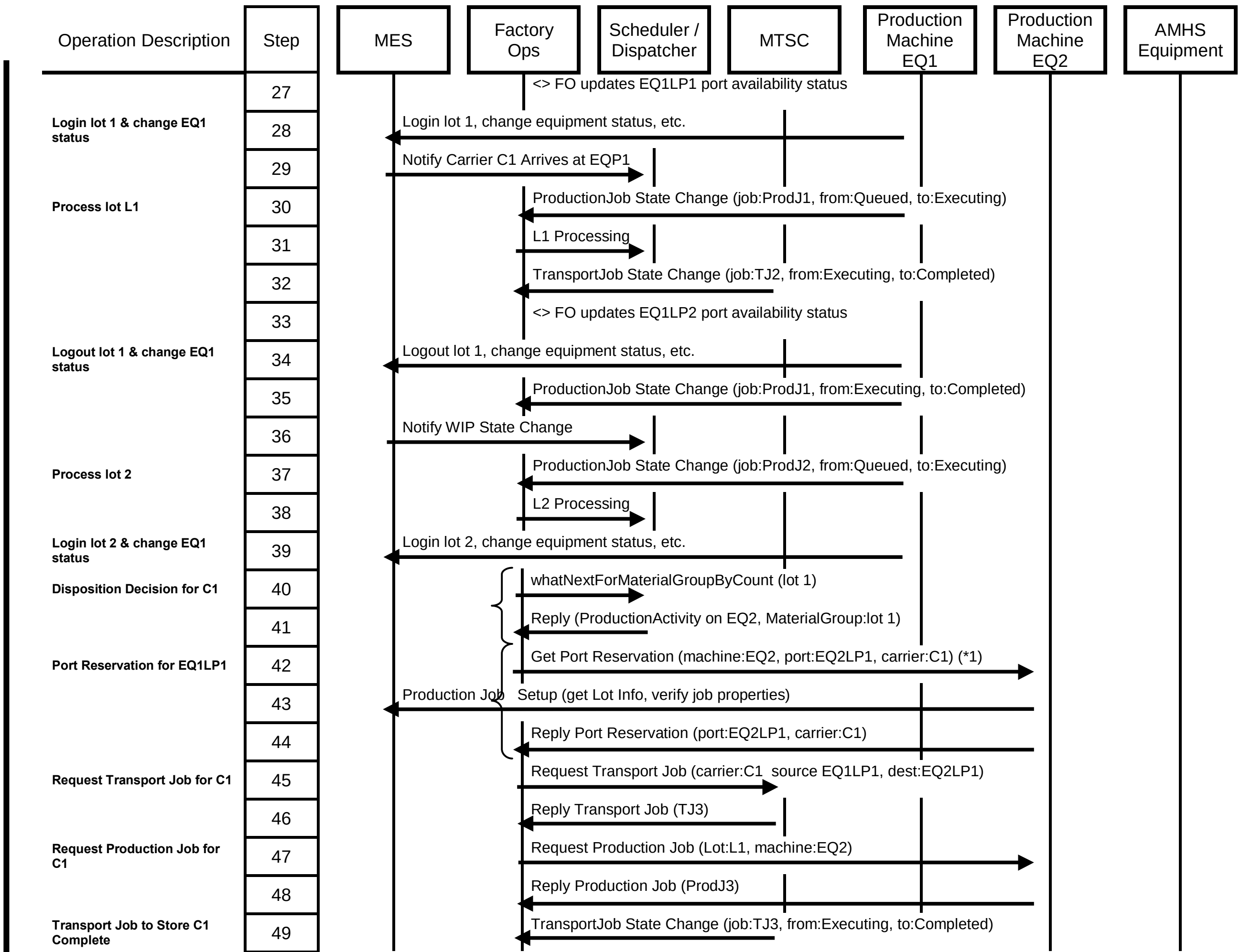
Figure R2-4
Scenario Case 2 Continued

R2-3 *Scenario 3* — Dispatch List Based Scheduler/Dispatcher, Stocker is Not managed by Scheduling Component

R2-3.1 Dispatch list based. EQ1->EQ2. After lot 1 processing on EQ1 is finished, Scheduler assigns lot 1 to EQ2. FO checks the EQ2 port status and finds the available port. FO makes the logistic decision to transfer lot 1 from EQ1 to EQ2 directly. Scheduler does not assign lots to Stocker. In this scenario 3, the direct transfer "from EQ1 to EQ2" is described.



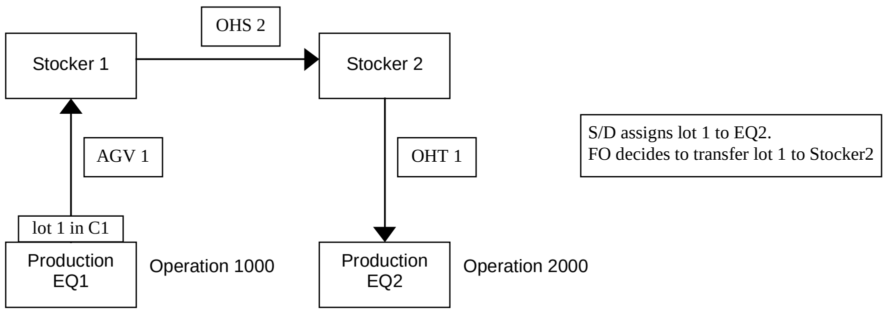


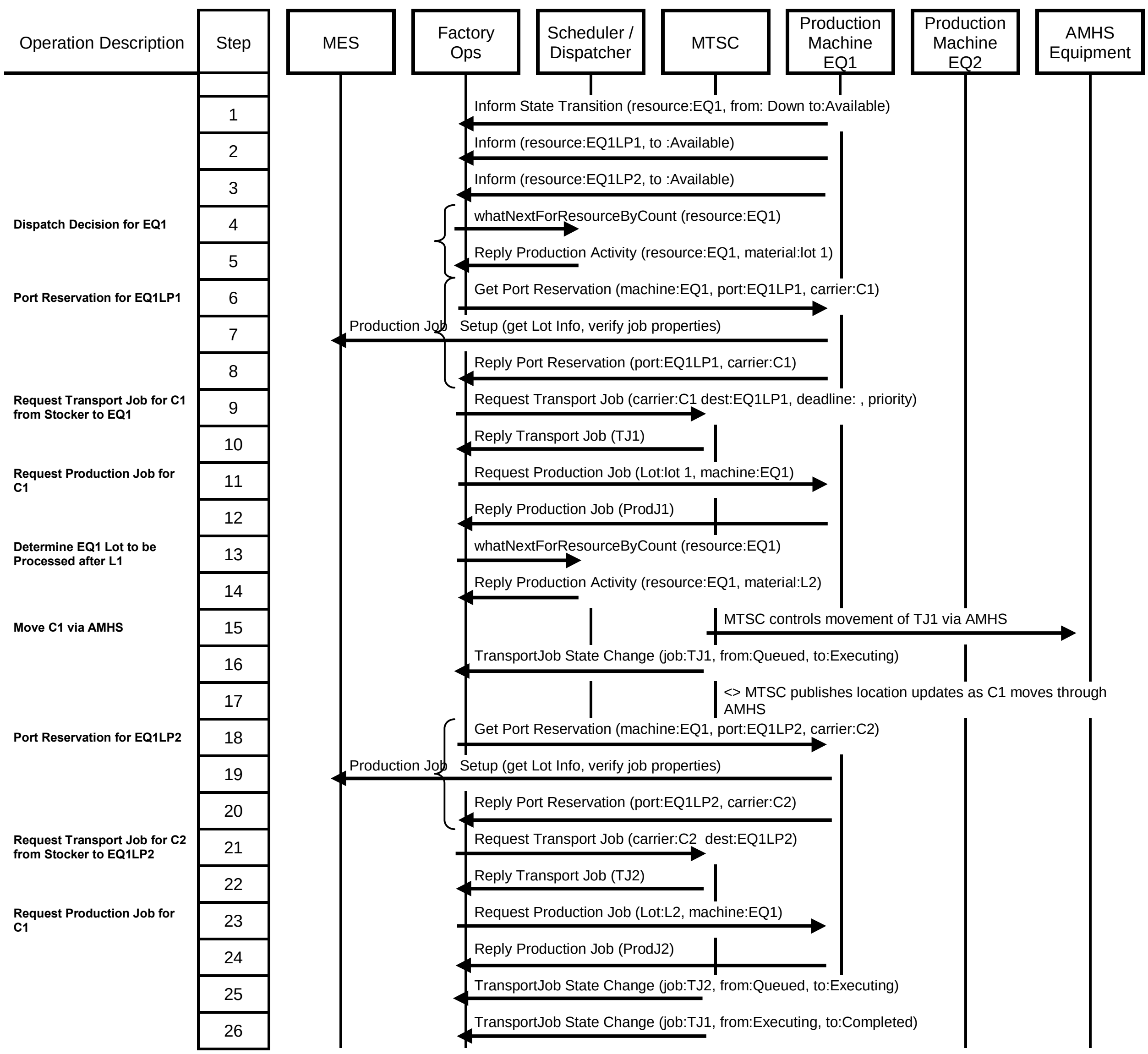


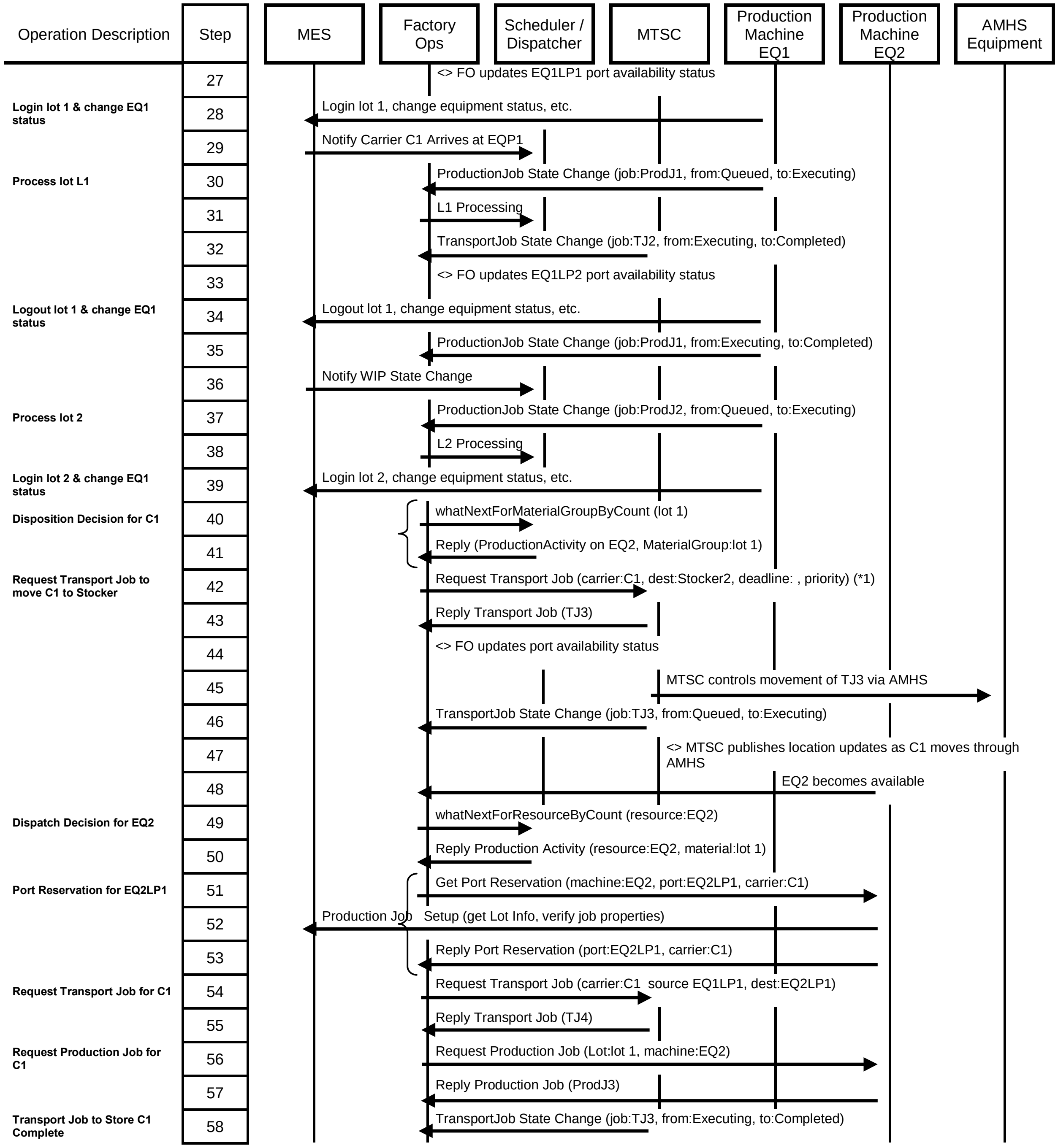
(*1) FO checks port status on tool. Finds port available. Delivers lot directly to EQ2.

R2-4 *Scenario 4* — Dispatch List Based Scheduler/Dispatcher, Stocker is Not managed by Scheduling Component

R2-4.1 Dispatch list based. EQ1->Stocker->EQ2. After lot 1 processing on EQ1 is finished, Scheduler assigns lot 1 to EQ2. FO checks the EQ2 port status and finds No available port. FO makes the logistic decision to transfer lot 1 from "EQ1 to Stocker 2" instead of "from EQ1 to EQ2". Scheduler does not assign lots to Stocker. In this scenario 4, the separate transfers "from EQ1 to Stocker 2" and "from Stocker 2 to EQ2" are described.



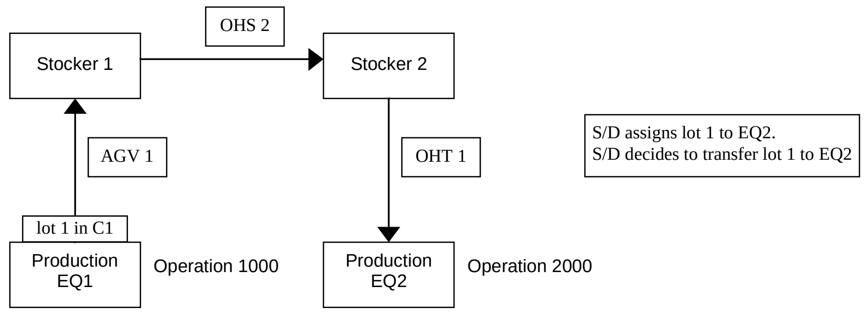


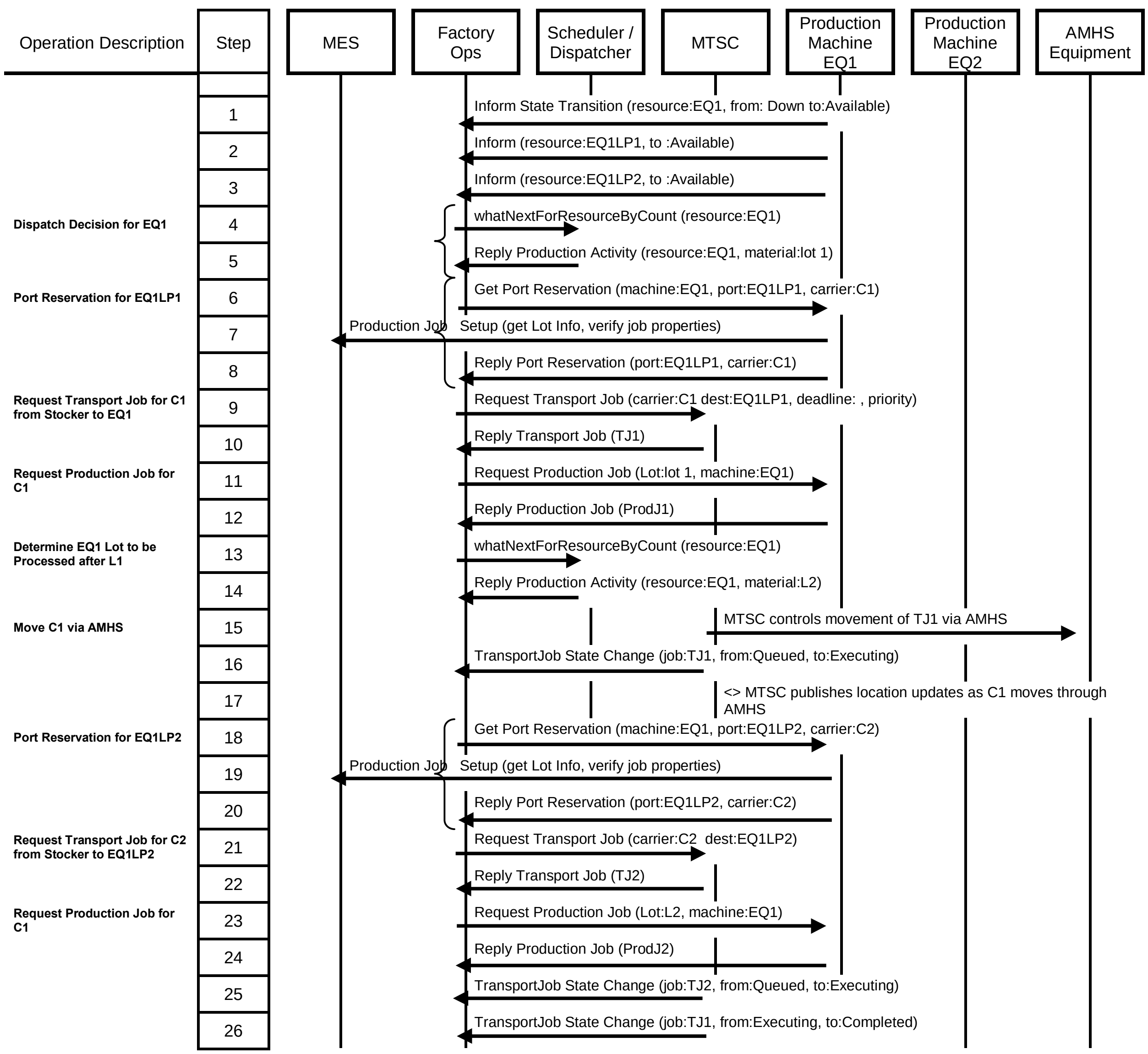


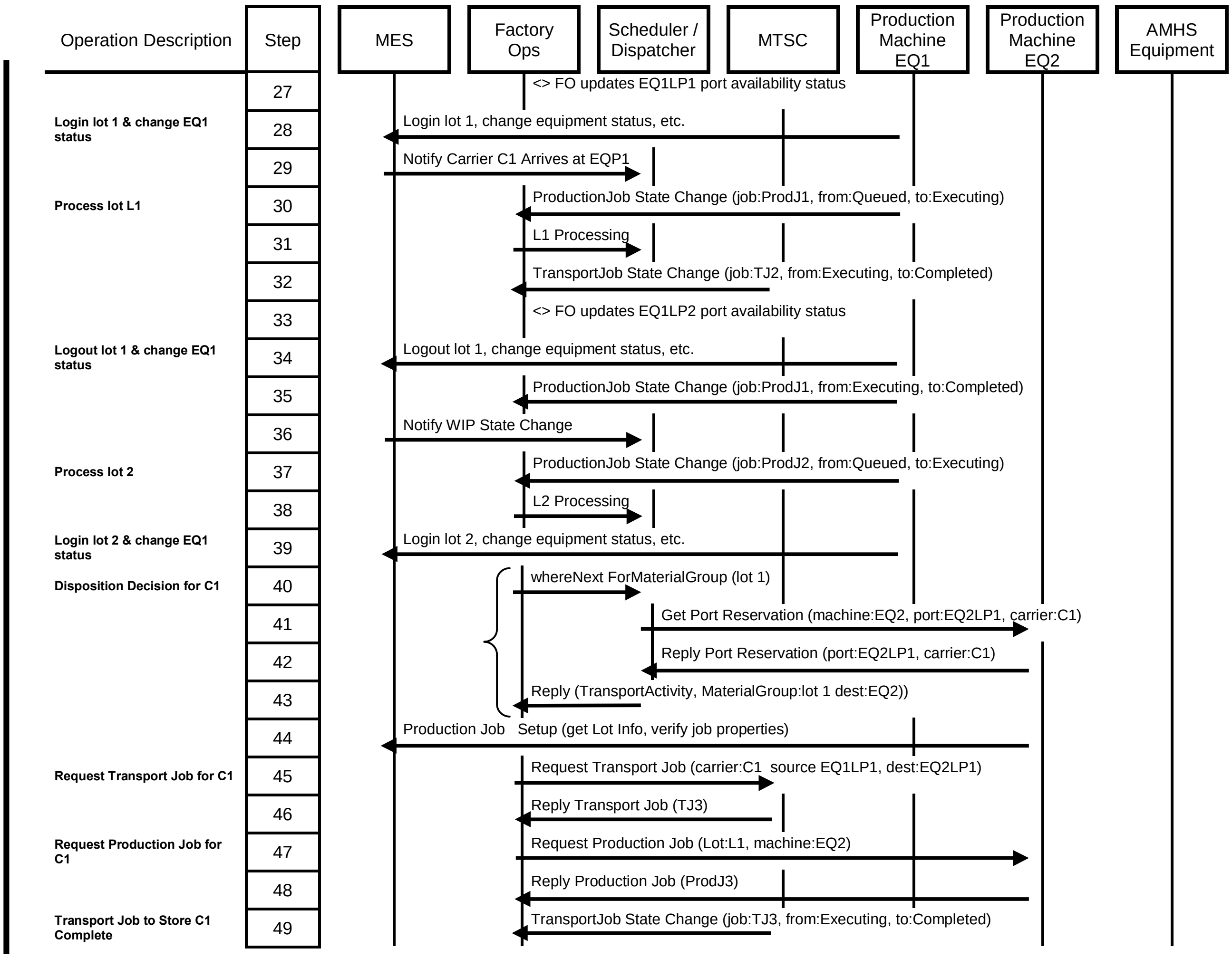
(*1) FO checks port status on tool. Finds no ports available. Delivers lot to stocker close to tool.

R2-5 *Scenario 5* — Dispatch List Based Scheduler/Dispatcher, Stocker is managed by Scheduling Component

R2-5.1 Dispatch list based. EQ1->EQ2. After lot 1 processing on EQ1 is finished, Scheduler assigns lot 1 to EQ2. Scheduler additionally checks the EQ2 port status and finds the available port. Scheduler makes the logistic decision to transfer lot 1 from EQ1 to EQ2 directly. Scheduler assigns lots to Stocker when the next assigned equipment is not available. In this scenario 5, the direct transfer "from EQ1 to EQ2" is described.

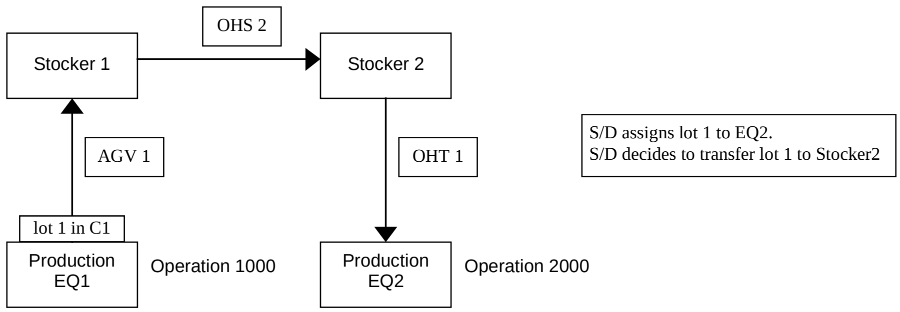


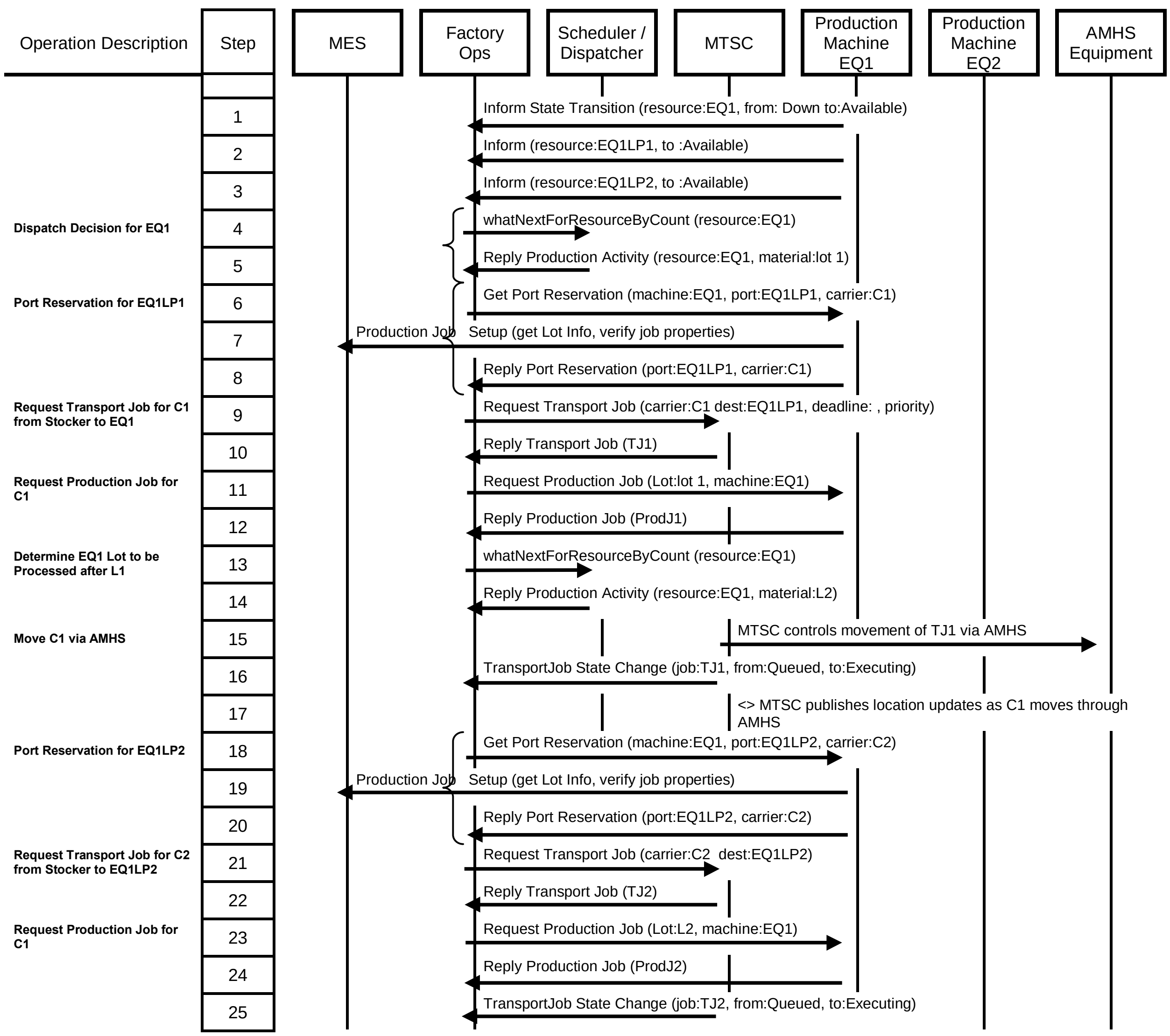


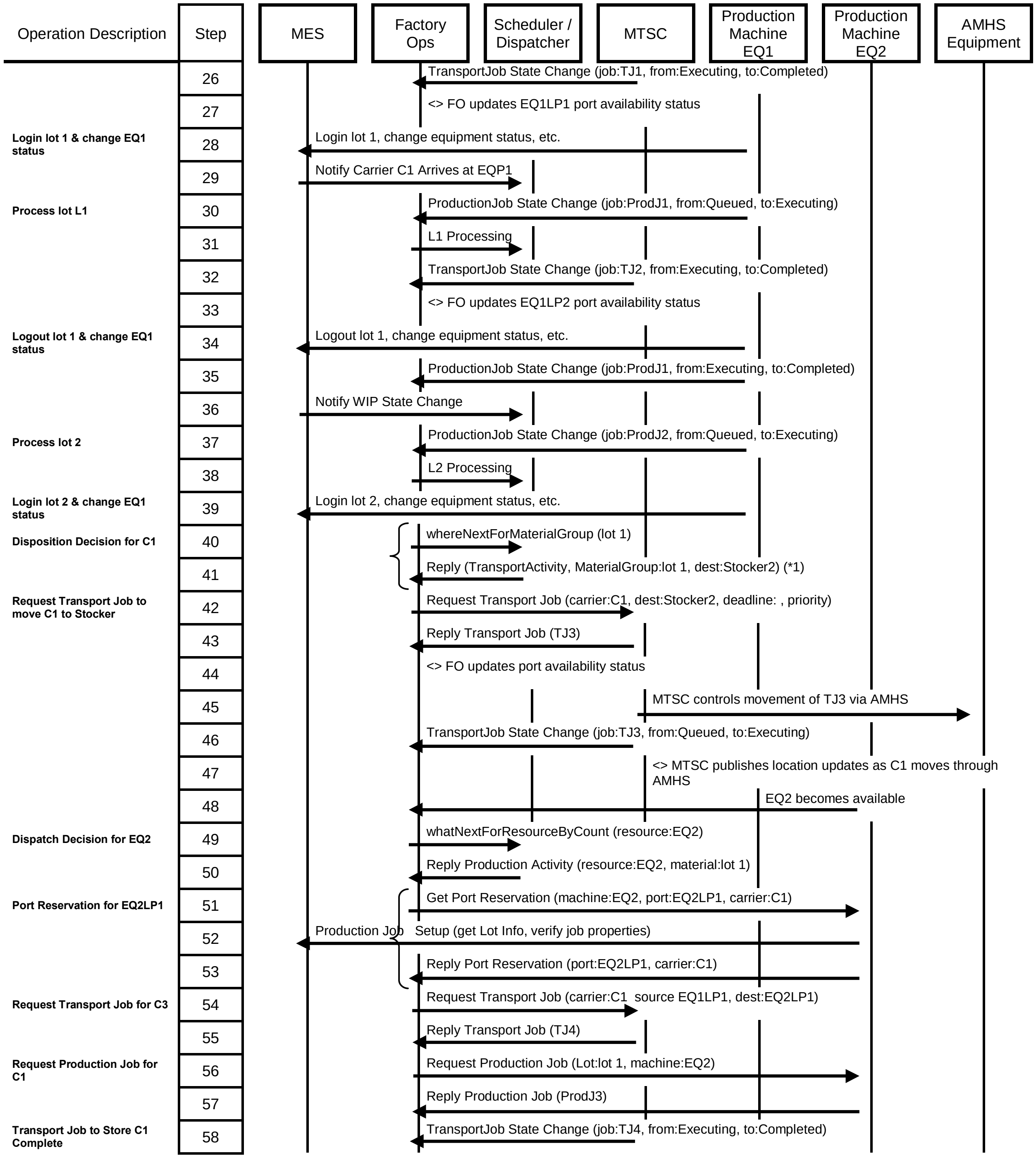

Operation Description
Step
MES
Factory Ops
Scheduler / Dispatcher
MTSC
Production Machine EQ1
Production Machine EQ2
AMHS Equipment
27
<> FO updates EQ1LP1 port availability status
Login lot 1 & change EQ1 status
28
Login lot 1, change equipment status, etc.
29
Notify Carrier C1 Arrives at EQP1
Process lot L1
30
ProductionJob State Change (job:ProdJ1, from:Queued, to:Executing)
31
L1 Processing
32
TransportJob State Change (job:TJ2, from:Executing, to:Completed)
33
<> FO updates EQ1LP2 port availability status
Logout lot 1 & change EQ1 status
34
Logout lot 1, change equipment status, etc.
35
ProductionJob State Change (job:ProdJ1, from:Executing, to:Completed)
36
Notify WIP State Change
Process lot 2
37
ProductionJob State Change (job:ProdJ2, from:Queued, to:Executing)
38
L2 Processing
Login lot 2 & change EQ1 status
39
Login lot 2, change equipment status, etc.
Disposition Decision for C1
40
whereNext ForMaterialGroup (lot 1)
41
Get Port Reservation (machine:EQ2, port:EQ2LP1, carrier:C1)
42
Reply Port Reservation (port:EQ2LP1, carrier:C1)
43
Reply (TransportActivity, MaterialGroup:lot 1 dest:EQ2))
44
Production Job Setup (get Lot Info, verify job properties)
Request Transport Job for C1
45
Request Transport Job (carrier:C1 source EQ1LP1, dest:EQ2LP1)
46
Reply Transport Job (TJ3)
Request Production Job for C1
47
Request Production Job (Lot:L1, machine:EQ2)
48
Reply Production Job (ProdJ3)
Transport Job to Store C1 Complete
49
TransportJob State Change (job:TJ3, from:Executing, to:Completed)

R2-6 *Scenario 6* — Dispatch List Based Scheduler/Dispatcher, Stocker is managed by Scheduling Component

R2-6.1 Dispatch list based. EQ1->Stocker->EQ2. After lot 1 processing on EQ1 is finished, Scheduler assigns lot 1 to EQ2. FO checks the EQ2 port status and finds the available port. Scheduler makes the logistic decision to transfer lot 1 "from EQ1 to Stocker 2" instead of "from EQ1 to EQ2". Scheduler assigns lots to Stocker when the next equipment is not available. In this scenario 6, the separate transfers "from EQ1 to Stocker 2" and "from Stocker 2 to EQ2" are described.







(*1) Scheduler/Dispatcher checks the next equipment EQ2 status and port availability. EQ2 Status: Processing, Available Ports: No vacant port. Scheduler/Dispatcher decides to transfer lot 1 to Stocker 2.

RELATED INFORMATION 3
ASSUMED CASE OF SCHEDULER/DISPATCHER

NOTE: This related information is not an official part of SEMI E105. This related information was approved for publication by full letter ballot procedures on February 1, 2001.

The assumed two cases of scheduler/dispatcher were used to have an analysis and to make scenarios when the interfaces defined in SEMI E105 ware developed. This related information describes the assumed two case of scheduler/dispatcher to make easier for the standard user to understand SEMI E105. SEMI E105 does not limit the case of Scheduler/Dispatcher to these two assumed scheduler/dispatcher.

R3-1 *Dispatch List Based Scheduler/Dispatcher*

R3-1.1 *Basic Functions*

Dispatch List Based Scheduler/Dispatcher has a waiting lots list in each operation and has a capability to prioritize the existing lots.

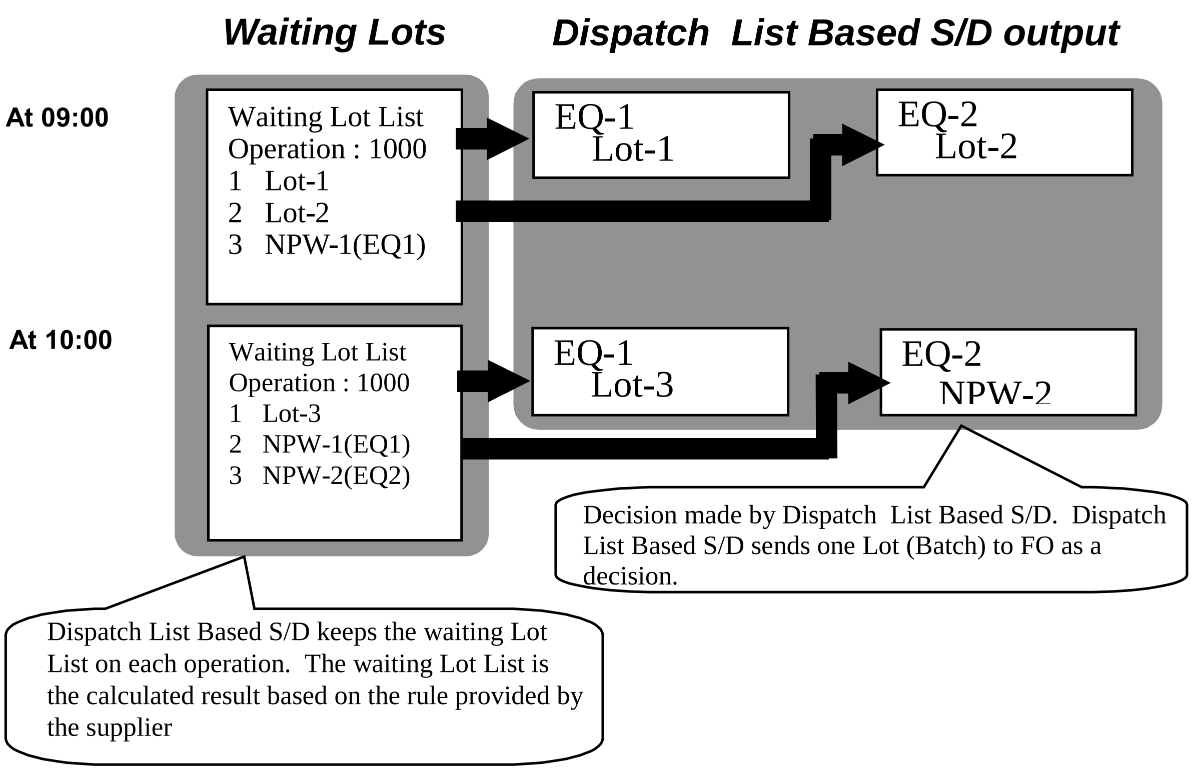


Figure R3-1

R3-1.2 *Case 1* – Factory Operation decides storage machine (Refer to Scenarios R2-3 and R2-4)

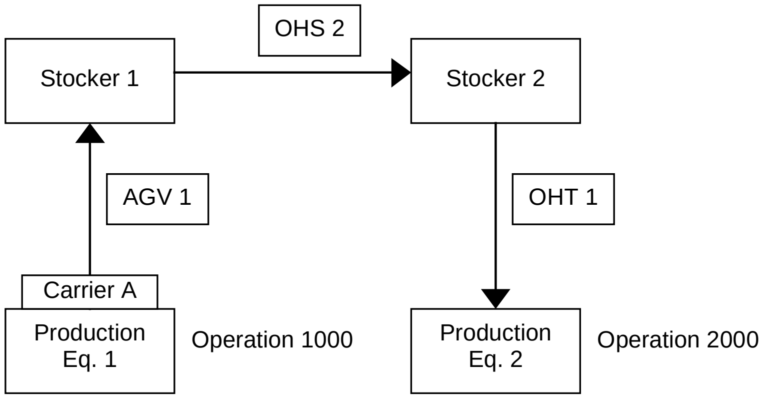


Figure R3-2

1. Carrier A processing on Eq.1 (Operation 1000) is finished.
2. Next operation for Carrier A is “2000” and the production equipment in operation “2000”is Eq.2 only.
3. Factory Operation makes the logistic decision .

(1) Transfer Carrier A from Eq.1 to Eq.2

or

(2) Transfer Carrier A from Eq.1 to Stocker 2.

4. Factory Operation uses the following interfaces defined in section 6.1.6. (*1)

- whatNextForResourceByCount
- whatNextForMaterialGroupByCount
- whatNextForDurableByCount

5. Factory Operation dose not use the following interfaces defined in section 6.1.6. (*1)

- whereNextForMaterialGroup
- whereNextForDurable

6. Scheduler / Dispatcher shows the waiting Lot list in operation “2000” (Eq.2) to Factory Operation

R3-1.2 *Case 2* – Scheduler / Dispatcher decides storage machine (Refer to Scenarios R2-5 and R2-6)

1. Carrier A processing on Eq.1 (Operation 1000) is finished.
2. Next operation for Carrier A is “2000” and the production equipment in operation “2000”is Eq.2 only.
3. Scheduler / Dispatcher checks the port status of Eq.2 and makes the logistic decision .

(1) Transfer Carrier A from Eq.1 to Eq.2

or

(2) Transfer Carrier A from Eq.1 to Stocker 2.

4. Factory Operation uses the following interfaces defined in section 6.1.6. (*1)

- whatNextForResourceByCount
- whereNextForMaterialGroup
- whereNextForDurable

5. Factory Operation dose not use the following interfaces defined in section 6.1.6. (*1)

- whatNextForMaterialGroupByCount
- whatNextForDurableByCount

R3-2 *Simulator Based Scheduler/Dispatcher (Refer to Scenarios R2-1 and R2-2)*

R3-2.1 *Basic Functions*

Simulator Based Scheduler / Dispatcher has a forecast list for each production equipment and provides the lot list with forecast time stamp to Factory Operation.

Factory Operation uses “forecastFor…” interfaces defined in section 6.1.6. (*1)

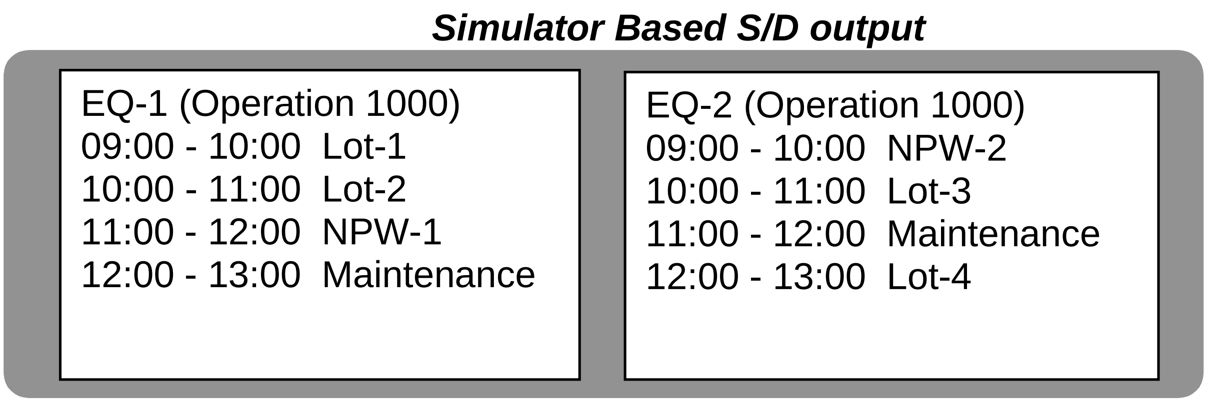


Figure R3-3

Remarks

In (*1), the conformance of each interfaces to each case of Scheduler/Dispatcher are described. These are only for reference and are not the requirement to the Scheduler/Dispatcher product. For example, Simulator Based Scheduler / Dispatcher may support “whatNextFor…” interfaces.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user’s attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI E107-1101
PROVISIONAL SPECIFICATION OF ELECTRIC FAILURE LINK DATA FORMAT FOR YIELD MANAGEMENT SYSTEM

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the Japanese Information & Control Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published March 2001.

1 Purpose

1.1 The objective of this document is standardization of the specific data format passed from the test equipment to the Yield Management System. The Yield Management System is a kind of data server for detail test data and geometrical defect data of patterns on a wafer as described in the Terminology section of this document.

1.2 This document assumes a Yield Management System in which test equipment electrical failure information is managed and analyzed in an integrated manner. Examples of test equipment failure information include bit map data, bin data, and inpsection information obtained by devices such as wafer inspection equipment and review tools. Standardization of the data file format helps to reduce the development burden on customers and related vendors.

2 Scope

2.1 This document specifies the data file format for transferring from test equipment to a Yield Management System.

2.2 This document is an extension of the general map data item standard, i.e. SEMI G81, and the general map data format document, currently under development. This document does not redefine the general specification.

2.3 The scope of this document is just defining data items and their formats. Data file creation methods, data creating environments and file naming conventions are outside of the scope of this document. Also, communication protocols to transfer the data are beyond the scope of this document.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This document has provisional status because the common Specification for Map Data Format and a general map data format document are currently under development. Data format is related to YMS Link and this needs to be completed in Section 8.1.6, Map Data Format for YMS Link to be in conformance. In addition, the example of data file in Related Information must be revised and the idea of Map Data Format for YMS Link Data should be removed.

NOTE 1: A standard for Map Data Format is currently under development.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communication Standard 2 Message Content (SECS-II).

SEMI E30.1 — Inspection and Review Specific Equipment Model (ISEM).

SEMI G81 — Specification for Map Data Items

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *analog data* — One of three categories of data: measured values such as voltage or current obtained when test equipment measures a semiconductor device's electrical characteristics, parameter values which are test parameters when measuring, and limit values which are decision parameters if test results are pass or fail.

5.2 *bin data* — same as Category below.

5.3 *fail bit map data* — data representing memory cell electrical failure information according to its location information, in units of the die or wafer.

5.4 *category* — data indicating the type of electric failure or rank of characteristics of die tested by the test equipment. Used in the same manner as Bin Data in this standard.

5.5 *cell-logical-address* — gives the electrical location of a memory cell in a die.

5.6 *cell-logical-io-number* — number identifying the IO data which can be simultaneously electrically accessed within a memory device.

5.7 *cell-physical-address* — gives location of a memory cell in a die on two-dimensional plane.

5.8 *die* — a unit equivalent to one die on a wafer. Also known as Chip.

5.9 *electrical failure information* — failure information generated by test equipment; e.g. Bit Map Data, Bin Data and Analog Data.

5.10 *error class* — specifies the type of electrical failure configuration in a memory cell group. Bit-fail, line-fail and block-fail are examples.

5.11 *inspection information* — inspection results for a wafer, indicating defect location and defect details obtained as the result of inspection used in wafer fabrication and the inspection process, such as appearance inspection, contaminant inspection, etc.

5.12 *test equipment* — equipment which tests the electrical characteristics and functions of semiconductor devices.

5.13 *test program name* — name of program used on test equipment when testing a die electrically.

5.14 *yield management system (YMS)* — a system that stores visual inspection data of geometrical defects on wafer and electrical test data of each die. The system processes those data statistically to discover correlation between them. Correlation leads to discovery the cause of failures and understanding of production situation in order to help improve yield. Defect data is standardized in SEMI E30.1 (ISEM).

6 Requirements

6.1 *Map Data Item* — All map data items appear in map data except those standardized in this document shall be specified in the common map data item document, SEMI G81.

6.2 *Map Data Format* — All map data formats appear in map data except those standardized in this document shall be specified in a common map data format document currently under development.

7 General

7.1 *General File Format*

NOTE 3: A standard for Data representation is currently under development.

8 Description

8.1 The fail-bit map data item specifications defined in this document are shown in Table 2. The columns in this table are described in the following sections.

8.1.1 *Item Name Column* — The name by which the data item is referenced.

8.1.2 *Data Type Column* — The type of the data as defined in Table 1.

Table 1 Data Types and Sizes

Type	*Definition*
String	A string of ASCII characters from zero to “Size” characters in length.
Integer	A string of numeric characters (0..9) that represent an integer value.
Float	A string representing a floating point value in exponent format.

8.1.3 *Size Column* — See SEMI G81.

8.1.4 *Description Column* — See SEMI G81.

8.1.5 *Coordinate System Conventions* — See SEMI G81.

Table 2 Data Items for YMS Link

Item Name	*Data Type*	*Size*	*Description*
Comment	String	256	Comment Area. [Comment] = ‘Engineering Test’
TestProgramName	String	256	Name of test program when test equipment obtains test data. [TestProgramName] = ‘pro123a’
TestEquipmentId	String	256	Test equipment identification code. [TestEquipmentId] = ‘tester1’
DieCoordinate	String	13	The die coordinates’ origin location and coordinate axis direction for expressing location coordinates within a die. See Figure 2 and Table 7. [DieCoordinate] = ‘TopLeftXY’ [DieCoordinate] = ‘BottomLeftXY’ [DieCoordinate] = ‘TopLeftYX’

Item Name	*Data Type*	*Size*	*Description*
			[DieCoordinate] = 'BottomLeftYX' [DieCoordinate] = 'TopRightXY' [DieCoordinate] = 'BottomRightXY' [DieCoordinate] = 'TopRightYX' [DieCoordinate] = 'BottomRightYX'
ErrorClassList	String	---	Error type category list, per error class definition. See Figure 2.
ErrorClassNumber	String	3	Error class number from 0 to 255.
ErrorQuality	String	16	Describes the quality of the specified [ErrorClassNumber]. This may be "bit-fail" or "line-fail" or some other value defined by an application.
ErrorDescription	String	256	A description of the specified [ErrorClassNumber], e.g. "100MHz".
FailBitDataTemplate	String	---	Defines the data items and order for expressing the fail bit error class data analyzed within a die by die address and coordinate values within the die. See Figure 2. Defines the items and order for outputting the following fail bit data. See Table 3.
FailBitData	String	---	The list of data expressing the fail bit error class. Data analyzed within a die in accordance with the fail bit data definition. Expresses it as die address and coordinates within a die. See Figure 2.
AnalogDataTemplate	String	---	Defines analog data items and order. These are measured values such as voltage, current, etc. on measuring semiconductor device's electrical characteristics by the test equipment, setting values which are test parameters when measuring, and limit values which are decision parameters if test results are pass or fail. See Table 4.
Invalid	String	14	Defined to indicate invalid data for Analog Data field.
AnalogData	String	---	List of analog data, per analog data definition. These are the semiconductor device's electrical characteristics measured by the test equipment.
ErrorTotal	Integer	10	Total number of electrical errors in the tested/analyzed substrate, by error class type.
TestDie	Integer	10	Total number of dies which were tested/analyzed on the substrate.

Table 3 Data Items for FailBitDataTemplate

Item Name	*Data Type*	*Size*	*Description*
Seq	Integer	10	Sequential number assigned in ascending order, starting with 1.
XAddress	Integer	5	X address of defective die with fail bit data.
YAddress	Integer	5	Y address of defective die with fail bit data.
XMin	Float	14	X minimum coordinate value of fail bit data's error range. Unit 'um'.
XMax	Float	14	X maximum coordinate value of fail bit data's error range. Unit 'um'.
YMin	Float	14	Y minimum coordinate value of fail bit data's error range. Unit 'um'.
YMax	Float	14	Y maximum coordinate value of fail bit data's error range. Unit 'um'.
XCenter	Float	14	X-direction center point coordinate value of fail bit data's error range. Unit 'um'.
YCenter	Float	14	Y-direction center point coordinate value of fail bit data's error range. Unit 'um'.
XSize	Float	14	X-direction size of fail bit data's error range. Unit 'um'.
YSize	Float	14	Y-direction size of fail bit data's error range. Unit 'um'.
Area	Float	14	Area of fail bit data's error range. Unit 'um'.
DefectCate	String	16	Category name of fail bit data.
XMinPhysic	Integer	10	X minimum cell physical address of fail bit data's error range.
XMaxPhysic	Integer	10	X maximum cell physical address of fail bit data's error range.
YMinPhysic	Integer	10	Y minimum cell physical address of fail bit data's error range.

Item Name	*Data Type*	*Size*	*Description*
YMaxPhysic	Integer	10	Y maximum cell physical address of fail bit data's error range.
IoNumber	Integer	10	Cell logical IO number of fail bit data's error range.
XMinLogic	Integer	10	X minimum cell logical address of fail bit data's error range.
XMaxLogic	Integer	10	X maximum cell logical address of fail bit data's error range.
YMinLogic	Integer	10	Y minimum cell logical address of fail bit data's error range.
YMaxLogic	Integer	10	Y maximum cell logical address of fail bit data's error range.

Table 4 Data Items for AnalogDataTemplate

Item Name	*Data Type*	*Size*	*Description*
XAddress	Integer	5	X address of die with analog data.
YAddress	Integer	5	Y address of die with analog data.
TestNumber	Integer	7	Test number corresponding to analog data.
Note	String	256	Note
Measure	Float	14	Analog data measured value.
MeasureUnit	String	4	Unit of above. See Tables 5 and 6.
Std	Float	14	Standard deviation, etc., for measuring analog data.
Parameter	Float	14	Analog data measurement parameter value.
ParameterUnit	String	4	Unit of above. See Tables 5 and 6.
UpperLimitData	Float	14	Upper limit of first type of parameter for judging analog data.
LowerLimitData	Float	14	Lower limit of first type of parameter for judging analog data.
TestResult	String	256	Analog data PASS/FAIL or decision result such as category type number, etc.

Table 5 Unit Table

Unit Code	*Description*
s	Seconds
Hz	Hertz
A	Amperes
V	Volts
Ohm	Ohms
W	Watts
F	Farad
H	Henry
%	Percent
dB	Decibel
lsb	Least Significant Bit
rad	Radian
deg	Degree

Table 6 Prefix Symbol Table

Prefix Symbol	*Multiplicative*
T	10^{12}
G	10^{9}
M	10^{6}
k	10^{3}
m	10^{-3}
u (micro)	10^{-6}
n	10^{-9}
p	10^{-12}

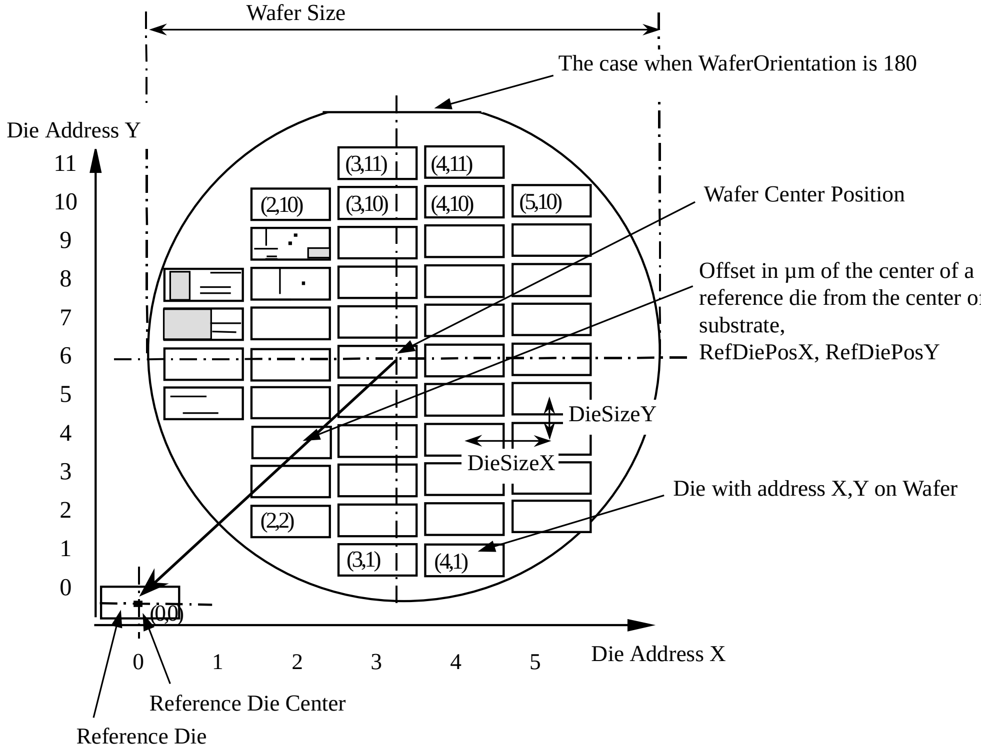
Example:

[MeasureUnit] = 'V' or 'mV'

[ParameterUnit] = 'A' or 'uA'

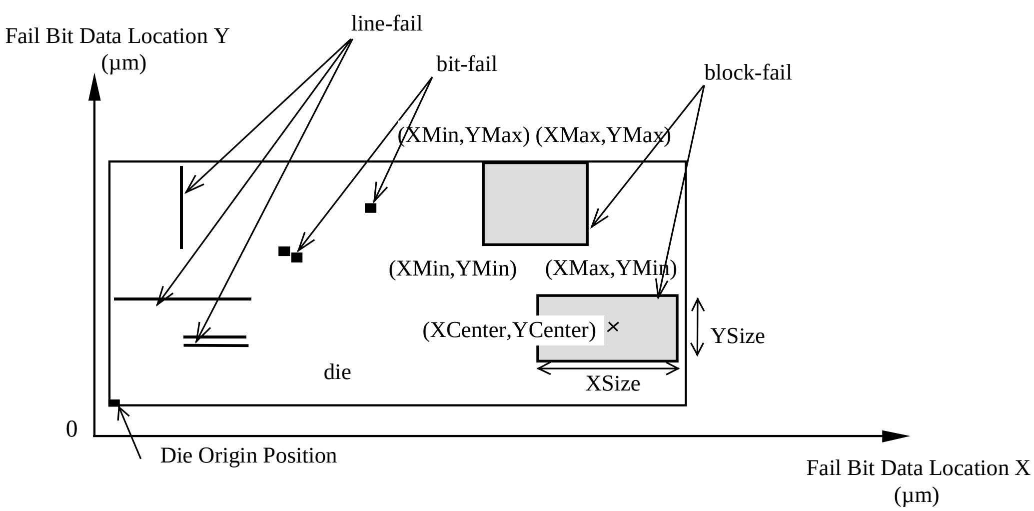
The units above are a subset of those in Section 9 ("Units of Measure") of SEMI E5 (SECS-II).

8.1.6 *Map Data Format of YMS Link* — This section is reserved for data format of above items.



(The case of BottomLeft)

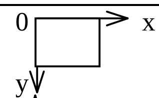
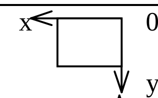
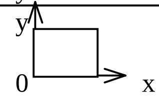
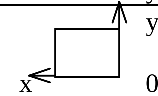
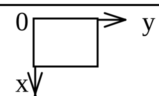
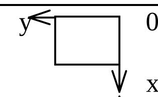
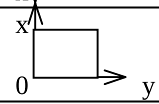
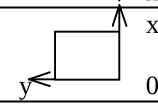
Figure 1
Wafer Coordinates



(The case of BottomLeftXY)

Figure 2
Die Coordinates

Table 7 Die Coordinates

Coordinate Information	*Meaning*	*Coordinate Information*	*Meaning*
TopLeftXY		TopRightXY	
BottomLeftXY		BottomRightXY	
TopLeftYX		TopRightYX	
BottomLeftYX		BottomRightYX	

9   Map Data Format for YMS Link Data

9.1   This section is reserved for future standardization of the separate document for Map Data Format currently under development. Format definition will be added with conformance to the standard.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI E107, but was approved for publication by full letter ballot procedure on December 1, 2000.

R1-1 Example Datafile

```
Map = {
FormatRevision = “2.00"
CreateDate = “03-18-2000 15:07:50”
ProductId = "product1234"
LotId = "lot1234"
WaferId = “wafer1234”
Status = “prerepair_map”
Comment = "Engineering Test"
TestProgramName = "pro123a"
TestEquipmentId = “tester1”
WaferOrientation = 180
WaferSize = 200
DieSizeX = 4.8987000000e+03
DieSizeY = 8.7395000000e+03
ReferenceDieList = {
        PosX = -2030.55 PosY = 1427.98
}
WaferCoordinate = “TopLeft”
DieCoordinate = “BottomLeftXY”
MapType = “Die”
BinType = “Decimal”
BinList = {
        Code = 001 Count = 35 Quality = “Pass”
        Code = 002 Count = 4 Quality = “Fail”
        Code = 003 Count = 1 Quality = “Fail”
}
Data = {
        007 018 001
        008 018 002
        009 018 003
        010 018 002
}
ErrorClassList = {
        Class = “0” Quality = "bit-fail"
        Class = “1” Quality = "line-fail"
        Class = “2” Quality = "block-fail"
}
FailBitDataTemplate = Seq XAddress YAddress XMin XMax YMin YMax XCenter YCenter XSize YSize Area
DefectCate
FailBitData = {
        1 8 18 0.12345000e+03 0.91234000e+03 1.06367000e+03 7.27391000e+03
        0.51789500e+03 4.16879000e+03 0.78889000e+03 6.21024000e+03    4.89919623e+06 "block-fail"
        2 10 18 3.03120000e+03 3.03210000e+03 1.58330000e+03 1.58580000e+03
        3.03165000e+03 1.58455000e+03 9.00000000e-01 2.50000000e+00     2.25000000e+00 "bit-fail"
}
AnalogDataTemplate = XAddress YAddress TestNumber Note Measure
MeasureUnit TestNumber Comment Measure MeasureUnit TestResult
TestNumber Comment Measure MeasureUnit TestResult
Invalid = “99999”
```

AnalogData = {
8 18 100 “CONTACT” –0.600 “V” 200 “IDD” 125.0 “mA” “PASS” 300 “IDDS” 100.0 “µA” “PASS”
9 18 100 “CONTACT” –0.567 “V” 200 “IDD” 120.2 ”mA” “PASS” 300 “IDDS” 321.0 “µA” “FAIL”
10 18 100 “CONTACT” –0.612 “V” 200 “IDD” 123.4 “mA” “PASS” 300 “IDDS” 99.4 “µA” “PASS”
11 18 100 “CONTACT” 99999 “V” 200 “IDD” 99999 “mA” “PASS” 300 “IDDS” 99.4 “µA” “PASS”
}
ErrorTotal = 234
TestDie = 3
}

R1-2 An Idea of Map Data Format for YMS Link Data

<Comment>::= ‘Comment’ ‘=’ <string[256]><CR>
<TestProgramName>::= ‘TestProgramName’ ‘=’ <string[256]><CR>
<TestEquipmentId>::= ‘TestEquipmentId’ ‘=’ <string[256]><CR>
<DieCoordinate>::= ‘DieCoordinate’ ‘=’ ‘TopLeftXY’ | ‘BottomLeftXY’ | ‘TopLeftYX’ | ‘BottomLeftYX’ | ‘TopRightXY’ | ‘BottomRightXY’ | ‘TopRightYX’ | ‘BottomRightYX’ <CR>

<ErrorClassList>::= ‘ErrorClassList’ ‘=’ ‘{ ‘ <CR><Errors><CR> ‘} ’ <CR>
<Errors>::= <Error><CR>[<Errors>]
<Error>::= <ErrorItem>[<Error>]
<ErrorItem>::= <ErrorClassNumber> | <ErrorQuality> | <ErrorDescription>
<ErrorClassNumber>::= ‘Class’ ‘=’ <string[3]><WS>
<ErrorQuality>::= ‘Quality’ ‘=’ <string[16]><WS>
<ErrorDescription>::= ‘Description’ ‘=’ <string[256]><WS>

<FailBitDataTemplate>::= ‘FailBitTemplate’ ‘=’ <FailBitDataItems><CR>
<FailBitDataItems>::= <FailBitDataItem><WS>[<FailBitDataItems>]
<FailBitDataItem>::= ‘Seq’ | ‘XAddress’ | ‘YAddress’ | ‘XMin’ | ‘XMax’ | ‘YMin’ | ‘YMax’ | ‘XCenter’ | ‘YCenter’ | ‘XSize’ | ‘YSize’ | ‘Area’ | ‘DefectCate’ | ‘XMinPhysic’ | ‘XMaxPhysic’ | ‘YMinPhysic’ | ‘YMaxPhysic’ | ‘IoNumber’ | ‘XMinLogic’ | ‘XMaxLogic’ | ‘YMinLogic’ | ‘YMaxLogic’

<FailBitData>::= ‘FailBitData’ ‘=’ ‘{ ‘ <CR><FailBitDataRecords><CR> ‘} ’ <CR>
<FailBitDataRecords>::= <FailBitDataRecord><CR>[<FailBitDataRecords>]
<FailBitDataRecord>::= <FailBitDataField>[<FailBitDataRecord>]
<FailBitDataField>::= <Seq> | <XAddress> | <YAddress> | <XMin> | <XMax> | <YMin> | <YMax> | <XCenter> | <YCenter> | <XSize> | <YSize> | <Area> | <DefectCate> | <XMinPhysic> | <XMaxPhysic> | <YMinPhysic> | <YMaxPhysic> | <IoNumber> | <XMinLogic> | <XMaxLogic> | <YMinLogic> | <YMaxLogic>
<Seq>::= <Integer[10]><WS>
<XAddress>::= <Integer[5]><WS>
<YAddress>::= <Integer[5]><WS>
<XMin>::= <Float[14]><WS>
<XMax>::= <Float[14]><WS>
<YMin>::= <Float[14]><WS>
<YMax>::= <Float[14]><WS>
<XCenter>::= <Float[14]><WS>
<YCenter>::= <Float[14]><WS>
<XSize>::= <Float[14]><WS>
<YSize>::= <Float[14]><WS>
<Area>::= <Float[14]><WS>
<DefectCate>::= <String[16]><WS>
<XMinPhysic>::= <Integer[10]><WS>

```
<XMaxPhysic>::= <Integer[10]><WS>
<YMinPhysic>::= <Integer[10]><WS>
<YMaxPhysic>::= <Integer[10]><WS>
<IoNumber >::= <Integer[10]><WS>
<XMinLogic>::= <Integer[10]><WS>
<XMaxLogic>::= <Integer[10]><WS>
<YMinLogic>::= <Integer[10]><WS>
<YMaxLogic>::= <Integer[10]><WS>

<AnalogDataTemplate>::= ‘AnalogDataTemplate’ ‘=’ <AnalogDataItems><CR>
<Invalid>:: =‘=’ <String[14]><CR>
<AnalogDataItems>::= <AnalogDataItem><WS>[<AnalogDataItems>]
<AnalogDataItem>::= ‘XAddress’ | ‘YAddress’ | ‘TestNumber’ | ‘Comment’ | ‘Measure’ | ‘MeasureUnit’ | ‘Std’ |
‘Parameter’ | ‘ParameterUnit’ | ‘UpperLimit’ | ‘LowerLimit’ | ‘TestResult’

<AnalogData> ::= ‘AnalogData’ ‘=’ ‘{ ’ <CR><AnalogDataRecords><CR> ‘} ’ <CR>
<AnalogDataRecords>::= <AnalogDataRecord><CR>[<AnalogDataRecords>]
<AnalogDataRecord>::= <AnalogDataField>[<AnalogDataRecord>]
<AnalogDataField>::= <XAddress> | <YAddress> | <TestNumber> | <Note> | <Measure> | <MeasureUnit> | <Std>
| <Parameter> | <ParameterUnit> | <UpperLimit> | <LowerLimit> | <TestResult>
<XAddress>::= <Integer[5]><WS>
<YAddress>::= <Integer[5]><WS>
<TestNumber>::= <Integer[7]><WS>
<Note>::= <String[256]><WS>
<Measure>::= <Float[14]><WS>
<MeasureUnit>::= <String[4]><WS>
<Std>::= <Float[14]><WS>
<Parameter>::= <Float[14]><WS>
<ParameterUnit>::= <String[4]><WS>
<UpperLimit>::= <Float[14]><WS>
<LowerLimit>::= <Float[14]><WS>
<TestResult>::= <String[256]><WS>

<ErrorTotal>::= ‘ErrorTotal’ ‘=’ <Integer[10]><CR>
<TestId>::= ‘TestId’ ‘=’ <Integer[10]><CR>
```

R1-3 An Example of Format in XML

R1-3.1 Following format definitions are potential map data formats in XML. Because basic map data format specification is standardization process, this document reserves data format until the basic format is standardized, to keep consistent with the document. Following descriptions are just examples to help understanding.

R1-3.2 The first example result in longer file but more descriptive. Templates for Fail-bit Data and Analog Data are eliminated and components of each data unit expressed as attributes rather than data elements.

```
<?xml version = "1.0" ?>
<! DOCTYPE YmfLdfMap [
<! ELEMENT Comment              (#PCDATA)>
<! ELEMENT TestProgramName      (#PCDATA)>
<! ELEMENT TestEquipmentId      (#PCDATA)>

<! ELEMENT DieCoodinate         (TopLeftXY | BottomLeftXY | TopLeftYX |
                            BottomLeftYX | TopRightXY | BottomRightXY |
                            TopRightYX | BottomRightYX)>
<! ENTITY TopLeftXY             "TopLeftXY">
<! ENTITY BottomLeftXY          "BottomLeftXY">
```

```
<! ENTITY TopLeftYX              "TopLeftYX">
<! ENTITY BottomLeftXY           "BottomLeftXY">
<! ENTITY TopRightXY             "TopRightXY">
<! ENTITY BottomRightXY          "BottomRightXY">
<! ENTITY TopRightYX             "TopRightYX">
<! ENTITY BottomRightYX          "BottomRightYX">

<! ELEMENT ErrorClassList                  (ErrorClassElement)*>
<! ATTLIST ErrorClassElement               ErrorClassNumber CDATA #REQUIRED
ErrorQuality CDATA #REQUIRED
ErrorDescription CDATA #IMPLIED
>

<! ELEMENT FailBitData           (FailBitDataItem)*>

<! ELEMENT Invalid                         (#PCDATA)>
<! ELEMENT AnalogData            (AnalogDataItem)*>

<! ELEMENT ErrorTotal            (#PCDATA)>
<! ELEMENT TestDie                         (#PCDATA)>

<! ATTLIST FailBitDataItem
                                Seq CDATA               #REQUIRED
                                XAddress CDATA          #REQUIRED
                                YAddress CDATA          #REQUIRED
                                XMin CDATA              #REQUIRED
                                XMax CDATA              #REQUIRED
                                YMin CDATA              #REQUIRED
                                YMax CDATA              #REQUIRED
                                XCenter CDATA           #REQUIRED
                                YCenter CDATA           #REQUIRED
                                XSize CDATA             #REQUIRED
                                YSize CDATA             #REQUIRED
                                Area CDATA              #REQUIRED
                                DefectCate CDATA        #REQUIRED
                                XMinPhysic CDATA        #IMPLIED
                                XMaxPhysic CDATA        #IMPLIED
                                YMinPhysic CDATA        #IMPLIED
                                YMaxPhysic CDATA        #IMPLIED
                                IoNumber CDATA          #IMPLIED
                                XMinLogic CDATA         #IMPLIED
                                XMaxLogic CDATA         #IMPLIED
                                YMinLogic CDATA         #IMPLIED
                                YMaxLogic CDATA         #IMPLIED
                                >

<! ELEMENT AnalogDataItem        (AnalogDataMeas)+>
<! ATTLIST AnalogDataItem
                                XAddress CDATA          #REQUIRED
                                YAddress CDATA          #REQUIRED
                                >

<! ELEMENT AnalogDataMeas        (MeasureUnit, ParameterUnit)>
<! ATTLIST AnalogDataMeas
                                TestNumber CDATA        #REQUIRED
                                Note CDATA              #IMPLIED
```

```
                                        Measure CDATA           #REQUIRED
                                        Std CDATA               #IMPLIED
                                        Parameter CDATA         #IMPLIED
                                        UpperLimitData CDATA    #IMPLIED
                                        LowerLimitData CDATA    #IMPLIED
                                        TestResult CDATA        #IMPLIED
                                        >

<! ELEMENT MeasureUnit                  EMPTY)>
<! ATTLIST MeasureUnit
                                        Multicative (T | G | M | K | m | u | p | n |
                                                f)      #IMPLIED
                                        Unit (s | Hz | A | V | Ohm | W | F | H | pc | db |
                                                lsb | rad | deg)    #REQUIRED
                                        >

<! ELEMENT ParameterUnit                EMPTY)>
<! ATTLIST ParameterUnit
                                        Multicative (T | G | M | K | m | u | p | n |
                                                f)      #IMPLIED
                                        Unit (s | Hz | A | V | Ohm | W | F | H | pc | db
                                                | lsb | rad | deg)    #REQUIRED
                                        >
]>


<YmfLdfMap>
<Comment></Comment>
<TestProgramName></TestProgramName>
<TestEquipmentId></TestEquipmentId>
<DieCoordinate></DieCoordinate>

<ErrorClassList>
        <ErrorClassElement ErrorClassNumber= "" ErrorQuality = "" />
</ErrorClassList>


<FailBitData>
        <FailBitDataItem Seq=""  XAddress=""  YAddress=""  XMin=""  XMax=""
                                        YMin=""  YMax=""  XCenter=""  YCenter=""
                                        XSize=""  YSize=""  Area=""  DefectCate=""
                                        XMinPhysic=""  XMaxPhysic=""  YMinPhysic=""  YMaxPhysic=""
                                        IoNumber=""  XMinLogic=""  XMaxLogic=""
                                        YMinLogic=""  YMaxLogic="" />
</FailBitData>


<Invalid></Invalid>

<AnalogData>
        <AnalogDataItem                 XAddress=""  YAddress=""  Note="" >
                <AnalogDataMeas         TestNumber=""  Note=""  Measure=""  Std=""  Parameter=""
                                        UpperLimitData=""  LowerLimitData=""  TestResult="" >
                        <MeasureUnit    Multicative=""  Unit="" />
                        <ParameterUnit  Multicative=""  Unit="" />
                </AnalogDataMeas>
```

```xml
        </AnalogDataItem>
</AnalogData>

<ErrorTotal></ErrorTotal>
<TestDie></TestDie>

</YmfLdfMap>
```

Example of above, except Data Type Definitions, is as follows.

```xml
<YmfLdfMap>
<Comment>This is an example for Engineering test.</Comment>
<TestProgramName>SampleTestProgram123.tp</TestProgramName>
<TestEquipmentId>TesterABC123</TestEquipmentId>
<DieCoordinate>TopLeftXY</DieCoordinate>

<ErrorClassList>
        <ErrorClassElement ErrorClassNumber= "0" ErrorQuality = "Bit-Fail" />
        <ErrorClassElement ErrorClassNumber= "1" ErrorQuality = "Line-Fail" />
        <ErrorClassElement ErrorClassNumber= "2" ErrorQuality = "Block-Fail" />
</ErrorClassList>


<FailBitData>
        <FailBitDataItem Seq="1"  XAddress="6"  YAddress="18"
                                XMin="0.12345000e+03"  XMax="0.91234000e+03"
                                YMin="1.06367000e+03"  YMax="7.27391000e+03"
                                XCenter="0.51789500e+03"  YCenter="4.16879000e+03"
                                XSize="0.78889000e+03"  YSize="6.21024000e+03"
                                Area="4.89919623e+06"  DefectCate="block-fail"  />
        <FailBitDataItem Seq="2"  XAddress="10"  YAddress="18"
                                XMin="3.03120000e+03"  XMax="3.03210000e+03"
                                YMin="1.58330000e+03"  YMax="1.58580000e+03"
                                XCenter="3.03165000e+03"  YCenter="1.58455000e+03"
                                XSize="9.00000000e-01"  YSize="2.50000000e+00"
                                Area="2.25000000e+00"  DefectCate="bit-fail"  />
</FailBitData>


<Invalid>99999</Invalid>

<AnalogData>
        <AnalogDataItem                 XAddress="8"  YAddress="18"  >
                <AnalogDataMeas         TestNumber="100"  Note="CONTACT"  Measure="-0.600"  >
                        <MeasureUnit    Unit="V" /> </AnalogDataMeas>
                <AnalogDataMeas         TestNumber="200"  Note="IDD"  Measure="125.0"
                                TestResult="PASS"  >
                        <MeasureUnit    Multicative="m"  Unit="A" /> </AnalogDataMeas>
                <AnalogDataMeas         TestNumber="300"  Note="IDDS"  Measure="100.0"
                                TestResult="PASS"  >
                        <MeasureUnit    Multicative="u"  Unit="A" /> </AnalogDataMeas>
        </AnalogDataItem>
        <AnalogDataItem                 XAddress="9"  YAddress="18"  >
                <AnalogDataMeas         TestNumber="100"  Note="CONTACT"  Measure="-0.567"  >
                        <MeasureUnit    Unit="V" /> </AnalogDataMeas>
```

```
                <AnalogDataMeas        TestNumber="200"  Note="IDD"  Measure="120.2"
                        TestResult="PASS"  >
                    <MeasureUnit     Multicative="m"  Unit="A" /> </AnalogDataMeas>
                <AnalogDataMeas        TestNumber="300"  Note="IDDS"  Measure="321.0"
                        TestResult="PASS"  >
                    <MeasureUnit     Multicative="u"  Unit="A" /> </AnalogDataMeas>
        </AnalogDataItem>
        <AnalogDataItem                XAddress="10"  YAddress="18"  >
                <AnalogDataMeas        TestNumber="100"  Note="CONTACT"  Measure="99999"  >
                    <MeasureUnit     Unit="V" /> </AnalogDataMeas>
                <AnalogDataMeas        TestNumber="200"  Note="IDD"  Measure="99999"
                        TestResult="PASS"  >
                    <MeasureUnit     Multicative="m"  Unit="A" /> </AnalogDataMeas>
                <AnalogDataMeas        TestNumber="300"  Note="IDDS"  Measure="99.4"
                        TestResult="PASS"  >
                    <MeasureUnit     Multicative="u"  Unit="A" /> </AnalogDataMeas>
        </AnalogDataItem>
</AnalogData>

<ErrorTotal>234</ErrorTotal>
<TestDie>3</TestDie>

</YmfLdfMap>
```

R1-3.3 Next one has opposite nature of above. Fail-bit Data and Analog Data are not defined as specific types. Components of such data in each data unit are aligned pre-declared template to eliminate data size.

```
<?xml version = "1.0" ?>
<! DOCTYPE YmfLdfMap [
<! ELEMENT Comment            (#PCDATA)>
<! ELEMENT TestProgramName    (#PCDATA)>
<! ELEMENT TestEquipmentId    (#PCDATA)>

<! ELEMENT DieCoordinate              (TopLeftXY |   BottomLeftXY |   TopLeftYX |
                  BottomLeftYX |   TopRightXY |   BottomRightXY |
                  TopRightYX |   BottomRightYX)>
<! ENTITY TopLeftXY           "TopLeftXY">
<! ENTITY BottomLeftXY        "BottomLeftXY">
<! ENTITY TopLeftYX           "TopLeftYX">
<! ENTITY BottomLeftXY        "BottomLeftXY">
<! ENTITY TopRightXY          "TopRightXY">
<! ENTITY BottomRightXY       "BottomRightXY">
<! ENTITY TopRightYX          "TopRightYX">
<! ENTITY BottomRightYX       "BottomRightYX">

<! ELEMENT ErrorClassList             (ErrorClassElement)*>
<! ATTLIST ErrorClassElement          ErrorClassNumber CDATA #REQUIRED
ErrorQuality CDATA #REQUIRED
ErrorDescription CDATA #IMPLIED
>
<! ELEMENT FailBitData        (FailBitDataItem)*>
<! ELEMENT Invalid                    (#PCDATA)>
<! ELEMENT AnalogData         (AnalogDataItem)*>
<! ELEMENT ErrorTotal         (#PCDATA)>
```

```
<! ELEMENT TestDie                        (#PCDATA)>


<! ELEMENT FailBitDataItem        ANY>
<! ELEMENT FailBitDataTemplate (Seq |   XAddress |   YAddress |   XMin |   XMax |   YMin |   YMax |
                                 XCenter |   YCenter |   XSize |   YSize |   Area |   DefectCate |
                                 XMinPhysic |   XMaxPhysic |   YMinPhysic |   YMaxPhysic |
                                 IoNumber |   XMinLogic |   XMaxLogic |   YMinLogic |   YMaxLogic)+>

<! ENTITY Seq                  "Seq">
<! ENTITY XAddress             "XAddress">
<! ENTITY YAddress             "YAddress">
<! ENTITY XMin                 "XMin">
<! ENTITY XMax                 "XMax">
<! ENTITY YMin                 "YMin">
<! ENTITY YMax                 "YMax">
<! ENTITY XCenter              "XCenter">
<! ENTITY YCenter              "YCenter">
<! ENTITY XSize                "XSize">
<! ENTITY YSize                "YSize">
<! ENTITY Area                 "Area">
<! ENTITY DefectCate           "DefectCate">
<! ENTITY XMinPhysic           "XMinPhysic">
<! ENTITY XMaxPhysic           "XMaxPhysic">
<! ENTITY YMinPhysic           "YMinPhysic">
<! ENTITY YMaxPhysic           "YMaxPhysic">
<! ENTITY IoNumber             "IoNumber">
<! ENTITY XMinLogic            "XMinLogic">
<! ENTITY XMaxLogic            "XMaxLogic">
<! ENTITY YMinLogic            "YMinLogic">
<! ENTITY YMaxLogic            "YMaxLogic">

<! ELEMENT AnalogDataItem                 ANY>
<! ELEMENT AnalogDataTemplate             (XAddress |   YAddress |   TestNumber |   Note |   Measure |
                                 MeasureUnit |   Std |   Parameter |   ParameterUnit |
                                 UpperLimitData |   LowerLimitData |   TestResult)>

<! ENTITY XAddress             "XAddress">
<! ENTITY YAddress             "YAddress">
<! ENTITY TestNumber           "TestNumber">
<! ENTITY Note                 "Note">
<! ENTITY Measure              "Measure">
<! ENTITY MeasureUnit          "MeasureUnit">
<! ENTITY Std                  "Std">
<! ENTITY Parameter            "Parameter">
<! ENTITY ParameterUnit        "ParameterUnit">
<! ENTITY UpperLimitData       "UpperLimitData">
<! ENTITY LowerLimitData       "LowerLimitData">
<! ENTITY TestResult           "TestResult">

]>


<YmfLdfMap>
<Comment></Comment>
<TestProgramName></TestProgramName>
```

```
<TestEquipmentId></TestEquipmentId>
<DieCoordinate></DieCoordinate>

<ErrorClassList>
        <ErrorClassElement ErrorClassNumber= "" ErrorQuality = "" />
</ErrorClassList>

<FailBitDataTemplate>
</FailBitDataTemplate>

<FailBitData>
        <FailBitDataItem></FailBitDataItem>
</FailBitData>

<Invalid></Invalid>

<AnalogDataTemplate>
</AnalogDataTemplate>

<AnalogData>
        <AanalogDataItem></AanalogDataItem>
</AnalogData>

<ErrorTotal></ErrorTotal>
<TestDie></TestDie>

</YmfLdfMap>
```

Example of above except Data Type Definitions is as follows.

```
<YmfLdfMap>
<Comment>This is an example for Engineering test.</Comment>
<TestProgramName>SampleTestProgram123.tp</TestProgramName>
<TestEquipmentId>TesterABC123</TestEquipmentId>
<DieCoordinate>TopLeftXY</DieCoordinate>

<ErrorClassList>
        <ErrorClassElement ErrorClassNumber= "0" ErrorQuality = "Bit-Fail" />
        <ErrorClassElement ErrorClassNumber= "1" ErrorQuality = "Line-Fail" />
        <ErrorClassElement ErrorClassNumber= "2" ErrorQuality = "Block-Fail" />
</ErrorClassList>

<FailBitDataTemplate>
        Seq XAddress YAddress XMin XMax YMin YMax XCenter YCenter XSize YSize
        Area DefectCate
</FailBitDataTemplate>

<FailBitData>
        <FailBitDataItem>1 8 18
        0.12345000e+03 0.91234000e+03 1.06367000e+03 7.27391000e+03
        0.51789500e+03 4.16879000e+03 0.78889000e+03 6.21024000e+03
        4.89919623e+06 block-fail </FailBitDataItem>
        <FailBitDataItem>2 10 18
        3.03120000e+03 3.03210000e+03 1.58330000e+03 1.58580000e+03
```

```
        3.03165000e+03 1.58455000e+03 9.00000000e-01 2.50000000e+00
        2.25000000e+00 Bit-fail </FailBitDataItem>
</FailBitData>

<Invalid>99999</Invalid>

<AnalogDataTemplate>
        XAddress YAddress TestNumber Note Measure MeasureUnit
        TestNumber Comment Measure MeasureUnit TestResult
        TestNumber Comment Measure MeasureUnit TestResult
</AnalogDataTemplate>

<AnalogData>
        <AanalogDataItem>8 18
        100 CONTACT -0.600 V
        200 IDD 125.0 mA PASS
        300 IDDS 100.0 uA PASS</AanalogDataItem>
        <AanalogDataItem>9 18
        100 CONTACT -0.567 V
        200 IDD 120.2 mA PASS
        300 IDDS 321.0 uA PASS</AanalogDataItem>
        <AanalogDataItem>10 18
        100 CONTACT 99999 V
        200 IDD 99999 mA PASS
        300 IDDS 99.4 uA PASS</AanalogDataItem>
</AnalogData>

<ErrorTotal>234</ErrorTotal>
<TestDie>3</TestDie>

</YmfLdfMap>
```

Table R1-1 Items and Attributes Used Yield Management specific part

Name	*Element or Attribute*	*Define In*	*Mandatory and Optional*	*Relation Items*
Comment	Attribute	Yms Map Data Items	Optional	---
TestProgramName	Attribute	Yms Map Data Items	Optional	---
TestEquipmentId	Attribute	Yms Map Data Items	Optional	---
DieCoordinate	Attribute	Yms Map Data Items	Optional	WaferLocation
ErrorClassList	Element	Yms Map data Format	Optional	---
ErrorClassNumber	Attribute	Yms Map Data Items	Optional	ErrorClassList
ErrorQuality	Attribute	Yms Map Data Items	Optional	ErrorClassList
ErrorDescription	Attribute	Yms Map Data Items	Optional	ErrorClassList
FailBitDataTemplate	Element	Yms Map data Format	Optional	---
FailBitData	Element	Yms Map data Format	Optional	FailBitDataTemplate
AnalogDataTemplate	Element	Yms Map data Format	Optional	---
Invalid	Attribute	Yms Map Data Items	Optional	---
AnalogData	Element	Yms Map data Format	Optional	AnalogDataTemplate
ErrorTotal	Attribute	Yms Map Data Items	Optional	ErrorClassList
TestDie	Attribute	Yms Map Data Items	Optional	---

Table R1-2 Attributes Used for FailBitData

Item Name	*Item or Attribute*	*Define In*	*Mandatory and Optional*	*Relation Items*
Seq	Attribute	Map Data Items	Mandatory	---
XAddress	Attribute	Map Data Items	Mandatory	WaferLocation
YAddress	Attribute	Map Data Items	Mandatory	WaferLocation
XMin	Attribute	Map Data Items	Mandatory	DieCoordinate
XMax	Attribute	Map Data Items	Mandatory	DieCoordinate
YMin	Attribute	Map Data Items	Mandatory	DieCoordinate
YMax	Attribute	Map Data Items	Mandatory	DieCoordinate
XCenter	Attribute	Map Data Items	Mandatory	DieCoordinate
YCenter	Attribute	Map Data Items	Mandatory	DieCoordinate
XSize	Attribute	Map Data Items	Mandatory	DieCoordinate
YSize	Attribute	Map Data Items	Mandatory	DieCoordinate
Area	Attribute	Map Data Items	Mandatory	DieCoordinate
DefectCate	Attribute	Map Data Items	Mandatory	ErrorClassList
XMinPhysic	Attribute	Map Data Items	Mandatory	DieCoordinate
XMaxPhysic	Attribute	Map Data Items	Mandatory	DieCoordinate
YMinPhysic	Attribute	Map Data Items	Mandatory	DieCoordinate
YMaxPhysic	Attribute	Map Data Items	Mandatory	DieCoordinate
IoNumber	Attribute	Map Data Items	Mandatory	DieCoordinate
XMinLogic	Attribute	Map Data Items	Mandatory	DieCoordinate
XMaxLogic	Attribute	Map Data Items	Mandatory	DieCoordinate
YMinLogic	Attribute	Map Data Items	Mandatory	DieCoordinate
YMaxLogic	Attribute	Map Data Items	Mandatory	DieCoordinate

Table R1-3 Attributes Used for AnalogData

Item Name	*Item or Attribute*	*Define In*	*Mandatory and Optional*	*Relation Items*
XAddress	Attribute	Map Data Items	Mandatory	WaferLocation
YAddress	Attribute	Map Data Items	Mandatory	WaferLocation
TestNumber	Attribute	Map Data Items	Mandatory	---
Note	Attribute	Map Data Items	Optional	---
Measure	Attribute	Map Data Items	Optional	---
MeasureUnit	Attribute	Map Data Items	Optional	---
Std	Attribute	Map Data Items	Optional	---
Parameter	Attribute	Map Data Items	Optional	---
ParameterUnit	Attribute	Map Data Items	Optional	---
UpperLimitData	Attribute	Map Data Items	Optional	---
LowerLimitData	Attribute	Map Data Items	Optional	---
TestResult	Attribute	Map Data Items	Optional	---

SEMI E109-0302
PROVISIONAL SPECIFICATION FOR RETICLE AND POD MANAGEMENT (RPMS)

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Facilities Committee on October 14, 2001. Initially available at www.semi.org Decemeber 2001; to be published March 2002. Originally published July 2001.

1 Purpose

1.1 This document provides standardized behavior for lithography, reticle inspection, and bare reticle stocker equipment. It also provides for standardized communication with lithography, reticle inspection, and bare reticle stocker equipment. This includes the coordination, execution, and completion of automated and manual reticle pod transfers to and from the equipment, transfer of reticles to and from the reticle pods, movement of the reticles within the equipment, identification and verification of both reticle pods and reticles, inspection and qualification of reticles, and other relevant information such as tracking reticle usage.

2 Scope

2.1 This is a provisional standard that covers host and equipment communication for equipment that handle reticles. This only includes equipment that handle reticles both in and outside of a reticle pod. The provisional status is required because of the immaturity of implementations of integrated equipment with Automated Material Handling Systems (AMHS) or Automated Reticle Handling Systems (ARHS), and additional specifications may yet be defined to add further functionality. Also, further exception handling and error recovery scenarios need to be defined.

2.2 The scope of this document is to define standards that facilitate the host's knowledge and role in automated and manual reticle pod transfers, reticle transfers to and from the reticle pod, internal reticle movement, identification and verification of ReticleID, inspection and qualification of reticles, and tracking reticle usage. Specifically, this document provides state models and scenarios that define the host interaction with the equipment for the following:

- Reticle pod transfer between AMHS vehicles and production equipment, bare reticle stockers, and reticle inspection equipment reticle load ports.
- Reticle transfers to/from lithography production equipment internal reticle library space.
- Equipment and reticle load port access mode switching.
- Reticle Pod to load port association.
- Reticle Pod ID verification and Reticle Pod slot map verification.

2.3 In order for the provisional status to be removed, the following issues must be resolved:

- Linkage to process job management standard.
- Implementations of this standard must prove validity of the standard before the provisional status can be removed.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard applies to semiconductor equipment that handles reticles and reticle carriers. This standard is intended to be used for lithography production, bare reticle storage, and reticle inspection equipment. It may or may not be applied to other types of equipment.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load port

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E39 — Object Services Standard: Concept, Behavior, and Services

SEMI E41 — Exception Management (EM) Standard

SEMI E53 — Event Reporting

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O interface

SEMI E99 — Carrier ID Read/Write Functional Standard

SEMI E100 — Specification for a Reticle SMIF Pod (RSP) Used to Transport and Store 6 inch or 230 mm Reticles

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGT* — Automated Guided Transport

5.1.2 *AGV*— Automated Guided Vehicle

5.1.3 *AMHS* — Automated Material Handling System

5.1.4 *ARHS* — Automated Reticle Handling System

5.1.5 *GEM* — Generic Equipment Model

5.1.6 *IRL* — Internal Reticle Library

5.1.7 *OHT* — Overhead Hoist Transport

5.1.8 *PGV* — Person Guided Vehicle

5.1.9 *PIO* — Parallel Input/Output Interface

5.1.10 *RGT* — Rail Guided Transport

5.1.11 *RGV* — Rail Guided Vehicle

5.1.12 *RSP* – Reticle SMIF Pod

5.2 *Definitions*

5.2.1 *Automated Material Handling System* — an automated system to store and transport materials within the factory.

5.2.2 *Automated Reticle Handling System* — a specific type of Automated Material Handling System to store and transport reticles and reticle pods within the factory.

5.2.3 *automation* — the degree to which activities of machines or production systems are self-acting. In this standard automation provides methods that will reduce the amount of operator intervention required.

5.2.4 *buffer* — a set of one or more locations for holding reticles at/inside the production equipment.

5.2.5 *collection event* — a collection event is an event (or grouping of related events) on the equipment that is considered to be significant to the host.

5.2.6 *content map* — Ordered list of reticle identifiers corresponding to slot 1,2,3…n. (Note that this is redundant with the definition in Table 6).

5.2.7 *host* — the factory computer system or an intermediate system that represents the factory and the user to the equipment.

5.2.8 *internal reticle library* — a set of locations within the equipment to store reticles. These locations exclude load ports.

5.2.9 *Internal Pod Buffer* — storage area for reticle pod that is internal to the equipment.

5.2.10 *load* — the operation of placing a pod on a load port.

5.2.11 *load port* — the interface location on the equipment where pods are loaded and unloaded.

5.2.12 *Multi-Reticle Pod* — TBD

5.2.13 *object instantiation* — the act of storing of information related to a physical or logical entity so that it can be recalled on demand based on its public identifier.

5.2.14 *on-line equipment* — equipment that is connected to, and able to communicate fully with, the host.

5.2.15 *pod* — in this document pod refers to an RSP or a Multi Reticle SMIF Pod.

5.2.16 *PodID* — a readable and unique identifier for the pod.

5.2.17 *PodID read* — the process of the equipment reading the PodID from the carrier.

5.2.18 *PodID tag (tag, ID tag)* — a physical device for storing PodID and other information. There are two basic types of tags, read-only tags and read/write tags. [SEMI E99]

5.2.19 *process equipment* — equipment used to produce product, such as semiconductor devices. This excludes metrology and material handling equipment.

5.2.20 *production equipment* — equipment used to produce product, such as semiconductor devices, including substrate sorting, process, and metrology equipment and excluding material handling equipment.

5.2.21 *properties* — a set of name value pairs assigned to an object or used in a service message to include additional information about the object (i.e., pod, port, etc.).

5.2.22 *re-initialization* — a process where production equipment is either powered off then on or when some kind of hardware or software reset is initiated to cause the equipment to reset and possibly reload its software. On production equipment that contains some kind of mass storage device this can also be called a "reboot".

5.2.23 *read position* — any position where the tag on a pod can be read.

5.2.24 *reticle* — a mask that contains the patterns to be reproduced on a substrate; the image may be equal to or larger than the final projected image.

5.2.25 *Reticle SMIF Pod (RSP)* — minienvironment compatible carrier capable of holding one 6 inch or one

230 mm reticle in a horizontal orientation during transport and storage and is compatible with a Standard Mechanical Interface (SMIF) per SEMI E19.4.

5.2.26 *single communication connection* — exactly one physical connection using exactly one logical session and a standard set of messages.

5.2.27 *slot map* — the information that relates which slots in a reticle pod hold reticles, both correctly and incorrectly.

5.2.28 *slot map read* — the process of the equipment reading the slot map for substrate position and placement within the pod.

5.2.29 *standard message set* — messages conforming to standard message specifications.

5.2.30 *transfer unit* — maximum number of pods allowed in a specific transfer service:

- AA is the maximum number of pods allowed for acquisition at the transfer source.
- BB is the maximum number of pods allowed for deposit at the transfer destination.
- CC is the maximum number of carrier pods allowed for transfer in one transport vehicle.

The transfer unit is the minimum of AA, BB, and CC.

NOTE 2: At the time this document was originally written, December 2000, transfer unit for reticle transfer to process equipment is expected to be equal to one. Transfer unit to other equipment may be greater than one.

5.2.31 *unload* — the operation of removing a pod from a load port.

5.2.32 *write position* — any position on a load port or in an internal buffer from which the tag on a pod can be written to. This position may vary on any particular equipment depending on the write technology selected by the end user. The read position and the write position may or may not be the same position.

6 Requirements

6.1 Reticle and Pod Management compliant equipment is required to provide certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and equipment control. These requirements shall be satisfied through compliance to the following sets of standards:

6.2 *Generic Equipment Model Standard (GEM) SEMI E30*

- Event Notification
- Status Data Collection
- Equipment Constants
- Alarm Management
- Equipment Control
- Remote Control
- Error Messages
- Dynamic Event Report Configuration

6.3 *Object-Based Standards*

- Object Services Standard (SEMI E39)
- Event Reporting (SEMI E53)
- Exception Management (SEMI E41)

7 Conventions

7.1 *Objects*

7.1.1 Whenever the equipment is required to know about specific kinds of entities, and required to manage information concerning these entities, it is useful to treat these entities as objects that comply with the basic requirements of SEMI E39 (OSS). This is especially true whenever there are a large number of objects of a given type or when the entities are transient rather than permanent. In both cases, it is difficult to describe a general way for the host and equipment to specify which particular entity is referenced and to get information related only to a specific one out of many.

7.1.2 By defining these entities as objects that comply with SEMI E39, it is only necessary for the host to specify the type of object and its specific identifier in order to inquire about one or more properties of the specific entity of interest.

7.1.3 *Object Properties*

7.1.3.1 A property (attribute) is information about an individual object that is presented as a name/value pair. The name is a formally reserved text string that represents the property, and the value is the current setting for that property.

7.1.3.2 Properties shall be accessible to the host via the service GetAttr and SetAttr for the Reticle Pod object. Reticle object, and Reticle location object.

- get the list of IDs for the current reticle pods at the equipment, and
- get the specified properties for one or more individual reticle pods.

7.1.4 *Rules for Object Properties*

- Attributes with RO access can not be changed using SetAttr service as defined in OSS.

- Attributes with RW access can be changed using SetAttr service as defined in OSS.
- Additional attributes may be specified by the user or the equipment supplier by using an attribute name starting with "UD" (User Defined). Care should be taken to ensure the name of the attribute is unique.

7.1.5 *Object Attribute Table*

7.1.5.1 The object attribute table is used to list all the attributes related to the defined object as shown below the access is defined as Read only (RO) or Read/Write (RW). The REQD column is used to specify whether the attribute is required for implementation. Finally, the Form column is used to specify the format of that particular attribute.

Table 1 Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y	Text = "Carrier"

7.2 *State Model Methodology*

7.2.1 A state model has three elements: definitions of each state and sub-state, a diagram of the states and the transitions between states, and a state transition table. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an Appendix of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.[1]

7.2.2 *State Model Requirements*

7.2.2.1 The state models included in this standard are a requirement for RPMS compliance. A state model consists of a state model diagram, state definitions, and a state transition table. All state transitions in this standard, unless otherwise specified, shall correspond to collection events.

7.2.2.2 A state model represents the host's view of the equipment, and does not necessarily describe the internal equipment operation. All Reticle and Pod Management state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the RPMS state model for transition to another state. In this case, the equipment makes the required transition without any additional actions in this situation.

7.2.2.3 Some equipment may need to include additional sub-states other than those in this standard. Additional sub-states may be added, but shall not change the Reticle and Pod Management defined state transitions. All expected transitions between Reticle and Pod Management states shall occur.

7.2.2.4 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

- Actions taken upon exit of the previous state.
- Actions taken upon entry of the new state.
- Actions taken which are most closely associated with the transition.

Table 2 State Transition Table

Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

1 Elsevier Science, P. O. Box 945, New York, NY 10159-0945, http://www.elsevier.nl/homepage/browse.html

7.3 *Services*

7.3.1 Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message that does not require a response.

7.3.2 *Service Message Description*

7.3.2.1 A service message description table defines the parameters used in a service, as shown in the following table:

Table 3 Service Message Description Table

Service Name	*Type*	*Description*

NOTE 1: Type can be either "N" = Notification or "R" = Request & Response.

7.3.2.2 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

7.3.3 *Service Message Parameter Definition*

7.3.3.1 A service parameter dictionary table defines the description, range, and type for parameters used by services, as shown in the following table:

Table 4 Service Message Parameter Definition Table

Parameter Name	*Form*	*Description*

NOTE 1: A row is provided in the table for each parameter used on a service.

7.3.4 *Service Message Definition*

7.3.4.1 A service message description table defines the parameters used in a service message. It also describes each message and its cause/effect to the equipment. The columns labeled Req/Ind and Resp/Conf link the parameters to the direction of the message.

Service Parameter	*Req/Ind*	*Resp/Conf*	*Description*

7.3.4.2 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the "Request". The receiver terms this message the "Indication". The receiver may then send a "Response", which the original sender terms the "Confirmation".

7.3.4.3 The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

"M"	Mandatory Parameter – must be given a valid value.
"C"	Conditional Parameter – may be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the values of other parameters.
"U"	User-Defined Parameter.
"-"	The parameter is not used.
"="	(for response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7.4 *Alarm Requirements Definition*

7.4.1 An alarm requirements definition table defines the specific set of alarms required by RPMS. The table is divided up by equipment configuration, and then by alarm. The danger and affected columns are marked with "X" characters to show each alarm and its possible impact to operators, equipment, and material. The table format is shown in the following example:

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
Configuration 1	Alarm 1	X		X	X	X
	Alarm 2		X			X
Configuration 2	Alarm 3	X		X	X	
	Alarm 4	X			X	X

8 Overview

8.1 The Reticle and Pod Management standard defines the behavior, data, and services required for equipment supporting automated reticle pod transfer, reticle pod management, and reticle management. This document provides a standard interface for host/equipment communications regarding the transfer of reticle pods, reticle pod identification and verification, transfer of reticles to and from equipment, reticle identification and verification, reticle inspection and qualification, and tracking of reticles. The standardized reticle pod transfer host interface include transfers to and from the external reticle load ports and internal reticle pod locations, the standardized reticle host interface include transfers to and from the reticle pod, transfers to and from the internal reticle library positions, and reticle identification, inspection, verification, qualification and tracking of reticles.

8.2 *Single Connection Requirement*

8.2.1 The expectation of the production and storage equipment supplier is that this standard be implemented in conjunction with the GEM interface to their production equipment and without the use of a separate communication connection.

9 Load Port

9.1 A reticle pod load port (port) is used by the factory to load and unload reticle pods to and from Lithography, reticle inspection, and bare reticle storage equipment. A reticle pod load port may be used as a reticle pod input load port, a reticle pod output load port, or as a reticle pod input/output load port, depending upon equipment type, configuration and/or factory practices. This classification may be fixed or it may be programmable by the user. A reticle pod load port is generally designed to handle one specific carrier type, reticle SMIF pods (RSP).

9.1.1 The equipment supplier is free to implement Load Ports as objects, but this is not a requirement for compliance to this standard.

9.2 *Load Port Numbering*

9.2.1 The reticle pod load port number shall be assigned incrementally from the bottom left to bottom right, then top left to top right when facing the reticle load ports. The numbering system should start with 101 to differentiate from FOUP load ports. The reticle pod load port-numbering requirement is to provide a common reference base to external entities, such as humans.

9.3 *Reticle Pod Slot Numbering*

9.3.1 The slot numbers for a reticle pod shall be assigned incrementally from the bottom, starting with "1."

9.4 *Reticle Pod Load Port Resource Sharing*

9.4.1 A model of a reticle pod load port must account for any mechanical assemblies that are either active during reticle pod transfer or are capable of interacting with the transfer. The reticle pod load port is responsible for such mechanisms when the reticle pod load port is in the TRANSFER READY state. If these mechanisms are shared with other reticle pod load ports, then the sharing must be coordinated.

9.5 *Reticle Pod Load Port Transfer State Model*

9.5.1 The purpose of the Reticle Pod Load Port Transfer State Model is to define the host view of a reticle pod transfer, which includes the host interactions with the equipment necessary to transfer reticle pods to and from equipment reticle pod load ports. Each reticle pod load port on the equipment shall maintain an independent instance of this state model.

9.5.2 *Reticle Pod Load Port Transfer State Model Diagram*

9.5.2.1 Figure 1 is the diagram for the Reticle Pod Load Port Transfer State Model.

9.5.3 *Reticle Pod Load Port Transfer State Definitions*

9.5.3.1 RETICLE POD LOAD PORT TRANSFER — The super state for the IN SERVICE and OUT OF SERVICE states.

9.5.3.2 OUT OF SERVICE — Transfer to/from this reticle pod load port is disabled. A transition to IN SERVICE is required to continue using this reticle pod load port for transfers.

9.5.3.3 IN SERVICE — Transfer to/from this reticle pod load port is enabled. A transition to OUT OF SERVICE disables the reticle pod load port for transfer use.

9.5.3.4 TRANSFER READY — A sub-state of IN SERVICE. The reticle pod load port is available for pod transfer. The transfer can either be manual or automated, and can be a load or an unload. This state contains two sub-states, which are used depending on whether or not a reticle pod is present on the load port (READY TO LOAD and READY TO UNLOAD).

9.5.3.5 READY TO LOAD — A sub-state of TRANSFER READY. When transitioning to the TRANSFER READY state, if a reticle pod is not present on the specified reticle pod load port, this is the active sub-state. In this state, the reticle pod load port is available to be loaded with an external reticle pod.

9.5.3.6 READY TO UNLOAD — A sub-state of TRANSFER READY. When transitioning to the TRANSFER READY state, if a reticle pod is present on the specified reticle pod load port, this is the active sub-state. In this state, the reticle pod load port is available for unloading of a reticle pod from the reticle pod load port to material handling equipment. When the reticle pod load port is being used by the equipment, the state shall transition to TRANSFER BLOCKED.

9.5.3.7 TRANSFER BLOCKED — The reticle pod transfer state is neither READY TO LOAD nor READY TO UNLOAD. Because of reticle pod load port related activity being performed, transfer is not available to/from this reticle pod load port at this time.

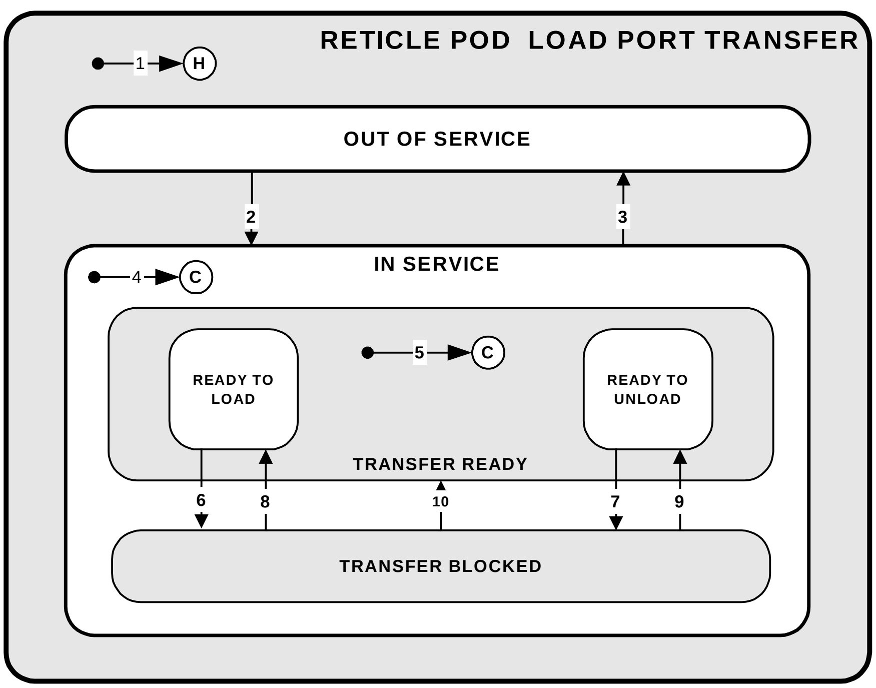


Figure 1
Reticle Pod Load Port Transfer State Model Diagram

9.5.4 *Reticle Pod Load Port Transfer State Transition Table*

Table 5 Reticle Pod Load Port Transfer State Transition Definition

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	OUT OF SERVICE or IN SERVICE (History)		This transition is based on what the current transfer status was prior to system reset. Data required to be available for this event report: PortID
2	OUT OF SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE.	IN SERVICE		Reticle Pod Load port is now usable for transfer. Data required to be available for this event report: PortID
3	IN SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of OUT OF SERVICE.	OUT OF SERVICE		Reticle Pod Load port is now rendered unusable for transfer. Attempted usage of the reticle pod load port for reticle pod transfer after the state transition results in an alarm. Data required to be available for this event report: PortID
4	IN SERVICE	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization.	TRANSFER READY or TRANSFER BLOCKED		This is the default entry into IN SERVICE. The state is TRANSFER BLOCKED if the reticle pod, or reticle pod load port, is not available for pod transfer. Otherwise, the state is TRANSFER READY. Data required to be available for this event report: PortID
5	TRANSFER READY	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization. *Failed Transfer:* If a transfer fails, this transition is activated by transition #10.	READY TO LOAD or READY TO UNLOAD		When entering the TRANSFER READY state, if a reticle pod is present, the sub-state is READY TO UNLOAD, else the sub-state is READY TO LOAD. If the state is READY TO LOAD, data required to be available for this event report: PortID If the state is READY TO UNLOAD, data required to be available for this event report: PortID PodID
6	READY TO LOAD	*Manual*: "The equipment recognizes the logical indication of the start of a manual load transfer. This trigger is configurable by the user, examples are included in table 8." *Automated*: The PIO load transfer is beginning and the PIO ready signal is activated.	TRANSFER BLOCKED		Data required to be available for this event report: PortID

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
7	READY TO UNLOAD	*Manual*: The equipment recognizes a logical indication of the start of an unload transfer. *Automated*: The PIO unload transfer is beginning and the PIO ready signal is activated.	TRANSFER BLOCKED		Data required to be available for this event report: PortID
8	TRANSFER BLOCKED	*Manual:* The reticle pod unload transfer has completed, and the reticle load port is now empty and ready for load transfer. *Automated:* The PIO unload transfer ends with a PIO complete signal.	READY TO LOAD		Data required to be available for this event report: PortID
9	TRANSFER BLOCKED	*Manual: Activities using reticles contained within the pod have completed* the reticle pod is ready to be removed. *Automated:* Handling for reticles destined for the reticle pod has completed, or a CancelPod/ CancelPodAtPort service has been issued, and the reticle pod is ready to be removed. This is indicated by a PIO unload request signal.	READY TO UNLOAD		The reticle pod on the reticle pod load port can now be unloaded from the reticle load port to an external entity. Data required to be available for this event report: PortID PodID
10	TRANSFER BLOCKED	The transfer was unsuccessful, and the reticle pod was not loaded or unloaded.	TRANSFER READY		The sub-state of TRANSFER READY, which is decided by transition #5. Data required to be available for this event report: PortID

10 Reticle Pod Object

10.1 Information about a reticle pod is encapsulated as an object. This allows the host to exchange information with the equipment about one or more specific reticle pods using services defined in SEMI E39, Object Services Standard. A reticle pod has properties (attributes) that are defined in Table 6, Pod Attribute Definition.

10.2 *Object Instantiation*

10.2.1 The reticle pod object is a software representation of the reticle pod in the equipment. Under normal circumstances this object is instantiated by the equipment when the host uses the Bind, ReticleTransferJob, or PodNotification service or when the equipment successfully reads the PodID from the reticle pod. A reticle pod object is instantiated by PodID read only if there are no currently existing objects of the same object type with the PodID just read. A reticle pod object can also be instantiated by either the ProceedWithPod or CancelPod Services on an UNASSOCIATED port. (This implies a failed PodID read event.) The ContentMap attribute will be an empty list (a list of zero) when the instantiation is done by PodID read. The SlotMap attribute should be a list consisting of all slots enumerated as “UNDEFINED” when the reticle pod object is instantiated by PodID read.

10.2.2 From the host point of view, an object is instantiated if the host is able to query the equipment about that object, it' s current state, and other attributes. Once instantiated, the object is considered destroyed (no longer instantiated) if the response to such queries is “unknown object”.

10.2.3 Summary of reticle pod object instantiation:

1. Bind, ReticleTransferJob, or PodNotification Service;
2. PodID read with no currently existing pod objects having the PodID just read; and
3. ProceedWithPod or CancelPod Service on an UNASSOCIATED port with a pod.

10.2.4 *Reticle Pod Object Identifier (ObjID)*

10.2.4.1 The purpose of an Object Identifier is to allow references to an object within the system. The object identifier is created when an object is instantiated and should be unchanged or persistent until the end of the object lifecycle. The Object Identifier shall be unique at the equipment during lifecycle of the object. The PodID is the Reticle Pod Object Identifier. The equipment is responsible for ensuring uniqueness of the PodID prior to instantiation by the bind, pod notification, or ReticleTransferJob service.

10.2.5 *Reticle Pod Object Destruction*

10.2.5.1 Normally, the Reticle Pod Object reaches the end of its lifecycle when the reticle pod is unloaded from the equipment. Abnormally, the Reticle Pod Object reaches the end of it's lifecycle when a CancelBind, CancelReticleTransferJob, or CancelPodNotification service is executed prior to the reticle pod being loaded, or when an equipment based pod verification fails following pod instantiation by the bind service.

10.2.5.2 Summary of reticle pod object destruction:

1. A reticle pod is unloaded from the equipment;
2. A CancelBind, CancelReticleTransferJob or CancelPodNotification service is received; and
3. An equipment based verification fails (after the object has been instantiated via the bind services).

10.3 *Reticle Pod Attribute Definitions*

10.3.1 The following table contains the attributes that are of importance to the host and/or the equipment in order to manage the history and the reports about the reticle carrierpod object.

10.3.2 *REQD Column*

10.3.2.1 All attributes in the following table are required to be associated with the reticle pod object. However only the attributes marked with a "Y" in the REQD column are always required to be maintained and updated by the equipment. The attributes marked with an "N" in the REQD column are only required to be maintained if they are provided by the host by either the Bind, PodNotification, ReticleTransferJob or ProceedWithPod Services or if the equipment has means of determining the attribute values. (For example, if the equipment has a ReticleID reader, the equipment can determine the ContentMap).

10.3.3 *ACCESS Column*

10.3.3.1 Even though a value may be marked as RO (read only), the initial value for the attribute may be provided by the host when attached to either the Bind, PodNotification, ReticleTransferJob or ProceedWithPod services. The only other time the PodCapacityStatus attributes are updated is at the first ProceedWithPod service.

10.3.4 *Pod Attribute Definition Table*

Table 6 Pod Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type.	RO	Y	Text equal to "Reticle Pod".
ObjID	Object identifier.	RO	Y	Text 1 to 80 characters equal to the PodID.
Capacity	Maximum number of reticles in pod.	RO	Y	Positive integer. If a pod arrives at a load port with no warning the default value is one.
PodIDStatus	Current state of the PodID verification.	RO	Y	Enumerated: ID NOT READ, WAITING FOR HOST ON ID STATUS, ID VERIFICATION OK, ID VERIFICATION FAILED.
ReticlePodAccessing-Status	The current accessing state of the reticle pod by the equipment. The current substate of the ReticlePodAccessingStatus state model.	RO	Y	Enumerated: NOT AVAILABLE, AVAILABLE, IN ACCESS, COMPLETE
ContentMap	Ordered list of reticle identifiers corresponding to slot 1,2,3….n	RO	Y	Ordered list of n elements, where n is equal to the value of "Capacity" above, and each element consists of a ReticleID. When a slot has no reticle, the ReticleID value should be null.
ReticlePodLocationID	Identifier of current location of the reticle pod.	RO	Y	Text 1 to 80 characters.

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ReticlePodLocking-Status	The current state of pod locking by the equipment. The current substate of the ReticlePodLockingStatus.	RO	Y	Enumerated: NOT LOCKED, RELEASED AND LOCKED, HOLD
SlotMap	Ordered List of slot status as provided by the host until a successful slot map read, then as read by the equipment.	RO	Y	Ordered List of n elements where n is equal to the value of "Capacity" above. 1. Enumerated $_1$. n. Enumerated$_n$ Enumerated: UNDEFINED, EMPTY, CORRECTLY OCCUPIED. The number shown above is the slot number.
SlotMapStatus	Current state of slot map verification.	RO	Y	Enumerated: SLOT MAP NOT READ, WAITING FOR HOST ON SLOT STATUS, SLOT MAP VERIFICATION OK, SLOT MAP VERIFICATION FAILED.

10.3.5 *Rules for Reticle Pod Attributes*

- The equipment shall change object attributes, ContentMap, SlotMap, and Reticle count, provided by the host. All other attributes, such as LocationID, shall be set and maintained by the equipment.
- The attributes, Capacity, ContentMap, Reticle count, shall be provided with Bind, PodNotification, ReticleTransferJob, or ProceedWithPod service before or when SlotMap is provided.
- The SlotMap shall be provided with Bind, PodNotification, ReticleTransferJob or ProceedWithPod to verify PodID, when the SlotMap verification is equipment based. And it shall not be provided when the SlotMap verification is host based.
- Reticle pod properties may be provided before the reticle pod arrives as part of the Bind, PodNotification, or ReticleTransferJob service and should be retained until either a CancelBind, CancelPodNotification, or CancelReticleTransfer-Job service is received or the reticle pod is removed.
- Reticle pod properties may also be provided by the ProceedWithPod service. The reticle pod properties that are provided by the ProceedWithPod service may differ based whether or not the object is instantiated by the service.
- Reticle pod properties that are required shall be actively updated by the equipment.

10.3.6 *Reticle Pod Location*

10.3.6.1 A reticle pod location, signified by LocationID, is used for tracking. A reticle pod location is any physical area that is capable of holding a pod. It is not intended to represent entire mechanisms, which may have a variety of other properties of interest, but only that portion where a reticle pod may rest.

10.3.7 *Reticle Pod Location Examples*

10.3.7.1 Reticle Pod Locations include reticle pod load port locations, internal pod buffer locations, as well as grippers, conveyors, and elevators that are used internally for moving the pod from one fixed location to another.

10.3.8 *Slot Map Relation to Content Map* — The slot map attribute and content map attribute hold similar information. The purpose of these attributes differs. The slot map is provided so that the equipment or host can quickly verify that the pod has reticles correctly placed in the correct slot (as provided by the host). This verification is based on a slot map read. The content map is provided so that the host can communicate the specific ReticleID in a specific slot as delivered and that the equipment can communicate the specific ReticleID that it places in a specific slot.

10.3.9 *Reticle Pod Location Naming* — All locations shall be assigned a unique name. Information about the reticle pod location can be obtained by querying the Pod Object for the ReticlePodLocationID or by asking the equipment for the PodLocationMatrix. The text form of the ReticlePodLocationID shall be descriptive of the location.

10.3.10 *Capacity*

10.3.10.1 The Capacity parameter can be sent to the equipment by the host in either the PodNotification, Bind, ReticleTransferJob, or the ProceedWithPod service. However the equipment shall update this *10.3.10.2* parameter based on the results of the read slot map operation. Furthermore, the equipment shall update the parameter based on it's own actions. . If the equipment does not know the value of Capacity prior to instantiation, the equipment shall instantiate the reticle pod object with the value of one for Capacity.

10.3.11 *Reticle Pod Accessing Status*

10.3.11.1 The ReticlePodAccessingStatus is used by the host to know whether or not the reticle pod owned by the equipment can be transferred from the equipment.

10.3.11.2 Enumerated values of ReticlePodAccessing-Status correspond to the substates of ReticlePodAccessingStatus (see Figure 2).

10.4 *Reticle Pod State Model*

10.4.1 The purpose of the Reticle Pod State Model is to define the host's view of a reticle pod. The equipment shall maintain a separate and independent state model for each reticle pod in/at the equipment.

10.4.2 *Reticle Pod State Model Diagram*

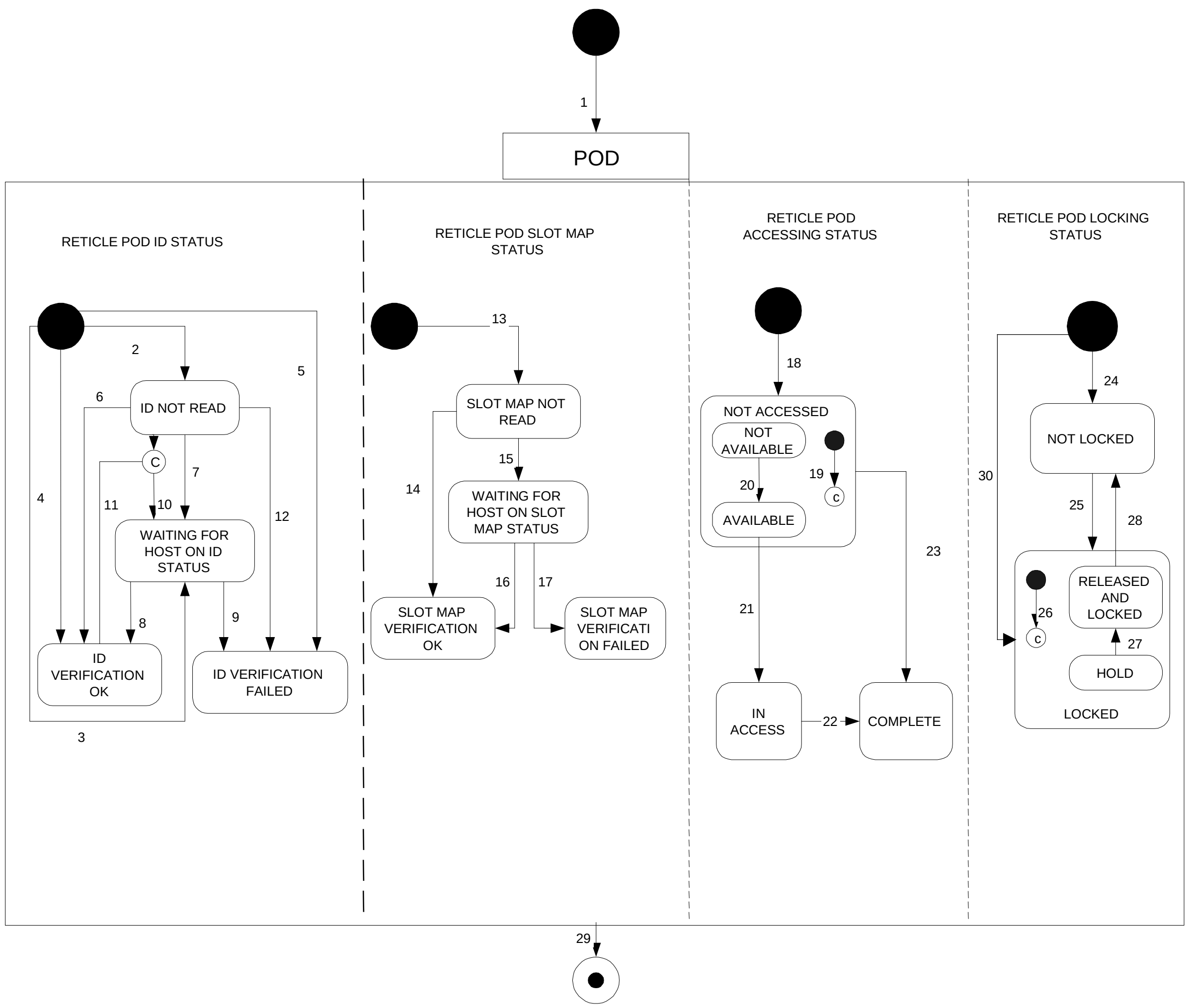


Figure 2
Reticle Pod State Model Diagram

10.4.3 *Reticle Pod State Definitions*

10.4.3.1 *RETICLE POD* — The RETICLE POD state has four ANDed (orthogonal) substates: RETICLE POD ID STATUS, RETICLE POD SLOT MAP STATUS, RETICLE POD ACCESSING STATUS, AND RETICLE POD CLAMPING STATUS.

10.4.3.1.1 *RETICLE POD ACCESSING STATUS* — This is a substate of RETICLE POD and indicates the current accessing status of the pod. It has three substates, NOT ACCESSED, IN ACCESS, and COMPLETE. The initial default entry substate is NOT ACCESSED.

10.4.3.1.1.1 *NOT ACCESSED* — This is a substate of RETICLE POD ACCESSING STATUS and is active when the reticle pod has not been opened. It has two substates NOT AVAILABLE and AVAILABLE.

10.4.3.1.1.1.1 *NOT AVAILABLE* — This is a substate of NOT ACCESSED and is active when the reticle pod has been instantiated via service but has not been received by the equipment.

10.4.3.1.1.1.2 *AVAILABLE* — This is a substate of NOT ACCESSED and is active when the reticle pod has been received by the equipment but not opened.

10.4.3.1.1.2 *IN ACCESS* — This is a substate of RETICLE POD ACCESSING STATUS and is active when reticle pod has been opened once, and the reticle pod should not be unloaded from the equipment. In this state the slot map is read and reticles may be moved in and out of the reticle pod.

10.4.3.1.1.3 *COMPLETE* — This is a substate of RETICLE POD ACCESSING STATUS and is active when all known activity, as defined by the ReticleTransferJob service, for the reticle pod has completed, or the PodComplete service has been received, and the reticle pod has been closed. The reticle pod may be unloaded from the equipment.

10.4.3.1.2 *RETICLE POD LOCKING STATUS* — This is a substate of RETICLE POD and indicates the current status of the pod with respect to removability.

10.4.3.1.2.1 *NOT LOCKED* — This is a substate of RETICLE POD LOCKING STATUS and is active when there are no physical or logical mechanisms that prevent removal of the reticle pod by an external entity.

10.4.3.1.2.2 *LOCKED* — This is a substate of RETICLE POD LOCKING STATUS and is active when there are physical mechanisms that prevent removal of the reticle pod by an external entity. It has two substates RELEASED AND LOCKED and HOLD.

10.4.3.1.2.2.1 *RELEASED AND LOCKED* — This is a substate of LOCKED and is active when the pod may be released by the equipment.

10.4.3.1.2.2.2 *HOLD* — This is a substate of LOCKED and is active when there are physical or logical mechanisms that prevent removal of the pod engaged and the pod release flag is set to host release and the PodRelease service has not been received.

10.4.3.1.3 *RETICLE POD ID STATUS* — This is a substate of RETICLE POD and indicates the current status of the pod with respect to its identifier. It has four substates, ID NOT READ, WAITING FOR HOST ON ID STATUS, ID VERIFICATION FAILED, ID VERIFICATION OK. The initial substate is conditional based on information the equipment has about the reticle pod. When the PodID is provided by the Bind, ReticleTransferJob, or the PodNotification service, the reticle pod object shall be instantiated in the ID NOT READ substate. When the PodID is provided by the PodID read, the reticle pod shall be instantiated in the WAITING FOR HOST ON ID STATUS substate. When the Reticle Pod is instantiated by the ProceedWithPod service, the reticle pod shall be instantiated in the ID VERIFICATION OK substate. Finally when the reticle pod is instantiated by the CancelPod service, the pod will be instantiated in the ID VERIFICATION FAILED substate.

10.4.3.1.3.1 *ID NOT READ* — This is a substate of RETICLE POD ID STATUS. This state is active whenever the PodID has not been read by the equipment.

10.4.3.1.3.2 *ID VERIFICATION FAILED* — This is a substate of RETICLE POD ID STATUS and is active when the PodID has verification by the host with the CancelPod service. This is a final state.

10.4.3.1.3.3 *ID VERIFICATION OK* — This is a substate of RETICLE POD ID STATUS and is active as soon as the PodID has been accepted. The ID is determined to be accepted by either successful verification by the equipment or the host, or by bypassing ID read because a PodID reader is not available and the BypassReadID variable is set to true. This is a final state.

10.4.3.1.3.4 *WAITING FOR HOST ON ID STATUS* — This is a substate of RETICLE POD ID STATUS and is active during the period of time when the PodID has been read by the equipment successfully or unsuccessfully and has not yet been verified.

10.4.3.1.4 *RETICLE POD SLOT MAP STATUS* — This is a substate of RETICLE POD and indicates the current status of the reticle pod with respect to its slot map. It has four substates, SLOT MAP NOT READ,

WAITING FOR HOST ON SLOT MAP STATUS, SLOT MAP VERIFICATION FAILED, SLOT MAP VERIFICATION OK. The initial default entry sub-state is SLOT MAP NOT READ.

10.4.3.1.4.1 *SLOT MAP NOT READ* — This is a substate of RETICLE POD SLOT MAP STATUS and is the default entry state. It is active when the Reticle Pod is first loaded at the equipment until the Slot Map has been read successfully by the equipment.

10.4.3.1.4.2 *SLOT MAP VERIFICATION FAIL* — This is a substate of RETICLE POD SLOT MAP STATUS and is active when the Slot Map has been read by the equipment and has failed verification by the host. This is a final state.

10.4.3.1.4.3 *SLOT MAP VERIFICATION OK* — This is a substate of RETICLE POD SLOT MAP STATUS and is active as soon as the slot map has been verified. This is a final state.

10.4.3.1.4.4 *WAITING FOR HOST ON SLOT MAP STATUS* — This is a substate of RETICLE POD SLOT MAP STATUS and is active when the equipment is waiting for input from the host.

10.4.4 *Reticle Pod State Transition Table*

10.4.4.1 Table 7 indicates the triggers and the expected behavior of the instantiated reticle pod object.

Table 7 Reticle Pod State Transition Definition

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
1	(no state)	A reticle pod is instantiated.	RETICLE POD	None.	Data required to be available for this event report: PodID
2	(no state)	*Normal:* A Bind, ReticleTransferJob or PodNotification service is received.	ID NOT READ	None.	Data required to be available for this event report: PodID
3	(no state)	*Normal:* A PodID not currently existing at the equipment is successfully read. *Abnormal:* A PodID is read successfully but an equipment based verification failed.	WAITING FOR HOST ON ID STATUS	None.	Data required to be available for this event report: PodID PortID Normally, this transition will happen after a successful ID read if a bind or ReticleTransferJob service has not been issued (host based verification) or abnormally if a bind or ReticleTransferJob service is followed by a successful ID read and an unsuccessful equipment based verification.
4	(no state)	*ID Read fail*: A ProceedWithPod service is received.	ID VERIFICATION OK	A reticle pod is instantiated having the PodID provided by the ProceedWithPod service.	Data required to be available for this event report: PodID This transition can happen only if a bind or ReticleTransferJob, service has not been received.
5	(no state)	*ID Read fail:* A CancelPod service is received.	ID VERIFICATION FAIL	A reticle pod is instantiated having the PodID provided by the Cancel Pod service.	Data required to be available for this event report: PodID This transition can happen only if a bind or ReticleTransferJob service has not been received.

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
6	ID NOT READ	PodID is read successfully and the equipment has verified the PodID successfully.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID PodID
7	ID NOT READ	PodID is read unsuccessfully.	WAITING FOR HOST ON ID STATUS	None.	Data required to be available for this event report: PortID PodID
8	WAITING FOR HOST ON ID STATUS	A ProceedWithPod service is received.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID PodID
9	WAITING FOR HOST ON ID STATUS	A Cancel Pod Service is received.	ID VERIFICATION FAILED	None.	Data required to be available for this event report: PortID PodID
10	ID NOT READ	$BypassReadID_i$ variable is set to FALSE, and a reticle pod is received when the id reader is not in service or not installed.	WAITING FOR HOST ON ID STATUS	Wait for ProceedWithPod.	Data required to be available for this event report: PortID PodID
11	ID NOT READ	$BypassReadID_i$ variable is set to TRUE, and a reticle pod is received when the id reader is not in service or not installed.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID PodID
12	ID NOT READ	The equipment successfully reads, but unsuccessfully verifies a reticle PodID.	ID VERIFICATION FAILED	None.	This transition should be followed by the equipment performing a self initiated CancelBind service (see transition 29) Data required to be available for this event report: PodID (of the pod instantiated in the Bind service) Data required to be available for this event report: PortID PodID
13	(no state)	A reticle pod is instantiated.	SLOT MAP NOT READ	None.	No event is required for this transition.
14	SLOT MAP NOT READ	Slot Map is read and verified successfully by the equipment.	SLOT MAP VERIFICATION OK	None.	Data required to be available for this event report: PortID (if valid) PodID LocationID

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
15	SLOT MAP NOT READ	*Normal host based verification:* Slot Map is read successfully and the equipment is waiting for host verification. *Equipment based verification:* Slot map is read successfully but equipment based verification has failed. *Slot map read fail:* Slot Map cannot be read.	WAITING FOR HOST ON SLOT MAP STATUS	Save new slot map in the SlotMap attribute.	Data required to be available for this event report: PortID (if valid) PodID LocationID SlotMap (if valid) Reason
16	WAITING FOR HOST	A ProceedWithPod service is received.	SLOT MAP VERIFICATION OK	Proceed with the Reticle Pod as instructed.	Data required to be available for this event report: PortID (if valid) PodID LocationID
17	WAITING FOR HOST	A CancelPod service is received.	SLOT MAP VERIFICATION FAIL	Prepare the Reticle Pod for Unload.	Data required to be available for this event report: PortID (if valid) PodID LocationID
18	(no state)	A reticle pod object is instantiated.	NOT ACCESSED	None.	Data required to be available for this event report: PodID
19	(no state)	A reticle pod object is instantiated.	NOT AVAILABLE or AVAILABLE	None.	This is the default entry into NOT ACCESSED. If the reticle is instantiated by service, the state is NOT AVAILABLE. If instantiated by PodID read the state is AVAILALBLE Data required to be available for this event report: PodID
20	NOT AVAILABLE	The reticle pod is received by the equipment.	AVAILABLE	None.	Data required to be available for this event report: PodID PortID
21	AVAILABLE	The equipment opens the reticle pod.	IN ACCESS	None.	Data required to be available for this event report: PodID

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
22	IN ACCESS	*Normal with ReticleTransfer-Job service for pod with OutputPortID not equal to zero:* The actions defined in the reticle transfer job have completed and the equipment closes the reticle pod. *PodComplete service:* The host sends the PodComplete service and the equipment closes the reticle pod. *Internal Pod Buffer:* The PodOut service has been received. *Abnormal:* The pod has failed slot map verification and / or a CancelPod service is received and the pod is ready for unload.	COMPLETE	None.	Data required to be available for this event report: PodID
23	NOT ACCESSED	*Via ID verification failure:* The pod has failed ID verification and the carrier is ready for unload. *Via Service:* A CancelBind, CancelPodNotification, CancelPod, or CancelReticleTransferJob has been received prior to pod arrival.	COMPLETE	None.	Data required to be available for this event report: PodID
24	(no state)	A reticle pod is instantiated.	NOT LOCKED	None.	Data required to be available for this event report: PodID PortID
25	NOT LOCKED	A reticle pod is clamped or otherwise physically restrained from removal by an entity external to equipment.	LOCKED	None.	Data required to be available for this event report: PortID PodID
26	NOT LOCKED	A reticle pod is clamped or otherwise physically restrained from removal by an entity external to equipment.	RELEASED AND LOCKED or HOLD	None.	This is the default entry into LOCKED. If the PodRelease flag is set to Equipment Release the state is RELEASED AND LOCKED. If the PodRelease flag is set to Host Release the state is HOLD. Data required to be available for this event report: PortID PodID
27	HOLD	A PodRelease service has been received by the equipment.	RELEASED AND LOCKED		

#	Previous State	Trigger	New State	Actions	Comment
28	RELEASED AND LOCKED	*MANUAL Access Mode:* The POD ACCESSING state enters COMPLETE and a reticle pod is unclamped or has had any restraints preventing removal by an external entity removed. *AUTO Access Mode and Unclamp control trigger set to Pod Closed:* The POD ACCESSING state enters COMPLETE and a reticle pod is unclamped or has had any restraints preventing removal by an external entity removed. *AUTO Access Mode and Unclamp control trigger set to AMHS Triggered Unclamp:* The POD ACCESSING state is COMPLETE and the AMHS arrives and starts a PIO sequence.	NOT LOCKED	None.	Data required to be available for this event report: PortID PodID
29	POD	*Normal:* The reticle pod is unloaded from the equipment. *Abnormal by service:* CancelBind, CancelPodNotification, or CancelReticleTransferJob service is received prior to pod load. *Abnormal by equipment:* An equipment-based verification fails and the equipment performs a self-initiated CancelBind service.	(no state)	The equipment destroys the instance of this reticle pod object.	Data required to be available for this event report: PodID
30	(no state)	A Reticle Pod is loaded, locked, and the id is read on a load port for which no previous reticle pod has been instantiated	LOCKED		Data required to be available for this event report: PodID PortID

NOTE 1: Only one collection event report is required when entering the Reticle Pod State Model (instantiating a reticle pod object). This event report shall include the entry state of the all the substates of Reticle Pod State Model, (including RETICLE POD ID STATUS substate, the RETICLE POD SLOT MAP STATUS substate, the RETICLE POD ACCESSING STATUS, and the RETICLE POD LOCKING STATUS).

10.4.5 *Slot Map Read Details*

10.4.5.1 The Slot Map shall be read on all production equipment prior to removal of reticles from the reticle pod.

10.4.6 *Pod Read Failure* — A pod read failure occurs when the PodID reader is present, in service, and reports that it is unable to read the ID of a pod. This represents a transient random failure rather than a steady condition.

10.4.7 *Bypass Read ID* — A PodID reader may be unavailable: either out of service, not installed, or otherwise malfunctioning and unable to execute a read operation. This represents a steady condition that often is known in advance. The equipment shall provide a user-configurable variable BypassReadID that the user is able to set to specify the action to take when a pod is received to an ASSOCIATED load port. In this case, the reticle pod object is instantiated in the ID NOT READ state, and when the reticle pod is received, the state model transitions to either WAITING FOR HOST or ID VERIFICATION OK, depending upon whether BypassReadID is FALSE (the default value) or TRUE. When TRUE, then the PodID received in the Bind is used automatically. Otherwise, the pod transitions to WAITING FOR HOST and waits for the host to send a ProceedWithPod. The ID used will be the ID included with the ProceedWithPod.

11 Access Mode

11.1 *Access Mode State Model*

11.1.1 The Access Mode State Model defines the host view of equipment access mode, as well as the host interactions with the equipment necessary to switch the access mode. Each Reticle Load Port has its own Access Mode State Model. There are two access mode states. These are defined in Section 11.3.3.

11.1.2 The access mode for a reticle pod load port may be switched at anytime by the host or the operator, except when the Reticle Load Port Reservation State Model for that Reticle Pod Load Port is in the RESERVED state or during reticle pod transfer. Reticle pod transfer boundaries, for determining when access mode may be changed, are designated by Table 8, Reticle Pod Transfer Boundaries.

Table 8 Reticle Pod Transfer Boundaries

Transfer Type	*Transfer Method*	*Starting Boundary*	*Ending Boundary*
LOAD	MANUAL	This starting boundary is specified by the user. Known examples of the starting boundary include but are not limited to; the presence sensor detecting a pod, a pod load port operator access door opening, input to the equipment by the operator through a switch at the load port or the equipment console.	This ending boundary is specified by the user. Known examples of the ending boundary include but are not limited to; a preset configurable time following presence and placement sensor detecting a pod, a pod load port operator access door closing, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.
	AUTO	The PIO Ready signal is active for load.	The PIO signals a transfer complete.
UNLOAD	MANUAL	This starting boundary is specified by the user. Examples of the starting boundary include but are not limited to presence and placement sensor no longer detecting a pod, a pod load port operator access door opening, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.	This ending boundary is specified by the user. Examples of the ending boundary include but are not limited to a preset configurable time following presence and placement sensor no longer detecting a pod, a pod load port operator access door closing, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.
	AUTO	The PIO Ready signal is active for unload.	The PIO signals a transfer complete.

11.2 *Manual Pod Transfer Confirmation Trigger*

11.2.1 For a manual transfer completion confirmation, the production equipment supplier must implement a software or hardware mechanism for an operator to inform the equipment that the pod transfer is complete, but also support methods such as timers that allow equipment to consider a manual transfer complete without operator input.

11.3 *Access Mode Initial Value*

11.3.1 Also, when equipment re-initialization occurs, the access mode(s) must be remembered, and used as the initial value when initializing. Since the access mode is remembered through re-initializations, the initial value that is used the very first time the software is ever loaded is not important. The equipment supplier is free to set this default value.

11.3.2 *Access Mode State Model Diagram*

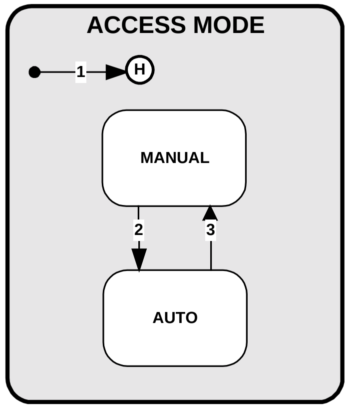


Figure 3
Access Mode State Model Diagram

11.3.3 *Access Mode State Definitions*

11.3.3.1 *ACCESS MODE* — The parent state for the MANUAL and AUTO sub-states.

11.3.3.2 *MANUAL* — A sub-state of ACCESS MODE. When the production equipment or specified reticle pod load port is in this mode, only manual (non-AMHS) pod transfers are allowed. The production equipment shall have the capability of generating an alarm if an automated (AMHS) delivery is attempted.

11.3.3.3 *AUTO* — A sub-state of ACCESS MODE. When the production equipment or specified reticle pod load ports are in this mode, only automated (AMHS) pod transfers are allowed. The production equipment shall have the capability of generating an alarm if a manual delivery is attempted.

11.3.4 *Access Mode State Transition Table*

11.3.4.1 Table 9 defines the transitions for the Access Mode State Model.

Table 9 Access Mode State Transition Definitions

#	*Previous State*	*Trigger*	*New state*	*Actions*	*Comments*
1	(no state)	System restart.	MANUAL or AUTO (History)	The access mode returns to the mode it was previous to the system reset.	Data required to be available for this event report: PortID
2	MANUAL	The host or operator has executed a Change-Access service with the value of AUTO. This trigger can happen at anytime, except during a reticle pod transfer.	AUTO		Manual deliveries are not allowed after this state transition. The operator may also trigger this transaction from the production equipment console. Data required to be available for this event report: PortID
3	AUTO	The host or operator has executed a ChangeAccess service with the value of MANUAL. This trigger can happen at anytime, except during pod transfer.	MANUAL		The operator may also trigger this transaction from the production equipment console or a manual switch at the reticle load port. Automated transfers are not allowed after this state transition. Data required to be available for this event report: PortID

12 Reservation State Model

12.1 The purpose of the Reticle Load Port Reservation State Model is to define the host view of future activity at a specific reticle load port.

12.1.1 The Reticle Load Port Reservation State Model, the ReserveAtPort service and CancelReserveAtPort enable the following items:

1. They enable the host to inform the equipment of a future reticle pod delivery without specifying the reticle PodID and at the same time allow host based verification. (Equipment based verification is enabled via the Load Port/Pod Association State Model, the Bind service, ReticleTransferJob, and the PodNotification service detailed in Sections 13, 18.4.2, 18.5.15, and 18.4.11 of SEMI E109.)
2. They enable the equipment to send a state change event to the host if the operator (either local or remote) informs the equipment of a future pod delivery to a reticle load port without specifying the reticle PodID. Thus the host knows that the operator expects to use that reticle load port for something the host did not request for AMHS based delivery.
3. The Bind, ReticleTransferJob, and CancelBind, CancelReticleTransferJob services also trigger changes in the Reticle Load Port Reservation State Model. If the Reticle Load Port Reservation state model is in the NOT RESERVED state, the Bind or ReticleTransferJob service triggers a transition to the RESERVED state. If the Reticle Load Port Reservation is in the RESERVED State, the CancelBind or CancelReticleTranserJob service triggers a transition to NOT RESERVED.

12.1.2 For Lithography, reticle inspection, and bare reticle stocker equipment, the Reservation State Model, the ReserveAtPort service, the CancelReserveAtPort service, and all other associated functionality is a user option and not necessary for fundamental compliance.

12.1.3 For equipment implementing the reservation state model, the equipment shall provide a reticle load port reservation state model for each load port.

12.2 *Reservation Visible Signal*

12.2.1 When a port reservation has taken place, the equipment shall display a visible signal indicating that the designated load port is in the Reserved State. Examples of visible signals for the associated load port are: Blinking LEDs, flags, color indicators, or other methods that allow easy recognition that the load port is reserved; proximity to or location on the load port is recommended. The visible signal shall remain present as long as the load port state remains RESERVED. When the state changes to NOT RESERVED the visible indicator shall cease. This capability is not required for fundamental compliance to RPMS.

12.3 *Load Port Reservation State Model Diagram*

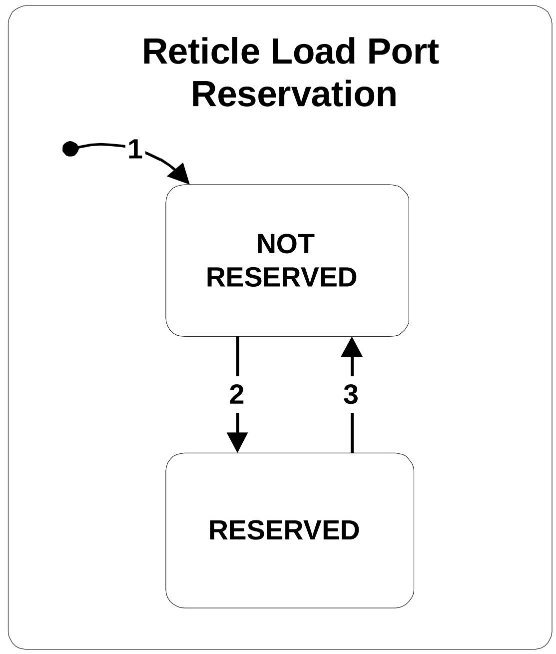


Figure 4
Reticle Load Port Reservation State Model Diagram

12.4 *Reticle Load Port Reservation State Definitions*

12.4.1 *RETICLE LOAD PORT RESERVATION* — The super state of the substates NOT RESERVED and RESERVED.

12.4.2 *NOT RESERVED* — A substate of LOAD PORT RESERVATION, this state is active when there is no reservation existing at the load port.

12.4.3 *RESERVED* — A substate of LOADPORT RESERVATION, this state is active when there is a reservation for future activity at the load port. When in this state, the access mode for a load port may not be changed.

12.5 *Reticle Load Port Reservation State Transition Table*

Table 10 Reticle Load Port Reservation State Transition Table

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	NOT RESERVED		No event report is required for this transition.
2	NOT RESERVED	*Service:* If reserved by service, the host or operator sends a ReserveAtPort, ReticleTransferJob, or a Bind service to the production equipment. *PodOut:* This happens when the equipment physically initiates a PodOut operation.	RESERVED	If the user has configured the equipment to use the reservation visible signal indicator, it is activated for this load port.	Data required to be available for this event report: PortID PodID may be included when a pod out, ReticleTransferJob or a bind service triggers this transition.
3	RESERVED	*Service:* If a reservation is cancelled by service, the host or operator sends a CancelBind, CancelReticleTransferJob, or a CancelReservationAtPort. *Pod arrival:* A pod arrives at the reserved port.	NOT RESERVED	If the user has configured the equipment to use the reservation visible signal, the indicator is deactivated for this load port.	Data required to be available for this event report: PortID

12.6 *Relation of Reservation to Association*

12.6.1 The following figure indicates the relationship of Association to Reservation.

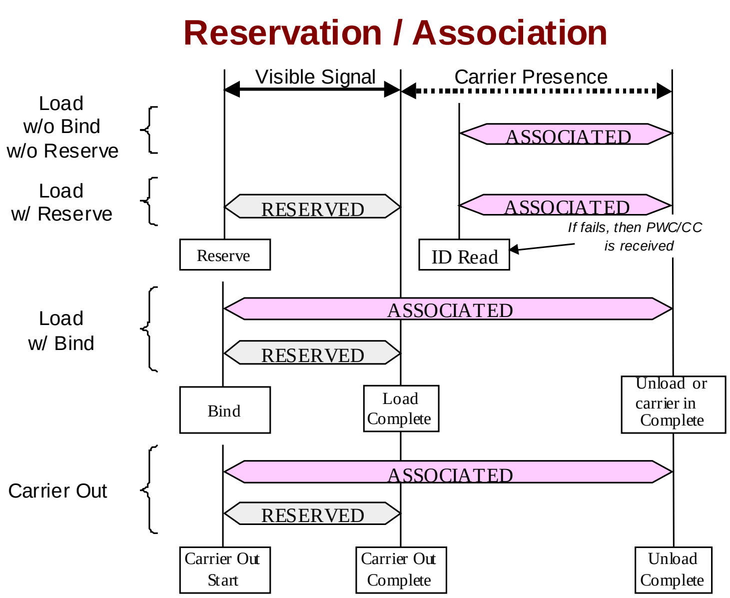


Figure 5
Relation of Reservation to Association

13 Reticle Pod Load Port/Pod Association State Model

13.1 The purpose of the Reticle Pod Association State Model is to define the host view of pod to reticle load port association of the production equipment, as well as the host interactions with the production equipment necessary to associate a reticle pod to a reticle load port, and to perform equipment based pod verification. Each reticle load port shall maintain an independent instance of the Pod Association State Model. Each instance of this state model must not influence the state of the same state model for a different reticle load port.

13.1.1 This state model provides the ability to perform PodID verification with two different methods. If the PodID is provided before the equipment reads the PodID, the PodID that becomes associated with the reticle load port can be used later for equipment based pod verification. If the association happens by PodID read (not by a service execution), then the production equipment shall report the PodID information in a data collection event.

13.2 *Reticle Pod Load Port/Pod Association State Model Diagram*

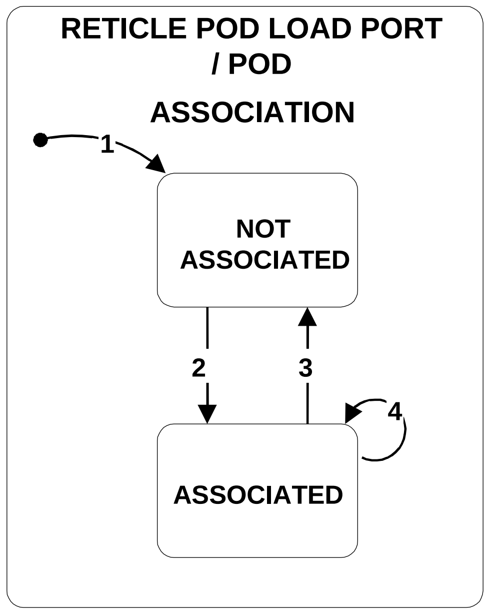


Figure 6
Reticle Pod Load Port/Pod Association State Model Diagram

13.2.1 *Reticle Pod Load Port/Pod Association State Definitions*

13.2.1.1 *RETICLE POD LOAD PORT/POD ASSOCIATION* — The parent state of the NOT ASSOCIATED and ASSOCIATED sub-states.

13.2.1.2 *NOT ASSOCIATED* — A sub-state of RETICLE POD LOAD PORT/POD ASSOCIATION. There is no pod association present for this load port.

13.2.1.3 *ASSOCIATED* — A sub-state of RETICLE POD LOAD PORT/POD ASSOCIATION. A PodID has been associated with this reticle load port. The reticle pod load port is not available for a new pod association.

13.2.2 *Reticle Pod Load Port/Pod Association State Transition Table*

13.2.2.1 Table 11 defines the transitions of the Reticle Pod Load Port/Pod Association State Model.

Table 11 Reticle Pod Load Port/Pod Association State Transition Definitions

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	NOT ASSOCIATED		No pod associations exist for reset/re-initialized equipment. Data required to be available for this event report: PortID
2	NOT ASSOCIATED	*Service:* If associated by service, the host sends a Bind or ReticleTransferJob service to the production equipment. *PodID Read:* If associated by a PodID read, the production equipment creates the association at the time the PodID read is performed.	ASSOCIATED	The association visible signal indicator is activated for this reticle pod load port.	If the Bind or ReticleTransferJob service is performed before the PodID is read by the production equipment, the production equipment can perform the PodID verification. Once the PodID to reticle pod load port association is complete, the reticle pod load port is not available for association until the state returns to NOT ASSOCIATED again. Data required to be available for this event report: PortID PodID
3	ASSOCIATED	*Service:* If an association cancellation is desired, this can be done by the host sending a CancelBind or CancelReticleTransfer-Job service to the production equipment. *Reticle Pod Unload:* An association cancellation may also be performed by removing the reticle pod from the reticle pod load port.	NOT ASSOCIATED	The association visible signal indicator is deactivated for this reticle pod load port.	A reticle pod unload may happen before or after processing occurs. The reticle pod load port is available for another association. Data required to be available for this event report: PortID
4	ASSOCIATED	Production equipment based pod verification fails, and the pod assumes the ID value from the reticle pod that is on the reticle pod load port.	ASSOCIATED	The existing PodID that was associated by a Bind or ReticleTransferJob service is unassociated by the production equipment and the new PodID is now associated to the Reticle Pod Load Port. The production equipment shall delay further action until receiving either a CancelPod or a ProceedWithPod command from the host.	This transition only occurs when the Bind or ReticleTransferJob command has been used. Data required to be available for this event report: PortID PodID

14 Reticle Object

14.1 Information about a reticle is encapsulated as an object. This allows the host to exchange information with the equipment about one or more specific reticle using services defined in SEMI E39, Object Services Standard. A reticle has properties (attributes) that are defined in Table 12, Reticle Attribute Definition.

14.2 *Object Instantiation*

14.2.1 The reticle object is a software representation of the reticle in the equipment. Under normal circumstances this object is instantiated by the equipment when the host uses the Bind, ReticleTransferJob, PodNotification, ProceedWithPod service (when it included the content map attribute), MoveReticle service, when the equipment successfully reads the ReticleID from the reticle pod tag, or when the equipment successfully reads the ReticleID from the reticle itself. A reticle is instantiated by reticle pod tag read or ReticleID read only if there are no currently existing objects with the ReticleID just read. A reticle object can also be instantiated by either the ProceedWithPod or CancelPod Services when these services contain the content map. A Reticle can be instantiated by the MoveReticle Service if the ReticleID(s) provided by the service have not been previously instantiated.

14.2.2 From the host point of view, an object is instantiated if the host is able to query the equipment about that object, it' s current state, and other attributes. Once instantiated, the object is considered destroyed (no longer instantiated) if the response to such queries is “unknown object”.

14.2.3 Summary of possible reticle object instantiation methods:

1. Bind, ReticleTransferJob, or PodNotification Service that contains the content map attribute;
2. PodID tag read containing the content map with no currently existing reticle objects having the ReticleID just read from the pod tag;
3. ReticleID read with no currently existing reticle objects having the ReticleID just read from the ReticleID read;
4. ProceedWithPod or CancelPod Service containing the content map attribute;
5. MoveReticle Service when the reticle is not previously instantiated.

14.2.4 *Reticle Object Identifier (ObjID)*

14.2.4.1 The purpose of an Object Identifier is to allow references to an object within the system. The object identifier is created when an object is instantiated and should be unchanged or persistent until the end of the object lifecycle. The Object Identifier shall be unique at the equipment during lifecycle of the object. The ReticleID is the Reticle Object Identifier. The equipment is responsible for ensuring uniqueness of the ReticleID prior to instantiation by the bind, PodNotification, ReticleTransferJob, or MoveReticle service.

14.2.5 *Reticle Object Destruction*

14.2.5.1 Normally, the Reticle Pod Object reaches the end of its lifecycle when the reticle pod containing the reticle is unloaded from the equipment. Abnormally, the Reticle Object reaches the end of its lifecycle when a CancelBind, CancelReticleTransferJob, or CancelPodNotification service (if the original Bind, ReticleTransferJob, or PodNotification service contained the contentmap) is executed prior to the reticle pod being loaded, when a CancelMoveReticle service is executed prior to reticle removal from the reticle pod (if the reticle was instantiated using the MoveReticle command), when an equipment based pod verification fails following reticle pod and reticle instantiation by the bind service, ReticleTransferJob, or reticle pod tag read.

14.2.5.2 Summary of reticle object destruction:

1. A reticle pod is unloaded from the equipment;
2. A CancelBind, CancelReticleTransferJob, or CancelPodNotification service that contained the content map is received; and
3. An equipment based verification fails (after the object has been instantiated via the bind, ReticleTransferJob service, or reticle pod tag read).
4. A CancelMoveReticle service is executed prior to reticle removal from the reticle pod (when the content map has not been provided by other service or reticle pod tag read).
5. Manual removal of the physical reticle.

14.3 *Reticle Attribute Definitions*

14.3.1 The following table contains the attributes that are of importance to the host and/or the equipment in order to manage the history and the reports about the reticle object.

14.3.2 *REQD Column*

14.3.2.1 All attributes in the following table are required to be associated with the reticle object. However only the attributes marked with a “Y” in the REQD column are always required to be maintained and updated by the equipment. The attributes marked with an “N” in the REQD column are only required to be maintained if they are provided by the host by either the Bind, PodNotification, ReticleTransferJob, ProceedWithPod, or MoveReticle Services or if the equipment has means of determining the attribute values. (for example, if the equipment has a ReticleID reader, the equipment can determine the ContentMap).

14.3.3 *ACCESS Column*

14.3.3.1 Even though a value may be marked as RO (read only), the initial value for the attribute may be provided by the host when attached to either the Bind, PodNotification, ReticleTransferJob or ProceedWithPod services. The only other time the PodCapacityStatus attributes are updated is at the first ProceedWithPod service.

Table 12 Reticle Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type.	RO	Y	Text equal to “Reticle”
ObjID	Object identifier.	RO	Y	Text 1 to 80 characters equal to the ReticleID.
# of Exposures	Count of the number of exposures since the reticle was loaded to the equipment.	RO	Y	Non negative integer
QualificationInterval-Time	The amount of time (in minutes) allowed between equipment inspections of a reticle. If this time is exceeded, the reticle state must transition to REJECTED.	RO	Y	52
Qualification-TerminationTime	The actual time if when a qualified reticle will expire and the reticle state must transition to rejected.	RO	Y	20
ReticleStatus	Current state of the Reticle.	RO	Y	Enumerated: RETICLE NOT PRESENT, QUALIFIED, IN USE, RETICLE PRESENT, RETICLE QUALIFICATION, REJECTED
ReticleAllocationStatus	The current allocation state of the reticle by the equipment. The current substate of the Allocation state model.	RO	Y	Enumerated: NOT ALLOCATED, ALLOCATED
ReticleLocationID	The specific location of the reticle.	RO	Y	Enumerated: Equipment dependent text Example locations: Inspection position, ReticleID read position, storage location 1.
Reticle type	The type of reticle.	RO	Y	Enumerated: Equipment dependent text Example subtypes: phase shift, binary

14.4 *Reticle State Model*

14.4.1 The purpose of the Reticle State Model is to define the host’s view of a reticle. The equipment shall maintain a separate and independent state model for each reticle pod in/at the equipment.

14.4.2 *Reticle State Model Diagram*

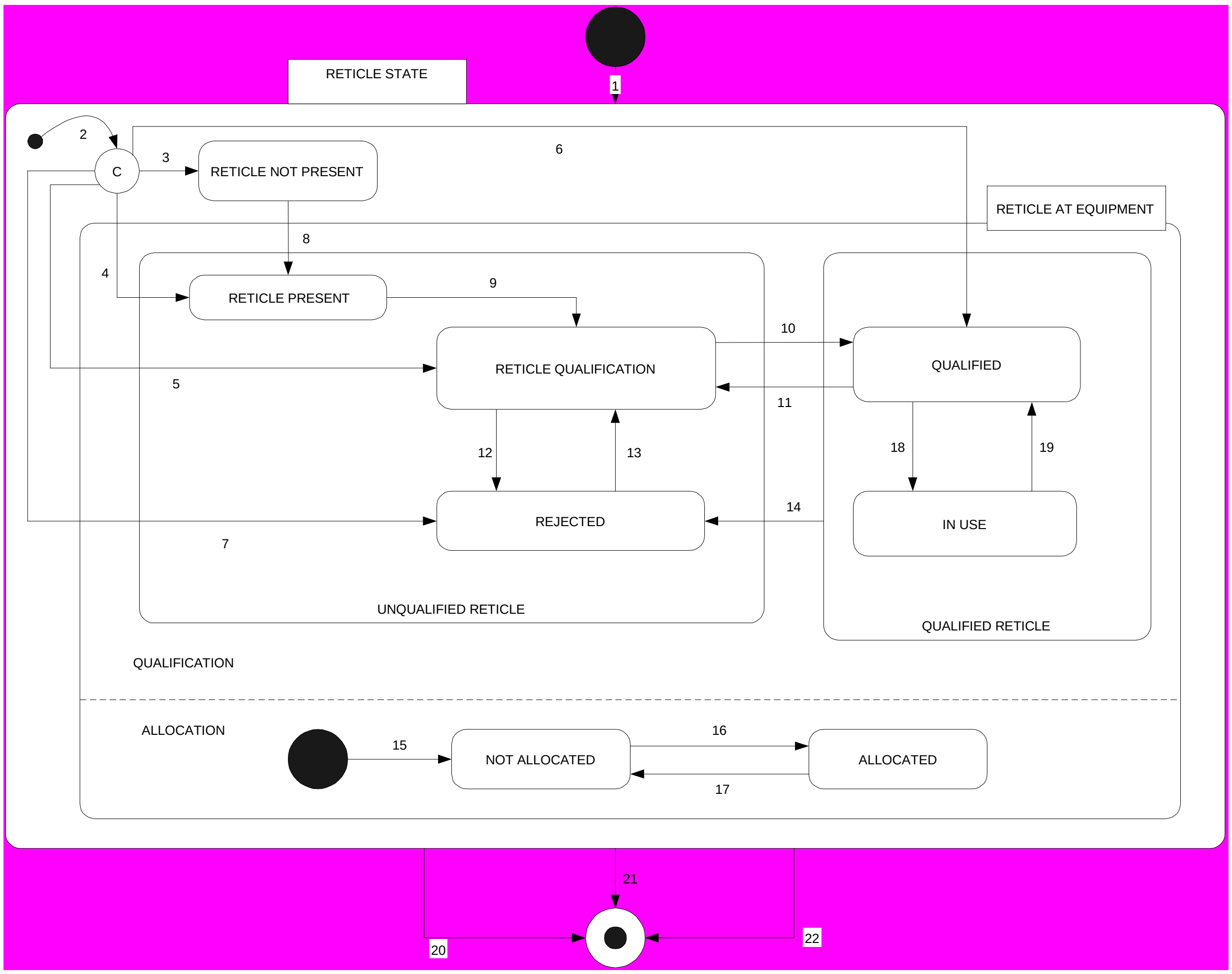


Figure 7
Reticle State Model Diagram

14.4.3 *Reticle State Definition*

14.4.3.1 *RETICLE NOT PRESENT* — This is a subset of RETICLE STATE and is active when the reticle is not present on the Equipment. The reticle has been instantiated with a Bind, PodNotification, ReticleTransferJob, or MoveReticle service.

14.4.3.2 *RETICLE AT EQUIPMENT* — This is a subset of RETICLE STATE and is active when the reticle is present. The reticle is physically present on the Equipment. **There are two ANDed states: Qualification (indicating if the reticle may be used) and Allocation (shows if the reticle is allocated to a lot inside the lot queue) .** There is very little relation between the ANDed state.

14.4.3.2.1 *QUALIFICATION* — This is a substate of the RETICLE AT EQUIPMENT and is active when the reticle is physically present. There are two substates UNQUALIFIED RETICLE and QUALIFIED RETICLE.

14.4.3.2.1.1 *UNQUALIFIED RETICLE* — This is a substate of QUALIFICATION and is active when the reticle is physically present but not QUALIFIED. There are three substates, RECTICLE PRESENT, RETICLE QUALIFICATION, AND REJECTED.

14.4.3.2.1.1.1 *RECTICLE PRESENT* — This is a substate of UNQUALIFED RETICLE and is active when the reticle is waiting to be selected for qualification. The physical ReticleID is not read in this state

14.4.3.2.1.1.2 *REJECTED* — This is a substate of UNQUALIFIED RETICLE and is active when the reticle did not pass the qualification(s) due to an unexpected ReticleID or poor inspection results. The operator or the host (depending on the control mode) will have to decide if the reticle must be re-qualified or removed from the equipment.

14.4.3.2.1.1.3 *RETICLE QUALIFICATION* — This is a substate of UNQUALIFIED RETICLE and is active when the reticle is being qualified for production. The ReticleID is being read from the ReticleID and / or a reticle inspection for particles is being performed.

14.4.3.2.1.2 *QUALIFIED RETICLE* — This is a substate of QUALIFICATON and is active when the reticle may be used for production. It has two substates QUALIFIED and IN USE.

14.4.3.2.1.2.1 *IN USE* — This is a substate of QUALIFIED RETICLE and is active when any kind of processing on the reticle is being done (i.e. the reticle is not at an inventory position).

14.4.3.2.1.2.2 *QUALIFIED* — This is a substate of QUALIFIED RETICLE and is active when the reticle is at an inventory position, including either the internal reticle buffer or a reticle pod.

14.4.3.2.2 *ALLOCATION* — This is a substate of RETICLE AT EQUIPMENT, and is active when the reticle is physically present.

14.4.3.2.2.1 *NOTALLOCATED* — This is a substate of ALLOCATION and the reticle is not allocated to a lot in the queue.

14.4.3.2.2.2 *ALLOCATED* — This is a substate of ALLOCATION and the reticle is allocated to one or more lots in the queue.

14.4.4 *Reticle State Transition Table* — Table 13 indicates the triggers and the expected behavior of the instantiated reticle object.

Table 13 Reticle State Transition Definition

#	*Current State*	*Trigger*	*New (Sub-)State*	*Action*	*Comment*
1	-	A reticle is instantiated.	RETICLE NOT PRESENT or RETICLE AT EQUIPMENT	None.	If the reticle is instantiated via the ReticleTransferJob it must be moved from the pod into the internal reticle library according to the ' ReticleTransferJob' instructions.
2	-	*By Service:* A reticle is instantiated via the Bind, PodNotification, or ReticleTransferJob, message in which the content map is provided, or the reticle is instantiated via a MoveReticle service for which the Reticle Pod has not been received by the equipment. *By Reticle Pod Tag Read:* A reticle is instantiated after placing a reticle pod on a load port via a reticle PodID tag read. that provided the content map. *By ReticleID read:* A reticle is instantiated via a ReticleID read.	RETICLE NOT PRESENT or RECTICLE PRESENT or RETICLE QUALIFICA-TION		Data required to be available for this event report: PodID

#	*Current State*	*Trigger*	*New (Sub-)State*	*Action*	*Comment*
3	-	A reticle is instantiated via the Bind, PodNotification, or ReticleTransferJob, message in which the content map is provided, or the reticle is instantiated via a MoveReticle service for which the Reticle Pod has not been received by the equipment.	RETICLE NOT PRESENT		Data required to be available for this event report: PodID
4	-	A reticle is instantiated after placing a reticle pod on a load port via a reticle PodID tag read that provided the content map or via a MoveReticle service for which the Reticle Pod has been received by the equipment.	RECTICLE PRESENT	None.	This transition happens only if the content map has not been provided to the equipment prior to reticle pod load port receiving a reticle pod.
5	-	A reticle is instantiated via a ReticleID read and a particle inspection is still required.	RETICLE QUALIFICA-TION		Data required to be available for this event report: PodID PortID
6	-	A reticle is instantiated via a ReticleID read and no particle inspection is required.	QUALIFIED		Data required to be available for this event report: PodID PortID
7	-	A reticle is instantiated via a read and has been found to be the incorrect ID.	REJECTED		Data required to be available for this event report: PodID PortID
8	RETICLE NOT PRESENT	A Reticle Pod load port receives a previously instantiated reticle pod for which the equipment holds the content map attribute.	RECTICLE PRESENT		
9	RECTICLE PRESENT	The equipment has begun to qualify a previously instantiated reticle.	RETICLE QUALIFICA-TION		
10	RETICLE QUALIFICA-TION	*Equipment based* – Equipment decides based on preset criteria that a reticle is suited for use. *Host based* – The equipment receives the OktoUseReticle Service.	QUALIFIED		Reticle qualification includes both ID verification and quality verification. Reticle is able to be used.
11	QUALIFIED	Host based – The equipment receives a Re-qualify service.	RETICLE QUALIFICA-TION	Start reticle inspection.	
12	RETICLE QUALIFICA-TION	*Equipment based* – Equipment determines that an incorrect reticle has been delivered or that a reticle inspection failed. *Host based* – The equipment receives a RejectReticle service from the host. *Operator based* – An operator issues a RejectReticle command from the equipment operator interface.	REJECTED		Data required to be available for this event report: PodID PortID Reject Reason
13	REJECTED	*Host based* – The equipment receives a Re-qualify service. *Equipment based* – A re-inspection is automatically triggered by the Equipment.	RETICLE QUALIFICA-TION	Start reticle inspection.	

#	*Current State*	*Trigger*	*New (Sub-)State*	*Action*	*Comment*
14	QUALIFIED RETICLE	*Host based* - The equipment receives a RejectReticle service from the host. *Equipment based* -Inspection results of the reticle are expired. *Operator based* – An operator issues a RejectReticle command from the equipment operator interface.	REJECTED		
15	-	A reticle is instantiated.	NOT ALLOCATED		
16	NOT ALLOCATED	*Production Equipment:* The reticle becomes allocated to a pre-processing or processing lot. Inspection Equipment: The reticle becomes allocated to an inspection. Bare Reticle Stockers: The reticle is selected for kitting.	ALLOCATED		
17	ALLOCATED	The last lot allocation to the reticle by a pre-processing or processing lot is removed because this lot has moved to an other state OR the equipment has been restarted.	NOT ALLOCATED		
18	QUALIFIED	*For Exposure Equipment:* An-exposure process has started. *For Reticle Inspection Equipment:* A Reticle Inspection has started. *For Bare Reticle Stockers:* A reticle kitting has started.	IN USE		This transition should take place as soon as the needed physical movement of a reticle for processing or inspection has begun.
19	IN USE	*For Exposure Equipment:* A reticle exposure process has finished. *For Reticle Inspection Equipment:* An inspection process has finished.	QUALIFIED		
20	RETICLE AT EQUIPMENT	Reticle pod containing the reticle is removed from the machine.	-	Delete reticle object.	
21	RETICLE AT EQUIPMENT	Reticle has been manually removed from the equipment.	-	Delete reticle object.	Abnormal situation
22	RETICLE AT EQUIPMENT	*Via service:* Reticle object has been destroyed via a CancelBind, CancelReticleTransferJob, CancelPodNotification, or CancelMoveReticle service from the host prior to the Reticle being physically read. *Via equipment based verification failure:* A reticle instantiated via Bind, ReticleTransferJob, PodNotification, Pod Tag read (for a pod tag that holds the contentmap attribute of the pod) or MoveReticle service failed equipment based verification and the equipment destroys the reticle object.	-	Delete reticle object.	Abnormal situation

15 Verification

15.1 Verification is the operation of comparing an actual value with an expected value. Verification may be performed by either the host or the equipment, depending upon whether the host is using the Bind, ReticleTransferJob, or PodNotification service or not.

15.1.1 If the host provides the expected value before the actual value is obtained by the production equipment, then the production equipment shall perform the verification.

15.1.2 If the host does not provide the expected value before the actual value is read, then the production equipment shall provide to the host, the information necessary for host based verification.

15.1.3 There are three values that are defined by Reticle and Pod Management that require verification: PodID, Pod Slot Map, and ReticleID.

15.2 *PodID Verification*

15.2.1 Table 14 defines the methods for verifying the PodID.

Table 14 PodID Verification Methods

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Reticle Pod Is Loaded*	*Host Actions after Load*
Production Equipment Based	*Bind or ReticleTransferJob Service:* The host executes the Bind or ReticleTransferJob service to associate a reticle pod load port and a PodID.	*Bind or ReticleTransferJob Service:* The production equipment reads the PodID from the reticle pod, compares it to the podID supplied with the Bind or ReticleTransferJob service.	
		Verification Passed: Transition 6 of the Reticle Pod State Model occurs. The production equipment proceeds with processing.	*Verification Passed:* None.
		Verification Failed: The equipment initiates Transition 12 of the reticle pod state model then Transition 29 and the reticle pod object created via the bind or ReticleTransferJob service is destroyed. The equipment also initiates Transition 3 of the reticle pod state model and a reticle pod object with the PodID equal to the one determined by the PodID read is instantiated. The reticle pod shall not be opened by the equipment until and unless the ProceedWithPod service is received from the host.	*Verification Failed:* The host uses either the CancelPod service to force the reticle pod to be readied for unload, or indicates to the production equipment that it may proceed with the unexpected reticle pod, by sending the ProceedWithPod service. In both cases the PodID specified in the service is equal to the one determined by the PodID read.
	PodNotification Service: The host executes the PodNotification service to inform the equipment of the future arrival of a pod to an unspecified reticle pod load port.	*PodNotification Service:* The production equipment reads the PodID from the reticle pod, compares it to the PodID supplied with a PodNotification service.	
		Verification Passed: Transition 6 of the Reticle Pod State Model occurs. The production equipment proceeds with processing.	*Verification Passed:* None.

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Reticle Pod Is Loaded*	*Host Actions after Load*
		Verification Failed: Not Applicable; because there is no association between a reticle pod load port and a reticle pod, equipment based verification failure is not possible. If a reticle pod that has not been instantiated arrives at a load port, the equipment shall consider this as host based verification.	*Verification Failed:* Not Applicable, because there is no association between a reticle pod load port and a reticle pod, equipment based verification failed is not possible. If a reticle pod that has not been instantiated arrives at a reticle pod load port, the equipment shall consider this as host based verification." The host will respond with either a ProceedWithPod or a CancelPod Service. (See Host Based verification method).
Host Based	None required, the host may issue a ReserveAtPort service.	The production equipment reads the PodID and reports it to the host in an event report. Following PodID read the equipment initiates Transition 3 of the Reticle Pod State Model and a reticle pod object with the PodID equal to the one determined by the PodID read is instantiated. The reticle pod shall not be opened the equipment until and unless the ProceedWithPod service is received from the host.	*Verification Passed:* The host sends a ProceedWithPod service indicating the verification passed.
			Verification Failed: The host uses the CancelPod or CancelPodAtPort service to force the equipment to prepare the pod for unload.

15.3 *Slot Map Verification*

15.3.1 Table 15 defines the methods for verification of the Reticle Pod Slot Map. Some user's factory operations may not require strict management of the slot map. In this case the user may use the host based verification method.

Table 15 Slot Map Verification Methods

Verification Method Desired	*Host Actions Before Verification*	*Equipment Action When Pod is Loaded*	*Host Actions After Load*
Production Equipment Based	The host provides a Slot Map with the Bind, PodNotification, ReticleTransfer-Job, or the ProceedWithPod service.	The production equipment checks the reticle pod slot map and compares it to the slot map supplied by the host. Either transition 14, or 15 of the Pod State Model occurs.	*Verification Passed:* None, the production equipment proceeds with the pod. *Verification Failed:* If the host decides to cancel processing, the host issues the CancelPod service. If the host decides to continue processing, the host issues the ProceedWithPod service.
Host Based	None.	The production equipment checks the reticle pod slot map and reports it to the host in an event report. The host has the responsibility for verifying the slot map.	*Verification Passed:* The host sends a ProceedWithPod indicating the verification passed. *Verification Failed:* If the host decides to cancel processing, the host issues the CancelPod service. If the host decides to continue processing, the host issues the ProceedWithPod service.

15.4 *ReticleID Verification*

15.4.1 Table 16 below defines the Optional methods for ReticleID verification.

Table 16 ReticleID Verification Methods

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Reticle Pod Is Loaded*	*Equipment Action when Reticle is removed from cassette*	*Host Actions after Load*
Production Equipment Based	*Bind, PodNotification, ReticleTransferJob, or MoveReticle Service prior to Pod Arrival:* The host executes a Bind, PodNotification or ReticleTransferJob service that includes the ContentMap and the ReticleIDs.	*Bind, PodNotification, ReticleTransferJob Service, or MoveReticle Service prior to Pod Arrival:* Transition 8 of the Reticle State Model Occurs (from RETICLE NOT PRESENT to RETICLE PRESENT (E.Ch). The equipment must verify the ReticleID successfully.	Transition 9 of the Reticle State Model occurs. The ReticleID is read.	
			Verification Passed: The equipment may proceed with reticle qualification.	*Verification Passed:* None.
			Verification Failed: The equipment initiates Transition 12, then Transition 22 of the reticle state model the reticle object created via the service is destroyed. The equipment also initiates Transition 5 (if a particle inspection is required) or Transition 6 (if a particle inspection is not required) of the model and a reticle object with the ReticleID equal to the one determined by the ReticleID read is instantiated (if not currently instantiated)	*Verification Failed:* The host uses either the RejectReticle service to indicate that the equipment should not use the reticle for processing, or indicates to the production equipment that it may proceed with the unexpected reticle, by sending the OKtoUseReticle service. In both cases the ReticleID specified in the service is equal to the one determined by the ReticleID read.
	MoveReticle Service after Pod Arrival prior to reticle instantiation: The host executes a MoveReticle service.	Transition 4 of the Reticle State Model Occurs (from no state to RECTICLE PRESENT).	Transition 9 of the Reticle State Model occurs. The ReticleID is read.	
			Verification Passed: The equipment may proceed with reticle qualification.	*Verification Passed:* None.
			Verification Failed: The equipment initiates Transition 12, then Transition 22 of the reticle state model the reticle object created via the service is destroyed. The equipment also initiates Transition 5 (if a particle inspection is required) or Transition 6 (if a particle inspection is not required) of the reticle state model and a reticle object with the ReticleID	*Verification Failed:* The host uses either the RejectReticle service to indicate that the equipment should not use the reticle for processing, or indicates to the production equipment that it may proceed with the unexpected reticle, by sending the OKtoUseReticle service.

Verification Method Desired	*Host Actions before Load*	*Equipment Action When Reticle Pod Is Loaded*	*Equipment Action when Reticle is removed from cassette*	*Host Actions after Load*
			equal to the one determined by the ReticleID read is instantiated.	In both cases the ReticleID specified in the service is equal to the one determined by the ReticleID read.
	MoveReticle after pod arrival and reticle instantiation via pod tag read: None	Equipment reads the pod tag and instantiates the reticle object via transition 4.	Transition 9 of the Reticle State Model occurs. The ReticleID is read.	
			Verification Passed: The equipment may proceed with reticle qualification.	*Verification Passed:* None.
			Verification Failed: The equipment initiates Transition 12, the Transition 22 of the reticle state model the reticle object created via the service is destroyed. The equipment also initiates Transition 5 (if a particle inspection is required) or Transition 6 (if a particle inspection is not required) of the reticle state model and a reticle object with the ReticleID equal to the one determined by the ReticleID read is instantiated.	*Verification Failed:* The host uses either the RejectReticle service to indicate that the equipment should not use the reticle for processing, or indicates to the production equipment that it may proceed with the unexpected reticle, by sending the OKtoUseReticle service. In both cases the ReticleID specified in the service is equal to the one determined by the ReticleID read.
Host Based	None required, the host may issue a ReserveAtPort service.	The production equipment reads the PodID and reports it to the host in an event report. Following PodID read the equipment initiates Transition 3 of the Reticle Pod State Model and a reticle pod object with the PodID equal to the one determined by the PodID read is instantiated. The reticle pod shall not be opened by the equipment until and unless the ProceedWithPod service is received from the host.	The production equipment reads the ReticleID and reports it to the host in an event report. Following the ReticleID read the equipment initiates Transition 5 (if a particle inspection is required) or Transition 6 (if a particle inspection is not required) of the Reticle State Model and a reticle object determined by the ReticleID read is instantiated.	*Verification Passed:* The host sends a OKtoUseReticle service indicating the verification passed. The equipment may proceed with reticle qualification.
				Verification Failed: The host uses the RejectReticle service to indicate that the equipment should not use the reticle for processing.

15.5 Table 17 clarifies the relation of the reservation and verification to the related services.

Table 17 Reservation and Verification Relation to Service

	Reser-vation	*PodID Verification*	*Cassette SlotMap Verification*	*ReticleID Verification*	*Service Used*	*Information Provided with Service*			
						Port ID	*Pod ID*	*Slot Map*	*Content Map and ReticleID*
1	Yes	Equipment based	Equipment based	Equipment based	Bind, or ReticleTransferJob	Yes	Yes	Yes	Yes
2	Yes	Equipment based	Host based	Host based	Bind,	Yes	Yes	No	No
3	Yes	Host based	Host based	Host based	ReserveAtPort	Yes	No	No	No
					ProceedWithPod (following ID read and host verification)	No	Yes	No	No
4	Yes	Host based	Equipment based	Host based	ReserveAtPort	Yes	No	No	No
					ProceedWithPod to provide slotmap (following ID read and host verification)	No	Yes	Yes	No
5	No	Equipment based	Equipment based	Equipment based	PodNotification	No	Yes	Yes	Yes
6	No	Equipment based	Host based	Host based	PodNotification	No	Yes	No	No
7	No	Host based	Equipment based	Host based	ProceedWithPod to provide slotmap (following ID read and host verification)	No	Yes	Yes	No
8	No	Host based	Host based		ProceedWithPod (following ID read and host verification)	No	Yes	No	

16 Reticle Pod Release Control

16.1 For equipment, where Pod Read/Write technology is used and the Host initiates writing, the reticle pod or reticle cassette must remain at the write position where the tag may be accurately written on until the Host has completed all of its read and write operations. For this purpose, a variable that affects the equipment releasing a pod is defined.

16.2 *Pod Hold Trigger* — Equipment shall allow the user to select a trigger to release the carrier pod when reading/writing is complete. Release does not mean the equipment must move the pod from the location it currently occupies, only that it is permissible to do so.

16.2.1 *Pod Hold Trigger set to Host Release* — If the Pod Hold trigger is set to Host Release, equipment shall hold the pod at the write position until the PodRelease service is received.

16.2.2 *PodHold Trigger set to Equipment Release* — If the Pod Hold trigger is set to Equipment Release, the equipment shall release the reticle pod based on the when the equipment has finished removing all reticles from the pod, finished placing all reticles in the pod, and in the case where the equipment initiates writing until the equipment has finished writing.

16.3 Fixed Buffer Equipment shall allow the user to select a trigger to unclamp the reticle pod based on AMHS arrival at the equipment. If the access mode is MANUAL, the unclamp control trigger has no effect.

16.3.1 *UnclampControl trigger set to* *PODCOMPLETE Triggered Unclamp* — The equipment automatically unclamps the reticle pod when the reticle pod status is COMPLETE.

16.3.2 *UnclampControl trigger set to AMHS Triggered Unclamp* — The equipment behavior depends upon the Reticle Load Port Access State. If the Reticle Pod Load port Access State is AUTO, the reticle pod remains clamped until AMHS has arrived. The AMHS arrives and begins a PIO unload sequence.

17 Reticle Location Object Definition

17.1 A Reticle Location Object (RLO) provides a model for identifying reticle locations. Each RLO on an equipment is assigned a reticle location ID to uniquely identify it. The assignment shall be documented by the equipment supplier. There are two types of substrate locations: reticle pod reticle location, which is the location or position (e.g., slot) in the reticle pod, and equipment reticle location, which is on the equipment resource. The equipment reticle location is a persistent object, while the reticle pod reticle locations are dynamic objects that shall be created or deleted by the placement or removal of reticle pods on the equipment. The intent is to follow E90 in regards to location object management. The reticle location object is a subtype of the substrate location object.

17.1.1 Source reticle locations and Destination reticle locations are the points at which reticles transfer to/from the equipment's internal reticle locations (often locations at which processing occurs). A reticle pod reticle location is the Source or Destination reticle location when a pod is used to transfer the reticle. An equipment reticle location can be the Source or Destination reticle location when the reticle is transferred directly (without a pod).

17.2 *Reticle Location State Model* — Figure below shows the dynamic behavior of the reticle location using the Harel state chart representation.

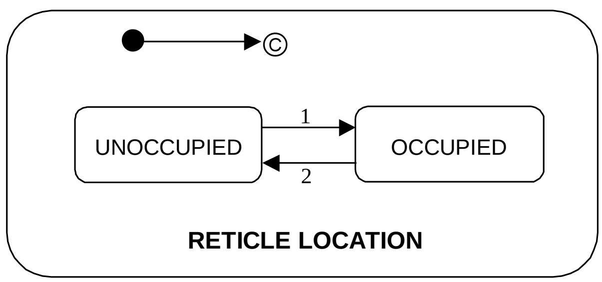


Figure 8
Reticle Location State Model Diagram

17.3 *Reticle Location State Definitions*

17.3.1 *RETICLE LOCATION* — the superstate of UNOCCUPIED and OCCUPIED.

17.3.2 *UNOCCUPIED* — the state in which the reticle location does not hold or have a reticle.

17.3.3 *OCCUPIED* — the state in which the reticle location holds a reticle.

17.4 *Substrate Location State Transition*

Table 18 Reticle Location State Model Transition Table

#	*Current State*	*Trigger*	*New State*	*Action*	*Comment*
1	UNOCCUPIED	Reticle moves onto the substrate location.	OCCUPIED	None.	Data required to be available for this event: ReticleID
2	OCCUPIED	Reticle moves off the location.	UNOCCUPIED	Update reticle tracking history.	Data required to be available for this event: ReticleID

17.5 *Reticle Location Object Attributes*

17.5.1 Table 19 defines attributes for Reticle location objects. These attributes can be accessed by using GetAttr and SetAttr messages as defined in SEMI E39 (OSS).

Table 19 Reticle Location Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqmt*	*Format*
ObjID	Object Identifier	RO	Y	Text equal to the Reticle Location ID
ObjType	Object type	RO	Y	Text = "ReticleLoc"
ReticleID	Reticle IDentifier relevant to the location	RO	Y	Text
ReticleLocation-State	Reticle Location state	RO	Y	Enumerated: UNOCCUPIED OCCUPIED

18 Services

18.1 The purpose of this section is to define the message services required to support Reticle Management functionality.

18.1.1 This message service definition has four parts:

- A service description table.
- A service parameter table.
- A service parameter value table that specifies the type and range of the parameters.
- A service state mapping table that defines the states in which each service is valid.

18.2 *Service Message Description*

18.2.1 There are two types of services:

- An initial message and response between the service user and the service provider.
- A notification message from the service provider to the service user that does not require a response.

18.2.2 The "TYPE" column in the following table is used to indicate whether the service consists of a request/response message pair, "R", or a single notification message, "N".

18.2.3 The "Requirement" level column in the following table is used to indicate whether the service is a fundamental requirement, "F", or an additional capability "A" for RPMS.

Table 20 Service Message Description

Service Name	*Type*	*Requirement level*	*Description*
Bind	R	F	This service shall associate a PodID to a load port and shall cause the load port to transition to the RESERVED state.
CancelAllPodOut	R	A	This service shall cause all PodOut services to be removed from the queue.
CancelBind	R	F	This service cancels a PodID to load port association and shall cause the load port to transition to the NOT RESERVED state.
CancelMoveReticle	R	A	This service cancels a prior MoveReticle service provided that MoveReticle service has not been started.
CancelPod	R	F	This service shall Cancel the current pod related action, and the production equipment shall return the pod to the unload position of the load port, or an internal buffer position, depending on the pod's position in the production equipment.
CancelPodAtPort	R	F	This service shall Cancel the current pod related action, and the production equipment shall return the pod to the unload position of the load port.
CancelPod-Notification	R	F	This service shall cause the equipment to destroy a pod object instantiated through a prior PodNotification.
CancelPodOut	R	A	This service shall cause a specified PodOut service to be removed from the queue by the production equipment.

Service Name	*Type*	*Requirement level*	*Description*
CancelReservation-AtPort	R	F	This service shall cause the equipment to remove the reservation at the specified Port and to deactivate the visible signal.
CancelReticle-TransferJob	R	A	The service cancels a reticle PodID to load port associations and shall cause the load port to transition to the NOT RESERVED state. Also it shall cause the equipment to refrain from removing the reticles from the reticle pod specified in a previous ReticleTransferJob service. Finally it shall cause the equipment to refrain from removing the reticles from the equipment specified in the same previous ReticleTransferJob service.
ChangeAccess	R	F	This service shall change the access mode of the specified Ports at the production equipment. If a load port is dedicated to either Automated delivery or Manual delivery, the access mode cannot be changed.
ChangeServiceStatus	R	F	This service shall change the transfer status of a specified load port at the production equipment.
Clamp	R	A	This service shall cause the equipment to engage any clamping mechanisms that are independent of opening the pod.
ClosePod	R	A	This service shall cause the equipment to close the pod.
IndexDown	R	A	This service shall cause the equipment to index the cassette down when it is safe for equipment, operators, and reticles to do so.
IndexUp	R	A	This service shall cause the equipment to index the cassette up when it is safe for equipment, operators, and reticles to do so.
MoveReticle	R	A	This service shall cause the equipment to move a reticle from one position to another either internal to internal, internal to external, external to internal, or external to external.
OktoUseReticle	R	F	This service shall change the qualification status of the specified reticle to QUALIFIED.
OpenPod	R	A	This service shall cause the equipment to open the pod.
PodComplete	R	F	This service shall change the reticle pod accessing status to COMPLETE.
PodIn	R	A	This service shall cause a pod to be moved from a load port to an internal buffer location. Used in anomaly situations.
PodNotification	R	F	This service shall cause the equipment to instantiate a pod object.
PodOut	R	A	This service shall cause a pod to be moved from the internal buffer to a load port. This service can be queued by the production equipment.
PodRelease	R	A	Release the pod from Pod Hold.
PodTagReadData	R	A	Read data from PodID tag.
PodTagWriteData	R	A	Write data to the PodID tag.
ProceedWithPod	R	F	This service shall instruct the production equipment to proceed with using the specified pod.
RejectReticle	R	F	This service shall cause the equipment to change the qualification state to REJECTED.
Re-qualifyReticle	R	A	This service shall cause the equipment to reinspect the reticle.
ReserveAtPort	R	F	This service shall cause the equipment to reserve the specified Port and activate a visible signal. This service is a possible transfer boundary.
ReticleTransferJob	R	A	This service shall associate a PodID to a load port and shall cause the load port to transition to the RESERVED state. It will also cause the equipment to begin removal, identification, and qualification of specific reticles in the pod as well as placement of specific reticles into the pod upon pod arrival and verification.
SetQualification-IntervalTime	R	A	This service shall set the maximum interval time between reticle inspections.
Unclamp	R	A	This service This service shall cause the equipment to release any clamping mechanisms that prevent removal of the pod. The pod must be closed prior to execution of this service.

18.3 *Service Message Parameter Definition*

18.3.1 The following is a list of required parameters used in conjunction with service messages.

Table 21 Service Message Parameter Definition

Parameter Name	*Form*	*Description*
AccessMode	Enumerated AUTO, MANUAL	The desired access mode of the ports specified.
ArrivingReticleList	Ordered list of ReticleID, ReticlePropertiesList, and removal instructions corresponding to the slot number.	Ordered List of n structures where n is equal to the value of the pod attribute “Capacity,” and each structure consists of a ReticleID, a ReticlePropertiesList, and an enumerated removal instruction. List of structure ReticleID ReticlePropertiesList Enumerated Enumerated: REMOVE PASS BY
AttributeData	Could be several different data types.	The data value associated with AttributeID.
AttributeID	Text 1 to 40 characters	The ID of the object attribute in a PropertiesList.
PodID	Text 1 to 64 characters	ID number of a pod.
Qualification-IntervalTime	U2	The time in minutes allowed between equipment inspections of a reticle.
RPMAcknowledge	Enumerated: • Acknowledge, service has been performed • Service does not exist • Cannot perform now • At least parameter is invalid • Acknowledge, service will be performed with completion notified later with parameters for response • No such object exists	Acknowledgement of request.
RPMStatus	A structure consisting of RPMAcknowledge and Status.	Return information for a service.
Data	Text	User data.
DataSeg	Protocol-specific	Indicates specific section of data to read or write.
DataSize	Unsigned integer	Indicates the number of bytes of data to read or write.

Parameter Name	*Form*	*Description*
DepartingReticle-List	Ordered list of ReticleID and instructions to remove from the equipment and place in the reticle cassette corresponding to the slot number of the cassette to which the reticle will be placed.	Ordered List of n structures where n is equal to the value of the pod attribute "Capacity," and each structure consists of a ReticleID and an enumerated instruction. List of structure ReticleID Enumerated Enumerated: CURRENTLY OCCUPIED PLACE PASS BY When no reticle is targeted to be placed in a slot, the ReticleID should be null. When the enumeration is equal to CURRENTLY OCCUPIED or PASS BY the ReticleID should be null.
DestinationLocation	LocationID	The location for which a reticle is to be moved.

Parameter Name	*Form*	*Description*
ErrorCode	Enumerated: *Valid for all services listed below* Unsupported option [service] requested Command not valid for current state Insufficient parameters specified Parameters improperly specified *Bind* Load port does not exist Object identifier already in use Invalid attribute value Unknown attribute name *CancelAllPodOut* (none) *CancelBind* Load port does not exist Unknown object instance *CancelPod* Load port does not exist Unknown object instance *CancelPodAtPort* Load port does not exist *CancelPodNotification* Unknown object instance *CancelPodOut* Unknown object instance *CancelReservationAtPort* Load port does not exist *PodIn* Unknown object instance *PodNotification* Object identifier already in use Invalid attribute value Unknown attribute name *PodOut* Load port does not exist Unknown object instance *ChangeAccess* Load port does not exist *ChangeServiceStatus* Load port does not exist *ProceedWithPod* Load port does not exist Unknown object instance Invalid attribute value Unknown attribute name *ReserveAtPort* Load port does not exist	Contains the code for the specific error found.
ErrorText	Text	Text in support of the error code.
InputPortID	Integer 0, 101 to 255	ID number of the load port where the Pod will be delivered. The InputPortID number should be the same as the load port number. When the value of the InputPortID = zero, the Pod will be picked up from the internal buffer.

Parameter Name	*Form*	*Description*
OutputPortID	Integer 0, 101 to 255	ID number of a load port where the Pod will be presented for removal. The OutputPortID number should be the same as the load port number. When the value of the OutputPortID = zero, the Pod will be delivered to the internal buffer.
PortID	Integer 1 to n.	ID number of a load port. The PortID number should be the same as the load port number.
PortList	List 1 to n items.	List of n items $PortID_1$ . . n $PortID_n$
PodPropertiesList	List 1 to n name/value pairs.	List of n items 1. $AttributeID_1$ $AttributeData_1$ . . n. $AttributeID_n$ $AttributeData_n$
ReticlePlacement-Instruction	Enumerated: 0=PLACE 1=PASS BY 2=CURRENTLY OCCUPIED	The instructions for placing reticles in pod slot.
ReticleProperties-List	List 1 to n name/value pairs.	List of n items 1. $AttributeID_1$ $AttributeData_1$ . . n. $AttributeID_n$ $AttributeData_n$
ReticleLocation-PropertiesList	List 1 to n name/value pairs.	List of n items 1. $AttributeID_1$ $AttributeData_1$ . . n. $AttributeID_n$ $AttributeData_n$
ReticleRemoval-Instruction	Enumerated: 0=REMOVE 1=PASS BY	The instructions for removing reticles from a pod slot.
ServiceStatus	Enumerated: IN SERVICE, or OUT OF SERVICE.	The desired transfer service status of the specified list of load ports.
SourceLocation	LocationID	The source location from which to move a reticle.
Status	A list of ErrorCode/ErrorText pairs.	Reports any errors found.

18.4 *Fundamental Service Message Definitions*

18.4.1 The following tables specify the allowable/required parameters for each service. The column marked "REQ/OPT", specifies which parameters are required to be supported for RPMS compliance ("R"=Required, "O"=Optional).

18.4.2 *Bind*

18.4.2.1 The Bind service is used to associate a PodID with a load port. The Bind can contain a PropertiesList of pod object attributes that are supplied by the host. A pod object is instantiated when this service is used successfully. The Bind service will be rejected if the pod specified has already been instantiated through the Bind or

PodNotification service, or a PodID read. The Bind service also triggers a transition in the Load Port Reservation state model from NOT RESERVED to RESERVED.

Table 22 Bind Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The PortID where a pod is expected.
PodID	M	—	The expected PodID.
PodPropertiesList	C	—	A list of name value pairs providing attributes for the pod object being instantiated with the Bind service.
CMStatus	—	M	Information concerning the result of the service.

18.4.3 *CancelBind*

18.4.3.1 The CancelBind request is used to cancel the association between a port and a PodID. The pod object is destroyed when this service is used successfully. The CancelBind service also triggers a transition in the Load Port Reservation state model from RESERVED to NOT RESERVED.

Table 23 CancelBind Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	C	—	The PortID for which to cancel the load port to pod association. Either PortID or PodID must be specified.
PodID	C	—	The PodID for which to cancel the load port to pod association. Either PortID or PodID must be specified.
CMStatus	—	M	Information concerning the result of the service.

18.4.4 *CancelPod*

18.4.4.1 The CancelPod request is used to stop a reticle pod. If the reticle pod is at a reticle pod load port, then it shall be made ready for unload. The production equipment shall reject this service if issued after reticles have been removed for processing.

Table 24 CancelPod Service Parameters

Parameter Name	*Req/Opt*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID to cancel.
CMStatus	—	M	Information concerning the result of the service.
PortID	C	—	The PortID where the pod object is located. This parameter is not required if the pod object has been previously instantiated.

18.4.5 *CancelPodAtPort*

18.4.5.1 CancelPodAtPort is used to abort any pod at a designated port. This service can be used when the podID of the pod at the designated port is unknown.

Table 25 CancelPodAtPort Service Parameters

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	Any pod that exists on the load port specified shall be made ready for unloading.
CMStatus	—	M	Information concerning the result of the service.

18.4.6 *CancelPodNotification*

18.4.6.1 The CancelPodNotification is used by the host to request the equipment cancel a previous PodNotification service. This service shall cause the equipment to destroy the pod object specified.

Table 26 CancelPodNotification Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID of the pod object to destroy.
CMStatus	—	M	Information concerning the result of the service.

18.4.7 *ChangeAccess*

18.4.7.1 The ChangeAccess message requests a change of access mode for the load ports specified in the PortList.

Table 27 ChangeAccess Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
AccessMode	M	—	The new desired access mode.
PortID	M	—	The port to use the new access mode.
CMStatus	—	M	Information concerning the result of the service.

18.4.8 *ChangeServiceStatus*

18.4.8.1 The ChangeServiceStatus service is used to request the production equipment change a load port service state.

Table 28 ChangeServiceStatus Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	PortID to designate the new service status.
ServiceStatus	M	—	The new service state.
CMStatus	—	M	Information concerning the result of the service.

18.4.9 *OktoUseReticle*

18.4.9.1 The OktoUseReticle service is sent by the host to indicate that the reticle may be used for processing. The equipment should change the reticle state model qualification status to QUALIFIED.

Table 29 OktoUseReticle Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
ReticleID	M	—	ReticleID to designate the new qualification status.
RPMStatus	—	M	Information concerning the result of the service.

18.4.10 *PodComplete*

18.4.10.1 The PodComplete service is used by the host to inform the equipment that all actions for transferring reticles in and out of the pod are complete. This service is used when the equipment has not previously received a ReticleTransferJob service for the pod.

Table 30 PodComplete Parameters

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID of the Pod that is complete.
PortID	C	—	The Port ID the Pod currently occupies.
CMStatus	—	M	Information concerning the result of the service.

18.4.11 *PodNotification*

18.4.11.1 The PodNotification service is used by the host to inform the equipment that a Pod with the ID specified will be arriving at the equipment. The load port is not specified; therefore no pod to load port association takes place. A pod object with the ObjID equal to the PodID specified in the service is instantiated. The PodNotification service will be rejected if the pod specified has already been instantiated through the Bind or PodNotification service, or a PodID read.

Table 31 PodNotification Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID of the pod object to instantiate.
PodPropertiesList	C		The PropertiesList of the pod to instantiate.
CMStatus	—	M	Information concerning the result of the service.

18.4.12 *ProceedWithPod*

18.4.12.1 The ProceedWithPod service is sent by the host to indicate that the pod operations may continue. When using host based verification it is used by the host to indicate to the production equipment that the verification of PodID and/or the Cassette Slot Map is correct. For successful production equipment based verification the production equipment shall not require this message before proceeding with the pod. For failed production equipment based verification the production equipment shall require either a CancelPod or ProceedWithPod service.

18.4.12.2 Using Table 30, for the Host based PodID verification case, the ProceedWithPod service sent by the host after the first PodID read is referred to as ProceedWithPod #1, the ProceedWithPod service sent after slot map read is referred to as ProceedWithPod #2.

Table 32 ProceedWithPod Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	C	—	The PortID for which processing may proceed.
PodID	M	—	The PodID for which processing may proceed.
PodPropertiesList	C	—	A list of name value pairs providing attributes for the pod object.
CMStatus	—	M	Information concerning the result of the service.

18.4.13 *RejectReticle*

18.4.13.1 The RejectReticle service is sent by the host to indicate that the reticle may no longer be used for processing, unless it is requalified. The equipment shall change the reticle state model qualification status to REJECTED.

Table 33 RejectReticle Service Parameter Definition

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
ReticleID	M	—	ReticleID to be removed.
RPMStatus	—	M	Information concerning the result of the service.

18.4.14 *SetQualificationIntervalTime*

18.4.14.1 The SetQualifiactionIntervalTime service is sent by the host to change the time between inspection for a specific or a list of specific reticles. This service uses SETATTR as defined in SEMI E39.

Table 34 SetQualificationIntervalTime Service Parameter Definition

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
ReticleID	M	M	The reticleID for which to change the time between reticle inspections.
Qualification-IntervalTime	M	M	The time in minutes allowed between equipment inspections of the reticle.

18.5 *Additional Service Message Definitions*

18.5.1 *CancelAllPodOut*

18.5.1.1 The CancelAllPodOut service is sent to internal buffer production equipment to cancel all PodOut services in queue.

Table 35 CancelAllPodOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
CMStatus	—	M	Information concerning the result of the service.

18.5.2 *CancelMoveReticle*

18.4.4.1 The CancelMoveReticle service is sent by the host to cancel a MoveReticle service. The equipment shall refrain from removing the reticle specified. This shall apply on if the move has not been started.

Table 36 CancelMoveReticle

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
ReticleID	M	—	The ReticleID which should not be removed.
RPMStatus	—	M	Information concerning the result of the service.

18.5.3 *CancelPodOut*

18.5.3.1 The CancelPodOut service is sent to internal buffer production equipment to cancel a queued PodOut.

Table 37 CancelPodOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	PodID for the PodOut service that is being cancelled.
CMStatus	—	M	Information concerning the result of the service.

18.5.4 *CancelReservationAtPort*

18.5.4.1 The CancelReservationAtPort service is sent by the host to cancel a reservation at the load port. The load port will enter the UNRESERVED State after receiving this service. A Port reserved by the physical initiation of a pod out operation may not be cancelled by this service.

Table 38 CancelReservationAtPort Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The Port ID to reserve.
CMStatus	—	M	Information concerning the result of the service.

18.5.5 *CancelReticleTransferJob*

18.5.5.1 The CancelReticleTransferJob is sent by the host to cancel a previous ReticleTransferJob service.

Table 39 CancelReticleTransferJob Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID of the pod for which to cancel the load port to pod association.
PortID	M	—	The Port ID for which to cancel the load port to pod association.
RPMStatus	—	M	Information concerning the result of the service.

18.5.6 *Clamp*

18.5.6.1 The Clamp service is used by the host if the equipment has separate mechanisms for clamping the carrier that are independent of opening the carrier. It is used to instruct equipment to engage the independent clamping mechanism. It is used by the host when “macro” instructions such as provided by Bind, PodNotification, ProceedWithPod and ReticleTransferJob have not been provided.

Table 40 Clamp Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	C	—	The PodID of the pod to clamp. Either the PodID or the PortID must be specified.
PortID	C	—	The PortID for which to clamp a carrier. Either the PodID or the PortID must be specified.
CMStatus	—	M	Information concerning the result of the service.

18.5.7 *Close Pod*

18.5.7.1 The ClosePod service is used by the host to request the equipment close a pod.

Table 41 ClosePod Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	C	-	The PortID where a pod is to be closed. Either PortID or PodID must be specified.
PodID	C	-	The PodID for which the door should be closed. Either PortID or PodID must be specified.
CMStatus	—	M	Information concerning the result of the service.

18.5.8 *IndexDown*

18.5.8.1 The IndexDown service is sent by the host to indicate that the equipment should index the reticle cassette to the position where reticle may be removed from the cassette when it is safe for equipment, personnel, and reticles to do so.

Table 42 IndexDown Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	PortID to designate the new service status.
PodID	C	—	The ID of the pod to index down.
CMStatus	—	M	Information concerning the result of the service.

18.5.9 *IndexUp*

18.5.9.1 The IndexUp service is sent by the host to indicate that the equipment should index the reticle cassette to the position where the reticle pod may be removed from the equipment when it is safe for equipment, personnel, and reticles to do so. This service is optional.

Table 43 IndexUp Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	PortID to designate the new service status.
PodID	C	—	The ID of the pod to index up.
CMStatus	—	M	Information concerning the result of the service.

18.5.10 *MoveReticle*

18.5.9.1 The MoveReticle service is used to move reticles from one reticle location to another. This can include moving a reticle from a reticle pod location (external to a tool) to an internal reticle library, ReticleID read location, process location, or a different reticle pod location or from an internal location to another internal location or to a reticle pod location.

Table 44 MoveReticle Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	PortID to designate the new service status.
ReticleID	C	—	The ID of the Reticle to move, either the ReticleID or the SourceLocation must be used.
SourceLocation	C	—	The ReticleLocationID of the location from which to move the reticle, either the SourceLocation or the ReticleID must be used.
Destination-Location	M	—	The ReticleLocationID of the location to which the reticle shall move.
CMStatus	—	M	Information concerning the result of the service.

18.5.11 *OpenPod*

18.5.11.1 The OpenPod service is used by the host to request the equipment open a pod

Table 45 OpenPod Service Parameter Definitions

Paramter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	C	-	The PortID where a pod is to be opened. Either PortID or PodID must be specified.
PodID	C	-	The PodID for which the door should be opened. Either PortID or PodID must be specified.
CMStatus	—	M	Information concerning the result of the service.

18.5.12 *PodIn*

18.5.12.1 The PodIn service is only used to request the internal buffer equipment internalize a carrier that has been moved to the load port via a previous PodOut service. When using host based verification, the production equipment shall move the pod in to the internal buffer for the first time after receiving the ProceedWithPod request. If the PodIn service is received by the production equipment without previously having received a PodOut service for the carrier, the service will be refused.

Table 46 PodIn Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The CarrierID for the carrier to internalize.
CMStatus	—	M	Information concerning the result of the service.

18.5.13 *PodOut* — The PodOut service is sent to internal buffer production equipment, to request that the equipment move the specified carrier to a load port, as soon as the carrier is completed. When the CarrierOut service is started, the destination load port state becomes TRANSFER BLOCKED, and the load port's association state becomes ASSOCIATED.

18.5.13.1 *PodOut Queuing*

18.5.13.1.1 This service request can be queued by the production equipment. The production equipment is required to support a queue of n size, where n is equal to the sum of the number of internal buffer locations and the number of internal FIMS ports. The order of the queue is FIFO for each load port. If the load port is not specified in service request, the equipment chooses which load port queue to place the PodOut service. The queued service does not take effect until the current substrate handling action is complete (i.e., filling, emptying of the pod) and the load port is in the NOT ASSOCIATED state. When a PodOut service is queued and the production equipment load port is currently in the TRANSFER BLOCKED state, the production equipment shall keep the load port in the TRANSFER BLOCKED state. Then, after the port is cleared, the PodOut service shall begin.

Table 47 PodOut Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	PodID for the carrier to be moved out.
PortID	C	—	If omitted, the production equipment shall select an appropriate port at the time the pod is ready to be moved.
CMStatus	—	M	Information concerning the result of the service.

18.5.14 *PodRelease*

18.5.14.1 PodRelease request is used to tell the equipment that the pod is ready to be moved away from the read or write position. Equipment shall deny the request if LocationID and PodID are mismatched.

Table 48 PodRelease Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the pod. Either LocationID or PodID must be used.
PodID	C	—	The PodID of the pod. Either LocationID or PodID must be used.
CMStatus	—	M	Information concerning the result of the service.

18.5.15 *PodTagReadData*

18.5.15.1 PodTagReadData is used to request a block of data from the PodID tag. Equipment shall deny the request if LocationID and PodID are mismatched.

Table 49 PodTagReadData Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the pod. Either LocationID or PodID must be used.
PodID	C	—	The PodID of the pod. Either LocationID or PodID must be used.
DataSeg	C	—	Indicates a specific section of data.
DataSize	C	—	Indicates the number of bytes to read.
Data	—	C	Data from the PodID tag. May be NULL if no data exists for the given section.
CMStatus	—	M	Information concerning the result of the service.

18.5.16 *PodTagWriteData*

18.5.16.1 PodTagWriteData is used to request that a block of data be written to the PodID tag. Equipment shall deny the request if LocationID and PodID are mismatched.

Table 50 PodTagWriteData Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
LocationID	C	—	The ID for the location of the pod. Either LocationID or PodID must be used.
PodID	C	—	The PodID of the pod. Either LocationID or PodID must be used.
DataSeg	C	—	Indicates a specific section of data.
DataSize	C	—	Indicates the number of bytes to read.
Data	M	—	Data from the PodID tag. May be NULL if no data exists for the given section.
CMStatus	—	M	Information concerning the result of the service.

18.5.17 *Re-QualifyReticle*

18.5.17.1 The Re-QualifyReticle service is sent by the host to indicate that a reticle should be re-qualified.

Table 51 Re-QualifyReticle Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
ReticleID	M	—	ReticleID to remove from equipment.
CMStatus	—	M	Information concerning the result of the service.

18.5.18 *ReserveAtPort*

18.5.18.1 The ReserveAtPort service is sent by the host to indicate future activity at the load port. This allows for reserving the port but doing host based ID verification. The load port will enter the RESERVED State after receiving this service.

Table 52 ReserveAtPort Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PortID	M	—	The Port ID to reserve.
CMStatus	—	M	Information concerning the result of the service.

18.5.19 *ReticleTransferJob*

18.5.19.1 The ReticleTransferJob service is sent by the host to inform the equipment of the expected arrival of a reticle pod to a reticle pod load port and/or the expected departure of a reticle pod. The equipment should create an association between the reticle pod and reticle load port. The equipment should transition the load port reservation state model to RESERVED. The ReticleTransferJob service is also used by the host to inform the equipment which reticles contained in the reticle pod should be removed and placed in the equipment. Lastly the ReticleTransferJob service is used by the host to inform the equipment which reticles contained in the equipment should be removed from the equipment and placed in the reticle pod. This service is optional.

Table 53 ReticleTransferJob Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	M	—	The PodID of the pod which will delivered to the equipment.
InputPortID	M	—	The Port ID where the pod will be received. If zero: The pod must be picked from the tool's internal buffer (for internal buffer equipment only). Either InputPortID or OutputPortID must be used (both may be specified as well).
OutputPortID	M	—	The Port ID to which the pod will be delivered after having executed all related reticle actions. If zero: The pod will remain in the tool's internal buffer (for internal buffer equipment only). Either InputPortID or OutputPortID must be used (both may be specified as well).
PodPropertiesList	C	—	A list of name value pairs providing attributes for the pod object being instantiated with the ReticleTransferJob service.
ArrivingReticleList	C	—	The list of reticles to remove from the reticle pod and place in the equipment. Either ArrivingReticleList or DepartingReticleList must be used.
DepartingReticleList	C	—	The list of reticle to remove from the equipment and place in the reticle pod. Either ArrivingReticleList or DepartingReticleList must be used.
RPMStatus	—	M	Information concerning the result of the service.

18.5.20 *Unclamp*

18.5.13 The Unclamp service is used by the host if the equipment has separate mechanisms for unclamping the carrier that are independent of opening the carrier. It is used to instruct equipment to disengage the independent clamping mechanism. It is used by the host when “macro” instructions such as provided by Bind, PodNotification, ProceedWithPod and ReticleTransferJob have not been provided by the host.

Table 54 Unclamp Service Parameter Definitions

Parameter Name	*Req/Ind*	*Rsp/Conf*	*Description*
PodID	C	—	The PodID of the pod to unclamp. Either the PodID or the PortID must be specified.
PortID	C	—	The PortID for which to unclamp a carrier. Either the PodID or the PortID must be specified.
CMStatus	—	M	Information concerning the result of the service.

19 Pod Tag Read/Write

19.1 Some technologies allow data to be stored on a PodID tag where it can be subsequently read and/or modified. In one case the equipment can write information to the PodID tag. For example, the equipment will have knowledge of the ReticleID of a reticle placed in a pod. At this time the equipment may write the ReticleID on the PodID tag. In another case, it is the host that specifies when this data is written and read, because the equipment has no knowledge of the contents of the data. The read operations shall be performed only when the pod is at the read position. The write operations shall be performed only when the pod is at the write position.

NOTE 3: The read and write positions may be the same position. The host shall be able to both read and write whenever PodHold switch is set to Host Release and the pod is at the respective read or write position. Once the host has completed all of its read and write operations for that pod, then the host sends the PodRelease request to the equipment. The PodRelease service informs the equipment that pod read or pod write is complete. The PodRelease service has a different purpose from the PodOut service. The intent of the PodOut service request is to move the pod to a load port, while the intent of the PodRelease service request is to inform equipment that it may move the pod away from the read or write position. Therefore, PodOut may also be used with the PodRelease command. If PodHold is Host Release, then the pod shall be kept at the write position until an PodRelease service request is received, regardless of when a PodOut is sent. If PodHold is set to Equipment Release, then the PodRelease request has no effect.

20 Additional Events

20.1 This section identifies data collection events that are not related to State transitions for variable data items. The intent of this section is to ensure certain data is available for specific events that are not related to state transitions, not to define all the additional collection events for RPMS. Also, all state transitions in RPMS state models are required to have associated event reports.

20.2 *Buffer Capacity Changed Event*

20.2.1 An event shall be generated whenever Buffer Capacity changes. This applies to all internal buffers and internal buffer partitions.

20.2.2 Data required to be available for this event report:

- BufferPartitionInfo.

20.3 *Pod Closed Event*

20.3.1 If the pod is equipped with a door, an event shall be generated when a pod door has been closed.

20.3.2 Data required to be available for this event report:

- PodID,
- LocationID, and
- PortID (if valid)

20.4 *Pod Location Change Event*

20.4.1 An event shall be generated whenever a pod has changed location. This applies to both load ports, substrate ports, and internal buffer locations.

20.4.2 Data required to be available for this event report:

- PodID,
- LocationID (new destination location), and
- PodLocationMatrix.

20.5 *Pod Opened Event*

20.5.1 If the pod is equipped with a door, an event shall be generated when a pod door has been opened.

20.5.2 Data required to be available for this event report:

- PodID,
- LocationID and
- PortID (if valid).

20.6 *PodID Read Fail Event*

20.6.1 An event shall be generated when the equipment attempts to read a PodID and fails at a port in the NOT ASSOCIATED STATE.

20.6.2 Data required to be available for this event report:

- PortID

20.7 *ID Reader Unavailable Event*

20.7.1 An event shall be generated whenever an id reader becomes unavailable for any reason. This applies to all load ports.

20.7.2 Data required to be available for this event report:

- Port ID

20.8 *ID Reader Available Event*

20.8.1 An event shall be generated whenever an id reader becomes available. This applies to all load ports.

20.8.2 Data required to be available for this event report:

- Port ID

20.9 *Reticle Usage Warning Limit Event*

20.9.1 An Event shall be generated whenever a reticle is nearing the configurable limits of usage

20.9.2 Data required to be available for this event

- ReticleID

20.10 *ReticleTransferJob Complete Event*

20.10.1 An event shall be generated whenever a ReticleTransferJob completes.

20.10.2 Data required to available for this event:

- PodID

21 Variable Data

21.1 The purpose of this section is to define the list of variable data requirements for RPMS equipment. Values of these variables are available to the host via collection event reports and host status queries. Some of the data items listed are valid for internal buffer production equipment only, and are marked as such.

21.2 *Variable Data Definitions*

21.2.1 The following table defines variable data that shall be provided by the production equipment. Also, for the objects defined by Reticle and Pod Management, the identifier of that object and all of the attributes of that object shall be available for inclusion in event reports associated with that object. Subscripted variables are used either as items within a list or to differentiate data representing different entities. Subscripted variables are always valid.

Table 55 Variable Data Definitions

Variable Name	*Description*	*Type*	*Access*	*Comment*
$AccessMode_i$	The access mode for the i^{th} load port.	Enumerated: MANUAL, AUTO	RO	
AvailPartitionCapacity	The current available buffer capacity for a logical partition inside internal buffer equipment (PartitionCapacity - # of pods in partition).	Positive integer	RO	Only applicable to internal buffer production equipment.
$AvailPartitionCapacity_i$	The AvailPartitionCapacity for the i^{th} PartitionID within the internal buffer.	Positive integer	RO	Only applicable to internal buffer production equipment.
BufferCapacityList	The current PartitionType, AvailPartitionCapacity, and PartitionCapacity for all logical buffer partitions.	List of n groups of items 1. $BufferPartitionInfo_1$ . . n. $BufferPartitionInfo_n$	RO	Only applicable to internal buffer production equipment.
BufferPartitionInfo	The related information for a logical buffer partition.	Structure of 4 items PartitionID PartitionType AvailPartitionCapacity PartitionCapacity	RO	Only applicable to internal buffer production equipment.
$BufferPartitionInfo_i$	The related information for the i^{th} buffer partition.	Structure of 4 items $PartitionID_i$ $PartitionType_i$ $AvailPartitionCapacity_i$ $PartitionCapacity_i$	RO	Only applicable to internal buffer production equipment.
BypassReadID	Enables or disables automatic ID acceptance when the PodID reader is unavailable.	Boolean	RW	If TRUE, the ID provided with Bind is used automatically.
PodID	The ID of the pod.	Text	RO	
$PodID_I$	The PodID at the i^{th} locationID.	Text	RO	
PodLocationMatrix	A list all the pods at/in the equipment. Both internal to the equipment, and on equipment load ports.	List of n pairs of items 1. $LocationID_1$ $PodID_1$ . . n. $LocationID_n$ $PodID_n$	RO	The $PodID_i$ shall be null if there is no pod at the $locationID_i$. If a pod is at $LocationID_i$, but the $PodID_i$ is not known, the value of $PodID_i$ shall be “UNKNOWN”.
LocationID	The ID of a pod location.	Text	RO	Pod locations are any location at/in the production equipment where a pod may rest.
$LocationID_i$	The LocationID of the i^{th} pod location.	Text	RO	Pod locations are any location at/in the production equipment where a pod may rest.
PartitionCapacity	The total PartitionCapacity for a logical internal buffer partition.	Positive integer	RO	Only applicable to internal buffer production equipment.
$PartitionCapacity_i$	The PartitionCapacity for the i^{th} PartitionID of the internal buffer.	Positive integer	RO	Only applicable to internal buffer production equipment.

Variable Name	*Description*	*Type*	*Access*	*Comment*
PartitionID	The ID of a logical internal buffer partition.	Text	RO	Used to identify separate material types in an internal buffer.
$PartitionID_i$	The ID of the i^{th} logical partition of the internal buffer.	Text	RO	Used to identify separate material types in an internal buffer.
PartitionType	The type of a logical partition within an internal buffer.	Text	RO	Only applicable to internal buffer production equipment. Some examples of logical buffer PartitionType are Product, Dummy, Substrate, and Seed.
$PartitionType_i$	The PartitionType corresponding with the i^{th} PartitionID.	Text	RO	Only applicable to internal buffer production equipment. Some examples of logical buffer PartitionType are Product, Dummy, Substrate, and Seed.
PortAssociationState	The association state of a load port.	Enumerated: ASSOCIATED, NOT ASSOCIATED	RO	
$PortAssociationState_i$	The association state of the i^{th} load port.	Enumerated: ASSOCIATED, NOT ASSOCIATED	RO	
PortAssociationState-List	The current association state for all load ports.	A list of n items 1. $PortAssociationState_1$ . . n. $PortAssociationState_n$	RO	This can be used to re-synchronize the host.
PortID	ID of a load port.	Positive integer	RO	
$PortID_I$	ID of the load port where the pod transfer is taking place. One PortID exists for each load port.	Positive integer	RO	
PortStateInfo	The PortAssociationState combined with the PortTransferState.	List of 2 items PortAssociationState PortTransferState	RO	A combination of both port states.
$PortStateInfo_i$	The PortAssociationState combined with the PortTransferState for the i^{th} load port.	List of 2 items $PortAssociationState_i$ $PortTransferState_i$	RO	A combination of both port states.
PortStateInfoList	List of PortStateInfo for all load ports.	List of n items 1. $PortStateInfo_1$ . . n $PortStateInfo_n$	RO	A list of all the port states for all the ports.
PortTransferState	The current transfer state of a load port.	Enumerated: OUT OF SERVICE, TRANSFER BLOCKED, READY TO LOAD, READY TO UNLOAD	RO	Super states are not included, only sub states.
$PortTransferState_i$	The current transfer state of the i^{th} load port.	Enumerated: OUT OF SERVICE, TRANSFER BLOCKED, READY TO LOAD, READY TO UNLOAD	RO	Super states are not included, only sub states.

Variable Name	*Description*	*Type*	*Access*	*Comment*
PortTransferStateList	The current Load Port Transfer State for all load ports.	A list of n items 1. $PortTransferState_1$ . . n. $PortTransferState_n$	RO	This can be used to re-synchronize the host.
Reason	The reason for transition 14, SLOT MAP NOT READ to WAITING FOR HOST.	Enumerated: VERIFICATION NEEDED, VERIFICATION BY EQUIPMENT UNSUCCESSFUL, READ FAIL, IMPROPER WAFER POSITION	RO	Information to aid host in deciding appropriate action.
Reject Reason	The reason a reticle is rejected.	Enumerated: ID Verification failedParticle qualification failed Rejected By Host Rejected By Operator Inspection Results Expired	RO	Information to aid the host in understanding why a reticle is rejected.

22 Alarms

22.1 This section includes specific alarms that are required to be implemented by RPMS compliant equipment.

22.2 *Alarm List Table*

22.2.1 Table 55 is a listing of required alarms for both fixed buffer and internal buffer equipment. This list is only a subset of the pod transfer alarms. There may be more pod transfer related alarms that are not listed here.

Table 56 Alarm List

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
Fixed & Internal Pod Buffer Equipment	PIO Failure	X		X	X	X
	Access Mode Violation	X		X	X	X
	Attempt To Use Out Of Service Load Port	X			X	X
	Pod Presence Error	X		X	X	X
	Pod Placement Error	X		X	X	X
	Pod Open/Close Failure	X			X	X
Fixed and Internal Pod Buffer Equipment	Duplicate PodID	X				X
Fixed & Internal Pod Buffer Equipment	Pod Removal Error	X		X	X	X
Duplicate Reticle ID	A duplicate reticle is detected.	X				X
Pod Pick/Place error	The internal robot that moves the Pods failed to pick or place a pod. Can be triggered if the state of the system after a pick or place is inconsistent (i.e., both robot and pod think they are empty).	X			X	X

Equipment		Danger		Affected		
Configuration	Alarm Text	Potential	Imminent	Operator	Equipment	Material
Reticle Pick/Place error	The internal robot that moves the reticles failed to pick or place a reticle. Can be triggered if the state of the system after a pick or place is inconsistent (i.e. both robot and pod think they are empty).	X			X	X
Automation Error	Automation errors that do not fit other categories have been detected.	X		X	X	X

22.3 *Alarm Usage*

22.3.1 Reticle and Pod Management requires standardization on the alarm codes. Many errors may be mapped to a sinlge "generic" alarm code. In this case, the recovery scenario would be the same but the alarm text shall contain a more descriptive explanation of the error. For example, the Pod Open/Close alarm can be caused by many different opener errors.

22.3.2 This alarm applies to both Fixed and Internal Pod Buffer Equipment.

22.3.3 For any load port Alarm condition, process equipment should not stop processing current jobs.

Table 57 Alarm Information

Alarm Description	*Alarm Code*	*Auto Clear*	*Set trigger*	*Clear Trigger*
PIO Failure	1	NO	E84 error	Manual intervention
Access Mode Violation (unexpected load)	2	NO	Operator places pod on load port with access mode set to auto.	Operator switches to manual Operator removes the pod Operator switches to auto Operator clears alarm at UI
Access Mode Violation (unexpected unload)		NO	Operator takes a pod off load port with access mode set to auto.	Operator clears alarm at UI
Attempt to use out of service load port	3	YES	Pod placed on load port with transfer state set to out-of-service.	Pod is removed
Pod placement/placement error	4	YES	Sensors detect pod is not properly placed at pod opener.	Sensors detect pod is properly placed at pod opener or no pod present
Pod Open/Close error	5	NO	Opener errors while opening or closing.	Manual intervention
Duplicate Pod ID	6	Yes	A duplicate pod is detected.	Methods vary by equipment type
Pod Removal Error	7	NO	Pod removed before the Pod is in the READY TO UNLOAD state.	Operator clears alarm at UI
Duplicate Reticle ID	8	YES	A duplicate reticle is detected.	Methods vary by equipment type
Pod Pick/Place error	9	NO	The internal robot that moves the Pods failed to pick or place a pod. Can be triggered if the state of the system after a pick or place is inconsistent (i.e. both robot and pod think they are empty).	Manual intervention
Reticle Pick / Place error	10	NO	The internal robot that moves the reticles failed to pick or place a reticle. Can be triggered if the state of the system after a pick or place is inconsistent (i.e. both robot and pod think they are empty).	Manual intervention

Alarm Description	Alarm Code	Auto Clear	Set trigger	Clear Trigger
Automation Error	11	NO	Equipment and Alarm dependent, alarms that do not fit other categories.	Manual intervention

22.4 *Duplicate PodID at Production Equipment*

22.4.1 If the equipment receives a pod with a PodID that is the same as that of another pod present at the equipment, the following rules shall apply:

1. The second pod with a PodID shall not be processed.
2. If processing on the first pod with the PodID has not begun, it should not be processed.
3. If processing on the first pod has begun a Duplicate PodID In Process event shall be issued to notify the host.

23 Requirements for Compliance

23.1 Table 56 provides a checklist for RPMS compliance.

Table 58 RPMS Compliance Statement

Fundamental RPMS Requirements	*RPMS Section*	*Implemented*	*RPMS Compliant*
Load Port Numbering	9.2	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Pod Slot Numbering	9.3	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Pod Load Port Transfer State Model	9.5	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Pod Object Implementation	10	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Object Implemenation	14	☐ Yes ☐ No	☐ Yes ☐ No
Reticle State Model	14.4	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Pod Load Port/Pod Association State Model	13	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Location Object Implementation	17	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Location State Model	17.2	☐ Yes ☐ No	☐ Yes ☐ No
PodID Verification Support	15.2	☐ Yes ☐ No	☐ Yes ☐ No
Slot Map Verification Support	15.3	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Verification Support	15.4	☐ Yes ☐ No	☐ Yes ☐ No
Fundamental Services Implementation	18.4	☐ Yes ☐ No	☐ Yes ☐ No
Additional Events Implementation	20	☐ Yes ☐ No	☐ Yes ☐ No
Variable Data Definitions	21.2	☐ Yes ☐ No	☐ Yes ☐ No
Alarms Implementation	22	☐ Yes ☐ No	☐ Yes ☐ No
Additional RPMS Capabilities	*RPMS Section*	*Implemented*	*RPMS Compliant*
Reservation Visible Signal	12.2	☐ Yes ☐ No	☐ Yes ☐ No
Reticle Pod Load Port Reservation State Model	12	☐ Yes ☐ No	☐ Yes ☐ No
ReticleTransferJob	18.5.11	☐ Yes ☐ No	☐ Yes ☐ No
Access Mode State Model	11	☐ Yes ☐ No	☐ Yes ☐ No
Additional Services Implementation	18.5	☐ Yes ☐ No	☐ Yes ☐ No

APPENDIX 1
APPLICATION NOTES

NOTE: The material in this appendix is an official part of SEMI E109 and was approved by full letter ballot procedures on April 30, 2001 by the North American Regional Standards Committee.

A1-1 This is a place holder for the description of when the Alarms can be cleared.

SEMI E109.1-0302
PROVISIONAL SPECIFICATION FOR SEC-II PROTOCOL FOR RETICLE AND POD MANAGEMENT (RPMS)

This specification was technically approved by the Global Information and Control Committee and is the direct responsibility of the North American Information and Control Committee. Current edition approved by the North American Facilities Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002.

1 Purpose

1.1 This document maps the services of SEMI E109 to SECS-II streams and functions. This document also maps the data of SEMI E109 to E5 data definitions

2 Scope

2.1 This is a provisional standard that covers host and equipment communication for equipment that handle reticles. This includes equipment that handle reticles both inside and outside of a reticle pod. The provisional status is required because of the immaturity of implementations of integrated equipment with Automated Material Handling Systems (AMHS) or Automated Reticle Handling Systems (ARHS). Additional specifications may be defined to add further functionality. Also, further exception handling and error recovery scenarios need to be defined.

2.2 This document applies to all implementations of SEMI E109 that use SECS-II message protocol (SEMI E5). Compliance to this standard requires compliance to both SEMI E109 and SEMI E5.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard applies to semiconductor equipment that handles reticles and reticle carriers. This standard is intended to be used for lithography production, bare reticle storage, and reticle inspection equipment. It may or may not be applied to other types of equipment

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E39.1 — SECS-II Protocol for Object Services Standard (OSS)

SEMI E109 — Provisional Specification for Reticle and Pod Management (RPMS)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of the standards.

5 Services Mapping

5.1 This sections shows the specific SECS-II streams and functions that shall be used for SECS-II implementations of the services defined in SEMI E109, as well as the parameter mapping for data attached to services.

5.2 *Services Message Mapping*

5.2.1 Table 1 defines the relationships between SEMI E109 services and SECS-II messages.

Table 1 Service Message Mapping

Service Name	*Stream/Function*	*SECS-II Message Name*
Bind	S3F17/F18	Carrier Action Request/Acknowledge
CancelAllPodOut	S3F33/F34	Cancel All Pod Out Request/Acknowledge
CancelBind	S3F17/F18	Carrier Action Request/Acknowledge
CancelMoveReticle	S14F19/20	Generic Service Request/Acknowledge
CancelPod	S3F17/F18	Carrier Action Request/Acknowledge
CancelPodAtPort	S3F17/F18	Carrier Action Request/Acknowledge
CancelPodNotification	S3F17/F18	Carrier Action Request/Acknowledge
CancelPodOut	S3F17/F18	Carrier Action Request/Acknowledge
CancelReservationAtPort	S3F25/F26	Port Action Request/Acknowledge
CancelReticleTransferJob	S3F35/F36	Carrier Action Request/Acknowledge
ChangeAccess	S3F27/F28	Change Access/Acknowledge
ChangeServiceStatus	S3F25/F26	Port Action Request/Acknowledge
Clamp	S3F17/F18	Carrier Action Request/Acknowledge
ClosePod	S3F17/F18	Carrier Action Request/Acknowledge
IndexDown	S3F17/F18	Carrier Action Request/Acknowledge
IndexUp	S3F17/F18	Carrier Action Request/Acknowledge
MoveReticle	S14F19/F20	Generic Service Request/Acknowledge
OktoUseReticle	S14F19/F20	Generic Service Request/Acknowledge
PodComplete	S3F17/F18	Carrier Action Request/Acknowledge
PodIn	S3F17/F18	Carrier Action Request/Acknowledge
PodNotification	S3F17/F18	Carrier Action Request/Acknowledge
PodOut	S3F17/F18	Carrier Action Request/Acknowledge
PodRelease	S3F17/F18	Carrier Action Request/Acknowledge
PodTagReadData	S3F29/F30	Carrier Tag Write Data Request/Acknowledge
PodTagWriteData	S3F17/F18	Carrier Action Request/Acknowledge
ProceedWithPod	S3F17/F18	Carrier Action Request/Acknowledge
RejectReticle	S14F19/F20	Generic Service Request/Acknowledge
Re-qualifyReticle	S14F19/F20	Generic Service Request/Acknowledge
ReserveAtPort	S3F25/F26	Port Action Request/Acknowledge
ReticleTransferJob	S3F35/F36	Reticle Transfer Job Request/Acknowledge
SetQualificationIntervalTime	S14F3/4	SetAttr Request
Unclamp	S3F17/F18	Carrier Action Request/Acknowledge

5.3 *Services Parameter Mapping*

5.3.1 Table 2 maps the SEMI E109 service parameters to SECS-II Data Items.

NOTE 2: Use of parameters not specified for a given message in SEMI E109 is prohibited. SECS-II data items not used for a given message shall be sent as zero length items.

Table 2 Service Parameters to SECS-II Data Item Mapping

Parameter Name	*Parameter Range*	*SECS-II Data Item*
AccessMode	Enumerated: 0=MANUAL 1=AUTO	PORTACCESS
ArrivingReticleList	List of n structures, where n = capacity Reticle ID ReticleRemovalinstruction ReticlePropertiesList When a slot in a pod contains no reticle, the value for Reticle ID should be null, the ReticleRemovalInstruction$_n$ should be PASS BY, and the ReticlePropertiesList, should be a zero length list.	L,n 1. L,3 1.<RETICLEID$_1$> 2.< RETREMOVEINSTR$_1$> 3. L,m 1. L,2 1. <ATTRID$_{1,1}$> 2. <ATTRDATA$_{1,1}$> : m. L,2 1.<ATTRID$_{1,m}$> 2.<ATTRDATA$_{1,m}$> : n. L,3 1.<RETICLEID$_n$> 2. <RETREMOVEINSTR$_n$> 3. L,m 1. L,2 1. <ATTRID$_{n,1}$> 2. <ATTRDATA$_{n,1}$> : m. L,2 1. <ATTRID$_{n,m}$> 2. <ATTRDATA$_{n,m}$>
CMAcknowledge	Enumerated	CMAACK
CMStatus	Structure	L,2 1.<CAACK> 2.Status
Data	1-80 characters	DATA
DataSeg	1-80 characters	DATASEG
DataSize	0-65,535 (integer)	DATALENGTH

Parameter Name	*Parameter Range*	*SECS-II Data Item*
DepartingReticleList	List of n structures, where n = capacity Reticle ID ReticlePlacementInstruction When a slot in a pod contains no reticle and will not have a reticle placed, the value for Reticle ID should be null and the ReticlePlacmentInstruction$_n$ should be PASS BY.	L,n 1. L,2 1.<RETICLEID$_1$> 2.<RETPLACEINSTR$_1$> : n. L,2 1.<RETICLEID$_n$> 2.<RETPLACEINSTR$_n$>
DestinationLocation	1-80 characters	RPMDESTLOC
ErrorCode	Enumerated	ERRCODE
ErrorText	1-80 characters	ERRTEXT
InputPortID	U1(0, 101 to 255)	INPTN
OutputPortID	U1(0, 101 to 255)	OUTPTN
PodAttributeData	Any	ATTRDATA
PodAttributeID	1 to 40 characters	ATTRID
PodID	1 to 64 characters	PODID
PodPropertiesList	List of AttributeID and AttributeData	L,n 1.L,2 1.<ATTRID$_1$> 2.<ATTRDATA$_1$> : n.L,2 1.<ATTRID$_n$> 2.<ATTRDATA$_n$>
PortID	U1(101 to 255)	PTN
PortList	List of PortID	L,n 1.<PTN$_1$> : n.<PTN$_n$>
ReticleAttributeData	Any	ATTRDATA
ReticleAttributeID	1 to 40 characters	ATTRID
ReticleLocation-AttributeData	Any	ATTRDATA
ReticleLocation-AttributeID	1 to 40 characters	ATTRID
ReticlePlacement-Instruction	Enumerated: 0 = PLACE 1 = PASS BY 2 = CURRENTLY OCCUPIED	RETPLACEINSTR

Parameter Name	*Parameter Range*	*SECS-II Data Item*
ReticleRemoval- Instruction	Enumerated: 0 = REMOVE 1 = PASS BY	RETREMOVEINSTR
ReticleID	1-64 characters	RETICLEID
ReticleLocation- PropertiesList	List of AttributeID and AttributeData	L,n 1.L,2 1.<ATTRID$_1$> 2.<ATTRDATA$_1$> : n.L,2 1.<ATTRID$_n$> 2.<ATTRDATA$_n$>
ReticlePropertiesList	List of AttributeID and AttributeData	L,n 1.L,2 1.<ATTRID$_1$> 2.<ATTRDATA$_1$> : n.L,2 1.< ATTRID$_n$> 2.< ATTRDATA$_n$>
RPMAcknowledge	Enumerated: 0 = Acknowledge, service has been performed 1 = Service does not exist 2 = Cannot perform now 3 =At least parameter is invalid 4 = Acknowledge, service will be performed with completion notified later with parameters for response 5 = Service is not completed or prohibited 6 = no such objects exist 7-63 Reserved	RPMACK
RPMStatus	List of RPMAcknowledge and Status	L,2 1.<RPMACK> 2. L,n 1. L,2 1. <ERRCODE$_1$> 2. <ERRTEXT$_1$> : n. L,2 1. <ERRCODE$_n$> 2. <ERRTEXT$_n$>
ServiceStatus	Enumerated: 0= OUT OF SERVICE 1= IN SERVICE	PORTACTION

Parameter Name	*Parameter Range*	*SECS-II Data Item*
SourceLocation	1-80 characters	RPMSOURLOC
Status	List of n errors	L,n 1.L,2 1.<ERRCODE$_1$> 2.<ERRTEXT$_1$> : n.L,2 1.<ERRCODE$_n$> 2.<ERRTEXT$_n$>

5.4 *Object Service Parameter Mapping*

5.4.1 Table 3 maps the SEMI E109 service parameters that use S14F19 to SECS-II Data Items

Table 3 Object Service Parameters for SECS-II

Parameter Name	*Format*	*SECS-II Data Item*	*SECS-II Format*
ObjectAction	“CancelMoveReticle” “MoveReticle” “OktoUseReticle” “RejectReticle” “Re-qualifyReticle”	SVCNAME	20
RPMAcknowledge	Enumerated	SVCACK	51
ServiceParameter	One or more arguments (parameters) providing additional information concerning the action requested. Structure composed of ServiceParameterName and ServiceParameterValue	L,2 1.SPNAME 2.SPVAL	
ServiceParameterName	" ReticleID" " PortID" " DestinationLocation" " SourceLocation" " QualificationIntervalTime" “Status”	SPNAME	20
ServiceParameterValue	Depends on parameter used	SPVAL	10, 20, 51, 52
Status	One or more arguments (parameters) providing information concerning the result of the action requested. Structure composed of ErrorText and ErrorCode.	L,2 1.SPNAME 2.SPVAL	
ErrorCode	Enumerated	SPNAME	51
ErrorText	Text	SPVAL	20

5.5 *SECS-II Data Items without Corresponding E109 Parameters*

5.5.1 Table 4 contains the SECS-II data items that do not correspond to SEMI E109 service parameters.

Table 4 Additional Data Item Requirements Table

Function	*SECS-II Data Item*
Used by S3,F17 to differentiate between “Bind”, “CancelPod”, “CancelPodNotification”, “CancelPodOut”, “CancelPodAtPort”, “CancelBind”, “Clamp”, “ClosePod”, “IndexDown”, “IndexUp”, “PodComplete”, “PodIn”, “PodNotification”, “PodOut”, “PodRelease”, “PodTagReadData”, “PodTagWriteData”, “ProceedWithPod”, and “Unclamp” services.	CARRIERACTION
Used to satisfy SECS-II conventions for linking a multi-block inquiry with a subsequent multi-block message. Neither required nor specified by RPMS.	DATAID
Used to inform receiver of total message length size for SECS-II multi-block conventions. Neither required nor specified by SEMI E109.	DATALENGTH
Used to satisfy SECS-II multi-block requirements. Neither required nor specified by SEMI E109**.**	GRANT
Used by S3F25 to differentiate between port related ChangeServiceStatus, CancelReservationatPort and ReserveatPort services.	PORTACTION
Used by S3F27 to specify desired Access mode.	ACCESSMODE

6 Variable Data Item Mapping

6.1 This sections shows the specific SECS-II data classes, and formats needed for the SECS-II implementation of SEMI E109 data items.

Table 5 Variable Data Item Mapping Table

Variable Name	*Class*	*Format*
Access Mode	DVVAL	51 (U1)
Access Mode$_i$	SV	51 (U1)
AvailPartitionCapacity	DVVAL	51 (U1)
AvailPartitionCapacity$_i$	SV	51 (U1)
BufferCapacityList	SV	L,n 1.<BufferPartitionInfo$_i$> . . n.<BufferPartitionInfo$_i$>
BufferPartitionInfo	DVVAL	L,4 1.<PartitionID> 2.<PartitionType> 3.<AvailPartionCapacity> 4.<PartitionCapacity>

Variable Name	*Class*	*Format*
BufferPartitionInfo$_i$	SV	L,4 1.<PartitionID$_i$> 2.<PartitionType$_i$> 3.<AvailPartionCapacity$_i$> 4.<PartitionCapacity$_i$>
BypassReadID	DVVAL	11 (BOOLEAN)
PodID	DVVAL	20 (A[1-64])
PodID$_i$	SV	20 (A[1-64])
PodLocationMatrix	SV	L,n 1.L,2 1.<LocationID$_1$> 2.<PodID$_1$> . . n.L,2 1.<LocationID$_n$> 2.<PodID$_n$>
LocationID	DVVAL	20 (A[1-64])
LocationID$_i$	SV	20 (A[1-64])
PartitionCapacity	DVVAL	51 (U1)
PartitionCapacity$_i$	SV	51 (U1)
PartitionID	DVVAL	20 (A[1-64])
PartitionID$_i$	SV	20 (A[1-64])
PartitionType	DVVAL	20 (A[1-64])
PartitionType$_i$	SV	20 (A[1-64])
PortAssociationState	DVVAL	51 (U1)
PortAssociationState$_i$	SV	51 (U1)
PortAssociationStateList	SV	L,n 1.<PortAssociationState$_i$> . . n <PortAssociationState$_n$>
PortID	DVVAL	51 (U1)
PortID$_i$	SV	51 (U1)
PortStateInfo	DVVAL	L,2 1.<PortAssociationState> 2. <PortTransferState>

Variable Name	*Class*	*Format*
$PortStateInfo_i$	SV	L,2 1.<$PortAssociationState_i$> 2. <$PortTransferState_i$>
PortStateInfolist	SV	L,n 1.<$PortStateInfo_1$> . . n.<$PortStateInfo_n$>
PortTransferState	DVVAL	51 (U1)
$PortTransferState_i$	SV	51 (U1)
PortTransferStateList	SV	L,n 1.<$PortTransferState_1$> . . n.<$PortTransferState_n$>
Reason	DVVAL	51 (U1)

SEMI E116-0702
PROVISIONAL SPECIFICATION FOR EQUIPMENT PERFORMANCE TRACKING

This specification was technically approved by the Global Information & Control Committee and is the direct responsibility of the North American Information & Control Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002.

1 Purpose

1.1 This document provides specification for implementing basic equipment performance tracking for production equipment. Provisions in this document enable the host computer to track basic equipment performance in an automated and consistent matter, without operator or host input. This document provides specification for equipment suppliers to:

- Track basic equipment states (no operator or host input required).
- Track basic equipment states in a modular manner, for both major modules and the overall equipment.
- Report basic equipment state changes to a host computer, at both module and equipment level.
- Report equipment's time in state to a host computer, at both module and equipment level.
- Report reasons to a host computer for why equipment is blocked from performing its task, at both module and equipment level.
- Report information to a host computer to allow computation of equipment run rate, at both module and equipment level.

1.2 Equipment users require the ability to track equipment performance without dependence on user input to eliminate inaccuracies due to incorrect or untimely input from the user. The ability to track equipment performance without user input is essential in 300 mm wafer factories where operational scenarios require minimal manual interaction. EPT defines concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent matter without operator or host input.

1.3 EPT enables factory managers to identify the current states of factory equipment, both at the equipment level and at the module level (e.g. processing chambers), without dependence on user input. EPT enables factory engineers to evaluate the time that equipment and modules spent in different states and identify areas for improvement. EPT enables factory engineers to obtain directly from the equipment the reasons why the equipment or module is prevented from performing. EPT provides industrial engineers the equipment data which, when combined with external data from the Manufacturing Execution System (MES), will enable accurate calculation of SEMI E10 states and SEMI E79 metrics at the equipment-level and the module-level. EPT allows capital equipment managers to obtain run-rate information at the equipment-level and module-level to identify requirements for new equipment purchases. EPT enables automation engineers to develop reusable host interfaces by using a standardized collection event and data variables to collect equipment state data.

2 Scope

2.1 The Scope of this standard is to define equipment behavior states and the data required to track basic equipment performance for production equipment. These requirements are intended to facilitate equipment-level and module-level state tracking and to communicate state information to the host for simple equipment performance tracking, without requiring host or operator input.

2.2 Specifically, this document provides:

- An Equipment Performance Tracking (EPT) state model that defines triggers for state changes.
- Specification of data variables required to communicate basic equipment performance data to the host computer.
- Specification of event messages used to communicate basic equipment performance data to the host computer.
- Specification of requirements for run rate information.
- Requirements for EPT compliance.

2.3 This standard specifies the concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent manner, without operator or host input. It does not specify the report of E10 states from the equipment to a host computer, as this information requires user input and is already specified by SEMI E58.

2.4 This standard does not conflict with SEMI E58 nor does it inhibit the equipment's ability to report out SEMI E10 states via SEMI E58.

2.5 This standard is a building block towards SEMI E10 and SEMI E79 by providing accurate equipment information required for SEMI E10 and SEMI E79 metrics, without dependence on operator or host input, eliminating inaccuracies due to incorrect or untimely input from the user. EPT assists both SEMI E10 and SEMI E79 by providing a modular approach to equipment performance tracking, allowing the state of the equipment to be determined by the states of its major modules. EPT assists SEMI E79 by providing task-level detail of the equipment or module's current activity, allowing performance metrics to be tracked at the task level.

2.6 This is a provisional standard. In order to have the provisional status removed, the following areas must be completed:

- Equipment Interlock Information
- Equipment Process Monitoring Information
- Equipment Maintenance Trigger Information
- Application of EPT State Model to load ports and internal buffers

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This standard applies to semiconductor production equipment. Other types of equipment have not been examined. However, it may be used for other types of equipment when applicable.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E79 — Standard for Definition and Measurement of Equipment Productivity

SEMI E90 — Specification for Substrate Tracking

SEMI E98 — Provisional Standard for the Object-Based Equipment Modeling (OBEM)

SEMI 101 — Provisional Guide for EFEM Functional Structure Model

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *EFEM* — Equipment Front End Module

5.1.2 *EPT* — Equipment Performance Tracking

5.1.3 *GEM* — Generic Equipment Model [SEMI E30]

5.2 *Definitions*

5.2.1 *EPT module* — a major component of the equipment that affects processing or throughput.

For purposes of simplification, an EPT module executes one and only one task at a time. Each EPT Module has an EPT state model that is maintained by the equipment.

5.2.2 *EPT state* — the state of IDLE, BUSY, or BLOCKED within EPT state model.

5.2.3 *event report* — a message the equipment sends to the host on the occurrence of a collection event.

5.2.4 *fault* — an exception.

5.2.5 *host* — the factory computer system or an intermediate system that represents the factory and the operator to the equipment.

5.2.6 *intended function* — a manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment, measurement functions for metrology equipment, as well as process functions such as physical vapor deposition and wire bonding. Complete equipment may have more than one intended function. [SEMI E58]

5.2.7 *material* — the basic unit of process. For the purposes of this standard, material is a set of one or more substrates.

5.2.8 *module* — a major component of equipment that contains at least one material location and performs some task on material. Equipment modules may be aggregates of equipment subsystems, I/O devices, and other modules. [SEMI E98]

5.2.9 *substrate* — the basic unit of material on which work is performed to create a product. Examples include wafers, die, plates used for masks, flat panels, circuit boards, and leadframes. [SEMI E90]

5.2.10 *task* — a planned and repeatable activity with an expected duration and a definite beginning and end (e.g. Move wafer from cassette to stage, Pre-align wafer, Align reticle, Preheat chamber, Increase vacuum). NOTE: Actual durations may vary.

5.2.11 *trigger* — an event that causes a change in the state of the equipment. Examples are changes in sensor readings, alarms, and messages received from the host, and operator commands.

5.2.12 *unit* — any wafer, die, packaged device, or piece thereof (included product and non-product units). [SEMI E10]

5.2.13 *user* — any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment's viewpoint, both the operator and the host represent the user. [SEMI E58]

6 Requirements

6.1 An EPT compliant implementation requires provision of certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and provision of an internal time-and-date clock. These requirements may be satisfied through compliance to SEMI E30 for the following sets of requirements:

- Clock Services
- Event Notification
- Status Data Collection
- Equipment Constants
- Alarm Management

6.2 An EPT compliant implementation requires support of SEMI E90.

6.3 An EPT compliant implementation requires a documented list of all EPT modules contained within the equipment.

6.4 An EPT compliant implementation requires an EPT state model for the equipment and for each EPT module.

6.5 Each EPT module shall have a documented list of tasks that the module may perform.

7 Conventions

7.1 This document follows the conventions for state model methodology and service definitions used by the SEMI standards referenced in Section 4.

7.2 *State Model Methodology*

7.2.1 A state model has three elements: definitions of each state and sub-state, a diagram of the states showing the valid transitions between states, and a corresponding state transition table that defines the triggers for each transition. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an Appendix of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.

7.2.2 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

1) Actions taken upon exit of the previous state.
2) Actions taken upon entry of the new state.
3) Actions taken that are most closely associated with the transition.

7.2.3 No differentiation is made between these cases.

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
Transition #					

7.3 *Variable Data Item Definition*

7.3.1 The variable item dictionary contained in this document defines the variable name, description, type (format), access (read/write or read only), and comments about the variable. This is depicted in the format of the following table:

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*

7.4 *Event Description*

7.4.1 The collection event description table contained in this document includes the event name, the state model transition, the description, and the data required for the event. This is depicted in the format of the following table:

EVENT NAME	*STATE MODEL TRANSITION NUMBER*	*DESCRIPTION*	*REQUIRED DATA*

8 Overview

8.1 This section defines the concepts that enable EPT to provide information required for determining equipment performance.

8.2 Equipment processing times, including throughput and cycle times, are determined by two factors: (1) the sequence of tasks performed by the equipment, including the number of each task performed, as well as the series and parallel relationships between tasks, and (2) the execution time of each individual task. By tracking equipment systems in terms of modules that perform tasks, it will be possible to precisely identify the affect of both factors toward overall system performance.

8.3 EPT enables tracking to this level of detail by introducing the concept of an EPT module and the concept of a task. EPT-compliant equipment are required to report events according to a breakdown of equipment operations into tasks and EPT modules. An EPT module is an equipment component that affects processing or throughput, and is capable of executing only one task at a time. Examples of EPT modules include process stations, process chambers, wafer handling systems, etc. A task is a planned and repeatable activity with an expected duration and a definite beginning and end. Examples of tasks include the following:

- Move wafer from cassette to stage
- Pre-align wafer
- Align reticle
- Preheat chamber
- Increase vacuum etc.

8.4 EPT-compliant equipment consist of EPT modules that perform tasks. Thus, the state of the equipment can be effectively modeled as a composition of the states of the EPT modules. In addition, EPT provides detailed information required for performance tracking by providing the task-level details and run-rate information for each EPT module.

8.5 EPT modules and tasks are to be defined such that each EPT module executes only one task at a time. An example is given in Related Information Section R1-7. Each equipment system must have defined at least as many EPT modules as tasks that may be performed simultaneously by that system.

8.6 Each task should be defined such that the units involved (e.g., wafers, substrates, reticles), the EPT modules involved (e.g., process station, robot, etc.), and the task type (e.g., "process", "support", etc.) are constant throughout the duration of the task. A change in any of the following items should result in the start of a new task or completion of current task:

- Change in material involved (e.g. arrival of wafer, removal of wafer)
- Change of EPT modules involved (e.g. robot moves wafer, chamber processes wafer)
- Change in task type (e.g. purge recipe followed by production recipe)

NOTE 2: It is not practical for equipment to define tasks or modules at an indefinite level of detail. It is therefore recommended that in each instance for which the material involved, the EPT modules involved, and the task types are all constant, events for only one task should be reported. Any further breakdown is not required for EPT compliance. EPT places no limitations on supplemental event reporting within any task. However, these supplemental events should not be reported as EPT events.

9 EPT State Model

9.1 This section defines the basic Equipment Performance Tracking State Model, which is applied to the equipment and its EPT modules.

9.2 *EPT State Model Requirements*

9.2.1 The EPT state model is intended to capture the different states of the equipment and its EPT modules from an operational point of view:

- Busy executing a task
- Blocked from executing a task
- Idle (no tasks executing)

9.2.2 The equipment shall maintain an EPT state model for each major module (e.g. process stations and chambers, wafer handling systems, etc.) through which a unit passes throughout the entire equipment from removal of units from the carrier to the return of units to the carrier.

9.2.3 The equipment shall maintain an EPT state model for any major component of the equipment that impacts processing and throughput.

9.2.4 The equipment shall maintain its own EPT state model for the overall equipment.

9.2.5 The equipment is responsible for communicating all EPT state transitions.

9.2.6 The EPT state model can be applied to the Equipment Front-End Module (EFEM).

9.2.7 The state of the EFEM/carrier/load port related modules shall not impact the overall equipment state.

9.3 *EPT State Model Diagram*

9.3.1 Figure 1 shows the EPT state module diagram.

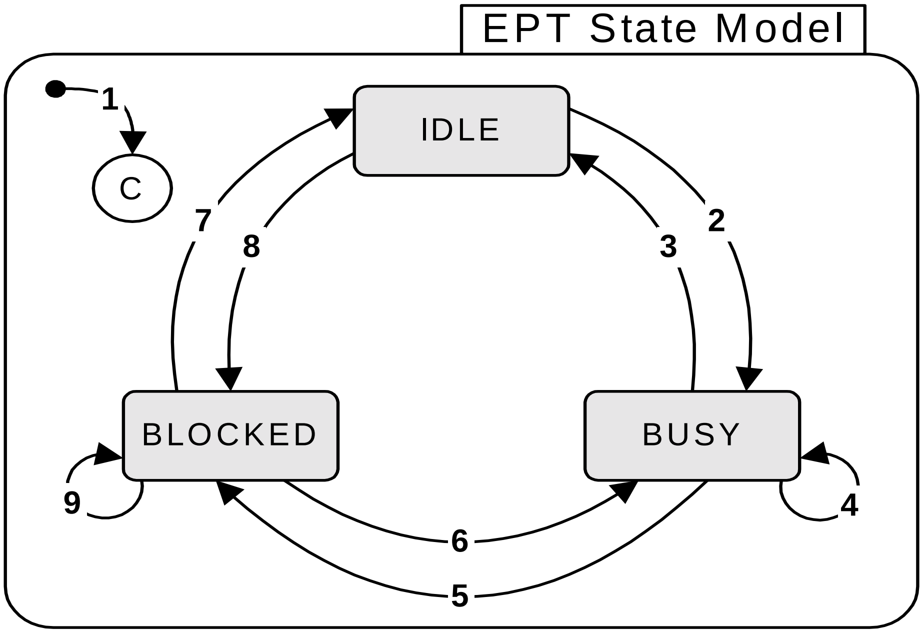


Figure 1
Equipment Performance Tracking State Model

9.4 *EPT State Definitions*

This section describes the EPT states.

9.4.1 IDLE

9.4.1.1 *EPT Module* — The following conditions are required for the module to be in the IDLE state:

- No material is present in the module and
- The module is not executing a task and
- No fault condition exists in the module that prevents it from starting a new task.

9.4.1.2 *Equipment* — The following condition is required for the equipment to be in the IDLE state:

- All of the equipment's EPT modules are in the IDLE state (excluding EFEM/carrier/load port related modules)

9.4.1.3 For both the equipment and modules the following conditions may exist in the IDLE State:

- The equipment or module is maintaining and monitoring environmental requirements (e.g. background temperature, particle monitoring, etc).

9.4.2 BUSY

9.4.2.1 *EPT Module* — The following conditions are required for the module to be in the BUSY state:

- The module is executing a task and
- No fault condition exists in the module that prevents the execution of a task.

9.4.2.2 *Equipment* — The following condition is required for the equipment to be in the BUSY state:

- At least one EPT module is BUSY (excluding EFEM/carrier/load port related modules).

9.4.2.3 For both the equipment and modules the following conditions may exist in the BUSY State:

- Material is present.

9.4.3 BLOCKED

9.4.3.1 *EPT Module* — One or more of the following conditions are required for the module to be in the BLOCKED state:

- Conditions exist that do not allow the EPT module to continue or start execution of a task (excluding EFEM/carrier/load port related modules):
- A fault condition(s) exists that prevents the EPT module from completing its task.
- A fault condition(s) exists that prevents the EPT module from starting a new task.
- The EPT module is pausing (or aborting) as the result of a pause (or abort) directive.
- The EPT module has paused its task and is awaiting a resume directive.
- The EPT module fails to initialize upon start-up.

9.4.3.2 *Equipment* — All of the following conditions are required for the EPT equipment to be in the BLOCKED state:

- At least one EPT module is BLOCKED (excluding EFEM/carrier/load port related modules) and
- No EPT modules are BUSY (excluding EFEM/carrier/load port related modules)

9.4.3.3 For both the EPT equipment and modules the following conditions may exist in the BLOCKED State:

- Material is present.

9.5 *EPT State Transition Table – Module Level*

9.5.1 This section defines the state transitions for the EPT modules within the equipment.

9.5.2 For each status variable updated with the event change, the corresponding event variable shall also be updated (see Table 5).

Table 1 Basic EPT State Transitions – Module Level

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
1	(No state)	EPT module initialization completed.	IDLE [OR] BLOCKED	• No EPT event is triggered • $EPTState_i$ = IDLE or BLOCKED • $PreviousEPTState_i$ = NoState • $NumIdle_0$ is set • $NumBlocked_0$ is set • $PreviousTaskName_i$ = “No Task” • $PreviousTaskType_i$ = 0 • $EPTStateTime_i = 0$	• If no Fault conditions exist and no material is present, transition to IDLE • If Fault conditions exist, or EPT module cannot be initialized, then transition to BLOCKED • If Material is present, then transition to BLOCKED

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
2	IDLE	EPT module starts execution of a new task.	BUSY	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = BUSY • *PreviousEPTState$_i$* =IDLE • *TaskName$_i$* is set • *TaskType$_i$* is set • *NumBusy$_0$* incremented • *NumIdle$_0$* decremented	
3	BUSY	EPT module completes execution of task. [AND] Material is removed from the EPT module.	IDLE	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = IDLE • *PreviousEPTState$_i$*=BUSY • *TaskName$_i$* = “No Task” • *TaskType$_i$* = 0 • *PreviousTaskName$_i$* is set • *PrevoiusTaskType$_i$* is set • *NumIdle$_0$* incremented • *NumBusy$_0$* decremented	
4	BUSY	EPT module starts execution of a new task upon the normal completion of the previous task.	BUSY	• *EPTStateChange$_i$* event is triggered • *TaskName$_i$* is set • *TaskType$_i$* is set	EPTStateTime$_i$ does not change. Thus when the module transitions out of BUSY state, the value of EPTStateTime$_i$ will reflect the total time the module was BUSY. PreviousEPTState$_i$ does not change. Thus, PreviousEPTState$_i$ will continue to reflect the state of the module before it was BUSY.
5	BUSY	A pause command is received that pauses the EPT module. [OR] An abort command is received that aborts the EPT module. [OR] A Fault condition occurs that prevents the EPT module from executing its task.	BLOCKED	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *BlockedReason$_i$ is* set • *BlockedReasonText$_i$* is set • *EPTState$_i$* =BLOCKED • *PreviousEPTState$_i$* =BUSY • *NumBlocked$_0$* incremented • *NumBusy$_0$* decremented	TaskName$_i$ and TaskType$_i$ do not change. The variables continue to reflect the information of the task that is currently blocked from executing.

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
6	BLOCKED	All fault conditions that prevented task execution are cleared and the EPT module resumes execution of its task or starts execution of a new task. [OR] A resume command is received that enables the EPT module to resume its task.	BUSY	• *EPTStateChange*$_i$ event is triggered • *EPTStateTime*$_i$ is calculated • *EPTState*$_i$ = BUSY • *PreviousEPTState*$_i$ =BLOCKED • *TaskName*$_i$ is set • *TaskType*$_i$ is set • *BlockedReason*$_i$ = 0 • *BlockedReasonText*$_i$ = "Not Blocked" • *NumBusy*$_0$ incremented • *NumBlocked*$_0$ decremented	
7	BLOCKED	All fault conditions that prevented task execution are cleared. [AND] All material is removed from the EPT module. [AND] EPT module can begin a new task.	IDLE	• *EPTStateChange*$_i$ event is triggered • *EPTStateTime* $_i$ is calculated • *EPTState*$_i$ =IDLE • *PreviousEPTState*$_i$ =BLOCKED • *TaskName*$_i$ = "No Task" • *TaskType*$_i$ = 0 • *PreviousTaskName*$_i$ is set • *PrevoiusTaskType*$_i$ is set • *BlockedReason*$_i$ = 0 • *BlockedReasonText*$_i$ = "Not Blocked" • *NumIdle*$_0$ incremented • *NumBlocked*$_0$ decremented	
8	IDLE	Material arrives at the EPT module and the EPT module cannot begin executing a task on the material. [OR] A fault condition occurs which prevents the EPT module from starting a new task.	BLOCKED	• *EPTStateChange*$_i$ event is triggered • *EPTStateTime*$_i$ is calculated • *BlockedReason*$_i$ is set • *BlockedReasonText*$_i$ is set • *EPTState*$_i$ = BLOCKED • *PreviousEPTState*$_i$ = IDLE • *NumBlocked*$_0$ incremented • *NumIdle*$_0$ decremented	

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
9	BLOCKED	Fault conditions occur that prevent the EPT module from resuming a blocked task, or starting a new task.	BLOCKED	• *$EPTStateChange_i$* event is triggered • *$BlockedReason_i$* is set • *$BlockedReasonText_i$* is set	$EPTStateTime_i$ does not change. Thus when the module transitions out of BLOCKED state, the value of $EPTStateTime_i$ will reflect the total time the module was BLOCKED from processing. $PreviousEPTState_i$ does not change. Thus, $PreviousEPTState_i$ will continue to reflect the state of the module before it was BLOCKED from processing.

9.6 *EPT State Transition Table for Equipment*

9.6.1 This section defines the State Transitions for the Equipment, in terms of its EPT modules.

Table 2 Basic EPT State Transitions – Equipment Level

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
1	(No state)	Equipment initiation completed (includes initialization of EPT modules).	IDLE [OR] BLOCKED	• *$EPTStateChange_0$* event is triggered • *$EPTState_0$* = IDLE or BLOCKED • *$PreviousEPTState_0$* = NoState • *$EPTStateTime_0$* = 0	• If any EPT module transitions to BLOCKED, then transition to BLOCKED • If all EPT modules transition to IDLE, then transition to IDLE
2	IDLE	Any EPT module transitions to BUSY.	BUSY	• *$EPTStateChange_0$* event is triggered • *$EPTStateTime_0$* is calculated • *$EPTState_0$* = BUSY • *$PreviousEPTState_0$* =IDLE	
3	BUSY	All EPT modules have transitioned to IDLE. [AND] All material is removed from Equipment.	IDLE	• *$EPTStateChange_0$* event is triggered • *$EPTStateTime_0$* is calculated • *$EPTState_0$*= IDLE • *$PreviousEPTState_0$* =BUSY	

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
4	BUSY	Any EPT module transitions to BUSY from BUSY. [OR] Any EPT module transitions to BUSY when at least one other EPT module was already BUSY.	BUSY	• No event required	This event parallels the module-level BUSY events, and thus is not required
5	BUSY	At least one EPT module transitions from BUSY to BLOCKED when no other EPT modules are BUSY. [OR] At least one EPT module transitions from BUSY to IDLE when at least one EPT module is already BLOCKED and no other EPT modules are BUSY.	BLOCKED	• $EPTStateChange_0$ event is triggered • $EPTStateTime_0$ is calculated • $BlockedReason_0$ is set • $BlockedReasonText_0$ is set • $EPTState_0$=BLOCKED • $PreviousEPTState_0$ =BUSY	
6	BLOCKED	At least one EPT module that was BLOCKED transitions to BUSY. [OR] At least one EPT module that was IDLE transitions to BUSY.	BUSY	• $EPTStateChange_0$ event is triggered • $EPTStateTime_0$ is calculated • $EPTState_0$= BUSY • *PreviousEPT* $State_0$ =BLOCKED	
7	BLOCKED	All EPT modules that were BLOCKED have transitioned to IDLE. [AND] No EPT modules are BUSY.	IDLE	• $EPTStateChange_0$ event is triggered • $EPTStateTime_0$ is calculated • $EPTState_0$=IDLE • $PreviousEPTState_0$ =BLOCKED	
8	IDLE	Any EPT module that was IDLE transitions to BLOCKED.	BLOCKED	• $EPTStateChange_0$ event is triggered • $EPTStateTime_0$ is calculated • $BlockedReason_0$ is set • $BlockedReasonText_0$ is set • $EPTState_0$= BLOCKED • $PreviousEPTState_0$ = IDLE	

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
9	BLOCKED	An EPT module that was already BLOCKED transitions again to BLOCKED. [OR] Any EPT module transitions to BLOCKED when at least one other EPT module was already BLOCKED. [OR] Any EPT module transitions to IDLE when at least one other EPT module was already BLOCKED.	BLOCKED	• *$EPTStateChange_0$* event is triggered • *$BlockedReason_0$* is set • *$BlockedReasonText_0$* is set	$EPTStateTime_0$ does not change. Thus when the equipment transitions out of BLOCKED state, the value of $EPTStateTime_0$ will reflect the total time the equipment was BLOCKED from processing. $PreviousEPTState_0$ does not change. Thus, $PreviousEPTState_0$ will continue to reflect the state of the equipment before it was BLOCKED from processing.

10 EPT Variable Data Definitions – Module Level and Equipment Level

10.1 The purpose of this section is to define variable data requirements for EPT events. The variable data is updated by the equipment at the time an EPTStateChange event occurs in the corresponding EPT state model. These variables are reported to the host via collection events reports and/or status queries from the host. Table 3 defines the EPT status variables required at the EPT module level. Table 4 defines the EPT status variables required at the equipment level. Table 5 defines the EPT event variables required at both the EPT module and equipment level.

10.2 *Variable Data Dictionary – Module Level*

10.2.1 This section defines the EPT module data variables that must be kept valid at all times. When queried for these data variables, the equipment shall send the current value of the data variable.

Table 3 Variable Data Definitions – Module Level

VARIABLE NAME	DESCRIPTION	TYPE	ACCESS	COMMENT
$ModuleName_i$	The name of the EPT module.	Text, 0 to 80 characters	RW	There exist i ModuleName variables, where i is the number of EPT modules. $ModuleName_0$ is unused. $ModuleName_1$ contains name of 1^{st} EPT module, $ModuleName_2$ contains name of 2^{nd} EPT module, etc.
$EPTState_i$	The current EPT state of the EPT module.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED There exist i+1 EPTState variables, where i is the number of EPT modules. $EPTState_1$ contains state of 1^{st} EPT module, $EPTState_2$ contains state of 2^{nd} EPT module, etc.

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
$PreviousEPTState_i$	The previous EPT State of the EPT module.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED 3 = No State There exist i+1 PreviousEPTState variables, where i is the number of EPT modules. $EPTState_1$ contains previous state of 1st EPT module, $EPTState_2$ contains previous state of 2nd EPT module, etc.
$EPTStateTime_i$	Time spent in previous EPT state.	Unsigned Double	RO	Seconds This is the time period between the entry into the previous EPT state and the entry into the current EPT State There exist i+1 EPTStateTime variables, where i is the number of EPT modules. $EPTStateTime_1$ contains time in EPT state for 1st EPT module, $EPTStateTime_2$ contains time in EPT state for 2nd EPT module, etc.
$TaskName_i$	Name of the task that was started.	Text, 0 to 80 characters	RO	There exist i+1 TaskName variables, where i is the number of EPT modules. $TaskName_1$ contains task name for 1st EPT module, $TaskName_2$ contains task name for 2nd EPT module, etc. TaskName is defined by the equipment supplier.
$TaskType_i$	The type of task that module i is currently executing.	Enumerated	RO	No Task Process – adding value (e.g. exposing) Support – incapable of adding value (e.g. Handling/Transport) Equipment Maintenance (e.g. equipment initiated clean cycle) Equipment Diagnostics (e.g. equipment-initiated health check) Unspecified There exist i+1 TaskType variables, where i is the number of EPT modules. $TaskType_1$ contains type of task for 1st EPT module, $TaskType_2$ contains type of task for 2nd EPT module, etc.

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
$PreviousTaskName_i$	The name of task that module i was previously executing.	Text	RO	There exist i+1 PreviousTaskName variables, where i is the number of EPT modules. $PreviousTaskName_1$ contains previous task name for 1st EPT module, $PreviousTaskName_2$ contains time previous task name for 2nd EPT module, etc.
$PreviousTaskType_i$	The type of task that module i was previously executing.	Enumerated	RO	No Task Process – adding value (e.g. exposing) Support – incapable of adding value (e.g. Handling/Transport) Equipment Maintenance (e.g. equipment initiated clean cycle) Equipment Diagnostics (e.g. equipment-initiated health check) Unspecified There exist i+1 TaskType variables, where i is the number of EPT modules. $TaskType_1$ contains type of task for 1st EPT module, $TaskType_2$ contains type of task for 2nd EPT module, etc.
$BlockedReason_i$	A numeric code that identifies the most recent block condition of a module.	Enumerated	RO	$BlockedReason_i$ shall have one of the following values: 0 – Not Blocked 1 – Unknown 2 – Safety Threshold 3 – Error Condition 4 – Parametric Exception 5 – Aborting, Aborted 6 – Pausing, Paused 7 – Reserved 8 – Reserved 9 – Reserved There exist i+1 BlockedReason variables, where i is the number of EPT modules. $BlockedReason_1$ contains Blocked Reason for 1st EPT module, $BlockedReason_2$ contains Blocked Reason for 2nd EPT module, etc.
$BlockedReasonText_i$	A description of the current block condition of a module. The reason why the transition was made to the BLOCKED state.	Text, 0 to 80 characters	RO	There exist i+1 BlockedReasonText variables, where i is the number of EPT modules. $BlockedReason_1$ contains Blocked Reason text for 1st EPT module, $BlockedReason_2$ contains Blocked Reason text for 2nd EPT module, etc.

10.3 *Variable Data Dictionary – Equipment Level*

10.3.1 This section defines the Equipment data variables that must be kept valid at all times. When queried for these data variables, the equipment shall send the current value of the data variable.

Table 4 Variable Data Definitions – Equipment Level

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
EqpName	The name of the equipment.	Text, 0 to 80 characters	RW	
$EPTState_0$	The current EPT state of the equipment.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED
$PreviousEPTState_0$	The previous EPT State of the equipment.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED 3 = No State
$EPTStateTime_0$	Time spent in previous EPT state for the equipment.	Unsigned Double	RO	Seconds This is the time period between the entry into the previous EPT state and the entry into the current EPT State
$NumModules_0$	Total Number of EPT modules on the equipment.	Unsigned integer	RO	$NumModules_0$ = $NumBusy_0$ + $NumBlocked_0$ + $NumIdle_0$
$NumBusy_0$	Number of BUSY EPT modules on the equipment.	Unsigned integer	RO	$NumBusy_0$ = $NumModules_0$ - $NumBlocked_0$ - $NumIdle_0$
$NumBlocked_0$	Number of BLOCKED EPT modules on the equipment.	Unsigned integer	RO	$NumBlocked_0$ = $NumModules_0$ - $NumBusy_0$ - $NumIdle_0$

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
$NumIdle_0$	Number of IDLE EPT modules on the equipment.	Unsigned integer	RO	$NumIdle_0 = NumModules_0 - NumBusy_0 - NumBlocked_0$
$BlockedReason_0$	The number of the block condition that initiated the transition to the BLOCKED state for the equipment.	Enumerated	RO	0 – Not Blocked 1 – Unknown 2 – Safety Threshold 3 – Error Condition 4 – Parametric Exception 5 – Aborting, Aborted 6 – Pausing, Paused 7 – Reserved 8 – Reserved 9 – Reserved
$BlockedReasonText_0$	The reason why the transition was made to the BLOCKED state for the equipment.	Text, 0 to 80 characters	RO	Description of the Blocked reason

10.4 The data items *TaskType* and *PreviousTaskType* may take on one of the following values:

0. No Task — Value for *TaskType* when the EPT module is IDLE , and value for the *PreviousTaskType* when the EPT module transitions out of the IDLE state or initial state (no state).
1. Process — Tasks expected under normal or desired manufacturing operations that are capable of adding value by either (1) a physical-chemical change or (2) providing critical process information (e.g., inspection or metrology). This includes tasks that are dependent on a recipe ID, dependent on parameters (e.g., target etch thickness), or recipe and parameter independent (e.g., fixed purge time for all recipes or regardless target etch thickness).
2. Support — Tasks expected under normal or desired manufacturing operations that are incapable of adding value according to the criteria for a process task. These include alignment, handling and other transport, and environmental changes by supporting EPT modules (e.g., pumpdown and vent operations in a load lock).
3. Maintenance — Any equipment-initiated task that is intended to change the state of the equipment for the purpose of maintaining equipment functionality or performance. This includes clean cycles, purges not expected under normal or desired manufacturing operations, and certain reset operations that do not put the EPT module or equipment in a non-operational state.
4. Diagnostics — Any equipment-initiated task that obtains information about the status of the equipment for the purpose of determining the equipment's health or identifying an equipment problem(s). This excludes any task that is intended to change the status of the equipment, as in a maintenance task. This also excludes metrology and inspection tasks that provide critical information about the process even if those tasks also provide equipment diagnostic information as a byproduct.
5. Unspecified — A placeholder for unspecified task types.

10.4.1 NOTES: The following notes resolve ambiguities that arise from limitations of the equipment or EPT module point of view. From the equipment or EPT module point of view:

- process maintenance activities (e.g., monitor wafers) and engineering activities (e.g., new process qualification runs) may be indistinguishable from normal or desired manufacturing operations. These operations shall be reported as either process or support operations.
- equipment maintenance activities (e.g., equipment qualification runs monitor wafers) may be indistinguishable from normal or desired manufacturing operations. These operations shall be reported as either process or support operations.

- activities executed for exception handling (e.g., pausing, aborting, stopping, or otherwise moving to a safe state) may be indistinguishable from support tasks. Examples include handling/transporting wafers to safe locations, pumping, venting, purging, etc. If the equipment or module implementing EPT does not have *reasonable inherent knowledge of purpose* regarding these activities, the tasks should be always declared as support tasks. If the equipment or module implementing EPT does have reasonable inherent knowledge of purpose regarding these activities, these activities shall be either (1) modeled as task faults or otherwise blocked conditions, or (2) exempted entirely from treatment under EPT. In case 2, the affected EPT module or modules must be in a BLOCKED state due to related conditions reported to the EPT state model(s).

10.5 Blocked Reason Text Requirements:

- Fault Condition: Blocked reason text should begin with "Fault: - 'appropriate text'"
- Pause Condition: Blocked reason text should begin with "Pause: - 'appropriate text'"
- Abort Condition: Blocked reason text should begin with "Abort: - 'appropriate text'"

11 EPT Events

11.1 This section defines the required events and variable data associated with transitions in the EPT state model.

11.2 Table 5 defines the data variables that are valid at the time of an EPT State Change event. When the equipment or EPT module triggers an EPTStateChange event, the value of the data variable shall be updated to reflect the data valid at the time the event occurred.

Table 5 Variable Data Definitions – Event Variables

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
EPTState	The new (resulting) EPT state of the module or equipment at the end of an EPT state transition.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED
PreviousEPTState	The previous EPT state of the module or equipment of an end of an EPT state transition.	Enumerated	RO	0 = IDLE 1 = BUSY 2 = BLOCKED 3 = No State
EPTStateTime	Time spent in previous EPT state for the equipment or module.	Unsigned Double	RO	Seconds This is the time period between the entry into the previous EPT state and the entry into the current EPT State
Clock	The time and date at the end of an EPT state transition.	Formatted numeric text: timestamp format	RO	When included in an event report, Clock represents the timestamp for the occurrence of the event
TaskName	Name of the task that was started by the module or equipment at the occurrence of an EPT state transition.	Text, 0 to 80 characters	RO	TaskName is defined by the equipment supplier.

VARIABLE NAME	*DESCRIPTION*	*TYPE*	*ACCESS*	*COMMENT*
TaskType	The type of task that was started by the module or equipment at the occurrence of an EPT state transition.	Enumerated	RO	No Task Process – adding value (e.g. exposing) Support – incapable of adding value (e.g. Handling/Transport) Maintenance (e.g. equipment initiated clean cycle) Diagnostics (e.g. equipment-initiated health check) Unspecified
PreviousTaskName	Name of the task that was completed by the module or equipment at the occurrence of an EPT state transition.	Text, 0 to 80 characters	RO	
PreviousTaskType	The type of the task that was completed by the module or equipment at the occurrence of an EPT state transition.	Enumerated	RO	No Task Process – adding value (e.g. exposing) Support – incapable of adding value (e.g. Handling/Transport) Maintenance (e.g. equipment initiated clean cycle) Diagnostics (e.g. equipment-initiated health check) Unspecified
NumBusy	Number of BUSY EPT modules on the equipment at the end of an EPT state transition.	Unsigned integer	RO	NumBusy = i - NumBlocked - NumIdle where i is the number of EPT modules
NumBlocked	Number of BLOCKED EPT modules on the equipment at the end of an EPT state transition.	Unsigned integer	RO	NumBlocked = i - NumBusy - NumIdle where i is the number of EPT modules
NumIdle	Number of IDLE EPT modules on the equipment at the end of an EPT state transition.	Unsigned integer	RO	NumIdle = i - NumBusy - NumBlocked where i is the number of EPT modules
BlockedReason	The number of the block condition that initiated the transition to the BLOCKED state for the module or equipment.	Enumerated	RO	0 – Not Blocked 1 – Unknown 2 – Safety Threshold 3 – Error Condition 4 – Parametric Exception 5 – Aborting, Aborted 6 – Pausing, Paused 7 – Reserved 8 – Reserved 9 – Reserved

VARIABLE NAME	DESCRIPTION	TYPE	ACCESS	COMMENT
BlockedReasonText	The reason why the transition was made to the BLOCKED state for the module or equipment.	Text, 0 to 80 characters	RO	Description of the Blocked reason

11.3 All events require the following data variables to be available:

< Clock > *(Clock* represents the timestamp for the occurrence of the event*)*
< EPTState >
<PreviousEPTState>
< EPTStateTime >
<TaskName>
<TaskType>
<PreviousTaskName>
<PreviousTaskType>
<NumBusy>
<NumIdle>
<NumBlocked>
Additional data required for specific transitions are shown in Table 6.

Table 6 Events

EVENT NAME	***STATE MODEL TRANSITION NUMBER***	***DESCRIPTION***	*REQUIRED DATA*
EPTStateChange$_0$	1, 2, 3, 4, 5, 6, 7, 8, 9	Triggered by a EPT State change at the equipment-level.	<EqpName > The following additional data is required for Transitions 5, 8 and 9: < Blocked Reason> < BlockedReasonText>
EPTStateChange$_i$	1, 2, 3, 4, 5,6, 7, 8, 9	Triggered by an EPT State change at the EPT module-level. There exist i+1 EPTStateChange events, where i is the number of EPT modules. EPTStateChange$_1$ is triggered by a state change at the 1st EPT module, EPTStateChange$_2$ is triggered by a state change at the 2nd EPT module, etc.	<ModuleName> The following additional data is required for Transitions 5, 8 and 9: < Blocked Reason> < BlockedReasonText>

12 Run Rate Information

12.1 This section defines the EPT requirements for Run Rate Information. Run Rate is calculated as the number of units processed divided by the amount of time used to process those units. Equipment is not required by EPT to report its own run rate since the period of time may vary according to user requirements. However, EPT does require that the equipment provide sufficient information for the user to calculate run rate.

12.2 *Support for Run Rate (Throughput) Calculations*

12.2.1 The equipment shall report E90 events to provide data for the user to calculate Run Rate. These events must be generated at both the module-level and the equipment-level in order for an equipment to be EPT-compliant. The equipment must provide E90 events for each EPT module through which the wafer moves throughout the entire equipment.

12.2.2 At the equipment level, run rate information can be calculated by the user by using the total time from the point of time the first substrate in a run is removed from its carrier and the point in time the final substrate is returned to its destination carrier. The equipment is required to provide a method for tracking substrates as they move from position to position within it. This requirement is satisfied through compliance to SEMI E90 Specification for Substrate Tracking.

12.2.3 Each EPT module that contains a material location shall provide E90 events that can be used by the user to calculate the number of units processed and the time used for processing. Time for processing can be calculated by the user as the time between the arrival of the substrate in the EPT module and the departure of the substrate from the EPT module. Each EPT module shall provide events for the arrival and departure of the substrate. This requirement is satisfied through compliance of the EPT modules to the SEMI E90 state model for substrates and substrate locations.

13 Requirements for Compliance

13.1 Table 7 provides a checklist for EPT compliance.

Table 7 EPT Compliance Statement

Fundamental EPT Requirements	*EPT Section*	*Implemented*	*EPT Compliant*
EPT State Model for Equipment	9	☐ Yes ☐ No	☐ Yes ☐ No
EPT State model for each EPT module	9	☐ Yes ☐ No	☐ Yes ☐ No
EPT Variable Data	10	☐ Yes ☐ No	☐ Yes ☐ No
EPT Events	11	☐ Yes ☐ No	☐ Yes ☐ No
EPT Run Rate Information	12	☐ Yes ☐ No	☐ Yes ☐ No

14 Related Documents

14.1.1 International SEMATECH Equipment Performance Management User Requirements Document

14.1.2 ISMT/J300E Equipment Performance Management Operator Requirements Document (URD)

14.1.3 Harel, D., “Statecharts: A Visual Formalism for Complex Systems,” Science of Computer Programming 8 (1987) 231-274.

RELATED INFORMATION 1
EXAMPLES OF EQUIPMENT PERFORMANCE TRACKING (EPT)

NOTE: This related information is not an official part of SEMI E116 and was derived from North American Information and Control. This related information was approved for publication by full letter ballot procedures on April 30, 2002.

R1-1 An Example of Equipment Performance Tracking on a Carrier Handling Module

R1-1.1 This section provides examples of equipment performance tracking to clarify the application of the standard to modules that are part of the Equipment Front-End Module (EFEM).

R1-2 Carrier Handling Module (CHM)

R1-2.1 The Carrier Handler is a part of EFEM, excluding any Substrate Handler, which is defined in SEMI E101. A Carrier Handling Module is similar but different from the definition. It is a more general subsystem to handle carriers without handling substrates in EFEM that is applicable to various analyses and applications. The Carrier Handling Module is a logical module that may or may not represent an existing physical module.

R1-2.2 The advantages of applying Equipment Performance Tracking to the Carrier Handling Module are as follows:

- Any equipment, except certain specific ones such as an expose tool within a linked litho tool in the lithography process, has one or more Carrier Handling Modules.

The state of the Carrier Handling Module leads to whole input and output of material to and from an equipment.

- Monitoring the Equipment Performance Tracking state of the Carrier Handling Module helps control loading to or unloading from equipment on appropriate time.
- The state can reveal what related SEMI standards, i.e. SEMI E87 and SEMI E90, may not address.
- Estimation of capabilities about sub-components on a Carrier Handling Module is available with tracking the state.
- Each component that makes up the Carrier Handling Module may experience mechanical failure. This can cause the entire Carrier Handling Module to be in an out of service state. Tracking time between failures would be valuable.

R1-3 Components to track performance of Carrier Handling Module

R1-3.1 Generally, a Carrier Handling Module has the following components.

- Carrier Handoff PIO (SEMI E84) Port
- Carrier Transfer Mechanism
- Carrier ID Reader
- Carrier ID Writer
- FOUP Opener
- Carrier Slot Mapper

R1-3.2 This section investigates the following composition to represent examples for Fixed Buffer type and Internal Buffer type equipment. An example of a Carrier Handling Module is illustrated in Figure R1-1. Number of installed components are listed in the Table 1.

Table R1-1 Typical Composition of Carrier Handoff Module

Number Installed	*Carrier Handoff PIO*	*Carrier Transfer Mechanism*	*Carrier ID Reader*	*Carrier ID Writer*	*FOUP Opener*	*Slot Mapper*
Internal Buffer Type	2	4	2	1	1	1
Fixed Buffer Type	2	2	2	2	2	2

Note: Several Carrier Transfer Mechanisms are usually docking mechanism for Fixed Buffer type. For Internal Buffer type, one of them is a Carrier Transfer Robot in internal buffer, one is a Docking Mechanism inside the internal buffer and the other one is Carrier Transfer Mechanism to pass carrier between Load Port and the Internal Buffer.

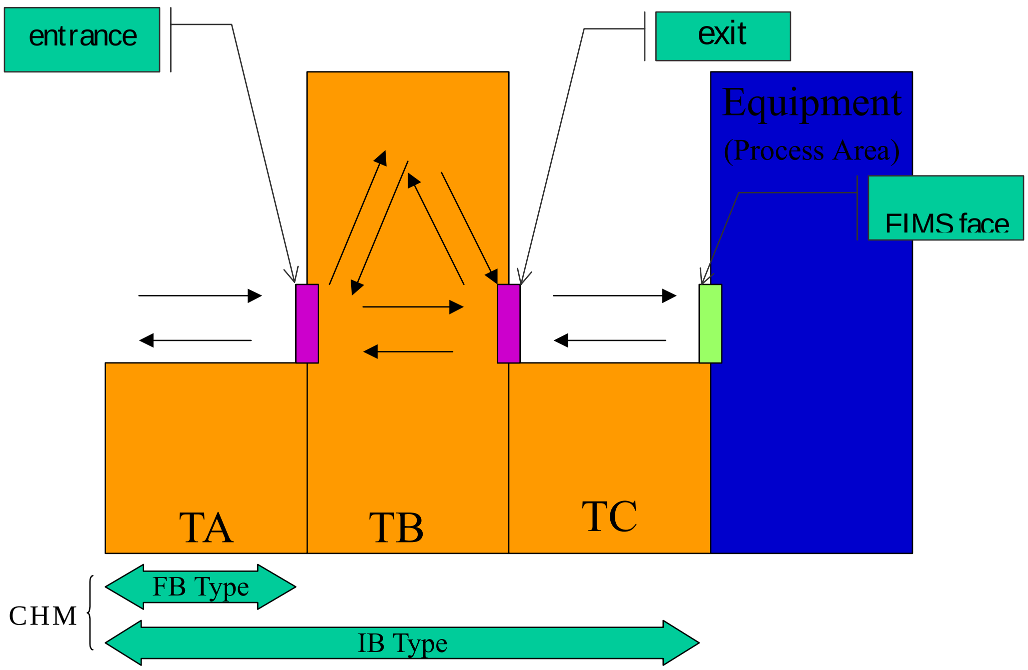


Figure R 1-1 Carrier Handling Module

<u>In Diagram R1-1, the following translation applies</u>
FB Type = Fixed Buffer Type
IB Type = Internal Buffer Type
TA = Transport A
TB = Transport B
TC = Transport C

R1-4 Triggers of Transition for each Components of Carrier Handling Module

The following tables describe triggers to change the state of components for specific tasks.

Table R1-2 Triggers of Transitions for specific tasks of Carrier Handoff PIO

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Receiving VALID signal in E84.	BUSY	Set off handoff sequence	Loading or Unloading sequence. Processing or moving wafers between carrier and process container before Unloading.
3	BUSY	Receiving COMPT signal in E84 or Timeout in handoff sequence.	IDLE	Waiting disconnected	Loading or Unloading sequence is completed or terminated. Processing or moving wafers between carrier and process container after Loading.

Table R1-3 Triggers of Transitions for specific tasks of Carrier Transfer Mechanism on Loadport of Fixed Buffer Type or FIMS port of IB

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Docking or Undocking Started	BUSY	None	Carrier moving sequence before docking. Processing or moving wafers between carrier and process container before undocking.
3	BUSY	Docking or Undocking Complete	IDLE	None	Processing or moving wafers between carrier and process container after docking.

Table R1-4 Triggers of Transitions for specific tasks of Carrier Transfer Mechanism in Internal Buffer Unit

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Transfer Started	BUSY	Moves carrier to destination	
3	BUSY	Transfer Complete	IDLE	None	Ready to unload or remove from port.

Table R1-5 Triggers of Transitions for specific tasks of Carrier ID Reader

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Reading Started	BUSY	None	Carrier moving sequence before reading.
3	BUSY	Reading Complete	IDLE	Verification	Processing or moving wafers between carrier and process container after opening.

Table R1-6 Triggers of Transitions for specific tasks of Carrier ID Writer

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Writing Started	BUSY	None	Processing wafers before writing.
3	BUSY	Writing Complete	IDLE	Waiting next writing or any post writing action	Carrier moving sequence after writing.

Table R1-7 Triggers of Transitions for specific tasks of FOUP Opener

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Opening or Closing Started	BUSY	None	Carrier moving sequence before opening.
3	BUSY	Opening or Closing Complete	IDLE	None	Processing or moving wafers between carrier and process container after opening.

Table R1-8 Triggers of Transitions for specific tasks of Slot Mapper

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
2	IDLE	Scanning Started	BUSY	None	Carrier moving sequence before mapping.
3	BUSY	Scanning Complete	IDLE	Waiting next scan	Processing or moving wafers between carrier and process container after mapping.

Table R1-9 Triggers of Transitions Common for all Components of Carrier Handling Module

#	*Previous State*	*Trigger*	*New State*	*Action(s)*	*Comment*
1	(no state)	Initialization is complete	IDLE	None	
7	BLOCKED	Get Recovered	IDLE	None	
8	IDLE	Unable to do task	BLOCKED	None	
9	BLOCKED	Get another Fault	BLOCKED	None	

R1-5 Operation Scenarios for Carrier Handling Module

R1-5.1 A couple of following scenarios are typical for different type of Carrier Handling Module.

R1-5.2 *Carrier Handling Module for Fixed Buffer Type*

R1-5.2.1 Beside the number of Loadports, following table shows just one set of components out of them.

R1-5.2.2 Indicated subsystems: PIO = Carrier Handoff PIO Port, CID-R = Carrier ID Reader, X'fer Transfer Mechanism = Carrier Transfer Mechanism (Docking Mechanism), CID-W = Carrier ID Writer, Opener = FOUP Opener, Mapper = Carrier Slot Mapper

Table R1-10 Scenario of Fixed type Carrier Handling Module

Event #	*Description*	*Time*	*PIO*	*CID-R.*	*X'fer Mech*	*CID-W*	*Opener*	*Mapper*
0	Carrier Handling Module and all components starting in "IDLE"	0:00	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE
1	Loading Started	0:30	BUSY	↑	↑	↑	↑	↑
2	Loading Completed	1:00	IDLE	↑	↑	↑	↑	↑
3	ID Reading Started	1:05	↑	BUSY	↑	↑	↑	↑
4	ID Reading Complete	1:10	↑	IDLE	↑	↑	↑	↑
5	ID Verification	-	↑	↑	↑	↑	↑	↑
6	Docking Started	1:20	↑	↑	BUSY	↑	↑	↑
7	Docking Complete	1:50	↑	↑	IDLE	↑	↑	↑
8	Opening Start	1:55	↑	↑	↑	↑	BUSY	↑
9	Opening Complete	2:25	↑	↑	↑	↑	IDLE	↑
10	Mapping Started	2:30	↑	↑	↑	↑	↑	BUSY
11	Mapping Complete	2:15	↑	↑	↑	↑	↑	IDLE
12	Slotmap Verification	-	↑	↑	↑	↑	↑	↑
13	Process Started	12:15	↑	↑	↑	↑	↑	↑
14	Process Completed	47:15	↑	↑	↑	↑	↑	↑
15	Writing Started	47:20	↑	↑	↑	BUSY	↑	↑
16	Writing Complete	48:10	↑	↑	↑	IDLE	↑	↑
17	Closing Start	48:10	↑	↑	↑	↑	BUSY	↑
18	Closing Complete	48:40	↑	↑	↑	↑	IDLE	↑
19	Undocking Started	48:45	↑	↑	BUSY	↑	↑	↑
20	Undocking Complete	49:15	↑	↑	IDLE	↑	↑	↑
21	Unloading Started	52:25	BUSY	↑	↑	↑	↑	↑
22	Unloading Complete	52:55	IDLE	↑	↑	↑	↑	↑
23	Carrier Handling Module and all components returning in "IDLE"	52:55	↑	↑	↑	↑	↑	↑

R1-5.3 *Carrier Handling Module for Internal Buffer Type*

R1-5.3.1 It is assumed that Carrier Slot Mapper and Carrier ID Writer are mounted at an FIMS port next to Internal Buffer located inside of the equipment. The following table shows the set of components of a single Loadport.

R1-5.3.2 Indicated subsystems: PIO = Carrier Handoff PIO Port, CID-R = Carrier ID Reader, X'fer A = Carrier Transfer Mechanism from Handoff position to Carrier In/Out position, X'fer B = Carrier Transfer Mechanism of Internal Buffer, X'fer C = Carrier Transfer Mechanism (Docking Mechanism) for internal FIMS port, CID-W = Carrier ID Writer, Opener = FOUP Opener, Map = Carrier Slot Mapper

Table R1-11 Scenario of Fixed type Carrier Handling Module

Event #	*Description*	*Time*	*PIO*	*CID-R.*	*X'fer A*	*X'fer B*	*X'fer C*	*CID-W*	*Opener*	*Map*
0	Carrier Handling Module and all components starting in "IDLE"	0:00	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE	IDLE
1	Loading Started	0:30	BUSY	↑	↑	↑	↑	↑	↑	↑
2	Loading Completed	1:00	IDLE	↑	↑	↑	↑	↑	↑	↑
3	ID Reading Started	1:05	↑	BUSY	↑	↑	↑	↑	↑	↑
4	ID Reading Complete	1:10	↑	IDLE	↑	↑	↑	↑	↑	↑
5	ID Verification	-	↑	↑	↑	↑	↑	↑	↑	↑
6	Transfer Started	1:20	↑	↑	BUSY	↑	↑	↑	↑	↑

Event #	*Description*	*Time*	*PIO*	*CID-R.*	*X'fer A*	*X'fer B*	*X'fer C*	*CID-W*	*Opener*	*Map*
7	Transfer Complete	1:35	↑	↑	IDLE	↑	↑	↑	↑	↑
8	Moving Started	1:40	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	2:25	↑	↑	↑	IDLE	↑	↑	↑	↑
10	Docking Started	2:30	↑	↑	↑	↑	BUSY	↑	↑	↑
11	Docking Complete	2:50	↑	↑	↑	↑	IDLE	↑	↑	↑
12	Opening Start	2:55	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Opening Complete	3:25	↑	↑	↑	↑	↑	↑	IDLE	↑
14	Mapping Started	3:30	↑	↑	↑	↑	↑	↑	↑	BUSY
15	Mapping Complete	3:15	↑	↑	↑	↑	↑	↑	↑	IDLE
16	Slotmap Verification	-	↑	↑	↑	↑	↑	↑	↑	↑
17	Wafer Moving Started	3:30	↑	↑	↑	↑	↑	↑	↑	↑
18	Wafer Moving Completed	7:00	↑	↑	↑	↑	↑	↑	↑	↑
12	Closing Start	7:05	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Closing Complete	7:20	↑	↑	↑	↑	↑	↑	IDLE	↑
21	Undocking Started	7:25	↑	↑	↑	↑	BUSY	↑	↑	↑
22	Undocking Complete	7:45	↑	↑	↑	↑	IDLE	↑	↑	↑
8	Moving Started	7:50	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	8:35	↑	↑	↑	IDLE	↑	↑	↑	↑
17	Process Started	16:15	↑	↑	↑	↑	↑	↑	↑	↑
18	Process Completed	147:15	↑	↑	↑	↑	↑	↑	↑	↑
8	Moving Started	146:30	↑	↑	↑	BUSY	↑	↑	↑	↑
9	Moving Complete	147:15	↑	↑	↑	IDLE	↑	↑	↑	↑
10	Docking Started	147:20	↑	↑	↑	↑	BUSY	↑	↑	↑
11	Docking Complete	147:40	↑	↑	↑	↑	IDLE	↑	↑	↑
19	Writing Started	147:45	↑	↑	↑	↑	↑	BUSY	↑	↑
20	Writing Complete	148:10	↑	↑	↑	↑	↑	IDLE	↑	↑
12	Opening Start	148:10	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Opening Complete	148:25	↑	↑	↑	↑	↑	↑	IDLE	↑
17	Wafer Moving Started	148:30	↑	↑	↑	↑	↑	↑	↑	↑
18	Wafer Moving Completed	152:00	↑	↑	↑	↑	↑	↑	↑	↑
12	Closing Start	152:05	↑	↑	↑	↑	↑	↑	BUSY	↑
13	Closing Complete	152:20	↑	↑	↑	↑	↑	↑	IDLE	↑
21	Undocking Started	152:25	↑	↑	↑	↑	BUSY	↑	↑	↑
22	Undocking Complete	152:45	↑	↑	↑	↑	IDLE	↑	↑	↑
23	Moving Started	152:50	↑	↑	↑	BUSY	↑	↑	↑	↑
24	Moving Complete	153:35	↑	↑	↑	IDLE	↑	↑	↑	↑
25	Transferring Started	153:40	↑	↑	BUSY	↑	↑	↑	↑	↑
26	Transferring Complete	153:55	↑	↑	IDLE	↑	↑	↑	↑	↑
27	Unloading Started	202:25	BUSY	↑	↑	↑	↑	↑	↑	↑
28	Unloading Complete	202:55	IDLE	↑	↑	↑	↑	↑	↑	↑
29	Carrier Handling Module and all components returning in "IDLE"	202:55	↑	↑	↑	↑	↑	↑	↑	↑

R1-6 Tracking Performance for Whole Carrier Handling Module

R1-6.1 Even composition and property of equipment are dependent on equipment type, operation and usage depends on equipment user. Because actual usage deeply affects the whole performance of the Carrier Handling Module and/or Equipment, the user is responsible for reconstructing the performance from performance tracking events for each component.

R1-7 EPT Module / Task Definition Example

R1-7.1 Figure R1-2 shows a simple module and the associated actions/tasks that correspond. The EPT Tasks have been diluted to the level that will allow a serial chain of tasks to occur. The Internal Tasks column is present to show that the equipment may have much more happening concurrently at a more detailed level. Table R1-12 shows a possible task-based process flow in this module.

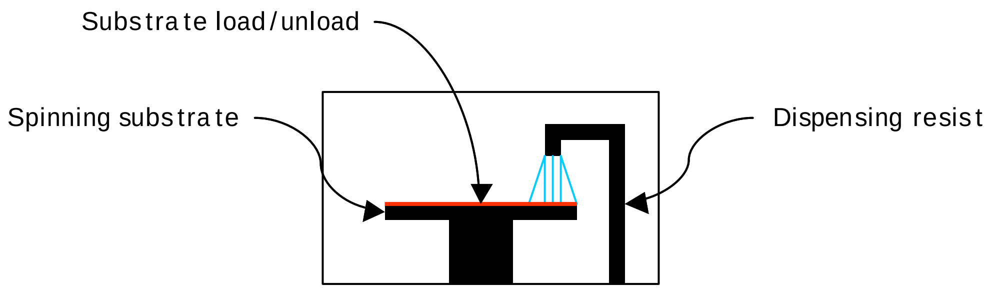


Figure R1-2
Example EPT Module

Table R1-12 Example EPT Tasks

Step	*Action*	*Possible Internal Tasks*	*EPT Active Task*
1	Loading the substrate	Receiving the substrate Substrate alignment	Substrate load
2	Coating the substrate	Substrate spin (accelerate) Substrate spin (steady) Dispense resist Substrate spin (decelerate)	Substrate coat
3	Unloading the substrate	Substrate alignment Substrate removal	Substrate unload

SEMI INTERNATIONAL STANDARDS

FACILITIES STANDARDS AND SAFETY GUIDELINES

Semiconductor Equipment and Materials International

SEMI F1-96
SPECIFICATION FOR LEAK INTEGRITY OF HIGH-PURITY GAS PIPING SYSTEMS AND COMPONENTS

NOTE: This entire document was revised in 1995.

1 Purpose

This specification defines the leak testing requirements and leakage rates for high-purity gas piping systems and components used in semiconductor manufacturing. It is also intended as an aid in the procurement and installation of equipment, materials, and services.

2 Scope

2.1 This specification applies to high-purity gas piping systems and components used in semiconductor manufacturing facilities and comparable research and development areas.

2.2 It includes testing methods for complete systems, subsystems, and individual components.

2.3 It states requirements for both the user and manufacturer and establishes leak rate limits for acceptance testing and qualification testing.

3 Limitations

3.1 This specification is not a replacement for safety regulations. It is the responsibility of the user to ensure that piping systems and components comply with all applicable safety regulations.

3.2 *Interferences*

3.2.1 Mass spectrometer leak testing with helium can result in misleading indications due to high permeability of polymeric materials by helium. Permeation is often indicated by a delayed leakage indication and a continually rising apparent leakage rate. Helium tracer gas under pressure is absorbed by permeable materials, and subsequent desorption can inhibit later testing at sensitive levels. Therefore, perform the tests in this order: inboard, internal, and outboard.

3.2.2 For low pressure tests, 1 MPa (147 psig) or less, the space to be filled with tracer gas must be purged or evacuated to avoid dilution. This applies both to enclosures and to the interiors of test objects.

3.2.3 Long tubing lines or small diameter tubing at an inlet may require purging to ensure that the tracer gas reaches the test object.

3.2.4 Conductance between the test object and the leak detector must be adequate to ensure test sensitivity. Restrictions such as regulators or check valves between the test object and the leak detector may require testing the test object before installing the downstream components.

3.2.5 Air flow can severely hinder capture of leaking gas by a detector probe. If possible, such air flow should be reduced to a minimum during testing. If testing must be performed in an area with substantial air flow, a protective film, such as is described in ASTM E 499, Method B, should be placed around the probe tip when examining each joint.

3.2.6 Temperature variations may affect leak performance. However, this specification does not address this effect.

4 Referenced Documents

All documents cited shall be the latest published revisions.

4.1 *SEMI Document*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 *ASTM Standards*[1]

E 493 — Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode

E 498 — Standard Methods of Testing for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode

E 499 — Standard Methods of Testing Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode

5 Terminology

5.1 *acceptance test* — A test conducted on each component, subsystem, or system produced. It is the basis for acceptance or rejection by the purchaser. The purpose of acceptance testing is to provide a check to ensure that the component, subsystem, or system has been properly assembled or manufactured.

5.2 *component* — An individual piece or a complete assembly of individual pieces capable of being joined

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

with other pieces or components. The typical components referred to by this specification are valves, fittings, regulators, pressure gauges, pressure and flow sensors, and tubing welded to fittings.

5.3 *design pressure* — Of a system or subsystem, the pressure at the most severe condition of internal and external pressure expected during normal service. The maximum pressure expected in any portion of a system or subsystem is typically determined by the maximum adjustable setting of the last pressure regulator that supplies it, the supply pressure to the regulator, or the actuation pressure of any relief device incorporated.

5.4 *high-purity* — Of a system, subsystem, or component used for the control of chemicals (gases or liquids), designed and constructed in such a manner that it does not introduce significant impurities, particulate or molecular, into the flow stream it controls or regulates.

NOTE: Such systems, subsystems, or components are designed and constructed such that, if an impurity is introduced into the flow path, it can be readily purged to an insignificant level.

5.5 *leak* — A path (or paths) in a sealed system that will pass tracer gas when a pressure differential or diffusion path exists. There are two leak mechanisms: a mechanical passage and a material through which gas can diffuse or permeate. A leak may have both mechanisms operating in parallel.

5.6 *leakage, inboard* — Leakage from outside to inside occurring when the internal pressure is less than the external pressure acting on a component. Inboard leakage is typically determined by introducing a tracer gas around the exterior of the piping system or component under test.

NOTE: Inboard leak tests are easier tests to conduct to high sensitivity levels, but are typically not indicative of pressurized operating conditions. It is difficult to correlate an inboard leak test to the performance of a component, subsystem, or system when under internal pressure. Also, the internal collapsing forces created by external pressure may mask leaks which may exist under pressurized operating conditions.

5.7 *leakage, internal* — Leakage occurring within a component across a flow barrier, such as the seat of a closed valve.

5.8 *leakage, outboard* — Leakage from inside to outside occurring when the internal pressure is greater than the external pressure acting on a component. Outboard leakage is typically determined by introducing a tracer gas into the interior of the piping system or component under test.

5.9 *may* — A term indicating that a provision is neither required nor prohibited by this specification.

5.10 *measured leak rate* — The rate of leakage of a given component, subsystem, or system measured under specific conditions and employing a tracer gas.

NOTE: When testing with high-pressure 100% helium on a mass spectrometer leak detector, measured leak rates must be converted to equivalent standard leak rates.

5.11 *qualification test* — A test conducted on samples of production articles manufactured to a single design to establish the performance rating of a product. The tests are extensive and closely controlled and completely analyze the characteristics of a component for use in a high-purity installation.

5.12 *rated pressure* — The manufacturer's recommended maximum allowable operating pressure at the manufacturer's rated temperature.

5.13 *shall* — A term indicating that a provision is a requirement of this specification.

5.14 *should* — A term indicating that a provision is recommended as good practice but is not a requirement of this specification.

5.15 *shutoff valve* — A valve designed for, and capable of, positive closure to prevent flow within a system. Typical shutoff valves include manually actuated, power-actuated, or spring-actuated, fail-safe shutoff valves. Generally excluded are self-actuated valves such as check valves, pressure regulators, flow controllers, and other devices not intended to provide positive shutoff.

5.16 *standard leak rate* — The flow of helium at 21.1°C (70°F) and 101.3 kPa (1 atm) through a leak when the partial pressure of helium on the high side is 101.3 kPa and the partial pressure on the low side is below 133 Pa (1 torr).

NOTE: Express leak rates in kiloPascal-liters per second (kPa-L/sec). Calculate the standard leak rate of helium from the measured leak rate by multiplying by the ratio of 101.3 kPa to the partial pressure of helium, as follows:

$$\text{Standard} = \frac{101.3\ \text{kPa}(1\ \text{atm}) \times \text{measured leak rate}}{\text{actual He partial pressure}}$$

5.17 *subsystem* — An assembly of two or more components manufactured as a single entity. A subsystem must be combined with one or more additional components or subsystems to form a complete system. The typical subsystems referred to by this specification are gas source manifolds, gas distribution manifolds, and gas control manifolds within the process equipment.

5.18 *system* — An integrated structure of components and subsystems capable of performing, in aggregate, one or more specific functions. For the purpose of this specification, a system includes the gas source manifold, its connection to the gas source, the distribution piping, and the gas control manifold within the process equipment.

6 Ordering Information

Orders for equipment or services requiring leak testing in accordance with this specification shall include:

a. This specification number and date of issue.

b. Acceptance test requirements and applicable test paragraphs of this specification for the specific product being purchased.

c. Qualification test requirements, if any, and applicable test paragraphs of this specification for the specific product being purchased.

d. The design pressure to be used for internal and outboard leakage testing of systems, subsystems, or components.

e. Whether certification of the qualification or acceptance tests and a report of test results is required.

7 Requirements

7.1 *Personnel Qualifications* — Personnel performing tests in accordance with this specification shall have suitable training and experience. Such personnel should, as a minimum:

a. be trained and experienced in the use of mass spectrometer leak detectors,

b. be familiar with the use of the ASTM test methods referenced by this specification, and

c. be familiar with the operation and calibration of the specific equipment used in performing the tests.

7.2 *Tests*

7.2.1 Prior to initial operation, test each component, subsystem, and system in accordance with this specification.

7.2.2 If repairs or additions are made after the leakage tests, retest the affected portions of the component, subsystem, or system.

7.3 *Test Conditions*

7.3.1 All joints, including welds, shall be uninsulated, unpainted, and exposed for examination during the test.

7.3.2 Isolate portions of a system that are not being tested during the test.

7.3.3 Tracer gas pressure shall not exceed the manufacturer's pressure rating.

7.3.4 Conduct leakage tests at a temperature between 18°C (64°F) and 26°C (78°F).

7.4 *Leak Rate Limits*

Table 1

Direction	*Component*	*Component*	*Subsystem*		*System*	
	kPa - L/sec	*atm - cc/sec*	*kPa - L/sec*	*atm - cc/sec*	*kPa - L/sec*	*atm - cc/sec*
Inboard	10^{-10}	10^{-9}	10^{-9}	10^{-8}	10^{-10} (per point)	10^{-9}
Internal	10^{-10}	10^{-9}	10^{-10}	10^{-9}	10^{-10}	10^{-9}
Outboard	10^{-10}	10^{-9}	10^{-9}	10^{-8}		1 ppm
			(or 1 ppm increase in atmospheric concentration if by probe method)		1 ppm increase in atmospheric concentration	

NOTES:

a. The internal leakage specifications apply only if the test object is rated for positive closure.

b. The internal leakage specification applies to each positive closure. If positive shutoff devices are in parallel, the specification applies to the parallel devices as a group.

c. When piping systems or components employ polymeric seals, the internal and outboard leak rates specified above shall be modified by multiplying the stated values by 100.

d. When new construction projects preclude measurement of outboard leakage at the leak rates specified above, the outboard leakage limits shall be modified by multiplying the stated values by 100.

8 Test Methods

8.1 *Dangers*

8.1.1 Testing of systems, subsystems, or components with high pressure gas could cause explosive rupture of these items, with the resulting fragmentation causing death or serious injury. In addition, if a component of the system under test were to fail, an unrestricted supply of tracer gas could cause pressurization and rupture of the test enclosure. Such testing shall not be performed without shielding that will protect the operator and other personnel in the event of equipment failure. The source of tracer gas should be provided with a suitable device that will limit or shut off the flow in the event of component rupture.

8.1.2 Some elements of a piping system may not be designed for pressurization. Pressurization of such system elements could cause explosive rupture, with the resulting fragmentation causing death or serious injury. Such elements shall not be tested in a manner inconsistent with the manufacturer’s specifications. Valves used to isolate these elements of systems must be rated for higher pressure than the proposed test pressure.

8.1.3 Some components may be designed for closure only in one direction or only under pressure or vacuum. Testing of such components in a manner other than that for which they are designed could cause explosive rupture, with the resulting fragmentation causing death or serious injury. Such components shall not be tested in a manner inconsistent with the manufacturer’s specifications.

8.2 *Tracer Gas* — (Unless otherwise specified in Sections 8.4 through 8.6.)

8.2.1 For those tests in which the test object is enclosed in or sprayed with tracer gas, 100% helium.

8.2.2 For those tests in which the test object is pressurized with tracer gas, 101.3 kPa (1 atm) of helium plus nitrogen to pressurize to the design pressure.

8.2.3 The use of helium with a purity level of less than 100 ppb total contaminants and filtered at point of use to less than 0.1 µm is required.

8.2.4 Inboard tests are performed at one atmosphere.

8.2.5 Internal and outboard tests are performed at the design pressure.

8.3 The use of a dry, oil-free helium mass spectrometer leak detector is recommended to prevent hydrocarbon contamination of the piping system or component during inboard and internal leak testing.

8.4 *Components*

8.4.1 *Inboard*

8.4.1.1 *Reference Method* — ASTM E 498, Method A. Component acceptance shall be based upon total component integrity in accordance with ASTM E 498, Article 6.8. Components that are too large to enclose in a single helium envelope may be enclosed in segments to determine total integrity.

8.4.1.2 Test each component for total inboard leakage by introducing helium into a bag or other enclosure around the component. Ensure that the enclosure is sufficiently well-purged of air to minimize dilution of the helium. In instances where the bagging technique is not practical, the inboard leakage method of Section 8.6.1.2 may be substituted.

8.4.1.3 *Test Time* — Monitor the leak rate for 15 seconds.

8.4.2 *Internal–Qualification Test*

8.4.2.1 *Reference Method* — ASTM E 498, Method A. Connect the outlet side of the closed component to the leak detector. Apply tracer gas at the component's design pressure to the inlet side. Inlet and outlet sides shall be as designated by the manufacturer.

8.4.2.2 *Tracer Gas* — 100% helium.

8.4.2.3 *Test Time* — Monitor the leak rate for 15 seconds.

8.4.3 *Internal–Acceptance Test*

8.4.3.1 *Reference Method* — ASTM E 498, Method A. Connect the outlet side of the closed component to leak detector. Apply tracer gas at atmospheric pressure to the inlet side. Inlet and outlet sides shall be as designated by the manufacturer.

8.4.3.2 *Tracer Gas* — 100% helium.

8.4.3.3 *Tracer Gas Pressure* — Atmospheric.

8.4.3.4 *Test Tim* — Monitor the leak rate for 15 seconds.

8.4.4 *Outboard—Method 1*

8.4.4.1 *Reference Method* — ASTM E 498, Method B, modified as follows:

a. Cap the outlet of the component with a high integrity fitting.

b. For valves and regulators, open the flow path through the component. Install the component in a vacuum chamber. A leak tight gas flow passage must extend from the test component to the exterior of the vacuum chamber.

c. Connect the leak detector to the vacuum chamber and evacuate the chamber.

d. Pressurize the test component.

NOTE: Special fixtures may be required to test components with tube stub ends to insure personnel safety and to prevent component damage.

8.4.4.2 *Test Time* — Maintain the test condition for one minute.

8.4.5 *Outboard–Method 2* — Same as for Method 1, except use 100% helium as the tracer gas.

8.4.6 *Unassembled Components*

8.4.6.1 Components that are assembled by the purchaser, rather than the manufacturer, or that are altered or repaired by the purchaser, shall be tested by the purchaser in accordance with this specification.

8.4.6.2 Test of such components by the purchaser shall not be performed under conditions that exceed the manufacturer's ratings.

8.5 *Subsystems*

8.5.1 *Inboard*

8.5.1.1 *Reference Method* — ASTM E 498, Method A. Subsystem acceptance shall be based upon total subsystem integrity in accordance with ASTM E 498, Article 6.8.

8.5.1.2 Test for total inboard leakage by introducing helium into a bag or other enclosure around the subsystem. Ensure that the enclosure is sufficiently well-purged of air to minimize dilution of the helium. In instances where the bagging technique is not practical, the inboard leakage method of Section 8.6.1.2 may be substituted.

8.5.1.3 Test time should be based on actual times to record a standard capillary leak placed at the furthest point in the subsystem from the leak detector.

8.5.1.4 Subsystems that are too large to enclose in a single helium envelope may be tested in segments to determine total integrity.

8.5.2 *Internal—Method 1*

8.5.2.1 *Reference Method* — ASTM E 498, Method A, modified as follows:

a. Close the shutoff valve and pressurize the inlet with tracer gas.

b. Connect the leak detector to the closest point available to the valve outlet. Keep the evacuated portion of the subsystem as small as practicable.

8.5.2.2 Test each subsystem for internal leakage of each shutoff valve.

8.5.2.3 Test time should be based on actual times to record a standard capillary leak placed at the furthest point in the subsystem from the leak detector.

8.5.3 *Internal—Method 2* — As in Method 1, except use 100% helium as the tracer gas.

8.5.4 *Outboard——Method 1*

8.5.4.1 *Reference Method* — ASTM E 493, Method B, modified such that the subsystem shall be prefilled and maintained at constant pressure during the test.

NOTE: The pressure may be different for different portions of the subsystem.

8.5.4.2 *Test Time* — Monitor the leak rate for 15 seconds.

8.5.5 *Outboard——Method 2*

8.5.5.1 *Reference Method* — ASTM E 499, Method A, direct probing. Examine each joint with a detector probe.

8.6 *Systems*

8.6.1 *Inboard*

8.6.1.1 *Reference Method* — ASTM E 498, Method A.

8.6.1.2 Test each system for total inboard leakage by spraying a small stream of tracer gas around each point of possible leakage.

8.6.1.3 Test time should be based on actual times to record a standard capillary leak placed at the furthest point in the system from the leak detector.

8.6.2 *Internal*

8.6.2.1 *Reference Method* — ASTM E 498, Method A, modified as follows:

a. Close the shutoff valve and pressurize the inlet with tracer gas.

b. Connect the leak detector to the closest point available to the valve outlet. Keep the evacuated portion of the subsystem as small as practicable.

8.6.2.2 Test each subsystem for internal leakage of each shutoff valve.

8.6.2.3 Test time should be based on actual time to record a standard capillary leak placed at the furthest point in the subsystem from the leak detector.

8.6.3 *Internal—Method 2* — Same as in Method 1, except use 100% helium as the tracer gas.

8.6.4 *Outboard*

8.6.4.1 *Reference Method* — ASTM E 499, Method A, Direct Probing. Each joint shall be examined with a detector probe.

9 Certification

When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that the articles furnished have been tested in accordance with applicable paragraphs of this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10 Related Documents

10.1 *ANSI Standard*[2]

ANSI/ASME B31.3 — Chemical Plant and Petroleum Refinery Piping

10.2 *ASTM Standards*[3]

ASTM E 425 — Standard Definitions of Terms Relating to Leak Testing

ASTM E 479 — Standard Guide for Preparation of a Leak Testing Specification

10.3 *Other Document*[4]

McMaster, Robert C., ed., Nondestructive Testing Handbook, 2nd ed., Volume One: Leak Testing.

2 American National Standards Institute, 1430 Broadway, New York, NY 10018

3 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4 American Society for Nondestructive Testing, 4153 Arlingate Plaza, Caller Number 28518, Columbus, OH 43228

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SEMI F2-94
SPECIFICATION FOR 316L STAINLESS STEEL TUBING FOR GENERAL PURPOSE SEMICONDUCTOR MANUFACTURING APPLICATIONS

1 Purpose

The purpose of this specification is to identify the applicable ASTM tubing specification requirements and to define the special material chemical composition requirements for 316L stainless steel tubing which is to be used for general purpose applications in semiconductor manufacturing facilities.

2 Scope

This specification covers grades of nominal-wall-thickness stainless steel tubing as designated in Table 1 of ASTM A 269, for use in chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities and in comparable research and development areas.

3 Referenced Documents

The referenced documents are to be their current editions as published by their sponsors.

3.1 *ASTM Standards*[1]

A 262 — Practices for Determining Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 269 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 450/A 450M — Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 632 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service

E 112 — Methods for Determining Average Grain Size

3.2 *Military Standards*[2]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-753 — Corrosion Resistant Steel Parts: Sampling, Inspection and Testing for Surface Passivation

3.3 *ANSI/ASME Standards*[3]

B31.1 — Power Piping

B31.3 — Chemical Plant and Petroleum Refinery Piping

B46.1 — Surface Texture: Surface Roughness, Waviness, and Lay

Boiler and Pressure Vessel Code — Section III NCA, The Rules for Construction of Nuclear Power Plant Components

3.4 *ISO Standards*[4]

ISO 9000 — Quality Management and Quality Assurance Standards

4 General Requirements

Material furnished under this specification shall conform to the requirements of ASTM A 269 for nominal sizes 1/2 inch diameter and larger and to the requirements of ASTM A 632 for nominal sizes smaller than 1/2 inch diameter, and to the additional requirements herein.

5 Ordering Information

5.1 Orders for material under this specification shall include the following, as required to describe the material adequately:

- Quantity (meters, feet, or number of lengths)
- Grade (per Table 1 of ASTM A 269)
- Size (nominal outside diameter and nominal wall thickness)
- This specification number
- Surface condition (if applicable)
- Special requirements and any supplementary requirements selected

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

4 International Organization for Standardization, 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland

6 Process

6.1 The steel shall be processed in accordance with the section on Process of ASTM A 269.

7 Manufacture

Tubing shall be made by the seamless process and must be cold finished.

8 Heat Treatment

8.1 All tubing shall be furnished in the heat treated condition in accordance with the section on Heat Treatment of ASTM A 269. If grain size is restricted by the supplementary requirement specified in Section 17.3 of this specification, the minimum annealing temperature shall not apply, provided that the tubing passes the intergranular corrosion test of Section 13 of this specification.

8.2 All tubing shall be vacuum annealed, or bright annealed in an unmixed hydrogen atmosphere, followed by rapid cooling. The adequacy of the cooling rate shall be confirmed by the intergranular corrosion test of Section 13 of this specification.

9 Surface Condition

9.1 *Inside Surface* — The tubing shall be supplied with a cold finished and annealed inside surface having a maximum surface roughness as specified in the order.

9.2 *Outside Surface* — The outside surface of the tubing shall have a commercial mill finish unless otherwise specified by the purchaser.

9.3 *Surface Roughness* — When specified as per Section 9.1 or 9.2, surface roughness shall be measured in accordance with ANSI B46.1, using a stylus-type instrument and a cutoff of 760 µm (0.030 inches). Results reported shall be Roughness Average (R_a), expressed in micrometers or microinches.

10 Cleanliness

10.1 Tubing shall be supplied in accordance with the supplementary requirement for Cleanliness of ASTM A 632.

10.2 Tubing surface shall be free of any metallic iron that can be detected by either Method 102 or Method 103 of MIL-STD-753.

11 Chemical Composition

11.1 Chemical composition of the steel shall conform to the requirements of the section on Chemical Composition of ASTM A 269 for nominal sizes 1/2 inch diameter and larger and to the section on Chemical Composition of ASTM A 632 for nominal sizes smaller than 1/2 inch diameter.

11.2 Sulfur content shall be 0.003% to 0.010% for all nominal sizes.

12 Mechanical Properties

12.1 Tubing shall conform to the applicable requirements of ASTM A 450/A 450M unless otherwise provided herein.

12.2 Hardness of all sizes shall conform to the section on Hardness Requirements of ASTM A 269.

12.3 Tensile properties of all sizes shall conform to the section on Mechanical Properties of ASTM A 632.

13 Metallurgical Requirements

Tubing shall pass an intergranular corrosion test conducted in accordance with the supplementary requirement for Intergranular Corrosion Test of ASTM A 262. A minimum of two samples per lot shall be tested.

14 Nondestructive Testing Requirement

14.1 Eddy current testing shall be performed in accordance with the procedure and evaluation outlined in the section on Nondestructive Electric Test of ASTM A 450/A 450M except that the calibration reference notches shall not exceed 10% of the specified wall thickness of the tubing or 0.075 mm (0.003 inches), whichever is greater. If the form of product supplied makes this test technically infeasible, alternative non-destructive testing methods shall be agreed upon by the purchaser and supplier.

14.2 At the option of the purchaser, hydrostatic testing shall be conducted and evaluated in accordance with the requirements of the section on Hydrostatic Test of ASTM A 450/A 450M.

15 Permissible Variations in Dimensions

Sampling for dimensional variations shall be performed in accordance with MIL-STD-105 with double normal sampling and a 2 1/2% Acceptable Quality Level (AQL). The permissible variations in dimensions shall be as outlined in Table 3 of ASTM A 269 for nominal sizes 1/2 inch diameter and larger and in Table 3 of ASTM A 632 for nominal sizes smaller than 1/2 inch diameter. Dimensions shall apply after treatment of the inside surface if the supplementary requirements listed in Section 17.1 or 17.2 of this specification are specified.

NOTE: The supplementary requirements listed in Section 17.1 or 17.2 of this specification may remove significant amounts of material. Purchasers should allow for such material removal when specifying dimensions of tubing prior to supplementary surface treatments.

16 Quality Assurance Requirements

The supplier's quality assurance program shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, NCA-3800 or of ISO 9000.

17 Supplementary Requirements

The following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order.

17.1 *Electropolished Inside Surface* — The tubing shall be supplied with an electropolished inside surface having a maximum surface roughness as specified on the order.

17.2 *Alternative Finish (Inside Surface)* — The purchaser may specify alternate chemical treatment for the inside surface. Such treatment shall not promote grain boundary attack; the intergranular corrosion test requirement of Section 13 shall apply after chemical treatment.

17.3 *Restricted Grain Size* — At the option of the purchaser, ASTM grain size number may be restricted to 7 or finer, per ASTM E 112, provided that a maximum hardness lower than that given in the section on Hardness Requirements of ASTM A 269 is not also imposed.

18 Certification

18.1 The supplier shall provide the following reports and certifications with all shipments of tubing:

18.1.1 Type of tubing (seamless or welded)

18.1.2 Size (nominal outside diameter and wall thickness)

18.1.3 Material composition report shall be provided to verify the above required grade, sulfur content, and grain size

18.1.4 Tubing provided in accordance with this specification shall be mill and heat traceable, and permanently etched for correspondence to the applicable mill test reports.

SEMI F3-94
GUIDE FOR WELDING STAINLESS STEEL TUBING FOR SEMICONDUCTOR MANUFACTURING APPLICATIONS

1 Purpose

1.1 The purpose of this guide is to provide instructions to increase the awareness of the user to the available procedures for welding stainless steel gas distribution systems, and to provide information from which subsequent evaluations and standardization can be derived.

2 Scope

2.1 This guide covers the general requirements for the welding of stainless steel gas distribution systems.

3 Referenced Documents

NOTE: The following documents become part of the guide to the extent that they are included herein.

3.1 The referenced documents are to be their current edition as published by their sponsors.

3.2 SEMI Specification

SEMI F2 — Specification for 316L Stainless Steel Tubing for General Purpose Semiconductor Manufacturing Applications

3.3 *ANSI/ASME Specifications*[1]

B16.25 — Butt Welding Ends

B31.3 — Chemical Plant and Petroleum Refining Piping

Boiler and Pressure Vessel Code — Section IX, Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators

3.4 *AWS Specification*[2]

AWS D10.9 — Specification and Qualification of Welding Procedures and Welders for Piping and Tubing

3.5 *ASTM Specification*[3]

A450 (Section 25) — General Requirements for Carbon, Ferritic Alloy, and Austenitic Steel Tubes

1 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

2 American Welding Society, 550 NW LeJeune Road, P.O. Box 351040, Miami, Florida 33135

3 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4 General Requirements

4.1 All welding performed under this guide should conform to the applicable requirements of the ASME Boiler and Pressure Vessel Code, Section IX, ANSI B16.25, B31.3 Chapter V, and AWS D10.9, to the extent that they are included herein.

5 Materials

5.1 All materials to be welded should be manufactured to ASTM specifications and so certified by the manufacturer. Certification should conform to ASTM A-450, Section 25.

5.2 All seamless austenitic stainless steel tubing should be in conformance with SEMI F2.

6 Testing of Welders

6.1 All welds should be based upon Welding Procedure Specifications and be documented with associated Procedure Qualification Records in accordance with ASME Boiler and Pressure Vessel Code, Section IX, or with AWS D10.9.

6.2 Qualification of the welding procedures to be used, and of the performance of welders and welding operators, should conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section IX, Articles II and III, or AWS D10.9.

7 Welding Procedure

7.1 *Component Preparation*

7.1.1 All weld end preparation should be done in such a manner as to minimize the introduction of contaminants into the system.

7.1.2 All cutting of component or tubing weld ends should be done with a sharp-edged tool. No lubricants of any kind should be allowed.

7.1.3 All component and tubing weld ends that are to be cut should be de-burred without chamfering.

7.1.4 All welding ends requiring preparation for procedures requiring the use of filler material should be prepared in accordance with ANSI/ASME B16.25.

7.1.5 Surfaces for welding should be clean and should be free from oxidation, discoloration, oil, scale, chips, or other material that is detrimental to welding.

7.1.6 All components should be maintained in a clean condition until welded into the system.

7.2 *Welding Requirements*

7.2.1 Welding equipment used to make welds should be operated in accordance with the manufacturer's operating and safety instructions.

7.3 *Welding Procedures*

7.3.1 Prior to the welding of a particular size, wall thickness, alloy, and heat of material, sample welds should be made, dissected, and analyzed.

7.3.2 These welds should be checked for poor penetration, joint contamination, joint soundness, surface oxidation, discoloration, pitting, cracking, defects of fit-up, or defects of workmanship.

7.3.3 Once a sample weld is found to be acceptable, the sample weld should be the on-site work sample against which other welds of the same size, wall thickness, alloy, and heat of material are judged. All essential and supplementary essential variables should be documented in the procedure qualification record.

7.3.4 Any significant deviation(s) from the on-site work sample (7.3.3) will cause the weld(s) to be rejected. Rejected welds should be removed and replaced.

7.3.5 Sample test welds should be made periodically. These tests should be compared to the on-site work sample (7.3.3). Deviation from the on-site work sample should be cause for rejection. The sample test welds should be made at/when:

1. The beginning of each shift.
2. The end of each shift.
3. Any change in welding procedure, materials, tubing size, equipment, or equipment adjustments are made.
4. Any time that a concern or deviation to the weld quality has occurred.

7.3.6 Sample test welds should be kept on file and may be reviewed at any time during the construction.

7.3.7 Where a weld is found defective, the preceding two welds should be tested as indicated in Paragraph 7.3.2. If either of these welds shows signs of poor penetration, joint contamination, lack of joint soundness, surface oxidation, discoloration, pitting, cracking, defects of fit-up, or defects of workmanship, then all welds made since the last welding procedure was established should be removed and replaced.

7.4 *Weld Set-up*

7.4.1 Check parameters and verify that they are in accordance with the qualified welding procedure.

7.5 *Purging*

7.5.1 During welding, all tubes, fittings, valves, sub-assemblies, and all other components should be continuously purged.

7.5.2 Automatic orbital head welding equipment should supply a constant gas-backing shield to the weld head during welding.

7.5.3 During all welding, a sufficient amount of purge/shield gas should be maintained until the weld head is removed from the newly welded parts.

7.5.4 Both purge/shield gas supply lines should contain flow indicators to ensure proper purging.

7.6 *Weld Identification*

7.6.1 A daily log should be maintained on all welds, and as-built drawings recording all data should be maintained in the welding area.

7.6.2 All welds should be identified with a code number and cross-referenced with the drawings for future evaluation.

7.7 *Additional Requirements*

7.7.1 Maintain sufficient distance between weld joints and valve seats to avoid damage to valve seats or valve stem tips.

APPENDIX 1
SAMPLE WELDING SPECIFICATION

NOTE: This related information is not an official part of this SEMI guide and is not intended to modify or supercede the official guide. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

A1-1 General

A1-1.1 The entire piping system will be kept under a continuous purge until all welding is complete.

A1-1.2 All tools and fixtures used for the assembly and welding shall be maintained clean and shall not be removed for use outside of the Class 100 preparation area.

A1-2 Tubing Preparation Requirements

A1-2.1 Use only tools and handling techniques that will not mar, disturb the shape of, or in any way reduce the quality of the materials used in this system.

A1-2.2 Tubing must be under inert gas purge during the cutting and end-facing/truing operation.

A1-2.3 Tube ends shall be covered while the purge is removed using a technique that will minimize the amount of infiltration or contamination. Covers shall be of non-particulating material.

A1-2.4 Cut ends shall be de-burred and faced to be square to an appropriate tolerance, per orbital welding equipment manufacturer's recommendation. The tubing shall not be scratched during de-burring. Abrasive wheels shall not be used. A lathe, milling, or portable end prep tool that clamps to the exterior of the tube is permitted.

A1-2.5 Make all necessary preparations for installing tubing and tube sub-assemblies so that exposure of the interior surface to atmosphere is minimized.

A1-2.6 Tubing and tube sub-assemblies shall be mechanically fitted into place, dimensionally verified, clearances verified, welding parameters set, and all pre-weld procedures completed in readiness to begin the welding process prior to removing protective covers.

A1-3 Welding Process Requirements

A1-3.1 Welding shall be by the gas tungsten arc welding (GTAW) process with backing shielding and inside tubing purge. All stainless steel tubes shall be joined using an automatic orbital butt-welding machine.

A1-3.2 During welding, all gas lines must be continuously purged.

A1-3.2.1 Stainless steel tubing purge lines shall be used. Flow measurement and control shall be with a clean rotameter.

A1-3.2.2 Weld shield purge gas shall be filtered with a 0.01 µm filter connected to the inlet bulkhead fitting of the welder.

A1-3.3 Every weld shall be tagged, logged, and inspected.

A1-3.3.1 A daily log shall be maintained on all welds and an as-built isometric drawing recording all data shall be maintained in the welding area.

A1-3.3.2 All welds shall be identified with a code number and cross-referenced with the isometric drawings for future evaluation.

A1-3.4 As much welding as is feasible will be performed in the preparation area in the form of sub-assemblies.

A1-3.5 Alignment of tubing of nominal size 2" in diameter and larger for orbital welding shall be by an external clamping jig where space permits.

A1-3.6 Valves shall be located so as to allow space to operate the valve after installation at the job site.

A1-4 Welding Procedure Requirements

A1-4.1 All materials, testing of welders, and welding procedures shall comply with the requirements of SEMI F3.

A1-4.2 Set up the fabrication in a suitable preparation area or at the job site.

A1-4.3 Make all necessary preparations for installing tube and tube sub-assemblies such that exposure of the interior surface to atmosphere is minimized. Insure that there is purge flow prior to welding.

A1-4.4 On tubes larger than a nominal size of 1/2", place a reducing cap on the discharge end of the tube with a 12-mm (0.5") or smaller outlet.

A1-4.5 Insert the tube ends into the orbital tube weld holder for butt-welding.

A1-4.6 Perform only one weld joint at a time.

A1-4.7 The completed sections of the piping system should never be without positive purge pressure and flow to all system extremities. System extremities should *not* be capped in such a way as to permit purge flow to stop. This purge must be maintained at all times, including overnight and during weekends and breaks.

A1-4.8 Sub-assemblies, after completion, shall be purged and covered for subsequent installation in the field.

A1-4.9 A backing shield (purge through the weld head) is required during welding.

A1-4.10 Where a weld is found defective, the preceding two welds should be tested as described in Paragraph 7.3.2 of SEMI F3. If either of these welds shows signs of poor penetration, joint contamination, lack of joint soundness, surface oxidation, discoloration, pitting, cracking, defects of fit-up, or defects of workmanship, then all welds made since the last welding procedure was established should be removed and replaced.

A1-4.11 On-site work sample welds shall be made before each series of welding operations. On-site sample welds shall also be made at the start of each workday and any time any welding parameter is changed.

A1-4.12 Sample test welds shall be made periodically. These tests shall be compared to the on-site work sample. Deviation from the on-site work sample shall be cause for rejection. The sample test welds shall be made at/when:

1. The beginning of each shift.
2. The end of each shift.
3. Any change in welding procedure, materials, tubing size, equipment, or equipment adjustments are made.
4. Any time a concern or deviation to the weld quality has occurred.

A1-4.13 If the system becomes contaminated due to a fabrication technique, the contaminated sections shall be re-cleaned.

A1-4.14 Welding at the job site shall be enclosed in a clean work area.

A1-4.15 When the welding is performed in a clean envelope, the envelope shall have openings for the tube to extend in two directions, a clean polyester film window, and openings for the hands. HEPA-filtered air shall be supplied to the envelope under pressure to ensure a clean working environment.

A1-4.16 The envelope shall be installed prior to removal of the tube caps. Full purge through the tube to be welded shall be completed before removing the clean envelope to attach the weld head.

A1-4.17 Final positioning of the weld head and weld process shall be performed within the clean envelope.

APPENDIX 2
HEXAVALENT CHROMIUM ALERT

NOTE: This related information is not an official part of this SEMI guide and is not intended to modify or supercede the official guide. It has been derived from the cited document. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

A2-1 General

A2-1.1 Hexavalent chromium, which is given off when stainless steel is welded, causes lung cancer in humans. For information about hexavalent chromium, refer to HESIS Hazard Alert, June 1992, Hazard Evaluation System & Information Service, California Occupational Health Program, 2151 Berkeley Way, Annex 11, Third Floor, Berkeley, CA 94704.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F4-1000
SPECIFICATION FOR PNEUMATICALLY ACTUATED CYLINDER VALVES

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilites Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available on SEMI OnLine September 2000; to be published October 2000. Originally published in 1990; previously published February 2000.

1 Purpose

1.1 This specification establishes the minimum design and performance requirements for pneumatically actuated cylinder valves used in semiconductor manufacturing. It is also intended as an aid in the procurement of these valves.

2 Scope

2.1 This specification applies to pneumatically actuated valves for use on cylinders containing gases used in semiconductor manufacturing facilities and in comparable research and development areas.

2.2 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification is not a replacement for safety regulations. It is the responsibility of the user to ensure that pneumatically actuated cylinder valves comply with all applicable safety regulations.

3.2 This specification excludes design or performance requirements for any electrically operated devices used in conjunction with, or as a replacement for, pneumatic actuators.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

SEMI F19 — Specification for the Finish of the Wetted Surfaces of Electropolished 316L Stainless Steel Components

SEMI F20 — Specification for 316L Stainless Steel Bar, Extruded Shapes, Plate and Investment Castings for Components Used in High Purity Semiconductor Manufacturing Applications

SEMI F32 — Test Method for Determination of Flow Coefficient for High Purity Shutoff Valves

SEMI S5 — Safety Guideline for Flow Limiting Devices

4.2 *ASME Document*[1]

B1.1 — Unified Inch Screw Threads (UN and UNR Thread Form)

4.3 *CGA Standards*[2]

CGA G-4.1 — Cleaning Equipment for Oxygen Service

CGA S-1.1 — Pressure Relief Device Standards - Part 1 - Cylinders for Compressed Gases

CGA S-7 — Method for Selecting Pressure Relief Devices for Compressed Gas Mixtures for Cylinders

CGA V-1 — Compressed Gas Cylinder Valve Outlet and Inlet Connections

CGA V-9 — Compressed Gas Association Standard for Compressed Gas Cylinder Valves

4.4 *ISO Standards*[3]

ISO 68 — General Purpose Screw Threads - Basic Profile

ISO 261 — General Purpose Metric Screw Threads - General Plan

4.5 *US Code of Federal Regulations*[4]

Title 49 CFR, Parts 100–199 —Transportation

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Definitions*

5.1.1 *burst pressure* — a pressure at which rupture or uncontrolled leakage of one or more of the pressure retaining components of the device occurs.

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1 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

2 Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202

3 International Organization for Standardization, Case Postale 56, Geneve 20, CH-1211, Switzerland

4 Department of Transportation, Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, D.C. 20402-9328

5.1.2 *cylinder* — a pressure vessel designed for pressures higher than 276 kPa (40 psia), having a circular cross-section, and a maximum water capacity of less than 454 kg (1,000 lbs.). It does not include a portable tank, multi-unit tank car tank, cargo tank, or tank car.

5.1.3 *cylinder valve* — a mechanical device attached to a compressed gas cylinder that permits flow into or out of the cylinder when the device is in the open position and prevents flow when in the closed position.

5.1.4 *disconnect shutoff* — a device, which will not permit the flow of gas through an open cylinder valve without attachment to an outlet connector.

5.1.5 *flow coefficient* (Cv) — a numeric constant used to characterize the flow capacity of a valve.

5.1.6 *manual locking device* — a device used to prevent the cylinder valve from opening during transportation or service.

5.1.7 *manual override* — a device used for opening the cylinder valve manually.

5.1.8 *normal temperature* — a temperature of 21°C ± 6°C (70°F ± 10°F).

5.1.9 *normally closed* — a design in which the cylinder valve closure member automatically assumes the closed position upon loss of compressed gas to the actuator.

5.1.10 *packless valve* — a valve with a diaphragm or bellows stem seal instead of a packing or O-ring seal at the stem.

5.1.11 *pneumatic actuator* — a device which converts compressed gas pressure into mechanical motion and force to move the cylinder valve closure member.

5.1.12 *proof pressure* — a pressure greater than the cylinder valve's rated pressure that the cylinder valve can withstand without impairing its ability to meet the leak rate limits specified in SEMI F1 upon return to rated pressure.

5.1.13 *rated pressure* — the pressure at which the cylinder valve can meet the performance and qualification requirements of this specification. Rated pressure shall be specified by the manufacturer.

5.1.14 *valve closure member* — that part of the cylinder valve which is positioned in the flow stream to permit or obstruct flow, depending on its closure position.

5.1.15 *wetted surface* — surface within the interior of the cylinder valve, which is in contact with the controlled gas. The surface in contact with the gas used to actuate the cylinder valve is not, for the purpose of this specification, considered a "wetted surface".

6 Design Requirements

6.1 *General* — Components not covered by this specification or CGA Standards shall be constructed such that they do not compromise the safety, substantiality, and durability of the valve or actuator.

6.2 *Configuration* — The cylinder valve shall be a packless valve design with a normally closed actuator.

6.3 *Size* — The cylinder valve and actuator shall be of a design size which permits the use of a protective transportation cover which satisfies the requirements of 49 CFR Section 173.40(d)(2).

6.4 *Materials* — Ferrous materials used for the wetted surfaces shall be per SEMI F20. Other materials may be supplied to satisfy specific material or performance requirements, provided they are compatible with the gas service.

6.5 *Inlet* — The inlet of the cylinder valve shall have tapered external threads as specified by CGA V-1 or other recognized governmental or industry standards for the connection of cylinder valves to gas cylinders.

6.6 *Outlet* — The outlet of the cylinder valve shall conform to a CGA 630/710 series connection in accordance with CGA V-1 or other recognized governmental or industry standards for the outlet connections of gas cylinder valves.

6.7 *Actuator Pressure* — The actuating pressure required to open the cylinder valve fully shall not exceed 550 kPa (gauge) (80 psig).

6.8 *Manual Override* — A manual override shall be supplied.

6.9 *Vents* — Vent hole(s) for mass spectrometer helium leak testing shall be supplied at appropriate locations.

6.10 *Internal Volume* — The wetted surfaces should be configured, and the internal volume minimized, to enhance the efficacy of purging.

6.11 *Particle Control* — The design should minimize accumulation and generation of particles.

6.12 *Threaded Fasteners* — Threaded fasteners used in the covers, housings, casings, and any external mounting brackets shall have threads conforming to, as applicable, the ASME B1.1, ISO 68, or ISO 261 standards.

6.13 *Cleanliness* — The cylinder valve and actuator shall be cleaned, as a minimum, per CGA Standard G-4.1.

7 Optional Design Requirements

7.1 *Flow Limiting Device* — Provision for limiting flow, per SEMI S5, shall be supplied when specified.

7.2 *Pressure Relief Devices* — Pressure relief devices must be required in accordance with CGA S-1.1 or S-7.

7.3 *Disconnect Shutoff* — A disconnect shutoff shall be supplied when specified.

7.4 *Manual Locking Device* — A manual locking device shall be supplied when specified.

7.5 *Electropolish* — Cylinder valves shall be electropolished per SEMI F19 when specified.

7.6 *Cleanliness* — Cleaning above the minimum requirements of CGA G-4.1 may be specified.

7.7 *Position Indicator* — A device for visual confirmation of open or closed position may be specified.

8 Qualification Requirements

8.1 *General* — Any new cylinder valve design or substantially revised cylinder valve design shall be tested prior to production to demonstrate compliance with this specification.

8.1.1 *Leakage* — Cylinder valves shall be leak tested using the methods and leak rate limits specified in SEMI F1 for qualification of components.

8.1.2 *Operating Temperature Range* — The cylinder valves shall perform satisfactorily at any temperature between -40°C (-40°F) and 55°C (131°F).

8.2 *Qualification Cylinder Valve Samples* — Nine cylinder valves shall be selected at random from the pre-production manufacturing phase of the product for qualification to this specification.

a. One cylinder valve shall be used for the Flow Coefficient and Transportation Vibration Tests.

b. Three cylinder valves shall be used for the Pressure Tests.

c. Three cylinder valves shall be used for the Endurance Test.

d. Two cylinder valves shall be used for the Tip-Over Tests.

8.3 *Flow Coefficient Test* — The flow coefficient of a fully open cylinder valve tested without a flow restrictor shall be a minimum of 0.1. The method of test for determining the flow coefficient shall be as prescribed by SEMI F32.

8.4 *Transportation Vibration Test* — After being subjected to vibration for one hour at a frequency of 3400 to 3600 vibrations per minute at an amplitude of 0.8 mm (0.031 in.) to 1.6 mm (0.063 in.), the cylinder valve shall not exceed the inboard, outboard, and internal leak rate limits specified.

8.5 *Pressure Tests*

8.5.1 *Back Pressure* — The cylinder valve shall not exceed the internal leak rate limits specified in SEMI F1 with the cylinder valve closed, the rated pressure applied at the outlet, and the inlet connected to the leak detector.

8.5.2 *Proof Pressure* — The proof pressure at normal temperature shall be a minimum of 1.67 times the rated pressure. Tests shall be conducted following the back pressure test with the cylinder valve open, the outlet capped, and the pressure relief port capped or plugged. After exposure to an aerostatic proof pressure for ten minutes, the cylinder valve shall not exceed the inboard, internal, and outboard leak rate limits specified in SEMI F1.

8.5.3 *Burst Pressure* — The burst pressure at normal temperature shall be a minimum of three times the rated pressure. Tests shall be conducted hydrostatically following the proof pressure test with the cylinder valve open, the outlet capped, and the pressure relief port capped or plugged. Visible outboard leakage is not permitted during the burst test. After testing, the cylinder valve need not be functional.

8.5.3.1 *Pressure Rating Determination* — The rated pressure shall be less than or equal to the pressure determined from the burst pressure test as follows:

$$P \leq 0.33BT_m/T_a$$

Where:

P = Rated pressure

B = The lowest burst pressure recorded for the three specimens tested

T_a = The actual tensile strength of the failed test specimen material obtained from Certified Material Test Reports.

T_m = The specified minimum tensile strength of the failed specimen material.

NOTE 2: The factor of T_m/T_a is included to normalize between the particular steel stock from which the test specimens were made and the minimum tensile strength of the specified steel.

8.6 *Endurance Test* — The cycle life of the cylinder valve shall be at least 5,000 operational cycles. During and after 5,000 operations, the cylinder valve shall not exceed the inboard, internal, and outboard leak rate limits specified in SEMI F1. A cycle shall consist of one opening and one closing of the cylinder valve.

8.6.1 Cylinder valves shall be operated alternately through minimum and maximum temperatures specified in Section 8.1.2 in 1000 cycle increments until completion of the specified number of cycles. The first thermal cycle shall take the cylinder valves to maximum temperature. Cylinder valves shall be at thermal equilibrium while mechanically cycling. Initially, and at the completion of every 1000 cycles, the cylinder valves shall not exceed the inboard, internal, and outboard leakage tests specified in SEMI F1 at normal temperature.

8.6.2 The cylinder valve inlet pressure shall be the cylinder valve rated pressure. Cylinder valves shall be cycled at a rate of one cycle per ten seconds, equally divided between opening and closing. During the off cycle, the cylinder valve's downstream pressure shall be allowed to decay to 50% or less of the inlet pressure.

8.7 *Tip-Over Test* — After being subjected to tip-over tests the cylinder valves shall show no evidence of structural damage, shall not exceed the inboard, internal, and outboard leak rates specified in SEMI F1, and shipping caps or other protective devices shall be able to be removed or adjusted so that the valve can be operated.

8.7.1 Tip-over testing shall be conducted in accordance with CGA V-9, Section 5.2.6.4.

8.7.2 The tip-over tests shall be performed with the cylinder valve installed on a 166 kPa (2400 psig), 250 mm (10 inches) diameter by 1550 mm (61 inches) long (including cap) gas cylinder, or onto a smaller cylinder if the valve is restricted by the manufacture for use on the smaller cylinder.

8.7.3 A shipping cap or other protective device shall be installed onto the cylinder during the tip-over tests. If a special cap or protective device is used it shall conform to the requirements of CGA V-9, Appendix E-49 CFR cylinder drop protocol.

9 Manufacturing Requirements

9.1 *Acceptance Testing*

9.1.1 Each cylinder valve shall be acceptance tested for inboard, internal, and outboard leakage per SEMI F1.

9.1.2 Each actuator shall be tested for leakage of less than 1 sccm at 550 kPa (80 psig).

9.1.3 Each cylinder valve shall be visually inspected for cleanliness, damage, proper markings, and actuator function, as a minimum.

9.2 *Marking* — Each cylinder valve shall be permanently identified with the following minimum information:

9.2.1 Manufacturer's name or logo.

9.2.2 Manufacturer's part number or part number code.

9.2.3 Outlet type (CGA number or other specification identification).

9.2.4 Pressure relief device marked in accordance with CGA pamphlet S-1.1 or other specification identification.

9.2.5 Manufacturer's serial number or code that will provide traceability for materials, test data, and assembly date.

9.2.6 Flow limiting information when the flow limiting device is integral to the cylinder valve and not intended for removal.

9.3 *Traceability* — The manufacturer shall use a program to qualify raw materials, parts, assemblies, and purchased components and to provide traceability of all components (manufactured or purchased) used in production of cylinder valves.

9.4 *Instructions*

9.4.1 Clear, concise instructions and diagrams stated in terms clearly understandable and adequate for proper installation and safe operation shall be provided with each cylinder valve.

9.4.2 Instructions for periodic maintenance or repair, as required, shall be made available by the manufacturer. No repairs or maintenance shall be conducted without these instructions. Parts that require replacement shall be identified.

9.5 *Maintenance* — Ideally, the cylinder valve shall be capable of fulfilling the performance and qualification requirements of this specification after any of the maintenance procedures specified by the cylinder valve manufacturer. Maintenance shall be performed by only those persons the cylinder valve manufacturer deems qualified.

10 Related Documents

10.1 *Military Specification*[5]

MIL-DTL-2E — Valves, Cylinder, Gas

5 Military Specification, Commanding Officer, Naval Publications and Forms Center, Attention: MPFC 105, 5801 Tabor Avenue, Philadelphia, PA 19120

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F5-1101
GUIDE FOR GASEOUS EFFLUENT HANDLING

This guide was technically approved by the Global Environmental Health & Safety Committee and is the direct responsibility of the North American Environmental Health & Safety Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1990.

NOTICE: This document, as balloted, is intended to replace SEMI F5-90 in its entirety.

NOTICE: Paragraphs entitled "NOTE" are not an official part of this guide and are not intended to modify or supersede the official guide. These have been supplied by the Task Force to enhance usage of the guide.

1 Purpose

1.1 The purpose of this guide is to provide the semiconductor industry with the general knowledge and background information for understanding the principles of exhaust systems.

1.2 It includes suggestions for layout and selection as well as application of appropriate methods and equipment for abating emissions.

1.3 This guide is intended for use in abatement selection for both gaseous and particulate contaminant materials potentially emitted from semiconductor manufacturing facilities.

2 Scope

2.1 *Applicability* — This guide presents a review and evaluation of available information including:

- Chemical and physical properties of chemical compounds and elements, that are, or may be, released from semiconductor manufacturing operations,
- Some current industry practices for separating exhaust systems for different groups of materials,
- Potential methods for abating emissions of gaseous and particulate contaminants exhausted from semiconductor manufacturing operations at "End-of-Pipe",
- Potential methods for abating emissions of gaseous and particulate contaminants exhausted from semiconductor manufacturing processes at "Point-of-Use" and reasons why they should be used for some processes,
- Standard industry methods of recovery, replacement, and "usage reduction" for minimizing release of materials.

2.2 *Contents* — This document contains the following sections:

2.3 This guide does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guide makes only a few recommendations regarding the fire protection aspects of exhaust systems. Additional recommendations on the risk assessment of systems, compatibility of materials, and the potential need for use of non-combustible materials or the fitting of fire detectors, sprinklers etc., are within the scope of other documents.

3.2 Methods for treating solid or liquid waste (created by emission abatement processes) and methods for recovery of gases are not discussed in this document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S5 — Safety Guideline for Flow Limiting Devices

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

4.2 *Code of Federal Regulations* — United States Environmental Protection Agency[1]

40 CFR Part 63 (Clean Air Act 112 (b)(1))

4.3 *Uniform Codes*[2]

Uniform Fire Code — Article 80 — Hazardous Material

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — Chemical Vapor Deposition

5.1.2 *EPI* — epitaxial deposition

5.1.3 *HAP* — Hazardous Air Pollutants [as defined by 40 CFR Part 63 (Clean Air Act 112 (b)(1))

5.1.4 *PFC* — perfluorocompounds

5.1.5 *POU* — Point of use

5.1.6 *VOC* — Volatile Organic Compounds

5.2 *Definitions*

5.2.1 *classification of emissions* — understanding the composition of process exhausts.

5.2.2 *efficiency* — the ratio (or fraction or proportion) of removed chemical species to its input amount

5.2.3 *End-of-Pipe Abatement* — abatement technologies that can be fitted at the discharge point of the exhaust system.

5.2.4 *flow capacity* — the maximum flow any specific equipment can handle.

5.2.5 *occupational exposure limits (OELs)* — for the purpose of this document, OELs are generally established on the basis of an eight-hour workday. Various terms are used to refer to OELs, such as permissible exposure levels, Threshold Limit Values®, maximum acceptable concentrations, maximum exposure limits, and occupational exposure standards. However, the criteria used in determining OELs can differ among the various countries that have established values. Refer to the national bodies responsible for the establishment of OELs. (Threshold Limit Value is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.2.6 *Point-of-Use Abatement* — abatement technologies that can be fitted at the point of discharge of the gaseous emission from semiconductor process equipment. These devices are also called exhaust conditioners.

5.2.7 *removal capacity* — amount of a species which can be removed.

5.2.8 *usage reduction* — reducing the total volume of process chemicals requiring abatement.

6 Philosophy

6.1 Gaseous mixtures potentially emitted from numerous processes could also produce hazards within exhaust ducts.

6.2 With increasing legal requirements worldwide on both worker safety and general environmental protection, more effective exhaust management is required.

6.3 This demands a detailed understanding of the chemical and physical properties of the chemical compounds being emitted from processes, and of the conditions under which they are released.

6.4 Careful design of the abatement systems is required to attain both high efficiency and maximum economy.

7 Classification of Emissions

7.1 The following fundamental points regarding exhaust emissions should be considered:

- Exhaust contaminants might be solely the material used in the process (e.g., isopropyl alcohol (IPA) from a rinse chamber)
- In plasma and thermal chambers many reactions occur, both those desired and others; therefore by-products are also key components of exhaust emissions.
- In theory, most possible combinations of the elements in the input gases may be found as compounds in the exhaust. In practice, the main components will be the unused process gas (the percentage consumed in the process varies, and

1 United States Government Code of Federal Regulations, free from the web site at http://www.epa.gov

2 International Conference of Building Officials (ICBO), 5360 Workman Mill Road, Whittier, CA 90601-2298

may be as low as 10%). Additional by-products will have different and sometimes more hazardous properties.

7.2 Considerable research has been conducted into various hazardous by-products of processes, from explosive solids to organochlorine compounds with mutagenic properties. (See Sections 13.1 through 13.3.)

7.3 In considering selection of exhaust systems and abatement technology, it is essential to review all the materials likely to be present in the exhaust.

7.4 Contributions from the materials on the wafer must also be considered, as they often cause blocked exhausts (e.g., aluminum etches produce aluminum chloride (a by-product of removal of aluminum from the wafer with chlorinated gases)).

7.5 Processes that produce specific hazardous by-products should be evaluated for appropriate point-of-use abatement technology before discharge to an exhaust system.

7.6 Gaseous and particulate contaminants emitted from semiconductor manufacturing can be divided conveniently into nine major groups, each of which *might* justify its own exhaust system.

7.6.1 *Group-1 Acid* — Easily hydrolyzable acids, (e.g., hydrogen chloride hydrolyzes into hydrochloric acid.)

7.6.2 *Group-2 Acid aerosols ("difficult–to-scrub")* — This group includes acids that generate aerosols and that are not easily removed by simple water scrubbers (e.g., aqua regia, sulfuric and nitric).

NOTE 2: High concentrations of easily soluble acids will also fall into the "difficult-to-scrub" category.

7.6.3 *Group-3 Ammonia* — Exhaust streams containing ammonia

7.6.4 *Group-4 Volatile Organic Compounds (VOCs)* — Exhausts containing volatile organic compound vapors or flammable gas discharge requiring destruction.

7.6.5 *Group-5 Pyrophoric* — Exhausts containing pyrophoric gases.

7.6.6 *Group-6 Emergency Release Discharges* — Enclosures are provided with additional exhausts to contain sudden unanticipated releases of gas from cylinders, etc.

7.6.7 *Group-7 Special/Direct* — Additional exhausts used to keep specific gases separate for recovery purposes (e.g., hydrogen (H_2) reclamation from EPI or PFC reclamation from CVD tools, Oxides of Nitrogen (NO_x)).

7.6.8 *Group-8 General Exhaust Systems without End-of-Pipe Treatment* — Exhaust of heat or post-treatment exhaust from POU abatement systems.

7.6.9 *Group-9 Highly Toxic Gas Exhaust* — Highly toxic gases especially those with poor warning properties (e.g., arsine, phosphine, diborane, germane). The end user has a primary responsibility to prevent discharge of these gases above a regulated level (e.g., usually one-half (1/2) of Immediately Dangerous to Life and Health (IDLH) levels).

NOTE 3: Facility exhaust systems may be called by a number of different names such as: Acid, Corrosive, Ammonia, Scrubbed, VOC, Solvent, Incinerated, Highly Toxic, Toxic, Dedicated, Special, PFC, General, Heat, Treated, or others. The actual facility exhaust system name, and what groups are routed to each system, will vary by factory and by country.

7.7 The groups listed in Section 7.6 are not a definitive division, but represent a summation of common industry practice for separation. The division is based on three basic principles:

- avoiding mixing of incompatible gases in the exhaust,
- potential need for different end-of-pipe abatement technologies, and,
- keeping materials separate for recovery.

7.8 The number of separate exhaust systems used is entirely a decision for each facility, based on the following:

- processes and chemicals used,
- the number of each type of process,
- whether recovery of gases is required,
- whether point-of-use (POU) abatement is installed, and
- compatibility of emissions with each other or the effluent handling system.

7.9 In theory, if POU abatement systems are fitted to all sources of gaseous effluent all exhaust could then be combined into a single exhaust system.

7.9.1 In practice most facilities operate a compromise between the two extremes with two to four separate exhaust systems and point-of-use abatement systems fitted only to certain sources. The decision (as to which combination to use) will often be based on economic and space constraints.

7.9.2 Safety and environmental factors listed below, should always be considered first when determining specific gaseous sources that require POU abatement systems.

7.10 Many types of process equipment use and exhaust incompatible gases sequentially (e.g., silane and then nitrogen trifluoride (NF_3) as elements of a deposition and cleaning cycle).

7.10.1 With more than one of these processes being discharged asynchronously into a common exhaust duct, undesired reactions may occur.

7.10.2 It is possible to avoid this problem by fitting the equipment outlet with three-way valves to divert the discharge to the correct exhaust system, depending on equipment process step. Three-way valves may not be necessary if pump ballast-gas flow is increased to dilute gases.

7.10.2.1 Switching must accurately account for the gas transmission times from process chamber inlet to the exhaust valve.

7.10.2.2 Introduction of additional mechanical devices could create major hazards, reliability, and service or maintenance issues.

7.10.2.3 Valves must incorporate failsafe designs to ensure pump outlet is not shut off.

7.10.3 An alternative solution is to fit a local POU abatement system that treats at least one component and is not adversely affected by the other components.

7.11 *Point-of-Use (POU) Abatement Devices*

7.11.1 POU abatement devices are designed to operate at the process tool or pump outlet, and to remove hazardous gases BEFORE they enter the exhaust ductwork.

7.11.2 An end-of-pipe scrubber does not protect the facility from reactions in the ductwork. Reactions between process gases, as discussed above, or reactions with other process by-products within the ductwork itself are not prevented by end-of-pipe systems either.

7.11.3 POU abatement devices may be appropriate wherever the exhaust gases can react in the ductwork.

7.11.4 If process systems are not treated with POU abatement devices, the higher concentrations of hazardous gases will present a higher risk during a leak into the facility space.

7.11.5 Improperly functioning POU abatement devices can create backpressure that can increase the risk of a leak.

7.12 Four significant consequences can be foreseen from effluent gas reactions in the ductwork:

7.12.1 *Blocked Ducts* — Reactions between gases, or condensation of vapors, can produce solids and semi-solids (such as crystals, slurries or gels) that will block the ductwork.

7.12.1.1 Collection of solids can create dead leg sections that may contain reactive byproducts or unused raw materials. Catastrophic release of these trapped materials could generate a significant hazard.

7.12.1.2 Extensive downtime (for clean out, or ducts collapsing under the weight of accumulated solids) is a possible undesirable outcome of this condition.

7.12.1.3 Solids deposited (such as from metal etching) can, themselves, be both corrosive and hazardous, leading to health risks for people performing cleaning in ductwork. (See Related Documents 13.1 through 13.3).

7.12.1.4 Blocked ducts may result in toxic process gases or by products escaping into the work area.

7.12.2 *Duct Corrosion* — Etching and some chamber cleaning process emissions are corrosive. Both metallic (including stainless steel) and plastic ducting can be attacked, resulting in the release of hazardous gas or condensed liquids into the workplace.

7.12.3 *Duct Fires or Explosions* — Flammable and pyrophoric gases can ignite in the ductwork. If the ductwork is combustible or has flammable or combustible deposits in it (e.g., hydrocarbon pump oil), facility fires can result.

7.12.4 Additional information on protection of Industrial Exhaust systems from fires may be found in FM Global Loss Prevention Data Sheet 7-78, "Industrial Exhaust Systems".

NOTE 4: Destruction of whole production lines with multi-million dollar cost impact has resulted from such incidents.

7.12.5 *Formation of Ammonium Compounds* — If ammonia is discharged into a duct with acid compounds, a sub-micron ammonium compound fume can be generated, that is not easily removed by end-of-pipe systems.

7.12.5.1 The result is visible discharges.

7.12.5.2 Ammonium compounds produce solids in the duct.

7.13 If any of the above reactions can occur in the process exhaust, POU abatement should be considered.

7.14 Exhausts of oil-lubricated vacuum pumps should be fitted with well-maintained oil mist separators/ filters.

7.15 POU abatement devices may also be needed upstream of the recovery device for the recovery of some gaseous compounds (e.g., hydrogen (H_2), PFC gases).

8 End-of-Pipe Abatement Technologies

8.1 *Group 1 — Acid Abatement*

8.1.1 The appropriate abatement technology for this category is commonly called " wet scrubbing."

8.1.2 Many, if not all, of the semiconductor processes have traditionally been exhausted through centralized wet scrubbers.

8.1.2.1 This procedure has limited technical acceptability and may not meet the requirements of all regulatory agencies.

8.1.2.2 This technology should be targeted at abatement of acid gases, vapors, mists, and fumes emitted from CVD, dry etching, and wet chemical operations.

8.1.2.3 Most wet chemical processes are typically carried out under local exhaust ventilation devices, such as fume hoods, or in specially designed rooms that are totally exhausted. These types of operations include:

- Processes used to clean wafers or clean wafer handling equipment (such as quartz components, tubing),
- Processes used in wafer fabrication for surface treatment such as oxide, silicon nitride and other surface treatments, (e.g., metal etching), and
- Processes used for development of positive photoresist.

8.1.2.4 The chemical species emitted depends on both the chemicals used in the processes and the conditions of use.

8.1.2.5 Volatile acids (e.g., hydrochloric (HCl), hydrofluoric, nitric, and acetic) yield corresponding gases and vapors, especially when heated.

8.1.2.5.1 The reaction of hydrochloric and nitric acids in aqua regia yields nitrosyl chloride (NOCl) vapor and elemental chlorine (Cl_2) gas.

8.1.2.5.2 When sulfuric acid is heated, it yields both sulfuric acid vapor (H_2SO_4) and sulfur trioxide (SO_3).

8.1.2.5.3 Phosphoric acid (H_3PO_4) is not significantly volatile, but spray may be carried over into the exhaust system by mechanical entrainment.

8.1.2.5.4 Under appropriate conditions, spray droplets of any of the chemicals used may be mechanically entrained into the ventilation air exhausted from the various processes.

8.1.3 Design and selection of scrubbing equipment for the acid exhaust systems must take into account both the chemical and physical properties of the materials being emitted.

8.1.4 The principles involved in collection of particulate matter (including liquid aerosols) are entirely different from those determining absorption of gases.

8.1.5 *Current Practice*

8.1.5.1 Exhausts carrying acid compounds comprise the largest volume of air discharged from a typical semiconductor manufacturing plant.

8.1.5.2 The current practice is to connect most or all of the corrosive sources to a central building exhaust system and to discharge the combined gas streams to one or more large wet scrubbers.

8.1.5.2.1 A variety of scrubber types might be used, but the two main types are cross-flow and counter-current scrubbers equipped with packing material of some type.

8.1.5.3 The scrubbers usually are fed with a stream of water (potable, recycled, etc.).

8.1.5.4 A side stream of water is bled from the scrubber to a wastewater line.

8.1.5.5 It is futile to discharge organic solvents to water scrubbers even if the organic solvents are, to some degree, soluble in water.

8.1.5.5.1 Any dissolved organic solvent will eventually be desorbed from the water and will escape to the atmosphere, or be discharged as wastewater. Additionally, these organics could serve to propagate biological growth in the scrubber.

8.1.5.6 Exhausts from process tools are frequently discharged to the appropriate building exhaust systems, either with or without point-of-use abatement.

8.1.5.7 Arsine and phosphine, which have only slight solubility in water, pass through the water scrubbers so that the effect of discharging these gases into the building scrubber system is limited to dilution. Fluorine and chlorine also have limited solubility in water and may pass through water scrubbers without sufficient abatement. POU abatement devices should be considered for these types of gases.

8.1.5.8 Preliminary oxidation of these and numerous other process gases results in formation of fine fumes and other aerosols that will be collected with only low efficiencies by the typical large, low-energy wet scrubbers.

8.1.5.9 If ammonia is discharged into a system that also carries hydrogen chloride, hydrogen fluoride, nitric acid, or sulfuric acid; it will react, in the vapor phase, to form sub-micron solid aerosols of ammonium chloride, ammonium fluoride, ammonium nitrate, or ammonium sulfate, respectively.

8.1.5.10 Any exhausts carrying ammonia should be discharged to a separate scrubber or a point-of-use ammonia abatement used at the process discharge.

8.1.6 *Chemistry of Pollutants*

8.1.6.1 Effective abatement of any compound requires careful consideration of the chemistries and physical states of the specific compounds being abated.

8.1.6.2 The packed-bed scrubbers commonly employed should generally be adequate for absorption of readily soluble gases, if appropriate operating conditions are also maintained.

8.1.6.3 Misuse can negate the potential performance of the scrubbers.

8.1.6.4 As scrubbers are low-energy devices (pressure drops on the order of 2.5 to 10 cm (1-4 inches) of water, they are incapable of effectively collecting fine aerosols such as the ammonium salts mentioned above.

8.1.6.5 The most economic design approach, therefore, is to arrange the exhaust system and use POU abatement devices to avoid formation of such aerosols, where possible.

8.1.6.6 The practice of using only recirculated water in the scrubber, to absorb acid vapors and to neutralize the water bleed stream should be reviewed to ensure that scrubber efficiency is not affected.

8.1.6.7 Acid gases, such as hydrogen chloride and hydrogen fluoride, are readily soluble in water. The partial pressure of acid gases in equilibrium with the solution, which increases with increasing solute concentration, reduces the absorption of additional gas. Reduction in absorption can be minimized by increasing the rate of water blow-down (i.e., using more fresh water make-up).

8.1.6.8 However, increasing the rate proportionately increases the consumption of water and the volume of water that must be treated before discharge as wastewater.

8.1.6.9 The introduction of an alkaline solution (e.g., sodium hydroxide) in the scrubber can assist in removing compounds from the gas stream if the use of water alone does not provide adequate removal efficiencies. The use of additives in the scrubber can, in itself, create safety and environmental concerns.

8.1.6.10 Some of the neutralized absorbent must be bled off from the recirculated stream to prevent the brine concentration from reaching an excessively high level, but water consumption and the volume of waste can still be reduced by alkaline solution.

8.1.6.11 Aqua regia is a reactive mixture of nitric and hydrochloric acids. The reaction produces nitrosyl chloride and elemental chlorine:

$$HNO_3 + 3HCl \rightarrow NOCl + Cl_2 + 2H_2O$$

8.1.6.12 The nitrosyl chloride vapor is readily decomposed by absorption in an alkaline solution:

$$NOCl + 2NaOH \rightarrow NaNO_2 + NaCl + H_2O$$

8.1.6.13 Elemental chlorine has only a limited solubility in water, and an alkaline solution (pH > 10) must be used to attain adequate absorption efficiencies:

$$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$$

8.1.6.14 During the initial reaction of the nitric and hydrochloric acids, hydrogen chloride gas and nitric acid vapors are volatilized along with the nitrosyl chloride and chlorine.

8.1.6.15 Nitrogen dioxide may also be produced by decomposition of nitric acid.

8.1.6.16 All these compounds can be absorbed, to some degree, in an alkaline solution.

8.1.6.17 If a pollutant is in a particulate form (solid or liquid), its collection is only slightly affected by its chemical nature or solubility.

8.1.6.18 The dominant factor determining particulate collectability is particle size.

8.1.6.19 Abatement of particulate compounds requires a high-energy method (usually creating an extremely high pressure-drop across the abatement device) which can be costly in both energy and abatement device size requirements.

8.1.7 *Scrubber Design and Selection*

8.1.7.1 A variety of commercially available scrubbers are applicable to absorption of readily soluble gases.

8.1.7.2 These include packed-bed counter-current, co-current, and horizontal cross-flow scrubbers, horizontal spray chambers, vertical spray towers, and gas-atomizing scrubbers such as the venturi scrubber.

8.1.7.3 To some extent, the choice of scrubber type is a matter of preference, as it is usually possible to obtain equivalent performance on the soluble gases with different types of devices; however, more packing or higher liquid loading may be required on some devices.

8.1.8 The choice is likely to be limited by a consideration of practical or economic factors such as cost, available space, and weight (e.g., it is possible to reduce the size of the scrubber, usually at the cost of increased energy consumption).

NOTE 5: See Appendix 1 for absorber design criteria.

8.2 *Group 2 — Acid Aerosols*

8.2.1 Part of acid emissions may be in the form of mists (fine droplets or aerosols) rather than gases. These may be composed of relatively non-volatile acids such as phosphoric and sulfuric acids.

8.2.1.1 The mechanisms of removal of particulate matter (including liquid aerosols) from gas streams are entirely different from those involved in the absorption of gases (See Sections 13.1 through 13.3).

8.2.1.2 The critical factor in the collection process is the particle size of the mist. If the mist is relatively coarse, as apparently is the case in most instances, the same types of scrubbers that are used for gas absorption should collect the mists with adequate efficiency.

8.2.1.3 If a mist having a particle size in the micrometer or sub-micrometer range is encountered, it will be necessary to use a high-energy scrubber or a scrubber with a high-pressure-drop, sub-micron filter to obtain adequate collection efficiency.

8.2.1.4 Whenever such a fine mist or other aerosol is encountered, the gas stream from the source should be abated at point-of-use or separately from the other exhaust gas streams in the plant so as to minimize energy costs.

8.2.1.5 Abatement systems utilizing a scrubber with a high-pressure-drop, sub-micron filter are being used in the semiconductor industry to reduce emissions from aqua-regia processes, hot nitric baths and spray etchers using nitric acid (entrained in exhaust).

8.2.2 It has been determined experimentally that the collection efficiency of a scrubber on a given mist or dust is a function of the energy consumed in the exposure of the particle to the liquid in the scrubbing process.

8.2.2.1 The relationship between energy consumption and efficiency is little affected by the geometry or size of the scrubber or by the method by which the energy is applied to making contact between the gas and the liquid (See Sections 13.1 through 13.3).

8.2.2.2 The energy consumption required to attain a given efficiency increases with a decrease in the size of the aerosol (e.g., mist or dust). In most of the scrubbers used in the semiconductor industry, the energy consumed is drawn from the gas stream in the form of pressure drop.

8.2.3 The energy/efficiency relationship provides a convenient and practical method for particle and aerosol scrubber design. It is essentially independent of the size of the scrubber, at least down to a very small size (perhaps 150 to 300 L/min (5–10 ft^3/min) capacity, and possibly even smaller). Hence, a small pilot unit can be used to determine performance on an actual plant exhaust stream.

8.2.3.1 Tests can also be made under laboratory conditions, using synthetic aerosols generated for the purpose.

8.2.3.2 The major problem in using synthetic aerosols is in replicating the aerosols actually encountered in practice.

8.2.3.3 The pilot plant scrubber should be tested over a range of pressure drops to give a well-defined pressure drop/efficiency correlation.

8.3 *Group 3 — Ammonia*

8.3.1 Ammonia gas (NH_3) can be either a process gas or evolved from ammonium hydroxide used in wet chemical cleaning of wafers. As previously discussed, ammonia (NH_3) exhausted through the acid system will react with the acids present producing an ammonium salt aerosol that is not easily abated.

8.3.1.1 Packed-bed scrubbers are not very efficient at removing sub-micron ammonium halide aerosols, even though they are water-soluble.

8.3.2 Wet scrubber technologies, as listed above, are suitable for removal of ammonia provided they are operated and maintained at low pH (e.g., 3–5).

8.3.2.1 This is normally achieved by the use of sulfuric acid dosing.

8.3.3 Processes that emit both ammonia and acid gases (such as nitride deposition) should be fitted with a point-of-use ammonia scrubber, prior to being exhausted to the acid exhaust.

8.4 *Group 4 — Volatile Organic Compounds (VOCs)*

8.4.1 VOCs can represent a large proportion of exhausted air streams within typical semiconductor operations. The pollutants are produced from processes such as solvent cleaning, and photoresist application and stripping. Such processes typically contribute flammable, hazardous, and/or environmentally harmful compounds (e.g., VOCs, which participate in ozone formation in the atmosphere) to the exhausted air stream.

8.4.2 There are three primary abatement technologies used at end of pipe for this category: adsorption, recovery and oxidation. Adsorption generally uses hydrophobic zeolite or activated carbon. The oxidation process usually is thermal or may be catalytic.

8.4.3 *Emission Sources and Chemicals Emitted*

8.4.3.1 VOCs usually have high vapor pressures and can be hazardous, flammable, or may tend to form photochemical smog. Processes using them (such as solvent cleaning, photoresist application, vapor degreasing and photoresist stripping) are carried out under local exhaust hoods or in exhausted enclosures.

8.4.3.2 Chemicals emitted may include: acetone, ethyl benzene, ethyl lactate, hexamethyldisilazane (HMDS), isopropyl alcohol, methanol, methyl ethyl ketone (MEK), n-butyl acetate, n-methyl-2-pyrrolidone (NMP), petroleum distillates (VM&P naphtha), propylene glycol monomethyl ether acetate (PGMEA) and xylenes.

8.4.3.3 The chemical species emitted are typically vapors of the specific VOCs being used. These vapors are entrained in large volume air streams and are thus diluted to low levels.

8.4.4 *Current Practices*

8.4.4.1 New regulations and proposed legislation, being implemented worldwide, require significant reductions in total VOC emissions (often measured in terms of mass discharged).

8.4.4.2 Removal of VOCs from exhaust streams can be accomplished by adsorption, (e.g., fluidized bed and concentrator systems), oxidation, or a combination of adsorption and oxidation systems. Adsorption technologies, with subsequent desorption and condensation, can be used to recover VOCs as a liquid.

8.4.4.3 End-of-pipe abatement is most commonly used for VOCs. Point-of-use systems, using the same technologies as end-of-pipe, are employed where exhaust facilities preclude use of an end-of-pipe unit, or as additional abatement to meet regulatory requirements.

NOTE 6: See Appendix 1 for VOC abatement design and selection criteria.

8.5 *Group 5 — Pyrophoric Gases*

8.5.1 Where separate exhausts for pyrophoric gases have been installed, it has been practice to fit a large air dilution chamber at the end of pipe. The reasoning has been that this will ensure safety by dilution and result in oxidation of any residual pyrophoric gases. However, oxidation may not occur since research has shown that silane, once diluted to <1.5 % in nitrogen, does not undergo appreciable oxidation when subsequently mixed with air.

8.5.2 Due to the risks associated with ducting pyrophoric gases through a facility, it is strongly recommended that these gases be abated at point-of-use. This avoids the need for a separate pyrophoric gas exhaust. If POU abatement is provided, the discharge from the POU abatement system can be directed to the acid or general exhaust system.

NOTE 7: See Appendix 2 for POU abatement of pyrophoric gases.

8.6 *Group 6* — See section 10 for Emergency Release Discharge Exhaust provisions.

8.7 *Group-7 — Special/Direct*

8.7.1 Recovery of specific gases such as hydrogen (H_2) may be necessary to reduce the massive risk of duct fire when large quantities of flammable gases are discharged.

8.7.2 PFC reclamation maybe required by environmental permits in some jurisdictions.

8.7.3 Abatement of Oxides of Nitrogen (NO_x) may be necessary to meet environmental regulations in some jurisdictions.

8.8 *Group 8 — General Exhaust*

8.8.1 This exhaust group is used to handle exhaust emissions that include heat and excessive nitrogen flow.

8.8.2 Heat exhaust is used to reduce the heat load on the balance of the building.

8.8.3 Exhaust of large volumes of nitrogen or other asphyxiant gas is used to keep potential asphyxiation hazards away from people.

8.8.4 Discharge from general exhaust should be to a location where the heat or reduced oxygen will not be a hazard to personnel.

8.8.5 General exhaust can sometimes be used for discharge of post-treatment emissions from POU abatement systems.

8.8.5.1 In such a case, the discharge permit for the POU abatement system should be consulted for proper management.

8.9 *Group 9 — Highly Toxic Gases*

8.9.1 Gases such as arsine, phosphine, diborane, germane, etc., can be treated in a variety of ways, depending upon their concentration and their byproducts (e.g., gas reactor columns, adsorption systems).

8.9.2 These gases would not likely be allowed in a burn system (even though many of them might be pyrophoric) because they could release hydrides from the air intake.

8.9.3 These gases may be prohibited, in some jurisdictions, from being discharged with no other treatment than dilution.

8.9.4 Highly toxic gases have also been known to create problems in a thermal oxidation system, because of the residue they leave behind and the periodic need for personnel to clean oxidation systems.

8.9.5 Selectors of systems for discharge of highly toxic gases should be careful to meet all regulatory requirements and should be conscious of the discharge location for the emission residue.

9 Point-of-Use (POU) Abatement Technologies

9.1 The selection of a suitable POU abatement device is dependent on the process exhaust gases to be abated.

9.2 To determine a valid abatement method, identify the exhaust composition from the process as well as the input process gases in order to select a suitable abatement technology.

9.3 The choice may also depend on other factors (e.g., whether removal of PFC gases is required or not).

9.4 The location of a POU abatement system in the process exhaust train must be reviewed for pressure drop, condensation, particles, moisture backstreaming, etc.

9.5 Many types of POU abatement devices are available and they can broadly be divided into six types of technologies listed below.

1. Wet scrubbing systems,
2. Oxidation systems,
3. Cold bed systems (adsorbers/ chemisorbers),
4. Hot chemical bed systems,
5. Reactor systems (e.g., plasma, microwave),
6. Traps/filters/cyclones/precipitators,

NOTE 8: See Appendix 2 for explanations of each technology type.

9.6 Units may employ one or more of these technologies, depending on the application.

9.7 Where a technology using an exhaustible cartridge/canister is employed, consideration must be given to adequate means of detecting bed exhaustion and to proper disposal techniques.

10 Provisions For Emergency Release

10.1 Routine releases, from hazardous gas cylinders and sources are usually minimal (e.g., from gas line purges).

10.2 Emergency or accidental releases, from gas cylinders in use, may be controlled through mechanical systems that lower the frequency, time and rate of releases.

10.3 Enclosing gas cylinders and non-welded mechanical fittings in exhausted gas cabinets that protect the systems from damage can minimize the frequency of accidental releases.

10.3.1 Proper design and installation of gas delivery and purge systems can reduce the likelihood of severe leaks.

10.4 The duration of accidental releases can be lessened by activation of fail-closed valves or gas cylinder closure devices activated by monitoring and/or alarm systems.

10.5 Equipping gas cylinders with restrictive flow orifices can lower the rate of accidental release. SEMI S5 - Safety Guideline for Flow Limiting Devices provides guidance on the use of restrictive flow devices.

10.6 Exhaust of the gas cabinets should be designed to contain sudden unanticipated releases of gas from cylinders and piping.

10.6.1 These exhausts are typically used to manage gas cabinets and other very high volume exhaust flow systems that will only occasionally have emissions present.

10.6.2 Some jurisdictions do not allow for discharge without treatment of emergency release discharges.

10.7 Each system selector should research their own regulations before determining the proper route and method for discharging and treating emergency releases.

10.8 Accidental releases from gas cylinders in use may be controlled through mechanical systems that lower the concentration exhausted into the environment. In some jurisdictions there are requirements (e.g., Uniform Fire Code, Article 80) to lower the concentration of accidental release, in exhaust to the environment, below a threshold (such as one-half (1/2) of Immediately Dangerous to Life and Health (IDLH) levels).

10.8.1 Dilution air, in excess of otherwise required gas cabinet exhaust, can be used to reduce the concentration of gas accidentally released into the exhaust, except where a jurisdiction specifically prohibits this practice.

10.8.2 As another method to reduce the concentration of gas in the atmospheric discharge during accidental releases, abatement devices serving the gas cabinet exhaust can be used instead of, or in addition to, dilution air.

10.8.2.1 Accidental release abatement devices may be any of the types described in this guide.

10.8.2.2 In some applications, gas cabinet exhaust is diverted to an abatement device only upon detection of an accidental release.

10.8.2.3 When designing diversion systems, the ability of the abatement device to operate after extended periods of disuse must be considered.

11 Summary Table

11.1 See Table 1 for suggestions about using POU and end-of-pipe abatement systems for different types of processes, materials, and exhaust systems.

12 Alternative Approaches

12.1 This guide is primarily concerned with handling gas effluents that arise from semiconductor processing. Capture and abatement is not the only approach to avoid release of hazardous materials. If possible, use of the hazardous materials should be avoided. In theory the following approach should be used:

12.1.1 Replace the hazardous material with one that is non-hazardous or less hazardous.

12.1.2 If replacement is not possible, use less of the material.

12.1.3 If possible, totally enclose the system so all material is recovered and reused.

12.1.4 If none of the above can be achieved, fit effective abatement devices.

13 Related Documents

NOTE 9: Unless otherwise indicated, all documents cited shall be the latest published versions.

13.1 *SEMATECH Documents*[3]

TT97093364A-XFR — Point-of-Use (POU) Control Systems for Semiconductor Process Emissions (ESHC003), October 30, 1997, J. Michael Sherer, P.E., Motorola (available online from www.sematech.org\ public\ docubase\ summary\ 3364AXFR.htm)

13.2 *FM Global Documents*[4]

Property Loss Prevention Sheet 7-78 — Industrial Exhaust Systems

13.3 *Other Documents*

Design and Selection of Spray/Mist Elimination Equipment[5]

Toxicological Investigation in the Semiconductor Industry[6]

Reactions of Exhaust Deposits from Silicon Deposition Tools[7]

Treatment of Organochlorines from Plasma Etch Processing[8]

Toxicological Hazards of Plasma Etch Waste Products[9]

Packed Column Internals[10]

13.4 *I300I/International Sematech*[11]

Emissions Characterization 2.4b — www.I300I.org, Zero Impact Process Team.

3 SEMATECH/International SEMATECH, 2706 Montopolis Drive, Austin, Texas 78741-6499

4 FM Global Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02062 or the FM Global Web Site at: www.fnglobal.com

5 Chemical Engineering Volume 91, No. 21, 82–89 (October 15, 1984), Holmes, T. L.; and Chen, G. K.

6 Toxicology & Industrial Health 8 (141) 1992 by Bauer; et. al.

7 Semiconductor Safety Association Conference, Orlando, April 1997 by Creighton S.; Plaster, M.; and Nicholson, T.

8 Semiconductor Safety Technology, March 1995 by Baker, D.; Smith, J.; and Mawle, P.

9 Semiconductor Safety Technology, July 1996 by Bauer. F; Wolff, I.; and Schmidt, R.

10 Chemical Engineering, Volume 91, No. 5, pp 40–51 March 5, 1984 by Chen, G. K.

11 I300I/International Sematech, 2706 Montopolis Drive, Austin, Texas 78741-6499

Table 1 Exhaust System Selection Table

Process	*Gases/Chemicals*	*Reason for POU Abatement*	*POU Abatement Present*	*End-of-pipe Exhaust System Type*
Solvent/strippers	VOC		Yes	General
			No	VOC
Vapor prime	HMDS		No	Acid or ammonia
Acid baths	HCl/HF/Acetic		No	Acid
Acid baths	Aqua regia/hot nitric		No	Acid aerosols
			Yes	Acid
Ammonia baths	NH_3		No	Ammonia
			Yes	Acid
Gas bottle purge	Corrosives		No	Acid
			Yes	Acid
	Ammonia		No	Ammonia
			Yes	Acid
	Hydrides/pyrophorics		Yes	General
			No	General
Chemical dispensing	Ammonia		No	Ammonia
	VOC		No	VOC
	Corrosives		No	Acid
Chemical wafer thinning of raw wafers	HNO_3/NO_x		Yes	Acid
			No	NOx/acid scrubber
EPI	H_2/Hydrides/HCl	Fire and safety Solids blockage	Yes	Acid, H_2 reclaim, or general
Dry etching – metal	Cl and Br chemistries	Blockage/Corrosion	Yes	Acid
Dry etching – oxide/poly/etc.	Fluoride chemistry		No	Acid
LPCVD nitride	SiH_2Cl_2/NH_3	Solids blockage Fire and safety	Yes	Acid
LPCVD poly/oxide	SiH_4/fluoride chemistry	Fire and safety Solids blockage	Yes	Acid
PECVD – poly/oxide	SiH_4/fluoride chemistry	Fire and safety Solids blockage	Yes	Acid
PECVD nitride and tungsten	$SiH_4/WF_6/H_2$	Fire and safety Solids blockage	Yes	Acid
	SiH_4/NH_3	Fire and safety Solids blockage	Yes	Acid
Implant	Hydrides, BF_3	Hazardous deposits	Yes	Acid
RTP	Ammonia		No	Ammonia
			Yes	General

NOTE T1: POU Abatement may be used for the reduction of PFCs and by-products from the process.

APPENDIX 1
END-OF-PIPE ABATEMENT DESIGN

NOTE: The material in this appendix is an official part of SEMI F5 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 Referenced Documents

A1-1.1 Gas-Liquid Reactions[12]

A1-1.2 Design and Selection of Spray/Mist Elimination Equipment[13]

A1-1.3 Absorption, Distillation, and Cooling Towers[14]

A1-1.4 Perry's Chemical Engineers' Handbook[15]

A1-1.5 Absorption and Extraction[16]

A1-1.6 Mass Transfer[17]

A1-1.7 Mass-Transfer in Co-current Gas-Liquid Flow[18]

A1-1.8 Mass-Transfer Operations[19]

A1-2 Principles

A1-2.1 Principles of gas absorption and methods of design of gas absorption equipment are treated extensively in chemical engineering literature (See Sections A1-1.1–A1-1.8). The sources cited present rigorous methods for design.

A1-2.2 Practical design of scrubbers is at least semi-empirical; and in the case of air pollution abatement systems, design is often directly based on experimental data.

A1-2.2.1 Consequently, designs should be based on mass-transfer coefficients that have been determined experimentally under, as nearly as possible, the conditions of expected scrubber operation.

A1-2.2.2 It should be noted that the typical concentrations of the existing empirical data base is several orders of magnitude greater than the typical concentrations of corrosives exiting a semiconductor plant (before end-of-pipe scrubbers), therefore the efficiencies in these data bases may not be representative of low concentrations.

A1-2.2.3 Attempts at developing the empirical database at these low concentrations suggest that actual removal efficiencies are lower than those predicted by most scrubber design texts.

A1-2.2.4 As a result, new scrubbers may need to have additional packing to ensure theoretical removal efficiencies are achieved.

A1-2.3 Rigorous custom design of a scrubber for a particular service requires full knowledge of the conditions that are to be encountered as well as of the performance that is to be attained.

A1-2.3.1 Gas flow rates should normally be known fairly accurately — at least when the plant is originally designed.

A1-2.3.2 Concentrations of acid and caustic gases will need to be estimated.

A1-2.3.3 Conditions to be met may be changed several times over the probable life of the scrubbing equipment, as changes are made in the semiconductor fabrication processes and the exhaust system.

A1-2.3.4 Exhaust flow may also be increased, to accommodate equipment additions, thus raising the possibility the scrubber may become overloaded.

A1-2.4 Studies by SEMATECH indicate that the concentration of corrosives in the exhaust entering the end-of-pipe scrubber(s) range from <1 ppmv to as high as 10 ppmv. Additionally, the typical scrubber with 99+ % theoretical removal efficiency was actually achieving removal efficiencies ranging from 80%–95%.

A1-2.5 Scrubbers being applied to corrosive pollutants are usually standardized units assembled by a number of vendor companies. These units are designed to handle specified ranges of gas flow, but in other respects are not designed but simply built. If they are packed-bed scrubbers, they are usually fitted with standard depths of packing. The liquid flow rates can be varied within limits; but otherwise, the performance potentials are fixed unless there are provisions for changing the depth of packing and perhaps the kind of packing. Once the system is installed, such changes to increase the efficiency will probably increase the

12 McGraw-Hill, New York (1970), Danckwerts, P.V.

13 Chemical Engineering Volume 91, No. 21, pp 82-89 (October 15, 1984), Holmes, T. L.; and Chen, G. K.

14 Longmans, Green, London (1961), Norman, W. S.

15 6th Edition, McGraw-Hill; New York (1984), Perry, R. H.; and Green, D.

16 2nd Edition; McGraw-Hill, New York (1952), Sherwood, T. K.; and Pigford, R. L.

17 McGraw-Hill, New York (1975), Sherwood, T.K.; Pigford, R. L.; and Wilke, C. R.

18 Chemical Engineering Sciences Volume 33, No. 12, pp1675-1680 (1978), Shilimkan, R. V. and Stepanek, J. B.

19 3rd Edition; McGraw-Hill, New York (1980), Treybal, R.E.

pressure drop of the scrubber, which will require adding to the fan capacity.

A1-2.6 To ensure, in advance, that the scrubber will have adequate removal efficiency, performance tests can be conducted. Measurements should be made of the contaminant concentrations in typical plant exhaust gas streams, and the resulting data should be used to set conservative performance requirements for the scrubber. Performance tests on the scrubber should be conducted prior to exposing the scrubber to the semiconductor plant exhaust, preferably at the vendor's facility. Performance tests should identify the critical operating variables and optimize the settings to achieve optimal removal efficiencies at the lowest cost.

A1-2.6.1 Onsite performance tests may be preferable, when qualifying abatement systems, so that accurate process conditions can be produced. Permit exemptions may be obtained for the time-period of system qualification.

A1-2.7 Design and construction of scrubbers are simplified by two factors: the exhaust gas streams are at essentially ambient temperature, and they carry few insoluble solids. The low temperature allows use of corrosion-resistant plastic construction. The absence of significant solids avoids blockages in the scrubbers, which favors use of efficient gas-liquid contactors such as packed beds.

A1-2.8 Two of the most favored scrubber types are the counter-current packed tower and the horizontal cross-flow scrubber. In some instances, the choice between these devices may be determined by plant layout. As usually constructed, these two scrubber types have low to moderate gas pressure drops and are primarily suited to absorption of gases. They will also collect the coarser mists and sprays but are unsuited to collection of fine mists and fumes having particle sizes under 2 to 3 micrometers.

A1-2.9 In principle, the counter-current tower offers the highest efficiency with the least consumption of absorbent liquid. However, if untreated water is recirculated through the tower, as is commonly done in semiconductor plants, the advantages of the countercurrent operation are lost. On the other hand, if the absorbed gas is reacted with an appropriate reagent in the water, essentially the same performance can be obtained with either the countercurrent or co-current operation (see Section A1-1.7). In co-current operation, it is possible to use higher gas velocities to obtain higher mass transfer rates so that the scrubber can be made smaller. Gas pressure drops will also be increased, but this may be desirable if it is necessary to collect a fine aerosol as well as absorb a gas.

A1-2.10 Horizontal cross-flow packed-bed scrubbers may have advantages where the installation imposes restrictions on height or other similar layout problems. However, in other respects, they do not offer fundamental advantages over the packed tower scrubbers.

A1-2.11 Under special circumstances, other types of scrubbers may be appropriate for collection of aerosols. High-energy scrubbers, of the venturi type, or scrubbers with high-pressure drop, sub-micron filters (e.g., fiber bed) are appropriate where fine aerosols must be collected. Wherever possible, measures should be taken to avoid formation of such aerosols; but when they are unavoidably produced, the source should be ventilated through a separate scrubbing system of appropriate design.

A1-2.12 Packing in scrubbers provides a large interfacial area between the liquid and the gas, and also induces fluid turbulence to promote mass transfer. Packing is commonly placed in scrubbers in a random manner. Raschig and Pall rings as well as Berl saddles were common early packing materials used. In recent years, numerous proprietary packing designs have been introduced, with the objective of providing increased mass-transfer efficiency with reduced gas pressure drop. The validity of claims for superior performance has been established by the SEMATECH experiments in Section 13.1.

A1-2.13 Numerous precautions are required when installing and operating packed-bed scrubbers. It is essential to attain an even distribution of liquid over the packing; channeling of liquid or gas flow results in loss of removal efficiency. Inadequate liquid distribution can result in a reduction of the removal efficiency to as little as one seventh of theoretical (See Referenced Document A1-1.9). The predominant liquid distribution system employed is spray nozzle style. This style is inexpensive, however, it is difficult to maintain and tends to entrain more water than weir-style. Weir-style liquid distribution systems are more expensive. However, they require less preventive maintenance, provide equal liquid distribution over a wide range of flow rates, and are less prone to liquid carry-over. Precautions are treated at length in previously cited literature.

A1-2.14 A critical aspect of any scrubber design is the separation of entrainment. Carry-over of spray from a scrubber can produce maintenance issues and mist emissions. Failure to provide adequate entrainment separation has been one of the most common problems in scrubber installations. The predominant mist separator employed is a mesh style. Mesh style separators are effective on the smaller water droplets associated with spray nozzles; however, maintenance due to solids and/or biological growth is required. The chevron style is typically used in conjunction with a weir, as they are not very effective on the smaller droplet associated with spray nozzles; however they are very immune to plugging from solids and/or biological growth. The entrainment separators are discussed in Sections A1-1.3 and A1-1.5.

A1-2.15 Chlorine, fluorine and possibly other soluble gases can be entrained in scrubber wastewater, and released in facilities drains/vents. Materials such as fluorine are incompatible with many plastics and can damage drains/ vents resulting in leak, odors, and facilities interruptions.

A1-3 VOC Abatement Equipment Design and Selection

A1-3.1 *Design Criteria for Adsorption Systems*

A1-3.1.1 Adequate contact time must be achieved between adsorption media and VOC-laden exhaust stream. The adsorption matrix must be sized so that adequate residence time within the media is maintained. Also, the exhaust stream flow must be distributed uniformly over the adsorption matrix.

A1-3.1.2 Pressure drop across the adsorption matrix should be minimized to reduce energy consumption for air handling equipment.

A1-3.1.3 Materials of construction must be resistant to any corrosive action by the VOC' s or by-products formed during adsorption or adsorbent matrix regeneration.

A1-3.1.4 Hydrophobic zeolites and activated carbon in fixed beds, fluid beds or rotating wheels are being used for adsorption.

A1-3.1.5 Adsorption materials have a finite capacity for VOC adsorption and must be regenerated when their capacity is exhausted.

A1-3.1.6 Monitoring of the exhaust stream as it exits the adsorption bed may be necessary to determine when regeneration or replacement of the adsorption medium is needed.

A1-3.1.7 Pretreatment of the VOC-laden exhaust stream for removal of entrained particles or liquids may be required to prevent plugging of the adsorption unit.

A1-3.1.8 Regeneration is accomplished by flushing the adsorption bed with a carrier, typically steam, hot air or hot nitrogen.

A1-3.1.8.1 Desorbed VOC' s must be recovered or destroyed.

A1-3.1.8.2 Current practices for VOC recovery requires condensation or distillation.

A1-3.1.8.3 Current practices for VOC destruction is usually oxidation.

A1-3.2 *Design Criteria for Oxidation Systems*

A1-3.2.1 Adequate residence time, mixing with air and temperature, must be provided for high efficiency destruction of the VOC' s.

A1-3.2.2 Pretreatment of the VOC-laden exhaust stream for removal of entrained particles or liquids may be required to prevent plugging of the oxidation unit.

A1-3.2.3 Downstream abatement of the oxidation unit exhaust will be required if corrosive combustion products [such as hydrogen chloride (HCl) from chlorinated vapors] or particles [such as silicon dioxide (SiO_2) from hexamethyldisilazane (HMDS)] are present.

A1-3.2.4 Concentrations of the incoming VOC' s should be limited, especially when using a concentrator. Typical incoming VOC concentrations should not exceed 25% of LEL.

A1-3.2.5 Energy costs for heating VOC-laden exhaust streams must be considered. Straight thermal oxidizers are costly to use with high-volume, low VOC concentration exhaust streams. Therefore, a concentration process followed by recuperative or regenerative oxidation offers a more cost-effective solution.

A1-3.2.5.1 Catalytic oxidation may also offer cost savings; however, the composition of incoming compounds must not poison the catalyst.

A1-3.2.5.2 A regenerative thermal oxidizer (without a preceding concentrator) may offer cost savings in certain applications.

A1-3.2.6 Hybrid systems (combinations of adsorption and oxidation systems) may provide a cost-effective approach for abating dilute concentrations of VOCs in exhaust streams by combining adsorption beds with recuperative/regenerative oxidation, to destroy the VOCs.

A1-3.2.6.1 All design considerations for adsorption systems and oxidation systems are relevent for any of the multitude of possible hybrid systems.

A1-3.2.6.2 Levels of oxidation by-products must also be considered such as oxides of nitrogen (NOx), carbon monoxide (CO) and products of incomplete combustion (PICs).

A1-3.2.7 Potential problem areas to be reviewed in any equipment selection procedure:

A1-3.2.7.1 *Halogenated Materials* — Additional care must be exercised with chlorinated compounds, which can be subject to stricter regulatory requirements. Ensure that any oxidation unit does not create new and more hazardous compounds, such as dioxins.

A1-3.2.7.2 *Sulfur and Hexamethyldisilazane (HMDS)* — Both have the potential to poison many catalysts, and hexamethyldisilazane (HMDS) will oxidize to form silicon dioxide, which can result in particle build up in heat exchangers and oxidizers.

A1-3.2.7.3 *Moisture Levels* — Moisture can significantly affect adsorption capability.

APPENDIX 2
POU ABATEMENT TECHNOLOGY TYPES

NOTE: The material in this appendix is an official part of SEMI F5 and was approved by full letter ballot procedures on August 27, 2001.

A2-1 POU Abatement Technology Types:

1. Wet scrubbing systems
2. Oxidation systems
3. Cold bed systems (adsorbers/ chemisorbers)
4. Hot chemical bed systems
5. Reactor systems (e.g., plasma, microwave)
6. Traps/filters/cyclones/precipitators

A2-2 Wet Scrubbing Systems

A2-2.1 *Water Scrubber*

A2-2.1.1 *Principle of Operation* — Exhaust gas is passed through an enclosed space into which water is sprayed. The desired result is that gases will dissolve in or react with the water. A large contact area between gas and water is required to maximize the dissolution or reaction. Numerous designs exist to achieve this. The “packed-bed” scrubber is filled with open structure objects (e.g., hollow balls) that are fully wetted by the water spray. The gas passes over this large wet surface area. If the water spray is in the opposite direction to the gas path the design is “counter current”; if in the same direction, it is “co-current”; and if at 90° it is “cross flow”. Other designs to maximize gas/water contact use meshes, atomized sprays, or multi chamber systems that reverse the gas direction several times.

A2-2.1.2 *Capacity* — Total gas flow is determined by the size of the unit.

A2-2.1.3 *Efficiency* — Efficiency is determined by the solubility of the gas in water and retention time in the unit as well as the given mass transfer from gas to liquid phase. Acid gases are best removed; many other process gases may not be removed. If gas does dissolve in water then effectiveness of unit will be determined by design input gas flow and inlet compound concentrations.

A2-2.1.4 *Limitations* — Water scrubbers are only suitable for water-soluble gases. Many process gases (e.g., silicon compounds) will produce insoluble solids (silica) on contact with water resulting in solids forming that may block the water sprays, scrubber packing or gas inlet port.

NOTE 1: Compatibility of scrubber drains with the compounds being entrained in the liquid effluent should be considered.

A2-2.2 *Water Scrubber with Energy Input (e.g., Venturi)*

A2-1.2.1 *Principle of Operation* — Same as water scrubber but gas and water are forced to mix by the input of energy. Most commonly this is done by a venturi through which the gas and water pass. Other designs have used rapidly rotating blades in the enclosed scrubbing space. The “active” scrubbing area is often combined with a passive spray chamber or packed bed.

A2-2.2.2 *Capacity* — Energy enhanced water scrubbers have the same capacity as water scrubbers.

A2-2.2.3 *Efficiency* — Added energy improves efficiency over water scrubbers due to forced mixing, which improves efficiency of particulate removal.

A2-2.2.4 *Limitations* — The limitations are the same as for water scrubbers.

A2-2.3 *Chemical Dosed Scrubber*

A2-2.3.1 *Principle of Operation* — Chemical Dosed Scrubbers operate the same as a water scrubber but a chemical solution is added to the water. This increases the range of gases that can be removed, from those that dissolve in water to those that will react with the chosen chemical solution. The chemical medium is selected to react with the known input gases producing water-soluble salts. The two reaction systems most commonly employed are acid/base and reduction/oxidation (redox). Addition of solutions of sodium hydroxide (NaOH), potassium hydroxide (KOH) or sulfuric acid are frequently used to enhance effectiveness, and where chemical oxidation is needed hypochlorites, periodates, or peroxides are introduced.

A2-2.3.2 *Capacity* — Same as water scrubber.

A2-2.3.3 *Efficiency* — Same as water scrubber but increased efficiency by using chemical dosing. The number of gases, which can be removed, will also increase.

A2-2.3.4 *Limitations* — Even though a wider range of gases can be removed with this chemical dosing, it is applicable only to those emissions that can be water scrubbed. The potential for fouling by silica solids remains. Potassium hydroxide (KOH) or (sodium hydroxide (NaOH) solutions have to be increased to approximately 5% to ensure dissolution of silicates. Chemical dosing adds another hazardous material and may result in liquid wastes that require treatment.

A2-2.4 *Chemical Dosed Scrubber with Energy Input (e.g., Venturi)*

A2-2.4.1 *Principle of Operation* — Same as Water Scrubber with Energy Input (e.g., Venturi) above, with the benefits of Chemical Dosed Scrubber.

A2-3 Oxidation Systems

A2-3.1 *Burn Systems*

A2-3.1.1 *Principle of Operation* — Burn systems are designed for silane abatement by utilizing the pyrophoric properties of this gas. The process gas containing silane is injected into a steel container through which a stream of air is passing. The silane auto-ignites and oxidizes to form silica powder, which deposits in the system or is carried into the exhaust duct.

A2-3.1.2 *Capacity* — Governed by the build up of powders, small units may need cleaning out every few months, larger units will provide a year's capacity.

A2-3.1.3 *Efficiency* — When burn systems are correctly set up, nearly complete oxidation will occur, providing that the input silane concentration is greater than 1.5%.

A2-3.1.4 *Limitations* — Burn systems are suited only to silane (or other pyrophoric effluent) abatement. Not appropriate for mixed gas process. If silane is diluted to less than 1.5% in nitrogen before input no measurable oxidation will occur and the silane will pass directly to the exhaust.

A2-3.2 *Flame Oxidation*

A2-3.2.1 *Principle of Operation* — Oxidation of hydride gases by combustion. These systems use a chamber containing a fuel gas flame through which the process gas is passed. The resulting oxides from combustion pass into the exhaust and may be abated downstream.

A2-3.2.2 *Flow Capacity* — To calculate flow capacity, combine the total discharge flows that constitute input to the abatement device. Include pump dilution and purge quantities. .

A2-3.2.3 *Efficiency* — For simple burner designs, efficiency can vary widely as gas flow changes; specific units have been designed to ensure good mixing of fuel/air and gas; these can deliver efficiencies greater than 99.9%.

A2-3.2.4 *Limitations* — Suited only to processes where the input gases can be safely combusted. Design must ensure by-products are minimized (e.g., chlorinated compounds like phosgene/dioxins and oxides of nitrogen). Produces combustion byproducts of process gases, therefore, is often combined with a wet scrubber to remove by-products or other water-soluble gases.

A2-3.3 *Hot Chamber Oxidation*

A2-3.3.1 *Principle of Operation* — Exhaust gas is passed into an electrically heated chamber (typically 800° C) where it is mixed with air. The heated mixture oxidizes, more quickly than in a simple burn system, but without a flame from fuel oxidation to assist.

A2-3.3.2 *Flow Capacity* — To calculate flow capacity, combine the total discharge flows that constitute input to the abatement device. Include pump dilution and purge quantities.

A2-3.3.3 *Efficiency* — Hydride gases will be oxidized and removed to below the OEL.

A2-3.3.4 *Limitations* — On its own, hot chamber oxidation technology is suited only to hydrides or other gases that will readily oxidize at the temperature of the hot chamber. This method is often combined with a wet scrubber to remove oxidized by-products or other water-soluble gases.

A2-3.4 *Non-Flame Oxidation*

A2-3.4.1 *Principle of Operation* — Non-flame systems use an incandescent porous wall for combustion without a flame. Fuel and air are mixed and passed through the matrix of the porous wall, which operates at around 900° C. When process exhaust gases are passed into this zone, they are oxidized.

A2-3.4.2 *Flow Capacity* — To calculate flow capacity, combine the total discharge flows that constitute input to the abatement device. Include pump dilution and purge quantities.

A2-3.4.3 *Efficiency* — Hydride gases can be oxidized by a method similar to other combustion techniques. High efficiency oxidation is needed to oxidize more stable fluorinated compounds.

A2-3.4.4 *Limitations* — Non-flame oxidation produces oxidation by-products, and therefore must often be combined with a wet scrubber to remove particulate matter or water-soluble gases.

A2-4 Cold Bed Systems (Adsorbers/ Chemisorbers)

A2-4.1 *Adsorption*

A2-4.1.1 *Principle of Operation* — Exhaust gas is passed through a container (cylinder, canister, or drum) filled with adsorbent granules. These are commonly based on activated charcoal. Some gases are physically adsorbed into the granules while the non-adsorbed gases pass through into the facility exhaust.

A2-4.1.2 *Flow Capacity and Removal Capacity* — Both capacities of these systems are a function of the container size (mass of granules) and surface area.

A2-4.1.3 *Efficiency* — For a single gas, efficiency can approach 100% until the bed capacity is reached. However, since the gas is only held physically it can be displaced by another compound, causing the efficiency to drop significantly.

A2-4.1.4 *Limitations* — Adsorption traps hazardous compounds and does not destroy them. Gases are adsorbed at different rates and the capacity of the bed for different gases will also vary. A more strongly adsorbed gas entering the bed after a less strongly adsorbed compound can displace the first gas re-releasing the first gas to the exhaust. The waste material must be kept sealed in the container and evaluated for hazards. Exposure to air, water, or heat can cause gases adsorbed in the material to be released.

A2-4.2 *Chemisorption*

A2-4.2.1 *Principle of Operation* — Exhaust gas is passed through a container of granules that consist of either:

- adsorbent granule coated with some reactive chemical;
- reactive porous medium e.g., soda lime; or
- a resin matrix coated with some reactive chemical.

A2-4.2.1.1 Gases are adsorbed into the porous matrix and then chemically react either with the granules themselves or with the coating. These reactions are designed to convert the gas into a solid material (typically a salt) that remains attached to the granules.

A2-4.2.1.2 Reactive chemicals are typically either bases (metal hydroxides) or oxidizers (e.g., permanganates, or metal oxides).

A2-4.2.2 *Flow Capacity and Removal Capacity* — Both capacities of these systems are a function of the container size (mass of granules) and surface area.

A2-4.2.3 *Efficiency* — Acid/Base and Redox reactions are most readily accomplished. Therefore, with acidic gases and hydride gases, efficiency can be high; with removal below OEL. With other gases, e.g., PFCs and halogenated carbon compounds, efficiency is often minimal or none.

A2-4.2.4 *Limitations* — There may be adsorption as well as chemisorption, so the spent material must be evaluated for hazards, since gases can desorb from it. This is especially true for chlorine (Cl_2) when the bed uses hydroxides. These will form OCl compounds that on exposure to air or moisture will regenerate chlorine.

A2-4.2.4.1 Materials used for chemisorption can themselves be hazardous (e.g., heavy metals or caustic (KOH/NaOH)) therefore, unused canisters may be classified as hazardous items.

A2-4.3 *Adsorption with Subsequent Air Oxidation*

A2-4.3.1 *Principle of Operation* — These systems are designed and offered mainly for high flows of arsine (AsH_3) and phosphine (PH_3), used in the deposition of III-V materials (such as gallium arsenide (GaAs), indium phosphide (InP)). These gases are adsorbed into a carbon bed, into which air is subsequently fed at a controlled rate to oxidize the adsorbed hydride into oxides that will remain in the granules.

A2-4.3.2 *Flow Capacity and Removal Capacity*— Both capacities of these systems are a function of the container (drum) size (mass of granules) and surface area.

A2-4.3.3 *Efficiency* — Capable of removing hydrides to below OEL.

A2-4.3.4 *Limitations* — Hydride is adsorbed into the carbon bed, the oxidation of this is exothermic. When air is fed in to oxidize the hydride, it is possible to start combustion of the carbon bed, unless the flow rate is well controlled.

A2-5 Hot Chemical Bed Systems

A2-5.1 *Hot Bed Reactors*

A2-5.1.1 *Principle of Operation* — Exhaust gases are passed through a steel container (cartridge/drum) that is filled with reactive material. The material is maintained at an elevated temperature, typically 250 to 550 degrees C. The gases chemically react with the fill material and are converted into inorganic salts that remain fused into the matrix of the fill material. There are versions with a single fill material that are specific to abatement of one gas, and versions with two or more zones of fill material that can abate a wide range of gas compounds.

A2-5.1.2 *Flow Capacity and Removal Capacity* — Both capacities of hot bed systems are a function of the cartridge size (mass of granules) and surface area.

A2-5.1.3 *Efficiency* — Efficiency of these systems is generally high, with gases removed to below OELs. Stable PFC gases are not removed by all systems.

A2-5.1.4 *Limitations* — Fill material can also react with oxygen or moisture so hot bed systems are not always suited to wet processes or where air is used.

A2-5.2 *Hot Catalytic Bed*

A2-5.2.1 *Principle of Operation* — Gas is passed into a steel cartridge, which is held at an elevated temperature, that contains granules of a catalyst. The target-input gas is catalytically converted to other gases [e.g., ammonia (NH_3) to nitrogen (N_2) and hydrogen (H_2), and oxides of nitrogen (NOx) to nitrogen (N_2) and oxygen (O_2)].

A2-5.2.2 *Removal Capacity* — In theory, if not poisoned, a catalyst bed should last for a long time. Units available are claimed to be able to operate for one-year before bed change.

A2-5.2.3 *Efficiency* — Efficiency of hot catalytic bed systems is normally high, with removal of the target gas to below OEL levels.

A2-5.2.4 *Limitations* — Hot catalytic bed units are designed to be gas specific. Catalysts can be sensitive to other compounds; so for complex gas mixtures in process exhausts they may not be suitable on their own.

A2-5.3 *Hot Reactor Beds with Gas Inputs*

A2-5.3.1 *Principle of Operation* — Exhaust gases are passed into a hot bed as in hot bed reactors above, but concurrently with the process gas another gas is introduced (e.g., air or steam). The gases then react together in the bed, either with each other or with the bed material. Hazardous gases are converted either to solid salts that remain fused into the bed matrix, or other gases [e.g., carbon dioxide (CO_2)] that pass on into the exhaust.

A2-5.3.2 *Flow Capacity and Removal Capacity* — Both capacities of these systems are a function of the container (cartridge) size (mass of granules) and surface area.

A2-5.3.3 *Efficiency* — Process gases [e.g., phosphine (PH_3), carbon monoxide (CO)] are normally removed to below the OEL.

A2-5.3.4 *Limitations* — These systems are suited only to processes where the end products will be either stable solids or inert gases.

A2-6 Reactor Systems (Plasma, Microwave, etc.)

A2-6.1 *Principle of Operation* — Gases are abated in the vacuum line (before or after the vacuum pump) by passing them through a reaction chamber, containing plasma, to enhance reaction of gases such as silane into a solid material. For high efficiency PFC conversion, it is necessary to inhibit recombination by the addition of a material (e.g., moisture, or a hydrogen/oxygen mixture). Two types of reactors exist - large plasma volume/small surface area, in which a downstream particle trap is utilized; and small plasma volume/large surface area, where solid films are deposited. Other reactor systems (e.g., microwave systems) are also being developed.

A2-6.2 *Flow Capacity and Removal Capacity* — Reactor systems are designed for the process system effluent and are sized to handle specific process flows.

A2-6.3 *Efficiency* — With inputs of up to 300 sccm of silane, removal efficiencies of greater than 99% have been documented. At higher flows efficiency can be reduced. High removal efficiencies of PFCs have also been demonstrated.

A2-6.4 *Limitations* — Silane will form solids in the plasma. Gaseous by-products will pass into the exhaust. Solids transmission into the vacuum pump will be reduced, but additional abatement devices may be required downstream if by-products need to be removed. Formation of hydrogen (H_2) as a by-product should be considered to ensure that the H_2 outlet concentration is below the lower flammable limit.

A2-7 Traps/Filters/Cyclones/Precipitators

A2-7.1 *Principle of Operation* — Designed to remove the particulate component in exhausts. Some processes produce solid powders (e.g., silica) and other processes generate condensable vapors. These vapors, on compression in the pump and cooling in the exhaust, condense into solid materials. Numerous designs exist to collect these solids out of the gas stream. These include filters (paper/bag etc.), cooled condensation chambers, cyclones, and electrostatic precipitators.

A2-7.2 *Removal Capacity* — Removal capacity is normally measured as the mass of solid the unit can collect before it partially blocks. As they are blocked, these systems generate a backpressure, which can prevent effective removal of material or create a process disturbance.

A2-7.3 *Efficiency*— Efficiency for these various units is difficult to measure. It is usually assessed pragmatically in terms of increased interval between exhaust clean out.

A2-7.4 *Limitations*— These various units must be used with care and only when not associated with hazardous gases. Often solid exhaust materials are mixed with hazardous gases. If these gases are present in the trapped solids a dangerous situation can result. Where gases and solids are mixed it is safer to keep material volatile and abate all by a POU abatement technology from the sections above. If only non-hazardous gases are left these systems can provide cost-effective abatement to keep ducts clear. They can also be used in combination with other technologies.

SEMI F6-92
GUIDE FOR SECONDARY CONTAINMENT OF HAZARDOUS GAS PIPING SYSTEMS

1 Purpose

To provide a guide for the design, fabrication, and operation of secondarily contained distribution piping for hazardous production material (HPM) gases.

2 Scope

This guide covers the general requirements for hazardous production material distribution piping in those industries that are included under the H-6 Classification of the Uniform Building Code, or Articles 51 or 80 of the Uniform Fire Code, or of other applicable local codes. This guide does not include requirements for individual exhausted enclosures (e.g., valve boxes and gas cabinets).

3 Applicable Documents

3.1 *SEMI Documents*

SEMI F1 — Specification for Leak Integrity of Toxic Gas Piping Systems

SEMI F2 — Specification for Seamless Austenitic Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S4 — Safety Guideline for the Segregation/Separation of Gas Cylinders Contained in Cabinets

3.2 *ANSI/ASME Standard*[1]

B31.3 — Chemical Plant and Petroleum Refinery Piping

3.3 *Federal Regulations*[2]

29 CFR — Title 29 of the Code of Federal Regulations (CFR), Part 1910

49 CFR — Title 49 of the Code of Federal Regulations (CFR), Chapter I

3.4 *ICBO Codes*[3]

UBC CH 9 — Chapter 9 of the Uniform Building Code, Requirements for Group H Occupancies

UFC ART 51 — Article 51 of the Uniform Fire Code, Semiconductor Fabrication Facilities Using Hazardous Production Materials

UFC STD 79-3 — Standard No. 79-3 of the Uniform Fire Code

UFC ART 80 — Article 80 of the Uniform Fire Code, Hazardous Materials

UFC ART 90 — Article 90 of the Uniform Fire Code, Regulation of Facilities Where Materials Which Are or May Become Toxic Gases Are Found

3.5 *NFPA Standards*[4]

NFPA 70/ ART 500 — Article 500 of the National Electrical Code, Hazardous (Classified) Locations

NFPA 497M — Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations

NFPA 704 — Identification of the Fire Hazards of Materials

3.6 *ACGIH Publication*[5]

TLV [6] — American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices

4 Terminology

4.1 *closed secondary containment* — Secondary containment that has a sealed annulus. In closed containment systems, the annular space either holds a certain pressure of gas or a certain level of vacuum. In closed containment, a change in the pressure or vacuum would be indicative of a leak in either the primary or secondary system.

1 American National Standards Institute, 1430 Broadway, New York, NY 10018

2 United States Government Printing Office, Washington, D.C. 20402

3 International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601

4 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

5 American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211

6 TLV is a registered trademark of ACGIH.

4.2 *controlled work area* — A space within a building where HPM's may be stored, handled, dispensed, or used.

4.3 *equilibrium vapor concentration (EVC)* — The state of a material at which vapor pressure has stabilized and is no longer rising or falling. The EVC value (in parts per million) of a material is determined by multiplying the vapor pressure by 10^6 and dividing by atmospheric pressure (760 mmHg at sea level).

4.4 *hazardous production material (HPM)* — A solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704 and that is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous.

4.5 *highly toxic gas* — A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

4.6 *immediately dangerous to life and health (IDLH)* — A concentration of airborne contaminants, normally expressed in parts per million or milligrams per cubic meter, which represents the maximum level from which one could escape within thirty minutes without any escape-impairing symptoms or irreversible health effects. This level is established by the National Institute of Occupational Safety and Health (NIOSH).

4.7 *level of concern (LOC)* — Equal to 0.1 of the IDLH value.

4.8 *lower detectable limit of instrument (LDL)* — The lowest concentration of a substance that will give an instrument response with a signal-to-noise ratio of at least 3 db.

4.9 *material hazard index (MHI)* — A numeric value used for ranking chemical production materials in order to determine the level of controls necessary for regulation. MHI is determined by dividing the equilibrium vapor concentration (EVC) of a material at 25°C by the level of concern (LOC) value for the material.

4.10 *open secondary containment* — Secondary containment with an open-ended annular space. This annulus must be directed to a system designed to handle the contained HPM.

4.11 *permissible exposure limit (PEL)* — The maximum permitted eight hour time-weighted average concentration of an airborne contaminant. The maximum permitted time-weighted average exposures to be used are those published in 29 CFR 1910.1000.

4.12 *pressure decay method* — The method of detection of leakage through pressure loss, over a period of time, within a vessel or piping system.

4.13 *primary containment* — The first level of containment (i.e., the inside portion of the container that comes into immediate contact on its inner surface with the material being contained).

4.14 *pyrophoric* — Capable of spontaneous ignition in air at or below a temperature of 54.5°C (130°F).

4.15 *secondary containment* — Level of containment that is external to and separate from primary containment. Secondary containment is a method of safeguarding used to prevent unauthorized releases of toxic or hazardous gases into uncontrolled work areas. Secondary containment means those methods or facilities in addition to the primary containment system.

4.16 *threshold limit value/time-weighted average (TLV/TWA)* — As defined by the American Conference of Governmental Industrial Hygienists (ACGIH).

4.17 *uncontrolled work area* — Any area outside of a secondary containment system where people are likely to be present.

4.18 *vacuum decay method* — Leakage detection determined by the loss of vacuum (increase in pressure), over a period of time within a vessel or piping system.

5 Containment Function

5.1 Secondary containment should, in case of release, segregate the hazardous production material (HPM) from the surrounding area.

5.2 Secondary containment systems should include provisions to contain and detect substances which pose health or property hazards and to direct such substances into areas or facilities that can safely treat, dispose of, or dilute them prior to release into the atmosphere.

6 Containment Application

Secondary containment may be used on any system if deemed appropriate by the authority responsible for the system. Secondary containment should be mandatory for all HPM's that are included in the following categories:

6.1 Those substances with threshold limit values (TLV) below the lower detectable limit (LDL) of the detection systems in use.

6.2 Those substances that provide inadequate warning properties.

6.3 Those substances that fall into the following categories:

6.3.1 Any HPM's which have a material hazard index (MHI) value equal to or greater than 500,000.

6.3.2 Highly toxic gas.

6.3.3 Pyrophorics.

6.3.4 Substances with unknown, but potentially high toxicities (e.g., organometallics).

6.3.5 Materials with an NFPA 704 reactivity rating of 3 or 4.

6.3.6 Any corrosives that are not contained in inert process piping.

6.4 Where piping containing HPM's is installed in a manner to conceal it from view.

6.5 Where piping containing HPM's is installed in uncontrolled or unventilated areas such as drop ceilings or behind walls.

6.6 Where required by UBC H-6 or other existing codes.

6.7 Where there is any reasonable possibility of a leak in the primary containment due to normal wear and tear, possible abuse, or corrosive attack to the piping on the inside or exterior.

7 Containment Methods

The method of containment may take many forms provided that the method is sound in engineering design. This design should be in conformance to nationally recognized codes and standards as well as to the requirements of local safety jurisdictions.

8 Materials of Construction

8.1 *Chemical Compatibility* — If there is a possibility that the HPM, or its reaction products, is corrosive, to any extent, to the secondary containment, one should develop a procedure to verify the integrity of the containment system. This verification procedure need only be performed in the event that the HPM, or its reaction products, contacts the containment (see Section 9).

8.2 *Fire Resistance* — If walls are used as the secondary containment system, they should be constructed of materials resistant of fire. The fire rating of the secondary containment should be as follows:

8.2.1 Two hour rating for pyrophorics;

8.2.2 One hour rating for all others.

9 Design Requirements

9.1 *Design Pressure* — The system should be designed to provide secondary containment with the ability to withstand the pressure of the entire volume of the potential leaking source without leakage.

9.1.1 Closed secondary containment systems should have sufficient design pressure to withstand the pressure of the entire contents of the source of the HPM. The design safety factor must be consistent with ANSI B31.3.

9.1.2 Open secondary containment systems should have sufficient design pressure to withstand the release at full tank pressure or the entire contents of the HPM released within a time of two minutes.

9.1.3 Special consideration should be given to the containment of pyrophorics. Some pyrophorics can develop considerable explosive pressure. The elimination of oxygen from the annulus of a containment system should be considered in lieu of explosive pressure data.

9.2 *Resistance to External Forces* — The method of construction of secondary containment systems should be sufficient to withstand:

9.2.1 Normal physical abuse found in the industrial workplace.

9.2.2 Seismic zone activity as shown in the UBC (Uniform Building Code) or other applicable codes.

9.3 *Leak Integrity* — The system should be designed to provide secondary containment with sufficient leak integrity to prevent exceeding the PEL of the HPM in uncontrolled work areas.

9.3.1 Primary piping should be leak tested in accordance with SEMI F1.

9.3.2 Closed secondary containment systems should have the same leak integrity as the primary containment except the closed secondary containment systems should be leak tested with the annulus pressurized to 2 times the maximum operating pressure with argon containing at least 10% helium. There should be no drop in pressure for a period of 12 hours.

9.3.3 Open secondary containment systems should be leak tested to the same criteria as closed secondary containment systems per 9.3.2 above.

10 Separation of HPM's

A single secondary containment may be used to contain more than one HPM provided that those HPM's are not reactive with any other HPM in the common containment. Documents that should be considered for proper separation of HPM's include:

10.1 SEMI S4, Safety Guideline for the Segregation/Separation of Gas Cylinders Contained in Cabinets

10.2 Materials Safety Data Sheets

10.3 NFPA Fire Protection Guide on Hazardous Materials

11 Cross Connections

There should be no mechanical cross connection of secondary containment systems with other systems not designed specifically for the secondary containment of the particular HPM's.

12 Monitoring

The annulus should be monitored for leakage of the primary system in accordance with the following:

12.1 The sensitivity of the detection system should be sufficient to detect leakage at 1/2 Threshold Limit Values (TLV's) at the discharge to treatment of an open secondary containment system.

12.2 Detection of leakage into the annulus of the secondary containment system should include alarm systems.

12.3 Detection methods may include:

12.3.1 Direct detection of the HPM or its reaction products (open secondary containment system).

12.3.2 Pressure decay method (closed secondary containment system).

12.3.3 Vacuum decay method (closed secondary containment system).

13 Leak Management

The secondary containment system should be designed to control and direct leaking materials. Control of HPM's may consist of dilution, absorption, incineration, scrubbing, venting, or those methods deemed safe and suitable to the governing authorities responsible for the facility. The initiation of the secondary containment alarm system should be automated. This system should automatically institute the management of the leaking HPM in the event of a breach of the primary system.

14 Periodic Testing - After Installation

14.1 Secondarily contained piping systems must be inspectable. The method of inspection must be able to reveal the current strength and leak integrity of the primary and secondary containment systems.

14.2 The secondary containment must be periodically leak tested in accordance with the criteria set forth in Section 9.3 of the above. Structural testing of both the process piping and the secondary containment should be conducted to the maximum pressure specified in Section 9.1 of the above.

14.3 Any secondarily contained piping system failing the periodic inspection should be repaired or replaced immediately.

SEMI

SEMI F7-92 (Reapproved 0299)
TEST METHOD TO DETERMINE THE TENSILE STRENGTH OF TUBE FITTING CONNECTIONS MADE OF FLUOROCARBON MATERIALS

This test method was technically reapproved by the Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available on www.semi.org February 1999; to be published February 1999. Originally published in 1992.

1. Purpose

1.1 This method provides a uniform procedure to determine the tensile strength of tube fitting connections made of fluorocarbon materials.

2. Scope

2.1 This method can be used to characterize tube fitting connections on the basis of test data developed under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 Tube defined in this method has a circular cross section and is made of fluorocarbon materials.

2.3 All parts of the tube fittings tested by this method in contact with the internal fluid are made of fluorocarbon materials.

2.3.1 Parts such as a nuts or grippers are not limited to being made of a fluorocarbon material.

2.4 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other, threaded seals are beyond the scope of this document.

2.5 When using this method for making comparisons among various tube fittings and/or manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

2.6 The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary units are in parentheses for reference purposes only and have been rounded to the nearest whole value.

3. Referenced Documents

3.1 *ASTM Standards*[1]

D3307 PFA — Fluorocarbon Molding and Extrusion Materials

D3296 — Standard Specification for FEP Fluorocarbon Tube

4. Summary of Method

4.1 Subject tube fitting connections made of fluorocarbon materials to extreme tensile forces.

5. Significance and Use

5.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fitting designs of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the tensile strength can be made.

5.2 It is the intent of this method to provide a procedure in which the tensile force will be applied to tube fitting connections made of fluorocarbon materials. By using this method, accurate comparisons of various tube fitting designs can be achieved.

5.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this method.

5.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

6. Terminology

6.1 *characterize* — To describe the quality of.

6.2 *failure* — Tube separation from a tube fitting connection or tearing of the tube.

6.3 *subject* — To expose to.

6.4 *tensile* — Longitudinal, so as to lengthen the test object.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

7. Description of Test Equipment

7.1 A test apparatus capable of securing the test specimen while accurately providing a uniform rate of pull to the specimen. The test instrument shall have the capability of recording the maximum tensile force applied to the test specimen.

7.2 See Figure 1 for basic tensile test apparatus.

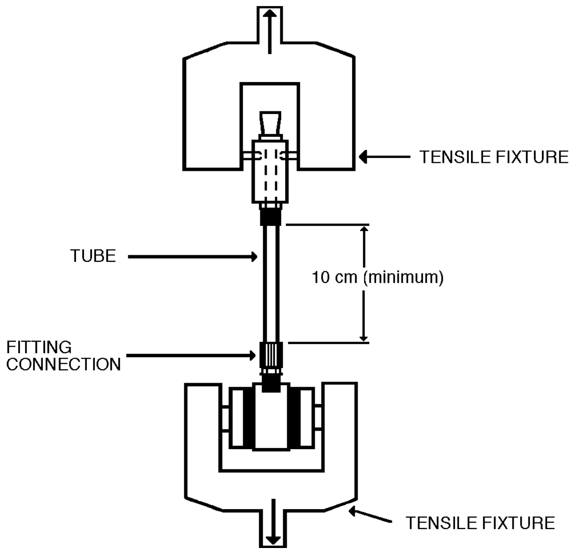

Figure 1
Basic Tensile Test Apparatus

8. Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance rating of the products under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test.

9. Test Specimens and Conditioning

9.1 *Sample Size* — A minimum of three specimens shall be tested.

9.2 *Specimen Size* — The specimen length shall be no less than 10 cm (4 in) between the tensile fixture and the tube end of the fitting connection.

9.3 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

9.4 *Specimen Conditioning* — All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to tensile forces.

10. Calibration

10.1 Calibrate the tensile test equipment's rate of pull to 2.5 cm (1 in) per minute, ± 5%.

10.2 Calibrate the tensile force instrument to ± 2% full scale.

11. Test Procedure

11.1 Assemble a test fitting connection, per manufacturer's specification, to one end of the tube. (See 9.2.)

11.2 Install the fitting connection to the tensile fixture (see Figure 1) in a manner that prevents distortion of the connection.

11.3 Secure the open end of the tube to the tensile fixture, leaving a minimum of 10 cm (4 in) of exposed tube.

11.4 Begin pulling the test specimen at a rate of 2.5 cm (1 in) per minute.

11.5 Continue applying tensile force until the tube pulls through the fitting connection or until tearing of the tube occurs.

11.5.1 If the tube releases from the tensile fixture, the data from that specimen must be disregarded and an additional specimen tested.

11.6 Record on test data sheet (see Appendix 1 for a sample) the mode of failure and the maximum tensile force applied, in Newtons (lbs).

12. Calculations

12.1 Calculate the average "maximum tensile force" and record.

12.2 Calculate the standard deviation of "maximum tensile force" and record.

13. Data Accuracy

13.1 *Tensile Force* — Newtons: ± 2%.

14. Test Data Sheet

The test data sheet shall include the following information:

14.1 Date tested.

14.2 Operator and test facility.

14.3 Description of items tested, including:

Tubing — manufacturer, O.D., wall thickness, part number, and material type.

Fitting — manufacturer, type, size, part number, and material type.

14.4 Maximum tensile force for each specimen.

14.5 Average and standard deviation of maximum tensile forces.

14.6 Mode of failure for each specimen.

NOTE: A sample test data sheet is provided as Appendix 1.

APPENDIX 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of this SEMI test method and is not intended to modify or supercede the official test method. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Tensile Force — Newtons

Sample	*Maximum Tensile Force*	*Mode of Failure*
1		
2		
3		
Average =		
Standard Deviation =		

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SEMI F8-0998
TEST METHOD FOR EVALUATING THE SEALING CAPABILITIES OF TUBE FITTING CONNECTIONS MADE OF FLUOROCARBON MATERIALS, WHEN SUBJECTED TO TENSILE FORCES

1 Purpose

1.1 This method provides a uniform procedure to determine the sealing capabilities of tube fitting connections made of fluorocarbon materials when the connections are subjected to tensile forces.

2 Scope

2.1 This method can be used to characterize tube fitting connections on the basis of test data developed under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 Tube defined in this method has a circular cross section and is made of fluorocarbon materials.

2.3 All parts of the tube fittings tested by this method in contact with the internal fluid are made of fluorocarbon materials.

2.3.1 Parts such as a nut or gripper are not limited to being made of a fluorocarbon material.

2.4 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other, threaded seals are beyond the scope of this document.

2.5 When using this method for making comparisons between various tube fittings and/or manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

2.6 The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary units are in parentheses for reference purposes only and have been rounded to the nearest whole value.

3 Referenced Documents

3.1 *ASTM Standards*[1]

D 3307 PFA — Fluorocarbon Molding and Extrusion Materials

D 3296 — Standard Specification for FEP Fluorocarbon Tube

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4 Summary of Method

4.1 Subject tube fitting connections made of fluorocarbon materials to extreme tensile forces, while maintaining a specified pressure to the internal cavity of the fitting and tube.

5 Significance and Use

5.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fitting designs made of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the sealing capabilities of tube fitting connections can be made.

5.2 It is the intent of this method to provide a procedure in which the air pressure and tensile force will be applied to tube fitting connections made of fluorocarbon materials. By using this method, accurate comparisons of various tube fitting designs can be achieved.

5.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this method.

5.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

6 Terminology

6.1 *Acronyms*

6.1.1 *O.D.* — Outside diameter

6.1.2 *P/N* — Part number

6.2 *Definitions*

6.2.1 *characterize* — To describe the quality of.

6.2.2 *failure* — Tube separation from a tube fitting connection or tearing of the tube.

6.2.3 *standard deviation* — A measure of the variation among the members of a statistical sample.

6.2.4 *submersion tank* — A transparent tank filled with isopropyl alcohol to allow observation of air leakage from the tube fitting connection.

6.2.5 *subject* — To expose to.

6.2.6 *tensile* — Longitudinal, so as to lengthen the test object.

7 Description of Test Equipment

7.1 A supply of compressed air. Pressure to be within ± 2% of specified.

7.2 Isopropyl alcohol.

7.3 An instrument to record the tensile force applied to the test specimen.

7.4 A test apparatus:

7.4.1 Capable of securing the test specimen while allowing the specimen to be internally pressurized.

7.4.2 Capable of accurately providing a uniform rate of pull to the specimen.

7.4.3 With a transparent submersion tank capable of containing a fluid for observing leakage. The minimum fluid level shall be 2.5 cm (1 in) above the test connection.

7.4.4 The apparatus shall allow the test specimen to be internally pressurized to 250 kPa (36 psig).

7.5 See Figure 1 for basic tensile and leak test apparatus.

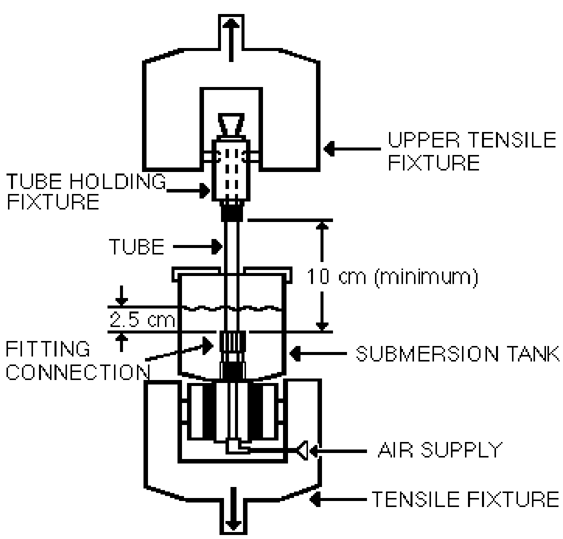

Figure 1
Basic Tensile and Leak Test Apparatus

8 Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance rating of the products under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test.

9 Test Specimens and Conditioning

9.1 *Sample Size* — A minimum of three specimens shall be tested.

9.2 *Specimen Size* — The specimen length shall be no less than 10 cm (4 in) between the upper tensile fixture and the tube end of the fitting connection.

9.3 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

9.4 *Specimen Conditioning* — All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to pressure and tensile forces.

10 Calibration

10.1 Calibrate the tensile test equipment's rate of pull to 2.5 cm (1 in) per minute, ± 5%.

10.2 Calibrate the tensile force instrument to ± 2% full scale.

11 Test Procedure

11.1 Assemble a test fitting connection, per manufacturer's specification, to one end of the tube.

11.2 Install the fitting connection to the tensile fixture, in the submersion tank (see Figure 1) in a manner that prevents distortion of the connection.

11.3 Secure free end of tube to the upper tensile fixture, leaving a minimum of 10 cm (4 in) of exposed tube.

11.4 Fill the submersion tank with isopropyl alcohol to a height of 2.5 cm (1 in) above the top of the test connection.

11.5 Cover the submersion tank in case of a fluid splash.

11.5.1 The cover must allow for slight clearance around tube.

11.6 Pressurize the test specimen with an internal air pressure of 250 kPa (36 psig), regardless of tube size.

11.7 Begin pulling the test specimen at a rate of 2.5 cm (1 in) per minute.

11.8 Record on test data sheet (see Related Information 1 for a sample), the minimum tensile force in Newtons (lbs) when leakage is first observed from the fitting connection.

11.9 Lower the air pressure to one atmosphere immediately after observing any leakage.

11.10 Continue pulling until the tube pulls through the fitting connection or until tearing of the tube occurs.

11.10.1 If the tube releases from the tensile fixture, the data from that specimen must be disregarded and an additional specimen tested.

11.11 Record on test data sheet the mode of failure and the maximum tensile force applied in Newtons (lbs).

11.11.1 It is possible that the tensile force required to cause leakage and the maximum tensile force may be the same. If this situation occurs, indicate the force reading on both areas of the test data sheet.

12 Calculations

12.1 Calculate the average "force to cause leakage" and record.

12.2 Calculate the average "maximum tensile force" and record.

12.3 Using the three actual forces:

12.3.1 Calculate the standard deviation of "force to cause leakage" and record.

12.3.2 Calculate the standard deviation of "maximum tensile force" and record.

13 Data Accuracy

13.1 *Tensile Force* — Newtons: ± 2%

14 Test Data Sheet

The test data sheet shall include the following information:

14.1 Date tested.

14.2 Operator and test facility.

14.3 Description of items tested, including:

Tubing — manufacturer, O.D., wall thickness, part number, and material type.

Fitting — manufacturer, type, size, part number, and material type.

14.4 Force to cause leakage for each specimen.

14.5 Average and standard deviation of the forces to cause leakage.

14.6 Maximum tensile force for each specimen.

14.7 Average and standard deviation of maximum tensile forces.

14.8 Mode of failure for each specimen.

NOTE: A sample test data sheet is provided as Related Information 1.

RELATED INFORMATION 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F8 and is not intended to modify or supercede the offical test method. It has been derived from industry specifications. Publication was authorized by full letter ballot procedure. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Tensile Force — Newtons

Specimen	*Force to Cause Leakage*	*Maximum Tensile Force*	*Mode of Failure*
1			
2			
3			
Average =			
Standard Deviation =			

SEMI F9-0998
TEST METHOD TO DETERMINE THE LEAKAGE CHARACTERISTICS OF TUBE FITTING CONNECTIONS MADE OF FLUOROCARBON MATERIALS, WHEN SUBJECTED TO A SIDE LOAD CONDITION

1 Purpose

1.1 This method provides a uniform procedure to determine the leakage characteristics of tube fitting connections made of fluorocarbon materials, when subjected to side loading.

2 Scope

2.1 This method can be used to characterize tube fitting connections on the basis of test data developed under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 Tube defined in this method has a circular cross section and is made of fluorocarbon materials.

2.3 All parts of the tube fittings tested by this method in contact with the internal fluid are made of fluorocarbon materials.

2.3.1 Parts such as a nut or gripper are not limited to being made of a fluorocarbon material.

2.4 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other, threaded seals are beyond the scope of this document.

2.5 When using this method for making comparisons between various tube fittings and/or manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

2.6 The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary units are in parentheses for reference purposes only and may have been rounded to the nearest whole value.

3 Summary of Method

3.1 Subject tube fitting connections made of fluorocarbon materials to a side load condition that is a result of bending the tube in a uniform arc, while maintaining a specified pressure to the internal cavity of the fitting and tube.

4 Significance and Use

4.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fitting designs made of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the side load capabilities can be made.

4.2 It is the intent of this method to provide a procedure in which tube fitting connections made of fluorocarbon materials will be subjected to extreme side loading. By using this method, accurate comparisons of various tube fitting designs can be achieved.

4.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this document.

4.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

5 Terminology

5.1 *Acronyms*

5.1.1 *O.D.* — Outside diameter

5.1.2 *P/N* — Part number

5.2 *Definitions*

5.2.1 *bend radius* — The distance from the center of an imaginary circle on which the arc of the bent tube falls to a point on the arc.

5.2.2 *characterize* — To describe the quality of.

5.2.3 *kinking* — A collapse of the tube wall caused by excessive bending.

5.2.4 *"L"* — The tube length required to produce a uniform 180° arc, at a specified tube bend radius.

NOTE: The symbol "L" is unique in that it is used only in this test method.

5.2.5 *"R"* — The theoretical value to determine the tube bend radius, used during testing.

NOTE: The symbol "R" is unique in that it is used only in this test method.

5.2.6 *side load* — A result of bending a tube in a specified arc, consequently subjecting the tube fitting connection to a radial stress.

5.2.7 *subject* — To expose to.

5.2.8 *submersion tank* — A transparent tank, filled with isopropyl alcohol, to allow observation of air leakage from a tube fitting connection.

6 Description of Test Equipment

6.1 A supply of compressed air. Pressure to be within ± 2% of specified value.

6.2 Isopropyl alcohol.

6.3 An instrument for measuring lengths of tubing (e.g., tape measure).

6.4 A special apparatus which has a fixture for attaching the fitting body, while also providing a means to clamp the free end of tube, to maintain a tube bend radius.

6.4.1 The apparatus shall allow the test specimen to be internally pressurized.

6.4.2 The apparatus shall have a transparent submersion tank capable of containing a fluid for observing leakage. The minimum fluid level shall be 2.5 cm (1 in) above the test connection.

6.5 See Figure 1 for a basic side load test apparatus.

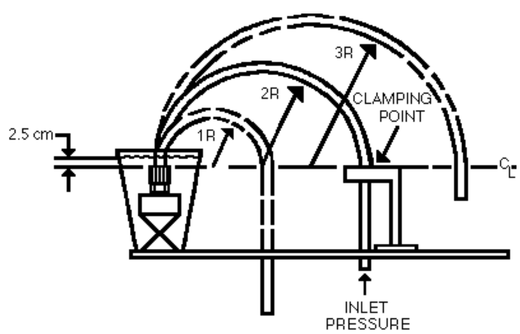

Figure 1
Side Load Test Apparatus

7 Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance rating of the products under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test.

8 Test Specimens and Conditioning

8.1 *Sample Size* — A minimum of three specimens shall be tested.

8.2 *Tube* — The tubing used for this evaluation shall be of straight lengths, not previously coiled.

8.3 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

8.4 *Specimen Conditioning* — All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to pressurization and bending of the tube.

9 Test Procedure

9.1 Perform the following calculation to determine the "R" value.

9.1.1 For a tubing outside diameter (O.D.) of 1.5 cm (.59 in) or less: R = Tube O.D. × 5.

9.1.2 For a tubing outside diameter (O.D.) greater than 1.5 cm (0.59 in): R = Tube O.D. × 5.

NOTE: The constants (5 and 10) in Sections 9.1.1 and 9.1.2 were derived from the extrapolation of the actual "Minimum Bend Radius" of tubing from various manufacturers.

9.2 Perform the calculation in Section 9.2.1 to determine the tube length required to produce a 180° arc at a tube bend radius of R.

9.2.1 L = R × 3.14

9.3 Cut three tubes of equal length per the following formula: 3L + 15 cm (6 in).

9.4 Install a fitting body to the test fixture, in the submersion tank.

9.5 Install a tube into the fitting body and assemble the connection per manufacturer's specification.

NOTE: To prevent side loading of the fitting connection prior to bending of the tube, provide a method of supporting the tube.

9.6 Measure from the tube end of the fitting connection and place a mark on the tube (within ± 1% of calculated value) in five separate locations as determined below:

- 0.5L
- 1.0L
- 1.5L
- 2.0L
- 3.0L

9.7 Use the following formula to determine the actual tube bend radius used and record on test data sheet (see Related Information 1 for a sample):

- 0.5R
- 1.0R
- 1.5R
- 2.0R
- 3.0R

9.8 Fill the submersion tank with isopropyl alcohol to a minimum height 2.5 cm (1 in) above the top of the test connection.

9.9 Pressurize the test specimen with an internal air pressure of 250 kPa (36 psig), regardless of tube size.

9.10 Observe the connection for a minimum of one minute for bubble leakage (bbl/min) and record on test data sheet under the column entitled “STRAIGHT”.

9.11 Carefully bend the tube in a uniform 180° arc with a radius of 3R and clamp the free end to the test fixture. (See Section 9.7 for specific R value.) Proper tube length at the clamping point is determined in Section 9.6.

9.11.1 R value tolerances =

- Tubes with 1.5 cm (0.59 in) O.D. or less = ± 5%
- Tubes with greater than 1.5 cm (0.59 in) O.D. = ± 1%

9.12 Observe the connection for a minimum of one minute for bubble leakage. Record leakage on the appropriate area of the test data sheet. If no leakage is observed, note as “None”.

9.13 Repeat Sections 9.11 and 9.12 for the remaining tube bend radius of 2R, 1.5R, 1R, and 0.5R, in descending order.

9.13.1 Should any tube kink prior to achieving 0.5R, testing of that sample will be discontinued. The radius at which kinking occurred shall be recorded and noted as “kink”.

9.13.2 To reduce the effects caused by creep of the material the total time from initial bending of the tube until achieving the 0.5R value is to be less than ten minutes.

9.14 After completion of the first sample, replace the fitting and tube with new specimens and repeat Sections 9.4 through 9.13.2 for a total of three samples.

10 Test Data Sheet

The test data sheet shall include the following information:

10.1 Date tested.

10.2 Operator and test facility.

10.3 Description of items tested, including:

Tubing — Manufacturer, O.D., wall thickness, part number, and material type.

Fitting — Manufacturer, type, size, part number, and material type.

10.4 The actual tube bend radius for each nominal bend radius.

10.5 The leakage rate, in bubbles per minute, for each sample at each radius.

NOTE: A sample test data sheet is provided as Related Information 1.

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RELATED INFORMATION 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F9 and is not intended to modify or supercede the official test method. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Leakage— (bbl/min.) [ ] = Acutal Tube Bend Radius, cm(s)

		3R	*2R*	*1.5R*	*1R*	*0.5R*
Sample	Straight	[ ]	[ ]	[ ]	[ ]	[ ]
1						
2						
3						

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SEMI F10-0698
TEST METHOD TO DETERMINE THE INTERNAL PRESSURE REQUIRED TO PRODUCE A FAILURE OF A TUBE FITTING CONNECTION MADE OF FLUOROCARBON MATERIALS

1 Purpose

1.1 This method provides a uniform procedure to determine the internal pressure required to produce failure of fitting connections made of fluorocarbon materials.

2 Scope

2.1 This method can be used to characterize tube fitting connections on the basis of test data developed under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 Tube defined in this method has a circular cross section and is made of fluorocarbon materials.

2.3 Tube fittings defined in this method are made of fluorocarbon materials for all parts in contact with the internal fluid.

2.3.1 Parts such as a nut or gripper are not limited to being made of a fluorocarbon material.

2.4 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other threaded seals are beyond the scope of this document.

2.5 When using this method for making comparisons among various tube fittings and/or manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

2.6 The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary units are in parentheses for reference purposes only and may have been rounded to the nearest whole value.

3 Referenced Document

3.1 *ASTM Standard*[1]

ASTM D 1599 — Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings

4 Summary of Method

4.1 This test method consists of pressurizing tube fitting connections made of fluorocarbon materials to failure by continuously increasing the internal hydraulic pressure. New tubing and fitting samples are required at each specific elevated fluid temperature condition, and failures are to occur within 60 to 70 seconds from initial exposure to the high pressure fluid.

5 Significance and Use

5.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fitting designs made of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the pressure limits can be made.

5.2 It is the intent of this method to provide a procedure to determine the maximum pressure limits of tube fitting connections made of fluorocarbon materials. By using this method, accurate comparisons of various tube fitting designs can be achieved.

5.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this method.

5.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

6 Terminology

6.1 *characterize* — To describe the quality of.

6.2 *failure* — Any external leakage of fluid through the tube wall or the tube fitting connection, whether it be catastrophic or a slow leak.

6.3 *free end closure* — A metal tube fitting connection which is securely fastened to the tube and does not contribute to the restraint of the test specimen.

6.4 *isolation valve* — A valve used to separate the high temperature fluid from the high pressure fluid or to separate the samples from each other.

NOTE: This definition is used in only this test method.

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1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

6.5 *pressure containing envelope* — The internal area of a specimen which contains the fluid media.

6.6 *standard deviation* — A measure of the variation among the members of a statistical sample.

6.7 *subject* — To expose to.

7 Description of Test Equipment

7.1 This test method requires the use of two hydraulic systems.

7.1.1 A high pressure system capable of applying a continuous increase of the internal hydraulic pressure to the test specimen.

7.1.2 A low pressure, high temperature circulation system capable of controlling a fluid temperature within ± 3°C (± 5°F) of a specified test temperature.

7.1.2.1 The pressure is to be 75 kPa (11 psig) or less for all temperatures, within the range of 25° to 200°C (77° to 392°F).

7.2 *Test Fluid* — When testing at or below 82°C (180°F), an SAE 20 weight hydraulic oil may be used. When testing at elevated fluid temperatures, use a synthetic oil that is acceptable for elevated temperatures of up to 200°C (392°F) and compatible with the test stand and test specimens.

7.3 An instrument to record the peak pressure within 1% of full scale.

7.4 An instrument to monitor temperature within ± 1°C (± 2°F).

7.5 *Specimen Support* — Any support is acceptable as long as it does not contribute to the restraint of the specimen in either the circumferential or axial direction.

7.6 An enclosure that will allow observation of the test specimen and that is also capable of controlling the ambient temperature to 31° ± 6°C (88° ± 11°F).

7.7 See Figure 1 for basic pressure and circulation system.

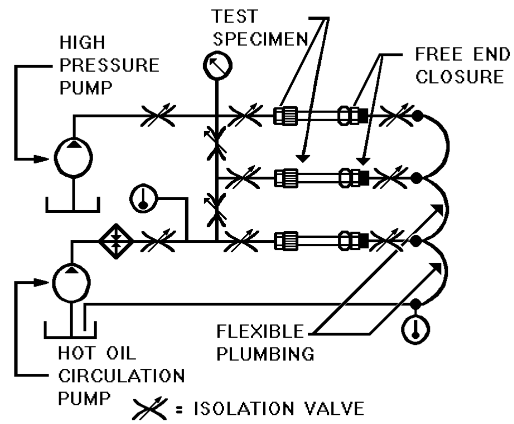

Figure 1
Basic Pressure and Circulation System

8 Safety Precautions

WARNING: This test method will subject test specimens to conditions that exceed the normal performance rating of the product under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test, as catastrophic failures of the test specimens are expected. The hydraulic plumbing and safety enclosure is to be constructed of materials which are capable of containing a fluid at 200°C (392°F).

9 Test Specimens and Conditioning

9.1 *Sample Size* — A minimum of three specimens shall be tested at each temperature condition.

9.1.1 The three connections will be conditioned simultaneously. See Figure 1 for a basic pressure and circulation system.

9.2 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

9.3 *Specimen Conditioning* — All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to pressure.

9.4 A fluid at the specified temperature must be circulated through all the test specimens for a minimum of one-half hour.

10 Test Procedure

10.1 Install three fitting connections, assembled per manufacturer's specifications, to the test system. Allow for a minimum of 30 cm (12 in.) of tube length between the test fitting connection and the free end closure.

10.2 The plumbing *must* permit free movement of each test specimen to allow for distortion.

10.3 Using the low pressure circulation system (see Section 7.1.2), condition the test specimens to 25°C (77°F) per 9.4. The system pressure is not to exceed 75 kPa (11 psig) during conditioning.

10.4 Properly position the isolation valves in such a way that only one specimen will be pressure tested, while the remaining specimens continue to have heated fluid circulating through them.

WARNING: Take all necessary precautions when positioning the isolation valves, due to the potential harm which might be caused by an accidental exposure to the high temperature fluid.

10.4.1 Test each specimen within two minutes after isolating it from the hot oil circulation system.

10.5 Using the high pressure system (see Section 7.1.1), pressurize the specimen until failure occurs.

10.5.1 Increase the pressure at a uniform and constant rate such that failure occurs between 60 to 70 seconds from initial exposure to the high pressure fluid.

10.6 Record on test data sheet (see Appendix 1 for sample test data sheet) the pressure and temperature at which the failure occurred. To identify mode of failure, record pressure reading under column:

"T" — for tube failure.

"F" — for fitting connection failure.

10.7 Repeat 10.1 through 10.5, substituting, for the fluid temperature in Section 10.2, the remaining six temperatures: 75°C (167°F), 100°C (212°F), 125°C (257°F), 150°C (302°F), 175°C (347°F), and 200°C (392°F).

11 Calculations

11.1 Calculate the average pressure for each test temperature and record in kPa (psig).

11.2 Calculate the standard deviation for each test temperature and record.

12 Data Accuracy

12.1 *Pressure* — kPa: ± 2%

12.2 *Fluid Temperature* — ± 1°C (± 2°F)

13 Test Data Sheet

The test data sheet shall include the following information:

13.1 Date tested.

13.2 Operator and test facility.

13.3 Description of items tested, including:

Tubing — manufacturer, O.D., wall thickness, part number, and material type.

Fitting — manufacturer, type, size, part number, and material type.

13.4 The actual temperature for each test.

13.5 The failure pressure for each sample, in the appropriate column.

13.6 The average and standard deviation for each failure mode of each specimen.

NOTE: A sample test data sheet is provided as Related Information 1.

RELATED INFORMATION 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F10 and is not intended to modify or supercede the official standard. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Tube:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Max. Pressure — kPa   T = Tube Failure, F = Fitting Connection Failure

Actual Temperature								
Sample	*25°C T*	*25°C F*	*75°C T*	*75°C F*	*100°C T*	*100°C F*	*125°C T*	*125°C F*
1								
2								
3								
Average =								
Standard Deviation =								

Actual Temperature						
Sample	*150°C T*	*150°C F*	*175°C T*	*175°C F*	*200°C T*	*200°C F*
1						
2						
3						
Average =						
Standard Deviation =						

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SEMI F11-0998
TEST METHOD TO OBTAIN AN INDICATION OF THE THERMAL CHARACTERISTICS OF TUBE FITTING CONNECTIONS MADE OF FLUOROCARBON MATERIALS

1 Purpose

1.1 This method provides a uniform procedure to determine the thermal characteristics of tube fitting connections made of fluorocarbon materials.

2 Scope

2.1 This method can be used to characterize tube fitting connections on the basis of test data developed under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 Tube defined in this method has a circular cross section and is made of fluorocarbon materials.

2.3 Tube fittings defined in this method are made of fluorocarbon materials for all parts in contact with the internal fluid.

2.3.1 Parts such as a nut or gripper are not limited to being made of a fluorocarbon material.

2.4 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other, threaded seals are beyond the scope of this document.

2.5 When using this method for making comparisons among various tube fittings and/or manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

2.6 The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary units are in parentheses for reference purposes only and have been rounded to the nearest whole value.

3 Summary of Method

Subject tube fitting connections made of fluorocarbon materials to extreme internal pressure and temperature conditions.

3.1 Test specimens are subjected to a constant internal pressure while controlling the increase of fluid temperature in uniform increments, with a cool down period between each elevated temperature condition.

3.2 After completion of the entire temperature range, test a new set of fittings and tubing with an increased pressure.

4 Significance and Use

4.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fitting designs made of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the thermal characteristics can be made.

4.2 It is the intent of this method to provide a procedure in which thermal transition testing of tube fitting connections made of fluorocarbon materials will be performed. By using this method, accurate comparisons of various tube fitting designs can be achieved.

4.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this document.

4.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

5 Terminology

5.1 *Acronyms*

5.1.1 *O.D.* — Outside Diameter

5.1.2 *P/N* — Part number

5.2 *Definitions*

5.2.1 *characterize* — To describe the quality of.

5.2.2 *free end closure* — A metal tube fitting connection which is securely fastened to the tube and does not contribute to the restraint of the test specimen.

5.2.3 *subject* — To expose to.

5.2.4 *thermal transition* — A change from a specific elevated fluid temperature down to room temperature and then to an elevated temperature higher than previously tested, with the entire process repeated for multiple temperature conditions.

6 Description of Test Equipment

6.1 A hydraulic system capable of applying a constant internal hydraulic pressure to all test specimens while allowing a uniform fluid flow rate through each specimen.

6.1.1 The pressure capability shall range from 100 to 1200, ± 35 kPa (15 to 174, ± 5 psig).

6.1.2 The fluid flow rate shall be adequate to maintain the fluid temperature at each specimen to ± 2.8°C (± 5°F) of the specified fluid temperature.

6.1.3 The fluid temperature capability shall range from 25°C to 200°C (77°F to 392°F), within a one hour time interval from hot to cool and vice versa.

6.2 An enclosure that will allow observation of the test specimens and is capable of controlling the ambient temperature to 31° ± 6°C (88° ± 11°F).

6.3 An instrument to monitor pressure within ± 1% of full scale.

6.4 An instrument to monitor temperature within ± 1°C (2°F).

6.5 An instrument to monitor time.

6.6 *Specimen Support* — Any support is acceptable as long as it does not contribute to the restraint of the specimen in either the circumferential or axial direction.

6.7 See Figure 1 for basic test system.

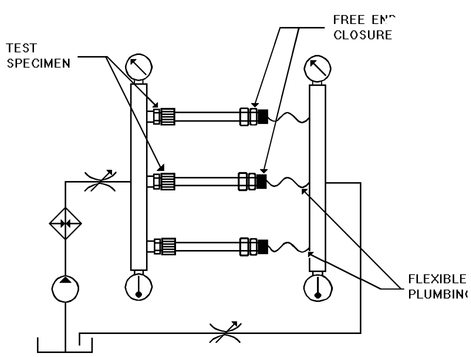

Figure 1
Basic Test System

7 Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance ratings of the products under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test. The hydraulic plumbing and safety enclosure are to be constructed of materials which are capable of containing a fluid at 200°C (392°F).

8 Test Specimens and Conditioning

8.1 *Sample Size* — A minimum of three specimens shall be tested at each pressure condition.

8.2 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

8.3 *Specimen Conditioning* — All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to pressure.

9 Test Procedure

9.1 Install three fitting connections, assembled per manufacturer's specifications, to the test manifold. Allow for a minimum of 30 cm (12 in) of tube length between the test fitting connection and free end closure. (See Figure 1.)

9.1.1 The apparatus should include a section of flexible line from the free end enclosure to return manifold to allow for expansion.

9.2 Circulate 25°C (77°F) fluid through the test samples with a constant pressure of 100 kPa (15 psig) for one hour.

9.2.1 When three failures occur at any given pressure during the initial room temperature condition (prior to the specimens having been subjected to any elevated temperature conditions), testing is terminated.

9.3 Increase the fluid temperature to 75°C (167°F) for a total time of two hours from the time the temperature was initially increased. The maximum time allowed to achieve the elevated temperature is one hour. (See Figure 2.)

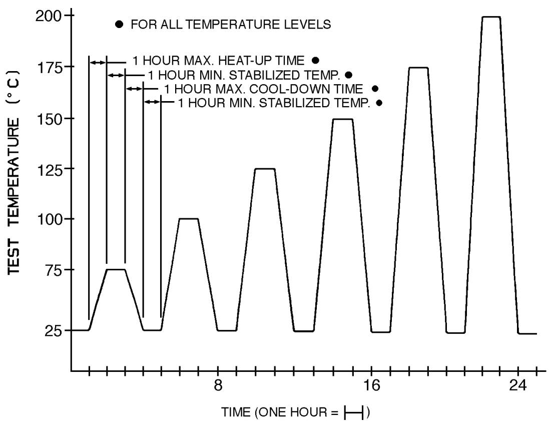

Figure 2
Thermal Transition Chart

9.4 Lower the fluid temperature to 25°C (77°F) for a total of two hours. The maximum time allowed to achieve the 25°C (77°F) temperature condition is one hour.

9.5 Repeat Sections 9.3 and 9.4, substituting, for the fluid temperature in Section 9.3, the remaining five temperatures: 100°C (212°F), 125°C (257°F), 150°C (302°F), 175°C (347°F), and 200°C (392°F).

9.5.1 The test samples should be at 25°C (77°F) prior to stopping the test at the end of a work shift.

9.5.1.1 The two hours at 25°C (77°F) will be equally divided between the present day cool-down time and the next day start-up time.

9.6 Monitor each of the three connections for external leakage throughout all test parameters.

9.7 Any external leakage at a tube connection will be recorded as a failure on the test data sheet (see Related Information 1 for sample test data sheet).

9.7.1 Leakage observed, once an elevated temperature is reached, will be recorded as a failure at that temperature.

9.7.2 Leakage at or during the cool-down cycle is to be recorded as a failure of the previously tested elevated temperature condition.

9.7.3 Leakage observed while increasing the temperature to the next condition is to be recorded as a failure of the previous elevated temperature condition.

9.8 Once a connection shows leakage and its failure pressure and temperature has been recorded, any additional leakage is not taken into consideration.

9.8.1 If leakage is not excessive, the connection can remain in the system until testing at that pressure has been completed.

9.8.2 If leakage of a connection becomes excessive, the connection may be retightened or replaced in order to continue testing of the remaining specimens. Take precautions not to disturb the remaining test specimens.

WARNING: Due to the extreme danger of high temperature fluids, take all necessary precautions when retightening or replacing a connection, to prevent accidental exposure to the heated fluid.

9.9 After three connection failures are recorded, or the 200°C (392°F) temperature has been achieved, a new set of fittings is to be installed for the next pressure condition.

9.10 Repeat Sections 9.2 through 9.9 for the remaining six pressures: 200 kPa (29 psig), 400 kPa (58 psig), 600 kPa (87 psig), 800 kPa (116 psig), 1000 kPa (145 psig), and 1200 kPa (174 psig).

10 Data Accuracy

10.1 Fluid Temperature — ± 1°C (± 2°F)

10.2 Pressure — kPa: ± 2%

11 Test Data Sheet

The test data sheet shall include the following information:

11.1 Date tested.

11.2 Operator and test facility.

11.3 Description of items tested, including:

Tubing — Manufacturer, O.D., wall thickness, part number, and material type.

Fitting — Manufacturer, type, size, part number, and material type.

11.4 The actual temperatures and pressures at which failures occur.

NOTE: A sample test data sheet is provided as Related Information 1.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F11 and is not intended to modify or supercede the official guide. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Failure Temperatures = 25°, 75°, 100°, 125°, 150°, 175°, or 200°C

kPa	*Actual kPa*	*Failure #1*	*Failure #2*	*Failure #3*
100				
200				
400				
600				
800				
1000				
1200				

NOTE: Record the pressures and temperatures at which failures occur.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F12-0998
TEST METHOD TO DETERMINE THE SEALING CAPABILITIES OF FITTINGS, MADE OF FLUOROCARBON MATERIAL, AFTER BEING SUBJECTED TO A HEAT CYCLE

1 Purpose

1.1 This method provides a uniform procedure to determine the sealing capabilities of fluorocarbon resin fittings, after they have been subjected to an elevated ambient temperature and cooled to room temperature (hereafter referred to as a "Heat Cycle").

2 Scope

2.1 This method can be used to characterize the thermal characteristics of tube fitting connections on the basis of test data obtained under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 When using this test method, a fitting body temperature range of 23° – 125°C (73° – 257°F) should be maintained.

2.3 Tube defined in this method is made of fluorocarbon materials.

2.4 Tube fittings defined in this method are made of fluorocarbon materials for all parts in contact with the internal fluid. Parts such as nuts and grippers are not limited to being made of a fluorocarbon material.

2.5 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other seals are beyond the scope of this document.

2.6 When using this method for making comparisons between various tube fitting manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

NOTE: The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary Units are in parentheses for reference purposes only and have been rounded to the nearest whole value.

3 Summary of Method

3.1 Measure the leakage of the tube fitting connection after being exposed to a heat cycle by subjecting the fitting to an internal pressure with nitrogen.

4 Significance and Use

4.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fittings made of fluorocarbon materials (which are chemically resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the sealing capabilities of tube fitting connections can be made.

4.2 It is the intent of this method to provide a procedure which evaluates the sealing capability of the tube fitting connection when subjected to a change in ambient temperature.

4.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this method.

4.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

5 Terminology

5.1 *Acronyms*

5.1.1 *O.D.* — Outside diameter

5.1.2 *P/N* — Part number

5.2 *Definitions*

5.2.1 *constant temperature oven* — Hot-air oven used to condition the specimens to the specified temperature.

5.2.2 *excessive leakage* — Gas leakage (measured in bubbles) from a fitting connection greater than can be humanly counted.

5.2.3 *seal cap* — An end closure or plug to block the open end of a tube or fitting to allow the specimen to be pressurized with nitrogen gas]

5.2.4 *subject* — To expose to.

5.2.5 *submersion tank* — A transparent tank filled with room temperature isopropyl alcohol used for observing leakage of nitrogen from the tube fitting connection. A cover or lid that does not create an air-tight seal is recommended while the specimen is being subjected to pressure.

6 Apparatus

6.1 Constant Temperature Oven

6.1.1 The constant temperature oven must have sufficient capacity to accommodate the specimens and control the temperature within ± 3°C (± 5°F).

6.1.2 See Figure 1 for test set-up.

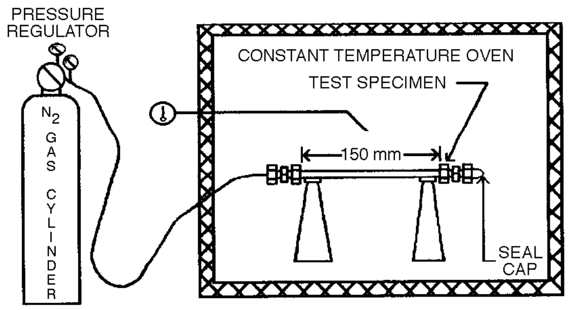

Figure 1
Test Set-Up

6.2 *Nitrogen Supply*

6.2.1 The supply of nitrogen must have a pressure regulator to control the pressure to the specimens accurately.

6.2.2 The nitrogen supply must include an instrument for monitoring pressure to within 2% of the test range (650 kPa, 94 psi).

6.3 *Submersion Tank* — The submersion tank is used for observing leakage of nitrogen from the fitting connection. (See Figure 2.) It consists of a container capable of holding enough isopropyl alcohol to allow the specimen to be submerged 25 ± 5 mm (1 ± .2 in) below the fluid surface at a 45° ± 5° angle.

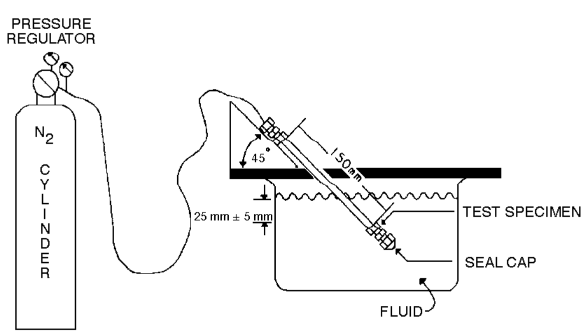

Figure 2
Submersion Tank for Observing

7 Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance ratings of the products under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test.

8 Test Specimens and Conditioning

8.1 *Sample Size* — Test at least three specimens at each test condition.

8.2 *Specimen Tubing Length* — At least 150 mm (6 in).

8.3 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

8.4 All specimens must be conditioned for a minimum of one hour in an air environment of 23° ± 2.8°C (73° ± 5°F) prior to being subjected to test.

9 Test Procedure

9.1 A representative specimen must be assembled and should accompany the test specimens during the heat cycle but will be used for the sole purpose of monitoring temperature.

NOTE: The representative specimen must be of the same size and type as the test specimens being tested. The representative specimen shall not be pressurized during any portion of the test.

9.1.1 Insert a temperature probe into the center of the representative fitting specimen. Ensure that the temperature probe is sealed from the oven environment to prevent any of the heated air from entering the specimen. (See Figure 3.)

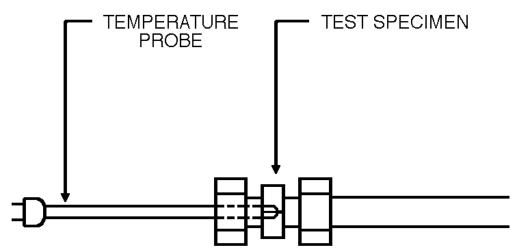

Figure 3
Placement of Probe

9.1.2 Place the representative specimen among the test specimens to monitor temperature during the heat cycle.

9.2 Assemble the test specimens in accordance with manufacturer's specifications. The test specimens shall be as described in Section 8. A seal cap shall also be attached to allow the specimen to be pressurized.

9.3 Submerge each test specimen as shown in Figure 2, and subject it to the specified pressure for the 23°C (73°F) column based on tube size as shown in Table 1. (See Appendix 1.) Observe the fitting connection for leakage for a minimum of one minute. Record the leakage results in the Proof Test area of the Test Data Sheet. (See Related Information 1.) This is a proof test to determine the integrity of the fitting connection before it is subjected to a heat cycle.

9.3.1 If excessive leakage (more than can be humanly counted) occurs, stop the test, and record as excessive leakage on the Test Data Sheet. (See Related Information 1.)

9.4 Condition the specimens to 75°C (167°F) by placing the specimens into the oven (see Figure 1) while subjecting them to the specified pressure for that temperature and tube size as shown in Table 1. (See Appendix 1.)

NOTE: More than one specimen may be conditioned simultaneously. Only fittings with the same test pressure and temperature should be conditioned simultaneously. Specimens must be leak tested individually.

9.4.1 The specimens shall remain in the oven 15 minutes after it has stabilized to the specified temperature.

9.4.2 Release nitrogen pressure from the specimens, remove from the oven, and allow to cool to room temperature 23° ± 2.8°C (73° ± 5°F). Do not disturb the specimens while cooling.

9.4.3 After the temperature of the specimens has reached room temperature, allow the specimens to remain undisturbed for 15 additional minutes before leak testing.

9.5 Submerge each specimen as shown in Figure 2, and pressurize to the specified pressure for the 23°C (73°F) temperature. Observe the fitting connection for leakage for a minimum of one minute.

9.6 Release the pressure in the specimen, and record the results on the Test Data Sheet. (See Related Information 1.)

NOTE: The release of pressure from the specimen when removing from the oven and from the submersion tank is for safety reasons, and compliance is strongly recommended.

9.6.1 Unit of measure for leakage is the number of nitrogen bubbles per minute.

9.6.2 Leakage from the seal cap is beyond the scope of this document and is not required to be measured or recorded.

9.7 After completion of leakage measurement, repeat Sections 9.4 through 9.6 ten times (cycles) at the same pressure and temperature level with the same specimens.

9.7.1 If excessive leakage (more than can be humanly counted) occurs, stop the test, and record as excessive leakage on the Test Data Sheet. (See Related Information 1.)

9.8 After completion of ten cycles, repeat the test with new specimens starting at Section 9.2, but substituting for the temperature in Section 9.4, 100°C (212°F) and 125°C (257°F) as shown in Table 1. (See Appendix 1.)

10 Data Accuracy

10.1 *Pressure* — ± 2%

10.2 *Temperature* — ± 1°C (± 2°F)

11 Test Data Sheet

The test data sheet shall include the following information:

11.1 Date tested.

11.2 Operator and test facility.

11.3 Description of items tested, including:

Tubing — Manufacturer, O.D., wall thickness, part number, and material.

Fitting — Manufacturer, type, size, part number, and material.

11.4 All of the data described in Section 9.

NOTE: A sample test data sheet is included as Related Information 1.

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI F12 by full letter ballot procedure.

Table 1 Nitrogen Pressure for Each Test Temperature

Tube Size (Diameter × Thickness in mm (in)	*Test Temperature: °C (°F)*			
	23 (73)	*75 (167)*	*100 (212)*	*125 (257)*
	Test: Pressure kPa (psi)			
Ø3 × 0.5 (0.020 in)	570 (82)	320 (46)	230 (33)	200 (29)
Ø 3.18 (1/8 in) × 5	540 (78)	320 (46)	230 (33)	200 (29)
Ø 4 × 0.5	420 (60)	240 (35)	170 (25)	140 (20)
Ø 6 × 1	570 (82)	320 (46)	230 (33)	200 (29)
Ø 6.35 (1/4 in) × 0.5	270 (39)	150 (22)	110 (16)	90 (13)
Ø 6.35 (1/4 in) × 1.2 (0.050 in)	650 (94)	370 (54)	260 (38)	220 (32)
Ø8 × 1	430 (62)	240 (35)	170 (25)	140 (20)
Ø8 × 1.2	510 (73)	290 (42)	210 (30)	170 (25)
Ø8.53 (3/8 in) × 0.8 (0.031 in)	320 (46)	200 (29)	150 (22)	120 (17)
Ø8.53 (3/8 in) × 1.6 (0.063 in)	650 (94)	320 (46)	230 (33)	200 (29)
Ø10 × 1	340 (49)	190 (28)	140 (20)	120 (17)
Ø10 × 1.6	530 (79)	320 (46)	230 (33)	200 (29)
Ø12 × 1	280 (40)	180 (26)	120 (17)	100 (15)
Ø12 × 1.6	460 (66)	260 (38)	190 (28)	160 (23)
Ø12.7 (1/2 in) × 1.6	520 (75)	250 (36)	180 (26)	150 (22)
Ø19.06 (3/4 in) × 1.6	290 (42)	160 (23)	120 (17)	100 (15)
Ø25 × 1.5	210 (30)	120 (17)	80 (12)	70 (10)
Ø25 × 2	270 (39)	160 (23)	120 (17)	100 (15)
Ø25.4 (1 in) × 1.6	210 (30)	120 (17)	80 (12)	70 (10)

RELATED INFORMATION 1
SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F12 and is not intended to modify or supercede the official test method. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

	Amount of Leakage: Bubbles per Minute								
Test Temperature	*75°C*			*100°C*			*125°C*		
Test Sample	1	2	3	1	2	3	1	2	3
Proof Test									
Heat Cycle	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx
1st time									
2nd time									
3rd time									
4th time									
5th time									
6th time									
7th time									
8th time									
9th time									
10th time									

SEMI F13-1101
GUIDE FOR GAS SOURCE CONTROL EQUIPMENT

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1993.

1 Purpose

1.1 The purpose of this document is to provide a guide for the design and operational requirements of gas source control equipment which is used to control pressure and flow from a gas cylinder to the point of use.

2 Scope

2.1 This document describes the components and minimum performance criteria for gas source control equipment used with hazardous production material (HPM) semiconductor gases. This guide also includes recommended component functions and operating requirements.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Related Documents

3.1 These documents should be used in the design, fabrication, installation, and operation of gas source control equipment.

3.2 *SEMI Standards and Safety Guidelines*

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

SEMI F2 — Specification for 316L Stainless Steel Tubing for General Purpose Semiconductor Manufacturing Applications

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI F4 — Guide for Remotely Actuated Cylinder Valves

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F14 — Guide for the Design of Gas Source Equipment Enclosures

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S4 — Safety Guideline for the Segregation/ Separation of Gas Cylinders Contained in Cabinets

SEMI S5 — Safety Guideline for Flow Limiting Devices

3.3 *Compressed Gas Association Documents*[1]

Pamphlet P-1 — Safe Handling of Compressed Gases in Containers

Standard V-1 — Compressed Gas Cylinder Valve Outlet and Inlet Connections

3.4 *National Fire Protection Association Document*[2]

NFPA 704 — Identification of the Hazards of Materials for Emergency Response

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Referenced Standards

4.1 Various codes and ordinances apply in different municipalities. These documents must be followed for the installation and operation of these systems. These codes may include:

Applicable Occupancy Codes — Uniform Building Code (UBC)[3]

Article 51 — Uniform Fire Code (companion document to above UBC)

Article 80 — Uniform Fire Code (companion document to above UBC)

Applicable Occupancy Codes — BOCA National Building Code[4], BOCA National Fire Prevention Code[4]

Local Ordinances — As applicable.

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

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1 Compressed Gas Association, Inc. (CGA), 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202

2 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269

3 International Conference of Building Officials (OCBO), 5360 Workman Mill Road, Whitter, CA 90601

4 Building Officials and Code Administrators International, Inc. (BOCA), 4051 W. Flossmoor Road, Country Club Hills, IL 60478

5 Terminology

5.1 *automatic shut-off (ASO)* — A remotely actuated valve, preferably the cylinder valve, but possibly a valve located close to the cylinder valve, which can isolate the product as close to the cylinder valve as possible. It may also be a device which attaches to the cylinder valve stem or handle to close the valve.

5.2 *compressed gas association (CGA)* — Organization that sets standards for the handling and safe use of gases. Used in this document to refer to the cylinder valve outlet connection for each product as designated by the CGA.

5.3 *cylinder* — A pressure vessel designed for pressures higher than 276 kPa (40 pounds per square inch absolute) and having a circular cross section. It does not include a portable tank, multi-unit tank car tank, cargo tank, or tank car. It also refers to non-DOT low pressure containers used for liquid product having low vapor pressure.

5.4 *gas source control equipment (GSCE)* — Refers to the equipment assembly beginning at the product exit from the cylinder valve to the beginning of the distribution piping leading to the point of use (POU). These assemblies are usually mounted on panels and are sometimes referred to as process panel systems.

5.5 *hazardous production material (HPM)* — A solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes which have, as their end product, materials which are not hazardous.

5.6 *high pressure isolation (HPI) valve* — A shut-off valve located on the high-pressure side of a gas piping system that, when closed, isolates the purged volume from the pressure regulator and other downstream components.

5.7 *low pressure isolation (LPI) valve* — A shut-off valve located on the low-pressure side of a gas system that, when closed, isolates the purged volume from the distribution piping and all other downstream components.

5.8 *point of use (POU)* — Refers to the manufacturing tool which uses the product. Point of use is distinguished from the GSCE by having its own design criteria, separate function, and physical separation from the GSCE.

5.9 *product* — Refers to the gas phase in the cylinder.

6 Configuration

6.1 *Manual/Auto Operation*

6.1.1 Manual equipment without automation is adequate if it includes an ASO plus excess flow device. (Where required, per UFC articles 51 and 80.) Automated purging is generally more efficient than manual purging and is, therefore, recommended. The ASO function is achieved if the ASO valve automatically defaults to a closed position via a pneumatically actuated valve, or separate actuator that will close a manual cylinder valve. Either method should be fail-safe (default to a closed position on loss of power and/or pneumatics). This could also be initiated by any number of abnormal circumstances.

6.1.2 *Fully Automatic* — This is a broad category of designs using any number of transducers, remotely operated valves, and logic to accomplish safeguarding, monitoring, and automatic purging. Extension of this approach to central data collection, analysis, and reporting via computers and special programs offers the capability of further reducing hazards and enhancing safety.

6.2 *Cylinder Connections*

6.2.1 Compressed gas cylinders are connected to the panel equipment using the connection on the outlet of the cylinder valve. The appropriate regulatory agency has designated one or more connections for each product gas.

6.2.2 Other containers for liquid or low vapor pressure materials may require the connection of two fittings. One of these is used to admit gas, which either pressurizes the product, allowing liquid withdrawal, or absorbs the product, allowing withdrawal of a gas-phase mixture of the product and the gas. The other fitting is used for withdrawal. The types and labeling of the connections vary among suppliers.

6.2.3 *High Pressure Pigtail* — A semi-flexible assembly of piping, subjected to cylinder pressure, which is used to connect the cylinder to the rigidly mounted components on the panel. The intent of this flexible assembly is to accommodate the location of the cylinder outlet.

6.2.4 *No Pigtail* — An alternate acceptable method allows cylinders to be elevated or lowered to match the fixed height of the connection point on fixed panel equipment.

6.3 *Cross Contamination*

6.3.1 *Purge Gas Cylinder Contamination by Process Gas* — Purge gas is supplied from cylinders, with each purge gas cylinder limited to a single process gas panel or several panels using the same process gas class or different mixture ratios of the same process gas class. A check valve should be installed in each line connecting the purge gas to the process panel equipment.

6.3.2 *Process Gas Cylinder Contamination by Purge Gas* — The purpose of purging is to remove air or residual process gas from the panel equipment (or part of it) back to the internal cavity of the closed cylinder valve.

WARNING: Check valves are not acceptable in this part of the process gas system because purging would be defeated. Cross contamination can only be prevented by safeguards which assure complete cylinder valve closure and process gas venting, before purging begins.

6.4 *Materials* — All materials furnished should be manufactured to nationally recognized standards. Metals used for the wetted surfaces should be type 3l6L stainless steel, or other materials that provide equal or improved compatibility with the gas in service. Nonmetallic seals that are used in valve or regulator seats must also be compatible with the product in service.

6.5 *Joints* — All welded joints should be butt welded (no socket welds) and should comply with SEMI F3. Connection fittings should be face seal type.

6.6 *Particle Control* — Particle contamination is controlled through the proper selection of components and system hardware, good design practices, clean fabrication methods, and proper operation of the system.

6.7 *Internal Volume* — The internal cavities should be configured for minimum surface area and internal volume to enhance purging. Dead end legs should be eliminated or kept to a minimum volume and length.

6.8 *Maintainability* — Planned maintenance or forced repair is facilitated or inhibited by specific design concepts and features. From a safety point of view, it is mandatory to be able to purge the entire GSCE (all cavities) and to have a downstream shutoff (low pressure isolation valve) and disconnect fitting.

7 Performance Recommendations

7.1 *Functional Recommendations*

7.1.1 The ASO should be designed to close based on an alarm or fail signal from an auxiliary component. It should be designed to fail closed and should have a working pressure at least 1.1 times the product cylinder pressure. If a pressure sensor is located between the ASO and the cylinder valve, as depicted in Figure 1, it should also have a working pressure at least 1.1 times the product cylinder pressure.

7.1.2 *Pressure Reduction* — Gases are most commonly required at POU at less than 100 psig. Cylinder pressure is reduced to the lower pressure by a gas pressure regulator, when necessary.

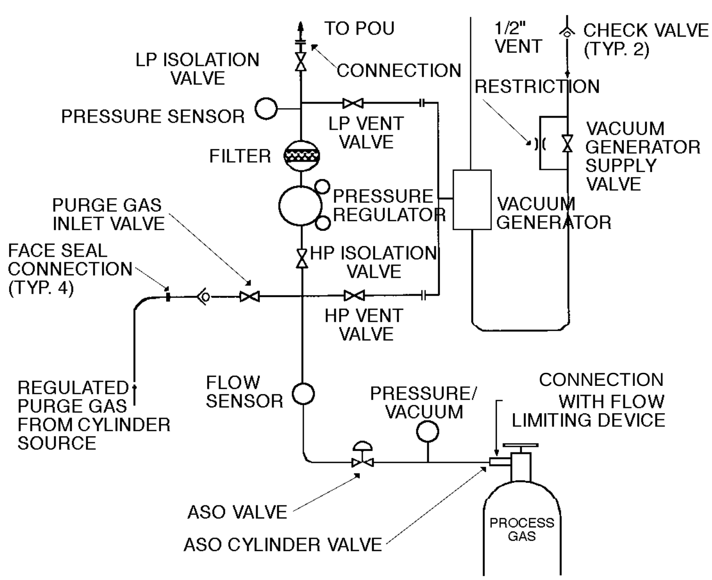


Figure 1
Typical Gas Source Control System

7.1.3 *Excess Pressure Control* — Provisions should be made to protect the distribution piping and process equipment from excessive pressure. This protection may include a pressure transducer, pressure switch, or indicating transmitter connected to close the ASO, a relief valve piped into the exhaust, or a redundant pressure regulator with primary regulator failure indication.

7.1.4 *Cylinder Content*s — The product remaining in the cylinder is determined by gas pressure measured by either a pressure transducer or gauge, or in the case of material in liquid/vapor phase, by the cylinder weight measured by a scale.

7.1.5 *Delivery Pressure* — The pressure delivered by the regulator is displayed by a pressure indicator. This can be either a gauge or transducer readout.

7.1.6 *Filters* — Particles from ambient sources, entering with the product or generated by the system elements, can be captured by including one or more filters at a variety of locations within the system. This practice tends to protect the components and the process.

7.1.7 *Purge Gas Connection* — A purge gas connection is provided via a branched connection to admit clean, dry, inert purge gas through an on-off valve. This is commonly located between the cylinder connection and high pressure isolation valve in the panel system. Gas purging is used for installation of a new system, before disconnecting a spent cylinder, after connecting a fresh cylinder, and for removal of equipment for maintenance purposes.

7.1.8 *Vent Outlets* — The normal purpose of the vent valves is to discharge process gas, air, and purge gas in conjunction with purging operations. Under special circumstances, they are used to reduce pressure in the equipment and/or transfer product. One or more vents may be used at various locations, and downstream venting may be either atmospheric pressure or vacuum from a venturi or pump. Vacuum venting is strongly recommended.

7.1.9 *High Pressure Indication* — A pressure indicator in common with the high pressure line connected to the cylinder valve is required to indicate the presence of residual process gas, or an open or leaking cylinder or panel valve. It also shows application of adequate purge gas pressure, and, in cases where vacuum-assisted purging is employed, an indication of the vacuum level should be included.

7.1.10 *Cylinder Connection Makeup* — After a fresh cylinder has been connected, the integrity of the cylinder valve connection can be tested with the use of the pressure indicator mentioned in Section 7.1.9.

7.2 *Failure Modes* — Any one of a number of conditions will require emergency action. Some are more serious than others. In some cases, the consequence is shutdown of the panel equipment and venting to a properly controlled discharge system. These failures should be addressed in the hardware and operational design phase of the system.

7.2.1 *Excessive Delivery Pressure* — Due to equipment malfunction or operator error.

7.2.2 Leaking fitting or component malfunction may require gas detection monitor.

7.2.3 *Excess Flow* — This can be the result of operator error or catastrophic conditions, such as a sheared delivery line.

7.2.4 Cabinet exhaust failure.

7.2.5 Mechanical failure of panel equipment parts or downstream equipment.

7.2.6 Destruction to plant through fire, explosion, earthquake, crash, etc.

7.2.7 Inadvertent mishandling of distribution equipment.

7.2.8 Process tool problems.

7.2.9 Control system failure.

7.2.10 *System Abuse/Misuse* — Source gas quality may affect service life and operability of the system. Poor gas product quality may cause a reduction in performance of the system that can lead to premature hardware component failures.

8 Acceptance Test

8.1 All gas source control equipment should undergo an acceptance test, agreed to and understood by the customer and supplier, before it is delivered. This test should ensure that all control and operational functions perform as required by the customer's and/or supplier's specifications.

9 Qualification Test

9.1 GSCE should be qualified at its installed location with an inert gas prior to installing the process gas cylinder. This test should include the operation of all control and hardware functions, interface with the process tool and all interconnected safety devices, systems, and alarms. This should also include a system wide leak test of all possible leak points, such as fittings and welds.

10 Labeling

10.1 The GSCE panel should be labeled for the product. Further labeling as defined in SEMI F14 should be affixed to the outside of the door of the enclosure.

11 Instructions

11.1 The purchaser's requirements will dictate the information provided with the equipment. Minimum acceptable instructions will vary with the complexity of the equipment (e.g., manual, automatic, microprocessor or pneumatically controlled, analog or digital, etc.) In all cases, the following information should be included:

11.1.1 "**WARNING:** Read Instructions Before Proceeding. (Instructions No. xxx for System No. xxx)

Do not proceed without understanding the status of the equipment as received, or damage may result."

11.1.2 *Installation*

11.1.2.1 Certified status of equipment as shipped should include:

11.1.2.2 Leak integrity,

11.1.2.3 Particle level,

11.1.2.4 Contaminants,

11.1.2.5 Storage requirements,

11.1.2.6 Status indicators,

11.1.2.7 Removal of shipping safeguards,

11.1.2.8 Physical mounting and connection details, and

11.1.2.9 Purging during preparation and start-up.

11.1.3 *Start-Up Method*

11.1.3.1 Perform purge for initial start,

11.1.3.2 Pre-process (with substitute inert gas),

11.1.3.2.1 Confirm all component functions,

11.1.3.2.2 Confirm all operating levels and setpoints, and

11.1.3.2.3 Confirm leak integrity.

11.1.4 *Process Service* — Operational purge procedures that include the number of purge cycles and purge pressure and vent dwell times, that take into account the configuration of the system and the intended process gas, should be determined before process gas is installed.

11.1.5 *Maintenance* — Maintenance purge procedures and panel repair and replacement procedures should be defined before process gas is installed.

NOTE 3: Special warnings about the potential for dead space in components or fittings, etc. (in normal or failed mode) should be identified to avoid producing a hazardous condition for any subsequent operation or handling at any location.

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI F13 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 Scope

A1-1.1 Under special circumstances, it may be necessary to cease using a product and remove it from the cabinet to a safer and/or less populated environment. This can be done in a number of ways.

A1-1.2 If the cylinder valve cannot be opened or closed, the gas supplier must be notified. Prior arrangements between the supplier and user of procedures should be in place, so that the required actions can be readily accomplished.

A1-2 Transfer Out of Cylinder

A1-2.1 Close the low pressure isolation valve, disconnect at the downstream side of either of the vent valves and connect to a suitable receiver with means of pumping if required. This depends upon knowledgeable operators, and the procedure to be followed must reflect the features of the particular GSCE and the product to be transferred. Extreme caution must be observed.

A1-3 Removal of the Cylinder

A1-3.1 A cylinder with a faulty or questionable cylinder valve may have to be removed. When a redundant valve and disconnect is installed in the pigtail, it may be closed, disconnected, and removed with the cylinder with relative ease and security. When a redundant valve is not present and a particular design allows it, the purge inlet valve, vent valve, and the HP isolation valve may be closed and removed with the pigtail still connected to the questionable cylinder. Adequate purging should precede this procedure.

SEMI F14-93 (Reapproved 0699)
GUIDE FOR THE DESIGN OF GAS SOURCE EQUIPMENT ENCLOSURES

This standard was technically reapproved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org February 1999; to be published June 1999. Originally published in 1993.

Editorial changes were made to sections 3.1.1, 6.2.1, and 6.2.2.

1 Purpose

1.1 This document summarizes gas source equipment enclosure design considerations. It is intended for use by manufacturers and purchasers.

2 Scope

2.1 Design considerations pertaining to gas source equipment enclosures are described herein. Modifications required to accommodate specific gases, cylinders, or unusual applications (e.g., process equipment) are not addressed.

3 Referenced Documents

3.1 Various codes and ordinances apply in different municipalities. These documents must be followed for the installation and operation of these systems. These codes may include:

3.1.1 *NFPA Standards*[1]

NFPA 13 — Installation of Sprinkler Systems

NFPA 69 — Explosion Prevention Systems

NFPA 70 — National Electrical Code

NFPA 91 — Exhaust Systems for Air Conveying Materials

3.1.2 *ICBO Model Code*[2]

Uniform Fire Code, 1991 Edition

3.1.3 *SEMI Safety Guideline*

SEMI S4 — Safety Guideline for the Segregation/ Separation of Gas Cylinders Contained in Cabinets

3.1.4 Other Publications

Industrial Ventilation, A Manual of Recommended Practice[3]

BOCA National Building Code[4]

BOCA National Fire Prevention Code[4]

Standard Building Code[5]

3.1.5 *Local Ordinances*

As applicable.

4 Terminology

4.1 *gas cylinder* — Usually means a high pressure compressed gas cylinder governed by Department of Transportation (DOT) regulations. It also refers to non-DOT low pressure containers used for liquid product having low vapor pressure.

4.2 *gas source equipment enclosure (enclosure)* — An enclosure for the storage of gas containers and associated equipment.

5 Functions

5.1 Five important functions are provided by an enclosure and its associated safety devices.

5.1.1 *Leaking Gas Containment* — Personnel, equipment, and the immediate working environment are protected from the hazards of leaking gases.

5.1.2 *Fire Protection* — Personnel and equipment are protected from the consequences of internal and external fires.

5.1.3 *Mechanical Protection* — The cylinder and associated equipment are protected from impact and seismic forces. (For further information, see UFC 51, *Workstations and Fabrication Areas*.)

5.1.4 *Access Control* — Unauthorized persons are inhibited from using gases and operating associated

[1] *National Fire Protection Association, Batterymarch Park, Quincy, MA 02269*

[2] *International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601*

[3] *American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211*

[4] *Building Officials & Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60477*

[5] *Southern Building Code Congress International, 900 Montclair Road, Birmingham, AL 35213*

equipment.

5.1.5 *Gas Separation* — Gases that are chemically incompatible or belong to dissimilar hazard classes should be separated.

6 Design Considerations

6.1 *Regulatory Requirements* — The enclosure should conform to local, state, and federal regulations.

6.2 *Materials*

6.2.1 Enclosure top, sides, and doors should be constructed of 2.7 mm (12 gage) or thicker cold-rolled sheet steel or other suitable material so as to provide adequate mechanical stability.

6.2.2 Floors should be constructed of cold-rolled sheet steel or other suitable material, typically 3.4 mm (10 gage) or thicker, so as to adequately resist deformation by the heaviest intended cylinder.

6.2.3 Windows and skylights should be 6.5 mm (0.25 in) thick wired safety glass or other suitable material.

6.2.4 All materials should be noncombustible.

6.3 *Dimensions* — The enclosure should completely surround the gas cylinders and requisite accessory equipment. The design should incorporate minimum internal dimensions while still allowing safe and easy access to cylinders and equipment.

6.3.1 Heights of shelves for short cylinders should be adjustable so that cylinder valves and associated equipment are readily accessible through the limited-area access port.

6.3.2 Distances above cylinders should be adequate for installation and operation of associated equipment.

6.4 *Enclosure Interior Access*

6.4.1 *Door* — A gasketed door should enable safe and convenient installation and removal of intended cylinders, and installation, removal, and maintenance of associated equipment. The door should be self-closing and self-latching. The threshold should not interfere with cylinder installation and removal.

6.4.2 *Limited-Area Access Port* — The enclosure should have one or more limited-area ports that enable access to controls and associated equipment within the enclosure without compromising the air velocity across the face of the access port(s). The average air velocity across the faces of access ports should not be less than 1 m/s (200 fpm); a minimum air velocity of 0.75 m/s (150 fpm) should exist at any point.

6.4.2.1 Access ports should be self-closing.

6.4.3 *Window* — One or more windows should be provided to enable observation of equipment within the enclosure without compromising enclosure integrity.

6.4.4 *Security* — Lockable doors and access ports should be provided when unauthorized access to the enclosure interior must be precluded.

6.5 *Ventilation* — The enclosure should enable removal of leaking gas by local exhaust ventilation. The advantages of local exhaust ventilation over general ventilation are more fully described in NFPA 69, NFPA 91, and in Industrial Ventilation.

6.5.1 *Exhaust Connection* — The enclosure should enable connection to an exhaust system that will handle the required exhaust at an average duct velocity that does not exceed 8.5 m/s (1,700 fpm). The total exhaust flow includes that across open access ports as well as that through any supplementary air inlets.

6.5.2 *Air Flow Path* — In addition to access ports, the enclosure should include an air inlet located at the extremity of the enclosure opposite from the exhaust connection, so that ventilation of the entire enclosure is provided. The air flow path should adequately scavenge gas from all regions within the enclosure.

6.5.2.1 Structures (e.g., brackets or shelves) within the enclosure should not adversely affect exhaust capability.

6.5.2.2 Gaskets should be provided on all doors, access ports, and other penetrations.

6.6 *Fire Protection*

6.6.1 *Sprinklers* — Provisions for internal sprinklers should be made when necessary.

6.6.1.1 Sprinklers should be capable of providing adequate cooling to maintain cylinders and associated equipment at a temperature that will not actuate relief devices in the event of an internal or external fire.

6.6.1.2 Sprinkler actuation temperature should be greater than the anticipated maximum operating temperature of the enclosure interior under typical operating conditions, but less than the cylinder pressure relief device actuation temperature.

6.6.1.3 When the enclosure may be exposed to corrosive atmospheres, corrosion-resistant sprinklers should be provided. (For further information, see NFPA 13, *Corrosion-Resistant, Wax-Coated, or Similar Sprinklers*.)

6.7 *Mechanical Stabilization*

6.7.1 Provision for anchoring the enclosure to stable architectural elements should be made.

6.7.2 Fasteners should meet anticipated seismic loads in seismically active areas.

6.7.3 A means of securing each cylinder within the enclosure should be provided.

6.8 *Surface Finishes*

6.8.1 All exterior surfaces and equipment should be treated or finished to resist attack by weather elements.

6.8.2 Interior surfaces and equipment should be treated or finished to resist corrosive or solvent effects.

6.8.3 All surfaces should be free of burrs, sharp edges, and other flaws that could injure users.

6.9 *Interior Illumination* — Illumination of the enclosure interior should be adequate for safe operation of contained equipment. When ambient light is inadequate, several approaches may be taken to provide additional lighting:

6.9.1 A skylight may be provided.

6.9.2 With nonflammable gases, internal electric lights may be provided.

6.9.3 With flammable gases, power cables should not penetrate the enclosure interior except as provided for Class I, Division 2 locations (NEC, Article 501). Either internal explosion-proof lights may be provided, or external standard lights may project through an unopenable window.

6.9.4 All interior surfaces should reflect light efficiently.

6.10 *Labels*

6.10.1 *Gas Labels* — A label clearly displaying the chemical formula and common name of the gas should be attached to the enclosure exterior surface; its color should contrast with that of the enclosure.

6.10.2 *Hazard Warning Labels* — A label clearly stating requisite hazard warnings should be mechanically attached to the enclosure exterior surface in accordance with local building code requirements.

6.10.3 *Information Labels* — A label providing important specific information such as, but not limited to, emergency contacts, telephone numbers, manifold schematics, and first aid recommendations should be attached to the enclosure exterior surface.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI

SEMI F15-93 (Reapproved 0699)
TEST METHOD FOR ENCLOSURES USING SULFUR HEXAFLUORIDE TRACER GAS AND GAS CHROMATOGRAPHY

This Test Method was technically reapproved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org February 1999; to be published June 1999. Originally published in 1993.

1 Purpose

1.1 The purpose of this test method is to provide a standardized method to test the ability of enclosures to contain gases and vapors and a standardized format to record and document test results.

2 Scope

2.1 This test method applies to any enclosure that possesses a local exhaust (secondary ventilation) system.

2.2 In this test method, the tracer gas of choice is sulfur hexafluoride (SF_6). It is recognized that other gases have been used as tracers, but for the purposes of this test method, tracer gas means SF_6.

3 Limitations

3.1 This test method is intended to test the containment ability of a local exhaust system within an enclosure under the manufacturer's specified operating conditions. Thus, test data obtained by means of this test method apply only to the local exhaust conditions that existed within the enclosure during the testing. Extrapolation of the test data to other exhaust operating conditions is not usually possible.

3.2 Use of this test method requires a knowledge of the principles of gas analysis as well as flow and pressure measurement, gas chromatographic instrumentation, and gas sampling techniques.

3.3 An acceptable enclosure, as determined in Section 7.1, does not imply a safe condition for routine equipment operation with a leak and/or a tubing/fitting failure. An acceptable enclosure is one that will contain potential worst case leaks in an emergency, non-routine situation. The fact that an enclosure is acceptable does not imply that the enclosure is safe to operate when a hazardous gas leak has been detected.

4 Referenced Documents

4.1 *SEMI Document*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 *ASTM Documents*[1]

ASTM E 260 — Practice for Packed Column Gas Chromatography

ASTM E 697 — Practice for Use of Electron Capture Detectors in Gas Chromatography

4.3 *NFPA Standards*[2]

NFPA 13 — Identification of the Hazards of Materials for Emergency Response

NFPA 704 — Standard System for the Identification of Fire Hazards of Materials

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *equivalent release concentration (ERC)* — The theoretical concentration of a process gas that would be measured outside an enclosure in the event of a process line failure. The ERC can be expressed as a percentage of the TLV or PEL of the process gas.

5.2 *hazardous production material (HPM)* — For the purposes of this test method, a gas or vapor that has a degree-of-hazard rating in health, flammability, or reactivity of 3 or 4, as ranked by NFPA 704, that is used directly in a research, laboratory, or production process that has as its end product materials which are not hazardous.

6 Summary of Method

6.1 A test is performed by releasing tracer gas at a constant flow rate within an enclosure to simulate a worst case leak and then measuring on the periphery of the enclosure for the presence or absence of tracer. The lack of measurable tracer indicates that the release of potentially hazardous gases or vapors within the enclosure at the tracer injection point(s) will not result in their migration to the outside of the enclosure. Gas

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

2 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269 samples are taken by means of disposable syringes, sample bags, or sample vials. Gas samples are analyzed by means of electron capture gas chromatography.

7 Procedure

7.1 *Test Design*

7.1.1 Determine the type of enclosure to be tested, such as: non-access, access, vacuum pump, equipment cabinet, or other.

7.1.2 Determine the volume of the enclosure.

7.1.3 Measure the exhaust flow rate from the enclosure.

7.1.4 Calculate the air changes per minute of the enclosure by dividing the exhaust flow rate (7.1.3 above) by the enclosure volume (7.1.2).

7.1.5 Calculate the time at which the tracer concentration in the enclosure will achieve approximate equilibrium. Concentration equilibrium occurs when the tracer concentration in the enclosure stops changing as a function of time for a constant tracer release rate. Divide 3 by the air changes per minute to establish this time. Use this as the time to take the first sample after initiating a test. Appendix 1 provides a derivation of the equilibrium time.

NOTE: This test method is intended to test the containment ability of the local exhaust system within an enclosure when operated according to the manufacturer's specifications. Thus, testing should be performed with the local exhaust operating under its manufacturer's recommended conditions.

7.1.6 If an excess flow control system is used, determine the trip point for each hazardous gas used. If different gases are used in the enclosure, the largest trip point should be used to calculate the tracer release flow rate.

7.1.7 If no excess flow system or flow-restricting orifice is used, the maximum accidental release rate must be calculated from the known maximum system pressure and either valve coefficients or tubing ID. An equation for flow through straight tubing is provided in Appendix 2.

7.1.8 In the absence of guidance in the above two sections, a standard test is the release of tracer gas through 6.35 mm (0.25 inch) OD by 0.89 mm (0.035 inch) wall tubing at a rate of 28 standard liters per minute (slpm) (1 scfm). Appendix 3 derives a general equation, A3-7, that can be used when this is not the case.

7.2 *Reagents and Materials* — Use SF_6 diluted in an inert gas, such as nitrogen or argon, as the tracer source, to minimize measurement difficulties associated with small leaks of pure SF_6 from the supply cylinder and its associated piping.

7.3 *Sampling*

7.3.1 In selecting the location of samples collected outside the enclosure, consider 1) potential leak points, 2) the direction of the release, and 3) laminar flow characteristics in the area surrounding the enclosure. Samples should be collected from all sides of the enclosure, downstream in the prevailing room air flow, and in the operating personnel occupancy areas.

7.3.2 The time required for the enclosure to reach equilibrium should be considered when establishing the time to begin sampling. The first sample after initiating tracer flow should be taken at the enclosure equilibrium time. Collect additional samples at 1 to 2 minute intervals until the tracer source is shut off. One sample should be taken 1 minute after the tracer source is shut off. The test duration can be changed to accommodate a particular test.

7.3.3 Collect background (baseline) samples from the area surrounding the enclosure at predetermined locations. When logistics permit, analyze the background samples before releasing the tracer gas. If background levels above approximately 1 ppb are detected, evaluate the integrity of the SF_6 tracer delivery system, and postpone the test until the concentration is less than 1 ppb. Other sources of SF_6 in the immediate test area may also cause this background.

NOTE: If testing is performed with an SF_6 background, the background concentration must be measured and subtracted from any subsequently measured tracer concentration value.

7.3.4 Release tracer gas within the enclosure being tested by means of an injection manifold, shown schematically in Figure 1. The tracer injection manifold must be capable of measuring flow rates to an accuracy of ± 5%. The tracer gas delivery line must be routed into the enclosure and attached to a potential leak point without violating the integrity of the enclosure.

NOTE: To minimize tracer gas contamination of the area surrounding an enclosure during a test, the end of the tracer injection line should be capped, except when performing an injection test.

7.3.5 Perform several tests with differing directions of release relative to any opening or penetration in the enclosure. The location and direction of the release shall effectively simulate an actual gas release or tubing/fitting failure within the enclosure. A worst case failure can be simulated by locating the tracer injection point at the potential leak location closest to a penetration or opening within the enclosure with the direction of tracer injection pointed directly at the opening or penetration.

7.3.6 After initiation of tracer injection, collect grab air samples from the area surrounding the enclosure at predetermined times and locations. These samples should be analyzed immediately after collection. If this is not possible, they should be sealed. Label the samples as to time and location. Samples may be taken with a) Containers that are non-absorbent, inert, and that have low permeability (such as polyvinyl fluoride film or polyester film sample bags or polyethylene, polypropylene, nylon, or glass bottles) or b) disposable syringes. Disposable syringes can be used to inject samples into the gas chromatograph directly.

7.3.7 Record a) the actual (measured) tracer gas release rate, b) the actual SF_6 concentration in the tracer gas being used, and c) the actual release time during a test.

7.3.8 Collect air samples as described in Section 7.3.6, and analyze them for the presence or absence of tracer gas using a gas chromatograph. The measurement of a non-zero tracer concentration in the area surrounding an enclosure indicates incomplete containment of contaminants within the enclosure.

7.3.9 Analyze samples according to ASTM E 260 and ASTM E 697 in conjunction with the chromatograph manufacturer's operating procedures. Samples may be analyzed immediately after a test, or they may be stored for future analysis. Experience has shown no degradation of concentration in polypropylene syringes when stored for several months as long as the needle or syringe is plugged. Polypropylene syringes should be discarded after one use to eliminate the possibility of cross contamination of samples.

8 Calculations and Interpretation of Results

8.1 The maximum concentration of SF_6 measured in a sample collected outside the enclosure is used to calculate the Equivalent Release Concentration (ERC) by the following formula:

$$\text{ERC} = \frac{\text{Conc. of process gas} \times \text{Measured SF}_6 \text{ Conc.}}{\text{Tracer Injection gas conc.}}$$

The above formula assumes the process gas tubing that fails is the same diameter as the tracer gas injection tubing. Appendix 3 contains a general equation that can be used when this is not the case.

8.2 Compare the Equivalent Release Concentration to the hazardous process gas TLV or PEL, whichever is lower. If the ERC is above the prescribed limits, the enclosure is not considered to be acceptable; if the ERC is less than or equal to the prescribed limit, the enclosure is considered acceptable. SEMI S2 recommends appropriate control limits for an enclosure.

9 Reporting Results

9.1 Present all results in tabular form in a manner which unambiguously notes those enclosure(s) that do not satisfy the criteria of SEMI S2. The exhaust operating conditions during each test must be provided along with each measured ERC value.

9.2 Describe tracer gas injection points within individual enclosures to detail location and proximity to openings, penetrations, exhaust grillwork, access panels, and other potential leakage sites, such that worst case leak conditions have been simulated.

9.3 Describe the unit being tested by manufacturer, model number, and serial number to provide identification of the unit being tested.

9.4 Tabulate and record the name, supply concentration, maximum flow rate, and TLV or PEL for each hazardous gas or vapor used within each enclosure being tested.

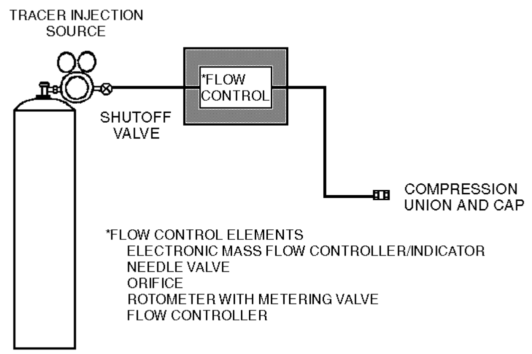


Figure 1

Schematic Drawing of Injection Manifold

10 Related Documents

29 CFR 1910.1000 — Code of Federal Regulations, Title 29, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

ACGIH — American Conference of Governmental Industrial Hygienists, 6500 Glenway, Building D-7, Cincinnati, OH 45211-4438, (513)661-7881. Industrial Ventilation - A Manual for Recommended Practice, 20th ed. ISBN: 0-936712-65-1.

American Industrial Hygiene Association — 345 White Pond Drive, Akron, OH 44320, (216)873-2442. Workplace Environmental Exposure Level Guides.

ASTM — American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. ASTM Standard E741-83 (Determining Air Leakage Rate by Tracer Dilution).

BOCA — Building Officials and Code Administrators International Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795, (708)799-2300. National Fire Prevention Code.

Grot, R.A. and P.L. Lagus — "Applications of Tracer Gas Analysis to Industrial Hygiene Investigations," *Industrial Hygiene News*, May 1991.

Orcutt, J.R. — "Characterization of Hazardous Gas Releases by Tracer Gas Simulation," *Hazardous Assessment and Control Technology in Semiconductor Manufacturing*, ACGIH, Cincinnati, OH, 1988.

SBCCI — Southern Building Code Congress International, 900 Montclair Road, Birmingham, AL 35213-1206, (205)591-1853. Standard Fire Prevention Code.

Tubby, R.L. — "Tracer Gas Testing of Secondary Exhaust Systems on Hazardous Gas Enclosures," *SSA Journal*, Vol. 5, June 1991.

UFC — Uniform Fire Code. International Conference of Building Officials and Western Fire Chiefs Association, 5360 South Workman Mill Road, Whittier, CA 90601. 1988 Edition, ISSN 0896-9736.

APPENDIX 1
EQUILIBRIUM TIME FOR TRACER INJECTION

If a tracer gas is injected at a constant rate into an enclosure that possesses a constant ventilation rate, the concentration as a function of time is given as

$$C(t) = (F/q)\,[1 - \exp\{-(q/V)t\}] \qquad (A1\text{-}1)$$

where $C(t)$ = Concentration within the enclosure
F = Injection rate of tracer gas
q = Ventilation rate of enclosure
V = Volume of enclosure
t = Elapsed time since initiating injection

Note that the term (q/V) contained in the exponential is the air change rate. In order for the concentration C(t) to be constant, the exponential term must be approximately zero. This is generally taken as the time when the exponential term is equal to e^{-3}. The time at which this occurs can be found by setting (q/V)t = 3 and solving for t. Thus,

$$(q/V)t = 3 \qquad (A1\text{-}2)$$

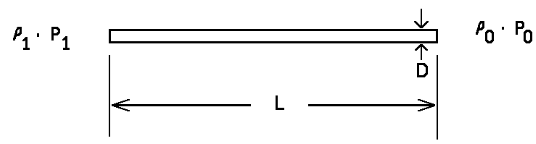
from which it follows that the equilibrium time is given as,

$$t = 3/(q/V) \qquad (A1\text{-}3)$$

$$t = 3(V/q) \qquad (A1\text{-}4)$$

APPENDIX 2
EQUATION FOR FLOW IN A STRAIGHT TUBE

Flow in a straight tube may be calculated if the tube characteristics, as well as the upstream and downstream pressures, are known. In the following, the upstream (drive side) conditions have a subscript of 1, while the downstream (ambient) conditions have a subscript of 0.



$$\gamma M_1^2 = \frac{1-\left(\frac{P_0}{P_1}\right)^2}{4f\left(\frac{L}{D}\right)+\ln\left(\frac{P_1}{P_0}\right)^2} \qquad (A2\text{-}1)$$

$$W = A(\rho_1 P_1 \gamma M_1^2)^{0.5} \qquad (A2\text{-}2)$$

$$\rho_1 = \rho_0\left(\frac{P_1}{P_0}\right) \qquad (A2\text{-}3)$$

where ρ_0 = $0.00129\ g/cm^3$
γ = 1.4
P = Pressure (dynes/cm^2)
$4f$ = 0.02 (*for smooth pipe*)
L = Length (cm)
D = Diameter (cm)
W = Mass Flowrate (g/sec)
A = Area of Flow Line (cm^2)

NOTE: Atmospheric pressure, 10^6 dynes/cm^2, is approximately 14.7 psia.

APPENDIX 3
GENERAL EQUATION RELATING PROCESS GAS FLOW RATE TO TRACER INJECTION RATE

In this appendix, a general equation relating process gas flow rate, tracer injection flow rate, and measured SF_6 concentration outside an enclosure to the ERC is provided. In the following, Q and L are given in volume units per unit time. Concentrations C are given in units of either vol./vol. or %. Whatever units are chosen should be used consistently in Equation A3-7.

Let the tracer injection rate into a volume be Q and the ventilation rate in this volume be L. At equilibrium, the concentration of tracer within this volume is Q/L = C_{source}. If, in the laboratory, one measures a concentration of tracer gas C_{lab}, then the Dilution Ratio, D, can be calculated as equal to

$$C_{lab}/C_{source}\,]_{tracer} = D_{tracer} \qquad \text{(A3-1)}$$

For any conserved chemical specie, D is constant. Thus, for a process gas released within the volume, one can form an analogous ratio

$$C_{lab}/C_{source}\,]_{process} = D_{process} \qquad \text{(A3-2)}$$

For all conserved chemical species, D is constant, hence

$$D_{tracer} = D_{process} \qquad \text{(A3-3)}$$

From this, one can form

$$C_{lab}/C_{source}\,]_{tracer} = C_{lab}/C_{source}\,]_{process} \qquad \text{(A3-4)}$$

so that

$$C_{lab}/C_{source}\,]_{tracer} \times C_{source}\,]_{process} = C_{lab}\,]_{process} \qquad \text{(A3-5)}$$

Here $C_{lab}\,]_{process}$ is the previously identified ERC.

For releases in the same test volume, this equation can be written

$$\{\, C_{lab}\,]_{tracer} \times (Q/L)]_{process}\} \,/\, (Q/L)]_{tracer} = ERC \qquad \text{(A3-6)}$$

Since the ventilation rate is the same

$$C_{lab}\,]_{tracer} \times Q_{process} \,/\, Q_{tracer} = ERC \qquad \text{(A3-7)}$$

This equation allows the calculation of ERC when simulating a leak within an enclosure using a different diameter tubing or different flowrate. In the case where the flowrates (or tubing size and injection pressure) are the same for the tracer and the process gas, Equation A3-7 simplifies to that in Section 5.1.

SEMI F16-94
SPECIFICATION FOR 316L STAINLESS STEEL TUBING WHICH IS TO BE FINISHED AND ELECTROPOLISHED FOR HIGH PURITY SEMICONDUCTOR MANUFACTURING APPLICATIONS

1 Purpose

The purpose of this specification is to identify the applicable ASTM tubing specification requirements and to define the special material composition, wall thickness, ordering, and quality assurance requirements for 316L stainless steel tubing which is to be finished into electropolished tubing, component tube stubs, and fittings made from tubing for use in high purity semiconductor manufacturing facility applications.

2 Scope

This specification defines the special criteria for procuring nominal sizes of unfinished 316L stainless steel tubing which is to be finished into tubing, component tube stubs, and fittings made from tubing for use in high purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

3 Referenced Documents

The referenced documents are to be their current editions as published by their sponsors.

3.1 *ASTM Standards*[1]

A 262 — Practices for Determining Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 269 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 270 — Seamless and Welded Austenitic Stainless Steel Sanitary Tubing

A 450/A 450M — Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 632 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service

E 112 — Methods for Determining Average Grain Size

3.2 *Military Standards*[2]

3.3 *MIL-STD-105* — Sampling Procedures and Tables for Inspection by Attributes

3.4 *ANSI/ASME Standards*[3]

B31.1 — Power Piping

B31.3 — Chemical Plant and Petroleum Refinery Piping

Boiler and Pressure Vessel Code — Section III NCA, The Rules for Construction of Nuclear Power Plant Components

4 General Requirements

Tubing furnished under this specification shall conform to the requirements of ASTM A 450 and A 269 for nominal sizes 1/2 inch diameter and larger and to the requirements of ASTM A 450 and A 632 for nominal sizes smaller than 1/2 inch diameter, and to the additional requirements herein.

5 Ordering Information

5.1 Orders for material under this specification shall include the following, as required to describe the material adequately:

- Quantity (meters, feet, or number of lengths)
- Grade per Table 1 of ASTM A 269
- Size (nominal outside diameter and nominal wall thickness)
- This specification number
- Surface condition (if applicable)
- Special requirements and any supplementary requirements selected

6 Process

The steel shall be processed in accordance with the section on Process of ASTM A 269.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 American National Standards Institute, 1430 Broadway, New York, NY 10018

7 Manufacture

7.1 Tubing shall be made by the seamless process for all sizes, except that welded tubing may be acceptable for nominal sizes 3 inches and above in diameter if the permissible variations in outside diameter are in accordance with Table 2 of ASTM A 270 and the other criteria specified herein are met.

7.2 Tubing must be cold finished.

8 Heat Treatment

8.1 All tubing shall be furnished in the heat treated condition in accordance with the section on Heat Treatment in ASTM A 269. If grain size is restricted by the supplementary requirement specified in Section 17.2 of this specification, the minimum annealing temperature shall not apply, provided that the tubing passes the intergranular corrosion test of Section 13 of this specification.

8.2 All tubing shall be vacuum annealed, or bright annealed in an undiluted hydrogen atmosphere, followed by rapid cooling. The adequacy of the cooling rate shall be confirmed by the intergranular corrosion test of Section 13 of this specification.

9 Surface Condition

The surface condition of tubing shall be in accordance with the requirements of the section on Finish of ASTM A 270.

10 Cleanliness

10.1 Tubing shall be supplied in accordance with the supplementary requirement for Cleanliness of ASTM A 632.

10.2 Tubing surface shall be sealed with polyethylene caps after being purged with nitrogen or a suitable inert gas. Capped tubing shall be heat sealed in a single 0.15 mm (6 mil) polyethylene bag.

11 Chemical Composition

11.1 Chemical composition of the steel shall conform to the requirements of the section on Chemical Composition in ASTM A 269 for nominal sizes 1/2 inch diameter and larger and to the section on Chemical Composition in ASTM A 632 for nominal sizes smaller than 1/2 inch diameter.

11.2 Sulfur content shall be from 0.003% to 0.010% for all nominal sizes.

12 Mechanical Properties

12.1 Tubing shall conform to the applicable requirements of ASTM A 450/A 450M unless otherwise provided herein.

12.2 Hardness of all sizes shall conform to the section on Hardness Requirements of ASTM A 269.

12.3 Tensile properties of all sizes shall conform to the section on Mechanical Properties of ASTM A 632.

13 Metallurgical Requirements

Tubing shall pass an intergranular corrosion test conducted in accordance with the supplementary requirement for Intergranular Corrosion Test of ASTM A 262. A minimum of two samples per lot shall be tested.

14 Nondestructive Testing Requirement

14.1 Eddy current testing shall be performed in accordance with the procedure and evaluation outlined in the section on Nondestructive Electric Test of ASTM A 450/A 450M except that the calibration reference notches shall not exceed 10% of the specified wall thickness of the tubing or 0.075 mm (0.003 inches), whichever is greater. If the form of product supplied makes this test technically infeasible, alternative non-destructive testing methods shall be agreed upon by the purchaser and supplier.

14.2 At the option of the purchaser, hydrostatic testing shall be conducted and evaluated in accordance with the requirements of the section on Hydrostatic Test of ASTM A 450A/450M.

15 Permissible Variations in Dimensions

15.1 Sampling for dimensional variations shall be performed in accordance with MIL-STD-105 with double normal sampling and a 2 1/2% Acceptable Quality Level (AQL).

15.2 The permissible variations in dimensions shall be as outlined in Table 2 of ASTM A 270 for all sizes.

15.3 Nominal wall thickness for tubing to be finished as shown in Table 1. The finished thicknesses must also comply with ANSI/ASME B31.1 and B31.3 specifications for the intended service temperature and pressure. A tolerance of ±10% shall apply to the wall thicknesses specified.

Table 1 Nominal Wall Thickness for Various Tube Nominal Sizes

Nominal O.D.	*Tube Wall Thickness*
1/4", 3/8"	1.02 mm (0.040")

1/2"	1.32 mm (0.052")
3/4", 1", 1 1/2", 2", 3"	1.75 mm (0.069")
4", 6"	2.11 mm (0.083")

16 Quality Assurance Requirements

The supplier's quality assurance program shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, NCA-3800 or of ISO 9000.

17 Supplementary Requirements

The following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order.

17.1 *Alternative Finish (Inside Surface)* — The purchaser may specify alternate chemical treatment for the inside surface. Such treatment shall not promote grain boundary attack; the intergranular corrosion test requirement of Section 13 shall apply after chemical treatment.

17.2 *Restricted Grain Size* — At the option of the purchaser, ASTM grain size number may be restricted to 7 or finer, per ASTM E 112, provided that a maximum hardness lower than that given in the section on Hardness Requirements of ASTM A 269 is not also imposed.

18 Certification

18.1 The supplier shall provide the following reports and certifications with all shipments of tubing:

18.1.1 Type of tubing (seamless or welded)

18.1.2 Size (nominal outside diameter and nominal wall thickness)

18.1.3 Material composition report shall be provided to verify the above required grade, sulfur content, and grain size

18.1.4 Tubing provided in accordance with this specification shall be mill and heat traceable and permanently etched for correspondence to the applicable mill test reports.

SEMI F17-95
SPECIFICATION FOR HIGH PURITY QUALITY ELECTROPOLISHED 316L STAINLESS STEEL TUBING, COMPONENT TUBE STUBS, AND FITTINGS MADE FROM TUBING

1 Purpose

The purpose of this specification is to define the ordering, surface condition, and quality assurance requirements for high purity quality electropolished 316L stainless steel tubing, component tube stubs, and fittings made from tubing.

2 Scope

This specification defines the special criteria for nominal sizes of electropolished 316L stainless steel tubing, component tube stubs, and fittings made from tubing for use in high purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

3 Referenced Documents

The referenced documents are to be to their current editions as published by their sponsors.

3.1 *SEMI Standard*

SEMI F16 — Specification for 316L Stainless Steel Tubing Which Is to Be Finished and Electropolished for High Purity Semiconductor Manufacturing Applications

3.2 *ANSI/ASME Standards*[1]

B31.1 — Power Piping

B31.3 — Chemical Plant and Petroleum Refinery Piping

B46.1 — Surface Texture: Surface Roughness, Waviness, and Lay

3.3 *ASTM Standards*[2]

A 269 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 632 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service

1 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4 General Requirements

The finished tubing, component tube stubs, and fittings made from tubing furnished under this specification shall use the tubing governed by SEMI F16 and shall meet the additional finish requirements herein.

5 Ordering Information

Orders for finished tubing, component tube stubs, or fittings made from tubing under this specification shall include the following, as a minimum, to describe the item:

- Quantity (meters, feet, number of items, or number of lengths)
- Type of tubing (seamless or welded)
- Size (nominal outside diameter and wall thickness)
- Length (specific or random)
- Other specific dimensions (such as for fittings).

6 Surface Condition

6.1 The internal surface of all finished tubing, component tube stubs, and fittings made from tubing shall be electropolished.

6.2 The internal surface of the finished tubing, component tube stub, or fitting made from tubing shall be free from all macroscopic pitting, staining or discoloration, and surface flaws. The O.D. of the tube shall be homogeneous in texture and brightness and free of obvious flaws.

6.3 Finished tubing, component tube stubs, and fittings made from tubing shall be measured for internal surface finish. Testing shall verify conformance to a surface roughness standard of one of the following:

Table 1 Roughness Average (R_a)

Multiple Measurements		*Maximum Single Measurement*	
micrometers	*microinches*	*micrometers*	*microinches*
0.25	10	0.30	12
0.18	7	0.25	10
0.13	5	0.18	7

7 Surface Condition Measurements

7.1 *Surface Roughness* — When specified as per Section 6.3, surface roughness shall be measured in accordance with ANSI B46.1, using a stylus-type instrument and a cutoff of 760 micrometers (0.030 inches), or equivalent process (which shall be submitted for approval to the customer prior to order acceptance). The results reported shall be Roughness Average (R_a), expressed in micrometers or microinches.

7.1.1 Measurements shall be made at 0, 90, 180, and 270 degrees around the tube's inner circumference.

7.2 Scanning Electron Microscopy (SEM) photographs of the electropolished internal surfaces of tubing, component tube stubs, and fittings made from tubing shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer. SEM analysis shall verify that no more than 40 defects shall be distinguishable in a 3400 to 3600× field view in a 64 × 89 mm (2 1/2" × 3 1/2") picture.

7.3 Chemical analysis, using electron spectroscopy for chemical analysis (ESCA), shall be performed on the electropolished internal surfaces of tubing, component tube stubs, and fittings made from tubing and shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer. Elemental composition shall be expressed in atomic percent units and shall verify a minimum chromium oxide to iron oxide ratio of 2.2:1.

7.4 Auger Electron Spectroscopy (AES) analysis shall be performed on the electropolished internal surfaces of tubing, component tube stubs, and fittings made from tubing and shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer.

8 Cleanliness

8.1 After electropolishing, finished tubing shall be final cleaned with a process that uses deionized (DI) water with a minimum resistivity of 17.5 megohm-cm at 25°C as the final cleaning agent, and nitrogen or a suitable filtered inert gas, as a drying agent. Both the water and the gas shall be heated to a minimum of 60°C.

8.2 Tubing, component tube stubs, and fittings made from tubing shall be sealed with polyethylene caps pressed over 0.05 mm (1.75 mil) or thicker polyamide squares after having been purged with nitrogen or a suitable inert gas. Capped tubing, stubs, or fittings shall be heat-sealed in a single 0.15 mm (6 mil) or thicker polyethylene bag.

9 Permissible Variations in Dimensions

9.1 The permissible variations in dimensions shall be as outlined in Table 3 of ASTM A 269 for nominal sizes 1/2" diameter and larger and in Table 3 of ASTM A 632 for nominal sizes smaller than 1/2" diameter.

9.2 Finished wall thicknesses for tubing, component tube stubs, and fittings made from tubing are shown in Table 1. The finished thicknesses must also comply with the requirements of ANSI/ASME B31.1 and B31.3 for the intended service temperature and pressure. The appropriate tolerances per Section 9.1 shall apply to these finished wall thicknesses.

Table 2 Finished Wall Thickness for Various Tube Sizes

Nominal O.D.	*Finished Tube Wall Thickness*
1/4", 3/8"	0.89 mm (0.035")
1/2"	1.25 mm (0.049")
3/4", 1", 1 1/2", 2", 3"	1.65 mm (0.065")
4", 6"	2.11 mm (0.083")

10 Certification

The supplier shall provide the following reports and certification with all shipments of electropolished tubing, component tube stubs, or fittings made from tubing:

10.1 Type of tubing (seamless or welded)

10.2 Size (nominal outside diameter and wall thickness)

10.3 Material composition report

10.4 Heat code identification. Tubing, component tube stubs, and fittings made from tubing shall be mill- and heat-traceable and permanently etched for correspondence to the applicable mill test reports

10.5 Surface roughness certification

10.6 Microscopic surface condition certification (SEM)

10.7 Surface chemistry certification (ESCA)

10.8 Surface depth profile certification (Auger).

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F18-95
GUIDE FOR DETERMINING THE HYDROSTATIC STRENGTH OF, AND DESIGN BASIS FOR, THERMOPLASTIC PIPE AND TUBING

1 Purpose

To identify a test method for measuring the hydrostatic strength of thermoplastic pipe and tubing, a method for estimating long-term hydrostatic strength, and recommendations for developing design bases.

2 Scope

2.1 This guide references the industry-recognized Standard Test Method for determining the time-to-failure of plastic pipe under constant internal pressure.

2.2 This guide references the industry-recognized Standard Test Method for determining the long-term hydrostatic strength of plastic pipe in order to obtain the hydrostatic design basis of the pipe material.

2.3 This guide references the Technical Report of policies and procedures for developing recommended hydrostatic design stresses for thermoplastic pipe materials from 23°C to 93.3°C (73°F to 200°F).

3 Referenced Documents

3.1 *ASTM Standards*[1]

D 1598 — Standard Test Method for Time-to-Failure of Plastic Pipe under Constant Internal Pressure

D 2837 — Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

3.2 *PPI Technical Report*[2]

TR-3/92 — Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials

4 Terminology

Currently this document contains no terminology.

5 Summary of Referenced Documents

5.1 *ASTM Standards*

5.1.1 *D 1598* — This test method consists of exposing specimens of pipe/tube to a constant internal pressure while in a controlled environment. Such a controlled environment may be accomplished by immersing the specimens in a controlled-temperature water or air bath. The time-to-failure is measured.

5.1.2 *D 2837* — The procedure for estimating long-term hydrostatic strength is essentially an extrapolation, with respect to time, of a stress-time regression line based on data obtained in accordance with ASTM D 1598. Stress-failure time plots are obtained for the selected temperature and environment: the extrapolation is made in such a manner that the long-term hydrostatic strength is estimated for these conditions.

5.2 *PPI Technical Report*

5.2.1 *TR-3/92* — These policies and procedures are for development of recommendations for thermoplastic pipe compounds based on test data from good quality pipes made by specific processing techniques. These recommendations may or may not be valid for pipes made by differing processing techniques.

6 Comments

6.1 The Hydrostatic Stress Committee of the Plastic Pipe Institute (PPI) has recommended a minimum safety factor of 200% based on the hydrostatic design basis. The safety factor is intended to make allowance for manufacturing and testing variables such as normal variations in the material, manufacturing process, dimensions, and in the evaluation procedures (ASTM D 2837 and D 1598).

6.2 Application conditions also need to be taken into consideration and may require an increased safety factor. For example, with liquid hydrocarbons and other chemicals, temperature can have a disproportional effect on the long-term performance of the tubing or pipe. No general safety factor has been established for these types of services, so each case should be designed on its own merit.

NOTE: It is strongly recommended that the user of pipe/tube confirm that the product has been tested per ASTM D 1598, D 2837, and TR-3/92 to ensure a proper pressure rating.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Plastic Pipe Institute, 355 Lexington Avenue, New York, NY 10017

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F19-95
SPECIFICATION FOR THE FINISH OF THE WETTED SURFACES OF ELECTROPOLISHED 316L STAINLESS STEEL COMPONENTS

1 Purpose

The purpose of this specification is to provide a standard for the quality of the internal (wetted) surfaces of electropolished 316L stainless steel components used in the chemical (gas and liquid) distribution systems of semiconductor manufacturing facilities.

2 Scope

2.1 This specification defines the wetted surface characterization requirements and the finish acceptance criteria for electropolished 316L stainless steel components.

2.2 The surface characterization tests to be performed are specified herein, and the existing standards for performing these tests are referenced.

2.3 Terms specific to this technology are either listed herein as they relate to the acceptance criteria of this specification or are defined in the referenced documents as they relate to a specific test process.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI F2 — Specification for 316L Stainless Steel Tubing for General Purpose Semiconductor Manufacturing Applications

SEMI F16 — Specification for 316L Stainless Steel Tubing Which Is to Be Finished and Electropolished for High Purity Semiconductor Manufacturing Applications

Doc. 2335[1] — Test Method for Determination of Surface Roughness by Contact Profilometry for Chemical Distribution System Components

Doc. 2336[1] — Test Method for Auger Electron Spectroscopy (AES) Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Chemical Distribution System Components

Doc. 2337[1] — Test Method for ESCA Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Chemical Distribution Systems Components

3.2 *ANSI/ASME Standards*[2]

B46.1 — Surface Texture: Surface Roughness, Waviness, and Lay

3.3 *ASTM Standards*[3]

A 182 — Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service

A 240 — Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 269 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 276 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes

A 479 — Specification for Stainless and Heat-Resisting Steel Wire, Bars, and Shapes for Use in Boilers and Other Pressure Vessels

A 632 — Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service

F 1372 — Test Method for SEM Analysis of Metallic Surface Condition for Gas Distribution System Components

4 Terminology

4.1 *Terms Defined in ANSI/ASME B46.1*

4.1.1 *flaws* — Unintentional irregularities which occur at one place or at relatively infrequent or widely varying intervals on the surface. Flaws include such defects as cracks, blowholes, inclusions, checks, ridges, and scratches.

4.1.2 *lay* — The direction of the predominant surface pattern, ordinarily determined by the production method used.

4.1.3 *measured surface* — A representation of the surface obtained by instrument or other means.

1 Draft Documents 2335, 2336, and 2337 will be developed and balloted by the SEMI F&ESH Committee, using materials contributed by SEMATECH. The methods were written and developed by a SEMATECH-sponsored task force, validated by Research Triangle Institute, and subsequently published by SEMATECH as SEMASPEC's. The methods were also proposed, and then withdrawn, by ASTM Committee F1.10.

2 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

3 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4.1.4 *nominal surface* — The intended surface contour, the shape and extent of which is shown and dimensioned on a drawing or descriptive definition.

4.1.5 *roughness* — The finer irregularities of the surface texture, usually including those irregularities which result from the manufacturing process. These are considered to include traverse feed marks and other irregularities within the limits of the roughness sampling length.

4.1.6 *surface texture* — The repetitive or random deviations from the nominal surface which form the three dimensional topography of the surface. Surface texture includes roughness, waviness, lay, and flaws.

4.1.7 *waviness* — The more widely spaced component of surface texture. Unless otherwise noted, waviness is to include all irregularities whose spacing is greater than the roughness sampling length. Waviness may result from such factors as machine or work deflections, vibrations, chatter, heat treatment, or warping strains. Roughness may be considered as superimposed on a "wavy" surface.

4.2 *Additional Terms*

4.2.1 *blistering* — A surface discontinuity whose appearance pattern is like that of orange peel with randomly chipped or flaked off areas.

4.2.2 *dent* — A protrusion on the wetted surface that can be associated with an irregularity on the external surface.

4.2.3 *frostiness* — A continuous surface discontinuity whose appearance pattern is like that of a sparkly, very fine, sandy-textured surface.

4.2.4 *haze* — The appearance of a localized diminishing in brightness or luster of a surface when compared to the adjacent surfaces.

4.2.5 *inclusion* — A piece of foreign material that is embedded in the surface and is visible to the unaided eye.

4.2.6 *orange peel* — A continuous surface discontinuity whose irregular surface appearance pattern is like that of an orange peel.

4.2.7 *pit or stringer (multiple pits)* — A small cavity or series of small cavities visible to the unaided eye.

4.2.8 *scratch* — An elongated mar in the surface, not associated with the predominant surface texture pattern, that is visible to the unaided eye.

5 General Requirements

Electropolished components furnished under this specification shall be in accordance with the surface characterization requirements and the surface finish acceptance criteria defined herein.

6 Material Requirements

Materials used for components to be electropolished, so as to produce the surface characterization requirements contained herein, shall be in accordance with the metallurgical criteria defined in any of the following material specifications:

ASTM A 182, A 240, A 269, A 276, A 479, and A 632

SEMI F2 and SEMI F16

7 Surface Characterization Requirements

7.1 The internal (wetted) surface of all components shall be electropolished in accordance with a qualified process applicable to the material composition and type of component being processed.

7.2 Components used to qualify the electropolishing process shall be maintained by the component supplier.

7.3 Chemical analysis (ESCA) shall have been performed on the electropolished surface of the components used to qualify the process in accordance with a separate document currently under development, so as to certify surface elemental composition and process effectiveness. Elemental composition shall be expressed in atomic percent units, and the analysis shall have verified a minimum chromium-to-iron ratio of 1.5:1 and a chromium oxide enrichment of a minimum chromium oxide-to-iron oxide ratio of 2:1. Certified laboratory analysis reports shall be maintained by the component supplier.

7.4 The chrome oxide layer, as determined by Auger (AES) depth profiling, at 1/2 oxygen peak, shall also have been performed on the electropolished surface of the components used to qualify the process in accordance with SEMI Doc. 2336 so as to certify that the chrome oxide layer is equal to or greater than 2 nanometers (20 Angstroms). Certified laboratory analysis reports shall be maintained by the component supplier.

7.5 Scanning Electron Microscopy (SEM) photographs shall have been taken of the electropolished surface used in accordance with ASTM F 1372 to qualify the process of components made from materials defined in Section 6 above. These photographs shall be maintained by the component supplier.

8 Surface Finish Acceptance/Non-Acceptance Criteria

8.1 Acceptance/non-acceptance for flaws caused by material irregularities, machining processes, or handling shall be in accordance with the following criteria:

8.1.1 Any flaws that have been polished out to the degree that they can be considered waviness as defined above and meet the surface characterization requirements in Section 7 are acceptable.

8.1.2 Process machine marks that fall within the specified surface finish R_a acceptance criteria and meet the surface characterization requirements in Section 7 are acceptable.

8.1.3 Macroscopic pits and inclusions that are within the surface finish R_a acceptance criteria and meet the surface characterization requirements in Section 7 are acceptable.

8.1.4 Scratches caused by machining process or inspection tools that meet the surface finish R_a acceptance criteria and then have been electropolished so as to meet the surface characterization requirements in Section 7 are acceptable. All other scratches of indeterminate source are not acceptable.

8.1.5 Dents are not acceptable.

8.1.6 Any protrusion on the wetted surface that is not associated with an irregularity on the external surface will be judged according to the roughness/waviness acceptance criteria.

8.2 Acceptance/non-acceptance for surface finish effects caused by the electropolishing process shall be in accordance with the following criteria:

8.2.1 Surface contaminants (e.g., water spots, rust, process residue, and chemical staining) are not acceptable.

8.2.2 Electropolished (EP) surfaces shall have no unintentional interruptions in the electropolishing.

8.2.3 Surface finish shall be evaluated using the method specified in SEMI Doc. 2335 for compliance with the R_a surface finishes specified in ANSI B46.1.

8.2.4 The degree to which orange peel is acceptable shall be evaluated using the acceptable/non-acceptable component sample library which was established during the process certification.

8.2.5 Haze is not acceptable.

8.2.6 The degree to which frosting is acceptable shall be evaluated using the acceptable/non-acceptable component sample library which was established during the process certification.

8.2.7 Blistering is not acceptable.

8.3 *Other Acceptance Criteria*

8.3.1 Components electropolished by a process qualified by the customer for the production of components of that model shall be acceptable as long as the process is requalified periodically as agreed by the supplier and customer.

8.3.2 The surface finish of welds, screw slots, bellows and any other irregular-surfaced components will be considered acceptable if they have been electropolished by the process qualified for components of that model.

8.3.3 Frosting, pits, or scratches that occur within 0.020 of the edge of a surface to be welded and which do not exceed 0.010 in depth are acceptable.

9 Quality Assurance Requirements

9.1 The component supplier shall provide the following reports and certifications with all shipments of processed components:

9.1.1 Name/description of component(s)

9.1.2 Quantity of components by size or description,

9.1.3 Certification for each size or category of components that the process was performed in accordance with a qualified process specification which meets the surface chemistry requirements of Section 6 above.

9.1.4 Copies of certified laboratory reports of the surface chemistry analysis performed to qualify the process used (when requested by the customer).

9.1.5 Copies of certified laboratory reports of the surface chemistry analysis performed on specific components or heat lots (when requested by the customer).

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F20-0997
SPECIFICATION FOR 316L STAINLESS STEEL BAR, EXTRUDED SHAPES, PLATE, AND INVESTMENT CASTINGS FOR COMPONENTS USED IN HIGH PURITY SEMICONDUCTOR MANUFACTURING APPLICATIONS

1 Purpose

1.1 The purpose of this specification is to define the restricted melting processes and material composition of 316L stainless steel required for use in the manufacture of components for high-purity chemical (gas or liquid) distribution systems.

2 Scope

2.1 This specification defines the requirements for 316L stainless steel bar, forgings, and extruded shapes as specified in ASTM A 276, plate stock as specified in ASTM A 240, and investment castings as specified in ASTM A 743/A 743M, except as defined herein, for use in the manufacture of components used in high-purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

3 Referenced Documents

3.1 *ASTM Standards*[1]

A 182/A 182M — Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service

A 240/A 240M — Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 — Practices for Determining Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 276 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes

A 479/A 479M — Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 480/A 480M — Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip

A 484/A 484M — Specification for General Requirements for Stainless and Heat-Resisting Wrought Steel Products (Except Wire)

A 743/A 743M — Specification for Castings, Iron - Chromium, Iron - Chromium - Nickel, Corrosion Resistant, for General Application

A 751 — Test Methods, Practices and Terminology for Chemical Analysis of Steel Products

E 45 — Recommended Practice for Determining the Inclusion Content of Steel

E 112 — Test Methods for Determining Average Grain Size

4 Ordering Information

4.1 Orders for bar, forgings, extruded shapes, plate, or investment castings under this specification shall include:

4.1.1 Quantity (kilograms, pounds, meters, inches, or feet)

4.1.2 Cross section description (round, square, hex, etc. or detailed drawing)

4.1.3 Size (nominal diameter or shape dimensions for other than those identified with an extrusion drawing)

4.1.4 Length (specific or random)

4.1.5 This specification number

5 General Requirements

5.1 Bar stock, forgings, extruded shapes, or plate furnished under this specification shall conform to the requirements of ASTM A 182/A 182M, ASTM A 276, ATSM A 479/A 479M, ASTM A 484/A 484M, and the additional requirements herein.

5.2 Plate stock furnished under this specification shall conform to the requirements of ASTM A 240, A 480/A 480M, and the additional requirements herein.

5.3 Investment castings furnished under this specification shall conform to the requirements of ASTM A 743/A 743M except yield/ultimate strengths shall be at least 80% of their respective minimum values.

6 Manufacture

6.1 The steel billet material used for processing shall be manufactured by such primary melting processes as

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

Argon Oxygen Decarburization (AOD), Vacuum Oxygen Decarburization (VOD), or Vacuum Induction Melting (VIM), and such remelt processes as Vacuum Arc Remelt (VAR) or ElectroSlag Remelt (ESR), to conform with the purity requirements specified herein.

6.2 Processed bars shall be furnished annealed and cold-finished, and extruded shapes shall be furnished hot-finished, descaled, and stretch-straightened ("Condition A" in the section on Manufacture in ASTM A 276, except elongation may be a minimum of 20% for "lightly cold worked T316L").

6.3 The annealing temperature used to achieve the grain size requirement of Section 8.1 shall be 982°C (1800°F) minimum.

6.4 The steel billet material used for investment casting shall be manufactured by the Vacuum Induction Melting (VIM) plus Vacuum Arc Remelt (VAR) route per Sections 6.1 and 6.2, and remelted and cast using VIM. Castings shall be furnished in the solution treated and Hot Isostatic Pressed (HIP) condition.

7 Chemical Composition

7.1 *Material Type* — Material shall be type 316L stainless steel, as specified in Table 1 of ASTM A 182/A 182M, ASTM A 240, ASTM A 276, ASTM A 479/A 479M, or ASTM A 743/A 743M except where otherwise specified herein.

7.2 *Composition Tolerance* — No deviations in material composition from the minimum or maximum values specified in the appropriate ASTM document or herein shall be allowed without approval by the purchaser.

7.3 *Sulfur Content* — Sulfur content shall range from 0.001 to 0.004 percent.

7.4 *Product Analysis* — A heat analysis shall be made in accordance with ASTM A 751. The result of the heat analysis shall be reported to the purchaser. In addition to the elements listed in Table 1 of ASTM A 276, the concentrations of the following elements shall be reported and are specified as:

7.4.1 *Aluminum* — 0.02 max

7.4.2 *Calcium* — 0.02 max

7.4.3 *Copper* — 0.25 max

7.4.4 *Niobium* — 0.05 max

7.4.5 *Selenium* — 0.02 max

7.4.6 *Titanium* — 0.02 max

8 Metallurgical Requirements

8.1 *Grain Size* — Grain size per ASTM E 112 shall be predominately 5 or finer for bar stock nominal size of 3 inches in diameter and smaller, and 3 or finer for bar stock greater than 3 inches.

8.2 *Casting Grain Size* — Castings shall have equiaxed grain size appropriate to meeting properties defined in Section 5.3.

8.3 *Nonmetallic Inclusions* — The inclusion content of the material shall be determined from representative samples of the material heat, in accordance with ASTM E 45, Method A, but with ratings based on Plate III. JK ratings at billet stage shall not exceed:

Inclusion Type	*A(Sulfide)*	*B (Alumina)*	*C (Silicate)*	*D (Globular Oxide)*
Thin	1.0	1.0	1.0	1.0
Heavy	1.0	1.0	1.0	1.0

JK ratings shall be provided with the material composition report.

8.4 *Intergranular Corrosion* — Material shall be capable of meeting the intergranular corrosion test specified in Practice E of ASTM A 262. This requirement shall apply in the sensitized condition (1 hour at 677°C [1250°F]).

9 Mechanical Properties

9.1 Mechanical properties of all sizes and shapes shall conform to the section on Mechanical Properties of the appropriate ASTM specification and to Section 6.2 or 5.3.

10 Certification

10.1 A certified copy of the results of all tests required by this specification shall be provided at the time of shipment. The test report shall also include the material melting process, the heat number, and the purchase order, and shall be positively relatable to the lot of material represented.

11 Product Marking

11.1 Bar and extruded shapes shall be permanently marked with the following information:

11.1.1 Manufacturer's name

11.1.2 Purchaser's name and order number

11.1.3 ASTM specification number(s)

11.1.4 This specification number

11.1.5 Heat number

11.1.6 Material type (i.e., 316L)

11.2 Where including all of these is impractical due to size, the heat number and customer purchase order number shall be included as a minimum.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI

SEMI F21-95
CLASSIFICATION OF AIRBORNE MOLECULAR CONTAMINANT LEVELS IN CLEAN ENVIRONMENTS

1 Purpose

The purpose of this standard is to classify microelectronics clean environments with respect to their molecular (non-particulate) contaminant levels. This standard classification provides a consistent means of communicating acceptable contaminant levels of groups of specific airborne molecular contaminants. See Related Information 1 appended to this standard.

2 Scope

This standard classification is to be used in the specification of semiconductor clean environments (including process tool environments) and of contamination control and measurement equipment performance.

3 Referenced Documents

None.

4 Terminology

4.1 *acid* — A corrosive material whose chemical reaction characteristic is that of an electron acceptor.

4.2 *base* — A corrosive material whose chemical reaction characteristic is that of an electron donor.

4.3 *condensable* — A substance (other than water), typically having a boiling point above room temperature at atmospheric pressure, capable of condensation on a clean surface.

4.4 *dopant* — A chemical element which modifies the electrical properties of a semiconductive material.

5 Basis of Classification

Classification is by the maximum allowable total gas phase concentration of each category of material. This classification system is depicted in Section 6. The combination of a quantitative class for each of the four categories yields a classification describing an environment.

5.1 The maximum cumulative gas phase concentrations of the four categories may be different.

5.2 Each category is designated by the letter "M," followed by the first letter of the category name A, B, C, or D.

5.3 The integer following the category designator shall indicate the maximum total gas phase concentration in parts per trillion molar (pptm 1×10^{-12}). For example, a category M?-10 has a maximum allowable total concentration of 10 parts per trillion molar for the category of interest.

6 Classification

Material Category	*1**	*10**	*100**	*1000**	*10,000**
Acids	MA-1	MA-10	MA-100	MA-1000	MA-10,000
Bases	MB-1	MB-10	MB-100	MB-1000	MB-10,000
Condensables	MC-1	MC-10	MC-100	MC-1000	MC-10,000
Dopants	MD-1	MD-10	MD-100	MD-1000	MD-10,000

*Concentration, in parts per trillion

7 Reference Test Methods

Analytical methods capable of measuring the classified levels at the agreed level of confidence shall be used.

8 Related Documents

8.1 SEMI Draft Doc. 2237, "Test Method for the Determination of Inorganic Contamination from Mini-environments," 1/18/94.

8.2 SEMI Draft Doc. 2238, "Test Method for the Determination of Organic Contamination from Mini-environments," 1/18/94.

8.3 Berro, N., Cook, J.P.D., et al., "Airborne Contamination of Semiconductor Wafers Traced to Humidification Plant Additives," *Journal of the IES*, pp. 15-18, November 1993.

8.4 Buchmann, K. and Rudolph, J., "Gas Chromatography of Radioactive Inorganic Compounds," *Journal of Radiational Chemistry*, 32(2): 245 - 64, 1976.

8.5 Dixon, W.J., "Processing Data for Outliers," *Biometrics*, 9(7): 74 - 89.

8.6 Kasi, S.R., Liehr, M., Thiry, P.A., et al., "Hydrocarbon Reaction with HF-Cleaned Si (100) and Effects on Metal-Oxide-Semiconductor Device Quality," *Applied Physics Letters*, 59: 108 - 110, 1992.

8.7 Kelly, T.J. and Kinkead, D.A., "Testing of Chemically Treated Adsorbent Air Purifiers," *ASHRAE Journal*, August 1993.

8.8 Kinkead, D.A., "Controlling a Killer: How to Win the War Over Gaseous Contaminants," *Cleanrooms*, June 1993.

8.9 Kinkead, D.A. and Higley, J.K., “Targeting Gaseous Contaminants in Wafer Fabs: Fugitive Amines,” *Microcontamination*, pp. 37 - 40, June 1993.

8.10 Mori, E.J., Dowdy, J.D., and Shive, L.W., “Correlating Organophosphorus Contamination of Wafer Surfaces with HEPA Filter Installation,” *Microcontamination*, pp. 35 - 37, November 1992.

8.11 Muller, A.J., et al., “Volatile Cleanroom Contaminants: Sources and Detection,” *Solid State Technology*, September 1994, page 61.

8.12 Muller, A.J., Psota-Keity, L.A., and Sinclair, J.K., “Concentrations of Organic Vapors and Their Surface Arrival Rates at Surrogate Wafers During Processing in Clean Rooms,” *Proceedings of the Electrochemical Society: Semiconductor Cleaning Technology*, Hollywood, FL, Ruzyllo, J. and Novak, R.E. (eds.), vol. 90-9, pp. 204 - 211, 1990.

8.13 Seeman, D.J., “Fluid Seal Urethane Gels/Chemical Compounds: The Need to Establish Standards and Standard Test Procedures for Their Acceptance in the Cleanroom Environment,” *Proceedings of 38th Annual Technical Meeting of IES*, Nashville, TN, pp. 492 - 497, May 1992.

8.14 Stevie, F.A., Harrus, A.S., Muller, A.J., et al., “Boron Contamination of Surfaces in Silicon Microelectronics Processing: Characterization and Causes,” *Journal of Vacuum Science and Technology*, A9(5), 2813, 1991.

8.15 Tolg, G. and Tschopel, P., “Sources of Error in Trace Inorganic Analytical Chemistry,” *Systemic Errors in Trace Analysis*, Verlag VCH, Weinheim, 1993 in print.

RELATED INFORMATION 1 SPECIFIC CONTAMINANTS TO MEASURE FOR VERIFICATION OF ENVIRONMENTAL COMPLIANCE

NOTE: This related information is not an official part of SEMI F21 and is not intended to modify or supercede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Although it is difficult to compile an inclusive list, the originating task force recommends that the user test the air for each of the contaminants listed.

R1-1 Acids

- Hydrofluoric
- Sulfuric
- Hydrochloric
- Nitric
- Phosphoric
- Hydrobromic

R1-2 Bases

- Ammonia (ammonium hydroxide)
- Tetramethylammonium hydroxide
- Trimethylamine
- Triethylamine
- Trimethyldisilazane
- NMP
- Cyclohexylamine
- Diethylaminoethanol
- Methylamine
- Dimethylamine
- Ethanolamine
- Morpholine

R1-3 Condensables

- Silicone (boiling point ≥ 150°C)
- Hydrocarbon (boiling point ≥ 150°C)

R1-4 Dopants

- Boron (usually as boric acid)
- Phosphorous (usually as organophosphates)
- Arsenic (usually as arsenates)

RELATED INFORMATION 2
EXAMPLE OF AN ANALYSIS REPORT

Note: This related information is not an official part of SEMI F21 and is not intended to modify or supercede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Analysis for compliance with SEMI Standard Classification MA-10:

Site :	FAB 3	
Test date and duration :	18 August 1994, 0800 -1700, 9 hours	
Contaminants measured :	Hydrofluoric acid	1 pptm
	Sulfuric acid	1 pptm
	Hydrochloric acid	2 pptm
	Nitric acid	1 pptm
	Phosphoric acid	2 pptm
	Hydrobromic acid	1 pptm
	Total	8 pptm
Detection Limits :	1 pptm for each analyte	
Confidence Level :	95%	
Assumptions made :	All acids determined as anions after water scrubbing; anions can be from other sources but are assumed to be in the acid form for reporting purposes.	
Conclusion :	This environment meets the MA -10 criterion in SEMI F21.	

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SEMI F22-0697
GUIDE FOR GAS DISTRIBUTION SYSTEMS

1 Purpose

This reference document is intended to outline for the user the common systems configurations, components, and subcomponents of high purity gas distribution systems in a semiconductor fabrication facility. Related specifications are also noted.

2 Scope

2.1 Outlined in this document are both bulk and specialty gas distribution systems.

2.2 Components and subcomponents are identified from the point-of-supply to the point-of-connection to the process tool.

3 Limitations

3.1 The gas distribution system configurations noted in this reference document are provided solely as a guide to indicate common industry practice. They are not presented as, or intended to be, a representation of best engineering practice.

3.2 The reference documents noted are provided for general guidance only and are not intended to portray a code compliance protocol. The users should always consult local authorities to determine specific applicable codes and regulations. Agencies, regulatory or otherwise, noted herein are representative only of the U.S.

3.3 Specifications, SEMI Standards or other, are noted to assist the user as a reference only.

4 Referenced Documents

None.

5 Terminology

5.1 *Acronyms*

5.1.1 *AOV* — Air-operated valves

5.1.2 *ASO* — Automatic shutoff valve

5.1.3 *POC* — Point of connection

5.1.4 *POU* — Point of use

5.1.5 *VMB* — Valve manifold box

5.2 *Terminology*

5.2.1 *air-operated valves (AOV)* — Are those which require pneumatic energy to initiate or terminate flow or to change flow path (e.g., normally closed, partially open, double acting).

5.2.2 *automatic shutoff valve (ASO)* — A mechanically, electrically, or pneumatically activated valve which has the sole purpose of terminating flow if a predetermined condition is exceeded. For cryogenic supply systems, ASO's are used in conjunction with a low temperature sensing device.

5.2.3 *check valve* — A mechanical gas system component which prevents reverse flow.

5.2.4 *effluent treatment system* — A device which, through mechanical, chemical, cryogenic, absorbent, or other means, abates hazardous gas effluent to "environmentally safe levels" through dilution, neutralization, entrapment, or distillation.

5.2.5 *excess flow device* — A mechanical or electrical component which senses and signals an AOV or itself to terminate flow in the event predetermined flow is exceeded.

5.2.6 *face seal fitting* — A high purity fitting which incorporates two machined faces and a metallic gasket within a male/female nut configuration to attain a high leak integrity seal.

5.2.7 *filter* — A porous device, generally constructed of polymer, metal, or ceramics and housed in a metal chamber, which traps particles, preventing them from being transported downstream.

5.2.8 *flow restrictor* — A component, generally an orifice, which prohibits gas flow beyond a predetermined flow.

5.2.9 *gas box* — A gas distribution subsystem which generally contains the final shut-off valve(s) prior to the POC. It may also contain filter(s) and a regulator.

5.2.10 *hazardous gas detectors* — Analytical instruments which placed in strategic locations in and around gas distribution systems and components are used to detect potentially unnoticeable releases at extremely low levels.

5.2.11 *low temperature sensing device* — A component which protects the system downstream of the vaporizer from cryogenic temperatures by initiating an alarm or triggering a valve shut-down.

5.2.12 *nitrogen generation plant* — A system which, generally through cryogenic distillation, separates and purifies nitrogen from ambient air. Other air separation techniques may be used but are not considered in this document.

5.2.13 *point of connection (POC)* — Is often used interchangeably with POU, indicating the final connection between the system and the process tool.

5.2.14 *point of use (POU)* — Is often used interchangeably with POC, indicating the final connection between the system and the process tool.

5.2.15 *pressure relief valve* — A device which, at a given design pressure set point, releases gas pressure to prevent system over-pressurization.

5.2.16 *pressure transducer* — A component which mechanically or electrically senses the pressure within a gas system and transmits a signal to a readout or a control device.

5.2.17 *process gas panel* — A subsystem, generally contained within a gas cabinet, that delivers process gas from the cylinder to the specialty gas distribution system.

5.2.18 *purifier* — Generally a catalytic, resinous, or diatomaceous material within a pressure vessel which removes particulate and/or trace gas impurities from a gas stream.

5.2.19 *regulator* — Generally a mechanical device which alters the pressure within a gas system.

5.2.20 *segregation* — A practice in design and operation to prevent non-compatible gases from co-mingling.

5.2.21 *tube trailer* — A bulk gas supply system which manifolds high pressure, DOT-specified, vessels (cylindrical tubes) on a portable trailer.

5.2.22 *vacuum generator* — A component in a process gas panel which, via a suction created by an inert gas venturi, allows for evacuation of the gas system to levels of 16.7 kPa (25" mercury) or less.

5.2.23 *valve manifold box (VMB)* — A gas distribution subsystem designed to allow the distribution of a single process cylinder gas to multiple process tools. Its manifold design uses a series of valves (manual or AOV), regulators, filters, and vacuum generator(s), and may be controlled manually or automatically.

5.2.24 *vaporizer* — A component which, through heat transfer, is designed to convert a cryogenic liquid to a gas.

6 Bulk Gas Distribution Systems

6.1 *Cryogenic Liquid Supply (see Figure 1)*

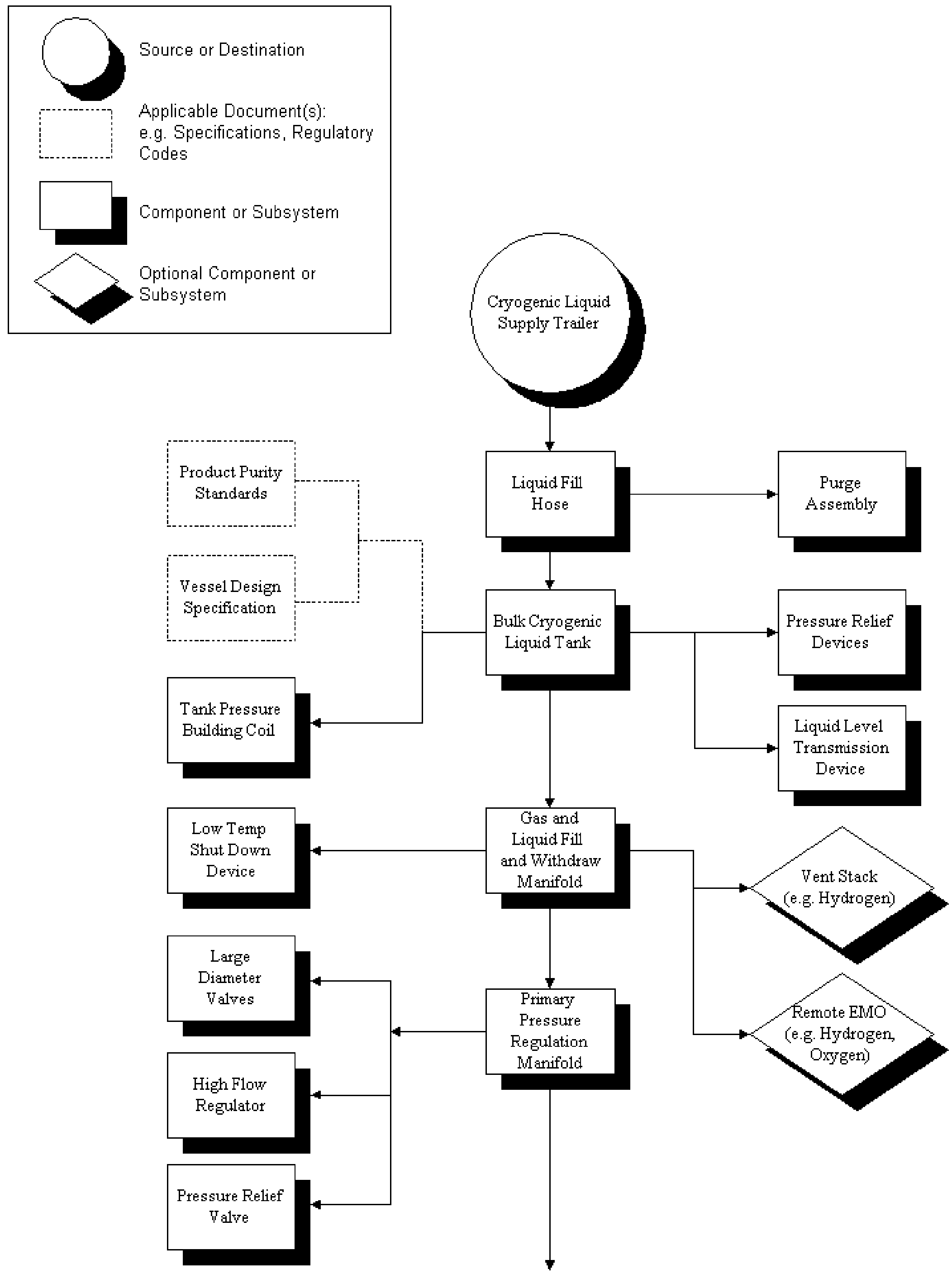

Figure 1
Bulk Gas (Cryogenic) Supply System Flow Chart

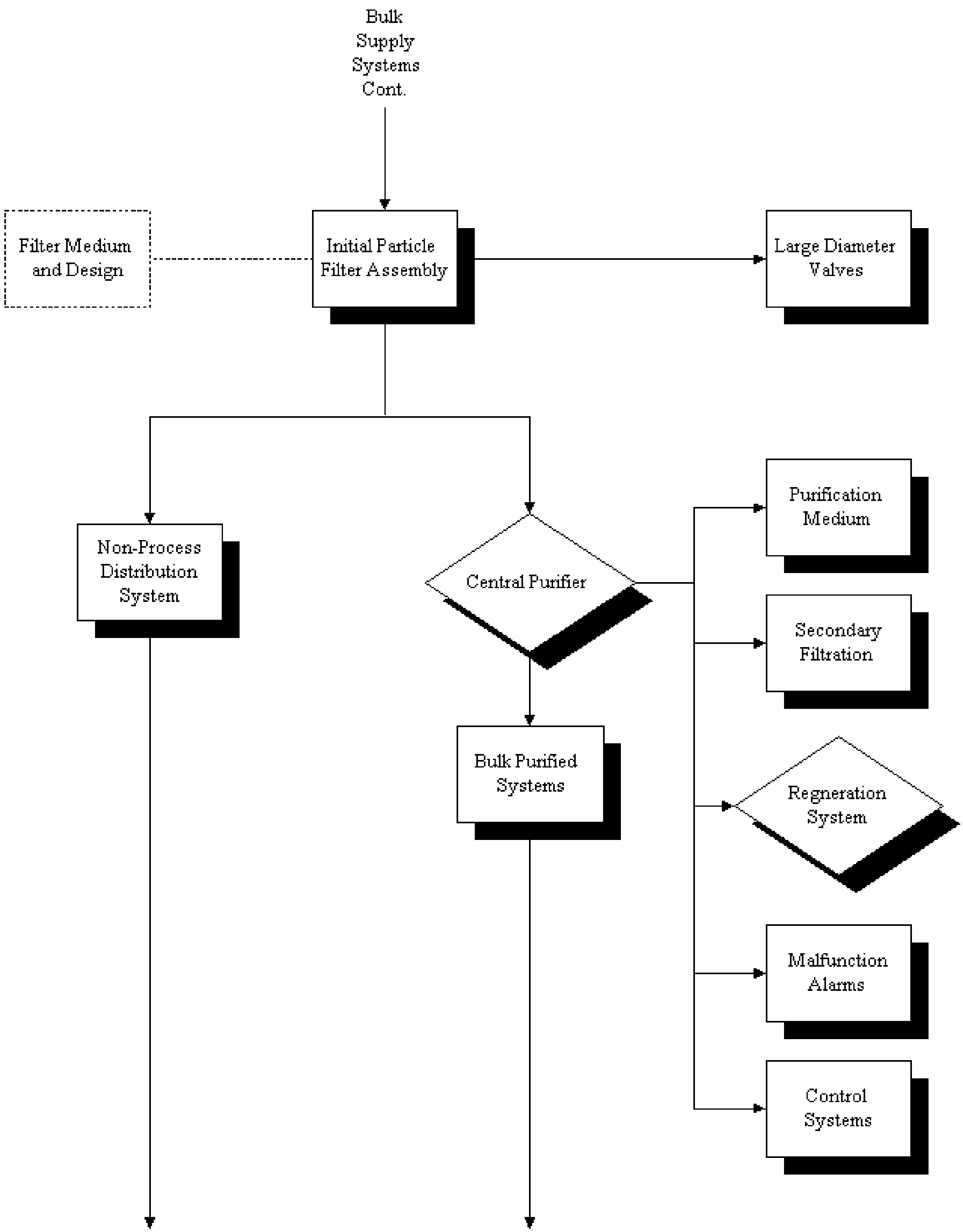

Figure 1
Bulk Gas (Cryogenic) Supply System Flow Chart (cont.)

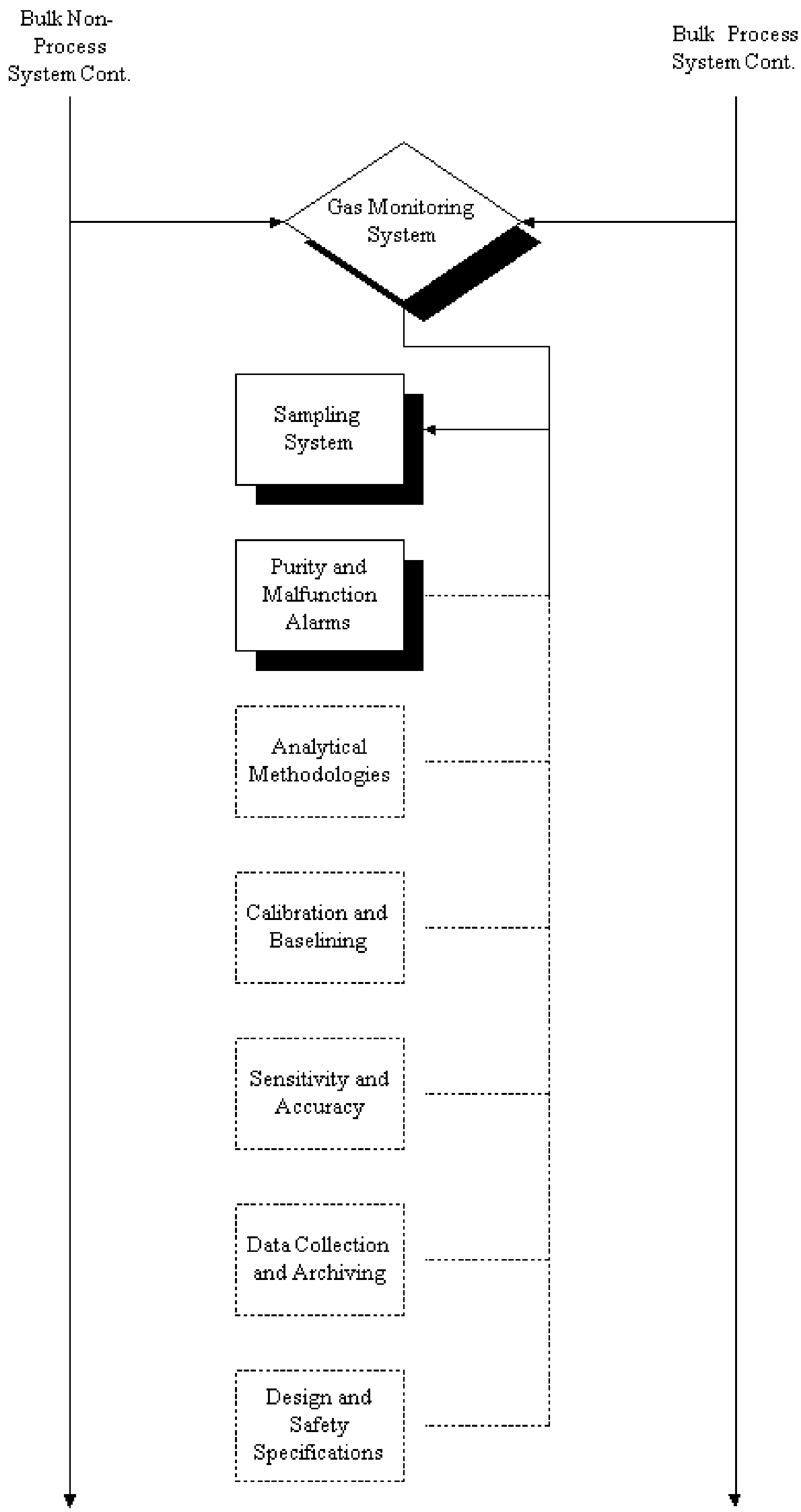

Figure 1
Bulk Gas (Cryogenic) Supply System Flow Chart (cont.)

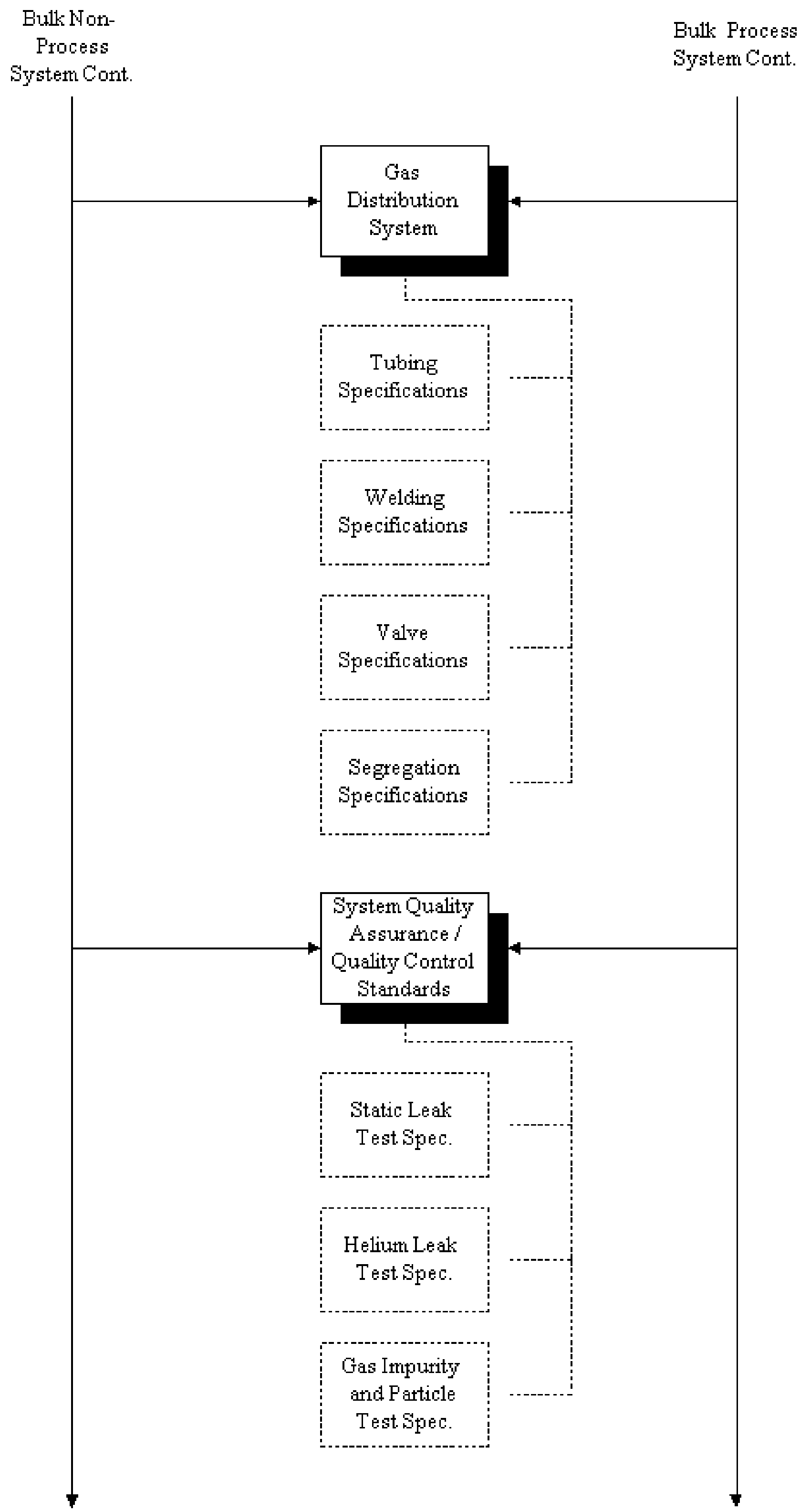

Figure 1
Bulk Gas (Cryogenic) Supply System Flow Chart (cont.)

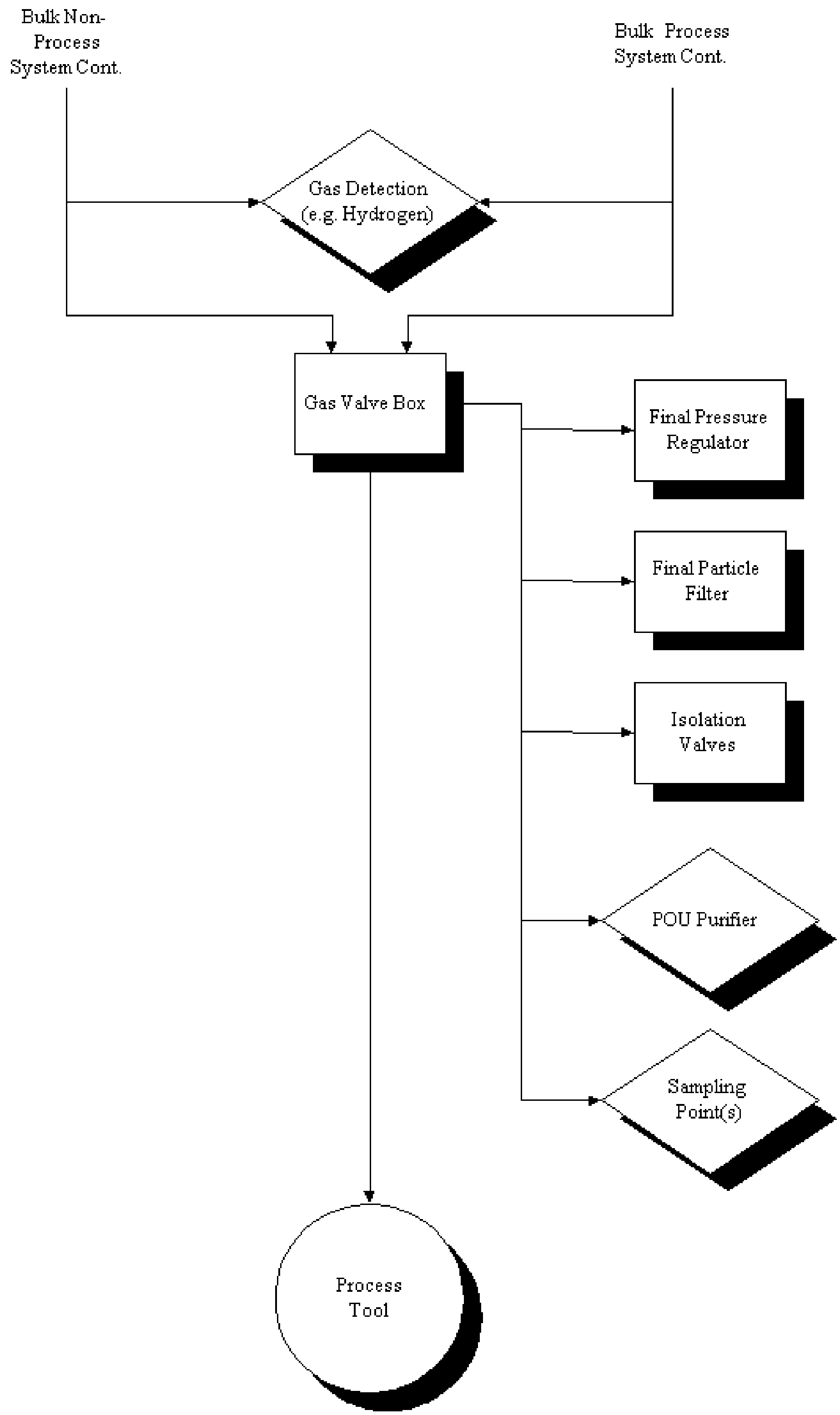

Figure 1
Bulk Gas (Cryogenic) Supply System Flow Chart (cont.)

6.1.1 *Cryogenic Liquid Storage Tank Pad*

6.1.1.1 Product fill hose manifold

6.1.1.2 Gas, liquid withdraw manifold

6.1.1.3 Liquid vaporizers

6.1.1.4 Pressure relief valve(s)

6.1.1.5 Automatic shutoff valve (ASO)

6.1.1.6 Low temperature sensing and shutoff device

6.1.1.7 Liquid level indicator (local and remote)

6.1.1.8 Vessel design specification (e.g., ASME[1] in US)

6.1.1.9 Tank pressure building coil

6.1.1.10 *Emergency Manual Off (EMO)* — hydrogen and oxygen only

6.1.1.11 Product purity standards

6.1.2 *Primary Pressure Regulation Manifold*

6.1.2.1 Regulator design specification

6.1.2.2 Large diameter valve design specification

6.1.2.3 Bypass configuration

6.1.2.4 Pressure relief valves

6.1.3 *Initial Particle Filter Skid*

6.1.3.1 Qualification standard

6.1.3.2 Filtration medium design

6.1.3.3 Bypass configuration

6.1.4 *Central Purifier*

6.1.4.1 Purification medium, type, and qualification standards

6.1.4.2 Regeneration requirements

6.1.4.3 Electronics

6.1.4.4 Control system

6.1.4.5 Malfunction alarms

6.1.5 *Gas Monitoring System*

6.1.5.1 Sampling system and standards

6.1.5.2 Analytical methodologies and standards

6.1.5.3 Calibration and baselining

6.1.5.4 Sensitivity and accuracy

6.1.5.5 Data collection and archiving

6.1.5.6 Purity standards and operational alarms

6.1.5.7 Test stand design and safety considerations

6.1.5.8 Portable system specifications

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1 American Society of Mechanical Engineers — An industry trade organization which sets standards for storage vessels, etc.

6.2 *High Pressure Tube Trailer Supply (See Figure 2)*

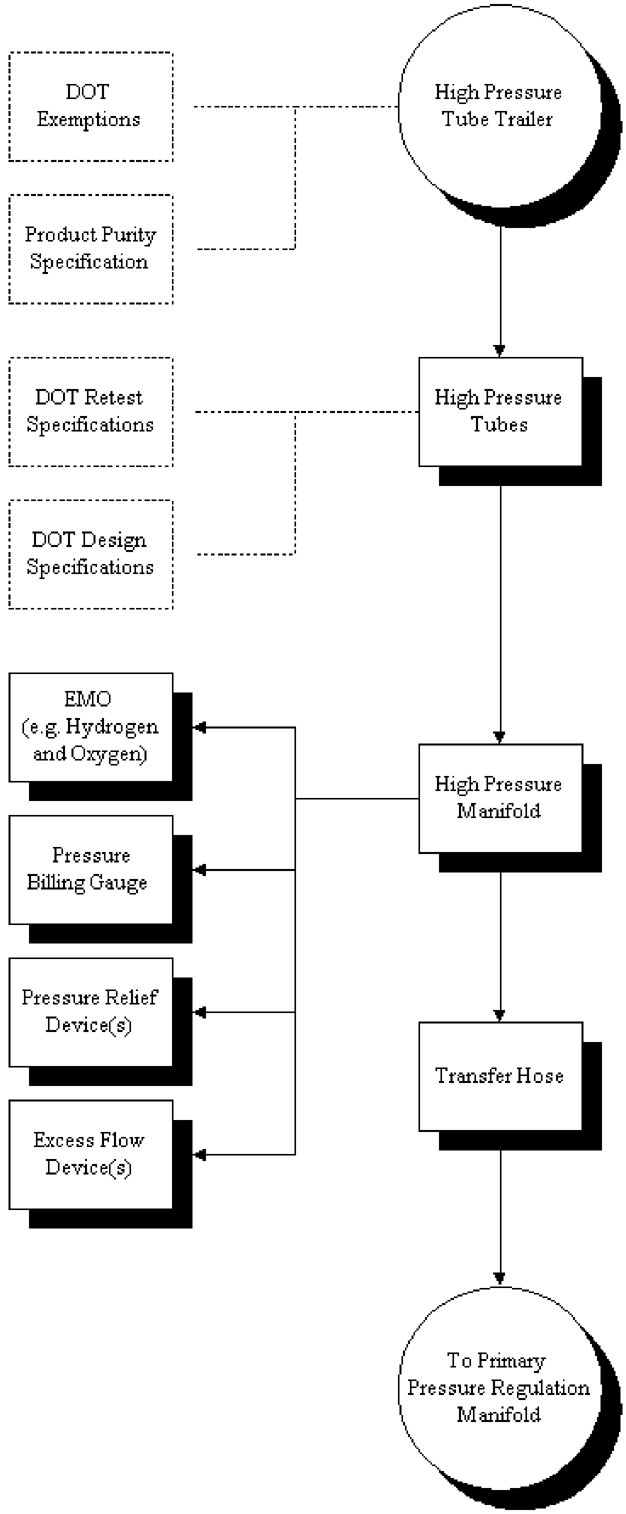

Figure 2
Bulk Gas High Pressure Gaseous Supply System Flow Chart

6.2.1 Regional regulatory cylinder specification (e.g., DOT[2] in US region)

6.2.2 Regional valve specification (e.g., CGA[3] in US region)

6.2.3 High pressure manifold

6.2.4 Relief devices

6.2.5 Excess flow devices (e.g., for H_2)

6.2.6 Product purity standard

6.2.7 Transfer hose

6.2.8 Emergency manual off (EMO) (e.g., for H_2, O_2)

6.2.9 Pressure billing gauge

6.2.10 Tube retest specification (e.g., DOT in US region)

---

2 Department of Transportation (DOT) — The US regulatory agency governing transport of hazardous materials.

3 Compressed Gas Association (CGA) — An industry trade organization which sets standards for cylinder outlet connections in the US.

6.3 *On-Site Nitrogen Supply (see Figure 3)*

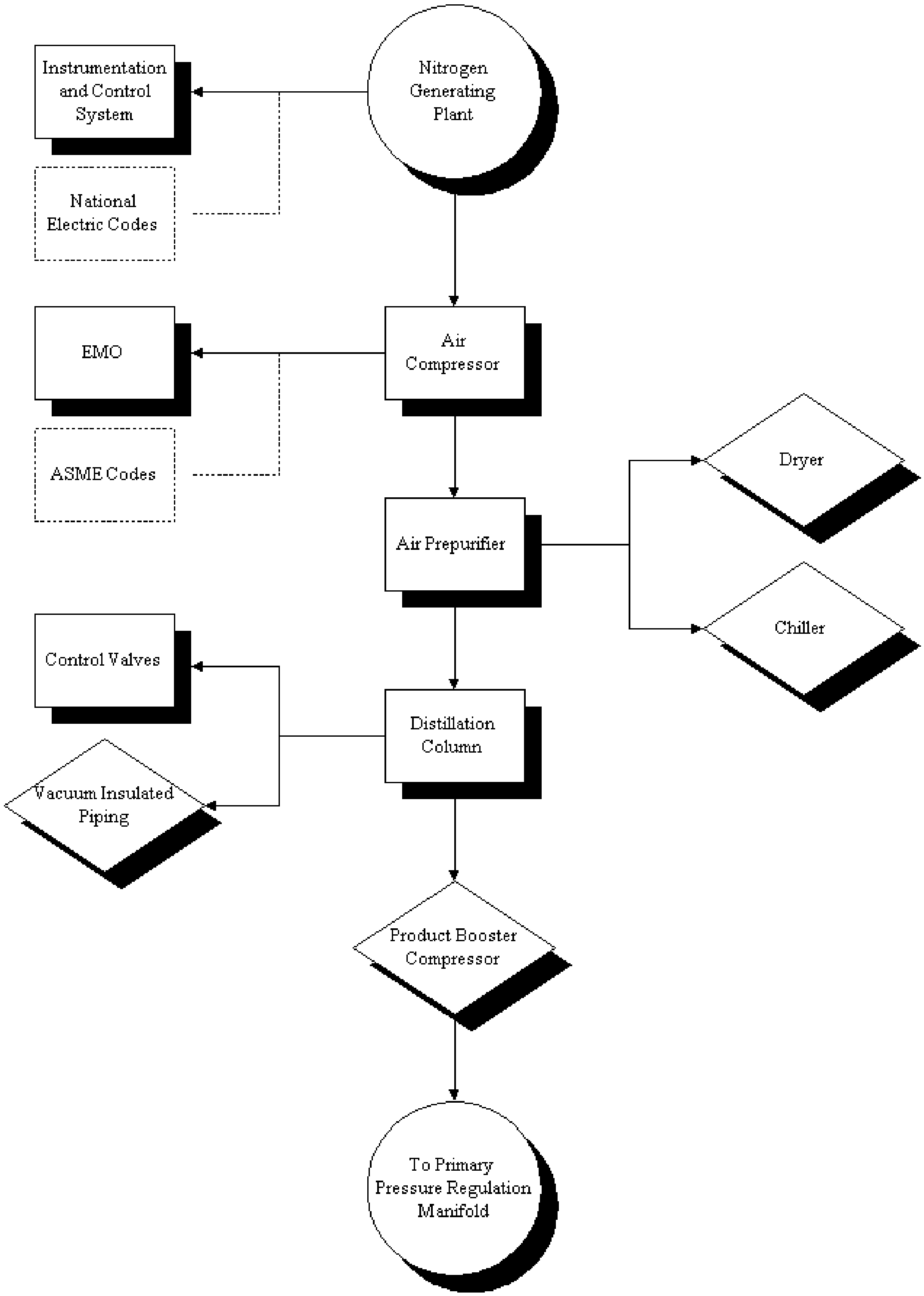

Figure 3
On-Site Nitrogen Supply System Flow Chart

6.3.1 Air compressor

6.3.2 Production control system

6.3.3 Air prepurifier for moisture and hydrocarbon removal

6.3.4 Process instrumentation

6.3.5 Control valves

6.3.6 Distillation column

6.3.7 Product booster compressor

6.3.8 National electric codes

6.3.9 Regional vessel guidelines (e.g., ASME (American Society of Mechanical Engineers) in US region)

6.3.10 Vacuum-insulated piping for liquid add/withdraw

6.3.11 EMO station

6.3.12 Chiller

7 Specialty Gas Distribution Systems

7.1 *Process Gas Panel System (see Figure 4)*

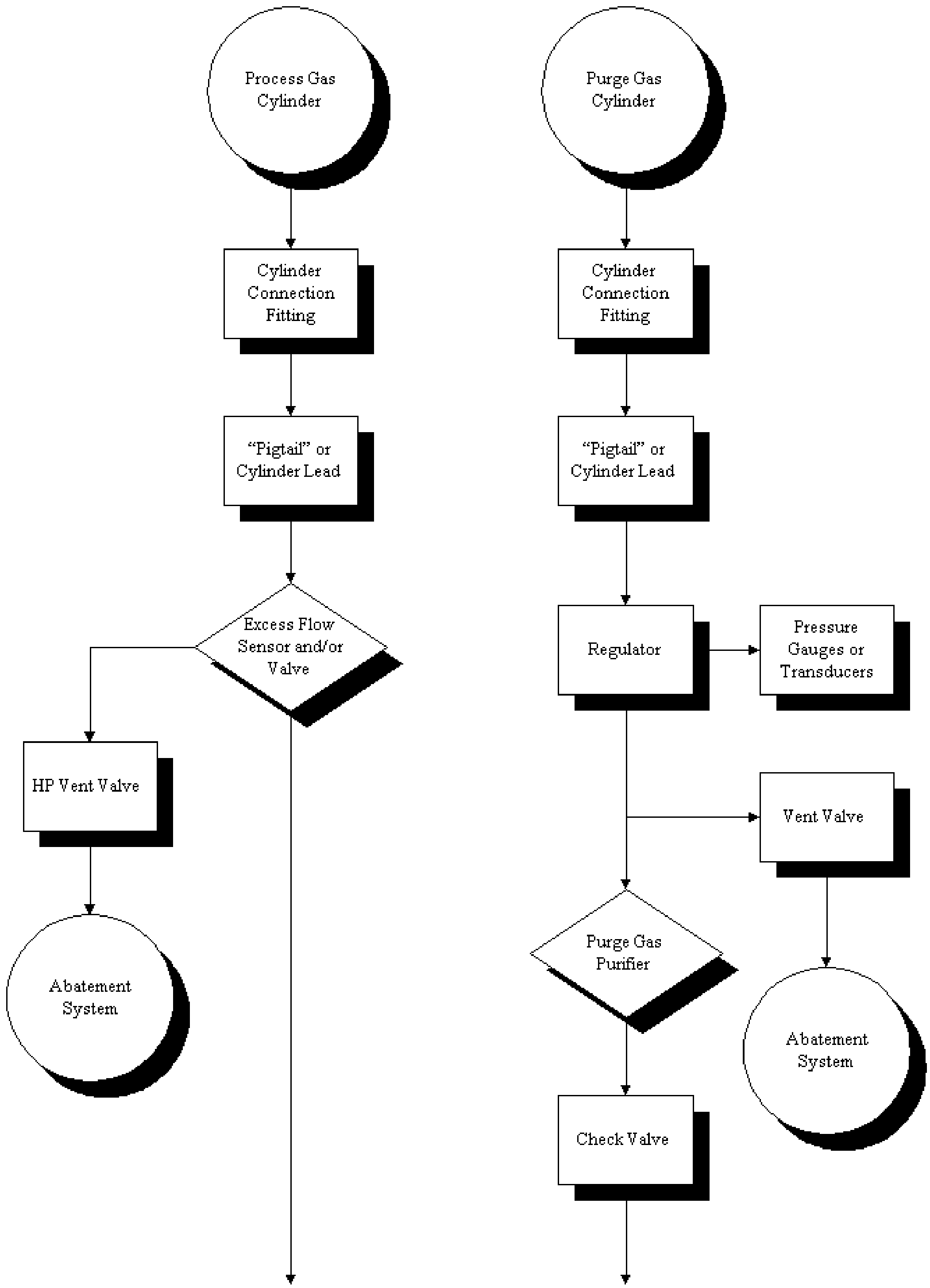

Figure 4
Specialty Gas Cabinet System Flow Chart

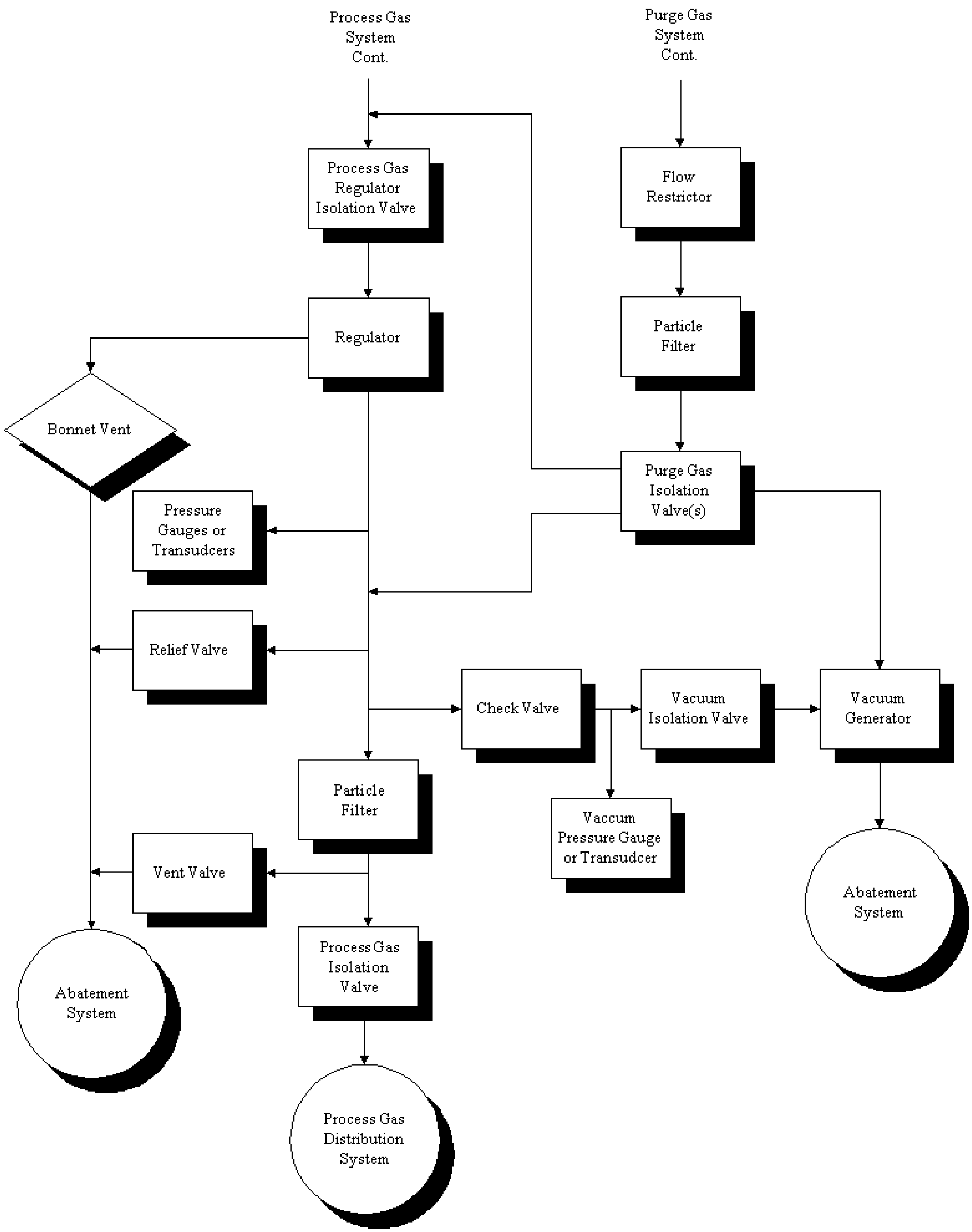

Figure 4
Specialty Gas Cabinet System Flow Chart (cont.)

7.1.1 *High Pressure*

7.1.1.1 “Pigtail”/Cylinder connection assembly

7.1.1.2 Pressure transducer

7.1.1.3 Excess flow sensor

7.1.1.4 Nitrogen check valve

7.1.1.5 Nitrogen flow restrictor

7.1.1.6 Nitrogen purge valve

7.1.1.7 Vent valve

7.1.1.8 Process valve (regulator isolation)

7.1.1.9 Valve specifications

7.1.1.10 Tubing material specifications

7.1.2 *Low Pressure*

7.1.2.1 Pressure relief valve

7.1.2.2 Pressure transducer

7.1.2.3 Particle filter

7.1.2.4 Vent valve

7.1.2.5 Process valve

7.1.3 *Pressure Regulator and Component Specifications*

7.1.4 *Vacuum Generator System*

7.1.4.1 Venturi

7.1.4.2 Venturi supply valve

7.1.4.3 Supply check valve

7.1.4.4 Vacuum/pressure gauge

7.2 *Nitrogen Purge Panel System*

7.2.1 *High Pressure*

7.2.1.1 “Pigtail”/Cylinder connection assembly

7.2.1.2 Pressure gauge

7.2.1.3 Vent valve

7.2.1.4 Process valve (regulator isolation)

7.2.1.5 Pressure regulator

7.2.1.6 Low Pressure

7.2.1.7 Pressure gauge

7.2.1.8 Particle filter

7.2.1.9 Process valve

7.3 *Distribution Lines — Gas Delivery System (Facilities)*

7.3.1 Tubing specifications

7.3.2 Welding specifications

7.3.3 Valve specifications

7.3.4 System design specifications

7.3.5 Segregation specifications (cross contamination prevention)

7.3.6 System Quality Assurance/Quality Control standards

7.3.6.1 Static leak test and specification

7.3.6.2 He leak rate test and specification

7.3.6.3 Particle generation test and specification

7.3.6.4 Gaseous impurity test and specification

7.3.7 Hazardous gas detection requirements

7.4 *Gas Box*

7.4.1 Secondary pressure regulator

7.4.2 Secondary particle filtration

7.4.3 Isolation valves

7.4.4 Sampling point(s)

7.4.5 POU purification

7.5 *Valve Manifold Box*

7.5.1 Face seal connection

7.5.2 Isolation valve

7.5.3 Micro weld fitting

7.5.4 3/8 inch or 1/2 inch 316L SS tubing manifold

7.5.5 Micro weld fitting

7.5.6 1/4 inch 316L SS tubing stick line

7.5.7 Isolation valve

7.5.8 Pneumatic isolation valve

7.5.9 Face seal connection

7.5.10 Purge gas inlet micro weld fitting

7.5.11 Pressure regulator

7.5.12 Flow through pressure transducer or dead space pressure transducer or pressure gauge

7.5.13 Excess flow device

7.5.14 Vent gas outlet micro tee weld fitting

7.5.15 Face seal connection

7.5.16 Isolation valve

7.5.17 Tubing to tool

Termination inside the tool gas jungle area with an isolation valve as part of the tool.

7.6 *Tool Gas Jungle*

7.6.1 Process gas segregation

7.6.2 Manual isolation valve

7.6.3 AOV

7.6.4 MFC

7.6.5 Final particle filtration

7.6.6 Hazardous gas detection

7.6.7 Control systems

7.6.8 Electronics

8 Related Documents

8.1 *SEMI Documents*

SEMI E12 — Standard for Standard Pressure, Temperature, Density, and Flow Units Used in Mass Flow Meters and Mass Flow Controllers

SEMI E16 — Guideline for Determining and Describing Mass Flow Controller Leak Rates

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

SEMI E18 — Guideline for Temperature Specifications of the Mass Flow Controller

SEMI E27 — Standard for Mass Flow Controller and Mass Flow Meter Linearity

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

SEMI F2 — Specification for 316L Stainless Steel Tubing for General Purpose Semiconductor Manufacturing Applications

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI F4 — Guide for Remotely Actuated Cylinder Valves

SEMI F5 — Guide for Gaseous Effluent Handling

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F13 — Guide for Gas Source Control Equipment

SEMI F14 — Guide for the Design of Gas Source Equipment Enclosures

SEMI F15 — Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography

SEMI F16 — Specification for 316L Stainless Steel Tubing Which is to be Finished and Electropolished for High Purity Semiconductor Manufacturing Applications

SEMI F17 — Specification for High Purity Quality Electropolished 316L Stainless Steel Tubing, Component Tube Stubs, and Fittings Made from Tubing

SEMI F19 — Specification for the Finish of the Wetted Surfaces of Electropolished 316L Stainless Steel Components

SEMI F20 — Specification for 316L Stainless Steel Bar, Extruded Shapes, and Plate for Components Used in High Purity Semiconductor Manufacturing Applications

SEMI S1 — Safety Guideline for Visual Hazard Alerts

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S4 — Safety Guideline for the Segregation/Separation of Gas Cylinders Contained in Cabinets

SEMI S5 — Safety Guideline for Flow Limiting Devices

SEMI S6 — Safety Guideline for Ventilation

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F23-0697
PARTICLE SPECIFICATION FOR GRADE 10/0.2 FLAMMABLE SPECIALTY GASES

1 Purpose

The purpose of this document is to set a maximum permissible particle concentration for 10/0.2 grade flammable specialty gases and to describe a reference method for its verification.

2 Scope

This document applies only to flammable gases delivered through specialty gas systems at pressures up to 8×10^5 Pa (8 atmospheres). This method is not suitable for direct sampling from high pressure cylinders at pressures above 8×10^5 Pa (8 atmospheres). This document applies only to the following gas:

Hydrogen (H_2)

3 Referenced Documents

3.1 *SEMI Document*

SEMI C6.3 — Particle Specification for Grade 20/0.2 Hydrogen (H_2) Delivered as Pipeline Gas

3.2 *Other Document*

JIS B 9921 — Japanese Industrial Standard (1989), "Light Scattering Automatic Particle Counter"

4 Terminology

4.1 *Variables*

V_{Mi}=	Volume of the i^th^ sample interval of the system gas
V_{Bi}=	Volume of the i^th^ sample interval of the background
X_{Mi}=	Concentration of particles observed in the i^th^ sample of interval of the system gas
X_{Bi}=	Concentration of particles observed in the i^th^ sample of interval of the background
N_M=	Number of sample intervals of the system gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the system gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the system gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

4.2 *gas sample volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1×10^5 Pa (1 atmosphere) pressure. Standard cubic feet (SCF) is defined at 21.1°C (70°F) and 1×10^5 Pa (1 atmosphere) pressure.

4.3 *average observed concentration of counts* ($\overline{X}_M$, $\overline{X}_B$) — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{\Sigma X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{\Sigma X_{Bi}}{N_B}$$

4.4 *calculated concentration of particles* ($\overline{X}_C$) — The concentration of particles in the system gas obtained by correcting the observed concentration in the system gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

4.5 *standard deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \sqrt{\frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)}}$$

$$S_B = \sqrt{\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)}}$$

NOTE: The third is obtained from the first two, i.e.:

$$S_C = \sqrt{S_M{}^2 + S_B{}^2}$$

5 Requirements

5.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 6.

5.2 The specification will be considered met if the calculated concentration of particles plus 2 times the standard deviation does not exceed 10 particles per 25 standard liters, i.e.:

$\overline{X}_C + 2 \times S_C \leq 10$ particles/25 standard liters

6 Apparatus

Particle Counter — An instrument suitable for counting particles in compressed flammable gases at a pressure of up to 8×10^5 Pa (8 atmospheres) with a 50% counting efficiency should reach 90% at 0.3 micrometer or smaller. The resolving power of the instrument near 0.2 micrometer should be no worse than 10%. The counting efficiency is determined by a calibration at 1×10^5 Pa (1 atmosphere) pressure using p olystyrene latex spheres in an inert gas and a reference particle counter with a proven counting efficiency of not less than 95% at 0.2 micrometer.

NOTE: Suitable test methods for determining counting efficiency and resolving power are contained in Japanese Industrial Standard JIS B 9921 (1989), "Light Scattering Automatic Particle Counter". More sensitive particle counters result in a higher measured particle concentration.

7 Test Method

NOTE: The details of the sampling configuration, measurement procedure, and instrument calibration procedure and frequency, must be agreed upon by the user and supplier, taking into account good engineering practice. Material safety data sheets should be referred to for safe handling of specialty gases.

7.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing nitrogen, believed to be free of particles 0.2 micrometer or more in diameter, through the instrument and recording the total number of counts. The nitrogen purge assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Count a minimum of 3 equal intervals, each of at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 4. $\overline{X}_B$ must not exceed 2 counts per 25 standard liters.

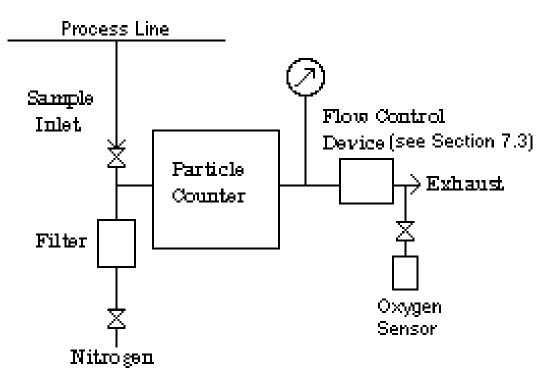

Figure 1
Schematic Diagram of Configuration for Obtaining Particle Samples from Flammable Specialty Gas Systems

7.2 The sampling point should be near the point of use, and sampling lines should be clean and as short as possible.

7.3 The sampling system configuration is shown in Figure 1. The specialty gas system should be connected through a sample valve directly to the particle counter, a pressure gauge, and a flow control device (FCD). When sampling is performed using wall tap sample ports, the aspiration efficiency should be checked using the method described in Related Information 1. The sampling system should contain minimum dead volume and sample tube length. All components in the sampling system should be leak tight and cleaned in accordance with good engineering practice. A leak check of the system should be performed in accordance with normally accepted practice. The FCD may be part of the particle counter. The particle counter should be maintained at the pressure of the gas system. The FCD can be a metering valve and a flow meter or a critical orifice. The exhaust line should be leak tight and piped to an appropriate exhaust system. The exhaust line diameter should be large enough to produce no more than 1×10^4 Pa (1.5 psi) pressure drop during purge and sample flow.

NOTE: The alternative sampling configurations described in SEMI C6.3 can also be used for hydrogen.

7.4 Using the high purity nitrogen system shown in Figure 1, purge the sampling system and particle counter for at least 5 minutes at the instrument manufacturer's specified flow rate. The exact purge time should take into account the reactivity of the gas and should be sufficient to purge the entire exhaust line. An oxygen sensor should be placed at the system exhaust to verify less than 1 ppmv oxygen in the purge nitrogen. The purging must be performed before flammable gas is introduced into the sampling system and after completion of the measurement. The valve leading to the oxygen sensor should be closed when flammable gas is being sampled. The valve leading from the purge nitrogen system should be closed when sampling specialty gases and/or a back flow prevention device should be included in the purge nitrogen system.

NOTE: It is known that flammable gases can react with oxygen present in the sampling system. Nitrogen purging of the sampling system reduces the risk of reaction. The purity of the purge nitrogen should be sufficient to remove reactive substances from the sampling system.

7.5 Count the particles in each of at least 3 equal intervals. Each sample interval must be at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Data obtained during the first 5 minutes after the sample valve is opened may be discarded. Record the number of counts in the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 4.

NOTE: For small volume specialty gas systems, the user and supplier may agree to a smaller sample gas volume than that stated above. The sample point location and the process line pressure and flow rate during the test should be recorded.

8 Report

The report shall contain the values of all the variables defined in Section 4.

9 Related Documents

Hart, J. J., W. T. McDermott, A. E. Holmer, and J. P. Natwora, Jr. Particle Measurement in Specialty Gases. Solid State Technol., 38(9):111-116, September 1995.

Wang, H. C. and R. Udischas. Counting Particles in High Pressure Electronic Specialty Gases. Solid State Technol., 37(6):97-107, June 1994.

RELATED INFORMATION 1 NOTES ON ASPIRATION EFFICIENCIES OF WALL TAP SAMPLE PORTS

NOTE: This related information is not an official part of SEMI F23 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Introduction

Isokinetic sample probes are usually not provided in speciality gas systems. Particle sampling is usually performed using wall tap sample ports. Wall tap sample ports are oriented 90° to the process line flow as shown in Figure R1-1. Non-isokinetic flow into the sample tube results from the 90° change in flow direction. Additional deviation from isokinesis can result from stream tube contraction or expansion when the velocities U and v are not equal. The effects of non-isokinetic flow on the measurement should be checked. The particle sampling process should be performed with an aspiration efficiency close to 1.

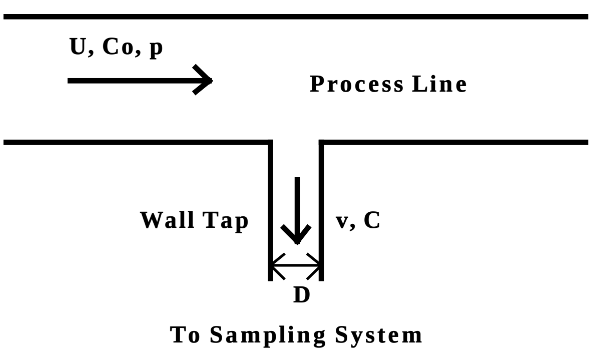

Figure R1-1
Schematic Diagram of Process Line and Wall Tap Sample Port

R1-2 Variables

d_p=	Diameter of particle (cm)
ρ_p=	Intrinsic density of particle (g/cm^3)
η=	Dynamic viscosity of the gas (g/s-cm)
λo=	Mean free path of the gas at atmospheric pressure (cm)
p=	Pressure of the gas (Pa)
P_O=	Atmospheric pressure (= 1×10^5 Pa)
D=	Diameter of wall tap sample tube (cm)
U=	Average velocity of the process line flow (cm/s)
v=	Average velocity of the sample line flow (cm/s)
C*=	Stokes-Cunningham slip correction factor
S_{tk}=	Stokes number
R=	Velocity ratio
Co=	Particle concentration in the process line (cm^{-3})
C=	Particle concentration in the sample line (cm^{-3})

R1-3 Calculations

The Stokes-Cunningham slip correction factor is calculated for particles in the size range of interest:

$$C^* = 1 + 2.492\frac{p_o \lambda o}{p d_p} + 0.84\frac{p_o \lambda o}{p d_p}\ e^{-0.435 p d_p / p_o \lambda 0}$$

Calculate the velocity ratio and Stokes number. The intrinsic particle density may assume a worst case value of 10 g/cm^3:

$$R = U/v$$

$$S_{tk} = \frac{d_p^2\, \rho_p \mathrm{UC}^*}{18\eta \mathrm{D}}$$

A wall tap sample port can be approximated as a sampling probe oriented 90° to the flow. Calculate the aspiration efficiency:

$$\frac{C}{Co} = \frac{1}{1 + 8 S_{tk}\ R^{1/2}}$$

Repeat the calculations for particle sizes in the range of interest. When the aspiration efficiency is significantly different from 1, the calculated efficiency should be used to correct the measured particle concentration, C.

R1-4 References

Stevens, D. C. Review of Aspiration Coefficients of Thin-Walled Sampling Nozzles. J. Aerosol Sci., 17(4):729-743, 1986.

Vincent, J. H., D. C. Stevens, D. Mark, M. Marshall, and T. A. Smith. On the Aspiration Characteristics of Large-Diameter, Thin-Walled Aerosol Sampling Probes at Yaw Orientations With Respect to the Wind. J. Aerosol Sci., 17(2):211-224, 1986.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F24-0697
PARTICLE SPECIFICATION FOR GRADE 10/0.2 INERT SPECIALTY GASES

1 Purpose

The purpose of this document is to set a maximum permissible particle concentration for 10/0.2 grade inert specialty gases and to describe a reference method for its verification.

2 Scope

This document applies only to inert gases delivered through specialty gas systems at pressures up to 8×10^5 Pa (8 atmospheres). This method is not suitable for direct sampling from high pressure cylinders at pressures above 8×10^5 Pa (8 atmospheres). This document applies only to the following gas:

Argon (Ar)
Halocarbon 23 (CHF_3)
Halocarbon 116 (C_2F_6)
Helium (He)
Nitrogen (N_2)
Sulfur Hexafluoride (SF_6)
Tetrafluoromethane (CF_4)

3 Referenced Documents

3.1 *SEMI Document*

SEMI C6.5 — Particle Specification for Grade 10/0.2 Nitrogen (N_2) and Argon (Ar) Delivered as Pipeline Gas

3.2 *Other Document*

JIS B 9921 — Japanese Industrial Standard (1989), “Light Scattering Automatic Particle Counter”

4 Terminology

4.1 *Variables*

V_{Mi}=	Volume of the i^{th} sample interval of the system gas
V_{Bi}=	Volume of the i^{th} sample interval of the background
X_{Mi}=	Concentration of particles observed in the i^{th} sample of interval of the system gas
X_{Bi}=	Concentration of particles observed in the i^{th} sample of interval of the background
N_M=	Number of sample intervals of the system gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the system gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the system gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

4.2 *gas sample volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1×10^5 Pa (1 atmosphere) pressure. Standard cubic feet (SCF) is defined at 21.1°C (70°F) and 1×10^5 Pa (1 atmosphere) pressure.

4.3 *average observed concentration of counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{\Sigma X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{\Sigma X_{Bi}}{N_B}$$

4.4 *calculated concentration of particles ($\overline{X}_c$)* — The concentration of particles in the system gas obtained by correcting the observed concentration in the system gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

4.5 *standard deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \sqrt{\frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)}}$$

$$S_B = \sqrt{\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)}}$$

NOTE: The third is obtained from the first two, i.e.:

$$S_C = \sqrt{S_M{}^2 + S_B{}^2}$$

5 Requirements

5.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 6.

5.2 The specification will be considered met if the calculated concentration of particles plus 2 times the standard deviation does not exceed 10 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2 \times S_C \leq 10 \text{ particles/25 standard liters}$$

6 Apparatus

Particle Counter — An instrument suitable for counting particles in compressed inert gases at a pressure of up to 8×10^5 Pa (8 atmospheres) with a 50% counting efficiency at 0.2 micrometer or smaller. The counting efficiency should reach 90% at 0.3 micrometer or smaller. The resolving power of the instrument near 0.2 micrometer should be no worse than 10%. The counting efficiency is determined by a calibration at 1×10^5 Pa (1 atmosphere) pressure using polystyrene latex spheres in an inert gas and a reference particle counter with a proven counting efficiency of not less than 95% at 0.2 micrometer.

NOTE: Suitable test methods for determining counting efficiency and resolving power are contained in Japanese Industrial Standard JIS B 9921 (1989), "Light Scattering Automatic Particle Counter". More sensitive particle counters result in a higher measured particle concentration.

7 Test Method

NOTE: The details of the sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice. Material safety data sheets should be referred to for safe handling of specialty gases.

7.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing nitrogen, believed to be free of particles 0.2 micrometer or more in diameter, through the instrument and recording the total number of counts. The nitrogen purge assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Count a minimum of 3 equal intervals, each of at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 4. $\overline{X}_B$ must not exceed 2 counts per 25 standard liters.

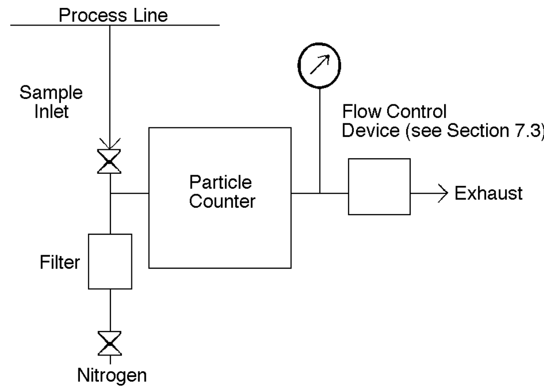

Figure 1
Schematic Diagram of Configuration for Obtaining Particle Samples from Inert Specialty Gas Systems

7.2 The sampling point should be near the point of use, and sampling lines should be clean and as short as possible.

7.3 The sampling system configuration is shown in Figure 1. The specialty gas system should be connected through a sample valve directly to the particle counter, a pressure gauge, and a flow control device (FCD). When sampling is performed using wall tap sample ports, the aspiration efficiency should be checked using the method described in Related Information 1. The sampling system should contain minimum dead volume and sample tube length. All components in the sampling system should be leak tight and cleaned in accordance with good engineering practice. A leak check of the system should be performed in accordance with normally accepted practice. The FCD may be part of the particle counter. The particle counter should be maintained at the pressure of the gas system. The FCD can be a metering valve and a flow meter or a critical orifice. The exhaust line should be leak tight and piped to an appropriate exhaust system. The exhaust line diameter should be large enough to produce no more than 1×10^4 Pa (1.5 psi) pressure drop during purge and sample flow.

NOTE: The alternative sampling configurations described in SEMI C6.5 can also be used for nitrogen or argon.

7.4 Using the high purity nitrogen system shown in Figure 1, purge the sampling system and particle counter for at least 5 minutes at the instrument manufacturer's specified flow rate. The exact purge time should be sufficient to purge the entire exhaust line. The purging must be performed before sample gas is introduced into the sampling system and after completion of the measurement. The valve leading from the purge nitrogen system should be closed when sampling specialty gases and/or a back flow prevention device should be included in the purge nitrogen system.

7.5 Count the particles in each of at least 3 equal intervals. Each sample interval must be at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Data obtained during the first 5 minutes after the sample valve is opened may be discarded. Record the number of counts in the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 4.

NOTE: For small volume specialty gas systems, the user and supplier may agree to a smaller sample gas volume than that stated above. The sample point location and the process line pressure and flow rate during the test should be recorded.

8 Report

The report shall contain the values of all the variables defined in Section 4.

9 Related Documents

Hart, J. J., W. T. McDermott, A. E. Holmer, and J. P. Natwora, Jr. Particle Measurement in Specialty Gases. Solid State Technol., 38(9):111-116, September 1995.

Wang, H. C. and R. Udischas. Counting Particles in High Pressure Electronic Specialty Gases. Solid State Technol., 37(6):97-107, June 1994.

RELATED INFORMATION 1 NOTES ON ASPIRATION EFFICIENCIES OF WALL TAP SAMPLE PORTS

NOTE: This related information is not an official part of SEMI F24 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Introduction

Isokinetic sample probes are usually not provided in speciality gas systems. Particle sampling is usually performed using wall tap sample ports. Wall tap sample ports are oriented 90° to the process line flow as shown in Figure R1-1. Non-isokinetic flow into the sample tube results from the 90° change in flow direction. Additional deviation from isokinesis can result from stream tube contraction or expansion when the velocities U and v are not equal. The effects of non-isokinetic flow on the measurement should be checked. The particle sampling process should be performed with an aspiration efficiency close to 1.

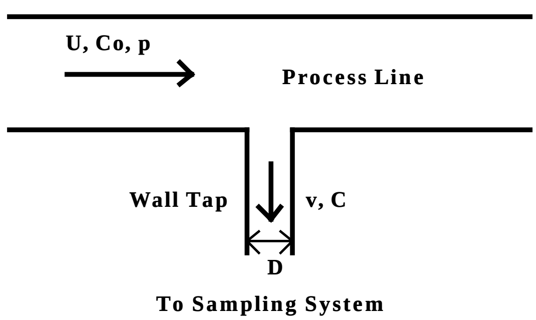

Figure R1-1
Schematic Diagram of Process Line and Wall Tap Sample Port

R1-2 Variables

d_p=	Diameter of particle (cm)
ρ_p=	Intrinsic density of particle (g/cm^3)
η=	Dynamic viscosity of the gas (g/s-cm)
λo=	Mean free path of the gas at atmospheric pressure (cm)
p=	Pressure of the gas (Pa)
P_O=	Atmospheric pressure (= 1×10^5 Pa)
D=	Diameter of wall tap sample tube (cm)
U=	Average velocity of the process line flow (cm/s)
v=	Average velocity of the sample line flow (cm/s)
C*=	Stokes-Cunningham slip correction factor
S_{tk}=	Stokes number
R=	Velocity ratio
Co=	Particle concentration in the process line (cm^{-3})
C=	Particle concentration in the sample line (cm^{-3})

R1-3 Calculations

The Stokes-Cunningham slip correction factor is calculated for particles in the size range of interest:

$$C^* = 1 + 2.492 \frac{p_o \lambda o}{p d_p} + 0.84 \frac{p_o \lambda o}{p d_p} \, e^{-0.435 p d_p / p_o \lambda}$$

Calculate the velocity ratio and Stokes number. The intrinsic particle density may assume a worst case value of 10 g/cm^3:

$$R = U/v$$

$$S_{tk} = \frac{d_p^2 \rho_p U C^*}{18 \eta D}$$

A wall tap sample port can be approximated as a sampling probe oriented 90° to the flow. Calculate the aspiration efficiency:

$$\frac{C}{Co} = \frac{1}{1 + 8 S_{tk} R^{1/2}}$$

Repeat the calculations for particle sizes in the range of interest. When the aspiration efficiency is significantly different from 1, the calculated efficiency should be used to correct the measured particle concentration, C.

R1-4 References

Stevens, D. C. Review of Aspiration Coefficients of Thin-Walled Sampling Nozzles. J. Aerosol Sci., 17(4):729-743, 1986.

Vincent, J. H., D. C. Stevens, D. Mark, M. Marshall, and T. A. Smith. On the Aspiration Characteristics of Large-Diameter, Thin-Walled Aerosol Sampling Probes at Yaw Orientations With Respect to the Wind. J. Aerosol Sci., 17(2):211-224, 1986.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F25-0697
PARTICLE SPECIFICATION FOR GRADE 10/0.2 OXIDANT SPECIALTY GASES

1 Purpose

The purpose of this document is to set a maximum permissible particle concentration for 10/0.2 grade oxidant specialty gases and to describe a reference method for its verification.

2 Scope

This document applies only to oxidant gases delivered through specialty gas systems at pressures up to 8×10^5 Pa (8 atmospheres). This method is not suitable for direct sampling from high pressure cylinders at pressures above 8×10^5 Pa (8 atmospheres). This document applies only to the following gas:

Oxygen (O_2)
Nitrous Oxide (N_2O)
Nitrogen Trifluoride (NF_3)

3 Referenced Documents

3.1 *SEMI Document*

SEMI C6.2 — Particle Specification for Grade 20/0.02 Oxygen Delivered as Pipeline Gas

3.2 *Other Document*

JIS B 9921 — Japanese Industrial Standard (1989), “Light Scattering Automatic Particle Counter”

4 Terminology

4.1 *Variables*

V_{Mi}=	Volume of the i^th sample interval of the system gas
V_{Bi}=	Volume of the i^th sample interval of the background
X_{Mi}=	Concentration of particles observed in the i^th sample of interval of the system gas
X_{Bi}=	Concentration of particles observed in the i^th sample of interval of the background
N_M=	Number of sample intervals of the system gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the system gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the system gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

4.2 *gas sample volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1×10^5 Pa (1 atmosphere) pressure. Standard cubic feet (SCF) is defined at 21.1°C (70°F) and 1×10^5 Pa (1 atmosphere) pressure.

4.3 *average observed concentration of counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{\Sigma X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{\Sigma X_{Bi}}{N_B}$$

4.4 *calculated concentration of particles ($\overline{X}_C$)* — The concentration of particles in the system gas obtained by correcting the observed concentration in the system gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

4.5 *standard deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \sqrt{\frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)}}$$

$$S_B = \sqrt{\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)}}$$

NOTE: The third is obtained from the first two, i.e.:

$$S_C = \sqrt{S_M{}^2 + S_B{}^2}$$

5 Requirements

5.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 6.

5.2 The specification will be considered met if the calculated concentration of particles plus 2 times the standard deviation does not exceed 10 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2 \times S_C \leq 10 \text{ particles/25 standard liters}$$

6 Apparatus

Particle Counter — An instrument suitable for counting particles in compressed oxidant gases at a pressure of up to 8×10^5 Pa (8 atmospheres) with a 50% counting efficiency at 0.2 micrometer or smaller. The counting efficiency should reach 90% at 0.3 micrometer or smaller. The resolving power of the instrument near 0.2 micrometer should be no worse than 10%. The counting efficiency is determined by a calibration at 1×10^5 Pa (1 atmosphere) pressure using polystyrene latex spheres in an inert gas and a reference particle counter with a proven counting efficiency of not less than 95% at 0.2 micrometer.

NOTE: Suitable test methods for determining counting efficiency and resolving power are contained in Japanese Industrial Standard JIS B 9921 (1989), "Light Scattering Automatic Particle Counter". More sensitive particle counters result in a higher measured particle concentration.

7 Test Method

NOTE: The details of the sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice. Material safety data sheets should be referred to for safe handling of specialty gases.

7.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing nitrogen, believed to be free of particles 0.2 micrometer or more in diameter, through the instrument and recording the total number of counts. The nitrogen purge assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Count a minimum of 3 equal intervals, each of at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 4. $\overline{X}_B$ must not exceed 2 counts per 25 standard liters.

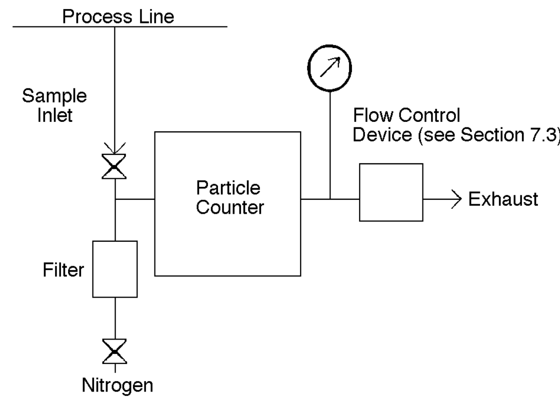

Figure 1
Schematic Diagram of Configuration for Obtaining Particle Samples from Oxidant Specialty Gas Systems

7.2 The sampling point should be near the point of use, and sampling lines should be clean, free of combustible substances, and as short as possible.

7.3 The sampling system configuration is shown in Figure 1. The specialty gas system should be connected through a sample valve directly to the particle counter, a pressure gauge, and a flow control device (FCD). When sampling is performed using wall tap sample ports, the aspiration efficiency should be checked using the method described in Related Information 1. The sampling system should contain minimum dead volume and sample tube length. All components in the sampling system should be leak tight and cleaned in accordance with good engineering practice. A leak check of the system should be performed in accordance with normally accepted practice. The FCD may be part of the particle counter. The particle counter should be maintained at the pressure of the gas system. The FCD can be a metering valve and a flow meter or a critical orifice. The exhaust line should be leak tight and piped to an appropriate exhaust system. The exhaust line diameter should be large enough to produce no more than 1×10^4 Pa (1.5 psi) pressure drop during purge and sample flow.

NOTE: The alternative sampling configurations described in SEMI C6.2 can also be used for oxygen.

7.4 Using the high purity nitrogen system shown in Figure 1, purge the sampling system and particle counter for at least 5 minutes at the instrument manufacturer's specified flow rate. The exact purge time should take into account the reactivity of the gas and should be sufficient to purge the entire exhaust line. The purging must be performed before oxidant gas is introduced into the sampling system and after completion of the measurement. The valve leading from the purge nitrogen system should be closed when sampling specialty gases and/or a back flow prevention device should be included in the purge nitrogen system.

NOTE: It is known that oxidant gases, although non-flammable, may support combustion. Cleaning in accordance with good engineering practice and nitrogen purging of the sampling system reduce the risk of reaction. The purity of the purge nitrogen should be sufficient to remove reactive substances from the sampling system.

7.5 Count the particles in each of at least 3 equal intervals. Each sample interval must be at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Data obtained during the first 5 minutes after the sample valve is opened may be discarded. Record the number of counts in the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 4.

NOTE: For small volume specialty gas systems, the user and supplier may agree to a smaller sample gas volume than that stated above. The sample point location and the process line pressure and flow rate during the test should be recorded.

8 Report

The report shall contain the values of all the variables defined in Section 4.

9 Related Documents

Hart, J. J., W. T. McDermott, A. E. Holmer, and J. P. Natwora, Jr. Particle Measurement in Specialty Gases. Solid State Technol., 38(9):111-116, September 1995.

Wang, H. C. and R. Udischas. Counting Particles in High Pressure Electronic Specialty Gases. Solid State Technol., 37(6):97-107, June 1994.

RELATED INFORMATION 1
NOTES ON ASPIRATION EFFICIENCIES OF WALL TAP SAMPLE PORTS

NOTE: This related information is not an official part of SEMI F25 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Introduction

Isokinetic sample probes are usually not provided in speciality gas systems. Particle sampling is usually performed using wall tap sample ports. Wall tap sample ports are oriented 90° to the process line flow as shown in Figure R1-1. Non-isokinetic flow into the sample tube results from the 90° change in flow direction. Additional deviation from isokinesis can result from stream tube contraction or expansion when the velocities U and v are not equal. The effects of non-isokinetic flow on the measurement should be checked. The particle sampling process should be performed with an aspiration efficiency close to 1.

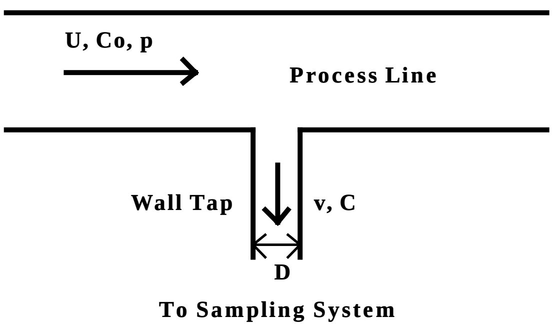

Figure R1-1
Schematic Diagram of Process Line and Wall Tap Sample Port

R1-2 Variables

d_p=	Diameter of particle (cm)
ρ_p=	Intrinsic density of particle (g/cm^3)
η=	Dynamic viscosity of the gas (g/s-cm)
λo=	Mean free path of the gas at atmospheric pressure (cm)
p=	Pressure of the gas (Pa)
P_O=	Atmospheric pressure (= 1×10^5 Pa)
D=	Diameter of wall tap sample tube (cm)
U=	Average velocity of the process line flow (cm/s)
v=	Average velocity of the sample line flow (cm/s)
C*=	Stokes-Cunningham slip correction factor
S_{tk}=	Stokes number
R=	Velocity ratio
Co=	Particle concentration in the process line (cm^{-3})
C=	Particle concentration in the sample line (cm^{-3})

R1-3 Calculations

The Stokes-Cunningham slip correction factor is calculated for particles in the size range of interest:

$$C^* = 1 + 2.492\frac{p_o \lambda o}{pd_p} + 0.84\frac{p_o \lambda o}{pd_p}\ e^{-0.435 pd_p \ / \ p_o \lambda o}$$

Calculate the velocity ratio and Stokes number. The intrinsic particle density may assume a worst case value of 10 g/cm^3:

$$R = U/v$$

$$S_{tk} = \frac{d_p^2\ \rho_p UC^*}{18\eta D}$$

A wall tap sample port can be approximated as a sampling probe oriented 90° to the flow. Calculate the aspiration efficiency:

$$\frac{C}{Co} = \frac{1}{1 + 8 S_{tk}\ R^{1/2}}$$

Repeat the calculations for particle sizes in the range of interest. When the aspiration efficiency is significantly different from 1, the calculated efficiency should be used to correct the measured particle concentration, C.

R1-4 References

Stevens, D. C. Review of Aspiration Coefficients of Thin-Walled Sampling Nozzles. J. Aerosol Sci., 17(4):729-743, 1986.

Vincent, J. H., D. C. Stevens, D. Mark, M. Marshall, and T. A. Smith. On the Aspiration Characteristics of Large-Diameter, Thin-Walled Aerosol Sampling Probes at Yaw Orientations With Respect to the Wind. J. Aerosol Sci., 17(2):211-224, 1986.

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SEMI

SEMI F26-0697
PARTICLE SPECIFICATION FOR GRADE 10/0.2 TOXIC SPECIALTY GASES

1 Purpose

The purpose of this document is to set a maximum permissible particle concentration for 10/0.2 grade toxic specialty gases and to describe a reference method for its verification.

2 Scope

This document applies only to toxic gases delivered through specialty gas systems at pressures up to 8×10^5 Pa (8 atmospheres). This method is not suitable for direct sampling from high pressure cylinders at pressures above 8×10^5 Pa (8 atmospheres). This document applies only to the following gas:

Ammonia (NH_3)
Arsine (AsH_3)
Phosphine (PH_3)

3 Referenced Documents

3.1 *Japanese Industrial Standard*

JIS B 9921 — Japanese Industrial Standard (1989), "Light Scattering Automatic Particle Counter"

4 Terminology

4.1 *Variables*

V_{Mi}=	Volume of the i^th^ sample interval of the system gas
V_{Bi}=	Volume of the i^th^ sample interval of the background
X_{Mi}=	Concentration of particles observed in the i^th^ sample of interval of the system gas
X_{Bi}=	Concentration of particles observed in the i^th^ sample of interval of the background
N_M=	Number of sample intervals of the system gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the system gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the system gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

4.2 *gas sample volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1×10^5 Pa (1 atmosphere) pressure. Standard cubic feet (SCF) is defined at 21.1°C (70°F) and 1×10^5 Pa (1 atmosphere) pressure.

4.3 *average observed concentration of counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{\Sigma X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{\Sigma X_{Bi}}{N_B}$$

4.4 *calculated concentration of particles ($\overline{X}_C$)* — The concentration of particles in the system gas obtained by correcting the observed concentration in the system gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

4.5 *standard deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \sqrt{\frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)}}$$

$$S_B = \sqrt{\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)}}$$

NOTE: The third is obtained from the first two, i.e.:

$$S_C = \sqrt{S_M{}^2 + S_B{}^2}$$

5 Requirements

5.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 6.

5.2 The specification will be considered met if the calculated concentration of particles plus 2 times the standard deviation does not exceed 10 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2 \times S_C \leq 10 \text{ particles/25 standard liters}$$

6 Apparatus

Particle Counter — An instrument suitable for counting particles in compressed toxic gases at a pressure of up to 8×10^5 Pa (8 atmospheres) with a 50% counting efficiency should reach 90% at 0.3 micrometer or smaller. The resolving power of the instrument near 0.2 micrometer should be no worse than 10%. The counting efficiency is determined by a calibration at 1×10^5 Pa (1 atmosphere) pressure using p olystyrene latex spheres in an inert gas and a reference particle counter with a proven counting efficiency of not less than 95% at 0.2 micrometer.

NOTE: Suitable test methods for determining counting efficiency and resolving power are contained in Japanese Industrial Standard JIS B 9921 (1989), "Light Scattering Automatic Particle Counter". More sensitive particle counters result in a higher measured particle concentration.

7 Test Method

NOTE: The details of the sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice. Material safety data sheets should be referred to for safe handling of specialty gases.

7.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing nitrogen, believed to be free of particles 0.2 micrometer or more in diameter, through the instrument and recording the total number of counts. The nitrogen purge assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Count a minimum of 3 equal intervals, each of at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 4. $\overline{X}_B$ must not exceed 2 counts per 25 standard liters.

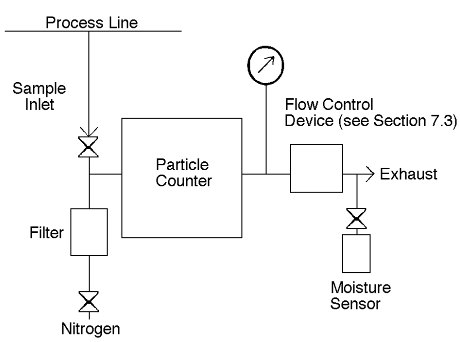

Figure 1
Schematic Diagram of Configuration for Obtaining Particle Samples from Toxic Specialty Gas Systems

7.2 The sampling point should be near the point of use, and sampling lines should be clean and as short as possible.

7.3 The sampling system configuration is shown in Figure 1. The specialty gas system should be connected through a sample valve directly to the particle counter, a pressure gauge, and a flow control device (FCD). When sampling is performed using wall tap sample ports, the aspiration efficiency should be checked using the method described in Related Information 1. The sampling system should contain minimum dead volume and sample tube length. All components in the sampling system should be leak tight and cleaned in accordance with good engineering practice. A leak check of the system should be performed in accordance with normally accepted practice. The FCD may be part of the particle counter. The particle counter should be maintained at the pressure of the gas system. The FCD can be a metering valve and a flow meter or a critical orifice. The exhaust line should be leak tight and piped to an appropriate exhaust system. The exhaust line diameter should be large enough to produce no more than 1×10^4 Pa (1.5 psi) pressure drop during purge and sample flow.

7.4 Using the high purity nitrogen system shown in Figure 1, purge the sampling system and particle counter for at least 5 minutes at the instrument manufacturer's specified flow rate. The exact purge time should take into account the reactivity of the gas and should be sufficient to purge the entire exhaust line. A moisture sensor should be placed at the system exhaust to verify less than 1 ppmv water in the purge nitrogen. The purging must be performed before toxic gas is introduced into the sampling system and after completion of the measurement. The valve leading to the moisture sensor should be closed when toxic gas is being sampled. The valve leading from the purge nitrogen system should be closed when sampling specialty gases and/or a back flow prevention device should be included in the purge nitrogen system.

NOTE: It is known that toxic gases may produce injurious or lethal effects. Nitrogen purging of the sampling system reduces the risk of exposure to toxic gases. The purity of the purge nitrogen should be sufficient to remove reactive substances from the sampling system.

7.5 Count the particles in each of at least 3 equal intervals. Each sample interval must be at least 25 standard liters (0.95 SCF), or 30 minutes, whichever is greater. Data obtained during the first 5 minutes after the sample valve is opened may be discarded. Record the number of counts in the sample volume for each interval. Calculate $\overline{X}_C$ and SC, as defined in Section 4.

NOTE: For small volume specialty gas systems, the user and supplier may agree to a smaller sample gas volume than that stated above. The sample point location and the process line pressure and flow rate during the test should be recorded.

8 Report

The report shall contain the values of all the variables defined in Section 4.

9 Related Documents

Hart, J. J., W. T. McDermott, A. E. Holmer, and J. P. Natwora, Jr. Particle Measurement in Specialty Gases. Solid State Technol., 38(9):111-116, September 1995.

Wang, H. C. and R. Udischas. Counting Particles in High Pressure Electronic Specialty Gases. Solid State Technol., 37(6):97-107, June 1994.

RELATED INFORMATION 1 NOTES ON ASPIRATION EFFICIENCIES OF WALL TAP SAMPLE PORTS

NOTE: This related information is not an official part of SEMI F26 and is not intended to modify or supercede the official standard. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Introduction

Isokinetic sample probes are usually not provided in speciality gas systems. Particle sampling is usually performed using wall tap sample ports. Wall tap sample ports are oriented 90° to the process line flow as shown in Figure R1-1. Non-isokinetic flow into the sample tube results from the 90° change in flow direction. Additional deviation from isokinesis can result from stream tube contraction or expansion when the velocities U and v are not equal. The effects of non-isokinetic flow on the measurement should be checked. The particle sampling process should be performed with an aspiration efficiency close to 1.

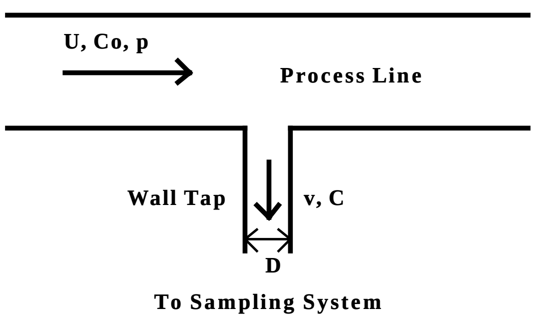

Figure R1-1
Schematic Diagram of Process Line and Wall Tap Sample Port

R1-2 Variables

d_p=	Diameter of particle (cm)
ρ_p=	Intrinsic density of particle (g/cm^3)
η=	Dynamic viscosity of the gas (g/s-cm)
λo=	Mean free path of the gas at atmospheric pressure (cm)
p=	Pressure of the gas (Pa)
P_O=	Atmospheric pressure (= 1×10^5 Pa)
D=	Diameter of wall tap sample tube (cm)
U=	Average velocity of the process line flow (cm/s)
v=	Average velocity of the sample line flow (cm/s)
C*=	Stokes-Cunningham slip correction factor
S_{tk}=	Stokes number
R=	Velocity ratio
Co=	Particle concentration in the process line (cm^{-3})
C=	Particle concentration in the sample line (cm^{-3})

R1-3 Calculations

The Stokes-Cunningham slip correction factor is calculated for particles in the size range of interest:

$$C^* = 1 + 2.492\frac{p_o \lambda o}{p d_p} + 0.84\frac{p_o \lambda o}{p d_p}\ e^{-0.435 p d_p / p_o \lambda o}$$

Calculate the velocity ratio and Stokes number. The intrinsic particle density may assume a worst case value of 10 g/cm^3:

$$R = U/v$$

$$S_{tk} = \frac{d_p^2\ \rho_p U C^*}{18 \eta D}$$

A wall tap sample port can be approximated as a sampling probe oriented 90° to the flow. Calculate the aspiration efficiency:

$$\frac{C}{Co} = \frac{1}{1 + 8 S_{tk}\ R^{1/2}}$$

Repeat the calculations for particle sizes in the range of interest. When the aspiration efficiency is significantly different from 1, the calculated efficiency should be used to correct the measured particle concentration, C.

R1-4 References

Stevens, D. C. Review of Aspiration Coefficients of Thin-Walled Sampling Nozzles. J. Aerosol Sci., 17(4):729-743, 1986.

Vincent, J. H., D. C. Stevens, D. Mark, M. Marshall, and T. A. Smith. On the Aspiration Characteristics of Large-Diameter, Thin-Walled Aerosol Sampling Probes at Yaw Orientations With Respect to the Wind. J. Aerosol Sci., 17(2):211-224, 1986.

SEMI F27-0997
TEST METHOD FOR MOISTURE INTERACTION AND CONTENT OF GAS DISTRIBUTION SYSTEMS AND COMPONENTS BY ATMOSPHERIC PRESSURE IONIZATION MASS SPECTROMETRY (APIMS)

1 Purpose

1.1 This test will determine the quantity of removable moisture and the degree of interaction with trace concentrations of gas phase moisture, of gas distribution systems and components. APIMS is currently the technique of choice for such tests because it is essentially the only commercially available method capable of ppt moisture analysis and because of its superior response time. This method may provide guidelines for the application of other techniques with similar detection limits and response time to APIMS which are not commercially available at this time.

1.2 The results of this test can be used for qualitative ranking of systems and components and can also be used, by a sufficiently sophisticated user, as input for numerical simulation of distribution system behavior.

2 Scope

2.1 *System and Component Types* — This procedure applies to in-line components to be used to contain electronics grade materials in semiconductor gas distribution systems. The following components are expected to yield meaningful results when tested according to the present method: tubing, connectors (fittings), particle filters, valves (check, relief, shut-off, and metering), regulators, flow-through transducers/sensors, mass flow controllers and meters. Components with dead volumes, such as pressure gauges, can be tested according to this method, but the results will be difficult to interpret. Additional criteria besides those considered here need to be developed for testing components with dead volumes.

2.1.1 As gas phase moisture levels are dominated by desorption from surfaces, the procedure is expected to be most useful for components of large surface area such as particle filters and tubing. Components with very small wetted surface areas may have moisture interactions which are too small to measure using this test. Check valves and relief valves can be tested only if their operating parameters are consistent with the test conditions.

2.1.2 Tubing samples must be rather long (3 – 4 m) to yield useful results, but they can be bent into a U shape in order to be accommodated into a practical test bench. Radii of curvature should be no less than 6 times the internal diameter of the tube and the minimum number of bends should be used. Most ultra-high purity components are currently supplied with metal gasket connectors, so the test bench employed should be fitted with mating connectors. This type of fitting is usually welded to tubing, which is not recommended as it introduces a potential source of uncontrolled variability to the experiments. Instead, a compression fitting on the tube and a suitable adapter should be used. The compression fitting should not be disconnected after initial connection until the test series is over. In this way, deterioration in integrity of the connection can be avoided. The same type of gasket to compression fitting adapter should be used for all tubing samples.

2.1.3 Purifiers require special test procedures and are not addressed here.

2.1.4 Simple systems consisting of components connected in line can be tested by the present method. Complex systems (i.e., those with more than one potential inlet and/or outlet) will show performance which varies depending on the test configuration (which inlets and outlets are chosen). Testing of such systems is not addressed by the current document.

2.2 *Gases* — The procedure will be carried out in nitrogen. The results will provide a ranking with respect to moisture contribution which may be applied with due caution to components intended for use in other gas streams. Other "inert" gases will have different purging characteristics and may dry a component more quickly or slowly. Reactive gases may react chemically with moisture. Considerations relating to corrosion resistance are outside the scope of the present document, although the test procedure may prove useful in corrosion studies.

2.3 *Operating Situations* — Moisture contribution from a component may be the result of contamination arising in its manufacture, or from subsequent exposure to ambient air or non-dry gas. Thus, it is necessary to consider two main situations:

1. The "initial dry-down" situation, which is determined by the moisture content of the component as received with the effects of manufacturing process and design, surface quality, pretreatment and packaging convoluted together.

2. The “Response to upset” situation, which is determined by the amount of moisture taken up by the component and subsequently released in any exposure after receipt.

3 Limitations

3.1 This test method allows the determination of moisture interactions which can be used, for example, to rank components in order of decreasing moisture interaction. Because different degrees of moisture interaction are desirable in different situations, selecting the “best” components requires consideration of how they will be used in a given distribution system, either qualitatively or through numerical simulation of distribution system behavior.

4 Referenced Documents

4.1 *SEMI Documents*

A test method for moisture contribution as measured using a conventional hygrometer is in preparation by SEMI Japan as of this writing. That test should be considered when certification to ~ 20 ppb moisture is sufficient. The output of the moisture generator, used in this text, shall be verified according to SEMI C15, Test Method for ppm and ppb Humidity Standards.

5 Terminology

5.1 *Acronyms*

5.1.1 *ppm* — Molar parts per million (µmole/mole). The same as ppmv.

5.1.2 *ppb* — Molar parts per billion (nmole/mole). The same as ppbv.

5.1.3 *ppt* — Molar parts per trillion (pimole/mole). The same as pptv.

5.2 *Definitions*

5.2.1 *induction time* — The elapsed time between when humidified gas is input to the test component and when moisture is detected at the moisture analyzer. For a component and test system which are perfectly transparent to moisture the induction time is equal to the residence time of the gas in the system.

5.2.2 *peak height* — The maximum moisture concentration recorded when a moisture input of predefined length and concentration is introduced to a test component.

6 Required Equipment

6.1 *APIMS* — The APIMS used for moisture detection can be of any type. In order to be considered valid, any series of moisture tests shall reference two single point calibrations, one at the beginning and one at the end of the series. These calibrations shall both be made under the same analytical conditions (flow, pressures, plate voltages, etc.) as the tests and the results shall be within 5% of each other. Provided this condition is met, the interval between calibrations may be left to the discretion of the operator; however, it is suggested that calibration should be carried out whenever the equipment is moved and/or every two weeks of operation.

6.2 *Dry Gas and Moisture Generator* — A source of extremely dry nitrogen (less than 100 ppt moisture) and a moisture generator capable of delivering up to 13 slm nitrogen doped with 50 ppb moisture is required. This generator may be the same as used to calibrate the APIMS. The output of the generator shall be verified according to SEMI C15.

Most ultra-high purity components are currently fitted with metal gasket type connectors. The same type of connector should, therefore, be incorporated into the test bench for connection to the test components.

6.3 *Test Blank* — Any series of tests shall include the results of testing a blank. The blank shall be the shortest convenient length (no more than 1 m) of 1/4" electropolished stainless steel (EPSS) tubing with suitable fittings and/or adapters at either end to enable it to be inserted in place of the test specimen.

6.4 *Moisture Pulse Generator* — A valving arrangement capable of switching rapidly between dry and humidified nitrogen is also required. An example of such a design is shown in Figure 1. In this design, flow is maintained in both the humidified and dry gas lines at all times. By simultaneously switching valves V_1 and V_3, or V_2 and V_3, either humidified or dry gas is directed through the test specimen while the other gas stream is directed to vent. Note that there is a bypass loop so that flow can be maintained to the APIMS when the specimen is removed. In this design, all gas lines, but especially those lines between V_1 and V_3 and between V_2 and V_3, should be as short as possible and constructed of EPSS tubing of high quality. Maintaining gas lines at a constant temperature between 50 and 80°C wherever possible is also recommended.

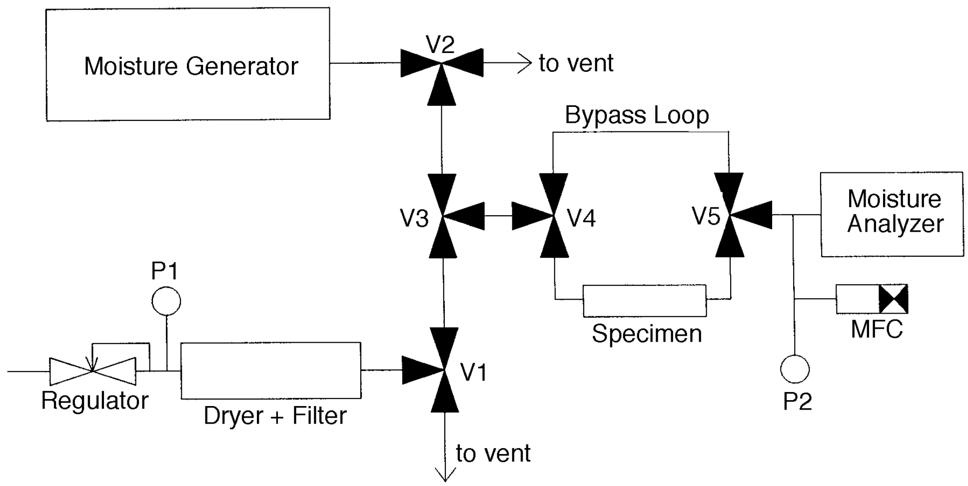

Figure 1
Moisture Test Schematic

6.4.1 The bypass loop will contain a stagnant volume of gas during testing. To avoid exposing the APIMS to a large moisture upset whenever it is fed the gas contained in the bypass loop, the loop should be thoroughly baked out (at ≥ 200°C) and protected from atmospheric contamination thereafter. Valve V_4 should be such that some flow can be maintained through the bypass loop and the test specimen simultaneously as well as through each separately. Use of pneumatic valves to facilitate rapid and simultaneous switching is recommended.

6.4.2 Other arrangements than that shown may also be used. The moisture pulse generator should be designed so as to give the fastest possible response of the blank to a change in input moisture level.

6.4.3 Use of a glove box or other such enclosure about the test specimen and adjacent piping, to minimize exposure of the system to ambient contamination when removing and introducing the test specimen, will improve the precision of moisture content measurements but not of moisture interaction measurements. Use of such an enclosure is, therefore, left to the discretion of the operator.

6.5 *Temperature Control and Measurement* — A stable temperature during the test is of critical importance. The test component shall be kept at 35°C. **TESTS AT DIFFERENT TEMPERATURES CANNOT BE COMPARED**. Ideally, the blank and device under test should be maintained in a temperature-controlled chamber. However, if this is impractical, heating tape can be used. Temperature shall be measured at 1 m intervals on tubing. Measurement at one point is adequate for small components. Temperature control should be to ± 1°C. A continuous record of temperature during the test shall be maintained.

7 Procedure

7.1 *Blank Tests* — A blank test shall be carried out after each calibration. If initial dry-down testing of components is not of interest, the initial dry-down test of the test blank may be omitted and the test blank brought to equilibrium with zero gas in whatever manner is most convenient, except that the test blank should not be heated above 200°C. Permanent changes in moisture interaction have been observed at temperatures above this level.

7.1.1 *Initial Dry Down* — Start the experiment with the blank in place of the test specimen and a flow of dry gas through the APIMS. The APIMS output should be at equilibrium with the lowest moisture level of interest, and in any case no higher than 500 ppt. The flow rate through the test blank should be set according to the Flow Table (see Section 7.3).

7.1.1.1 Switch the gas flow to pass primarily through the bypass loop while maintaining a small flow through the test blank. Remove the test blank completely from the system. If a glove box or other such enclosure is used, do not remove the test blank from the glove box. Immediately reconnect the test blank to V_4, leaving it disconnected from V_5. Allow dry nitrogen to flow through the test blank for five minutes to purge the air from inside before reconnecting to V_5. Switch the gas to flow only through the blank and not through the bypass loop. The APIMS will show an increase in moisture concentration. Record the APIMS output until it reaches 500 ppt or for 24 hours, whichever is less.

7.1.1.2 Repeat the above test twice for a total of three data sets.

7.1.2 *Moisture Input Test* — After the APIMS has returned to equilibrium with its initial moisture level, switch the input gas to 50 ppb moisture (by switching valves V_1, V_2, and V_3 simultaneously, if the arrangement of Figure 1 is used) while recording the APIMS response. Maintain this moisture input for 20 minutes. Switch the input to the test blank back to dry nitrogen and record the decease in moisture level until the initial background is again reached.

7.1.2.1 Repeat the above test twice for a total of three data sets.

7.2 *Tests on Actual Specimen*

7.2.1 *Initial Dry Down* — This portion of the test is designed to determine the quantity of removable moisture on the wetted surfaces of a component in the condition in which it is typically supplied. Thus, the results of this test will reflect, by design, any precautions which the supplier has taken to remove moisture and maintain its dryness during shipping.

7.2.1.1 Start the test as in Section 7.1.1. The test specimen should not be unpacked until after the APIMS has equilibrated with the background moisture level. If a glove box or other such enclosure is used, unpack the component in the glove box. Switch the dry nitrogen flow to pass through the bypass loop while maintaining a small component through the test blank. Undo the final layer of packing and any shipping caps or plugs on the component at this point. Remove the sample blank and connect the test specimen to valve V_4 as quickly as possible. Allow the dry nitrogen flow to purge out any ambient air in the specimen for five minutes, then connect the specimen to V_5. Switch the gas to flow only through the test specimen and not through the bypass loop. The APIMS will show an increase in moisture concentration. Record the APIMS output until it reaches 500 ppt or for 24 hours, whichever is less.

7.2.1.2 After 24 hours, the dry-down part of the test can be terminated. If necessary, the moisture level can be reduced below 500 ppt by baking the component at 200°C or the maximum temperature allowed by the manufacturer for six hours and/or purging at the highest flow of dry gas available. If this is not sufficient to reduce the moisture concentration below 500 ppt, the test may be abandoned.

7.2.2 *Moisture Input Test* — After the APIMS has returned to equilibrium with its initial moisture level, switch the input gas to 50 ppb moisture (by switching valves V_1, V_2, and V_3 simultaneously, if the arrangement of Figure 1 is used) while recording the APIMS response. Maintain this moisture input for 20 minutes. Switch the input to the test blank back to dry nitrogen and record the decease in moisture level until the initial background is again reached.

7.2.2.1 Repeat the above test twice for a total of three data sets.

7.2.2.2 In case the moisture level recorded by the APIMS does not reach 50 ppb within 20 minutes, an additional test should be performed in which the moisture input should be continued until equilibrium is reached. Then switch the input to the test specimen back to dry nitrogen and record the decease in moisture level until the initial background is again reached. This test should be repeated once (two data sets total).

7.2.3 *Bake-Out Test* — Heat component to maximum bake temperature, according to manufacturer's specifications, for three hours. Allow it to return to room temperature. Continue by repeating the moisture input test, after baking, as in Section 7.2.2.

7.3 *Temperature, Flow Rate, and Pressure Specification* — The recommended test pressure is 700 kPa (7 bar). However, lower test pressures are appropriate for some models of APIMS. Also, the maximum pressure rating of the test components should not be exceeded. The component temperature shall be maintained at 35 ± 1°C during the test.

In the case of tubing, the test shall be carried out at a single flow determined by the tubing diameter according to the following table. In the case of valves, regulators, mass flow controllers (MFC's), and passive components (gauges, flow meters, and fittings), the test will be carried out at a single flow determined by the table according to the size of the connecting tube stubs. Regulators should be tested in the fully-open condition (i.e., with the regulator adjusted for minimum pressure drop). The quantity of published data on regulator interaction with moisture is limited, and experiments to investigate the effect of varying the pressure drop across the regulator are encouraged but are not part of this test. MFC's should be tested with a flow control device upstream and the MFC not actively controlling the flow through it (usually referred to as the "purge" setting). It may not be possible to test a given MFC at the specified flow if the flow rating of the MFC is much less than the specified flow. As MFC's are not expected to vary greatly in performance according to their flow rating, MFC's to be tested should generally be chosen to be compatible with the table. If this is not possible, then the MFC should be tested at its rated flow (lower than the flow in the table). This can then be considered a conservative test, as the MFC operated at higher flow would be expected to dry down more quickly.

Particle filters with the same size tubing connectors often have somewhat different sizes and very different flow ratings. In order to be able to make reasonable comparisons between the performance of different filters, it is essential to test filters of similiar size at the same flow. However, the flow dependence of the moisture response of particle filters is more complex than that of tubing, and they must be tested at more than one flow in order to model their behavior. In order to meet this requirement and provide data which can be readily compared with the conditions under which the filters can be expected to be used in practice, filters shall be tested at two flows: The first, according to the size of the connecting tube stubs, the second, to be 25% of the rated flow of the filter or 50 slm, whichever is less.

For systems of components, the system shall be tested at the lowest flow of those determined for each component in the system considered separately. If the system includes a filter, it shall be tested at that flow and additionally, at 25% of the rated flow of the filter or 50 slm, whichever is less.

<table>
<tr><th>Tubing Outer Diameter (nominal)</th><th>Flow (all components)</th><th>Flow for Second Test on Filters</th></tr>
<tr><td>≥ 1/8", < 1/2"
(≥ 3.2 mm, < 12.7 mm)</td><td>6 slm</td><td rowspan="2">25% of rated flow or 50 slm whichever is less</td></tr>
<tr><td>≥ 1/2"
(≥ 12.7 mm)</td><td>13 slm</td></tr>
</table>

8 Reporting Results

Complete moisture response curves for all test specimens and relevant test blanks should be included. A summary sheet may compare components in terms of “induction time,” peak height, and/or decay time. Temperature, pressure, and flow measurements, and as complete a record as possible of all experimental variables should be noted.

SEMI F28-0997
TEST METHOD FOR MEASURING PARTICLE GENERATION FROM PROCESS PANELS

1 Purpose

1.1.1 The purpose of this document is to define a method for testing process panels intended for

1.1.2 nels tested for the purposes of qualification for this installation.

1.2 This document describes a test method designed to draw comparisons of particulate generation performance of process panels. This test method evaluates the cleanliness of process panels in the "as received" condition as well as under normal operating conditions. The "as received" test is intended to enable the user to evaluate the fabrication, cleaning, and packaging techniques of the manufacturer of the process panel. The test under actual operating conditions is intended to allow the user to evaluate the manufacturer's component selection as well as the quality of the panel design. The specific flow rates described in both test methods are representative of relatively high flow conditions for a typical process panel.

2 Scope

2.1 This test method addresses total particle counts greater than the minimum detection limit (MDL) of the particle counter and does not consider classifying data into various size ranges.

2.2 This procedure utilizes a particle counter applied to process panels typically used in semiconductor applications. It applies to process gas supply systems (e.g., gas cabinets) which include a process panel, an inert purge panel, and a system vent. Both automatic and manual process panels are within the scope of this test procedure. Panels, as defined in this test method, are considered to consist of 6.35 mm O. D. × 0.89 mm wall (1/4" O.D. × 0.035" wall) tubing and components.

3 Limitations

3.1 This test method specifies flow and mechanical stress conditions considered typical of conditions which would be expected under moderately aggressive operating conditions. These conditions should not exceed those recommended by the manufacturer. Actual performance under operating conditions at lower flow rates or less aggressive conditions may differ. This test method does not address particle generation under vibrating conditions.

installation in high-purity gas distribution systems. Application of this test method is expected to yield comparable data among process pa

3.2 The test medium is limited to nitrogen, argon, or clean dry air (CDA). Performance with other gases may differ.

3.3 The accuracy of the data generated by this method is limited to the accuracy of the particle measuring instruments utilized.

3.4 This method is written with the assumption that the operator understands the use of the apparatus at a level equivalent to six months of experience.

3.5 This document is not intended as a methodology for monitoring on-going particulate performance once a particular process panel has been tested. Also, this method does not include extended dynamic particle count testing (particle generation after thousands of cycles).

3.6 Auto-crossover systems are not within the scope of this test procedure.

NOTE: It should be mentioned that test results from panels equipped with final outlet filters can differ significantly from test results from panels without filters.

4 Referenced Documents

NOTE: The appropriate particle counter manufacturer's operating and maintenance manuals should be consulted when using this test method.

4.1 *Federal Document*[1]

FED-STD-209 — Federal Standard Clean Room and Work Station Requirements, Controlled Environment

5 Terminology

5.1 *Acronyms*

5.1.1 *CDA* — Clean, dry air

5.1.2 *EP* — Electropolished

5.1.3 *LPC* — Laser particle counter

5.1.4 *psi* — Pounds per square inch

5.1.5 *psia* — Pounds per square inch absolute

1 Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

5.1.6 *psid* — Pounds per square inch differential

5.1.7 *psig* — Pounds per square inch gauge

5.1.8 *scfm* — Standard cubic feet per minute

5.1.9 *slpm* — Standard liters per minute

5.1.10 *SL* — Standard liters

5.2 *Definitions*

5.2.1 *background counts* — Counts contributed by the test apparatus (including counter electrical noise) with a spool piece in place of the test object.

5.2.2 *Compressed Gas Association (CGA)* — Also frequently used to refer to a fitting, as defined and specified by the Compressed Gas Association, which is used to connect a gas source cylinder to a panel inlet.

5.2.3 *condensation nucleus counter (CNC)* — A discrete particle counting instrument that detects particles, in a gaseous stream, by measuring light scattered from droplets grown to measurable size by condensation of supersaturated vapor upon the particles.

5.2.4 *dynamic test* — A test performed to determine particle contribution as a result of valve actuation or regulator adjustment in a process panel during normal operation.

5.2.5 *process panels* — A gas source control piping system for delivering process gases as defined in SEMI F13.

5.2.6 *sample flow rate* — The volumetric flow rate drawn by the particle counter for particle detection.

5.2.7 *sampling time* — The time increment over which counts are recorded.

5.2.8 *source pressure* — Pressure of the source gas applied to the cylinder connection at the panel inlet.

5.2.9 *spool piece* — A null component consisting of a straight piece of electropolished tubing and appropriate fittings used in place of the test component to establish the baseline.

5.2.10 *standard conditions* — 101.3 kPa, 0.0°C (14.73 psia, 32°F).

5.2.11 *static test* — A test performed on an as-received process panel with all valves in the fully-open position.

5.2.12 *test duration* — Total time required to complete the test procedure.

5.2.13 *test flow rate* — Volumetric flow rate of the test gas at standard conditions as defined in Section 5.2.10.

5.2.14 *test pressure* — Pressure immediately downstream of the test panel.

6 Test Procedure

6.1 *Test Conditions*

6.1.1 *Precautions* — This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.

6.1.1.1 Exhaust from the CNC may contain hazardous and/or flammable vapors and should be properly treated before being released to atmosphere.

6.1.2 The test is to be conducted at a normal indoor temperature of between 18°C (64°F) and 26°C (78°F).

6.1.3 Test apparatus must be enclosed in a Class 100 environment (per current revision of Federal Standard 209). Use procedures necessary to maintain Class 100 when handling test apparatus and test components.

6.1.4 Care should be taken to protect the test apparatus from excessive vibration. For example, vacuum pumps and compressors should be isolated from the system.

6.2 *Apparatus and Materials*

6.2.1 *Test Gas* — Clean, dry nitrogen or air is to be used [minimum dryness -60°C dew point at 790 kPa (100 psig) and < 10 ppm total hydrocarbons]

6.2.2 *Filters* — Filters are required to provide “particle-free” test gas. Each filter must be nine-log retentive, per manufacturer’s specifications, to 0.02 µm particles and have a pressure drop of less than 6.9 kPa (1 psid) at the specified test pressure and flow rate. The filter must be capable of achieving less than 1 particle[3] (≥ 0.02 µm) per cubic foot of test gas under test conditions.

6.2.3 *Pressure Regulator* — Pressure regulators are required to maintain system test pressures.

6.2.4 *Pressure Gauge* — Pressure transducers or gauges are required to monitor system test pressures.

6.2.5 *Flow Control Device* — A 0–100 slpm flow control device is required for controlling the test flow rate.

6.2.6 *Tubing* — A 6.35 mm O.D. × 0.89 mm wall (1/4" O.D. × 0.035" wall) tubing is required. The tubing shall have an average surface roughness of 0.25 micrometer (10 microinch) Ra or less. Electropolished tubing (as defined in SEMI F16) is recommended.

6.2.7 *Sampler* — The sampling system consists of a diffuser equipped with a pressure reducing device (e.g., critical orifice) and a sample probe. All parts of the sampling system are to be electropolished with a surface roughness of 0.25 micrometer (10 microinch) Ra or less. If a critical orifice is to be used for pressure reduction, it is not required to be electropolished. The diffuser and sample probe must be sized to obtain isokinetic sampling at the specified test conditions. The critical orifice must be sized to obtain the specified panel pressure at the specified test flow rate.

6.2.8 *Spool Piece* — Spool pieces shall be electropolished 316L stainless steel tubing with a surface finish of 0.25 micrometer (10 microinch) Ra or better. The spool piece is to be installed in the system in place of the test device while obtaining background counts for the system.

6.2.9 *Fittings* — Use face seal connectors or compression fittings depending on test panel end connections.

6.2.10 *Gaskets* — Use non-plated metal gaskets where required.

6.2.11 A CNC capable of detecting particles at least as small as 0.02 µm at a 50% efficiency envelope as defined by Federal Standard 209, with a sampling flow rate of 1.23 SLPM (0.05 scfm) or greater, is to be used for particle counting. A laser particle counter, capable of detecting particles at least as small as 0.1 mm, may be used in addition to, or in place of, the CNC. Test durations in this test method have been established based on a sampling flow rate of 1.23 SLPM (0.05 scfm).

6.2.11.1 Instruments should be calibrated regularly, according to manufacturer's recommendations. For the CNC, this includes routine checks of sample flow rate, working fluid level, and zero.

6.2.11.2 The CNC and data collection equipment should have power surge suppression.

6.2.11.3 *Setup and Schematic* — See Figure 1

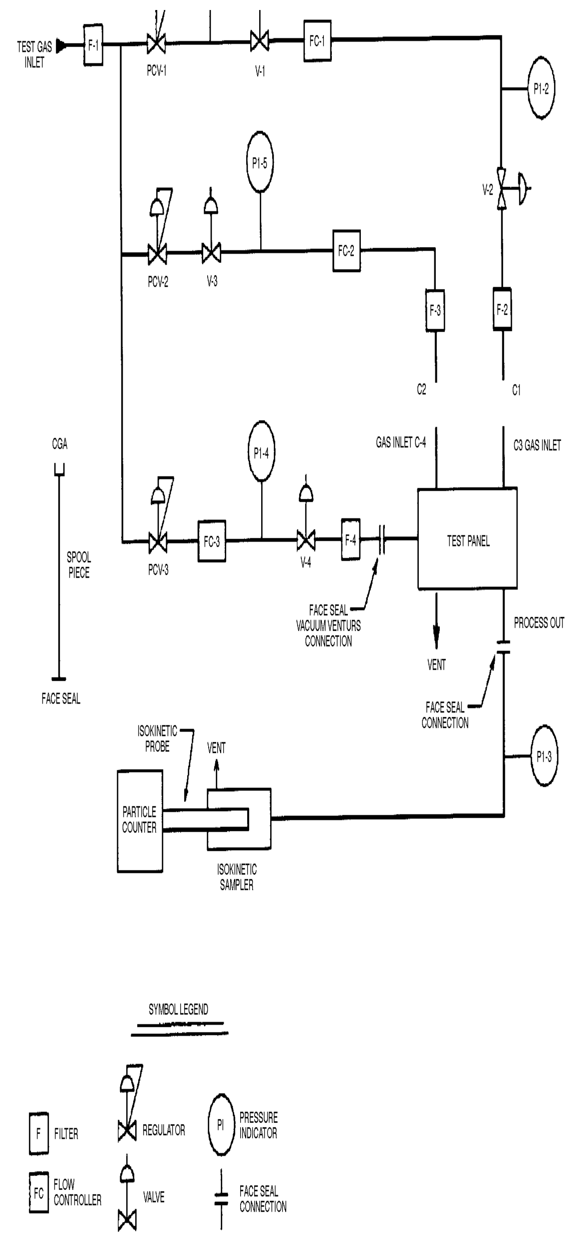

Figure 1
Panel Test Apparatus

6.2.11.4 The spool piece is to be installed when the test stand is not in use. A continuous low flow is to be maintained to purge the system. The particle counter may be turned off. For an extended shutdown, the system (excluding the CNC) should be pressurized and capped.

6.2.11.5 After initial construction, the spool piece should be installed and the system should be cleaned up by running a high-flow rate of test gas (> 60 SLPM) and gently tapping all components (except the CNC) downstream of the final filter. This procedure should be followed by a start-up phase which characterizes system cleanliness by conducting the entire test protocol with the spool piece installed.

6.3 *Test Procedures*

NOTE: Ensure the counter is counting continuously and reporting data each minute. For the duration of the test, the counter should be continuously counting, except where noted in the test protocol.

This test method classifies panels into three pressure ranges: high, medium, and low. The test pressures and flow rates for each pressure classification are given in Table 1 below.

Table 1 Panel Test Conditions

Panel Pressure Class	*High*	*Medium*	*Low*
Inlet Supply Pressure	3450 KPa (500 psig)	550 KPa (80 psig)	210 KPa (30 psig)
Panel Outlet Pressure	210 KPa (30 psig)	210 KPa (30 psig)	0 KPa (0 psig)
Test Flow Rate	60 slpm	60 slpm	5 slpm

The test flow rates stated in the above table are meant to serve as a general guideline. The actual test flow rates may vary depending on the maximum panel flow rate as recommended by the manufacturer. The maximum test flow rate should be the manufacturer's maximum recommended flow rate. If no such maximum flow rate is recommended by the manufacturer, the flow rates in the above table should be used.

6.3.1 *Background Test* — Ensure that all valves depicted in Figure 1 are in the closed position. Connect the spool piece to the purge gas inlet (C-2) and the isokinetic sampler inlet. Ensure that the spool piece and proper adapters are in place on the test apparatus. (C-1 should be capped at this time.)

6.3.1.1 Close valve V-3. Adjust the regulator (PCV-2) until PI-5 indicates the appropriate pressure in Table 1. Open valve V-3 and use FC-2 to establish the specified test flow rate listed in Table 1. Measure the static background count. Background count is established when the counter has sampled a minimum of 74 SL (3 scf), and the arithmetic average during the last 74 SL (3 scf) of gas sampled is < 71 particles/m^3 (< 2 particles/scf). At a sample flow rate of 1.23 SLPM (0.05 scfm), the time required is one hour. Ensure that the background counts are stable or decreasing. If background cannot be achieved after 147 SL (6 scf) have been sampled, there may be a problem with the counter or test apparatus.

6.3.1.2 Disconnect the spool piece from C-2 and connect it to C-1. Cap C-2 at this point.

6.3.1.3 Open valve V-1 and close valve V-2. Adjust the regulator (PCV-1) until PI-2 indicates the appropriate supply pressure listed in Table 1. Open valves V-1 and V-2 to establish flow. Using the flow control device (FC-1) set the appropriate test flow rate listed in Table 1. Measure the static background count. Background count is established when the counter has sampled a minimum of 74 SL (3 scf), and the arithmetic average during the last 74 SL (3 scf) of gas sampled is < 71 particles/m3 (< 2 particles/scf). At a sample flow rate of 1.23 SLPM (0.05 scfm), the time required is one hour. Ensure that the background counts are stable or decreasing. If background cannot be achieved after 147 SL (6 scf) have been sampled, there may be a problem with the counter or test apparatus.

6.3.1.4 Actuate valve V-2 at 1 cycle per minute to measure the background counts under dynamic test conditions. Dynamic background count is established when the counter has sampled a minimum of 74 SL (3 scf), and the arithmetic average during the last 74 SL (3 scf) of gas sampled is < 106 particles/m^3 (< 3 particles/scf). At a sample flow rate of 1.23 SLPM (0.05 scfm), the time required is 1 hour. If dynamic background cannot be achieved after 147 SL (6 scf) have been sampled, there may be a problem with the counter or test apparatus.

6.3.2 *Static Test* — Using the flow control device (FC-1), decrease the flow rate to 2.5–5.0 SLPM (0.1–0.2 scfm), so that some flow remains in the system while the test component is installed.

6.3.2.1 Remove the spool piece by first disconnecting the downstream fitting and then the upstream fitting. Immediately install the test panel with all of the process valves in the fully-open position by first connecting the process gas inlet (C-3) fitting and then the process outlet fitting. Uncap C-2 and connect it to the purge gas inlet (C-4) connection of the panel with V-3 in the closed condition. In order to minimize atmospheric contamination and prevent the counter from cooling off, removal of the spool piece and installation of the test panel should take no longer than 2 minutes. Extreme care should be taken to minimize contamination of the test apparatus during this operation. The test panel is to be removed from its inner bag in the Class 100 test area. If the process outlet connection of the test panel has mechanical fittings, these fittings are to be properly connected. If the process outlet has butt weld tube stubs, the connection is to be made with clean compression fittings. Do not permanently crimp any ferrules onto the tube stubs. Nylon ferrules are acceptable. The purge gas inlet connection (C-4) should also be connected at this time. The outlet vent connection should be capped at this time. If this connection is not capped by the manufacturer, it should be covered with Aclar or Nylon 66 squares and taped so as to insure against contamination by the immediate environment. If applicable, all pneumatic valves should be connected using the maximum recommended actuator pressure as specified by the manufacturer.

6.3.2.2 Adjust the panel's process regulator to obtain the appropriate process outlet pressure as indicated in Table 1. Using the flow control device (FC-1), increase the flow to obtain the appropriate test flow rate as indicated in Section 6.3.

6.3.2.3 Turn on the counter and conduct the steady state test. All of the valves on the process panel are to be tested in a fully-open position until 74 SL (3 scf) of gas have been sampled. Cumulative data should be recorded at one-minute intervals.

NOTE: The flow rates in Section 6.3 represent the maximum test flow rates. If a more thorough test is desired, the static portion of the test should be repeated at intervals of 20%, 40%, 60%, and 80% of the full test flow rate. Testing at the lower flow rates may in some instances be more indicative of panel performance under actual use conditions.

6.3.3 *Dynamic Test* — This test is to immediately follow the static test. To conduct the dynamic test, actuate the panel's final process outlet valve at the rate of 1 cycle/minute for 60 minutes. Each cycle consists of having the valve in the open position for 58 seconds and in the closed position for 2 seconds.

6.3.4 *Cylinder Change Test* — Close V-2, open V-3 and V-4, and adjust PCV-2 until PI-5 reads 3450 Kpag (500 psig). Adjust the flow rate and pressure to the vacuum venturi using FC-3 and PCV-3. The flow rate and pressure should be set to the manufacturer's recommended values. Next perform a simulated cylinder change purge and evacuation sequence following the valve sequencing, dwell times, pressure settings, etc. as specified by the manufacturer.

6.3.5 *Final Steady State Test* — Close V-4, V-3, and open V-2. Repeat the step in Section 6.3.2.3.

6.3.6 *Unregulated Flow Test (optional)* — In some instances, it may be desirable to test the panel with its regulator in the fully-open position. Such a test will give an indication of panel particulate performance without the additional contribution of particles from an operating regulator. In this instance, steps 6.3–6.3.5 should be repeated with the regulator in the wide open condition.

6.4 *Data Analysis and Reporting* — The following test conditions are to be reported in the data presentation:

1. Date and time of test
2. Operator
3. Test flow rate
4. Test pressures
5. Panel type, manufacturer, and serial number
6. Particle counter manufacturer, serial number, sample flow rate, model number, specified particle size sensitivity, and calibration date
7. Test gas type and dew point
8. A schematic of the test apparatus, including manufacturer's and model numbers of all test apparatus components
9. Calibration dates for all instrumentation.

6.4.1 *Data Presentation* — Graph the static and dynamic portions of the test separately as counts/minute (measured by the counter) versus time, including the appropriate background (measured with the spool piece in place) with each. Also graph the entire data set as counts per minute versus time.

6.4.1.1 Present the entire raw data set in tabular form.

6.4.2 *Data Reduction* — The statistical analysis is based on the assumption that the particles generated are randomly distributed and are statistically independent of each other. The background counts are independent of the particle performance of the component. The particle counts observed from the test include the counts from the component and the background count. Let:

$\overline{X}_B$ = *average background particle count*

$\overline{X}_t$ = *average total particle count from test*

$\overline{X}_c$ = *average particle count generated by the test component*

Therefore,

$$\overline{X}_t = \overline{X}_c + \overline{X}_B$$

6.4.2.1 A statistical analysis of the data is performed to determine the mean, standard deviation, and the standard error for each particle size range.

6.4.2.2 The sample mean, X, or average of the data for each state is given by:

$$\overline{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$

where X_i is the observed counts for the state and n is the number of samples.

6.4.2.3 The sample standard deviation is a measure of the variability of the data about the mean. The standard deviation, s, for each state is expressed as:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (Xi - \overline{X})^2}{n-1}}$$

6.4.2.4 The standard error, Se or standard deviation of the sampling distribution of the mean for each state is given below:

$$Se = \frac{s}{\sqrt{n}}$$

6.4.2.5 The average particle count for the total number of particles generated, or the sample mean, is an estimation of the population mean. For a 95% confidence level, the population mean, μ_p, will be within two standard errors of the sample mean, or:

$$\mu_p = \overline{X} \pm 2\ Se$$

6.4.2.6 In order to determine if there is statistical evidence of the component having an effect on the observed particle count, a test must be conducted to see if the actual difference between the average background count, X_B, and the average test count, X_t, exceeds two standard errors in a distribution of differences between means. The average particle count generated by the test component, X_c, is given by:

$$\overline{X}_c = \overline{X}_t - \overline{X}_B$$

6.4.2.7 The standard error in a distribution of differences between means is expressed as:

$$S_{ec} = \sqrt{S_{et}^{\ 2} + S_{eB}^{\ 2}}$$

6.4.2.8 The 95% confidence interval of the test component itself is then determined by:

$$\overline{X}_c \pm 2\ S_{ec}$$

6.4.2.9 If this confidence interval includes 0, then this implies that there is not strong statistical evidence of the component having an effect on the observed particle count. If this interval does not include 0, then this implies there is strong statistical evidence that the component does have an effect on the observed particle count.

6.4.2.10 Present in tabular form the average particle count and the associated upper and lower confidence limits (as calculated in Section 6.4.2) for each test state. In addition, present the background test data separately as a distinct element.

7 Related Documents

Agarwal, J. K. and Sem, G. J., "Continuous Flow, Single Particle Counting Condensation Nucleus Counter", Journal of Aerosol Science, v.11.4. July 1950: 343–357

Fissan, H. and Schwientek, "Sampling and Transport of Aerosols", TSI Journal of Particle Instrumentation, v.2.2. July–December 1987: 3–10

Hinds, W. C. Aerosol Technology: "Properties, Behavior, and Measurement of Airborne Particles", John Wiley & Sons. 1982: 187–194

VanSlooten, R. A., "Statistical Treatment of Particle Counts in Clean Gases", Microcontamination, v.4.2. February 1986: 32–38

ANSI/ASME B46.1[2] — "Specification for Surface Texture - Surface Roughness, Waviness, and Lay"

2 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

SEMI F29-0997
TEST METHOD FOR PURGE EFFICACY OF GAS SOURCE SYSTEM PANELS

1 Purpose

1.1 This document defines the purge efficacy test method recommended for determining the minimum acceptable level of purge efficacy for gas source systems used in semiconductor manufacturing. It is also intended as an aid to the procurement of gas source equipment.

NOTE: Users of this specification are encouraged to submit suggested revisions or other comments to SEMI.

2 Scope

2.1 This specification applies to gas source equipment used in semiconductor manufacturing facilities and comparable research and development areas. It includes contamination testing requirements for gas source systems.

2.2 The tests covered by this document are as follows:

2.2.1 Purge efficacy with a non-interactive gas using manufacturers' standard purge sequence.

2.2.2 Purge efficacy with a non-interactive gas using the test method specified purge sequence.

2.2.3 Purge efficacy with an interactive gas using manufacturers' standard purge sequence.

2.2.4 Purge efficacy with an interactive gas using the test method specified purge sequence.

3 Limitations

3.1 The document is not intended to determine the safe operation of a gas source system. The test method described here is for determining the removal efficacy of hazardous gas from the pigtail portion of the gas panel during routine cylinder change operations (pre-purge). It does not address the purge condition after the change of the cylinder (post-purge) nor the purge of the entire gas source system which is usually performed following its initial installation or during maintenance (maintenance purge).

3.2 Because the response time of moisture and oxygen analyzers utilizing different technologies can differ significantly, this can lead to the possibility that different instruments will report different peak heights when measuring identical contaminant spikes. Therefore, results of tests should only be compared when similar analyzers are used.

4 Referenced Documents

None.

5 Terminology

5.1.1 *clean dry air (CDA)* — Filtered air filtered to 0.02 mm and dried to a dew point of at least -80°C.

5.1.2 *dry down* — Removal of residual moisture in a gas delivery or distribution system, often accomplished by flowing a stream of high purity dry inert gas continuously through the system for an extended period of time.

5.1.3 *dwell time* — The time for which vacuum or pressure is applied during the evacuation or pressurization steps of a purge operation.

5.1.4 *interactive gas* — A gas that will readily adsorb to the surface of a vessel used to contain or transport it. Examples of interactive gases are hydrogen chloride and moisture.

5.1.5 *non-interactive gas* — A gas that will not adsorb to the surface of a vessel used to contain or transport it. Examples of non-interactive gases are oxygen and nitrogen.

5.1.6 *ppb* — Molar parts per billion, same as ppbv.

5.1.7 *ppm* — Molar parts per million, same as ppmv.

5.1.8 *pigtail* — The pigtail is the part of the gas source equipment that is the flexible connection between the cylinder and the gas panel.

5.1.9 *pigtail bleed* — A pigtail bleed is a reverse flow of purge gas from the pigtail to minimize atmospheric intrusion into the gas panel.

5.1.10 *purge cycle* — Following the initial process vent step, a cycle is defined as a pressurization step followed by an evacuation step.

5.1.11 *purified nitrogen* — Nitrogen purified to meet the following characteristics:

Moisture	< 20 ppb
Oxygen	< 10 ppb
Total hydrocarbons	< 1 ppm
CO_2	< 1 ppm
CO	< 1 ppm

6 Ordering Information

6.1 Orders for equipment or services requiring purge efficacy testing in accordance with this test method shall include the following:

6.1.1 This test method number and date of issue.

6.1.2 Test requirements as defined in the detailed specifications for the specific product being purchased.

6.1.3 Whether certifications of tests and a report of the test results is required.

7 Requirements

7.1 *Personnel Qualification* — Personnel performing tests in accordance with this specification shall have suitable training and experience. Such personnel should, as a minimum,

7.1.1 be trained and experienced in operation of gas source control equipment,

7.1.2 be trained and experienced in the use of oxygen and moisture analyzers, and

7.1.3 be familiar with the operation and calibration of the specific equipment used in performing the tests.

8 Apparatus

8.1 *Oxygen Analyzer* — The oxygen analyzer should meet or exceed the following characteristics:

Limit of Detection	10 ppb
Accuracy	± 10 ppb

8.2 *Moisture Analyzer* — The moisture analyzer should meet or exceed the following characteristics:

Limit of Detection	10 ppb
Accuracy	± 10 ppb

8.3 *Pressure Transducer* — The transducer should be of a high-purity type with minimal dead volume and meet or exceed the following characteristics:

Accuracy	± 3.4 kPa (0.5 psi)
Hysteresis	± 3.4 kPa (0.5 psi)
Non-Repeatability	± 0.7 kPa (0.1 psi)

8.4 *Mass Flow Controller or Flow Meter* — The mass flow controller or flow meter should be accurate to ± 0.2 slpm.

8.5 *Moisture Source* — The moisture source must be capable of providing a 2 slpm continuous flow of 2.0 ± 0.2 ppm moisture in nitrogen mixture at 138 kPa (g) [20 psi (g)] for a minimum of 30 minutes.

9 Procedure

9.1 Purge efficacy determination with non-interactive gas at manufacturer's recommended pressure, vacuum, and dwell times.

9.1.1 Connect gas source equipment as in Figure 1.

NOTE: To avoid biasing the test results by substantially increasing piping volume to be purged, the dead space between the cylinder connection and the valves isolating the analyzer and the contaminant source must be small compared to the total pigtail volume. The use of mono-block valve and flow-through type pressure transducer is highly recommended.

However, the pigtail is connected to the cylinder valve during the purge in an actual cylinder change operation. The small additional volume to be purged in the test setup may be used to account for the volume of the cylinder valve outlet cavity, which must be purged during a cylinder change.

9.1.2 To challenge the gas panel with a known contaminant gas, completely fill and pressurize the gas source system to 207 kPa (g) [30 psi (g)] with CDA as measured at the pigtail with the pressure transducer.

9.1.3 Using purified nitrogen as the purge gas, complete one purge cycle at the manufacturer's recommended pressure, vacuum, and dwell times.

9.1.4 Flow purified nitrogen using a pigtail bleed at 1 slpm or at the oxygen analyzer manufacturer's recommended flow rate, whichever is higher, into the oxygen analyzer for 10 minutes or until below the detection limit of the oxygen analyzer.

9.1.5 Record the pressure and peak oxygen concentration in Table 1. It is highly recommended that, in addition to the peak oxygen concentration, the oxygen concentration readings also be recorded at regular intervals during the measurement, so that a graph of the oxygen concentration level in the pigtail bleed gas versus time can be drawn if necessary.

9.1.6 Repeat steps 9.1.2–9.1.5 for 2, 5, 25, and 50 purge cycles at the manufacturer's recommended pressure, vacuum and dwell times. Additional tests using other purge cycle numbers are encouraged and may provide a more complete characterization of the purge performance of the test piece.

9.1.7 Plot the peak residual oxygen concentration versus cycles as in Figure 2 for manufacturer's recommended pressure, vacuum, and dwell times.

9.2 Purge efficacy determination with non-interactive gas at standard pressure, vacuum and dwell times.

9.2.1 Connect the gas source equipment as in Figure 1.

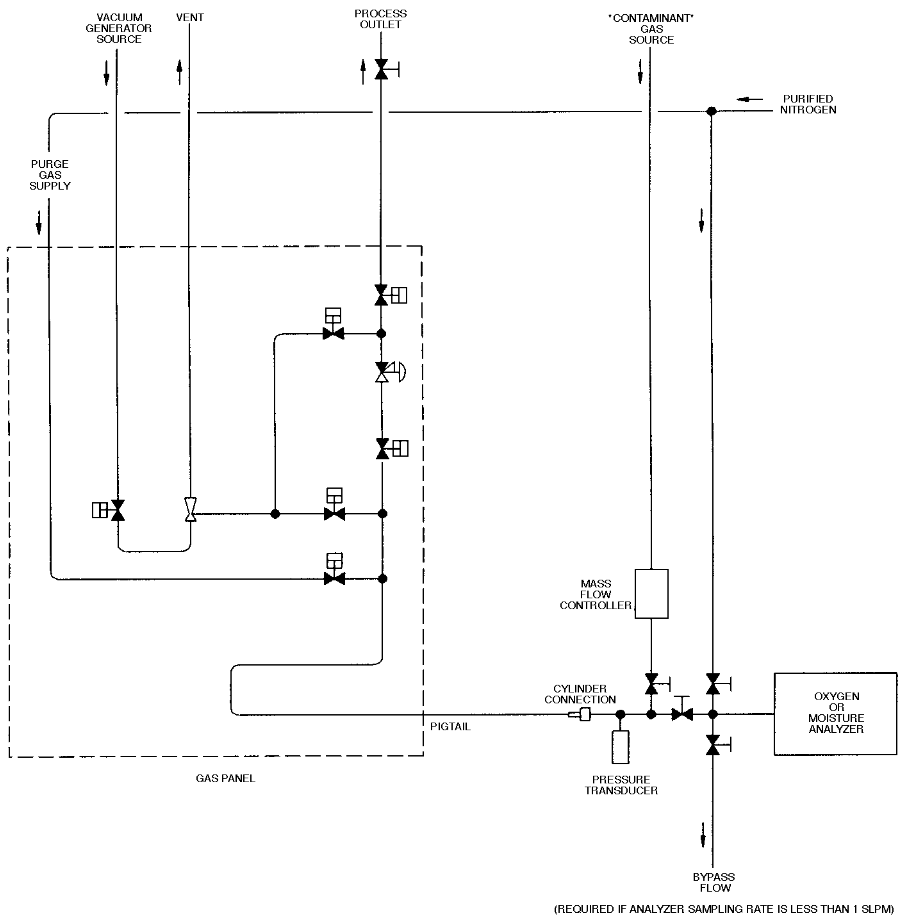

Figure 1
Test Schematic

9.2.2 To challenge the gas panel with a known contaminant gas, completely fill and pressurize the gas source system to 207 kPa (g) [30 psi (g)] with CDA as measured at the pigtail with the pressure transducer.

9.2.3 Using purified nitrogen as the purge gas, complete one purge cycle with the purge gas pressure at 522 kPa (g) [80 psi (g)], vacuum at -75 kPa (g) [-22" Hg (g)], and dwell times for pressurization and vacuum evacuation at 5 and 15 seconds, respectively.

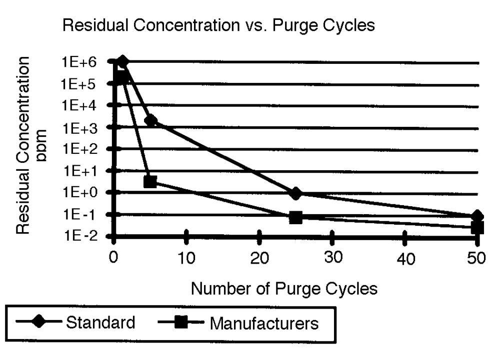

Figure 2
Data Presentation for Purge Efficacy — Non-Interactive Gas

9.2.4 Flow purified nitrogen using a pigtail bleed at 1 slpm or at the oxygen analyzer manufacturer's recommended flow rate, whichever is higher, into the oxygen analyzer for 10 minutes or until below the detection limit of the oxygen analyzer.

9.2.5 Record the pressure and vacuum measured with the transducer and the peak oxygen concentration as in Table 1. It is highly recommended that, in addition to the peak oxygen concentration, the oxygen concentration readings also be recorded at regular intervals during the measurement, so that a graph of the oxygen concentration level in the pigtail bleed gas versus time can be drawn if necessary.

Table 1 Data Collection Form

	Manufacturer's Recommended Purge Parameters	*SEMI Standard Purge Parameters*
Pressure		kPa (g)
Vacuum		kPa (g)
Cycles	Peak Residual Oxygen	
1		
5		
25		
50		

9.2.6 Repeat steps 9.2.2–9.2.5 process for 2, 5, 25, and 50 cycles. Additional tests using other purge cycle numbers are encouraged and may provide a more complete characterization of the purge performance of the test piece.

9.2.7 Plot the peak residual oxygen concentration versus number of cycles as in Figure 2 for standard pressures, vacuum, and dwell time.

9.3 Purge efficacy determination with interactive gas at manufacturer's pressure, vacuum, and dwell times.

9.3.1 Connect gas source equipment as in Figure 1.

9.3.2 To challenge the gas panel with a known contaminant gas, flow wet (2 ppm) N_2 at 2 slpm and 138 kPa (g) [20 psi (g)] for 30 minutes or until the process outlet concentration reaches the inlet concentration, whichever is less.

9.3.3 Using purified nitrogen as the purge gas, complete one purge cycle at manufacturer's recommended pressure, vacuum, and dwell times.

9.3.4 Flow purified nitrogen using a pigtail bleed at 1 slpm or at the moisture analyzer manufacturer's recommended flow rate, whichever is higher, into the moisture analyzer for 30 minutes or until below the detection limit of the moisture analyzer.

9.3.5 Record the pressure and vacuum measured with the pressure transducer and peak residual moisture concentration in Table 2. It is highly recommended that, in addition to the peak moisture concentration, the moisture concentration readings also be recorded at regular intervals during the measurement, so that a graph of the moisture concentration level in the pigtail bleed gas versus time can be drawn if necessary.

9.3.6 Repeat steps 9.3.2–9.3.5 process for 2, 3, 4, 5, 10, 25, and 50 cycles. Additional tests using other purge cycle numbers are encouraged and may provide a more complete characterization of the purge performance of the test piece.

9.3.7 Plot the peak residual moisture concentration versus number of cycles as in Figure 3 for manufacturer's pressure, vacuum, and dwell time.

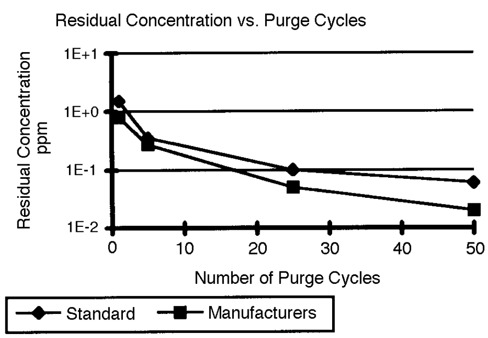

Figure 3
Data Presentation for Purge Efficacy Interactive Gas

9.4 Purge efficacy determination with interactive gas at standard pressure, vacuum, and dwell time.

9.4.1 Connect gas source equipment as in Figure 1.

9.4.2 To challenge the gas panel with a known contaminant gas, flow wet (2 ppm) N_2 at 2 slpm and 138 kPa (g) [20 psi (g)] for 30 minutes or until the process outlet concentration reaches the inlet concentration, whichever is less.

9.4.3 Using purified nitrogen as the purge gas, complete one purge cycle with the purge gas pressure at 522 kPa (g) [80 psi (g)], vacuum at -75 kPa (g) [-22" Hg (g)], and dwell times for pressurization and vacuum evacuation at 5 and 15 seconds, respectively.

9.4.4 Flow purified nitrogen using a pigtail bleed at 1 slpm or at the moisture analyzer manufacturer's recommended flow rate, whichever is higher, into the moisture analyzer for 30 minutes or until below the detection limit of the moisture analyzer.

9.4.5 Record the pressure and vacuum measured with the pressure transducer and peak residual moisture concentration in Table 2. It is highly recommended that, in addition to the peak moisture concentration, the moisture concentration readings also be recorded at regular intervals during the measurement, so that a graph of the moisture concentration level in the pigtail bleed gas versus time can be drawn if necessary.

9.4.6 Repeat steps 9.4.2–9.4.5 process for 2, 3, 4, 5, 10, 25, and 50 cycles. Additional tests using other purge cycle numbers are encouraged and may provide a more complete characterization of the purge performance of the test piece.

9.4.7 Plot the peak residual moisture concentration versus number of cycles as in Figure 4 for standard pressure, vacuum, and dwell time.

Table 2 Data Collection Form

	Manufacturer's Recommended Purge Parameters	*SEMI Standard Purge Parameters*
Pressure		kPa (g)
Vacuum		kPa (g)
Cycles	Peak Residual Moisture	
1		
5		
25		
50		

10 Certification

10.1 When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that the articles furnished have been tested in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

11 Related Documents

11.1 *SEMI Document*

SEMI F13 — Guide for Gas Source Control Equipment

11.2 *Compressed Gas Association Document*

CGA Pamphlet P1 — Safe Handling of Compressed Gases

SEMI F30-0298
START-UP AND VERIFICATION OF PURIFIER PERFORMANCE TESTING FOR TRACE GAS IMPURITIES AND PARTICLES AT AN INSTALLATION SITE

1 Purpose

1.1 The purpose of this procedure is to verify the performance of purifiers by employing analytical instrumentation to measure gas impurities and particles to customer specifications. If specific inlet challenge(s) and/or inlet measurements are required, it should be discussed beforehand with the customer. Inlet impurities must be measured by part-per-million (PPM) or part-per-billion (PPB) analytical equipment. This procedure applies only to large scale bulk purifiers rated at greater than 50 liters-per-minute (LPM) flowrate.

2 Scope

2.1 Verify performance of large scale purifiers in nitrogen, argon, helium, oxygen, and hydrogen service. Verification tests are done at PPB or sub-PPB levels of gaseous impurities and sub-micron sizes of particles measured downstream of any installed filter modules. Tests are done at maximum achievable flow of purifier, and/or customer's specified percentages of maximum flow.

3 Limitations

3.1 PPB and sub-PPB gaseous impurity levels are achievable using atmospheric presssure ionization mass spectrometry (APIMS), which is the preferred method of choice, and the reduction gas detector (RGD)-gas chromatograph. APIMS is currently not available for oxygen service. A partial list of non-APIMS measuring equipment for use in oxygen service is in Appendix 1 for commonly measured impurities.

4 Referenced Documents

4.1 Approved procedures for operation of analytical equipment.

4.2 Approved gas sampling and purifier procedures.

5 Terminology

None.

6 Summary of Method

6.1 The purifier is started, and the operation is checked. Each purifier bed is regenerated, and analytical tests are done. The analytical results determine if the purified gas meets the customer specifications.

7 Interferences

7.1 The following sources might contribute to misleading or high analytical results. Some identified sources are unpurged, dead-ended piping or isolation valves, leaks in gas distribution system, insufficient purge flow, and insufficient system clean-up time.

8 Apparatus

8.1 Face seal fitting(s) with metal gaskets and stainless steel tubing for sampling.

8.2 Dynamic dilution system for diluting calibration standards to PPB and sub-PPB levels for calibration of analytical equipment.

8.3 *APIMS* — The sample gas, nitrogen, is introduced into an APIMS where a small amount of it is ionized. By collision with ionized nitrogen, impurity molecules are ionized with high efficiency. The mass analyzer, which can be a quadrupole, time-of-flight (TOF), or even a magnetic sector, separates and focusses the ions by their mass-to-charge ratio. An electron multiplier detects and counts each ion fragment and amount.

8.4 *Reduction Gas Detector-Gas Chromatograph (RGD-GC)* — The reduction gas detector is a heated mercuric oxide bed that reacts with reducing gases, such as hydrogen and carbon monoxide. The mercury evolved is detected and displayed as a peak. The GC employs a heated molecular sieve column to separate the H_2 and CO.

8.5 *Ultratrace Analytical Instrumentation Required other than APIMS* — Ultratrace instrumentation is defined as having sufficient sensitivity to measure all impurities of interest at the specified level of the customer at the PPB or sub-PPB.

8.6 Particle counter.

8.7 Data collection and reduction system.

9 Reagents and Materials

9.1 Certified calibration standards.

10 Safety Precautions

10.1 The testing area should have adequate room ventilation and atmospheric monitors.

10.2 Instruments should be exhausted to vent, and if required in Class 1 environments, should be case-purged or in an approved enclosure.

10.3 Testing personnel should be aware of customer alarm and evacuation procedures.

10.4 Designated customer contact required during testing.

11 Sampling

11.1 Test each purifier bed independently to verify performance to customer specifications. Refer to gas supplier's certificate of conformance for inlet impurity levels. Refer to Figure 1 for overall test sequence.

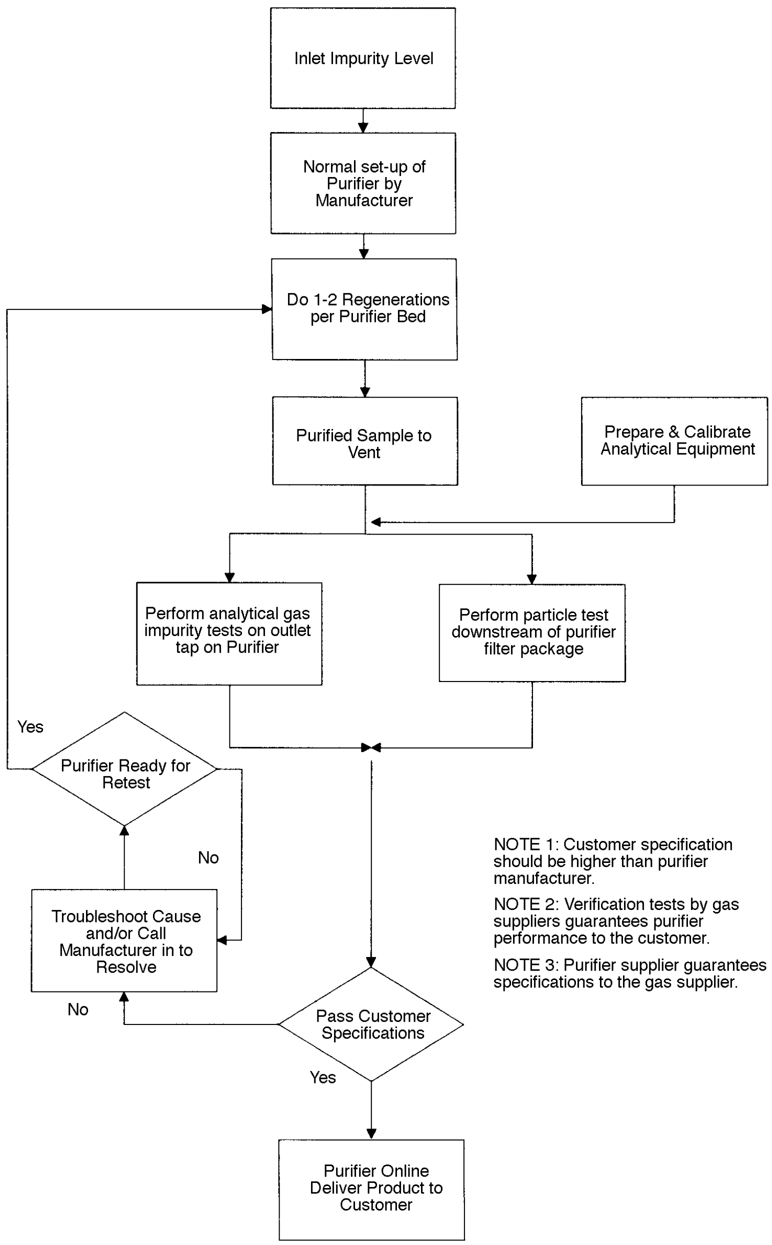

Figure 1
Overall Test Sequence

12 Preparation of Apparatus

12.1 *Sampling System* — Use appropriate clean tubing and fittings, or clean before use. Purge system prior to sampling.

12.2 *Dynamic Dilution System* — Use certified standards and dilute using equation (1) to calculate final concentration (C_F). For moisture, certified moisture permeation devices can be used.

(1) $C_c \times D.F. = C_F$

C_c = PPM - or PPB - certified cylinder standard concentration.

C_F = final concentration.

D.F. = dilution factor which is calculated by taking the flow (in liters) of the certified standard and dividing by total flow (in liters). Dilution factors can be multiplied in series, if diluting more than once.

Example 1: What is the final concentration for dynamically diluting 10 ml of a 100 PPB impurity into 1 liter?

$$100 \text{ PPB} \times [0.010 \text{ liter}/1.010 \text{ liter}] = 0.99 \text{ PPB}$$

12.2.1 Calibration should be done in the region specified by the purifier manufacturer. For example, if the purifier has an outlet impurity guarantee of 1 PPB of each impurity, then the test equipment should be calibrated with levels at approximately 1 PPB, not at 30 PPB and extrapolated down. Also, multipoint calibration data is preferred.

12.3 APIMS, RGD-GC, ultratrace analytical instrumentation. Particle counter.

12.3.1 Start-up and purge the instrumentation. Perform calibration. Determine if calibration is satisfactory. Proceed to sampling section.

12.4 *Data Collection System* — Check for proper signal inputs, range inputs, and sampling intervals.

12.5 *Data Reduction System* — Prepare data as print-outs and/or graphs. Include statistical analysis as required. Generate final report.

13 Calibration and Standardization

13.1 See Section 12, Preparation of Apparatus.

14 Procedure

14.1 *Trace Gas Impurity Measurement*

14.1.1 Connect sample source to analytical equipment.

14.1.2 Start data collection.

14.1.3 Stop sampling. Review preliminary data. If it is within customer specification, disconnect sample source. If it does not meet specifications, investigate cause or refer to manufacturer literature to resolve. Once condition is corrected, repeat tests.

14.1.4 Repeat procedure for next bed or sampling point. If instrumentation is relocated, calibration check is required.

14.2 *Particle Counting*

14.2.1 Select sample location. Ideal location is a permanently installed pitot probe.

14.2.2 Select where the particle tests will be done on the pipe.

14.2.3 Use Reynold's equation to determine the required gas rate for turbulent flow to the particle counter. Use this value or higher for sampling purposes. Reynold's number greater than 2100 are suggested for turbulent flow.

14.2.4 Reduce incoming sample pressure to the particle counter by following manufacturer's recommendation or by best practice.

14.2.5 Test particles with turbulent flow through pipeline, if possible. However, do not exceed the manufacturer's maximum rated flow for the purifier.

14.2.6 Start data collection.

14.2.7 Stop sampling. Review preliminary data. If it is within customer specification, disconnect sample source. If it does not meet specifications, investigate cause or refer to manufacturer's literature to resolve. Once condition is corrected, repeat tests.

14.2.8 Repeat procedure for next bed or sampling point.

15 Calculations or Interpretation of Results

15.1 Results are interpreted by trending analysis, averaging, or steady-state analysis.

16 Reporting Results

16.1 Sample location.

16.2 Operator identification.

16.3 Test parameters and conditions (pressures, flowrates, temperatures, etc.).

16.4 Test date and duration.

16.5 Description of instrumentation.

16.6 Calibration information for analyzer(s).

16.7 Report test results by data table and/or graphs.

16.8 Comments on testing.

16.9 Conclusion.

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI F30 by full letter ballot procedure.

Partial List of Analytical Equipment for Use in Oxygen Service	
Impurity	Analytical Equipment
H_2O	Dewpoint Detection Electrolytic Peizoelectric Capacitance (aluminum oxide, silicon array) Fourier Transform Infrared (FTIR)
CH_4, Total Hydrocarbons, Nonmethane Hydrocarbons	Flame-Ionization Detector-Gas Chromatograph (FID-GC) Discharge Ionization Detector (DID)-GC
CO	Reduction Gas Detector (RGD)-GC Nondispersive Infrared (NDIR) DID-GC
CO_2	Methanator on FID-GC DID-GC NDIR
H_2	RGD-GC
Particles	Special counters required for O_2 service: for 0.01 µ or greater, condensation nucleus counter for 0.1 µ or greater, laser counter

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F31-0698
GUIDE FOR BULK CHEMICAL DISTRIBUTION SYSTEMS

1 Purpose

1.1 This guide defines components of Bulk Chemical Distribution Systems and sets forth Basic Design Elements and optional design features common to BCD Systems.

2 Scope

2.1 This guide applies to BCD Systems used in semiconductor manufacturing facilities for supplying liquid chemicals to wafer cleaning and other manufacturing processes.

3 Limitations

3.1 This guide is not intended to be applicable to every possible use and type of chemical dispensing system but only to those systems that originate with sources of single lots of liquid materials of 55 gallons or more, and which operate in a way that splits a single liquid stream into multiple streams. This guide excludes slurry systems, small liquid chemical dispensing systems, chemical waste systems, and many other types of systems that dispense fluids.

3.2 This guide excludes construction protocols for BCD Systems, such as clean manufacturing practices, integrity of fabrication, and prequalification of materials.

3.3 This guide does not intend to cover all the important safety considerations which relate to Bulk Chemical Distribution Systems.

3.4 References to "containers" in this document are not limited to "Bulk Containers" as defined in the Code of Federal Regulations (CFR) Section 49 or Department of Transportation (DOT) Regulations.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *DOT*[1]

Department of Transportation

4.3 *Federal Regulations*[2]

49 CFR — Title 49 of the Code of Federal Regulations

5 Terminology

5.1 *Acronyms*

5.1.1 *CDM* — Chemical Dispensing Module

5.1.2 *CDU* — Chemical Dispensing Unit

5.1.3 *DIW* — Deionized Water

5.1.4 *MDU* — Modular Dispensing Unit

5.2 *Definitions*

5.2.1 *blending* — Combination of two or more chemicals to create a mixture which contains a desired ratio of constituents.

5.2.2 *chemical dispense system* — The module used for filtering and for dispensing chemical into the distribution piping network which may be referred to by a number of manufacturer's specific designations: CDM, CDU, and MDU.

5.2.3 *chemical reprocessing unit* — A subsystem which purifies or recycles a chemical.

5.2.4 *chemical transfer* — The technique used to move chemical between different points in the distribution system.

5.2.4.1 *pressurization* — The use of high purity nitrogen or other appropriate gas to displace liquid through the distribution system.

5.2.4.2 *pumping* — A mechanical or pneumatically operated technique used to create hydraulic force in the system.

5.2.4.3 *hybrid system* — A combination of pressurization and pumping techniques used to transfer chemical.

5.2.5 *day tank* — A vessel that stores that amount of chemical which may be consumed within one or more days. This holding vessel usually stores prefiltered

1 Department of Transportation, 400 Seventh Street, SW, Washington, D.C. 20590

2 United States Government Printing Office, Washington, D.C. 20402

chemical until it is transferred to the manufacturing process.

5.2.6 *decontamination* — Cleaning up of a BCD System, or any subsystems thereof, by introducing chemical solutions into the piping systems. This procedure occurs during qualification and prior to commissioning the system.

5.2.7 *dilution* — Combination of a concentrated chemical and DIW to create a lower concentration of the aqueous chemical.

5.2.8 *on-site gas-to-chemical generation* — The contacting of a liquid and gas phase to create a stable liquid solution. The chemical is generated on-site in a form suitable for distribution through a dispense system.

5.2.9 *pickling* — Conditioning of the system by filling it with the actual chemical or another chemical for which the system is designed. This chemical will stay in the system for a specified period of time. The purpose of this conditioning is to leach out impurities prior to actually using any chemical in the manufacturing process.

5.2.10 *polishing* — The process of flowing chemical through a filter one or more times to reduce the particulate levels of the chemical.

5.2.11 *primary containment* — Tubing, piping, or components whose wetted surface is directly in contact with the chemical. These components are generally made from fluoropolymer materials such as Perfluoroalkoxy (PFA).

5.2.12 *secondary containment* — Tubing or piping which contains the primary piping or tubing. The purpose of this configuration is to control leaks and to protect against spills. Secondary containment of solvent systems generally uses stainless steel material, and acid or base systems generally use Schedule 40 Polyvinylchloride (PVC) material boxes such as VMB. This may also be used as secondary containment.

5.2.13 *stabilized filtration* — A design feature that provides for the continuous flow of chemical through filters to minimize shocking and pulsating of the filters.

5.2.14 *surge suppression* — Use of a device or in-line chamber that minimizes flow pulsations caused by a pump. This may also be referred to as pulsation dampener.

5.2.15 *valve manifold box (VMB)* — A chemical-resistant enclosure which houses manual and/or pnuematically actuated valves, tees, and fittings.

5.2.16 *vessel* — A vessel fabricated from or containing an inner lining of chemically inert and resistant materials which is specifically designed to maintain the purity level of the chemical for a long period of time. All containers are fabricated from or at least contain an inner lining of chemically inert and resistant materials and are specifically designed to maintain the purity level of the chemical for long periods of time. The larger containers are generally designed in conformance to Department of Transportation Regulations (DOT) and may be transported by ground. These containers have fittings which are compatible to this purpose so that they may be hooked up to the BCD Systems directly. Such containers include:

5.2.16.1 *drum* — A container for storing chemicals, generally with a cylindrical shape and not more than 55 gallons or 200 liters in size.

5.2.16.2 *tote* — A container for storing chemicals, generally 110, 220, or 330 gallons in size and requiring an outer shell to provide structural support to the vessel.

5.2.16.3 *ISO container* — A container for storing chemicals, usually large in size, able to be transported directly, and designed in compliance with criteria from the International Standards Organization.

5.2.17 *wetted surface* — Any surface which comes into contact with the chemical.

6 General Requirements

6.1 *Materials* — Components of the BCD Systems must be appropriate to the application and conform to electrical, mechanical, and chemical requirements as defined by the physical installation environment, local and national code interpretations, process requirements, and delivery specifications.

6.2 *System Installation* — The Bulk Chemical Distribution System is installed according to a protocol which ensures mechanical integrity, leakproof operation, and minimal contamination to any liquids being distributed throughout the system.

6.2.1 System Installation procedures include a rinsedown protocol which may include any of the following: (1) a flushing procedure with DIW; (2) a sanitization step using hydrogen peroxide; (3) a drying step using nitrogen gas; and (4) a “pickling” process using the actual chemical, or a less concentrated form of the chemical. For solvent systems, the rinse-down chemicals introduced are generally the same as the solvent that is designated to be used in the system, whereas for acid systems, the rinse down solutions may include DIW, ozonated water, or a dilute form of hydrogen peroxide.

6.2.2 The protocol for System Installation and start-up follows a predefined sequence of events which incorporates all of the physical activities and testing parameters and establishes check points for approvals at each stage.

6.3 *Acceptance Tests* — Acceptance tests are conducted on each subsystem or system produced. They are the basis for acceptance or rejection by the purchaser.

6.3.1 Acceptance testing may include performance demonstrations, demonstration of reliability criteria, and achievement of purity standards. Safety considerations are addressed elsewhere.

6.4 *Qualification Testing* — Qualification testing is performed on the liquid chemicals being transported through each chemical piping subsystem.

6.4.1 Qualification testing may include tests for trace metals, anions, particles, and total organic carbon. Assay analysis is recommended for blending or dilution operations.

6.5 *Chemical Specifications* — Particulate BCD Systems are specified as to the level of impurities at the point of use as compared to the quality of the incoming chemical. Impurities in the chemical are generally specified in terms of particles per ml; metallic impurities are specified for each element and for total adders; and organic impurities are specified for total added.

7 Basic Design Elements

7.1 *General* — Each Bulk Chemical Distribution System contains certain basic components and a variety of design options to meet particular customer and facility needs. A simple example system is shown in Figure 1.

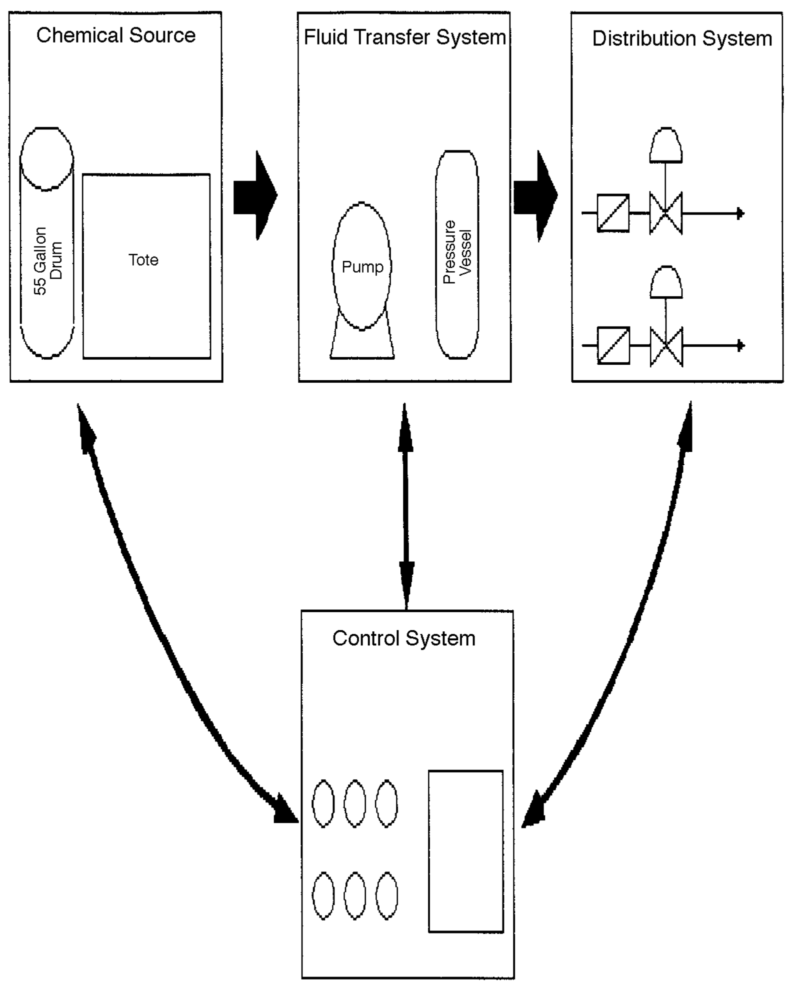

Figure 1
Schematic of Basic Bulk Chemical Distribution System

7.2 *Source* — The source of all fluids for incoming Bulk Chemical Distribution Systems is a container suitable for holding reactive chemicals in a size 55 gallons or greater, which may include drums, totes, vessels, or ISO containers.

7.3 *Fluid Transfer* — Fluids in the Bulk Chemical Distribution Systems are transported through pipes using either a pumping system, a pressure differential system, or some combination of the two types of basic systems. All fluids are transported in secondary containment piping systems for safety reasons.

7.4 *Distribution* — The transfer is made from the source by means of certain types of mechanisms, usually through one or more valve manifold boxes, that direct the fluid to a point of use, to subordinate levels of distribution, and/or to a day tank.

7.5 *Control Systems* — Manual and/or automated mechanical, pneumatic, hydraulic, optical, and electronic systems control the movement of the liquids. This includes the volume, flow rate, pressure, start-up, and shut-off.

8 Optional Design Features

8.1 *Polishing* — BCD Systems may be designed with the possibility of chemical recirculation (1) from the incoming source and back, to polish the incoming chemical; (2) from the day tank and back for further polishing or timed recirculation if activity is limited; and (3) fabwide in continuous recirculation.

8.2 *Filtration* — Chemicals in the system may be recirculated through filters placed on-line in the system. The relevant design issues include types of filters, efficiency, useful lifetime, qualification, filter bleed, removal, and replacement.

8.3 *Day Tank* — The vessel that generally stores a limited amount of chemical volume generally equivalent to that used in about one day of operation. This holding vessel usually stores prefiltered chemical before it is transferred to the manufacturing process.

8.4 *Blending* — Certain chemicals in distribution are blended together for use in the semiconductor manufacturing process. For example, Buffered Oxide Etchant is a blend of Hydrofluoric Acid and Ammonium Fluoride and may be sourced as two separate chemicals and blended together in the correct concentrations within the BCD Systems.

8.5 *Dilution* — Certain chemicals used in the semiconductor manufacturing process require various concentrations, depending on the process used at a particular point in the system. For example, 49% Hydrofluoric Acid is brought in as the source chemical and then mixed with DIW in a blend unit to achieve various concentrations of 10:1, 100:1, etc., depending on the requirements of the manufacturing process.

8.6 *Automated Control Systems* — Electronic systems may be programmed to control system parameters such as volume, pressure, fill rate, flow, drain times, maintenance diagnostics, purge cycles, recirculation, and bypass.

8.7 *Sampling Ports* — Sampling ports may be incorporated into the system to facilitate chemical sampling for qualification and monitoring programs.

8.8 *On-Site Chemical Generation* — Liquid chemicals, such as Ammonium Hydroxide, may be generated on-site at the required concentration from a clean Ammonia gas source and DIW to the required concentration. Generally, this activity is done in a location apart from the dispense room. The resulting chemical is used as a source for the distribution system.

8.9 *Reprocessing* — Integrated with the general chemical distribution system may be a chemical reprocessing unit which purifies or recycles a chemical such as sulfuric acid, isopropanol, or hydrofluoric acid. Such a system enables the chemical to reenter the system as a clean source of material for manufacturing processing.

8.10 *Stabilized Filtration* — Some systems include a design feature that provides for the continuous flow of chemical over filters to minimize shocking and pulsating of the filters.

8.11 *Surge Suppression* — Some systems include a device or in-line chamber that minimizes hydraulic forces caused by a pump. This option may also be referred to as pulsation dampener.

9 Monitoring and Maintenance of Systems

9.1 *General Considerations* — Bulk Chemical Distribution Systems may require a significant level of maintenance and monitoring to determine that specifications and performance are initially and continually met.

9.2 *Functional Management System* — The entire dispense system can be monitored by means of PC/PLC/ or any hybrid system, recording events as they occur and alerting operators as necessary to take corrective action. Monitoring systems may include a variety of operational parameters:

9.2.1 on-line real-time monitoring of all chemical dispense units

9.2.2 status of components and subsystems

9.2.3 events logging

9.2.4 data management

9.2.5 reliability parameters, including lead detection

9.2.6 chemical usage

9.2.7 display of dispense systems

9.2.8 communication gateway to the factory alarm system

9.2.9 on-line documentation

9.2.10 predictive maintenance planning

9.2.11 chemical interruptions to the fab by location, indicating location of fault.

9.3 *Maintenance* — Maintenance of the BCD Systems includes routine and preventative maintenance of pumps, filters, valves, and other components.

9.4 *Monitoring Programs* — Each BCD System should be monitored to determine if liquid chemicals delivered to the tools for use in the manufacturing process continually meet specifications and are within initial and ongoing established process control limits.

9.4.1 Monitoring programs may include periodic testing of the liquid chemicals to determine levels of particles, trace metals assay, and other parameters of interest. Certain tests may be done continuously on-line (e.g., particles), and other analytical tests are performed periodically from samples taken at various points in the system.

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SEMI F32-0998
TEST METHOD FOR DETERMINATION OF FLOW COEFFICIENT FOR HIGH PURITY SHUTOFF VALVES

1 Purpose

1.1 This test method describes how to determine two criteria used in selecting valves of appropriate size for gases and liquids.

1.2 Methods and equations are specified and/or referenced to assist in accurate calculation of pressure drops across valves tested by this method.

2 Scope

2.1 This method establishes the testing criteria for determination of two coefficients specified in ANSI/ISA-S75.02:

- Valve flow coefficient (C_v)
- Critical pressure drop ratio factor (x_T)

2.2 This method is to be used with ANSI/ISA-S75.02. This method applies to manual and actuated valves for use in both gas and liquid distribution systems used in semiconductor manufacturing facilities. It is a test method, where existing test methods are referenced and limitations are imposed on test conditions. Specific equations for calculating flow coefficients, choked flow parameters, and pressure drops are referenced to the appropriate ISA section.

3 Limitations

3.1 This method will limit the use and interpretation of ANSI/ISA-S75.02 for use by manufacturers and users of valves designed for the semiconductor industry.

3.2 This method is not intended to be used to determine flow coefficients for valves used in vacuum service.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *ANSI Documents* [1]

ANSI/API 2530 — Part 2: Natural Gas Fluids Measurement - Concentric, Square-Edged Orifice Met

ANSI/ISA-S-75.01 — Flow Equations for Sizing Control Valves

ANSI/ISA-S75.02 — Control Valve Capacity Test Procedure

5 Terminology

5.1 *Acronyms*

5.1.1 ΔP — Pressure drop across valve, kPa (psi).

5.1.2 F_k — Ratio of specific heats factor, where:

$$F_k = \frac{k}{1.40}$$

5.1.3 F_L — Liquid pressure recovery factor

$$F_L = \frac{Q_{\max\, m^3/h}}{0.0865 * C_v * \sqrt{\dfrac{P_{1\,kPa} - 0.96 * P_{v\,kPa}}{S_f}}}$$

$$F_L = \frac{Q_{\max\, gpm}}{1.00 * C_v * \sqrt{\dfrac{P_{1\,psia} - 0.96 * P_{v\,psia}}{S_f}}}$$

5.1.4 *gpm* — Gallons per minute

5.1.5 *k* — Specific heat ratio

5.1.6 P_1 — Absolute pressure at upstream pressure tap, kPa (psi).

5.1.7 P_2 — Absolute pressure at downstream pressure tap, kPa (psi).

5.1.8 P_v — Absolute vapor pressure of liquid at inlet temperature, kPa (psi).

5.1.9 *psia* — Pounds per square inch absolute

5.1.10 *psid* — Pounds per square inch differential

5.1.11 *Q* — Volumetric flow rate

5.1.12 Q_{max} — Maximum flow rate (choked flow conditions) at a given upstream condition.

5.1.13 *scfh* — Standard cubic feet per hour

5.1.14 S_f — Specific gravity of a liquid relative to water.

5.1.15 S_g — Specific gravity of a gas relative to air.

5.1.16 *T* — Absolute temperature of test gas or liquid, °K (°R).

1 American National Standards Institute, 11 West 42nd St., New York, NY 10036, Telephone: 212.642.4900, Fax: 212.398.0023

5.1.17 x — Ratio of pressure drop to absolute inlet pressure, dimensionless, where:

$$x = \frac{\Delta P_{kPa}}{P_{1_{kPa}}} \mid x = \frac{\Delta P_{psid}}{P_{1_{psia}}} \mid$$

5.1.18 x_T — Ratio of pressure drop to absolute inlet pressure ($\Delta p/p_1$) at choked flow condition, dimensionless.

5.1.19 Y — Expansion factor for compressible fluids, where:

$$Y = 1 - \frac{x}{3 \times F_k \times x_T}$$

5.2 *Definitions*

5.2.1 *flow coefficient* C_v — A numeric constant used to characterize the flow capacity of a valve.

5.2.2 *vapor pressure condensation point* — Pressure at which fluid phase changes from liquid to gas, for a given upstream condition.

5.2.3 *vena contracta* — Point in a duct where the diameter of the fluid stream is smaller than the diameter of the duct.

6 Test Fluids

6.1 *Incompressible (Liquid) Fluid* — Water is the standard liquid test fluid.

6.2 *Compressible (Gaseous) Fluid* — Nitrogen is the standard gaseous test fluid. When using Nitrogen, care should be taken to assure that the fluid does not approach the vapor pressure condensation point at the vena contracta.

7 Test Setup

7.1 *Test Valve*

7.1.1 The test valve can be any high purity valve, or a combination of valve with tube connections, fittings connection, or expanders which are normally attached as part of the valve assembly as purchased. It is important to note that the definition of the "test valve" is inclusive of all connections and fittings, as supplied by the manufacturer. This specifically differs from the ISA procedure, whereby a method is provided to differentiate the pressure drop contribution of the attached fittings. It is recognized that flow coefficients may vary slightly depending upon the end connection used. Examples of typical test valves are shown in Figure 1.

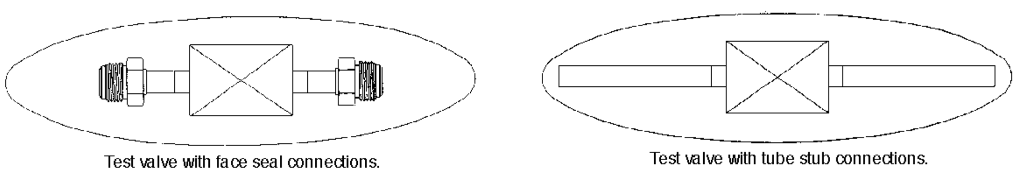

Figure 1
Test Valve with Various Connections

7.2 *Test Section Requirements*

7.2.1 Fixturing of the test valve shall be made in accordance with ANSI/ISA-S75.02, Table 1, where the test valve is the complete valve assembly including connections, as described above. For reference, ANSI/ISA-S75.02 test setup is shown in Figure 2.

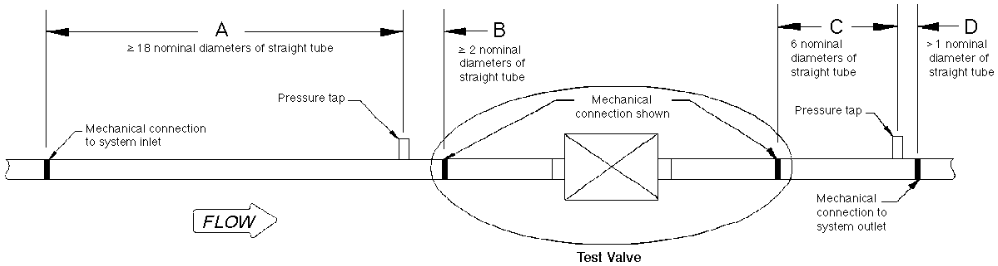

Figure 2
Fixturing Requirements, Standard Test Section

7.2.2 *Tube Connections* — Connections to the test valve are to be the same as would normally be performed by the end user as installed. Tube connections are to be full penetration welded by automatic orbital head, with purge gas.

7.2.3 *Face Seal Connections* — Face seal connectors supplied with the test valve may be either male or female. An appropriate mating connector shall be welded into the inlet and outlet tubing using full penetration orbital head welds, and connected to the valve with standard seals.

7.2.4 *Compression Fitting Connections* — Valves supplied with tube stubs may be connected with compression fittings.

8 Test Procedure

8.1 *Setup* — The test setup shall be as shown in ANSI/ISA-S75.02, Section 3.1. For reference, see Figure 3. The flowmeter may be upstream or downstream of the test valve, and can also be placed downstream of the throttle valve when necessary to vent to atmosphere.

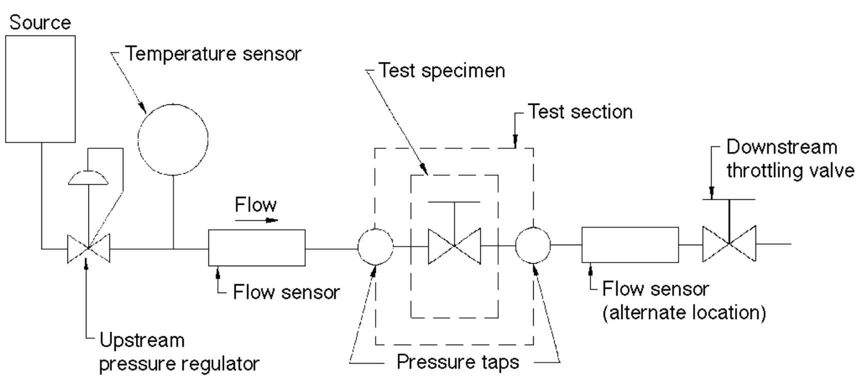

Figure 3
Test Setup

8.1.1 *Pressure Taps* — Pressure taps should be welded into the system per ANSI/ISA-S75.02.

8.1.2 *Pressure Measurement* — Pressure measurement devices can be analog gauge, electronic transducer, or both. They should be calibrated to maintain the minimum accuracy necessary for the governing flow equations.

8.1.3 *Throttle Valve(s)* — A throttle valve shall be positioned downstream. There is no valve style restriction, however they should be sized sufficiently for the required flowrate.

8.1.4 *Flow Measurement* — Depending upon the test media, several types of flow measurement devices may be used. These devices may include: turbine meter, orifice plate, bell prover, mass flow meter, and timed volumetric capture. Flow measurement devices should be calibrated to maintain the minimum accuracy necessary for the governing flow equations. All flow measurements should be normalized to standard conditions per ANSI 2530. Install and calibrate per manufacturer's recommended procedure.

8.1.5 *Temperature Measurement* — Temperature measurement devices should be calibrated to maintain the minimum accuracy necessary for the governing flow equations.

8.2 *Incompressible Fluid*

8.2.1 *Procedure*

8.2.1.1 The test procedure is specified in ANSI/ISA-S75.02, Section 5.1.

8.2.2 *Test Limitations*

8.2.2.1 It is critical that the absolute upstream pressure meets the criteria specified in ANSI/ISA-S75.02, paragraph 5.1.3, as referenced below:

$$P_{1_{kPa}} = \frac{2 \times \Delta P_{kPa}}{F_L^{\,2}} \mid P_{1psia} = \frac{2 \times \Delta P_{psid}}{F_L^{\,2}} \mid$$

Equation 1
Absolute Upstream Pressure

8.2.2.2 The liquid pressure recovery factor, F_L is calculated from the maximum attainable flowrate, Q_{max}. If Q_{max} cannot be experimentally determined, the value of F_L can be estimated. See the referenced section for details.

8.3 *Compressible Fluid*

8.3.1 *Procedure*

8.3.1.1 The test procedure is specified in ANSI/ISA-S75.02, paragraph 7.1.

8.3.2 *Test Limitations*

8.3.2.1 If possible, at least 3 data points should be taken at flowrates where the fluid approaches incompressible behavior. To attain these conditions, the pressure drop ratio, x, should be less than or equal to 0.02. Additional data points should be taken at increasing flowrates up to the maximum possible for the system.

9 Coefficients Calculation

9.1 *Flow Coefficient, C_v*

9.1.1 The flow coefficient, C_v, can be calculated using both incompressible and compressible fluids. For incompressible fluids, ISA provides a relatively simple method for determining C_v. For compressible fluids, the ISA test method for calculating C_v requires the determination of the choked flow pressure drop ratio, x_T,, and ultimately the expansion factor, Y, which characterizes the valve geometry and fluid properties at sonic velocities in the vena contracta. It has been determined through considerable testing that the expansion factor is critical in calculating actual pressure drops across a valve when flow rates cause the fluid density to change due to pressure and velocity changes.

9.2 *Pressure Drop Ratio Factor, x_T*

9.2.1 The ISA test method requires the experimental determination of the flow coefficient C_v and a second coefficient x_T, the pressure drop ratio factor.

9.2.2 x_T is equal to the critical pressure ratio of the ISA flow equation, and is close but not necessarily identical to the experimentally observed pressure ratio at choked flow. x_T is chosen to correlate the experimentally observed choked flow. The ISA equation will then predict choking at a pressure drop ratio close to, but not identical with, the experimentally observed value.

9.2.3 There are two methods to determine the pressure drop ratio factor. The procedure of ANSI/ISA-S75.02, Section 7.2 requires that C_v be determined at values of x less than 0.02, and that choking actually be achieved to determine x_T. The alternate procedure of paragraph 7.3 does not actually require choked flow and uses all the data points to determine C_v, not just a few points at a small value of x.

9.2.4 In practice, valves used in the semiconductor manufacturing facility, when connected as described above, may not be able to achieve choked flow across the pressure taps provided by this procedure. This will happen when choked flow occurs first in some other part of the test setup or connections. However, the alternative test procedure of ANSI/ISA-S75.02, Section 7.3 will give the correct values of C_v and x_T in this case.

9.2.5 The ISA alternative method determines the pressure drop ratio factor by measuring flowrate vs.

pressure ratio, and analyzes the data to compute the choked flow pressure drop ratio, x_T. This method has been found, through exhaustive testing, to be a very accurate and reliable method to determine the expansion factor, without having to achieve choked flow in the test valve itself.

10 Pressure Drop Calculation

10.1 The determination of both flow coefficient and expansion factor are critical in calculating the pressure drop across a valve flowing compressible fluid. Use of the flow coefficient C_v only, will yield a pressure drop which is lower than the actual value.

10.1.1 *Incompressible Flow*

10.1.1.1 To calculate pressure drop across a valve flowing an incompressible media, only the C_v coefficient must be provided by the valve manufacturer. The following equation has been derived from ANSI/ISA-S75.01, Section 4.1, and should be used for pressure drop computations:

$$\Delta P_{kPa} = 0.0865 * \left(\frac{Q_{m^3/hr}}{C_v} \right)^2 \times S_f$$

$$\left(\Delta P_{psid} = \left(\frac{Q_{gpm}}{C_v} \right)^2 \times S_f \right)$$

Equation 2
Pressure Drop for Incompressible Flow

10.1.2 *Compressible Flow*

10.1.2.1 To calculate pressure drop across a valve flowing a compressible media, both C_v and x_T coefficients may be used to determine more accurately the pressure drop. Contact the valve manufacturer for values of C_V and x_T coefficients. Equation 3 has been derived from ANSI/ISA-S75.01, Section 6.1, and should be used for pressure drop computations. Equation 4 is a close approximation of Equation 3 that computes pressure drop directly.

$$\Delta P_{kPa} = \left(\frac{Q_{m^3/hr}}{4.17 \times C_v \times Y \times P_{1kPa}} \right)^2 \times S_g \times T_{\circ K} \times P_{1_{KPa}}$$

$$\left(\Delta P_{psid} = \left(\frac{Q_{scfh}}{1360 \times C_v \times Y \times P_{1_{psia}}} \right)^2 \times S_g \times T_{\circ R} \times P_{1_{psia}} \right)$$

Equation 3
Pressure Drop for Compressible Flow – ISA Iterative Solution

$$\Delta P = \frac{P_{1_{kPa}} \times x_T}{1.125} \left[1 - \sqrt{1 - \frac{1.125}{x_T} \left(\frac{S_g \times Q_{m^3/hr}}{3905.6 \times C_v \times P_{1_{kPa}}} \sqrt{\frac{T_{\circ K}}{S_g}} \right)^2} \right]$$

$$\left(\Delta P = \frac{P_{1_{psia}} \times x_T}{1.125} \left[1 - \sqrt{1 - \frac{1.125}{x_T} \left(\frac{S_g \times Q_{scfm}}{16.04 \times C_v \times P_{1_{psia}}} \sqrt{\frac{T_{\circ R}}{S_g}} \right)^2} \right] \right)$$

Equation 4
Pressure Drop for Compressible Flow – Non-Iterative Solution

NOTE: The numerical value of x used in these equations must not exceed the choking limit (x_T) regardless of the actual value of x.

11 Related Documents

11.1 *ISO Document*[2]

ISO 6358 — Pneumatic fluid power — Components using compressible fluids — Determination of flow-rate characteristics

11.2 *SAE Documents*[3]

ARP 24B — Determination of Hydraulic Pressure Drop

ARP 868 — Pressure Drop Test for Fuel System Components

2 International Organization for Standardization, Casa Posatale 56, CH-1211, Geneve 20 , Switzerland

3 Society of Automotive Engineers, World Headquarters, 400 Commonwealth Dr., Warrendale, PA 15096-0001, Telephone: 724.776.4841, Fax: 724.776.5760

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SEMI F33-0998
METHOD FOR CALIBRATION OF ATMOSPHERIC PRESSURE IONIZATION MASS SPECTROMETER (APIMS)

1 Purpose

1.1 This test method may provide guidelines for the calibration of the APIMS for measurement of impurities in nitrogen, argon, helium and hydrogen. APIMS is currently the technique of choice for measurements of low level impurities in gas distribution systems and components because it is essentially the only commercially available method capable of ppt impurity analysis and it has a superior response time. This method may provide guidelines for application of other techniques with similar detection limits and response time to APIMS which are not commercially available at this time.

2 Scope

2.1 This method applies to the analyte calibration of the APIMS for a target impurity range of 100 ppt to as high as 100 ppb impurity range. The actual calibration range should bracket the impurity measurement range of interest, dependent upon the measurement to be conducted. Anything else is outside the range of the calibration.

3 Limitations

3.1 The actual range of calibration will depend upon the type of APIMS used. Counting detection electronics will saturate in the 200,000 CPS to 1,000,000 CPS range, depending upon the make and model. Counting detection will have to use different ions in different concentration regions, depending upon the impurity. The actual calibration procedure will be different for APIMS using analog detection versus counting detection. Interference between impurities can cause limitation in measurements in the presence of multiple impurity species.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI C9.1 — Guide for Analysis of Uncertainties in Gravimetrically Prepared Gas Mixtures

SEMI C15 — Test Method for ppm and ppb Humidity Standards

5 Terminology

5.1 *Acronyms*

5.1.1 *APIMS* — Atmospheric Pressure Ionization Mass Spectrometer

5.1.2 *CPS* — Counts per second

5.1.3 *m/z* — *m* in atomic mass units and *z* in elementary charge units

5.1.4 *NIST* — National Institute of Standards and Technology

5.1.5 *ppb* — Molar parts per billion (nmole/mole). The same as ppbv.

5.1.6 *ppm* — Molar parts per million (µmole/mole). The same as ppmv.

5.1.7 *ppt* — Molar parts per trillion (pimole/mole). The same as pptv.

5.1.8 R^2 — The statistic described by the ratio of the sum of squares of the regression divided by the total sum of the squares.

5.2 *Definitions*

5.2.1 *zero gas* — Nitrogen, argon, helium or hydrogen with an estimated level an order of magnitude, or more, lower than the lowest calibration point for each impurity of interest.

6 Summary of Method

6.1 The calibration of the APIMS is conducted by adding known concentrations of impurities to a zero gas and measuring the corresponding ion intensities. A calibration response factor can be determined by regression analysis.

7 Interferences

7.1 It is essential to confirm that the mass chosen is indeed representative of the species of interest and that other commonly present impurities do not contribute at the same mass. For example: the intensity of the peak at m/z = 29 correlates with the concentration of H_2 in N_2, because of the N_2H^+ formation. However, spurious signal at this peak can arise in two different ways:

(i) Contributions of other ions of the same mass, such as $N^{14}N^{15+}$ or $C_2H_5^+$.

(ii) Contributions of the same ion from different parent species, i.e., N_2H^+ due to recombination of matrix gas nitrogen with fragments of H_2O, CH_4, etc. Before using m/z = 29 as a measure of H_2 in N_2, interference such as these must be understood. This also may apply to other ions.

7.2 High impurity levels can cause clustering with, or quenching of, the other impurity ions and affect the sensitivity of the APIMS for those impurities. This is especially true for impurity levels of 10 ppb and above.

8 Apparatus

8.1 *APIMS* — The APIMS used for impurity detection can be of any type.

8.2 *Impurity Standard* — Any device (either standard cylinder or permeation tube based or of any other type) that can reliably deliver impurity concentrations usually in the range of 100 ppb to 10 ppm with an accuracy of ± 5%. The standards should be traceable to an applicable national standard, such as NIST.

8.3 *Dynamic Dilution System* — A dilution system that can dilute the output gas of the impurity standard with a zero gas to produce a gas with impurity concentrations in the range of interest.

9 Reagents and Materials

9.1 Zero gas

9.2 Impurity standard

10 Safety Precautions

10.1 This method applies to calibration and measurement of impurities in nitrogen, argon, helium and hydrogen. This method does not address the additional safety precautions for APIMS calibration and impurity measurement in hydrogen gas.

11 Test Specimen

11.1 Not applicable.

12 Preparation of Apparatus

12.1 The impurity standard and zero gas should be connected to the dynamic dilution system, which is in turn connected to the inlet of the APIMS. The entire dilution system should be purged until all impurities have stabilized at a constant dilution system flow, for all components in the dilution system. The relative standard deviation for each analyte should be less than 10% for the past 12 hours before the calibration. Constant pressure and flow should be maintained to the APIMS ionization region at all time.

13 Calibration and Standardization

13.1 *Definition of an Impurity Standard* — An impurity “standard” is defined to be any device capable of delivering a flow of known impurity level gas at a controlled pressure. (See Section 8.2.)

13.2 *Examples of Standards* — Some examples of impurity standards and the principles upon which they are based are as follows:

13.2.1 *Cylinder Standards* — The “standard” will include a regulator specified for use with the cylinder. The impurity concentration can be calculated based on that added to the cylinder in preparation. A minimum use pressure must be specified.

13.2.2 Permeation and effusion tube standards. These must include purification means and some means of regulating the outlet pressure. The impurity delivery rate can be calculated based on the weight loss of the tube as a function of time.

13.2.3 Moisture standard methods based on saturation of gas with water vapor at a fixed temperature and pressure. The moisture concentration in the gas may then be calculated from a knowledge of the saturation vapor pressure of water over a plane of the pure phase of ice at the saturation temperature and of the interaction virial coefficients of the gas-vapor mixture. The two-pressure and two temperature methods are refinements of this approach requiring additional chambers whose temperature and pressure must be known.

13.3 *Dilution of Standards* — For all impurity generation methods, lower concentrations can be generated by dynamic dilution, i.e., by combining a known flow of the standard gas with a known flow of zero gas. A diluted standard is acceptable provided:

13.3.1 The zero gas should have an impurity level at least an order of magnitude below the stated level of the analysis (to be verified using the same flow path as during the subsequent analysis, and at the lowest flow rate actually used in the calibration).

13.3.2 The absolute accuracy of the dilution system components are verified by comparison with a reliable flow standard. The frequency of verification must take into account the transport of the instrument and other changes that will affect the dilution system.

13.3.3 The linearity of the dilution system can be demonstrated over the entire range of operation. This last criterion is particularly important whenever some portion of the combined flow is discarded, as mixing problems can easily arise at large dilution factors.

13.4 *Mass Calibration* — The mass scale of the mass spectrometer should be calibrated according to the manufacturer’s instructions over the mass range of interest.

13.4.1 The validity of the mass selected for each impurity must be confirmed (i) by demonstrating that the intensity at the mass increases monotomically with added concentration of the impurity species of interest and (ii) that other usually present impurity species do not make significant contributions to the intensity at that mass. Tables 1–4 list the typical masses for various species in argon, nitrogen, hydrogen and helium.

Table 1 Common Masses in Argon Bulk Gas

m/z	*Ions*	*Source*
14	N^+	Analyte
15	CH_3^+	Analyte
16	CH_4^+	Analyte
17	OH^+	Analyte
18	H_2O^+	Analyte
19	H_3O^+	Analyte
20	Ne^+	Bulk Gas Impurity
28	CO^+	Analyte
32	O_2^+	Analyte
36	Ar^+	Bulk Gas Isotope
37	$(H_2O)_2H^+$	Analyte
38	Ar^+	Bulk Gas Isotope
40	Ar^+	Bulk Gas
41	ArH^+	Analyte
44	CO_2^+	Analyte
68	$ArCO^+$	Analyte
68	ArN_2^+	Analyte
76	Ar_2^+	Bulk Gas Isotope
78	Ar_2^+	Bulk Gas Isotope
80	Ar_2^+	Bulk Gas

NOTE: In APIMS, the same ion may be formed even though different parent molecules are introduced into the ionization region. Thus, it is necessary to be sure that the chosen m/z represents the ion of interest and that the ion of interest originates from the molecule of interest.

Table 2 Common Masses in Nitrogen Bulk Gas

m/z	*Ions*	*Source*
12	C^+	Analyte
14	N^+	Bulk Gas
15	CH_3^+	Analyte
16	CH_4^+	Analyte
17	OH^+	Analyte
18	H_2O^+	Analyte
19	H_3O^+	Analyte
28	N_2^+	Bulk Gas
28	CO^+	Analyte
29	N_2H^+	Analyte
29	COH^+	Analyte
29	$C_2H_5^+$	Analyte
29	N_2^+	Bulk Gas Isotope
32	O_2^+	Analyte
37	$(H_2O)_2H^+$	Analyte
42	N_3^+	Bulk Gas
43	N_3H^+	Analyte
44	CO_2^+	Analyte
44	N_2O^+	Analyte
46	$N_2H_2O^+$	Analyte
55	$(H_2O)_3H^+$	Analyte
56	N_4^+	Bulk Gas
70	N_5^+	Bulk Gas

NOTE: In APIMS, the same ion may be formed even though different parent molecules are introduced into the ionization region. Thus, it is necessary to be sure that the chosen m/z represents the ion of interest and that the ion of interest originates from the molecule of interest.

Table 3 Common Masses in Hydrogen Bulk Gas

m/z	*Ions*	*Source*
2	H_2^+	Bulk Gas
17	CH_5^+	Analyte
18	H_2O^+	Analyte
19	H_3O^+	Analyte
29	N_2H^+	Analyte
29	COH^+	Analyte
33	O_2H^+	Analyte
34	$O_2H_2^+$	Analyte
35	$O_2H_3^+$	Analyte
37	$(H_2O)_2H^+$	Analyte
45	CO_2H^+	Analyte

NOTE: In APIMS, the same ion may be formed even though different parent molecules are introduced into the ionization region. Thus, it is necessary to be sure that the chosen m/z represents the ion of interest and that the ion of interest originates from the molecule of interest.

Table 4 Common Masses in Helium Bulk Gas

m/z	*Ions*	*Source*
4	He^+	Bulk Gas
5	HeH^+	Analyte
8	He_2^+	Bulk Gas
9	He_2H^+	Analyte
12	He_3^+	Bulk Gas
12	C^+	Analyte
14	N^+	Analyte
15	CH_3^+	Analyte
16	He_4^+	Bulk Gas
16	CH_4^+	Analyte
18	H_2O^+	Analyte
20	Ne^+	Bulk Gas Isotope
22	HeH_2O^+	Analyte
24	$NeHe^+$	Bulk Gas Impurity
26	$He_2H_2O^+$	Analyte
28	N_2^+	Analyte
28	CO^+	Analyte
28	He_7^+	Bulk Gas
32	O_2^+	Analyte
40	Ar^+	Bulk Gas Impurity
44	CO_2^+	Analyte
44	$ArHe^+$	Bulk Gas Impurity

NOTE: In APIMS, the same ion may be formed even though different parent molecules are introduced into the ionization region. Thus, it is necessary to be sure that the chosen m/z represents the ion of interest and that the ion of interest originates from the molecule of interest.

14 Procedure

14.1 Zero gas should be passed through the dilution system and the APIMS. Based on prior calibrations, the system should be below 100 ppt, or at least an order of magnitude lower than the lowest calibration point, for the impurities to be calibrated.

14.2 Prior to beginning the calibration, record all relevant parameters, such as discharge voltage, lens voltages, ionization chamber pressure and/or flow, gas type, etc.

14.3 The user should use the zero gas only, plus a minimum of 5 challenge concentrations, with a minimum of 5 data points, with the blended data points spanning the range of interest of impurity measurement, excluding the zero point, while maintaining constant flow to the APIMS. Allow each challenge concentration to stabilize for at least 15 minutes, and the signal variation should be less than 3% before taking data points at that concentration. Record the relevant ion intensities as a function of time, for each stabilized concentration.

14.4 Once the linearity of the calibration has been established, a single point calibration check is permitted, as long as the accuracy of the dilution system is confirmed.

15 Calculations or Interpretation of Results

15.1 Perform a regression analysis for the individual ion intensities against the impurity concentration. Be sure to use only ion intensities below the saturation region of your APIMS ion counting electronics, if using counting detection. (Ask the manufacturer for the saturation region of the units counting electronics.) The R^2 from the fit of all the regression coefficients should be 0.98 or above. If this is not the case, the calibration will have to be repeated as described in the previous section.

16 Reporting Results

16.1 As a minimum, the calibration will include the following information for each impurity:

$$y = c_0 + c_1 * x \quad (1)$$

where,

y is the ion intensity, c_0 is ion intensity background, c_1 is the linear response factor, and x is the impurity level.

16.2 As an option, a quadratic regression may be reported for the calibration, and will include the following information for each impurity:

$$y = c_0 + c_1 * x + c_2 * x^2 \quad (2)$$

where,

y is the ion intensity, c_0 is ion intensity background, c_1 is the first order response factor, c_2 is the second order response factor and x is the impurity level.

The c_0/c_1 ratio or negative x - intercept is useful to define the background concentration of each particular ion. All regression coefficients should be reported.

17 Precision and Accuracy

17.1 This method does not explicitly consider the estimation of the accuracy of the impurity standard in detail, because such a calculation can be made by applying procedures described elsewhere. The precision and accuracy required in validation will vary with the proposed application and may be left to the discretion of the user of the method. If an accuracy statement is given, then a propagation of error calculation must be provided to estimate the accuracy of the validation.

SEMI F34-0998
GUIDE FOR LIQUID CHEMICAL PIPE LABELING

1 Purpose

1.1 This document establishes a recommended scheme for labeling liquid process chemical piping systems used in semiconductor manufacturing facilities and equipment.

1.2 consistent labeling system facilitates rapid identification of piping contents and avoids confusion within the industry by eliminating the need for each company or locality to develop their own guides.

2 Scope

2.1 This guide applies to components typically found in a liquid process chemical piping system for semiconductor manufacturing processes. The following list of included components is not exhaustive:

- Piping
- Valves
- Filters
- Regulators
- Tubing

3 Limitations

3.1 This guide does not replace or supersede any labeling or identification requirements established by local, state, or national authorities. Local laws and regulations should be reviewed to ensure compliance.

3.2 This guide does not apply to containers regulated by the United States Department of Transportation (DOT), International Air Transport Association (IATA) or other regulatory bodies.

3.3 This guide was prepared to address piping systems conveying liquid process chemicals located within semiconductor facilities. See Sections 6.6 and 6.11 for application inside equipment.

4 Referenced Documents

NOTE: All documents cited should be the latest published versions.

4.1 *ANSI Document*[1]

ANSI/ASME A13.1 — Scheme for the Identification of Piping Systems

5 Terminology

5.1 *liquid chemical distribution system* — The collection of components and subsystems used to control and deliver liquid process chemicals from a source location to a point of use in a semiconductor manufacturing facility.

6 Recommendations

6.1 Piping system labels and identification, should be designed, and implemented in accordance with the following recommendations.

6.2 The following color schemes should be used to identify all liquid process chemical piping systems. When a chemical has characteristics of more than one category, the color scheme should be determined by the most significant health or safety hazard of the chemical.

6.3 Background colors may be applied to the piping by using pigments, paints, or other means acceptable to the owner; or may be applied as the background color for labels or tags used to identify the contents of the piping system.

6.4 Primary label information consists of the name of the material contained in the piping system; spelled out in the predominant language of the country or region where the piping system is used. Additional languages may be used to supplement the primary language.

1 American National Standards Institute, 11 West 42nd Street, 13th floor, New York, NY 10036, USA, Telephone:+ 1.212.642.4900, Telefax:+ 1.212.398.0023, E-mail: info@ansi.org, WWW: http://www.ansi.org/

Table 1 Piping and Label Color Codes

Chemical Category	*Background Color*	*Text Color*
Highly Toxic, Poisonous	Black	White
Flammable, Combustible, and Pyrophoric	Red	White
Acidic	Orange	Black
Basic (Caustic)	Magenta	White
Oxidizer	Yellow	Black
Non-Toxic, Non-Flammable,Low to Moderate Physical Hazard	Green	White

6.5 Additional information such as the chemical category, chemical formula, acronyms, hazard ratings, or other information may be added, provided that it does not interfere with the primary information required. A separate label may be used for the additional information.

6.6 The color field label length and lettering sizes shown in Table 2 should be used for all diameters of pipe and tubing. For pipe diameters smaller than 12.7 mm (0.5 inch), the label should be large enough to wrap at least half way around the pipe, and not obstruct the text. If labeling inside equipment, the size of the labels may be adjusted, provided they remain easily seen and readable. Consideration should be given to using tags instead of labels.

NOTE: Labeling sizes for piping 19 mm (0.75 inch) or larger in outside diameter were taken directly from ANSI A13.1. Smaller sizes were developed for this guide.

6.7 The height of the label should be at least two times (2×) the height of the text, with the text centered in the label. The label should allow a length of background color on each end of the text at least one half pipe diameter in length but not less than 12.7 mm (0.5 inch).

6.8 The orientation of text on the label should conform to local customs, conventions, or practices.

6.9 Directional flow arrows should be applied to all piping systems indicating the direction of material flow within the system. The arrow(s) should be included as part of the primary label but may be applied separately within close proximity to the primary label (e.g., less than 5 cm (2 inches) for pipe diameters up to 5 cm (2 inches); less than 15 cm for larger pipe diameters).

6.10 Labels should be applied to the piping system at the following minimum locations:

- On both sides of a barrier penetration (i.e., walls, floors, ceilings, equipment enclosures, etc.). The labels should be applied within 1 meter (3.3 feet) or as close as practical to the barrier.
- As close as practical to all changes in direction where the length of run in the new direction is 1 meter (3.3 feet) or greater. Where several directional changes are made within a short length of run, labels need not be applied at every change in direction, but should be applied at sufficient intervals to readily identify the piping.
- On long runs, the labels should be applied at intervals not exceeding 6 meters (20 feet). Shorter intervals should be used for small diameter pipe and where several pipes are run in close proximity.
- Where several pipes are run parallel to each other, the labeling for all pipes should be in line with each other (i.e., should not be staggered).
- A sufficient number of labels should be applied at each location to ensure that they can be readily seen and read from all viewing or approach direction(s).
- Each side of a “T” connection should be labeled within 1 meter (3.3 feet) of the “T”.

Table 2 Recommended Label and Text Sizes for Various Piping Diameters

Outside Diameter of Pipe or Covering		*Minimum Length of Label*		*Minimum Height of Letters*	
Millimeters	*Inches*	*Millimeters*	*Inches*	*Millimeters*	*Inches*
Less than 13	Less than 0.5	51	2	3	0.125
13–19	0.5–0.75	102	4	6	0.25
19–38	0.75–1.5	203	8	13	0.5
38–64	1.5–2.5	203	8	19	0.75
64–203	2.5–8	305	12	32	1.25
203–254	8–10	610	24	64	2.5
Over 254	Over 10	813	32	89	3.5

6.11 Where it is impractical to attach markings or labels directly to the pipe, a tag may be used. The tag should be durable for the environment in which it is used and should be securely attached to the piping system such that it cannot be easily removed or relocated from its installed position. The tag or tags should contain the same information as defined for labels in Sections 6.4 and 6.5. Standard color-coding for tags should be the same as defined for labels in Table 1. Tags should be installed at the same locations as required for other identification methods defined in Section 6.10.

7 Related Documents

7.1 *ANSI Document*

ANSI Z535.1 — Safety Color Code

7.2 *BSI Document*[2]

BS 1710 — Identification of Pipelines and Services

7.3 *DIN Document*[3]

DIN 2403 — Kennzeichnung von Rohrleitungen nach dem Durchflußstoff (Identification Code for Pipe Lines According to Media)

7.4 *ISO Documents*[4]

ISO 3864 — Safety Colours and Safety Signs

ISO/DIS 14726-1 — Ships and Marine Technology — Identification Colours for the Contents of Piping Systems — Part 1: Main Colours and Media (Revision of ISO/R 508:1966) { ISO/R 508:1966 was withdrawn by TC 8 in 1986}

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3 DIN Deutsches Institut für Normung, Burggrafenstrasse 6, D-10787 Berlin, Germany, Postal Address: D-10772 Berlin, Telephone:+ 49.30.26.01.0, Telefax:+ 49.30.26.01.12.31, Telex: 18 42 73 din d, Telegram: deutschnormen berlin, E-mail: postmaster@din.de, WWW: http://www.din.de/

4 International Organization for Standardization, Central Secretariat, 1 rue de Varembe, Case postale 56, CH-1211, Geneve 20, Switzerland, Telephone:+ 41.22.749.01.11, Fax:+ 41.22.733.34.30, E-mail: central@iso.ch, WWW: http://www.iso.ch/

7.5 United States Department of Transportation Document[5]

Title 49, Code of Federal Regulations

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5 US Government Printing Office, Washington, D.C., USA

SEMI F35-0998
TEST METHOD FOR ULTRA-HIGH PURITY GAS DISTRIBUTION SYSTEM INTEGRATION VERIFICATION USING NON-INVASIVE OXYGEN MEASUREMENT

NOTE: This document that was previously designated as SEMI E71 (Test Method for Ultra-High Purity Gas Distribution System Integration Verification Using Non-Invasive Oxygen Measurement) has been re-designated as SEMI F35.

1 Purpose

1.1 This test method defines a procedure to monitor the integrity of ultra-high purity (UHP) gas distribution systems by detecting the ingress of atmospheric oxygen. This test method would be used to evaluate an "active" UHP gas distribution system on a continuous basis by using *non-invasive* O_2 measurement, without requiring an interruption of the process tools using the UHP gases of interest.

1.2 This test method should be used to protect semiconductor fabrication processes using the UHP gases, which may be sensitive to contamination by any of the common atmospheric impurities, such as N_2, O_2, H_2O, CO_2, before product yield problems develop.

1.3 This is the first such test method that describes a noninvasive leak detection and locating procedure. It differs from SEMI F1, which is an invasive technique for identifying leak sources using a mass spectrometer and a helium tracer gas.

2 Scope

2.1 This test method applies to UHP gas distribution systems used in semiconductor manufacturing facilities and comparable research and development areas.

2.2 This test method applies to bulk gas distribution systems carrying UHP gases such as N_2, Ar, He, H_2, N_2O, SF_6, and many halocarbons. In most cases, O_2 is present only in ultra-low trace levels (typically less than 1.0 ppb).

2.3 This test method will provide real-time monitoring of UHP gas distribution systems, resulting in meaningful system integrity verification, atmospheric contaminant trending analysis, and leak locating.

2.4 This test method will provide the user with sufficient information to identify and troubleshoot sources of atmospheric leakage into the UHP gas distribution system.

2.5 This test method includes the specification of the required O_2 analytical equipment, standard methods for proper use of the O_2 analytical equipment, and manipulation of the O_2 data in identifying atmospheric leak sources.

3 Limitations

3.1 This test method will only be successful in identifying the presence and location of leaks from atmospheric air using O_2 as the tracer gas representative of all atmospheric air contaminants (i.e., N_2, O_2, H_2O, CO_2). There is no capability to identify cross-contaminant species between different UHP gases which only contain ultra-low trace levels of O_2 or outward leaks to atmosphere.

3.2 This test method will not focus specifically on the process of detecting the exact location of every possible atmospheric air leakage source. Rather, it will describe techniques and examples demonstrating how atmospheric air leaks can be reliably identified and located, in general.

3.3 Results from this test method may not ensure that other common atmospheric impurities (e.g., H_2O) are below their required specification limits after a leak has been identified, corrected, and O_2 levels have returned to normal. For example, since O_2 diffuses more quickly and has a weaker surface adsorption than H_2O, O_2 will be the first atmospheric impurity detected. However, H_2O will likely be the last atmospheric impurity to be purged out once a leak has been identified and repaired.

3.4 This test method is not a direct substitution for SEMI F1.

3.5 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.

4 Referenced Documents

4.1 *SEMI Standard*

SEMI F1 — Specification for Leak Integrity of HighPurity Gas Piping Systems and Components

5 Terminology

5.1 *atmospheric impurities* — The common impurities to UHP gases that are found in atmospheric air.

NOTE: Impurities such as N_2, O_2, H_2O, CO_2.

5.2 *contaminant signature* — Typical baseline performance of a specific sample point within a large distribution system with respect to its O_2 impurity concentration. This is considered to be a normal and acceptable impurity level.

5.3 *critical sample point* — Gas sample point which is monitored continuously because it is deemed in a critical location in the distribution system, or that which is most sensitive to causing product/process quality problems from the ingress of atmospheric air impurities.

5.4 *investigative sample point* — Gas sample point which is selected for spot checking analysis as part of an investigation to locate an atmospheric air leak source.

5.5 *low detectable limit* — Defined as the smallest level of O_2 measurement which can be quantified after performing a blank test on zero gas. For our purposes, this is determined to be 2 times the total peak-to-peak noise over 8 hours while the O_2 analyzer is sampling on zero gas.

5.6 *ppbv* — Parts per billion by volume.

5.7 *point of use* — The connection point where the gas distribution system connects to the process tool which uses the UHP gas.

5.8 *sensitivity* — Defined as the smallest detectable step change in O_2 that the analyzer is capable of sensing.

5.9 *ultra-high purity (UHP) gas distribution system* — Semiconductor fab gas delivery system which typically contains impurities from atmospheric air of < 0.2 ppb at the input source, and atmospheric impurities at the point-of-use of typically < 1 ppb.

5.10 *weekly zero drift* — Total analyzer drift while measuring zero gas over a 1-week time period. Includes all components of analyzer drift.

5.11 *zero gas* — Test gas which is known to contain less than 0.1 ppb of O_2 as an impurity.

6 Summary of Method

6.1 The user must identify critical sampling locations in the UHP gas distribution system. These points are either specific process tool points-of-use or key lateral branch lines, which must avoid atmospheric contamination, or representative of a critical purity zone containing process tools that are particularly sensitive to atmospheric contaminants.

6.2 Connect O_2 analysis equipment to these critical sample points for continuous monitoring.

6.3 Qualify the performance of the O_2 analysis equipment before collecting data.

6.4 Begin continuous monitoring of critical sample points. Identify typical or baseline “contaminant signature” performance of the UHP gas distribution system.

6.5 Use continuous trend data to identify problematic events (contaminant spikes) and/or significant changes from the “contaminant signature” performance level.

6.6 Use additional investigative sample point measurements (spot checks) along with observable correlations to gas distribution system usage to locate and correct atmospheric leak sources.

7 Interferences

7.1 While sampling from any point in the gas distribution system, it is critical that the sample be delivered to the O_2 analytical equipment without introducing additional atmospheric O_2. This could create significant errors in the analysis. Observing a higher O_2 reading after reducing the sample flow to the analyzer may be an indication that there is a leak between the sample point and the O_2 analysis equipment.

7.2 An O_2 analyzer may become inaccurate due to improper calibration or simply due to long-term analyzer drift. This will cause inaccurate O_2 readings which do not represent the true performance of the UHP gas distribution system. The O_2 analyzer must be operated per the manufacturer’s recommendation for calibration technique, calibration frequency, and other routine maintenance.

7.3 Some O_2 analytical methods have cross-sensitivity to other gaseous components which may be found in UHP gases (i.e., H_2, CO, CH_4, and other hydrocarbons).

8 Requirements

8.1 *Personnel Qualification* — Personnel performing these tests in accordance with this test method shall have suitable training and experience. Such personnel shall, as a minimum, be knowledgeable of:

8.1.1 The operation and calibration of the specific equipment used in performing this test.

8.1.2 The proper procedures in handling UHP gases as agreed upon by supplier and user.

8.1.3 The proper safety procedure in handling combustible or toxic gases as agreed upon by supplier and user.

8.1.4 The behavior of atmospheric leak sources relative to position, pressure/flow, and gas usage.

9 Apparatus

9.1 An analyzer must be selected which is capable of continuous ultra-low trace O_2 measurements, with the ability to report measurements with at least once per minute frequency.

9.2 The ultra-low trace O_2 analyzer shall meet or exceed the following specifications. These specifications are appropriately defined in Section 5:

Sensitivity	< 0.1 ppb
Low Detectable Limit	< 0.3 ppb
Weekly Zero Drift	< 0.5 ppb
Response Time	< 10 minutes for 90% of a 0–1 ppb O_2 step change

NOTE: The O_2 analysis must be conducted using an analytical method which meets or exceeds the specifications required by this test method. If not, the user will not be able to confidently distinguish true gas distribution system impurity trends from false analyzer trends.

10 Safety Precautions

10.1 This test method is not a replacement for safety regulations. It is the responsibility of the user to ensure that the UHP gas distribution systems under analysis comply with applicable safety regulations, as agreed to between gas supplier and user.

10.2 It is also the responsibility of the user to comply with applicable safety regulations governing the operation of the required O_2 analytical equipment, as specified by the analyzer manufacturer.

11 Identify Sample Point Locations

11.1 Identify the critical sample point locations in the UHP gas distribution system which allow for a continuous gauging of overall system integrity. These shall include, at a minimum:

11.1.1 An exit purity O_2 measurement of the UHP gas at the furthest point of the gas distribution system within the fab.

11.1.2 Sample point locations representing sub-sections of the UHP gas distribution system, which are deemed critical for the avoidance of atmospheric impurities.

11.1.3 Point-of-use process tool locations which are deemed critical for the avoidance of atmospheric impurities.

11.2 A source purity O_2 measurement of the UHP gas entering the gas distribution system is suggested to be used as a reference comparison against other points within the fab.

11.3 Additional investigative (spot check) O_2 measurements may be required at sample point locations which aid in deducing the location of suspected atmospheric leak sources. This will vary from situation to situation. (See Section 16.)

11.4 The exact sample tap location must be representative of the measurement point of interest. Avoid measurement of dead-leg locations.

12 Preparation of Sample Point Locations

12.1 Thoroughly pre-purge the sample point prior to connecting the O_2 analyzer.

12.2 Thoroughly cycle-purge any regulators or other components in the sample system. Cycle the pressure at least 20 times with a high/low pressure ratio of at least 5 times.

12.3 Connect the O_2 analyzer to the sample point using appropriate UHP gas lines and fittings. Avoid using long lengths of bellows-type tubing because of long purge-down requirements. Avoid using Teflon or plastic tubing of any kind. Teflon and most other plastics are extremely permeable to O_2 and will cause atmospheric O_2 leakage. Only a few feet of plastic tubing can introduce ppm levels of O_2.

12.4 Establish flow from the sample point to the O_2 analyzer per the manufacturer's recommendations.

13 Calibration and Qualification

13.1 Follow the manufacturer's recommendations for initial start-up and calibration of the O_2 analyzer.

13.2 After initial start-up and calibration, adhere to the manufacturer's recommendations for routine calibration and maintenance needed to achieve the required performance specification as described in Section 9.2.

13.3 There will be two modes of O_2 measurement:

13.3.1 *Critical Sample Point O_2 Measurement*

13.3.1.1 Applicable to O_2 measurements performed continuously on the critical sample point locations identified earlier.

13.3.1.2 Prior to continuous data collection use of the analyzer, validate it by demonstrating the capability required in the specification for Weekly Zero Drift. Chart the zero baseline drift and peak-to-peak noise while on zero gas for 1 week.

13.3.1.3 Re-validate the O_2 analyzer performance by running a 24-hour blank test on zero gas monthly.

13.3.2 *Investigative Sample Point O_2 Measurement*

13.3.2.1 Applicable to spot check O_2 measurements performed in the investigation of locating atmospheric leak sources.

13.3.2.2 The O_2 analyzer must be operated for a time period sufficient to establish the "contaminant signature" at the point of interest.

13.3.2.3 Validate the O_2 analyzer with a blank test prior to each use. Chart zero baseline drift over a period of time which is twice as long as the expected time required to make the O_2 measurement. If a measurement can typically be made successfully in less than one hour, then verify the zero drift and peak-topeak noise with a two-hour blank test.

14 Data Collection Procedure

14.1 Collect all O_2 measurement data at a minimum of 1 point/minute using a chart recorder or data acquisition device.

14.2 Graph data points with sufficient resolution to observe trends over a one-week period. The graph must also be able to resolve O_2 spikes which may last only 10–15 minutes.

15 Interpretation of Results

15.1 Generate graphs of the baseline "contaminant signature" for each critical sample point location. Compare the baseline "contaminant signature" with the O_2 analyzer's blank run on zero gas to validate that the analyzer is producing useful data. The base-line "contaminant signature" should exhibit equal or greater O_2 variation than the blank run on zero gas.

15.2 *Problem Identification*

15.2.1 Observe data from critical sample point locations and look for deviations (abnormal trends or events) from the baseline "contaminant signature".

15.2.2 Determine if deviations (observed trends or events) are sufficient to impede mandatory atmospheric impurity specifications or influence critical product/process quality.

15.2.2.1 If yes, proceed into Section 16.

15.2.2.2 If no, continue observing O_2 data from critical sample point locations.

16 Atmospheric Leak Locating Procedure

16.1 Familiarize yourself with Figure 1 before proceeding with the remainder of Section 16.

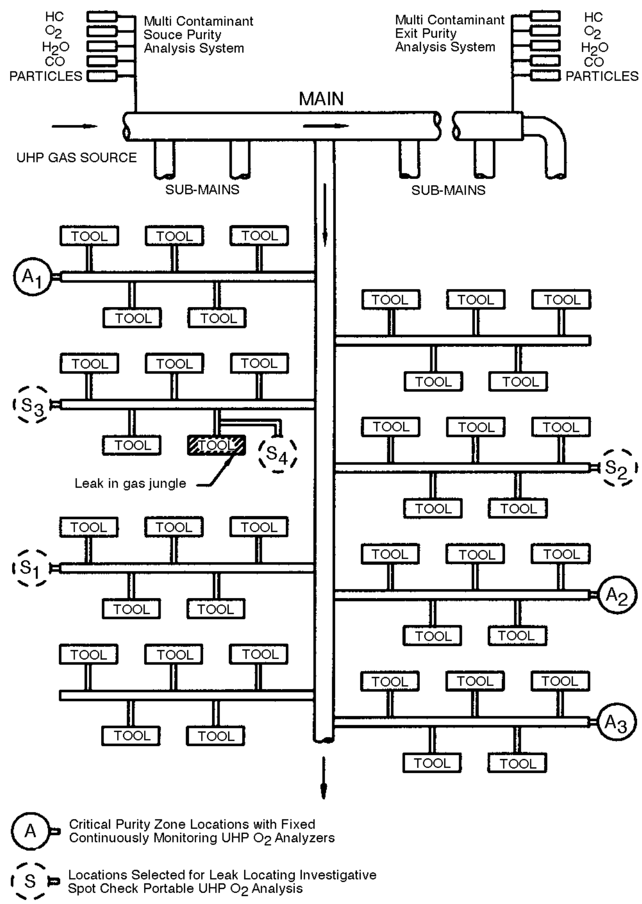

Figure 1
Typical Fab UHP Gas Distribution System

16.2 Isolate a zone where the contamination is likely to originate from by comparing the O_2 levels at the critical continuous monitoring sample point locations. Assume the leak source is somewhere between the last uncontaminated sample point and the first contaminated sample point going downstream. Some knowledge of the gas distribution flow path will be required here.

16.3 Compare the data from the O_2 analyzer detecting the contamination with pressure and flow data, or gas usage demand over time in the specific lateral of the gas distribution system where the O_2 analysis is being made.

16.4 Correlate the changes in O_2 readings which show abnormally high O_2 levels with specific tool cycles that cause the UHP gas pressure and flow in the lateral line to change. The timing of the analyzer's response to these usage demands will give some clues as to the approximate position of the atmospheric leak source.

NOTE: Back-contamination is likely originating in a leg which is dead at the time the O_2 analyzer responds. Actual response time will depend on the time needed for the contaminant to travel to the O_2 analyzer plus the response time of the O_2 analyzer.

16.5 If no demand cycles in the lateral cause O_2 readings to change, then the source of contamination is likely to occur further upstream in the distribution system, prior to the intersection of the lateral in question. This assumes that there is always a net flow of gas in the line leading to the intersection of the lateral being checked.

16.6 Perform an investigative O_2 measurement (spot check) with a portable O_2 analyzer at each lateral location that is suspected in causing contamination in the main or sub-main line which supplies the lateral where the contamination was originally detected. Work upstream away from the lateral which showed a sign of contamination.

16.7 Once the lateral with the contamination source has been identified, use the steps outlined in Sections 16.3 and 16.4 to locate the exact point of the atmospheric leak source.

16.8 Refine the selection of investigative sample point locations along with a careful study of system flow dynamics until the leak is pinpointed and repaired.

16.9 Confirm that the leak source has been corrected by providing an investigative O_2 measurement downstream of the leak source.

17 Example in Locating Leak Source

17.1 See Figure 1 which is a schematic representation of a typical fab branching type gas distribution system. Since a loop type gas distribution system has one less piping level between the main line and the tools, it is more straightforward to monitor and diagnose. This example, although more complex, has been demonstrated in practice. It shows how an atmospheric leak originating at a single tool location can back-contaminate a sub-main distribution line, yet not contaminate all the way back to the main line. In this example, the contamination would not be detected by the UHP analysis instrumentation typically installed on the main line.

17.2 The "contaminant signature" oxygen analyzers are installed at critical purity locations, shown in Figure 1 as A_1, A_2, and A_3. These analyzers show baseline "contaminant signature" O levels of 0.2–0.5 ppb. By definition, as established by the user for each critical purity location, these are normal contaminant levels at these locations.

A_2 and A_3 begin showing excursions up to 1–2 ppb that last for several minutes, then settle back into the normal 0.2–0.5 ppb range. The excursions take place infrequently at first, but then develop some regularity. Although the absolute O_2 level detected does not yet indicate that the potential atmospheric leak (H_2O and N_2 included) would pose a direct risk to the critical purity of process tools located nearby, it does differ significantly from the baseline "contaminant signature". This prompts an investigation before a full-scale process production problem results.

Each of the lateral lines being monitored by A_2 and A_3 shows the same level of O_2 contamination, so it is deduced that the contamination is coming from the sub-main line which feeds both laterals. Since analyzer A_1 does not show the contamination, it is further deduced that the leak source is located between A_1 and A_2.

17.3 Working back upstream along the sub-main, investigative O_2 measurements are made at each lateral location ahead of the A_2 lateral. These investigative O_2 measurements are made using a portable O_2 analyzer per Sections 12 and 13.

17.4 At S_1 and S_2, similar O_2 contamination events are observed as compared with points A_2 and A_3. Further, no lateral line flow changes (due to tool gas demand cycles in those laterals) cause any change in the O_2 level.

17.5 At the third lateral, sampled as S_3 in Figure 1, the O_2 level is significantly higher (ranging between 5–10 ppb), with periodic spikes of 50–100 ppb. At this point, it is observed that when the usage in lateral S_3 drops to zero (a dead leg condition), analyzers A_2 and A_3 show O_2 readings above the "contaminant signature". It is therefore deduced that the S_3 lateral is the source of the atmospheric leak.

17.6 By correlating the O_2 data at S_3 with the gas usage from the tools on this lateral, the leak source can be further traced within this lateral. (Refer to Figure 2.)

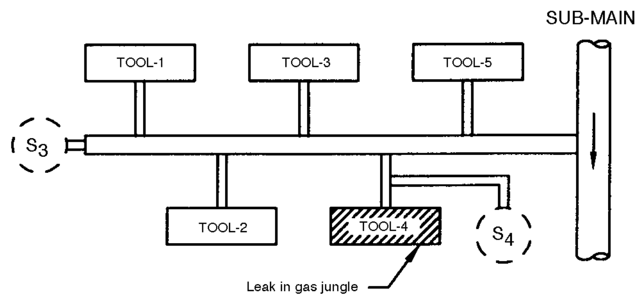

Figure 2
Branch UHP Gas Line with Ambient Air Leak Contaminating Sub-Main Line

17.6.1 When Tool-1, Tool-2, or Tool-3 demands gas, the O_2 reading drops in proportion to the total flow of gas in the lateral line. The higher flow rates act to dilute the effects of the leak source and thus lower the O_2 reading at S_3.

17.6.2 It is observed that when Tool-5 demands gas, there is no change in the O_2 reading at S_3. Therefore, it is deduced that the leak source is located further out along the lateral line.

17.6.3 When Tool-4 demands gas, it causes a more significant drop in the O_2 reading at S_3. Further, it is observed that the time required for the analyzer to respond after Tool-4 begins demanding gas correlates to the time needed for the analyzer's sample flow alone to purge down the lateral line volume up to the analyzer, when Tool-1, -2, and -3 are not demanding gas.

17.6.4 This deductive inference technique pinpoints the leak source to the Tool-4 lateral line.

17.6.5 After Tool-4 has stopped demanding gas (yet before any other Tools on this lateral demand gas), the O_2 reading at S_3 continues to drop gradually over several minutes. It then gradually begins to elevate once again. This indicates that the actual leak is not very close to the connection of Tool-4 at the lateral line. It suggests more that the leak source is closer to the tool itself.

17.7 A final investigative sample point is selected along the line leading to Tool-4. This is shown as S_4 in Figure 2. It is observed that the O_2 readings drop to 0.2–0.5 ppb when Tool-4 demands gas. S_4 begins to show an O_2 elevation after the Tool-4 stops demanding gas. This concludes that the leak source is originating from Tool-4 itself.

18 Related Documents

18.1 *SEMI Standard*

SEMI E49.9 — Guide for Ultrahigh Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F36-0299
GUIDE FOR DIMENSIONS AND CONNECTIONS OF GAS DISTRIBUTION COMPONENTS

1. Purpose

1.1 The purpose of this guide is standardization of dimensional and mechanical/electrical connection attributes for components used within gas distribution systems. Standardization of these component interfaces will allow for interchangeability of gas distribution system components. Filters/purifiers, shut-off valves, pressure regulators, MFC/MFMs, and pressure transducers are the types of gas distribution components that would benefit from being interchangeable.

2. Scope

2.1 This guide is for use with 1/4-inch distribution systems at operating pressures no greater than 345 kPa (50 psi).

2.2 The guide includes the following items:

a) Physical characteristics specific to each component. These include a generalized drawing of the component, specific end-to-end lengths for each type of end connection, maximum envelope dimensions, base-to-centerline dimensions, tolerances, and bottom mounting information.

b) Electrical connections specific to each component, where applicable. These include pin-outs and types of connectors.

3. Limitations

3.1 This guide is not intended to dictate how to build a gas distribution system, but to allow for interchangeability of components.

3.2 This standard does not include recommendations for sensor-bus compliant interfaces.

3.3 This standard does not apply to surface mount components used in modular type gas systems.

4. Referenced Documents

4.1 None.

5. Terminology

5.1 *component* — An individual piece or a complete assembly of individual pieces capable of being joined with other pieces or components.

5.2 *filter* — A porous device, generally constructed of polymer, metal, or ceramics and housed in a metal chamber, which traps particles, preventing them from being transported downstream.

5.3 *mass flow controller* (MFC) — A self-contained device (consisting of a transducer, control valve, and control and signal-processing electronics) commonly used in the semiconductor industry to measure and regulate the mass flow of gas.

5.4 *mass flow meter* (MFM) — A self-contained device, consisting of a mass flow transducer and signal-processing electronics, commonly used in the semiconductor industry to measure the mass flow of gas.

5.5 *pressure regulator* — A valve designed to reduce a high incoming pressure (for example, from a cylinder) to a lower outlet pressure by automatically opening to allow flow until a desired, preset pressure on the outlet side is reached, then automatically throttling closed to stop further pressure increase.

5.6 *pressure transducer* — A component which mechanically or electrically senses gas pressure. It typically consists of a sensor and signal-processing electronics which enables remote indication of gas pressure.

5.7 *purifier* — An in-line device used for the removal of homogeneous impurities from gases, typically consisting of a packed-bed of active solids contained in a stainless steel housing. The active purification media may remove impurities such as moisture, oxygen, CO, CO_2, hydrocarbons, hydrogen, or nitrogen from specific gases using a variety of chemical reaction, physisorption, or chemisorption mechanisms. Point-of-use purifiers often contain a particle filter within the same housing.

5.8 *valve* — A device that controls the flow or pressure of a gas. Valve functions can include shutoff, metering, backflow prevention, and pressure relief.

6. Ordering Information

6.1 Device manufacturers may use this guide when procuring processing equipment to communicate to the equipment supplier the interface specifications required for interchangeability of components. This document may also be used by semiconductor processing equipment suppliers to specify standardized interfaces to component and module suppliers.

6.2 Orders for components in accordance with this standard shall include:

a) This standard number and date of issue.

b) Reference to the table number.

c) Reference to the option number, if applicable.

7. Filters and Purifiers

7.1 Filters less than 30 SLM and purifiers less than 1 SLM should conform to the interface design recommendations appearing in Figure 1 and Table 1.

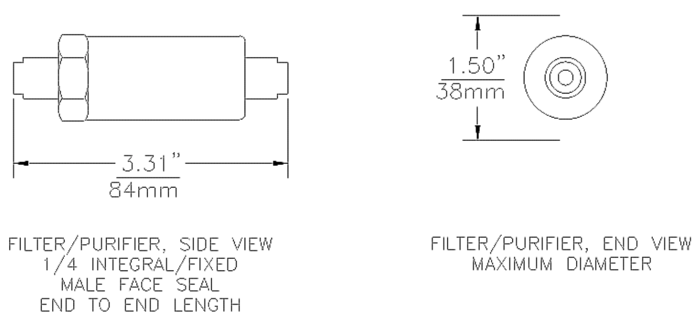

Figure 1
Filter and Purifier Interface Design

Table 1 Filter and Purifier Interface Recommendations

	Filter and Purifier
End-to-End Lengths:	
1/4-inch Integral/fixed male face seal	84 mm (3.31 in.)
1/4-inch Swivel face seal (male or female)	-
1/4-inch Tube weld	-
NOTE: The tolerance on length for machined components is ± 0.15 mm (0.006 in.) from the component centerline to each end. The tolerance on length for welded components is ± 0.5 mm (0.020 in.) from the component centerline to each end.	
Overall Component Envelope:	
Maximum Diameter	38 mm (1.5 in.)
Base to Centerline of Flow Path:	-
Mounting provisions:	
Threaded holes	None required
Pattern	-
Fittings:	
Process	1/4-inch
Control:	None required

8. Shut-off Valves

8.1 Shut-off valves should conform to the interface design recommendations appearing in Figure 2 and Table 2.

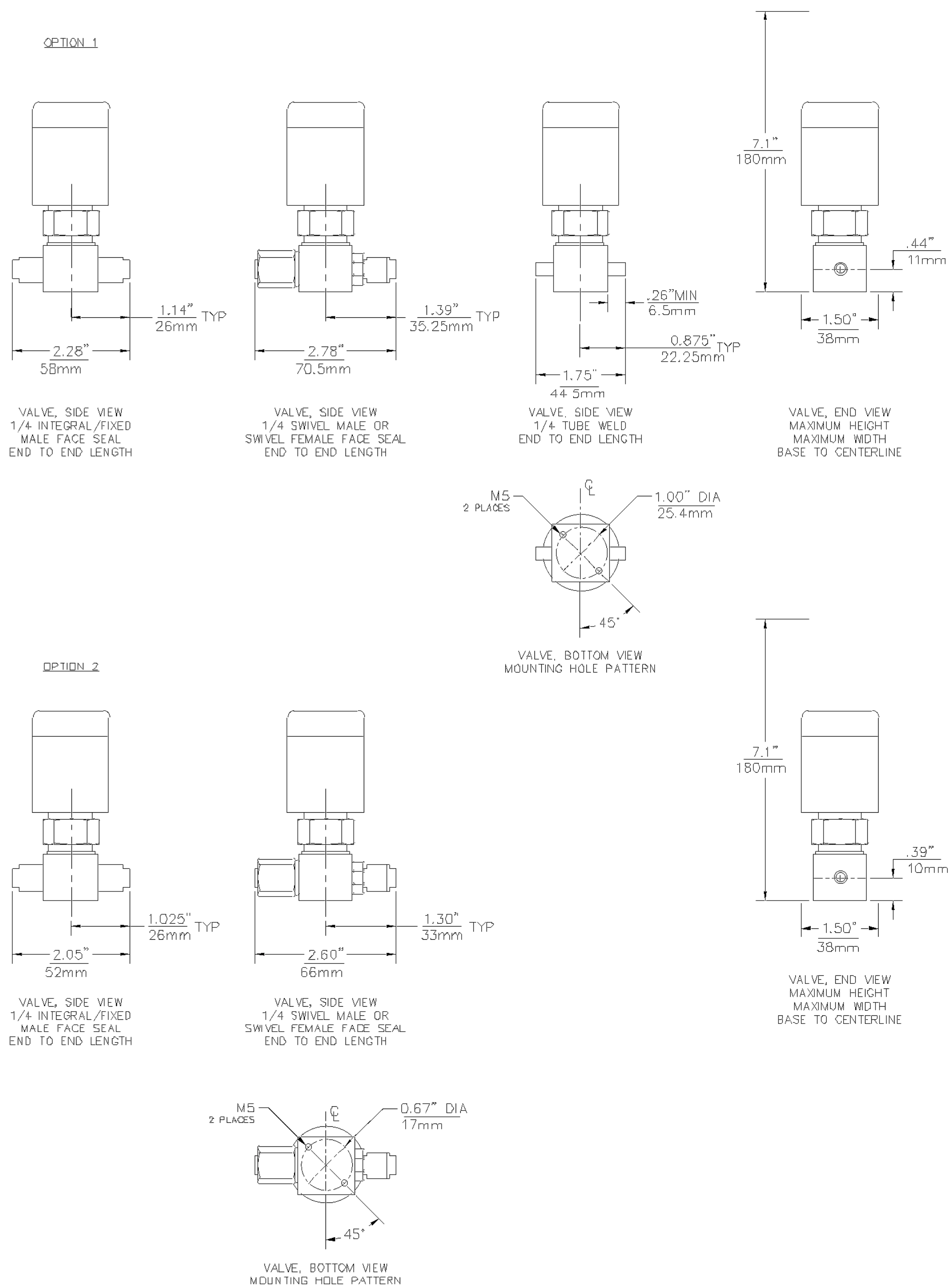

Figure 2
Shut-off Valve Interface Design

Table 2 Shut-off Valve Interface Recommendations

	Option 1 Shut-off Valves	Option 2 Shut-off Valves
End-to-End Lengths:		
1/4 inch Integral/fixed male face seal	58 mm (2.28 in.)	52 mm (2.05 in.)
1/4 inch Swivel face seal (male or female)	70.5 mm (2.78 in.)	66 mm (2.60 in.)
1/4 inch Tube weld	44.5 mm (1.75 in.)	-
NOTES: 1) The minimum length for each tube weld stub should be 6.5 mm (0.26 in.). 2) The tolerance on length for machined components is ± 0.15 mm (0.006 in.) from the component centerline to each end. The tolerance on length for welded components is ± 0.50 mm (0.020 in.) from the component centerline to each end.		
Overall Component Envelope:		
Maximum height	180 mm (7.1 in.)	
Maximum width (Excluding lever and toggle handles)	38 mm (1.5 in.)	
Base to Centerline of Flow Path:	11 mm (0.44 in.) ± 0.3 mm (0.012 in.)	10 mm (0.39 in.) ± 0.3 mm (0.012 in.)
Mounting Provisions:		
Threaded holes	M5 × 0.8 – 6H; 6 mm (0.24 in.) perfect thread depth	M5 × 0.8 – 6H; 5mm (0.20 in.) perfect thread depth
Pattern	25.4 mm (1.00 in.) bolt circle centered on bottom of base with two threaded holes 180° apart and 45° off of the vertical or horizontal axis. One hole in each of the upper left and lower right quadrants when looking at the bottom of the component.	17 mm (0.67 in.) bolt circle centered on bottom of base with two threaded holes 180° apart and 45° off of the vertical or horizontal axis. One hole in each of the upper left and lower right quadrants when looking at the bottom of the component.
NOTE: The M5 × 0.8 threaded mounting holes will accept 10–32 screws, but 10–32 threaded holes will not accept M5 × 0.8 screws.		
Fittings:		
Process	1/4-inch	
Control:	Manual and Pneumatic	

9. Pressure Regulators

9.1 Pressure regulators should conform to the interface design recommendations appearing in Figure 3 and Table 3.

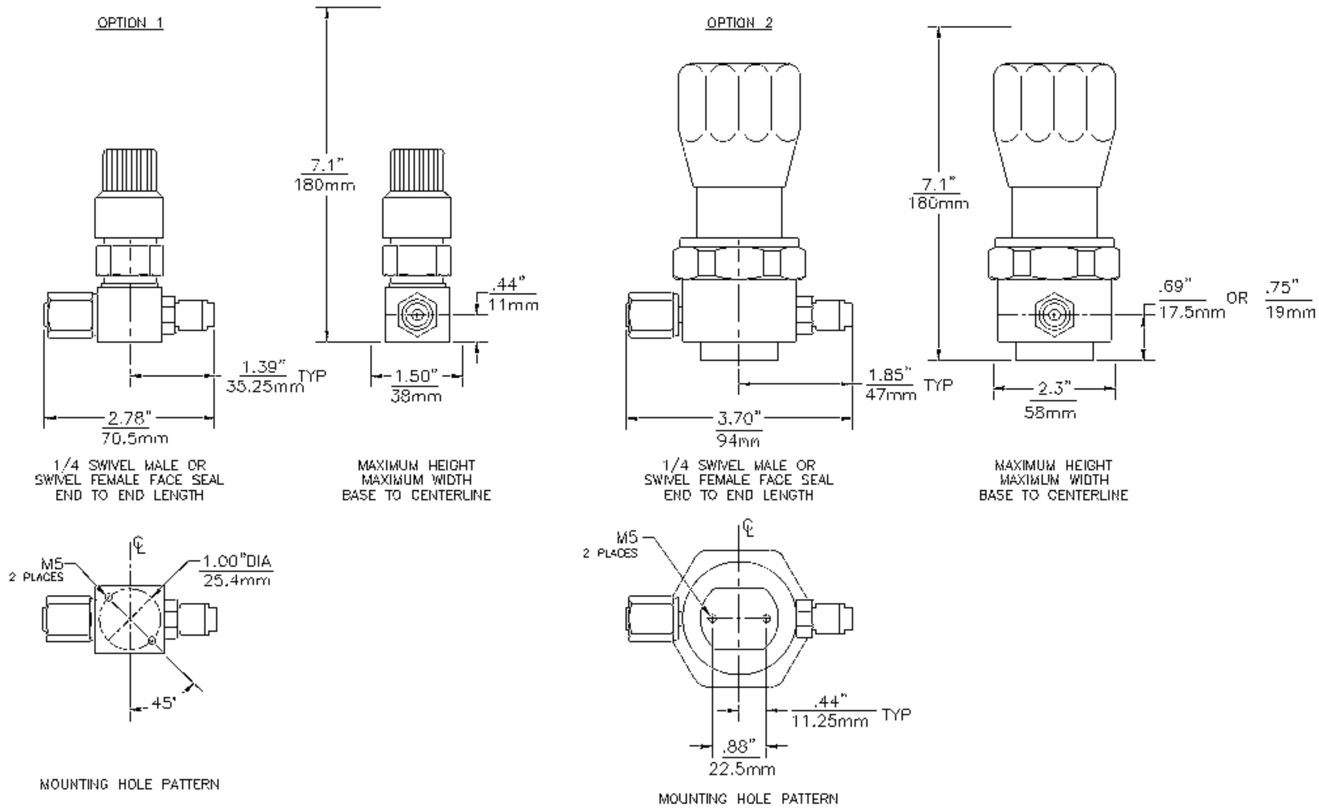

Figure 3
Pressure Regulator Interface Design

Table 3 Pressure Regulator Interface Recommendations

	Option 1 Pressure Regulators	Option 2 Pressure Regulators
End-to-End Lengths:		
1/4-inch Integral/fixed male face seal	-	-
1/4-inch Swivel face seal (male or female)	70.5 mm (2.78 in.)	94 mm (3.70 in.)
1/4-inch Tube weld	-	-
NOTE: The tolerance on length for machined components is ± 0.15 mm (0.006 in.) from the component centerline to each end. The tolerance on length for welded components is ± 0.50 mm (0.020 in.) from the component centerline to each end.		
Overall Component Envelope:		
Maximum height	180 mm (7.1 in.)	180 mm (7.1 in.)
Maximum width	38 mm (1.5 in.)	58 mm (2.3 in.)
Base to Centerline of Flow Path:	11 mm (0.44 in.) ± 0.3 mm (0.012 in.)	17.5 mm (0.69 in.) ± 0.3 mm (0.012 in.) or 19 mm (0.75 in.) ± 0.3 mm (0.012 in.)
Mounting Provisions:		
Threaded holes	M5 × 0.8 – 6H; 6 mm (0.24 in.) perfect thread depth	M5 × 0.8 – 6H; 6 mm (0.24 in.) perfect thread depth
Pattern	25.4 mm (1.00 in.) bolt circle centered on bottom of base with two threaded holes 180° apart and 45° off of the vertical or horizontal axis. One hole in each of the upper left and lower right quadrants when looking at the bottom of the component.	Two threaded holes, centered on bottom of base, in line with flow path, spaced 22.5 mm (0.88 in.) between centers
NOTE: The M5 × 0.8 threaded mounting holes will accept 10–32 screws, but 10–32 threaded holes will not accept M5 × 0.8 screws.		
Fittings:		
Process	1/4-inch	
Control:	Manual	

10. MFCs and MFMs

10.1 MFCs and MFMs should conform to the interface design recommendations appearing in Figure 4 and Table 4.

10.2 A nine pin connector was specified along with a signal for each pin to allow for MFC/MFM interchangeability. If additional signals are required, an additional connector should be specified. If signals are different, an alternate connector should be specified.

10.3 Current technology limits the MFC and MFM base-to-centerline dimension to 12.7 mm (0.50 in.). If future technologies permit, 11 mm (0.44 in.) should be considered as an option for the base-to-centerline dimension. This recommendation would improve modularity by permitting selection of each component type with a common base-to-centerline dimension.

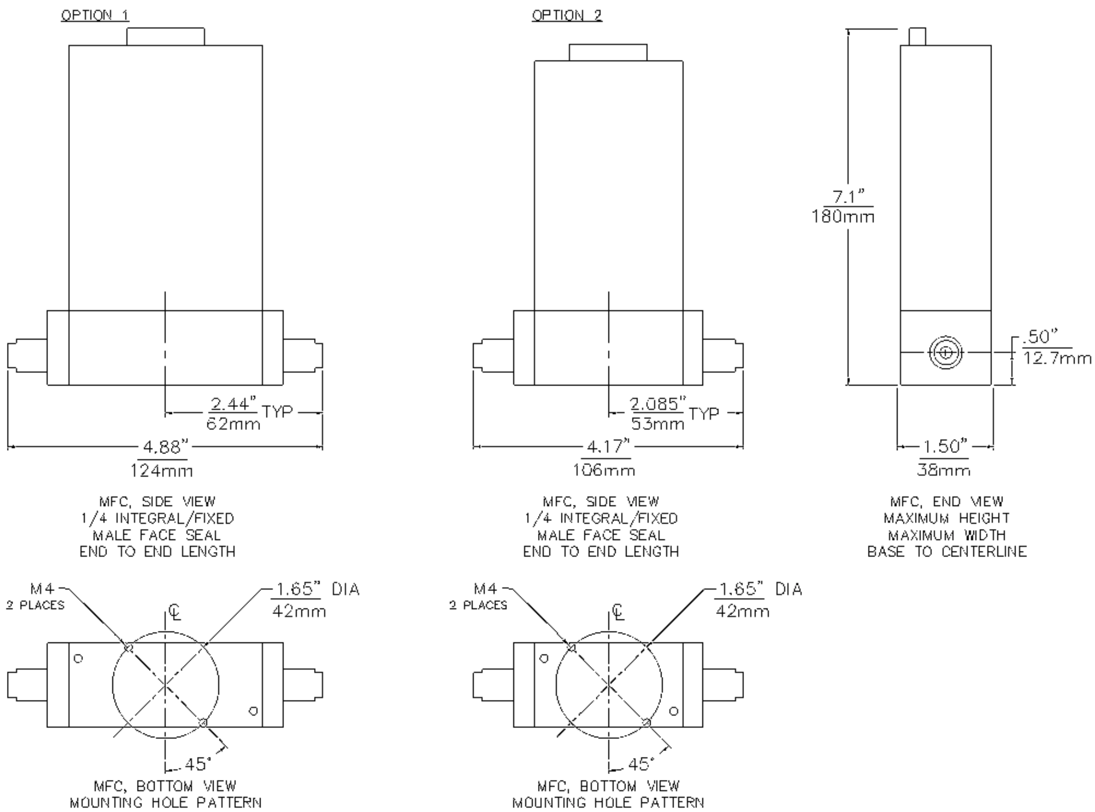

Figure 4
MFC and MFM Interface Design

Table 4 MFC and MFM Interface Recommendations

	Option 1 **MFC and MFM**	**Option 2** **MFC and MFM**
End-to-End Lengths:		
1/4-inch Integral/fixed male face seal	124 mm (4.88 in.)	106 mm (4.17 in.)
1/4-inch Swivel face seal (male or female)	-	-
1/4-inch Tube weld	-	-
NOTE: The tolerance on length is ± 0.50 mm (0.020 in.) from the component centerline to each end.		
Overall Component Envelope:		
Maximum height	180 mm (7.1 in.)	
Maximum width	38 mm (1.5 in.)	
Base to Centerline of Flow Path:	12.7 mm (0.50 in.) ± 0.3 mm (0.012 in.)	
Mounting provisions:		
Threaded holes	M4 × 0.7 – 6H; 3 mm (0.12 in.) minimum perfect thread depth	
Pattern	42 mm (1.65 in.) bolt circle centered on bottom of base with two threaded holes 180° apart and 45° off of the vertical or horizontal axis. One hole in each of the upper left and lower right quadrants when looking at the bottom of the component.	
Fittings:		
Process	1/4-inch	
Control:	Electrical 9-pin sub-D connector Analog signal pin out as follows:	
	Pin 1.	Valve Closed (Ground Pin to Close Valve)
	Pin 2.	0–5 V_{DC} Flow Signal Output
	Pin 3.	+15 V_{DC} Power Supply
	Pin 4.	Power Common
	Pin 5.	-15 V_{DC} Power Supply
	Pin 6.	0–5 V_{DC} Setpoint Input
	Pin 7.	Output Common
	Pin 8.	Setpoint Common
	Pin 9.	Valve Test Point

11. Pressure Transducers

11.1 Pressure transducers should conform to the interface design recommendations appearing in Figure 5 and Table 5.

11.2 To improve modularity of gas distribution systems the following recommendation should be considered for future pressure transducer design. This recommendation would match the pressure transducer interface design to the dimensions of both the shut-off valve Option 1 found in Table 2 and pressure regulator Option 1 found in Table 3.

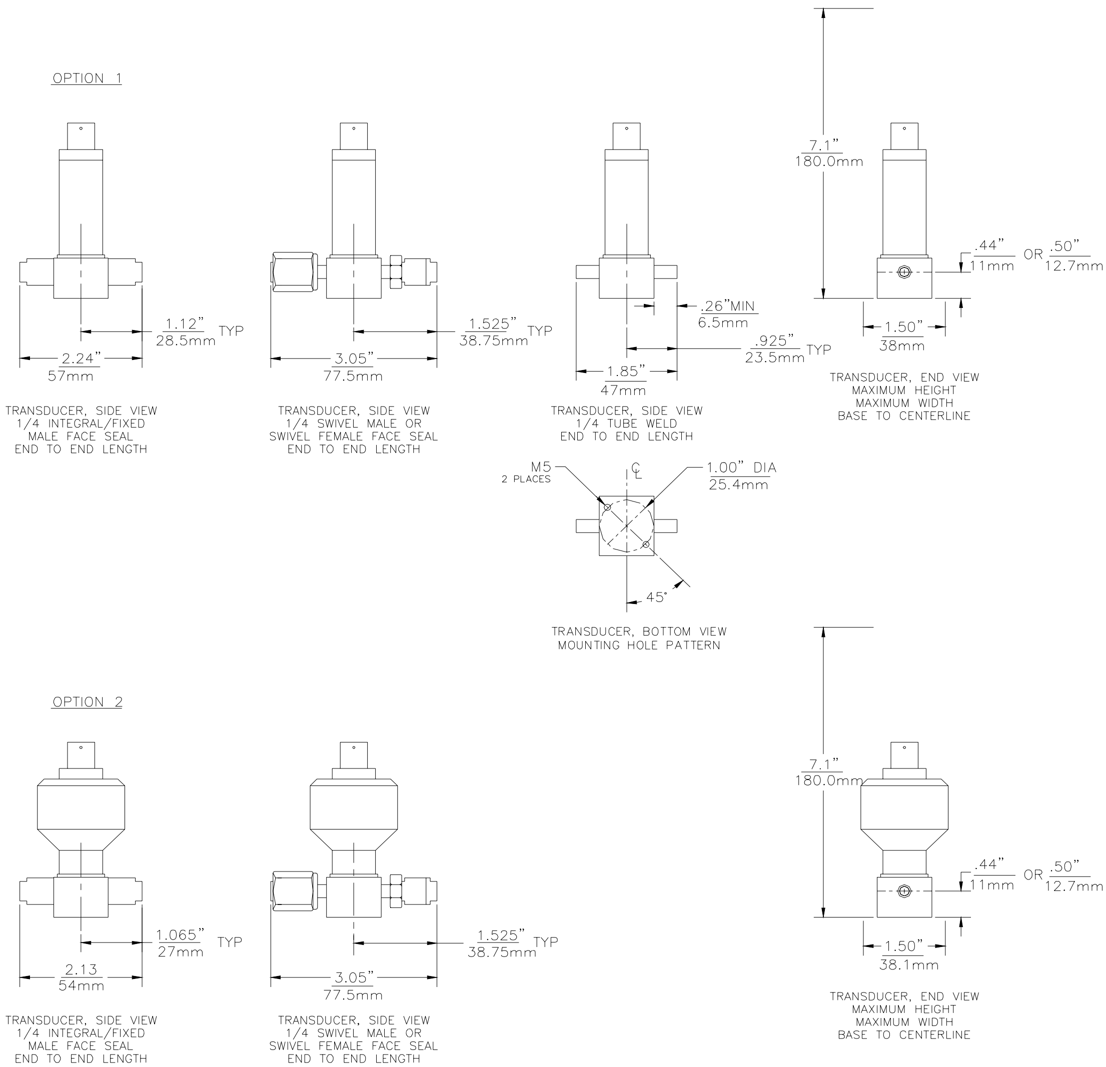

Figure 5
Pressure Transducer Interface Design

Table 5 Pressure Transducer Interface Recommendations

	Option 1 Pressure Transducers with Four-pin Connector	Option 2 Pressure Transducers with Six-pin Connector
End-to-End Lengths:		
1/4-inch Integral/fixed male face seal	57 mm (2.24 in.)	54 mm (2.13 in.)
1/4-inch Swivel face seal (male or female)	77.5 mm (3.05 in.)	77.5 mm (3.05 in.)
1/4-inch Tube weld	47 mm (1.85 in.)	-
NOTES: 1) The minimum length for each tube weld stub should be 6.5 mm (0.26 in.). 2) The tolerance on length for machined components is ± 0.15 mm (0.006 in.) from the component centerline to each end. The tolerance on length for welded components is ± 0.50 mm (0.020 in.) from the component centerline to each end.		
Overall Component Envelope:		
Maximum height	180 mm (7.1 in.)	
Maximum width	38 mm (1.5 in.)	
Base to Centerline of Flow Path:	11 mm (0.44 in.) ± 0.3 mm (0.012 in.) or 12.7 mm (0.50 in.) ± 0.3 mm (0.012 in.)	
Mounting Provisions:		
Threaded holes	M5 × 0.8 – 6H; 6 mm (0.24 in.) perfect thread depth	None required
Pattern	25.4 mm (1.00 in.) bolt circle centered on bottom of base with two threaded holes 180° apart and 45° off of the vertical or horizontal axis. One hole in each of the upper left and lower right quadrants when looking at the bottom of the component.	-
NOTE: The M5 × 0.8 threaded mounting holes will accept 10–32 screws, but 10–32 threaded holes will not accept M5 × 0.8 screws.		
Fittings:		
Process	1/4-inch	
Control:		

Option 1 Electrical Four-pin round connector Signal pin out as follows:			**Option 2** Electrical Six-pin round connector Signal pin out as follows:		
	Amperage Configuration	Voltage Configuration		Amperage Configuration	Voltage Configuration
Pin A	+4–20 mA excitation	+ power input	Pin A	+4–20 mA excitation	+ power input
Pin B	optional (open if not used)	pressure output/signal output	Pin B	optional (open if not used)	optional (open if not used)
Pin C	optional (open if not used)	optional (open if not used)	Pin C	-4–20 mA negative	power and signal ground
Pin D	-4–20 mA negative	power and signal ground	Pin D	optional (open if not used)	optional (open if not used)
			Pin E	optional (open if not used)	pressure output/signal output
			Pin F	optional (open if not used)	optional (open if not used)

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SEMI F37-0299
METHOD FOR DETERMINATION OF SURFACE ROUGHNESS PARAMETERS FOR GAS DISTRIBUTION SYSTEM COMPONENTS

1. Purpose

1.1 The purpose of this test method is to define a method for determining numerical values for surface roughness parameters measured on gas distribution system components. Application of this method is intended to yield comparable data among users of this method.

2. Scope

2.1 This document will specify methods, measuring equipment, and test conditions for mechanical profile surface roughness measurement of gas distribution system components. This test method will not require nor recommend numerical values for specific surface roughness parameters. This test method is intended for use in quality control and process development for specification of and manufacturing of gas distribution system components.

3. Limitations

3.1 Numerical values for specific surface roughness parameters obtained using this test method may not provide sufficient information for determining the performance of the component, such as dry down times, corrosion resistance or amount of particle generation. Surface roughness measurement is one of many evaluation techniques for assessing the performance or quality of a surface. This document is not concerned with characteristics such as component design, material, dimensions, appearance, etc. While surface defects traversed by the stylus may be included in the roughness measurement, this method does not govern the evaluation of surface defects. Surface defects may be measured by methods such as SEM and EDX. This test method is intended to measure surface features on the order of 10 μm in size. It is not intended to detect submicron surface features.

4. Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *ASME Document*[1]

B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

4.2 *ASQ Document*[2]

Z1.9 — Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming

5. Terminology

5.1 *Acronyms*

5.1.1 *EDX* — Energy Dispersive X-Ray Spectroscopy

5.1.2 *SEM* — Scanning Electron Microscopy

5.1.3 *SEM* — Scanning Electron Microscope

5.2 *Definitions*

5.2.1 *cutoff* — A length selected to limit the spacing of surface irregularities. It separates a surface's roughness from its waviness.

5.2.2 *distinct regions* — Visually unique areas of a surface defined by patterns of lay or differences in the appearance of surface roughness. In-line bores of different sizes or orientations and each leg of a shaped component should be considered distinct regions.

5.2.3 *evaluation length* — The actual length over which surface roughness is assessed.

5.2.4 *lay* — The general direction of orientation of surface features.

5.2.5 *skid* — A stylus probe support which acts as both a filter and a datum for probe movements.

5.2.6 *skidless* — A type of instrument that does not use an external skid attached to the probe to act as a datum. Instead, it references a datum plane internal to the measurement equipment.

5.2.7 *stylus* — The object which mechanically probes the surface.

5.2.8 *surface roughness* — The finer irregularities of the surface texture, usually including those

1 The American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202 irregularities that result from the inherent action of the production process, for example traverse feed marks from cutting tools [ASME B46.1-1995].

5.2.9 *surface texture* — Repetitive or random deviations from the nominal surface that forms the three-dimensional topography of the surface. Surface texture includes roughness, waviness, lay, and flaws [ASME B46.1-1995].

5.2.10 *waviness* — The more widely spaced component of surface texture. Waviness may result from such factors as machine or workpiece deflections, vibrations, chatter, heat treatment, or warping strains. Roughness may be considered as superimposed on a "wavy" surface.

6. Sampling

6.1 Acceptability criteria should be specified by the user and be developed in accordance with published sampling plans such as *ASQ Z1.9, Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming*.

7. Apparatus

7.1 The instrument should be a stylus type as defined by ASME B46.1, Section 2. Due to the limitations of skidded instruments (Type IV and V), a skidless instrument (Type I) is preferable.

7.2 The instrument should be calibrated using standard laboratory practices and manufacturer's recommendations with a roughness metrology standard calibrated by a certified testing laboratory and traceable to NIST[3].

7.3 In order to resolve the features of the surface, a stylus with a conical tipped radius of 5 µm (200 µin) should be used.

8. Units of Measure

8.1 Surface roughness should be described by means of the Roughness Average, R_a, as defined per ASME B46.1.

8.2 Measurements should be specified in micrometers (µm) or microinches (µin).

9. Preparation of Apparatus

9.1 The surface should be clean and free from loose debris before taking a measurement.

9.2 The instrument should be sufficiently isolated from vibrations, which will artificially increase roughness measurements.

9.3 Surfaces inaccessible to the stylus probe may be exposed by sectioning a sample(s). Samples should be sectioned to avoid damage to the surface to be measured and should be cleaned appropriately to remove sectioning debris.

10. Procedure

10.1 Select a single random location for measurement within each distinct region of interest on each component.

10.2 Measurements shall be taken perpendicular to the lay. If this is not practical, measurements may be taken in the direction of process gas flow through the component.

10.3 Instrument cutoff length should be set to 0.800 mm (0.030 in.).

10.4 The evaluation length, or measurement length, should be at least 3.81 mm (0.150 in.) where sufficient length is available.

11. Reporting

11.1 Average R_a is defined as the average of all R_a measurements taken over a population.

11.2 Maximum R_a is defined as the maximum of all R_a measurements taken over a population.

11.3 Both Average R_a and Maximum R_a should be reported for a given population. A population can be defined as:

- a set of single measurements on multiple components
- a set of multiple measurements on a single component
- a set of multiple measurements on multiple components

12. Precision and Accuracy

12.1 Some variance in Roughness Average is to be expected on a single surface from measurement to measurement. No two measurements (as taken by different operators, on different instruments, or at different locations on the surface of a component) will contain the same data points. Because different instruments will acquire data points at different rates, and evaluation lengths may differ, a typical Roughness Average measurement can include hundreds to tens of thousands of data points.

[3] *National Institute of Standards and Technology, Gaithersburg, MD 20899*

Reported measurements on the same surface can be expected to deviate up to 20%.

13. Related Documents

13.1 *ANSI Standard*[4]

Y14.36 — Surface Texture Symbols

13.2 *BSI Standard*[5]

BS 1134 — Assessment of Surface Texture, Part 1: Methods and Instrumentation and Part 2: Guidance and General Information

13.3 *DIN Standard*[6]

DIN 4768 — Determination of Surface Roughness Values R_a, R_z, R_{max} with Electric Stylus Instruments

13.4 *ISO Standard*[7]

ISO 4288 — Rules and Procedures for the Measurement of Surface Roughness Using Stylus Instruments

13.5 *JIS Standard*[8]

JIS B 0651 — Instruments for the Measurement of Surface Roughness by the Stylus Method

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[4] *American National Standards Institute, 1430 Broadway, New York, NY 10018*

[5] *British Standards Institution, 389 Chiswick High Road, GB-London W4 4AL, Telephone: + 44.181.996.90.00, Telefax: + 44.181.996.74.00, E-mail: info@bsi.org.uk, WWW: http//www.bsi.org.uk/*

[6] *DIN Deutsche Institut für Normung, Burggrafenstrasse 6, D-10787 Berlin, Germany, Postal Address: D-10772 Berlin, Telephone: + 49.30.26.01.0, Telefax: + 49.30.26.01.12.31, Telex: 18 42 73 din d, Telegram: deutschnormen berlin, E-mail: postmaster@din.de, WWW: http://www.din.de/*

[7] *International Standards Organization, Case Postale 56, CH-1211, Geneve 20, Switzerland*

[8] *Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo 107, Japan*

SEMI F38-0699
TEST METHOD FOR EFFICIENCY QUALIFICATION OF POINT-OF-USE GAS FILTERS

This Test Method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org January 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this document is to define a comprehensive standard test sequence to qualify the particle filtration efficiency achievable using Point-of-Use (POU) gas filters.

2 Scope

2.1 This test method defines an evaluation method for Point-of-Use filters of various media (e.g., metallic, ceramic, and polymeric) typically used for filtering inert and process gases in semiconductor applications. Point-of-Use filters are designed to handle relatively low flow rates (0.5 – 50 slm.) and moderately high pressure drops. The filter housing and filtration element are combined into one sealed and inseparable unit.

2.2 This test method is intended to demonstrate the ability of a Point-of-Use gas filter to equal or exceed a specific particle filtration efficiency class when challenged with a monodispersed aerosol in the size range described in Section 6.6.

2.2.1 The efficiency class of the test method is defined as the log reduction value (LRV), where LRV is the Log [Input Concentration/System Background Level].

3 Limitations

3.1 These test methods do not apply to gas filter cartridges.

3.2 These test methods do not apply to bulk gas filters.

3.3 The various media (e.g., metallic, ceramic, and polymeric) may have slightly different critical particle sizes (most penetrating particle sizes). Therefore, many challenge tests have to be performed over a range of particle sizes to assure that the "worst case" challenge has been performed.

3.4 The efficiency test is for steady state flow and room temperature only. Comparison to efficiency in pulsed flow, elevated temperature etc., will have to be developed separately.

3.5 Statistical evaluation on the variability in efficiency of a media type should be done with a valid sample size. This evaluation is not within the scope of this test method.

3.6 The upper concentration limit of the CNC as specified by the manufacturer should not be exceeded. Exceeding the CNC concentration will understate the challenge concentration due to coincidence counting, thus affecting filter efficiency calculations.

3.7 This is not intended as a method for precise determination of filter efficiency. It is intended as a means for determining if a filter has an efficiency equal to or better than an approximate nominal value.

3.8 Commercially available radioactive neutralizers have pressure limitations. Users should be aware of these limits.

4 Referenced Documents

4.1 None.

5 Summary of Method

5.1 The test sequence consists of three steps:

5.1.1 Static background with filter.

5.1.2 Filter challenge with first monodispersed particle size (see Section 6.6 for particle size test sequence).

5.1.3 Filter challenge with subsequent monodispersed particle sizes.

6 Apparatus and Facility

6.1 *Gas Source* — Clean, dry gas (nitrogen or air) with less than 0.5 ppm moisture and less than 0.5 ppm total hydrocarbons.

6.2 *Particle Detector* — A condensation nucleus counter (CNC) with a counting efficiency of 50% at 0.01 micron, as reported by the manufacturer, is recommended to measure total particle concentration of particles greater than 0.01 micron. The CNC must meet a background level as specified in Section 7.1.2.

6.3 *Test Environment* — Particle challenge testing does not require a clean area. Testing in a Class 100 area is recommended but not required. Refer to Section 6.7 for installation precautions.

6.4 *Configuration for Efficiency Test* — One example of the configuration is shown in Figure 1. The setup shown in Figure 1 is intended only as a guideline. This system consists of:

- an aerosol generation system
- aerosol concentration detectors
- an air flow measuring system
- a filter pressure drop sensor
- the test filters.

6.5 *Test Flow Rate* — Maximum manufacturer's rated flow rate.

6.6 *Challenge Particle Sizes* — Experimentation of various media (e.g., metallic, ceramic, and polymeric) have resulted in most penetrating particle sizes ranging from .05 - .11 micron.[1 2 3 4]

6.6.1 Several monodispersed particle challenge tests shall be done over a range of particle sizes so that testing at the most penetrating particle size is performed. An electrostatic classifier must be used to produce a monodispersed challenge.

6.6.2 Due to the effects of particle loading in relation to filtration efficiency, a clean filter should be used for each particle size challenge. The differential pressure across the test filter should be continuously monitored to eliminate the possibility of particle loading. The following particle increments are a guideline. Smaller increments are achievable and are desirable.

6.6.2.1 Challenge Particle Size In Microns:

- 0.05
- 0.07
- 0.10

6.7 *Sample Installation* — Reasonable precautions shall be taken when installing the test filter to avoid particle contamination of the system from ambient. These precautions may include, but are not limited to: installation in a Class 100 laminar flow area, installation in a purged glove bag or other controlled ambient enclosure, use of a purge flow downstream of the sample point so that all parts of the system are under purge, isolation, or termination of the CNC sample flow, and isolation of the isokinetic sampler exhaust from ambient.

6.8 Customary practices shall be employed for the design of the sampling system. This includes any specialized equipment or procedures recommended by the CNC manufacturer. Every effort should be taken to minimize differences in the particle concentrations of the sampling volume relative to the actual test volume. Care should be taken to provide an adequate exhaust length so that back diffusion of particles does not affect background at 2 times the sampling flow rate. This length will depend upon the particle concentration in the ambient environment and on other factors.

6.9 *Test Particle* — Solid non-volatile particles. Sodium chloride is recommended, but other particles could be used such as polystyrene latex beads (PSL) if sufficiently high concentrations can be generated.

7 Procedure

7.1 *Static Background Test*

7.1.1 Purge the system at a high velocity flush of 100 slm or the maximum flow rate that the system components will allow.

7.1.2 Purge the system at test flow rate (Section 6.5). Measure the particle concentration with clean gas to determine the background concentration. The background count is established when the counter has sampled a minimum of 3 scf (85 sl), and the arithmetic average during the last 3 scf (85 sl) of gas sampled is <2 particles/scf (<0.07 particles/sl). The sample interval shall be 1 minute in duration. Ensure that the background counts are stable or decreasing. If background cannot be achieved after 6 scf (170 sl) have been sampled, there may be a problem with the counter or test apparatus. Past experience has shown this to be an adequate volume of gas to give a satisfactory low level background particle counts.

7.2 *Penetration Test*

7.2.1 An example of the apparatus is shown in Figure 1. The input particle concentration is measured by CNC-B, while the output particle concentration is measured by CNC-A. The pressure and flow rates in both legs should be carefully balanced (by maintaining

[1] *Rubow, K.L., C.B. Davis (1991) "Particle Penetration Characteristics of Porous Metal Filter Media for High Purity Gas Filtration", Proceedings of Institute of Environmental Sciences Annual Technical Meeting*

[2] *Rubow, K.L., and Liu, B.Y.H., Evaluation of Ultra-High Efficiency Membrane Filters, Proceedings of the 30th Annual Technical Meeting, Institute of Environmental Sciences, 1984.*

[3] *Rubow, K.L., Liu, B.Y.H., and Grant, D.C., Characteristics of Ultra-High Efficiency Membrane Filters in Gas Applications; Journal of Environmental Sciences, May/June, 1988.*

[4] *B. Gotlinsky, P. Conner, D. Capitanio, L. Johnson, and S. Tousi, Testing of All-Metal Filters for High Purity Semiconductor Process Gases, Proceedings of the 37th Annual Technical Meeting, Institute of Environmentak Sciences, 1991.*

an identical differential pressure in both legs) to insure that the challenge level is the same.

7.2.2 Set the first and subsequent challenge particle sizes per Section 6.6.

7.2.3 Particle challenge concentrations should be set to the maximum output of the electrostatic classifier for each of the particle size tests (Section 6.6). This will determine the test volume and the duration of the test. Generally this requires generating a polydispersed aerosol having a mean size close to the desired monodispersed aerosol size. Any difference between the flow rate exiting the electrostatic classifier and the test flow rate specified in Section 6.5 will be made up by dilution gas as shown in Figure 1.

7.2.4 The total particle challenge must be limited to 1×10^9 particles per liter of filter rated flow in slm. This is done to limit the effects of a particle cake build-up which would enhance the efficiency of the test filter. The test should be concluded upon exposure to 1×10^9 particles per liter of rated flow or after 10 downstream counts are observed, whichever occurs first.

7.2.4.1 As an example, a 10 liter per minute filter would be challenged in one minute with (10 slm) × (1 minute) × (1×10^9 particles/liter) or 1×10^{10} particles. If the challenge concentration is 1×10^8 particles per liter and the flow rate is 10 slm, then the test would need to last 10 minutes or when 10 downstream particles were observed.

7.2.4.2 The sample interval shall be 1 minute in duration. The sample interval in the penetration test is equivalent to the sample interval in the system background test (Section 7.1.2).

7.2.5 Measure the input and output particle concentration.

7.2.6 Calculate the ratio of output to input particle concentration.

8 Reporting of Test Results

8.1 Raw data shall be reported for each test in the format of a table, including the number of sample intervals, the sampling volume of each interval, the sampling time of each interval, and the total number of particles registered in each interval. In addition, the relevant parameters for each test described in Sections 8.2 and 8.3 should be identified.

8.2 *Static Background Test* — Identify the period of time required to obtain 45 consecutive sampling intervals without a particle being detected for the spool piece and test filter.

8.3 *Penetration Test* — Identify the input concentration, the output concentration, the ratio of output to input concentration (fractional penetration), and the challenge particle size. The most penetrating particle size is the challenge particle at the largest fractional penetration. Care must be taken to distinguish between true penetration and system background counts (see Section 8.5) as measured in Section 7.1.2.

8.4 *Efficiency Class*

8.4.1 If no penetration is observed then report the POU Gas Filter passed a X LRV efficiency test, where X = the maximum detectable efficiency for the test (as defined in Section 2.2). No penetration is defined as when the filter output is not statistically different from the system background (as defined in Section 8.5).

8.4.2 If penetration is observed , then report that the POU Gas Filter failed a X LRV efficiency test, where X is the maximum detectable efficiency for the test (as defined in Section 2.2). Penetration is defined as when the filter output is statistically different from the system background (as defined in Section 8.5).

The LRV defines the number of nines in the efficiency.

Example: A filter with a fractional penetration of 0.00001 has a LRV of 5 and an efficiency of 99.999%

8.5 *Data Reduction*

8.5.1 The statistical analysis is based on the assumption that the particles generated are randomly distributed and are statistically independent of each other. The background counts are independent of the particle performance of the component. The particle counts observed from the test include the counts from the component and the background count.

Let:

$\overline{X}_B$ = average background particle count

$\overline{X}_t$ = average total particle count from test

$\overline{X}_c$ = average particle count generated by the test component

Therefore,

$$\overline{X}_t = \overline{X}_c + \overline{X}_B$$

8.5.2 A statistical analysis of the data is performed to determine the mean, standard deviation, and the standard error for each particle size range.

8.5.3 The sample mean, X, or average of the data for each state is given by:

$$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$

where X_i

is the observed counts for the state and n is the number of samples.

8.5.4 The sample standard deviation is a measure of the variability of the data about the mean. The standard deviation, s, for each state is expressed as:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (Xi - \bar{X})^2}{n-1}}$$

8.5.5 The standard error, Se or standard deviation of the sampling distribution of the mean for each state is given below:

$$Se = \frac{s}{\sqrt{n}}$$

8.5.6 The average particle count for the total number of particles generated, or the sample mean, is an estimation of the population mean. For a 95% confidence level, the population mean, μ_p, will be within two standard errors of the sample mean, or:

$$\mu_p = \bar{X} \pm 2 \ Se$$

8.5.7 In order to determine if there is statistical evidence of the component having an effect on the observed particle count, a test must be conducted to see if the actual difference between the average background count, X_B, and the average test count, X_t, exceeds two standard errors in a distribution of differences between means. The average particle count generated by the test component, X_C, is given by:

$$\bar{X}_c = \bar{X}_t - \bar{X}_B$$

8.5.8 The standard error in a distribution of differences between means is expressed as:

$$S_{ec} = \sqrt{S_{et}^2 + S_{eB}^2}$$

8.5.9 The 95% confidence interval of the test component itself is then determined by:

$$\bar{X}_c \pm 2 \ S_{ec}$$

8.5.10 If this confidence interval includes 0, then this implies that there is not strong statistical evidence of the component having an effect on the observed particle count. If this interval does not include 0, then this implies there is strong statistical evidence that the component does have an effect on the observed particle count.

8.5.11 Present in tabular form the average particle count and the associated 95% confidence limits (as calculated in Section 8.5.9) for each test state. In addition, present the background test data separately as a distinct element.

8.5.12 Calculation of the Efficiency Class

8.5.12.1 The efficiency class shall be calculated in such a fashion that that:

LRV = Log [Input Concentration / $\bar{X}_B + 2S_{eB}$].

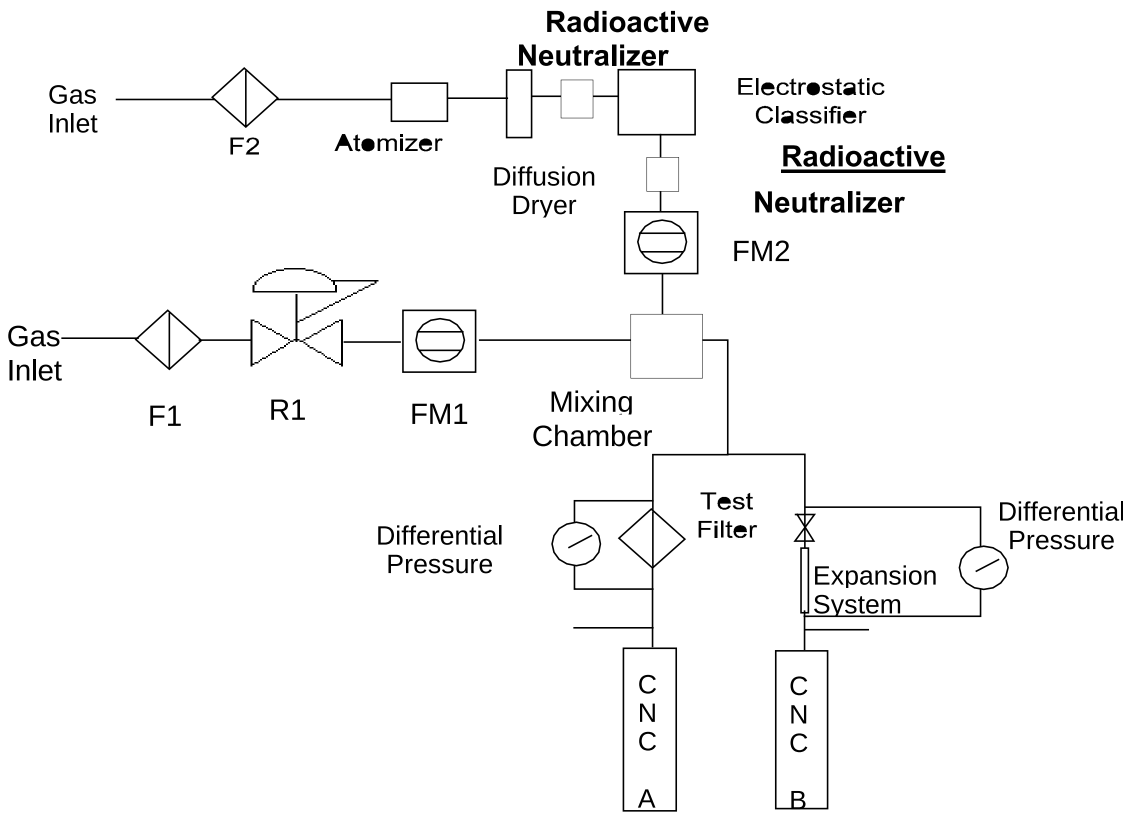

Figure 1
Schematic Diagram of Filter Test System

F1, F2 = 10” PTFE Membrane Filter or Equivalent Filter with Sufficient Flow Capacity (LRV ≥ 9)

R1 = @ 0 - 100 psig Outlet Regulator

FM1, FM2 = Low Flow (0 - 50 slm) Flowmeter

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SEMI F39-0699
GUIDELINE FOR CHEMICAL BLENDING SYSTEMS

This guideline was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org January 1999; to be published June 1999.

1 Purpose

1.1 This guideline establishes terminology, classification, performance characterization, and qualification methods for chemical blending equipment.

2 Scope

2.1 This guideline applies to chemical blending equipment interfaced with Bulk Chemical Distribution Systems (BCDS).

3 Limitations

3.1 This guideline does not cover subject matter concerning chemical distribution capability of some chemical blending equipment, chemical blending methodology, or materials of construction used in this equipment.

4 Referenced Documents

4.1 *SEMI F31* — Guide for Bulk Chemical Distribution Systems

5 Terminology

5.1 *accuracy* — A quantity describing the deviation of the mean blend ratio produced by the chemical blending equipment from the desired constituent ratio.

5.2 *assay* — A term used to determine the amount of a chemical constituent in a blend.

5.3 *baseline contamination level* — The level of impurity measured in the source fluids, including UPW and chemical.

5.4 *batch* — The end quantity of chemical resulting from the blending of the chemical constituents.

5.5 *blending* — Combination of two or more chemicals to create a mixture which contains a desired ratio of constituents. A dilution process by this definition is also a blending process. However, blending is a more general case where UPW is not always one of the constituents. Therefore, the term blending will be used in the remainder of the document.

5.6 *Central Limit Theorem (CLT)* — The CLT is a probability theorem which allows the approximation of normality for any distribution. The CLT applied to chemical blending states that if a sufficient number of random samples are taken from the distribution of all chemical produced by chemical blending equipment, then the average measurement of these samples can be approximated to follow a normal distribution. A rule of thumb for the "sufficient number of batches" is thirty or greater.

5.7 *dilution* — Combination of a concentrated chemical and UPW to create a lower concentration of the aqueous chemical.

5.8 *duty cycle* — The normal percentage of time that the chemical blending equipment is operating.

5.9 *mixing* — Mechanical energy imparted to a combination of two or more chemical constituents used to create a homogenous solution.

5.10 *on-site blending* — Chemical blending equipment used for blending chemical on location of the semiconductor manufacturing facility

5.11 *precision or repeatability* — A quantity describing the degree of achieving the same ratio of chemical constituents in the blend over time.

5.12 *production rate* — The volume of chemical able to be blended and provided to the BCDS per day.

6 Classification

6.1 Batch Blending — The process of chemical blending where the chemical constituents are combined and mixed in a tank before being made available for use.

6.2 Feed-forward Controlled Blending — Blending process which uses information (i.e. incoming chemical assay) of the chemical constituents as the basis for combining these constituents. Examples of feed-forward blending processes include, but are not limited to, those processes that use weight or volume for control.

6.3 Feedback Controlled Blending — Blending process which combines constituents based on measurements of the blended chemical. Examples of feedback controlled blending process include, but are not limited to, those processes controlled by measurements of density, conductivity, and chemical assay (by titration).

6.4 In-line Blending — The process of chemical blending where the chemical constituents are combined in line and are immediately available for use.

7 Performance Characterization

7.1 *Blending Repeatability* :

7.1.1 *Batch Blending*

7.1.1.1 Sample Collection: A sample of at least thirty batches of blended chemical is taken. Assay of this chemical is measured.

7.1.1.2 Calculations: The mean and standard deviation of the batches are computed.

7.1.1.3 Reporting: When reporting repeatability, either of two methods is acceptable. Both methods quote precision in terms of the chemical assay.

7.1.1.3.1 Repeatability at one concentration = mean ± 3σ (where σ is in units of concentration)

7.1.1.3.2 Repeatability in range of concentrations: Individually calculate percent relative standard deviation at 3σ = (3σ / mean) × 100% for representative concentrations within the desired range (30 samples for each concentration, calculate a standard deviation and mean for each concentration). Repeat largest percent relative standard deviations at 3σ and concentration range examined or report percent relative standard deviation at 3σ for each individual concentration.

7.1.1.3.3 Multiple Components: If more than one non-aqueous chemical constituent exists in the blend, the precision for each must be quoted individually.

7.1.2 *In-Line Blending*

7.1.2.1 Sample Collection: At least thirty samples of blended chemical are taken. The time interval between samples must be at least one hour. Assay of this chemical is measured.

7.1.2.2 Calculations: The mean and standard deviation of the samples are computed.

7.1.2.3 Reporting: When reporting repeatability one of two methods is acceptable. Both methods quote precision in terms of the chemical assay.

7.1.2.3.1 Repeatability at one concentration = mean ± 3σ (where σ is in units of concentration)

7.1.2.3.2 Repeatability in range of concentrations: Individually calculate percent relative standard deviation at 3σ = (3σ / mean) × 100% for representative concentrations within the desired range (30 samples for each concentration, calculate a standard deviation and mean for each concentration). Repeat largest percent relative standard deviations at 3σ and concentration range examined or report percent relative standard deviation at 3σ for each individual concentration.

7.1.2.3.3 Multiple Components: If more than one non-aqueous chemical constituent exists in the blend, the precision for each must be quoted individually.

7.2 *Blending Accuracy*

7.2.1 Since calculation of accuracy takes into account both equipment operational parameters (calibration frequency and drift) and also changes in chemical input (feed forward blending), calculation of blend accuracy will not be standardized. However, by definition, a reported accuracy can not be less than blend precision.

7.2.2 *Reporting of Accuracy*

7.2.2.1 Accuracy at one concentration = desired concentration ± 3σ

7.2.2.2 Accuracy in range of concentrations: Report range of concentrations where this accuracy applies and the accuracy in terms of a percentage of the chemical concentration. Report accuracy with statistical significance of 3σ.

7.3 *Production Rate*

7.3.1 All production rates described should reference the duty cycle, i.e. the percentage of time that the equipment is operating to achieve the quoted production rate.

7.3.2 Batch Production Rate = batch volume / time to produce one batch (hours) × 24 hours × duty cycle

7.3.3 In-line Production Rate = flow rate (volume /day) of blended chemical × duty cycle

7.4 *Purity*

7.4.1 Particles — Particle performance should be expressed in the same manner as BCDS (i.e. ≤ x particles / ml @ ≥ 0.y μm)

7.4.2 Trace Metals — Metallic purity performance should be expressed in a similar manner as BCDS. However, blending systems, by definition, have several source materials, which could include water. Each source material contributes to the "baseline contamination level" (equivalent to drum contamination level in BCDS). A volumetric combination (based on the volumetric combination of source materials) of the contamination levels should be used to construct the baseline contamination level.

7.4.3 Ionic Contamination / TOC — Should be expressed in a similar manner as BCDS.

7.5 *Uptime*

7.5.1 MTBA — Mean Time Between Assists should be expressed in the same manner as BCDS

7.5.2 MTBF — Mean Time Between Failures should be expressed in the same manner as BCDS

8 Qualification Methods

8.1 Purity — The purity of the equipment will be qualified in a similar manner to that of BCDS.

8.2 Assay — The assay of each of the chemical constituents ($c_{mean,blend}$) should be compared to that of the customers upper ($UCL_{specification}$) and lower ($LCL_{specification}$) control limits for the chemical assay. The customer specification must be expressed as their desired 3σ limits. The standard deviation for the blend (σ_{blend}) should be determined by the same method described for determining blending repeatability. The number of batches or samples to determine this standard deviation should be agreed upon by the equipment supplier and the customer. The blending unit shall be deemed qualified when both of the following are satisfied for all constituents.

8.2.1 $UCL_{specification} > C_{mean, blend} + 3\sigma_{blend}$

8.2.2 $LCL_{specification} < C_{mean,blend} - 3\sigma_{blend}$

SEMI F40-0699
PRACTICE FOR PREPARING LIQUID CHEMICAL DISTRIBUTION COMPONENTS FOR CHEMICAL TESTING

This practice was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org January 1999; to be published June 1999.

1 Purpose

1.1 This document defines component preparation and pretreatment procedures for chemical test methods used to evaluate liquid chemical distribution system components.

2 Scope

2.1 This document includes preparation procedures that can be applied to components such as tubing, piping, valves, regulators, fittings, gaskets, O-rings, and filter housings.

2.2 This document defines and specifies all of the component pretreatment and analyze preparation procedures for liquid chemical distribution system components common to the test methods listed (see Table 3). Each type of component should be pretreated and prepared according to the procedures of this document before it can be tested using the identified chemical test methods.

2.3 This document defines preparation and pretreatment procedures used for the evaluation of liquid chemical distribution system components in test fluids. This practice is intended for use with 49% HF, 30% H_2O_2, 29% NH_4OH, IPA and ultrapure water. The document defines the purity of chemicals that can be used for leaching and rinsing liquid chemical distribution system components.

3 Limitations

3.1 Although ozonated water is commonly used in ultrapure water systems, no provisions are made in this document for evaluations using ozonated water. Therefore, some of the procedures may not be directly applicable to ozonated water.

3.2 The preparation procedures described in this practice primarily involve static testing including agitation. Dynamic testing, i.e., continuous flow, may alter the chemical test results. Static component preparation procedures are not directly applicable to dynamic testing.

3.3 This preparation procedure applies to ambient temperature only with the exception of ultrapure water which may be tested at ambient temperature and up to 85°C.

3.4 Filter cartridges are not covered in this document due to the requirement for dynamic testing.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *DSC* — differential scanning calorimetry

5.1.2 *FEP* — fluorinated ethylene-propylene

5.1.3 *FTIR* — Fourier transform infrared spectroscopy

5.1.4 H_2O_2 — hydrogen peroxide

5.1.5 *HF* — hydrofluoric acid

5.1.6 *IPA* — Isopropyl alcohol

5.1.7 NH_4OH — ammmonium hydroxide

5.1.8 *NVR* — nonvolatile residue

5.1.9 *PE* — polyethylene

5.1.10 *PFA* — perfluoroalkoxy

5.1.11 *PP* — polypropylene

5.1.12 *PVDF* — polyvinylidene fluoride

5.1.13 *TGA* — thermal gravimetric analysis

5.1.14 *TOC* — total organic carbon

5.1.15 *UPW* — ultrapure water

5.2 *Definitions*

5.2.1 *blank extraction* — A container of test fluid which does not see the component under test. It follows the entire procedure and is handled in the same manner in order to show the background of the lab or test area.

6 Summary of Practice

6.1 This document describes two different component preparation procedures (see Figure 1):

a) procedure for preparing components and collecting a sample for extraction analyses

b) procedure for pretreating or preparing components for bulk polymer analysis.

6.2 Table 1 specifies the flush time, soak time, and container material for extracting leachable contaminants. Sample size requirements for bulk analyses are listed in Table 2.

6.3 This practice should be performed before analysis by industry standard extraction and bulk test methods used to evaluate liquid chemical distribution component. Available industry standard test methods are listed in Table 3 and the Related Documents section.

7 Apparatus and Materials

7.1 *Containers*, as defined in Table 1.

7.1.1 All containers and caps used in component and blank extraction should be thoroughly cleaned. A typical recommended cleaning procedure is outlined in Section 11.3. However, any cleaning procedure is acceptable as long as the subsequent blank extraction yields impurity concentrations that do not exceed 10% of the specification for the material being tested. For example, if a given impurity is specified for a maximum of 1.0 $\mu g/cm^2$, the blank extraction concentration should not exceed 0.1 $\mu g/cm^2$.

NOTE: In situations where the detection limit is greater than 10% of the specification for the polymer material, the detection limit of the instrument converted into $\mu g/cm^2$ will suffice, provided it does not exceed the specification for the material being tested.

7.2 *Test Fluids*

7.2.1 For purposes of this practice, references to water shall be understood to mean ultrapure water as defined by maximum individual metal and anion impurity levels of 0.1 parts per billion by weight 1×10^{-9} (ppbw) or less, total organic carbon (TOC) levels of 10 ppbw or less, nonvolatile residue levels of 0.1 parts per million by weight 1×10^{-6} (ppmw) or less, resistivity of 18 megohm-cm or greater, and reactive silica impurity of less than 1.0 ppb.

7.2.2 References to HF, NH_4OH and H_2O_2 shall be understood to refer to chemicals with a minimum of a semiconductor grade purity and meet the criteria in section 7.1.1. The impurity concentrations of the chemical must not exceed 10% of the lowest anticipated concentration for the analyte(s) of interest.

7.2.3 *Ultrapure Nitric Acid*, less than 1 ppb for each trace metal.

7.2.4 *Ultrapure Hydrochloric Acid*, less than 1 ppb for each trace metal.

7.2.5 *Ultrapure Isopropyl Alcohol*, less than 1 ppb for each trace metal.

8 Precautions

8.1 *Safety Precautions*

8.1.1 This practice may involve hazardous materials, operations, and equipment. This practice does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this practice.

8.2 *Technical Precautions*

8.2.1 The component preparations must be conducted in clean environments that prevent contamination of the components and containers at the parts per trillion level for the analyte(s) of interest. A clean environment may require the use of a cleanroom (for those procedures which can be performed in a cleanroom).

8.2.2 For all testing other than differential scanning calorimetry (DSC), thermal gravimetric analysis (TGA), and Fourier transform infrared spectroscopy (FTIR), the component preparation should take place in a controlled environment to minimize contamination.

9 Sampling and Test Specimens

9.1 The components selected for testing should reflect the current manufacturing capabilities of the supplier.

10 Procedure for Preparing Components and Collecting an Extraction Sample for Analysis

10.1 Component preparation for contaminants that can be leached from liquid chemical distribution components is different from component preparation for bulk polymer analysis. Components are flushed and then soaked to extract surface contamination. Refer to Table 1 for procedures for handling specific components.

10.2 The liquid chemical distribution system components described in this section are divided into two groups:

a) Components that require capping (see Section 9.5).

b) Components that require a container (see Section 9.6).

10.3 Each group is discussed individually. Use Table 1 to determine the appropriate group for each component.

10.4 *General Procedure*

10.4.1 The blank extraction is a container of test fluid without a component which follows the entire procedure and is handled in the same manner. Please consult the specific test method for the number of test fluid samples to be prepared and the statistical treatment. This would include a number of containers for both component and blank extractant. Use cleaned containers that meet the criteria specified in Section 7.1.1. An example of a cleaning procedure is outlined in Section 11.3.

10.4.2 Use UPW to fill and then drain the component or container 10 times. After each fill, leave the water in the component or container for two minutes before draining.

10.4.3 Fill an 11th time with the appropriate test fluid (see Section 2.3); use this fill for the test. Refer to Table 1 to determine the soak time for each component or container.

10.4.4 Agitate once a day for one minute. Orbital shakers or manual agitation can be used, but no foreign materials may contact the test fluid; therefore, stir bars cannot be used. Components and/or containers are to remain sealed during agitation to prevent splashing or spilling. Components in containers (such as gaskets) should remain completely submerged throughout the extraction.

10.5 *Components that Require Capping (Tubing, Piping, Valves, Regulators, and Filter Housings)*

10.5.1 This practice is appropriate for static samples with one end permanently sealed and one end loosely capped. Since the sealing process may contaminate the sample, one end should be sealed prior to precleaning. Use cleaned caps meeting the criteria specified in Section 7.6.1. The cap must be manufactured from the same material as the component or from a compatible material that will not contaminate the sample.

10.5.2 As surfactants and solvents may leave a residue that could alter the test results, do not use them for precleaning.

10.5.3 During sample collection for metal analysis, the components must be acid stabilized to a pH of 2 (approximately 3 drops of concentrated nitric acid per 250 mL of UPW) to stabilize for certain trace metals (i.e., iron and chromium).

10.5.4 *Tubing and piping:* Fill the component with test fluid to within one inch of the top of the component to allow free space for agitation. In the case of tubing or pipes, to maximize the exposed surface area of the pipe to the volume of fluid and to minimize the surface area of the end cap, it is recommended that the ratio of the surface area of the pipe to the surface area of the end cap be 10 or greater. The equation to determine the ratio is 4L/D, where L is the length of the pipe or tubing and D is the diameter.

10.5.5 *Valves, regulators, and fittings:* To allow for maximum fluid volume, fill valves, regulators, and fittings with the appropriate test fluid to within five mL of the top to allow for agitation. Multiple components may be required to obtain the necessary volume for the test. Valves, regulators, and fittings must be capped at both ends. In the case of valves, this practice assumes that normally opened valves will be used.

10.5.6 *Filter housings:* Fill the component with the appropriate test fluid to within one inch of the top of the housing to allow free space for agitation. The inlet and outlet of the housing must be capped.

10.5.7 Example of procedure for components that require capping

10.5.7.1 Clean and prepare 8 covered containers per Sections 10.4.1 and 7.1.1.

10.5.7.2 Flush component and blank extraction containers (3 components and 5 blank extraction containers) according to Section 10.4.2 (rinse 10 times for 2 minutes per Table 1).

10.5.7.3 Fill all components and blank extraction containers with the test media of choice (see Section 2.3 for definition of test media).

10.5.7.4 Soak according to Section 10.4.3 (soak one week per table 1), agitate all components and blank extraction containers once a day for one minute per Section 10.4.4.

10.5.7.5 Decant the contents of the component into 3 remaining empty containers.

10.5.7.6 At completion of this practice analytical tests should be performed on test fluid from each container see test methods noted in Table 3 and related documents section.

10.6 *Components that Require a Container (Gaskets, and O-Rings)*

10.6.1 Containers must have sufficient internal volume to perform the required test. Often, 100 mL of extracted test fluid will be required per test.

10.6.2 Surfactants and solvents may leave a residue that could alter the test results; do not use them for pre-cleaning.

10.6.3 During sample collection for metal analysis, the components must be acid stabilized to a pH of 2 (approximately 3 drops of concentrated nitric acid per 250 mL of UPW) to stabilize for certain trace metals (i.e., iron and chromium).

10.6.4 *Gaskets and O-rings:* A minimum of two grams of component per 100 mL of test fluid is required to perform any of the tests. To concentrate a sample and lower the detection limit of the test method, increase the amount of component per 100 mL of fluid.

10.6.5 Example of procedure for components that require a container

10.6.5.1 Clean and prepare 8 covered containers per Section 10.4.1 and 7.1.1.

10.6.5.2 Place the component into 3 containers per Section 10.6.

10.6.5.3 Flush all containers (3 with components and 5 as blanks) according to Section 10.4.2 (rinse 10 times for 2 minutes per Table 1).

10.6.5.4 Fill all containers with the test media of choice (see Section 2.3 for definition of test media).

10.6.5.5 Soak according to Section 10.4.3 (soak one week per table 1), agitate all containers once a day for one minute per Section 10.4.4.

10.6.5.6 At completion of this practice analytical tests should be performed on test fluid from each container see test methods noted in Table 3 and related documents section.

11 Procedure for Preparing Components for Bulk Polymer Analysis

11.1 Table 2 lists the amount of material required to achieve the indicated level of detection. Obtaining the amount may require using 1) an entire component, 2) a segment of a large component (such as piece of piping or valve), or 3) an appropriate quantity of smaller components (such as O-rings).

11.2 No further pretreatment is required except for inorganic analysis. See Section 11.3.

11.3 *Additional Pretreatment for Inorganic Bulk Analysis*

11.3.1 If the intent of the inorganic analysis is to examine the as-received material from a supplier, no further pretreatment is required.

11.3.2 After the proper amount of the material is obtained, place it in a clean container and clean it using the procedure outlined below.

NOTE: This procedure may also be used to pre-clean containers and caps to meet the criteria specified in Section 7.1.1. If pre-cleaning performance criteria is not achieved with this procedure another procedure should be used or the concentrations, times, and temperatures noted in this procedure could be varied to achieve required result.

11.3.3 Agitate the material in ultrapure IPA for 2 minutes. Drain the IPA from the material and replenish with ultrapure IPA. Allow the material to soak for 30 minutes.

11.3.4 Drain the IPA from the material and replace with UPW. Agitate the material for 2 minutes.

11.3.5 Soak the material in 1:1 ultrapure nitric acid : UPW for 2–4 hours.

11.3.6 Drain the nitric acid from the material and replace with UPW. Agitate the material for 2 minutes.

11.3.7 Soak the material in 1:1 ultrapure HCl : UPW for 2–4 hours.

11.3.8 Drain the HCl from the material and replace with the test fluid. Agitate the material for 2 minutes. Drain the material and replenish with test fluid and agitate for an additional two minutes.

12 Data Presentation

12.1 See Table 3 for a list of the units to report for individual component types. Record the following:

a) Report the test fluid used and test temperature.

b) Report if the components were prepared for testing as received or after the rinse pretreatment.

c) Report the volume of test fluid used.

d) Report the soak time

e) Report the wetted surface area of the component. If the precise wetted surface area is not known please record the assumed or estimated wetted surface area and note it is estimated.

f) If multiple components (such as gaskets, or O-rings) were used, report the total wetted surface area of the components.

g) Report the manufacturer, model number, and lot number (if known) for each component tested.

13 Related Documents

13.1 *ASTM Standards* [1]

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[1] *American Society for Testing and Materials (ASTM). 1916 Race St. Philadelphia, PA 19103.*

ASTM D859 — Standard Test Method for Silica in Water

ASTM D1068 — Standard Test Method for Iron in Water

ASTM D1353 — Standard Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products

ASTM D4327 — Standard Test Methods for Anions in Water by Ion Chromatography

ASTM D4779 — Standard Test Method for Total, Organic, and Inorganic Carbon in High Purity Water by Ultraviolet (UV) or Persulfate Oxidation or Both, and Infrared Detection

13.2 *SEMATECH Documents* [2]

SEMATECH 92010935B–STD — Provisional Test Method for Electrical Resistivity of UPW

SEMATECH 92010936B–STD — Provisional Test Method for the Determining Leachable Trace Inorganics from UPW Distribution System Components

SEMATECH 92010937B–STD — Provisional Test Method for Evaluating Bulk Polymer Samples of UPW Distribution System Components (FTIR Method)

SEMATECH 92010938B–STD — Provisional Test Method for Determining Bulk Trace Metals in Polymer Materials for UPW Distribution System Components

SEMATECH 92010939B–STD — Provisional Test Method for Evaluating Bulk Polymer Samples of UPW Distribution System Components (DSC and TGA Methods)

SEMATECH 92010940B–STD — Provisional Test Method for Determining the Water Retention Capacity of Ion-Exchange Resins Used in UPW Distribution Systems

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[2] *SEMATECH. 2706 Montopolis Dr. Austin, TX 78741.*

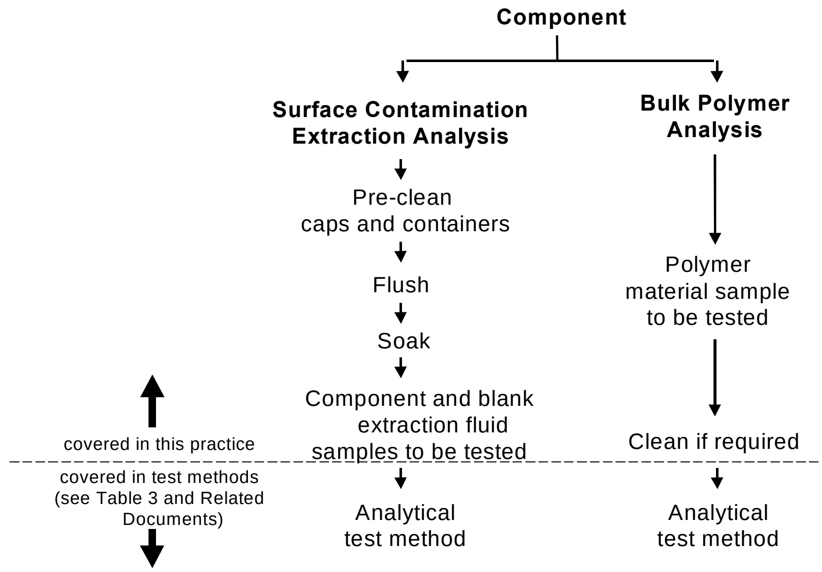

Figure 1
Summary of Practice

Table 1 Component Handling for Extraction Test Preparation

Component	No. of Flushes x Flush Time (min.)	Soak Time	Capped Component or Container	Container Material	Section
Tubing, Piping	10 x 2 min.	1 week	capped component	N/A	9.5.4
Valves, Regulators, Fittings	10 x 2 min.	1 week	capped component	N/A	9.5.5
Filter Housings	10 x 2 min.	1 week	capped component	N/A	9.5.6
O-rings, Gaskets	10 x 2 min.	1 week	container	PFA FEP PP glass (see NOTE*)	9.6.4

***** NOTE: The container and transfer vessel materials used depend on the test to be performed. Use the following materials for the noted test methods.

Test Method	**Material**
TOC, NVR	glass
anions	PP, glass
inorganics, resistivity, silica	PFA, FEP

Table 2 Material Requirements for Bulk Analysis

	Inorganics	FTIR	Thermal Analysis	Water Absorption
Weight (gms)	1–2	< 5	0.007–0.01	10
Detection Limit	0.1 ppm	N/A	N/A	0.1%

Table 3 Reporting Units for Aqueous Liquid Components

Test Method	Aqueous Liquid Component	Reporting Units
Leachable Trace Inorganics, Anions, TOC	tubing, piping, valves, regulators, fittings, gaskets, O-rings, filter housings	$\mu g/cm^2$
Bulk Trace Inorganics	tubing, piping, valves, regulators, fittings, gaskets, O-rings, filter housings	$\mu g/cm^2$
Nonvolatile Residue	tubing, piping, valves, regulators, fittings, gaskets, O-rings, filter housings	$\mu g/cm^2$

SEMI F41-0699
GUIDE FOR QUALIFICATION OF A BULK CHEMICAL DISTRIBUTION SYSTEM USED IN SEMICONDUCTOR PROCESSING

This Guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org January 1999; to be published June 1999.

1 Purpose

1.1 This Guide sets forth a logical and systematic approach to the qualification of a Bulk Chemical Distribution System that may be used by users and suppliers as a basis for developing site-specific BCDS specifications and performance criteria.

2 Scope

2.1 The qualification process includes evaluation of chemical from the chemical source, the fluid transfer system, the distribution piping, the day tank, as well as other intermediary points of transfer and storage that may be included in the qualification plan.

2.2 This guide assumes that the BCDS has been installed per the BCDS manufacturer's recommendations and the customer's specifications, and has been appropriately leak tested and shown to meet all requirements of mechanical and physical integrity up to the POU.

2.3 BCDS are typically tested for particle levels and trace metal impurities according to specified levels agreed upon in advance. For certain applications or specific chemicals, other testing may become incorporated in the qualification process. These other tests may include assay analysis, anion analysis, TOC analysis, moisture analysis, etc.

3 Limitations

3.1 This guide does not define the test methods that should be used for evaluation of samples taken during the qualification process, or distinguish test methods that will generate accurate and reliable results from those that will not generate accurate or reliable results.

3.2 This guide does not define or describe the sampling methodologies that are required in order to physically take a representative and a non-contaminated batch sample. However, appropriate sampling procedures and equipment must be used consistent with the actual specifications.

3.3 This guide does not define the type of containers that should be used for sampling. Pretreatment of containers is necessary to assure that the data generated by testing actually measures the chemical being delivered to the process tool and not the impurities in the container itself, from the environment, or from human handling.

3.4 This guide does not address the type, level, or frequency of testing necessary and appropriate for ongoing monitoring of a BCDS.

3.5 This guide does not address the special case of a system designed and used for the generation and distribution of high purity water used in semiconductor processing.

3.6 This guide does not address the testing and prequalification of materials, subassemblies, or components used in a BCDS.

3.7 This guide does not address the protocols and requirements defined by the manufacturer concerning the installation of the BCDS.

3.8 This guide does not define the actual specifications generally negotiated between the user and the manufacturer of the BCDS, against which chemical samples are tested and qualification is passed.

3.9 This guide does not address the qualification process for chemicals through the process tool. While the sampling considerations and timing make the initial tool qualification a natural adjunct to the BCDS qualification, the responsibility for this task generally falls within a different jurisdiction and is generally handled separately.

4 Referenced Documents

4.1 *SEMI Documents*

4.1.1 *SEMI S-2* — Safety Guideline for Semiconductor Manufacturing Equipment

4.1.2 *SEMI E-4* — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

4.1.3 *SEMI F31* — Guide for Bulk Chemical Distribution Systems

4.2 *Other Document*

4.2.1 *SIA National Technology Roadmap For Process Chemicals*[1]

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *BCDS* — Bulk Chemical Distribution System

5.2 *Definitions*

5.2.1 *pickling* — To condition the BCDS by exposing to an aggressive chemical that extracts impurities from the internal surfaces of the system.

5.2.2 *sample* — Sample taken from a system into a sampling container and measured off-line.

6 Pre-Chemical Qualification

6.1 Advantage of Pre-Chemical Qualification — The pre-chemical qualification is designed to ensure that the piping systems and storage tanks are able to accept chemicals. This step is often initiated after the UPW system is functional and an acceptable resistivity is achieved but before chemicals are authorized to be brought on-site. Although UPW does not extract high levels of metallic and ionic impurities from the BCDS materials of construction, this step can ensure that the BCDS and distribution piping is free of any gross contamination that may have been introduced into the system during installation. In addition, the UPW flush can be effective for the elimination of some types of particles.

6.2 Particle Qualification — The BCDS is flushed with UPW and the levels of particles are measured using an on-line optical particle counter. The steps followed include:

6.2.1 Install an acceptable UPW water filter element(s) per the filter and BCDS manufacturer's specifications.

6.2.2 Fill the BCDS with UPW and recirculate internally to ensure that all piping is filled with UPW.

6.2.3 Begin sampling to a liquid particle counter downstream of the filters either at the outlet of the BCDS, the POU, or both. Follow an approved particle counting sampling procedure.

6.2.4 Continue recirculating and flushing until the particle concentrations in the desired channel or channels are observed at levels below the agreed-upon specification. An example of typical specification is the average of five consecutive ten minute readings of <X particles/ml @ ≥ Y micron.

[1] *Semiconductor Industry Association, 181 Metro Drive, Ste 150, San Jose, CA 95110, USA*

6.3 Metallic Qualification — After reaching the particle specification for the UPW, a sample of UPW may be taken for trace metal analysis. This sample can be taken at the outlet of the BCDS, at an end point sample station and/or at the POU. An appropriate sample bottle precleaned for this test should be used to collect a sample. The sample bottle should be preconditioned before use and contamination-free techniques used for the actual sampling.

6.3.1 The steps to follow are:

6.3.1.1 Fill the sample bottle with the required volume for the analytical method to be used. The volume varies depending on analytical procedures and lab instrumentation.

6.3.1.2 Send samples to a designated laboratory capable of performing trace metal analysis. Use only a laboratory that has experience with these types of samples and that can test reliably in the sub-ppb range. The number of elements and concentrations that are to be analyzed will vary depending on customers' requirements.

6.3.1.3 Evaluate data and compare to the agreed-upon specification. A typical specification is <X ppb total and <X ppb per element.

6.3.1.4 If the trace metal specification is not met, drain or flush the entire BCDS and distribution piping and repeat the process.

6.3.1.5 If a maximum level of impurities is desired, a sample of the UPW used to charge the system should be tested to establish a baseline and to ensure that the incoming UPW is not the source of high impurities.

6.3.1.6 Once the BCDS has been qualified for particles and trace metals in UPW, the qualification of the BCDS in Chemical may be initiated.

7 Chemical Conditioning of The System

7.1 Advantages of Conditioning the System — Another precleaning step that may be used independently or in conjunction with a UPW flush is to condition the BCDS by actively flushing it with an aggressive chemical that extracts impurities from the internal surfaces of the system. This step is sometimes referred to as "pickling" the system. This extra step can help minimize the amount of time consumed in the qualification process by utilizing a chemical with more aggressive extraction properties than the actual chemical to be used in the line, thereby increasing the rate at which impurities are removed. This can shorten the amount of time needed until the actual chemical can be put into the line and shown to meet the qualification specifications. Since a goal of a well-designed qualification protocol is to minimize the amount of high purity chemical flushed to drain during the qualification process, this approach may also prove to be more cost effective depending on the cost of the chemical used for pickling, compared to the cost of the process chemical designated for use in the line.

7.2 Conditioning With Same Chemical — A variation on the above approach is to "pickle" the system with the process chemical that is intended to be used in the BCDS line a 24-72 hour soak period and flushing the chemical to drain. While the process chemical may not be as aggressive in cleaning up the line, this approach has the advantage that the extracted metals have the same fingerprint as those that might otherwise be observed during the final qualification testing, and the final qualification may be done immediately following this step, without further preparation.

7.3 Testing the Preconditioning Chemical — Rather than relying on an arbitrary or predetermined lengths of time for preconditioning the BCDS, test samples are often taken and analyzed to ensure that the required level of impurities has actually been obtained. This testing is often commissioned by the equipment manufacturer and not reported to the customer as part of the BCDS qualification. Indicator elements are often analyzed that are either of particular concern in the process chemical, or elements such as Ca, Cr, Cu, Fe, Mg, Na, Ni, and Zn, that are known as common impurities in chemicals and that are also highly detrimental in semiconductor processing.

7.4 Conditioning Procedure — The three most common chemicals (HCL, HF, and HNO3) used for precleaning the BCDS are aggressive in extracting metallic impurities and particles. The steps followed include:

7.4.1 Install an acceptable chemical filter element(s) per the filter and BCDS manufacturer's specifications.

7.4.2 Fill the BCDS and distribution piping with the chemical of choice and recirculate internally to ensure that all piping is filled. This may include all distribution piping. Let the chemical soak the materials of construction in a static manner for a period of 24 to 72 hours, or continue recirculating the chemical as a closed loop for the same amount of time.

7.4.3 Flush the chemical from the system.

7.4.4 Depending on the chemical used, a UPW rinse step or an inert gas purge step for drying may be required prior to filling the system with the actual chemical for the qualification testing.

Note: The precleaning chemicals used may add undesirable contaminants (i.e. F^- from Hydrofluoric acid, Cl^- from hydrochloric acid, etc.). Therefore, if any of these chemicals are used, additional testing may be required to determine that these materials have not added contaminants in excess of any specification. These contaminants may be tested in the UPW rinse step or in the final chemical qualification step.

7.5 Solvent Systems — The type of chemical used for flushing solvent BCDS systems is different than that used for oxidizers and corrosive chemicals since solvent systems can be made from stainless steel and metal materials for reasons of safety and chemical compatibility. Generally, IPA, or the chemical to be used in the system, is used for the aqueous pre-clean step in flushing a system where solvents are to be used.

8 Final Chemical Qualification

8.1 Initial Considerations — Notwithstanding any of the steps taken to prepare the BCDS for qualification testing, certain issues should be considered prior to starting any sampling required in the qualification process:

8.1.1 Determination about the adequacy of the sampling points. — The sampling points are generally coincident with the location of pre-existing sample ports on the Valve Manifold Box, day tank and other distribution points. The adequacy of the sampling points depends on their accessibility, environmental controls, ability to flush prior to sampling, and safety considerations.

8.1.2 Adequacy of data. — Due to sampling error, possibility of environmental contamination, handling problems, and impurities in sampling containers, samples should be taken in duplicate or triplicate, with two samples sent to the lab for testing and one sample retained in case of a dispute.

8.1.3 Use of proper precleaned sampling containers. — Sampling containers must be chemically compatible and precleaned in a manner consistent with the desired specification level for impurities. Sample bottle preparation differs depending on the type of testing to be performed.

8.1.4 Use of a contamination-free sampling device for samples pulled from an open vessel or a drum.

8.1.5 Proper training for personnel assigned to sampling. — The proper training is required to ensure that personnel charged with sampling follow appropriate safety and contamination-free protocols.

8.2 Particle Qualification — For most accurate results, particle levels should be measured on-line with a optical particle counter capable of measuring the size of particle that is included in the guaranteed specification. Batch samples may be taken and measured for particles in a lab, but special care is needed to prequalify containers used for this sampling, and data integrity may be compromised for the smallest sized particles due to various contamination sources. An example of a protocol generally followed to measure particle on-line includes:

8.2.1 Remove all UPW in the BCDS and distribution piping.

8.2.2 Remove UPW filters or replace incompatible chemical filters if present.

8.2.3 Install specified filter element per the BCDS and filter manufacture's specifications.

8.2.4 Commission the BCDS and distribution piping with the process chemical.

8.2.5 Recirculate chemical through the BCDS and through all POU to drain.

8.2.6 Drain all chemicals from the BCDS and distribution piping.

8.2.7 Refill entire system with chemical and begin circulation through filters and out to POU to drain.

8.2.8 Begin sampling to a liquid particle counter downstream of the filters either at the outlet of the BCDS, the POU, or both. Follow a prescribed particle counting sampling procedure.

8.2.9 The number of particle samples and sample duration time should be calculated based on the total volume of chemical desired to be examined by the particle counter. A "sufficient" volume of chemical should be examined by the particle counter during the qualification period. As an example, the particle concentration could be measured over at least a five-hour period with thirty consecutive ten-minute samples taken. In this example, the average of the last consecutive 30 samples would be calculated and compared to the specification.

8.2.10 The particle concentration is considered acceptable if the average is less than the specification.

8.3 Metallic Qualification — Metallic impurities are generally specified both in terms of level of impurity by element and total amount of impurities. The customer's specification generally lists each element to be included in the analysis or may refer to the list of elements published by SEMI for each chemical at different purity grades. The maximum impurity levels may be described as an absolute value (e.g. 1ppb maximum impurity), or in terms of the quantity of impurities that may be added by the BCDS including the distribution piping. This amount of "total adders" is determined by measuring the impurity levels of the incoming chemical from the storage or supply vessel compared to the purity level of the chemical at the end point sample station or POU. The number of samples and location of samples vary depending on the type of specification. When qualifying to a “metallic impurities added” specification, a sample must be taken from the incoming chemical supply drums for an incoming baseline. The testing protocols includes:

8.3.1 Precondition all sampling bottles before use and follow appropriate sampling protocol.

8.3.2 Send samples to a lab for trace metal analysis specifying the level of testing required and the number of elements to be tested. The level of testing required depends on the agreed upon specification. As a rule of thumb, the detection limits of the analysis should be at least 10X's lower than the impurity level to be achieved for each element. In addition, the lab should follow high standards of quality control for trace metal analysis including analysis in duplicate, duplicate blanks, use of internal standards, instrument calibration using primary standards, and QC checks.

8.3.3 Review the data that is reported and compare it to the customer requirement.

8.3.4 If the system does not meet the specification then repeat the procedure until the system is qualified.

8.3.5 Where maximum levels of impurities are specified, a sample of the incoming chemical should either be measured as part of the qualification process, or retained, to ensure that the incoming chemical is not a significant source of contamination.

8.3.6 For purposes of metallic qualification, soak periods similar to those referenced in Section 7.2 are recommended.

9 Other Considerations

9.1 Accelerated Qualification Techniques — Although process chemicals such as hydrofluoric and hydrochloric acid may reach acceptable levels of purity after a few weeks in the BCDS, other chemicals such as sulfuric acid and ammonium hydroxide extract impurities much more slowly and significant levels of impurities are observed even after several months. The BCDS conditioning process described above is one approach to preleaching impurities from the BCDS. Other variations include combinations of static and dynamic rinses and emphasis on the use of dilute HF as the aqueous preclean chemical that is particularly effective for iron removal, however, it contributes high levels of fluoride which may be a concern for some qualification processes.

9.2 Specialty Chemicals — Certain CVD chemicals have high levels of organics which raise concerns about chemical decomposition, residues and particulate formation. These concerns may require customized approaches to the design of a BCDS qualification. For example, reservoir replacement for these types of chemicals with vapor pressure from 1-5 Torr and above may require the use of vacuum less than the vapor pressure of the chemical whereas low vapor pressure chemicals with vapor pressures from 1-5 Torr, and viscous materials, may require a solvent purge. In addition, purging and pickling of he BCDS and chemical delivery lines should be performed per Sections 7.1 and 7.2. CAUTION: UPW introduced into the lines frequently interacts with the CVD chemicals causing decomposition.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F42-0600
TEST METHOD FOR SEMICONDUCTOR PROCESSING EQUIPMENT VOLTAGE SAG IMMUNITY

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on March 2 and April 10, 2000. Initially available on www.semi.org May 2000; to be published June 2000. Originally published June 1999.

1 Purpose

1.1 The purpose of this document is to define the test method used to characterize the susceptibility of semiconductor processing, metrology, and automated test equipment to voltage sags.

2 Scope

2.1 This document defines the testing procedures and test equipment required to characterize the susceptibility of equipment to voltage sags by showing voltage sag duration and magnitude performance data for the equipment.

NOTE 1: Characterizing equipment voltage sag immunity allows for the identification of tolerances, if any, that may exist between the actual equipment immunity and any one or more voltage sag performance specifications.

2.2 This test method is intended for, but not limited to, the following equipment types:

- Etch equipment (Dry & Wet)
- Film deposition equipment (CVD & PVD)
- Thermal equipment
- Surface prep and clean
- Photolithography equipment (Stepper & Tracks)
- Chemical Mechanical Polishing equipment
- Ion Implant equipment
- Metrology equipment
- Automated test equipment

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not address testing for over-voltage conditions.

3.2 International, national and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 *IEEE Standard* [1]

IEEE 1250 — Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Definitions*

5.1.1 *device under test (DUT)* — the semiconductor process, metrology, or automated test equipment intended to be tested, including the equipment mainframe and all subsystems whose electrical power is directly affected by the operation of the equipment's EMO system.

5.1.2 *emergency off circuit (EMO)* — a control circuit which when de-activated, places the equipment into a safe shut down condition and will restrict all hazardous potentials to the main power enclosure. This is a state in which all hazardous voltage has been removed from the equipment, all hazardous production materials flow has been stopped, any radiation sources de-energized or totally contained, any capacitors grounded, all moving parts stopped, internal and external heat sources shut off, and the equipment presents minimum hazard to personnel or the facility. [SEMI S2]

5.1.3 *point of connection (POC)* — the point where the facility utility connects to the exterior of the equipment.

5.1.4 *ride-through capability* — the ability of equipment to withstand momentary interruptions or sags [IEEE 1250]. Also known as voltage sag immunity.

1 The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA

5.1.5 *sag generator* — test apparatus capable of reducing voltage supplied to the device under test for specific time durations.

5.1.6 *voltage sag* — an rms reduction in the ac voltage, at power frequency, for durations from half-cycle to a few seconds [IEEE 1250]. Also known as voltage dip.

6 Test Apparatus

6.1 *Data Acquisition System (DAS):* The DAS will allow monitoring of the device under test and selected subsystems during the test. The DAS must measure the voltage and current at least two cycles (40/33 ms) before, during, and at least two cycles (40/33 ms) after the voltage sag event. The DAS must have the performance characteristics defined in Table 1.

NOTE 3: (40/33 ms) refers to 40 ms at 50 Hz or 33 ms at 60 Hz.

Table 1 Data Acquisition System Performance Requirements

Parameter	*Requirement*
Measurement Accuracy	± 3 percent of reading
Minimum Sample Rate	900 Hz
Minimum Number of Analog Inputs	As required by the Test Plan (see Section 10.1.4)

6.2 *Digital Volt Meter (DVM)* — A digital meter with current and voltage measurement probes. Minimum performance requirements of 1% accuracy, true rms, and resolution of 3 1/2 digits.

6.3 *Sag Generator* — The sag generator must be capable of providing voltage sags of controlled magnitude and duration relative to the nominal supply voltage of the DUT. The sag generator must be able to create voltage sags over the range of durations and magnitudes as required. The sag generator must be capable of producing independent output voltages on each phase of the load. The sag generator must have the performance characteristics in Table 2 (see Related Information 1).

Table 2 Sag Generator Performance Requirements

Parameter	*Requirement*
Insertion loss (the difference between sag generator input and output voltages when set to 100% of nominal)	Less than 1.5%
Change in output voltage as load is varied from 0–100% (steady state load regulation)	± 5%
Output current capability	As required by the DUT.
Capability to supply inrush current	Not to be limited by the sag generator.
Under all conditions, the maximum deviation from required voltage (dynamic load regulation)	Less than ± 10% for not more than 1 cycle (20/17 ms).

7 Safety Precautions

NOTE 4: The following are safety guidelines for voltage sag testing and as such should be considered only recommendations since regional safety regulations vary. International, national and local codes, regulations and laws should be consulted to ensure that the equipment and procedures meet regulatory requirements in each testing location.

7.1 Work should be conducted in accordance with industry standard safety procedures. Since panels may need to be open in order to connect voltage probes and route power leads to and from the sag generator, this work is classified as Type 2 Energized Electrical Work per SEMI S2. Test equipment manufacturer's safety recommendations should be followed.

7.2 *Worker Safety*

7.2.1 During testing lock and tag (lockout/tagout) procedures should be followed to control hazardous energy (reference appropriate regional regulations and requirements). No circuit should be connected or wired when electricity is present. This includes power connections as well as the connection of various monitoring probes.

7.2.2 The area immediately surrounding the device under test (DUT) should be cordoned off and appropriate signs like "Test In Progress" should be posted.

7.2.3 Appropriate personal protective equipment should be worn at all times.

7.2.4 Only authorized personnel should be allowed within the cordoned off test area.

7.2.5 Work should be done as described in the test procedure (see Section 10).

7.2.6 Proper connections should be traced and verified before energizing.

7.3 *Equipment Safety*

7.3.1 The sag generator should have a fail-safe design.

NOTE 5: Subjecting equipment to repeated voltage sags of less than 80% nominal for longer than 3 seconds may damage equipment.

7.3.2 The sag generator should be protected by an appropriately sized branch circuit breaker at the utility power source. This will protect the sag generator and DUT from short circuits and overcurrent conditions.

7.3.3 Every effort should be made to protect the DUT. As with other equipment tests damage to the DUT is possible. Although only a remote possibility, the equipment owner should be made aware of the potential for damage.

8 Sampling and Test Specimens

8.1 Characterization tests are conducted on samples of production articles, not on each item produced. Characterization tests apply to equipment that is manufactured to a single design either in multiple quantities or one-of-a-kind. The equipment selected for testing should reflect current production models of the supplier.

8.2 The intent of this document is to make reasonable efforts to test the semiconductor process, metrology, and automated test equipment as a complete operating system under the actual intended conditions of end use. To simulate the worst-case condition, the tests described in this document should be performed during the most sensitive process mode of the equipment as determined by the equipment supplier.

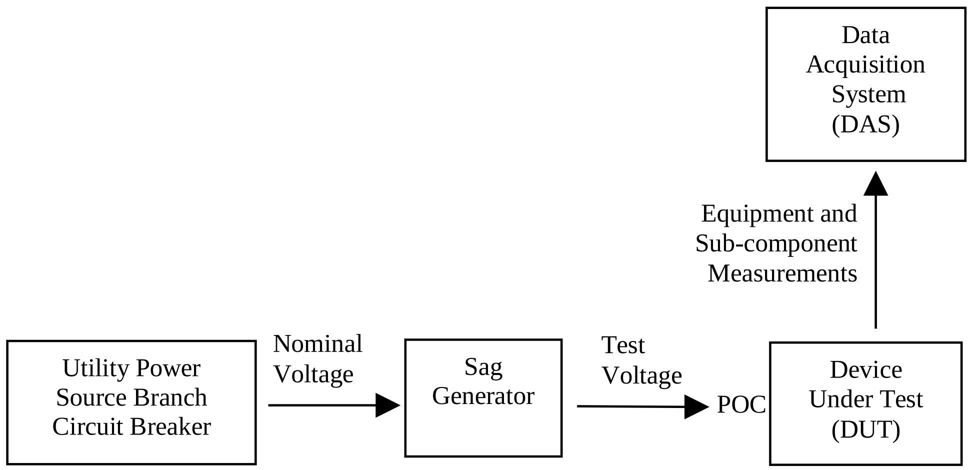
9 Test Setup

9.1 The test setup should consist of a sag generator and a data acquisition system as shown in Figure 1.

9.2 When the current required by the DUT is within the sag generator's rating, the sag generator shall be connected between the incoming utility power source and the point of connection (POC) on the DUT. If the current required by the DUT is greater than the rating of the sag generator, then individual subsystems of the DUT can be tested separately.

9.2.1 If DUT subsystem testing is required due to the limitation of the sag generator, each subsystem must be tested independently with the other parts of the DUT operating. Tested in this manner, any interlocks or alarms that might activate during the test will be apparent. Testing the DUT main power module may require providing power to only the main power module, leaving the subsystems turned off. After the characteristics of the DUT main power module EMO circuit are known, testing of DUT subsystems can begin as described.

9.2.2 Power down the DUT.



NOTE: Single-phase test fixture is shown for clarity.

Figure 1
Test Setup

9.2.3 De-energize and lockout/tagout the DUT POC.

9.2.4 De-energize and lockout/tagout the voltage supply at the DUT utility power source branch circuit breaker.

9.2.5 Identify the utility power source branch circuit breaker to be used to power the sag generator, then, turn off and lockout/tagout this device.

9.2.6 Following the sag generator manufacturer's instructions, connect the input of the sag generator for each phase, ground, and neutral (if required) to the utility power source branch circuit breaker identified in Section 9.2.5.

9.2.7 Following the sag generator manufacturer's instructions, connect the output of the sag generator to the DUT POC.

9.2.8 Following the DAS manufacturer's instructions, connect the DAS channels to the appropriate measurement points on the DUT. The data acquisition measurement points should be defined in the test plan (see Section 10.1.4). Typical data acquisition measurement points for semiconductor equipment are listed in Table 3.

Table 3 Typical Data Acquisition Measurement Points

No	*Data Acquisition Measurement Points*
1	Ia, phase A current
2	Ib, phase B current
3	Ic, phase C current
4	Va-n, phase a-n voltage
5	Vb-n, phase b-n voltage
6	Vc-n, phase c-n voltage
7	Instrument Power Supplies output voltage
8	Emergency Off Relay contact
9	Equipment power contactor contact
10	Equipment controller power supplies output voltage

9.2.9 During all voltage sag tests, the output of the sag generator must be monitored by the DAS system. The magnitude of the DAS monitored sag waveform must be used to determine the magnitude of the actual event since the magnitude may vary from the pre-sag setting on the test equipment.

9.2.10 Visually inspect all connections.

9.2.11 Remove the lockout/tagout at the sag generator utility power supply branch circuit breaker.

9.2.12 Energize the sag generator's utility power source branch circuit.

9.2.13 Initialize the sag generator system and set the output for 100% of the DUT nameplate nominal voltage.

9.2.14 Using a digital voltmeter, measure and record the phase voltage(s) at the output of the sag generator.

9.2.15 Remove lockout/tagout at the DUT POC.

9.2.16 Energize the DUT.

9.2.17 Bring the DUT on-line in an idle state.

9.2.18 Using a digital voltmeter, measure and record the phase voltage(s) at the output of the sag generator. If needed, adjust the output of the sag generator for 100% of the DUT nameplate nominal voltage.

9.2.19 Set the sag generator for a 95% of DUT nominal, 10 cycle (200/167 ms) sag voltage on one phase.

9.2.20 From the sag generator controller, trigger the sag event.

9.2.21 From the DAS, verify that the test sag event is within the specified tolerance.

9.2.22 From the DAS, verify that all monitoring points are recording the expected status information.

10 Test Procedure

10.1 In order to arrive at meaningful and comparable results from voltage sag immunity testing on semiconductor equipment the following steps should be followed.

10.1.1 The test engineer should first study and understand the DUT power flow and safety interlocking systems of the DUT.

10.1.2 The test engineer should then determine the purpose of the test (e.g. To characterize the susceptibility of the DUT to voltage sags within a defined duration range and to a defined minimum voltage magnitude).

10.1.2.1 The test engineer should define the duration range minimum and maximum over which the test voltage sag should be applied to the DUT (e.g. 0.05 seconds to 1.0 seconds, as described in voltage sag ride-through specification, etc.).

10.1.2.2 The test engineer should define the voltage magnitude minimum(s) that should be applied to the DUT over the test duration range (e.g. 0 volts nominal for maximum duration, as described in voltage sag ride-through specification, etc.).

10.1.3 The test engineer should define that testing is complete for each phase mode when either an equipment interrupt occurs at the minimum test duration regardless of the voltage magnitude, or, the test is conducted at the defined minimum voltage magnitude without equipment interrupt.

10.1.4 Based on the knowledge gained in the study of the DUT and the purpose of the test, the test engineer should prepare a specific Test Plan that references this test method with date of issue and includes, at a minimum:

- identify the most sensitive process mode and the process mode(s) to be used during tests
- minimum sag voltage to be applied (e.g. 0%, 50%, etc.)
- sag voltage incremental change not greater than 5% (e.g. 5%)
- maximum sag duration at each sag voltage (e.g. determined by voltage sag ride-through specification, potential for DUT damage, etc.)
- sag test durations (e.g. 0.05, 0.2, 0.5, 1.0 seconds)
- phase modes required (e.g. phase-to-neutral, phase-to-phase)
- point-on-wave of the sags (location on the sine wave where voltage sag begins): if controllable, set at 0°. If not controllable, noted as such.
- data acquisition measurement points (e.g. Table 3).

10.2 The following test procedure should be conducted in both the DUT idle state and the DUT's most sensitive process mode (see Section 8.2).

10.3 The following test procedure should be conducted with the sags applied in each phase mode identified in the Test Plan (see Section 10.1.4).

10.3.1 For single-phase loads, the sags should be applied from phase-to-neutral, for a total of one mode.

10.3.2 For three-phase loads without a neutral conductor, the sags should be applied from phase-to-phase between each pair of phases, for a total of three modes.

10.3.3 For three-phase loads with a neutral conductor, the sags should be applied from phase-to-neutral for each phase, and from phase-to-phase between each pair of phases, for a total of six modes.

10.4 Using a DVM, measure and record the actual test site voltages at the line side of the sag generator, phase-to-neutral (if available) and phase-to-phase (if available).

10.5 Verify that the test setup is complete (see Section 9).

10.6 Set the sag generator to 100% of the DUT nameplate nominal voltage. Cycle through the following test procedure.

10.6.1 Set the sag generator to the next lower sag voltage based on the sag voltage increment determined in the Test Plan, not greater than 5% (see Section 10.1.4).

10.6.2 Set the sag generator to the minimum sag duration for this sag voltage in the Test Plan (see Section 10.1.4).

10.6.3 Trigger the sag event. Record the results, including the magnitude (sag depth) and duration.

NOTE 6: It is advantageous to record additional detail, such as DAS waveforms, if a DUT interruption occurs.

10.6.4 Set the sag generator to the next longer sag duration for this sag voltage in the Test Plan (see Section 10.1.4)

10.6.5 Trigger the sag event. Record the results, including the magnitude (sag depth) and duration.

10.6.6 Repeat Sections 10.6.4 thru 10.6.5 until all durations are complete for this sag voltage magnitude per the Test Plan, then, continue to Section 10.6.7.

10.6.7 Repeat Sections 10.6.1 thru 10.6.6 until all sag voltage magnitudes are complete for this phase mode per the Test Plan, then, continue to Section 10.6.8.

10.6.8 If required, reconfigure the test setup for the next phase mode and repeat Sections 10.6.1 thru 10.6.7 until the test is complete for all phase modes, then, continue to Section 10.6.9.

10.6.9 If required, return the test setup to the original phase mode and repeat Sections 10.6.1 thru 10.6.8 until the test is complete for all process modes (e.g. idle state, most sensitive process mode).

11 Interpretation of Test Results

11.1 The injection of voltage sags into semiconductor equipment can lead to numerous shutdown mechanisms. Typical semiconductor equipment voltage sag shutdown mechanisms include EMO circuitry, instrument and controller power supplies, motion control drives, and voltage monitoring relays.

11.2 The shutdown or dropout of equipment components is best identified when monitored by a DAS that is tightly coupled to the control of the sag generator. Figures 2 and 3 display the shutdown of a power supply during a 55% of nominal 10-cycle (200/167 ms) voltage sag.

11.3 Figure 2 displays the actual voltage sag output from the sag generator and Figure 3 displays the output of the power supply. With the DAS it can be seen that the power supply output begins to decay 3 cycles (60/50 ms) into the 55% of nominal sag event, causing the DUT to interrupt.

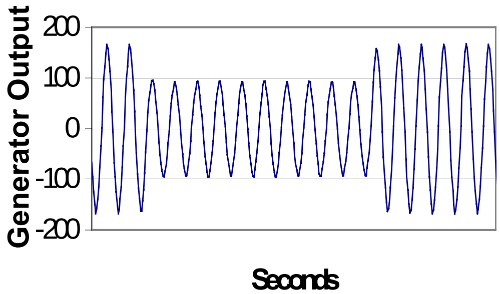


Figure 2
Sag Generator Output

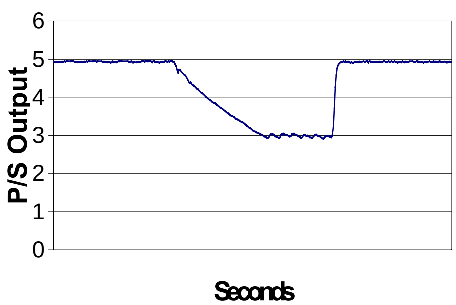


Figure 3
Power Supply Voltage Sag Shut Down Example

12 Reporting Test Results

12.1 Report the specific test plan used and, if used, the voltage sag ride-through specification.

12.2 Report the manufacturer, model number, revision (if known) and process application for the DUT.

12.3 Report the type of sag generator and the accuracy of the test apparatus.

12.4 Report the outcome of the voltage sag testing in both a tabular form (see Tables 4 and 5) and plotted on a graph(s), voltage magnitude (Y axis) and duration (X axis). Separate graphs should be plotted in order to represent the results of the single-phase testing and the phase-to-phase testing. If used, overlay a plot of the voltage sag ride-through specification onto the voltage sag testing outcome graph(s) (see Figures 4 and 5).

12.5 Report the outcome of the sag event including the cause of the DUT interrupt (e.g., EMO relay dropped out, power supply shutdown, etc.).

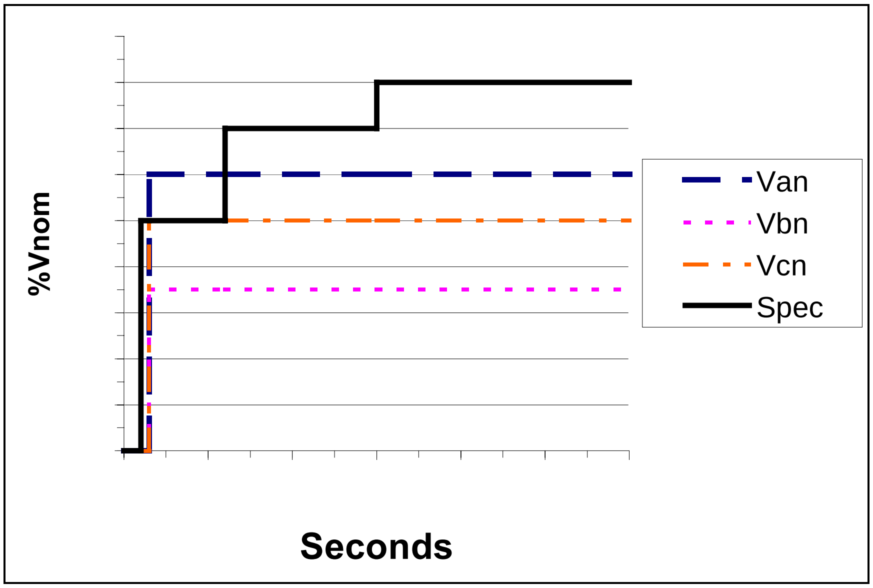
12.6 Report conclusions of voltage sag immunity testing of the DUT (e.g., Key immunity data points, compliance/non-compliance with voltage sag ride-through specification, corrective actions taken, etc.).

Table 4 Example of Test Data Sheet for Characterizing to Voltage Sag Ride-Through Specification Limits

Event	*% Va-n*	*% Vb-n*	*% Vc-n*	*DUT Mode (Idle or Processing)*	*Voltage Sag Duration*	*Result*	
						Actual Time to Interrupt (Seconds)	*Comments*
1	95	100	100	Processing	0.05	OK	Equipment OK.
2	95	100	100	Processing	0.20	OK	Equipment OK.
3	95	100	100	Processing	0.50	OK	Equipment OK.
4	95	100	100	Processing	1.00	OK	Equipment OK.
5	90	100	100	Processing	0.05	OK	Equipment OK.
6	90	100	100	Processing	0.20	OK	Equipment OK.
7	90	100	100	Processing	0.50	OK	Equipment OK.
8	90	100	100	Processing	1.00	OK	Equipment OK.
↓	↓	↓	↓	↓	↓	↓	↓
34	55	100	100	Processing	0.20	0.16	Equipment Shutdown: EMO Relay CR1 dropout
35	55	100	100	Processing	0.50	INT	No Test - Beyond Interrupt
36	55	100	100	Processing	1.00	INT	No Test - Beyond Interrupt
37	50	100	100	Processing	0.05	OK	Equipment OK.
38	50	100	100	Processing	0.20	0.16	Same result as event 34.
↓	↓	↓	↓	↓	↓	↓	↓
77	100	50	100	Processing	0.05	OK	Equipment OK.
78	100	50	100	Processing	0.20	OK	Equipment OK.
79	100	50	100	Processing	0.50	OK	Equipment OK.
80	100	50	100	Processing	1.00	OK	Equipment OK.
↓	↓	↓	↓	↓	↓	↓	↓
117	100	100	50	Processing	0.05	OK	Equipment OK.
118	100	100	50	Processing	0.20	OK	Equipment OK.
119	100	100	50	Processing	0.50	OK	Equipment OK.
120	100	100	50	Processing	1.00	OK	Equipment OK.

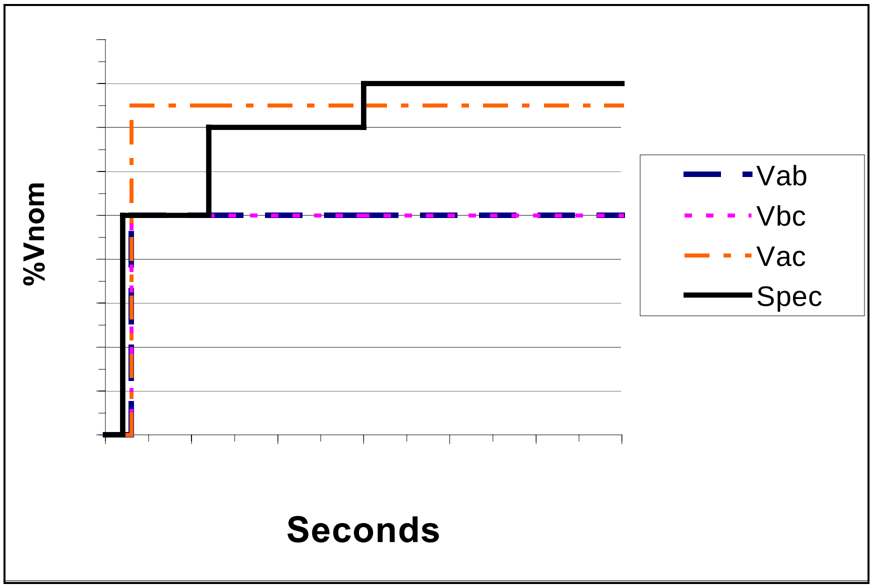
Table 5 Example of Test Data Sheet for Characterizing Equipment Susceptibility to Voltage Sags

Event	*% Va-n*	*% Vb-n*	*% Vc-n*	*DUT Mode (Idle or Processing)*	*Voltage Sag Duration*	*Result*	
						Actual Time to Interrupt (Seconds)	*Comments*
1	95	100	100	Processing	0.05	OK	Equipment OK.
2	95	100	100	Processing	0.20	OK	Equipment OK.
3	95	100	100	Processing	0.50	OK	Equipment OK.
4	95	100	100	Processing	1.00	OK	Equipment OK.
↓	↓	↓	↓	↓	↓	↓	↓
53	30	100	100	Processing	0.05	OK	Equipment OK.
54	30	100	100	Processing	0.20	0.16	Equipment Shutdown: EMO Relay CR1 dropout
55	30	100	100	Processing	0.50	INT	No Test - Beyond Interrupt
56	30	100	100	Processing	1.00	INT	No Test - Beyond Interrupt
↓	↓	↓	↓	↓	↓	↓	↓
129	100	35	100	Processing	0.20	OK	Equipment OK.
130	100	35	100	Processing	0.50	OK	Equipment OK.
131	100	35	100	Processing	1.00	OK	Equipment OK.
132	100	30	100	Processing	0.05	OK	Equipment OK.
133	100	30	100	Processing	0.20	0.16	Power Supply PS1 dropout
↓	↓	↓	↓	↓	↓	↓	↓
233	100	100	5	Processing	0.05	OK	Equipment OK.
234	100	100	5	Processing	0.20	0.16	Equipment Shutdown: EMO Relay CR1 dropout
235	100	100	5	Processing	0.50	INT	No Test - Beyond Interrupt
236	100	100	5	Processing	1.00	INT	No Test - Beyond Interrupt
237	100	100	0	Processing	0.05	OK	Equipment OK.
238	100	100	0	Processing	0.20	0.16	Same result as event 234.
239	100	100	0	Processing	0.50	INT	No Test - Beyond Interrupt
240	100	100	0	Processing	1.00	INT	No Test - Beyond Interrupt
.	.	.	.				



NOTE: Equipment did not meet standard during A to neutral sag events.

Figure 4
Example of Single-Phase Test Results



NOTE: Equipment did not meet specification during A-C to sag events.

Figure 5
Example of Phase-to-Phase Test Results

13 Related Documents

13.1 *IEC Standard* [2]

13.1.1 *IEC 61000-4-11* — Electromagnetic Compatibility (EMC) - Part 4: Testing and Measuring Techniques - Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests.

NOTICE: SEMI makes no warranties or representations as to the suitability of the test method set forth herein for any particular application. The determination of the suitability of the test method is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These test methods are subject to change without notice.

The user's attention is called to the possibility that compliance with this test method may require use of copyrighted material or of an invention covered by patent rights. By publication of this test method, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this test method. Users of this test method are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

2 International Electrotechnical Commission, 3, rue de Varembé PO Box 131, 1211 Geneva 20 Switzerland

RELATED INFORMATION 1
SAG GENERATORS

NOTE: This related information is not an official part of SEMI F42 and has been derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on December 18, 1998. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Types of Sag Generators

R1-1.1 As defined in the test instrumentation section of IEC-61000-4-11, there are two common types of voltage sag generator devices – variable transformer-switch type and the power amplifier type.

R1-1.2 Both units shown in this section can inject phase-shifting into the output waveform. All units except the contactor based transformer-switch type are capable of some point-on-wave controllability.

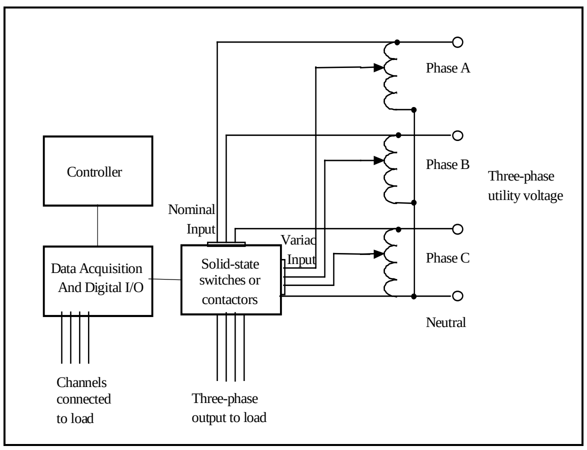


Figure R1-1
Transformer-Switch Type Sag Generator

R1-2 Transformer-Switch Type

R1-2.1 This type of sag generator has been built with either insulated gate bipolar transistor (IGBT), silicon control rectifier (SCR), or contactors used as the switching devices. The IGBT based switch is the most controllable with the ability to precisely control the point on the waveform in which the voltage sag starts and finishes (0-360 degrees). With an SCR switch, the point on wave of the voltage sag starts can be controlled, but the cutoff point of the voltage sag will be fixed at zero degrees. In real power systems, the point-on-wave in which the voltage sag occurs is somewhat random and unpredictable. A contactor based unit simulates the randomness of a real power system in that the point-on-wave in which the voltage sag begins is not controllable, but is dependent on the lag time between energizing the coil of the contactor and contactor closure. Figure R1-1 below displays a three-phase sag generator test fixture with data acquisition.

R1-2.2 As shown in Figure R1-1, voltage sags are injected into the load referenced to the neutral. Since the three variable transformers shown only need to carry current during the voltage sag, they do not need to be rated for continuous current.

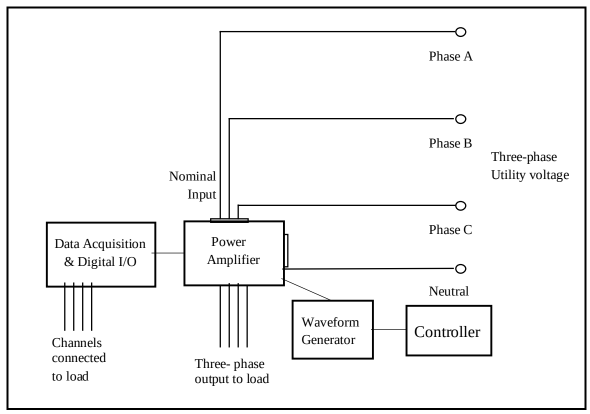


Figure R1-2
Power Amplifier Type Sag Generator

R1-3 Power Amplifier Type

R1-3.1 This type of system utilizes a controller, wave-form generator, data acquisition systems, and power amplifier section. Since this type of amplifier can be highly configurable, it can simulate most any point-on-wave or phase-shift desired. The power amplifier-based sag generator will be typically heavier and less portable than its transformer-switch counterpart. A conceptual three-phase version of this type of sag generator test fixture is shown in Figure R1-2.

NOTICE: SEMI makes no warranties or representations as to the suitability of the test method set forth herein for any particular application. The determination of the suitability of the test method is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These test methods are subject to change without notice.

The user's attention is called to the possibility that compliance with this test method may require use of copyrighted material or of an invention covered by patent rights. By publication of this test method, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this test method. Users of this test method are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F43-0699
TEST METHOD FOR DETERMINATION OF PARTICLE CONTRIBUTION BY POINT-OF-USE PURIFIERS

This Test Method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org February 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this document is to define a method for testing POU purifiers intended for installation into a high-purity gas distribution system and semiconductor manufacturing process equipment. Application of this test method is expected to yield comparable data among POU purifiers tested for the purposes of qualification for its installation.

2 Scope

2.1 This document describes a test method designed to draw comparisons of particulate generation performance of POU purifiers tested under standard conditions. The procedure utilizes a condensation nucleus counter (CNC) applied to in-line gas purifiers typically used in semiconductor applications. It applies to purifiers of various media and up to 5 cm (~ 2 in.) i.d. in size and for room temperature operation. The purifier's rated flow should be in the range of 0-50 standard liter per minute (slpm). For applications of this method to larger purifiers, the testing flow rate should be higher than specified in this method.

2.2 The experimental set up described in this method can be used for testing either POU purifiers or stand-alone POU filters.

3 Limitations

3.1 This procedure addresses total particle count greater than the minimum detection limit (MDL) of the condensation nucleus particle counter and does not consider classifying data into various size ranges.

3.2 This methodology specifies flow and mechanical stress conditions in excess of those considered typical. These conditions shall not exceed those recommended by the manufacturer. Actual performance under normal operating conditions may differ.

3.3 The test medium is limited to nitrogen and argon. Performance with other gases may vary.

3.4 This method does not include extended particle count testing or testing under challenging conditions.

3.5 The accuracy of the data generated by this method is limited to the accuracy of the particle measuring instruments utilized.

3.6 This method is written with the assumption that the operator understands the use of the apparatus at a level equivalent to six months of experience.

4 Referenced Documents

4.1 FED-STD-209. Federal Standard Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones. General Services Administration.

5 Terminology

5.1 *Acronyms*

CNC – condensation nucleus counter

DUT – device under test

EP – electropolished

kPa – kiloPascal

LPC – laser particle counter

POU – point of use

psi – pounds per square inch

psia – pounds per square inch absolute

psid – pounds per square inch differential

psig – pounds per square inch guage

Ra – roughness average

Rmax – roughness maximum

scfm – standard cubic feet per minute

slpm – standard liters per minute

5.2 *Definitions*

5.2.1 *background counts* — counts contributed by the test apparatus (including counter electrical noise) with the spool piece in place of the test object.

5.2.2 *CNC* — condensation nucleus counter. A light scattering instrument that detects particles in a gaseous stream by condensing supersaturated vapor on the particles.

5.2.3 *control product* — a sample component that gives consistent, stabilized counts at or below the expected counts from the test components. The product is run periodically in accordance with the test protocol to assure that the system is not contributing particles significantly different from expected levels. In the absence of a control product, a spool piece can be used as a control product of low particle emission rate.

NOTE 1: The control product may have to be changed periodically if its performance degrades with testing. Between tests, the control product must be bagged in accordance with the original manufacturer's packaging and stored in a clean manner. The control product is used to allow the system to consider the disruption caused by changes in flow due to the actuation of any valve, such as significant fluctuations in flow, pressure, turbulence, and vibration.

5.2.4 *dynamic test* — a test performed to determine particle contribution as a result of pulsing flow through the DUT.

5.2.5 *impact test* — a test performed to determine particle contribution as a result of mechanical shock applied to the DUT.

5.2.6 *Nine–log retention* — number of particles upstream of the purifier or filter are 1,000,000,000; number of particles down-stream of the purifier or filter is 1.

5.2.7 *sample flow rate* — the volumetric flow rate drawn by the counter for particle detection. The counter may draw higher flow for other purposes (e.g., sheath gas).

5.2.8 *sampling time* — the time increment over which counts are recorded.

5.2.9 *spool piece* — a null component consisting of a straight piece of electropolished tubing and appropriate fittings used in place of the DUT to establish the baseline.

5.2.10 *static test* — a test performed to determine particle contribution under steady flow condition through the DUT.

5.2.11 *test duration* — total time required to complete the test procedure. (See Section 7.3)

5.2.12 *test flow rate* — mass flow through device under test.

5.2.13 *test pressure* — pressure immediately downstream of the test component. (See Figure 1.)

5.2.14 *test temperature* - ambient temperature at which the experiment is being conducted.

6 Safety Precautions

6.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.

6.2 Exhaust from the CNC may contain hazardous and/or flammable vapors and should be properly vented.

6.2.1 Only inert gases like nitrogen and argon should be used for purifier testing. **No air is allowed in the purifier testing procedure described in this document**.

6.3 Care should be taken to minimize the purifier's exposure to room air during and after testing.

7 Test Protocol

7.1 *Test Conditions*

7.1.1 The test is to be conducted at a normal indoor temperature of between 18°C (64°F) and 26°C (78°F). Environmental temperature within this range is not expected to have any measurable effect on particle detection. Follow manufacturer's recommended handling procedures.

7.1.2 Test apparatus must be enclosed in a Class 100 environment (per current revision of Federal Standard 209). If a clean hood is used, the hood should be located within a clean environment. Use procedures necessary to maintain Class 100 when handling test apparatus and test component.

7.1.3 Care should be taken to protect the test apparatus from excessive vibration. For example, vacuum pumps and compressors should be isolated from the system.

7.2 *Apparatus*

7.2.1 *Materials*

7.2.1.1 *Test gas* — Nitrogen of minimum dryness of <10 PPM moisture at 790.57 kPa (100psig) with <10 ppm of total hydrocarbons.

7.2.1.2 *Filters* — Electronics grade filters are required to provide "particle-free" test gas. Each filter must be nine-log retentive per manufacturer's specifications to 0.02 µm. The filter must be capable of achieving less than 2 particles ≥ 0.02 µm per cubic foot of test gas under test conditions.

7.2.1.3 *Pressure regulator* — Made of electropolished 316L with an internal surface finish of 0.18 µm (7 µin.) Ra and 0.25 µm (10 µin.) Rmax to maintain system pressure.

7.2.1.4 *Pressure gauge* — made of electropolished 316L stainless steel, with an internal surface finish of 0.18 µm (7 µin.) Ra and 0.25 µm (10 µin.) Rmax, to monitor system test pressure.

7.2.1.5 *Standard testing flow control device* — Use flow meters with ranges appropriate for testing from 0-50 slpm.

7.2.1.6 *Tubing* — Made of electropolished 316L stainless steel, with and internal surface finish of 0.18 µm (7 µin.) Ra and 0.25 µm (10 µin.) Rmax.

7.2.1.7 *Sampler* — The sampler is to be constructed according to the drawing and sampler design criteria given in Appendix 1 Sampler Design Criteria. The sampler collects gas from the stream exiting the test device, where the sample is near-isokinetic in design.

7.2.1.8 *Upstream adapter* — The upstream adapter piece connects 12.7 mm (1/2–in.) tubing to the test device. For 12.7 mm (1/2–in.) test devices, the adapter is a simple face-seal connector. For 6.35 mm (1/4–in.) test devices, the adapter is a tapered cone between 6.35 mm and 12.7 mm (1/4– and 1/2–in.) face-seal connections.

7.2.1.9 *Downstream adapter* — The downstream adapter piece connects 12.7 mm (1/2–in.) tubing of the sampler to the test device. For 12.7 mm (1/2–in.) test devices, the adapter is a simple face seal connector. For 6.35 mm (1/4–in.) test devices, the adapter is a tapered cone between 6.35 mm (1/4–in.) and 12.7 mm (1/2–in.) face-seal connections.

7.2.1.10 *Spool Pieces* — Spool pieces shall be the same diameter as the fittings on the test piece and be 15 cm (6 in.) in length. The spool piece is to be installed in the system in place of the DUT while obtaining background counts for the system.

7.2.1.11 *Fittings* — Face seal connectors or compression fittings dependent on test component end connections. The end connection fittings of each DUT being compared must be of the same type.

7.2.1.12 *Gaskets* — Use metal gaskets for attaching the test device and adapter pieces. New gaskets should be used for each new connection. The use of metal gaskets is recommended in order to minimize the particles that may be generated by installation of the test piece. The use of silver plated metal gaskets should be avoided because they shed particles after installation.

7.2.1.13 *Mechanical shock device* — To provide mechanical shock by impact to the test device (see Figure 2).

7.2.1.14 *Actuator* — A gas (compressed air or nitrogen) operated device connected to the valve stem to open and close the valve.

7.2.1.15 *Actuator pressure* — Minimum actuator gas line pressure required to fully open and close the valve during the dynamic test.

7.2.2 *Instrumentation*

7.2.2.1 A CNC whose counting efficiency characteristics fall within the envelope defined in FED STD 209 for counting ultrafine particles is to be used for particle counting. Test durations in this test method have been established based on a sampling flow rate of 0.05 scfm.

7.2.2.2 Instruments should be calibrated regularly, according to manufacturer's recommendations. For the CNC, this includes routine checks of instrument operation as specified by the manufacturer.

7.2.2.3 The CNC and data collection equipment must have power surge suppression.

7.2.3 *Setup and Schematic*

7.2.3.1 Assemble the test apparatus according to the schematic drawing of the test apparatus used shown in Figure 1. Install the test apparatus inside a class 100 clean room. Adjust the inlet gas pressure to the required pressure of 30 psig using the pressure regulator R1 as indicated by an electronics grade pressure gauge P1. The filtered gas flow is then diverted to flow through either of the two flowmeters located downstream of the valve V1.

7.2.3.1.1 The test gas delivered from the flow meters is filtered again by an electronics grade filter F2. The test gas pressure at this point is measured by another electronics grade pressure gauge P2 installed upstream of filter F2. A pneumatic valve PV1 is installed downstream of the filter F2 for obtaining the particle counts for the dynamic test portion (including the background) of the test method. The test gas is filtered once again by another electronics grade filter F3 before it is delivered to the spool piece and the test component.

7.2.3.1.2 Particles released from the spool piece and the test component are measured by a CNC located downstream of these components. A representative sample of the gas flow is sampled by the CNC through an isokinetic sampler located downstream of the test devices. The CNC measures particle concentration every minute, sampling at a flow rate of 0.05 scfm, to provide a continuous measurement of particle counts for the static, dynamic, and impact tests on the test pieces. The particle data can also be collected and stored in a computer using a data acquisition program.

7.2.3.1.3 A schematic drawing of a recommended test apparatus is given in Figure 1. A list of parts used in the construction of the recommended test stand is presented in Table 1. The dimensions of the tubing and components used for the construction of the recommended test apparatus are given because they have been found to be critical to the proper operation of the test apparatus as required by the specification. Deviations from these dimensions have resulted in some lab facilities not meeting the requirements of the specification.

7.2.3.2 The spool piece is to be installed when the test stand is not in use. A continuous low flow (0.1 scfm) is to be maintained to purge the system. The particle counter may be turned off. For an extended shutdown, the system (excluding the CNC) should be pressurized and capped.

7.2.3.3 After initial construction, the spool piece should be installed and the test apparatus (except the CNC) should be pressurized and tested for leaks in the system. It is recommended that a helium leak detector or a pressure decay method be used to detect leaks in the system. The system should then be cleaned by running a high flow rate of test gas with simultaneous gentle tapping of all components (except the CNC) downstream of the final filter F3. This procedure should be followed by a start-up phase which characterizes system cleanliness by conducting the entire test protocol with the control product installed. This start-up phase should continue and be repeated as necessary until the counts from the control product have stabilized at or below the expected number of counts from the test components.

7.3 *Test Procedures*

NOTE: Ensure the counter is counting continuously and reporting data every minute. For the duration of the test, the counter should be continuously counting, except where noted in the test protocol.

7.3.1 *Background Test*

7.3.1.1 Ensure that the spool piece and proper adapters are in place on the test apparatus.

7.3.1.2 *Static Test* — Close the pneumatic valve (PV1). Set regulator R1 to 30 psig. Open the pneumatic valve (PV1) to establish flow. Using the flow control device, set the test flow to manufacturer's recommended maximum flow. Measure the static background count. Background count is established when the counter has sampled a minimum of 3 scf, and the arithmetic average during the last 3 scf of gas sampled is <2 particles/scf. At a sample flow rate of 0.05 scfm, the time required is one hour. Ensure that the background counts are stable or decreasing. If background cannot be achieved after 6 scf have been sampled, there may be a problem with the counter or test apparatus.

7.3.1.3 *Dynamic Test* — Set the actuator pressure of PV1 to its minimum pressure recommended by the manufacturer to fully open the valve. Actuate the pneumatic valve PV1 at 30 cycles per minute to measure the background counts under dynamic test conditions. Dynamic background count is established when the counter has sampled a minimum of 3 scf, and the arithmetic average during the last 3 scf of gas sampled is < 3 particles/scf. (Estimated dynamic background count will be verified and altered if necessary during the validation phase of this test method.) At a sample flow rate of 0.05 scfm, the time required is 1 hour. If dynamic background cannot be achieved after 6 scf have been sampled, there may be a problem with the counter or test apparatus.

7.3.1.4 Stop the pneumatic valve cycling. Flush the system for 10 minutes under static test conditions.

7.3.1.5 *Purifier Impact Test* — Impact the spool piece once per minute for ten minutes with the mechanical shock device (See Figure 2). The impact background count should be <4 particles/scf over the ten minutes of the test. (Estimated impact background count will be verified and altered if necessary during the validation phase of this test method.) If impact background cannot be achieved, repeat the shock a second time. If the impact background count specification still cannot be met, there may be a problem with the counter or test apparatus.

7.3.1.6 Flush the system for 30 minutes at the test flow rate. Record the resulting count.

7.3.1.7 Turn the CNC pump off while leaving the CNC power on.

7.3.2 *Purifier Static Test*

7.3.2.1 Using the flow control device, decrease the flow rate to 0.1–0.2 scfm, so that some flow remains in the system while the test purifier is installed.

7.3.2.2 Remove the spool piece by first disconnecting the downstream fitting and then the upstream fitting. Immediately install the test component in a fully open position by first connecting the upstream fitting and then the downstream fitting. Removal of the spool piece and installation of the test component to minimize reactions of the purifier with room air and extraneous contamination and prevent the counter from cooling off should take no longer than 3 minutes. Extreme care should be taken to minimize contamination of the test apparatus during this operation. The test component is to be removed from its inner bag in the Class 100 test area. If the test component has mechanical fittings, these fittings are to be properly connected. If the test component has tube ends, the component is to be installed with clean compression fittings. Do not permanently crimp any ferrules onto the tube stubs. Nylon ferrules are acceptable.

7.3.2.3 Using the flow control device, set the test flow to manufacturer's recommended maximum flow.

7.3.2.4 Turn on the counter pump and conduct the static test. The purifier is to be tested with the valve PV1 in the fully open position until 85 standard liters (3 scf) of gas have been sampled. Cumulative data should be recorded at one-minute intervals.

7.3.3 *Purifier Dynamic Test*

7.3.3.1 This test is to immediately follow the static test. To conduct the dynamic test, set the actuator pressure of the actuator attached to valve PV1 to its minimum actuator pressure as recommended by the manufacturer to fully open the valve. Actuate valve PV1 at the rate of 30 cycles/minute for 60 minutes. A cycle consists of off *and* on actuation of the valve. The off and on cycles should be of equal duration.

7.3.4 *Purifier Impact Test*

7.3.4.1 This test is to immediately follow the dynamic test. Maintain the test flow rate for 10 minutes, with the valve PV1 in the fully open position. Impact the purifier once a minute for 10 minutes, using the mechanical shock device. Purge the test component by maintaining the test flow rate for 30 minutes.

7.3.5 Turn the counter pump off and then decrease the test gas flow rate to ~ 5 slpm.

7.3.6 Remove the test purifier by first disconnecting the downstream fitting and then the upstream fitting, and immediately install the spool piece by connecting the upstream fitting followed by the downstream fitting. The removed purifier should be immediately valved off or capped to prevent its exposure to room air.

7.4 *Data Presentation*

7.4.1 The following test conditions are to be reported in the data presentation:

- Date and time of test
- Operator
- Test flow rate (scfm)
- Test pressure (psig)
- Test temperature (°C)
- Purifier type, manufacturer, serial number, lot number, and model number
- CNC manufacturer, serial number, sample flow rate (scfm), model number, and calibration date
- Test gas type and dew point (°C)
- A schematic of the test apparatus, including manufacturer's and model numbers of all test apparatus components
- Calibration dates for the flow meters and the test date

7.4.2 Graph the static, dynamic and impact portions of the test separately as counts/minute (measured by the counter) versus time, including the appropriate background (measured with the spool piece in place) with each. Also graph the entire data set as counts per minute versus time. If different filters are to be compared, graph their entire data sets together.

7.4.3 Present the entire raw data set in tabular form.

8 Related Documents

8.1 The appropriate particle counter manufacturer's operating and maintenance manuals should be consulted when using this test method.

8.2 On particle counter efficiencies: Agarwal, J. K. and Sem, G. J. "Continuous Flow, Single Particle Counting Condensation Nucleus Counter." *Journal of Aerosol Science*, v.11.4. July 1980:343–357.

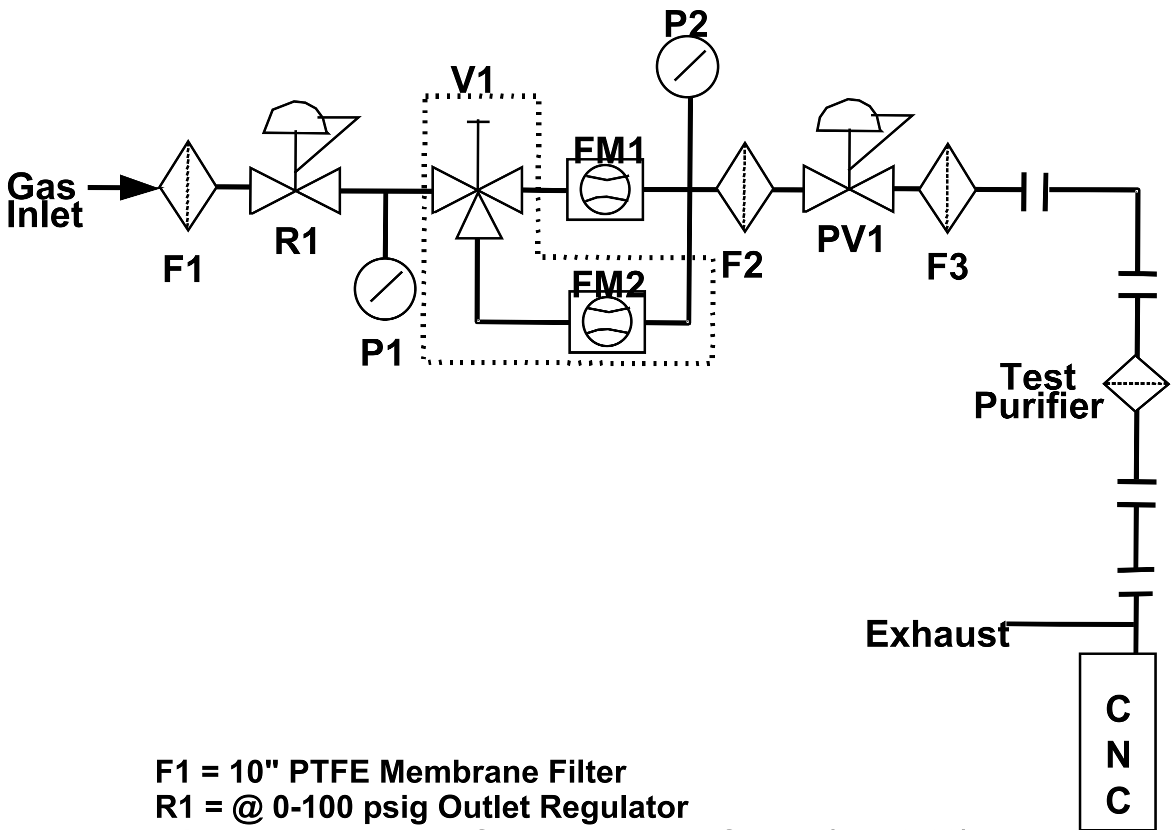
8.3 On flow calculations: D. E. Dickie, ed. *Crane Handbook*. Construction Safety Association of Toronto. Ontario, Canada. 1975.

8.4 Statistical reference: Van Slooten, R. A., "Statistical Treatment of Particle Counts in Clean Gases. " *Microcontamination*, v.4.2. Feb. 1986:32–38.

8.5 Hinds, W. C. Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles. John Wiley & Sons. 1982:187–194.

8.6 Fissan, H. and Schwientek. "Sampling and Transport of Aerosols." *TSI Journal of Particle Instrumentation*, v.2.2. July–December 1987:3–10.

8.7 SEMI F1-96, Specification for Leak Integrity of High Purity Gas Piping Systems and Components.



F1 = 10" PTFE Membrane Filter
R1 = @ 0-100 psig Outlet Regulator
P1, P2 = Electronics Grade Pressure Gauge (30"-0-60)
V1 = Three-Way Valve
FM1 = Low Flow (0-2 scfm) Flowmeter
FM2 = High Flow (0-20 scfm) Flowmeter
F2, F3 = Electronics Grade Filter
PV1 = Electronics Grade Pneumatic Valve

Figure 1

Schematic of Particle Test Loop

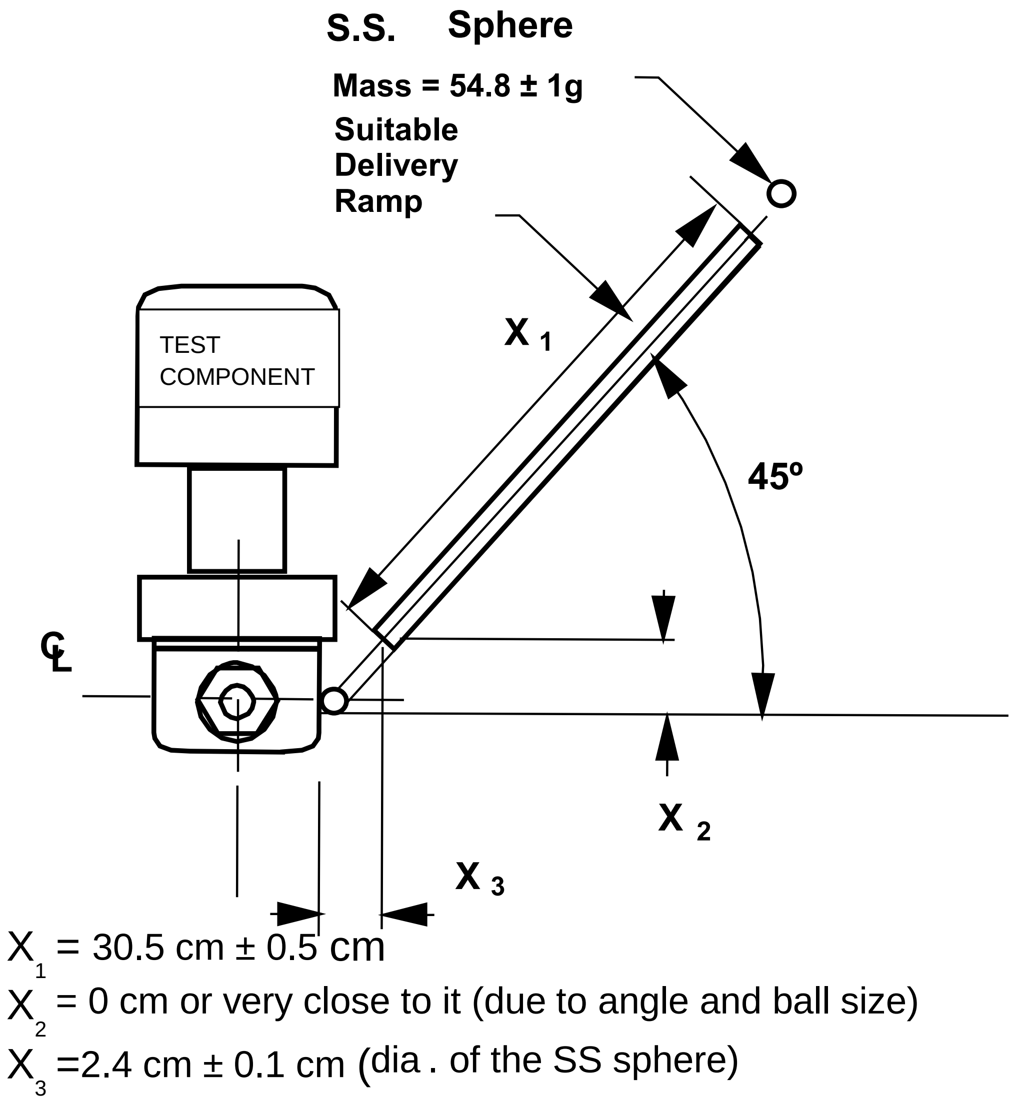


Figure 2

Mechanical Shock Device

NOTE 1: X3 will change with a change on sphere size.

NOTE 2: Position the delivery ramp so that the position of impact is at the midpoint of the axial centerline of the device under test.

Table 1 Parts List for the Recommended Particle Test Apparatus

Item number	Description
1	1/4 in. diameter electropolished (EP) SS tube
2	1/4 in. to 1/2 in. tube reducing union
3	1/2 in. diameter EP SS tube
4	PTFE membrane filter with 3/8 in. face seal
5	Pressure regulator, 0-300 inlet pressure, 0-100 outlet pressure
6	1/2 in. butt weld tee
7	1/2 in. tube to 3/8 in. NPT female connector
8	0-60 psig electronics grade pressure gauge
9	1/2 in. to 1/2 in. union
10	1/2 in. 3-way SS ball valve
11	1/4 in. tube to 1/2 in. port reducer
12	0.2-2 std ft^3 flowmeter
13	1-15 std ft^3 flowmeter
14	1/2 in. SS union
15	1/2 in. dia, 3-ft flexible SS tube
16	1/2 in. union elbow
17	1/2 in. pneumatic valve
18	1/2 in. to 1/4 in. SS reducer gland
19	Test component
20	3-way normally closed solenoid air valve
21	Solenoid valve cycle controller
22	1/2 in. welded tee
23	1 1/2 in. dia., 4-ft long exhaust tube
24	1/2 in. tube to 1/4 in. NPT adapter
25	1/8 in. dia., 17 in. long SS sample tube
26	1/4 in. to 1/8 in. reducer union
27	1/4 in. dia., 30 in. long SS sample loop
28	1/4 in. to 3/8 in. reducer union
29	Condensation Nucleus Counter

APPENDIX 1
SAMPLER DESIGN CRITERIA

A-1.1 The average velocity of gas flowing through the sampler should approximate the average velocity in the tubing in which the sampler is inserted. The sample flow rate used to calculate the sampler diameter is the total flow drawn by the counter.

A-1.2 Gradual expansion to atmospheric pressure is recommended for sampling. Critical orifice expansion may alter the particle level of the sample.

A-1.3 The tip of the sampling probe should have a 30 degree taper on the outside diameter.

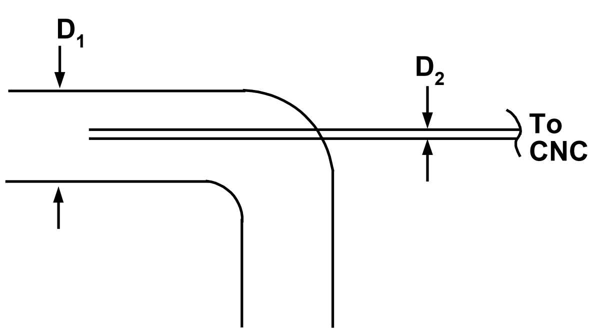
A-1.4 The pick-off point should be approximately centered within the flow stream.

A-1.5 The pick-off point should be approximately 15 diameters of the primary flow tube upstream or downstream of any connection.

A-1.6 There should be enough volume in the exhaust portion of the sampler to supply the CNC for one minute. This volume represents 60 times the volume that will be drawn by the CNC while the valve is closed during the dynamic testing. Minimum sample flow through the CNC is 5 slpm.

A-1.7 State the minimum volume after the probe or generate a sample blank using the stated volume until background counts are reached.

Under static flow conditions, the sampler size is within 50% of the size required to achieve isokinetic sampling. For particles of interest <0.5 um, Hinds[1] and Fissan[2] indicate that any unlikely isokinetic sampling biases are significant. During dynamic testing, isokinetic sampling is compromised regardless of the sample tube size.



Isokinetic Sampler Calculation

To establish isokinetic sampling condition:

$V_1 = V_2$
$Q = AV$ or $V = Q/A$
so $Q_1/A_1 = Q_2/A_2$
therefore, $A_2 = A_1\,(Q_2/Q_1)$ or $D_2 = D_1\,(Q_2/Q_1)^{1/2}$

where:

Q = flow rate (volumetric)
A = area (internal cross section)
V = velocity (average)
D = diameter (internal)

subscripts:

1 = main flow line
2 = sample flow line

If pressure correction at point of flow control device is needed, then:

$$Q_s = [(P + 14.7)/14.7]^{1/2} \times Q_A$$

where:

Q_A = actual flow rate
Q_S = standard flow rate
P = pressure, psig

Temperature variances are assumed to be negligible.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F44-0699
GUIDELINE FOR STANDARDIZATION OF MACHINED STAINLESS STEEL WELD FITTINGS

This guideline was technically approved by the Global Facilities Committee and is the direct responsibility of the Japanese Facilities Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available on www.semi.org May 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this guideline is to prevent confusion among the manufacturers of stainless steel weld fittings, piping fabricators and end users and to standardize the dimensions of weld fittings.

2 Scope

2.1 This guideline applies to 6.35 mm (1/4in.), 9.53 mm (3/8in.) and 12.7 mm (1/2in.); the machined stainless steel weld fittings elbows and tees made for use in the semiconductor industry.

3 Referenced Documents

3.1 None.

4 Terminology

4.1 *elbow weld fittings* — machined fittings shaped like the letter "L", for welding tubes in a right angle. (see Figure 1)

4.2 *tee weld fittings* — machined fittings shaped like the letter "T", for welding tubes in a T-shape. (see Figure 2)

4.3 *weld fittings* — machined fittings to be welded or welded fittings.

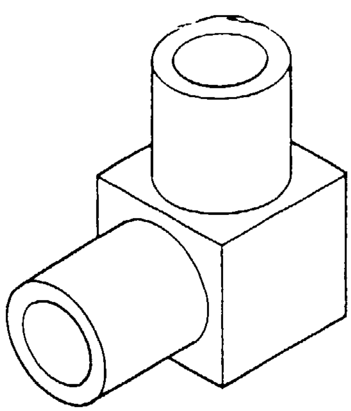


Figure 1
Elbow Weld Fittings

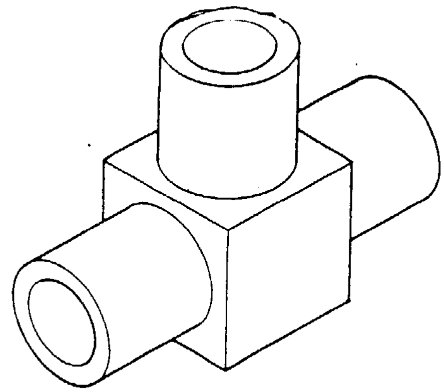


Figure 2
Tee Weld Fittings

5 Dimensions of Weld Fittings

5.1 *Elbow Weld Fittings* (see Figures 3A and 3B)

5.2 *Tee Weld Fittings* (see Figures 4A and 4B)

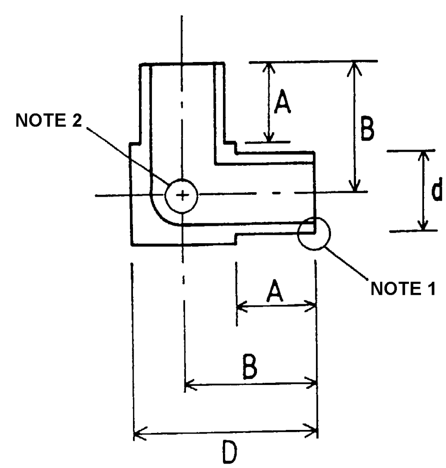


Figure 3A
Dimensions of Elbow Weld Fittings

NOTE 1: Machined tube weld ends shall be square tolerance ± 0.5°.

NOTE 2: Intersection shall be square tolerance ± 0.5°.

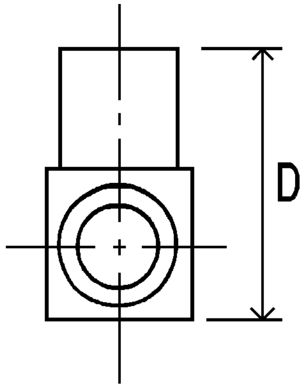


Figure 3B
Dimensions of Elbow Weld Fittings

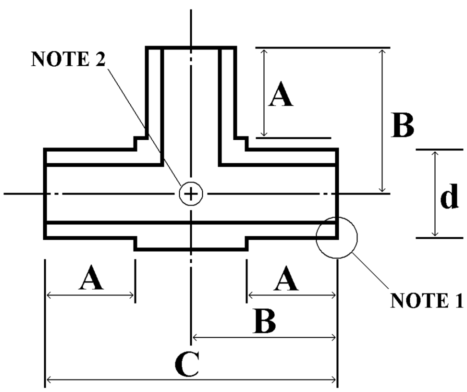


Figure 4A
Dimensions of Tee Weld Fittings

NOTE 1: Machined tube weld ends shall be square tolerance ± 0.5°.

NOTE 2: Intersection shall be square tolerance ± 0.5°.

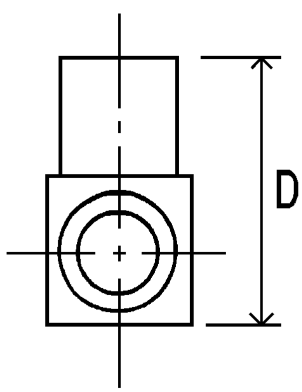


Figure 4B
Dimensions of Tee Weld Fittings

6 Marking The Weld Fittings

6.1 Marks include 1), 2), 3), 4), 5), 6) and 7). Marks 1) through 4) shall be made on the weld fittings body. Marks 5) - 7) shall be made on weld fittings body or its package (both individual bagging and box).

1) Manufacturer's name
2) Material designator
3) Surface finish designator
4) Heat Number (optional)
5) Lot Number
6) Model (Part Number)
7) Wall thickness of tube end

6.2 To be agreed upon between supplier and user for marking items and marking locations. The example below explains marking applications. (see Figures 5A and 5B)

6.3 Manufacturer's name, Material designator, Surface finish designator and Heat Number should be marked on the body. The Heat Number shall be marked either on the body of the cube along with the other information, but if space is limited, then the Heat Number marked on the tube Outside Diameter close to the body block is permissible.

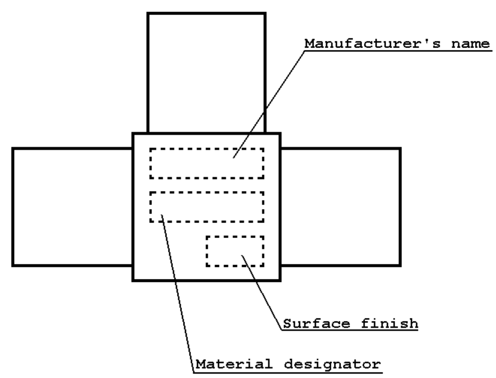


Figure 5A
Marking Application Example

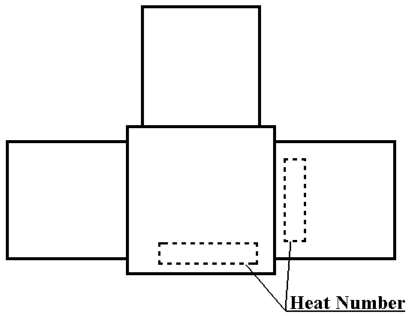


Figure 5B
Marking Application Example

7 Outside Diameter Tolerance

7.1 The Outside Diameter tolerance of 6.35 mm (1/4 in.), 9.53 mm (3/8 in.) and 12.7 mm (1/2 in.) is + 0.1 mm, - 0.0 mm (+ 0.004 in., - 0.000 in.).

8 Wall Thickness of Tube End

8.1 Wall thickness of tube end should be either 1 mm (0.039 in.) or 0.89 mm (0.035 in.), 1.24 mm (0.049 in.) and the thickness should be marked on the weld fitting body or its package. Wall thickness tolerance is ± 8%.

Table 1 Dimensions and Tolerance

Nominal Diameter	*d*	*A*	*B*	*C*	*D*
6.35 (1/4)	6.35 (0.25)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	10.3 ± 0.1 (0.4055 ± 0.004)	20.6 ± 0.1 (0.811 ± 0.004)	14.25 ± 0.1 (0.561 ± 0.004)
9.53 (3/8)	9.53 (0.375)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	11.9 ± 0.1 (0.4685 ± 0.004)	23.8 ± 0.1 (0.937 ± 0.004)	17.45 ± 0.1 (0.687 ± 0.004)
12.7 (1/2)	12.7 (0.5)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	13.5 ± 0.1 (0.5315 ± 0.004)	27.0 ± 0.1 (1.063 ± 0.004)	20.65 ± 0.1 (0.813 ± 0.004)

Dimensions : mm (in.)

SEMI F45-0699
GUIDELINE FOR STANDARDIZATION OF MACHINED STAINLESS STEEL REDUCING WELD FITTINGS

This guideline was technically approved by the Global Facilities Committee and is the direct responsibility of the Japanese Facilities Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available on www.semi.org May 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this guideline is to prevent confusion among the manufacturers of stainless steel reducing weld fittings, piping fabricators and end users and to standardize the dimensions of weld fittings.

2 Scope

2.1 This guideline applies to 6.35 mm (1/4 in.), 9.53 mm (3/8 in.) and 12.7 mm (1/2 in.); the machined stainless steel reducing weld fittings elbows and tees made for use in the semiconductor industry.

3 Referenced Documents

3.1 None.

4 Terminology

4.1 *reducing elbow weld fittings* — machined fittings shaped like the letter "L", for welding tubes in a right angle. (see Figure 1)

4.2 *reducing tee weld fittings* — machined fittings shaped like the letter "T", for welding tubes in a T-shape. (see Figure 2)

4.3 *reducing weld fittings* — machined fittings to be welded or welded fittings.

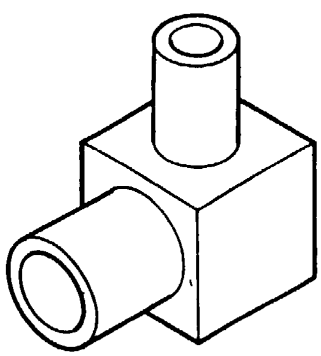


Figure 1
Reducing Elbow Weld Fittings

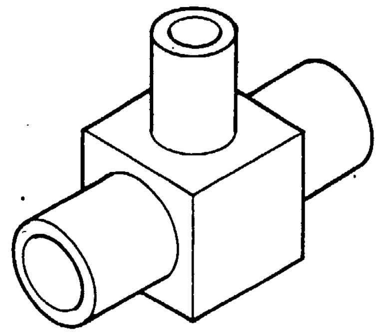


Figure 2
Reducing Tee Weld Fittings

5 Dimensions of Reducing Weld Fittings

5.1 *Reducing Elbow Weld Fittings* (see Figures 3A and 3B)

5.2 *Reducing Tee Weld Fittings* (see Figures 4A and 4B)

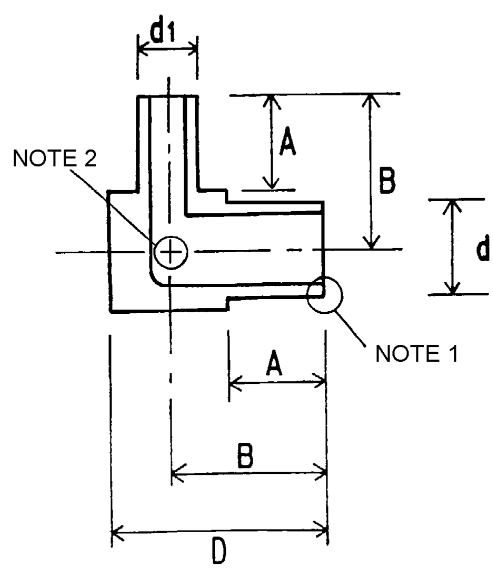


Figure 3A
Dimensions of Reducing Elbow Weld Fittings

NOTE 1: Machined tube weld ends shall be square tolerance ± 0.5°.

NOTE 2: Intersection shall be square tolerance ± 0.5°.

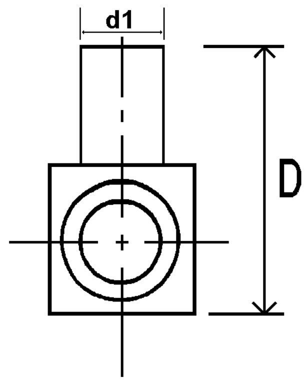


Figure 3B
Dimensions of Reducing Elbow Weld Fittings

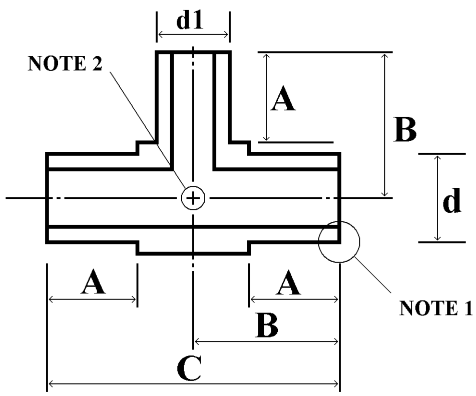


Figure 4A
Dimensions of Reducing Tee Weld Fittings

NOTE 1: Machined tube weld ends shall be square tolerance ± 0.5°.

NOTE 2: Intersection shall be square tolerance ± 0.5°.

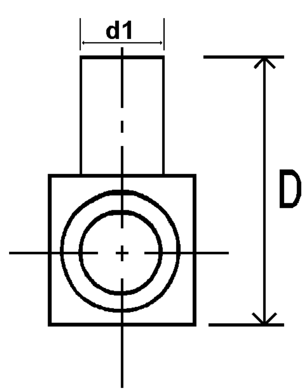


Figure 4B
Dimensions of Reducing Tee Weld Fittings

6 Marking the Reducing Weld Fittings

6.1 Marks include 1), 2), 3), 4), 5), 6) and 7). Marks 1) through 4) shall be made on the reducing weld fittings body. Marks 5) - 7) shall be made on the reducing weld fittings body or its package (both individual bagging and box).

1) Manufacturer's name
2) Material designator
3) Surface finish designator
4) Heat Number
5) Lot Number (optional)
6) Model (Part Number)
7) Wall thickness of tube end

6.2 To be agreed upon between supplier and user for marking items and marking locations. The example below explains marking applications. (see Figures 5A and 5B)

6.3 Manufacturer's name, Material designator, Surface finish designator and Heat Number should be marked on the body. The Heat Number shall be marked either on the body of the cube along with the other information, but if space is limited, then the Heat Number marked on the tube Outside Diameter close to the body is permissible.

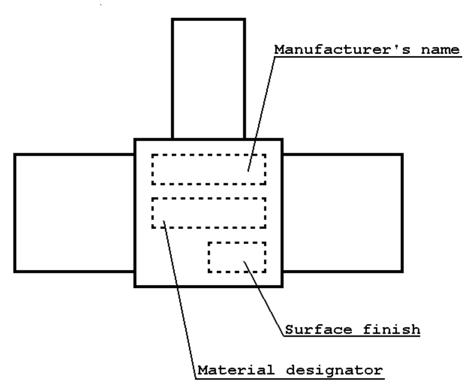


Figure 5A
Marking Application Example

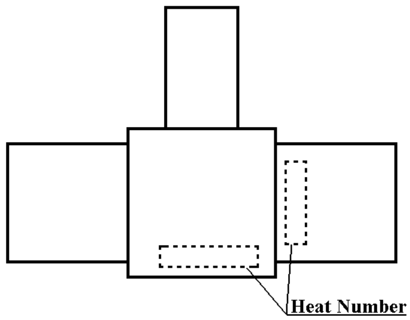


Figure 5B
Marking Application Example

7 Outside Diameter Tolerance

7.1 The Outside Diameter tolerance of 6.35 mm (1/4 in.), 9.53 mm (3/8 in.) and 12.7 mm (1/2 in.) is + 0.1 mm, - 0.0 mm (+ 0.004 in., - 0.000 in.).

8 Wall Thickness of Tube End

8.1 Wall thickness of tube end should be either 1 mm (0.039 inch) or 0.89 mm (0.035 inch), 1.24 mm (0.049 inch) and the thickness should be marked on the reducing weld fitting body or its package. Wall thickness tolerance is ± 8%.

Table 1 Dimensions and Tolerance

Nominal Diameter	*d*	*d1*	*A*	*B*	*C*	*D*
9.53 × 6.35 (3/8 × 1/4)	9.53 (0.375)	6.35 (0.25)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	11.9 ± 0.1 (0.4685 ± 0.004)	23.8 ± 0.1 (0.937 ± 0.004)	17.45 ± 0.1 (0.687 ± 0.004)
12.7 × 6.35 (1/2 × 1/4)	12.7 (0.5)	6.35 (0.25)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	13.5 ± 0.1 (0.5315 ± 0.004)	27.0 ± 0.1 (1.063 ± 0.004)	20.65 ± 0.1 (0.813 ± 0.004)
12.7 × 9.53 (1/2 × 3/8)	12.7 (0.5)	9.53 (0.375)	6.35 + 0.1/ - 0.05 (0.25 + 0.004/ - 0.002)	13.5 ± 0.1 (0.5315 ± 0.004)	27.0 ± 0.1 (1.063 ± 0.004)	20.65 ± 0.1 (0.813 ± 0.004)

Dimensions: mm (in.)

SEMI F46-0999
GUIDE FOR ON-SITE CHEMICAL GENERATION (OSCG) SYSTEMS

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available on www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 This guide establishes the minimum System and Overall Implementation requirements for requirement of On-Site Chemical Generation (OSCG) used in semiconductor manufacturing. It is also intended to establish a common basis for developing detailed guides in subsequent documents concerning design, performance, and certification of OSCG systems.

2 Scope

2.1 This guide applies to the OSCG system design used for the generation of chemicals, particularly ultra high purity, used in the silicon wafer, integrated circuit, and/or substrate manufacturing processes. These will include, but are not limited to, various concentrations of NH_4OH, HCl, HF, and NH_4F aqueous solutions.

2.2 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicablity of regulatory limitations prior to use.

3 Limitations

3.1 This guide is not intended to cover all chemicals used in these processes but only to those that can be generated, on-site, by means of reacting ultra-pure process gas with the appropriate liquid solution.

3.2 This guide is not intended to be applicable to "Point-of Use" generated process solutions.

3.3 This guide excludes construction protocols for OSCG such as clean manufacturing, integrity of fabrication, and prequalification of materials.

3.4 This guide does not intend to cover all the important safety considerations which relate to the OSCG systems, feed gas, equipment, or installations.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

blending (or dilution) — the combination of two or more chemicals (one of which may be DI water) to create the desired solution mixture.

clean sampling — a specifically designed scheme to allow for the taking of chemical samples, avoiding any contamination from the operator or background environment of the area.

day tank — a chemical storage vessel, of appropriate material(s), used to store a volume of product chemical that could be consumed in one or more days.

DI water — high purity 18 megohm water

OSCG system — the stand-alone unit that produces (or uses) a high purity gas and reacts it with water (or the appropriate aqueous solution) to produce the desired ultra pure chemical solution. This unit is intended for use on the manufacturing site and in a centralized scheme to support all or a portion of the site's chemical requirement(s).

overall implementation — this term is used to refer to the entire scope for an OSCG installation, including the Gas Storage/Supply system, the OSCG system, chemical storage tanks, chemical plumbing, and interface with the chemical distribution system. Gas supplies are covered in related guides.

process plumbing — tubing or piping whose surface is directly in contact with the chemical. Typically constructed from high purity perfluorinated materials or other high purity polymers.

product chemical — the name given to the actual chemical produced on site by the OSCG system.

pump — a mechanical or pneumatically operated device used to create hydraulic force for chemical transfer.

QC tank — storage tank for the staging of chemical to be quality verified prior to release to the Product storage tank. This optional quality verification scheme allows for 100% chemical verification.

secondary containment — pipe or tubing that contains the process plumbing intended to provide a second level of containment in the event of failure of the primary process plumbing. Clear PVC pipe is typically, but not exclusively, used for the secondary containment.

SPC scheme — an alternate quality verification scheme that would involve random sampling and analysis of product chemical. This scheme relies on Statistical Process Control to monitor and ensure product chemical quality.

6 General Requirements

6.1 *Materials* — Only specific materials are permitted to be in direct contact with the gas(es) and/or chemical(s) used or produced in the OSCG system. This is driven by both chemical compatibility to ensure long term system survivability and product chemical purity.

6.1.1 *Cabinet Construction* — Polypropylene or other suitable materials house chemical handling components (pumps, valves, filters, etc). All cabinets must be designed to be leak tight and provide a minimum of 110% liquid containment within the cabinet.

6.1.2 *Process Plumbing and Components* — Polymeric materials are recommended for all plumbing and components that will be in direct, routine contact with the chemical solutions.

6.1.3 *Feed Gas Plumbing and Components* — Feed Gas, prior to purification (when gas purification is part of the OSCG system), will be plumbed using compatible materials such as stainless steel.

6.1.4 *Storage Tanks* — Liner materials used in chemical storage tanks that will be in direct contact with the chemical solution will be chosen to maintain chemical purity.

6.2 *Overall System Installation*

6.2.1 All OSCG systems, support equipment, process plumbing, and tanks will be installed and facilitated according to vendor guide which ensures mechanical integrity, leak integrity, minimal contamination, and overall proper operation.

6.2.2 All OSCG implementations will require the following basic components: Feed Gas Storage and Delivery Subsystem, the OSCG system(s), some type of Quality Control Scheme with "Clean Sampling" provisions, Product Chemical Storage with a suitable volume of Product storage, and, optionally, a Back-up Chemical scheme.

6.2.3 Prior to any introduction of chemical to any system or subsystem, a complete water test is performed to verify leak integrity. This process will also be used to provide the initial clean-up of all systems, tanks, and process plumbing.

6.2.4 The protocol for the installation and start-up of all systems and subsystems follows a predefined procedure and timeline which incorporates all of the physical activities, testing parameters, and check points for approval at each stage.

6.2.5 Cleanroom environment is not necessary.

6.3 *Initial System Qualification* — The following general procedure will be required for the initial mechanical and chemical qualification of the OSCG installation.

6.3.1 Electro-mechanical check-out

6.3.2 Initial chemical charge

6.3.3 Initial processing to fill and purge all systems, plumbing, and tanks with chemical.

6.3.4 Initial sampling to verify purity and assay.

6.3.5 Continuous processing to prove purity and capacity through a specific number of samples.

6.3.6 Continuous processing to establish overall system reliability.

7 Basic Design Specifications

7.1 *General* — Each OSCG installation contains certain basic components and a variety of design options to meet a specific customer's needs. This section describes the basic installation requirements.

7.2 *Feed Gas Storage* — All OSCG implementation will require an appropriately sized Feed Gas storage vessel.

7.2.1 The Feed Gas Storage vessel should be of sufficient volume per customer, vendor, and logistical considerations.

7.2.2 The gas delivery system must be designed to deliver sufficient gas flowrates at the correct pressure to the OSCG system.

7.2.3 The appropriate containment and controls are required to ensure safe and reliable operation.

7.3 *Gas Supply Plumbing* — Gas supply plumbing will be required to bring Feed gas from the storage vessel to the OSCG system.

7.3.1 Materials used for the gas supply plumbing will be chosen based on compatibility with the specific feed gas.

7.3.2 Supply plumbing size will be chosen based on the flow requirements and delivery distance to ensure adequate supply volume and pressure at the OSCG system.

7.3.3 Secondary containment may be required based on the Feed gas, delivery plumbing routing, and local and/or company codes.

7.3.4 An appropriate component design must be used for the gas/liquid interface(s).

7.4 *The OSCG System* — The appropriate OSCG system will be defined based on overall capacity requirements.

7.4.1 The OSCG system can provide feed gas purification and chemical generation within a stand alone packaged unit or use externally purified feed gases. Optional Feed gas purification may also be provided in this package.

7.4.2 The OSCG system will have a dedicated control system to control all process parameters and monitor all system safety interlocks including external safety systems.

7.4.3 The OSCG will provide pressurized chemical to the Product Quality verification subsystem.

7.5 *Product Quality Verification* — All OSCG installation will include some type of Product sampling and quality verification scheme.

7.5.1 The standard quality verification scheme will provide for an in-line, "Clean Sample" station to allow for random samples to be taken for analysis.

7.5.2 A SPC quality assurance scheme can be utilized to track and record product chemical purity and assay guides. Readings are plotted using X-bar/R format and reacted to based on standard SPC rules.

7.5.3 In this scheme product chemical is transferred to the Product storage tank directly from the OSCG system, through the sampling subsystem or directly to chemical delivery systems.

7.6 *Product Storage* — All OSCG implementation will include a Product chemical storage scheme to ensure chemical availability to the customer.

7.6.1 Product storage is achieved, typically, by including an appropriately sized storage tank. This tank becomes the source to the chemical distribution system.

7.6.2 Product storage volume is defined to provide suitable inventory of product chemical storage. This will provide chemical available to the distribution system during periods of both scheduled and unscheduled maintenance.

7.6.3 Additionally, a back-up supply of prequalified chemical may be available to transfer into the Product tank, if required.

7.7 *Central Monitoring System* — A central CPU based monitoring system is required for multiple purposes in the overall implementation.

7.7.1 The central CPU will communicate with all subsystems and tanks to share information, as required, to ensure total system operations.

7.7.2 The central CPU also provides data logging and database features to track and log product quality and system failure data as required.

7.7.3 The central CPU can also provide a remote monitoring feature and interface with the customer's facility tracking system (if desired).

8 Optional Configurations and Support Systems

8.1 *Feed Gas Supply* — Some customers may already have an existing source of an appropriate Feed gas for the OSCG system. Implementation schemes can be configured to utilize this existing gas storage and supply system. The existing system will need to meet the vendors guides for gas purity and line pressures.

8.2 *Product Storage and Staging Tanks* — Some customers may already have tanks that can be used for Product Storage and/or staging applications. Implementation schemes can be configured to utilize these existing storage tanks. The existing tanks must meet vendors guides for materials, inlets/outlets, and volume. Level sensor data will be provided to the central CPU system.

8.3 *Multiple OSCG Systems* — Depending on capacity requirements, OSCG installations can be configured to have multiple Generator systems in parallel. All product outputs should have the capability to be sampled individually before combining into a common product stream for storage.

8.4 *Support Systems* — Various support systems and options can be provided to support the overall implementation scheme.

8.4.1 Stand-alone, water-cooled Chiller(s) may be required, if the house chilled water is not available.

8.4.2 Redundant pump options should be available in any pumping system to allow for either manual switch over or automatic back-up.

8.4.3 Transfer pumping systems or transfer options should be available for the transfer of chemical from or to remote storage tanks.

8.5 *Chemical Distribution* — Chemical distribution systems may or may not be in existence at specific customer sites. The distribution of chemical from the product storage to use points will be important to maintain chemical purity. These distribution systems should be available as a directly supplied option or offered through a sub-contracted supplier.

8.6 *Filtration Options* — Recirculation filtration of either QC tanks or the Product storage tank is important to control particle levels in the final chemical. Recirculation filtration options should be provided, depending on the specific chemical storage configuration.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F47-0200
SPECIFICATION FOR SEMICONDUCTOR PROCESSING EQUIPMENT VOLTAGE SAG IMMUNITY

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on www.semi.org January 2000; to be published February 2000. Originally published September 1999.

1 Purpose

1.1 Semiconductor factories require high levels of power quality due to the sensitivity of equipment and process controls. Semiconductor processing equipment is especially vulnerable to voltage sags. This document defines the voltage sag ride-through capability required for semiconductor processing, metrology, and automated test equipment.

1.2 The requirements in this international standard were developed to satisfy semiconductor industry needs. While more stringent than existing generic standards, this industry-specific specification is not in conflict with known generic equipment regulations from other regions or generic equipment standards from other organizations (see Related Information section).

1.3 It is the intent of this standard to provide specifications for semiconductor processing equipment that will lead to improved selection criteria for sub-components and improvements in equipment systems design. While it is recognized that in certain extreme cases or for specific functions battery storage devices may be appropriate, it is not the intent of this standard to increase the size or use of battery storage devices provided with equipment. Focus on improvements in equipment component and system design should lead to a reduction or elimination in the use of battery storage devices to achieve equipment reliability during voltage sag events.

2 Scope

2.1 This document specifies the minimum voltage sag ride-through capability design requirements for equipment used in the semiconductor industry. The expected equipment performance capability is shown graphically on a chart representing voltage sag duration and percent deviation of equipment nominal voltage. Standard evaluation test method references are also included.

2.2 The primary focus for this specification is semiconductor processing equipment including but not limited to the following tool types:

- Etch equipment (Dry & Wet),
- Film deposition equipment (CVD & PVD),
- Thermal equipment,
- Surface prep and clean,
- Photolithography equipment (Stepper & Tracks),
- Chemical Mechanical Polishing equipment,
- Ion Implant equipment,
- Metrology equipment, and
- Automated test equipment.

2.3 This specification applies to semiconductor processing equipment to include the equipment mainframe and all subsystems whose electrical power is directly affected by the operation of the equipment's EMO system.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Not included in this standard are over voltage conditions, voltage sag duration of less than 0.05 seconds (50 milliseconds), and voltage sag duration of greater than 1.0 seconds. If necessary, the Information Technology Industry Council (ITIC) "CBEMA-curve" contained in IEEE 446, IEEE 1100, and SEMI E51 can be used to specify additional requirements outside the range of this document (see Related Information, Section R1-1).

3.2 This specification does not address wafer quality with regard to processing variation caused by voltage sags. It is recommended that each equipment supplier consider the effects of voltage sags on their equipment processes. If voltage sags above the defined line can result in known wafer quality problems, then an appropriate notification-only scheme should be considered in the equipment design. To be in conformance with this standard that notification scheme should not be classified as an equipment interrupt per SEMI E10.

3.3 This standard addresses specifications for semiconductor processing equipment voltage sag immunity. Factory systems voltage sag immunity and electric utility voltage sag performance are covered in other related standards.

3.4 This standard is intended to be a performance specification, it is not intended to address design issues related to safety which are covered elsewhere in the SEMI Standards (see SEMI S2).

NOTE 1: Safety related systems may require ride-through capability for conditions up to and including full power failure. Further, if hazards could result from voltage sags greater than those allowable in Table 1, provisions should be made to negate or eliminate such hazards.

3.5 International, national and local codes, regulations and laws should be consulted to ensure that the equipment meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

SEMI F42 — Test Method for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *IEEE Standards* [1]

IEEE 446 — IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book)

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *assist* — an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:

- The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).
- There is no replacement of a part, other than specified consumables.
- There is no further variation from specification of equipment operation [SEMI E10].

5.2 *failure* — any unplanned interruption or variance from the specifications of equipment operation other than assists [SEMI E10].

5.3 *interrupt* — any assist or failure [SEMI E10].

5.4 *ride-through capability* — the ability of equipment to withstand momentary interruptions or sags [IEEE 1250]. Also known as voltage sag immunity.

5.5 *voltage sag* — an rms reduction in the ac voltage at power frequency for durations from half-cycle to a few seconds [IEEE 1250]. Also known as voltage dip.

6 Ordering Information

6.1 Semiconductor manufacturers may use this standard when procuring processing equipment to specify equipment ride-through requirements capability to the equipment supplier. This document may also be used by semiconductor processing equipment suppliers to specify ride-through requirements to component and module suppliers.

6.2 Orders for equipment in accordance with this standard shall include:

a) This specification number and date of issue.

b) Requirements for qualification testing per SEMI F42.

c) Any certification showing passage of qualification tests required to be provided (optional).

d) Any test results required to be included in reports to be provided (optional).

7 Requirements

7.1 Semiconductor processing, metrology, and automated test equipment must be designed and built to conform to the voltage sag ride-through capability shown in Figure 1. Equipment must continue to operate without interrupt (see Terminology) during conditions identified in the area above the defined line.

7.2 The requirements defined in this specification apply to two phase (phase-to-phase) and single phase (phase-to-neutral) voltage incidents.

7.3 The performance curve is defined by values shown in Table 1—voltage sag duration and percent deviation from equipment nominal voltage.

NOTE 3: For recommendations on equipment ride-through capability below 0.05 seconds (50 milliseconds) and above 1.0 seconds, see Related Information at the end of this document.

1 The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA

8 Test Methods

8.1 Qualification tests are conducted on samples of production articles, not each item produced. Qualification testing of equipment to requirements in this specification should be performed per SEMI F42.

9 Related Documents

9.1 *SEMI Standard*

SEMI S9 — Electrical Test Methods for Semiconductor Manufacturing Equipment

9.2 *CENELEC Standard* [2]

EN 50082-2 — Electromagnetic Compatibility — Generic Immunity Standard, Part 2: Industrial Environments

9.3 *IEC Standard* [3]

IEC 61000-4-11 — Electromagnetic Compatibility (EMC) — Part 4: Testing and Measuring Techniques — Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

9.4 *IEEE Standard*[1]

IEEE 1346 — Electric Power System Compatibility with Electronic Process Equipment

NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

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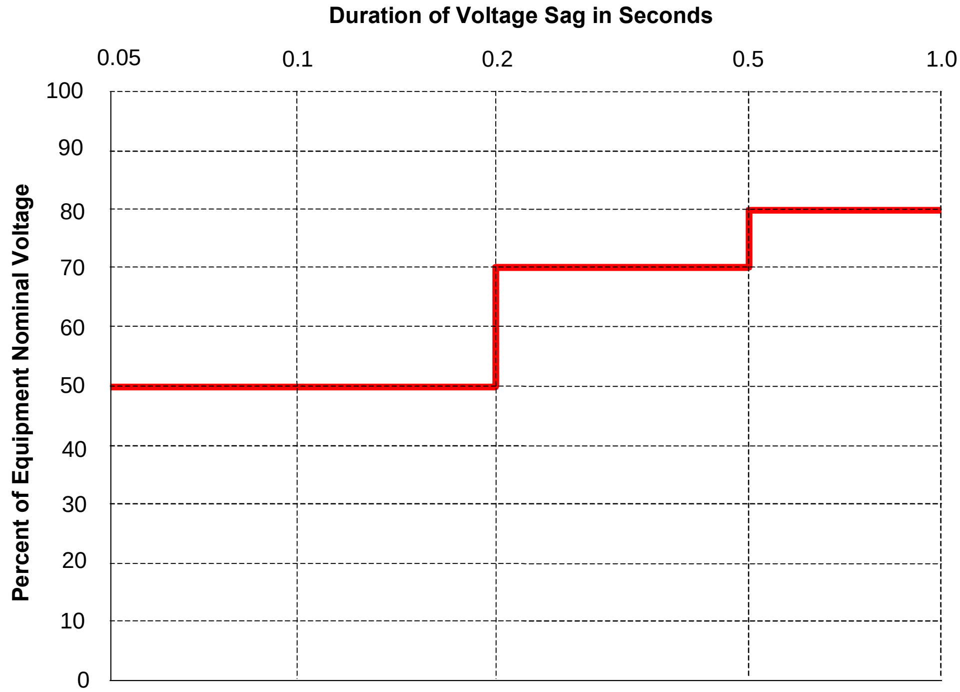
2 European Committee for Electrotechnical Standardization, Rue de Stassart, 35, B – 1050, Brussels

3 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland

Table 1 Voltage Sag Duration and Percent Deviation from Equipment Nominal Voltage

VOLTAGE SAG DURATION				*VOLTAGE SAG*
Seconds (s)	*Milliseconds (ms)*	*Cycles at 60 hz*	*Cycles at 50 hz*	*Percent (%) of Equipment Nominal Voltage*
< 0.05 s	< 50 ms	< 3 cycles	< 2.5 cycles	Not specified
0.05 to 0.2 s	50 to 200 ms	3 to 12 cycles	2.5 to 10 cycles	50%
0.2 to 0.5 s	200 to 500 ms	12 to 30 cycles	10 to 25 cycles	70%
0.5 to 1.0 s	500 to 1000 ms	30 to 60 cycles	25 to 50 cycles	80%
> 1.0 s	> 1000 ms	> 60 cycles	> 50 cycles	Not specified



NOTE: Equipment must continue to operate without interrupt during voltage sags above the line.

Figure 1
Required Semiconductor Equipment Voltage Sag Ride-Through Capability Curve

RELATED INFORMATION 1
RELATIONSHIP TO OTHER ELECTRICAL STANDARDS

NOTE: This related information is not an official part of SEMI F47 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Basis for this Industry-Specific Semiconductor Standard

R1-1.1 The Information Technology Industry Council (ITIC) "CBEMA-curve," contained in IEEE 446, IEEE 1100, and SEMI E51, was used as a starting point in establishing recommended ride-through limits. The following curve (see Figure R1-1) was developed to define voltage sag ride-through for use with semiconductor processing equipment. Primarily due to testing limitations, only the portion between 0.05 seconds (50 milliseconds) and 1.0 seconds was selected for inclusion in the specification. As future test equipment, methods, and data are developed the specified duration limits may be expanded. Recommended voltage sag ride-through capability limits from zero to 100 seconds are included here for reference (see Figure R1-1). While not currently included in this SEMI specification the wider range should be considered when designing equipment and selecting components.

R1-1.2 Over voltage conditions also covered in the ITIC CBEMA-curve contained in IEEE 446, IEEE 1100, and SEMI E51, are not considered in the scope of this industry-specific specification primarily due to the extremely low number of semiconductor equipment interruptions caused by over voltage events. While not in the scope of this specification, over voltage conditions should not be ignored and use of existing equipment protection techniques should be continued (see SEMI E51 or IEEE 446 for generic equipment over voltage ride-through specifications).

R1-2 Relationship to Generic Electrical Standards

R1-2.1 This SEMI standard is intended to be coordinated with related SEMI, IEC and IEEE standards. The relationship of this SEMI specification to many other standards that address equipment immunity, test methods, and safety was considered in development of this specification. For example, the emerging IEC Generic Immunity standard for industrial environments currently published by CENELEC as EN 50082-2 recommends a generic equipment immunity limit for Europe. When published by IEC, this standard will provide a generic equipment voltage sag immunity limit. Another example is the US National Fire Protection Association on Industrial Machinery (NFPA 79), which sets a generic equipment voltage sag immunity limit for the United States.

R1-2.2 These emerging generic limits were considered in the establishment of ride-through limits for semiconductor equipment. However, most generic equipment limits are less stringent than the existing CBEMA-curve currently referenced in SEMI E51. For most installations meeting the CBEMA limits (a specification which was developed for computer business equipment) still results in an unacceptable number of semiconductor equipment interrupts. Therefore, the requirements in this international standard were developed to better suit the semiconductor industry. While more stringent, this industry-specific specification is not in conflict with known generic equipment regulations from other regions or generic equipment standards from other organizations.

R1-2.3 Another published IEC standard defines a generic immunity test method for voltage sags (dips), IEC 61000-4-11. This standard does not provide limits but does provide a voltage sag test method for single-phase equipment rated less than 16 amps. It has been considered in defining voltage sag ride-through parameters and it may provide an interim voltage sag immunity test method. As noted in this document, a test method for three-phase equipment greater than 16 amps is being developed for use with semiconductor equipment.

R1-2.4 The generic type standards developed for industrial or consumer equipment by organizations like IEC, ITIC, and IEEE provide a foundation for industry-specific standards like those published by SEMI Standards. In acknowledgement of this tiered approach to standardization there are provisions for recognizing industry-specific or product-type standards by organizations like IEC. Typically, product-type standards when developed by industry-specific organizations take precedent over the broader based generic industrial standards.

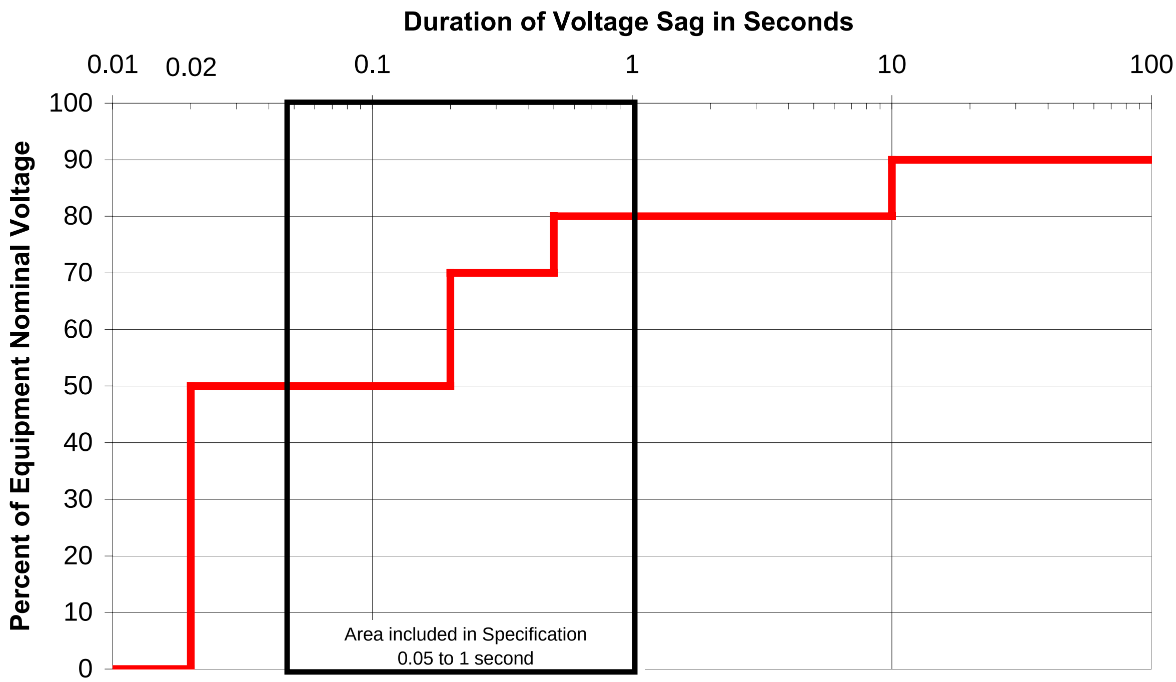


Figure R1-1
Recommended Semiconductor Equipment Voltage Sag Ride-Through Capability Curve from 0 to 100 Seconds

SEMI

SEMI F48-0600
TEST METHOD FOR DETERMINING TRACE METALS IN POLYMER MATERIALS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available on www.semi.org April 2000; to be published June 2000.

1 Purpose

1.1 This method provides a procedure for determining the nonvolatile trace inorganic impurities in bulk polymeric materials.

2 Scope

2.1 Following digestion by dry ashing (DDA) or digestion in closed vessel (DCV) preparation techniques, samples previously obtained and cleaned according to SEMI F40 are analyzed for trace inorganics using inductively coupled plasma-mass spectrometry (ICP–MS), graphite furnace atomic absorption spectroscopy (GFAAS), and/or inductively coupled plasma-atomic emission spectroscopy (ICP–AES).

2.2 Materials for analysis include, but are not limited to:

- Raw polymer materials (resins), such as pellets of perfluoroalkoxy (PFA), polyvinylidene fluoride (PVDF), ethylenechlorotrifluoroethylene (ECTFE), polyetheretherketone (PEEK), polypropylene (PP), polyethylene (PE), acetal resin, polyvinyl chloride (PVC), Perfluoromethylether-based Perfluoroalkoxy (MFA) and powders of polytetrafluoroethylene (PTFE).
- Polymer components of tubing, piping, fittings, valves, regulators, filter housings, filter cartridges, O–rings and gaskets used in ultrapure water (UPW) and liquid chemical distribution systems (LCDS). See Section 3.8 for further information.
- Ion-exchange resins
- Polymer products used in the manufacturing of semiconductor devices, such as wafer carriers and wands, as well as accessories internal to wet equipment (e.g., drums in spin rinse dryers, tanks in quick dump rinsers). See Section 3.8 for further information.

2.3 The DDA sections of this document refer to an ashing technique, whereby the sample is placed into a platinum or quartz crucible and thermally decomposed. Thermal decomposition in muffle furnace or microwave muffle furnace may also be used. Additionally, oxygen plasma may be used separately or in conjunction with these techniques.

2.4 The DCV sections of this document refer to closed vessel microwave acid decomposition at elevated temperature and pressure. Alternatively closed vessel thermal conduction heating may also be applied.

2.5 ICP–MS, GFAAS, and ICP–AES are all appropriate methods for inorganic analysis. ICP–MS is the preferred method because it is more sensitive and efficient. Alternate procedures may be used if they meet the same analytical performance criteria. Each laboratory is responsible for verifying the validity of each method within its own operation.

2.6 This method is applicable for the elements found in Table 1:

Table 1 List of Applicable Elements (See NOTE 1.)

Aluminum	Magnesium
Barium	Manganese
Calcium	Nickel
Chromium	Potassium
Cobalt	Sodium
Copper	Strontium
Iron	Tin
Lead	Titanium
Lithium	Zinc
Molybdenum	Zirconium

NOTE 1: See Limitations, Section 3.3.

2.7 This method may be used for other materials, or other nonvolatile elements, if the end-user wishes and performance is demonstrated for the analyte of interest, in the matrices of interest, at the concentration levels of interest.

2.8 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The accuracy of the method is limited by the detection limits of the instruments and by the sample preparation procedure.

3.2 This procedure anticipates analysis levels in the ppm (mass/mass) range. Impurities less than 0.1 ppm may not be detected by this method.

3.3 When extending the method to other elements recovery should be evaluated during validation. Poor recovery rates are often found for volatile elements such as boron (B), arsenic (As), antimony (Sb), mercury (Hg), gold (Au), and tungsten (W) because of the relatively high temperature sample preparation method and poor stability of some elements in aqueous solution. Elements forming volatile halogenides can be affected due to the in-situ production of hydrogen halogenides when halogenated polymers are ashed.

3.4 This is a bulk analysis technique. For leachable testing or surface analysis refer to the Related Documents (Section 16) of this method.

3.5 Due to the rapid advances in digestion technology, consult the manufacturer's recommended instructions for guidance when conducting analyses using the DCV sections of this document.

3.6 DCV techniques can generate gaseous digestion reaction products, very reactive, or volatile materials at high pressures. Spontaneous venting which can occur during sample heating may cause venting of the vessels with potential loss of sample and analytes. Sample sizes greater than 0.25 g may accentuate this event.

3.7 In the use of the DCV technique, TiO2, alumina, and other oxides may not be totally dissolved. Sequestering of target analyte elements may occur.

3.8 Although this method allows the sampling of small pieces of polymer that are mechnically removed from a larger item, obtaining such samples in a clean manner may be difficult. Multiple sampling, separation and preparation techniques might be necessary to establish confidence in the results.

3.9 This document is not intended to supersede international, national or local codes, regulations, and laws. Each should be consulted to ensure that the method meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI F40 — Practice for Preparing Liquid Chemical Distribution Components for Chemical Testing

4.2 *ASTM Standard*[1]

ASTM D4375 — Standard Practice for Basic Definitions, Notation, and Symbology for Statistics in Committee D19 on Water

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *AAS/GFAAS* — atomic absorption spectroscopy/ graphite furnace atomic absorption spectroscopy

5.1.2 *amu* — atomic mass unit

5.1.3 *DCV* — digestion in closed vessel

5.1.4 *DDA* — digestion by dry ashing

5.1.5 *GFAAS* — graphite furnace atomic absorption spectroscopy

5.1.6 *ICP–AES* — inductively coupled plasma–atomic emission spectroscopy

5.1.7 *ICP–MS* — inductively coupled plasma–mass spectrometry

5.1.8 *ppb* — parts per billion by mass (ng/g)

5.1.9 *ppm* — parts per million by mass (µg/g)

5.1.10 *UPW* — ultrapure water (see Section 9.4)

6 Summary of Test Method

6.1 Samples previously prepared using SEMI F40 are ashed or digested under pressure within a digestion device, and trace inorganics in the residue are dissolved into acid and UPW. The sample is then analyzed by ICP–MS, GFAAS, and/or ICP–AES to determine the inorganic content of the material. This method applies only to nonvolatile metals (i.e., alkali metals, alkaline earths, and transition metals).

6.2 Data from different tests can be compared to determine the inorganic content in different materials and in the same material from different manufacturers.

7 Significance and Use

7.1 Determining the metallic contamination concentration in bulk polymer materials used in either distribution systems for process fluids or products in direct contact with the wafer is important criterion for deciding the suitability of a material. For example, ultrapure water contaminated by distribution system components may adversely affect microelectronic and other processes.

7.2 This method measures the total amount of impurities in the bulk of the material. These impurities will not necessarily leach into a process fluid stream.

1 American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103

8 Apparatus

8.1 *Muffle Furnace* — With temperature control ranging up to a minimum of 700°C and equipped with a means to regulate air circulation.

8.2 Microwave Muffle Furnace

8.3 *Crucibles* — Made of either platinum or quartz and with a 30 mL capacity.

8.4 ICP–MS

8.5 GFAAS

8.6 *ICP–AES* — Either simultaneous or sequential reading type.

8.7 Chemical Fume Hood

8.8 Propane Torch or Appropriate Heating Source with a minimum temperature of 650°C.

8.9 Device for digestions under a pressure of at least 30 bar (435 psi), with temperature control. This can be a laboratory microwave-based system or a system based on other heating sources.

8.9.1 In the case of microwave digestion devices: Laboratory microwave digestion systems should be used that possess appropriate temperature control of chemical reactions. Closed microwave systems must have controlled pressure relief.

8.9.2 Digestion vessels of appropriate internal volume should be used and construction should be of appropriate chemically inert materials. If the vessel is pressurized, it should be capable of withstanding a minimum pressure of 30 atm (30 bar or 435 psi), with controlled pressure relief of reagents and digestion products.

NOTE 2: Only microwave manufacturer's approved vessels for that device should be used.

8.9.3 In case of a laboratory microwave digestion device: Oscillating turntable to insure homogeneous distribution of microwave radiation to all vessels.

8.9.4 Filter paper, qualitative or equivalent.

8.9.5 Filter funnel, polypropylene, polyethylene or equivalent.

8.10 Volumetric flasks, 20 mL or 50 mL capacity or equivalent.

8.11 Analytical balance, of appropriate capacity, with a ± 0.0001 g or appropriate precision for the weighing of the sample. Optionally, the vessel with sample and reagents may be weighed, with an appropriate precision balance, before and after microwave processing to evaluate the seal integrity in some vessel types.

9 Materials

9.1 Argon Gas 99.99% pure or better.

9.2 *Standards and Reference Materials*

9.2.1 For preparation of multi-element standard solutions, use NIST[2], NIST-traceable, or other appropriate international standards as stock solutions.

9.2.2 From these stock solutions, multi-element working standard solutions must be prepared daily by pipeting the appropriate volumes of the trace metal standards and diluting to the desired concentrations.

NOTE 3: Prepare these working standards using the same amount of acid as used for the sample.

9.2.3 For validation purposes, use appropriate international reference materials that match the sample matrix as close as possible.

9.3 All reagents should be of appropriate purity or high purity (acids for example, should be sub-boiling distilled where possible) to minimize the blank levels due to elemental contamination. If the purity of a reagent is questionable, analyze the reagent to determine the level of impurities. The reagent blank must be less than the minimum detection limit in order to be used.

9.3.1 Ultrapure Hydrochloric Acid less than 1 ppb for each trace metal.

9.3.2 Ultrapure Nitric Acid less than 1 ppb for each trace metal.

9.4 *Ultrapure Water*

9.4.1 For purposes of this test, references to water shall be understood to mean ultrapure water as defined by maximum individual metal and anion impurity levels of 0.1 ppb or less, nonvolatile residue levels of 0.1 ppm or less, resistivity of 18 megohm-cm or greater, and reactive silica impurity of less than 1.0 ppb.

10 Precautions

10.1 *Safety Precautions*

10.1.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

2 National Institute of Standards and Technology, 100 Bureau Dr., Gaithersburg, MD, 20899-001 USA, (301) 975-6478, <www.nist.gov>

10.1.2 Care must be taken in the handling and use of the acids to avoid acid burns or contamination of the acid. Acid should be neutralized before disposal.

10.1.3 Care must be taken when using the propane torch to avoid burns. The torch should not be used near flammable materials or solvents.

10.1.4 Care must be taken when using the muffle furnace to avoid burns.

10.1.5 When ashing fluoropolymeric materials, the ashing must be performed in a fume hood. When heated, fluoropolymer materials outgas hydrofluoric acid fumes and may also emit fluoropolymeric particles which, if inhaled, can cause a condition known as "polymer fume fever." If hot fluoropolymer fumes are inhaled, remove the individual to a well-ventilated area and seek medical attention.

10.1.6 The outer layers of vessels used in the DCV technique are frequently not as acid or reagent resistant as the liner material. To retain the performance and safety required these outer layers must be neither chemically degraded nor physically damaged. Routine examination of the vessel materials may be required to ensure their safe use.

10.1.7 Only DCV containers with pressure relief or control mechanisms or containers with suitably inert polymeric or quartz liners and pressure relief mechanisms are considered acceptable for use with this process.

NOTE 4: Only microwave manufacturer's approved vessels for that device should be used.

10.1.8 Use of laboratory microwave systems is required for this method. Users are advised not to use domestic (kitchen) type microwave ovens or cookware. Nor should inappropriately sealed containers without pressure relief for microwave acid digestions be used. See Section 16.3.1 for additional information on safety issues concerning the use of laboratory microwave systems.

10.1.9 Toxic nitrogen oxide(s), hydrogen fluoride, and toxic chlorine (from the addition of hydrochloric acid) fumes are usually produced during digestion. Therefore, all steps involving open or the opening of digestion vessels must be performed in a properly operating fume ventilation system.

10.1.10 The analyst should wear appropriate protective clothing, such as gloves and face protection, and must not at any time permit a solution containing hydrofluoric acid to come in contact with skin or lungs.

10.2 *Technical Precautions – Digestion by Dry Ashing (DDA)*

10.2.1 Flaming and ashing temperatures must be controlled so that they do not exceed 650°C to minimize metal loss due to volatilization. If the crucible becomes excessively hot for longer than about one minute during flaming, it may have overheated. When testing the method for recovery rates, it will become apparent that the sample has been overheated from the low recovery of metals.

10.2.2 One method of cleaning the crucibles and covers is to flame them with a propane torch or other appropriate heating source until they are sufficiently hot, allow them to cool, rinse in dilute ultrapure nitric acid, and then rinse in ultrapure water.

10.2.3 When ashing a sample, take care that all of the ash residue remains in the crucible.

10.2.4 Several factors concerning selection of crucible materials should be considered when performing the DDA technique. For example, the crucible itself can contribute elevated levels of its own composition into samples at trace levels. Temperature restrictions are another factor to consider in the selection of the crucible material. Corrosion of the crucible during the decomposition of the sample should also be considered. For example, in the ashing of fluorinated materials, platinum is preferred over quartz glass that could be etched by the liberated hydrogen fluoride.

10.3 *Technical Precautions – Digestion in Closed Vessel (DCV)*

10.3.1 Trace analysis requires a thorough cleaning. One method of cleaning the vessels is to leach with hot (1:1) hydrochloric acid (greater than 80 C, but less than boiling) for a minimum of two hours followed with hot (1:1) nitric acid (greater than 80 C, but less than boiling) for a minimum of two hours and rinsed with reagent water and dried in a clean environment.

10.4 *Other Technical Precautions*

10.4.1 When switching between high concentration samples and low concentration samples, all crucibles or digestion vessels should be cleaned according to the corresponding and recommended cleaning procedure. This cleaning procedure should also be used whenever the prior use of the digestion vessels is unknown or cross contamination from vessels is suspected.

10.4.2 Trace metallic levels of reagent blanks must be significantly lower than those in the sample in order to obtain accurate results for the analyte of interest.

10.4.3 Perform sample preparation in a clean environment and under a fume hood to minimize contamination.

11 Sampling

11.1 *Sampling of Test Specimens*

11.1.1 Test specimens shall be representative of the polymer material being tested and shall be free of embedded particles and extraneous surface contamination when visually inspected.

11.1.2 Two samples of each material shall be prepared per SEMI F40. This test is performed in duplicate. More samples may be analyzed if desired.

NOTE 5: The samples are cleaned and weighed according to SEMI F40. The sample preparation described in this document begins with either the ashing (DDA) or digestion under pressure (DCV) of the polymer material.

11.2 *Sample Preparation – Digestion by Dry Ashing (DDA)*

NOTE 6: Digestion by ashing using an oxygen plasma asher differs considerably from the described procedures that refer to ashing in open crucibles. Specific instructions are available from the instrument manufacturers.

11.2.1 Clean the digestion container and cover using appropriate methods for the vessel materials and procedures being employed.

11.2.2 Place the sample into a cleaned crucible. For at least two additional samples, add the recovery spike as discussed in Section 12.

11.2.3 Use a propane torch or other appropriate heating source to carefully flame the outside of the crucible until the polymer inside the crucible is completely charred. Do not flame exceedingly, i.e., do not allow a platinum crucible, for example, to become red hot, as excessive heat will allow some metals to volatilize.

NOTE 7: This step must be carried out in a well-ventilated fume hood.

11.2.4 Prepare at least three procedural blanks by flaming three or more empty crucibles using the method discussed in Section 11.2.3. The results from these blanks will be used to determine the metallic contribution from the crucibles themselves, from the reagents and from the test procedure. These procedural blanks should be treated like any other sample. Crucibles should be rotated in and out of service so that the same crucibles are not always used for blanks.

11.2.5 Place the charred sample crucibles and blank crucibles in a muffle furnace, cover the crucibles with the cleaned covers, and continue to char at 500 to 650°C until all the carbon is removed (usually over a period of 6–18 hrs). The removal of all carbon is indicated by the absence of black material in the sample.

NOTE 8: Some oxides (such as SnO_2) are black and may confound this determination. If a sample is still black after 18 hours, assume that it is an oxide and continue with the procedure.

11.2.6 Allow the crucibles to cool.

11.2.7 Add the appropriate amount (1–2 mL) of concentrated ultrapure hydrochloric acid to each crucible.

11.2.8 Evaporate the hydrochloric acid to dryness in a chemical hood at less than 100°C if necessary to permit instrumental compatibility.

NOTE 9: The presence of chloride in the sample can result in interferences for the determination of arsenic and vanadium by ICP-MS.

11.2.9 Continue preparing the sample as described in Section 11.4.

11.3 *Sample Preparation – Digestion in Closed Vessel (DCV)*

11.3.1 Clean the digestion container and cover using appropriate methods for the vessel materials and procedures being employed.

11.3.2 Place the sample into a cleaned digestion container. For at least two additional samples, add the recovery spike as discussed in Section 12.

11.3.3 Add the reagents needed for the digestion.

11.3.4 Prepare at least three procedural blanks by adding the same amount of all reagents, but no sample, to three or more additional containers. The results from these blanks will be used to determine the metallic contribution from the containers themselves, from the reagents and from the test procedure. These procedural blanks should be treated like any other sample. Containers should be rotated in and out of service so that the same containers are not always used for blanks.

11.3.5 The analyst should be aware of the potential for a vigorous reaction. If a vigorous reaction occurs upon the initial addition of reagent or the sample is suspected of containing easily oxidizable materials, allow the sample to predigest in the uncapped digestion vessel. Heat may be added in this step for safety considerations (for example the rapid release of carbon dioxide from easily oxidized polymeric material). Once the initial reaction has ceased, the sample may continue through the digestion procedure.

11.3.6 Seal the vessel according to the manufacturer's directions.

11.3.7 Properly place the vessel in the digestion system according to the manufacturer's recommended specifications and connect appropriate temperature and pressure sensors to vessels according to manufacturer's specifications.

11.3.8 Set the parameters of the digestion device to manufacturer's recommendations.

NOTE 10: If the pressure exceeds the pressure limits of the vessel, the pressure will be reduced by the relief mechanism of the vessel.

NOTE 11: Pressure control for a specific matrix is applicable if instrument conditions are established using temperature control. Because each matrix will have a different reaction profile, performance using temperature control must be developed for every specific matrix type prior to use of the pressure control system.

11.3.9 At the end of the digestion program, allow the vessels to cool for an appropriate period of time before removing them from the system. When the vessels have cooled to near room temperature, determine if the microwave vessels have maintained a seal throughout the digestion. Due to the wide variability of vessel designs, a single procedure is not appropriate. The use of a spiked control sample is appropriate to ensure that analyte loss has not occurred due to vessel venting. For vessels with burst disks, a careful visual inspection of the disk may identify compromised sample digestions.

11.3.10 Complete the preparation of the sample by carefully uncapping and venting each vessel in a fume hood. Vent the vessels using the procedure recommended by the vessel manufacturer. Transfer the sample to an appropriate acid cleaned container.

11.3.11 If the digested sample contains particulates, which may clog nebulizers or interfere with injection of the sample into the instrument, the sample may be centrifuged, allowed to settle, or filtered.

11.3.11.1 If necessary, centrifugation at 2,000–3,000 rpm for 10 minutes is usually sufficient to clear the supernatant.

11.3.11.2 *Settling* — If undissolved material remains such as TiO, or other refractory oxides, allow the sample to stand until the supernatant is clear. Allowing a sample to stand overnight will usually accomplish this.

11.3.11.3 *Filtering* — If necessary, the filtering apparatus must be thoroughly cleaned and pre-rinsed with dilute (approximately 10% V/V) nitric acid. Filter the sample through qualitative filter paper into a second acid-cleaned container.

11.3.12 Continue preparing the sample as described in Section 11.4.

11.4 *Preparation of the Sample for Analysis*

11.4.1 If the sample was obtained from the DDA method, add 0.5 mL concentrated nitric acid to each crucible.

11.4.2 For samples obtained from the DCV method, transfer or decant the sample into volumetric ware.

11.4.3 Dilute either obtained sample to a required volume with ultrapure water (usually 20 mL). Alternatively, a gravimetric dilution of the samples is also appropriate. The samples are now ready for analysis. See Related Documents, Section 16 for applicable trace inorganics test methods.

12 Recovery Preparation and Percentage Recovery Rate Determination

12.1 Metal recovery percentage must be determined for all instruments by the individual laboratory. This is accomplished via spiking a crucible or digestion vessel containing a polymer sample with a known concentration of metals. Then, determining the percentage of each metal recovered after the decomposition process or acid digestion. The following provides the recommended method for spiking:

12.1.1 Add a known volume of a standard to a crucible or digestion container containing a polymer sample.

12.1.2 *For DDA* — Gently evaporate the standard solution to dryness.

12.1.3 Digest the dried standard and dried polymer using the same procedure as for the samples. Typical recovery rates are 70–110% for the alkali, alkaline earths, and most transition metals.

13 Data Analysis

13.1 *Calculations*

13.1.1 The concentration of trace metals in the solution must be calculated to determine the concentration in µg/g (ppm) of the polymeric material using the following equation:

polymer concentration (µg/g) =
= solution concentration
(µg/L) × solution volume (L) / mass of the polymer(g)

13.1.2 Since the procedural blank does not contain a weighed sample, the results must be transformed to solid concentrations (in µg/g) by using the average weight of the samples (see Section 11.1.2 and corresponding NOTE).

14 Data Presentation

NOTE 12: Use the Report Form provided in Section 17 of this document.

14.1 *Sample Information*

14.1.1 Provide the date(s) of the test, the person and/or company requesting the analysis, the method in which the sample was obtained (e.g., if it was separated from a larger component and delivered to the laboratory), operator and laboratory performing the test, type of material (e.g., PFA pellets, injection molded PVDF valve, perfluoroelastomer O-ring), material supplier, material model and lot number(s), date sample was obtained and if the sample is a prototype or production material.

14.2 *Methods*

14.2.1 Provide the method of cleaning the sample as well as indicating if the sample arrived pre-cleaned from the requester or if it was cleaned in the laboratory performing the test.

14.2.2 Check the applicable box for the type of digestion. Complete as well the information regarding the conditions.

14.3 *Results*

14.3.1 Use Table 1, Trace Metals in Bulk Polymer Worksheet in Section 17.3 to report the results of the analysis along with detection limits and recovery rates for all elements required in the samples.

NOTE 13: For this document, the detection limit is defined as the concentration equivalent to three standard deviations of the results of the procedural blanks (see Section 13.1.2).

NOTE 14: The procedural blanks should be averaged and then subtracted from each sample (see Columns 3 and 4 of Table 1).

NOTE 15: If multiple samples of the same polymer material are evaluated, an average and standard deviation must be reported.

15 Precision and Bias

15.1 Expected variations in the blank are due to environmental and instrument variation.

15.2 Expected variation in the samples is 20–30% and is due to environmental, instrumental, and ashing or digestion variations.

15.3 This test does not give an indication of the variations found in the polymer sample material.

15.3.1 Analyze multiple samples of the same polymer material to determine the variation.

15.3.2 Refer to ASTM D4375 for information regarding sample populations to determine differences between materials.

16 Related Documents

16.1 *References Pertaining to ICP–MS*

Dams, R. F. J., Goossens, J., Moens, L. "Spectral and Non-Spectral Interferences in Inductively Coupled Plasma Mass Spectrometry" Microchim. Acta 119 (1995):277-286.

Evans, E. H., Giglio, J. J., "Interferences in Inductively Coupled Plasma Mass Spectrometry" J Anal. Atom. Spectrom. 8 (1993):1-18.

Jarvis, K. E., Gray, A. L., Houk, R. S. "Handbook of Inductively Coupled Plasma mass Spectrometry" Blackie, Glasgow 1992 (USA: Chapman and Hall, New York).

Shao, Y. and G. Horlick. "Recognition of Mass Spectral Interferences in Inductively Coupled Plasma–Mass Spectrometry." *Applied Spectroscopy* 45 (1991):143.

16.2 *References Pertaining to ICP–AES*

Garbarino, J.R., B.E. Jones, G.P. Stein, W.T. Belser, and H.E. Taylor. "Statistical Evaluation of an ICP–AES Method for Routine Water Quality Testing." *Applied Spectroscopy* 39 (1985):535.

Winge, R.K., V.S.Fassel, R.N. Kniseley, E. De Kalb, and W.J. Haas Jr. "ICP as an Analytical Source." *Spectrochimica Acta* 32B (1977):327

16.3 *References Pertaining to Microwave Digestion*

Kingston, H. M. Skip and Haswell, Steve, Eds., Microwave Enhanced Chemistry: Fundamentals, Sample Preparation, and Applications, ACS Professional Reference Book Series, American Chemical Society, Washington, DC, 1997.

16.4 *U.S. EPA Documents*[3]

U.S. EPA Method 3052 — Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices

U.S. EPA RCRA SW-846 — Chapter 3, sections on clean chemistry and microwave decomposition.

16.5 *SEMATECH Documents*[4]

SEMASPEC #92010956B–STD — SEMATECH Provisional Test Method for Analyzing the Plastic Surface Composition and Chemical Bonding of Components of UPW Distribution Systems (ESCA Method)

SEMASPEC #92010936B–STD — SEMATECH Provisional Test Method for the Determination of Leachable Trace Inorganics from UPW Distribution System Components

3 Environmental Protection Agency, 401 M St., SW, Washington, DC 20460, USA

4 SEMATECH, 2706 Montopolis Dr., Austin TX 78741

17 Report Form

17.1 Sample Information Test Date(s): ________________

17.1.1 Person/Company Requesting Analysis: ____

17.1.2 Method of Obtaining Sample: ____

17.1.3 Operator and Laboratory Performing Test: _____________________________________

17.1.4 Sample Material: ________________ Sample Supplier: ___________________

17.1.5 Model/Lot Number: _________________ Date of Sample: ____________________

17.1.6 Circle one: Pre-Production Material or Final Production Material

17.2 *Methods*

17.2.1 Sample Cleaning Technique (SEMI F40 or other): _______________________________

17.2.2 Digestion Technique (check one)

☐ Dry Ashing
Type of Crucible: _______
Temperature of Ashing: _____°C
Time of Ashing: _________ hours

☐ Closed Vessel
Vessel Material: _____________
Reaction Conditions: _______________________
____

17.3 *Results*

Table 1 Trace Metals in Bulk Polymer Worksheet

Element	*Detection Limit (µg/g)*	*Procedural Blank (µg/g)*	*Result with Blank Subtraction (µg/g)*	*% Recovery*
Aluminum				
Barium				
Calcium				
Chromium				
Cobalt				
Copper				
Iron				
Lead				
Lithium				
Molybdenum				
Magnesium				
Manganese				
Nickel				
Potassium				
Sodium				
Strontium				
Tin				
Titanium				
Zinc				
Zirconium				

SEMI F49-0200
GUIDE FOR SEMICONDUCTOR FACTORY SYSTEMS VOLTAGE SAG IMMUNITY

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 A guide defining a systems approach to power conditioning is needed for semiconductor and flat panel display (FPD) facilities. Semiconductor and FPD factories require high levels of power quality due to the sensitivity of equipment and process controls. Semiconductor and FPD processing equipment is especially vulnerable to voltage sags. The facility electrical system distributes power to process equipment, support equipment, and facility infrastructure equipment. Facility electrical distribution systems should be designed to integrate the voltage sag susceptibility of all the equipment with the power quality supplied by the utility. Installing effective and efficient facilities power conditioning requires identification of appropriate conditioning technologies and properly applying the conditioning equipment.

1.2 Utilizing recommendations in this guide should result in effective power conditioning of the facility electrical distribution system such that the process equipment, associated support equipment and facilities infrastructure equipment function within acceptable ranges.

2 Scope

2.1 This guide is intended for facilities engineers, equipment engineers, and facilities managers who specify compatibility requirements for equipment and utility services, and in particular for electrical power requirements such as those found in SEMI E51.

2.2 This document provides recommendations for implementing a systems approach to identification and resolution of voltage sag events that disturb the performance of semiconductor process equipment. A program recommending facilities electrical distribution system monitoring and control strategies for both the direct and indirect effect of voltage sags on wafer processing is outlined as follows:

- Reasons for monitoring and conditioning (see Section 7.1).
- Facilities electrical distribution system power monitoring and conditioning (see Section 7.2).
- Quantifying process equipment performance (see Section 7.3).
- Quantifying support equipment and facilities infrastructure equipment performance (see Section 7.4).
- Utility power monitoring strategies (see Section 7.5).
- Measurement and modeling strategies (see Section 7.6).
- Power enhancing and conditioning strategies for use in the facilities electrical distribution system (see Section 7.7).

2.3 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guide addresses power quality monitoring and conditioning solutions primarily within the facilities electrical distribution system. Process equipment and utility performance are covered in other related standards.

3.2 This guide does not address the impact of voltage sags on equipment beyond the effect to the electrical components. Effects on interdependent equipment interlocks are not examined in detail in this document.

3.3 This guide is not intended to address design or materials issues related to safety which are addressed elsewhere in the SEMI guidelines (see SEMI S2).

3.4 This document is not intended to supersede international, national or local codes, regulations and laws. Each should be consulted to ensure that the equipment meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

4.2 *IEEE Standards*[1]

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

IEEE 1159 — IEEE Recommended Practice on Monitoring Electrical Power Quality

IEEE 1346 — IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *facilities infrastructure equipment* — component, modules, and systems used to transport materials like chemicals, power, water, effluent, and exhaust in semiconductor factories.

5.2 *process equipment* — fabrication equipment, inspection equipment, and cassette stage equipment used in semiconductor manufacturing.

5.3 *support equipment* — ancillary equipment not part of the process equipment main chassis.

5.4 *voltage sag* — an rms reduction in the ac voltage, at power frequency, for durations from half-cycle to a few seconds.

6 Impact

6.1 The primary goal of this guide is mitigation of the effects of utility voltage sags on semiconductor processing equipment, support equipment, and facilities infrastructure equipment. A voltage sag event adversely affecting only one of these pieces of equipment can cause processing equipment to malfunction. Both the direct and indirect effect of voltage sags on process equipment should be managed. Voltage sags can effect process equipment directly through the electrical power points of connection. Voltage sags can also indirectly effect process equipment through fluctuations in air, gas, liquid, and other utility streams caused when voltage sags effect support equipment and facility infrastructure equipment.

6.2 Examples of processing equipment, support equipment, and facilities infrastructure equipment are listed below. The interaction of these three types of equipment is shown in Figure 1.

6.2.1 *Process Equipment*

- Etch (dry & wet)
- Film deposition (CVD & PVD)
- Thermal
- Surface prep and clean
- Photolithography (exposure & coater/developer)
- Chemical Mechanical Polishing
- Ion Implant
- Metrology
- Automated test

6.2.2 *Support Equipment*

- Vacuum system (roughing, turbo, and cryogenic pumps)
- RF generator
- Residual gas analyzer (RGA)
- Water heater
- Chiller
- Photolithography stepper laser light source power supplies
- Photolithography coat/developer temperature/ humidity controllers
- Emission control (burn boxes)

1 The Institute of Electrical and Electronic Engineers, Inc. (IEEE), 345 East 47th Street, New York, NY 10017-2394, USA

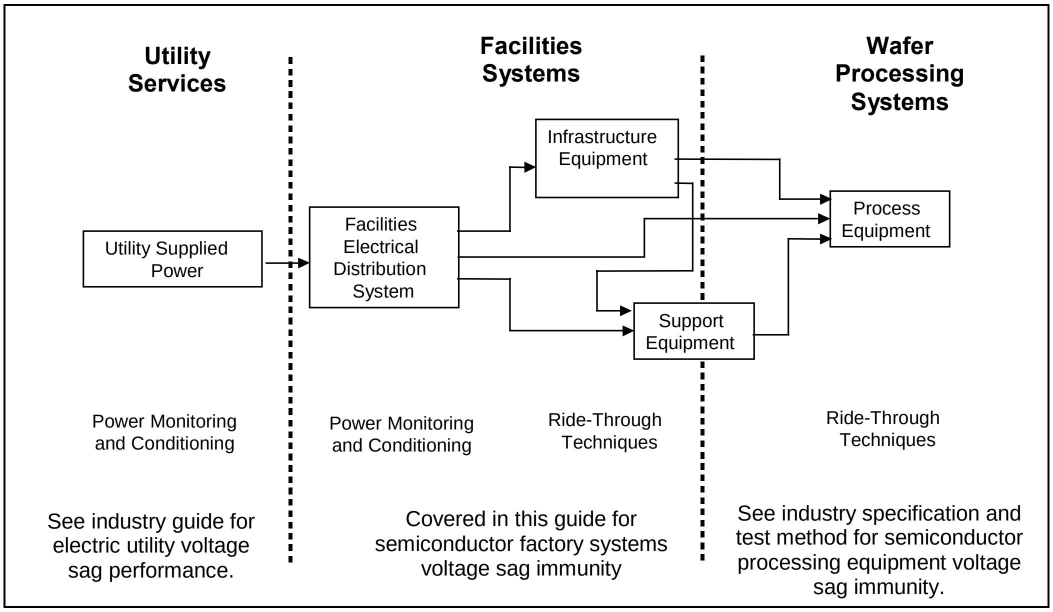


Figure 1
Power Quality Interfaces
(See Related Documents section.)

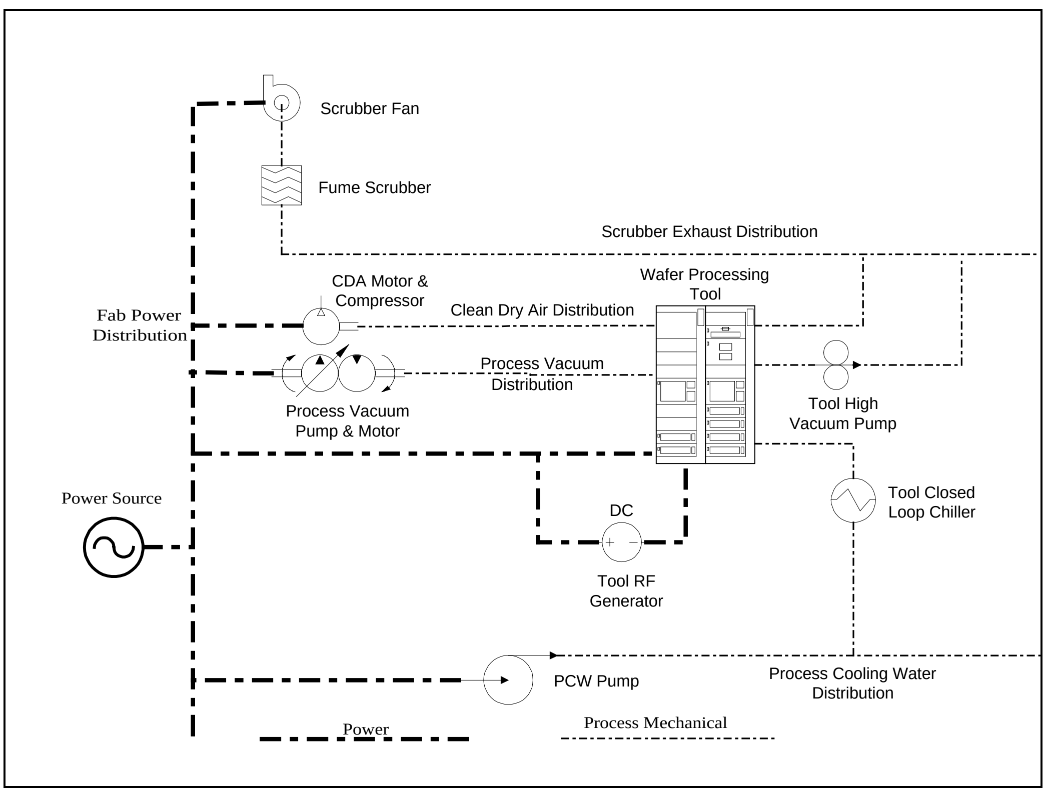


Figure 2
Typical Interconnection of Facility Infrastructure Equipment with Process and Support Equipment

6.2.3 *Facilities Infrastructure Equipment*

- Exhaust systems (scrubbers and VOC exhaust fans and controls)
- Process cooling water system (pumps and controls)
- Air compressors (and controls)
- Vacuum system (pumps and controls)
- Bulk and specialty gas distribution systems (pumps and controls)
- Liquid chemical distribution systems (pumps and controls)
- Power distribution systems

7 Power Monitoring and Conditioning Recommendations

7.1 *Reasons for Monitoring and Conditioning*

7.1.1 Semiconductor manufacturing facility electrical distribution systems should be designed to transport power to process equipment, support equipment, and other facilities infrastructure equipment without degradation to the electrical power quality. The system should recognize electrical power that does not meet specification and provide proper power conditioning so as not to impact wafer processing.

7.1.2 Power monitoring is used to measure electrical system power quality performance for the following reasons.

a) Monitoring data can be compared to equipment voltage sag specifications to identify problems.

b) Selection and control of power conditioning devices are dependent upon monitoring measurements.

7.1.3 Power conditioning is implemented to correct for gaps in equipment voltage sag susceptibility and point of connection electrical power performance. Power conditioning is occasionally implemented where the risk of unacceptable equipment performance is high, where equipment performance tolerance is outside specifications, and where equipment interruption is costly.

7.2 *Monitoring and Conditioning Program*

7.2.1 Quantify the process equipment, support equipment, and facilities infrastructure equipment voltage sag susceptibility using industry standard specifications and test methods. (See Sections 7.3 and 7.4.)

7.2.2 Set-up monitors for utility power quality (see Section 7.5).

7.2.3 Measure and/or model the impact of the facility electrical distribution system on the utility power delivered to the process equipment (see Section 7.6).

7.2.4 Model and evaluate cost/benefit of power conditioning solutions where there are gaps or high risks. Select and implement identified power conditioning solutions into the facilities electrical distribution system. (See Section 7.7.)

7.2.5 Maintain the installed power conditioning equipment and monitor the power either continuously or periodically to assure performance and evaluate results.

7.3 *Process Equipment Performance*

7.3.1 Facility design specifications should include requirements for processing equipment voltage sag immunity (see industry specification for semiconductor processing equipment voltage sag immunity). (See Related Documents section.)

7.3.2 Variability in process equipment manufacturing and supplied utility power quality preclude interruption free manufacturing. This variation comes from multiple sources:

a) Verification of representative samples of equipment does not guarantee 100% of the equipment will meet the same requirements.

b) Factors such as location, load changes, capacity, weather, and transmission/ distribution equipment, limit how well utility power quality can be controlled.

c) The tests, themselves, are not variation free; the test equipment, calibration processes, and the test personnel can introduce further variability.

7.3.3 The risk of manufacturing interruptions can be considerably reduced through two approaches.

a) Create a margin between allowable voltage sag for the supplied utility power and process equipment voltage sag immunity.

b) Provide added protection from interruptions due to voltage sag events by enhancing the power quality in the facilities distribution system. (This approach is covered in this document, see Scope and the middle segment of Figure 1.)

7.4 *Support and Facilities Infrastructure Equipment Performance*

7.4.1 The effects that support equipment and facilities infrastructure equipment have on process equipment should be considered.

7.4.2 Process and support equipment typically contain flow, temperature, or pressure sensors. If facility infrastructure equipment malfunctions due to a voltage sag event, the diminished flow of a required fluid or gas will cause the support or process equipment to alarm, malfunction, or stop.

7.4.3 A typical interconnection of facility infrastructure equipment with process and support equipment is illustrated in Figure 2. The various support and facilities infrastructure systems that can have an indirect effect on process equipment performance when subjected to voltage sag events are listed below:

- Process cooling water,
- Scrubbed exhaust,
- Volatile organic compound (VOC) exhaust,
- Gas cabinets and gas monitoring system controllers,
- Compressed dry air,
- Process vacuum,
- Automated wafer transport systems,
- Computer integrated manufacturing (CIM) systems,
- Gas leak detection systems,
- Exhaust abatement systems, and
- Bulk chemical delivery system.

7.4.4 Since the supplied utility power quality effects all the equipment within the factory, performance requirements for support equipment and facilities infrastructure equipment should be specified using the same standards used for processing equipment. Applying the same voltage sag susceptibility specifications for semiconductor processing equipment (see industry specification for semiconductor processing equipment voltage sag immunity) to the support equipment and the facilities infrastructure equipment has the following benefits: (See Related Documents section.)

a) Use of the same specification for all equipment allows for consistency when monitoring and conditioning for the effects of voltage sag events.

b) The same performance verification test methods as those used for processing equipment can be applied to the support equipment and facilities infrastructure equipment.

7.4.5 Where it is inefficient to have support and/or facilities infrastructure equipment supplied to meet the same specifications as process equipment, the facility electrical distribution system may be required to compensate for any specification gap.

7.5 *Monitoring Strategies*

7.5.1 Use power disturbance monitors and/or digital fault recorders to monitor voltage to detect compliance (see IEEE 1159). Monitor current to identify disturbance sources and assist in solutions.

7.5.2 Locate continuous monitoring at the electrical utility service, all major facility electrical distribution centers, and all critical equipment electrical points of connection. Perform periodic monitoring for at least one location of each equipment type in order to characterize the electrical environment under normal conditions (i.e., to create a baseline). Additional monitoring should be performed when experiencing unexplained operational problems. A comparison of baseline data to monitored data for equipment experiencing problems is recommended for evaluating the power supplied to the equipment.

7.5.3 Provide time synchronization for multiple monitors to allow for the correlation of a single voltage sag event between all monitors.

7.5.4 In order to understand the impact, correlate monitored voltage sag events with known wafer processing effects within the process equipment.

7.6 *Measuring and Modeling Strategies*

7.6.1 A single voltage sag event originating outside the factory will vary in magnitude and duration when measured at differing locations throughout the facility. This is largely due to differing lengths and type of distribution conductors feeding equipment located throughout the facility. In addition, the electrical interactions of the reactive and non-linear elements of equipment effect the voltage sag measurements.

7.6.2 Voltage sag events that originate within the facility electrical distribution system will vary in magnitude and duration when measured at differing locations throughout the facility. These voltage sag events are usually a result of a current flow increase and the associated voltage drop across the conductors between the source and load. The location along the current flow path greatly effects the voltage sag measured.

7.6.3 Computer design tools should be used to model the electrical distribution system in order to calculate anticipated voltage sags for utility or site originated faults. If limitations exist such that voltage sag monitors are not located at every piece of equipment, then event measurements can be adjusted from modeling information to determine voltage sag values at other locations.

7.6.4 As a means for measuring effectiveness in a business environment, it would be useful to statistically model the effect of voltage sag events on the manufacturing processes. The variations mentioned in Section 7.3.2, above, preclude a deterministic approach to how well a wafer fabrication process will perform for a given voltage sag event. A statistical correlation model would aid in estimating the correlation between voltage sags and manufacturing cost, and can be used to validate the effectiveness of power enhancement and conditioning programs.

7.6.5 *Example of Voltage Sag Event Modeling*

7.6.5.1 A voltage sag event originating on the electrical utility system often exhibits different characteristics when measured at different locations on facility electrical distribution systems. The variance in voltage sag characteristics can create different effects on similar equipment. Variances can usually be explained by examining 1) the characteristics of voltage sag at the utility interfaces, 2) the type and connection configuration of voltage transformations, and 3) the voltage levels and corresponding phase relationships at the terminals of infrastructure, support, and process equipment within the facility.

7.6.5.2 The types of faults that can occur on a utility system are:

- Line to line to line,
- Line to line to line to ground,
- Line to line,
- Line to line to ground, and
- Line to ground.

7.6.5.3 The utility network can be modeled to predict the voltage sag characteristics due to various types of faults at the electrical interfaces between a semiconductor manufacturing facility and utility. The most common utility system fault type is a single line to ground fault. An example of the translation of a voltage sag resulting from a line to ground voltage sag event is provided in the following sections.

7.6.5.4 Typical voltage transformations from the utility interface to utilization voltage levels are illustrated in Figure 3. Under normal conditions, the three phase voltages are all approximately equal and displaced 120º from each other. During a voltage sag event due to an unbalanced fault, this relationship changes. Delta-wye transformers between the origin of the fault and the equipment being studied will further affect the phase and magnitude relationships. The degree to which voltage phase shift and magnitude changes occur at each transformation throughout the facility distribution system should be considered when examining impacts on individual equipment.

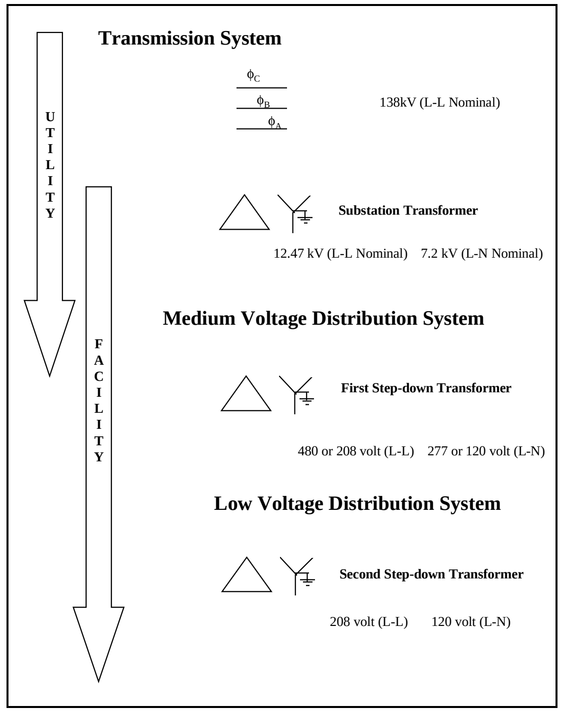


Figure 3
Typical Semiconductor Factory Voltage Transformations

7.6.5.5 Figure 4 illustrates the variations in magnitude of a voltage sag event within a facility during a single line to ground fault on a utility transmission line. This example illustrates a worst case situation, where a single-phase fault occurs at a substation transformer primary-side terminal. (See Related Documents section.)

7.6.5.6 Many devices in process, support, and facilities infrastructure equipment are not connected to all three phases. Because the voltage sag response of these devices may dictate the sag response for the entire equipment assembly, understanding device connection configuration and sag response characteristics is of critical importance. Sag depth and duration, the point on the wave at which the sag begins, and the corresponding phase relationships are all known to be factors in determining the sag response of many common devices.

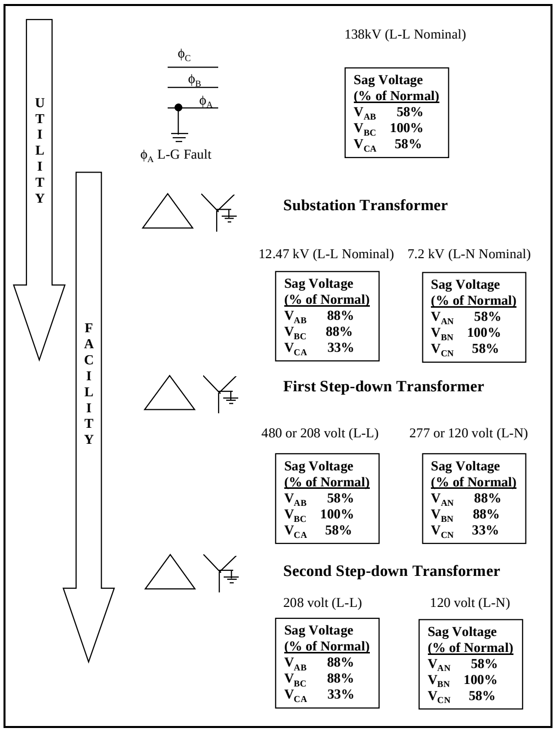


Figure 4
Example of Voltage Sag Levels during a Single Line to Ground Fault

7.6.5.7 Figure 4 illustrates the importance of phase relationships in the sag response of a 120-volt control circuit emergency off (EMO) relay which is connected to phase A (or phase B) in a 208-volt facility distribution system derived with only one low voltage transformation. In this example the voltage sags to only 88% of nominal on these phases, but drops to 33% of nominal on phase C. The industry specification for semiconductor processing equipment voltage sag immunity does not specify that equipment ride-through a sag to 33% of nominal voltage.

7.6.5.8 If two low voltage transformations were used to derive the 208-volt facility system (see Figure 4), phase B voltage would be unaffected during the utility voltage sag, but phases A and C would sag to 58% of nominal. Industry standards typically require equipment to ride-through a sag of this depth. However, a tolerance designed into the facility system may be necessary to provide adequate system protection.

7.7 *Power Enhancing and Conditioning Strategies*

7.7.1 While it is desirable to reduce and eliminate battery storage devices provided by equipment suppliers with individual pieces of process equipment, battery storage devices may be appropriate as a centralized or distributed part of a facilities distribution system (when evaluated in a systems approach to power enhancement and conditioning).

7.7.2 Facility power systems enhancements should be examined on a case-by-case approach to determine the appropriate measure of power conditioning to be applied. In general, the following types of equipment are frequently used to mitigate the effects of utility voltage sag events in semiconductor factories.

- Constant voltage transformers (typically applied on control systems)
- Diesel engine based uninterruptible power supplies (UPS)
- Magnetic synthesizers
- Motor-generators
- Rotary UPS
- Static UPS
- Static transfer switches with alternate power systems

7.7.3 Other power enhancement techniques and equipment available for use in facilities electrical distribution systems include but are not limited to the following:

- Capacitors for voltage regulation,
- Filters for power conditioning,
- High resistance grounding,
- Isolation of electrical circuit from other loads,
- Power line conditioners,
- Primary and secondary selective rather than radial distribution systems,
- Super-conducting magnetic energy storage systems,
- Transformer load tap changers, and
- Voltage regulators.

7.7.4 Power enhancement and conditioning equipment can be applied at selected equipment components, selected distribution circuits, or selected distribution buses. For power conditioning equipment application guidelines see IEEE 1100 and 1346.

8 Related Documents

8.1 *SEMI Standards*

Under development.

8.2 *CENELEC Standard* [2]

EN 50082-2 — Electromagnetic compatibility - Generic immunity standard, Part 2. Industrial environments.

8.3 *IEC Standard*[3]

IEC 61000-4-11 — Electromagnetic Compatibility (EMC) - Part 4: Testing and Measuring Techniques - Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

8.4 *IEEE Standards*[1]

IEEE Std 493 — IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

IEEE Std 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 European Committee for Electrotechnical Standardization (CENELC), Rue de Stassart, 35, B - 1050 Brussels

3 International Electrotechnical Commission (IEC), 3 rue de Varembé, PO Box 131, 1211 Geneva 20, Switzerland

SEMI F50-0200
GUIDE FOR ELECTRIC UTILITY VOLTAGE SAG PERFORMANCE FOR SEMICONDUCTOR FACTORIES

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 This guide provides a framework for semiconductor and flat panel display (FPD) manufacturers and their electric utility service providers to minimize the effect of voltage sag events on semiconductor processing. In particular, this guide focuses on electric utility power quality performance goals that are complementary to voltage sag immunity levels for semiconductor processing equipment and facilities infrastructure equipment (see Figure 1). Recommendations for measuring and evaluating voltage sag performance, evaluating utility system enhancements, and implementation of a continuous improvement process are included since no electric utility industry standards exist.

1.2 Utility systems are designed, constructed, and operated to meet utility industry regulations and requirements. One important requirement for semiconductor factories is power system reliability. Utilities measure reliability in minutes of voltage outages per customer per year. Semiconductor factories require a high level of power system reliability, any service outage is usually unacceptable. A second important requirement is power quality. Power quality relates to disturbed voltage waveforms, not outages. When utilities implement measures to increase power system reliability, power quality can be adversely affected. The structured approach defined in this guide can achieve high levels of power quality without sacrificing power reliability.

1.3 The intent of this guide is to help semiconductor manufacturers achieve both high levels of power reliability and power quality from energy utility providers. By becoming familiar with the cause and effect relationships of voltage sag events on the utility's side of the electric meter, semiconductor manufacturers and electric utilities can work together to pursue efficient solutions for improved voltage sag ride-through in semiconductor factories.

2 Scope

2.1 The scope of this guide extends beyond a discussion of typical electric utility reliability and quality improvement techniques to developing a continuous improvement process for electric utility voltage sag performance (depicted graphically in Figure 2). Factors in this process include the following:

- Define desired performance criteria by setting goals for voltage sag event duration and magnitude (see Section 6.1).
- Measure performance for both proposed and existing semiconductor factory sites (see Section 6.2).
- Summarize voltage sag event data and identify the impact on semiconductor processing and facilities infrastructure equipment (see Section 6.3).
- Recommend improvements that include consideration of cost, benefit, and risk. Improvements can include corrective action to eliminate system faults, changes to service configurations, and power enhancements (see Section 6.4).
- Select and implement improvements. Establish a continuous improvement process (see Section 6.5).

2.2 For the purposes of this document, the term Electric Utility refers to energy service providers (that sell energy to semiconductor manufacturers) and/or electric transmission and distribution providers (that deliver energy through their power lines).

2.3 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

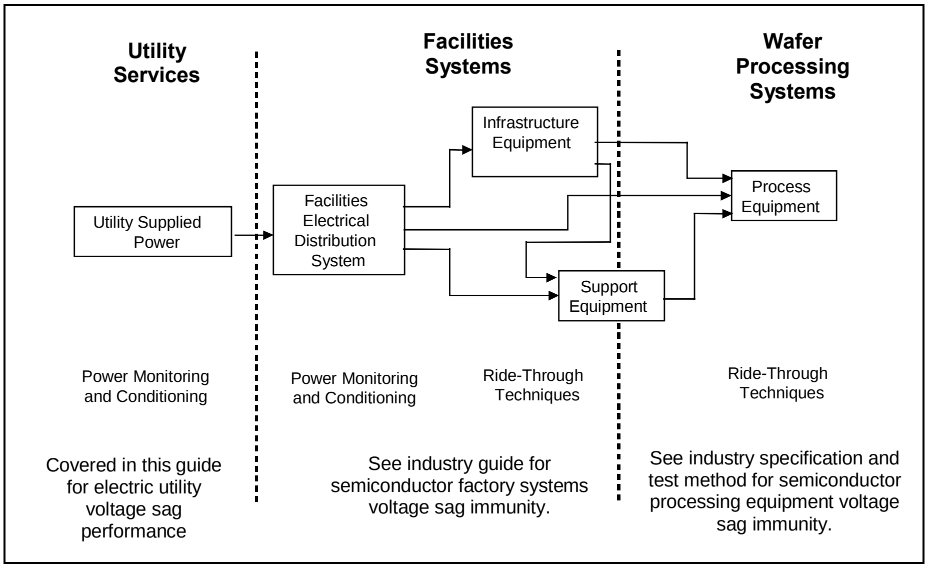


Figure 1
Power Quality Interfaces
(See Related Documents section.)

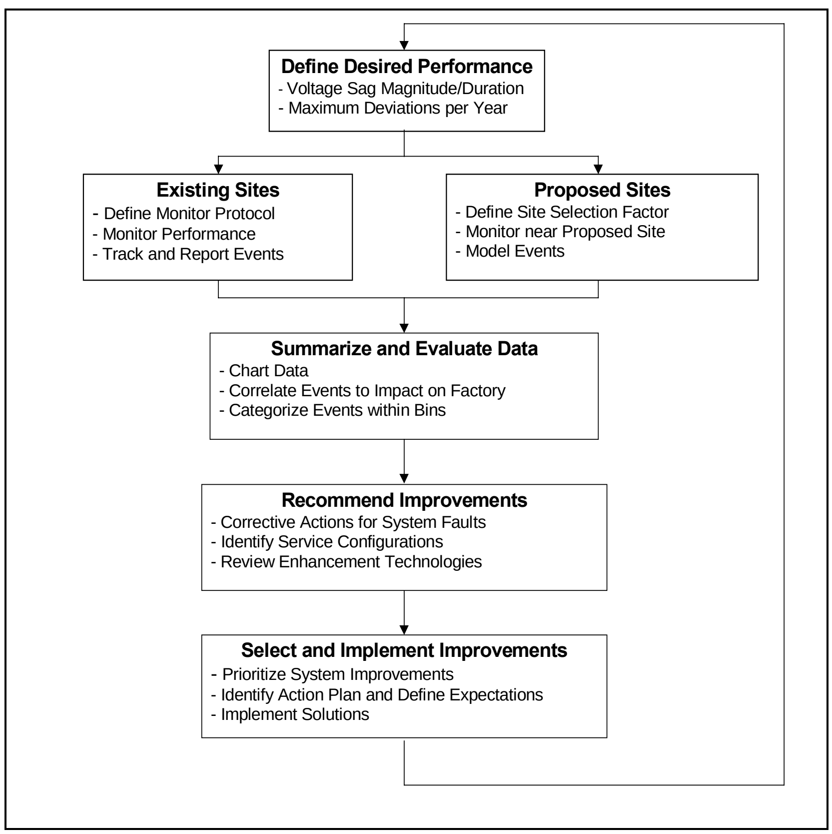


Figure 2
Continuous Improvement Process

3 Limitations

3.1 This guide addresses electric utility power quality monitoring and enhancement techniques primarily related to semiconductor factory energy utility providers. Process equipment and factory systems are covered in other related standards.

3.2 This standard is not intended to address design or materials issues related to safety which are addressed elsewhere in the SEMI guidelines (see SEMI S2).

3.3 This document is not intended to supersede international, national or local codes, regulations and laws. Each should be consulted to ensure that the equipment meets regulatory requirements in each location.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *IEEE Standards*[1]

IEEE 1159 — IEEE Recommended Practice for Monitoring Electric Power Quality

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

IEEE 1346 — IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *electric utility* — the company identified as the contractual provider of electrical power and energy to the customer point of delivery. Also known as the electric service provider.

5.2 *voltage sag* — an rms reduction in the ac voltage at power frequency for durations from half-cycle to a few seconds (see IEEE 1250). Also known as voltage dip.

6 Electric Utility Voltage Sag Performance Recommendations

6.1 *Define Voltage Sag Performance*

6.1.1 Defining a goal for acceptable voltage sag duration and magnitude is useful in establishing a benchmark or reference point for monitoring improvement. Events can be identified and categorized within the realm of the electric utility or the semiconductor manufacturer. Industry specifications for semiconductor processing equipment voltage sag immunity (which define the level of voltage sag immunity required for semiconductor processing equipment) are recommended as a performance goal. Using this goal for the performance of electric utility services will provide consistency with semiconductor processing equipment capabilities. (See Related Documents section.)

6.1.2 The goal for the maximum number of deviations from specified performance per year is zero. However, it is useful to recognize that utility generation, transmission, and distribution systems are subject to environmental and regulatory conditions that may negatively influence the ability to provide zero deviations on a continuous basis.

6.1.2.1 Document regulatory and environmental requirements that will limit the electric utility's choices when implementing improvements, such as rate structures or rights-of-way.

6.2 *Measure Performance*

6.2.1 *Measuring Performance at Proposed Semiconductor Factory Sites*

6.2.1.1 Factory site selection teams should consider the importance of power and power quality when evaluating potential sites. To insure that power quality considerations are properly factored into the site selection process, a selection factor should be assigned to power quality and reliability criteria.

6.2.1.2 Utility electrical service configurations should be considered when measuring and comparing reliability and power quality performance at different locations. The load profile for the proposed factory is used to determine the standard utility electrical service configuration. Usually, larger factories (> 10 MW) exceed allowable loading for lower voltage distribution systems (< 69 kV), therefore a high voltage service is the typical configuration for larger semiconductor factories. Selection of the highest available service voltage is preferred for reliability due to two factors. First, the area of exposure is greater for lower voltages since they include both higher and lower voltage system distribution lines and equipment. Second, higher voltage systems can provide energy to lower voltage system faults with little or no impact to high voltage system voltages, whereas, lower voltage systems are greatly impacted by faults not buffered by transformers.

6.2.1.3 The preferred method for comparing power quality and reliability from different locations involves creating a summary of the number of voltage sag events

1 The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA

that fall into different magnitude-duration categories. Data from different categories should be adjusted by weighting factors to enable valid comparison. See IEEE 1346 for suggested voltage sag event category and weighting factors.

6.2.1.4 Model events.

6.2.1.4.1 If actual disturbance data is not available, modeling results based on simulation of actual electrical faults should be calculated and reviewed. These studies called area of vulnerability analysis determine transmission lines and equipment where faults can adversely impact a semiconductor factory.

NOTE 2: As monitoring data is later collected, the modeling results should be validated.

6.2.1.5 Monitor events near proposed site(s).

6.2.1.5.1 Define monitoring protocol per the method outlined in Section 6.2.2.2.

6.2.1.5.2 Upon establishing an appropriate electrical service configuration, reliability and power quality information relative to that service configuration should be requested from the electric utility. Depending upon utility rate structures, semiconductor manufacturers may be required to pay separately for this analysis. Where available, the information provided should include actual disturbance data from other selected sites collected in accordance with IEEE 1159. Strive for data on sites that have similar electrical service configurations and are located electrically close to the proposed site (e.g., ideally, from the same transmission or distribution line).

6.2.2 *Measuring Performance at Existing Semi-conductor Factory Sites*

6.2.2.1 Preparation for monitoring.

6.2.2.1.1 Review existing industry typical voltage sag performance data for utility point-of-service.

6.2.2.1.2 Review existing site voltage sag performance data, usually taken at a variety of locations within the factory.

6.2.2.1.3 Review existing utility voltage sag performance data for the area around the factory site, usually a 20–30 mile radius of the service area is sufficient.

6.2.2.1.4 Review existing utility area of vulnerability modeling studies for power flow and system power quality.

6.2.2.1.5 Document the existing utility and manufacturing site electrical design and operating procedures.

6.2.2.2 Define the monitoring protocol.

6.2.2.2.1 Define where measurement devices will be located, how many to be installed, who will operate and maintain them, and what are the standards for calibration.

6.2.2.2.2 Define sensitivity settings. Usually magnitude triggers are set as tightly as possible (95% of nominal voltage). This will generate a large amount of data that will verify trends and maximize comparison opportunities between cause and effect. After several evaluation cycles magnitude triggers can be moved closer to the criteria (90% of nominal voltage), in order to focus improvement efforts on the more significant sags.

6.2.2.3 Monitor the voltage sag performance.

6.2.2.3.1 Location of monitor(s) should be such that the utility point-of-service to the factory is represented by the recorded data. Data recorded remote from the utility point-of-service will be effected by other utility or factory system components. Remote data should be adjusted to represent a utility point-of-service equivalent.

6.2.2.4 Track and report events.

6.2.2.4.1 Define the reporting format for all events and who will receive the reports. (Example: Reports to contain magnitude, duration, time/date stamp and impact on process, if known. All events are summarized and reported monthly. All out-of-specification events only are reported same day as event. All reports distributed to both factory and utility representatives.)

6.3 *Summarize Data and Evaluate Impact*

6.3.1 Summarizing monitoring data.

6.3.1.1 Figure 3 shows how monitoring data can be graphically reported using charts representing magnitude and duration.

6.3.1.2 Monitored and measuring power quality performance provides the semiconductor manufacturer and their electric utility with empirical data on which to base voltage sag performance and improvement decisions.

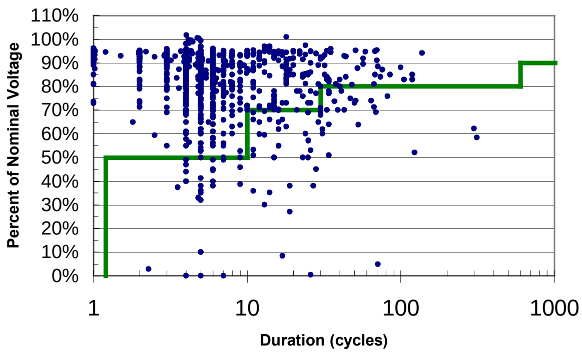


Figure 3
Example of Chart Summarizing Monitoring Data

6.3.2 Correlate data to impact on factory.

6.3.2.1 For new sites, categorize voltage sag events within magnitude/duration bins.

6.3.2.2 When evaluating new sites that are located in different electrical utility service areas it is beneficial to normalize the voltage sag data prior to comparison. The use of magnitude/duration bins to place historical or predicted event data creates discrete blocks of like kind events. The impact on factories, causes of events, and potential improvements may be evaluated on each individual bin or groups of bins. Increasing the number of magnitude/duration bins used in the data comparison refines the accuracy, but also increases the effort needed to translate events into discrete data bins. (See IEEE 1346 and Related Information 2.)

6.3.2.3 For existing sites, define categories of event impact on manufacturing process. For example:

- In Spec Event/No known impact
- In Spec Event/Minor impact
- In Spec Event/Major impact
- Out of Spec Event/No known impact
- Out of Spec Event/Minor impact
- Out of Spec Event/Major impact

6.3.2.3.1 The boundary between major and minor impact is often cost or number of wafer moves lost converted to an equivalent cost.

6.4 *Recommend Improvements*

6.4.1 Analyze costs, benefits, and risks.

6.4.1.1 The improvement recommendation process should include the equivalent of identifying the costs related to the disturbances, the costs related to improvements, and the effectiveness of improvements. The risks should be identified for taking no action, the possibility that events will occur during the implementation of improvements, and that events will occur as a result of unknown factors resulting from the installation of improvements. Improvements can include corrective action to eliminate system faults, changes to service configurations, and power enhancements.

6.4.2 Corrective action to eliminate system faults.

6.4.2.1 The key to influencing an electric utility's voltage sag performance is mutual understanding of measurement and improvement processes. Voltage sags on utility electric systems are created because of faults (short circuits) caused by a variety of events, including lightning, trees contacting power lines, equipment failure, and vehicles striking power poles. In order to reduce the number of voltage sag events, it is important to understand the specific cause of each fault. Semiconductor manufacturers should request that electric utilities share disturbance investigation reports and statistics. If data is not available, or tracking fault causes is not a focus (many utilities track only outage causes) then a fault tracking system should be established.

6.4.2.2 Many times, the initially identified fault cause (for example lightning) has a more specific cause (for example a contaminated insulator), with an even more specific root cause (for example salt contamination on coastal power lines in dry weather seasons). Identifying this root cause helps to establish the appropriate corrective action (for example, improved insulator cleaning practices to include weather considerations on coastal lines). Semiconductor manufacturers and their electric utilities should work together to ensure voltage sag event root cause identification processes exists.

6.4.2.3 Analysis steps for electric utilities to identify the root cause of system faults include the following:

Step 1 Locate the fault and identify what initiated the fault.

Step 2 Investigate the underlying causes of the fault to discover the root cause.

Step 3 Track faults and root causes in a database.

Step 4 Identify corrective actions.

6.4.2.4 Some of the more obvious corrective actions include additional animal guards on exposed electrical devices to reduce the effects from inadvertent touch. Additional patrols and early removal of birds nests, sources of nesting material, reduction in potential roosting and nesting sites, sealing any possible entry to electrical equipment against wildlife intrusion, and designs using larger phase spacing and higher Basic

Impulse Insulation Levels (BIL) are just some of the ways that events can be eliminated.

6.4.3 *Service Configurations*

6.4.3.1 Determine the factors that are fixed for the purposes of improvement development and evaluation. Some examples include, but are not limited to, physical location of site, utility system configuration beyond the immediate vicinity of the site, and electric rate structures.

6.4.3.2 Once the electrical reliability and power quality needs of a semiconductor factory are identified and the reliability and power quality of the electrical network in the area has been characterized, electric utility service configuration can be considered. The electric utility and the semiconductor manufacturer should jointly develop a plan that balances reliability and power quality. This plan should consider the following service configuration options.

6.4.3.3 High voltage service configurations.

6.4.3.3.1 Utility electrical service configurations have a significant effect on the levels of power quality and reliability. Semiconductor manufacturing facilities can typically derive the highest service quality and reliability from electrical service provided at the highest voltage level. By bringing service to the semiconductor factory from the highest available voltage system, semiconductor facilities can eliminate their exposure to electrical disturbances on lower voltage systems. Seldom are disturbances that result from events originating in lower voltage systems transferred into the higher voltage systems to any significant degree. Utility industry studies have indicated approximately 60–75% fewer voltage sag events (below 70% of nominal) on the high voltage systems.

6.4.3.3.2 For plants with loads greater than 10 MW, the highest voltage available is usually service at a voltage between 69 kV and 345 kV. Voltages above this range, while widely used by utilities, are not usually economical to adapt to loads less than 60 MW and may require lengthy regulatory approvals. If new overhead power lines are required, environmental and public issues associated with locating the lines may reduce access to higher voltage lines.

6.4.3.4 Redundancy.

6.4.3.4.1 All on-site facilities and internal factory distribution should have at least N+1 component redundancy. Where N is the number of components required to operate for maximum loading conditions and +1 indicates a single additional component that will operate to maintain the system capability in the event that one of the original components is out-of-service. If the plant is to be operated with no annual shutdowns for maintenance, then the system should be designed with enough redundancy to maintain every component in the plant without dropping service to any load. This requires at least a dual feed system that originates with two or more utility sources and continues throughout the semiconductor factory with appropriate transfer schemes to keep the loads energized at all times and to transfer loads without interruptions.

6.4.3.4.2 The most reliable service is one where there are multiple sources connected in a network to the semiconductor factory. This allows for adequate power supply, even if one of the sources fails. If a network is not available, a dual feed system can be configured to provide an immediate transfer to the backup system in the case of primary source failure, reducing outage time to near zero. Additionally, if the two sources are independent, a static transfer switch may increase quality to a level higher than that of a network. If only one source is available to a semiconductor factory with a load of less than five megawatts, an alternative is on site generation combined with a voltage sag ride-through system.

6.4.3.5 Minimize exposure.

6.4.3.5.1 When choosing source configurations, it is important to consider exposure at the semiconductor factory site. The more line length the factory is connected to, the more exposure there is.

a) It might not be desirable to have three lines serving the plant if one is a long line that is prone to failures. As a rule of thumb, more than three lines connected in a network may reduce quality without adding significantly to reliability.

b) If service is taken from a distribution class circuit, then consider purchasing a so-called express or dedicated feeder from the utility to isolate the plant from neighboring facilities.

c) Review the line routes with the utility and consider changes to reduce exposures, such as: where the poles are vulnerable to being struck by vehicles, or where trees are growing close to the transmission lines.

6.4.4 *Power Enhancements Technologies*

6.4.4.1 All disturbances will not be eliminated from the utility grid. In order to achieve the next step in plant protection, it may be necessary to implement some type of custom power option. Custom power is so called because it is thought to be a custom solution tailored to the needs of the process and the unique situation of the site. Custom power options usually involve some type of power enhancement and conditioning system. These power electronics systems are most often connected between the semiconductor factory and the electric utility at the point of common coupling (also known as the electrical service point). Many custom power options include some energy storage to ride through the disturbance, but they are usually designed to carry the factory through only momentary interruptions. In fact, for large factories (>10 MW) some available ride-through systems only operate to boost the voltage during sags and will not carry the factory site through even short outages. The trade-off is cost versus protection. The systems should be economically evaluated as well as matched technically to the needs of the site.

6.4.4.2 Electric utility provided custom power options should be balanced against factory system voltage sag immunity covered in industry guide for factory systems voltage sag immunity.

6.5 *Select and Implement Improvements*

6.5.1 Both the electric utility and the semiconductor manufacturer should agree criteria methodology for prioritizing improvements. The following are examples of prioritization criteria.

- Expected frequency of disturbances.
- Impact of fault on electric utility and semiconductor processing.
- Relative cost of system improvement.
- Ability of action to reduce effects.

6.5.2 Select improvement to be implemented, identify the schedules for installation, and define the new system performance expectations.

6.5.3 Implement selected improvements.

6.5.4 With identified fault tracking and root cause analysis processes electric utilities will be in a position to communicate the cause of events, their corrective actions, and the impact of improvements. Results will be both immediate and long-term, but to ensure that the continuous improvement process remains successful, the impacts of improvements should be tracked. The results of this tracking should provide feedback to the continuous improvement process as a whole.

7 Related Documents

7.1 *SEMI Standards*

SEMI F42 — Test Method for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI F47 — Provisional Specification for Semiconductor Processing Equipment Voltage Sag Immunity

SEMI F49 — Guide for Semiconductor Factory Systems Voltage Sag Immunity

SEMI E51 — Guide for Typical Facilities Services and Termination Matrix

7.2 *IEEE Standards*[1]

IEEE 141 — IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

IEEE 446 — IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

IEEE 493 — IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

IEEE 1100 — IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

IEEE 1250 — IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

NOTE 3: As listed or revised, all documents cited shall be the latest publications of adopted standards.

RELATED INFORMATION 1
VOLTAGE SAG PERFORMANCE AT SEMICONDUCTOR FACTORY SITES

NOTE: This related information is not an official part of SEMI F50 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on December 15, 1999. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Typical Electric Utility System Performance

R1-1.1 Although most large semiconductor sites are served from dedicated substations, data collected from utility (medium-voltage) distribution circuits can be useful in establishing a baseline for electric utility system performance. As part of the EPRI*[2] Distribution Power Quality (DPQ) study, data was collected for a two-year period from approximately 300 different BMI PQNode monitors. These monitors were located on 100 different feeders at 24 geographically dispersed utilities. The power quality database created in conjunction with this study is probably the most extensive in existence. The data derived from this study provides a statistically based assessment of the level of power quality on electric utility distribution circuits (voltage range from 4.16kV to 34.5kV).

R1-1.2 Almost every category of power quality data was collected in the DPQ study, however, only voltage sag and interruption data is assumed to be pertinent to this activity. In the DPQ study, a voltage sag event was initiated when the rms voltage dropped below 95% of nominal for one cycle (data analysis was performed only for events with magnitudes less than or equal to 90%). An interruption event was initiated when the voltage dropped below 10% of nominal for 120 seconds. Although waveforms were captured for most sag and interruption events, almost all of the data analysis was performed on the basis of minimum voltage magnitude (as a percentage on nominal) and maximum duration during the event.

R1-1.3 *DPQ Key Results*

- The average interruption rate per site, per month was approximately 0.5.
- The average sag rate per site, per month was approximately 4 (10% < V < = 90%).
- The ratio of voltage sags to interruptions was approximately 10:1.
- Almost all voltage sag events have only a single component.
- Most voltage sags had duration of less than 10 cycles.

R1-1.4 The Figure R1-1 represents a summary of the voltage sag and interruption data in a contour format. The contour lines on the graph represent the expected number of disturbance events that are more severe (longer or deeper) than the duration and magnitude grid.

R1-2 Semiconductor Factory Site Disturbance Data

R1-2.1 The DPQ study provides a baseline of the power quality that exists on typical utility distribution systems. However, only one of the semiconductor manufacturing sites from which data was collected is served from a typical utility distribution system. Fourteen of the fifteen semiconductor sites surveyed were served from dedicated substations owned by either the customer or the utility. A comparison between DPQ and semiconductor site data (for large facilities) indicates that application of DPQ data would yield a more restrictive tool tolerance standard. It is recommended, therefore, that data from semiconductor sites be utilized to develop an initial curve and that the curve be validated against DPQ data.

R1-2.2 Voltage sag and interruption data was accumulated for 14 different semiconductor manufacturing sites geographically dispersed throughout the United States. One additional site was located outside of the United States. Data represented in this report was provided by semiconductor manufacturing companies.

R1-2.3 All of the data collected was in the form of magnitude and duration point values. Although the validity of characterizing the electrical system performance is this manner has been questioned, it remains the most common data format for disturbance data.

R1-2.4 The coverage of the disturbance data is typically represented as the product of number of years (or months) monitored and the number of monitors present. In this report, the unit for data coverage is Monitor-Years. One Monitor-Year of data is the quantity of data derived by one monitor for a one-year period. The data for semiconductor sites covers 30.5

2 Electric Power Research Institute, Inc., 3412 Hillview Ave., Palo Alto, CA 94304-1395, USA

Monitor-Years. The minimum coverage for a site was 0.8 Monitor-Years (one monitor for 10 months). The site with the maximum coverage had eight Monitor-Years of data. The average for all sites was approximately 1.9 Monitor-Years.

R1-2.5 Shown below is a scatter graph of all of the 1076 disturbances that were reported. The graph represents the magnitudes and duration for all voltage sags and interruptions at all sites. The magnitude value is the minimum voltage level during the sag represented as a percent of the nominal voltage. Also shown on the graph is the pertinent portion of the Information Technology Industry Council (ITIC) “CBEMA-curve,” contained in IEEE Standards 446 and 1100.

R1-2.6 The total number of events on or below the CBEMA curve was 166. Thirteen of the fifteen semiconductor sites averaged at least one event below the CBEMA each year. The average number of events below CBEMA, per site, each year was approximately 5.4. If the semiconductor manufacturers employed the new CBEMA curve for a tolerance standard, most would have experienced a significant number of equipment interruptions.

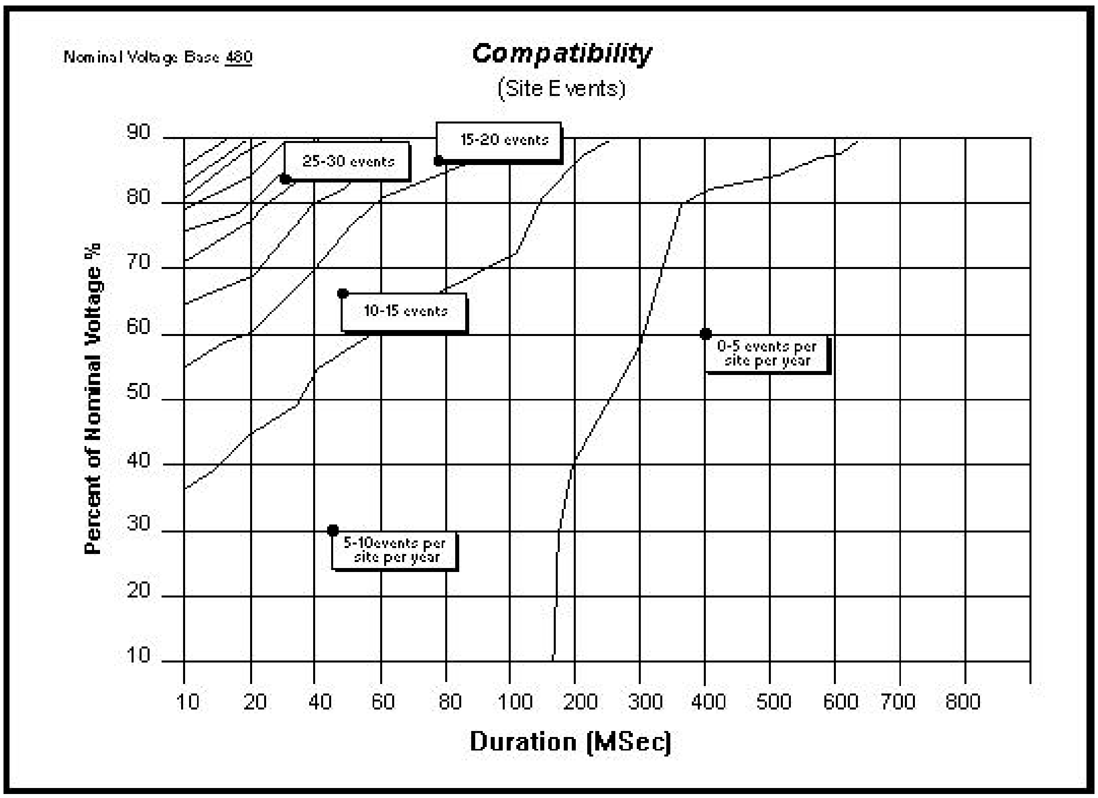


Figure R1-1
Typical Electric Utility System Performance

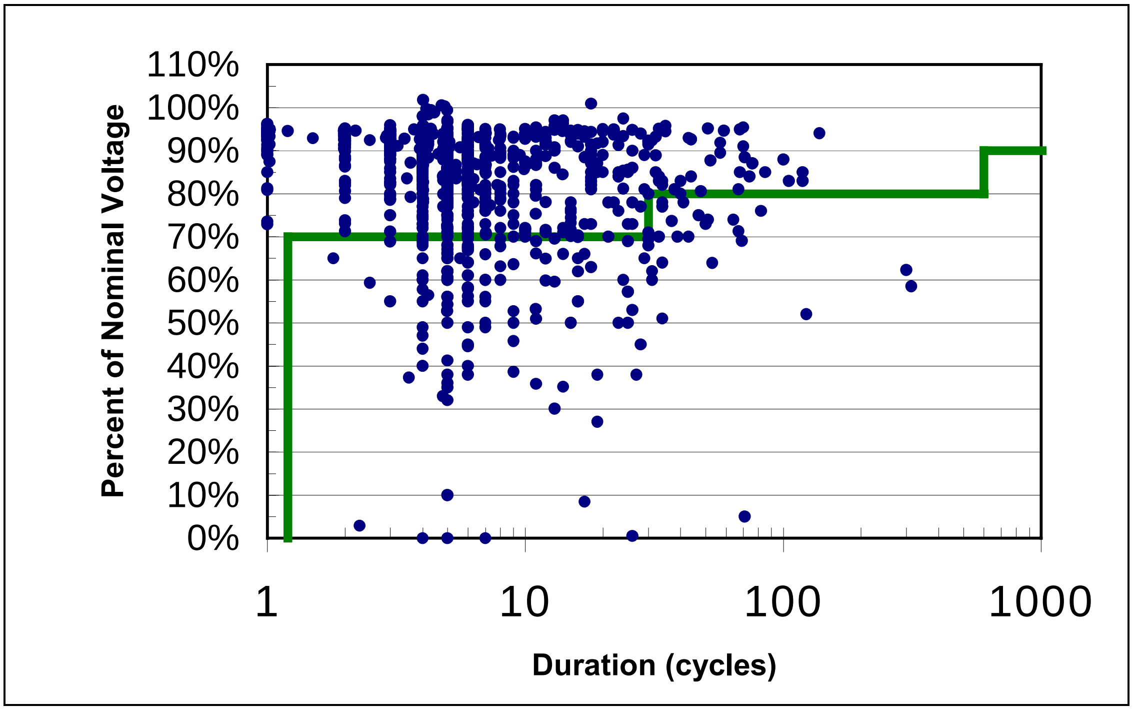


Figure R1-2
Semiconductor Factory Site Disturbance Data

RELATED INFORMATION 2
EXAMPLE OF MEASURED PERFORMANCE DATA REPORTED IN MAGNITUDE AND DURATION BINS

NOTE: This related information is not an official part of SEMI F50 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on December 15, 1999. Determination of the suitability of the material is solely the responsibility of the user.

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R2-1 Excerpt from IEEE 1346 – Annex D Constructing Coordination Charts [3]

R2-1.1 The use of bins to count the number of voltage sag events on a utility service is developed in IEEE 1346[4] as a step within a procedure for developing number of sags per year contour graphs. The bin tables are themselves useful as a tool for comparison of voltage sag performance of electrical systems. The paragraphs and tables below have been included to explain the use of bins in the standardization of historical or predicted events.

R2-1.2 Table R2-1 shows a grid of nine sag magnitude ranges in rows and five sag duration ranges in columns. The combination of nine rows and five columns produce a total of 45 magnitude/duration bins. Each measured or predicted sag will have a magnitude and duration that fits in only one of the 45 bins. The magnitude bin is a range of sag voltages expressed as a percentage of nominal. The time bin is a range of sag durations expressed as seconds. Each sag will have associated with it one magnitude and one time bin. The number in each table entry will correspond to the number of sags that have magnitudes and times in the same bins. Interruptions would go into the lower row of bins according to the duration. The number bins may vary depending on coordination needs for a particular case. However, this selection of 45 bins is reasonably convenient.

R2-1.3 For this example, assume each of the 45 bins contains one sag event. This means there are 45 sags per year and the characteristics of each sag fits in a unique bin. The 15 bins in the lower-right corner have bold italic highlighting to promote understanding as this example continues.

R2-1.4 Table R1-2 shows the cumulative number of sag events that are worse than or equal to each bin from Table R1-1. “Worse than” means the magnitude is lower and the duration is longer. The row and column headings show only single values instead of ranges. For example, there are 15 sags in the 50% magnitude, 0.4s entry of Table R1-2. The bold number 15 in Table R1-2 is the sum of all 15 individual bold entries in Table R1-1. This means 15 sags will have magnitude less than or equal to 50% and duration longer than 0.4s.

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4 IEEE 1346 — Recommended Practice for Evaluating Electrical Power and System Compatibility with Electronic Process Equipment. Copyright © 1998 by The Institute of Electrical and Electronic Engineers. All Rights Reserved.

Table R2-1 Count of Events in Each Bin

	Time Bin in Seconds				
Magnitude Bin	*0.0s < 0.2s*	*0.2s < 0.4s*	*0.4s < 0.6s*	*0.6s < 0.8s*	*>/= 0.8s*
> 80–90%	1	1	1	1	1
> 70–80%	1	1	1	1	1
> 60–70%	1	1	1	1	1
> 50–60%	1	1	1	1	1
> 40–50%	1	1	**1**	**1**	**1**
> 30–40%	1	1	**1**	**1**	**1**
> 20–30%	1	1	**1**	**1**	**1**
> 10–20%	1	1	**1**	**1**	**1**
0–10%	1	1	**1**	**1**	**1**

Table R2-2 Sum of Events Worse Than or Equal to Each Magnitude and Duration

Magnitude			*Time in Seconds*		
% of Nominal Voltage	*0.0s*	*0.2s*	*0.4s*	*0.6s*	*0.8s*
90%	45	36	27	18	9
80%	40	32	24	16	8
70%	35	28	21	14	7
60%	30	24	18	12	6
50%	25	20	**15**	10	5
40%	20	16	12	8	4
30%	15	12	9	6	3
20%	10	8	6	4	2
10%	5	4	3	2	1

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SEMI F51-0200
GUIDE FOR ELASTOMETRIC SEALING TECHNOLOGY

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 The purpose of this document is to introduce a basic guide for the use of seals in semiconductor fabrication equipment. Also, to introduce the diverse chemical and physical requirements for the many process applications, and to reduce cost of ownership and improve up-time through the use of appropriate sealing materials. It is important that equipment users, suppliers, OEMs, and seal manufacturers use the same terminology and that communication can take place at the same level so that actual performance of the equipment can be discussed.

2 Scope

2.1 This guide is applicable to the use of seals in specific operating environments used in the fabrication of semiconductor devices. The guide will aid in defining the seal parameters for the various process environments. It includes those elastomeric seals that come in contact with process liquids and or gases.

2.2 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The application of this guide is limited to elastomeric sealing technology performance as used in semiconductor manufacturing and related process equipment.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C3 — Specifications for Gases

SEMI D9 — Definitions for Flat Panel Display Substrates

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments

SEMI F21 — Classification of Airborne Molecular Contaminant Levels in Clean Environments

SEMI P5 — Specification for Pellicles

SEMI S4 — Safety Guideline for the Segregation/Separation of Gas Cylinders Contained in Cabinets

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ATM* — Atmospheric

5.1.2 *BCD* — Bulk Chemical Dispensing System

5.1.3 *CVD* — Chemical Vapor Deposition

5.1.4 *DI* — De-ionized

5.1.5 *HDP* — High Density Plasma

5.1.6 *HF* — Hydrofluoric Acid

5.1.7 *LPCVD* — Low Pressure Chemical Vapor Deposition

5.1.8 *MOCVD* — Metal Organic Chemical Vapor Deposition

5.1.9 *OEM* — Original Equipment Manufacturer

5.1.10 *PPB* — Parts per Billion

5.1.11 *PVD* — Physical Vapor Deposition

5.1.12 *RF* — Radio Frequency

5.1.13 *RTP* — Rapid Thermal Process

5.1.14 *T.O.C. (total organic carbons*) — hydrocarbons which can appear in a process from a variety of sources including breakdown of O-ring materials.

5.1.15 *UPDI* — Ultra Pure De-ionized

5.1.16 *UV* — Ultraviolet

5.2 *Definitions*

5.2.1 *acid* — a corrosive material whose chemical reaction characteristic is that of an electron acceptor (SEMI F21, SEMI S4).

5.2.2 *anion* — a negatively charged ion that is attracted to an anode in electrolysis.

5.2.3 *cation* — a positively charged ion; an ion that is attracted to the cathode in electrolysis. These are typically ions of metallic elements.

5.2.4 *chemical/mechanical wear* — injury to the surface of an object or partial obliteration of or altering caused by rubbing, stress or chemical/mechanical use.

5.2.5 *chemical breakdown* — the degradation of a seal as the result of a chemical reaction.

5.2.6 *chemical property* — chemical durability is a measure of corrosion or attack of a glass surface when subjected to a specific reagent, such as acid, base, or water at a specific concentration for a specific time and temperature (SEMI D9).

5.2.7 *chemical reaction* — a process that involves change in the structure of ions or molecules.

5.2.8 *compatibility* — the ability of the molecules of a seal to coexist with process chemistries without the degradation of either.

5.2.9 *corrosives* — a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. A chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described in the U.S. Department of Transportation in Appendix A to 49 CFR 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces (SEMI S4).

5.2.10 *de-ionized water* — (specified with specific resistivity $\geq$ 18 MΩcm, cations: Na, Fe, Ca $\leq$ 0.2 µg/l) (SEMI E45).

5.2.11 *degradation* — a chemical reaction leading to the reduction to a simpler molecular structure. See also chemical breakdown.

5.2.12 *ion* — an atom or group of atoms that has lost or gained one or more electrons.

5.2.13 *leachables* — atoms or molecules which escape from the body of a material under vacuum, heat or chemical attack.

5.2.14 *leak rate* — rate at which an environment loses a vacuum (Millitorr litres/second).

5.2.15 *outgassing* — process whereby molecules of air or other gases adhere to the surface of the vacuum vessel or component therein and become liberated under vacuum conditions. Sometimes known as degassing.

5.2.16 *oxidizer gas* — a gas which will support combustion or increase the burning rate of a combustible material with which it may come in contact (SEMI S4).

5.2.17 *particle* — materials which can be distinguished from the film whether on the film surface or embedded in the film (SEMI P5).

5.2.18 *particle generation* — molecules of material generated due to degradation of a material.

5.2.19 *permeation* — the tendency for a gas or liquid to pass through a seal structure by osmosis or diffusion.

5.2.20 *silica* — silicon dioxide, occurring as quartz, etc.

5.2.21 *swell resistance* — the ability of a material to resist increasing its volume when it has been immersed in a liquid or exposed to vapor.

5.2.22 *temperature* — a measure of heat usually expressed in degrees Celsius or Fahrenheit. Temperature values shall be expressed in degrees Celsius (SEMI C3).

5.2.23 *weight loss* — reduction in mass of a sealing compound through the result of a chemical or physical reaction.

5.2.24 *vacuum integrity* — a subjective measure of the efficiency of a vacuum vessel.

6 Related Documents

6.1 S*EMI Standard*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI F40 — Practice for Preparing Liquid Chemical Distribution Components for Chemical Testing

6.2 *Other Documents*

Millipore 9th Annual Microelectronics Technical Symposium, May 20, 1991, “Contamination Derived from O-Rings”, Robert Matthews[1]

RTP’97 5th International Conference on Advanced Thermal Processing of Semiconductors, “Sealing Technology for the Semiconductor Industry”, Dalia Vernikovsky[2]

1 Millipore Corporation, 80 Ashby Road, Bedford, MA, USA, 01730-2271

2 Greene, Tweed & Co., 2157D O’Toole Avenue, San Jose, CA, USA, 95131

7 Considerations for Use in Ultra Pure De-ionized Water (UPDI)

NOTE 2: See Figure 1.

7.1 De-ionized water is used in many wafer processing steps and shall not contribute any contaminants to the processes. The most common sealing requirements in DI water systems are filters, valves, flow and pressure regulators, and fittings.

7.2 Contaminants in DI water fall primarily into three categories. They are ion contamination, T.O.C.'s and bacterial growth. Contaminant levels are usually measured in parts per billion (PPB).

7.3 Ion contamination problems are caused by anionic and cationic elements in DI water such as fluorides, chlorides, sulfates, etc. These can be leached from seals as well as the DI plumbing.

7.4 Cations (mostly metallic ions) are leached from seals as well as the plumbing that delivers the DI water. In order to kill bacteria which have a propensity to grow in DI water, the water is either heated (80°C+), ozonated, or bombarded with UV light, or possibly a combination of these three elements. This poses unique problems for seals used in the DI system and can cause the following problems: Contamination of the DI water caused by T.O.C.'s being leached from the seals and plumbing.

7.5 Seal breakdown caused by ozone attack, or seal deterioration due to UV exposure. T.O.C.'s are of great concern since they can adhere to wafers and result in degraded oxide quality and hazy films. Ozone and UV deterioration of the seals usually leads to particulate contamination. These can be as small as single atoms or molecules to gross particle size contamination.

7.6 Considerations:

- What method of sterilization (i.e., chemical, thermal or radiation)?
- Concerns for cations, anions, or T.O.C.'s?
- Seal life expectation?

8 Considerations for Use in Corrosives (Acids, Bases), Oxidizers, and Solvents

NOTE 3: See Figure 2.

8.1 Inorganic wet chemicals at high concentration levels and in some cases at elevated temperatures are readily used in front-end semiconductor processing in the fabrication of semiconductor devices. Most common sealing requirements are in acid recirculation and chemical distribution systems (mostly BCD's). Component systems include pumps, filters, megasonic seals, gaskets for pipeline interfaces and valves.

8.2 Of primary concern when specifying a specific seal for an application are issues relating to resistance to chemical reaction. Design considerations should include resistance to chemical breakdown, static vs. dynamic environments, pressure, temperature, leachables, particle generation.

8.3 Chemical and Thermal Degradation involves the incompatibility of the seals to the process chemistries. An example is Hydroflouric Acid (HF) dissolves silicone elastomers. The same is true of temperature degradation (i.e., Piranha or Phosphoric Acids) where the process temperature causes thermally and chemically induced effects on the seal. That also contributes to the mechanical failure of the seal.

8.4 Leaching is most commonly associated with metal filler systems of the seal, which usually introduce metallic ions. This is a continuous occurrence as long as the seal is in the system.

8.4.1 *Particles* — Particles can be the result of mechanical damage of the seal or as a result of leaching or chemical degradation or foreign material present on the seal surface. Particles can end up on the wafer and cause defects.

8.4.2 *Summary* — All cases of the above contamination can create electrical shorts, voids, and unwanted doping.

8.4.3 *Solvents* — Incompatibility of elastomers or seals with solvent chemistries may cause contamination.

8.4.3.1 For example, there are degrees of incompatibility:

8.4.3.1.1 If the seal is dissolved by the solvent, then a catastrophic failure occurs where the solvent leaks out of the liquid process loop. This is associated with mis-processed wafers.

8.4.3.1.2 Another type of solvent seal interaction is the swelling of the elastomer or the leaching of small amounts of elastomer. Excessive swelling of the elastomer can result in premature seal failures and a higher cost of ownership caused by increased frequency of seal change outs.

9 Considerations for Use In Thermal Processes

NOTE 4: See Figure 3.

9.1 Diffusion processes are used primarily for growth of oxide layers and to anneal crystal damage caused by implant. Diffusion furnaces are usually batch process equipment where the process atmosphere is constrained within quartz tubes. The seals of these tubes are exposed to temperatures of 250–300°C. This requires that the seals not only be capable of withstanding these high temperatures but also that they not out-gas or permeate adversely affecting the purity of the process. Also of concern is the possible particle generation caused by the seals as they expand and contract due to temperature cycling (see Section 8.4.1).

9.1.1 Factors include:

- Temperature capability of material and process temperature.
- Static or dynamic state of seal.
- Proper sizing and fit of seal to gland.

10 Considerations for Use in Plasma Systems (Etch, CVD, and PVD)

NOTE 5: See Figure 4.

10.1 Considerations for sealing components for use in plasma applications shall include proximity to plasma, plasma reactor temperature, chemical composition of plasma, plasma energy, and chemical leaching by the plasma.

10.2 Contamination from the inherent seal components and particle generation is directly related to other considerations mentioned above.

10.2.1 Factors include:

- Seal composition and resistance to chemical attack.
- Proximity to source and intensity of RF.
- Temperature capability of material and process temperature.
- Static or dynamic state of seal.
- Proper sizing and fit of seal to gland.

Categories for Consideration

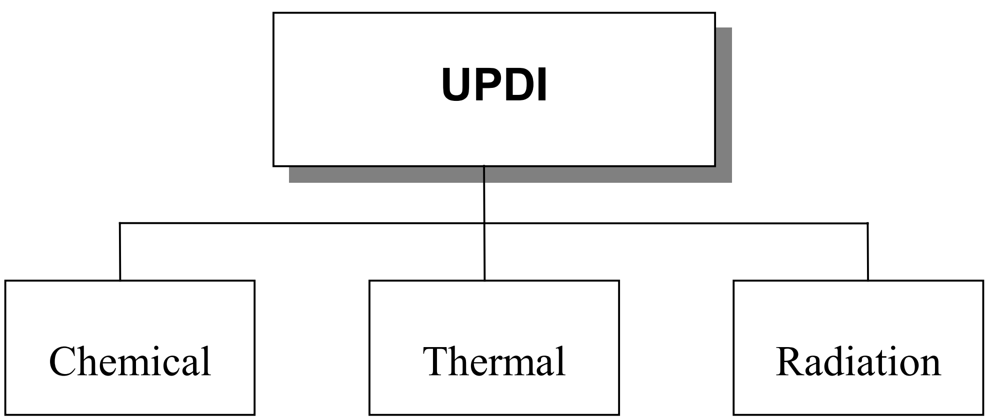

Figure 1
UPDI Chart

Categories for Consideration

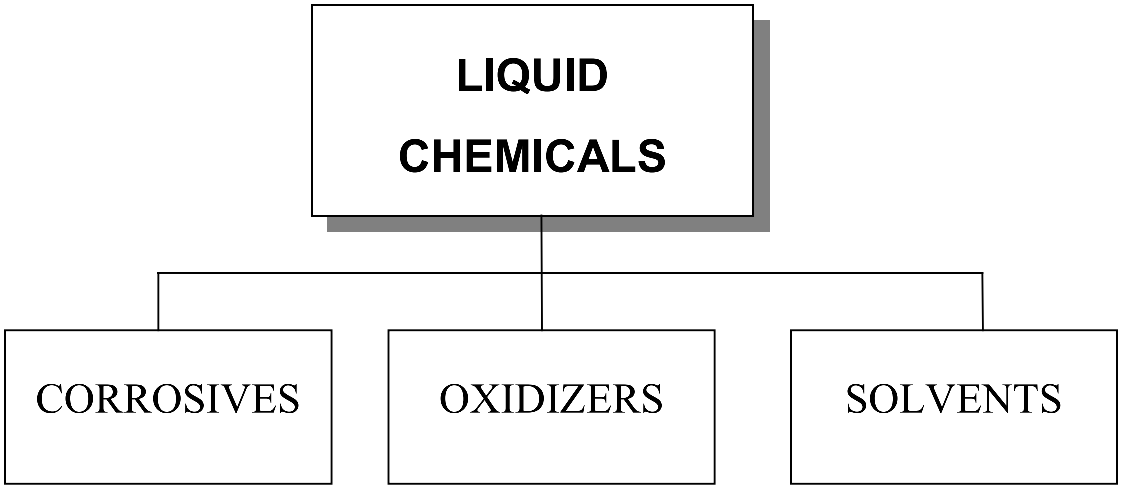

Figure 2
Liquid Chemical Chart

Categories for Consideration

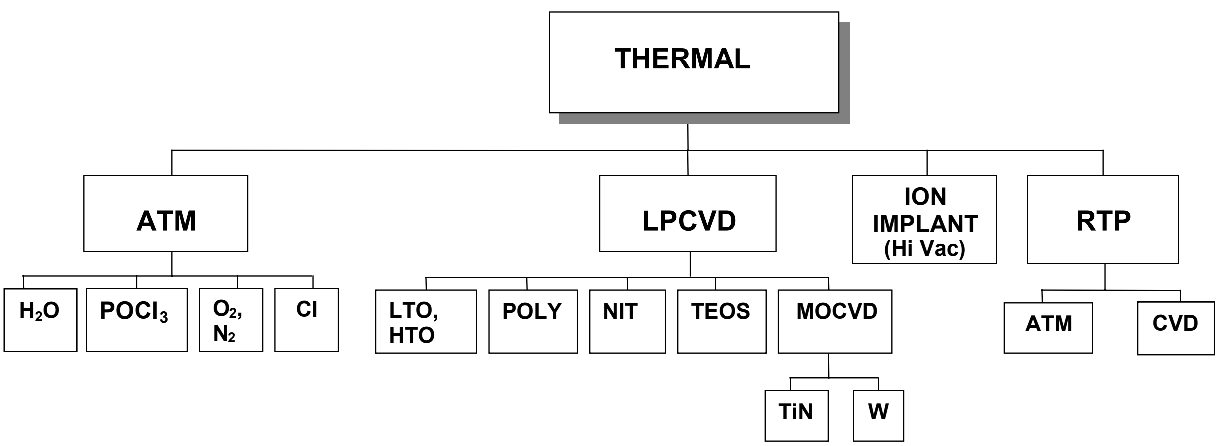

Figure 3
Thermal Chart

Categories for Consideration

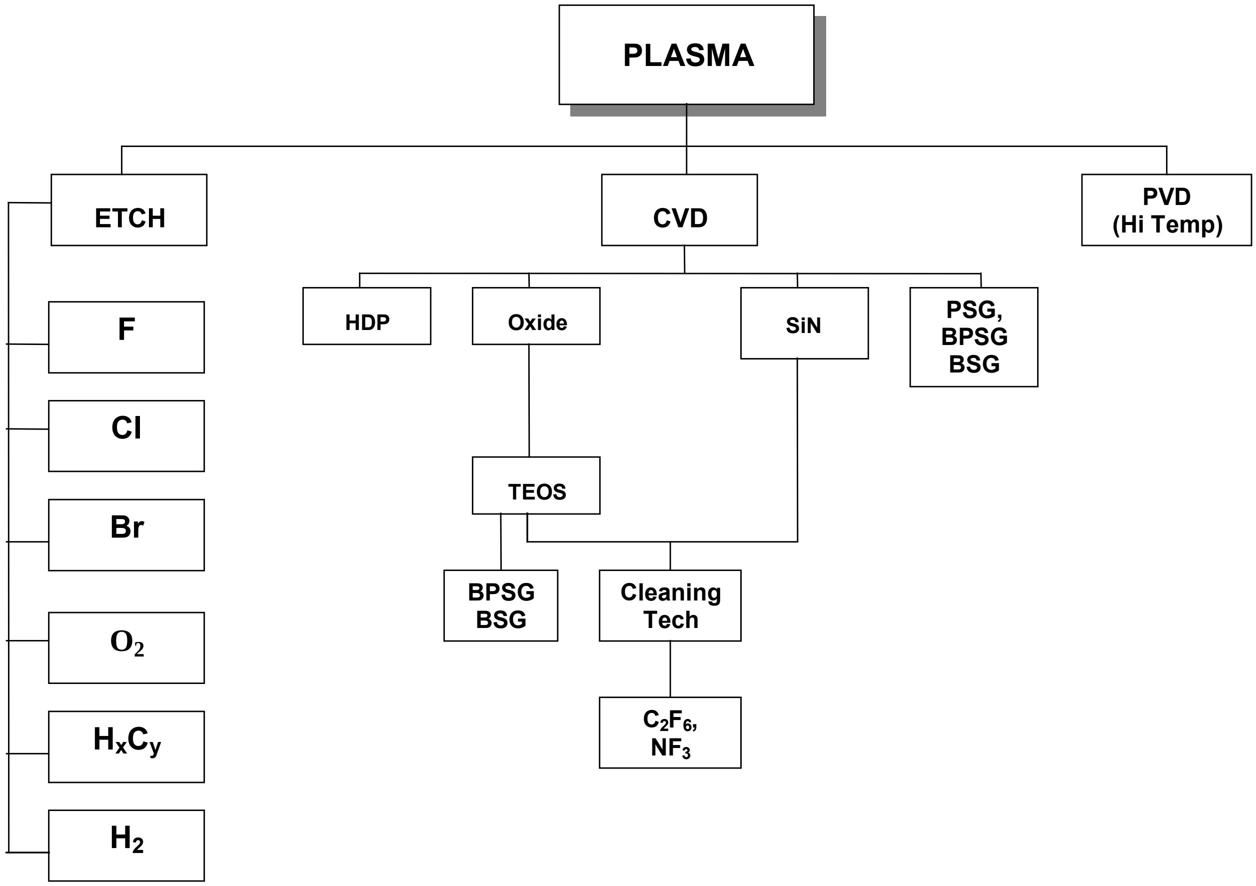

Figure 4
Plasma Chart

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SEMI F52-1101
DIMENSIONAL SPECIFICATION FOR METRIC PFA TUBES FOR LIQUID CHEMICAL DISTRIBUTION IN SEMICONDUCTOR AND FLAT PANEL DISPLAY MANUFACTURING

This specification was technically approved by the Global Liquid Chemical Distribution Systems Committee and is the direct responsibility of the Japanese Liquid Chemical Distribution Systems Committee. Current edition approved by the Japanese Regional Standards Committee on June 19, 2001. Initially available on www.semi.org August 2001; to be published November 2001. Originally published June 2000.

1 Purpose

1.1 This document defines sizes and their measurement methods of metric PFA tubes for liquid chemical distribution in semiconductor and flat panel display manufacturing equipment and facilities.

2 Scope

2.1 This document applies to metric tubes made from PFA.

2.2 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ISO Standards* [1]

ISO 4397 — Fluid Power System and Components – Connectors and Associated Components – Outside Diameters of Tubes and Inside Diameters of Hoses

3.2 *JASO Standards* [2]

JASO F 409-91 — Fittings for Polyamide (Nylon) Tube

JASO M 317-73 — Nylon Tube for Automobile Air Brake Piping

3.3 *JIS Standards* [3]

JIS B 7502 — External Micrometer

JIS B 8381 — Fittings for Flexible Tube Used at Atmospheric Pressure

JIS K 6890 — Tube Made from Tetra-fluoroethylene Resin

3.4 *SAE Standards* [4]

SAE J 844 — Nonmetallic Air Brake System Tubing

SAE J 1394 — Metric Nonmetallic Air Brake System Tubing

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *ID* — Inside Diameter

4.1.2 *ISO* — International Organization for Standardization

4.1.3 *JASO* — Japan Automobile Standard

4.1.4 *JIS* — Japanese Industrial Standard

4.1.5 *OD* — Outside Diameter

4.1.6 *PFA* — Tetrafluoroethylene Perfluoroalkylvinylether Copolymer

4.1.7 *SAE* — Society of Automotive Engineers

4.2 *Definitions*

4.2.1 *dial thickness gauge* — an instrument used to measure wall thickness with a dial meter.

4.2.2 *liquid chemical* — acid, alkali, organic solvent, and pure water used for wet stations; resists and developers used for track system; and other chemicals used for process or maintenance (such as slurry of chemical-mechanical polishing) of equipment or facilities.

4.2.3 *outside diameter tolerance* — allowable deviation of the outside diameter of PFA tube from the specified dimension.

4.2.4 *projector* — an instrument used to measure shape and dimension of an object by optically projecting it at a given magnification. Also referred to as a measuring projector or profile projector.

1 International Organization for Standardization, 1, rue de Varembe, Case postale 56 CH-1211 Geneve.

2 Japanese Automobile Standards Organization / Society of Automotive Engineers of Japan, Goban-cho Center Bldg., 10-2 Goban-cho, Chiyoda-ku, Tokyo 102-0076.

3 Japan Standards Association, 4-1-24 Akasaka, Minato-ku, Tokyo 107-8440.

4 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

4.2.5 *wall thickness* — thickness of the wall of the PFA tube.

4.2.6 *wall thickness deviation* — deviation of wall thickness.

4.2.7 *wall thickness tolerance* — allowable deviation of actual measurement of wall thickness from its specification.

5 Nominal Size and Dimensional Specification

5.1 A nominal tube size is indicated by “outside diameters/inside diameter”. This document provides specifications for eight nominal tube sizes as shown in Table 1.

5.2 The indication of the nominal size for metric PFA tubes is preferably printed on each package for shipping.

Table 1 Tube Size (mm)

OD/ID	25/22	19/16	12/10	10/8	8/6	6/4	4/3	3/2
OD Tolerance	± 0.2	± 0.15	± 0.15	± 0.12	± 0.12	± 0.1	± 0.1	± 0.1
Wall Thickness	1.5	1.5	1.0	1.0	1.0	1.0	0.5	0.5
Wall Thickness Tolerance	± 0.15	± 0.15	± 0.1	± 0.1	± 0.1	± 0.1	± 0.05	± 0.05
Wall Thickness Deviation	0.15	0.15	0.1	0.1	0.1	0.1	0.05	0.05

NOTE 1: The specified sizes should be measured at 23 ± 3°C. The specimen should be kept in the environment for more than 1 hour prior to the measurement.
NOTE 2: Refer to JASO F 409-91 and JASO M 317-73 for outside and inside diameter of 10/8, 8/6 and 6/4 tubes.
NOTE 3: Refer to JIS B 8183 for outside and inside diameter of 8/6 and 6/4 tubes.
NOTE 4: Refer to JIS B 6890 for outside and inside diameter of 12/10, 10/8, 8/6, 6/4, 4/3 and 3/2 tubes.
NOTE 5: Refer to SAE J 844 for outside diameter of 19/16 tube.
NOTE 6: Refer to SAE J 1394 for outside and inside diameter of 8/6 and 6/4 tubes.
NOTE 7: Refer to ISO 4397 for outside diameter of 25/22, 12/10, 10/8, 8/6 and 4/3 tubes.

6 Measurement Procedures

6.1 *Outside Diameter* — Measure the diameters at both ends of tube with a dial thickness gauge at 4 points in 45 degree intervals (see Figure 1). It is calculated with the following formula:

*Outside Diameter = 1/2 * (maximum reading + minimum reading)*

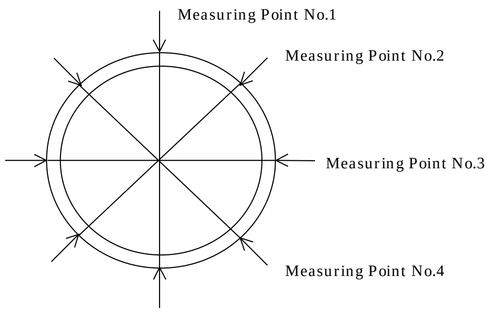

Figure 1
Outside Diameter Measurement

6.2 *Wall Thickness* — Measure the wall thickness at both ends of tube with a dial thickness gauge at 8 points in 45 degree intervals (see Figure 2). If it is not practical to use a dial thickness gauge, prepare a 1 mm long test piece and measure it with a projector. It is calculated with the following formula:

*Wall Thickness = 1/2 * (maximum reading + minimum reading)*

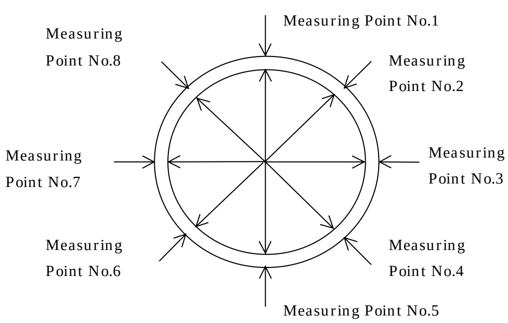

Figure 2
Wall Thickness Measurement

6.3 *Wall Thickness Deviation* — Use maximum and minimum readings of Section 6.2 and calculate the deviation with the following formula:

Wall Thickness Deviation = maximum reading – minimum reading

6.4 Other specifications including surface roughness, deviation from circular form, and physical property values may be determined upon agreement between the supplier and user.

6.5 Refer to JIS B 7502, External Micrometer for a dial thickness gauge.

7 Related Documents

7.1 *SEMI Standards*

SEMI F7 — Test Method to Determine the Tensile Strength of Tube Fitting Connections Made of Fluorocarbon Materials

SEMI F8 — Test Method for Evaluating the Sealing Capabilities of Tube Fitting Connections Made of Fluorocarbon Materials, When Subjected to Tensile Forces

SEMI F9 — Test Method to Determine the Leakage Characteristics of Tube Fitting Connections Made of Fluorocarbon Materials, When Subjected to a Side Load Condition

SEMI F10 — Test Method to Determine the Internal Pressure Required to Produce a Failure of a Tube Fitting Connection Made of Fluorocarbon Materials

SEMI F11 — Test Method to Obtain an Indication of the Thermal Characteristics of Tube Fitting Connections Made of Fluorocarbon Materials

SEMI F12 — Test Method to Determine the Sealing Capabilities of Fittings, Made of Fluorocarbon Materials, after Being Subjected to a Heat Cycle

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SEMI F53-0600
TEST METHOD FOR EVALUATING THE ELECTROMAGNETIC SUSCEPTIBILITY OF THERMAL MASS FLOW CONTROLLERS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on March 2, 2000. Initially available on www.semi.org April 2000; to be published June 2000.

1 Purpose

1.1 The purpose of this document is to define a structured method for testing and evaluating the electromagnetic susceptibility of thermal mass flow controllers.

2 Scope

2.1 This document contains the requirements and test method that can be used to evaluate whether a thermal mass flow controller will maintain its functional characteristics when subjected to EMI levels typical of the industry. The test method covers both the radiated susceptibility (RS) and conducted susceptibility (CS) of the controller when exposed to EMI. The electromagnetic susceptibility requirements are extracted from MIL-STD-461C and SAMA PMC-33.1, and the test method is a composite of the RS03, CS01, CS02, and CS06 test methods defined in MIL-STD 462.

2.2 This test method does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This test method is not designed for AC-powered MFCs. The test method addresses electromagnetic susceptibility of MFCs through DC power leads and control signals.

4 Referenced Standards

4.1 *Military Standards* [1]

MIL-STD-461C — Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference

MIL-STD-462 — Measurement of Electromagnetic Interference Characteristics

MIL-STD-463A — Electromagnetic Interference and Electromagnetic Compatibility Technology Definitions and Systems of Units

4.2 *Scientific Apparatus Makers Associations* [2]

SAMA PMC — 33.1 Electromagnetic Susceptibility of Process Control Instrumentation, Scientific Apparatus Makers Associations

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CS* — conducted susceptibility

5.1.2 *dB* — decibels

5.1.3 *DC* — direct current

5.1.4 *EMC* — electromagnetic compatibility

5.1.5 *EMI* — electromagnetic interference

5.1.6 *GHz* — gigahertz

5.1.7 *kHz* — kilohertz

5.1.8 *MFC* — mass flow controller

5.1.9 *MHz* — megahertz

5.1.10 *MIL-STD* — Military Standard

5.1.11 *psia* — pounds per square inch absolute

5.1.12 *psig* — pounds per square inch gauge

5.1.13 *RF* — radio frequency

5.1.14 *RG-58* — a specification for a particular type of coaxial cable

5.1.15 *rms* — root mean square

5.1.16 *RS* — radiated susceptibility

5.1.17 *T* — teslas

1 Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120

2 Portions of this method are excerpted from SAMA Standard PMC 31.1-1980 with permission of the publisher, Process Measurements & Control Section, SAMA, 1101 16th St., N. W. Washington, DC 20036

5.1.18 *V* — volt

5.1.19 *V/m* — volts/meter

5.2 *Definitions*

5.2.1 *conducted susceptibility* — equipment vulnerability to conducted emissions.

5.2.2 *electromagnetic* — all energy of electrical or magnetic nature; i.e., electric current flow or magnetic field.

5.2.3 *electromagnetic compatibility* — the capability of electronic equipment or systems to be operated in the intended operational electromagnetic environment at designed levels of efficiency.

5.2.4 *electromagnetic interference* — impairment of a wanted electromagnetic signal by an electromagnetic disturbance.

5.2.5 *ground* — a conducting connection, whether intentional or accidental, by which an electric circuit or piece of equipment is connected to the earth, or to some conducting body of relatively large extent.

5.2.6 *limit* — the level of susceptibility that a stated standard allows.

5.2.7 *noise (electrical)* — unwanted electrical signals that produce undesirable effects in the circuits of control systems in which they occur.

5.2.8 *radiated susceptibility* — equipment vulnerable to radiated emissions.

5.2.9 *stable* — the state a signal level obtains when its magnitude varies by less than or equal to ± 2.0% of full scale over a one minute period.

6 Summary of Method

6.1 This test method describes the test equipment and procedures for determining if the thermal mass flow controller is susceptible to both radiated and conducted interference. Initially, the controller is exposed to radiated electric fields over a frequency range from 14 kHz to 1 GHz at field strength levels less than 10 volts/meter (V/m). Furthermore, the controller's power leads will be tested for susceptibility to voltage transients with 10 µs rise times. See flow chart of the test method, Figure 1.

7 Interferences

7.1 MFCs are located in areas where electromagnetic (EM) fields are present. If an MFC is susceptible to the fields, then the delivered flow by the MFC could be adversely effected. The magnitude of the EM field's effect on the MFC performance shall be quantified by this test method.

8 Apparatus

8.1 Radiated Electric Field Susceptibility (RS-03)

8.2 Signal Generator, 14 kHz to 1 GHz

8.3 Audio Power Amplifier, 14 kHz to 1 MHz

8.4 RF Power Amplifier #1, 1 MHz to 400 MHz

8.5 RF Power Amplifier #2, 500 MHz to 1 GHz

8.6 Field Strength Meter

8.7 Oscilloscope

8.8 Parallel Element Antenna, 14 kHz to 20 MHz

8.9 Biconical Antenna, 30 MHz to 200 MHz

8.10 Conical Log Spiral Antenna, 300 MHz to one GHz

8.11 Tripod

8.12 Coaxial Cable, 50-ft, RG-58, with BNC male plugs at each end.

8.13 X10 Attenuator Scope Probe

8.14 Assorted Coax Cables for Interconnects

8.15 *Flow Standard* — Installed downstream and in series with the flow through the MFC. The flow standard shall be capable of measuring flow to within ± 0.3% of full scale.

8.16 *Flow Output Monitor* — Connected to the MFC output and signal common/ground points. The monitor/recorder shall be capable of measuring over a range of 0–10 VDC to within ± 5 mV.

8.17 Transient Susceptibility of Power and Control Leads (CS-06) (Conducted Susceptibility)

8.18 Spike Generator, with series and parallel outputs

8.19 Oscilloscope, dual channel

8.20 X10 Attenuator Probe

8.21 X100 Scope Attenuator Probe, two each

8.22 Test Leads, 12-in long with banana plugs at each end, four each

9 Reagents and Materials

9.1 *Test Gas* — Nitrogen with a dew point of less than or equal to -40°C and at a source delivery pressure of 35 psig.

10 Safety Precautions

10.1 *Safety Precautions* — This test method may involve hazardous materials, operations, and equipment.

10.2 The user must have a working knowledge of the respective instrumentation, must practice proper handling of test components, and must understand good laboratory practices. The user should not operate the components in such a manner as to exceed the ratings (i.e., pressure, temperature, flow, and voltage).

10.3 *Technical Precautions* — These tests are to be performed in a shielded or screened room to prevent possible problems with nearby instrumentation or electrical systems caused by the EM fields. At a minimum, the instrumentation associated with this test series (see Figure 2) must be shielded from the EM fields to ensure their proper operation.

11 Preparation of Apparatus

11.1 The test gas source and delivery system must be capable of satisfying the test volume flow rate at a constant pressure, ± 0.1 psia.

11.2 The test gas source and delivery system must be capable of delivering a gas at ambient temperature ± 1°C for the duration of each analysis. The ambient temperature shall be held to 22°C ± 1°C.

12 Calibration and Standardization

12.1 For each test, verify that calibration of test equipment is up-to-date.

13 Procedure

13.1 Install the MFC into the test setup per manufacturer's recommendations.

13.2 Apply power to all devices shown in Figure 3 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

13.3 Purge the system with nitrogen for a length of time equal to ten times the amount of time it takes to replace the system volume once, when the test MFC is at its full-scale rated flow rate.

13.4 Close inlet shut-off valve. Then close the outlet shut-off valve located adjacent to the MFC (see Figure 2). Adjust the MFC setpoint to zero flow. Wait for the signals to become stable. Record the following on the data sheet:

- MFC indicated flow,
- Flow standard flow,
- Ambient temperature,
- Gas temperature, and
- Gas pressure.

13.5 Ensure that the inlet and outlet shut-off valves adjacent to the MFC (see Figure 2) are open. Adjust the MFC setpoint to 50%. Ensure that all manufacturer's recommended conditions are met for the MFC. Once the output signals become stable, record the MFC output signal, the flow standard output signal, the ambient and gas temperature, and the gas pressure on the data sheet in Table 1.

13.6 Ensure that the MFC power leads and control signal cables are shielded in the area that will be irradiated by the EM fields. The cable shielding shall be intact up to the connector. The type of shielding and connector shall be recorded on the data sheet in Table 1.

13.7 *Radiated Electric Field Susceptibility (RS-03)*

13.7.1 Testing from 14 kHz to 20 MHz:

13.7.1.1 Mount the parallel element antenna on a tripod at a distance of one meter from the controller and connect the antenna to the audio power amplifier using the 50-ft length of RG-58 coaxial cable (see Figure 3). Set the switch to low frequency range.

13.7.1.2 Connect the amplifier input to the signal generator output.

13.7.1.3 Turn on amplifier and signal generator.

13.7.1.4 Using the X10 probe, connect the scope across the antenna terminals.

NOTE 2: It is important to use the X10 probe rather than a coax that terminates in 50 ohms. The audio amplifier will not drive the required voltage into 50 ohms.

13.7.1.5 Set frequency output of the signal generator to 14 kHz.

13.7.1.6 Turn off signal generator modulation and set voltage across the antenna input connector at 35-V rms.

NOTE 3: With this voltage applied to the antenna at frequencies below one MHz, the required field strength of 10 V/m at a distance of one meter from the antenna should be established.

13.7.1.7 If, at any frequency, the required voltage cannot be developed across the antenna terminals, set to the maximum possible without exceeding equipment ratings.

13.7.1.8 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.9 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, flow standard output, and the frequency on the data sheet in Table 1.

13.7.1.10 Before changing frequency as described in Sections 13.7.1.10–13.7.1.15, reduce the voltage amplitude to zero.

13.7.1.11 Set frequency to 20 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.12 Set frequency to 50 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.13 Set frequency to 100 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.14 Set frequency to 200 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.15 Set frequency to 500 kHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.16 Set frequency to one MHz and repeat Sections 13.7.1.6–13.7.1.9.

13.7.1.17 Shut down the test equipment. Then remove the audio amplifier and install RF power amplifier #1 in its place.

13.7.1.18 Having exceeded one MHz, turn antenna switch to the high frequency range.

13.7.1.19 Turn on test equipment and resume testing.

13.7.1.20 Set output of the signal generator to two MHz and set field strength to 10 V/m, using field strength meter at the controller location.

NOTE 4: If, at any frequency, the required field cannot be developed, set to the maximum possible without exceeding equipment ratings.

13.7.1.21 When voltage is set, turn on modulation and adjust for 50% amplitude modulation with the internal one kHz source.

13.7.1.22 Check operation of the controller in the presence of this radiated field. Record the MFC indicated flow, the flow standard output, and the frequency on the data sheet.

13.7.1.23 Before changing frequency as described in Sections 13.7.1.23–13.7.1.25 reduce the field amplitude to zero.

13.7.1.24 Set frequency to 5 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.25 Set frequency to 10 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.26 Set frequency to 20 MHz and repeat Sections 13.7.1.19–13.7.1.22.

13.7.1.27 After testing at fixed frequencies, sweep the signal source from 50 kHz to 20 MHz at an amplitude of about 35 V rms or 10 V/m. If a malfunction occurs during the sweep, stop and go back to that frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate the problems, not to completely define them.

13.7.1.28 Reduce signal source output to zero and de-energize test equipment.

13.7.1.29 Disconnect and remove parallel element antenna.

13.7.1.30 Testing from 30 MHz to 200 MHz:

13.7.1.31 Mount biconical antenna on the tripod. Test in a sequence similar to that in Sections 13.7.1.1–13.7.1.9.

13.7.1.32 Verify that RF power amplifier #1 is still in place.

13.7.1.33 At a minimum, test at the following frequencies: 30 MHz, 40 MHz, 50 MHz, 60 MHz, 70 MHz, 80 MHz, 90 MHz, 100 MHz, 120 MHz, 140 MHz, 160 MHz, 180 MHz, and 200 MHz.

13.7.1.34 At each frequency, set the field strength to 10 V/m using the field strength meter at the controller location with the antenna in both the vertical and the horizontal positions.

13.7.1.35 Check operation of the controller in the presence of the radiated fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet.

13.7.1.36 After testing at fixed frequencies, sweep the signal source from 30 MHz to 200 MHz. If a malfunction occurs during the sweep, stop and go back to the faulty frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and can create strong transient noise during the switching. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

13.7.1.37 Reduce signal source output to zero and de-energize test equipment.

13.7.2 Testing from 300 MHz to one GHz:

13.7.2.1 Mount the conical log spiral antenna on the tripod. Test in a sequence similar to that in Sections 13.7.1.1–13.7.1.9.

13.7.2.2 Verify that RF power amplifier #1 is still in place.

13.7.2.3 Test at the following frequencies, using RF power amplifier #1: 300 MHz and 400 MHz. Record the MFC indicated flow, flow standard outputs, and the frequency for each test point on the data sheet.

13.7.2.4 After completion of the test at 400 MHz, reduce amplitude of signal source to zero and shut down test equipment.

13.7.2.5 Disconnect RF power amplifier #1, install RF power amplifier #2, turn on equipment, and resume testing.

13.7.2.6 Test at the following frequencies using RF power amplifier #2: 500 MHz, 600 MHz, 700 MHz, 800 MHz, 900 MHz, and 990 MHz.

13.7.2.7 Check operation of the controller in the presence of the fields generated. Record the MFC indicated flow, the flow standard outputs, and the frequency for each test point on the data sheet.

13.7.2.8 After testing at fixed frequencies, sweep the signal source from 300 MHz to 990 MHz. If a malfunction occurs during the sweep, stop and go back to that frequency range and try to find the malfunction by testing at single frequencies. Record the MFC indicated flow, the flow standard outputs, and the frequency on the data sheet. If the malfunction cannot be found by testing at single frequencies and only shows up when sweeping, the problem is probably that the signal source has to switch ranges at certain frequencies and during the switching can create strong transient noise. Only the results at single frequencies can be trusted; the sweep is only to locate problems, not to completely define them.

13.7.2.9 Reduce signal source output to zero, de-energize test equipment, and disassemble test setup.

13.8 *Transient Susceptibility of Power and Control Leads (CS-06) (Conducted Susceptibility)*

NOTE 5: If any calibration is required during the performance of this procedure, such calibration shall be done in accordance with manufacturers' specifications.

13.8.1 *Spikes on DC Power Lines*

13.8.1.1 Verify that the test equipment and DC power are off before making connections for performing tests on DC-powered equipment.

13.8.1.2 Connect the parallel output of the spike generator between the binding posts as shown in Figure 4.

NOTE 6: The output from the spike generator must be from the *parallel output*. Otherwise, the DC power supply would be shorted by a low DC resistance.

13.8.1.3 The spike is injected across the DC power line to ground, not in series.

13.8.2 Spike on positive DC Lead:

13.8.2.1 Connect spike generator output between positive DC lead and ground and adjust spike generator output control for minimum amplitude.

13.8.2.2 Using the X100 probe, connect one channel on the scope to monitor the amplitude of the spike applied on the positive lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.2.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the positive lead. If the pulses are negative, reverse leads at the generator output.

13.8.2.4 Apply DC power.

13.8.2.5 With the scope synchronized to line voltage and the spike repetition rate set so that the spike will move slowly across the screen, increase spike amplitude to 100% of the voltage rating of the input power or MFC malfunction. Record the MFC indicated flow, the flow standard outputs, and the spike amplitude on the data sheet.

13.8.2.6 If the controller is not initially susceptible below the voltage rating and if the equipment is digital, hold the upper limit condition for five minutes. This condition need only be held momentarily if the controller is analog. Record the MFC indicated flow and flow standard outputs on the data sheet.

13.8.2.7 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.2.8 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.2.9 Energize test equipment.

13.8.2.10 Repeat Sections 13.8.2.4 through 13.8.2.6 with the negative voltage spikes applied to the positive lead. Then go on to Section 13.8.2.11.

13.8.2.11 Reduce spike amplitude to zero, de-energize test equipment, and turn off DC power.

13.8.3 Spike on negative DC Lead:

13.8.3.1 Connect spike generator output between negative DC lead and ground and adjust spike generator output control for minimum amplitude.

13.8.3.2 Using the X100 probe, connect one channel of the scope to the negative lead in order to monitor the amplitude of the spike applied on the negative lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.3.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the negative lead. If pulses are negative, reverse leads at generator output.

13.8.3.4 Repeat Sections 13.8.2.4 through 13.8.2.6 with the positive voltage spikes applied to the negative lead. Then go on to Section 13.8.3.5.

13.8.3.5 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.3.6 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.3.7 Energize test equipment.

13.8.3.8 Repeat Sections 13.8.2.4 through 13.8.2.6 with the negative voltage spikes applied to the negative lead. Then go on to Section 13.8.3.9.

13.8.3.9 Reduce spike amplitude to zero, de-energize test equipment, turn off the DC power, and disconnect equipment from test setup patch panel.

13.8.4 Spike on control (setpoint) signal lead:

13.8.4.1 Connect spike generator output between control signal lead and ground and adjust spike generator output control for minimum amplitude.

13.8.4.2 Using the X100 probe, connect one channel on the scope to monitor the amplitude of the spike applied on the setpoint lead. Put the scope probe ground clip on the green wire safety ground, not on any of the spike generator output terminals.

13.8.4.3 Energize test equipment and observe polarity of low amplitude spikes to determine the polarity of the transient. Connection to the generator output should be such that positive spikes are applied on the setpoint lead. If pulses are negative, reverse leads at generator output.

13.8.4.4 Apply the maximum DC control signal level.

13.8.4.5 Repeat Sections 13.8.2.5 and 13.8.2.6 with the positive voltage spikes applied to the setpoint lead. Then go on to Section 13.8.4.6.

13.8.4.6 Reduce spike amplitude control, de-energize test equipment, and turn off DC power before switching spike polarity.

13.8.4.7 Reverse leads at the spike generator output to apply negative spikes to the controller.

13.8.4.8 Energize test equipment.

13.8.4.9 Apply the maximum DC control signal level.

13.8.4.10 Repeat Sections 13.8.2.5 and 13.8.2.6 with negative voltage spike applied to the setpoint lead.

13.8.4.11 Reduce spike amplitude to zero, de-energize test equipment, turn off the DC power, and disconnect equipment from test setup patch panel.

14 Calculations or Interpretation of Results

14.1 *Calculations*

NOTE 7: Use the data sheet (see Table 1) to record the test data. Then record the calculated values at each data point in Table 2.

14.1.1 Convert MFC indicated flow output data (v) and the flow standard output data to percent of full-scale flow as follows:

MFC Indicated Flow:

Percent of Full-Scale Flow =

$$\frac{\text{Output Data (v)} \times 100}{\text{Full Scale output (v)}}$$

14.1.2 Record on data sheet for each measurement point.

14.1.3 Flow Standard (actual flow)

14.1.3.1 Follow the manufacturer's recommendations for the flow standard output conversion to percent of full scale.

14.1.4 Record on data sheet for each measurement point.

14.1.5 Calculate the zero-corrected percent of full-scale values for both the MFC indicated flow and the flow standard output as follows:

MFC Indicated Flow or Standard Flow = MFC or Flow Standard Value (%FS) at a Data Point – MFC or Flow Standard Value (%FS) at the Zero Flow

14.1.6 Record these values at each data point in Table 2.

14.1.7 Calculate the change in flow for the MFC and flow standard as follows:

Change in Flow (%FS) = MFC Standard Value (%FS) Corrected for Zero – MFC or Flow Standard Value (%FS) Corrected for Zero at Reference Conditions

14.1.7.1 Where reference conditions are defined by 50% FS flow with the EMI source at zero field strength.

14.1.8 Record these values in Table 2.

14.2 *Interpretation of Results*

14.2.1 The changes in flow columns in Table 2 give an indication of the effect of EM susceptibility, both radiated and conducted. If the effect is larger than can be tolerated for the process in the fab, two steps may be necessary. EM field strength and frequency measurements should be made at the fab under normal operating conditions. If EM measurements in the fab match areas that cause unacceptable effects on the MFC, shielding may be necessary to reduce the effect. Shielding design is beyond the scope of this test method.

15 Illustrations

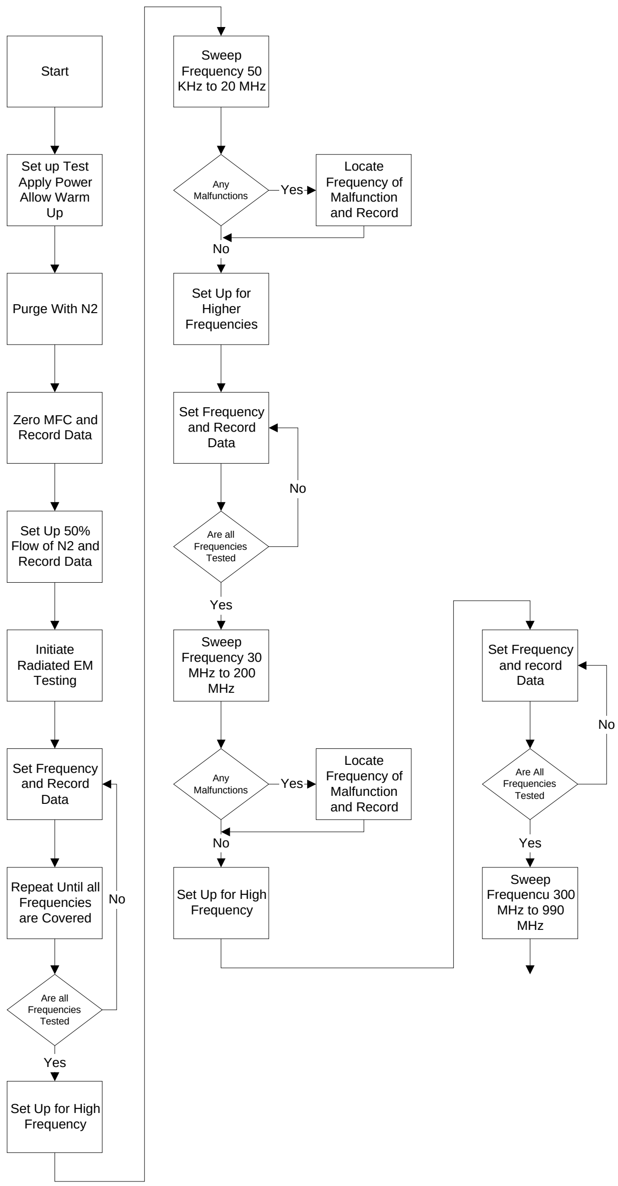

Figure 1
Flow Chart of Test Method

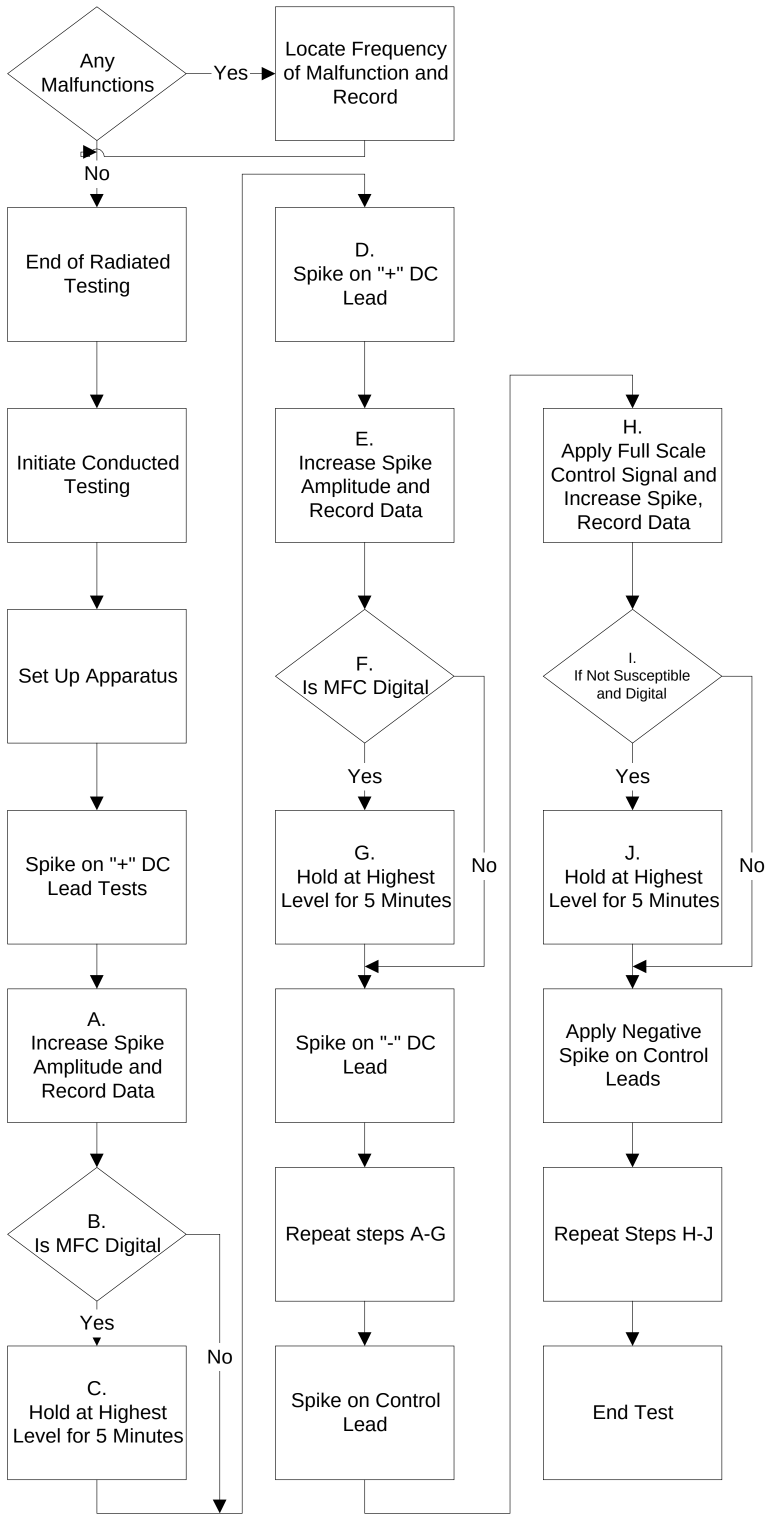

Figure 1 (continued)
Flow Chart of Test Method

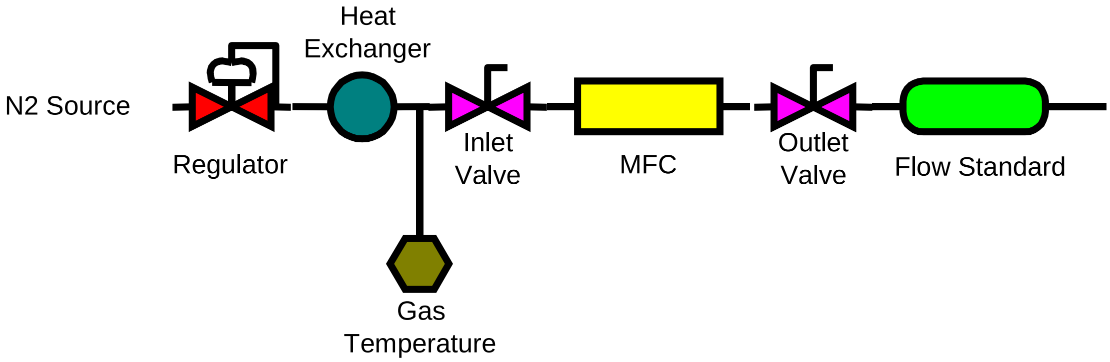

Figure 2
MFC Test Setup

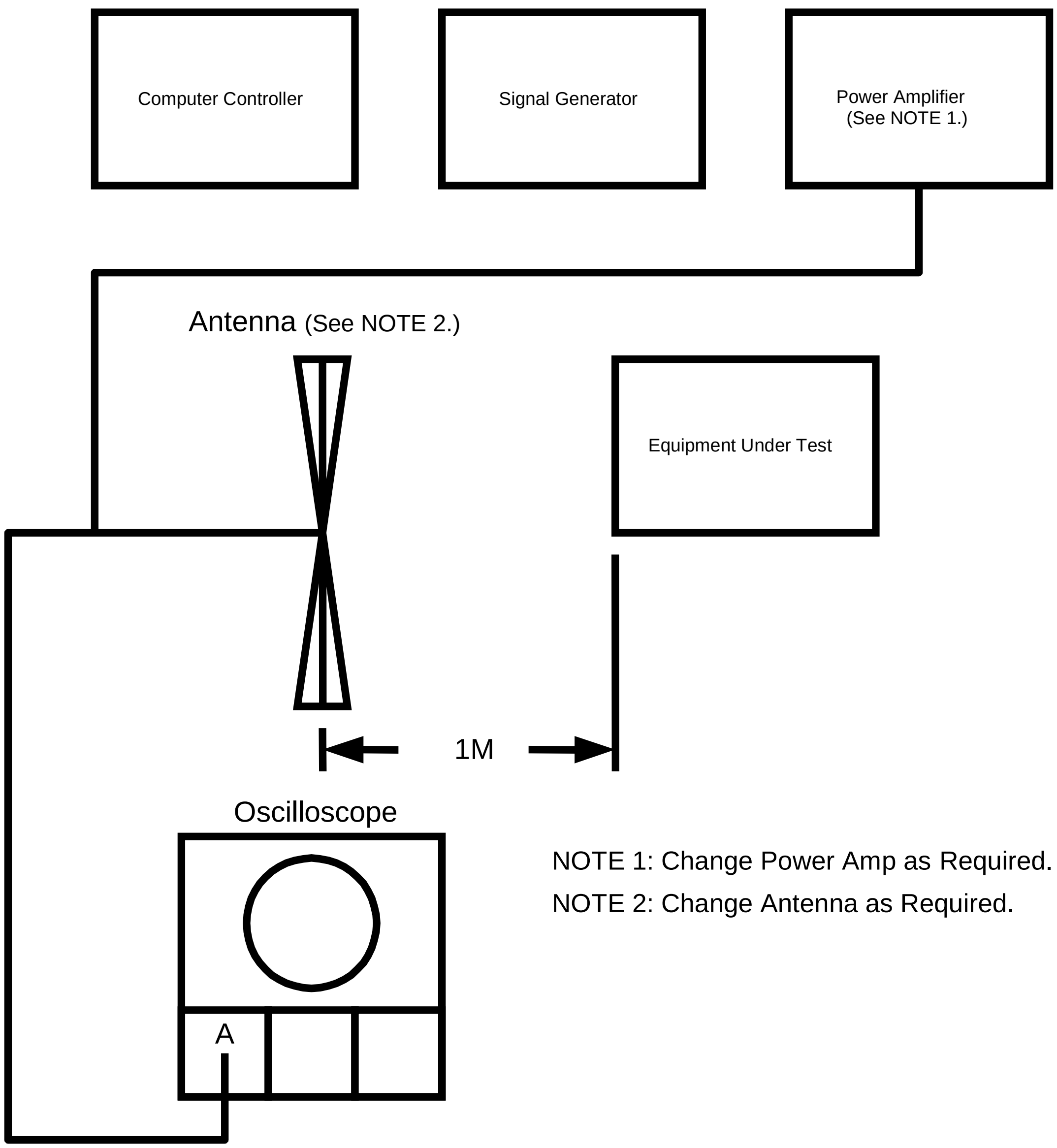

Figure 3
Radiated Electric Field Susceptibility Test Setup

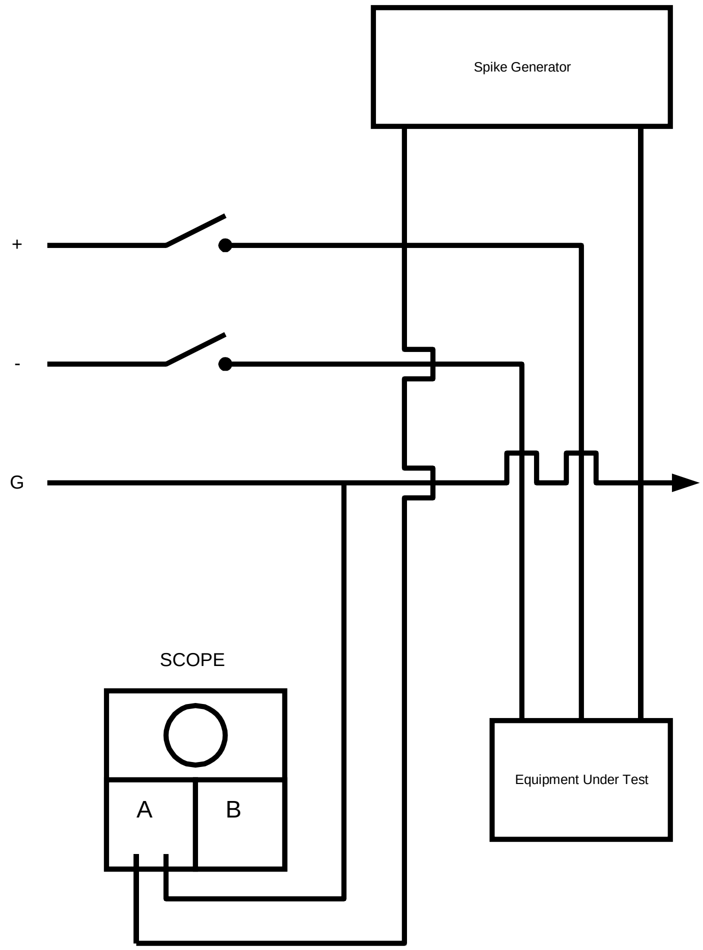

Figure 4
Transient Susceptibility (Conducted) Test Setup

Table 1 Data Sheet for EM Susceptibility Testing

Initial Condition	
MFC Indicated Output	
Flow Standard Output	
Ambient Temperature	°C
Gas Temperature	°C
Gas Pressure	psig

MFC Cable Shielding and Connector	
Cable Shielding	
Type of MFC Connector	

EM Susceptibility Testing *I. EM Field-Radiated*						
Data Points	Frequency (Hz)	Field Strength (V/m)	MFC Indicated Flow (V)	Flow Standard Output	MFC Indicated Flow (%FS)	Flow Standard (%FS)
1						
2						
3						
: :						

EM Susceptibility Testing *II. EM Field-Conducted*						
Data Points	Spike Amplitude (V)	Location of Spike Input	MFC Indicated Flow (V)	Flow Standard Output	MFC Indicated Flow (%FS)	Flow Standard (%FS)
1						
2						
3						
: :						

Table 2 Results of Electromagnetic Susceptibility Testing

A. Radiated Susceptibility						
Data Points	Freq. (Hz)	Field Strength (V/m)	MFC Indicated Flow (%FS), corrected for zero	Flow Standard (FS%), corrected for zero	Change in Flow from Reference	
					MFC (%FS)	Std. (%FS)
1						
2						
3						
4						
5						
: :						

B. Conducted Susceptibility						
Data Points	Spike Amplitude (V)	Location of Spike Input	MFC Indicated Flow (%FS), corrected for zero	Flow Standard (FS%), corrected for zero	Change in Flow from Reference	
					MFC (%FS)	Std. (%FS)
1						
2						
3						
4						
5						
6						
: :						

SEMI F54-1000
TEST METHOD FOR MEASURING THE COUNTING EFFICIENCY OF CONDENSATION NUCLEUS COUNTERS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on July 13, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000. Previously published June 2000.

1 Purpose

1.1 Particle specifications for gases require the use of condensation nucleus counters (CNCs) having specified counting efficiencies. This document provides the test method for determining the counting efficiencies of CNCs.

2 Scope

2.1 This document provides the method for 1) generating an aerosol standard consisting of sodium chloride (NaCl) particles having sizes 0.01 micrometer and larger suspended in air at atmospheric pressure (1×10^5 Pa), 2) controlling the size and concentration of particles in the aerosol, and 3) using the aerosol to determine the counting efficiency of a CNC as a function of particle size. This method is suitable for CNCs having a lower size sensitivity of 0.01 micrometer or larger.

NOTE 1: Suitable test methods for calibrating optical particle counters are contained in ASTM F328 and JIS B 9921.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document does not provide the method for adjusting the CNC's counting efficiency.

3.2 This document does not provide the method for determining the CNC's background noise level, maximum concentration limit, or maximum detectable particle size.

4 Referenced Standards

4.1 *ASTM standards*[1]

ASTM D1193 — Standard Specification for Reagent Water

ASTM F328 — Standard Practice for Calibration of an Airborne Particle Counter Using Monodisperse Spherical Particles

4.2 *JIS standard*[2]

JIS B 9921 — Japanese Industrial Standard, Light Scattering Automatic Particle Counter

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *aerosol electrometer* — an instrument that converts the charge flow in an aerosol stream to an electrical current signal.

5.2 *aerosol standard* — an aerosol containing particles of a known size and concentration.

5.3 *coincidence error* — the inaccuracy in a measured particle concentration caused by multiple particles in the optical sensing volume of an instrument.

5.4 *concentration limit* — the maximum concentration of particles in an aerosol to avoid a coincidence error of 10% or greater in an instrument.

5.5 *counting efficiency* — the ratio of the concentration of particles reported by the CNC to that reported simultaneously from the same aerosol by a reference instrument.

5.6 *lower size sensitivity* — the particle size corresponding to 50% counting efficiency for the CNC.

5.7 *monodisperse aerosol* — *a*n aerosol having a narrow distribution of particle sizes. The maximum band width of a monodisperse aerosol is defined in Section 8.7.

5.8 *particle concentration* — the number of particles per unit volume in a gas.

5.9 *polydisperse aerosol* — an aerosol having a wide distribution of particle sizes.

NOTE 3: Additional terminology is contained in ASTM F328 and JIS B 9921.

1 American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA

2 Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo 107, Japan

6 Summary of Method

6.1 The measurement is performed using aerosol standards consisting of NaCl particles suspended in air. Aerosols are produced by nebulizing a solution of NaCl in water. After drying and charge neutralization, particles of the required size are extracted from the aerosol using an electrostatic classifier (EC). The concentration of particles in the resulting monodisperse aerosol is then recorded by the CNC and compared to that measured simultaneously by a reference instrument. Examples of suitable reference instruments are described in Section 8.8.

NOTE 4: This method has been shown to provide repeatable results in tests performed in separate laboratories on similar CNCs. Examples of these tests are found in Agarwal and Sem[3] and Bartz, et al[4].

7 Requirements

7.1 The reference instrument must have a proven counting efficiency of not less than 95% over the entire range of particle sizes tested. Low counting efficiency in the reference instrument results in an error in the measured particle concentration. The counting efficiency for the reference instrument must be checked by the manufacturer against a calibrated standard, such as a calibrated aerosol electrometer.

7.2 Coincidence error in either the CNC or the reference instrument causes inaccuracy in the measured particle concentration. The concentration limit for each instrument must be obtained from the manufacturer's specifications. The particle concentration in the aerosol standard must be kept below both concentration limits.

7.3 When an aerosol electrometer is used as the reference instrument, the minimum detectable particle concentration must be obtained from the manufacturer's specifications. A particle concentration below the minimum detectable value will cause inaccurate results. The particle concentration in the aerosol standard must be kept above the minimum detectable particle concentration.

7.4 The transport loss of particles from the EC to the CNC, and from the EC to the reference instrument must be checked. Any disparity in particle transport loss to the two instruments will cause erroneous results. The method for calculating the transport loss of particles in sample lines is found in Pui, et al[5]. The transport loss must be calculated for each particle size tested. Record all transport loss calculations.

7.5 When an aerosol electrometer is used as the reference instrument, a correction must be made for multiple charging of particles in the aerosol standard. Multiple charging can cause substantial error when measuring particles larger than 0.06 micrometer. The correction factor for multiple charging must be obtained from the manufacturer of the EC. An example of the method for calculating the correction factor is found in Liu and Pui[6].

8 Apparatus

8.1 *Atomizer* — A sub-micrometer aerosol generator capable of nebulizing a liquid solution. The atomizer must be capable of producing a stable aerosol containing particles as small as 0.01 micrometer after drying.

8.2 *Liquid Trap* — A device which allows free passage of an aerosol stream containing sub-micrometer particles, but which removes the entrained liquid phase by gravitational settling into a reservoir.

8.3 *Diffusion Drier* — A device which allows free passage of an aerosol stream containing sub-micrometer particles, but which dries the aerosol by diffusion of water vapor into a surrounding desiccant medium. The design flow rate of the diffusion drier must at least match the output flow rate of the atomizer.

8.4 *Aerosol Neutralizer* — A bipolar charging device which neutralizes aerosols by producing both positive and negative air ions. The neutralizer must reduce the charge on the particles to the Boltzmann equilibrium level. The design flow rate of the neutralizer must at least match the output flow rate of the atomizer.

8.5 *Bypass Filter* — A high efficiency point of use gas filter. The design flow rate of the bypass filter must at least match the output flow rate of the atomizer.

8.6 *Mixing Vessel* — A device which disperses particles in a flowing aerosol by inducing turbulence.

8.7 *Electrostatic Classifier* (EC) — A device which extracts particles from a polydisperse aerosol according to their electrical mobility. The electrical mobility of a particle depends upon its size and charge. The EC must extract a monodisperse aerosol standard having a

3 Agarwal, J. K. and Sem, G. J. Continuous Flow, Single-Particle-Counting Condensation Nucleus Counter. Journal of Aerosol Science, 11: 343-357 (1980)

4 Bartz, H., Fissan, H., Helsper, C., Kousaka, Y., Okuyama, K., Fukushima, N., Keady, P. B., Kerrigan, S., Fruin, S. A., McMurry, P. H., Pui, D. Y. H. and Stolzenburg, M. R. Response Characteristics for Four Different Condensation Nucleus Counters to Particles in the 3-50 nm Diameter Range. Journal of Aerosol Science, 16 (5): 443-456 (1985)

5 Pui, D. Y. H, Ye, Y. and Liu, B. Y. H. Sampling, Transport, and Deposition of Particles in High Purity Gas Supply System. Proceedings 9th ICCCS: 287-293, (1988)

6 Liu, B. Y. H. and Pui, D. Y. H. A Submicron Aerosol Standard and the Primary, Absolute Calibration of the Condensation Nuclei Counter. Journal of Colloid and Interface Science, 47 (1): 155-171 (1974)

narrow band width. The mobility band width of the extracted aerosol must be no greater than 20% of the mean particle mobility. The method for calculating electrical mobility and mobility band width are found in Liu and Pui[6].

8.8 *Reference Instrument* — An instrument which can measure the concentration of particles in an aerosol. The calibration of the reference instrument must have been checked against a calibrated standard within the past 12 months. Calibration and maintenance records for the reference instrument must be maintained. Suitable reference instruments include aerosol electrometers and CNCs having lower size sensitivities below 0.01 micrometer.

8.9 *Condensation Nucleus Counter (CNC) or Condensation Particle Counter (CPC)* — The particle counter to be used in process gas particle measurements, and for which the calibration check is required. The CNC detects sub-micrometer particles using nucleation and droplet growth of a super-saturated working fluid.

8.10 *Tubing* — In order to minimize particle losses, all tubing used to transport charged aerosol particles must be constructed from electrically conductive materials (e.g., stainless steel) and grounded.

9 Reagents and Materials

9.1 De-ionized or distilled water in accordance with ASTM D1193, Type 1 is required to dissolve NaCl for aerosol generation.

9.2 NaCl is required for aerosol generation.

9.3 A supply of dry, oil-free compressed air is required to generate and transport aerosols in the apparatus.

10 Preparation of Apparatus

10.1 The test apparatus is shown in Figure 1. The particle concentration in the aerosol is controlled using a bypass filter. If the flow rate of the monodisperse aerosol from the EC is insufficient to supply the CNC and reference instrument simultaneously, filtered air must be added to the stream. The air must be added to the aerosol upstream of a mixing vessel. If the flow rate of the monodisperse aerosol from the EC is greater than that required to supply the CNC and reference instrument simultaneously, the excess aerosol must be vented.

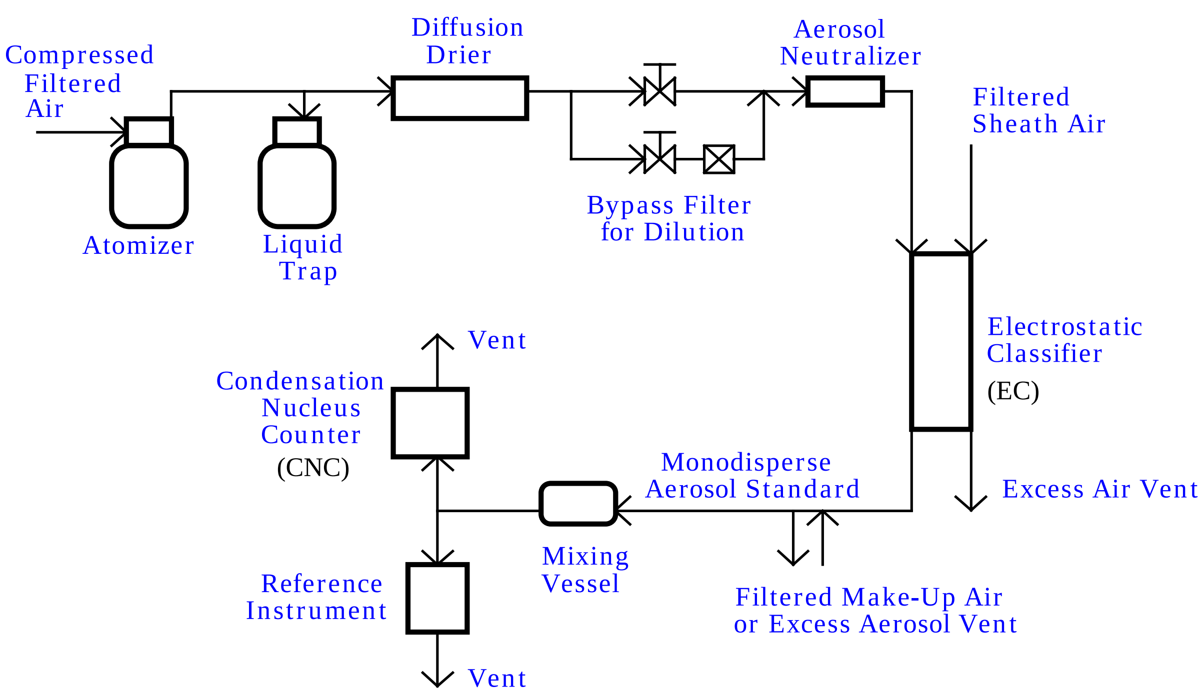

Figure 1
Schematic Diagram of Test Apparatus

11 Calibration and Standardization

11.1 All flow meters and voltage indicators used in the apparatus, including instruments incorporated into the EC and particle counters, must have been checked for proper calibration against calibrated standards within the past 12 months. Record all calibration data.

12 Procedure

12.1 Fill the atomizer reservoir with a solution of NaCl in water. The required NaCl concentration depends upon the range of particle sizes to be tested, and must be determined from the atomizer manufacturer's specifications. Record the concentration of NaCl in the solution.

12.2 Determine the required aerosol, sheath air and excess air flow rates for the EC. The flow rates depend upon the range of particle sizes to be tested and the required mobility bandwidth, and must be determined from the EC manufacturer's specifications.

12.3 Close the bypass filter valve. Adjust the flow rates of the atomizer, CNC, and reference instrument to their manufacturer's specified values. Adjust the flow rates of the EC to their required values as described in Section 12.2. Adjust the flow rate of the make-up air or aerosol vent to the required value as described in Section 10.

12.4 Set the EC voltage to obtain the selected particle size for testing. Record the voltage setting and the selected particle size.

12.5 Observe the particle concentration indicated by the reference instrument. If the particle concentration exceeds the concentration limit of the reference instrument or the CNC, adjust the flow rate through the bypass filter to lower the aerosol particle concentration. After adjusting the bypass flow rate, check all flow rates to ensure that they remain at the required values. Record all flow rates.

12.6 Wait for the particle concentrations indicated by the CNC and reference instrument to become steady; the concentrations indicated by each instrument must not change by more than 5% over a five minute interval. In order to minimize the error in the recorded particle concentrations, a minimum of 500 particles must be counted in a sample. Record the steady particle concentrations indicated by the CNC and reference instrument.

12.7 If another particle size is to be tested, return to Section 12.4.

NOTE 5: At least eight different particle sizes must be tested. The particle sizes must be selected such that the measured CNC counting efficiency at least spans the range 50% to 95% (0.50 to 0.95). In order to eliminate systematic error, the particles sizes must be tested in random order.

13 Calculation and Interpretation of Results

13.1 When an aerosol electrometer is used as the reference instrument, correct the measured particle concentrations for multiple charging, as described in Section 7.5.

13.2 For each particle size tested, calculate the ratio of the concentration of particles reported by the CNC to that reported by the reference instrument. This ratio represents the counting efficiency of the CNC.

13.3 Plot the calculated counting efficiency against the particle size as shown in Figure 2. This plot shows the measured counting efficiency curve of the CNC.

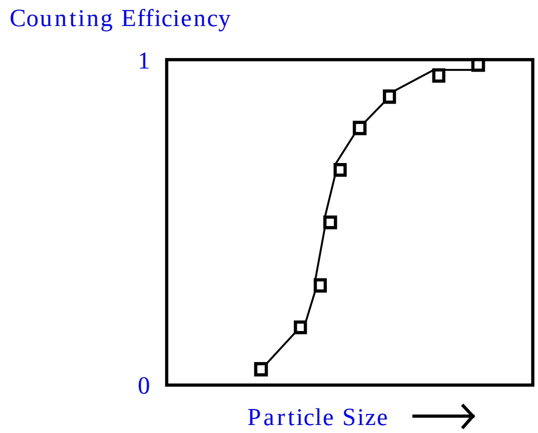

Figure 2
Schematic Plot of Measured Counting Efficiency

13.4 Determine the lower size sensitivity of the CNC, as defined in Section 5. (The counting efficiency at any particle size can be estimated using linear interpolation between the data points.)

14 Reporting Results

14.1 The test record must include the following items:

a. test date;

b. test operator;

c. serial numbers of the reference instrument, CNC and EC;

d. all particle transport loss calculations as described in Section 7.4;

e. all flow meter and voltage indicator calibration data as described in Section 11;

f. all raw data and calculations utilized in the test method as listed in Sections 12 and 13;

g. counting efficiency of the CNC as a function of particle size; and

h. the lower size sensitivity of the CNC.

Appendix 1 contains an example report form.

15 Precision and Accuracy

15.1 This method requires a minimum of 500 particles counted in a sample. For Poisson distributed data, the relative standard deviation of the measured particle concentration is less than 5% when at least 500 particles are counted in a sample.

APPENDIX 1
EXAMPLE REPORT FORM

NOTE: The material in this appendix is an official part of SEMI F54 and was approved by full letter ballot procedures on July 13, 2000 by the North American Regional Standards Committee.

A1-1 Test dates:______________________________

A1-2 Operator(s) performing test:______________________________

A1-3 Serial numbers:____________________ Reference instrument____________________

CNC____________________ EC____________________

A1-4 Attach flow meter and voltage indicator calibration data as described in Section 11.

A1-5 Data and calculations:______________________________

____

Data Point (Use Additional Sheets as Necessary)

	1	2	3	4	5	6	7	8
NaCl Concentration (gm/l)								

Flow Rates (cm^3/s)

EC Aerosol								
EC Sheath								
EC Excess Air								
CNC								
Reference Instrument								
Make-up Air or								
Excess Aerosol Vent								

EC Voltage (V)								
Particle Size (micrometer)								

Measured Particle Concentrations (Particles/cm^3)

CNC **(1)**								
(1) Corrected for Transport Loss **(2)***								
Reference Instrument **(3)**								
(3) Corrected for Multiple Charging (Electrometers Only) **(4)***								
(4) Corrected for Transport Loss **(5)***								
Counting Efficiency = (2)/(5)								

A1-6 Attach plot of counting efficiency as a function of particle size

A1-7 Lower size sensitivity (micrometer)* ___________

* Attach calculations.

NOTICE: SEMI makes no warranties or representations as to the suitability of the test method set forth herein for any particular application. The determination of the suitability of the test method is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These test methods are subject to change without notice.

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SEMI F55-0600
TEST METHOD FOR DETERMINING THE CORROSION RESISTANCE OF MASS FLOW CONTROLLERS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on April 10, 2000. Initially available on www.semi.org May 2000; to be published June 2000.

1 Purpose

1.1 A mass flow controller (MFC) is often used to control corrosive gases under unfavorable conditions. This test method is intended to help differentiate between MFC designs on the basis of relative resistance to corrosion-induced failure.

2 Scope

2.1 This test is intended to show the effect of corrosion caused when a corrosive gas such as HCl is contaminated by an oxidizer such as atmospheric moisture. For the purpose of this test HCl is the preferred test gas, however this test can also be performed with other gasses. This test method describes a corrosive gas exposure test for mass flow controllers. The test is intended to accelerate the corrosion while simulating conditions that may be found within process equipment and gas systems in the semiconductor industry. As the relationship between corrosion and performance may differ with MFC design, corrosion is not measured directly. The effects of corrosion are detected by observing changes in MFC calibration and other operating parameters.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This test method should not be expected to yield comparable quantitative results from one test facility to another.

3.2 Results may be compromised by the methods used to construct the apparatus.

3.3 This test is designed to be a destructive test. The MFC tested will be destroyed. This test is intended only for MFCs manufactured for use in HCl or a similar highly corrosive gaseous environment. MFCs manufactured for non-corrosive service may develop leaks or other catastrophic failures if tested by this method. For practical reasons in constructing and operating the test bed, test samples may be limited to 100 sccm N_2 equivalent full scale (FS) flow.

3.4 This method does not measure corrosion directly by analyzing or inspecting the gas-wetted surfaces following exposure to a corrosive. No attempt is made to detect particles in the exit gas stream resulting from the corrosion process.

4 Referenced Documents

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *DUT* — device under test

5.1.2 *FS* — full scale

5.1.3 *kPa* — kiloPascal

5.1.4 *MFC* — mass flow controller

5.1.5 *MFM* — mass flow meter

5.1.6 *ppbv* — parts per billion by volume

5.1.7 *ppmv* — parts per million by volume

5.1.8 *sccm* — standard cubic centimeters per minute using a standard temperature of 0° C and a standard pressure of 101.32 kPa.

5.2 *Definitions*

5.2.1 *actual flow* — for the purpose of this standard, the output value of the reference flowmeter.

5.2.2 *ambient temperature* — the temperature of the medium surrounding the device. Under ordinary laboratory benchtop conditions, ambient temperature is the temperature of the room.

5.2.3 *indicated flow* — the electrical output of the device under test (DUT).

5.2.4 *valve drive* — electrical output from the DUT which is analogous to the level of power supplied to the control valve. This output is sometimes called valve voltage.

6 Summary of Method

6.1 Corrosive gas and moisture-containing N_2 are alternately flowed through the DUT with intervening dry N_2 purges. The test MFC is monitored over time for changes in performance resulting from corrosion.

6.2 This test is intended to be an accelerated simulation of the effects of alternating corrosive and moisture-exposure conditions. The test records how long it takes for corrosion to affect calibration. MFCs that are more resistant to corrosion failures should last longer under the test conditions. A dry N_2 purge separates each MFC's exposure to the corrosive gas and to the moisture-containing gas. This purging favors MFC designs that perform well in corrosive service because those MFCs can be dried out quickly with limited purging.

6.3 This method is expected to yield data that can be used to compare the relative performance of components tested for the purpose of qualification.

7 Interference's

7.1 Portions of the gas system exposed to HCl may require replacement or cleaning and refurbishment between test sequences to avoid invalidating subsequent tests by prematurely contaminating DUTs. Take care in the design and maintenance of the system so that particles shed from upstream piping components as a byproduct of corrosion are minimized so that they do not affect the DUT.

8 Apparatus

8.1 *Containment System* — to contain corrosive gas leaks that may develop in the DUT or gas system. The portion of the system that contains the corrosive gas should be operated in a suitable secondary containment environment.

8.2 *Power Supply*, *Controls*, and *Data Collection Devices* — capable of recording data 20 times per second. Signals should be measured with a resolution of one mV or better. Data may be recorded in convenient units such as volts, sccm, or percent of FS. For the purpose of analysis and reporting, data should be converted to percent of FS except for valve drive, which may be reported in either percent of maximum drive or volts.

8.3 *DUT*

8.4 *Data Acquisition System* — Recommended as a data collection system to facilitate test sequencing and data collection.

8.5 *Plumbing* — with tubing and gas-switching valves constructed from 316L electropolished stainless steel or other material that exhibits superior corrosion resistance compared to 316L. The use of materials such as plastics, which retain or are permeable to water vapor, are not appropriate. All-metal sealed valves (no elastomers) are readily available and must be used.

8.6 The test plumbing is intended to represent the technology level found in the semiconductor process gas piping in which a typical DUT will operate.

8.7 A filter has not been specified immediately upstream of the DUT because it would harbor contaminates and make it difficult to alternate gas types.

8.8 *Dry N_2 Source* — pressure regulated source with a moisture level no greater than 50 ppbv.

8.9 *Dry HCl Source* — pressure regulated source with a moisture level no greater than 500 ppbv.

8.10 *Reference Flowmeter* — traceable with calibration certificate, calibrated for N_2, FS flow 100% to 125% of the FS N_2 equivalent flow range of the DUT Accuracy better than 5%, linear to 0.5% FS repeatable to 0.15% over a three-hour period, and reproducible to 0.3% of the test flow for the duration of the test .

NOTE 2: As this test is concerned with changes in DUT calibration and not the value of DUT calibration itself, the accuracy of the reference flowmeter is not paramount.

8.11 *Moisture Generator* — to introduce water vapor in a concentration of 100 ppmv (μl/l) ± 20% in N_2.

8.12 *Moisture Analyzer* — to periodically verify the output of moisture generator.

9 Reagents and Materials

9.1 *HCl*

9.2 *N_2*

10 Safety Precautions

10.1 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

NOTE 3: The DUT will be contaminated with corrosive material at the conclusion of this test. Caution should be exercised in handling. A contaminated DUT should be properly decontaminated.

10.2 Become familiar with the safe handling practices associated with the corrosive gas before undertaking this test.

11 Preparation of Apparatus

11.1 The test apparatus is the source of three gases—dry N_2, dry HCl, and N_2 containing a known level of water vapor. Each gas can be valved through the DUT individually with minimal cross contamination. The DUT actively controls the gas flow in each case. The gas then flows into either a scrubbed exhaust system for safe disposal or a reclamation system. A reference flowmeter in the dry N_2 supply line is used to detect changes in calibration of the DUT when dry N_2 is flowing in series through both devices.

11.2 *Setup and Schematic* — See Figure 1 for a schematic of the test apparatus. This schematic may not show in detail all the components required in an actual system.

11.3 Supply the manufacturer's recommended power to the DUT. Provide MFC setpoint and purge command (if available). Monitor the following:

11.3.1 DUT setpoint input.

11.3.2 DUT indicated flow output.

11.3.3 DUT valve drive output (if available)

11.3.4 actual flow (output of reference flowmeter)

11.4 Verify that the proper moisture levels exist in each of the test gases.

11.5 Provide a purge flow loop that maintains a constant flow of dry N_2 in the line from the DUT to the exhaust system. Flow in this loop must be sufficient to prevent back diffusion into the DUT of moisture generated in the exhaust system, particularly when flow into the DUT is shut off for measuring zero.

11.6 If the moisture generator is supplied from the same N_2 source that supplies the dry N_2, take precautions to avoid the diffusion of moisture from the moisture generator into the dry N_2 line. Such precautions may include the use of separate pressure regulators and other valving.

11.7 Moisture generators typically take time to stabilize. A continuous flow should be maintained through the moisture generator during the test to maintain a stable moisture flow. This may require diverting the output flow to a vent when not flowing through the DUT.

11.8 Periodically verify the moisture concentration of wet N_2 with a suitable moisture analyzer.

11.9 Follow manufacturer set-up procedures for all equipment.

11.10 Conduct the test at an ambient temperature of 22 ± 2°C.

11.11 The DUT moisture generator, flowmeters, and other instrumentation should have been stabilized at room temperature for 24 hours before beginning the tests. It is not necessary to flow gas during this stabilization time.

11.12 All portions of the plumbing system that could contain HCl must be helium leak tested per SEMI F1 before introducing HCl into the system. When changing the DUT or other components, at least those portions of the system that were changed must be re-tested.

NOTE 4: Small leaks in a corrosive gas system can become much larger without warning.

12 Calibration and Standardization

12.1 Calibrate all instrumentation using current standards that are traceable to an appropriate standards laboratory. In the absence of appropriate standards, use manufacturer recommendations for calibration.

13 Procedure

NOTE 5: Refer to Figure 2 for a flowchart of the following test.

13.1 Set the pressure of each of the HCl and Dry N_2 gas sources at 140 kPa ± 5%. Set the pressure of the N2 to the moisture generator to the appropriate value recommended by the manufacturer. If the test must be run at some other pressure, because of a limitation of the DUT, report this fact in the test results.

13.2 Start the wet N_2 flow to vent or through the moisture analyzer. Establish a stable moisture concentration at 100 ppmv ± 20% before beginning the test sequence. Set the wet N_2 to flow within ± 5% of the DUT flow that will be run during the test.

13.3 Place the DUT control valve in the purge or fully open position by supplying a purge command or a 200% setpoint. Purge with dry N_2 at a rate of one to two times FS flow for one hour to establish initial conditions. The purge rate is controlled by adjusting the supply pressure and is monitored by a purge-rate flowmeter located in the gas-supply path. Follow the manufacturer's procedure for fully opening the DUT control valve.

13.4 Provide a setpoint to the DUT for 80 ± 5% of FS flow.

13.5 Determining the Test Baseline and Measurement Repeatability.

NOTE 6: Data throughout this test may be recorded in a format similar to that found in Table A1.1.

13.6 Open valve V1 and flow dry N_2 at a setpoint of 80% ± 5% of the DUT FS and wait 10 minutes.

13.7 Record:

13.7.1 DUT setpoint

13.7.2 DUT indicated flow

13.7.3 DUT valve drive output (if available)

13.7.4 Actual flow

13.8 Stop flow by closing V1. Drive the MFC control valve to a closed position by providing a zero setpoint or as otherwise provided by the manufacturer. Allow the MFC indicated flow output to stabilize for a minimum of three minutes.

13.9 Record the DUT indicated flow and the actual flow during the zero flow condition.

13.10 Repeat Sections 13.6 through 13.9 twelve times. This will yield 12 data points for each of the six measured parameters.

13.11 For each of the six parameters recorded, perform the following calculation on the 12 baseline data points to determine the repeatability of the measurement:

$$\frac{(\text{highest value - lowest value})}{\text{average of the 12 values}} \times 100$$

13.12 If each of the six parameters is not repeatable within 0.2% during these two hours, subsequent test data may not be valid and the problem should be resolved before proceeding with the test.

13.13 Baseline

NOTE 7: Use the averaged value of the measurements made in Section 13.13 for each parameter as the baseline for that parameter in the following tests.

13.14 *Test Sequence* — Without changing the DUT setpoint, repeat the test sequence in Sections 13.19-13.22 every 30 minutes, continuously, 24 hours per day, seven days per week until one of the following test termination conditions is met.

13.15 The test should not be interrupted because the DUT may continue to corrode during the interruption, making test results non-repeatable. The output of the moisture generator should be measured periodically during the test sequence to ensure that it remains within the test specifications.

13.16 Terminate the test sequence if:

13.16.1 The DUT fails to function

13.16.2 The actual-flow shift from baseline exceeds 25%

13.16.3 The valve drive exceeds the manufacturer's limits

13.16.4 The DUT indicated flow differs from commanded setpoint by > 5%

13.16.5 The test exceeds 5000 cycles

13.17 Flow dry N_2 for five minutes. After five minutes, record data on the six test parameters as done in Section 13.7, interrupting flow to record the DUT indicated flow and reference flowmeter output at zero flow. After taking measurements, flow dry N_2 again so that the total length of this step is 10 minutes. Record data as shown in Figure 3.

13.18 Flow dry HCl for seven minutes.

13.19 Repeat Section 13.19 and then proceed to Section 13.22.

13.20 Flow wet N_2 for three minutes. If no test termination condition is met as described in Section 13.18, repeat Sections 13.19 - 13.22. If a test termination condition is met, proceed to Section 13.23.

13.21 After the test has been completed, place the DUT control valve in the purge or fully open position. Purge with dry N_2 for one hour or at least 50 volume changes. Cycle the purge gas for 15 seconds on and 15 seconds off by opening and closing V1 for the duration of the purge. Follow the manufacturer's procedure for fully opening the DUT control valve.

NOTE 8: Verify purge flow with the reference flowmeter or by using other means. Corrosion may have rendered the control valve inoperable. An alternate approach for purging any corrosive material from the system may have to be followed.

13.22 Alternate Approach to Purging.

13.23 If gas cannot be purged through the DUT, cycle-purge each end of the DUT separately using Sections 13.26 through 13.28.

13.24 With valves V2 and V3 closed for the duration of the procedure, close valve V6 and pressurize both sides of the system by opening V1 and V7 for 15 seconds.

13.25 Vent pressure through the exhaust system by closing V1 and opening V6 for 15 seconds.

13.26 Repeat pressure and vent cycles for a minimum of one hour.

13.27 Remove the DUT. Preserve the test system, if desired, by taking steps to exclude atmospheric moisture. Such steps could include capping the system and shutting all valves. Alternately, the DUT may be replaced with a spool piece. The system can then be continuously purged with dry N_2.

NOTE 9: The DUT will be contaminated with corrosive material. See *Precautions* in Section 10. Preserve the DUT for failure analysis, if desired.

14 Calculations or Interpretation of Results

14.1 Report data in a tabular format and graph per Appendix 1. Any parameter which changes more than 1% from its baseline should also be graphed. Note the reason the test was terminated. Test results may be summarized in a single parameter by reporting the number of test cycles to reach a 2% shift in actual flow or to reach DUT failure, whichever occurs first. In this test, more data is reported than is required to calculate the gross test result. The extra data is used when analyzing test results to determine the cause of failure. Further explanation of the significance of the data is beyond the scope of this test method.

15 Data Analysis.

15.1 Calculate any parameter-shift in percent as follows:

$$\frac{\text{(baseline value - current value)}}{\text{baseline value}} \times 100$$

16 Reporting Results

16.1 Report the number of test cycles to reach a 2% shift in actual flow or to reach DUT failure, whichever occurs first.

17 Precision and Accuracy

17.1 This method is limited in its precision by the calibration of the measurement devices, the temperature of the apparatus, and the concentration of water vapor in N_2. Sources of bias are unknown at this time, but they probably include peculiarities in the construction of the apparatus.

18 Related Documents

18.1 Material safety data sheet (MSDS) for hydrogen chloride, which can be obtained from a supplier of the gas.

19 Illustrations

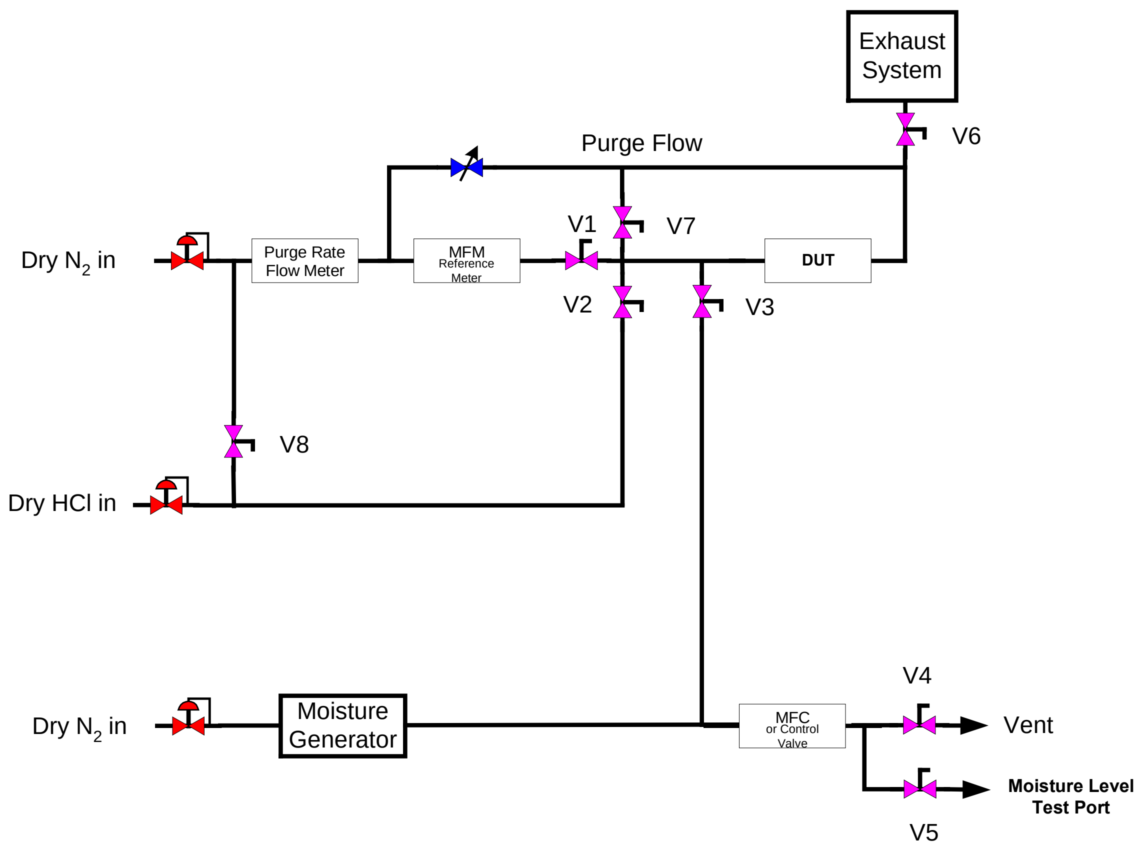

Figure 1
Schematic of Apparatus

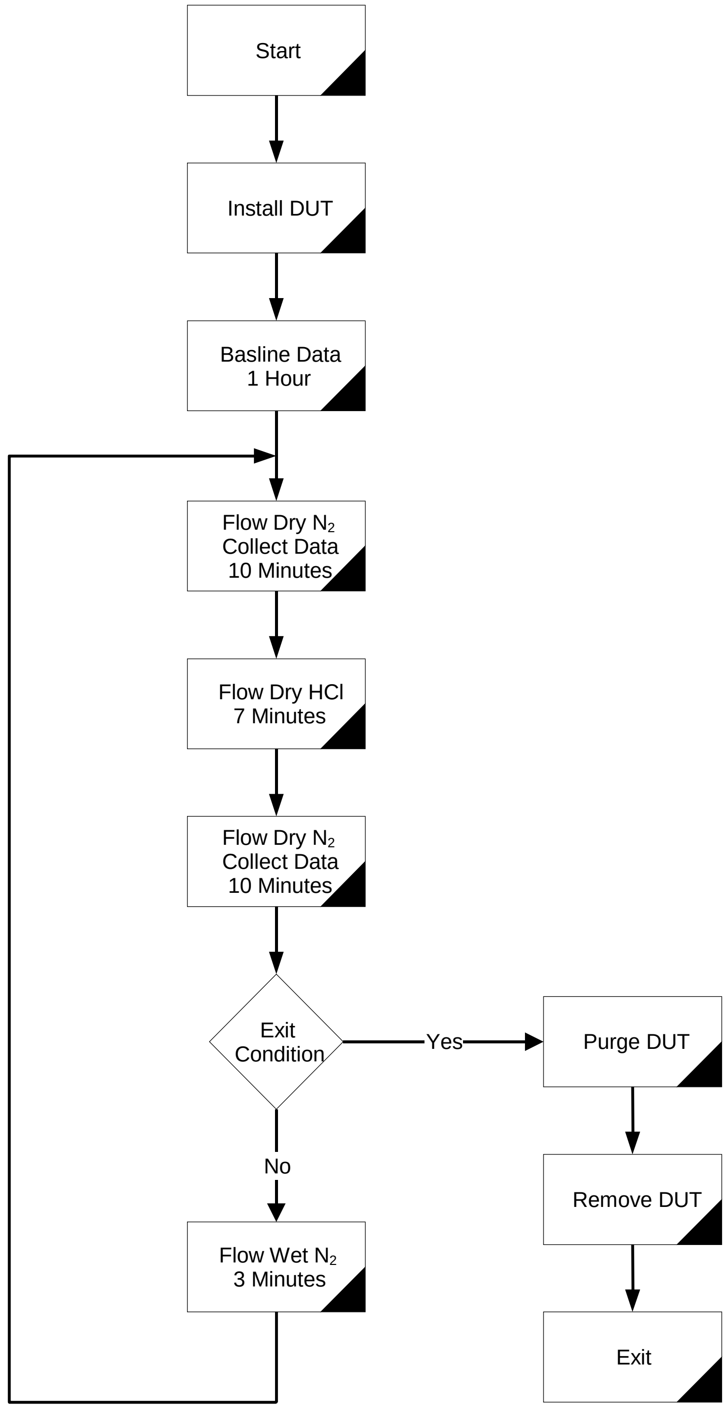

Figure 2
Test Flowchart

APPENDIX 1
TEST REPORT CORROSION TEST

NOTE: The material in this appendix is an official part of SEMI F55 and was approved by full letter ballot procedures on April 10, 2000 by the North American Regional Standards Committee.

MFC Identification:	Wxyz Instruments, Model 123, Serial 230967
Calibrated for:	100 scm^3 HCl
Reference Flowmeter:	Mnop Company, Model 1023, Serial 37863, 100 sccm N_2
Test dates:	March 28 to May 5, 1993
Test Laboratory:	Flow Test and S.D. Associates, Inc.
Test supervised by:	George Smith

Table A1-1 Data in tabular format

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*
TEST CYCLE #	*TEST CYCLE HOURS*	*DUT SET-POINT %*	*DUT INDICATED %*	*DUT ZERO %*	*REFERENCE FLOW ZERO %*	*ACTUAL FLOW %*	*CALIBRATION SHIFT % CHANGE*	*VALVE DRIVE VOLTS*
base line	base line	75.04	75.05	-0.13	0.03	71.12	0.0	-7.062
100	50	75.01	74.8	0.14	0.04	71.56	0.6	-7.066
200	100	75.00	74.82	0.13	-0.04	71.38	0.4	-7
300	150	74.99	75.1	-0.01	-0.03	71.26	0.2	-7.056
400	200	75.02	75.01	0.02	0.01	71.3	0.3	-7.049
500	250	74.98	74.96	-0.01	-0.03	71.36	0.3	-7.009
600	300	75.02	74.96	0.00	0.03	71.18	0.1	-6.997
700	350	74.99	74.92	0.11	-0.04	71.32	0.3	-7.042
800	400	75.00	75.15	-0.06	-0.04	71.37	0.4	-7.010
900	450	75.02	74.9	0.04	0.01	71.69	0.8	-6.997
1000	500	74.99	75.01	-0.09	0.04	71.96	1.2	-7.056
1100	550	75.01	74.82	0.13	0.04	72.55	2.0	-7.136
1200	600	75.03	75.1	-0.13	-0.02	72.92	2.5	-7.100
1300	650	75.05	75.19	-0.15	-0.03	74.17	4.3	-7.277
1400	700	74.96	75.09	-0.12	-0.01	76.15	7.1	-7.348
1500	750	75.04	75.05	-0.09	-0.01	79.86	12.3	-7.666
1600	800	74.96	75.15	-0.13	0.05	88.36	24.2	-8.278
1700	850	74.96	74.99	0.03	-0.02	110.53	55.4	-9.732

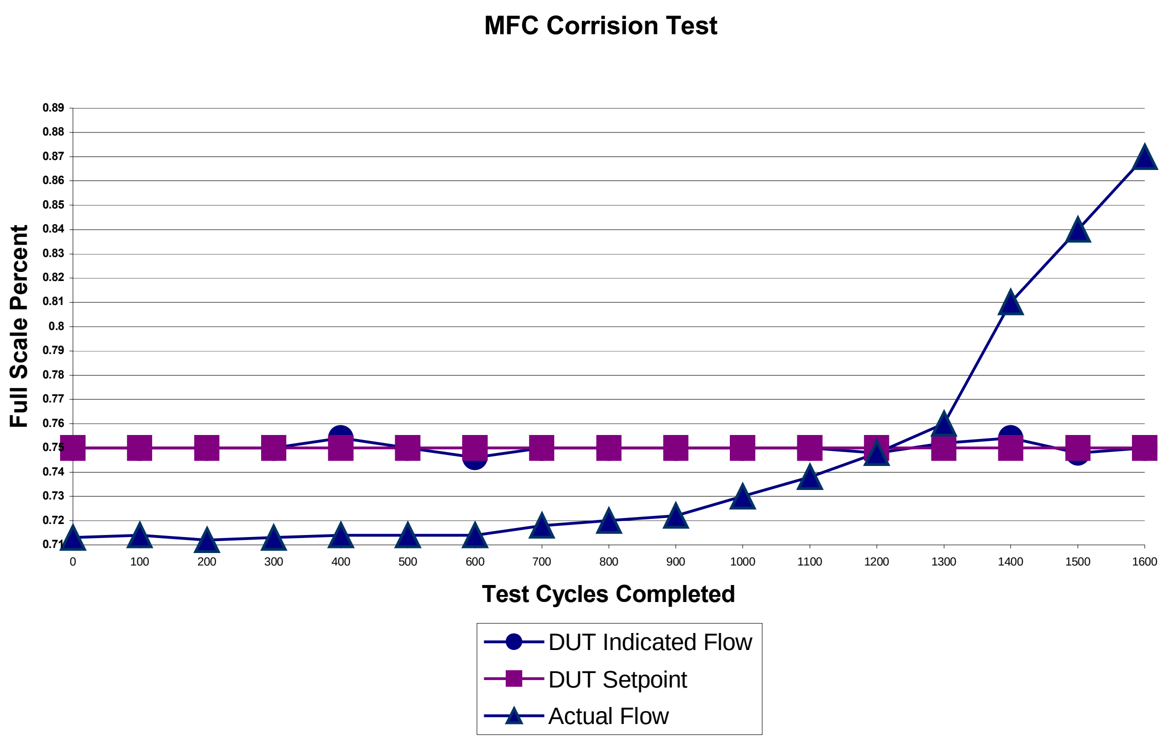

Figure A1-1
Test Results Graph

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F56-0600
TEST METHOD FOR DETERMINING STEADY-STATE SUPPLY VOLTAGE EFFECTS FOR MASS FLOW CONTROLLERS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on April 10, 2000. Initially available on www.semi.org May 2000; to be published June 2000.

1 Purpose

1.1 The purpose of this document is to define a method for characterizing mass flow controllers (MFCs) being considered for installation into a high-purity gas distribution system. This method will quantify the steady-state supply voltage effects on the MFC's ability to accurately deliver set point flow values.

2 Scope

2.1 This procedure applies to thermal mass flow controllers. It is intended to measure the delivered mass flow rate variation as a function of deviation from the reference steady-state supply voltage. The test method is designed for DC-powered MFCs. The supply voltage effects include voltage depression and over-voltage variations in the DC supply.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This test method is not designed for AC-powered MFCs. This test method addresses steady-state effects and does not address any effects caused by transient power supply behavior.

4 Referenced Standards

4.1 None.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *DUT* — device under test

5.1.2 *MFC* — mass flow controller

5.1.3 *NIST* — National Institute of Standards and Technology

5.1.4 *psia* — pounds per square inch absolute

5.1.5 *psig* — pounds per square inch gauge

5.2 *Definitions*

5.2.1 *actual flow* — flow value measured by the flow standard.

5.2.2 *indicated flow* — flow value derived from the MFC.

5.2.3 *Reference voltage(s)* — manufacturer's recommended power supply voltage(s).

5.2.4 *stable* — the state a signal level obtains when its magnitude varies by less than or equal to ±2.0% of full scale over a one-minute period.

6 Summary of Method

6.1 This test method consists of varying the steady-state supply voltage to an MFC in ±1% (of rated supply) increments from the reference voltage span. Both the positive and negative supply voltages will be varied independently and together in 1% increments. The MFC flow output is monitored at 0% and 100% of its operating range (see Table 1). At each incremental change as well as at the reference supply voltage, the MFC flow and flow standard outputs are recorded at 0% and 100% of its operating range. The test shall end when a ±3% of full-scale output flow change is noted between the flow at the reference voltage and at an incremental change point. A flow chart outlines the procedure (see Figure 1).

7 Interference's

7.1 Because of fluctuations in ambient temperature or a changing load on the power supply, the reference steady-state supply voltages may change. These changes in supply voltages may adversely effect the MFC's ability to deliver setpoint flow. The magnitude of this effect can be measured by this test method.

7.2 The user of an MFC can use the data generated by this method to evaluate the impact of steady-state supply voltage variations on the MFC's ability to deliver setpoint flow values. Knowing the magnitude of this effect and the power level variations, allows the user to decide on what measures to take to reduce this effect, if necessary.

8 Apparatus

8.1 The equipment and instrumentation required to complete this test method are shown in Figure 2.

8.2 *DC Power Supply*, to provide the required voltage to the MFC under test, with the capability to vary its output over the range of ±30 VDC at 500 mA, and with ripple less than 0.1% rms.

8.3 DC Power Supply Monitor/Recorder, placed in parallel with the DC power supply, and capable of measuring the DC voltage to within ±5 mV over the entire operating range of the supply.

8.4 Flow Output Monitor, connected to the MFC output and signal common/ground points. The monitor/recorder shall be capable of measuring over a range of 0–10 VDC to within ±5 mV.

8.5 *Flow Standard*, installed downstream and in series with the flow through the MFC. The flow standard shall be capable of measuring flow changes within ±0.3% of full scale.

8.6 *Current Meter*, connected in series in the power common line of the DC power supply, capable of measuring over a range of 0–200 mA to within ±1 mA.

9 Reagents and Materials

9.1 *Test Gas*, nitrogen

10 Safety Precautions

10.1 The user must know the respective instrumentation, practice proper handling of test components, and understand good laboratory practices.

10.2 The user should not exceed the ratings (such as pressure, temperature, flow, and voltage) of the components.

11 Preparation of Apparatus

11.1 *Setup and Schematic* — See Figures 2 and 3.

11.2 The test gas source and delivery system must be capable of satisfying the test volume flow rate at a constant pressure, ±0.1 psia.

11.3 The test gas source and delivery system must be capable of delivering a gas at ambient temperature ±2°C for the duration of each analysis. The ambient temperature shall be held to 22 ±1°C.

12 Calibration and Standardization

12.1 All instrumentation shall be calibrated with NIST traceable standards and shall be under current calibration.

13 Procedure

13.1 Install the MFC into the test setup per manufacturer's recommendations.

13.2 Apply power to all devices shown in Figure 2 per manufacturer's specifications. Allow the devices to warm up for the duration specified by the equipment manufacturer.

13.3 Set the DC power supply to the manufacturers recommended reference voltage. Verify the voltage magnitude using the power supply monitor.

13.4 Purge the system with nitrogen for a length of time equal to ten times the amount of time it takes to replace the system volume with the test MFC at its full-scale rated flow rate.

13.5 Close the inlet shut-off valve and then the outlet shut-off valve located adjacent to the MFC (see Figure 3). Adjust the MFC setpoint to zero flow. Follow the manufacturer's recommendations for adjusting the MFC zero. If the MFC has an auto-zero function, leave it active and note this fact on the data sheet in Table 1. Wait for the signals to become stable. Record on the data sheet (see Table 1) three separate readings of the MFC flow output, the power supply voltages, and the current of the power supply common.

13.6 Vary the positive DC power supply voltage in +1% steps from the reference value while holding the negative supply at its reference value.

NOTE 1: If reference voltage is +15 V, the first step is a change in voltage of +0.15 V.

13.7 After the monitored signals become stable, record the MFC zero value, the current value, and the power supply voltage magnitudes. Record the measurements at each step-change of power level on the data sheet. Continue to increase the positive supply voltage span until the MFC zero point changes by ±3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the voltage level changes to +115% of original value.

13.8 Return the power supply level to the original reference value and repeat Section 13.5.

13.9 Repeat the procedure described in Section 13.6, with the following exception: Decrease the power supply span in 1% decrements until either the MFC zero changes by ±3% of full scale, the zero output point remains unstable for five minutes, or 85% of the original value is reached.

13.10 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.10.

13.11 Repeat Sections 13.6 through 13.9, with the following exception: Vary the negative DC power supply while holding the positive power supply at its reference value.

13.12 Vary both DC power supply voltages together in +1% steps from the reference value.

NOTE 2: If the reference voltages are ±15 V (30 V span), the first step is a change in voltage of ±0.15 V increasing the span to ±15.15 V (30.3 V span).

13.13 After the monitored signals become stable, record the MFC zero value, the current value, and the power supply voltage magnitudes. Record the measurements at each step change of power level on the data sheet. Continue to increase the supply voltage span until the MFC zero point changes by ±3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the voltage level changes to +115% of original value.

13.14 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.13.

13.15 Repeat Section 13.11, with the following exception: Decrement the power supply voltages by 1% and go to Section 13.14.

13.16 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.15.

13.17 Open the inlet and outlet shut-off valves that are adjacent to the MFC (see Figure 3) and adjust the MFC set point to 100%. Insure that all reference conditions are within the specified tolerances. Once the output signals become stable, record the MFC output signal, the power supply voltage, the flow standard output, and the current value.

13.18 Vary the positive DC power supply voltage in +1% increments from the reference while holding the negative power supply at its reference value as described in Section 12.6. Record, on the data sheet, the measurements of MFC flow output, power supply voltage, flow standard output, and current meter signal after the values become stable. Continue to increase the voltage in 1% increments until the MFC or flow standard signal changes by ± 3% of full scale, or the MFC output signal remains unstable for five minutes, or the voltage level changes to +115% of original value.

13.19 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.18.

13.20 Open the inlet and outlet shut-off valves that are adjacent to the MFC and adjust the MFC setpoint to 100%. Repeat the procedure described in Section 12.16, but decrease the positive supply voltage in 1% decrements until either the flow signal changes by ±3% of full scale, the MFC output signal remains unstable for five minutes, or 85% of the original value is reached.

13.21 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.20.

13.22 Repeat Sections 13.15 through 13.19, with the following exception: Vary the negative DC supply voltage level while holding the positive power supply at its reference value and go to Section 13.21.

13.23 Repeat Section 13.15 and then go to Section 13.22.

13.24 Vary both DC power supply voltages together in +1% steps from the reference value.

NOTE 3: If the reference voltages are ± 15 V (30 V span), then the first step is a change in voltage of ±0.15 V increasing the span to ±15.15 V.

13.25 After the monitored signals become stable, record the MFC flow and flow standard values, the current value, and the power supply voltage magnitudes. Record three measurements at each step-change of power level on the data sheet. Continue to increase the supply voltage span until either the flow changes by ± 3% of full scale flow, the MFC zero output point remains unstable for five minutes, or the power level has been changed to +110% of span (±16.5 V).

13.26 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 13.24.

13.27 Open the inlet and outlet shut-off valves that are adjacent to the MFC and adjust the MFC setpoint to 100%. Repeat the procedure described in Section 13.22, with the following exception: Decrease the supply voltages together in 1% decrements until either the flow signal changes by ± 3% of full scale, the MFC output signal remains unstable for five minutes, or until the supply voltage span has changed ± 15% (± 12.75 V). Then go to Section 13.25.

13.28 Return the power supply level to the original reference value, repeat Section 13.5, and go to Section 14.

14 Calculations or Interpretation of Results

14.1 Convert the MFC indicated flow output data and the flow standard output data to percent of full scale flow as follows:

14.2 MFC Indicated Flow:

$$\%FullScaleFlow \cdots = \cdots \left(OutputData(v) \div FullScaleOutput \right) \times 100$$

where the output data is in Column B in data sheet. Record this result in Column G on the data sheet.

14.3 Flow Standard (actual flow):

14.3.1 Follow the manufacturer's recommendation for the flow standard output (Column C in data sheet) conversion to percent of full-scale flow. Record this result in Column H of the data sheet.

14.4 Calculate the average value of the three data-flow points at each power level setting for the MFC indicated flow (Column G) and the flow standard (Column H) in the data sheet. Record the averages in Columns I and J of the data sheet, respectively.

14.5 Determine the span by subtracting the zero value (Column G or H) at a particular power supply variation setting from the 100% flow value (Column G or H) at the same power variation setting. These span values for the MFC and the flow standard are to be recorded in Table 2.

$$Span = 100\% avg.(ColumnG \vdots or \vdots H) - 0\% avg.(ColumnG \vdots or \vdots H)$$
$$@the \vdots same \vdots power \vdots variation \vdots setting$$

14.6 Calculate the change in flow at a power supply level by subtracting the MFC indicated value (Column I) from the flow standard value (Column J). Record these results in Column K of the data sheet. Calculate the voltage variation from the reference voltage value as a percent change as follows:

$$\text{voltage change (VC)} = \frac{\text{voltage value - reference voltage}}{\text{reference voltage}} \times 100$$

Record this result in Column L and M of the data sheet for the positive and negative power supplies, respectively.

15 Reporting Results

15.1 Present the data as shown in Table 2 for both zero and span.

15.2 Present the data plots for the values in Table 2 as illustrated in Figure 4.

16 Precision and Accuracy

16.1 The precision and bias of this test method will be determined during validation.

17 Related Documents

SAMA Standard PMC 31.1-1980, Generic Test Methods for the Testing and Evaluation of Process Measurement and Control Instrumentation.[1]

IEC Publication 546-1976, Methods of Evaluating the Performance of Controller with Analogue Signals for Use in Industrial Process Control.[2]

1 Portions of this method are excerpted from SAMA Standard PMC 31.1-1980 with permission of the publisher, Process Measurement and Control Section, SAMA, 1101 16th St., N. W., Washington, DC 20036.

2 Available from the Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056.

18 Illustrations

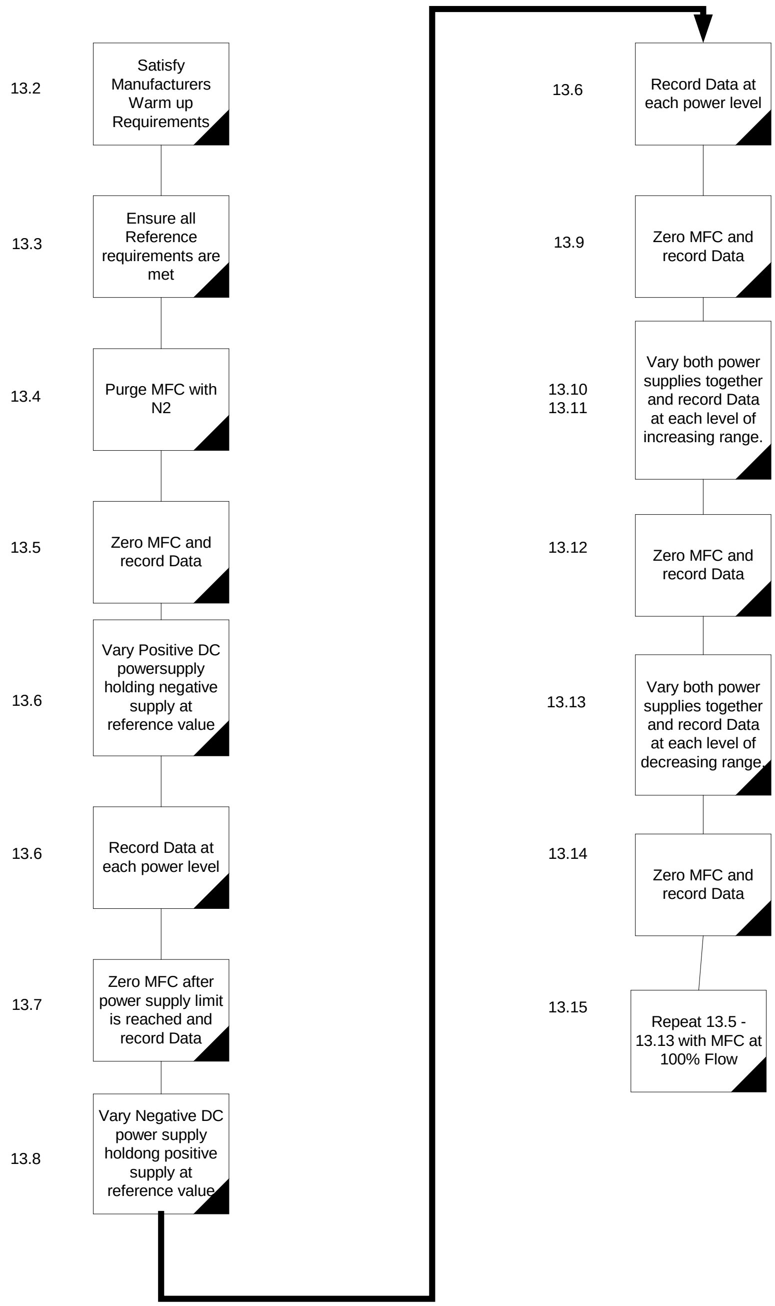


Figure 1
Flow Chart

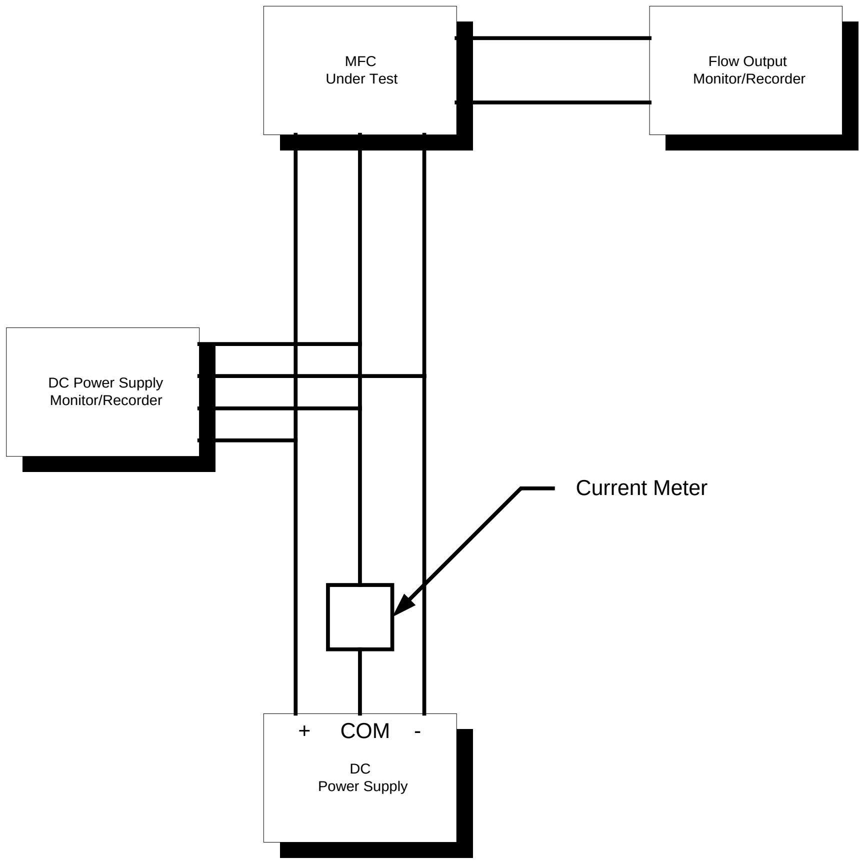


Figure 2
Test Setup for DC Supply Voltage effects

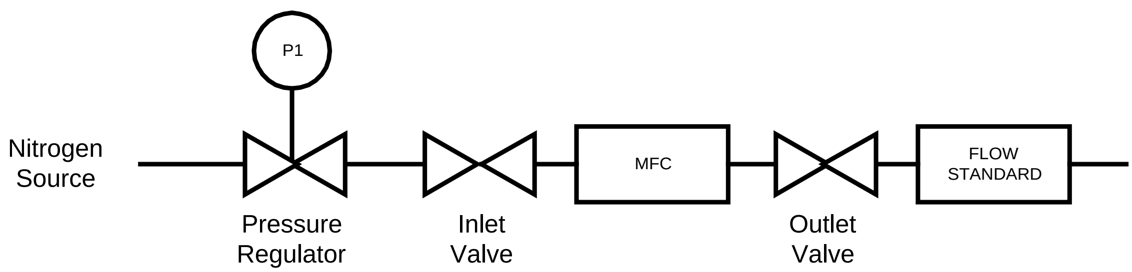
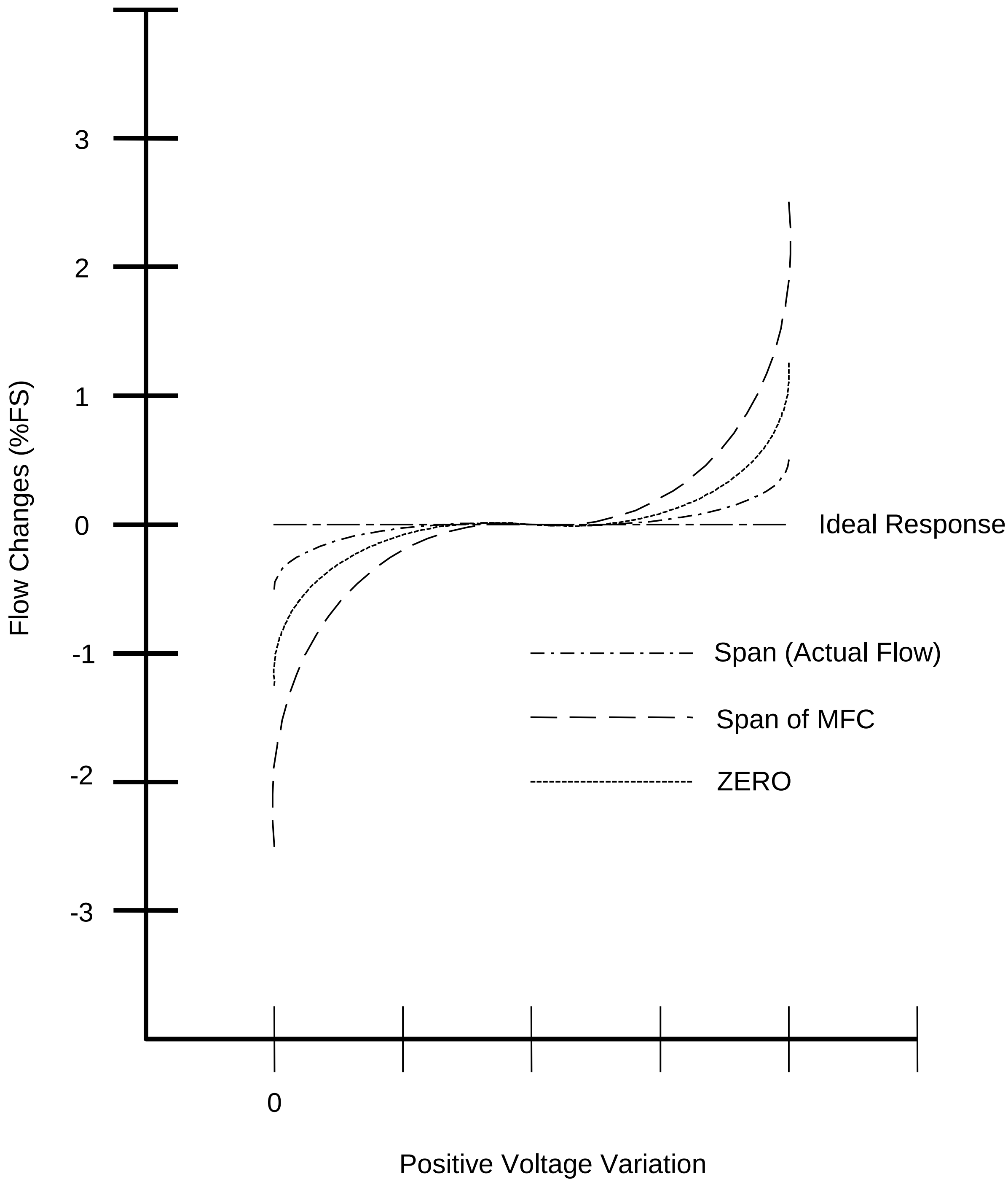


Figure 3
Flow Setup



A similar plot would be obtained:
Zero and span effects as a result of varying the negative power
zero and span effects as a results of varying both power supplies

Figure 4
Data Plots

Table 1 Data Sheet

Data Sheet 1 Data from Steady State Power Supply Effects										
	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column L	Column M
Data Pnts	MFC Setpoint	MFC Indicated Flow (V)	Flow Standard Output (V)	Positive Power Supply Level (V)	Negative Power Supply Level (V)	Power Supply Current Level (mA)	MFC Indicated Flow %FS	Flow Standard %FS	Positive Power Supply Var. (%)	Negative Power Supply Var. (%)
1	0	0	0	15	-15	30	0	0	0	0
2	0	0	0	15	-15	30	0	0		
3	0	0	0	15	-15	30	0	0		
. . .										
4	0	0.015	0	15.15	-15	30	0.3	0	1.0	0
5	0	0.010	0	15.15	-15	30	0.3	0		
6	0	0.010	0	15.15	-15	30	0.3	0		
. . .										
7	0	0.015	0	14.85	-15	30	0.3	0	-1.0	0
8	0	0.010	0	14.85	-15	30	0.2	0		
9	0	0.015	0	14.85	-15	30	0.3	0		
.										
10	0	0.010	0	15	-15.15	30	0.3	0	0	1.0
11	0	0.010	0	15	-15.15	30	0.3	0		
12	0	0.010	0	15	-15.15	30	0.3	0		
.										
13	0	0.005	0	15	-14.85	30	0.1	0	0	-1.0

Table 2 Zero and Span Effects as a Function of Steady-State Power Supply

Power Supply Voltage Change (% of reference)		*Change in Zero of MFC (%FS)*	*Span of MFC (%FS)*	*Span - Actual Flow (%FS)*
Positive	*Negative*			
0	0	0	0	0
-1	0	0.25	99.8	100.0
. . .	. . .	. . .	. . .	. . .
0	0	0	0	0
-1	0			
. . .	. . .			
0	0			
0	+1			
. . .	. . .			
0	0			
1	-1			
. . .	. . .			
0	0			
1	1			

NOTICE: SEMI makes no warranties or representations as to the suitability of the test method set forth herein for any particular application. The determination of the suitability of the test method is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These test methods are subject to change without notice.

The user's attention is called to the possibility that compliance with this test method may require use of copyrighted material or of an invention covered by patent rights. By publication of this test method, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this test method. Users of this test method are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F57-0301
PROVISIONAL SPECIFICATION FOR POLYMER COMPONENTS USED IN ULTRAPURE WATER AND LIQUID CHEMICAL DISTRIBUTION SYSTEMS

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on October 18, 2000. Initially available on www.semi.org November 2000; to be published March 2001. Originally published October 2000.

NOTE: This specification is considered provisional since it lacks a complete set of requirements for particles in Table 2 as well as particle test methods for components as noted in Table 1. At the time of publication, only a small database of values existed for PFA valves. Test methodologies will be generated for components and this document will be re-balloted at a later date.

1 Purpose

1.1 This document specifies minimum performance requirements for ultrahigh purity (UHP) polymer components used throughout semiconductor ultrapure water and liquid chemical distribution systems including bulk supply, facility distribution, and process equipment applications.

2 Scope

2.1 Polymer component purity and mechanical specifications are included in this standard along with references for qualification test methods. Certification, traceability, and packaging requirements are also included.

Purity Requirements:

- Particle Contribution
- Ionic Contamination
- Metallic Contamination
- Total Organic Carbon Contamination
- Surface Roughness

Mechanical Requirements:

- Temperature/Pressure Rating
- Chemical Resistance Rating
- Reliability

2.2 Polymer piping system components consisting of but not limited to the items shown in Table 1 are designed to contain and supply the following types of liquid chemicals:

- Acids, bases and oxidizers
- Aqueous salt solutions
- Ultrapure Water (UPW)

Table 1 Required Performance Specifications and Testing by Component Type

Test	*Particles*	*Ionic Contamination*	*Metallic Contamination*	*Total Organic Carbon*	*Surface Roughness*
Section	*7.2*	*7.3*	*7.4*	*7.5*	*7.6*
Table	*2*	*3*	*4*	*5*	*6*
Pipe/Tubing		x	x	x	x
Fittings		x	x	x	x
Valves	(See NOTE 1.)	x	x	x	x
Filter Housings		x	x	x	x
Pressure Transducers		x	x		x
Flow Meters		x	x		x
Gauge Guards		x	x		x
Regulators		x	x		x

NOTE 1: A method for this requirement is being developed. At the time of publication, only a small database of values existed for PFA valves. As the database encompasses more polymer materials, limits will be set for this parameter. Then, this document will be re-balloted.

2.3 Unless purchased separately, polymer components constructed of sub-pieces, such as o-rings, gaskets, and diaphragms, must meet the requirements of this document at the functional component level, not as individual sub-pieces. For example an o-ring in a union must not degrade the overall quality of the union such that it fails to meet the requirements of this document. Components and spare parts purchased separately, such as gaskets and O-rings, must meet this standard, if applicable.

2.4 This document and associated tests specify wetted stream performance requirements for polymer components in an as supplied, native state and reflect the current capabilities of the manufacturers of polymer components.

2.5 Leach out tests and associated requirements referenced within this document provide values from static, not dynamic, conditions. To determine the corresponding concentration that may result in a flowing dynamic stream, please see the Related Information Section on Theoretical Dynamic Concentration (TDC) located at the end of this document.

2.6 *Polymer Materials*

2.6.1 It is the intent of this specification to focus component qualification on performance. However, a discussion of recommended materials may benefit the reader and is therefore included.

2.6.2 Care must be taken to ensure that the materials are compatible with the liquid streams (as shown in Section 2.2) for long term applications. Additionally, it is important that the materials used be compatible with the application temperature and/or methods for bacterial reduction such as ozone, UV light and/or hydrogen peroxide.

2.6.3 The requirements of this specification often mandate the use of existing materials of choice, such as high purity grades of perfluoroalkoxy (PFA), polytetrafluoroethylene (PTFE), and polyvinylidene fluoride (PVDF). However, unique design specifications or new materials may result in instances where significant efficiencies may be achieved while maintaining substantially equivalent performance with regard to this specification. These scenarios could result in the use of new or existing materials such as ethylenechlorotrifluoroethylene (ECTFE), polyetheretherketone (PEEK), polypropylene (PP), acetal resin (such as Delrin®™[1], Celcon®™[1] and others), polyvinyl chloride (PVC), perfluoromethylether-based perfluoroalkoxy (MFA), etc.

1 Delrin is a trademark of DuPont; Celcon is a trademark of Hoechst Celanese.

2.6.4 Due to purity and traceability issues, reprocessed or regrind material must not be used.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document applies solely to polymer components. Performance specifications for subassemblies or bulk distribution systems may be found in other SEMI standards (see Related Documents Section 12.6).

3.2 This document does not include specifications for pumps, storage tanks, ion exchange resin tanks, drums, day tanks, pressure vessels, lined stainless steel products, filters, UV sterilization systems, reverse osmosis systems and ancillary equipment, sensors, monitors, or ultra-filtration equipment.

3.3 Organic liquids, such as isopropyl alcohol and methyl alcohol, are typically in contact with stainless steel or other non-polymeric components. The polymer components described within this document are NOT intended for use with such organic liquids.

3.4 Polymer components described within this document are intended for use in UHP service only. Their specified performance requirements may exceed the needs of components used in drainage and other lesser quality liquids.

3.5 This standard is not intended to address design or materials issues related to safety which are addressed elsewhere in the SEMI guidelines (see SEMI S2).

3.6 The tests referenced in this document are designed to assess contamination from the polymer components in an as received state. Assembly steps, such as welding and cleaning, may actually add some contaminants. The effects of the assembly are beyond the scope of this document, but should be considered by the supplier and/or user (see SEMI E49.7).

3.7 Leach out values listed in Tables 3, 4 and 5 reflect testing in UPW for polymer component comparison purposes. The relative leach out performance of polymer components in actual use with other chemicals (e.g. acids and bases) cannot be directly derived by using the UPW data. It is incumbent upon the user to determine if a component is suitable for use based on these requirements (see Section 2.6.2).

3.8 This document is not intended to supersede international, national or local codes, regulations, and laws. Each should be consulted to ensure that the manufactured polymer components meet regulatory requirements in each location.

4 Referenced Documents

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E49.7 — Guide for Subsystem Assembly and Testing Procedures - Polymer Systems

SEMI F40 — Practice For Preparing Liquid Chemical Distribution Components for Chemical Testing

SEMI S2 — Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *ASTM Standards*[2]

ASTM D4327 — Anions in Water by Chemically Suppressed Ion Chromatography

ASTM D4779 — Total, Organic, and Inorganic Carbon in High Purity Water by Ultraviolet (UV) or Persulfate Oxidation, or Both, and Infrared Detection

ASTM D5904 — Standard Test Method of Total Carbon, Inorganic Carbon, and Organic Carbon in Water by UV, Persulfate Oxidation and Membrane Conductivity Detection

4.3 *ISO Standards*[3]

ISO 1167 — Plastic pipes for the transport of fluids - Determination of the resistance to internal pressure

ISO 12162 — Thermoplastic materials for pipes and fittings for pressure applications - Classification and designation - Overall service (design) coefficient

5 Terminology

5.1 *Definitions*

5.1.1 *Liquid Chemical Distribution System* — the collection of components and subsystems used to deliver liquid process chemicals from a source location to a point of use.

5.1.2 *Ultrapure Water Distribution System* — the collection of components and subsystems used to deliver ultrapure water from a source location to a point of use.

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959, USA

3 International Organization for Standardization, 1 rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

6 Ordering Information

6.1 Device manufacturers may use this standard when procuring facilities or processing equipment to specify required component performance to the supplier. Facilities services and process equipment suppliers may also use this document to specify performance requirements to component and subassembly suppliers.

6.2 Orders for polymer components or subassemblies in accordance with this standard shall include the specification number and date of issue.

7 Purity Requirements

7.1 The values found in Tables 3 through 6 were constructed from existing databases of high purity grades of PVDF and PFA. They represent characteristics of piping system polymer components, which are currently providing end-users with satisfactory results. Other materials with other particle leach out or surface roughness characteristics may or may not be acceptable. The end-user may need to test such materials to determine if they will meet both the static values of this document as well as any final delivered fluid requirements.

7.2 *Particle Contribution*

7.2.1 Importance of Test: Particles released from within polymer components can come into direct contact with wafers and cause unwanted surface contamination or disrupt photolithography process steps, thereby decreasing yields.

7.2.2 Particle contribution specification and testing are restricted to polymer components as indicated in Table 1.

7.2.3 Polymer components shall conform to the particle contribution specifications appearing in Table 2.

7.2.4 A Rinse Time Test (see Table 2) provides a measure of the particle shedding from a component when it is initially removed from its packaging in a cleanroom environment and immediately tested.

7.2.5 The various cycle evaluations (see Table 2) provide a measure of the particle shedding that results from actuating the valve and the subsequent cleanup over time. In addition, these tests provide a measure of degradation (increased particle shedding) of the valve as it is cycled.

7.2.6 The performance requirement values in Table 2 for the Initial Cycle Test, the 2000 Cycle Test and the 200,000 Cycle Test represent averages after subtracting a pre-cycle test background average.

7.3 *Ionic Contamination*

7.3.1 Importance of Test: Ionic contamination can have a corrosion and/or etching effect on semiconductor devices during fabrication, causing immediate or future device failure. Evaporation of solutions containing ionics may leave surface residue.

7.3.2 Ionic contamination specification and testing are required for all polymer components as indicated in Table 1. The ionic contaminants specified within this document have been derived, in part, from industry guidelines for UPW used in semiconductor processing.

7.3.3 Polymer components shall conform to the ionic contamination specifications appearing in Table 3. Use SEMI F40 to prepare the component for analysis and ASTM D4327 to analyze polymer components.

7.3.4 The Static Value is derived from a prolonged static leach out test, using UPW as the test media and lasting for a period of 7 days. Static values do not directly relate to the trace contaminant values, which could be present in a flowing stream of liquid. Testing temperature of polymer components shall be 85 ± 5°C. A specific testing temperature is specified to achieve comparable data for polymer components and is not indicative of service temperatures. For most contaminants, testing at a lower temperature will give lower static values.

7.3.5 A mathematical relationship between the static leach out value (provided in this specification) and the corresponding concentration which may result in a flowing stream can be theoretically calculated. This value is offered for demonstration purposes only and is known as the Theoretical Dynamic Concentration (TDC). It is expressed in parts per billion (μg/liter) in the example calculation provided in the Related Information 1 Section of this document.

7.4 *Metallic Contamination*

7.4.1 Importance of Test: Metallic contamination can have an effect on altering the electrical properties of semiconductor devices.

7.4.2 Metallic contamination specification and testing are required for all polymer components as indicated in Table 1. The metallic contaminants specified within this document have been derived, in part, from industry guidelines for UPW used in semiconductor processing

7.4.3 Polymer components shall conform to the metallic contamination specifications appearing in Table 4. Use SEMI F40 to prepare the component for analysis and an industry standard test method to analyze polymer components (see Related Documents Section 12.5 for an applicable leachable trace inorganics test method).

7.4.4 See Section 7.3.4 for Static Value definition.

7.4.5 See Related Information 1 for Theoretical Dynamic Concentration calculation.

7.5 *Total Organic Carbon (TOC)*

7.5.1 Importance of Test: TOC can have an effect on silicon oxidation, uniformity of etching and gate oxide breakdown voltage of semiconductor devices.

7.5.2 TOC specification and testing are restricted to polymer components as indicated in Table 1.

7.5.3 Polymer components shall conform to the TOC contamination specifications appearing in Table 5. Use SEMI F40 to prepare the component for analysis and ASTM D4779 or D5904 to analyze polymer components.

7.5.4 See Section 7.3.4 for Static Value definition.

7.5.5 See Related Information 1 for Theoretical Dynamic Concentration calculation.

7.6 *Surface Roughness*

7.6.1 Importance of Test: Surface roughness can influence microbial proliferation, provide an entrapment area for microcontamination build up and/or promote shedding of the polymer itself within a distribution system.

7.6.2 Surface Roughness specification and testing is required for all polymer components as indicated in Table 1.

7.6.3 Polymer components shall conform to surface roughness specifications appearing in Table 6. For ease of use and comparison purposes, the preferred method of testing is by use of a stylus in direct contact with the component surface, known as contact profilometry (see Related Documents Section 12.5 for an applicable surface roughness test method).

7.6.4 As softer plastics may exhibit microscopic damage due to the stylus and give smoother than expected results, additional testing may be required. When initially setting up the equipment, evaluate softer plastics immediately with a 10x magnification visual examination to make sure damage has not occurred. Lines, scratches or artifacts originating from stylus contact would indicate damage. In the event that damage is present, a lighter stylus head should be used.

Table 2 Particle Contribution Requirements

Description	*Qualification Test Method*	*Units*	*Value*	*Notes*
Rinse Time Test	TBD	Hours	TBD	Section 7.2
Initial Cycle Test	TBD	*Particles/liter ≥ 0.1 µm	TBD	Section 7.2
2000 Cycle Test	TBD	*Particles/liter ≥ 0.1 µm	TBD	Section 7.2
200,000 Cycle Test	TBD	*Particles/liter ≥ 0.1 µm	TBD	Section 7.2

* Cycle Test values are a result of subtracting the pre-cycle test background average. See Section 7.2.6.

TBD = To be determined (see NOTE 1 under Table 1).

Table 3 Surface Extractable Ionic Contamination Requirements

Description	*Component Preparation Practice*	*Qualification Test Method*	*Static Value at 85 ± 5°C for 7 days (µg/m²)*	*Notes*
Bromide	SEMI F40	ASTM D4327	≤ 100	Section 7.3
Chloride	SEMI F40	ASTM D4327	≤ 3000	Section 7.3
Fluoride	SEMI F40	ASTM D4327	≤ 60,000	Section 7.3
Nitrate	SEMI F40	ASTM D4327	≤ 100	Section 7.3
Nitrite	SEMI F40	ASTM D4327	≤ 100	Section 7.3
Phosphate	SEMI F40	ASTM D4327	≤ 300	Section 7.3
Sulfate	SEMI F40	ASTM D4327	≤ 300	Section 7.3

NOTE 1: Optional testing may be required by the end user for ammonium.

Table 4 Surface Extractable Metallic Contamination Requirements

Description	*Component Preparation Practice*	*Qualification Test Method*	*Static Value at 85 ± 5°C for 7 days (µg/m²)*	*Notes*
Aluminum	SEMI F40	(See NOTE 1.)	≤ 10	Section 7.4
Barium	SEMI F40	(See NOTE 1.)	≤ 15	Section 7.4
Boron	SEMI F40	(See NOTE 1.)	≤ 10	Section 7.4
Calcium	SEMI F40	(See NOTE 1.)	≤ 30	Section 7.4
Chromium	SEMI F40	(See NOTE 1.)	≤ 1	Section 7.4
Copper	SEMI F40	(See NOTE 1.)	≤ 15	Section 7.4
Iron	SEMI F40	(See NOTE 1.)	≤ 5	Section 7.4
Lead	SEMI F40	(See NOTE 1.)	≤ 1	Section 7.4
Lithium	SEMI F40	(See NOTE 1.)	≤ 2	Section 7.4
Magnesium	SEMI F40	(See NOTE 1.)	≤ 5	Section 7.4
Manganese	SEMI F40	(See NOTE 1.)	≤ 5	Section 7.4
Nickel	SEMI F40	(See NOTE 1.)	≤ 1	Section 7.4
Potassium	SEMI F40	(See NOTE 1.)	≤ 15	Section 7.4
Sodium	SEMI F40	(See NOTE 1.)	≤ 15	Section 7.4
Strontium	SEMI F40	(See NOTE 1.)	≤ 0.5	Section 7.4
Zinc	SEMI F40	(See NOTE 1.)	≤ 10	Section 7.4

NOTE 1: See Related Documents Section 12.5 for an applicable leachable trace inorganics test method.

Table 5 Surface Extractable Total Organic Carbon (TOC) Contamination Requirements

Description	*Component Preparation Practice*	*Qualification Test Method*	*Static Value at 85 ± 5°C for 7 days (µg/m²)*	*Notes*
TOC	SEMI F40	ASTM D4779 or D5904	≤ 60,000	Section 7.5

Table 6 Surface Roughness Requirements

Description	*Qualification Test Method*	*Units*	*Ra max. Value*	*Notes*
Extruded	(See NOTE 1.)	µm (µin)	≤ 0.25 (≤ 10)	Section 7.6
Injection Molded	(See NOTE 1.)	µm (µin)	≤ 0.38 (≤ 15)	Section 7.6
Machined	(See NOTE 1.)	µm (µin)	≤ 0.62 (≤ 25)	Section 7.6

NOTE 1: See Related Documents Section 12.5 for an applicable surface roughness test method.

8 Mechanical Requirements

8.1 Upon request, suppliers shall provide data and/or information for the following polymer components mechanical requirements. This information is typically found in product catalogs and component data sheets.

- dimensional tolerances
- flow characteristics
- leak integrity
- mechanical strength characteristics

8.2 All polymer components will conform to supplier's provided data and/or information regarding dimensional tolerances, flow characteristics, leak integrity, and mechanical strength characteristics.

8.3 *Temperature/Pressure Rating*

8.3.1 Polymer components are required to be manufactured in such a manner so as to meet the temperature and internal pressure requirements of ISO 1167, ISO 12162, or other superseding local regulations as applicable.

8.4 *Chemical Resistance Rating*

8.4.1 Polymer components are required to be manufactured to meet the chemical resistance requirements specified by the component suppler, and/or other superseding local regulations as applicable.

8.5 *Reliability*

8.5.1 Upon request, the manufacturer should provide component reliability data accompanied by the associated test and failure analysis methods. This typically involves life cycle testing of components to include results expressed in cycles (e.g. >1,000,000 cycles for valves). The test media used for life cycle testing of polymer components can effect life cycle testing results and should be considered when comparing and selecting polymer components.

9 Certification

9.1 The component supplier is responsible for defining, establishing, and executing a testing program for polymer components based on the requirements outlined within this document.

9.2 Such a program will specify the frequency of testing, the test component(s) and any necessary corrective action plan in the event that a test component fails to meet these requirements during testing.

9.3 To avoid the inefficiencies involved in testing every size of every product type, test polymer components shall be selected by the component supplier which will be representative product of similar processing, or production techniques.

9.4 Upon request, the component supplier is responsible for maintaining and supplying documentation that proves their polymer components consistently meet the requirements of this document.

9.5 The supplier is not required to perform all tests on each individual lot or product type of polymer components shipped. Instead, the product will be certified as meeting the requirements in this document based on the outcome of the representative component tests and periodic testing program. However, if the purchaser performs the test(s) and the product fails to meet the requirement(s), the product may be subject to rejection.

9.6 Qualification tests and certification documents shall reflect current production capabilities.

10 Traceability Requirements

10.1 It will be the responsibility of the component supplier to establish and maintain an incoming raw material certification, inspection, and traceability process, which will ensure that manufactured polymer components meet the requirements of this document.

10.2 Every deliverable item shall have some scheme of identification on the exterior bag or box so that traceability is provided from the raw material supplier to the final finished, packaged product.

10.3 In addition, piping, tubing, valves, gauge guards, pressure transducers, and pressure regulators shall have permanent, non-contaminating identification (e.g. laser marking, heat stamping, or chemical resistant label) on the product itself to provide traceability.

10.4 In the event that component installation by the purchaser obliterates such identification, it becomes the responsibility of the purchaser to maintain traceability records.

11 Packaging Requirements

11.1 Double bagging using a clear material that will allow inspection is required for polymer components specified in this document. Both the inner and outer bags will be heat-sealed and shall prevent damage from normal handling. Vacuum sealing, air evacuation, and/or dry inert gas purging are optional on the inner bag.

11.2 The ends of valves, gauge guards, pressure regulators, and tubing will be protected using some non-contaminating method before bagging.

11.3 The outer bag will have a label affixed which clearly identifies the component, part number, lot number and any other necessary traceability characteristics (see Section 10).

11.4 Shipping containers and cartons must provide adequate protection of polymer components so those articles will meet the requirements contained within this document upon delivery to the purchaser.

11.5 It should be noted that some packaging materials could release substantial amounts of TOC when they are heat-sealed. This might lead to an organic deposition on the polymer component.

12 Related Documents

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

12.1 *SEMI Standards*

SEMI E49.2 — Guide for High Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.3 — Guide for Ultrahigh Purity Deionized Water and Chemical Distribution Systems in Semiconductor Manufacturing Equipment

12.2 *ASTM Standards*[1]

ASTM D1784 — Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds

ASTM D3222 — Unmodified Poly (Vinylidene Fluoride) (PVDF) Molding, Extrusion, and Coating Materials

ASTM D3275 — E-CTFE-Fluoroplastic Molding, Extrusion, and Coating Materials

ASTM D3307 — PFA-Fluorocarbon Molding and Extrusion Materials

ASTM D3915 — Rigid Poly (Vinyl Chloride) (PVC) and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds for Plastic Pipe and Fittings Used in Pressure Applications

ASTM D4101 — Propylene Plastic Injection and Extrusion Materials

12.3 *DIN Standards*[4]

DIN 16774-1 — Plastic Moulding Materials; Polypropylene And Propylene Copolymer Thermoplastics; Classification and Designation

DIN 3442-1 — Fittings of PP (Polypropylene); Requirements and Testing

DIN 3442-2 — Fittings of PP (Polypropylene); Ball Valves, Dimensions

DIN 3442-3 — Polypropylene (PP) Valves; Diaphragm Valves; Dimensions

DIN 8077 — Polypropylene (PP) Pipes PP-H 100, PP-B 80; PP-R 80 - Dimensions

DIN 8078 — Polypropylene (PP) Pipes - PP-H (Type 1), PP-B (Type 2), PP-R (Type 3) - General Quality Requirements and Testing

12.4 *CEN Standards*[5]

PREN 1452-1 — Plastics Piping Systems for Water Supply - Unplasticized Poly (Vinyl Chloride) (PVC-U) Part 1: General

PREN 1452-2 — Plastics Piping Systems for Water Supply - Unplasticized Poly (Vinyl Chloride) (PVC-U) Part 2: Pipes

PREN 1452-3 — Plastics Piping Systems for Water Supply - Unplasticized Poly (Vinyl Chloride) (PVC-U) Part 3: Fittings

PREN 1452-4 — Plastics Piping Systems for Water Supply - Unplasticized Poly (Vinyl Chloride) (PVC-U) Part 4: Valves and Ancillary Equipment

PREN 1452-5 — Plastics Piping Systems for Water Supply - Unplasticized Poly(Vinyl Chloride) (PVC-U) Part 5: Fitness for Purpose of the System

PREN 12202-1 — Plastics Piping Systems for Hot and Cold Water - Polypropylene (PP) - Part 1: General

PREN 12202-2 — Plastics Piping Systems for Hot and Cold Water - Polypropylene (PP) - Part 2: Pipes

4 Deutsches Institut fur Normung e.v., available from Beuth Verlag, Burggrafenstrasse 6, D-10787 Berlin, Germany

5 European Committee For Standardization, 36, rue de Stassart, B-1050 Brussels, Belgium

PREN 12202-3 — Plastics Piping Systems for Hot and Cold Water - Polypropylene (PP) - Part 3: Fittings

PREN 12202-5 — Plastics Piping Systems for Hot and Cold Water - Polypropylene (PP) - Part 5: Fitness for Purpose of the System

12.5 *ISO Standard* [2]

ISO 10931-1 — Plastic piping systems for industrial applications - PVDF - Part 1: General

ISO 10931-2 — Plastic piping systems for industrial applications - PVDF - Part 2: Pipes

ISO 10931-3 — Plastic piping systems for industrial applications - PVDF - Part 3: Fittings

ISO 10931-4 — Plastic piping systems for industrial applications - PVDF - Part 4: Valves

ISO/FDIS 10931-5 — Plastic piping systems for industrial applications - PVDF - Part 5: Fitness for Purpose of the System

ISO/DIS 15874-1 — Plastics piping systems for hot and cold water -- Polypropylene (PP) -- Part 1: General

ISO/DIS 15874-2 — Plastics piping systems for hot and cold water -- Polypropylene (PP) -- Part 2: Pipes

ISO/DIS 15874-3 — Plastics piping systems for hot and cold water -- Polypropylene (PP) -- Part 3: Fittings

ISO/DIS 15874-5 — Plastics piping systems for hot and cold water -- Polypropylene (PP) -- Part 5: Fitness for purpose of the system

12.6 *SEMATECH Documents*[6]

SEMASPEC 92010936B-STD — Provisional Test Method for Determining Leachable Trace Inorganics in Ultra Pure Water Distribution System Components”

SEMASPEC 92010950B-STD — Provisional Test Method for Visual Characterization of Surface Roughness for Plastic Surfaces of UPW Distribution System Components

6 SEMATECH, 2706 Montopolis Drive, Austin, Texas 78741, USA

Table 7 Related Standards for Plastic Piping Materials

	PP	*PVDF*	*PVC*	*PFA*	*ECTFE*
Materials	PREN 12202-1 DIN 16774 ISO/DIS 15874-1 ASTM D4101	ISO 10931-1 ASTM D3222	PREN 1452-1 ASTM D1784 ASTM D3915	ASTM D3307	ASTM D3275
Pipes	PREN 12202-2 DIN 8077 DIN 8078 ISO/DIS 15874-2	ISO 10931-2	PREN 1452-2	No standards	No standards
Fittings	PREN 12202-3 ISO/DIS 15874-3	ISO 10931-3	PREN 1452-3	No standards	No standards
Valves	DIN 3442-1 DIN 3442-2 DIN 3442-3	ISO 10931-4	PREN 1452-4	No standards	No standards
Systems	PREN 12202-5 ISO/DIS 15874-5	ISO/FDIS 10931-5	PREN 1452-5	No standards	No standards

NOTE 1: See Related Documents Sections 12.2, 12.3, 12.4, and 12.5.

RELATED INFORMATION 1
THEORETICAL DYNAMIC CONCENTRATION (TDC)

NOTE: This related information is not an official part of SEMI F57 and was derived from the work of the originating task force. This related information was approved for publication by full letter ballot procedures on August 28, 2000.

R1-1 TDC Definition and Calculation

R1-1.1 For purposes of demonstrating a theoretical mathematical relationship between the maximum allowed static leach out values (provided in this specification) and a corresponding concentration which may result in a flowing stream, this related information on Theoretical Dynamic Concentration (TDC) is being provided.

R1-1.2 The Static Value as defined in this document (see Section 7.3.4) is a measure of the weekly accumulated mass transfer of contaminant (contaminant flux per week) from the material being tested into static ultrapure water (UPW). The value is calculated based upon measurement of total leached mass of a contaminant per unit area of the surface that was wetted in the test apparatus. Since the duration of the static test is fixed at 7 days, the information is simply reported as mass/area (Tables 3, 4, and 5 use units of $\mu g/m^2$).

R1-1.3 The Theoretical Dynamic Concentration (TDC) is a mathematical conversion of the static value into a theoretical prediction of concentration of a contaminant incorporated into the flowing liquid by contact with the contaminant generating (or transmitting) polymer component wall. The conversion depends upon a model which assumes a uniform rate of contaminant generation that is equal to the average rate over the 7 day Static Value test (7d * 24 hr/d * 3600 sec/hr = 6.05 x 10^5 sec). The model also assumes a non-depleting source of the contaminant in steady state transport conditions through the component/liquid interface. In general, this assumption is only true early in the life of the piping system installation. Values have been found to decrease in time. Calculation of TDC for specification limit purposes can be derived by dividing the static value limit for the component (adjusted for wetted surface area of the component) by the volume of liquid affected by contact with the component.

R1-2 TDC Example

R1-2.1 Referring to the concentrations shown in Tables 3, 4 and 5, a 1 meter long, 60 mm inner diameter pipe with an UPW constant fluid velocity of 1.5 meters/second is selected as an example. Since several factors will affect the actual concentration in a flowing stream the TDC should be considered as approximate, not absolute.

I.D. $d = 60$ mm

Length $l = 1.0$ m

Fluid velocity = 1.5 m/sec

R1- 2.2 Example of TDC Calculation:

a) Surface area of tube I.D.

$= \pi dl$
$= (\pi)(0.060 \text{ m})(1.0 \text{ m})$
$= 0.188 \text{ m}^2$
$= 1.88 \times 10^{-1} \text{ m}^2$

b) Volume of tube I.D.

$= \pi (d/2)^2 l$
$= (\pi)(0.060/2 \text{ m})^2 \ (1.0 \text{ m})$
$= 2.83 \times 10^{-3} \text{ m}^3$
$= (2.83 \times 10^{-3} \text{ m}^3)(1 \times 10^3 \text{ liter/m}^3)$
$= 2.83$ liter

c) Volume of liquid transported through tube per second

= (1.5 m/sec) (2.83 liter/m)
= 4.25 liter/sec

d) Volume of liquid transported through tube per week

$= (4.25 \text{ liter/sec})(6.05 \text{ x } 10^5 \text{ sec/wk})$
$= 2.57 \times 10^6$ liter/wk

e) Assume a Static Value limit of $10 \mu g/m^2$

$= (10 \ \mu g/m^2)(1.88 \times 10^{-1} \text{ m}^2)$
$= 1.88 \ \mu g$

f) Using the values from d and e, above,

TDC = $1.88 \ \mu g / 2.57 \times 10^6$ liter

TDC = 7.3×10^{-7} µg/liter

(or, 7.3×10^{-4} parts per trillion in liquids with an approximate density of 1 gram/cm^3)

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The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI F58-1000
TEST METHOD FOR DETERMINATION OF MOISTURE DRY-DOWN CHARACTERISTICS OF SURFACE-MOUNTED AND CONVENTIONAL GAS DISTRIBUTION SYSTEMS BY ATMOSPHERIC PRESSURE IONIZATION MASS SPECTROMETRY (APIMS)

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000.

1 Purpose

1.1 This document describes the procedure for determination of the moisture dry-down characteristics (quantity of removable moisture) of surface mounted and conventional gas distribution systems (integrated gas distribution systems). APIMS is currently the method of choice for such dynamic tests because it is the commercially available technique capable of ppt moisture analysis with the fastest response time. This test method may provide guidelines for the application of other techniques with similar detection limits and response time to APIMS which are not commercially available at this time.

1.2 The results of this test can be used for qualitative ranking of gas delivery based on the design. It can also be used by a sufficiently sophisticated user as input for numerical simulation of distribution system behavior.

2 Scope

2.1 This test method applies to all types of surface mounted and conventional gas distribution systems used in semiconductor processing.

2.2 *Test Medium* — The test procedure will be carried out in nitrogen. Other "inert" gases will have different purging characteristics and may dry a system more quickly or slowly. Reactive gases may react chemically with moisture. Considerations relating to corrosion resistance are outside the scope of the present document, although the test procedure may prove useful in corrosion studies. The results will provide a ranking with respect to moisture contribution arising as a result of differences in design, which may be applied with due caution to systems intended for use in other gas applications.

2.3 *Operating Situations* — Moisture contribution from a gas delivery system may be the result of contamination arising in its manufacture, or from subsequent exposure to ambient air or non-dry gas. Thus, it is necessary to consider two main situations:

2.3.1 The "initial dry-down" situation, which is determined by the moisture content of the components in the system (as received) with the effects of manufacturing process and design, surface quality, pre-treatment and packaging convoluted together.

2.3.2 The "response to upset" situation, which is determined by the amount of moisture taken up by the system and subsequently released in any exposure after receipt.

2.4 *Safety Issues* — This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This test method allows the determination of moisture interactions which can be used, for example, to rank systems in order of decreasing moisture interaction. Because different degrees of moisture interaction are permissible in different situations, selecting the "best" system requires consideration of how they will be used, either qualitatively or through a numerical simulation of distribution system behavior. The results of this test can only be used for qualification for gas delivery systems based on different designs. It cannot be used for production purposes and/or certification/testing.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI C15 — Test Method for ppm and ppb Humidity Standards

SEMI F27 — Test Method for Moisture Interaction and Content of Gas Distribution Systems and Components by Atmospheric Pressure Ionization Mass Spectrometry (APIMS)

SEMI F33 — Method for Calibration of Atmospheric Pressure Ionization Mass Spectrometer (APIMS)

4.2 *ASTM Standards*[1]

ASTM-F1397-93 — Standard Test Method for Determination of Moisture Contribution by Gas Distribution System Components

5 Summary of Test Method

5.1 This test method consists of initial drydown and moisture input tests for both surface-mounted and conventional gas delivery systems.

6 Terminology

6.1 *Abbreviations and Acronyms*

6.1.1 *APIMS* — Atmospheric Pressure Ionization Mass Spectrometry.

6.1.2 *EPSS* — electropolished stainless steel.

6.1.3 *ppm* — molar parts per million (µmole/mole). The same as ppmv.

6.1.4 *ppb* — molar parts per billion (nmole/mole). The same as ppbv.

6.1.5 *ppt* — molar parts per trillion (pmole/mole). The same as pptv.

6.1.6 *slpm* — standard liters per minute, the gas volumetric flow rate measured in liters per minute at 0°C and 1 atm.

6.2 *Definitions*

6.2.1 *baseline* — an instrument response under steady state conditions.

6.2.2 *glove box* — an enclosure that contains a controlled atmosphere, usually inert.

6.2.3 *induction time* — the elapsed time between when humidified gas is introduced to the test system and when moisture is detected at the moisture analyzer. For a test system which is perfectly transparent to moisture, the induction time is equal to the residence time of the gas in the system.

6.2.4 *peak height* — the maximum moisture concentration recorded when a moisture input of pre-defined length and concentration is introduced to a test system.

6.2.5 *response time* — the time required for the test system to reach steady state after a change in concentration.

1 Available from American Society for Testing and Materials, 100 Barr Harbor Dr, West Conshohocken, PA 19428. Fax: 1-610-832-9555. World Wide Web: http://www.astm.org.

6.2.6 *test system* — the gas delivery system under test

7 Required Equipment

7.1 *APIMS* — The APIMS used for moisture detection can be of any type. Calibration of the APIMS shall be performed as per SEMI F33, one at the beginning and one at the end of the series. These calibrations shall both be made under the same analytical conditions (flow, pressures, plate voltages, etc.) as the tests and the results shall be within 5% of each other. Provided this condition is met, the interval between calibrations may be left to the discretion of the operator; however, it is suggested that calibration should be carried out whenever the equipment is moved and/or every two weeks of operation.

7.2 *Dry Gas and Moisture Generator* — A source of extremely dry nitrogen (less than 200 ppt moisture) and a moisture generator capable of delivering up to 13 slpm nitrogen doped with 200 ppb moisture is required. This generator may be the same as used to calibrate the APIMS. The output of the generator shall be verified according to SEMI C15.

7.2.1 Most ultra-high purity gas panels are currently fitted with metal gasket type connectors. The same type of connector should, therefore, be incorporated into the test bench for connection to the test system.

7.3 *Test Blank* — Any series of tests shall include the results of testing a blank. The blank shall be the shortest convenient length (no more than 1 m) of 1/4" EPSS tubing with suitable fittings and/or adapters at either end to enable it to be inserted in place of the test system.

7.4 *Moisture Pulse Generator* — A valve arrangement capable of switching instantaneously between dry and humidified nitrogen is also required. An example of such a design is shown in Figure 1. In this design, flow is maintained in both the humidified and dry gas lines at all times. By simultaneously switching valves V_1 and V_3, or V_2 and V_3, either humidified or dry gas is directed through the test system while the other gas stream is directed to vent. Note that there is a bypass loop so that flow can be maintained to the APIMS when the test system is removed. In this design, all gas lines, but especially those lines between V_1 and V_3 and between V_2 and V_3, should be as short as possible and constructed of EPSS tubing of high quality. Maintaining gas lines at a constant temperature between 50 and 80ºC wherever possible is also recommended.

7.4.1 The bypass loop will contain a stagnant volume of gas during testing. To avoid exposing the APIMS to a large moisture upset whenever it is fed with the gas contained in the bypass loop, the loop should be thoroughly baked out (at ≥ 200°C) and protected from atmospheric contamination thereafter. Valve V_4 should be such that some flow can be maintained through the bypass loop and the test system simultaneously as well as through each separately. Use of pneumatic valves to facilitate rapid and simultaneous switching is recommended.

7.4.2 Other arrangements than that shown may also be used. The moisture pulse generator should be designed so as to give the fastest possible response of the blank to a change in input moisture level.

7.5 *Temperature Control and Measurement* — A stable temperature during the test is of critical importance. The test system shall be kept at 30ºC. TESTS AT DIFFERENT TEMPERATURES CANNOT BE COMPARED. Ideally, the blank and test system should be maintained in a temperature-controlled chamber. However, if this is impractical, a heating tape can be used. Temperature control should be to ± 1ºC. A continuous record of temperature during the test shall be maintained.

8 Procedure

8.1 *Blank Tests* — A blank test shall be carried out after each calibration. If initial dry-down testing of system is not of interest, the initial dry-down test of the test blank may be omitted and the test blank brought to equilibrium with zero gas in whatever manner is most convenient, except that the test blank should not be heated above 200ºC. Permanent changes in moisture interaction have been observed at temperatures above this level.

8.1.1 *Initial Dry-down* — Start the experiment with the blank in place of the test system and a flow of dry gas through the APIMS. The APIMS output should be at equilibrium with the lowest moisture level of interest, and in any case no higher than 200 ppt.

8.1.1.1 Switch the gas flow to pass primarily through the bypass loop while maintaining a small flow through the test blank. Remove the test blank completely from the system. If a glove box or other such enclosure is used, do not remove the test blank from the glove box. Immediately reconnect the test blank to V_4, leaving it disconnected from V_5. Allow dry nitrogen to flow through the test blank for five minutes to purge the air from inside before reconnecting to V_5. Switch the gas to flow only through the blank and not through the bypass loop. The APIMS will show an increase in moisture concentration. Record the APIMS output until it reaches 800 ppt or 48 hours, whichever is less.

8.1.1.2 Repeat the above test twice for a total of three data sets.

8.2 *Tests on Actual Test System*

8.2.1 *Initial Dry-down* — This portion of the test is designed to determine the quantity of removable moisture on the wetted surfaces of the system in the condition in which it is typically supplied. Thus, the results of this test will reflect, by design, any precautions which the supplier has taken to remove moisture and maintain its dryness during shipping.

8.2.1.1 Start the test as in Section 8.1.1. The test system should not be unpacked until after the APIMS has equilibrated with the background moisture level. If a glove box or other such enclosure is used, unpack the system in the glove box. Switch the dry nitrogen flow to pass through the bypass loop while maintaining a small flow through the test blank. Bake the sample line to APIMS at 170°C for 10 min and the APIMS ion chamber at 150°C for 10 min. Undo the final layer of packing and any shipping caps or plugs on the system at this point. Remove the sample blank and connect the test system to valve V_4 as quickly as possible. Ensure that the gas lines going to APIMS will be under N_2 purge during the removal of test blank and installation of test system. Allow the dry nitrogen flow to purge out any ambient air in the system for five minutes, then connect the system to V_5. Switch the gas to flow (1.2 slpm) only through the test system and not through the bypass loop. The APIMS will show an increase in moisture concentration. Record the APIMS output until it reaches 200 ppt or for 24–48 hours, whichever is less.

8.2.1.2 After 24–48 hours, the initial dry-down part of the test can be terminated. Remove the filters from the test system and install special spool pieces. This is done since filters have a large surface area and would dominate the dry-down performance.

8.2.2 *Moisture Input Test* — Flow 1.2 slpm of dry nitrogen gas (200 ppt moisture) through appropriate process channels of the test system. Connect the outlet of the gas panel to the sample line connecting to the APIMS. Bake the appropriate process channels using heater tapes at 60°C for 12 h to remove atmospheric contamination.

8.2.2.1 At the conclusion of baking, equilibrate the test system to 30°C. Bake the sample line at 170°C for 10 min and ion source of APIMS at 150°C for 10 min. Perform a leak check at the inlet and outlet connections of the test system using 1% methane gas in nitrogen, after warming up the APIMS for 30 min. Switch the input gas to nitrogen with 200 ppb moisture (by switching valves V_1, V_2, and V_3 simultaneously, if the arrangement shown in Figure 1 is used) while recording the APIMS response. Maintain this input for 20 min and then switch the input gas to dry nitrogen (200 ppt moisture) and monitor the dry-down.

9 Reporting Results

9.1 Complete moisture response curves for all test systems and relevant test blanks should be included. A summary sheet may compare systems in terms of "induction time," peak height, and/or decay time (detected moisture concentrations may be plotted as a function of time for the test systems). Temperature, pressure, and flow measurements, and as complete a record as possible of all experimental variables should be noted.

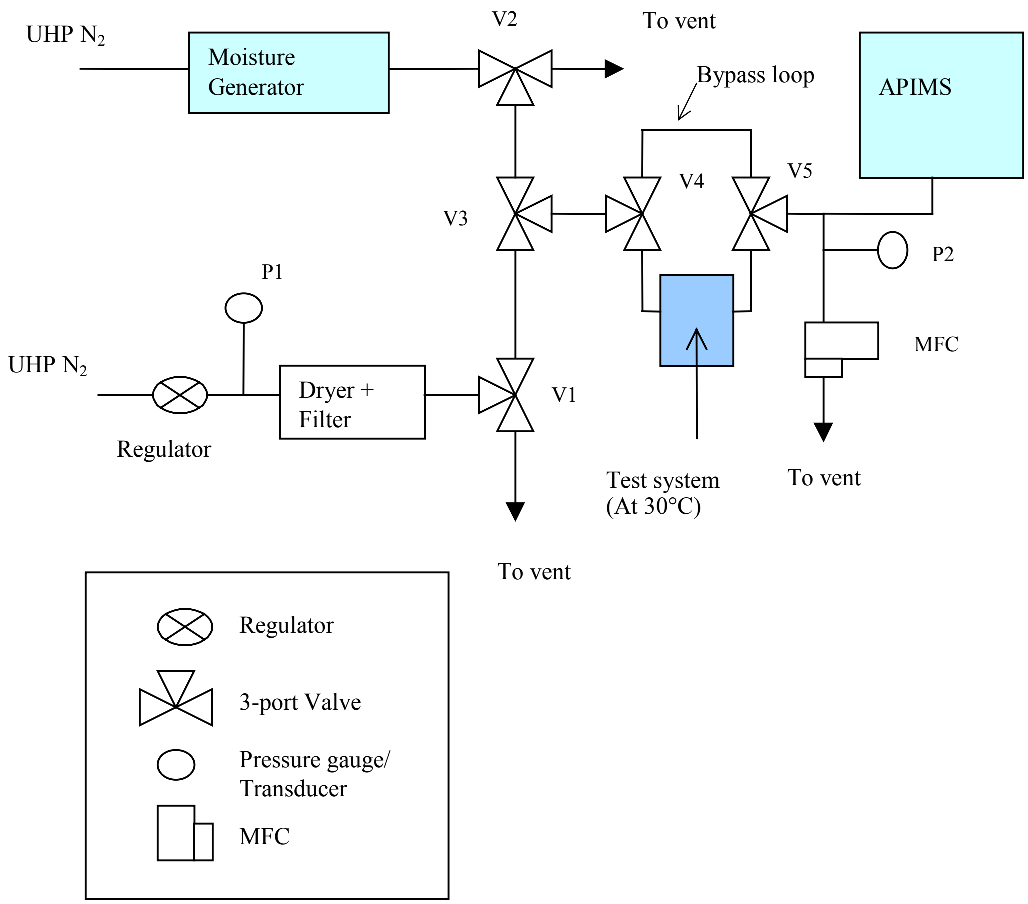

Figure 1
APIMS Moisture Test Schematic

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature with respect to any materials mentioned herein. These standards are subject to change without notice.

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SEMI F59-0302
TEST METHOD FOR DETERMINATION OF FILTER OR GAS SYSTEM FLOW PRESSURE DROP CURVES

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition aproved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published October 2000.

NOTE: This document was entirely rewritten for publication in 2002.

1 Purpose

1.1 The purpose of this document is to define a method for testing filters or gas systems being considered for installation into a high-purity gas distribution system or on semiconductor manufacturing equipment, respectively. Application of this test method is expected to yield comparable data among filters or gas systems.

1.2 This document establishes a test method for preparing a pressure drop versus flow rate curves for filters and gas systems.

2 Scope

2.1 This procedure applies to clean filters including those cartridges of metal, ceramic and membrane construction. The pressure drops for integral housing/cartridge combination units are determined as a single set of values. For housings with removable filter cartridges, the flow curves of the housing and housing/cartridge combination are determined separately.

2.2 This procedure applies to high-purity gas systems. This procedure applies to face-seal, surface mount—modular, and monolithic integrated gas systems.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate and safety health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 For separable filtration units, a single cartridge pressure drop value cannot be combined to give the pressure drop value for an extended length cartridge, because of the limitations imposed by a common outlet port for the assembly.

3.2 This method is written with the assumption that the operator understands the use of the apparatus at a level equivalent to six months of experience.

3.3 This method is written to test a filter under normal operating conditions. It does not prescribe a procedure for reverse flow testing since operation of the filter in this manner is not recommended by the manufacturers.

3.4 Components that induce line pressure changes on a system such as pressure regulators, and MFCs are not considered in this test method.

3.5 Proper flow of low vapor pressure gases can be effected by small pressure drops and may need to be evaluated independently.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *ASME Performance Test Code PTC 19.5, 1972* — "Applications." Part II of "Fluid Meters, Interim Supplement on Instruments and Apparatus."[1]

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CDA* — clean, dry air

5.1.2 *°C* — degrees Celsius

5.1.3 *DUT* — device under test

5.1.4 *kg* — kilogram

5.1.5 *kPa* — kilopascals, (kNm^{-2})

5.1.6 *m* — meter

5.1.7 *MFC* — mass flow controller

5.1.8 *N* — Newton ($kg\ m/s^2$)

5.1.9 *P* — pressure in kiloPascal (kPa)

5.1.10 *POC* — point of connection

5.1.11 *psi* — pounds per square inch

5.1.12 *psia* — pounds per square inch absolute

5.1.13 *psid* — pounds per square inch differential

5.1.14 *psig* — pounds per square inch gauge

1 American Society of Mechanical Engineers (ASME) International, 3 Park Avenue, New York, NY 10016-5990

5.1.15 *s* — second

5.1.16 *scfm* — standard cubic feet per minute

5.1.17 *slpm* — standard liters per minute

5.1.18 *T* — (K) temperature in Kelvin

5.1.19 *ΔP* — differential pressure in kPa

5.1.20 *ΔP(Housing)* — (kPa, differential) differential pressure of housing in kiloPascal, differential

5.1.21 *ΔP(Unit)* — (kPa, differential) differential pressure of filtration unit in kiloPascal, differential

5.1.22 *ΔP(cartridge)* — (kPa, differential) differential pressure of cartridge element in kiloPascal, differential

5.2 *Definitions*

5.2.1 *filter cartridge* — the filtration element.

5.2.2 *filter housing* — the shell that contains the filter cartridge.

5.2.3 *filtration unit* — the assembly consisting of a filter cartridge and housing.

5.2.4 *gas box* — a gas distribution subsystem which generally contains the final shut-off valve(s) prior to the POC.

5.2.5 *gas pallet* — individual gas distribution subsystems within a gas box that control flow of gas to individual process chambers.

5.2.6 *gas stick* — a series of components for an individual gas within a gas box. It may contain valves, a regulator, a pressure transducer, a purge line, an MFC, and a filter.

5.2.7 *integral unit* — the filter cartridge and housing are not separable.

5.2.8 *normal conditions* — 101.3 kPa (14.7 psia) and ambient temperature conditions 293.15 K (20 °C).

5.2.9 *separable unit* — the filter cartridge and housing can be disassembled.

5.2.10 *spool flow through component* — a null component consisting of an electropolished flow passage and appropriate fittings used in place of the test component.

5.2.11 *standard conditions* — 101.3 kPa, 273.15 K (14.7 psia, 0°C).

6 Summary of Method

6.1 This test method describes the test equipment and procedures for determining the flow pressure drop of filters or gas systems. The differential pressure is measured across a DUT at various inlet pressures and flows. If the filtration unit is separable the individual contributions from the housing and cartridge are determined.

7 Interferences

7.1 Test stand must be of adequate dimensions so that it does not limit the flow through the test DUT. The pressure drop for the test stand must be insignificant compared to the pressure drop for a DUT at the test flow rate.

8 Apparatus

8.1 pressure regulator

8.2 downstream flow regulating valve

8.3 flow meter capable of measuring flow rates to better than 5% full scale and of appropriate range.

8.4 several pressure transducers or gauges

8.5 differential pressure transducer (0.67 kPa, (0.1 psi) sensitivity)

8.6 Test stand

8.7 Temperature measuring device (°C)

9 Reagents and Materials

9.1 Test Gas nitrogen or CDA filtered to < 0.02 micrometer with a dew point of less than or equal to –40°C.

10 Safety Precautions

10.1 *Safety Precautions* — This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

10.2 The user must have a working knowledge of the respective instrumentation, must practice proper handling of test components, and must understand good laboratory practices. The user should not operate the components in such a manner as to exceed the ratings (i.e., pressure, temperature, flow and voltage).

11 Test Specimen

11.1 A gas box may consist of several gas pallets that uniquely control flow of gases to a specific process chamber. More than one gas stick layout is possible on the pallet. The user shall test only one stick at a time for pressure drop measurement. The gas stick may be removed from the pallet to attach to the test fixture.

11.2 Pressure regulators and MFCs shall be maintained in their fully open position during testing.

11.3 When comparing different gas system designs, it is useful to use components of similar design.

11.4 If the stick design contains a filter that dominates the pressure drop on the system, such filters shall be replaced by spool flow through components

12 Preparation of Apparatus

12.1 Construct a test stand for the measurement of gas flow rates and pressure drop across a DUT. Examples of such a test stand are shown in Figures 1a or 1b as schematic drawings.

12.2 The gas supply is filtered by an electronics grade high purity point-of-use gas filter before it is delivered to the DUT through a pressure regulator.

12.3 A flow meter can be installed either upstream or downstream of the DUT. See Figures 1a or 1b. The test filter is upstream of a throttle valve to allow for control of the flow through the DUT.

12.4 Inlet pressure is measured immediately upstream of the DUT by a pressure gauge or pressure transducer.

12.5 Pressure drop across the test specimen is measured by an electronic differential pressure transducer capable of reading 0.67 kPa (0.1 psid) across the test device.

12.6 Flow measurements are carried out through a flow meter installed upstream or downstream of the test filter. See Figures 1a or 1b.

NOTE 2: The flow measurement can be influenced by both upstream and downstream pressure fluctuations. It is necessary to verify the accuracy of any flow measurement under the test conditions used to complete this testing.

12.7 A temperature measurement device can be installed in the test stand to measure the gas stream temperature.

12.8 Figure 2 gives the piping requirements for the test stand configuration.

12.9 Figure 3 gives the recommended pressure connection to be followed in constructing the test apparatus.

13 Calibration and Standardization

13.1 For each test, verify that calibration of test equipment is up-to-date.

13.2 A series of flow meters should be used to cover the full range of flows that will be tested.

14 Procedure

14.1 *Integral Filtration Unit*

14.1.1 Assemble the filtration unit into the test apparatus. (See Figure 1.)

14.1.2 Set the inlet pressure using the pressure regulator to 10% of the filter's maximum rated inlet pressure or to 205 kPa (29.7 psia) whichever is less. Pressure is read on the inlet pressure gauge.

14.1.3 Adjust the flow rate using the regulating valve to give 10 % of the maximum rated flow. Adjustments to the inlet pressure regulator may be required to maintain a constant inlet pressure of 205 kPa (29.7 psia). The flow and pressure adjustments can be an iterative process requiring several iterations to achieve the desired flow rate and inlet pressure. The flow rate is read on the flow meter and recorded.

14.1.4 Read and record the ambient temperature, inlet pressure, pressure drop across the test filter, ambient pressure, and flow rate corrected for upstream pressure based on manufacturer's recommendation.

14.1.5 Repeat steps in Sections 14.1.3 and 14.1.4 at 25%, 50%, 75% and 100% of the maximum rated flow.

14.1.6 Repeat steps in Sections 14.1.2 through 14.1.5 at several inlet pressures: 309 kPa (44.7 psia), 516 kPa (74.7 psia), and 723 kPa (104.7 psia).

14.1.7 Additional testing of the filter at higher pressures can be completed up to the maximum rated pressure.

14.1.8 When the filter has a lower maximum pressure rating than 90 psig, it is recommended that the filter be tested at pressures of 33%, 67% and 100% of the filter's maximum pressure rating, with tests being limited by the sensitivity of the differential pressure device.

14.2 *Separable Filtration Unit* **-** *Filter Housing*

14.2.1 Assemble the empty filter housing into the test apparatus.

14.2.2 Set the inlet pressure using the pressure regulator to 10% of the housing's maximum rated inlet pressure or to 205 kPa (29.7 psia) whichever is less. The inlet pressure is read on the inlet pressure gauge and recorded.

14.2.3 Adjust the flow rate using the regulating valve to give 10% of the maximum rated flow. Adjustments to the inlet pressure regulator may be required to maintain a constant inlet pressure of 205 kPa (29.7 psia). The flow and pressure adjustments can be an iterative process requiring several iterations to achieve the desired flow rate and inlet pressure. The flow rate is read on the flow meter and recorded.

14.2.4 Read and record the ambient temperature, ambient pressure, inlet pressure, pressure drop across the test filter, and flow rate corrected for upstream pressure based on manufacturer's recommendation.

14.2.5 Repeat steps in Sections 14.2.3 and 14.2.4 at 25%, 50%, 75%, 100% of the filter cartridge's maximum rated flow.

14.2.6 Repeat steps in Sections 14.2.2 through 14.2.5 at several inlet pressures. For example, test at 309 kPa (44.7 psia), 516 kPa (74.7 psia), and 723 kPa (104.7 psia).

14.2.7 Additional testing of the filter at higher pressures can be completed up to the maximum rated pressure.

14.2.8 When the filter has a lower maximum pressure rating than 90 psig, it is recommended that the filter be tested at pressures of 33%, 67% and 100% of the filter's maximum pressure rating, with tests being limited by the sensitivity of the differential pressure device.

14.3 *Separable Filtration Unit – Assembled Cartridge and Housing*

14.3.1 Assemble the filter cartridge into the filter housing.

14.3.2 Assemble the filtration unit into the test apparatus.

14.3.3 Set the inlet pressure using the pressure regulator to 10% of the filter's maximum rated inlet pressure, or to 205 kPa (29.7 psia), whichever is less. The inlet pressure is read on the inlet pressure gauge/transducer and recorded. This pressure should be the same as used for the filter housing test in Section 14.2.2.

14.3.4 Adjust the flow rate using the regulating valve to give 10% of the maximum rated flow. Adjustments to the inlet pressure regulator may be required to maintain a constant inlet pressure of 205 kPa (29.7 psia). The flow and pressure adjustments can be an iterative process requiring several iterations to achieve the desired flow rate and inlet pressure. The flow rate is read on the flow meter and recorded. This should be the same as used for the filter housing test in Section 14.2.3.

14.3.5 Read and record the ambient temperature, ambient pressure, inlet pressure, pressure drop, and flow rate.

14.3.6 Repeat steps in Sections 14.3.3 and 14.3.5 at 25%, 50%, 75% and 100% of the maximum rated flow. These should be the same flow settings as used in Section 14.2.5.

14.3.7 Repeat steps in Sections 14.3.2 through 14.3.6 at several inlet pressures. For example, test at 309 kPa (44.7 psia), 516 kPa (74.7 psia), and 723 kPa (104.7 psia).

14.3.8 Additional testing of the filter at higher pressures can be completed up to the maximum rated pressure. These inlet pressure settings should be the same as used in Section 14.2.7.

14.3.9 When the filter has a lower maximum pressure rating, it is recommended that the filter be tested at pressures of 33%, 67% and 100% of the filter's maximum pressure rating, with tests being limited by the sensitivity of the differential pressure device.

14.3.10 The flow curve for the filter cartridge is determined by subtracting the pressure drop of the housing from the pressure drop of the assembled filtration unit at respective flow rates and inlet test pressures.

14.4 *Gas System*

14.4.1 Assemble the DUT into the test apparatus. (See Figure 1.)

14.4.2 Set the inlet pressure using the pressure regulator to 205 kPa (29.7 psia). Pressure is read on the inlet pressure gauge.

14.4.3 Adjust the flow rate using the regulating valve to give 1 slpm. Adjustments to the inlet pressure regulator may be required to maintain a constant inlet pressure of 205 kPa (29.7 psia). The flow and pressure adjustments can be an iterative process requiring several iterations to achieve the desired flow rate and inlet pressure. The flow rate is read on the flow meter and recorded.

14.4.4 Read and record the ambient temperature, inlet pressure, pressure drop across the DUT, ambient pressure, and flow rate.

14.4.5 Repeat steps in Sections 14.4.2 through 14.4.4 at flow rates of 5, 10, 25, 50, 75, and 100 slpm.

14.4.6 Repeat steps in Sections 14.4.2 through 14.4.5 at several inlet pressures: 308 kPa (44.7 psia), 515 kPa (74.7 psia), and 791 kPa (114.7 psia).

14.4.7 Additional testing of the DUT may be performed at higher pressures up to the maximum rated pressure. Where components are not specified to operate at the required flow rates and pressures listed in Sections 14.4.5 and 14.4.6 then tests shall be performed to the highest pressures and flows attainable while remaining within the component's maximum operating specification.

15 Calculations or Interpretation of Results

15.1 Complete Tables 1–3 as needed for the DUT.

15.2 Graph the pressure drop versus the flow rate. An example of such a graph is shown in Figure 4 with separate lines for different inlet pressure settings.

16 Precision and Accuracy

16.1 All measurements shall be recorded to the greatest precision allowed by the instruments unless accuracy in the overall measurement is not affected by lower precision.

16.2 Accuracy of all instruments shall be recorded.

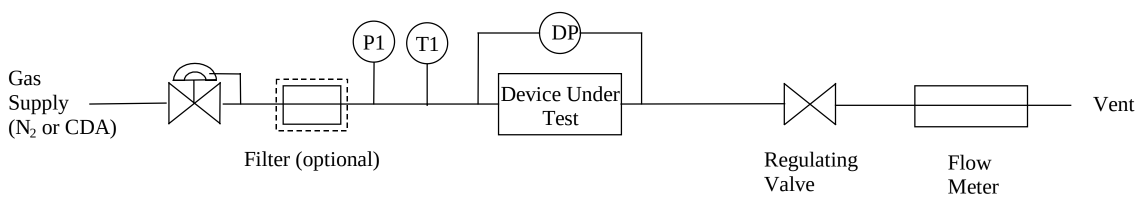


Figure 1a
Flow Pressure Drop Test Stand Schematic, Option 1

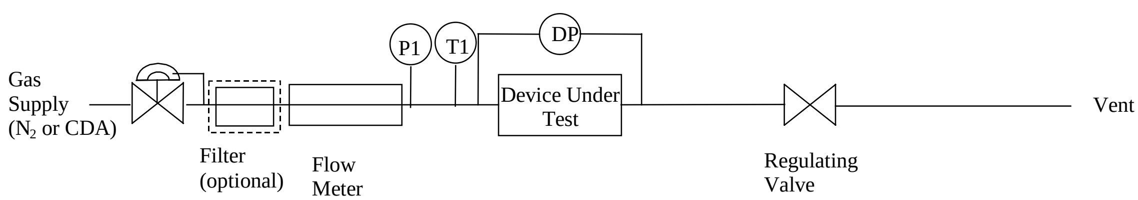


Figure 1b
FLow Pressure Drop Test Stand Schematic, Option 2

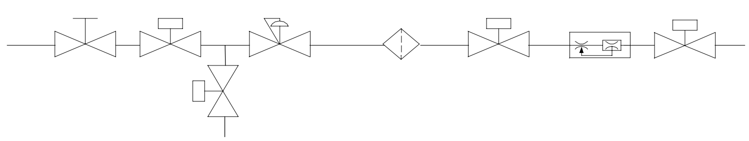
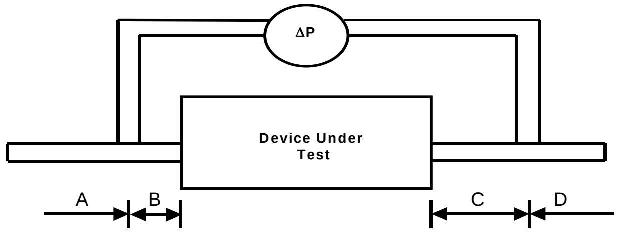


Figure 1c
Sample Gas System for Testing



A — At least 16 nominal pipe diameters of straight pipe.

B — 2 Nominal pipe diameters of straight pipe.

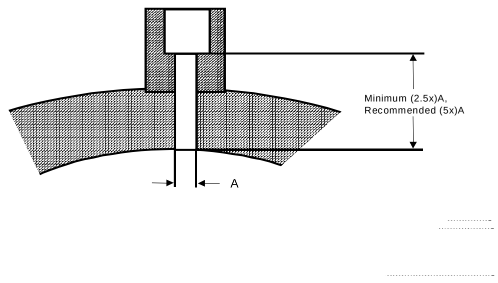
C — 6 Nominal pipe diameters of straight pipe.

D — At least 1 nominal pipe diameters of straight pipe.

NOTE 1: Dimension “A” may be reduced to 8 nominal diameters if straightening vanes are used. Design of straightening vnes can be found in ASME Performance Test Code PTC 19.5-1972, “Applications – Part 2 of “Fluid Meters, Interim Supplement on Instruments and Apparatus.”

NOTE 2: If an upstream flow disturbance consists of two elbows in series and they are in different planes, dimension “A” must exceed 16 nominal pipe diameters unless straightening vanes are used.

Figure 2
Piping Requirements – Standard Test Section



Size of Pipe	*“A” Not Exceeding*	*“A” Not Less than*
Less than 50 mm (2 in.)	6 mm (1/4 in.)	3 mm (1/8 in.)
50 mm to 75 mm (2–3 in.)	9 mm (3/8 in.)	3 mm (1/8 in.)
100 mm to 200 mm (4–8 in.)	13 mm (1/2 in.)	3 mm (1/8 in.)
250 mm and greater (10 in. and greater)	19 mm (3/4 in.)	3 mm (1/8 in.)

NOTE 1: Edge of hole must be clean and sharp or slightly rounded, free from burrs, wire edges or other irregularities. In no case shall fitting protrude inside pipe.

NOTE 2: Any suitable method of making the physical connection is acceptable if above recommendations are adhered to.

See ASME Performance Test Code PTC 19.5-1972, “Applications. Part II of Fluid Meters, Interim Supplement on Instruments and Apparatus.

Figure 3
Recommended Pressure Connection

Table 1 DUT Flow Pressure Drop for Integral Filtration Unit or Gas System

DUT Unit Identification

Test Number ______________________

Date ______________________

Operator Name ______________________

Barometric Pressure ______________________

Test Gas ______________________

Integral Filtration Unit or Gas System

	Ambient Temperature (^oC)	*Inlet Pressure (psig, gauge)*	*ΔP(Unit) Differential Pressure, unit (psid, differential)*	*Flow Meter Reading (units)*	*Normal Flow Rate(m^3/hr)*

Table 2 Filter Flow Pressure Drop for Housing with Cartridge Element Removed

Filter Unit Identification

Test Number ______________________

Date ______________________

Operator Name ______________________

Barometric Pressure ______________________

Test Gas ______________________

Housing with Cartridge Removed

	Ambient Temperature (°C)	*Inlet Pressure (psig, gauge)*	*ΔP(Housing) Differential Pressure, Housing (psid, differential)*	*Flow Meter Reading (units)*	*Normal Flow Rate (m^3/hr)*

Table 3 Filter Flow Pressure Drop for Cartridge Element

Cartridge Pressure Drop

ΔP(cartridge) = ΔP(Unit) – ΔP(Housing)

Normal Flow Rate (m^3/hr)	*ΔP(Unit) Differential Pressure, unit (psid, differential)*	*ΔP(Housing) Differential Pressure, Housing (psid, differential)*	*ΔP(cartridge) Differential Pressure, Cartridge (psid, differential)*

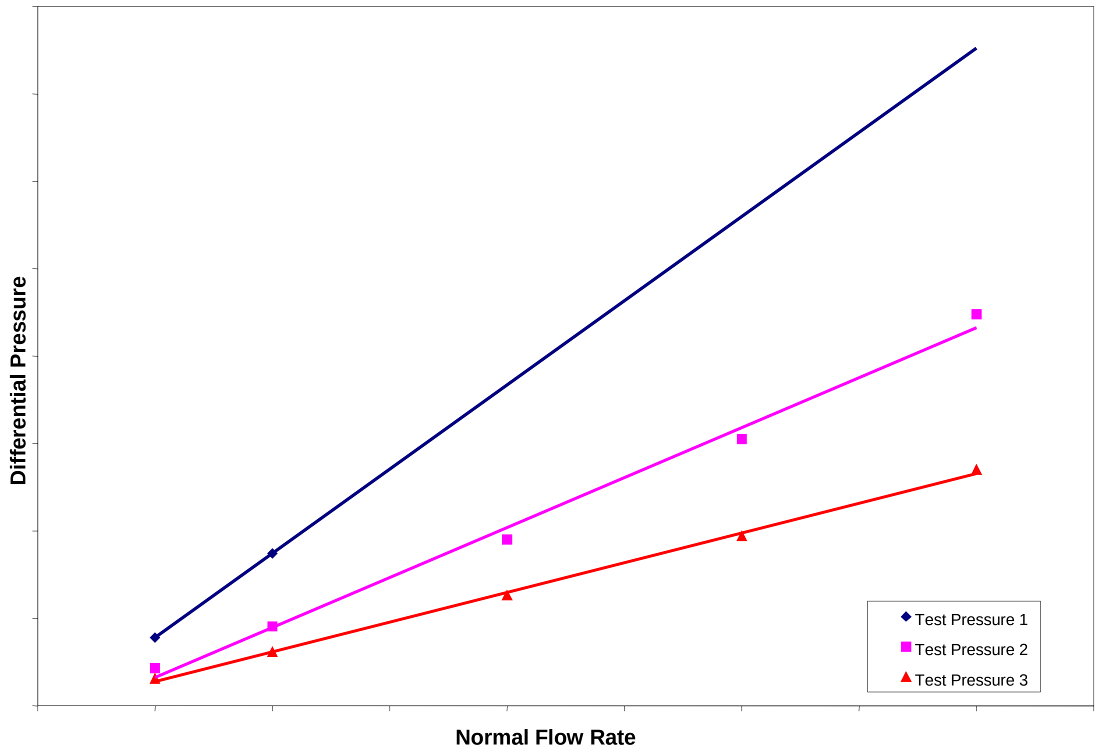


Figure 4
Example of a Flow Pressure Drop Curve for a Filter

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SEMI F60-0301
TEST METHOD FOR ESCA EVALUATION OF SURFACE COMPOSITION OF WETTED SURFACES OF PASSIVATED 316L STAINLESS STEEL COMPONENTS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001.

1 Purpose

1.1 The purpose of this document is to define a method for testing passivated 316L stainless steel components being considered for installation into a high-purity gas distribution system. Application of this test method is expected to yield comparable results among components tested for the purposes of qualification for this installation.

1.2 This document defines a method of testing the interior surfaces of stainless steel tubing, fittings, valves, and other components to determine the surface composition and chemistry, as a measure of the effectiveness of passivation processes.

1.3 The objective of this method is to describe a general set of instrument parameters and conditions that will achieve precise and reproducible measurements of important surface chemistry within the chromium-enriched oxide layer.

2 Scope

2.1 This document describes a test method to characterize "as received" surface composition and chemistry encompassing all chromium-enriched stainless steel surfaces in tubing, fittings, valves, and other components. This procedure involves measurement of total Cr/Fe ratios, Cr^{ox}/Fe^{ox} oxide species ratios, and the surface elemental compositions by Electron Spectroscopy for Chemical Analysis (ESCA), also called X-ray Photoelectron Spectroscopy (XPS).

2.2 This document also describes the test method for a compositional ESCA depth profile measurement for Cr, Fe, Ni, O and C from the as-received surface, through the oxide layers, and extending into the base metal. The depth profile measurement evaluates the oxide thickness and the relative composition throughout the modified surface layer as a result of the passivation process.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This test method is intended to be used by ESCA analysts familiar with the instrumentation and technique. The ESCA instrument must be calibrated and maintained to pertinent manufacturer's specifications. The method is not intended to preclude the use of any particular brand or model of surface analysis equipment. While most of the test methodology has been developed using specific instrumentation, this method can be adapted to most surface analytical instrumentation.

3.2 The effects of the depth of analysis of the technique and surface contamination affect the results of this test method. These are discussed in the attached appendix. Surface roughness, non-planarity of the surface, and differential sputtering rates for the different chemical species also cause measurement uncertainties in this test method

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI F19 — Specification for the Finish of the Wetted Surfaces of Electropolished 316L Stainless Steel Components.

4.2 *ASTM Standards*[1]

A276 — Standard Specification for Stainless Steel Bars and Shapes.

A751 — Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products.

E673 — Standard Terminology Relating to Surface Analysis.

E902 — Standard Practice for Checking the Operating Characteristics of X-ray Photoelectron Spectrometers.

1 American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

E1078 — Standard Guide for Specimen Handling in Auger Electron Spectroscopy and X-ray Photoelectron Spectroscopy.

4.3 *NIST Standard*[2]

SRD20 — NIST X-ray Photoelectron Spectroscopy Database.

4.4 *Physical Electronics*[3]

Moulder, et al. — Handbook of X-ray Photoelectron Spectroscopy.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *ESCA* — Electron Spectroscopy for Chemical Analysis.

5.1.2 *XPS* — X-ray Photoelectron Spectroscopy, an equivalent name for ESCA.

5.2 *Definitions*

5.2.1 *sampling volume* — the volume from which photoelectrons are detected. The x-ray spot size and/or the lens and aperture system of the electron analyzer determine lateral dimensions. A length of three times the photoelectron mean free path is considered the maximum depth sensitivity. Sampling volume is dependent on the sample material and TOA. The acceptance angle of the analyzer will also influence the distribution of the depth information.

5.2.2 *take-off angle (TOA)* — the angle that the collection lens forms with the sample plane.

6 Summary of Method

6.1 *Data Acquisition*

6.1.1 Acquire elemental survey and calculate elemental composition of "as received" wetted surface.

6.1.2 Acquire chromium and iron regions at high resolution. Calculate total Cr/Fe ratio and Cr oxide/Fe oxide ratios from these regions.

6.1.3 Acquire a compositional depth profile to determine the relative abundance of C, O, Cr, Fe and Ni. Additional elements may be included as desired (i.e., molybdenum, silicon and nitrogen). If minor elements are included in the profile the instrument parameters should be chosen to allow for a detection limit of 1 atomic percent (at%) or better.

6.2 *Reporting* — Data is provided consisting of:

6.2.1 A survey spectrum extending from at least 0-1100eV.

6.2.2 The high-resolution Cr ($2p_{3/2}$) and Fe ($2p_{3/2}$) spectra from the as-received surface.

6.2.3 A compositional depth profile plot including C, O, Cr, Fe and Ni as a function of sputtering time.

7 Possible Interferences

7.1 *Mo (3d) and S (2s)* — use S (2p) for quantification of sulfur. Molybdenum will appear as a doublet; quantity may be overestimated.

7.2 *Fe ($2p_{3/2}$) and Ni Auger* — ignore.

7.3 *Mo (3p) and N (1s)* — the ability to accurately quantify the nitrogen will depend upon the chemical state of both the nitrogen and molybdenum. In some cases the nitrogen will be overestimated from a survey scan quantification.

8 Apparatus

8.1 *Instrumentation* — Any ESCA instrument with definable area of analysis approximately 1 mm or less and sufficient count rate to provide detection of low level contaminants at one atomic percent or greater. A count rate of at least 100,000 counts per minute for clean Au ($4f_{7/2}$) should indicate sufficient sensitivity.

8.2 The instrument should have peak resolution of 1 eV FWHM Au ($4f_{7/2}$) or better (i.e., < 1 eV) to ensure species separation of metallic and oxide forms of chromium and iron.

8.3 If the instrument is of a variable take-off angle (TOA) design, the geometry should be set to a TOA of approximately 35^{o}. Instruments with geometries significantly different from this, or with magnetic electron collection lens may provide analysis from a different sampling volume. The angle of the incident X-ray irradiation with respect to the sample plane and TOA must be recorded.

8.4 Data reduction software must have the ability to select an iterated Shirley-curve background.

9 Reagents and Materials

9.1 *Instrument Calibration Materials* — Refer to instrument manufacturer recommendations or ASTM E902. A measurement of the binding energy difference between the Au ($4f_{7/2}$) at 84.0 eV and Cu ($2p_{3/2}$) at 932.6 eV is an acceptable method of calibrating analyzer linearity. A value of $\pm 3\sigma$ based upon a minimum of 10 historical measurements of less than ± 0.25 eV is acceptable.

2 National Institute of Standards and Technology, Gaithersburg, MD 20899

3 Physical Electronics, Eden Prairie, MN 55344

9.2 *Statistical Process Control Material* — A nominal 316L material with a composition range within the guidelines of ASTM A276. The composition of the bulk material should be determined by methods consistent with ASTM A751.

10 Safety Precautions

10.1 This test method does not purport to address the safety considerations associated with use of high voltage, vacuum, and X-ray producing equipment. The method assumes an ESCA analyst with knowledge of instrumentation and associated safety precautions.

11 Test Specimen

11.1 Specimens are to be sectioned to appropriate size for the particular ESCA instrument using a clean, dry hacksaw or dry low speed bandsaw. Any sample preparation shall avoid introducing contamination onto the surface to be measured. In addition, preparation must avoid excessive heating of the sample, i.e., the surface temperature shall not exceed 50°C, to avoid oxide growth or change in surface composition.

11.2 Sample preparation should preferably be done by the component manufacturer. Following sectioning the sample(s) are to be cleaned and packaged per the manufacturer's standard final cleaning and packaging procedures.

11.3 If sample preparation is done by other than the manufacturer, the sample(s) may be cleaned in DI water. If the sample(s) are not to be analyzed immediately they should be packaged by wrapping in clean metal foil or sealing in cleanroom quality nylon bags.

11.4 If sample preparation is done by other than the manufacturer this shall be stated in the report narrative and the analytical results are not to be interpreted as indicative of the manufacturer's quality of cleaning and packaging procedures. A note to this effect shall be included in all tables of reported results of the composition of the surface.

11.5 After preparation, samples should be analyzed promptly, with allowance for shipping times and queuing time at the analyst.

12 Preparation of Apparatus

12.1 Instruments shall be routinely tested in accordance with manufacturer recommendations to assure proper performance. The instrument vacuum shall be 1.0E-7 Torr or better during the analysis.

13 Calibration and Standardization

13.1 Proper instrument calibration is necessary to provide the most accurate and reproducible results, particularly if results are compared among different laboratories. Instrument calibration for sensitivity factors and binding energies shall be performed in accordance with the instrument manufacturer recommendations or other accepted method, such as that provided in ASTM E902.

13.2 The general ESCA calibration procedures described above are suitable for most analyses and provide reasonably accurate relative quantitative information regarding the surface chemistry. However, in order to establish the most accurate measurement practical and to maintain the desired level of reproducibility over time, an application-specific statistical process control (SPC) shall be established for this test method to determine the appropriate sensitivity factors for Cr, Fe, Ni and Mo in 316L stainless steel. The bulk composition of the SPC material should have an assay consistent with the acceptable composition range of 316L for Cr, Fe, Ni and Mo, as set forth in ASTM A276. The bulk composition of the SPC material should be determined by methods consistent with ASTM A751. The relative sensitivity factors established for the quantification of data should reflect the nominal composition of the bulk 316L SPC standard after a sputter cleaning sufficient to remove any surface contamination and the oxide passive layer. A $\pm 3\sigma$ relative precision should be established from a minimum of 10 SPC measurements with the following tolerances:

Cr	± 10%
Fe	± 10%
Ni	± 25%
Mo	± 30%

As referenced from ASTM A276-97, a typical 316L material has a composition range in terms of wt% of:

Cr	16–18
Ni	10–14
Mo	2–3
C	< 0.03
Mn	< 2.0
P	< 0.045
S	< 0.03
Si	< 1.0
N	< 0.1
Fe	Balance.

Note that ESCA data is reported in atomic percent.

13.3 The sputter conditions established for the SPC surface cleaning shall be the same as those established for the ESCA depth profile measurement part of this standard. A minimum sputtering etch cleaning of the SPC sample of ≥ 10 nanometers is recommended in order to remove surface contamination, the oxide passive layer and establish equilibrium. Note that the degree of preferential sputtering and other ion etching artifacts are a function of the matrix material and the ion gun conditions.

13.4 Calibration frequency of the application specific SPC should be designed to establish a record of the reproducibility and accuracy of the measurement, as reflected by the nominal composition of the 316L standard. A minimum frequency of one per week is recommended, or immediately prior to performing a measurement in accordance with this test method.

13.5 A sputter rate calibration shall be performed prior to an ESCA profile measurement conducted in accordance to this test method. The ion sputter rate determination shall be made using standard thin films of 100 nanometers or less of SiO_2 on Si. The method of determining the thickness of the oxide film shall be based upon the oxygen concentration profile. The oxide – substrate interface shall be specified as the point at which the oxygen concentration decreases to ½ its maximum value in the SiO_2 film, ignoring the first sputter cycle.

13.6 Multiple samples may be analyzed following a single sputter rate determination if the ion gun parameters have not been adjusted and the ion gun performance is documented as stable over the period in question.

14 Procedure

14.1 *As-Received Surface Analysis*— The sample is to be mounted in accordance with manufacturer's recommendations and in a manner consistent with ultra-high vacuum surface analytical procedures. Some of these practices are detailed in ASTM-E1078. The area to be analyzed should be mounted parallel to the sample holder surface so that TOA is well known.

14.1.1 Place the sample in the ESCA introduction chamber for pump down. Transfer to the analytical chamber at the manufacturer's recommended base pressure. Align the sample with respect to the X-ray beam and analyzer so that optimum count rate from the desired analytical location is obtained. The use of a collimated high voltage electron beam to align the sample should be avoided, as this may pyrolyze surface carbon and potentially alter surface oxide chemistry. The surface area to be analyzed should be free of visible particles and large defect features, if possible.

14.1.2 A beam size as close to 1 mm as possible should be used to ensure measurement of a representative surface. If surface curvature is great (e.g., < 1/4" tubing), a smaller beam may be employed. Elemental survey data (0–1100 eV) are to be measured from the sample surface to determine the elements present and their approximate surface abundance. A high throughput analyzer setting may be used to obtain a signal to noise ratio (S/N) sufficient to detect common surface contaminants such as sulfur and phosphorus at one atomic percent or better.

14.1.3 Using instrument settings sufficient to provide a FWHM peak width of 1.0 eV or less on Au ($4f_{7/2}$), measure chromium, iron, and carbon regions. A typical region width is 20 eV. Suggested ranges are as follows: Cr ($2p_{3/2}$) from 570 to 590 eV, Fe ($2p_{3/2}$) from 700 to 720 eV, and C (1s) from 275 to 295 eV. Signal to noise ratios of greater than 20 are suggested.

14.1.4 A consistent method of data reduction of high-resolution surface spectra is necessary in order to provide meaningful comparison of the relative Cr:Fe ratios.

14.1.5 The spectra shall be charge compensated with respect to the maximum of the Cr ($2p_{3/2}$) set to 577 eV. An iterated Shirley method of background subtraction shall be applied to the Fe ($2p_{3/2}$) and Cr ($2p_{3/2}$) spectral regions, using a minimum of three iterations.

14.1.6 The curve fit regions shall typically extend from:

Cr ($2p_{3/2}$)	570–582 eV
Fe ($2p_{3/2}$)	704–717 eV

14.1.7 The curve fit peak parameters should be initialized as follows:

Cr ($2p_{3/2}$)	Peak Position	FWHM	% gaussian
1	574	1.5	80
2	576.5	2.0	80
3	577.5	2.0	80

Fe ($2p_{3/2}$)	Peak Position	FWHM	% gaussian
1	707	1.0	80
2	708	1.0	80
3	710	1.4	80
4	711.5	1.4	80
5	713	1.4	80

14.1.8 The curve fit routine should apply the following tolerances for the band limit parameters of all peaks defined above:

FWHM delta	≤ 0.2 eV
% gaussian delta	≤ 10%
Curve fit position delta	≤ 0.25 eV

14.1.9 An automated form of data reduction is recommended to enhance reproducibility and minimize analyst subjectivity associated with the curve fit procedure. If it is necessary to deviate from the curve fit parameters outlined above in order to obtain a satisfactory curve fit it should be noted in the formal report. Possible sources for the anomalous behavior include an excessive concentration of iron oxide or a sufficiently aged sample surface, such that the oxide surface chemistry and structure has modified.

14.2 *Depth Profile Analysis*— The ESCA depth profile may be performed following acquisition of the initial as-received surface survey scan and high-resolution spectra using the same sample x-y position and take-off angle of 35°.

14.2.1 The depth profile may be acquired in either continuous mode (simultaneous sputter etching and data acquisition) or alternating sputter etch/data acquisition mode. The following acquisition windows are recommended:

Spectral line	Lower limit	Range
C	280 eV	15 eV
O	525 eV	15 eV
Cr	570 eV	15 eV
Ni	848 eV	15 eV
Fe	700 eV	25 eV

14.2.2 If only an elemental compositional profile is acquired, any pass energy may be selected as long as the remaining acquisition parameters defined by the number of sweeps, step size and dwell time result in ≤ 1.0at% detection of the matrix elements followed in the depth profile.

14.2.3 The composition profile should extend far enough into the depth of the sample to reach the base metal composition of the 316L material, but a minimum of 100Å from the surface as referenced to the calibrated sputter rate in SiO_2.

15 Calculations and Interpretation of Results

15.1 Most manufacturers supply software for determination of elemental composition. The elemental composition should be calculated using sensitivity factors appropriate to the instrument, each element, and resolution settings for each measurement.

15.2 The total Cr/Fe ratio is calculated by adding peak areas from all species of each element, adjusting for different numbers of scans and sensitivity factors, and dividing the Cr result by the Fe result. The Cr oxide/ Fe oxide ratio is calculated in a similar manner, except that only peaks 2 and 3 for Cr and only peaks 3 through 5 for Fe (oxide species) are used. The formulas are as follows:

$$\text{Total Cr/Fe} = \frac{(\Sigma \text{ Cr peak areas})/\text{\# Cr scans/Cr sensitivity factor}}{(\Sigma \text{ Fe peak areas})/\text{\# Fe scans/Fe sensitivity factor}}$$

$$\frac{\text{Cr Oxide/}}{\text{Fe Oxide}} = \frac{(\Sigma \text{ Cr oxide peak areas})/\text{\# Cr scans/Cr sens. factor}}{(\Sigma \text{ Fe oxide peak areas})/\text{\# Fe scans/Fe sens. factor}}$$

16 Reporting Results

16.1 *As-Received Surface Results* — A tabular summary of the elemental composition of all elements detected in the surface survey spectrum is to be supplied with the associated elemental survey spectrum. If sample preparation has been done by other than the component manufacturer all tables of as-received surface analysis results shall include a note stating: "Sample preparation was not performed by the component manufacturer. Results are not to be interpreted as indicative of the component manufacturer's quality of cleaning and packaging procedures."

16.1.1 Tabular summaries of total Cr/Fe ratio and Cr oxide/ Fe oxide are also to be supplied, with associated $Cr(2p_{3/2})$, $Fe(2p_{3/2})$, and C(1s) narrow region spectra.

16.1.2 Acquisition parameters, including manufacturer, model and TOA; X-ray source (Al or Mg); beam size; and other pertinent settings are to be supplied. Analyst identity and analysis date are also required information. Each table and graph must be clearly labeled with sample identification.

16.2 *Depth Profile Results* — Compositional depth profile data plots shall display the atomic concentration of Fe, Cr, Ni, C, and O at minimum versus the sputter time or the equivalent depth from the calibrated sputter rate in SiO_2.

16.2.1 The method applied to determine the oxide thickness shall be specified in the report. A commonly accepted method of quantifying the oxide thickness is determined as the sputter time/depth at which the oxygen concentration decreases to ½ the maximum value. The carbon thickness may be determined similarly.

APPENDIX 1
DISCUSSION OF EFFECTS OF DEPTH OF ANALYSIS ON DEPTH PROFILE ANALYSIS BY ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS OF PASSIVATED STAINLESS STEEL

NOTE: This appendix is being balloted as an official part of SEMI F## by full letter ballot procedure, but the recommendation in this appendix are optional and are not required to conform to this standard. This appendix is derived from presentations made to the SEMI Surface Analysis Task Force.

A1-1.1 The purpose of this appendix is to describe the ESCA (sometimes referred to as X-Ray Photoelectron Spectroscopy (XPS)) technique and explain the interpretation of the depth profile analysis with respect to the structure and composition of the passive oxide layer on stainless steel. The effect of the depth of analysis on the measured chromium to iron ratio, the oxide thickness, and the depth of enrichment is discussed. The discussion applies to depth profile analyses performed by Auger electron spectroscopy, also.

A1-1.2 *ESCA* — The ESCA technique makes use of an X-ray beam for a probe. The surface of interest is illuminated with X-rays, typically Al kα radiation, which has a well-defined energy of 1486.6 eV. When an x-ray photon and an electron interact, the electron adsorbs all of the energy of the photon, 1486.5 eV; it cannot react with it partially. The electron then has sufficient energy to leave the atom and move into the matrix. The electron's energy in the matrix is 1486.6 eV minus its binding energy to the atom from which it escaped. Its binding energy is indicative of the element or compound from which it came and the orbital from which it was removed. Such an electron is termed a "photoelectron".

A1-1.3 In a typical ESCA instrument, a monochromatic beam of x-rays is focused at a point of interest on a surface. A cloud of electrons is generated at the surface by the x-rays. This electron cloud is made up of secondary electrons, Auger electrons and photoelectrons. (NOTE: The generation of Auger electrons is a byproduct of the process. If the photoelectron was an inner shell electron, when it leaves the atom it creates an ion in an excited state. Once the ion is created it can de-excite via the Auger process. The presence of Auger electrons in an ESCA survey can be used to determine what elements were present.) The mechanisms of ESCA photoelectron and Auger electron generation are illustrated in Figure A1-1.

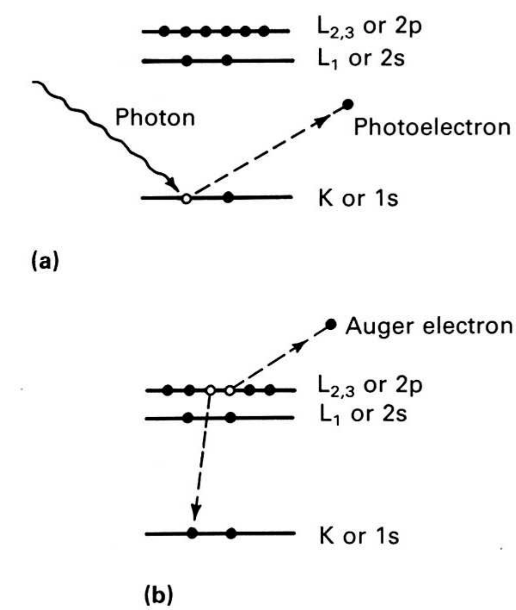

Figure A1-1
Schematic representation of the ESCA photoelectron and Auger electron generation processes.

A1-1.4 An electron lens is focused at the same point as the x-ray beam and a portion of the electron cloud enters the lens. From the lens, the electrons enter an electron analyzer that measures the number of electrons as a function of their kinetic energy. The kinetic energy is subtracted from the incident x-ray photon energy, and the resulting binding energy is then plotted as the x-axis with the number of electrons at each energy on the y-axis. An example is shown in Figure A1-2. The binding energy can be indicative not only of the element from which the electron came but also the chemical bonding state of the element.

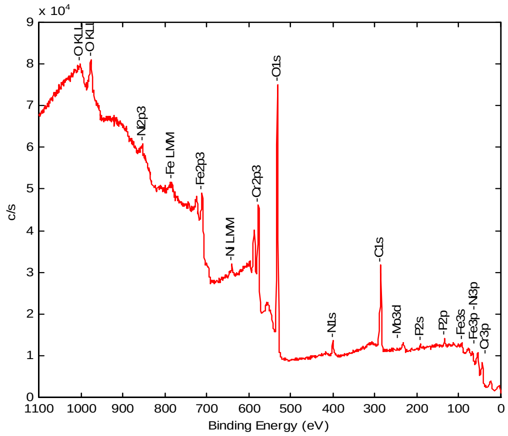

Figure A1-2
Example of ESCA spectrum of the oxide passive surface of stainless steel

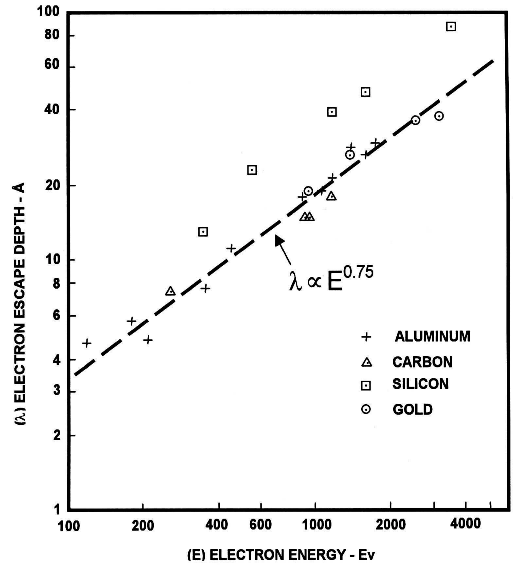

Figure A1-3
The electron escape depth of low energy electrons in some metals.

A1-1.5 *Illuminated Volume and Surface Sensitivity* — The incident x-ray beam penetrates well below the surface. Photoelectrons and Auger electrons are generated all through this illuminated volume. The inelastic mean free path (IMFP) of an electron in a solid is the mean distance through the solid that an electron can travel before losing some of its energy (suffering an inelastic interaction). The IMFP is a function of the electron's energy and the matrix through which it is traveling. Electrons with an energy of approximately 1 keV have an IMFP of about 10 Å. That means that a 1 keV electron will travel, on average, 10 Å before interacting with the matrix and giving up some of its energy. In other words it will be scattered to lower energy and will not be part of the photoelectron or Auger electron line for its element. The IMFP is a statistical parameter and an electron may travel several IMFPs before having a collision. The "several IMFPs" is called the escape depth of the electron, or the depth of analysis, as shown in Figure A1-3. Although ESCA and Auger are considered surface analytical tools, their depth of analysis is on the order of 50 Å, or about one to two times the depth of the oxide film found on a typical passivated stainless steel surface.

A1-1.6 *Depth of Analysis Function* — There has been some discussion with respect to the "Depth of Analysis Function". There is one school that believes that it is 5 IMFPs and another that uses 3 IMFPs. These two functions will be referred to as 5λ and 3λ respectively. It will be seen that it makes little difference which function is used even though the depth of the oxide films is of the order of the functions. These functions are seen in Figure A1-4, which shows the proportion of the total signal generated from each depth below the surface. The y-axis is in decimal and the x-axis is in angstroms from the surface. The first point of the 5λ curve is 0.16 at the 1st angstrom level. That means that 16% of the signal comes from the 1st angstrom, 14% from the 2nd angstrom level and so on down to 1% from the 25th angstrom level. Thus elements that do not appear on the surface or in the first 24 angstroms in from the surface, but do exist at the 25 Å level will be detected.

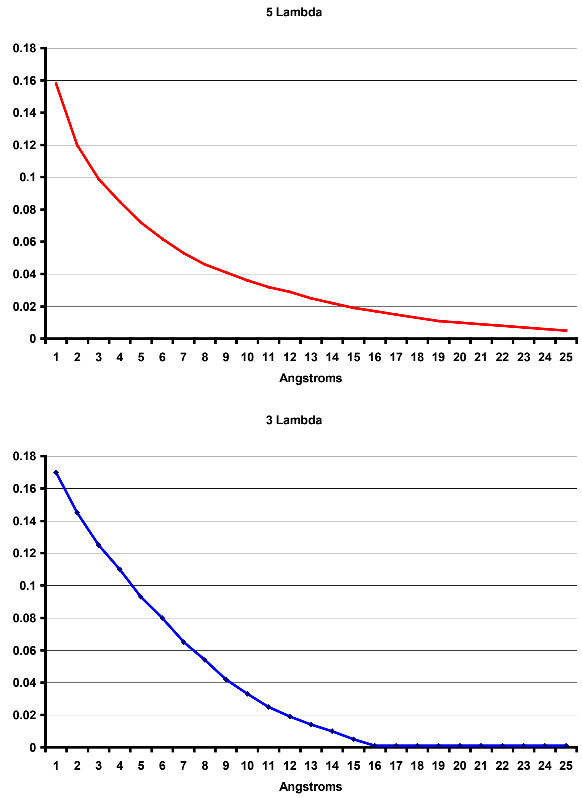

Figure A1-4
These two graphs represent the "Depth of Analysis" that will be seen when analyzing 1 keV electrons. The top curve is the 5λ curve and bottom the 3λ.

A1-1.7 *Modeling* — Figure A1-5 is the composition profile of a "perfect" oxide. It represents 25 Å of pure Cr_2O_3 on an atomically flat 316L stainless steel surface, with no surface or interfacial contamination present. Figures A1-6a and A1-6b are the theoretical depth profiles derived by assuming a depth of analysis of 5λ and 3λ respectively. The first factor to note is that Fe, Ni and Mo appear most or all of the way through the depth profile of the oxide due to the contribution of the metal substrate to the detected signal, the "depth of analysis" effect as introduced above. 1 keV electrons can escape from as deep as 25 Å. This must be appreciated when interpreting these depth profiles.

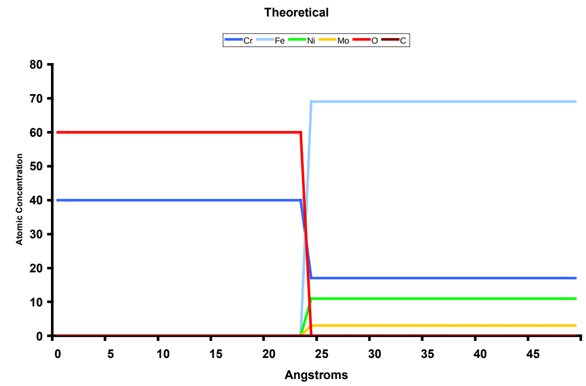

Figure A1-5
Composition versus depth of a pure Cr_2O_3 layer on stainless steel.

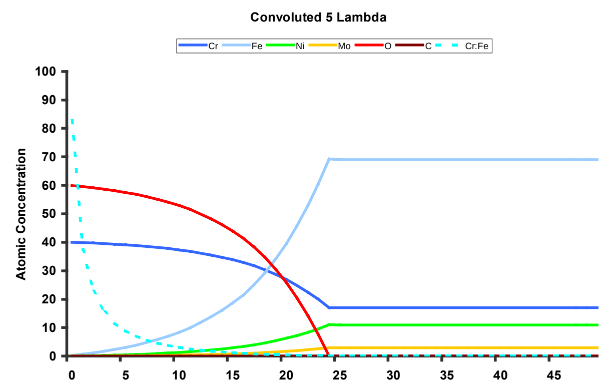

Figure A1-6a
Theoretical depth profile of Figure A1-5 assuming 5λ depth of analysis.

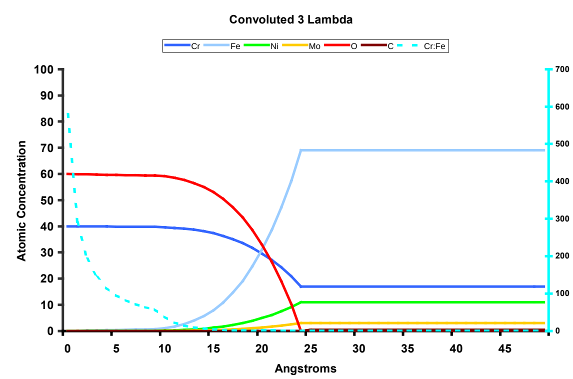

Figure A1-6b
Theoretical depth profile of Figure A1-5 assuming 3λ depth of analysis.

A1-1.8 The second factor to notice is the thickness of the oxide. Historically, the FWHM of the oxygen profile has been used as the measure of oxide thickness.

It is apparent in Figures A1-5 and A1-6 that this underestimates the oxide thickness by 15 to 20%.

A1-1.8.1 It should also be noted that the Cr:Fe ratio measured from Figures A1-5 and A1-6 has its maximum value at the initial surface, decreasing as the depth profile progresses, whereas the actual Cr:Fe ratio in Figure A1-5 is infinite down to 25 Å. Most actual depth profiles exhibit a maximum of the Cr:Fe ratio at some depth below the initial surface, referred to as the depth of maximum enrichment. This is a consequence of variation in the actual composition of the oxide, possibly having a higher concentration of Fe near the surface, a phenomenon commonly termed a "detached iron oxide layer", or of contamination on the surface, generally hydrocarbons. These are discussed in the next section.

A1-1.9 *Effects of Detached Iron Oxide Layer and Surface Contamination* — The model composition profile of Figure A1-7 shows 3 Å of pure Fe_2O_3 over 22 Å of pure Cr_2O_3 on 316L stainless steel. This is a model of a detached iron oxide layer. Figure A1-8 is the theoretical depth profile of this model derived assuming a depth of analysis of 5 lambda. Note that the initial Cr value in the profile is higher than the Fe value, even though the surface is pure Fe_2O_3. This is a consequence of the depth of analysis detecting the Cr from levels beneath the surface. The Cr:Fe ratio for this model has its maximum value at 3 Å below the initial surface. The theoretical depth profile using a depth of analysis of 3λ is very similar.

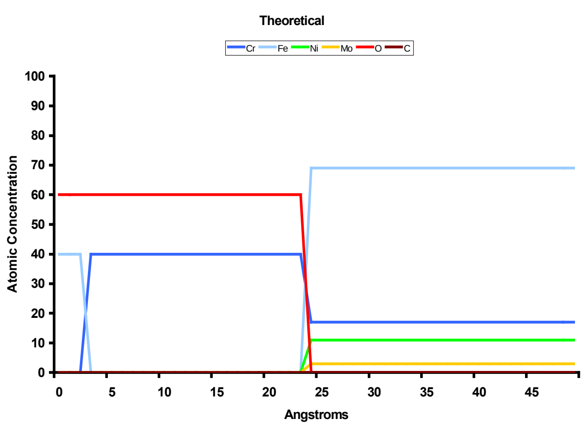

Figure A1-7
Composition versus depth of a Fe_2O_3 layer over a Cr_2O_3 layer on stainless steel.

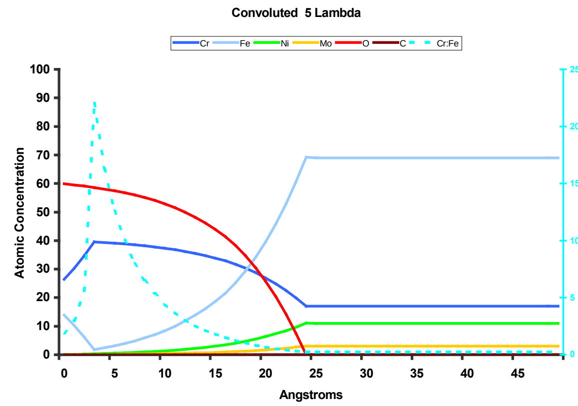

Figure A1-8
Theoretical depth profile of Figure A1-7 assuming 5λ depth of analysis.

A1-1.10 The model composition profile of Figure A1-9 shows 3 Å of pure carbon over 22 Å of pure Cr_2O_3 on 316L stainless steel, representing an idealized model of the adsorbed hydrocarbon contamination generally found on stainless steel surfaces exposed to the atmosphere. Figure A1-10 is the theoretical depth profile of this model assuming a depth of analysis of 5λ. In this case the O, Cr and Fe atomic concentration values are reduced by the presence of the carbon until the depth profiling proceeds past the carbon, but they have the same relative values (ie: same Cr:Fe ratio) versus depth as derived in the uncontaminated model. The maximum of the Cr:Fe ratio is seen to be at the initial surface. Although the actual oxide thickness is less in this model, the FWHM measure of the oxide thickness from the depth profile is the same due to the presence of the carbon layer. Note that the Oxygen concentration profile initially increases to a maximum, then decreases. This is typical of Oxygen concentration profiles seen on actual samples, which will generally have some adsorbed hydrocarbon contamination on the surface.

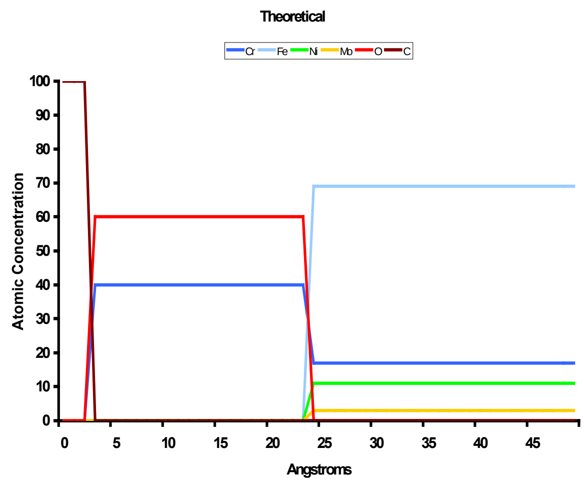

Figure A1-9
Composition versus depth of a carbon layer over a Cr_2O_3 layer on stainless steel.

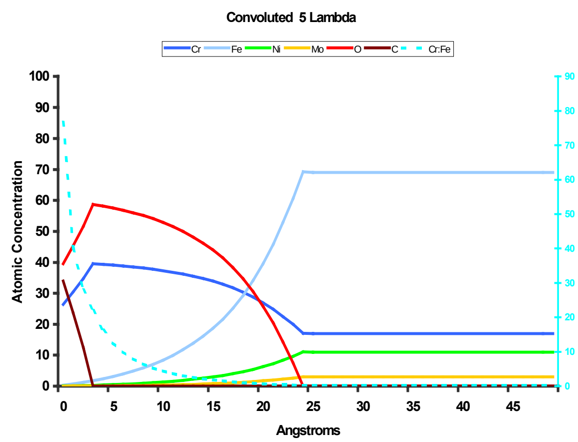

Figure A1-10
Theoretical depth profile of Figure A1-9 assuming 5λ depth of analysis.

A1-1.11 The model composition profile of Figure A1-11 shows a 3 angstrom carbon layer over 3 Å of pure Fe_2O_3 over 19 Å of pure Cr_2O_3 on 316L stainless steel. Figure A1-12 is the theoretical depth profile of this model assuming a depth of analysis of 5λ. This profile is seen to be similar to the depth profiles generally observed for passivated stainless steel. The Cr:Fe ratio maximum occurs below the initial surface, and the initial surface atomic concentrations of the elements of interest are diluted by the presence of the carbon layer on the surface. The oxide thickness, as measured by the FWHM technique, is affected by both the presence of the carbon layer and the depth of analysis.

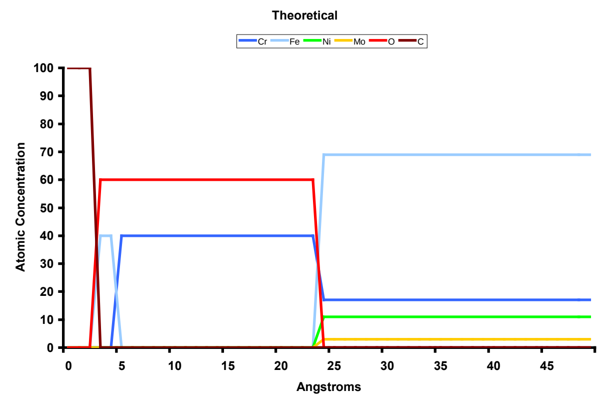

Figure A1-11
Composition versus depth of a carbon layer over a Fe_2O_3 layer over a Cr_2O_3 layer on stainless steel.

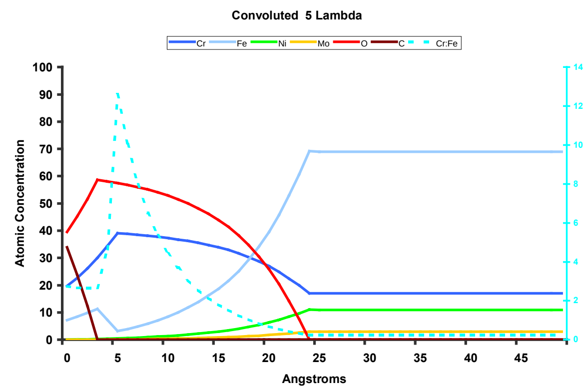

Figure A1-12
Theoretical depth profile of Figure A1-11 assuming 5λ depth of analysis.

A1-1.12 It must be emphasized that these derived depth profiles are for models with perfect interfaces and perfect compositions instead of the compositional gradients observed in real systems. Additional measurement uncertainties result from roughness and non-planarity of the surface, and from differential sputtering rates for different chemical species during depth profiling.

A1-1.13 The depth profiles of real systems must be interpreted with an understanding of the effects described in this Appendix and a realization that they are not ideal. The same considerations pertain to Auger depth profile analysis.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI F61-0301
GUIDE FOR ULTRAPURE WATER SYSTEM USED IN SEMICONDUCTOR PROCESSING

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001.

1 Purpose

1.1 This guide establishes the typical definitional requirements for an ultrapure water (UPW) system used in semiconductor manufacturing. It is intended to establish a common basis for developing detailed specifications in subsequent documents concerning design, performance and certification and monitoring of UPW systems.

1.2 This document may be used by users and suppliers as a basis for developing site-specific UPW specifications and performance criteria.

2 Scope

2.1 This guide applies to ultrapure water systems used in semiconductor manufacturing facilities for supplying high purity water for chemical dilutions, wafer processing and other manufacturing processes.

2.2 This guide can be used to understand the design elements and functionality of all UPW systems, which includes a Reverse Osmosis (RO) and a Deionization (DI) process. However, it is most applicable to newer designed UPW systems that support submicron linewidth device manufacturing.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guide does not define the actual specifications generally negotiated between the user and the manufacturer of the UPW system, against which water samples are tested and qualification is passed.

3.2 This guide does not address the testing and prequalification of materials, subassemblies, or components used in a UPW system.

3.3 This guide does not address the protocols and requirements defined by the manufacturer concerning the installation of the UPW system.

3.4 This guide does not address the type, level, or frequency of testing necessary and appropriate for ongoing monitoring of a UPW system.

3.5 This guide does not address the frequency or scope of ongoing maintenance for UPW systems including change out of resin beds and replacement of filters.

3.6 This guide does not intend to cover any of the important safety considerations that relate to the proper installation, operation, or maintenance of a UPW system.

4 Terminology

4.1 *Acronyms and Abbreviations*

4.1.1 *TOC* — Total organic carbon, also Total Oxidizable Carbon. Refers to organic compounds.

4.1.2 *UPW* — Ultrapure Water System consisting of multiple components including a Reverse Osmosis (RO) and a Deionization (DI) process.

4.2 *Definitions*

4.2.1 *activated Carbon* — a media filter used to remove oxidizing agents, like chlorine and chloramines, and remove (adsorb) certain TOC compounds.

4.2.2 *anion* — a negatively charged ion.

4.2.3 *cation* — a positively charged ion.

4.2.4 *clarifier* — a piece of water treatment equipment, typically used at municipal drinking water plants, to remove suspended solids from surface water and/or to soften surface water.

4.2.5 *degasification* — the removal of a certain amount of volatile compounds dissolved in water.

4.2.6 *deionization* (DI) — the removal of undesirable ions from water.

4.2.7 *DI storage* — generally refers to a storage tank that contains DI water, located between the primary and polishing ion exchange subsystems.

4.2.8 *DI (deionized) water* — generally refers to water that has passed through a full-train ion exchange system or RO water that has been polished by ion exchange.

4.2.9 *dissolved solids* — contaminants in water that are so small that they are uniformly distributed, including ions and the smallest TOC and silica compounds.

4.2.10 *dual-beds* — an ion exchange scheme where a cation exchange unit is followed by an anion exchange unit.

4.2.11 *electrodeionization (EDI)* — a water treatment technology that utilizes mixed-bed ion exchange plus an electrical potential to remove undesirable dissolved solids. Also referred to in the industry as CDI (Continuous Deionization).

4.2.12 *filtration* — the removal of suspended solids by passing water through some form of solid or semi-solid medium.

4.2.13 *final filter* — generally the final treatment step in a UPW system; used to remove suspended solids.

4.2.14 *full-train DI* — an ion exchange scheme where a cation exchange unit is followed by an anion exchange unit and a mixed-bed ion exchange unit.

4.2.15 *ground water* — water located below the surface of the earth, also called *well water*.

4.2.16 *heat exchanger* — a piece of equipment used to control the temperature of a water stream.

4.2.17 *ion exchange* — a water treatment technology used in a high-purity water treatment application to exchange undesirable cations for hydrogen ions and undesirable anions for hydroxide ions.

4.2.18 *loop* — the distribution system that includes the continuous circulation of UPW from the Final Filter back to the DI storage tank. End users draw off of the loop.

4.2.19 *low-pressure UV units* — units that use UV lamps that have a slight vacuum within. Typically, low-pressure lamps are called *254 nm* for ozone destruction and bacterial inactivation or *185 nm* for TOC reduction.

4.2.20 *medium-pressure UV units* — units that use UV lamps that have a positive pressure within. Used with bacterial inactivation/ozone destruction lamps or TOC reduction lamps.

4.2.21 *microfiltration* — generally refers to filters designed to remove suspended solids less then one micron in size but greater than 0.1 micron in size.

4.2.22 *mixed-beds* — ion exchange vessels used to polish already purified water, in which both cation and anion exchange occurs.

4.2.23 *multimedia filter* — generally refers to a suspended-solids removal piece of equipment that contains two or more filtering media such as anthracite and sand, or anthracite, sand and garnet.

4.2.24 *Ozone* — Ozone (O_3) may be injected into the *Supply* and/or *Return* line to control microbiological contaminants and also to enhance the action of TOC breakdown in downstream TOC reducing UV units.

4.2.25 *polishing ion exchange* — a cation/anion exchange step located downstream of primary ion exchange.

4.2.26 *pretreated water* — generally refers to treated water that is fed to reverse osmosis (RO) units.

4.2.27 *primary ion exchange* — the first cation/anion exchange step in a high purity water treatment scheme.

4.2.28 *raw water* — any untreated natural water like river water, lake water, ground water, or seawater. May also refer to the treated feed water that enters a plant from a municipal drinking water source or other source.

4.2.29 *return* — the UPW sent to but not used by end users that returns to the DI storage tank.

4.2.30 *reverse osmosis (RO)* — a filtration technology that utilizes a semi-permeable membrane to remove essentially all suspended solids and the vast majority of all dissolved solids. Generally refers to water (permeate) that has passed through a reverse osmosis (RO) membrane.

4.2.31 *RO storage* — generally refers to a storage tank that contains RO water.

4.2.32 *scale inhibitor* — a chemical used to minimize or eliminate the precipitation of slightly-soluble salts, like calcium carbonate (limestone) or calcium sulfate (gypsum), within water treatment equipment.

4.2.33 *supply* — the UPW sent to end users.

4.2.34 *surface water* — water located on the surface of the earth, such as river water, lake water, and seawater.

4.2.35 *TOC* — total organic carbon, also Total Oxidizable Carbon. Refers to organic compounds.

4.2.36 *treated water* — water that has passed through water treatment equipment and/or received chemical injections in order to modify the dissolved and/or suspended solids content of the water.

4.2.37 *ultrafiltration* — generally refers to filters designed to remove all submicron suspended solids.

4.2.38 *ultraviolet (UV)* — electromagnetic energy with around a 100–400 nm (nanometer) wavelength.

4.2.39 *UPW (ultra pure water)* — the highest purity water produced by a semiconductor water treatment system, which is sent to the end users for use in manufacturing.

5 General Requirements

5.1 *Materials* — Components of the UPW system must be appropriate to the application and conform to electrical, mechanical, and purity requirements, as well as the corrosive properties of the UPW chemistry. These requirements are defined by the physical installation environment, local and national code interpretations, process requirements, and delivery specifications.

5.2 *System Installation* — The UPW system is installed according to a protocol that ensures mechanical integrity, leakproof operation, and no or minimal contamination being added from distribution throughout the system.

5.3 *Acceptance Tests* — Acceptance tests are conducted on each subsystem or system produced. Such tests may include performance demonstrations, demonstrations of reliability criteria, and achievement of purity standards. Such tests are the basis for acceptance or rejection by the purchaser against a pre-negotiated set of criteria for the performance of the system.

5.4 *Qualification Testing* — Qualification testing may include tests for resistivity, temperature, pressure, TOC, dissolved oxygen, particle levels, bacteria, total silica, dissolved silica, non-volatile residue, ions, and metals.

5.5 *Monitoring* — UPW systems are monitored for continuing performance against desired and achievable levels of quality. Action limits are generally set to determine when system performance suggests that corrective action is required.

5.6 *UPW specifications* — UPW systems are generally guaranteed to deliver a certain quality of water on an ongoing basis. The guaranteed performance is established in advance between the UPW equipment manufacturer and the system owner. Both qualification testing and monitoring testing use the guaranteed specifications to determine the parameters and levels of purity to be tested.

5.7 *Recycle/Reclaim Opportunities* — There can be several opportunities for using water within a UPW system, and should be recognized during the design phase when possible. Examples are; use of 1st pass reject for cooling tower make-up water, returning UF reject to Primary or Feed water Tank, re-use of last stage rinse waters as UPW for lower grade use areas, i.e., CMP, isolation of CMP waste stream, for possible reclaim/reuse.

6 Source Water

6.1 *Raw Water* — is the raw material from which UPW is made. Untreated raw water is natural water that is obtained from a surface source such as a lake or river, or from a ground water source. The raw water to a UPW system is most frequently treated *Municipal Drinking Water*.

6.2 *Municipal Drinking Water* — Most natural raw waters must be treated in order to produce drinking water that meets federal and state requirements. There are upper limits for inorganic contaminants (e.g., asbestos, arsenic, copper, and lead), pesticides, volatile organic chemicals (e.g., benzene, trichloroethylene, toluene, and xylene), turbidity, microbiological contaminants, and radiological contaminants (e.g., radon 226, radon 228, tritium, and strontium 90). *Municipal Water Treatment* may utilize only chlorination, or filtration and chlorination for certain ground water sources. For many surface water sources, coagulation (injection of aluminum or iron salts), flocculation (injection of a long-chain polymer), sedimentation, lime or lime/soda ash softening, filtration, chlorination or chloramination (chlorine plus ammonia) and other steps may be required.

7 Major Treatment Processes

7.1 *Pretreatment* includes all of the water treatment steps ahead of the *Reverse Osmosis Membrane Treatment* step. These steps are primarily required to protect the membrane units from scaling with sparingly soluble salts, fouling with living or non-living suspended particles, or chemical attack by pH, oxidizing agents or other dissolved contaminants. Pretreatment equipment may include media filtration, micro filtration, or ultrafiltration (bulk suspended solids removal), 1–5 micron cartridge filtration (polishing step for suspended solids removal), sodium-cycle cation exchange (softening, to remove scale-forming cations), acid injection (to minimize cellulose acetate membrane damage and/or to control carbonate scales), scale inhibitor injection (to control scaling), activated carbon filtration (to remove oxidizing agents and certain organic molecules), and sulfite ion injection (to remove oxidizing agents).

7.2 Reverse osmosis *Membrane Treatment* provides extremely high rejection of dissolved ions (charged atoms and molecules), organic (carbon containing) compounds, silica (silicon containing) compounds, and virtually complete rejection of suspended contaminants, but will not reject dissolved gases and volatile organic compounds as well. Reverse osmosis (RO) units may be configured in a *double-pass* arrangement consisting of two RO membrane units in series. *Permeate* (filtered water) from the first RO unit is sent to the second RO unit to be filtered again. It is not uncommon for the permeate from a double-pass RO unit to have a resistivity reading up to 0.5–4 Megohm-cm, with less than one milligram per liter of organic and silica contaminants. The more contaminants removed in the membrane treatment step, the lower the loading on the *Polishing* steps.

7.3 *Volatiles Removal* — The removal of dissolved oxygen, carbon dioxide, other gases, and volatile organic compounds is a necessary treatment step. The removal of these volatile contaminants is accomplished to acceptable levels in vacuum degasifiers and in membrane degasification units. The removal of volatiles that can form ions and the removal of volatile organic compounds reduce the loading on downstream *Polishing* equipment.

7.4 *Polishing* — The relatively low level of contaminants that were not removed in the *Membrane Treatment* and *Volatiles Removal* steps are polished down to acceptable levels in the *Polishing* steps. Ionic, organic, and silica contaminants are removed in typically two stages of *Ion Exchange* in series (primary beds and polishing beds). Organic compounds, measured as TOC (Total Organic Carbon, or Total Oxidizable Carbon), that are found downstream of the RO membrane units may be subjected to *TOC Reduction* ultraviolet (UV) irradiation (185 nanometer low pressure units or medium pressure units) to convert most of them into ionic compounds that can be effectively removed by *Primary Ion Exchange Units* (usually consisting of Separate Beds, Mixed Beds or EDI/CDI/E-Cell). TOC compounds that exit the primary ion exchange units are typically subjected to TOC reducing UV irradiation to break them into ionized compounds to be removed by the *Polishing Ion Exchange Units*. The vast majority of all living suspended particles (mainly bacteria) that enter any 254 nm UV unit are inactivated. Downstream filters with a pore size of less than or equal to 0.45 micron remove the inactivated bacterial bodies. The final filter prior to *Distribution* typically has a pore size of less than 0.2 micron.

8 Distribution

8.1 *Distribution* is frequently composed of one or more *Loops*. Each loop consists of UPW that continuously recirculates through appropriate piping from the final filters, to the manufacturing areas requiring UPW (end users), and back to a tank located within the *Polishing* section to be polished again. The UPW to the end-user area is commonly called the *Supply*. The UPW that travels from the end-user area back to the water treatment area is commonly called the *Return*. Ozone may be injected into the *Supply* and/or *Return* line to control microbiological contaminants and also to enhance the action of TOC breakdown in downstream TOC reducing UV units. Sometimes ozone is injected into the *Supply* line for similar reasons (requires de-ozonation at the end-use points). Sometimes the UPW in the distribution loop is heated (hot loop) for particular processes.

8.2 *Basic System Components*

8.3 *General* — Each UPW system contains certain basic components and a variety of design options to meet particular customer and facility needs. An example of a UPW system is shown in Figure 1 attached.

9 Related Documents

9.1 *SEMI Standards*

SEMI F4 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI F31 — Guide for Bulk Chemical Distribution Systems

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

9.2 *SIA*[1]

National Technology Roadmap For Process Chemicals

1 Semiconductor Industry Association, 181 Metro Drive, Ste 150, San Jose, CA 95110, USA

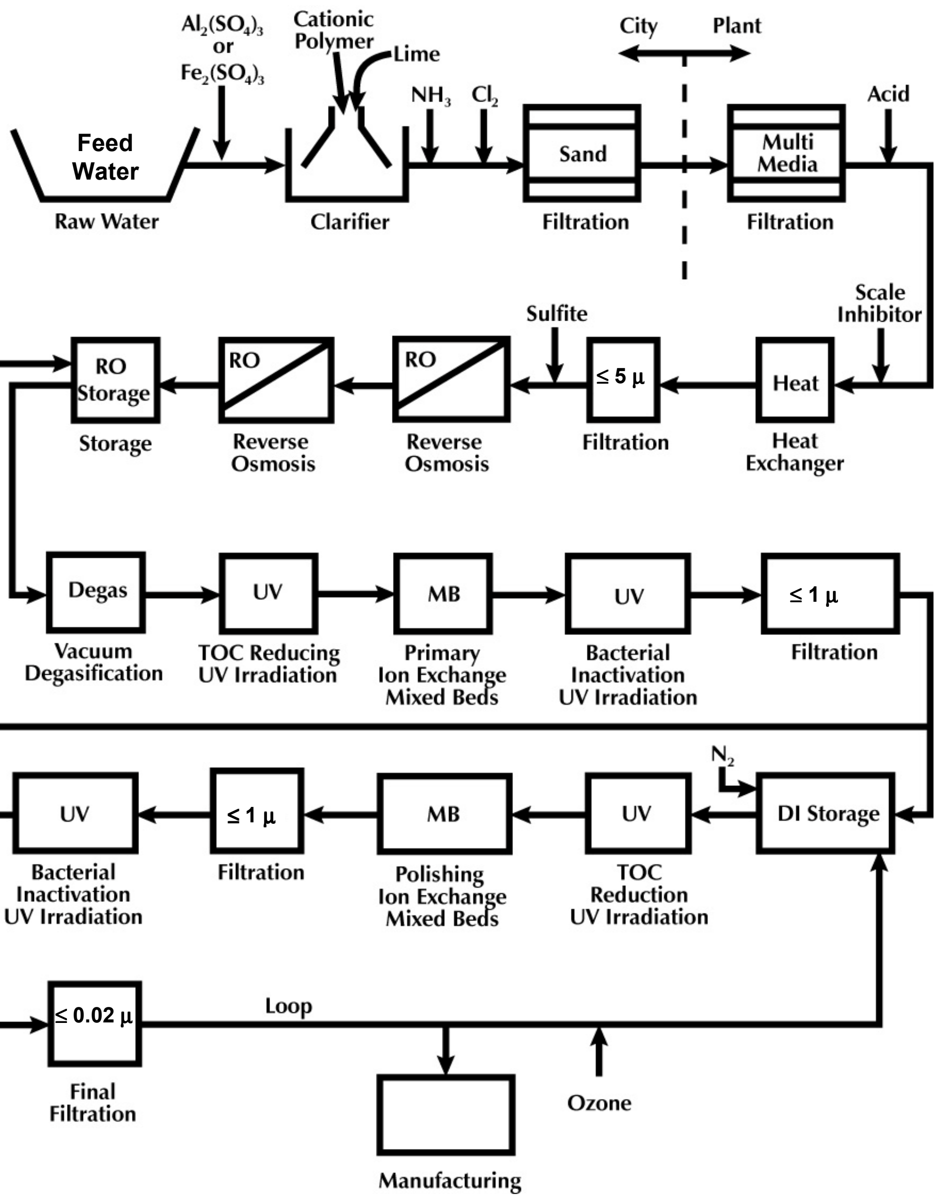

Figure 1
Schematic of a Typical Ultrapure Water System

SEMI F62-0701
TEST METHOD FOR DETERMINING MASS FLOW CONTROLLER PERFORMANCE CHARACTERISITICS FROM AMBIENT AND GAS TEMPERATURE EFFECTS

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Facilities Committee on March 22, 2001. Initially available at www.semi.org May 2001; to be published July 2001.

1 Purpose

1.1 The purpose of this document is to define a method for testing MFCs being considered for installation into a gas distribution system and to quantify ambient and gas temperature effects on the MFC's indicated and actual flow.

2 Scope

2.1 This test method applies to metal and polymer sealed MFCs with flow rates up to 30 slpm. The tests include those listed below and are to be performed in the following order:

1. Ambient Temperature Effects (Steady State and Transient)
2. Gas Temperature Effects (Steady State and Transient)

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This method evaluates mass flow controllers in typically encountered, realistic operating conditions.

3.2 This test method does not address operational influences outside of the manufacturer's published limitations.

4 Referenced Standards

4.1 None.

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *DUT* — device under test

5.1.2 *g* — gravity

5.1.3 *kPa* — kiloPascal

5.1.4 *MFC* — mass flow controller

5.1.5 *NIST* — National Institute of Standard Technologies

5.1.6 *sccm* — standard cubic centimeters per minute

5.1.7 *slpm* — standard liters per minute

5.2 *Definitions*

5.2.1 *stability, long term* — reading ± 2% for over one hour.

5.2.2 *stability, short term* — reading ± 2% within five minutes.

5.2.3 *zero setpoint* — manufacturer's setpoint for no flow from the MFC.

5.3 *Descriptions of Terms*

5.3.1 MFC_1 — inlet mass flow controller.

5.3.2 T_a — the temperature in the environmental control chamber.

5.3.3 T_g — gas temperature at the inlet to the DUT.

5.3.4 T_{max} — maximum manufacturer-rated temperature for an MFC.

5.3.5 T_{min} — 20°C or manufacturer rated minimum temperature, whichever is greater.

5.3.6 TC_g — temperature coefficient due to changing gas temperature of DUT.

5.3.7 TC_e — temperature coefficient due to changing environmental temperature of DUT.

5.3.8 Q_a — for the purpose of this method, the output value of the flow standard in units of mass flow.

5.3.9 Q_{ind} — for the purpose of this method, the output value of the device under test in units of mass flow.

5.3.10 Q_{sp} — for the purpose of this method, the intended output in mass flow units for a particular setpoint.

5.3.11 V_a — valve A

5.3.12 V_b — valve B

5.3.13 $V_{I\,i}$ — inlet isolation valve

5.3.14 V_{io} — outlet isolation valve

6 Significance and Use

6.1 This test method defines a procedure for testing components being considered for installation in a gas distribution system. Application of this method is expected to yield data allowing an end user to choose among components tested for the purpose of qualification for this installation.

7 Apparatus

7.1 See Figures 1a and 1b for schematics of the set-ups.

7.2 *Flow Measurement Device*, National Institute of Standard Technologies (NIST) traceable and capable of measuring steady-state and transient flow characteristics, preferably with differential pressure sensors across a flow restriction. This device should have a relative accuracy of at least 2 to 1 with respect to the DUT.

7.3 *Temperature Measurement Device*, to measure test gas temperature, NIST traceable and capable of real-time measurement, with a low mass (< 0.05 g) sensor and with low thermal losses through the leads (< 0.3 mW/°C).

7.4 *Pressure Measurement Device*, to measure test gas pressure, NIST traceable, and capable of real-time measurement to measure test gas pressure.

7.5 *Gas Pressure Control Regulators*, to maintain test gas pressure at 275 kPa ± 5 kPa.

7.6 *Gas Temperature Control*, heat exchangers and heaters to maintain the gas temperature equal to the test temperature within ± 1 °C at the test flow rates.

7.7 *Environmental Chamber*, capable of stable temperature control (± 1°C) from at least T_{min} to a point exceeding the maximum rated MFC temperature by 10°C.

8 Reagents and Materials

8.1 *Test Gas*, clean, dry nitrogen.

8.2 *Tubing*, cleaned and maintained to have no adverse effects on the test.

8.3 *Valves*, capable of unimpaired operation at 100°C.

9 Safety Precautions

9.1 All manufacturers' recommendations should be followed and noted when testing the unit. Any safety precautions should always be followed.

9.2 This standard does not purport to address all of the safety problems, if any associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

10 Technical Precautions

10.1 The flow standard may read a non-zero value due to heating of the gas in the test to determine transient effects on the zero. These readings should be noted.

11 Preparation of Apparatus

11.1 *Setup and Schematic*, (see Figure 1a) *Ambient Temperature Effects*

11.1.1 Install an ambient temperature sensing device within 5–10 centimeters horizontally adjacent to the MFC body. The probe should not be in contact with the MFC body or the environmental chamber walls.

11.1.2 Position the gas temperature sensor in the center of the gas stream no more than 10 cm upstream from the inlet surface of the MFC body.

11.1.3 After installation of the MFC, flow nitrogen at a 100% setpoint to purge the system for a sufficient time to remove atmospheric contamination.

11.1.4 If the MFC has a selectable Auto Zero function, note this on all data presentation documents before proceeding with the test.

11.1.5 Minimize the length of tubing between the heater and the device under test to reduce gas temperature changes.

11.2 *Setup and Schematic*, (see Figure 1b) *Gas Temperature Effects*

11.2.1 Install a base temperature sensing device, T_e adjacent to the MFC body. The probe should be in contact with the MFC body.

11.2.2 Install an ambient temperature sensing device within 5–10 centimeters horizontally adjacent to the MFC body. The probe should not be in contact with the MFC body or the environmental chamber walls.

11.2.3 Position the gas temperature sensor in the center of the gas stream no more than 10 cm upstream from the inlet surface of the MFC body.

11.2.4 After installation of the MFC, flow nitrogen at a 100% setpoint to purge the system for a sufficient time to remove atmospheric contamination.

11.2.5 If the MFC has a selectable Auto Zero function, note this on all data presentation documents before proceeding with the test.

12 Calibration and Standardization

12.1 The flow standard, temperature standards, and pressure standards used are to be NIST traceable.

12.2 All ancillary equipment must be calibrated and maintained to the manufacturer's recommendations. Current calibration records must be maintained.

13 Conditioning

13.1 Reference conditions as listed in Appendix 1 are to be maintained unless otherwise noted.

14 Procedure

14.1 *Environmental Temperature Effect*

14.1.1 Install the test specimen in the test set-up according to the manufacturer's recommendations, see Figure 1a.

14.1.2 Set the environmental chamber temperature (T_e) to T_{min} and allow it to stabilize for one hour. Ensure that gas temperature (T_g) and ambient temperature (T_e) are within 2°C of each other before beginning data collection.

14.1.3 Close V_{ii} and V_{io}, and record the MFC Q_{ind} at a zero setpoint.

14.1.4 Open V_{ii} and V_{io}. Change the MFC flow setpoints to 25%, 50%, 75%, and 100% of full rated scale.

NOTE 1: T_g and T_e must be within 2°C of each other.

14.1.5 At each setpoint, record T_g, Q_{ind} once, and a minimum of 10 values at a maximum of five second intervals of T_e and Q_a for at least 60 seconds. Record the average of the 10 values as shown in Table 3.

14.1.6 Repeat Section 14.1.3.

14.1.7 Maintain the setpoint at zero and change the environmental chamber temperature T_{em} to the next level indicated in Figure 2.

14.1.8 Record the Q_{ind} at the zero setpoint in real time (max 30-second intervals) as the temperature T_e is changing. See example of data collection shown in Table 4.

14.1.9 Allow temperature T_e to stabilize for a minimum of one hour.

NOTE 2: The time for the T_e to stabilize at each level should be increased to two hours if the indicated flow at T_e level 1 and 9, or 2 and 8, or 3 and 7, or 4 and 6 are not within 5% of each other. See Figure 2.

14.1.10 Open the isolation valves V_{ii} and V_{io}.

14.1.11 Repeat Sections 14.1.3–14.1.9 for each T_e level, as shown in Figure 2.

14.2 *Gas Temperature Effect*

14.2.1 Install the test specimen in the test set-up according to the manufacturer's recommendations, see Figure 1b.

14.2.2 Allow the system to stabilize for one hour. See Figure 1. Refer to Figure 4 for flow chart.

14.2.3 Set the heater temperature to raise the gas temperature, T_g, such that T_g is elevated 10°C above ambient.

14.2.4 Simultaneously open V_{ii} and close V_{io}. Continue to monitor T_g, T_e, indicated flow, and actual flow for one hour. If after one hour, the actual flow or T_g has not achieved long-term stability, or if T_g is not equal to T_e + 10 (±2°C), continue until these conditions are met or until an additional one hour period has elapsed. If long-term stability is not achieved, note this occurrence and record the average value of 10 samples minimum taken at maximum five-second intervals for each of T_g, T_e, indicated flow, and actual flow as shown in Table 5, for at least 60 seconds.

NOTE 3: If T_g is not 10°C above ambient return to 14.2.3 and adjust the temperature.

14.2.5 Repeat 14.2.3–14.2.4 until all required setpoints have been run.

15 Calculations or Interpretation of Results

15.1 *Calculations*

15.1.1 The measured values for Q_{ind}, Q_a, and T_g are determined by an arithmetic average of samples taken at time intervals after stability has been achieved at each temperature and flow condition.

15.1.2 The ambient temperature coefficient of flow shall be calculated as follows:

$$TC_e(\%/°C) = \frac{Q_a2 - Q_a1}{Q_{sp}\ x\ (T_e2 - T_e1)}\ x\ 100$$

where Q_{a1} and Q_{a2} are the actual flow rates measured at ambient temperatures T_{e1} and T_{e2} respectively. For zero setpoint use the following.

$$TC_{zero} = \frac{Q_a2 - Q_a1}{Q_{fullscale}\ x\ (T_g2 - T_g1)}\ x\ 100$$

This yields a result expressed as a percent of reading per °C. See example of data collection and analysis shown in Table 3. Final TC_e is to be presented in Table 2 format.

15.1.3 The gas temperature coefficient of flow is to be calculated as follows:

$$TC_g(\%/°C) = \frac{Q_a2 - Q_a1}{Q_{sp}\, x\, (T_g2 - T_g1)}\, x\, 100$$

where Q_{a1} and Q_{a2} are the actual flow rates measured at gas temperatures T_{g1} and T_{g2} respectively. For zero setpoint use the following.

$$TC_{zero} = \frac{Q_a2 - Q_a1}{Q_{fullscale}\, x\, (T_g2 - T_g1)}\, x\, 100$$

This yields a result expressed as a percent of reading per °C. Refer to Table 5 for an example of data collection and analysis. Final TCg is to be presented in Table 1 format.

16 Reporting Results

NOTE 4: All special features (remote electronics, auto zero, etc.) should be noted on the testing results for comparative analysis.

16.1 The gas temperature coefficient at each flow rate is to be displayed as shown in Table 1.

16.2 The gas temperature coefficient data from Table 1 is to be displayed as shown in Figure 5. The gas temperature, actual flow, and indicated flow are to be displayed versus time as shown in Figure 6.

16.3 The ambient temperature coefficient is to be presented in tabular form as shown in Table 2.

16.4 The data for the steady-state effect from Table 2 should be presented as shown in Figure 7. The data for the transient effect from Table 4 should be presented as shown in Figure 8.

17 Illustrations

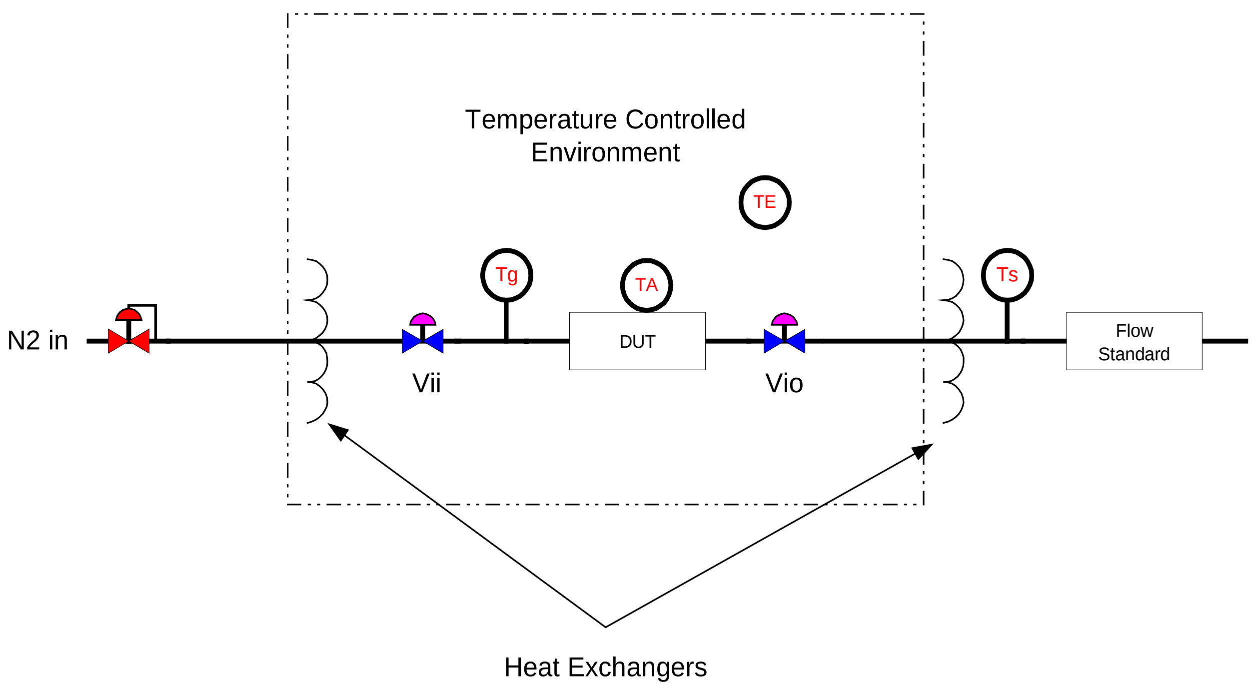

Figure 1a
Ambient Temperature Effect Test Apparatus

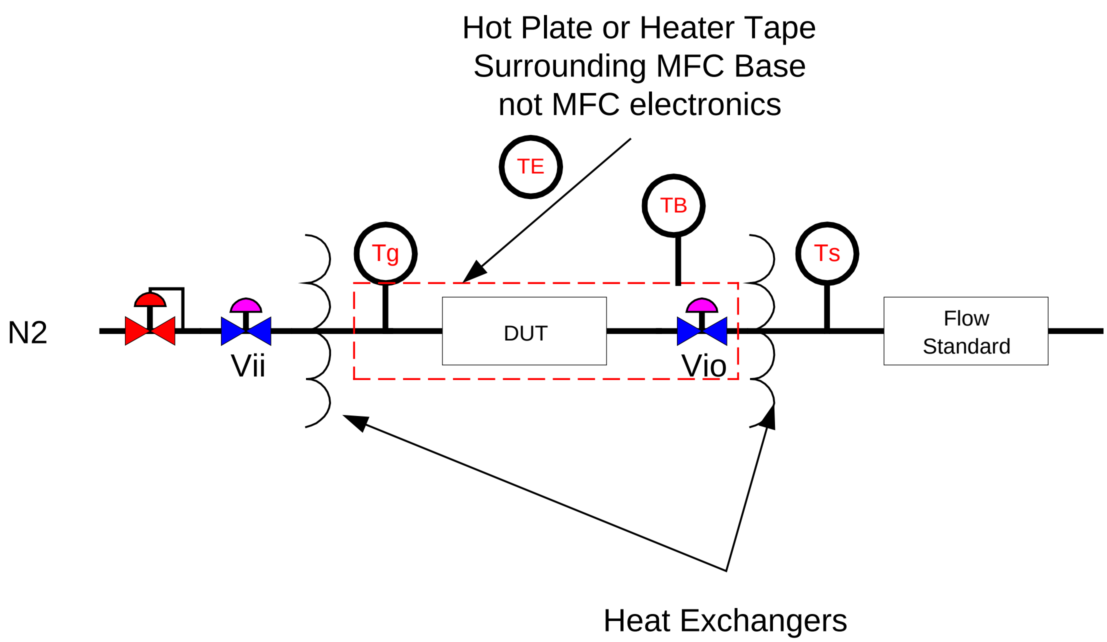

Figure 1b
Gas Temperature Effect Test Apparatus

NOTE 5: Flow Standard may be located upstream or down stream.

Step m	$\mathbf{T_{em}}$
1.	$\mathbf{T_{min}}$
2.	$\mathbf{T_{min} + 1/4\ (T_{max} - T_{min})}$
3.	$\mathbf{T_{min} + 1/2\ (T_{max} - T_{min})}$
4.	$\mathbf{T_{min} + 3/4\ (T_{max} - T_{min})}$
5.	$\mathbf{T_{max}}$
6.	$\mathbf{T_{min} + 3/4\ (T_{max} - T_{min})}$
7.	$\mathbf{T_{min} + 1/2\ (T_{max} - T_{min})}$
8.	$\mathbf{T_{min} + 1/4\ (T_{max} - T_{min})}$
9.	$\mathbf{T_{min}}$

Figure 2
Ambient Temperature Setpoint ($\mathbf{T_{em}}$)

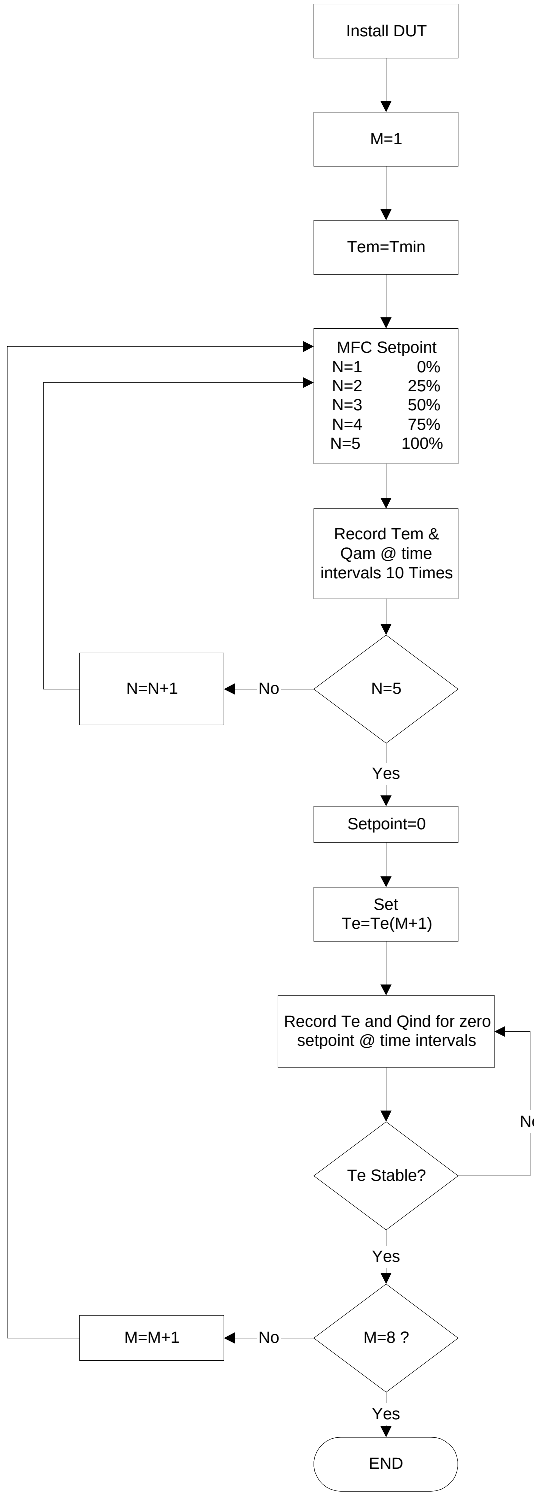

Figure 3
Ambient Temperature Test Procedure Flow Chart

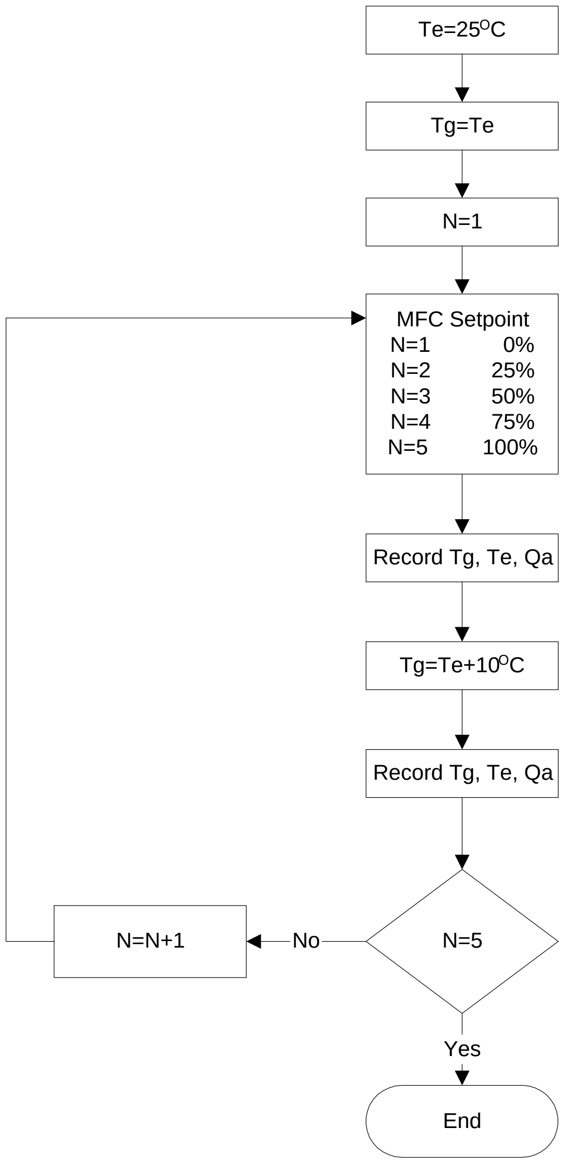

Figure 4
Gas Temperature Test Procedure Flow Chart

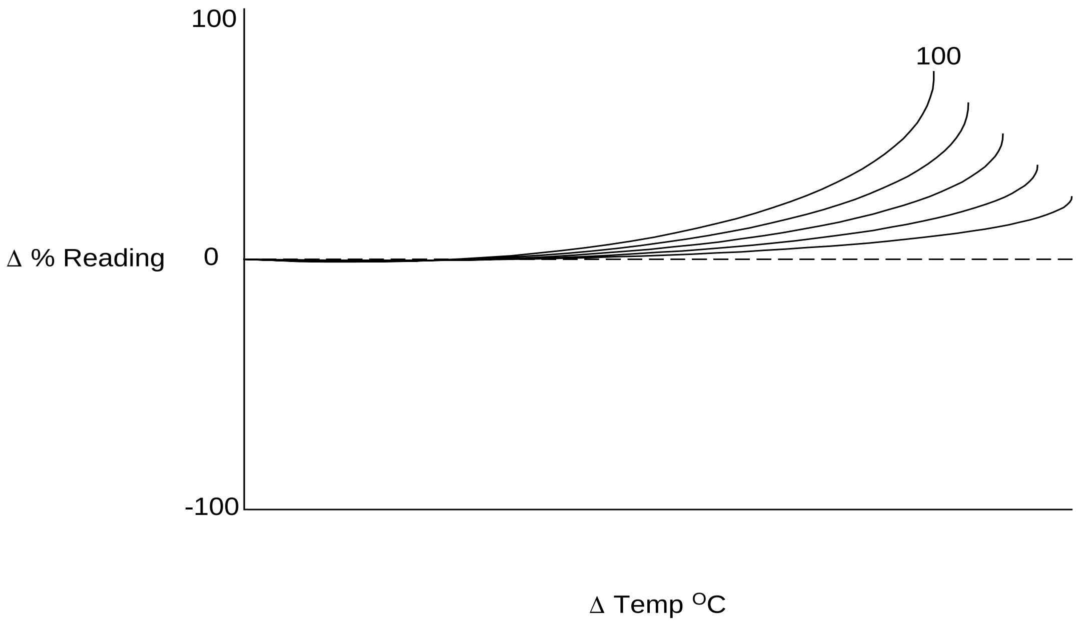

Figure 5
Steady State Ambient Temperature Effects

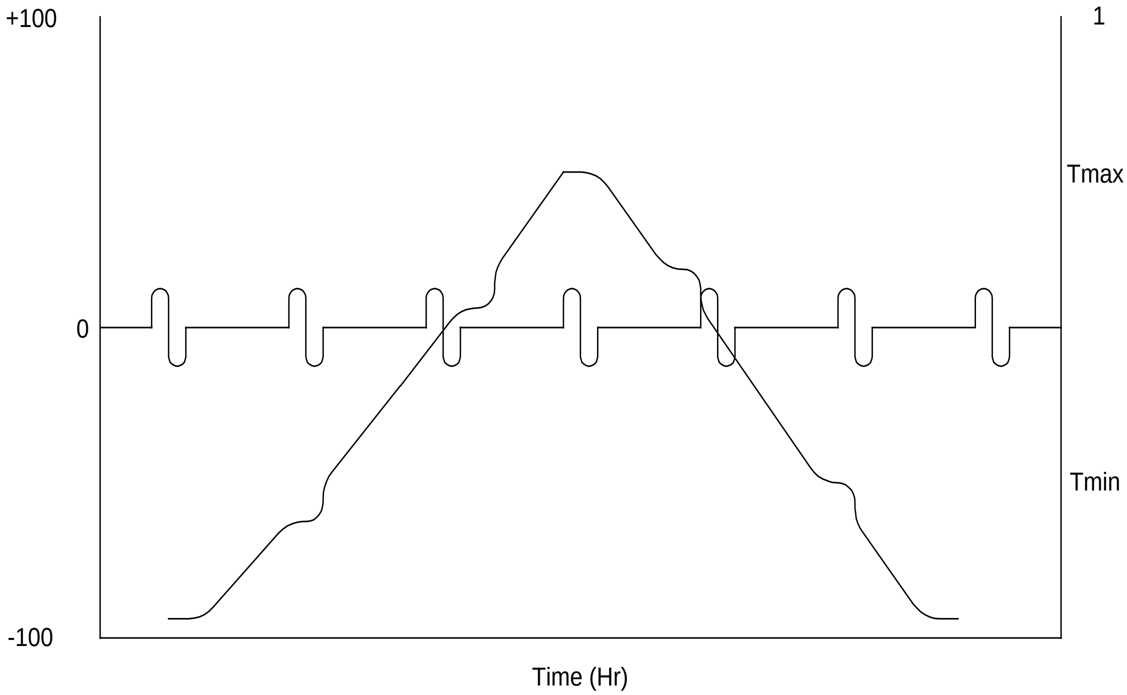

Figure 6
Transient Ambient Temperature Effects

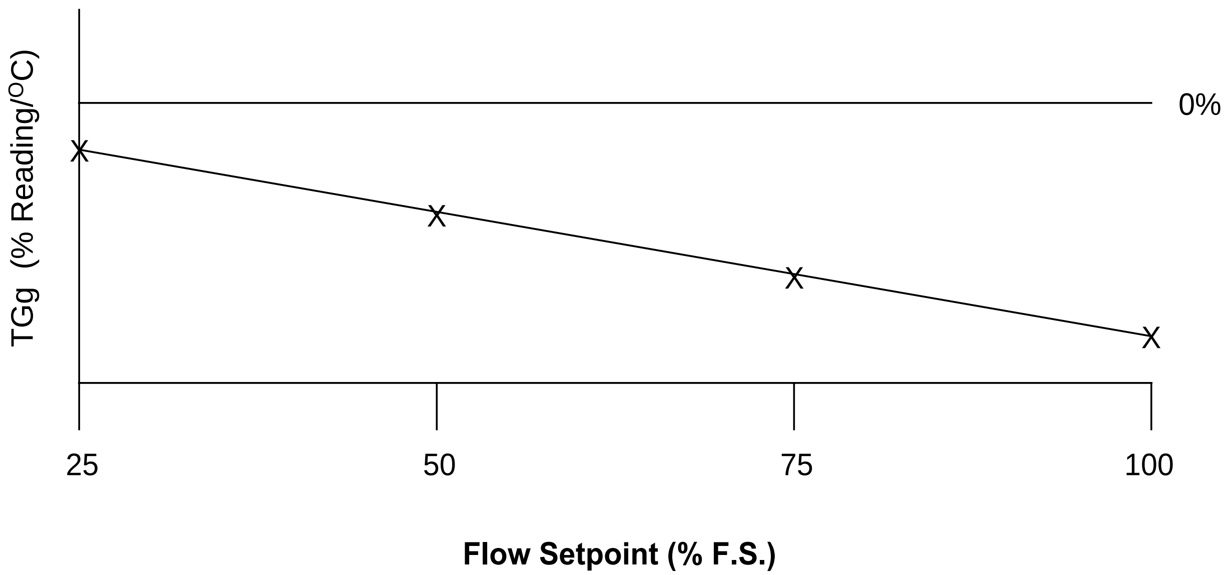

Figure 7
Gas Temperature Effect on Steady State Span

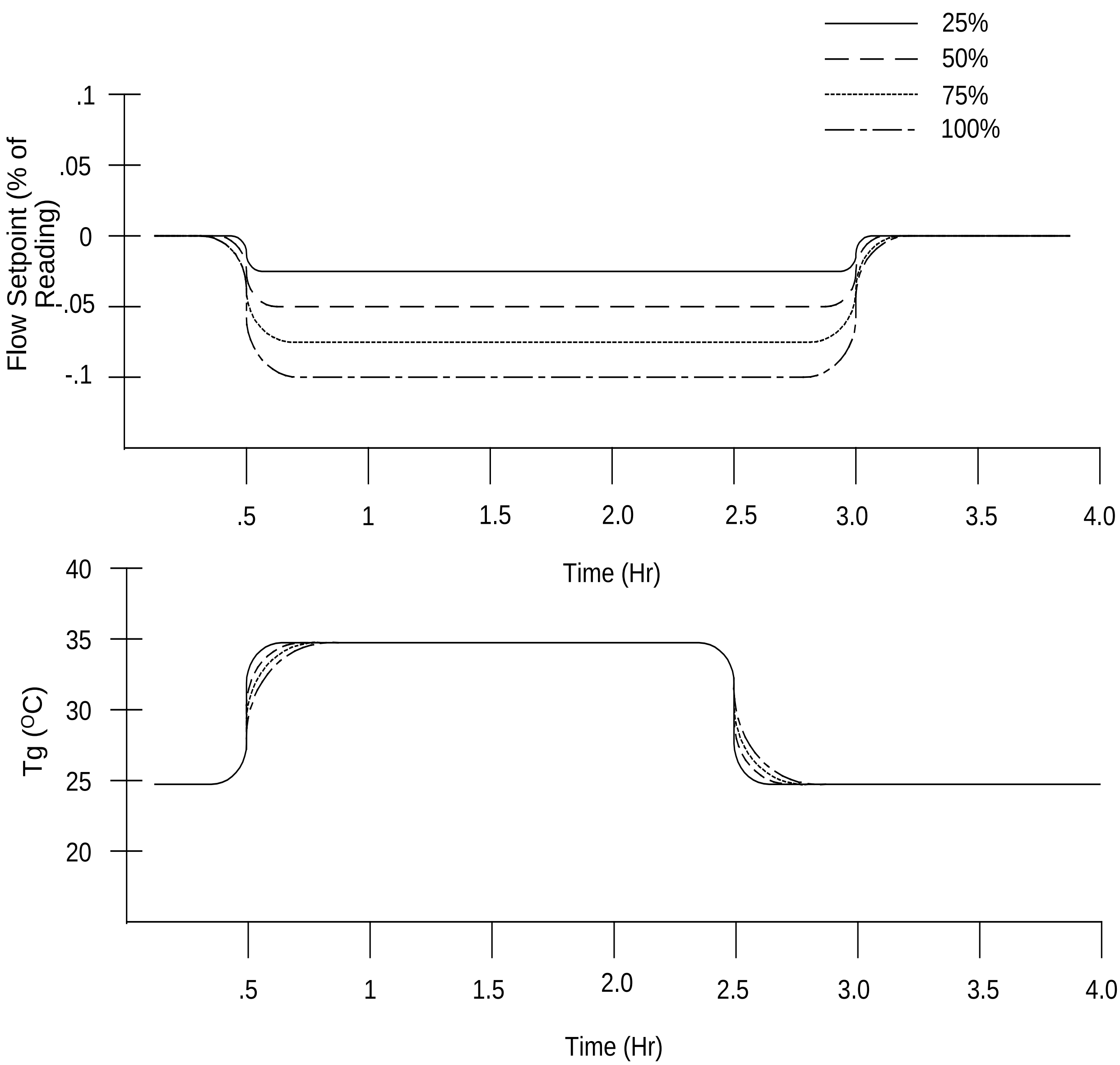

Figure 8
Transient Gas Temperature Effect

Table 1 TC_e Readings

TC_e (% Reading/°C)								
	T_{e2}-T_{e1}	T_{e3}-T_{e2}	T_{e4}-T_{e3}	T_{e5}-T_{e4}	T_{e5}-T_{e6}	T_{e6}-T_{e7}	T_{e7}-T_{e8}	T_{e8}-T_{e9}
Flow Setpoint % F.S.								
25								
50								
75								
100								
0								

NOTE 1: Plot as in Figure 7.

Table 2 TC_g Readings

Flow Setpoint (%F.S.)	TC_g(% reading/°C)
25	-0.06
50	-0.08
75	-0.09
100	-0.11
0	

NOTE 1: Plot as in Figure 5.

Table 3 Data Presentation for 500 sccm MFC

Data Collection									
	T_{e1} Q_{a1}	T_{e2} Q_{a2}	T_{e3} Q_{a3}	T_{e4} Q_{a4}	T_{e5} Q_{a5}	T_{e6} Q_{a6}	T_{e7} Q_{a7}	T_{e8} Q_{a8}	T_{e9} Q_{a9}
0% S.P. Q_{ind}									
25% S.P. Q_{ind} T_g Avg. of 10 readings									
50% S.P. Q_{ind} T_g Avg. of 10 readings									
75% S.P. Q_{ind} T_g Avg. of 10 readings									
100% S.P. Q_{ind} T_g Avg. of 10 readings									

Data Presentation

$$Tc_e = \frac{Q_a(30)-Q_a(20)}{T_e(30)-T_e(20)\ Q_{s.p.}} \times 100\%$$

$$Tc_e = \frac{134-122}{30.1-20.1\ (125)} \times 100\%$$

$$= 0.96\% \text{ of Reading @ 125 sccm}$$

Table 4 Sample Data for 500 sccm MFC

T_g	T_s	T_e	Q_{sp}	Q_{ind}	Q_A	*Time min.*
		20.1		10		.5
		20.2		15		1
		20.3		11		1.5
		20.4		14		2
		20.5		24		2.5
		. . .		. . .		
		30.9		36		60
		. . .				
		40.0		48		120
		39.0		40		480
		30.0		36		560
		20.0		10		600

NOTE 1: Plot as in Figure 8.

Table 5 Gas Temperature Data Collection

Set point (sccm)	T_s (℃)	T_g (℃)	T_b (℃)	T_e (℃)	Q_a (sccm)	Q_{ind}
0		22.0		21.8	0.00	
25		22.1		21.9	24.94	
25		33.2		22.2	24.52	
50		22.1		21.8	50.08	
50		32.1		21.7	49.21	
75		22.0		21.6	75.13	
75		31.8		21.5	74.02	
100		21.9		21.4	100.18	
100		31.7		21.4	98.83	

$$TC_g = \frac{Q_{af}-Q_{ai}}{[(T_g-T_e)_f-(T_g-T_e)_i]\ Q_{sp}} \times 100\%$$

Example: For the 50 sccm setpoint data collection sample,

$$TC_g = \frac{49.21\text{ sccm}-50.08\text{ sccm}}{[(32.1°C-21.7°C)-(22.1°C-21.8°C)](50\text{ sccm})} \times 100\%$$

$= -0.17\%$ of reading at 50 sccm

APPENDIX 1

NOTE: This appendix is being balloted as an official part of SEMI F062-0701 by full letter ballot procedure. Determination of the suitability of the material herein is solely the responsibility of the user.

(Mandatory Information)

A1-1 Reference Values

Ambient Temperature	23 ±2°C
Gas Temperature	Same as Ambient
Ambient Pressure	101.3 kPa +4.7 kPa (1013 mbar +4.7 kPa - 15.3 kPa)
Gas Pressure, Inlet	274 ± 34 kPa
Gas Pressure, Outlet	101.3 kPa
Gas Pressure, Inlet	172 ± 34 kPa
Gas Pressure, Outlet	< 0.13 kPa
Relative Humidity	40% ± 10%, Noncondensing
Magnetic Field	< 50 µT
Electromagnetic Field	< 100 µV/m
Vibration	< 0.5 m/s
Shock	≤ 3g

SEMI F63-0701
GUIDELINES FOR ULTRAPURE WATER USED IN SEMICONDUCTOR PROCESSING

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Facilities Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001.

1 Purpose

1.1 This guide is provided for multiple purposes. It may be used as a basis for establishing performance criteria for purchases of new UPW equipment. It may also be used internally by facility engineers to set process control parameters for the operation of their UPW systems. This guide may be used by process engineers to establish reasonable expectations about the quality of the UPW being supplied to them by facilities.

NOTICE: These suggested guidelines are published as technical information and are intended for informational purposes only.

2 Scope

2.1 Water is used extensively in the production of semiconductor devices for all wet processing steps such as the rinsing of wafers. Ultrapure Water (UPW) is typically produced for this purpose using Reverse Osmosis/Deionized resin bed technologies. The quality of the water impacts device yield and as linewidths decrease, requirements for higher purity water may increase.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Standards*

SEMI F61 — Guide For Ultrapure Water System Used in Semiconductor Processing

3.2 *ASTM Standards*[1]

ASTM D-5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry.

ASTM F-1094 — Test Method For Microbiological Monitoring of Water Used For Processing Electron and Microelectronic Devices by Direct- Pressure Tap Sampling Valve and by the Pre-sterilized Plastic Bag Method.

4 Limitations

4.1 This guide is not intended to set an absolute number for performance of a particular UPW system. Performance guidelines should be determined based on the design of the UPW system, the components used in the water system, the sensitivity of the manufacturing process to the purity of the water, the sensitivity of the instrumentation, and the budget available to maintain and monitor the water system.

4.2 This set of guidelines has been established from a variety of sources and inputs including 1.) an industry survey that SEMI provided to members of its standards activities in facilities; 2.) typical UPW levels from a large selection of semiconductor UPW systems as measured by several independent laboratories that test high purity water for the semiconductor industry; 3.) specifications from water system equipment manufacturers; 4.) and input from producers and users of UPW during SEMI standards committee meetings and through the balloting process. However, it is up to each individual owner of a UPW system to set specifications for the purity of its water based on its own needs and available resources.

4.3 This guide is reflective of a particular design approach for a UPW system. The guidelines can be produced from a properly maintained UPW system as described and diagrammed in SEMI F61 and is typical output from existing high-end semiconductor manufacturing plants with state-of-the-art water systems. The purity of water generated in other types of water systems may differ greatly.

4.4 The guidelines are targeted to UPW produced for semiconductor manufacturing. There exists an ASTM standard D5127 which should be considered in setting specifications for the purity of reagent grade water needed in a laboratory for analytical testing of semiconductor materials and process chemicals.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, website: www.astm.org

5 Use of the Guidelines

5.1 Sampling methods and contamination control are of paramount importance when attempting to measure the listed parameters at the levels specified.

5.2 The quality of the data measured will depend on which testing method and calibration techniques are used. Consequently, trends observed in the values may be more meaningful than absolute values.

6 Units

6.1 Parts per billion (ppb) is equivalent to ng/mL or µg/L.

6.2 Parts per million (ppm) is equivalent to mg/L.

6.3 Micron is a unit of length equal to one millionth of a meter, or one thousandth of a millimeter.

6.4 Colony Forming Units (CFU) is a measurement of bacteria organisms.

7 Description of Parameter Tests

NOTE 2: Since SEMI Guidelines do not require analytical data or methods to support them, the recommendation of specific analytical methods are only for informational purposes. Alternative methods may also be applicable.

7.1 *Resistivity (megohm-centimeters or Mohm–cm)*

7.1.1 Resistivity (conductivity) is only measured accurately with on-line instrumentation.18.25 MOhm is the theoretical upper limit for pure water at 25°C.

7.2 *Total Oxidizable Carbon (TOC) (ppb)*

7.2.1 Involves oxidation of organic materials and detection of carbon dioxide produced by the reaction, as measured in conductivity or infrared photometry.

7.3 Dissolved oxygen (ppb) is only measured accurately with on-line instrumentation.

7.4 *Particulate Matter (Particles/L)*

7.4.1 On-line methods using laser technology are recommended for accurate trend analysis.

7.5 *Bacteria (CFU/L)*

7.5.1 Triplicate samples are cultured based on the ASTM method F 1094 using a minimum sample size of 1L.

7.6 *Silica*

7.6.1 Total Silica (ppb) may be measured by Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS), Inductively-Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) or Inductively Coupled Plasma Mass Spectroscopy (ICP-MS).

7.6.2 Dissolved Silica (ppb as SiO_2) may be measured by heteropoly blue photometry or by Ion Chromatography.

7.7 *Ions and Metals (ppb)*

7.7.1 Many anions and cations may be determined using Ion Chromatography.

7.7.2 Up to 68 metals may be determined by GFAAS, ICP-AES, or ICP-MS. Most typically measured metals are shown in Table 1.

8 Parameters and Typical Concentrations

8.1 Table 1 lists each parameter with its range of performance.

Table 1 Parameters and Range of Performance

Typical Linewidth	*0.13 to 0.5 MICRONS*
PARAMETER	**RANGE OF PERFORMANCE**
Resistivity on-line @ 25°C (Mohm–cm)	17.9 to 18.2
TOC on-line (ppb)	1 to 5
Dissolved Oxygen on-line (ppb)	0.5 to 20
On-line Particles/L (micron range)	
0.05–0.1	100 to 1000
0.1–0.2	50 to 500
0.2–0.3	20 to 100
0.3–0.5	10 to 50
> 0.5	0 to 4
Bacteria (CFU/L)	
1 L Sample	0 to 5
Silica	
Silica - total (ppb)	0.5 to 3
Silica - dissolved (ppb as SiO_2)	0.2 to 1
Ions & Metals (ppb)	
Ammonium	0.02 to 0.1
Bromide	0.02 to 0.1
Chloride	0.02 to 0.1
Fluoride	0.02 to 0.1
Nitrate	0.02 to 0.1
Nitrite	0.02 to 0.1
Phosphate	0.02 to 0.1
Sulphate	0.02 to 0.1
Aluminum	0.02 to 0.1
Barium	0.02 to 0.1
Boron	0.02 to 20
Calcium	0.02 to 0.1
Chromium	0.02 to 0.1

Typical Linewidth	*0.13 to 0.5 MICRONS*
Copper	0.02 to 0.1
Iron	0.02 to 0.1
Lead	0.02 to 0.1
Lithium	0.02 to 0.1
Magnesium	0.02 to 0.1
Manganese	0.02 to 0.1
Nickel	0.02 to 0.1
Potassium	0.02 to 0.1
Sodium	0.02 to 0.1
Strontium	0.02 to 0.1
Zinc	0.02 to 0.1

SEMI F64-0701
TEST METHOD FOR DETERMINING PRESSURE EFFECTS ON INDICATED AND ACTUAL FLOW FOR MASS FLOW CONTROLLERS

This specification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Facilities Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001.

1 Purpose

1.1 The purpose of this document is to define a method for characterizing a MFC being considered for installation into a gas distribution system. This method will quantify the effect of transient and steady state inlet and outlet pressure conditions on the performance of the MFC.

1.2 This document provides a common basis for communication between manufacturers and users regarding testing and describing MFC pressure effects.

2 Scope

2.1 This test method measures the upstream (inlet) and downstream (outlet) transient pressure influences on indicated and actual flow.

2.2 This test method yields the results of actual output flow versus MFC set-point and indicated flow as influenced by steady state inlet pressure.

2.3 This test method applies to MFCs with maximum flow ranges of up to 1000 sccm.

NOTE 1: Due to the higher sensitivity of lower flow rate MFC's when pressure transients occur, the flow range for this document is limited to 1000 sccm.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This test method is limited to analyzing the effect of pressure on performance characteristics of MFCs and is not a verification of the state of calibration, linearity, or accuracy.

3.2 This test method does not address pressures in excess of the DUT's maximum working pressure as specified by the manufacturer.

3.3 This test method is limited to reasonable pressure transients; i.e., fluctuations that are otherwise tolerated by common semiconductor process equipment.

3.4 This test method does not address operational influences outside of the manufacturer's published limitations.

3.5 This test method does not address the effects of interruptions of the gas supply.

4 Referenced Standards

4.1 None.

5 Terminology

5.1 *Definitions*

5.1.1 *actual flow* — flow as indicated by flow standard (see Figures 1 and 2).

5.1.2 *indicated flow* — flow as indicated by the device under test (DUT).

5.1.3 *ramp* — constant rate of change in pressure (dp/dt = k).

5.1.4 *stability* — the ability of a condition to exhibit only natural, random variation in absence of unnatural, assignable cause variation.

5.1.5 *step change* — an exponential step in pressure with a time constant of one second or less.

5.2 *Abbreviations and Acronyms*

5.2.1 δM — deviation of mass of material relative to steady-state mass delivery.

5.2.2 ΔP — change in pressure with respect to time

5.2.3 ΔQ — steady state deviation of actual flow during inlet pressure ramp from that while inlet pressure is constant.

5.2.4 δQ_- — maximum negative deviation of actual flow from nominal.

5.2.5 δQ_+ — maximum positive deviation of actual flow from nominal.

5.2.6 τ — pneumatic time constant

5.2.7 *DUT* — device under test

5.2.8 *MFC* — mass flow controller

5.2.9 *MV* — metering valve

5.2.10 P_1 — inlet pressure

5.2.11 P_2 — outlet pressure

5.2.12 PC_A — pressure coefficient of actual flow per pressure change at a set point.

5.2.13 PC_O — pressure coefficient of indicated flow per pressure change at zero flow.

5.2.14 PC_S — pressure coefficient of span flow per pressure change.

5.2.15 *Psia* — pounds per square inch absolute

5.2.16 *Psig* — pounds per square inch gauge

5.2.17 Q_A — actual flow

5.2.18 Q_{FS} — rated full scale flow

5.2.19 Q_I — indicated flow

5.2.20 Q_N — nominal actual flow during steady state conditions.

5.2.21 Q_R — steady state actual flow while inlet pressure is being ramped.

5.2.22 Q_{SP} — set-point flow

5.2.23 T — time

5.2.24 t_f — time when Q_A is within 0.5% of reading of Q_N.

5.2.25 t_o — time when pressure transient is initiated.

5.2.26 t_s — settling time to Q_N

5.2.27 v — voltage

5.2.28 V_{eq} — equivalent internal control volume of the DUT.

5.2.29 V_{ip} — valve, pump isolation

6 Summary of Test Method

6.1 *Inlet Pressure Step and Ramp Change* — The effects of fast-step and slow-ramp changes to the pressure on actual flow out of the MFC is observed. See Figures 6 and 7.

6.2 *Inlet Pressure Effect Steady State* — The effects of a pressure increase/decrease on actual flow is observed once the increase/decrease has reached steady state. See Figure 8.

6.3 *Outlet Pressure Step Change* — The effects of an outlet pressure change on actual flow is observed. See Figure 9.

6.4 *Crosstalk Pressure Effect* – The effects of pressure changes due to switching multiple flow devices on the same gas line. See Figure 11.

7 Interferences

7.1 The accuracy rating of the measuring equipment shall be superior to that of the DUT. Preferably the measuring equipment will have an accuracy that is four times better than the DUT. Calibration equipment must have a valid calibration certificate.

7.2 Take care when using test instruments with a specified accuracy expressed in percent of full scale as the accuracy is limited at lower percentages.

7.3 Installation effects on the flow should be minimized.

7.4 Verify electrical signals directly at the DUT connector to ensure that the signals at the DUT and standard agree with the signals at the data recording equipment.

7.5 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

7.6 The results of this test method depend on the accuracy and repeatability of the pressure measurement devices used in the test system. Take care to stay within the specified pressure ranges of these devices and verify their accuracy prior to and following MFC evaluation activities.

7.7 The cleanliness level of the test gas should be compatible with the DUT. The minimum requirement placed on the test gas is that it be free of contamination that could influence the operational characteristics of the test article and instruments.

7.8 The test gas source and delivery system must be capable of satisfying the test volume flow rate at a constant pressure ± 0.7 kPa (± 0.1 psi).

7.9 The ambient temperature should be held to 22°C ±2°C for the duration of each analysis.

8 Significance and Use

8.1 The significance of the stability calculations in this method is to allow the MFC user to assess the transient pressure effects on the DUT. In application, this method will provide a consideration affecting gas system designs and MFC selection.

9 Apparatus

9.1 *Equipment Required for Methods A–1 and A–2*

9.1.1 Inlet test gas filter

9.1.2 Shutoff valve (qty 2).

9.1.3 Pressure transducers, available range 0–446 kPa (0–50 psig), with measurement accuracy of ± 0.2% and time constant less than 20 msec (qty 2).

9.1.4 Dome-loaded pressure control, or other device capable of producing specified pressure transients.

9.1.5 Flow standard, with time constant less than 20 msec and with full scale that is 200% of the DUT's full scale, accurate to 1% of full scale, linear to 0.5% of full scale, and capable of resolving to 0.2% of full scale.

9.1.6 Data acquisition system measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

9.2 *Equipment Required for Method B*

9.2.1 Inlet test gas filter.

9.2.2 Shutoff valve (qty 2).

9.2.3 Pressure transducer, available range 0–791 kPa (0–100 psig), with measurement accuracy of ± 0.1% and time constant less than 20 msec.

9.2.4 Two-stage pressure regulator, capable of 0–690 kPa (100 psia) control.

9.2.5 Flow standard, with full scale that is at least 120% of the DUT's full scale, accurate to 1% of full scale, linear to 0.5% of full scale, and capable of resolving to 0.2% of full scale.

9.2.6 Data acquisition system measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

9.3 *Equipment Required for Method C*

9.3.1 Inlet test gas filter.

9.3.2 Manual metering valve.

9.3.3 Pressure transducer, available range 0–446 kPa (0–50 psig), with measurement accuracy of ± 0.2% and time constant less than 20 msec.

9.3.4 Pressure transducer, 0–101.325 kPa ± 1% and with time constant less than 20 msec (qty 1).

9.3.5 Shutoff valves (qty 2).

9.3.6 Isolation valve (qty 1).

9.3.7 Vacuum pump, with pumping speed of at least 30 lpm, with throttling and isolation valve.

9.3.8 Flow standard, with time constant less than 20 msec and with full scale that is 200% of DUT full scale accurate to 1% of full scale, linear to 0.5% of full scale, and capable of resolving to 0.2% of full scale.

9.3.9 Data acquisition system measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

9.4 *Equipment Required for method D*

9.4.1 Pressure transducer, available range 0–446 kPa (0–50 psig), with measurement accuracy of ± 0.2% and time constant less than 20 msec. (2)

9.4.2 Flow standard, with time constant less than 20 msec and with full scale that is 200% of DUT full scale accurate to 1% of full scale, linear to 0.5% of full scale, and capable of resolving to 0.2% of full scale.

9.4.3 Isolation valve (qty 1).

9.4.4 Data acquisition system measures the electrical signals from the device under test. The data acquisition system may also read the signals from the flow standard, record test data and control the test sequence.

9.4.5 MFC with time constant less than 20 msec and a full scale flow rate that is 10 times the full scale flow rate of the DUT.

10 Materials

10.1 Clean, dry nitrogen, with a dew point less than or equal to -40°C, at a delivery pressure of 791 kPa (100 psig).

11 Safety Precautions

11.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before using this method.

12 Test Specimen

12.1 Allow all components in the test apparatus to warm up following the manufacturer's specification.

12.2 Take necessary steps when switching gases to ensure that only the desired gas is in the DUT and flow standard at the time the test is performed.

13 Preparation of Apparatus

13.1 *Setup and Schematic* — See Figures 1, 2, and 10.

13.2 *Plumbing Design Requirements for Methods A and C*

13.3 The test system must be highly conductive and must have no changes in direction closer than 20 tubing diameters upstream of the DUT.

13.4 The pneumatic time constant for the system shall be calculated as shown below:

τ = (Volume × Pressure Drop)/(Pressure × Volumetric Flow)

where:

- Volume is measured between the flow standard and the DUT
- Pressure drop is across the flow standard
- Pressure is the pressure in the defined volume
- Volumetric flow is as measured by the standard

13.5 The pneumatic time constant added to the flow standard time constant should ideally be less than 100 msec and should be recorded if larger. For method C, the volume between MV and V_{ip} should be kept to a minimum.

13.6 The system must be relatively leak free, i.e., the maximum inboard leak rate should be 2×10^{-7} atm cc/s He.

13.7 The system must be supported and isolated in a manner that keeps it from vibration, shock, and other conditions that could influence the results of this test.

14 Procedure

14.1 *Inlet Transient Pressure Effects (Method A-1)*

14.1.1 Assemble the test MFC into the test apparatus. (See Figure 1.)

14.1.2 Satisfy the manufacturer's warm-up requirements for the MFC.

14.1.3 Set the inlet pressure (P_1) to 274 kPa (25 psig).

14.1.4 Give the DUT a 50% set-point (Q_{SP} = ½Q_{FS}) and wait for Q_I to reach stability.

14.1.5 Adjust the pressure control device to initiate a step in P_1 to 287 kPa (27 psig) with a time constant of one second (see Figure 3c).

14.1.6 Wait until Q_I and Q_A have reached stability.

14.1.7 Using the pressure control device, initiate a step in P_1 to 274 kPa (25 psig) with a time constant of one second.

14.1.8 Give the DUT a 100% set-point (Q_{SP} = Q_{FS}) and wait for stability.

14.1.9 Repeat Sections 14.1.5 through 14.1.7.

14.2 *Process Side Effects (Method A-2)*

14.2.1 Assemble the test MFC into the test apparatus (see Figure 1).

14.2.2 Satisfy the manufacturer's warm-up requirements for the MFC.

14.2.3 Set the inlet pressure (P_1) to 274 kPa (25 psig).

14.2.4 Give the DUT a 50% set point (Q_{SP} = ½Q_{FS}) and wait for Q_I to reach stability.

14.2.5 Using the pressure control device, initiate a ramp in P_1 to 356 kPa (37 psig) (see graph in Figure 4c). Use a ramp rate between 0.7 kPa (0.1 psi) per second and 21.0 kPa (3psi) per second. Record the ramp rate used on the data sheet.

14.2.6 Wait until Q_I and Q_A have reached stability.

14.2.7 Using the pressure control device, initiate a ramp as in 14.2.5, initiate a ramp in P_1 to 274 kPa (25 psig) (see graph in Figure 4c).

14.2.8 Repeat Sections 14.2.5 through 14.2.7.

14.3 *Inlet Pressure Effects, Steady State (Method B)*

14.3.1 Assemble the DUT in the test apparatus (see Figure 1).

14.3.2 Satisfy the manufacturer's warm-up requirements for the DUT.

14.3.3 Set the inlet pressure (P_1) to 205 kPa (15 psig).

14.3.4 Close V_{io}, open DUT control valve.

14.3.5 Wait until Q_R and Q_A have reached stability. Record P_1, Q_I and Q_A (see Table A3.1).

14.3.6 Open V_{io} and give the DUT a 50% set-point. (Q_{SP} = ½Q_{FS}).

14.3.7 Wait until Q_I and Q_A have reached stability. Record P_1, Q_I and Q_A (see Table A3.1).

14.3.8 Give the DUT a 100% set-point (Q_{SP} = Q_{FS}).

14.3.9 Wait until Q_I and Q_A have reached stability. Record P_1, Q_I and Q_A (see Table A3.1).

14.3.10 Set inlet pressure (P_1) to 446 kPa (50 psig) and repeat Sections 14.3.4 through 14.3.9.

14.4 *Outlet Pressure, Step Change (Method C)*

14.4.1 Assemble the test MFC into the test apparatus. (See Figure 1.)

14.4.2 Satisfy the manufacturer's warm-up requirements for the MFC.

14.4.3 Set the inlet pressure (P_1) to 274 kPa (25 psig) (see Figure 9).

14.4.4 Give the DUT a 50% set point (Q_{SP} = ½Q_{FS}).

14.4.5 Throttle the pump rate until P2 = 26.664 kPa.

14.4.6 Open V_{io} and adjust the metering valve, MV, until P_2 = 101.325 kPa.

14.4.7 Allow Q_I to reach stability. Record P_1, Q_I, and Q_A (see Table A3).

14.4.8 Close V_{io}. P_2 should = 26.664 kPa.

14.4.9 Allow Q_I to reach stability. Record P_1, Q_I, and Q_A (see Table A3).

14.4.10 Give the DUT a 100% set point and repeat Sections 14.4.5 through 14.4.9.

14.5 *Crosstalk Pressure Effect (Method D)*

14.5.1 Assemble the DUT in the test apparatus (see Figure 10).

14.5.2 Satisfy the manufacturer's warm-up requirements for the DUT.

14.5.3 Set the inlet pressure (P_1) to 274 kPa (25 psig)

14.5.4 Give the DUT a 100% set point ($Q_{SP} = Q_{FS}$).

14.5.5 Give the 10× MFC a 100% set point ($Q_{SP} = Q_{FS}$).

14.5.6 Wait until the DUT and MFC achieve stability.

14.5.7 Record P_1, P_2, the indicated flow from the DUT, the indicated flow from the MFC and the indicated flow from the flow standard continuously with the data acquisition system.

14.5.8 While monitoring command the 10 × MFC to a zero set-point. Wait until the DUT becomes stable then command the 10× MFC to a 100% set Point.

14.5.9 Sample Plot is shown in Figure 11.

15 Calculations or Interpretation of Results

15.1 See Appendix 1 for detailed information on data collection and interpretation for Methods A-1, A-2, B, and C.

15.2 *Calculations* — The indicated MFC flow output data and the flow standard output data should be converted to percent of full scale flow as follows:

$$\%\text{ of full scale flow} = \frac{\text{output data (v)}}{\text{full scale output (v)}} \times 100 \qquad (1)$$

15.3 *Interpretation* — Collect the following data and report as an effect of transient pressure conditions:

15.4 Plot of indicated flow, actual flow, and flow set point versus time.

15.5 Duration of instability. Maximum and minimum deviations from the steady state actual and indicated flows. Calculate the positive and negative integrals, along with the total integral of variations in the actual and indicated flows.

15.6 Inlet (P_1) and outlet (P_2) values.

15.7 The number of repetitions required to achieve a confidence factor of 95% for each test step.

15.8 Data plots for the measured values must be generated and presented in a manner similar to that shown in Figures 3, 4, and 5 and in Table 1.

16 Related Documents

16.1 *Military Standards*[1]

MIL-STD 45662 — Calibration Systems Requirements

1 Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A

17 Illustrations

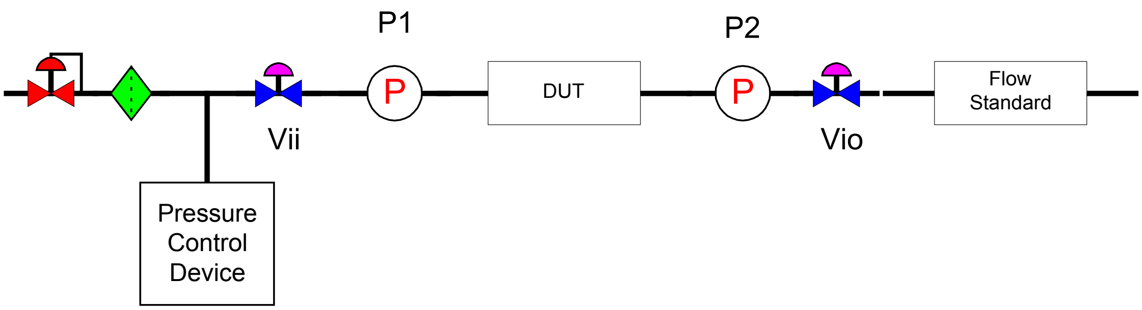

Figure 1
Test Schematic for Methods A, A_1, A_2, and B

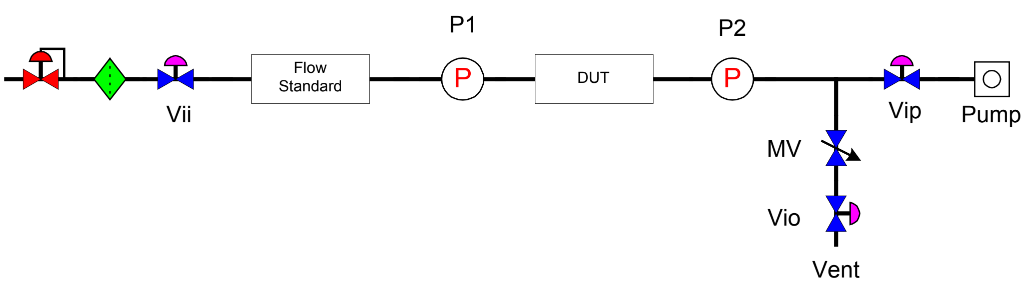

Figure 2
Test Schematic for Method C

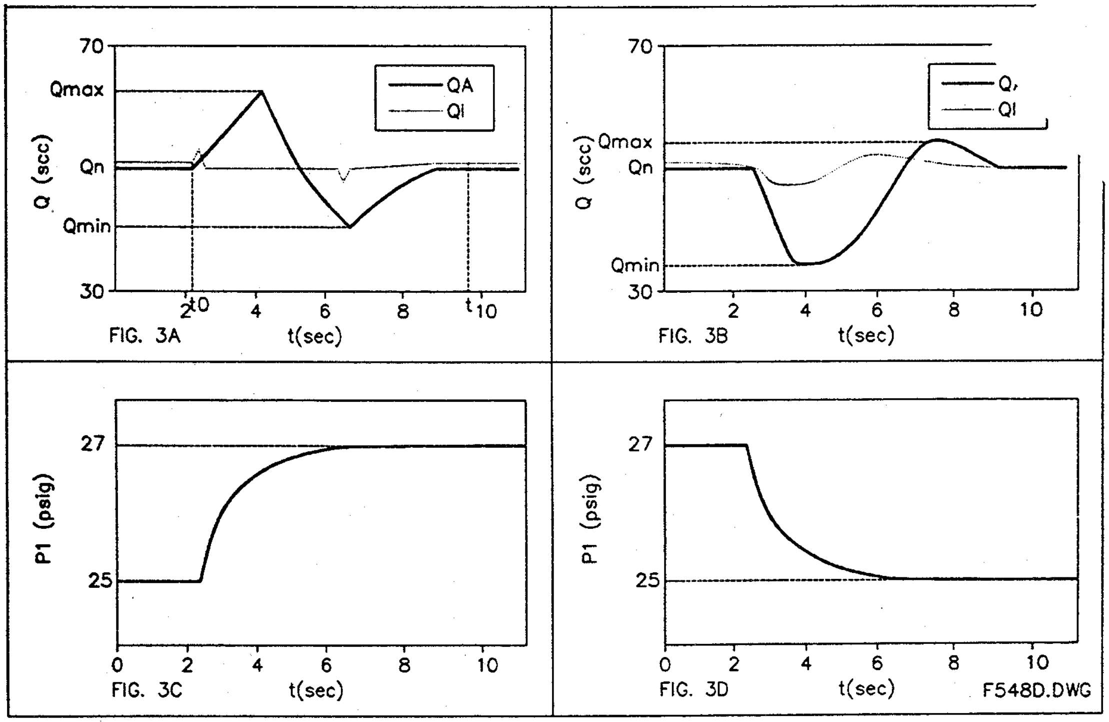

Figure 3
Q and P_1 versus t: Data Presentation for Method A-1 (see Appendix 1)

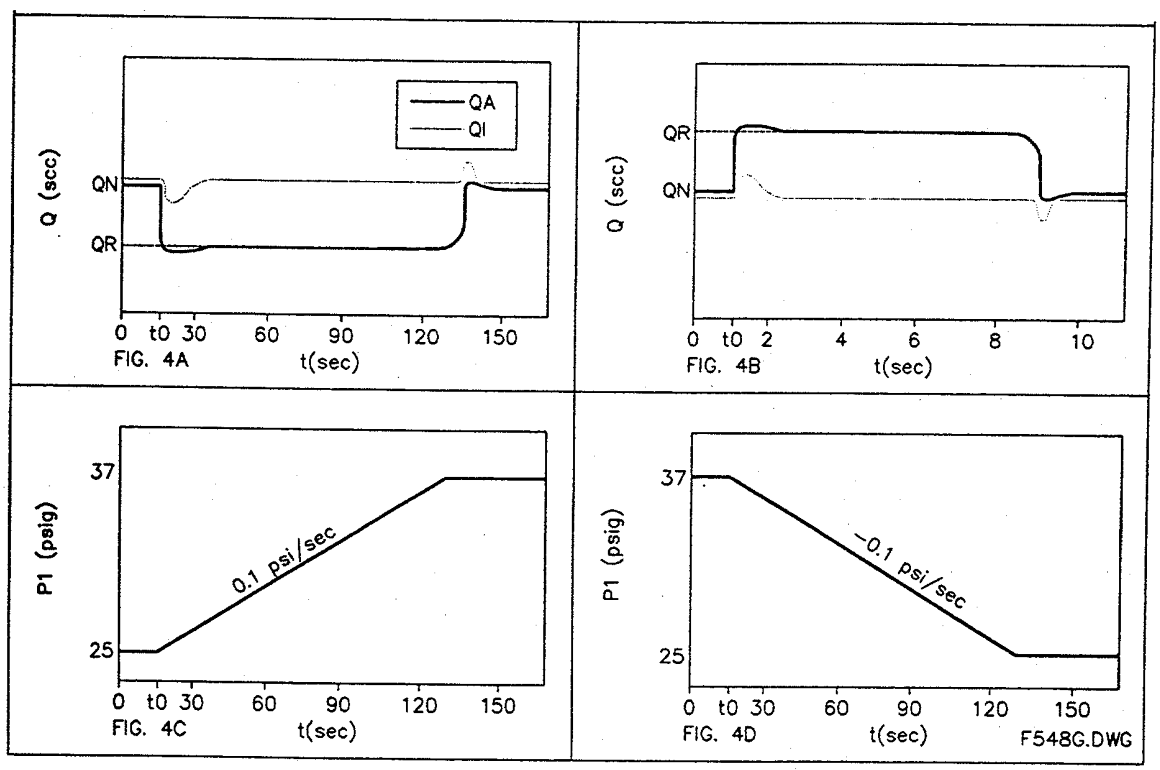

Figure 4
Q and P_1 versus t: Data Presentation for Method A-2 (see Appendix 1)

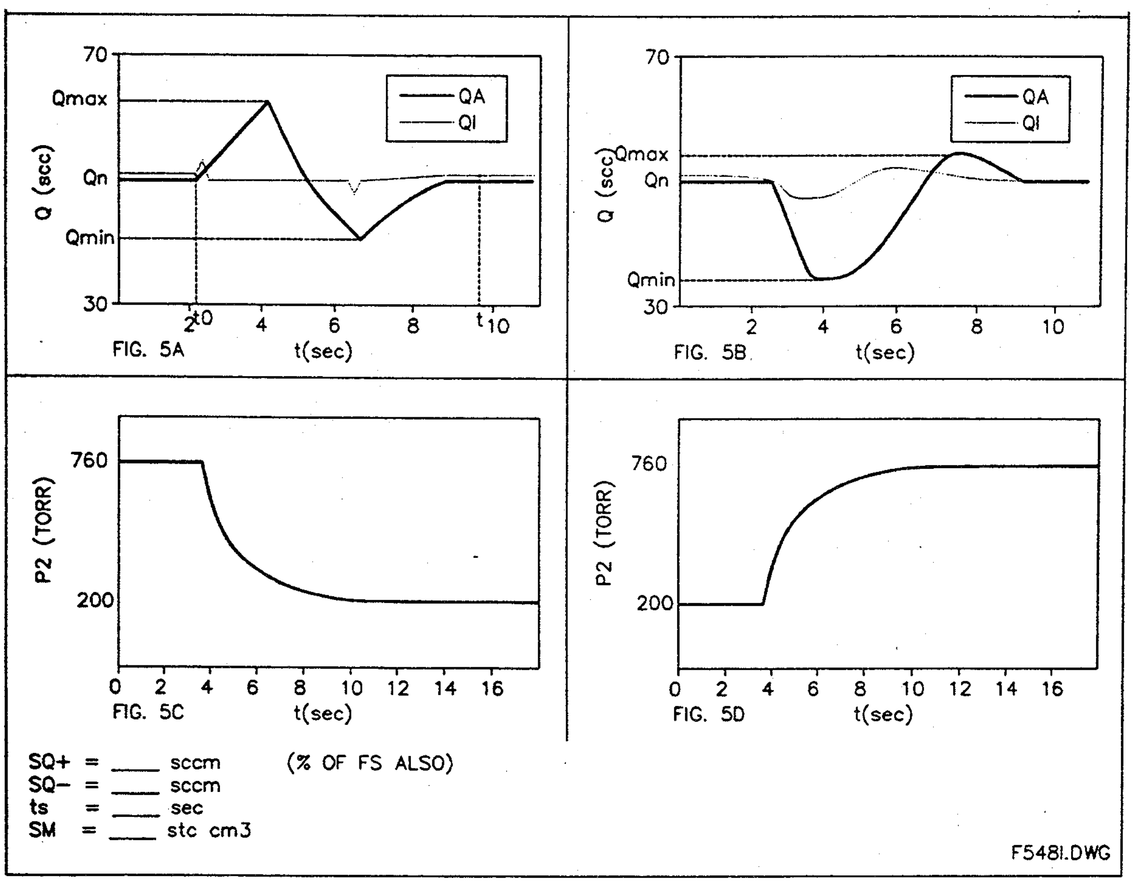

Figure 5
Q and P_2 versus t: Data Presentation for Method C (see Appendix 1)

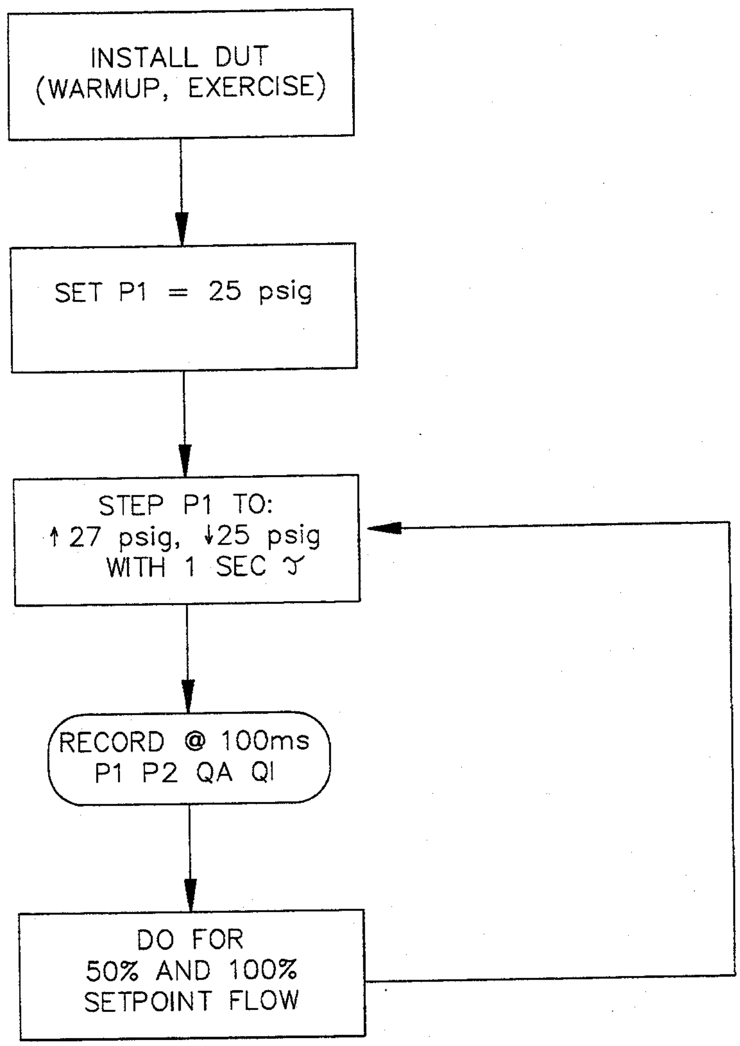

Figure 6
Method A-1 Flowchart

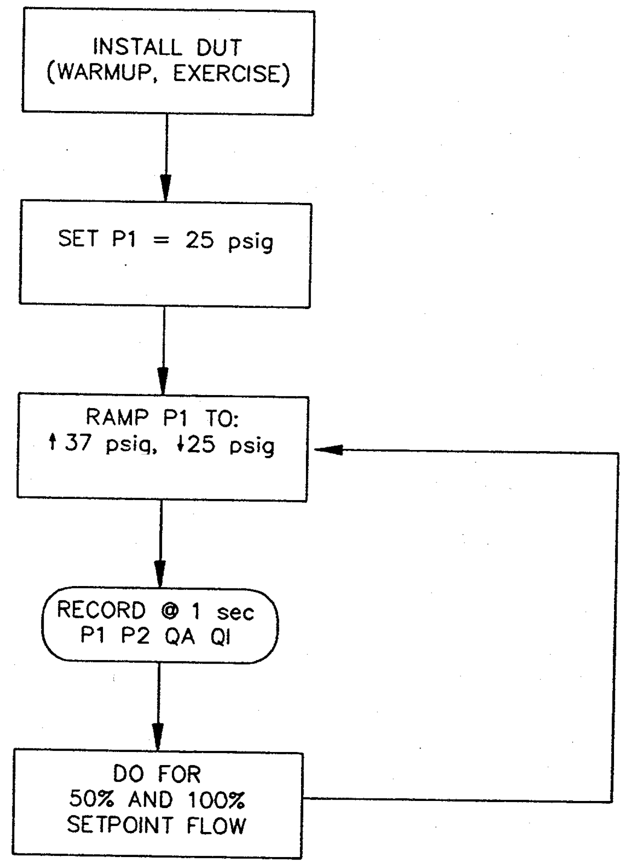

Figure 7
Method A-2 Flowchart

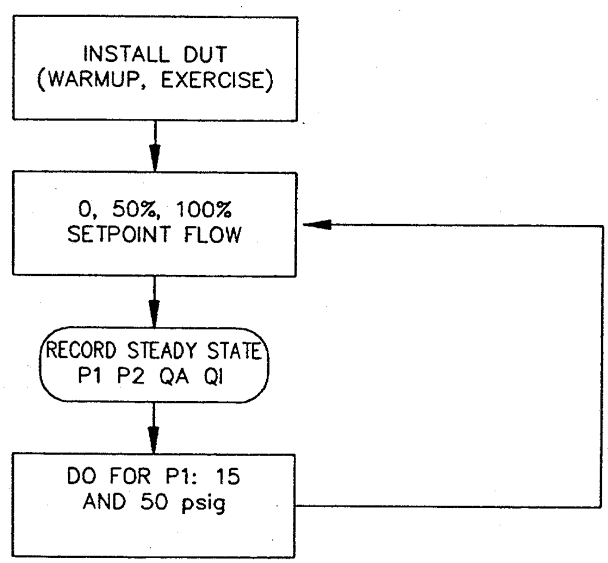

Figure 8
Method B Flowchart

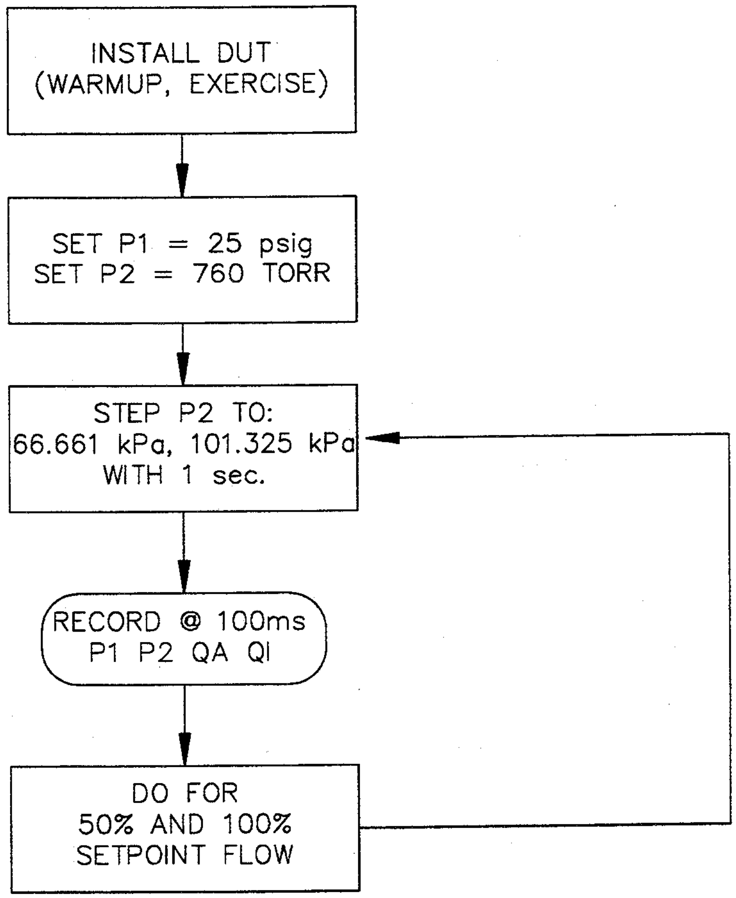

Figure 9
Method C Flowchart

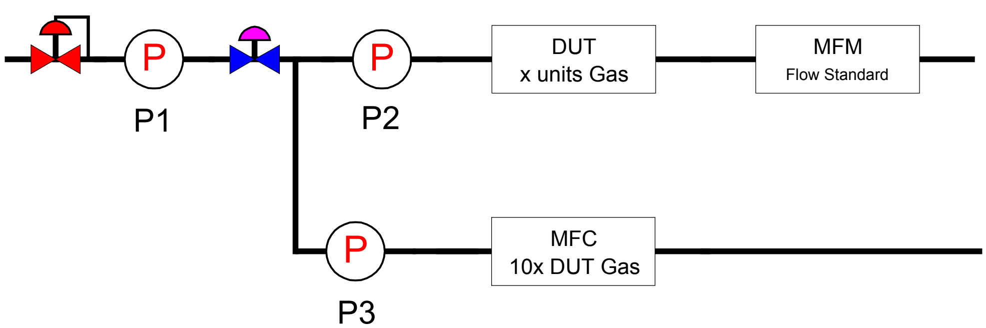

Figure 10
Test Schematic for Method D

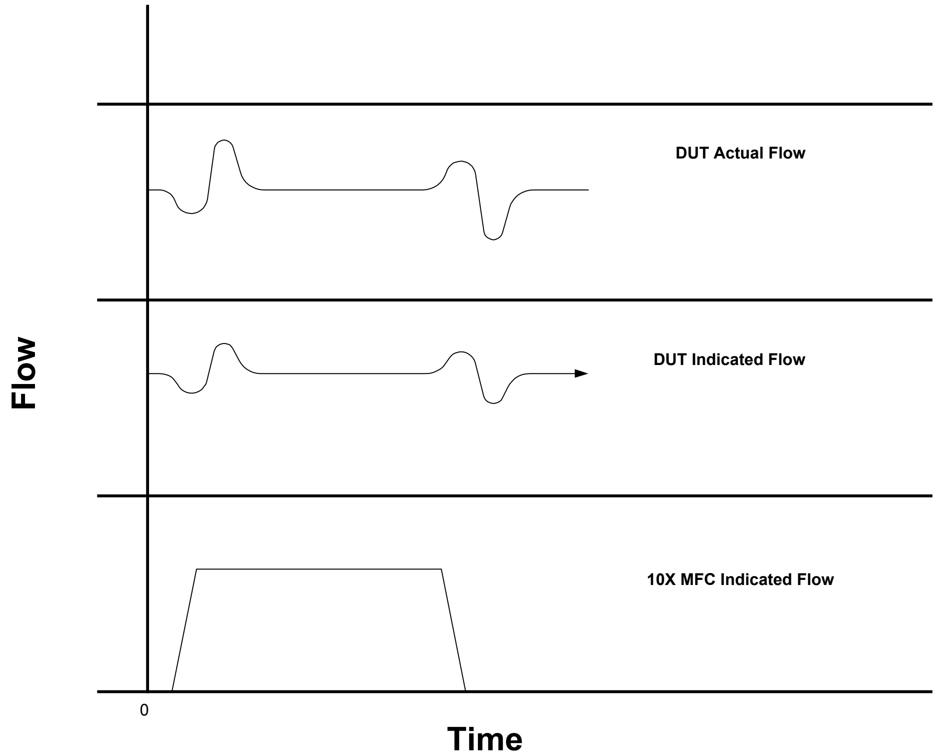

Figure 11 Plots
Test Method D

Table 1 Data Presentation for Method B (see Appendix 1)

PC_o= __________% of FS/psi

	@ 50% FS	@ FS
PC_A (% of reading/psi)		

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI F64 and was approved by full letter ballot procedures on April 30, 2001 by the Facilities Regional Standards Committee.

A1–1 Data Analysis: Method A-1

Table A1–1 Sample Data Sheet: Methods A-1 and A-2

Date: ________________ Time: __________
D.U.T. # ________________ Ambient Temp __________°C
Standard Flow Device:________________
Full Scale:________________ sccm
Ramp Rate (Method A-2) ______________kPa/sec

Time (sec)	*P1 (psig)*	*Q_A (sccm)*	*Q_I (sccm)*
0	25.01	50.00	50.01
0.05	25.01	50.01	50.01
0.10	25.02	50.00	50.02
0.15	25.01	49.99	50.01
. . .	. . .	. . .	. . .
2.20	25.40	52.68	51.38
2.25	25.85	55.23	52.56
. . .	. . .	. . .	. . .
6.30	26.89	46.28	49.23

A1–1.1 *Data Interpretation, Method A-1*

A1–1.1.1 δQ_+ = maximum positive deviation of actual flow from nominal

$\delta Q_+ = Q_{max} - Q_N$

where:

Q_{max} = maximum value of Q_A

Q_N = average value of Q_A during time when P_1 = initial steady state

δQ_- = maximum negative deviation of actual flow from nominal

$\delta Q_- = Q_{min} - Q_N$

where:

Q_{min} = minimum value of Q_A

For example (see Table A1–1), if Q_N = 50.01 sccm, Q_{max} = 55.23 sccm, and Q_{min} = 46.28 sccm, then

δQ_+ = 55.23 sccm - 50.01 sccm = 5.22 sccm

δQ_- = 46.28 sccm - 50.01 sccm = -3.73 sccm

A1–1.1.2 t_s is settling time to Q_N; i.e.,

t_s = elapsed time from initiation of pressure transient (t_o) to when Q_A is within 0.5% of reading of Q_N (t_f) = t_f - t_o

δM is deviation of mass of material delivered during the disturbance relative to steady state mass delivery; i.e.,

$$\delta M = \sum_{t_i=t_o}^{t_f} \frac{(Q_A - Q_N)(t_{ih} - t_i)}{60\ \text{sec / min}} \qquad (2)$$

This quantity may be thought of as the net area between the Q_A versus time curve and the Q_N versus time line. See Figure A1–1 below.

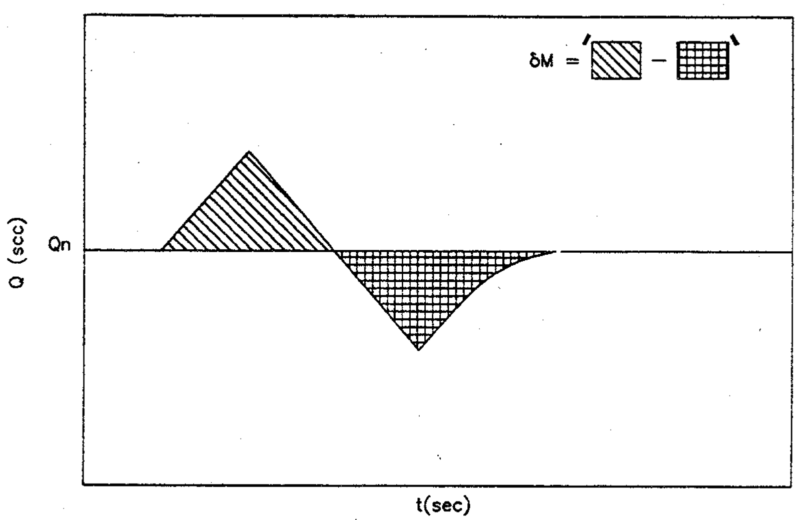

Figure A1–1
Q_N versus t (sec)

NOTE 1: δM is expressed in units of sccm.

A1–2 Data Analysis: Method A-2

Refer again to Table A1–1

A1–2.1 *Data Interpretation, Method A-2*

Q_R is the steady state actual flow while the inlet pressure is being ramped. It is calculated by averaging Q_A values from time t_o + 50 sec to t_o + 110 sec.

ΔQ is the steady state deviation of actual flow during the inlet pressure ramp from that while inlet pressure is constant; i.e.,

$$\Delta Q = Q_R - Q_N \qquad (3)$$

V_{eq} is the equivalent internal control volume of the DUT. Note that it may not represent the actual internal volume of the DUT; i.e.,

$$V_{eq} = \frac{\Delta Q}{P_1} x (\frac{14.7 \text{ psi/std. atm}}{60 \sec / \min}) \tag{4}$$

For example, if ΔQ = 5.02 sccm and P1 = 0.7 kPa (0.1 psi)/sec, then

Veq = [(5.02 sccm)/(0.7 kPa (0.1 psi)/sec)] × [(101.325 kPa (14.7 psi)/std. atm)/(60 sec/min)] = 12.3 ccm

A1–3 Data Analysis: Method B

Table A1–2 Sample Data Sheet: Method B

Date:________________ Time: __________
DUT #________________ Ambient Temp __________°C
Standard Flow Device ________________
Full Scale________________ sccm

P1 (psig)	*Setpoint Flow (sccm)*	*Q_A (sccm)*	*Q_I (sccm)*
15.02	0	0.00	-0.01
15.00	50	50.01	50.01
15.01	100	100.12	100.01
50.06	0	0.00	-0.05
50.04	50	50.12	50.01
50.03	100	100.56	100.02

A1–3.1 *Data Interpretation, Method B*

PC_o is the pressure coefficient of indicated flow per pressure change at zero flow; i.e.,

$$PC_A(\%) = \frac{\Delta Q_A}{\Delta P_1 Q_{sp}} x100 \tag{5}$$

$$PC_o(\%) = \frac{Q_{If} - Q_{Ii}}{(P_{If} - P_{Ii})Q_{FS}} x100 \tag{6}$$

PC_A is the pressure coefficient of actual flow per pressure change at a setpoint; i.e.,

For example, from Table A2.1,

PC_o (%) = {[-0.05 sccm-(-0.01 sccm)]/[(50.06 psig-15.02 psig)(100 sccm)]} × 100
= -0.0011% of FS/psi

PC_A (@ 50%) = [50.12 sccm-50.01 sccm]/[(50.04 psig-15.00 psig)(50 sccm)] × 100
= 0.0063% of reading/psi at 50 sccm

PC_A (@ FS = [100.56 sccm-100.12 sccm]/[(50.03 psig-15.01 psig)(100 sccm)] × 100
= 0.013% of reading/psi at 100 sccm

A–4 Data Analysis: Method C

Table A4–1 Sample Data Sheet: Method C

Date:________________ Time: __________

DUT #________________ Ambient Temp __________°C

Standard Flow Device ________________

Setpoint________________ sccm

Te = ________________ °C P1 = __________psig

Time (sec)	*P2 (kPa)*	Q_A *(sccm)*	Q_I *(sccm)*
0	101.338	50.05	50.0
0.05	101.338	50.05	50.0
. . .	. . .	. . .	. . .
2.20	95.086	52.28	51.5
2.25	88.406	54.56	52.1
. . .	. . .	. . .	. . .
8.45	32.424	50.08	50.0
8.50	31.811	50.07	50.0
. . .	. . .	. . .	. . .
15.20	26.838	50.06	50.0

A1–4.1 *Data Interpretation, Method C – See Appendix A1–1.1*

SEMI F65-1101
DIMENSIONAL SPECIFICATION FOR MOUNTING BASES OF DIAPHRAGM VALVES USED WITH METRIC PFA TUBES

This specification was technically approved by the Global Liquid Chemical Distribution Systems Committee and is the direct responsibility of the Japanese Liquid Chemical Distribution Systems Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This document specifies dimensions of mounting base and their clearance hole sizes for bolts and the hole locations of diaphragm valves used with metric PFA tubes in liquid chemical distribution facilities and process equipment for semiconductor and flat panel display manufacturing.

1.2 To avoid any disturbance of future development and to facilitate interchangeability of diaphragm valves, this document has a limited scope as specified in Section 2.

2 Scope

2.1 This document applies to mounting bases for two way valves with a diaphragm designed to shut off and/or regulate a liquid chemical flow in tubes whose sizes are listed in Table 1.

2.2 The valves are made from materials such as PTFE or PFA, which have high corrosion resistance and low contamination contribution to the fluid.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ISO Standards*[1]

ISO 273 — Fasteners – Clearance Holes for Bolts and Screws

ISO 2768-1 — General Tolerance – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications

3.2 *JIS Standards*[2]

JIS B 1001 — Diameter of Clearance Holes and Counterbores for Bolts and Screws

JIS B 0405 — General Tolerance – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *PFA* — tetrafluoroethylene perfluoroalkylvinyl-ether copolymer

4.1.2 *PTFE* — polytetrafluoroethylene

4.2 *Definitions*

4.2.1 *back pressure* — a maximum allowable pressure applied to outlet of a diaphragm valve.

4.2.2 *liquid chemicals* — acid, alkali, organic solvent, and pure water used for wet stations; resists and developers used for track system; and other chemicals used for process or maintenance (such as slurry of chemical-mechanical polishing) of equipment or facilities.

4.2.3 *mounting bases* — plates which are attached to diaphragm valves to mount the valves to equipment or a facility.

5 Dimensional Specification

5.1 *Mounting Base Dimensions* — the length (l) and width (w) of the mount base plate indicated in the Figure 1 and the values for different tube sizes are specified in Table 1.

5.2 *Clearance Hole Locations* — the location of the clearance holes for bolts are indicated with “w” and “l” in the Figure 1 and the values for different tube sizes are specified in Table 1.

5.3 *Clearance Hole Sizes* — the size of clearance holes (ϕD) for different tube sizes are specified in the Table 1 according to ISO 273 (JIS B 1001).

1 International Organization for Standardization (ISO), 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland.

2 Japan Standards Association, 4-1-24, Akasaka, Minato-ku, Tokyo, Japan 107-8440.

5.4 Where the dimension depends on the valve design considering the back pressure, the upper row in Table 1 applies to the valves that withstand up to 0.2 megapascals (MPa) (29 pounds per square inch (psi)) back pressure, and the lower row applies to the valves that withstand more than 0.2 MPa (29 psi) back pressure.

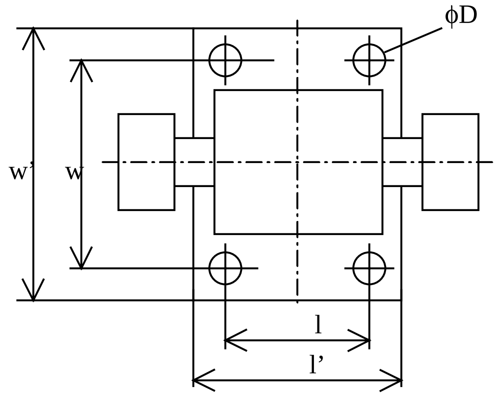

Figure 1
Top View of A Typical Diaphragm Valve with A Mounting Base

Table 1 Dimensional Specifications

*Tube Size (mm) (OD / ID)**	*Back Pressure (Mpa)*	*l' (mm)*	*l (mm)*	*w' (mm)*	*w (mm)*	*ϕD (mm)*	*Bolt Type (example)*
25 / 22	≤ 0.2	60	48	96	84	7	M6
	> 0.2	68	56				
19 / 16	≤ 0.2	44	32	76	64	7	M6
	> 0.2	52	40	84	72		
12 / 10	≤ 0.2	34	22	62	50	7	M6
	> 0.2	46	34	70	58		
10 / 8	≤ 0.2	34	22	62	50	7	M6
	> 0.2	46	34	68	56		
6 / 4	≤ 0.2	32	20	56	44	7	M6
	> 0.2	40	28	60	48		

Note 1: OD and ID are outside diameter and inside diameter of the tube respectively.
Note 2: Refer to ISO 2768-1 or JIS B 0405 for tolerances.

6 Measurements

6.1 The mounting base must be conditioned for a minimum of one hour in an air environment of 23 ± 3ºC (73.4 ± 5.4ºF) prior to measuring the dimensions.

SEMI F66-1101
SPECIFICATION FOR PORT MARKING AND SYMBOL OF STAINLESS STEEL VESSELS FOR LIQUID CHEMICALS

This specification was technically approved by the Global Liquid Chemical Distribution Systems Committee and is the direct responsibility of the Japanese Liquid Chemical Distribution Systems Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This document specifies port marking and symbol of stainless steel vessels for liquid chemicals used in semiconductor and flat panel display manufacturing equipment and liquid chemical distribution facilities.

2 Scope

2.1 This document covers stainless steel vessels with tubes that penetrate into the vessels as inlets or outlets of liquid chemical to/from the vessels.

2.2 A vessel which uses coupling (quick coupling) at its tube end (port) is excepted from the scope.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 None.

4 Terminology

4.1 *dip tube* — a piece of tube which penetrates into a vessel as an inlet or outlet of liquid chemical to/from the vessel.

4.2 *liquid chemical* — organic or inorganic liquid chemical used for semiconductor or flat panel display manufacturing.

4.3 *port* — an end of a tube attached to a vessel.

5 Requirements for Port Marking

5.1 The dip tube port shall be marked as "DIP". If more than one dip tube port exists on a vessel, each port shall be marked as "DIP".

5.2 *Additional Marking* — A description to identify multiple ports may be added to the dip port marking such as DIP-1 or DIP (1).

5.3 *Location of Marking* — "DIP" marking shall be located where it will clearly identify the dip tube port. If more than one dip tube ports exist on a vessel, each marking shall be located so that the corresponding port is clearly identified.

5.4 *Method of Marking* — The marking shall be engraved, etched, or labeled properly so that the "DIP" marking shall not be removed. Color of the marking is optional.

5.5 *Size of Marking* — The marking shall be sized so that it is clearly readable.

6 Requirements for Symbol

6.1 A symbol illustrated in Figure 1 shall be used to draw a stainless steel vessel with a dip tube. A dip tube shall be identified in the symbol as a line penetrating into a rectangle.

6.2 If more than one dip tube exists on a vessel, the symbol shall have the same number of lines which correspond to the dip tubes.

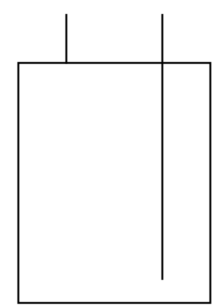

Figure 1
Symbol for Stainless Steel Vessel with a Dip Tube

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SEMI F67-1101
TEST METHOD FOR DETERMINING INERT GAS PURIFIER CAPACITY

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this document is to define a test method to quantify impurity removal capacity of inert gas purifiers.

2 Scope

2.1 To determine the impurity capacity of a gas purifier at the point of breakthrough. Capacity tests are done by adding ppm levels of a given gaseous impurity to a pure zero gas and monitoring the effluent of the test purifier for active impurity species.

NOTE 1: Mixtures of two or more impurities for multi impurity removal purifiers is a more representative method for determining capacity.

2.2 This document is intended for point of use (POU) inert gas purifiers where inlet purity is 99.9995% or higher.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate and safety health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The inherent limitation to this method is the limit of detection (LOD) of the analytical instrument employed by the user.

3.2 This test method can only be used to compare purifier capacity results if the user application for flow rate, pressure, and temperature are the same as the test conditions. Different users and/or different operating conditions may result in different purifier performance results.

3.3 In testing mixtures of impurities, some impurities may influence the capacity results. Discussion with the manufacturer is highly recommended prior to testing.

3.4 The test method does not apply to particulates.

3.5 This test method can only be used to compare the capacity of different purifiers, when the purifiers are sized for the appropriate flow rate. Comparing purifiers of different maximum flow ratings will result in misleading information.

3.6 This test method will provide capacity information only for impurities that are used in the challenge gas.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F22 — Guide for Gas Distribution Systems

SEMI F33 — Method for Calibration of Atmospheric Pressure Ionization Mass Spectrometer (APIMS)

4.2 *ANSI Standards*[1]

ANSI B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *APIMS* — atmospheric pressure ionization mass spectrometer

5.1.2 *°C* — degrees Celsius

5.1.3 *DUT* — device under test

5.1.4 *°F* — degrees Fahrenheit

5.1.5 *in* — inch

5.1.6 *kPa* — kiloPascal

5.1.7 *LOD* — limit of detection

5.1.8 *m* — meter

5.1.9 *MFC* — mass flow controller

5.1.10 *NMHC* — non methane hydrocarbons

5.1.11 *POU* — point of use

5.1.12 *ppb* — parts per billion, volume basis

1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

5.1.13 *ppm* — parts per million, volume basis

5.1.14 *psi* — pounds per square inch

5.1.15 *psia* — pounds per square inch absolute

5.1.16 *psig* — pounds per square inch gauge

5.1.17 R_a — surface roughness average (as defined in ANSI B46.1)

5.1.18 $R_{a,max}$ — surface roughness maximum (as defined in ANSI B46.1)

5.1.19 *s* — second

5.1.20 *sccm* — standard cubic centimeters per minute

5.1.21 *slpm* — standard liter per minute

5.2 *Definitions*

5.2.1 *activation* — the process of initially preparing the purifier media to be chemically reactive with gas impurities.

5.2.2 *activation temperature* — temperature at which DUT was initially prepared.

5.2.3 *atmospheric pressure ionization mass spectrometer (APIMS)* — an instrument consisting of an atmospheric pressure ion source where gas phase impurities are ionized via charge exchange reactions with the bulk gas. These ions are directed into a vacuum chamber where they are then separated by a mass analyzer and detected by an electron multiplier.

5.2.3.1 *ion source* — the section of a mass spectrometer used to generate sample ions by electron impact, chemical ionization, or charge exchange.

5.2.3.2 *mass analyzer* — a device that utilizes electric and/or magnetic fields to separate charged particles or ions according to their mass-to-charge (m/e) ratios. Examples of mass analyzers include quadrupole, magnetic and/or electric sector, time of flight, and ion traps.

5.2.3.3 *electron multiplier* — a device that detects and amplifies electro-magnetic phenomena such as positive/negative ions.

5.2.4 *back pressure regulator* — a self-contained device, consisting of a mechanical or electrical sensor and control device, commonly used in the semiconductor industry to maintain a constant pressure upstream of the regulator.

5.2.5 *breakthrough* — the point in time when an individual impurity level in the purifier effluent exceeds the level specified by the manufacturer. Typically in the range of 1–100 ppb.

5.2.6 *challenge gas* — a gas mixture containing high levels of gas impurities. Typically, a challenge gas has impurities of between 500 ppm to 1% which is used to shorten the test duration; however, challenges in the range of 1–10 ppm for the impurities is more representative.

5.2.7 *gaseous impurities* — gas phase elements and compounds in the gas stream other than the process or base gas.

5.2.8 *impurity analyzer* — an appropriate analyzer to measure the concentration of desired impurities in a gas stream from the ppm to the percent (%) concentration range.

5.2.9 *inert gas* — a gas, which at ambient conditions, does not react chemically with other materials or chemicals.

5.2.10 *limit of detection (LOD)* — lowest concentration that can be detected by an instrument. LOD is typically defined as three times the standard deviation of the mean noise level (see SEMI F6, lower detectable limit of instrument).

5.2.11 *mass flow controller (MFC)* — a self-contained device, consisting of a mass flow transducer, control valve, and control and signal-processing electronics, commonly used in the semiconductor industry to measure and regulate the mass flow of gas (as defined in SEMI E29).

5.2.12 *pure gas* — an inert gas, minimum purity of 99.9995%, and less than 1 ppb of each impurity that is specified to be removed by the DUT.

5.2.13 *purifier* — generally a catalytic (getter, reactive), resinous, or diatomaceous material within a pressure vessel which removes particulate and/or trace gas impurities from a gas stream (as defined in SEMI F22).

5.2.14 *purifier capacity* — the total quantity of each trace gas impurity that may be sorbed by the purifier media. Defined as liters impurity/liter purifier media.

5.2.15 *regeneration* — the process of reactivating the purifier media.

5.2.16 *test duration* — total time required to complete the test procedure.

5.2.17 *test flow rate* — flow rate through DUT (slpm).

5.2.18 *test pressure* — pressure immediately upstream of the DUT.

5.2.19 *test temperature* — operating temperature of DUT.

5.2.20 *ultratrace analytical instrumentation* — instrumentation that has sufficient sensitivity to measure all impurities of interest at the specified level of the customer, the ppb or sub-ppb level.

5.2.21 *zero gas* — nitrogen, argon, helium or hydrogen with an estimated level an order of magnitude, or more, lower than the lowest calibration point for each impurity of interest (as defined in SEMI F33).

6 Summary of Method

6.1 This method will allow a user to quantify the impurity removal capacity of a given inert gas purifier for that impurity.

7 Safety Precautions

7.1 This test method may involve hazardous materials, operations, and equipment. The test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.

7.2 Exhaust from the DUT should be properly vented.

7.3 Only the appropriate gas should be used for purifier testing. Use of the inappropriate gas may cause exothermic reactions and possible explosions.

7.4 Electric discharges or mechanical friction might trigger combustion within a getter. Avoid situations where there is an accumulation of electrostatic charge.

7.5 Purifiers are generally designed for use with impurity levels less than 1% and should not be used to purify air or other inappropriate gases. Contact the manufacturer if there is any question as to the suitability for a particular gas.

7.6 Care should be taken to minimize the purifier's exposure to room air (even filtered air). Room air may chemically react with some purifiers shortening the purifier lifetime. Follow manufacturer's installation procedures.

8 Test Protocol

8.1 *Test Conditions*

8.1.1 The test should be conducted following manufacturers recommended handling procedures to activate new media or regenerate existing purifier media.

8.1.2 The test is to be conducted at a room temperature maintained between 18°C (64°F) and 26°C (78°F). Environmental temperature fluctuations within this range are not expected to have any measurable effect on the instrumentation used to detect the level of impurities. Follow instrument manufacturer's operating procedures.

8.1.3 Testing performed at high impurity challenge may alter test results, and may not be appropriate to do for all types of purifiers. Any significant temperature change during the test could have adverse or false effects on the capacity results.

8.1.4 For a mixture of more than 1 impurity, competing reactions may occur between impurities, which may lead to different results.

8.2 *Apparatus*

8.2.1 *Materials*

8.2.1.1 *Test Gas* — a mixture of pure gas and challenge gas. Select the appropriate concentration level. For initial studies, a higher concentration range, e.g., 500 ppm to 1% is suggested for each given impurity. For more representative studies done over longer time periods, 1–10 ppm for each given impurity is suggested.

8.2.1.2 *Pressure Regulators* — all wetted internal surfaces, where appropriate, should be made of electropolished 316L stainless steel with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to control system pressures.

8.2.1.3 *Pressure Gauge* — all wetted internal surfaces, where appropriate, should be made of electropolished 316L stainless steel with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to monitor system pressures.

8.2.1.4 *Standard Test Flows* — use appropriate mass flow devices. One MFC with appropriate range of 0–50 slpm for the pure gas is suggested. Various MFCs with appropriate ranges of 0–25 sccm, 0–100 sccm and 0–1 slpm for the challenge gas is suggested.

8.2.1.5 *Tubing* — made of electropolished 316L stainless steel, with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to transport gas.

8.2.1.6 *Fittings* — the appropriate size face-seal fitting is used.

8.2.1.7 *Gaskets* — use metal gaskets for all connections. New gaskets should be used for each new connection. Use of cleanroom gloves is required when handling gaskets and fittings.

8.2.2 *Instrumentation*

8.2.2.1 An APIMS or other ultratrace analytical instrumentation is used to determine the level of each gaseous impurity exiting the DUT.

8.2.2.2 An impurity analyzer is used to measure higher concentrations of impurities such as found in the test gas.

8.2.2.3 Electronically controlled mass flow controllers are used to accurately blend the impurity challenge level.

8.2.2.4 Data collection equipment is used to gather output from the ultratrace analytical instrumentation.

8.2.2.5 All instruments used should be calibrated regularly, according to manufacturer's specifications.

8.2.3 *Test Set-up and Schematic*

8.2.3.1 Assemble the test setup according to Figure 1. Do not install the DUT until a purge flow is established through MFC1.

8.2.3.2 For the test set-up, pure gas is blended with challenge gas to create a test gas mixture.

8.2.3.3 The DUT is connected, purged per the manufacturer's recommendation, positioned with the appropriate attitude (if required by the manufacturer), and heated (if required by manufacturer) under pure gas flow.

8.2.3.4 Challenge gas flow is introduced and the impurity analyzer measures the impurity levels. If appropriate, the APIMS or other ultratrace analytical instrumentation may be used to measure the test gas while the test gas bypasses the DUT. See Section 9 on Exposure Precautions.

8.2.3.5 Measure and record the test gas concentration for the desired impurity.

8.2.3.6 Following measurement of the test gas, the bypass should be purged with pure gas to ensure impurity removal from the section of the test set-up that is downstream of the DUT.

8.3 *Test Procedures* — Refer to Figure 1.

8.3.1 Use of the impurity analyzer is recommended to protect the APIMS or ultratrace analytical instrumentation from high impurity concentrations which may harm the instrument. The test may be conducted without the impurity analyzer at the risk of exposing the APIMS or ultratrace analytical instrumentation to high impurity concentrations.

8.3.2 *Analytical Instrumentation Setup*

8.3.2.1 Set up and calibrate the analytical instrumentation (APIMS or ultratrace analytical instrumentation and impurity analyzer) according to manufacturer specifications. This includes establishing the appropriate flow rate to the instrument.

8.3.2.2 Acquire zero data to establish the analytical instrumentation baseline and stability prior to starting the test.

8.3.3 Establish flow of pure gas through the manifold bypass:

8.3.3.1 Start with all valves closed except purge gas to analytical instrumentation (V11 and V13 open).

8.3.3.2 Open V1 and adjust R1 to the suggested operating pressure range of 275–415 kPa (40–60 psig).

8.3.3.3 Open V2, V8, V9 and adjust R3 to provide appropriate backpressure for operation of the APIMS or other ultratrace analytical instrumentation. R3 will vent excess gas providing the volume challenge to the DUT. Set MFC1 to the appropriate flow rate. Readjust R1 and R3 to obtain the proper operating conditions.

8.3.4 Monitor drydown of the manifold bypass:

8.3.4.1 Close V11 and Open V10.

8.3.4.2 Purge the bypass manifold until the impurity level is in the range of the APIMS or ultratrace analytical instrumentation.

8.3.4.3 Close V13 and Open V12. Close V10 and Open V11.

8.3.4.4 Purge the bypass manifold until the moisture impurity level at the APIMS or ultratrace analytical instrumentation is below 1.0 ppb.

8.3.5 Re-isolate the APIMS or ultratrace analytical instrumentation:

8.3.5.1 Close V12 and Open V13. Maintain a constant purge to the analytical instrumentation.

8.3.6 Install the DUT, Purging with Pure Gas:

8.3.6.1 Open V6. Remove the DUT inlet face-seal connection. Quickly install the DUT inlet. Remove the DUT outlet face-seal connection and install the DUT outlet. Open V7.

8.3.6.2 Isolate the manifold bypass, directing all flow through the DUT, close V8 and V9.

8.3.6.3 Adjust R1 and R3 until P1 measures the stated purifier operating pressure.

8.3.6.4 Purge the DUT per the manufacturer's recommendation. If required, heat the DUT per manufacturer's recommendation.

8.3.7 Monitor the impurity level at the outlet of the DUT until stable:

8.3.7.1 Initial impurity monitoring may be done with the impurity analyzer. Close V11, open V9 and V10.

8.3.7.2 When the impurity level is in the range of the APIMS or ultratrace analytical instrumentation, Close V13 and Open V12. Close V9 and V10, Open V11.

8.3.7.3 Monitor impurity level until stable.

8.3.8 Initiate Impurity Challenge:

8.3.8.1 Isolate the DUT and APIMS or ultratrace analytical instrumentation. Close V7 and V12, open V13.

8.3.8.2 Open V3 and adjust R2 to the suggested operating pressure range of 275–415 kPa (40–60 psig). Open V5 and set MFC2 to the desired flow. (See Appendix 1 to determine the desired flow for MFC2).

8.3.8.3 Verify test gas impurity. Open V4, V8, and V10 and then close V5 and V11, supplying test gas to the impurity analyzer. Adjust R2 as necessary to maintain appropriate pressure for supplying MFC2. Monitor test gas impurity until stable and verified to theoretical impurity value (See Appendix 1).

8.3.8.4 Initiate test. Direct input test gas through the DUT to the APIMS or ultratrace impurity analyzer, Open V6 and V7. Open V12 and close V13. Isolate impurity analyzer, Close V8 and V10. Open V11.

8.3.8.5 Zero test gas flow totalizers (Pure Gas MFC1 and challenge gas through MFC2) beginning Purifier Capacity Test.

8.3.9 Determination of purifier capacity:

8.3.9.1 The test will require several weeks or months depending on the purifier's capacity for retention of and the concentration of the impurity.

8.3.9.2 The test may be done on newly activated media or may be done using existing media that has been regenerated. The test may be destructive to the DUT.

8.3.9.3 Constant monitoring of the purifier effluent over the duration of the test is preferred. However, periodic monitoring, e.g. every few hours is sufficient.

8.3.9.4 The test gas can be periodically monitored at the impurity analyzer by closing V11 and opening V8 and V10. If significant, ensure that flow volume to impurity analyzer during this time is subtracted from total volume input through DUT. In addition, instrument calibration should be monitored as recommended by the manufacturer.

8.3.9.5 Monitor trends in outlet purity until the breakthrough point for the impurity is detected. Time, liters of gas, and outlet purity should be recorded.

8.4 Repeat test for each new impurity to be analyzed using a new or regenerated DUT.

9 Exposure Precautions

9.1 The APIMS or ultratrace analytical instrument should not be exposed to high levels of impurities. After installation of the purifier, it should be purged well, per the manufacturer's recommendation. A typical recommendation might be to purge a minimum of 150 bed volumes before directing the flow to the APIMS.

10 Calculation of Purifier Capacity

10.1 Use the following formula to calculate Purifier Capacity:

10.2 (Test Duration (min)) × (Test Flow Rate slpm) = Total Liters Test Gas (TLTG)

10.3 Impurity(liters) = (TLTG) × ppm × 10^{-6}

10.4 Purifier Capacity = (Total Impurity (liters)/(Purifier Volume(liters))

10.5 Purifier Capacity is reported as total liters of each given impurity per liter purifier, and is a dimensionless number.

11 Reporting Results

11.1 The following test conditions should be reported:

11.1.1 Date and time of test,

11.1.2 Operator,

11.1.3 Pure gas flow rate (slpm),

11.1.4 Challenge gas flow rate (sccm),

11.1.5 Test pressure kPa (psig or psia),

11.1.6 DUT operating temperature (° C),

11.1.7 Purifier manufacturer, model, and serial number, and volume,

11.1.8 Ultratrace analytical instrumentation used,

11.1.9 Test gas impurities and levels, and

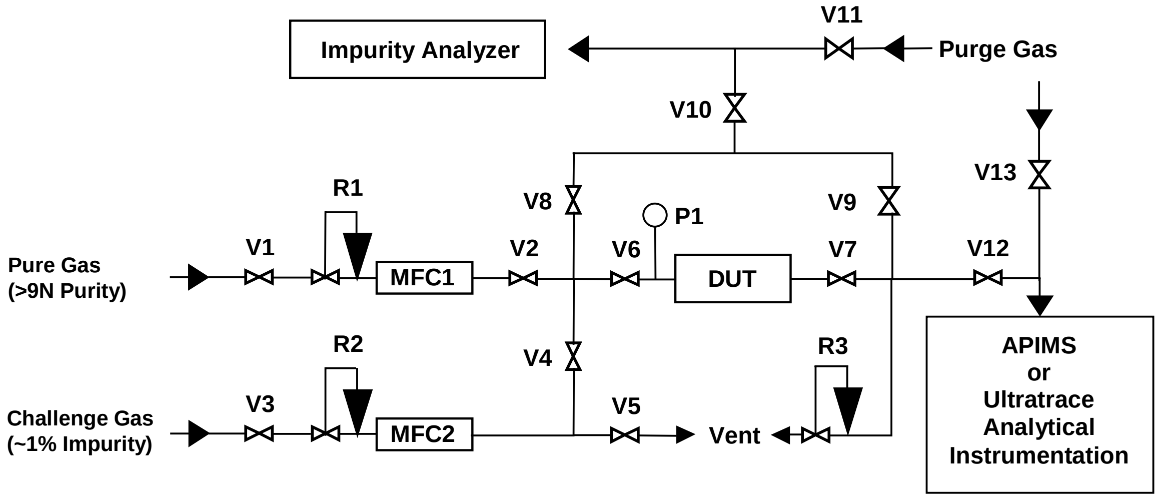
11.1.10 Calibration certificates for the mass flow devices, pressure gauges and ultratrace analytical instrumentation.

12 Related Documents

SEMI F30 — Start-up and Verification of Purifier Performance Testing for Trace Gas Impurities and Particles at an Installation Site

SEMI F43 — Test Method for Determination of Particle Contribution by Point-Of-Use Purifiers

NOTE 3: Unless otherwise indicated, all documents cited shall be the latest published versions.



Legend

DUT = Device Under Test
P1 = Test Pressure
R1 = Pure Gas 0–100 psig Regulator
R2 = Challenge Gas 0–100 psig Regulator
R3 = Vent Gas 0–100 psig Back Pressure Regulator
V1 = Pure Gas Source Isolation Valve
V2 = Pure Gas System Isolation Valve
V3 = Challenge Gas Source Isolation Valve
V4 = Challenge Gas System Isolation Valve
V5 = Challenge Gas Vent Isolation Valve
V6 = DUT Inlet Isolation Valve
V7 = DUT Outlet Isolation Valve
V8 = DUT Bypass Inlet Isolation Valve
V9 = DUT Bypass Outlet Isolation Valve
V10 = Impurity Analyzer Sample Isolation Valve
V11 = Impurity Analyzer Purge Gas Isolation Valve
V12 = APIMS/UAI Sample Isolation Valve
V13 = APIMS/UAI Purge Gas Isolation Valve
MFC1 = Pure Gas Mass Flow Controller
MFC2 = Challenge Gas Mass Flow Controller

Figure 1
Suggested Point of Use Purifier Capacity Test Setup

APPENDIX 1
MFC SIZING

NOTE: The material in this appendix is an official part of SEMI F67 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 To determine purifier efficiency, the concentration of impurity entering the purifier and the quantity of impurity downstream of the purifier must be determined.

A1-2 Determine the manufacturer's recommended flow rate for the purifier. As an example, assume a flow rate of 5 slpm.

A1-3 Determine the flow rate of challenge gas required. As an example, 5 sccm of a 1% challenge gas would be blended into 4,995 sccm of pure gas to generate a 10 ppm test gas.

$$\text{TestGas} = \frac{10{,}000\ \text{PPM} \times 5\ \text{sccm}}{5\ \text{sccm} + 4{,}995\ \text{sccm}} = 10\ \text{PPM}$$

SEMI F68-1101
TEST METHOD FOR DETERMINING PURIFIER EFFICIENCY

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this document is to define a test method to quantify the efficiency of a purifier for removal of an active gaseous impurity from a matrix gas.

2 Scope

2.1 To determine the efficiency of a gas purifier to remove a given impurity species. Efficiency tests are performed by adding ppm levels of gaseous impurities to a pure matrix gas and monitoring the effluent of the test purifier for active impurity species. Tests are done at supplier recommended flow rate, operating temperature and pressure.

2.2 To establish a method of determining instantaneous purifier efficiency.

2.3 The test method applies to point of use (POU) and large scale purifiers.

2.4 This method is for UHP efficient removal of low level contaminants.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate and safety health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The inherent limitation to this method is the limit of detection (LOD) of the analytical instrument employed by the user.

3.2 This test method can only be used to compare purifier efficiency results if the user application for flow rate, pressure, and temperature are the same as the test conditions. Different user and/or different operating conditions may result in different purifier performance results.

3.3 In testing mixtures of impurities, some impurities may influence the efficiency results of other impurities. Discussion with the manufacturer is highly recommended prior to testing.

3.4 The test method does not apply to particulates.

3.5 This test method will provide efficiency information only for impurities that are used in the challenge gas.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E29 — Standard Terminology for the Calibration of Mass Flow Controllers and Mass Flow Meters

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F22 — Guide for Gas Distribution Systems

SEMI F33 — Method for Calibration of Atmospheric Pressure Ionization Mass Spectrometer (APIMS)

4.2 *ANSI Standards*[1]

ANSI B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *APIMS* — atmospheric pressure ionization mass spectrometer

5.1.2 *°C* — degrees Celsius

5.1.3 *DUT* — device under test

5.1.4 *°F* — degrees Fahrenheit

5.1.5 *in* — inch

5.1.6 *kPa* — kiloPascal

5.1.7 *LOD* — limit of detection

5.1.8 *m* — meter

5.1.9 *MFC* — mass flow controller

5.1.10 *NMHC* — non methane hydrocarbons

5.1.11 *POU* — point of use

5.1.12 *ppb* — parts per billion, volume basis

1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

5.1.13 *ppm* — parts per million, volume basis

5.1.14 *psi* — pounds per square inch

5.1.15 *psia* — pounds per square inch absolute

5.1.16 *psig* — pounds per square inch gauge

5.1.17 R_a — surface roughness average (as defined in ANSI B46.1)

5.1.18 $R_{a,max}$ — surface roughness maximum (as defined in ANSI B46.1)

5.1.19 *s* — second

5.1.20 *sccm* — standard cubic centimeters per minute

5.1.21 *slpm* — standard liters per minute

5.1.22 *UHP* — ultra high purity

5.2 *Definitions*

5.2.1 *activation* — the process of initially preparing the purifier media to be chemically reactive with gas impurities.

5.2.2 *activation temperature* — temperature at which DUT was initially prepared.

5.2.3 *atmospheric pressure ionization mass spectrometer (APIMS)* — an instrument consisting of an atmospheric pressure ion source where gas phase impurities are ionized via charge exchange reactions with the bulk gas. These ions are directed into a vacuum chamber where they are then separated by a mass analyzer and detected by an electron multiplier.

5.2.3.1 *ion source* — the section of a mass spectrometer used to generate sample ions by electron impact, chemical ionization, or charge exchange.

5.2.3.2 *mass analyzer* — a device that utilizes electric and/or magnetic fields to separate charged particles or ions according to their mass-to-charge (m/e) ratios. Examples of mass analyzers include quadrupole, magnetic and/or electric sector, time of flight, and ion traps.

5.2.3.3 *electron multiplier* — a device that detects and amplifies electro-magnetic phenomena such as positive/negative ions.

5.2.4 *back pressure regulator* — a self-contained device, consisting of a mechanical or electrical sensor and control device, commonly used in the semiconductor industry to maintain a constant pressure upstream of the regulator.

5.2.5 *breakthrough* — the point in time when an individual impurity level in the purifier effluent exceeds the level specified by the manufacturer. Typically in the range of 1–100 ppb.

5.2.6 *challenge gas* — a gas mixture containing high levels of gas impurities. Typically, a challenge gas has impurities of between 500 ppm to 1% which is used to shorten the test duration; however, challenges in the range of 1–10 ppm for the impurities is more representative.

5.2.7 *efficiency* — a measure of the ability of a purifier to remove active impurities from a matrix gas stream. It is calculated as the ratio of the difference between the inlet concentration and the concentration of impurity leaving the purifier to the concentration of impurity entering the purifier.

5.2.8 *gaseous impurities* — gas phase elements and compounds in the gas stream other than the process or base gas.

5.2.9 *impurity analyzer* — an appropriate analyzer to measure the concentration of desired impurities in a gas stream from the ppm to the percent (%) concentration range.

5.2.10 *inert gas* — a gas, which at ambient conditions, does not react chemically with other materials or chemicals.

5.2.11 *limit of detection (LOD)* — lowest concentration that can be detected by an instrument. LOD is typically defined as three times the standard deviation of the mean noise level (see SEMI F6, lower detectable limit of instrument).

5.2.12 *mass flow controller (MFC)* — a self-contained device, consisting of a mass flow transducer, control valve, and control and signal-processing electronics, commonly used in the semiconductor industry to measure and regulate the mass flow of gas (as defined in SEMI E29).

5.2.13 *pure gas* — an inert gas, minimum purity of 99.9995%, and less than 1 ppb of each impurity that is specified to be removed by the DUT.

5.2.14 *purifier*— generally a catalytic (getter, reactive), resinous, or diatomaceous material within a pressure vessel which removes particulate and/or trace gas impurities from a gas stream (as defined in SEMI F22).

5.2.15 *purifier capacity* — the total quantity of each trace gas impurity that may be sorbed by the purifier media. Defined as liters impurity/liter purifier media.

5.2.16 *regeneration* — the process of reactivating the purifier media.

5.2.17 *test duration* — total time required to complete the test procedure.

5.2.18 *test flow rate* — flow rate through DUT (slpm).

5.2.19 *test pressure* — pressure immediately upstream of the DUT.

5.2.20 *test temperature* — operating temperature of DUT.

5.2.21 *ultratrace analytical instrumentation* — instrumentation that has sufficient sensitivity to measure all impurities of interest at the specified level of the customer, the ppb or sub-ppb level.

5.2.22 *zero gas* — nitrogen, argon, helium or hydrogen with an estimated level an order of magnitude, or more, lower than the lowest calibration point for each impurity of interest (as defined in SEMI F33).

6 Summary of Method

6.1 This method will allow a user to quantify the impurity efficiency of a point-of-use (POU) or large scale purifier.

7 Safety Precautions

7.1 This test method may involve hazardous materials, operations, and equipment. The test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.

7.2 Exhaust from the DUT should be properly vented.

7.3 Only the appropriate gas should be used for purifier testing. Use of inappropriate gases may cause exothermic reactions and possible explosions.

7.4 Electric discharges or mechanical friction might trigger combustion within a getter. Avoid situations where there is an accumulation of electrostatic charge.

7.5 Purifiers are generally designed for use with impurity levels less than 1% and should not be used to purify air or other inappropriate gases. Contact the manufacturer if there is any question as to the suitability for a particular gas.

7.6 Care should be taken to minimize the purifier's exposure to room air (even filtered air). Room air may chemically react with some purifiers shortening the purifier lifetime. Follow manufacturer's installation procedures.

8 Test Protocol

8.1 *Test Conditions*

8.1.1 The test should be conducted following manufacturer's recommended handling procedures to activate new media or regenerate existing purifier media.

8.1.2 The test is to be conducted at a room temperature maintained between 18°C (64°F) and 26°C (78°F). Environmental temperature fluctuations within this range are not expected to have any measurable effect on the instrumentation used to detect the level of impurities. Follow instrument manufacturer's operating procedures.

8.2 *Apparatus*

8.2.1 *Materials*

8.2.1.1 *Test Gas* — a mixture of pure gas and challenge gas. The mixture should contain gaseous impurities of between 1 ppm and 10 ppm.

8.2.1.2 *Pressure Regulators* — all wetted internal surfaces, where appropriate, should be made of electropolished 316L stainless steel with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to control system pressures.

8.2.1.3 *Pressure Gauge* — all wetted internal surfaces, where appropriate, should be made of electropolished 316L stainless steel with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to monitor system pressures.

8.2.1.4 *Standard Test Flows* — use appropriate mass flow devices. One MFC with appropriate range of 0–50 slpm for the pure gas is suggested. Various MFCs with appropriate ranges of 0–25 sccm, 0–100 sccm and 0–1 slpm for the challenge gas are suggested.

8.2.1.5 *Tubing* — made of electropolished 316L stainless steel, with an internal surface finish of 0.18 µm (7 µin) R_a and 0.25 µm (10 µin) $R_{a,max}$, to transport gas.

8.2.1.6 *Fittings* — the appropriate size face-seal fitting is used.

8.2.1.7 *Gaskets* — use metal gaskets for all connections. New gaskets should be used for each new connection. Use of cleanroom gloves is required when handling gaskets and fittings.

8.2.2 *Instrumentation*

8.2.2.1 An APIMS or other ultratrace analytical instrumentation is used to determine the level of each gaseous impurity exiting the DUT.

8.2.2.2 An impurity analyzer is used to measure higher concentrations of impurities such as found in the test gas.

8.2.2.3 Electronically controlled mass flow controllers are used to accurately blend the impurity challenge level.

8.2.2.4 Data collection equipment is used to gather output from the ultratrace analytical instrumentation.

8.2.2.5 All instruments used should be calibrated regularly, according to manufacturer specifications.

8.2.3 *Test Setup and Schematic*

8.2.3.1 Assemble the test setup according to Figure 1. For a large scale system which may include components such as flow meters, pressure regulation and indication, and bypass loops around the purifying media(s), the test setup may be modified accordingly in order to use these built in attributes while adhering to the procedural steps. Do not install the DUT until a purge flow is established through MFC1.

8.2.3.2 Pure gas is blended with challenge gas to create a test gas mixture containing approximately 1–10 ppm of gaseous impurities.

8.2.3.3 The DUT is connected, purged per the manufacturer's recommendation, positioned with the appropriate attitude (if required by the manufacturer), and heated (if required by manufacturer) under pure gas flow.

8.2.3.4 Challenge gas flow is introduced and the impurity analyzer measures the impurity levels. If appropriate, the APIMS or other ultratrace analytical instrumentation may be used to measure the test gas while the test gas bypasses the DUT. See Section 9 on Exposure Precautions.

8.2.3.5 Measure and record the test gas concentration for the desired impurity.

8.2.3.6 Instantaneous impurity efficiencies may be calculated at any point by knowing the level of each impurity entering and exiting the purifier.

8.3 *Test Procedures* — Refer to Figure 1.

8.3.1 Use of the impurity analyzer is recommended to protect the APIMS or other ultratrace analytical instrumentation from impurity spikes which may harm the instrument. The test may be conducted without the impurity analyzer at the risk of such spikes.

8.3.2 *Analytical Instrumentation Setup*

8.3.2.1 Set up and calibrate the analytical instrumentation (APIMS or ultratrace analytical instrumentation and impurity analyzer) according to manufacturer specifications. This includes but is not limited to establishing the appropriate flow rates to the instruments.

8.3.2.2 Acquire zero data to establish the instrumentation baseline and stability prior to starting the test.

8.3.3 Establish flow of pure gas through the manifold bypass:

8.3.3.1 Start with all valves closed except purge gas to analytical instrumentation (V11 and V13 open).

8.3.3.2 Open V1 and adjust R1 to the suggested operating pressure range of 275–415 kPa (40–60 psig).

8.3.3.3 Open V2, V8, V9 and adjust R3 to provide appropriate backpressure for operation of the APIMS or other ultratrace analytical instrumentation. R3 will vent excess gas providing the volume challenge to the DUT. Set MFC1 to the appropriate flow rate.

8.3.4 Monitor drydown of the manifold bypass:

8.3.4.1 Close V11 and Open V10.

8.3.4.2 Purge the bypass manifold until the impurity level is in the range of the APIMS or ultratrace analytical instrumentation.

8.3.4.3 Close V13 and Open V12.

8.3.4.4 Purge the bypass manifold until the moisture impurity level at the APIMS or ultratrace analytical instrumentation is below 1.0 ppb.

8.3.5 Re-isolate the APIMS or ultratrace analytical instrumentation:

8.3.5.1 Close V12 and Open V13. Close V10 and open V11. Maintain a constant purge to the analytical instrumentation.

8.3.6 Install the DUT, purging with Pure Gas (may not be necessary, as installed in the test set-up for large scale systems):

8.3.6.1 Open V6. Remove the DUT (purifier) inlet face-seal connection. Quickly install the DUT inlet. Remove the DUT outlet face-seal connection and install the DUT outlet. Open V7.

8.3.6.2 Isolate the manifold bypass, directing all flow through the DUT, close V8 and V9.

8.3.6.3 Adjust R1 and R3 until P1 measures the stated purifier operating pressure.

8.3.6.4 Purge the DUT (purifier) per the manufacturer's recommendation. If required, heat the DUT (purifier) per manufacturer's recommendation.

8.3.7 Monitor the impurity level at the outlet of the DUT until stable:

8.3.7.1 Initial impurity monitoring may be done with the impurity analyzer. Close V12, Open V9 and V10. Close V11.

8.3.7.2 When the impurity level is in the range of the APIMS or ultratrace analytical instrumentation, Close V13 and Open V12. Close V9 and V10, Open V11.

8.3.7.3 Monitor impurity level until stable.

8.3.8 Initiate Impurity Challenge:

8.3.8.1 Isolate the DUT and APIMS or ultratrace analytical instrumentation. Close V7 and V12, open V13.

8.3.8.2 Open V3 and adjust R2 to the suggested operating pressure range of 275–415 kPa (40–60 psig). Open V5 and set MFC2 to the desired flow. (See Appendix 1 to determine the desired flow for MFC2).

8.3.8.3 Verify test gas impurity. Close V5 and V11, Open V4, V8, and V10 supplying test gas to the impurity analyzer. Monitor test gas impurity until stable and verified to theoretical impurity value (See Appendix 1).

8.3.8.4 Initiate test. Isolate impurity analyzer, Close V8 and V10, Open V11. Input test gas through the DUT to the APIMS or ultratrace impurity analyzer, Open V6 and V7. Close V13 and Open V12.

8.3.8.5 Monitor and record the outlet impurity level until stable.

8.3.8.6 If necessary, repeat the test for a different challenge gas mixture.

8.3.9 Determination of instantaneous purifier efficiency:

8.3.9.1 The test may be done on newly activated media or may be done using existing media that has been regenerated. The test may be destructive to the DUT (purifier).

8.3.9.2 Repeat the test as necessary to provide a statistically valid number of test results. A discussion of what is statistically valid is beyond the scope of this document.

9 Exposure Precautions

9.1 The APIMS or ultratrace analytical instrument should not be exposed to high levels of impurities. After installation of the purifier, it should be purged well, per the manufacturer's recommendation. A typical recommendation might be to purge a minimum of 150 bed volumes before directing the flow to the APIMS.

9.2 Alternative instrumentation should be used to measure the challenge gas when the concentration of the challenge gas is greater than the normal calibration range of the APIMS or other ultratrace analytical instrumentation.

10 Calculation of Instantaneous Purifer Efficiency

10.1.1.1 Use the following formula to calculate the Instantaneous Purifier Efficiency:

$$\%eff = \left(1 - \frac{outlet\,impurity}{inlet\,impurity}\right) \times 100$$

Example: Let impurity outlet = 10 ppb and impurity inlet = 10 ppm,

$$\%eff = \left(1 - \frac{10}{10{,}000}\right) \times 100 = 99.9$$

11 Reporting Results

11.1 The following test conditions should be reported:

11.1.1 Date and time of test,

11.1.2 Operator,

11.1.3 Pure gas flow rate (slpm),

11.1.4 Challenge gas flow rate (sccm),

11.1.5 Test pressure kPa (psig or psia),

11.1.6 DUT operating temperature (° C),

11.1.7 Purifier manufacturer, model, and serial number, and volume,

11.1.8 Ultratrace analytical instrumentation used,

11.1.9 Test gas impurities and levels (Table 1), and

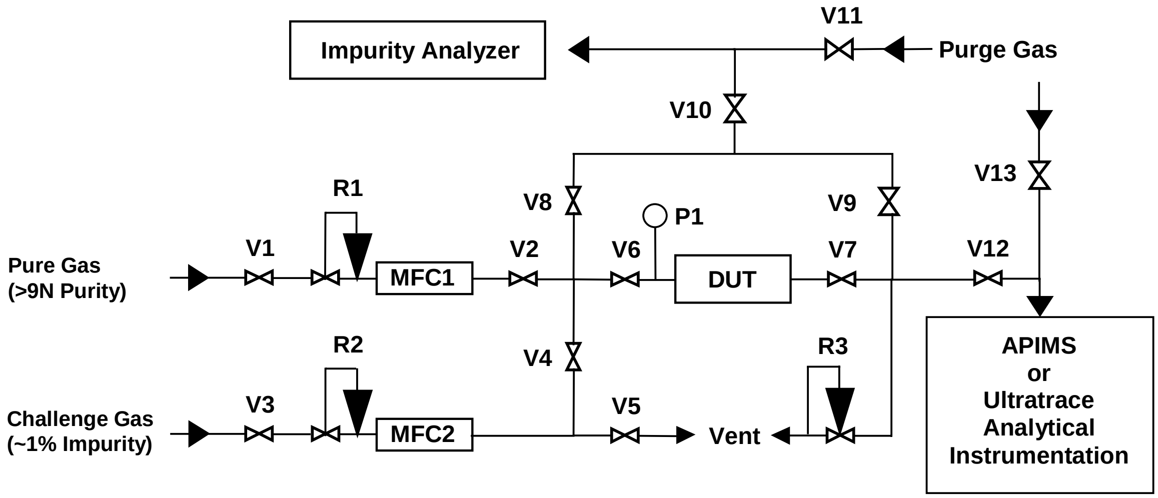
11.1.10 Calibration certificates for the mass flow devices, pressure gauges and ultratrace analytical instrumentation.

12 Related Documents

SEMI F30 — Start-up and Verification of Purifier Performance Testing for Trace Gas Impurities and Particles at an Installation Site.

SEMI F43 — Test Method for Determination of Particle Contribution by Point-Of-Use Purifiers.

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.



Legend

DUT = Device Under Test
P1 = Test Pressure
R1 = Pure Gas 0–100 psig Regulator
R2 = Challenge Gas 0–100 psig Regulator
R3 = Vent Gas 0–100 psig Back Pressure Regulator
V1 = Pure Gas Source Isolation Valve
V2 = Pure Gas System Isolation Valve
V3 = Challenge Gas Source Isolation Valve
V4 = Challenge Gas System Isolation Valve
V5 = Challenge Gas Vent Isolation Valve
V6 = DUT Inlet Isolation Valve
V7 = DUT Outlet Isolation Valve
V8 = DUT Bypass Inlet Isolation Valve
V9 = DUT Bypass Outlet Isolation Valve
V10 = Impurity Analyzer Sample Isolation Valve
V11 = Impurity Analyzer Purge Gas Isolation Valve
V12 = APIMS/UAI Sample Isolation Valve
V13 = APIMS/UAI Purge Gas Isolation Valve
MFC1 = Pure Gas Mass Flow Controller
MFC2 = Challenge Gas Mass Flow Controller

Figure 1
Suggested Point of Use Purifier Efficiency Test Setup

Table 1 Efficiency Of DUT Parameters

EFFICIENCY OF DUT						
Impurity	*Pure Gas Flow* (slpm)	*Challenge Flow* (sccm)	*Inlet Conc* (ppm)	*Outlet Conc* (ppb)	*Zero Gas* (ppb)	*Analyzer*
CH_4						
H_2						
O_2						
N_2						
CO_2						
NMHC						

APPENDIX 1
MFC SIZING

NOTE: The material in this appendix is an official part of SEMI F68 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 To determine purifier efficiency, the concentration of impurity entering the purifier and the quantity of impurity downstream of the purifier must be determined.

A1-2 Determine the manufacturer's recommended flow rate for the purifier. As an example, assume a flow rate of 5 slpm.

A1-3 Determine the flow rate challenge gas required. As an example, 5 sccm of a 1% challenge gas would be blended into 4,995 sccm of pure gas to create at 10 ppm test gas.

$$\text{Test Gas} = \frac{10{,}000 \text{ PPM} \times 5 \text{ sccm}}{5 \text{ sccm} + 4{,}995 \text{ sccm}} = 10 \text{ PPM}$$

As a large scale system, with a flow of 1,000 slpm, a flow of 1 slpm of challenge gas (1% impurity) is required to create a 10 ppm challenge.

$$\text{Test Gas} = \frac{10{,}000 \text{ PPM} \times 1 \text{ slpm}}{1 \text{ slpm} + 999 \text{ slpm}} = 10 \text{ PPM}$$

SEMI F69-0302
TEST METHODS FOR TRANSPORT AND SHOCK TESTING OF GAS DELIVERY SYSTEMS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002.

1 Purpose

1.1 This document provides test methods for qualifying the mechanical integrity of gas delivery systems through vibration and shock testing.

2 Scope

2.1 The test methods recommended herein provide for vibration (transport simulation) and shock testing of gas delivery systems for semiconductor processing.

2.2 The test methods recommended herein apply to gas delivery systems not crated or packaged for shipment. Specifically, the test methods are to be applied to the assembled and interconnected gas delivery components and their associated mounting panel (back plane), with or without a sheet metal enclosure.

2.3 For the purpose of this guideline, transportation vibration, and its simulation, are expectedly more severe than in-use vibrational levels. Thus the transportation simulation test is considered acceptable to assess mechanical integrity adequate for both shipment and life-cycle vibrational stress of the gas delivery systems.

2.4 The intent of the shock test is to provide further assessment of equipment malfunction that may result from shocks experienced during unpacking, installation, or use in the field.

2.5 Successful completion of the tests recommended herein is a recommended metric of mechanical integrity for gas delivery systems architecture, design, and assembly techniques.

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document, as a guide, does not provide detailed information sufficient for conducting the tests. It is the responsibility of the user and testing entity to procure a copy of the referenced test procedures from the issuing organization(s).

3.2 The test methods recommended herein are intended to evaluate gas delivery systems architectures, design principles, and assembly methodologies, not individual production gas delivery systems.

3.3 The functional components of gas delivery systems, for example mass flow controllers and pressure transducers, may be adversely affected by the forces seen during these tests. Such components may require recalibration after testing.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

4.2 *Military Standards*[1]

MIL-STD-810 — Environmental Engineering Considerations and Laboratory Tests

5 Terminology

5.1 *bag leak test* — A helium leak testing procedure in which the system undergoing leak test is placed in a helium-filled plastic bag while connected to a functional helium leak detector.

5.2 *g* — A unit of force equal to that exerted by gravity upon a mass in equilibrium on the earth's surface. Expressed in Newtons (kg-m/sec.^{2}).

5.3 *leak tight* — Having a helium leak rate no greater than that specified by the customer or end-user.

6 Vibration Testing

NOTE 2: Vibration testing should be performed in its entirety before continuing to the shock testing.

6.1 In general, conduct vibrational testing according to MIL-STD-810, Part Two, Laboratory Test Method 514.5, Procedure 1, Category 4, for 3 hours in each axis (a total of 9 hours). This will subject the gas delivery

1 DODSSP, Building 4 / Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5094

systems to the equivalent physical stress of a 4828 kilometer (3000 mile) motor freight shipment over improved or paved highways. Because vibration tables are commonly single-axis devices, the gas delivery systems will be subjected to single-axis random vibrational frequencies in the range of 5—500 Hz, sequentially, in each of its three axes.

6.2 Prior to initiating the test, examine the gas delivery systems for physical defects and document the results.

6.3 Prior to initiating the test, thoroughly prepare the gas delivery systems for testing. This includes, but is not limited to, insuring all fasteners and sealing mechanisms are tightened to manufacturers' or design specifications.

6.4 The MIL-STD-810 transportation test recommended herein provides for different acceleration levels for each of the 3 axes of the device under test. Because the majority of gas delivery systems are shipped in a vertical orientation, this convention is maintained for the purpose of the transportation simulation tests. Thus the vertical orientation would have the gas delivery system mounted vertically with respect to the vibration table top (see Figure 2), the longitudinal orientation would have the gas delivery system mounted flat to the vibration table top (see Figure 1), and the transverse orientation would have the gas delivery system mounted on its side, against the vibration table top (see Figure 3). Note that the terms "vertical," "longitudinal," and "transverse," are contextual to motor freight transport, and receive different acceleration levels, within MIL-STD-810. A simplified and conservative approach to applying MIL-STD-810 involves applying the highest acceleration level, associated with the vertical axis, to all three orientations as illustrated in Figures 1–3.

6.5 Mount the gas delivery system, in any of its untested axes, securely to the vibration table. See Figures 1–3.

6.6 Prior to initiating the test at the test site, make certain that the gas delivery system is leak tight using inboard test procedures per SEMI F1. A bag leak test method is recommended in conjunction with this test.

6.7 Initiate and run for 3 hours the vibration test corresponding to the orientation of the gas delivery system.

6.8 At the conclusion of the test, examine the gas panel for physical defects and document the results

6.9 At the conclusion of the test, leak test the gas delivery system using inboard leak procedures per SEMI F1. A bag leak test method is recommended in conjunction with this test. Alternatively, by agreement with the customer, all leak testing may be withheld until completion of all shock and vibration testing. This presumes specific failure mode information is not required.

6.10 Repeat Sections 6.5 through 6.9 until all 3 axes are tested.

6.11 The post-test report should include, at minimum, the following:

(1) Pre-test examination results.

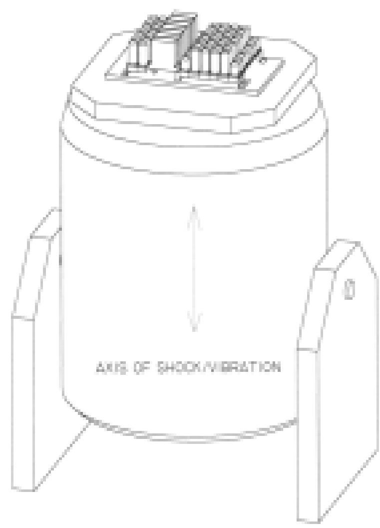
(2) Pre-test leak rates.

(3) Summary and chronology of test events, test interruptions, and test failures.

(4) All vibration measurement data.

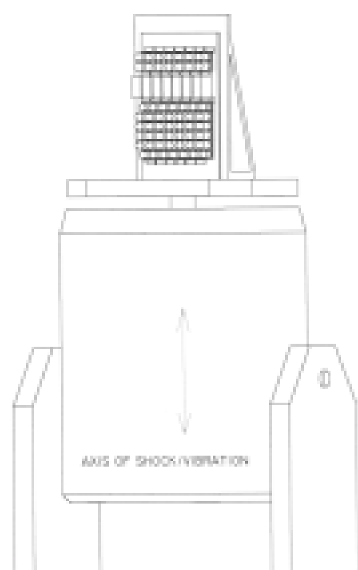
(5) Post-test examination results.

(6) Post-test leak rates.



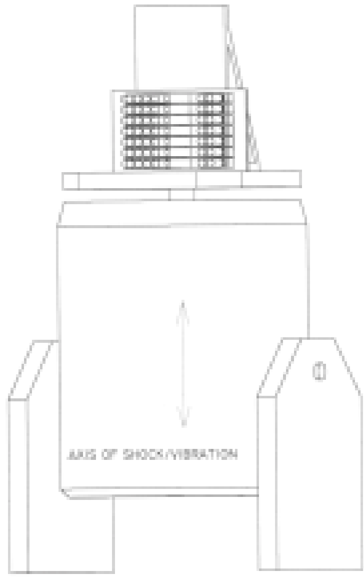
NOTE 1: Plane of gas sticks is parallel to shock/vibe table and transverse to test input.

Figure 1
Horizontal Orientation



NOTE 1: Plane and axes of gas sticks are normal to shock/vibe table and parrallel to test input.

Figure 2
Vertical Orientation



NOTE 1: Plane of gas sticks is normal to shock/vibe table and axes of sticks are transverse to test input.

Figure 3
Lateral Orientation

7 Shock Testing

7.1 In general, conduct shock testing according to MIL-STD-810, Part Two, Laboratory Test Method 516.5, Procedure 1 (Functional Shock). This test will subject the gas delivery system to a peak acceleration of 40 g's employing a terminal peak sawtooth shock pulse.

7.2 The test should be conducted in each of the gas delivery system's three axes as illustrated in Figures 1–3.

7.3 Prior to initiating the test, examine the gas delivery system for physical defects and document the results.

7.4 Prior to initiating the test, thoroughly prepare the gas delivery system for testing. This includes, but is not limited to, insuring all fasteners and sealing mechanisms are tightened to manufacturers' or design specifications.

7.5 Prior to initiating the test, make certain that the gas delivery system is leak tight using inboard test procedures per SEMI F1. A bag leak test method is recommended in conjunction with this test.

7.6 Secure the gas delivery system under test to the shock table in one of its three orientations: horizontal, vertical, or lateral. The gas delivery system should be fastened directly to the table with no cushion or other intermediary between the two. A rigid mounting is desirable, taking caution not to introduce stress to the gas delivery system.

7.7 Conduct the shock test.

7.8 At the conclusion of the test, examine the gas panel for physical defects and document the results.

7.9 If, as a result of the test, an apparent physical failure occurred that would likely prevent the safe operation of the gas panel and/or would likely compromise the leak tightness of the gas panel, the physical failure should be corrected, the gas panel retested for leak tightness, and the test repeated.

7.10 At the conclusion of the test, leak test the gas delivery system using inboard leak procedures per SEMI F1. A bag leak test method is recommended in conjunction with this test. Alternatively, by agreement with the customer, all leak testing may be withheld until completion of all shock and vibration testing. This presumes specific failure mode information is not required.

7.11 Repeat 7.6 through 7.10 for a second orientation.

7.12 Repeat 7.6 through 7.10 for the third and final orientation.

7.13 The post-test report should include, at minimum, the following:

1) Pre-test examination results.

2) Pre-test leak rate.

3) Summary and chronology of test events, test interruptions, and test failures.

4) All shock measurement data, including that of any accelerometers mounted to the gas delivery system.

5) Post-test examination results for all three axes.

6) Post-test leak rate for all three shock tests.

SEMI F70-0302
TEST METHOD FOR DETERMINATION OF PARTICLE CONTRIBUTION OF GAS DELIVERY SYSTEM

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the Japanese Facilities Committee. Current edition approved by the Japanese Regional Standards Committee on January 11, 2002. Initially available at www.semi.org January 2002; to be published March 2002.

1 Purpose

1.1 The purpose of this document is to provide a standardized methodology and procedure for measuring the particle contribution performance of a gas delivery system in terms of number of particles added to gas flowing through the system. This standardized procedure is intended to be used commonly by the component suppliers, gas suppliers, equipment suppliers, and users.

2 Scope

2.1 This test method applies to all types of surface mount and conventional gas delivery systems used in semiconductor manufacturing facilities and comparable research and development areas.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 All components must meet quality requirements as established and controlled by manufacturers prior to testing (e.g., dimensional, functional, etc.).

3.2 Care should be exercised in handling of components to maintain manufacturer's specifications.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *ISO Standards*[1]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments – Part 1: Classification of air cleanliness

4.2 *JIS Standards*[2]

JIS B 9921 — Light Scattering Automatic Particle Counter

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CNC* — condensation nucleus counter

5.1.2 *LPC* — laser particle counter

5.1.3 *MFC* — mass flow controller

5.1.4 *MFM* — mass flow meter

5.1.5 *slm* — standard liters per minute, the gas volumetric flow rate measured in liters per minute at 0°C and 1 atm.

5.2 *Definitions*

5.2.1 *background counts* — particle counts contributed by the test apparatus (including false counts) with the spool piece in the place of the test object as function of particle size.

5.2.2 *counting efficiency* — the ratio of the particle concentration calculated from the particle counts to the actual particle concentration in the sampled gas for particles equal to or larger than a given particle size.

5.2.3 *design flow rate* — flow rate normally applied to the gas delivery system.

5.2.4 *false counts* — particle counts contributed by electrical noise or by other events and not particles in the sampled gas.

5.2.5 *gas delivery system* — a system installed in semiconductor manufacturing equipment to supply process and carrier gases to reactors, which typically consists of tubing, fittings, valves, filters, mass flow controllers and regulators; can be surface mount or conventional system.

5.2.6 *minimum counting particle diameter* — a predefined minimum diameter of particles to be counted in this test method.

1 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland, website: www.iso.ch

2 Japanese Standards Association, 1-24, Akasaka, 4-Chome, Minato-ku, Tokyo 107 Japan

5.2.7 *particle counts* — a counted value from a laser particle counter (LPC) or condensation nucleus counter (CNC) shown for particles or larger than or equal to the minimum counting particle diameter.

5.2.8 *sample flow rate* — the volumetric flow rate through the particle counter.

5.2.9 *spool piece* — a null component consisting of a straight piece of electropolished tubing or like object and appropriate fittings used in place of the test system to establish the background.

5.2.10 *test flow rate* — the volumetric flow rate through the test systemRequired Apparatus

6 Required Apparatus

6.1 *Filter* — Filters with the following performance specified by the manufacturer.

Characteristic	*Performance*	*Condition*
Filtration Efficiency	9 log	particle size: 0.02 μ m
Flow Rate	300 slm	inlet pressure: 0.34 MPa

6.2 *Tubing Material* — 1/4 inch or 3/8 inch SUS 316L electropolished tubing or better.

6.3 *Particle Counter* — The particle counter may be either LPC or CNC of which the minimum counting particle diameter is 0.1 μ m or smaller, and has the following performance as specified by JIS B 9921.

6.3.1 *Counting Efficiency*

Diameter of Polystyrene Latex Standard Particle	*Counting Efficiency*
Minimum countable particle diameter of the counter (See NOTE 1.)	50 ± 20 %
1.5 to 2.0 × Minimum countable particle diameter of the counter	100 ± 10 %

NOTE 1: For a CNC, the minimum countable diameter shall be defined as a diameter having counting efficiency of 50 ± 20%.

6.3.2 *False Count* — Equal to or less than 1 in 5 minutes.

6.3.3 *Acceptable Error of Flow Rate* — ± 5%

6.4 *Sampler* — A system used to perform partial sampling of the gas stream exiting the test system, that consists of a diffuser equipped with a pressure reducing device in which gradual expansion to atmospheric pressure occurs and a sample probe. It is desirable that the sampler is designed to obtain isokinetic sampling. The average velocity of gas flowing through the sample probe should approximate the average velocity in the external tubing in which the sample probe is inserted. The sample probe overlap with the external tube must be of appropriate length, and it must be confirmed before use that the surrounding atmospheric gas is not drawn in the sample.

7 Test Condition

7.1 *Test Gas* — Liquid Nitrogen (LN_2) or cleaner Nitrogen (N_2) or Argon (Ar).

7.2 *Temperature* — Room temperature (between 18 and 26° C)

7.3 *Environment* — ISO/FDIS 14644-1 class 5 or better.

8 Preparation of Apparatus

8.1 Set up apparatus and the gas supply system as shown in Figure 1.

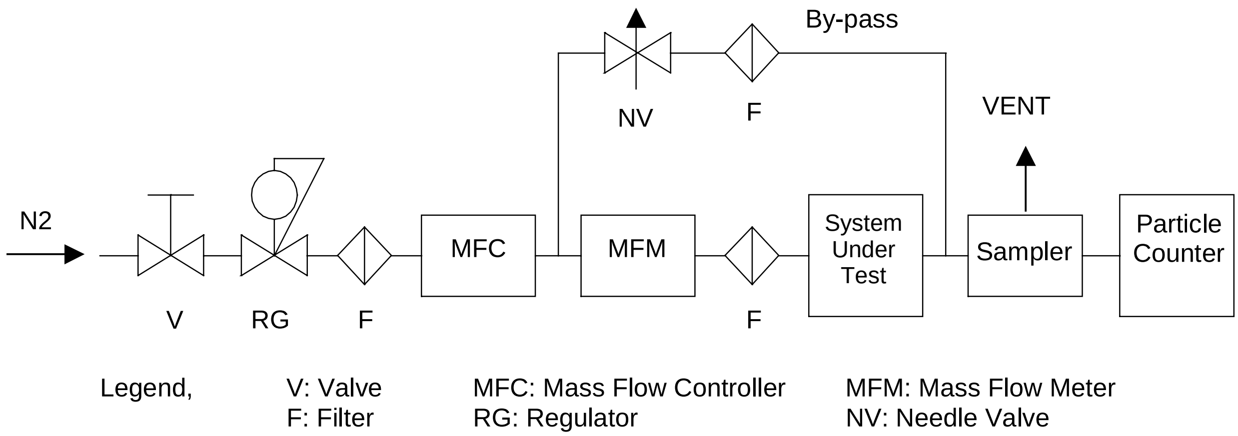


Figure 1
Test Set Up Basic Flow Diagram

8.2 If the test flow rate is equal to or less than the sample flow rate required by the particle counter, insert a filter in place of the sampler to fulfill the sample flow rate. (See Figure 2.)

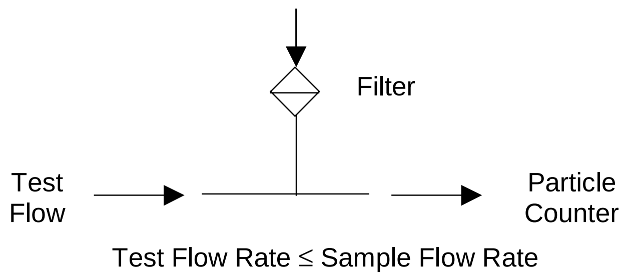


Figure 2
Full Sampling

8.3 If the test flow rate is higher than the sample flow rate required by the particle counter, use the sampler for partial sampling. (See Figure 3.) To establish the test flow rate and obtain an isokinetic condition, it is required to adjust the MFC in the test set up and the NV on the by-pass line. The by-pass line is required to have a capability to handle the maximum test flow when the valves in the system under test is closed position during the pulse test.

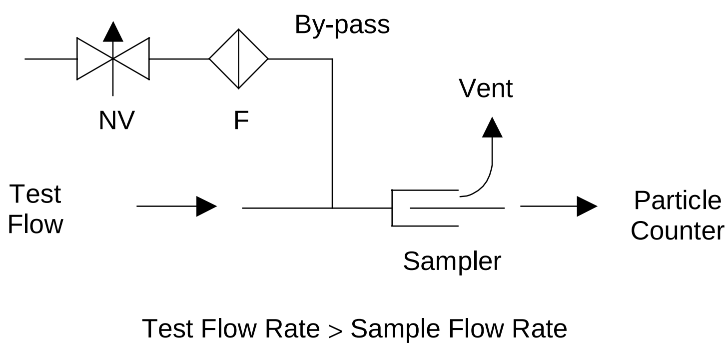


Figure 3
Partial Sampling

9 Procedure

9.1 A typical gas delivery system configuration is shown in Figure 4. The following test procedure shall be interpreted to apply to the actual test system and recorded by the operator.

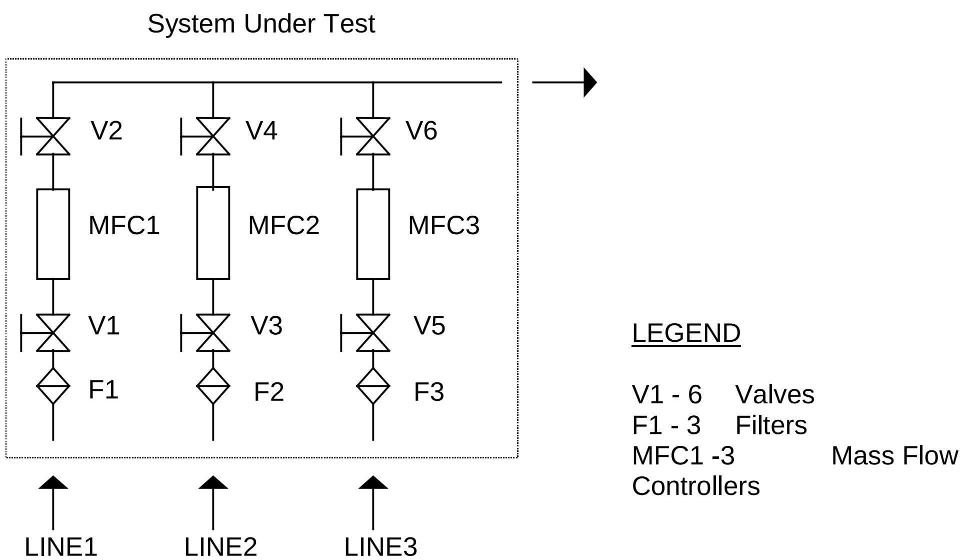


Figure 4
Typical Gas Delivery System Configuration

9.2 *Determination of Background Counts*

9.2.1 For test set up, insert a spool piece in place of the system under test (i.e. the gas delivery system) as in Figure 1.

9.2.2 Establish the test flow rate as 1.5 times of the design flow rate and supply N_2 (or Ar). In this case the design flow rate is determined as the flow rate of the line which has maximum flow rate in the system under test. Purge the test set up for more than 10 minutes.

9.2.3 Confirm the particle count is not more than 1 during 10 minutes after the purge. If the total volume of the test flow is less than 28.3 liters, extend the sampling time until it achieves more than 28.3 liters. If the particle count is more than 1, repeat Sections 9.2.2 and 9.2.3.

9.2.4 Replace the spool piece with the test system.

9.3 *Static Flow Test*

9.3.1 Close all valves in the line 2 and 3, set the MFCs as full scale or purge mode if available and fully open the valves in the line 1.

9.3.2 Supply N_2 (or Ar) to the line 1 with 1.5 times of the design flow rate of the line 1 and purge the test set up for more than 10 minutes. In many case, this will require the activation of the valve override on any MFCs on the test line. It is also required to verify that all components in the system can withstand 1.5 times the design flow rate.

9.3.3 Count particles for more than 10 minutes. If the total volume of the test flow is less than 28.3 liters, extend the sampling time until it achieves more than 28.3 liters.

9.3.4 Repeat Sections 9.3.2 and 9.3.3 per all lines.

9.4 *Pulse Flow Test*

9.4.1 Close all valves in the line 2 and 3, set the MFCs as full scale or purge mode if available and fully open the valves in the line 1.

9.4.2 Supply N_2 (or Ar) to the line 1 with 1.5 times of the design flow rate of the line 1 and purge the test set up for more than 10 minutes.

9.4.3 Actuate V1 at the rate of 30 cycles/minute for 10 minutes if V1 is pneumatically operated valve. For manually operated valve, actuate the valve at 4 cycles/minute for 10 minutes. Each cycle consists of on and off actuation of the valve. The on and off cycles should be of equal duration. If the total volume of the test flow is less than 28.3 liters, extend the sampling time until it achieves more than 28.3 liters. Count particles during the period.

9.4.4 Repeat Section 9.4.3 for V2.

9.4.5 Repeat Sections 9.4.1 to 9.4.4 per all lines.

NOTE 2: For the pulse test, the total volume of the test flow shall be half of the test flow rate multiplied by the sampling time.

10 Calculation and Report

10.1 The following test conditions are to be included in the test report:

- counter type (LPC or CNC)
- manufacturer of counter
- counter model (manufacturer's model # or part #)
- sample flow
- particle diameter
- sampler diameter
- sample probe diameter
- test gas
- background count
- valve operation interval (for the pulse flow test)
- flow diagram of the system under test

10.2 *Calculation of Data* — The test result is reported in number of particles in liters denoted by floating point representation with two significant digits (ex. 2.3×10^{-2}/L). The method of calculation is shown in Section 10.2.1.

10.2.1 The following formula is used to calculate the particles in a liter:

$$PARTICLES = \frac{N}{V}$$

where N: Total particle counts in 10 minutes or in the extended period if the total volume of the test flow is less than 28.3 liters.

V: Total sampling volume in liter in 10 minutes (mass flow meter read value) or in the extended period if the total volume of the test flow is less than 28.3 liters.

If the sample flow rate is equal to or more than the test flow rate, V is equal to the total volume of the test flow in liter in the sampling time.

If the sample flow rate is less than the test flow rate, V is equal to the total volume of the sample flow in liter in the sampling time.

10.3 *Report Format* — Sample report formats are given in Appendixes 1 and 2.

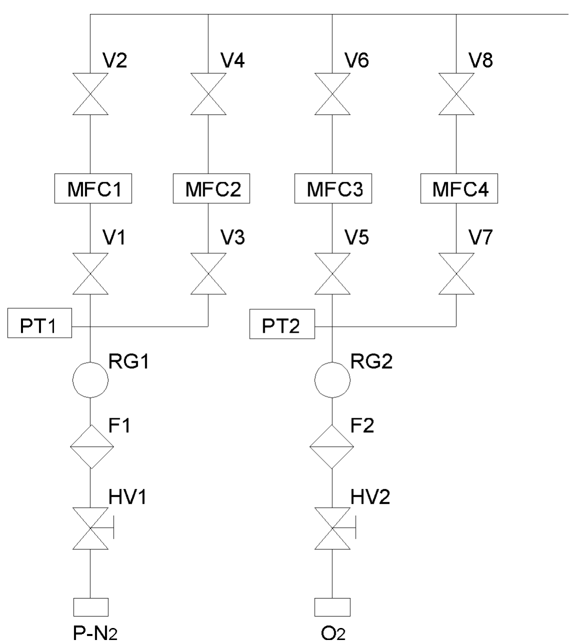
APPENDIX 1
SAMPLE REPORT FORMAT FOR STATIC FLOW PARTICLE TEST

NOTE: This appendix is being balloted as an official part of SEMI F70 by full letter ballot procedures, but the recommendation in this appendix are optional and are not required to conform to this standard.

STATIC FLOW PARTICLE TEST REPORT

Line	*Design Flow (l/min)*	Test Flow (l/min)	*Sampling Method*	Total sampling volume (l)	Total particle count	*Particle Count (particle/l)*
P-N_2	200	300	Partial Sampling	283	3	1.1×10^{-2}
O_2	10	15	Full Sampling	150	2	1.3×10^{-2}

Flow Diagram of System Under Test



Test Condition	
Counter Type:	LPC
Manufacturer of the Counter	A
Counter Model	B
Sample Flow:	28.3 l/min
Particle Diameter:	≥ 0.1 μ m
Sampler Diameter:	30.0 mm
Sample Probe Diameter:	7.53 mm
Test Gas	LN_2
Background Count:	0

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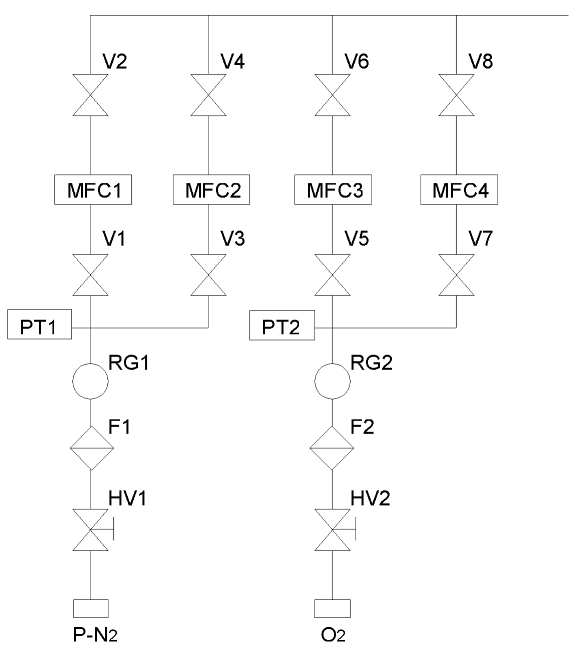
APPENDIX 2
SAMPLE REPORT FORMAT FOR PULSE FLOW PARTICLE TEST

NOTE: This appendix is being balloted as an official part of SEMI F70 by full letter ballot procedures, but the recommendation in this appendix are optional and are not required to conform to this standard.

PULSE FLOW PARTICLE TEST REPORT

Line	*Design Flow (l/min)*	*Test Flow (l/min)*	*Sampling Method*	*Total Sampling Volume (l)*	*Total Particle Count*	*Drive Valve #*	*Particle Count (particle/l)*
P-N_2	200	300	Partial Sampling	141.5	4	V1	1.4×10^{-2}
					3	V2	1.1×10^{-2}
					3	V3	1.1×10^{-2}
					4	V4	1.4×10^{-2}
O_2	0.5	0.75	Full Sampling	28.5 (See NOTE 1.)	1	V5	3.5×10^{-2}
					1	V6	3.5×10^{-2}
					0	V7	0
					1	V8	3.5×10^{-2}

Flow Diagram of System Under Test



Test Condition

Counter Type:	LPC
Manufacturer of counter	A
Counter Model	B
Sample Flow:	28.3 l/min
Particle Diameter:	≥ 0.1 μ m
Sampler Diameter:	30.0 mm
Sample Probe Diameter:	7.53 mm
Test gas:	LN_2
Background Count	0
Valve Operation Interval:	30 cycle/ minute

NOTE 1. The test period for O2 line was extended to 76 minutes in order that the total volume of the test flow achieves more than 28.3 liters.

SEMI S1-0701
SAFETY GUIDELINE FOR EQUIPMENT SAFETY LABELS

This safety guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1986; previously published in 1990.

This document replaces S1-90 in its entirety.

1 Purpose

1.1 This guideline provides guidance for the content and format of equipment safety labels and gives examples of symbols to use.

1.2 This guideline is intended for use by equipment manufacturers to create safety labels that alert persons to hazards associated with the equipment.

1.3 This guideline is intended to provide a unified international semiconductor-industry-specific safety labeling format.

2 Scope

2.1 This guideline is intended to assist in developing safety labels for manufacturing equipment used in the semiconductor industry.

NOTE 1: This guideline may also be used for the design of safety signs for the facilities where semiconductor manufacturing equipment is installed.

NOTE 2: The guidance provided in this document may also be adapted to help communicate safety information in installation instructions, operation and maintenance manuals, and other similar written communication relating to a product.

NOTE 3: This guideline may also be adapted for the design of computerized user interfaces on equipment.

NOTE 4: In order to present a more consistent user interface, it is recommended that the use of the words DANGER, WARNING, and CAUTION, in such interfaces be limited to the meanings and uses given for them in this guideline.

2.2 This document contains the following sections:

1. Purpose
2. Scope
3. Limitations
4. Referenced Standards
5. Terminology
6. General Provisions
7. Formats
8. Signal Words
9. Symbols
10. Word Messages
11. Lettering
12. Colors
13. Placement
14. Translation
15. Related Documents

Appendix 1 — Safety Symbols

Appendix 2 — Translations of Signal Words

2.3 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Various components or assemblies used in semiconductor manufacturing equipment may carry safety labels that are designed and affixed in accordance with other international standards. It is not the intent of this guideline to replace or supersede such labeling requirements.

3.2 Some safety label formats and content are dictated by other applicable standards and guidelines or by law (e.g., laser labeling and chemical hazard communication labeling in certain countries of use). It is not the intent of this guideline to replace or supersede such labeling requirements.

3.3 New safety labels and safety labels that are significantly redesigned should conform to the latest version of SEMI S1. This guideline is not intended to be applied retroactively.

4 Referenced Standards

NOTE 5: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.1 *SEMI Standards*

SEMI S10 — Safety Guideline for Risk Assessment

4.2 *ANSI Standards*[1]

ANSI Z535.1 — Safety Color Code

ANSI Z535.3 — Criteria for Safety Symbols

ANSI Z535.4 — Product Safety Signs and Labels

4.3 *ISO Standards*[2]

ISO 3864 — Safety Colours and Safety Signs

4.4 *IEC Standards*[3]

IEC 61310-1 — Safety of Machinery - Indication, Marking and Actuation - Part 1: Requirements for Visual, Auditory and Tactile Signals

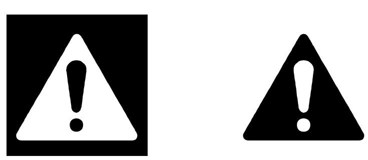
5 Terminology

5.1 *hazard* — a condition that is a prerequisite to a mishap.

5.2 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

5.3 *panel* — area of a safety label having a distinctive background color which is different from other areas, or which is delineated by a line, border, or margin. See Figures 3 and 4 for examples of panel placement.

5.4 *safety alert symbol* — a specific symbol (see Figure 1) that indicates a potential personal injury hazard.



(Left: For DANGER, Right: For WARNING and CAUTION)

Figure 1
Safety Alert Symbols for Signal Word Panel Use

5.5 *safety label* — a sign, label, or decal that provides safety information.

5.6 *signal word* — the word that calls attention to the safety label and designates a degree or level of hazard seriousness.

5.7 *surround shape* — a geometric configuration that is placed around a symbol and which conveys additional safety information.

5.8 *symbol* — a graphical representation, either abstract or representational, of a hazard, a consequence of engaging a hazard, or a method to avoid a hazard, or some combination of these ideas.

NOTE 6: Some label design standards use the term "pictorial" in the same sense as this guideline uses the term "symbol."

5.9 *target audience* — the audience to be advised of the hazard.

6 General Provisions

6.1 Safety labels should communicate information about specific hazards. Safety labels should be simple, direct, and understandable by the target audience.

6.2 *Content* — Safety labels should communicate:

6.2.1 the seriousness of the hazard (indicated by the signal word);

6.2.2 the nature of the hazard (e.g., type of hazard) or the probable consequence of engaging the hazard; and

6.2.3 how the hazard can be avoided.

6.3 See Figure 2 for examples of how this information can be communicated on a safety label.

1 American National Standards Institute, 11 West 42nd Street, New York, New York 10036, USA, http://www.ansi.org

2 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland, http://www.iso.ch

3 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland, http://www.iec.ch

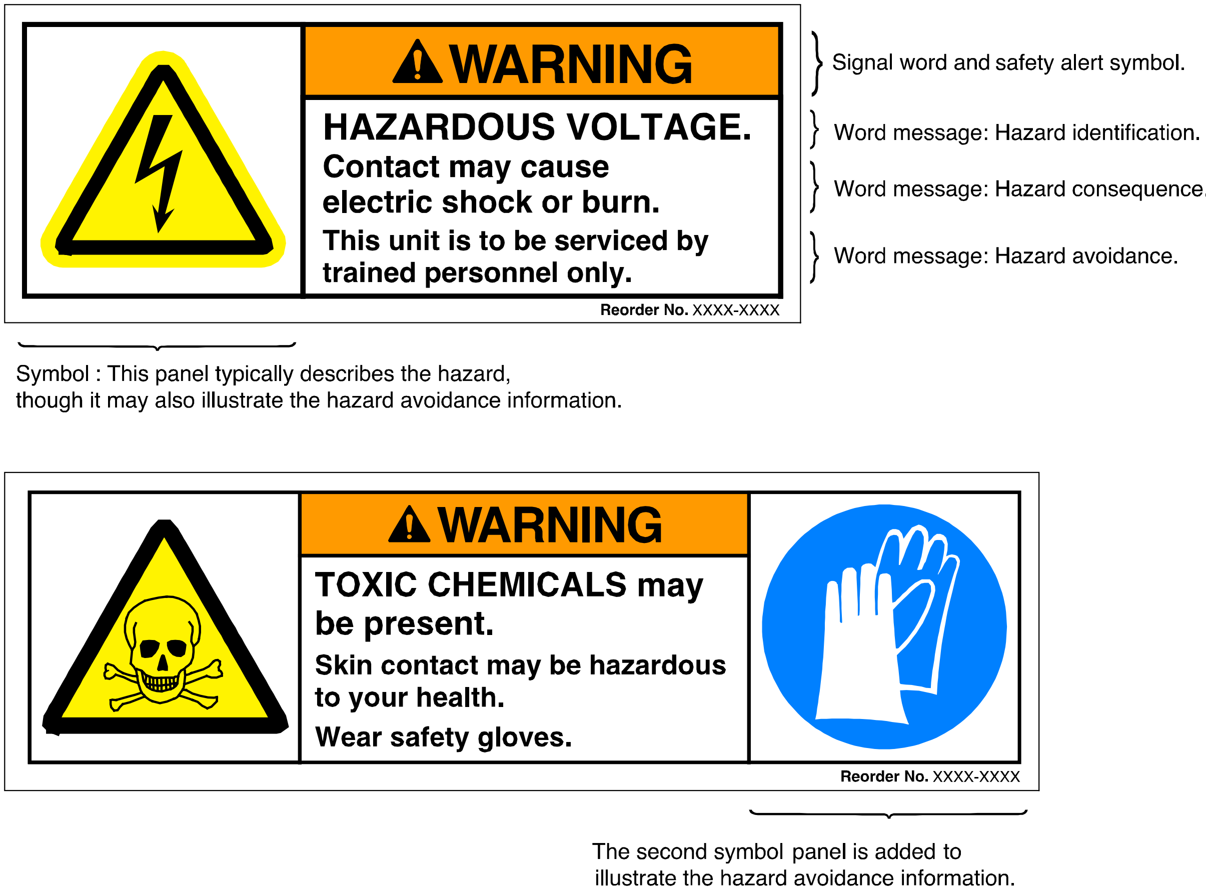


Figure 2
Examples of How Product Safety Labels Communicate Content
(Note that the order and content of the word message is flexible).

6.4 *Identifier* — Safety labels should have a unique identifier (e.g., a part number) printed on the label, to facilitate ordering replacement labels from the equipment manufacturer.

NOTE 7: If a safety label becomes illegible, the user may want to replace it.

6.5 *Durability* — Safety labels should have a reasonable useful life. Determination of reasonable useful life should take into consideration the expected life of the product and the intended environment of use.

NOTE 8: Two factors that may be used for judging useful life are color stability and legibility when viewed at a safe viewing distance. Legibility is affected by letter height.

7 Formats

7.1 Safety labels should consist of at least three panels: signal word panel, word message panel, and symbol panel. Figure 3 provides examples of some possible horizontal and vertical formats incorporating these panels.

EXCEPTION 1: A symbol panel is not necessary for labels that indicate only potential property damage hazards.

EXCEPTION 2: When space limitations exist, such as under guards or on small parts, for safety labels whose target audience is maintenance or service personnel, symbol-only formats with surround shapes (i.e., no signal word, word message, or symbol panels; see Figures 7, 8, and 9) may be used. In this case, borders around the surround shapes should be used. Alternatively, for the same situations, a safety label may be used that has a signal word panel and a word message panel but does not have a symbol panel.

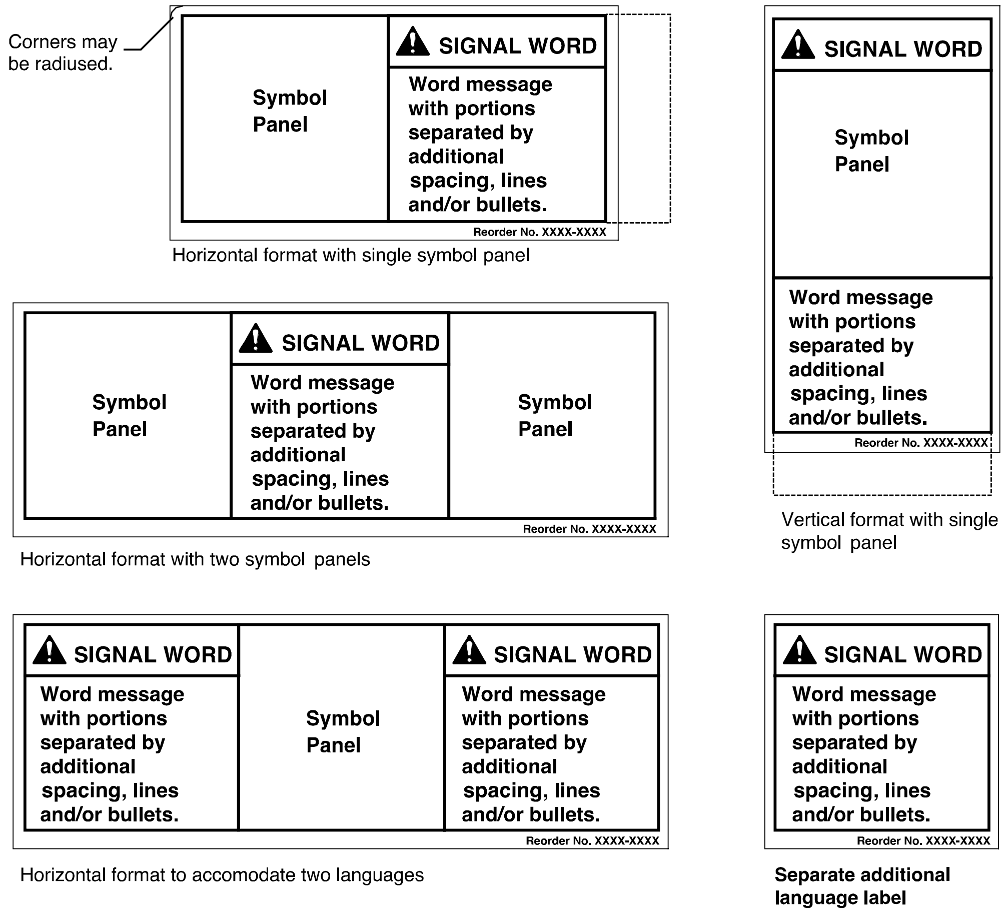


Figure 3
Examples of Format Options for Product Safety Labels

7.2 *Multiple Hazard Formats* — More than one hazard may be conveyed on a single safety label (see Figure 4 for examples).

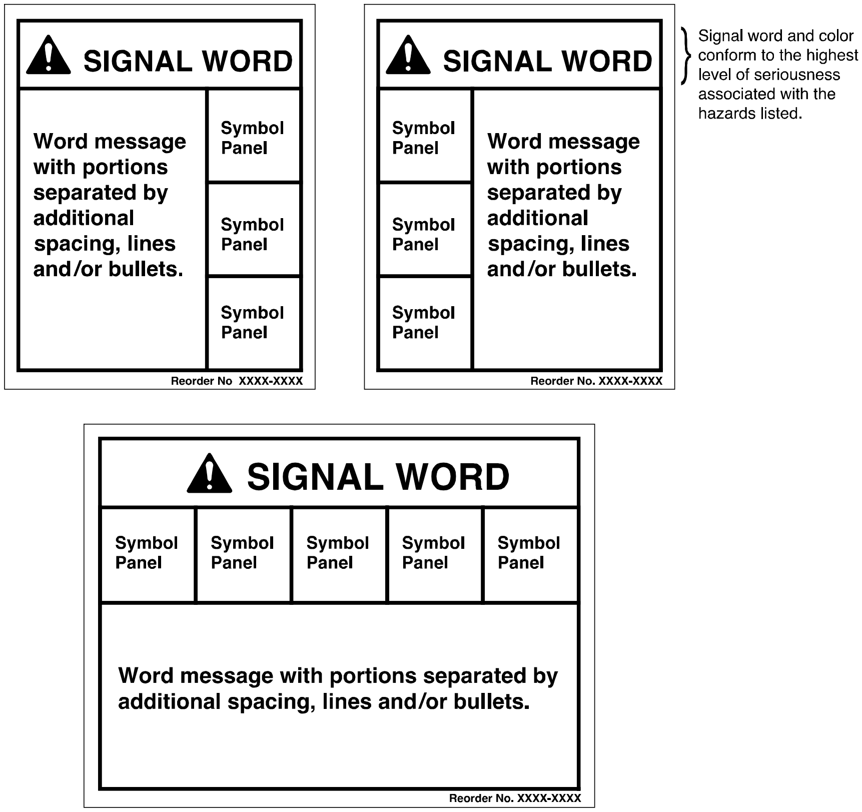


Figure 4
Examples of Multi-Hazard Safety Label Formats

8 Signal Words

8.1 The signal words for safety labels are DANGER, WARNING, and CAUTION.

8.1.1 DANGER is the signal word used to indicate an imminently hazardous situation that, if not avoided, will result in death or severe injury. This signal word is to be limited to the most extreme situations.

8.1.2 WARNING is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in death or severe injury.

8.1.3 CAUTION is the signal word used to indicate a potentially hazardous situation which, if not avoided, could result in moderate or minor injury. It may also be used to alert against unsafe practices.

NOTE 9: CAUTION without the safety alert symbol may be used as a signal word to indicate a potentially hazardous situation which, if not avoided, could result in property damage.

NOTE 10: SEMI S10 contains examples of ways to categorize severe, moderate, and minor injuries.

8.2 The signal word is placed in the signal word panel.

8.2.1 For DANGER, WARNING, and CAUTION signal words, the safety alert symbol (see Figure 1) is located immediately to the left of and on the same level as the signal word (see Figure 5).

Figure 5
Signal Word Panels

8.2.2 The safety alert symbol should not be used to alert persons to property-damage-only hazards.

8.2.3 When multiple hazard situations are addressed on one safety label, and the hazards are classified at different levels of seriousness, the signal word corresponding to the greatest hazard level should be used.

9 Symbols

9.1 Symbols are graphic representations chosen to convey specific safety messages.

9.2 The symbol panel should contain the safety label's symbol(s).

9.2.1 More than one symbol panel may be used on a safety label.

NOTE 11: See also Section 7.2.

9.2.2 More than one symbol may be used in each symbol panel.

9.3 Symbols may be used to clarify or supplement a portion of a safety label's word message.

NOTE 12: In some cases, symbols may replace the word message. See the exception to Section 10.2.

9.4 A symbol should represent the nature of the hazard, or the potential consequence of engaging the hazard, or actions to be taken to avoid the hazard.

9.5 Symbols should be compatible with the safety label's word message.

NOTE 13: It is preferable to use the symbols shown in Appendix 1.

NOTE 14: For additional information on symbol design, see Annex A of ANSI Z535.3.

9.6 Symbols should be shown in their appropriate surround shape as defined in Section 9.10.

9.7 When an effective symbol does not exist or cannot be created to illustrate the specific hazard or specific avoidance information, the ISO 3864 general warning symbol should be used with a text message that conveys specific information about the hazard (see Figure 6).

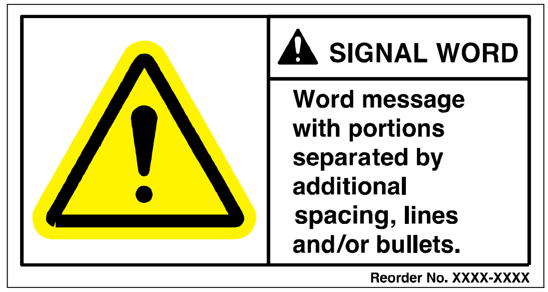


Figure 6
Safety Label with General Warning Symbol

9.8 *Location* — Symbols should be located on safety labels in the areas designated in the examples in Figures 2, 3, and 4, or located in a similar manner. If multiple symbols are used on a multi-hazard safety label, the symbols should appear in the same order as the safety information described in the word message.

EXCEPTION: Location of the safety alert symbol is governed by section 8.2.1.

9.9 *Safety Alert Symbol* — The safety alert symbol is composed of an equilateral triangle surrounding an exclamation mark.

NOTE 15: See Figures 1 and 5 and Section 12.3.4 for format and color information.

9.10 *Symbol Surround Shapes* — Safety symbols should be shown in their appropriate surround shapes (see Figures 7, 8, and 9).

NOTE 16: This is for purposes of international harmonization. The surround shapes have been taken from ISO 3864 and IEC 61310-1.

9.10.1 *Hazard Identification Surround Shape (see Figure 7)* — A symbol located inside a hazard identification surround shape should be used to indicate a personal injury hazard.

9.10.1.1 *Format and Color* — The background color should be yellow. The triangular band should be black. The symbol or pictorial representing the hazard should be black. The border should be yellow; the border is optional if the surrounding background is yellow or white. See Figure 7 for more information.

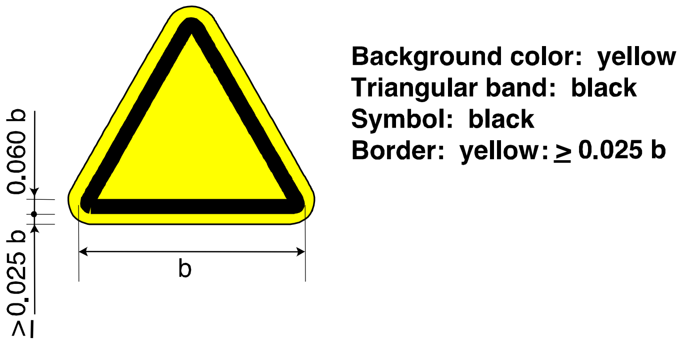


Figure 7
Hazard Identification Symbol Surround Shape

9.10.2 *Prohibition Surround Shape (see Figure 8)* — A symbol located inside a prohibition surround shape should be used to indicate that an action should not be taken or should be stopped.

9.10.2.1 *Format and Color* — The prohibition surround shape should be a circular band with a diagonal bar. The background color should be white. The circular band and diagonal bar should be red. The symbol representing the prohibited action should be black and is preferably shown behind the red slash. The border should be white; the border is optional if the surrounding background is white or yellow. See Figure 8 for more information.

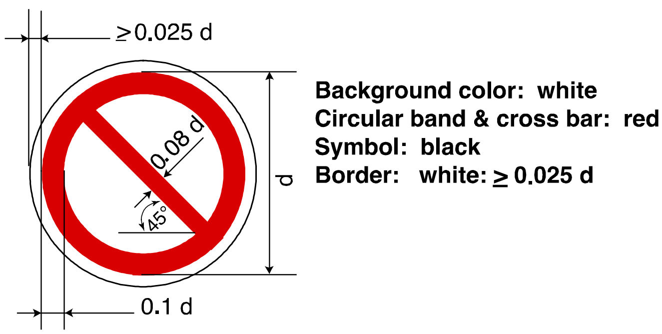


Figure 8
Prohibition Symbol Surround Shape

9.10.3 *Mandatory Action Surround Shape (see Figure 9)* — A symbol located inside a mandatory action surround shape should be used to indicate that an action should be taken to avoid a hazard.

9.10.3.1 *Format and Color* — The background color should be blue. The symbol representing the mandatory action should be white. The border should be white; the border is optional if the surrounding background is white. See Figure 9 for more information.

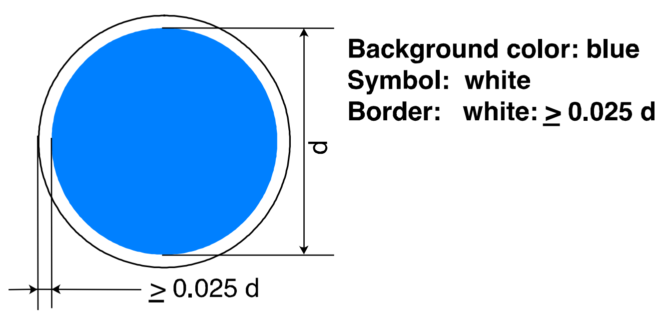


Figure 9
Mandatory Action Symbol Surround Shape

10 Word Message

10.1 The word message is placed in the word message panel.

10.2 The word message preferably contains a description of the hazard, the consequence of engaging the hazard, and how to avoid the hazard. The ordering of this content in the word message is flexible.

EXCEPTION: Parts or all of the word message may be omitted, depending on such factors as whether the message can be inferred from a symbol, other text messages, user training, or the context in which the safety label is used.

10.3 The word message on a safety label should be concise and readily understood.

10.4 Messages on the same safety label that warn of different hazards should be formatted, when feasible, to prevent them from visually blending together. Bullets, lines, and extra line spacing are examples of such formatting.

10.5 When detailed instructions, precautions, or consequences would require a lengthy message, the message may alternatively refer the reader to another source for additional safety information. Examples of such sources include safety instructions, operation and maintenance manuals, service manuals, operating procedures, and safety bulletins.

11 Lettering

11.1 Signal words should be in the lettering style shown in Appendix 2.

11.2 For languages using the "Roman" alphabet, such as the official languages used in the Americas and in much of the European Union, the lettering should be a combination of upper- and lowercase sans serif letters. Uppercase only lettering may be used for short messages or for emphasis of individual words.

NOTE 17: Preferred Roman sans serif lettering styles include those named Arial, Arial Bold, Folio Medium, Franklin Gothic, Helvetica, Helvetica Bold, and Univers.

11.3 Lettering should be of a size that enables a person with normal vision, including corrected vision, to read the safety label at a safe viewing distance from the hazard.

NOTE 18: Related Information 1 provides an example of a method of calculating minimum letter heights.

NOTE 19: The proportions and spacing of individual letters also affect readability.

12 Colors

12.1 *Color Specifications* — Colors should conform to those colors specified in ISO 3864.

NOTE 20: For purposes of reproduction, the closest PANTONE color match for opaque safety colors is:

- Red – PANTONE 485
- Orange – PANTONE 152
- Yellow – PANTONE 109
- Blue – PANTONE 2945

(PANTONE is a registered trademark of Pantone, Inc.).

NOTE 21: Perceived color will be different under colored light (e.g., "yellow room") conditions. The committee knows of no current technical solution.

12.2 *Symbol and Surround Shape Color Specifications* — See section 9.10 for symbol and surround shape color criteria.

12.3 *Signal Word Panel* — The three signal words should be colored as follows (see Figure 5):

12.3.1 The word DANGER should be in white letters on a red background.

12.3.2 The word WARNING should be in black letters on an orange background.

12.3.3 The word CAUTION should be in black letters on a yellow background.

12.3.4 *Safety Alert Symbol* — The solid triangle portion should be the same color as the signal word lettering, and the exclamation mark portion should be the same color as the signal word panel background.

12.4 *Optional Use of Red* — The color red may be used in a symbol to indicate heat or fire.

13 Placement

13.1 *Location of Safety Labels* — Safety labels should be permanently attached to the equipment and, when possible, located near the hazard.

13.2 *Safe Viewing Distance* — Safety labels should be placed to allow the viewer enough time to:

- be informed by the safety label; and
- have sufficient time to avoid the hazard or take appropriate evasive action to reduce the potential harm from the hazard.

13.3 *Placement* — Safety labels should be placed so that they are legible, non-distracting, and not hazardous in themselves.

13.4 *Inadvertent Removal, Visual Blockage* — Safety labels should not be located in areas where they may be removed by the motion of equipment or rendered ineffective by situational conditions.

13.4.1 Safety labels should not be blocked from view by moveable panels such as doors, windows, and racks where this would limit the effectiveness of the blocked label.

14 Translation

14.1 This guideline is not intended to suggest that safety labels be written in or translated into any particular language.

NOTE 22: National laws may require that safety label information be provided in one or more particular languages.

15 Related Documents

15.1 *ANSI Standards*[1]

ANSI C95.2 — Radio-Frequency Warning Symbol

ANSI N2.1 — Radiation Symbol

ANSI N12.1 — Fissile Material Symbol

ANSI Z136.1 — Safe Use of Lasers

ANSI Z535.2 — Environmental and Facility Safety Signs

ANSI Z535.5 — Accident Prevention Tags

15.2 *NEMA Standard*[4]

NEMA 77 — Standards for Warning Labels

15.3 *NFPA Standards*[5]

NFPA 70 — National Electrical Code

NFPA 178 — Standard Symbols for Fire Fighting Operations

15.4 *NIST Documents*[6]

NBSIR 80-2003 — Workplace Safety Symbols

NBSIR 80-2088 — The Assessment of Safety Symbol Understandability by Different Testing Methods

NBSIR 82-2485 — Symbols for Industrial Safety

15.5 *United States of America Government Document*[7]

21 CFR Part 1040 — Performance Standards for Light-Emitting Products

15.6 *IEC Standards*[8]

IEC 60825-1 — Safety of Laser Products - Part 1: Equipment Classification, Requirements and User's Guide

15.7 *ISO Standards*[9]

ISO 9186 — Comprehension Testing of Graphical Symbols

4 National Electrical Manufacturers Association, 2101 L Street, N.W., #300, Washington, D.C. 20037, USA, http://www.nema.org

5 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA, http://www.nfpa.org

6 U.S. Department of Commerce, National Institute of Standards and Technology, Center for Building Technology, Washington, D.C., USA, http://www.nist.gov/public_affairs/faqs/qpubs.htm

7 U.S. Government Printing Office, Washington, D.C., USA, http://bookstore.gpo.gov/prf/ordinfo.html

8 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland, http://www.iec.ch

9 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland, http://www.iso.ch

APPENDIX 1
SAFETY SYMBOLS

NOTE: The material in this appendix is an official part of SEMI S1 and was approved by full letter ballot procedures on April 30, 2001 by the North American Regional Standards Committee.

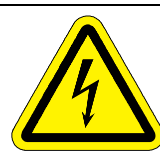
This appendix illustrates symbols used on safety labels for hazards commonly found in the semiconductor manufacturing industry. Additional symbols may need to be developed for other hazards (see *ANSI Z535.3-1998 Informative Annex A* for an example of symbol development guidelines).

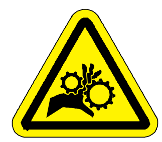
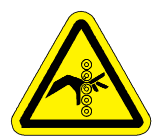
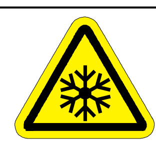
To determine what symbol should be used on a safety label, it is first necessary to determine what message is to be communicated. Symbols may enhance a safety label's meaning and may be useful to communicate across many languages.

When appropriate, the following symbols should be used.

NOTE A1-1: Some symbols (e.g., laser, biohazard, and radiation) are required by law or regulation in some jurisictions.

Table A1-1 Hazard Identification Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**Flammable Material**	**IEC 61310**		Flames
2	**Explosive Material, Explosion Hazard**	**IEC 61310**		Object exploding
3	**Danger: Electricity, Electrical Hazard**	**IEC 61310, ISO 3864**		Lightning bolt
4	**Corrosive Material, Corrosion**	**IEC 61310**		Test tube, hand, drops
5	**Toxic Material, Poison**	**IEC 61310**		Skull and crossbones
6	**Slip Hazard**	**ANSI Z535.3**		Person falling on surface
7	**Trip Hazard**	**ANSI Z535.3**		Person tripping over object

#	*Referent*	*Source*	*Symbol*	*Description*
8	**Drop, Fall Hazard**	**IEC 61310**		Person falling
9	**Lifting Hazard, Heavy Object**			Person bent over weight, strain flare above back
10	**Tipover**			Person with object tipping over and arrow
11	**Entanglement Hazard (hand in gears)**	**ANSI Z535.3**		Hand in gears Note: other body parts or orientations may be substituted as necessary
12	**Pinch point (hand in rollers)**	**ANSI Z535.4**		Hand in rollers Note: other body parts or orientations may be substituted as necessary
13	**Cut/Sever (hand and sharp object)**	**ANSI Z535.3**		Hand and sharp object Note: other body parts or orientations may be substituted as necessary
14	**Crush Hazard**			Hand between two surfaces, arrow Note: other body parts or orientations may be substituted as necessary
15	**Heat, Hot Surface**	**ISO 3864, ISO 7000**		Heat waves
16	**Cold**			Snow flake
17	**Strong Magnetic Field**			Horseshoe magnet

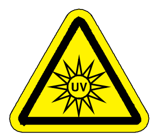
#	*Referent*	*Source*	*Symbol*	*Description*
18	**Radioactive Material,** **Radiation Hazard**	**IEC 61310**		Abstract three blades
19	**Laser Beam**	**IEC 60825-1**		Radiating sunburst, line
20	**Biological Risk,** **Biohazard**	**IEC 61310**		Abstraction
21	**Non-Ionizing Radiation,** **Radio Frequency**	**IEC 61310**		Abstract radiation transmitter
22	**UV Light Hazard**			The letters "UV" inside a sunburst
23	**Inhalation Hazard (e.g., toxic gas, asphyxiation hazard)**			Human figure breathing in particles
24	**General Warning** **(should be supplemented with words)**	**ISO 3864**		Exclamation point (See Figure 6 for an example of a safety label using the General Warning symbol)

Table A1-2 Mandatory Action Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**Wear Eye Protection**	**IEC 61310**		Head with eyeglasses
2	**Wear Ear Protection**	**IEC 61310**		Head with ear protection

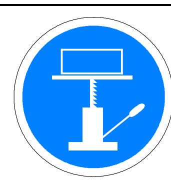
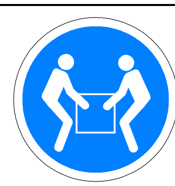
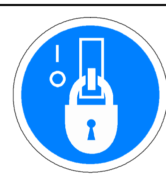
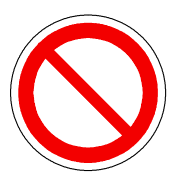
#	*Referent*	*Source*	*Symbol*	*Description*
3	**Wear Head Protection**	**IEC 61310**		Head with hard hat
4	**Wear Respiratory Protection**	**IEC 61310**		Head with respirator
5	**Wear Safety Boots**	**IEC 61310**		Shoes (one with metal plate shown)
6	**Wear Safety Gloves**	**IEC 61310**		Two gloves
7	**Lift with Mechanical Assistance**			Mechanical jack supporting object
8	**Lift with Two Persons**			Two persons grasping object
9	**Read Manual**			Person reading open book
10	**Lock Out in De-Energized State**			ON and OFF symbols next to locked clasp

Table A1-3 Prohibition Symbols

#	*Referent*	*Source*	*Symbol*	*Description*
1	**No Smoking**	**ANSI Z535.3**		Lighted cigarette
2	**No Open Flame**	**IEC 61310**		Lighted match
3	**No Access For Unauthorized Persons**	**IEC 61310**		Person shouting with outstretched hand
4	**No Portable Transmitters**			Wireless telephone
5	**No Pacemakers**			Ball and line attached to heart
6	**General Prohibited Action** **(should be supplemented with words)**	**ISO 3864**		Prohibition surround shape

APPENDIX 2
TRANSLATIONS OF SIGNAL WORDS

NOTE: The material in this appendix is an official part of SEMI S1 and was approved by full letter ballot procedures on April 30, 2001 by the North American Regional Standards Committee.

Translation of the signal words and word message are optional considerations. If the signal word of a safety label is to be translated, the following translations should be used.

Language	DANGER	WARNING	CAUTION
Chinese:	危險	警告	注意
Danish:	FARE	ADVARSEL	FORSIGTIG
Dutch:	GEVAAR	WAARSCHUWING	VOORZICHTIG
English:	DANGER	WARNING	CAUTION
Finnish	VAARA	VAROITUS	HUOMIO
French:	DANGER	AVERTISSEMENT	ATTENTION
German:	GEFAHR	WARNUNG	VORSICHT
Greek:	ΚΙΝΔΥΝΟΣ	ΠΡΟΕΙΔΟΠΟΙΗΑΣΗ	ΠΡΟΣΟΧΗ
Italian:	PERICOLO	AVVERTENZA	ATTENZIONE
Japanese:	危険	警告	注意
Korean:	위험	경고	주의
Norwegian:	FARE	ADVARSEL	FORSIKTIG
Portuguese:	PERIGRO	ATENÇÃO	CUIDADO
Russian:	ОПАСНО	ОСТОРОЖНО	ВНИМАНИЕ
Spanish:	PELIGRO	ADVERTENCIA	ATENCIÓN
Swedish:	FARA	VARNING	OBSERVER
Turkish:	TEHLİKE	UYARI	DİKKAT

NOTICE:

Paragraphs entitled "NOTE" are not an official part of this safety guideline and are not intended to modify or supersede the official safety guideline. These have been supplied by the committee to enhance the usage of the safety guideline.

SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of the guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These guidelines are subject to change without notice.

The user's attention is called to the possibility that compliance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. Users of this guideline are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
MINIMUM LETTER HEIGHT CALCULATIONS

NOTE: This related information is not an official part of SEMI S1 and is not intended to modify or supersede the official guideline. It has been derived from the informative Annex B of ANSI Z535.4-1998. Publication is authorized by vote of the responsible committee. Determination of the suitability of this material is solely the responsibility of the user.

R1-1 A common concern when designing safety labels is determining the minimum letter height of text. This Related Information describes one method that may be used to determine a minimum letter height.

Table R1-1 Examples of Word Message Uppercase Letter Heights at Various Viewing Distances

Viewing Distance	***Minimum** Letter Height for FAVORABLE Reading Conditions*	***Recommended** Letter Height for FAVORABLE Reading Conditions*	***Recommended** Letter Height for UNFAVORABLE Reading Conditions*
300 mm (12 in.) or less*	2 mm (0.08 in)	2 mm (0.08 in)	2 mm (0.08 in)
600 mm (24 in.)	2.5 mm (0.10 in)	4 mm (0.16 in)	4 mm (0.16 in)
900 mm (35 in.)	3 mm (0.12 in)	4.75 mm (0.19 in)	6 mm (0.24 in)
1.2 m (47 in.)	3.5 mm (0.14 in)	5.5 mm (0.22 in)	8 mm (0.31 in)
1.5 m (59 in.)	4 mm (0.16 in)	6.25 mm (0.25 in)	10 mm (0.39 in)
1.8 m (71 in.)	4.5 mm (0.18 in)	7 mm (0.28 in)	12 mm (0.47 in)
2.1 m (83 in.)	5 mm (0.20 in)	7.75 mm (0.31 in)	14 mm (0.55 in)
2.4 m (94 in.)	5.5 mm (0.22 in)	8.5 mm (0.33 in)	16 mm (0.63 in)

* 2 mm (0.079 in.) is the suggested minimum type size for use on safety labels.

Calculations for **Recommended** Letter Heights (in mm) for FAVORABLE Reading Conditions:

600 mm or less: (viewing distance in mm) / 150

>600 mm to 6 m: [(viewing distance in mm - 600) x .0025] + 4

Calculation for **Recommended** Letter Heights for UNFAVORABLE Reading Conditions (all distances):

(viewing distance) / 150

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SEMI S2-0302
ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINE FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

This safety guideline was technically approved by the Global Environmental, Health, and Safety Committee and is the direct responsibility of the North American Environmental, Health, and Safety Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available on www.semi.org December 2001; to be published March 2002. Originally published in 1991; previously published in February 2000.

1 Purpose

1.1 This safety guideline is intended as a set of performance-based environmental, health, and safety (EHS) considerations for semiconductor manufacturing equipment.

2 Scope

2.1 *Applicability* — This guideline applies to equipment used to manufacture, measure, assemble, and test semiconductor products.

2.2 *Contents* — This document contains the following sections:

1. Purpose
2. Scope
3. Limitations
4. Referenced Standards
5. Terminology
6. Safety Philosophy
7. General Provisions
8. Evaluation Process
9. Documents Provided to User
10. Hazard Warning Labels
11. Safety Interlock Systems
12. Emergency Shutdown
13. Electrical Design
14. Fire Protection
15. Heated Chemical Baths
16. Ergonomics and Human Factors
17. Hazardous Energy Isolation
18. Mechanical Design
19. Seismic Protection
20. Automated Material Handlers
21. Environmental Considerations
22. Exhaust Ventilation
23. Chemicals
24. Ionizing Radiation
25. Non-Ionizing Radiation and Fields
26. Lasers
27. Sound Pressure Level
28. Related Documents

Appendix 1 — Enclosure Openings

Appendix 2 — Design Principles and Test Methods for Evaluating Equipment Exhaust Ventilation

Appendix 3 — Design Guidelines for Equipment Using Liquid Chemicals

Appendix 4 — Ionizing Radiation Test Validation

Appendix 5 — Non-Ionizing Radiation (Other than Laser) and Fields Test Validation

Appendix 6 — Fire Protection: Flowchart for Selecting Materials of Construction

2.3 *Precedence of Sectional Requirements* — In the case of conflict between provisions in different sections of this guideline, the section or subsection specifically addressing the technical issue takes precedence over the more general section or subsection.

2.4 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guideline is intended for use by supplier and user as a reference for EHS considerations. It is not intended to be used to verify compliance with local regulatory requirements.

3.2 It is not the philosophy of this guideline to provide all of the detailed EHS design criteria that may be applied to semiconductor manufacturing equipment. This guideline provides industry-specific criteria, and refers to some of the many international codes, regulations, standards, and specifications that should be considered when designing semiconductor manufacturing equipment.

3.3 Existing models and subsystems should continue to meet the provisions of SEMI S2-93A. Models with redesigns that significantly affect the EHS aspects of the equipment should conform to the latest version of SEMI S2. This guideline is not intended to be applied retroactively.

3.4 In many cases, references to standards have been incorporated into this guideline. These references do not imply applicability of the entire standards, but only of the sections referenced.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E6 — Facilities Interface Specifications Guideline and Format

SEMI F5 — Guide for Gaseous Effluent Handling

SEMI F14 — Guide for the Design of Gas Source Equipment Enclosures

SEMI F15 — Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography

SEMI S1 — Safety Guideline for Equipment Safety Labels

SEMI S3 — Safety Guideline for Heated Chemical Baths

SEMI S6 — Safety Guideline for Ventilation

SEMI S7 — Safety Guidelines for Environmental, Safety, and Health (ESH) Evaluation of Semiconductor Manufacturing Equipment

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

SEMI S9 — Safety Guideline for Electrical Design Verification Tests for Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

SEMI S12 — Guidelines for Equipment Decontamination

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment.

SEMI S14 — Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment

4.2 *ANSI Standards*[1]

ANSI/IEEE C95.1 — Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

ANSI/RIA R15.06 — Industrial Robots and Robot Systems -- Safety Requirements

4.3 *CEN/CENELEC Standards*[2]

EN 775 — Manipulating industrial robots--Safety

EN 1050 — Safety of Machinery--Risk Assessment

EN 1127-1 — Explosive atmospheres -- Explosion prevention and protection -- Part 1: Basic concepts and methodology

4.4 *IEC Standards*[3]

IEC 61010-1 — Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Equipment, Part 1: General Requirements

4.5 *ISO Standards*[4]

ISO 10218 — Manipulating industrial robots--Safety

4.6 *NFPA*[5] *Standards*

NFPA 12 — Standard on Carbon Dioxide Extinguishing Systems

NFPA 13 — Standard for Installation of Sprinkler Systems

NFPA 72 — National Fire Alarm Code

NFPA 497 — Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

NFPA 704 — Identification of the Fire Hazards of Materials

NFPA 2001 — Standard on Clean Agent Fire Extinguishing Systems

4.7 *Other Standards and Documents*

ACGIH, *Industrial Ventilation Manual*[6]

1 American National Standards Institute, 11 West 42nd Street, New York, New York 10036, USA, www.ansi.org

2 European Committee for Standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat: rue de Stassart 35, B-1050 Brussels, Belgium

3 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland, www.iec.ch

4 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland, www.iso.ch

5 National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, Massachusetts, 02269-9101, USA, www.nfpa.org

ASHRAE Standard 110 — Method of Testing Performance of Laboratory Fume Hoods[7]

Burton, D.J., *Semiconductor Exhaust Ventilation Guidebook*[8]

Uniform Building Code™ (UBC)[9]

Uniform Fire Code™[10]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ACGIH®* — American Conference of Governmental Industrial Hygienists (ACGIH is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.1.2 *ASHRAE* — American Society of Heating, Refrigeration, and Air Conditioning Engineers

5.2 *Definitions*

5.2.1 *abort switch* — a switch that, when activated, interrupts the activation sequence of a fire detection or fire suppression system.

5.2.2 *accredited testing laboratory* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards; and recognized by a governmental or regulatory body.

5.2.3 *baseline* — for the purposes of this document, "baseline" refers to operating conditions, including process chemistry, for which the equipment was designed and manufactured.

5.2.4 *breathing zone* — imaginary globe, of 600 mm (two foot) radius, surrounding the head.

5.2.5 *capture velocity* — the air velocity that at any point in front of the exhausted hood or at the exhausted hood opening is necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the exhausted hood.

6 ACGIH, 1330 Kemper Meadow Road, Cincinnati, Ohio 45240, USA, www.acgih.org

7 ASHRAE, 1791 Tullie Circle, NE, Atlanta, Georgia 30329, USA, www.ashrae.org

8 IVE, Inc., 2974 South Oakwood, Bountiful, Utah 84010, USA, www.eburton.com

9 International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298, USA, www.icbo.org

10 International Fire Code Institute, 5360 Workman Mill Road, Whittier, California 90601-2298, USA, www.ifci.org

5.2.6 *carcinogen* — confirmed or suspected human cancer-causing agent as defined by the International Agency for Research on Cancer (IARC) or other recognized entities.

5.2.7 *chemical distribution system* — the collection of subsystems and components used in a semiconductor manufacturing facility to control and deliver process chemicals from source to point of use for wafer manufacturing processes.

5.2.8 *cleanroom* — a room in which the concentration of airborne particles is controlled to specific limits.

5.2.9 *coefficient of entry (C_e)* — the ratio of actual airflow into the exhausted hood to the theoretical airflow if all hood static pressure could be converted into velocity, as would be the case if the hood entry loss factor (K or F_h) were zero. $C_e = (VP/|SP_h|)^{0.5}$ where VP = duct velocity pressure and SP_h = hood static pressure (see also Appendix 2).

5.2.10 *combustible material* — for the purpose of this guideline, a combustible material is any material that does propagate flame (beyond the ignition zone with or without the continued application of the ignition source) and does not meet the definition in this section for noncombustible material. (See also the definition for *noncombustible material*.)

5.2.11 *equipment* — a specific piece of machinery, apparatus, process module, or device used to execute an operation. The term "equipment" does not apply to any product (e.g., substrates, semiconductors) that may be damaged as a result of equipment failure.

5.2.12 *face velocity* — velocity at the cross-sectional entrance to the exhausted hood.

5.2.13 *facilitization* — the provision of facilities or services.

5.2.14 *fail-safe* — designed so that a failure does not result in an increased risk.

NOTE 2: For example, a fail-safe temperature limiting device would indicate an out-of-control temperature if it were to fail. This might interrupt a process, but would be preferable to the device indicating that the temperature is within the control limits, regardless of the actual temperature, in case of a failure.

5.2.15 *failure* — the termination of the ability of an item to perform a required function. Failure is an event, as distinguished from "fault," which is a state.

5.2.16 *fault* — the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources.

5.2.17 *fault-tolerant* — designed so that a reasonably foreseeable single point failure does not result in an unsafe condition.

5.2.18 *flammable gas* — any gas that forms an ignitable mixture in air at 20 °C (68 °F) and 101.3 kPa (14.7 psia).

5.2.19 *flammable liquid* — a liquid having a flash point below 37.8 °C (100 °F).

5.2.20 *flash point* — the minimum temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid, or within the test vessel used.

5.2.21 *gas cylinder cabinet* — cabinet used for housing gas cylinders, and connected to gas distribution piping or to equipment using the gas. Synonym: gas cabinet.

5.2.22 *gas panel* — an arrangement of fluid handling components (e.g., valves, filters, mass flow controllers) that regulates the flow of fluids into the process. Synonyms: gas jungle, jungle, gas control valves, valve manifold.

5.2.23 *gas panel enclosure* — an enclosure designed to contain leaks from gas panel(s) within itself. Synonyms: jungle enclosure, gas box, valve manifold box.

5.2.24 *hazard* — a condition that is a prerequisite to a mishap.

5.2.25 *hazardous production material (HPM)* — a solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous.

5.2.26 *hazardous voltage* — unless otherwise defined by an appropriate international standard applicable to the equipment, voltages greater than 30 volts rms, 42.4 volts peak, 60 volts dc are defined in this document as hazardous voltage.

NOTE 3: The specified levels are based on normal conditions in a dry location.

5.2.27 *hood* — in the context of Section 22 and Appendix 2 of this guideline, "hood" means a shaped inlet designed to capture contaminated air and conduct it into an exhaust duct system.

5.2.28 *hood entry loss factor (K or F_h)* — a unitless factor that quantifies hood efficiency. If the hood is 100% efficient, then K or $F_h = 0$. Related equations:

$Q = 4.043A[(SP_h/d)/(1+F_h)]^{0.5}$

where:

Q = volumetric flow rate in m^3/sec,

A = cross sectional area of the duct in m^2,

SP_h = hood static pressure in mm water gauge (w.g.),

and d = density correction factor (unitless).

(US units: $Q = 4005A[(SP_h/d)/(1+F_h)]^{0.5}$

where:

Q = volumetric flow rate in cfm.

A = cross sectional area of the duct in ft^2,

SP_h = hood static pressure in inches water gauge (w.g.),

and d = density correction factor (unitless).)

5.2.29 *incompatible* — as applied to chemicals: in the context of Section 23 of this guideline, describes chemicals that, when combined unintentionally, may react violently or in an uncontrolled manner, releasing energy that may create a hazardous condition.

5.2.30 *intended reaction product* — chemicals that are produced intentionally as a functional part of the semiconductor manufacturing process.

5.2.31 *interlock* — a mechanical, electrical or other type of device or system, the purpose of which is to prevent or interrupt the operation of specified machine elements under specified conditions.

5.2.32 *ionizing radiation* — alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions in human tissue.

5.2.33 *laser* — any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of controlled stimulated emission.

5.2.34 *laser product* — any product or assembly of components that constitutes, incorporates, or is intended to incorporate a laser or laser system (including laser diode), and that is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product.

5.2.35 *laser source* — any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. General energy sources, such as electrical supply mains, should not be considered to be laser energy sources.

5.2.36 *laser system* — a laser in combination with an appropriate laser energy source, with or without additional incorporated components.

5.2.37 *likelihood* — the expected frequency with which a mishap will occur. Usually expressed as a rate (e.g., events per year, per product, or per substrate processed).

5.2.38 *local exhaust ventilation* — local exhaust ventilation systems operate on the principle of capturing a contaminant at or near its source and moving the contaminant to the external environment, usually through an air cleaning or a destructive device. It is not to be confused with laminar flow ventilation. Synonyms: LEV, local exhaust, main exhaust, extraction system, module exhaust, individual exhaust.

5.2.39 *lower explosive limit* — the minimum concentration of vapor in air at which propagation of flame will occur in the presence of an ignition source. Synonyms: LEL, lower flammability limit (LFL).

5.2.40 *maintenance* — planned or unplanned activities intended to keep equipment in good working order. (See also the definition for *service.*)

5.2.41 *mass balance* — a qualitative, and where possible, quantitative, specification of mass flow of input and output streams (including chemicals, gases, water, deionized water, compressed air, nitrogen, and by-products), in sufficient detail to determine the effluent characteristics and potential treatment options.

5.2.42 *material safety data sheet (MSDS)* — written or printed material concerning chemical elements and compounds, including hazardous materials, prepared in accordance with applicable standards.

NOTE 4: Examples of such standards are USA government regulation 29 CFR 1910.1200, and Canadian WHMIS (Workplace Hazardous Material Information System).

5.2.43 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

NOTE 5: For the purpose of this guideline, a "series of events" is limited to those events resulting from a single point failure. See also Section 6.5.

5.2.44 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz). (See also the definition for *combustible material*.)

5.2.45 *non-ionizing radiation* — forms of electro-magnetic energy that do not possess sufficient energy to ionize human tissue by means of the interaction of a single photon of any given frequency with human tissue. Non-ionizing radiation is customarily identified by frequencies from zero hertz to 3×10^{15} hertz (wavelengths ranging from infinite to 100 nm). This includes: static fields (frequencies of 0 hertz and infinite wavelengths); extremely low frequency fields (ELF), which includes power frequencies; subradio-frequencies; radiofrequency/microwave energy; and infrared, visible, and ultraviolet energies.

5.2.46 *non-recycling, deadman-type abort switch* — a type of abort switch that must be constantly held closed for the abort of the fire detection or suppression system. In addition, it does not restart or interrupt any time delay sequence for the detection or suppression system when it is activated.

5.2.47 *occupational exposure limits (OELs)* — for the purpose of this document, OELs are generally established on the basis of an eight hour workday. Various terms are used to refer to OELs, such as permissible exposure levels, Threshold Limit Values®, maximum acceptable concentrations, maximum exposure limits, and occupational exposure standards. However, the criteria used in determining OELs can differ among the various countries that have established values. Refer to the national bodies responsible for the establishment of OELs. (Threshold Limit Value is a registered trademark of the American Conference of Governmental Industrial Hygienists.)

5.2.48 *operator* — a person who interacts with the equipment only to the degree necessary for the equipment to perform its intended function.

5.2.49 *parts-cleaning hood* — exhausted hood used for the purpose of cleaning parts or equipment. Synonym: equipment cleaning hood.

5.2.50 *positive-opening* — as applied to electromechanical control devices. The achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (i.e., contact separation is not dependent upon springs).

5.2.51 *potentially hazardous non-ionizing radiation emissions* — for the purposes of this guideline, non-ionizing radiation emissions outside the limits shown in Appendix 5 are considered potentially hazardous.

5.2.52 *pyrophoric material* — a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

5.2.53 *radio frequency (rf)* — electromagnetic energy with frequencies ranging from 3 kHz to 300 GHz. Microwaves are a portion of rf extending from 300 MHz to 300 GHz.

5.2.54 *readily accessible* — capable of being reached quickly for operation or inspection, without requiring climbing over or removing obstacles, or using portable ladders, chairs, etc.

5.2.55 *recognized* — as applied to standards; agreed to, accepted, and practiced by a substantial international consensus.

5.2.56 *rem* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 rem = 0.01 sievert.

5.2.57 *reproductive toxicants* — chemicals that are confirmed or suspected to cause statistically significant increased risk for teratogenicity, developmental effects, or adverse effects on embryo viability or on male or female reproductive function at doses that are not considered otherwise maternally or paternally toxic.

5.2.58 *residual* — as applied to risks or hazards: that which remains after engineering, administrative, and work practice controls have been implemented.

5.2.59 *risk* — the expected losses from a mishap, expressed in terms of severity and likelihood.

5.2.60 *safe shutdown condition* — a condition in which all hazardous energy sources are removed or suitably contained and hazardous production materials are removed or contained, unless this results in additional hazardous conditions.

5.2.61 *safety critical part* — discrete device or component, such as used in a power or safety circuit, whose proper operation is necessary to the safe performance of the system or circuit.

5.2.62 *service* — unplanned activities intended to return equipment that has failed to good working order. (See also the definition for *maintenance*.)

5.2.63 *severity* — the extent of the worst credible loss from a mishap caused by a specific hazard.

5.2.64 *sievert (Sv)* — unit of dose equivalent. Most instruments used to measure ionizing radiation read in dose equivalent (rems or sieverts). 1 Sv = 100 rems.

5.2.65 *standard temperature and pressure* — for ventilation measurements, either dry air at 21°C (70°F) and 760 mm (29.92 inches) Hg, or air at 50% relative humidity, 20°C (68°F), and 760 mm (29.92 inches) Hg.

5.2.66 *supervisory alarm* — as applied to fire detection or suppression systems; an alarm indicating a supervisory condition.

5.2.67 *supervisory condition* — as applied to fire detection or suppression systems; condition in which action or maintenance is needed to restore or continue proper function.

5.2.68 *supplemental exhaust* — local exhaust ventilation that is used intermittently for a specific task of finite duration.

5.2.69 *supplier* — party that provides equipment to, and directly communicates with, the user. A supplier may be a manufacturer, an equipment distributor, or an equipment representative. (See also the definition for *user*.)

5.2.70 *testing* — the term "testing" is used to describe measurements or observations used to validate and document conformance to designated criteria.

5.2.71 *trouble alarm* — as applied to fire detection or suppression systems; an alarm indicating a trouble condition.

5.2.72 *trouble condition* — as applied to fire detection or suppression systems; a condition in which there is a fault in a system, subsystem, or component that may interfere with proper function.

5.2.73 *user* — party that acquires equipment for the purpose of using it to manufacture semiconductors. (See also the definition for *supplier*.)

5.2.74 *velocity pressure (VP)* — the pressure required to accelerate air from zero velocity to some velocity V. Velocity pressure is proportional to the kinetic energy of the air stream. Associated equation:

$VP = (V/4.043)^2$, where V = air velocity in m/s, and VP = velocity pressure in mm water gauge (w.g.).

[U.S. units: $VP = (V/4005)^2$, where

V = velocity in feet per second, and

VP = velocity pressure in inches water gauge (w.g.)]

5.2.75 *volumetric flow rate (Q)* — in the context of Section 22 and Appendix 2 of this guideline, Q = the volume of air exhausted per unit time. Associated equation: Q = VA, where V = air flow velocity, and A = the cross-sectional area of the duct or opening through which the air is flowing at standard conditions.

5.2.76 *wet station* — open surface tanks, enclosed in a housing, containing chemical materials used in the manufacturing of semiconductor materials. Synonyms: wet sink, wet bench, wet deck.

6 Safety Philosophy

6.1 A primary objective of the industry is to eliminate or control hazards during the equipment's life cycle (i.e., the installation, operation, maintenance, service, and disposal of equipment).

6.2 The assumption is made that operators, maintenance personnel, and service personnel are trained in the tasks that they are intended to perform.

6.3 The following should be considered in the design and construction of equipment:

- regulatory requirements;
- industry standards;
- this guideline; and
- good engineering and manufacturing practices.

6.4 This guideline should be applied during the design, construction, and evaluation of semiconductor equipment, in order to reduce the expense and disruptive effects of redesign and retrofit.

6.5 No reasonably foreseeable single-point failure condition or operational error should allow exposure of personnel, facilities, or the community to hazards that could result in death, significant injury, or significant equipment damage.

NOTE 6: The intent is to control single fault conditions that result in significant risks (i.e., Critical, High, or Medium risks based on the example risk assessment matrix in SEMI S10).

6.6 Equipment safety features should be fail-safe or of a fault-tolerant design and construction.

6.7 Components and assemblies should be used in accordance with their manufacturers' ratings and specifications, where using them outside the ratings would create a safety hazard.

6.8 A hazard analysis should be performed to identify and evaluate hazards. The hazard analysis should be initiated early in the design phase, and updated as the design matures.

6.8.1 The hazard analysis should include consideration of:

- the application or process;
- the hazards associated with each task;
- anticipated failure modes;
- the probability of occurrence and severity of a mishap;
- the level of expertise of exposed personnel and the frequency of exposure;
- the frequency and complexity of operating, servicing and maintenance tasks; and
- safety critical parts.

NOTE 7: EN 1050 contains examples of hazard analysis methods.

6.8.2 The risks associated with hazards should be characterized using SEMI S10.

6.9 The order of precedence for resolving identified hazards should be as follows:

6.9.1 *Design to Eliminate Hazards* — From the initial concept phase, the supplier should design to eliminate hazards.

NOTE 8: It is recommended that the supplier continue to work to eliminate identified hazards.

6.9.2 *Incorporate Safety Devices* — If identified hazards cannot be eliminated or their associated risk adequately controlled through design selection, then the risk should be reduced through fixed, automatic, or other protective safety design features or devices.

NOTE 9: It is recommended that provisions be made for periodic functional checks of safety devices, when applicable.

6.9.3 *Provide Warning Devices* — If design or safety devices cannot effectively eliminate identified hazards or adequately reduce associated risk, a means should be used to detect the hazardous condition and to produce a warning signal to alert personnel of the hazard.

6.9.4 *Provide Hazard Warning Labels* — Where it is impractical to eliminate hazards through design selection or adequately reduce the associated risk with safety or warning devices, hazard warning labels should be provided. See Section 10 for label information.

6.9.5 *Develop Administrative Procedures and Training* — Where hazards are not eliminated through design selection or adequately controlled with safety or warning devices or warning labels, procedures and training should be used. Procedures may include the use of personal protective equipment.

6.9.6 A combination of these approaches may be needed.

7 General Provisions

7.1 This guideline should be incorporated by reference in equipment purchase specifications. The user and supplier should agree on deviations from this guideline. The intent is for the user to purchase equipment conforming with SEMI S2, not to design the equipment.

7.2 The equipment must comply with laws and regulations that are in effect at the location of use. All equipment requiring certification or approval by government agencies must have this certification or approval as required by regulations.

NOTE 10: It is recommended that the supplier request from the user information regarding local laws and regulations.

7.3 The manufacturer should maintain an equipment/product safety program to identify and eliminate hazards or control risks in accordance with the order of precedence (see Section 6.9).

7.3.1 The supplier should provide the user's designated representative with bulletins that describe safety related upgrades or newly identified significant hazards associated with the equipment. This should be done on an ongoing basis as needed.

7.4 Model-specific tools and accessories necessary to operate, maintain, and service equipment safely should be provided with the equipment or specified by the supplier.

NOTE 11: The official values in this guideline are expressed in The International System of Units (SI). Values that:

- are expressed in Inch-Pound (also known as "US Customary" or "English") units,
- are enclosed in parentheses, and
- directly follow values expressed in SI units

are not official, are provided for reference only, and might not be exact conversions of the SI values.

8 Evaluation Process

8.1 This section describes the evaluation of equipment to this guideline, the contents of the evaluation report, and supporting information needed to perform the evaluation.

8.2 *General* — The evaluating party (see Section 8.4) should evaluate the equipment according to this guideline and create a written evaluation report.

NOTE 12: The intent is that the "should" provisions of this guideline be used as the basis for evaluating conformance. The intent is also that the "may," "suggested," "preferred," "recommended," and "NOTE" provisions of this guideline not be used for evaluating conformance.

8.2.1 Conformance to specific sections of SEMI S2 may be achieved by instructions included in the supplier's equipment installation instructions (reference SEMI E6) or other documentation.

8.3 *Evaluation Report Contents: General* — The evaluation report should include only the manuals (Section 9.6) and the design-specific sections (Sections 10 through 27). The Appendices should be used in the evaluation, and referenced in the report, only as they pertain to the specific application.

8.3.1 For each numbered section, the evaluation report should state one of the following, and provide supporting rationale:

- "Conforms" — equipment conforms to the section or to the intent of the section.
- "Does not Conform" — equipment conforms to neither the section nor to the intent of the section.
- "N/A" — section is not applicable to equipment.

8.3.1.1 The results of a risk assessment indicating no significant risk may be used in determining that the equipment conforms to the intent of a section.

8.3.1.2 The evaluation report should include a determination per SEMI S10 of the level of risk associated with nonconformance findings.

8.3.1.3 Supporting rationale may include test data or documented engineering rationale.

8.4 *Evaluation Report Contents: Other Information* — The evaluation report should also include:

- manufacturer's model number;
- serial number of unit(s) evaluated;
- the date(s) that the equipment was evaluated;
- a system/equipment description including configuration, options, and essential diagrams; and
- a statement of the qualifications of the evaluating party. An in-house body, independent laboratory, or product safety consulting firm ("third party") meeting the provisions of SEMI S7 may be used to supply testing or evaluation of conformance to this document.

8.5 *Supporting Information Provided to Evaluator* — The following documentation should be provided to, or developed by, the evaluator, as necessary to demonstrate conformance to the provisions of this guideline.

NOTE 13: It is recommended that the manufacturer's typical configuration and process be used for evaluation purposes. Alternatively, a process agreed upon between the user and the supplier may be used.

NOTE 14: Special options or configurations that may pose additional hazards and are not included in the initial evaluation may need a separate review. It is recommended that upgrades, retrofits, and other changes that affect the safety design of the equipment be evaluated for conformance.

8.5.1 *General Information*

- Written system description, including hardware configuration and function(s), power requirements, power output, and other information necessary to understand the design and operation of the equipment.
- Engineering data used to provide the rationale that the equipment and subassembly seismic anchorages are designed to satisfy the applicable design loads (see Section 19, Seismic Protection).
- Descriptions of the purpose and function of safety devices, such as: emergency off devices (EMOs), interlocks, pressure relief devices, and limit controls.

- A hazard analysis (see Section 6.8).
- Ergonomics evaluation (see Section 16).
- A list of safety critical parts and, for each one, evidence of certification, or documentation showing that the component is suitable for its application.
- A residual fire risk assessment as described in Section 14.2.
- Tests results, certifications, and design specifications that are necessary to evaluate the equipment with respect to fire safety. Descriptions of the fire detection and suppression equipment and controls should also be provided.

8.5.2 *Industrial Hygiene Information*

8.5.2.1 An industrial hygiene report, which should include, as applicable:

- ventilation assessment (see Section 22);
- chemical inventory and hazard analysis (see Section 23);
- ionizing radiation assessment (see Section 24);
- non-ionizing radiation assessment (see Section 25);
- laser assessment (see Section 26); and
- audio sound pressure level assessment (see Section 27).

8.5.3 *Environmental Information* (see Section 21) — Documentation substantiating the following:

- consideration or inclusion of features that conserve resources (e.g., energy, water, deionized water, compressed gases, chemicals, and packaging);
- consideration of features that would promote equipment and component reuse or refurbishing, or material recycling upon decommissioning;
- consideration or inclusion of features for resource recycling or reuse;
- chemical selection methods and criteria (see Section 21.2.3);
- consideration of integrating effluent and emission controls into the equipment; and
- efforts to reduce wastes, effluents, emissions, and by-products.

NOTE 15: For purposes of Section 8.5.3, documentation may include design notes, metrics (whether normalized or not), meeting minutes, pareto evaluations, or other analyses.

9 Documents Provided to User

9.1 This section describes the documents that the supplier provides to the user.

9.2 *Evaluation Report* — Upon request by the user, the supplier should provide the user with a summary of the SEMI S2 evaluation report (see Section 8) or the full report.

9.2.1 Nonconformances noted in the report should be addressed by the supplier, by providing either an action plan or a justification for acceptance. The justification should include countermeasures in place and a risk characterization per SEMI S10.

9.3 *Seismic Information* — Refer to Section 19 of this document.

9.4 *Environmental Documentation* — The manufacturer should provide the user with the following environmental documentation as applicable:

9.4.1 Energy consumption information, including idle, average, and peak operating conditions, for the manufacturer’s most representative (“baseline”) process.

9.4.2 Mass balance, including idle, average, and peak operating conditions, for the manufacturer’s most representative (“baseline”) process.

NOTE 16: The mass balance may include resource consumption rates, chemical process efficiencies, wastewater effluent and air emission characterization, solid and hazardous waste generation (quantity and quality), and by-products.

9.4.3 Information regarding routes of unintended release (of effluents, wastes, emissions, and by-products) and methods and devices to monitor and control such releases. This should include information on features to monitor, prevent, and control unintended releases (see Section 21.2.4).

9.4.4 Information regarding routes of intended release (of effluents, wastes, and emissions) and features to monitor and control such releases (see Section 21.2.5).

9.4.5 A list of items that become solid waste as a result of the operation, maintenance, and servicing of the equipment, and that are constructed of or contain substances whose disposal might be regulated (e.g., berylium-containing parts, vapor lamps, mercury switches, batteries, contaminated parts, maintenance wastes).

9.5 *Industrial Hygiene Information* — Refer to Sections 22–27 of this document.

9.6 *Manuals*

9.6.1 The supplier should provide the user with manuals based on the originally intended use of the equipment. The manuals should describe the scope and normal use of the equipment, and provide information to enable safe facilitization, operation, maintenance, and service of the equipment.

9.6.2 The manuals should conform to SEMI S13.

NOTE 17: Fire suppression agents, and chemicals used to test fire detection or suppression systems, fall under the MSDS provisions of SEMI S13 when they are provided with the equipment.

NOTE 18: Hazardous energies within fire detection or suppression systems fall under the hazardous energy control provisions of SEMI S13 when fire detection or suppression systems are provided with the equipment.

9.6.3 In addition to the provisions of SEMI S13, the manuals should include:

- specific written instructions on routine Type 4 tasks, excluding troubleshooting (refer to Section 13.3);
- instructions for energy isolation ("lockout/tagout") (refer to Section 17.2);
- descriptions of the emergency off (EMO) and interlock functions;
- a list of hazardous materials (e.g., lubricants, cleaners, coolants) required for maintenance, ancillary equipment or peripheral operations, including anticipated change-out frequency, quantity, and potential for contamination from the process;
- a list of items that become solid waste as a result of the operation, maintenance, and servicing of the equipment, and that are constructed of or contain substances whose disposal might be regulated (e.g., berylium-containing parts, vapor lamps, mercury switches, batteries, contaminated parts, maintenance wastes); and
- maintenance and troubleshooting procedures needed to maintain the effectiveness of safety design features or devices (i.e., engineering controls).

9.6.4 Information should be provided regarding potential routes of unintended releases (see Section 21.2.4).

9.6.5 Recommended decontamination and decommissioning procedures should be provided in accordance with SEMI S12, and should include the following information:

- identity of components and materials of construction, in sufficient detail to support recycling, refurbishment, and reuse decisions (see Section 8.5.3); and
- residual hazardous materials, or parts likely to become contaminated with hazardous materials, that may be in the equipment prior to decommissioning.

NOTE 19: It is recommended that the manual state that changes to the typical process chemistry or to the equipment could alter the anticipated environmental impact.

9.6.6 *Maintenance Procedures with Potential Environmental Impacts* — The supplier's recommended maintenance procedures should:

- identify procedural steps during which releases might occur, and the nature of the releases; and
- identify waste characteristics and methods to minimize the volume of effluents, wastes, or emissions generated during maintenance procedures.

9.7 *Fire Protection Documentation* — The equipment supplier should provide:

- a summary fire protection report as described in Section 14.3;
- descriptions of optional fire risk mitigation features (see Section 14.3.2);

  NOTE 20: It is recommended that this be provided prior to purchase.

- fire detection system operations, maintenance, and test manuals;
- fire suppression system operations, maintenance, and test manuals;
- acceptance documents provided by licensed designers and installers (see Sections 14.4.4.12 and 14.4.5.16); and
- a list of any special apparatus needed to test the fire detection or suppression features of the equipment. The list should note whether the apparatus is included with the equipment, or is sold separately.

10 Hazard Warning Labels

10.1 Where it is impractical to eliminate hazards through design selection or to adequately reduce the associated risk with safety or warning devices, hazard warning labels should be provided to identify and warn against hazards.

10.2 Labels should be durable and suitable for the environment of the intended use.

10.3 Labels should conform to SEMI S1.

EXCEPTION: Some hazard label formats and content are dictated by law (e.g., laser labeling and chemical hazard communication labeling in certain countries of use) and may not conform to SEMI S1.

11 Safety Interlock Systems

11.1 This section covers safety interlocks and safety interlock systems.

NOTE 21: If a fire detection or suppression system is provided with the equipment, see Section 14 for additional information.

11.2 Where appropriate, equipment should use safety interlock systems that protect personnel, facilities, and the community from hazards inherent in the operation of the equipment.

NOTE 22: Safety critical parts whose primary function is to protect the equipment (e.g., circuit breakers, fuses) are typically not considered to be safety interlocks.

11.3 Safety interlock systems should be designed such that, upon activation of the interlock, the equipment, or relevant parts of the equipment, is automatically brought to a safe condition.

11.4 Upon activation, the safety interlock should alert the operator immediately.

EXCEPTION: Alerting the operator is not expected if a safety interlock triggers the EMO circuit (see Section 12) or otherwise removes power to the user interface.

NOTE 23: An explanation of the cause is preferred upon activation of a safety interlock.

11.5 Safety interlock systems should be fault-tolerant and designed so that the functions or set points of the system components cannot be altered without disassembling, physically modifying, or damaging the device or component.

EXCEPTION: When safety interlock systems having adjustable set points or trip functions are used, access should be limited to maintenance or service personnel by requiring a deliberate action, such as using a tool or special keypad sequences, to access the adjustable devices or to adjust the devices.

NOTE 24: This section does not address the defeatability of safety interlocks. See Section 11.7 for additional information.

11.6 Electromechanical devices and components are preferred, but solid-state devices and components may be used, provided that the safety interlock system, or relevant parts of the system, are evaluated for suitability for use. The evaluation for suitability should take into consideration abnormal conditions such as overvoltage, undervoltage, power supply interruption, transient overvoltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration, and jarring.

EXCEPTION: Where the severity of a reasonably foreseeable mishap is deemed to be Minor per SEMI S10, a software-based interlock may be considered suitable.

NOTE 25: Where a safety interlock is provided to safeguard personnel from a Severe or Catastrophic mishap as categorized by SEMI S10, consideration of positive-opening type switches is recommended.

NOTE 26: Evaluation for suitability for use may also include reliability, self-monitoring, and redundancy as addressed under standards such as NEMA ICS 1.1 and UL 991.

NOTE 27: Solid-state devices include operational amplifiers, transistors, and integrated circuits.

11.7 The safety interlock system should be designed to minimize the need to override safety interlocks during maintenance activities.

11.7.1 Safety interlocks that safeguard personnel during operator tasks should not be defeatable without the use of a tool.

11.7.2 When maintenance access is necessary to areas protected by interlocks, defeatable safety interlocks may be used, provided that they require an intentional operation to bypass.

11.7.2.1 Upon exiting or completing the maintenance mode, all safety interlocks should be automatically restored.

11.7.2.2 If a safety interlock is defeated, the maintenance manual should identify administrative controls to safeguard personnel or to minimize the hazard.

11.8 The restoration of a safety interlock should not initiate equipment operation or parts movement where this can give rise to a hazardous condition.

11.9 Switches and other control device contacts should be connected to the ungrounded side of the circuit so that a short circuit to ground does not result in the interlocks being satisfied.

11.10 Where a hazard to personnel is controlled through the use of an enclosure, the enclosure should either: require a tool to gain access and be labeled regarding the hazard against which it protects personnel; or be interlocked. In addition to enclosures, physical barriers at the point of hazard should be included where inadvertent contact is likely.

NOTE 28: Where the removal of a cover exposes a hazard, consider additional labels. See Section 10 for guidance.

12 Emergency Shutdown

12.1 The equipment should have an "emergency off" (EMO) circuit. The EMO actuator (e.g., button), when activated, should place the equipment into a safe shutdown condition, without generating any additional hazard to personnel or the facility.

EXCEPTION 1: An EMO circuit is not needed for equipment rated 2.4 kVA or less, where the hazards are only electrical in nature, provided that the main disconnect meets the accessibility provisions of Section 12.5.2 and that the effect of disconnecting the main power supply is equivalent to activating an EMO circuit.

EXCEPTION 2: Assemblies that are not intended to be used as stand-alone equipment, but rather within an overall integrated system, and that receive their power from the user's system, are not required to have an emergency off circuit. The assembly's installation manual should provide clear instructions to the equipment installer to connect the assembly to the integrated system's emergency off circuit.

NOTE 29: It is recommended that the emergency off function not reduce the effectiveness of safety devices or of devices with safety-related functions (e.g., magnetic chucks or braking devices) necessary to bring the equipment to a safe shutdown condition effectively.

NOTE 30: If a fire detection or suppression system is provided with the equipment, see Section 14 for additional information.

12.1.1 If the supplier provides an external EMO interface on the equipment, the supplier should include instructions for connecting to the interface.

12.2 Activation of the emergency off circuit should deenergize all hazardous voltage and all power greater than 240 volt-amps in the equipment beyond the main power enclosure.

EXCEPTION 1: A non-hazardous voltage EMO circuit (typically 24 volts) and its supply may remain energized.

EXCEPTION 2: Safety related devices (e.g., smoke detectors, gas/water leak detectors, pressure measurement devices, etc.) may remain energized from a non-hazardous power source.

EXCEPTION 3: A computer system performing data/alarm logging and error recovery functions may remain energized, provided that the energized breaker(s), receptacle(s), and each energized conductor termination are clearly labeled as remaining energized after EMO activation. Hazardous energized parts that remain energized after EMO activation should be insulated or guarded to prevent inadvertent contact by maintenance personnel.

EXCEPTION 4: Multiple units mounted separately with no shared hazards and without interconnecting circuits with hazardous voltages, energy levels or other potentially hazardous conditions may have:

- separate sources of power and separate supply circuit disconnect means if clearly identified, or
- separate EMO circuits, if they are clearly identified.

12.2.1 The EMO circuit should not include features that are intended to allow it to be defeated or bypassed.

12.2.2 The EMO circuit should consist of electromechanical components.

12.2.3 Resetting the EMO switch should not re-energize circuits, equipment, or subassemblies.

12.2.4 The EMO circuit should shut down the equipment by deenergizing rather than energizing control components.

12.2.5 The EMO circuit should require manual resetting so that power cannot be restored automatically.

12.3 The emergency off button should be red and mushroom shaped. A yellow background for the EMO should be provided.

NOTE 31: Non-lockable self-latching (i.e., twist- or pull-to-release) EMO buttons may be required by regulations.

12.4 All emergency off buttons should be clearly labeled as "EMO," "Emergency Off," or the equivalent and should be clearly legible from the viewing location. The label may appear on the button or on the yellow background.

12.5 Emergency off buttons should be readily accessible from operating and regularly scheduled maintenance locations and appropriately sized to enable activation by the heel of the palm.

12.5.1 Emergency off buttons should be located or guarded to minimize accidental activation.

12.5.2 No operation or regularly scheduled maintenance location should require more than 3 m (10 feet) travel to an EMO button.

12.5.3 The person actuating or inspecting the EMO button should not be exposed to serious risks of tripping or falling or of coming in contact with energized electrical parts, moving machinery, surfaces or objects operating at high temperatures, or other hazardous equipment.

12.6 See Section 13.5 for additional EMO guidelines when EMOs are used with UPSs.

13 Electrical Design

13.1 This section covers electrical and electronic equipment that use hazardous voltages.

13.2 *Types of Electrical Work* — The following are the four types of electrical work defined by this guideline:

Type 1 — Equipment is fully deenergized.

Type 2 — Equipment is energized. Energized circuits are covered or insulated.

NOTE 32: Type 2 work includes tasks where the energized circuits are or can be measured by placing probes through suitable openings in the covers or insulators.

Type 3 — Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are no greater than 30 volts rms, 42.4 volts peak, 60 volts dc or 240 volt-amps in dry locations.

Type 4 — Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are greater than 30 volts rms, 42.4 volts peak, 60 volts dc, or 240 volt-amps in dry locations. Potential exposures to radio-frequency currents, whether induced or via contact, exceed the limits in Table A5-1 of Appendix 5.

13.3 *Energized Electrical Work* — The supplier should design the equipment to minimize the need to calibrate, modify, repair, test, adjust, or maintain equipment while it is energized, and to minimize work that must be performed on components near exposed energized circuits. The supplier should move as many tasks as practical from category Type 4 to Types 1, 2, or 3. Routine Type 4 tasks, excluding troubleshooting, should have specific written instructions in the maintenance manuals.

13.4 *Electrical Design* — Equipment should conform to the appropriate international, regional, national or industry product safety requirements.

13.4.1 Nonconductive or grounded conductive physical barriers should be provided:

- Where it is necessary to reach over, under, or around, or in close proximity to hazards.
- Where dropped objects could cause shorts or arcing.
- Where failure of liquid fittings from any part of the equipment would result in the introduction of liquid into electrical parts.
- Over the line side of the main disconnect.
- Where maintenance or service tasks on equipment in dry locations are likely to allow inadvertent contact with uninsulated energized parts containing either: potentials greater than 30 volts rms, 42.4 volts peak, or 60 volts dc; or power greater than 240 volt-amps.

NOTE 33: A dry location can be considered to be one that is not normally subject to dampness or wetness.

NOTE 34: Removable nonconductive and noncombustible covers are preferred.

13.4.2 Where test probe openings are provided in barriers, the barriers should be located, and the probe openings should be sized, to prevent inadvertent contact with adjacent energized parts, including the energized parts of the test probes.

13.4.3 Where failure of components and assemblies could result in a risk of electric shock, fire, or personal injury, those components and assemblies should be certified by an accredited testing laboratory and used in accordance with the manufacturer's specifications, or otherwise evaluated to the applicable standard(s).

NOTE 35: With the exception of implementation of ground fault protection, shunt trip units that require power to trip (actuate) are not recommended to be used in a safety control circuit, because they are not fail-safe.

13.4.4 Electrical wiring for power circuits, control circuits, grounding (earthing) and grounded (neutral) conductors should be color coded according to appropriate standard(s) per Section 13.4, or labeled for easy identification at both ends of the wire. Where color is used for identification, it is acceptable to wrap conductor ends with appropriate colored tape or sleeving; the tape or sleeving should be reliably secured to the conductor.

EXCEPTION 1: Internal wiring on individual components, e.g., motors, transformers, meters, solenoid valves, power supplies.

EXCEPTION 2: Flexible cords.

EXCEPTION 3: Nonhazardous voltage multi-conductor cables (e.g., ribbon cables).

EXCEPTION 4: When proper color is not available for conductors designed for special application (e.g., high-temperature conductors used for furnaces and ovens).

13.4.5 Grounding (earthing) conductors and connectors should be sized to be compatible in current rating with their associated ungrounded conductors according to appropriate standard(s) per Section 13.4.

13.4.6 Electrical enclosures should be suitable for the environment in which they are intended to be used.

13.4.7 Enclosure openings should safeguard against personnel access to uninsulated energized parts. (Refer to Appendix 1 for examples of openings for protection against access from operators.)

13.4.8 Top covers of electrical enclosures should be designed and constructed to prevent objects from falling into the enclosures. (Refer to Appendix 1 for examples of acceptable top enclosure openings.)

13.4.9 The current interrupting capacity (also known as amperes interrupting capacity, or AIC) of the equipment main disconnect should be identified in the facility installation and maintenance manuals.

13.4.10 The equipment should be provided with main overcurrent protection devices and main disconnect devices rated for at least 10,000 rms symmetrical amperes interrupting capacity (AIC).

NOTE 36: Some facilities may require higher AIC ratings due to electrical distribution system design.

EXCEPTION: Cord- and plug-connected single phase equipment, rated no greater than 240 volts line-to-line/150 volts line-to-ground and no greater than 2.4 kVA, may have overcurrent protection devices with interrupting capacity of at least 5,000 rms symmetrical amperes interrupting capacity (AIC).

13.4.11 Equipment should be designed to receive incoming electrical power from the facility to a single feed location that terminates at the main disconnect specified in Section 13.4.9. This disconnect, when opened, should remove all incoming electrical power in the equipment from the load side of the disconnect. The disconnect should also have the energy isolation (“lockout”) capabilities specified in Section 17.

EXCEPTION 1: Equipment with more than one feed should be provided with provisions for energy isolation (lockout) for each feed and be marked with the following text or the equivalent at each disconnect: “WARNING: Risk of Electric Shock or Burn. Disconnect all [number of feed locations] sources of supply prior to servicing.” It is preferred that all of the disconnects for the equipment be grouped in one location.

EXCEPTION 2: Multiple units mounted separately with no shared hazards and without interconnecting circuits with hazardous voltages, energy levels or other potentially hazardous conditions may have:

- separate sources of power and separate supply circuit disconnect means, if they are clearly identified; or
- separate EMO circuits, if they are clearly identified.

13.4.12 A permanent nameplate listing the manufacturer’s name, machine serial number, supply voltage, phase, frequency and full-load current should be attached to the equipment where plainly visible after installation. Where more than one incoming supply circuit is to be provided, the nameplate should state the above information for each circuit.

NOTE 37: Additional nameplate information may be required depending on the location of use.

13.5 *Uninterruptable Power Supplies (UPSs)* — This section applies to UPSs with outputs greater than: 30 volts rms, 42.4 volts peak; 60 volts dc; or 240 volt-amps.

13.5.1 Whenever a UPS is provided with the equipment, its location and wiring should be clearly described within the installation and maintenance manual.

13.5.2 Power from the UPS should be interrupted when any of the following events occur:

- the emergency off actuator (button) is pushed; or
- the main equipment disconnect is opened; or
- the main circuit breaker is opened.

EXCEPTION: Upon EMO activation, the UPS may supply power to the EMO circuit, safety related devices, and data/alarm logging computer systems as described in the exception clauses of Section 12.2.

13.5.3 The UPS may be physically located within the footprint of the equipment provided that the UPS is within its own enclosure and is clearly identified.

13.5.4 The UPS should be certified by an accredited testing laboratory and be suitable for its intended environment (e.g., damp location, exposure to corrosives).

13.5.5 The UPS wiring should be identified as “UPS Supply Output” or equivalent at each termination point where the UPS wiring can be disconnected.

13.6 *Electrical Safety Tests*

13.6.1 Equipment connected to the facility branch circuit with a cord and plug should not exhibit surface leakage current greater than 3.5 milliampere (mA) measured from any point on the surface of the equipment covers and associated controls to earth ground. (Refer to SEMI S9 or other appropriate standards for recognized test methods.)

EXCEPTION: Equipment with leakage current exceeding 3.5 mA is acceptable if documentation is provided to substantiate that the equipment is fully compliant with an applicable product safety standard that explicitly permits a higher leakage current.

13.6.2 Equipment grounding circuits should have a measured resistance of one-tenth (0.1) ohm or less between the main equipment grounding conductor terminal and any accessible metal surfaces that are: accessible to operator without the use of tools; and likely to become energized in a single-point failure condition. Refer to SEMI S9 or other appropriate standards for recognized test methods.

13.7 Equipment in which flammable liquids or gases are used should be assessed to determine if additional precautions (e.g., purging) in the electrical design are necessary.

NOTE 38: NFPA 497 and EN 1127-1 provide methods for making this assessment.

14 Fire Protection

14.1 *Overview* — This section applies to fire hazards that are internal to the equipment.

14.1.1 This section provides minimum safety considerations for fire protection designs and controls on the equipment.

14.1.2 This section also provides minimum considerations for fire detection and suppression systems when provided with the equipment.

NOTE 39: Detailed guidance on fire risk assessment and mitigation for semiconductor manufacturing equipment is provided in SEMI S14.

14.2 *Risk Assessment*

14.2.1 A documented risk assessment should be performed or accepted by a party qualified to determine and evaluate fire hazards and the potential need for controls. The risk assessment should consider normal operations and reasonably foreseeable single-point failures within the equipment. It should not consider exposure to fire or external ignition sources not within the specified use environment.

NOTE 40: This risk assessment can be combined with the overall hazard analysis performed for this guideline, provided the risk assessor has the required professional expertise to perform risk assessments for fire hazards. SEMI S7 describes qualifications for such an assessor.

14.2.2 If an accurate risk assessment depends on the user's adherence to specified procedures or conditions of use, the supplier should describe such procedures or conditions and state their importance.

14.2.3 SEMI S14 should be used to assess and report risks to property and the environment.

14.3 *Reporting*

14.3.1 A summary report should be provided to the user. The summary should include the following characterizations, per SEMI S10, for each residual fire hazard identified:

- the assigned Severity;
- the assigned Likelihood; and
- the resulting Risk Category.

14.3.2 Optional fire risk reduction features should be described in the pre-purchase information provided to the user.

14.3.3 The scope and effectiveness of the means of fire risk reduction should also be identified and reported, including the expected risk reduction (as described in Section 14.3.1).

14.3.4 If, due to fire hazards within the equipment, thermal or non-thermal (e.g., smoke) damage is possible outside of the equipment, then this possibility should be reported to the user. This report should include a qualitative description of the foreseen scenario.

14.4 *Fire Risk Reduction*

14.4.1 *Materials of Construction* — Equipment should be constructed of noncombustible materials wherever reasonable. If process chemicals do not permit the use of noncombustible construction, then the equipment should be constructed of materials, suitable for the uses and compatible with the process chemicals used, that contribute least to the fire risk.

NOTE 41: Some regional codes (e.g., Uniform Fire Code) may require construction with noncombustible materials.

14.4.1.1 The flowchart in Appendix 6 may be used for the selection of materials of construction for equipment.

14.4.1.2 Any portion of equipment that falls within the scope of SEMI F14 (Guide for the Design of Gas Source Equipment Enclosures) should be designed in accordance with that guide.

14.4.2 *Elimination of Process Chemical Hazards* — The option of substituting non-flammable process chemicals for flammable process chemicals should be considered.

14.4.3 *Engineering Controls*

14.4.3.1 Fire risks resulting from process chemicals may be reduced using engineering controls (e.g., preventing improper chemical mixing, preventing temperatures from reaching the flash point).

14.4.3.2 Fire risks resulting from materials of construction may be reduced using engineering controls (e.g., non-combustible barriers that separate combustible materials of construction from ignition sources, installing a fire suppression system that extinguishes ignited materials).

14.4.3.3 Equipment power and chemical sources that present unacceptable fire risks should be interlocked with the fire detection and suppression systems to prevent start-up of the equipment or delivery of chemicals when the fire detection or suppression is inactive.

NOTE 42: Some jurisdictions require interlocking.

NOTE 43: Refer to Section 6.5 for criteria for acceptability.

14.4.3.4 Shutdown or failure of a fire detection or suppression system need not interrupt the processing of product within the equipment by immediately shutting down the equipment, but should prevent additional processing until the fire detection or suppression is restored. Software or hardware may be used for this function.

14.4.3.5 Controlling smoke by exhausting it (using the supplier-specified equipment exhaust) from the cleanroom may be used to reduce fire risks from the generation of products of combustion. When used, this reduction method should be combined with detection or suppression when flames can be propagated.

NOTE 44: Controlling smoke may be sufficient when smoke is the only consequence (e.g., smoldering components that generate smoke).

NOTE 45: For controlling smoke to be effective, the smoke must be removed not only from the equipment, but also from the cleanroom. This is typically accomplished by using ducted exhaust.

NOTE 46: The use of exhaust to remove smoke may be subject to regulations, such as building and fire codes.

NOTE 47: The use of exhaust to remove smoke may create hazards within the exhaust system. Therefore, a description of the expected discharge (i.e., anticipated air flow rate, temperature, and rate of smoke generation) into the exhaust system may be important information for installation of equipment.

14.4.4 *Fire Detection* — The following criteria apply to any fire detection system determined to be appropriate for fire protection by the fire risk assessment:

NOTE 48: Heat detectors, smoke sensing devices, and other devices used solely for monitoring equipment status may not need to meet these requirements. Some local jurisdictions, however, may require that all smoke detectors be connected to building systems and be compliant with all applicable fire alarm codes.

14.4.4.1 The fire detection system, which includes detectors, alarms and their associated controls, should be certified by an accredited testing laboratory and suitable for the application.

NOTE 49: Such certifications typically require that the components of fire detection systems are readily identifiable and distinguishable from other components in the equipment.

14.4.4.2 The fire detection, alarm and control system should be installed in accordance with the requirements of the certification in Section 14.4.4.1, and in accordance with requirements of the appropriate international or national codes or standards (e.g., NFPA 72).

14.4.4.3 The fire detection system should be capable of interfacing with the facility's alarm system. It may be preferable for the equipment supplier to specify the location and performance of detectors, but not provide them, so that the user may better integrate the detection in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

14.4.4.4 The fire detection system should activate alarms audibly and visually at the equipment.

14.4.4.5 Manual activation capability for the fire detection system should be considered, for the purpose of providing notification to a constantly attended location.

14.4.4.6 Activation of trouble or supervisory conditions should result in all of the following:

- notification of the operator;
- allowing the completion of processing of substrates in the equipment;
- prevention of processing of additional substrates until the trouble or supervisory condition is cleared; and
- providing, through an external interface, a signal to the facility monitoring system or a constantly attended location.

14.4.4.7 The fire detection system should be capable of operating at all times, including when the equipment is inoperable (e.g., equipment controller problems) or in maintenance modes (e.g., some or all of the equipment's hazardous energies are isolated ("locked out")).

EXCEPTION: Operability is not required during maintenance of the fire detection system.

NOTE 50: For the purposes of this section, "inoperable" includes the equipment state after an EMO is activated, and during maintenance of a duration less than the battery life expectancy of the fire detection system. Therefore, it is recommended that the detection system not require hazardous energies (e.g., line alternating current) to operate following an EMO activation.

14.4.4.8 A back-up power supply, capable of sustaining the detection system for 24 hours, should be provided.

NOTE 51: Back-up power must be provided in accordance with local regulations. The requirements for back-up power vary among jurisdictions.

14.4.4.9 The fire detection system should remain active following EMO activation.

14.4.4.10 There may be cases where the internal power supply for a detection system cannot supply power for the full length of extended maintenance procedures (i.e., procedures longer than the expected duration of the back-up power supply). In such cases, the supplier should provide written procedures for either removing the fire hazard or safely supplying power to the fire detection system.

14.4.4.11 Activation of the fire detection system should shut down the equipment within the shortest time period that allows for safe equipment shutdown. This includes shutdown of any fire-related hazard source that could create additional fire risks for the affected module or component.

NOTE 52: See Sections 14.4.3.3 and 14.4.3.4 for related provisions.

EXCEPTION 1: A non-recycling, deadman abort switch is acceptable on detection systems that are used for equipment shutdown, but not on those used for activation of a suppression system.

EXCEPTION 2: Activation of the fire detection system should not remove power from fire and safety systems.

14.4.4.12 The equipment design and configuration should not prevent licensed parties from certifying the design and installation of fire detection systems.

NOTE 53: This is not meant to suggest installation by licensed parties; however, some jurisdictions require fire detection and suppression system installers to be licensed as specified by the jurisdiction.

14.4.5 *Fire Suppression* — The following criteria apply to any fire suppression system determined to be appropriate by the fire risk assessment.

NOTE 54: As a fire detection system is generally required to provide the initiating sequence for the suppression system, it is the intention of this guideline that this be the same fire detection system described in Section 14.4.4.

14.4.5.1 The fire suppression system, which includes nozzles, actuators, and their associated controls, should be certified by an accredited testing laboratory and suitable for the application.

NOTE 55: Such certifications typically require that the components of fire suppression systems are readily identifiable and distinguishable from other components in the equipment. This includes adequate labeling of piping.

14.4.5.2 The fire suppression agent should be accepted for the application by an accredited testing laboratory. The suppression agent selection process should include an evaluation of potential damage to a cleanroom, and the least damaging effective agent should be selected. If more than one agent is effective, the options should be specified to the user so that the user may specify which agent should be provided with the equipment. The supplier should also specify if the user may provide the agent.

14.4.5.3 The fire suppression agent and delivery system should be designed and installed in accordance with the appropriate international or national standard (e.g., NFPA 12, NFPA 13, NFPA 2001). It may be preferable for the equipment supplier to specify the location and performance of suppression system components, but not provide them, so that the user may better integrate the suppression in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

14.4.5.4 Activation of the fire suppression system should alarm audibly and visually at the equipment. This may be done by the same system that initiates activation.

14.4.5.5 If the discharge is likely to present a risk to personnel, the alarm should provide adequate time to allow personnel to avoid the hazard of the agent discharge.

14.4.5.5.1 If there is a confined space in the equipment, the asphyxiation hazard posed by the suppression system should be assessed.

14.4.5.6 The fire suppression system should be capable of operating at all times, including when equipment is inoperable and during equipment maintenance.

NOTE 56: For the purpose of this section, “inoperable” includes the equipment state after the EMO is activated.

EXCEPTION: Most suppression systems contain sources of hazardous energy. These sources should be capable of being isolated (i.e., “locked out”) to protect personnel.

14.4.5.7 The fire suppression system should remain active following EMO activation.

14.4.5.8 There may be cases where the internal power supply for a suppression system cannot supply power for the full length of extended maintenance procedures (i.e., procedures longer than the expected duration of the back-up power supply). In such cases, the supplier should provide written procedures for either removing the fire hazard or safely supplying power to the fire suppression system.

14.4.5.9 Allowances can be made to provide for the deactivation of an automatic discharge of the suppression system when in the maintenance mode. Such deactivation switches should be supervised (i.e., if the suppression system is deactivated, there should be an indication to the user and the resumption of production in the equipment should be prevented.)

NOTE 57: Hazardous energies associated with the fire suppression system may be isolated (i.e., "locked out") using an energy isolation procedure (see Section 17) during equipment maintenance.

NOTE 58: The permissibility of deactivation of suppression systems varies among jurisdictions.

14.4.5.10 A back-up power supply, capable of sustaining the suppression system for 24 hours, should be included where the suppression system requires independent power from the detection system used to activate the suppression.

NOTE 59: The requirements for back-up power vary among jurisdictions.

14.4.5.11 The fire suppression system should be capable of interfacing with the facility's alarm system. This may be done via the fire detection system.

14.4.5.12 Activation of the fire suppression system should shut down the equipment within the shortest time period that allows for safe equipment shutdown.

NOTE 60: See Sections 14.4.3.3 and 14.4.3.4 for related provisions.

EXCEPTION: Activation of the fire suppression system should not remove power from fire and safety systems.

14.4.5.13 The fire suppression system should be capable of manual activation, which should shut down the equipment and activate an alarm signal locally and at a constantly attended location.

14.4.5.14 The fire suppression system should be tested on a representative sample of the equipment. The test procedure should include a suppression agent discharge test, unless precluded for health or environmental reasons. This test may be performed at the equipment supplier's or other similar facility, but should be performed under conditions that adequately duplicate any factors (e.g., equipment exhaust) that may reduce the effectiveness of the suppression. This representative sample need not be fully operational, but should duplicate those factors (e.g., exhaust, air flow) that could negatively affect the performance of the system.

14.4.5.15 Procedures for controlling access to the suppression agent source (e.g., protecting agent cylinders from disconnection by unauthorized personnel) should be provided.

14.4.5.16 The equipment design and configuration should not prevent licensed parties from certifying the design and installation of fire suppression systems.

NOTE 61: This is not meant to suggest installation by licensed parties; however, some jurisdictions require fire detection and suppression system installers to be licensed as specified by the jurisdiction.

14.4.5.17 *Installation of Piping for Fire Suppression Agent* — The fire suppression piping system should be:

- made from corrosion-resistant components,
- designed to minimize water accumulation around components and control other conditions that promote corrosion, and
- designed so mechanical inspections are easily performed.

14.4.5.18 Piping should be designed, installed, and tested to ensure that it is capable of containing the high pressures generated by the discharge of the suppression agent.

14.4.5.19 The supplier should provide information necessary for proper field installation of piping.

14.5 *Warnings and Safe Work Practices* — Warnings and safe work practices related to fire detection and suppression features of the equipment (e.g., restrictions on using open flames within range of active fire detection systems, hazardous stored energy in pressurized suppression systems) should be part of the documentation provided by the supplier.

14.6 *Maintenance and Testing of Fire Detection and Suppression Systems* — The equipment supplier should provide detailed maintenance and testing procedures for the fire systems provided with each piece of equipment. These procedures should include testing frequency, as well as details of special equipment required for testing.

14.6.1 Chemical generating test apparatus (e.g., canned smoke) should be avoided for cleanroom applications.

NOTE 62: Information about UV/IR generating sources used for testing fire detection systems may require consideration of Section 25 (Non-Ionizing Radiation).

14.6.2 The maintenance testing procedure should include testing of the facility interface and verifying that all the equipment fire detection and suppression systems are functional.

14.6.3 The detection and suppression systems should be designed so that preventative maintenance of components does not degrade their performance (e.g., by resulting in displacement or destruction of sensors).

14.6.4 Supplier should document the sound pressure level generated during suppression agent discharge, if the test is performed.

14.6.5 Materials or procedures used for testing and maintenance of the fire detection and suppression system should not degrade the equipment's ability to perform its intended function.

14.6.6 Suppliers should describe hazardous energies present in fire detection and suppression systems, and provide instructions for their proper isolation (see Section 17.2).

14.7 *Environmental* — Suppliers should provide guidance to users regarding the impact on emissions of any fire suppression agents used in the equipment.

15 Heated Chemical Baths

15.1 Refer to SEMI S3 for the minimum safety design considerations for heated chemical baths. Each heated chemical bath should have the following:

- grounded or GFCI-protected heater;
- power interrupt;
- manual reset;
- automatic temperature controller;
- liquid level sensor;
- fail-safe over-temperature protection;
- proper construction materials;
- exhaust failure interlock; and
- overcurrent protection.

NOTE 63: See Section 14 for fire protection risk assessment considerations for baths using combustible or flammable chemicals.

16 Ergonomics and Human Factors

16.1 *General* — Ergonomics and human factors design principles should be incorporated into the development of equipment to identify and eliminate or mitigate ergonomics- and human factors-related hazards.

16.2 *Provisions for Conformance* — Equipment should be assessed to the guidelines set forth in SEMI S8. The Supplier Ergonomic Success Criteria (SESC; see SEMI S8), or the equivalent, should be used to document the assessment.

17 Hazardous Energy Isolation

17.1 *General*

17.1.1 Lockable energy isolation capabilities should be provided for tasks that may result in contact with hazardous energy sources.

17.1.2 Where service tasks may be safely performed on subassemblies, energy isolation devices (e.g., circuit breakers, disconnect switches, manual valves) may be provided for the subassemblies for use as an alternative to shutting down the entire equipment system. The isolation devices should isolate all hazardous energy to the subassemblies and be capable of being locked in the position in which the hazardous energy is isolated.

17.1.3 The person actuating or inspecting an energy isolating device should not be exposed to serious risks of tripping or falling or of coming in contact with energized electrical parts, moving machinery, surfaces or objects operating at high temperatures, or other hazardous equipment.

NOTE 64: Hazardous energies include electrical, stored electrical (e.g., capacitors, batteries), chemical, thermal/cryogenic, stored pressure (e.g., pressurized containers), suspended weight, stored mechanical (e.g., springs), generated pressure (e.g., hydraulics and pneumatics), and other sources that may lead to the risk of injury.

NOTE 65: In order to minimize down-time and provide ease of use, it is preferred to have energy isolation devices located in the areas where maintenance or service is performed.

NOTE 66: Energy isolation devices for incompatible hazardous energy sources (e.g., electrical and water, incompatible gases) are recommended to be separated.

NOTE 67: Isolation of hazardous energy may include: deenergizing of hazardous voltage; stopping flow of hazardous production material (HPM); containing HPM reservoirs; depressurizing or containing HPM and pneumatic lines; deenergizing or totally containing hazardous radiation; discharging of residual energy in capacitors; stopping of hazardous moving parts; and shutting off hazardous temperature sources.

NOTE 68: Energy isolation devices with integral locking capabilities are preferred, but may not be feasible or commercially available, in which case detachable lockout adapters may be used.

NOTE 69: See Section 14 for information on fire protection hazardous energies.

17.2 *Installation and Maintenance Manuals*

17.2.1 Installation and maintenance manuals should identify the types of hazardous energies within the equipment.

17.2.2 Installation and maintenance manuals should provide specific instructions for the equipment on how to:

- shut down the equipment in an orderly manner;
- locate and operate all the equipment's energy isolating devices;
- affix energy isolating (“lockout/tagout”) devices;
- relieve any stored energies;
- verify that the equipment has actually been isolated and deenergized; and
- properly release the equipment from its isolated state.

17.2.3 Where the manufacturer provides written maintenance procedures for tasks within subassemblies, and intends that these tasks be performed without controlling hazardous energies at the entire equipment level, the installation and maintenance manuals should provide appropriate energy isolation procedures at the subassembly level.

17.3 *Electrical Energy Isolation*

17.3.1 The main energy isolation capabilities (equipment supply disconnect) should be in a location that is readily accessible and should be lockable only in the deenergized position.

NOTE 70: For equipment with multiple incoming supply sources, it is recommended that all of the energy isolation devices be located in one area.

17.4 *Non-Electrical Energy Isolation*

17.4.1 The equipment should include provisions and procedures so that hazardous energy sources, such as pressurized systems and stored energy, can be isolated or reduced to a zero energy state prior to maintenance or service work.

17.4.2 The hazardous energy isolation devices should be in a location that is readily accessible.

17.4.3 The hazardous energy isolation devices should be capable of being locked in the position in which the hazardous energy is isolated.

18 Mechanical Design

18.1 This section covers hazards due to the mechanical aspects of the equipment.

NOTE 71: This is similar to the essential requirements of European Union directives. The supplier has the option of demonstrating compliance by choosing standards that are appropriate to the machine and application.

NOTE 72: Pressurized vessels must meet applicable codes and regulations.

18.2 *Machine Stability* — Equipment, components, and fittings should be designed and constructed so that they are stable under reasonably foreseeable shipping, installation, and operating conditions. The need for special handling devices and anchors should be indicated in the instructions. Unanchored equipment in its installed condition should not overbalance when tilted in any direction to an angle of 10 degrees from its normal position.

NOTE 73: See IEC 61010-1 for an example of stability tests.

18.3 *Break-up During Operation* — The various parts of the equipment and its linkages should be able to withstand the stresses to which they are subjected when used as designed. Precautions should be taken to control risks from falling or flying objects.

18.3.1 The potential effects of fatigue, aging, corrosion, and abrasion for the intended operating environment should be considered as part of the mechanical hazards risk assessment.

18.3.2 Where a risk of rupture or disintegration remains despite the measures taken (e.g., a substrate chuck that loses its vacuum), the moving parts should be mounted and positioned in such a way that, in case of rupture, their fragments will be contained.

18.3.3 Both rigid and flexible pipes carrying liquids or gases should be able to withstand the foreseen internal and external stresses and should be firmly attached or protected against external stresses and strains. Based on the application, an appropriate factor of safety should be included.

18.4 *Moving Parts* — The moving parts of equipment should be designed, built, and positioned to avoid hazards. Where hazards persist, equipment should be fitted with guards or protective devices that reduce the likelihood of contact that could lead to injury.

18.4.1 Where the machine is designed to perform operations under different conditions of use (e.g., different speeds or energy supplies), it should be designed and constructed in such a way that selection and adjustment of these conditions can be performed safely.

18.4.2 *Selection of Protection Against Hazards Related to Moving Parts* — Guards or protective devices used to protect against hazards related to moving parts should be selected on the basis of a risk assessment that includes the:

- hazards that are being guarded against;
- probability of occurrence and severity of injury of each hazard scenario; and
- frequency of removal of guards.

18.4.3 Guards and protection devices. Guards should:

- reduce the risk that personnel will contact the mechanical hazard to an acceptable level; and
- not give rise to additional risk.

18.5 *Lifting Operations* — Equipment presenting hazards due to lifting operations (e.g., falling loads, collisions, tipping) should be designed and constructed to reduce the risk to an acceptable level.

18.6 *Extreme Temperatures* — Surfaces that are accessible to personnel, and that are at high (per temperature limits in Table 1) or very cold temperatures (below -10°C [14°F]), should be fitted with guards or designed out.

18.6.1 Where it is not feasible to protect or design out the exposures to extreme temperature, temperatures exceeding the limits are permitted, provided that either of the following conditions is met:

- unintentional contact with such a surface is unlikely; or
- the part has a warning indicating that the surface is at a hazardous temperature.

19 Seismic Protection

NOTE 74: Users have facilities located in areas that are susceptible to seismic activity. The end user may require more stringent design criteria because of increased site vulnerability (e.g., local soil conditions and building design may produce significantly higher accelerations) and local regulatory requirements. Certified drawings and calculations may be required in some jurisdictions.

19.1 *General* — The equipment should be designed to control the risk of injury to personnel, adverse environmental impact, equipment and facility damage due to movement, overturning, or leakage of chemicals (including liquid splashing), during a seismic event. The design should also control equipment damage due to failure of fragile parts (e.g., quartzware, ceramics) during a seismic event.

NOTE 75: These criteria are intended to accomplish two things:

(1) allow equipment suppliers to correctly design the internal frame and components to withstand seismic forces; and

(2) allow equipment designers to provide end-users with the information needed to appropriately secure the equipment within their facility.

19.1.1 Because preventing all damage to equipment may be impractical, the design should control the failure of parts that may result in increased hazard (e.g., hazardous materials release, fire, projectile).

NOTE 76: It is recommended that the hazard analysis described in Section 6.8 be used to evaluate both the risk of part failure and the effectiveness of control measures.

19.1.1.1 These parts should be accessible for evaluation of damage.

NOTE 77: SEMI S8 contains guidelines for maintainability and serviceability; these may be used to determine accessibility.

19.2 *Design Loads* — The equipment, subassemblies, and all devices used for anchoring the equipment should be designed as follows:

19.2.1 For equipment containing hazardous production materials (HPMs), the equipment should be designed to withstand a horizontal loading of 94% of the weight of the equipment, acting at the equipment's center of mass.

19.2.2 For equipment not containing hazardous production materials (HPMs), the equipment should be designed to withstand a horizontal loading of 63% of the weight of the equipment, acting at the equipment's center of mass.

NOTE 78: Subassemblies may include transformers, vessels, power supplies, vacuum pumps, monitors, fire suppression components, or other items of substantial mass that are attached to the equipment.

Table 1 Potentially Hazardous Surface Temperatures

Accessible Parts	*Maximum Surface Temperature, in °C*		
	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
Handles, knobs, grips, etc., held or touched for short periods (5 seconds or less) in normal use.	60	70	85
Handles, knobs, grips, etc. held continuously in normal use.	51	56	60
External surfaces of equipment, or parts inside the equipment, that may be touched.	65	80	95

19.2.3 Horizontal loads should be calculated independently on each of the X and Y axes, or on the axis that produces the largest loads on the anchorage points.

19.2.4 When calculating for overturning, a maximum value of 85% of the weight of the equipment should be used to resist the overturning moment.

NOTE 79: Because equipment may be placed into service anywhere in the world, it is recommended that the seismic protection design of the equipment be based upon requirements that allow the equipment, as designed, to be installed in most sites worldwide. The above loads are based on 1997 Uniform Building Code (UBC) requirements for rigid equipment in Seismic Zone 4, and are assumed to satisfy most design situations worldwide.

NOTE 80: If the equipment or internal component is flexible as defined by the UBC, is located above the midheight of the building, or is within 5 km of a major active fault, the horizontal design loadings in Sections 19.2.1 and 19.2.2 may not be conservative. Likewise, there are several conditions for which the horizontal design loadings are overly conservative (e.g., rigid equipment with rigid internal components located at grade, or sites with favorable soils conditions). For these conditions, designing based on the more detailed approach in the UBC may result in a more economical design. It is recommended that the user engage a professional mechanical, civil, or structural engineer to make these determinations.

19.3 The supplier should provide the following data and procedures to the user. This information should be included in the installation instructions as part of the documentation covered in Section 9.

- A drawing of the equipment, its support equipment, its connections (e.g., ventilation, water, vacuum, gases) and the anchorage locations identified in Section 19.4.
- The type of feet used and their location on a base frame plan drawing.
- The weight distribution on each foot.
- Physical dimensions, including width, length, and height of each structurally independent module.
- Weight and location of the center of mass for each structurally independent module.
- Acceptable locations on the equipment frame for anchorage.

NOTE 81: A "structurally independent module" reacts to seismic loads by transferring substantially all of the loads to its own anchorages, as opposed to transferring the loads to adjacent modules.

19.4 The locations of the tie-ins, attachments, or seismic anchorage points should be clearly identified.

NOTE 82: It is not the intent of SEMI S2 that the supplier provide the seismic attachment point hardware. Such hardware may be provided as agreed upon between supplier and user.

NOTE 83: It is the responsibility of the user to verify that the vibration isolation, leveling, seismic reinforcing, and load distribution is adequate.

20 Automated Material Handlers

20.1 This section covers automated material handlers, which include:

- substrate handlers;
- industrial robots and industrial robot systems; and
- unmanned transport vehicles (UTVs).

NOTE 84: Substrate handlers typically handle a single substrate at a time, and are distinguished from industrial robots by their small load capacity.

20.2 *General* — The means of incorporating personnel safeguarding into automated material handlers should be based on a hazard analysis. The hazard analysis should include consideration of the size, capacity, speed, and spatial operating range of the handler.

20.2.1 *Subsystem Stops* — If a separate stop button is used for the automated material handler, it should be differentiated from the EMO button.

20.3 *Substrate Handlers* — See Section 20.2, *General.*

20.4 *Industrial Robots and Industrial Robot Systems* — Industrial robots and industrial robot systems should meet the requirements of appropriate national or international standards, e.g., ANSI/RIA R15.06, ISO 10218, EN 775. If there are deviations from these standards because of semiconductor applications of the robot, these deviations may be found acceptable based on risk assessments.

20.5 *UTVs*

NOTE 85: There are two basic types of UTVs: (1) the floor-traveling (including both rail-guided and rail-independent) UTV, that automatically travels on the floor to a specified destination where it is unloaded or loaded; and (2) the space-traveling UTV, which automatically travels without resting on the floor (e.g., in the space below the ceiling) to a specified destination where it is loaded or unloaded. UTVs do not include rail-guided mechanisms that are attached to equipment (such as in wet benches).

20.5.1 *Collision Avoidance* — UTVs generally travel in wide areas and are used in a system rather than stand alone operation. UTVs should be equipped with a non-contact approach sensing device so that they do not inadvertently contact people or other objects.

20.5.2 *UTVs: Loading and Unloading Equipment*

20.5.2.1 UTVs should be interlocked with equipment such as semiconductor process equipment, automated load ports, stockers, ground-based conveyors, and automated warehouses as needed to ensure that the load remains secure and that the UTV and transfer components are not in conflict with one another.

20.5.2.2 If loading results in an unsafe condition, the equipment should detect and indicate the condition, and movement of all loading equipment should stop immediately. The system should not reset or restart automatically.

21 Environmental Considerations

21.1 This section covers environmental impacts throughout the life of the equipment.

NOTE 86: It is recommended that environmental impacts be balanced against other factors, including safety and health, legal, and regulatory requirements.

NOTE 87: It is recommended that the manufacturer maintain awareness of relevant environmental regulations, either internally or through the user.

NOTE 88: The user is responsible for providing the manufacturer with information regarding any environmental restrictions that are specific to a given site and that may impact equipment design (e.g., cumulative emissions limits, permit requirements, site-specific programs).

NOTE 89: See Section 14 for fire suppression emission issues.

NOTE 90: References to “process” in this section are meant to refer to the baseline process.

21.2 *Design*

21.2.1 The following design guidelines apply to all phases of equipment life, from concept to decommissioning and disposal.

NOTE 91: The documentation described in Sections 8.5.3 and 9.4 provide information that can be used for evaluating conformance to this section.

21.2.2 *Resource Conservation*

21.2.2.1 The manufacturer should consider resource conservation (i.e., reduction, reuse, recycling) during equipment design, for example:

- water reuse or water recycling within the equipment;
- reduced chemical consumption, energy use, and water use (e.g., reducing resource use when no process is occurring);
- reduced use of resources during maintenance procedures (e.g., parts cleaning procedures could include minimum rinse rates and rinse times);
- recycling or reusing chemicals in the equipment, rather than consuming only new materials;
- reducing volume of packaging, increasing recycled content of packaging, and/or designing reusable packaging.

21.2.3 *Chemical Selection*

21.2.3.1 Chemical selection for process, maintenance, and utility uses (e.g., gases, etchants, strippers, cleaners, lubricants, and coolants) should take into account effectiveness, environmental impacts, volume, toxicity, by-products, decommissioning, disposal, and recyclability; use of the least hazardous chemical is preferred. To the extent practicable, the utilities, maintenance, and process should be designed so that the equipment operates without the use of:

- ozone depleting substances (ODSs) as identified by the Montreal Protocol, such as chlorofluorocarbons (CFCs), methylchloroform, hydrochlorofluorocarbons (HCFCs), and carbon tetrachloride, or
- perfluorocompounds (PFCs), including CF_4, C_2F_6, NF_3, C_3F_8, and SF_6, and CHF_3 due to their global warming potential.

21.2.4 *Prevention and Control of Unintended Releases*

21.2.4.1 Equipment design, including feed, storage, and waste collection systems, should prevent potential unintended releases. At a minimum:

21.2.4.2 Secondary containment for liquids should be capable of holding at least 110% (see first row of Table A3-1 of Appendix 3) of the volume of the single largest container, or the largest expected volume for any single point failure.

NOTE 92: In some circumstances secondary containment may be specified by the equipment supplier, but provided by the user.

21.2.4.3 Chemical storage containers and secondary containment should be designed for accessibility and easy removal of collected material.

21.2.4.4 Secondary containment should have alarms and gas detection or liquid sensing, as appropriate, or have recommended sensing points identified in the equipment installation instructions.

21.2.4.5 Equipment design should allow personnel to determine all in-equipment container levels conveniently without having to open the containers, where ignorance of the level could result in an inadvertent release.

21.2.4.6 Overfill level detectors and alarms should be provided for in-equipment containers.

21.2.4.7 Secondary containment and other control systems should be designed to ensure that chemicals cannot be combined, where the combination could result in an inadvertent release.

21.2.4.8 Equipment components should be compatible with chemicals used in the manufacturing process. Chemical systems should be designed for the specified operating conditions, and have sufficient mechanical strength and corrosion resistance for the intended use.

21.2.4.9 Equipment should be able to accept a signal from a monitoring device and stop the supply of chemical, at the first non-manual valve within the affected system.

21.2.4.10 Chemical distribution systems should be capable of automatic shutoff and remote shutdown.

21.2.5 *Effluents, Wastes, and Emissions*

NOTE 93: It is recommended that the manufacturer document its efforts to minimize the equipment's generation of hazardous wastes, solid wastes, wastewater, and air emissions.

NOTE 94: It is recommended that SEMI F5 be used for guidance in gaseous effluent handling.

21.2.5.1 Equipment design that allows connection to a central waste collection system is preferred, except where collection at the equipment may facilitate recycling or reuse opportunities or otherwise reduce environmental impacts.

NOTE 95: It is recommended that individual drains and exhausts be kept separate (e.g., separate outlets for acid drain, solvent drain, deionized (DI) water drain; acid exhaust, solvent exhaust).

21.2.5.1.1 Point-of-use collection containers should be designed for accessibility as well as the possible reuse and recycling of the collected materials.

21.2.5.2 Equipment should use partitions, double-contained lines, or other similar design features to prevent the mixing of incompatible waste streams.

21.2.5.3 The manufacturer should evaluate the feasibility of including integrated controls for effluent and emission treatment.

21.2.5.4 Dilution in excess of process or safety requirements should not be used to reduce contaminant discharge concentrations.

21.2.5.5 Segregation of effluents, wastes, and emissions should be provided in the following cases:

- where chemically incompatible;
- where segregation facilitates recycling or reuse; or
- where separate abatement or treatment methods are required.

NOTE 96: It is recommended that the equipment design documentation show evidence of consideration of by-products generated during equipment operation, clean-up, maintenance, and repair. By-products can include deposits in drains or ducts, and replaceable parts (e.g., batteries, vapor lamps, contaminated parts).

21.2.6 *Decommissioning and Disposal*

21.2.6.1 Equipment design should address (see Section 8.5.3 for documentation provisions) construction material and component reuse, refurbishment, and recycling.

21.2.6.2 The equipment should be designed to facilitate equipment decontamination and disposal, e.g., by use of removable liners or replaceable modules. This includes minimizing the number of parts that become contaminated with hazardous materials.

NOTE 97: It is recommended that SEMI S12 "Guidelines for Equipment Decontamination" be used for guidance during equipment decontamination.

22 Exhaust Ventilation

22.1 Equipment exhaust ventilation should be designed to prevent potentially hazardous chemical exposures to employees as follows:

22.1.1 As primary control when normal operations present potentially hazardous chemical exposures to employees by diffusive emissions that cannot be otherwise prevented or controlled (e.g., wet decks, spin coaters).

NOTE 98: In the context of this section, "primary control" means that it is the control of first choice (e.g., rather than personal protective equipment).

22.1.2 As supplemental control when intermittent activities (e.g., chamber cleaning, implant source housing cleaning) present potentially hazardous chemical exposures to employees which cannot reasonably be controlled by other means. Supplemental exhaust hoods or enclosures may be integrated into the equipment design, or supplied completely by the equipment user.

22.1.2.1 When a procedure (e.g., cleaning) specified by the supplier requires exhaust ventilation, the supplier should include the minimum criteria for exhaust during the procedure.

22.1.3 As secondary control when a single-point failure presents the potential for employee exposures to hazardous materials, and this exposure cannot be controlled by other means (e.g., use of all welded fittings).

EXCEPTION: Secondary exhaust control enclosures for non-welded connections (e.g., valve manifold boxes that enclose piping jungles) are not included in this guideline for those hazardous gases that are transported below atmospheric pressure (e.g., via vacuum piping systems) if it can be demonstrated that equivalent leak protection is provided. Equivalent protection may include such things as equipping the vacuum delivery system with a fail-safe (e.g., to close) valve automatically activated by a loss of vacuum pressure. Loss of vacuum pressure should also activate a visual and audible alarm provided in visual or audible range of the operator.

22.2 Equipment exhaust ventilation should be designed and a ventilation assessment conducted (see Section 23.5, Appendix 2, and SEMI S6) to control, efficiently and safely, for potential worst-case, realistic employee exposures to chemicals during normal operation, maintenance, or failure of other equipment components (hardware or software). All design criteria and test protocols should be based on recognized methods. See also Section 23.3.

22.3 Documentation should be developed showing the equipment exhaust parameters and relevant test methods, and should include (see also Appendix 2):

- duct velocity (where needed to transport solid particles);
- volumetric flow rate Q;
- capture velocity (where airborne contaminants are generated outside an enclosure);
- face velocity (where applicable);
- hood entry loss factor F_h or K;
- coefficient of entry $C_{e.}$;
- hood static pressure SP_h;
- duct diameter at the point of connection to facilities; and
- location(s) on the duct or hood where all ventilation measurements were taken.

22.4 Exhaust flow interlocks should be provided by the manufacturer on all equipment that uses hazardous production materials (HPMs) where loss of exhaust may create a hazard. Flow (e.g., pitot probe) or static pressure (e.g., manometer) switches are the preferred sensing methods.

NOTE 99: Sail switches (switches that are connected to a lever that relies upon air velocity to activate) are generally not recommended.

NOTE 100: It is recommended that the pressure or flow measuring point be located upstream of the first damper.

NOTE 101: Section 11 contains provisions for safety interlocks.

22.4.1 When the exhaust falls below the prescribed set point, an alarm should be provided within audible or visible range of the operator, and the process equipment should be placed in a safe stand-by mode. A time delay and exhaust setpoint for the equipment to go into standby mode may be allowable, based on an appropriate risk assessment. The system should be capable of interfacing with the facility alarm system.

NOTE 102: It is recommended that non-HPM chemical process exhaust be equipped with audible and visible indicators only.

22.4.2 Exhaust flow interlocks and alarms should require manual resetting.

22.4.3 Exhaust flow interlocks should be fault-tolerant.

22.5 Equipment and equipment components should be designed using good ventilation principles and practices to ensure chemical capture and to optimize exhaust efficiency (see Appendix 2).

NOTE 103: It is recommended that exhaust optimization be achieved with total equipment static pressure requirements of –1 to –38 mm (–0.05 to –1.5") H_2O (see also Section A2-1 of Appendix 2, and Section 8.3.6.1 of SEMI S6-93).

23 Chemicals

23.1 The manufacturer should generate a chemical inventory identifying the chemicals anticipated to be used or generated in the equipment. At a minimum, this should include chemicals in the recipe used for equipment qualification or “baseline” recipe, as well as intended reaction products and anticipated by-products. Chemicals on this list that can be classified as hazardous production materials (HPMs), or odorous (odor threshold < 1 ppm) or irritant chemicals (according to their material safety data sheets), should also be identified.

23.2 A hazard analysis (see Section 6.8) should be used as an initial determination of chemical risk as well as to validate that the risk has been controlled to an appropriate level.

23.2.1 The hazard analysis, at a minimum, should address the following conditions:

- potential mixing of incompatible chemicals;
- potential chemical emissions during routine operation;

- potential chemical emissions during maintenance activities; and
- potential key failure points and trouble spots (e.g., fittings, pumps).

23.2.2 All routes of exposure (e.g., respiratory, dermal) should be considered in exposure assessment.

23.3 The order of preference for controls in reducing chemical-related risks is as follows:

23.3.1 substitution or elimination (see also Section 21.2.2);

23.3.2 engineering controls (e.g., enclosure, ventilation, interlocks);

23.3.3 administrative controls (e.g., written warnings, standard operating procedures);

23.3.4 personal protective equipment.

23.4 The design of engineering controls (e.g., enclosure, ventilation, interlocks) should include consideration of (see also Appendix 3):

- pressure requirements;
- materials incompatibility;
- equipment maintainability;
- chemical containment; and
- provisions for exhaust ventilation (see Section 22).

23.5 During equipment development, the supplier should conduct an assessment that documents conformance to the following airborne chemical control criteria (see also Appendix 2). All measurements should be taken using recognized methods with documented sensitivities and accuracy. A report documenting the survey methods, equipment operating parameters, instrumentation used, calibration data, results, and discussion should be available.

23.5.1 There should be no chemical emissions to the workplace environment during normal equipment operation. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 1% of the Occupational Exposure Limit (OEL) in the worst-case personnel breathing zone. Where a recognized method does not provide sufficient sensitivity to measure 1% OEL, then the lower detection limit of the method may be used to satisfy this criterion.

23.5.2 Chemical emissions during maintenance activities should be minimized. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 25% of the OEL, in the anticipated worst-case personnel breathing zone, during maintenance activities.

23.5.3 Chemical emissions during equipment failures should be minimized. Conformance to this section can be shown by demonstrating ambient air concentrations to be less than 25% of the OEL, in the anticipated worst-case personnel breathing zone, during a realistic worst-case system failure.

NOTE 104: The use of direct reading instrumentation under simulated operating, maintenance, or failure conditions is the preferred measurement method. Where used, it is recommended that the sample location(s) be representative of the worst-case, realistic exposure locations(s). It is recommended that the peak concentration be directly compared to the OEL to demonstrate conformance to Sections 23.5.1–23.5.3.

NOTE 105: It is recommended that integrated sampling methods be used when direct-reading instrumentation does not have adequate sensitivity, or when direct-reading technology is not available for the chemicals of interest. Where integrated sampling is used, it is recommended that the sample duration and locations(s) be representative of the worst-case, realistic, anticipated exposure time and locations. The resulting average concentration is directly compared to the OEL to demonstrate conformance to Sections 23.5.1–23.5.3.

NOTE 106: Tracer gas testing (see SEMI F15 for an acceptable method) may be used when direct-reading instrumentation does not have adequate sensitivity, or when direct-reading technology is not available for the chemicals of interest. Tracer gas testing should be used where testing conditions may be hazardous (e.g., system failure simulation with potential release of hazardous gas to atmosphere). It is recommended that tracer gas testing be used only when an accurate rate of chemical emission can be determined. Where used, it is recommended that the sample location(s) be representative of the worst-case, realistic exposure location(s).

23.5.4 Chemical emissions outside the enclosure during a realistic worst-case system failure should be less than the lower of the following two values: 25% of the lower explosive limit (LEL), or 25% of the OEL.

23.6 Equipment that uses hazardous gases may require continuous detection and, if so, should have sample points mounted in the equipment, or have recommended sampling points identified in the equipment installation instructions. Where the gas supply is part of or controlled by the equipment, the equipment should be able to accept a signal from an external monitoring device and shut down the supply of the gas.

23.7 Appropriate hazard warning labels should be placed at all chemical enclosure access openings.

24 Ionizing Radiation

24.1 This section covers equipment that produces ionizing radiation (e.g., X-rays, gamma rays) or uses radioactive sources.

24.2 Accessible emissions of ionizing radiation should be designed as low as reasonably achievable. This criteria can be met by demonstrating conformance to the provisions in Sections 24.2.1 and 24.2.2 and Appendix 4.

24.2.1 Accessible levels of ionizing radiation during normal operations should be less than 2 microsieverts (0.2 millirem) per hour above background. See also Table A4-1 of Appendix 4.

24.2.2 Accessible levels of ionizing radiation during maintenance and service procedures should be less than 10 microsieverts (1 millirem) per hour above background. See also Table A4-1 of Appendix 4.

24.2.3 Access to radioactive contamination or internal exposure (e.g., inhalation, ingestion) to radioactive materials should be minimized. The hazards and controls for the prevention of personnel contamination and internal exposures should be detailed in the operation and maintenance manuals.

NOTE 107: The use of radioactive material is strictly regulated around the world. Import, export, and transportation of radioactive materials is also highly regulated. Licenses may be required to possess, use, and distribute radioactive materials.

NOTE 108: Many regions require both user and import licenses, and the timely acquisition of these licenses depends on the information provided by the equipment supplier.

NOTE 109: Radiation producing machines are also regulated around the world. Regulations and licensing requirements may cover activities such as importing, exporting, installing, servicing and using radiation producing equipment.

24.2.4 The manufacturer should supply, in the user documentation, a contact phone number and address for the manufacturer's radiation safety support personnel.

24.3 Equipment should be designed to minimize access or exposure to ionizing radiation during normal operation, maintenance, and service. Potential exposures should be controlled in the following order of preference:

24.3.1 *Engineering Controls* — Engineering controls (e.g. shielding, interlocks) should be the primary mechanism to minimize emission of ionizing radiation or access to ionizing radiation.

24.3.1.1 Radiation shielding for the equipment facilities connections (e.g., gas and exhaust lines) should be designed such that removal and replacement of the shielding during installation is minimized.

24.3.2 Non-defeatable safety interlocks should be provided on barriers preventing maintenance access to radiation fields in excess of 10 microsieverts (μSv) or 1 millirem per hour.

24.3.3 *Administrative Controls* — When administrative controls (e.g., distance, time, standard operating procedures, labeling) are to be used, the equipment supplier should provide detailed documentation explaining the use of the administrative controls.

24.4 Equipment utilizing or producing ionizing radiation should be labeled appropriately.

NOTE 110: Label contents are typically controlled by regulation in the country in which the equipment is to be used.

24.5 The manufacturer should conduct an assessment to document conformance to the criteria specified in Sections 24.2.1 through 24.2.2 during normal equipment operation, maintenance, and service.

24.5.1 A radiation survey should be used to confirm design compliance and serve as a baseline survey (see also Table A4-1 of Appendix 4).

24.5.2 Measurements should be taken using recognized methods with documented sensitivities and accuracy. A report documenting the survey methods, equipment operating parameters, instrumentation used, calibration data, source locations, results, and discussion should be made available.

24.5.3 If supplemental administrative controls are recommended based on survey results or calculations, a discussion should be provided in the operations and maintenance manuals describing the source locations, radiation levels, and recommended control measures.

NOTE 111: Ionizing radiation sources must be registered or licensed according to the regulations of the country of destination. These radiation sources must conform to the regulations of central or local government agencies, whichever is stricter.

NOTE 112: It is recommended that equipment containing radioactive materials should demonstrate conformance to licensing with local regulatory agencies prior to shipment.

NOTE 113: Equipment that uses particle acceleration in its process has the potential for generating ionizing radiation as a result of nuclear interactions between the accelerated particles and various materials. These materials can include materials of construction of the equipment, accumulated residual process materials in the equipment, and the target materials.

25 Non-Ionizing Radiation and Fields

25.1 This section covers equipment that produces non-ionizing radiation, except laser sources, in the following categories:

- static electric and magnetic (0 Hz),
- sub-radio frequency electric and magnetic fields (< 3 kHz),
- radio frequency (3 kHz–300 GHz),
- infrared radiation (700 nm–1 mm),
- visible Light (400 nm–700 nm), and
- ultraviolet Light (180–400 nm).

25.2 Potentially hazardous non-ionizing radiation emissions that are accessible to any personnel should be limited to the lowest practical level. This criterion can be met by demonstrating conformance to the following provisions:

EXCEPTION: Emissions of non-ionizing radiation exceeding the cardiac pacemaker limits in Appendix 5 but less than the levels in Sections 25.2.1 and 25.2.2 should be identified with appropriate labeling. See also Section 25.5.1.

25.2.1 Accessible levels of non-ionizing radiation during normal operations are less than the Operator-Accessible Limit (see Appendix 5);

25.2.2 Accessible levels of non-ionizing radiation during maintenance and service procedures are less than the Maintenance- and Service-Accessible Limit (see Appendix 5).

25.3 Sources of potentially hazardous non-ionizing radiation should be identified in the operation and maintenance manuals, and appropriate parameters listed. Parameters include frequency, wavelength, power levels, continuous wave or pulsed (see also Appendix 5). If pulsed, parameters also include the pulse repetition rate, pulse duration, and description of the pulse waveform.

EXCEPTION: Visible sources which are intended to be viewed or which provide illumination (e.g., display panels, visible alarm indicators), and are not lasers, do not need to be identified.

NOTE 114: It is recommended that UV/IR generators that are part of fire protection test apparatus, and are provided with the equipment, be considered as possible sources of potentially hazardous non-ionizing radiation.

25.4 Equipment should be designed to minimize access or exposure to non-ionizing radiation during normal operation, maintenance, and service. Potential exposures should be controlled in the following order of preference:

25.4.1 engineering controls (e.g., enclosure, shielding, guarding, grounding, interlocks);

25.4.2 administrative controls (e.g., written warnings, standard operating procedures, labeling); and

25.4.3 personal protective equipment.

25.5 Equipment utilizing or producing potentially hazardous non-ionizing radiation should be labeled.

25.5.1 Hazard warning labels should be provided by the manufacturer when emission levels are measured that may impact cardiac pacemakers or magnetizable prostheses. These warning labels should be located where the emissions exceed the pacemaker limit. (See Appendix 5 for pacemaker labeling levels and references.)

25.6 The manufacturer should conduct an assessment to document conformance to the criteria specified in Sections 25.2.1 and 25.2.2. Engineering calculations may be used as part of this assessment. All measurements should be taken using recognized methods with documented sensitivities and accuracy. A report documenting the survey methods, equipment operating parameters, instrumentation used, calibration data, source location(s), and discussion should be provided. See Appendix 5.

25.6.1 If supplemental administrative controls are recommended based on survey results or calculations, a discussion should be provided in the operations and maintenance manuals describing the source location(s), radiation levels, and recommended control measures.

25.6.2 Administrative control procedures recommended for operation, maintenance, or service activities should be documented in the operations and maintenance manuals.

26 Lasers

26.1 Equipment should be identified with a laser product classification based on the laser energy accessible during operation, per the applicable standard.

NOTE 115: A Class 1 label may be required in some jurisdictions, but is not currently required in the United States.

26.1.1 The laser energy (or power), wavelength, and temporal mode (continuous wave or pulsed) should be identified in the documentation provided to the user.

NOTE 116: The laser product classification for some equipment will be Class 1 or 2, even though an embedded laser is of a higher hazard classification.

26.1.1.1 If pulsed, the pulse repetition rate, pulse duration and description of the pulse waveform should be identified in the documentation provided to the user.

26.1.1.2 For Class 3b or 4 embedded laser systems, the above information and the physical location of the laser sources within the laser product should be identified in the documentation provided to the user and in the maintenance manual.

26.1.2 Equipment should not exceed the laser product classification of Class 2; however, individual lasers may exceed this classification prior to integration into the final equipment assembly.

26.2 Equipment, including beam diagnostic or alignment tools, should be designed to prevent injury from all lasers during normal operation, and should minimize risk of injury during maintenance or service. Potential exposures should be controlled in the following order of preference:

26.2.1 Engineering controls (e.g., enclosures, shielding, filters, use of fiber optics to transmit energy, interlocks).

26.2.2 Temporary enclosures or control measures for maintenance, service, and non-routine tasks.

26.2.3 Administrative controls (e.g., written warnings, standard operating procedures, labeling).

26.2.4 Personal protective equipment.

NOTE 117: Temporary enclosures and personal protective equipment are considered to be administrative controls, because they require human action to implement.

NOTE 118: Certain classes of laser products are regulated around the world. Regulations and licensing requirements may cover activities such as importing, exporting, distributing, demonstrating, installing, servicing, and using these laser products.

26.3 The equipment supplier should provide the following in the operation and maintenance manuals:

- a description of laser-related hazards present during operation, maintenance, or service, and methods to minimize the hazard;
- justification for any procedures that require a laser controlled area and the dimensions of this hazard zone;
- administrative controls used in maintenance and service activities; and
- a description of necessary personal protective equipment.

26.4 The following detailed information should be available for the evaluator:

- justification for when engineering controls are not feasible to limit exposure during operation or maintenance tasks, and how administrative controls provide equivalent protection (see Section 26.2); and
- documentation showing compliance with an appropriate international laser product safety or industry standard, or the national standard for country of use.

27 Sound Pressure Level

27.1 Equipment should be designed to control exposures to sound pressure levels equal to or greater than 80 dBA continuous or intermittent sound pressure level, and 120 dB instantaneous (impulse) sound pressure level.

NOTE 119: It is recommended that efforts be made to decrease sound pressure levels as they approach 80 dBA (i.e., 77 to 80 dBA), due to the additive sound pressure level effects of multiple pieces of equipment in the same vicinity.

27.2 The order of preference for controlling exposures is as follows:

27.2.1 *Engineering Controls* (e.g., source sound pressure level reduction, absorption, enclosures, barriers, acoustic dampening) — At a minimum, the design of the engineering controls should consider the sound pressure levels and type, the frequency, and the appropriate control technologies.

27.2.2 *Administrative Controls* — Acceptable administrative controls should be limited to supplemental hazard warning labels and operating procedures.

NOTE 120: Noise labeling is typically implemented as signs located in the users facility.

27.3 Sound level surveys should be conducted by the manufacturer during equipment development for equipment that may emit hazardous sound pressure levels.

27.3.1 The survey should be conducted in accordance with a recognized standard. In addition, the following test criteria should be applied:

27.3.1.1 The equipment mode of operation during the sound pressure level tests should simulate as closely as possible the actual modes and operating positions that may be experienced by the equipment user.

27.3.1.2 Measurements should be taken in locations that best simulate actual positions of operators relative to the equipment. As a general guideline, the microphone should be traversed 1 meter from the equipment, 1.2 meters above the ground to simulate seated operators, 1.5 meters above the ground to simulate standing operators, and 3.5 meters (or as far as possible) away from the nearest walls or sound-reflecting objects. Measurements are taken 360 degrees around the equipment wherever possible.

Table 2 Sound Pressure Level Test Criteria

NOTE 121: Background level may be subtracted using an accepted method. If the sound pressure level difference is less than 3 dBA, the contribution of the source from the background cannot be adequately distinguished and the survey results would not be valid for values over 80 dBA.

Difference between sound pressure level measured with noise source operating and background sound pressure level (dBA)	*Correction to be subtracted from the sound pressure level measured with the noise source operating to obtain the sound pressure level due to noise source alone (dBA)*
3	3
4	2.5
5	1.7
6	1.3
7	1
8	0.8
9	0.6
10	0.4

27.3.2 If the measured sound pressure level is less than 70 dBA, the manufacturer should provide to the evaluator test data documenting sound pressure levels, survey equipment, equipment calibration, test conditions and results.

27.3.3 If the measured sound pressure level is greater than 70 dBA, the test data should include all of the information in Section 27.3.2, and should also include the expected duration of personnel exposure.

27.3.4 If measured sound pressure level is greater than 75 dBA, information should be provided in the equipment maintenance manual describing the sound pressure level(s) and location(s).

28 Related Documents

28.1 The following documents are sources of principles and practices of ventilation design.

ACGIH, Hazard Assessment and Control Technology in Semiconductor Manufacturing, 1989, distributed by Lewis Publishers, Chelsea, Michigan.

ANSI/AIHA, Standard Z9.5-1992 Laboratory Ventilation

Burgess, Ellenbecker, Treitman, Ventilation for Control of the Work Environment, John Wiley, NY, 1989

Burton, D.J., IVE, Inc., Industrial Ventilation Workbook, 3rd Edition, 1995, Lab Ventilation Workbook, 1994; 2974 South Oakwood, Bountiful, Utah 84010

NFPA 45, Fire Protection for Laboratories Using Chemicals, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA, USA

Williams, M. and D.G. Baldwin, Semiconductor Industrial Hygiene Handbook, Noyes Publications, Park Ridge, NJ, 1995, ISBN 0-8155-1369-0

APPENDIX 1
ENCLOSURE OPENINGS

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A1-1 This appendix provides guidance on sizes of openings in enclosures.

Table A1-1 Examples of Openings for Protection Against Access from Operators

Distance Between Opening and Danger Point		*Maximum Opening*	
mm	*inches*	*mm*	*inches*
13–38	0.5–1.5	6	0.250
38–64	1.5–2.5	10	0.375
64–89	2.5–3.5	11.9	0.470
89–140	3.5–5.5	16	0.625
140–165	5.5–6.5	19	0.750
165–191	6.5–7.5	22	0.875

A1-1.1 Alternatively, an IEC accessibility probe, as specified in SEMI S9, may be used to determine suitability of mesh openings.

A1-2 *Top Openings in Electrical Enclosures* — The top openings in electrical enclosures should meet one of the following:

- not exceed 5 mm in any dimension, or
- not exceed 1 mm in width regardless of length, or
- be so constructed that direct, vertical entry of a falling object is prevented from reaching uninsulated live parts within the enclosure by means of trap or restriction (see Figure A1-1 below for examples of top cover designs that prevent such direct entry), or
- meet the intent through other equivalent means.

Figure A1-1

SLANTED OPENINGS **VERTICAL OPENINGS**

APPENDIX 2
DESIGN PRINCIPLES AND TEST METHODS FOR EVALUATING EQUIPMENT EXHAUST VENTILATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A2-1 Introduction

A2-1.1 This appendix provides specific technical information relating to Section 22. In general, it provides guidelines for:

- ventilation design for semiconductor manufacturing equipment, and
- test validation criteria.

A2-1.2 This appendix is intended to be used as a starting point for reference during equipment design.

A2-1.3 This appendix is not intended to limit hazard or test evaluation methods or control strategies (e.g. design principles) employed by manufacturers or users. Many different methods may be employed if they provide a sufficient level of protection.

A2-1.4 This appendix is not intended to provide exhaustive methods for determining final ventilation specifications. Other methods may be used where they provide at least equivalent sensitivity and accuracy.

A2-1.5 The exhaust velocities, volume flow rates and pressures listed are derived from a mixture of successful empirical testing and regulatory requirements.

A2-1.6 Test validation criteria are generally referenced from the applicable internationally recognized standard. It is the user's responsibility to ensure that the most current revision of the standard is used.

Table A2-1 Ventilation

Hood Type	*Recommended Test Methods*	*Typical Design and Test Exhaust Parameters (See NOTE 1.)*	*References*
Wet Station	Primary: vapor visualization, air sampling Supplemental: Capture velocity, slot velocity, tracer gas, air sampling	0.28–0.50 m/s (55–100 fpm) capture velocity for non-heated 0.36–0.76 m/s (70–150 fpm) capture velocity for heated 110–125% of the laminar flow volume flow rate across the top of the deck	ACGIH Industrial Ventilation Manual SEMI F15
Gas Cylinder Cabinets	Primary: face velocity, tracer gas Supplemental: vapor visualization	1.0–1.3 m/s (200–250 fpm) face velocity	ACGIH Industrial Ventilation Manual SEMI F15
Equipment Gas Panel Enclosure	Primary: tracer gas, static pressure Supplemental: vapor visualization	4–5 air changes per minute –1.3 to –2.5 mm (–0.05 to –0.1 in.) H_2O static pressure	ACGIH Industrial Ventilation Manual SEMI F15
Diffusion Furnace Scavenger	Primary: face velocity, vapor visualization Supplemental: tracer gas, air sampling	0.50–0.76 m/s (100–150) fpm face velocity NOTE: Do not use hot wire anemometer.	ACGIH Industrial Ventilation Manual SEMI F15
Chemical Dispensing Cabinets	Primary: static pressure Supplemental: vapor visualization, air sampling where safe, tracer gas where emission rates can be accurately calculated	–1.3 to –2.5 mm (–0.05 to –0.1 in.) H_2O static pressure 2–3 air changes per minute	ACGIH Industrial Ventilation Manual SEMI F15

Hood Type	*Recommended Test Methods*	*Typical Design and Test Exhaust Parameters (See NOTE 1.)*	*References*
Parts-Cleaning Hoods	Primary: face velocity, vapor visualization Supplemental: tracer gas, air sampling	0.40–0.64 m/s (80–125 fpm) face velocity	ASHRAE Standard 110 SEMI F15 ACGIH Industrial Ventilation Manual
Pump and Equipment Exhaust Lines	Primary: static pressure Supplemental: tracer gas	–6 to –25 mm (–0.25 to –1.0 in.) H_2O static pressure 125% maximum volume flow rate from pump	ACGIH Industrial Ventilation Manual SEMI F15
Glove Boxes	Primary: static pressure, tracer gas Supplemental: vapor visualization, air monitoring	No consensus for a reference at the time of publication of this guideline.	ACGIH Industrial Ventilation Manual SEMI F15
Drying/ Bake/ Test Chamber Ovens	Primary: static pressure, tracer gas Supplemental: vapor visualization, air monitoring	–1.3 to –2.5 mm (–0.05 to –0.1 in.) H_2O static pressure	SEMI F15 ACGIH Industrial Ventilation Manual
Spin-Coater (cup only)	Primary: vapor visualization, velometry Supplemental: air sampling	(see SEMI S2 Sections 23.5.1–3)	ACGIH Industrial Ventilation Manual
Supplemental Exhaust	Primary: capture velocity, vapor visualization, air sampling	0.50–0.76 m/s (100–150 fpm) capture velocity	ACGIH Industrial Ventilation Manual

NOTE 1: All measurements should be within ± 20% of average for face velocity, ± 10% of average along the length of each slot for slot velocity, and ± 10% of average between slots for slot velocity.

A2-2 Exhaust Optimization

A2-2.1 Exhaust optimization is the use of good ventilation design to create efficient equipment exhaust. The design and measurement methods discussed below confirm that equipment exhaust is acting as the manufacturer intended. This information is not meant to prohibit alternate methods of achieving or verifying good ventilation design. References for ventilation design are included at the end of this Appendix.

A2-2.2 *Design Recommendations*

A2-2.2.1 Equipment exhaust design can attempt to reduce inefficient static pressure losses caused by: friction losses from materials; openings, and duct geometries (elbows, duct expansions or contractions); turbulent air flow; fans; internal fittings such as blast gates and dampers; directional changes in airflow.

A2-2.2.2 Other good design principles can include minimizing distance between the source and hood, and reducing enclosure volumes.

A2-2.2.3 For non-chemical issues such as heat from electrical equipment, heat recapture rather than exhaust may be appropriate.

A2-2.2.4 The possible impact of highly directional laminar airflow found in most fabs should be considered when designing equipment exhaust.

A2-2.3 *Recommended Equipment Controls* — The location of internal blast gates or dampers inside equipment, and their appropriate settings, should be clearly identified. The number of equipment dampers and blast gates should be minimized. Gates/dampers should be lockable or otherwise securable. Static pressure or flow sensors installed on equipment by the manufacturer should have sufficient sensitivity and accuracy to measure exhaust flowrate fluctuations that place the equipment out of prescribed ranges.

A2-2.4 *Recommended Measurement/Validation Method* — Measurements should be made to identify optimal exhaust levels and confirm that safety and process requirements are being addressed. The manufacturer should be able to identify any critical equipment locations for chemical capture, and quantify appropriate exhaust values. Multiple validation/ measurement methods may be needed.

A2-2.4.1 Measurements should be done after equipment components are assembled.

A2-2.4.2 Computer modeling can be done to predict exhaust flow and hazardous material transport in equipment by solving fluid mechanics conservation of energy and mass equations. Modeling can be used in the equipment design stage or to improve existing equipment. Computer models should be verified experimentally, using one or more of the methods discussed below.

A2-2.4.3 Tracer gas testing provides a method to test the integrity of hoods by simulating gas emission and measuring the effectiveness of controls. Testing until there is a failure, and then slightly increasing the flow rate until the test is successful, can be used to help minimize air flow specifications.

A2-2.4.4 Chemical air or wipe monitoring can be used to confirm that chemical transport is not occurring into unintended areas of the equipment.

A2-2.4.5 Velocity profiling will confirm expected airflows, the direction of flow, and the effect of distance.

A2-2.4.6 Vapor visualization will confirm expected airflows, the direction of flow, and the effect of distance. Vapor visualization is the observation of aerosols (e.g., aerosols generated by using water, liquid nitrogen, or dry ice) so that exhaust flow patterns can be observed. Smoke tubes or aerosols may also be used, however they can produce contamination.

A2-3 Chemical Laboratory Fume Hoods, Parts Cleaning Hoods

Lab fume hoods and part cleaning hoods are designed to control emission by enclosing a process on five sides and containing the emission within the hood.

A2-3.1 *Design Recommendations*

A2-3.1.1 Fully enclosed on five sides, open on one side for employee access and process/parts placement and removals.

A2-3.1.2 Front (employee access side) should be provided with sliding door and/or sash.

A2-3.1.3 Minimize size of the hood based on process size.

A2-3.1.4 Minimize front opening size based on size of process and employee access needs.

A2-3.1.5 Ensure hood construction materials are compatible with chemicals used.

A2-3.2 *Control Specifications* — Face velocity is the specification generally used with hoods open on only one side.

A2-3.2.1 Generally acceptable laboratory fume hood face velocities range from 0.40 to 0.60 m/s (80–120 fpm) with no single measurement ± 20 % of average. 0.64 to 0.76 m/s (125–150 fpm) is recommended for hoods in which carcinogens or reproductive toxicants may be used.

A2-3.2.2 Velocities as low as 0.30 to 0.40 m/s (60–80 fpm) can be effective but require no cross drafts or competing air movement in the work area.

A2-3.2.3 An average face velocity of 0.50 m/s (100 fpm) is generally found to be acceptable in most applications.

A2-3.2.4 Face velocities of 0.64 to 0.76 m/s (125 to 150 fpm) may be required when a lab hood is installed in an area with laminar air flow.

A2-3.2.5 Face velocity above 0.76 m/s (150 fpm) should be avoided to prevent eddying caused by a lower pressure area in front of an employee standing at the hood.

A2-3.3 *Recommended Measurement/Validation Method*

A2-3.3.1 The preferred method is measurement of average face velocity and hood static pressure. Measurements are taken with a velometer or anemometer. Multiple measurements are taken in a grid, at least 10 to 40 per square meter (1–4 per square foot) of open area, in the plane opening of the hood. This allows representative, evenly spaced measurements to be taken (see also open-surface tanks).

A2-3.3.2 Additional confirmation by visualization check of containment using smoke or vapor testing.

A2-3.3.3 ASHRAE Method 110, or equivalent (use appropriate sections), for tracer gas testing of lab hoods may be used as a supplemental verification provided that an accurate emission rate can be defined. (ASHRAE 110 lists 3 tests: “as manufactured,” “as used,” and “as installed.” The “as manufactured” test is the test that is used most frequently.)

A2-4 Wet Stations

Wet stations are slotted hoods designed to capture laminar air flow while also capturing wet process emissions from the work area. Wet stations can be open on the front, top and both sides (it is usually preferable to enclose as much as possible).

A2-4.1 *Design Recommendations*

A2-4.1.1 Slots should be provided uniformly along the length of the hood for even distribution of airflow.

A2-4.1.2 Additional lip exhaust slots should be provided around tanks or sinks to control emissions.

A2-4.1.3 The plenum behind the slots should be sized to ensure even distribution of static pressure. These slots should be designed to ensure adequate airflow is provided by the side slots, and to minimize turbulence that could reduce exhaust performance.

A2-4.1.4 Velocity along length of slot should not vary by more than 10% of the average slot velocity.

A2-4.1.5 Additional use of end or side panels/baffles can reduce negative impact of side drafts.

A2-4.1.6 Exhaust volume settings should consider laminar air flow volumes and be balanced to minimize turbulence and to ensure capture.

A2-4.1.7 The station design should consider airflow patterns in the operating zone to minimize turbulent horizontal airflow patterns into and across the work deck.

A2-4.1.8 Additional considerations to reduce exhaust demand include providing covered tanks, and recessing tanks below deck level.

A2-4.2 *Control Specifications*

A2-4.2.1 Wet station specifications are complicated by the fact that wet stations generally do not have an easily definable face velocity to measure. A number of methods have been used and are all acceptable if used consistently and provided documentation indicates chemical containment meets the 1% of the OEL at distances beyond the plane of penetration at the exterior of the wet station.

A2-4.2.2 Maintain an average capture velocity of 0.33 to 0.50 m/s (65–100 fpm) immediately above a bath.

A2-4.2.3 Calculate the total exhaust volume requirement by determining the total volumetric flow of laminar air hitting the deck and increasing this value by 20 to 25%.

A2-4.2.4 For some wet stations that are partially enclosed from the top, an artificial plane opening ("face") can be defined where the downward laminar air flow penetrates the capture zone (at "face velocity") of the wet station. Depending on the hood design and laminar air flow provided, average face velocities can range from 0.20 to 0.50 m/s (40 to 100 fpm). The measurement location can greatly influence the measured face velocity; therefore, this method should be supplemented with at least one of the preceding methods for greater accuracy and reproducibility at the user's facility.

A2-4.3 *Recommended Measurement/Validation Method*

A2-4.3.1 Confirmation of capture using vapor visualization.

A2-4.3.2 Confirmation of laminar flow of make up air into the station using vapor visualization.

A2-4.3.3 Tracer gas testing may be used as supplemental verification, provided an emission rate can be accurately defined.

A2-5 Supplemental Exhaust

Supplemental exhaust, if not designed into the equipment, can be provided by a flexible duct with a tapered hood. This can be placed in the work area to remove potential contaminants before they enter the breathing zone. Supplemental exhaust is frequently used during maintenance or service.

A2-5.1 *Design Recommendations*

A2-5.1.1 Retractable or movable non-combustible flex ducting for easy reach and placement within 150 to 300 mm (6 to 12 inches) of potential emissions to be controlled.

A2-5.1.2 Manual damper at hood to allow for local control, i.e., shut off when not required.

A2-5.1.3 Tapered hood with a plane opening as a minimum. The additional use of flanges or canopies to enclose the process will result in improved efficiency.

A2-5.2 *Control Specifications*

NOTE A2-1: This is one equation that is most commonly used. Other equations may be appropriate; see also ACGIH Industrial Ventilation Manual, and Semiconductor Exhaust Ventilation Guidebook.

A2-5.2.1 A minimum capture velocity of 0.50 m/s (100 fpm) is required at the contaminant generation point for releases of vapor via evaporation or passive diffusion. Ventilation should not be relied upon to prevent exposures to hazardous substances with release velocities (e.g., pressurized gases). For a plane open ended duct without a flange, the air flow required at a given capture velocity can be calculated by:

$Q = V(10X^2 + A)$

Where: Q = required exhaust air flow in m^3/s (cfm)

V = capture velocity in m/s (fpm) at distance X from hood

A = hood face area in square meters (square feet)

X = distance from hood face to farthest point of contaminant release in meters (feet). NOTE: This is only accurate when X is within 1.5 diameters of a round opening, or within 0.25 circumference of a square opening.

A2-5.3 *Recommended Measurement/Validation Method*

A2-5.3.1 Measurement of capture velocity at farthest point of contaminant release. Measurements taken with a velometer or anemometer.

A2-5.3.2 Confirmation by visualization check of capture using vapor capture testing.

A2-6 Equipment Gas Panel Enclosures

Equipment gas panel enclosures, also known as gas boxes, jungle enclosures, gas jungle enclosures, valve manifold boxes, and secondary gas panel enclosures, are typically six-sided fully enclosed enclosures with access panels/doors on at least one side. These ventilated enclosures are designed to contain and remove hazardous gases from the work area in the event of a gas piping failure or leak. Gas panel enclosures are typically of two types, those requiring no access while gas systems are charged, and those that must be opened during processing while gas systems are charged. There is also a distinct difference in control specifications for those with pyrophorics or other flammables vs. other HPMs, specifically in the control of pocketing.

A2-6.1 *Design Recommendations*

A2-6.1.1 Compartmentalize potential leak points.

A2-6.1.2 Minimize the total size of the panel and its enclosure.

A2-6.1.3 Minimize size and number of openings.

A2-6.1.4 Minimize static pressure requirements of the enclosure; control has been shown to be achievable with –1.3 to –2.5 mm (–0.05 to –0.1 in.) w.g.

A2-6.1.5 Design for sweep. Minimize the number and size of openings. Seal unnecessary openings (e.g., seams, utility holes).

A2-6.1.6 Where routinely used access doors are required:

- Make the access door as small as practical.
- Place the openings to the enclosure in the access door to minimize air flow requirements.
- Provide baffles behind the door to direct leaks away from the door and openings.
- Compartmentalize the enclosure so that access to one area does not affect air flow control in other areas.

A2-6.2 *Control Specifications*

A2-6.2.1 Exhaust volumes as low as 4–5 air changes per minute or less can be specified and meet the S2 criteria in Section 23.5 if the design principles listed above are considered when designing equipment and enclosures.

A2-6.2.2 Where there is potential for chemical exposure during access which can be controlled by face velocity, the enclosure should also provide a minimum face velocity of 0.36 to 0.76 m/s (70 to 150 fpm) when open. Face velocity should not be relied upon to control emissions from a pressurized fitting.

A2-6.2.3 Enclosures for pyrophoric or flammable gases should be designed to ensure adequately uniform dilution (i.e., prevent “pocketing”) and to prevent accumulation of pyrophoric and flammable gases above their lower explosive limit. Uniform dilution can generally be verified through exhaust vapor visualization techniques. Ventilation flow rate should be adequate to maintain concentrations below 25% of the lower explosive limit for the gas with the lowest LEL that is used in the enclosure. This can generally be verified using engineering calculations to verify dilution, and vapor visualization to verify mixing.

A2-6.3 *Recommended Measurement/Validation Method*

A2-6.3.1 Preferred validation by tracer gas testing per SEMI F15.

A2-6.3.2 Additional confirmation by visualization check of air flow, mixing and sweep using smoke or vapor testing.

A2-6.3.3 Measurement of average face velocity at inlet(s), opening(s), or routinely used access doors. Measurements should be taken with a velometer or anemometer. For larger openings, multiple measurements are taken in a grid, at least 10 to 40 per square meter (1–4 per square foot) of open area. Useful equation: $V = 4.043\ (VP/d)^{0.5}$, where V = velocity in m/s, VP = velocity pressure in mm H_2O, and d = density correction factor (unitless).

A2-7 Equipment Exhaust Ventilation Specifications and Measurements

A2-7.1 Specifications for equipment exhaust should be provided by the supplier and define:

A2-7.1.1 The control specification or standard for the hood or enclosure, i.e., face velocity or capture velocity if applicable.

A2-7.1.2 The airflow in the duct required to maintain the control volume or flow required. Measurements should be made using the ACGIH pitot traverse method described below.

A2-7.1.3 The location where the Pitot traverse measurement in the duct was made.

A2-7.1.4 Static pressure requirements.

A2-7.1.5 Coefficient of Entry (C_e) (see definitions and Section 22.3).

A2-7.1.6 Hood Loss Factor (K or F_h) (see definitions and Section 22.3).

A2-8 Duct Traverse Method

A2-8.1 Because the air flow in the cross-section of a duct is not uniform, it is necessary to obtain an average by measuring velocity pressure (VP) at points in a number of equal areas in the cross-section. The usual method is to make two traverses across the diameter of the duct at right angles to each other. Reading are taken at the center of annular rings of equal area. Whenever possible, the traverse should be made 7.5 duct diameters downstream and 3 diameters upstream from obstructions or directional changes such as an elbow, hood, branch entry, etc. Where measurements are made closer to disturbances, the results should be considered subject to some doubt and checked against a second location. If agreement within 10% of the two traverses is obtained, reasonable accuracy can be assumed and the average of the two readings used. Where the variation exceeds 10%, a third location should be selected and the two air flows in the best agreement averaged and used. The use of a single centerline reading for obtaining average velocity is a very coarse approximation and is *not* recommended. If a traverse cannot be done, then the centerline duct velocity should be multiplied by 0.9 for a coarse estimate of actual average duct velocity. Center line duct velocity should not be used less than 5 duct diameters from an elbow, junction, hood opening, or other source of turbulence.

A2-8.2 For ducts 150 mm (6 in.) and smaller, at least 6 traverse points should be used. For round ducts larger than 150 mm (6 in.) diameter, at least 10 traverse points should be employed. For very large ducts with wide variation in velocity, 20 traverse points will increase the precision of the air flow measurement.

A2-8.3 For square or rectangular ducts, the procedure is to divide the cross-section into a number of equal rectangular areas and measure the velocity pressure at the center of each. The number of readings should not be less than 16. Enough readings should be made so the greatest distance between centers is less than 150 mm (6 in.).

A2-8.4 The following data are required:

A2-8.4.1 The area of the duct at the traverse location.

A2-8.4.2 Velocity pressure at each point in the traverse and/or average velocity and number of points measured.

A2-8.4.3 Temperature of the air stream at the time and location of the traverse.

A2-8.4.4 The velocity pressure readings obtained are converted to velocities, and the velocities (not the velocity pressures) are averaged. Useful equation: $V = 4.043\ (VP/d)^{0.5}$, where V = velocity in m/s, VP = velocity pressure in mm H_2O, and d = density correction factor (unitless). Some monitoring instruments conduct this averaging internal to the instrument.

A2-8.5 Flow measurement taken at other than standard air temperatures should be corrected to standard conditions (i.e., 21°C [70°F], 760 mm [29.92 in.] Hg).

APPENDIX 3
DESIGN GUIDELINES FOR EQUIPMENT USING LIQUID CHEMICALS — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A3-1 Introduction

A3-1.1 This appendix provides specific technical information relating to Section 23. In general, it provides information on potential hazards, recommended control methods, and design considerations.

A3-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g., design principles) employed by manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.

A3-1.3 This appendix is intended to be used as a starting point for reference during equipment design. An example would be during a formal hazard analysis in a brainstorming session.

Table A3-1 Liquid Chemicals

<table>
<tr><th>Potential Hazard</th><th>Recommended Control Method</th><th>Design Considerations</th></tr>
<tr><td rowspan="3">Exposure to operators</td><td>Containment, control, and alarm notification for spills, leaks or vapors.</td><td>Appropriately sized secondary containment (minimum 110% volume of entire contents)
Equipment exhaust
Leak sensors to initiate auto shutdown.</td></tr>
<tr><td>Controlled access to chemical containment areas.</td><td>Door/access cover interlocks that automatically depressurize the area of the system being accessed.</td></tr>
<tr><td>Control of access to point-of-operation hazards.</td><td>Physical guarding/presence-sensing devices</td></tr>
<tr><td rowspan="2">Exposure to maintenance personnel</td><td>Control of chemical delivery pressure; control of residual chemicals.</td><td>Depressurization upon system failure, interlock activation, or normal shutdown
Transparent doors/covers allow visual inspection.</td></tr>
<tr><td>Serviceability</td><td>Built-in system purge and flush capabilities
System components accessible and easy to service.</td></tr>
<tr><td rowspan="2">General equipment and component failure</td><td>Chemical resistance/compatibility</td><td>Appropriate materials used for equipment construction and components.</td></tr>
<tr><td>Pressure rating</td><td>Pressurized systems designed to withstand 150% of maximum foreseeable pressure, or provide a suitable relief valve.</td></tr>
<tr><td rowspan="4">Chemical delivery system leak</td><td>Durable bulk chemical containers</td><td>Use of approved (e.g., DOT, UN Dangerous Goods) containers in bulk distribution systems.</td></tr>
<tr><td>Control of pressurized vessels and piping.</td><td>Provide visual pressure indicators with or without alarms.
Pressurized vessels and piping are designed and built to recognized standards.</td></tr>
<tr><td>Spill control</td><td>Automatic system pressure check prior to allowing dispense.
Use of normally closed valves on distribution lines.</td></tr>
<tr><td>Drum change-out controls</td><td>Over-fill sensors on chemical baths
Monitoring for excess flow.
Keyed and color-coded quick-connects</td></tr>
</table>

Potential Hazard	*Recommended Control Method*	*Design Considerations*
Fire	Control of ignition sources.	NFPA 70 (NEC) Class I, Div. 2 wiring methods, intrinsically safe components, or nitrogen-purged enclosures Physical separation of ignition sources and/or potentially flammable atmospheres. Use of low voltage to reduce the risk for ignition.
	Control of static electricity (i.e., one type of ignition source).	Maintain ground continuity
	Heat/fire/chemical detection Limiting concentrations of fuels and oxidizers.	(No consensus for a specific recommendation at the time of publication of this guideline.)

APPENDIX 4
IONIZING RADIATION TEST VALIDATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A4-1 Introduction

A4-1.1 This appendix provides specific technical information relating to Section 24. In general, it provides information on hazard evaluation methods, examples of control strategies, and test validation criteria.

A4-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g. design principles) employed by the manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.

A4-1.3 Test validation criteria are generally referenced from the applicable internationally recognized standard. It is the users responsibility to ensure that the most current revision of the standard (or its national equivalent) is used.

Table A4-1 Ionizing Radiation

Ionizing Radiation Type	*Emission Limit microsievert/hr (millirem/hr)*	*Test Method*
X or Gamma	Operator 2 µSv/hr (0.2 mrem/hr)	Direct doserate measurement with an Ion Chamber (or equivalent) calibrated to ± 10% of true doserate at the surface of the equipment (or at the closest approach) in all areas where the operator may have access with the ionizing radiation source active.
X or Gamma	Maintenance and Service 10 µSv/hr (1 mrem/hr)	Direct doserate measurement with an Ion Chamber (or equivalent) calibrated to ± 10% of true doserate during simulated maintenance and service procedures. Measurements should be made at the surface emitting the ionizing radiation or the closest approach to the emitting surface with the ionizing radiation source active. NOTE: For these measurements, panels and/or shields should be removed only if removal is required for maintenance or service activities.

A4-2 Basic Radiation Control Methods

Time — If the radiation field exists and it must be entered, then minimize the time spent in the field to minimize the exposure to the individual. This gives a linear dose reduction.

Distance — If the radiation field is present, stay as far away form the source as possible to perform the required tasks. Dose is reduced by the square of the distance from the source.

Shielding — If the radiation field is intense and the source is small, shielding the source is generally the most practical.

Quantity — If there exists an opportunity to minimize the amount of radiation or radioactive material that is required for the task, then the exposure can be minimized also.

APPENDIX 5
NON-IONIZING RADIATION (OTHER THAN LASER) AND FIELDS TEST VALIDATION — Design and Test Method Supplement Intended for Internal and Third Party Evaluation Use, But Not for Field Survey of Installed Equipment

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A5-1 Introduction

A5-1.1 This appendix provides specific technical information relating to Section 25. In general, it provides information on hazard evaluation methods and test validation criteria.

A5-1.2 This appendix is not intended to limit hazard evaluation methods or control strategies (e.g., design principles) employed by manufacturers. Alternative methods are acceptable if they provide an equivalent level of hazard control.

A5-1.3 Test validation criteria are generally referenced from the applicable internationally recognized standards. It is the user's responsibility to ensure that the most current revision of the standard is used.

A5-2 Non-Ionizing Radiation Surveys should be conducted at the maximum operational power level and, when applicable, at the most limiting frequency.

A5-3 Measurements should be taken at the exterior surfaces of the equipment and at surfaces that maintenance and repair personnel could encounter, whenever practical (electric field measurements with paddle-shaped sensors may not be possible in some places due to the size and shape of the sensor). Measurements for the purpose of evaluating emissions accessible to operators should be taken at the operators console and material loading station.

A5-4 Measurements to assess electromagnetic emissions from equipment for safety purposes should be taken in an area that is reasonably free of energy of the wavelengths/frequencies of interest, especially if the strength of the energy fluctuates in a manner that is unpredictable. Instruments used for safety-related measurements should be calibrated at a facility capable of calibrating such instruments using standards traceable to the National Institute of Standards and Technology in the USA or an equivalent standards service elsewhere, per the guidance of the instrument manufacturer. This should be determined by conducting surveys in the test area before the equipment is set up for the measurements. Measurements taken for safety purposes can also be combined with measurements taken to address electromagnetic interference concerns. The specific measurement locations may vary between electromagnetic interference and safety-related measurements.

NOTE A5-1: The values in the table below are shown as 20% of the limit stated in the applicable standard (referenced).

Table A5-1 Non-Ionizing Radiation

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Static[4] 0 Hz. (e.g., static magnets in etch/implant equipment)	Magnetic Field Strength (A/m or Gauss) (See NOTES 1 and 2.)	8 mT (80 G)	40 mT (400 G)	0.5 mT (5 G)	Use a Hall effect probe at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measure field at exterior surfaces of equipment (2 to 3 cm from the surface). Locate 5 gauss (G) line to post pacemaker warnings and 30 G to identify where flying tools, etc. and dislocations of magnetizable prostheses could become a hazard.

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Sub Radio-frequency[1] 1 Hz to 3 kHz (e.g., electromagnets in etch equipment) *See exception below for 50 and 60 Hz power frequencies.	Electric Field Strength (V/m) (See NOTE 1.)	1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m	1–100 Hz 5 kV/m* 100 Hz to 3 kHz 500,000/f (Hz) in V/m	1 kV/m	Use a displacement sensor. Determine the maximum field strength and orientation at the surface of the equipment (2–3 cm). Remove field perturbations by using a long non-conductive handle extension or remote fiber optic readout. Locate 1 kV/m line to post pacemaker warnings.
Sub Radio-frequency[1] 1 Hz to 3 kHz (e.g., electromagnets in etch equipment) *See exception below for 50 and 60 Hz power frequencies.	Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)	1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*	1–300 Hz 12/f (Hz) in mT 300 Hz to 3 kHz 0.04 mT (400 mG)*	0.1 mT (1 G)	Use a loop sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location). The sensor should be almost contacting the equipment surface (2 cm from surface). Identify 1 G line to post pacemaker warnings.
Power Frequency (50 or 60 Hz) [1,5] (e.g., electromagnets in etch equipment)	Electric Field Strength (V/m) (See NOTE 1.)	1 kV/m	2 kV/m	1 kV/m	See Sub radiofrequency Electric Field Testing Method, but probe is positioned as needed to determine distance to 1 kV/m.
Power Frequency (50 or 60 Hz) [1,5] (e.g., electromagnets in etch equipment)	Magnetic Field Strength (A/m or G) (See NOTES 1 and 2.)	0.02 mT (200 mG)	0.1 mT (1 G)	0.1 mT (1 G)	See Sub radiofrequency Magnetic Field Testing Method, but probe is positioned as needed to determine distance to 1 G pacemaker criterion.
Radio-frequency Field [2] 3 kHz to 100 kHz (e.g., RF used to generate plasma)	Induced current and contact current (mA)	Frequency-dependent: 180f (kHz) in mA through both feet 90f through each foot 90f for contact. where f is in MHz	Frequency-dependent: 400f (kHz) in mA through both feet, 200f through each foot 200f for contact. where f is in MHz	NA	Contact instrument vendor for suitable instrument based on frequency and emission characteristics. Measurement of induced and contact currents for freq. < 100 MHz should be made when approaching 20% of the applicable electric field emission limit.

Energy Category	*Physical Quantity Measured (units)*	*Operator-Accessible Limit*	*Maintenance- and Service-Accessible Limit*	*Pacemaker Labeling Level*	*Testing Methods*
Radio-frequency Field [2] 100 kHz to 100 MHz (e.g., RF used to generate plasma)	Induced current and contact current (mA)	18 mA through both feet 9 mA through each foot 9 mA contact	40 mA through both feet 20 mA through each foot 20 mA contact	NA	Contact instrument vendor for suitable instrument based on frequency and emission characteristics. Measurement of induced and contact currents for freq. < 100 MHz should be made when approaching 20% of the applicable electric field emission limit.
Radio-frequency Field [2] 3 kHz to 300 MHz (e.g., RF used to generate plasma)	Electric Field Strength (V/m) (See NOTE 1.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a diode rectifier or displacement sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measurements should be made at 20 cm from the surface.
Radio-frequency Field [2] 3 kHz to 300 MHz (e.g., RF used to generate plasma)	Magnetic Field Strength (A/m) (See NOTES 1 and 2.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a coil sensor at each location (use three axis probe or make three mutually orthogonal measurements at each location) Measurements should be made at 20 cm of the surface.
Radio-frequency Fields [2] 300 MHz to 300 GHz (e.g., RF used to generate plasma)	Power Density (mW/cm^2) (See NOTE 1.)	Frequency dependent (see ANSI/IEEE C95.1). 20% of Uncontrolled limit in Table 2 of C95.1	Frequency dependent (see ANSI/IEEE C95.1). 20% of Controlled limit in Table 1 of C95.1	NA	Use a diode rectifier or thermocouple at each location (use three axis probe or make three mutually orthogonal measurements at each location). Measurements should be made at 20 cm of the surface.

NOTE 1: It is assumed that electric and magnetic fields exist separately at frequencies below 300 MHz. It is assumed that electric and magnetic fields exist as a combined entity (electromagnetic radiation) at higher frequencies. Two evaluations are needed at frequencies <300 MHz and only one (usually made by measuring the electric field) at higher frequencies.

NOTE 2: 1 gauss (G) ≈ 79.55 amperes per meter (A/m). 1 tesla (T) = 10,000 G, 1 millitesla (mT) = 10 G.

Table A5-2 Optical Energy

Optical Energy	*Physical Quantity Measured (units)*	*Access Limit*	*Testing Methods*
Infrared Energy[1] 700 nm to 1 mm (e.g., heating lamps)	Irradiance W/m^2 (See NOTES 1, 2, and 3.) Radiance W/m^2 - sr	Wavelength dependent 20% of the applicable exposure limits. (See Reference 1.)	Thermocouple, thermopile, pyroelectric, photoelectric Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s).

Optical Energy	*Physical Quantity Measured (units)*	*Access Limit*	*Testing Methods*
Visible Light[1] 400 nm to 700 nm (e.g., heating lamps)	Irradiance $\mu W/cm^2$ (See NOTES 1, 2, and 3.) Radiance W/m^2 - sr	Wavelength dependent 20% of the applicable exposure limits. (See Reference 1.)	Thermocouple, thermopile, pyroelectric, photoelectric Direct measurement locating the maximum irradiance and orientation of the light energy at the closest approach to view port(s) or accessible leakage point(s).
Ultraviolet Energy[1] 315 nm to 400 nm (e.g., plasma, stepper)	Irradiance mW/cm^2 (See NOTES 1 and 2.)	0.2 mW/cm^2	Photoelectric detectors with filters and or controlled phosphors Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s).
Ultraviolet Light[1] 180 nm to 315 nm (e.g., plasma, stepper)	Effective Irradiance $\mu W/cm^2$ (See NOTE 4.)	0.02 $\mu W/ cm^2$	Photoelectric detectors with filters and/or controlled phosphors (See NOTE 5.) Direct measurements locating the maximum irradiance and orientation of the energy at the closest approach to the view port(s) or accessible leakage point(s).

NOTE 1: "Irradiance" is essentially the same as "power density."

NOTE 2: Lamp manufacturer data can sometimes be used to estimate and evaluate exposures using a spreadsheet.

NOTE 3: These guidelines cover visible, IR-A, and IR-B, and are frequency dependent. Separate evaluations may be needed for thermal or photochemical retinal hazards and infrared eye hazards.

NOTE 4: "Effective irradiance" is irradiance adjusted to account for the wavelength-dependent biological hazard. Permissible exposure time = 0.003 J/cm2 divided by the effective irradiance.

NOTE 5: Instrumentation is commercially available that accounts for the wavelength dependence of the standard and gives results in effective irradiance.

A5-5 References

1. 1996 TLVs and BEIs Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices, ACGIH, Cincinnati, OH

2. ANSI/IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1-1991, Piscataway, New Jersey

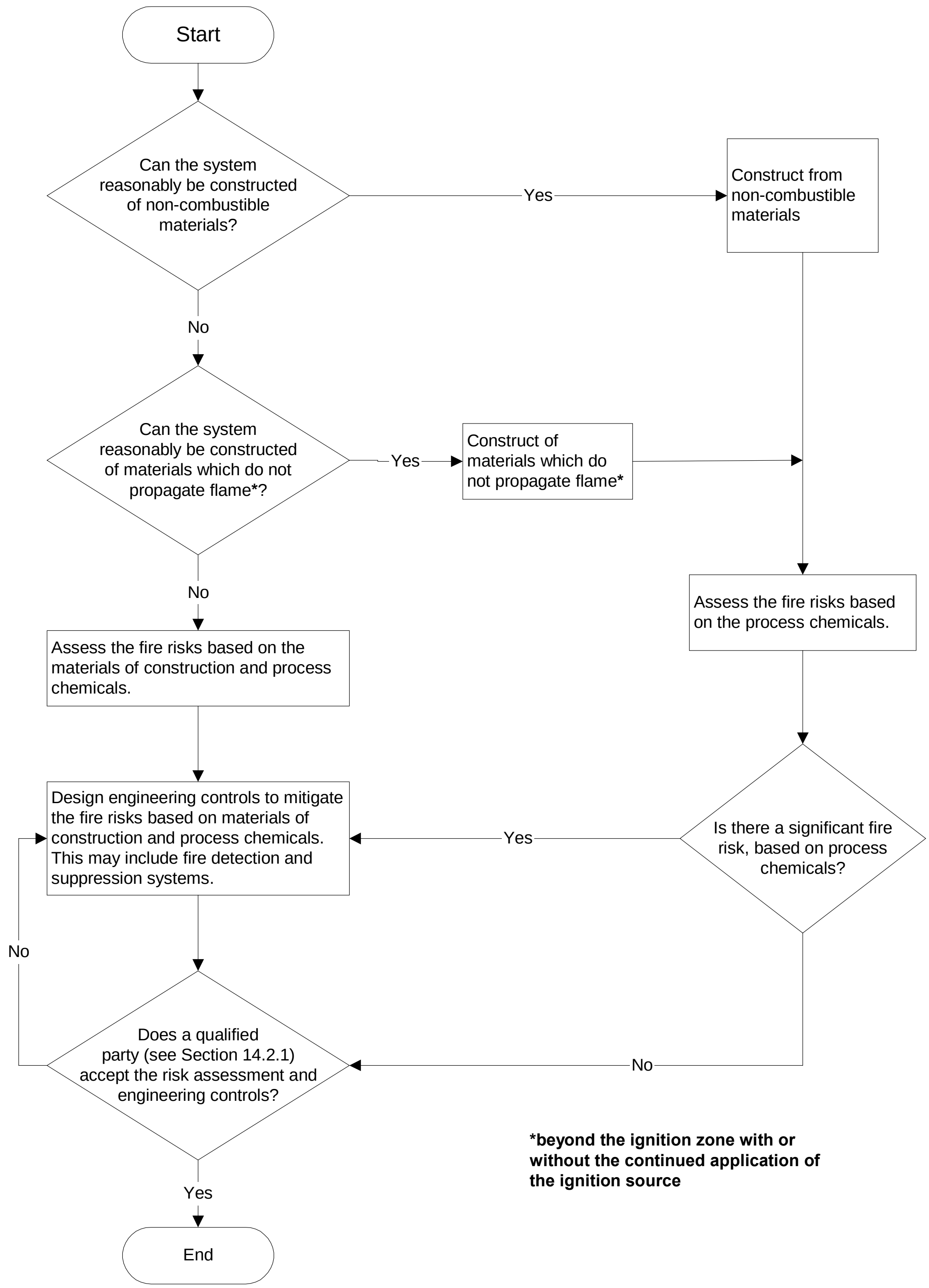
3. Guidelines on Limits of Exposure to Broad-Band Incoherent Optical Radiation (0.38 to 3 µM), Health Physics Vol. 73, No. 3 (September), pp.539-554, 1997

4. ICNIRP 1994 "Guidelines on Limits of Exposure to Static Magnetic Fields," Health Physics Vol 66 (1) (January), pp. 100-106, 1994

5. Interim Guidelines on the Limits of Exposure to 50/60 Hz Electric and Magnetic Fields, IRPA/ICNIRP Guidelines, Health Physics Vol. 58, No. 1 (January), pp. 113-122, 1990

APPENDIX 6
FIRE PROTECTION: FLOWCHART FOR SELECTING MATERIALS OF CONSTRUCTION

NOTE: The material in this appendix is an official part of SEMI S2 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.



***beyond the ignition zone with or without the continued application of the ignition source**

NOTICE: Paragraphs entitled "NOTE" are not an official part of this safety guideline and are not intended to modify or supersede the official safety guideline. These have been supplied by the committee to enhance the usage of the safety guideline.

SEMI makes no warranties or representations as to the suitability of the guideline set forth herein for any particular application. The determination of the suitability of the guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. This guideline is subject to change without notice.

The user's attention is called to the possibility that compliance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. Users of this guideline are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

CONTENTS

RELATED INFORMATION 1
EQUIPMENT/PRODUCT SAFETY PROGRAM

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R1-1 Preface

R1-1.1 Compliance with design-based safety standards does not necessarily ensure adequate safety in complex or state-of-the-art systems. It is often necessary to perform hazard analyses to identify hazards that are specific to the system, and develop hazard control measures that adequately control the associated risk beyond those that are covered in existing design-based standards. This document provides guidelines for developing a deliberate, planned equipment/product safety (EPS) program integrating the compliance assessment activities with hazard analyses and other activities needed to provide a safe system throughout the life of equipment or products.

R1-1.2 An effective EPS program reduces the cost, schedule slips, and liability associated with the late identification and correction of hazards. To be most effective, an EPS program should be begun by the manufacturer early during the design phase. Starting early allows safety to be designed into the system and its subsystems, equipment, facilities, processes, procedures, and their interfaces and operations. These guidelines are designed to assist the manufacturer in planning and implementation of an effective EPS program.

R1-1.3 The lowest costs for implementing safety can be achieved when hazards are identified and resolved before hardware is built and firmware or software is coded. This guide is intended to provide the basis for a methodology for implementing a safety program for early and continued hazard identification and the elimination or reduction of associated risks.

R1-1.4 EPS program success depends directly upon management emphasis and support applied during the system design and development process and throughout the life cycle of the product. This emphasis should include the following management controls:

R1-1.4.1 Agreement from management that the EPS program will be maintained and supported throughout the product or facility life cycle;

R1-1.4.2 Clear and early statements of agreement with EPS objectives and requirements;

R1-1.4.3 Understanding of, and participation in, the risk acceptance process; and

R1-1.4.4 Continuing consideration of risk reduction during the management review process.

R1-2 Purpose

R1-2.1 This guide describes an approach for developing and implementing an EPS program of sufficient comprehensiveness to identify the hazards of a product and to develop design and administrative controls to prevent incidents. The EPS program addresses hazards from many sources to include system design, hazardous materials, advancing technologies, and new techniques. The goal is to eliminate hazards or reduce the associated risk to an acceptable level.

R1-3 Scope

R1-3.1 This guide applies to every activity of the product life cycle (e.g., research, technology development, design, test and evaluation, production, construction, checkout/calibration, operation, maintenance and support, modification and disposal).

R1-4 General Guidelines

R1-4.1 *EPS Program* — The supplier should establish and maintain an EPS program to support efficient and effective achievement of overall EPS objectives. Depending upon the needs of the company, the EPS Program may be a company wide program covering all projects, separate programs for each project, or some combination of the two.

R1-4.1.1 *Management System* — The supplier should establish an EPS management system to implement provisions of this guide commensurate with the needs of the program. The program manager should be responsible for the establishment, control, incorporation, direction and implementation of the EPS program policies and should assure that risk is identified and eliminated or controlled. The supplier should establish internal reporting systems and procedures for investigation and disposition of product related incidents and safety incidents, including potentially hazardous conditions not yet involved in an incident.

R1-4.2 *EPS Design Guidelines*

R1-4.2.1 EPS design requirements should be specified after review of pertinent standards, specifications, regulations, design handbooks, safety design checklists, and other sources of design guidance for applicability to the design of the system. The supplier should establish EPS design criteria derived from applicable data including the preliminary hazard analyses. These criteria should be the basis for developing system specification EPS requirements. The supplier should continue to expand the criteria and requirements for inclusion in development specification during the subsequent program phases.

R1-5 Detailed Guidelines

R1-5.1 The purpose of the EPS program is to ensure that the equipment or product is designed and documented in a manner that reduces the safety risk associated with that equipment or product to a level that is acceptable to the customer. This consideration applies to all life cycle phases of the equipment or product. The following sections include detailed elements of a formal EPS program. Management should select or tailor the elements appropriate to their needs.

R1-5.2 *EPS Program Plan (EPSPP*) — The purpose of a EPS Program Plan (EPSPP) is to describe the tasks and activities of EPS management and engineering required to identify, evaluate, and eliminate/control hazards, or reduce the associated risk to an acceptable level throughout the system life cycle. The plan provides a basis of understanding of how to organize and execute an effective EPS program.

R1-5.2.1 *EPS Program Scope and Objectives* — Each EPSPP should describe, as a minimum, the following four elements of an effective EPS program:

- a planned approach for task accomplishment,
- qualified people to accomplish tasks,
- authority to implement tasks through all levels of management, and
- appropriate commitment of resources (both staffing and funding) to assure tasks are completed.

The scope and objectives should:

- Describe the scope of the overall program and the related EPS program.
- Identify the tasks and activities of EPS management and engineering functions. Describe the interrelationships between EPS and other functional elements of the program. Identify the other program requirements and tasks applicable to EPS.
- Account for major required EPS tasks and responsibilities.

R1-5.2.2 *EPS Function* — The EPSPP should describe:

R1-5.2.2.1 The EPS function within the organization of the total program, including organizational and functional relationships, and lines of communication. Other functional elements that are responsible for tasks that impact the EPS program should be included. This description should include the integration/management of associate suppliers, subcontractors and engineering firms. Review and approval authority of applicable tasks by EPS should be described.

R1-5.2.2.2 The responsibility and authority of EPS personnel, other supplier organizational elements involved in the EPS effort, subcontractors, and EPS groups. Identify the organizational unit responsible for executing each task and the authority in regard to resolution of identified hazards.

R1-5.2.2.2.1 One highly effective organizational approach to hazard resolution authority is through the use of a EPS Working Group (EPSWG). The activities of the EPSWG could include:

- Identifying safety deficiencies of the program and providing recommendations for corrective actions or prevention of reoccurrence.
- Reviewing and evaluating the hazard analyses to develop agreement that the hazards have been properly identified and controlled.
- Provide recommendations to the proper level of management concerning the need for additional hazard controls and the acceptability of residual risks.
- The staffing of the EPS function.
- The procedures by which the supplier will integrate and coordinate the EPS efforts.
- The process through which supplier management decisions will be made.
- Details of how resolution and action relative to EPS will be effected at the program management level possessing resolution and acceptance authority.

R1-5.2.3 *EPS Program Milestones* — The EPSPP should include:

- Identification of the major EPS program milestones. These should be related to major program milestones, program element responsibility, and required inputs and outputs.
- A program schedule of EPS tasks, including start and completion dates, reports, and reviews.
- Identification of subsystem, component, software safety activities as well as integrated system level activities (i.e., design analyses, tests, and demonstrations) applicable to the EPS program but specified in other engineering studies and development efforts to preclude duplication.

R1-5.2.4 *General EPS Guidelines and Criteria* — The EPSPP should:

- Describe general engineering requirements and design criteria for safety.
- Describe the risk assessment procedures (see SEMI S10). The hazard severity categories, hazard likelihood categories, and the EPS precedence that should be followed to satisfy the safety requirements of the program.
- Describe closed-loop procedures for taking action to resolve identified unacceptable risks including those involving non-developmental items.

R1-5.2.5 *Hazard Analysis* — The EPSPP should describe:

- The analysis techniques and formats to be used to identify hazards, their causes and effects, hazard elimination, or risk reduction requirements and how those requirements are met.
- Recommended techniques for identification of hazards and hazard scenarios include Preliminary Hazard Lists, Preliminary Hazard Analysis, HAZOPs, FMEA, FTA, "what if?" and process control analyses. Other types of hazard analysis techniques are discussed in a variety of sources, such as EN 1050, Annex B. No single method is the best for all types of systems, subsystems, subsystem interaction or facilities. A combination of techniques may be most appropriate.
- The integration of subcontractor or supplier hazard analyses and safety data with overall system hazard analyses.
- Efforts to identify and control hazards associated with materials used during the system's life cycle.

R1-5.2.6 *System Safety Data* — The EPSPP should describe the approach for collecting and processing pertinent historical hazard, incident, and safety lessons learned, data.

R1-5.2.7 *Safety Verification* — The EPSPP should describe:

- The verification (test, analysis, inspection, etc.) methods to be used for making sure that safety is adequately demonstrated. Identify any requirements for safety certification, safety devices or other special safety verification or documentation requirements.
- Procedures for transmitting safety-related verification information to the customer or others for review and analysis.

R1-5.2.8 *Audit Program* — The EPSPP should describe the techniques and procedures to be employed to make sure the objectives and requirements of the EPS program are being accomplished.

R1-5.2.9 *Incident Reporting* — The supplier should describe in the EPSPP the incident alerting/notification, investigation and reporting process including notification of the customer.

R1-5.2.10 *EPS Interfaces* — The EPSPP should identify:

- The interface between EPS and all other applicable safety disciplines.
- The interface between EPS, systems engineering, and all other support disciplines such as: maintainability, quality control, reliability, software development, human factors engineering, and others as appropriate.
- The interface between EPS and product design, integration and test disciplines.

R1-5.3 *Hazard Analysis Documentation*

The hazard analysis process is used to identify hazards and their controls. This information should be documented in a closed loop tracking system to track the implementation of the controls and may also be required for presentation to management, the customer and others. The safety documentation could include a system description, the identification of hazards and their residual risks, as well as special procedures and precautions necessary for safety.

The documentation should include the following:

R1-5.3.1 *System Description* — This should consist of summary descriptions of the physical and functional characteristics of the system and its components. Reference to more detailed system and component descriptions, including specifications and detailed review documentation should be supplied when such documentation is available. The capabilities, limitations and interdependence of these components should be expressed in terms relevant to safety. The system and components should be addressed in relation to its function and its operational environment. System block diagrams or functional flow diagrams may be used to clarify system descriptions. Software and its role(s) should be included in this description.

R1-5.3.2 *Data* — This should consist of summaries of data used to determine the safety aspects of design features.

R1-5.3.3 *Hazard Analysis Results* — This should consist of a summary or a total listing of the results of the hazard analysis. Contents and formats may vary according to the individual requirements of the program. The following data elements may be used for documenting the results of hazard analyses:

R1-5.3.3.1 *System/Subsystem/Unit* — The particular part of the system that is the concern in this part of the analysis. This is generally a description of the location of the component being considered.

R1-5.3.3.2 *Component/Phase* — The particular phase/component with which the analysis is concerned. This could be a system, subsystem, component, software, operating/maintenance procedure or environmental condition.

R1-5.3.3.3 *Hazard Scenario Description* — A description of the potential/actual hazards inherent in the item being analyzed, or resulting from normal actions or equipment failure, or handling of hazardous materials.

R1-5.3.3.4 *Effect of Hazard* — The detrimental effects that could be inflicted on the subsystem, system, other equipment, facilities or personnel, resulting from this hazard. Possible upstream and downstream effects can also be described.

R1-5.3.3.5 *Recommended Action(s*) — The recommended action(s) that are necessary and sufficient to eliminate or control the hazard. Sufficient technical detail is required in order to permit the design engineers and the customer to adequately develop and assess design criteria resulting from the analysis. Include alternative designs and life cycle cost impact where appropriate.

R1-5.3.3.6 *Risk Assessment* — A risk assessment for each hazard (classification of severity and likelihood). This may include an assessment of the risk prior to taking any action(s) to eliminate or control the hazard and a separate assessment of the risk following implementation of the Recommended Action(s). (See SEMI S10.)

R1-5.3.3.7 *Remarks* — Any information relating to the hazard not covered in other blocks; for example, applicable documents, previous failure data on similar systems, or administrative directions.

R1-5.3.3.8 *Status* — The status of actions to implement the recommended control, or other, hazard controls. The status should include not only an indication of “open” or “closed,” but also reference to the drawing(s), specification(s), procedure(s), etc., that support closure of the particular hazard. The person(s) or organization(s) responsible for implementation of the control should also be recorded.

RELATED INFORMATION 2
ADDITIONAL STANDARDS THAT MAY BE HELPFUL

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Table R2-1

International Standards	*Title*
IEC 60204-1	Safety of Machinery - Electrical Equipment of Machines, Part 1
IEC 60417	Graphical Symbols for Use on Equipment
IEC 60664	Insulation Coordination for Equipment within Low-voltage Systems
IEC 60825-1	Safety of Laser Products, Part 1: Equipment Classification, Requirements and User's Guide
IEC 60950	Safety of Information Technology Equipment, including Electrical Business Equipment
IEC 60990	Methods of measurement of touch current and protective conductor current
IEC 61310-1	Safety of Machinery - Indication, Marking and Actuation - Part 1: Requirements for Visual, Auditory and Tactile Signals
ISO 3461-1	General Principles for the Creation of Graphical Symbols - Part 1: Graphical Symbols for Use on Equipment
ISO 3864	Safety Colours and Safety Signs
ISO 7000	Graphical Symbols for Use on Equipment - Index and Synopsis
USA Standards	*Title*
ANSI Z535.1 to ANSI Z535.5	Labeling and Marking
ANSI/UL 94	Tests for Flammability of Plastic Materials for Parts in Devices & Appliances
ANSI/UL 499	Electric Heating Appliance
ANSI/UL 508	Industrial Control Equipment
ANSI/UL 991	Tests for Safety-Related Controls Employing Solid-State
UL 1012	Power Units Other than Class 2
ANSI/UL 1778	UPS Equipment
ANSI/UL 1950	Information Technology Equipment
ANSI/UL 1998	Safety-Related Software
ANSI/UL 3101-1	Electrical Equipment for Laboratory Use; Part 1: General Requirements
ANSI Z136.1	American National Standard for Safe Use of Lasers
ASTM Volume 10.03	Electrical Protective Equipment
ISA S82.02	Electrical and Electronic Test and Measuring Equipment
ISA S82.03	Electrical and Electronic Process Measuring and Control
Factory Mutual Data Sheet 7-7	Semiconductor Fabrication Facilities
FMRC 3810	Electrical and Electronic Test, Measuring and Process Control Equipment
NFPA 70	National Electrical Code
NFPA 70E	Electrical Safety Requirements for Employee Workplaces
NFPA 79	Electrical Standard for Industrial Machinery
NFPA 318	Standard for the Protection of Cleanrooms
NEMA 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1.1	Safety Guidelines for the Application, Installation, and Maintenance of Solid-State Control
OSHA 29 CFR 1910.132-138	Personal Protective Equipment
OSHA 29 CFR 1910.147	The control of hazardous energy (lockout/tagout)
OSHA 29 CFR 1910.332-335	Safety Related Work Practices [electrical]

1997 Uniform Building Code, Section 1632	Structural Design Requirements -- Earthquake Design -- Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures
UL73	Motor Operated Appliances
UL471	Commercial Refrigerators and Freezers
UL698	Industrial Control Equipment for use in Hazardous Locations
UL1450	Motor-Operated Air Compressors, Vacuum Pumps and Painting Equipment
UL1740	Robots and Robotic Equipment
UL1995	Heating and Cooling Equipment
UL2011	Factory Automation Equipment
UL3111-1	Electrical Measuring and Test Equipment
UL3121-1	Process Control Equipment
Canadian Standards	*Title*
CAN/CSA C22.1	Canadian Electrical Code, Part I
CAN/CSA C22.2 No. 0	General Requirements - Canadian Electrical Code, Part II
CAN/CSA C22.2 No. 107.1	Commercial and Industrial Power Supplies
CAN/CSA C22.2 No. 234	Safety of Component Power Supplies
CAN/CSA C22.2 No. 950	Safety of Information Technology Equipment, including Electrical Business Equipment
CAN/CSA C22.2 No. 1010	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
European Standards	*Title*
EN 292-1	Safety of Machinery - Basic terminology and Technical principles
EN 292-2	Safety of Machinery - Technical Principles and Specifications
EN 294	Safety of Machinery - Safety distance to prevent danger zones being reached by upper limbs
EN 418	Functional Aspects of Machinery Emergency Stop Equipment
EN 626-2	Elimination or reduction of risk to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures
EN 811	Safety of Machinery - Safety distance to prevent zones being reached by lower limbs
EN 953	Safety of machinery - guards - general requirements for the design and construction of fixed and moving guards
EN 954-1	Safety of machinery - safety-related parts of control systems, Part 1: General principle for design.
EN 1037	Safety of machinery - Prevention of unexpected start-up
EN 1088	Safety of Machinery - Interlocking devices with and without guard locking
EN 1093-1	Evaluation of the emission of airborne hazardous substances - Part 1: Selection of test methods
EN 1093-9	Evaluation of the emission of airborne hazardous substances - Part 9: Pollutant concentration parameter - Room Method
EN 50178	Electronic equipment for use in power installations
EN 60204-1	Safety of Machinery - Electrical equipment of machines, Part 1
EN 60529	Degree of Protection Provided by Enclosure (IP Codes)
EN 60825-1	Safety of Laser Products, Part 1: Equipment Classification, Requirements and User's Guide
EN 60950	Specifications for Safety of Information Technology Equipment, including Electrical Business Equipment
EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory

Japanese Standards	*Title*
JIS C 0602	General Rules of Color Identification for Protective Conductor and Neutral Conductor
JIS C 4610	Circuit breakers for equipment
JIS B 6015	Electrical Equipment of Machine Tools
JIS C 8371	Residual current operated circuit breakers

RELATED INFORMATION 3
HAZARD LABELS

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R3-1 INTRODUCTION: The system shown below is a single label design that combines requirements from ANSI Z535, used in the USA, and ISO 3864 and IEC 1310-1, used elsewhere in the world. *The suitability of this design for any specific jurisdiction must be determined by the equipment manufacturer.*

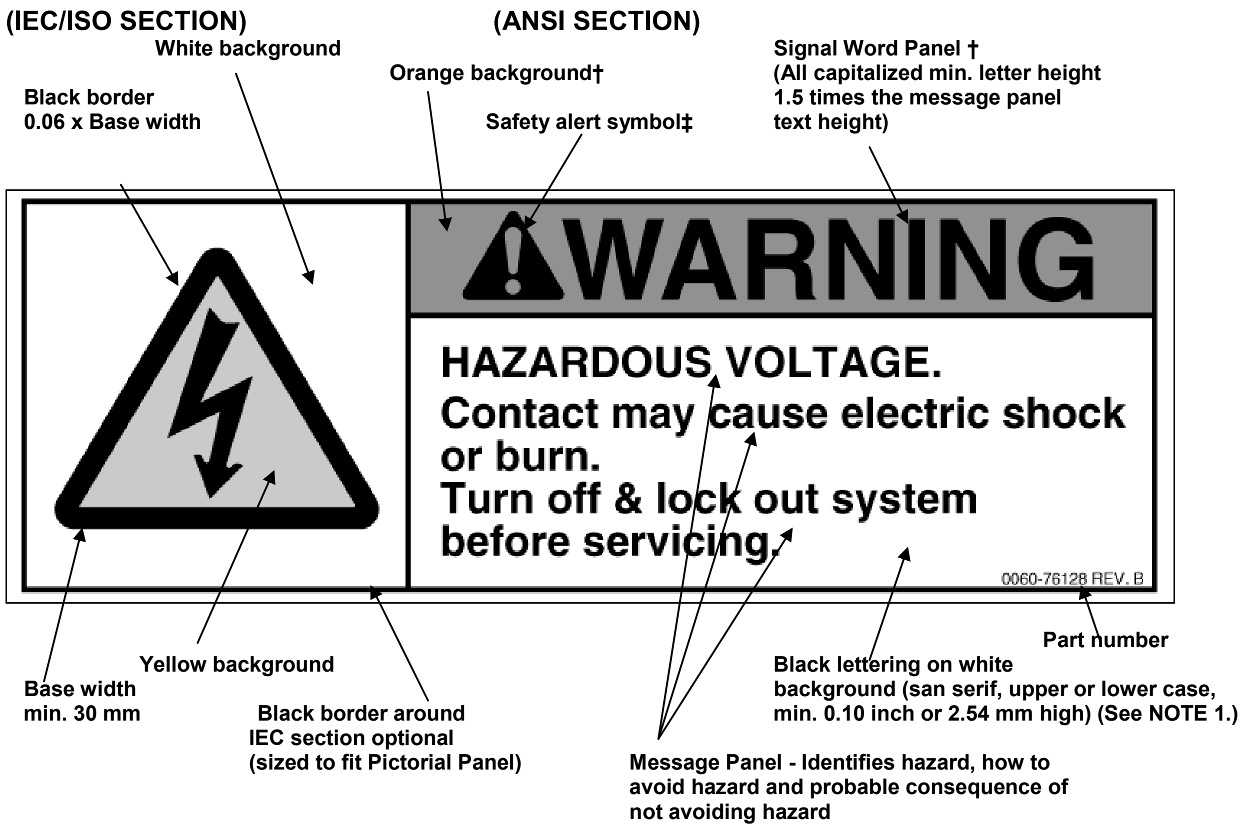


Figure R3-1
Example of a Combination ANSI/IEC Hazard Label Format

†SIGNAL WORD (san serif font)	‡SAFETY ALERT SYMBOL
DANGER - White Lettering / Red Background (Safety Red: per ANSI Z535.4 - 15 parts Warm Red, 1 part Rubine Red, 1/4 part Black)	**White Triangle / Red Exclamation Point**
WARNING - Black Lettering / Orange Background (Safety Orange: per ANSI Z535.4 - 13 parts Yellow, 3 parts Warm Red, 1/4 part Black)	**Black Triangle / Orange Exclamation Point**
CAUTION - Black Lettering / Yellow Background (Safety Yellow: per ANSI Z535.4 - Pantone 108C)	**Black Triangle / Yellow Exclamation Point**

NOTE 1: Message Panel Letter height (min. 0.10 inch or 2.54 mm high) for FAVORABLE reading conditions may, in some instances be reduced further for application to small products or products having limited surface area on which to apply the message. However, it should not be less than 0.05 in. (1.27 mm) for lower case letter height.

NOTE 2: Upon request from end-user(s), translation(s) to other languages may also be deemed appropriate.

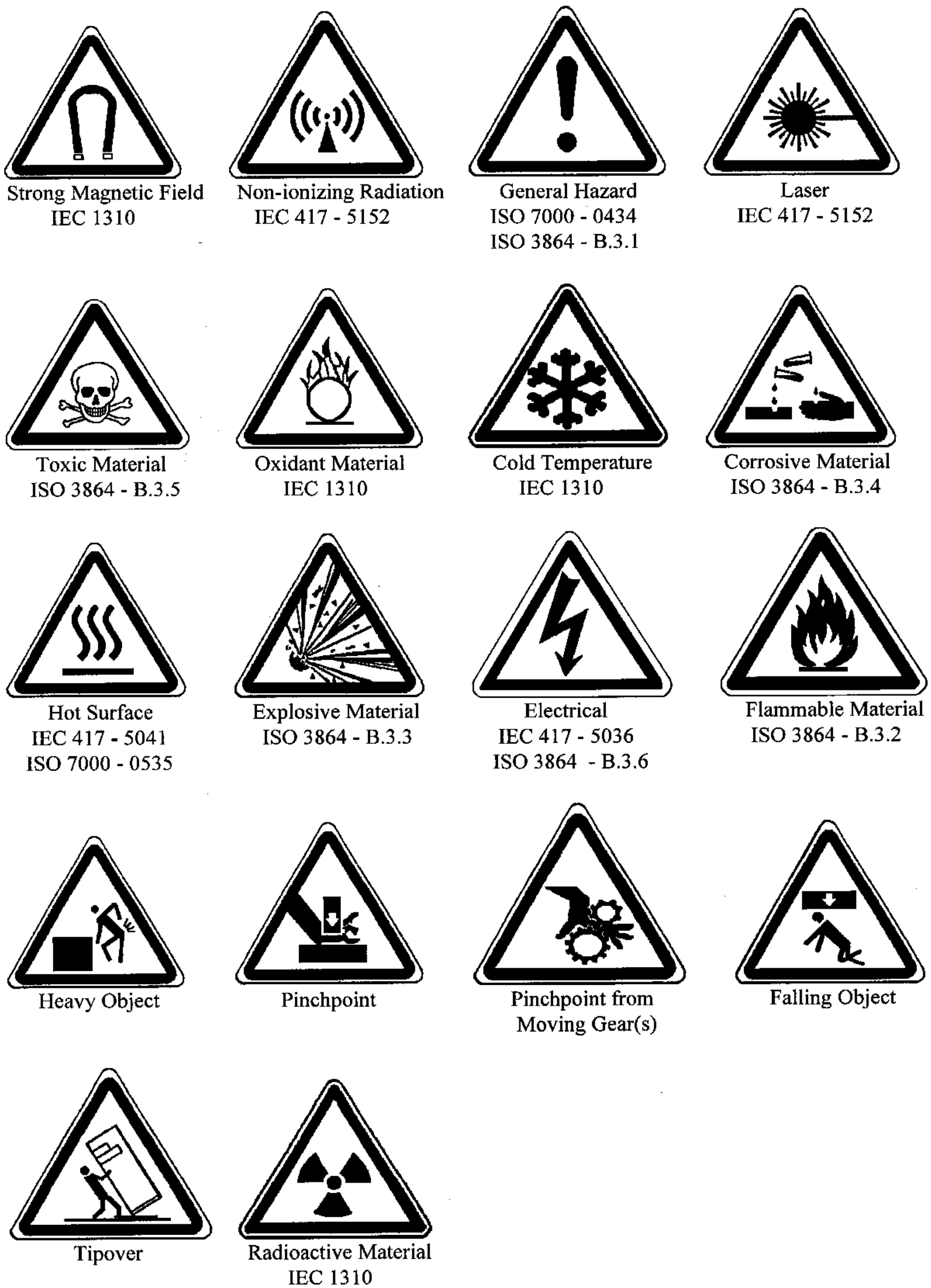


Figure R3-2
Suggested IEC/ISO Symbols for Various Hazards

RELATED INFORMATION 4
EMO REACH CONSIDERATIONS

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R4-1 INTRODUCTION: Although SEMI S8 limits EMO button heights to 164 cm, it does not explicitly address the situation where a person must reach over, say, a work surface to reach the EMO button. The calculations shown below show one method of addressing this situation. *Other issues, besides those shown below, must also be taken into account when locating EMO buttons; see SEMI S2 and SEMI S8.*

The maximum height allowed for an EMO is determined by the following equation: (design for 5% female)

Max height = Shoulder Height + B

Max height should never exceed:

164 cm for standing station

100 cm for sitting station

Where:

A = Length of horizontal barrier to EMO

B = Distance above shoulder

C = Upper limb length for 5% female (always 51.5 cm)

And for 5% female:

Standing shoulder height = 114.0 cm

Sitting shoulder height = 46.5 cm

Ex. Standing:

$B^2 = C^2 - A^2$

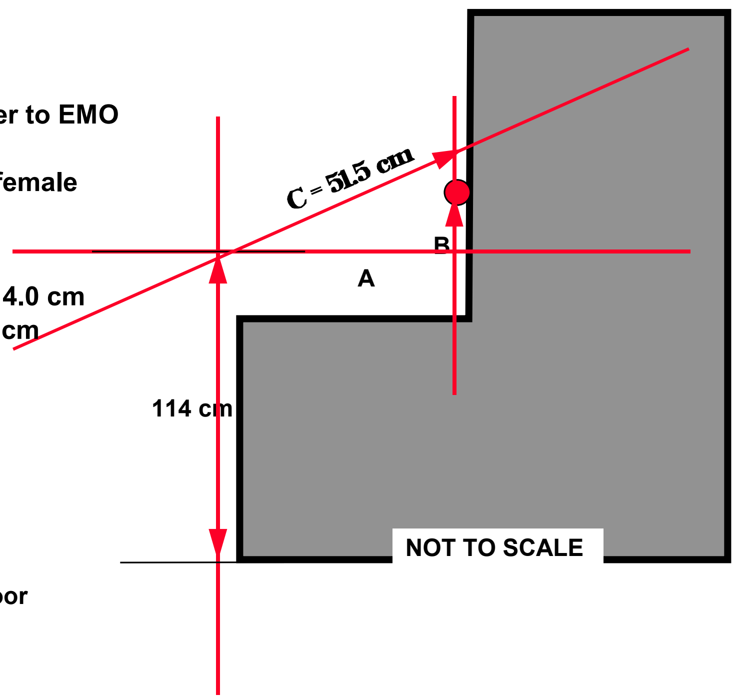
If A = 30 cm then

$B^2 = 51.5^2 - 30^2$

B = 41.8 cm

The button could be located at a maximum of:

114 + 41.8 = 155.8 cm from the floor



RELATED INFORMATION 5
SEISMIC PROTECTION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R5-1 Seismic Protection Checklist

Supporting Review Criteria for Seismic Protection of Related Components

If the answer to Questions A.1 or A.2 is "No," or the answer to any other of these questions in the checklist is "Yes," then a detailed analysis may need to be performed by a structural or mechanical engineer.

A. Equipment Anchorage

1. Have lateral force and overturning calculations been performed (see example)?
   ❑ Yes ❑ No Comments:

2. Are all modules fastened at a minimum of four points and can the fasteners support the forces identified in question 1 above?
   ❑ Yes ❑ No Comments:

3. Is it possible that there could be excessive seismic anchor movements that could result in relative displacements between points of support or attachment of the components (e.g., between vessels, pipe supports, main headers, etc.)?
   ❑ Yes ❑ No Comments:

4. Is there inadequate horizontal support?
   ❑ Yes ❑ No Comments:

5. Is there inadequate vertical supports and/or insufficient lateral restraints?
   ❑ Yes ❑ No Comments:

6. Are support fasteners inappropriately secured?
   ❑ Yes ❑ No Comments:

7. Is there inadequate anchorage of attached equipment?
   ❑ Yes ❑ No Comments:

NOTE R5-1: One way of judging whether supports, fasteners, or anchorages are "inadequate" or inappropriately secured" is to determine whether their stress levels under seismic loading stay below the allowable stress levels set by building code. Such allowable stress levels are typically a fraction < 1 of the yield strength.

B. Equipment Assembly, Installation and Operation

1. Are the materials of construction of the components susceptible to seismic damage?
   ❑ Yes ❑ No Comments:

2. Are there significant cyclic operational loading conditions that may substantially reduce system fatigue life?
   ❑ Yes ❑ No Comments:

3. Are there any threaded connections, flange joints, or special fittings?
   ❑ Yes ❑ No Comments:

4. If answer to Question 4 is "Yes," are these connections, joints, or special fittings in high stress locations?
   ❑ Yes ❑ No Comments:

5. Are there short or rigid spans that cannot accommodate the relative displacement of the supports (e.g., piping spanning between two structural systems)? Is hazardous gas piping provided with a "pigtail" (i.e., spiral) or bent 3 times (z, y, and z direction) to absorb 3-dimensional displacements?
   ❑ Yes ❑ No Comments:

6. Are there large, unsupported masses (e.g., valves) attached to components?
   ❑ Yes ❑ No Comments:

7. Are there any welded attachments to thin wall components?
   ❑ Yes ❑ No Comments:

8. Could any sensitive equipment (e.g., control valves) be affected ?
   ❑ Yes ❑ No Comments:

C. Seismic Interactions

1. Are there any points where seismically induced interaction with other elements, structures, systems, or components could damage the components (e.g., impact, falling objects, etc.)?
   ❑ Yes ❑ No Comments:

2. Could there be displacements from inertial effects?
   ❑ Yes ❑ No Comments:

R5-2 Derivation of Section 19, Seismic Load Guidelines

R5-2.1 The horizontal loadings of 94% and 63%, found in Sections 19.2.1 and 19.2.2, were based on following assumptions for factors in formula 32-2 in Section 1632.2 of the 1997 Uniform Building Code (UBC):

- a_p = 1.0 (i.e., treat the equipment as a rigid structure)
- C_a = 0.44(1.2) (i.e., seismic zone 4, soil profile type S_D, and site 5 km from a seismic source type A)
- I_p = 1.0 and 1.5 for non-HPM and HPM equipment, respectively
- h_x/h_r = 0.5 (i.e., equipment attached at point halfway between grade elevation and roof elevation)
- R_p = 1.5 (i.e., shallow anchor bolts).

Starting with equation 32-2, letting $I_p = 1.5$, and substituting the above values:

- $F_{p\ (ultimate)}$ $= [(1.0 * 0.44(1.2) * 1.5)/ 1.5]\ [1 + 3(0.5)]\ W_p$
  $= [0.44(1.2)]\ [1 + 1.5]\ W_p$
  $= [0.528]\ [2.5]\ W_p$
  $= [1.32]\ W_p$

NOTE R5-2: This number is now adjusted from ultimate strength loading to yield strength loading by dividing by 1.4:

- $F_{p\ (yield)}$ $= F_{p\ (ultimate)} / 1.4$
  $= [1.32] / 1.4\ W_p$
  $= [0.94]\ W_p$

And for $I_p = 1.0$,

- $F_{p\ (yield)}$ $= [.94]\ [1.0/1.5]\ W_p$
  $= [.63]\ W_p$

Notes re selection of a_p value of 1.0:

- Table 16-O of 1997 UBC, line 3.C., was interpreted to read: "Any *flexible* equipment..."
- in structural terms, the structure of typical semiconductor equipment is considered "rigid."

R5-2.2 *Assumptions Used for Above Derivation*

R5-2.2.1 Because typical semiconductor equipment is considered rigid, a frequency response analysis was not considered to be necessary.

R5-2.2.2 Seismic waves typically have vertical as well as horizontal components associated with them; however, these components typically arrive out of phase (i.e., they do not reach maximum values simultaneously). The vertical component serves to, in effect, reduce the amount of equipment mass that is available to resist overturning or toppling. The task force chose to take this into account by limiting the calculated weight available to resist overturning to 85% of the weight of the equipment. An alternate method, not chosen by the task force, could have been to simultaneously apply a vertical (Z) force.

R5-3 Source for Examples of Seismic Anchorage Details

R5-3.1 Detailed illustrations of examples of seismic anchorage details were developed by Working Group #9 of the Japan 300 mm ("J300") effort, and were printed in their Report No. 9 in the *2nd Lecture, ICs Factory Design for 300 mm Wafer Line Standardizing Study, December, 1996.*

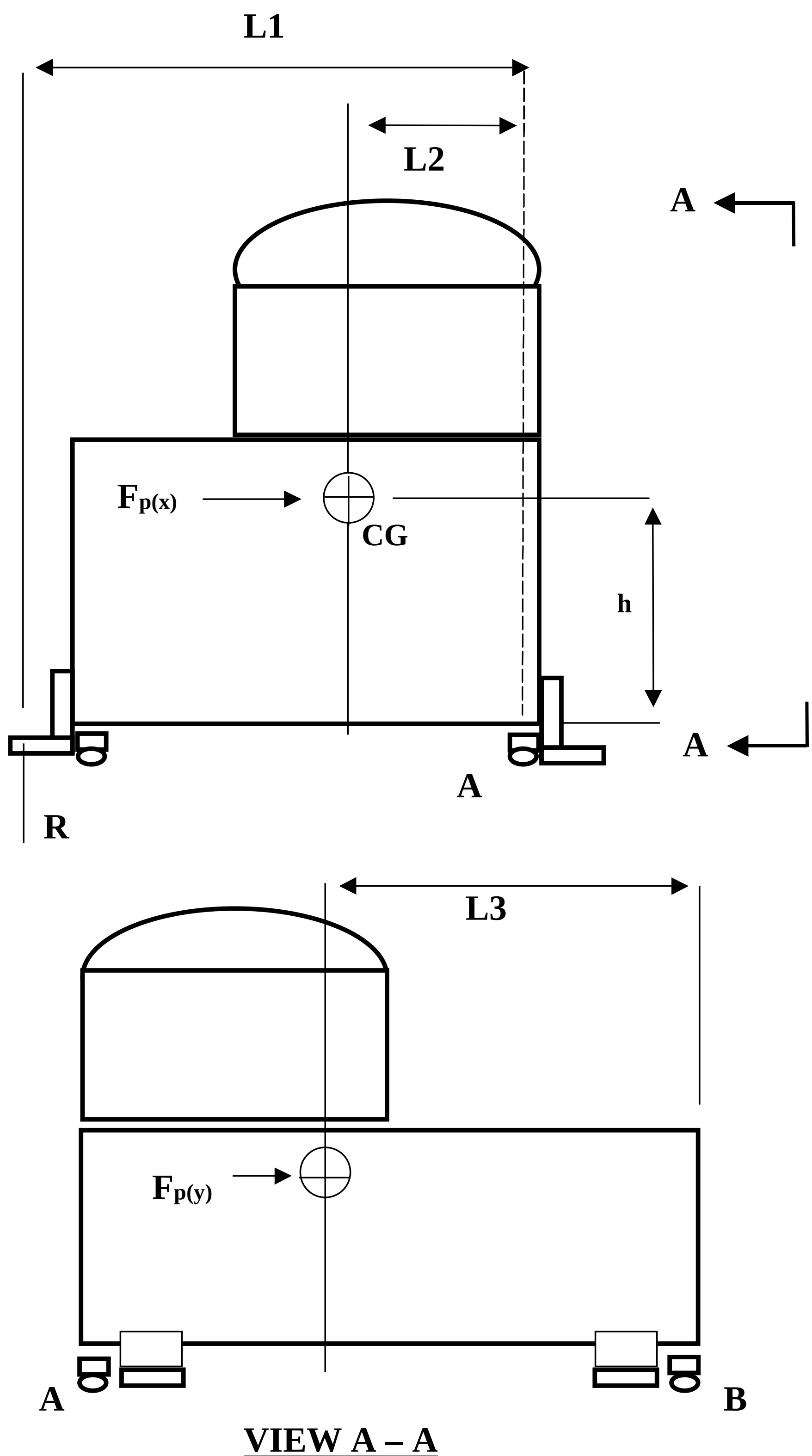


Figure R5-1
Design Example

DESIGN EXAMPLE (continued; refer to Figure R5-1 for illustration of example)

Disclaimer: the calculations below are not a complete seismic analysis. A complete analysis might also include such things as: stress distribution through a multiple-fastener connection; prying action; bearing stress; simultaneous combined stresses on the fasteners; and a review of weld geometry. A complete seismic analysis should be done by a qualified engineer.

R5-4 Calculation of Lateral Force

R5-4.1 Lateral force on each leg is equal to F_P/# of legs = $F_P/4$

R5-4.2 The lateral force acts as shear on the floor anchor fasteners and shear or tensile loading on the equipment anchor fasteners depending upon orientation. The actual reactions of the fasteners should be calculated by a qualified engineer.

R5-5 Calculation of Overturning Force

R5-5.1 Sum the moments of the reactions on the system about line through the legs A and B:

$$(CW =+)\ \sum M_{AB} = 0 = F_P(h) - 0.85W_P(L_2) - 2R(L_1) = 0$$

$$R = \frac{F_P(h) - 0.85W_P(L_2)}{2L_1}$$

$$F_P = 0.94W_P$$

$$R = \frac{W_P(0.94h - 0.85L_2)}{2L_1}$$

If 0.94h ≥ $0.85L_2$, then there is a tension reaction, R, at the two anchors, to resist overturning of system.

Example:
L1 = 50 inch
L2 = 20 inch
h= 36
W = 5000 lbs

Lateral force = Fp/4 = 0.94(5000)/4 = 1175

Overturning force = $R = \frac{W_P(0.94h - 0.85L_2)}{2L_1}$

$$= \frac{5000\,(0.94(36) - 0.85(20))}{2(50)}$$

R = 842 lbs

RELATED INFORMATION 6
CONTINUOUS HAZARDOUS GAS DETECTION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R6-1 *Scope* — This related information provides a list of gases for which continuous monitoring is recommended, and another list of gases for which continuous monitoring may be recommended depending on variables listed below. The list is not intended to be exhaustive (gases that do not appear on the list may need to be continuously monitored).

R6-2 *Intent* — The purpose of this Related Information is to provide equipment manufacturers with an indication as to what gases are currently continuously monitored by device manufacturers, as guidance for when it may be appropriate to provide an interface (see also Section 23).

R6-3 The following variables should be taken into consideration when determining the necessity for continuous monitoring:

- Chemical toxicity,
- Warning property/OEL ratio,
- Delivery pressure,
- LEL,
- Flow rate of potential leak,
- Engineering controls in place, and
- Concentration.

Monitoring Recommended	*Monitoring May Be Recommended*
	ammonia
arsine	
boron trifluoride	
	bromine
	carbon dioxide
carbon monoxide	
	carbon tetrabromide
chlorine	
diborane	
dichlorosilane	
disilane	
fluorine	
germane	
germanium tetrafluoride	
flammable mixtures containing hydrogen	
	hydrogen bromide
hydrogen chloride	
hydrogen fluoride	
hydrogen selenide	
hydrogen sulfide	
	Methane
methyl chloride	
	methyl fluoride
nitric oxide	
	nitrogen dioxide
	nitrous oxide
nitrogen trifluoride	
ozone	
phosphine	
silane	
silicon tetrachloride	
silicon tetrafluoride	
sulfur dioxide	
trichlorosilane	
tungsten hexafluoride	

RELATED INFORMATION 7
DOCUMENTATION OF IONIZING RADIATION (SECTION 24 AND APPENDIX 4) INCLUDING RATIONALE FOR CHANGES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R7-1 International Background Information

R7-1.1 *The International Atomic Energy Agency (IAEA)*

Mailing address:

P.O. Box 100
Wagramerstrasse 5
A-1400, Vienna, Austria

Telephone: (+43-1) 2060-0; Facsimile: (+43-1) 20607:
E-mail: Official.Mail@iaea.org

R7-1.2 Basic approaches to radiation protection are consistent all over the world. The International Commission on Radiation Protection (ICRP) recommends that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below the individual dose limits. The total individual dose limit for radiation workers over 5 years is 100 mSv, and for members of the general public, is 1 mSv per year. These dose limits have been established based on a prudent approach by assuming that there is no threshold dose below which there would be no effect. This hypothesis proposes that any additional dose will cause a proportional increase in the chance of a health effect. This relationship has not yet been established in the low dose range where the dose limits have been set.

R7-1.3 The ICRP and the IAEA recommend the individual dose must be kept as low as reasonably achievable and consideration must be given to the presence of other sources that may cause simultaneous radiation exposure to the same group of the public. Also, allowance for future sources or practices must be kept in mind so that the total dose received by an individual member of the public does not exceed the dose limit.

R7-2 How Does This Apply to the Semiconductor Industry?

R7-2.1 A person who can potentially be exposed to ionizing radiation during the normal course of business in excess of the annual limit for the general public should be considered a radiation worker. A radiation worker is trained to recognize and protect him or herself from the hazards of ionizing radiation. They may require exposure monitoring to determine compliance with local radiation regulations. Radiation workers are covered by a radiation safety program. A radiation safety program is an administrative control. Engineering controls minimize the need for spending resources in a large scale radiation program.

R7-2.2 The exposure limit for the radiation worker is 20 millisievert (2000 millirem) per year. Based on a 40 hour/week, 50 week/working year basis, the allowable ionizing radiation emissions are 10 microsieverts/hr (1.0 millirem/hr). This exposure rate should be evaluated as an emission rate from any accessible surface of the equipment (the closest approach to the surface that the radiation is penetrating).

R7-2.3 Maintenance technicians for radiation machines should be participants in the radiation safety program as radiation workers. The equipment should be designed to allow maintenance technicians access to areas that do not exceed 10 microsieverts/hr.

R7-2.4 Service technicians for radiation machines should be participants in their employer's radiation safety program as radiation workers. The equipment should be designed to allow service technicians access to areas that exceed the 10 microsievert per hour level when operating, but not while the radiation is present.

R7-2.5 The person operating radiation producing equipment (Operator) should not be considered a radiation worker. The emission limit for the operator accessible areas is recommended to be 20% of the occupational limit. The maximum allowable ionizing radiation emissions for operator accessible areas is recommended to be 2 microsieverts/hr (0.2 millirem/hr). This exposure rate should be evaluated as an emission rate from any surface foreseeably accessible by an operator of the equipment, and should be measured as an instantaneous rate.

R7-3 Definitions

R7-3.1 *accessible* — a significant part of the whole body, head, or eyes.

R7-3.2 *bremsstrahlung* — is radiation produced by slowing of charged particles. The term means "braking radiation."

NOTE R7-1: During design of shielding, the properties of the radiation should be considered as well as the properties of the shielding materials. Bremsstrahlung production should be minimized. Some shielding materials are considered hazardous materials. These hazardous properties should be considered and identified.

R7-3.3 *radiation machine* — means any device capable of producing ionizing radiation except those devices with radioactive material as the only source of radiation.

R7-3.4 *radiation producing machine* — is a radiation machine that produces ionizing radiation as a by-product of the process it uses, e.g., ion implanter or scanning electron microscope.

R7-3.5 *radiation worker* — "worker" means an individual engaged in radiation related work under a license or certificate of registration issued by the Agency and controlled by a licensee or registrant, but does not include the licensee or registrant.

R7-3.6 *radioactive material* – means any material (solid, liquid, or gas) that emits ionizing radiation spontaneously.

R7-3.7 *X-ray machine* — is a radiation machine that generates X-rays as a primary function of the equipment. This category of radiation machine has a specific limit due to the existence of performance standards against which the equipment is evaluated. The equipment must be below this limit to be sold in some parts of the world.

R7-3.8 *X-rays* — are produced with electricity and therefore can be turned off. X-rays seem to be the most prevalent radiation type in semiconductor manufacturing equipment. They are produced when charged particles are slowed or stopped. This slowing results in "bremsstrahlung." The majority of the equipment does not intentionally produce X-rays. This energy is a by-product of the process.

R7-4 Radioactive Materials

R7-4.1 Gamma radiation is a by-product of atomic transformations (decay) and is a release of energy from the nucleus. This radiation energy must be shielded since there is no off switch.

R7-4.2 Radioactive Materials are controlled by licensing. There are quantities of certain radioactive materials that are exempt from regulation. These sources should be identified.

R7-4.3 External radiation hazards from radioactive materials include gamma rays. These are controlled and evaluated much like the X-rays.

R7-4.4 Internal radiation hazards from radioactive materials include Alpha and Beta particles. Radioactive materials ingested or inhaled can be metabolized or damage surrounding tissue. Allowable levels of airborne radioactivity and radionuclide intakes are specified in regulations. The objective is still to maintain all exposure to ionizing radiation (internal and external) as low as reasonably achievable, but always less than the allowable regulatory limits.

RELATED INFORMATION 8
DOCUMENTATION OF NON-IONIZING RADIATION (SECTION 25 AND APPENDIX 5) INCLUDING RATIONALE FOR CHANGES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R8-1 The user of this table is responsible for obtaining the current revision of the standards cited for Occupational Exposure Limits (OEL).

R8-2 The emission values in Appendix 5 that are not to be exceeded were chosen based on a review of all known international standards as well as a consideration for best available control technology (i.e., lowest values currently achievable for each radiation type). Where a general public limit existed, 20% of this value was selected. Where there was no public limit, the value selected is generally 20% of the OEL value (instantaneous field strength measurement peak). The latter case would have the occupational and general public levels the same. Where there was an occupational exposure limit specified in a standard, the maintenance emission limit was set at 20% of this level.

R8-3 Most health standards differentiate between “occupational” and “general public” exposure criteria. IEEE C95.1 differentiates between “controlled access” and “uncontrolled access” exposures. According to C95.1 “controlled access” environments are those where “locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons, or as the incidental result of transient passage through areas where analysis shows the exposure levels may be above those shown in Table 2 but do not exceed those of Table 1, and where the induced currents may exceed the values in Table 2, Part B, but do not exceed the values of Table 1, Part B.” According to C95.1, “uncontrolled access” environments are “locations where there is the exposure of individuals who have no knowledge or control of their exposure. The exposure may occur in living quarters or workplaces where there are no expectations that the exposure levels may exceed those shown in Table 2 and where induced currents do not exceed those in Table 2, Part B.” Task force members advise that C95.1 “controlled access” and other “occupational exposure” standards should be applied to personnel performing maintenance and service of equipment and that “uncontrolled access” or other “general public” standards should be applied to equipment operators during routine work and to other locations. These IEEE definitions are particularly relevant to broadcast facilities as well as normal industrial environments such as fabs. Task force members recommend that uncontrolled access limits be applied to fetal exposure.

R8-4 As with the rationale in the Ionizing section, the operator is considered a member of the general public or to be in an uncontrolled area. Maintenance or service technicians should be trained to know how to control the hazardous energy and protect themselves from the hazard and its adverse effects.

R8-5 *References*

1. 1996 TLVs and BEIs Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices, ACGIH, Cincinnati, OH
2. Guidelines on Limits of Exposure to Broad-Band Incoherent Optical Radiation (0.38 to 3 µM), Health Physics Vol. 73, No. 3 (September), pp.539-554, 1997
3. ICNIRP 1994 “Guidelines on Limits of Exposure to Static Magnetic Fields”, Health Physics Vol 66 (1) (January), pp. 100-106, 1994
4. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1-1991, Piscataway, New Jersey
5. Interim Guidelines on the Limits of Exposure to 50/60 Hz Electric and Magnetic Fields, IRPA/ICNIRP Guidelines, Health Physics Vol. 58, No. 1(January), pp. 113-122, 1990

RELATED INFORMATION 9
LASER CHECKLIST

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Laser Manufacturer: ________________________________

Model #: ________________________________

Serial #: ________________________________

Laser Hazard Classification: (During Operation)

1. Classification Number (e.g. 1, 2, 3a, 3b, 4): ________
2. Classification Standard(s) (e.g. FDA/CDRH, IEC, JIS, etc.): ________

NOTE R9-1: If any laser contained in the equipment is Class 2, 3a, 3b or 4 laser system or product, the vendor should make available upon request a hazard evaluation to include the following information for each laser in the equipment (where applicable):

Laser Parameters

1. Laser medium type (HeNe, Nd:YAG, CO_2, Argon, Excimer, GaAs, etc.): __________

Note: For Excimer lasers, specify gases: _______________

2. Wavelength(s) in nanometers (nm): _______________

3. Continuous Wave

A. Peak Power in Watts (W): ________

B. Available Power in Watts (W): ________

C. Irradiance in Watts/square centimeter (W/cm^2): _ ________

4. Pulse Characteristics

A. Duration of Pulse in Seconds (s): ________

B. Energy per Pulse in Joules (J): ________

C. Frequency of Pulses (Pulse Repetition Frequency) in Hertz (Hz): ________

D. Average Power in Watts (W): ________

E. Radiant Exposure in Joules/square centimeter (J/cm^2): ________

F. Q-Switch controlled pulses ( ) Yes ( ) No

5. Beam Parameters

A. Emerging beam diameter in millimeters (mm): ________

B. Expanded beam diameter in millimeters (mm): ________

C. Beam divergence in milliradians (mr): ________

D. Collecting optics type: ________

E. Focal length in millimeters (mm): ________

Laser Control Measures

1. Identify protective measures required during maintenance. __________________

____

2. Laser Controlled Area required for Maintenance procedures? ( ) Yes ( ) No

3. Laser Controlled Area required for Service procedures. ( ) Yes ( ) No

4. If a Nominal Ocular Hazard Distance (NOHD) is used as a control measure, then provide the NOHD calculations. See IEC 60825-1 for NOHD calculations.

NOTE R9-2: Attach a diagram of the laser beam path and the irradiance/radiant exposure at each significant point.

Personnel Protective Equipment (PPE) (for laser radiation hazards in excess of the MPE)

1. Optical Density (OD) of PPE required during maintenance activities: ___________

2. OD of PPE required during service activities: ___________

3. Recommended PPE manufacturer and model #: ______________________________

Table R9-1 Equipment Safety Features

Equipment Safety Features (not an inclusive list)			*USA*	*Europe*	*Japan*	
			21 CFR 1040.10	*EN 60825-1*	*JIS 6802*	
			Paragraph	*Paragraph*	*Paragraph*	*Examples*
1.	Protective Housing	( ) Yes ( ) No	(f)(1)	4.2	4.2.1	Aluminum or steel enclosures, windows that provide adequate attenuation, optical fibers or beam tubes.
2.	Safety Interlocks	( ) Yes ( ) No	(f)(2)	4.3	4.2.2	See Section 11 of SEMI S2.
3.	Remote Interlock Connector	( ) Yes ( ) No	(f)(3)	4.4	4.2.3	Usually a 12 to 24 volt set of contacts available to the user to integrate additional room control measures.
4.	Key Control	( ) Yes ( ) No	(f)(4)	4.5	4.2.4	A key that is not removable in the operations mode.
5.	Laser Radiation Emission Warning	( ) Yes ( ) No	(f)(5)	4.6	4.2.5	A light or indicator that warns the user of the emission through the aperture.
6.	Beam Attenuator	( ) Yes ( ) No	(f)(6)	4.7	4.2.6	Shutters, beam blocks or water-cooled beam dumps
7.	Location of Controls	( ) Yes ( ) No	(f)(7)	4.8	4.2.7	
8.	Viewing Optics	( ) Yes ( ) No	(f)(8)	4.9	4.2.8	Must block all hazardous wavelengths to acceptable levels.

Equipment Safety Features (not an inclusive list)			*USA*	*Europe*	*Japan*	
			21 CFR 1040.10	*EN 60825-1*	*JIS 6802*	
			Paragraph	*Paragraph*	*Paragraph*	*Examples*
9.	Scanning Safeguard	( ) Yes ( ) No	(f)(9)	4.10	4.2.9	Shuts down if the scanning mechanism (such as a rotating mirror or galvanometer) fails.
10.	Manual Reset Mechanism	( ) Yes ( ) No	(f)(10)	4.3.1	4.2.2(c)	A button or circuit that must be energized before the equipment resumes its functions.
11.	Class Designation & Warning Labels	( ) Yes ( ) No	(g)	5	4.3	Identify which standard was used for each hazard classification.
12.	Aperture Label	( ) Yes ( ) No	(g)(5)	5.7	4.3.7	Identify the aperture.
13.	Positioning of Labels	( ) Yes ( ) No	(g)(9)	5.1	4.3.1	Conspicuous, but size is not specified.
14.	User Information	( ) Yes ( ) No	(h)(1)	6.1	4.4.1	SOPs, instruction manuals
15.	Service Information	( ) Yes ( ) No	(h)(2)	6.2	4.4.2	Accessible laser radiation levels during Service
16.	Measurements	( ) Yes ( ) No	(e)	8	3.4	
17.	Classification	( ) Yes ( ) No	(c)	9	3.3.3	
18.	Certification Information		21 CFR	TBD by Europe	TBD by Japan	
19.	Certification Label	( ) Yes ( ) No	1010.2			
20.	Identification Label	( ) Yes ( ) No	1010.3			

RELATED INFORMATION 10
LASER CERTIFICATION REQUIREMENTS BY REGION OF USE

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Table R10-1 Regional Laser Standards

	USA	*Europe*	*Japan*	*Pacific Rim*
Classification Standards	21 CFR 1040.10	EN 60825-1	JIS C 6802	IEC 60825-1
Certification Standards	21 CFR 1000-1010	TBD	TBD	TBD

R10-1 USA

Food and Drug Administration (FDA)
Center for Devices and Radiological Health (CDRH)

R10-1.1 Laser products must comply with the performance requirements of Title 21 of the Code of Federal Regulations Part 1040.10 (21 CFR 1040.10). Manufacturers (including modifiers) of laser products must certify to the FDA/CDRH in writing that the product complies with the requirements of 21 CFR SubChapter J.

R10-1.2 The reporting requirements are detailed in 21 CFR 1000–1010. Product report forms and the guidance document are available from the CDRH. These documents should soon be available from the CDRH Web server at:

http://www.fda.gov/cdrh

R10-1.3 The CDRH Office of Compliance can be reached by telephone at (301) 594-4654

R10-1.4 The CFR references may be obtained by searching the website at:

http://www.access.gpo.gov/nara/cfr/cfr-table-search.html

but these documents do not include figures or tables.

R10-1.5. When a laser product is imported, the importing company is considered the laser manufacturer and must certify the laser product.

R10-2 Europe

International Electrotechnical Commission (IEC)

R10-2.1. European governments have adopted IEC 60825-1 as the laser product safety standard. Manufacturers of laser products should comply with Section 2 of the IEC 60825-1 document. An IEC committee is currently working on a checklist for laser product manufacturers to follow to assess compliance with the IEC document. Other IEC 60825 series documents may apply to the product either now or in the future.

R10-2.2. EN 60825-1 is the normative standard, which has been adopted by the European Union and EFTA countries.

R10-2.2.1 The EN 60825-1 should be available through the various European government agencies or government printing offices.

R10-2.3. The laser product manufacturer should review ISO 11553 for requirements that apply to laser equipment that processes materials.

R10-2.4. The IEC document can be obtained from:

International Electrotechnical Commission
3, rue de Varembé • PO Box 131
1211 Geneva 20 • Switzerland
Tel: +41 22 919 02 11 • Fax: +41 22 919 03 00

or other participating national standards association (available on websites).

R10-2.5. The ISO document can be obtained from:

International Standards Organization (ISO)
1, rue de Varembé
Case postale 56
CH-1211 Genève 20
Switzerland
Telephone: + 41 22 749 01 11
Telefax: + 41 22 733 34 30

or other participating national standards association (available on websites).

R10-2.6 The IEC Website is located at:
http://www.iec.ch

R10-2.7 The ISO Website is located at:
http://www.iso.ch/

R10-3 Japan

R10-3.1. The Japanese Safety Association published an English version of the Japanese laser safety standard based on the IEC 60825 series document. This standard is Japanese Industrial Standard (JIS) C 6802. The Japanese version is still the official standard, but the English version has the warning hazards described with the Japanese symbols in the images.

R10-3.2. As in the IEC document the manufacturing requirements are specified in Section 2. There is a companion document JIS C 6801 that provides the Glossary of terms and their translations into English.

R10-3.3. The JIS documents can be obtained through the Japanese Safety Association.

R10-3.4. Japanese Standards Association
1-24 Akasaka 4
Minato-Ku
JP-107 TOKYO
TP: +81 3 3583 80 03
TF: +81 3 3586 20 29
http://www.jsa.or.jp/eng/catalog/frame.html is searchable

R10-3.5. Websites:
(In English) http://www.hike.te.chiba-u.ac.jp/ikeda/JIS/index.html
(In Japanese) http://www.jsa.or.jp

R10-4 Other (e.g., Pacific Rim)

R10-4.1 The manufacturer is responsible to determine the appropriate standard to use in other countries.

R10-4.2 In the absence of any specific standard for a country, the IEC 60825-1 document should be used as the guide for compliance

R10-4.3 In many countries, prefectures, states, or provinces, local laser safety regulations exist. Much of this regulation is aimed at the user, but may include product performance requirements. The manufacturer has the responsibility to identify these requirements.

R10-4.4 Addresses of many national standards organizations are found at:

http://www.iec.ch/cs1sot-e.htm

RELATED INFORMATION 11
OTHER REQUIREMENTS BY REGION OF USE

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R11-1 *Japan* — Earth Leakage Breaker/Ground Fault Circuit Interrupter/Ground Fault Equipment Protection Circuit Interrupter/ Residual Current Devices

R11-1.1 Japanese regulations may require the use of Ground Fault Circuit Interrupter (GFCI), Ground Fault Equipment Protection Circuit Interrupter (GFEPCI), Residual Current Devices (RCD), or Earth Leakage Breaker (ELB) with the equipment.

EXCEPTION 1: The rating of the equipment is less than 20 amperes and less than 150 volts rms.

EXCEPTION 2: The equipment is supplied from the ungrounded secondary of an AC mains isolation transformer.

R11-1.2 The GFCI, GFEPCI, RCD or ELB, when required to satisfy Japanese requirements, should have trip ratings of not greater than 30 mA and 0.1 second.

EXCEPTION 1: If there is no accessible live circuit during maintenance tasks, trip ratings of up to 300 mA are acceptable.

EXCEPTION 2: If the equipment satisfies Exception 1 and the earth impedance is less than 50 ohms, a GFCI, GFEPCI, RCD or ELB of 500 mA maximum is acceptable.

EXCEPTION 3: If the equipment is connected to a source of supply that is provided with a GFCI, GFEPCI, RCD or ELB, an additional GFCI, GFEPCI, RCD or ELB is not required for the equipment.

R11-2 *USA*

R11-2.1 *Nameplates* — In addition to the nameplate requirement noted in the Electrical section of S2, equipment evaluated as "Industrial Machinery" per NFPA 79 and intended for use in the United States may be required to display additional nameplate information, such as ampere rating of the largest motor or load, short circuit interrupting capacity of the machine overcurrent protective device where furnished as part of the equipment, and the electrical diagram number(s) or the number of the index to the electrical diagrams. Furthermore, where overcurrent protection is provided, the equipment must be marked "overcurrent protection provided at machine supply terminals."

R11-2.1 *Hazard Communication* — Federal government OSHA regulations, found in 29 CFR 1910.1200, establish various requirements for labeling of containers of hazardous chemicals and providing Material Safety Data Sheets.

R11-3 *Europe*

R11-3.1 *Nameplates* — In addition to the nameplate requirement noted in the Electrical section of S2, equipment evaluated as "Industrial Machinery" per IEC 60204-1 (EN 60204-1) and intended for use in Europe may be required to display additional nameplate information, such as: certification mark, where required; current rating of the largest motor or load; short-circuit interrupting capacity of the machine overcurrent protective device, where furnished as part of the equipment; and the electrical diagram number(s) or the number of the index to the electrical drawings.

R11-3.1.1 Where only a single motor controller is used, this information may instead be provided on the machine nameplate where it is plainly visible.

R11-3.1.2 The full-load current shown on the nameplate shall be not less than the combined full-load currents for all motors and other equipment that can be in operation at the same time under normal conditions of use. Where unusual loads or duty cycles require oversized conductors, the required capacity shall be included in the full-load current specified on the nameplate.

R11-3.2 European Union requires compliance to CE marking.

R11-4 *Worldwide* — Hazard Alert Labels

R11-4.1 *USA* — Labels intended for use in the USA should conform to ANSI Z535.4.

R11-4.2 *Other Countries* — Labels intended for use in countries other than the USA should conform to ISO 3864.

RELATED INFORMATION 12
LIGHT TOWER COLOR AND AUDIBLE ALERT CODES

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

R12-1 Colors for Light Towers

R12-1.1 Where used for safety, a light tower should have the following characteristics:

Table R12-1 Light Tower Color Code

Color	*Explanation*	*Examples*
Red	Hazardous, dangerous or abnormal condition requiring immediate attention	Pressure/temperature out of safe limits; Voltage drop; Breakdown Overtravel of a stop position Indication that a protective device has stopped the machine, e.g., overload
Yellow	Abnormal, caution/marginal condition; Change or impending change of critical condition requiring monitoring and/or intervention (e.g., by re-establishing the intended function)	Pressure/temperature exceeding normal limits Tripping of protective device Automatic cycle or motors running; some value (pressure, temperature) is approaching its permissible limit. Ground fault indication. Overload that is permitted for a limited time.
Green	Normal condition; machine ready	Pressure/temperature within normal limits Indication of safe condition or authorization to proceed. Machine ready for operation with all conditions normal or cycle complete and machine ready to be restarted.

R12-2 Audible Alert (Buzzer) Code

R12-2.1 Where used for safety, audible alert (buzzer) for the light tower should have the following characteristics:

Table R12-2 Light Tower Buzzer Code

Color	*Audible Alert (Buzzer)*
Red	Continuous
Yellow	Intermittent
Green	Intermittent/no sound (selectable)

RELATED INFORMATION 13
SURFACE TEMPERATURE DOCUMENTATION

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

The following is some of the research leading to the values in Table 1 in Section 18 of this guideline.

R13-1 The proposed Hazardous Temperature Limits were derived from UL1950[11] and IEC950[12] by adding ambient temperature (25°C) to the maximum temperature rise allowed for external parts of information technology equipment. Because several SEMI members have questioned whether these limits might subject operators and maintenance personnel to contact with potentially hazardous temperatures, a review has been done of several other sources of suggested temperature limits.

R13-2 The proposed hazardous surface temperatures for handling and touching of metal handles, knobs, etc., for brief periods in normal use is 60°C. Assuming a brief handling time to be 5 seconds or less, this limit is supported in MIL-STD-1472[13], MIL-HDBK-759A[14] and EN563[15] (which are the same or more conservative by 2°C), and is equal to the pain and tissue damage threshold listed in the Human Factors Design Handbook[16]. Thus, this temperature limit seems appropriate for momentary (five seconds or less) contact with uncoated metal handles, knobs, etc., and other material with high thermal conductivity.

R13-3 The proposed hazardous surface temperatures for handling and touching of glass/porcelain handles, knobs, etc., for brief periods in normal use is 70°C. This temperature limit is supported by MIL-STD-1472 and EN563. MIL-HDBK-759 is not applicable because it must be assumed that it applies only to material with high thermal conductivity.

R13-4 The proposed hazardous surface temperatures for handling and touching of plastic/rubber handles, knobs, etc., for brief periods in normal use is 85°C. This temperature limit is similarly supported by MIL-STD-1472 and EN563. MIL-HDBK-759 is not applicable.

R13-5 The proposed hazardous surface temperatures for continuous handling and touching of metal handles, knobs, etc., during normal usage is 55°C. It is suggested, based on observations of semiconductor equipment in use, that a continuous handling time of one minute be used. With this duration, the limit of the MIL-STD and the MIL-HDBK ranges from 49 to 52°C. The EN563 burn threshold limit for contact with metal for one minute is 51°C. The burning heat pain level listed in the Human Factors Design Handbook is 49°C (no time frame given; assume high thermal conductivity material). Thus, the proposed temperature limit appears to be somewhat high for reasonably foreseeable extended handling contact with uncoated metal handles, knobs, etc., and other material with high thermal conductivity. The Section 18 Table 1 limit is 51°C, which might be somewhat painful to more sensitive personnel, but should not result in tissue damage.

R13-6 The proposed hazardous surface temperatures for extended handling and touching of glass/porcelain handles, knobs, etc., during normal usage (again assuming 1 minute) is 65°C. The limit of MIL-STD-1472D is 59°C for "prolonged contact" with glass. The EN563 burn threshold limit at 1 minute is 56°C. Thus, the proposed temperature limit appears to be slightly high for reasonably foreseeable extended handling contact with glass/porcelain surfaces of moderate thermal conductivity. The Section 18 Table 1 limit is 56°C, which is the more conservative of the recommendations. This limit could be raised based upon the results of the risk assessment for actual and foreseeable normal usage.

R13-7 Similarly, the proposed hazardous surface temperatures for extended handling and touching of plastic/rubber handles, knobs, etc., during normal usage (again assuming 1 minute) is 75°C. The limit of MIL-STD-1472D is 69°C for "prolonged contact" with plastic. The EN563 burn threshold limit at 1 minute is 60°C. Thus, the proposed temperature limit again appears to be slightly high for reasonably foreseeable extended handling contact with plastic/rubber surfaces of low thermal conductivity. The Section 18 Table 1 limit is 60°C, which is the more conservative of the recommendations. This limit could be raised based upon the results of the risk assessment for actual and foreseeable normal usage.

R13-8 The proposed hazardous surface temperatures for external surfaces and internal parts which may be

11 UL 1950, Safety of Information Technology Equipment, 1989 (Underwriters Laboratory Standard).

12 IEC 950, Safety of Information Technology Equipment, 1986 (International Electrotechnical Commission Standard).

13 MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment & Facilities (Military Standard).

14 MIL-HDBK-759A, Handbook for Human Engineering Design Guidelines, 1981 (Military Handbook).

15 EN 563, Safety of Machinery – Temperatures of Touchable Surfaces, 1994 (European Normative Standard).

16 Human Factors Design Handbook, Second Edition, Woodson, Tillman & Tillman, 1992 (Reference).

touched are 70°C for metal, 80°C for glass/porcelain, and 95°C for plastic/rubber. It is assumed that this limit applies to inadvertent touching by the operator/maintenance person, resulting in the person instantly breaking contact with the hot surface. There are no analogs in either the MIL-STD or the MIL-HDBK for these temperature limits. The EN563 burn threshold range for one-second contact with uncoated metal is 65 to 70°C, while the range for one-second contact with glass is 80 to 86°C. The proposed temperature limit appears to be slightly high for reasonably foreseeable inadvertent contact with external metal surfaces. The Section 18 Table 1 limit for contact with external metal surfaces is 65°C, which is the conservative end of the EN563 range.

R13-9 No information was available to support or refute the temperature limits for contact with external plastic/rubber surfaces. With regard to internal parts, the proposed temperature limits may be adequate given the foreseeable cooling which would likely occur prior to handling of internal parts. The actual thermal lag of components likely to be handled could be verified by thermocouple readings on specific equipment during a risk assessment.

Table R13-1 Allowable Surface Temperatures (°C) for Handles, Knobs, Grips, etc., Held for Short Periods Only (5 seconds or less)

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	58	70	n/a
MIL-STD-1472	60	68	85
MIL-HDBK-759	60	n/a	n/a
Section 18 Table 1 Value	60	70	85

Table R13-2 Allowable Surface Temperatures (°C) for Handles, Knobs, Grips, etc., Held in Normal Use

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	51	56	60
MIL-STD-1472	49	59	69
MIL-HDBK-759	52	n/a	n/a
Section 18 Table 1 Value	51	56	60

Table R13-3 Allowable Surface Temperatures (°C) for External Surface of Equipment Which May Be Momentarily Touched

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	65-70	80-86	n/a
MIL-STD-1472	n/a	n/a	n/a
MIL-HDBK-759	n/a	n/a	n/a
Section 18 Table 1 Value	65	80	95

Table R13-4 Allowable Surface Temperatures (°C) for Parts, Inside the Equipment, Which May Be Momentarily Touched

	Metal	*Glass, Porcelain, Vitreous Material*	*Plastic, Rubber*
EN563	n/a	68	85
MIL-STD-1472	n/a	n/a	n/a
MIL-HDBK-759	n/a	n/a	n/a
Section 18 Table 1 Value	65	80	95

SEMI

SEMI S3-91
SAFETY GUIDELINES FOR HEATED CHEMICAL BATHS

NOTICE: These guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 Purpose/Scope

This safety guideline pertains to open top heated chemical baths, or “wet stations”, used in the manufacturing of semiconductors. The purpose of this guideline is to provide general safety information for the construction, operation, and maintenance of chemical baths heated by electric immersion, externally bonded or heat exchange type heating devices. This guideline is not intended to provided detailed design information for the individual components of the heating systems, but rather to supply the safety criteria for the design of these systems. (See Figure 1.)

2 Introduction

2.1 Failure to follow the manufacturer’s instructions as to the application or installation of heating systems used for chemical baths can result in accidents and fires in which such systems may be implicated.

2.2 The human element plays a major role in how well the hardware is used. The user of heated chemical bath systems needs to understand the available technology to minimize the risk involved.

2.3 The issue of bath operation and maintenance has been included in this guideline to support the safe use and maintenance of heated baths over their normal service life.

3 Heated Bath Methodology

3.1 *Electric Immersion Heaters* — Electric immersion bath heaters are resistive element heaters. The element itself is typically protected by an outer sheathing which acts as a corrosion and electrical barrier. The element is mounted to the inside of the bath.

3.2 *External Tank Heaters* — External type heaters are normally bonded by a mastic to the outside of a chemical bath. The most common types are manufactured from a thin metal foil material that results in a very low profile configuration.

3.3 *Heat Exchangers* — The most common type of heat exchanger employs a separate heating source that may be remote from the station. This heating source can be electrically powered to generate steam or some other heat transfer fluid. The heat transfer fluid is then delivered by chemically compatible plumbing to the bath and recirculated to the heater.

4 Minimum Heated Bath Safety Requirements

To ensure the safe operation and maintenance of heating systems, the following features are required.

- overcurrent protection
- power interrupt
- manual reset
- automatic temperature controller
- liquid level sensor
- overtemperature protection
- proper grounding and ground fault protection
- compatible construction materials

NOTE: Interlocks should operate as outlined in SEMI S2. These features should be totally compatible with each other.

4.1 *Overcurrent Protection* — A fused disconnect switch or circuit breaker sized for the amperage of the heater.

4.2 *Power Interrupt* — In the event of an overtemperature, low liquid level, or ground fault condition, power to the heater(s) is interrupted upon receiving the respective signal. The interrupt should be separate from any relay incorporated into the automatic temperature controller. The interrupt should be wired in such a manner that any signal from the liquid level sensor, overtemperature sensor, or ground fault condition should shut off power to the heaters and place the system in a “fail safe” condition.

4.3 *Manual Reset* — This reset should be incorporated into the power interrupt device so that when the system shuts off power to the heating element, a manual reset is required to re-energize the system.

4.4 *Automatic Temperature Controller* — An automatic temperature controller maintains the liquid at a set temperature by turning the heating element on and off. The controller is activated by signals from a sensor that is located at the bath. To preserve the integrity of this system, quarterly service/testing and calibration in accordance with the manufacturer's recommendations should be performed.

4.5 *Liquid Level Sensor* — This sensor will act to shut down the heating element if the liquid level falls below a safe operating level. When employing either an immersion or externally mounted type heater, it is recommended that this level be no less than five centimeters (two inches) above the heating element's "hot zone" as established by the manufacturer. This should prevent the element from losing the heat sink created by the liquid.

4.5.1 The selection of a suitable sensor should take into account:

4.5.1.1 The physical properties of the liquids being heated and the environmental conditions to which the sensor(s) will be subjected.

4.5.1.2 The mode of failure, if the sensor fails.

4.5.2 To preserve the integrity of these components, they should be tested on a quarterly basis and serviced following the manufacturer's recommendations.

4.6 *Overtemperature Protection*

4.6.1 *Liquid Overtemperature* — A dedicated liquid overtemperature sensor should typically be set to trip at a temperature below the autoignition temperature of the chemical being used in the bath, and in no case higher than 10°C (18°F) above the normal operating temperature.

4.6.1.1 This temperature setting should compensate for the initial over-shoot often encountered when bringing the liquid from ambient to operating temperature.

4.6.1.2 The sensor should be located in the liquid at an elevation approximating the top of the heating elements "hot zone" and no more than seven centimeters (three inches) away from the heater.

4.6.2 *Heating Element Overtemperature* — When using an electrical immersion type heater, a sensor should be used to shut down the heating element if the surface temperature of the element exceeds a preset value. The sensor is typically placed between the resistance coil and the protective sheath covering.

4.7 *Proper Grounding & Ground Fault Protection* — The amount of insulation surrounding a heater element depends upon the type of heater. This insulation not only provides protection from the corrosive properties of the solution, but also acts as an electrical barrier. If the barrier breaks down, it is possible for the solution to become energized.

4.7.1 The electric heater elements should be equipped with a ground, the construction of which should be approved by a nationally recognized testing laboratory (NRTL).

4.7.2 A ground fault circuit interrupter (GFCI) should be used to preclude worker exposures to potential electrical shock.

4.7.3 The station or equipment in which the heated bath will be used needs to be reviewed to ensure that all National Electrical Code requirements have been addressed.

4.8 *Compatible Construction Materials* — All portions of the station that could come in contact with process chemicals should be constructed from materials compatible with these chemicals. It is recommended that metal materials be used in the station's construction when using combustible or flammable solutions.

5 Operation and Maintenance

5.1 Before heated baths are put into service, a detailed review of the wet station operation and maintenance should be conducted for all employees operating or servicing the station. New employees should receive the same information prior to work assignment.

5.1.1 All safety features included with the station's heating system should be user tested, and the frequency of testing should be noted in the user's periodic maintenance procedures.

NOTE: Recommended minimum frequency of testing is quarterly and after any station maintenance.

5.1.2 Vendor-supplied information on the bath operation and limitations that may apply should be reviewed and appropriate employee training conducted.

5.1.3 When the user plans to install the baths and to perform maintenance, the suppliers should provide guidance to ensure that all aspects of the system, such as the controller and the heated bath safety systems, are integrated properly.

5.1.4 Review the process requirements to ensure that operating temperatures are within the range and capability of the safety controls. For flammable and combustible liquids, operating temperatures should be below the ignition temperature.

5.1.5 Limit the interchanging of parts that were not included in the original design unless so advised by the supplier. Alternate parts can lead to failures resulting in a fire or physical injury.

6 Related Documents

6.1 UFC 1988 edition.

6.2 OSHA Safety & Health Standards (29 CFR 1910).

6.3 Joseph Lotti, "Electric Immersion Heater Redundant Control System", presented to Semiconductor Safety Association Annual Conference, May 1986.

6.4 Factory Mutual Insurance Corporation, "Plastics and Plastic-Lined Tanks with Electric Immersion Heaters," 7-6.

6.5 National Electrical Code, "Articles 500, 501, Hazardous Locations," latest edition.

6.6 National Electrical Code, "Articles 250, 422, 427, and 516, Grounding, Appliances, Fixed Electrical Heating for Pipe Lines and Vessels and Spray Application, Dipping and Coating Processes."

6.7 SEMI S2, Safety Guidelines for Semiconductor Manufacturing Equipment.

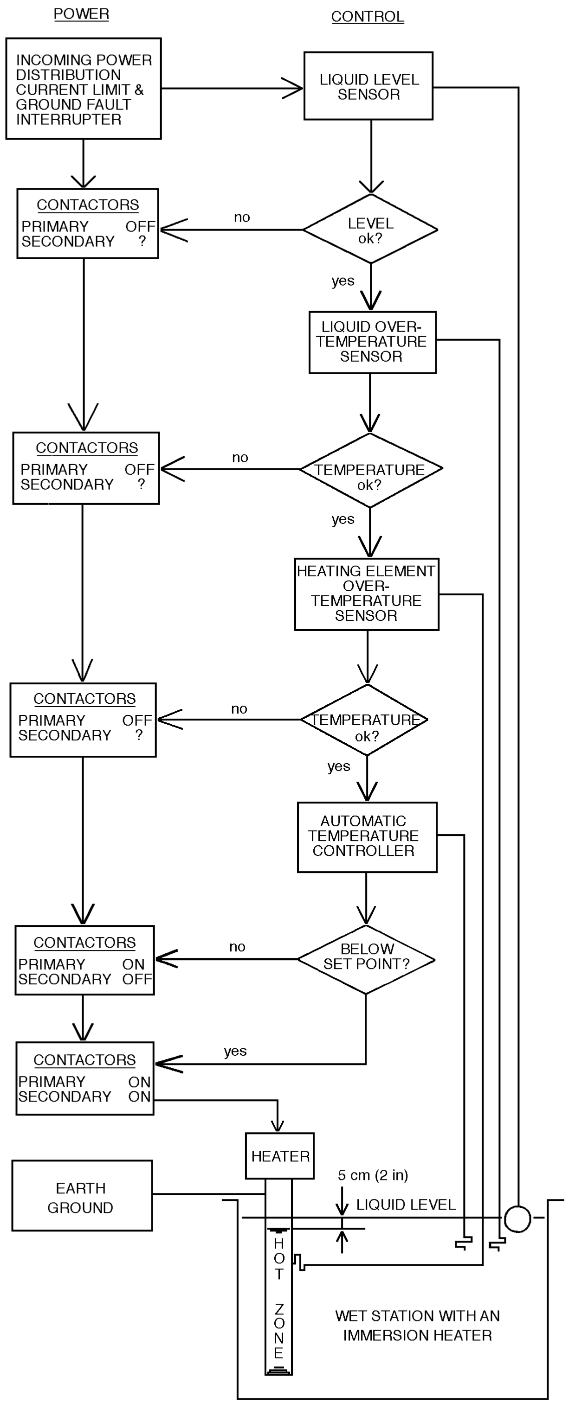

POWER
CONTROL
INCOMING POWER DISTRIBUTION CURRENT LIMIT & GROUND FAULT INTERRUPTER
LIQUID LEVEL SENSOR
CONTACTORS
PRIMARY OFF
SECONDARY ?
no
LEVEL ok?
yes
LIQUID OVER-TEMPERATURE SENSOR
CONTACTORS
PRIMARY OFF
SECONDARY ?
no
TEMPERATURE ok?
yes
HEATING ELEMENT OVER-TEMPERATURE SENSOR
CONTACTORS
PRIMARY OFF
SECONDARY ?
no
TEMPERATURE ok?
yes
AUTOMATIC TEMPERATURE CONTROLLER
CONTACTORS
PRIMARY ON
SECONDARY OFF
no
BELOW SET POINT?
CONTACTORS
PRIMARY ON
SECONDARY ON
yes
HEATER
EARTH GROUND
5 cm (2 in)
LIQUID LEVEL
HOT ZONE
WET STATION WITH AN IMMERSION HEATER

Figure 1

NOTICE: These guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of these guidelines is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These guidelines are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI S4-92
SAFETY GUIDELINE FOR THE SEGREGATION/SEPARATION OF GAS CYLINDERS CONTAINED IN CABINETS

NOTICE: This guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: The configuration generally considered to be the best is **one cylinder of process gas per gas cabinet.** An inert gas may be in the same cabinet with a process gas.

1 Purpose

This safety guideline provides the method for determining which types of gas (in cylinders) should be maintained in separate gas cabinets and which types may be combined with other types. The guideline is designed to be used by those working or doing research in semiconductor-related technology, but the application is not limited to this field. The guideline also recommends a classification scheme which is consistent with that given by Federal OSHA in 29 CFR 1910.1200.

2 Scope

This guideline refers to gases; however, it also includes those materials stored in cylinders as liquids and used in gaseous form because of their vapor pressure, or because they may be transported as a vapor by a carrier gas. It also includes all sizes and types of cylinders. It does not include those special cases where cylinder gases are incorporated within a specific piece of process equipment as a part of the equipment, such as lecture bottles. The primary intent of the guideline is directed to a cylinder gas in use in, or being dispensed in, the manufacturing process. Mixtures of two or more gases should be considered to have the hazardous properties of their individual components. If the dilution of the hazardous component removes the hazard, the mixture may then be classified according to its actual characteristics.

3 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *29 CFR 1910.1200* — Published by The Office of the Federal Register, Washington, D.C. 20037.

3.2 *49 CFR 172.101* — Published by The Office of the Federal Register, Washington, D.C. 20037.

3.3 *49 CFR 173* — Published by The Office of the Federal Register, Washington, D.C. 20037.

3.4 *16 CFR 1500* — Published by The Office of the Federal Register, Washington, D.C. 20037.

3.5 *Uniform Fire Code* — Published by International Conference of Building Officials and Western Fire Chiefs Association.

3.6 *Identification of Fire Hazards of Materials* — NFPA 704, National Fire Protection Association.

3.7 *Hazardous Chemicals Data* — NFPA 49, National Fire Protection Association.

3.8 *BOCA National Fire Prevention Code* — Published by Building Officials and Code Administration.

3.9 *SBCCI Standard Fire Prevention Code* — Published by Southern Building Code Conference International, Inc.

3.10 *Matheson Gas Data Book* — 6th Edition, 1988.

3.11 *Gases for the Electronics Industry* — 1988 Edition, Distributed by Union Carbide Corporation.

4 Related Documents

4.1 *Safe Handling of Compressed Gas in Containers* — Compressed Gas Association, Pamphlet P-1, CGA.

4.2 *Uniform Building Code* — Published by International Conference of Building Officials.

4.3 *Dangerous Properties of Industrial Materials* — N. Irving Sax, Seventh Edition, 1988.

4.4 *A Gas Cabinet Standard for Use by the Electronics Industry* — L. Fluer, 1981.

5 Terminology

5.1 *cylinder* — Pressure vessel designed for containing chemicals at a pressure higher than 276 kPa (40 psia) and having a circular cross section. It does not include a portable tank, multiunit tank car tank, cargo tank, or tank car.

5.2 *acid* — A corrosive material whose chemical reaction characteristic is that of an electron acceptor.

5.3 *base* — A corrosive material whose chemical reaction characteristic is that of an electron donor.

5.4 *corrosive* — A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. A chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described in the U. S. Department of Transportation in Appendix A to 49 CFR 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces.

5.5 *flammable gas* — A gas which is flammable in a mixture of 13% or less (by volume) with air, or the flammable range with air is wider than 12% regardless of the lower limits.

NOTE: Certain gases which meet the above criteria may be labeled as nonflammable by the Department of Transportation in 49 CFR 172.101. Ammonia, for example, is not flammable at less than 13%; however, the *Matheson Gas Data Book*, 6th Edition and the Union Carbide catalog, *Gases for the Electronics Industry*, 1988 Edition lists its flammable range as 15-28%, giving it a 13% range (wider than 12%).

5.6 *gas cabinet* — A metal enclosure which is intended to provide local exhaust ventilation, protection for the gas cylinder from fire from without the cabinet, and protection for the surroundings from fire from within.

5.7 *gas* — Materials [which] are shipped in compressed gas cylinders, or act as a gas upon release at normal temperatures and pressure, or are used or handled as a gas, whether or not in strict accordance with the definition of a compressed gas as set forth in Article 9 of the Uniform Fire Code.

5.8 *hazardous production materials (HPM)* — A solid, liquid, or gas that has a degree of hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes which have as their end product materials which are not hazardous. (Uniform Fire Code, Section 51.102)

5.9 *inert gas* — A gas which at ambient conditions does not react chemically with other materials.

5.10 *oxidizer gas* — A gas which will support combustion or increase the burning rate of a combustible material with which it may come in contact.

5.11 *pyrophoric gas* — A gas which upon contact with air will ignite spontaneously at or below a temperature of 54°C (130°F).

5.12 *separation of gases* — The National Fire Codes use the terms, "separated," "segregated," and "isolated" when referring to storage of hazardous materials. Separation as defined by NFPA 49 is "storage within the same fire area, but separated by as much space as practical, or by intervening storage from incompatible materials." Segregated storage is generally defined by NFPA Standards as "storage in the same room, but physically separated by space or barrier from incompatible materials." Isolation is defined by NFPA 49 as "storage away from incompatible materials in a different storage room or in a separate and detached building located at a safe distance."

NOTE: For the purposes of this document, the terms "separation" and "segregation" will both be understood to have the meaning "being kept in different gas cabinets."

5.13 *toxic gas* — A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

5.14 *highly toxic gas* — A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

5.15 *irritant* — A chemical, which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of the contact. A chemical skin irritant if, when tested on the intact skin of albino rabbits by the method of 16 CFR 1500.41 for four hours exposure or by other appropriate techniques, it results in an empirical score of five or more. A chemical is an eye irritant, if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques.

5.16 *water reactive* — A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

5.17 *unstable (reactive)* — A chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure, or temperature.

5.18 *other health hazard* — (Those items in this section that are not listed elsewhere are included here.) A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.

5.19 *carcinogen* — A chemical is considered to be a carcinogen if:

(a) it has been evaluated by the International Agency for Research on Cancer (IARC), and found to be a carcinogen or potential carcinogen; or

(b) it is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or

(c) it is regulated by OSHA as a carcinogen.

6 Requirements

6.1 The requirements for the segregation/separation of gases are found in the Uniform Fire Code, BOCA National Fire Prevention Code, and SBCCI Standard Fire Prevention Code. The thrust of these requirements is summed up in the following excerpts from the Uniform Fire Code:

“Separate cabinets shall be provided for each class of hazardous materials. Flammables, acids, bases, oxidizers, toxics, and other incompatible materials shall not be stored within the same cabinet. Inert materials may be intermingled with other materials.”

“Separation requirements within storage rooms. Flammables, corrosives, oxidizers, water-reactive solids, and liquids within a storage room shall be separated from each other in accordance with Table No. 51-110-A of the Uniform Fire Code. Table No. 51-110-A provides the requirements if distance is to be the method of segregation/separation.”

The code further states “HPM gas shall be separated from HPM liquids and solids by at least a one-hour fire-resistive occupancy separation.”

It should be noted that the code recognizes gas cabinets as the first method of segregation/separation.

6.2 Gases should be classified according to the following categories and assigned a symbol as shown:

Classification	*Symbol*
Flammable	F
Pyrophoric	P
Corrosive Acid	CA
Corrosive Base	CB
Toxic or Highly Toxic	T or HT
Oxidizer	O
Inert	I
Irritant	IRR
Water Reactive	WR
Unstable (Reactive)	UR
Other Health Hazard (Target Organic Toxics)	OHH
Carcinogen	CAR

A material may be assigned more than one category if it possesses more than one of these characteristics.

Gases should be separated from one another if they do not possess the same classification symbols in all categories. The exception to this rule is the classification (I) designating an inert gas. An inert gas does not have to be separated from any other gas.

A list of gases and their classification symbols appears in Appendix 1.

Appendix 2 is a matrix of 52 of the materials generally used in gaseous or vapor form. The black dot in the matrix system indicates those gases at the dot intersection may be placed in the same cabinet. (Local Code may permit some other combinations.) This represents the minimum level for gas separation. The best system is one gas per cabinet (an inert gas may also be in the same cabinet).

APPENDIX 1

Gas	*Classification*
Ammonia	F-CB-IRR
Argon	I
Arsenic Pentafluoride	HT-CA-CAR-OHH-WR
Arsine	HT-F
Boron Trichloride	CA
Boron Trifluoride	T-CA
Carbon Dioxide	I
Carbon Tetrachloride	CAR-OHH
Chlorine	T-CA-O
Diborane	T-P-IRR-WR
Dichlorosilane	T-F-CA-WR
Diethyl Telluride	F-IRR
Diethyl Zinc	P-UR-WR-CA
Dimethyl Zinc	P-UR-WR-CA
Halocarbon 11 (trichlorofluoromethane)	I*
Halocarbon 12 (dichlorodifluoromethane)	I*
Halocarbon 13 (chlorotrifluoromethane)	I*
Halocarbon 13B1 (bromotrifluoromethane)	I*
Halocarbon 14 (tetrafluoromethane)	I
Halocarbon 23 (fluoroform)	I*
Halocarbon 115 (chloropentafluoroethane)	I*
Halocarbon 116 (hexafluoroethane)	I
Germane	HT-F-IRR-UR
Helium	I
Hydrogen	F
Hydrogen Chloride	CA
Hydrogen Fluoride	T-CA
Hydrogen Sulfide	T-F-IRR
Methyl Chloride	F-IRR
Methyl Fluoride	F-IRR
Nitric Oxide	HT-O-IRR
Nitrogen	I
Nitrogen Trifluoride	O-IRR
Nitrous Oxide	O
Oxygen	O
Perfluoropropane	I*
Phosphine	HT-P
Phosphorous Pentafluoride	T-CA-WR
Silane	P
Silicon Tetrachloride	CA-WR
Silicon Tetrafluoride	T
Sulfur Hexafluoride	I*
Trichlorosilane	F-CA-UR
Triethyl Aluminum	P
Trimethyl Aluminum	P
Trimethyl Antimony	T-F
Trimethyl Arsine	T-F
Trimethyl Gallium	P
Trimethyl Indium	P
Trimethyl Phosphine	T-F
Tungsten Hexafluoride	T-CA

* Generally considered as inert; however, may react in a hazardous way under special conditions.

Additional materials may be used at the present time or may be suggested in the future. Any new material should be categorized in a way that material of similar chemical characteristics are treated. If detailed chemical data is not available, the material should be considered in the worst case and should only be stored with inert materials.

APPENDIX 2

× Indicates Compatible Materials

	Ammonia	Argon	Arsenic Pentafluoride	Arsine	Boron Trichloride	Boron Trifluoride	Carbon Dioxide	Carbon Tetrachloride	Chlorine	Diborane	Dichlorosilane	Diethyl Zinc	Diethyl Telluride	Dimethyl Zinc	Halocarbon 11	Halocarbon 12	Halocarbon 13	Halocarbon 13B1	Halocarbon 14	Halocarbon 23	Halocarbon 115	Halocarbon 116	Germane	Helium	Hydrogen	Hydrogen Chloride	Hydrogen Fluoride	Hydrogen Sulfide	Methyl Chloride	Methyl Fluoride	Nitric Oxide	Nitrogen	Nitrogen Trifluoride	Nitrous Oxide	Oxygen	Perfluoropropane	Phosphine	Phosphorous Pentafluoride	Silane	Silicon Tetrachloride	Silicon Tetrafluoride	Sulfur Hexafluoride	Trichlorosilane	Triethyl Aluminum	Trimethyl Aluminum	Trimethyl Antimony	Trimethyl Arsine	Trimethyl Gallium	Trimethyl Indium	Triethyl Indium	Trimethyl Phosphine	Tungsten Hexafluoride
Tungsten Hexafluoride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Trimethyl Phosphine		×					×												×			×		×								×																			×	
Triethyl Indium		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trimethyl Indium		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trimethyl Gallium		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trimethyl Arsine		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trimethyl Antimony		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trimethyl Aluminum		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Triethyl Aluminum		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Trichlorosilane		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Sulfur Hexafluoride		×	×		×	×	×	×	×						×	×	×	×	×	×	×	×		×		×	×					×	×			×		×		×	×	×	×									×
Silicon Tetrafluoride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Silicon Tetrachloride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Silane		×					×												×			×		×								×							×													
Phosphorous Pentafluoride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Phosphine		×					×												×			×		×								×					×															
Perfluoropropane		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Oxygen		×					×	×											×			×		×								×			×																	
Nitrous Oxide		×					×	×											×			×		×								×		×																		
Nitrogen Trifluoride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Nitrogen	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Nitric Oxide		×					×												×			×		×							×	×																				
Methyl Fluoride		×					×												×			×		×					×	×		×																				
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Hydrogen Sulfide		×					×												×			×		×				×				×																				
Hydrogen Fluoride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Hydrogen Chloride		×	×		×	×	×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Hydrogen		×					×	×											×			×		×	×							×																				
Helium	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Germane		×					×												×			×	×	×								×																				
Halocarbon 116	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Halocarbon 115		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Halocarbon 23		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Halocarbon 14	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Halocarbon 13B1		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Halocarbon 13		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Halocarbon 12		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Halocarbon 11		×					×	×							×	×	×	×	×	×	×	×		×								×				×						×										
Dimethyl Zinc		×					×	×				×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Diethyl Telluride		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Diethyl Zinc		×					×					×	×	×					×			×		×								×												×	×	×	×	×	×	×		
Dichlorosilane		×					×				×								×			×		×								×																				
Diborane		×					×			×									×			×		×								×																				
Chlorine		×					×		×										×			×		×		×	×					×	×					×		×	×	×	×									×
Carbon Tetrachloride		×					×	×						×	×	×	×	×	×	×	×	×		×	×							×		×	×	×						×										
Carbon Dioxide	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Boron Trifluoride		×			×	×	×												×			×		×		×	×					×	×					×		×	×	×	×									×
Boron Trichloride		×			×	×	×												×			×		×		×	×					×	×					×		×	×	×	×									×
Arsine		×		×			×												×			×		×								×																				
Arsenic Pentafluoride		×	×				×												×			×		×		×	×					×	×					×		×	×	×	×									×
Argon	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Ammonia	×	×					×												×			×		×								×																				

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The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI S5-93
SAFETY GUIDELINE FOR FLOW LIMITING DEVICES

NOTICE: This guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 Purpose

This safety guideline is intended to suggest a method to limit the rate of release of hazardous gases from the gas cylinder valve during transportation, storage, and use.

2 Scope

This guideline covers flow limiting devices for valves on cylinders containing hazardous gases. It covers uncontrolled releases of gases at or downstream of the valve outlet. It does not cover gas releases caused by failure of the cylinder, the valve connection to the cylinder, actuation of the cylinder pressure relief device, or failure of the valve.

3 Safety Warnings

3.1 *Installation* — Only the cylinder owner should install, remove, or otherwise service the flow limiting device. Special equipment and procedures may be required to perform any installation or service operation safely. No other person should install, remove, replace, clean, adjust, or otherwise alter the flow limiting device unless authorized by the cylinder owner.

3.2 *Purging* — The addition of a flow limiting device in the cylinder valve may restrict gas flow during purging. The purchaser must assure that adequate purging methods are used to prevent plugging the flow limiting device.

NOTE: The user should purge the valve after use with the same procedure used in the initial purge of the cylinder. This is important to prevent contamination of the valve and reduce the probability of creating a hazard at the cylinder supplier's plant.

4 Referenced Documents

4.1 *NFPA Documents*[1]

NFPA 704 — Standard System for the Identification of Fire Hazards of Materials

NFPA 49 — Hazardous Chemicals Data

5 Terminology

5.1 *Design Flow Rate* — The maximum flow rate exiting a gas cylinder valve when the valve is in a fully open position. All flow rates are given in standard liters per minute (slpm).

5.2 *Hazardous Gases* — Gases supplied in cylinders which are listed in NFPA 49 with a degree of hazard rating 3 or 4 in Health, Flammability, or Reactivity, or which would be so rated by experienced, technically competent persons when evaluated in accordance with the criteria set forth in NFPA 704.

5.3 *Flow Limiting Device* — A device installed in a valve that is designed to reduce the maximum flow from the valve under full flow conditions.

6 Flow Limiting Device Requirements

6.1 The valves used for gas cylinders containing the hazardous gases listed in Table 3 should be supplied with flow limiting devices. Table 3 lists those hazardous gases for which flow limiting devices can now be applied by reason of testing and experience. Annually, SEMI will consider modifying Table 3 as new information becomes available. SEMI will encourage testing by its members of hazardous gases not listed in Table 3.

6.2 The flow limiting device should be installed by the gas supplier or cylinder owner.

6.3 The flow limiting device will not allow equivalent air flows out of the valve outlet to exceed the design flow rates listed in Table 1, but will allow flow within the range indicated. The choice of design flow rate A, B, or C will be made by the purchaser.

The design flow rates in Table 1 are specified at 700 kiloPascals (kPa) (100 pounds per square inch gauge (psig)) of air. A purchaser should calculate, using the method specified in Paragraphs 6.3.1 and 6.3.2, the flow rate of the gas being purchased at various pressure to determine the proper flow limiting device for her application. The choice of the flow limiting device should be the smallest rate which satisfies the process requirements. Table 4 gives minimum flow rates for the gases listed in Table 3 at 700 kPa discharging to atmospheric pressure.

1 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

6.3.1 *Effect of Pressure*

$$Q = \frac{(P_{init} + P_{atm}) \times Q_D}{(P_D + P_{atm})} \qquad \text{(Equation 1)}$$

P_{init} is the initial gauge pressure in the gas cylinder for which the flow rate is being calculated.

Q is the maximum flow rate of the gas in slpm.

P_{atm} is standard atmospheric pressure (101 kPa or 14.7 psig) at sea level.

P_D is design final cylinder pressure for the cylinder (700 kPa or 100 psig).

Q_D is the design flow rate.

EXAMPLE: What is the maximum flow rate of air through a 4.5 slpm flow limiting device at 7000 kPa (1015 psig)?

$$Q = \frac{7000\,kPa + 101\,kPa}{700\,kPa + 101\,kPa} \times 4.5\,slpm$$

$$= 40\,slpm \text{ air}$$

NOTE: This formula is valid only for values of P_{init} and P_D greater than 101 kPa. Table 1 gives flow rates at 700 kPa. This formula corrects for pressure P.

Effect of Gas Specific Gravity

$$Q = \frac{Q_D}{\sqrt{specific\ gravity}} \qquad \text{(Equation 2)}$$

Specific gravity of the gas is relative to air. In case of mixtures, the specific gravity of the gas mixture should be used.

EXAMPLE: What is the flow range for silane at 700 kPa (100 psig) through a "C" flow limiting device?

$$Q = \frac{Q_D}{\sqrt{1.114}} =$$

$$= \frac{6.0\,slpm}{1.055} \text{ to } \frac{8.0\,slpm}{1.055}$$

Therefore, silane flow is 5.7 slpm to 7.6 slpm.

6.4 *Identification* — The preferred method of identifying the flow limiting devices or the valves, in the case of built-in devices, is by the letters A, B, or C as shown in Table 1. Other means of identification, requiring identification by the supplier as to the device installed, may be used if they are clear and unambiguous, except the single letters A-Z should not be used other than as defined herein.

6.5 *Materials* — The flow limiting device should be made of materials which are compatible with the gas in the cylinder.

6.6 *Service Life* — Removable flow limiting devices may be reused, but should be tested by the gas supplier or cylinder owner to assure that the flow rate is as listed in Table 1. Valves with non-removable flow limiting devices should be tested by the gas supplier or cylinder owner before each use to assure that the design flow is as specified in Table 1.

Table 1 Design Flow Rates for Flow Limiting Devices

Flow Limiting Device Size Designation	*Design Air Flow at 700 kPa (slpm)*	*Preferred Identification*
A	1.0–2.0	A
B	3.0–4.9	B
C	6.0–8.0	C

Table 2 Maximum Flow Rates of Air for Flow Limiting Devices

Flow Limiting	*Maximum Flows in slpm at 7000 kPa*	*Maximum Flows in slpm at 14000 kPa*
A	17.7	35.2
B	43.4	86.3
C	70.9	140.8

All flow rates and gas densities are referred to in Standard Liters per Minute at normal conditions (21.1°C, 101 kPa).

Table 3 Hazardous Gases for Use with Flow Limiting Devices

Arsine
Carbon Monoxide
Diborane
Germane
Hydrogen
Nitrogen Trifluoride
Phosphine
Silane
Stibine
Mixtures of the above gases with Argon, Hydrogen, Helium, and Nitrogen which meet the criteria of Section 5.2.

Table 4 Minimum Flow Rates for Gases at 700 kPa through Flow Limiting Devices

		Flow Rates at 700 kPa in slpm		
	Specific Gravity	*A*	*B*	*C*
Air	1.00	1.00	3.00	6.00
Argon	1.38	0.85	2.55	5.11
Arsine	2.695	0.61	1.83	3.65
Carbon Monoxide	0.967	1.02	3.05	6.10
Diborane	0.95	1.03	3.08	6.16
Germane	5.21	0.62	1.85	3.70
Helium	0.138	2.69	8.08	16.15
Hydrogen	0.0695	3.79	11.38	22.76
Nitrogen	0.967	1.02	3.05	6.10
Nitrogen Trifluoride	2.45	0.64	1.92	3.83
Phosphine	1.183	0.92	2.76	5.52
Silane	1.114	0.95	2.84	5.68
Stibine	4.10	0.49	1.48	2.96

NOTE: The above figures are from calculation only and should be treated as such.

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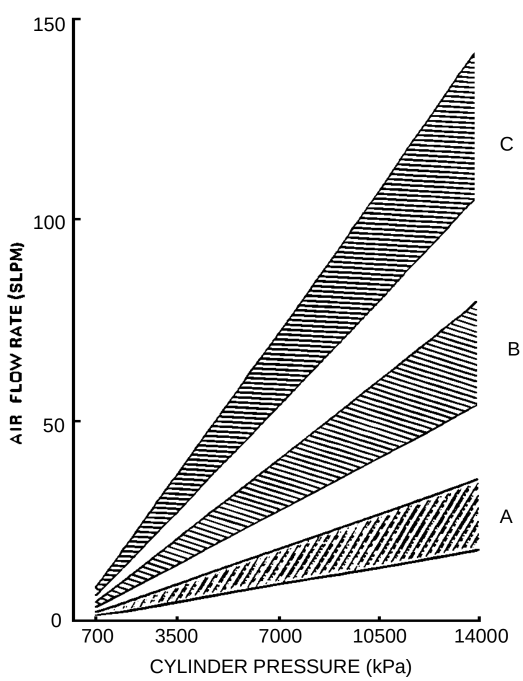

Figure 1
Air Flow Rate

SEMI S6-93
SAFETY GUIDELINE FOR VENTILATION

NOTICE: This guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 Introduction

The equipment supplier should design an internal equipment exhaust system that is efficient when connected to potential users' exhaust systems. Seldom, if ever, are users' systems designed for a specific piece of process equipment or set of process equipment. Most users' exhaust systems are designed and installed to industry-accepted exhaust principles.

2 Purpose

This document is intended to help the semiconductor equipment supplier design equipment exhaust systems to a common set of performance criteria as well as to provide assistance to both users and suppliers in the understanding of exhaust requirements for equipment systems. It is not intended to establish design specifications. The supplier will still own, and be responsible for, the information it specifies. This guideline has six concurrent performance-related objectives.

2.1 Ensure hazardous gases, fumes, and vapors are controlled (during normal operations of equipment and facilities services) such that concentrations present in the work room air should be less than 1.0% of the Threshold Limit Value (TLV), as established by the American Conference of Governmental Industrial Hygienists (ACGIH) or Permissible Exposure Limit (PEL) as published by the appropriate regulatory agency, whichever is lower.

2.2 Ensure exhaust is provided within specifications to support the proper operation of equipment.

2.3 Optimize the user's exhaust system(s).

2.4 Use the most cost effective methods to interface with user's exhaust systems.

2.5 Provide a platform for communicating "special case" exhaust requirements.

2.6 Establish guidelines for measurement and communication of equipment exhaust requirements.

3 Scope

This guideline applies to all semiconductor equipment that incorporates exhausted enclosures that are intended to be connected to user facilities' exhaust system(s). This document is written with the assumption that the users' exhaust distribution systems will be designed with central fans, ducting, and, where applicable, abatement equipment. Where users use other types of exhaust systems, equipment suppliers should acquire exhaust specifications from the users. Whether equipment is connected to a central exhaust system or to one which serves only that piece of equipment, this guideline should be applied.

4 Referenced Documents (see Appendix 2)

5 Terminology

5.1 *balancing* — Adjustments made after the ventilated equipment and the ventilation system are installed to assure that airflow to each piece of ventilated equipment is within design specifications.

5.2 *capture* — To entrain undesirable elements (gases, fumes, vapor, and particles) in the exhaust stream for removal.

5.3 *dilute* — To reduce the concentration of undesirable elements to acceptable levels. Dilution is a function of flow volume.

5.4 *flow velocity (V)* — The average speed at which the effluent stream travels through the exhaust duct. It is measured in meters per second (m/s) or feet per minute (fpm).

5.5 *flow volume (Q)* — The volumetric flow rate of the effluent stream passing a given location in the exhaust system per unit of time. It is measured in cubic meters per second (m^3/s) or cubic feet per minute (cfm).

5.6 *initiate motion* — To use an exhaust stream to start contaminants (or machine parts) moving from a rest position.

5.7 *long radius elbow* — An exhaust duct elbow that has a center line radius 1.5 or more times the duct diameter.

5.8 *set point tolerance* — The range (+/-) of static pressure within which an exhaust enclosure will perform efficiently and effectively.

5.9 *static pressure (SP)* — The measure of differential pressure across the duct wall to the ambient pressure (inside the duct). The unit of measure is pascals (Pa, Newtons per square meter (N/m^2)) or inches of water.

5.10 *traverse measurements* — Multiple air flow measurements taken at points of equal separation, in a matrix pattern, along the face plane of an exhaust duct or opening in an exhaust enclosure.

5.11 *vena contracta* — A point in a duct where the diameter of the air stream is smaller than the diameter of the duct.

6 Attributes of Typical Semiconductor Facilities' Exhaust Systems

6.1 A typical semiconductor facility's exhaust system has three measurable working elements: (1) flow velocity, (2) flow volume, and (3) pressure.

6.1.1 Flow Volume is related to the Flow Velocity by the equation Q = VA. In this equation, Q = volumetric flow rate, V = average velocity, and A = duct cross sectional area (m^2 or ft^2).

6.2 There are three duct pressure measurements possible: (1) static pressure, (2) velocity pressure, and (3) total pressure.

6.2.1 In exhaust distribution systems with central fans and abatement equipment (typical of semiconductor facilities), exhaust duct pressure (static) upstream of the fan is less than the ambient pressure outside of the duct.

6.2.2 While Velocity Pressure (VP) and Total Pressure (TP) provide a more reliable measure of Flow than Static Pressure, VP and TP are normally not specified for semiconductor facilities' exhaust systems; therefore, they will not be discussed in these guidelines. If more information is desired on VP or TP, it can be found in "Industrial Ventilation" (Appendix 2, Reference 1).

7 Exhaust Usage Typical of Semiconductor Operations

Semiconductor equipment typically uses exhaust to perform one or more of the following tasks:

7.1 *Capture* — Capture should occur as close to the source as practical to prevent exposure of personnel or products to the undesirable elements.

7.1.1 Capture is a function of Flow Velocity. Chapter 3 of "Industrial Ventilation," A Manual of Recommended Practice, 20th Edition, (Appendix 2, Reference 1) outlines the design principles and required velocity calculations for proper capture of process emissions.

7.2 *Moving* is also a function of Flow Velocity. The exhaust requirements specified by the equipment supplier should be adequate to maintain motion of undesirable elements once they are captured in the exhaust stream.

7.3 *Dilution* is a function of Flow Volume. Dilution may also provide reactive elements to undesirable elements entrained in the exhaust stream (for example, air and silane).

7.4 *Holding* — The movement of the exhaust stream is often used to activate and hold safety control devices, such as vane switches or differential pressure gauges in the active state. Such safety control devices should be used to sense adequate exhaust pressure or flow to ensure safe operation of the process equipment.

7.5 *Initiation of Motion* — The use of exhaust to intiate motion in the semiconductor industry is a special case application and should be resolved at the time of purchase. Most semiconductor-related gases, vapors, fumes, and fine particles (less than 20 microns in diameter) move with the air in which they are mixed.

8 Key Elements of Exhaust Specifications

8.1 SEMI S2 establishes specific requirements for exhaust enclosures of equipment that use hazardous materials. Access to enclosures serving hazardous materials requires special design. If there is a potential for exposure of personnel to hazardous materials when the access hatch is open, an average face velocity (measured at the hatch opening) sufficient to capture the hazardous materials should be maintained in the hatch opening. (SEMI S2 also has recommendations for exhaust monitoring and alarms. S2 should be fully understood before designing exhaust systems for hazardous materials.)

8.2 Properties of chemicals (density, vapor pressure, boiling point, flammability, etc.), the state of the materials within the exhausted enclosure (solid, liquid, or gas), and conditions such as temperature and concentration will determine the final design and exhaust specifications of the equipment enclosure. Equipment suppliers should use available reference books and Material Safety Data Sheets (MSDS) to obtain information on chemical properties. The equipment's process requirements will dictate the state and condition of the material.

8.3 When developing specifications for equipment exhaust systems to be given to the equipment user, equipment suppliers should incorporate all of the key elements that will provide clear and accurate information. These key elements are:

1. Point of measurement.
2. Duct size at the point of measurement.
3. Flow through the duct.

4. Air density.
5. Temperature of the exhaust stream when it enters the exhaust system.
6. Static pressure at the point of measurement.
7. Physical condition of the process equipment at the time of measurement.
8. Peak, normal, and special exhaust requirements.
9. Equipment environmental conditions anticipated (installed).
10. Stability and tolerance requirements of the specifications.
11. Priority of exhaust attributes when the system is balanced. (What is the primary intent of the exhaust, secondary, etc.?)
12. Instruments and practices used (and recommended) for taking measurements.
13. Design information on the complete equipment exhaust system (including materials of construction).
14. Constituents of the exhaust stream.

Each of these key elements is discussed in detail in Sections 8.3.1 through 8.3.14.

8.3.1 The point of measurement for the equipment exhaust duct should be clearly defined. Information given to locate the point of measurement should include a diagram of the exhaust connection with locations of the traverse points used.

8.3.1.1 Turbulence in the duct at the point of measurement should be minimized. The measurement point should be in a straight section of duct. It should be downstream in the connecting duct past the vena contracta from the last transition made in the equipment. It should be far enough from fittings, dampers, or sprinkler heads to minimize their interference with the measurements. Normal recommended practice is 7.5 duct diameters from any point of connection or fitting. See "HVAC Systems Testing, Adjusting, and Balancing," (Appendix 2, Reference 3).

8.3.1.2 Equipment users typically use a throttling damper for exhaust balancing where the equipment drop connects to the rest of the exhaust system. Balancing measurements should be taken on the equipment side of these balancing dampers. The supplier may elect to provide a damper, at or near the equipment connection point, to be used only as a trimming device over a narrow performance band around the equipment flow and pressure specifications. Features of this damper should be designed to prevent complete blockage of exhaust flow.

8.3.2 Duct size is the inside diameter of the exhaust connection from the equipment. The supplier should provide any other dimensions needed to design the connection of the exhaust system to the equipment.

8.3.2.1 The duct size of the equipment connection should fall in the low flow velocity range of the duct friction table. See "HVAC Systems Duct Design" (Appendix 2, Reference 2). Low flow velocity ducts will promote flexibility and ease of interface to exhaust systems serving multiple equipment. When particles are to be captured and removed, design the system for the minimum flow velocity that will ensure capture.

NOTE: Exhaust system designers should always keep in mind the difficulty that can be experienced in flow velocity measurements in unduly large ducts. Tool connections should be sized for accurate flow measurements.

8.3.2.2 The design of the equipment exhaust connection should allow for long radius connecting elbows at the point of connection. This will reduce friction losses. Additionally, the equipment supplier should avoid configurations that would require an angle of entrance into the user's branch ducts of greater than 30 degrees.

8.3.2.3 Duct connection configuration should be such that liquid spills or releases within the equipment enclosures will not enter the facility's exhaust system.

8.3.3 Flow through the equipment enclosure, and the duct at the point of connection, can be specified in velocity or volume. Normally, the balancing engineer will measure Flow Velocity and convert velocity to Flow Volume using the equation Q = VA. (See Section 6.1.1.)

8.3.3.1 Section 8.3.6 of this document shows the pressure guidelines for semiconductor exhaust systems. The equipment supplier should establish, through testing, the Flow Velocity and Volume required for efficient operation of its equipment's exhaust system. The user and the supplier should agree, before the purchase of the equipment, on the safety control devices to be used. Any safety control device requiring flows or pressures outside these ranges is a special case and should be resolved at the time of purchase.

8.3.4 Exhaust specifications should be stated in Standard Air Density (kg/m^3 or lb/ft^3), as defined in "Industrial Ventilation," (Appendix 2, Reference 1). If the measurements are of non-standard air, state the correction factor for density. Users should correct field balancing measurements taken above 600 meters (2000 feet) elevation before comparing them to suppliers' specified data. Additionally, the supplier-specified data must be corrected to sea level if it was measured above 600 meters elevation.

8.3.4.1 Flow measurements taken at other than standard air temperatures (21.1°C (70°F)) should be corrected to standard conditions.

8.3.4.2 Corrections for altitude and temperature should use the following relationship:

$M^3/s = (m^3/s)(294.3/T_K)(D)$

$CFM = (cfm)(530/T_R)(D)$

M^3/s = Standard cubic meters per second

m^3/s = Measured cubic meters per second

CFM = Standard cubic feet per minute

cfm = Measured cubic feet per minute

T_K = Measured temperature in degrees K ($T_K = T_C + 273.2$)

T_C = Measured temperature in degrees C

T_R = Measured temperature in degrees R ($T_R = T_F + 459.7$)

T_F = Measured temperature in degrees F

D = Altitude density correction factor

Altitude	*Density Correction Factor*
sea level	1.00
300 m (1000 ft)	0.96
600 m (2000 ft)	0.93
900 m (3000 ft)	0.89
1200 m (4000 ft)	0.86
1500 m (5000 ft)	0.83

8.3.5 The expected temperature of the exhaust stream (from the supplier's equipment) at the connection to the user's exhaust system should be included in the specifications. The connecting duct material should be compatible with this temperature. The normal operating and maximum high and minimum low temperatures should be specified.

8.3.6 Static pressure is measured at the same traverse point as discussed in Section 8.3.1. The equipment specifications should define the minimum Static Pressure, at the point of connection, required for proper equipment operation.

8.3.6.1 The target Static Pressure range at the point of connection to equipment is -125 to -250 Pa (-0.5 inches to -1.0 inches of water). This permits flexibility of equipment placement with minimal need for pressure boosting devices, such as booster fans.

8.3.6.2 For exhaust Static Pressure requirements lower than -1.0 inches of water, the equipment supplier must establish, with the user's concurrence, the specifications for a safe booster add-on device. A larger negative number is a lower exhaust pressure. Normally, users will install boosters only when their exhaust distribution system cannot reach the specified static pressure. As each user's facility is unique, booster add-on devices should be separate from the equipment's functional design and used only as a last resort.

8.3.7 The physical settings and configuration of the process equipment when specified flow and pressure measurements are made is critical to the repeatability of the measurements.

8.3.7.1 Exhaust enclosures, capture zones, and entry points in the equipment should isolate the area to be exhausted from adjacent areas. Internal ducts, partitions, and guide plates in the equipment should be leak tight to prevent the release of contamination from the exhaust stream.

8.3.7.2 To capture, move, or dilute contaminants effectively within the equipment's exhaust enclosure, there must be a continuous supply of make-up air. The enclosure should be designed such that the make-up air is drawn from a selected area through designed openings in the enclosure walls. Care should be taken to ensure the make-up air does not contain, or potentially contain, vapors or fumes that could be incompatible with the exhaust enclosures material of construction, components, or target materials being exhausted.

8.3.7.3 Minimize the volume of the enclosures where possible to reduce the load on the exhaust system and on its companion make-up air system.

8.3.7.4 Enclosures supplied with, or as part of, equipment should be designed so that exhaust properly sweeps all potential emission release points.

8.3.7.5 Aerodynamic "dead spots" inside the enclosure should be minimized.

8.3.7.6 Components that have no potential for release should be located outside the enclosure, when possible. Additionally, the handles for any valves located inside the exhausted enclosure should be positioned outside of the enclosure to reduce the need to open the enclosure.

8.3.7.7 Verification that the exhaust enclosure provides the desired capture of contaminants can be accomplished by using Sulfur Hexafluoride as a tracer gas (see SEMI F15). Verification that aerodynamic "dead spots" have been eliminated can be accomplished by use of “clean smoke” generated from a deionized water vapor generating system.

8.3.7.8 Once capture has been verified, measurements should be taken at specific openings (make-up air slots, access ports, or windows, etc.) to establish the minimum flow velocity necessary at these specific openings to achieve capture.

8.3.7.9 Record the position of covers, doors, dampers, valved openings, etc., and flow restrictions (such as fluid levels in vessels which exhaust air serves or flows through) at the time of the ventilation tests so that the test can be duplicated.

8.3.7.10 The supplier should specify how to duplicate these conditions at the time of field adjustment and balance. If the original conditions are not duplicated, the exhaust losses through the equipment may vary. The major risk is that the equipment exhaust level will be set as close to the suppliers’ specifications as possible and may not provide the safety level intended during actual equipment operation.

8.3.8 The equipment may require different exhaust flow or pressure during the process cycle than in standby or maintenance modes. The supplier should provide specifications for normal operating mode demands, peak demand, and any other demand level required for employee safety. The normal, peak, and other critical safety condition demands should be compensated for in both the system design and the field balance.

8.3.9 Equipment data used to establish exhaust specifications should reflect the equipment’s environmental conditions anticipated when installed (e.g., bulkhead mounted equipment is supplied with data for a bulkhead installation).

8.3.9.1 Typical user clean rooms are designed using the “bay” and “chase” concept. The bay is served with 100% ceiling-supplied, HEPA-filtered air. Vertical air flow below the ceiling is typically 0.5 m/s (100 FPM) across the entire bay. The chase section is the return air plenum for the bay air supply system. The typical pressure differential across the bay wall is 2.5 to 7.5 Pa (0.01 to 0.03 inches of water), with the lower pressure on the chase side.

8.3.9.2 Bulkhead or through-the-wall mounted equipment should tolerate this pressure differential.

8.3.9.3 Cabinet or enclosure exhaust applications should be designed so that back streaming into the clean bay or chase is prevented.

8.3.10 The set point tolerance at time of initial installation should be included in the specification. Performance stability over time for the exhaust flow and pressure requirements, needed to support equipment operations and safe working conditions, should also be specified.

8.3.10.1 The users’ exhaust distribution systems typically hold a balance setting ±10% of the set point(s) over time. Equipment which integrates high or low exhaust level alarms, requiring tighter stability control, are special cases and should be identified at the time of purchase.

8.3.10.2 The supplier-specified set points for Exhaust Flow, Volume, and Pressure should include a tolerance of -0% +10%. (This is the common acceptance range established for exhaust distribution system balance.)

8.3.11 The five methods of exhaust use discussed in Section 7 drive different priorities when establishing exhaust specifications.

8.3.11.1 The “initiate motion” and “hold” functions are either pressure or velocity driven, depending on the safety equipment selected by the supplier.

8.3.11.2 “Capturing” and “moving” are typically velocity-dependent.

8.3.11.3 “Dilution” is flow volume dependent.

8.3.11.4 The equipment exhaust specification should focus on the exhaust attribute (see Section 6) associated with the exhaust use (see Section 7). If multiple uses are being met, the supplier should prioritize Pressure, Flow, and Flow Volume for balancing.

8.3.12 The instruments and practices used for taking measurements to establish equipment specifications should be recommended in the specifications and used in field balance operations.

8.3.12.1 A hot wire anemometer is acceptable for velocities less than 150 m/s (500 FPM). A low range differential pressure gauge (0 to 60 Pa or 0.0 to 0.25 inches of water) is acceptable for velocities over 150 m/s (500 FPM).

8.3.12.2 An inclined/vertical manometer or high range differential pressure gauge is acceptable for measuring static pressure.

8.3.12.3 Conversion charts should be developed to indicate what flow volume is present at various points on the inclined/vertical manometer or differential pressure gauge.

8.3.12.4 Equipment suppliers should include recommendations in the equipment specifications for the proper selection of the pitot tube, static tip, etc., to use when measuring exhaust flow and pressure.

8.3.12.5 The description, operation, maintenance, and limitations of these and alternate instruments is covered

8.3.12.6 in Chapter 9 of "Industrial Ventilation," A Manual of Recommended Practice, 20th Edition, (Appendix 2, Reference 1). A companion reference is Chapter 5 of HVAC Systems Testing, Adjusting, and Balancing, (Appendix 2, Reference 3).

8.3.12.7 As with any test performed to establish or verify specifications, the measuring instruments used should be in good working condition and current calibration.

8.3.12.8 If an air balancing contractor is used, it should be certified by the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB) as meeting their technical standards for membership.

8.3.12.9 For additional information, see National Standards for Field Measurement and Instrumentation - Total System Balance, Volume Two, No. 12173, (Appendix 2, Reference 6). Also see Procedural Standards for Testing of Cleanrooms, (Appendix 2, Reference 4).

8.3.13 The exhaust specification provided to the user by the supplier should include design information on the complete equipment exhaust system. A prototype exhaust data worksheet is shown in Appendix 1. The supplier should also provide:

8.3.13.1 A scaled drawing of the equipment exhaust system showing all connections, dampers, monitoring devices, etc.

8.3.13.2 A diagram of the exhaust connection with critical dimensions, established set point, and the location of the traverse point used to develop the specifications.

8.3.13.3 Any special case exceptions.

8.3.13.4 A list of materials used in the construction of the exhaust enclosure and materials for components of the exhaust system.

8.3.14 The supplier should provide the user with a list of constituents that could be expected in the exhaust stream when the equipment and the users' exhaust system are operating within design specifications. Information typically required is:

8.3.14.1 Percent by volume.

8.3.14.2 Percent by weight.

8.3.14.3 State of constituent (liquid, gas, or solid).

8.3.14.4 Temperature of the composite exhaust stream under normal operations.

8.3.14.5 Information should be based on a continuous twenty-four hour operation of the equipment. (Extrapolation is generally acceptable if the method used is well-documented and can be duplicated.)

APPENDIX 1
PROCESS EQUIPMENT EXHAUST REQUIREMENT SUMMARY

Page 1 of 2

Manufacturer____

Equipment Name________________________________ Model_______________

Supplier Representative________________________ Date_________________

Demand Status ___________Normal __________Peak ___________Other (Explain)___________

Doors, Hatches & Covers ___________Closed __________% Open _________Removed

Chemical Location	Chemical Contents	Condition
1. ____________________	______________________	______Empty ______Full
2. ____________________	______________________	______Empty ______Full
3. ____________________	______________________	______Empty ______Full
4. ____________________	______________________	______Empty ______Full
5. ____________________	______________________	______Empty ______Full
6. ____________________	______________________	______Empty ______Full

Electrical Power ______On ______Off _______Disconnected

Equipment at Operating Temperature ______Yes ______No

Other Utilities ______On ______Off _______Disconnected

Process Material Positions ______Occupied ________Empty

Equipment Status at Time of Measurement

_______Up and at Idle _______Up and Ready to Start Cycle

_______Specific Point in the Process Cycle

(Explain)____

____

_______Down for Installation/Modification _______Down for Cleaning

_______Down for Preventive Maintenance _______Down for Repair

PROCESS EQUIPMENT EXHAUST REQUIREMENT SUMMARY (continued)

NOTE: Repeat this sheet for each exhaust connection to the machine.

Manufacturer ____

Equipment Name ______________________________ Model ____________

Demand Status ____________Normal ________Peak ________Other (Explain)________

Duct Connection Identity ____

Connection Inside Diameter ______________________________centimeters (inches)

Connection Outside Diameter ______________________________centimeters (inches)

	*Priority	Target	Tolerance	Stability
Flow Volume m/s (CFM)	_______	______	-0% +______%	±_______%
Flow Velocity m/s (FPM)	_______	______	-0% +______%	±_______%
Static Pressure pascals (inches of water)	_______	______	-0% +______%	±_______%

Data Corrected to Sea Level ______Yes ______No

Data Corrected to Std Air Density ______Yes ______No

Exhaust Stream Temperature ______°C (°F) ______°C (°F) ______°C (°F)

Min Normal Max

Measurement Location

Altitude__________m (ft) ambient temperature__________°C (°F) Humidity____________

Chemical Make-up of Expected Effluent Stream

Element	State	% Concentration	Volume	Weight
__________	________	______________	________	______
__________	________	______________	________	______
__________	________	______________	________	______
__________	________	______________	________	______
__________	________	______________	________	______

Exhaust Schematic Diagram Included _______Yes _______No

* Priority is the rank order importance (from one to four) of the indicated value in proper operation of the equipment. The balance will adjust to priority one values at the expense of other values in this sheet.

APPENDIX 2
REFERENCED DOCUMENTS

A2-1 Industrial Ventilation

A Manual of Recommended Practice
20th EditionCopyright 1988
Library of Congress Catalog Card Number: 62-12929

Published by: ACGIH (American Conference of Government Industrial Hygienists)
6500 Glenway Ave., Building D-7
Cincinnati, OH 45211-4438
Telephone: 513-661-7881

A2-2 HVAC Systems Duct Design

1981 Second Edition

Published by: SMACNA (Sheet Metal and Air Conditioning Contractors' National Association, Inc.)
8224 Old Courthouse RoadTyson's Corner
Vienna, VA 22183
Telephone: 703-790-9890

A2-3 HVAC Systems

Testing, Adjusting, and Balancing
Third Printing - June 1986

Published by: SMACNA (Sheet Metal and Air Conditioning Contractors' National Association, Inc.)

A2-4 Procedural Standards for Certified Testing of Cleanrooms

First Edition — October 1988

Published by: NEBB (National Environmental Balancing Bureau) 8224 Old Courthouse Road Tyson's Corner Vienna, VA 22180

A2-5 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices

Published by: ACGIH

A2-6 AABC National Standards for Field Measurement and Instrumentation — Total System Balance

Volume Two, No. 12173

Published by: AABC (Associated Air Balance Council)
1518 K Street Northwest
Suite 503
Washington, D.C. 20005
Telephone: 202-737-0202

A2-7 ASHRAE 1981 Fundamentals Handbook

Chapter 33 Duct Design

Published by: ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.)
1791 Tullie Circle, N.E.Atlanta, GA 30329
Telephone: 404-636-8400

A2-8 SEMI S2, Safety Guidelines for Semiconductor Manufacturing Equipment

Published by: SEMI (Semiconductor Equipment and Materials International)
3081 Zanker Road
San Jose, CA 95134
Telephone: 408-428-9600

A2-9 SEMI F15, Test Method for Enclosures Using Sulfur Hexafluoride Tracer Gas and Gas Chromatography

Published by: SEMI

NOTICE: This guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the guideline set forth herein for any particular application. The determination of the suitability of the guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. This guideline is subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI S7-96
SAFETY GUIDELINES FOR ENVIRONMENTAL, SAFETY, AND HEALTH (ESH) EVALUATION OF SEMICONDUCTOR MANUFACTURING EQUIPMENT

NOTICE: This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

NOTE: This entire document was revised in 1995.

1 Purpose

1.1 The purpose of this document is to provide guidance to the equipment manufacturer or supplier, the evaluator, and the user to define responsibilities and to ensure the objective evaluation of designs and equipment.

1.2 Preservation of employee safety and conformance to environmental regulations are important criteria when selecting semiconductor manufacturing equipment. A basic expectation is that the equipment manufacturer will design and build inherently safe (to the operator, facility, and environment) equipment and will provide documentation that the equipment has been evaluated against a specific set of criteria, verifying conformance thereto.

1.3 A safety evaluation is important for a variety of reasons, including: operator safety, equipment reliability, conformance to regulatory (e.g., OSHA, EPA, local fire and building codes) and insurance requirements. These are intended to ensure a safe and environmentally responsible workplace.

2 Scope

2.1 This document defines the requirements for ESH evaluation of equipment design and operation.

2.2 These guidelines include:

- Purpose
- Scope
- Referenced Documents
- Terminology
- Codes, Regulations, and Standards
- Requirements for Third Party Evaluators
- Contracting with an Evaluator
- Documentation Provided to the Evaluator by the Supplier
- Evaluation Methods
- Contents of Reports
- Provision of Reports to Potential Users

2.3 The evaluation program is designed to be used in addressing the ESH aspects of new, refurbished, or resold process tools prior to the tool being delivered to the user.

2.4 The evaluator may be within the supplier's organization. As some equipment suppliers do not maintain a comprehensive ESH equipment evaluation program in-house, third party contractor(s) may be used. In either case, the evaluator should meet the requirements listed in Section 6.

3 Referenced Documents

NOTE: All documents cited shall be the latest published versions.

3.1 *SEMI Document*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

3.2 *ANSI Document*[1]

Z34.1 — Third Party Certification Program

4 Terminology

4.1 *supplier* — The party providing the equipment to, and communicating directly with, the user. It may be the manufacturer or an equipment representative or distributor. The supplier has the responsibilities of obtaining the required information from the manufacturer or other sources and of providing it to the evaluator.

4.2 *user* — The purchaser of semiconductor manufacturing who will use the equipment.

5 Codes, Regulations, and Standards

5.1 Semiconductor equipment should conform to the applicable codes, regulations, and standards. The

[1] American National Standards Institute, 1430 Broadway, New York, NY 10018

evaluation should include accordance with the codes, guidelines, and the local regulations of potential users. To assist in this, the supplier should provide the evaluator with a list of jurisdictions in which the supplier intends to market the equipment.

6 Requirements for Third Party Evaluators

6.1 The evaluator should have at least five years' experience in the semiconductor equipment or fabrication or similar industry and:

a. be established in accordance with ANSI Z34.1, Third Party Certification Program; or

b. consist of individual(s) who are registered or certified professional(s) in the discipline(s) in which the evaluations were performed; or

c. consist of individual(s) with baccalaureate or higher degrees in related technical discipline(s) (engineering or science).

NOTE: In the United States, the United Kingdom, and several other countries, the "baccalaureate" or "bachelor of science" degree is awarded upon completion of a technical course of study, typically of four years, at a college or university. It is the degree prerequisite for professional registration in most U.S. states and for study towards a master's degree or doctorate.

7 Contracting with an Evaluator

7.1 The supplier initiates the evaluation by providing a "scope of work" to the evaluator. This scope should define the services to be provided, including the standards and guidelines that will be used to evaluate the equipment and the responsibilities of each party.

7.2 The evaluator is responsible only to the supplier.

7.3 Changes made to the equipment to bring it into accord with codes, regulations, and guidelines are the responsibility of the supplier.

8 Documentation Provided to the Evaluator by the Supplier

8.1 Any previous evaluations of equipment related to the included documents, with all appropriate documentation.

8.2 Material Safety Data Sheets (MSDS's) for all chemicals used in the maintenance of the equipment and for those used in baseline and known, user-intended processes.

8.3 When information is known for user intended or baseline process(s), the evaluator should be provided the estimated consumption of raw materials and the amount(s) of by-products generated as described in Section 20.2.1 of SEMI S2.

8.4 Copies of the equipment's installation, maintenance, and operation manuals.

8.5 Copies of any hazard analysis or safety reviews of the subject equipment.

8.6 A list of all assemblies and sub-assemblies.

8.7 Design drawings and schematics.

9 Evaluation Methods

9.1 The evaluator should ensure the review of the supplier's documents (listed above) and the outlining of deficiencies with corrective and/or improvement recommendations.

9.2 The ESH testing and evaluation may proceed concurrently with the document review by agreement of the parties.

9.3 After the supplier has addressed all deficiencies noted in the third party report, the supplier should review the actions taken with the evaluator. If appropriate, the evaluator may re-evaluate some or all of the areas addressed.

10 Contents of Reports

10.1 An interim report should be provided to the supplier after evaluator has performed the agreed services. It should include an overview of the services performed, the standards, guidelines, and codes against which the equipment was evaluated, and the evaluator's findings. Items found in conformance with the documents should be documented as well as those found to be deficient.

10.2 The evaluator's final report should be provided after the supplier and the evaluator have agreed that the changes made have brought the equipment into conformance with the applicable documents. This report should be attached to the supplier's bid to a potential user.

10.3 If the evaluator and the supplier differ in their interpretation of requirements of the applicable documents, the creator of the document in question should be consulted for an interpretation. If the difference remains unresolved, the evaluator should include this and any other unresolved issues in its final report.

10.4 The final report should be signed by the evaluator and should contain at least the following sections:

10.4.1 *Management Summary* — A brief description of the evaluation, recommendations, and results. A statement that the equipment does or does not conform (with noted exceptions) with the ESH specifications, guidelines, and codes that were used for the evaluation.

10.4.2 *System Description* — Type of equipment evaluated and its function.

10.4.3 *Analysis and Test Methods* — Specific tests used to determine the compliance with the criteria. This should include a point-by-point evaluation of requirements listed in the pertinent specifications.

10.4.4 *Environmental, Safety, and Health Assessment* — The detailed results of the evaluation, including the point-by-point results, using SEMI S2 as an outline. If a section is not applicable, so state.

10.4.5 *Body* — The body of the report should describe the type of ESH evaluations, methods, and test equipment used, and results achieved. The methods used may include: fault testing, fault tree analysis, task analysis, industrial hygiene analysis, chemical mass balance, and ergonomics assessment.

10.4.6 *Recommendations* — Listings of recommendations made by the evaluator and statements that the recommendations were implemented, rejected, or otherwise addressed.

10.4.7 *Detailed Analysis and Test Worksheets* — Copies of the laboratory and field test data.

10.4.8 *Additional Information/Remarks* — Any information that may clarify tests performed, exceptions not specifically defined in the documents, precautions for certain applications of the equipment, or conditions of operation.

11 Provision of Reports to Potential Users

11.1 Whenever possible, copies of the evaluator's final report should be made available to potential users. If the supplier considers some information in the evaluator's report proprietary, the supplier should write an overview report that includes all environmental, safety, and health information with all proprietary information deleted.

11.2 Deficiencies that have been remedied and now meet the appropriate standards do not need to be listed in the report available to users.

11.3 This modified report should be signed by the evaluator.

SEMI S8-0701
SAFETY GUIDELINES FOR ERGONOMICS ENGINEERING OF SEMICONDUCTOR MANUFACTURING EQUIPMENT

These safety guidelines were technically approved by the Global Environmental Health & Safety Committee and are the direct responsibility of the North American Environmental Health & Safety Committee. Current edition approved by the North American Regional Standards Committee on March 22 and April 30, 2001. Initially available on www.semi.org May 2001; to be published July 2001. Originally published in 1995; previously published October 2000.

NOTE: The official values in this guideline are expressed in The International System of Units (SI). Values that:

— are expressed in inch-pound (also known as “US Customary” or “English”) units,

— are enclosed in parentheses, and

— directly follow values expressed in SI units

are not official, are provided for reference only, and might not be exact conversions of the SI values.

1 Purpose

1.1 These guidelines provide ergonomics design principles and considerations for semiconductor manufacturing equipment.

1.2 The purpose of these guidelines is to promote compatibility between the user and the equipment in the manufacturing environment. The following general principles are integral to the ergonomics design and evaluation of equipment:

1.2.1 The equipment should be designed to optimize safety by distributing tasks. Tasks should be distributed among hardware, software, and users to make the best use of their respective capabilities and to minimize limitations and hazards. Appropriate distribution of tasks will also optimize performance.

1.2.2 Equipment should be designed to minimize potential for errors and mishaps, by conforming to users’ expectations.

1.2.3 The equipment design should reduce fatigue and injury by fitting the equipment to the expected body size, strength, and range of motion characteristics of the user population. Such design will also facilitate task performance.

2 Scope

2.1 The guidelines address safety aspects of ergonomics engineering in the design of semiconductor manufacturing equipment. It should be noted that in order to ensure comprehensive coverage of potential safety hazards, some guidelines also address general design goals for effective human-machine performance. The guidelines apply to the design, operation, maintenance, and service of semiconductor manufacturing equipment, as well as, to a limited extent, equipment installation (see Section 7.3).

2.2 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 International, national, and local standards, codes, and regulations must be consulted to ensure that equipment meets regulatory requirements**.**

3.2 Human factors data compiled in references and specifications are influenced by the population from which they were drawn and the reason they were collected. Human factors design criteria are sometimes based on studies using few subjects or are context-specific. Ergonomics experts should be consulted where data development or interpretation is required.

3.3 The equipment design should incorporate reasonable accommodations for users with special needs, such as left-handedness and color blindness. Where feasible the design should also accommodate users with hearing or vision impairments and/or physical disabilities. It should be understood that although designing for the target user population will accommodate some users with special needs, these guidelines cannot anticipate and fully accommodate all such users.

3.4 Existing models and subsystems that meet previous versions of SEMI S8 should continue to meet the guidelines of SEMI S8 in force at the time of design. Models with redesigns that significantly affect the ergonomic design of the equipment should include conformance to the latest version of SEMI S8 for the redesign.

NOTE 1: Conformance with this document is believed to be a suitable substitute for conformance with its predecessors.

3.5 Conformance with the guidelines in Appendix 1 (SESC) constitute conformance with SEMI S8.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E95 — Specification for Human Interface for Semiconductor Manufacturing Equipment

SEMI S1 — Safety Guideline for Visual Hazard Alerts

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

4.2 *CEN/CENELEC Standards*[1]

4.2.1 European Norm (EN) standards are listed herein for application to semiconductor manufacturing equipment to be used in the European Union (EU). As EN standards are intended for use with a broad range of industrial and consumer products, conflicts with SEMI safety guidelines are likely. Additionally, provisional EN (prEN) standards are subject to revision prior to adoption.

EN 894-2 — Safety/Ergonomics for Displays

EN 894-3 — Safety/Ergonomics for Control Actuators

EN 60204-1 — Safety of Machinery — Electrical Equipment of Machines, Part 1. Specification for General Requirements

4.3 *Military Standard* [2]

MIL-STD-1472 — Human Engineering Design Criteria for Military Systems, Equipment, and Facilities

4.4 *NFPA Document*[3]

NFPA 79 — Electrical Standard for Industrial Machinery

4.5 *ISO Document*[4]

ISO 9241 — Ergonomic Requirements for Office Work with Visual Display Terminals

4.6 *Other Standards*

Humanscale, The MIT Press, Massachusetts Institute of Technology, Cambridge, MA 02142, 1974

ANSI/IES RP7[5] — Practice for industrial lighting

Waters, Thomas, et. al., *Application Manual for the Revised NIOSH Lifting Equation*, U.S. Department of Health and Human Services (NIOSH), Cincinnati, OH, 1994.

A. Mital, A.S. Nicholson, M.M. Ayoub: *A Guide to Manual Materials Handling*, Taylor and Francis, London, 1993.

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *MAWL* — Maximum Acceptable Weight of Lift

5.1.2 *MMH* — Manual Material Handling

5.1.3 *SESC* — Supplier Ergonomics Success Criteria (See Appendix 1.)

5.2 *Definitions*

5.2.1 *administrative controls* — administrative controls modify the way in which a job is performed without involving equipment design. They are non-engineering controls which include: job rotation, job enlargement, work-rest scheduling, micro-breaks, and stretching exercises. Engineering controls are preferred over administrative controls.

5.2.2 *anthropometric considerations* — design considerations based upon anthropometric (e.g., size and strength) limitations of user personnel.

5.2.3 *anthropometry* — description of the physical measurement of humans (e.g., size, strength).

5.2.4 *cognitive* — relating to human information processing, perception, and attention.

5.2.5 *critical controls and displays* — controls and displays which prevent the equipment from entering, or indicate that equipment is entering an unsafe condition in which hazards to personnel or damage to equipment may occur. Emergency Off (EMO) switches, interlock defeat indicators, and malfunction alarms are examples of critical controls and displays.

5.2.6 *cumulative trauma disorder* — a disorder which results from the accumulation of stresses (e.g., forces, repetitive movements, etc.) to a body part over a period of time.

5.2.7 *duration* — the length of time of a cycle or the entire task, which represents the time of exposure to single or multiple risk factors.

1 European committee for standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat: rue de Stassart 35, B-1050 Brussels, Belgium

2 Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20555, USA

3 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA

4 International Organization for Standardization, C.P.56, CH-1211 Geneva 20, Switzerland

5 American National Standards Institute, 1430 Broadway, New York, NY 10018 USA

5.2.8 *emergency off (EMO)* — a control circuit which, when activated, places the equipment into a safe shutdown condition.

5.2.9 *engineering control* — a method to eliminate or mitigate a hazard through equipment design.

5.2.10 *ergonomic-related hazard* — an equipment or workplace condition that creates stress to the user that contributes to the risk of developing either an acute injury or a cumulative trauma disorder.

5.2.11 *ergonomic issues* — those issues dealing with the user's physical and cognitive needs, capabilities, and human performance limitations in relation to the design of machines, tasks, and other features of the human's working environment.

5.2.12 *ergonomics* — the study of human mental and physical capability in relation to the working environment and the equipment operated by the worker.

5.2.13 *excessive reach* — a reach which may result in biomechanical or other stress to the user.

5.2.14 *extended reach* — a reach which requires either stretching, stooping, crouching, bending forward at the waist greater than 20 degrees, or shoulder flexion or abduction greater than 45 degrees.

5.2.15 *force* — the mechanical effort to accomplish a specific movement or exertion. These include: static exertions, which produce no motion but have significant duration; dynamic exertions, which are motions including lifting, pushing, pulling; and contact stress, which is localized pressure exerted against the skin by an external force.

5.2.16 *frequency* — how often a task is performed over time.

5.2.17 *frequently used* — used in processing or job cycle at least once every hour. Multiple tool operation by a single operator should be considered.

5.2.18 *human error* — errors which include: failure to perform a required function; performing a function that has an undesirable consequence; failure to recognize and correct a hazardous condition; or inadequate or incorrect response to a contingency.

5.2.19 *inadvertent actuation* — accidental or unintentional activation or deactivation of a control.

5.2.20 *infrequently used* — used in processing or job cycle less frequently than once every hour. Multiple tool operation by a single operator should be considered.

5.2.21 *installation* — the activities performed after the equipment is received at a user site through preparation for initial service, including transportation, lifting, uncrating, placement, leveling, and facilities fit up.

5.2.22 *lateral pinch* — grip in which the object is held between the thumb and the side of the index finger (often referred to as key grip).

5.2.23 *maintenance* — planned or unplanned activities intended to keep equipment in good working order.

5.2.24 *mock up* — a full size physical model of the equipment, generally made of relatively inexpensive materials, used for human factors evaluation.

5.2.25 *neutral posture* — the position of the human body in which the joints are least stressed. Generally, the body in its neutral position is standing erect with the eyes looking forward, and the arms hanging by the sides.

5.2.26 *non-neutral (awkward) postures* — The position of a joint(s) away from its neutral, or least stressed, posture.

5.2.27 *normal line of sight* — the line extending from the eyes, perpendicular to the interoccular line and 15 degrees below the horizontal position of the eye.

5.2.28 *operation* — consists of functions by which the operator causes the equipment to perform its intended purpose; these may include loading product and setting or manipulating external controls.

5.2.29 *operator* — a user that interacts with the equipment only to the degree necessary for the equipment to perform its intended function.

5.2.30 *override* — to take precedence over the current control system state.

5.2.31 *palmar pinch* — grip where the fingers press against the palm of the hand, with the object held between the fingers and the palm. Thumb is not used (e.g., picking up a sheet of plywood).

5.2.32 *personal protective equipment (PPE)* — equipment and clothing worn to reduce potential for personal injury from hazards associated with the task to be performed (e.g., chemical gloves, respirators, safety glasses, etc.). In the context of this document, cleanroom attire (e.g., gloves, smocks, booties, hoods) is not considered personal protective equipment.

5.2.33 *power grip* — a grip in which the fingers and thumb wrap entirely around the handle such that the thumb contacts or overlaps the index finger.

5.2.34 *postural stress* — stress occurring when a body position places undue load on the muscles, tendons, nerves, and blood vessels, or produces pressure on a joint.

5.2.35 *primary viewing area* — the 30 degree cone around the normal line of site (15 degrees above, below, and to either side of the line of sight).

5.2.36 *problem tasks* — tasks which have been defined as presenting ergonomically incorrect conditions that are likely to cause biomechanical stresses or injury to personnel, misoperation, or damage to equipment or the product.

5.2.37 *risk factors* — those elements of the design which allow an increased potential for injury/illness to personnel, or for damage to equipment, environment, or product.

5.2.38 *semiconductor manufacturing equipment* — equipment used in the design, development, manufacture, assembly, measurement and test of semiconductors, and associated semiconductor support processes.

5.2.39 *service* — unplanned activities intended to return equipment, which has failed, to good working order.

5.2.40 *static posture* — a fixed position, with minimal movement of the particular body parts.

5.2.41 *stooping* — bending the head and shoulders, or the general body, forward and downward from an erect position.

5.2.42 *task* — a group of related job elements performed within the work cycle and directed toward a specific objective.

5.2.43 *task analysis* — an analytical process employed to determine the specific actions required of the user when operating, maintaining, or servicing equipment, or doing work on single or multiple tools. Within each task, steps are described in terms of the perception, decision-making, memory storage, posture, and biomechanical requirements, as well as the expected errors.

5.2.44 *tip pinch* — grip in which the object is held between the tips of the thumb and index finger.

5.2.45 *user* — person interacting with the equipment. Users may include operators, maintainers, service personnel, and others.

5.2.46 *user population* — a specific cross section of persons that may reasonably be expected to interact with the equipment to perform operation, maintenance, or service tasks.

5.2.47 *validation testing* — testing to confirm effectiveness of design. An item's "effectiveness" is viewed in terms of its functional design, specific to SEMI S8.

5.2.48 *WIP nest* — a storage structure for Work in Process (WIP).

5.2.49 *work environment* — the location where semiconductor devices and associated support processes are designed, developed, manufactured, assembled, measured, and tested.

5.2.50 *workplace layout* — the physical arrangement of equipment in the facility.

5.2.51 *workspace* — the available area where the user is expected to operate, maintain, and service the equipment.

5.2.52 *workstation* — the location where equipment controls and displays are found or the location of loading/unloading of material.

6 General Guidelines

6.1 *Ergonomics-Related Safety Issues* — Ergonomics-related safety issues may exist whenever equipment design, installation, operation, service, or maintenance factors result in task demands that exceed the information processing or physical capabilities of properly trained users. For example, ergonomics-related safety issues may result from:

6.1.1 Static or awkward postures,

6.1.2 Repetitive motion,

6.1.3 Poor access, inadequate clearance, and excessive reach,

6.1.4 Lifting of heavy or bulky components,

6.1.5 Displays that are difficult to read or understand,

6.1.6 Controls that are confusing to operate or require too much force, and

6.1.7 Use of non-specific warnings or faults to communicate machine problems.

6.2 Safety-related issues should be designed out or otherwise reduced to an acceptable level prior to production. Ergonomics-related safety issues are reduced by implementing sound ergonomics engineering principles in design, and structuring job requirements around human performance capabilities and limitations.

6.3 Equipment should be designed to reduce or eliminate the potential types of error caused by human-machine or human-task mismatch (e.g., inadvertent actuation, errors of omission, or commission).

6.4 Engineering controls are the preferred means to reduce hazards. Where an engineering approach to ergonomic hazard control is not feasible, the user should implement administrative controls to mitigate hazards by reducing the duration, frequency, or severity of exposure.

6.5 Highest priority should be placed on issues which have the potential of resulting in injury to personnel. Secondary priority should be placed on issues which have the potential of resulting in significant damage to equipment.

6.6 Information exchange between equipment suppliers and users regarding human-machine interface issues is encouraged during the development stage, as part of beta site testing, after equipment is in full production, and throughout the life cycle of the equipment.

6.7 Ergonomics evaluation should be performed throughout the conception, design, build, and install phases to determine whether ergonomics guidelines have been met. The examination should yield a completed SESC document (see Appendix 1).

6.7.1 Equipment evaluation should identify risk factors associated with equipment design that affect operation, training, installation, maintenance, or service tasks.

6.7.2 Use of mock-ups and simulations are beneficial to identify and resolve ergonomic issues before the design is finalized. Testing should be performed with individuals who are representative of the user population under anticipated working conditions.

6.7.3 The evaluation should include consideration of multiple pieces of equipment under the control of one individual, resulting in an operation being repeated several times sequentially. The supplier should state the criteria for this scenario and include it in the report.

6.8 The overall objective is to provide for equipment effectiveness and for worker safety, convenience, and comfort when operating and maintaining the equipment.

6.9 Damage or undue deterioration of required garments or PPE should not occur as a result of equipment operation. Controls, such as knobs and switches, should be designed to be compatible with gloves worn by users for contamination control or personal protection. For example, cleanroom gloves typically reduce grip strength by 15%. Equipment displays should consider the potential for impaired vision and hearing that may occur with the use of cleanroom hoods, chemical goggles, or face shields.

6.10 Technical documentation (e.g., manuals) and on-equipment instructions (e.g., labels, indicators and screen menus) should be consistent in action, terminology, symbols, and format.

6.11 Equipment customized to meet specific customer requirements should not increase the level of ergonomic risk.

6.12 For recommendations on human interface design, see SEMI E95.

NOTE 3: SEMI E95 provides information on human computer interface. It is not the intent of S8 to incorporate the requirements of SEMI E95 by reference.

7 Documentation

7.1 The supplier should provide an evaluation of the equipment to SEMI S8 using Appendix 1, “Supplier Ergonomic Success Criteria” for measurable criteria. The evaluation should include a determination of the level of risk associated with non-conformance items. Evaluation of risk should be compatible with the SEMI S10 severity categories; catastrophic, severe, moderate, and minor.

7.1.1 For each item in Appendix 1 which does not meet the criteria, the evaluation report should include the measured actual dimensions, and state any supporting rationale for non-compliance. Supporting rationale may include test data or documented engineering judgment. EXCEPTION: For Section 1, the manual material handling analysis, the evaluation report should provide documented calculations regardless of the outcome of the analysis.

7.1.2 The evaluation report should also include the following information: manufacturer’s model number, serial number of unit evaluated, date the equipment was evaluated, a list of all tasks which were evaluated as part of the analysis and the name of the person performing the evaluation.

7.2 Supplier provided documentation should include administrative controls intended by the supplier to mitigate ergonomic risks.

7.3 Supplier provided documentation should illustrate any installation requirement necessary to meet SEMI S8 guidelines (e.g., Diagram should show clearance area required for opening hinged panels, operator working area, allowable range of vertical foot adjustment to keep ergonomic measurements within SESC acceptable limits, etc.).

8 Related Documents

8.1 *SEMI Standard*

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

8.2 *ANSI Documents*[5]

ANSI Z535.4 — Product Safety Signs and Labels

8.3 *CEN/CENELEC Standards*[6]

EN 614-1 — Safety of Machinery — Ergonomic Design Principles, Part 1. Terminology and General Principles

EN 894-1 — Safety/Ergonomics for Operator Interaction

EN 50099-2 — Safety/Marking Principles

8.4 NIOSH Documents[7]

NIOSH Publication No. 81-122 — *Work Practices Guide for Manual Lifting*, National Institute for Occupational Safety and Health, 1981.

Revised NIOSH Equation, *Ergonomics*, Vol. 36, No. 7, 1993.

8.5 *SAE Document*[8]

SAE J833 — Human Physical Dimensions

8.6 *SEMATECH Documents*[9]

Preventing User-Hostile Interfaces in IC-Fab Equipment — Ergonomic Approaches for Preventing Ten Frequent Interface Problems, Miller, Dwight P. and Whitehurst, Hugh, SEMATECH Technology Transfer #92091299NA-ENG, Nov. 1992.

SEMATECH SCC User interface Style Guide, 1.0. 92061179A-ENG, August 21, 1992.

8.7 *Other Documents*

Bailey, Robert W., *Human Performance Engineering*, Prentice Hall, 1989.

Eastman Kodak Company, *Ergonomic Design for People at Work, Vols. 1 and 2*, Van Nostrand-Reinhold, 1983.

EN ISO 7250 — *Basic human body measurements for technological design*

EN ISO 14738 — *Safety of Machinery, Anthropometric requirements for the design of workstations at machinery*

Grandjean, E., *Fitting the Task to the Man: A Textbook of Occupational Ergonomics* (4th Ed.), Taylor & Francis, 1988.

Grether W.F. and Baker C.A., 1972, Visual Presentation of Information in Van Cott and Kincade *Human Engineering to Equipment Design,* Washington DC, US Government Printing Office.

Konz, S., *Work Design*: *Industrial Ergonomics* (3rd Ed), Publishing Horizons, 1990.

Pheasant, Stephen, Bodyspace — *Anthropometry, Ergonomics and Design*, Taylor & Francis, 1988.

Salvendy, Gavriel (ed.), *Handbook of Human Factors*, Wiley, 1987.

Sanders, Mark S. and McCormick, Ernest, *Human Factors in Engineering and Design* (7th Ed), McGraw-Hill Book Company, 1993.

Snook, Stover and V. Ciriello, The Design of Manual Handling Tasks — Revised Tables of Maximum Acceptable Weights and Forces, *Ergonomics*, Vol. 34, No. 9, 1991.

VanCott, Harold P. and Kinkade, Robert (eds.), *Human Engineering Guide to Equipment Design*, U. S. Government Printing Office, 1972.

NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

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6 European Committee for Standardization (CEN)/European Committee for Electrotechnical Standardization (CENELEC), Central Secretariat, rue de Stassart 35, B-1050 Brussels, Belgium

7 National Institute for Occupational Safety and Health, Technical Information Branch, 4676 Columbia Pkwy, Cincinnati, OH 45226

8 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096 USA

9 SEMATECH, Technology Transfer, 2706 Montopolis Dr., Austin, TX 78741 USA

APPENDIX 1
SUPPLIER ERGONOMIC SUCCESS CRITERIA (SESC)

NOTE: The material in this appendix is an official part of SEMI S8 and was approved by full letter ballot procedures by the North American Regional Standards Committee.

Table A1-1 Supplier Ergonomic Success Criteria Checklist

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
1	**Manual Material Handling**			
1.1	Potentially hazardous manual material handling tasks performed as part of operations, maintenance, or service are analyzed utilizing appropriate procedures. NOTE: Two hand lifting or lowering tasks should be analyzed: if the object being handled weighs more than 44.5 N (10 lbs.); OR, if the object weighs more than 22.2 N (5 lbs.) and the anticipated frequency is greater than 1 lift every 5 minutes. See Appendix 2 for further information.	Analysis and results documentation. Table A2-2, Appendix 2, or the equivalent, should be used to document 2 hand lift/lower analysis.		
2	**Product Loading in a Standing Posture** (Applicable to all media other than wafer cassettes including JEDEC trays, magazines, and reticle cassettes.			
2.1	Clearance provided for finger thickness.	minimum 38 mm (1.5 in.)		
2.2	Clearance provided for hand thickness.	minimum 76 mm (3.0 in.)		
2.3	Reach distance measured from the leading edge of the tool or obstruction to the hand/product coupling point(s).	maximum 330 mm (13 in.)		
2.4	Vertical coupling point of hand to product in load position	maximum 1010 mm (40 in.) minimum 890 mm (35 in.)		
3	**Wafer Cassette Loading**			
3.1	Wafer cassette loading should not require greater than 10 degrees cassette rotation in any axis. NOTE: Unless otherwise specified, you should assume that 200 mm or smaller wafers are transported in the vertical orientation and that 300 mm wafers are transported in the horizontal orientation.	less than 10 degrees rotation in any axis		
3.2	Load port height, vertical distance from standing surface (150–200 mm wafers).	maximum 960 mm (38 in.) minimum 890 mm (35 in.)		
3.3	Maximum lip height in front of cassette load port over which cassette is lifted (150–200 mm wafer cassettes only). Measure lip height from the load surface.	maximum 30 mm (1.2 in.)		
3.4	Reach distance from the leading edge of the tool or obstruction to the coupling point(s) on rotation device or the product grasp point.	maximum 330 mm (13 in.)		
3.5	Minimum hand clearance on either side of the cassette, measured from the side of the cassette to the nearest adjacent object.	minimum 76 mm (3.0 in.)		

Section	*Indicator*	*Acceptance Criteria* *Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
4	**Work in Process Storage** (specific to wafer cassettes)			
4.1	Integral wafer cassette/lot box storage shelf height (150 and 200 mm wafer cassette/lot boxes only)	maximum (1 box deep) 1520 mm (60 in.) maximum (2 boxes deep) 1220 mm (48 in.) minimum 460 mm (18 in.)		
5	**Manual Wafer Cassette Rotation Device Design**			
5.1	Handle height, couple point for hand(s) from standing surface.	maximum 1206 mm (47.5 in.) minimum 838 mm (33 in.)		
5.2	Hand grip(s) shall allow for a full "power grip" similar to grabbing a rung on a ladder or holding a pistol.	Allows for a full power grip in either pronated (palm facing down) or neutral (handshake position) posture.		
5.3	Single hand lift force	maximum 37.8 N (8.5 lb.) This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.		
5.4	Two hand lift force	maximum 64.5 N (14.5 lb.) This value includes a 15% capacity reduction due to cleanroom glove use. Wrist deviation reduces further strength capacity by 15%.		
6	**Handle Design** (Handle dimensions are correct for use of bare hand or use of typical cleanroom gloves) NOTE: See Appendix 3 for depiction of handle types.			
6.1	Handle surface finish	all edges radiused		
6.2	Cylindrical handle			
6.2.1	Cylindrical handle diameter (D)	maximum 38 mm (1.5 in.) minimum 25 mm (1.0 in.)		
6.2.2	Cylindrical handle length (L)	minimum 127 mm (5.0 in.)		
6.3	Circular or triangular handle			
6.3.1	Circular or triangular handle diameter (D)	maximum 90 mm (3.5 in.) minimum 50 mm (2.0 in.)		
6.3.2	Circular or triangular handle height (thickness) (H)	maximum 25 mm (1.0 in.) minimum 19 mm (0.75 in.)		
6.4	Ball handle			
6.4.1	Ball handle diameter	maximum 63 mm (2.5 in.) minimum 38 mm (1.5 in.)		
6.5	Pliers handle			
6.5.1	Pliers handle grip span (S)	maximum 89 mm (3.5 in.) open minimum 38 mm (1.5 in.) closed		
6.5.2	Pliers handle length (L)	minimum 127 mm (5.0 in.)		
6.6	Pistol grip handle			
6.6.1	Pistol grip handle diameter (D)	maximum 63 mm (2.5 in.) minimum 38 mm (1.5 in.)		
6.6.2	Pistol grip handle length (L)	minimum 127 mm (5.0 in.)		

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
6.7	Enclosed handles NOTE: Handle diameter refers to the surface of the handle presented to the inside of the curled fingers. Enclosed handles need not be made solely from cylindrical stock.			
6.7.1	Enclosed handle, full hand power grip (suitcase handle) Width (W) Depth (D) Diameter (d)	minimum 127 mm (5.0 in.) minimum 45 mm (1.75 in.) maximum 25 mm (1.0 in.)		
6.7.1.1	Diameter (d), requiring no greater than 71 N (16 lbf) force	minimum 6.3 mm (0.25 in.)		
6.7.1.2	Diameter (d), requiring no greater than 89 N (20 lbf) force	minimum 13 mm (0.5 in.)		
6.7.1.3	Diameter (d), requiring no greater than 200 N (40 lbf) force	minimum 19 mm (0.75 in.)		
6.7.2	Enclosed handle, three fingers Width (W) Depth (D) Diameter (d) Force	minimum 90 mm (3.5 in.) minimum 38 mm (1.5 in.) minimum 6.3 mm (0.25 in.) maximum 71 N (16 lbf)		
6.7.3	Enclosed handle, two fingers Width (W) Depth (D) Diameter (d) Force	minimum 60 mm (2.5 in.) minimum 38 mm (1.5 in.) minimum 6.3 mm (0.25 in.) maximum 51 N (11.5 lbf)		
6.7.4	Enclosed handle, one finger Width (W) Depth (D) Diameter (d) Force	minimum 38 mm (1.5 in.) minimum 38 mm (1.5 in.) minimum 3.2 mm (0.13 in.) maximum 27 N (6 lbf)		
6.8	Hook grasp handle			
6.8.1	Hook grasp handle (four fingers) Opening length (L) Opening width (W) Depth (d) Lip length (l)	minimum 90 mm (3.5 in.) minimum 38 mm (1.5 in.) minimum 50 mm (2.0 in.) minimum 50 mm (2.0 in.)		
6.8.2	Hook grasp handle pull force (four fingers)	maximum 80 N (18.0 lb.)		
6.9	Finger pull handle			
6.9.1	Finger pull handles (four fingers) Opening length (L) Opening width (W) Depth (d) Lip length (l)	minimum 90 mm (3.5 in.) minimum 25 mm (1.0 in.) minimum 19 mm (0.75 in.) minimum 19 mm (0.75 in.)		
6.9.2	Finger pull handles pull force (four fingers)	maximum 9.8 N (2.2 lb.)		
7	**Maintainability and Serviceability**			
7.1	Minimum lighting level in routine maintenance areas is required where the operator has to read information, use a hand tool, or make a connection. This provision can be met by providing integral lighting or portable lighting which can be temporarily attached such that it does not have to be hand held.	minimum 300 lux (30 fc)		

Section	Indicator	Acceptance Criteria Metric Units (US Customary Units)	Actual	Conforms/Does Not Conform/Not Applicable
7.2	Full Body Clearance NOTE: Clearances should be approached from a task analysis point of view. Clearances should be provided based on the nature of the tasks performed in the designated area.			
7.2.1	Any posture: upper body clearance (shoulder width)	minimum 610 mm (24 in.)		
7.2.2	Standing: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3)	 minimum 1980 mm (78 in.) minimum 690 mm (27 in.)		
7.2.3	Sitting-on-Floor: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3) working height	 minimum 1000 mm (39 in.) minimum 690 mm (27 in.) minimum 280 mm (11 in.)		
7.2.4	Squatting: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3) working height	 minimum 1220 mm (48 in.) minimum 790 mm (31 in.) minimum 460 mm (18.1 in.)		
7.2.5	Kneeling: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3) working height	 minimum 1450 mm (57 in.) minimum 1220 mm (48 in.) minimum 640 mm (25.2 in.)		
7.2.6	Kneeling Crawl: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3)	 minimum 740 mm (29 in.) minimum 1520 mm (60 in.)		
7.2.7	Stooping: overhead clearance, measured from the floor forward horizontal clearance (see NOTE 3) working height	 minimum 1450 mm (57 in.) minimum 1020 mm (40 in.) minimum 640 mm (25.2 in.)		
7.2.8	Supine (lying on back): height length	 minimum 430 mm (17 in.) minimum 1980 mm (78 in.)		
7.2.9	Prone or crawl space: height length	 minimum 510 mm (20 in.) minimum 2440 mm (96 in.)		
7.3	Hand/Arm Clearance (where appropriate to do so, dimensions have been adjusted for the use of cleanroom gloves)			
7.3.1	Clearance provided for finger access, round (dia) or square: one finger 2, 3, or 4 finger twist of small knob	 minimum 32 mm (1.25 in.) minimum object diameter + 58 mm (2.3 in.)		
7.3.2	Clearance provided for flat hand to wrist access: height, palm thickness width, palm width	 minimum 89 mm (3.5 in.) minimum 114 mm (4.5 in.)		
7.3.3	Clearance provided for fist to wrist access: height, palm thickness width, palm width	 minimum height 89 mm (3.5 in.) minimum width 127 mm (5.0 in.)		

Section	*Indicator*	*Acceptance Criteria* *Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
7.3.4	Clearance provided for two hands arm to shoulders access (does not ensure visual access): reach width height	 maximum 610 mm (24.0 in.) minimum 483 mm (19 in.) minimum 114 mm (4.5 in.)		
7.3.5	Clearance provided for two hands, hand to wrist access (does not ensure visual access): reach width height	 maximum 203 mm (8.0 in.) minimum 191 mm (7.5 in.) minimum 114 mm (4.5 in.)		
7.3.6	Clearance provided for one arm to shoulder access, diameter or square area (does not ensure visual access).	minimum 132 mm (5.2 in.)		
7.3.7	Clearance provided for one arm to elbow access, diameter or square area (does not ensure visual access).	minimum 119 mm (4.7 in.)		
7.4	Maintenance and Service Access			
7.4.1	Enclosures or covers must, unless fully removable, be self-supporting, in the open position, and not require manual support during maintenance. Exceptions may be allowed for self closing doors for fire safety or compliance reasons.	Supports present		
7.4.2	Access covers should be equipped with full-handed grasp areas or other means for opening them.	Handles present, refer to Section 6 for design criteria.		
7.4.3	Height of access cover handle over the entire range of motion required for operation or maintenance. There should be no greater than a 254 mm (10 in.) deep obstruction in front of the handle.	maximum 1700 mm (67 in.)		
7.5	Replaceable Components			
7.5.1	Serviceable components are replaceable as modular packages, and are configured for rapid removal and replacement.	Serviceable components configured as described.		
7.5.2	Serviceable components should not be stacked directly on one another (*i.e.*, a lower layer should not support an upper layer).	Serviceable components independently accessible.		
7.5.3	Heavy components (objects which have a lifting index of 0.5 or greater, see SESC, Section 1.0) or bulky components (greater than 36 inches in length) requiring frequent removal/installation should include guide/locating aids to assist in positioning.	Guide/locating pins present.		
7.5.4	Cables, connectors, plugs, and receptacles should be labeled, keyed, color coded, or otherwise configured to make connection easier and prevent cross connection. This feature is assessed only if a SEMI S2 assessment is not being conducted.	Identification present, keyed where needed.		
7.5.5	Circuit boards mounted in a card cage configuration should have gripping or ejecting aids for mounting and removal.	Finger access, gripping, or ejecting aids available.		
8	**Display Location**			

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
8.1	Location for operator primary interface, standing station (see NOTE 1)			
8.1.1	Height of video display terminal (single monitor). Does not include touchscreens, measured from floor to center of screen.	maximum 1470 mm (58 in.) minimum 1320 mm (52 in.)		
8.1.2	Height of video display terminal (stacked monitors). Does not include touchscreens, measured from floor to top line of the top monitor.	maximum 1680 mm (66 in.) The primary monitor in a stacked configuration is the bottom monitor.		
8.1.3	Height of infrequently used video display terminal (viewed briefly less often than once per hour) measured to top line of monitor.	maximum 1680 mm (66 in.)		
8.1.4	Height of very infrequently used video display terminal (viewed briefly less often than once per day) measured to top line of monitor.	maximum 1880 mm (74 in.)		
8.1.5	Height of infrequently viewed visual signal measured to the top of the signal. This guideline does not apply to light towers.	maximum 2130 mm (84 in.)		
8.1.6	Height of touch screen monitor.	maximum 1370 mm (54 in.), measured from floor to uppermost active pad on screen minimum 910 mm (36 in.), measured from floor to lowest active pad on the screen See Section 9 for horizontal reach criteria.		
8.1.7	Tilt angle of touch screen monitor between 41 and 48 inches in height to top of screen.	Upward minimum 30 degrees		
8.1.8	Tilt angle of touch screen monitor less than 41 inches in height to top of screen.	Upward minimum 45 degrees		
8.2	Location for operator primary interface, seated station (see NOTE 2)			
8.2.1	Height of video display terminal (single monitor), does not include touchscreens, measured from floor to centerline of monitor.	maximum 1190 mm (47 in.) minimum 940 mm (37 in.)		
8.2.2	Height of video display terminal (stacked monitors), does not include touchscreens, measured from floor to top line of top monitor.	maximum 1400 mm (55 in.) minimum 940 mm (37 in.) The primary monitor in a stacked configuration is the bottom monitor.		
8.2.3	Tilt angle of video display terminal greater than 55 inches in height to top of screen. This line item becomes significant in the event that the maximum height criteria cannot be met.	Downward minimum 15 degrees		
8.2.4	Height of touch screen monitor.	maximum 1070 mm (42 in.) measured from floor to highest active pad on the screen minimum 760 mm (30 in.) measured from floor to lowest active pad on the screen See Section 9 for horizontal reach criteria.		
8.3	Display characteristics			

Section	*Indicator*	*Acceptance Criteria* *Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
8.3.1	Lateral distance from the centerline of the display to the centerline of the input device(s). See MIL-STD-1472 for a depiction of this.	maximum 320 mm (12.6 in.)		
8.3.2	Character height (Specific to Chinese, Korean, and Japanese characters.)	Character height is greater than or equal to the viewing distance divided by 143. Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.)		
8.3.3	Character height (All characters other than Chinese, Korean, and Japanese.)	Character height is greater than or equal to the viewing distance divided by 215. Recommended viewing distance is between 457 mm (18 in.) and 762 mm (30 in.)		
9	**Hand Control Location** (These criteria only apply to controls, tools, and materials accessed for routine production operation and maintenance.)			
9.1	Standing station (see NOTE 1)			
9.1.1	Vertical location of very infrequently used controls (controls used less often than once every 24 hours) measured from the standing surface to the centerline of the control.	maximum 1640 mm (64.5 in.) minimum 0 mm (0 in.)		
9.1.2	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Controls should not be located above 1638 mm (64.5 in.) or below 838 mm (33 in.). Interpolate for intermediate values. Height of 1638 mm (64.5 in.) Height of 1524 mm (60 in.) Height of 1422 mm (56 in.) Height of 1321 mm (52 in.) Height of 1219 mm (48 in.) Height of 1118 mm (44 in.) Height of 1016 mm (40 in.) Height of 914 mm (36 in.) Height of 838 mm (33 in.)	reach 254 mm (10.0 in.) reach 368 mm (14.5 in.) reach 432 mm (17.0 in.) reach 470 mm (18.5 in.) reach 483 mm (19.0 in.) reach 470 mm (18.5 in.) reach 394 mm (15.5 in.) reach 292 mm (11.5 in.) reach 178 mm (7.0 in.)		
9.1.3	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the equipment or obstacle. Controls should not be located above 1270 mm (50 in.) or below 940 mm (37 in.). Interpolate for intermediate values. Height of 1270 mm (50 in.) Height of 1219 mm (48 in.) Height of 1168 mm (46 in.) Height of 1118 mm (44 in.) Height of 1067 mm (42 in.) Height of 1016 mm (40 in.) Height of 940 mm (37 in.)	reach 292 mm (11.5 in.) reach 330 mm (13.0 in.) reach 368 mm (14.5 in.) reach 394 mm (15.5 in.) reach 406 mm (16.0 in.) reach 394 mm (15.5 in.) reach 318 mm (12.5 in.)		
9.2	Seated station (see NOTE 2)			

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
9.2.1	Location of infrequently used and/or critical controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Controls should not be located above 1397 mm (55 in.) or below 533 mm (21 in.). Interpolate for intermediate values. Height of 1397 mm (55 in.) Height of 1270 mm (50 in.) Height of 1168 mm (46 in.) Height of 1067 mm (42 in.) Height of 965 mm (38 in.) Height of 864 mm (34 in.) Height of 762 mm (30 in.) Height of 660 mm (26 in.) Height of 533 mm (21 in.)	reach 356 mm (14.5 in.) reach 432 mm (17.0 in.) reach 470 mm (18.5 in.) reach 483 mm (19.0 in.) reach 483 mm (19.0 in.) reach 470 mm (18.5 in.) reach 445 mm (17.5 in.) reach 381 mm (15.0 in.) reach 254 mm (10.0 in.)		
9.2.2	Location of frequently used controls. Maximum reaches are indicated for various heights. Reaches are measured from the leading edge of the work surface or obstacle. Controls should not be located above 1067 mm (42 in.) or below 762 mm (30 in.). Interpolate for intermediate values. Height of 1067 mm (42 in.) Height of 1016 mm (40 in.) Height of 965 mm (38 in.) Height of 914 mm (36 in.) Height of 864 mm (34 in.) Height of 813 mm (32 in.) Height of 762 mm (30 in.)	reach 330 mm (13.0 in.) reach 368 mm (14.5 in.) reach 394 mm (15.5 in.) reach 406 mm (16.0 in.) reach 419 mm (16.5 in.) reach 419 mm (16.5 in.) reach 419 mm (16.5 in.)		
10	**Workstation Design**			
10.1	Standing station (see NOTE 1)			
10.1.1	Work surface edge radius where the operator can assume a static posture in contact with the edge.	minimum 6.4 mm (0.25 in.) radius		
10.1.2	Height of keyboard, trackball, or mouse (to home row, top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in Section 9, Hand Control Location (standing station).	maximum 1020 mm (40 in.) minimum 970 mm (38 in.)		
10.1.3	Height of microscope eyepieces. Must be adjustable.	maximum 1730 mm (68 in.) minimum 1270 mm (50 in.)		
10.2	Seated station (see NOTE 2)			

Section	*Indicator*	*Acceptance Criteria Metric Units (US Customary Units)*	*Actual*	*Conforms/Does Not Conform/Not Applicable*
10.2.1	Height of keyboard, trackball, or mouse. (to home row, top of ball/mouse). NOTE: In applications where input devices (keyboard, trackball, or mouse) are used more like machine controls (intermittent one finger entry on the keyboard, intermittent short term use of the mouse or trackball) than for standard typing (continuous use of keyboard for entry of long character strings, extended use of trackball or mouse in graphical environment), it is appropriate to use the height and reach locations described in Section 9, Hand Control Location (seated station).	maximum 760 mm (30 in.) minimum 710 mm (28 in.)		
10.2.2	Vertical leg clearance.	minimum 673 mm (26.5 in.)		
10.2.3	Horizontal leg clearance, depth at knee level.	minimum 508 mm (20 in.)		
10.2.4	Horizontal leg clearance, depth at foot level.	minimum 660 mm (26 in.) depth × 254 mm (10 in.) vertical foot clearance		
10.2.5	Horizontal leg clearance, width.	minimum 610 mm (24 in.)		
10.2.6	Height of microscope eyepiece. Must be adjustable.	maximum 1370 mm (54 in.) minimum 1220 mm (48 in.)		
10.2.7	Thickness of work surface.	maximum 51 mm (2.0 in.)		
10.2.8	Work surface edge radius where the operator can assume a static posture in contact with the edge.	minimum 6 mm (0.25 in.) radius		

NOTE 1: A standing station is one where the operator can assume a standing posture or a seated posture in a tall stool which places the operator at approximately the same stature.

NOTE 2: A seated station is one where a short cylinder office style chair is used.

NOTE 3: Distance measured away from the equipment or obstruction for body clearance in the given posture.

APPENDIX 2
LIFTING, STRENGTH, AND MATERIALS HANDLING

NOTE: The material in this appendix is an official part of SEMI S8 and was approved by full letter ballot procedures by the North American Regional Standards Committee.

A2-1 General Considerations

A2-1.1 For recommended guidelines regarding the percentage of a user's maximum grip strength to be exerted in execution of a task see Related Information 1, Table R1-3.

A2-1.2 Where standard product or containers are to be handled at equipment load and unload stations, mechanization should be considered for orientation and handling. Where manual handling is necessary, the design should reduce extended reaching, lifting, pulling, and awkward postures. Simultaneous lifting and twisting should be avoided. Load, unload, and lift over points should be located such that the floor to hand height is 84–107 cm (33–42 in.), optimal design target is 102 cm (40 in.).

A2-1.3 Handles or cutouts should be designed to facilitate use of the power grip (e.g., similar to that used to hold a pistol). Avoid handles that require pinch grips or awkward postures. Handles should allow carrying close to the body.

A2-1.4 Lifting and handling tasks performed in a stooping position should be avoided. Stooping occurs when the vertical material handling height is less than 84 cm (33 in.), or the horizontal reach distance is greater than 46 cm (18 in.) in front of body.

A2-1.5 For two handed push/pull activities the floor to hand height should be between 97 cm (38 in.) and 112 cm (44 in.).

A2-1.6 Consideration should be given to the standing surface to minimize the risk of slips and falls.

A2-1.7 Awkward postures should be avoided. Refer to Related Information 1, Table R1-2 for a list of recommended ranges of awkward postures to avoid.

A2-1.8 For a 2-person handling task, there should be adequate coupling locations and adequate body clearance for the activity. Analyses need to be performed and documented for each person lifting if any of the parameters (e.g., horizontal reach) are different.

A2-2 Selecting and Using the Appropriate MMH Analysis Tool(s)

A2-2.1 Three general MMH evaluation tools are identified in the following matrix. The three tools are the "Application manual for the Revised NIOSH Lifting Equation" lifting equation, biomechanical models, and psychophysical capacity tabular data. Table A2-1 was designed to assist in determining which analysis tools are appropriate for a particular task. For each unique characteristic of the task, a checkmark in the analysis tool column indicates that the analysis tool is appropriate. If there is any aspect of the task that does not show a check mark in a particular tools column, that analysis tool is not appropriate to evaluate the task. Note that in many situations multiple tools are appropriate. In situations where the 1991 NIOSH equation is appropriate, the assessor should use it, because it typically will provide the most conservative results. In other situations, the assessor may use any of the appropriate tools.

A2-2.2 Correct application of the 1991 NIOSH equation is described in Waters, Thomas, et. al., Application manual for the Revised NIOSH Lifting Equation, U.S. Department of Health and Human Services (NIOSH), Cincinnati, OH, 1994.

A2-2.3 There are many sources of psychophysical data. One such source is A. Mital, A.S. Nicholson, M.M. Ayoub, A Guide to Manual Materials Handling, Taylor and Francis, London, 1993.

A2-2.4 Biomechanical analysis can be completed using biomechanical modeling software.

Table A2-1 Criteria to Determine Appropriate MH Analysis Tool(s)

MH Type	*"If" Condition*	*NIOSH (1991)*	*Bio Model*	*Psycho Physical*
2 Hand Lift or Lower	F < 1 lift/5 minutes	✔	✔	✔
	F > 1 lift/5 minutes	✔		✔
	F > 9 lifts/minute	✔		
	Twisting Occurs	✔	✔ (3D)	✔
	Handle Design is an Issue	✔		✔
	Limited Headroom During Lift			✔
	Work Duration > 8 hours			✔
	Load Placement Clearance is an Issue	✔		✔
	Load Asymmetry is an Issue	✔	✔ (3D)	✔
	Length of Object Measured in Frontal Plane of Body > 26"		✔ (3D)	
	Exposure to Heat Stress			✔
1 Hand Lifts	Posture = Standing		✔	✔
	Posture = Kneeling or Seated			✔
1 or 2 Hand Carry	NOTE: Carry is Operationally Defined as Horizontal Movement of Load ≥ 7 feet			✔
1 or 2 Hand Push/Pull	Distance < 7 feet and F < 1 Push/Pull/5 minutes		✔	✔
	Distance ≥ 7 feet and F ≥ 1 Push/Pull/5 minutes			✔
	Push/Pull Task Requires Significant Sustained Forces (e.g., slide box along floor)			✔
Lift/Lower in Non-Standard Postures	Kneeling, Sitting, or Lying			✔

NOTE 1: Under Bio Model, 3D indicates that only a 3-dimensional biomechanical model is appropriate for the task condition.

Table A2-2 Two Hand Lift/Lower Manual Material Handling Analysis Documentation

NIOSH Analysis

Horizontal (origin)	Horizontal (destination)	Vertical	Distance	Asymmetry (origin)	Asymmetry (destination)	Frequency	Duration	Coupling
measure	measure	measure	measure	measure	measure	measure	measure	measure
multiplier	multiplier	multiplier	multiplier	multiplier	multiplier	multiplier	multiplier	multiplier

Precision placement req.

Recom-mended weight limit	Lifting index

Psychophysical Analysis

Box size	Range of lift	Frequency

MAWL

Headroom limitation	Load clearance	Load asymmetry	Asymmetry	Work duration	Coupling
measure	measure	measure	measure	measure	measure
multiplier	multiplier	multiplier	multiplier	multiplier	multiplier

Adjusted MAWL	Lifting index

Conclusions

one person lift	Recommended weight limit	Lifting index

two person lift	Recommended weight limit	Lifting index

APPENDIX 3
HANDLE DESIGN DIAGRAMS

NOTE: The material in this appendix is an official part of SEMI S8 and was approved by full letter ballot procedures by the North American Regional Standards Committee.

A3-1 Handle Design

A3-1.1 The following diagrams are intended to clarify the criteria described in Section 6 of Appendix 1.

A3-1.1.1 Cylindrical handle

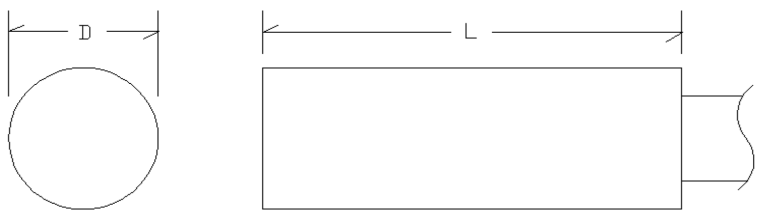

Figure A3-1
Cylindrical Handle

D - Handle diameter
L - Handle length

A3-1.1.2 Circular handle, or triangular handle

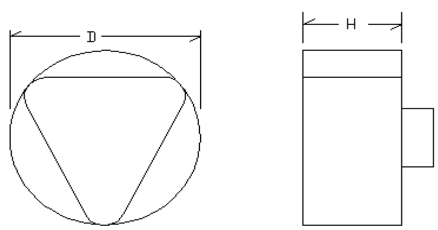

Figure A3-2
Circular Handle, or Triangular Handle

D - Handle diameter
H - Handle height (thickness)

A3-1.1.3 Pliers handle

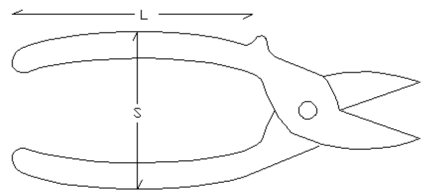

Figure A3-3
Pliers Handle

L - Handle length
S - Handle grip span

A3-1.1.4 Pistol grip handle

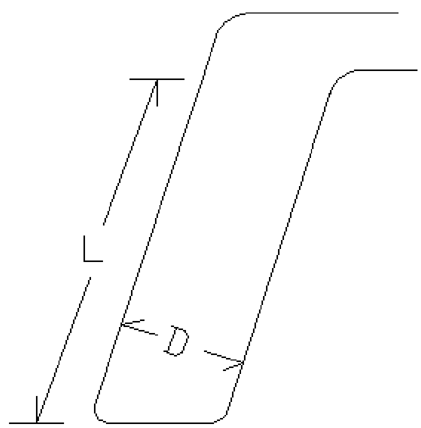

Figure A3-4
Pistol Grip Handle

D - Handle diameter
L - Handle length

A3-1.1.5 Enclosed handle

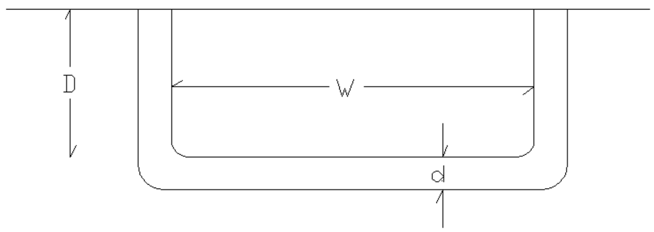

Figure A3-5
Enclosed Handle

D - Handle depth
W - Handle width
d - Handle diameter

A3-1.1.6 Hook grasp handle, or finger pull handle

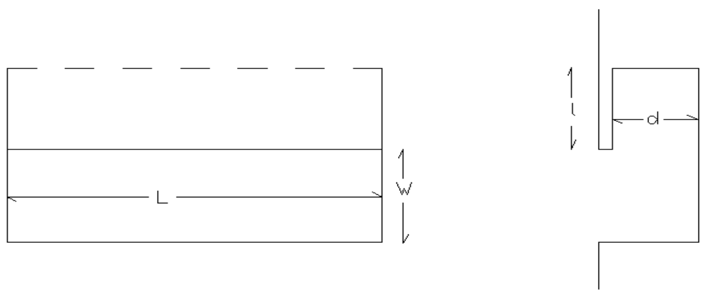

Figure A3-6
Hook Grasp Handle, or Finger Pull Handle

W - Handle opening width
L - Handle opening length
l - Handle lip length
d - Handle depth

NOTICE: These guidelines address aspects of ergonomics engineering and include numerous general design goals for effective human-machine performance. SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of the guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These guidelines are subject to change without notice.

The user's attention is called to the possibility that conformance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. User's of this guideline are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1
ANTHROPOMETRIC RESOURCE DATA

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

Table R1-1 Selected Body Dimensions for Females and Males (see Figures R1-1 and R1-2)

Criteria		*5th Percentile Female (Asian)*		*95th Percentile Male (U.S.)*	
Standing Dimensions		**cm**	**inch**	**cm**	**inch**
Stature	(A)	147.1	57.9	189.50	74.60
Eye Height	(B)	135.6	53.4	176.30	69.40
Shoulder height	(C)	120.6	47.5	157.20	61.90
Elbow height	(D)	89.4	35.2	121.40	47.80
Knuckle height	(E)	67.6	26.6	83.10	32.70
Seated Dimensions		**cm**	**inch**	**cm**	**inch**
Seated height	(F)	78.0	30.7	97.30	38.30
Eye height	(G)	66.0	26.0	84.30	33.20
Shoulder height	(H)	51.0	20.1	64.50	25.40
Elbow height	(I)	16.5	6.5	28.70	11.30
Buttock-knee length	(J)	47.0	18.5	65.00	25.60
Popliteal height	(K)	35.0	13.8	52.10	20.50
Knee height	(L)	43.4	17.1	63.20	24.90
Reach		**cm**	**inch**	**cm**	**inch**
Standing vertical grip reach	(M)	171.2	67.4	213.4	84.0
Sitting vertical grip reach	(N)	85.5	33.7	135.6	53.4
Forward grip reach	(O)	58.0	22.8	78.7	31.0

NOTE 1: Dimensions based on Pheasant (1988), MIL-STD-1472, and SAE J833 (1989).

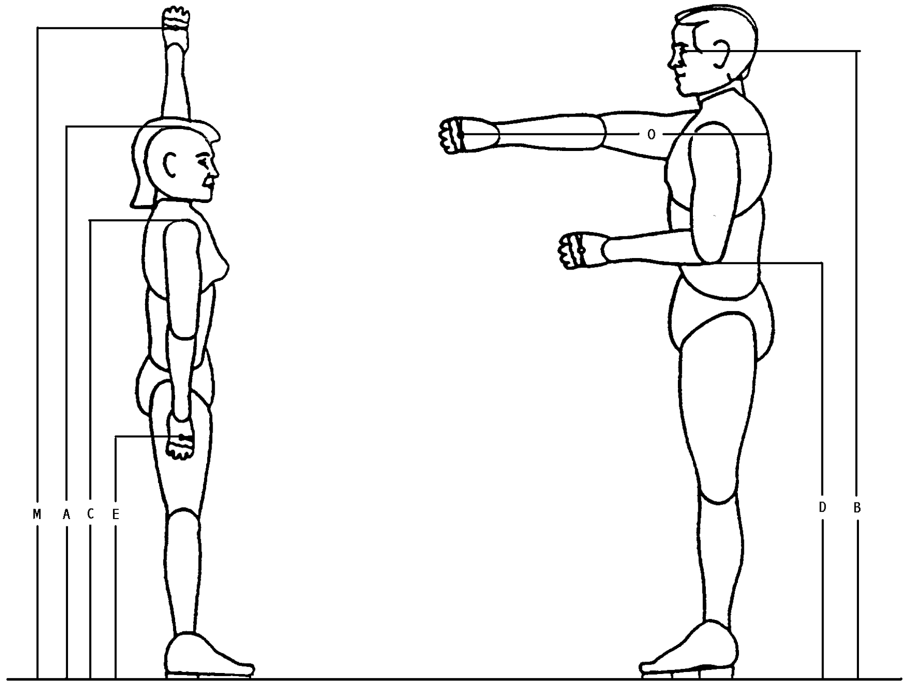

Figure R1-1
Selected 5th Percentile Female and 95th Percentile Male Standing Dimensions

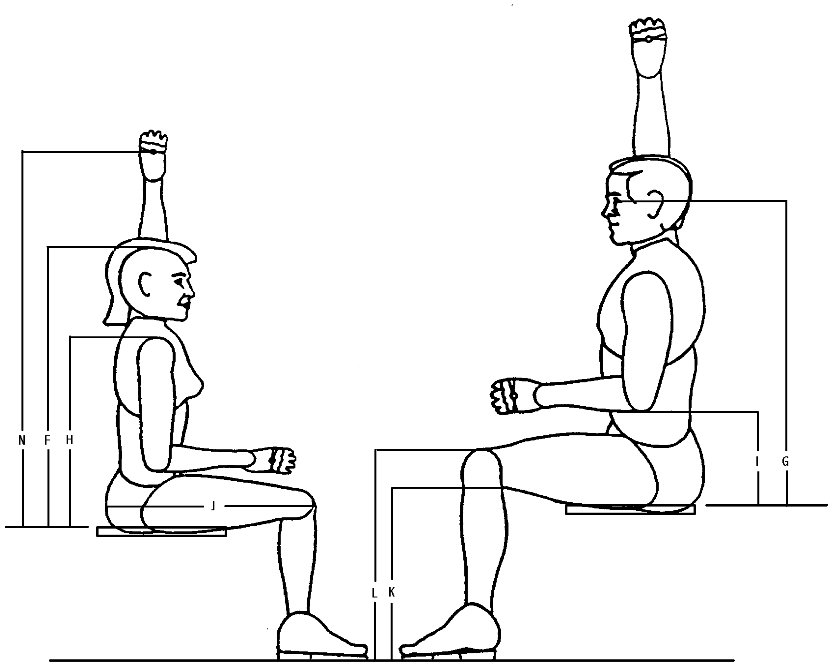

Figure R1-2
Selected 5th Percentile Female and 95th Percentile Male Seated Dimensions

Table R1-2 Awkward Postures

Body Part	*Awkward Posture (angle in degrees)*	*Comments*
Upper extremities		
Shoulder flexion (1)	> 45	Shoulder flexion is defined as reach in front of body mid-line.
Shoulder extension (2)	> 0	Shoulder extension is defined as reach behind body mid-line.
Shoulder abduction	> 45	NOT SHOWN. Abduction is movement of elbow away from body.
Forearm rotation	NA (See NOTE 3.)	NOT SHOWN. Forearm rotation is rotational movement at elbow (e.g., turning knob).
Forearm pronation	> 30	NOT SHOWN. Pronation is "palm facing down". Measured from neutral (handshake) position. Note that forearm pronation is less stressful than either rotation or supination.
Forearm supination (3)	> 30	Supination is "palm facing up". (Note that forearm is supinated in Figure R1-3.) Measured from neutral (handshake) position.
Wrist flexion (4)	> 10	Flexion is closing (reducing) the angle of the wrist.
Wrist extension (5)	> 15	Extension is opening (increasing) the angle of the wrist.
Wrist ulnar/radial deviation	> 10	Deviation is side to side movements of the wrist. Ulnar deviation is bending the wrist in the direction of the little finger. Radial deviation is bending the wrist in the direction of the thumb.
Neck flexion (6)	> 20	Neck flexion is bending the neck forward (e.g., looking downward).
Neck extension (7)	> 0	Neck extension is bending the neck back (e.g., looking up).
Neck rotation	> 45	Neck rotation is turning the neck (e.g., looking to the side).
Back (standing)		
Back bend, forward flexion (8)	> 20	Definition of "Awkward Posture" applies if posture is static.
Back twist	> 30	Measured from mid-sagittal plane of body. (See NOTE 2.)
Seated postures		
Elbow flexion (9)	< 90, OR > 120	A 90 elbow angle is defined as the theoretical "neutral" position.
Back trunk-thigh angle (10)	< 90	Increasing the trunk-thigh angle reduces pressure on the lower back.
Knee angle (11)	< 90	Increasing the angle at the knees reduces stress at the knees.

NOTE 1: Numbers in parentheses refer to numbers in Figure R1-3.

NOTE 2: Mid-sagittal plane is defined as a plane line drawn down the mid-line of the body, perpendicular to the back.

NOTE 3: Angle in degrees not available.

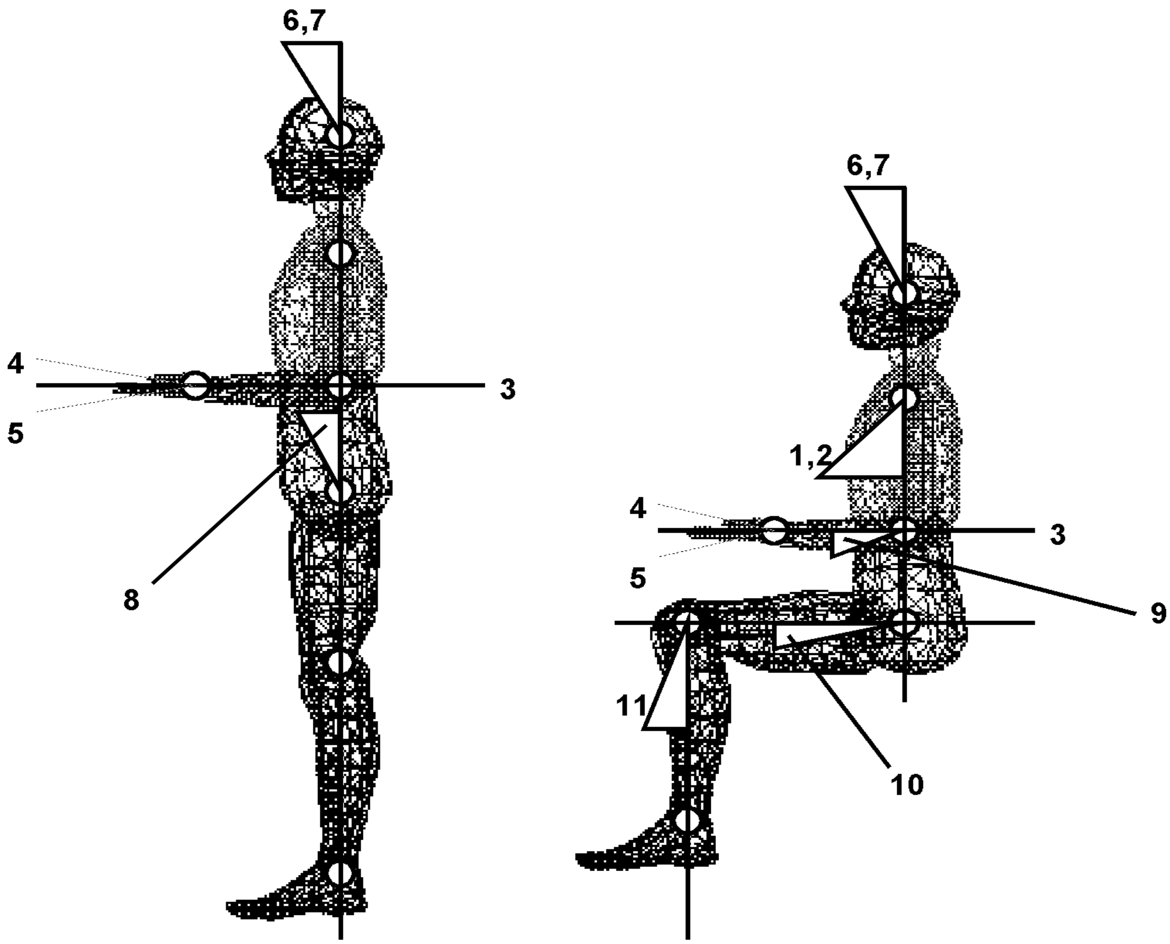

Figure R1-3
Postural Angles

Table R1-3 Maximum Grip Forces

Grip Type	*Glove Use*	*Maximum Force*		
		Infrequent Tasks	*Occasional Tasks*	*Static or Frequent Tasks*
Power Grip: The fingers of the hand wrap around the object, and the thumb overlaps the index finger (e.g., gripping a hammer).		137 N (30.9 lbf)	82 N (18.5 lbf)	41 N (9.4 lbf)
	with cleanroom gloves	116 N (26.3 lbf)	70 N (15.7 lbf)	35 N (8.0 lbf)
	with chemical gloves	111 N (25.0 lbf)	66 N (15.0 lbf)	33 N (7.6 lbf)
Lateral Pinch: Object is held between the thumb and the side of the index finger (often referred to as key grip).		35 N (7.9 lbf)	21.8 N (4.9 lbf)	10.7 N (2.4 lbf)
	with cleanroom gloves	30 N (6.7 lbf)	19 N (4.2 lbf)	9 N (2.0 lbf)
	with chemical gloves	28 N (6.4 lbf)	18 N (4.0 lbf)	9 N (1.9 lbf)
Tip Pinch: Object held between the tips of the thumb and index finger.		24.5 N (5.5 lbf)	14.7 N (3.3 lbf)	7.6 N (1.7 lbf)
	with cleanroom gloves	21 N (4.7 lbf)	13 N (2.8 lbf)	7 N (1.4 lbf)
	with chemical gloves	20 N (4.5 lbf)	12 N (2.7 lbf)	6 N (1.4 lbf)
Palmar Pinch: Fingers pressed against the palm of the hand, with the object held between the fingers and the palm. Thumb is not used (e.g., picking up a sheet of plywood).		36 N (8.2 lbf)	21.6 N (4.85 lbf)	11.1 N (2.5 lbf)
	with cleanroom gloves	31 N (7.0 lbf)	18 N (4.1 lbf)	9 N (2.1 lbf)
	with chemical gloves	29 N (6.6 lbf)	18 N (3.9 lbf)	9 N (2.0 lbf)

RELATED INFORMATION 2
ERGONOMIC RESOURCE DATA

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

Table R2-1 Standing Workstation Recommendations

Criteria	*Fixed Dimension cm (in.)*	*Adjustable Dimension cm (in.)*
Standing workstation height. Assumes hands are located primarily at work surface height.	maximum 102 cm (40 in.) (See NOTE 2) minimum 96 cm (38 in.)	maximum 122 cm (48 in.) minimum 91 cm (36 in.)
Keyboard height/trackball/mouse (to home row, top of ball or mouse)	maximum 102 cm (40 in.) minimum 96 cm (38 in.)	maximum 122 cm (48 in.) minimum 91 cm (36 in.)
Microscope eyepiece height	Installation of fixed location standing microscope is not recommended	maximum 173 cm (68 in.) minimum 127 cm (50 in.)
Foot clearance height	minimum 15 cm (6.0 in.)	NA
Foot clearance depth	minimum 15 cm (6.0 in.)	NA
Foot clearance width	minimum 49 cm (19 in.)	NA
Work surface edge radius	minimum 0.64 cm (0.24 in.)	NA
Infrequently used hand control height measured from the floor to the midpoint of the control.	maximum 164 cm (64.5 in.) minimum 84 cm (33 in.)	NA
Infrequently used hand control reach measured from leading edge of tool or obstruction.	maximum 64 cm (19 in.)	NA
Frequently used hand control height measured from the floor to the midpoint of the control.	maximum 127 cm (50 in.) minimum 94 cm (37 in.)	NA
Frequently used hand control horizontal reach measured from leading edge of tool or obstruction.	maximum 48 cm (14 in.)	NA

NOTE 1: Data adapted from Advanced Ergonomics Inc., 1994; Ayoub, 1973.
NOTE 2: Standing platform may be required for shorter populations for fixed height designs.

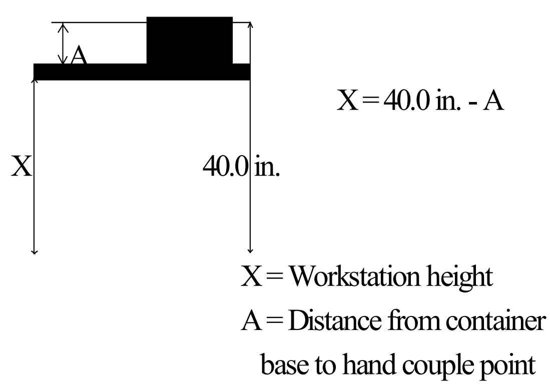

Figure R2-1
Formula for Determining Fixed Workstation Height

NOTE R1-1: For workstations where product handling is the primary task the fixed workstation height may need to be adjusted based on the product container size. The fixed height should allow the hand/container coupling point to be at 40.0 in. (101.6 cm) assuming normal light to moderate material handling/push/pull forces. Use the following formula to determine appropriate fixed heights. See Figure R2-1.

Table R2-2 Seated Workstation Recommendations

Criteria	*Fixed Dimension cm (in.)*	*Adjustable Dimension cm (in.)*
Sitting workstation height (D) (assumes hands are primarily at work surface level)	maximum 76 cm (30 in.) minimum 71 cm (28 in.)	maximum 84 cm (33 in.) minimum 58 cm (23 in.)
VDT Height (single monitor, measured to centerline)	maximum 119 cm (47 in.) minimum 94 cm (37 in.)	NA
VDT height (stacked monitors, measured to top line of top monitor)	maximum 140 cm (55 in.)	NA
Touch screen monitor height	maximum 107 cm (42 in.) (measured to uppermost active pad)	maximum 1214 mm (47.8 in.) minimum 894 mm (35.2 in.) (measured to center of screen)
Microscope eyepiece height (assumes a standard work surface height of 30")	NA	maximum 137 cm (54 in.) minimum 122 cm (48 in.)
Work surface thickness	minimum 5 cm (2 in.)	NA
Work surface edge radius	minimum 0.65 cm (0.25 in.)	NA
Vertical leg clearance	minimum 67 cm (26.5 in.)	NA
Horizontal leg clearance-depth at knee level	minimum 51 cm (20 in.)	NA
Horizontal leg clearance-depth at foot level	minimum 66 cm (26 in.) depth × 25 cm (10 in.) vertical clearance	NA
Horizontal leg width clearance	minimum 61 cm (24 in.)	NA

NOTE 1: Data adapted from ANSI/HFS 100; Ayoub 1973; Advanced Ergonomics Inc., 1994.
NOTE 2: Recommended dimensions are based on the assumption that a footrest and an adjustable chair are provided.

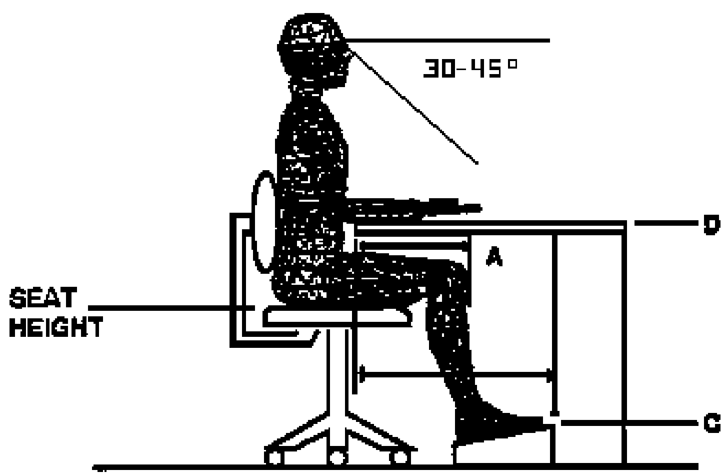

Figure R2-2
Seated Workstation Dimensions

Table R2-3 Sit/Stand Workstation Recommendations

Criteria	*Fixed Dimension cm (in.)*	*Adjustable Dimension cm (in.)*
Height of workstation above floor	minimum 96 cm (38 in.) maximum 102 cm (40 in.)	minimum 91 cm (36 in.) maximum 122 cm (48 in.)
Buttock support adjustment range	------	minimum 66 cm (26 in.) maximum 99 cm (39 in.)
Horizontal leg clearance (measured at knee level)	minimum 51 cm (20 in.)	NA
Horizontal leg clearance (measured at foot level)	minimum 66 cm (26 in.)	NA
Work surface angle		minimum 0 degrees maximum 45 degrees

NOTE 1: Data adapted from Grandjean, 1988; Humanscale, 1981.

RELATED INFORMATION 3
WORKSTATION DESIGN

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

R3-1 General Considerations

R3-1.1 To enable good system performance, equipment and workspaces should be designed to accommodate the physical dimensions of greater than 90 percent of user population. For recommended anthropometric data see Related Information 1, Table R1-1, Figures R1-1 and R1-2.

R3-1.2 Where impairment of safety might result in danger to life, such as the inability to exit or escape under emergency conditions, wider percentile ranges should be used (e.g., 1st through 99th percentile range).

R3-1.3 Many anthropometric databases cite unclothed dimensions.

R3-1.4 For standing, sitting, and sit/stand work station design recommendations see Related Information 2.

R3-1.5 Critical and frequently used equipment, tools, and work items should be placed in the operator's primary viewing area.

R3-1.6 Provision for placement of required materials and informational items used during operation should be accommodated in the design. Examples of materials/items include product boxes, wafer boxes, maintenance manuals, and shop orders.

R3-2 Working Postures

R3-2.1 Workspace configurations that require static or frequent awkward postures (where the limbs or torso deviate from a neutral position) should be avoided. For ranges of posture to avoid see Related Information 1.

R3-2.2 Equipment should be designed to avoid unsupported awkward static postures for operational tasks lasting more than 20 seconds and unsupported awkward static postures for maintenance and service tasks lasting for more than 40 seconds.

R3-2.3 Where applicable to tasks performed, equipment should be designed to allow both sitting and standing operation.

R3-2.4 Controls, tools, and materials should be located so that the most frequent activities are performed from a neutral posture.

R3-2.5 To prevent users from bending at the waist, the design should place users close to the point of operation by providing adequate leg and foot clearance and keeping work materials at an appropriate height. See the "Supplier Ergonomics Success Criteria" in Appendix 1 for design criteria. For recommended dimensions refer to Related Information 2, Tables R2-1, R2-2, and R2-3.

R3-3 Standing Workstations

R3-3.1 See the "Supplier Ergonomics Success Criteria" in Appendix 1 for standing workstation design criteria. For standing workstation design recommendations see Related Information 2, Table R2-1.

R3-3.1.1 Display screens should be perpendicular to the normal line of sight and the angle of the screen should be adjustable or positioned to minimize glare.

R3-4 Sitting Workstations

R3-4.1 See the "Supplier Ergonomics Success Criteria" in Appendix 1 for seated workstation design criteria. For further design recommendations see Related Information 2, Table R2-2.

R3-4.2 Sit/stand workstations are workstations where the operator can assume a standing posture or a seated posture using a task stool.

R3-4.3 For sit/stand workstations design recommendations see Related Information 2, Table R2-3.

RELATED INFORMATION 4
DESIGN FOR MAINTAINABILITY AND SERVICEABILITY

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

R4-1 General Considerations

R4-1.1 Equipment design should facilitate rapid and positive fault detection and isolation of defective items.

R4-1.2 Standard parts should be used whenever practicable. Where practical, components should be replaceable as modular packages and configured for rapid removal and replacement (e.g., use of a standard fastener throughout a design).

R4-1.3 Equipment requiring periodic calibration and adjustment should be readily accessible without disassembly.

R4-1.4 Use of cleanroom gloves reduces maximum allowable grip forces listed in Related Information 1, Table R1-3 by 15%.

R4-1.5 Use of cotton gloves reduces maximum allowable grip forces listed in Related Information 1, Table R1-3 by 26%.

R4-1.6 Use of chemical protective gloves reduces maximum allowable grip forces listed in Related Information 1, Table R1-3 by 19%.

R4-1.7 Component design should preclude improper mounting and installation of any component.

R4-1.8 Guides, tracks, or stops should be provided as necessary to facilitate handling and prevent damage to equipment or injury to personnel.

R4-1.9 Refer to ANSI/IES "Practice for Industrial Lighting" for recommended illumination based on task characteristics.

R4-1.10 Structural members or permanently installed equipment should not visually or physically prevent adjustment, servicing, removal of replaceable equipment, or other required maintenance tasks.

R4-1.11 Items which require rapid or frequent maintenance should be most accessible. Predicted or known high failure-rate items should be accessible for replacement with minimal removal of nearby or adjacent non-failed items. If it is necessary to remove non-failed items, then the total ergonomic impact must be assessed to determine conformance.

R4-1.12 Sufficient space should be provided for the use of standard test equipment and required maintenance tools without difficulty or hazard. Self-checking or built-in test features are recommended.

R4-2 Cables, Connectors, Plugs, Receptacles, and Circuit Boards

R4-2.1 Connectors which may need to be disconnected and reinstalled during the life of the tool that are mounted in close proximity should have clearance so that each one can be easily removed and reinstalled.

R4-3 Equipment Enclosures

R4-3.1 Equipment enclosures should be easily removable or sufficiently larger than the item they cover to facilitate installation and removal of components.

R4-3.2 Cover or shield holes should be large enough for fastener clearance without precise alignment.

R4-3.2.1 Access openings should be designed to permit unobstructed physical and visual operation. Size and shape of the access should allow for easy passage of equipment and body parts of a 95th percentile North American male with necessary PPE and tools, as appropriate.

R4-3.2.2 Unless prohibited from a microcontamination standpoint, access covers should be hinged or sliding. Lift off covers will require manual material handling analysis.

R4-3.3 The number and diversity of fasteners used should be minimized. Fasteners requiring non-standard tools should be avoided, except where access is to be restricted.

R4-3.3.1 Hinges, tongue-and-slot catches, and mounting pins should be used to minimize the number of fasteners required. Pin and hook arrangements are preferred to hinges for contamination control.

R4-3.3.2 Captive fasteners should be used where dropping or loss of such items could cause damage to equipment or create difficult or hazardous removal. Captive fasteners should also be provided for access covers requiring frequent removal.

R4-3.3.3 Fasteners should require the minimum number of turns compatible with mechanical stress, alignment, positioning, and load considerations. Items requiring removal for daily or more frequent inspection and servicing should use quick release fasteners.

RELATED INFORMATION 5
HAZARD ALERTS, LABELS, AND ALARMS

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

R5-1 Hazard Alerts

R5-1.1 Potential hazards to the user, equipment, or product should be identified and documented. An evaluation should be made as to the appropriate method(s) of alert, alert content, and location. More than one method of hazard alert may be necessary. Refer to SEMI S1.

R5-1.2 Hazard alerts should be consistent with information provided in operator and maintenance manuals and other training information materials.

R5-1.3 Hazard alerts can be provided by labels, signs, placards, visual alerts, auditory alarms, status indicators, or hazard alert systems integral with the equipment's operating system (e.g., displayed through the video display).

R5-1.4 Hazard alerts and fault messages should be specific and communicate the consequences of engaging hazards.

R5-2 Labels

R5-2.1 Hazard alert labels should be located such that they are readily visible to the intended viewer and alert the viewer to the potential hazard in time to take appropriate action.

R5-3 Audible Alarms

R5-3.1 To avoid noise pollution, alarms should be reserved for situations requiring immediate intervention to prevent personal injury, equipment damage, process disruption, or product damage.

R5-3.2 Alarm design should take into account impairments that may be caused by clothing and hearing and eye protection.

R5-3.3 Users should be provided with an input device for acknowledging and canceling alarms without erasing information that accompanies the alarm. The capability to cancel alarms should be evaluated for its impact on safety.

R5-3.4 Alarm decibel levels will require a setpoint above the background noise levels sufficient to meet local regulations.

RELATED INFORMATION 6
CONTROLS AND DISPLAYS

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

R6-1 General Considerations

R6-1.1 The selection and/or design of controls and displays should be based on careful analysis of equipment functionality requirements. This will determine what information the operator needs to make appropriate decisions and responses, thus reducing potential design-induced error.

R6-1.2 Potential errors due to inattention, stress, fatigue, sensory overload, etc., need to be considered during system design. This can be accomplished by ensuring that critical controls and displays attract the user's attention and that controls and displays are clearly labeled and arranged to reduce confusion. Whenever possible, functionally related controls and displays should be grouped together.

R6-1.3 Appropriate feedback should be provided for system status, mode of operation, operator input actions, and equipment malfunctions.

R6-1.4 Controls and displays should be clearly labeled/identified by function. Controls and displays can be coded by color, size, shape, or location to help discriminate between functions and identify critical information. Colors should be in accordance with NFPA 79 and EN 60204-1.

R6-1.5 Placement of labels should be consistent on pieces of equipment (e.g., either below or above controls and displays).

R6-1.6 To accommodate color blind users, color should be supplemental to other means of coding such as icons, words, flashing, shape, etc.

R6-2 Controls

In general, the design of controls should consider the following criteria:

R6-2.1 Control movement or activation should be compatible with users' expectations and provide positive evidence that an input has been accepted or that control action is being accomplished. Feedback can be visual, auditory, tactile, or a combination thereof.

R6-2.2 Controls should be designed and located to minimize awkward postures.

R6-2.3 Controls should be designed, positioned, or protected to prevent inadvertent actuation.

R6-2.4 The maximum width of frequently used control panels should be 68.6 cm (27 in.).

R6-2.5 Controls should be located away from chemical, thermal, radiation, electrical, or mechanical hazards. If such a location cannot be avoided, controls should be appropriately shielded and labeled.

R6-2.6 Control force requirements should be designed in accordance with HumanScale, NFPA 79, EN 60204-1, or another recognized standard.

R6-3 Visual Displays

R6-3.1 The type of visual display selected should depend on the nature of information conveyed and conditions of use. The effectiveness and utility of a visual display generally depends on visibility, legibility, and meaningfulness.

R6-3.2 Further information may be found in MIL-STD-1472 for non-VDT displays, and ISO 9241 for VDTs.

R6-3.3 The visibility of a display is determined by the viewing distance, the size of the display, the location, angle of view, local illumination characteristics, obstructions, or reflections.

R6-3.4 Critical and frequently used displays should be placed in the operator's primary viewing area.

R6-3.5 The display should be positioned so the user has a clear line of sight. Displays should not be located where they are obstructed (by controls, equipment, body parts, etc.) or subject to glare. Display viewing should not require awkward body postures.

R6-3.6 The legibility of a display is determined primarily by its visual angle and luminance contrast with the background.

R6-3.7 There should be sufficient contrast between the object, letters, or numbers on a display to separate them from the background, minimum ratio 3:1, preferred is 7:1 (ISO 9241). Too much contrast may result in glare.

R6-3.8 The ability of displayed information to communicate with the user clearly and precisely depends on the amount of information displayed. Display design should emphasize simplicity and usability to:

R6-3.8.1 Reduce error and decrease response time.

R6-3.8.2 Provide only the amount of information necessary and only at a level of precision required.

R6-3.8.3 Display content in a directly usable form with no transformation required.

R6-4 Auditory Displays

Auditory coding or signals may be used to alert a user to critical conditions or operations. Auditory coding should be supplementary to visual coding. Auditory displays can be used effectively when:

R6-4.1 Vision is overburdened or degraded,

R6-4.2 The message requires immediate action,

R6-4.3 The job requires the operator or maintainer to move around frequently,

R6-4.4 The message is simple and short,

R6-4.5 The message signals an event in time, or

R6-4.6 The message does not need to be referred to later.

R6-5 Control - Display Relationships

R6-5.1 The relationship between associated controls and displays (their organization and layout) is critical to optimizing system performance and minimizing operator error.

R6-5.2 Controls and displays should be organized into functional groups and positioned according to criticality, sequence of operation, and frequency of use.

R6-5.3 Control-display compatibility refers to the extent to which the relationship between a control operation and its effect is predictable by the user. Predictability is determined by individual and population cultural stereotypes (user expectations, previous experience, an idea of the way equipment works, etc.). Lack of compatibility degrades speed, accuracy of performance, and increases probability of error. Types of compatibility include sequential arrangement, spatial organization, and direction of movement. Technology transfer and utilization by a multi-cultural or multi-ethnic work force, as well as across global user populations should consider the impact of cultural and behavioral stereotypes.

R6-5.4 Display layout, control location, and operation should be similar throughout a particular type and/or model of equipment or system. Consistency is particularly important for color, shape, and size of controls, scale markings on displays, and labeling.

RELATED INFORMATION 7
USER COMPUTER INTERFACE

NOTE: This related information is not an official part of SEMI S8 and is not intended to modify or supersede the official guidelines. It was derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the user's responsibility.

R7-1 Operator Interaction

NOTE R7-1: Refer to ISO 9241 for detailed guidance.

R7-1.1 The dialogue should be suitable for the task.

NOTE R7-2: A dialogue is suitable for a task when it supports the user in the effective and efficient completion of the task.

R7-1.1.1 The dialogue should present the user only with information related to the completion of the task.

R7-1.1.2 The information displayed should be in a directly usable form to avoid the need to transpose, compute, interpolate, or translate.

R7-1.1.3 Help information should be task dependent.

R7-1.1.4 Any actions that can appropriately be allocated to the interface software for automatic execution should be carried out by the software without user involvement.

R7-1.1.5 When designing the dialogue, consideration should be given to the complexity of the task with respect to the users' skills and abilities.

R7-1.1.6 The format of input and output should be appropriate to the given task and user requirements.

R7-1.1.7 The dialogue should support the user when performing recurrent tasks.

R7-1.1.8 If default input capabilities exist for a given task (e.g., standard default values) it should not be necessary for the user to input such values. It should also be possible to replace default values with other values or other appropriate default values.

R7-1.1.9 During performance of a task in which data is changed, the original data should remain accessible if the task requires it.

R7-1.1.10 The dialogue should avoid forcing unnecessary task steps.

R7-1.2 The dialog should be self-descriptive.

NOTE R7-3: A dialogue is self-descriptive when each dialogue step is immediately comprehensible through feedback from the system or is explained to the user on request.

R7-1.2.1 After any user action, the dialogue should provide feedback, where appropriate. If severe consequences result from the user action, the system should provide explanation and request confirmation before carrying out the action.

R7-1.2.2 Feedback or explanations should be presented in consistent terminology, which is derived from the task environment, rather than from the dialogue system technology (e.g., when the user wants to input an order to load a cassette, LOAD should be the command rather than a code followed by pressing the ENTER key).

R7-1.2.3 Feedback or explanations should assist the user in gaining a general understanding of the dialogue system as a possible supplement to user training.

R7-1.2.4 Feedback or explanations should be based on the level of knowledge which the typical user may be expected to have.

R7-1.2.5 Feedback or explanations varying in types and length, based on user needs and characteristics, should be available for the user.

R7-1.2.6 To enhance their value for the user, feedback or explanations should strictly relate to the situation for which they are needed.

R7-1.2.7 The quality of feedback or explanations should minimize the need to consult user manuals and other external information, thus avoiding frequent media switches.

R7-1.2.8 If defaults exist for a given task they should be made available to the user.

R7-1.2.9 The user should be informed about changes in the dialog system status that are relevant to the task.

R7-1.2.10 When input is requested, the dialogue system should give information to the user about the expected input.

R7-1.2.11 The requirement to learn special program codes, long sequences, and special instructions should be avoided.

R7-1.3 The dialogue should be controllable.

NOTE R7-4: A dialogue is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met

R7-1.3.1 The speed of interaction should not be dictated by the operation of the system. It should always be under the control of the user according to the user's needs and characteristics.

R7-1.3.2 The dialogues should give the user control over how to continue with the dialogue. Exceptions may be made for critical alarms, fault situations, as well as process and safety reasons. User interrupt or abort options to terminate interactions should be provided.

R7-1.3.3 If the dialogue has been interrupted, the user should have the ability to determine the point of restart when the dialogue is resumed, if the task permits.

R7-1.3.4 If interactions are reversible and the task permits, it should be possible to undo at least the last dialogue step.

R7-1.3.5 Different user needs and characteristics require different levels and methods of interaction.

R7-1.3.6 The way that input/output data are represented (format and type) should be under the control of the user.

R7-1.3.7 Where alternative input/output devices exist, the user should have the option of which one to use.

R7-1.4 The dialogue should conform with user expectations.

NOTE R7-5: A dialogue conforms with user expectations when it is consistent and corresponds to the user characteristics, such as task knowledge, education, experience, and to commonly accepted conventions.

R7-1.4.1 Dialogue behavior and appearance within a dialogue system should be consistent.

R7-1.4.2 State change actions should be implemented consistently.

R7-1.4.3 Dialogues used for similar tasks should be similar so that the user can develop common task solving procedures.

R7-1.4.4 Immediate feedback on user input should be given where appropriate to user expectations. It should be based on the level of knowledge of the user.

R7-1.4.5 The cursor should be located where the input is wanted.

R7-1.4.6 If a response time is likely to deviate considerably from the expected response time, the user should be informed of this.

R7-1.5 The dialogue should be error tolerant.

NOTE R7-6: A dialogue is error tolerant if, despite evident errors in input, the intended result may be achieved with either no or minimal corrective action by the user.

R7-1.5.1 The application should assist the user in detecting and avoiding errors in input. The dialogue system should prevent any user input from causing undefined dialogue system states or dialogue system failures.

R7-1.5.2 Errors should be explained to help the user to correct them.

R7-1.5.3 Depending on the task, it may be desirable to apply special effort in presentation techniques to improve the recognition of error situations and their subsequent recovery.

R7-1.5.4 In cases where the dialogue system is able to correct errors automatically, it should advise the user of the execution of the corrections and provide the opportunity to override the corrections.

R7-1.5.5 User needs and characteristics may require that error situations are deferred, leaving the decision to the user when to handle them.

R7-1.5.6 Additional explanations should be provided during error correction on request.

R7-1.5.7 Validation/verification of data should take place before attempting to process the input.

R7-1.5.8 Additional controls should be provided for commands with serious consequences.

R7-1.5.9 Error correction should be possible without switching dialogue system states, where the task permits.

R7-1.6 The dialogue should be capable of individualization.

NOTE R7-7: A dialogue is capable of individualization when the interface software can be modified to suit the task needs, individual preferences, and skills of the user.

NOTE R7-8: Although, in many cases, providing users with customization capabilities is very desirable, it is not an acceptable substitute for ergonomically designed dialogues. In addition, customization capabilities should be provided only within certain limits such that modifications cannot cause users any potential discomfort (e.g., unacceptable noise levels with user configured auditory feedback).

R7-1.6.1 Mechanisms should be provided to allow the dialogue system to be adapted to the user's language and culture, individual knowledge and experience of task domain, perceptual, sensory-motor, and cognitive abilities.

R7-1.6.2 The amount of explanation (e.g., details in error messages, help information) should be modifiable according to the level of knowledge of the user.

R7-1.6.3 The user should be allowed to incorporate their own vocabulary to establish individual naming for objects and actions if it suits the contexts and tasks. It should also be possible for the user to add individualized commands.

R7-1.6.4 The user should be able to set up operational time parameters to match their individual needs.

R7-1.6.5 Users should be able to choose between different dialogue techniques for different tasks.

R7-1.6.6 Log in should be a separate procedure that is completed before a user may select an operational step. Passwords should be used to protect (limit access to) parts of the operating system which may be beyond the user's skill level to control safely.

R7-1.7 The dialogue should be suitable for learning.

NOTE R7-9: A dialogue is suitable for learning when it supports and guides the user in learning to use the system.

R7-1.7.1 Rules and underlying concepts which are useful should be made available to the users, thus allowing the users to build up their own grouping strategies and rules for memorizing activities.

R7-1.7.2 Relevant learning strategies, (e.g., comprehension oriented, learning by doing, learning by example) should be provided.

R7-1.7.3 Relearning facilities should be supported.

R7-1.7.4 A number of different means to help the user to become familiar with the dialogue elements should be provided.

R7-2 Video Display Terminals

NOTE R7-10: Refer to ISO 9241 and EN 894-2 for detailed guidelines.

R7-2.1 Display characteristics should be selected to suit the specific conditions of use. For example, the expected viewing distance, ambient levels of illumination, and lighting color (e.g., yellow illumination) in the work area should be considered.

R7-2.2 Displays should be perpendicular to the user's normal line of sight. The angle of the screen should be adjustable or positioned to minimize glare.

R7-2.3 Surfaces immediately adjacent to the display should have a matte finish to control glare.

R7-2.4 Areas coded by luminance only should differ in display luminance with respect to each other by ratio of at least 1.5:1.

R7-2.5 Where blink coding is used solely to attract attention, a single blink frequency of 1Hz to 5Hz with a duty cycle of 50% is recommended. Where readability is required during blinking, a single blink rate of 1/3Hz to 1Hz with a duty cycle of 70% is recommended. It should be possible to switch off the blinking of the cursor.

R7-2.6 The number of colors simultaneously presented on a display should be based on the performance requirements of the task. In general, the number of colors simultaneously presented should be minimized. For accurate identification, the default color set(s) should consist of no more than eleven colors in each set.

R7-3 Input Devices

NOTE R7-11: Refer to ISO 9241 and EN 894-3 for detailed guidelines.

R7-3.1 Input characteristics should be selected to suit the specific conditions of use. For example, the performed task, workstation arrangement, ambient levels of illumination in the work area, and related tasks should be considered.

R7-3.2 Keyboards should permit easy repositioning on the work surface. Other than for special applications with clearly defined tasks, the keyboard should be detachable. The keyboard should be stable during use (i.e., it should not slip or rock).

R7-3.3 Keyboard support surfaces should be adjustable to accommodate standing or seated operation where suitable.

SEMI S9-1101
SAFETY GUIDELINE FOR ELECTRICAL DESIGN VERIFICATION TESTS FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

This guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995.

NOTICE: This document as balloted is intended to replace SEMI S9-95 in its entirety.

NOTICE: Paragraphs entitled "NOTE" are not an official part of this document and are not intended to modify or supercede the official guideline. The task force has supplied them to clarify and to enhance usage of the guideline by equipment designers.

1 Purpose

1.1 The purpose of this document is to provide electrical design verification tests, test methods, and acceptance criteria for semiconductor manufacturing equipment. Some of these tests are used as part of the electrical safety evaluation in SEMI S2.

2 Scope

2.1 This safety guideline should be applied to one or more representative samples of the equipment (or parts of the equipment) used for the manufacturing, measurement, assembly, and testing of semiconductor products.

2.2 The following tests are discussed in this document:

- Leakage Current Test (Section 9.1)
- Grounding Continuity Test (Section 9.2)
- Starting Current Test (Section 9.3)
- Input Test (Section 9.4)
- Dielectric Test (Section 9.5)
- Strain Relief Test (Section 9.6)
- Transformer Output Short Circuit Test (Section 9.7)
- Power Supply Output Short Circuit Test (Section 9.8)
- Safety Circuit Function Test (Section 9.9)
- Safety Circuits Conductor Disconnection Test (Section 9.10)
- Capacitor Stored Energy Discharge Test (Section 9.11)
- Temperature Test (Section 9.12)

2.3 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this safety guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document is not intended to be a comprehensive compilation of electrical tests specified in product safety standards. This document is also not intended to replace any test methods described in any appropriate national or international product safety standards.

3.2 It is not the intent of this guideline to require repetition of tests where the equipment has been certified or tested to other relevant electrical product safety standards. Any applicable test from this guideline that has been previously completed under an applicable product standard and which satisfies the intent of that test should be accepted, even if there are differences in test methods.

3.3 Engineering analysis, when based on sound engineering principles, may serve as an alternative to conducting a test.

3.4 If it is evident from the design and construction of the equipment that a particular test is not safety-relevant, the test need not be performed.

3.5 This document is not intended to address production line or routine testing.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 *IEC Standard* [1]

IEC 61010-1 — Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *1500 ohm impedance network* — a network consisting of a 1500 ohm resistor in parallel with a 0.15 μF capacitor.

5.2 *accessible* — capable of being contacted by an IEC accessibility probe (IEC standard test finger, as described in IEC 61010).

NOTE 2: The test finger is also known, in various IEC documents, as the "jointed test finger" and "jointed standard test finger".

5.3 *full load current* — current when the equipment is operated at the maximum manufacturer's specified operating conditions including all motors and heaters designed to operate simultaneously.

5.4 *hazardous energy* — energy of 20 J (Joules) or more, or an available power level of 240 V*A or more.

5.5 *least favorable condition* — the condition which is most likely to result in a test failure.

5.6 *permanently connected equipment* — Equipment that is intended to be electrically connected to a supply by means of connection which can be detached only by the use of tools.

5.7 *primary circuit* — an internal circuit which is directly connected to the external supply mains or other equivalent source (such as a motor-generator set) which supplies the electric power. It includes the primary windings of transformers, motors, other load devices and the means of connection to the supply mains.

5.8 *safe condition* — a condition in which all relevant hazardous energy sources are removed or suitably contained and all relevant hazardous production materials are removed or contained, unless this results in additional hazardous conditions.

5.9 *PE Terminal* — a terminal which is bonded to conductive parts of a piece of equipment for safety purposes and is intended to be connected to an external protective earthing system.

5.10 *standby condition* — condition in which equipment is energized and in its idle state.

5.11 *tool* — an external device used to aid a person in performing a mechanical function. As used in this document, *tool* includes devices such as keys.

5.12 *V*A* — Volt-ampere.

6 Safety Precautions

6.1 The tests outlined in this document are to be performed by trained and qualified personnel who have knowledge of the techniques and the test apparatus described herein.

7 Calibration and Standardization

7.1 All test equipment should be calibrated and traceable to a calibration standards organization (e.g., National Institute of Standards and Technology (NIST) in the United States or the National Metrology Institute in Japan).

7.2 The calibration interval for test equipment should not exceed one year.

8 Test Conditions

8.1 Except where noted otherwise, the equipment should be tested under the least favorable conditions within the manufacturer's operating specifications. These conditions include:

- supply potential
- supply frequency
- position of movable parts
- operating mode (e.g. full temperature conditions, motors in operation)
- adjustment of thermostats, regulating devices, or similar controls in operator-accessible areas

8.2 *Test Supply Potential* — To determine the least favorable supply potential for a test, consider:

- multiple-nominal rated potentials (e.g., 120/240 V)
- extremes of nominal rated potential ranges (e.g., 208–240 V)

8.2.1 Consideration of the tolerance on a nominal rated potential (e.g., 120 ± 5%) is not necessary.

NOTE 3: Some standards (e.g., IEC 61010-1 and IEC 60950) may specify 90% and 110% of any rated supply voltage.

8.3 *Test Supply Frequency* — To determine the least favorable supply frequency for a test, consider the nominal frequencies as specified (e.g., 50 Hz, 60 Hz, or 50/60 Hz).

1 International Electrotechnical Commission, 1, rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland. Website: www.iec.ch

NOTE 4: Consideration of the tolerance on a nominal rated frequency (e.g., 50 ± 0.5 Hz) is not usually necessary.

8.4 As an alternative to carrying out tests on the complete equipment, tests may be conducted on circuits, components and sub-assemblies independent of the equipment, provided that the results of the tests would be representative of those performed as part of the assembled equipment.

EXCEPTION: The leakage current and grounding continuity tests identified in Sections 9.1 and 9.2 should be completed only on fully assembled equipment.

9 Electrical Tests

9.1 *Leakage Current Test for Cord-and-Plug Equipment*

9.1.1 *Test Equipment* — A 1500 ohm impedance network and a true RMS voltmeter with an accuracy of 1.0%. The impedance network can be a separate assembly or incorporated within a leakage current measuring instrument.

9.1.2 *Procedure* — For equipment connected to the facility branch circuit with a cord-and-plug (plug/socket combination), ensure that the equipment is isolated (e.g., by placing the equipment on a wooden or other isolating surface). Connect the equipment to its rated source of supply with the equipment grounding (PE) conductor disconnected and operate it at the least favorable conditions specified by the manufacturer. Connect the 1500 ohm impedance network between each accessible metal part and the supply equipment grounding (PE) conductor. In determining accessibility of live parts, remove all doors, panels, etc. that are to be removed by the operator during normal operation. Using a true RMS voltmeter, measure the voltage drop across the impedance network. Calculate the leakage current using the formula:

$$I_{leakage} = \frac{Voltage_{measured}}{1500\ ohms}$$

9.1.3 *Acceptable Results* — The maximum calculated leakage current does not exceed 3.5 mA.

9.2 Grounding Continuity Test

9.2.1 *Test Equipment* — Low range ohmmeter with a range to measure 0.10 ohm with an accuracy of 1.0%.

9.2.2 *Procedure* — Disconnect the equipment from the supply. For equipment installed with fixed wiring methods, disconnect the supply equipment grounding conductor (protective earthing conductor) from the main equipment grounding terminal (PE Terminal). Measure the resistance between the power supply equipment grounding terminal (PE Terminal) and each accessible metal part (handle, monitor, doors, etc.) on the equipment using a low-range ohm-meter. Upon test completion, reconnect the supply equipment grounding conductor (protective earthing conductor).

EXCEPTION: Grounding Continuity Test is not required to be measured where accessible metal surfaces are not likely to become energized in a single fault condition.

NOTE 5: Some standards (e.g., IEC 60204-1, IEC 61010-1) may specify this test to be performed using a current injection method.

9.2.3 *Acceptable Results* — The resistance between the grounding conductor terminal and each accessible part shall not exceed 0.1 ohm.

9.3 *Starting Current Test*

9.3.1 *Test Equipment* — None.

9.3.2 *Procedure* — Start the equipment in accordance with manufacturer's instructions three times from a completely stopped condition. Ensure that the time interval between successive starts is sufficient to allow the equipment return to ambient conditions.

9.3.3 *Acceptable Results* — None of the equipment's overload or overcurrent protections activates during this test.

NOTE 6: It is recommended that the peak inrush starting current be measured using an appropriate current measuring device and recorded in the test report.

9.4 *Input Test*

9.4.1 *Test Equipment* — True RMS current measuring equipment, with accuracy of 3.0%.

9.4.2 *Procedure* — Measure the input current to the equipment under the maximum normal operating load conditions (i.e., with all motors, heaters, etc. running at manufacturer's specified maximum loading conditions).

9.4.3 *Acceptable Results* — The measured current does not exceed 110% of the rated full load current value specified on the equipment nameplate.

9.5 *Dielectric Test*

9.5.1 *Test Equipment* — Timer with accuracy of ± 5 seconds. Dielectric Withstand Tester with means of indicating test potential, as well as an audible or visual indicator of electrical breakdown, or an automatic-reject feature for any unacceptable unit. In an alternating current test, the test equipment should include a transformer having sinusoidal output. This transformer should have a rating of 500 VA or greater unless it is provided with a voltmeter that directly measures the applied output potential.

9.5.2 *Procedure* — With the equipment disconnected from its supply, apply a dielectric withstand potential of 1500 Volts AC or 2121 Volts DC between live metal parts of primary circuit(s) and dead metal parts. Surge suppression components and devices, and electronic components certified by an accredited testing laboratory that may be damaged may be disconnected from the circuit for this test. For this test, the following conditions need to be set:

- The equipment should be at its maximum operating temperature
- Switches should be placed in the "on" position
- Circuits through contactors be completed by manually engaging the contacts or bypassing the contactor terminals.

9.5.2.1 Achieve the test potential gradually, starting from zero and holding at the maximum value for a period of one minute.

NOTE 7: A grounded circuit (neutral) conductor, if used in the circuit, is considered a live part.

NOTE 8: Where line-to-ground filter components are installed in the equipment, the DC dielectric potential specified above may be used as an equivalent.

9.5.3 *Acceptable Results* — The equipment does not have a dielectric breakdown as indicated by a puncture, flashover or sparkover.

NOTE 9: Breakdown is often indicated by an abrupt decrease or nonlinear advance of voltage as the voltage is increased. Similarly, a breakdown is often indicated by an abrupt increase in current. Partial discharge (corona) and similar phenomena are disregarded during application of the test voltage.

9.6 *Strain Relief Test*

9.6.1 *Test Equipment* — Timer with accuracy of ± 5 seconds. A calibrated weight to apply a force of 156 Newtons (35 lb) ± 1.56 Newtons (0.35 lb). A supporting surface to secure the equipment.

9.6.2 *Procedure* — For cord-and-plug connected equipment, strain relief is provided to prevent mechanical stress such as a pull or twist being transmitted to terminals, splices or interior wiring. Support the equipment on a surface so it will not move when the force is applied to the cord. Apply a direct pull of 156 N (35 pounds) to the equipment supply cord from the least favorable angle. If necessary use pulleys or other means to adjust the angle of force applied to the strain relief on the equipment. Apply the force gradually by slowly suspending the weight on the cord and maintain the applied force for a period of one minute.

9.6.3 *Acceptable Results* — The equipment supply cord does not displace to the extent that stress could be applied to the internal connections.

9.7 *Transformer Output Short Circuit Test*

9.7.1 *Test Equipment* — Timer with accuracy of ± 5 minutes. A substantial conductor suitable for carrying the short circuit current.

9.7.2 *Procedure* — With the equipment in its standby condition, short circuit the output of each power transformer.

NOTE 10: If overcurrent protection is connected to the output of the transformer under test, connect the short-circuit jumper after this protective device.

EXCEPTION 1: Where the overcurrent protective devices on the input or output of the transformer are rated at not more than 125% of the rated current of the transformer respectively and the overcurrent protective devices are certified by an accredited testing laboratory, the transformer need not be subjected to this test.

EXCEPTION 2: A thermally-protected or impedance-protected transformer that is certified by an accredited testing laboratory need not be subjected to this test.

9.7.3 *Acceptable Results* — A hazardous condition (e.g., smoke, fire, or molten material) does not exist within 8 hours or before activation of overcurrent protection, thermal protection, or other protective circuit/device whichever occurs first.

9.8 *Power Supply Output Short Circuit Test*

9.8.1 *Test Equipment* — Timer with accuracy of ± 5 minutes. A substantial conductor suitable for carrying the short circuit current.

9.8.2 *Procedure* — With the equipment in its standby condition, short circuit the output of each power supply, one at a time.

NOTE 11: If overcurrent protection is connected to the output of the power supply under test, connect the short circuit jumper after this protective device.

EXCEPTION: A power supply that is certified by an accredited testing laboratory and used in accordance with its certification and the manufacturer's instructions need not be subjected to this test.

9.8.3 *Acceptable Results* — A hazardous condition (e.g., smoke, fire, or molten material) does not exist within 8 hours or before activation of overcurrent protection, thermal protection, or other protective circuit/device whichever occurs first.

9.9 *Safety Circuit Function Test*

9.9.1 *Test Equipment* — Depends on safety devices being tested.

9.9.2 *Procedure* — Functionally test each safety circuit (e.g., EMO, Emergency Stop, End-of-travel sensors, loss of exhaust sensors, light curtains, and safety interlocks) by actuation and resetting.

9.9.3 *Acceptable Results* — The following sections provide the acceptable results for the applicable safety systems.

9.9.3.1 When the EMO is actuated, all hazardous voltage and all power greater than 240 volt-amps in the equipment beyond the main power enclosure should be de-energized, except where permitted by SEMI S2.

9.9.3.2 Actuation of the emergency stop and safety interlocks causes the equipment, or relevant parts of the equipment, to be automatically brought to a safe condition.

9.9.3.3 Resetting of the safety circuit should not cause the system to resume operation.

NOTE 12: This test documents the electrical functionality of the safety circuit(s). It is not intended to determine or document the appropriateness of the shutdown actions taken.

9.10 *Safety Circuit Conductor Disconnection Test*

9.10.1 Test Equipment — None.

9.10.2 *Procedure* — For each independent safety interlock (such as door interlock), EMO, and safety sensor (e.g., exhaust sensor, low fluid level sensor), disconnect each conductor, in turn, and each connector, in turn.

9.10.3 *Acceptable Results* — The following sections provide the acceptable results for the applicable safety circuits.

9.10.3.1 The opening of the safety circuit causes the equipment to be placed in a safe condition as if the safety device had been actuated

9.10.3.2 Reconnecting the conductor should not cause the system to resume operation.

9.11 *Capacitor Stored Energy Discharge Test*

9.11.1 *Test Equipment* — Timer with accuracy of ± 1 seconds. DC voltmeter with sensitivity of 1.0%.

9.11.2 *Procedure* — Test each capacitor which stores a hazardous energy (20 J or more). Monitor the voltage across the capacitor terminals continuously. Disconnect the equipment from the supply. Record the voltage across the capacitor terminals after 10 seconds.

9.11.3 *Acceptable Results* — The capacitor is discharged to less than 20 J within 10 seconds of equipment disconnection from the supply.

NOTE 13: The following formula is provided to calculate the energy.

$$J = \frac{1}{2} C V^2$$

where J is the energy in joules,

C is the capacitance in farads and

V is the potential in volts.

EXCEPTION: This criterion does not apply if a tool is necessary to remove a panel to reach the capacitor and the equipment is marked specifying the discharge time—5 minutes maximum—that is required for the capacitor to discharge to less than 20 J.

9.12 *Temperature Test*

9.12.1 T*est Equipment*— Timer with accuracy of ± 5 seconds. A thermometer with a full range resolution of 0.1°C.

9.12.2 *Procedure* — The equipment is to be operated at the manufacturer's maximum design load for 8 hours or until thermal equilibrium is reached (whichever occurs first). Measure and record the ambient room temperature. Measure and record the temperatures of the various components and devices for comparison with Table 1.

NOTE 14: Thermal equilibrium is considered to be attained when three successive readings taken at five minutes intervals indicate that there is no temperature change of the part exceeding 1.0 °C.

9.12.3 *Acceptable Results* — The measured temperatures do not exceed the values listed in Table 1.

Table 1 Maximum Temperature Limit

Parts of the Equipment	*Temperature Limit (°C)*
Knife switch blade and contact jaws	55
Fuse and fuse clip	110
Rubber and thermoplastic insulated conductors	See Note 1.
Field wiring terminals	--
Equipment marked for 60°C or 60/75°C supply wires	75
Equipment marked for 75°C supply wires	90
Buses and connecting straps or bars	125
Capacitors	See Note 2.
Power switching semiconductors	See Note 3.
Printed wiring boards	See Note 4.
Motors and Transformers	See Note 5.

NOTE 1: The temperature as marked on the conductor.
NOTE 2: The temperature marked on the capacitor.
NOTE 3: The case temperature for the applied power dissipation recommended by the semiconductor manufacturer.
NOTE 4: The operating temperature of the board as specified by the board manufacturer.
NOTE 5: The rated temperature of the motor or transformer as specified by the manufacturer, if provided. When not provided, use appropriate standards such as IEC 61010-1 for guidance.

10 Reporting Test Results

10.1 Include the following information on the test data form:

- Name, model, and serial number of the equipment
- Date of tests
- Name(s)/signature(s) of tester(s)
- Complete test methods and conditions
- Complete test results
- Complete test equipment information (type of test equipment, manufacturers' names, model numbers, serial numbers, and calibration information).

10.2 The general configuration and actual operating mode that was used for the test should be clearly documented. Where components are tested separately or only parts of the overall system are operational, this should be documented as a condition for the test results reported. This information can be on the test data form(s), or incorporated in the test report.

10.3 See Table 2 for a sample blank test data form.

Table 2 Sample Blank Test Data Form

Manufacturer:		Tester's Name:	
Name of Equipment:		Model No.:	
Serial No.:		Date:	
Location of Test Performed:			
(Test Name)			
Test Method:			
Test Result:			
Tester:		Reviewed:	
Equipment Used:	Model No.:	Serial No.:	Last Date Calibrated:

11 Related Documents

11.1 *SEMI Standards*

SEMI S1 — Safety Guidelines for Equipment Safety Labels

11.2 *IEC Documents*

IEC 60204 — Safety of Machinery – Electrical equipment of Machines, Part 1: General Requirements

IEC 60950 — Safety of Information Technology Equipment

SEMI S10-1296
SAFETY GUIDELINE FOR RISK ASSESSMENT

1 Purpose

1.1 This document provides a method for assessing the risk associated with any hazard and for ranking different hazards according to the risks they present. The method can be used to differentiate between those hazards which are acceptable and others which require further mitigation to reduce their risk to acceptable levels.

2 Scope

2.1 This method is applicable to hazards associated with semiconductor facilities, processes, and manufacturing equipment. It is used to evaluate the risks presented by identified hazards and provides consistent basis for prioritizing corrective action and allocating of limited resources according to the risks those hazards present.

3 Referenced Documents

None.

4 Terminology

4.1 *hazard* — A condition that is a prerequisite to a mishap.

4.2 *likelihood* — The expected frequency with which a mishap will occur. Usually expressed as a rate (e.g., events per year, per product, per wafer processed).

4.3 *mishap* — An unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

4.4 *risk* — The expected losses from a mishap, expressed in terms of severity and likelihood.

4.5 *severity* — The extent of the worst credible loss from a mishap caused by a specific hazard.

5 Procedures

5.1 *Mishap Severity & Likelihood* — Risk assessment first requires evaluating the expected severity and likelihood of occurrence for the mishap that results from the hazard. Examples of mishap severity and likelihood groups are presented in Tables 1 and 2.

For example, the risk assessment for a hazard that can credibly result in disabling injury and may occur once a year would be 2C (Severe/Possible), while a moderate hazard that is likely to occur more than five times per year would have a risk assessment of 3A.

NOTE 1: No standardized criteria for severity or likelihood groupings exist; users should develop groupings that are consistent with their own organization’s hazard control objectives and safety policies.

NOTE 2: Likelihood and severity may vary, depending on the activity phase (e.g. operation, maintenance or service.)

5.2 *Risk Assessment Matrix* — Once a hazard’s risk is determined, decisions can be made about whether the risk is acceptable or whether further mitigation is necessary. The Risk Assessment Matrix (such as the example shown in Figure 1) is a tool for making this judgment in a consistent, repeatable way.

The risk assessment categories tend to group together hazards with similar loss potentials (e.g., rare catastrophic loss and a frequent minor loss). The contours shown in Figure 1 are not standardized and users should define the matrix to suit their specific risk assessment criteria.

Besides establishing the risk assessment category for a single hazard, the matrix can be used to compare and prioritize different risks. This makes it easier to identify and concentrate resources on hazards having the greatest risk. The matrix can also be used to determine the effectiveness of alternative risk reduction strategies so that cost effective hazard reduction can be implemented.

Table 1 Severity Grouping

Severity Group	*People**	*Equipment/Facility**	*Property**
1 - Catastrophic	One or more fatalities.	System or facility loss.	Chemical release with acute, lasting environmental or public health impact.
2 - Severe	Disabling injury/illness.	Major subsystem loss or facility damage.	Chemical release with temporary environmental or public health impact.
3 - Moderate	Medical treatment or restricted work activity (OSHA recordable).	Minor subsystem loss or facility damage.	Chemical release triggering external reporting requirements.
4 - Minor	First aid only.	Non-serious equipment or facility damage.	Chemical release requiring only routine cleanup without reporting.

Table 2 Likelihood Grouping

Likelihood Group	*Expected Rate of Occurrence**
A - Frequent	More than five times per year.
B - Likely	More than once per year, but no more than five times per year.
C - Possible	More than once in five years, but no more than once per year.
D - Rare	More than once in ten years, but no more than once in five years.
E - Unlikely	No more than once in ten years.

* These descriptions are for example only. Use measures that are appropriate for your specific application.

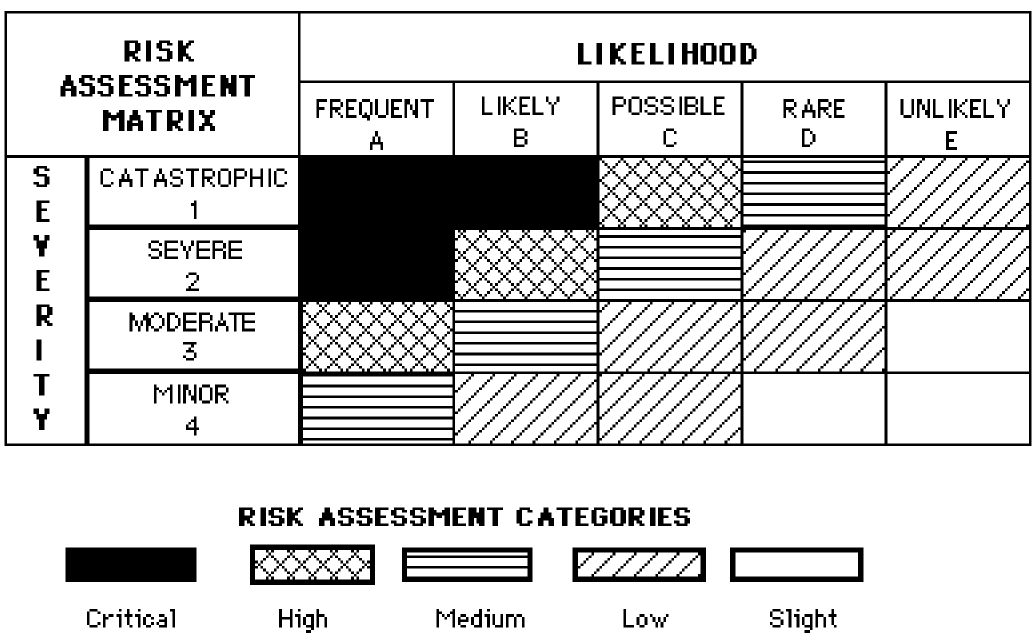

Figure 1
Sample Risk Assessment Matrix

6 Related Documents

6.1 *SEMI Standard*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability & Maintainability (RAM)

6.2 *United States Military Documents*[1]

MIL-STD-882C — System Safety Program Requirements

MIL-SPEC-1629A — Procedures for Performing a Failure Mode Effect and Criticality Analysis

6.3 *European Standard*[2]

EN 1050 — Safety of Machinery - Risk Assessment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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1 Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20555 USA

2 International Electrotechnical Commission, 1 rue de Varembe, Geneva, Switzerland

RELATED INFORMATION 1
EXAMPLE OF APPLICATION OF THIS METHOD

NOTE: This supplemental information is not an official part of SEMI S10 and is not intended to modify or supercede the document. It has been derived from practical application by task force members. Publication is authorized by full letter ballot. Determination of the suitability of this material is solely the responsibility of the user.

The severity and likelihood for each mishap have been determined and the resulting risk assessment assigned using the matrix in Figure 1.

Mishap Description	*Severity/*	*Likelihood*	*Risk Category*	*Priority*
I - Service personnel electrocuted due to accidental contact with exposed high voltage when main AC cabinet is opened.	1	B	Critical	1
II - Wafer handling blade breaks in slit valve during infrequentcalibration.	4	C	Low	3
III - Reactive chemicals mix in and destroy exhaust lines.	3	A	High	2

The “critical” and “high” risks presented in mishap descriptions I and III are likely considered unacceptable/undesirable and corrective action to reduce these risks will be indicated. However, the “low” risk of breaking a wafer handling blade during calibration may be considered allowable/acceptable without corrective action.

RELATED INFORMATION 2
EXPANDED HAZARD SEVERITY TABLE

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This table gives examples of human and equipment losses resulting from different hazard sources in each hazard severity category:

SEVERITY GROUPING	*HAZARD SOURCE*			
SEVERITY CATEGORY	*Electrical*	*Mechanical*	*Chemical*	*Radiation*
Catastrophic/Human	Death due to electrocution	Paralysis or death due to crushing	Death due to arsine release	Death due to exposure to X-ray source
Catastrophic/Equipment	Loss of tool due to electrical fire	Loss of system due to structural failure	Loss of fab due to pyrophoric release	Exhaust treatment system destroyed due to EMI induced switching failure
Severe/Human	Burn due to contact with exposed RF conductor	Loss of limb crushed by closing doors	Bone damage due to Hydrofluoric Acid exposure	Eye damage due to exposure to laser beam
Severe/Equipment	Heat Exchanger frame destruction due to electrical fire	Structural failure of ancillary equipment rack	Chamber/pump destruction due to incompatible chemicals	Magnetron destruction due to lack of plasma
Moderate/Human	Shock due to contact with exposed conductor	Strain/sprain due to heavy lifting	Burns due to acid spill	Skin burn due to unguarded UV source
Moderate/Equipment	Major PCB or transformer fire due to loose connector	RF generator destruction due to bracket failure	Gas line contamination due to cross connection	Broken susceptor due to EMI induced robot movement
Minor/Human	Startle due to contact with exposed conductor	Minor cut on extremity due to sharp edge	Skin irritation due to contact with solvents	Non-ionizing exposure at TLV
Minor/Equipment	Burned connector due to inadequate torque	Robot blade breakage due to slit valve closure	TEOS spill within secondary containment	EMI-induced CRT flutter

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI S11-1296
ENVIRONMENTAL, SAFETY, AND HEALTH GUIDELINES FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT MINIENVIRONMENTS

1 Purpose

1.1 These guidelines are intended as a minimum set of performance-based environmental, health, and safety considerations for minienvironments used in semiconductor manufacturing.

1.2 These guidelines are intended to be a supplement to SEMI S2 (see Section 3.1).

2 Scope

2.1 These guidelines apply to minienvironments used in the manufacturing, metrology, assembly, and testing of semiconductor products.

2.2 Equipment enclosed by, or used in conjunction with, the minienvironments is addressed separately by SEMI S2 (see Section 3.1). Examples are process tools and exhaust emissions abatement devices.

2.3 For "integrated minienvironments," only the minienvironment enclosure portion is addressed by these guidelines.

3 Referenced Documents

NOTE: Documents as listed or referenced shall be the latest available.

3.1 *SEMI Documents*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

3.2 *NFPA Documents*[1]

NFPA 255 — Standard Method of Test of Surface Burning Characteristics of Building Materials

NFPA 318 — Standard for the Protection of Cleanrooms

3.3 *Other Documents*

ACGIH — Industrial Ventilation - A Manual of Recommended Practice[2]

UL 181 — Standard for Safety Factory-Made Air Ducts and Air Connectors[3]

4 Terminology

4.1 *closed loop air supply* — A system in which air is recirculated from the minienvironment and returned to the minienvironment with minimal make-up air.

4.2 *emergency off (EMO)* — Control circuit which when activated, places the equipment into a safe shut down condition.

4.3 *integrated minienvironment* — The minienvironment that is an integral part of the tool.

4.4 *minienvironment* — A localized environment created by an enclosure to isolate the product from contamination and people.

4.5 *minienvironment end user* — The facility which uses a minienvironment for semiconductor fabrication.

4.6 *minienvironment supplier* — The party that builds, sells, or otherwise provides minienvironment enclosures.

4.7 *tool supplier* — The party that builds, sells, or otherwise provides the tools that are used together with the minienvironments.

5 General Requirements

5.1 *Safety and Health Design Requirements* — Minienvironment manufacturers should consider site-specific design requirements but must not compromise compliance with applicable regulatory requirements. The requirements covered in these guidelines are not all-inclusive. The minienvironment supplier should employ any additional applicable regulatory and industry standards that govern associated components. It is the minienvironment supplier's responsibility to work with the user and tool supplier to understand the local codes and variances.

1 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101

2 American Conference of Governmental Industrial Hygienists, 6500 Glenway, Building D-7, Cincinnati, OH 45211-4438

3 Underwriters Laboratories Inc., 33 Pfingsten Road, North Brook, IL 60062

5.2 *Environmental Design Requirements*

5.2.1 In order to assess the environmental impact of minienvironments, the minienvironment supplier should provide a listing of materials of construction showing the compatibility with chemical and process materials typically used in the given minienvironment. In the case of “non-typical” chemical and process chemicals, the minienvironment supplier and minienvironment end-user will evaluate the particular materials involved to ensure compatibility. “Nonprocess” chemical wastes (i.e., wastes not in contact with the product such as oil filters, pump oils, etc.) that are generated by routine preventative maintenance should be included.

5.3 Materials of construction should be in conformance with SEMI S2, Section 19.

6 Enclosure Interlocks

6.1 Not all enclosure panels, doors, and hatches require interlocks. There may be cases where the customer requires ports for manual access for product load/unload or tool adjustment without process tool interrupt. The need for interlocks should be assessed. If the overall level of safety is not compromised, interlocks need not be provided.

6.2 Interlocks are required when the minienvironment replaces an interlocked door or panel on the process tool or where the minienvironment provides the primary barrier to operator exposure to chemical, electrical, mechanical, thermal, radiation or other recognized hazards.

7 Chemical and Physical Hazards

7.1 The addition of the minienvironment and its associated components should not compromise equipment safety and health considerations required for conformance with SEMI S2.

7.2 *Shut-off Valves* — Manual shut-off valves for hazardous materials should be clearly visible, labeled, and easily accessible. Access to these valves should not be restricted by any part of the minienvironment.

8 Noise

The addition of a minienvironment system should not cause the noise level to exceed conformance with SEMI S2, Section 9 (see Section 3.1).

9 Ventilation & Exhaust

9.1 Recirculating air ducts, connectors, and ventilation components within the minienvironment, should be constructed of noncombustible material of Class 0 or Class 1 materials as tested in accordance with UL 181, Standard for Safety Factory-Made Air Ducts and Air Connectors.

9.2 Recirculating air duct materials should be compatible with chemical processes used in the given minienvironment; the minienvironment supplier should provide a listing of materials of construction showing the compatibility with chemical and process materials typically used in the given minienvironment. In the case of “non-typical” chemical and process materials, the minienvironment supplier and minienvironment end-user will evaluate the particular materials involved to ensure compatibility.

9.3 Exhaust should not be altered in any fashion to accommodate a process where flammable liquids are used or flammable vapors present. Dampers, where required for balancing or control of the exhaust system, should be of the locking type.

9.4 Primary exhaust and monitoring of the equipment/process enclosed should be incorporated as defined in SEMI S2 (see Section 3.1).

9.5 Minienvironments with a closed loop air supply should control fugitive emissions in accordance with SEMI S2, to prevent the buildup of gases and vapors within the enclosure.

9.6 Ventilation of tools and areas in which hazardous materials are used, should comply with the ACGIH reference in Section 3.2.

10 Electrical

The addition of the minienvironment and associated equipment should be in compliance with SEMI S2 (see Section 3.1).

11 Emergency Shutdown

Emergency off (EMO) buttons should be relocated, or additional EMO buttons installed, if the original EMOs are out of reach or obstructed due to mini-environment installation.

12 Ergonomics/Human Factors

12.1 Ergonomics/human factors should comply with SEMI S8 (see Section 3.1).

12.2 Areas of particular concern for minienvironments include load/unload ports and maintenance accesses. The design should discourage extended reaching, lifting, pulling, and manual orientation of product and/or containers.

13 Seismic Event Design

Minienvironments and associated equipment should be designed in conformance with SEMI S2, Section 17 (see Section 3.1).

14 Fire Suppression

14.1 Whenever possible, non-combustible materials should be used in minienvironment design and construction. Fire detection/suppression should be incorporated based on evaluation of the minienvironment size, materials of construction, the process, equipment enclosed, the facility design, and interaction with the facility fire detection/suppression systems.

14.2 If fire sprinklers are used, they should be the "quick response" (QR) type.

14.3 If the minienvironment prevents personnel exposure to the tool and process, an automatic gaseous fire suppression system may be used as an alternative to sprinklers. Gaseous extinguishing systems should be actuated by optical detectors.

15 Maintenance & Servicing

15.1 *Maintenance and Service Preparation of Minienvironments with Chemical Process Tools* — Exhaust design at the tool should be adequate to prevent the concentration buildup of fugitive vapor emissions in the tool and minienvironment. The exhaust should be maintained during maintenance and service operations even though the enclosure doors are open.

15.2 Hazardous materials should be avoided for service and maintenance requirements.

15.3 Minienvironment panels, doors, and access ports removed for service or maintenance, should be stored in a secure manner that will not permit these parts to fall, obstruct passage ways, or otherwise cause tripping or handling hazards.

SEMI S12-0298
GUIDELINES FOR EQUIPMENT DECONTAMINATION

1 Purpose

1.1 This document establishes guidelines for decontaminating equipment which has been exposed to hazardous materials and which is intended for further productive use. Equipment intended for further productive use may include, but is not limited to, that being offered for reuse, resale, repair, refurbishment, or relocation.

1.2 These guidelines should be adapted at each site with proper consideration given to local, state, national, and international regulations and organization policies.

2 Scope

2.1 These guidelines apply to the preparation for transfer or relocation of equipment which has been exposed to hazardous or toxic materials and may pose a threat to human health or the environment. These activities may include, but are not limited to, shutdown, dismantling, removing, labeling, and packaging prior to transport.

2.2 These guidelines describe minimum requirements for documentation of decontamination and notification of residual hazards associated with decontamination.

2.3 The level of decontamination required for equipment designated for reuse in the same service in the same location may be assessed on a case-by-case basis by the site Environmental, Health, and Safety organization.

2.4 These guidelines are intended to be used to ensure that decontamination prior to transport occurs to the greatest extent possible, while acknowledging practical limitations which may exist in individual circumstances.

3 Referenced Documents

None.

4 Limitations

4.1 These guidelines are not intended to address decontamination requirements for the preparation of equipment for final “end-of-life” disposal.

4.2 These guidelines are not intended to supersede applicable international, governmental, site, or original equipment manufacturer requirements.

5 Terminology

5.1 *decontamination* — The removal of materials in or on equipment.

5.2 *equipment* — Process tools, chemical (liquid or gas) controls and delivery systems, ancillary support systems, structures, piping, ductwork, parts, and subassemblies (e.g., vacuum pumps, pump packages, effluent/exhaust treatment systems).

5.3 *hazardous material* — Any chemical, substance, or compound which is defined or interpreted to pose risks or hazards to human health or the environment by applicable international, national, regional, or local laws or regulations.

5.4 *health hazard* — A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed persons. Health hazards include chemicals which are carcinogens, toxic or highly toxic materials, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.

5.5 *transferor* — The party with physical custody of the equipment and responsibility for transfer.

5.6 *transferee* — The party who will receive physical custody of the equipment.

6 Responsibility

6.1 It is the responsibility of the equipment transferor to ensure the removal or minimization of all hazardous materials associated with the subject equipment prior to transfer or relocation. Hazards not addressed in the guideline may exist, including undissipated electrical charges or mechanical energy. It is recognized that, in many cases, complete chemical decontamination cannot be achieved without destruction of the equipment. The equipment transferor should ensure that *all* known remaining potential hazards are clearly identified to the transferee.

6.2 It is the responsibility of the equipment transferor to ensure residues, waste materials, and scrap parts/ equipment that are generated as part of the equipment decontamination process are safely handled and appropriately disposed of as per local, state, national, and international regulations or standards.

7 Personnel Safety

7.1 Assessment and decontamination procedures should be performed only by properly trained and equipped personnel.

7.2 Any specific procedures used to follow these guidelines should be pre-approved by the site environmental, health, and safety organization prior to decontamination activities.

7.3 Assessment and decontamination procedures should include requirements for appropriate personal protective equipment.

8 Equipment Assessment Prior to Decontamination

8.1 An assessment should be performed on all equipment prior to transfer. Assessment of equipment should initially consider history of the equipment and visual inspection. If initial assessment shows a potential for equipment to have contacted hazardous materials during the life of the equipment, further assessment needs to be performed. (See the flowchart in Figure 1.)

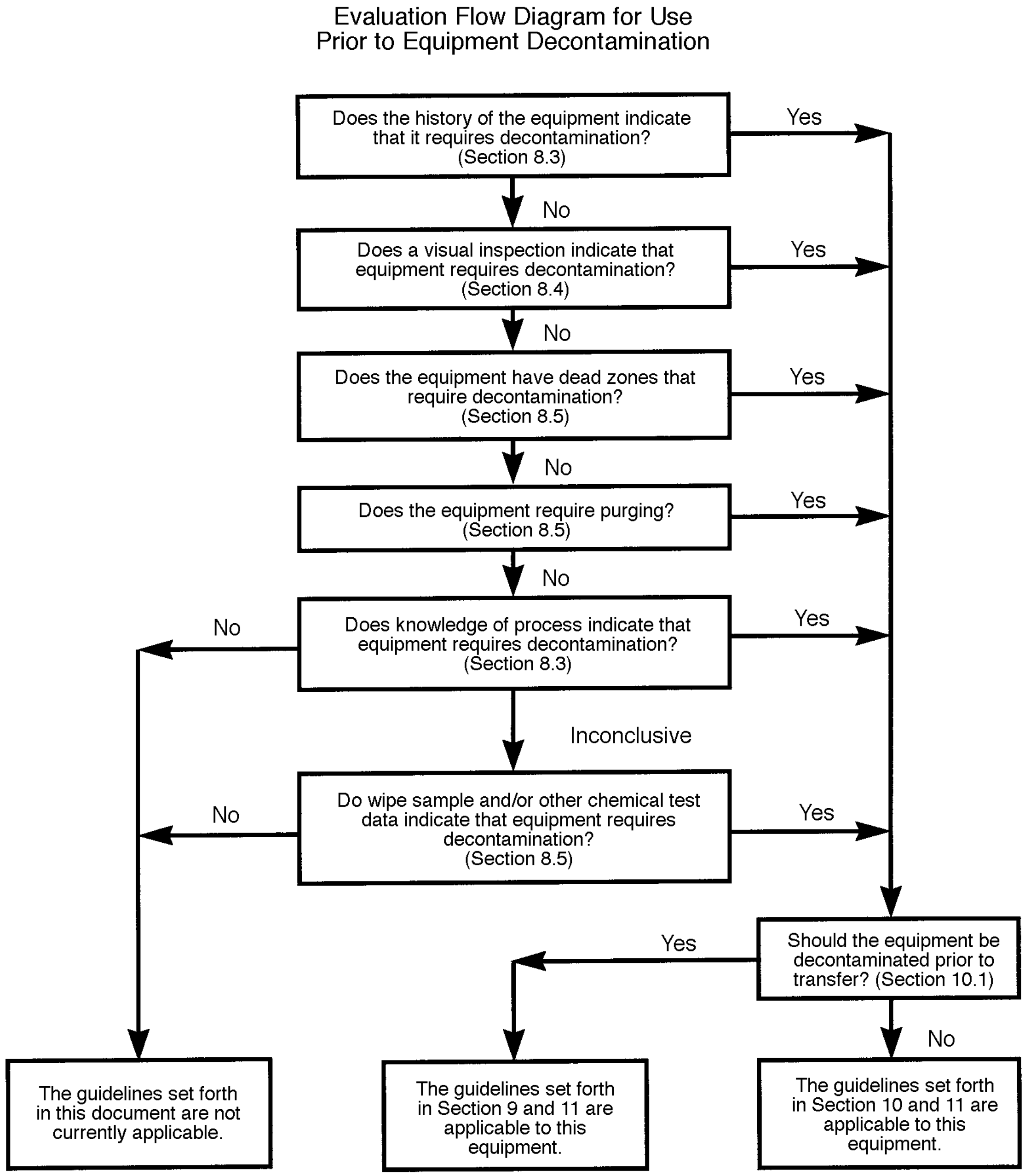


Figure 1
Equipment Assessment Flowchart

8.2 Prior to decontamination, the equipment should be evaluated for abnormalities or non-functionality that may affect the evaluation and decontamination efforts.

8.3 Decontamination should be performed on all areas of equipment which had potentially contacted hazardous materials during the life of the equipment, unless the areas are judged non-hazardous by the criteria set forth in this section. The areas to be decontaminated include external surfaces, internal areas which are accessible without disassembly, and areas accessible during normal operations. Normally inaccessible areas should be addressed on a case-by-case basis by the site Environmental, Health, and Safety organization. Normally removable parts may also require cleaning.

8.4 Visible residues on equipment surfaces, including liquids, powders, flakes, or films, potentially indicate the presence of hazardous materials. All visible indicators of hazardous materials should be assumed to be hazardous unless otherwise determined and documented by appropriate test, analysis, or evaluation.

8.5 Wipe sampling and chemical testing verifying the absence of materials posing physical and health hazards is recommended for all equipment that has been exposed to hazardous materials (regardless of the presence of visible residues).

8.5.1 It is recommended that professional guidance be used to determine the number, type, and location of samples that should be taken. *General guidance is available through air sampling strategy methodologies developed by NIOSH (Occupational Exposures Sampling Strategies) and through surface sampling strategies developed by the Nuclear Regulatory Commission (Manual for Conducting Radiological Surveys in Support of License Termination).*

8.6 If results of activities in Sections 8.2–8.5 indicate that equipment should be decontaminated prior to transfer, refer to Section 9 of this document. If results of activities in Sections 8.2–8.5 indicate that equipment requires decontamination but will not or cannot be decontaminated prior to transfer, see Section 10. If results of activities in Sections 8.2–8.5 indicate that equipment does not require decontamination prior to transfer, this guideline is not currently applicable to the equipment in its present state.

9 General Guidelines for Decontamination

9.1 All activity-specific safety and health procedures, including, but not limited to, hazardous energy control procedures, must be followed.

9.2 Equipment should be decontaminated before movement. If movement of the equipment is required prior to decontamination, precautions should be taken to remove potential sources of leakage, spillage, offgassing, or hazardous material emissions. These precautions may include draining, purging, and then the use of appropriate barriers, covers, or containment devices.

9.3 Chemical supply sources should be made safe prior to disconnecting or removal from the equipment and capped prior to the beginning of the cleaning process. Exhaust ventilation to control exposures to, and the spread of, airborne particulate should remain in service during equipment decontamination, or alternate exhaust provisions should be made.

9.4 Where equipment parts are routinely removed from the equipment for cleaning, such as those used in ion implanters, photoresist spinners/developers, and metal deposition chambers, these parts should be cleaned prior to equipment transfer.

9.5 Where equipment parts are routinely removed and replaced, such as filters, O-rings, or oil traps, these parts should be removed and replaced with clean parts or appropriate blanking device prior to equipment transfer. If any such parts are removed but not replaced, this fact should be noted on decontamination documentation (see Section 12 of this guideline).

9.6 All liquid and gas lines on the equipment should be appropriately purged, drained, protected against corrosion and process contamination, and securely sealed with blanking plugs, caps, or similar devices.

9.7 Thorough decontamination may not be achieved within component systems or equipment due to inaccessibility (i.e., “dead zone”) or to physical characteristics of materials. Equipment with such zones require additional cycle purges and/or disassembly for access and proper cleaning. If complete decontamination cannot be achieved, follow the guidelines outlined in Section 11.

9.8 While disconnecting equipment or removing components, gas leak monitoring and pH levels should be measured.

10 Requirements for Equipment Transfers without Complete Decontamination

10.1 It is recognized that, in some cases, complete chemical decontamination cannot or will not be desired or achieved for various reasons (e.g., it will destroy the equipment (i.e., pumps), there is a need for failure analysis). This section establishes guidelines for the transfer of equipment intended for further productive use which cannot or will not be completely decontaminated prior to transfer.

10.2 If the contaminated equipment is a sub-component or subassembly of a larger piece of equipment which will not be otherwise decontaminated, the contaminated sub-component or subassembly should be removed and transferred separately under the requirements of this section.

10.3 Prior to transfer, the transferor must ensure that any remaining potential hazards are clearly identified to persons handling, transporting, and receiving this equipment, as specified in Section 11. All requirements in Section 11 must be followed, with the exception of Section 11.3.2.

10.4 Prior approval must be obtained before transfer of contaminated equipment. Prior approval should consist of receipt of all documentation and certifications specified in Section 11 before shipment and a signed authorization from the receiver to accept the equipment.

10.5 Equipment which is not completely decontaminated is potentially a hazardous material. Transfer of this equipment, including transportation, must be in accordance with all applicable local, state, national, and international regulations and organization policies.

11 Documentation and Certifications

11.1 The documentation recommended by this guideline is in addition to that required by local, state, national, and international regulations.

11.2 Documentation and certifications should be securely attached in a clear, weatherproof bag and transported with the equipment.

11.3 The following documentation and certifications should be prepared prior to transfer of equipment:

11.3.1 A history of all hazardous materials used in the equipment and potential by-products, including concentrations, if known. At a minimum, list the hazardous materials used in the tool just prior to decontamination or transfer.

11.3.2 Documentation of the procedure used for decontaminating the equipment, including:

11.3.2.1 the cleaning procedures used (including chemicals used for cleaning),

11.3.2.2 liquid or gas purge procedure used,

11.3.2.3 testing procedure used to determine adequacy of decontamination,

11.3.2.4 results of tests, and

11.3.2.5 other significant information pertinent to the decontamination activities, including parts removed for separate decontamination.

11.3.3 When it is likely that hazardous material residues remain in or on the equipment, a warning must accompany the equipment. The warning should identify suspected hazards, state appropriate personal protective equipment that should be worn, and precautions that should be taken when handling the equipment.

11.3.4 Documentation should include the name and phone number of the responsible/knowledgeable parties in case of emergency or requirements for additional information.

11.3.5 A certification by a responsible site environmental, health, and safety representative that states the equipment has been prepared for transfer according to this guideline.

12 Related Documents

12.1 *SEMI Documents*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S4 — Safety Guidelines for the Segregation/ Separation of Gas Cylinders Contained in Cabinets

SEMI S9 — Electrical Test Methods for Semiconductor Manufacturing Equipment

12.2 *EPA Documents*

US EPA (Environmental Protection Agency) — EPA's "Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites," EPA/600/2-85/028, March 1985, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — "Chain of Custody Procedures," EPA/SW-846, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — Asbestos in Air Sampling, 40 CFR 763, Subpart E, Appendix A, Federal Register

US EPA — TEST METHODS FOR EVALUATING SOLID WASTES, EPA SW-846, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — INTEGRATED RISK INFORMATION SYSTEM, 1994, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

US EPA — EXPOSURE FACTORS HANDBOOK, 1989, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

12.3 *OSHA Documents*

CFR 1910.1200 — Hazard Communication Standard – Title 29, Federal Register, US Government Printing Office, Washington, D.C. 20402

OSHA (Occupational Safety and Health Administration), U.S. Department of Labor — OSHA TECHNICAL MANUAL, CPL 2 - 2.20B, Chapter 2, Sampling for Surface Contamination, February 5, 1990, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

OSHA (Occupational Safety and Health Administration), U.S. Department of Labor — OSHA's CHEMICAL SAMPLING INFORMATION, Directorate of Technical Support, Salt Lake City Technical Center, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

12.4 *Other Related Documents*

BOCA — National Fire Prevention Code published by Building Officials and Code Administration

CCR 5215(c)(2)(C) — Cal/OSHA's 4,4' — methylenebis (2-chloroaniline), MBOCAA, Barclays Law Publications, P.O. Box 3066, South San Francisco, CA 94083-3066

NIOSH (National Institute of Occupational Safety and Health), U.S. Department of Health and Human Services, CDC, Public Health Service — NIOSH's STATISTICAL SAMPLING STRATEGIES, Document #77-173, NTIS - PB 274792, Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

NIOSH (National Institute of Occupational Safety and Health), U.S. Department of Health and Human Services, CDC, Public Health Service — NIOSH's MANUAL OF ANALYTICAL METHODS, 3rd Ed., Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

SBCCI — Standard Fire Prevention Code published by Southern Building Code Conference International, Inc.

UFC (Uniform Fire Code) — Uniform Fire Code published by International Conference of Building Officials and Western Fire Chiefs Association, 5360 South Workman Mill Road, Whittier, CA 90601

US Nuclear Regulatory Commission — MANUAL FOR CONDUCTING RADIOLOGICAL SURVEYS IN SUPPORT OF LICENSE TERMINATION, NUREG/CR-5849, ORAU-92/C57, June 1992

RELATED INFORMATION 1
EXAMPLES OF WIPE SAMPLING PROCEDURES

NOTE: This related information is not an official part of SEMI S12 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Wipe sampling should be conducted primarily on nonporous surfaces. "Wet" (swab or filter paper with solvent) or "dry" (swab or filter paper without solvent) wipe sampling techniques may be used. These procedures are based on those contained in the US EPA's "Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites," EPA/600/2-85/028, March, 1985. The sample area has been decreased in the wet wipe sampling procedure from 0.25 m^2 to 100 cm^2 (0.01 m^2) due to the size of equipment and surfaces anticipated to be sampled for this SEMI Guideline. *Another relevant document on sampling for surface contamination is contained in the OSHA - Occupational Safety and Health Administration, U.S. Department of Labor, OSHA TECHNICAL MANUAL, CPL 2 - 2.20B, Chapter 2, Sampling for Surface Contamination, February 5, 1990*. Chemical-resistant gloves should be worn while performing these procedures. Gloves should be clean to avoid tainting the samples obtained and should be changed between the securing of samples to avoid cross-contamination.

R1-1 General Recommendations

R1-1.1 Assure that the marking method for the sample container and area to be wiped will not interfere with the intended analysis.

R1-1.2 Assure that the container will not absorb the material being sampled or add interfering material that will be detected during analyses.

R1-1.3 Assure that the wetting agent will not react with the material being sampled, interfere with the analysis, or degrade the shipping container.

R1-1.4 Should it become necessary to swipe an area other than 100 cm^2 (e.g., a lever or knob or other part of a tool), then record the estimated or, preferably, measured swipe area.

R1-1.5 Submit a blank with each batch of swipe samples. The blank is a sampling device (such as a swipe tab) of the same type and from the same batch as that used for the sampling and which is wetted and handled just like the samples, but which is not rubbed on a surface.

R1-1.6 Use appropriate personal protective equipment during sampling.

R1-1.7 Samples should be analyzed by a competent and appropriately certified laboratory for the hazardous materials being evaluated.

R1-1.8 The *sampling* and *analytical* methods used should be *appropriate for the agent in question, with the NIOSH Manual of Analytical Methods, EPA's Test Methods for Evaluation of Solid Wastes (EPA SW-846), and OSHA's Sampling and Analytical Methods being established methodologies*. *If new methods are to be* developed or reviewed, *they should be* approved by an industrial hygienist certified by the American Board of Industrial Hygiene or by another appropriately certified or registered professional.

R1-2 Wet Wipe Sampling Procedure

R1-2.1 Mark off a square area of approximately 100 cm^2 on the surface to be wiped, using a template which is cleaned between each sampling event. If a template is unavailable or the area to be wiped is less than 100 cm^2, note the exact dimensions and establish markings on the four outer corners of the area to be wiped.

R1-2.2 Label the appropriate wet sample container with the information listed in R1-1.5.

R1-2.3 Hold a filter paper with a clean, *impervious*, gloved hand or metal clamp, and saturate the wipe with either deionized water, isopropyl alcohol, *or other wetting* agent, depending on the *hazardous material* to be sampled.

R1-2.4 Wipe the sampling area starting at the outside edge and progressing toward the center, making concentric circles of decreasing size, applying moderate pressure. Fold the wipe sample with the exposed side in, and fold it over again.

R1-2.5 Carefully place the completed wipe sample in the container for storage and transportation, without allowing the sample to contact any other surfaces.

R1-3 Dry Wipe Sampling Procedure

R1-3.1 Label the appropriate dry sample container with the information listed in R1-1.5.

R1-3.2 Hold a filter paper wipe with a clean, impervious, gloved hand.

R1-3.3 Wipe the sampling area, starting at the outside edge and progressing toward the center, making concentric circles of decreasing size, applying maximum pressure. Fold the wipe sample with the exposed side in, and fold it over again.

R1-3.4 Label a glass-stoppered jar or zipper-closure plastic bag with the information listed in R1-1.5.

R1-3.5 Carefully place the completed wipe sample in the container for storage and transportation without allowing the sample to contact any other surfaces.

R1-4 Scrape and Bulk Sampling

NOTE: A scrape sample is one made by abrading material and collecting it in a container which is sent to a laboratory for analysis. Scrape sampling might be done to assure lead and hexavalent chromium are not present in paint on the exterior of a tool. Bulk sampling requires the collection of *adequate amounts of the suspected material to allow for meeting minimum detection limits of the sampling and analytical techniques being used. Close consultation is needed with the accredited laboratory performing the analysis.*

R1-5 Sample Control

R1-5.1 Label each sample container with the following information before sampling:

- Sample Number
- Sample Location (where was sample taken from)
- Sample Type *and Media Used*
- Date of Sample
- Name of Person Performing Sampling
- Areas Sampled (in cm^2)

R1-5.2 Record each sampling event in a log book. Include a rough sketch of the equipment, associated areas of concern, and exact sampling locations. Also include any other pertinent notes or details which may affect the interpretation of sample results.

R1-5.3 Follow the chain of custody procedures outlined in EPA SW-846.

R1-5.4 Analyze samples using standard methods, such as those specified by *NIOSH*, *OSHA* or *EPA* SW-846, whenever possible. (See Section R1-1.8 for additional details.)

RELATED INFORMATION 2
EXAMPLE OF METHOD FOR ESTABLISHING "NON-HAZARDOUS" LEVELS

NOTE: This related information is not an official part of SEMI S12 and is not intended to modify or supersede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

This method was compiled from various sources. The applicability of this method and the validity of its assumptions in the application for which it is considered must be determined by an appropriate professional.

R2-1 Method 1

This method is designed to be protective of the health and safety of untrained and unprotected individuals. In this method, "non-hazardous" level is determined by assessment of the risk posed by potential exposure to the contaminant(s). (This method is based on the assumptions that 1) the exposed portions of a worker's body collect a single layer of the contaminant, with a density half that of the layer on the contaminated surface, in the course of a day and that 2) this contaminant is then incorporated, at the end of the day, into the body by either absorption or ingestion.) This method is, therefore, probably inappropriate for contaminants which are absorbed rapidly throughout the day.

R2-1.1 Toxicity criteria are determined for each of the chemicals identified as potentially leaving a residue. As an example, toxicity criteria used are reference doses (RfDs) for human uptake of chemicals (US EPA's Integrated Risk Information System, 1996), and no significant risk levels (NSRLs) defined under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). Daily exposures to the RfD (expressed in mg/kg-day) over a lifetime are not expected to cause adverse health effects (non-cancer effects). Daily exposure to the NSRL (μg/day) over a lifetime are considered to pose an insignificant (less than 1 in 100,000) increased cancer or reproductive risk.

R2-1.2 Oral and dermal exposures are considered. Dermal exposure is assumed to occur through direct contact with contaminated work *surfaces* (i.e., hands, arms, and face). Oral exposure is assumed to occur though *direct* contact with *contaminated work surfaces and* hands, and subsequent contact between hand and mouth.

R2-1.3 The equations used in this method to calculate the oral and dermal “Health-Based Cleanup Levels (HBCL’s)” are:

$$HBCL_{oral} = \frac{RfD \times BW}{SA_O \times MF \times CE \times AF_O \times EF}$$

$$HBCL_{dermal} = \frac{RfD \times BW \times ED}{SA_d \times CE \times AF_d \times EF}$$

Where :

$RfD =$ EPA RfD [mg/kg – day]

$BW =$ Body weight [70 kg]

$ED =$ Exposure duration [0.5 days]

$SA_O =$ Surface area of exposed hands [0.084 m^2]

$SA_d =$ Surface area of exposed hands, forearms, and head [0.316 m^2]

$MF =$ Fraction of exposed dermal are contacted by mouth [0.5/day]

$CE =$ Skin contact efficiency [0.5]

$AF_O =$ Gastro-intestinal absorption factor [1.0] (conservative)

$AF_d =$ Dermal absorption factor [0.01]

$EF =$ Exposure factor [12 hours/24 hours; 250 days/365 days; 40 years/70 years = 0.20]

Body weight and surface area factors are as suggested by EPA’s *Exposure Factors Handbook* (1989). The fraction of skin contaminant that will be ingested orally (MF) is conservatively assumed to be 50%. This is approximately equivalent to a person ingesting all of the chemical that contacts the palms of the hands, but not the backs. Contact efficiency (CE) refers to the fraction of chemical that is removed from the contaminated surface through contact with the skin. It is assumed that no more than 50% of the chemical contamination from equipment will rub off the surface and adhere to the skin. Oral and dermal absorption factors are chosen as the most conservative numbers due to limited available data.

The exposure factor (EF) represents the fraction of time that a person could be expected to be in contact with chemical contamination from exposed surfaces. Exposure to surfaces is assumed to follow an occupational exposure scenario. This scenario includes the following conservative assumptions:

- A person works at the facility for 40 years of a 70-year lifetime;
- Exposure occurs 250 days per year (365 days);
- The skin is in contact with the chemicals for 12 hours per day. This assumes that the chemicals are not removed from the skin until washed, and the skin is washed only once per day.

R2-1.4 The final HBCL for each chemical is then the lower of the levels for oral or dermal exposure routes.

NOTE: These HBCLs represent levels that are considered to be health-protective for a person who contacts equipment with residual contamination on a daily basis. These values are based on extremely conservative assumptions and are likely to provide an overestimate of a health-protective clean-up level.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI S13-0298
SAFETY GUIDELINES FOR OPERATION AND MAINTENANCE MANUALS USED WITH SEMICONDUCTOR MANUFACTURING EQUIPMENT

NOTICE: These safety guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the user of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Purpose

1.1 These guidelines present considerations when drafting operation and maintenance manuals in order to help hazard reduction in operation and maintenance of equipment used in semiconductor manufacturing. These guidelines supplement Section 18 of SEMI S2.

2 Scope

2.1 These guidelines apply to the operation and maintenance manuals used with equipment that is used for production, measurement, assembling, and testing of semiconductor products. These guidelines contain the following items:

- Purpose
- Scope
- Referenced Documents
- Terminology
- Concept of Operation and Maintenance Manuals
- Hazards Inherent in Equipment
- Hazardous Energy Control Procedures
- Hardware Safety Interlocks
- Hazard Alerts
- Hazard Inherent in Equipment
- Material Safety Data Sheet (MSDS)
- Personal Protective Equipment (PPE)
- Inspection of System Equipment and Maintenance of Consumables
- Training Requirements
- Place of Supplier's Contact in Case of Emergency
- Laws and Regulations
- Related Documents

3 Referenced Documents

NOTE: All documents cited shall be the latest publications of adopted standards and guidelines.

3.1 *SEMI Documents*

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

3.2 *ANSI Documents*[1]

ANSI Z535.4 — American National Standard for Product Safety Signs and Labels

ANSI Z400.1 — American National Standard for Hazardous Industrial Chemicals - Material Safety Data Sheets - Preparation

ANSI Guide for Developing User Product Information

3.3 *Other Document*[2]

International Labor Convention No. 170 — Convention Concerning Safety in the Use of Chemicals at Work

4 Terminology

4.1 *caution* — Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices (ANSI Z535.4).

4.2 *danger* — Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations (ANSI Z535.4).

4.3 *equipment* — The system equipment, its component parts, and auxiliary or peripheral equipment.

4.4 *warning* — Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury (ANSI Z535.4).

NOTE: Danger or Warning should not be considered for property damage accidents unless personal injury risk appropriate to these levels is also involved. Caution is permitted for property-damage-only accidents (ANSI Z535.4).

1 American National Standards Institute, 1430 Broadway, New York, NY 10018

2 International Labour Organization, CH-1211, Geneva 22, Switzerland

NOTE: Additional terminology is given in SEMI S2 and SEMI S10.

5 Concept of Operation and Maintenance Manuals

5.1 Operation and maintenance manuals should provide sufficient information on proper operation methods and appropriate maintenance methods to enable safe operation and maintenance. Warnings of potential hazards and how to avoid or minimize hazards should be provided.

5.2 Operation and maintenance manuals should conform to the *ANSI Guide for Developing User Product Information*, or an equivalent, to ensure that they have easy-to-read and understandable contents.

5.3 The operation and maintenance manuals should be designed so that the user can readily understand the risk associated with each task.

5.4 Where contractually agreed upon, by request of the user, or where required by law, the operation and maintenance manuals should be provided in the primary language of the location in which the equipment is to be used. However, the language in which the manuals were created should be identified.

5.5 Safety measures provided in the equipment according to the equipment user's requisition or request may be described separately. The additional safety features can be provided with the manuals as a separate attachment.

6 Hazards Inherent in Equipment

6.1 The equipment supplier should use the result of a risk assessment of the equipment, of which method is provided in SEMI S10, to determine the risk of hazards inherent in equipment.

6.2 Hazards in the equipment should be summarized in a safety section of the manuals, including their location and safety procedures recommended by the supplier. Such hazards may be located, for example, within a plasma etcher, at the RF unit, vacuum pump, gas supply and exhaust unit, or chiller.

7 Hazardous Energy Control Procedures

7.1 Any source of electrical, chemical, thermal, or mechanical energy, radiation and compressed air, or liquid energy that exists in equipment which may be hazardous to workers maintaining the equipment should be described in the maintenance manual, along with the procedures for isolation and control of the hazardous energies.

8 Hardware Safety Interlocks

8.1 The equipment supplier should describe the hardware safety interlocks provided for the equipment and their operation in a list or similar format in the operation and maintenance manuals. The interlock list should include, but not be limited to, hazards protected, detection methods, and equipment conditions after the interlocks are activated.

8.2 The locations of hardware safety interlocks protecting personnel should be clearly indicated using a layout sketch.

9 Hazard Alerts

9.1 The equipment supplier should explain in the operation and maintenance manuals the meaning of hazard alerts on the equipment. Examples of hazard alerts include: visual alerts, auditory alarms, status indicators; or hazard alert systems integral with the equipment's operating system (e.g., displayed through the video display).

9.2 The equipment supplier should describe the location of each hazard alert label attached to the equipment.

10 Hazards Inherent in Tasks

10.1 In operation and maintenance manuals, hazards inherent in each task should be indicated using the signal words "Danger," "Warning," or "Caution." The recommended safety procedures should be followed to avoid the hazard and resulting potential injury. The signal word and the explanations for such a hazard should be enhanced by, for instance, enlarging the letters or surrounding them with a box.

10.2 The equipment supplier should include the definitions of "Danger," "Warning," and "Caution" in the operation and maintenance manuals.

11 Material Safety Data Sheet (MSDS)

11.1 The equipment supplier should attach, to the operation and maintenance manuals of the subject system, a material safety data sheet (MSDS) covering those chemical substances which are inherent in, and shipped with, the equipment, including those to which operators or workers may be exposed during operation, maintenance, or inspection of said equipment. For those chemical substances which are used for processing, the manual should state that the user must obtain the MSDS from their chemical supplier.

11.2 Adopted by the International Labor Convention No. 170 and ANSI Z400.1, the MSDS calls for the following points to be described:

11.2.1 The name of the business corporation compiling the particular MSDS.

11.2.2 The name of the substance and its chemical formula, constitutional formula, molecular weight, CAS No., UN No., etc.

11.2.3 Categorization of its hazards or toxicity.

11.2.4 First aid measures.

11.2.5 Measures to be taken in case of fire.

11.2.6 Measures to be taken when leakage occurs.

11.2.7 Handling and storage precautions.

11.2.8 Exposure prevention measures.

11.2.9 Physical and chemical properties.

11.2.10 Matters relevant to hazardousness.

11.2.11 Matters relevant to toxicity.

11.2.12 Matters relevant to ecological effect.

11.2.13 Cautions when disposing of the substance.

11.2.14 Cautions when transporting the substance.

11.2.15 Applicable laws and regulations.

11.2.16 Date of enactment, standards cited, etc.

12 Personal Protective Equipment (PPE)

12.1 Personal protective equipment (such as goggles, aprons, gloves, masks, safety shoes, and helmets) to be worn when operating or maintaining a system should be identified. The operation and maintenance manuals should clarify which of the personal protective equipment is needed for each task.

12.2 The equipment supplier should state in the manuals that the use of PPE should be in accordance with instruction manuals provided by the PPE suppliers, except where additional instructions by the equipment supplier are required for the specific use of PPE.

13 Inspection of System Equipment and Maintenance of Consumables

13.1 The equipment supplier should describe recommended methods of the daily check before the start and after the end of each day's work and periodic inspections in the operation and maintenance manuals.

13.2 The equipment supplier should provide a list of consumable parts and materials, with their replacement intervals, maintenance methods, and part/material number in the manuals.

13.3 The equipment supplier should provide information on the specific tools and PPE necessary for said inspections and maintenance in the manuals.

14 Training Requirements

14.1 The equipment supplier should describe the training required for safe operations and maintenance in the operation and maintenance manuals.

15 Place of Supplier's Contact in Case of Emergency

15.1 The equipment supplier should indicate, in the operation and maintenance manuals, or as a separate attachment, whom to contact in case of emergency or equipment failure.

15.2 When the contact is changed, the equipment supplier should promptly notify the user in writing and inform the user of the new contact.

16 Laws and Regulations

NOTE: The contents of this section should be addressed in the terms and conditions of sale and/or other contractual agreements between the supplier and user. When the supplier recognizes the necessity based on the local condition or custom, the following information may be included in the operation and maintenance manuals:

16.1 *Relevant Administrative Laws and Regulations* — These may include, but not be limited to, laws and regulations relevant to installation, operation, maintenance, and decommissioning of the equipment.

16.1.1 The supplier may describe, in the manual, the laws and regulations of the user's jurisdiction relevant to operation, maintenance, and supervision of the system.

16.1.2 The supplier may describe the measure of support by the supplier for the implementation of laws and regulations after delivery of the equipment.

NOTE: The supplier and user should jointly investigate the laws and regulations of the jurisdiction where the equipment is to be used, and they should incorporate these requirements into the purchase specification. In addition, the supplier should describe the laws and regulations considered, and means of compliance implemented, during the development and production of the equipment.

16.2 *Issues Regarding Product Liability (PL)*

16.2.1 The supplier should inform the user of the following to ensure better mutual understanding of the issues regarding product liability for the equipment:

16.2.1.1 How a field retrofit is announced and implemented.

16.2.1.2 When the equipment manufacturer discontinues production of the equipment and what repair and maintenance services are available after discontinuation of production of the equipment.

16.2.1.3 The extent of responsibility when equipment of another manufacturer is added to the equipment on user's own judgment.

16.2.1.4 How parts should be handled by the user for the transport for repair.

16.2.1.5 The extent of responsibility for repair or maintenance work to be carried out by personnel dispatched by the supplier or the manufacturer. (The equipment supplier should describe, in the manual, the possibility of not being able to carry out servicing for reasons of safety and health care of the dispatched personnel, if the equipment user refuses to disclose the names and contents of processing materials being used and/or processing piping, for reasons of confidentiality or trade secret protection.)

16.2.1.6 The extent of responsibility on the part of the equipment supplier when a user transports, reuses, resells, or modifies the equipment for his or her own use.

16.2.1.7 The extent of responsibility with regard to the supplied parts and parts designed by the user.

16.2.1.8 The extent of responsibility of the equipment supplier when the user fails to observe the provisions and/or cautions given in the manuals.

17 Related Documents

17.1 *SEMI Document*

SEMI S1 — Safety Guideline for Visual Hazard Alerts

17.2 *Other Document*[3]

IEC 417 — Graphical Symbols for Use on Equipment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

3 International Electrotechnical Commission, 1 rue de Varembe, 1211, Geneva 20, Switzerland

SEMI S14-0200E
SAFETY GUIDELINES FOR FIRE RISK ASSESSMENT AND MITIGATION FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

These safety guidelines were technically approved by the Global Environmental Health and Safety Committee and are the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on September 3 and December 15, 1999. Initially available at www.semi.org February 2000; to be published February 2000.

E This document was modified in November 2000 to correct various errata. Changes were made to Section 7.7.5 and Note 21 (now Note 23).

1 Purpose

1.1 This document provides considerations to the manufacturers of semiconductor manufacturing equipment that will assist them in assessing and mitigating the risk to equipment and product associated with fire and combustion by-products.

1.2 Although these guidelines are written in the form of an assessment tool, they are intended for use throughout the design and development of semiconductor manufacturing equipment.

1.3 These guidelines may also be used by the users of such equipment and by other interested parties to assess and compare the described risks of various equipment designs or in the design and evaluation of ancillary equipment or modifications.

1.4 These guidelines are not intended to specify which techniques (e.g., selection of materials or detection systems) are to be used to mitigate fire risk. These guidelines do, however, recommend that the traditional risk management hierarchy of elimination, engineering controls, administrative controls, warning and work practices be followed.

1.5 The appropriate application of these guidelines will result in a report which identifies, analyzes and assesses residual fire risks.

2 Scope

2.1 These guidelines apply to equipment used to manufacture, measure, assemble, and test semiconductor products which is intended to be located in cleanrooms used for semiconductor manufacturing processes or areas within their recirculation airstream. They apply to all of the components of the equipment, as described herein.

NOTE 1: This document is not limited to the structural or large-area components of equipment.

2.2 This document applies to fire risks originating within the subject equipment that may result in damage to it, other equipment, products, or the facility.

2.3 This document identifies considerations for assessing the fire risk of semiconductor manufacturing equipment, means of categorizing the risks, and means of mitigating the risks.

2.4 These safety guidelines do not purport to address all of the safety issues associated with its use. It is the responsibility of the users of these safety guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 These guidelines do not establish acceptance criteria for residual risk.

3.2 This document recommends a hierarchy of approaches (e.g., elimination of a hazard is preferable to an engineering control) but neither prescribes which specific risk mitigation methods (e.g., change of material or elimination of an ignition source) are to be used nor ranks their relative merit.

3.3 These guidelines apply to the protection of property; they do not apply to the protection of personnel.

NOTE 2: Protection of personnel from fire risk is within the scope of SEMI S2.

3.4 This document applies to equipment in its scope when the equipment is used in the environment specified by the equipment supplier. Specifically, it does not apply to the behavior of equipment when it is subject to an external fire.

3.5 This document is not intended to be used to assess compliance with regulatory requirements, nor is it intended to be adopted as regulation.

3.6 Because of these limitations, it may be appropriate for purchasers of equipment to specify the applicable codes and standards and the acceptable level of residual risk.

NOTE 3: Applicable regional, and national codes, international regulations, and the equipment manufacturer's and user's requirements must also be considered. When a conflict exists, the regional and national codes take precedence.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E70 — Guide for Tool Accommodation Process

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S7 — Safety Guidelines for Environmental, Safety, and Health (ESH) Evaluation of Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

4.2 *NFPA Documents* [1]

National Fire Protection Association: NFPA 12 — Standard on Carbon Dioxide Fire Extinguishing Systems

National Fire Protection Association: NFPA 13 — Standard for the Installation of Sprinkler Systems

National Fire Protection Association: NFPA 72 — National Fire Alarm Code

National Fire Protection Association: NFPA 2001 — Standard on Clean Agent Fire Extinguishing Systems

4.3 *Factory Mutual Document* [2]

Factory Mutual Research Corp. Standard 4910 — Clean Room Materials Flammability Test Protocol

4.4 *Underwriters Laboratory Documents* [3]

Underwriters Laboratory Standard 94 — Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

Underwriters Laboratories Standard 746A — Polymeric Materials - Short Term Property Evaluations

Underwriters Laboratories Standard 746B — Polymeric Materials - Long Term Property Evaluations

Underwriters Laboratories Standard 746C — Polymeric Materials - Use in Electrical Equipment Evaluations

NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269

2 Factory Mutual Research Corp., 1151 Boston-Providence Turnpike, Norwood, MA 02062

3 Underwriters Laboratory, 333 Pfingsten Rd, Northbrook, IL 60062

5 Terminology

5.1 *abort switch* — a switch which, when activated, interrupts the activation sequence of a detection or suppression system.

5.2 *accredited testing laboratory* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards and recognized by a governmental or regulatory body.

5.3 *cleanroom* — a confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters (SEMI E70).

5.4 *combustible liquid* — a liquid that will burn and has a flash point at or above 37.8°C (100°F).

5.4.1 For the purpose of this guideline, a combustible liquid, when used by a system capable (under normal or single-fault conditions) of heating it above its flash point, is considered a flammable liquid.

5.5 *combustible material* — for the purpose of this document, a combustible material is any material which does not meet the definitions in this section for noncombustible materials.

NOTE 5: A list of criteria, guidelines and standards that may be used to evaluate the fire properties of materials is included in Appendix 2.

5.6 *flammable liquid* — a liquid having a flash point below 37.8°C (100°F).

5.7 *hazard* — a condition that is a prerequisite to a mishap.

5.8 *hazardous voltage* — unless otherwise defined by an appropriate international standard applicable to the equipment, voltages greater than 30 volts rms, 42.4 volts peak, 60 volts dc are defined in this document as hazardous voltage.

NOTE 6: The specified levels are based on normal conditions in a dry location environment.

5.9 *ignition energy* — sufficient energy to ignite a combustible material. The energy required depends on the form of the energy and the composition and form of the combustible material.

NOTE 7: The combustible material may be solid, liquid, or gas.

5.10 *likelihood* — the expected frequency with which a mishap will occur. Usually expressed as a rate (e.g., events per year, per product, per wafer processed).

5.11 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

5.12 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz).

5.13 *non-recycling deadman-type abort switch* — a type of abort switch that must be constantly held closed for the abort of the detection or suppression system. In addition, it does not restart or interrupt any time delay sequence for the detection or suppression system when it is activated.

5.14 *process chemicals* — solids, liquids, and gases used in the normal use of the equipment included in the scope of this document.

NOTE 8: Solids, liquids, and gases used in the maintenance procedures (e.g., isopropanol used as a cleaning agent) specified by the equipment supplier should be considered as well as those used in operation.

5.15 *pyrophoric material* — a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

5.16 *residual risk* — that risk which remains after engineering, administrative, and work practice controls have been implemented.

5.17 *risk* — the expected losses from a mishap, expressed in terms of severity and likelihood.

5.18 *safe shutdown condition* — a condition in which all hazardous energy sources are removed and hazardous production materials are removed or contained, unless this results in additional hazardous conditions.

5.19 *semiconductor manufacturing process* — those manufacturing steps which are part of the creation of active or passive electrical devices on a semiconducting wafer, including the deposition of passivation layers after final metallization, but excluding testing and dicing.

5.20 *severity* — the extent of the worst credible loss from a mishap caused by a specific hazard.

5.21 *supervisory alarm* — an alarm indicating a supervisory condition.

5.22 *supervisory condition* — a condition in which action or maintenance is needed to restore or continue proper function.

5.23 *trouble alarm* — an alarm indicating a trouble condition.

5.24 *trouble condition* — a condition in which there is a fault in a system, subsystem or component that may interfere with proper function.

6 Fire Risk Assessment

6.1 *Overview*

6.1.1 This section provides criteria for evaluation of the risks associated with several types of fire hazards.

6.1.2 For each identified hazard described in Section 6, the evaluator should analyze the contributing, causal, and mitigating factors. The evaluator should also review any assessment of the material, component, or equipment as a whole by an accredited testing laboratory.

6.1.3 The risk assessment should include both normal operation and the consequence of reasonably foreseeable, single-point failures within the equipment. It should not include exposure to fire or external ignition sources not within the intended use environment.

6.1.4 Certifications by an accredited testing laboratory of materials, components, or the equipment as a whole may be used in the fire risk assessment. However, such certifications are valid only to the extent that the conditions of use for the certification correlate to the conditions of use for the equipment whose fire risk is being assessed.

NOTE 9: For example, a personal computer certified to IEC 60950 might be incorporated into equipment for use as a controller. The material flammability requirements of IEC 60950 may or may not be sufficient for this use of the personal computer, depending upon its exposure to oxidizers and external sources of ignition when incorporated into the equipment. Also, the levels of smoke tolerable in the environment for which a general industry standard was written may exceed those tolerable in semiconductor manufacturing cleanrooms. Furthermore, if the equipment is intended to be used in a potentially explosive atmosphere, the certification to IEC 60950 would not sufficiently control its risk of being a source of ignition.

6.1.5 The consequences and the probability of fire from each identified hazard should be assessed and rated, as described in SEMI S10. See Appendix 1 for the criteria used for the assignments of Severity, Likelihood and Risk in this document.

6.1.5.1 The assigned Severity and Likelihood and resulting Risk category should be recorded as part of the analysis.

6.1.5.2 For those hazards for which the Risk depends on the conditions of use or use environment, the equipment supplier should make and state appropriate assumptions. If the equipment supplier is unable to make appropriate assumptions as to the Likelihood because it depends predominantly on factors in the users' sole control (e.g., adherence to specified procedures), the supplier should state that and provide an estimate of the Severity.

NOTE 10: The facilities requirements on which the risk assessment depends are to be specified by the equipment supplier.

6.1.6 For fire to occur, there must be a fuel, an oxidizer and a source of ignition. Elimination of any of these factors eliminates the risk of fire. Similarly, the Severity, Likelihood and Risk of a fire can be reduced by reducing one or more of these elements appropriately.

6.1.7 It is important to remember that there are often implicit oxidizers (e.g., room air) and sources of ignition (e.g., room temperature for a pyrophoric material).

6.1.8 The fire risk assessment should include the judgement of a qualified (as described in SEMI S7) party to determine the level of detail of the assessment. That party may group similar hazards for assessment and reporting.

NOTE 11: Such grouping could include, for example, all of the knobs and buttons of similar materials into one group, the heated surfaces into a second, and the several flammable liquids with similar properties into a third.

6.2 *Fuels*

6.2.1 Fuels include all those materials capable of reacting with an oxidizer in a fire. The risks of both the materials of which the equipment is constructed and the process chemicals used in it should be assessed.

6.2.2 *Materials of Construction*

6.2.2.1 The risk assessment should include all of the materials of construction, regardless of quantity or application.

NOTE 12: This includes small parts, such as knobs, buttons, electrical contactors**,** terminal strips, circuit boards, signal wire and power wiring as well as large components, modules (such as mini-environments) and subassemblies.

NOTE 13: Some of the smallest components can create a high risk, as in the potential for ignition by adiabatic compression of fluoropolymer seats in high pressure oxygen valves.

NOTE 14: The assessment can be simplified by grouping similar items together. Example 1: wiring that has the same type of insulation. Example 2: knobs, switches, handles and latches made from similar polymers. Identified groups should include their approximate total mass.

6.2.2.2 In assessing the risk, the evaluator should consider:

- the size of each component,
- the total quantity and distribution of similar components,
- the inherent properties of the material, such as ignitability, flame spread, heat of combustion, and byproducts (see Appendix 2 for guidance on evaluation of these properties),
- the exposure to oxidizers, and
- the exposure to ignition sources.

NOTE 15: The specification control of materials used in approved electrical components should also be considered. Approvals may allow for substitution of many materials with equivalent flammability ratings.

NOTE 16: The inherent properties of materials affect two types of risk within the equipment: flame spread risk and contamination risk (i.e., smoke damage from combustion byproducts). In the case of electrical and electronic components used in assemblies and equipment that are constructed and used in accordance with applicable standards (e.g., IEC 61010-1, IEC 60204-1), flame spread risk may be adequately controlled by the standard, and detailed assessment of the material properties of such components that affect flame spread may not be warranted. However, a significant contamination risk could still remain (e.g., a standard may allow a component mounted on a printed circuit board to fail and burn, as long as the burning remains local to the printed circuit board) and warrant a detailed assessment of related material properties of the components. The level of detail of the assessment may also be affected by the mitigation method chosen (see Section 7).

6.2.3 *Process Chemicals*

6.2.3.1 This portion of the risk assessment should include all of the process chemicals expected (based on the equipment supplier's recommended or baseline processes) to be used in the equipment. It should also include flammable and combustible wastes generated or collected within the equipment and fluids in the equipment which are required for its operation but which do not participate chemically in the process (e.g., vacuum pump oil).

6.2.3.2 In assessing the risk, the evaluator should consider:

- the quantity, concentration, state, temperature, and pressure of each chemical in each container,
- for those chemicals supplied automatically by the facility, the available flow, pressure, and total quantity,
- the aggregate supplies and distribution of similar chemicals,

- the inherent properties of the chemicals, such as flammable limits, flash point, autoignition temperature, heat of combustion, and the products of combustion and decomposition (see the Material Safety Data Sheets for guidance on evaluation of these properties),
- the exposure to oxidizers, and
- the exposure to ignition sources.

NOTE 17: Chemicals with similar fire properties may be considered together for the purpose of this assessment.

6.3 *Sources of Ignition*

6.3.1 Sources of ignition can be broadly divided into those within the equipment and those external to it.

6.3.2 *Internal Sources*

6.3.2.1 Potential electrical ignition sources:

- devices or conditions that in normal operation can generate ignition energy (e.g., heaters, static electricity, lasers);
- devices or conditions that in reasonably foreseeable assembly, use and/or wear conditions can generate ignition energy (e.g., power connectors, terminal strips);
- devices that in reasonably foreseeable single point failure modes can generate ignition energy (e.g., transformers, electronic components); and
- short circuits.

6.3.2.2 Potential chemical ignition sources:

- exothermic process chemical reactions,
- exothermic reactions from inadvertent mixing of process chemicals,
- exothermic reactions between process chemicals and materials of construction, and
- release of pyrophoric or air-reactive chemicals from processing or maintenance.

6.3.2.3 Sudden changes in process conditions:

- rapid (sometimes called “adiabatic”) compression of gas mixtures, and
- rapid increases in temperature.

6.3.2.4 Mechanical friction

6.3.3 *External Sources*

6.3.3.1 External sources include expected and foreseen conditions of the equipment’s use. As these are factors normally outside the control of the equipment supplier, their risks are difficult to assess. They are outside the scope of this document.

6.4 *Oxidizers*

6.4.1 The most common oxidizer is air, which is present within and around most semiconductor manufacturing equipment. Unless specific measures are taken to exclude air (e.g., inert pressurizing of an electrical enclosure), it should be assumed to be available in infinite supply.

6.4.2 It is possible that some materials of construction will act as oxidizers or will yield oxidizers when subjected to heat.

6.4.3 Several common process chemicals (e.g., oxygen and hydrogen peroxide) are oxidizers. Their risks should be assessed in a manner similar to that described above for process chemicals that are fuels.

6.5 *Reporting*

6.5.1 Although these guidelines are intended for use throughout the design and development process, it is not the intent of these guidelines that the equipment supplier should make all of the information recorded during the development of the equipment available to others. The equipment supplier should document the fire risk assessment and mitigation in three forms: internal records, a final fire risk assessment report, and a summary report.

6.5.2 Relevant analyses, assessments, and design decisions should be documented in the equipment supplier's internal records. These records need not, however, be made available to other parties.

6.5.3 *Final Fire Risk Assessment Report*

6.5.3.1 This report should contain an itemized list of the residual risks identified in reviewing the final design, considering the risks described in the preceding subsections or otherwise known or foreseen by the evaluator. Only those risks meeting the criteria in Appendix 1 should be included. For each identified residual risk, the report should:

- explain the mechanism of loss or damage;
- identify aggravating or necessary contributing factors;
- identify the mitigating factors;
- state the assigned Severity for each type of loss and present the rationale for its assignment. A “type” is a column in Table A1-1, e.g., “Equipment Physical Damage”;
- state the assigned Likelihood and present the rationale for its assignment; and

- state the resulting Risk category.

NOTE 18: Criteria for risks may be found in Appendix 1, Sections A1-2.5 through A1-2.8.

6.5.3.2 This report should also describe the fire risk mitigation techniques included in the equipment design.

6.5.3.3 The final fire risk assessment report should be prepared or reviewed by a party qualified, as described in SEMI S7, to do such work.

NOTE 19: This party may be an employee of the equipment supplier or may be a third party.

6.5.3.4 When this guideline is being used as part of a SEMI S2 equipment evaluation, the manufacturer should make the final fire risk assessment report available to the party performing the SEMI S2 evaluation.

6.5.3.5 The equipment supplier may make the final fire risk assessment report available to other parties.

6.5.4 *Summary Report*

6.5.4.1 The summary report should be prepared from the final fire risk assessment report and contain:

- a list of the residual fire risks and their ratings, and
- brief descriptions of the fire risk mitigation techniques included in the equipment.

6.5.4.2 The equipment supplier should provide the summary report to users of the equipment and may provide it to other parties.

7 Fire Risk Mitigation

7.1 *Overview*

7.1.1 This section describes several means of mitigating the risks of fire. It first describes ways in which the equipment and its use can be designed to minimize the risks. It also describes the use of detection and suppression systems.

NOTE 20: The description of a mitigation technique in this section is not intended to imply that such technique should be used for each system. Therefore, the decision to include a particular mitigation technique, such as detection or suppression, should be based on the assessed risk.

7.1.2 In mitigating risks, the general hierarchy of elimination, engineering controls, administrative controls, warning and work practices should be followed. Following this hierarchy comprises using techniques which are highest in it if several techniques are equally applicable. Design and use constraints, as well as relative cost, however, may justify using techniques from generally less preferable categories. In any case, the residual risk should be assessed and reported.

7.2 *Fuels*

7.2.1 *Materials of Construction*

7.2.1.1 The lowest fire risk is posed by noncombustible materials of construction. Available noncombustible materials are not, however, suitable or desirable for all applications within semiconductor manufacturing equipment.

NOTE 21: The properties necessary to perform the intended function of system components and the properties necessary to satisfy component-level standards may also restrict the use of noncombustible materials.

7.2.1.2 When materials which are combustible are chosen, the fire risk may be mitigated by:

- selecting those materials with the least undesirable properties as described above; and
- minimizing the total mass and distribution of such materials.

7.2.2 *Process Chemicals*

7.2.2.1 It may be possible to reduce the fire risk by changing the quantities and species of the chemicals used in the intended processes.

7.2.3 The fire risks of combustible materials of construction and flammable and combustible process chemicals may also be reduced by limiting those factors described in Section 6.

7.3 *Sources of Ignition*

7.3.1 Potential sources of ignition should be considered in conjunction with the fuels and oxidizers they might ignite.

7.3.2 Risks due to sources of ignition can be mitigated by:

- limiting their number,
- limiting their energy, and
- separating them from combustible materials of construction and from flammable and combustible process chemicals. Separation may be by distance or by barriers.

7.4 *Oxidizers*

7.4.1 Reducing the quantities or pressures of oxidizing process chemicals may reduce the fire risk.

7.4.2 The fire risks of oxidizing process chemicals may also be reduced by limiting those factors described in Section 6.

7.5 *Exhaust, Enclosures and Barriers*

7.5.1 Mechanical exhaust may reduce the risk of damage to the facility, other equipment, or other portions of the same equipment by limiting the spread of combustion and decomposition products. The mechanical exhaust could be provided by the equipment or by the facility.

7.5.2 Enclosures and barriers within the equipment may reduce the fire risk by separating the fuels and oxidizers from each other and from potential sources of ignition.

7.5.3 These design features may also limit the spread of fire, reducing both the loss of equipment and the emission of combustion and decomposition products.

7.6 *Fire Detection, Alarm and Control*

7.6.1 The fire detection system, which includes detectors, alarms and their associated controls, should be accepted for the application by an accredited testing laboratory and installed in accordance with the terms of that acceptance. The components should be suitable for the environments in which they are to be used.

7.6.2 The fire detection, alarm and control system should be installed in accordance with an appropriate national or international standard.

NOTE 22: NFPA 72 is such a standard.

7.6.3 The fire detection system should be capable of interfacing with the facility's alarm system. It may be preferable for the equipment supplier to specify the location and performance of detectors, but not provide them, so that the user may better integrate the detection in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

NOTE 23: Such devices, used solely for internal equipment protection, as opposed to fire risk mitigation, may not require compliance with fire alarm standard or regulations or Subsections 7.6 and 7.7. Some local jurisdictions, however, require that all smoke detectors be connected to building systems.

7.6.4 Activation of the fire detection alarm should be annunciated audibly and visually at the equipment.

7.6.5 Activation of the trouble or supervisory alarm should:

- notify the operator;
- allow the completion of processing of the wafers in the equipment; and
- preclude starting processing of additional wafers until the trouble or supervisory condition is cleared.

NOTE 24: Some local jurisdictions require that such alarms signal the building/facility fire alarm systems.

7.6.6 The fire detection system should be capable of operating at all times, including when equipment is inoperable or in maintenance modes. For the purpose of this section, "inoperable" includes the equipment state after an EMO is activated, and after the equipment has had its hazardous energies isolated (i.e., has been "locked out"). Therefore, the detection system must not require hazardous voltages (e.g., line alternating current) to operate. A battery back-up power supply, capable of sustaining the detection system for 24 hours, should be included.

NOTE 25: The requirements for battery back-up vary among jurisdictions.

EXCEPTION: Maintenance of the fire detection system.

7.6.7 Activation of the fire detection system should shut down the equipment within the shortest time period which allows for safe equipment shutdown.

EXCEPTION: A non-recycling, deadman type abort switch is acceptable on detection systems which are used primarily for equipment shutdown, but not on those used for activation of a suppression system.

EXCEPTION: Activation of the fire detection system should not remove power from fire and appropriate safety systems.

7.7 *Fire Suppression*

7.7.1 The selection of the suppression agent should consider the effectiveness of the agent, amount and location of storage, method of delivery, and potential for environmental impact, both within the facility and to the community.

7.7.2 The fire suppression agent should be accepted for the application by an Accredited Testing Laboratory.

7.7.3 The fire suppression system should be installed in accordance with an appropriate national or international standard.

NOTE 26: NFPA 12, NFPA 13, and NFPA 2001 are such standards.

7.7.4 Activation of the fire suppression system should be annunciated audibly and visually at the equipment. This is not intended to be separate from the annunciation for detection.

7.7.5 The fire suppression system should be capable of operating at all times, including when equipment is inoperable and during equipment maintenance. For the purpose of this section, "inoperable" includes the equipment state after an EMO is activated. Some suppression systems comprise sources of hazardous energy which must be capable of being isolated to protect personnel.

EXCEPTION: Allowances can be made to provide for the deactivation of an automatic discharge of the suppression system when in the maintenance mode. Such deactivation switches should be supervised, i.e., if the suppression system is deactivated, there should be an indication to the user and the resumption of production in the tool should be precluded.

NOTE 27: Hazardous energies associated with the fire suppression system (e.g., release of a compressed suppression agent) may be isolated, using an energy isolation procedure, during equipment maintenance.

NOTE 28: The permissibility of deactivation of the suppression system varies among jurisdictions.

7.7.6 A battery back-up power supply, capable of sustaining the suppression system for 24 hours, should be included.

NOTE 29: The requirements for battery back-up vary among jurisdictions.

7.7.7 The fire suppression system should be capable of interfacing with the facility's alarm system.

7.7.8 It may be preferable for the equipment supplier to specify the location and performance of suppression system components, but not provide them, so that the user may better integrate the suppression in the equipment with that in the facility. This alternative should be negotiated explicitly with the user.

7.7.9 The fire suppression system should be capable of manual activation, which should shut down the equipment.

EXCEPTION: Activation of the fire suppression system should not remove power from fire and safety systems.

7.7.10 The entire fire protection system should be tested on a representative sample of the equipment. The test procedure should include a suppression agent discharge test, unless precluded for health or environmental reasons.

7.7.10.1 This test may be performed at the equipment supplier's or other, similar facility, but should be performed under conditions that adequately duplicate any factors (e.g., equipment exhaust) that may reduce the effectiveness of the suppression.

7.8 *Maintenance of Fire Detection and Suppression Systems*

7.8.1 The equipment supplier should provide detailed maintenance and testing procedures for the fire systems provided with each piece of equipment. These procedures should include testing frequency, as well as details of special equipment required for testing.

7.8.2 The maintenance testing procedure should include testing the facility interface and verifying that all the equipment fire protection systems are functional.

7.8.3 The detection and suppression systems should be designed so that preventive maintenance of components does not degrade their performance, e.g., by resulting in the displacement of sensors.

8 Related Documents

8.1 *SEMI Standard*

SEMI S11 — Environmental, Safety, and Health Guidelines for Semiconductor Manufacturing Equipment Minienvironments

8.2 *NFPA Documents*

National Fire Protection Association: NFPA 70 — *National Electric Code (NEC)*

National Fire Protection Association: NFPA 318 — *Standard for Protection of Cleanrooms*

National Fire Protection Association: NFPA 496 — *Purged and Pressurized Enclosures for Electrical Equipment*

National Fire Protection Association: NFPA 497 — *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

8.3 *Other Documents*

Building Officials and Code Administrators (BOCA)[4], NBC: National Building Code

Factory Mutual System Data Sheet 7-7, Semiconductor Fabrication Facilities

International Conference of Building Officials (ICBO)[5], UBC: Uniform Building Code

International Fire Code Institute[6], UFC: Uniform Fire Code

International SEMATECH[7], Process Compatibility Parameters for Wet Bench Plastic Materials (Technology Transfer # 98123623A)

Southern Building Code Congress International (SBCCI)[8], SBC: Standard Building: Code

4 Building Officials & Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60477
5 ICBO, 5360 South Workman Mill Rd., Whittier, CA 90601
6 International Fire Code Institute, 5360 South Workman Mill Rd., Whittier, CA 90601
7 SEMATECH Technology Transfer, 2706 Montopolis Drive, Austin, TX 78741 (The document is available, in .pdf format, at www.sematech.org/public/docubase/summary/3623aeng.htm.)
8 SBCCI, 900 Montclair Rd, Birmingham, AL 35213-1206

APPENDIX 1
RISK ASSESSMENT CRITERIA

NOTE: The material in this appendix is an official part of SEMI S14 and was approved by full letter ballot procedures on September 3, 1999 by the North American Regional Standards Committee.

A1-1 The risk assessment should be performed for each identified fire hazard using the method provided in SEMI S10 and the following definitions of Likelihood and Severity Groupings and Risk Categories.

NOTE A1-1: Unlike SEMI S10, in which the tables are provided only as examples, this document defines the Severity, Likelihood, and Risk to be used herein.

A1-2 *Severity*

A1-2.1 The Severity Groupings are given in Table A1-1.

Table A1-1 Severity Groupings

Severity Group	*Equipment Physical Damage*	*Equipment Loss of Use*	*Facility Loss of Use (Minimum Times)*	*Environmental and Real Property Contamination*
1 Catastrophic	Loss of entire piece of equipment	One year	One week	Lasting facility or environmental impact
2 Severe	Loss of major subsystem	One month	One day	Temporary facility or environmental impact
3 Moderate	Loss of minor subsystem	One week	One shift	Limited to the equipment, but requiring more than routine cleanup
4 Minor	Non-serious equipment loss	One day	Less than one shift	Requiring routine cleanup but not external reporting

A1-2.2 The Severity should be assigned for each of the columns for which information is available.

A1-2.3 The most severe Group assigned should be used in determining the risk.

A1-2.4 Each of the Severities should be reported.

A1-2.5 Contamination is by release of materials that were used in the equipment or by combustion or thermal degradation byproducts.

A1-2.6 To be included in the assessment, a foreseen occurrence must be unplanned and include a loss.

A1-2.7 Losses exclude the performance of the design function of protective devices, such as fuses.

A1-2.8 The scope of the assessment in this document is limited to the consequences of fire.

A1-3 *Likelihood*

A1-3.1 The Likelihood Groupings are given in Table A1-2.

Table A1-2 Likelihood Groupings

Likelihood Group	*Expected Frequency (% of Systems per Year)*
A Frequent	More than 1%
B Likely	More than 0.2% but not more than 1%
C Possible	More than 0.04%, but not more than 0.2%
D Rare	More than 0.02%, but not more than 0.04%
E Unlikely	Not more than 0.02%

A1-3.2 “System” refers to the equipment as configured and offered by the supplier.

A1-4 *Risk*

A1-4.1 The Risk should be calculated based on the Severity and Likelihood assigned above and the Risk Categories defined in Table A1-3.

Table A1-3 Risk Categories

	Likelihood				
Severity	*A*	*B*	*C*	*D*	*E*
1	Critical	Critical	High	Medium	Low
2	Critical	High	Medium	Low	Low
3	High	Medium	Low	Low	Slight
4	Medium	Low	Low	Slight	Slight

A1-4.2 The Risks are to be reported in total for the equipment as offered for sale. (e.g., if the equipment being evaluated is a cluster tool, the risks should be reported by the system integrator for the assembled tool, not the individual modules.)

NOTE A1-2: Although the risks for cluster tools should be reported for the assembled tool, the modules are not necessarily contiguous and this may bear on the risk.

NOTE A1-3: The Risks of components or subsystems may be increased or decreased by their integration into the equipment being assessed.

APPENDIX 2
ASSESSMENT OF THE FIRE PROPERTIES OF MATERIALS

NOTE: The material in this appendix is an official part of SEMI S14 and was approved by full letter ballot procedures on September 3, 1999 by the North American Regional Standards Committee.

A2-1 This Appendix describes the qualitative criteria for evaluating some of the relevant fire properties of materials. It also provides references to several standards which may be used in these evaluations. Each of the standards listed defines test methods and provides quantitative criteria for consideration.

A2-2 *Preferable Materials:*

A2-2.1 Require higher heat fluxes to be ignited.

A2-2.2 Once ignited may burn locally in the ignition area, but they will not propagate a fire beyond the ignition zone.

A2-2.3 Generate lower quantities of smoke and corrosive products or generate smoke and corrosive products that are less damaging.

A2-3 The following standards provide means of assessing the fire properties of materials. Each of these standards specifies the types of materials and uses of materials to which it applies and the fire properties that its application assesses. Therefore, each must not be used outside of the scope for which it was written. It may be appropriate to use different standards for assessing the materials used in different components in the equipment.

NOTE A2-1: There are many other standard methods available for characterizing the fire properties of materials and it is not the intent of the document to exclude methods other than those listed here, as long as the methods are applied appropriately.

A2-3.1 Factory Mutual Research Corp. Standard 4910, *Clean Room Materials Flammability Test Protocol*

A2-3.2 Underwriters Laboratory Standard 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

A2-3.3 Underwriters Laboratories Standard 746A, *Polymeric Materials - Short Term Property Evaluations*

A2-3.4 Underwriters Laboratories Standard 746B, *Polymeric Materials - Long Term Property Evaluations*

A2-3.5 Underwriters Laboratories Standard 746C, *Polymeric Materials - Use in Electrical Equipment Evaluations*

RELATED INFORMATION 1
TEST PROTOCOL FOR WET BENCH MATERIALS PROCESS COMPATIBILITY

NOTE: This related information is not an official part of SEMI S14 and is not intended to modify or supersede the official guideline. It has been derived from the cited work. Publication is authorized by vote of the responsible committee. Determination of the suitability of this material is solely the responsibility of the user.

R1-1 SEMATECH has published the results of a study on testing of polymeric materials for use in wet benches. The Abstract and citation are provided as Related Information 1 to SEMI S14, Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment as the responsible committee believes the information in this document may be of use in identifying materials that are appropriate for the described applications and consistent with appropriate management of fire risks.

R1-2 The report, SEMATECH Document ID #: 98123623A-ENG, entitled Process Compatibility Parameters for Wet Bench Plastic Materials, was written by Archibald Tewarson, Avtar S. Jassal, Latif Ahmed, and Mark Camenzind and published 30 December 1998.

R1-3 SEMATECH retains the copyright to the document, but has granted SEMI permission to include the Abstract and citation in this Safety Guideline. The complete document (90 pages) is available from SEMATECH's web site:

http://www.sematech.org/public/docubase/abstract/tech-5.htm.

R1-4 *Abstract*

R1-4.1 This report presents a test protocol of accepted analytical procedures to determine the process compatibility parameters for commonly used wet bench plastic materials (PP, FRPP, and PVC) and proposed plastic materials (CPVC, ECTFE, and PVDF) that may be used for wet bench construction. Three industry standard test methods were used to determine the outgassing, leaching, and extraction parameters, defined in combination as the process compatibility parameters. To supplement them, the presence of critical elements at the surface of the materials and the condition of the surface were examined before and after exposure to water and chemicals. Changes in the mass of plastic materials as a result of outgassing, leaching, and extraction were also used to supplement the parameters. The report includes details of the test procedures, data analysis, surface topography of the plastic materials, before and after exposure to water and chemicals, and discussion of the results.

SEMI S15-0200
SAFETY GUIDELINE FOR THE EVALUATION OF TOXIC AND FLAMMABLE GAS DETECTION SYSTEMS

This safety guideline was technically approved by the Global Environmental, Health, and Safety Committee and is the direct responsibility of the North American Environmental, Health, and Safety Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on www.semi.org January 2000; to be published February 2000.

1 Purpose

1.1 This guideline provides considerations for the evaluation of fixed gas detection systems used to monitor for safety of plant personnel, product and materials, the local environment and community. It provides an evaluation guide and reference sources appropriate to facilities and equipment where toxic and flammable gases are used and stored in gaseous or liquid form.

2 Scope

2.1 This guideline applies to toxic and flammable gas detection and addresses performance characteristics of gas detection systems.

2.2 It also describes several technologies available for detection of such gases and their performance characteristics.

2.3 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this safety guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guideline does not include applicable fire and safety code regulations.

3.2 The gases or liquids which should be monitored are not listed.

3.3 This guideline does not suggest the appropriate levels of detectability. Such levels may be determined by reviewing accepted government and non-governmental agency standards, such as those promulgated by ACGIH, USEPA, and USOSHA.

3.4 Process related issues and corrective actions in the case of gas leaks are not discussed in this guideline.

3.5 This guideline makes no recommendation of any specific technology or manufacturer, nor does it provide installation and operation recommendations.

3.6 This guideline provides neither a comprehensive list of all gases, nor recommended areas for monitoring of toxic and flammable gases.

3.7 Not all known analytical methodologies for monitoring of toxic and flammable gases are described in this guideline.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ACGIH* — American Conference of Governmental Industrial Hygienists

5.1.2 *EMI* — Electromagnetic interference

5.1.3 *EU* — European Union

5.1.4 *RFI* — Radio frequency interference

5.1.5 *USEPA* — United States Environmental Protection Agency

5.1.6 *USOSHA* — United States Occupational Safety and Health Administration

5.2 *Definitions*

5.2.1 *challenge gas* — a gas/chemical used to create a response in the gas detection system.

5.2.2 *conditioning* — the necessity to expose a gas/chemical sensor to the target gas/chemical to enable more rapid detection of that gas/chemical.

5.2.3 *fail-safe relay* — an alarm relay that is "fail-safe" returns to a safe operating condition when power is lost.

5.2.4 *filter lag* — relative to gas/chemical sensors, the time delay in the detection of a challenge gas/chemical due to the incorporation of a chemical, mechanical or electrical filter.

5.2.5 *latching* — relative to discrete alarm contacts, the alarm relay will not reset when the alarm condition ceases to exist. The alarm must be manually or remotely reset by operator interface.

5.2.6 *poisoning* — the interaction of a gas/chemical other than the target gas/chemical that temporarily or permanently disables the sensor from reliably detecting the presence of the target gas/chemical, or otherwise renders the device inoperable.

5.2.7 *span drift* — the percentage change in a known calibration point or span of a sensor or gas detection system over time.

5.2.8 *surrogate gas/chemical* — a substitute gas/chemical that is more benign than the gas/chemical it is replacing. This concept is used in the calibration of gas/chemical sensors when a highly toxic or corrosive challenge gas is undesirable. The surrogate gas/chemical will simulate the interaction with the sensor of the gas/chemical for which it is substituted.

5.2.9 *target gas* — the specific gas intended to be detected.

5.2.10 *zero drift* — the percentage change in the zero point or baseline of a sensor or gas detection system over time.

6 Performance Characteristics

6.1 The performance characteristics (the test results of which should be reliable and repeatable) are as identified below. These are factors one should consider in the evaluation of a gas detection system (from the point of detection through the output signal) for a specific application. A form for compiling a comparison table is provided as Appendix 1.

6.2 *Accuracy* — What is the stated accuracy of the system? Over what time period will that accuracy be valid (before calibration of the gas detection system is necessary)?

6.3 *Alarms* — What is the range for setting the alarms for each gas detection point? Are the alarms user-adjustable for set and reset time delays, latching or non-latching, normally open or closed, fail-safe or non fail-safe? How many alarm levels are available per detection point? Is there a fail alarm and what conditions will activate that alarm? Are the alarms dedicated to each detection point or are they common to a group of monitoring points?

6.4 *Calibration*

6.4.1 Is calibration required? If so, how often? How is it accomplished? Can it be done away from the point of detection or must it be done on site? What equipment is needed to perform the calibration? Can a surrogate gas be used for calibration? Can the calibration be accomplished by one individual? Is calibration accuracy affected by humidity?

6.4.2 During start-up, how much time must elapse before the gas detection system can be calibrated?

6.5 *Certifications and Classifications* — Does the gas detection system have the necessary performance or safety approvals for the specific application and location (e.g., UL, CE, SEMI S2)?

6.6 *Communications (serial)* — What types of serial communication are available from the gas detection system? What communication protocols are supported? Is it one-way or two-way communication?

6.7 *Conditioning Requirements* — Is the monitoring equipment always ready and able to detect a gas leak or must it be preconditioned on a periodic (regular) basis to ensure response times are achieved?

6.8 *Cost of Ownership* — What is the initial cost for the equipment and installation? What is the long-term cost of ownership of the system (consumables, calibration equipment, and labor)? What is the cost (hardware and installation) to expand the system (additional points of detection) and/or change the gas configuration?

6.9 *Data Archiving* — Are data documentation or data archiving system available as a part of the gas detection system?

6.10 *Diagnostics* — What system diagnostics are included? Can electrical or mechanical failures within the system be detected? Will a fault alarm be activated? Are diagnostics communicated over analog and/or digital outputs? Are faults archived by the gas detection system? Will an inoperative system be identified through a self-activated alarm (fail-safe)? Will the system alert the user that a calibration is required? Are communication outputs supervised?

6.11 *Display* — What local displays are available on the gas detection systems? Where is the display located? Does the display show gas concentration level with engineering units and identify active alarms with signal lights? Are other diagnostic and control functions displayed when activated? Is the display easy to read from a distance?

6.12 *Drift* — What is the zero and span drift over 30, 60, 90, and 180 days? Does the gas detection system compensate for drift?

6.13 *Environmental Conditions* — What are the temperature and relative humidity specifications for the gas detection system for normal operation as well as for storage of consumable parts? Could environmental changes such as quick humidity transients or temperature changes cause the gas detection system to spike or drift into an alarm condition?

6.14 *Equipment Failure* — Is the gas detection system capable of reporting all single point failures that disable detection? What failure mode disables both detection of gas and reporting failure?

6.15 *Expansion Flexibility* — Is the gas detection system capable of expansion to accommodate additional detection points? How easy is it to integrate into the user's system (hardware, installation, programming, etc.)?

6.16 *Extraction Detection Systems*

6.16.1 *Sampling Distance* — What is the maximum sampling distance for the gas detection system? Will all the gas entering the sample line at the point of detection reach the central monitor? What is the sample loss due to the challenge gas absorbing onto the sample tubing walls?

6.16.2 *Sample Cycle Time* — How frequently, if multiple points are sampled, is the same detection point surveyed by the extraction detection system, at the desired alarm level?

6.16.3 *Sample Contamination* — What, if any, is the potential for contamination of the sample line tubing and manifolding equipment when multiple gases are monitored within the same extraction system? What combination of gases should be avoided due to chemical interaction on wetted materials?

6.17 *Filter Lag* — Does the gas detection system use any mechanical, chemical or electronic filters (for cross sensitivity, particles, etc.) which could slow the sampling response? If so, what lag time is expected for each gas type?

6.18 *Installation - Wiring Configuration* — How many wires are required per detection point? Can the system be wired in a highway configuration (bus, ring, star, etc.)? Are special barriers or grounds required to ensure no earth loop faults exist?

6.19 *Isolation* — Does the gas detection system require any special electrical isolation or grounding?

6.20 *Limits of Detection*

6.20.1 *Lowest Alarm Level* — What is the lowest alarm level setting for the gas detection system which will not activate due to sensor drift or insufficient signal to noise ratio?

6.20.2 *Limit of Detection* — What is the absolute lowest value that a sensor can detect, for each gas?

6.20.3 *Upper Limit of Detection* — What is the highest level of gas that can be quantified reliably by the gas detection system?

6.21 *Linearity* — What is the linearity over the full measuring range of the gas detection system output?

6.22 *Maintenance Interval* — What is the manufacturer's recommended maintenance frequency? What is involved to perform this maintenance? What items potentially require maintenance or periodic replacement (pumps, sensors, tapes, etc.)?

6.23 *Other Utilities* — In addition to electrical power, what other utilities are required to operate the system (e.g., compressed air, hydrogen, oxygen, etc.)?

6.24 *Outputs* — Does the gas detection system have analog, digital, and relay outputs? How many are available per system?

6.25 *Physical Size* — What is the physical size of the gas detection system for both the detection head (or sampling point) and the control systems or central monitor, including the required floor space?

6.26 *Poisoning* — Is the gas detection system susceptible to gases or vapors which would reduce the performance (ability to detect gas) of the system or render it contaminated and inoperative?

6.27 *Position Effect (Attitude Sensitivity)* — Is there a specific orientation of the sensor, detector, or sampling point required for the gas detection system to function optimally?

6.28 *Power Outage* — When system power is lost, what happens to the gas detection system? Once power is restored, what is the time lag before the system is fully functional?

6.29 *Power Requirements* — What are the power requirements (i.e., AC, DC, voltage, and amperage) of the system? What is the power draw of the total gas detection system?

6.30 *Recovery Time* — What is the amount of time it takes the gas detection system, once exposed to challenge gas, to recover to 10% of the original target gas concentration value?

6.31 *Repeatability* — What is the ability of the gas detection system to produce the same detection results within a certain percentage, when repeatedly exposed to the same gas concentration?

6.32 *Reliability* — What is the expected life of the various portions of the gas detection system (including the main unit, detection sensors, and consumables)?

6.33 *Replacement/Replenishment* — Does the system contain consumable items? How frequently must they be replaced? Can they be replaced by the user or is a factory person required for servicing?

6.34 *Resolution* — What is the level of resolution for changes in gas concentration? That is, to what extent can the gas detection system detect a changing challenge gas concentration? Is this user selectable?

6.35 *Response Time* — From the point of release of the challenge gas, how long does it take the gas detection system to reach 90% of the challenge gas concentration?

6.36 *RFI/EMI Susceptibility* — Does the gas detection system meet the requirements for CE Marking for RFI/EMI immunity and per SEMI E33?

6.37 *Self-Test* — Does the gas detection system have an automatic or user initiated self-test routine? How is it accomplished? What is the interval for the self-test? Can the operator override the self-test? Is the self-test just an electrical check or is gas actually generated? Is the generated gas the target gas?

6.38 *Sensor Exchange* — Do sensors require on-site calibration only or can they be factory calibrated? Are additional adjustments or programming operations required when replacing a sensor? Is there a warm-up period for the sensors before they are functional (for calibration purposes)? If so, how long?

6.39 *Sensor Specificity* — Are gas specific sensors available for every gas that must be monitored? What are the known interferences to the gas detection system that could cause a false alarm or mask a real alarm?

6.40 *Service & Support* — What is the manufacturer's capabilities to service and support their equipment once it is has been installed? Does the manufacturer have a 24 hour/7 day service support program in place?

6.41 *Spare Parts Availability* — What is the availability of spare parts from the manufacturer? Are emergency spare parts always available?

6.42 *Special Handling Considerations* — Are there items that require special handling, storage, or disposal? If so, what are the considerations?

6.43 *Storage and Shelf-Life Requirements* — What are the storage (environmental) requirements for the consumable items (e.g., electrochemical sensors and paper tapes)? Do these items have a shelf-life and if so how long?

6.44 *System Check* — Does the gas detection system have a system check facility? If so, is this done on a continuous or interval basis? What is the interval?

6.45 *System Expandability & Flexibility* — Is the gas detection system universal, in the sense that the user can change from one gas sensor to another by only exchanging the sensing elements? How much modification is required? Can this be done in the field by the user or must the detection system be returned to the manufacturer for service?

6.46 *Wake Up Requirement* — Does the gas monitor's sensor require periodic doses of challenge gas or electrical charges to ensure the sensor will continually operate? If so, what is the interval required for each gas type or electrical challenge?

6.47 *Warm Up Period* — Upon installation or sensor replacement, how long does it take for the gas detection system's sensor to stabilize after power is applied?

6.48 *Warranty* — What is the warranty period of the gas detection system?

7 Gas Detection Technologies Available

7.1 Several gas detection technologies are described in the following paragraphs. As additional technologies become available, they should be considered, using the performance characteristics described above.

7.2 *Acoustic (Hydrogen Gas Measurement Only)* — Piezoelectric crystals send and receive pulsed ultrasound. These sound waves travel through two tubes of air, one tube filled with sample air, the other with reference air. The returned pulses are counted, normalized for temperature, and compared. Through mathematical calculations the result represents the concentration of hydrogen gas present in percent by volume or percent LEL.

7.3 *Catalytic* — Catalytic gas sensors measure flammable gases by comparison of the change in resistance across a Wheatstone bridge. The sensor contains two resistive elements (beads), one active which increases its resistance when exposed to gas, and the other which maintains a constant resistance. The sensor output is then conditioned by the gas detection system and generates a current output proportional to the gas concentration in percent of lower explosive limit (LEL).

7.4 *Electrochemical* — Electrochemical gas sensors measure toxic gases and contain components (electrodes and electrolyte) designed to react when exposed to a specific toxic gas or a family of gases; the reaction generates a current which is measured and conditioned by the gas detection system and represents an output which is proportional to the concentration of gas, measured in parts per million (ppm) or parts per billion (ppb).

7.5 *FTIR* — Fourier-transform infrared (FTIR) gas detection systems use spectrophotometric techniques to detect and measure gas. Infrared light is passed through a gas sample, and the resulting absorbency spectrum is analyzed to determine its constituents. A current output is generated which is proportional to the concentration of gas present.

7.6 *Infrared* — Monochromatic infrared gas detection systems measure the absorption of radiation (light) by a gas sample. The absorption is translated into a current output which is proportional to concentration. Each gas has a unique absorption wavelength which the system must be tuned to make an accurate measurement.

7.7 *Ion Detection* — Ion detection is useful for detecting SiO_2 particles which are created by the burning of certain gases such as silane, TEOS and TEOA. SiO_2 "smoke" is created when these gases are burned, and this can be detected with an ionization detector chamber, which operates similarly to a smoke detector. SiO_2 particles entering the chamber create a signal that is calibrated to represent the presence of a known concentration of the target gas. A gas detection system using this method is typically used in a sample draw system and can be used either by itself or in conjunction with a pyrolyzer to condition (burn) the gas entering the detection head.

7.8 *Molecular Emission Spectrometer* — Sample air is injected into a reaction chamber. In the reaction chamber, a flame, fed by hydrogen and sample air, is the activating reaction. When a sample gas enters the flame, reactions of the target gas result in additional light emissions. The resulting light passes through two optical filters and is converted to electronic signals in a dual photomultiplier tube. The signals are combined to produce a linear, quantitative output.

7.9 *Paper Tape* — Paper tape systems use the color change of a chemically impregnated tape to detect toxic gases. The tape changes color when exposed to a challenge gas; the color change is then detected by a photocell, analyzed, and converted into a concentration value (ppm or ppb).

7.10 *Solid State* — One type of solid state sensor is made of a metal oxide (typically tin-oxide) material that changes resistance in response to the presence of a toxic gas; the gas detection system measures this resistance change and converts it into a concentration value. Thin film semiconductor sensors absorb the target gas onto the semiconductor, resulting in a transfer of electrons which causes a measured change in the resistance of the semiconductor and reported as a ppm or ppb concentration.

8 Related Documents

8.1 *SEMI Documents*

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

8.2 American Conference of Governmental Industrial Hygienists (ACGIH)[1] — *Threshold Limit Values for Chemical Substances in the Work Environment*

8.3 *Uniform Fire Code*[2]

UFC Article 51 — Semiconductor Fabrication Facilities

UFC Article 80 — Hazardous Materials

8.4 *National Fire Protection Association*[3]

NFPA 49 — Hazardous Chemical Data

NFPA 70 — National Electric Code

NFPA 72 — National Fire Alarm Code

NFPA 318 — Protection of Cleanrooms

8.5 *International Fire Code*[4]

8.6 Santa Clara, California Uniform Fire Code,[5] *Amendments 1998 Edition*

8.7 *Southern Building Code Congress International*[6]

Standard Building Code — Chapter 22: Hazardous Materials, 1994 Edition

1 American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadows Drive, Cincinnati, OH 45240-1634
2 Published by International Conference of Building Officials and Western Fire Chiefs Association, 5360 South Workman Mill Road, Whitter, CA 90601
3 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269
4 International Fire Code Institute, 9300 Jollyville Road, Suite 105, Austin, TX 78759
5 Santa Clara Fire Department, 777 Benton Street, Santa Clara, CA 95050
6 Southern Building Code Congress International (SBCCI), 900 Montclair Road, Birmingham, AL 35213

8.8 *US Government*

Occupational Safety and Health Organization (OSHA)[7] *29 CFR - Sections 1910.119 and 1910.1000*

US Environmental Protection Agency (EPA)[8] *40 CFR 68.13, Subpart C*

7 US Government Printing Office, Washington, D.C. 20402
8 Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402

APPENDIX 1
TABLE FOR COMPARISON OF PERFORMANCE CHARACTERISTICS

NOTE: The material in this appendix is an official part of SEMI S15 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

Table A1-1

Performance	*Manufacturer/Technology*				
Characteristics	*A.*	*B.*	*C.*	*D*	*E.*
Accuracy					
Alarms					
Calibration					
Certifications and Classifications					
Communications (Serial)					
Conditioning Requirements					
Cost of Ownership					
Data Archiving					
Diagnostics					
Display					
Drift					
Environmental Conditions					
Equipment Failure					
Expansion Flexibility					
Extractive Systems: Sampling Distance Sample Cycle Time Sample Contamination					
Filter Lag					
Installation (Wiring Configuration)					
Isolation					
Limits of Detection: Lowest Alarm Level Limit of Detection Upper limit of Detection					
Linearity					
Maintenance Interval					
Other Utilities					
Outputs					
Physical Size					
Poisoning					
Position Effect (Attitude Sensitivity)					
Power Outage					
Power Requirements					
Recovery Time					
Repeatability					

Performance	*Manufacturer/Technology*				
Characteristics	*A.*	*B.*	*C.*	*D*	*E.*
Reliability					
Replacement/ Replenishment					
Resolution					
Response Time					
RFI/EMI Susceptibility					
Self-test					
Sensor Exchange					
Sensor Specificity					
Service and Support					
Spare Parts Availability					
Special Handling Considerations					
Storage and Shelf-life Requirements					
System Check					
System Flexibility					
Wake Up Requirements					
Warm Up Period					
Warranty					

NOTICE: SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of this guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. This guideline is subject to change without notice.

The user's attention is called to the possibility that compliance with this guideline may require use of copyrighted material or of an invention covered by patent rights. By publication of this guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this guideline. Users of this guideline are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI S16-0600
ENVIRONMENTAL, HEALTH AND SAFETY GUIDELINES FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT DISPOSAL

These guidelines were technically approved by the Global Environmental, Health and Safety Committee and are the direct responsibility of the Japanese Environmental, Health and Safety Committee. Current edition approved by the Japanese Regional Standards Committee on April 28, 2000. Initially available on www.semi.org June 2000; to be published June 2000.

1 Purpose

1.1 This document provides guidelines to minimize hazards to workers and impacts to the environment during equipment and component disposal.

2 Scope

2.1 These guidelines apply to the disposal of semiconductor manufacturing equipment, its materials and components and equipment design consideration to facilitate disposal.

2.2 These guidelines are intended to be voluntary best practices for this industry. These guidelines apply to disposal parties, equipment designers, equipment manufacturers, equipment suppliers and equipment owners. The information should be provided to the disposal party by the equipment owner prior to contract negotiations.

2.3 These safety guidelines do not purport to address all of the safety issues associated with its use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitation

3.1 These guidelines are not intended to supersede the applicable codes and regulations of the region where the equipment is disposed.

3.2 Section 6 in these guidelines should be applied not to existing models and subsystems but to newly designed models and subsystems after publication of these guidelines.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI S1 — Safety Guidelines for Visual Hazard Alerts

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

SEMI S12 — Environment, Health and Safety Guidelines for Equipment Decontamination

SEMI S13 — Safety Guidelines for Operation and Maintenance Manuals Used with Semiconductor Manufacturing Equipment

4.2 *ISO Documents*[1]

ISO11469 — Plastics; Generic Identification and Marking of Plastic Products

ISO14001 — 1996 Environment Management Systems, Specifications with Guideline for Use

4.3 *CEN*[2] / *CENELEC*[3] *Document*

EN1050 — Safety of Machinery—Principles for Risk Assessment

4.4 *OSHA Document*[4]

29 CFR 1910. 1200 — Labor

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 Terminology defined in SEMI S1, S2, S12, and S13 should be referred to except if otherwise specified below.

5.1.1 *decontaminate* — to remove all known hazards from equipment, including chemical, physical, electrical, to a level that will not pose a threat or harm to humans or the environment. This level may be set by each country, state and local regulations or industry practice.

5.1.2 *decontamination* — the process required to remove hazards to an acceptable level of risk (see Section 5.1).

1 International Standards Organization, 1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland.

2 European Committee for Standardization, 36, rue de Stassart, B-1050 Brussels, Belgium

3 European Committee for Electrotechnical Standardization, Rue de Stassart, 35, B-1050 Brussels, Belgium

4 US Government Printing Office, Washington, D.C. 20402

5.1.3 *disposal* — to dispose of equipment and/or component/material based on legislation or industry/regional standard practices.

5.1.4 *disposal party* — a party who disposes of equipment and its components.

5.1.5 *EMAS* — Eco-Management and Audit Scheme which came into force in July, 1993 and operational in the EU Member States in April, 1995.

5.1.6 *equipment owner* — a party who surrenders equipment to a disposal party or disposals of potentially contaminated materials or components.

5.1.7 *hazardous energy* — energy with the potential to affect human health or the environment.

5.1.8 *hazardous material* — materials including chemicals (solid, liquid or gas) that pose a threat to the environment or human health as defined by international, each country and local regulations.

5.1.9 *Material Safety Data Sheet (MSDS)* — written or printed material concerning chemical elements and compounds, including hazardous materials, prepared in accordance with applicable standards such as the International Labor Convention (ILC) No. 170, provisions of USA government regulation 29 CFR 1910,1200, or Canadian WHMIS (Workplace Hazardous Material Information System).

6 Equipment Design for Disposal

6.1 The equipment design should comply with environment section of SEMI S2.

6.2 The equipment design should consider the following regarding disassembly prior to waste treatment:

6.2.1 The equipment design should encourage refurbishing, reuse or recycling.

6.2.1.1 The equipment design should enable disassembly down to the component or subassembly size to facilitate refurbishing or recycling.

6.2.1.2 The equipment design should provide for the ability to appropriately decontaminate all components.

6.2.2 The equipment design should consider enabling all hazardous energies in/on the equipment to be reduced to a non-hazardous level upon equipment disassembly. If a hazardous energy still remains, see Section 7 of this document.

6.2.2.1 This includes the ability to release or remove any trapped materials.

6.2.3 The equipment design should avoid mixing of incompatible chemicals upon equipment disassembly. If this is not feasible, an appropriate hazard alert label based on SEMI S1 should be affixed at each applicable position (see Section 7 of this document).

6.2.4 The equipment design should prevent release of hazardous materials to the environment upon equipment disassembly. If this is not feasible, see Section 7 of this document.

6.3 Chemicals used to maintain the equipment or chemicals used in the baseline process should comply with following sub-sections.

6.3.1 Materials for which special disposal procedures are required, such as batteries (lithium, ni-cad, mercury and silver), mercury and fluorescent lamps, and other potentially hazardous material should be accompanied by material safety data sheet (MSDS) or other document describing necessary information for disposal and instructions for safe handling and disposal.

6.3.2 Additional information on proper disposal of materials, designed into the equipment with the intent of being contaminated but disposable, but not hazardous themselves until contaminated, such as absorbents and adsorbents, should also be provided with disposal procedures which minimize environmental impact and personnel effect.

6.3.3 Equipment containing ionizing radiation sources subject to licensing by federal or local agencies should be constructed so as to allow the easy removal of ionizing radiation sources. Disposal of ionizing radiation sources must be in compliance with applicable each country, state and local regulations.

6.4 Construction materials and components of equipment should be selected by considering their environmental impacts based on the supplier's environment management program. Environment management programs should be constructed based on ISO14001, EMAS or other environment management system.

6.5 The hazardous and primary construction materials of equipment should be provided in document such as operation and/or maintenance manuals based on the supplier's environment management program.

6.5.1 Recycling category identification should be molded as part of the material or labeled on the material. This requirement should only be applied to non-metallic materials which are capable of being molded or labeled.

6.5.2 Identification and marking of plastics should comply with ISO11469 unless local regulations differ. This requirement should be applied to only materials which are able to be molded or labeled.

7 Information Provided by the Supplier

7.1 The supplier should provide the equipment owner with operation and/or maintenance manuals or similar documents drafted according to SEMI S13, which include the following information on the materials used in equipment, subassemblies and components upon the delivery of the equipment:

NOTE 2: The supplier may gather appropriate information at the time of design in conjunction with a disposal party.

7.1.1 Primary materials of appropriate disassemble-able unit in consideration with reuse, refurbishing, recycling and disposal of each component such as, chemicals (e.g., mercury), metals (e.g., stainless steel, steel, or copper), plastics (e.g., ABS - i.e., Acrylonitorile Butadiene Styrene plastics - or non-combustible ABS), glass, or ceramics.

7.1.2 Describe opportunities for reuse, refurbishing or material recycling of every component or recyclable subassembly. If there are no opportunities, a waste disposal method should be recommended based on assumption of usage with baseline process by the supplier. (e.g., ABS can be recycled after decontamination as class X plastic and mercury requires reclaim or hazardous waste disposal.)

7.1.3 *Disassembly Procedure*

7.1.3.1 A disassembly procedure should be recommended by the supplier to the level required to facilitate complete decontamination and material separation for waste disposal.

7.1.3.2 The disassembly procedure should include procedures to remove all hazardous energies.

7.1.3.3 The disassembly procedure should prevent the mixture of incompatible chemicals. If it is not feasible, administrative control procedures should be included.

7.1.3.4 If the chemicals/materials described from Sections 7.1.3.4.1 to 7.1.3.4.4 are hazardous, the disassembly procedure should prevent the release of them to the environment. The chemicals include:

7.1.3.4.1 Chemicals used to maintain the equipment (e.g., lubricant and coolant).

7.1.3.4.2 Other potentially hazardous items which are parts of the equipment, such as capacitors, batteries, lamps or mercury, which require special disposal procedures.

7.1.3.4.3 Chemicals used in the baseline process of the equipment manufacturer.

7.1.3.4.4 Anticipated byproducts of the baseline process.

NOTE 3: Byproducts are changeable according to several kinds of conditions such as exhaust diameter/length/volume, chamber volume/pressure/configuration, maintenance method/cycle, and evacuation frequency.

7.1.3.4.5 The disassembly procedure should address any hazards of ionizing radiation sources, if they are present, and address safe removal and storage procedures.

7.1.4 Disposal procedure should be a safer way based on the result of risk assessment such as SEMI S10 or EN 1050 and job hazard analysis.

8 Information Provided by the Equipment Owner

8.1 Prior to disposal, the equipment owner should provide the following information to the disposal party in order to reflect all residual waste hazards. This information should be provided to any party handling the waste regardless of intention to dispose or recycle the equipment unless the component in question is fully decontaminated.

8.1.1 Relevant information provided by the supplier per Section 7 of this document.

8.1.2 Chemicals used in the equipment owner specific process other than the baseline process and its byproducts.

8.1.3 Decontamination and waste disposal method for parts contaminated by an equipment owner specific process other than the baseline process.

8.1.4 The minimal information of necessary personal protective equipment (PPE) based on the equipment usage history.

NOTE 4: PPE and necessary training are to be specified by the employer of those personnel to be protected.

8.1.5 The details of the decontamination procedure and any remaining chemicals and their locations after the equipment owner has completed initial decontamination of the equipment.

9 Selection of the Disposal Party

9.1 The disposal party must comply with regional/national codes and regulations related to the receipt, transfer and disposal of equipment.

NOTE 5: A specially controlled industrial waste disposal license as well as a specially controlled waste collection and transfer license may be typically required by the relevant country's government.

9.2 The incident and compliance record of the waste disposal party should be considered at the time when a selection of the disposal party is made.

10 Equipment Disposal Procedure

10.1 The possibility of refurbishing the entire piece of equipment should be considered before disassembly and disposal is selected.

10.1.1 When refurbishing of the entire equipment is chosen, only the disposal parts which are not able to be refurbished at the time should be decontaminated or considered for disposal. This results in a significant reduction in waste.

10.2 *Equipment Decontamination and Packaging for Transfer* — Equipment being transferred should comply with SEMI S12 and all applicable hazardous materials shipping regulations. If the equipment has to be transported prior to decontamination, it should be ensured, that no contaminants may be released (e.g., by appropriate packaging).

10.3 *Disassembly and Decontamination* — The equipment owner or disposal party should follow all local regulations regarding disassembly and disposal.

10.3.1 If there is an equipment owner specific process, the specifics of that process and its hazards should be provided to the disposal party by the equipment owner.

10.4 *Material Separation* — Only materials that cannot be refurbished, recycled or reused should be categorized for other disposal methods (e.g., incineration and landfill) under this disposal assessment procedure.

10.4.1 First decontaminate any contaminated material which is capable of further decontamination.

10.4.2 Discard any materials incapable of decontamination by appropriate contaminated waste disposal categories or process (e.g., incineration, hazardous landfill, etc.).

10.4.3 Further separate materials into reusable components (e.g., pumps, motors, electronics, etc.).

10.4.3.1 This includes any components with a potential for refurbishing.

10.4.4 Separate recyclable materials by categories (e.g., metals, class of plastics, etc.).

10.4.5 Separate into reclamation categories (e.g., mercury recovery from lamps, lead recovery from batteries, etc.).

10.5 The equipment owner should confirm that the disposal party follows the procedures required by this document through checking manifest and/or implementing practical inspection periodically as well as applicable regional codes and regulations.

10.6 Ionizing radiation sources, if present, should be disposed of in accordance with each applicable country, state and local regulations. All applicable licensing and reporting requirements should be met.

11 Documentation and Records

11.1 Documentation should be prepared and maintained by the equipment owner according to applicable codes and regulations for the region or locality where disposal occurs.

11.2 Documentation showing final disposition of each class of material should be returned to the equipment owner by the disposal party.

SEMI S17-0701
SAFETY GUIDELINE FOR UNMANNED TRANSPORT VEHICLE (UTV) SYSTEMS

This safety guideline was technically approved by the Global Environmental Health and Safety Committee and is the direct responsibility of the Japanese Environmental Health and Safety Committee. Current edition approved by the Japanese Regional Standards Committee on February 1, 2001. Initially available at www.semi.org April 2001; to be published July 2001.

NOTICE: Paragraphs entitled "NOTE:" are not an official part of this document and are not intended to modify or supersede the official guideline.

1 Purpose

1.1 These guidelines are intended as a set of environmental, safety, and health considerations for unmanned transport vehicle (UTV) systems. UTV systems are used to automate the movement of material within semiconductor factories. Unmanned transport vehicle systems include both floor-traveling vehicle systems and space-traveling vehicle systems.

2 Scope

2.1 This guideline applies to UTV systems used in semiconductor manufacturing.

2.2 This guideline addresses both floor-traveling and space-traveling UTV systems. Floor-traveling vehicle systems include automatic guided vehicle (AGV) systems and rail guided vehicle (RGV) systems. Space-traveling vehicle systems include interbay overhead transport vehicle systems and intrabay overhead hoist transport vehicle (OHT) systems.

2.3 Evaluations for conformance to this document should include all equipment that is provided by the UTV system supplier including separate items such as rails, control panels, power panels, and any other type of equipment necessary for operation of the unmanned transport vehicles.

2.4 This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.5 This document contains the following sections:

- Purpose
- Scope
- Limitations
- Referenced Standards
- Terminology
- Equipment Evaluation
- Clearances and Interfaces
- Emergency Shutdown
- Manual Operation
- Vehicle Travel
- Material Protection
- Load/Unload Operation
- Hazard Indicators
- Hazardous Materials
- Related Documents

3 Limitations

3.1 This safety guideline may have only limited application to vehicles without on-board power (direct or induced) such as primary-grounded linear–motor-driven overhead transport vehicle systems used for interbay transport. Determinations of applicability should be made by section when evaluating such systems.

3.2 This safety guideline does not address rail-guided or robotic mechanisms included as part of semiconductor processing equipment. This type of equipment should be evaluated as part of the processing equipment per SEMI S2.

3.3 Person Guided Vehicles (PGVs) are not unmanned vehicles, therefore PGVs are not addressed by this standard.

3.4 This document does not supersede international, national or local codes, regulations and laws, which may impose separate requirements for assessing the safety of installations.

NOTE 1: Users should provide information to UTV suppliers about regulations for the location of use.

4 Referenced Standards

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.1 *SEMI Standards*

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

4.2 *ANSI Standard*[1]

ANSI/RIA R15.06 — Industrial Robots and Robot Systems - Safety Requirements

4.3 *CENELEC Standards*[1]

EN775 — Manipulating Industrial Robots – Safety

4.4 *ISO Standards*[2]

ISO 10218 — Manipulating Industrial Robots – Safety

5 Terminology

5.1 *automated operation* — system operation under full pre-programmed control of the computer controller.

5.2 *automatic guided vehicle (AGV)* — a floor based vehicle, with or without robotic manipulators, used for transporting loads and operating without the need for assistance by factory personnel. AGVs travel without mechanical guidance.

5.3 *bumper* — a shock absorber for a UTV. A bumper is typically equipped with a contact switch or sensor on it. And if the bumper switch or sensor is activated, the UTV will stop immediately.

5.4 *EMO* — an actuator (e.g., button) which, when activated, places the equipment into a safe shutdown condition, without generating any additional hazard to personnel or the facility.

5.5 *E-Stop* — emergency stop feature provided to stop all moving parts but not necessarily isolating or controlling all energy sources.

5.6 *end user customer* — as related to UTVs, the company operating the factory in which the UTVs are installed.

5.7 *fault-tolerant* — designed so that a reasonably foreseeable single point failure does not result in an unsafe condition.

5.8 *floor-traveling vehicle* — a vehicle that automatically travels on the factory floor to a specified station where a load/unload operation is performed automatically or manually. Floor-traveling vehicles include automatic guided vehicles (AGV) and rail guided vehicles (RGV).

5.9 *hoist* — the assembly on a space-traveling vehicle that performs the load/unload operation by transferring a load [e.g., carrier(s), pod(s)] to and from an overhead vehicle.

5.10 *interbay transport* — movement of loads [e.g., carrier(s), cassette(s), reticle(s)] between functional work areas or bays.

5.11 *intrabay transport* — movement of loads [e.g., carrier(s), cassette(s), reticle pod(s)] within a functional work area or bay.

5.12 *load* — load is the object to be transported by UTV. Load includes a carrier (cassette, box, pod, etc.) and its contents.

5.13 *load/unload operation* — the action necessary to move a load [e.g., carrier(s), cassette(s) reticle pod(s)] to and from a vehicle. This operation may involve hoisting, manual, or robotic manipulation to transfer loads between a vehicle and semiconductor manufacturing equipment (such as process equipment or stockers). See Figure 1.

5.14 *manual operation* — defined as any control outside of automated operation.

5.15 *overhead hoist transport (OHT)* — a rail guided vehicle and hoist used to transport material above the factory floor over the heads of factory personnel.

5.16 *rail guided vehicle (RGV)* — a floor-based vehicle, with or without robotic manipulators, used to transport loads and operating on a guide rail without the need for assistance by factory personnel.

5.17 *space-traveling vehicle* — a vehicle that automatically travels through space, such as in the region just below a factory ceiling, to a specified station where a load/unload operation is performed automatically or manually. Space-traveling vehicles include interbay overhead transport vehicles and intrabay overhead hoist transport vehicles (OHT).

1 American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036

2 International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland

5.18 *station* — the destination point where an unmanned transport vehicle is programmed to stop for load/unload operation (also known as a control point).

5.19 *travel* — the automated motion of a vehicle along a rail or programmed path from one station to another station. Travel does not include load/unload operation. See Figure 1.

5.20 *unmanned transport vehicle (UTV)* — a vehicle used to automate the movement of production material within semiconductor factories. There are two types of UTVs, floor-traveling vehicles and space-traveling vehicles.

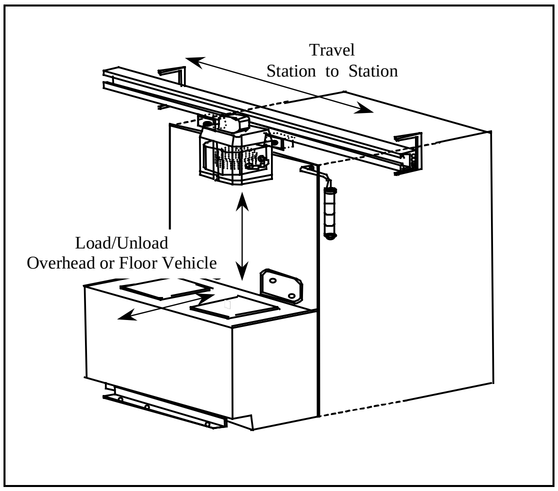


Figure 1
Delineation of Travel vs. Load/Unload

6 Equipment Evaluation

6.1 *Equipment Evaluation for both Floor-Traveling and Space-Traveling Vehicles* — All UTV equipment should be evaluated against the following referenced provisions.

6.2 All UTV equipment should be evaluated against appropriate sections of SEMI S2 for environmental, safety, and health considerations.

6.2.1 Evaluations to the provisions in the following sections of SEMI S2 are applicable to declare conformance to this document.

a) Electrical Design

b) Emergency Shutdown

c) Automated material handlers (This Automated material handlers section only applies to the robotics portion of UTV equipment, when provided.)

d) Hazard Warning Labels

e) Seismic Protection

f) Documents provided to User

6.2.2 At the discretion of the evaluator, additional provisions in SEMI S2 may be considered for evaluation based on the functionality of the UTV equipment.

6.3 All UTV equipment should be evaluated against SEMI S8 for ergonomic considerations.

6.4 All UTV equipment should be evaluated against the applicable Electro Magnetic Compatibility (EMC) regulations of the proposed installation site.

6.5 In addition to the provisions referenced in Section 6.1, UTV equipment should also be evaluated to the provisions contained in the following sections of this document.

7 Clearances and Interfaces

7.1 *Body Shape of both Floor-Traveling and Space-Traveling Vehicles* — The body of a UTV should be free of any dangerous parts such as sharp edges and protrusions. The UTV body surface should have a smooth finish.

7.2 *Minimum Clearance for Floor-Traveling Vehicles* — Where passageways are used for emergency egress, they should be provided on at least one side of the UTV. International, national or local codes, regulations, and laws should be used to determine passageway width.

7.3 *Minimum Clearance for Space-Traveling Vehicles* — The lowest part of the space-traveling vehicle, including the load, should maintain a minimum clearance of 2135 mm (7 feet) above the walking floor.

NOTE 3: Some end user customers may request a higher minimum clearance, or a minimum clearance between the space-traveling vehicle and the top of other equipment, to accommodate clearances specified by SEMI E15.1.

7.4 *Interfaces with Building Structures for both Floor-Traveling and Space-Traveling Vehicles* — UTV suppliers should provide for optional vehicle interfaces with building structures like doors, elevators, and walls.

7.4.1 If UTVs are required to operate in conjunction with building structures, such as automatic doors or elevators, UTVs should be capable of communicating with the facility to assure safe door opening/closing.

7.4.2 If it is necessary for a UTV to travel through a building firewall, the firewall pass through should be specified and/or designed to maintain the fire rating of the wall in the event of a fire.

8 Emergency Shutdown

8.1 *Emergency Shutdown for both Space-Traveling and Floor-Traveling Vehicles* — In addition to the emergency shutdown provisions of SEMI S2, UTV equipment should also conform to the following provisions.

8.1.1 The UTV should be equipped with an emergency off (EMO) circuit that, when activated, immediately stops the operation and motion of the UTV, including both travel and load/unload operation. The EMO circuit should be activated whenever the following actions occurs:

a) An EMO button on the UTV is pressed.

b) An EMO at a fixed floor location is pressed.

NOTE 4: See Section 9.2 for handheld remote control.

8.1.2 Once an EMO circuit has been activated, the UTV should not move under its own power until the cause of the emergency condition has been resolved and the system has been reset by a human operation. The system should not reset or restart automatically.

8.2 *Position of EMO Buttons on Floor-Traveling Vehicles* — Structure-mounted EMO buttons should be located for easy accessibility by factory personnel.

8.2.1 Vehicle-mounted EMO Buttons should be accessible and visible from all sides of the vehicle, typically on the four-corners of a floor-traveling vehicle.

8.3 *Position of EMO Buttons for Space-Traveling Vehicle Systems* — EMO buttons should be located for easy accessibility by factory personnel, for example:

- Near control panels or operator terminals including handheld vehicle remote controls.
- Near process equipment load ports or stations.
- On walls or other fixed locations in the factory area where space-traveling vehicles operate.

NOTE 5: Some end user customers may request EMO buttons included on the space-traveling vehicle.

8.3.1 Since space-traveling vehicle EMO buttons are typically remote from the vehicles, space-traveling systems should provide a method of determining the location of the activated EMO button. This will ensure that the emergency condition can be identified and resolved prior to resetting the system per Section 8.1.2.

9 Manual Operation

9.1 *Manual Movement of both Space Traveling and Floor-Traveling Vehicles* — When the EMO is activated, the UTV should be capable of brake release to allow for release of a potentially trapped person.

9.1.1 The UTV should be equipped with a manual movement function that permits a human operator to maneuver the vehicle in the event of a problem. In the event of a problem, manual movement of all vehicle functions including travel and load/unload should be allowed.

9.2 *Manual/Remote Operation of both Space-Traveling and Floor-Traveling Vehicles* — Except for EMO and E-Stop, any control of a vehicle outside of automated operation should be exclusive. Other devices should not override vehicle control or cause movement of more than one vehicle at a time.

EXCEPTION: Those controls that do not cause motion.

9.2.1 Manual control of a vehicle motion that could present a hazard if control is lost should be controlled with an enabling type switch, such that movement is enabled only when a switch is continuously held (pressed) by an operator.

9.2.1.1 Handheld remote controls should have an E-Stop or EMO function to allow operators to stop movement that could cause risk to themselves or others. If remote control is wireless, this function should not be marked or labeled as an EMO.

9.2.1.2 During handheld remote control operation, the UTV should stop any vehicle motion that could create a hazard if power or the communication signal is lost.

10 Vehicle Travel

10.1 *Collision Avoidance for both Space-Traveling and Floor-Traveling Vehicles* — UTVs should provide for protection of persons in the same traveling space from injury. Damage to property or equipment from traveling vehicles should also be prevented.

10.1.1 The UTV system supplier should provide documentation specifying safe practices for working within traveling space of the UTVs, to include documented administrative procedures necessary to work safely while performing maintenance on or near operating UTV systems.

10.1.2 UTVs should be equipped with non-contact approach sensing system so those vehicles do not inadvertently contact people or other obstacles during the traveling motion of the UTV. Non-contact approach sensing systems should consist of either electromechanical (preferred) or solid-state devices and components and be designed to be fault-tolerant.

10.1.2.1 If an overhead vehicle is provided with a fault-tolerant contact sensing system (such as a bumper switch), as primary safety protection for people, the circuitry of the secondary non-contact system is not limited to electromechanical or solid state devices and components.

10.1.2.2 Where solid-state devices and components are used in an approach sensing system circuit, the system and relevant parts of the system should be evaluated for suitability for use. Abnormal conditions such as overvoltage, undervoltage, power supply interruption, transient overvoltage, ramp voltage, electromagnetic susceptibility, electrostatic discharge, thermal cycling, humidity, dust, vibration, and jarring should be considered.

EXCEPTION: When the severity of a reasonably foreseeable mishap is deemed to be Minor per SEMI S10, a software based control may be considered suitable.

10.1.2.3 Upon request by the user customer, suppliers should provide a test piece or set of test pieces (appropriate to the sensor device provided) along with procedures for testing and calibration.

10.1.3 When a UTV detects a vehicle or obstacle, the UTV should decelerate and stop automatically before it touches that vehicle or obstacle. If the non-contact approach sensing device should be disabled (for example because the UTV is negotiating a sharp turn), the UTV should decelerate and issue a warning (see Hazard Alarms and Displays section of this document) to indicate that the sensing device has been disabled.

10.1.4 In an area where multiple UTVs are operating, the capability to prevent the collision of one vehicle with another should be provided and to satisfy Section 10.1.3, should consider the following conditions:

a) The distance between a given vehicle and the vehicle that follows it.

b) The timing at which one stream of vehicles merges with another.

c) The timing at which a vehicle branches out from a stream of vehicles to pass another vehicle moving toward it.

d) The distance that separates two vehicles when they pass each other.

10.2 *Collision Detection for Floor-Traveling Vehicles* — In addition to Section 10.1, floor-traveling vehicles should also be equipped with a contact sensing device (such as a bumper switch) capable of detecting collision in the direction in which motion can create a hazard.

10.2.1 The bumpers should have a shape and structure that does not pose a risk to personnel or to objects around the floor-traveling vehicle.

10.2.2 The bumpers should be equal to or larger than the width of the floor-traveling vehicle body, as measured perpendicular to the direction of its traveling motion.

10.2.3 The maximum allowable distance between a bumper and the floor is 15 mm (0.6 inch).

EXCEPTION: If this provision cannot be maintained, (such as when the floor-traveling vehicle enters an elevator, or changes in floor height) the distance should be explicitly stated in the operation manuals (and the specifications) as an alert or warning notice to appropriate personnel.

10.2.4 If an obstacle contacts a bumper, the floor-traveling vehicle should be able to stop within the bumper stroke, irrespective of the speed at which the vehicle is traveling. If this provision cannot be met for technical reasons, the floor-traveling vehicle supplier should clearly indicate the maximum speed at which the vehicle can stop within the bumper stroke.

10.2.5 There should not be any device that disables the functionality of the bumper switch or sensor on floor-traveling vehicles.

10.2.6 If a bumper switch or sensor has been activated by contact, a floor-traveling vehicle should not restart until the system has been reset by a human operation.

NOTE 6: Since space-traveling vehicles travel in dedicated space above the heads of factory personnel, criteria for space-traveling vehicle bumpers are not included.

10.3 *Protective Zones for Space-Traveling Vehicles* — Written administrative procedures for creating a protective zone around personnel, required to work overhead in the path of space-traveling vehicles, should be included in documentation provided by the UTV system supplier.

NOTE 7: Implementation of these administrative procedures is the responsibility of the end user customer.

10.4 *Travel Speed of Floor-Traveling Vehicles* — Floor-traveling vehicles, intended for use in areas where there are both operating vehicles and personnel present, should be equipped with a variable speed-setting mechanism.

10.4.1 The variable speed settings designed for use in areas with both operating vehicles and personnel should not exceed 60 meters/minute (196 feet/minute). Any variable speed settings exceeding 60 meters/minute (196 feet/minute) should be reserved for use in dedicated and unmanned areas for which personnel safety can be assured.

10.4.2 The variable speed setting mechanism of a floor-traveling vehicle should be designed so that only authorized personnel, following access control procedures, can change the vehicle's speed setting.

NOTE 8: Criteria for traveling speeds of space-traveling vehicles are not included in this sub-section.

11 Material Protection

11.1 *Material Protection for both Floor Traveling and Space-Traveling Vehicles* — UTVs should provide for protection of the load when the UTV is traveling and during load/unload operations until safe transfer has been confirmed. UTV's should have an appropriate communication interface (For example SEMI standards such as SEMI E23 or SEMI E84). The UTV system supplier should document the exact method of confirmation.

11.1.1 UTVs should be designed so a single point of failure of the UTV system does not allow a load to fall.

11.1.2 Vehicles should be designed to prevent any load/unload movement when in traveling mode.

11.1.3 UTV load holding mechanisms should have load-shift prevention mechanism (such as stoppers), so that if the vehicle stops suddenly, the load is securely held in place.

11.2 *Material Protection for Floor-Traveling Vehicles* — In addition to the load protection provisions in Section 11.1, the following should also be provided on floor-traveling vehicles.

11.2.1 The floor-traveling vehicle should be designed to prevent loads from being placed on the vehicle so that the load overhangs any edge (length or width) of the vehicle.

11.3 *Material Protection for Space-Traveling Vehicles* — In addition to the load protection provisions in Section 11.1, the following should also be provided on space-traveling vehicles:

11.3.1 If secondary protection is required to meet Section 11.1.2 or to prevent loads from falling, covers or shields should be provided along rails to protect personnel from injury from falling loads.

11.3.2 Inadvertent lowering or uncontrolled drops of the vehicles' hoist mechanisms or loads should also be prevented.

12 Load/Unload Operation

12.1 *Protection from Load/Unload Motion of both Floor-Traveling and Space-Traveling Vehicles* — UTVs should have protection functions during load/unload operation to insure safety of the vehicle, the load and the equipment, until load/unload is completed.

12.1.1 Safety of personnel entering the load/unload area should be provided by a method agreed upon by the UTV supplier and the user.

12.1.2 UTVs should have an appropriate communication interface in order to provide the following functions. Examples for such interfaces are SEMI E84 or E23.

- confirm safe transfer of a load
- prevent transfer of loads prior to load port readiness
- notify affected factory personnel of abnormal load/unload conditions
- prevent transfer of loads when equipment is in manual delivery mode (PGV mode)
- prevent transfer of loads when equipment is at risk.

12.1.3 The UTV system supplier should provide to the end user customer documentation to ensure the UTV system interfaces properly with manufacturing equipment shields (if required), communications protocols, or other method necessary to prevent transfer of loads when equipment is at risk.

12.2 *Protection from Load/Unload Motion of Floor-Traveling Vehicles* — In addition to the load/unload provisions in Section 12.1, the following should also be provided on floor-traveling vehicles:

12.2.1 Load/unload mechanisms (transfer robots) on floor-based vehicles should be isolated or shielded as necessary to restrict contact with factory personnel. Measures should also be taken to prevent inadvertent motion of load/unload mechanisms.

12.2.2 If robotic manipulators are used on floor-traveling vehicles for load/unload operations, the robotic manipulator should meet requirements of the appropriate international or national standard (e.g., ISO 10218, EN775, or ANSI/RIA 15.06). If there are deviations from these general industry standards because of unique semiconductor applications, these deviations should be documented by the evaluator and assigned a risk factor according to a risk assessment.

13 Hazard Indicators

NOTE 9: The integrated design of any hazard indicator system or other safety system requires a coordinated effort among the UTV system supplier, the process equipment supplier, and the end user customer. The following are the minimum hazard indicators to be designed into UTV system equipment.

13.1 *Hazard Alarms and Lamps for both Floor-Traveling and Space-Traveling Vehicles* — The following indicators should be provided on all UTVs, but should be able to be configured to be compatible with the overall factory design for safety.

13.1.1 UTV suppliers should provide documentation of available configurations.

13.1.2 *Malfunction Alarm* — In the event of a malfunction, the UTV should both light a lamp(s) and generate an alarm sound to alert personnel.

NOTE 10: Malfunction alarms typically require the system to be reset by a human operation.

13.1.3 *Manual Operation Indicator* — The UTV should indicate if it is under manual operation, defined as any control of a vehicle outside of automated operation.

13.1.4 *Sensor Disabled Lamp* — The UTV should light a lamp(s) to indicate when the non-contact approach sensing device is disabled (for example, because the UTV is negotiating a sharp turn).

13.2 *Hazard Alarms and Lamps for Floor-Traveling Vehicles* — In addition to the indicators in Section 13.1, the following indicators should also be provided on floor-traveling vehicles:

13.2.1 *Startup Alarm* — When a floor-traveling vehicle restarts after stopping for 5 seconds or more, the vehicle should set off an audible alarm sound at least one second before it begins to move.

13.2.2 *Traveling Alarm* — When the floor-traveling vehicle is traveling, the vehicle should generate audible alarm sounds either continuously or intermittently as appropriate for the area in which the vehicle is operating.

13.2.3 *Turn Signal Lamps* — To indicate a floor-traveling vehicle is preparing to turn/spin-turn (right or left) and during the turn cycle, the vehicle should light turn signal lamp(s). Turn signal lamps should be clearly visible from the side in the direction of the turn.

13.2.4 *Automated Operation Indicator* — The floor-traveling vehicle should light lamp(s) to indicate it is in automated operation.

13.3 *Hazard Alarms and Lights for Space-Traveling Vehicles* — In addition to the indicators in Section 13.1, the following indicator should also be provided on space-traveling vehicles.

13.3.1 *Hoist Alarm* — The space-traveling vehicle and/or hoist should generate audible alarm sounds indicating that the hoisting mechanism is moving (raising or lowering).

NOTE 11: The same audible alarm device can be used to generate startup, traveling, hoist, or malfunction alarms, provided that different sounds are used to indicate each condition.

13.4 *Visual Hazard Alerts for both Floor-Traveling and Space-Traveling Vehicle Areas* — To assure personnel safety in the UTV operation area, information about the recommended system of safety measures should be provided by the UTV system supplier (including items such as alerts, signs, color coding, and safety poles for the vehicle operating area).

13.4.1 The UTV system supplier should provide information about style and placement of road signs, for posting along floor traveling vehicle paths and at load/unload or maintenance stations.

NOTE 12: End user customers may need to provide additional visual hazard alerts for posting on building structures (such as walls, columns, and doors) and/or equipment surrounding the UTV operation area.

13.5 *Visual Hazard Alerts on Floor-Traveling Vehicles* — In addition to the information about operational area visual hazard alerts (noted in Section 13.4), the floor-traveling vehicle supplier should provide all visual hazard alerts required for the floor-traveling vehicle. These visual hazard alerts should be clearly visible from all sides of the UTV.

13.6 *Visual Hazard Alerts for Space-Traveling Vehicles* — In addition to the operational area visual hazard alerts noted in Section 13.4, the following visual hazard alerts should also be provided by space-traveling vehicle suppliers.

13.6.1 The UTV system supplier should provide marking of maintenance station areas and their hazards, as well as a method of marking the floor location where maintenance descent occurs.

NOTE 13: End user customers may need to mark load/unload stations to identify the existence of the hazard. UTV system suppliers should suggest a method of marking these areas.

14 Hazardous Materials

14.1 *Batteries for Floor-Traveling and Space-Traveling Vehicles* — If the UTV requires the use of batteries, the following should be included in the documentation provided by the UTV supplier.

14.1.1 Specifications provided by the UTV system supplier for battery recharging, battery maintenance and battery storage areas should specify the following. This provision can be waived only if the batteries used are sealed with no possibility of gas emission.

- Requirements for eye-washing equipment.
- Requirements for ventilation.
- Restrictions on smoking and other sources of ignition.
- Personnel splash protection requirements during electrolyte handling.

14.1.2 The UTV system supplier should provide disposal requirements for batteries that constitute hazardous waste (such as lead, nickel cadmium or lithium).

NOTE 14: Disposal requirements should comply with national or local codes, regulations, and laws.

NOTE 15: Per SEMI S2 environmental guidelines, the UTV system supplier should provide information on the nature, volume, and risks of potential hazardous waste (such as lead or lithium).

NOTE 16: Battery charging stations may have to meet international, national, or local regulations (such as EU Directives or U. S. Department of Labor, Occupational, Safety and Health Act Regulations).

14.2 *Spill Prevention for Floor-Traveling and Space-Traveling Vehicles* — If the UTV requires the use of lubricants, the UTV supplier should meet the following spill and slip hazard provisions.

14.2.1 Any UTV with an internal oil-reservoir (such as a gearbox) should be structurally designed to prevent any oil from dripping out of the vehicle.

14.2.2 Space-traveling vehicle track lubricants should be restricted to those lubricant types and quantities that will not drip from the vehicle or create a slip hazard.

14.2.3 Rail guided vehicle or track lubricants should be restricted to those lubricant types and quantities that will not drip (e.g., onto sub-Fab floors). Neither should they create a slip hazard on the walking surfaces beside the rail or on the top of the rail itself.

15 Related Documents

15.1 *SEMI Standards*

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E64 — Provisional Specification for 300-mm Cart to SEMI E15.1 Docking Interface Port

SEMI S1 — Safety Guideline for Visual Hazard Alerts

15.2 *ANSI Standard*[3]

ANSI/ASME B56.5 — Safety Standard for Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles

15.3 *CEN Standards*[4]

EN 1525 — Safety of Industrial Trucks – Driverless Trucks and their Systems

15.4 *U.S. Government Regulations*[5]

29 CFR 1910 — U. S. Department of Labor, Occupational, Safety and Health Act Regulations

15.5 *JIS Standards*[6]

JIS D 6801 — Glossary of Terms Relating to Automatic Guided Vehicle Systems

JIS D 6802 — General Rules on the Safety of Automatic Guided Vehicle Systems

JIS D 6803 — General Rules on the Design of Automatic Guided Vehicles

JIS D 6804 — General Rules on the Design of Automatic Guided Vehicle Systems

JIS D 6805 — Testing Method of Characteristics and Functions of Automatic Guided Vehicles

15.6 *VDI Standards*[7]

VDI 2510 — Automated Guided Vehicle Systems (AGVS)

VDI-3643 — Self-Powered Trolley System – Load 500kg

3 American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036

4 European Committee For Standardization, 36, rue de Stassart, B-1050 Brussels, Belgium

5 Code of Federal Regulations, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

6 Japanese Industrial Standards available in Japanese language only through Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo, Japan 107-8440

7 Verein Deutscher Ingenieure (VDI), Postfach 101139, D-40002 Düsseldorf, Germany

RELATED INFORMATION 1
PROTECTIVE DEVICE OPTION CONSIDERATION FOR LOAD/UNLOAD OPERATIONS AT SEMICONDUCTOR MANUFACTURING EQUIPMENT LOAD STATIONS

NOTE: This Related Information is not an official balloted part of SEMI S17. It is included to assist the user of the document in making decisions about possible options.

R1-1 Purpose

R1-1.1 This Related Information should act as an application note for consideration and selection of safety devices that may be provided to protect load/unload operations where risks are generated by space traveling vehicles.

R1-1.2 Space traveling vehicle suppliers are not required to provide such devices, except as necessary to comply with local jurisdictional requirements.

NOTE R1-1: Refer to the main document for devices recommended for protecting equipment.

R1-2 Scope

R1-2.1 *Protective Devices* — As related to UTV equipment, devices designed to protect personnel or equipment from injury or damage during raising or lowering of loads into position.

R1-2.2 Protective devices should be considered when space-traveling vehicles with hoisting mechanisms are present.

R1-2.3 Protective devices function to warn of, or prevent transfer of, loads when personnel or equipment are at risk.

R1-2.3.1 This application note covers the following types of devices:

- Sensors
- Shields
- Alarms
- Signs and visual alerts
- Communication protocol

NOTE R1-2: This should not be considered a complete list there could be many other solutions.

R1-3 Limitations

R1-3.1 This Related Information is not intended to apply to situations where load ports are installed only in locations inaccessible to personnel walking on the factory floor (such as SEMI E15.1 Option 2 load ports).

R1-3.2 This Related Information does not apply to factories using only floor-traveling vehicles or PGVs.

R1-4 Considerations

R1-4.1 Protective devices should be considered for preventing transfer of loads when personnel or equipment are at risk.

R1-4.2 Protective device integration should be considered a coordinated effort between UTV supplier, manufacturing equipment supplier and the end user customer.

R1-5 Lookdown Sensors

R1-5.1 *Lookdown Sensors* — Such sensors surround the hoisting mechanism and look down to the loadport to determine if anything is within the path of descent.

R1-5.2 Lookdown sensors are one type of protective device that allows for the overhead vehicle to "see" if there is anything in the expected path of descent.

R1-5.3 Lookdown sensors can serve the function of protecting equipment from impact.

R1-5.4 Lookdown sensors should be capable of communicating the need for operator intervention back to a location that can notify the proper personnel.

R1-6 Shield Options

R1-6.1 *Shield Device* — Shield devices are physical shielding which is placed to block access to a hazard area.

R1-6.2 Shield devices, when selected, should be capable of fitting within the dimensional limitations of the load ports. (See SEMI E15.1 for dimensional requirements and exclusion zones for 300 mm load ports.)

R1-6.3 Shield device types include:

- Curtain Sensor
- Safety Guard
- Automatic Doors

R1-6.4 Shield devices, when chosen, should prevent simultaneous load/unload operation by a floor-traveling vehicle or person and a space-traveling vehicle.

R1-6.5 *Protective Device Interlocks* — These confirmation signals from shield devices are used to interrupt the transfer process if a shield is breached.

R1-6.5.1 In the case of UTV systems, protective device interlocks should communicate to the UTV equipment either directly or through the manufacturing equipment.

R1-6.5.2 Communication should be via a protected-path communications protocol that is fail safe.

R1-7 Alarms

R1-7.1 A*larms* — Alarms consist of audible and visual notices of hazards that may be approaching.

R1-7.2 Alarms may also be selected as protective devices.

R1-7.3 Alarms may be field configurable to allow for selection of type of audible or visual allowed, or to allow for selection of either audible or visual and elimination of the other type.

R1-8 Signs and Visual Alerts

R1-8.1 Signs such as “Caution”, “Warning”, or other sign appropriate to the potential hazard may be selected as a method of protection.

R1-8.2 Signs should be compatible with SEMI S1, or should be approved by the local jurisdictional authority.

R1-8.3 *Visual Alerts* — an indicator applied to floors or vertical surfaces surrounding a potential are of delivery, which indicates to persons present that a potential hazard exists in the area.

R1-8.4 Visual alerts may include:

- Striped tape on the floor
- Warning barriers
- Railings

NOTE R1-3: This should not be considered a complete list there could be many other solutions.

R1-9 Communication Protocol

R1-9.1 *Communication Protocol* — A method of communicating the status of the equipment to a centrally monitored location. This may be direct or through the equipment communication path.

R1-9.2 Protective devices offered should be capable of communicating with floor-traveling and space-traveling UTVs through some type of interface.

R1-10 Providing Information

R1-10.1 If protective devices are offered, the UTV supplier should provide documentation to the end user customer about protective devices available.

R1-10.2 Information should be provided to the user to explain the function of any protective devices that may be offered.

R1-10.3 Information may also be needed by suppliers of other equipment to insure adequate communication between equipment types.

SEMI INTERNATIONAL STANDARDS

FLAT PANEL DISPLAY

Semiconductor Equipment and Materials International

SEMI D3-91
QUALITY AREA SPECIFICATION FOR FLAT PANEL DISPLAY SUBSTRATES

1 Purpose

1.1 This document defines various areas on the pattern surface of a flat panel display substrate and describes their relationship. It assumes the existence of terminology and a banking convention described in other SEMI flat panel display documents.

2 Applicable Documents

2.1 *SEMI Documents*

SEMI D4 — Method for Referencing Flat Panel Display Substrates

Definitions for Flat Panel Display Substrates

3 Significance

The patterns placed on a flat panel display substrate are expected to occur only in a specified, central area, and certain requirements are applied in that area to both the substrate and pattern quality. The substrate peripheral area(s) outside this zone have different specified properties. Defining the terms to apply and the geometric relationship in these various areas will assist the suppliers and users of substrates and processing/inspection equipment.

4 Summary

4.1 A substrate edge length is defined in two dimensions, L_X and L_Y, with nominal and tolerance values for each.

4.2 A quality area is defined by two dimensions, QA_X and QA_Y, with nominal and tolerance values for each.

4.3 A fixed edge exclusion area is defined for the substrate edges to be placed against reference (also called "banking") pins.

4.4 Two variable edge exclusion areas result from combining the above three dimension sets.

5 Procedure

5.1 Locate the properties in Sections 5.2 – 5.4 relative to the substrate origin, using the nominal values assigned by the substrate specification.

5.2 Let L_X = the substrate edge length in the x-direction, and

L_Y = the substrate edge length in the y-direction. (See Figure 1.)

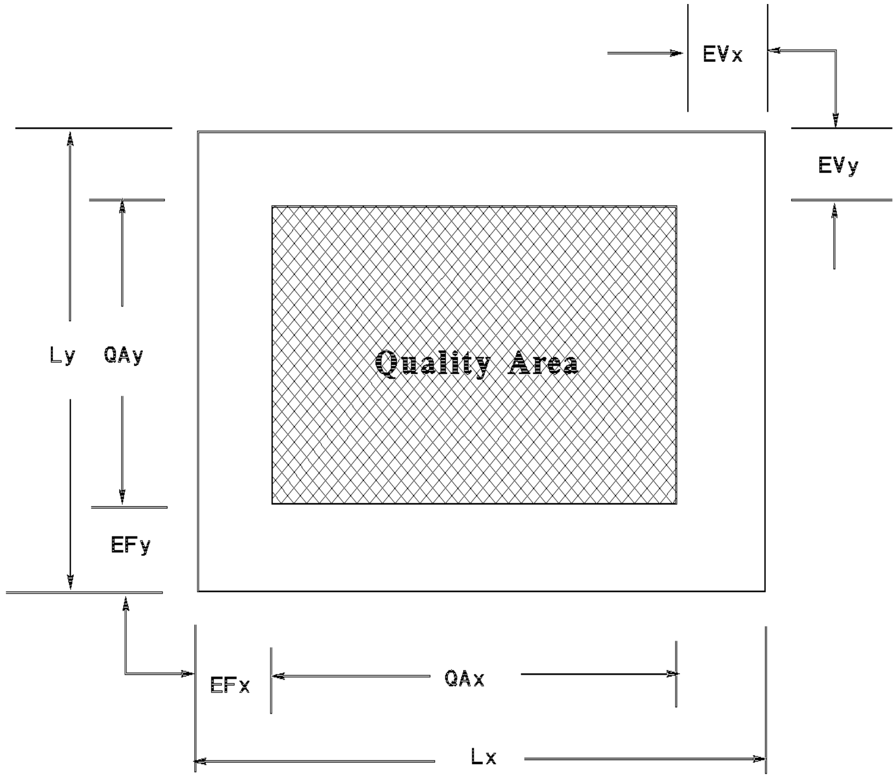
5.3 Let EF_X = the fixed edge exclusion area along the substrate's lower edge, and

EF_Y = the fixed edge exclusion area along the substrate's left edge.

5.4 Let QA_X = the quality area's edge length in the x direction, and

QA_Y = the quality area's edge length in the y direction.

5.5 Then EV_X and EV_Y, the variable edge exclusions, are not specified. They result from the interaction of substrate tolerance variations from nominal with the fixed location origin.



L_X, L_Y

QA_X, QA_Y are specified, nominal dimensions

EF_X, EF_Y

EV_X, EV_Y are not specified, but result from tolerance effects.

Figure 1
Substrate Area Relationships

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI D5-94
STANDARD SIZE FOR FLAT PANEL DISPLAY SUBSTRATES

1 Purpose

This standard covers the specification of nominal edge length and thickness and related tolerances of a flat panel display substrate.

2 Scope

These dimensions apply to substrates that are principally used in fabricating AMLCD displays. These dimensions may also be applicable to substrates for other display types. The edge lengths specified range from 300 × 300 mm to 500 × 500 mm. A single thickness, 1.1 mm, applied to all substrates.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D4 — Method for Referencing Flat Panel Display Substrates

SEMI D12 — Specification for Edge Condition of Flat Panel Display (FPD) Substrates

4 Dimensions

4.1 *Edge Length*

Table 1 Standard (Arithmetical Progression) Edge Length (mm)

300 × 300	300 × 350	300 × 400	300 × 450	300 × 500
	350 × 350	350 × 400	350 × 450	350 × 500
		400 × 400	400 × 450	400 × 500
			450 × 450	450 × 500
				500 × 500

NOTE 1: For substrates larger than 500 mm × 500 mm, it is recommended that the edge lengths be increased in increments of 50 mm.

Table 2 Standard Edge Length (mm)

320 mm × 300 mm
320 mm × 400 mm
360 mm × 465 mm

Table 3 Edge Length Tolerance

Nominal	*Tolerance*
< 400 mm	± 0.2 mm
≥ 400 mm	± 0.3 mm

4.2 *Thickness* — 1.1 ± 0.1 mm

NOTE 2: Nominal values and tolerances for thickness <1.1 mm, and >1.1 mm are under discussion.

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SEMI D6-1101
SPECIFICATION FOR EDGE LENGTH AND THICKNESS FOR LIQUID CRYSTAL DISPLAY (LCD) MASK SUBSTRATES

This specification was technically approved by the Global Flat Panel Display Materials and Components Committee and is the direct responsibility of the Japanese Flat Panel Display Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1992; previously published June 1999.

1 Purpose

1.1 This specification defines standard edge length and thickness dimensions and tolerances for substrates used to fabricate liquid crystal display masks.

2 Scope

2.1 These dimensions apply to photomasks that are principally used in fabricating liquid crystal displays. The edge lengths specified range from 202.8 × 202.8 mm to 700 × 800 mm.

2.2 Substrates with an edge length less than 200 mm follow the specifications for a semiconductor mask (see SEMI P1).

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standard*

SEMI P1 — Specification for Hard Surface Photomask Substrates

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 None.

5 Ordering Information

5.1 Ordering information shall be discussed between suppliers and users.

6 Edge Length Specification

6.1 *Edge Length* — Units are in mm. See Tables 1A and 2A, 1B and 2B, 1C and 2C, and 1D and 2D for a combination of materials, edge length, and thickness.

6.2 *Edge Length Tolerance* — ± 0.4 mm. Applies to all groups.

6.3 *Thickness, Tolerance*

6.3.1 Thickness of substrates shall be specified by the edge length group and materials as shown in Tables 2A, 2B, and 2C.

6.3.2 *Tolerance* — For Groups A and B: –0.4 ~+ 0.2 mm. For Group C: See Table 2C. For Group D: See Table2D.

6.4 *Material* — See Section 7.

Table 1A Edge Length (Group A) in mm

202.8 × 202.8				
200 × 250	250 × 250			
	250 × 300	300 × 300		
		300 × 350	350 × 350	
			350 × 400	400 × 400

Table 2A Plate Thickness and Materials (Group A) in mm

Material			
HTE	*MTE/LTE*	*ULTE*	*Thickness(mm)*
+	+	+	3.0
+			4.8
	+	+	5.0

Table 1B Edge Length (Group B) in mm

330 × 450			
	400 × 500		
		450 × 550	
			500 × 600

Table 2B Plate Thickness and Materials (Group B) in mm

Material			
HTE	*MTE/LTE*	*ULTE*	*Thickness(mm)*
+			4.8
	+	+	5.0

Table 1C Edge Length (Group C) in mm

620 × 720
650 × 750
650 × 800
700 × 800

Table 2C Plate Thickness and Materials (Group C) in mm

Material		
ULTE	*Thickness (mm)*	Tolerance (mm)
+	5.0	± 0.2
+	8.0	-0.4 ~+ 0.2

Table 1D Edge Length (Group D) in mm

390 × 610

Table 2D Plate Thickness and Materials (Group D) in mm

Material		
ULTE	*Thickness (mm)*	*Tolerance (mm)*
+	6.0	± 0.2

7 Material Specification

7.1 Substrate material shall be specified as high thermal expansion (HTE), medium thermal expansion (MTE), low thermal expansion (LTE), or ultra low thermal expansion (ULTE). Examples of HTE materials are soda lime glasses; of MTE materials are borosilicate and aluminosilicate glasses; of LTE materials are aluminosilicate glasses; and of ULTE materials are synthetic quartz glasses.

7.2 Substrate materials shall conform to thermal expansion and optical transmittance characteristics specified in SEMI P1.

7.3 Selected physical properties of HTE, MTE, LTE, and ULTE materials are provided for information in SEMI P1, Appendix 1.

8 Related Document

8.1 *SEMI Standards*

SEMI D21 — Terminology for Flat Panel Display Masks

SEMI D7-94
FPD GLASS SUBSTRATE SURFACE ROUGHNESS MEASUREMENT METHOD

1 Purpose

This document defines the method of FPD glass substrate surface roughness measurement by stylus method surface roughness measurement instrument.

2 Scope

This specification shall be used by vendors and/or buyers of glass substrates for flat panel display and is effective for all glass substrates used.

3 Referenced Documents

3.1 *ISO Documents*

ISO486-1982 — Surface Roughness — Parameters, Their Values and General Rules for Specifying Requirements

ISO3274-1975 — Instruments for the Measurement of Surface Roughness by the Profile Method — Contact (Stylus) Instruments of Consecutive Profile Transformation

ISO4287/1-1984 — Surface Roughness — Terminology — Part 1: Surface and its Parameters

3.2 *JIS Document*

JIS B0601-1982 — Definitions and Designation of Surface Roughness

4 Terminology

4.1 *stylus method surface roughness measuring instrument* — Instrument that traces on a section of a surface by a stylus, records irregularity on the surface in a enlarged form, and indicates its amplitude as roughness parameters.

The type of instrument in this standard is specified to an instrument which is sometimes called as a profiler for very thin films and steps.

4.2 *long wavelength cutoff* — Wavelength that the attenuation ratio of its amplitude becomes 75% when the traced profile is passed through the high-pass wavelength filter which eliminates waviness element.

4.3 *short wavelengh cutoff* — Wavelength that the attenuation ratio of its amplitude becomes 75% when the traced profile is passed through the low-pass wavelength filter which eliminates noise element.

5 Measurement Instrument

5.1 *Method* — Stylus method surface roughness measuring instrument defined in Sections 3.1 or 3.2, or an instrument which meets those conditions.

5.2 *Stylus*

Material — diamond
Shape — circular cone or rectangular cone
Tip Radius — 2 µm or less

5.3 *Measuring Force* — 0.1 mN (0.01gf) or above, 0.7 mN (0.07gf) or less.

5.4 *Sampling Interval* — 1 µm or less.

5.5 Vertical noise amplitude p-p value: 3 nm (=30 Å) or less.

6 Measurement Conditions

6.1 Long Wavelength Cutoff, λc — 0.08 mm or close.

6.1.1 Short Wavelength Cutoff, λs — 0.0025 mm or less.

6.1.2 Evaluation length, Le — 0.4 mm.

6.1.3 *Surface Roughness Parameter* — Maximum height of the profile Ry5(ISO4287/1-1984)(=Rz (DIN4768-1990)) or 10 point height of irregularities which is close to Ry5, Rz (JIS B0601-1982).

7 Test Specimen

7.1 A clean FPD glass substrate. No stains or oils should be seen by the naked eye.

8 Measurement Procedure

8.1 Contact the specimen on the stage of the instrument and leave for five minutes to condition the specimen to room temperature.

8.2 Put the stylus on the specimen, measure roughness by tracing the surface, and calculate the defined roughness parameter.

8.3 Change the measurement location to the location near the previous location and measure again.

8.4 Change the measurement location to the location defined in section 9 and repeat the above measurement.

9 Measurement Location

Describe the measurement location on the report, for example, measure the following two locations:

a. the center of the specimen
b. the point which is 20 mm inside from both edges of the orientation corner

10 Calculations or Interpretation of Results

Show the measurement results in nm (nanometers) and round fractions of .5 and over to the next highest whole numbers.

Table 1 Example: Measurement Results

Maximum Height: Ry5	n1	n2
The Center	**nm	**nm
The Corner	**nm	**nm

Measurement Conditions

Surface — The pattern surface
Instrument — (type of instrument and name of maker)
Stylus tip radius — 2 µm
Tracing speed — ** µm/sec
Measuring force — 0.* mN
Cutoff λc — 0.08 mm

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SEMI D8-94
SPECIFICATION FOR OVERLAY CAPABILITIES OF FPD STEPPERS

1 Purpose

This specification provides a means for specifying the overlay performance of microlithographic stepping exposure systems used to expose resist–coated FPD display substrates (“FPD steppers”).

2 Scope

2.1 FPD substrates may contain a single–layer pattern in which separate sections are created by multiple reticles, unlike the patterns that are produced on semiconductor wafers by a single reticle. This specification defines the parameters required for specifying overlay performance of FPD steppers, for both single– and multiple–reticle applications. These parameters can be used for single–tool two–layer performance (e.g., layer 1 – layer 2) using two or more reticles. They can also be used for inter–tool performance of a single layer using two nominally identical reticles (e.g., layer 1 – layer 1).

2.2 This specification does not address the quality differences between different reticles used to qualify the tool(s). However, these differences must be quantified to validate the statistical derivation of performance measurements against this specification.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI Compilation of Terms

SEMI P18 — Specification for Overlay Capabilities of Wafer Steppers

3.2 *ASTM Document*

Standard 15D — Manual on the Presentation of Data and Control Chart Analysis[1]

3.3 *NIST Document*

Handbook 91 — Experimental Statistics, M G Natrella[2]

4 Terminology

alignment — Of an FPD substrate, the mechanical positioning of reference points on FPD substrates (“alignment marks” or “alignment targets”) to reference points on the reticle(s). The measure of alignment is the overlay at the positions on the FPD substrate where the alignment marks are placed. See *direct alignment* and *indirect alignment*.

overlay — Of an FPD substrate, a vector quantity defined at every point within the patterned area. It is the difference, O, between the vector position, P_1, of a substrate geometry, and the vector position of the corresponding point, P_2, in an overlaying pattern, which may consist of photoresist:

$$O = P_2 - P_1$$

The overlay value, O, may be decomposed into orthogonal components O_x and O_y along the directions of the stepper stage motions.

direct alignment — The mechanical positioning of alignment marks on the FPD substrate directly to the reference points on the reticle(s). Contrast with *indirect alignment*.

indirect alignment — The mechanical positioning of (a.) alignment marks on the FPD substrate to one set of reference points in the stepper, and (b.) alignment marks on the reticle(s) to a second set of reference points in the stepper. Contrast with *direct alignment*.

5 Ordering Information

5.1 Purchase orders of steppers furnished to this specification shall include the following items:

5.1.1 Total patterned area, A_T. For multiple reticle patterns, each unique reticle pattern on the substrate shall have a separate value A_{T1}, A_{T2}..A_{Tn}.

5.1.2 Overlay error for each specified area:

5.1.2.1 *O*, or

5.1.2.2 O_X and O_Y.

5.1.3 Number of data points with which each reticle pattern overlay is to be characterized, and method(s) of overlay calculation.

6 Test Methods

6.1 The test methods for overlay characterization shall be agreed upon between supplier and user.

1 Available from ASTM, 1516 Race Street, Philadelphia, PA 19103. Telephone: 215-299-5400, FAX: 215-299-2630

2 Available from National Institute for Standards and Technology, Publications Department, Gaithersburg, MD 28099. Telephone: 301-975-2000

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI D9-1101
TERMINOLOGY FOR FPD SUBSTRATES

This terminology was technically approved by the FPD Materials and Components Committee and is the direct responsibility of the Japanese FPD Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on April 19, 2001. Initially available at www.semi.org August 2001; to be published November 2001. This document was originally published in 1994.

NOTE: This document was revised in its entirety in 2001.

1 Purpose

1.1 This document provides terms and definitions of materials and defects within and on the surface of flat panel display (FPD) substrates, and of dimensional, thermal, chemical, optical and mechanical properties of FPD substrates.

2 Scope

2.1 These terms and definitions are applicable to both front and back substrates used in FPD fabrication.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI D3 — Quality Area Specification for FPD Substrates

SEMI D5 — Standard Size for FPD Substrates

SEMI D7 — FPD Glass Substrate Surface Roughness Measurement Method

SEMI D11 — Specification for FPD Glass Substrate Cassettes

SEMI D12 — Specification for Edge Conditions of FPD Substrates

SEMI D15 — FPD Glass Substrate Surface Waviness Measurement Method

SEMI D24 — Specification for Glass Substrates Used to Manufacture Flat Panel Displays

3.2 *Other*

Semiconductor Equipment Association of Japan (SEAJ) Liquid Crystal Display Manufacturing Equipment Dictionary

4 Definitions

4.1 *Internal Defects*

4.1.1 *bubble* — A gaseous inclusion.

4.1.2 *open bubble* — a gaseous inclusion which is so close to the surface that it is obviously open and/or one so close to the surface that it may be broken open with the point of a soft lead pencil.

4.1.3 *inclusion* — Opaque or partially melted particle of refractory or batch material embedded in glass. Its size is usually determined by the size of the distorted area.

4.1.4 *devitrification* — a crystalline area within the glass.

4.1.5 *knot* — an embedded glassy transparent lump having an irregular or tangled appearance. Its size is usually determined by the size of the distorted area.

4.2 *Material on the Surface*

4.2.1 *cullet* — small transparent glass particles that are adhered or fused to the glass substrate surface.

4.2.2 *particle* — a micron-size piece of foreign material on the glass surface.

4.2.3 *stain* — organic or inorganic material on the surface.

4.2.4 *blur* — any erosion of the surface; generally cloudy in appearance, it sometimes exhibits an apparent color.

4.3 *Surface Defects*

4.3.1 *scratch* — a surface fissure generally caused during handling.

4.3.2 *sleek* — a very shallow type of scratch on the polished surface that is sometimes invisible when the viewing angle is changed.

4.3.3 *latent scratch* — a scratch which is usually invisible but when subjected to an etching action by dipping into a detergent or a corrosive solution, such as an acid, the previously invisible scratch becomes visible due to the minor removal of surface glass.

4.3.4 *chip* — a region of material missing from the edge of the glass substrate, which is sometimes caused by processing or handling.

4.3.5 *pit/dig* — small indentation on the glass substrate surface.

4.3.6 *bump* — a small protuberance on the glass substrate.

4.3.7 *crack* — a fissure located at the sheet edge area or central area.

4.3.8 *streak* — a defect with a very small undulation on the glass substrate surface.

4.4 *Dimensional Properties*

4.4.1 *outsize dimension* — vertical and horizontal dimensions of the glass substrate.

4.4.2 *thickness* — the distance between the front surface and the back surface of a glass substrate at same single point.

4.4.3 *thickness variation* — any differences between maximum and minimum values within the thickness of a glass substrate.

4.4.4 *warp* — defined as the maximum distance from a reference plane to the guaranteed surface, this includes twists, partial rises or declines in the glass compared with the reference plane. Warp expression a condition of the whole glass (substrate).

4.4.5 *waviness* — the residual unevenness after the long wavelength component (warp) and the short wavelength component (surface roughness) have been eliminated. This is also called "FPD Waviness" when referring specifically to FPD substrates, as in SEMI D15.

4.4.6 *surface roughness* — the criterion for the smoothness of the sheet surface. Usually the randomly selected areas on the sheet surface are measured by a surface analyzer. Details are defined in SEMI D7.

4.4.7 *beveling* — grinding out or shaping substrate edges by lapping or grinding.

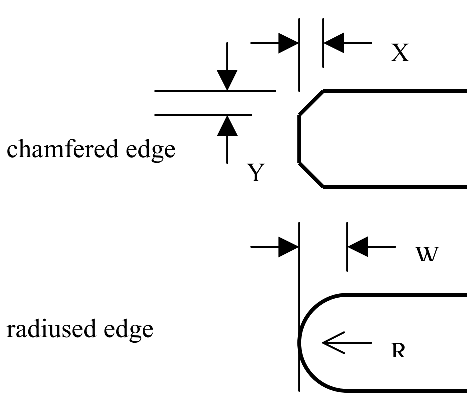

Figure 1
Beveling

4.4.7.1 *chamfered edge* — a beveled angle of approximately 45° in respect to the surface and cut edge surface. One characteristic is that part of the cut edge surface remains. For this reason, R-beveled edges have come to be used in conjunction with chamfered edges in liquid crystal applications. Chamfered edges with particularly small widths are also referred to as "string bevels". (See Figure 1.)

4.4.7.2 *R beveled edge* — a beveled shape of an arc in respect to the surface and cut edge surface. One characteristic is that the complete cut edge surface is ground with a wheel and processed into a frosted glass state. Generally, in TFT liquid crystals, R-beveled edges are used more often. (See Figure 1.)

4.4.8 *orientation corner* — the corner of a substrate which identifies the pattern surface and the rotational orientation. It is defined by the X and Y dimensions in the following figure. It is also commonly known as "orientation flat" or "orifra".

4.4.9 *corner cut* — removal of the corners of the substrate by either lapping or grinding. As with the orientation corner, this is defined by the X and Y dimensions, but generally, most corner cuts have a X and Y of the same length.

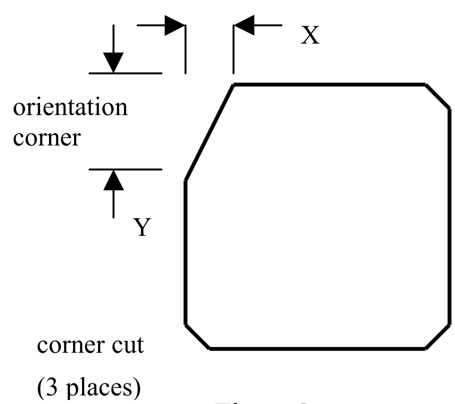

Figure 2
Orientation Corner and Corner Cut

4.4.10 *squareness* — deviation of the outline of the substrate from a true square or rectangle. Using the drawing below, it is defined as PS or PL, but must be recorded with a or b dimensions. Dimensions a and b can be decided voluntarily, but generally, most applications use a = S and b = L. (See Figure 3.)

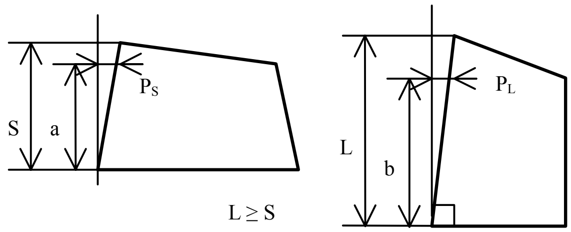

Figure 3
Squareness

4.5 *Thermal Properties*

4.5.1 *coefficient of thermal expansion* — expansion is the change in length per initial length caused by a thermal change. Concretely, it is shown as ΔL/L0, where ΔL = L2 – L1 and L0, L1, and L2 are the lengths of the material at the temperature T0, T1, T2 respectively. Usually, the coefficient of expansion (A), means the average coefficient of expansion over the temperature range T1 to T2. This is shown in the following equation.

$$\alpha = (\Delta L/\Delta T)/L_0 = [(L_2 - L_1)/(T_2 - T_1)]/L_0$$

4.5.2 *thermal shrinkage* — when the substrate is heat treated along a specific thermal profile, the relaxation of thermal stress, and the structure change occur in material and create the shrinkage of the substrate. Usually it is described with ΔL/L0, where, ΔL is the amount of change and shown as ΔL = L0 – L. L0 is the length of material before heat treatment and L is after heat treatment.

4.5.3 *strain point* — temperature of the glass when its viscosity is approximately $10^{14.5}$ Pa/sec. Strain point is defined by two methods in ASTM: Test Method C336 (Elongation of Glass Fibers) and Test Method C598 (Bending in Glass Beams). In practice, the strain point of glass is the maximum temperature at which glass can be processed without triggering unnecessary strain. Internal strain can be relieved by keeping (the glass) at this temperature for 4 hours.

4.5.4 *annealing point* — temperature of the glass when its viscosity is approximately 10^{13} Pa/sec. The annealing point is the temperature at which internal strain can be relieved in 15 minutes.

4.5.5 *softening point* — temperature of the glass when its viscosity is approximately $10^{7.6}$ Pa/sec. Softening point is defined in ASTM C338.

4.6 *Chemical Properties*

4.6.1 *chemical durability* — a measure of corrosion or attack of a glass surface when subjected to a specific reagent, such as acid, base, or water at a specific concentration for a specific time and temperature.

4.7 *Optical Properties*

4.7.1 *transmittance* — Percentage of incident light which permeates the glass. It is defined as I/Io, where Io is the strength of the incident light, and I is strength of the permeated light. Transmittance is effected by material composition, temperature, thickness and light wavelength.

4.7.2 *refractive index* — ratio of the speed of light in the material and in a vacuum at a specific wavelength. The refractive index of substrate glass is between approximately 1.50 and 1.53.

4.8 *Mechanical Properties*

4.8.1 *density* — mass per unit volume. Decided by the mass of the material's atomic composition and the volume (comparative capacity, mol capacity) which it occupies.

4.8.2 *Young's modulus* — a type of elasticity ratio, which shows the stretch (or compression) elasticity. When stretch (or compression) deformation stress σ and the strain ε resulting from the stress are proportionate, the proportionate constant E = σ/ ε is called Young's Modulus, a material characteristic.

4.8.3 *shear modulus* — a type of elasticity ratio which shows divergence elasticity. When divergent deformation stress τ and the strain Φ resulting from the stress are proportionate, the proportionate constant G = τ/Φ is called Shear Modulus, a material characteristic.

4.8.4 *Poisson's ratio* — the ratio between Young's modulus and shear modulus.

4.8.5 *Vickers hardness* — a type of pressure test. A diamond pyramid indentator with a face angle of 136° is pressed into the glass surface to find the degree of hardness by measuring trace indentation on the overall squareness.

4.9 *Electrical Properties*

4.9.1 *dielectric constant* — the proportionate dielectric constant which is the ratio between a vacuum dielectric constant and the material dielectric constant.

4.9.2 *dielectric loss* — the phenomenon, or volume, of (electricity) loss through heat when a dielectric is introduced to an alternating current.

4.9.3 *resistivity* — the reciprocal of electric conductivity.

4.10 *pattern surface* — the main area where device patterns can be formed, determined by the orientation corner, etc.

4.11 *quality area* — the center area to the substrate where specified substrate quality criteria (primarily internal defects, surface contamination, surface defects, waviness, and surface roughness) are applicable.

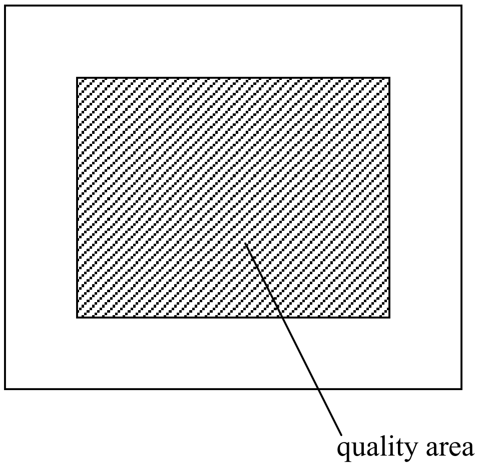

Figure 4
Quality Area

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SEMI D10-95
TEST METHOD FOR CHEMICAL DURABILITY OF FLAT PANEL DISPLAY GLASS SUBSTRATES

1 Purpose

1.1 This test procedure evaluates quantitatively the durability of flat panel display (FPD) glass substrates using reagents employed in FPD production processes.

2 Scope

2.1 This standard may be used by vendors and/or buyers of glass substrates for FPD.

2.2 This standard defines three methods for testing chemical durability of various flat panel display substrates: (Method A) Weight Loss, (Method B) Step Measurement Using Profilometry, and (Method C) Surface Haze. Each method provides a measure of the amount of material that is removed from a substrate during a controlled chemical reaction sequence. This sequence is nominally identical for each method.

3 Limitations

3.1 These tests are not applicable to calculating variations in chemical durability in local areas within a substrate.

3.2 The calculations assume that all edges are nominally straight. They do not include adjustments for corner cuts.

3.3 The chemicals used in these practices are potentially harmful and should be handled in a fume hood with the utmost care at all times. **Warning** - Hydro- fluoric acid solutions are particularly hazardous. **Precaution:** They should not be used by anyone who is not familiar with the specific preventive measures and first aid treatments given in the appropriate Material Safety Data Sheet.

4 Referenced Documents

4.1 *SEMI Standard*

SEMI D5 — Standard Size for FPD Display Substrates

4.2 *ASTM Document*[1]

C729 75 — Test Method for Density of Glass by Sink Float Comparator

4.3 *JIS Documents*[2]

JIS B0651 — Instruments for the Measurement of Surface Roughness by the Stylus Method

JIS B7601 — Trip Balances

JIS B7507 — Vernier, Dial, and Digital Callipers

JIS K7105 — Testing Methods for Optical Properties of Plastics

4.4 *ISO Document*[3]

ISO 3274 — Instruments for the Measurement of Surface Roughness by the Profile Method Contact (Stylus) Instruments of Consecutive Profile Transformation Contact Profile Meters, System M

5 Terminology

5.1 *haze* —A method to measure the degree of haze created on the FPD glass substrate surface by a chemical etch sequence.

5.2 *step measurement using profilometry* — A method to measure depths of etching by comparing the differences in heights between etched and non-etched parts of a specimen measured by profilometry or an equivalent method.

5.3 *weight loss method* — A method to calculate depths of etching by comparing differences in specimen weights before and after the etch sequence.

6 Apparatus

6.1 For all chemical reactions, the following apparatus shall be used.

6.1.1 *Reaction Vessel*

Material: Teflon or other suitably etch-resistant material.

Shape and Capacity: Cylindrical wide-mouthed sealable vessel, suitable for the size and quantity of samples to be tested.

6.1.2 *Thermostatically Controlled Shaker Bath or Equipment*

Shaking Stroke: 10 to 60 mm.

1 American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

2 Japan Standards Association, 4-1-24, Minato-ku, Tokyo 107, Japan

3 American National Standards Institute, 11 W. 42nd St., New York, NY 10036

Shaking Frequency: 30 - 90/min., controllable to ± 10/min.

Operating Temperature Range: 20 to 150°C, controllable to ± 1°C.

6.1.3 *Oven* — Controllable to ± 10° over an operating range of 50 to 200°C.

6.1.4 *Desiccator* — Room temperature, with sufficient capacity and size for all samples to be tested.

6.1.5 *Caliper* — Per JIS B7507, or equivalent.

6.2 For the measurements, one of the following shall be used.

6.2.1 *Method A* — Balance per JIS B7601, or equivalent.

6.2.2 *Method B* — Profilometer per ISO 3274, JIS B0651, or equivalent.

6.2.3 *Method C* — Haze measurement equipment with integrating sphere per JIS K7105, or equivalent.

NOTE: It is ideal to use haze measurement equipment which automatically measures total transmittance, diffuse transmittance, and haze values.

7 Reagents and Materials

7.1 No specific requirement is defined for the reagents and materials. As long as the test conditions are reported with the result, any combination of chemical reagents with any concentration can be used for the test. The test conditions should reflect actual process conditions which are specific for the Flat Panel Display manufacturers. Some reagents suggested for the test are provided in Related Information 1 as a reference.

7.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsiblity of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

8 Sample Preparation

8.1 Prepare at least a specimen from a lot of the substrates to be tested. The specimen is a rectangular plate about 25 × 50 mm edge length for Methods A and B, or 40 × 40 mm edge length for Method C.

If they are not already chamfered, specimen edges and corners should be chamfered slightly to remove chips and prevent cracking. If repeated tests are expected, prepare an appropriate quantity of test specimens.

8.2 Measure edge lengths of the test specimens, and calculate total surface area, A:

$$A = (L \times W \times 2) + \{ L + W) \times T \times 2)\} \quad (1)$$

where

L = one edge length of test specimen in cm,

W = adjacent edge length of test specimen in cm,

T = thickness of test specimen in cm,

A = total surface area of test specimen in cm^2.

8.3 Clean all test specimens by a method appropriate for the history of the material. The cleaning method should not cause any corrosion. Clean the specimens by an appropriate neutral or alkali detergent for approximately 10 minutes using an ultrasonic bath.

8.3.1 Rinse them continuously in a stream of deionized water, having a conductivity of less than 1µ S/cm, for 1 minute using the ultrasonic bath. Finally, dry them.

8.4 Place all specimens on a clean heat resistant sample holder. Dry the specimens at 140 ± 10°C for 30 minutes.

8.5 Place all specimens in a desiccator containing silica gel or calcium sulfate and cool them, for a minimum of 1 hour, to room temperature.

8.6 If Method A will be used, weigh the test specimen to 0.1 mg or 0.01 mg as required using the balance.

8.7 If Method B will be used, coat about a half portion of each test specimen by an appropriate coating material durable to the test media and conditions. (Wax, varnish, epoxy resins, adhesive tape, etc., may be used.)

9 Procedure

9.1 *Test Specimen Processing*

9.1.1 Prepare cylindrical wide-mouthed sealable vessels, sample holders, etc., made of materials which do not react with the test medium under the test conditions. Use a reaction vessel in which the test specimen, while on the sample holder, is sufficiently immersed in the required volume of test reagent.

9.1.2 Place the test specimen on the sample holder with spacing of 1 to 2 cm between the test specimen and bottom of the empty vessel. When a part of the specimen is coated by protective material, position the sample so that its coated portion faces down. The test specimen may be leaned against the vessel wall if the test is to be done in relatively brief or slightly corrosive conditions, or in concentrated, extremely corrosive media.

9.1.3 Pour the test reagents into the reaction vessel. Volume of the test medium shall be 5 to 10 ml per cm^2 of specimen surface area. Preheat the test medium to the specified test temperature.

9.1.4 Place the reaction vessel in the preheated shaker bath with specified shaking stroke and frequency. Close the reaction vessel loosely, and expose the specimen at specified temperature for specified time.

9.1.5 At the completion of specified test time, immediately remove the reaction vessel from the shaker bath. Remove the test specimens from the reaction vessel using soft forceps, and rinse the specimens immediately by deionized water at appropriate temperature. When the specimen temperature is high following this process, rinse the specimens completely with water of gradually decreasing temperature. Finish it by deionized water at room temperature. Less caution is required when the reaction temperature is low. A synthetic rubber or plastic glove may be used instead of forceps if sufficient care is taken. In all cases, the surface of the test specimen shall not be scrubbed. Never dry the test specimen during this operation. Generation of cracks or chips due to thermal or mechanical shocks should be avoided.

9.1.6 For Method B samples, remove coating by appropriate non-corrosive method, and clean samples again. In this case, residue from the coating material should not contaminate the overall test specimen.

9.1.7 Place the test specimens on a clean heat-resistant sample holder, and dry them at 140 ± 10°C for 30 minutes.

9.1.8 Place the specimens in the desiccator and allow them to cool to room temperature.

9.2 *Measurement Method*

9.2.1 *Method A (Weight Change)*

9.2.1.1 Weigh the test specimen to 0.1 mg or 0.01 mg as required, using the balance.

9.2.1.2 Calculate the areal weight change with the following equation.

$$W_A = \frac{W_2 - W_1}{A} \qquad (2)$$

where

W_1 = the initial weight of the test specimen in mg,

W_2 = weight of the test specimen in mg after the test,

A = is surface area of test specimen in cm^2, as calculated in 8.2, and

W_A = the areal weight change, in mg• cm^{-2}.

NOTE: A negative result indicates areal weight loss, and a positive result indicates areal weight gain.

9.2.1.3 Calculate penetration depth of corrosion, P, of the test sample by the following equation.

$$P = \frac{10 W_A}{D} \qquad (3)$$

where

W_A = the areal weight change in mg• cm^{-2}

D = the density of the substrate material in mg• cm^{-3} (see 9.2.1.4) and

P = penetration depth in µm

NOTE: A negative result indicates loss of material, and a positive result indicates material gain.

9.2.1.4 When density of the materials is unknown, use the value measured by the method described in ASTM C729.

9.2.2 *Method B (Profilometry)*

9.2.2.1 Measure the height, H, in µm, of the step between the unetched (coated) section and the etched (uncoated) section by a calibrated surface profilometer. Trace length shall be between 2 and 4 mm, with the boundary between the two sections located near the center of the trace.

Repeat this measurement at least 3 times.

9.2.2.2 Calculate the average penetration depth P:

$$P = \frac{H_1 + H_2 + \bullet\bullet\bullet\bullet\bullet + H_N}{N} \qquad (4)$$

NOTE: A negative result indicates loss of material, and positive result indicates material gain.

9.2.3 *Method C (Surface Haze)*

9.2.3.1 Measure total transmittance, Tt, and diffuse transmittance, Td, and calculate the haze value from the following expression:

$$H = \frac{Td}{Tt} \times 100 \qquad (5)$$

where

Tt = total transmittance,

Td = diffuse transmittance, and

H = haze value in %.

10 Reporting Results

10.1 Report date and time of test, ambient temperature, test operator, test conditions (reagent and concentration, volume of the test medium, test temperature, test time, stroke length, and frequency of shaking), specimen size and total surface area, specimen cleaning method, and the following:

10.1.1 *Method A* — The areal weight change (W_A), the initial weight of the specimen (W_1), the density of the substrate material (D), and calculated depth of corrosion (P).

10.1.1.1 *Method B* —Penetration depth (P).

10.1.1.2 *Method C* — The average, maximum and minimum value of total transmittance (Tt), diffuse transmittance (Td), and haze value (H).

10.2 *Remarks* — In a typical test, one specimen is immersed in an unused medium of specified volume in a reaction vessel during a specified time. However, as long as various conditions are described in the report, even irregular methods may be allowed. Repetitive usage of a medium may not markedly affect the result when the test is done in relatively brief or slightly corrosive conditions, or in concentrated, extremely corrosive media.

11 Precision and Accuracy

11.1 Interlaboratory evaluation of these test methods is planned to verify their suitability and reliability. Until the results are established, use of this test method for commercial transactions is not recommended unless the parties to the test establish the degree of correlation that can be obtained.

11.2 No standards exist against which any bias of this test method can be evaluated.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI D10 and is not intended to modify or supercede the official standard. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

NOTICE: This related information does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this related information to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

A1-1 The following chemicals and test conditions are recommended when this test is applied to flat panel display glass substrates:

Buffered hydrofluoric acid (1:5) 49% HF, 49% NH_4F, at 40°C for 10 minutes.

Hydrofluoric acid nitric acid (1:5) 49% HF, 70% HNO_3, at 40°C for 10 minutes.

Hydrochloric acid (diluted) (1:1) 36% HCl, H_2O, at 50°C for 20 minutes.

Sodium hydroxide solution (10%) at 50°C for 20 minutes.

SEMI D11-95
SPECIFICATION FOR FLAT PANEL DISPLAY GLASS SUBSTRATE CASSETTES

1 Purpose

This document describes cassettes that are used with glass substrates in the fabrication and processing of subassemblies and masks for flat panel displays (FPD).

2 Scope

2.1 This document applies to cassettes that hold a quantity of rectangular FPD substrates. Selected terms and definitions and summary specifications are included. The specifications for single-substrate cassettes will be developed in other documents.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI E1 — Specification for 3", 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI D3 — Quality Area of FPD Substrates

SEMI D5 — Standard Size for FPD Substrates

SEMI D6 — Standard Size and Thickness for Flat Panel Display Mask Substrates

SEMI D20 — Defect Terminology for Flat Panel Display Masks

SEMI D21 — Definitions for Flat Panel Display Masks

4 Terminology

The following descriptions assume that the cassette orientation places the substrates in a horizontal plane.

4.1 *cassette bottom plate* — The bottom plate of the cassette. It is parallel to the substrate plane. It is physically different from the cassette top plate for purposes of machine interface and for mechanical positioning by operators.

4.2 *cassette front* — The area between top and bottom cassette plates through which substrates pass during loading and unloading.

4.3 *cassette plate opening* — An opening in the cassette top and bottom plate that provides access to the glass substrates for external roller driver mechanisms to move substrates into/from the cassette.

4.4 *cassette rear* — The area between top and bottom cassette plates opposite the cassette front.

4.5 *cassette top plate* — The upper plate of the cassette. It is parallel to the substrate plane. It is physically different from the cassette bottom plate for the purpose of machine interface and for mechanical positioning by operators.

4.6 *First mizo clearance* — The distance between the inside surface of the bottom plate and the centerline of the nearest mizo.

4.7 *First mizo dimension* — The distance between the outside surface of the bottom plate and the centerline of the nearest mizo.

4.8 *glass substrate cassette* — a container for holding glass substrates for processing, storage, and transportation during the fabrication of FPD.

4.9 *inner height* — The shortest distance between the inside surface of the bottom plate and the inside surface of the top plate.

4.10 *mizo* — A term (plural form = mizo) describing a family of rails that support the substrates. They may be smooth-sided, toothed symmetrically, or toothed non-symmetrically. Precise mizo contours are not described in this document.

4.11 *mizo base* — The innermost portion of a mizo.

4.12 *mizo centerline* — 1/2 the mizo clearance.

4.13 *mizo clearance* — The minimum dimensions between two adjacent mizo teeth, into which a substrate can be placed.

4.14 *mizo depth* — The distance between the base of the mizo and the top of the tooth. It is also called ‘tooth height.’

4.15 *mizo flat* — The distance along the mizo base between two adjacent mizo teeth.

4.16 *mizo opening width* — The distance between the extreme ends of two adjacent mizo teeth.

4.17 *mizo pitch* — The distance between adjacent mizo centerlines.

4.18 *mizo plate* — A plate that contains mizo for supporting glass substrates.

4.19 *mizo plate space* — The distance between adjacent mizo plates. It is used in the alignment of substrates after loading.

4.20 *mizo size* — The distance between opposite mizo bases.

4.21 *substrate clearance* — The difference between the substrate width and the mizo size.

4.22 *substrate load depth* — The shortest distance between the front surface of the cassette and the front surface of the substrate stops.

4.23 *substrate stop* — A portion of the cassette, located at the cassette rear, that provides a mechanical stop for substrates during their insertion.

4.24 *tooth* — The protrusion, on the inner surface of the mizo-pocket plate, that contains the mizo shape.

4.25 *tooth height* — See "mizo depth."

5 Cassette Specification

5.1 An FPD substrate cassette contains the following items:

5.1.1 One cassette bottom plate.

5.1.2 One cassette top plate.

5.1.3 One or more substate stops. A mizo plate may be used as a substrate stop.

5.1.4 Three or more mizo plates.

5.2 *Capacity* — Two or more substrates.

5.3 *Dimensions and Tolerances* — To be agreed upon between supplier and user. The following table and figures explain application of the above definitions and located related dimensions.

5.4 *Material* — To be agreed upon between supplier and user. Construction may be of one or more molded or machined parts.

Table 1 Cassette Designations

Symbol	*Description*
A1	Outer height
A2	Outer width
A3	Outer length
B1	Mizo per plate
B2	Mizo pitch
B3	The distance between the first mizo centerline and the last mizo centerline
B4	Substrate load depth
B5	The distance between the cassette rear and the inside surface of the substrate stop
B6	The distance between the cassette front and the front edge of the substrate
C1	Mizo opening width
C2	Mizo depth
C3	Mizo clearance
C4	Mizo size
C5	Tooth size
C6	Substrate clearance
D1	First mizo dimension
D2	First mizo clearance
D3	Thickness of the cassette bottom plate
D4	Thickness of the cassette top plate
D5	Inner height
D6	Width of mizo plate space

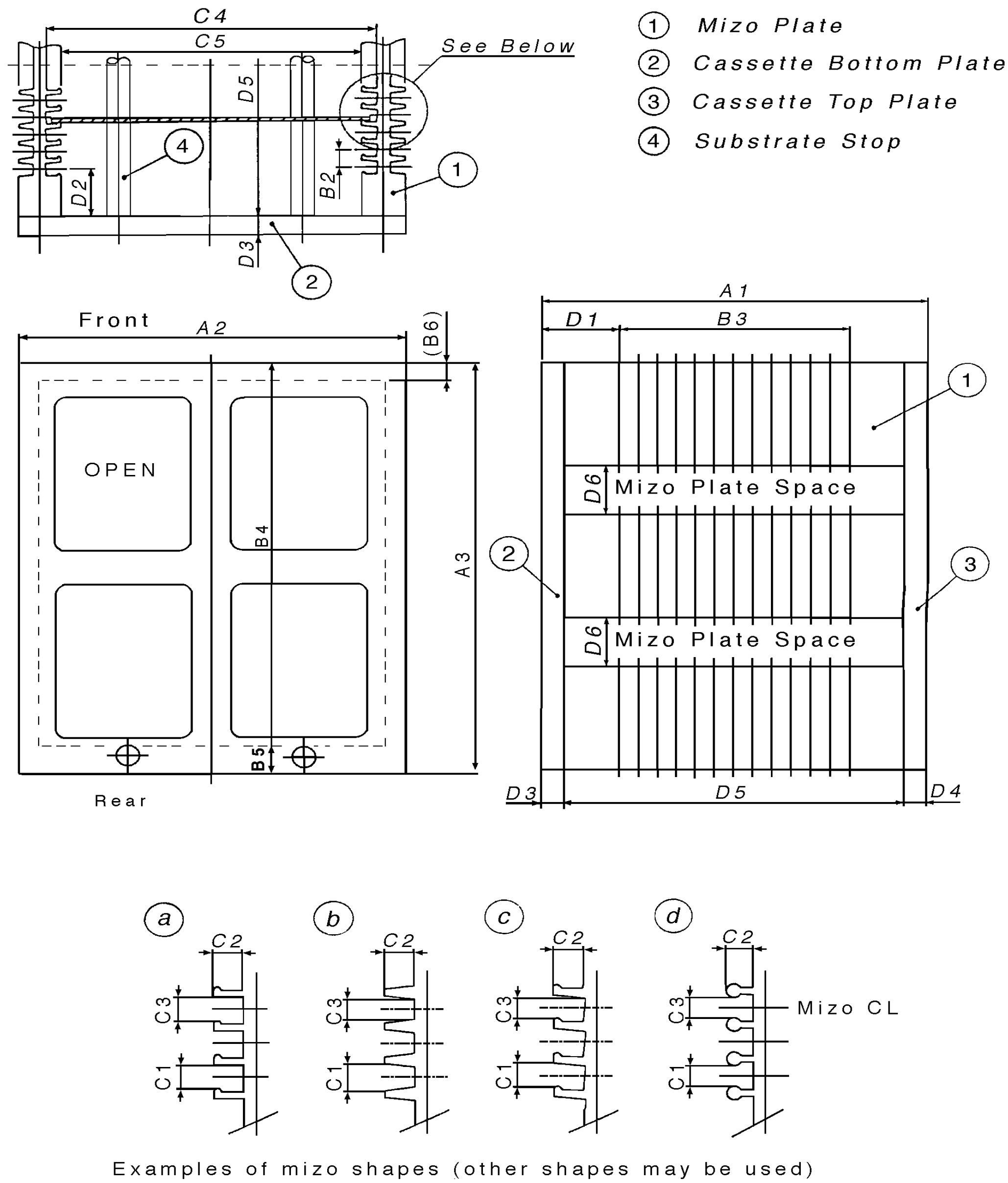

Figure 1
FPD Substrate Cassette (Detail View)

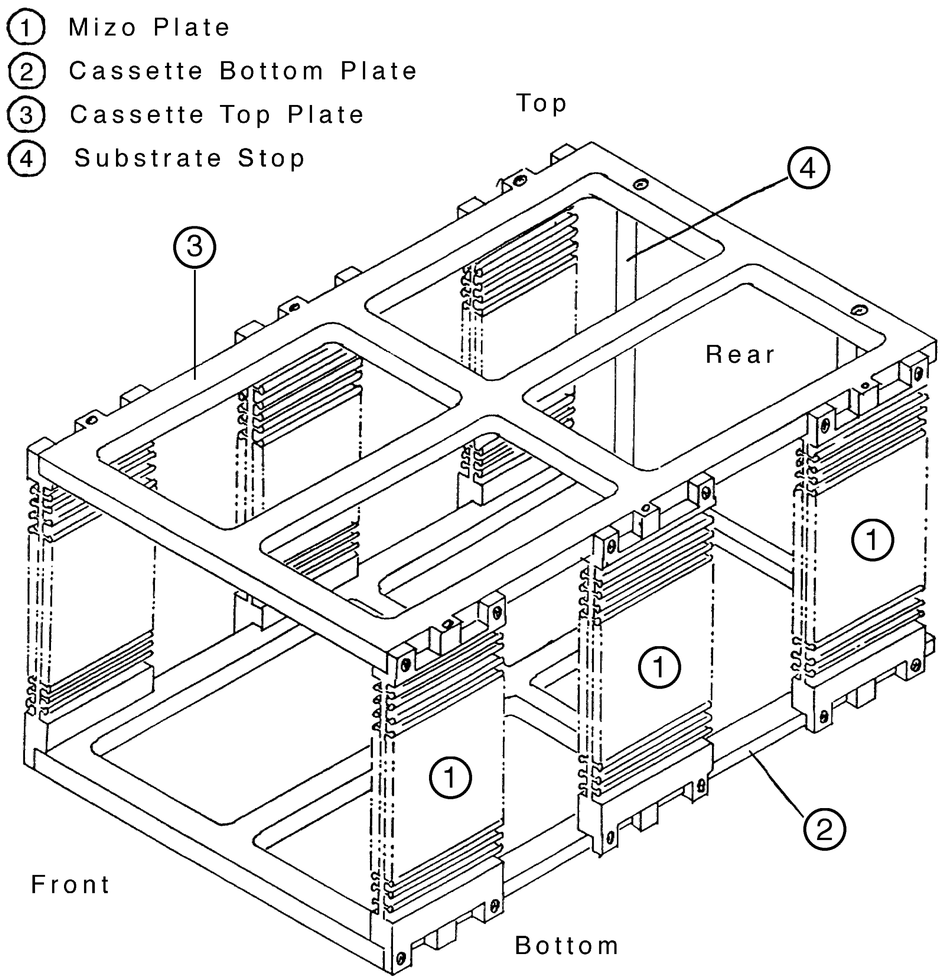

Figure 2

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI D12-95
SPECIFICATION FOR EDGE CONDITION OF FLAT PANEL DISPLAY (FPD) SUBSTRATES

1 Purpose

1.1 This document defines various aspects of the edges of a flat panel display substrate and describes their relationships. It assumes the existence of terminology described in other SEMI flat panel display documents. It applies to substrates whose nominal thickness specification is 1.1 mm.

2 Scope

2.1 *Significance* — The edges of a flat panel display substrate are important in both the specifications for and uses of the material. They effect the means for producing, handling, storing, and processing substrates. Defining the terminology and the geometric properties of these edges will assist both the producers and users of substrates and processing/inspection equipment.

3 Applicable Documents

3.1 *SEMI Documents*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D4 — Method for Referencing Flat Panel Display Substrates

4 Terminology

4.1 *corner* — of a substrate, any corner other than the orientation corner.

4.2 *edge length* — of a substrate, the nominal length of an edge, including that portion at the edge corner(s) from which material may have been removed for finishing purposes. It is "…defined by two dimensions X and Y, with nominal and tolerance values for each."

4.3 *orientation convention* — a means for denoting the rotational orientation of a substrate.

4.4 *orientation corner* — the corner of a substrate which identifies the pattern surface and rotational orientation.

5 Edge Condition

5.1 All edges shall be treated for purposes of operator safety and to minimize particulate generation. Edges shall be chamfered per Figure 1; other edge treatments are being developed as outlined in Related Information 1.

5.2 Other edge-related parameters shall be per Table 1.

6 Corner Condition

6.1 The orientation corner is asymmetrical for all substrates, with dimensions per Figure 2.

6.2 The edge condition within all corner areas shall meet the criteria of Section 5.

Table 1

Parameter	*Nominal*	*Tolerance*
Length	< 400 mm ≥ 400 mm	± 0.2 mm ± 0.3 mm
Squareness	≤ ± 1/1000 of longer edge for chamfered edge	

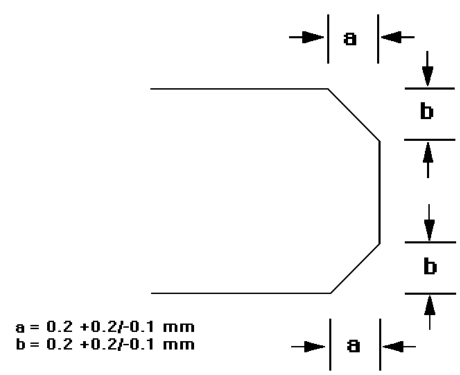

Figure 1
Chamfered Edge

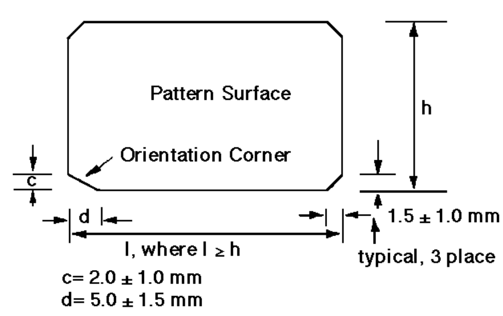

Figure 2
Substrate Corner Dimensions
(shown in 0,0 orientation)

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI D12 and is not intended to modify or supercede the official standard. Rather, this note describes methods for producing FPD substrate edges which may be under development. Publication was authorized by full letter ballot. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Current Practice

The edges of FPD substrates are modified during the substrate manufacturing process so that, in subsequent panel processing, operator safety is improved and particulate generation is minimized. Currently, a "chamfered edge" process is in general use. This modifies the two "corners" of each edge as shown in Figure 1.

R1-2 Future Developments

Other edge treatments may prove more efficient, and several alternate approaches are under development. Two of these are a "Radiused Edge" and "Rounded Edge," shown in Figures 3A and 3B. The radiused edge initially appears simple, but appropriate values of R, for various substrate thicknesses (T), are being examined for manufacturability. For cases where R > T, the proper "edge blend," where R intercepts the substrate pattern and back surfaces, may prove difficult to define and control.

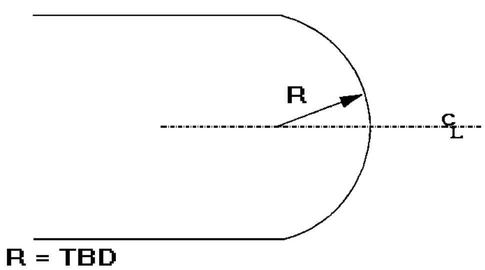

Figure 3A
Radiused Edge

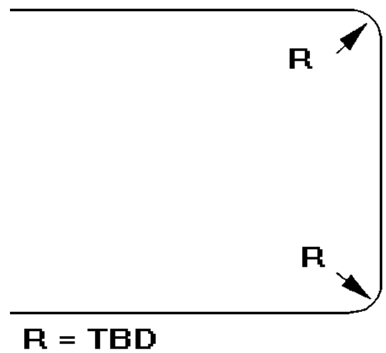

Figure 3B
Rounded Edge

SEMI D13-1101
TERMINOLOGY FOR FPD COLOR FILTER ASSEMBLIES

These specifications were technically approved by the Committee and are the direct responsibility of the Japanese FPD Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on April 19, 2001. Initially available at www.semi.org August 2001; to be published November 2001. This document was originally published in 1995.

1 Purpose

1.1 These terms and definitions describe various elements and characteristics of FPD color filter (CF) assemblies. They are intended to assist in future CF standardization activity.

2 Scope

2.1 Color filters comprise the front plate assembly in a colored flat panel display. They consist of a number of material layers such as glass substrate, color filter layer, black matrix, overcoat layer, and Indium Tin Oxide (ITO) films. Each of these layers has various properties which may need to be specified, produced, controlled, and characterized. This document provides an overview of these layers, with terms and definitions for selected elements, and indicates the appearance of some color filter defects. This document may be useful in developing material specifications, inspection criteria, and test methods.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document does not contain detailed measuring and test methods. Such methods may be developed separately, and references to them may be incorporated into color filter specification documents where appropriate. The assembly of color filters into a flat panel display assembly is not covered herein.

4 Related Standards

4.1 *SEMI Standards*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D20 — Defect Terminology for Flat Panel Display Masks

SEMI D21 — Terminology for Flat Panel Display Masks

SEMI M21 — Specification for Assigning Addresses to Rectangular Elements in a Cartesian Array

5 Color Filter Elements (see Figure 1)

5.1 *alignment control projection* — a rib-shaped protrusion created within the display pixel on the color filter film surface for the purpose of controlling alignment direction of the liquid crystal.

5.2 *backside ITO film* — a thin film of Indium Tin Oxide formed on the glass surface on the back of the color filter substrate.

5.3 *black matrix (BM)* — layer which blocks light transmission. It provides a boundary between color filter pixels, preventing the transmitting light between adjacent pixels.

5.4 *color filter layer* — colored layer through which light is transmitted. It is deposited in three colors—red, green, and blue—which are patterned to produce an array of contiguous, rectangular, or square-shaped pixels.

5.5 *glass substrate* — the base material onto which black matrix and color filter layer are deposited. Also called the Front Plate. After assembly into a Display, its back surface faces the observer. See SEMI D3 and SEMI D21 for parameters, definitions, and dimensional specifications.

5.6 *ITO Film* — a thin film of Indium Tin Oxide.

5.7 *overcoat layer* — transparent material deposited over the color filter material. This provides a smooth surface and enough adhesion for subsequent ITO material deposition.

5.8 *post spacer* — a fixed pillar-shaped spacer formed outside of the pixel opening.

5.9 *reflective film* — a light-reflective layer created on the color filter substrate below the color filter layer.

6 Color Filter Pixel (RGB) Layout

6.1 The color filter pixels are arranged in one of several array patterns. The array is constructed from m vertical columns and n horizontal rows of identical pixels of dimensions a horizontally and b vertically. The number of pixels in different rows and columns may vary to suit the application. These are illustrated in Figure 2.

7 Color Filter Types and Fabrication Methods

7.1 *Fabrication Methods*

7.1.1 *photolithography* — Patterning method by using micro photolithograph machines and photopatternable materials. Precise patterns can be formed.

7.1.2 *color photoresist method* — Defined as color photoresist, it is possible to create a pattern through a direct exposure method using color pigment or dye dispersed on a photoresist.

7.1.3 *dyeing* — Dyeable photoresist materials are patterned by photolithographic image processing. These patterned materials are dyed by a special method. The various colors may be introduced sequentially.

7.1.4 *etching* — Dye or pigment-dispersed color material is coated on substrate, and it is patterned by photolithographic etching method.

7.1.5 *printing* — Pigment-dispersed color ink is placed and patterned on the substrate by printing method.

7.1.6 *electric deposition* — Micro cells capsulating pigment particles are dispersed in water solvent and deposited on the selected electrode on glass substrate.

7.1.6.1 *patterned ITO method* — Color filter layers are accumulated using a micell distribution liquid for each color of the ITO pattern formed according to the various RGB color filter layers.

7.1.6.2 *resist pattern method* — Color filter layers are accumulated on non-patterned ITO film by using a micell distribution liquid through openings (windows) in the photoresist according to the RGB pattern.

7.1.7 *multi-layer interference CF (Dichroic CF)* — Multiple layers of inorganic transparent thin films are patterned by photolithography method.

7.1.8 *ink jet method* — Color filter layers are formed by pigment or dye-colored ink blown out from an ink jet head nozzle onto the substrate pixels.

7.1.9 *others* — Fabrication methods other than those above.

7.2 *coloring materials* — Other than the multi-layer interference method, these are formed using pigments or dyes.

7.2.1 *pigment* — This can be pigment in fine powder form dispersed into plastic, or it can be pigment in fine powder form then capsulated in micell (microcell) and dispersed in a water solution.

7.2.2 *dye* — Patterned plastic or gelatin is colored using dye. Also, dyed plastic or gelatin can be patterned using photolithography.

7.2.3 *inorganic permeable thin film* — A clear thin film of inorganic material formed through methods such as vacuum deposition or sputtering.

7.2.4 *Other*

Table 1 Color Filter Fabrication Methods and Materials

Fabrication Method (main category)	*Fabrication Method (subcategory)*	*Material*
Photolithography	Color Resist Method	Pigment/Dye
	Dyeing Method	Dye
	Etching Method	Pigment/Dye
Printing		Pigment
Electric Disposition	Patterned-ITO Method	Pigment
	Resist Pattern Method	Pigment
Mulit-layer Interference	Vacuum Evaporation Method	Inorganic Material
	Sputtering Method	Inorganic Materials
Ink Jet Method		Pigment/Dye

8 Visible Defects

8.1 *black defect* — Black dot-shaped defect existing in the quality area that can be detected using transmitted light.

8.2 *white defect* — White dot-shaped defect existing in the quality area that can be detected using transmitted light.

8.3 *BM (Black Matrix) spot* — A dot-shaped defect caused by extraneous BM material deposited within the quality area, not related to the BM pattern.

8.4 *BM (Black Matrix) pin hole or pinhole* — A dot-shaped defect located within the BM pattern.

8.5 *decolorant* — The absence of a color element in a normally tri-colored pixel. This may occur in a partial area of one pixel.

8.6 *color non-uniformity* — Variation in brightness or chromaticity within the quality area.

8.7 *color spot* — A mixing or overlapping of color materials within an RGB pixel.

8.8 *reflectance non-uniformity* — Variation in reflectance of the surface of color filter within the quality area.

8.9 *hill* — A gently sloping projection smaller than the cell gap width. Will cause cell gap defect.

8.10 *stain* — A small-area spot, with no appreciable thickness, on the surface of some color filter material. It may be caused by introduction of foreign substances during processing.

8.11 *layer particle* — A three-dimensional substance adhered to the surface of some color filter layer material.

8.12 *protrusion* — A large, severe projection larger than the cell gap width. Will cause cell gap defect.

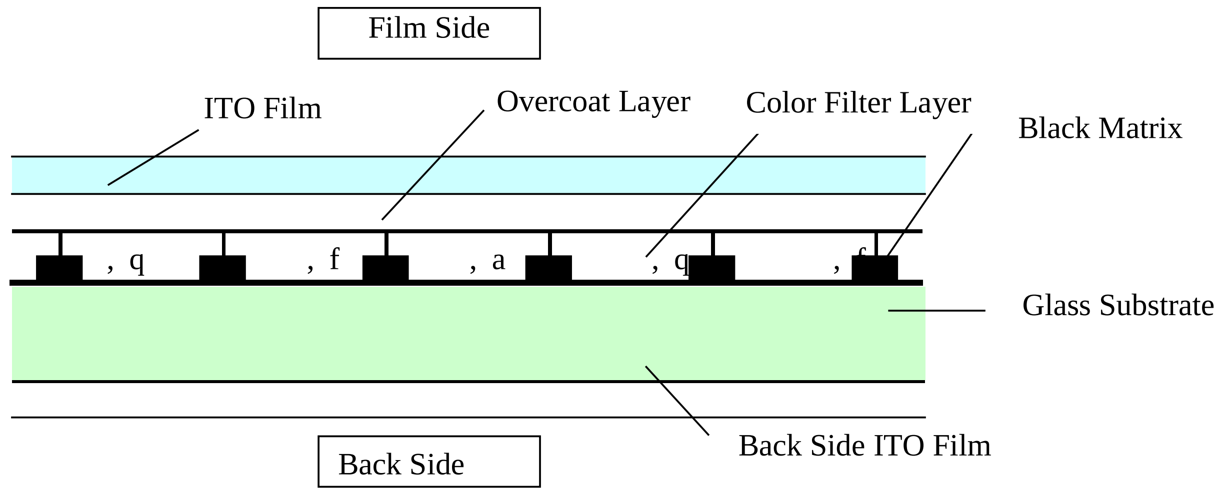

Figure 1
Color Filter Elements

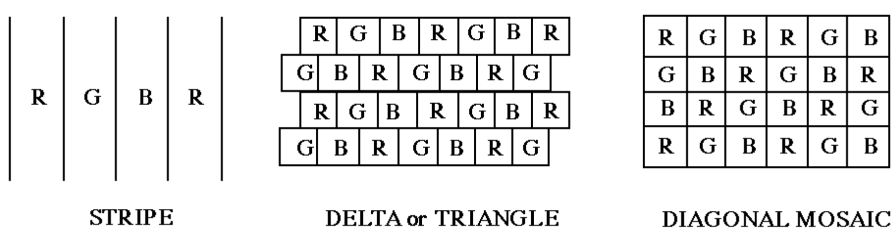

Figure 2
Color Filter Array Patterns

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SEMI D14-96
SPECIFICATION FOR IMAGE FIELD STITCHING CAPABILITIES OF FPD STEPPERS

1 Purpose

1.1 This specification provides a means for specifying the image field stitching performance of microlithographic stepping exposure systems used to expose resist-coated FPD display substrates ("FPD steppers").

2 Scope

2.1 Patterns produced on FPD display substrates by FPD steppers are often composed of multiple interconnected fields, in contrast to conventional silicon-based semiconductors where exposure field patterns are generally isolated from each other. In FPD manufacturing, the ability to perform this inter-field alignment is an important characteristic of FPD stepper performance. This specification defines the parameters required to specify stitching performance of FPD steppers for both single- and multiple-reticle applications.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI D8 — Specification for Overlay Capabilities of FPD Steppers

SEMI Compilation of Terms

3.2 *ASTM*[1]

Standard 15D — Manual on the Presentation of Data and Control Chart Analysis

3.3 *NIST*[2]

Handbook 91 — Experimental Statistics, M G Natrella

4 Terminology

4.1 *butting error, on an FPD substrate* — See stitching error.

4.2 *photocomposition error on an FPD substrate* — See stitching error.

4.3 *stitching on an FPD substrate* — The process of aligning and exposing multiple adjacent interconnected fields using an FPD stepper.

4.4 *stitching error on an FPD substrate* — A vector quantity defined at every point along exposure field boundaries within the patterned area. (See also butting area and photocomposition error.) It is the difference, *O*, between the vector position, P_1, on one side of an exposure field boundary, and the vector position of the corresponding point, P_2, on the other side of the exposure field boundary. (see also butting area and photo compositon):

$$O = P_2 - P_1$$

The stitching error value, *O*, may be decomposed into orthogonal components O_x and O_y along the directions of the stepper stage motions.

The stitching error value, *O*, may also be decomposed into orthogonal components $O_{=}$, parallel to, and $O_{\perp}$, perpendicular to the directions of the exposure field boundaries.

NOTE: $O_{=}$ and $O_{\perp}$ are commonly referred to as "shear" stitching error and "overlap" stitching error.

5 Ordering Information

5.1 Purchase orders for steppers furnished to this specification shall include the following items:

5.1.1 *Permissible Stitching Error*

5.1.1.1 *O*, or

5.1.1.2 O_x and O_y, or

5.1.1.3 $O_{=}$ and $O_{\perp}$.

5.1.2 Number of data points to be analyzed and method(s) of overlay calculation.

6 Test Methods

6.1 The test methods for stitching error characterization shall be agreed upon between user and supplier.

1 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 National Institute of Standards and Technology, Publications Department, Gaithersburg, MD 28099

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SEMI D15-1296
FPD GLASS SUBSTRATE SURFACE WAVINESS MEASUREMENT METHOD

1 Purpose

1.1 This document covers the measurement of FPD glass substrate surface waviness by measuring instruments employing mechanical stylus, optical stylus, and optical interferometric measurement methods.

2 Scope

2.1 This test method is applicable to the documentation of waviness of all types of glass substrates used for flat panel displays.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D4 — Method for Referencing Flat Panel Display Substrates

SEMI D9 — Definitions for Flat Panel Display Substrates

3.2 *ISO Documents*[1]

ISO 1101 - 1983 — Technical drawings — Geometrical Tolerances — Tolerances of Form, Orientation, Location and Run-Out — Generalities, definitions, symbols, indications on drawings.

ISO 3274 - 1975 — Instruments for the Measurement of Surface Roughness by the Profile Method — Contact (Stylus) Instruments of Consecutive Profile Transformation

4 Terminology

4.1 *bandpass filtered waviness profile* — A profile obtained by removing the long wavelength form components and short wavelength roughness components from a sampled real profile (see Figure 2).

4.2 *2CR filter* — A profile filter equivalent to a series of two CR filter circuits (see ISO 3274).

The standard transmission coefficients at cut-off wavelength are 75%.

4.3 *evaluation length, L_e* — The length of the profile used for assessing the waviness profile under evaluation. A traced length after deduction of both pre-travel and post-travel.

4.4 *FPD waviness, W_{fpd}* — Moving minimum zone method straightness of waviness. The maximum value of a minimum zone method straightness of a certain sampling length within an evaluation length. An approximation in Appendix 1 can be used as well.

DISCUSSION — In fact, it takes a long time to calculate W_{fpd} by the above method because of too large a number of sampling lengths which are all sampled data points within evaluation length minus the number of data points within a sampling length.

Therefore, is recommended that the computer approximation method described in Appendix 1 be used to save time.

Another manual evaluation method is the following:

1. Prepare the template which has a sampling length width window.
2. Scan the template with fitting properly on the recorded chart of bandpass-filtered waviness profile through the evaluation length.
3. Read out every straightness of the profile within the window of the template on every fitted position.
4. The maximum value of all of the readings is W_{fpd}.

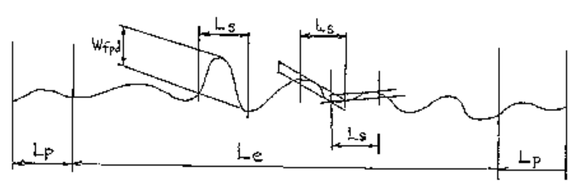

Figure 1
Explanation of L_e, L_p, L_s

4.5 *long wavelength cut-off, λ_L* — Wavelength that the attenuation ratio of its amplitude becomes a standard value when the traced profile is passed through the high-pass wavelength filter which eliminates form element.

4.6 *minimum zone method straightness* — The smallest distance between two parallel straight lines between which all of objective profile is included (see ISO 1101, Section 3.1).

1 American National Standards Institute, 11, W. 42nd St., New York, NY 10036

4.7 *optical interferometric flatness Measuring instrument* — instrument that analyzes the surface irregularities of a target, from the distribution of light intensity of laser interferometer between the target surface and datum flat.

4.8 *optical stylus method measuring instrument* — Instrument that uses the same profile method that a stylus method instrument uses. This instrument uses the displacement transducer to apply the spotlight to the target surface instead of using the stylus to apply the spotlight.

4.9 *phase correct filter* — A profile filter which does not cause phase shifts between total profile and filtered profile.

The standard transmission coefficients at cut-off wavelength are 50%.

4.10 *pre-travel (and post-travel),* L_p — Eliminated portions from a traced length for avoiding the profile distortion caused by transient response of the cut-off filter.

Recommended pre-travel with 2CR filter is double the long wavelength cut-off, λ_L, at the beginning of the traced length and no post-travel.

Recommended both pre-travel and post-travel with phase correct filter are the same as long wavelength cut-off, λ_L.

4.11 *real profile* — An intersection of a target surface with a plane perpendicular to the surface (see Figure 2).

4.12 *sampling length,* L_s — the length of the profile for calculations of waviness parameters in an evaluation length (L_e).

4.13 *short wavelength cut-off,* λ_c — Wavelength that the attenuation ratio of its amplitude becomes a standard value when the traced profile is passed through the low-pass wavelength filter which eliminates roughness element.

4.14 *streak* — A defect whose appearance is a transparent line on the glass substrate surface. It can either be caused by a micro surface discontinuity or a cord due to the heterogeneity of glass composition.

4.15 *stylus method measuring instrument* — Instrument that traces on a section of a surface by a stylus, records irregularity on the surface in an enlarged form, and indicates its amplitude as parameters (see ISO 3274).

4.16 *traced length* — Total traversing length of stylus or spotlight.

4.17 *waviness* — Components of surface irregularities with spatial wavelength intermediate between long wavelength (flatness) and short wavelength (roughness) (see Figure 2).

DISCUSSION — Especially on FPD substrates, those components cause visual irregularity of the shade of the panel due to deviations of the cell gap.

Waviness includes not only periodic waviness, but also streaks.

5 Measuring Instrument

5.1 *Method* — Stylus method measuring instrument, optical stylus instrument, or optical interferometric flatness measuring instrument.

5.2 *Stylus or Spotlight*

5.2.1 *Shape* — circular cone or sphere

5.2.2 *Tip radius* — from 2µm to 0.8 mm (0.03 inch)

5.2.3 *Spotlight* diameter of optical stylus method — 0.2 mm (0.0079 inch) or less

5.2.4 *Horizontal resolution of interferometer* — 0.2 mm (0.0079 inch) or less

5.3 *Measuring Force for Stylus Method* — 4 mN (0.4 gf) or less

5.4 *Sampling Interval* — 0.2 mm (0.0079 inch) or less

5.5 *Profile Filter* — 2CR filter or phase correct filter

DISCUSSION — The filtering method should be specified because the evaluated value of W_{fpd} with phase correct filter will be smaller than that with 2CR filter.

6 Measurement Conditions

6.1 *Target Surface* — The pattern surface (see SEMI D4, Section 5)

6.2 *Long Wavelength Cut-Off,* λ_L — 8 mm (0.3 inch) or 25 mm (1 inch)

6.3 *Short Wavelength Cut-Off,* λ_c — 0.8 mm (0.03 inch)

6.4 *Evaluation Length,* L_e — Is recommended to be Q_{ax} or Q_{ay}, total edge length of quality area of a substrate. If Q_{ax} or Q_{ay} is longer than (L_t - 2*λ_L), L_e is recommended to be (L_t – 2*λ_L).

If the measurable length of the instrument is shorter than the recommended length, then the overlapped section, which contains several traced profiles covering all of the recommended lengths, should be used to evaluate W_{fpd}.

6.5 *Sampling Length, L_s* — Is recommended to be 20 mm (0.79 inch) at λ_L = 8 mm (0.3 inch) or 25 mm (1 inch) at λ_L = 25 mm (1 inch).

7 Test Specimen

7.1 A clean FPD glass substrate. No strain or oils should be seen by the naked eye with fluorescent lamps or incandescent lamps.

8 Measurement Procedure

8.1 Put the specimen on the leveled stage of the instrument without bend and leave for five minutes or more to condition the specimen to room temperature.

8.2 Put the stylus on the specimen and measure a real profile parallel to the edge of substrate by tracing the surface.

8.3 Apply the bandpass profile filter to the real profile and get the bandpass-filtered waviness profile.

8.4 *Calculate the FPD Waviness* — W_{fpd} with manual template method or computer-aided method from the bandpass-filtered waviness profile.

9 Reporting Results

9.1 *Measurement Location and Direction* — Describe the measurement location and direction on the report; for example, measure along the following two directions:

a. the center line of the specimen parallel to the long edge

b. the center line of the specimen parallel to the short edge

9.2 *Interpretation of Results* — Show the measurement results in units of 0.01 µm (micron) and count fractions of 0.5 and over as a unit and cut away the rest.

Table 1 Example: Measurement Result

Direction	L_e	W_{lcd}
Long Edge	**mm	0. **µm
Short Edge	**mm	0. **µm

Measuring Condition

Surface — The pattern surface

Instrument — Stylus method (type of instrument)

Long cut-off, λ_L — 8 mm

Short cut-off, λ_c — 0.08 mm

Sampling length, L_s — 20 mm

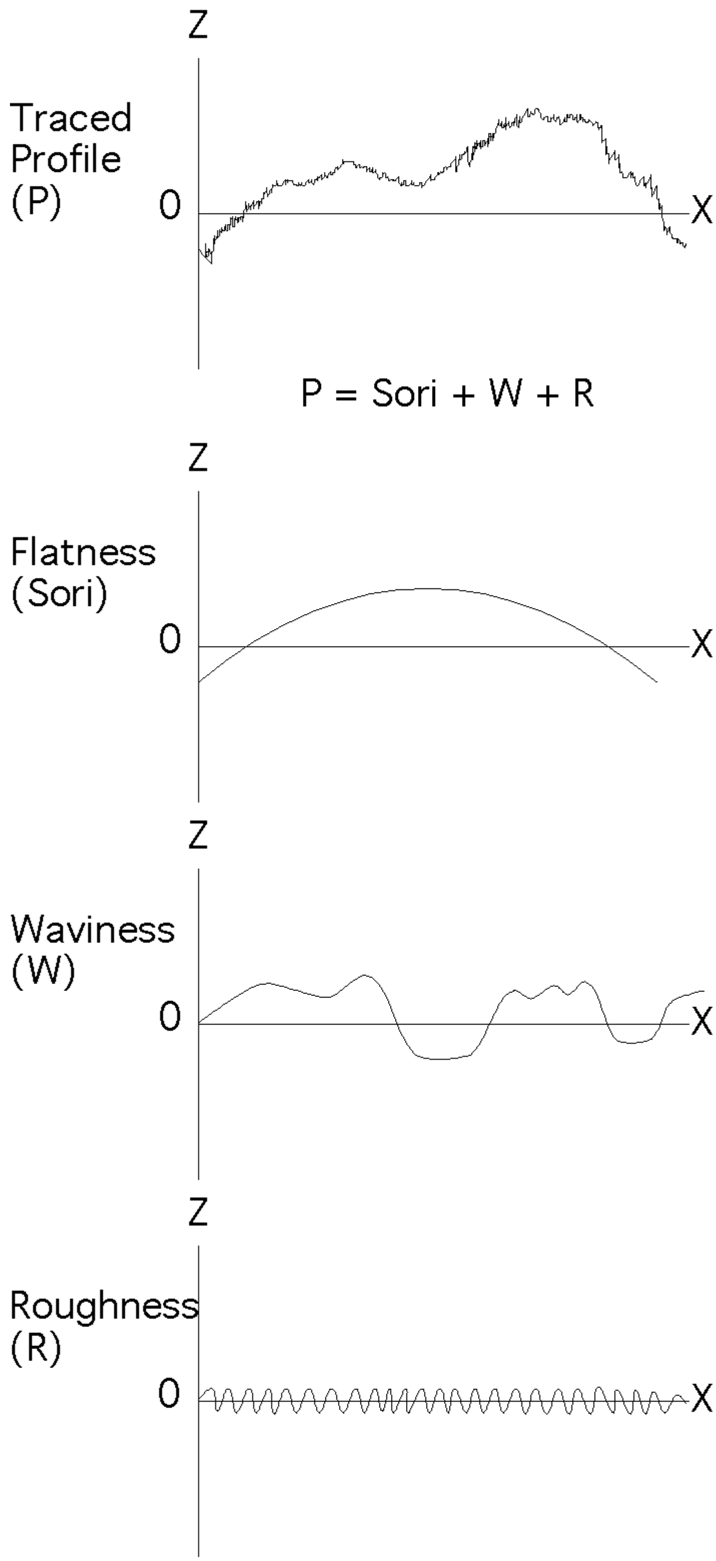

Figure 2
Explanation of Surface Profiles

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI D15 by full letter ballot procedure.

.A1-1 Purpose

A1-1.1 FPD waviness W_{fpd} requires a large amount of calculation on this standard.

A1-1.2 Therefore, the approximate calculation method shown below can be used instead.

A1-2 Terminology

A1-2.1 local peak of profile — The highest point of profile between two adjacent minima of the profile.

A1-2.2 local valley of profile — The lowest point of profile between two adjacent maxima of the profile.

A1-2.3 window — A sampling length for evaluation.

A1-3 Calculation Method

A1-3.1 Search all local peaks and local valleys within the evaluation length.

A1-3.2 Calculation of a waviness value based on a local peak.

A1-3.2.1 Calculation of a waviness value, W_{iL}, based in the left window of a local peak, P_i (position X_i).

1. Open the left window (L_1 - X_i) with L_s/2 width from the local peak, P_i.
2. Search the lowest point, V_L (position L_2), in the window (L_1 - X_i).
3. Find the point $L_3 = L_2 + L_s$ and open the window (X_i - L_3).
4. Search the lowest point, V_{LR}, in the window (X_i - L_3).
5. $W_{iL} = |Z_i - (V_L + V_{LR}) /2|$

A1-3.2.2 Calculation of a waviness value, Wi_R, based in the right window of a local peak, P_i.

1. Open the right window (X_i - R_1) with L_s/2 width from the local peak, P_i.
2. Search the lowest point, VR (position R_2), in the window (X_i - R_1).
3. Find the point $R_3 = R_2$ - Ls and open the window (R_3 - X_i).
4. Search the lowest point, V_{RL}, in the window (R_3 - X_i).
5. $W_{iR} = |Z_i - (V_R + V_{RL}) /2|$

A1-3.2.3 Calculate W_{iL} and W_{iR} on all local peaks, P_i, then calculate the maximum value, WP_{max}.

$WP_{max} = \max \{W_{iL}, W_{iR}\}$ (i = 1 to n)

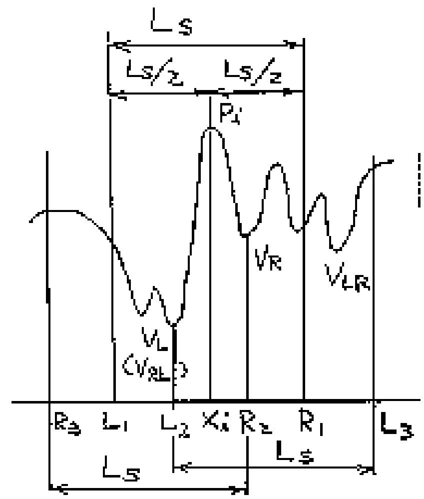

Figure A1-1
Calculation Points of a Local Peak

A1-3.3 Calculation of a waviness value based on a local valley.

A1-3.3.1 Calculation of a waviness value, W_{jL}, based in the left window of a local valley, V_j (position X_j).

1. Open the left window (L_1 - X_j) with L_s/2 width from the local valley, V_j.
2. Search the highest point, P_L (position L_2), in the window (L_1 - X_j).
3. Find the point $L_3 = L_2 + L_s$ and open the window (X_j - L_3).
4. Search the highest point, P_{LR}, in the window (X_j - L_3).
5. $W_{jL} = |Z_j - (P_L + P_{LR}) /2|$

A1-3.3.2 Calculation of a waviness value, W_{jR}, based in the right window of a local valley, V_j.

1. Open the right window (X_j - R_1) with L_s/2 width from the local valley, V_j.

2. Search the highest point, P_R (position R_2), in the window (X_j - R_1).

3. Find the point $R_3 = R_2 - L_s$ and open the window (R_3 - X_j).

4. Search the highest point, P_{RL}, in the window (R_3 - X_j).

5. $W_{jR} = |Z_j - (P_R + P_{RL}) /2|$

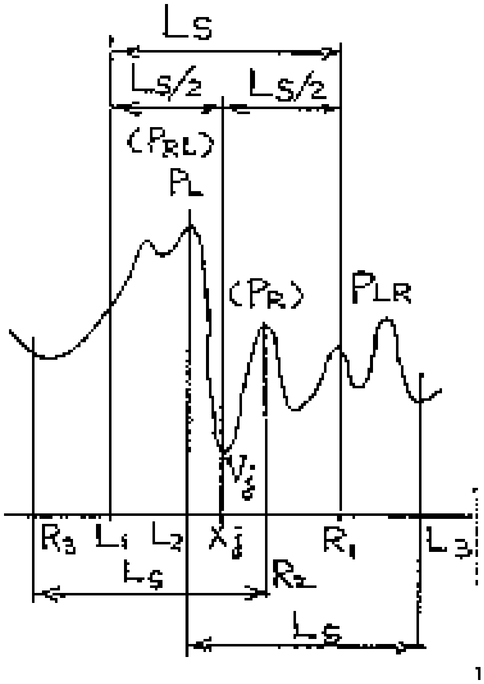

Figure A1-2
Calculating Points of a Local Valley

A1-3.3.3 Calculate W_{jL} and W_jR on all local valleys, V_j, then calculate the maximum value, WV_{max}.

$WV_{max} = \max \{W_{jL}, W_{jR}\}$ (j = 1 to n)

A1-3.4 *Calculation of FPD Waviness, W_{fpd}* — Calculate the maximum value among all maximum values calculated in Sections 3.2.3 and 3.3.3.

$W_{fpd} = \max \{WP_{max}, WV_{max}\}$

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI D16-0998
SPECIFICATION FOR MECHANICAL INTERFACE BETWEEN FLAT PANEL DISPLAY MATERIAL HANDLING SYSTEM AND TOOL PORT

This specification was technically approved by the Flat Panel Display Equipment Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Stadards Committee July 1998. Published on SEMI OnLine September 1998; print version published September 1998.

1 Purpose

1.1 This specification defines feature requirements on and about tool ports of process tools used in manufacturing of flat panel displays. These feature requirements facilitate the interfacing of transport equipment to the tool by standardizing the feature requirements. Such standards are intended to promote cost-effective interfacing while preserving freedom of choice in material handling equipment.

2 Scope

2.1 These standards define mechanical features on or about the process tool port, and in front of or on the tool face. Although these features are intended for specific functions, they do not set design requirements for any particular functionality. The interface requirements are meant to be universal and to avoid the promotion of any particular form of transport. Therefore, they are useful for the interfacing of continuous direct WIP transports, such as conveyors, or discrete vehicles of foreseeable future design, such as AGVs, to the process tool port. The dimensions incorporated in the standard apply to single panel handling as well as substrate carriers.

3 Limitations

3.1 Current display manufacturing utilizes several substrate sizes, many of them “non-standard.” This proposed interface specification includes dimensions for the substrate sizes of 550 × 650 mm, and 600 × 720 mm and anticipates the establishment of standard dimension in future substrate sizes. For these future substrate sizes, a universal dimensioning method based on substrate size may be possible.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI D5 — Standard Size for Flat Panel Display Substrates

SEMI D11 — Specification for Flat Panel Display Glass Substrate Cassettes

5 Terminology

5.1 *Definitions*

5.1.1 *facial datum plane* — the plane coincident with the front face of the tool and perpendicular to the horizontal and vertical datum planes.

5.1.2 *horizontal datum plane* — the plane coincident with the top surface of the floor and perpendicular to the facial datum plane of the tool.

5.1.3 *vertical datum plane* — the plane that bisects the tool port and is perpendicular to the horizontal and facial datum planes.

5.2 *Functional Description of Dimensions*

5.2.1 *X1* — width of exclusion zone reserved for vertical material handling devices; maximum.

5.2.2 *X2* — width of the tool port at Z7 below tool load plane. This defines the horizontal limit of the tool port in the x-y plane at that level, beyond which space is reserved for transport equipment; maximum.

5.2.3 *Y1* — maximum tool port protrusion from the tool face. This dimension defines the limits of tool port attachments.

5.2.4 *Y2* — the centerline distance between substrate and tool face when the substrate is delivered to the tool port; ± 10 mm.

5.2.5 *Y3* — depth of the exclusion zone used for PGV cart alignment devices; maximum.

5.2.6 *Y4* — overhead exclusion zone for ceiling-hung material delivery systems; maximum.

5.2.7 *Y5* — maximum protrusion from tool port. May be used for mounting docking devices (mostly PGVs).

5.2.8 *Z1* — height of tool port; ± 10 mm (load plane of reference).

5.2.9 *Z2* — the lowest point on an overhead delivery system; minimum.

5.2.10 *Z3* — the maximum volume height of an overhead delivery system. This dimension extends the full width of the tool.

5.2.11 *Z4* — the height of the exclusion zone used for PGV cart alignment devices.

5.2.12 *Z5* — the maximum height of the protrusion used for docking devices.

5.2.13 *Z6* — the location for the bottom plane of the first substrate. This dimension is not specified in this document.

5.2.14 *Z7* — height of exclusion zones used by conveyor rails and fork lifts; maximum.

6 Requirements

6.1 Dimensions and tolerances of the required features are specified in Table 1 and Figures 1A and 1B.

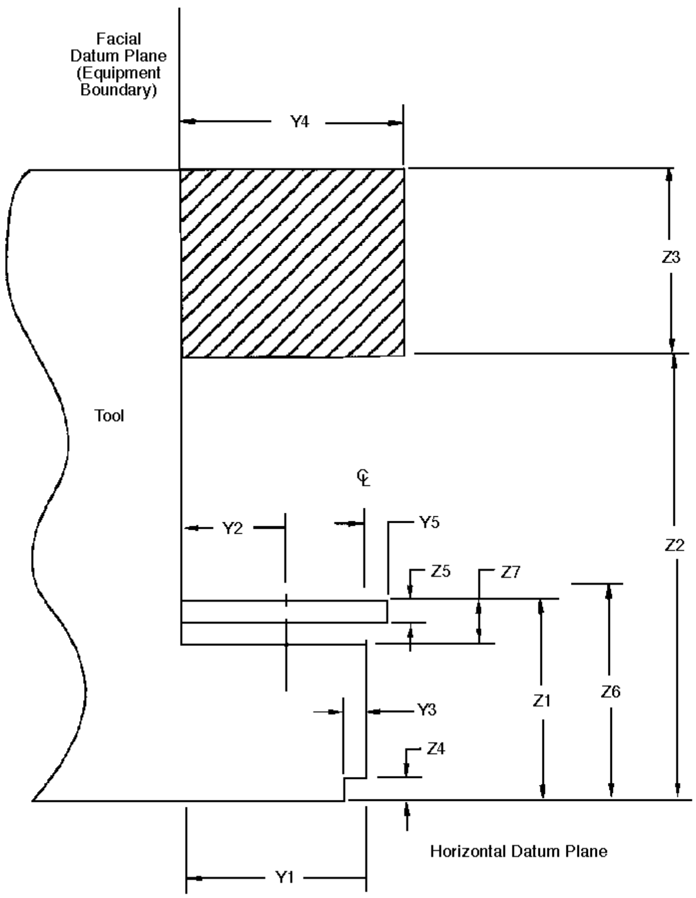


Figure 1A
Proposed Transport System to Tool Interface

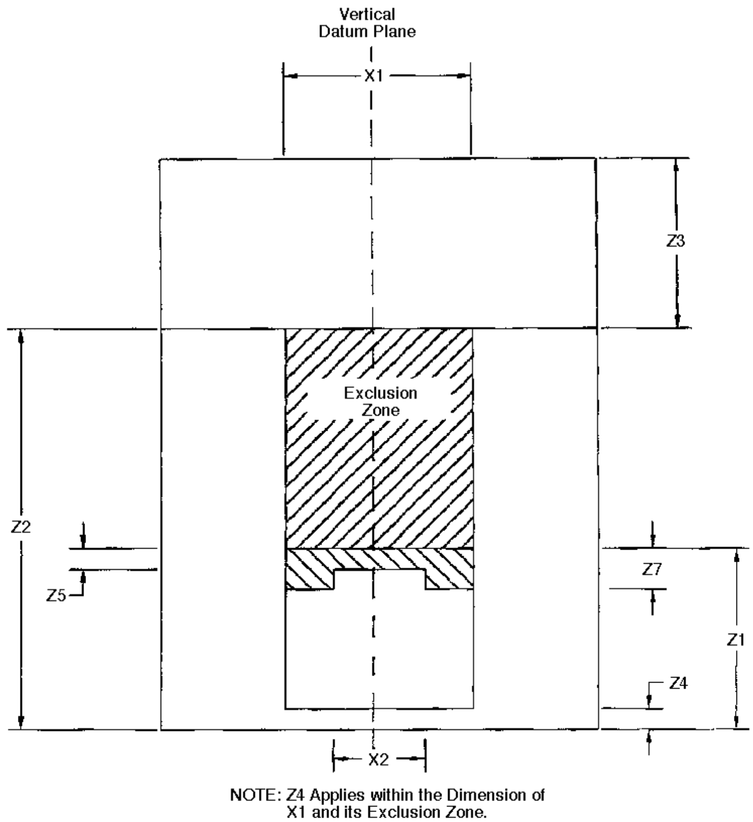


Figure 1B
Proposed Transport System to Tool Interface

6.2 Centerline location of the substrate, as it is delivered by the material handling equipment, with respect to the tool face may not coincide with the centerline location of the substrate when the latter is finally positioned on the tool port for substrate handling.

6.3 Substrate delivery is to be horizontal, active (pattern) face up.

6.4 The single substrate or carrier is to have a horizontal loading orientation with shorter side parallel to the tool face plane.

6.5 Load height of the single substrate or carrier shall be adjustable on the material handling system within 20 (± 10) mm of the nominal height.

6.6 There should be no obstruction between the load port and the material delivery system within the defined adjustable range of the load port height.

6.7 Load and unload mechanisms must allow operator-assisted loading. This implies clearance space for the operator, as well as mechanisms that allow manual override.

Table 1 Substrate Edge Length, Interface Dimensions, and Tolerances (mm)

	Interface Dimensions and Tolerances													
Edge Length (mm)	*X1 max.*	*X2 max.*	*Y1 max.*	*Y2 ± 10 mm*	*Y3 max.*	*Y4 max.*	*Y5 max.*	*Z1 ± 10 mm*	*Z2 min.*	*Z3 max.*	*Z4 max.*	*Z5 max.*	*Z6*	*Z7 max.*
550 × 650	925	450	800	400	100	1000	100	900	2000	850	100	105	tba	200
600 × 720	980	500	865	435	100	1065	100	900	2000	850	100	105	tba	200
960 × 1100	1450	900	1360	650	100	1500	100	900	2000	850	100	105	tba	200

SEMI D17-0200
MECHANICAL SPECIFICATION FOR CASSETTES USED TO SHIP FLAT PANEL DISPLAY GLASS SUBSTRATES

This specification was technically approved by the Global Flat Panel Display – Equipment Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available on SEMI OnLine January 2000; to be published February 2000. Originally published September 1998.

1 Purpose

1.1 This standard specifies selected requirements of the cassettes used to ship flat panel substrates from the substrate finisher to the display maker and between process-added users.

1.2 This document incorporates pertinent dimensional data from SEMI D18, Specification for Cassettes Used for Horizontal Transport and Storage of Flat Panel Display Substrates.

2 Scope

2.1 This standard is intended to set levels of specification for a reusable cassette to ship clean glass substrates and process-added substrates between organizations without compromising substrate integrity. This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at common mechanical interfaces.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Substrate size and thickness are not specified so as not to cause constraints on supplier/customer relationships.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI D18 — Specification for Cassettes Used for Horizontal Transport and Storage of Flat Panel Display Substrates

SEMI E15 — Specification for Tool Load Port

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

See Figure 1 and Table 1.

5.1 *bilateral datum plane* — a vertical plane that equally bisects the substrate and that is perpendicular to both the horizontal and facial datum planes.

5.2 *carrier capacity* — the number of substrates that a carrier holds.

5.3 *cassette* — as defined in SEMI E44.

5.4 *cassette bottom domain* — volume (below z4 above the horizontal datum plane) that contains the bottom of the cassette.

5.5 *cassette front* — the area between the cassette top and bottom domains through which substrates pass during loading and unloading.

5.6 *cassette placement sensing pads* — surfaces on the bottom of the cassette for triggering optical or mechanical sensors.

5.7 *cassette rear* — the area between the cassette top and bottom domains opposite the cassette front.

5.8 *cassette rear domains* — volumes (from z4 above the horizontal datum plane to z9 above the top substrate) that contain rear columns which prevent the substrates from exiting the cassette rear.

5.9 *cassette side domains* — volumes (from z4 above the horizontal datum plane to z9 above the top substrate) that contain the mizo teeth and mizo plates that support the substrates.

5.10 *cassette top domain* — volume (higher than z9 above the top substrate) that contains the top of the cassette.

5.11 *conveyor rails* — features on the bottom of the cassette for supporting the cassette on roller conveyors.

5.12 *conveying surface* — entire bottom surface of cassette (z15 above the horizontal datum plane), excluding the v-rail, v-groove, and float roller zones, for supporting the cassette on roller conveyors.

5.13 *facial datum plane* — a vertical plane that equally bisects the substrates when the centers of the substrates are aligned and that is parallel to the front side of the carrier (where substrates are removed or inserted) and is perpendicular to the bilateral datum plane. On tool load ports, it is also parallel to the load face plane (as defined in SEMI E15) on the side of the tool where the carrier is loaded and unloaded.

5.14 *first nominal substrate height* — the distance (z5) from the horizontal datum plane to the first nominal substrate seating plane.

5.15 *first substrate end-effector clearance* — the distance (dimension z9) between the top of the cassette bottom domain and the first nominal substrate seating plane.

5.16 *horizontal datum plane* — load height as defined in SEMI E15.

5.17 *mizo plate* — a plate that contains mizo teeth and may provide structure to the cassette.

5.18 *mizo teeth* — elements that support the substrates in the cassette.

5.19 *nominal center line* — the intersection of the facial and bilateral datum planes.

5.20 *nominal substrate seating plane* — a horizontal plane that contains the nominal bottom surface of the substrate as it rests on the mizo teeth.

5.21 *optical substrate sensing paths* — lines of sight for optically sensing the positions of the substrates.

5.22 *polystyrene latex sphere (PSL)* — Reference material used to calibrate surface inspection systems.

5.23 *robotic handling flanges* — projections on the cassette for handling of the cassette.

5.24 *substrate extraction volume* — the open space for extracting a substrate from the cassette.

5.25 *substrate pick-up zone* — the space that includes the volume in which the substrate bottom may be found.

5.26 *substrate pitch* — the distance between adjacent nominal substrate seating planes.

6 Requirements

6.1 *Physical Protection of Substrate*

6.1.1 No chipping, scratching, or other damage shall occur under normal handling and shipping conditions.

6.1.2 Substrates shall be contained to prevent excess movement during shipment.

6.2 *Provisions for Tracking and Identification* — Provision for a printed label should be made.

6.3 *Thermal Requirements* — Construction materials shall withstand cleaning temperatures of 90ºC, following which the cassette shall meet the dimensional and other requirements of this specification.

6.4 *Loading/Unloading of Substrates*

6.4.1 Cassettes furnished to this specification must be compatible with manual and automated loading/ unloading systems, while minimizing cassette volume.

6.4.2 Such cassettes must also facilitate transfer of substrates to and from, a Transportation/Automation Cassette.

6.5 *Cassette Physical Alignment Interface* — The cassette should be registered to the tool interface by one of the three following registration types, A, B, or C. The locations of the registration features have been chosen such that all three types may coexist on the same cassette.

6.5.1 *Cassette Physical Alignment Interface Type A* — This interface consists of three features (not specified, but recommended to be inverted V-shaped grooves) placed on the bottom of the cassette that mate with three coupling pins located on the tool interface. The coupling pins are located by dimensions x14 and y13 relative to the bilateral and facial datum planes respectively.

6.5.1.1 *Coupling Pin Shapes* — The physical alignment mechanism on the bottom of the wafer carrier consists of features (not specified in this standard) that mate with three pins underneath. As shown in Figure 5 and defined in Table 3, each pin is radially symmetric about the vertical center axis line and can be seen as the intersection of a cylinder of diameter d1 and a sphere of radius r3 (which might contact a flat plate). An additional rounding radius r5 provides contact with angled mating surfaces, and blend radii r4 and r6 smooth the resulting edges. The final roughness height of the overall surface finish must be less than or equal to r7. Dimensions r2 and z13 have zero tolerance because they only give a distance to another toleranced dimension. (Dimensions in parenthesis are not part of the requirements in this standard but are intended to clarify the preparation of manufacturing instructions.)

6.5.1.2 The three features on the bottom of the cassette that mate with the coupling pins must provide a lead-in capability that corrects a cassette misalignment of up to 10 mm (0.4 in.) in any horizontal direction, although 15 mm (0.6 in.) is recommended. The exclusion zones for the three coupling features on the cassette are shown in Figure 3 and Table 1 and specified by dimensions x14, z9 and r1.

6.5.2 *Cassette Physical Alignment Interface Type B* — This interface consists of three features, a v-rail, float surface, and facial datum plane v-groove. The v-rail and float surface are located on the bottom of the cassette and mate with the two v-rail rollers and one float surface roller, respectively, mounted on the tool interface. The facial datum plane v-groove is located about the facial datum plane through the bottom surface of the cassette and mates with the facial datum plane lock pin located on the tool interface shown in Figure 3. The v-rail roller and the float surface roller are located by dimensions x15 and x16 relative to the bilateral datum plane, respectively, shown in Figure 6. The dimensiona relative to the facial datum plane for the v-rail rollers are not specified but recommended to be located furthest from and symmetrical about the facial datum plane as shown in Figures 3 and 6. The float surface roller revolute axis must lie on the facial datum plane.

6.5.2.1 The v-rail and float surface rollers are defined in Figure 7 and Table 4. Each roller is radially symmetric about the revolute axis. The rollers are circumferentially radiused of dimension r8. The diameter of the rollers is not specified, but the tangential surface created by dimension r8 must lie on the horizontal datum plane. The facial datum plane lock pin radius is equal to r8 and must be positioned into the facial datum plane v-groove to fully constrain the cassette to the facial datum plane. The facial datum plane lock pin is translated out of the facial datum plane v-groove to allow the cassette to be rolled in and out of the tool interface. Although only three rollers are specified, it is recommended to increase the total number of rollers so that the cassette is fully supported while being loaded and unloaded to the tool interface. All rollers, except for the v-rail and float roller, must be positioned so that the tangent of the r8 dimension lies below the horizontal datum plane.

6.5.2.2 The three features on the bottom of the cassette that mate with the rollers and lock pin must provide a lead-in capability that corrects a cassette misalignment of up to 10 mm (0.4 in.) in any horizontal direction, although 15 mm (0.6 in.) is recommended. The v-rail and facial datum plane v-groove are not specified but recommended to be inverted v-shaped grooves. The v-rail is recommended to extend the full length of the cassette from the cassette front to the cassette rear. The float surface is not specified but recommended to be a flat surface extending the full length of the cassette from the cassette front to the cassette rear. The exclusion zones for these features are shown in Figures 3 and 6 and specified by dimensions x15 and x16 through x22.

6.5.3 *Cassette Physical Alignment Interface Type C* — To be developed.

6.6 *Conveyor Rails* — If the cassette is to be transported on roller conveyors, each conveyor rail should extend the maximum distance from front to back. The exclusion zones for conveyor rails are shown in Figures 3 and 6 and specified by dimensions x13 and x22 and extend to the outer boundary of the cassette.

6.7 *Conveying Surface* — If the cassette is to be transported on roller conveyors that support the entire bottom of the cassette, the bottom surface excluding the v-rail, v-groove, and float roller zones is to be used. The location of this surface with respect to the horizontal datum plane is specified by dimension z3.

6.8 *Substrate Orientation* — The substrates must be horizontal when the carrier is placed on the coupling.

6.9 *Cassette Sides and Rear* — Figure 2 shows a top view of the boundaries of the cassette side domains (which contain the parts of the cassette higher than z4 above the horizontal datum plane and lower than z9 above the top substrate). Table 1 defines the dimensions shown in this and following figures.

6.10 *Cassette Top* — The boundaries of the cassette top domain contain any part of the cassette hither than z9 above the top substrate.

6.11 *Cassette Bottom* — Figure 3 shows a bottom view of the boundaries of the cassette bottom domain (which contains any part of the cassette lower than z4 above the horizontal datum plane). When the cassette is fully down, the cassette placement sensing pads must be z2 above the horizontal datum plane.

6.12 *Vertical Dimensions*

6.12.1 Figure 4 shows the vertical dimensions of the left half of the cassette as viewed from the rear. Note that z5 (the height of the bottom nominal substrate seating plane above the horizontal datum plane) and z8 (the distance between adjacent nominal substrate seating planes) are given as reference dimensions with no tolerance. This means that the sum of actual height variations in the cassette from the horizontal datum plane to the mizo tooth or slot holding each substrate must be contained within the tolerance of z6 with no further stack-up at each higher substrate.

6.12.2 The open space for the substrate extraction volume is indicated by dimensions x6 and y7 and is symmetric about the bilateral and facial datum planes, respectively. The top of the extraction volume is z7 above the nominal substrate seating plane and its bottom is half of the minimum z7 dimension above the nominal substrate seating plane. The cassette must give extra horizontal clearance once the substrate is picked up from wherever it ends up (within the bounds of the substrate pick-up volume) after transport in the cassette.

6.12.3 The open space for the substrate set-down volume is indicated by dimensions x5 and y6 and is symmetric about the bilateral and facial datum planes, respectively. The top of this volume is half of z7 above the nominal substrate seating plane and its bottom is z6 above the nominal substrate seating plane. The substrate should be placed within the bounds of the substrate set-down volume to avoid touching the edge of the substrate to the side of the cassette.

6.12.4 The substrate pickup zone is defined by an area indicated by dimensions x5 and y5 and is symmetric about the bilateral and facial datum planes, respectively. Its top and bottom are the upper and lower tolerance of z6 around the nominal substrate seating plane. If a substrate is placed in the substrate set-down volume and is then pushed to the rear of the cassette, then the entire bottom of the substrate must be contained in the substrate pick-up zone.

6.13 *Particle Generation* — The cassette will not add more than 0.05 particles/cm^2 of a size ≥ 0.5 µm (PSL equivalent) per substrate pass per shipping cycle. The shipping cycle is to be defined by the customer.

6.14 *Inner and Outer Radii* — All concave features may have as much as a 1 mm (0.04 in.) radius to allow for cleaning and to prevent contaminant build-up. All required convex features (such as the robotic handling flanges and the corners of the cassette top and bottom domains) must also have a minimum radius of 1 mm (0.04 in.) to prevent large stress contacts of the cassette that might cause wear and particles.

6.15 *Dimensional Tolerances* — Width (W), Length (L), and Height (H): ± 5 mm

6.16 *Special Design Features*

6.16.1 Compatible with automated cleaning tools.

6.16.2 External features that are compatible with material handling systems such as, but not limited to, Guided Vehicles, Stocker, and Conveyors.

Table 1 Cassette Registration Type A Coupling Pin Dimensions

Symbol Used	*Shown In*	*Dimensions Description*	*Algebraic Relation or Value*
d1	Figure 5	diameter of pin centered on the center axis line	= 12 ± 0.05 mm (0.4724 ± 0.002 in.)
r2	Figure 5	radial distance from the center axis line to the origin of shoulder radius *r*5	= 6 mm (0.2362 in.)
r3	Figure 5	radial distance from the intersection of the center axis line and *z13* to the top of the pin	= 15 ± 0.05 mm (0.5906 ± 0.002 in.)
r4	Figure 5	blend radius for the intersection of *r*3 and *r*5	= 2 ± 0.1 mm (0.0787 ± 0.004 in.)
r5	Figure 5	radial distance from the intersection of the horizontal datum plane and *r*2 to the far shoulder of the pin	= 15 ± 0.05 mm (0.5906 ± 0.002 in.)
r6	Figure 5	blend radius for the intersection of *r*5 and *d*1	= 2 ± 0.1 mm (0.0787 ± 0.004 in.)
r7	Figure 5	roughness (R_a) as defined in ISO 4287	0.30 µm (12 µin.) max.
z13	Figure 5	vertical distance from the horizontal datum plane to the origin of top radius *r*3	= 2 ± 0 mm (0.08 in.)

Table 2 Cassette Registration Type B Roller Pin Dimensions

Symbol Used	*Shown In*	*Dimensions Description*	*Algebraic Relation or Value*
r8	Figure 7	radius about roller circumference revolved about the revolute axis	= 4.8 ± 0.12 mm
r9	Figure 7	radius of roller measured from the tangential surface created by *r*8 to the revolute axis	≥ 20 ± 0.12 mm

Table 3 Cassette Side Domains

Symbol Used	*Shown In*	*Datum Measured From*	*Boundary or Feature Measured To*	*Algebraic Relation or Value*
r1	Figure 3	center of coupling exclusion zone	outside edge of coupling exclusion zone	< 15 mm
x1	Figure 2	bilateral datum plane	encroachment of cassette side domains on substrate extraction volume	$\geq \frac{W * 0.57}{2}$
x2	Figure 2	bilateral datum plane	outside edge of cassette side domains	≤ W + 37
x3	Figure 2	bilateral datum plane	inside edge of rear cassette domains	≥ x1 – 40
x4	Figure 2	bilateral datum plane	outside edge of rear cassette domains	$\geq \frac{W * 0.57}{2}$
x5	Figure 2	nominal substrate center line	outside edge of substrate pick-up zone	≥ W + 2
x6	Figures 2 and 4	nominal substrate center line	encroachment of cassette side domains on substrate extraction volume	≥ x5
x7	Figure 2	nominal substrate center line	outside edge of cassette top and bottom domain	≤ W + 37
x8	Figure 3	bilateral datum plane	inside edge of cassette sensing pad areas	= W * 0.71 ± 5.0 mm
x9	Figure 3	bilateral datum plane	outside edge of cassette sensing pad areas	= W * 0.78 ± 5.0 mm
x10	Figure 4	bilateral datum plane	encroachment of cassette top domain on robotic handling flange space	≤ W * 1.02
x11	Figure 4	bilateral datum plane	far side of robotic handling flanges	≤ W * 1.05
x12	Figure 3	bilateral datum plane	inside edge of conveyor rail exclusion zones	≥ W * 0.752
x13	Figure 3	bilateral datum plane	outside edge of conveyor rail exclusion zones	≤ W * 0.877
x14	Figure 3	bilateral datum plane	center of coupling exclusion zones	= W * 0.9455 ± 0.1 mm
x15	Figures 3 and 6	bilateral datum plane	centerline of v-rail roller	= W * 0.815 ± 0.2 mm
x16	Figure 6	bilateral datum plane	centerline of float roller	= x19 ± 2.0 mm
x17	Figure 3	bilateral datum plane	inside edge of facial datum plane v-groove	= W * 0.0245 ± 0.2 mm
x18	Figure 3	bilateral datum plane	outside edge of facial datum plane v-groove	= W * 0.020 ± 0.2 mm
x19	Figure 6	bilateral datum plane	left edge of v-groove exclusion zone	≥ W * 0.069
x20	Figure 6	bilateral datum plane	right edge of v-groove exclusion zone	≥ W * 0.109
x21	Figure 6	bilateral datum plane	inside edge of float roller exclusion zone	≤ W * 0.742
x22	Figure 6	bilateral datum plane	outside edge of float roller exclusion zone	≥ W * 0.884
y1	Figure 2	facial datum plane	encroachment of cassette side domain	≥ L * 0.031
y2	Figure 2	facial datum plane	encroachment of cassette side domain	≤ L * 0.454
y3	Figure 2	facial datum plane	encroachment of cassette side domain	≥ L * 0.515
y4	Figure 2	facial datum plane	encroachment of cassette side domain	≤ L * 0.938
y5	Figure 2	facial datum plane	outside edge of substrate pick-up volume	≤ L + 1
y6	Figure 2	facial datum plane	encroachment of cassette side domains on substrate set-down volume	≥ L + 1
y7	Figure 2	facial datum plane	encroachment of cassette side domains on substrate extraction volume	≥ L + 3
y8	Figure 2	facial datum plane	boundary of rear cassette domain	≤ L * 1.12

Symbol Used	*Shown In*	*Datum Measured From*	*Boundary or Feature Measured To*	*Algebraic Relation or Value*
y9	Figure 2	facial datum plane	outside edge of cassette top and bottom plate domain	≤ L * 1.21
y10	Figure 3	facial datum plane	inside edge of cassette top and bottom plate indent	≤ L * 0.985
y11	Figure 3	facial datum plane	inside edge of cassette sensing pad areas	≥ L * 0.708
y12	Figure 3	facial datum plane	outside edge of cassette sensing pad areas	≤ L * 0.954
y13	Figure 3	facial datum plane	center of coupling exclusion zones	= L * 0.923 ± 0.1 mm
z1	Figure 4	horizontal datum plane	bottom of cassette bottom domain	≥ 2 mm
z2	Figure 4	horizontal datum plane	bottom of cassette sensing pads	= 3 ± 0.5 mm
z3	Figure 6	horizontal datum plane	bottom surface of conveying surface	= 2 ± 0.5 mm
z4	Figure 4	horizontal datum plane	top of cassette bottom domain	≤ 40 mm
z5	Figure 4	horizontal datum plane	bottom nominal substrate seating plane	= 60 mm
z6	Figure 4	each nominal substrate seating plane	bottom of substrate	= ± 0.5 mm
z7	Figure 4	each nominal substrate seating plane	encroachment of cassette side domains on clearance above the substrate	See Table 4.
z8	Figure 4	each nominal substrate seating plane	adjacent nominal substrate seating planes	See Table 4.
z9	Figure 4	top nominal substrate seating plane	bottom of cassette top domain	≥ z7 + 1 mm
z10	Figure 4	top nominal substrate seating plane	bottom of clearance under robotic handling flange	≤ 30 mm
z11	Figure 4	top nominal substrate seating plane	top of clearance under robotic handling flange	= 40 ± 1 mm
z12	Figure 4	top nominal substrate seating plane	top of top cassette domain	≤ 50 mm
z14	Figure 6	horizontal datum plane	top of v-rail, v-groove, and float roller exclusion zones	= 24.86 ± 0.12 mm

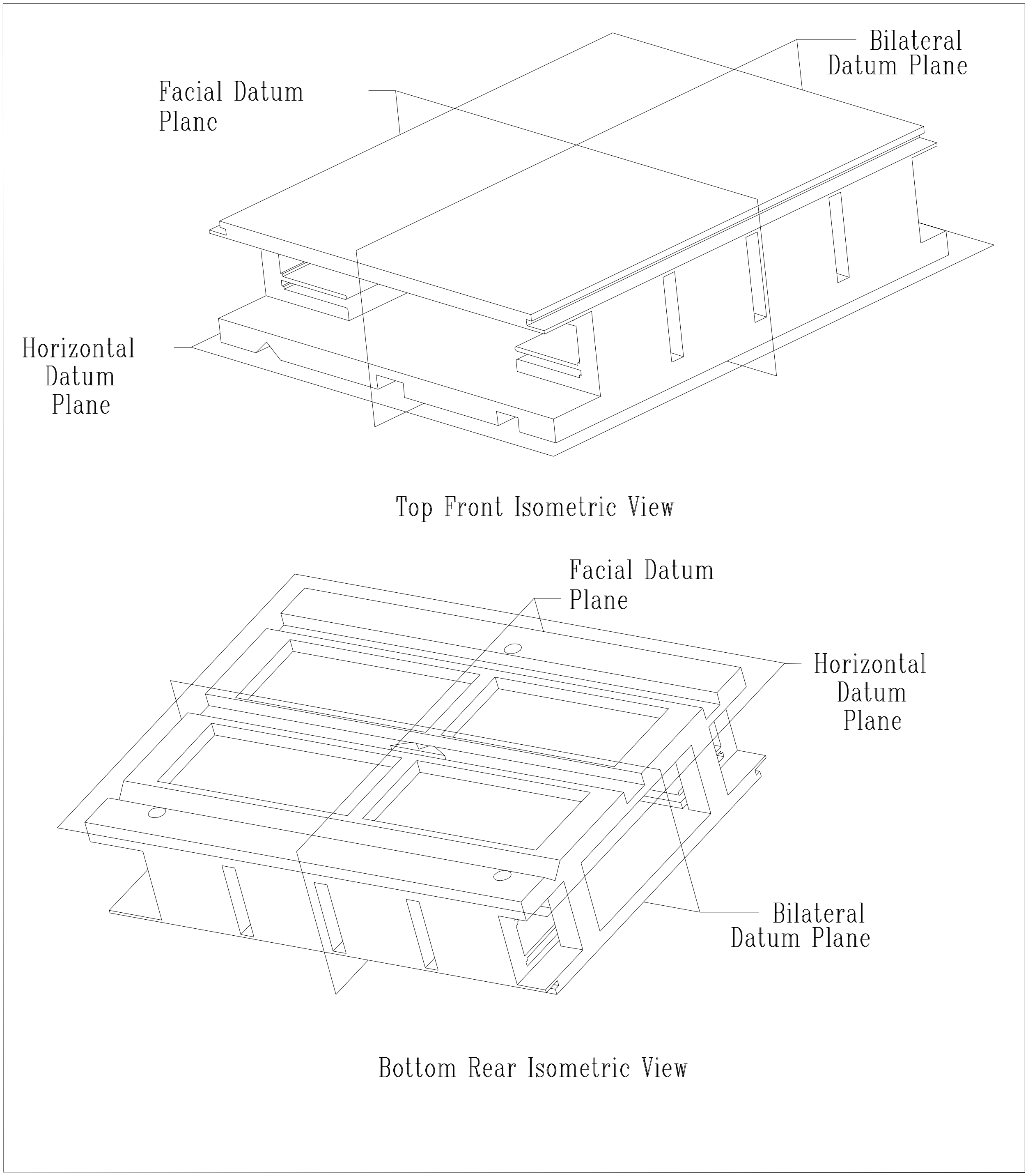


Figure 1
Isometric Views

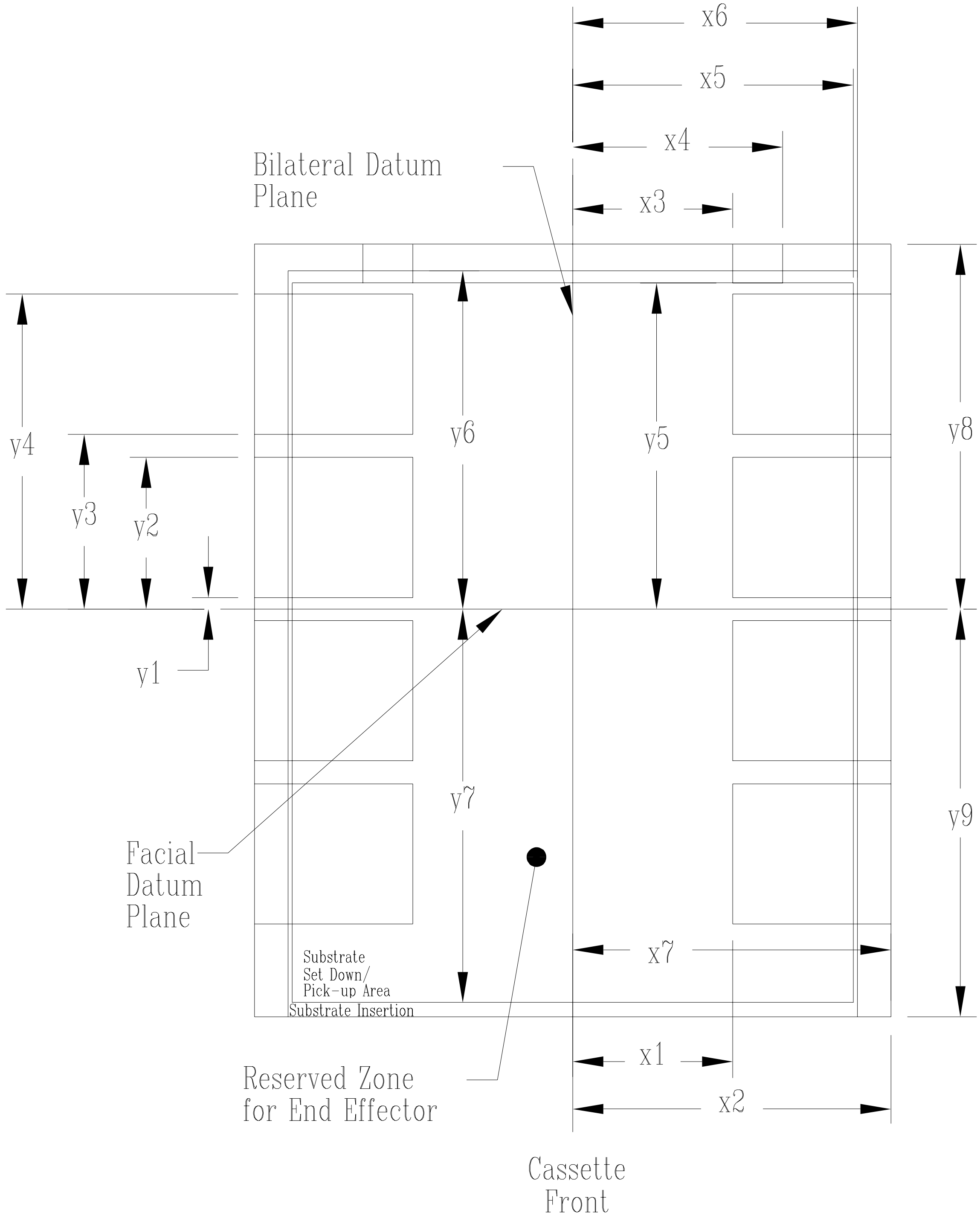


Figure 2
Cassette Side Domains

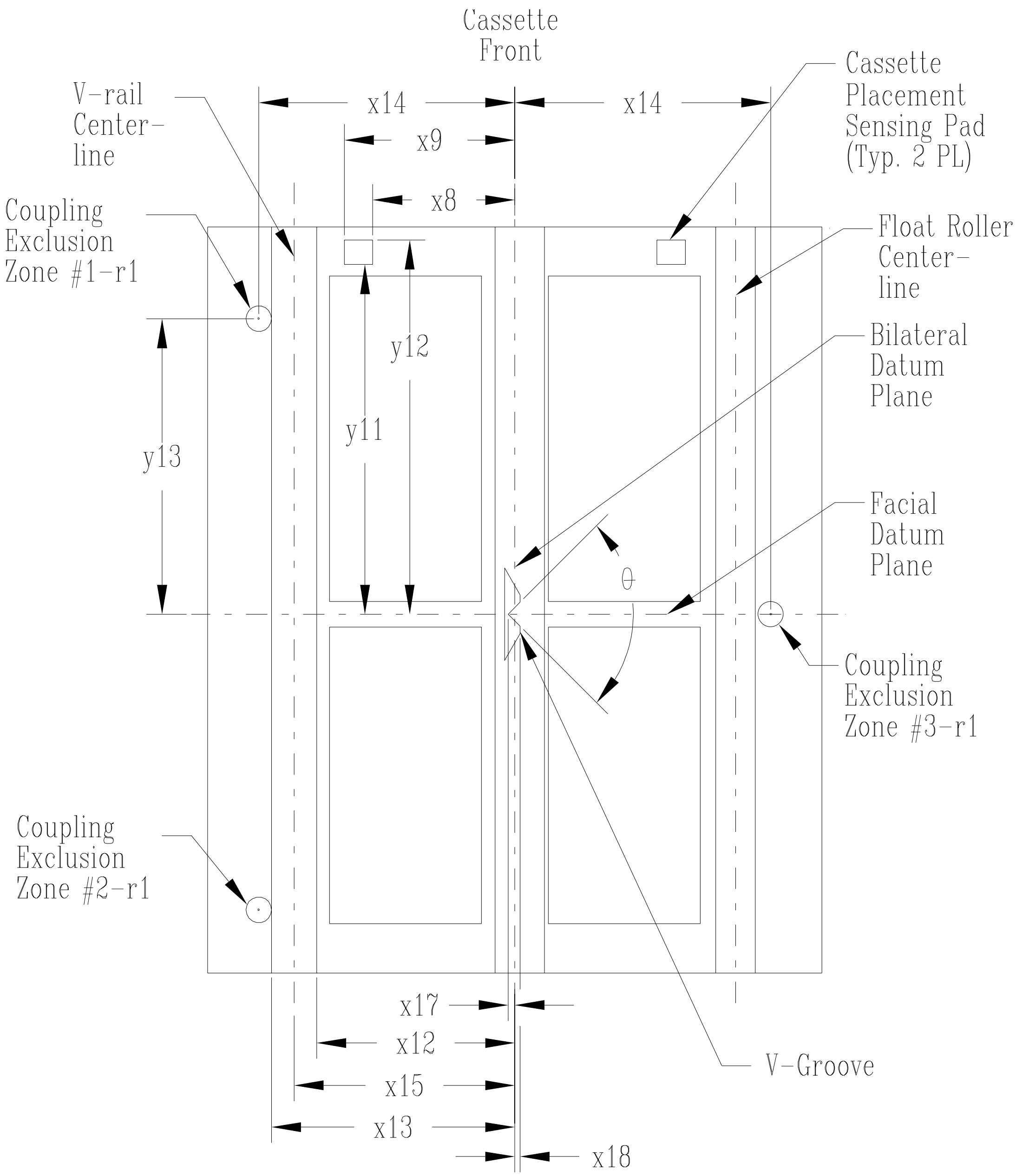


Figure 3
Cassette Bottom Domain

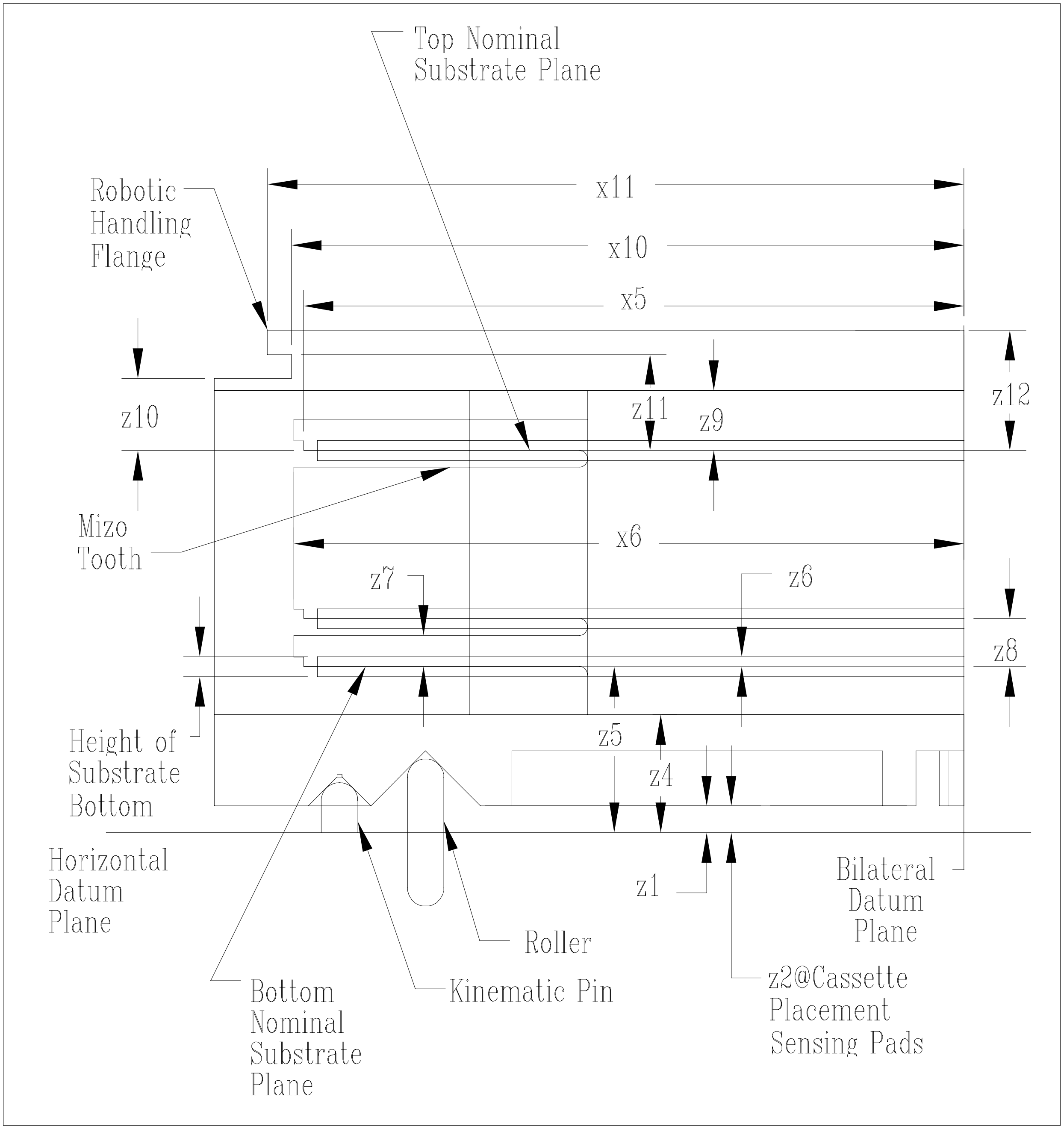


Figure 4
Cassette Vertical Dimensions

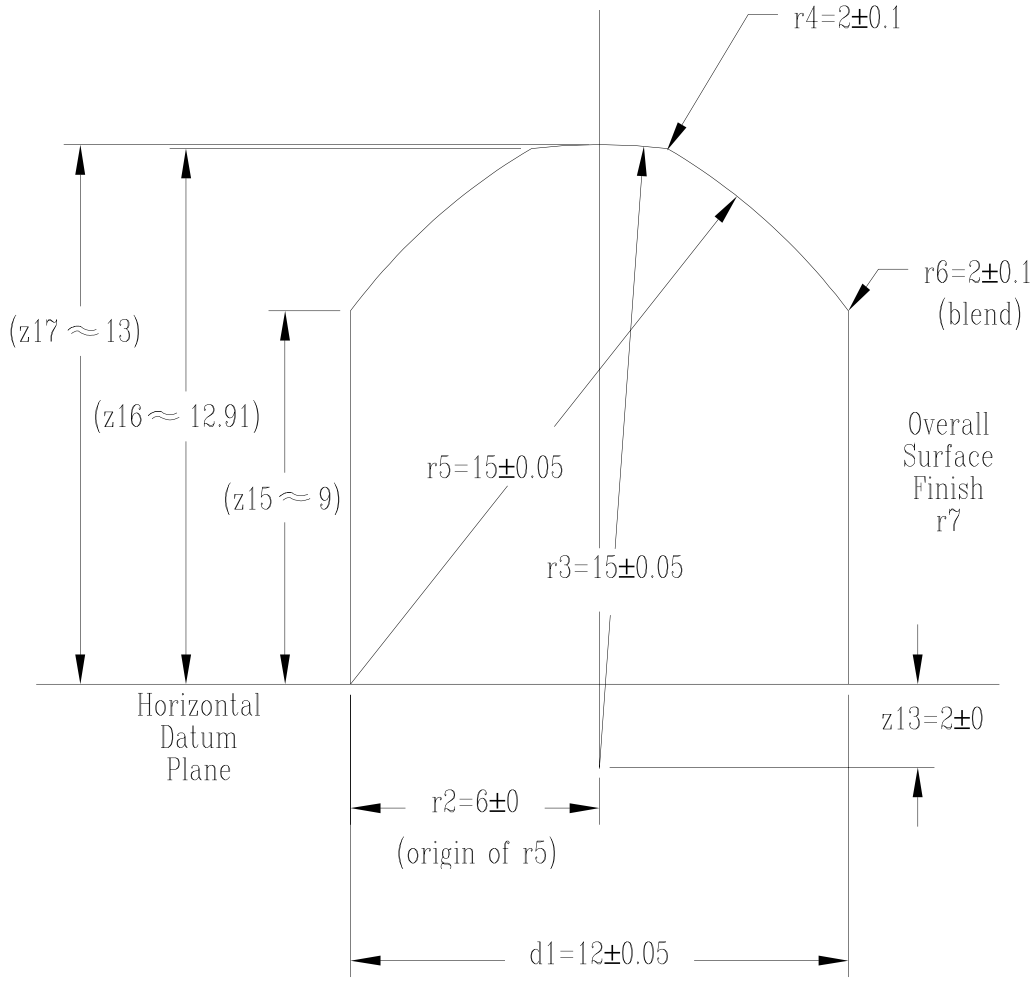


Figure 5
Cassette Physical Alignment Interface – Type A
Coupling Pin Shape

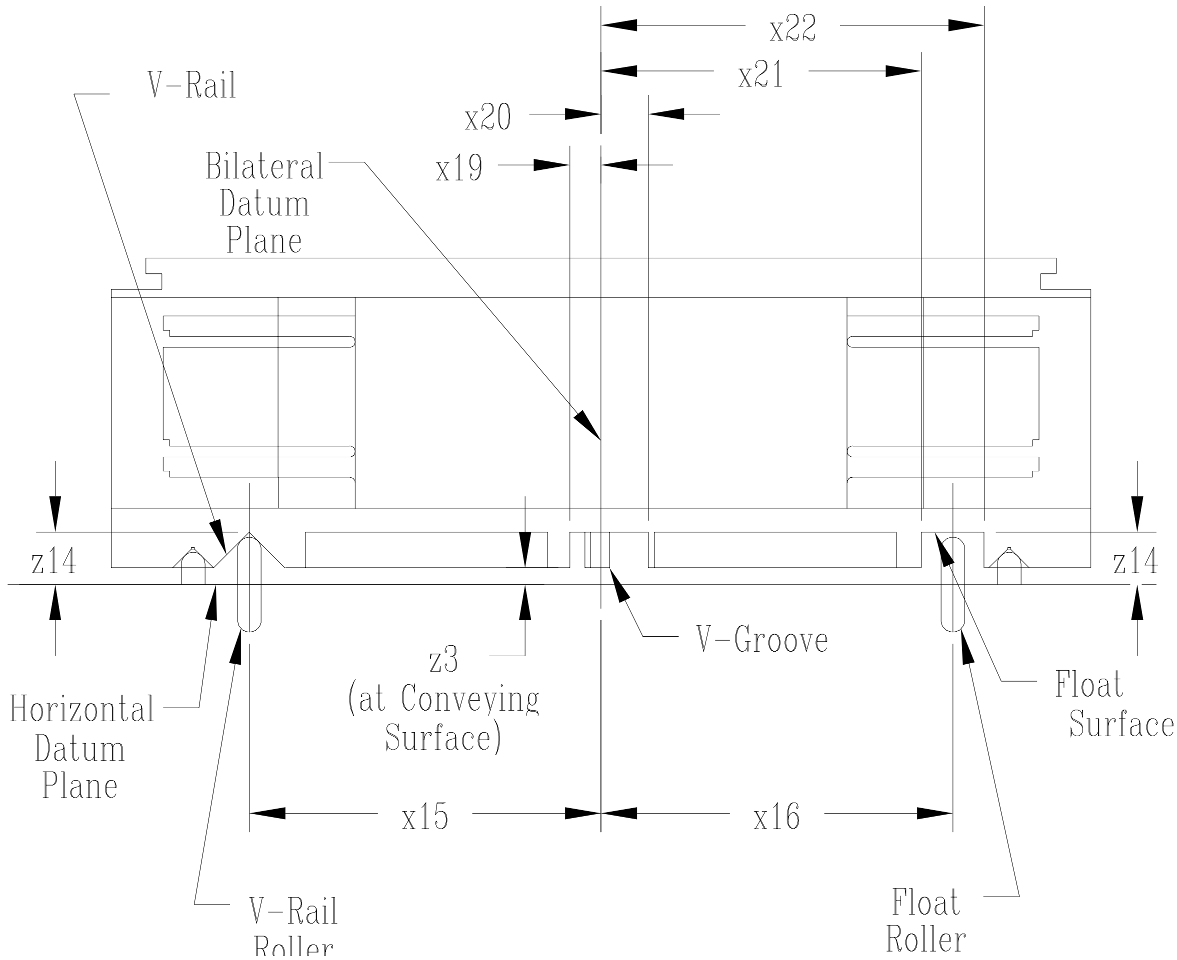


Figure 6
Cassette Physical Alignment Interface – Type B
Roller Position

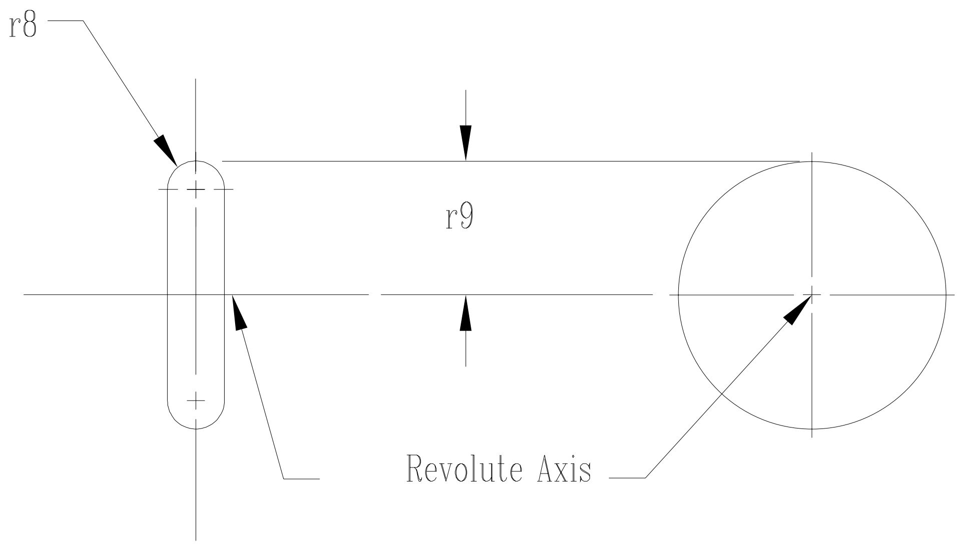


Figure 7
Cassette Physical Alignment Interface – Type B
Roller Shape

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI D17 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee. Determination of the suitability of the material herein is solely the responsibility of the user.

A1-1 Application Notes

A1-1.1 The shape of the teeth holding the substrates is not specified in this standard. The tooth surface that touches the substrate should have a large radius to minimize stress on the substrate and tooth.

A1-1.2 Extra clearance (larger than the pitch) has been added below the bottom substrate (for non-random sequential access to the substrates with a faster or less precise robot). To increase the stability of Type A Cassettes, the points on the cassette bottom that are the most distant from the lines connecting each pair of coupling pins should be made as close as practical to the horizontal datum plane so that the cassette cannot tip very far off of the kinematic coupling.

SEMI D18-0299^E
SPECIFICATION FOR CASSETTES USED FOR HORIZONTAL TRANSPORT AND STORAGE OF FLAT PANEL DISPLAY SUBSTRATES

This specification was technically approved by the Flat Panel Display Equipment Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Standards Committee on August 15, 1998. Initially available at www.semi.org September 1998; to be published February 1999.

E This document was editorially modified in October 2000 to correct a formatting error. Changes were made to Figure 5.

1 Purpose

1.1 This standard specifies the cassettes used to horizontally transport and store glass substrates 0.7 mm-1.1 mm thick (max) in a flat panel display (FPD) manufacturing facility.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Most of the requirements given in this specification are in the form of algebraic expressions defining maximum or minimum dimensions referenced from the length and width of the intended substrate with very few required surfaces. Only the mechanical interfaces for cassettes are specified; no materials requirements or microcontamination limits are given. However, this standard has been written so that cassettes of various designs and materials can be manufactured in conformance with it.

3 Referenced Standards

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Standards*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D5 — Standard Size for Flat Panel Display Substrates

SEMI D6 — Standard Edge Length and Thickness for Flat Panel Display Mask Substrates

SEMI D9 —Definitions for Flat Panel Display Substrates

SEMI D11 — Specification for Flat Panel Display Glass Substrate Cassettes

SEMI D21 — Terminology for Flat Panel Display Masks

SEMI E15 — Specification for Tool Load Port

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

4 Terminology

4.1 *bilateral datum plane* — a vertical plane that equally bisects the substrate and that is perpendicular to both the horizontal and facial datum planes.

4.2 *carrier capacity* — the number of substrates that a carrier holds.

4.3 *cassette* — (as defined in SEMI E44)

4.4 *cassette bottom domain* — volume (below *z*4 above the horizontal datum plane) that contains the bottom of the cassette.

4.5 *cassette bottom opening* — an opening through the cassette bottom domain that provides access to the glass substrates for external roller drive mechanisms to move substrates into/from the cassette.

4.6 *cassette front* — the area between the cassette top and bottom domains through which substrates pass during loading and unloading.

4.7 *cassette rear* — the area between the cassette top and bottom domains opposite the cassette front.

4.8 *cassette rear domains* — volumes (from *z*4 above the horizontal datum plane to *z*9 above the top substrate) that contain rear columns which prevent the substrates from exiting the cassette rear.

4.9 *cassette placement sensing pads* — surfaces on the bottom of the cassette for triggering optical or mechanical sensors.

4.10 *cassette side domains* — volumes (from *z*4 above the horizontal datum plane to *z*9 above the top substrate) that contain the mizo teeth and mizo plates that support the substrates.

4.11 *cassette top domain* — volume (higher than *z*9 above the top substrate) that contains the top of the cassette.

4.12 *conveyor rails* — features on the bottom of the cassette for supporting the cassette on roller conveyors.

4.13 *conveying surface* — entire bottom surface of cassette (*z*15 above the horizontal datum plane), excluding the V-rail, V-groove, and float roller zones, for supporting the cassette on roller conveyors

4.14 *facial datum plane* — a vertical plane that equally bisects the substrates when the centers of the substrates are aligned and that is parallel to the front side of the carrier (where substrates are removed or inserted) and is perpendicular to the bilateral datum plane. On tool load ports, it is also parallel to the load face plane (as defined in SEMI E15) on the side of the tool where the carrier is loaded and unloaded.

4.15 *first substrate end-effector clearance* — the distance (dimension *z*9) between the top of the cassette bottom domain and the first nominal substrate seating plane.

4.16 *first nominal substrate height* — the distance (dimension *z*5) from the horizontal datum plane to the first nominal substrate seating plane.

4.17 *horizontal datum plane* — load height as defined in SEMI E15.

4.18 *mizo plate* — a plate that contains mizo teeth and may provide structure to the cassette.

4.19 *mizo teeth* — elements that support the substrates in the cassette.

4.20 *nominal center line* — the intersection of the facial and bilateral datum planes.

4.21 *nominal substrate seating plane* — a horizontal plane that contains the nominal bottom surface of the substrate as it rests on the mizo teeth.

4.22 *optical substrate sensing paths* — lines of sight for optically sensing the positions of the substrates.

4.23 *robotic handling flanges* — projections on the cassette for handling of the cassette.

4.24 *substrate extraction volume* — the open space for extracting a substrate from the cassette.

4.25 *substrate pitch* — the distance between adjacent nominal substrate seating planes.

4.26 *substrate set-down volume* — the open space for inserting and setting down a substrate in the cassette.

4.27 *substrate pick-up volume* — the space that contains entire bottom of a substrate if the wafer is pushed to the rear of the cassette.

5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify cassettes over a reasonable lifetime of use, not just those in new condition. The purchaser needs to specify the time period, the number of cycles and any special conditions to which the cassettes will be exposed. It is under these conditions that the cassettes must remain in compliance with the requirements listed in Section 6.

5.2 *Temperature Ranges* — The purchase of the cassettes needs to specify three sets of temperatures to which the cassettes might be exposed. An operating temperature range is the set of environmental temperatures in which the cassettes will remain in compliance with the requirements listed in Section 6 (e.g. 23°C ± 5°C). A temporary temperature range is the set of environmental temperatures to which the cassettes can be exposed such that when the cassettes return to the operating temperature range, the cassettes will be in compliance with the requirements listed in Section 6 (e.g. 90°C maximum during cleaning of the cassette). Also, the purchaser needs to specify a range of temperatures for the substrates that might be inserted in the cassettes.

5.3 *Pitch and Capacity Options* — The purchaser needs to specify the pitch and capacity of the cassettes. Table 2 provides two options of pitch and capacity. Additional pitch and capacity options are not yet defined, but should be specified in the same manner.

5.4 *Material* — To be agreed upon between supplier and user. Construction may be of one or more molded or machines parts.

6 Requirements

6.1 *Dimensions* — Most of the dimensions of the cassette are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane (see Figure 1).

6.2 *Cassette Physical Alignment Interface* — The cassette should be registered to the tool interface by one of the three following types of registrations (Type A, B or C). The locations of the registration features have been chosen such that all three types may coexist on the same cassette

6.2.1 *Cassette Physical Alignment Interface-Type A* — This registration consists of three features (not specified, but recommended to be inverted V-shaped grooves) placed on the bottom of the cassette that mate with three coupling pins located on the tool interface. The coupling pins are located by dimensions *x*14 and *y*13 relative to the bilateral and facial datum planes respectively.

6.2.1.1 *Coupling Pin Shapes* — The physical alignment mechanism on the bottom of the wafer carrier consists of features (not specified in this standard) that mate with three pins underneath. As shown in Figure 5 and defined in Table 3, each pin is radially symmetric about the vertical center axis line and can be seen as the intersection of a cylinder of diameter *d*1 and a sphere of radius *r*3 (which might contact a flat plate). An additional rounding radius *r*5 provides contact with angled mating surfaces, and blend radii *r*4 and *r*6 smooth the resulting edges. The final roughness height of the over-all surface finish must be less than or equal to *r*7. Dimensions *r*2 and *z*13 have zero tolerance because they only give a distance to another toleranced dimension. (Dimensions in parenthesis are not part of the requirements in this standard but are intended to clarify the preparation of manufacturing instructions.)

6.2.1.2 The three features on the bottom of the cassette that mate with the coupling pins must provide a lead-in capability that corrects a cassette misalignment of up to 10 mm (0.4 in.) in any horizontal direction, although 15 mm (0.6 in.) is recommended. The exclusion zones for the three coupling features on the cassette is shown in Figure 3 and Table 1 and specified by dimensions *x*14, *z*9 and *r*1.

6.2.2 *Cassette Physical Alignment Interface-Type B* — Consists of three features, a V-rail, float surface, and facial datum plane V-groove. The V-rail and float surface are located on the bottom of the cassette and mate with the two V-rail rollers and one float surface roller, respectively, mounted on the tool interface. The facial datum plane V-groove is located about the facial datum plane through the bottom surface of the cassette and mates with the facial datum plane lock pin located on the tool interface shown in Figure 3. The V-rail roller and the float surface roller are located by dimensions *x*15 and *x*16 relative to the bilateral datum plane respectively shown in Figure 6. The dimension relative to the facial datum plane for the V-rail rollers are not specified but recommended to be located furthest from and symmetrical about the facial datum plane as shown in Figure 3 and 6. The float surface roller revolute axis must lie on the facial datum plane.

6.2.2.1 The V-rail and float surface rollers are defined in Figure 7 and Table 4. Each roller is radially symmetric about the revolute axis. The rollers are circumferentially radiused of dimension *r*8. The diameter of the rollers is not specified but the tangential surface created by dimension *r*8 must lie on the horizontal datum plane. The facial datum plane lock pin radius is equal to *r*8 and must be positioned into the facial datum plane V-groove to fully constrain the cassette to the facial datum plane. The facial datum plane lock pin is translated out of the facial datum plane V-groove to allow the cassette to be rolled in and out of the tool interface. Although only three rollers are specified it is recommended to increase the total number of rollers so that the cassette is fully supported while being loaded and unloaded to the tool interface. All rollers except for the V-rail and float roller must be positioned so that the tangent of the *r*8 dimension lies below the horizontal datum plane.

6.2.2.2 The three features on the bottom of the cassette that mate with the rollers and lock pin must provide a lead-in capability that corrects a cassette misalignment of up to 10 mm (0.4 in.) in any horizontal direction, although 15 mm (0.6 in.) is recommended. The V-rail and facial datum plane V-groove are not specified but recommended to be inverted V-shaped grooves. The V-rail is recommended to extend the full length of the cassette from the cassette front to the cassette rear. The float surface is not specified but recommended to be a flat surface extending the full length of the cassette from the cassette front to the cassette rear. The exclusion zones for these features are shown in Figure 3 and 6 and specified by dimensions *x*15, *x*16 through *x*22.

6.2.3 *Cassette Physical Alignment Interface-Type C* — to be developed.

6.3 *Conveyor Rails* — If the cassette is to be used on roller conveyors, each conveyor rail should extend the maximum distance from front to back. The exclusion zones for conveyor rails are shown in Figure 3 and 6 and specified by dimensions *x*13 and *x*22 and extends to the outer boundary of the cassette.

6.4 *Conveying Surface*—If the cassette is to be transported on roller conveyors that support the entire bottom of the cassette, the bottom surface excluding the V-rail, V-groove, and float roller zones is to be used. The location of this surface with respect to the horizontal datum plane is specified by dimension *z*3.

6.5 *Substrate Orientation and Numbering* — The substrates must be horizontal when the carrier is placed on the coupling, and the substrates are numbered in increasing order from bottom to top (so the bottom substrate is substrate number 1, the next substrate up is substrate number 2, etc.)

6.6 *Cassette Sides and Rear* — Figure 2 shows a top view of the boundaries of the cassette side domains (which contain the parts of the cassette higher than *z*4 above the horizontal datum plane and lower than *z*9 above the top substrate). Table 1 defines the dimensions shown in this and following figures.

6.7 *Cassette Top* — The boundaries of the cassette top domain contain any part of the cassette higher than *z*9 above the top substrate.

6.8 *Cassette Bottom* — Figure 3 shows a bottom view of the boundaries of the cassette bottom domain (which contains any part of the cassette lower than *z*4 above the horizontal datum plane). When the cassette is fully down, the cassette placement sensing pads must be *z*2 above the horizontal datum plane.

6.9 *Vertical Dimensions* — Figure 4 shows the vertical dimensions of the left half of the cassette as viewed from the rear. Note that *z*5 (the height of the bottom nominal substrate seating plane above the horizontal datum plane) and *z*8 (the distance between adjacent nominal substrate seating planes) are given as reference dimensions with no tolerance. This means that the sum of actual height variations in the cassette from the horizontal datum plane to the mizo tooth or slot holding each substrate must be contained within the tolerance of *z*6 with no further stack-up at each higher substrate.

6.9.1 The open space for the substrate extraction volume is indicated by dimensions *x*6 and *y*7 and is symmetric about the bilateral and facial datum planes, respectively. The top of the extraction volume is *z*7 above the nominal substrate seating plane and its bottom is half of the minimum *z*7 dimension above the nominal substrate seating plane. The cassette must give extra horizontal clearance once the substrate is picked up from wherever it ends up (within the bounds of the substrate pick-up volume) after transport in the cassette.

6.9.2 The open space for the substrate set-down volume is indicated by dimensions *x*5 and *y*6 and is symmetric about the bilateral and facial datum planes, respectively. The top of this volume is half of *z*7 above the nominal substrate seating plane and its bottom is *z*6 above the nominal substrate seating plane. The substrate should be placed within the bounds of the substrate set-down volume to avoid touching the edge of the substrate to the side of the cassette.

6.9.3 The substrate pick-up volume is defined by an area indicated by dimensions *x*5 and *y*5 and is symmetric about the bilateral and facial datum planes, respectively. Its top and bottom are the upper and lower tolerance of *z*6 around the nominal substrate seating plane. If a substrate is placed in the substrate set-down volume and is then pushed to the rear of the cassette, then the entire bottom of the substrate must be contained in the substrate pick-up volume.

6.10 *Pitch and Capacity* — Table 2 shows the different options with regard to the substrate pitch (spacing) and the cassette capacity.

6.11 *Inner and Outer Radii* — All concave features may have as much as a 1 mm (0.04 in.) radius to allow for cleaning and to prevent contaminant build-up. All required convex features (such as the robotic handling flanges, and the corners of the cassette top and bottom domains) must also have a minimum radius of 1 mm (0.04 in.) to prevent small contact patches with large stresses that might cause wear and particles.

Table 1 Cassette Side Domains

Symbol Used	*Shown in*	*Datum Measured From*	*Boundary or Feature Measured To:*	*Algebraic Relation or Value*
*r*1	Figure 3	center of coupling exclusion zone	outside edge of coupling exclusion zone	<15
*x*1	Figure 2	bilateral datum plane	encroachment of cassette side domains on substrate extraction volume	$\geq \frac{W \times 0.57}{2}$
*x*2	Figures 2	bilateral datum plane	outside edge of cassette side domains	$\leq W1 + 37$
*x*3	Figures 2	bilateral datum plane	inside edge of rear cassette domains	$\geq x1 - 40$
*x*4	Figures 2	bilateral datum plane	outside edge of rear cassette domains	$\geq \frac{W \times 0.57}{2}$
*x*5	Figures 2 and 4	nominal substrate center line	outside edge of substrate pick-up volume	$\geq W1 + 2$
*x*6	Figures 2 and 4	nominal substrate center line	encroachment of cassette side domains on substrate extraction volume	$\geq x5$
*x*7	Figures 2	nominal substrate center line	outside edge of cassette top and bottom domain	$\leq W1 + 37$

Symbol Used	*Shown in*	*Datum Measured From*	*Boundary or Feature Measured To:*	*Algebraic Relation or Value*
*x*8	Figure 3	bilateral datum plane	inside edge of cassette sensing pad areas	$= W_1 \times 0.71 \pm 5.0$
*x*9	Figure 3	bilateral datum plane	outside edge of cassette sensing pad areas	$= W_1 \times 0.78 \pm 5.0$
*x*10	Figure 4	bilateral datum plane	encroachment of cassette top domain on robotic handling flange space	$\leq W_1 \times 1.02$
*x*11	Figure 4	bilateral datum plane	far side of robotic handling flanges	$\leq W_1 \times 1.05$
*x*12	Figures 3	bilateral datum plane	inside edge of conveyor rail exclusion zones	$\geq W_1 \times 0.752$
*x*13	Figures 3	bilateral datum plane	outside edge of conveyor rail exclusion zones	$\leq W_1 \times 0.877$
*x*14	Figure 3	bilateral datum plane	center of coupling exclusion zones	$= W_1 \times 0.9455 \pm 0.1$
*x*15	Figures 3 and 6	bilateral datum plane	centerline of V-rail roller	$= W_1 \times 0.815 \pm 0.2$
*x*16	Figure 6	bilateral datum plane	centerline of float roller	$= x19 \pm 2.0$
*x*17	Figure 3	bilateral datum plane	inside edge of facial datum plane V-groove	$= W_1 \times 0.0245 \pm 0.2$
*x*18	Figure 3	bilateral datum plane	outside edge of facial datum plane V-groove	$= W_1 \times 0.020 \pm 0.2$
*x*19	Figure 6	bilateral datum plane	left edge of V-groove exclusion zone	$\geq W_1 \times 0.069$
*x*20	Figure 6	bilateral datum plane	right edge of V-groove exclusion zone	$\geq W_1 \times 0.109$
*x*21	Figure 6	bilateral datum plane	inside edge of float roller exclusion zone	$\leq W_1 \times 0.742$
*x*22	Figure 6	bilateral datum plane	outside edge of float roller exclusion zone	$\geq W_1 \times 0.884$
*y*1	Figure 2	facial datum plane	encroachment of cassette side domain	$\geq L_1 \times 0.031$
*y*2	Figure 2	facial datum plane	encroachment of cassette side domain	$\leq L_1 \times 0.454$
*y*3	Figure 2	facial datum plane	encroachment of cassette side domain	$\geq L_1 \times 0.515$
*y*4	Figure 2	facial datum plane	encroachment of cassette side domain	$\leq L_1 \times 0.938$
*y*5	Figure 2	facial datum plane	outside edge of substrate pick-up volume	$\leq L_1 + 1$
*y*6	Figure 2	facial datum plane	encroachment of cassette side domains on substrate set-down volume	$\geq L_1 + 1$
*y*7	Figure 2	facial datum plane	encroachment of cassette side domains on substrate extraction volume	$\geq L_1 + 3$
*y*8	Figure 2	facial datum plane	boundary of rear cassette domain	$\leq L_1 \times 1.12$
*y*9	Figures 2	facial datum plane	outside edge of cassette top and bottom plate domain	$\leq L_1 \times 1.21$
*y*10	Figures 3	facial datum plane	inside edge of cassette top and bottom plate indent	$\leq L_1 \times 0.985$
*y*11	Figure 3	facial datum plane	inside edge of cassette sensing pad areas	$\geq L_1 \times 0.708$
*y*12	Figure 3	facial datum plane	outside edge of cassette sensing pad areas	$\leq L_1 \times 0.954$
*y*13	Figure 3	facial datum plane	center of coupling exclusion zones	$= L_1 \times 0.923 \pm 0.1$

Symbol Used	*Shown in*	*Datum Measured From*	*Boundary or Feature Measured To:*	*Algebraic Relation or Value*
*z*1	Figure 4	horizontal datum plane	bottom of cassette bottom domain	≥ 2
*z*2	Figure 4	horizontal datum plane	bottom of cassette sensing pads	=3 ± 0.5
*z*3	Figure 6	horizontal datum plane	bottom surface of conveying surface	=2 ± 0.5
*z*4	Figure 4	horizontal datum plane	top of cassette bottom domain	≤ 40
*z*5	Figure 4	horizontal datum plane	bottom nominal substrate seating plane	= 60
*z*6	Figure 4	each nominal substrate seating plane	bottom of substrate	= ± 0.5
*z*7	Figure 4	each nominal substrate seating plane	encroachment of cassette side domains on clearance above the substrate	See Table 2.
*z*8	Figure 4	each nominal substrate seating plane	adjacent nominal substrate seating planes	See Table 2.
*z*9	Figure 4	top nominal substrate seating plane	bottom of cassette top domain	≥ *z*7 + 1
*z*10	Figure 4	top nominal substrate seating plane	bottom of clearance under robotic handling flange	≤ 30
*z*11	Figure 4	top nominal substrate seating plane	top of clearance under robotic handling flange	= 40 ± 1
*z*12	Figure 4	top nominal substrate seating plane	top of top cassette domain	≤ 50
*z*14	Figure 6	Horizontal Datum Plane	top of V-rail, V-groove, and float roller exclusion zones	= 24.86 ± 0.12

W= the length in millimeters of the substrate edge perpendicular to the bilateral datum plane.

W_1= one half the length of W

L= the length in millimeters of the substrate edge perpendicular to the facial datum plane.

L_1= one half the length of L

All values in millimeter (mm)

Table 2 Pitch and Capacity Options

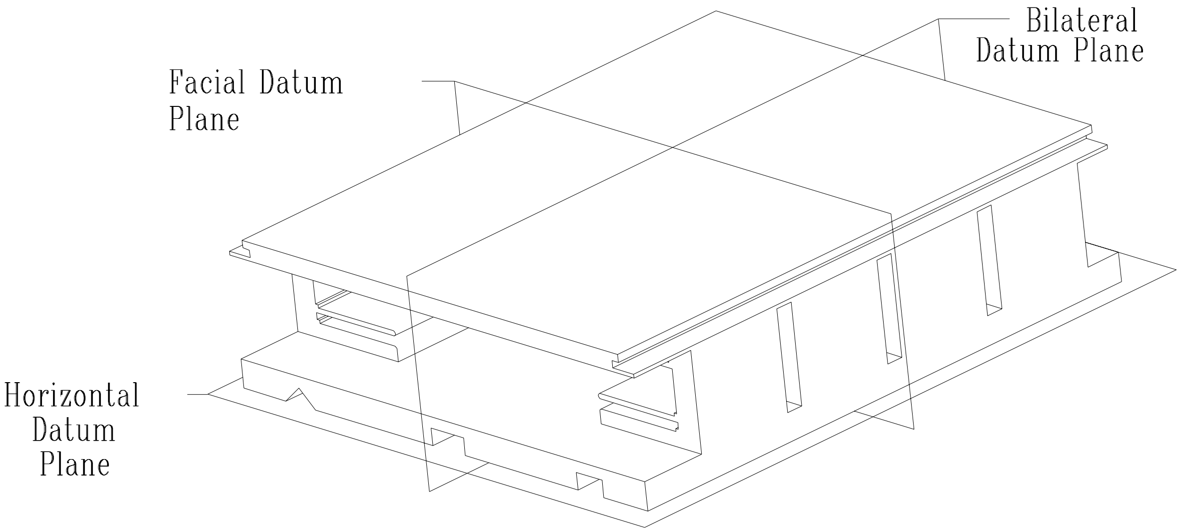
Substrate Size	*Cassette Capacity (c)*	*Substrate Pitch (z8)*	*Substrate Clearance (z7)*	*Resulting Cassette Height (z5-z1)+((z8*(c-1))+z12*
550 mm x 650 mm	25 substrates	20 mm (0.79 in.)	16 mm (0.63 in.) minimum	580 mm (22.83 in.) maximum
600 mm x 720 mm	25 substrates	20 mm (0.79 in.)	16 mm (0.63 in.) minimum	580 mm (22.83 in.) maximum
960 mm x 1100 mm	20	30 mm (1.18 in.)	20 mm (0.79 in.)	678 mm (26.7 in.) maximum
4	not yet defined			

Table 3 Type A Cassette Registration - Coupling Pin Dimensions

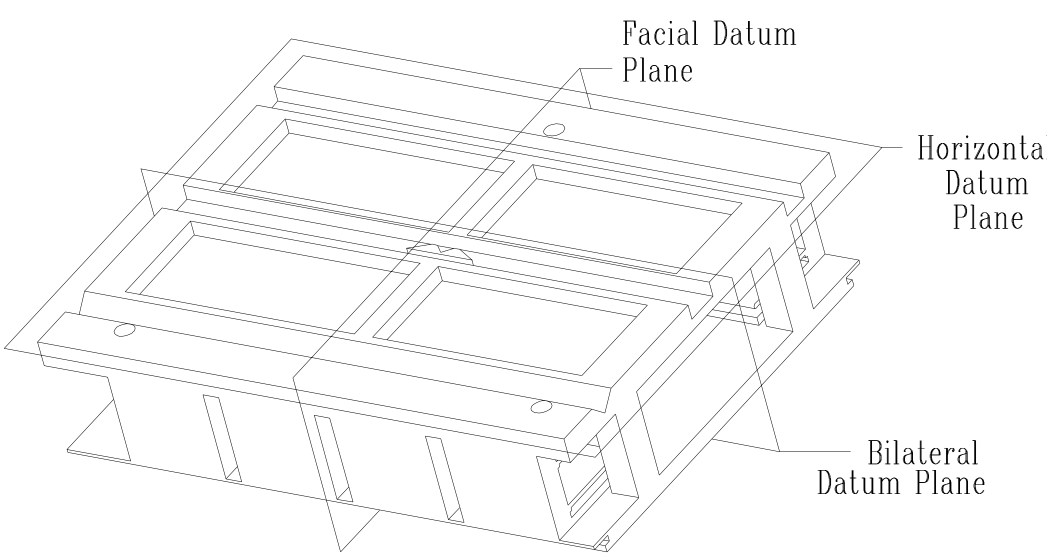
Symbol Used	*Shown In:*	*Dimensions Description*	*Algebraic Relation or Value*
*d*1	Figure 5	diameter of pin centered on the center axis line	12 ± 0.05 mm (0.4724 ± 0.002 in.)
*r*2	Figure 5	radial distance from the center axis line to the origin of the shoulder radius *r*5	6 mm (0.2362 in.)
*r*3	Figure 5	radial distance from the intersection of the center axis line and *z*13 to the top of the pin	15 ± 0.05 mm (0.5906 ± 0.002 in.)
*r*4	Figure 5	blend radius for the intersection of *r*3 and *r*5	2 ± 0.1 mm (0.0787 ± 0.004 in.)
*r*5	Figure 5	radial distance from the intersection of the horizontal datum plane and *r*2 to the far shoulder of the pin	15 ± 0.05 mm (0.5906 ± 0.002 in.)
*r*6	Figure 5	blend radius for the intersection of *r*5 and *d*1	2 ± 0.1 mm (0.0787 ± 0.004 in.)
*r*7	Figure 5	Roughness (R_a) as defined in *ISO 4287*	0.30 µm (12 µin.) maximum
*z*13	Figure 5	vertical distance from the horizontal datum plane to the origin of top radius *r*3	2 mm (0.08 in.)

Table 4 Type B Cassette Registration - Roller Dimensions

Symbol Used	*Shown In:*	*Dimensions Description*	*Algebraic Relation or Value*
r8	Figure 7	Radius about roller circumference revolved about the revolute axis	= 4.8 ± 0.12 mm
r9	Figure 7	Radius of roller measured from the tangential surface created by r8 to the revolute axis	≥ 20 ± 0.12 mm



Top Front Isometric View



Bottom Rear Isometric View

Figure 1
Isometric Views

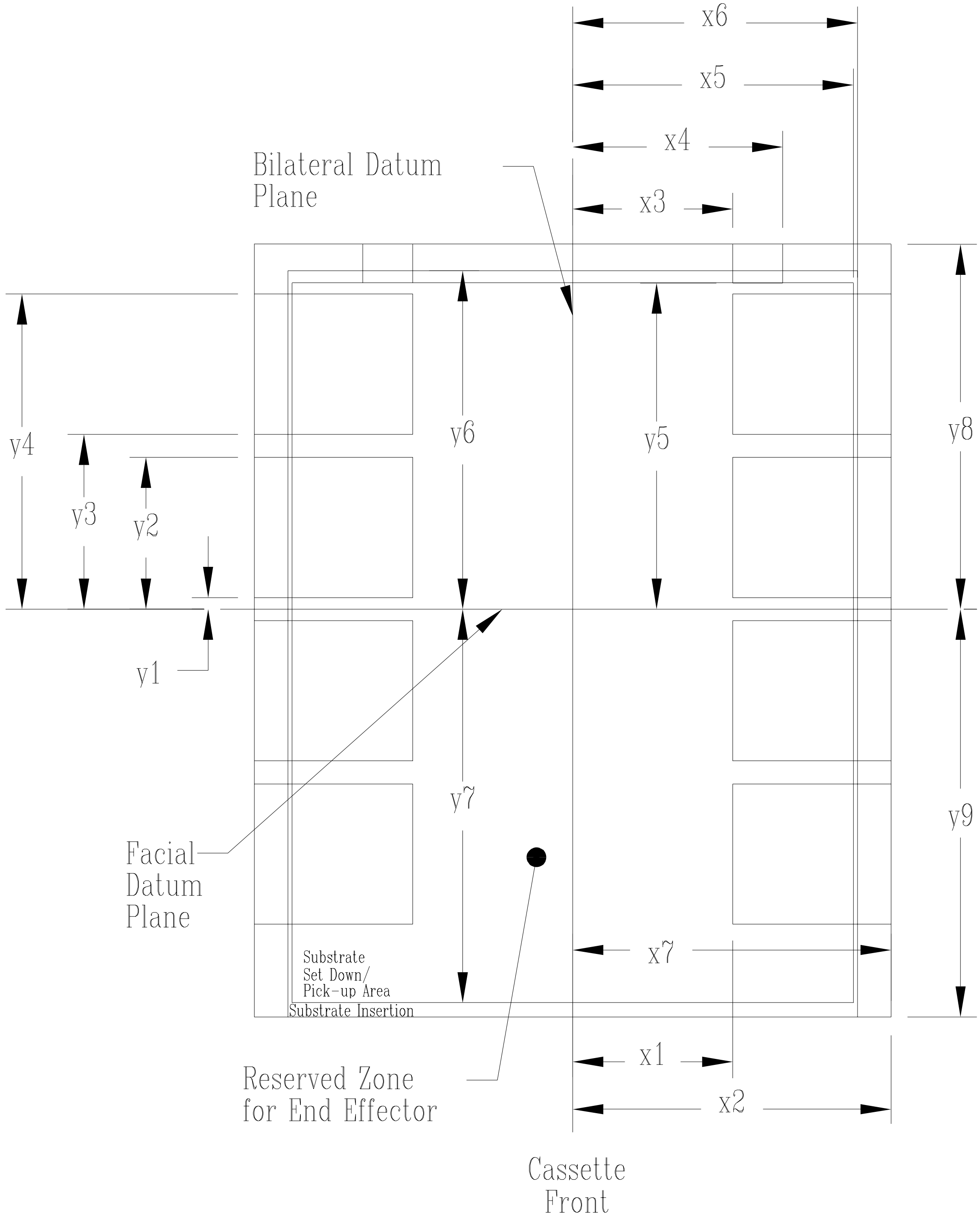


Figure 2
Cassette Side Domains

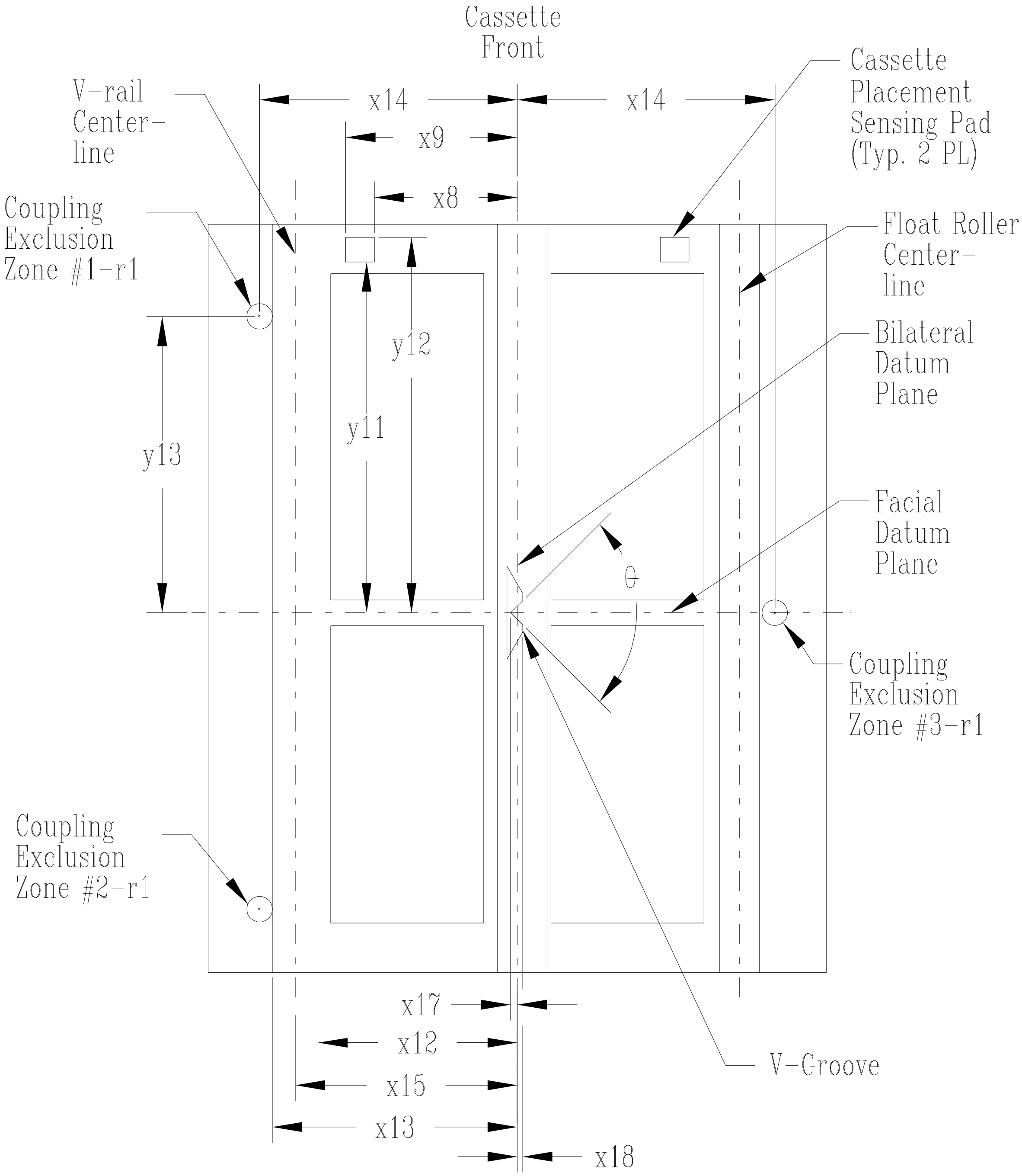


Figure 3
Cassette Bottom Domain

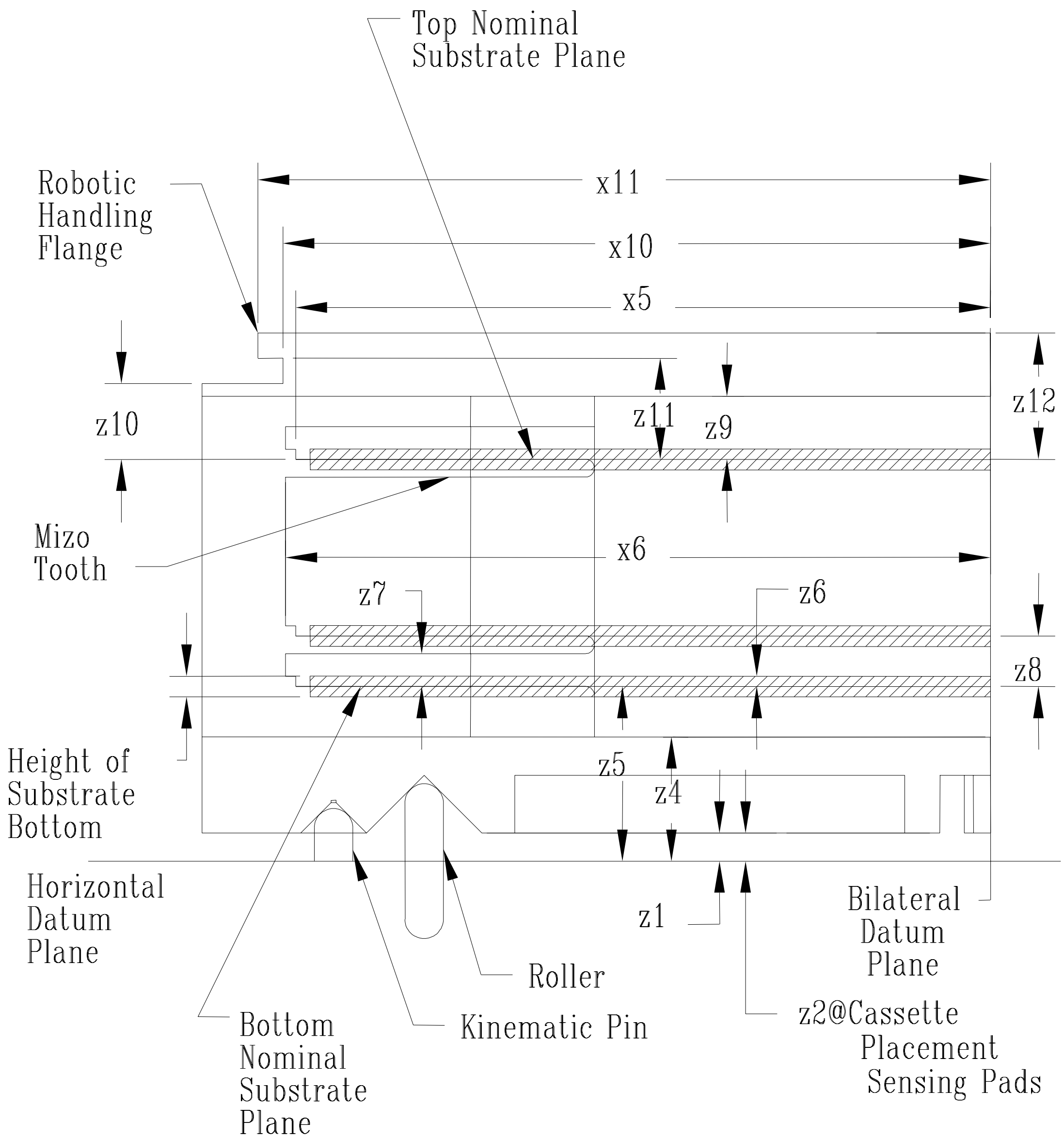


Figure 4
Cassette Vertical Dimensions

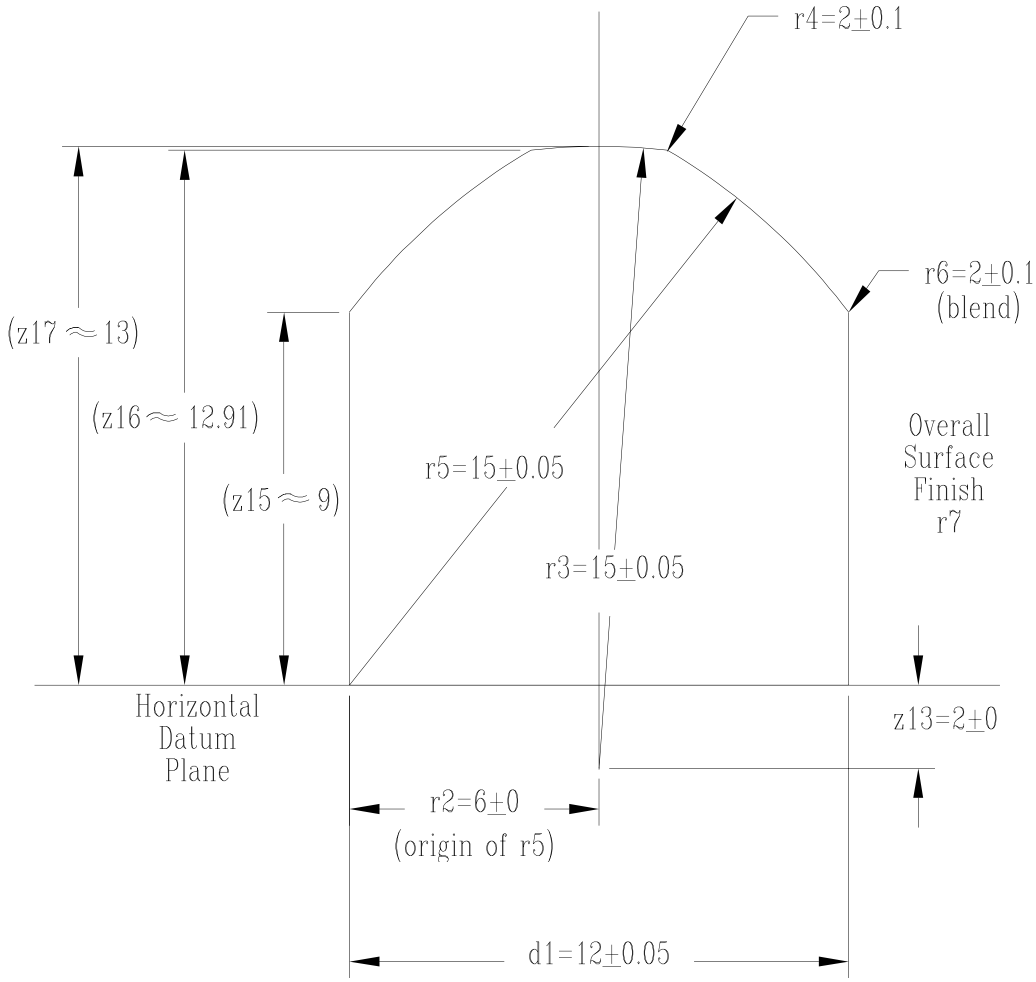


Figure 5
Cassette Physical Alignment Interface-Type A
Coupling Pin Shape

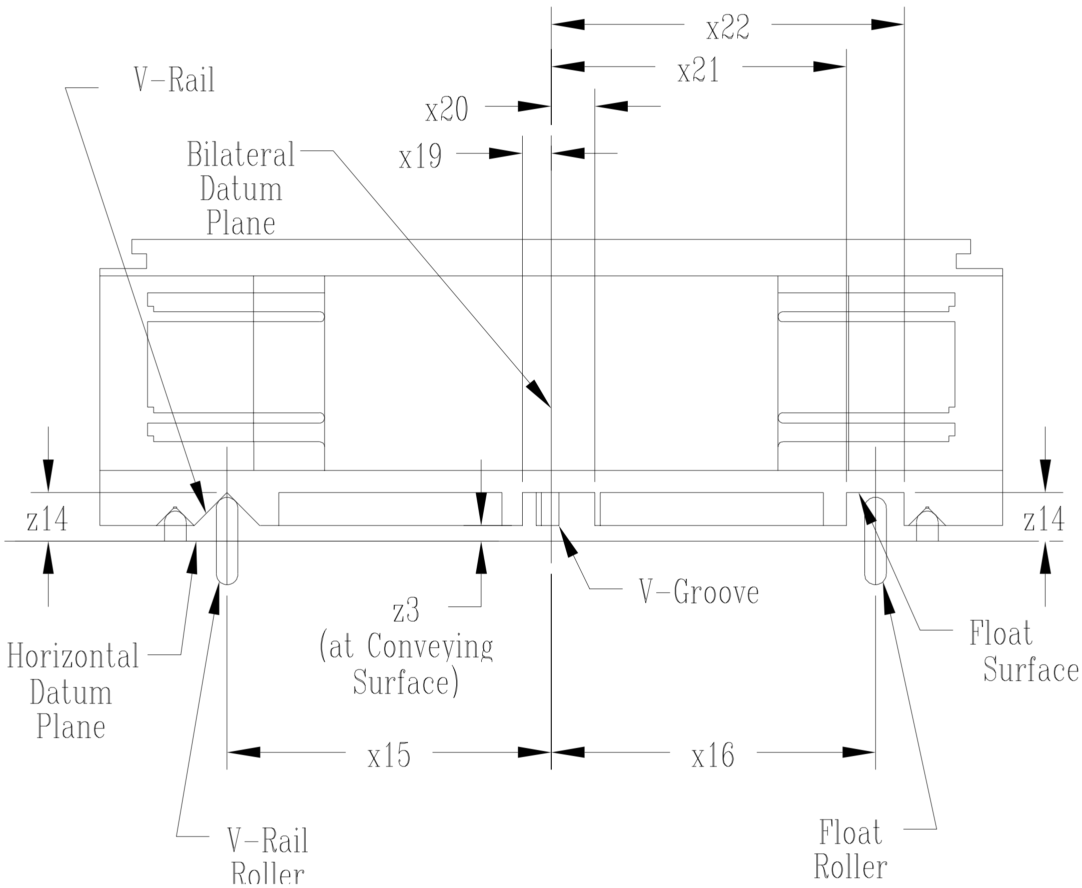


Figure 6
Cassette Physical Alignment Interface-Type B
Roller Position

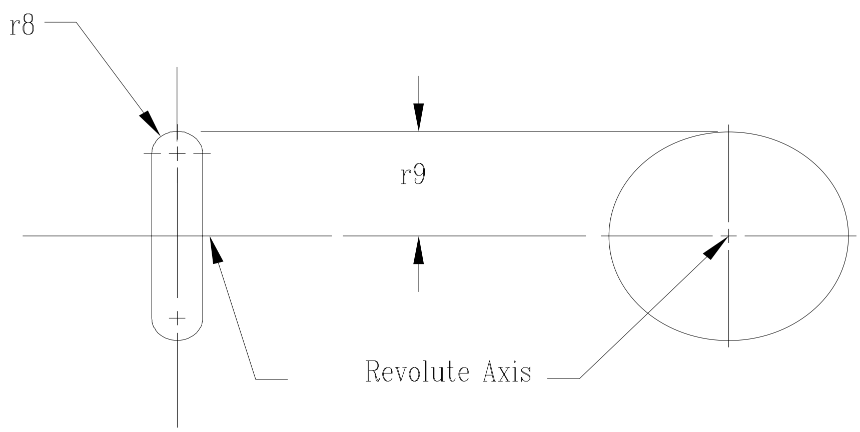


Figure 7
Cassette Physical Alignment Interface-Type B
Roller Shape

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI D18 and was approved by full letter ballot procedures on August 15, 1998.

A1-1 Application Notes

A1-1.1 The shape of the teeth holding the substrates is not specified in this standard. The tooth surface that touches the substrate should have a large radius to minimize stress on the substrate and tooth.

A1-1.2 Extra clearance (larger than the pitch) has been added below the bottom substrate (for non-random sequential access to the substrates with a faster or less precise robot). To increase the stability of Type A Cassettes the points on the cassette bottom that are the most distant from the lines connecting each pair of coupling pins should be made as close as practical to the horizontal datum plane so that the cassette cannot tip very far off of the kinematic coupling.

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SEMI D19-0299[E]
TEST METHOD FOR THE DETERMINATION OF CHEMICAL RESISTANCE OF FLAT PANEL DISPLAY COLOR FILTERS

This test method was technically approved by the Global Flat Panel Display - Materials and Components Committee and is the direct responsibility of the Japanese Flat Panel Display - Color Filter Committee. Current edition approved by the Japanese Regional Standards Committee on September 18, 1998. Initially available on SEMI OnLine February 1999; to be published February 1999.

[E] This document was editorially modified in March 2000 to correct a formatting error. Changes were made to Section 11.4.

1 Purpose

1.1 This standard establishes two methods for evaluating the chemical resistance of FPD color filters. One of these methods is qualitative, the other is quantitative.

2 Scope

2.1 These methods may be used by suppliers and users of color filters for FPD applications, for use in judging quality of production and developing samples.

2.2 These methods test the chemical resistance of color filters by utilizing chemicals and conditions typically employed in FPD manufacturing.

2.3 These methods are destructive.

3 Limitations

3.1 This standard specifies only the methods for testing and evaluating chemical resistance of FPD color filters; however, it does not specify the criteria against which the test results are compared.

3.2 This standard specifies only items for color filters, but not for flat panel displays incorporating color filters.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *JIS Standards*[1] *(available in Japanese only)*

JIS Z8113 — Glossary of Lighting Terms

JIS Z8120 — Glossary of Optical Terms

JIS Z8722 — Methods of Measurement of Color of Reflecting

JIS Z8730 — Method for Specification of Color Difference for Opaque Materials

4.2 *Others*[2]

IEC Publication 50 (845) — International Electrochemical Vocabulary (IEV)

5 Terminology

5.1 *color illuminator* — A light source having a uniform illumination plane which radiates diffuse light onto the back surface of a sample to permit direct observation of the sample.

5.2 Definitions of additional terms used in this document may be found in JIS Z8113, JIS Z8122 and IEC Publication 50 (845).

6 Summary of Method

6.1 A sample is placed in a suitable test container at controlled temperature for a specified period of time.

6.2 The sample is removed from the bath and residual chemicals removed.

6.3 The sample is examined visually for qualitative changes in appearance.

6.4 The sample is examined by microscope and/or surface profiler (stylus type) for material swelling.

6.5 The sample is measured per color layer for spectra transmittance.

6.6 The color difference for each color layer is calculated in one of two systems.

7 Apparatus

7.1 *Test Container* — A clean container shall be used with a sufficient size and depth to accommodate the sample and appropriate chemicals. The container material must be chosen which will not be affected by tests executed under this method. Note that chemicals should not change in quality by test container.

7.2 *Instrumentation*

7.2.1 *Color Illuminator* — This light source shall have chromaticity, color rendering, luminance and intensity uniformity, diffusion, and a sufficient illumination area for observation of the samples to be measured.

7.2.2 *Floodlight* — This light shall have luminance uniformity and an illumination area sufficient for the samples to be measured.

1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo 107, Japan

2 International Electrotechnical Commission, 3 rue de Varembe, CH 1211 Geneva 20, Switzerland

7.2.3 *Microscope* — The microscope used shall have appropriate magnification, normally 50×–400×.

7.2.4 *Spectrophotometer* — The spectrophotometer shall be in conformance with JIS Z8722 or an equivalent standard.

7.2.5 *Surface Profiler* — The equipment which can measure the thickness with X-Y stage.

8 Reagents and Test Conditions

8.1 No specific requirements are described for the reagents. As long as the test conditions are reported with the test result, any combination of chemical reagents with any condition can be used for the test. The test conditions should reflect actual process conditions, which are specific for the selected FPD manufacturer. Some reagents suggested for the test are given in Table 1.

Table 1 Chemicals Used for Chemical Resistance Tests and Related Conditions

Chemical[1]	*Liquid Temperature (C)*	*Soak Time (minutes)*
N-methyl-2 pyrolidone (NMP)	23 ± 2	30
γ-butyrolactone	23 ± 2	30
2-propanol (IPA)	23 ± 2	30
2-ethoxyethyl-acetate (ECA)	23 ± 2	30
2-methoxyethanol	23 ± 2	30
2.38% tetramethyl-ammoniumhydroxide (TMAH)	23 ± 2	30
18% HCl	23 ± 2	30
18% HCl	40 ± 5	10
5% NaOH	23 ± 2	10
5% KOH	23 ± 2	10

[1] % = % by weight

8.2 This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

9 Samples

9.1 FPD color filters are used as samples. For HCl resistance tests, color filters without ITO should be used.

NOTE 1: The test report shall identify whether or not ITO is present on the sample.

10 Procedure

10.1 Pour the selected chemicals into a test container.

10.2 Adjust the temperature of the chemicals to a predetermined value.

10.3 Place the sample, film side up, into the chemicals and cover the test container to prevent chemical evaporation.

10.4 Leave the sample in the chemicals for a predetermined period of time.

10.5 Remove the sample from the chemical bath. Completely remove all chemicals remaining on the sample.

NOTE 2: For chemicals, temperature and soaking time, refer to Section 8, *Reagents and Test Conditions.*

10.6 Evaluate the sample condition according to the following criteria:

10.6.1 *Change of Appearance* — During each test, observe any change of appearance, e.g., wrinkles, cracks, change of surface conditions due to swelling, film peeling, and discoloration. The sample is compared with untreated sample. Various observation techniques can be employed, including the following which is included for reference only:

10.6.1.1 Visual observation of transmission of the color filter by use of a color illuminator (Figure 1).

10.6.1.2 Visual observation of reflectance of the film side of the color filter by use of a floodlight.

10.6.1.3 Microscope observation or transmission of a color filter by use of transmitted illumination.

10.6.1.4 Microscope observation of reflectance of the color filter by use of reflected illumination.

10.6.1.5 A surface profiler (stylus type) is used in order to measure the changes of film thickness of the color filter.

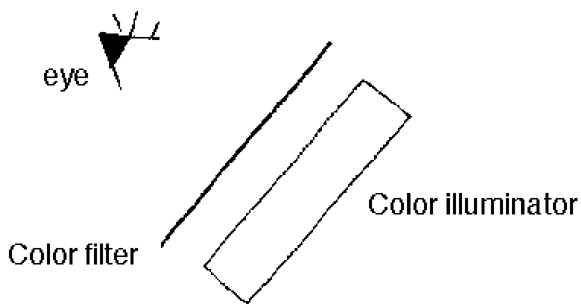

Figure 1
Visual Observation of Transmission of a Color Filter by Use of a Color Illuminator

10.6.2 *Color Differences*

10.6.2.1 Measure transmitted spectra of each colored layer of the color filter at any location. The center area of the sample is recommended.

10.6.2.2 Calculate tri-stimulus values of each colored layer of the color filter in accordance with JIS Z8730.

10.6.2.3 Repeat 10.6.2.1 and 10.6.2.2 on the same location of the sample.

10.6.2.4 Calculate color difference for each colored layer in the L*a*b* color system or the L*u*v* color specification system from the tri-stimulus values measured before and after this test, according to the method specified in JIS Z8730. Calculate either the difference)E*ab or)E*uv as the amount of color change of the color filter.

NOTE 3: Both the L*a*b* and L*u*v* color specification system can be used to evaluate the color change.

11 Report

Report the following:

11.1 Report date

11.2 Test date

11.3 Ambient temperature, in C

11.4 Conditions of the sample (construction of FPD color filter) – presence or absence of ITO film

11.5 Test conditions (name of chemicals, concentration, temperature and volume of chemicals, soaking time)

11.6 Observed changes in sample appearance between, before, and after the test.

11.7 The calculated color differences, for measurement location on each sample, and the color system used for these calculations.

12 Precision and Accuracy

No test data currently exists on which to base these statements. Tests are planned to develop such data for both single-laboratory repeatability and multi-laboratory reproducibility, on samples of the same nominal characteristics, and across a range of nominal characteristics.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI D20-1000
DEFECT TERMINOLOGY FOR FLAT PANEL DISPLAY MASKS

This terminology was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the Japanese Flat Panel Display Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on July 28, 2000. Initially available on SEMI OnLine September 2000; to be published October 2000. Originally published in 1993.

1 Purpose

1.1 This document defines defect terminology for FPD masks. By this standard, it is intended that the concepts of terms which should be used at the technical conferences, business discussion, etc are clarified and that standardization as to masks will be promoted.

2 Scope

2.1 These terms apply to photomasks that are principally used in fabricating flat panel display.

2.2 These definitions do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these definitions to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the definitions set forth herein for any particular application. The determination of the suitability of the definitions is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These definitions are subject to change without notice.

3 Referenced Documents

None.

4 Terminology

4.1 *pin hole* — a small hole-shaped opening defect on the chrome-pattern.

4.2 *intrusion* — an absence of chrome extending inward from boundary.

4.3 *pattern disconnect* — an intrusion which completely separates the continuity of the chrome-pattern.

4.4 *missing pattern image* — complete disappearance of the designed chrome-pattern.

4.5 *spot* — isolated chrome residue on the etched area.

4.6 *protrusion* — an extension of chrome beyond the desired boundary.

4.7 *bridge* — an extension of chrome which connects completely and continuously from an edge to another edge.

4.8 *edge roughness* — subtle roughness and/or jagged zone on the pattern edge.

4.9 *round of corner* — unintended round on the pattern corner.

4.10 *flaw*

4.10.1 *scratch* — relatively thick and deep linear friction defect on the surface of the glass.

4.10.2 *sleek* — extremely thin and light linear friction defect on the surface of the glass.

4.10.3 *pit* — small dot-shaped depression on the surface of the glass.

4.11 *chipping* — chipping of edge of the glass caused by cutting or treatment.

4.12 *bubble* — void in the interior of the glass substrate.

4.13 *foreign substance*

4.13.1 *particle* — relatively high foreign substance attached on the surface of the substrate.

4.13.2 *contamination* — cluster of relatively small substances attached on the surface of the substrate in the shape of thin film.

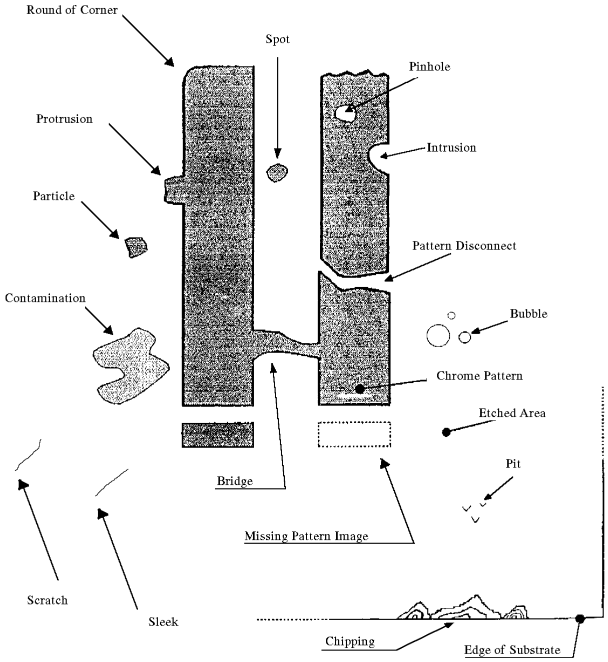

Figure 1
Image of Defects for FPD Mask

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SEMI D21-1000
TERMINOLOGY FOR FLAT PANEL DISPLAY MASKS

This terminology was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the Japanese Flat Panel Display Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on July 28, 2000. Initially available on SEMI OnLine September 2000; to be published October 2000. Originally published in 1992.

1 Purpose

1.1 This document defines terminology for FPD masks. By this standard, it is intended that the concepts of terms which should be used at the technical conferences, business discussion, etc are clarified and that standardization as to masks will be promoted.

2 Scope

2.1 These terms apply to photomasks that are principally used in fabricating flat panel display.

2.2 These definitions do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these definitions to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the definitions set forth herein for any particular application. The determination of the suitability of the definitions is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These definitions are subject to change without notice.

3 Referenced Documents

None.

4 Pattern Dimension

4.1 *Long Dimension Accuracy*

4.1.1 *Long Dimension* — The distances in the X and Y directions between the outermost elements of a pattern on the mask.

4.1.1.1 *Long Dimension Error* — The difference (ΔD) between the measured value (DM) and designed value (DD) of the long distance.

$\Delta D = DM - DD$

4.1.2 *Rectangularity* — Rectangularity of array pattern. Generally, it is indicated as deviation between X coordinate 3 and 4 , when Y coordinate of 1 and 2 are coincident.

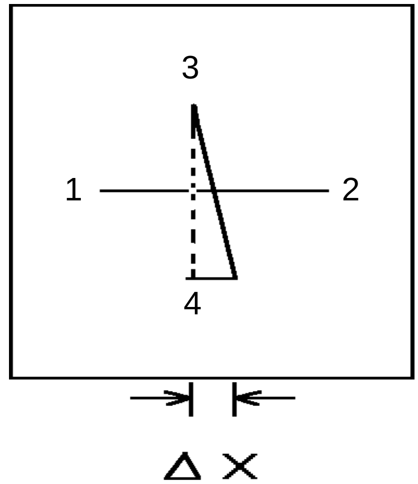

Figure 1
Rectangularity

4.2 *Overlay Accuracy* — Deviation between two or more masks in the direction of the long dimension X, Y. Generally, the two methods are as follows:

- Deviation is measured by comparing the two masks.
- Deviation is measured by comparing measured data of each long dimension of the two masks.

4.3 *Element Dimension Accuracy* — Dimension accuracy of element (line or space).

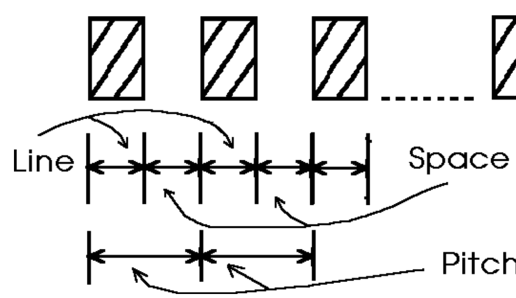

Figure 2
Element Dimension Accuracy

4.4 *Repeat Pitch Accuracy* — Deviation of measured pitch length from designed value.

4.5 *Stitching Error* — Joint accuracy of a pattern when a pattern is composed in a mask (e.g., pattern composition by a stepper). Usually, it is deviation as shown in the following figure.

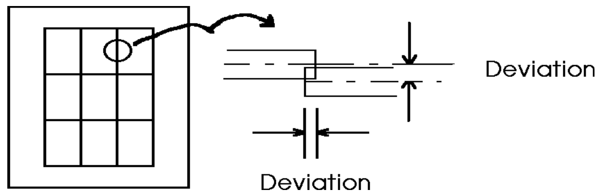

Figure 3
Stitching Error

5 Pattern Positioning Accuracy

5.1 *Pattern Positioning Accuracy* — Relation between the actual and desired locations of a printed pattern on a glass substrate.

5.2 *End Plane Reference* — Positioning accuracy of the printed pattern measured from the reference edge of a glass mask.

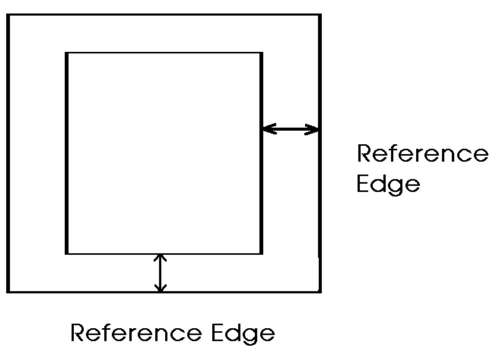

Figure 4
Pattern Positioning Accuracy

5.2.1 Reference Edge: Two adjacent edges are considered as the reference edge.

5.3 *Pattern Rotation* — Deviation of a printed pattern on a glass mask caused by rotation. Usually, it is expressed by the difference between two measured distances at separated points within one side as shown in the figure.

$\theta = (D_1 - D_2)/C_1$

Usually fix the value of C_1 and use the value of $D_1 - D_2$.

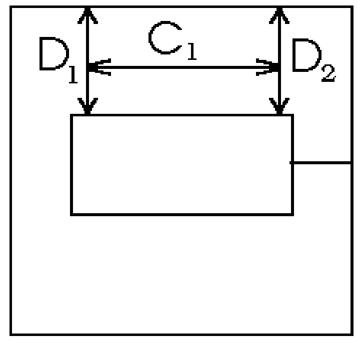

Figure 5
Pattern Rotation

5.4 *Cell Rotation in Multiimages* — Cell's slant rotation against axis of light in case of exposure by stepper and similar equipment. (Generally, it is measured by vernier outside of cells.)

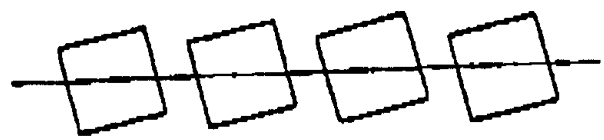

Figure 6
Cell Rotation in Multiimages

5.5 *Gaps of Cells in Multiimages* — X and Y directions' gaps of cells against designed grating which should be exposed primarily by stepper and similar equipment. (Generally, it is measured by gaps between cells which are next to each other with vernier outside of cells.)

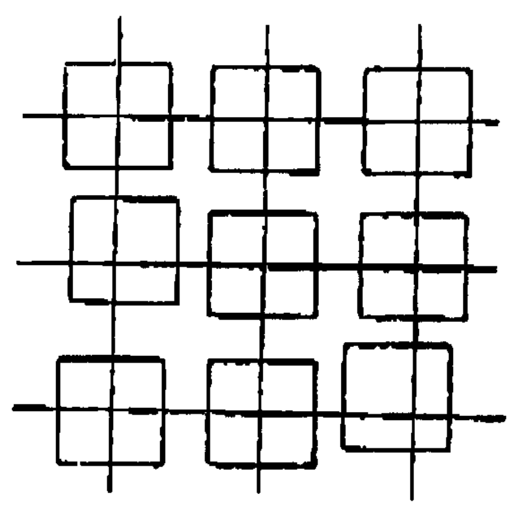

Figure 7
Gaps of Cells in Multiimages

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SEMI D22-0999
TEST METHOD FOR THE DETERMINATION OF COLOR, TRANSMITTANCE OF FPD COLOR FILTER ASSEMBLIES

This test method was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the Japanese Flat Panel Display Committee. Current edition approved by the Japanese Regional Standards Committee on June 1, 1999. Initially available on SEMI OnLine August 1999; to be published September 1999.

1 Purpose

1.1 This standard establishes practices for measuring selected characteristics of FPD color filters. These methods are applicable to manufacturing, quality control, and development operations.

2 Scope

2.1 This document defines means to measure.

2.2 Transmittance and chromaticity of color filter elements by measuring the characteristics of flux passed through a subpixel.

2.3 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicablity of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI D13 — Terms and Definitions for FPD Color Filter Assemblies

3.2 *ASTM Standards*[1]

D523 — Standard Test Method for Specular Gloss

E430 — Standard Test Methods for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry

E1392 — Standard Practice for Angle Resolved Optical Scatter Measurements on Specular or Diffuse Surfaces

F1049 — Test Method for Measuring the Effective Surface Roughness of Optical Components by Total Integrated Scattering

3.3 *ISO Standard*[2]

ISO 5/2 — Photographic density measurements, Part 2: Geometric Conditions for Transmission Density

3.4 *CIE Standards*[3]

CIE 1931 — Standard Colorimetric System (Colorimetry – Official Recommendations of the CIE

CIE 1976 (L*,a*,b*) — Color Space (Recommendations on Uniform Color Spaces

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

None.

5 Summary of Method

5.1 The measurement equipment is set to appropriate illumination wavelength, incident beam angle, and spot size.

5.2 For measurements of chromaticity and spectral transmittance.

5.2.1 The sample to be measured is placed on the stage and the illumination spot is located on an area free of color filter or other coating material for a reference sample.

5.2.2 Reference data is taken and only the other coating material for the reference is removed.

5.2.3 The sample is repositioned to place the illumination spot on the desired target area and the sample data is taken.

5.3 Measurement data for both reference and color filter are recorded.

5.4 A graph of the resulting data is prepared.

6 Apparatus

6.1 Measurement equipment shall have the following capabilities:

6.1.1 Optical wavelength: variable between 380 and 780 mm, in increments of ≤ 10 nm.

---

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshocken, PA 19428-2959, tel. 610.832.9585, fax 610.832.9555

2 ISO Central Secretariat, 1, rue de Valembé, Case Postable 56, CH-1211, Geneva 20, Switzerland

3 CIE International Commission on Illumination, Kegelgasse 27, A-1030 Vienna, Austria

6.1.2 Measurement spot size of incident beam at sample surface: adjustable from 2 µm to 50 µm.

6.1.3 Incident beam angle, relative to sample normal.

6.1.3.1 For transmittance measurements: 0° ± 5°.

6.1.4 Sample stage: sufficient mechanical travel to permit measurements within the color filter area and in the transparent area of the substrate outside the color filter material.

7 Reference Material

7.1 For transmittance measurements, use the sample to be measured and measure transmittance in a portion of the surface that is clear of color filter material. This establishes the level against which transmittance of the area containing the color filter material is compared.

8 Calibration

8.1 Calibrate the equipment in accordance with manufacturer's instructions.

8.2 Record characteristics of the instrument observed during this calibration, e.g., linearity, phase shift, etc.

9 Measurement Procedure

9.1 Place the sample(s) on the stage of the measurement equipment.

9.1.1 Set equipment properties for desired values as follows:

9.1.1.1 Wavelength,

9.1.1.2 Spot size,

9.1.1.3 Incident beam angle,

9.1.2 Measure reference surface and record results, and

9.1.3 Measure color filter area at desired locations and record results.

10 Report

10.1 Data and time of test; operator ID.

10.2 Equipment manufacturer, model, serial number and software revision.

10.3 Reference material used.

10.4 Equipment set-up (wavelength, spot size, beam angle).

10.5 Direction of beam relative to orientation of the sample pattern.

10.6 Measured parameter and value, at each measurement location.

10.7 Sketch of measurement location.

10.8 For transmittance measurement, generate a graph with:

X-axis = wavelength, and

Y-axis = measured transmittance.

10.9 For chromaticity measurements, generate a graph in accordance with:

10.9.1 CIE 1931 – x, y graph

10.9.2 CIE 1976 – (L*, a*, b*) or (L*, u*, v*).

11 Precision and Accuracy

11.1 No test data currently exists on which to base these statements. Tests are planned to develop such data for both single-laboratory repeatability and multi-laboratory reproducibility, on samples of the same nominal characteristics, and across a range of nominal characteristics.

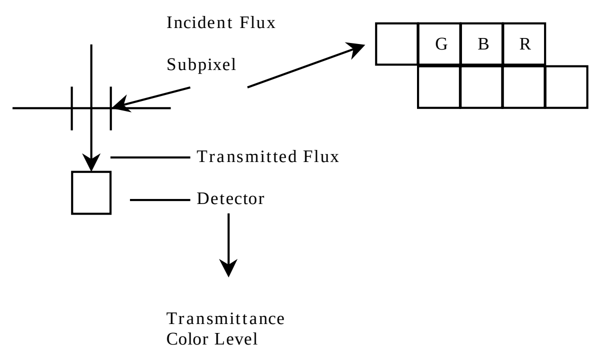

Figure 1
Transmittance and Color Level Measurements

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI D23-0999
GUIDE FOR COST OF EQUIPMENT OWNERSHIP (CEO) CALCULATION FOR FPD EQUIPMENT

This guide was technically approved by the Global Flat Panel Display Equipment Committee and is the direct responsibility of the Japanese Flat Panel Display Equipment Committee. Current edition approved by the Japanese Regional Standards Committee on June 1, 1999. Initially available on SEMI OnLine August 1999; to be published September 1999.

1 Purpose

1.1 The purpose of this document is to provide a standard, simple CEO calculation method for evaluating FPD manufacturing equipment. With this document, the following merits can be expected:

1.1.1 Both panel and equipment manufacturers, as well as material manufacturers can work from the same standard with regard to cost.

1.1.2 Panel manufacturers' basis for equipment comparison will become clear, which will, in turn, help in equipment selection.

1.1.3 The document will serve to clarify cost reduction items as well as benchmark cost reduction activities.

1.1.4 Direction for improvement for equipment manufacturers will become clear.

1.1.5 By doing a separate analysis, comparison, and evaluation of lines, equipment for different substrate sizes will become simpler.

2 Scope

2.1 This standard focuses on each equipment in the FPD production line. It is used to define the calculation method for cost of installing/operating that equipment, to define the calculation method for productivity of that equipment, and to quantify CEO of that equipment.

2.2 It is necessary to clarify the substrate sizes that can be handled by this equipment. However, this standard does not deal with the equipment process performance. It takes the point of view that each panel manufacturer should evaluate each equipment's process performance, including yield, based on their own process requirements.

2.3 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicablity of regulatory limitations prior to use.

3 Limitations

3.1 This standard does not attempt to include all elements necessary for equipment evaluation, and may be seen as incomplete from certain perspectives. However, it is believed that it will serve as the foundation for comparative evaluations.

4 Referenced Standards

None.

5 Terminology

5.1 Definitions for each of the items are listed in the following table.

6 CEO (Cost of Equipment Ownership) Table

6.1 Units in the document are for illustration only.

	Item	*Unit*	*Value*	*Definition & Formula*	*Notes*
A. Equipment Cost					
	(1) Base Cost	($)		Main Equipment Purchase Price	
	(2) Cost of Options	($)		Price of items which can be categorized as options separate from main equipment.	
	(3) Other Parts/Tools	($)		Price of tools and accessories (not included in main equipment or options price).	Enter maintenance-related consumables in D48 (Consumables).
	(4) Installation Cost	($)		Costs incurred in the installation of the equipment.	
	(5) Inspection Cost	($)		Costs incurred in inspection of the equipment.	
	(6) Shipping Cost	($)		Cost of shipping equipment to the installation location.	
	(7) Training Cost	($)		Cost of training in operation, maintenance, etc.	
	(8) Manual Cost	($)		Cost of manuals necessary for maintenance and operation.	
	(9) Other Costs	($)		Other necessary costs not included in above items.	
	(10) Subtotal	($)		Sum of (1) through (9).	If it is difficult to specify (1) through (9), it is possible to just enter (10).
	(11) Monthly Cost	($/month)		Monthly costs associated with equipment (10)/60 months.	Salvage value after 5 years is arbitrarily set here at 0. Adjust to real value as necessary.
B. Hook-Up Costs					
	(12) Materials (pipes, etc.)	($)		Costs for piping and other materials necessary to operate equipment.	
	(13) Power Connection	($)		Costs for connecting electricity, water, gas, air, etc. supplied by the factory to the equipment.	
	(14) Other	($)		Other installation costs not included in above items.	
	(15) Subtotal	($)		Sum of (12) through (14).	
	(16) Monthly Cost	($/month)		Monthly incidental installation costs (15)/60 months.	Salvage value after 5 years is arbitrarily set here at 0. Adjust to real value as necessary.
C. Clean Room Costs				For each area, if the shape is complex, use the square surface area.	Categorize clean area, gray area, and other dedicated areas according to the real situation of each factory.

	Item	*Unit*	*Value*	*Definition & Formula*	*Notes*
Clean Areas				Area for handling substrates and having the highest level of cleanliness.	
	(17) Main Equipment Dimensions (W*D)	(m^2)		Installed dimensions of the main equipment within the clean area.	
	(18) Accessory Dimensions (W*D)	(m^2)		Installed dimensions of pumps, power source, and other equipment outside of the main equipment within the clean area.	
	(19) Maintenance Area (W*D)	(m^2)		Dimensions of space in clean area necessary for maintenance of the equipment and accessories.	
	(20) Subtotal Area (W*D)	(m^2)		Subtotal of dimensions in clean area from above items (17) through (19).	
	(21) Floor Space (Unit Cost)	$\$/m^2$ • month		Monthly floor maintenance cost in clean area (by area unit).	
	(22) Monthly Dedicated Floor Cost	$/month		Monthly cost for clean area (20) $\times$ (21).	
Gray Area				Area with lower cleanliness level than above clean area.	
	(23) Main Equipment Dimensions (W*D)	(m^2)		Installed dimensions of the main equipment within the gray area.	
	(24) Accessory Dimensions (W*D)	(m^2)		Installed dimensions of pumps, power source, and other equipment outside of the main equipment within the gray area.	
	(25) Maintenance Area (W*D)	(m^2)		Dimensions of space in gray area necessary for maintenance of the equipment and accessories.	
	(26) Subtotal Area (W*D)	(m^2)		Subtotal of dimensions in gray area from above items (23) through (25).	
	(27) Floor Space (Unit Cost)	$\$/m^2$ • month		Monthly floor maintenance cost in gray area (by area unit).	
	(28) Monthly Dedicated Floor Cost	($/month)		Monthly costs for gray area (26) $\times$ (27).	
Other Dedicated Floor Area				Area with the lowest level of cleanliness (i.e., sub-floor, etc.).	
	(29) Dedicated Dimensions (W*D)	(m^2)		Installed dimensions of the main equipment in other dedicated floor area.	
	(30) Floor Space (Unit Cost)	$\$/m^2$ • month		Monthly floor maintenance cost in other dedicated floor area (by area unit).	
	(31) Monthly Dedicated Floor Cost	($/month)		Monthly costs for other dedicated floor area (29) $\times$ (30).	
D. Running Costs					

	Item	*Unit*	*Value*	*Definition & Formula*	*Notes*	
Power/ Utilities					Normal use and maximum use values entered by equipment manufacturer.	
					Normal Use [Unit]	Maximum Use [Unit]
	(32) Electricity	($/month)		Monthly cost of electricity necessary to operate equipment.	[ ]	[ ]
	(33) Cooling Water	($/month)		Monthly cost of cooling water necessary to operate equipment.	[ ]	[ ]
	(34) Air	($/month)		Monthly cost of air conditioning necessary to operate equipment.	[ ]	[ ]
	(35) Gas Exhaust Processing	($/month)		Monthly cost of gas exhaust processing necessary to operate equipment.	[ ]	[ ]
	(36) Liquid Waste Processing	($/month)		Monthly cost of liquid waste processing necessary to operate equipment.	[ ]	[ ]
	(37) Vacuum Line	($/month)		Monthly cost of vacuum volume necessary to operate equipment.	[ ]	[ ]
	(38) Nitrogen Gas	($/month)		Monthly cost of nitrogen gas necessary to operate equipment.	[ ]	[ ]
	(39) Dry Gas	($/month)		Monthly cost of dry gas necessary to operate equipment.	[ ]	[ ]
	(40) Other	($/month)		Other monthly power & utilities costs necessary to operate equipment.		
	(41) Power/Utilities Subtotal	($/month)		Subtotal of monthly power & utilities costs necessary to operate equipment; sum of (32) through (40).		
Process Materials Costs				Cost of materials necessary for processing.	Example: Resist, chemicals, process gases, cleaning gas, sputter target, etc. Enter by equipment in (42) to (46).	
	(42)	($/month)		Monthly cost	For the item name, enter each item necessary for the equipment.	
	(43)	($/month)		Monthly cost	For the item name, enter each item necessary for the equipment.	
	(44)	($/month)		Monthly cost	For the item name, enter each item necessary for the equipment.	
	(45)	($/month)		Monthly cost	For the item name, enter each item necessary for the equipment.	
	(46)	($/month)		Monthly cost	For the item name, enter each item necessary for the equipment.	
	(47) Process Materials Subtotal	($/month)		Subtotal of monthly costs for process materials; sum of (42) through (46).		

	Item	*Unit*	*Value*	*Definition & Formula*	*Notes*
Maintenance Costs				Expenditures (to external) for maintenance.	
	(48) Consumables	($/month)		Monthly cost for scheduled replacement parts.	
	(49) Scheduled Maintenance	($/month)		Monthly cost for scheduled maintenance.	Forecast maintenance
	(50) Other	($/month)		Monthly maintenance costs not included in above items.	
	(51) Maintenance Subtotal	($/month)		Subtotal of monthly expenditures (to external) for maintenance; sum of (48) through (50).	
	(52) Running Cost Subtotal	($/month)		Monthly running cost total: (41) + (47) + (51).	
E. Labor Costs				In-house labor costs	
	(53) Operator	($/month)		Equipment operator monthly labor cost	
	(54) In-house maintenance	($/month)		Equipment maintenance monthly labor cost	
	(55) Labor Cost Subtotal	($/month)		Subtotal of above costs (53) + (54).	Managers and engineers not included.
F. Cost Total					
	(56) Cost	($/month)		Total monthly costs necessary for operation of equipment: (11) + (16) + (22) + (28) + (31) + (52) + (55).	
G. Runtime					
	(57) Operating time	(hr/month)		Hours per month of factory operation	
	(58) 1-Item process time	(hr/ process)		Process recipe exchange time	
	(59) Number of processes/month	(process/ month)		Number of process recipe exchanges per month	
	(60) Process time	(hr/month)		Hour per month of process recipe exchange (58) $\times$ (59)	
	(61) Scheduled maintenance time	(hr/month)		Monthly scheduled maintenance time	
	(62) Start-up inspection time	(hr/month)		Time necessary, per month, for start-up.	
	(63) Down time (mc failure)	(hr/month)		Down time, per month, for machine failure.	
	(64) Other down time	(hr/month)		Down time, per month, not included in above items.	Product wait time not included.
	(65) Run time	(hr/month)		Monthly operation time (57) – [Σ (60) through (64)].	
H. Process Capacity					
	(66) Sheets/hour	(sheets/hr)		Number of sheets processed per hour	
	(67) Process capacity	(sheets/ month)		Number of sheets processed per month (65) $\times$ (66)	

	Item	*Unit*	*Value*	*Definition & Formula*	*Notes*
I. C.E.O. Cost of Equipment Ownership					
	(68) Cost per Substrate	($/sheet)		(56)/(67)	

7 Related Documents

7.1 *SEMI Standards*

SEMI E35 — Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI E35.1 — Guide for Cost of Equipment Ownership Comparison Metric

7.2 *STEP '95 COO & RAM Textbook*

FPD Expo '95 Tutorial Seminar Textbook — a-Si TFT-LCD Front End Manufacturing Technology – Cost Reduction Seen from a Production Technology Viewpoint

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI D24-0200
SPECIFICATION FOR GLASS SUBSTRATES USED TO MANUFACTURE FLAT PANEL DISPLAYS

This specification was technically approved by the Global Flat Panel Display – Material and Components Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Standards Committee on September 3, 1999. Initially available on SEMI OnLine November 1999; to be published February 2000.

1 Purpose

1.1 This standard specifies selected geometrical requirements of glass substrates used to manufacture flat panel displays.

2 Scope

2.1 This standard is intended to set levels of specification for glass substrates to insure repeatable manufacture of flat panel displays and uniformity of substrates from all vendors. This standard will also insure inter-changeability at all mechanical interfaces within process tools as well as with Transportation and Automation Cassettes.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Substrate size (edge length and width) and thickness are **not** specified so as not to infringe on supplier/customer relationships. Wherever possible, tolerances are specified independent of substrate size. Additional documents will be developed to specify the standard method of measuring each dimension.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI D3 — Quality Area Specification for Flat Panel Display Substrates

SEMI D4 — Method for Referencing Flat Panel Display Substrates

SEMI D5 — Standard Size for Flat Panel Display Substrates

SEMI D6 — Specification for Edge Length and Thickness for Flat Panel Display Mask Substrates

SEMI D7 — FPD Glass Substrate Surface Roughness Measurement Method

SEMI D9 — Definitions for Flat Panel Display Substrates

SEMI D12 — Specification for Edge Condition of Flat Panel Display (FPD) Substrates

SEMI D15 — FPD Glass Substrate Surface Waviness Measurement Method

4.2 *ISO Standard*[1]

ISO 1101 — Technical drawings — Geometrical Tolerances — Tolerances of Form, Orientation, Location and Run-Out — Generalities, definitions, symbols, indications on drawings

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *FPD Waviness* W_{fpd} — surface profile calculated by a moving minimum zone method. It is expressed as the maximum value of a minimum zone method straightness of a certain sampling within an evaluation length. An approximation in Appendix 1 of SEMI D15 can be used as well.

NOTE 2: It is recommended that the computer approximation method described in Appendix 1 of SEMI D15 be used.

5.2 *minimum zone method straightness* — the smallest distance between two parallel straight lines between which all of objective profile is included (see ISO 1101, Section 3.1).

5.3 *reference edges* — the two edges adjacent to the orientation corner.

5.4 *squareness* — the total variation of the position of the short sides of a substrate relative to straight lines drawn between the ends of, and perpendicular to, the long reference edge of the substrate.

5.5 *warp* — the gap between a) the bottom surface of an FPD substrate and b) the reference plate on which the substrate rests.

NOTE 3: Warp in other applications has traditionally been the TIR, or peak-to-valley of a surface (top, or bottom or median surface) of a substrate, measured with respect to a reference plane.

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1 ISO Central Secretariat, C.P. 56, CH-1211 Geneve 20, Switzerland; available in the U.S. from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

6 Test Methods

NOTE 4: The methods described below are approximations, except where they are followed by a reference such as SEMI D7. Formal test methods supporting the parameters in this document will be developed where needed; these will be published as separate documents. References to them will then be added to this document.

6.1 *Thickness* — Measure with differential (2-probe) gage using optical, non-contact, or contact sensors.

6.2 *Edge Squareness* — measure per Figure 2.

6.3 *Edge Conditions* — to be determined.

6.4 *Edge Straightness* — measure per Figure 2.

6.5 *Total Thickness Variation* — to be determined.

6.6 *Flatness, medium sheet* — to be determined.

6.7 *Roughness* — SEMI D7 roughness measurement method (contact stylus method, tip radium ≤ 2 μm).

6.8 *Warp* — Feeler gage with thickness equal to the specified maximum warp value, inserted between substrate bottom edge and surface plate, at any point or at specified points along the edges (formal test method/description to be developed).

6.9 *Waviness* — see SEMI D15.

7 Requirements

See Table 1.

8 Ordering Information

8.1 Purchase orders for substrates furnished to this specification shall include the following items:

8.1.1 Edge length

8.1.1.1 Long reference edge

8.1.1.2 Short reference edge

8.1.2 Orientation corner dimensions, from Table 1

8.1.3 Quality edge area exclusion

8.1.4 Thickness

8.1.4.1 Nominal

8.1.4.2 Tolerance

8.1.5 Warp

8.1.6 Straightness

NOTE 5: Table of Figures:

Table 1 Specification for Gen III and Larger Active-Matrix LCD Substrates

Reference Information	*Range A*		*Range B*		*Reference Documents*
Edge Length Ranges	550 to 650 mm × 650 to 830 mm		750 to1000 mm × 900 to 1100 mm		
Edge Length Dimensions	600 × 720 mm, 650 × 830 mm, 550 × 650 mm		800 × 950 mm	900 × 1100 mm	
Edge Length Tolerance[1]	± 0.40 mm		± 0.40 mm	± 0.50 mm	SEMI D5 – Std. Sizes for FPD Substrates
Squareness[1]	± 0.83 mm		W = ± 0.80 mm L = ± 0.95 mm	± 1.0 mm	SEMI D4 – Referencing of FPD Substrates
Edge Condition[9]	Rounded[9] Bevel width = 0.1 mm – 0.6 mm, — extension onto top/bottom surfaces		Rounded[9] Bevel width = 0.1 mm – 0.6 mm		
Orientation Corner[2]	1 Corner, Symmetric C1x = 4.0 ± 1.0 mm C1y = 4.0 ± 1.0 mm	1 Corner, Asymmetric C1x = 5.0 ± 1.5 mm C1y = 2.0 ± 1.5 mm	1 Corner, Asymmetric C1x = 5.0 ± 1.5 mm C1y = 2.0 ± 1.5 mm		
Corner Cut	3 corners C2x & C2y = 1.5 ± 1.0 mm		3 corners C2x & C2y = 1.5 ± 1.0 mm		SEMI D12 – Edge Condition
Quality Area[3] Edge Exclusion	≤ 10 mm		≤ 20 mm[11]		SEMI D3 – Quality Area for FPD Substrates
Thickness	0.7 mm ± 0.07 mm		0.7 mm ± 0.07 mm		SEMI D5 – Std. Sizes for FPD Substrates
	1.1 mm ± 0.10 mm		1.1 mm ± 0.10 mm		
Total Thickness Variation[4]	60 µm		100 µm		
Local Thickness Variation[5]	≤ 20 µm for ≤ 130 mm		≤ 20 µm for ≤ 130 mm		
Waviness[6] [W_{fpd}]	≤ 0.1 µm, with λ_C = 0.8 mm, λ_L= 8 mm L_S = 20 mm		≤ 0.1 µm, with λ_C = 0.8 mm, λ_L= 8 mm L_S = 20 mm		SEMI D15 – Surface Waviness Measurement
Warp[7]	≤ 0.60 mm		≤ 1.0 mm		
Roughness, R_a	≤ 20 nm		≤ 20 nm		SEMI D7 – Roughness Measurement
Straightness[8]	± 0.4 mm		± 0.4 mm		

NOTES:

1 For dimensional tolerance and squareness the long edge typically has the maximum tolerance. See Figures 1 and 2.

2 An asymmetric orientation corner is specified for purposes of mechanical orientation and operator's visual confirmation of orientation within a cassette. Optical means of identifying orientation is under investigation. See Figure 5.

3 Quality Area is that area in which the specified criteria apply.

4 Total thickness variation is the peak to valley (TIR) of the entire substrate front surface relative to a reference plane when the substrate back surface is constrained against a vacuum chuck. This scale is typically important for some film deposition and lithography processes. See Figure 6.

5 Local thickness variation is the absolute value of the maximum deviation of the substrate from a plane constructed in any 100–130 mm square area, within the Quality Area, when the substrate back surface is constrained against a vacuum chuck. This scale is typically important for lithographic stepper processes.

6 Waviness is the rms (root mean square) surface profile, within the quality area, over 0.8–8 mm spatial wavelengths.

7 See Figure 3.

8 See Figure 2.

9 See Figure 4.

10 This table applies to the indicated edge length ranges and thicknesses.

11 Example: For an 800 × 950 mm substrate, the effective process area, which excludes portions not processable for physical reasons, would be ≥ 760 × ≥ 910 mm.

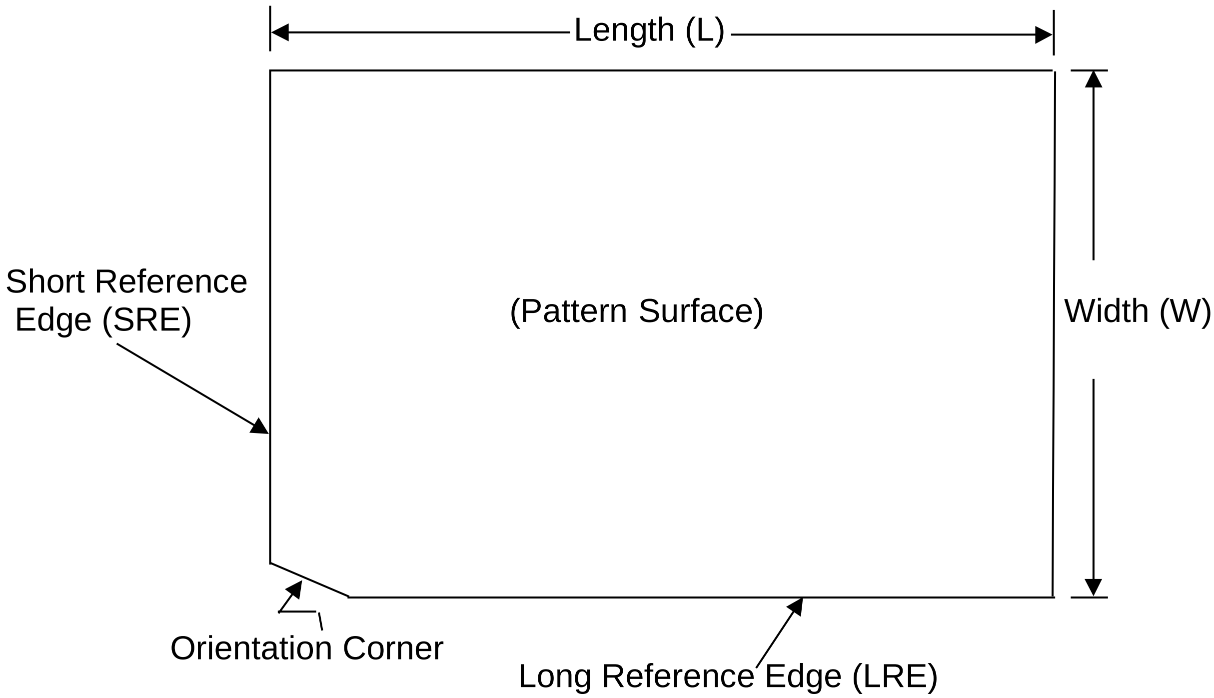
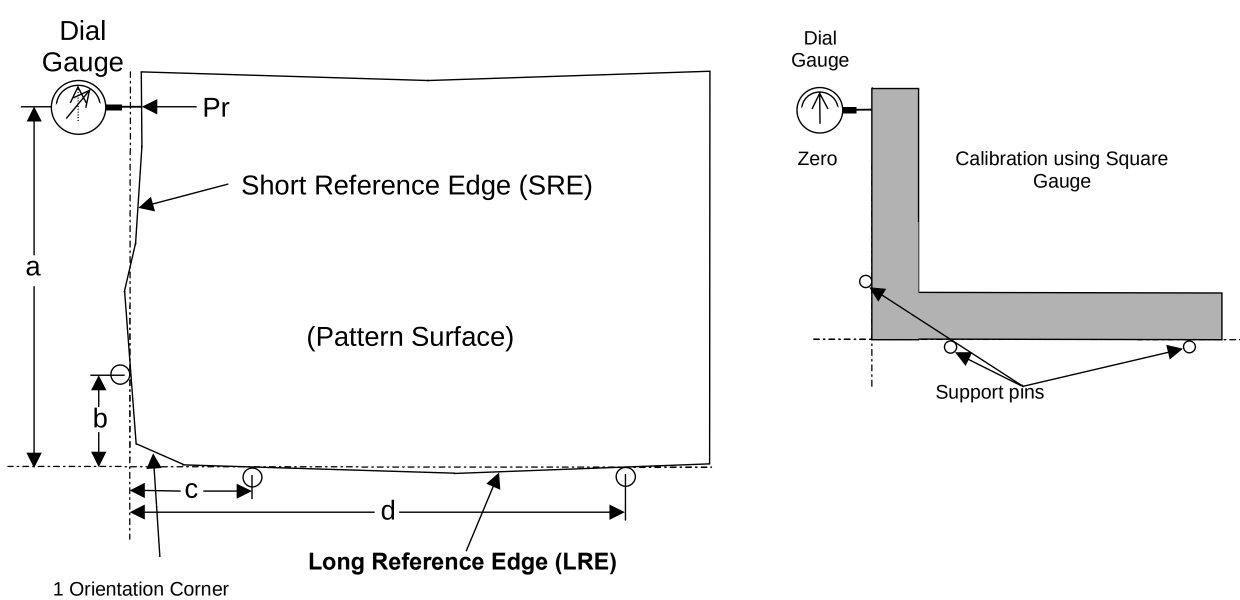


Figure 1
Reference Items



NOTE: a, b, c, and d are defined between supplier and customer.

Figure 2
Squareness

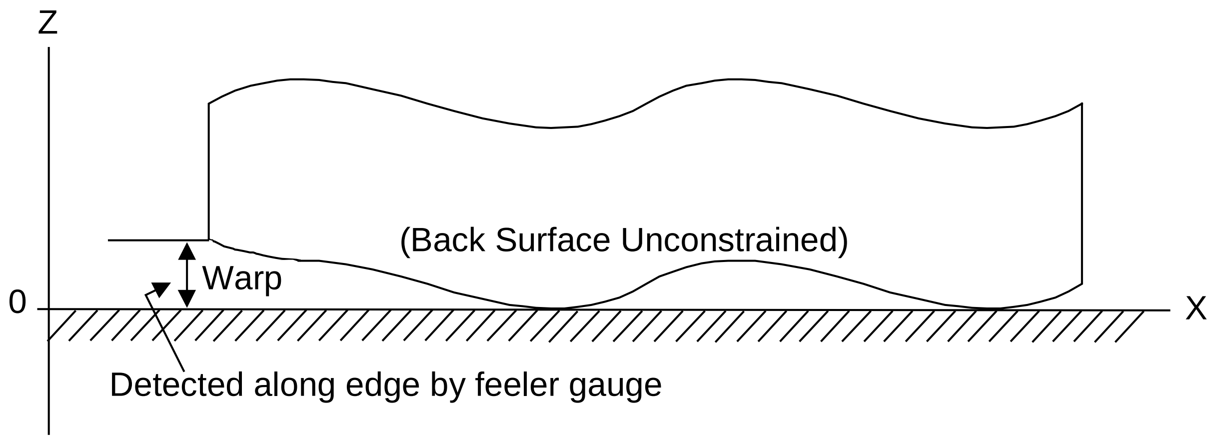


Figure 3
Warp

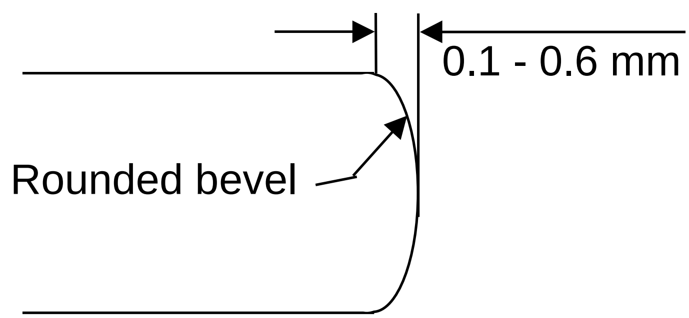


Figure 4
Edge Condition

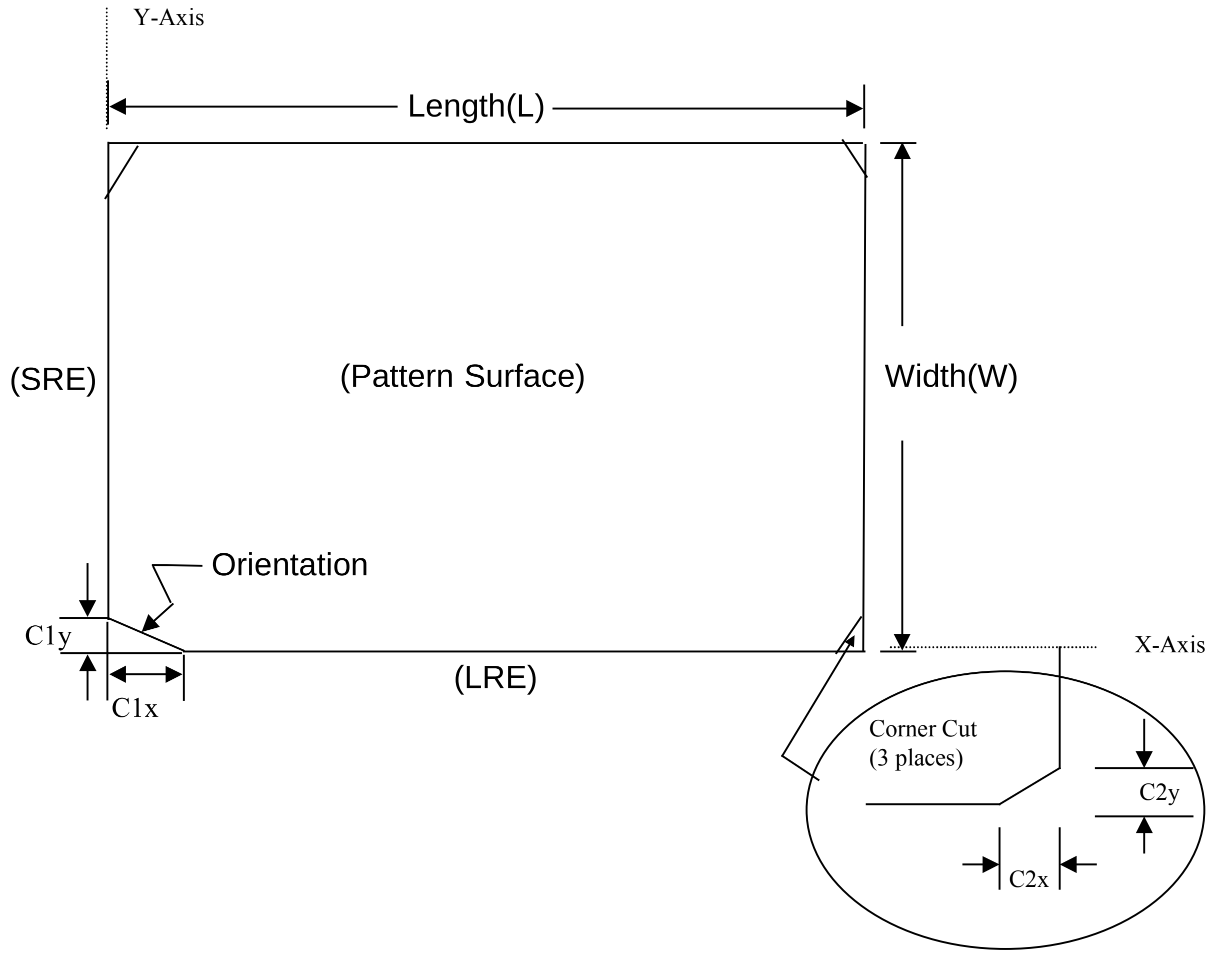


Figure 5
Orientation Corner and Corner Cuts

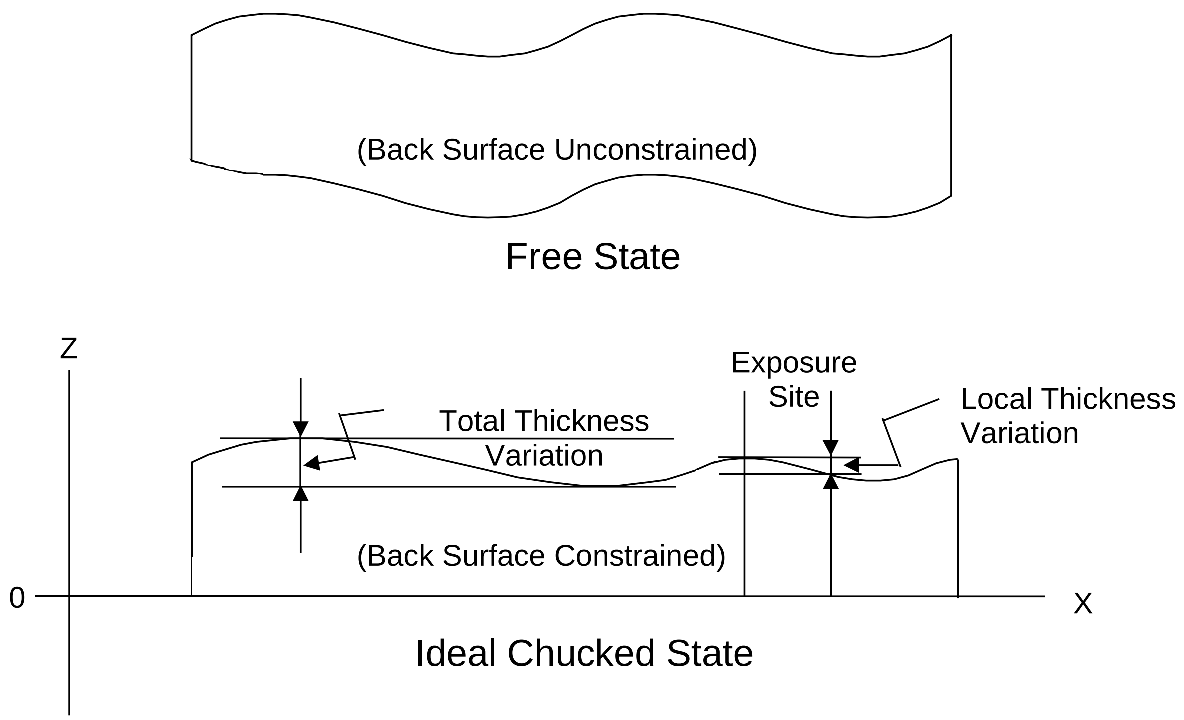


Figure 6
Total Thickness Variation and Local Thickness Variation

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SEMI D25-0600
SPECIFICATION FOR FLAT PANEL DISPLAY SUBSTRATE SHIPPING CASE

This specification was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the Japanese Flat Panel Display Committee. Current edition approved by the Japanese Regional Standards Committee on April 21, 2000. Initially available on SEMI OnLine May 2000; to be published June 2000.

1 Purpose

1.1 This document provides the packing and shipping specifications and/or guides for FPD glass substrates, which are called fourth generation substrates ($800 \times 950 \times 0.7$ mm or $800 \times 950 \times 1.1$ mm).

1.2 The objective of this document is to provide cost-effective packing and shipping in terms of packing materials, storage, and shipping, while making sure that packing meets the quality and automation requirements.

2 Scope

2.1 This document defines a specification for a full box type shipping case (see Figure 2) to be used for packing and shipping of 4^{th} generation FPD glass substrates from the manufacturer of the glass substrate to the user.

2.2 The application of this packing specification is limited to the following four FPD glass substrates:

2.2.1 Bare glass substrates which can be used as array substrates, and do not have film deposition.

2.2.2 Bare glass substrates which can be used as facing substrates and color filter substrates, and do not have film deposition.

2.2.3 Array substrates which do have film deposition.

2.2.4 Facing substrates and color filter substrates which do have film deposition.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Prerequisites and Limitations

3.1 This specification does not apply to:

3.1.1 cassettes used for intra/inter bay transfer inside the user's plant;

3.1.2 the semi-separating type the contact type packi-ng method (see Figure 4) or the full corner supporter type and the double side supporter type (see Figure 3)

3.2 The premise for glass substrates for this packing specification is as follows.

3.2.1 *Size*

W (mm):	Short Edge
L (mm):	Long Edge
t (mm):	Thickness

W = 800 mm W tolerance: see SEMI D24
L = 950 mm L tolerance: see SEMI D24
t = 1.1 t tolerance = see SEMI D24
t = 0.7 t tolerance = see SEMI D24

3.2.2 *Squareness* — see SEMI D24 *Beveling* — R beveling

3.2.3 *Orientation Corner* — see SEMI D24

3.2.4 *Corner Cut* — see SEMI D24

3.2.5 *Edge Exclusion Area* — see SEMI D24

3.2.6 *Sag* — In the event of the glass substrate being placed horizontally on the support as shown in Figure 1, sag is defined by h2 (two sides supported), and h4 (four sides supported) (Unit = mm) (see Figure 1).

3.2.7 *Density* — Less than 2.8 g/cm^3

3.3 When the glass substrates are shipped, they shall be loaded vertically.

3.4 When the glass substrates are shipped, a standard sized pallet shall be used for efficient loading on the truck platform or the floor of the container (see Appendices 1 and 2). The standard size used here is less than $1,100 \times 1,100$ mm^2 or, at the outside, $1,100 \times 1,200$ mm^2.

3.5 When the glass substrates are shipped, the loading should be as efficient as possible utilizing the available space, in line with:

- The smallest height for truck platforms and containers is 2,300 mm (see Appendices 1 and 2).
- Taking into consideration the head clearance when loading and unloading by forklift, as well as the height of the shipping case, the maximum height of the load is approximately 2,000 mm. If more efficient loading can be achieved, multiple boxes can be stacked.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI D9 — Definitions for Flat Panel Display Substrates

SEMI D11 — Specification for Flat Panel Display Glass Substrate Cassettes

SEMI D24 — Specification for Glass Substrates Used to Manufacture Flat Panel Displays

4.2 *JIS Documents*[1]

JIS D4002 — Internal Dimensions for Rear Body of Motor Trucks

JIS Z0604 — Wooden Flat Pallets

4.3 *ISO Documents*[2]

ISO 668 — Series 1, Freight Container – Classification, Dimensions and Ratings

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

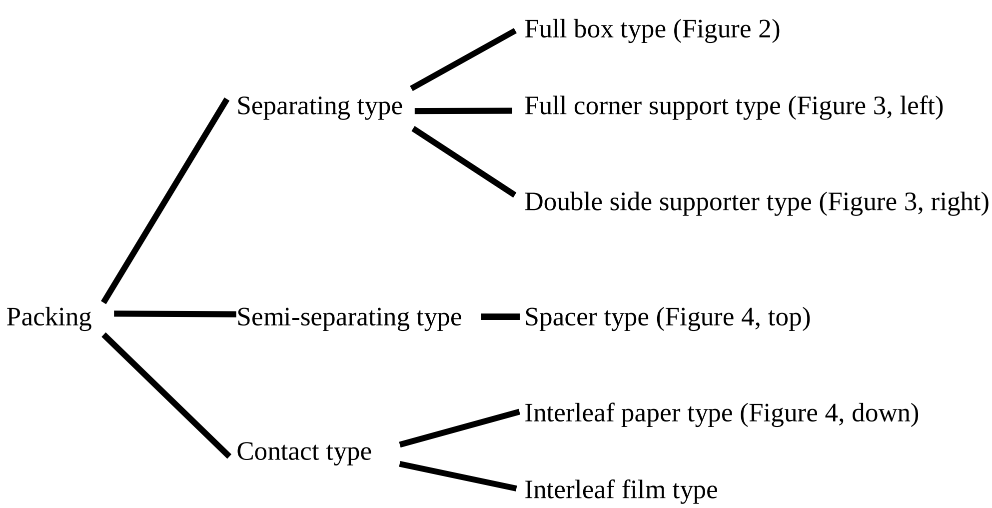
5 Terminology

5.1 *Size of exposed portion* — The length of the glass substrate exposed from the packing box (full box type) when the lid of the packing box is open.

6 Packing

6.1 *Classification*

6.1.1 Classification of packing is as follows:



6.2 *Packing Box Dimensions* — Figure 5 shows the key dimensions and tolerances of the packing box for the full box type.

6.2.1 *Packing Box Loading and Unloading*

6.2.1.1 Vertical loading shall be used to load and unload the glass substrates to and from the packing box (see Figure 6).

6.2.1.2 Vertical loading requires a tall loader/unloader because of the height of the loading direction. The ceiling height of the room where the loading equipment is installed has to be designed accordingly.

1 Japan Standards Association, 4-2-24, Minato-ku, Tokyo 107, Japan

2 ISO Central Secretariat, C.P. 56, CH-1211 Geneve 20, Switzerland

6.2.1.3 A suggested method for loading/unloading substrates from the shipping case with an automatic vertical loader/unloader is to tilt the box as shown in Figure 7. Align the substrates on one side of the clearance of the mizo and proceed with loading/unloading.

6.2.1.4 An alternative method for loading/unloading would be to rotate the packing box 90°, as shown in Figure 8.

6.2.1.5 Loading and unloading the substrates also can be done manually without using an automatic loader/unloader.

6.2.2 *Packing Box Size*

6.2.2.1 The shorter side of the substrate (side W, or the 800 mm side) as the vertical direction (direction z in Figure 5) during shipping. This way, the size of the substrate determines the inside measurements of the packing box, H: 800 mm (direction z), W: 950 mm (direction x).

6.2.2.2 The outside measurements of the packing box shall be H: 980 mm × W: 1,200 mm × L: ≤ 1100mm (Figure 5). It is important to note that the height of 980 mm indicates that it is possible to stack up the packing boxes, i.e. 980 mm × 2 = 1,960 mm, and still be less than the possible maximum height (2,000 mm) of the truck load.

6.2.2.3 The length of the packing box is determined by the calculated product of the pitch size between the substrates times the number of substrates stored in the box. the length (L in Figure 5) of the packing box cannot exceed 1,100 mm

6.2.3 *Packing Box Lid*

6.2.3.1 The packing box must prevent the substrates from getting contaminated as well as to give pressure to the substrates for securing them from both top and bottom. The lid must securely seal and be able to latch closed to the packing box by a lock. The latching mechanism must allow easy automatic lock and unlock as well.

6.2.3.2 The lid shall also have automatic and manual opening/closing capability. The inside of the lid is covered with a shock absorber that functions to secure the glass substrates by pressing them from the top and bottom.

6.2.4 *Mizo Pitch and Capacity of Packing Boxes*

6.2.4.1 The sag, h4 = 20 mm will be for the substrates of the size 800 × 950 × 0.7 mm as shown in Appendix 3, when a sudden turn, acceleration, or braking during shipping forces a 1G acceleration against the substrates. From this point of view, the pitch required here is a little bit larger than 20 mm. However, since all the substrates in the box are affected by the acceleration at the same time and in the same direction, the distance between the substrates will remain constant which means the substrates should not touch each other.

6.2.4.2 The mizo pitch, must be standardized by each shipping case supplier, but must range from a minimum of 9 mm to a maximum of 22 mm ± 0.2 mm. Table 1 shows possible number of substrates per shipping case at a given pitch.

Table 1 Pitch and Number of Substrates

Pitch (mm)	*Number of Substrates (pc)*
22	40
18	50
15	60
11	80
9	100

6.2.4.3 The first mizo clearance (see Figure 9) is to be more than 40.0 mm at the center of the groove. The distance from the reference plane to the first mizo is the sum of the first mizo clearance and the thickness of the side of the box which is the reference plane, and its allowance is ± 1.0 mm. The allowance of cumulative pitch distance is less than ± 2.0 mm, and that of each pitch is less than ± 1.0 mm.

6.2.4.4 Mizo clearance shall be designed to store the glass substrate of a thickness ranging from 0.7 mm to 1.1 mm.

6.2.5 *Size of Exposed Portion*

6.2.5.1 In this document, the size of f1 in Figure 10 is called “the size of the exposed portion” which is set as f1 = 100 mm. Size h in Figure 10 is the shorter side of the substrate at 800 mm. The size of f2 is 700 mm which means one eighth of the whole substrate is exposed.

6.2.6 *Reference Plane*

6.2.6.1 The reference plane needs to be determined as follows from three directions, x, y, and z in Figure 5 for automatic transferring:

x: Both sides or center position
y: Both sides or center position
z: Bottom surface of the box (not the bottom of the skid described later)

6.2.6.2 Specifically use the small area as a reference surface in Figure 11. The detail of the position and size of the reference surfaces shall be standardized to use a compatible reference for two different design boxes. Also the center line of substrate is automatically defined by symmetrical location between substrate and reference plane of case.

6.2.7 *Transfer and Lift Method for Packing Boxes*

6.2.7.1 It is expected that not only boxes containing glass substrates but also empty boxes are fairly heavy. At least, they probably cannot be carried by hand. Therefore, it is assumed that whether the box contains glass substrates or not and whether the box is in a regular room or a clean room, it shall be lifted by a forklift and transferred mechanically. To accommodate a mechanical transfer and lift, skids must be installed at the bottom of the box so that the forklift can insert its tongues underneath the box (see Figure 5). The height of the skids shall be standardized for each shipping case supplier, but not exceed 150 mm.

6.2.7.2 Assuming lifting of the box and short distance, transfer is done using a balancer; the packing box is required to have handles, as shown in Figure 12, on the sides of the box. The structure of the handles shall be designed in such a way that it does not hinder the reference plane.

6.2.8 *Packing Box Strength*

6.2.8.1 The weight of the contents of the box, with the prescribed number of substrates, can be calculated from the density of substrates. The packing box has to be strong enough to bear that weight. Moreover, it has to be strong enough to hold another full box on top of itself (need to specify less than or equal to weight).

6.2.8.2 Stacking three boxes with glass substrates is prohibited. Therefore there is no need for the packing box strength to hold two boxes on top of one box. However, empty boxes may be stacked three high, but the box has to be designed to bear the weight of two empty boxes.

6.2.8.3 The handles shall be strong enough to hold the weight when the box is filled with glass substrates as well as a full box on top or two empty boxes on top.

6.2.9 *Packing Box Material*

6.2.9.1 Because of this, packing box material is not covered in this document. Neither carcinogen nor de-gasification is covered. For the purpose of cleaning, cleanliness, and particle reduction, the material of the box has to be washable and solvent-resistant. The addition of draining holes is acceptable. Material must meet cleanliness, mechanical strength, and durability in line with specifications of this document.

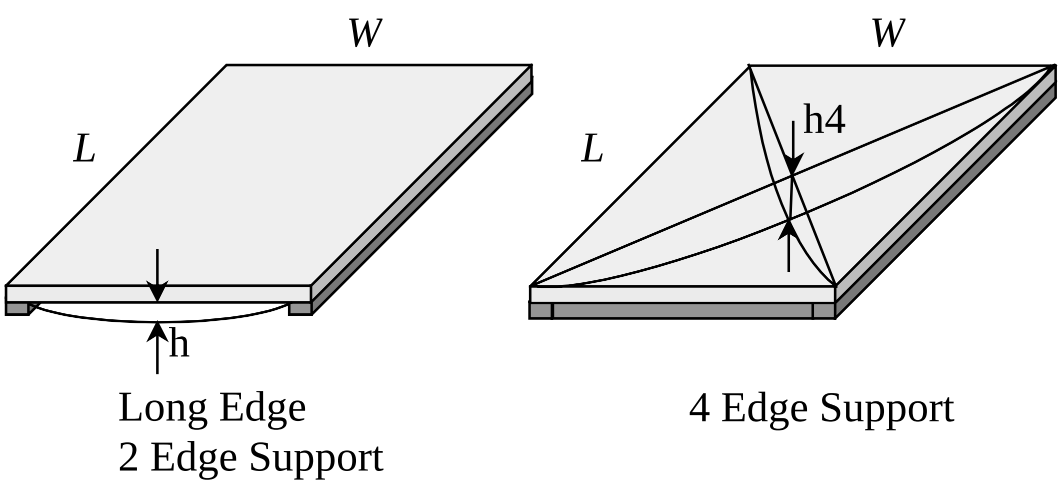


Figure 1
Sag

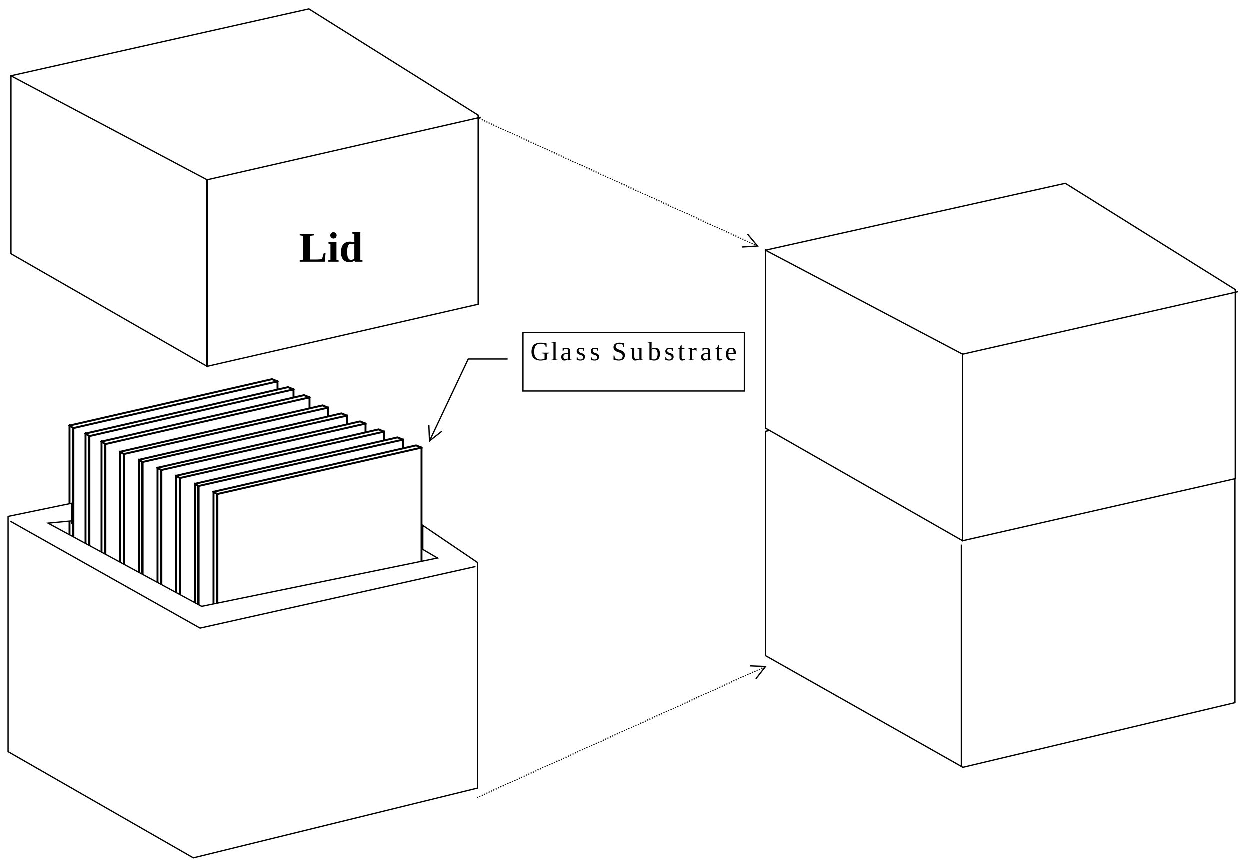
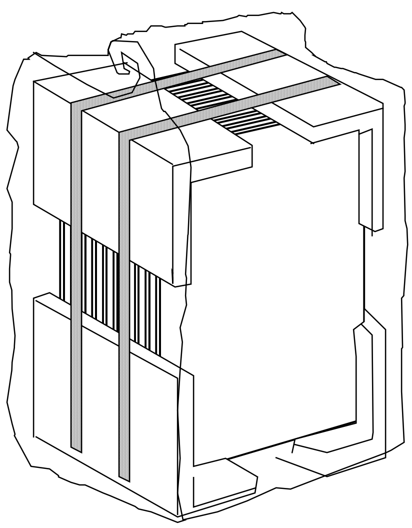
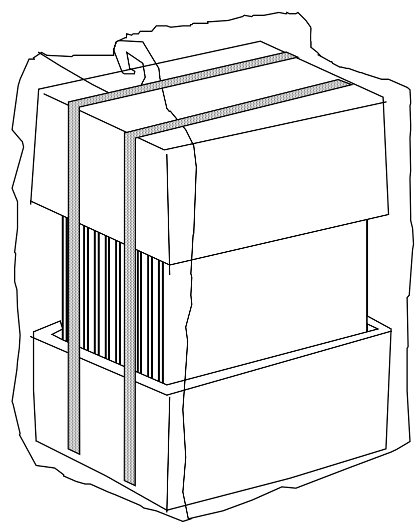


Figure 2
Full Box Type

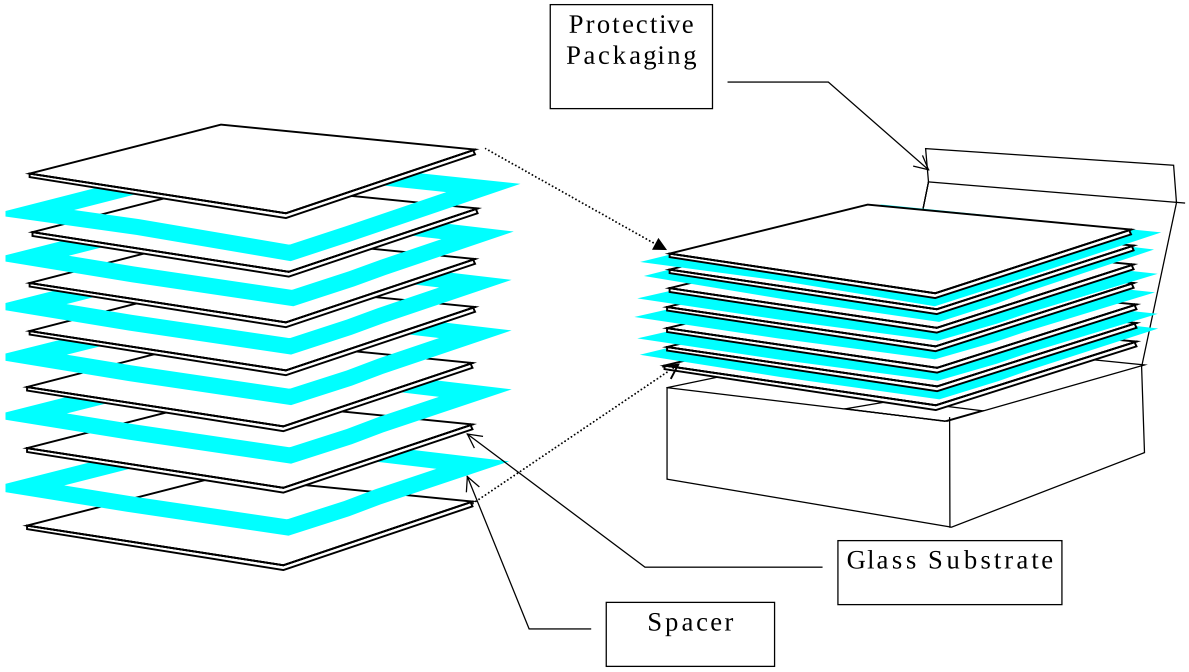


4 Corner Supporter Type

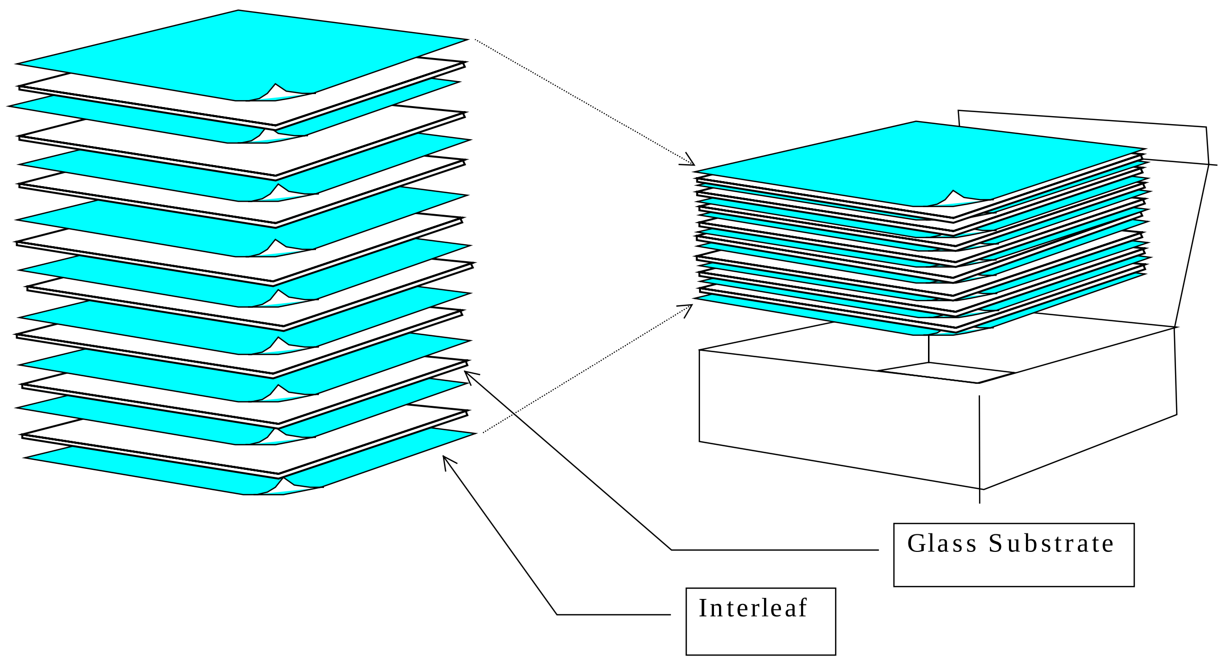


2 Edge Supporter Type

Figure 3
Partial Box Type



Spacer Type



Interleaf Type

Figure 4
Separator Contact Types

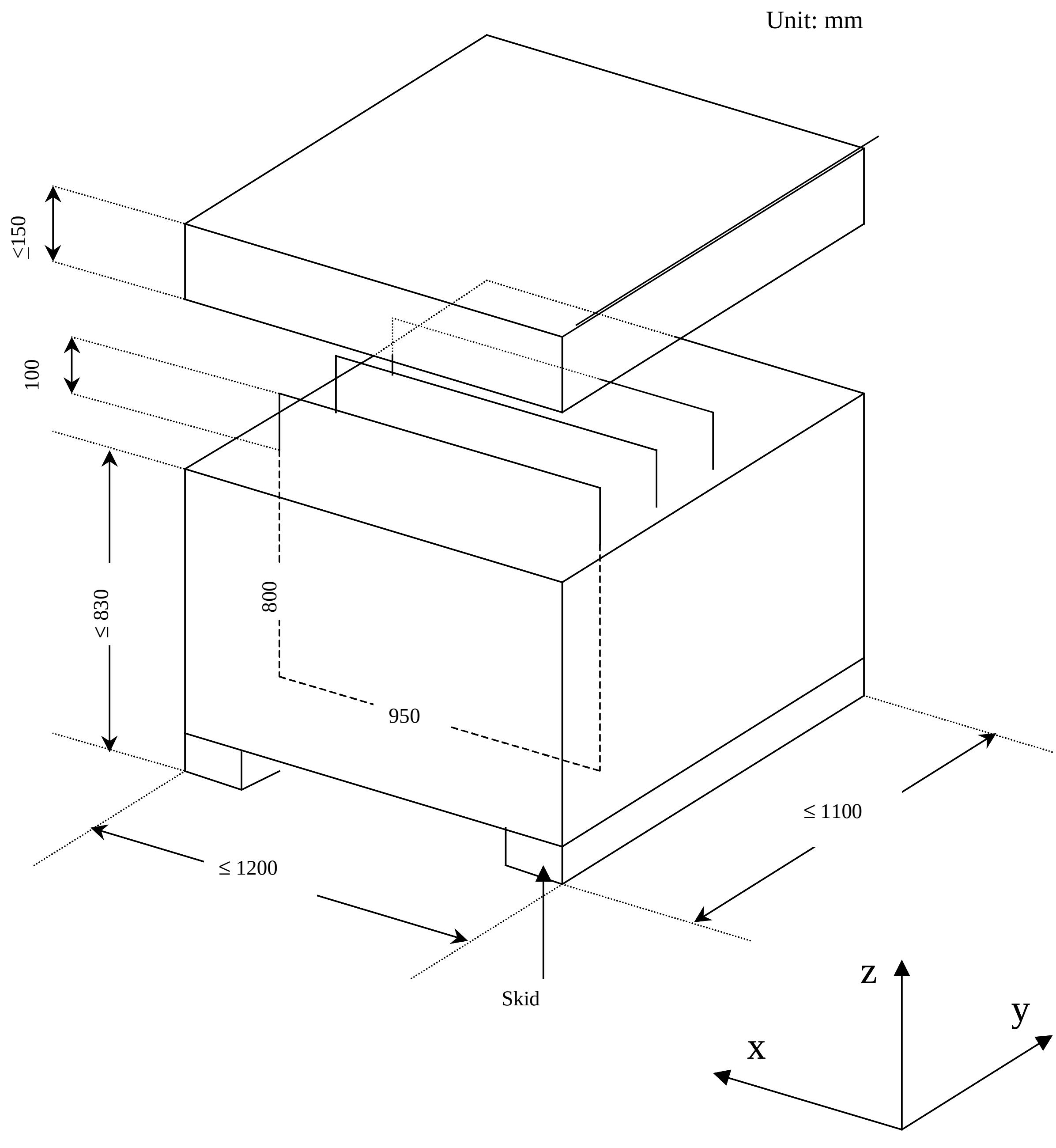


Figure 5
Packing Box Concept

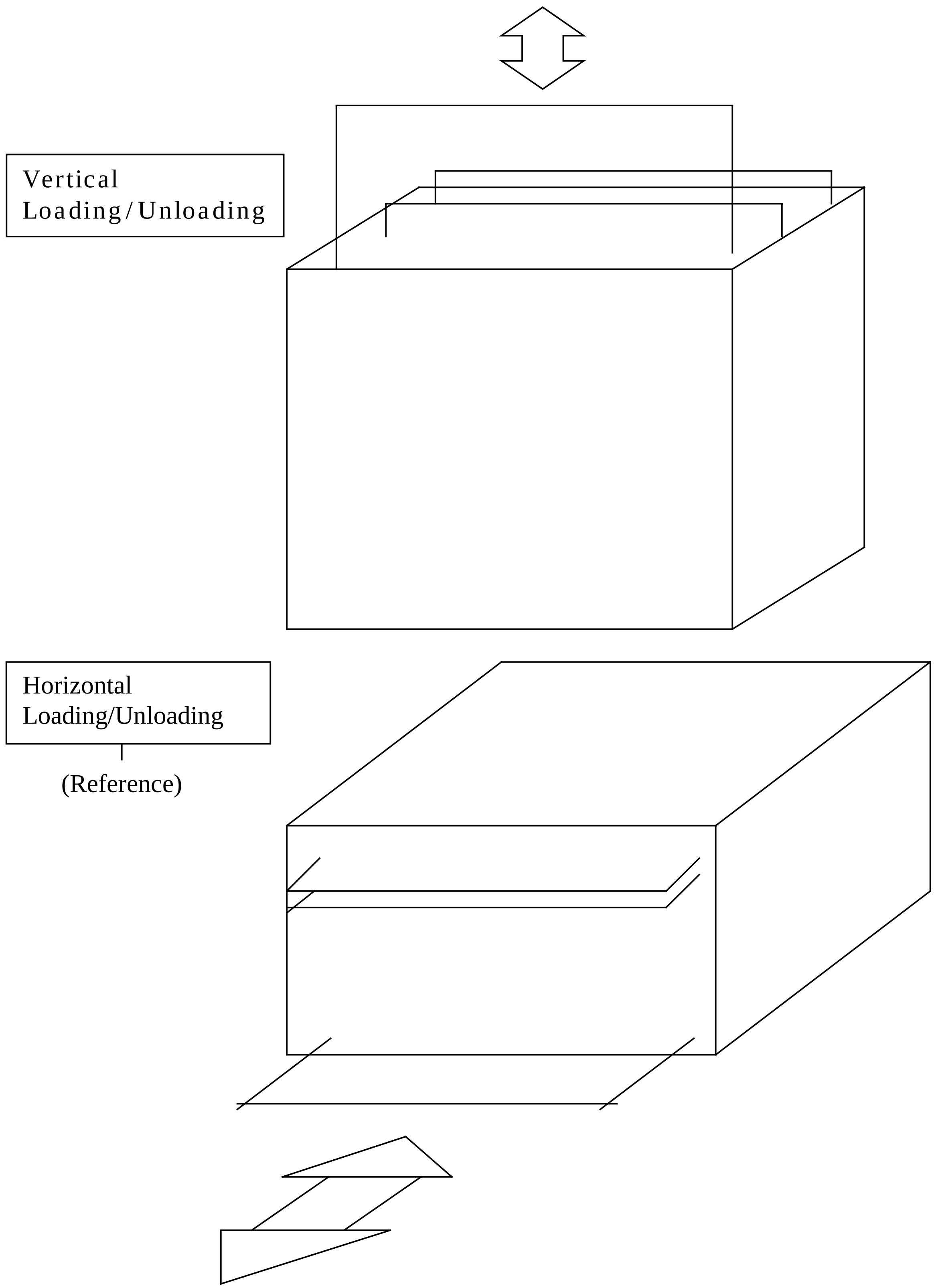


Figure 6
Loading/Unloading Method

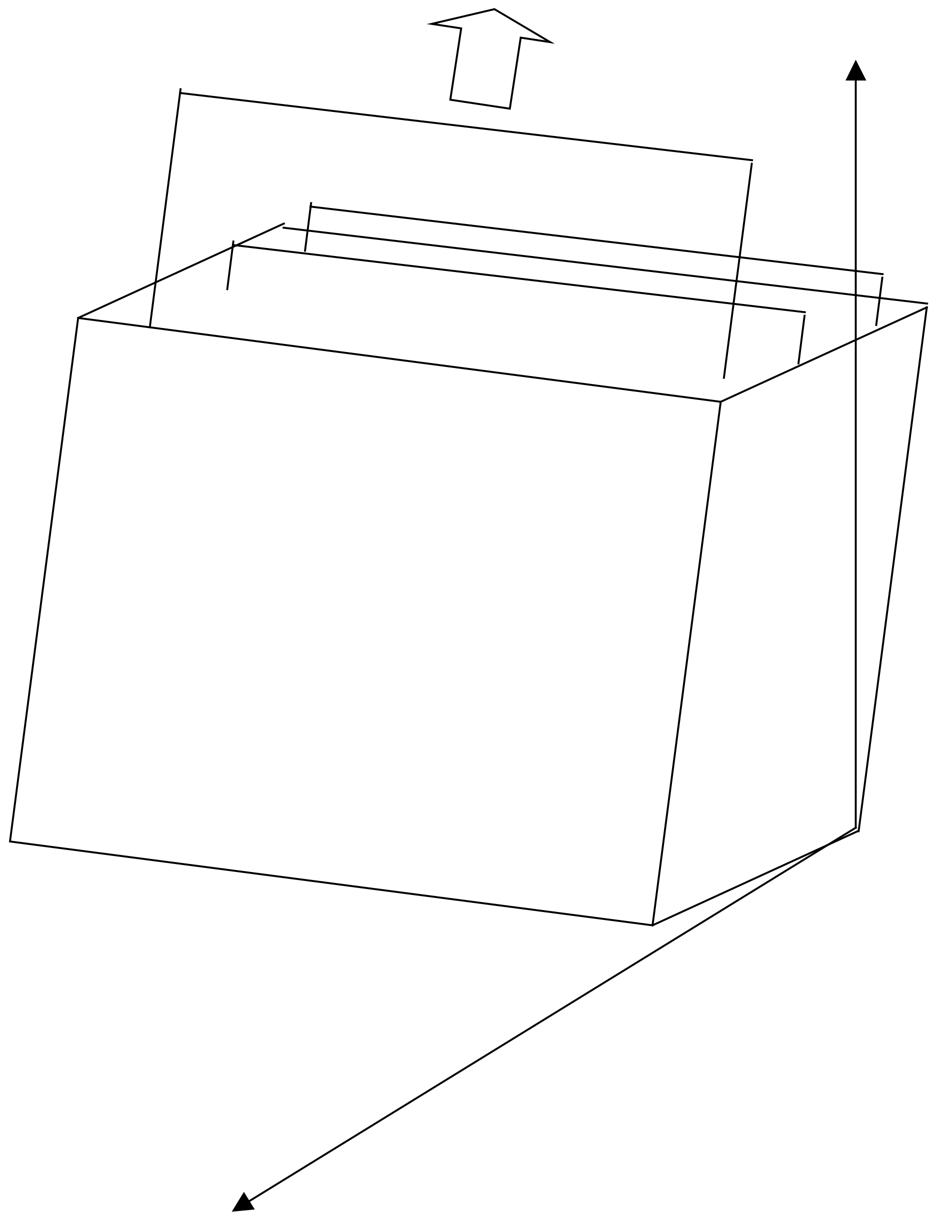


Figure 7
Leaning Vertical Unloading

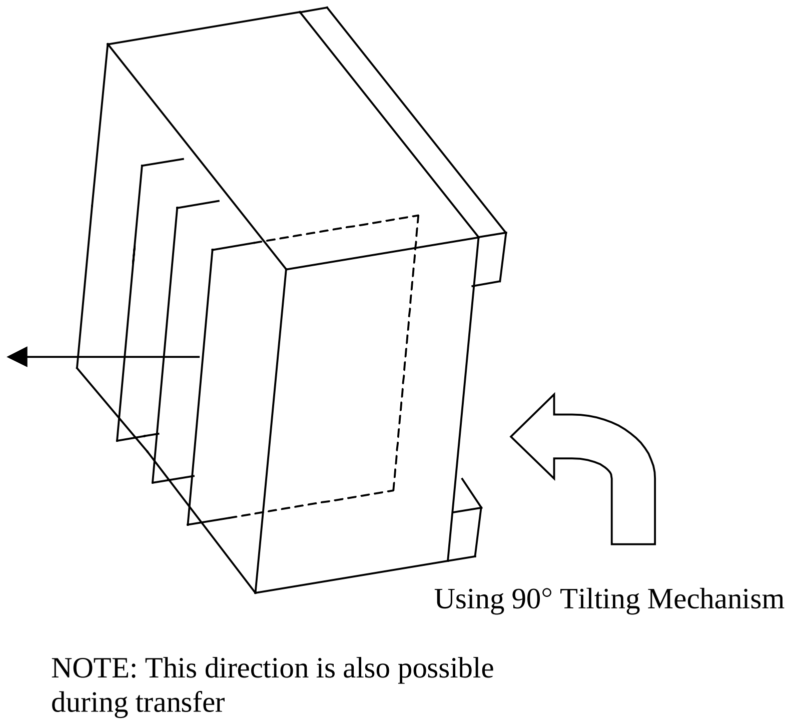


Figure 8
Removing Glass with a 90° Tilting Mechanism

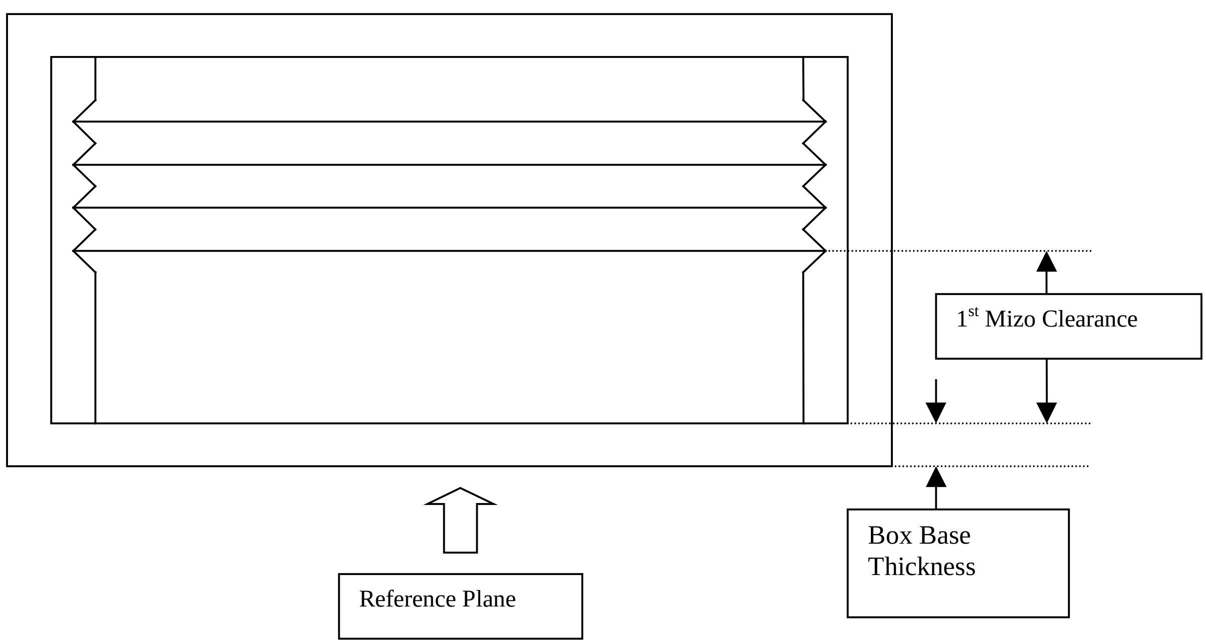


Figure 9
Mizo Definition

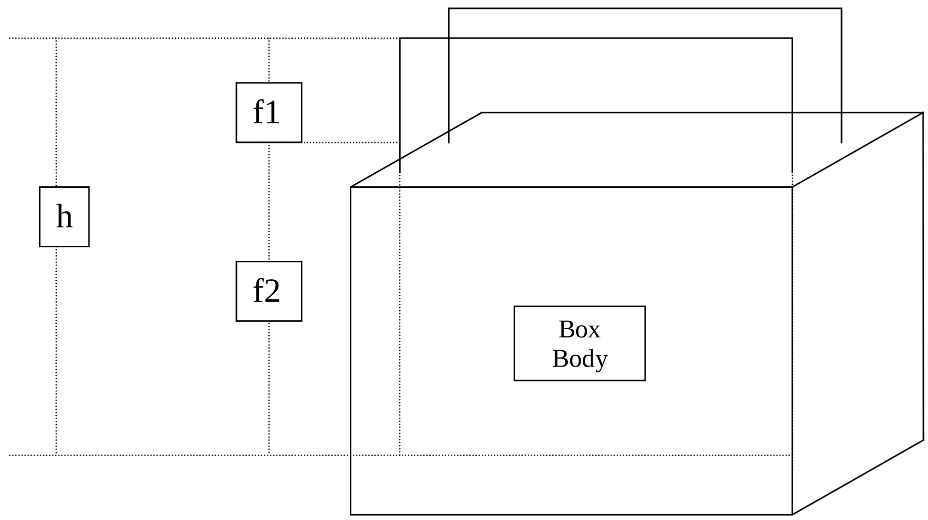


Figure 10
Size of Exposed Portion

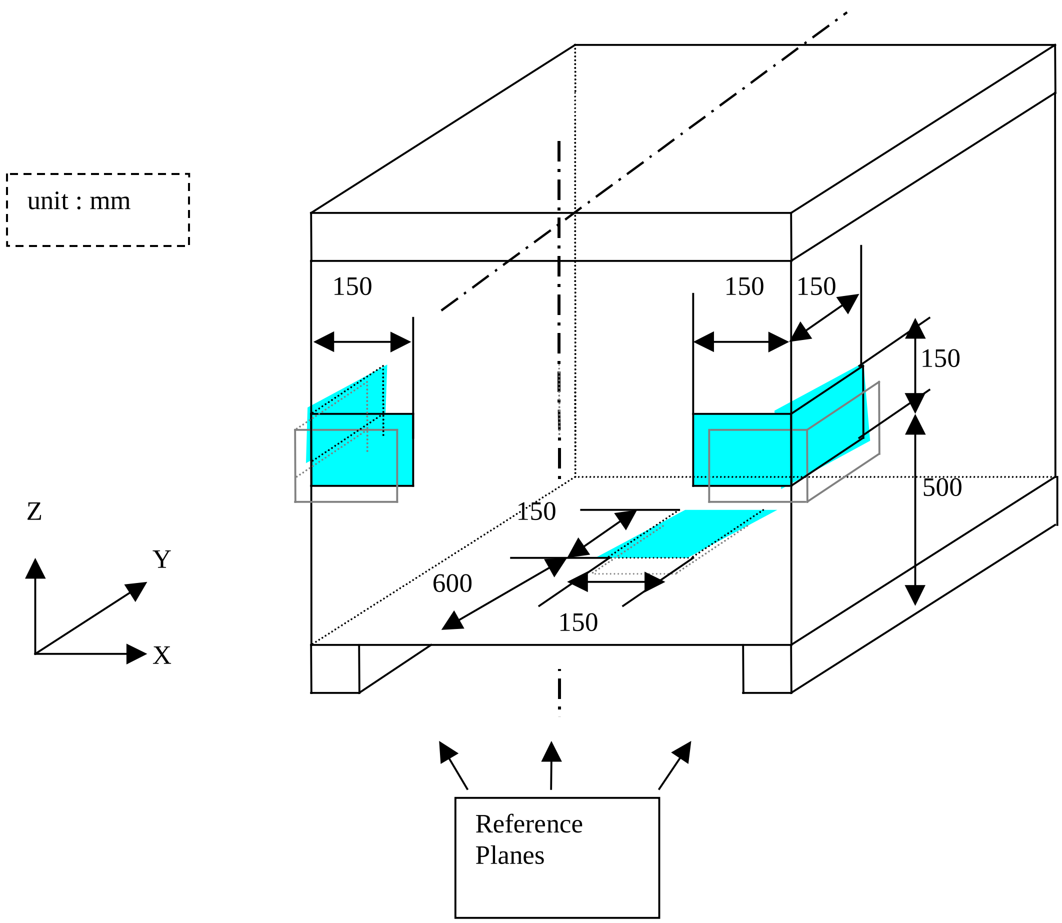


Figure 11
Polishing Reference Planes

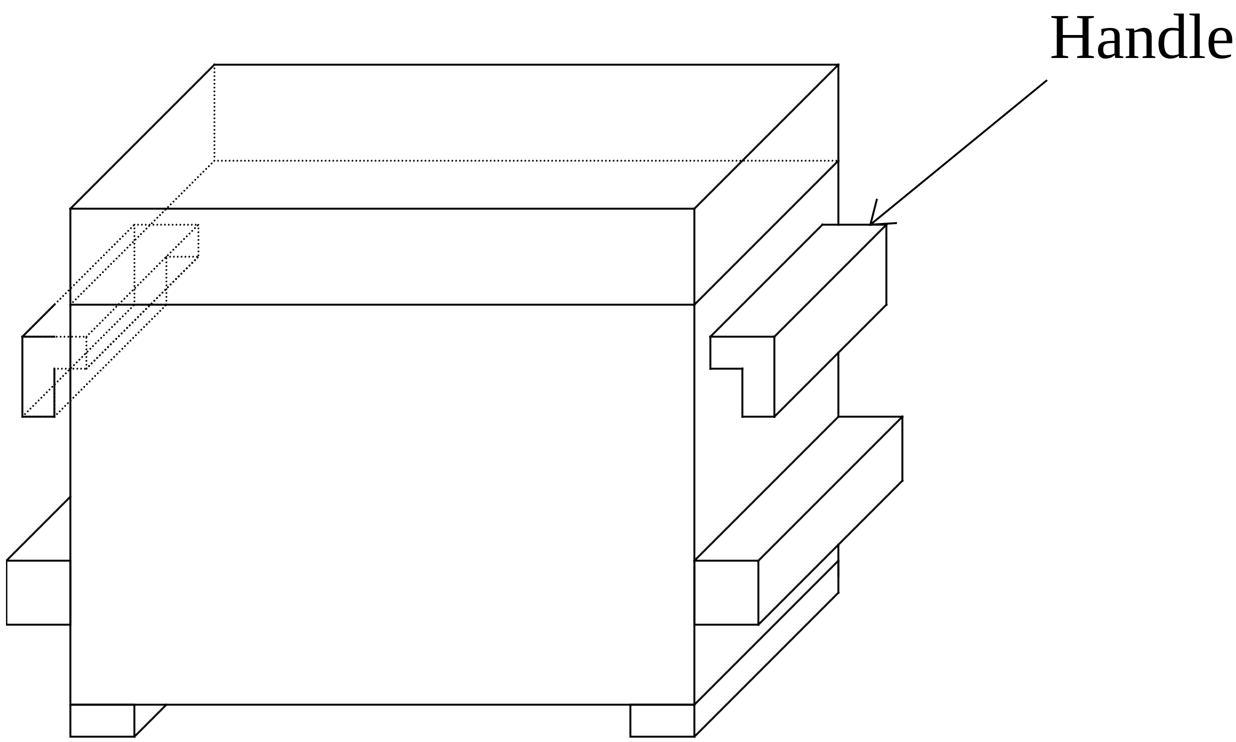


Figure 12
Packaging Handles

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI D25 and was approved by full letter ballot procedures on April 21, 2000 by the Japanese Regional Standards Committee.

A1-1 Truck Platform Dimensions

NOTE: This data only applies in Japan.

Reference: JIS D4002 Internal Dimensions for Rear Body of Motor Trucks

A1-1.1 *Dimensions* — The platform inner dimensions are categorized by width and length and listed in the table below. These dimensions shall be selected on the basis of their feasibility with regard to the functions of the chassis and the shape, use and special equipment of the platform. The dimensions represent the minimum dimensions for each category.

Table A1-1 Platform Inner Dimensions (mm)

Width Category	Symbol	A	B
	Ordinary Platform	2340	2120
	Van Body	2370	2150
Length Category		9600	
		9000	
		8400	
		7800	
		7200	7200
		6600	6600
		6000	6000
		5400	5400
		4800	4800
		4200	4200
Note		5-12 tons	4 ton wide 5-6 ton narrow

A1-1.2 *Dimension Naming* — Naming of the inner dimensions of the platform is accomplished by using the type (either Ordinary Platform or Van Body), the symbol for the width category and the length category in meters. Example:

Ordinary A – 8. 4

Van B - 6. 6

Length Category

Width Category

Van Body

At present, it seems that generally 10 ton-class trucks use A, and 4 ton trucks use B. The following information was gathered from one transport company:

10 Ton – W=2330	L=9560	H=2280
4 Ton – W=2100	L=6700	H=2300

(Unit = mm)

Measurements may differ depending on the manufacturer and model.

A1-2 Shipping Model

A1-2.1 The shipping model (Figure A1-15) shows the storing of fourth generation flat panel display glass substrates in the packing box as described in this specification, a glass substrate manufacturer transporting substrates to a user, and the user returning the box.

A1-2.2 For covering the outside of the packing box, a plastic bag over the top is recommended. If the contamination of the bottom part of the box is a concern, prevention is not limited. In any case, the goal of this shipping model is to make it as simple as possible and to reduce the cost and investment.

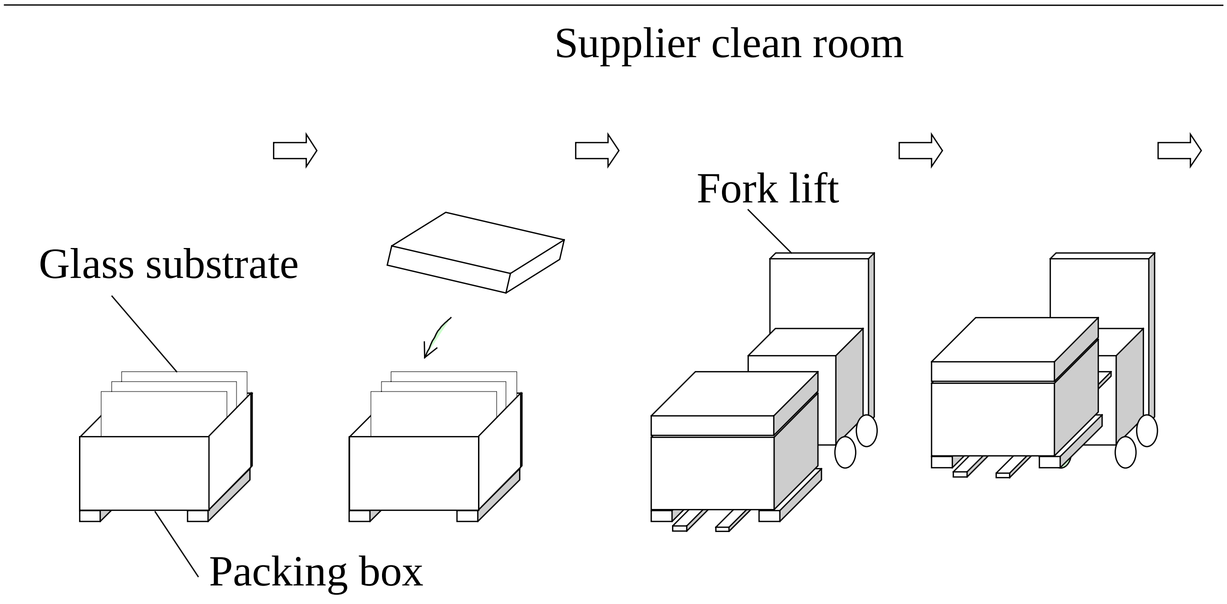


Figure A1-1
Supplier Clean Room

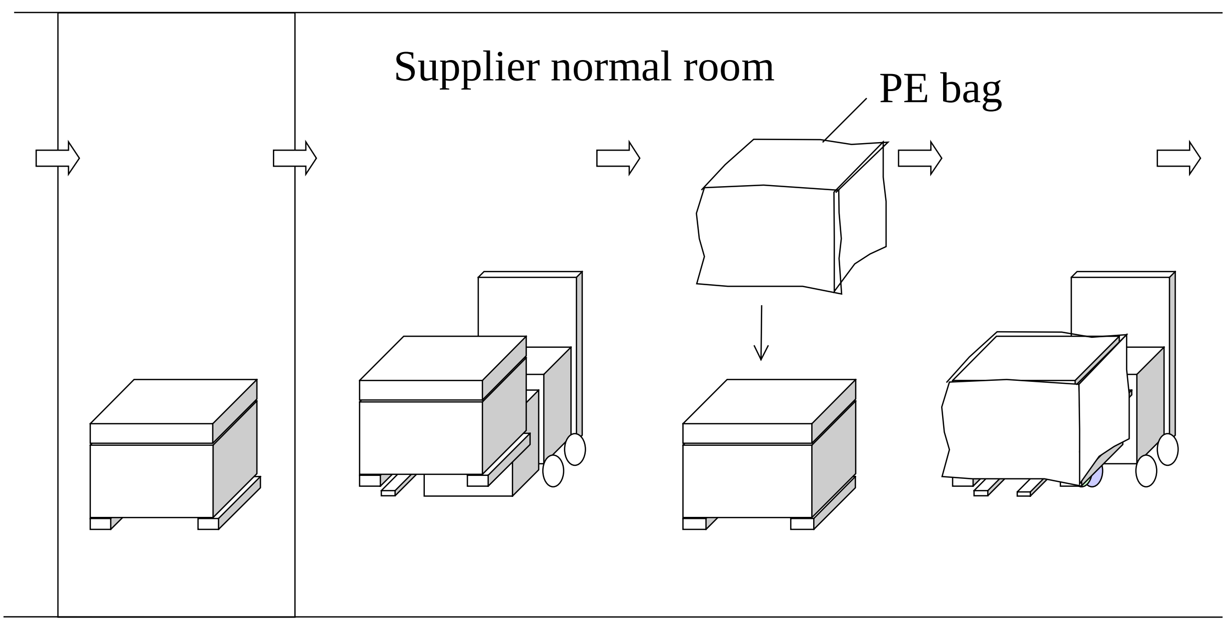


Figure A1-2
Supplier Normal Room (1)

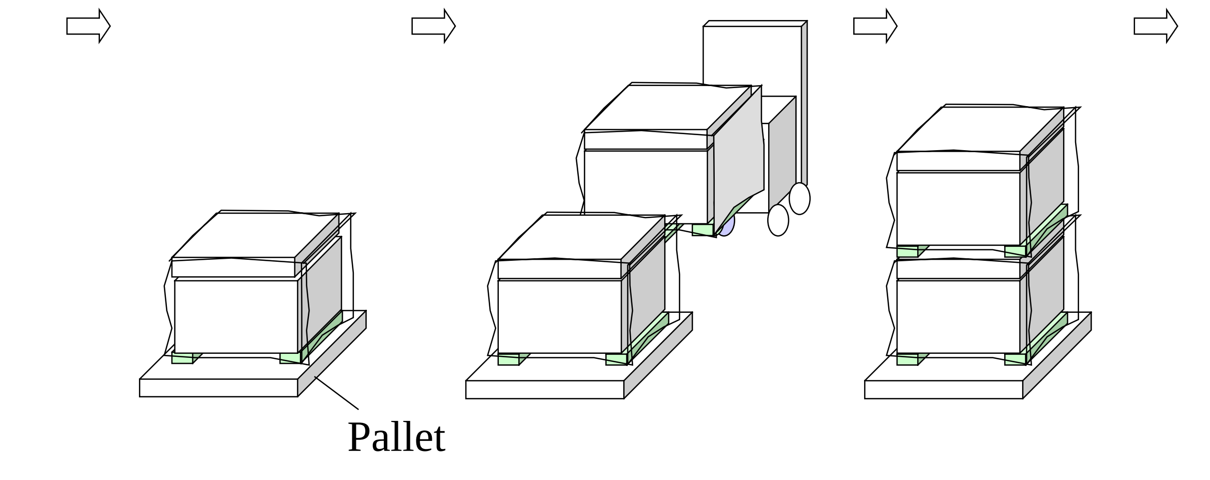


Figure A1-3
Supplier Normal Room (2)

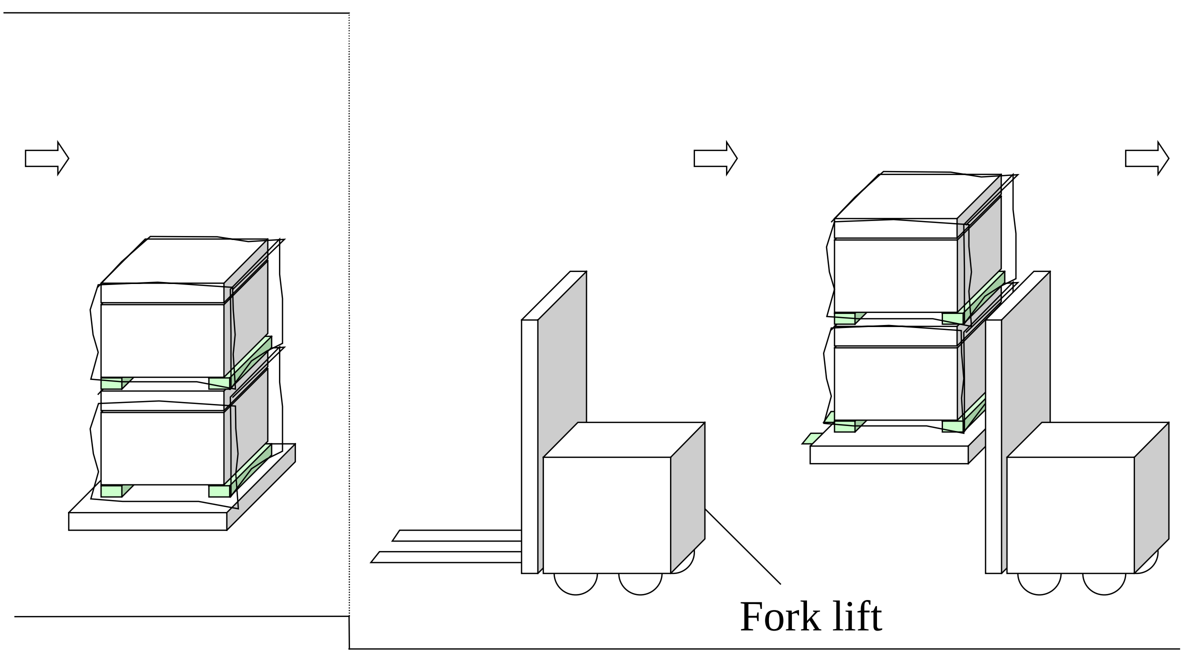


Figure A1-4
Supplier Normal Room (3)

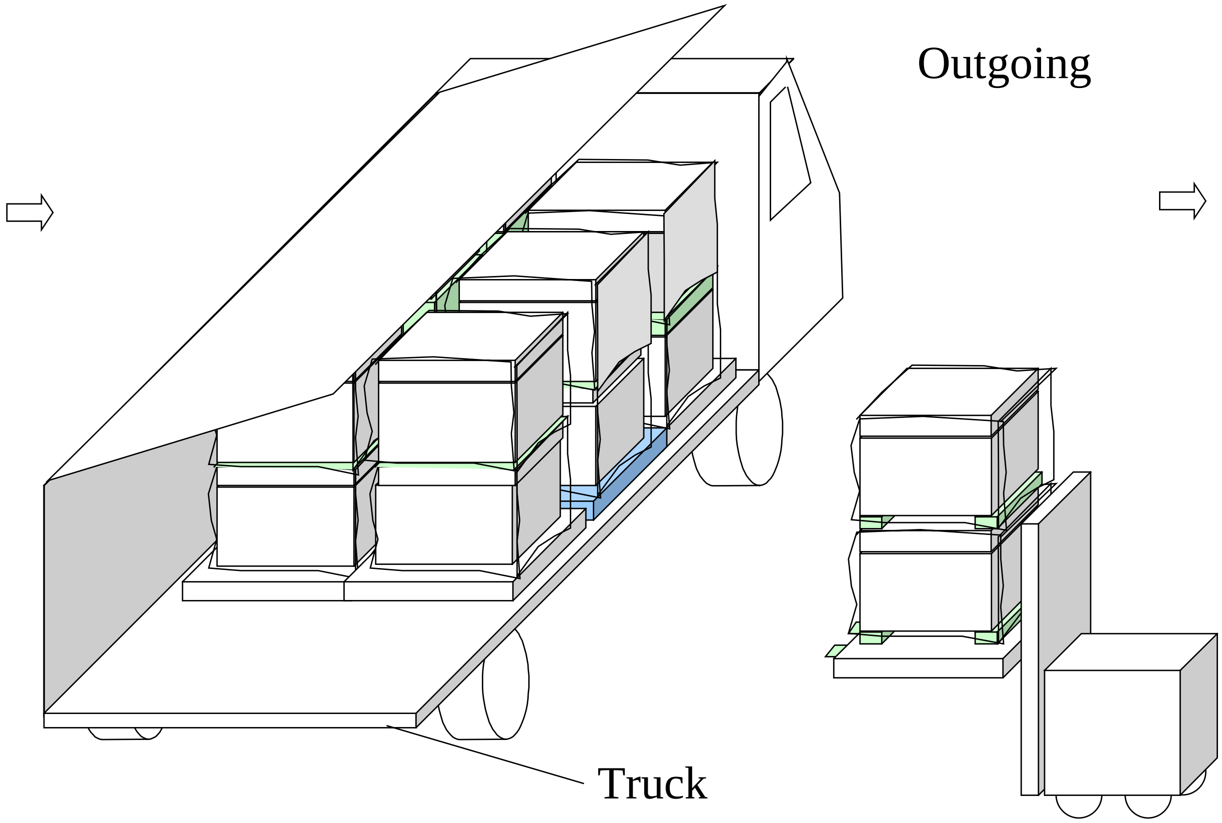


Figure A1-5
Outgoing

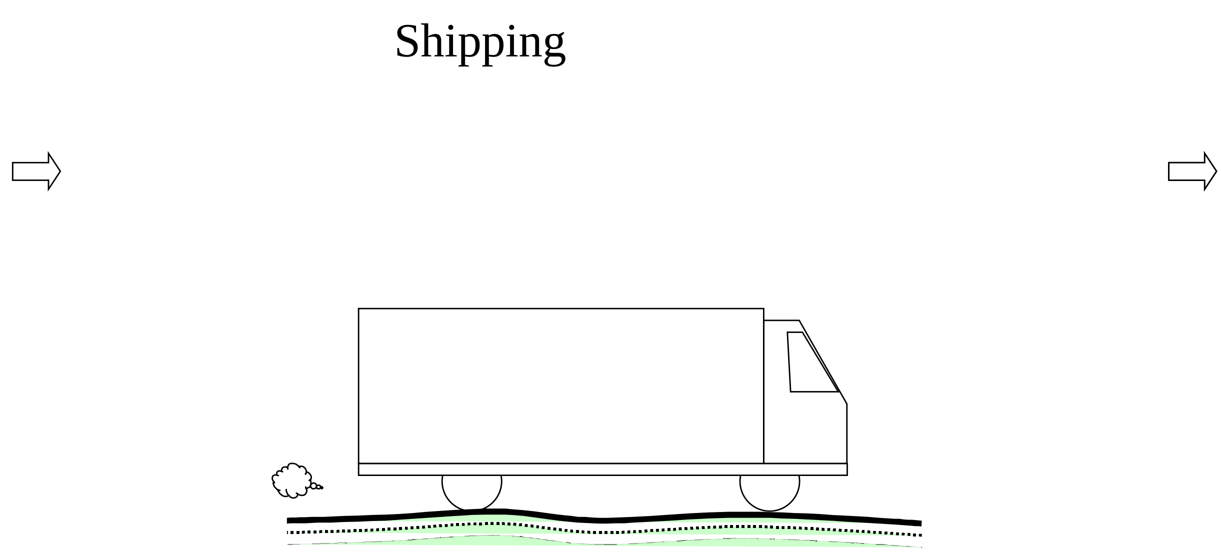


Figure A1-6
Shipping

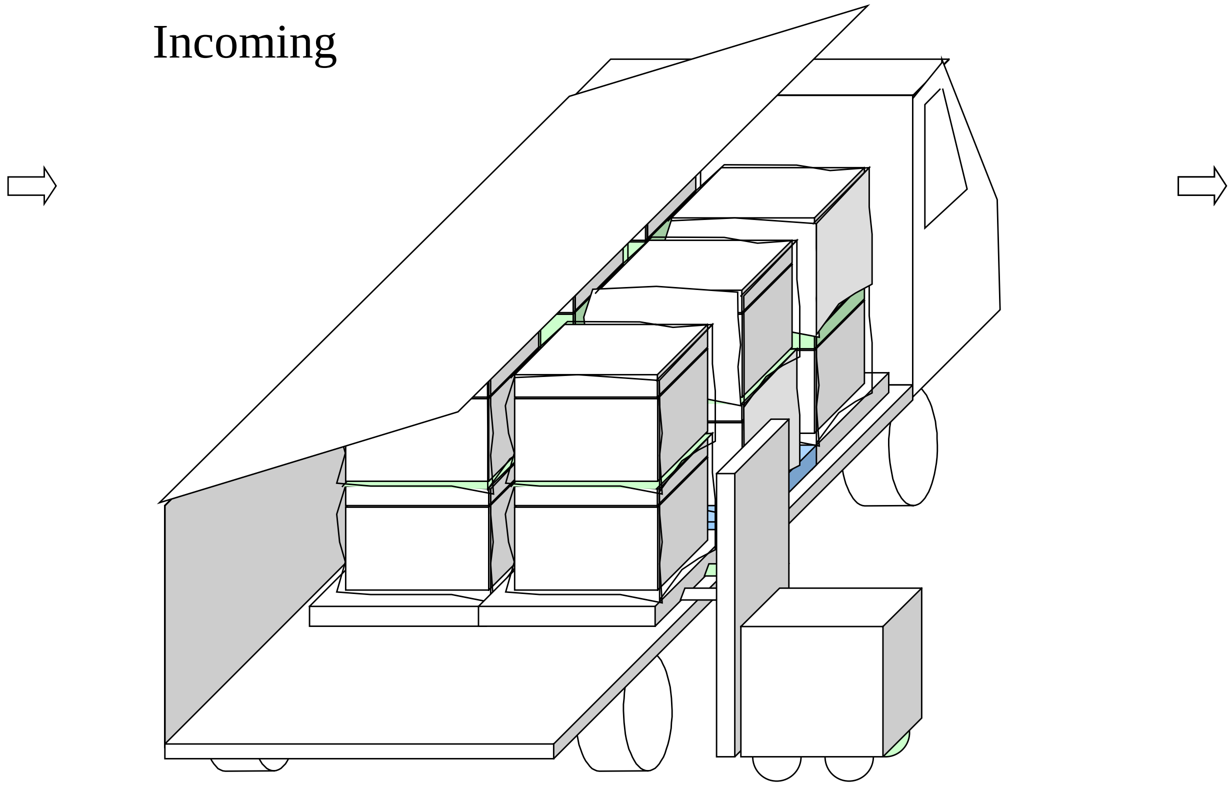


Figure A1-7
Incoming

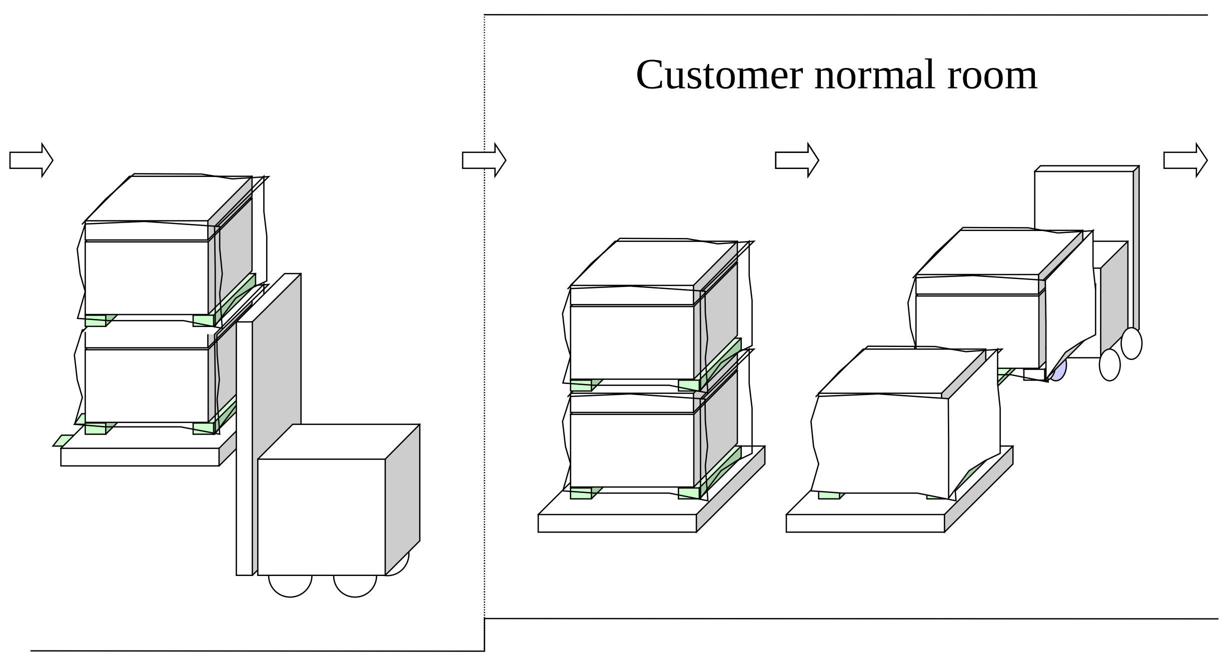


Figure A1-8
Customer Normal Room

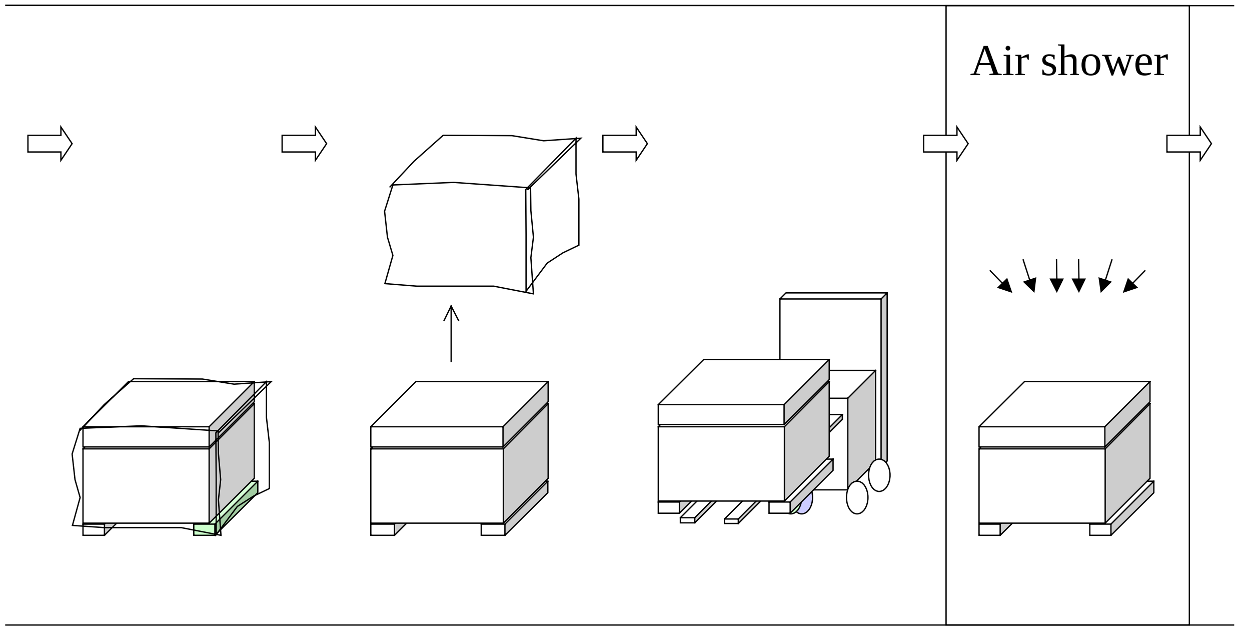


Figure A1-9
Customer Normal Room to Air Shower

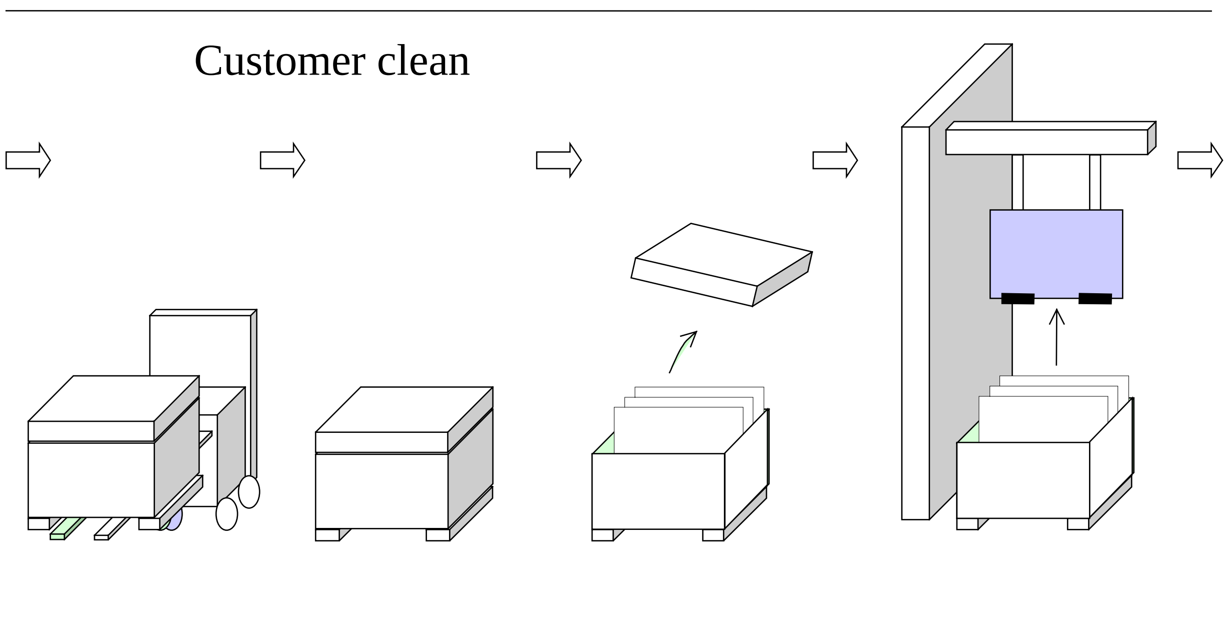


Figure A1-10
Customer Clean Room

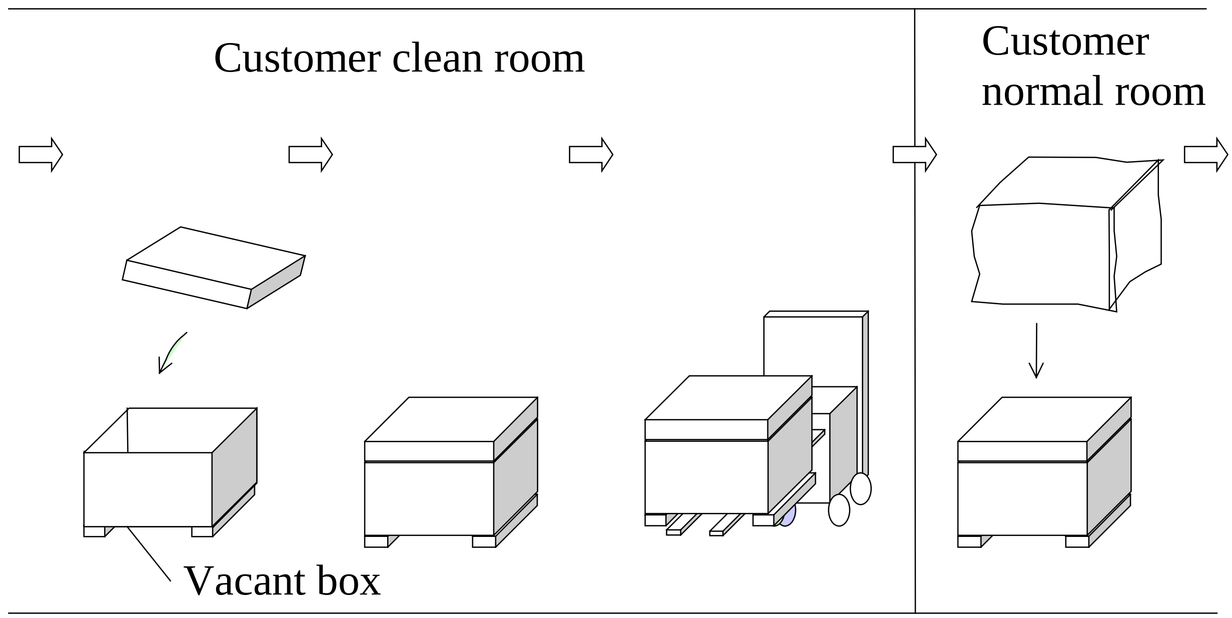


Figure A1-11
Vacant box, from Customer Clean Room to Customer Normal Room

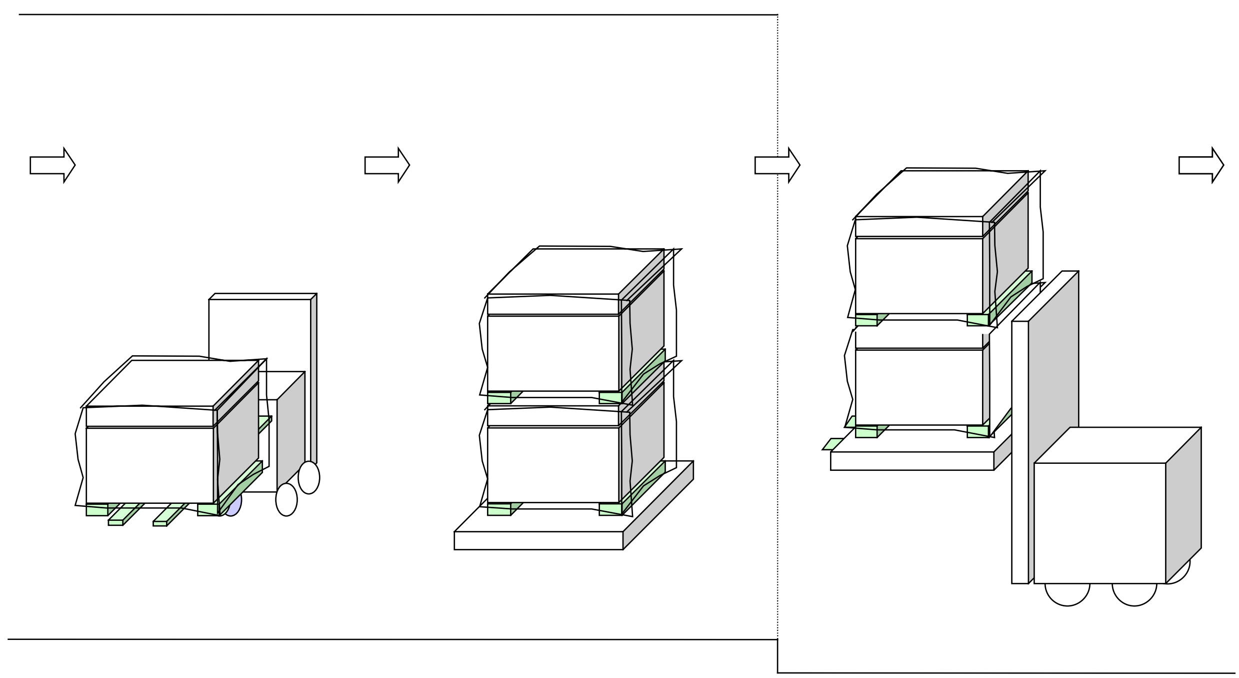


Figure A1-12
Vacant Box, Customer Normal Room

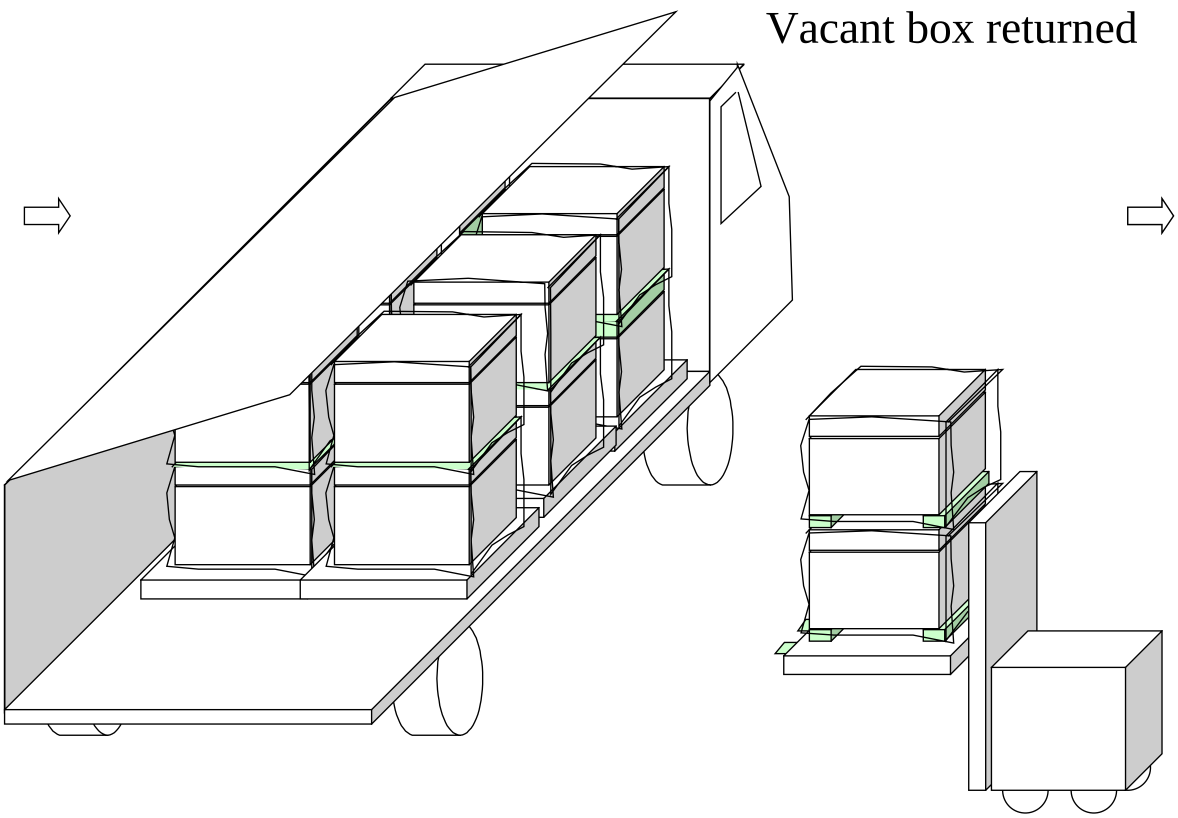


Figure A1-13
Vacant Box Returned

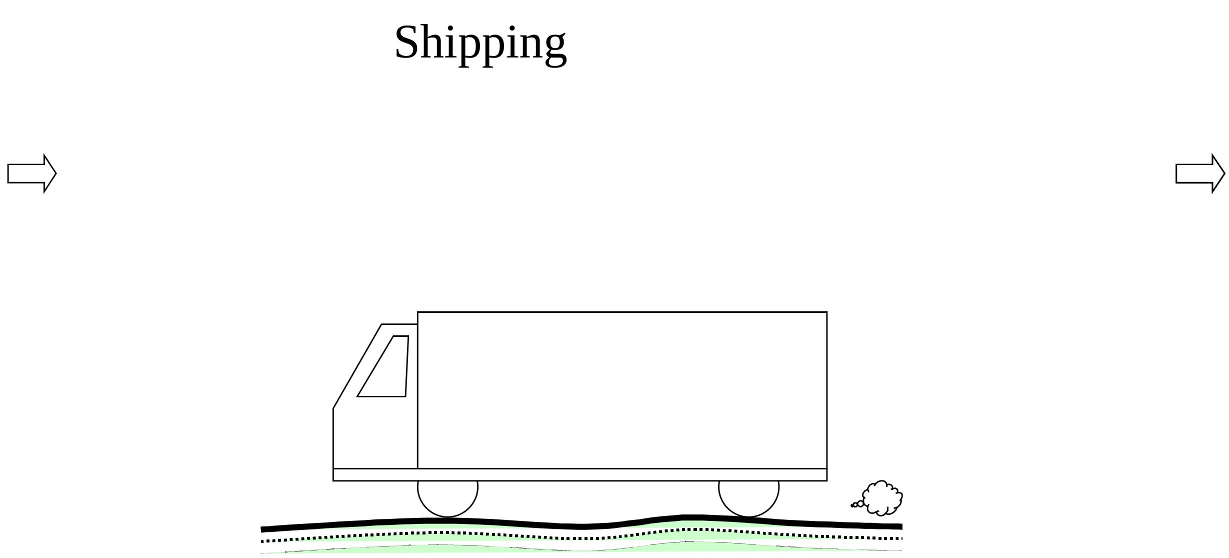


Figure A1-14
Shipping

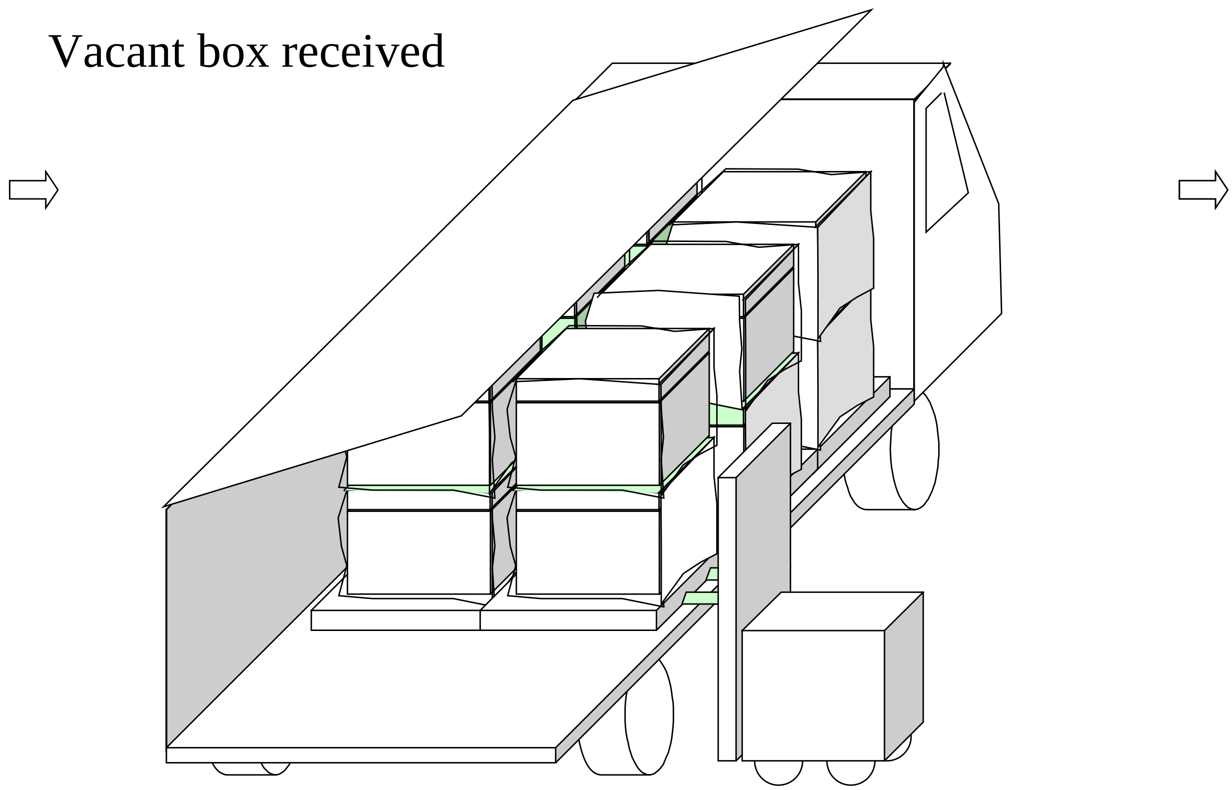


Figure A1-15
Vacant Box Received

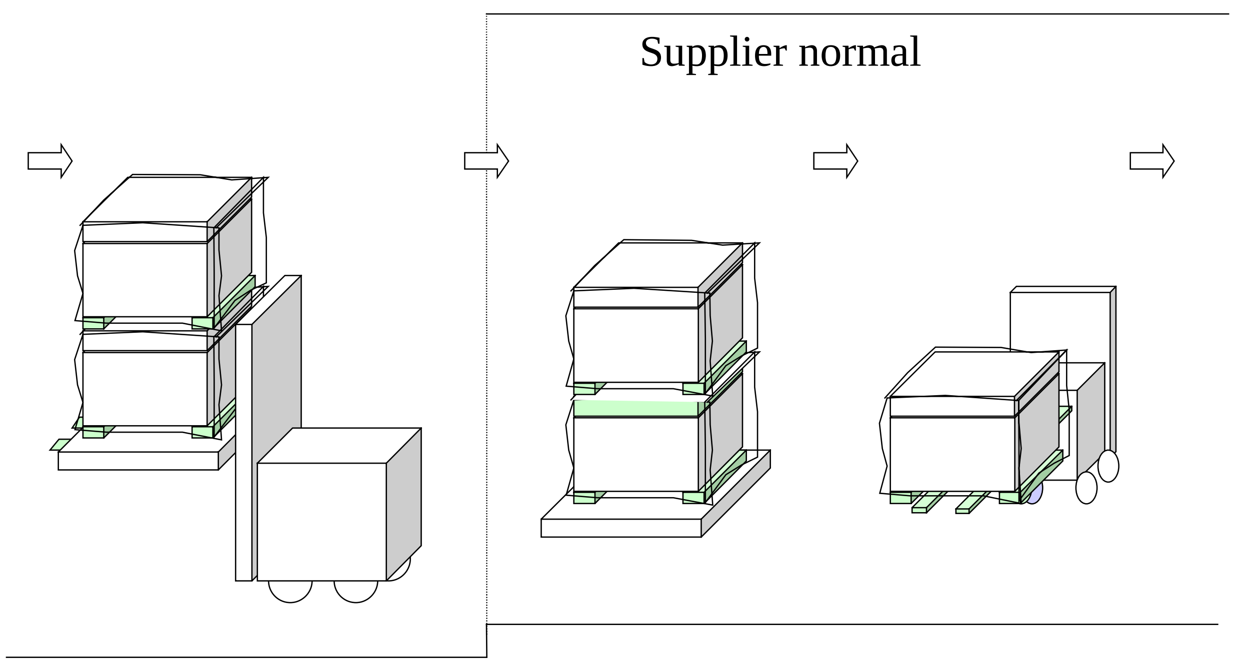


Figure A1-16
Vacant Box, Supplier Normal Room

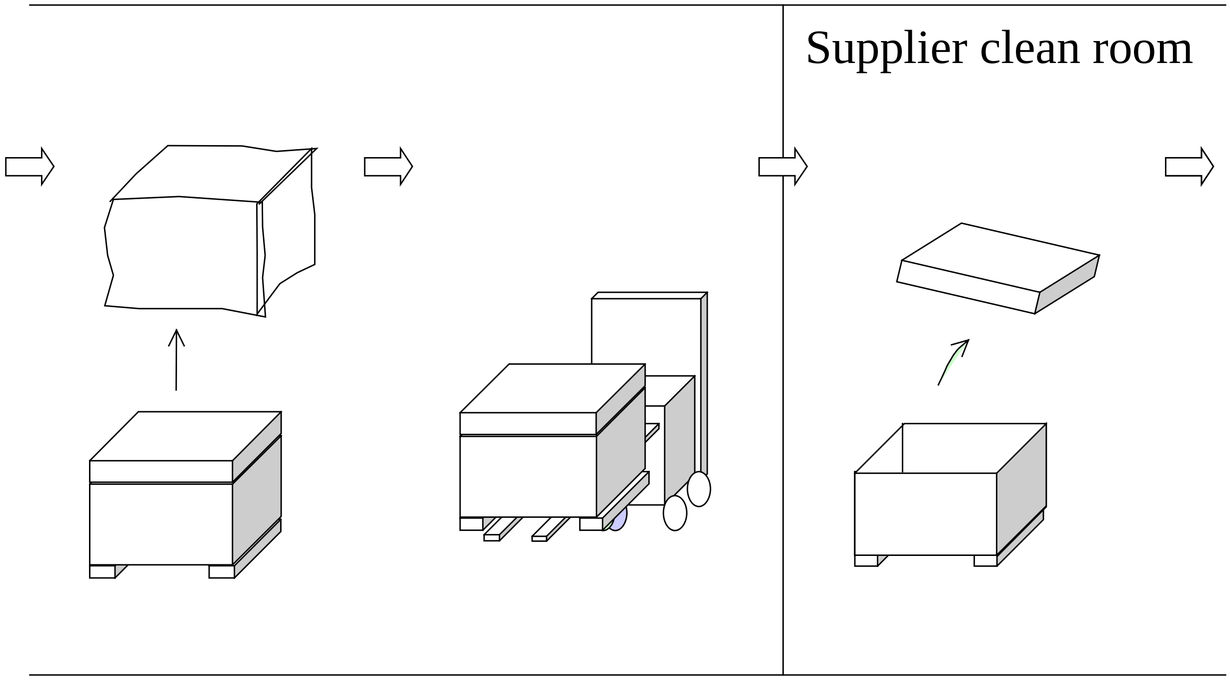


Figure A1-17
Vacant Box, Supplier Clean Room

APPENDIX 2

NOTE: The material in this appendix is an official part of SEMI D25 and was approved by full letter ballot procedures on April 21, 2000 by the Japanese Regional Standards Committee.

A2-1 40 Foot Container Size

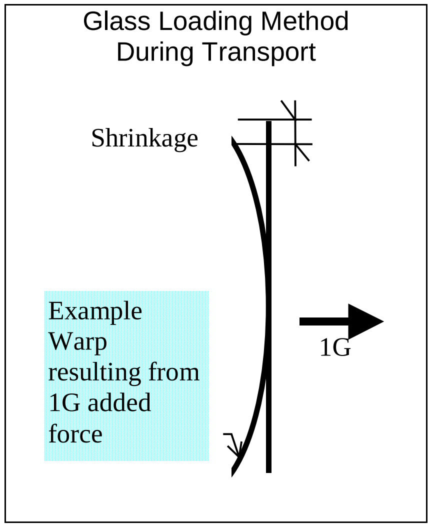
Reference: ISO 668, Series 1 Freight Container – Classification, Dimensions and Ratings

W=2350 L=12060 H=2390 (Unit = mm)

APPENDIX 3

NOTE: The material in this appendix is an official part of SEMI D25 and was approved by full letter ballot procedures on April 21, 2000 by the Japanese Regional Standards Committee.

A3-1 Sag Caused by Acceleration



Unit = mm

Substrate Size	*G Value*	*Support Method*	*Span*	*Sag*	*Curved Shrinkage*	*Substrate Dimensions*		*Memo*
						Long Edge	*Short Edge*	
800 × 950 × 0.7	**1**	**4**	**--**	**20**	**1.4**	**950**	**800**	Sag is for substrates
		2	800	52	9.0	950	800	supported in
			950	103	30.2	950	800	horizontal.

NOTE: Calculated by Asahi Glass Company

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI D26-1000
PROVISIONAL SPECIFICATION FOR LARGE AREA MASKS FOR FLAT PANEL DISPLAYS (NORTH AMERICA)

This specification was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Standards Committee on July 14, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000.

1 Purpose

1.1 This specification establishes a set of standards to assist in specifying and ordering large area masks for the Flat Panel Display industry. A major objective is to improve the cycle time, order process efficiency and reduce the overall cost of manufacturing for both the mask maker and the customer.

1.2 This specification is intended for use in North America as an emerging market. However, the applicability of this specification is not restricted or limited to this region alone. This standard was developed to address a North American need for a common set of requirements for specifying, manufacturing, and ordering large area masks.

2 Scope

2.1 The following areas are covered by this document:

2.1.1 Registration and Accuracy

2.1.2 Critical Dimensions

2.1.3 Centrality

2.1.4 Pellicles

2.1.5 Edge Length and Thickness

2.1.6 Symbology

2.1.7 Data Formats

2.1.8 Auto Inspection Artifacts

2.1.9 Product Labeling

2.2 This specification is being issued so that the industry may evaluate the concept covered before its adoption as a full standard. It is expected that initial application will occur mostly in North America, however, nothing in this standard limits its use to this market region.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The document does not seek to be comprehensive. Instead, the areas listed are meant to help move the current industry towards an agreed upon set of standards that are useful in reducing the overall cost of supplying masks for use by FPD manufacturers. The document only describes 1X full field masks up to 620 × 720 mm for all display types except for Plasma, TN and STN LCD technologies.

4 Referenced Standards

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI D6 — Specification for Edge Length and Thickness for Flat Panel Display Mask Substrates

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P5 — Specification for Pellicles

SEMI P6 — Specification for Registration Marks for Photomasks

SEMI T8 — Specification for Marking of Glass Flat Panel Display Substrates with a Two-Dimensional Matrix Code Symbol

4.2 *AIM International Technical Specifications*[1]

AIM International Symbology Specification – Data Matrix

5 Terminology

Each section of the document defines the terms used in that section, with the exception of:

5.1 *alignment bar, of a data matrix symbol* — A solid line of contiguous filled cells abutting a line of alternatively filled and empty cells (AIM International Symbology Specification Data Matrix)

1 AIM International Inc., 11860 Sunrise Valley Drive, Suite 100, Reston, VA 20191, tel y703.391.7621, fax 703.391.7624

5.2 *border column* — The outermost column of a data matrix code symbol. This column is a portion of the finder pattern.

5.3 *border row* — The outermost row of a data matrix code symbol. This row is a portion of the finder pattern.

5.4 *cell, of a data matrix code symbol* — The area within which a dot may be placed to indicate a binary value.

6 Ordering Information

6.1 Purchase orders for substrates furnished to this specification shall include the following items:

Checklist:

6.2 Edge length

6.3 Long reference edge

6.4 Short reference edge

6.5 Orientation corner dimensions

6.6 Quality edge area exclusion

6.7 Thickness

6.8 Tolerance for all specified dimensions

6.9 Warp

6.10 Marking

6.10.1 Marking message characters

6.10.1.1 Quantity (46 to *mm*, where mm = 72)

6.10.1.2 Content of message characters related to Customer Specification Number, and message characters 47 and up, if present.

6.10.1.3 Location of mark, if different from Section 9.5.5

7 Requirements

7.1 *Materials Specification* — Substrate material shall be specified as high thermal expansion (HTE), medium thermal expansion (MTE), low thermal expansion (LTE), or ultra low thermal expansion (ULTE). Examples of HTE materials are soda lime glasses; examples of ULTE materials are synthetic quartz glasses. Substrate materials shall conform to thermal expansion and optical transmittance characteristics specified in SEMI P1. Selected physical properties of HTE, MTE, LTE, and ULTE materials are provided for information in SEMI P1.

7.2 *Overlay* — Overlay refers to alignment of the printed pattern of one mask to another of the same set. Overlay error shall not exceed ± 6.0 µm for soda lime plates and ± 2.0 µm for quartz plates when plate temperature is maintained within ± 1°C. Alignment or registration marks per SEMI P6 may be used to facilitate measurements.

7.3 *Positional Accuracy* — Relation between actual and desired locations of a printed feature on a glass substrate. This is a tolerance to be agreed upon by the end user and mask designer. The following guidelines should be used, with measurements being taken in a temperature and humidity controlled environment:

- ± 0.0157 µm/mm/ °C for soda lime masks
- ± 0.00394 µm/mm/ °C for quartz masks

Dimensioning from a central reference point shall be used.

7.4 *Critical Dimensions (CD)* — The gauging or measurement process is fundamental to manufacturing of masks. The purpose of this section is to define standard CD patterns to provide consistent evaluation and testing of micropatterning equipment, metrology instruments and processes used in large area mask photomask manufacturing.

7.4.1 Figures 1 and 2 are intended to illustrate the proper layout of each pattern cell and to define appropriate design elements used within each basic cell. The user will determine all appropriate dimensions for the feature as they apply to specific processing/ equipment situations.

7.4.2 *L-bar cell (see Figure 1)* — The L-bar cell is designed to be a measurement site for isolated features as well as line and space groups in orthogonal axes. The basic cell consists of one or more groups of nested L-shaped lines at a specific pitch. The pitch is defined as twice the nominal feature width. The center L-bar of each group shall extend beyond the ends of the other L-bars by at least 10µm. This implies that the number of bars is odd.

7.4.3 *Contact array cell (see Figure 2)* — The contact array cell is designed to provide resolution and proximity effect information over a wide range of contact sizes. The design elements will consist of a 5 × 5 contact array and an isolated contact. The 5 × 5 array will produce the maximal proximity for the center contact.

7.4.4 A label to indicate the nominal feature width must be placed near each basic cell. The labels must be of a clearly printable size. The details of the pattern cells, such as the orientation, magnitude, range of line widths and polarity of tone (clearfield vs. darkfield) shall be defined by the user.

7.4.4.1 The target CD should closely represent the size of the most critical feature in the end user's process, not necessarily the minimum feature. A reasonable tolerance is ± 10% of the target CD.

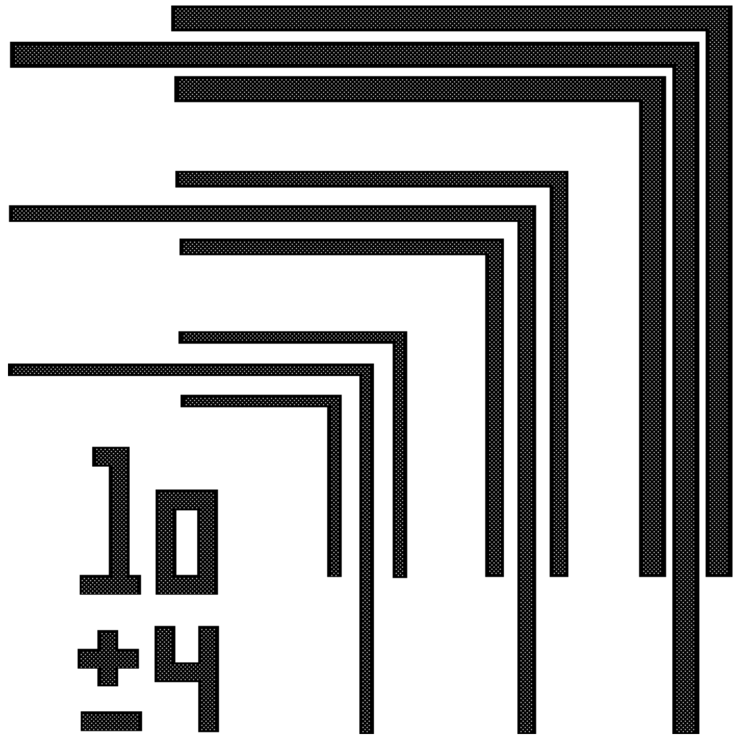


Figure 1
L-Bar Cell

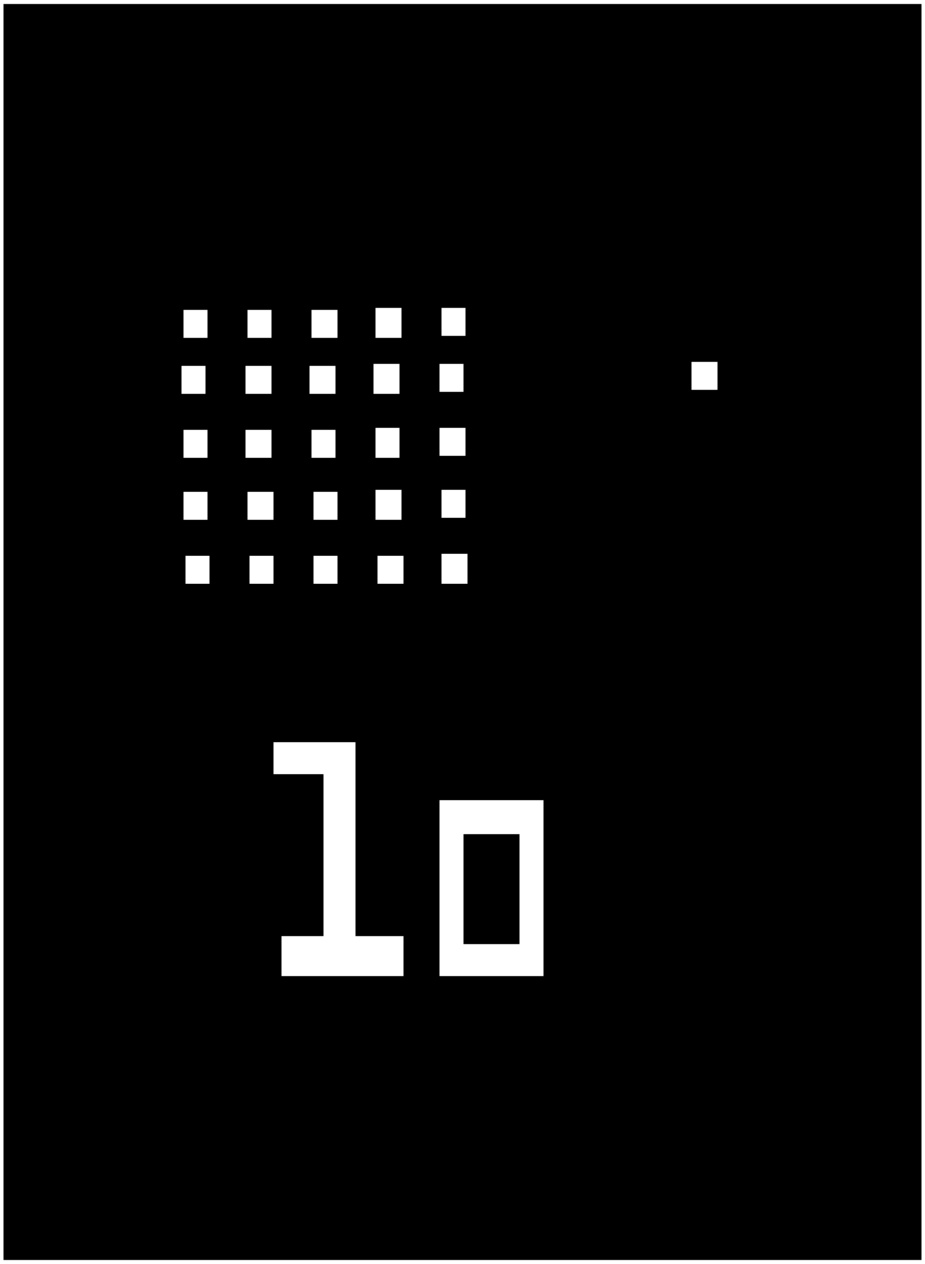


Figure 2
Contact Array Cell

7.5 *Centrality* — This section defines the placement of a patterned photo image onto a Mask Substrate relative to known reference points. It is defined as the physical (datum) position of a specific point on a photo pattern relative to a separate point on the substrate designated to be the photomask center.

7.5.1 *Requirements* — Pattern Placement Tolerance ± 400μm in x and y relative to coordinates on the photomask designated as center when referenced to the 0.000, 0.000 datum (see Figure 3).

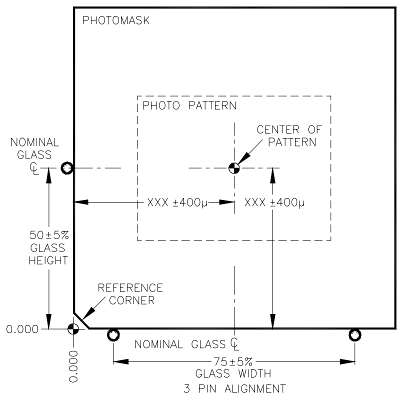


Figure 3
Pattern Placement Tolerance

7.5.2 *Reference 0.000, 0.000* — A datum identified as a point on the extension of a line drawn between the mask contact points on the bottom 2 pins, which is directly below the mask contact point on the third pin (see Figure 4).

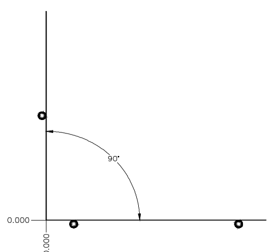


Figure 4
Reference Datum

7.6 *Pellicles (see SEMI P5)*

7.6.1 For Polychromatic exposure systems: Shape, Size, and Standoff of Pellicle

7.6.1.1 *Shape* — This is determined by agreement between the user and supplier.

7.6.1.2 *Size* — This is determined by agreement between the user and supplier, but expression of tolerance is as follows:

7.6.1.3 Outer diameter tolerance — + 0, -x

7.6.1.4 Inner diameter tolerance — + x, -0

7.6.1.5 *Standoff* — This is determined by agreement between the user and supplier. But expression of tolerance is as follows:

7.6.1.6 *Tolerance* — + 0, -x

Film Characteristics Polymer Films — Type - AR-coated or non AR-coated (see Table 1)

7.6.1.7 *Exposure Range* — 360 nm - 440 nm.

7.6.1.8 *Optical Transmission Rate* — There are the following two types depending on optical transmission rate at an incident angle of 90° from surface of pellicle.

Table 1 Film Characteristics Polymer Films

Type	*Average*	*Minimum*
AR-Coated	≥ 94%	88%
Non-AR-Coated	≥ 91%	82%

7.6.1.9 *Thickness* — This is determined by agreement between the user and supplier.

7.6.1.10 *Thickness Conformity* — This is determined by agreement between the user and supplier.

7.6.1.11 *Thickness Uniformity* — This is determined by agreement between the user and supplier.

7.6.1.12 *Film Thickness* — This is determined by agreement between the user and supplier

7.6.1.13 *Mechanical Strength* — The requirements for air blow are determined within ranges shown below:

- The air blow gun should be used; air pressure: ≤ 2.1 kgf/cm^2 (at input of the air blow gun);
- Nozzle diameter of the air blow gun: ≤ 2 mm. Distance between the nozzle tip and the film: ≥ 25 mm

7.6.2 *Defect Limits* — Maximum defect limits based on the pellicle standoff and the numerical aperture of the given type of exposure system are given in Table 1. Any departure from these defect limits shall be agreed to between supplier and user. Maximum defect limits are given in Table 2.

7.6.2.1 *Adhesives*

7.6.2.1.1 *Film Adhesive* — Film must be sealed on the entire top of the frame, with a minimum of 50% of the frame width at any location.

7.6.2.1.2 *Frame Adhesive* — Frame adhesive must be continuous and allow no gaps between pellicle frame and adhesive and between adhesive and photomask after attachment. No part of the frame adhesive may extend beyond the frame wall, and its edges must be free of visually detectable stringers (and particles). Adhesive should form a complete seal between the frame and the mask over a minimum of 40% of the width of the frame.

7.6.2.2 *Frame* — Pellicle frame must have no visually detectable machining burrs, discontinuities in anodization, or particles.

7.6.2.3 *Light Resistance* — This is expressed by total exposure energy value (mJ/cm^2 or J/cm^2) on pellicle film resulting in a 1% loss of transmission at any wavelength in the range 360 nm–440 nm. Also the test conditions (special characteristics of exposure wavelength, exposure energy between 360 nm–440 nm, exposure conditions, and others) must be clearly stated.

Table 2 Maximum Defect Limits

Characteristics	*Max. # Allowable*	*Size counted for Max. # Allowable*
Non-removable		
Particles	None	≥ 50 µm
Pinholes	None	> limit of detection
Scratches	None	Width ≥ 50 µm
Dirt	None	> limit of detection

7.6.3 *Pellicles for g, h and i Exposure Systems* — This specification includes the characteristics of pellicles for use in "g" (436 nm), "h" (405 nm), and "i" (365 nm) line exposure systems.

7.6.3.1 *Shape, Size, and Standoff of Pellicle*

7.6.3.1.1 *Shape* — This is determined by agreement between the user and supplier.

7.6.3.1.2 *Size* — This is determined by agreement between the user and supplier, but expression of tolerance is as follows:

- Outer diameter tolerance: +0, -x
- Inner diameter tolerance: +x, -0

7.6.3.1.3 *Standoff* — 6.3 mm and 4.0 mm should be standard.

7.6.3.1.3.1 Tolerance — + 0, -x

7.6.3.2 *Film Characteristics Polymer Films* — Type: AR-coated or non AR-coated.

7.6.3.3 *Exposure Wavelength* — "g", "h", and/or "i" lines.

7.6.3.4 *Optical Transmission Rate* — There are the following two types depending on optical transmission rate at incident angle of 90° from surface of pellicle at the specified wavelength(s).

Table 3 Film Characteristics Polymer Films

Type	*Minimum*
AR Coated	99 %
Non AR Coated	98 %

7.6.3.5 *Thickness* — This is determined by agreement between the user and supplier.

7.6.3.6 *Thickness Conformity* — This is determined by agreement between the user and supplier.

7.6.3.7 *Thickness Uniformity* — This is determined by agreement between the user and supplier.

7.6.3.8 *Film Thickness* — This is determined by agreement between the user and supplier.

7.6.3.9 *Mechanical Strength* — The requirements for air blow are determined within ranges shown below:

7.6.3.9.1 The air blow gun should be used. Air pressure: ≤ 2.1 kgf/cm^2 (at input of the air blow gun). Nozzle diameter of the air blow gun: ≤ 2 mm.

7.6.3.9.2 Distance between the nozzle tip and the film: ≥ 25 mm.

7.6.3.10 *Defect Limits* — Maximum defect limits based on the pellicle standoff and the numerical aperture of the given type of exposure system are given in Table 4. Any departure from these defect limits shall be agreed to between the user and supplier.

7.6.3.11 *Frame* — Pellicle frame must have no visually detectable machining burrs, discontinuities in anodization, or particles.

7.6.3.12 *Light Resistance* — This is expressed by total exposure energy value (mJ/cm^2 or J/cm^2) of specified wavelength on pellicle film resulting in a 0.5% loss of transmission at any wavelength in the range 360–440 nm. Also, the test conditions (half bandwidth of exposure specified wavelength, energy of exposure specified wavelength, exposure conditions, and others) must be clearly specified.

Table 4 Maximum Defect Limits

Characteristics	*Max. No. Allowable*	*Size Counted for Max. No. Allowable*
Non-removable		
Particles	None	> 20 µm
Pinholes	None	> limit of detection
Scratches	None	Width > 20 µm
Dirt	None	> limit of detection

7.7 *Edge Length and Thickness* — These dimensions apply to photomasks that are principally used in fabricating flat panel display. The edge lengths specified range from 202.8 mm × 202.8 mm to 620 mm × 720 mm. Substrates with an edge length less than 200 mm follow the specification for a semiconductor mask (see SEMI P1and SEMI D6).

7.7.1 *Edge Length and Tolerance* — Units are in mm. See Table A1 and A2 and Table B1 and B2 and Table C1 and C2 for a combination of materials, edge length, and thickness.

7.7.1.1 *Edge Length Tolerance* — + 0.4 mm. Applies to all groups.

7.7.2 *Thickness Center Point* — Thickness of substrates at center point shall be specified by the edge length group and materials as shown in Tables A2, B2 and C2.

7.7.2.1 *Tolerance* — ≤ 5 mm ± 0.2 mm, 8 mm + 0.2 mm, - 0.4 mm.

Table A-1 Edge Length (mm) (Group A)

202.8 × 202.8				
200 × 250	250 × 250			
	250 × 300	300 × 300		
		300 × 350	350 × 350	
			350 × 400	400 × 400

Table B-1 Plate Thickness and Materials (Group A)

MATERIAL			
HTE	*MTE/LTE*	*ULTE*	*Thickness (mm)*
+	+	+	3.0
+			4.8
	+	+	5.0

Table A-2 Edge Length (mm) (Group B)

330 × 450			
	400 × 500		
		450 ×550	
			500 × 600

Table B-2 Plate Thickness and Materials (Group B)

MATERIAL			
HTE	*MTE/LTE*	*ULTE*	*Thickness (mm)*
+			4.8
+	+	+	5.0

Table C-1 Edge Length (Group C)

620 × 720 mm
650 × 750 mm
650 × 800 mm
700 × 800 mm

Table C-2 Plate Thickness and Materials (Group C)

MATERIAL	
ULTE	*Thickness (mm)*
+	5.0
+	8.0

7.7.2.2 The active area is defined as area within the plate that is within 20 mm from the edge of the plate (See Figure 5).

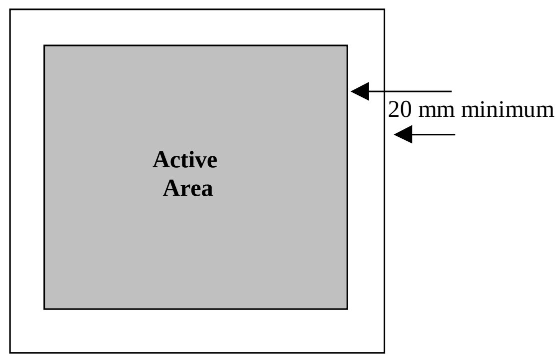


Figure 5
Defined Active Area

7.8 *Data Formats*

7.8.1 *Data Transfer Standards* — CAD data for mask generation can be designed with and delivered to the vendor in several different standardized data transfer formats. Among these are DXF, Gerber and its variants (274-D, 274-X, F9XXX, and BARCO DPF), GDSII, EDIF, IGES, and IPC-D-350.

7.8.2 *Non-Recommended Practices* — The following is a summary of some design practices and CAD entities that *should be avoided* when using DXF and Gerber data formats, since their use can have at best unintended results.

7.8.2.1 *DXF*

- Commands regarding 3D CAD.
- Parameters which control the view only, such as 3DFACE, VIEWPORT, STYLE, VIEW, DIMSTYLE, UCS, APPID, ATTRIB, ATTDEF, and POINT
- HATCH

- Outlines constructed with ARC and LINE that do not match exactly at the corners
- Duplicated entities
- Self-intersecting poly-lines
- VERTEX flags options
- TAPERED POLYLINE entities (different start and end width), straight or arced
- SHAPE entities
- ELLIPSE entities
- "Stretched" BLOCK entities – blocks with different X- and Y-scale factor
- Rotated BLOCK entities
- POINT entities
- Any of the "Curve-fitted" POLYLINE entities, such as "SPLINE" shapes
- "Paint & Scratch" LAYER entities without a specific identification of which layers should be opaque and which should be clear, and in which order.
- TEXT entities without the appropriate font files.
- TEXT entities with special attributes (mirror, rotate, slant, etc.).
- XREF BLOCK entities.
- Non-decimal linear and angular coordinates.
- Radian angular units.

7.8.2.2 *Gerber*

- Self-intersecting entities (line draws, outlines, "butterfly targets", etc.).
- Arrayed arrays (nested).
- Drawn apertures using shapes other than round (square apertures may be used only if drawn parallel to either axis).

7.8.3 *Recommended Practices* — The following is a summary of some recommended design practices DXF and Gerber data formats.

7.8.3.1 *DXF*

- SOLID entities
- TRACE entities
- CIRCLE entities
- BLOCKS, with a minimum level of nesting as required by the design
- Closed, zero width POLYLINE or LWPOLYLINE entities to describe complex CAD feature outlines
- TEXT objects that are exploded and exported as POLYLINE entities, either as closed zero width, or POLYLINE entities with width
- Decimal units for inches, mils, millimeters, microns, or degrees.

7.8.4 *Gerber*

- Subfigure or SR codes.
- POEX/POIN or G36/G37 codes.
- Complex apertures and aperture macros.
- Embedded apertures and parameters.

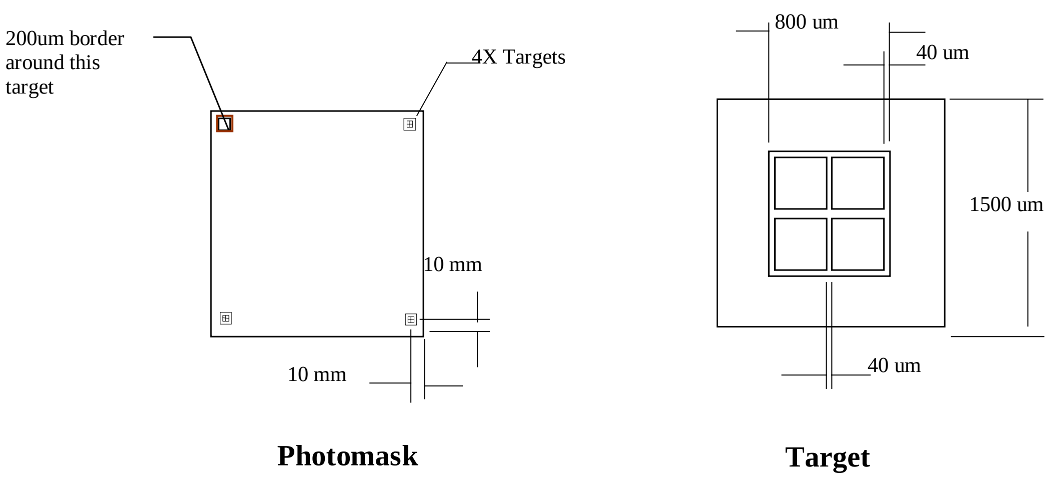


Figure 6
Location and Pattern

7.8.5 *Design Rules* — A comprehensive and well-presented set of design rules is an invaluable communication tool between the customer and supplier. For the manufacture of large area precision glass and quartz substrate photomasks having geometry's in the low to sub-micron range, design rules are an essential component of any successful program designed to minimize the risks of introducing errors and delays into the process.

7.8.5.1 The best match occurs when there is a commonality between the customer's design capabilities and vendor's requirements.

7.8.5.2 Design rule documents are usually unique to each Large Area Mask supplier, and the details depend mainly upon the vendor's software repertoire and their ability to process certain types of data.

7.8.5.3 The type of Computer Aided Design software package used by the customer to design their product must be capable of either exporting data in a format that the vendor can readily use, or the vendor must be capable of using data in the native format of the customer's design package.

8 Test Methods

8.1 *Auto Inspection Artifacts* — To perform any automated inspection of a photomask, the inspection equipment and photomask pattern must be precisely located. This is done with four alignment targets on the photomask. The alignment targets are part of the photomask pattern and are located near each corner of the photomask. The target in the upper left corner will also have a 200 micron border around it with a 10 micron space between the target and the border. When appropriate, this additional border will also be used as a closure test by exposing the targets first and then the border at the end of the plate exposure.

8.1.1 4 Alignment targets provide optimum alignment accuracy.

8.1.2 Greater distance between the targets provides greater alignment accuracy.

8.1.3 The target locations near the edge of the glass provide the maximum product image area.

8.1.4 The target pattern can be easily located visually on the photomask.

8.1.5 The target can be clear on dark or dark on clear.

9 Product Labeling

9.1 *General* — Large Area Masks used in FPD manufacturing are valuable, fragile and prone to contamination prior to use. The content of a LAM is difficult to discern unless each unit contains a unique ID that can be read by various tools. To simplify AMHS and process/metrology tool operations, this ID needs to be consistently readable on the bare mask, with and without resist coating; ideally it would be readable through the plastic container in which the mask is shipped. See Figures 7–10.

9.2 *Summary* — The labeling specified herein consists of a rectangular two-dimensional (2-D), machine-readable, binary Data Matrix symbology located on the pattern surface of LAMs, within the edge region and near the orientation corner. The specification defines a 46-character default message that is included in all mark fields, and option for up to 26 additional characters, for a total of 72 message characters (see SEMI T8).

9.3 *Field Construction* — While this specification does not specify the marking techniques that may be employed when complying with its requirements, it is assumed the symbol may be obtained through lithographic techniques, for instance during the mask exposure sequence.

9.4 *Shape and Size of the Data Matrix Code Symbol*

9.4.1 *Data Matrix Code Symbol Dimensions*

9.4.1.1 Each rectangular matrix code symbol shall be composed of an array of 16 rows and 36 or 48 columns as defined in AIM International Symbology Specification – Data Matrix. It may contain an alignment bar.

9.4.1.2 Cell spacing shall be 25 µm, center to center.

9.4.1.3 Matrix code symbol nominal dimensions are:

a. 4 × 9 mm, for a 16 row × 36 column field, or
b. 4 × 12 mm, for a 16 row × 48 column field.

9.4.2 *Dot Size* — The nominal shape of the dot produced in the matrix may be circular or square. Its diameter or edge length shall be 250 ± 10 µm.

9.4.3 *Border Rows and Columns (see Figure 9)*

9.4.3.1 One border row and one border column shall contain a dot in each cell. There are identified as the primary border row and the primary border column. These are used by the code reader to determine the orientation of the matrix.

9.4.3.2 The opposing (secondary) border row and column shall contain dots in alternating cells.

9.4.3.3 For these rectangular matrix code symbols, the reference point of the symbol shall be the physical center point of the cell common to the primary border row and the primary border column.

9.5 *Content of the Data Matrix Code Symbol*

9.5.1 Each rectangular matrix code symbol shall contain between 46 message characters (for 16 rows × 36 columns) and 72 message characters (for 16 rows × 48 columns), encoded in accordance with AIM International Symbology Specification – Data Matrix.

9.5.2 The message characters may include any of those designated as “mostly upper case” Annex K of AIM International Symbology Specification – Data Matrix. 8-bit characters may also be encoded with reduced field capacity. The first 20 characters shall contain two elements:

a. a vendor-assigned 15-character mask identification code, followed by

b. a 1-character field concatenation symbol (+) and 2-character field ID (per ANSI MH 10.8)

9.5.3 The next 26 message characters shall contain two elements:

a. a customer-assigned 13-character part #, followed by

b. a 1-character field concatenation symbol (+) followed by a 2-character field ID and

c. a 12-character customer-assigned part revision number.

9.5.4 The remaining message characters, if any, shall contain information as agreed between the vendor and the user. This may require field identifiers and field concatenation.

9.5.4.1 Field identifiers listed in ANSI MH 10.8.2 include:

a. Customer part number revision: 2P

b. Customer specification number: 20P

c. Customer specification revision: 21P

d. Customer drawing number: 12P

e. Customer drawing number revision: 22P

9.5.5 *Location of the Data Matrix Code Symbol*

9.5.5.1 With the substrate positioned front surface up and with the orientation corner toward the operator and to the operator’s left, the reference point of the data matrix code symbol shall be placed toward the orientation corner and

8 ± 1 mm from the substrate’s y-edge; this provides clearance for corner cuts or other elements adjacent to the corner, and

3 ± 1 mm from the substrate’s x-edge; this approximately centers the field between the x-edge and the FQA boundary.

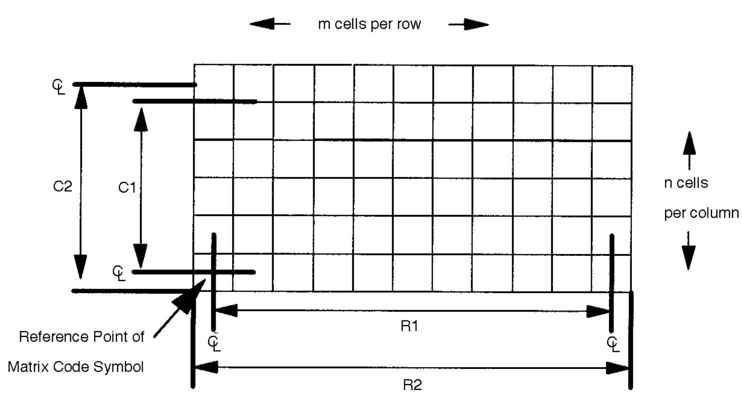


Figure 7
Data Matrix Field

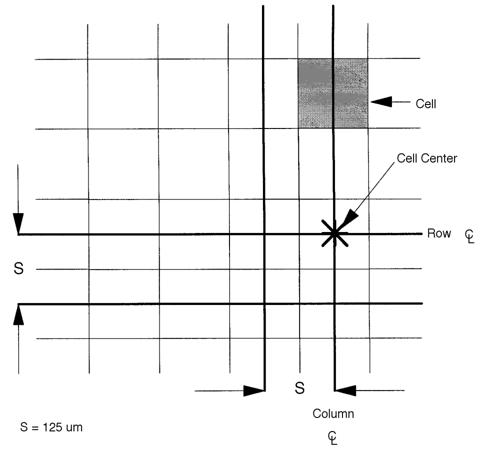


Figure 8
Data Matrix Cell Dimensions

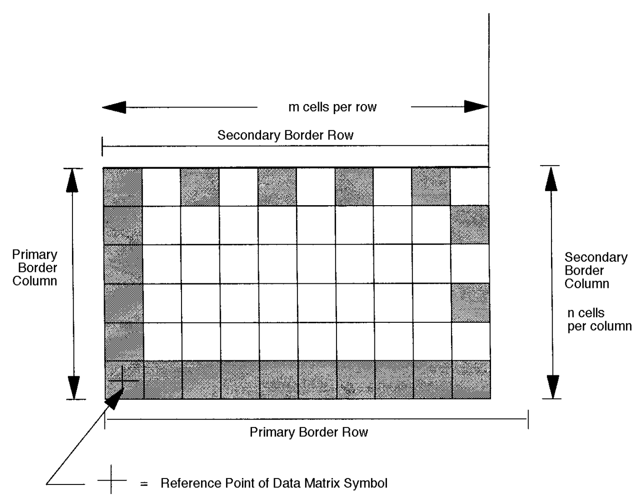


Figure 9
Border Rows and Columns

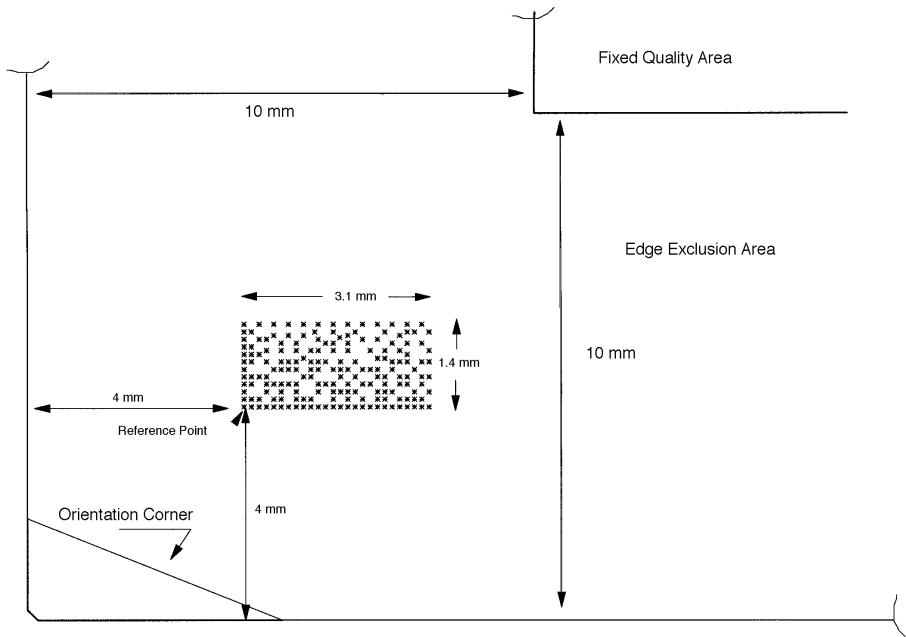


Figure 10
Data Matrix Code Field in Edge Exclusion Area

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI D27-1000
GUIDE FOR FLAT PANEL DISPLAY EQUIPMENT COMMUNICATION INTERFACES

This guide was technically approved by the Global Flat Panel Display Committee and is the direct responsibility of the North American Flat Panel Display Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available at www.semi.org August 2000; to be published October 2000.

1 Purpose

1.1 This is a guide for implementing equipment communication features for successful integration and automation in a flat panel display manufacturing facility.

2 Scope

2.1 This guide includes references to other SEMI standards. It also includes definitions and explanations specific to FPD equipment automation.

2.2 The scope of this guide is limited to equipment communication features that interface with factory automation systems.

2.3 This guide does not reference physical or electrical interfaces, except to the extent necessary to implement the features described. For example, a serial data cable connector could be specified to have 9 pins or 25 pins.

2.4 This guide may not be applicable to all types of FPD equipment. It only applies to those for which a direct data communication interface will be implemented between the equipment and the factory automation systems.

2.5 This guide does not address all software standards that may be applicable, but addresses a subset that is necessary for effective integration and automation.

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The other SEMI standards referred to in this document have been carefully reviewed for applicability to FPD manufacturing. However, when referring to other SEMI standards used in this specification, the reader should allow for some editorial exceptions in order to apply the specification to FPD equipment. For example, if another SEMI specification referenced here uses the term "wafer", the reader can assume that this also applies to FPD substrates, and likewise with "silicon" and glass or plastic. These minor differences in no way impact the interpretation or implementation of those standards in FPD manufacturing equipment and factory systems.

3.2 This guide is not an all-inclusive list of applicable standards, but is a starting point for defining requirements of these equipment automation functions, and a guideline for implementation.

4 Referenced Standards

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E37 — High-Speed SECS Message Services (HSMS), Generic Services

SEMI E37.1 — High-Speed SECS Message Services, Single-Session Mode (HSMS-SS)

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O

5 Terminology

5.1 The following define some descriptive terms that can be used to refer to systems that meet the requirements of the standards referenced herein.

5.1.1 *SECS Compliant* — This term is often used to describe systems which comply completely with both the SEMI E4 (SECS-I) and SEMI E5 (SECS-II) standards. However, it is more appropriate to identify the system as "SECS-I Compliant" and/or "SECS-II" compliant. This distinction is important because SECS-II can be implemented independently from SECS-I. The term "SECS Compliant" is ambiguous, but commonly used. It is suggested that the following terms be used instead to describe the equipment and host communication interface.

5.1.2 *SECS-I Compliant* — This term is used to identify a system that complies completely with SEMI E4.

5.1.3 *SECS-II Compliant* — This term is used to identify a system that complies completely with SEMI E5.

5.1.4 *HSMS Compliant* — This term is used to describe systems which comply with SEMI E37 (HSMS) and either SEMI E37.1 (HSMS-SS) or SEMI E37.2 (HSMS-GS) or both. However, it is more appropriate to identify the system as either “HSMS-SS Compliant” or “HSMS-GS Compliant”, since they both imply compliance with SEMI E37, and the user must know exactly which of the two is supported. The term “HSMS Compliant” is ambiguous, but commonly used.

5.1.5 *HSMS-SS Compliant* — This term is used to identify a system that complies completely with SEMI E37 and SEMI E37.1. This protocol has been adopted for use in FPD.

5.1.6 *HSMS-GS Compliant* — This term is used to identify a system that complies completely with SEMI E37 and SEMI E37.2.

5.1.7 *GEM* — Generic Equipment Model as defined in SEMI E30.

5.1.8 *GEM Compliant* — This term is defined in SEMI E30.

5.1.9 *Fully GEM Capable* — This term is defined in SEMI E30.

5.1.10 *System* — Either manufacturing equipment or factory host.

6 Data Transfer

6.1 For optimum compatibility, systems supporting the automation capabilities described herein should support all requirements defined for at least one of the following SEMI protocol standards:

6.1.1 SEMI E4 (SECS-I)

6.1.2 SEMI E37.1 (HSMS-SS). Note that this requires implementation of SEMI E37.

6.1.2.1 HSMS-SS compliant interfaces are preferred for FPD manufacturing because of its performance and logistical advantages, and because it allows other protocols to operate on the same connection simultaneously.

6.1.2.2 However, SECS-I interfaces are acceptable in systems where the performance of a serial interface is sufficient. Since many off-the-shelf component software implementations support both protocols, it is relatively easy to design systems which can be configured to support either.

7 Data Format

7.1 The system should support all minimum requirements of SEMI E5 (SECS-II). Although more modern data communication specifications are available (e.g. HTML), SECS-II has unique aspects which are valuable in microelectronics manufacturing. Also, there are many available “off-the-shelf” software packages which provide the SECS-II feature set.

7.2 Furthermore, for maximum compatibility and reliability, the implementation of any optional SEMI E5 objects (data items, variable items, messages, etc.) on the system should meet the requirements of SEMI E5. For example, if an FPD system implements the S7,F3 message, it must do so in compliance with SEMI E5 to be considered “SECS-II Compliant”. It is possible to implement “user-defined” SECS-II messages, and it is allowed by SEMI E5.

7.3 However, it is usually unnecessary to use such custom SECS-II messages. Complicated scenarios such as production sequence control, inline production, consumable management, and material handling can all be implemented using standard SECS-II messages. Many SECS-II messages are designed to be very generic and very flexible such as the Remote Command message (S2F41 or S2F49) which can contain any number of parameters of any type in any format. Many of the basic SECS-II data items such as variables can also take on any type of value in any format.

7.4 User-defined data items and messages are more difficult to integrate into FPD factory automation systems and should be avoided.

8 GEM and SEM

8.1 *Generic Equipment Model (GEM)*

8.1.1 Any reference to the term “GEM” (Generic Equipment Model) with respect to FPD manufacturing equipment will be construed as a reference to SEMI E30. The system provider should ensure that this term is used only for those systems which rigidly adhere to SEMI E30. End-users will make certain assumptions about the capabilities of “GEM” systems based on the requirements of SEMI E30.

8.1.2 SEMI E30 is applicable to FPD manufacturing equipment. FPD equipment suppliers may choose to implement GEM. In order for FPD equipment to be “GEM Compliant” or “Fully GEM Capable”, it must meet the requirements of SEMI E30 without exception. However, it may not be necessary to implement certain optional GEM capabilities for effective FPD automation.

8.1.3 The implementation of SEMI E30, or lack thereof, is usually a point of much negotiation between equipment supplier and end-user. SEMI E30 provides a useful template for identifying which capabilities are to be provided and which are not. The "GEM Compliance Statement" document should be provided by the equipment supplier to describe the capabilities of the interface, whether or not the system is GEM Compliant.

8.1.4 GEM is not applicable to host systems, but host systems must implement a compatible set of features to work effectively with GEM equipment.

8.2 *Specific Equipment Model (SEM)*

8.2.1 The concept of a Specific Equipment Model, which requires compliance with SEMI E30 (GEM), could be applied to FPD equipment as well. This document does not address SEMs. The user may wish to review the published SEM standards and determine their applicability in an FPD implementation.

9 Interfaces to Material Transfer Systems

9.1 *Carrier Transfer Parallel I/O Interfaces*

9.1.1 Material handling systems are critical for many FPD manufacturing operations. But, not all equipment support the automated transfer of material to and from the equipment. This section only applies to systems, which support automated carrier transfer.

9.1.2 For compatibility with many automated material handling systems on the factory floor, FPD equipment should support all requirements for at least one of the following SEMI carrier transfer parallel I/O standards:

9.1.2.1 *SEMI E23 (Cassette Transfer Parallel I/O Interface)* — Note that the diagram in SEMI E23 showing placement of the photo-coupled I/O interface with respect to the carrier stage (CS) shows specific CS size measurements. However, this is just an example and not a requirement of SEMI E23. The requirement is that the photo sensor must be on the front edge of the CS and its center aligned with the center of the CS. This applies to a CS of any size.

9.1.2.2 *SEMI E84 (Enhanced Carrier Handoff Parallel I/O Interface)* — Note that SEMI E84 references SEMI E1.9, SEMI E15, SEMI E15.1, SEMI E47.1, and SEMI E64 which are semiconductor specific standards and not applicable to FPD. However, none of the requirements in these documents are prerequisites for implementing SEMI E84. SEMI E84 is applicable to FPD and can be implemented independently.

SEMI D28-1101
SPECIFICATION FOR MECHANICAL INTERFACE BETWEEN FLAT PANEL DISPLAY MATERIAL HANDLING EQUIPMENT AND TOOL PORT, USING AUTOMATED GUIDED VEHICLE (AGV), RAIL GUIDED VEHICLE (RGV), AND MANUAL GUIDED VEHICLE (MGV)

This specification was technically approved by the Global Flat Panel Display Material Handling Committee and is the direct responsibility of the Japanese Flat Panel Display Material Handling Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This specification defines a common set of feature requirements on and about tool ports of process tools used in manufacturing of flat panel displays. These standardized feature requirements are intended to facilitate the interfacing of AGV, RGV, and MGV equipment to the process tool. Such standards are intended to promote cost-effective interfacing while preserving freedom of choice in material handling equipment, using AGV, RGV, and MGV.

2 Scope

2.1 This specification defines mechanical features on or about the tool port, and in front of or on the tool face. Although these features are intended for specific functions of AGV, RGV, and MGV, the interface requirements are meant to avoid the promotion of any particular form of transport.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Current display manufacturing utilizes several substrate sizes, many of them “non-standard.” This specification includes dimensions for the substrate sizes of 550 × 650 mm, 600 × 720 mm, 680 × 880 mm, 730 × 920 mm, and 800 × 950 mm and anticipates the establishment of standard dimensions in future substrate sizes.

4 Referenced Standards

4.1 None.

5 Ordering Information

5.1 Since this document is not a product specification but an interface specification, ordering information is not applicable.

6 Terminology

6.1 *Definitions*

6.1.1 *cassette loading position* — center point at under-surface of a cassette after loading by transport equipment.

6.1.2 *facial datum plane* — a plane that is parallel to the tool face and vertical to both vertical and horizontal datum planes at the cassette loading position.

6.1.3 *horizontal datum plane* — a plane that is parallel to the floor surface at the cassette loading position.

6.1.4 *vertical datum plane* — a plane that is vertical to both facial and horizontal datum planes at the cassette loading position.

6.2 *Dimensional Functions*

6.2.1 *X1* — width of the exclusion zone above the horizontal datum plane, which is needed by the transport equipment in loading cassettes.

6.2.2 *X2* — width of the exclusion fork zone below the horizontal datum plane, which is needed by the transport equipment in loading cassettes.

6.2.3 *X3* — width of the exclusion zone required for MGV cart alignment equipment.

6.2.4 *Y1* — dimension between the facial datum plane and the front of the tool port.

6.2.5 *Y2* — dimension between the facial datum plane and the tool face, which is the exclusion zone needed by the transport equipment in loading cassettes.

6.2.6 *Y3* — depth of exclusion zone required for MGV cart alignment equipment.

6.2.7 *Z1* — height between the horizontal datum plane and the floor surface.

6.2.8 *Z2* — height of exclusion zone above the horizontal datum plane, which is needed by the transport equipment in loading cassettes.

6.2.9 *Z4* — height of exclusion zone required for MGV cart alignment equipment.

6.2.10 *Z5* — height of exclusion fork zone below the horizontal datum plane, which is needed by the transport equipment in loading cassettes.

7 Requirements

7.1 Dimensions and tolerances of the required characteristics are shown in Table 1 as well as Figures 1A and 1B.

7.2 The cassette is stored horizontally with the shorter side parallel to the tool face and horizontal datum plane.

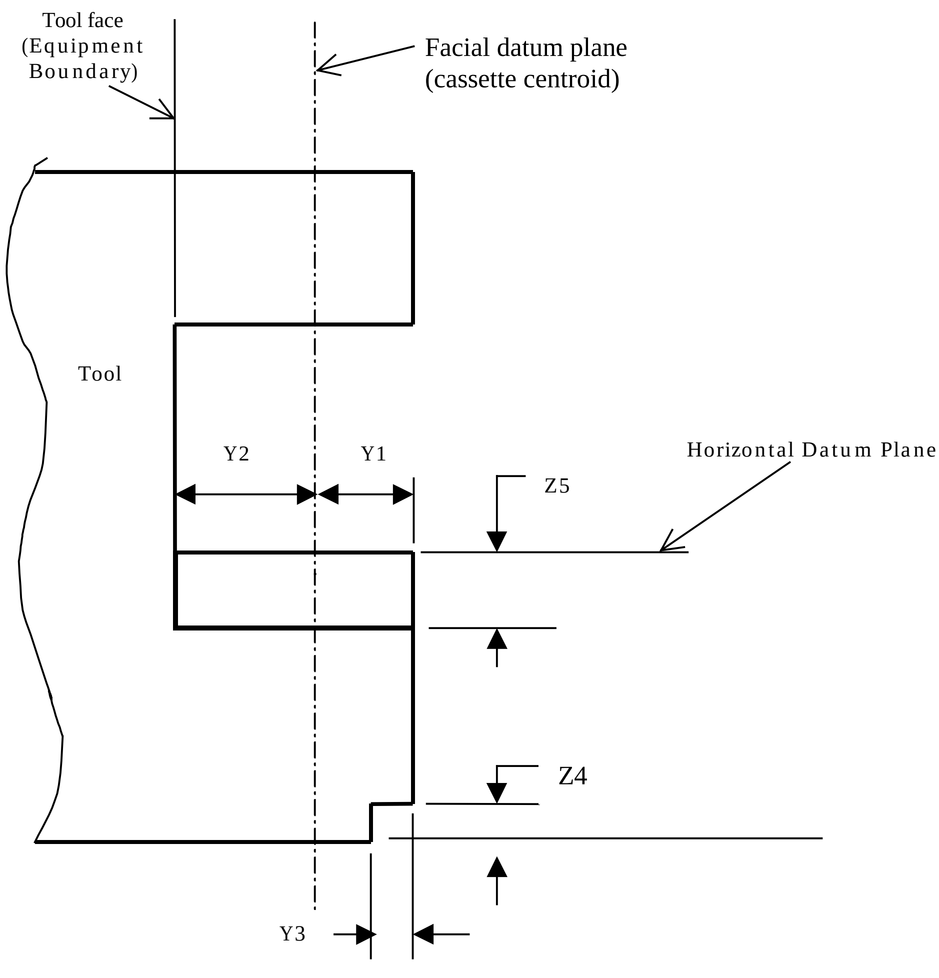


Figure 1A
(Arrow 'A' View)
Side View of Tool port

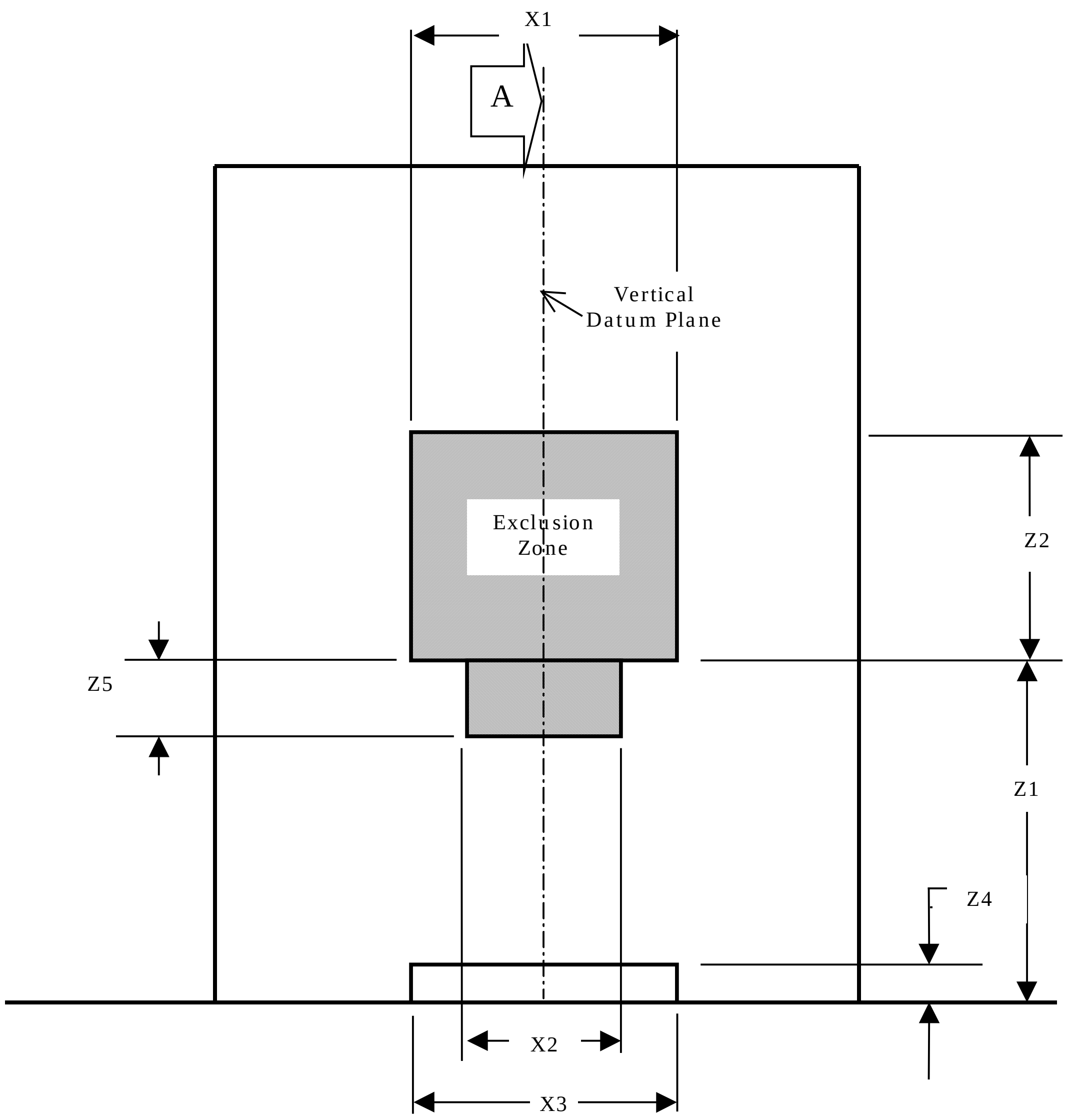


Figure 1B
Front View of Tool port

Table 1 Substrate Edge Length, Interface Dimensions, and Tolerances

Substrate Edge Length [mm]	*Interface Dimensions and Tolerances[mm]*									
	X1 max.	*X2 max.*	*X3 max.*	*Y1 max.*	*Y2 max.*	*Y3 max.*	*Z1 ± 2 mm*	*Z2 max.*	*Z4 max.*	*Z5 max.*
550 × 650	925	450	600	500	440	130	900, 950	1000	150	250
600 × 720	980	500	600	535	475	130	900, 1000	1000	150	250
680 × 880	1100	560	600	615	565	130	1000, 1100	1000	150	300
730 × 920	1150	600	600	630	590	130	1000, 1100	1000	150	300
800 × 950	1200	660	600	650	605	130	1000, 1100	1000	150	300

NOTE 1: Two values are specified for Z1, either value can be chosen.

8 Related Documents

8.1 *SEMI Standards*

SEMI D5 — Standard Size for Flat Panel Display Substrates

SEMI D11 — Specification for Flat Panel Display Glass Substrate Cassettes

SEMI D16 — Specification for Mechanical Interface Between Flat Panel Display Material Handling System and Tool Port

8.2 *Semiconductor Equipment Association of Japan (SEAJ)*

Semiconductor Equipment Association of Japan (SEAJ) Liquid Crystal Display Manufacturing Equipment Standardization Guideline – for Glass Substrate Size 800 × 950 (SEAJ/P-S3005-98, SEAJ/P-S3006-98), June 1998 [1]

8.3 *SEMI PCS-FPD*

SEMI PCS-FPD — Production Cost Saving (PCS) Forum – FPD Phase III Report, June 1999 [2]

1 Semiconductor Equipment Association of Japan, 7-10, Shinjuku 1-chome, Shunjuku-ku, Tokyo, 160-0022 Japan, tel:+81-3-3353-7589, fax:+81-3-3353-7970, http://www.seaj.or.jp

2 SEMI PCS-FPD — Production Cost Saving (PCS) Forum – FPD Phase III Report, June 1999, Semiconductor Equipment and Materials International, 3081 Zanker Road , San Jose, CA 95134-2127 U.S.A.tel.+1-408-943-6900 fax:+1-408-428-9600 http://www.semi.org

RELATED INFORMATION 1
ASSUMED DIMENSIONS FOR SUBSTRATE EDGE AND CASSETTE SIZE

NOTE: This related information is not an official part of SEMI D28 and was derived from work of the originating committee. This related information was approved for publication by full letter ballot procedures on August 3, 2001.

Table R1-1 Cassette Size

Substrate Edge length [mm]	*Cassette size [mm] Width×Length×Height*
550 × 650	591 × 682 × 524
600 × 720	642 × 755 × 695
680 × 880	736 × 923 × 706
730 × 920	792 × 978 × 770
800 × 950	870 × 1010 × 810

NOTE 1: 550 × 650, 600 × 720, 680 × 880, and 730 × 920 are the sizes which are actually adopted at the manufacturing sites. As for 800 × 950, please refer to SEMI PCS-FPD-Phase III Report.
NOTE 2: Cassette sizes in Table R1-1 were used only hypothetically as assumption to prescribe dimensions in Table 1.

SEMI D29-1101
TEST METHOD FOR HEAT RESISTANCE IN FLAT PANEL DISPLAY (FPD) COLOR FILTERS

This test method was technically approved by the Global Flat Panel Display Materials and Components Committee and is the direct responsibility of the Japanese Flat Panel Display Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this document is to standardize the method for measurement of heat resistance in color filters used for flat panel displays (FPD).

2 Scope

2.1 This method is to be used by suppliers and users of FPD color filters to measure quality in products as well as items under development.

2.2 This method is used in general FPD production to test the resistance of color filters to heat.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI D19 — Test Method for the Determination of Chemical Resistance of Flat Panel Display Color Filter

SEMI D22 — Test Method for the Determination of Color, Transmittance of Flat Panel Display Color Filter Assemblies

3.2 *ISO Standards*[1]

ISO 7724 [2,3] — Paints and varnishes -- Colorimetry

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *atomic force microscope (AFM)* — a device which precisely measures surface shape by gauging the reciprocal active force between atoms through use of a probe.

4.2 *clean oven* — a device that heats a specimen through circulation of heated air through an air filter.

4.3 *confocal scanning laser microscope* — a microscope which is able to create an image of just the focal point by concentrating light on a specimen using a confocal laser. This device can also measure surface shape by recording height information, which matches the focal point of each scans line image.

5 Summary of Method

5.1 Measure spectral transmittance, chromaticity, and surface shape of specimen.

5.2 Place specimen in heating device and leave at specified temperature for specified length of time.

5.3 Remove specimen from heating device and cool them.

5.4 Observe visually and by microscope to see if any exterior changes have occurred in the specimen.

5.5 Measure spectral transmittance, chromaticity, and surface shape of specimen.

6 Apparatus

6.1 *Heating Device and Holders*

6.1.1 *Heating Device* — Use a clean oven. The heating device being used must have the accuracy of temperature verified. Also, the device should have enough capacity to be able to heat the specimen evenly to the target temperature promptly. For example, there are devices where it is necessary to place a metal block inside to increase the heating capacity to the specimen.

6.1.2 *Holder* — First the holder should be raised to the specified temperature and then the specimen should be set in the holder.

1 International Organization for Standards(ISO), 1, rue de Varembe, Case, postale 56 CH-1211 Geneva 20, Switzerland. Tel: +41-22-749-01-11, E-mail: central@iso.ch, http://www.iso.ch

2 Available in Japanese as JIS Z8730 — Method for Specification of Color Differences for Opaque Material. Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, 107-8440 Japan. Tel: +81-3-3583-8000, E-mail: webmaster@jsa.or.jp, http://www.jsa.or.jp

3 The expression method of its color differences is equal to the method defined in Publication of CIE No. 87 (1990) Parametric Effects in Color – Difference Evaluation. Commission Internationale de l'Eclairage, Kegelgasse 27, A-1030 Vienna, Austria. Tel: +43-1-714-31-87-0

6.2 *Measurement Devices*

6.2.1 *3-dimensional Profile Measurement Device* — Use a Stylus type surface roughness measurement device, AFM or laser microscope.

6.2.2 *Color Illuminator* — See SEMI D19.

6.2.3 *Floodlight* — See SEMI D19.

6.2.4 *Microscope* — See SEMI D19.

6.2.5 *Spectrophotometer* — Use a device in conformance with SEMI D22.

7 Test Conditions

7.1 As long as the test condition should be written in the test result, any combination of temperature and heating time can be acceptable in the conditions. The test conditions used should reflect actual conditions in the manufacturing process of flat panel displays. Table 1 contains a reference for test temperature, maintain time and atmosphere.

Table 1 Test Conditions

Item	*Device Condition*	*Test Temperature*	*Maintain time*
1	Room Air	180°C (± 2°C) 200°C (± 2°C) 230°C (± 2°C)	1 hour (± 5%)
2	Nitrogen Gas	180°C (± 2°C) 200°C (± 2°C) 230°C (± 2°C)	1 hour (± 5%)

8 Test Specimen

8.1 Use FPD color filters for specimens. In the test report, note the existence or non-existence of Transparent Conductive Film (ITO etc.).

9 Procedure

9.1 Adjust the temperature on the heating device and make sure of the furnace temperature.

9.2 Measure the spectral transmittance, chromaticity. Observe the surface of each color layer of the specimen. (The measurement method is described in Sections 9.6 and 9.7.)

9.3 Mount the specimen in the heating device.

9.4 After the temperature returns to the specified temperature, keep the specimen for the prescribed length of time.

9.5 Remove the specimen from the heating device and cool them to room temperature.

9.6 Inspect change of the outlook and the profile of the specimen according to the following procedures.

9.6.1 Observe the existence of peculiar changes in exterior appearance before and after each test (e.g. wrinkles, cracks, color “mura” etc.). It is possible for the users of this standard to use various appropriate methods of observation.

9.6.2 Visual observation by color illuminator from backside.

9.6.2.1 Visual observation by a floodlight from front side.

9.6.2.2 Microscope observation with transmitted illumination.

9.6.2.3 Microscope observation with reflected illumination.

9.6.2.4 Surface roughness measurement using a stylus-type surface roughness measurement device, AFM or laser microscope.

9.7 Measure the color changes according to the following procedures.

9.7.1 Measure the spectral transmittance and chromaticity of each color layer after heating using the method described in SEMI D22. (Measurements must be taken at the same location as before heating.)

9.7.2 Before and after the test, calculate the color difference ΔE^*ab or ΔE^*uv, in each color layer, according to ISO 7724, from the chromaticity of each color layer.

10 Reporting Results

10.1 Report the following items:

10.1.1 report date,

10.1.2 test date,

10.1.3 heating device type and conditions of use,

10.1.4 condition of specimen (with/without Transparent Conductive Film (ITO etc.), size, etc.),

10.1.5 conditions of test (temperature, length of time),

10.1.6 existence of change in outward appearance,

10.1.7 chromaticity, spectral transmittance of each color layer before and after thermal treatment (number of measuring points, position),

10.1.8 color difference of each color layer before and after thermal treatment, and

10.1.9 change in spectral transmittance at specified wavelength (e.g. back-light peak wavelength, etc.).

11 Related Documents

11.1 *SEMI Standards*

SEMI D13 — Terminology for FPD Color Filter Assemblies

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI D30-1101
TEST METHOD FOR LIGHT RESISTANCE IN FLAT PANEL DISPLAY (FPD) COLOR FILTERS

This test method was technically approved by the Global Flat Panel Display Materials and Components Committee and is the direct responsibility of the Japanese Flat Panel Display Materials and Components Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this document is to standardize the method for measurement of light resistance in color filters used for flat panel displays (FPD).

2 Scope

2.1 This method is to be used by suppliers and users of FPD color filters to measure quality in products as well as items under development.

2.2 This method shall be used in general FPD production to test the resistance of color filters to light.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determines the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI D19 — Test Method for Chemical Resistance of FPD Color Filter

SEMI D22 — Test Method for the Determination of Color, Transmittance of FPD Color Filter Assemblies

3.2 *JIS Standards (available in Japanese only)*[1]

JIS B7751 — Light-exposure and light-and-water-exposure apparatus (Enclosed carbon-arc type)

3.3 *ISO Standards*[2]

ISO 4892 — Methods of exposure to laboratory light sources

ISO 7724 [3,4] — Paints and varnishes -- Colorimetry

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *atomic force microscope (AFM)* — a device which precisely measures surface shape by gauging the reciprocal active force between atoms through use of a probe.

4.2 *fade meter* — a device which tests for the existence of external change or characteristics in materials by long term irradiation using fixed brilliance from a prescribed light source.

5 Summary of Method

5.1 Measure spectral transmittance, chromaticity, and surface shape of specimen.

5.2 Place specimen in light exposure apparatus and irradiate for specified length of time.

5.3 Remove specimen from light exposure apparatus.

5.4 Observe visually and by microscope to see if any exterior changes have occurred in the specimen.

5.5 Measure spectral transmittance, chromaticity, and surface shape of specimen.

6 Apparatus

6.1 *Light Exposure Apparatus* — Choose a test device to use from the following devices and specify which device was used in the report.

6.1.1 Carbon-arc Fade Meter

6.1.2 Sunshine Carbon-arc Fade Meter

6.1.3 Xenon-arc Fade Meter

1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, 107-8440 Japan. Tel: +81-3-3583-8000, E-mail: webmaster@jsa.or.jp, http://www.jsa.or.jp

2 International Organization for Standards(ISO), 1, rue de Varembe, Case, postale 56 CH-1211 Geneva 20, Switzerland. Tel: +41-22-749-01-11, E-mail: central@iso.ch, http://www.iso.ch

3 Available in Japanese as JIS Z8730 — Method for Specification of Color Differences for Opaque Material.

4 The expression method of its colour differences is equal to the method defined in Publication of CIE No. 87 (1990) Parametric Effects in Color – Difference Evaluation. Commission Internationale de l'Eclairage, Kegelgasse 27, A-1030 Vienna, Austria. Tel: +43-1-714-31-87-0

6.2 *Measuring and Inspection Devices*

6.2.1 *Color Illuminator* — This light source shall have chromaticity, color rendering, luminance and intensity uniformity, diffusion, and a sufficient illumination area for observation of the specimen to be measured (See SEMI D19).

6.2.2 *Floodlight* — This light shall have luminance uniformity and an illumination area sufficient for the specimens to be measured (See SEMI D19).

6.2.3 *Microscope* — Use a microscope which has either transmitted illumination or reflected illumination, or both, and has a sufficient magnification ratio (See SEMI D19).

6.2.4 *Spectrophotometer* — The spectrophotometer shall be in conformance with SEMI D22.

6.2.5 *Surface Shape Measurement Device* — Use a Stylus-type surface roughness measurement (film thickness measurement) device, AFM or laser microscope.

7 Test Conditions

7.1 The principle test conditions are described in Table 1. In the case where tests are performed under conditions in addition to these, clearly state those conditions.

Table 1 Test Conditions

Item	*Device*	*Test Interval*	*Color Filter Condition*	*Evaluation Item*	*Reference Standard*
1	Carbon-arc Fade Meter	100 hrs. ± 5%	With/Without ITO	1. External Change	JIS B7751
2	Sunshine Carbon-arc Fade Meter	100 hrs. ± 5%	Glass Surface Irradiation	2. Color Difference ΔE*ab or ΔE*uv	ISO 4892
3	Xenon-arc Fade Meter	500 hrs. ± 5%	With UV-cut Filter	3.Transmittance Change	ISO 7724

8 Test Specimen

8.1 Use FPD color filters for specimens. In the test results, note the existence or non-existence of Transparent Conductive Film (ITO etc.). Specimen used in the test are cut to an appropriate size for the specified holder of the equipment above, and fastened at the specified distance from the light source. At this time, in order to test in conditions close to actual use, an UV-cut filter is attached to the glass surface, and light is radiated from UV-cut filter side.

9 Procedure

9.1 Turn on the light source of the light exposure apparatus and stabilize it.

9.2 Measure the spectral transmittance, chromaticity, and surface shape of each color layer of the specimen. (The measurement method is described in Sections 9.6 and 9.7.)

9.3 Mount the specimen in the light expose apparatus.

9.4 Radiate light on the specimen for the prescribed length of time. In order to keep the brilliance of the light source uniform over this period of time, control the light source according to the procedures accompanying your inspection device.

9.5 Remove the specimen from the light exposure device.

9.6 Inspect the change of the outlook and the profile of the specimen according to the following procedures.

9.6.1 Observe the existence of peculiar changes in exterior appearance before and after each test (e.g. wrinkles, cracks, color “mura” etc.).

9.6.1.1 Visual observation by a color illuminator from backside.

9.6.1.2 Visual observation by a floodlight from front side.

9.6.1.3 Microscope observation of color filter with transmitted illumination.

9.6.1.4 Microscope observation of color filter with reflected illumination.

9.6.1.5 Surface roughness measurement using a stylus-type surface roughness measurement device, AFM or laser microscope.

9.7 Measure the color changes according to the following procedures.

9.7.1 Measure the spectral transmittance and chromaticity of each color layer after the light resistance test using the method described in SEMI D22. (Measurements must be taken at the same location as before the test.)

9.7.2 Before and after the test, calculate the color difference ΔE*ab or ΔE*uv, in each color layer, according to ISO 7724, from the chromaticity of each color layer.

10 Reporting Results

10.1 Report the following items:

10.1.1 report date,

10.1.2 test date,

10.1.3 light exposure apparatus type and conditions of use,

10.1.4 condition of specimens (with/without Transparent Conductive Film (ITO etc.), size, etc.),

10.1.5 conditions of test (light source, brilliance, length of time, etc.),

10.1.6 existence of change in outward appearance,

10.1.7 chromaticity of each color layer before and after thermal treatment (number of measuring points),

10.1.8 color difference of each color layer before and after thermal treatment, and

10.1.9 change in spectral transmittance at specified wavelength (e.g. back-light peak wavelength, etc.).

11 Related Documents

11.1 *SEMI Standards*

SEMI D13 — Terminology for FPD Color Filter Assemblies

SEMI INTERNATIONAL STANDARDS

GASES

Semiconductor Equipment and Materials International

SEMI C3-0699
SPECIFICATIONS FOR GASES

IMPORTANT NOTICE: This specification is incomplete. The incomplete sections are noted as "To Be Determined." The Gases Committee has agreed to publish this section prior to completion as a service to the Semiconductor Industry.

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on February 28, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1986; previously published in 1995.

1 Preface

1.1 Recognizing the importance of impurity content of gases in the manufacture of semiconductors, suppliers responded by introducing products with improved analytical characterization, notably for trace impurities.

1.2 The SEMI Gases Committee began its efforts in the spring of 1979. With this publication, the Committee establishes the definitions, general procedures, specifications, and analytical procedures for the gases listed in the index.

1.3 Products which meet all of the requirements may be described as "meeting SEMI specifications."

1.4 Where an analytical procedure different from that provided is substituted by a supplier or user, the burden of proof is on said supplier or user to confirm the equivalency. It should be noted that the following list of criteria was considered when determining the specified analytical method.

Reliability

Ease of Use

Maintenance

Precision

Accuracy

Sensitivity

Versatility

Availability of Equipment

1.5 The specifications provided by this work are intended to serve for gases to be used in the manufacture and processing of semiconductors and advanced electronic devices and circuits. The specifications and the associated test procedures are guidelines based on the experience of suppliers and users. The function of the specifications is to establish desired standards of quality.

1.6 Where feasible, a specification of content shall be expressed as a numerical limit in units of mole per mole (mole/mole).

1.7 For a major component, the value (assay or purity) shall be expressed as a minimum permissible limit. For an impurity, the value shall be expressed as a maximum permissible limit.

1.8 A gas conforming to the specifications will commonly contain more of the major component than the minimum permissible limit or contain less of an impurity (or several impurities) than the SEMI C3 maximum permissible limit. In neither case shall the gas be considered as of higher quality than that defined by the specification.

1.9 It is not practical to consider every impurity or contaminant that might be present. For certain applications, it is recognized that more stringent or additional specifications and procedures might be required. The intent of these specifications and the associated procedures is, on one hand, to assure that a gas is suitable for the common uses to which it may be put in the manufacture and processing of semiconductor devices and, on the other hand, to be consistent with contemporary manufacturing processes for that gas.

1.10 The Committee is continuing work on improvement of specifications and procedures and addition of other gases and systems such as mixed gases. The Committee welcomes comments, suggestions, and recommendations.

2 Definitions

2.1 *Abbreviations and Symbols* — In this work, abbreviations and symbols used shall be restricted to those listed in Table 1.

Table 1 Abbreviations and Symbols

Abbreviation or Symbol	*Explanation*
ASTM	American Society for Testing and Materials
atm	atmosphere
BP	Boiling point
°C	temperature, degrees Celsius

Abbreviation or Symbol	*Explanation*
cc	cubic centimeter(s)
CGA	Compressed Gas Association
cm	centimeter
DOT	Department of Transportation (U.S.)
°F	temperature, degrees Fahrenheit
ft	foot, feet
g	gram(s)
L	liter(s)
lb	pound(s)
max	maximum
min	minimum
mL	milliliter(s)
mm	millimeter(s)
MP	melting point
mw	molecular weight (g/mole)
ohm-cm	ohm - centimeter
ppm	mole/mole x 10^6
ppb	mole/mole x 10^9
ppba	mole/mole x 10^9 atomic
ppbw	weight/weight x 10^9
psia	pounds per square inch absolute
psig	pounds per square inch gauge
SCF	standard cubic foot (feet)
temp.	temperature
vol	volume
vol/vol	volume/volume
wt.	weight
w/v	weight/volume
ww	weight/weight

2.2 *accuracy* — (To Be Determined)

2.3 *assay* — determination of the content of a specific component with no evaluation of other components.

2.4 *comparison of analytical results with specific limits* — in the comparison of an analytical result for a test with the numerical limit associated with that specification, the result shall be rounded to the number of significant figures indicated for that limit. (See Rounding Numbers, SEMI C3, Section 2.22).

2.4.1 Consequently, a specification stated as 96% minimum will be met by a result as small as 95.5%, and that stated as 96.0% minimum will be met by a result as small as 95.95%. A specification of 0.1% maximum will be met as large as 0.14%, and that of 0.10% maximum by a result as large as 0.104%.

2.5 *cryogenic liquid* — liquid with a normal boiling point below –150°C.

2.6 *cylinder pressure* — pressure contained in a gas cylinder prior to regulation.

2.7 *cylinder tare weight* — containers which are stamped to denote the weight of the container or the weight of the container and the valve less the product. The weight does not include the weight of any protective cylinder cap.

2.8 *density* — weight per unit volume (w/v) is expressed as grams per liter for gases at zero degrees Celsius, one atmosphere.

2.9 *detection limit* — the detection limit for all the analytical methods that appear in this section of the BOSS must be established for each impurity defined. The detection limit must be stated as well as the statistical method used to establish that detection limit. The analytical method should be chosen such that the detection limit is at or below the specification.

2.10 *dewpoint* — the temperature at which liquid first condenses when vapor is cooled.

2.11 *expression of content and concentration* — unless otherwise stated, a specification limit and the analytical result related to it shall be expressed in units of mole per mole (mole/mole).

2.12 *filtration* — (To Be Determined)

2.13 *Gas Purity Guideline* — A Gas Purity Guideline is a proposed specification recommended by one or more users as needed in the future for the production of semiconductor devices. They reflect future needs in which test methods are not generally available at the time of proposal. These guidelines are approved by the Gases Committee for publication in the Standards Book. Products meeting these guidelines are not necessarily commercially available.

2.14 *heavy metals* — (To Be Determined)

2.15 *liquified compressed gas* — a gas which under the charged pressure is partially liquid at a temperature of 21.1°C (70°F).

2.16 *metals* — (To Be Determined)

2.17 *molecular weight* — the sum of the atomic weights of all the atoms in the molecule.

2.18 *nonliquified compressed gas* — a gas, other than a gas in solution, which under the charging pressure is entirely gaseous at a temperature of 21.1°C (70°F).

2.19 *physical properties* — physical properties shall not usually be employed for specification purposes; for information, however, representative values for a particular gas, as supplied, may be included as an item in the monograph for that gas.

2.20 *quality* — the quality is determined by subtracting the sum of the maximum acceptable gas phase impurity levels, expressed in percent, from 100. The result is truncated after the first significant figure which is not a nine. The quality does not represent an assay.

2.21 *rare gas* — any of the six gases, all noble, comprising the extreme right-hand group of the Periodic Table; namely helium, neon, argon, krypton, xenon, and radon.

2.22 *rounding numbers* — the following rules for rounding of measured or calculated values shall be employed:

2.22.1 When the figure next beyond the last place to be retained is less than 5, leave unchanged the figure in the last place retained.

2.22.2 When the figure next beyond the last place to be retained is greater than 5, increase by 1 the figure in the last place retained.

2.22.3 When the figure next beyond the last place to be retained is 5 and there are no figures beyond this 5 or only zeroes, (a) increase by 1 the figure in the last place retained if it is odd, or (b) leave the figure unchanged if it is even.

2.22.4 When the figure next beyond the last place to be retained is 5 and there are figures other than zeroes beyond this 5, increase by 1 the figure in the last place retained.

2.22.5 Obtain the rounded value in one step by direct rounding and not in two or more steps of successive rounding.

2.23 *specific gravity* — the ratio of the mass of a gas to the mass of an equal volume of air at a specified temperature. For liquids, it is the ratio of the mass of the liquid to the mass of an equal volume of water.

2.24 *specification and specification limits* — the specification limit should fall above or in the range of the result and its uncertainty.

2.25 *temperature* — temperature values shall be expressed in degrees Celsius.

2.26 *tolerances in measurements* — use the following guidelines for mixture tolerances:

2.26.1 Mixtures should be specified by the major component and the concentration of the desired minor component(s).

2.26.2 All component gases shall adhere to the appropriate SEMI specification, if available.

2.26.3 The impurity levels in the mixture shall not exceed the algebraic sum of the impurities specified for the designated components.

2.26.4 Mixtures shall be prepared according to the following mixing tolerances:

Concentration of Minor Component	*Preparation Tolerance Level*
10 - 99 ppm	± A 20%
100 - 999 ppm	± A 10%
0.1 - 50%	± A 5%

2.26.5 Standards used to verify mixing tolerance (henceforward called Certified Standards) shall meet the following requirements:

Range	*Preparation Tolerance of Each Minor Component*	*Analytical Accuracy of Each Minor Component*
0 - 9.9 ppm	To Be Determined	To Be Determined
10 - 99 ppm	± A 10%	± A 3%
100 - 999 ppm	± A 5%	± A 2%
0.1% - 50%	± A 4%	± A 2%

2.27 *Calibration Standards* — Calibration standards shall be as close as practical to specification and may not exceed ten times (10×) the specification unless specifically excepted in procedure.

3 Samples

3.1 *Sample Size* — The quantity of gas/liquid in a single sample container shall be sufficient to perform the analysis for all the listed specifications. If a single sample does not contain a sufficient quantity of gas/liquid to perform all of the required analyses, additional samples from the same source shall be taken under similar conditions.

3.2 *Gaseous Samples* — Gaseous samples shall be representative of the gaseous supply. Sampling shall be performed in accordance with one of the following:

3.2.1 By withdrawing a sample from the supply container through a suitable connection into the sample container. (For safety reasons, the sample container and sampling system must have a rated service pressure at least equal to the pressure in the supply container.)

3.2.2 By connecting the container being sampled directly to the analytical equipment.

3.2.3 By selecting a representative cylinder from the cylinders in the lot.

3.3 *Liquid Sampling (Vaporized)* — Vaporized liquid samples shall be representative of the liquid supply. Sampling shall be in accordance with one of the following:

3.3.1 By vaporizing liquid from the supply container in the sample tubing.

3.3.2 By flowing liquid from the supply container into, or through, a suitable container in which a representative sample is collected and then vaporized.

3.4 *Liquid Samples (Liquified Compressed Gases)* — A direct connection between the liquid phase of liquified compressed gas containers and the analytical equipment can be achieved, provided suitable flash vaporization is obtained.

3.5 *Lot Acceptance Tests* — These are analyses performed on the gas/liquid in the shipping container, or a sample thereof, which is representative of the lot. (The terms "lot" and "batch" may be used interchangeably.)

3.6 *Lots* — One of the following is to be used:

3.6.1 No specific quantity or any quantity of product agreed upon between the supplier and the customer.

3.6.2 All of the product supplied during the contract period.

3.6.3 All of the product supplied or containers filled during a calendar month.

3.6.4 All of the product supplied or containers filled during seven consecutive days.

3.6.5 All of the product supplied or containers filled during a consecutive 24-hour period.

3.6.6 All of the product supplied or containers filled during one eight-hour shift.

3.6.7 All of the product supplied in one shipment.

3.6.8 All of the product supplied in one shipping container.

3.6.9 All of the product supplied in the container(s) filled on one manifold at the same time.

3.7 *Number of Samples Per Lot* — The number of samples per lot shall be in accordance with one of the following:

3.7.1 One sample per lot.

3.7.2 Any number of samples agreed upon by the supplier and the customer.

4 Sampling

4.1 For gases provided in cylinders, a sample can be taken directly for analysis. For gases provided in bulk quantities or cylinders where direct sampling is not appropriate, a sample may be taken per SEMI sampling procedures.

4.2 *Sampling Procedures*

4.2.1 *Cryogenic Liquid Sample* — Liquid Samples for Oxygen, Nitrogen, and Argon, using the TTU-131/E sampler.

WARNING: DO NOT USE THIS PROCEDURE FOR THE SAMPLING OF LIQUID HYDROGEN.

4.2.2 *Applicable Document* — Military Specification MIL-S-27626D 16 August 1979, Amendment 1, 24 April 1981.

4.2.3 *General Description* — The TTU-131/E cryogenic sampler is a small, portable pressure vessel used to receive, vaporize, and contain a representative sample of cryogenic liquid from a supply source. The vaporized sample is withdrawn as a gas for analytical purposes.

4.2.4 *Theory* — The sampler is used to isolate a small but representative quantity of cryogenic liquid and vaporize the major component and all volatile impurities to form a homogeneous gas sample suitable for analysis. The cryogenic liquid is used to cool a shielding space and sampling cup prior to admitting the liquid to the sampling cup. The purpose of pre-cooling the sampling cup is to prevent concentrating impurities which could result when the warm cup causes the liquid to vaporize, leaving behind impurities with higher boiling points.

4.2.4.1 When the cup is adequately cooled, the sampling valve is opened, allowing liquid to fill the cup. When the sampling valve is closed, the liquid is trapped in the cup and will vaporize as a result of atmospheric heating. Once the sample is trapped, the flow of liquid is stopped.

4.2.5 *Preparation for Sampling*

4.2.5.1 The sample should be kept in the same product service to avoid sample contamination. If a product change is required, always thoroughly purge the sampler or evacuate to 100 microns prior to taking the sample.

4.2.5.2 When taking the sample, the sampler is to remain secured to the bottom half of the case and MUST be in an upright position.

4.2.5.3 Inspect the sampler vessel for any obvious physical defects, such as dents, gouges, bent fittings, etc. Since the sampler is a pressurized vessel, it should be removed from service if any damage is apparent.

4.2.6 *Sampling Procedure*

4.2.6.1 Remove cover.

4.2.6.2 Loosen inlet and outlet fittings dust caps located on side of the vessel.

CAUTION: SAFETY GLASSES AND PROTECTIVE GLOVES ARE REQUIRED WHEN OPERATING THIS EQUIPMENT. SAMPLING SHOULD BE DONE ONLY IN WELL VENTILATED AREAS.

4.2.6.3 Relieve pressure in vessel through vents in dust caps by cautiously opening inlet sampling valve.

4.2.6.4 When gauge indicates atmospheric pressure and flow ceases, close inlet sampling valve and remove dust caps.

4.2.6.5 Connect fill hose to supply tank and inlet fittings of sampler.

4.2.6.6 Open supply tank outlet valve. Gas and liquid will begin to flow from the sampler outlet.

CAUTION: WHEN OXYGEN IS SAMPLED, SOME ADDITIONAL PRECAUTIONS MUST BE OBSERVED. IF THERE IS NO FACILITY SUCH AS A CLEAN CONCRETE PAD ON WHICH THE LIQUID OXYGEN CAN EVAPORATE SAFELY, IT WILL BE NECESSARY TO CATCH THE LIQUID OXYGEN IN A CLEAN, PREFERABLY SEAMLESS ALUMINUM BUCKET. USE A LINE WITH MINIMUM INSIDE DIAMETER OF ONE-HALF INCH TO DIRECT THE LIQUID OXYGEN INTO THE BUCKET. FURTHERMORE, IT IS IMPORTANT THAT THERE IS NO RESTRICTION IN THIS LINE BECAUSE THE BACK PRESSURE DEVELOPED MAY BE SUFFICIENT TO CAUSE THE LIQUID IN THE CUP TO OVERFLOW INTO THE LARGE CHAMBER. ON WARMUP, THE PRESSURE IN THE SAMPLER COULD BECOME EXCESSIVE, PARTICULARLY IF THE SAMPLE WERE SUBCOOLED, NECESSITATING THE REPLACEMENT OF THE SAFETY RELIEF DEVICE.

4.2.6.7 Allow sampler to cool until a steady flow of liquid appears at outlet.

CAUTION: AVOID CONTACT WITH THE FLOW OF CRYOGENIC LIQUID. THE EXTREMELY LOW TEMPERATURE CAN CAUSE PAINFUL INJURIES.

4.2.6.8 Open inlet sampling valve completely to allow liquid to enter sampling cup.

4.2.6.9 After 30 seconds, close sampling valve.

4.2.6.10 Close supply tank outlet valve.

4.2.6.11 Disconnect fill hose.

4.2.6.12 Invert sampler for five minutes to allow sampling cup to empty and provide vaporization of liquid.

4.2.6.13 At ambient temperature the sampler should be at 400-500 psig, indicating that a good sample was obtained. A lower pressure would indicate a leak in the sampler or that the cup was not filled with liquid. If there is any doubt, release gas from sampler and take another sample.

4.2.6.14 Re-install inlet and outlet fitting caps. Do not tighten.

4.2.6.15 Affix a tag identifying the product to the inlet sampling valve handwheel.

4.2.6.16 Install cover.

4.3 *Gas Phase Sample* — (To Be Determined)

4.4 *Liquid Sample* — (To Be Determined)

4.5 *Delivery to Analytical Instruments* — (To Be Determined)

5 Quantification (To Be Determined)

5.1 *Linear Response*

5.1.1 Direct Comparison

5.1.2 Calibration Curve

5.2 *Non-Linear Response*

5.2.1 Direct Comparison

5.2.2 Calibration Curve

6 Gas Chromatography

6.1 The analysis of many gaseous impurities in bulk and specialty gases is done by means of a gas chromatography separation of impurities from the gas matrix and quantification using a broad range of sensitive and sometimes selective detectors. This section will provide a guide for the format and representation of such a procedure. Figure 1 is designed to represent the format for submission of such methodology.

6.2 *Sample Introduction* — By its nature, gas chromatography implies the use of carrier gases into which the gaseous sample is injected and carried into the separation medium, either solid or liquid in nature.

The introduction of a gaseous sample into a carrier gas stream is accomplished by means of a sample injection valve. Valves for this purpose can be any of several types, although the most commonly used are either rotary or diaphragm valves using loops of stainless steel tubing of a known volume. It is not necessary to diagram such sample introduction systems for a procedure unless the introduction system is unique to the application by way of special conditions for safety or other reasons critical to the accuracy of the sampling technique.

6.3 *Separations* — It is an acceptable and common practice to quantitate several gaseous impurities with a single gas chromatographic separation. Occasionally a single injected sample volume will undergo "multidimensional" separation to achieve the necessary analysis. Rotary valves, diaphragm valves or Dean's pressure switching again are used to move impurities from one separation medium to another, or from one column to another. Where multidimensional techniques are used, they should be accompanied by flowpath diagrams which clearly indicate valving and their appropriate positions. The valving sequences used should have adequate explanation to clarify the separations.

6.4 *Columns* — Columns used are generally of 3.2 mm (1/8 in.) o.d. and 2.2 mm (0.085 in.) i.d. stainless steel of varying lengths and packed with one of many solid supports. Columns may be specified by length and packing material if these standard dimensions apply. If another dimension or material is used for the column itself, it should be specified by material type, and by o.d. and i.d. in mm. Packing materials should be specified by material, % coating and coating type if applicable, and mesh size. Capillary columns are assumed to be fused silica unless otherwise specified and should be specified by i.d. in mm, film thickness in µm, and length in meters. Column temperatures and applicable program rates should be given for each independently heated zone in degrees Celsius.

6.5 *Carrier and Support Gases* — Carrier and support gas flow rates for all separations should be specified. Carrier and support gases used should fall into the general purity requirements in Table 2 and purity need not be specified unless the analysis has specific purity requirements for safety, accuracy, or component lifetime. Flows should be specified in mL/min or L/min, or as linear velocity for open tubular capillary columns.

6.6 *Detectors* — Detector technology should be specified, and alternative detection may be assumed equivalent for detectors of like selectivity and sensitivity. Table 2 gives a reference of relative detector sensitivity and is provided as a guideline only. Detector parameters are less likely to be easily formatted since detector technologies vary widely in their specific parameters. All elements critical to achieving like sensitivity must be included, such as temperature, make-up gases and their flows, flame, combustion or reaction gas ratios or flows, voltages, currents, or any additional settings as outlined by the detector manufacturer.

6.6.1 Detection limits must be specified for each impurity for the actual methodology used. Because the lower detection limit can be greatly influenced by retention time for any impurity, it is important that the detection limit be derived for the impurity within the context of the method, and not solely on the detectability of the detector. Detection limits are assumed to be calculated on a mole/mole basis.

6.7 *Operating Procedures* — The standard procedure assumed for the gas chromatographic analysis of most gases is as follows:

1. Inject the calibration standard onto the column using a gas sampling valve. Record the retention time(s) and peak area(s) for all impurities detected.
2. Analyze the sample to be tested in the same manner as the calibration standard.
3. Repeat 1.
4. Compare the average peak area of the calibration standard with that of the sample being tested. (See Calculation of Concentration, in Section 6.9.)

6.7.1 The method should specify any additional valve switching or special parameters which are necessary for the successful analysis of the impurities specified for the procedure. It must also specify the order of elution if multiple impurities are detected.

6.8 *Calibration* — Calibration for these analytical procedures is generally by external, single point calibration. Calibration gas mixtures should be specified and are assumed to be within the range specified in Section 2.26. Calibration standards are assumed to be made in a balance of gas representative of the sample unless otherwise specified. If calibration techniques other than external, point calibrations are used, they must be described.

6.9 *Calculation of Concentration* — The calculation of the concentration of impurity within the sample is based on a comparison of the average peak area of the impurity in the calibration standard, to the average peak area of the impurity within the sample, based on the formula:

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

It is assumed that the results of such a calculation must not exceed the specification for the product being analyzed.

6.10 *Notes* — Any special requirements for any section within gas method may be included here. Notes should reflect the minimum requirements to successfully achieve the desired detection limits with the equipment specified.

1.1 Impurity analyzed - description of method (e.g., gas chromatograph with thermal conductivity detector).
1.1.1 Detection Limit - (mole/mole)
1.1.2 Instrument Parameters
1.1.2.1 Column(s):
Adsorbent, mesh size, length in meters, (dimensions if other than 1/8 in. by 0.085 in.)
1.1.2.2 Carrier Flow: mL/min, gas type
1.1.2.3 Support Gases:
1.1.2.4 Sample Volume: mL
1.1.2.5 Temperatures:
Detector: °C
Columns: °C
Other Equipment: °C
1.1.3 Calibration Standard - amount ppm (or ppb) impurity, balance if other than helium.
1.1.4 Operating Procedure (Parameters)
1.1.4.1 Order of elution
1.1.4.2 Special instructions
1.1.5 Notes
1.1.6 Figures

Figure 1

Format for Gas Chromatographic Method

7 Special Analyses

7.1 *Resistivity Measurement* — The American Society of Testing and Materials (ASTM) is developing a method to measure resistivity in substrates. This method may be referenced when it is finalized.

7.2 *Metal Analysis of Gaseous Silicon Compounds*

7.2.1 Because of the importance of trace elemental impurities impacting silicon device characteristics, there is an increasing need for the detection and quantitative analysis of low-level impurities in the silicon materials used in device fabrication. Some of these materials are gaseous silicon-containing compounds, such as silane and the chlorosilanes. For elemental analysis by FTIR or PLS, a compound must first be converted to a solid form such as a single crystalline rod or disc. For the quantitative determination of metals and some non-metallic elements, the gases can be passed through a series of bubblers containing high-purity DI water or dilute acids. The aqueous media can be concentrated and analyzed by suitable techniques such as ICP or AA spectroscopy. In both cases, the recovery is assumed to be 100% efficient or, in other words, there is no loss of any impurity from the silicon source.

7.2.2 FTIR (Fourier Transform Infrared) Spectroscopy, PLS (Photoluminescence Spectroscopy) and NAA (Neutron Activation Analysis) are probably the most useful tools for the detection and analysis of trace quantities of elemental impurities in solid silicon materials. NAA requires special silicon material specimens to be submitted to neutron irradiation in a nuclear reactor and the analysis facility to be approved by the Nuclear Regulatory Commission (NRC) and other government agencies. In contrast, FTIR and PLS do not require special governmental regulations, and the instrumentation is available on the open market.

7.2.3 An FTIR spectrometer is an infrared spectrometer in which a Michelson Interferometer is used in place of a grating or prism. The simplicity of the Michelson Interferometer, with only one moving part, an oscillating mirror, along with a He-Ne laser as a reference, provides nearly absolute frequency accuracy. This translates into a high spectral resolution. FTIR has greater detection efficiency since the energy-wasting slits required for dispersive spectrometers are not used. With a microcomputer to control the functions and to perform data processing, signal averaging is used to improve the signal-to-noise ratio. All these features lead to good reproducibility and rapid measurement results compared with conventional IR techniques.

7.2.3.1 As FTIR is a transmission method, it requires a single crystalline silicon specimen with flat, parallel, mirror-polished surfaces. For oxygen in silicon, the absorption peak at 9 microns is used for quantitative analyses. For carbon in silicon, the absorption band at 16 microns is used. Both measurements may be performed at room temperature. (The carbon determination has strong interference from the silicon phonon band, but can be resolved with high purity, carbon-free standards.) For the determination of shallow donors and acceptors, FTIR measurements must be made at liquid helium temperatures, but the through-put is low. Although the operation of today's FTIR instrument is relatively simple, the interpretation of the results through software and associated problems/solutions is not. Quantitative analysis is based upon the measured percent transmission at the characteristic wavelength and compared to standards. Detection limits at about 10-12°K are in the 10^{11} to 10^{13} atoms/cc for shallow donors and acceptors, 3.1×10^{14} atoms/cc for oxygen, and 2×10^{15} atoms/cc for carbon.

Table 2 Carrier Gases for GC Instruments

Detector	*Gas*	*Detection Level*					
		0 - 100 ppt	*100 ppt - 100 ppb*	*100 ppb - 100 ppm*	*100 ppm - 1%*	*1% - 10%*	*10% - 100%*
TCD/USD	Ar	N/A	N/A	99.9999%	99.999%	99.998%	99.995%
	H_2	N/A	N/A	99.9995%	99.999%	99.99%	99.99%
	He	N/A	N/A	99.9995%	99.9995%	99.999%	99.99%
	N_2	N/A	N/A	99.9995%	99.9995%	99.998% < 0.5 ppm O_2	99.998%
HID/DID	He	N/A	99.9999%	99.9999%	N/A	N/A	N/A
	He*	N/A	99.995%	99.995%	N/A	N/A	N/A
FID	He	N/A	N/A	99.9995%	99.999%	99.998%	99.99%
	N_2	N/A	N/A	99.999% < 0.05 ppm THC	99.999% < 0.05 ppm THC	99.998% < 0.5 ppm THC	99.998%
	H_2**	N/A	N/A	99.9995% < 0.2 ppm THC	99.999% < 0.5 ppm THC	99.99% < 0.5 ppm THC	99.99%
	Air**	N/A	N/A	HC Free < 0.1 ppm THC	Zero Air < 1 ppm THC	Zero Air < 1 ppm THC	Blended Air
FPD	He	N/A	99.9995%	99.999%	N/A	N/A	N/A
	N_2	N/A	99.999% < 0.05 THC	99.998% < 0.5 ppm THC	N/A	N/A	N/A
	H_2**	N/A	99.995% < 0.2 ppm THC	99.999% < 0.5 ppm THC	N/A	N/A	N/A
	Air**	N/A	HC Free < 0.1 ppm THC	Zero Air < 1 ppm THC	N/A	N/A	N/A
RGD	Ar	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	N/A	N/A
	N_2	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	99.999% < 1 ppm H_2/CO	N/A	N/A
	Air	Zero Air < 1 ppm H_2/CO	Zero Air < 1 ppm H_2/CO	Zero Air < 1 ppm H_2/CO	Zero Air < 1 ppm H_2/CO	N/A	N/A
ECD	N_2	99.9995%	99.998% < 0.5 ppm O_2	99.998% < 0.5 ppm O_2	N/A	N/A	N/A
	CH_4/Ar	EC Grade < 1 ppb Total Halocarbons	EC Grade < 1 ppb Total Halocarbons	EC Grade < 1 ppb Total Halocarbons	N/A	N/A	N/A
PID	He	N/A	99.9995%	99.995%	N/A	N/A	N/A
	N_2	N/A	99.9995%	99.998%	N/A	N/A	N/A
MS/MSD	H_2	99.9995% < 0.2 ppm THC	99.999% < 0.5 ppm THC	99.999% < 0.5 ppm THC	99.99% < 0.5 ppm THC	99.99% < 0.5 ppm THC	99.99% < 0.5 ppm THC
	Ar	99.999%	99.998%	99.998%	99.998%	99.998%	99.998%
	He	99.9995%	99.999%	99.999%	99.995%	99.995%	99.995%
	N_2	99.9995%	99.998%	99.998%	99.998%	99.998%	99.998%

*purge gas

**combustion gases

Table 3 Detectors for Gas Chromatography

Detector	*Type*	*Temp Limit*	*Analytes Analyzed**	*Carrier Gases*	*Selectivity*	*Detectability*	*Linear Range*
Thermal Conductivity (TCD)	U	400	CF_4, PH_3, SF_6, Fixed Gases	He, H_2, Ar, N_2	N/A	4×10^{-10} g/mL	$>10^5$
Ultrasonic (USD)	U		CO_2, O_2, N_2, CO	He, H_2, Ar, O_2, N_2, Air	N/A	1×10^{-9} g/mL	10^6
Helium Ionization (HID)	U	325	H_2, O_2, Ar, N_2, CO	He	N/A	4×10^{-14} g/mL	10^4
Discharge Ionization (DID)	U		same as HID	He	N/A	1×10^{-12} g/mL	10^4
Flame Ionization (FID)	S	420	C_1-C_5, C_xF_y, $C_xCl_yF_z$, CO, CO_2	H_2/Air**, He, N_2, H_2	Hydrocarbons	2×10^{-12} g/sec	$>10^7$
Flame Photometric (FPD)	S	420	H_2S	H_2/Air**, He, N_2, H_2	S/C 10^3-10^6:1 P/C > 10^5:1	S<1×10^{-11} g/mL P<1×10^{-12} g/mL	$S \geq 10^3$ $P \geq 10^4$
Reduction Gas (RGD)	S	300	CO, H_2	N_2, Ar, He, Air	H_2, CO	H_2 0.5 – 2 ppb CO 0.5 - 4 ppb	10^3-10^4
Electron Capture (ECD) (Ni^{63})	S	420		N_2, P5	halogens	5×10^{-15} g	10^4 (linearized)
Photoionization (PID)	S	350	PH_3, H_2S, AsH_3	Ar, H_2, N_2	By ionization energy	2×10^{-13} g/sec	$>10^7$
Thermionic (TID)	S	420		H_2, 8% H_2/He	N/P 1:5 N/C 5×10^4:1 P/C 10^5:1	N 1×10^{-13} g/sec P 5×10^{-14} g/sec	10^5
Mass Spectroscopy (MS)	S	320		He, H_2	variable with mass range	EI: 10-100 pg NICI: variable as low as 25 fg	10^5-10^6
Mass Density (MSD)	S						
Atomospheric Pressure Mass Spectroscopy (APIMS)							

*this does not represent detector capability; rather those analytes analyzed by current SEMI procedures

**used as combustion gases

7.2.4 Photoluminescence Spectroscopy (PLS) of single crystalline silicon specimens at liquid helium temperatures exhibits sharp emission lines. Electron hole pairs called excitons are formed by incident radiation (514.5 nm line from argon laser). The decay of these "exciton or multi-exciton" states yields the lines characteristic of the impurity atoms. For elemental detection, the observed emission lines must be assigned as being extrinsic (due to impurities) or intrinsic (due to silicon). The luminescence process itself appears too complex to attain precision or accuracy from basic calculations. The PLS emissions are analyzed as a function of wavelength, suggested to be 1077 to 1139 nm, for the elemental determination of shallow donors and acceptors in silicon. Quantitative measurements of impurities are based on the extrinsic-to-intrinsic intensity ratio and compared to standards. The PLS emissions are analyzed using a monochromator and detected by a photomultiplier. Sensitivity in the range of 5×10^{10} to 5×10^{11} atoms/cc has been claimed for B, Al, P, and As.

7.2.4.1 In order to obtain reliable measurements, the silicon specimens must be in single crystalline form with a mirrored surface. Epitaxial wafers with layers of thickness greater than 10 microns are suitable, since the sample's depth appears to be less than 5 microns. However, it is still in the development stage, and very few laboratories have such capability. A number of questions remain unanswered, including the following:

1. What is the effect of compensating impurities?

2. What is the effect of deep levels and intracenter transitions on the intensity ratios?
3. What is the effect of crystallographic defects? Of point defects? And of surface defects?
4. Interference from other shallow impurities may mask the detection of very low-level impurities. For instance, PLS signal of Al at 1078.5 nm may be affected by strong signals from As at 1079.0 nm or at 1078.2 nm.

7.2.4.2 CVD-deposited films in single crystalline form can be used for elemental detection of donors and acceptors for gaseous silicon compounds. However, PLS does not detect carbon, oxygen, or nitrogen. It is also not useful for metallic impurities. That is, in general, PLS is useful only for a very limited number of impurities.

7.2.5 Based on this analysis, it was recommended that the SEMI Gases Analytical Procedures Subcommittee should wait for further development of innovative and improved analytical techniques for the quantitative determination of low-level elemental impurities based on FTIR and PLS. Meanwhile, techniques such as ICP, AA, and Ion Chromatography may be applicable to a very large number of impurities of interest to the silicon semiconductor industry. Development and adaptation of these technologies should be encouraged.

7.2.6 AA (Atomic Absorption Spectrophotometry), ICP (Inductively Coupled Plasma Emission Spectrometry), and IC (Ion Chromatography) are probably the most valuable instrumental techniques for the detection and analysis of trace elemental impurities in aqueous media. These techniques usually require that the elements be dissolved in an aqueous medium. Due to this fact, and the fact that the elemental impurities are typically present in silane and the chlorosilanes at the ppb and sub-ppb levels (which is beyond the detection limits for these techniques for most elements) it is usually necessary to concentrate the impurities prior to analysis, such as by passing the gas through a series of impingers (i.e., gas bubblers) containing either DI water or, more commonly, acidic solutions. From analyses of the impinger solutions together with knowledge concerning impinger solution volume(s) and both the flow rate and period of flow of the gas, the concentration of the respective elements in the original gas should be readily calculated to a fairly high degree of accuracy.

7.2.6.1 Atomic Absorption Spectrophotometry can be used for elemental analyses for a multitude of elements in the periodic table at detection limits ranging from ppm to ppb, depending both on the exact configuration or setup and the element being analyzed. The principle of the technique involves conversion of an incoming aerosol into an atomic vapor which can absorb light from a primary light source, usually a hollow cathode lamp or an electrodeless discharge lamp (EDL), the latter providing improved sensitivity and lower detection limits for certain elements. In addition, a flameless (i.e., graphite furnace) technique can be used to increase sensitivities and detection limits 50 to 100 times better.

7.2.6.2 Complementary to Atomic Absorption Spectrophotometry is Flame Emission Spectrophotometry, which differs in the absence of a primary light source. Again, a flame is utilized to convert an incoming aerosol into an atomic vapor. However, the flame also thermally elevates the atoms to an excited electronic state, and, when the atoms return to the ground state, they emit light detectable by a photomultiplier. This technique is ideal for the analysis of Li, Ha, and K at ppm and sub-ppm levels.

7.2.6.3 Inductively Coupled Plasma Emission Spectrometry (ICP) is rapidly replacing Atomic Absorption Spectrophotometry for elemental analyses of liquids, since approximately 70% of the elements in the periodic table can be determined with better precision and equal or better sensitivity with minimal sample preparation. Detection limits, in fact, for this technique range from ppm to sub-ppb levels, depending both on instrumental and/or experimental conditions and the element being analyzed. ICP involves nebulizing liquid samples either directly or in diluted form into a spray chamber where a stream of argon gas carries the smaller sample droplets into the axial channel of an argon plasma which reaches temperatures of 4000-8000°K. The common technique employs an optical system for detection. Newer techniques are being investigated using a mass spectrometer as a detection system coupled to an ICP excitation source. This is referred to as ICP/MS.

7.2.6.4 Ion Chromatography (IC) uses the principle of ion exchange to separate anionic and cationic species at detection limits ranging from ppm to ppb, depending again both on the instrumental and experimental conditions and on the element being analyzed.

7.2.6.5 Detection of ionic species in IC is most commonly accomplished by an electrical conductivity detector capable of measuring most non-transition metal cations and anions to sub-ppm levels. An electrochemical detector (for amperometric detection) is available for measuring any electroactive species having an oxidation/reduction potential near the applied electrochemical cell potential. This latter detector is capable of measuring many ionic species at ppb levels (e.g., Br^-, CN^-, S^-, etc.).

7.2.6.6 Of the three aforementioned techniques, Atomic Absorption Spectrophotometry, Inductively Coupled Plasma Emission Spectrometry, and Ion Chromatography, the most sensitive method of analyzing for a multitude of elements is, without doubt, graphite furnace (i.e., flameless) Atomic Absorption Spectrophotometry. However, this instrumental technique suffers the disadvantage of being slow and tedious. Consequently, Inductively Coupled Plasma Emission Spectrometry is rapidly replacing Atomic Absorption Spectrophotometry for elemental analyses of liquids since it is a reasonably fast technique requiring minimal sample preparation with practical detection limits being superior to those of standard (i.e., flame) Atomic Absorption Spectrophotometry for most elements and approaching those of graphite furnace Atomic Absorption Spectrophotometry for many of the elements. An added attractive feature of Inductively Coupled Plasma Emission Spectrometry is that eventually it may be used to analyze for elements directly in gases. Preliminary work, in fact, is currently being conducted in this area by several research groups. Although Ion Chromatography can be used to analyze for a multitude of non-transition metal cations (e.g., Li^{+}, Na^{+}, K^{+}, Rb^{+}, Cs^{+} Ba^{+2}, Mg^{+2}, Ca^{+2}, Sr^{+2}, etc.) it is limited by the fact that currently only a few transition metals (e.g., Ni^{+2}, Cu^{+2}, Co^{+2}, Zn^{+2}, Fe^{+2}, Fe^{+3}, Cd^{+2}, etc.) can be analyzed by this instrumental technique. IC, however, has the advantage in that it can be used for analyzing for complex cationic and especially anionic species directly (e.g., NH_4^{+} , NO_2^{+}, NO_3^{-}, SO_3^{-}, SO_4^{-2}, PO_4^{-3}, $OC1^{-}$, SCN^{-}, CN^{-}, CO_3^{-2}, etc.) and for different oxidation states for certain elements (e.g., Fe^{+2} and Fe^{+3}), unlike the other techniques, which are strictly limited to elemental analyses only. Furthermore, IC is extremely valuable for analyzing ionic species, particularly anions (e.g., F^{-}, Cl^{-}, etc.) of many common elements which otherwise cannot be analyzed directly by either Atomic Absorption Spectrophotometry or Inductively Coupled Plasma Emission Spectrometry.

8 Standards

8.1 Certified Standards shall be made by weight traceable to the National Institute of Standards and Technology.

9 Determination of Precision

9.1 To Be Determined.

10 Safety

10.1 Because of the continuing evolution of safety precautions, it is impossible for this publication to provide definite statements related to the safe handling of individual chemicals. The user is referred to product labels, product data sheets, government regulations, and other relevant literature.

11 Gas Use Table (see Notes 1, 2)

Gas Use Table	Ammonia	Argon	Arsine	Boron Trichloride	Boron Trifluoride	Boron-11-Trifluoride	Carbon Tetrfluoride	Chlorine	Diborane	Dichlorosilane	Disilane	Helium	Hexafluoroethane	Hydrogen	Hydrogen Bromide	Hydrogen Chloride	Hydrogen Fluoride	Methyl Fluoride	Nitrogen	Nitrogen Trifluoride	Nitrous Oxide	Oxygen	Perfluoropropane	Phosphine	Silane	Silicon Tetrachloride	Sulfur Hexafluoride	Trichlorosilane	Trifluoromethane	Tungsten Hexafluoride
Annealing		X												X																
Carrier Gas for Bubblers												X							X											
Chamber Cleans							X						X			X				X										
CVD Carrier Gas		X												X																
CVD Source			X																											
CVD B Source									X																					
CVD P Source																								X						
CVD Epitaxial										X																				
CVD Nitride	X																													
CVD Oxides																					X	X			X	X				
CVD Polysilicon										X	X														X					
CVD Silicides																									X					
Epitaxial Silicon																									X	X		X		
CVD Silicon Nitride	X									X											X				X					
CVD Tungsten/Silicide																														X
Dopants			X																					X						
Etching		X												X			X													
Metal Etching		X		X				X					X		X	X				X						X				
Nitride Etching		X					X						X					X		X			X				X		X	
Oxide Etching		X					X						X			X		X		X			X				X		X	
Silicon Etching		X													X	X		X		X			X				X		X	
Ion Implant		X	X		X	X																		X						
Metal Gettering or CVD Tube Cleans																X														
Nitridation	X																													
Oxide Gettering																X						X								
Oxynitrides																					X									
Plasma Ashing																						X								
Pressurizing Systems												X							X											
Reactive Ion Etch		X																				X								
Reducing Gas														X																
Sputtering		X																												
Inert Gas Blanketing/Purging		X										X							X											

NOTE 1: This table is intended to identify various gases described in the SEMI standards and the typical uses for those gases in semiconductor processes. It is not all-inclusive. As other uses arise, they should be brought to the attention of the Gases Committee so that revisions can be made to this table as needed.

NOTE 2: Performance of a gas in an application may vary depending on the impurities in the gas. It is the responsibility of the user to determine the appropriate gas quality for any specific application.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.12-94
STANDARD FOR AMMONIA (NH_3) IN CYLINDERS, 99.998% QUALITY

1 Description

Ammonia is a colorless, alkaline gas having a pungent odor. Ammonia dissolves readily in water. It is shipped as a liquified gas under its own vapor pressure. It is combustible.

2 Specifications

QUALITY: 99.998% (See Note 1)

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide (CO)	1
Hydrocarbons $C_1 – C_3$	1
Nitrogen (N_2)	5
Oxygen (O_2)	2
Water (H_2O) (v/v)	3
TOTAL IMPURITIES	12

*An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	17.031	17.031
Boiling point at 1 atm	-33.4°C	-28.2°F
Density of gas at 0°C (32°F) and 1 atm	0.771 kg/m^3	0.0481 lb/ft^3
Specific gravity of gas at 0°C and 1 atm (air = 1)	0.597	0.597
Density of liquid at 21.1°C (70°F)	608.7 kg/m^3	38.00 lb/ft^3

4 Analytical Procedures (See Notes 2, 3, 4, 5)

4.1 *Carbon Monoxide, Oxygen and Nitrogen* — This procedure is for the determination of carbon monoxide, oxygen and nitrogen in ammonia using a gas chromatograph with a helium ionization detector. (See Note 6.)

4.1.1 *Detection Limits* — 25 ppb (mole/mole) carbon monoxide, 30 ppb (mole/mole) oxygen, 50 ppb (mole/mole) nitrogen.

4.1.2 *Instrument Parameters*

4.1.3 Columns:

Column 1:	HayeSep A or equivalent, 100/120 mesh, 32.8 m (10 ft) by 3.2 mm (1/8 in) 0.085 ID.
Column 2:	HayeSep A or equivalent, 100/120 mesh, 32.8 m by 3.2 mm 0.085 ID.

4.1.3.1 Carrier Flow: 30 mL/min helium, minimum of 99.9999% purity having a maximum of 40 ppb carbon dioxide.

4.1.3.2 Sample Volume: 1.0 mL.

4.1.3.3 Temperatures:

Detector	125°C
Columns	27°C

4.1.3.4 Determine the breakdown voltage of the detector. Set operating voltage at 10 volts below breakdown.

4.1.4 *Calibration Standards* — 1–2 ppm (mole/mole) carbon monoxide, 2–3 ppm (mole/mole) oxygen, 5-6 ppm (mole/mole) nitrogen, balance helium (having a total of other impurities of less than 1 ppm).

4.1.5 *Operating Procedure*

4.1.5.1 Set timing interval on sample select valve to 10 seconds.

4.1.5.2 Set timing interval on gas sampling valve to 3:30 minutes.

4.1.5.3 Set timing interval #3 to 4:20 minutes.

4.1.5.4 Do not change the initial sample flow setting once established.

4.1.5.5 Obtain a continuous flow of the calibration standard using a clean stainless steel line (0.02 in ID).

4.1.5.6 Inject the calibration standard onto the precolumn with the gas sampling valve. Record the retention times and peak areas. Order of elution is nitrogen, oxygen, and carbon monoxide.

4.1.5.7 Repeat step 4.1.4.6 until reproducibility of the reading is better than 1% of full scale.

4.1.5.8 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.1.5.9 Repeat 4.1.4.6.

4.1.5.10 Compare the average peak areas of the calibration standard to that of the ammonia sample being tested. Calculate the concentrations of carbon monoxide, oxygen and nitrogen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

4.2 *Hydrocarbons $C_1 - C_3$* — This procedure is for the determination of hydrocarbons C_1 – C_3 in ammonia. The sample shall be gas phase and analyzed using a gas chromatograph with a flame ionization detector. (See Notes 7, 8, 9, 10, 11, and 12)

4.2.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.2.2 *Instrument Parameters*

4.2.2.1 Columns:

Column 1: 13X molecular sieve, 3.2 mm (1/8 in) by 3.2 mm (1/8 in) ss, or equivalent.

Column 2: Silica gel (saturated) 4.6 m (15 ft) by 3.2 mm ss, or equivalent.

4.2.2.2 Carrier Flow: 50 mL/min helium.

4.2.2.3 Sample Volume: 5 mL.

4.2.2.4 Column Temperature: 40°C

4.2.2.5 Sample Flow: 150 mL/min.

4.2.2.6 Air Pressure and Flow: As specified by the instrument manufacturer's instructions.

4.2.2.7 Hydrogen Pressure and Flow: As specified by the instrument manufacturer's instructions.

4.2.3 *Calibration Standards* — 5–10 ppm (mole/mole) methane in nitrogen, 5–10 ppm (mole/mole) ethane, 5–10 ppm (mole/mole) propane in nitrogen.

4.2.4 *Operating Procedure*

4.2.4.1 Install the column switching as shown in Figure 1. Place the dual column switching valve in the molecular sieve column position for methane analysis. Use the silica gel column position for the analysis of C_2 – C_3 compounds.

4.2.4.2 Ignite the burner following the instrument manufacturer's instructions. Allow the system to stabilize for 15 minutes. (This is also indicated by a stable signal output.)

4.2.4.3 Inject the methane in nitrogen standard onto the molecular sieve column to determine the retention time for methane.

4.2.4.4 Inject the ethane and propane in nitrogen standard onto the silica gel column to determine the retention times for these compounds.

4.2.4.5 Inject the calibration standard onto the desired column to determine the peak area for the compound of interest. Record the retention times and peak areas.

4.2.4.6 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.7 Repeat 4.2.4.5.

4.2.4.8 Compare the average peak areas for at least three runs each of the calibration standard to that of the ammonia sample being tested. Calculate the concentration of hydrocarbons C_1 – C_3, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

4.3 *Water* — The method for the determination of water in ammonia is based on its decomposition by the reaction $2NH_3 \rightarrow N_2 + 3H_2$, which occurs completely and irreversibly when ammonia is passed over a nickel catalyst at 1000°C. Water passes through the catalyst unchanged. Therefore, the water content of ammonia may be determined by measuring the dewpoint of the stream of hydrogen and nitrogen produced by decomposition of ammonia. (See Notes 13 and 14)

4.3.1 *Apparatus* (shown in Figure 2)

4.3.1.1 The nitrogen and ammonia are connected to a tee with 3.2 mm (1/8 in) OD stainless steel tubing, keeping the lines as short as is practical.

4.3.1.2 The nitrogen may be fed from a regulator.

4.3.1.3 The ammonia should be fed through a stainless steel needle valve.

4.3.1.4 The furnace is a Lindberg Model 54032 or equivalent, with an Inconel reaction tube. The reaction tube is 0.6 m (24 in) long by 25 cm (1 in) OD and terminates in 1/8 in swaged tubing connectors.

4.3.1.5 The reaction tube is filled with nickel lumps, MCB Catalog number NX305 or equivalent.

4.3.1.6 The outlet of the furnace is connected by a 1.2 m (4 ft) by 3.2 mm (1/8 in) OD stainless steel tubing to a moisture analyzer suitable for determining the concentration of water is a mixture of hydrogen and nitrogen at the specified concentration. This length of tubing is required to permit adequate cooling of the gas between the furnace and the moisture analyzer.

4.3.1.7 The outlet of the moisture analyzer is connected to the inlet of a 0-10 CFH flowmeter.

4.3.1.8 The outlet of the flow meter is connected to an appropriate vent for the disposal of ammonia, nitrogen and hydrogen.

4.3.2 *Operating Procedure*

4.3.2.1 Start a nitrogen purge flow of approximately 5 CFH.

4.3.2.2 Set furnace to 950°C and allow to equilibrate (approximately 1.5 to 2 hours).

4.3.2.3 With the ammonia cylinder valve closed, disconnect the tubing from the cylinder outlet and open the ammonia inlet needle valve to allow the ammonia sample line to purge with nitrogen. Reconnect the tubing to the cylinder outlet and close the needle valve.

4.3.2.4 Shut off the nitrogen flow.

4.3.2.5 Open the ammonia cylinder valve and adjust the needle valve to obtain a flow of approximately 5 CFH.

4.3.2.6 Gradually increase the furnace temperature, periodically testing the gas for the presence of ammonia by placing a piece of wet red litmus paper in the vent stream. If ammonia is present, the paper will turn blue. When ammonia is no longer found, the appropriate catalyst temperature has been reached.

4.3.2.7 Measure the concentration of water in the nitrogen and hydrogen stream, following the instructions of the moisture analyzer manufacturer. Periodically test the vent stream for the presence of ammonia, as described in 4.3.2.6, and adjust the furnace temperature as necessary.

4.3.3 *Reporting of Measurement*

4.3.3.1 Double the water concentration obtained in 4.3.2.7 to correct for the doubling of gas volume by the decomposition of the ammonia.

4.3.3.2 Subtract twice the concentration of oxygen (as measured by the procedure specified in Section 4.1) in the sample from the concentration of water calculated in 4.3.3.1. This is necessary because oxygen in the ammonia reacts with the hydrogen formed by decomposition to produce additional water.

4.3.3.3 The concentration of water calculated in 4.3.3.2 in the ammonia may not exceed the limit specified in Section 3.

4.4 *Notes*

Note 1: This specification applies to the gas phase of the cylinder as delivered.

Note 2: Observe proper safety procedures for handling and venting the ammonia sample.

Note 3: Introduce the calibration standard as many times as necessary to achieve the desired precision.

Note 4: All the gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

Note 5: All carrier lines, carrier pressure regulators and sample containers are to be constructed of stainless steel and cleaned. The systems must be assembled without pipe threads, PTFE tape or polymeric seal materials.

Note 6: Due to the extreme sensitivity of the helium ionization detector, the system is to be helium leak tested to a maximum of 10^{-7} atm-cc/sec.

Note 7: It is good practice to keep carrier gas flowing through the instrument. This prevents the back-diffusion of moisture and carbon dioxide in the air from contaminating the column.

Note 8: When not analyzing samples, the dual column switching valve should be set at the molecular sieve position to prevent the silica gel column from drying out.

Note 9: The silica gel column will, after repeated use, tend to dry out. This will manifest itself by the peaks of each component becoming separated farther and farther apart. Overall sensitivity will drop as the peak areas decrease due to the peaks spreading out more and more.

Note 10: The condition of the silica gel column is restored by allowing the carrier gas to pass through the water-saturated silica gel trap that has been provided. (Normally the carrier gas bypasses this trap.)

Note 11: The flame should be extinguished when not in use; also the air and hydrogen is shut off; and the helium flow reduced.

Note 12: Until one is completely familiar with all sampling techniques, and interpretation of results, three consecutive determinations of the sample gas should be made. If results agree, then the analysis may be considered valid.

Note 13: The system should be checked for leaks prior to use to preclude atmospheric contamination of the sample.

Note 14: The moisture analyzer must be calibrated according to the manufacturer's specified method prior to use.

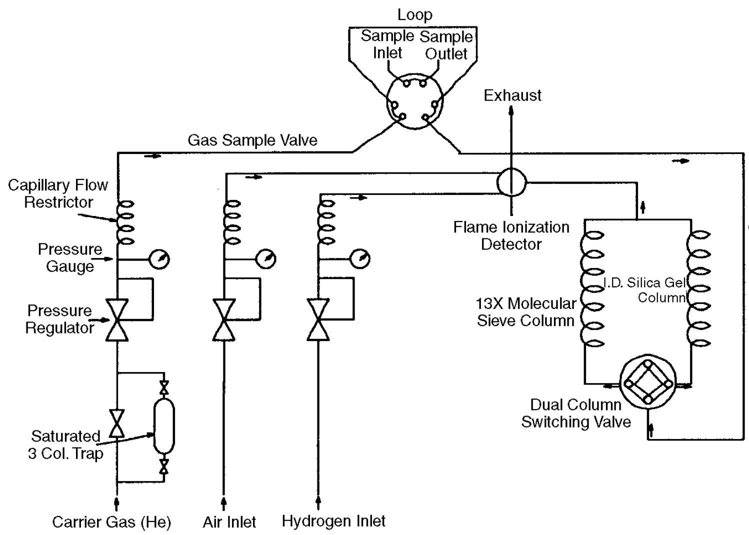
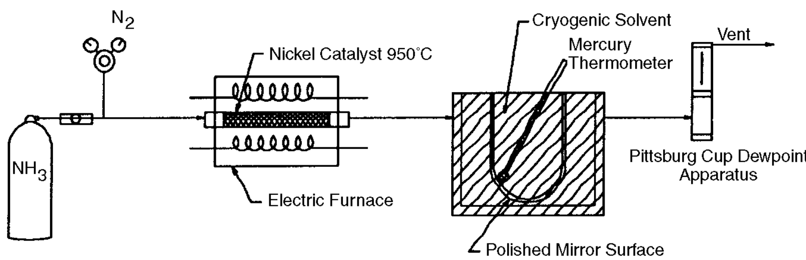


Figure 1



Reaction

$$2NH_3 \xrightarrow{\text{HEAT (950°C)}} N_2 + 3H_2$$

Figure 2
Electronic Ammonia Water Measurement

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SEMI C3.1-93 (Reapproved 1101)
STANDARD FOR ARGON (Ar), BULK LIQUID, 99.998% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1978; previously published in 1993.

1 Description

1.1 Argon is the most abundant member of the rare gas family. It is monatomic and is characterized by its extreme chemical inactivity. Argon is a colorless, odorless and tasteless gas somewhat soluble in water. It is normally delivered and stored as a cryogenic liquid.

2 Specifications

QUALITY: 99.998%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide and carbon dioxide ($CO + CO_2$)	0.5
Hydrogen (H_2)	1
Nitrogen (N_2)	10
Oxygen (O_2)	2
Particles	**
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	1
TOTAL LISTED IMPURITIES	15

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.
** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	39.948	39.948
Boiling point at 1 atm	-185.9°C	-302.6°F
Density of gas at 21.1°C (70°F) and 1 atm	1.656 kg/m^3	0.1034 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	1.38	1.38
Density of liquid at boiling point	139 kg/m^3	8.698 lb/ft^3

4 Analytical Procedures (See Notes 1 and 2.)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in argon using a gas chromatograph with a flame ionization detector and methanizer.

4.1.1 *Detection Limit* — 100 ppb.

4.1.2 *Instrument Parameters*

4.1.2.1 Column: Porapak T or Q, 3 m (9.8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standard* — 1–5 ppm carbon monoxide, 1–5 ppm carbon dioxide, balance argon.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

4.1.4.4 Compare the average peak area of the calibration standard to that of the argon sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.2 *Hydrogen and Nitrogen* — This procedure is for the determination of hydrogen and nitrogen in argon using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 0.5 ppm.

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 65.6 m (20 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 1.0 to 3.0 mL.

4.2.2.4 Temperatures:

Detector	125°C
Column Oven	25°C

4.2.3 *Calibration Standard* — 1–5 ppm hydrogen in argon, 10–30 ppm nitrogen in argon.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.3 Repeat 4.2.4.1. (See NOTE 1.)

4.2.4.4 Compare the average peak area of the calibration standard to that of the argon sample being tested. Calculate the concentrations of hydrogen and nitrogen, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in argon using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb.

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 3–15 ppm oxygen in argon or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the sample flow setting once established.

4.3.4.2 Introduce argon sample and record oxygen reading. The result may not exceed the specification in Section 2 of this standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in argon using a continuous flow flame ionization detector equipped with a total hydrocarbon analyzer. (See Notes 3, 4, and 5.)

4.4.1 *Detection Limit* — 0.1 ppm.

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air: 350-400 mL/min.

4.4.2.3 Set sample flow rates in accordance with instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Zero argon with known quantity of hydrocarbons at 0.1 ppm level.

4.4.3.2 The upper level span gas not exceeding 5 times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the flow settings for hydrogen, air and sample, once established.

4.4.4.2 Introduce the zero argon with known quantity of hydrocarbons and, using the 0–10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

NOTE 3: The 0–1 range can be used provided that zero and span gas standards in argon with known levels of hydrocarbons between 0–1 ppm are used in the calibration of the analyzer.

4.4.4.3 Introduce the span gas standard in argon and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

NOTE 4: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

4.4.4.4 Introduce argon sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

NOTE 5: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the common hydrocarbon impurities in argon can be totaled accurately and compared to methane.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in argon using a continuous flowing piezoelectric hygrometer.

4.5.1 *Detection Limit* — 0.1 ppm (vol/vol) or –90°C (–130°F).

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

NOTE 6: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the argon sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this standard.

SEMI C3.14-94 (Withdrawn 0701)
STANDARD FOR ARGON (Ar) IN CYLINDERS, 99.998% QUALITY

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Argon is the most abundant member of the rare gas family. It is monatomic and is characterized by its extreme chemical inactivity. Argon is a colorless, odorless and tasteless gas somewhat soluble in water, normally delivered and stored as a cryogenic liquid.

SEMI C3.46-93
STANDARD FOR ARGON (Ar), BULK LIQUID, 99.9992% QUALITY

1 Description

Argon is the most abundant member of the rare gas family. It is monatomic and is characterized by its extreme chemical inactivity. Argon is a colorless, odorless and tasteless gas somewhat soluble in water. It is normally delivered and stored as a cryogenic liquid.

2 Specifications

QUALITY: 99.9992%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide and carbon dioxide ($CO + CO_2$)	0.5
Hydrogen (H_2)	1
Nitrogen (N_2)	5
Oxygen (O_2)	0.5
Particles	**
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	0.5
TOTAL SPECIFIED IMPURITIES	8

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	39.948	39.948
Boiling point at 1 atm	-185.9°C	-302.6°F
Density of gas at 21.1°C (70°F) and 1 atm	1.656 kg/m^3	0.1034 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	1.38	1.38
Density of liquid at boiling point	139 kg/m^3	8.698 lb/ft^3

4 Analytical Procedures (See Notes 1, 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in argon using a gas chromatograph with a flame ionization detector and methanizer.

4.1.1 *Detection Limit* — 100 ppb (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column:

Porapak T or Q, 3 m (9.8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standard* — 0.2–1 ppm (mole/mole) carbon monoxide, 0.2–1 ppm (mole/mole) carbon dioxide, balance argon.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak area of the calibration standard to that of the argon sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.2 *Hydrogen and Nitrogen* — This procedure is for the determination of hydrogen and nitrogen in argon using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 0.5 ppm (mole/mole).

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 65.6 m (20 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 1.0 to 3.0 mL.

4.2.2.4 Temperatures:

Detector	125°C
Column Oven	25°C

4.2.3 *Calibration Standard* — 1–5 ppm (mole/mole) hydrogen in argon, 5–25 ppm (mole/mole) nitrogen in argon.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the argon sample being tested. Calculate the concentrations of hydrogen and nitrogen, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in argon using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole).

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 0.5–2.5 ppm (mole/mole) oxygen in argon or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce argon sample and record oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in argon using a continuous flow flame ionization detector equipped with a total hydrocarbon analyzer. (See Notes 3, 4, 5)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air: 350–400 mL/min.

4.4.2.3 Set sample flow rates in accordance with instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Zero argon with known quantity of hydrocarbons at 0.1 ppm level.

4.4.3.2 The upper level span gas not exceeding 5 times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the flow settings for hydrogen, air and sample, once established.

4.4.4.2 Introduce the zero argon with known quantity of hydrocarbons and, using the 0–10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.4.4.3 Introduce the span gas standard in argon and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.4.4.4 Introduce argon sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in argon using a continuous flowing piezoelectric hygrometer. (See Note 6)

4.5.1 *Detection Limit* — 0.1 ppm (vol/vol) or -90°C (-130°F).

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the

range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the argon sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this Standard.

4.6 *Notes*

Note 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

Note 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

Note 3: The 0–1 range can be used provided that zero and span gas standards in argon with known levels of hydrocarbons between 0–1 ppm are used in the calibration of the analyzer.

Note 4: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

Note 5: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the common hydrocarbon impurities in argon can be totaled accurately and compared to methane.

Note 6: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

SEMI C3.42-90
STANDARD FOR ARGON (Ar), VLSI GRADE, BULK (PROVISIONAL)

1 Description

Argon is the most abundant member of the noble gas family. It is monatomic and is characterized by its extreme chemical inactivity. Argon is a colorless, odorless and tasteless gas which is somewhat soluble in water.

2 Specifications

PURITY: 99.99990%

Impurities	*Maximum Acceptable Level (ppb)**
Carbon Dioxide (CO_2)	50
Carbon Monoxide (CO)	50
Hydrogen (H_2)	100
Nitrogen (N_2)	500
Oxygen (O_2)	50
Particles	**
Total Hydrocarbons (as CH_4)	100
Water (H_2O) (v/v)	100
TOTAL IMPURITIES	950

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	39.444	39.444
Boiling point at 1 atm	-185.9°C	-302.6°F
Density of gas at 21.1°C (70°F) and 1 atm	1.656 kg/m^3	0.1034 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	1.38	1.38
Density of liquid at boiling point	1393 kg/m^3	86.98 lb/ft^3

Note 1: A purifier is allowed to be used to meet this specification.

SEMI C3.2-0301
SPECIFICATION FOR ARSINE (AsH_3) IN CYLINDERS, 99.94% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 17, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1981; previously published in 1992.

1 Description

1.1 Arsine is a highly toxic, flammable, colorless gas with a disagreeable garlic-like odor. It is a hemolytic poison.

2 Specifications

QUALITY: 99.94%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Carbon monoxide and carbon dioxide ($CO + CO_2$)	2
Hydrocarbons (methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), and acetylene (C_2H_2))	1
Hydrogen (H_2)	500
Hydrogen Sulfide (H_2S)	1
Nitrogen (N_2)	10
Oxygen (O_2) + Argon (Ar)	5
Phosphine (PH_3)	10
Water (H_2O)	4
TOTAL LISTED IMPURITIES	533

Metals — See NOTE 2.

Particles — See NOTE 2.

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

NOTE 2: To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	77.946	77.946
Boiling point at 1 atm	-62.48°C	-80.46°F
Density of gas at 20°C (68°F) and 1 atm	3.243 kg/m^3	0.202 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	2.695	2.695
Density of liquid at B.P.	1653 kg/m^3	103.96 lb/ft^3

4 Analytical Procedures

4.1 *Carbon Monoxide, Carbon Dioxide, and Hydrocarbons (methane, ethane, ethylene, acetylene)* — This procedure is for the determination of carbon monoxide, carbon dioxide, and hydrocarbons in arsine using a gas chromatograph with a methanizer and a flame ionization detector. (See Note 1 and Figure 1.)

4.1.1 *Detection Limit* — 0.1 ppm each impurity.

4.1.2 *Instrument Parameters*

4.1.2.1 Column: Porapak QS, 3.5 m (12 ft) by 2 mm ID (1/8 in OD) ss or equivalent.

4.1.2.2 Carrier Flow: 35 mL/min helium.

4.1.2.3 Support Gases: Set the flow rates as specified by the instrument manufacturer.

Hydrogen:	30 mL/min added to the carrier gas between the column outlet and the methanizer inlet.
Air:	500 mL/min.

4.1.2.4 Temperatures:

Detector	110°C
Injector	40°C
Oven	40°C
Methanizer	370–400°C

4.1.2.5 Sample Volume: 3 mL.

4.1.3 *Calibration Standards* — 1–10 ppm each: carbon monoxide, carbon dioxide, methane, ethane, ethylene, and acetylene; balance helium.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. Order of elution is carbon monoxide, methane, carbon dioxide, acetylene, ethylene, ethane.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Vent the arsine after the ethane peak. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to those of the arsine sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

4.2 *Phosphine* — This procedure is for the determination of phosphine in arsine using a gas chromatograph with a thermal conductivity detector.

4.2.1 *Detection Limit* — 5 ppm (mol/mol).

4.2.2 *Instrument Parameters*

4.2.2.1 Column: Porapak QS, 3.5 m (12 ft) by 2 mm ID (1/8 in OD) ss or equivalent.

4.2.2.2 Carrier Flow: 35 mL/min helium.

4.2.2.3 Temperatures:

Detector	80°C
Injector	40°C
Oven	40°C

4.2.2.4 Sample Volume: 3 mL.

4.2.3 *Calibration Standard* — 10–50 ppm (mol/mol) phosphine, balance helium.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample being tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the arsine sample being tested. Calculate the concentration of phosphine, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

4.3 *Hydrogen, Nitrogen and Oxygen + Argon* — This procedure is for the determination of hydrogen, nitrogen, oxygen + argon in arsine using a gas chromatograph with a helium ionization detector.

4.3.1 *Detection Limits* — 100 ppb (mol/mol) hydrogen, 100 ppb oxygen + argon, 500 ppb nitrogen.

4.3.2 *Instrument Parameters*

4.3.2.1 Columns:

Column 1:	Porapak QS, 2.5 m (8 ft) by 3.2 mm (1/8 in) ID ss or equivalent
Column 2:	Molecular Sieve 5A, 3 m (10 ft) by 3.2 mm ID ss or equivalent.

4.3.2.2 Carrier Flow: 25 mL/min helium.

4.3.2.3 Temperatures:

Detector	10°C
Injector	30°C
Oven	30°C

4.3.2.4 Sample Volume: 3 mL.

4.3.3 *Calibration Standard* — 1–10 ppm nitrogen, 1–10 ppm oxygen, 1–10 ppm argon, 10–100 ppm hydrogen, balance helium.

4.3.4 *Operating Procedure*

4.3.4.1 Determination of the backflush time: Inject a methane sample (1–1000 ppm, balance helium) using a 10 port gas valve and backflush at different times. Select the backflush time so that the methane peak is split by the backflush.

4.3.4.2 Inject the calibration standard into the column using the same gas valve. Backflush at the time determined in 4.3.4.1 and record retention times and peak areas. Order of elution is hydrogen, oxygen + argon and nitrogen.

4.3.4.3 Inject the sample being tested in same manner as the calibration standard. Record the retention times and peak areas.

4.3.4.4 Repeat 4.3.4.2.

4.3.4.5 Compare the average peak areas of the calibration standard to those of the arsine sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

4.4 *Hydrogen Sulfide* — This procedure is for the determination of hydrogen sulfide in arsine using gas a chromatograph with a flame photometric detector.

4.4.1 *Detection Limit* — 0.1 ppm (mol/mol).

4.4.2 *Instrument Parameters*

4.4.2.1 Column: Porapak QS 3.5 m (12 ft) by 2 mm ID (1/8 in OD) ss or equivalent.

4.4.2.2 Carrier Flow: 35 mL/min helium. Set the flow rates as specified by the instrument manufacturer.

4.4.2.3 Support Gases:

Hydrogen:	30 – 40 mL/min.
Air:	300 – 400 mL/min.

4.4.2.4 Temperatures:

Detector	75°C
Injector	40°C
Oven	40°C

4.4.2.5 Sample Volume: 1.5 mL.

4.4.3 *Calibration Standard* — 1–10 ppm hydrogen sulfide, balance helium.

4.4.4 *Operating Procedure*

4.4.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention time and peak area.

4.4.4.2 Inject the sample being tested in the same manner as the calibration standard. Vent before arsine peak is eluted using same configuration as in Figure 1.

4.4.4.3 Repeat 4.4.4.1

4.4.4.4 Compare the average peak area of the calibration standard to those of the arsine sample being tested. Calculate the concentration of the hydrogen sulfide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.5 *Water* — This procedure is for the determination of moisture in arsine using continuous flow electrolysis of water in a phosphorus pentoxide (P_2O_5) cell.

4.5.1 *Detection Limit* — 1 ppm (vol/vol).

4.5.2 *Instrument Parameters*

4.5.2.1 *Flow Requirements* — Set the sample flow rate and pressure in accordance with manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently on a condensation dewpoint/frostpoint hygrometer.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain representative sample of gas to be analyzed and direct to unit as with the standards.

4.5.4.2 Determine the moisture content in the sample gas by comparing the indicated concentration with the calibration curve constructed in 4.5.3. The result may not exceed the specification in Section 2 of this Standard.

NOTE 1: Carrier gases should contain less than 0.1 ppm (mol/mol) carbon monoxide and less than 0.1 ppm (mol/mol) carbon dioxide.

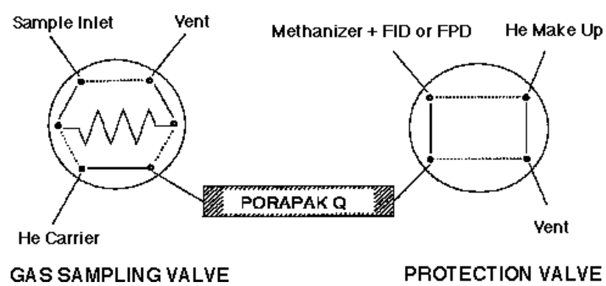

Figure 1
G. C. Configuration

SEMI C3.33-92
STANDARD FOR BORON TRICHLORIDE (BCl_3) (PROVISIONAL)

1 Description

Boron trichloride is a colorless gas at room temperature and atmospheric pressure which fumes in the presence of moist air. It has a choking odor.

2 Specifications

QUALITY: 99.9995% by wt. Liquid Phase

Impurities	*Maximum Acceptable Level (ppm)**
Chlorine (Cl_2)	10 Vapor Phase
Hydrogen Chloride (HCl)	1 Vapor Phase
Phosgene ($COCl_2$)	1 Vapor Phase
Aluminum (Al)	0.5 by wt. Liquid Phase
Calcium (Ca)	0.5 by wt. Liquid Phase
Copper (Cu)	0.5 by wt. Liquid Phase
Iron (Fe)	0.5 by wt. Liquid Phase
Magnesium (Mg)	0.5 by wt. Liquid Phase
Nickel (Ni)	0.5 by wt. Liquid Phase
Potassium (K)	0.5 by wt. Liquid Phase
Silicon (Si)	1 by wt. Liquid Phase
Sodium (Na)	0.5 by wt. Liquid Phase
TOTAL IMPURITIES	5 by wt. Liqiud Phase

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	117.17	117.17
Boiling point at atm	12.4°C	54.3°F
Density of gas at 20°C and 1 atm	5.326 kg/m^3	0.3325 lb/ft^3
Specific gravity	4.12	4.12
Density of liquid at –118°C	1372.8 kg/m^3	85.76 lb/ft^3

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacture's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position rspecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringment of such rights, are entirely their own responsibility.

SEMI C3.51-1101
SPECIFICATION FOR BORON TRICHLORIDE (BCl_3), 99.98% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995.

1 Purpose

1.1 To define the specification and analytical methods and validate the specifications for BCl_3.

2 Scope

2.1 This specification relates to a geometry of 0.5 μ or less (0.35 to 0.5 range) and describes analytical techniques using gas phase analysis.

3 Description

3.1 Boron trichloride is a colorless toxic and corrosive gas at room temperature and atmospheric pressure which fumes in the presence of moist air. It has a choking odor.

4 Referenced Standards

4.1 *ISO Standards*[1]

ISO 6145-1 — Preparation of calibration gas mixtures – Dynamic volumetric methods – Part 1: Methods of calibration

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Specifications

Quality: 99.98% vapor phase

Impurities	*Maximum Acceptable Level (ppm)**
Nitrogen (N_2)	5
Carbon Dioxide (CO_2)	2
Chlorine (Cl_2)	10
Hydrogen Chloride (HCl)	100
Phosgene ($COCl_2$)	1
Silicon Tetrachloride ($SiCl_4$)	2
* TOTAL LISTED IMPURITIES (excluding metals)	120
Iron (Fe)	0.5 wt.
Nickel (Ni)	0.5 wt.

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and precision of the provided procedure.

6 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	117.17	117.17
Boiling point at atm	12.4°C	54.3°F
Density of gas at 20°C and 1 atm	5.326 kg/m^3	0.3325 lb/ft^3
Specific gravity	4.12	4.12
Density of liquid at –18°C	1372.8 kg/m^3	85.76 lb/ft^3

7 Analytical Procedures

NOTE 2: The boiling point of boron trichloride is 12.4°C. It is recommended that, prior to the sampling operation, the cylinder should be allowed to reach room temperature to prevent the possibility of any suck-back.

7.1 *Nitrogen* — This procedure is for the determination of nitrogen in boron trichloride using a gas chromatograph fitted with a backflush valve and a thermal conductivity detector.

7.1.1 *Detection Limits* — 0.5 ppm nitrogen.

7.1.2 *Instrument Parameters*

7.1.2.1 Columns:

Column 1:	Porapak QS 60/80 mesh 2 m (6 ft) × 3.2 mm (1/8") OD SS or equivalent.
Column 2:	Molecular sieve 5A 60/80 mesh 2 m (6 ft) × 3.2 mm (1/8") OD SS or equivalent.

7.1.2.2 *Carrier Gas Flow* — Helium N6.0 Flow 25 mL/min

NOTE 3: The helium carrier gas should contain less than 10 ppb of the impurities it is desired to measure. This is best achieved by using a commercial helium gas purifier.

7.1.2.3 *Sample Volume* — 2.5 mL.

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

7.1.2.4 *Temperatures*:

Column Temperature	100°C
Detector Temperature	100°C

7.1.2.5 *Bridge Current* — 200 mA.

7.1.3 *Calibration Standard* — 1–10 ppm nitrogen in helium.

7.1.3.1 *Calibration* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

7.1.4 *Operating Procedure*

7.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Adjust the backflush valve operation sequence to present the nitrogen. Record the retention time and peak area. A sample chromatogram is shown in Figure 1.

NOTE 4: Introduce the calibration standard as many times as necessary to achieve the desired precision.

7.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention time and peak areas (see Note 2).

7.1.4.3 Repeat Section 7.1.4.1.

7.1.4.4 Compare the average peak areas of the nitrogen in the calibration standard to that of the boron trichloride sample being tested. Calculate the concentration of nitrogen using the formula below. The results may not exceed the specification in Section 5 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

7.2 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in boron trichloride using a gas chromatograph fitted with a backflush and a thermal conductivity detector.

7.2.1 *Detection Limits* — 0.5 ppm carbon dioxide.

7.2.2 *Instrument Parameters*

7.2.2.1 *Columns*:

Column 1	Porapak QS 60/80 mesh 3m (10 ft.) by 3.2 mm (1/8") OD SS or equivalent
Column 2	Porapak QS 60/80 mesh 2.5 m (8 ft.) by 3.2 mm (1/8") OD SS or equivalent

7.2.2.2 *Carrier Gas Flow* — Helium N6.0 flow 25 mL/mm (See Note 3.)

7.2.3 *Sample Volume* — 2.5 mL.

7.2.4 *Temperatures*:

Column Temperature	60°C
Detector Temperature	110°C

7.2.5 *Bridge Current* — 200 mA.

7.2.6 *Calibration Standard* — 1–5 ppm carbon dioxide in helium.

7.2.6.1 *Calibration* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

7.2.7 *Operating Procedure*

7.2.7.1 Inject the calibration standard into the column using a gas sampling valve. Adjust the backflush valve operation sequence to present the carbon dioxide peak. Record the retention time and peak area. A sample chromatogram is shown in Figure 2 (see Note 4).

7.2.7.2 Inject the sample to be tested in the same manner as the calibration standard (see Note 2). Record the retention time and peak areas.

7.2.7.3 Repeat Section 7.2.7.1.

7.2.7.4 Compare the average peak areas of the carbon dioxide in the calibration standard to that in the boron trichloride sample being tested. Calculate the concentration of carbon dioxide using the formula below.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

7.3 *Chlorine* — This procedure is for the analysis of chlorine in boron trichloride using a gas chromatograph with a thermal conductivity detector.

7.3.1 *Detection Limits* — 5 ppm chlorine.

7.3.2 *Instrument Parameters*

7.3.2.1 Column 60 m (200 ft.) 0.53 mm (1/32") ID Dimethyl silicone megabore capillary column (Ristek RTxi)

7.3.2.2 *Carrier Gas* — Helium: N6.0 25–30 mL/min (See Note 3.)

7.3.2.3 *Sample Volume* — 2.0 mL.

7.3.2.4 *Temperatures*:

Column Temperature	100°C
Detector Temperature	110°C

7.3.2.5 *Bridge Current* — 200 mA.

7.3.3 *Calibration Standard* — 5–10 ppm chlorine in helium.

7.3.3.1 *Calibration* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

7.3.4 *Operating Procedure*

7.3.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area. A sample chromatogram is shown in Figure 3 (see Note 4).

7.3.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention time and peak areas (see Note 2).

7.3.4.3 Repeat Section 7.3.4.1.

7.3.4.4 Compare the average peak areas of the chlorine in the calibration standard with that obtained in the boron trichloride sample being tested. Calculate the concentration of chlorine using the formula below. The results may not exceed the specification in Section 5 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

7.4 *Hydrogen Chloride, Phosgene, and Silicon Tetrachloride* — This procedure is for the determination of hydrogen chloride, phosgene, and silicon tetrachloride using a Fourier transform infra red (FTIR) analyzer.

7.4.1 *Detection Limits*

10 ppm hydrogen chloride

1 ppm phosgene

0.5 ppm silicon tetrachloride

7.4.2 *Instrument Parameters*

7.4.2.1 *Cell Path Length* — 16 cm × 16 mm ID K Br windows

7.4.2.2 *Wavenumbers*:

Hydrogen Chloride	2970–2990 (cm^{-1})
Phosgene	855–865 (cm^{-1})
Silicon Tetrachloride	610–630 (cm^{-1})

7.4.2.3 The associated sampling system must be equipped with inert gas purging and evacuation capabilities.

7.4.3 *Calibration Standards* — Prepare calibration standards for 10–100 ppm hydrogen chloride, 1–5 ppm phosgene, and 0.5–5 ppm silicon tetrachloride in boron trichloride.

NOTE 5: To ensure stability, the hydrogen chloride calibration standard should be prepared dynamically using a method defined in ISO 6145/part 1.1986. Phosgene and silicon tetrachloride standards may be prepared by syringe additions to liquid boron trichloride in the cooled sealed container.

7.4.4 *Operating Procedures*

7.4.4.1 Evacuate and purge the sampling system leading to the cell and purge the cell with dry nitrogen for 30 minutes. Fill the cell with calibration standard. Record the absorbance of hydrogen chloride, phosgene, and silicon tetrachloride. A sample spectrum is shown in Figures 4A, 4B, and 4C.

7.4.4.2 Fill the sample into the cell following the same procedures used in Section 7.4.4.1 above. Record the absorbance at the same wave number as the calibration standard. Calculate the concentrations of hydrogen chloride, phosgene, and silicon tetrachloride. The results should not exceed the amount specified in Section 3 of this specification.

$$\frac{\begin{matrix}\text{Measured}\\ \text{Absorbance of}\\ \text{the Sample}\end{matrix}}{\begin{matrix}\text{Measured}\\ \text{Absorbance of}\\ \text{the Standard}\end{matrix}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

NOTE 6: The following method should be adopted for cleaning metallic parts used for sampling hydrogen chloride gas:

a. Clean in a bath with methanol or isopropanol.

b. Ultrasonic clean in an appropriate solvent.

c. Rinse with isopropanol under Class 100 bench.

This cleaning method should be applied when a new cylinder has to be connected and repeated after ten samplings, or if a new cylinder has to be connected.

NOTE 7: Low-pressure plastic parts should be cleaned as follows using 18 MΩcm water:

a. Fill sampling lines with the following solutions for 30 minutes: NH_4OH 25%: H_2O_2 35%: H_2O = 1 to 1 to 5 parts by vol.

b. Wash sampling lines 5 times with water.

c. Fill sampling lines with the following solutions for 30 minutes: HCl 37%: H_2O_2 35%; H_2O = 1 to 1 to 5 parts by vol.

d. Wash sampling lines a minimum of 5 times with water. Terminate if the resistivity of the wash water from the lines is more than 18 MΩcm.

Cleaning of lines, flow meters and valves shall be completed before a new cylinder has to be analyzed and shall be repeated after 10 samplings, or if a new cylinder has to analyzed. The impingers must be rinsed with water after each sampling. Before a new cylinder has to be analyzed and after five samplings, the impingers must be cleaned using the above described procedures. Drying of the impingers is not recommended (contamination risks).

NOTE 8: Cleaning of cylinder valve.

Clean outside (visible parts, threads) with wipe. Clean the interior parts of the valve-outlet with methanol or isopropanol using a syringe, followed by a purge with filtered gas.

7.5 *Iron and Nickel* — This procedure is for the determination of iron and nickel in gas phase boron trichloride using atomic absorption or inductive coupled plasma methods.

7.5.1 *Detection Limits*

7.5.2 *Instrument Parameters* — Operate the designated analytical instruments according to the manufacturer's instructions.

7.5.3 *Sampling Procedure*

7.5.3.1 Clean all metallic and plastic components according to the procedures described in Notes 6 and 7. Use 18 MΩcm water.

7.5.3.2 Connect all components of the sampling system.

NOTE 9: The apparatus is charged with sufficient water to just cover the rim of the funnel (approximately 100 ml). A magnetic stirrer is introduced and the apparatus closed.

7.5.3.3 Connect the sampling system to the sample boron trichloride cylinder (see Note 8).

7.5.3.4 Purge with filtered argon (< 0.01 µ) at approximately 1 L/min. for 15 minutes prior to sampling. During this period, the apparatus is inclined so as to allow a higher flow rate without excessive agitation of the water.

NOTE 10: Due to the design of the apparatus, suck-back should be prevented, but this must be guarded against. A bubble rate of about one per second should be set.

7.5.3.5 While observing the sampling apparatus, operate the needle valve to admit sample slowly to the sampling apparatus. Initial absorption will be fast.

7.5.3.6 The sample flow is halted when no further absorption seems to be taking place (i.e., when bubble rate increases at the vent).

7.5.3.7 The argon purge is re-established for a further 15 minutes.

7.5.3.8 The apparatus is allowed to cool and the contents quantitatively transferred to a 250 ml polypropylene flask.

NOTE 11: The solution prepared above will contain some crystals of boric acid which have come out of solution during cooling. For the purpose of analysis, the concentration of boric acid must be reduced. Also the amount of BCl_3 samples need to be determined.

7.5.3.9 A 5 ml aliquot of the solution is titrated against 1 M NaOH using methyl red as an indicator. The quantity of sample boron trichloride taken is then calculated.

7.5.3.10 A sample of the solution is diluted × 10 with water. The aliquot is taken from the supernatant liquid.

7.5.3.11 Analysis is carried out in a suitable analyzer capable of meeting the required detection limits. A blank solution of 1% hydrochloric acid is used. Yttrium is used as an internal standard at a level of 0.2 ppm added to all analysis solutions.

7.5.3.12 Calibration curves are prepared using standard solutions covering the elements required. Traceable standards can be obtained from national and international bodies.

7.5.3.13 Calculate the concentration of iron and nickel content using the calibration curve and the volume of boron trichloride sampled.

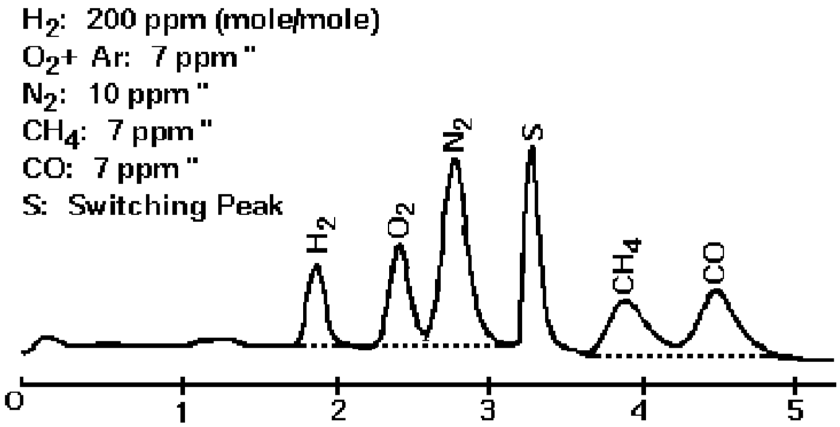

Figure 1
Chromatogram Showing the Determination of Nitrogen in Boron Trichloride

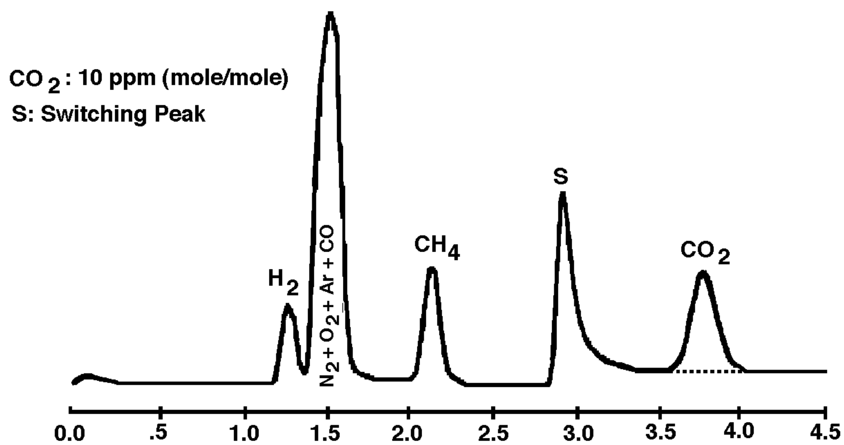

Figure 2
Chromatogram Showing the Determination of Carbon Dioxide in Boron Trichloride

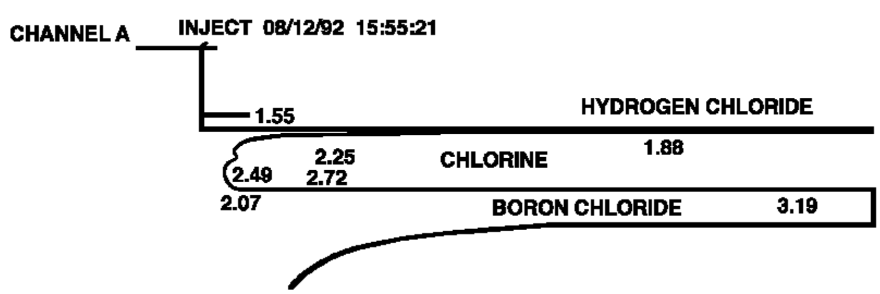

Figure 3
Chromatogram Showing the Determination of Chlorine in Boron Trichloride

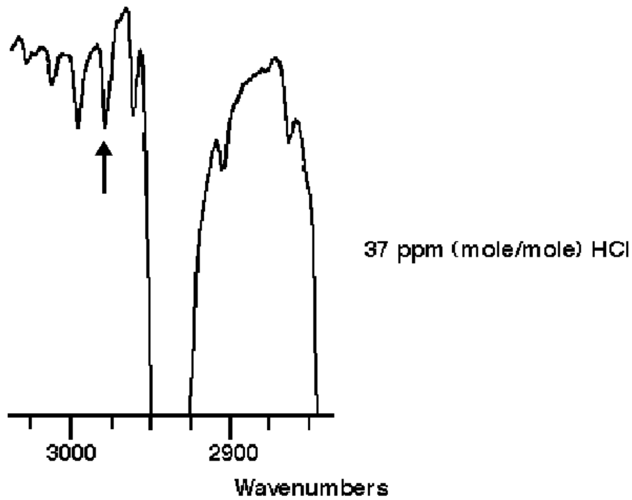

Figure 4A
Infra Red Absorption Spectra of Hydrogen Chloride in Boron Trichloride

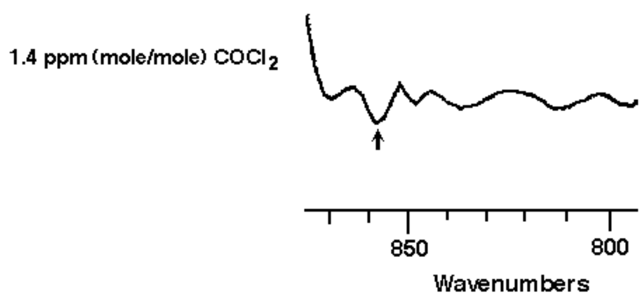

Figure 4B
Infra Red Absorption of Phosgene in Boron Trichloride

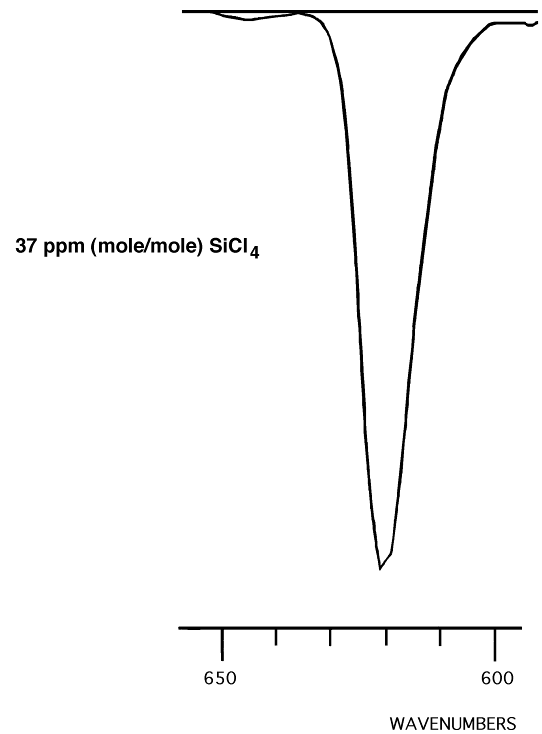

Figure 4C
Infra Red Absorption Spectra of Silicon Tetrachloride in Boron Trichloride

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SEMI C3.27-94
STANDARD FOR BORON TRIFLUORIDE (BF_3) IN CYLINDERS,99.0% QUALITY

1 Description

Boron trifluoride is a colorless gas. It fumes in moist air and has a pungent odor. Boron trifluoride is nonflammable and does not support combustion.

2 Specifications

QUALITY: 99.0%

Impurities	*Maximum Acceptable Level (ppm)**
Gases not soluble in water	0.94%
Particles	**
Silicon Tetrafluoride (SiF_4)	200
Sulfur Dioxide (SO_2)	21
Total Sulfates (SO_4^{-2})	7
TOTAL IMPURITIES	9628

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	67.81	67.81
Boiling point at 1 atm	-100.4°C	-149.0°F
Density of gas at 70°C (21.1°F) and 1 atm	3.076 g/L	0.192 lb/ft^3
Specific gravity of gas	2.7	2.7
Critical pressure	49.2 atm	723 psia
Critical Temperature	-12.25°C	9.95°F

4 Analytical Procedures

4.1 *Sampling Procedures* — Boron trifluoride is sampled separately for water-soluble gases and water-insoluble gases. The water-soluble components are collected in a plastic bottle which contains chopped ice. After the ice melts, weighed aliquots of the solution are taken for individual determinations. The water-insoluble components are collected in a modified gas collection tube.

4.1.1 *Apparatus*

4.1.1.1 Balance, l000-g capacity, capable of weighing to 0.01 g.

4.1.1.2 Polyethylene bottles (wide mouth, 1-L capacity) with caps.

4.1.1.3 Tygon[R] tubing, 6 mm (1/4 in).

4.1.1.4 PTFE tubing, 6 mm (1/4 in).

4.1.1.5 Valve assembly consisting of a needle valve with a stainless steel needle, a steel bushing and steel coupling with a steel gas cylinder connection; a gas take-off consisting of a steel sleeve from the valve with steel pipe leading to a 61 cm Tygon delivery tube. The delivery tube is a temporary connection and is replaced as needed (see Figure 1).

4.1.1.6 Trap: 1-liter polyethylene bottle fitted with a 2-hole Neoprene stopper and two 4-inch pieces of 1/4" PTFE tubing which do not extend below the stopper by more than 1 inch. The Tygon delivery tube is attached to one of the PTFE tubes in the stopper (Inlet to Trap). A 61 cm length of Tygon tubing is attached to the second piece of PTFE tubing in the stopper (Outlet from Trap). The trap is supported with a clamp and ring stand.

4.1.1.7 Modified gas collecting tube (see Figure 2); 250-mL Pyrex sampling tube (modified with a graduated scale on one end).

4.1.2 *Reagents*

4.1.2.1 Distilled-water ice, cracked.

4.1.2.2 Nitrogen, dry; 35 ppm water, or less.

4.1.3 *Operating Procedure* — Water-Insoluble Components

CAUTION: Perform all work in a hood.

4.1.3.1 Prepare the gas-collecting tube by washing with distilled water, rinsing with acetone, then drying in an air oven at 100–125°C. Flush with dry nitrogen for about one minute. Leave filled with dry nitrogen; close the stopcocks.

4.1.3.2 Connect the needle valve assembly apparatus to the cylinder to be tested.

4.1.3.3 Attach the gas-collecting tube to the valve nipple with a short piece of dry Tygon tubing.

4.1.3.4 Open the cylinder valve, open the gas collecting tube stopcocks, and very carefully crack open the needle valve.

4.1.3.5 Purge the tube for 5 minutes with a slow stream of BF_3 gas.

4.1.3.6 Close the needle valve, close the gas-collecting tube stopcocks, and then close the cylinder valve.

4.1.3.7 Proceed with the analysis, after removing the gas-collecting tube from the valve nipple.

4.1.4 *Operating Procedure* — Water Soluble Components

CAUTION: Perform all work in a hood.

4.1.4.1 Before attaching the Tygon delivery tube, purge the sampling valve system for 1 minute with a slow stream of boron trifluoride from the cylinder. Use a separate piece of tubing when purging.

4.1.4.2 Weigh an empty 1-L polyethylene bottle with cap to the nearest 0.01 g. Record this weight as A.

4.1.4.3 Fill the bottle with about 400 g of cracked, distilled-water ice. Re-weigh the bottle with cap to the nearest 0.01 g; record as weight B.

4.1.4.4 A sampling line is used to transfer BF_3 gas from the cylinder to the sample bottle.

4.1.4.5 Connect the Tygon delivery tube from the sampling valve apparatus to the trap. Support the Tygon tubing from the trap outlet; then open the needle valve and adjust until a steady flow of BF_3 is obtained. Insert this Tygon tubing (from the trap outlet) into the polyethylene sample bottle, extending down to the bottom of the bottle. Carefully introduce the BF_3 into the ice until most of the ice is melted, then close the needle valve and remove the Tygon tubing. Remove the sample bottle and cap it. Re-weigh the bottle, cap and contents to the nearest 0.01 g. Record this weight as C.

4.1.4.6 Mix thoroughly by careful inversion until all of the ice melts, being certain to keep the plastic bottle tightly capped so that none of the liquid is lost.

4.1.4.7 Proceed with the determination of water-soluble components, being sure to do the sulfur dioxide first, since opening the bottle repeatedly may result in a considerable loss of sulfur dioxide.

4.1.4.8 Calculations for sample size:

B-A = Grams of Ice (H_2O)

C-A = Weight of Solution (BF_3 Solution)

C-B = Weight of Water-soluble Material (grams of BF_3 gas)

$$\frac{\text{Grams of } BF_3 \text{ Gas}}{\text{Grams of Solution}} = \frac{C - B}{C - A} = F$$

$$\frac{\text{Grams } BF_3 \text{ needed for Method}}{F} = \frac{\text{Grams Solution}}{\text{Needed for Method}}$$

4.2 *Air* — This procedure describes the determination of insoluble gases in boron trifluoride gas. A known volume of boron trifluoride gas is absorbed in sodium chloride solution, then any undissolved gases remaining are measured and calculated as % air.

4.2.1 *Method Capabilities* — The range of this method is 0.05% to 2.3% (mole/mole).

4.2.2 *Apparatus*

4.2.2.1 The modified gas collecting tube shown in Section 4.1.1.7, Figure 2.

4.2.2.2 Separatory funnel, 2000-mL Pyrex (with 61-cm Tygon[R] tubing and pinch clamp attached to stopcock end).

4.2.2.3 Tygon tubing, 1/4 inch.

4.2.2.4 Balance, capable of weighing 1000 grams to 0.01 gram.

4.2.3 *Reagents* — All reagents used are reagent grade unless otherwise indicated.

4.2.3.1 Water. All water used in the preparation of reagents and in the procedure is either distilled or deionized.

4.2.3.2 Sodium chloride solution. Dissolve 300 g of sodium chloride in 1 liter of water.

4.2.4 *Calibration* — Gas Collecting Tube

4.2.4.1 Weigh the gas collecting tube to the nearest 0.1 g; weight - A, then clamp the tube securely on a ringstand with the calibrated stem up.

4.2.4.2 Fill the tube with distilled water and allow it to stand with the top stopcock open until it has reached room temperature.

4.2.4.3 Record the room temperature to the nearest 0.01°C; temperature - °C.

4.2.4.4 Close the top stopcock. Drain and dry both of the outer stems. Weigh the water-filled collecting tube to the nearest 0.1 g; weight - B.

4.2.4.5 The net weight of the water in the tube (B-A) in grams is equal to the volume of the tube in milliliters, corrected for the density of water at temperature °C. Determine this volume as follows:

$$\text{Volume in mL } - \frac{(B - A)}{D - E}$$

where D - Density (g/mL) of water at temperature °C (from Table 1).

Table 1 Density vs T°C for Water

Temp. °C	*Density g/mL*
20	0.99823
21	0.99802
22	780
23	756
24	732
25	0.99707
26	681
27	654
28	626
29	597
30	567

4.2.5 *Procedure*

4.2.5.1 Obtain the sample of BF_3 gas in the gas collecting tube. See Section 4.1.3 for sampling details.

4.2.5.2 Fill the separatory funnel with sodium chloride solution. Attach Tygon tubing and a pinch clamp to the funnel.

4.2.5.3 With a small dropper, fill the glass tubing leading to the stopcock opposite the calibrated end of the gas collecting tube with the salt solution. (Note: the gas collecting tube is inverted at this point.)

4.2.5.4 Open the separatory funnel stopcock and the pinch clamp on the Tygon tubing. Hold the tubing upright and when it completely fills with NaCl solution, slip the tubing onto the end of the gas collecting tube which was previously filled in step 4.2.5.3. (See Note 1.)

4.2.5.5 Hold the gas collecting tube vertical, with the calibrated end up and the entire collecting tube below the liquid level of the separatory funnel.

4.2.5.6 Open the lower stopcock of the gas collecting tube carefully and shake the tube to aid in dissolving of the BF_3 gas in the salt solution.

4.2.5.7 Bring the liquid level in the gas collecting tube equal to the liquid level in the separatory funnel.

4.2.5.8 Read and record the volume of undissolved gas in the upper calibrated end of the gas collecting tube and record this volume, to the nearest one-tenth of a milliliter; mL - F. Record the room temperature.

4.2.6 *Calculations*

4.2.6.1 F = Total milliliters of undissolved gas (from Section 4.2.5.8).

4.2.6.2 E = Total volume of gas collecting tube in mL; see Calibration — Gas Collecting Tube.

4.2.6.3

$$\frac{F}{E} \times 100 = \%air$$

Report to the nearest 0.01%.

4.3 *Sulfur Dioxide* — This procedure describes the determination of sulfur dioxide in boron trifluoride gas. A sample of the solution prepared in Section 4.1.4 is titrated with standard iodine solution to a starch end-point (blue). The sulfur dioxide is determined from the equivalents of iodine used in the titration.

4.3.1 Method Capabilities: The range of this method is 5 ppm to 1500 ppm (mole/mole).

4.3.2 *Apparatus*

4.3.2.1 Burette, 10 mL, graduated in units of 0.05 mL.

4.3.2.2 Beaker, 250-mL.

4.3.3 *Reagents* — All reagents used are reagent grade unless otherwise specified.

4.3.3.1 Water. All water used in the preparation of reagents and in the procedure is either distilled or deionized.

4.3.3.2 Iodine solution, 0.01 N. Prepare fresh daily and standardize.

4.3.3.3 Starch indicator solution, 10 g/L. Prepare a thin paste of 1 g of soluble starch with water. Pour the paste with constant stirring, into 100 mL of boiling water. Boil for one minute. Allow the solution to cool and add 2.5 g of potassium iodide. Keep the solution in a glass-stoppered bottle. Prepare fresh when the color obtained for end points is violet or red instead of blue. Alternatively, Thyodene dry indicator powder may be used.

4.3.4 *Operating Procedure*

4.3.4.1 Calculate the amount of sample (prepared in Section 4.1.4 that contains about 20 grams of BF_3 gas, rounding off to the nearest milliliter. Calculate the grams of BF_3 gas in this volume to the nearest 0.01 g, using the “F” factor in Section 4.1.4.8. Transfer this amount to a 250-mL beaker and add 5 drops of starch indicator.

4.3.4.2 Using a 10-mL burette graduated in 0.05 mL, titrate with iodine to a starch end-point (blue). Stir constantly with a Teflon stir-bar or equivalent. Record the volume of the iodine solution to the nearest 0.01 mL.

4.3.5 *Calculations*

$$\frac{\text{mL } I_2 \times \text{Normality of } I_2 \times 0.032 \times 1 \times 10^6}{\text{Grams of Water-Soluble Material}} = \text{ppm } SO_2$$

where : 0.032 the milliequivalent weight of SO_2;
1×10^6 is factor for conversion to ppm.

4.4 *Silicon Tetrafluoride* — This procedure describes the determination of silicon tetrafluoride in boron trifluoride gas. This method is based on the reaction of soluble silica with molybdate ion to form a greenish-yellow complex, B-silicomolybdic acid. This complex is then reduced to a blue complex by 1-amino-2-naphthol-4-sulfonic acid. The absorbance is measured at 650 nm and the amount of silicon tetrafluoride present is obtained from a calibration curve.

4.4.1 *Method Capabilities* — The range of this method is 45–450 ppm (mole/mole).

4.4.2 *Apparatus*

4.4.2.1 Photometer: One of the folowing is required, with preference in the order given. (See Note 2.)

a. Spectrophotometer, suitable for measurements at 650 nm.

b. Filter photometer, for measurements from 640 to 700 nm, if less sensitivity is preferred.

c. Fisher Electrophotometer, with a red filter and 23-mm cells.

4.4.2.2 Absorption cells, 1.0-cm light path (for use with a or b above).

4.4.2.3 Plastic beakers, 150-mL capacity.

4.4.2.4 Polyethylene weighing bottle with cap, 250-mL.

4.4.2.5 Plastic volumetric flasks, 100-mL.

4.4.2.6 Plastic pipets, 0, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0 and 10.0-mL sizes.

4.4.3 *Reagents* — All reagents are reagent grade unless otherwise specified.

4.4.3.1 Water. All water used in this method is either distilled or deionized and must be silica-free.

4.4.3.2 Boric acid solution, saturated. Dissolve 70 g of boric acid, H_3BO_3, in 800 mL of hot water. Dilute to 1000 mL and mix. Store in a plastic bottle.

4.4.3.3 Ammonium molybdate solution, 10%. Dissolve 50 g of ammonium molybdate, $(NH_4)_6MO_7O_{24}4H_2O$, in water and dilute to 500 mL. Store in a plastic bottle. Prepare fresh weekly.

4.4.3.4 Sulfuric acid, 5N, H_2SO_4. Carefully pour 35 mL of concentrated sulfuric acid into about 150 mL of water in an ice bath. Cool to room temperature, dilute to 250 mL and mix. Store in a plastic bottle.

4.4.3.5 Tartaric acid solution, 40%. Dissolve 80 g of tartaric acid in 140 mL of water. Dilute to 200 mL and mix. Store in a plastic bottle. Prepare fresh weekly.

4.4.3.6 l-Amino-2-naphthol-4 sulfonic acid solution, 2.5 g/L. Dissolve 30 g of sodium bisulfite in 100 mL of water in a 250-mL beaker. In a 100-mL beaker, dissolve 1 g of sodium sulfite in 25 mL of water and add 0.5 g of 1-amino-2-naphthol-4-sulfonic acid. Mix the two solutions and dilute to 200 mL. Store in a plastic bottle and filter before using. Prepare fresh weekly.

4.4.3.7 Sodium silicate standard solution, 1 mL = 10 micrograms Si. Dissolve 1.012 g sodium silicate (meta), Na_2SiO_3 $9H_2O$, in water in a 100-mL plastic volumetric flask and dilute to volume. Pipet 10.00 mL of this solution, using a polyethylene pipet, into a 1-liter plastic volumetric flask and dilute to volume. One mL of this dilution contains the equivalent of 10 micrograms Si.

4.4.4 *Calibration*

4.4.4.1 To a series of nine 150-mL plastic beakers, pipet 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, and 10.0 mL of sodium silicate standard solution. These additions correspond to 0, 10, 20, 30, 40, 50, 60, 80, and 100 micrograms of Si.

4.4.4.2 Into each beaker, pipet 25.0 mL of boric acid solution. Dilute to about 60 mL with water and mix.

4.4.4.3 Continue with Procedure Sections 4.4.5.3 – 4.4.5.9. Measure the absorption of each standard and then return to Calibration, Section 4.4.4.4.

4.4.4.4 Subtract the absorbance of the 0 microgram standard from each of the other standard absorbances and plot the net absorbance versus the corresponding micrograms of Si. Draw the best smooth line fitting the points and passing through the origin.

4.4.5 *Procedure* (To be run in triplicate)

4.4.5.1 Calculate the amount of sample prepared in Section 4.1.4 that contains about 0.5 g of BF_3 gas. Transfer this amount to a polyethylene bottle and weigh to the nearest 0.0001 g.

4.4.5.2 Wash this solution into a 150-mL plastic beaker. Add 25 mL of boric acid solution. Dilute to about 60 mL and mix.

4.4.5.3 Add 5 mL of ammonium molybdate solution and mix.

4.4.5.4 Adjust the pH to 1.1 to 1.5 with 5N sulfuric acid. Allow to stand 10 minutes.

4.4.5.5 Transfer the solution to a 100-mL plastic volumetric flask and add 10 mL of tartaric acid solution. Mix well.

4.4.5.6 Add 1 mL of 1-amino-2-naphthol-4-sulfonic acid solution. Dilute to 100 mL and mix. Allow to stand 30 minutes.

4.4.5.7 Prepare a reagent blank by treating a 50-mL aliquot of water as directed in Sections 4.4.5.2 through 4.4.5.6.

4.4.5.8 Set the wavelength of the spectrophotometer to 650 nm.

a. *Single Beam Spectrophotometer* — Rinse and then fill a 1-cm absorption cell with water. Place the cell into the cell holder and adjust the instrument to zero absorbance.

b. *Double Beam Spectrophotometer* — Rinse and then fill two matched 1-cm absorption cells with water and zero the instrument with water in both beams. Keep water in the reference beam and use the other matched cell for the blank, standards and samples.

4.4.5.9 Rinse a second matched 1-cm absorption cell with the blank solution and measure its absorbance. Then, using the same cell, measure the absorbance of each sample solution. Be sure to rinse the cell completely with the solution to be measured before each measurement. Recheck the instrument zero before each measurement.

4.4.5.10 Subtract the blank absorbance from the absorbance of the sample. Determine the corresponding micrograms of Si from the standard curve.

4.4.6 *Calculations*

$$\text{ppm SiF}_4 = \frac{\text{Micrograms of Si} \times 3.706 \times 1,000,000}{\text{Weight of sample} \times 1,000,000}$$

where :

3.706 converts Si to SiF_4

1,000,000 converts ug to g

1,000,000 converts to ppm.

4.5 *Sulfate* — This procedure describes the determination of sulfate in boron trifluoride gas. Sulfate ion is converted to a barium sulfate suspension under controlled conditions in such a manner as to form barium sulfate crystals of uniform size. Solutions are added to stabilize the suspension and minimize interferences. The resulting turbidity is determined by a turbidimeter, filter photometer or spectrophotometer and compared to a curve prepared from standard sulfate solutions.

4.5.1 *Method Capabilities* — The range of the method is 7 to 70 ppm (mole/mole). (See Note 3.)

4.5.2 *Apparatus*

4.5.2.1 Platinum dish, 100-mL capacity.

4.5.2.2 Steam bath (or Argand burner, if available).

4.5.2.3 Photometer: One of the following is required, with preference in the order given:

a. Turbidimeter

b. Spectrophotometer, for use at 420 nm, providing a light path of 4 to 5 centimeters.

c. Filter photometer, equipped with a violet filter having a maximum transmittance near 420 nm and providing a light path of 4 to 5 centimeters.

d. Fisher Electrophotometer, using a #525 Green Filter and 23-mm cells.

4.5.2.4 Stopwatch.

4.5.3 *Reagents* — All reagents used are reagent grade unless otherwise specified.

4.5.3.1 Water. All water used in the preparation of reagents and in the procedure is either distilled or deionized.

4.5.3.2 Sodium carbonate, Na_2CO_3.

4.5.3.3 Hydrochloric acid, concentrated, HC_l.

4.5.3.4 Barium chloride, $BaCl_2$ $2H_2O$.

4.5.3.5 Sodium chloride solution, 10% in water. Dissolve 10 grams sodium chloride in 100 mL water.

4.5.3.6 Gum Arabic Solution. Dissolve 0.5 gram gum arabic (acacia) in 100 mL of water, heat if necessary to dissolve, filter before using. Conditioning Reagent (may be used in place of gum arabic solution): Mix 50 mL glycerol with a solution containing 30 mL concentrated hydrochloric acid, 300 mL water, 100 mL 95% ethyl alcohol or isopropyl alcohol and 75 grams sodium chloride.

4.5.3.7 Standard sulfate solution, 1.00 mL = 0.100 mg SO_4^{-2}. Dissolve 0.1479 grams anhydrous sodium sulfate in 4 water and dilute to 1 L.

4.5.3.8 Sodium hydroxide, 1N, NaOH; dissolve 40 g of sodium hydroxide pellets in water and dilute to 1 L.

4.5.3.9 Nitric acid, concentrated, HNO_3.

4.5.4 *Calibration*

4.5.4.1 Calibrate the photometer according to the manufacturer's instructions.

4.5.4.2 Pipet 0, 1.0, 3.0, 3.0, 4.0, 5.0, 10.0 and 20.0 mL of the 0.100 mg SO_4^{-2} standard into each of eight separate 150-mL beakers. These additions correspond to 0, 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, and 2.0 mg SO_4^{-2}.

4.5.4.3 Follow the Procedure described in Sections 4.5.5.5 through 4.5.5.7.

4.5.4.4 Plot, on linear graph paper, the sulfate ion in grams against the corresponding photometer reading and draw the best smooth line through the points. (See Note 4.)

4.5.5 *Procedure*

4.5.5.1 Weigh a clean platinum dish to 0.0001 g; weight - A.

4.5.5.2 Calculate the amount of sample prepared in Section 4.1.4 that contains about 50 grams of BF_3 gas; transfer this amount to the platinum dish, then weigh the dish to the nearest 0.0001 g; weight - B.

4.5.5.3 Add about 0.1 gram of sodium carbonate and 10 mL of hydrochloric acid to the dish. Evaporate to dryness over a steam bath or an Argand burner. Repeat the evaporation 4 more times with 10-mL portions of hydrochloric acid.

4.5.5.4 Add 1 mL of hydrochloric acid and 5 mL of water to the dish; warm to dissolve any residue. Filter through Fisher G4 or equivalent filter paper in a 55-mm Buchner funnel, then transfer the filtrate to a 150-mL beaker. Wash the filter with water and transfer washings to the same 150-mL beaker.

4.5.5.5 Dilute to approximately 90 mL. Add 1 mL of 10% sodium chloride solution, 1.5 mL of freshly filtered gum arabic solution and mix. Adjust the pH to 1.75 with 1:10 hydrochloric acid or sodium hydroxide (1N). Dilute to 100 mL. (See Note 5.)

4.5.5.6 Place the beaker on a magnetic stirrer and while the solution is being stirred add 1 gram of barium chloride ($BaCl_2$ $2H_2O$) crystals. Begin timing immediately and stir for exactly 1 minute at a constant speed. (See Note 6.)

4.5.5.7 Immediately after the stirring is completed, pour some of the solution into the absorption cell of the photometer. Record the measured turbidity after 4 minutes. (See Note 7.)

4.5.5.8 Prepare a sample blank using the same quantities of all reagents except the barium chloride, which is withheld. Read the blank and obtain the correction.

4.5.5.9 After proper correction for the blank, determine the mg of sulfate from the calibration curve.

4.5.6 *Calculations*

$$\frac{\text{mg } SO_4^{-} \times 1 \times 10^6}{1000\,(B - A) \times F} = \text{ppm } SO_4^{-2}$$

where : F is from Section 4.1.4.8

4.6 *Notes*

Note 1: There should be no air bubbles in the connections between the gas collecting tube and the separatory funnel. A trace of a wetting agent such as Ultrawet (Atlantic Refining Co.) in the salt solution assists in freeing small air bubbles from the walls of connecting tubes.

Note 2: If the photometer being used measures in units other than absorbance, the appropriate conversion to absorbance must be made before calculating any results.

Note: 3 Color or suspended matter in large amounts may interfere with this procedure.

Note 4: A specific calibration curve must be prepared for each photometer. A new curve must be prepared if the instruments cell, lamp, or filter are changed, or if any other significant change in instrument or reagents is made.

Note 5: The conditioning reagent may be substituted for the gum arabic solution. In this case Procedure, Step 4.5.5.5 reads: Add 5.0 mL of conditioning reagent, then dilute to 100 mL with water. Proceed to Step 4.5.5.6.

Note 6: It is recommended that a timer be used to permit the magnetic stirrer to operate exactly one minute with a constant stirring speed. The important point is the speed of stirring and time should be constant for the standards and the samples.

Note 7: If the reading is off the calibration curve, prepare a new curve with standards in the required range, or take a smaller portion of sample.

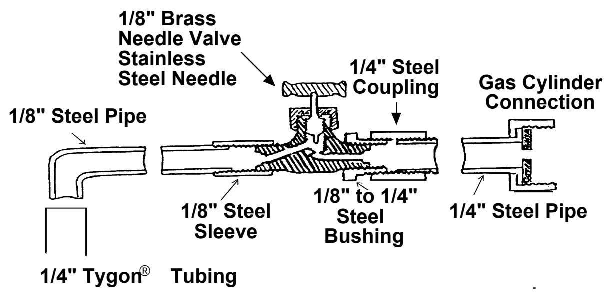

Figure 1
Preparation of Sample Solution in Ice

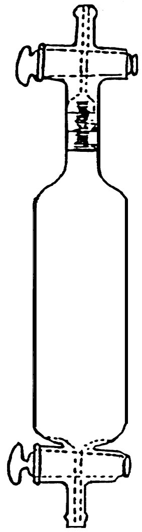

Figure 2
Modified Gas Collecting Tube

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SEMI C3.57-0600
SPECIFICATION FOR CARBON DIOXIDE, CO_2, ELECTRONIC GRADE IN CYLINDERS

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the European Gases Committee. Current edition approved by the European Regional Standards Committee on April 4, 2000. Initially available at www.semi.org May 2000; to be published June 2000.

1 Description

1.1 Carbon dioxide is a non-flammable, colorless, odorless, slightly acidic gas which is stable under normal conditions.

2 Specifications

Purity: 99.999%

Impurities	*Maximum Acceptable Level*
Nitrogen	4 ppm
Oxygen	1 ppm
Methane	0.5 ppm
Moisture	2 ppm

3 Referenced Standards

3.1 *DIN Standard*[1]

DIN 50457-1

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Physical Constants (for information only)

Formula	CO_2
Molecular weight	44
Melting point	-56.6°C
Boiling point	-78.5(s)°C
Critical temperature	30°C
Relative density, gas	1.52 (air=1)
Relative density, liquid	0.82 (water=1)
Vapor pressure 20°C	57.3 bar
Appearance/Color	Colorless gas
Odor	none

5 Analytical Procedures

5.1 *Nitrogen, oxygen and methane* — This procedure is for the determination of nitrogen, oxygen and methane using a gas chromatograph with discharge ionization detector and heartcut column switching.

5.1.1 *Detection Limit* — 100 ppb.

1 Deutches Institut für Normung e.V., BeuthVerlag GmbH, burggrafenstrasse 4-10, D10787 Berlin, Germany, www.din.de

5.1.2 *Instrument Parameters*

5.1.2.1 *Columns*

Column 1: Hayesep Q, 2 meters by 3 mm (Stainless-steel or nickel rich alloy).

Column 2: Molecular sieve 5A, 3 meters by 3 mm (Stainless-steel or nickel rich alloy) 80/100 mesh or equivalent.

5.1.2.2 *Carrier Flow*: 25 mL/minute helium.

5.1.2.3 *Sample Volume*: 2 mL.

5.1.2.4 Temperatures:

Detector	110°C
Column Oven	50°C
Injector	Ambient

5.1.3 *Calibration Standard* — 1–10 ppm (mole/mole) nitrogen, oxygen and methane, balance helium.

5.1.4 *Operating Procedure*

5.1.4.1 Inject the calibration standard into the gas chromatograph via the gas sampling valve. Record the retention times and peak areas for the components within the standard. The order of elution is: oxygen, nitrogen, methane.

5.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas. The carbon dioxide matrix gas is vented via the heartcut.

5.1.4.3 Repeat 5.1.4.1.

5.1.4.4 Compare the average peak areas of the calibration standard to that of the unknown carbon dioxide sample being tested. Calculate the concentrations of oxygen, nitrogen and methane using the formula below. The results shall not exceed the values specified in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\\text{Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\\text{Sample}\end{matrix}$$

5.2 *Moisture* — This procedure is for the determination of moisture in carbon dioxide using a direct readout moisture analyzer with a phosphorus pentoxide electrolytic cell.

5.2.1 *Detection Limit* — 100 ppb.

5.2.2 *Instrument Parameters*

5.2.2.1 *Flow requirements* — Zero and span the analyzer in accordance with the instrument manufacturers instructions. Set the sample gas flow to the rate specified by the manufacturer.

5.2.3 *Calibration standard* — The analyzer shall be calibrated at the time of use by reference to a standard gas calibration mixture containing a certified moisture content close to the expected value of the gas under test. If the analyzer indicates the certified moisture content, within the overall measurement uncertainties stated by the instrument and gas manufacturers, it may be used without further adjustment or calibration.

NOTE 2: Further Experimental detail may be found in DIN 50450-1.

5.2.4 *Sample system*

5.2.4.1 Use insulated stainless steel sample lines to prevent frosting during sampling.

5.2.4.2 Keep sample lines to a minimum length.

5.2.5 *Operating Procedure*

5.2.5.1 Follow the procedures specified in the instrument manufacturer's manual.

5.2.5.2 Allow the system to run until a stable reading is obtained for 5 minutes.

5.2.5.3 Read and record the concentration of moisture, in ppm, indicated on the moisture analyzer. The result obtained shall not exceed the value specified in Section 2 of this standard.

NOTE 3: This specification applies to gaseous phase product from a cylinder supply.

NOTE 4: It is recommended that the user discontinue use of the cylinder prior to the complete consumption of the liquid phase contents. The contents of cylinders containing liquefied product should be determined by weight and not pressure.

NOTE 5: Adopt a replicate sampling protocol for both calibration standard and unknown to achieve the required measurement uncertainty.

SEMI C3.21-90 (Withdrawn 1000)
STANDARD FOR CARBON TETRAFLUORIDE (CF_4) IN CYLINDERS (PROVISIONAL)

This document was balloted and approved for withdrawal in 2000.

1 Description

Carbon tetrafluoride is an inert, colorless, nonflammable gas. It is shipped in steel cylinders as a nonliquified gas.

SEMI C3.40-1000
STANDARD FOR CARBON TETRAFLUORIDE (CF_4), VLSI GRADE

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2000. Initially available at www.semi.org September 2000; to be published October 2000. Originally published in 1989; previously published in 1992.

1 Description

1.1 Carbon tetrafluoride is an odorless, colorless, nonflammable gas. It is a simple asphyxiant. It is also known as tetrafluoromethane.

2 Specifications

QUALITY: 99.997%

Impurities	*Maximum Acceptable Level (ppm) **
Carbon Dioxide (CO_2)	1
Carbon Monoxide (CO)	1
Nitrogen (N_2)	20
Other Halocarbons (CF_3Cl, CF_2Cl_2,CF_3H)	1
Oxygen (O_2)	5
Sulfur Hexafluoride (SF_6)	1
Water (H_2O) (v/v)	1
TOTAL IMPURITIES	30

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Chemical Specification

Total Hydrolyzable Fluorides as HF	1 ppm max.

4 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	88.005	88.005
Boiling point at 1 atm	-128.0°C	-198.4°F
Density of gas at 0°C (32°F) and 1 atm	3.946 kg/m^3	0.246 lb/ft^3
Specific gravity of gas at 0°C and 1 atm	3.05	3.05
Density of liquid at -80°C	1317 kg/m^3	82.22 lb/ft^3

5 Analytical Procedures (See Notes 1 and 2, and Figures 1 and 2.)

5.1 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in carbon tetrafluoride using a gas chromatograph with an ultrasonic detector.

5.1.1 *Detection Limit* — 0.5 ppm (mole/mole).

5.1.2 *Instrument Parameters*

5.1.2.1 Columns:

Column 1:	Haysep D, 100/120 mesh, 4.6 m (15 ft) by 3.2 mm (1/8 in) OD ss or equivalent.
Column 2:	Porapak QS, 100/120 mesh, 2.1 m (7 ft) by 3.2 mm OD ss or equivalent.

5.1.2.2 Carrier Flow: 16 mL/min helium.

5.1.2.3 Temperatures:

Detector	120°C
Column	50°C
Valve	90°C

5.1.2.4 Sample Volume: 1.0 mL

5.1.2.5 *Time Table* — Determine the times for valve switching and signal changes, and enter into the run table.

An example of a run table follows.

Valve	On	Off
1	0.01	*
2	9.20	*
3	0.01	12.00

* Valve left on until end of run.

5.1.3 *Calibration Standard* — 1–5 ppm carbon dioxide and balance helium.

5.1.4 *Operating Procedure*

5.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. The retention time for carbon dioxide is approximately 16 minutes.

5.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.1.4.3 Repeat 5.1.4.1.

5.1.4.4 Compare the average peak areas of the calibration standard to those of the carbon tetrafluoride sample being tested. Calculate the concentration of carbon dioxide in the sample, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.2 *Oxygen, Nitrogen and Carbon Monoxide* — This procedure is for the determination of oxygen, nitrogen, and carbon monoxide in carbon tetrafluoride using a gas chromatograph with an ultrasonic detector.

5.2.1 *Detection Limits* — 0.5 ppm (mole/mole) for each impurity.

5.2.2 *Instrument Parameters*

5.2.2.1 Columns:

Column 3:	Porapak QS, 100/120 mesh, 3.6 m (12 ft) by 3.2 mm (1/8 in) OD ss or equivalent.
Column 4:	Haysep D, 100/120 mesh, 4.6 m (15 ft) by 3.2 mm OD ss or equivalent.
Column 5:	Molecular Sieve 13X, 45/60 mesh, 2.1 m (7 ft) by 3.2 mm OD ss or equivalent.

5.2.2.2 Carrier Flow: 16 mL/min helium.

5.2.2.3 Temperatures:

Detector	120°C
Column	50°C
Valve	90°C

5.2.2.4 Sample Volume: 2.0 mL

5.2.2.5 *Time Table* — Determine the times for valve switching and signal changes, and enter into the run table.

An example of a run table follows.

Valve	On	Off
1	0.01	*
2	9.20	*
3	0.01	12.00

* Valve left on until end of run.

5.2.3 *Calibration Standard* — 1–5 ppm (mole/mole) each nitrogen, oxygen and carbon monoxide, balance helium.

5.2.4 *Operating Procedure*

5.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. The approximate retention times are: oxygen 11.1 minutes, nitrogen 11.6 minutes, carbon monoxide 14.5 minutes.

5.2.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.2.4.3 Repeat 5.2.4.1.

5.2.4.4 Compare the average peak areas of the calibration standard to those of the carbon tetrafluoride sample being tested. Calculate the concentrations of oxygen, nitrogen and carbon monoxide in the sample, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.3 *Fluorocarbon and Chlorofluorocarbon Impurities* — This procedure is for the determination of the volatile organic impurities in carbon tetrafluoride using a gas chromatograph with a flame ionization detector.

5.3.1 *Detection Limits* — 0.5 ppm (mole/mole) for each impurity.

5.3.2 *Instrument Parameters*

5.3.2.1 Column: 1% SP-1000 on Carbopak B (60/80), 7.3 m (24 ft) by 3.2 mm (1/8 in) OD ss or equivalent.

5.3.2.2 Carrier Flow: 40 mL/min helium.

5.3.2.3 Support Gases: Set the flow rates as specified by the instrument manufacturer.

5.3.2.4 Temperatures:

Injection Port	200°C
Detector	250°C
Initial Oven	35°C
Pre-Program Hold	7 min
Temperature Rise	10°C/min
Final Oven	150°C
Final Hold	10 min

5.3.2.5 Sample Volume: 2 mL.

5.3.3 *Calibration Standard* — 1–10 ppm (by volume) desired impurities in helium. Practical impurities may be trifluoromethane (CHF_3), hexafluoroethane (C_2F_6), dichlorodifluoromethane (CCl_2F_2), and chlorotrifluoromethane ($CClF_3$).

5.3.4 *Operating Procedure*

5.3.4.1 Attach a stainless steel diaphragm two-stage regulator to the standard cylinder. Connect the regulator to the 6 port chromatographic sampling valve.

5.3.4.2 Purge the sampling lines with the standard for at least one minute.

5.3.4.3 Pressurize the sampling lines to 5 psig.

5.3.4.4 Inject the standard into the gas chromatograph, and start the scan. Record the retention times and peak areas. Order of elution for the above mentioned standard is carbon tetrafluoride, trifluoromethane, hexafluoroethane, chlorotrifluoromethane, and dichlorodifluoromethane.

5.3.4.5 Inject the sample to be tested in the same manner as the calibration standard.

5.3.4.6 Repeat 5.3.4.1–5.3.4.4.

5.3.4.7 Compare the average peak areas of the calibration standard to those of the carbon tetrafluoride sample being tested. Calculate the concentration of each of the impurities using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.4 *Sulfur Hexafluoride* — This procedure is for the determination of sulfur hexafluoride in carbon tetrafluoride using a gas chromatograph with a thermal conductivity detector. (See Figure 2.)

5.4.1 Detection Limit — 0.5 ppm.

5.4.2 *Instrument Parameters*

5.4.2.1 Column: Super Q, 80/100 mesh, 4.9 m (16 ft) by 1.75 mm (1/16 in) ID, 3.2 mm (1/8 in) OD, ss or equivalent.

5.4.2.2 Carrier Flow: 19 mL/min helium.

5.4.2.3 Temperatures:

Detector	100°C
Oven	70°C
Gas sampling valve	70°C

5.4.2.4 Sample Volume: 1 mL.

5.4.3 *Calibration Standard* — 1 ppm sulfur hexafluoride, balance helium.

5.4.4 *Operating Procedures*

5.4.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention time and peak area.

5.4.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.4.4.3 Repeat 5.4.4.1.

5.4.4.4 Compare the average peak areas of the calibration standard to those of the carbon tetrafluoride sample being tested. Calculate the concentration of sulfur hexafluoride using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.5 *Water* — This procedure is for the determination of trace moisture (water) in carbon tetrafluoride using a continuous flowing electrolytic hygrometer.

5.5.1 *Detection Limit* — 1.0 ppm (vol/vol) or -76°C (-105°F).

5.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

5.5.3 *Operation Check* — Check the electrolytic hygrometer periodically. A gas, containing a known amount of water, should be passed through the hygrometer. Agreement between the electrolytic hygrometer and the moisture standard should be within their relative accuracies.

5.5.4 *Operating Procedure*

5.5.4.1 Obtain a continuous flow sample of gas, from the CF_4 source, using a clean, passivated stainless steel line which has been purged dry after exposure to ambient moisture. (See Notes 3 and 4.)

5.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the electrolytic moisture analyzer until a stable reading is obtained. The result may not exceed the specification in Section 2 of this standard.

5.6 *Hydrolyzable Fluorides as HF* — This procedure is for the determination of hydrolyzable fluorides in carbon tetrafluoride using fluoride ion selective electrode.

5.6.1 *Detection Limit* — Detection limits should be checked for any new implementation of a method. Detection limits below 0.1 ppm have been determined with this method. Detection limits can be improved by increasing the volume of gas sampled.

5.6.2 *Equipment*

5.6.2.1 mV meter (0.1 mV scale)

5.6.2.2 Reference electrode (single junction type)

5.6.2.3 Fluoride ion selective electrode

5.6.2.4 Magnetic stir bars (PTFE coated)

5.6.2.5 Magnetic stirrer

5.6.2.6 Plastic beakers (See note 5)

5.6.2.7 PTFE bubblers

5.6.2.8 1000 ml and 100 ml plastic volumetric flasks (See note 5)

5.6.2.9 0.2 ml and 1 ml plastic volumetric pipettes (See note 5)

5.6.2.10 Flow controller or flowmeter (0-1000 sccm CF_4)

5.6.3 Reagents

5.6.3.1 Distilled or deionized water

5.6.3.2 5 N sodium hydroxide

5.6.3.3 0.2 N sodium hydroxide

5.6.3.4 Glacial acetic acid

5.6.3.5 *Buffer Solution* — To 500 ml distilled or deionized water in a 1000 ml volumetric flask, add 57 ml glacial acetic acid and 58 g of sodium chloride. Adjust the pH to between 5.0–5.5 with 5 M sodium hydroxide. Cool to room temperature. Dilute to one liter with distilled or deionized water.

5.6.4 *Calibration Standard* — Sodium fluoride standard (10^{-3} M F^- in water, freshly prepared)

5.6.5 *Operating Procedure*

5.6.5.1 Prepare working standard by adding 100 ml 10^{-3} M F^- to 100 ml buffer solution.

5.6.5.2 Prepare a blank containing 50.0 ml 0.2 N NaOH and 50.0 ml buffer solution in a plastic beaker.

5.6.5.3 While stirring blank gently, record mV reading from the blank once reading is stable.

5.6.5.4 Successively add increments of working standard to the blank to generate a calibration curve. Record stable mV reading after each addition. Table 1 shows recommended increments and resultant concentrations.

Table 1 Calibration Concentrations

Added volume of Working Standard (ml)	*Total Volume (ml)*	*Resulting F- Concentration (M)*
0.2	100.2	1.0×10^{-6}
0.2	100.4	2.0×10^{-6}
0.4	100.8	4.0×10^{-6}
0.4	101.2	5.9×10^{-6}
0.8	102.0	9.8×10^{-6}
1.0	103.0	1.5×10^{-5}
2.0	105.0	2.4×10^{-5}

5.6.5.5 Put 50 ml 0.2 N NaOH into each of two bubblers connected in series

5.6.5.6 Establish a flow of < 1000 sccm of CF_4 through the bubblers using a suitable flow controller or flowmeter.

5.6.5.7 Sample approximately 15 liters of CF_4. Record flowrate and time of sampling to determine total volume sampled (flowrate x time). A wet test meter can also be used to measure total volume. The amount of gas sample must be the volume at STP. If the flowmeter or wet test meter is not reference to 0º and 760 torr, use the formula below to correct sample volume.

$$\text{Liters at STP} = \text{Measured Liters} \times \frac{760\,\text{Torr}}{P} \times \frac{T + 273}{273\,K}$$

P: Pressure of sampled gas (mm Hg)

T: Temperature of sampled gas or reference temperature of the flow controller or meter in ºC.

5.6.5.8 Transfer contents of each bubbler to individual 100 ml volumetric flasks and add 50 ml Buffer solution to each. Then, if necessary, add deionized or distilled water to bring the volume up to 100 ml.

5.6.5.9 Transfer contents to a plastic beaker

5.6.5.10 While stirring, measure and record mV readings for each sample.

5.6.5.11 Determine F^- concentration in solution using calibration curve generated in section 5.6.5.4.

5.6.5.12 Calculate gas phase hydrolyzable fluoride concentration using the equation below. Note: the equation assumes the hydrolyzable fluoride is hydrogen fluoride.

$$\text{Gas Phase HF}\,(\text{ppm}_y) = C \times 0.11 \times \frac{22.4\,\text{l/mole}}{Vs} \times 10^6$$

C: Measured hydrolyzable fluoride concentration (M) determined in section 5.6.5.11

Vs: Volume of CF_4 sampled (liters at STP)

5.6.5.13 The HF concentration of the second bubbler should be insignificant compared to the first bubbler. If significant HF levels are found in the second bubbler, resample with a lower flowrate.

5.7 *Notes*

Note 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

Note 2: All gases used in the analysis of the sample should not contain more than 10% of the specified value of the component of interest, unless otherwise stated.

Note 3: A passivation procedure is described in the Metals Handbook, 10th ed., Vol. 2, American Society for Metals, Metals Park, OH.

Note 4: The sampling system and hygrometer must be designed to operate at the sample pressure, or the sample pressure must be reduced, by a regulator with a diaphragm of stainless steel or other suitable material, to accommodate the pressure restrictions of the hygrometer.

Note 5: Polytetrafluoroethlyene, polymethylpentene and polypropylene are suitable plastic materials.

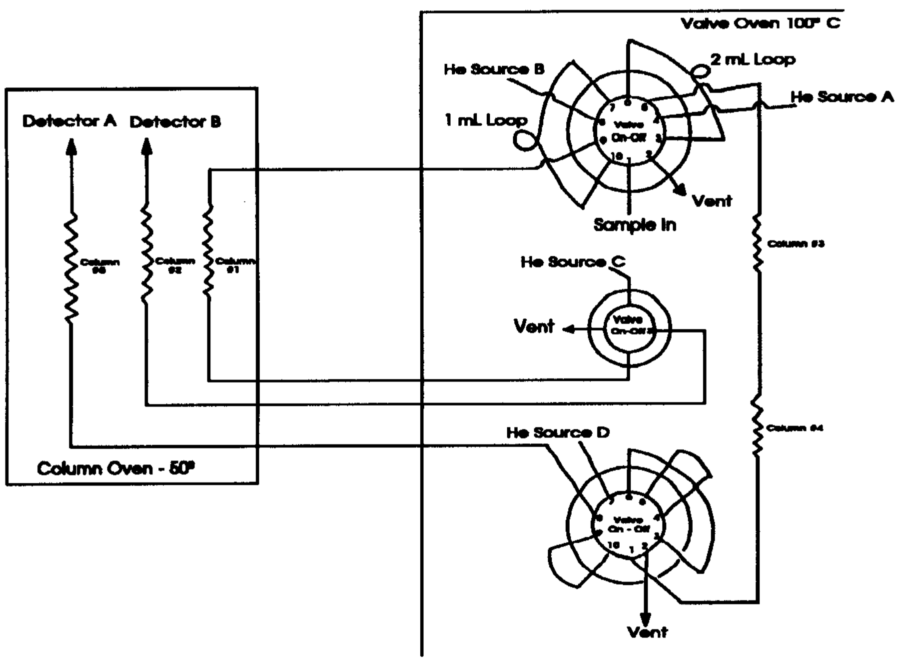

Figure 1
Configuration for the Analysis of CO_2, O_2, N_2, and CO in CF_4

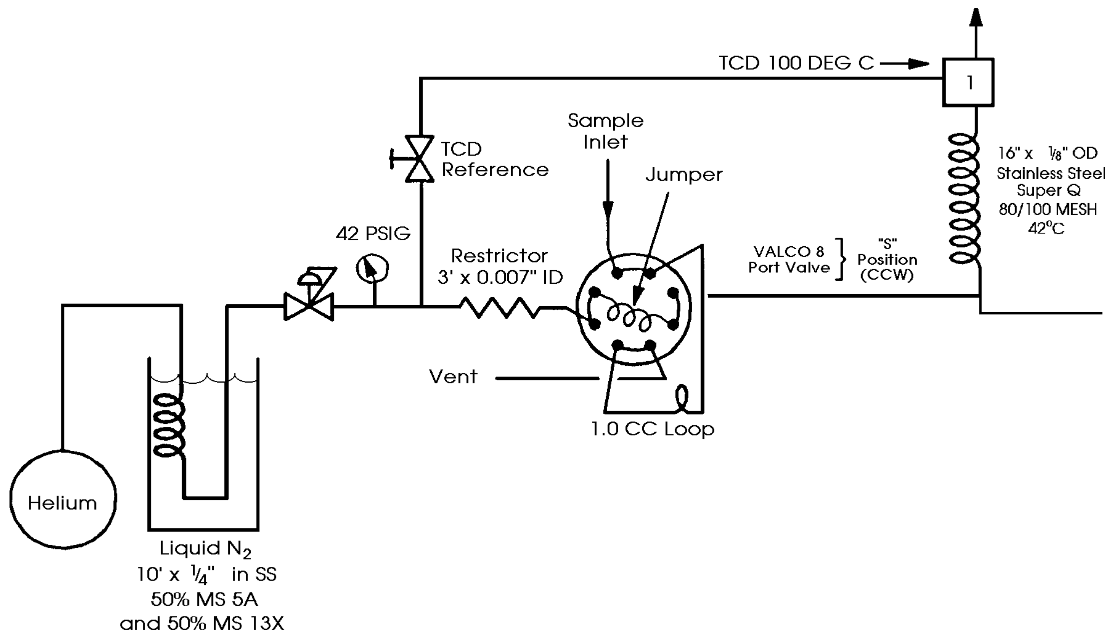

Figure 2
Configuration for the Analysis of SF_6 in CF_4

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SEMI C3.32-0301
SPECIFICATION FOR CHLORINE (Cl_2), 99.996% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 17, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1987; previously published in 1995.

1 Description

1.1 Gaseous chlorine is greenish-yellow and about 2.5 times as heavy as air. Chlorine has a disagreeable and suffocating odor.

2 Specifications

QUALITY: 99.996%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Carbon dioxide (CO_2)	10
Carbon monoxide (CO)	1
Hydrocarbons ($C_1 – C_2$)	1
Nitrogen (N_2)	20
Oxygen (O_2)	4
Water (H_2O) (v/v)	(See NOTE 2.)
TOTAL LISTED IMPURITIES (excluding chromium, iron, nickel, and sodium)	36

	Maximum Acceptable Level (ppm) (See NOTE 1.)
Chromium (Cr)	0.2 by wt. Liquid Phase
Iron (Fe)	0.2 by wt. Liquid Phase
Nickel	0.2 by wt. Liquid Phase
Sodium	1 by wt. Liquid Phase

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and on the precision of the provided procedure.

NOTE 2: It is not known whether H_2O remains as H_2O in Cl_2 or reacts to other species. For this reason, interpretation of H_2O measurement data is questionable. Test and acceptance criteria shall be determined between user and supplier. Possible methods include: a) determination of HCl by Fourier transform infrared spectrometry (FTIR), mass spectrometry, or gas chromatography; b) measurement of water by electrolysis in a P_2O_5 cell (reported in terms of H_2O equivalents); c) determination of water by FTIR.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	70.9	70.9
Boiling point at 1 atm	-34.05°C	-29.3°F
Density gas at 20°C (68°F) and 1 atm	2.980 kg/m^3	0.1860 lb/ft^3
Specific gravity	2.473	2.473
Density liquid at -118°C (-180.8°F)	1574.8 kg/m^3	98.26 lb/ft^3

4 Analytical Procedures

4.1 *Carbon Monoxide, Carbon Dioxide, and Hydrocarbons (CH_4, C_2H_2, C_2H_4, C_2H_6)* — This procedure is for the determination of carbon monoxide, carbon dioxide, and C_1–C_2 hydrocarbons in chlorine. The sample shall be vapor phase and analyzed using a gas chromatograph with a flame ionization detector/ methanizer combination. (See Figure 1 and Notes 1, 2, and 3.)

4.1.1 *Detection Limit* — 0.1 ppm (mol/mol).

4.1.2 *Instrument Parameters*

4.1.2.1 *Injection Valve* — 10 port corrosion-resistant.

4.1.2.2 *Sample Volume* — 2 mL.

4.1.2.3 Columns:

Column 1:	Porapak P, 3.1 m (10 ft) by 3.2 mm (1/8 in) OD ss or equivalent.
Column 2:	Porapak P, 3.1 m by 3.2 mm OD ss or equivalent.

4.1.2.4 *Carrier Flow* — 20 mL/min nitrogen.

4.1.2.5 *Column Temperature* — 40°C.

4.1.2.6 Air and Hydrogen Pressure and Flow — As specified by the instrument manufacturer.

4.1.3 *Calibration Standard* — 1–5 ppm (mol/mol) each component in nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Place the 10 port valve in the sample load position.

4.1.4.2 Turn on the methanizer heater and establish hydrogen flow. Allow unit to heat to operating temperature (as specified by the manufacturer).

4.1.4.3 Establish air flow and ignite burner following the instrument manufacturer's instructions. Allow the system to stabilize for 15 minutes.

4.1.4.4 Determine the time at which ethane elutes from the first column and absorbs onto the second column so one can vent the chlorine. Inject the calibration ethane standard and record the retention time of ethane obtained without returning the valve to the load position. Multiply this time by 0.6. The result will be the time during the analysis at which the injection valve should be returned to the load position, backflushing the chlorine to vent.

Repeat the injection of the ethane calibration standard, including the backflush, to ensure that enough time has passed to allow elution of ethane onto the second column.

4.1.4.5 Inject the remaining standards using the backflush technique. Record the retention times and peak areas.

4.1.4.6 Analyze the chlorine sample to be tested in the same manner as in 4.1.4.5. Repeat the sample injection until peak areas of the impurity of interest agree within 5%.

4.1.4.7 Analyze each of the calibration standards again as in 4.1.4.5.

4.1.4.8 Compare the average peak areas of the calibration standards to those of the chlorine sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Oxygen and Nitrogen* — This procedure is for the determination of oxygen and nitrogen in chlorine. The sample shall be vapor phase and analyzed using a gas chromatograph with a thermal conductivity detector. (See Figure 2 and Notes 1 and 2.)

4.2.1 *Detection Limits* — 2 ppm (v/v) oxygen, 5 ppm (v/v) nitrogen.

4.2.2 *Instrument Parameters*

4.2.2.1 *Injection Valve* — 10 port corrosion-resistant.

4.2.2.2 *Sample Volume* — 2 mL.

4.2.2.3 Columns:

Column 1:	Porapak Q, 1.8 m (6 ft) by 3.2 mm (1/8 in) OD ss or equivalent.
Column 2:	Molecular sieve 13×, 3.1 m (10ft) by 3.2 mm OD ss or equivalent.

4.2.2.4 *Carrier Flow* — 20 mL/min helium.

4.2.2.5 *Temperature:*

Column	30°C
Detector	50°C

4.2.3 *Calibration Standard* — 10–40 ppm (v/v) each component in helium.

4.2.4 *Operating Procedure*

4.2.4.1 Place the 10 port valve in the sample load position.

4.2.4.2 Inject the standard, wait one minute, then return the valve to the sample load position to backflush the principal gas to vent while allowing the oxygen and nitrogen to pass to the analytical column. Record the retention times and peak areas.

4.2.4.3 Inject the standard at least three times. All peak areas for a specific impurity should agree within 5%.

4.2.4.4 Inject the chlorine sample to be tested in the same manner as in 4.2.4.2 and 4.2.4.3. Record the retention times and peak areas.

4.2.4.5 Repeat 4.2.4.2 and 4.2.4.3.

4.2.4.6 Compare the average peak areas of calibration standards with that of the chlorine sample being tested. Calculate the concentrations of oxygen and nitrogen, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Trace Elements* — This procedure gives instructions for the determination of trace elements in liquid phase chlorine using inductively coupled plasma mass spectrometry (ICP-MS). (See Note 4.)

4.3.1 *Detection Limit* — (See Note 4.)

4.3.2 *Instrument Parameters* — (See Note 4.)

4.3.3 *Calibration Standards* — (See Note 4.) All instrument calibration standards should be prepared from NIST-traceable reference standards.

4.3.4 *Sample Collection Apparatus* — (See Notes 5 and 6 and Figures 3 and 4.)

4.3.4.1 *Cylinder Connector* — Stainless steel, or other suitable material, dependent on the cylinder valve used.

4.3.4.2 *Fluorocarbon Tubing* — 6.4 mm (1/4") and 3.2 mm (1/8") outer diameters required, lengths dependent on construction of apparatus.

4.3.4.3 *Fluorocarbon Needle Valve* — Two 6.4 mm (1/4") needle valves (designated as V1 and V2). (See Figure 3.)

4.3.4.4 *Fluorocarbon Ball Valve* — One 6.4 mm (1/4") ball valve and one 3.2 mm (1/8") ball valve (designated as V3 and V4, respectively). (See Figure 3.)

4.3.4.5 *Fluorocarbon T-Joint* — One 6.4 mm (1/4") T-joint.

4.3.4.6 *Fluorocarbon Cylinder Union* — One 6.4 mm (1/4") to 15.9 mm (5/8") iron pipe size female pipe thread adapter to attach to the stainless steel cylinder connector.

4.3.4.7 *Fluorocarbon Reducer* — One 6.4 mm (1/4") to 3.2 mm (1/8") reducing union.

4.3.4.8 *Flask Connector* — One Plasmatech #16F424 flask connector, or similar, attached to a cap for the 100 mL sampling flask.

4.3.4.9 *Sampling Flasks* — 100 mL polypropylene volumetric flask.

4.3.4.10 *Nitrogen Source* — A source of high-purity nitrogen to purge the sampling system prior to and after sampling and for evaporation.

4.3.4.11 *Scrubber Source* — A caustic scrubber source to neutralize chlorine from the sampling process. The scrubber is connected to an eductor tube, with the vacuum created by an N_2 source regulated at 20 psi.

4.3.5 *Operating Procedure*

4.3.5.1 Assemble the system according to Figures 3 and 4, ensuring that the connections are leak tight.

4.3.5.2 Wrap Teflon tape around the threads of a 100 mL volumetric flask to ensure a good seal. Connect the 100 mL polypropylene flask to the flask connector as shown in Figure 3. All 100 mL volumetric flasks used for sample collection should be prepared in a similar manner.

4.3.5.3 Clean the exterior of the cylinder CGA by rinsing it with (in succession) 10% HNO_3/DI H_2O, isopropanol/DI H_2O, and DI H_2O. The CGA must be free of residue. The CGA is then cleaned and dried with a cotton swab. Dry the exterior of the CGA with the high-purity N_2. Repeat the process for the nut and gland. The cylinder CGA must be completely dry prior to connecting the nut and gland.

4.3.5.4 Invert the cylinder with a cylinder inverter and connect the cylinder CGA to the nut and gland.

4.3.5.5 Purge the system by opening V1 and V2 and allowing high purity N_2 to flow through the system at 5–10 psig for a minimum of three minutes. The ball valves (V3 and V4) remain in the open position.

4.3.5.6 Close V1 and V2. To condition the sampling system, open the cylinder valve, then slowly open V2 to allow Cl_2 to flow into the sample flask. After collecting 70–100 mL of Cl_2, close the cylinder valve and open V1 to purge the system.

4.3.5.7 Discard the initial Cl_2 sample by passing it through to the scrubber, remove the flask and replace it with a labeled sample flask. Continue to purge the system for at least two minutes. Close V1 and V2. Open the cylinder valve, then slowly open V2.

4.3.5.8 Allow 100 g of sample to be introduced into the sample flask. Once this is completed, close V2, then close the cylinder valve. Open V1 and V2 to allow for purging of the Cl_2 in the sample flask with high purity N_2 flowing through the system at 5 psig. This will purge the Cl_2 at a rate of 7–10 gms per minute.

4.3.5.9 When the sample has been flushed, replace the sample flask with another flask. Loosely cap the sample flask to allow for any residual Cl_2 to evaporate. If additional samples from the same cylinder are desired, repeat Steps 4.3.5.5 through 4.3.4.9.

4.3.5.10 Close V1 and disconnect the cylinder valve connector from the cylinder valve. Return the cylinder to the upright position. Rinse the cylinder CGA and nut, gland with DI H_2O, and dry with N_2. Remove the cylinder from the cylinder inverter.

4.3.5.11 Repeat Steps 4.3.5.3 to 4.3.5.10 for additional cylinders.

4.3.5.12 After obtaining all samples of interest, hand dry the connector and place it into an oven to prevent corrosion and build-up of condensation. Clean the tubing and valve system with a 10% HNO_3/DI H_2O solution and store in a 25% HNO_3/DI H_2O solution.

4.3.5.13 Fill each sample flask with a solution of 5% ultrapure HNO_3/DI H_2O spiked with 25 ppb of an internal standard (such as indium) up to the graduation mark. Allow the samples to digest in the solution in the flasks for a minimum of one hour. (See Note 7.)

4.4 *Water* — This procedure is for the determination of moisture in gas phase chlorine using a continuous flow electrolysis of water in a phosphorous pentoxide (P_2O_5) cell. (See Notes 2 and 8.)

4.4.1 *Detection Limit* — 1 ppm (vol/vol).

4.4.2 *Flow Rate* — Set the sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards* — Construct a calibration curve which contains at least two points covering the range of interest.

4.4.4 *Operating Procedure*

4.4.4.1 Leak check the entire system using helium and a helium leak detector prior to use.

4.4.4.2 Pre-purge through the regulator/cross-purge assembly with a dry gas of known moisture content until the moisture content is measured below 1 ppm (vol/vol).

4.4.4.3 Direct samples of two standards, independently verified with a dewpoint/frostpoint hygrometer, spanning the range of moisture content of interest to the analyzer. After a stable reading is obtained, record the instrument's response to each standard.

4.4.4.4 Obtain a representative sample of the gas to be analyzed and direct it to the unit as with the standards. After a stable reading is obtained, record the instrument’s response.

4.4.4.5 Construct a calibration curve from the standard data and determine the moisture content in the sample gas. The result may not exceed the specification in Section 2 of this standard.

4.5 *Notes*

NOTE 1: Sample system should be constructed entirely of stainless steel or other suitable material due to the corrosive nature of the product.

NOTE 2: Sample must be appropriately vented for health and safety of operating personnel.

NOTE 3: Individual standards are required for accuracy and identification by retention time.

NOTE 4: Other accepted instrumental techniques are also appropriate for this analysis. In addition, operating procedures for ICP-MS instruments vary, depending on the manufacturer. In all cases, refer to individual instrument vendor instructions.

NOTE 5: All sampling flasks are leached with a 25% HNO_3/H_2O solution for at least 24 hours, rinsed thoroughly with DI H_2O, and filled with DI H_2O for at least 24 hours prior to use. On the day of sampling, flasks are rinsed thoroughly with DI H_2O and dried with N_2 prior to system setup.

NOTE 6: The tubing and Fluorocarbon valves are soaked in a 25% HNO_3/DI H_2O solution prior to use (either apart or pre-assembled). The tubing and valves are rinsed thoroughly with DI H_2O and dried with high-purity N_2 prior to system setup.

NOTE 7: A different digestion solution may be used, depending on possible interferences with a given analysis technique.

NOTE 8: All wetted surfaces, including P_2O_5 hygrometer and sample system, are to be of 316 stainless steel or other suitable material.

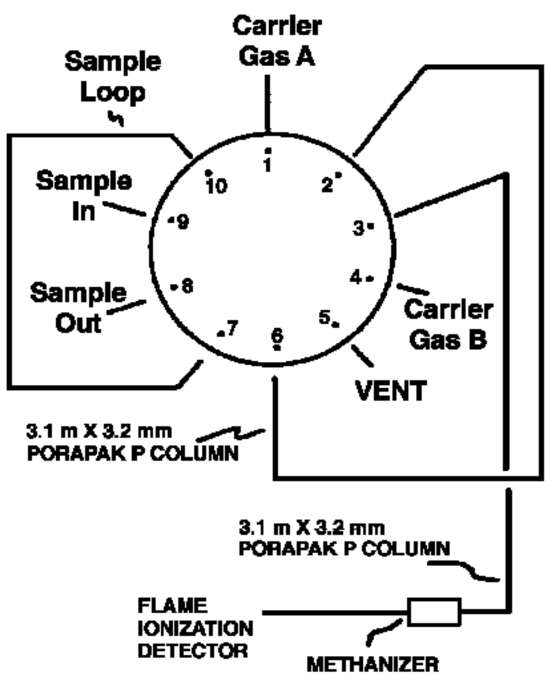

Figure 1
Carbon Monoxide, Carbon Dioxide, and Hydrocarbons Determination

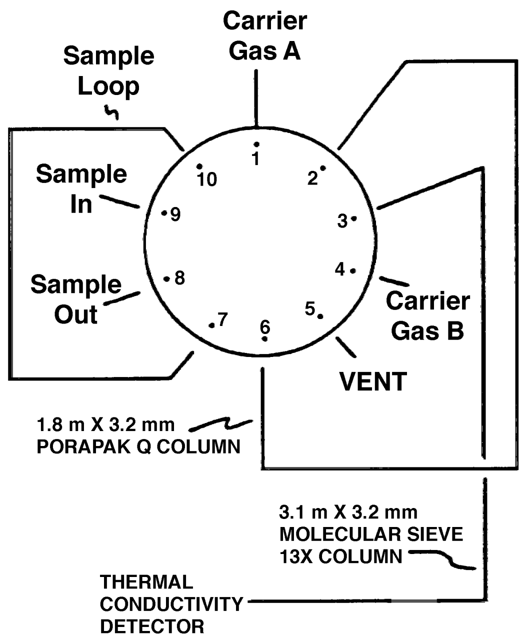

Figure 2
Oxygen and Nitrogen Determination

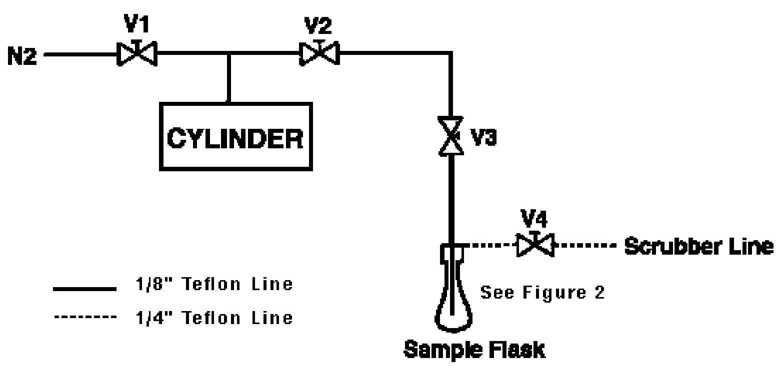

Figure 3
Metals Setup (Liquid Phase Analysis)

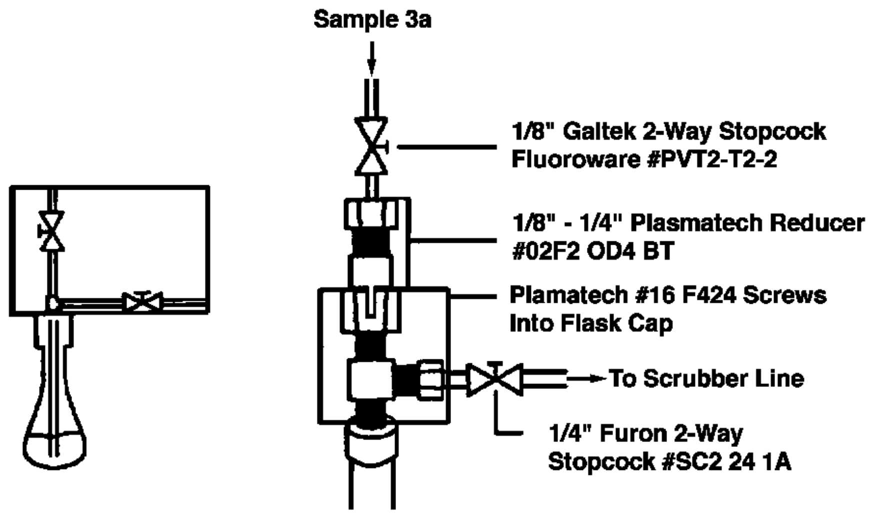

Figure 4

NOTICE: This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the specification set forth herein for any particular application. The determination of the suitability of the specification is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. This specification are subject to change without notice.

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SEMI C3.44-91 (Withdrawn 0701)
STANDARD FOR DIBORANE (B_2H_6) (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Diborane is toxic, flammable, colorless gas. It has a sickly sweet odor.

SEMI C3.56-0600
SPECIFICATION FOR DIBORANE MIXTURES

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the European Gases Committee. Current edition approved by the European Regional Standards Committee on April 4, 2000. Initially available at www.semi.org May 2000; to be published June 2000.

1 Purpose

1.1 To define the specification and analytical methods and validate the specifications for diborane mixtures.

2 Scope

2.1 Diborane is not used as a pure gas but as a mixture with balance gases of N_2, H_2, Ar, He, or SiH_4.

2.2 The quality of the mixture is affected by a number of factors which include:

- the purity of the gases used for mixture preparation;
- component filling precision;
- the cylinder preparation process and *in-situ* reactions of diborane with the internal surface of the cylinder.

2.2.1 Furthermore, the elapsed time after filling is important due to the chemical instability, and hence decomposition, of the diborane (see Appendix 1).

2.2.2 All component gases shall adhere to the appropriate SEMI specification, if available.

2.3 The quality of the final mixture can be checked after manufacturing by analyzing each cylinder for the concentration of diborane and for key impurities (tracers), namely H_2, N_2, O_2.

2.4 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *DIN Standard*[1]

DIN 50457-1

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Specifications

4.1 *Mixing Tolerances*

Concentration of Diborane	*Preparation Tolerance Level*
10–999 ppm	± 20%
0.1–10%	± 5%

4.2 *Analytical precision: Determination of Diborane Content*

Concentration of Diborane	*Analytical Precision*
10–99 ppm	± 3%
100–999 ppm	± 2%
0.1–10%	± 2%

N.B. Analytical precision is based on at least 6 replicate determinations

4.3 *Impurities*

4.3.1 In the final mixture the concentration of impurities should fulfill the following condition:

$$c_i(mix) = \left[\frac{x_{(diborane)}}{100} \bullet c_i(diborane)\right] + \left[\frac{x_{(main)}}{100} \bullet c_i(main)\right]$$

$c_i(mix)$ — concentration of impurity i in the mixture (ppm)

$c_i(diborane)$ — maximum concentration of impurity i in diborane (ppm)

$c_i(main)$ — maximum concentration of impurity i in the balance gas (ppm)

$x_{(diborane)}$ — concentration of diborane in the mixture (%)

$x_{(main)}$ — concentration of balance gas in the mixture (%)

5 Analytical Procedure for the Determination of Diborane Concentration

NOTE 2: This procedure is for the determination of the diborane content using a Fourier Transform Infrared analyzer.

5.1 *Detection limit* — 2 ppm (mole/mole)

1 Deutches Institut für Normung e.V., BeuthVerlag GmbH, burggrafenstrasse 4-10, D10787 Berlin, Germany, www.din.de

5.2 *Instrument parameters*

5.2.1 *Cell path length*

5.2.1.1 10 cm (mixtures 100 ppm to 10%)

5.2.1.2 10 m (mixtures up to 100 ppm)

Wavenumber — 2444–2739 cm^{-1}

Resolution — 4 cm^{-1}

5.2.2 *Sample Flow*

5.2.2.1 20 l/h at 10 cm path length

5.2.2.2 40 l/h at 10 m path length

5.3 *Calibration standard* — diborane in hydrogen

NOTE 3: Depending on the concentration of diborane and the storage temperature the standard can be unstable (Section 5). It is recommended to use an appropriate standard with a diborane concentration as low as possible and to store it at low temperature. If there are doubts about the stability of the standard the diborane concentration can be verified by wet chemical methods. (See DIN 50457-1.)

5.4 *Operating Procedures*

5.4.1 Purge the sampling system leading to the cell and the cell with dry nitrogen for 15 minutes and until a zero absorbance is obtained between 2444–2739 cm^{-1}. Then purge the cell with the calibration standard and record the absorption of diborane. When a steady absorbance reading is obtained, after approximately 5–10 minutes, the true concentration of the standard shall be recorded. Record the pressure in the gas cell using a calibrated pressure-measuring device.

5.4.2 To determine the concentration of diborane in the mixture set the sample flow through the cell following the same procedures as detailed above. Record the absorption at the same wave number as the calibration standard. Ensure that gas cell pressures are equal during calibration and the determination. Calculate the concentration of diborane. The result must conform to the specification in Section 4 of this standard.

APPENDIX 1
STABILITY OF DIBORANE MIXTURES (FOR INFORMATION ONLY)

NOTE: The material in this appendix is an official part of SEMI C3.56 and was approved by full letter ballot procedures on April 4, 2000 by the European Regional Standards Committee.

A1-1 The stability of diborane mixtures in N_2, Ar, or He depends on the concentration of diborane and on the storage temperature. At ambient temperature best stability is found for mixtures of diborane in hydrogen. No difference in stability could be found for different cylinder materials (steel, stainless steel, aluminum).

A1-2 The following values were measured for different concentrations of diborane at two different storage temperatures:

Storage Temperature	*Diborane Concentration (%) in Nitrogen after*				
	2	17	45	100	160 Days
8 °C	0.549	0.547	0.547	0.543	0.542
22 °C	0.549	0.544	0.539	0.530	0.526
8 °C	5.05	4.91	4.87	4.85	4.78
22 °C	5.05	4.92	4.83	4.72	4.49
8 °C	10.51	10.45	10.43	10.19	10.00
22 °C	10.59	10.30	10.08	9.44	8.85

A1-3 Based on these results it is recommended to keep mixtures at low temperature.

NOTICE: SEMI makes no warranties or representations as to the suitability of the specification set forth herein for any particular application. The determination of the suitability of the specification is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These specifications are subject to change without notice.

The user's attention is called to the possibility that compliance with this specification may require use of copyrighted material or of an invention covered by patent rights. By publication of this specification, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this specification. Users of this specification are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.18-94
STANDARD FOR DICHLOROSILANE (H_2SiCl_2) IN CYLINDERS, 97% QUALITY

1 Description

Dichlorosilane is a flammable, corrosive, colorless liquid which hydrolizes in the presence of moisture. It oxidizes readily and rapidly to release hydrogen chloride. It is easily ignited in the presence of air.

2 Specifications

QUALITY: 97% (liquid) (See Notes 1, 2, 3, and 4)

Impurities	*Maximum Acceptable Levels**
All Other Chlorosilanes (Monochlorosilane, Silicon Tetrachloride, Trichlorosilane)	3% (liquid phase)
Aluminum	1 ppbw (vapor phase derived)
Arsenic	0.5 ppbw (vapor phase derived)
Boron	0.3 ppbw (vapor phase derived)
Carbon	10 ppmw (vapor phase derived)
Iron	50 ppbw (liquid phase)
Phosphorus	0.3 ppbw (vapor phase derived)

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Electrical Specification

Resistivity*	greater than 50 ohm-cm (n-type) **

* The resistivity measurement technique is to be determined between supplier and user.

** Monocrystalline silicon formed from this material, not the material itself.

4 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	100.99	100.99
Boiling point at 1 atm	8.2°C	46.8°F
Density of gas at 25°C (77°F) and 1 atm	4.168 kg/m^3	0.260 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	3.48	3.48
Density of liquid at 25°C (77°F)	122 kg/m^3	7.62 lb/ft^3

5 Analytical Procedures (See Note 5)

5.1 *Other Chlorosilanes* — This procedure is for the determination of other chlorosilanes (monochlorosilane, trichlorosilane and silicon tetrachloride) in dichlorosilane using a gas chromatograph with a thermal conductivity detector.

5.1.1 *Detection Limit* — 10 ppm (mole/mole).

5.1.2 *Instrument Parameters*

5.1.2.1 Column: 3.05 m (10 ft) by 3.2 mm (1/8 in) stainless steel tubing packed with 20% OV-101 on 80/100 Chromosorb W-HP or equivalent.

5.1.2.2 Carrier Flow: 20 mL/min helium.

5.1.2.3 Sample Volume: 0.5 to 1.0 mL.

5.1.2.4 Temperatures:

Detector	350°C
Column	60°C ramped to 325°C at 10°C/min
Inlet	300°C

5.1.3 *Operating Procedure*

5.1.3.1 Inject a known sample of monochlorosilane, trichlorosilane and silicon tetrachloride in dichorosilane into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is monochlorosilane, dichlorosilane, trichlorosilane, silicon tetrachloride.

5.1.3.2 Inject the sample to be tested in the same manner as in 5.1.3.1. Record the areas of the peaks which have the same retention times as those in 5.1.3.1.

5.1.3.3 Repeat 5.1.3.1.

5.1.3.4 Calculate the purity of dichlorosilane in the sample, using the equations stated below. The result may not exceed the specification in Section 2 of this Standard.

5.1.4 *Calculations*

5.1.4.1 Determine the total area of the chlorosilane peaks (A_T) by adding the areas of the four peaks.

5.1.4.2 Divide the area of the dichlorosilane peak by A_T. Multiply the result by 100% to obtain the purity of the dichlorosilane.

5.2 *Notes*

Note 1: This specification applies to the appropriate phase of the cylinder as delivered.

Note 2: The liquid phase purity is to be based on the chlorosilane determination. In addition, argon + helium are to be controlled in the vapor phase to less than 0.5%. This argon + helium determination will not affect the percent purity determination.

Note 3: Initial purging of the vapor phase is recommended to reduce inert gas content used in the cylinder fill procedure.

Note 4: Analytical procedures for the doping elements, metals and selected impurities are to be determined between the user and supplier at the present time.

Note 5: The sample is extremely flammable and corrosive. Test for leaks before sampling. Ensure good electrical grounding.

SEMI C3.31-94
STANDARD FOR DICHLOROSILANE (H_2SiCl_2) IN CYLINDERS, 99% QUALITY (PROVISIONAL)

1 Description

Dichlorosilane is a flammable, corrosive, colorless liquid which hydrolizes in the presence of moisture. It oxidizes readily and rapidly to release hydrogen chloride. It is easily ignited in the presence of air.

2 Specifications

QUALITY: 99% (Liquid) (See Notes 1, 2, 3, 4.)

Impurities	*Maximum Acceptable Levels **
All other Chlorosilanes (Monochlorosilane not to exceed 0.5%)	1% (liquid phase)
Aluminum (Al)	1.0 ppbw (vapor phase derived)
Arsenic (As)	0.2 ppbw (vapor phase derived)
Boron (B)	0.1 ppbw (vapor phase derived)
Carbon (C)	1 ppmw (vapor phase derived)
Iron (Fe)	50 ppbw (liquid phase)
Phosphorus (P)	0.3 ppbw (vapor phase derived)

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Electrical Specification

Resistivity*	Greater than 150 ohm-cm (n-type)**

* The resistivity measurement is to be determined between supplier and user.

** Monocrystalline silicon formed from this material, not the material itself.

4 Analytical Procedures (see Note 5)

4.1 *Other Chlorosilanes* — This procedure is for the determination of other chlorosilanes (monochlorosilane, trichlorosilane and silicon tetrachloride) in dichlorosilane using a gas chromatograph with a thermal conductivity detector.

4.1.1 *Detection Limit* — 10 ppm (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column: 3.05 m (10 ft) by 3.2 mm (1/8 in) stainless steel tubing packed with 20% OV-101 on 80/100 Chromosorb W-HP or equivalent.

4.1.2.2 Column Flow: 20 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 1.0 mL.

4.1.2.4 Temperatures:

Detector	350°C
Column	60°C ramped to 325°C at 10°C/min.
Inlet	300°C

4.1.3 *Operating Procedure*

4.1.3.1 Inject a known sample of monochlorosilane, trichlorosilane and silicon tetrachloride in dichlorosilane into the column using a gas sampling valve. Record retention times and peak areas. The order of elution is monochlorosilane, dichlorosilane, trichlorosilane, silicon tetrachloride.

4.1.3.2 Inject dichlorosilane sample to be tested in the same manner as in 4.1.3.1. Record the areas of the peaks which have the same retention times as those in 4.1.3.1.

4.1.3.3 Calculate the purity of dichlorosilane in the sample, using the formula below. The result may not be less than the specification in Section 2 of this Standard.

4.1.3.4 Calculate the percentage the monochlorosilane in the sample using the equation stated below. The result may not be more than the specification in Section 2 of this Standard.

4.1.4 *Calculations*

4.1.4.1 Determine the total area of the chlorosilane peaks (A_T) by adding the areas of the four peaks.

4.1.4.2 Divide the area of the dichlorsilane peak by A_T. Multiply the result by 100% to obtain the purity of the dichlorosilane.

4.1.4.3 Divide the area of the monochlorosilane peak by A_T. Multiply the result by 100% to obtain the percentage of monochlorosilane.

4.2 *Notes*

Note 1: This specification applies to the appropriate phase of the cylinder as delivered.

Note 2: The liquid phase purity is to be based on the chlorosilane determination. In addition, argon + helium are to be controlled in the vapor phase to less than 0.5%. This argon + helium determination will not affect the percent purity determination.

Note 3: Initial purging of the vapor phase is recommended to reduce inert gas content used in the cylinder fill procedure.

Note 4: Analytical procedures for the doping elements, metals and selected impurities are to be determined between the user and supplier at the present time.

Note 5: The sample is extremely flammable and corrosive. Test for leaks before sampling. Ensure good electrical grounding.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI C3.34-92
STANDARD FOR DISILANE (Si_2H_6)

1 Description

Disilane is a pyrophoric, highly flammable, noncorrosive, colorless gas. It is toxic and a powerful irritant.

2 Specifications

QUALITY: 97% (See Note 1.)

Impurities	*Maximum Acceptable Level (ppm)**
Argon (Ar) + Oxygen (O_2)	1
Carbon dioxide (CO_2)	1
Carbon monoxide (CO)	1
Chlorosilanes (Total hydrolizable chlorides, reported as (Cl-))	5
Chromium (Cr)	**
Disiloxane ($H_3SiOSiH_3$)	5
Hydrogen (H_2)	500
Iron (Fe)	**
Monoethylsilane	50
Nickel (Ni)	**
Nitrogen (N_2)	10
Silane (SiH_4)	2.5%
Total methane, ethane, propane	10
Total trisilane and tetrasilane	500
Water (H_2O)	1
TOTAL SPECIFIED IMPURITIES (excluding chloride, chromium, iron and nickel)	2.6082%

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

Note 1: This specification applies to the gas phase of the cylinder as received.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	62.22	62.22
Boiling point at 1 atm	-14.8°C	5.4°C
Freezing point	-132.5°C	-206.5°C
Vapor density (air = 1)	2.38	2.38

4 Analytical Procedures

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in disilane using a gas chromatograph with a methanizer and a flame ionization detector. (See Figure 1, Notes 1 and 2.)

4.1.1 *Detection Limit* — 0.1 ppm for each impurity.

4.1.2 *Instrument Parameters*

4.1.2.1 Column: Porapak QS 3 m (10 ft) by 1.6 mm (1/16 in) ID ss or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 1.5 mL.

4.1.2.4 Support Gases: As specified by the instrument manufacturer.

Hydrogen: 20–30 mL per min added to the carrier gas between the column outlet and the methanizer inlet.

Air: 500 mL/min.

4.1.2.5 Temperatures:

Detector	110°C
Injector	60°C
Oven	60°C
Methanizer	370° – 400°C

4.1.3 *Calibration Standards* — 1–10 ppm carbon monoxide, 1–10 ppm carbon dioxide, balance helium.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is carbon monoxide, carbon dioxide. Repeat this operation.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard and vent after elution of carbon dioxide is completed, in case any silane is present. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1

4.1.4.4 Compare the average peak areas of the calibration standard to that of the disilane sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.2 *Methane, Ethane, Propane, and Silane* — This procedure is for the determination of hydrocarbons (methane, ethane, and propane) and silane in disilane using a gas chromatograph with a thermal conductivity detector.

4.2.1 *Detection Limit* — 3 ppm for each impurity.

4.2.2 *Instrument Parameters*

4.2.2.1 Column: Porapak QS 3 m (10 ft) by 1.6 mm (1/16 in) ID ss or equivalent.

4.2.2.2 Carrier Flow: 25 mL/min. Helium.

4.2.2.3 Sample Volume: 1 mL.

4.2.2.4 Temperatures:

Detector	80°C
Injector	60°C
Oven	60°C

4.2.3 *Calibration Standards* — 10–50 ppm methane, 5–10 ppm ethane, 5–10 ppm propane, 0.1 – 1% silane, balance helium.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is methane, silane, ethane, propane.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak areas of the calibration standard to that of the disilane sample being tested. Calculate the concentrations of methane, silane, ethane, and propane, using the formula below. The results may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.3 *Hydrogen, Nitrogen, and Argon* — This procedure is for the determination hydrogen, nitrogen, and argon in disilane using a gas chromatograph with a helium ionization detector.

4.3.1 *Detection Limit* — 100 ppb for hydrogen and argon, 500 ppb for nitrogen.

4.3.2 *Instrument Parameters*

4.3.2.1 Columns:

Column 1:	Porapak QS 2.5 m (8 ft) by 3.2 mm (1/8 in) OD ss or equivalent.
Column 2:	5A Molecular sieve, 3 m (10 ft) by 3.2 mm OD ss or equivalent.

4.3.2.2 Carrier Flow: 25 mL/min helium.

4.3.2.3 Sample Volume: 3 mL.

4.3.2.4 Temperatures:

Detector	100°C
Injector	30°C
Oven	30°C

4.3.3 *Calibration Standards* — 1–10 ppm nitrogen, 1–10 ppm argon, 10–100 ppm hydrogen, balance helium.

4.3.4 *Operating Procedure*

4.3.4.1 Determination of the backflush time: Inject a methane sample (1–1000 ppm, balance helium) using a 10 port gas valve and backflush at different times. Select the backflush time so that the methane peak is split by the backflush.

4.3.4.2 Inject the calibration standard into the column using a gas sampling valve. Backflush at the time determined in 4.3.4.1. Record retention times and peak areas. Order of elution is hydrogen, argon, nitrogen.

4.3.4.3 Inject the sample to be tested in same manner as the calibration standard. Backflush at the time determined in 4.3.4.1. Record the retention times and peak areas.

4.3.4.4 Repeat 4.3.4.2.

4.3.4.5 Compare the average peak areas of the calibration standard to that of the disilane sample being tested. Calculate the concentrations of hydrogen, nitrogen and argon using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.4 *Disiloxane, Monoethylsilane, Trisilane, and Tetrasilanes* — This procedure is for the determination of disiloxane, monoethylsilane, trisilane, and tetrasilanes in disilane using a gas chromatograph with a thermal conductivity detector.

4.4.1 *Detection Limits* — 5 ppm for disiloxane and 10 ppm for each of the other impurities.

4.4.2 *Instrument Parameters*

4.4.2.1 Column: 30% DC 200 on Chromosorb P, 80/100 mesh, 10 m (33 ft) by 3.2 mm (1/8 in) ss or equivalent.

4.4.2.2 Carrier Flow: 20 mL/min helium.

4.4.2.3 Sample Volume: 1 mL.

4.4.2.4 Temperatures:

Detector	120°C
Injector	60°C
Oven	60°C for 25 min then 10°C/min to 120°C

4.4.3 *Calibration Standard* — 100 ppm (mole/mole) each of trisilane, i-tetrasilane, and n-tetrasilane, and 10 ppm each disiloxane and monoethylsilane in helium. If one or several components cannot be obtained, use a 100 ppm monosilane standard and apply the following correction factors using the formula below (See Reference 1).

Trisilane CF = 0.54

i-tetrasilane CF = 0.42

n-tetrasilane CF = 0.41

Correction factors for disiloxane and monoethylsilane are not available. Use the same as disilane CF = 0.69. concentration of impurity = calculated concentration, using silane standard, × CF.

4.4.4 *Operating Procedure*

4.4.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. Order of elution is disiloxane, disilane, monoethylsilane, trisilane, i-tetrasilane, and n-tetrasilane.

4.4.4.2 Inject the sample to be tested in same manner as calibration standard. Record the retention times and peak areas.

4.4.4.3 Repeat 4.4.4.1.

4.4.4.4 Compare the average peak areas of the calibration standard to that of the disilane sample being tested. Calculate the concentrations of disiloxane, disilane, monoethylsilane, trisilane, i-tetrasilane, and n-tetrasilane, using the formula below. If necessary, correct the results using the specified correction factors in 4.4.3. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.5 *Water* — This procedure is for the determination of moisture in disilane using a continuous flow electrolysis of water in a phosphorus pentoxide (P_2O_5) cell. (See Note 3.)

4.5.1 *Detection Limit* — 1 ppm (volume/volume).

4.5.2 *Flow Requirement* — Set the sample flow rate and pressure in accordance with manufacturer's instructions.

4.5.3 *Operating Procedure*

4.5.3.1 Direct samples of three standards, independently verified with a dewpoint/frostpoint hygrometer, spanning the range of moisture content of interest to the analyzer. After a stable reading is obtained, record the instrument's response to each standard.

4.5.3.2 Obtain a representative sample of the gas to be analyzed and direct it to the unit as with the standards. After a stable reading is obtained, record the instrument's response.

4.5.3.3 Construct calibration curve from the standard data and determine the moisture content in sample gas. The result may not exceed the specification in Section 2 of this Standard.

4.6 *Total Chlorides* — This procedure is for the determination of total hydrolyzable chlorides in disilane by titration of a hydrolyzed sample of disilane. (See Figure 2.)

4.6.1 *Detection Limit* — 0.5 ppm.

4.6.2 *Instrument Parameters*

4.6.2.1 *Equipment*

1. Safety purge regulator with proper fittings.
2. Flow meter capable of measuring 0.25 standard liters per minute (0.5 SCF/hour) (Brooks or equivalent).
3. One cylinder of nitrogen with regulator.
4. One ice bath.
5. Three magnetic stirring bars.
6. Two 2000 mL heavy-duty sidearm flasks (Fisher Cat. No. 10-181G or equivalent).
7. One #9 one-hole rubber stopper.
8. One #9 two-hole rubber stopper.
9. Two borosilicate glass tubes with fritted cylinders (Fisher Cat. No. 11.138B or equivalent).
10. One gas washing bottle with fritted cylinder, 125 mL cap. (Fisher Cat. No. 03-040A or equivalent).
11. One buret, 50 mL capacity with PTFE stopcock (Fisher Cat. No. 03-700-22C or equivalent).

12. One buret stand (Fisher Cat. No. 14-688 or equivalent).
13. Miscellaneous clamps, support stands, and rubber hose.
14. Two 250 mL Erlenmeyer flasks.

4.6.3 *Reagents*

1. Potassium hydroxide flakes, technical (Fisher Cat. No. P-246 or equivalent).
2. Mercuric nitrate crystal (Fisher Cat. No. M-168 or equivalent).
3. Sodium chloride crystal (Fisher Cat. No. S-271 or equivalent).
4. Diphenyl carbazone (Fisher Cat. No. D-86 or equivalent).
5. Bromophenol blue (Fisher Cat. No. B-392 or equivalent).
6. Nitric acid (Fisher Cat. No. AA-200 or equivalent).
7. Ethanol, denatured (Fisher Cat. No. AA-407 or equivalent).

4.6.4 *Operating Procedure*

4.6.4.1 Fill each 2000 mL sidearm flask with about 1700 mL of 15% potassium hydroxide solution (15 g KOH per each 100 mL water).

4.6.4.2 Fill the gas washing bottle with about 75 mL of deionized water that has been degassed.

4.6.4.3 Assemble apparatus as shown in Diagram A and purge entire system with nitrogen for 30 minnutes.

4.6.4.4 Pass 30 liters (approximately one cubic foot) of disilane through the system at a rate of 0.25 liters per minute. Record the volume the disilane sample.

4.6.4.5 Stop disilane flow and purge system for 30 minutes.

4.6.4.6 Remove gas washing bottle from system and transfer contents quantitatively and with the aid of three 25 mL deionized water washings, to a 250 mL Erlenmeyer flask.

4.6.4.7 Add a few drops of indicator solution (5 g diphenyl carbazone plus 0.5 g bromophenol blue dissolved in 750 mL ethanol, plus 250 mL deionized water).

4.6.4.8 Add, in a drop-wise fashion, sufficient 0.2*N* HNO_3 (13 mL conc. HNO_3, diluted to 1 L in deionized water) in order to just turn the solution to yellow from purple.

4.6.4.9 Titrate with a solution of 5 g. mercuric nitrate $Hg(NO_3)_2$, (diluted to 1000 mL in deionized water; then 50 mL diluted to 500 mL in deionized water) which has been previously standardized to 5.0 mL of a sodium chloride solution (approximately 165 ng NaCl, accurately weighed, dissolved in 100 mL deionized water).

4.6.5 *Calibration*

4.6.5.1 Run titration blank consisting of 150 mL deionized water.

4.6.5.2 Calculate the concentration of chloride, using the formula below. The result may not exceed the specification in Section 3 of this Standard.

$$\frac{\text{mL sample - mL blank}}{\text{mL standard - mL blank}} \times \frac{\text{wt. of NaCl(g)}}{\text{100.0 mL}} \times$$

$$\frac{60.66\%\ Cl^-}{100\%\ NaCl} \times \frac{1000\ mL}{1\ L} \times \frac{.005\ L}{35.453\ g/mole} \times$$

$$\frac{0.082\ \text{atm L/mole K}}{1\ \text{atm}} \times \frac{294.26\ \ K}{\text{volume of gas samples}} \times$$

$$1 \times 10^6\ \text{ppm} = \text{ppm}\ Cl^-$$

4.6.6 *Final Calculation* — Convert the results from ppm (mole/mole) to ppm-wt using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\text{ppm - wt} = \text{ppm (mole/mole)} \times \frac{35.45}{62.22}$$

4.7 *Reference*

R.J. Bogaert, R.E. Rocheleau and B.N. Baron "Gas Chromatographic Determination of Silanes" J. of Chrom. Science Vol. 24, March 86.

4.8 *Notes*

Note 1: An optional temperature ramping during vent will shorten the analysis time.

Note 2: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) carbon dioxide.

Note 3: Direct gases for moisture measurment to the analyzer with stainless steel lines which have been purged.

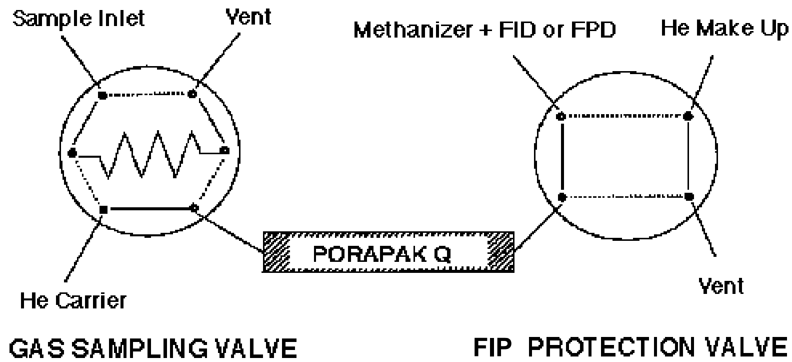

Figure 1
G.C. Configuration

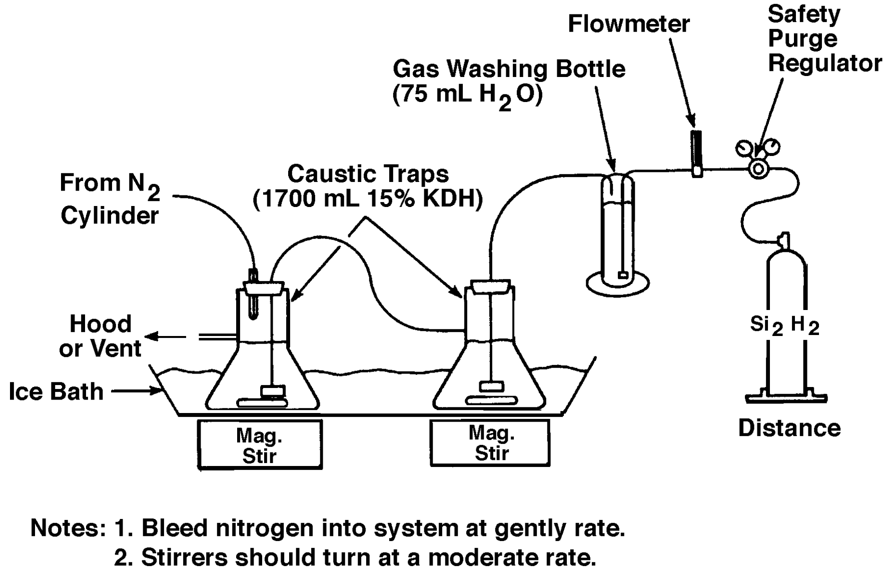

Figure 2
Chloride Scrubbing Apparatus

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SEMI C3.20-92 (Reapproved 0999)
STANDARD FOR HELIUM (He), IN CYLINDERS, 99.9995% QUALITY

This standard was technically reapproved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1982; previously published in 1992.

1 Description

1.1 Helium is a rare gas or cryogenic liquid that is inert, colorless, odorless, and tasteless.

2 Specifications

QUALITY: 99.9995%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide and carbon dioxide ($CO + CO_2$)	1
Nitrogen (N_2)	2
Oxygen (O_2)	0.5
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	0.5
TOTAL SPECIFIED IMPURITIES	4.5

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	4.003	4.003
Boiling point at 1 atm	-268.9°C	-452.0°F
Density of gas at 21.1°C (70°F) and 1 atm	0.1656 kg/m3	0.01034 lb/ft3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	0.138	0.138
Density of liquid at boiling point	124.9 kg/m3	7.798 lb/ft3

4 Analytical Procedures (See Notes 1, 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in helium using a gas chromatograph with a flame ionization detector and methanizer.

4.1.1 *Detection Limit* — 100 ppb (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column:

Porapak T or Q, 3 m (9.8 ft) by 3 mm (1/8 in) ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3 mm ss;

or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standards* — 1-10 ppm (mole/mole) carbon monoxide, 1-10 ppm (mole/mole) carbon dioxide, balance helium.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the helium sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{array}{c}\text{Concentration}\\ \text{of Standard}\end{array} = \begin{array}{c}\text{Concentration}\\ \text{of Sample}\end{array}$$

4.2 *Nitrogen* — This procedure is for the determination of nitrogen in helium using a gas chromatograph with a helium ionization detector.

4.2.1 Detection Limit — 500 ppb.

4.2.2 Instrument Parameters

4.2.2.1 Column: 5A molecular sieve, 1.9 m (6 ft) by 3.2 mm (1/8 in) ss, or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 3.0 mL.

4.2.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.2.3 *Calibration Standard* — 5-15 ppm nitrogen in helium.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the helium sample being tested. Calculate the concentration of nitrogen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in helium using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole).

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 1-10 ppm (mole/mole) oxygen in helium or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce helium sample and record oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Water* — This procedure is for the determination of trace moisture (water) in helium using a continuous flowing piezoelectric hygrometer. (See Note 3.)

4.4.1 *Detection Limit* — 0.1 ppm (vol / vol) or -90°C (-130°F).

4.4.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.4.4 *Operating Procedure*

4.4.4.1 Obtain a continuous flow of sample gas from the source using a clean and passivated 316 stainless steel line which has been purged dry after exposure to ambient moisture.

4.4.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric hygrometer until a stable reading is obtained. Determine the concentration of moisture by comparing the reading to the calibration curve obtained in 4.4.3. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in helium using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer. (See Notes 4, 5, 6.)

4.5.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.5.2 Flow Requirements

4.5.2.1 High purity, hydrocarbon-free (less than 1.0 ppm) hydrogen: 35-40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75-80 mL/min.

4.5.2.2 Dry, hydrocarbon-free (less than 1.0 ppm) air: 350-400 mL/min.

4.5.2.3 Set sample flow rates in accordance with instrument manufacturer's instructions.

4.5.3 *Calibration Standards*

4.5.3.1 Helium with known quantity of hydrocarbons at 0.5 ppm level.

4.5.3.2 The span gas not exceeding 5 times the concentration of the specification.

4.5.4 *Operating Procedure*

4.5.4.1 Do not change the initial flow settings for hydrogen, air and sample once established.

4.5.4.2 Introduce the zero helium with known quantity of hydrocarbons and, using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.5.4.3 Introduce the span gas standard in helium and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.5.4.4 Introduce helium sample into the analyzer and read the quantity of hydrocarbons on the analyzer. The result may not exceed the specification in Section 2 of this Standard.

4.6 *Notes*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

NOTE 3: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 4: The 0-1 range may be used provided that zero and span gas standards in helium with known levels of hydrocarbons between 0-1 ppm are used in the calibration of the analyzer.

NOTE 5: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero gas matrices must coincide with that of the sample gas.

NOTE 6: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the most common hydrocarbon impurities in helium can be accurately totaled and compared to methane.

SEMI C3.45-92 (Withdrawn 0701)
STANDARD FOR HEXAFLUOROETHANE (C_2F_6), 99.996% QUALITY (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Hexafluoroethane is one of the most stable of all organic compounds. It is inert, colorless, nonflammable, odorless and tasteless.

SEMI C3.37-0701
SPECIFICATION FOR HEXAFLUOROETHANE (C_2F_6), 99.97% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1989; previously published in 1993.

1 Description

1.1 Hexafluoroethane is one of the most stable of all organic compounds. It is inert, colorless, nonflammable, odorless and tasteless.

2 Specifications

QUALITY: 99.97%

Impurities	*Maximum Impurities Acceptable (ppm)**
Carbon Dioxide (CO_2)	1
Carbon Monoxide (CO)	1
Nitrogen (N_2)	100
Other Halogenated Hydrocarbons (CF_3Cl, CF_3H, CF_2HCl, C_2F_5Cl)	50
Oxygen (O_2)	25
Water (H_2O) (v/v)	40
TOTAL LISTED IMPURITIES	217

*An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Chemical Specification

Total Acidity	0.1 ppmw max.

4 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	138.01	138.01
Boiling point at 1 atm	-78.2°C	-108.8°F
Density of gas at 24°C (75°F) and 1 atm	5.734 kg/m^3	0.357 lb/ft^3
Specific gravity of gas at 24°C and 1 atm	4.823	4.823
Density of liquid at -80.0°C	1611 kg/m^3	100.6 lb/ft^3

5 Analytical Procedures (See Notes 1, 2, 3, and Figure 1)

5.1 *Oxygen, Nitrogen, Carbon Monoxide, and Carbon Dioxide* — This procedure is for the determination of oxygen, nitrogen, carbon monoxide, and carbon dioxide in hexafluoroethane using a gas chromatograph with an ultrasonic detector.

5.1.1 *Detection Limit* — 0.5 ppm (mol/mol) for each impurity.

5.1.2 *Instrument Parameters*

5.1.2.1 *Columns:*

Column 1:	Haysep D, 100/120 mesh, 4.6 m (15 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.
Column 2:	Porapak QS, 100/120 mesh, 2.1 m (7 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.
Column 3:	Porapak QS, 100/120 mesh, 3.6 m (2 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.
Column 4:	Haysep D, 100/120 mesh, 4.6 m (15 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.
Column 5:	Molecular Sieve 13×, 45/60 menh, 2.1 m (7 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.

5.1.2.2 Carrier Flow: 16 mL/min helium

5.1.2.3 Sample Volume: 1.0 and 2.0 mL

5.1.2.4 *Temperatures:*

Detector	120°C
Column 1, 2 and 5	50°C
Column 3 and 4	90°C
Valve	90°C

5.1.2.5 *Time Table* — Determine the times for valve switching and signal changes, and enter into the run table.

An example run table follows:

Valve	*On*	*Off*
1	0.01	*
2	9.20	*
3	0.01	12.00

* Valve left on until end of run.

5.1.3 *Calibration Standard* — 1–5 ppm (mol/mol) each carbon dioxide, nitrogen, oxygen and carbon monoxide, balance helium.

5.1.4 *Operating Procedure*

5.1.4.1 Inject a sample of the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. The approximate retention times are: oxygen 11.1 minutes, nitrogen 11.6

minutes, carbon monoxide 14.5 minutes and carbon dioxide 15.9 minutes.

5.1.4.2 Analyze the hexafluoroethane sample to be tested in the same manner as in 5.1.4.1

5.1.4.3 Repeat 5.1.4.1.

5.1.4.4 Calculate the concentration of oxygen, nitrogen, carbon monoxide and carbon dioxide in the sample, using the formula below. The result may not exceed specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

5.2 *Halogenated Hydrocarbons* — This procedure is for the determination of halogenated hydrocarbons in hexafluoroethane using a gas chromatograph with a flame ionization detector.

5.2.1 *Detection Limit* — 0.5 ppm (mol/mol).

5.2.2 *Instrument Parameters*

5.2.2.1 Column: 1% SP-1000 on Carbopak B, 60/80 mesh, 7.3 m (24 ft) by 3.2 mm (1/8 in) OD ss, or equivalent.

5.2.2.2 Carrier Flow: 40 mL/min helium

5.2.2.3 Support Gases: Set the flow rates as specified by the instrument manufacturer.

5.2.2.4 Sample Volume: 2.0 mL

5.2.2.5 Temperatures:

Detector	250°C
Initial Oven	35°C
Pre-Program Hold	7 min
Temperature Rise	10°C/min
Final Oven	150°C

5.2.3 *Calibration Standard* — 5 ppm (mol/mol) each CF_3H, C_2F_6, CF_3Cl, CF_2HCl, C_2F5Cl balance helium.

5.2.4 *Operating Procedure*

5.2.4.1 Inject a sample of the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. The order of elution is CF_3H, C_2F_6, CF_3Cl, CF_2HCl, C_2F_5Cl.

5.2.4.2 Analyze the hexafluoroethane sample to be tested in the same manner as in 5.2.4.1.

5.2.4.3 Repeat 5.2.4.1.

5.2.4.4 Calculate the concentration of each impurity in the sample using the formula below. Total the amounts of chlorofluorocarbons and hydrofluorocarbons. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \frac{\text{Concentration}}{\text{of Standard}} = \frac{\text{Concentration}}{\text{of Sample}}$$

5.3 *Water (See Note 4)* — This procedure is for the determination of trace moisture (water) in hexafluoroethane, using a continuous flowing electrolytic hygrometer.

5.3.1 *Detection Limit* — 1.0 ppm (ppmw). This is equivalent to a frostpoint of -76°C (-105°F).

5.3.2 *Sample Pressure and Flow* — Set in accordance with instrument manufacturer's instructions.

5.3.3 *Operation Check* — The instrument should be checked periodically for correct operation. A gas containing a known amount of moisture should be passed through the instrument. Agreement between the hygrometer and the standard should be within their relative accuracies.

5.3.4 *Operating Procedure*

5.3.4.1 Obtain a continuous flow sample of the hexafluoroethane source, using a clean, electropolished or passivated (see Note 5) stainless steel line which has been purged dry after exposure to ambient moisture.

5.3.4.2 After purging with a dry gas, allow the sample gas to flow through the sampling system and hygrometer until a stable reading is obtained. The reading may not exceed specification in Section 2 of this Standard.

5.4 *Notes*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should not contain more than 10% of the specified value of the component of interest, unless otherwise stated.

NOTE 3: Samples of hexafluoroethane should be equilibrated at no less than 22°C (72°F) for at least 24 hours prior to analysis to ensure that the material, whose critical temperature is 20°C (68°F), is single phase.

NOTE 4: The sampling system and hygrometer must be designed to operate at the sample pressure, or the sample pressure must be reduced (by a regulator with a stainless steel diaphragm) to accommodate the pressure restrictions of the hygrometer.

NOTE 5: A passivation procedure is described in Metals Handbook, Eighth Edition, Volume 2, ASM International, Metals Park, Ohio.

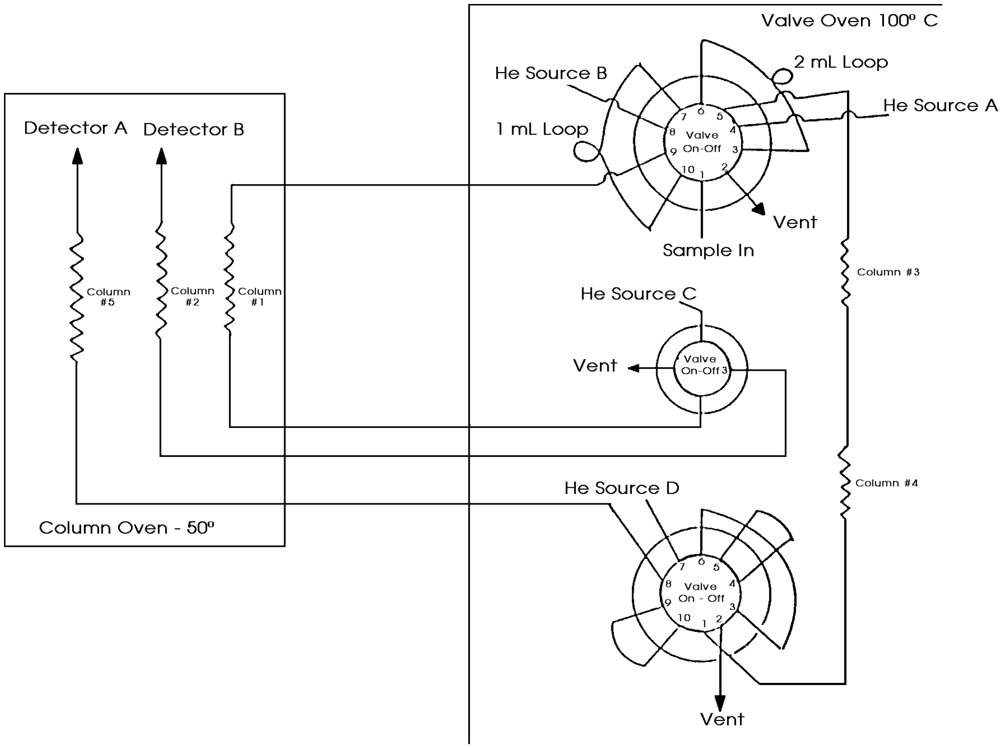

Figure 1
Configuration for the Analysis of O_2, N_2O_2 in C_2F_6

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SEMI C3.19-0200
STANDARD FOR HYDROGEN (H_2), 99.9995% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org January 2000, to be published February 2000. Originally published in 1982; previously in 1996.

1 Description

1.1 Hydrogen is a colorless gas. Its vapors are highly flammable, colorless, tasteless, and nontoxic. It is the lightest gas known.

2 Specifications

QUALITY: 99.9995%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Carbon Dioxide (CO_2)	0.5
Carbon Monoxide (CO)	0.5
Nitrogen (N_2)	2
Oxygen (O_2)	0.5
Particles	(See NOTE 2.)
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	0.5
TOTAL SPECIFIED IMPURITIES	4.5

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

NOTE 2: To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	2.016	2.016
Boiling point at 1 atm	–252.7°C	–423.0°F
Density of gas at 21.1°C (70°F) and 1 atm	0.0834401 kg/m^3	0.005209 lb/ft^3
Specific gravity of gas at 0°C (32°F) and 1 atm (air = 1)	0.06950	0.06950
Density of liquid at boiling point	68.6 kg/m^3	4.28 lb/ft^3

4 Analytical Procedures (See NOTES 1 and 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in hydrogen using a gas chromatograph with a flame ionization detector and methanizer.

4.1.1 *Detection Limit* — 100 ppb (mole/mole)

4.1.2 *Instrument Parameters*

4.1.2.1 *Column* — Porapak T or Q, 3 m (9.8 ft) by 3 mm (1/8 in) ID by 2.2 mm (0.085 in) OD stainless steel;

or

Chromosorb 102, 2 m (6.6 ft) by 3 mm stainless steel;

or equivalent.

4.1.2.2 *Carrier Flow* — 30 mL/min helium

4.1.2.3 *Sample Volume* — 0.5 to 2.0 mL

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standard* — 0.5–2.5 ppm (mole/mole) carbon monoxide, 0.5–2.5 ppm (mole/mole) carbon dioxide, balance hydrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat Section 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the hydrogen sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Nitrogen* — This procedure is for the determination of nitrogen in hydrogen using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 500 ppb (mole/mole)

4.2.2 *Instrument Parameters*

4.2.2.1 *Column* — 5A molecular sieve 1.9 m (6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID by stainless steel or equivalent.

4.2.2.2 *Carrier Flow* — 30 mL/min helium

4.2.2.3 *Sample Volume* — 3.0 mL

4.2.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.2.3 *Calibration Standard* — 0.5–2.5 ppm, (mole/mole) nitrogen in hydrogen.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.3 Repeat Section 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the hydrogen sample being tested. Calculate the concentration of nitrogen, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in hydrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole)

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer’s instructions.

4.3.3 *Calibration Standard* — 0.5–2.5 ppm (mole/mole) oxygen in hydrogen or in accordance with the instrument manufacturer’s instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce hydrogen sample and record oxygen reading. The result may not exceed the specification in Section 2 of this standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in hydrogen using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer. (See NOTES 3, 4, and 5.)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole)

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air: 350–400 mL/min.

4.4.2.3 Set sample flow rates in accordance with instrument manufacturer’s instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Zero hydrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.4.3.2 The upper level span gas not exceeding five times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the initial flow settings for hydrogen, air and sample once established.

4.4.4.2 Introduce the zero hydrogen with known quantity of hydrocarbons and using the 0–10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.4.4.3 Introduce the span gas standard in hydrogen and using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.4.4.4 Repeat Sections 4.4.4.2 and 4.4.4.3 until reproducibility of readings is better than 1% full scale.

4.4.4.5 Introduce hydrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in hydrogen using a continuous flowing piezoelectric hygrometer. (See NOTE 6.)

4.5.1 *Detection Limit* — 0.1 ppm (vol/vol) or –90°C (–130°F)

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer’s instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the hydrogen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this standard.

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

NOTE 3: The 0-1 range can be used provided that zero and span gas standards in hydrogen with known levels of hydrocarbons between 0 and 1 ppm are used in the calibration of the analyzer.

NOTE 4: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero gas matrices must coincide with that of the sample gas.

NOTE 5: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

NOTE 6: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

SEMI C3.30-96 (Reapproved 0999)
STANDARD FOR HYDROGEN (H_2), BULK, 99.9997% QUALITY

This standard was technically reapproved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1986; previously published in 1996.

1 Description

1.1 Hydrogen is a colorless gas. Its vapors are highly flammable, colorless, tasteless, and nontoxic. It is the lightest gas known.

2 Specifications

QUALITY: 99.9997% (see Note 1)

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide andcarbon dioxide ($CO + CO_2$)	0.2
Nitrogen (N_2)	2.0
Oxygen (O_2)	0.2
Particles	**
Total Hydrocarbons expressed as Methane (THC)	0.2
Water (H_2O) (v/v)	0.2
TOTAL IMPURITIES	2.8

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	2.016	2.016
Boiling point at 1 atm	-252.7°C	-423.0°F
Density of gas at 21.1°C (70°F) and 1 atm	0.0834401kg/m^3	0.005209 lb/ft^3
Specific gravity of gas at 0°C (32°F) and 1 atm (air = 1)	0.06950	0.06950
Density of liquid at boiling point	68.6 kg/m^3	4.28 lb/ft^3

4 Analytical Procedures

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in hydrogen using a gas chromatograph with a flame ionization detector and methanizer.

4.1.1 *Detection Limit* — 50 ppb (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column:

Porapak T or Z, 3 m (9.8 ft) by 3.2 mm (1/8 in) ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3.2 mm ss;

or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standard* — 1-5 ppm (mole/mole) carbon monoxide, 1-5 ppm (mole/mole) carbon dioxide, balance hydrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the hydrogen sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed specifications in Section 2 of this standard.

4.2 *Nitrogen* — This procedure is for the determination of nitrogen in hydrogen using a gas chromatograph with a helium ionization detector (see Notes 2, 3, 4, 5, 6, and Figures 1 and 2).

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.2.1 Detection Limit — 12 ppb.

4.2.2 Instrument Parameters

4.2.2.1 Columns:

Column 1 (Pre-Column):	Molecular sieve 5A, 60/80 Mesh, 2.4 m (8 ft) by 3.2 mm (1/8 in), ss, or equivalent.
Column 2 (Analytical Column):	Molecular sieve 5A, 60-80 Mesh, 2.4 m by 3.2 mm, ss, or equivalent.

4.2.2.2 Carrier Flow: 40 mL/min helium.

4.2.2.3 Sample Volume: 1.0 mL.

4.2.2.4 Temperatures:

Detector	100°C
Column	50°C
Hydrogen Purifier	300°C

4.2.2.5 Determine the breakdown voltage of the detector. Set operating voltage at 10 volts below breakdown.

4.2.3 *Calibration Standard* — 2 ppm (mole/mole) nitrogen, balance hydrogen (99.9999% purity).

4.2.4 *Operating Procedure*

4.2.4.1 Set timing interval on sample select valve to 10 sec.

4.2.4.2 Set timing interval on gas sampling valve to 3 minutes.

4.2.4.3 Set timing interval #3 to 5 minutes.

4.2.4.4 Do not change the initial sample flow setting once established.

4.2.4.5 Obtain a continuous flow of the calibration standard using a clean stainless steel line (0.5 mm (.02 in.) ID).

4.2.4.6 Inject the calibration standard onto the column with the gas sampling valve. Record the retention times and peak areas.

4.2.4.7 Repeat 4.2.4.6 until reproducibility of reading is better than 1% of full scale.

4.2.4.8 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.9 Compare the average peak area of the hydrogen sample being tested to that of the calibration standard. Calculate the concentration of nitrogen, using the formula below. The result may not exceed the specification in Section 2 of this standard.

4.3 *Oxygen* — This procedure is for the determination of oxygen in hydrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 50 ppb (mole/mole).

4.3.2 *Instrument Parameters* — Set the sample pressure and flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 1-10 ppm (mole/mole) oxygen in hydrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce hydrogen containing less than 2 ppm oxygen through a deoxygenation catalyst to verify that there is no leakage of air into the system and to demonstrate that the detection limit can be achieved.

4.3.4.3 Introduce the calibration standard. Using the span adjust knob, set the needle (or output reading) to match the level oxygen in the calibration gas.

4.3.4.4 Introduce hydrogen sample and record the oxygen reading. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.4 *Water* — This procedure is for the determination of trace moisture (water) in hydrogen using a continuous flowing piezoelectric hygrometer (see Note 7).

4.4.1 *Detection Limit* — 0.1 ppm (vol/vol) or -90°C (-130°F).

4.4.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.4.4 *Operating Procedure*

4.4.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.4.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.4.4.3 Determine the moisture content of the hydrogen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this standard.

4.5 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in hydrogen using a continuous flow flame ionization detector equipped total hydrocarbon analyzer. (See Note 8.)

4.5.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.5.2 *Flow Requirements*

4.5.2.1 High-purity, hydrocarbon-free (less than 1.0 ppm) hydrogen: 35-40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75-80 mL/min.

4.5.2.2 Dry, hydrocarbon-free (less than 1.0 ppm) air: 350-400 mL/min.

4.5.2.3 Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards*

4.5.3.1 Zero hydrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.5.3.2 *Span Gas* — Hydrogen with known quantity (1-10 ppm) hydrocarbons.

4.5.4 *Operating Procedure*

4.5.4.1 Do not change the initial flow setting for hydrogen, air and sample once established.

4.5.4.2 Introduce the zero hydrogen with known quantity of hydrocarbons and, using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.5.4.3 Introduce the span gas standard in hydrogen and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.5.4.4 Repeat steps 4.5.4.2 and 4.5.4.3 until reproducibility of readings is better than 1% of full scale.

4.5.4.5 Introduce hydrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

4.6 *Notes*

NOTE 1: A purifier is allowed to be used to meet this specification.

NOTE 2: All carrier lines must be cleaned stainless steel.

NOTE 3: The carrier gas must be 99.9998% purity helium with less than 40 ppb carbon dioxide.

NOTE 4: Use a stainless steel pressure regulator with no pipe threads, PTFE thread sealant or other plastic seal components for the carrier gas.

NOTE 5: Due to the extreme sensitivity of the helium ionization detector, it is imperative that the system be leak tested to 1 X 10^{-7} atm. cc/sec (helium) or lower with a helium leak detector.

NOTE 6: The hydrogen separator is the palladium tube type where the sample flows through a heated palladium tube through which the hydrogen selectively diffuses separating it from the impurities which are carried to the column by the helium carrier gas.

NOTE 7: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced, by a regulator with a diaphragm of stainless steel or other suitable material, to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 8: The 0-1 ppm range can be used provided that zero and span gas standards in hydrogen with known levels of hydrocarbons between 0-1 ppm are used in the calibration of the analyzer.

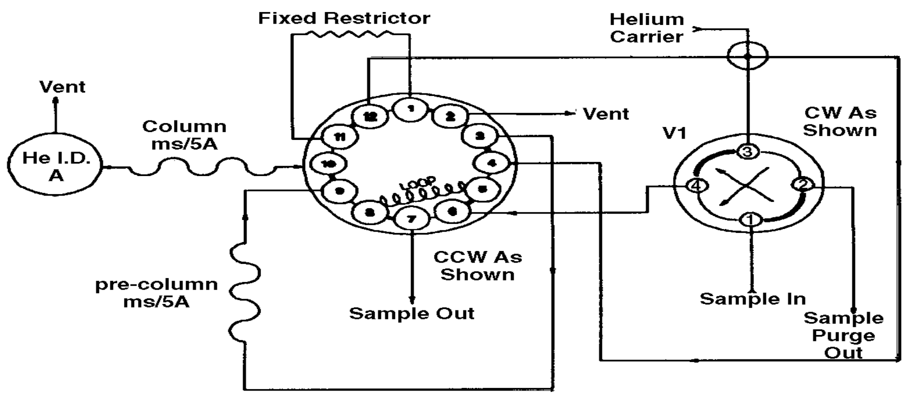

Figure 1
Analysis of Nitrogen

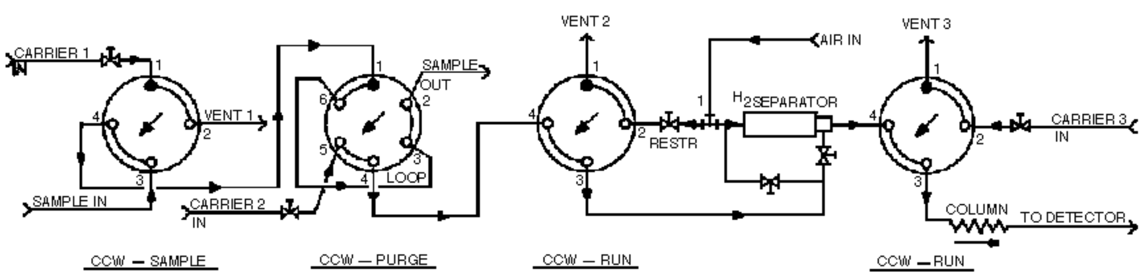

Figure 2
Flow Diagram for Discharge Ionization Detector Gas Chromatograph with Integral Hydrogen Separator

SEMI

SEMI C3.47-1101
SPECIFICATION FOR HYDROGEN BROMIDE (HBr), 99.98% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1993; previously published in 1995.

1 Description

1.1 Hydrogen Bromide is an irritating and corrosive gas with a sharp, penetrating, suffocating odor. It is colorless and nonflammable, but fumes in moist air.

2 Specifications

QUALITY: 99.98%, ASSAY (Total Acidity): 98% min

Impurities	*Maximum Impurities Acceptable (ppm)**
Carbon Dioxide (CO_2)	50
Carbon Monoxide (CO)	5
Hydrogen Chloride (HCl)	**
Methane (CH_4)	15
Oxygen (O_2) + Nitrogen (N_2)	50
Water (H_2O) (v/v)	5
TOTAL LISTED IMPURITIES (excluding metals)	125

Impurities	*Maximum Impurities Acceptable (ppm)**
Iron (Fe)	1 (by weight, vapor phase)

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.
** To be analyzed and reported (typically 500 ppm).

3 Physical Constants (for information only)

	Metric Units	*U.S. Units*
Molecular Weight	80.92	80.92
Boiling Point at 1 atm	-66.7°C	-88.1°F
Density of gas at 70°F (21.1°C) and 1 atm	3.333 g/L	0.208 lb/ft^3
Specific gravity of gas	2.7	2.7
Critical Pressure	85.16 bar	1234.8 psia
Critical Temperature	90°C	193.6°F

4 Analytical Procedures

4.1 *Nitrogen, Oxygen, Carbon Monoxide, Methane, and Carbon Dioxide* — This procedure is for the determination of nitrogen, oxygen + argon, carbon monoxide, methane, and carbon dioxide using a gas chromatograph with a discharge ionization detector.

4.1.1 *Detection Limits*

- N_2 < 10 ppb
- O_2 + Ar < 20 ppb
- CO < 20 ppb
- CH_4 < 10 ppb
- CO_2 < 10 ppb

4.1.2 *Instrument Parameters* — All components are analyzed using two columns and two detectors with a single injection. (See Figure 1.)

4.1.2.1 *Columns*:

- HayeSep Db 2.0 m (6 ft.) by 3.2 mm (1/8") O.D. by 2.2 mm (0.085") I.D.
- Molecular Sieve 5A 2.0 m (6 ft) by 3.2 mm (1/8") O.D by 2.2 mm (0.085") I.D. ss or equivalent (60/80 mesh)

4.1.2.2 *Carrier Flow* — 40 mL/min He

4.1.2.3 *Sample Volume* — 1.0 mL

4.1.2.4 Temperatures:

Detector	100°C
Column 1	40°C
Column 2	100°C

4.1.3 *Calibration Standards* — 5 ppm of each compound of interest including nitrogen, oxygen, carbon monoxide, methane, and carbon dioxide in helium.

4.1.4 *Operating Procedures*

4.1.4.1 Inject a sample of the calibration standard into the HayeSep column using a gas sample valve. Allow the effluent of HayeSep column to enter the Molecular Sieve column until after CO has eluted. Switch the switching valve to allow the methane and CO_2 to elute directly into detector A while oxygen, nitrogen, and CO separate on the molecular sieve column and elute into detector B. Record retention times and peak areas for all peaks. The order of elution from the HayeSep column to detector A is methane and CO_2. The order of elution on the molecular sieve column to detector B is oxygen, nitrogen, and CO.

4.1.4.2 Analyze the HBr sample to be tested in the same manner.

4.1.4.3 Analyze the calibration standard again.

4.1.4.4 Compare the average peak area of the calibration standard to that of the HBr sample being tested. Calculate the concentration of impurities, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Water* — This procedure is for the determination of trace moisture (water) in hydrogen bromide gas using a continuous flowing, cooled surface condensation point hygrometer.

NOTE 1: The National Institute of Standards and Technology (NIST) provides calibration services for the thermometer used in condensation point hygrometers.

NOTE 2: This method is not applicable if other constituents in the gas will condense before the moisture condensation i.e., excessive carbon dioxide and/or oil contamination.

NOTE 3: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced to accommodate the pressure restrictions of the analytical hygrometer using a regulator with a stainless steel diaphragm.

4.2.1 *Detection Limit* — 2.0 ppm.

4.2.2 *Flow Requirements:*

4.2.2.1 Sample flow rate and pressure will be set in accordance with the instrument manufacturer’s instructions.

4.2.2.2 Gas must flow past the chilled mirror where optic means are provided to detect the deposit (condensation) and to read the thermometer measuring the temperature of the mirror.

4.2.3 *Calibration*

4.2.3.1 A calibration thermometer designed to indicate temperatures in the –89°C (–121°F) range is required.

4.2.3.2 A calibration curve representing water added to dried hydrogen bromide vs condensation point is required. This can be obtained by preparing a standard of water balance nitrogen and mixing it with dry hydrogen bromide using a dynamic gas blender with mass flow controllers or calibrated flow meters. The hydrogen bromide gas can be dried by passing it over an activated molecular sieve (5A) or magnesium perchlorate.

4.2.4 *Operating Procedures*

4.2.4.1 Obtain a continuous flow of sample gas from the source using a clean stainless steel sampling line which has been purged dry after exposure to ambient moisture.

4.2.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the condensation point hygrometer for one-quarter hour to two hours to allow the entire system to reach equilibrium with regard to moisture content.

4.2.4.3 After equilibrium has been reached, cool the mirror to determine the actual condensation point of the sample. Follow the manufacturer’s recommendations to create the temperatures needed.

4.2.4.4 Continue to verify the condensation point for at least 30 minutes after a stable reading has been confirmed.

4.2.4.5 Correct the condensation point reading from the measured pressure to 1 atm of pressure. The result may not exceed the specification in Section 2 of this standard.

4.3 *Iron* — This procedure is for the determination of iron in gaseous hydrogen bromide and analyzed by inductively coupled plasma.

4.3.1 *Sampling Apparatus*

- 3 Teflon diaphragm valves (1/4" FNPT) (Fluoroware 201-10 or equivalent)
- 2 Teflon tees (1/4") (Fluoroware UT4FN-1 or equivalent)
- 50 ft. Teflon tubing (1/4") (Fluoroware AT250-047 or equivalent)
- Teflon flow meter (1/4" FNPT calibrated for HBr flow) (Fluoroware FM-4N-1P or equivalent)
- 8 Teflon connectors (1/4" tube to 1/4" MNPT (Fluoroware C4-CFN-1 or equivalent)
- 9 gas washing bottles (375 mL) (Savillex #507 or equivalent with 501-4-2 cap)
- Tee purge assembly (Matheson 4756-330 or equivalent)
- Manual control valve (Matheson 55A-330 or equivalent)
- Cylinder scale that can measure the mass of the cylinder to ± 1 g accuracy.

4.3.2 *Water* — 18 megaohm-cm DI water is used for all dilution blanks and washings.

4.3.3 *Reagents* — All reagents are of the highest purity available minimizing background metal contamination.

4.3.4 *Sampling Gaseous Hydrogen Bromide*

4.3.4.1 Assemble sampling apparatus in laboratory hood for safety.

4.3.4.2 Fill gas washing bottles (scrubbers) with 75 mL 18 megaohm-cm DI water.

4.3.4.3 Start nitrogen purge to remove air from system and to check for leaks.

4.3.4.4 Close V4 and nitrogen purge.

4.3.4.5 Close V2.

4.3.4.6 Open V1 and V3.

4.3.4.7 Open V2 and controlling flow rate at 1 L/min taking care not to over-pressurize system.

4.3.4.8 Continue flow through scrubber train #1 until scale shows that approximately 100 grams of HBr have been purged.

4.3.4.9 Open V4 and close V3. Record the weight of HBr cylinder.

4.3.4.10 Collect 100 grams of HBr in scrubber train #2. Close V1 and record weight of HBr sampled.

4.3.4.11 Open nitrogen purge and purge lines, scrubber train #1 and scrubber train #2, before disconnecting scrubbers.

4.3.5 *Sample Preparation*

4.3.5.1 For each scrubber train, quantitatively wash with DI water and add to 250 mL volumetric.

4.3.5.2 Wash associated tubing of each scrubber train with DI water and add to the 250 mL volumetric.

4.3.5.3 Make up reagent blank of water from the same lot of DI water used in the sampling.

4.3.6 *Calibration* — Make calibration standards by serial dilution of standard iron solution which is matrix matched traceable to NIST.

4.3.7 *Instrument Parameters* — Perform analysis on an inductively coupled plasma spectrometer or equivalent technique employing operating procedures suggested by manufacturer. Correct result to ppm (ppmw) basis on HBr used.

4.4 *Chloride Ion* — This procedure is for the determination of chloride ion in gaseous hydrogen bromide using ion chromatography.

4.4.1 *Detection Limit* — 5 ppb wt/vol.

4.4.2 Sample was prepared as in Section 4.3.5. The 250 mL aqueous sample was diluted further 500 to 1, by diluting one milliliter of 250 mL aqueous sample with DI water in a 500 mL volumetric flask.

4.4.3 *Instrument Parameters*

4.4.3.1 *Flow*:

- Eluent l0 mM NaOH at 1 cc/min.
- Regenerate 25 mM H_2SO_4 at 7 psi.

4.4.3.2 *Column* — AS5A with AG5A guard column

4.4.3.3 *Sample Size* — 25 microliters.

4.4.3.4 *Program* — Boost eluent concentration to 100 mM NaOH after elution of chloride peak (4.3 min). Continue 100 mM eluent flow for 7 minutes to elute bromide peak. Return to 10 mM NaOH at 12 minutes. Allow to equilibrate for 6 minutes.

4.4.4 *Calibration* — A multi-point calibration curve is constructed in the range of 10 ppb to 250 ppb (wt/vol) employing standards traceable to NIST.

4.4.5 Use procedures provided by manufacturer of ion chromatograph. Correct results and calculate them to pure HBr on a weight/weight basis.

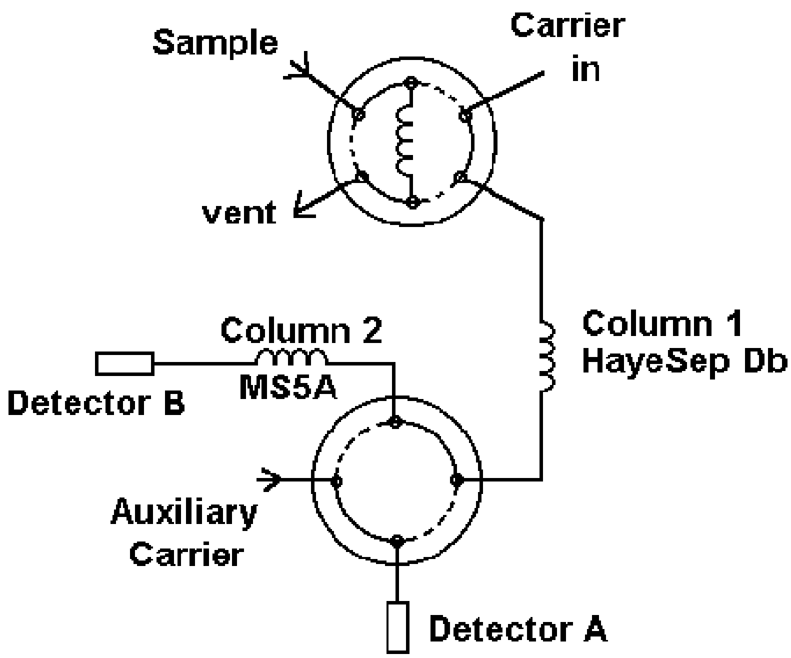

Figure 1
Column Configuration for the Analysis of CO, CO_2, and Hydrocarbons

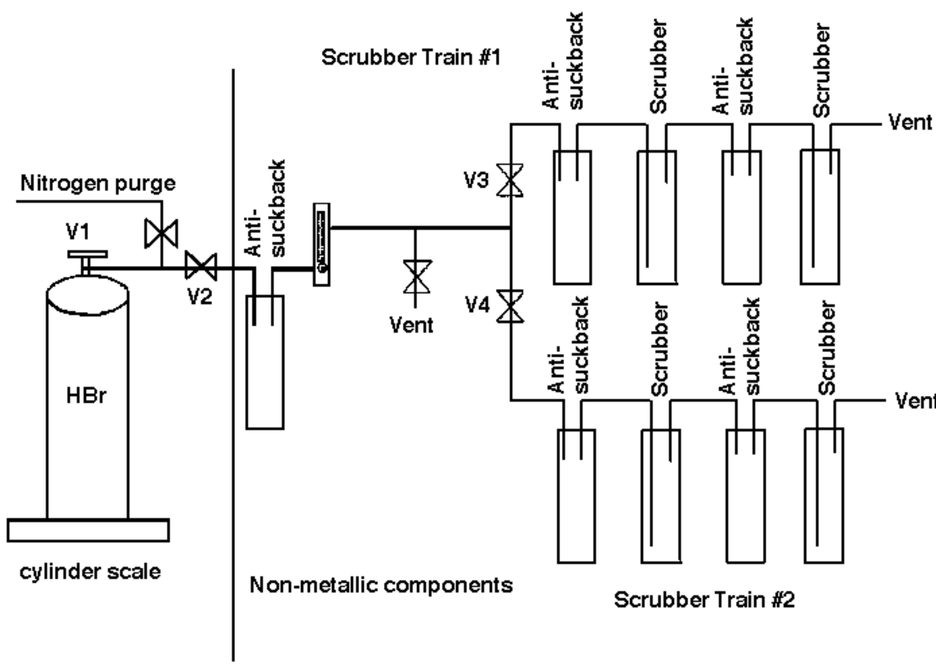

Figure 2
Iron Analysis Sampling Apparatus

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.36-94 (Withdrawn 0701)
STANDARD FOR HYDROGEN CHLORIDE (HCl), 99.994% QUALITY (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Hydrogen chloride is a colorless, pungent, corrosive gas having a suffocating odor. Hydrogen chloride is heavier than air and fumes strongly in moist air. It is very soluble in water and alcohol, and also soluble in ether. Hydrogen chloride is shipped as a liquified compressed gas stored under its own vapor pressure. As long as liquid is present in the cylinder, the pressure will remain fairly constant. When the liquid phase is exhausted, the cylinder pressure will drop rather rapidly.

SEMI C3.35-1101
SPECIFICATION FOR HYDROGEN CHLORIDE (HCl), 99.997% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1988; previously published in 1995.

1 Description

1.1 Hydrogen chloride is a colorless, pungent, corrosive gas having a suffocating odor. Hydrogen chloride is heavier than air and fumes strongly in moist air. It is very soluble in water and alcohol, and also soluble in ether. While in the cylinder under pressure, hydrogen chloride is in the form of a gas over liquid. As long as liquid is present in the cylinder, the pressure will remain fairly constant. When the liquid phase is exhausted, the cylinder pressure will drop rather rapidly.

2 Specifications

QUALITY: 99.997% (See Notes 1, 2, and 3.)

Impurities	*Maximum Acceptable Level (ppm)**
Carbon dioxide (CO_2)	10
Hydrogen (H_2)	5
Nitrogen (N_2)	10
Oxygen (O_2) + Argon (Ar)	1
Methane and Acetylene	1
Water (H_2O) (v/v)	1
TOTAL LISTED IMPURITIES (excluding metals)	28

	*Maximum Acceptable Level (ppm)**
Iron (Fe)	1 wt. vapor phase

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the procedure provided.

NOTE 1: Due to the reactive nature of the material and the impurities, this product should be used within a period which may be specified by the supplier.

NOTE 2: It is recommended that the user discontinue the use of a cylinder prior to complete consumption of the liquid phase. The content of cylinders should be determined by weight, not pressure.

NOTE 3: This specification applies to the gas phase of the cylinder as received.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	36.465	36.465
Boiling point at 1 atm	–85.°C	–121.°F
Density of gas at 21.1°C (70°F) and 1 atm	1.522 kg/m^3	0.095 lb/ft^3
Specific gravity of gas at 0°C (32°F) and 1 atm	1.268	1.268

4 Analytical Procedures

4.1 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in hydrogen chloride using a gas chromatograph with a thermal conductivity detector. A backflush is used to keep the main component from reaching the detector.

4.1.1 *Detection Limit* — 2 ppm.

4.1.2 *Instrument Parameters*

4.1.2.1 Column: Porapak Q, 2.4 m (8 ft) by 6.4 mm (1/4 in) OD ss or equivalent.

4.1.2.2 Carrier Flow: 40 mL/min helium.

4.1.2.3 *Temperatures*:

Detector	50°C
Column Oven	40°C

4.1.2.4 Sample Volume: 10 mL.

4.1.3 *Calibration Standard* — 100 ppm carbon dioxide in helium.

4.1.4 *Operating Procedure*

4.1.4.1 To determine the backflush time, inject the calibration standard, using a gas sampling valve. Record the retention time for carbon dioxide. Choose the backflush time so that the complete carbon dioxide peak is eluted.

4.1.4.2 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Backflush at the time determined in Section 4.1.4.1.

4.1.4.3 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas. Backflush the main component at the time determined in Section 4.1.4.1.

4.1.4.4 Repeat Section 4.1.4.2.

4.1.4.5 Compare the average peak area of the calibration standard to that of the hydrogen chloride sample being tested. Calculate the concentration of carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Hydrogen* — This procedure is for the determination of hydrogen in hydrogen chloride using a gas chromatograph with a thermal conductivity detector.

4.2.1 *Detection Limit* — 3 ppm.

4.2.2 *Instrument Parameters*

4.2.2.1 *Columns*:

Column 1:	Ascarite, 0.3 m (1 ft) by 9.6 mm (3/8 in) OD ss or equivalent.
Column 2:	Molecular Sieve 5A, 2.4 m (8 ft) by 6.4 mm (1/4 in) OD ss or equivalent.

4.2.2.2 Carrier Flow: 40 mL/min nitrogen.

4.2.2.3 *Temperatures*:

Detector	50°C
Column Oven	40°C

4.2.2.4 Sample Volume: 10 mL.

4.2.3 *Calibration Standard* — 50 ppm hydrogen in nitrogen.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard with that of the hydrogen chloride sample being tested. Calculate the concentration of hydrogen using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Iron* — This procedure is for the determination of iron sampled from gaseous hydrogen chloride and analyzed by inductively coupled plasma.

4.3.1 *Sampling Apparatus*

- 3 Teflon diaphragm valves (1/4" FNPT) (Fluoroware 201-10 or equivalent).
- 2 Teflon tees (1/4") (Fluoroware UT4FN-1 or equivalent).
- 50 ft. Teflon tubing (1/4") (Fluoroware AT250-047 or equivalent).
- Teflon flow meter (1/4" FNPT calibrated for HCl flow) (Fluoroware FM-4N-1P or equivalent).
- 8 Teflon connectors (1/4" tube to 1/4" MNPT (Fluoroware C4-CFN-1 or equivalent).
- 9 gas washing bottles (375 mL) (Savillex #507 or equivalent with 501-4-2 cap).
- Tee purge assembly (Matheson 4756-330 or equivalent).
- Manual control valve (Matheson 55A-330 or equivalent).
- Cylinder scale that can measure the mass of the cylinder to ± 1 g accuracy.

4.3.2 *Water* — 18 megohm-cm DI water is used for all dilution blanks and washings.

4.3.3 *Reagents* — All reagents are of the highest purity available minimizing background metal contamination.

4.3.4 *Sampling Gaseous Hydrogen Chloride*

4.3.4.1 Assemble entire sampling apparatus (see Figure 1) in laboratory hood for safety.

4.3.4.2 Fill gas washing bottles (scrubbers) with 75 mL 18 mega-ohm DI water.

4.3.4.3 Start nitrogen purge to remove air from system and to check for leaks.

4.3.4.4 Close V4 and close nitrogen purge.

4.3.4.5 Close V2.

4.3.4.6 Open V1 and V3.

4.3.4.7 Open V2, and, controlling flow rate at 1 L/min., take care not to over-pressurize system.

4.3.4.8 Continue flow through scrubber train #1 until scale shows that approximately 100 grams of HCl have been purged.

4.3.4.9 Open V4 and close V3. Record the weight of HCl cylinder.

4.3.4.10 Collect 100 grams of HCl in scrubber train #2. Close V1 and record weight of HCl sampled.

4.3.4.11 Open nitrogen purge and purge lines, scrubber train #1 and scrubber train #2, before disconnecting scrubbers.

4.3.5 *Sample Preparation*

4.3.5.1 For each scrubber train, quantitatively wash both scrubbers with DI water and add to 250 mL volumetric flask.

4.3.5.2 Wash associated tubing of each scrubber train with DI water and add to 250 mL volumetric flask.

4.3.5.3 Make up reagent blank of water from the same lot of DI water used in the sampling.

4.3.6 *Calibration* — Make calibration standards by serial dilution of standard iron solution traceable to NIST.

4.3.7 *Instrument Parameters* — Perform analysis on an inductively coupled plasma spectrometer employing operating procedures suggested by manufacturer. Correct result to ppm (wt/wt) basis on HCl used.

4.4 *Nitrogen* — This procedure is for the determination of nitrogen in hydrogen chloride using a gas chromatograph with a thermal conductivity detector.

4.4.1 *Detection Limit* — 1 ppm.

4.4.2 *Instrument Parameters*

4.4.2.1 *Columns*:

Column 1:	Ascarite, 0.3 m (1 ft) by 9.6 mm (3/8 in) OD ss or equivalent.
Column 2:	Molecular Sieve 5A, 2.4 m (8 ft) by 6.4 mm (1/4 in) OD ss or equivalent.

4.4.2.2 Carrier Flow: 40 mL/min helium.

4.4.2.3 *Temperatures*:

Detector	50°C
Column Oven	40°C

4.4.2.4 Sample Volume: 10 mL.

4.4.3 *Calibration Standard* — 100 ppm nitrogen in helium.

4.4.4 *Operating Procedure*

4.4.4.1 Inject the calibration standard using a gas sampling valve. Record the retention time and peak area.

4.4.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.4.4.3 Repeat Section 4.4.4.1.

4.4.4.4 Compare the average peak area of the calibration standard with that of the hydrogen chloride sample being tested. Calculate the concentration of nitrogen, using the formula below. The results may not exceed the specification in Section 2 of this Standard.

4.5 *Oxygen + Argon* — This procedure is for the determination of oxygen + argon in hydrogen chloride using a gas chromatograph with a thermal conductivity detector.

4.5.1 *Detection Limit* — 1 ppm. The oxygen and argon elute simultaneously and are therefore quantified as a sum.

4.5.2 *Instrument Parameters*

4.5.2.1 *Columns*:

Column 1:	Ascarite, 0.3 m (1 ft) by 9.6 mm (3/8 in) OD or equivalent.
Column 2:	Molecular Sieve 5A, 2.4 m (8 ft) by 6.4 mm (1/4 in) OD ss or equivalent

4.5.2.2 Carrier Flow: 40 mL/min helium.

4.5.2.3 *Temperatures*

: Detector	50°C
Column Oven	40°C

4.5.2.4 Sample Volume: 10 mL.

4.5.3 *Calibration Standard* — 1–5 ppm oxygen in helium.

4.5.4 *Operating Procedure*

4.5.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.5.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.5.4.3 Repeat Section 4.5.4.1.

4.5.4.4 Compare the average peak area of the calibration standard with that of the hydrogen chloride sample being tested. Calculate the total concentration of oxygen + argon, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.6 *Methane and Acetylene* — This procedure is for the determination of methane and acetylene in hydrogen chloride. Samples from gas phase are analyzed by a gas chromatograph with a flame ionization detector. A backflush is used to keep the main component from the detector. (See Figure 2.)

4.6.1 *Detection Limit* — 0.1 ppm for each impurity.

4.6.2 *Instrument Parameters*

4.6.2.1 *Column*:

Alumina-GC, 60-80 mesh, Chromopack, 1.5 m (5 ft) by 2 mm ID (1/8 in OD) ss;

or

Alumina-GC, 60-80 mesh, Chromopack, 2 m (6.7 ft) by 2 mm ID (1/8 in OD) ss;

or equivalent.

4.6.2.2 Detector Sensitivity: 0.012 coulombs/gram.

4.6.2.3 Carrier Flows (1 and 2): 30 mL/min helium.

4.6.2.4 Set the following rates as specified by the instrument manufacturer.

Support Gases:

Hydrogen Flow:	30 mL/min.
Air Flow:	450 mL/min.

4.6.2.5 *Temperatures*:

Detector	200°C
Column Oven	100°C

4.6.2.6 Sample Volume: 0.5 mL.

4.6.2.7 Sample Flow: 200 mL/min.

4.6.3 *Calibration Standard* — 5 to 10 ppm each methane and acetylene in nitrogen.

4.6.4 *Operating Procedure*

4.6.4.1 Install switching valve and columns.

4.6.4.2 Adjust carrier gas flows:

Switching valve in injection position

- Set a flow rate of 30 mL/min, with the regulator T1 measured at the FID outlet.

Switching valve in backflush position

- Set a flow rate of 30 mL/min, with the regulator T2 measured at the FID outlet.
- Set a flow rate of 30 mL/min, with the metering valve, measured at the pre-column outlet.

A last adjustment between the injection and backflush position may be carried out by the FID signal. For this, the baseline is recorded in the injection and backflush position. With the regulator T2, the flow rate is changed so far as there is no offset in the baseline while switching.

4.6.4.3 Adjust hydrogen and air flows and ignite the burner, following the instrument manufacturer's instructions. Allow the system to stabilize for at least 30 minutes.

4.6.4.4 *Determine backflush time* — Inject calibration standard and leave the switching valve in inject position until all components have been eluted. Determine retention times for methane and acetylene. Choose backflush time so that the acetylene peak is completely registered.

4.6.4.5 Inject the calibration standard. Backflush at the time determined in Section 4.6.4.4. Record the retention times and peak areas.

4.6.4.6 Inject the sample to be tested in the same manner as the calibration standard. Backflush at the time determined in Section 4.6.4.4. Record the retention times and peak areas.

4.6.4.7 Repeat Section 4.6.4.5.

4.6.4.8 Compare the average peak areas of the calibration standard with those of the hydrogen chloride sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed the specifications in Section 3 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.7 *Water* — This procedure is for the determination of trace moisture (water) in hydrogen chloride gas using a continuous flowing, cooled-surface condensation point hygrometer.

4.7.1 *Detection Limit* — 1.0 ppm.

4.7.2 *Flow Requirements*

4.7.2.1 Set the sample flow rate and pressure in accordance with the instrument manufacturer’s instructions.

4.7.3 *Calibration Standards*

4.7.3.1 A calibration thermometer designed to indicate temperatures in the –89°C (–121°F) range is required.

NOTE 4: The National Institute of Standards and Technology (NIST) provides calibration services for the thermometers used in condensation point hygrometers.

4.7.3.2 A calibration curve representing water added to dried hydrogen chloride vs. condensation point is required. This can be obtained by preparing a standard of water balance nitrogen and mixing it with dry hydrogen chloride using a dynamic gas blender with mass flow controllers or calibrated flowmeters. The hydrogen chloride gas can be dried by passing it over activated molecular sieve (5A) or magnesium perchlorate.

NOTE 5: This method is not applicable if other constituents in the gas will condense before the moisture condensation, e.g., carbon dioxide or oil.

4.7.4 *Operating Procedure*

4.7.4.1 Obtain a continuous flow of sample gas from the source using a clean stainless steel sampling line which has been purged dry after exposure to ambient moisture.

NOTE 6: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced to accommodate the pressure restrictions of the analytical hygrometer using a regulator with a diaphragm of stainless steel or other suitable material.

4.7.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the condensation point hygrometer for one-quarter hour to two hours to allow the entire system to reach equilibrium with regards to moisture content.

4.7.4.3 After equilibrium has been reached, cool the mirror to determine the actual condensation point of the sample.

4.7.4.4 Continue to verify the condensation point for at least 30 minutes after a stable reading has been confirmed.

4.7.4.5 Correct the condensation point reading from the measured pressure to 1 atm of pressure. The result may not exceed the specification in Section 2 of this standard.

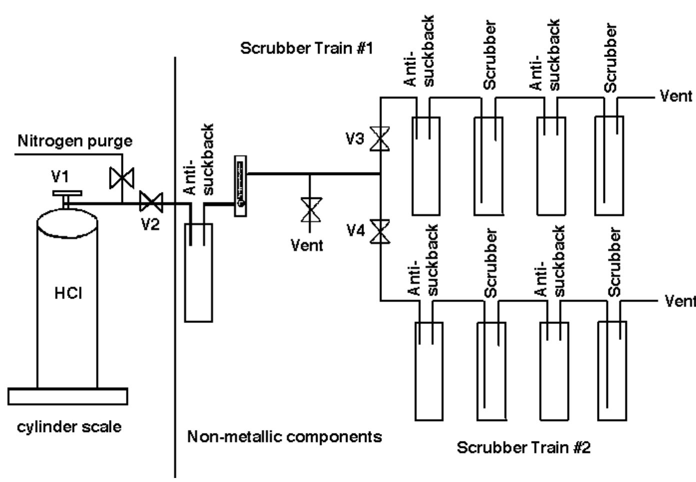

Figure 1
Metals Analysis Sampling Apparatus Vapor Phase Hydrolysis

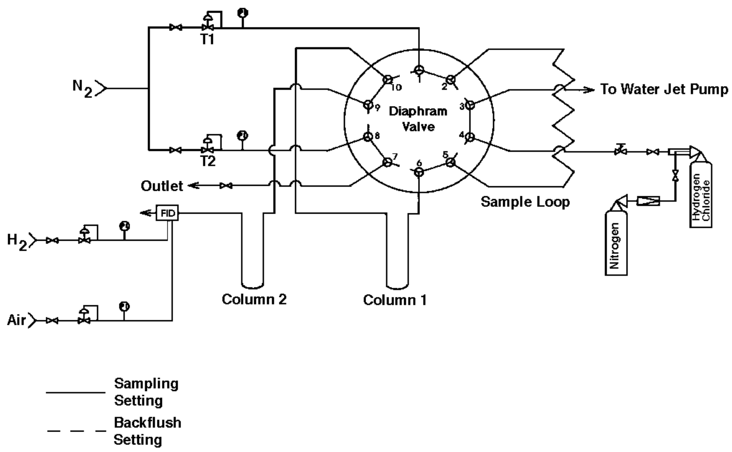

Figure 2
Column Configuration for the Analysis of Methane, Acetylene

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.43-90 (Withdrawn 0701)
STANDARD FOR HYDROGEN FLUORIDE (HF), ANHYDROUS (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Hydrogen fluoride is a highly toxic, irritating and corrosive gas with a sharp, pungent odor. It is colorless and nonflammable, but reacts violently with most organic materials.

SEMI C3.5-93 (Reapproved 0999)
STANDARD FOR NITROGEN (N_2), BULK LIQUID, 99.998% QUALITY

This specification was technically reapproved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1981; previously published in 1993.

1 Description

Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless liquid. Noncombustible; a cryogenic gas derived from liquid air by fractional distillation.

2 Specifications

QUALITY: 99.998%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon dioxide (CO2)	1
Carbon monoxide (CO)	5
Hydrogen (H_2)	2
Oxygen (O_2)	3
Particles	**
Total Hydrocarbons expressed as Methane (THC)	1
Water (H_2O) (v/v)	1
TOTAL SPECIFIED IMPURITIES	13

*An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	-195.8°C	-320.4°F
Density of gas at 21.1°C (70°F) and 1 atm	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1atm (air=1)	0.967	0.967
Density of liquid at boiling point	808.8 kg/m^3	50.49 lb/ft^3

4 Analytical Procedures (See Notes 1, 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in nitrogen using a gas chromatograph with a flame ionization detector and methanizer. (See Note 3.)

4.1.1 *Detection Limit* — 100 ppb (mole/mole).

4.1.2 Instrument Parameters

4.1.2.1 Column:

Porapak T or Q, 3 m (9.8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 0.5 to 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standards* — 1-5 ppm (mole/mole) carbon monoxide, 1-5 ppm (mole/mole) carbon dioxide, balance nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Hydrogen* — This procedure is for the determination of hydrogen in nitrogen using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 500 ppb (mole/mole).

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 1.9m (6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ss or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 3.0 mL

4.2.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.2.3 *Calibration Standard* — 1-5 ppm (mole/mole) hydrogen in nitrogen.

4.2.4 Operating Procedure

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentration of hydrogen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\\text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\\text{of Sample}\end{matrix}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole).

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 3-15 ppm (mole/mole) oxygen in nitrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the sample flow setting once established.

4.3.4.2 Introduce nitrogen sample and record oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a continuous flow flame ionization detector equipped total hydrocarbon analyzer. See Notes 4, 5, 6.)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35-40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75-80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1ppm) air: 350-400 mL/min.

4.4.2.3 Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Nitrogen with known quantity of hydrocarbons at 0.5 ppm level.

4.4.3.2 The upper level span gas not exceeding 5 times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the flow settings for hydrogen, air and sample once established.

4.4.4.2 Introduce the nitrogen with known quantity of hydrocarbons and, using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.4.4.3 Introduce the span gas standard in nitrogen and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.4.4.4 Introduce nitrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen using a continuous flowing piezoelectric hygrometer. (See Note 7.)

4.5.1 *Detection Limit* — 0.1 ppm (vol/vol) or -90°C (-30°F).

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the

range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the nitrogen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this Standard.

4.6 *Notes*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

NOTE 3: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) carbon dioxide.

NOTE 4: The 0-1 range can be used provided that zero and span gas standards in nitrogen with known levels of hydrocarbons between 0-1 ppm are used in the calibration of the analyzer.

NOTE 5: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

NOTE 6: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

NOTE 7: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

SEMI C3.15-93 (Reapproved 0999)
STANDARD FOR NITROGEN (N_2), IN CYLINDERS, 99.9992% QUALITY

This standard was technically reapproved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1982; previously published in 1993.

1 Description

1.1 Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless gas. Noncombustible; an asphyxiant gas; cryogenic. Derived from liquid air by fractional distillation.

2 Specifications

QUALITY: 99.9992%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon dioxide (CO_2)	1
Carbon monoxide (CO)	2
Hydrogen (H_2)	2
Oxygen (O_2)	1
Particles	**
Total Hydrocarbons expressed as Methane (THC)	1
Water (H_2O) (v/v)	1
TOTAL SPECIFIED IMPURITIES	8

* Analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	-195.8°C	-320.4°F
Density of gas at 21.1°C (70°F) and 1 atm	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	0.967	0.967
Density of liquid at boiling point	808.8 kg/m^3	50.49 lb/ft^3

4 Analytical Procedures (See Notes 1, 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in nitrogen using a gas chromatograph with a flame ionization detector and methanizer. (See Note 3.)

4.1.1 *Detection Limit* — 100 ppb (mole/mole).

4.1.2 *Instrument Parameters*

Column:

Porapak T or Q, 3 m (9.8 ft) by 3 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss;

or

Chromosorb 102, 2 m (6.6 ft) by 3 mm OD by 2.2 mm (0.085 in) ID ss;

or equivalent.

4.1.2.1 Carrier Flow: 30 mL/min helium.

4.1.2.2 Sample Volume: 0.5 to 2.0 mL.

4.1.2.3 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standards* — 1-5 ppm (mole/mole) carbon monoxide, 1-5 ppm (mole/mole) carbon dioxide, balance nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Hydrogen* — This procedure is for the determination of hydrogen in nitrogen using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 500 ppb (mole/mole).

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 1.9 m (6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss, or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 3.0 mL.

4.2.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.2.3 *Calibration Standard* — 1-5 ppm (mole/mole) hydrogen in nitrogen.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentration of hydrogen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole).

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 1-5 ppm (mole/mole) oxygen in nitrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce nitrogen sample and record oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer. (See Notes 4, 5, 6.)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35-40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75-80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air: 350-400 mL/min.

4.4.2.3 Set sample flow rates in accordance with instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Zero nitrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.4.3.2 The upper level span gas not exceeding 5 times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the initial flow settings for hydrogen, air and sample once established.

4.4.4.2 Introduce the zero nitrogen with known quantity of hydrocarbons and, using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.4.4.3 Introduce the span gas standard in nitrogen and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.4.4.4 Introduce nitrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Water* — This procedure is for the determination of moisture (water) in nitrogen using a continuous flowing, cooled-surface condensation, dewpoint/ frostpoint hygrometer. (See Notes 7, 8, 9.)

4.5.1 *Detection Limit* — 0.6 ppm (vol/vol) or -79°C (-110°F).

4.5.2 *Flow Requirements*

4.5.2.1 Set sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.5.2.2 Gas must flow past the chilled mirror where optic means are provided to detect the deposit (or frost) and to read the thermometer measuring the temperature of the mirror.

4.5.3 *Calibration Standard* — A calibration thermometer designed to indicate temperatures in the -79°C (-110°F) range required.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow of sample gas from the source using a clean stainless steel (or copper) sampling line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the dewpoint/frostpoint hygrometer for one hour to 24 hours to allow the entire system to reach equilibrium with regard to moisture content.

4.5.4.3 After equilibrium has been reached, cool down the mirror to determine the actual dewpoint/frostpoint of the sample gas. Follow the manufacturer's recommendations to create the temperatures needed.

4.5.4.4 Continue to verify the dewpoint/frostpoint for at least 30 minutes after a stable reading has been confirmed.

4.5.4.5 Correct the dewpoint reading from the measured pressure to 1 atm of pressure. The result may not exceed the specification in Section 2 of this Standard.

4.6 *Notes*

Note 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

Note 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

Note 3: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) carbon dioxide.

Note 4: The 0-1 range can be used provided that zero and span gas standards in nitrogen with known levels of hydrocarbons between 0-1 ppm are used in the calibration of the analyzer.

Note 5: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

Note 6: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the most common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

Note 7: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

Note 8: The National Institute of Standards and Technology (NIST) provides calibration services for the thermometers used in dewpoint/frostpoint hygrometers.

Note 9: This method is not applicable if other constituents in the gas will condense before water vapor, e.g., carbon dioxide and/or oil contamination.

SEMI C3.48-0200
STANDARD FOR NITROGEN (N_2), BULK LIQUID, 99.9994% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 19, 1999. Initially available at www.semi.org December 1999; to be published February 2000. Originally published in 1993; previously published in 1996.

1 Description

1.1 Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless liquid. Noncombustible; a cryogenic gas derived from liquid air by fractional distillation.

2 Specifications

QUALITY: 99.9994%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Carbon Dioxide (CO_2)	0.5
Carbon Monoxide (CO)	2
Hydrogen (H_2)	2
Oxygen (O_2)	0.5
Particles	(See NOTE 2.)
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	0.5
TOTAL SPECIFIED IMPURITIES	6

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

NOTE 2: To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	–195.8°C	–320.4°F
Density of gas at 21.1°C (70°F) and 1 atm	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	0.967	0.967
Density of liquid at boiling point	808.8 kg/m^3	50.49 lb/ft^3

4 Analytical Procedures (See NOTES 1 and 2)

4.1 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in nitrogen using a gas chromatograph with a flame ionization detector and methanizer. (See NOTE 3.)

4.1.1 *Detection Limit* — 100 ppb (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column:

Porapak T or Q, 3 m (9.8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel;

or

Chromosorb 102, 2 m (6.6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel;

or equivalent.

4.1.2.2 Carrier Flow — 30 mL/min helium

4.1.2.3 Sample Volume — 0.5 to 2.0 mL

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	60°C
Methanizer	350°C

4.1.3 *Calibration Standards* — 0.5–2.5 ppm (mole/mole) carbon monoxide, 0.5–2.5 ppm (mole/mole) carbon dioxide, balance nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, carbon dioxide.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat Section 4.1.4.1.

4.1.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The results may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration Standard} = \text{Concentration Sample}$$

4.2 *Hydrogen* — This procedure is for the determination of hydrogen in nitrogen using a gas chromatograph with a helium ionization detector.

4.2.1 *Detection Limit* — 500 ppb (mole/mole)

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 1.9 m (6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel or equivalent.

4.2.2.2 Carrier Flow — 30 mL/min helium

4.2.2.3 Sample Volume — 3.0 mL

4.2.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.2.3 Calibration Standard — 1–5 ppm (mole/mole) hydrogen in nitrogen.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat Section 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentration of hydrogen, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration Standard} = \text{Concentration Sample}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 100 ppb (mole/mole)

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 0.5–2.5 ppm (mole/mole) oxygen in nitrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the sample flow setting once established.

4.3.4.2 Introduce nitrogen sample and record oxygen reading. The result may not exceed the specification in Section 2 of this standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a continuous flow flame ionization detector equipped total hydrocarbon analyzer. (See NOTES 4, 5, and 6.)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole)

4.4.2 *Flow Requirements*

4.4.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.4.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air: 350–400 mL/min.

4.4.2.3 Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Nitrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.4.3.2 The upper level span gas not exceeding five times the concentration of the specification.

4.4.4 *Operating Procedure*

4.4.4.1 Do not change the flow settings for hydrogen, air and sample once established.

4.4.4.2 Introduce the zero nitrogen with known quantity of hydrocarbons and using the 0–10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.4.4.3 Introduce the span gas standard in nitrogen and using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.4.4.4 Introduce nitrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen using a continuous flowing piezoelectric hygrometer. (See NOTE 7.)

4.5.1 *Detection Limit* — 0.1 ppm (vol/vol) or –90°C (–130°F).

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the

range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the nitrogen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this standard.

4.6 *Notes*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

NOTE 3: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) carbon dioxide.

NOTE 4: The 0–1 range can be used provided that zero and span gas standards in nitrogen with known levels of hydrocarbons between 0 and 1 ppm are used in the calibration of the analyzer.

NOTE 5: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

NOTE 6: The effective response of a flame ionization detector equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

NOTE 7: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.28-0200
STANDARD FOR NITROGEN (N_2), VLSI GRADE IN CYLINDERS, 99.9996% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org January 2000, to be published February 2000. Originally published in 1985; previously in 1996.

1 Description

1.1 Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless liquid; chemically unreactive. Noncombustible; an asphyxiant gas; cryogenic. Derived from liquid air by fractional distillation.

2 Specifications

QUALITY: 99.9996%

Impurities	*Maximum Acceptable Level (ppm (See NOTE 1.)*
Carbon Dioxide (CO_2)	0.5
Carbon Monoxide(CO)	0.5
Hydrogen (H_2)	1
Oxygen (O_2)	0.5
Particles	See NOTE 2.
Total Hydrocarbons expressed as Methane (THC)	0.5
Water (H_2O) (v/v)	0.5
TOTAL SPECIFIED IMPURITIES	3.5

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

NOTE 2: To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	–195.8°C	–320.4°F
Density of gas at 21.1°C (70°F) and 1 atm	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	0.967	0.967
Density of liquid at boiling point	808.8 kg/m^3	50.49 lb/ft^3

4 Analytical Procedures (See NOTES 3 and 4)

4.1 *Carbon Monoxide and Hydrogen* — This procedure is for the determination of carbon monoxide and hydrogen in nitrogen using a gas chromatograph with a reduction gas detector.

4.1.1 *Detection Limits* — 2 ppb (mole/mole) carbon monoxide, 20 ppb (mole/mole) hydrogen

4.1.2 *Instrument Parameters* — (See NOTE 1.)

4.1.2.1 Column — Molecular Sieve 5A, 0.9 m (3 ft) by 3.2 mm ID (1/4 in) OD, stainless steel; or equivalent.

4.1.2.2 Carrier Flow — 40 mL/min air or nitrogen

4.1.2.3 Sample Volume — 2.0 mL

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	250°C

4.1.3 *Calibration Standards* — 1-5 ppm (mole/mole) carbon monoxide, 1-5 ppm (mole/mole) hydrogen, balance nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is hydrogen, then carbon monoxide. Run standard analysis in triplicate for stability determination relative to purging of calibration system components.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat Section 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and hydrogen, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\\text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\\text{of Sample}\end{matrix}$$

4.2 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in nitrogen using a continuous flow, non-dispersive infrared analyzer.

4.2.1 *Detection Limit* — 50 ppb (mole/mole)

4.2.2 *Flow Rate* — Set the sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.2.3 *Calibration Standards* — Zero nitrogen with a known quantity of carbon dioxide at not more than 0.05 ppm (mole/mole). Span gas nitrogen with a known concentration of 1-10 ppm (mole/mole) carbon dioxide.

4.2.4 *Operating Procedure*

4.2.4.1 Do not change the initial sample flow setting once established.

4.2.4.2 Introduce the zero nitrogen with known quantity of carbon dioxide and set the needle (or output reading) to read the correct level using the zero adjustment knob.

4.2.4.3 Introduce the span gas standard in nitrogen and using the span adjust knob, set the needle (or output reading) to match the level of carbon dioxide in the span gas.

4.2.4.4 Repeat steps 1 and 2 (Sections 4.2.4.2 and 4.2.4.3) until reproducibility of readings is better than 1% of full scale.

4.2.4.5 Introduce nitrogen sample into the analyzer and record the concentration of carbon dioxide. The result may not exceed the specification in Section 2 of this Standard.

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 50 ppb (mole/mole)

4.3.2 *Flow Requirements* — Set the sample pressure and flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standards* — 1-10 ppm (mole/mole) oxygen in nitrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce nitrogen containing less than 2 ppm oxygen through a deoxygenation catalyst to verify that there is no leakage of air into the system and to demonstrate that the detection limit can be achieved.

4.3.4.3 Introduce the calibration standard. Using the span adjust knob, set the needle (or output reading) to match the level of oxygen in the calibration gas.

4.3.4.4 Introduce nitrogen sample and record the oxygen reading. The result may not exceed the specification in Section 2 of this standard.

4.4 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen using a continuous flowing piezoelectric hygrometer. (See NOTE 2.)

4.4.1 *Detection Limit* — 0.1 ppm (vol/vol) or –90°C (–130°F).

4.4.2 *Flow Requirements* — Set the sample pressure and flow rate set in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.4.4 *Operating Procedure*

4.4.4.1 Obtain a continuous flow of sample gas from the source using a clean and passivated 316 stainless steel line which has been purged dry after exposure to ambient moisture.

4.4.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric hygrometer until a stable reading is obtained. Determine the concentration of moisture by comparing the reading to the calibration curve obtained in 4.4.3. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer. (See Notes 5, 6, and 7.)

4.5.1 *Detection Limit* — 0.1 ppm (mole/mole)

4.5.2 *Flow Requirements*

4.5.2.1 High purity, hydrocarbon-free (less than 1.0 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.5.2.2 Dry, hydrocarbon-free (less than 1.0 ppm) air: 350–400 mL/min.

4.5.2.3 Set the sample flow rates in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards*

4.5.3.1 Zero nitrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.5.3.2 *Span Gas* — Nitrogen with known quantity (1–10 ppm) hydrocarbons.

4.5.4 *Operating Procedure*

4.5.4.1 Do not change the initial flow settings for hydrogen, air and sample once established.

4.5.4.2 Introduce the zero nitrogen with known quantity of hydrocarbons and using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.5.4.3 Introduce the span gas standard in nitrogen and using the span adjust knob, set the needle (or output) to match the level of hydrocarbons in the span gas.

4.5.4.4 Repeat Sections 4.5.4.2 and 4.5.4.3 until reproducibility of readings is better than 1% of full scale.

4.5.4.5 Introduce nitrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

NOTE 1: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) hydrogen.

NOTE 2: The sampling system and hygrometer must be designed to operate under the sample pressure or the sample pressure must be reduced by a regulator with a diaphragm of stainless steel or other suitable material, to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 3: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 4: All gases used in the analysis of the sample should contain not more than 10% of the sample value of the component of interest unless otherwise specified.

NOTE 5: The 0–1 ppm range can be used provided that zero and span gas standards in nitrogen with known levels of hydrocarbons between 0 and 1 ppm are used in the calibration of the analyzer.

NOTE 6: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

NOTE 7: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the most common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

SEMI C3.29-96 (Reapproved 0999) STANDARD FOR NITROGEN (N_2), BULK GASEOUS, 99.9995% QUALITY

This standard was technically reapproved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1986; previously published in 1996.

1 Description

1.1 Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless liquid; chemically unreactive. Noncombustible; an asphyxiant gas; cryogenic. Derived from liquid air by fractional distillation.

2 Specifications

QUALITY: 99.9995% (see Note 1)

Impurities	*Maximum Acceptable Level (ppm*)*
Carbon dioxide (CO_2)	0.2
Carbon monoxide (CO)	2
Hydrogen (H_2)	2
Oxygen (O_2)	0.2
Particles	**
Total Hydrocarbons expressed as Methane (THC)	0.2
Water (H_2O) (v/v)	0.2
TOTAL IMPURITIES	4.8

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	-195.8°C	-320.4°F
Density of gas at 21.1°C (70°F) and 1 atm	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	0.967	0.967
Density of liquid at boiling point	808.8 kg/m3	50.49 lb/ft3

4 Analytical Procedures (see Notes 2, 3)

4.1 *Carbon Monoxide and Hydrogen* — This procedure is for the determination of carbon monoxide and hydrogen in nitrogen using a gas chromatograph with a reduction gas detector (see Note 4).

4.1.1 *Detection Limits* — 2 ppb (mole/mole) carbon monoxide, 20 ppb (mole/mole) hydrogen.

4.1.2 *Instrument Parameters*

4.1.2.1 Column: 5A molecular sieve, 0.9 m (3 ft) by 3 mm (1/4 in) ss, or equivalent.

4.1.2.2 Carrier Flow: 40 mL/min air or nitrogen.

4.1.2.3 Sample Volume: 2.0 mL.

4.1.2.4 Temperatures:

Detector	280°C
Column Oven	250°C

4.1.3 *Calibration Standard* — 1-5 ppm (mole/mole) carbon monoxide, 1-5 ppm (mole/mole) hydrogen in nitrogen.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is hydrogen, then carbon monoxide. Run standard analysis in triplicate for stability determination relative to purging of calibration system components.

4.1.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Compare the average peak areas of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and hydrogen, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in nitrogen using a continuous flow, non-dispersive infrared analyzer.

4.2.1 *Detection Limit* — 50 ppb (mole/mole).

4.2.2 Set sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.2.3 *Calibration Standard* — Zero nitrogen with a known quantity of carbon dioxide at not more than .05 ppm (mole/mole). Span gas nitrogen with a known concentration of 1-10 ppm (mole/mole) carbon dioxide.

4.2.4 *Operating Procedure*

4.2.4.1 Do not change the initial sample flow setting once established.

4.2.4.2 Introduce the zero nitrogen with known quantity of carbon dioxide and set the needle (or output reading) to read the correct level using the zero adjustment knob.

4.2.4.3 Introduce the span gas standard in nitrogen and using the span adjust knob, set the needle (or output reading) to match the levels of carbon dioxide in the span gas.

4.2.4.4 Repeat steps 1 and 2 until reproducibility of readings is better than 1% of full scale.

4.2.4.5 Introduce nitrogen sample into the analyzer and read the quantity of carbon dioxide on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 50 ppb (mole/mole).

4.3.2 Set sample pressure and flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standard* — 1-10 ppm (mole/mole) oxygen in nitrogen or accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the initial sample flow setting once established.

4.3.4.2 Introduce nitrogen containing less than 2 ppm oxygen through a deoxygenation catalyst to verify that there is no leakage of air into the system and to demonstrate that the detection limit can be achieved.

4.3.4.3 Introduce the calibration standard. Using the span adjust knob, set the needle (or output reading) to match the level of oxygen in the calibration gas.

4.3.4.4 Introduce nitrogen sample and record the oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen using a continuous flowing piezoelectric hygrometer (see Note 5).

4.4.1 *Detection Limit* — 0.1 ppm (vol/vol) or -90°C (-130°F).

4.4.2 *Flow Requirements* — Set sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standard* — Construct a calibration curve which contains at least three points covering the range of interest. The standards employed will be verified independently by another analytical method.

4.4.4 *Operating Procedure*

4.4.4.1 Obtain a continuous flow of sample gas from the source using a clean and passivated 316 stainless steel line which has been purged dry after exposure to ambient moisture.

4.4.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained. The result may not exceed the specification in Section 2 of this standard.

4.5 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer (see Notes 6, 7, 8).

4.5.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.5.2 Flow Requirements

4.5.2.1 High-purity, hydrocarbon-free (less than 1.0 ppm) hydrogen: 35-40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75-80 mL/min.

4.5.2.2 Dry, hydrocarbon-free (less than 1.0 ppm) air: 350-400 mL/min.

4.5.2.3 Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards*

4.5.3.1 Zero nitrogen with known quantity of hydrocarbons at 0.1 ppm level.

4.5.3.2 Span Gas: Nitrogen with known quantity (1-10 ppm) hydrocarbons.

4.5.4 *Operating Procedure*

4.5.4.1 Do not change the initial flow settings for hydrogen, air and sample once established.

4.5.4.2 Introduce the zero nitrogen with known quantity of hydrocarbons and, using the 0-10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.5.4.3 Introduce the span gas standard in nitrogen and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.5.4.4 Repeat steps 4.5.4.2 and 4.5.4.3 until reproducibility of readings is better than 1% of full scale.

4.5.4.5 Introduce nitrogen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this standard.

4.6 *Notes*

NOTE 1: A purifier is allowed to be used to meet this specification.

NOTE 2: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 3: All gases used in the analysis of the sample should contain not more than 10% of the sample value of the component of interest unless otherwise specified.

NOTE 4: Carrier gases should contain less than 0.1 ppm (mole/mole) carbon monoxide and less than 0.1 ppm (mole/mole) hydrogen.

NOTE 5: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 6: The 0-1 range can be used provided that zero and span gas standards in nitrogen with known levels of hydrocarbons between 0-1 ppm are used in the calibration of the analyzer.

NOTE 7: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

NOTE 8: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the most common hydrocarbon impurities in nitrogen can be accurately totaled and compared to methane.

SEMI C3.49-94
STANDARD FOR BULK NITROGEN (N_2), 99.99999% QUALITY

1 Description

Nitrogen is an odorless, tasteless, diatomic gas comprising approximately 78% of the earth's atmosphere; colorless liquid. Noncombustible; a cryogenic gas derived from liquid air by fractional distillation.

2 Specifications

Quality: 99.99999%, including rare gases

Impurities	*Maximum AcceptableLevel (ppb)**
Water (H_2O)	50
Oxygen (O_2)	10
Carbon dioxide (CO_2)	10
Carbon monoxide (CO)	10
Total Hydrocarbons expressed as Methane (THC)	10
Hydrogen (H_2)	10
Particles**	max 20 per/ft^3 >0.02µm
TOTAL SPECIFIED IMPURITIES	100 ppb

*An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** May be determined after purifier/filter. Sampling point to be agreed between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	28.013	28.013
Boiling point at 1 atm	-195.8°C	-320.4°F
Density of gas at 21.1°C and 1 atm (air=1)	1.1605 kg/m^3	0.07245 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air=1)	0.0967	0.0967
Density of liquid at boiling point	808.8 kg/m^3	50.49 lb/ft^3

4 Analytical Procedures (see Notes 1 and 2)

4.1 *Carbon Monoxide and Hydrogen* — This procedure is for the determination of carbon monoxide and carbon dioxide in nitrogen using a gas chromatograph fitted with a reduction gas detector. (See Note 3.)

4.1.1 *Detection Limit* — Hydrogen 3 ppb, CO, 0.3 ppb (mole/mole).

4.1.2 *Instrument Parameters*

4.1.2.1 Column 1: 1/8" OD 77" length Unibead 1S 60-80 mesh, Column 2: 1/8" OD 30 3/4" length MS5A

4.1.2.2 Carrier Flow: 20 mL/min at 105°C nitrogen

4.1.2.3 Sample Volume: 100 µL

4.1.2.4 Temperatures:

Detector	270°C
Column Oven	105°C

4.1.2.5 Calibration Standards 0.1-0.5 ppm (mole/mole) carbon monoxide, 0.1 - 0.5 ppm (mole/mole) hydrogen, balance nitrogen.

4.1.2.6 *Calibration Standards* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

4.1.3 *Operating Procedure*

4.1.3.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is hydrogen, carbon monoxide.

4.1.3.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.1.3.3 Repeat 4.1.4.1.

4.1.3.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentrations of carbon monoxide and hydrogen using the formula below. The results may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.2 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in nitrogen using a gas chromatograph with a flame ionization detector, fitted with a methaniser.

4.2.1 *Detection Limit* — 2 ppb (mole/mole)

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 1/8" OD 77" Length Hayesep D 100-120 mesh.

4.2.2.2

Carrier Flow:	30 mL/min nitrogen
Air Flow:	250 mL/min
Hydrogen Flow:	30 mL/min

4.2.2.3 Sample Volume: 5 mL

4.2.3 *Temperatures*:

Methaniser	315°C
Column Temperature	40°C

4.2.3.1 *Calibration Standard* — 0.1 ppm (mole/mole) carbon dioxide in nitrogen.

4.2.3.2 *Calibration Standards* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1

4.2.4.4 Compare the average peak area of the calibration standard to that of the nitrogen sample being tested. Calculate the concentration of carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.3 *Oxygen* — This procedure is for the determination of oxygen in nitrogen using a continuous flow analyzer using an electrochemical method.

4.3.1 *Detection Limit* — 2 ppb (mole/mole).

4.3.2 *Flow Rate* — Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standards* — 50 ppb (mole/mole) oxygen in nitrogen or in accordance with the instrument manufacturer's instructions.

4.3.4 *Operating Procedure*

4.3.4.1 Introduce nitrogen sample and record oxygen reading. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in nitrogen using a gas chromatograph fitted with a flame ionization detector and a back flush valve.

4.4.1 *Detection Limit* — 2 ppb (mole/mole).

4.4.2 *Instrument Parameters*

4.4.2.1 Column: 1/8" OD 77" Length Hayesep D 100-120 mesh.

4.4.2.2

Carrier Flow:	30 mL/min nitrogen
Air Flow:	250 mL/min
Hydrogen Flow:	30 mL/min

4.4.2.3 Sample Volume: 5mL

4.4.2.4 Temperatures: Column Temperature 40°C

4.4.2.5 *Calibration Standard* — 0.1 ppm (mole/mole) methane in nitrogen.

4.4.2.6 *Calibration Standards* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen using a continuous flowing phosphorous pentoxide hygrometer. (See Note 4.)

4.5.1 *Detection Limit* — 10 ppb (vol/vol)

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve in the range of interest. Verify the standards employed independently by established traceability to recognized national or international standards.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the

P_2O_5 moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the nitrogen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this Standard.

4.6 *NOTES*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

NOTE 3: Carrier gases should contain less than 0.1 ppb (mole/mole) carbon monoxide and less than 0.1 ppb (mole/mole) hydrogen.

NOTE 4: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

SEMI

SEMI C3.39-0999
STANDARD FOR NITROGEN TRIFLUORIDE (NF_3)

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1989; previously published in 1996.

1 Description

1.1 Nitrogen trifluoride is a toxic, odorless, colorless, nonflammable gas. It is a strong oxidizer and supports combustion.

2 Specifications

2.1 QUALITY: 99.98%

Impurities	*Maximum Acceptable Level (ppm) (see NOTE 1)*
Carbon Dioxide (CO_2)	10
Carbon Monoxide (CO)	10
Carbon Tetrafluoride (CF_4)	100
Nitrogen (N_2)	10
Nitrous Oxide (N_2O)	10
Argon/Oxygen	10
Sulfur Hexafluoride (SF_6)	10
Water (H_2O) (v/v)	1
TOTAL IMPURITIES	161 (see NOTE 1)

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Chemical Specification

Hydrolyzable Fluorides as HF	1 ppm

4 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	71.00	71.00
Density of gas at 21.1°C (70°F) and 1 atm	2.94 kg/m^3	0.1838 lb./ft.^{3}

5 Analytical Procedures

5.1 *Carbon Tetrafluoride* — This procedure is for the determination of carbon tetrafluoride in nitrogen trifluoride using a gas chromatograph with a thermal conductivity detector. (See Figure 1 and Note 1.)

5.1.1 Detection Limit — 1.0 ppm.

5.1.2 *Instrument Parameters*

5.1.2.1 Column: Super Q (80/100 mesh), 4.9 m (16 ft.) by 1.75 mm (1/16 in.) ID, 3.2 mm (1/8 in.) OD ss or equivalent.

5.1.2.2 Carrier Flow: 19 mL/min helium.

5.1.2.3 Sample Volume: 0.1 mL.

5.1.2.4 Temperatures:

Detector	100°C
Oven	42°C
Gas sampling valve	42°C

5.1.2.5 Valve material: Nitronic-60 or equivalent.

5.1.3 *Calibration Standard* — 100 ppm carbon tetrafluoride, balance helium.

5.1.4 *Operating Procedure*

5.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention time and peak area.

5.1.4.2 Inject nitrogen trifluoride sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.1.4.3 Repeat 5.1.4.1.

5.1.4.4 Compare the average peak area of the calibration standard to that of the nitrogen trifluoride sample being tested. Calculate the concentration of carbon tetrafluoride, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.2 *Carbon Dioxide, Nitrous Oxide, and Sulfur Hexafluoride* — This procedure is for the determination of carbon dioxide, nitrous oxide, and sulfur hexafluoride in nitrogen trifluoride using a gas chromatograph with a thermal conductivity detector. (See Figure 1.)

5.2.1 *Detection Limit* — 1.0 ppm for carbon dioxide, nitrous oxide, and sulfur hexafluoride.

5.2.2 *Instrument Parameters*

5.2.2.1 Column: Super Q (80/100 mesh), 4.9 m (16 ft.) by 1.75 mm (1/16 in.) ID, 3.2 mm (1/8 in.) OD ss or equivalent.

5.2.2.2 Carrier Flow: 19 mL/min helium.

5.2.2.3 Sample Volume: 1.0 mL.

5.2.2.4 Temperatures:

Detector	100°C
Oven	42°C
Gas sampling valve	42°C

5.2.2.5 Valve Material: Nitronic-60 or equivalent.

5.2.3 *Calibration Standard* — 10 ppm carbon dioxide, 10 ppm nitrous oxide, 10 ppm sulfur hexafluoride, balance helium.

5.2.4 *Operating Procedure*

5.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is carbon dioxide, nitrous oxide, sulfur hexafluoride. (See Figure 1 for valve configuration.)

5.2.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.2.4.3 Repeat 5.4.2.1.

5.2.4.4 Compare the average peak area of the calibration standard to that of the nitrogen trifluoride sample being tested. Calculate the concentration of each impurity using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.3 *Carbon Monoxide* — This procedure is for the determination of carbon monoxide in nitrogen trifluoride using a gas chromatograph with a methanizer and a flame ionization detector. (See Figure 1 and Note 2.)

5.3.1 Detection Limit — 0.1 ppm.

5.3.2 Instrument Parameters

5.3.2.1 Column: Carbosphere (80/100 mesh), 0.74 m (2.4 ft) by 1.75 mm (1/16 in) ID, 3.2 mm (1/8 in) OD ss or equivalent.

5.3.2.2 Carrier Flow: 25 mL/min helium.

5.3.2.3 Sample Volume: 0.5 mL.

5.3.2.4 Fuel gases:

Hydrogen:	Zero grade or better hydrogen at a flow rate of 45 mL/min is added to the carrier gas between the column outlet and the methanizer inlet.
Air:	Zero grade or better air is used at a flow rate of 300 mL/min.

5.3.2.5 Temperatures:

Detector	150°C
Oven	42°C
Methanizer	340°C
Gas sampling valve	70°C

5.3.2.6 Valve Material: Nitronic-60 or equivalent.

5.3.3 *Calibration Standard* — 10 ppm carbon monoxide, balance helium.

5.3.4 *Operating Procedure*

5.3.4.1 Inject the the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

5.3.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention time and peak area.

5.3.4.3 Repeat 5.3.4.1.

5.3.4.4 Compare the average peak area of the calibration standard to that of the nitrogen trifluoride sample being tested. Calculate the concentration of carbon monoxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

5.4 *Oxygen + Argon, Nitrogen* — This procedure is for the determination of oxygen + argon and nitrogen in nitrogen trifluoride using a gas chromatograph with a thermal conductivity detector. (See Figure 2 and Note 1.)

5.4.1 *Detection Limit* — 5 ppm of oxygen + argon and nitrogen.

5.4.2 *Instrument Parameters*

5.4.2.1 Column: Molecular sieve 13X (80/100 mesh), 6.1 m (20 ft) by 1.75 mm (1/16 in) ID, 3.2 mm (1/8 in) OD ss or equivalent.

5.4.2.2 Carrier Flow: 17 mL/min helium.

5.4.2.3 Sample Volume: 1.0 mL.

5.4.2.4 Temperatures:

Detector	140°C
Filament	240°C
Oven	100°C
Gas sampling valve	60°C

5.4.2.5 Valve Material: Nitronic-60 or equivalent.

5.4.3 *Calibration Standard* — 10 ppm oxygen, 10 ppm nitrogen, balance helium.

5.4.4 *Operating Procedure*

5.4.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. The order of elution is oxygen + argon (not separated) and nitrogen.

5.4.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

5.4.4.3 Repeat 5.4.4.1.

5.4.4.4 Compare the average peak area of the calibration standard to that of the nitrogen trifluoride sample being tested. Calculate the concentrations of oxygen + argon and nitrogen, using the formula below. The results may not exceed the specifications in Section 3 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

5.5 *Water* — This procedure is for the determination of trace moisture (water) in nitrogen trifluoride using a continuous flowing piezoelectric hygrometer. (See Notes 3 and 4.)

5.5.1 *Detection Limit* — 0.04 ppm (vol/vol) or -95°C (-139°F).

5.5.2 *Flow Requirements* — Set the sample pressure and flow rate set in accordance with the instrument manufacturer's instructions.

5.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed by another analytical method.

5.5.4 *Operating Procedure*

5.5.4.1 Obtain a continuous flow of sample gas from the source using a clean and passivated 316 stainless steel line which has been purged dry after exposure to ambient moisture.

5.5.4.2 After prepurging with a dry gas, allow the sample as to flow through the sampling system and the piezoelectric hygrometer until a stable reading is obtained. The result may not exceed the specification in Section 2 of this Standard.

5.6 *Hydrolyzable Fluorides as HF* — This procedure is for the determination of hydrolyzable fluorides in nitrogen trifluoride using fluoride ion selective electrode.

5.6.1 *Detection Limit* — Detection limits should be checked for any new implementation of a method. Detection limits below 0.1 ppm have been determined with this method. Detection limits can be improved by increasing the volume of gas sampled.

5.6.2 *Equipment*

5.6.2.1 mV meter (0.1 mV scale)

5.6.2.2 Reference electrode (single junction type)

5.6.2.3 Fluoride ion selective electrode

5.6.2.4 Magnetic stir bars (PTFE coated)

5.6.2.5 Magnetic stirrer

5.6.2.6 Plastic beakers (See NOTE 5.)

5.6.2.7 PTFE bubblers

5.6.2.8 1000 ml and 100 ml plastic volumetric flasks (see NOTE 5).

5.6.2.9 0.2 ml and 1 ml plastic volumetric pipettes (see NOTE 5).

5.6.2.10 Flow controller or flowmeter (0–1000 sccm NF_3)

5.6.3 *Reagents*

5.6.3.1 Distilled or deionized water

5.6.3.2 5 N sodium hydroxide

5.6.3.3 0.2 N sodium hydroxide

5.6.3.4 Glacial acetic acid

5.6.3.5 *Buffer Solution* — To 500 ml distilled or deionized water in a 1000 ml volumetric flask, add 57 ml glacial acetic acid and 58 g of sodium chloride. Adjust the pH to between 5.0–5.5 with 5 M sodium hydroxide. Cool to room temperature. Dilute to one liter with distilled or deionized water.

5.6.4 *Calibration Standard* — Sodium fluoride standard (10^{-3} M F^- in water, freshly prepared)

5.6.5 *Operating Procedure*

5.6.5.1 Prepare working standard by adding 100 ml 10^{-3} M F^- to 100 ml buffer solution.

5.6.5.2 Prepare a blank containing 50.0 ml 0.2 N NaOH and 50.0 ml buffer solution in a plastic beaker.

5.6.5.3 While stirring blank gently, record mV reading from the blank once reading is stable.

5.6.5.4 Successively add increments of working standard to the blank to generate a calibration curve. Record stable mV reading after each addition. Table 1 shows recommended increments and resultant concentrations.

Table 1 Calibration Concentrations

Added Volume of Working Standard (ml)	*Total Volume (ml)*	*Resulting F^- Concentration (M)*
0.2	100.2	1.0×10^{-6}
0.2	100.4	2.0×10^{-6}
0.4	100.8	4.0×10^{-6}
0.4	101.2	5.9×10^{-6}
0.8	102.0	9.8×10^{-6}
1.0	103.0	1.5×10^{-5}
2.0	105.0	2.4×10^{-5}

5.6.5.5 Put 50 ml 0.2 N NaOH into each of two bubblers connected in series.

5.6.5.6 Establish a flow of < 1000 sccm of NF_3 through the bubblers using a suitable flow controller or flowmeter.

5.6.5.7 Sample approximately 15 liters of NF_3. Record flowrate and time of sampling to determine total volume sampled (flowrate × time). A wet test meter can also be used to measure total volume. The amount of gas sample must be the volume at STP. If the flowmeter or wet test meter is not reference to 0º and 760 torr, use the formula below to correct sample volume.

$$\text{Liters at STP} = \text{Measured Liters} \times \frac{760\ \text{Torr}}{\text{P}} \times \frac{\text{T} + 273}{273\ \text{K}}$$

P: Pressure of sampled gas (mm Hg)

T: Temperature of sampled gas or reference temperature of the flow controller or meter in ºC.

5.6.5.8 Transfer contents of each bubbler to individual 100 ml volumetric flasks and add 50 ml Buffer solution to each. Then, if necessary, add deionized or distilled water to bring the volume up to 100 ml.

5.6.5.9 Transfer contents to a plastic beaker.

5.6.5.10 While stirring, measure and record mV readings for each sample.

5.6.5.11 Determine F^- concentration in solution using calibration curve generated in Section 5.6.5.4.

5.6.5.12 Calculate gas phase hydrolyzable fluoride concentration using the equation below. Note that the equation assumes the hydrolyzable fluoride is hydrogen fluoride.

$$\text{Gas Phase HF}\ (\text{ppm}_v) = \text{C} \times 0.11 \times \frac{22.4\ \text{l/mole}}{\text{Vs}} \times 10^6$$

C: Measured hydrolyzable fluoride concentration (M) determined in Section 5.6.5.11.

Vs: Volume of NF_3 sampled (liters at STP)

5.6.5.13 The HF concentration of the second bubbler should be insignificant compared to the first bubbler. If significant HF levels are found in the second bubbler, resample with a lower flowrate.

5.7 *Notes*

NOTE 1: Pass the carrier gas through a trap (3 m (10 ft.) by 6.4 mm (1/4 in.) OD) containing 50% by volume molecular sieve 5A and 50% by volume molecular sieve 13X submerged in liquid nitrogen.

NOTE 2: The methanizer catalyst can be destroyed by nitrogen trifluoride passing through to at high temperature. After the carbon monoxide peak is detected, the bulk nitrogen trifluoride is bypassed to vent by means of a four-port switching valve installed downstream of the separating column and before the methanizer (see Figure 1).

NOTE 3: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced, by a regulator with a diaphragm of stainless steel or other suitable material, to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 4: A passivation procedure is described in the Metals Handbook, 8th ed., Vol. 2, American Society for Metals, Metals Park, OH.

NOTE 5: Polytetrafluoroethlyene, polymethylpentene and polypropylene are suitable plastic materials.

SEMI C3.13-1000

STANDARD FOR NITROUS OXIDE (N_2O) IN CYLINDERS, 99.997% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available at www.semi.org September 2000; to be published October 2000. Originally published in 1982; previously published in 1993.

1 Description

1.1 Nitrous oxide is an oxidizing, colorless, liquefied gas with a sweetish odor. It is a simple asphyxiant. Vapor pressure is about 745 psig at 70°F.

2 Specifications

QUALITY: 99.997% (See Notes 1, 2)

Impurities	*Maximum Acceptable Level (ppm)**
Ammonia (NH_3)	5
Carbon Dioxide (CO_2)	2
Carbon monoxide (CO)	1
Hydrocarbons C_1-C_5	1
Nitric Oxide (NO)	1
Nitrogen (N_2)	10
Nitrogen dioxide (NO_2)	1
Oxygen (O_2)	2
Water (H_2O) (v/v)	3
TOTAL SPECIFIED IMPURITIES	26

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	44.01	44.01
Boiling point at 1 atm	-88.5°C	-127.4°F
Density of gas at 70°F (21.1°C) and 1 atm	1.947 g/L	0.1160 lb/ft^3
Specific gravity of gas	1.53	1.53
Critical pressure	71.46 atm	1052 psia
Critical temperature	36.4 °C	97.6°F

4 Analytical Procedures (See Note 3 and Appendix 1)

4.1 *Ammonia* — This procedure is for the determination of ammonia in nitrous oxide using an apparatus employing a detector tube filled with a color-reactive chemical.

4.1.1 *Detection Limit* — 0.2 ppm (mole/mole).

4.1.2 *Apparatus*

4.1.2.1 *Pressure Regulator* — Outlet Pressure Range 0–30 psig.

4.1.2.2 *Flowmeter* — Range 0–200 mL/min.

4.1.2.3 *Detector Tube* — Range 2–30 ppm.

4.1.2.4 Stop watch.

4.1.2.5 6 mm (1/4 in) flexible tubing.

4.1.3 *Operating Procedure*

4.1.3.1 Attach a suitable regulator to the cylinder outlet.

4.1.3.2 Connect the flowmeter to the regulator using flexible tubing.

4.1.3.3 Open the cylinder valve and purge the flowmeter with nitrous oxide.

4.1.3.4 After the line is thoroughly purged, stop the flow of nitrous oxide and attach the detector tube to the outlet of the flowmeter.

4.1.3.5 Start the flow of nitrous oxide and set the flow rate to 100 mL/min. The pressure and temperature of the sample must be within the tolerances specified by the manufacturer.

4.1.3.6 Pass 100 mL of nitrous oxide through the detector tube.

4.1.3.7 Determine the concentration of ammonia according to the detector tube manufacturer's instructions. The concentration may not exceed the specification in Section 2 of this Standard.

4.2 *Carbon Monoxide and Carbon Dioxide* — This procedure is for the determination of carbon monoxide and carbon dioxide in nitrous oxide using a gas chromatograph with a flame ionization detector and methanizer with back flush. (See Note 4 and Figure A1-1.)

4.2.1 *Detection Limit* — 1 ppm (mole/mole). (50 ppb depending on conditions)

4.2.2 *Instrument Parameters*

4.2.2.1 Columns:

Column 1: Porapak QS, 4.6 m (15 ft) by 5 mm (3/16 in) or equivalent.

Column 2: Molecular sieve 5A, 1.97 m (6 ft) by 5 mm, 80/100 mesh (reference only) or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 0.5 to 2.0 mL.

4.2.2.4 Temperatures:

Detector	35°C
Column Oven	35°C
Methanizer	500°C

4.2.3 *Calibration Standard* — 1–5 ppm (mole/mole) carbon monoxide, 1–5 ppm (mole/mole) carbon dioxide, balance nitrous oxide.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak areas. Order of elution is carbon monoxide, methane, carbon dioxide, and nitrous oxide. Back flush 18 minutes.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak areas of the calibration standard to that of the nitrous oxide sample being tested. Calculate the concentrations of carbon monoxide and carbon dioxide, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Hydrocarbons* $C_1 - C_5$ — This procedure is for the determination of hydrocarbons $C_1 - C_5$ in nitrous oxide using a gas chromatograph with a flame ionization detector.

4.3.1 *Methane Determination*

4.3.1.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.3.1.2 *Instrument Parameters*

4.3.1.2.1 Column: 5A molecular sieve, 1.9 m (6 ft) by 6.4 mm (1/4 in) OD by 5.3 mm (0.210 in) ID ss or equivalent.

4.3.1.2.2 Carrier Flow: 25 mL/min helium.

4.3.1.2.3 Sample Volume: 5.0 mL.

4.3.1.2.4 Temperature:

Column Oven	30°C

4.3.2 *Ethane Determination*

4.3.2.1 *Detection Limit* — 0.3 ppm (mole/mole).

4.3.2.2 *Instrument Parameters*

4.3.2.2.1 Column: Porapak Q, 1.9 m (6 ft) by 6.4 mm (1/4 in) OD by 5.3 mm (0.210 in) ID ss or equivalent.

4.3.2.2.2 Carrier Flow: 50 mL/min helium.

4.3.2.2.3 Sample Volume: 1.0 mL.

4.3.2.2.4 Temperature:

Column Oven	60°C

4.3.3 *Ethylene, Propane, Acetylene, Propylene, n-butane, and n-pentane Determination*

4.3.3.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.3.3.2 *Instrument Parameters*

4.3.3.2.1 Column: Phenylisocyanate/Porasil C, 3 m (10 ft) by 4.8 mm (3/16 in) OD by 3.7 mm (0.147 in) ID ss or equivalent.

4.3.3.2.2 Carrier Flow: 25 mL/min helium.

4.3.3.2.3 Sample Volume: 1.0 mL.

4.3.3.2.4 Temperature:

Column Oven	30°C

4.3.4 *Calibration Standards* — 1–5 ppm (mole/mole) methane in helium, 1–5 ppm (mole/mole) ethane in helium, 1–5 ppm (mole/mole) ethylene, 1–5 ppm (mole/mole) propane, 1–5 ppm (mole/mole) acetylene, 1–5 ppm (mole/mole) propylene, 1–5 ppm (mole/mole) n-butane, and 1–5 ppm (mole/mole) n-pentane, balance in helium.

4.3.5 *Operating Procedure*

4.3.5.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.3.5.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.3.5.3 Repeat 4.3.5.1.

4.3.5.4 Compare the average peak area of the calibration standard to that of the nitrous oxide sample being tested. Calculate the concentration of hydrocarbons C_1–C_5, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.4 *Nitric Oxide* — This procedure is for the determination of nitric oxide in nitrous oxide using chemiluminescence. The detector shall have a photomultiplier tube capable of sensing the light emission of the decaying nitrous oxide. The detector shall have variable attenuation, zero and span adjustments, display, and an onboard ozone generator. (See Note 5.)

4.4.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.4.2 *Instrument Parameters*

4.4.2.1 *Flow Requirements* — Set the zero gas, span gas, and sample gas in accordance with the instrument manufacturer's instructions.

4.4.3 *Calibration Standards*

4.4.3.1 Zero argon (99.99% minimum) with less than 0.1 ppm nitric oxide.

4.4.3.2 The upper level argon span gas (99.99% minimum) not exceeding 5 times the concentration of the specification.

4.4.3.3 The oxygen supplied to the ozone generator will contain less than 0.1 ppm nitric oxide.

4.4.4 *Operating Procedure*

4.4.4.1 Introduce the zero argon and set the instrument to zero with the zero adjust knob.

4.4.4.2 Introduce the span gas in argon and, using the span adjust knob, set the output reading to match the level of nitrous oxide in the span gas.

4.4.4.3 Repeat steps 4.4.4.1 and 4.4.4.2 until reproducibility of readings is better than 1% full scale.

4.4.4.4 Introduce the nitrous oxide sample into the analyzer and read the quantity of nitric oxide. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Nitrogen and Oxygen* — This procedure is for the determination of nitrogen and oxygen in nitrous oxide using a gas chromatograph with a helium ionization detector.

4.5.1 *Detection Limit* — 0.5 ppm (mole/mole).

4.5.2 *Instrument Parameters*

4.5.2.1 Columns:

Column 1: Porapak Q, 1.9 m (6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss, or equivalent.

Column 2: Molecular sieve 5A, 2.4 m (8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss, or equivalent.

4.5.2.2 Carrier Flow: 50 mL/min helium.

4.5.2.3 Sample Volume: 1.0 to 3.0 mL.

4.5.2.4 Temperatures:

Detector	125°C
Column Temperature	65°C

4.5.3 *Calibration Standards* — 5-20 ppm (mole/mole) nitrogen in helium and 1-5 ppm (mole/mole) oxygen in helium.

4.5.4 *Operating Procedure*

4.5.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.5.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak areas.

4.5.4.3 Repeat 4.5.4.1.

4.5.4.4 Compare the average peak area of the calibration standard to that of the nitrous oxide sample being tested. Calculate the concentrations of nitrogen and oxygen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration} \\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration} \\ \text{of Sample}\end{matrix}$$

4.6 *Nitrogen Dioxide* — This procedure is for the determination of nitrogen dioxide in nitrous oxide using an apparatus employing a detector tube filled with a color-reactive chemical.

4.6.1 *Detection Limit* — 0.05 ppm.

4.6.2 *Apparatus*

4.6.2.1 Pressure Regulator: Outlet Pressure Range 0-30 psig.

4.6.2.2 Flowmeter: Range 0–200 mL/min.

4.6.2.3 Detector tube: Range 0.2–6 ppm.

4.6.2.4 Stop Watch.

4.6.2.5 6 mm (1/4 in) flexible tubing.

4.6.3 *Operating Procedure*

4.6.3.1 Attach a suitable regulator to the cylinder outlet.

4.6.3.2 Connect the flowmeter to the regulator using flexible tubing.

4.6.3.3 Open the cylinder valve and purge the flowmeter with nitrous oxide.

4.6.3.4 After the line is thoroughly purged, stop the flow of nitrous oxide and attach the detector tube to the outlet of the flowmeter.

4.6.3.5 Start the flow of nitrous oxide and set the flow rate to 100 mL/min. The pressure and temperature of the sample must be within the tolerance specified by the manufacturer.

4.6.3.6 Pass 800 mL of gas through the detector tube.

4.6.3.7 Determine the concentration of nitrogen dioxide according to the detector tube manufacturer's instructions. The concentration may not exceed the specification in Section 2 of this Standard.

4.7 *Water* — This procedure is for the determination of trace moisture (water) in nitrous oxide using a piezoelectronic hygrometer.

4.7.1 *Detection Limit* — 1.0 ppm (vol/vol).

4.7.2 *Flow Requirements* — Follow the flow requirements specified in the manufacturer's instrument operation manual.

4.7.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. The standards employed will be verified independently by another analytical method.

4.7.4 *Sample System and Proper Operation*

4.7.4.1 The sample system shall be as shown in Figure A1-2.

4.7.4.2 Attach sample system to nitrous oxide cylinder.

4.7.4.3 Partially open valve 2.

4.7.4.4 Open valve 1 and adjust pressure to 50 psig, ± 5 psig.

4.7.4.5 Adjust valve 2 until a flow of 500 mL/min, ± 50 mL/min is venting.

4.7.4.6 Tubing, valves and fittings are to be cleaned and passivated 316 stainless steel.

4.7.4.7 Keep tubing lengths to a minimum.

4.7.5 *Operating Procedure*

4.7.5.1 Follow the procedures outlined in the instrument manufacturer's manual.

4.7.5.2 Allow the system to run until a stable reading is obtained for ten minutes.

4.7.5.3 Read the quantity of water on the analyzer meter. The result may not exceed the specification in Section 2 of this Standard.

4.8 *Notes*

NOTE 1: This specification applies to the gas phase of the cylinder as delivered.

NOTE 2: It is recommended that the user discontinue use of the cylinder prior to complete consumption of the liquid phase. The contents of cylinders should be determined by weight, not pressure.

NOTE 3: Rapid withdrawal of gaseous nitrous oxide from a liquified source (e.g., cylinder) can result in a significant cooling effect which may condense the nitrous oxide in the sampling lines.

NOTE 4: In order to prevent nitrous oxide interference, a helium backflush to vent is needed for 3–5 times the analysis time (estimated to be 3–5 minutes). Because nitrous oxide is converted into ammonia in the methanizer, stainless steel (ss) is required; copper tubing and fittings are not used. The backflush removes the nitrous oxide from Column No. 1 preparing the column for the next sample. Careful timing is required to identify carbon monoxide and carbon dioxide distinguishing both from the time methane would appear, if present. Carbon monoxide and carbon dioxide are converted to methane in the methanizer; therefore, both will be detected by the FID detector at the specific times determined by the analytical sequence of the standard.

NOTE 5: This method does not determine nitrous oxide impurities.

APPENDIX 1
GENERAL ANALYTICAL PRACTICES

NOTE: The material in this appendix is an official part of SEMI C3.13 and was approved by full letter ballot procedures on August 28, 2000 by the North American Regional Standards Committee.

NOTE A1-1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE A1-2: All the gases used in the analysis of the sample should not contain more than 10% of the specified value at the component of interest, unless otherwise specified.

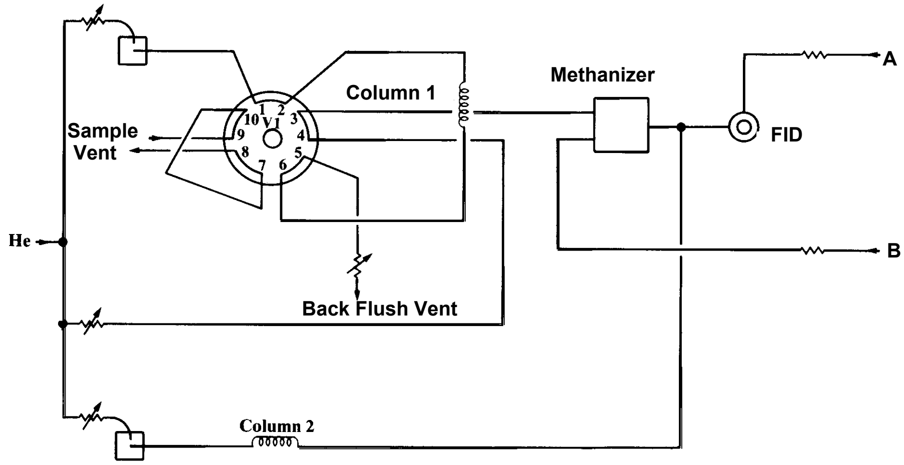

Figure A1-1
Valving Arrangement

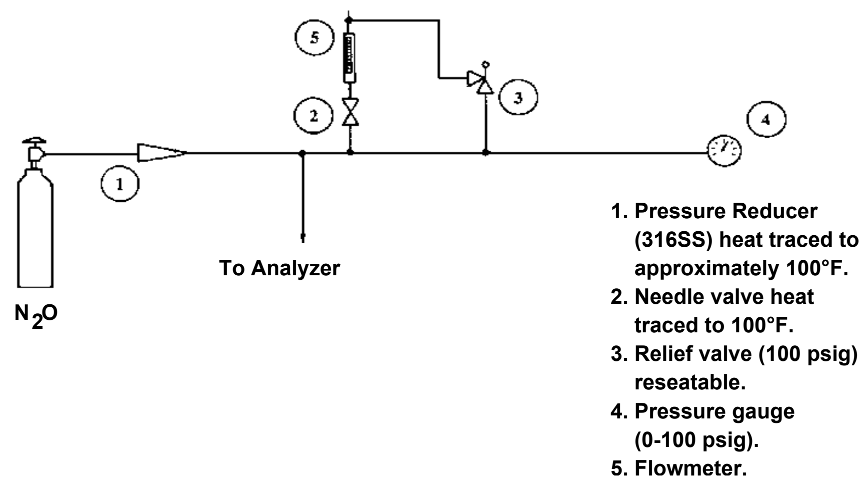

Figure A1-2
Nitrous Oxide Cylinder Sample System

SEMI C3.50-1000
GUIDELINE FOR NITROUS OXIDE (N_2O), 99.9994% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2000. Initially available at www.semi.org September 2000; to be published October 2000. Originally published in 1995.

1 Description

1.1 Nitrous oxide is an oxidizing, colorless, liquefied gas with a sweetish odor. It is a simple asphyxiant. Vapor pressure is about 745 psig at 70°F.

2 Specifications

QUALITY: 99.9994% (See Notes 1, 2)

Impurities	*Maximum Acceptable Level (ppm)**
Ammonia (NH_3)	0.1
Carbon Dioxide (CO_2)	0.5
Carbon Monoxide (CO)	0.1
Methane (CH_4)	0.1
Nitric Oxide (NO)	0.1
Nitrogen (N_2)	3.0
Nitrogen Dioxide (NO_2)	0.1
Oxygen (O_2) + Argon (Ar)	0.5
Water (H_2O) (v/v)	1.0
TOTAL SPECIFIED IMPURITIES	5.5

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	44.01	44.01
Boiling point at 1 atm	-88.5°C	-127.4°F
Density of gas at 70°F (21.1°C) and 1 atm	1.947 g/L	0.1146 lb/ft^3
Specific gravity of gas	1.53	1.53
Critical pressure	71.46 atm	1052 psia
Critical temperature	36.4°C	97.6°F

Note 1: This specification applies to the gas phase of the cylinder as delivered.

Note 2: It is recommended that the user discontinue use of the cylinder prior to complete consumption of the liquid phase. The contents of cylinders should be determined by weight, not pressure.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI C3.58-0600
SPECIFICATION FOR OCTAFLUOROCYLOBUTANE, C_4F_8, ELECTRONIC GRADE IN CYLINDERS

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the European Gases Committee. Current edition approved by the European Regional Standards Committee on April 4, 2000. Initially available at www.semi.org May 2000; to be published June 2000.

1 Description

1.1 Octafluorocyclobutane, also known as perfluorocyclobutane, is a gas under normal atmospheric conditions (15°C and 760 mm Hg).

1.2 The gas is a non-flammable, non-toxic, colorless and odorless gas which is stable under normal conditions.

2 Specifications

Purity: 99.99%

Impurities	*Maximum Acceptable Level*
Nitrogen/Oxygen	50 ppm
Moisture	5 ppm
Other halocarbons*	40 ppm
Acidity (as HF)	1 ppm mole

* R13, R23, R114, R113, R11, and R116

3 Referenced Standards

None.

4 Physical Constants (for information only)

Formula	C_4F_8 or $CF_2 \cdot CF_2 \cdot CF_2 \cdot CF_2$
Molecular weight	200
Melting point	-40.2°C
Boiling point	115°C
Relative density, gas	6.9 (air=1)
Relative density, liquid	1.6 (water=1)
Vapor pressure 20°C	2.7 bar
Appearance/Color	Colorless gas
Odor	none

5 Analytical Procedures

5.1 *Acidity* — This procedure is for the determination of acidity in octafluorocyclobutane using a classical chemical method of analysis, utilizing methyl red indicator.

5.1.1 *Detection Limit* — 1 ppm as HF.

5.1.2 *Apparatus*

5.1.2.1 Three 8 X one inch flat bottomed test tubes, flexible tubing, flowmeter, pressure regulator.

5.1.2.2 *Reagents* — 0.02% methyl red solution, 0.01N hydrochloric acid, freshly distilled or deionized water boiled to remove carbon dioxide.

5.1.2.2.1 0.02% methyl red: methyl red is 1-carboxybenzeneazodimethylaniline. This is the acid or alcohol soluble form which shall be used. Dissolve 20 mg of methyl red (acid form) in a mixture of 7.44 mL of 0.01M sodium hydroxide and 70 mL of alcohol and dilute to 100 mL with water. The alcohol must contain not less than 95% v/v ethanol.

5.1.2.2.2 0.01M hydrochloric acid: dilute 103.0 g of hydrochloric acid solution (SG 1.18) to 1000.0 mL with water to give 1M solution.

5.1.2.2.3 Dilute 10.0 mL of this solution to 1000.0 mL with water to give 0.01M solution.

5.1.2.2.4 Alternatively prepare by the dilution of a commercially available standard solution.

5.1.3 *Operating Procedure*

5.1.3.1 Attach a suitable regulator to the cylinder outlet.

5.1.3.2 Connect the flowmeter to the regulator using flexible tubing.

5.1.3.3 Open the cylinder valve and purge the flowmeter with octafluorocyclobutane.

5.1.3.4 Pour 50 mL of carbon dioxide free water into each of three 8 X one inch flat bottomed test tubes. Add 0.1 mL of 0.02% solution of methyl red in alcohol to each tube and label the tubes ‘a’ ‘b’ and ‘c’. Add 0.1 mL of 0.01M hydrochloric acid to tube ‘b’ and 0.2 mL of 0.01M hydrochloric acid to tube ‘c’. Pass a 23 liter gaseous sample of octafluorocyclobutane through the solution in tube ‘b’. Compare the color of tube ‘b’ after the test with the other two tubes. The intensity of the color produced in ‘b’ should be between those solutions ‘a’ and ‘c’. The formation of a pink color indicates acidity. A yellow color will be produced by alkalinity.

5.1.3.4.1 The colors of the test solutions before the test should be:

‘a’ — pale straw

‘b’ — pink

‘c’ — pink, slightly darker than ‘b’.

5.1.3.4.2 To differentiate the colors more readily after the test view the tubes by looking down through the solution rather than through the tubes. Place a sheet of white paper behind the tubes and carry out the comparisons in natural light.

6 Analytical Procedures - Instrumental Analysis

6.1 *Oxygen and Nitrogen* — This procedure is for the determination of oxygen and nitrogen in octafluorocyclobutane using a gas chromatograph with a thermal conductivity detector. Column switching is used to separate and elute the components and to backflush octafluorocyclobutane.

6.1.1 *Detection Limits* — oxygen 1 ppm (mole/mole), nitrogen 1 ppm (mole/mole).

6.1.2 *Instrument Parameters*

6.1.2.1 *Columns*: Pre-column: Molecular sieve 13X, 60/80 mesh, 2.5 m by 2.1 mm ss or equivalent. Main column: Molecular sieve 13X, 60/80 mesh, 1.5 m by 2.1 mm ss or equivalent. Ensure that all columns are conditioned before assembly.

6.1.2.2 *Gas Flows:* Helium carrier gas 25 mL/min for each column.

6.1.2.3 *Sample Volume*: 2.5 mL

6.1.2.4 *Temperatures:* Detector 100°C, Oven 90°C isothermal.

6.1.3 *Calibration Standard:* 1–50 ppm (mole/mole) oxygen and nitrogen in helium.

6.1.4 *Chromatogram* — See Figure 1.

6.2 *Halogenated Hydrocarbons* — This procedure is for the determination of halogenated hydrocarbons in octafluorocyclobutane using a gas chromatograph with a flame ionization detector.

6.2.1 *Detection Limits*

R13, R23, R114	1 ppm (mole/mole)each
R113	4 ppm (mole/mole)
R11, R116	10 ppm (mole/mole) each

6.2.2 *Instrument Parameters*

6.2.2.1 *Column* — Chromosorb 102, 80/100 mesh, 5 m by 2.1 mm ss or equivalent.

6.2.2.1.1 Ensure that the column is conditioned before assembly.

6.2.2.2 *Gas Flows* — Nitrogen carrier gas 25 mL/minute.

6.2.2.3 *Sample Volume* — 1 mL

6.2.2.4 *Temperatures* — Detector: 140°C, Oven: 80°C for 7 minutes, then increase 32°C/min up to 130°C.

6.2.3 *Calibration Standard:* 10–100 ppm (mole/mole) R11, R13, R23, R 113, R114, and R116 in nitrogen.

6.2.4 *Chromatogram* — See Figure 2.

6.3 *Water* — This procedure is for the determination of trace moisture (water) in Octafluorocyclobutane, using a continuous flowing electrolytic hygrometer.

6.3.1 *Detection Limit* — 1.0 ppm (vol/vol). This is equivalent to a frost point of -76°C (-106°F).

6.3.2 *Sample Pressure and Flow* — set in accordance with instrument manufacturer's instructions.

6.3.3 *Operation Check* — The instrument should be checked periodically for correct operation. A gas containing a known amount of moisture should be passed through the instrument. Agreement between the hygrometer and the standard should be within their relative accuracy.

6.3.4 *Operation Procedure*

6.3.4.1 Obtain a continuous flow sample of the Octafluorocyclobutane source, using a clean, electropolished or passivated (see Note 2) stainless steel line which has been purged dry after exposure to ambient moisture.

6.3.4.2 After purging with dry gas, allow the sample gas to flow through the sampling system and hygrometer until a stable reading is obtained. The reading may not exceed specification in Section 2 of this standard.

NOTE 1: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced, by a regulator with a diaphragm of stainless steel or other suitable material, to accommodate the pressure restrictions of the analytical hygrometer.

NOTE 2: A passivation procedure is described in the Metals Handbook, 8th ed., Vol. 2, American Society for Metals, Metals Park, OH.

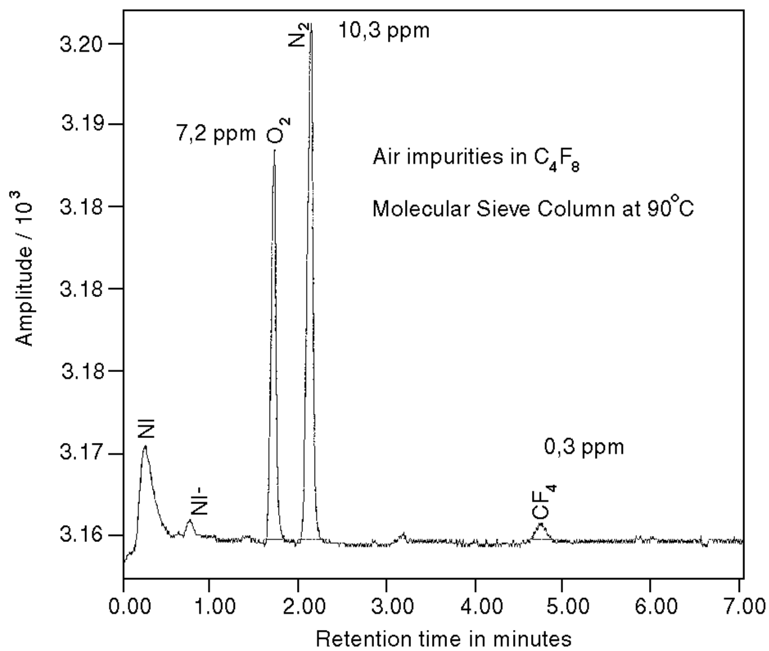

Figure 1
Oxygen and Nitrogen determination in Octafluorocyclobutane

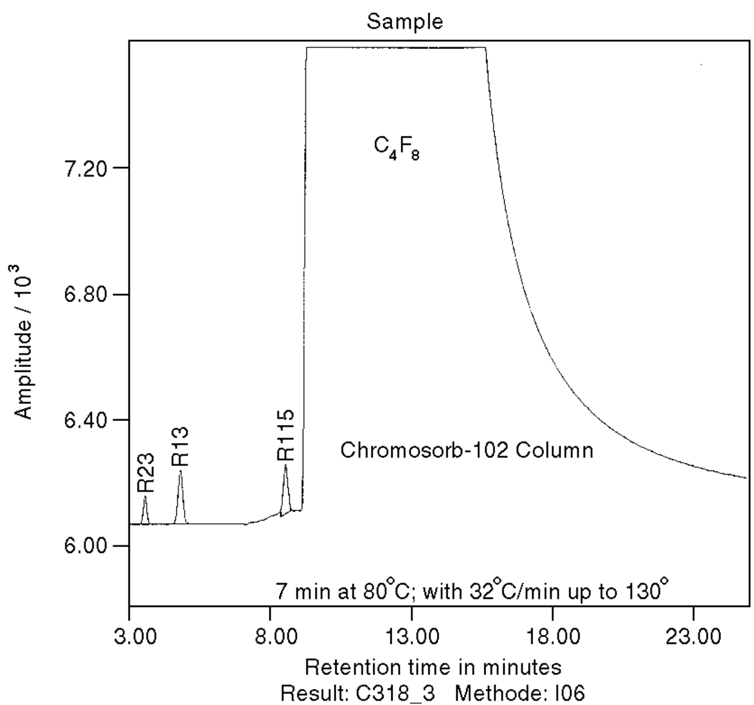

Figure 2
Determination of other halogenated hydrocarbons in Octafluorocyclobutane

SEMI C3.22-1000
STANDARD FOR OXYGEN (O_2), 99.5% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2000. Initially available at www.semi.org August 2000; to be published October 2000. Originally published in 1983; previously published in 1993.

1 Description

1.1 Oxygen is a colorless, odorless and oxidizing gas. It supports combustion.

2 Specifications

ASSAY: 99.5%

Impurities	*Maximum Acceptable Level (ppm)**
Carbon monoxide and Carbon dioxide ($CO + CO_2$)	5
Nitrogen (N_2)	100
Nitrous oxide (N_2O)	2
Particles	**
Total Hydrocarbons expressed as Methane (THC)	25
Water (H_2O) (v/v)	1
TOTAL IMPURITIES INCLUDING RARE GASES	5,000

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	31.999	31.999
Boiling point at 1 atm	-183°C	-297.4°F
Density of gas at 25°C (77°F) and 1 atm	1.309 kg/m^3	0.082 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	1.1049	1.1049
Density of liquid at boiling point	1142 kg/m^3	71.27 lb/ft^3

4 Analytical Procedures

4.1 *Carbon Monoxide, Carbon Dioxide, and Nitrous Oxide* — This procedure is for the determination of carbon monoxide, carbon dioxide and nitrous oxide in oxygen using infrared spectrophotometry.

4.1.1 *Detection Limits* — 0.5 ppm (mole/mole) carbon monoxide, 0.1 ppm (mole/mole) carbon dioxide, and 0.2 ppm (mole/mole) nitrous oxide.

4.1.2 *Instrument Parameters*

4.1.2.1 10 meter variable path infrared gas cell.

4.1.2.2 Grating infrared spectrophotometer.

4.1.2.3 Bourdon Vacuum Gauge.

4.1.3 *Calibration Standards* — 10 ppm (mole/mole) carbon monoxide, 10 ppm (mole/mole) carbon dioxide and 10 ppm (mole/mole) nitrous oxide, balance oxygen.

4.1.4 *Operating Procedure*

4.1.4.1 Pressurize the evacuated gas cell to 50 psia with the calibration standard. Scan the following wave numbers for absorbance: carbon monoxide 2172 cm^{-1}, nitrous oxide 2235 cm^{-1}, and carbon dioxide 2360 cm^{-1}.

4.1.4.2 Evacuate the cell and pressurize to 50 psia with the oxygen sample. Scan the appropriate wave numbers as in 4.1.4.1.

4.1.4.3 Compare the absorbance of the calibration standard to that of the oxygen sample being tested. Calculate the concentrations of carbon monoxide, carbon dioxide and nitrous oxide, using the formula below. The results may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Absorbance}}{\text{Standard Absorbance}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Nitrogen* — This procedure is for the determination of nitrogen in oxygen using a gas chromatograph with a thermal conductivity detector.

4.2.1 *Detection Limit* — 10 ppm (mole/mole).

4.2.2 *Instrument Parameters*

4.2.2.1 Column: 5A molecular sieve, 4.6 m (15 ft) by 3.2 mm (1/8 in) ss or equivalent.

4.2.2.2 Carrier Flow: 30 mL/min helium.

4.2.2.3 Sample Volume: 2.0 mL.

4.2.2.4 Temperatures:

Detector	200°C
Column Oven	21°C

4.2.3 *Calibration Standard* — 100 ppm (mole/mole) nitrogen in oxygen.

4.2.4 *Operating Procedure*

4.2.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention time and peak area.

4.2.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention time and peak area.

4.2.4.3 Repeat 4.2.4.1.

4.2.4.4 Compare the average peak area of the calibration standard to that of the oxygen sample being tested. Calculate the concentration of nitrogen, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in oxygen using a continuous flow flame ionization detector equipped total hydrocarbon analyzer. (See Notes 1, 2, 3.)

4.3.1 *Detection Limit* — 0.1 ppm (mole/mole).

4.3.2 *Flow Requirements*

4.3.2.1 High purity, hydrocarbon-free (less than 1.0 ppm) hydrogen: 35–40 mL/min or 40% hydrogen in either helium or nitrogen matrix at 75–80 mL/min.

4.3.2.2 Dry, hydrocarbon-free (less than 1.0 ppm) air: 350–400 mL/min.

4.3.2.3 Set sample flow rates in accordance with the instrument manufacturer's instructions.

4.3.3 *Calibration Standards*

4.3.3.1 Zero oxygen with known quantity of hydrocarbons at 0.5 ppm level.

4.3.3.2 The upper level span gas not exceeding 4 times the concentration of the specification.

4.3.4 *Operating Procedure*

4.3.4.1 Do not change the flow settings for hydrogen, air, and sample once established.

4.3.4.2 Introduce the zero oxygen with known quantity of hydrocarbons and, using the 0–10 ppm range, set the needle (or output) to read the correct level using the zero adjust knob.

4.3.4.3 Introduce the span gas standard in oxygen and, using the span adjust knob, set the needle (or output reading) to match the level of hydrocarbons in the span gas.

4.3.4.4 Introduce oxygen sample into the analyzer and read the quantity of hydrocarbons on the analyzer meter. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Water* — This procedure is for the determination of trace moisture (water) in oxygen using a continuous flowing, cooled-surface condensation, dewpoint/frost-point hygrometer. (See Notes 4, 5, 6.)

4.4.1 *Detection Limit* — 0.6 ppm (vol/vol) at -79°C (-100°F).

4.4.2 *Flow Requirements*

4.4.2.1 Set sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.4.2.2 Gas must flow past the chilled mirror where optic means are provided to detect the deposit (or frost) and to read the thermometer measuring the temperature of the mirror.

4.4.3 *Calibration Standard* — A calibration thermometer designed to indicate temperatures in the -79°C (-110°F) range is required.

4.4.4 *Operating Procedure*

4.4.4.1 Obtain a continuous flow of sample gas from the source using a clean stainless steel sampling line which has been purged dry after exposure to ambient moisture.

4.4.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the dewpoint/frostpoint hygrometer for one hour to 24 hours to allow the entire system to reach equilibrium with regard to moisture content.

4.4.4.3 After equilibrium has been reached, cool down the mirror to determine the actual dewpoint/frostpoint of the sample gas. Follow the manufacturer's recommendations to create the temperatures needed.

4.4.4.4 Continue to verify the dewpoint/frostpoint for at least 30 minutes after a stable reading has been confirmed.

4.4.4.5 Correct the dewpoint reading from the measured pressure to 1 atm of pressure. The result may not exceed the specification in Section 2 of this Standard.

4.5 *Assay of Oxygen* — This procedure describes the assay of oxygen using an “Orsat” device. This is a volumetric determination of nonabsorbable/reactable gas.

4.5.1 *Method Capability* — 99.9% Oxygen.

4.5.2 *Instrument Parameters* — See Diagram A.

4.5.2.1 Equipment:

1. 1-100 mL calibrated certified buret, calibrated every 0.1 mL for the top 5 mL equipped with a 3-way stopcock on the top.
2. 3-250 mL aspirator bottles.
3. 1 one-hole rubber stop.
4. 1-1/16 in OD soft copper wire made into hollow coils 3/8 in OD by 3/4 in long.
5. Sufficient 3/8 in OD tygon tubing.
6. Sufficient surgical rubber tubing.
7. 1 gallon distilled water.
8. 2 lbs technical grade ammonium chloride.
9. 1 gallon 27% ammonium hydroxide.

4.5.2.2 *Test Solution Preparation*

4.5.2.2.1 Two pounds of technical grade ammonium chloride are dissolved in one gallon of distilled water and stored in a glass jar. One-half gallon of this solution shall be combined with one-half gallon of 27% ammonium hydroxide.

4.5.3 *Equipment Assembly* — The equipment is to be assembled, as per Diagram A, in a suitable wood or metal frame so arranged that the aspirator bottle connected to the buret can be raised and lowered, as required, to transfer the gas being analyzed to and from the center aspirator bottle which is filled with copper coils. The two leveling bottles should be filled half full of testing solution and the buret and aspirator bottle, which contains the copper coils, should be completely filled.

4.5.4 *Operating Procedure*

4.5.4.1 Before analyzing the sample, perform a series of analyses using a source of oxygen of which the purity has been previously determined. This procedure is necessary to age the test solution properly and eliminate any air bubbles which may become trapped in the apparatus. Only after three consecutive analyses have been run, indicating the known purity, should you proceed with testing. (See Note 7.)

4.5.4.2 Attach rubber tubing from the regulator of the cylinder being tested to the stopcock of the buret. Rotate the stopcock so as to draw the sample into the gas measuring buret. Collect a little more than 100 mL (i.e., below the zero mark) in the buret, and then rotate the stopcock so as to shut off the oxygen flow and remove the rubber tubing attached to the intake of the buret. If the gas sample in the buret is below the zero mark raise the leveling bottle #1 so that its “water” level is even atmosphere so as to raise the “water” level in the buret to exactly zero (Diagram B, Fig. #1).

4.5.4.3 Rotate the stopcock to connect the aspirator bottle #3 containing the copper coils, and transfer the oxygen into this aspirator bottle by raising the leveling bottle #1 (Diagram B, Fig. #2). Invert bottle #3 containing the copper coils so that both the inlet stopper and the sided outlet are in a downward position and shake gently for 1 to 2 minutes. Stand test bottle #3 on its base and lower the leveling bottle so as to withdraw any residual gases into the gas measuring buret (Diagram B, Fig. #3). Transfer at least 25 to 30 mL of test solution from the left-hand leveling bottle #2 into the right-hand leveling bottle #l, through the copper coil bottle #3, and the gas buret while, at the same time, gently rocking and tapping the center bottle (Diagram B, Fig. #4). This will move any bubbles which might cling to the copper coil into the gas measuring buret.

4.5.4.4 Turn the stopcock off and raise the leveling bottle #l so that its liquid level is the same as the liquid level inside the upper portion of the gas buret. When the levels of the leveling bottle and the gas buret are the same, read the gas purity markings on the buret at the liquid level at this point.

4.5.5 *Maintenance*

4.5.5.1 Copper coils should be added to the test bottle as required to keep the bottles completely full. The gas buret should be kept clean with a strong detergent solution to eliminate drops of liquid that might hang up in the gas space and give incorrect purity readings. No readings should be taken when the space above the liquid level of the gas buret has any liquid drops hanging in it, as this will give an erroneous purity reading.

4.5.5.2 The solution must be replaced occasionally as it becomes exhausted. The necessity of replacement may be determined when the color begins to turn green, and by the increased length of shaking time required to get a minimum acceptable purity from the oxygen in a cylinder of known purity. Suspect an exhausted solution if analysis of a cylinder of known purity does not read the correct purity.

4.5.6 *Standardization*

4.5.6.1 The method of analysis stated above can be used as a primary standard, meaning cylinders analyzed by this method can be used as standards of measurement on electronic analyzers used to measure oxygen.

4.5.6.2 This method is specific to oxygen when carbon dioxide is not present in the sample gas. When carbon dioxide is one of the components of the sample gas, the carbon dioxide must first be scrubbed from the sample.

4.6 *Notes*

Note 1: The 0–1 range can be used provided that zero and span gas standards in oxygen with known levels of hydrocarbons between 0–1 ppm are used in the calibration of the analyzer.

Note 2: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

Note 3: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer to different hydrocarbons can vary and must be approximated. However, the response of the most common hydrocarbon impurities in oxygen can be accurately totaled and compared to methane.

Note 4: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

Note 5: The National Institute of Standards and Technology (NIST) provides calibration services for the thermometers used in dewpoint/frostpoint hygrometers.

Note 6: This method is not applicable if other constituents in the gas will condense before water vapor, e.g., carbon dioxide and/or oil contamination.

Note 7: This procedure will be required only immediately after changing the test solution or contaminating the apparatus with air.

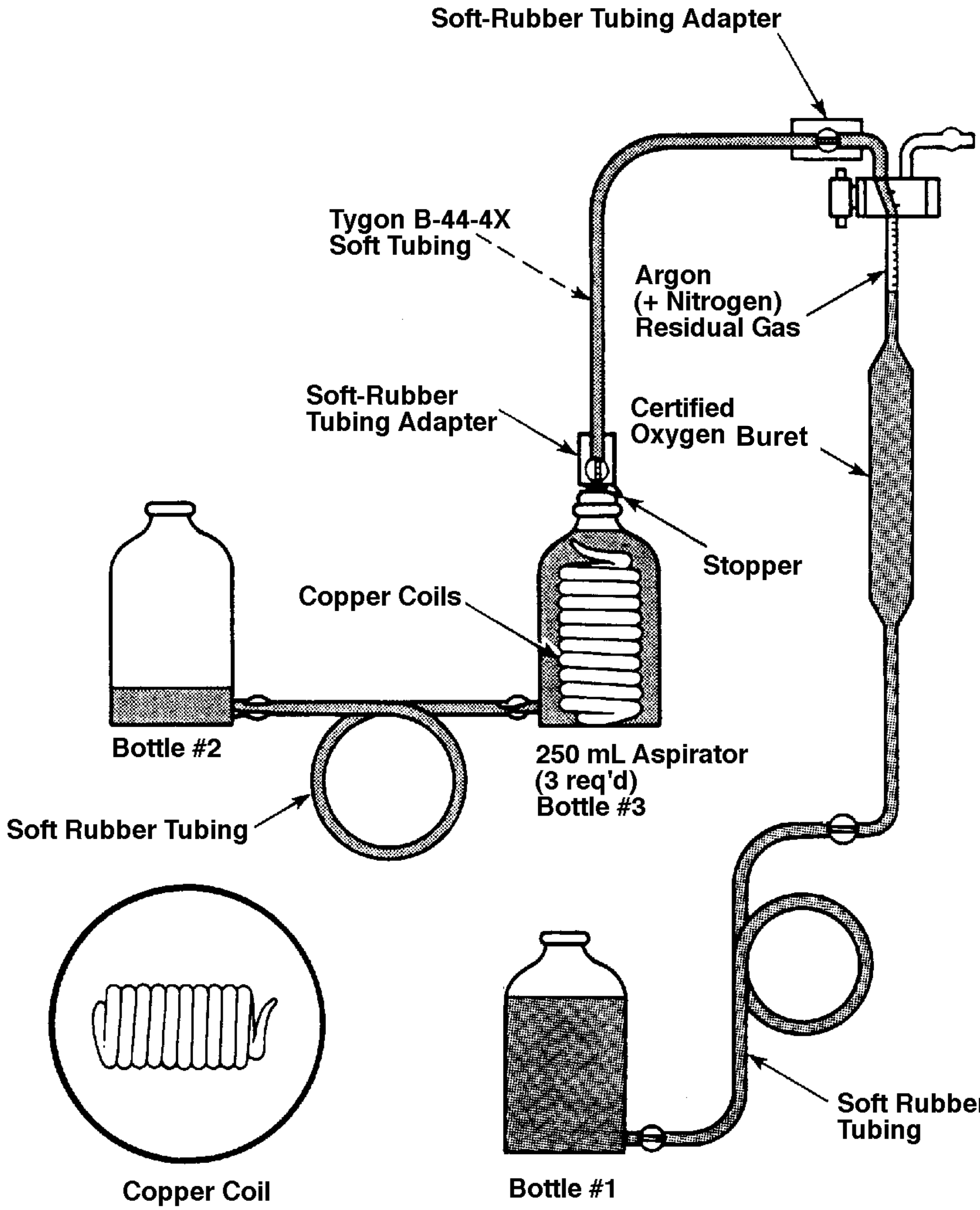
Soft-Rubber Tubing Adapter
Tygon B-44-4X
Soft Tubing
Argon
(+ Nitrogen)
Residual Gas
Soft-Rubber
Tubing Adapter
Certified
Oxygen Buret
Stopper
Copper Coils
Bottle #2
250 mL Aspirator
(3 req'd)
Bottle #3
Soft Rubber Tubing
Soft Rubber
Tubing
Copper Coil
Bottle #1

Diagram A

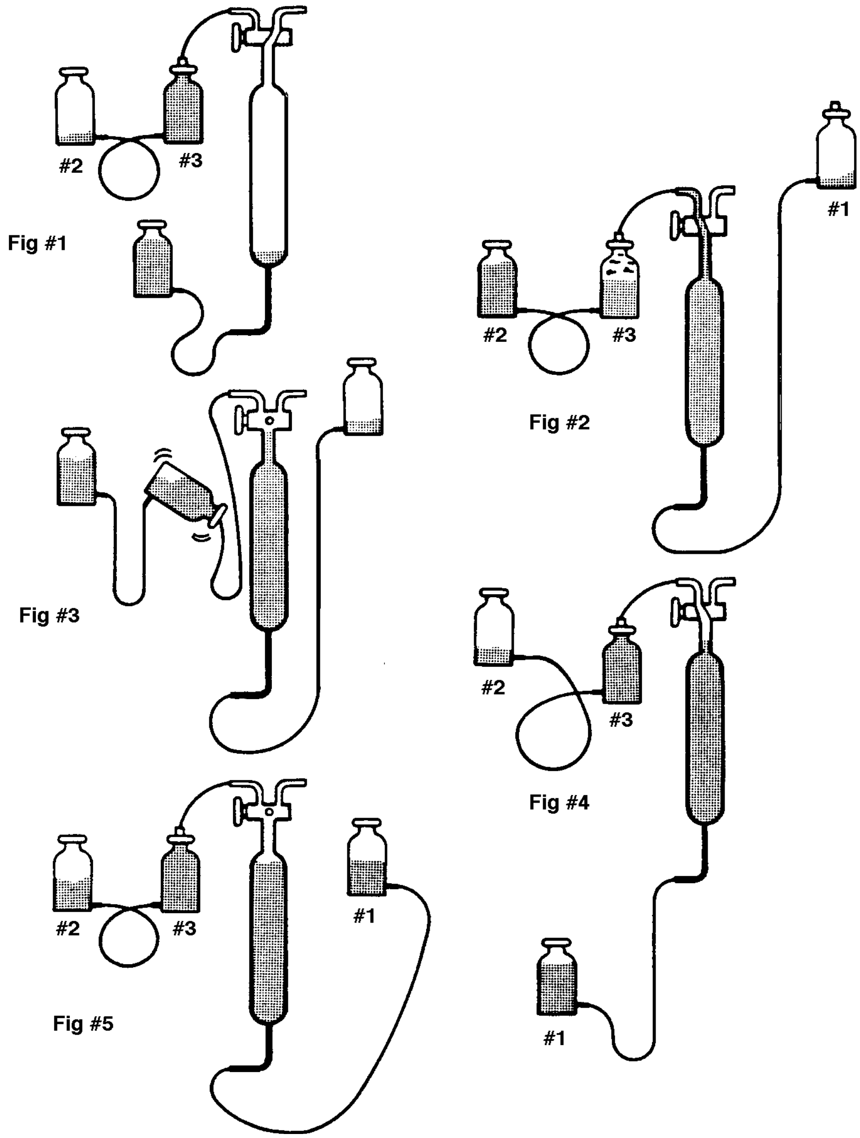

Diagram B

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI C3.16-95 (Withdrawn 1000)
STANDARD FOR OXYGEN (O_2) IN CYLINDERS, 99.50% ASSAY

This document was balloted and approved for withdrawal in 2000.

1 Description

Oxygen is a colorless, odorless, and oxidizing gas. It supports combustion.

SEMI C3.23-1000
STANDARD FOR OXYGEN (O_2), 99.98% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000. Originally published in 1984; previously published in 1995.

1 Description

1.1 Oxygen is a colorless, odorless, and oxidizing gas. It supports combustion.

2 Specifications

QUALITY: 99.98%

Impurities	*Maximum Acceptable Level (ppm)**
Argon (Ar)	100
Carbon Monoxide (CO)	1
Carbon Dioxide (CO_2)	1
Krypton (Kr)	10
Nitrogen (N_2)	30
Nitrous Oxide (NO)	1
Particles	**
Total Hydrocarbons expressed as Methane (THC)	1
Water (H_2O) (v/v)	1
TOTAL IMPURITIES	146

*An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	31.999	31.999
Boiling point at 1 atm	-183°C	-297.4°F
Density of gas at 25°C (77°F) and 1 atm	1.309 kg/m^3	0.082 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	1.1049	1.1049
Density of liquid at boiling point	1142 kg/m^3	71.27 lb/ft^3

4 Analytical Procedures (See Notes 1, 2)

4.1 *Argon* — This procedure is for the determination of argon using a gas chromatograph with a thermal conductivity detector.

4.1.1 *Detection Limit* — 25 ppm (mole/mole)

4.1.2 *Instrument Parameters*

4.1.2.1 Column: 3.6 m (12 ft) by 3.2 mm (1/8 in) stainless steel tubing packed with molecular sieve 5A, 60/80 mesh, washed to remove fines and activated at 300°C for 24 hours or equivalent.

4.1.2.2 Carrier Flow: 45 mL/min helium.

4.1.2.3 *Sample Volume:* 1–3 mL.

4.1.2.4 Temperatures:

Detector	40°C
Column	-50°C

4.1.3 *Calibration Standard* — 50–150 ppm (mole/mole) argon, balance helium.

4.1.4 *Operating Procedure*

4.1.4.1 With the valve in Position A, load the sample loop. Switch the valve to Position B to inject the sample into the column. After the argon has been detected, switch the valve back to Position A to backflush the oxygen from the column. Record the peak area and retention time.

4.1.4.2 Inject oxygen sample to be tested in the same manner as in 4.1.4.1. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Calculate the concentration of argon in the sample, using the formula below. The result may not exceed the specification Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Carbon Monoxide* — This procedure is for the determination of carbon monoxide using dual beam optical non-dispersive infrared spectrophotometry.

4.2.1 *Detection Limit* — 0.2 ppm (mole/mole)

4.2.2 *Instrument Parameters*

4.2.2.1 Detector: “Luft” type or equivalent

4.2.2.2 10" Infrared Gas Cell or gas cell with equivalent sensitivity

4.2.2.3 Sample Cell Pressure: 200 psig for full scale range 0–20 ppm carbon monoxide or appropriate pressure recommended by the cell manufacturer.

4.2.2.4 Sample Flowrate: 500 cc/minute or as specified by the instrument manufacturer.

4.2.2.5 Wavelength: 4.75 micrometers (4750 nm)

4.2.2.6 Wavenumber: 2100 cm^{-1}

4.2.3 *Calibration Standard* — 5 ppm (mole/mole) carbon monoxide, balance oxygen.

4.2.4 *Operating Procedure* (See Notes 5, 6.)

4.2.4.1 Open the zero gas (prepurified nitrogen or certified pure oxygen, independently measured to be less than 0.1 ppm CO) cylinder valve. Open valve V1, close valves V2 and V3. Flow the gas through the system and adjust the back pressure regulator to 200 psig as shown on gauge G. Adjust the flowrate on the flowmeter to 1000 cc/minute by adjusting valve V1. After a constant readout is observed, adjust the zero control knob of the analyzer to set the absorbance output to read zero.

4.2.4.2 Open the calibration gas standard cylinder valve. Close V1 and V2, and open valve V3. Flow the calibration gas through the system and adjust the back pressure regulator to 200 psig. Adjust the flowrate on the flowmeter to 1000 cc/minute. After a constant readout is observed, record the absorbance of the calibration standard, if the instrument indicates absorbance directly. If the instrument indicates concentration, adjust the span control to read the concentration of carbon monoxide in the calibration gas.

4.2.4.3 Introduce the oxygen sample into the analyzer by closing valves Vl and V3, opening valve V4 and slowly opening valve V2 until the flowrate on the flowmeter is 1000 cc/minute. Adjust the back pressure regulator to 200 psig. If the instrument indicates absorbance, read the absorbance of the sample and calculate the quantity of carbon monoxide, using the formula below. If the instrument indicates concentration, record the concentration. The results may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Measured Absorbance of Sample}}{\text{Measured Absorbance of Standard}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide using dual beam optical non-dispersive infrared spectrophotometry.

4.3.1 *Detection Limit* — 0.05 ppm (mole/mole)

4.3.2 *Instrument Parameters*

4.3.2.1 Detector: "Luft" type or equivalent

4.3.2.2 10" Infrared Gas Cell or gas cell with equivalent sensitivity

4.3.2.3 *Sample Cell Pressure* — 100 psig for full scale range 0–5 ppm carbon dioxide; 200 psig for full scale range of 0–2.5 ppm carbon dioxide or appropriate pressure as recommended by cell manufacturer.

4.3.2.4 Sample Flowrate: 500 cc/minute or as specified by the instrument manufacturer

4.3.2.5 Wavelength: 4.4 micrometers (4400 nm)

4.3.2.6 Wavenumber: 2250 cm^{-1}

4.3.3 *Calibration Standard* — 5 ppm (mole/mole) carbon dioxide, balance oxygen.

4.3.4 *Operating Procedure* — (See Notes 5 and 6)

4.3.4.1 Open the zero gas (prepurified nitrogen or pure oxygen, independently measured to be less than 0.1 ppm CO_2) cylinder valve. Open valve V1, close valves V2 and V3. Flow the gas through the system and adjust the back pressure regulator to 100 psig as shown on gauge G. Adjust the flowrate on the flowmeter to 1000 cc/minute by adjusting valve Vl. After a constant readout is observed, adjust the zero control knob of the analyzer to set the absorbance output to read zero.

4.3.4.2 Open the calibration gas standard cylinder valve. Close V1 and V2, and open valve V3. Flow the calibration gas through the system and adjust the back pressure regulator to 100 psig. Adjust the flowrate on the flowmeter to 1000 cc/minute. After a constant readout is observed, record the absorbance of the calibration standard, if the instrument indicates absorbance directly. If the instrument indicates concentration, adjust the span control to read the concentration of carbon dioxide in the calibration gas.

4.3.4.3 Introduce the oxygen sample into the analyzer by closing valves V1 and V3, opening valve V4 and slowly opening valve V2 until the flowrate on the flowmeter is 1000 cc/minute. Adjust the back pressure regulator to 100 psig. If the instrument indicates absorbance, read the absorbance of the sample and calculate the quantity of carbon dioxide, using the formula below. If the instrument indicates concentration, record the concentration. The results may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Measured Absorbance of Sample}}{\text{Measured Absorbance of Standard}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.4 *Krypton and Nitrogen* — This procedure is for the determination of krypton and nitrogen using a gas chromatograph with a thermal conductivity detector.

4.4.1 *Detection Limits* — 3 ppm (mole/mole) krypton, 3 ppm (mole/mole) nitrogen

4.4.2 *Instrument Parameter*

4.4.2.1 Column: 3.6 m (12 ft) by 3.2 mm (1/8 in) stainless steel tubing packed with molecular sieve 5A, 60/80 mesh, washed to remove fines and activated at 300°C for 24 hours or equivalent.

4.4.2.2 Carrier Flow: 45 mL/min helium.

4.4.2.3 Sample Volume: 25 mL.

4.4.2.4 Temperatures:

Detector	40°C
Column	25°C

4.4.3 *Calibration Standards* — 5–15 ppm (mole/mole) krypton, 15–5 ppm (mole/mole) nitrogen, balance helium.

4.4.4 *Operating Procedure*

4.4.4.1 With the valve in Position A, load the sample loop. Switch the valve to Position B to inject the sample into the column and allow the oxygen to pass through the column to vent. Switch valve to Position A to allow the krypton and nitrogen to be carried to the detector. Record the peak areas and retention times.

4.4.4.2 Inject the sample to be tested in the same manner as 4.4.4.1. Record the retention times and peak areas.

4.4.4.3 Repeat 4.4.4.1.

4.4.4.4 Calculate the concentrations of krypton and nitrogen using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.5 *Nitrous Oxide* — This procedure is for the determination of nitrous oxide using dual beam optical non-dispersive infrared spectrophotometry.

4.5.1 *Detection Limit* — 0.05 ppm (mole/mole)

4.5.2 *Instrument Parameters*

4.5.2.1 Detector: “Luft” type or equivalent

4.5.2.2 10" Infrared Gas Cell or gas cell with equivalent sensitivity

4.5.2.3 Sample Cell Pressure: 200 psig for full scale range 0–5 ppm nitrous oxide or appropriate pressure as recommended by the cell manufacturer.

4.5.2.4 Sample Flowrate: 500 cc/minute or as recommended by the instrument manufacturer

4.5.2.5 Wavelength: 4.5 micrometers (4500 nm)

4.5.2.6 Wavenumber: 2222 cm^{-1}

4.5.3 Calibration Standard: 5 ppm (mole/mole) nitrous oxide, balance oxygen.

4.5.4 *Operating Procedure* — (See Notes 5 and 6)

4.5.4.1 Open the zero gas (prepurified nitrogen or certified pure oxygen, independently measured to be less than 0.1 ppm N_2O) cylinder valve. Open valve V1, close valves V2 and V3. Flow the gas through the system and adjust the back pressure regulator to 200 psig as shown on gauge G. Adjust the flowrate on the flowmeter to 1000 cc/minute by adjusting valve Vl. After a constant readout is observed, adjust the zero control knob of the analyzer to set the absorbance output to read zero.

4.5.4.2 Open the calibration gas standard cylinder valve. Close Vl and V2, and open valve V3. Flow the calibration gas through the system and adjust the back pressure regulator to 200 psig. Adjust the flowrate on the flowmeter to 1000 cc/minute. After a constant readout is observed, record the absorbance of the calibration standard, if the instrument indicates absorbance directly. If the instrument indicates concentration, adjust the span control to read the concentration of nitrous oxide in the calibration gas.

4.5.4.3 Introduce the oxygen sample into the analyzer by closing valves Vl and V3, opening Valve V4 and slowly opening valve V2 until the flowrate on the flowmeter is 1000 cc/minute. Adjust the back pressure regulator to 200 psig. Read the absorbance of the sample and calculate the quantity of nitrous oxide, using the formula below. If the instrument indicates concentration, record the concentration. The result may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Measured Absorbance of Sample}}{\text{Measured Absorbance of Standard}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.6 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in oxygen using a continuous flow flame ionization detector-equipped total hydrocarbon analyzer. (See Notes 7, 8.)

4.6.1 *Detection Limit* — 0.1 ppm (mole/mole)

4.6.2 *Flow Requirements*

4.6.2.1 High purity, hydrocarbon-free (less than 0.1 ppm) hydrogen, 35–40 mL/min or 40% hydrogen in either helium or nitrogen at 75–80 mL/min.

4.6.2.2 Dry, hydrocarbon-free (less than 0.1 ppm) air, 350 mL–400 mL/min.

4.6.2.3 Set sample flow rate in accordance with the instrument manufacturer's instructions.

4.6.3 *Calibration Standards*

4.6.3.1 Zero oxygen with a known quantity of hydrocarbons of approximately 0.1 ppm.

4.6.3.2 Upper level balance oxygen span gas of not more than five times the concentration specified in Section 2 of this Standard.

4.6.4 *Operating Procedure*

4.6.4.1 Do not change initial flow settings for hydrogen, air and sample once established.

4.6.4.2 Introduce the zero oxygen with a known quantity of hydrocarbons and, using the 0–1 ppm range, set the output to read the correct level, using the zero adjust knob.

4.6.4.3 Introduce the span gas standard in oxygen and, using the span adjust knob, set the output to the level in the span gas.

4.6.4.4 Introduce the oxygen sample into the analyzer and read the quantity of hydrocarbons on the analyzer. The result may not exceed the specification in Section 2 of this standard.

4.7 *Water* — This procedure is for the determination of trace moisture (water) in oxygen using a continuous flowing, cooled-surface condensation, dewpoint/frost-point hygrometer. (See Note 9.)

4.7.1 *Detection Limit* — 0.6 ppm (vol/vol) at -79°C (-100°F)

4.7.2 *Flow Requirements*

4.7.2.1 Set sample flow rate and pressure in accordance with the instrument manufacturer's instructions.

4.7.3 *Calibration Standard* — A calibration thermometer designed to indicate temperatures in the -79°C (100°F) range is required.

4.7.4 *Operating Procedure*

4.7.4.1 An appropriately cleaned stainless steel or copper sampling line must be used. If it has been exposed to ambient moisture, it must be purged with dry gas prior to use.

4.7.4.2 Flow the sample gas through the hygrometer until the sampling system and instrument have reached equilibrium with the gas.

4.7.4.3 After equilibrium has been reached, cool the mirror of the hygrometer, as specified by its manufacturer, to determine the dewpoint/frostpoint of the sample gas.

4.7.4.4 Verify the dewpoint/frostpoint reading for at least 30 minutes after it becomes stable.

4.7.4.5 Correct the dewpoint/frostpoint reading to 1 atm pressure. Convert it to ppm (vol/vol) using an appropriate table. The result may not exceed the specification in Section 2 of this standard.

4.8 *Notes*

Note 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

Note 2: All gases used in the analysis of the sample should not contain more than 10% of the specified value of the component of interest, unless otherwise stated.

Note 3: A flow restrictor should be installed on the vent from port 8 to match the pressure drop of the detector.

Note 4: A flow controller is required on each carrier inlet.

Note 5: An example of an operating procedure is outlined below for the sample system shown in Figure 1. This procedure is appropriate only when the infrared gas cell is designed to withstand the 200 psig sample pressure.

Note 6: Operating procedures for other non-dispersive infrared analyzers vary depending on manufacturer. Refer to individual instrument vendor instructions in each case.

Note 7: As the flow rate and heat capacity of the matrix gas affect the instrument output, the zero and span gas matrices must coincide with that of the sample gas.

Note 8: The effective response of a flame ionization detector-equipped total hydrocarbon analyzer can vary among different hydrocarbons and must be approximated. However, the response of the most common hydrocarbon impurities can be accurately totaled and compared to methane.

Note 9: The sampling system and hygrometer must be designed to operate at the sample pressure, or the sample pressure must be reduced by a regulator with a diaphragm of stainless steel or other suitable material.

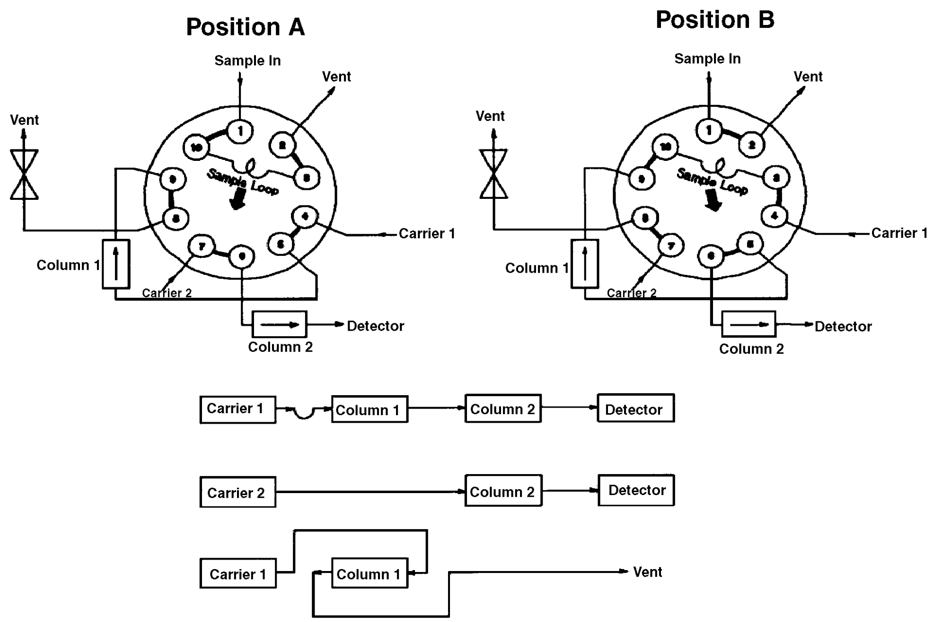


Figure 1

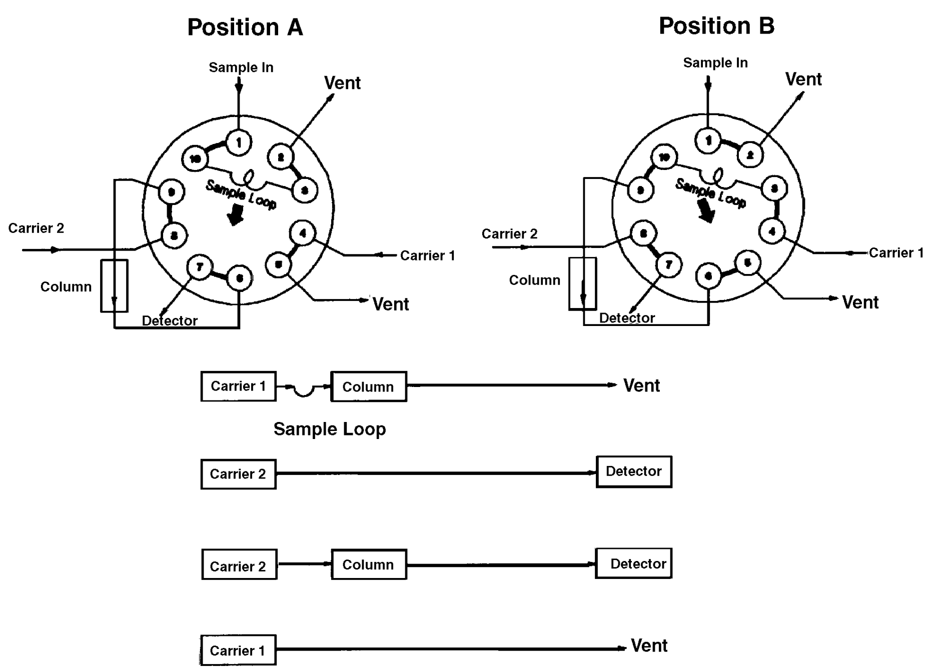
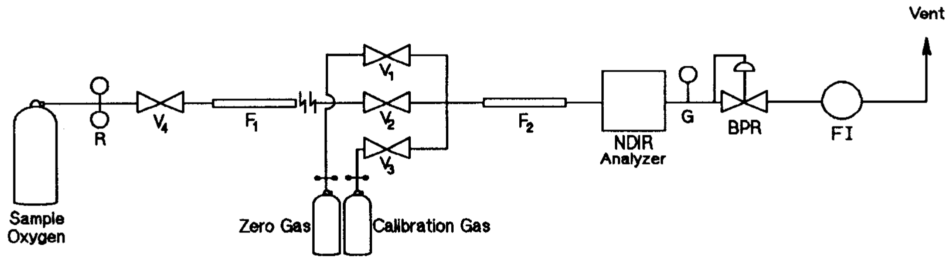


Figure 2



Legend:

V_4	Shut Off Valve
F_1	Particle Filter
$V_{1,2,3}$	Flow Control Valves
F_2	Fine Filter (Stainless Steel, 5 m element)
G	Sample Cell Pressure Gauge 0-500 psig
BPR	Back Pressure Regulator
FI	Flowmeter
R	Regulator

Note: All Components in contact with the sample must be contstructed of stainless steel, teflon, or glass.

Figure 3
Sample System for NDIR Analyzer

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.41-0697
STANDARD FOR OXYGEN (O_2), BULK, 99.9998% QUALITY (PROVISIONAL)

1 Description

Oxygen is a colorless, odorless, and oxidizing gas. It supports combustion.

2 Specifications

QUALITY: 99.9998% (See Note 1)

Impurities	*Maximum Acceptable Level (ppm) **
Argon (Ar)	1.0
Carbon Dioxide (CO_2)	0.1
Carbon Monoxide (CO)	0.1
Hydrogen (H_2)	0.1
Nitrogen (N_2)	0.5
Particles	**
Total Hydrocarbons (as CH_4)	0.1
Water (H_2O) (v/v)	0.1
TOTAL SPECIFIED IMPURITIES	2.0

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between user and supplier.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	31.999	31.999
Boiling point at 1 atm	-183.0°C	-297.4°F
Density of gas at 25°C (77°F) and 1 atm	1.309 kg/m^3	0.082 lb/ft^3
Specific gravity of gas	1.1049	1.1049
Density of liquid atboiling point	1142 kg/m^3	71.27 lb/ft^3

NOTE 1: A purifier is allowed to be used to meet this specification.

4 Analytical Procedures

4.1 *Argon and Nitrogen* — This procedure is for the determination of argon and nitrogen in oxygen using a gas chromatograph with a discharge ionization detector (see Figure 1).

4.1.1 *Detection Limit* — 0.1 ppm

4.1.2 Instrument Parameters

4.1.2.1 Column(s):

3 m (10 ft) by 3.2 mm (1/8") o.d. in Molecular Sieve 5A

3 m (10 ft) by 1/8 in Oxy–trap (See Figure 1)

4.1.2.2 Carrier Flow: 44 cc/min

4.1.3 Sample Volume: 0.1 mL

4.1.3.1 Temperatures:

Detector	100°C
Column	30°C
Oxytrap	150°C

4.1.4 *Calibration Standards* — 1–5 ppm nitrogen and argon in oxygen.

4.1.5 *Operating Procedures*

4.1.5.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak area. Order of elution is argon, nitrogen. If methane is present, the order is argon, nitrogen, methane.

4.1.5.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak area.

4.1.5.3 Repeat 4.1.4.1.

4.1.5.4 Compare the average peak areas of the calibration standard to that of the sample being tested. Calculate the concentrations of impurities as shown in SEMI C3. The result may not exceed the specification in Section 2 of this standard.

NOTE 2: Oxygen trap conditioned per manufacturer's recommendations using hydrogen, carbon monoxide, or blend in helium.

4.2 *Carbon Dioxide* — This procedure is for the determination of carbon dioxide in oxygen using a gas chromatograph with a flame ionization detector and a methanizer

4.2.1 *Detection Limit* — 0.02 ppm

4.2.2 *Instrument Parameters*

4.2.3 Column(s): 2.3 m (91 in) by 1/8 in HayeSep Db

4.2.3.1 Carrier Flow: 50 cc/min nitrogen

4.2.3.2 Sample Volume: 5 mL

4.2.3.3 Temperatures:

Detector	275°C
Column	50°C
Methanizer	295°C

4.2.4 *Calibration Standards* — 0.1–1 ppm carbon dioxide in oxygen.

4.2.5 *Operating Procedures*

4.2.5.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak area. Order of elution is: Oxygen + carbon monoxide, methane, carbon dioxide.

4.2.5.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak area.

4.2.5.3 Repeat 4.2.4.1

4.2.5.4 Compare the average peak areas of the calibration standard to that of the sample being tested. Calculate the concentrations of impurities as shown in SEMI C3. The result may not exceed the specification in Section 2 of this Standard.

NOTE 3: Sample and calibration sample are injected on column to vent until oxygen, carbon monoxide, and methane have eluted. Valve is returned to allow carbon dioxide to elute onto methanizer and flame ionization detector.

4.3 *Carbon Monoxide and Hydrogen* — This procedure is for the determination of carbon monoxide and hydrogen in oxygen using a gas chromatograph with a reduction gas detector.

4.3.1 *Detection Limit* — 0.002 ppm

4.3.2 *Instrument Parameters*

4.3.2.1 Column(s): 2 m (80 in) by 1/8 in Molecular Sieve 13×

4.3.2.2 Carrier Flow: 20 cc/min air

4.3.2.3 Sample Volume: 1 mL

4.3.2.4 Temperatures:

Detector	265°C
Column	105°C

4.3.3 *Calibration Standards* — 0.5 – 1 ppm hydrogen and carbon monoxide in nitrogen or oxygen.

4.3.4 *Operating Procedures*

4.3.4.1 Inject the calibration standard into the column using a gas sampling valve. Record the retention times and peak area. Order of elution is: Hydrogen, carbon monoxide.

4.3.4.2 Inject the sample to be tested in same manner as the calibration standard. Record the retention times and peak area.

4.3.4.3 Repeat 4.3.4.1

4.3.4.4 Compare the average peak areas of the calibration standard to that of the sample being tested. Calculate the concentrations of impurities as shown in SEMI C3. The result may not exceed the specification in Section 2 of this Standard.

4.4 *Total Hydrocarbons* — This procedure is for the determination of total hydrocarbons in oxygen with a total hydrocarbon analyzer.

4.4.1 *Detection Limit* — 0.05 ppm

4.4.2 *Instrument Parameters*

4.4.2.1 Flow Requirements:

Carrier Flow Rate: per manufacturer's recommendations

Purity: less than 0.05 ppm total hydrocarbons

Sample Flow Rate: manufacturer's recommendations

4.4.3 *Calibration Standards* — 0.1 – 1 ppm methane in oxygen.

4.4.4 *Operating Procedures*

4.4.4.1 Flow settings should not be changed once established.

4.4.4.2 Introduce the zero gas and adjust the instrument per manufacturer's recommendations to read the quantity known to be in the zero gas.

4.4.4.3 Introduce the span gas standard and adjust the instrument per manufacturer's recommendations to read the quantity known to be in the span gas. This result may not exceed specification in Section 2 of this standard.

4.5 *Water* — This procedure is for the determination of trace moisture (water) in O_2 using a continuous flowing piezoelectric hygrometer (see Note 4).

4.5.1 *Detection Limit* — 5 ppb

4.5.2 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

4.5.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently by another analytical method.

4.5.4 *Operating Procedure*

4.5.4.1 Obtain a continuous flow sample of gas from the source using a clean and passivated stainless steel line which has been purged dry after exposure to ambient moisture.

4.5.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and the piezoelectric moisture hygrometer until a stable reading is obtained.

4.5.4.3 Determine the moisture content of the oxygen sample by comparing the reading to calibration curve. The result may not exceed the specification in Section 2 of this standard.

NOTE 4: The sampling system and hygrometer must be designed to operate under the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the analytical hygrometer.

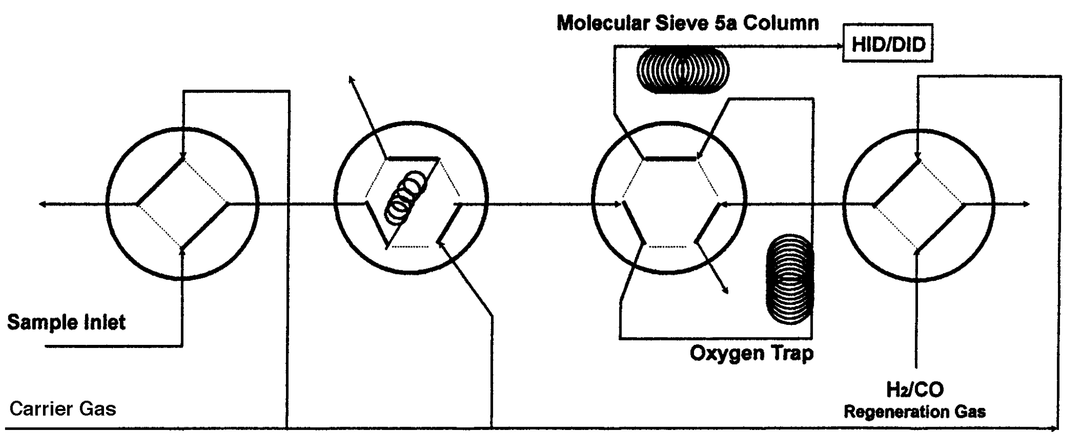


Figure 1
Analysis of Nitrogen and Argon in Oxygen Using Oxygen Trap

SEMI C3.6-0701
SPECIFICATION FOR PHOSPHINE (PH_3) IN CYLINDERS, 99.98% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2001. Initially available at www.semi.org May 2001; to be published July 2001. Originally published in 1981; previously published in 1995.

1 Description

1.1 Phosphine is a highly toxic, flammable, colorless gas with an odor of decaying fish. In high concentrations, it is pyrophoric. It is shipped as a liquid in cylinders under its own vapor pressure.

2 Specifications

QUALITY: 99.98%

Impurities	*Maximum Acceptable Level (ppm)**
Arsine (AsH_3)	10
Carbon dioxide (CO_2)	10
Carbon Monoxide (CO)	1
Heavy Metals	**
Hydrogen (H_2)	100
Nitrogen (N_2)	50
Oxygen (O_2) + Argon (Ar)	5
Particles	**
Hydrocarbons expressed as Methane (C_1–C_2)	4
Water (H_2O) (v/v)	1
TOTAL LISTED IMPURITIES	181

* An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

** To be determined between supplier and user.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	33.997	33.997
Boiling point at 1 atm	-87.7°C	-125.9°F
Density of gas at 25°C (77°F) and 1 atm	1.402 kg/m^3	0.0875 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	1.146	1.146
Density of liquid at boiling point	744 kg/m^3	46.45 lb/ft^3

4 Analytical Procedures

4.1 *Carbon Monoxide, Carbon Dioxide, and Hydrocarbons (expressed as methane)* — This procedure is for the determination of carbon monoxide, carbon dioxide, and hydrocarbons in phosphine using a gas chromatograph with a methanizer and a flame ionization detector. (See Note 1 and Figure 1.)

4.1.1 *Detection Limit* — 0.1 ppm each impurity.

4.1.2 *Instrument Parameters*

4.1.2.1 *Column* — Porapak QS, 3.5 m (12 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss or equivalent.

4.1.2.2 *Carrier Flow* — 35 mL/min helium.

4.1.2.3 *Support Gases*

Hydrogen: 30 mL/min added to the carrier gas between the column outlet and the methanizer inlet.

Air: 500 mL/min.

4.1.2.4 Temperatures:

Detector	110°C
Injector	40°C
Oven	40°C
Methanizer	370–400°C

4.1.2.5 Sample Volume — 3 mL.

4.1.3 *Calibration Standards* — 1–10 ppm each: carbon monoxide, carbon dioxide, methane, ethane*, ethylene*, and acetylene*, balance helium. *These components are for reference only.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard into the column using a gas sampling valve. Record retention times and peak areas. Order of elution is carbon monoxide, methane, carbon dioxide, acetylene, ethylene.

4.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Vent the phosphine after the ethylene peak. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 *Calculation of Concentrations*

4.1.4.4.1 *Carbon Monoxide and Carbon Dioxide* — Compare the average peak areas for the calibration standard to those of the phosphine sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed the specification in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.1.4.4.2 *Total Hydrocarbons Expressed as Methane (C_1–C_2)* — Compare the peak area of methane in the calibration standard with the sum of the areas of the hydrocarbons detected in the phosphine sample. Calculate the concentration of total hydrocarbons using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sum of areas for all Hydrocarbons detected}}{\text{Standard Peak Area for Methane}} \times \text{Concentration of Methane in Standard} = \text{THC Concentration of Sample}$$

4.2 *Hydrogen, Nitrogen, and Oxygen + Argon, Arsine* — This procedure is for the determination of hydrogen, nitrogen, oxygen + argon, and arsine in phosphine using a gas chromatograph with a discharge ionization detector. (See Note 2 and Figure 2.)

4.2.1 *Detection Limits* — 100 ppb (mol/mol) hydrogen, 100 ppb (mol/mol) oxygen + argon, 500 ppb (mol/mol) nitrogen, 5 ppm (mol/mol) arsine.

4.2.2 *Instrument Parameters*

4.2.2.1 *Columns:*

Column 1:	Porapak QS, 2.5 m (8 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss or equivalent.
Column 2:	Molecular Sieve 5A, 3 m (10 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID ss or equivalent.

4.2.2.2 *Carrier Flow* — 25 mL/min helium.

4.2.2.3 *Temperatures*

Detector	10°C
Injector	30°C
Oven	40°C

4.2.2.4 *Sample Volume* — 1 mL.

4.2.3 *Calibration Standard* — 5–50 ppm (mol/mol) nitrogen, 1–10 ppm (mol/mol) oxygen, 1–10 ppm (mol/mol) argon, 10–100 ppm (mol/mol) hydrogen, 5–10 ppm (mol/mol) arsine, balance helium.

4.2.4 *Operating Procedure*

4.2.4.1 *Determination of the Switching Time* — Inject the calibration sample in 4.2.3 above and note the time when the hydrogen peak appears through detector B. Switching valve 1 at that time will give an arsine peak through detector A and hydrogen, oxygen + argon, and nitrogen peaks through detector B.

4.2.4.2 Inject the calibration standard into the column using the same gas valve. Switch at the time determined in 4.2.4.1 and record retention times and peak areas. Order of elution is hydrogen, oxygen + argon, and nitrogen on detector B. Order of elution is phosphine and arsine on detector A.

4.2.4.3 Inject the sample being tested in same manner as the calibration standard. Record the retention times and peak areas.

4.2.4.4 Repeat 4.2.4.2.

4.2.4.5 Compare the average peak areas of the calibration standard to those of the phosphine sample being tested. Calculate the concentration of each impurity, using the formula below. The results may not exceed the specifications in Section 2 of this standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \text{Concentration of Standard} = \text{Concentration of Sample}$$

4.3 *Water* — This procedure is for the determination of moisture in phosphine using continuous flow electrolysis of water in a phosphorous pentoxide (P_2O_5) cell, modified as per the manufacturer's recommendation, for use with phosphine.

4.3.1 *Detection Limit* — 0.5 ppm (vol/vol).

4.3.2 *Instrument Parameters*

4.3.2.1 *Flow Requirements* — Set the sample flow rate and pressure in accordance with manufacturer's instructions.

4.3.3 *Calibration Standards* — Construct a calibration curve which contains at least three points covering the range of interest. Verify the standards employed independently on a condensation dew point/frost point hygrometer. Standards are prepared in nitrogen.

4.3.4 *Operating Procedure*

4.3.4.1 Obtain representative sample of gas to analyze and direct to unit as with the standards.

4.3.4.2 Determine the moisture content in sample gas by comparing the indicated concentration with the calibration curve constructed in 4.3.4.1. The result may not exceed the specification in Section 2 of this standard.

4.4 *Notes*

NOTE 1: Carrier gases should contain less than 0.1 ppm (mol/mol) carbon monoxide and less than 0.1 ppm (mol/mol) carbon dioxide.

NOTE 2: Carrier gas purity of helium must be 99.9999%.

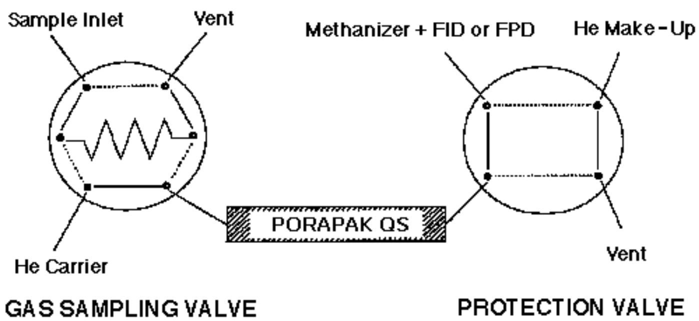


Figure 1
G.C. Configuration

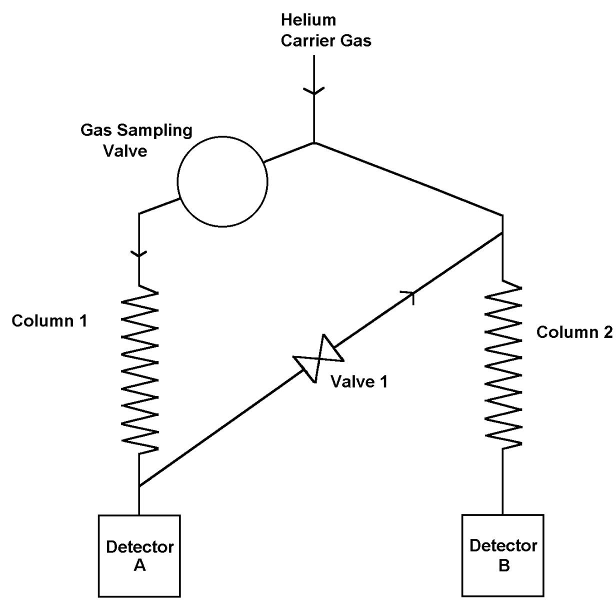


Figure 2
Column Configuration for H_2, N_2, and O_2 + Ar, AsH_3

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SEMI C3.54-0200
GAS PURITY GUIDELINE FOR SILANE (SiH_4)

This guideline was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org January 2000, to be published February 2000. Originally published in 1997.

1 Description

1.1 Silane is a pyrophoric, flammable colorless gas.

2 Specifications

Quality: 99.994%

Impurities	*Maximum Acceptable Level (ppm)*
Arsine (AsH_3)	1 ppb
Carbon Monoxide (CO)	0.1
Carbon Dioxide (CO_2)	0.1
Chlorosilanes (ionizable chlorides) including HC1, reported as chloride ($C1^-$)	1
Non-methane Hydrocarbons (C_2 - C_4)	0.1 total
Hydrogen (H_2)	50
Methane (CH_4)	0.1
Nitrogen (N_2)	1
Phosphine (PH_3)	0.1 ppb
Disiloxane ($H_3SiOSiH_3$)	1
Methyl Silane (SiH_3-CH_3)	1
Disilane (Si_2H_6)	1
Aluminum (Al)	0.2 ppba (See NOTE 1.)
Antimony (Sb)	0.2 ppba (See NOTE 1.)
Arsenic (As)	0.2 ppba (See NOTE 1.)
Boron (B)	0.02 ppba (See NOTE 1.)
Gallium (Ga)	0.2 ppba (See NOTE 1.)
Phosphorus (P)	0.02 ppba (See NOTE 1.)
Calcium (Ca) + Chromium (Cr) + Copper (Cu) + Iron (Fe) + Potassium (K) + Lithium (Li) + Magnesium (Mg) + Manganese (Mn) + Molybdenum (Mo) + Sodium (Na) + Nickel (Ni) + Lead (Pb) + Zinc (Zn)	1.0 ppba total (See NOTE 1.)
Water (H_20) (vol/vol)	1
Particles	(See NOTE 2.)
TOTAL SPECIFIED IMPURITIES	56.4033

NOTE 1: To be determined between supplier and user.

NOTE 2: ppba is defined to be atoms of impurity per 10^9 atoms of silicon.

3 Electrical Specification

Resistivity	greater than 10,000 ohm-cm (n-type)

4 Physical Constants

	Metric Units	*US Units*
Molecular weight	32.112	32.112
Boiling point at 1 atm.	–112°C	–169.6°F
Density of gas at 21.1°C (70°F) and 1 atm.	1.342 kg/m^3	0.0839 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm. (air = 1)	1.114	1.114
Density of liquid at boiling point.	711 kg/m^3	44.39 lb/ft^3

5 Procedures (See NOTE 1)

NOTE 1: Standardized test methods are being developed for all parameters at the purity level indicated. Until standardized test methods are published, test methodology shall be determined by user and producer.

SEMI C3.10-95 (Withdrawn 0701)
STANDARD FOR SILANE (SiH_4) (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Silane is a pyrophoric, flammable, colorless gas with a repulsive odor.

SEMI C3.55-0200
STANDARD FOR SILANE (SiH_4), BULK

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org January 2000; to be published February 2000.

1 Description

1.1 Silane is a pyrophoric, flammable colorless gas.

2 Specifications

QUALITY: 99.994%

Impurities	*Maximum Acceptable Level (ppm)*
Gas Phase	
Carbon Monoxide (CO)	0.1
Carbon Dioxide (CO_2)	0.1
Chlorosilanes (ionizable chlorides) including HCl, reported as chloride (Cl^-)	1
Non-methane Hydrocarbons (C_2-C_4)	0.1 total
Hydrogen (H_2)	50
Methane (CH_4)	0.1
Nitrogen (N_2)	1
Argon (Ar)	1
Disiloxane ($H_3SiOSiH_3$)	1
Methyl Silane (SiH_3-CH_3)	1
Disilane (Si_2H_6)	1
Water (H_2O)(vol/vol)	1
Particles	(See NOTE 1.)
Total Specified Impurities	57.4
Deposited Layer	
Carbon (C)	0.5 ppma (See NOTE 2.)
Oxygen (O)	1 ppma (See NOTE 2.)
Aluminum (Al)	0.2 ppba (See NOTE 2.)
Antimony (Sb)	0.2 ppba (See NOTE 3.)
Arsenic (As)	0.2 ppba (See NOTE 3.)
Boron (B)	0.2 ppba (See NOTE 3.)
Gallium (Ga)	0.2 ppba (See NOTE 3.)
Phosphorus (P)	0.2 ppba (See NOTE 3.)
Chromium (Cr)+ Copper (Cu)+ Iron (Fe)+ Nickel (Ni)+ Zinc (Zn)	1.0 ppba total (See NOTE 3.)

NOTE 1: To be determined between supplier and user.

NOTE 2: ppma is defined to be atoms of impurity per 10^6 atoms of silicon.

NOTE 3: ppba is defined to be atoms of impurity per 10^9 atoms of silicon.

3 Electrical Specification

Resistivity	greater than 2,000 ohm-cm (n-type)

4 Physical Constants

	Metric Units	*US Units*
Molecular weight	32.112	32.112
Boiling point at 1 atm.	-112°C	-169°F
Density of gas at 21.1°C (70°F) and 1 atm.	1.342 kg/m^3	0.0839 lb/ft^3
Specific gravity of gas at 21.1°C and 1 atm (air = 1)	1.114	1.114
Density of liquid at boiling point	711 kg/m^3	44.39 lb/ft^3

5 Analytical Procedures (see NOTE 1)

5.1 *Carbon Monoxide, Carbon Dioxide, Argon, Nitrogen and Methane* — This procedure is for the determination of of carbon monoxide, carbon dioxide, argon, nitrogen and methane in silane using a gas chromatograph with a discharge ionization detector.

5.1.1 *Detection Limit* — 30 ppb (mole/mole)

5.1.2 *Instrument Parameters*

5.1.2.1 Column:

HAYESEP D 60/80, 6.5 m (21.3 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel; or equivalent.

5.1.2.2 *Carrier Flow* — 25 mL/min helium

5.1.2.3 *Sample Volume* — 1 mL

5.1.2.4 Temperatures:

Detector	140°C
Column Oven	40°C for 4 min., to 120°C at 10°C/min., hold 120°C for 8 min.
Injection Temperature	45°C

5.1.3 *Calibration Standards* — 1 ppm (mole/mole) for all components to be tested, balance helium.

5.1.4 *Operating Procedures*

5.1.4.1 Inject the calibration standard and sample as described in Section 6.6 of SEMI C3. The order of elution is nitrogen, argon, carbon monoxide, methane, and carbon dioxide. (See NOTE 2.)

5.1.4.2 Compare the average peak area of the calibration standard to that of the silane sample being tested. Calculate the concentrations of the analytes as described in Section 6.8 of SEMI C3. The result shall be reported in the unit of concentration needed and to the number of significant digits of the variable with the least number of significant digits. This value may not exceed that specified in Section 2.

5.2 *Total Chlorides* — This procedure is for the determination of total chlorides in silane by titration of a hydrolyzed sample of silane. (See NOTE 1.)

5.2.1 *Detection Limit* — 0.5 ppm (mole/mole)

5.2.2 *Instrument Parameters* — See Figure 1.

5.2.2.1 *Equipment*

5.2.2.1.1 Safety purge regulator with proper fittings.

5.2.2.1.2 Flow meter capable of measuring 0.25 standard liters per minute (0.5 SCF/hour) (Brooks or equivalent), calibrated for silane.

5.2.2.1.3 One cylinder of nitrogen with regulator.

5.2.2.1.4 One ice bath.

5.2.2.1.5 Three magnetic stirring bars.

5.2.2.1.6 Two 2000 mL heavy-duty sidearm flasks (Fisher Cat. No. 10-181G or equivalent).

5.2.2.1.7 One #9 one-hole rubber stopper.

5.2.2.1.8 One #9 two-hole rubber stopper.

5.2.2.1.9 Two Pyrex-brand tubes with fritted cylinders (Fisher Cat. No. 11-138B or equivalent).

5.2.2.1.10 One gas washing bottle with fritted cylinder, 125 mL cap. (Fisher Cat. No. 03-040A or equivalent).

5.2.2.1.11 One buret, 50 mL capacity with Teflon stopcock (Fisher Cat. No. 03-700-22C or equivalent).

5.2.2.1.12 One buret stand (Fisher Cat. No. 14-688 or equivalent).

5.2.2.1.13 Miscellaneous clamps, support stands, and rubber hose.

5.2.2.1.14 Two 250 mL Erlenmeyer flasks.

5.2.2.2 *Reagents*

5.2.2.2.1 Potassium hydroxide flakes, technical (Fisher Cat. No. P-246 or equivalent).

5.2.2.2.2 Mercuric nitrate crystal (Fisher Cat. No. M-168 or equivalent).

5.2.2.2.3 Sodium chloride crystal (Fisher Cat. No. S-271 or equivalent).

5.2.2.2.4 Diphenyl carbazone (Fisher Cat. No. D-86 or equivalent).

5.2.2.2.5 Bromophenol blue (Fisher Cat. No. B-392 or equivalent).

5.2.2.2.6 Nitric acid (Fisher Cat. No. AA-200 or equivalent).

5.2.2.2.7 Ethanol, denatured (Fisher Cat. No. AA-407 or equivalent).

5.2.3 *Operating Procedure*

5.2.3.1 Assemble apparatus as shown in Figure 1 and purge entire system with nitrogen for 30 minutes.

5.2.3.2 Fill each 2000 mL sidearm flask with about 1700 mL of 15% potassium hydroxide solution (15 g KOH per each 100 mL water).

5.2.3.3 Fill the gas washing bottle with about 75 mL of deionized water that has been degassed.

5.2.3.4 Pass exactly one cubic foot of silane through the system at a rate of 0.5 cubic feet per hour.

5.2.3.5 Stop silane flow and purge system for 30 minutes.

5.2.3.6 Remove gas washing bottle from system and transfer contents quantitatively and with the aid of three 25 mL deionized water washings, to a 250 mL Erlenmeyer flask.

5.2.3.7 Add a few drops of indicator solution, 5 g diphenyl carbazone plus 0.5 g bromophenol blue dissolved in 750 mL ethanol, plus 250 mL deionized water.

5.2.3.8 Add, in a drop-wise fashion, sufficient 0.2 N $HN0_3$ (13 mL concentrated. $HN0_3$, diluted to 1 L in deionized water) in order to just turn the solution to yellow from purple.

5.2.3.9 Titrate with a solution of mercuric nitrate $Hg(NO_3)_2$, (diluted to 1000 mL in deionized water; then 50 mL diluted to 500 mL in deionized water) which has been previously standardized to 5.0 mL of a sodium chloride solution (approximately 165 ng NaCl, accurately weighed, dissolved in 100 mL deionized water).

5.2.4 *Calibration*

5.2.4.1 Run titration blank consisting of 150 mL deionized water.

5.2.4.2 Calculate the concentration of chloride, using the formula below. The result may not exceed the specification in Section 2 of this standard.

$$\frac{mL_{sample} - mL_{blank}}{mL_{standard} - mL_{blank}} \times \frac{wt.\,NaCl(g)}{100.0mL} \times \frac{60.66\%Cl-}{100\%NaCl} \times$$

$$\frac{100mL}{1L} \times \frac{0.005l}{35.453g/mole} \times \frac{0.082atmL/moleK}{28.316L} \times$$

1×10^{6} ppm = ppm Cl-

5.3 *Hydrocarbons $C_2 - C_4$* — This procedure is for the determination of hydrocarbons (methane, ethane, and propane) in silane using a gas chromatograph with a flame ionization detector.

5.3.1 Detection Limit — 50 ppb (mole/mole)

5.3.2 Instrument Parameters

5.3.2.1 Columns:

Column 1:	VZ-10, 60/80, 2 m (6.6 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel;
Column 2:	VZ-10, 60/80, 1 m (3.3 ft) by 3.2 mm (1/8 in) OD by 2.2 mm (0.085 in) ID stainless steel;

or equivalent.

5.3.2.2 Carrier Flow — 30 mL/min nitrogen

5.3.2.3 Sample Volume — 10 mL

5.3.2.4 Temperatures:

Detector	150°C
Column Oven	45°C

5.3.3 Calibration Standards — 1 ppm (mole/mole) for all components to be tested, balance helium.

5.3.4 Operating Procedures — (see SEMI C3, Section 6, Gas Chromatography for standard procedures).

5.3.4.1 Inject the calibration standard and sample as described in Section 6.6 of SEMI C3. The order of elution is methane, ethane, propane and butane (see NOTE 2).

5.3.4.2 Compare the average peak area of the methane peak in the calibration standard to that of the hydrocarbons found in the silane sample being tested. Calculate the concentrations of the analytes as described in Section 6.8 of SEMI C3 based on the methane response. The result shall be reported in the unit of concentration needed and to the number of significant digits of the variable with the least number of significant digits. This value may not exceed that specified in Section 2.

5.4 *Hydrogen* — This procedure is for the determination of hydrogen in silane using a gas chromatograph with a thermal conductivity detector.

5.4.1 *Detection Limit* — 15 ppm (mole/mole)

5.4.2 *Instrument Parameters*

5.4.2.1 Columns:

Molecular sieve 5A, 2.4 m (8 ft) by 6.4 mm (1/4 in) OD by 4.7 mm (0.185 in) ID, or equivalent.

5.4.2.2 *Carrier Flow* — 30 mL/min argon

5.4.2.3 *Sample Volume* — 1.0 mL

5.4.2.4 Temperatures:

Detector	40°C
Column Oven	40°C

5.4.3 *Calibration Standards* — 20–100 ppm (mole/mole), balance argon.

5.4.4 *Operating Procedures* — (see SEMI C3, Section 6, Gas Chromatography for standard procedures)

5.4.4.1 Inject the calibration standard and sample as described in Section 6.6 of SEMI C3. (See NOTE 2.)

5.4.4.2 Compare the average peak area of the hydrogen peak in the calibration standard to that of the hydrogen found in the silane sample being tested. Calculate the concentrations of the analytes as described in Section 6.8 of SEMI C3 based on the methane response. The result shall be reported in the unit of concentration needed and to the number of significant digits of the variable with the least number of significant digits. This value may not exceed that specified in Section 2.

5.5 *Disiloxane, Disilane and Methyl Silane* — This procedure is for the determination of disiloxane, disilane and methyl silane in silane using a gas chromatograph with flame ionization detector.

5.5.1 *Detection Limit* — 0.1 ppm (mole/mole)

5.5.2 *Instrument Parameters*

5.5.2.1 Column:

28% DC-200 on Chromosorb PAW, 45/60 mesh, 14 m (46 ft) SS, or equivalent.

5.5.2.2 Carrier Flow — 30 mL/min helium

5.5.2.3 Sample Volume — 2 mL

5.5.2.4 Temperatures — Column 60°C

5.5.2.5 *Calibration Standards* — 1–5 ppm (mole/mole)

5.5.3 *Operating Procedure* — (see SEMI C3, Section 6, Gas Chromatography for standard procedures).

5.5.3.1 Inject the calibration standard and sample as described in Section 6.6 of SEMI C3. The order of elution is silane matrix, methyl silane, siloxane (for information only) and disilane. (See NOTE 2.)

5.5.3.2 Compare the average peak area of the components being measured in the calibration standard to that of the same analytes found in the silane sample being tested. Calculate the concentrations of the analytes as described in Section 6.8 of SEMI C3. The result shall be reported in the unit of concentration needed and to the number of significant digits of the variable with the least number of significant digits. This value may not exceed that specified in Section 2.

5.6 *Water* — This procedure is for the determination of trace moisture (water) in silane using a vibrating quartz hygrometer.

5.6.1 *Detection Limit* — 0.1 ppm (vol/vol)

5.6.2 *Instrument Parameters*

5.6.2.1 *Flow Requirements* — Set the sample pressure and flow rate in accordance with the instrument manufacturer's instructions.

5.6.3 *Calibration Standards* — Check the hygrometer calibration with silane using an external permeation device. Construct a calibration curve which contains at least three points covering the range of interest. The standards employed will have been verified independently on a condensation dewpoint/frostpoint hygrometer. (See Figure 2.)

5.6.4 *Operating Procedure* — At the first start-up of the hygrometer, calibrate it with moisture standards in silane. Then check the calibration once a month and modify the hygrometer if necessary. Direct standard to unit with stainless lines which have been purged. Note that silane is spontaneously flammable. Thus the experimental set-up should be leak-free and thoroughly purged before the introduction of silane. Obtain representative sample of the gas to be analyzed and direct to the unit. Wait until the equilibrium and read the moisture content. The result may not exceed the specification.

5.6.4.1 Construct a calibration curve with previously verified standards. Direct standard to unit with stainless steel lines which have been purged.

5.6.4.2 Obtain representative sample of gas to be analyzed and direct to unit as with the standards. (See NOTE 1.)

5.6.4.3 Construct a calibration curve and determine the ppm moisture content in sample gas. The result may not exceed the specification in Section 2 of this standard.

5.7 *Elemental Analysis in Deposited Layer* — Procedures for the analysis of elemental impurities in deposited layers of polysilicon should be designated and should be referenced from a recognized industry standard (including but not limited to ISO, ASTM, etc.).

5.7.1 *Typical Detection Limits*

Compound	*Detection Limit*
Carbon (C)	0.2 ppma
Oxygen (O)	0.2 ppma
Boron (B)	0.02 ppba
Aluminum (Al)	0.02 ppba
Gallium (Ga)	0.02 ppba
Phosphorus (P)	0.02 ppba
Arsenic (As)	0.02 ppba
Antimony (Sb)	0.02 ppba
Iron (Fe)	0.3 ppba
Chromium (Cr)	0.01 ppba
Nickel (Ni)	0.2 ppba
Copper (Cu)	0.02 ppba
Zinc (Zn)	0.03 ppba

5.8 *Resistivity* — Procedures for the measurement of resistivity in deposited layers of polysilicon should be designated and should be referenced from a recognized industry standard (including but not limited to ISO, ASTM, etc.).

NOTE 1: Before performing this or any other analytical operation it is necessary to perform the following:

- Familiarize yourself with the products involved and the potential hazards by consulting the MSDS's for all hazardous substances involved and by consulting the CGA's "Handbook of Compressed Gases" for all gases involved.
- Know how to safely handle and store each hazardous gas by consulting the applicable CGA pamphlets.
- Use all necessary and applicable personal protective equipment.
- Follow all instructions relative to the safe operation of the equipment by consulting the LAC Safety Manual and applicable equipment manufacturers manual(s).

It must be noted that silane is a pyrophoric gas and all sample plumbing must be purged of air completely before introducing silane. Extra special attention must be paid to leak checking all connections and checking the vent plumbing to be certain that effluents are vented properly. If there are any questionable connections or leaks, report this to the supervisor immediately and do not proceed with the analysis.

NOTE 2: Introduce the calibration standard as many times as necessary to achieve the desired precision. Detection limit calculated on these calibrations should achieve at least that listed for this procedure.

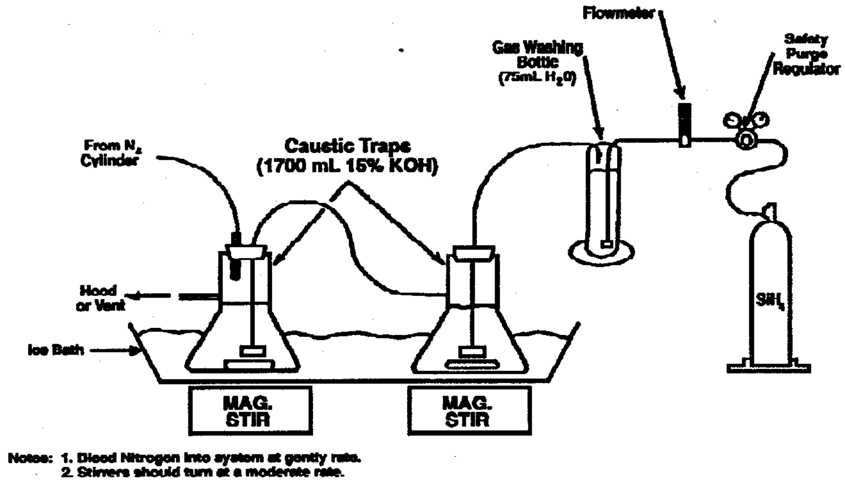


Figure 1
Chloride Scrubbing Apparatus

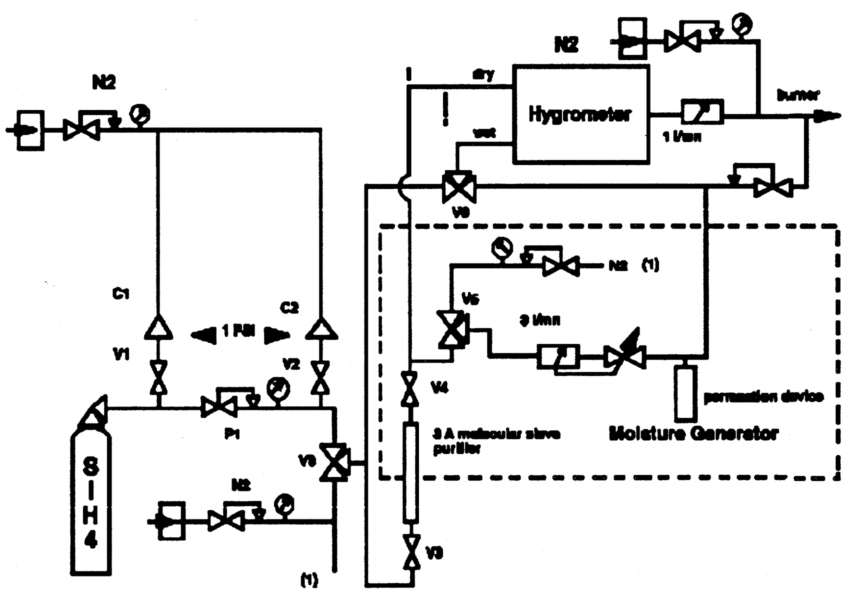


Figure 2
Moisture Analysis in Silane

SEMI C3.11-93 (Withdrawn 0701)
STANDARD FOR SILICON TETRACHLORIDE ($SiCl_4$) IN CYLINDERS (PROVISIONAL)

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Silicon tetrachloride is a corrosive, colorless liquid with a sharp pungent odor. It hydrolyzes rapidly to form hydrogen chloride.

SEMI C3.24-0301
SPECIFICATION FOR SULFUR HEXAFLUORIDE (SF_6) IN CYLINDERS, 99.97% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1984; previously published in 1995.

1 Description

1.1 Sulfur hexafluoride is colorless and odorless. It is noncombustible and has a low toxicity. It is shipped as a liquefied gas under its own vapor pressure.

2 Specifications

QUALITY: 99.97%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Air	100
Carbon Tetrafluoride (CF_4)	100
Hydrogen Fluoride (HF)	1
Water (H_2O) (mol/mol)	8
TOTAL LISTED IMPURITIES	209

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	146.054	146.054
Boiling point at 1 atm	-63.7°C	-82.7°F
Density of gas at 20°C (68°F) and 1 atm	6.162 kg/m^3	0.385 lb/ft^3
Specific gravity of gas at 21.1°C (70°F) and 1 atm (air = 1)	5.114	5.114
Density of liquid at -50°C	1910 kg/m^3	119.2 lb/ft^3

4 Analytical Procedures (Notes 1, 2, and 3)

4.1 *Air and Carbon Tetrafluoride* — This procedure is for the determination of air and carbon tetrafluoride using a gas chromatograph with a thermal conductivity detector.

4.1.1 *Detection Limit* — 1 ppm (mol/mol)

4.1.2 *Instrument Parameters*

4.1.2.1 Column: 2.4 m (8 ft) by 6.4 mm (1/4 in) OD, 5.1 mm (0.201 in) ID stainless steel tubing packed with Porapak Q (80/100 mesh) or equivalent.

4.1.2.2 Carrier Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 1 mL.

4.1.2.4 Temperatures:

Detector	110°C
Column	70°C

4.1.3 *Calibration Standards* — 90–100 ppm (mol/mol) carbon tetrafluoride, 90–110 ppm (mol/mol) Air (O_2/N_2 blend), balance helium.

4.1.4 *Operating Procedure*

4.1.4.1 Inject the calibration standard. Analyze the standard using the conditions described above. Record the retention times and peak areas.

4.1.4.2 Inject the sample to be tested in the same manner as the calibration standard. Record the retention times and peak areas.

4.1.4.3 Repeat 4.1.4.1.

4.1.4.4 Calculate the concentrations of air and carbon tetrafluoride in the sample, using the formula below. The result may not exceed the specification in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Hydrogen Fluoride* — This procedure is for the determination of hydrogen fluoride by quantitative collection in dilute sodium carbonate ($NaHCO_3$) and subsequent analysis by ion chromatography.

4.2.1 *Detection Limit* — 0.1 ppm for the method

Equipment Required:

500 mL Greenburgh impinger

50 mL Class A pipet

Type 316 stainless steel delivery system

5' Fluorocarbon tubing, 1/4 in OD by 0.03 in wall

Reagent Grade sodium bicarbonate

Deionized water

50 mL high-density polyethylene bottles

Assorted Class A volumetric flasks

Ion chromatograph

Anion column which separates:

F^-, Cl^-, Br^-, SO_4^{-2}, PO_4^{-3}

4.2.2 *Ion Chromatograph Parameters:*

Instrument:	Dionex 2000 (or equivalent)
Integrator:	Dionex 4270 (or equivalent)
Column:	HDIC AS4A (or equivalent)
Eluent:	0.001 M Na_2CO_3 + 0.001 M $NaHCO_3$
Flow Rate:	2 mL/minute
Pressure:	960 psia
Detector Conductivity Range:	3.0 microsiemens for less than 10 ppm
Sample:	100 microliters

4.2.3 *Calibration* — Calibrate the ion chromatograph by dissolving a weighed amount of ammonium fluoride (NH_4F) in deionized water and sequentially diluting it to a fluoride concentration of 0.1 ppmw in Class A volumetric flasks and analyzing it as specified by the instrument manufacturer.

4.2.4 *Operating Procedure*

4.2.4.1 Prepare a fresh solution of 1.7 mM sodium bicarbonate in deionized water.

4.2.4.2 Pipet 200 mL of the solution into a 500 mL Greenburgh impinger.

4.2.4.3 Bubble approximately 20 L of sulfur hexafluoride (SF_6) through the solution, using the delivery system shown in Figure 1.

4.2.4.4 Analyze the solution as specified by the instrument manufacturer.

4.2.4.5 *Calculation* — Calculate the concentration of hydrogen fluoride (HF) using the following formula:

$$\text{ppmv HFg} = \frac{(F^{-}\text{ppmw}) \times Vg}{19.00 \times mg}$$

Where:

F^- ppm	=	Fluoride concentration in trapped solution.
Vg	=	Volume of collection solution (mL).
mg	=	Moles of SF_6 bubbled through the collecting solution.
19.00	=	Molecular weight of F^-.

The result may not exceed the specification in Section 2 of this Standard.

4.3 *Water* — This procedure is for the determination of trace moisture (water) in sulfur hexafluoride using a continuous flowing electrolytic hygrometer. (See Notes 4, and 5.)

4.3.1 *Detection Limit* — 1.0 ppm (vol/vol) or -76°C (-105°F).

4.3.2 *Sample Pressure and Flow* — Set in accordance with instrument manufacturer's instructions.

4.3.3 *Operation Check* — Check the instrument periodically for correct operation. A gas containing a known amount of moisture should be passed through the instrument. Agreement between the hygrometer and the standard should be within their relative accuracies.

4.3.4 *Operating Procedure*

4.3.4.1 Obtain a continuous flow sample of sulfur hexafluoride source, using a clean, electropolished or passivated stainless steel line which has been purged dry after exposure to ambient moisture. (See Note 5.)

4.3.4.2 After prepurging with a dry gas, allow the sample gas to flow through the sampling system and hygrometer until a stable reading is obtained. The reading may not exceed the specification in Section 2 of this Standard.

4.4 *Notes*

NOTE 1: Introduce the calibration standard as many times as necessary to achieve the desired precision.

NOTE 2: All gases used in the analysis of the sample should not contain more than 10% of the specified value of the component of interest, unless otherwise stated.

NOTE 3: Observe proper safety procedures for handling and disposing of sulfur hexafluoride (SF_6).

NOTE 4: The sampling system and hygrometer must be designed to operate at the sample pressure, or the sample pressure must be reduced (by a regulator with a diaphragm of stainless steel or other suitable material) to accommodate the pressure restrictions of the hygrometer.

NOTE 5: A passivation procedure is described in Metals Handbook, Eighth Edition, Volume 2, ASM International, Metals Park, Ohio.

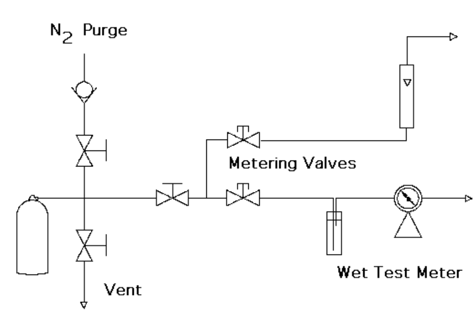


Figure 1

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C3.53-95 (Withdrawn 0701)
STANDARD FOR TRIFLUOROMETHANE (CHF_3), 99.95% QUALITY

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Description

Trifluoromethane (CHF_3) is a colorless, nonflammable, noncorrosive gas with a slight ethereal odor. It is shipped in cylinders as a liquified gas under its own vapor pressure.

SEMI C3.26-0301
SPECIFICATION FOR TUNGSTEN HEXAFLUORIDE (WF_6) IN CYLINDERS, 99.8% QUALITY

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1984; previously published in 1994.

1 Description

1.1 Tungsten hexafluoride is a colorless gas or colorless liquid. It is shipped as a liquefied gas under its own vapor pressure.

2 Specifications

QUALITY: 99.8%

Impurities	*Maximum Acceptable Level (ppm) (See NOTE 1.)*
Carbon Tetrafluoride (CF_4)	10
Hydrogen Fluoride (HF)	1000
Nitrogen (N_2)	50
Oxygen (O_2) + Argon (Ar)	50
Sulfur Hexafluoride	10
Silicon Tetrafluoride	10
TOTAL LISTED IMPURITIES	1130

NOTE 1: An analysis of significant figures has not been considered. The number of significant figures will be based on analytical accuracy and the precision of the provided procedure.

3 Physical Constants (for information only)

	Metric Units	*US Units*
Molecular weight	297.85	297.85
Boiling point at 1 atm	17.1°C	62.8°F
Density of gas at 22.8°C (73°F) and 1 atm	12.9 kg/m^3	0.805 lb/ft^3
Specific gravity of gas	10.8	10.8
Density of liquid at boiling point	3440 kg/m^3	214.8 lb/ft^3

4 Analytical Procedures (See Notes 1, 2, 3, 4, 5, 6, 7)

4.1 *Nitrogen and Oxygen + Argon* — This procedure is for the determination of nitrogen and oxygen + argon in tungsten hexafluoride using a gas chromatograph with a thermal conductivity detector.

4.1.1 *Detection Limits* — 10 ppm (mol/mol) nitrogen, and 10 ppm (mol/mol) oxygen + argon.

4.1.2 *Instrument Parameters*

4.1.2.1 Columns: (See Figures 1, 2)

Column 1:	Porapak S, 80/100 mesh, 1.5 m (5 ft) by 6.4 mm (1/4 in) OD, 5.1 mm (0.2 in) ID, ss or equivalent.
Column 2:	Molecular sieve 5A, 80/100 mesh, 1.8 m (6 ft) by 4.8 mm (3/16 in) OD, 3.7 mm (0.147 in) ID, ss or equivalent.

4.1.2.2 Column Flow: 30 mL/min helium.

4.1.2.3 Sample Volume: 2 mL

4.1.2.4 Temperatures

Detector	70°C
Column	40°C

4.1.3 *Calibration Standard* — 50 ppm (mol/mol) nitrogen, 50 ppm (mol/mol) oxygen, balance helium.

4.1.4 *Operating Procedures*

4.1.4.1 Determine the times for valve switching and signal changes, and enter into the run table. An example of a run table follows.

Time	*Position*	*Function*
0 min.	1	Purge sample through loop. Backflush Porapak column. Connect MS column to the TCD.
1 min.	2	Inject sample onto Porapak column. Allow oxygen + argon and nitrogen to elute from the Porapak column to the MS column. Sequentially elute the oxygen + argon and nitrogen from the MS column to the TCD.
4 min.	1	Backflush Porapak column to vent for 8 minutes.

4.1.4.2 Set the valves in Position 1 (Figure 1).

4.1.4.3 Flow the calibration standard through the 10-port valve. Analyze standard using the conditions described above. Record retention times and peak areas.

4.1.4.4 Flow the sample to be tested through the 10-port valve for 1 minute. Analyze in the same manner as in 4.1.4.3.

4.1.4.5 The standard is again run as in 4.1.4.3.

4.1.4.6 Calculate the concentrations of nitrogen and oxygen + argon in the sample, using the formula below. The result may not exceed the specifications in Section 2 of this Standard.

$$\frac{\text{Sample Peak Area}}{\text{Standard Peak Area}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.2 *Carbon Tetrafluoride, Hydrogen Fluoride, Silicon Tetrafluoride, and Sulfur Hexafluoride* — This procedure is for the determination of these gases in tungsten hexafluoride using infrared spectrophotometry. (See Note 2.)

4.2.1 *Detection Limits* — 10 ppm (mol/mol) carbon tetrafluoride, 1000 ppm (mol/mol) hydrogen fluoride, 10 ppm (mol/mol) silicon tetrafluoride and 10 ppm (mol/mol) sulfur hexafluoride.

4.2.2 *Instrument Parameters*

4.2.2.1 Cell path length: 10 cm

4.2.2.2 Sample Cell Pressure: 1 atmosphere

4.2.2.3 Wavenumbers:

Component	*Wavenumber (cm^{-1})*
Carbon Tetraflouride (CF_4)	1283
Hydrogen Fluoride (HF)	4076
Silicon Tetrafluoride (SiF_4)	1029
Sulfur Hexafluoride (SF_6)	948

4.2.3 *Calibration Standards* — 1% (mol/mol) hydrogen fluoride in tungsten hexafluoride, 100 ppm (mol/mol) silicon tetrafluoride in nitrogen, 25 ppm (mol/mol) each carbon tetrafluoride and sulfur hexafluoride in nitrogen.

4.2.4 *Operating Procedures*

4.2.4.1 Flow each calibration gas through the system for 1 minute. Pressurize the cell to 1 atmosphere. Record the absorbance of each calibration standard at the wavenumber listed in 4.2.2.3.

4.2.4.2 Flow the sample gas through the system for 1 minute. Pressurize the cell to 1 atmosphere. Record the absorbance at each of the appropriate wavenumbers. Calculate (See Note 1) the concentration of each gas, using the formula below. The results may not exceed the specification in Section 2 of this standard.

$$\frac{\begin{matrix}\text{Measured Absorbance}\\ \text{of the Sample}\end{matrix}}{\begin{matrix}\text{Measured Absorbance}\\ \text{of the Standard}\end{matrix}} \times \begin{matrix}\text{Concentration}\\ \text{of Standard}\end{matrix} = \begin{matrix}\text{Concentration}\\ \text{of Sample}\end{matrix}$$

4.3 *Notes*

NOTE 1: Tungsten hexafluoride interferes with the direct absorbance reading for silicon tetrafluoride. The absorbance for silicon tetrafluoride is determined by compensating for the interfering absorbance from the tungsten hexafluoride. Compensation is made by subtracting the absorbance contributed to this band by tungsten hexafluoride band at 930 cm^{-1}. This absorbance is halved and subtracted from the total peak absorbance at 1040 cm^{-1}, resulting in the peak absorbance for silicon tetrafluoride.

NOTE 2: Actual detection limits will be determined by the noise level and the resolution of the spectrometer. One way is to reduce the noise level is to use a Fourier Transform Infrared Spectrometer.

NOTE 3: All gases used in the analysis of the sample should not contain more than 10% of the specified value of the component of interest, unless otherwise stated.

NOTE 4: As tungsten hexafluoride has a low vapor pressure, the cylinder should be kept at room temperature (20°C) for at least 8 hours prior to analysis.

NOTE 5: Observe proper safety procedures for handling and disposing of tungsten hexafluoride.

NOTE 6: Prior to introducing tungsten hexafluoride purge the sample lines and instrument tubing with helium to remove moisture.

NOTE 7: Upon completing the analysis, cap off the manifold and instrument lines or purge the system with helium.

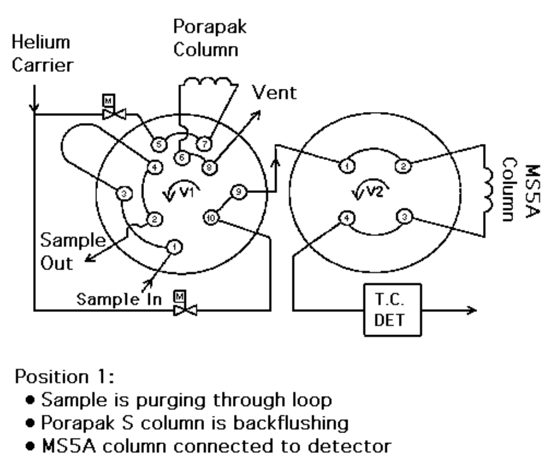
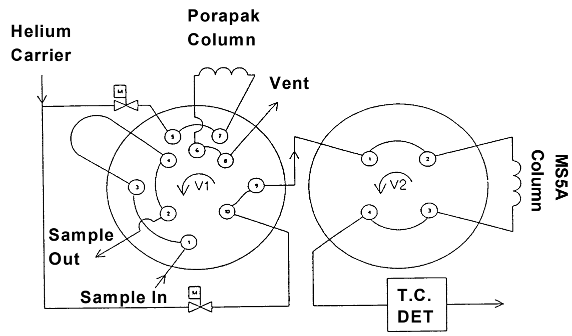


Figure 1



Position 2:
- **V1 is turned**
- **Sample flows through sample loop to the Porapak S column and then to MS5A column**

Figure 2

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SEMI C3.52-0200
STANDARD FOR TUNGSTEN HEXAFLUORIDE, 99.996% QUALITY

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org February 2000, to be published February 2000. Originally published in 1995; previously published in 1996.

1 Purpose

1.1 To define the specification and analytical methods and validate the specifications for WF_6.

2 Scope

2.1 This specification relates to a geometry of 0.5 µ or less (0.35 or 0.5 range) and describes analytical techniques using gas phase and liquid phase analysis.

3 Description

3.1 Tungsten hexafluoride is a colorless, odorless gas or a clear liquid.

4 Specifications

Quality: 99.996%

Impurities	*Maximum Acceptable Level*
Oxygen (O_2) & Argon (Ar)	1 ppm
Nitrogen (N_2)	5 ppm
Carbon Dioxide (CO_2)	1 ppm
Carbon Tetrafluoride (CF_4)	1 ppm
Hydrogen Fluoride (HF)	20 ppm
Silicon Tetrafluoride (SiF_4)	1 ppm
Sulfur Hexafluoride (SF_6)	1 ppm
Carbon Monoxide (CO)	1 ppm
TOTAL SPECIFIED IMPURITIES	31 ppm

Impurities	*Maximum Acceptable Level*
Cobalt (Co) & Manganese (Mn)	0.01 ppm w
Lead (Pb)	0.02 ppm w
Chromium (Cr), Zinc (Zn), & Uranium (U)	0.05 ppm w
Calcium (Ca) & Magnesium (Mg)	0.10 ppm w
Nickel (Ni), Copper (Cu), Sodium (Na), & Potassium (K)	0.15 ppm w
Iron (Fe)	0.02 ppm w
Thorium (Th)	0.1 ppm w
Molybdenum (Mo)	1 ppm w

5 Physical Constants

	Metric Units	*U. S. Units*
Molecular weight	297.85	297.85
Boiling point	17.1°C	62.8°F
Density of gas at 22.8°C (73°F) and 1 atm	12.9 kg/m^3	0.805 lb/ft^3
Specific gravity of gas	10.8	10.8
Density of liquid at boiling point	3440 kg/m^3	

6 Analytical Procedures (see NOTE 1)

6.1 *Carbon Tetrafluoride, Silicon Tetrafluoride, Carbon Dioxide, and Sulfur Hexafluoride* — This procedure is for the determination of carbon tetrafluoride, silicon tetrafluoride, carbon dioxide, and sulfur hexafluoride in tungsten hexafluoride using a gas chromatograph equipped with a helium ionization detector. A backflush is used in order to protect the detector from the main component.

6.1.1 *Detection Limits* — 0.3 ppm (mole/mole) carbon tetrafluoride, 1 ppm (mole/mole) silicon tetrafluoride, 0.1 ppm (mole/mole) carbon dioxide, and 0.5 ppm (mole/mole) sulfur hexafluoride.

6.1.2 *Instrument Parameters*

6.1.2.1 Columns:

Column 1:	10% Kel F Nr10 on Chromosorb T, 4.0 m (13 ft) by 3.2 mm (1/8 in) nickel or equivalent,
Column 2:	Preconditioned HAYESEP Q, 60/80 mesh, 3 m (10 ft) by 3.2 mm (1/8 in) or equivalent. The column should be treated by repeated WF_6 sample injections at 125°C.

6.1.2.2 *Carrier Flow* — 26 mL/min helium, 6.0 grade.

6.1.2.3 Temperatures:

Detector	50°C
Column Oven	50°C

6.1.2.4 *Sample Volume* — 2 mL

6.1.2.5 *Calibration Standards* — 1 and 5 ppm (mole/mole) carbon tetrafluoride, carbon dioxide, and sulfur hexafluoride in helium (see Figures 1 and 2).

10 ppm silicon tetrafluoride in helium or permeation device (see Figure 3).

6.1.3 *Operating Procedure*

6.1.3.1 Attach a suitable pressure regulator to the standard cylinders. Connect the regulator to the dedicated WF_6 handling system which is connected to the chromatographic sampling valve.

6.1.3.2 Purge the sampling lines with the standard for at least one minute.

6.1.3.3 Inject the standard into the gas chromatograph. Record the retention times and peak areas. Order of elution for the above mentioned standard is carbon tetrafluoride, silicon tetrafluoride, carbon dioxide, and sulfur hexafluoride.

6.1.3.4 Inject the WF_6 sample to be analyzed in the same manner as the calibration standard. Record the retention times and peak areas.

6.1.3.5 Compare the average peak areas of the calibration standard to that of the detected peak in tungsten hexafluoride. Calculate the concentration of each impurity using the standard and sample peak areas and the standard concentration. The results may not exceed the specifications.

6.2 *Oxygen and Argon, Nitrogen, and Carbon Monoxide* — This procedure is for the determination of oxygen and argon, nitrogen, and carbon monoxide in tungsten hexafluoride using a gas chromatograph equipped with a helium ionization detector. A backflush is used in order to protect the detector from the main component.

6.2.1 *Detection Limits*

6.2.2 *Instrument Parameters*

6.2.2.1 Columns:

Column 1:	10% Kel F Nr 10 on Chromosorb T, 4.0 m (13 ft) by 3.2 mm (1/8 in) nickel or equivalent.
Column 2:	Preconditioned HAYESEP Q, 60/80 mesh, 3 m (10 ft) by 3.2 mm (1/8 in) or equivalent. The columns should be treated by repeated WF_6 sample injections at 125°C.
Column 3:	Molecular sieve 5 A, 60/80 mesh, 2 m (6 ft) by 3.2 mm (1/8 in).

6.2.2.2 *Carrier Flow* — 26 mL/min helium, 6.0 grade.

6.2.2.3 Temperatures:

Detector	50°C
Column Oven	50°C

6.2.2.4 *Sample Volume* — 2 mL

6.2.2.5 *Calibration Standards* — 1 and 5 ppm (mole/mole) oxygen, nitrogen, and carbon monoxide in helium (see Figure 4).

6.2.3 *Operating Procedure*

6.2.3.1 Attach a suitable pressure regulator to the standard cylinder. Connect the regulator to the dedicated WF_6 handling system, which is connected to the chromatographic sampling valve.

6.2.3.2 Purge the sampling lines with the standard for at least one minute.

6.2.3.3 Inject the standard into the gas chromatograph. Switch the valves in order to operate in the same conditions as the WF_6 sample analysis. Record the retention times and peak areas. Order of elution for the above mentioned standard is oxygen and argon, nitrogen, and carbon monoxide.

6.2.3.4 Inject the WF_6 sample in the same manner as the calibration standard. Record the retention times and peak areas.

6.2.3.5 Compare the average peak areas of the calibration standard to that of the detected peak in the tungsten hexafluoride. Calculate the concentration of each impurity using the standard and sample areas and the standard concentration. The results may not exceed the specifications.

6.3 *Hydrogen Fluoride* — This procedure is for the determination of hydrogen fluoride in tungsten hexafluoride using Fourier Transform Infra Red (FTIR) analyzer.

6.3.1 *Detection Limit* — 0.5 ppm (mole/mole).

6.3.2 *Instrument Parameters*

- cell with CaF_2 windows
- HF band: 4038,8 cm^{-1}
- resolution: 2 cm^{-1}
- path length: 12 cm

6.3.3 *Calibration Standard* — Calibrate with low vapor pressure hydrogen fluoride or permeation device.

6.3.4 *Operating Procedure* — Carefully dry the cell before sampling tungsten hexafluoride. Then purge it with tungsten hexafluoride and record the concentration. When it is steady, that means the line is purged and the true hydrogen fluoride concentration is obtained.

6.4 *Elemental Impurities* — This procedure is for the determination of Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Th, U, and Zn in the nonvolatile residue of liquid phases tungsten hexafluoride (WF_6) and analyzed by Inductively Coupled Plasma Mass Spectrometry (ICPMS).

6.4.1 *Detection Limits (ppb wt/wt)* — Ca: 1.5; Co: 0.1; Cr: 0.8, Cu: 0.5; Fe: 1; K: 1.5; Mg: 0.1, Mn: 0.1, Mo: 0.5; Na: 0.6; Ni: 1; Pb: 0.1; Th, U: 0.01; and Zn: 0.8.

6.4.2 *Sampling Apparatus* — Figure 5 shows the sampling apparatus used for obtaining a liquid phase sample of WF_6. The sampling apparatus consists of:

- Cylinder Inverter,
- PFA Vessels,
- PFA Valves, and
- PFA Tubing.

The whole sampling system is placed inside a hood.

6.4.3 *Water* — At least 18 MΩ DI water should be used for all dilutions, blanks, and washing.

6.4.4 *Reagents* — All reagents are of the highest purity available minimizing background metal contamination. The following reagents are needed to prepare the sample and standards:

- Aqueous Ammonia,
- Aqueous HNO_3,
- Aqueous HF, and
- NIST traceable ICP standards.

6.4.5 *Sampling Liquid Tungsten Hexafluoride*

6.4.5.1 Place about 400 ml of DI water in each of the hydrolysis vessels. Obtain the weight of each of the hydrolysis vessels.

6.4.5.2 Assemble the apparatus as shown in Figure 1. Do not tighten the cylinder CGA connection. All PFA parts should be clean and dried prior to assembly.

6.4.5.3 Open valves V2, V3, V4 and V5. Set the house nitrogen pressure to approximately 15 psig. Purge the system with nitrogen for about 15 minutes. TIGHTEN THE CYLINDER CGA CONNECTION.

6.4.5.4 Close V2. The system should now be under pressure. Check for leaks and repair if necessary.

6.4.5.5 Open V1 and evacuate the system for approximately 10 minutes.

6.4.5.6 Close all valves.

6.4.5.7 Fill sample vessel by opening cylinder valve and valve V5. Fill the sample vessel approximately 2/3 full. Close cylinder valve.

6.4.5.8 Close V5. Open V2, V4, and V6. This will carry the WF_6 vapors to the hydrolysis vessel.

6.4.5.9 Purge the system with nitrogen for a few minutes after the WF_6 liquid in the sample cup has totally evaporated.

6.4.5.10 Close all valves. Remove the hydrolysis vessels and weigh the vessels.

6.4.5.11 The weight gain in the hydrolysis vessel will give the weight of the sampled WF_6. Typically the weight gain of the second and third vessels will be less than 1% of the weight gain of the first hydrolysis vessel.

6.4.5.12 Remove the sample vessel and dissolve the residue.

6.4.6 *Sample Preparation*

6.4.6.1 Add 20 ml DI water to a 100 ml volumetric flask.

6.4.6.2 Open the sample cup and add 5 ml of aqueous ammonia to the cup.

6.4.6.3 Swirl in the cup and place in a 100 ml volumetric flask.

6.4.6.4 Add 5 ml Nitric Acid to the cup.

6.4.6.5 Swirl and place in the same 100 ml volumetric flask.

6.4.6.6 Add 5 ml Hydrofluoric Acid to the cup.

6.4.6.7 Swirl and place in the same 100 ml volumetric flask as before.

6.4.6.8 Dilute the solution with DI water up to the mark of the 100 ml volumetric flask.

6.4.6.9 Analyze for metals in the sample.

6.4.7 *ICPMS Analysis Procedure*

6.4.7.1 This procedure is used to analyze for trace Na, K, Cr, Fe, Th and U using multi point calibration. Other elements can be analyzed using a single point calibration. Elements for which stable standards can not be obtained, can be analyzed using interpolation and a knowledge of the instrument response function. The ICPMS should be calibrated using matrix matched multielement standards. At least one spiked sample should be analyzed as part of the analytical procedure. The recovery of the spikes should be within ± 25%. At least three standards and a blank should be used for the calibration. Regression based approach should be used to calculate the response factors. The limit of detection (LOD) should be calculated following SEMI C10, Guide for Determination of Method Detection Limits.

6.4.7.2 The concentration of impurities in gas phase WF_6 is given by

$$\text{Conc. in } WF_6 = \frac{\text{Conc. in Solution} \times \text{Wt. of Solution}}{\text{Weight of Sampled } WF_6}$$

NOTE 1: All gases used in the analysis of the sample should contain not more than 10% of the specified value of the component of interest unless otherwise specified.

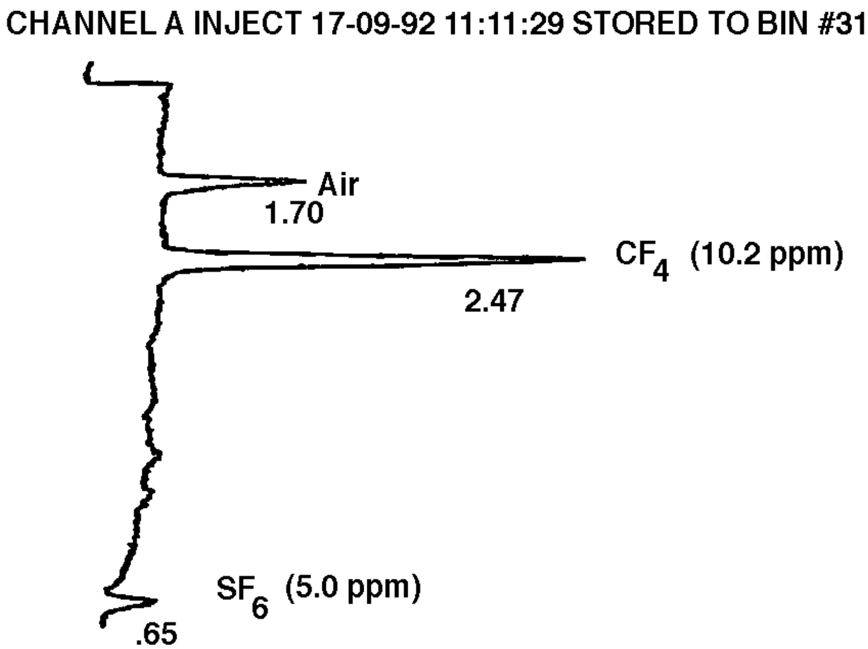

Figure 1
CF_4 and SF_6 Standards in He

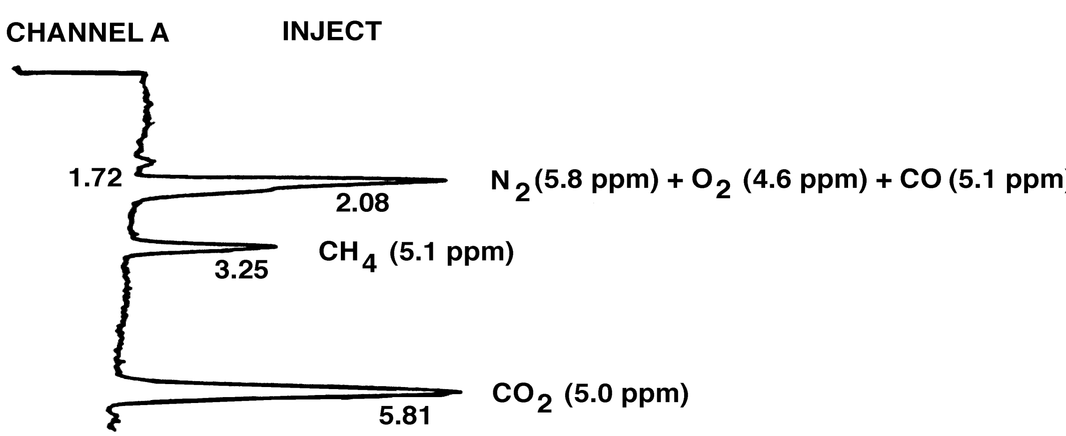

Figure 2
CO_2 Standards in He

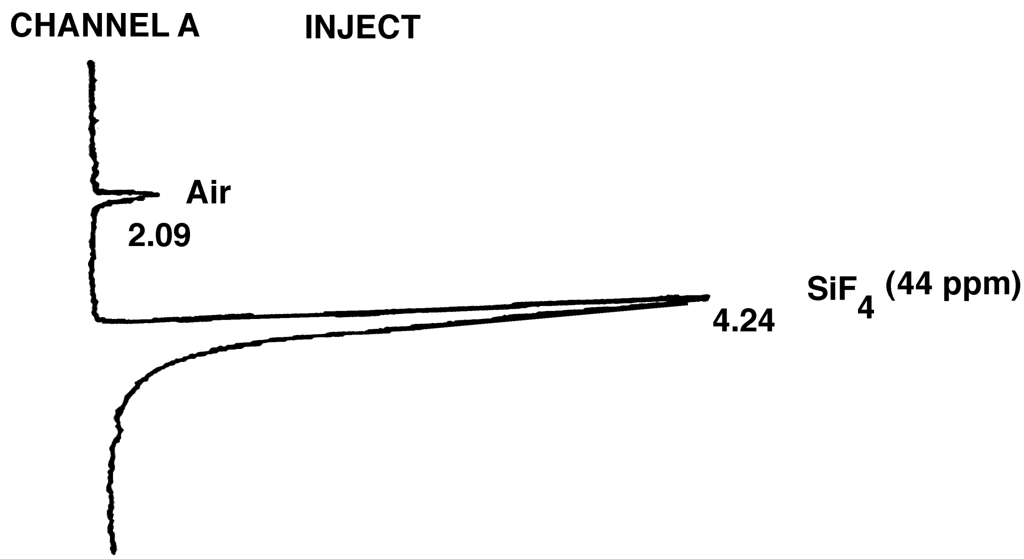

Figure 3
SiF_4 Standard in He

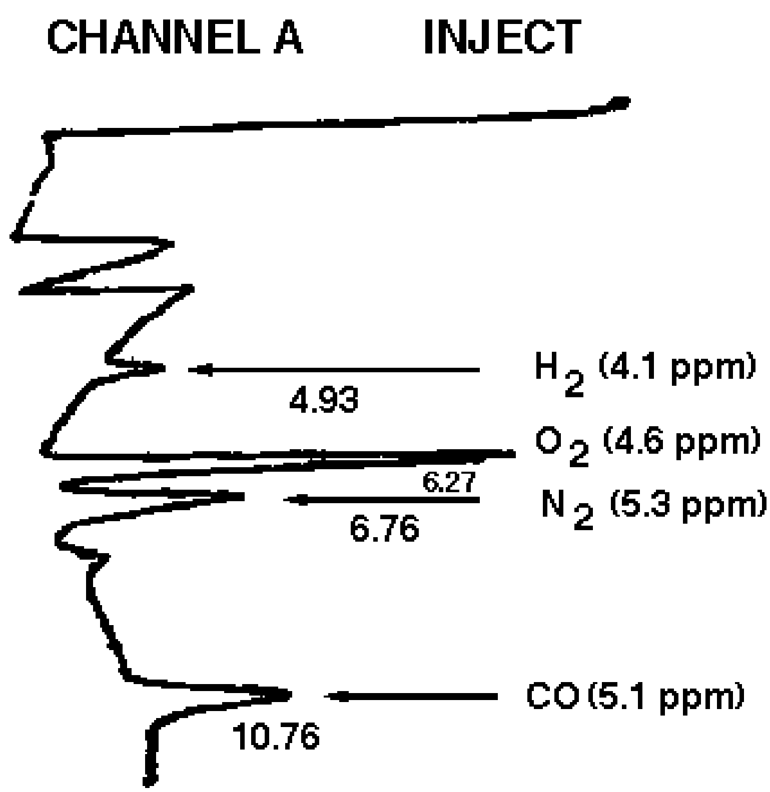

Figure 4
O_2, N_2, and CO Standards in He

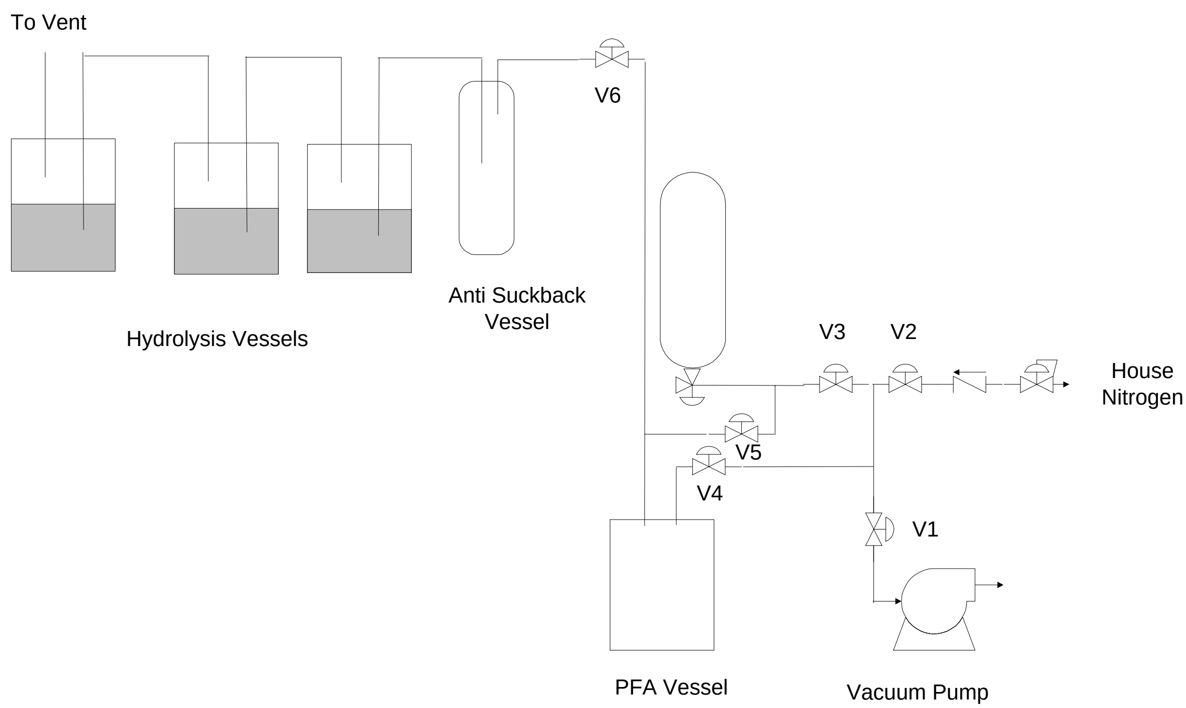

Figure 5
Sampling System for WF_6

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SEMI C6.3-89
PARTICLE SPECIFICATION FOR GRADE 20/0.2 HYDROGEN (H_2) DELIVERED AS PIPELINE GAS

1 Purpose

The purposes of this document are (1) to set a maximum permissible particle concentration for Grade 20/0.2 hydrogen gas and (2) to describe a reference method for its verification.

2 Scope

This document applies only to hydrogen gas delivered through pipelines; it is not applicable to cylinder gases or gases in their liquid state.

3 Selected Definitions

3.1 *Particle Size/Particle Diameter* — The optical equivalent diameter as detected by a given light scattering particle counter.

NOTE — The optical equivalent diameter varies from counter to counter and with differing particle shape and refractive index.

3.2 *Particle Concentration* — The total number of particles counted, divided by the total gas sample volume, and corrected for background count as defined in Section 3.4, rounded to the nearest integer, for particles equal to or larger than the specified size.

3.3 *Gas Sample Volume* — The volume of the sample, expressed in standard cubic feet (SCF) is the volume occupied by the gas sample at standard conditions, 20°C (68°F) and 1.00 atmosphere pressure.

3.4 *Background Count* — The total number of counts registered by a specific particle counter within the time needed to sample 1.0 SCF of gas under conditions where zero particles transverse the sensing volume, averaged over at least a sequence of twenty-four consecutive sampling periods of 1.0 SCF each or eight consecutive periods of 30 minutes each, whichever is longer. The background count is to be reported as mean number of count per SCF; the number of hours on which the average is based is also reported.

3.5 *Sampling Period* — The time needed to sample 1.0 SCF or 30 minutes, whichever is longer.

4 Apparatus

4.1 *Light Scattering Optical Particle Counter* — With a lower detection limit of 0.2 micrometers or less, based on a calibration with polystyrene latex spheres; and with a maximum background of 2 counts/SCF at 0.2 micrometers. It should be suitable for use in hydrogen service per the manufacturer's specifications or encased in an explosion-proof enclosure which satisfies Class I, Division I of the NFPA Code.

5 Test Method

NOTE — The precise details of any sampling configuration, measurement procedure, or any instrument calibration procedure and frequency must be agreed upon between user and supplier, taking into account good engineering practice.

5.1 The sampling point should be as close as practical to the downstream side of the supplier's final gas filter. Sampling lines should be as short as possible.

5.2 Suggested sampling probe configuration for turbulent main line flow:

Alternative a:	Figure 1a (preferred)
Alternative b:	Figure 1b
Alternative c:	Figure 1c
Alternative d:	Figure 1d

5.3 For configurations 1a, 1b and 1c, the flow rate in the sampling tube at pipeline pressure should be set so that the mean sampling flow velocity at the probe inlet matches as closely as possible the axial flow velocity in the pipeline. Sampling tube ID should be no less than 2 mm (0.08 in).

5.4 Determine the background count for the particle counter by using the standard method recommended by the instrument manufacturer using hydrogen gas.

6 Specification

6.1 Maximum permissible total concentration: 20 particles per SCF equal to or larger than 0.2 micrometers, after subtracting background count as defined in Section 3.4.

6.2 The specification will be considered as met, if the particle concentration does not exceed 20 particles per SCF in any five consecutive sampling periods as defined in Section 3.5.

7 Report

Report each of the five consecutive sampling periods to read as total number of particles per SCF7 of gas, equal to or larger than 0.2 micrometers optical equivalent diameter, without reference to any specific size distribution function. The background count shall be reported as defined in Section 3.4.

8 Calibration

The optical particle counter is normally calibrated using latex spheres of a known diameter suspended in a gas. Since the gas density and refractive index enter into the amount of scattering detected by the instrument, hydrogen should be used for calibration.

9 Safety

The lower explosive limit (LEL) for hydrogen in air is 4%; therefore, proper precautions should be taken to insure that the maximum possible concentration of hydrogen in air does not exceed 2%. The particle counter and any other ancillary equipment must be checked for leaks and the hydrogen exiting the equipment must be disposed of appropriately to insure that its concentration in air at any point does not exceed 2%.

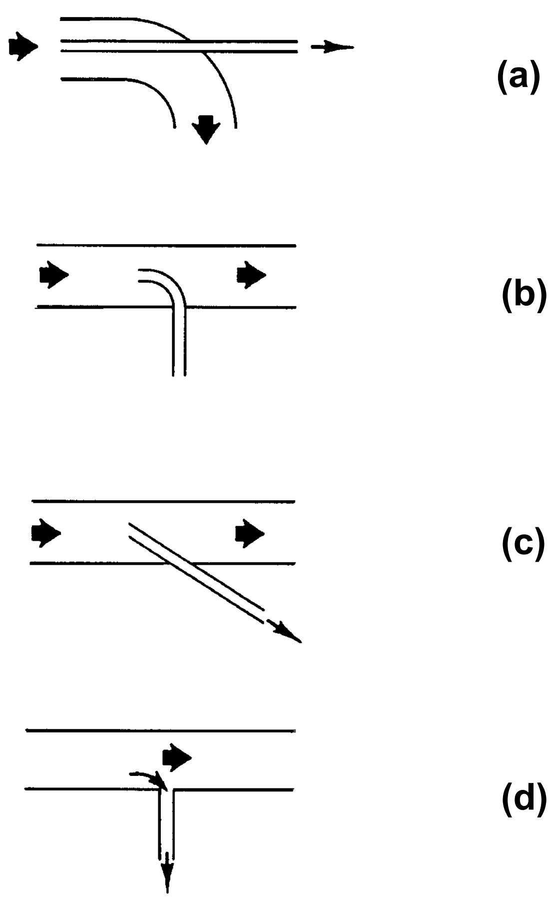

Figure 1
Schematic Diagrams of Configurations of Different Merit for Obtaining Particle Samples from Pipelines

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SEMI

SEMI C6.4-90
PARTICLE SPECIFICATION FOR GRADE 20/0.02 NITROGEN (N_2) AND ARGON (Ar) DELIVERED AS PIPELINE GAS

1 Purpose

The purposes of this document are: (1) to set a maximum permissible particle concentration for 20/0.02 grade nitrogen and argon bulk supply gases, and (2) to describe a reference method for its verification.

2 Scope

This document applies only to nitrogen gas and argon gas delivered through pipelines; it is not applicable to cylinder gases or gases in their liquid state.

3 Selected Definitions

3.1 *Variables*

V_{Mi}=	Volume of the i[th] sample interval of the pipeline gas
V_{Bi}=	Volume of the i[th] sample interval of the background
X_{Mi}=	Concentration of particles observed in the i[th] sample interval of the pipeline gas
X_{Bi}=	Concentration of particles observed in the i[th] sample interval of the background
N_M=	Number of sample intervals of the pipeline gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the pipeline gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the pipeline gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

3.2 *Gas Sample Volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C° (32°F) and 1.00° atmosphere pressure. Standard Cubic Feet (SCF) is defined at 21.1°C° (70°F) and 1.00° atmosphere pressure.

3.3 *Average Observed Concentration of Counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{\sum X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{\sum X_{Bi}}{N_B}$$

3.4 *Calculated Concentration of Particles ($\overline{X}_C$)* — The concentration of particles in the pipeline gas obtained by correcting the observed concentration in the pipeline gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

3.5 *Standard Deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \left[\frac{\sum\left(X_{Mi} - \overline{X}_M\right)^2}{\left(N_M - 1\right)}\right]^{1/2} \qquad S_B = \left[\frac{\sum\left(X_{Bi} - \overline{X}_B\right)^2}{\left(N_B - 1\right)}\right]^{1/2}$$

The third is obtained from the first two, i.e.:

$$S_C = \left(S_M{}^2 + S_B{}^2\right)^{1/2}$$

Note: These expressions are derived from an assumption of a Gaussian (Normal) distribution.

4 Apparatus

4.1 *Particle Counter* — An instrument suitable for counting particles in gaseous nitrogen or argon with a minimum detection efficiency of 90 percent at 0.02 micrometers as determined by the manufacturer of the particle counter. Condensation nucleus counters (CNCs) typically satisfy this requirement.

4.2 *Pressure Reducer* — An accessory required for counters operated at atmospheric pressure, it should preferably use expansion of the gas through a critical orifice.

5 Test Method

NOTE: The details of sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice.

5.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing air, nitrogen or argon, believed to be free of particles of 0.02 micrometers or more in diameter, through the instrument and recording the total number of counts. Count a minimum of 8 sample intervals, each at least 25 standard liters (0.95 SCF) or 30 minutes, whichever is greater. A suggested assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Calculate $\overline{X}_B$ as defined in Section 3. $\overline{X}_B$ must not exceed 2 particles per 25 standard liters.

5.2 The sampling point should be at outlet of system, and sampling lines should be as short as possible.

5.3 A suggested sampling probe configuration for turbulent main line flow is shown in Figure 2. The flow rate in the sampling tube at pipeline pressure should be set so that the mean sampling flow velocity at the probe inlet matches as closely as possible the axial flow velocity in the pipeline. The pitot sampling tube ID should be no less than 2 mm (0.08 inch). The orifice and sampling horn should be sized so that the mean flow velocity at the particle counter probe inlet matches the axial flow velocity in the horn as closely as possible.

5.4 Count the particles in each of at least 8 sample intervals. Each sample interval must be at least 25 standard liters or 30 minutes, whichever is greater. Record the number of counts and the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 3.

6 Specification

6.1 *Maximum Permissible Particle Concentration* — 20. particles per 25 standard liters as determined by the instrument specified in Section 4.

6.2 The specification will be considered met if the calculated concentration of particles plus two standard deviations does not exceed 20 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2^* S_C \leq 20. \text{ particles/25 standard liters}$$

7 Report

The report shall contain the values of all the variables defined in Section 3.

8 Precision

This test procedure defines the requirements to satisfy the specification at the 95 percent confidence level.

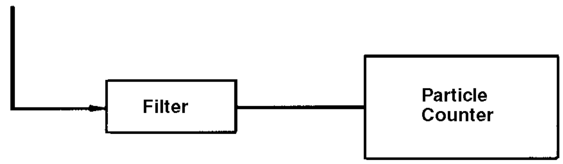

Figure 1
Suggested Assembly for DeterminingParticle Counter Background

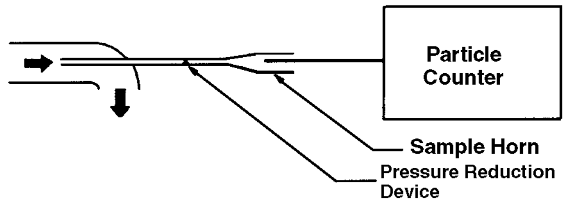

Figure 2
Schematic Diagram of Configuration for Obtaining Particle Samples from Pipelines

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SEMI C6.5-90
PARTICLE SPECIFICATION FOR GRADE 10/0.2 NITROGEN (N_2) AND ARGON (Ar) DELIVERED AS PIPELINE GAS

1 Purpose

The purposes of this document are: (1) to set a maximum permissible particle concentration for 10/0.2 grade nitrogen and argon bulk supply gases, and (2) to describe a reference method for its verification.

2 Scope

This document applies only to nitrogen gas and argon gas delivered through pipelines; it is not applicable to cylinder gases or gases in their liquid state.

3 Selected Definitions

3.1 *Variables*

V_{Mi}=	Volume of the i[th] sample interval of the pipeline gas
V_{Bi}=	Volume of the i[th] sample interval of the background
X_{Mi}=	Concentration of particles observed in the i[th] sample interval of the pipeline gas
X_{Bi}=	Concentration of particles observed in the i[th] sample interval of the background
N_M=	Number of sample intervals of the pipeline gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the pipeline gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the pipeline gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

3.2 *Particle Size/Particle Diameter* — The optical equivalent diameter as detected by a given light-scattering particle counter.

3.3 *Gas Sample Volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1.00 atmosphere pressure. Standard Cubic Feet (SCF) is defined at 21.1°C (70°F) and 1.00 atmosphere pressure.

3.4 *Average Observed Concentration of Counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{X_{Bi}}{N_B}$$

3.5 *Calculated Concentration of Particles ($\overline{X}_C$)* — The concentration of particles in the pipeline gas obtained by correcting the observed concentration in the pipeline gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

3.6 *Standard Deviation (S_M, S_B, S_C)* — a statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \left[\frac{\left(X_{Mi} - \overline{X}_M\right)^2}{\left(N_M - 1\right)} \right]^{1/2} \qquad S_B = \left[\frac{\left(X_{Bi} - \overline{X}_B\right)^2}{\left(N_B - 1\right)} \right]^{1/2}$$

The third is obtained from the first two, i.e.:

$$S_C = \left(S_M{}^2 + S_B{}^2\right)^{1/2}$$

Note: These expressions are derived from an assumption of a Gaussian (Normal) distribution.

4 Apparatus

4.1 *Particle Counter* — An instrument suitable for counting particles in gaseous nitrogen or argon with a lower detection limit of 0.2 micrometers or less, based on calibration with polystyrene latex spheres.

4.2 *Pressure Reducer* — An accessory required for counters operated at atmospheric pressure, it should preferably use expansion of the gas through a critical orifice.

5 Test Method

NOTE: The details of sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice.

5.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing air, nitrogen or argon, believed to be free of particles of 0.2 micrometers or more in diameter, through the instrument and recording the total number of counts. A suggested assemby for perfoming this test, using a filter which removes particles in this size range, is shown in Figure 1. A method recommended by the instrument manufacturer, such as internal recirculation through a filter, may be substituted for the system shown. Count a minimum of 8 sample intervals, each at least the time to sample 25 standard liters (0.95 SCF) or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 3. $\overline{X}_B$ must not exceed 2 particles per 25 standard liters.

5.2 The sampling point should be at outlet of system, and sampling lines should be as short as possible.

5.3 A suggested sampling probe configuration for turbulent main line flow is shown in Figure 2. The flow rate in the sampling tube at pipeline pressure should be set so that the mean sampling flow velocity at the probe inlet matches as closely as possible the axial flow velocity in the pipeline. The pitot sampling tube ID should be no less than 2 mm (0.08 inch). The orifice and sampling horn should be sized so that the mean flow velocity at the particle counter probe inlet matches the axial flow velocity in the horn as closely as possible.

5.4 Count the particles in each of at least 8 sample intervals. Each sample interval must be at least the time to sample 25 standard liters or 30 minutes, whichever is greater. Record the number of counts and the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 3.

6 Specification

6.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 4.

6.2 The specification will be considered met if the calculated concentration of particles plus two standard deviations does not exceed 10 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2^* S_C \leq 10. \text{ particles/25 standard liters}$$

7 Report

The report shall contain the values of all the variables defined in Section 3.

8 Precision

This test procedure defines the requirements to satisfy the specification at the 95 percent confidence level.

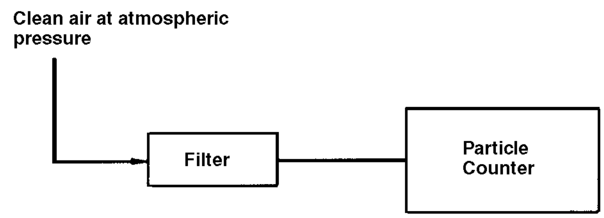

Figure 1
Suggested Assembly for Determining Particle Counter Background

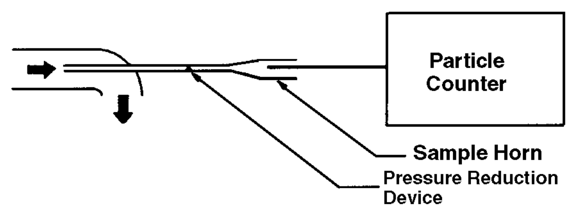

Figure 2
Schematic Diagrams of Configurations of Different Merit for Obtaining Particle Samples from Pipelines

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SEMI C6.6-90
PARTICLE SPECIFICATION FOR GRADE 10/0.1 NITROGEN (N_2) AND ARGON (Ar) DELIVERED AS PIPELINE GAS

1 Purpose

The purposes of this document are: (1) to set a maximum permissible particle concentration for 10/0.1 grade nitrogen and argon bulk supply gases, and (2) to describe a reference method for its verification.

2 Scope

This document applies only to nitrogen gas and argon gas delivered through pipelines; it is not applicable to cylinder gases or gases in their liquid state.

3 Selected Definitions

3.1 *Variables*

V_{Mi}=	Volume of the i[th] sample interval of the pipeline gas
V_{Bi}=	Volume of the ith sample interval of the background
X_{Mi}=	Concentration of particles observed in the i[th] sample interval of the pipeline gas
X_{Bi}=	Concentration of particles observed in the i[th] sample interval of the background
N_M=	Number of sample intervals of the pipeline gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the pipeline gas sample
$\overline{X}_B$ =	Average observed concentration of background counts
$\overline{X}_C$ =	Calculated concentration of particles in the pipeline gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
S_C=	Standard deviation of $\overline{X}_C$

3.2 *Particle Size/Particle Diameter* — The optical equivalent diameter as detected by a given light-scattering particle counter.

3.3 *Gas Sample Volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1.00 atmosphere pressure. Standard Cubic Feet (SCF) is defined at 21.1°C (70°F) and 1.00 atmosphere pressure.

3.4 *Average Observed Concentration of Counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{X_{Bi}}{N_B}$$

3.5 *Calculated Concentration of Particles ($\overline{X}_C$)* — The concentration of particles in the pipeline gas obtained by correcting the observed concentration in the pipeline gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

3.6 *Standard Deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \left[\frac{\left(X_{Mi} - \overline{X}_M\right)^2}{\left(N_M - 1\right)}\right]^{1/2} \qquad S_B = \left[\frac{\left(X_{Bi} - \overline{X}_B\right)^2}{\left(N_B - 1\right)}\right]^{1/2}$$

The third is obtained from the first two, i.e.:

$$S_C = \left(S_M^2 + S_B^2\right)^{1/2}$$

Note: These expressions are derived from an assumption of a Gaussian (Normal) distribution.

4 Apparatus

4.1 *Particle Counter* — An instrument suitable for counting particles in gaseous nitrogen or argon with a lower detection limit of 0.1 micrometers or less, based on calibration with polystyrene latex spheres.

4.2 *Pressure Reducer* — An accessory required for counters operated at atmospheric pressure, it should preferably use expansion of the gas through a critical orifice.

5 Test Method

NOTE: The details of sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice.

5.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing air, nitrogen or argon, believed to be free of particles of 0.1 micrometers or more in diameter, through the instrument and recording the total number of counts. A suggested assembly for perfoming this test, using a filter which removes particles in this size range, is shown in Figure 1. A method recommended by the instrument manufacturer, such as internal recirculation through a filter, may be substituted for the system shown. Count a minimum of 8 sample intervals, each at least 25 standard liters (0.95 SCF) or 30 minutes, whichever is greater. Calculate $\overline{X}_B$ as defined in Section 3. $\overline{X}_B$ must not exceed 2 particles per 25 standard liters.

5.2 The sampling point should be at outlet of system, and sampling lines should be as short as possible.

5.3 A suggested sampling probe configuration for turbulent main line flow is shown in Figure 2. The flow rate in the sampling tube at pipeline pressure should be set so that the mean sampling flow velocity at the probe inlet matches as closely as possible the axial flow velocity in the pipeline. The pitot sampling tube ID should be no less than 2 mm (0.08 inch). The orifice and sampling horn should be sized so that the mean flow velocity at the particle counter probe inlet matches the axial flow velocity in the horn as closely as possible.

5.4 Count the particles in each of at least 8 sample intervals. Each sample interval must be at least 25 standard liters or 30 minutes, whichever is greater. Record the number of counts and the sample volume for each interval. Calculate $\overline{X}_C$ and S_C, as defined in Section 3.

6 Specification

6.1 *Maximum Permissible Particle Concentration* — 10 particles per 25 standard liters as determined by the instrument specified in Section 4.

6.2 The specification will be considered met if the calculated concentration of particles plus two standard deviations does not exceed 10 particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2^* S_C \leq 10. \text{ particles/25 standard liters}$$

7 Report

The report shall contain the values of all the variables defined in Section 3.

8 Precision

This test procedure defines the requirements to satisfy the specification at the 95 percent confidence level.

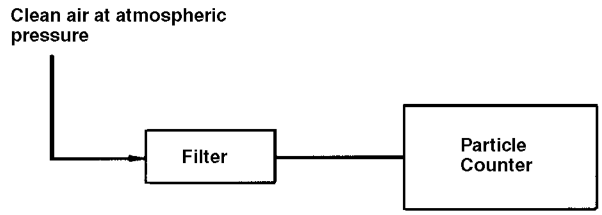

Figure 1
Suggested Assembly for Determining Particle Counter Background

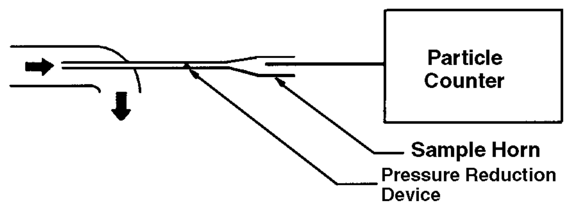

Figure 2
Schematic Diagram of Configuration forObtaining Particle Samples from Pipelines

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SEMI C6.7-93
PARTICLE SPECIFICATION FOR GRADE 10/0.2 NITROGEN IN HIGH PRESSURE GAS CYLINDERS

1 Purpose

The purposes of this document are (1) to set a maximum permissible particle concentration for 10/0.2 grade cylinder nitrogen, and (2) to describe a reference method for its verification.

2 Scope

2.1 This specification applies to nitrogen contained in high pressure gas cylinders; it is not applicable to pipeline gases.

2.2 A nitrogen cylinder consists of three components: (1) a cylinder bottle, (2) compressed nitrogen contained within, and (3) a cylinder valve. Each component can be a particle source. This specification applied to the total number of particles detected in the gas as obtained from the cylinder under a prescribed condition. No consideration is given to the origin of the particles.

2.3 It is known that pressure reduction, if not controlled, can produce a large number of artifact particles through nucleation and condensation. To avoid this complication, this specification adopts particle counters that can be operated at a pressure up to 200 bar (3000 psi), eliminating the need for pressure reduction and its associated problems.

2.4 It is known that particle content in cylinder gases varies with time because particles can be lost to cylinder walls by diffusion or sedimentation, and detached from cylinder walls by flow pulses or mechanical shocks. It is important to measure particle concentration under the worst conditions which represent typical handling of gas cylinders. This specification describes a standard shock test that fulfills the above requirements and provides a procedure to count particles immediately after the shock.

2.5 If this test method is to be used for more than one cylinder, then each cylinder must be tested. It is known that particle contamination in cylinder gases is a strong function of the handling history of the individual cylinders. Cylinders in the same batch of filling are usually returned from various customers after various periods of service. Uniform quality can not be assumed for the same batch of cylinders unless each of them has gone through a dedicated process that erases the memory of previous history prior to filling. Therefore, batch sampling at 10% or 20% cannot be accepted because of the significant differences among cylinders.

2.6 The requirement of 100% sampling restricts the total amount of gas in each cylinder that can be used for sampling purposes. This restriction, in turn, calls for certain relaxation of the statistical requirement for particle sampling at low concentration levels.

3 Definition

3.1 *Variables*

X_{Bi}=	Observed particle concentration in the i^{th} sample interval of the background
X_{Mi}=	Observed particle concentration in the i^{th} sample interval before shocks
X_{Ni}=	Observed particle concentration in the i^{th} sample after shocks
N_B=	Number of sample intervals of the background
N_M=	Number of sample intervals before shocks
N_N=	Number of sample intervals after shocks
$\overline{X}_B$ =	Averaged observed particle concentration of the background
$\overline{X}_M$ =	Averaged observed particle concentration before shocks
$\overline{X}_N$ =	Averaged observed particle concentration after shocks
X_P=	Calculated particle concentration before shocks
X_Q=	Calculated particle concentration after shocks
S_B=	Standard deviation of $\overline{X}_B$
S_M=	Standard deviation of $\overline{X}_M$
S_N=	Standard deviation of $\overline{X}_N$
SE_P=	Standard deviation of X_P
SE_Q=	Standard deviation of X_Q

3.2 *Averaged Observed Concentration (XB, XM, XN)*

$$\overline{X}_B = SUM(X_{Bi})/N_B$$

$$\overline{X}_M = SUM(X_{Mi})/N_M$$

$$\overline{X}_N = SUM(X_{Ni})/N_N$$

3.3 Calculate concentration (X_P, X_Q)

$$X_P = \overline{X}_M - \overline{X}_B$$

$$X_Q = \overline{X}_N - \overline{X}_B$$

3.4 Standard Deviation (S_B, S_M, S_N)

$S_B = [SUM(X_{Bi} - \overline{X}_B)^2/N_B - 1)]^{1/2}$

$S_M = [SUM(X_{Mi} - \overline{X}_M)2/(N_M - 1)]^{1/2}$

$S_N = [SUM(X_{Ni} - \overline{X}_N)2/(N_N - 1)]^{1/2}$

3.5 Standard Error (SE_P,SE_Q)

$SE_P = [(S_M2/N_M) + (S_B2/N_B)]^{1/2}$

$SE_Q = [(S_N2/N_N) + (S_B2/N_B)]^{1/2}$

4 Apparatus

4.1 *High-Pressure Particle Counter (HPC)* — An instrument capable of counting particles in compressed gaseous nitrogen at a pressure up to 200 bar (3000 psi), having a minimum counting efficiency of 50% at 0.2 µm and reaching 100% at 0.25 µm. This value is determined at ambient pressure by the instrument manufacturer using 0.2 µm monodisperse particles and a reference counter with a proven counting efficiency of 100% at 0.2 µm. Note that the nominal flow rate of the HPC is fixed at any pressure but the sample flow rate should be adjusted to within 5% of the manufacturer's specified flow rate, for the pressure and reported its equivalent standard flow rate at ambient pressure (1 bar).

4.2 *Impact Shock Device* — A device that can reproducibly impart an impact shock of 10^4 m/sec^2 with a 10% tolerance to a gas cylinder. A convenient set up as shown in Figure 1 can be used. A steel ball is attached to a chain with the other end fastened to the test cylinder. The ball is lifted to form a 90 degree angle with the cylinder, is released to follow a 90 degree free fall arc, and strikes the test cylinder. The desired ball mass and chain length are to be determined by monitoring the corresponding shock intensity by an accelerometer. For a typical 44 liter cylinder, a ball mass of 160 gm and a chain length of 60 cm can produce the desired impact shock.

5 Test Method

5.1 Determine the averaged background concentration ($\overline{X}_B$) by passing particle-free, compressed nitrogen through the HPC. Count a minimum of 5 sample intervals, each of at least 6 standard liters (0.2 SCF) or taken over a time period of 6 minutes, whichever is greater. A high purity gas filter can be used to remove particles greater than 0.2 µm. Calculate $\overline{X}_B$ as defined in Section 3. $\overline{X}_B$ must not exceed 1 particle per 30 second liters.

5.2 Set up the experimental apparatus as shown in Figure 2. Directly connect the test cylinder to a High-pressure Particle Counter (HPC), a pressure gauge, and a Flow Control Device (FCD). Note that NO REGULATOR is used before the HPC. The sampling line should be clean and as short as possible. The flow control device can be a metering valve and a flowmeter or a critical orifice.

5.3 Determine $\overline{X}_M$ by opening the cylinder valve and count the particles for at least 5 sample intervals, each of at least 6 standard liters (0.2 SCF) or taken over a time of 6 minutes, whichever is greater. Calculate X_P and SE_P as defined in Section 3.

5.4 Apply 4 impact shocks of approximately 10^4 m/sec^2 each, 10 sec apart, to the bare surface of the test cylinder. Each shock whould be applied at the approximate vertical midpoint of the cylinder; the four shocks should be separated from each other by approximately 90 degrees circumferentially.

5.5 Determine $\overline{X}_N$ by counting the particles after the shocks for at least 5 sample intervals, each of at least 6 standard liters (0.2 SCF) or taken over a time of 6 minutes, whichever is greater. The sampling should be completed within 2 hours after the shocks. Calculate X_Q and SE_Q as defined in Section 3.

6 Specification

6.1 *Maximum Permissible Particle Concentration* — 10 particles per 30 standard liters.

6.2 The specification will be considered met if the calculated concentration of particles plus two standard errors does not exceed 10 particles per 30 standard liters for both measurements before and after the impact shocks, i.e.:

$X_P + 2SE_P \leq 10$ particles/30 standard liters

and

$X_Q + 2SE_Q \leq 10$ particles/30 standard liters

7 Report

The report shall contain the value of the measured sample volumes, values of all the variables defined in Section 3, the mass of the steel ball, and length of the chain.

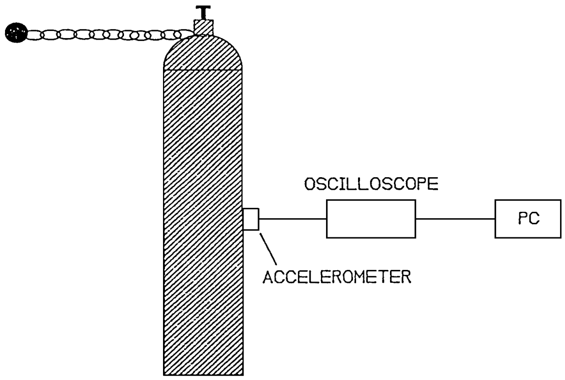

Figure 1

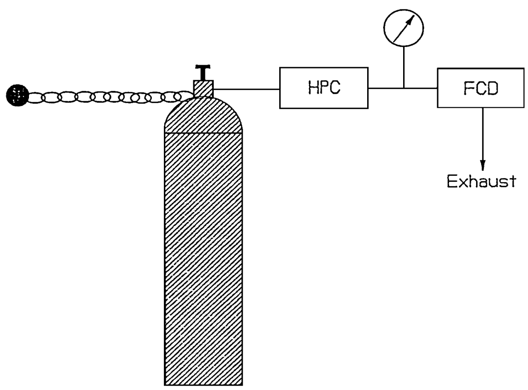

Figure 2

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SEMI C6.2-93
PARTICLE SPECIFICATION FOR GRADE 20/0.02 OXYGEN DELIVERED AS PIPELINE GAS

1 Purpose

The purposes of this document are: (1) to set a maximum permissible particle concentration for 20/0.02 grade oxygen bulk supply gas, and (2) to describe a reference method for its verification.

2 Scope

This document applies only to oxygen gas delivered through pipelines; it is not applicable to cylinder gas or oxygen gas in its liquid state.

3 Selected Definitions

3.1 *Variables*

V_{Mi}=	Volume of the i^th sample interval of the pipeline gas
V_{Bi}=	Volume of the i^th sample interval of the background
X_{Mi}=	Concentration of particles observed in the i^th sample interval of the pipeline gas
X_{Bi}=	Concentration of particles observed in the i^th sample interval of the background
N_M=	Number of sample intervals of the pipeline gas
N_B=	Number of sample intervals of the background
$\overline{X}_M$ =	Average observed concentration of counts in the pipeline gas sample
$\overline{X}_B$ =	Average observed concentration of backgroundcounts
$\overline{X}_C$ =	Calculated concentration of particles in the pipeline gas
S_M=	Standard deviation of $\overline{X}_M$
S_B=	Standard deviation of $\overline{X}_B$
SE_C=	Standard error of $\overline{X}_C$

3.2 *Gas Sample Volume (V_{Mi}, V_{Bi})* — The volume of the sample interval, expressed in standard liters at standard conditions, 0°C (32°F) and 1.00 atmosphere pressure. Standard Cubic Feet (SCF) is defined at 21.1°C (70°F) and 1.00 atmosphere pressure.

3.3 *Average Observed Concentration of Counts ($\overline{X}_M$, $\overline{X}_B$)* — The average concentration of counts, i.e.:

$$\overline{X}_M = \frac{X_{Mi}}{N_M} \qquad \overline{X}_B = \frac{X_{Bi}}{N_B}$$

3.4 *Calculated Concentration of Particles ($\overline{X}_C$)* — The concentration of particles in the pipeline gas obtained by correcting the observed concentration in the pipeline gas for the observed concentration in the background, i.e.:

$$\overline{X}_C = \overline{X}_M - \overline{X}_B$$

3.5 *Standard Deviation (S_M, S_B, S_C)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \left| \frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)} \right| \qquad S_B = \left[\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)} \right]$$

The third is obtained from the first two, i.e.:

$$S_C = \left(S_M^2 + S_B^2\right)^{\frac{1}{2}}$$

Note: These expressions are derived from an assumption of a Gaussian (Normal) distribution.

3.6 *Standard Deviation (S_M, S_B)* — A statistical measure of the spread of the concentration of the counts or particles. The first two are obtained from the interval and average concentrations and the number of intervals, i.e.:

$$S_M = \left[\frac{(X_{Mi} - \overline{X}_M)^2}{(N_M - 1)} \right] \qquad S_B = \left[\frac{(X_{Bi} - \overline{X}_B)^2}{(N_B - 1)} \right]$$

Note: These expressions are derived from an assumption of a Gaussian (Normal) distribution.

3.7 *Standard Error (SEC)*

$$SE_C = \left[\left| \frac{S_M^2}{N_M} \right| + \left(\frac{S_B^2}{N_M} \right) \right]^{\frac{1}{2}}$$

4 Apparatus

4.1 *Particle Counter* — An instrument suitable for counting particles in gaseous oxygen with a counting efficiency of 50 percent at 0.02 micrometers as determined by the manufacturer of the particle counter.

Condensation nucleus counters (CNCs) typically satisfy this requirement.

4.2 *Pressure Reducer* — An accessory required for counters operated at atmospheric pressure, it should preferably use expansion of the gas through a critical orifice.

5 Test Method

NOTE: The details of sampling configuration, measurement procedure, and instrument calibration procedure and frequency must be agreed upon by the user and supplier, taking into account good engineering practice.

5.1 Determine the average observed concentration of counts in the background ($\overline{X}_B$) by passing air or nitrogen or oxygen believed to be free of particles of 0.02 micrometers or larger in diameter, through the instrument and recording the total number of counts. Count a minimum of 8 sample intervals, each at least 25 standard liters (0.95 SCF) or 30 minutes, whichever is greater. A suggested assembly for performing this test, using a filter which removes particles in this size range, is shown in Figure 1. Calculate $\overline{X}_B$ as defined in Section 3. $\overline{X}_B$ must not exceed 2 particles per 25 standard liters.

5.2 The sampling point should be at outlet of system, and sampling lines should be as short as possible.

5.3 A suggested sampling probe configuration for turbulent main line flow is shown in Figure 2. The flow rate in the sampling tube at pipeline pressure should be set so that the mean sampling flow velocity at the probe inlet matches as closely as possible the axial flow velocity in the pipeline. The pitot sampling tube ID should be no less than 2 mm (0.08 inch). The orifice and sampling horn should be sized so that the mean flow velocity at the particle counter probe inlet matches the axial flow velocity in the horn as closely as possible.

5.4 Count the particles in each of at least 8 sample intervals. Each sample interval must be at least 25 standard liters or 30 minutes, whichever is greater. Record the number of counts and the sample volume for each interval. Calculate $\overline{X}_C$ and SE_C, as defined in Section 3.

6 Specification

6.1 *Maximum Permissible Particle Concentration* — 20. particles per 25 standard liters as determined by the instrument specified in Section 4.

6.2 The specification will be considered met if the calculated concentration of particles plus two standard errors does not exceed 20. particles per 25 standard liters, i.e.:

$$\overline{X}_C + 2*SE_C \leq 20. \text{ Particles/25 standard liters}$$

7 Report

The report shall contain the values of all the variables defined in Section 3.

8 Precision

This test procedure defines the requirements to satisfy the specification at the 95 percent confidence level.

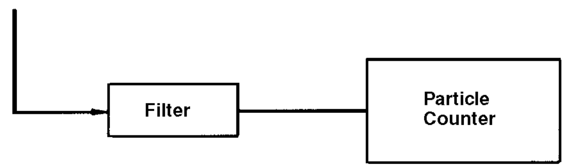

Figure 1
Suggested Assembly for Determining Particle Counter Background

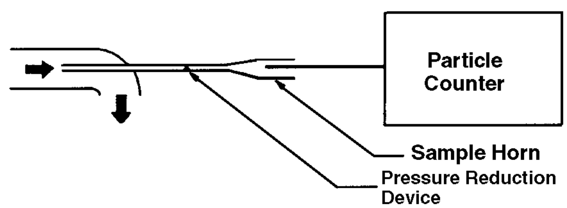

Figure 2
Schematic Diagrams of Configurations of Different Merit for Obtaining Particle Samples from Pipelines

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SEMI C9.1-93
GUIDE FOR ANALYSIS OF UNCERTAINTIES IN GRAVIMETRICALLY PREPARED GAS MIXTURES

1 Purpose

This document is intended to provide the minimum criterion for the analysis of uncertainty associated with preparation and use of gravimetric gas mixtures used for calibrating analytical instruments to determine whether various SEMI impurity specification are satisfied.

2 Scope

2.1 This guideline is intended for preparation of binary gas mixtures using individual cylinders.

2.2 It is the intent of this document to provide general guidelines for preparation of calibration gas mixtures in compliance with ISO 6142, with additional requirements to meet the needs of the semiconductor industry.

2.3 This guideline is applicable only to gaseous components which do not react between themselves or with the cylinder walls, and to condensable components which are totally vaporized under the test conditions. It is not intended for moisture calibration mixtures.

3 Reference Documents

ISO[1] 6142; Gas Analysis; Preparation of calibration gas mixtures - weighing methods.

Addendum 1 to ISO 6142 - Annex — Precautions to be taken when weighing, handling and filling cylinders.

4 Weight Traceability

The weights used to prepare the gas mixtures or certify the balance should be Class S1-tested at least annually with reference standards traceable to the National Institute of Standards and Technology or to another national standards organization.

5 Acceptable Mixture Criteria

5.1 *Cylinder* — Cylinder must comply with National or International Codes. The type of cylinder used for containment of the gas mixture may affect the stability of the mixture. Historical and experimental data should be requested from the supplier on the stability of similar mixtures. The cylinder material should be chosen based on its compatibility with the gas mixture.

5.2 *Valve* — The recommended valve should be packless type valve and the constuction materials selected according to their compatibility with the gas mixture.

5.3 *Homogenous Mixture* — The cylinder and its contents should be at room temperature prior to use. The cylinder mixture components must be mixed to insure a homogenous mixture.

5.4 *Stability* — The gas mixture will have a demonstrated stability within the acceptable relative uncertainties given in Section 6 for a period of 1 year. The minimum useful pressure should be in accordance with the suppliers recommendations.

5.5 *Balance Gas Purity* — The balance gas should be determined to contain less than 1 percent of the relative concentration for the minor component.

5.6 *Minor Component Purity* — The product used for the minor component addition should be analyzed to verify its composition.

5.7 *Analysis* — Confirmation analysis of the calibration mixture should be performed to determine if any gross weighing errors occurred.

6 Acceptable Relative Uncertainties

Using the ISO procedures the acceptable maximum relative uncertainties for the component of interest are given below.

Concentration Range	*Relative Uncertainty*
Standard Concentrations > 1000 ppm	2 percent
Standard Concentrations = < 1000 ppm > 100	2 percent
Standard Concentrations = < 100 ppm > 10	5 percent
Standard Concentrations = < 10 ppm > = 1	10 percent

7 Report

The composition of the mixture should be reported including the relative uncertainty for a given mixture.

---

1 International Organization for Standardization, Case portale 56, CH-1211, Geneve 20 (Switzerland)

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SEMI C13-95 (Withdrawn 1101)
TEST METHOD FOR PARTICLE SHEDDING AND PENETRATION PERFORMANCE OF POINT-OF-USE GAS FILTERS

NOTE: This document was balloted and approved for withdrawal in 2001.

1 Purpose

1.1 The purpose of this document is to define a comprehensive standard test sequence to derive particle-related qualification data for point-of-use (POU) filters.

2 Scope

2.1 This test method defines an evaluation method for point-of-use filters of various media (e.g., polymeric, ceramic, and metallic) typically used for filtering inert and process gases in semiconductor applications. Point-of-use filters are designed to handle relatively low flow rates (0.5 - 100 L/min.) and moderate-to high-pressure drops (0.5-15 psig). The filter housing and filtration element are combined into one sealed and inseparable unit.

3 Limitations

3.1 These test methods do not apply to gas filter cartridges, for which separate methods (SEMI C14) have been developed.

3.2 POU filters are designed and often used to tolerate a variety of conditions (e.g., baking, high-pressure drop, transient pressure surges) without compromising the removal of particles. Therefore, a single penetration test is not sufficient. A sequence of tests, designed to measure filter responses under various conditions, is necessary for POU filter evaluation.

3.3 The order of the test sequence will affect the test results, and it is designed for fair comparisons of different aspects of filter operations. Hence, it is important to follow the prescribed test sequence.

3.4 Depending on the application, a subset of this sequence (i.e., omitting the penetration or baking tests) may be used for some filters. In this case, only those filters tested by the abridged sequence may be compared.

3.5 The penetration test as described in this method is used to give a pass or fail indication under the test conditions. A complete characterization of the filtration efficiency using monodisperse aerosols will be developed separately.

4 Summary of Method

The test sequence (shown schematically in Figure 1) consists of five steps:

1. Break-in
2. Pulse
3. Baking (optional)
4. Final Purge (optional)
5. Penetration (optional)

5 Apparatus and Facility

5.1 *Gas Source* — Clean, dry nitrogen with less than 0.5 ppm moisture and less than 0.5 ppm total hydrocarbons.

5.2 *Particle Detector* — A condensation nucleus counter (CNC) with counting efficiency of 50% at 0.01 µm, as reported by the manufacturer, is recommended to measure total particle concentration greater than 0.01 µm.

5.3 *Test Environments* — The test component should be unpacked and assembled in a Class 100 clean area to prevent ambient contamination. Refer to 5.9 for installation precautions.

5.4 *Configuration for Break-In Test* — The apparatus consists of (1) a flow control system that can accurately regulate flow at 2 flow rates, the minimum and maximum system design flow rates, (2) a 25 cm (10 in.) cartridge filter immediately upstream of the test filter to provide zero-particle gas at the maximum system flow rate, and (3) a CNC downstream of the test filter.

5.4.1 Schematic of the apparatus is shown in Figure 2. This permits an instantaneous change of flow from 10 L/min. to 100 L/min. by opening the solenoid valve.

5.5 *Configuration for Pulse Test* — The apparatus is the same as for the break-in test.

5.6 *Configuration for Baking Test* — The configuration is shown in Figure 3. It is the same as for the break-in test, except that the test filter is placed in a heating device.

5.7 *Configuration for Penetration Test* — One example of the configuration is shown in Figure 4. An air compressor may be used to compress ambient air into a tank to form a compressed aerosol with a broad and fairly stable particle-size distribution. The capacity of the air compressor should be sufficient so that the particle size distribution remains unchanged for a flow up to 100 L/min. Other sources of particles may also be used as long as the concentration remains constant for the duration of the penetration test.

5.7.1 A flowmeter is used to set the challenge aerosol flow at manufacturer-rated flow. A CNC is used to measure particle concentration with and without the test filter.

5.8 *Test Flow Rates* — Two sets of test flow rates are recommended. For the purpose of comparing various brands of POU filters, the test flow rates specified in 5.8.1 should be used. For the purpose of predicting the filter performance in a given gas distribution system, the test flow rates specified in 5.8.2 should be used.

5.8.1 For the purpose of filter comparison, the filter is tested according to the manufacturer-rated flow rate, which can be classified into three categories:

Manufacturer-Rated Flow (L/min.)	*Minimum Test Flow (L/min.)*	*Maximum Test Flow (L/min.)*
2 < rated flow ≤ 10	2 × sampling flow rate	10
10 < rated flow ≤ 50	5	50
rated flow > 50	10	100

The minimum test flow rate is used to purge the apparatus before the shedding test, and the maximum test flow rate is the actual test flow rate.

5.8.2 For the purpose of performance prediction, the maximum flow rate of a gas distribution system containing the POU filter should be used. The maximum system flow rate occurs in the transient period when the flow limiting component is opened. Valves are often the flow limiting components in a typical gas distribution system.

5.8.2.1 Knowing the system operating pressure (P) and the discharge coefficient (C_v) of the flow limiting valve, the maximum test flow rate can be calculated as follows:

$$Q = 4220.7 * P * C_v \sqrt{\left(\frac{1}{SG * T}\right)}$$

where : Q = Flow in L/min

C_v = Valve discharge coefficient

SG = Specific gravity of gas relative to air

T = Absolute temperature of flowing gas (K)

P = Absolute system operating pressure (bar)

The minimum test flow rate is 10% of the maximum test flow rate.

For a system pressure of 3 bar (44 psia) and a C_v of 0.14 for the flow limiting valve, the maximum system flow rate is approximately 100 L/min.

5.9 *Sample Installation* — Reasonable precautions should be taken when installing the test filter or spool piece to avoid particle contamination of the system from ambient. These precautions may include, but are not limited to, installation in a Class 100 laminar flow area, installation in a purged glove bag or other controlled ambient enclosure, use of a purge flow downstream of the sample point so that all parts of the system are under purge, isolation, or termination of the CNC sample flow, and isolation of the isokinetic sampler exhaust from ambient.

5.10 *Sampling System Design* — Customary practices should be employed for the design of the sampling system. Care should be taken to provide an adequate exhaust length so that back diffusion of particles does not affect the system background at 2 times the sampling flow rate. This length will depend upon the particle concentration in the ambient environment and other factors.

6 Procedure

6.1 *Static Background Test*

6.1.1 This test applies to all configurations described in this document and should be performed prior to other tests.

6.1.2 Replace the test filter with a straight piece of electropolished tubing and appropriate fittings.

6.1.3 Purge the system at 100 L/min. Measure particle concentration for a minimum of 45 sample intervals, each at least 6 standard liters (0.19 scf) or 4 minutes, whichever is greater. Continue to purge the system until 45 consecutive sample intervals without a particle being detected are recorded.

6.2 *Dynamic Background Test*

6.2.1 This test applies to the apparatus for pulse test as shown in Figure 2.

6.2.2 Replace the test filter with a straight piece of electropolished tubing and appropriate fittings.

6.2.3 Purge at a flow rate of Q = 10 L/min. until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.2.4 Set the CNC sample interval time to 180 seconds. Synchronize the start of this test with the start of a CNC sample interval.

6.2.5 Purge at a flow rate of 10 L/min. for 190 seconds.

6.2.6 Instantaneously switch to a flow rate of 100 L/min. by turning ON the solenoid valve and purge for 160 seconds.

6.2.7 Turn OFF the solenoid valve and purge at a flow rate of 10 L/min. for 200 seconds.

6.2.8 Repeat 6.2.6 and 6.2.7 until no particles are detected from 20 consecutive flow pulses.

6.3 *Break-in Test*

6.3.1 The apparatus is shown in Figure 2. Purge at a flow rate of Q = 100 L/min. with a straight piece of electropolished tubing and appropriate fittings in place of the test component until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.3.2 Decrease the flow rate to the minimum test flow rate specified in 5.8. Replace the electropolished tubing with the test component and purge until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.3.3 Increase the flow rate to the maximum flow rate specified in 5.8 and record hourly particle concentration averages.

6.3.4 Stop the test when the first set of three consecutive hourly sampling intervals shows no particles being detected or when a maximum duration of 8 hours is reached.

6.4 *Pulse Test*

6.4.1 The apparatus is shown in Figure 2. Purge at the maximum test flow rate until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.4.2 Set the CNC sample interval time to 180 seconds. Synchronize the start of this test with the start of a CNC sample interval.

6.4.3 Purge at the minimum test flow rate for 190 seconds.

6.4.4 Instantaneously switch to the maximum test flow rate by turning ON the solenoid valve and purge for 160 seconds.

6.4.5 Turn OFF the solenoid valve and purge at the minimum test flow rate for 200 seconds.

6.4.6 Repeat 6.4.4 and 6.4.5 (160 secs. ON and 200 secs. OFF) for a series of 10 flow pulses.

6.5 *Baking Test*

6.5.1 The apparatus is shown in Figure 3. A straight piece of electropolished tubing and appropriate fittings are in place of the test component.

6.5.2 Set the flow at the minimum test flow rate. Bake the electropolished tubing at the same temperature as the filter manufacturer-specified maximum temperature. Monitor the concentration until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.5.3 Replace the electropolished tubing with the test component and bake the filter at the manufacturer specified maximum temperature for 20 minutes. Monitor the concentration.

6.5.4 Allow the filter to cool for 20 minutes. Monitor the concentration.

6.5.5 Repeat 6.5.3 and 6.5.4 for a series of 3 baking cycles.

6.6 *Final Purge Test*

6.6.1 Perform a final purge at the maximum test flow rate and record hourly particle concentration averages.

6.6.2 The test is stopped when the first set of 3 consecutive hourly sampling intervals without a particle being detected are recorded or when a maximum duration of 8 hours is reached.

6.7 *Penetration Test*

6.7.1 The apparatus is shown in Figure 4. The input particle concentration is measured by CNC-B, while the output particle concentration is measured by CNC-A. Set flowmeter-B at the minimum test flow rate and flowmeter-A at the manufacturer-rated flow rate.

6.7.2 Measure the input and output particle concentration simultaneously for a minimum of 5 sample intervals, each at least 6 standard liters (0.19 scf) or 4 minutes, whichever is greater.

6.7.3 Calculate the averaged ratio of output to input particle concentration.

7 Reporting of Test Results

7.1 Raw data should be reported for each test in the format of a table, including the number of sample intervals, the sampling volume of each interval, the sampling time of each interval, and the total number of particles registered in each interval. In addition, the relevant parameters for each test described in 7.2 - 7.8 should be identitified.

7.2 *Static Background Test* — Identify the period of time required to obtain 3 consecutive hourly sampling intervals without a particle being detected.

7.3 *Dynamic Background Test* — Identify the period of time required to obtain 20 consecutive flow pulses without a particle being detected.

7.4 *Break-in Test* — Identify the period of time required to obtain 3 consecutive hourly sampling intervals without a particle being detected at the maximum test flow rate and the total number of particles recorded during this period.

7.5 *Pulse Test* — Identify number of pulses during which particles were detected and the total number of particle counts.

7.6 *Baking Test* — Identify the total number of particles measured during the 3 cycles.

7.7 *Final Purge Test* — Identify the total number of particles counted and the time to reach the background level established in the break-in test.

7.8 *Penetration Test* — Identify the input concentration, which is approximately 3500 particles/sec. (10^8 particles/scf), the output concentration, and the ratio of output to input concentration.

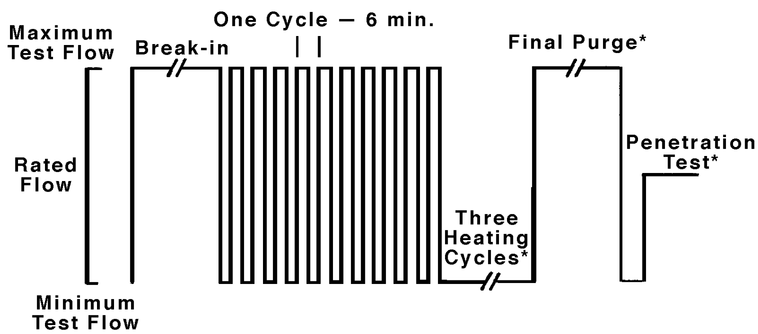

Figure 1
Schematic of a Standard Test Sequence for Evaluating POU Filters

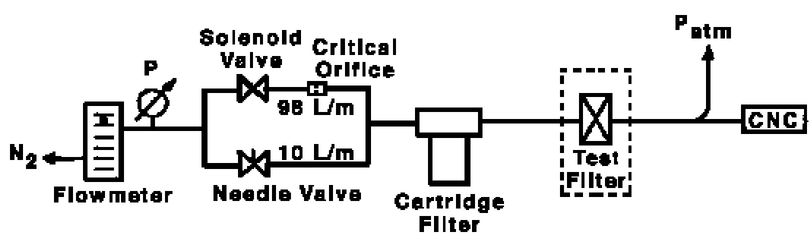

Figure 2
Schematic of the Break-in Test Setup

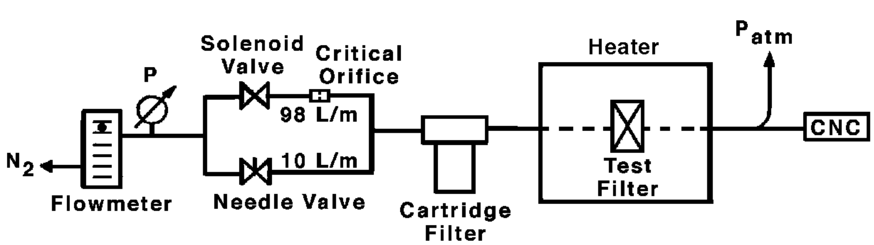

Figure 3
Schematic of the Baking Test Setup

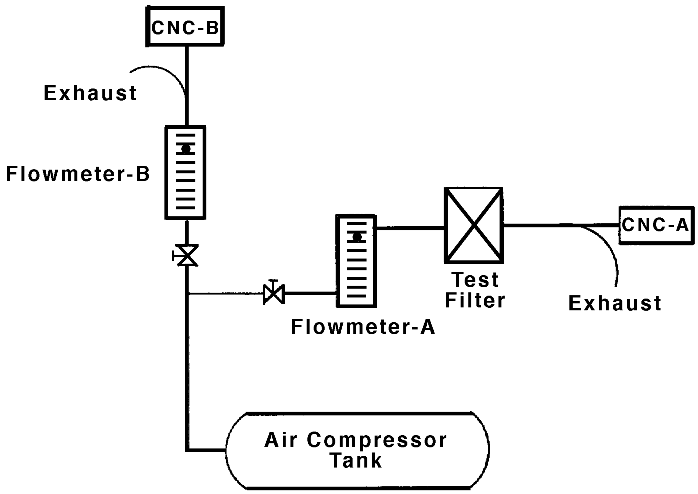

Figure 4
Schematic of the Penetration Test Setup

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SEMI C14-95
TEST METHOD FOR PARTICLE SHEDDING PERFORMANCE OF 25 cm GAS FILTER CARTRIDGES

1 Purpose

1.1 The purpose of this document is to define a comprehensive standard test sequence to derive particle-related qualification data for 25 cm (10 inch) filter cartridges.

2 Scope

2.1 This test method defines a particle shedding evaluation method for 25 cm filter cartridges of various media (e.g., PTFE, PVDF, polycarbonate, nylon, and polysulfone) commonly used individually or in assemblies to remove particles from gas lines. The filter cartridges are separable from the housings which can be cleaned and tested independently.

3 Limitations

3.1 These test methods do not apply to point-of-use (POU) filters, for which separate methods (SEMI C13) have been developed.

3.2 Cartridge filter performance cannot be characterized by a single data point, as conditions of use (e.g., pressure drop, transient pressure surges) determine the importance of a particular measurement. A sequence of tests, designed to measure filter responses under various conditions, is necessary when evaluating cartridge filters.

3.3 The order of the test sequence will affect the test results, and it is designed for fair comparisons of different aspects of filter operations. Hence, it is important to follow the prescribed test sequence.

4 Summary of Method

4.1 The test sequence (shown schematically in Figure 1) consists of three steps:

1. Break-in
2. Pulse
3. Final Purge

5 Apparatus and Facility

5.1 *Gas Source* — Clean, dry nitrogen or dry air with less than 0.5 ppm moisture and less than 0.5 ppm total hydrocarbons.

5.2 *Particle Detectors* — A condensation nucleus counter (CNC) with a counting efficiency of 50%, as reported by the manufacturer, at 0.01 µm is recommended to measure total particle concentration greater than 0.01 µm.

5.3 *Test Environments* — A clean room environment is not required during testing; however, the test component should be unpacked and assembled in a Class 100 clean area to prevent ambient contamination.

5.4 *Configuration for Break-in Test* — The schematic of the test setup apparatus is shown in Figure 2. All components used in the test apparatus, including the flowmeter, valves, tubing, and filter housing, are 2.5 cm (1 inch) components or have 2.5 cm (1 inch) inlet and outlet connections. The apparatus consists of (1) a differential pressure sensor that can accurately measure Δp in the range 0.01 bar (0.15 psid) to 0.2 bar (3.0 psid) between the upstream and downstream pressure of the test component, (2) a flow control system that permits instantaneous change of flow corresponding to a Δp of 0.01 bar to 0.2 bar across the filter, and (3) a CNC downstream of the test filter.

5.5 *Configuration for Pulse Test* — The schematic of the test setup is the same as the break-in test.

5.6 *Sample Installation* — Reasonable precautions should be taken when installing the test filter or spool piece to avoid particle contamination of the system from ambient air. These precautions may include, but are not limited to, installation in a Class 100 laminar flow area, installation in a purged glove bag or other controlled ambient enclosure, use of a purge flow downstream of the sample point so that all parts of the system are under purge, isolation, or termination of the CNC sample flow, and isolation of the isokinetic sampler exhaust from ambient.

5.7 *Sampling System Design* — Customary practices should be employed for the design of the sampling system. Care should be taken to provide an adequate exhaust length so that back diffusion of particles does not affect the system background at 2 times the sampling flow rate. This length will depend upon the particle concentration in the ambient environment and other factors.

6 Procedure

6.1 *Static Background Test*

6.1.1 This test applies to all apparatus described in this document and should be performed prior to other tests.

6.1.2 Remove the filter cartridge from the filter housing and replace the test filter in Figure 2 with the empty housing.

6.1.3 Purge the system at 100 m^3/hr (3530 standard cubic feet per hour (scfh)). Measure particle concentration for a minimum of 45 sample intervals, each at least 6 standard liters (0.19 scf) or 4 minutes, whichever is greater. Continue to purge the system until 45 consecutive sample intervals without a particle being detected are recorded.

6.2 *Dynamic Background Test*

6.2.1 This test applies to the apparatus for pulse test as shown in Figure 2 with the test filter replaced by an empty filter housing.

6.2.2 Purge at a flow rate of 5 m^3/hr (177 scfh) until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.2.3 Set the CNC sample interval time to 180 seconds. Synchronize the start of this test with the start of a CNC sample interval.

6.2.4 Purge at a flow rate of 5 m^3/hr (177 scfh) for 190 seconds.

6.2.5 Instantaneously switch to a flow rate of 100 m^3/hr (3530 scfh) by turning ON the solenoid valve and purge for 160 seconds.

6.2.6 Turn OFF the solenoid valve and purge at a flow rate of 5 m^3/hr (177 scfh) for 200 seconds.

6.2.7 Repeat 6.2.5 and 6.2.6 until 20 consecutive pulses without a particle being detected are recorded.

6.3 *Break-in Test*

6.3.1 The test setup apparatus is shown in Figure 2. Purge at a relatively low flow rate corresponding to a Δp of 0.01 bar (0.15 psid) across the filter until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.3.2 Increase the purge flow rate so that the corresponding Δp is at least 0.1 bar and the flow rate is at least 45 m^3/hr (1590 scfh).

6.3.3 Record hourly particle concentration averages.

6.3.4 Stop the test when no particles are detected in 3 consecutive hourly sampling intervals.

6.4 *Pulse Test*

6.4.1 The apparatus is shown in Figure 2. Purge at a relatively low flow rate corresponding to a Δp of 0.01 bar across the filter until 5 consecutive 60-second sample intervals without a particle being detected are recorded.

6.4.2 Set the CNC sample interval to 180 seconds. Synchronize the start of this test with the start of a CNC sample interval.

6.4.3 Purge at a low flow rate corresponding to a Δp of 0.01 bar across the filer for 190 seconds.

6.4.4 Instantaneously switch to a higher flow rate corresponding to a Δp of 0.1 bar (0.15 psid) across the filter by turning ON the solenoid valve and purge for 160 seconds.

6.4.5 Turn OFF the solenoid valve and purge at a low flow rate (Δp=0.01 bar) of 200 seconds.

6.4.6 Repeat 6.4.4 and 6.4.5 (160 secs ON and 200 secs OFF) for a series of 10 flow pulses.

6.5 *Final Purge Test*

6.5.1 Purge the filter at a Δp of 0.2 bar (3 psid) or a flow rate of 90 m^3/hr (3180 scfh), whichever is greater, for 3 hours. Record the particle concentration.

6.5.2 Decrease the flow so that Δp = 0.1 bar (0.15 psid) or the flow rate is 45m^3/hr (1590 scfh), whichever is greater, and purge for 1 hour. Record the particle concentration.

7 Reporting of Test Results

7.1 Raw data should be reported for each test in the format of a table including the number of sample intervals, the sampling volume of each interval, the sampling time of each interval, and the total number of particles registered in each interval. In addition, the relevant parameters for each test described in Sections 7.2 - 7.6 should be identified.

7.2 *Static Background Test* — Identify the period of time required to obtain 3 consecutive hourly sampling intervals without a particle being detected.

7.3 *Dynamic Background Test* — Identify period of time required to obtain 20 consecutive flow pulses without a particle being detected.

7.4 *Break-in Test* — Identify the period of time required to obtain 3 consecutive one hour sampling intervals without detection of particles and the total number of particles recorded during this period.

7.5 *Pulse Test* — Identify the number of pulses during which particles were detected and the total number of particle counts.

7.6 *Final Purge Test* — Identify the average particle concentration at each pressure.

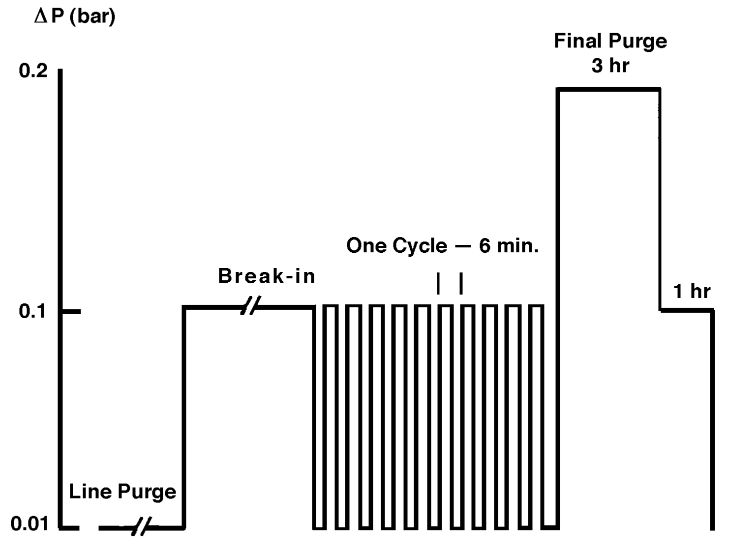

Figure 1
Schematic of a Standard Test Sequence for Evaluating 10-inch Filters

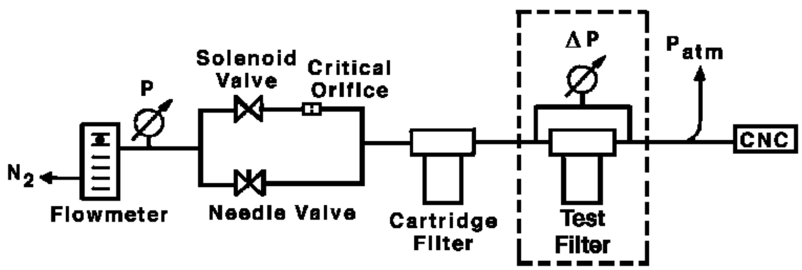

Figure 2
Schematic of the Line Purge Test Setup

SEMI C15-95

TEST METHOD FOR ppm AND ppb HUMIDITY STANDARDS

1 Purpose

1.1 This test will determine whether or not the quantity of moisture delivered by a gaseous moisture standard is in agreement with that predicted for the standard on the basis of physical principles. It is expected that this method will be used to validate moisture standards before they are first placed in use, when deviation from expected performance is likely or suspected, and at other times as seems necessary.

1.2 The test method assumes the existence of a reliable moisture analyzer. Although extensive precautions are described to ensure the validity of the analyzer, it is always possible that the test could yield a faulty result through some unforeseen defect in the analytical equipment.

1.3 Given that moisture generation is subject to many pitfalls, it will be required that the predicted moisture concentration delivered by the standard and the measurement of that level by the analyzer be independent, and that they agree. The level of agreement can vary depending on the degree of precision claimed for the moisture standard, but in any case the measured and predicted results should be within 10% over the entire range of the moisture standard. If not, then the validation should be repeated after verifying the physical measurement upon which the prediction is based and any other parameters deemed suspect.

2 Scope

2.1 This method is intended to be applicable to any type of gaseous standard delivering a quantity of moisture in the ppm range or lower, provided the delivered moisture concentration is predictable on the basis of fundamental principles of physics. Thus, any standards which rely solely on characterization by analysis are specifically excluded.

2.2 As part of this test, a procedure is described for qualifying certain moisture analyzers considered suitable for use in qualifying moisture standards. Moisture analyzers intended for other applications may need to satisfy different criteria.

2.3 As the most accurate and reliable moisture analyzers currently available operate primarily in the ppm range, this test focuses on validation of moisture standards in this range. The need for ppb moisture standards is addressed by specifying procedures for reducing the output of ppm moisture standards to the ppb range.

3 Limitations

3.1 If no higher level of accuracy is specified by the user, then a moisture standard shown to be valid by this method will generate moisture levels which deviate from the expected values by no more than 20%. The method leaves open to the user the option of using sound statistical methods to specify that a given moisture standard will generate levels showing a closer agreement with expected values.

3.2 Validation based on this test method is good for a limited time. The acceptable interval between validations depends on the nature of the standard and is not addressed by this method. Thus any citation of validation results should be accompanied by the date(s) on which validation was performed.

4 Referenced Documents

This method is based upon principles outlined in F. Mermoud, M.D. Brandt, and J.J.F. McAndrew, “Low Level Moisture Generation,” Analytical Chemistry, 63 (2): 198-202 (1991).

5 Device under Test (Test Specimen)

5.1 *Definition of a Moisture Standard* — A moisture “standard” is defined to be any device capable of delivering a flow of humidified gas at controlled pressure, with no input being provided by the user except nitrogen of UHP grade (moisture < 1 ppm) or air of equivalent purity. Any device, such as a permeation tube, which can provide a predictable amount of moisture but does not include a means to deliver gas to and from it, will not be considered a moisture standard by itself. A device which requires gas of higher purity than UHP grade will include a purifier capable of purifying UHP nitrogen to this level.

5.2 *Examples of Moisture Standards* — Some examples of moisture standards and the principles upon which they are based are as follows:

— Permeation and effusion tube standards. These must include purification means and some means of regulating the outlet pressure. The moisture delivery rate can be calculated based on the weight loss of the tube.

— Cylinder standards. The “standard” will include a regulator specified for use with the cylinder. The moisture concentration delivered can be calculated based on that added to the cylinder in preparation. A minimum use pressure must be specified.

— Methods based on saturation of gas with water vapor at a fixed temperature and pressure. The moisture concentration in the gas may then be calculated from a knowledge of the saturation vapor pressure of water over a plane of the pure phase of ice at the saturation temperature and of the interaction virial coefficients of the gas-vapor mixture. The two-pressure and two-temperature methods are refinements of this approach requiring additional chambers whose temperature and pressure must be known.

5.3 *Dilution of Standards* — For all moisture generation methods, lower concentrations can be generated by dynamic dilution (i.e., by combining a known flow of the standard gas with a known flow of dilution gas). A diluted standard is acceptable provided:

— The standard is validated at high concentration (with the lowest concentration validated being no more than 10,000 times the use concentration),

— The dilution gas has a moisture level below the stated precision of the analysis (to be verified using the same flow path as during the subsequent analysis, and at the lowest flow rate to be used),

— The absolute accuracies of the dilution system components are verified by comparison with a reliable flow standard,

— The linearity of the dilution system can be demonstrated over the entire range of operation.

The last criterion is particularly important whenever some portion of the combined flow is discarded, as mixing problems can easily arise at large dilution factors.

6 Procedure

Validation will be performed using a hygrometer whose output can be directly related to the moisture concentration on the basis of physical laws or using an analyzer which has recently been calibrated by comparison with such an analyzer.

6.1 *Hygrometer Qualification*

6.1.1 *Primary Hygrometers* — Hygrometers can be certified by the National Institute for Standards and Technology (NIST) in the U.S., and similar certification is available in other countries, although the lowest concentration at which certification is available will vary. Repeated certification at yearly or longer intervals can be used to establish reliability. A hygrometer which has been certified by a national standards laboratory to 1 ppm (or lower) moisture in air or nitrogen, and for which reliability has been established over a period greater than or equal to that which has elasped since certification occurred, is acceptable for validation of a moisture standard and will be referred to as a “primary” hygrometer.

Because hygrometers which are suitable for use as primary hygrometers may be less convenient or less readily available than other hygrometers, the use of other hygrometers for validation is also acceptable, provided adequate precautions are taken to ensure that they are operating correctly. These precautions (to be described below) require using a moisture source to compare a secondary hygrometer with the primary hygrometer. The moisture source need not have been validated in this case.

6.1.2 *Validation of Secondary Hygrometers* — Secondary hygrometers may be validated by comparing their output with a primary hygrometer when connected in parallel to the same moisture source. The degree of agreement required can vary depending upon the precision to be claimed, but in any case the difference in reading between the two hygrometers should be no more than 10% at any point. Comparison should be made at four moisture concentrations or at two per decade of proposed operation, whichever is less. Half of the comparisons should be made while increasing concentration and half while decreasing, including at least one comparison at the highest point of the concentration range. The first and last comparisons should be at the lowest point of the concentration range. For example, in order to validate a hygrometer for operation between 1 and 100 ppm, it would be acceptable to generate moisture levels at 1, 30, 100, 50, 1 ppm (in that order) and compare the primary with the secondary hygrometer. Comparison of the measured level between the two 1 ppm tests provides a ready indication of hysteresis in the system. If the secondary hygrometer requires calibration using its own standard, calibration should be effected before validation. However, it is acceptable to adjust the calibration in order to improve agreement with the primary hygrometer.

6.1.3 *Frequency of Hygrometer Validation* — The frequency of validation required for a secondary hygrometer will vary dependent upon the performance established for hygrometers of the same general type. If three successive monthly validations show continuing agreement (within 10%) with the primary hygrometer without calibration adjustment, the validation interval may be extended to three months. Similar extensions of validation interval to six months and one year may be made if no drift is apparent and no calibration adjustments are necessary to bring the secondary within 10% of the primary at all points.

6.2 *Validation Procedure for Moisture Standards*

6.2.1 *Validation Within the Range of an Available Primary Hygrometer* — If a primary hygrometer is available, and its detection limit is no higher than the lowest concentration at which it is desired to use the moisture standard, this is the simplest case. Use the standard to generate four concentration levels or two per decade (whichever is less) in which the standard will be used, half of the concentrations generated while increasing concentration, half while decreasing, including at least one comparison at the highest point of the concentration range. The first and last comparisons should be at the lowest point of the concentration range. If the generated levels, calculated according to the basic properties of the generator (e.g., weight loss of a permeation tube) agree with the measured levels to within 10%, the standard may be considered validated with an accuracy of 10%. Higher validation accuracy requires better agreement. It has been assumed that the precision of the primary hygrometer, as determined by a national standards laboratory, is much better than 10% and may be neglected for validation at the 10% level. Validation at higher accuracy requires explicit consideration of the certification precision.

If a standard only generates one level, connect it to the hygrometer and allow to come to equilibrium. Assuming the equilibrium level agrees with the calculated level of the generator, disconnect the hygrometer and bring it to equilibrium with either dry nitrogen or ambient air. Then reconnect the moisture standard and reestablish equilibrium between the standard and the hygrometer. Disconnect again and repeat a third time. If the three measurements agree within 10% among themselves and with the generated level, the standard is validated.

It is implicit in the above that the background moisture level of the system be less than 50 ppb so that it can be neglected for all measurements above 1 ppm with an error no larger than 5%. We can usually neglect background moisture in validating moisture standards in this concentration range.

6.2.2 *Validation Using Secondary Hygrometers* — If no primary hygrometer is available, then validation can be performed using a secondary hygrometer. If the lowest concentration to be generated using the standard is no higher than the detection limit of the primary hygrometer used for validation of the secondary hygrometer, then the procedure is as above, except that the secondary must first have been validated over the entire concentration range which the standard will be used to generate. (A secondary hygrometer and a moisture standard can be validated simultaneously if the primary and secondary hygrometers are connected in parallel to the moisture standard.)

When assessing the accuracy of validation using a secondary hygrometer, it is necessary to take into account the precision of the comparison of the primary hygrometer with the secondary hygrometer as well as the precision of the comparison of the generator with the secondary hygrometer.

7 Practice for Generating ppb Moisture Standards

The detection limit of the primary hygrometer will generally be on the order of 1 ppm, whereas it will frequently be necessary to use the moisture standard at concentrations below this level, by a factor of as much as 10,000. Therefore, valid methods for reducing concentration are necessary.

7.1 *Dilution of Validated Moisture Standards* — If a moisture standard validated in accordance with 6.2.0 or 6.2.1 is diluted with a zero gas stream satisfying the criteria of 5.3, then the resultant diluted standard may be considered valid and may be used for calibration of analyzers, such as APIMS.

7.2 *Consideration of Background Moisture* — In any ppb or lower moisture measurement, it is necessary to consider the background moisture level due to outgassing in the sampling system and residual moisture in the generator + analyzer. Often the background will be sufficiently large that it must be taken into account explicitly. The background moisture level is the moisture concentration measured in the absence of a moisture source (i.e., when the driest carrier gas available is fed to the analyzer using the same flow rate and flow path as is used for the sample gas during analysis).

It should be noted that the importance of the background level increases for measurements at low concentrations, and that the background level is sensitive to the materials of construction, to the design of the moisture generator, and to its operating temperature.

If the background moisture concentration is B (ppb), the concentration delivered by the moisture standard is C (ppb) and the dilution factor x is given by

$$x = \frac{\text{flow of moisture standard}}{\text{total flow}} \qquad (1)$$

then c, the delivered moisture concentration is given (in ppb) by

$$c = (1 - x)B + xC \qquad (2)$$

The accuracy of calibration will reflect the combined accuracy of the standard and the dilution system, together with the accuracy of the background determination; all must be taken into account in any statement of analytical uncertainty.

7.3 *Changing the Range of Performance of a Moisture Standard* — If a moisture standard is based on some device which is believed to deliver moisture at a constant rate, such as a permeation or effusion tube, the concentration range delivered by the moisture standard may be changed by delivering a substantially different flow of carrier gas. This usually requires changing a mass flow controller or other flow control device inside the standard for a flow controller of a different range. This may be done provided the new flow controller's performance is verified by comparison with a reliable flow standard.

The definition of dilution factor is revised to

$$x = \frac{\text{flow generated by original flow controller}}{\text{flow generated by new flow controller}} \qquad (3)$$

The background, B, is determined by removing the permeation or effusion tube from the system and capping off its point of connection, or by preventing the source from delivering moisture by some other means. The same equation for c applies as does the statement regarding analytical uncertainty.

7.4 *Validation at Intermediate Concentrations* — It may be desirable to validate a moisture standard at a concentration below the detection limit of the primary hygrometer, if that standard is to be used for very low-level generation. For example, if a standard based on a permeation device is intended to generate levels between 0.5 and 5 ppb at flows of 1 to 10 slm, it could be validated in the 0.5 to 5 ppm range using a frost-point hygrometer by replacing the flow controller with one operating between 1 and 10 sccm[1] . However, such a flow controller may not be readily available and is difficult to calibrate in any case. Instead, it is preferable to use a flow controller operating between 50 and 500 sccm to generate concentrations between 0.1 and 1.0 ppm together with a secondary hygrometer having a detection limit no higher than 50 ppb. This procedure is acceptable, provided that

— the secondary hygrometer has been validated with a primary hygrometer at least at one point in the range to be used for validation of the moisture standard,

— the moisture concentrations generated by the standard and that observed by the secondary hygrometer agree throughout the range of validation of the standard.

This approach could lead to errors if the hygrometer and the standard each exhibited a deviation from predicted performance, but these deviations would have to be the same and cancel, which is extremely unlikely.

In the case of operation in this mode, it will be necessary to know the background level of the system and use this as an input to the calculation of generated moisture levels. To continue the example of a permeation based system, if the permeation rate determined by weight loss is P (ng/min), the flow rate of carrier gas is F (sccm), K is a factor to convert ng/min to sccm moisture, and B is the experimentally determined background, then the generated moisture level, c_{gen}, is calculated according to

$$c_{gen} = \frac{KP}{F} + B \qquad (4)$$

For other moisture generation systems, it is similarly possible to calculate the generated moisture level while taking into account the background level of the system. This assumes that the background moisture concentration is constant, which is only approximately true. Thus, in applying this approach, in addition to the sources of error mentioned above, the estimate of analytical uncertainty must also include the variation in background moisture.

8 Validation Precision and Accuracy

This procedure does not explicitly consider the estimation of the accuracy of a moisture standard in detail, because such a calculation can be made by applying procedures described elsewhere. The accuracy required in validation will vary with the proposed application of the moisture standard and may be left to the discretion of the user of the procedure. It is recommended that a propagation of errors calculation be carried out to estimate the accuracy of the validation. If no such calculation is made, and the minimum criteria of the procedure are followed, it is estimated that a validated moisture generator may output moisture levels which differ from the true values by up to 20%.

1 It is assumed that, although flow controllers are calibrated using a standard, no unusual measures are used to enable the full accuracy of calibration to be achieved over the entire range of the flow controller. In practice this means that a flow controller has a usable dynamic range of 10-100% of its flow rating.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI C52-0301
SPECIFICATION FOR THE SHELF LIFE OF A SPECIALTY GAS

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the European Gases Committee. Current edition approved by the European Regional Standards Committee on December 20, 2000. Initially available at www.semi.org January 2001; to be published March 2001.

1 Purpose

1.1 The purpose of this document is to define terminology and to recommend minimum periods for the shelf lives of specialty gases. It is meant to provide consistency in terminology among gas suppliers and to provide a general guideline for users of these gases.

2 Scope

2.1 This document applies to the shelf life of properly packaged, filled and analyzed specialty gases as stored or supplied by a specialty gas manufacturer or supplier. In this document, shelf life is viewed from a quality point of view. The document does not address safety aspects associated with the prolonged storage of gases.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

None.

4 Terminology

4.1 *container* — a lecture bottle, cylinder, cylinder pack, drum or any other vessel which is used to supply a specialty gas.

4.2 *residual level* — The amount of product, as a fraction of the fill weight or fill pressure, which should be left in a container in order to minimize the impact on manufacturing processes of the higher level of impurities in the last gas fraction from a container.

4.3 *shelf life* — the period of time for which the specification of a gas is guaranteed by the supplier, starting from the time of analysis. It defines the period for which the supplier guarantees the actual level of impurities, as analyzed, to remain at or below the specification limit for a particular gas grade.

5 Requirements

5.1 *Factors Affecting the Shelf Life of a Specialty Gas* — Shelf life is a function of the following factors:

a. Thermal stability of the gas

b. Quality of the container and valve

- material selection
- leak tightness

c. Time-dependent reactions between

- gas and impurities
- gas and packaging materials

d. Filling and analytical operations

e. Transport and storage conditions

f. Amount of product in the container

5.1.1 The integrity of the valve is a key factor determining the shelf life of a gas, in particular for low vapor pressure gases. Time dependent reactions can be significantly reduced by purification of the gas to a level where impurities no longer have a significant effect over time, and by selection of proper packaging materials. Chemical and physical treatment of the internal container surface and/or passivation of this surface before filling also reduces the effect of time-dependent reactions. For material and gas compatibility information, please refer to the individual SEMI gas standards.

5.2 *Classification of Specialty Gases on the Basis of Shelf Life* — While there are a large number of specialty gases used in semiconductor manufacturing, for the purpose of defining shelf lives, they can be divided into four groups. It should be noted that for example chemically reactive gases are sometimes classified as non-reactive in the table below as the classification is done from a shelf-life point of view only.

5.2.1 *Non-reactive* — Under normal storage conditions, these gases do not react with ambient air, the packaging materials or the impurities commonly found in the specialty gas.

5.2.2 *Reactive* — These gases react either with ambient air or standard packaging materials.

5.2.3 *Corrosive* — These gases react with packaging materials usually in the presence of traces of moisture.

5.2.4 *Unstable* — These gases are thermally unstable and spontaneously decompose over time.

Table 1 Classification of Specialty Gases on the Basis of Shelf Life

Non-reactive	*Reactive*	*Corrosive*	*Unstable*
Air	AsH_3	BCl_3	B_2H_6
Ar	CO	BF_3	NO
CFH_3	D_2	$^{11}BF_3$	
CF_2H_2	GeH_4	ClF_3	
CF_3H	H_2	Cl_2	
CF_4	NF_3	F_2	
CH_4	PH_3	GeF_4	
CO_2	SeH_2	HBr	
C_2F_6	SiH_4	HCl	
C_3F_8	Si_2H_6	HF	
C_4F_8		NH_3	
C_5F_8		PF_5	
He		$SiCl_2H_2$	
Kr		$SiCl_3H$	
Ne		$SiCl_4$	
N_2		SiF_4	
N_2O		WF_6	
O_2			
SF_6			
Xe			

5.3 *Guaranteed Shelf Life Period* — The following guaranteed shelf life periods are recommended as a minimum.

Table 2 Guaranteed Shelf Life Period

Non-reactive	*Reactive*	*Corrosive*	*Unstable*
36 months	24 months	18 months	6 months

5.3.1 When proper packaging materials are chosen and the container is properly prepared (and passivated), impurity levels should in theory remain constant over time for an electronics grade specialty gas with the exception of the thermally unstable gases. For this reason, no maximum shelf life periods are recommended as these will depend on the level of analytical data collected by the manufacturer or supplier.

5.4 *Mixtures* — The shelf life of a mixture is recommended to be equal to the shelf life of the component in the mixture with the lowest shelf life. For example, the minimum shelf life of a reactive gas in a non-reactive gas matrix would be 24 months. The shelf life of a mixture should apply both to the impurity specifications and to the assay of the mixture.

5.4.1 Special attention should be paid to the preparation of the package for mixtures containing less than 1,000 ppm of a component. At such levels, adsorption effects may reduce the shelf life and minimization of the package internal surface roughness and/or passivation of the surface may be required.

5.5 *Residual Level* — The impact of the depletion of a container on impurity levels is still a matter of debate among gas suppliers. In general, the impurity levels of the first gas fraction from a container will differ from the last gas fraction. In particular moisture levels tend to rise at lower gas pressures as a result of the relative increase in importance of the internal container wall and its adsorbed moisture. In addition, in liquefied gases the co-existence of both a gas phase and a liquid phase can have a measurable effect on the distribution of impurities over the gas fractions. It is argued that at the point of liquid-dry some impurities, which prefer solution in the liquid phase over the gas phase, may see a dramatic rise. It is therefore recommended to always leave an amount of product in the container and to avoid a situation of "liquid dry" (i.e., when all of the liquid phase of a liquefied gas has been used).

SEMI INTERNATIONAL STANDARDS

MATERIALS

Semiconductor Equipment and Materials International

SEMI M1-0302
SPECIFICATIONS FOR POLISHED MONOCRYSTALLINE SILICON WAFERS

These specifications were technically approved by the Global Silicon Wafer Committee and are the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1978; previously published July 2001.

1 Purpose

1.1 These specifications cover requirements for monocrystalline high-purity silicon wafers used in semiconductor device manufacturing. Dimensional and crystallographic orientation characteristics and limits on surface defects are the only standardized properties set forth below.

1.2 A complete purchase specification requires that additional physical properties be specified along with test methods suitable for determining their magnitude. SEMI M18 provides a comprehensive listing of such properties and associated test methods and may be used for this purpose (see also Section 4).

1.3 These specifications apply specifically to silicon wafers with one chem-mechanically polished surface. Wafers polished on both sides, or unpolished, or with epitaxial deposits are not covered. Values given for thickness, TTV, bow, and warp apply only to wafers without back surface films or extrinsic gettering treatments. However, purchasers of such wafers may find these specifications to be a useful guide in defining their requirements.

1.4 For referee purposes, U.S. customary units shall be used for wafers of 2 and 3-inch nominal diameters, and SI (system international, commonly called metric) units for 80 mm and larger diameter wafers.

1.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory practices prior to use.

2 Referenced Standards

2.1 *SEMI Standards*

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

SEMI T2 — Specification for Marking of Wafers with a Two-Dimensional Matrix Code Symbol

NOTE 1: A revision to SEMI T2 to extend it to include rectangular code symbols is currently being balloted in a companion document.

2.2 *ASTM Standards*[1]

E 122 — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

F 21 — Test Method for Hydrophobic Surface Films by the Atomizer Test

F 22 — Test Method for Hydrophobic Surface Films by the Water-Break Test

F 26 — Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 28 — Method for Measuring the Minority-Carrier Lifetime in Bulk Germanium and Silicon

F 42 — Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 43 — Test Methods for Resistivity of Semiconductor Materials

F 47 — Test Method for Crystallographic Perfection of Silicon by Preferential Etch Techniques

F 76 — Test Methods for Measuring Hall Mobility and Hall Coefficient in Extrinsic Semiconductor Single Crystals

F 81 — Method for Measuring Radial Resistivity Variation on Silicon Slices

F 84 — Method for Measuring Resistivity of Silicon Slices with a Collinear Four-Probe Array

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 391 — Test Method for Minority Carrier Diffusion Length in Silicon by Measurement of Steady-State Surface Photovoltage

F 398 — Test Method for Majority Carrier Concentration in Semiconductors by Measurement of Wave Number or Wavelength of the Plasma Resonance Minimum

F 416 — Test Method for Detection of Oxidation Induced Defects in Polished Silicon Wafers

F 419 — Test Method for Net Carrier Density in Silicon Epitaxial Layers by Voltage-Capacitance of Gated and Ungated Diodes

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 533 — Test Method for Thickness and Thickness Variation of Silicon Slices

F 534 — Test Method for Bow of Silicon Slices

F 613 — Test Method for Measuring Diameter of Silicon Slices and Wafers

F 657 — Test Method for Measuring Warp and Total Thickness Variation on Silicon Slices and Wafers by a Noncontact Scanning Method

F 671 — Test Method for Measuring Flat Length on Slices of Electronic Materials

F 673 — Test Method for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

F 847 — Test Methods for Crystallographic Orientation of Flats on Single Crystal Silicon Slices and Wafers by X-Ray Techniques

F 928 — Test Methods for Edge Contour of Silicon Wafers

F 951 — Test Method for Radial Interstitial Oxygen Variation

F 1188 — Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F 1241 — Terminology of Silicon Technology

F 1366 — Test Method for Measuring Oxygen Concentration in Heavily Doped Silicon Substrates by Secondary Ion Mass Spectroscopy

F 1388 — Test Method for Generation Lifetime and Generation Velocity of Silicon Material by Capacitance-Time Measurements of MOS (Metal-Oxide-Silicon) Capacitors

F 1390 — Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

F 1391 — Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

F 1451 — Test Method for Measuring Sori on Silicon Wafers by Automated Noncontact Scanning

F 1526 — Standard Test Method for Measuring Surface Metal Contamination on Silicon Wafers by Total Reflection X-Ray Fluorescence Spectroscopy

F 1528 — Standard Test Method for Measuring Boron Contamination in Heavily Doped N-Type Silicon Substrates by Secondary Ion Mass Spectrometry

F 1530 — Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F 1535 — Test Method for Carrier Recombination Lifetime is Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

F 1617 — Standard Test Method for Measuring Surface Sodium, Aluminum, and Potassium on Silicon and Epi Substrates by Secondary Ion Mass Spectrometry

F 1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with P-Polarized Radiation Incident at the Brewster Angle

2.3 *DIN Standards*[2]

50430 — Messung des spezifischen elektrischen Widerstandes von stabformigen Einkristallen aus Silicium oder Germanium mit dem Zwei-Sonden-Gleichstrom-Verfahren (Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals in Bars by Means of the Two Point-Probe Direct Current Method)

50431 — Messung des spezifischen elektrischen Widerstandes von Einkristallen aus Silicium oder Germanium mit dem Vier-Sonden Gleichstrom-Verfahren bei linearer Anordnung der Sonden (Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals by Means of the Four-Point-Probe Direct Current Method with Collinear Four Probe Array)

50432 — Bestimmung des Leitungstyps von Silicium oder Germanium mittels Richttest oder Thermosonde (Determination of the Conductivity Type of Silicon or

2 DIN Standards, Deutsches Institut fur Normung e.v., available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000 Berlin 30, Germany

Germanium by Means of Rectification Test or Hot-Probe)

50433/1 — Bestimmung der Orientierung von Einkristallen mit einem Roentgengoniometer (Determination of the Orientation of Single Crystals by Means of X-Ray Diffraction)

50433/2 — Bestimmung der Orientierung von Einkristallen nach der Lichtfiguren-methode (Determination of the Orientation of Single Crystals by Means of Optical Reflection Figure)

50433/3 — Bestimmung der Orientierung von Einkristallen mittels Laue-Ruckstrahl-verfahren (Determination of the Orientation of Single Crystals by Means of Laue Back Scattering)

50434 — Nachweis von Kristalldefekten in Silizium-Einkristallen mittels Atztechnik an {111}- und {100}-Flachen (Detection of Crystal Defects in Silicon Monocrystals by Etching on {111} and {100} Surfaces)

50435 — Bestimmung der radialen Variation des spezifischen elektrischen Widerstandes an Silicium oder Germanium-Scheibenmitdem Vier-Sonden-Gleichstromverfahren (Determination of the Radial Resistivity Variation of Silicon or Germanium Slices by Means of a Four-Point-DC-Probe)

50438/1 — Bestimmung des Verunreinigungs-gehaltes in Silicium mittels Infrarot Absorption; Sauerstoff (Determination of Impurity Content in Silicon by Infrared Absorption; Oxygen)

50438/2 — Bestimmung des Verunreinigungs-gehaltes in Silicium mittels Infrarot Absorption; Kohlenstoff (Determination of Impurity Content in Silicon by Infrared Absorption; Carbon)

50440/1 — Messung der Rekombinations-Tragerlebensdauer in Silicium-Einkristallen nach der Photoleitfahigkeitsverfahren; Messung an quaderformigen Proben (Measurement of Recombination Carrier Lifetime in Silicon Single Crystals by Means of Photoconductive Decay Method; Measurement on Bar-Shaped Test Samples)

50441/1 — Messung der geometrischen Dimensionen von Halbleiterscheiben; Messung der Dicke (Measurement of the Geometric Dimensions of Semiconductor Slices; Measurement of Thickness)

50441/2 — Messung der geometrischen Dimensionen von Helblaiterscheiben; Prufung der Kantenverrundung (Measurement of the Geometric Dimensions of Semiconductor Slices; Testing of Edge Rounding)

50441/4 — Messung der geometrischen Dimensionen von Halbleiterscheiben: Scheibendurchmesser und Flattiefe (Measurement of the Geometrical Dimensions of Semiconductor Slices: Diameter and Flat Depth of Slices)

2.4 *JIS Standards*[3]

H 0609 — Test Methods of Crystalline Defects in Silicon by Preferential Etch Techniques

H 0611 — Methods of Measurement of Thickness Taper and Bow for Silicon Wafers

2.5 *Other Standards*

ANSI/ASME B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)[4]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes[5]

ISO 4287/1 — Surface Roughness – Terminology – Part 1: Surface and its Parameters[6]

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3 Terminology

3.1 Many terms relating to silicon technology are defined in ASTM Terminology F 1241.

3.2 Definitions for many of the polished wafer defect terms in Table 1 are given in ASTM Practices F 154 and F 523 and in ASTM Test Method F 416.

3.3 Other terms are defined as follows:

3.3.1 *acceptor* — an impurity in a semiconductor which accepts electrons excited from the valence band, leading to hole conduction.

3.3.2 *anisotropic, in semiconductor technology* — exhibiting different physical properties in differing crystallographic directions.

3.3.3 *anisotropic etch* — a selective etch which exhibits an accelerated etch rate along specific crystallographic directions.

3 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo 107, Japan

4 This standard is currently being revised by a committee of The American Society of Mechanical Engineers, United Engineering Center, 345 E. 47th St., New York, NY 10017. In this draft revision, terminology is collected in a document designated B46.1.1; this document should be referred to in connection with additional terms related to surface roughness. Note that the nomenclature and symbols in ASME B46.1.1 may differ from those employed herein. Also note that ASME B46.1.1 is still under development, and the terms and definitions therein may change prior to approval by ASME and ANSI.

5 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

6 ISO Central Secretariat, C.P. 56, CH-1211 Geneve 20 Switzerland; available in the U.S. from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

3.3.3.1 Discussion: Anisotropic etches are used to determine crystal orientation, to fabricate micromechanical structures, and to facilitate dielectric component isolation.

3.3.4 *azimuth, in ellipsometry* — the angle between the major axis of the ellipse and the plane of incidence.

3.3.5 *backside* — not preferred, use *back surface* as defined in ASTM Terminology F 1241.

3.3.6 *bipolar* — semiconductor device fabrication technology which produces transistors that use both holes and electrons as charge carriers.

3.3.7 *carrier, in semiconductor materials* — an entity capable of carrying electric charge through a solid, for example, valence holes and conduction electrons in semiconductors; charge carrier.

3.3.8 *chem-mechanical polish, in semiconductor technology* — a process for the removal of surface material from the wafer which uses chemical and mechanical actions to achieve a mirror-like surface for subsequent processing.

3.3.9 *chuck mark* — any physical mark on either surface of a wafer caused by a robotic end effector, chuck, or wand.

3.3.10 *cleavage plane* — a crystallographically preferred fracture plane.

3.3.11 *conductivity (electrical)* — a measure of the ease with which charge carriers flow in a material; the reciprocal of resistivity.

3.3.11.1 Discussion: In a semiconductor, the conductivity is proportional to the product of free carrier density, electron electrical, and carrier mobility. Most variant of all crystal properties, conductivity can range over 13 orders of magnitude. Conductivity can be locally modified by temperature, carrier injection, irradiation, or magnetic field. Symbol is σ and units are $(\Omega\bullet cm)^{-1}$.

3.3.12 *conductivity type, of a semiconductor crystal or wafer* — a property that identifies the majority charge carrier in the semiconductor; see also *n-type*, *p-type*.

3.3.13 *contaminant, particulate* — see *light point defect*.

3.3.14 *contamination, area* — matter, unintentionally added to the surface of a wafer, of extent greater than a single localized light scatterer.

3.3.14.1 Discussion: Area contamination may be foreign matter on the wafer surface resulting from chuck marks, finger or glove prints, stains, wax or solvent residues, etc.

3.3.15 *contamination, particulate* — a particle or particles on the surface of a wafer.

3.3.16 *crystal defect* — departure from the ideal arrangement of atoms in a crystal.

3.3.17 *crystal indices* — see *Miller indices*.

3.3.18 *crystallographic notation* — a symbolism based on Miller indices used to label planes and directions in a crystal as follows:

plane	(111)
family of planes	{111}
direction	[111]
family of directions	<111>

3.3.19 *depletion layer* — a region in which the mobile carrier charge density is not sufficient to neutralize the net fixed charge density of donors and acceptors; barrier layer; blocking layer; space-charge layer.

3.3.20 *dimple* — a shallow depression with gently sloping sides that exhibits a concave, spheroidal shape and is visible to the unaided eye under proper lighting conditions.

3.3.21 *donor* — an impurity or imperfection in a semiconductor which donates electrons to the conduction band, leading to electron conduction.

3.3.22 *dopant* — a chemical element, usually from the third or fifth columns of the periodic table, incorporated in trace amounts in a semiconductor crystal to establish its conductivity type and resistivity.

3.3.23 *doping* — addition of specific impurities to a semiconductor to control the electrical resistivity.

3.3.24 *edge exclusion area* – the area between the FQA and the actual periphery of the wafer. The area varies with the actual dimensions of the wafer.

3.3.25 *edge exclusion, nominal* (EE) – the distance from the FQA boundary to periphery of a wafer of nominal dimensions.

3.3.26 *edge profile* — on edge contoured wafers (whose edges have been shaped chemically or mechanically), a description of the contour of the boundary of the wafer that joins the front and back surfaces.

3.3.27 *etch* — a solution, a mixture of solutions, or a mixture of gases that attacks the surfaces of a film or substrate, removing material either selectively or nonselectively; see also *anisotropic etch*, *preferential etch*.

3.3.28 *fixed quality area (FQA)* — the central area of a wafer surface, defined by a nominal edge exclusion, *EE*, over which the specified values of a parameter apply.

3.3.28.1 Discussion: The boundary of the FQA is at all points the distance *EE* away from the periphery of a wafer of nominal dimensions. (See Figure 1.) The size of the FQA is independent of wafer diameter and flat length tolerances. For the purposes of defining the FQA, the periphery of a wafer of nominal dimensions at locations with notch fiducials is assumed to follow the circumference of a circle with diameter equal to the nominal wafer diameter. It may be necessary to specify exclusion areas where the values of a specified parameter do not apply for regions like: the notch, laser marks, or where handling/gripping devices contact the wafer.

3.3.29 *flat, on a semiconductor wafer* — a portion of the periphery of a circular wafer that has been removed to a chord; see also *primary orientation flat*, *secondary flat*.

3.3.30 *flat diameter* — the linear dimension across the surface of a semiconductor wafer from the center of the flat through the wafer center to the circumference of the wafer on the opposite edge along the diameter perpendicular to the flat. (See Figure 3.)

3.3.30.1 Discussion: The flat diameter may be associated with the primary orientation flat, with a secondary flat, if present, or with any other flat, if present. In such cases, the term may be modified as primary orientation flat diameter, *secondary flat diameter*, etc. In the case of opposing primary orientation and secondary flats, as occurs on [100] *n*-type wafers 125 mm and smaller in diameter, the concept of flat diameter does not apply because the diameter perpendicular to the flats does not intersect the wafer circumference.

3.3.31 *flatness* — for wafer surfaces, the deviation of the front surface, expressed in TIR or maximum FPD relative to a specified reference plane when the back surface of the wafer is ideally flat, as when pulled down by a vacuum onto an ideally clean flat chuck.

3.3.31.1 Discussion: The flatness of a wafer may be described as either:

1. The global flatness, or
2. The maximum value of site flatness as measured on all sites, or
3. The percentage of sites which have a site flatness equal to or less than a specified value.

3.3.32 *focal plane* — the plane perpendicular to the optical axis of an imaging system which contains the focal point of the imaging system.

3.3.32.1 Discussion: The reference plane used by an imaging system is coincident with or parallel with the focal plane. Full field imaging systems employ coincident global focal and reference planes. Partial field imaging systems employ either coincident site focal and reference planes or displaced site focal and global reference planes. If the reference plane is not coincident with the focal plane, it is displaced from the focal plane so that the point on the front surface at a site center lies in the focal plane.

3.3.33 *focal plane deviation (FPD)* — the distance parallel to the optical axis from a point on the wafer surface to the focal plane.

3.3.34 *four-point probe* — an electrical probe arrangement for determining the resistivity of a material in which separate pairs of contacts are used (1) for passing current through the specimen and (2) measuring the potential drop caused by the current.

3.3.35 *front side* — not preferred; use *front surface* as defined in ASTM Terminology F 1241.

3.3.36 *global flatness* — the TIR or the maximum FPD relative to a specified reference plane within the FQA.

3.3.37 *goniometer* — an instrument to measure angles.

3.3.37.1 Discussion: Goniometers are frequently used with x-ray diffraction equipment to measure crystal axis angles or for optical angle measurement.

3.3.38 *gradient, resistivity* — not preferred; see *resistivity variation*.

3.3.39 *groove, in a semiconductor wafer* — a shallow scratch with rounded edges that is usually the remnant of a scratch not completely removed by polishing.

3.3.40 *haze* — non-localized light-scattering resulting from surface topography (microroughness) or from dense concentrations of surface or near-surface imperfections; see also *laser light-scattering event*.

3.3.40.1 Discussion: Haze due to the existence of a collection of imperfections is a mass effect; individual imperfections of the type which result in haze cannot be readily distinguished by the eye or other optical detection system without magnification. In a particle counter, haze results in a background signal; this signal and laser light-scattering events together comprise the signal due to light-scattering from a wafer surface.

3.3.41 *hole* — a mobile vacancy in the electronic valence structure of a semiconductor which acts like a positive electron charge with positive mass; the majority carrier in *p*-type material.

3.3.42 *ingot, in silicon technology* — a cylinder or rectangular solid of polycrystalline or single crystal silicon, generally of slightly irregular dimensions.

3.3.42.1 Discussion: Silicon wafers are usually sliced from cylindrical single-crystal ingots that have been ground to a uniform diameter prior to slicing.

3.3.43 *laser light-scattering event* — a signal pulse that exceeds a preset threshold, generated by the interaction of a laser beam with a discrete scatterer at a wafer surface as sensed by a detector; see also *haze*.

3.3.43.1 Discussion: The amplitude of the signal, as measured by any combination of incidence orientation and collection orientation, does not convey topographic information (i.e., pit or particle). It does not allow the observer to deduce the size or origin of the scatterer without other detailed knowledge, such as its index of refraction and shape. In a particle counter, the background signal due to haze and laser light-scattering events together comprise the signal due to light-scattering from a wafer surface.

3.3.44 *lay* — the predominant direction of the surface texture.

3.3.44.1 Discussion: Although the texture of polished silicon wafers is generally isotropic, some epitaxial wafers exhibit a pattern of steps and ledges when examined by atomic force microscopy at near atomic resolution. Contoured wafer edges may also exhibit lay even after polishing.

3.3.45 *light point defect (LPD)* — not preferred, see *localized light-scatterer (LLS).*

3.3.45.1 Discussion: To some, the term light point defect implies a defective part; hence, a search was undertaken for a more neutral term. Several were tried, and finally, despite some objection to the difficulty of saying the code, the term localized light scatterer was approved as a replacement. This term is general in nature and can refer to features detected both visual inspection and by automated inspection using a scanning laser system.

3.3.46 *localized light-scatterer (LLS)* — an isolated feature, such as a particle or a pit, on or in a wafer surface, resulting in increased light-scattering intensity relative to that of the surrounding wafer surface; sometimes called light point defect.

3.3.46.1 Discussion: Localized light scatterers of sufficient size appear as points of light under high intensity optical illumination; these points of light can be observed visually, but the observation is a qualitative one. Localized light scatterers are observed by automated inspection techniques as laser-light scattering events. Automated inspection techniques are quantitative in the sense that scatterers with different scattering intensities can be segregated. However, the amplitude of the scattered light intensity (laser light-scattering event), as measured by any combination of incident beam direction and collection optics, does not by itself convey topographical information; particles and pits cannot be distinguished solely on the basis of amplitude data. Also, the observer cannot deduce the size or shape of the LLS from the signal amplitude alone. The presence of LLS's does not necessarily decrease the utility of the wafer.

3.3.47 *lot* — for the purposes of this document, (a) all of the wafers of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of wafers as above which have been identified by the supplier as constituting a lot.

3.3.48 *majority carrier* — type of charge carrier constituting more than one half the total charge-carrier concentration (e.g., holes in *p*-type material).

3.3.49 *maximum FPD* — the largest of the absolute values of the focal plane deviations.

3.3.50 *microroughness* — surface roughness components with spacing between irregularities (spatial wavelength) less than about 100 µm.

3.3.51 *Miller indices, of a crystallographic plane* — the smallest integers proportional to the reciprocals of the intercepts of the plane on the three crystal axes of unit length.

3.3.52 *minority carrier* — type of charge carrier constituting less than one half the total charge-carrier concentration (e.g., electrons in *p*-type material).

3.3.53 *notch, on a semiconductor wafer* — an intentionally fabricated indent of specified shape and dimensions oriented such that the diameter passing through the center of the notch is parallel with a specified low index crystal direction.

3.3.54 *orthogonal misorientation* — in wafers cut intentionally "off orientation," the angle between the projection of the vector normal to the wafer surface onto a {111} plane and the projection on that plane of the nearest <100> direction. (See Figure 2.)

3.3.55 *particle* — a small, discrete piece of foreign material or silicon not connected crystallographically to the wafer.

3.3.55.1 Discussion: Particles may be pieces of solid material or condensate from liquids or gases. Particles are observed by automated inspection as laser light-scattering events, but they may also be observed visually under high intensity illumination as points of light or studied by other methods, including scanning electron microscopy. Particles on wafer surfaces can usually be removed by non-etching cleaning.

3.3.56 *point defect* — a localized crystal defect such as a lattice vacancy, interstitial atom, or substitutional impurity. Contrast with *light point defect*.

3.3.57 *preferential etch* — a selective etch that etches regions of different crystal strain or conductivity at different rates, used to delineate crystal defects or regions of differing conductivity on wafer surfaces.

3.3.58 *primary orientation flat* — the flat of longest length on the wafer, oriented such that the chord is parallel with a specified low index crystal plane; *major flat*.

3.3.59 *profilometer* — an instrument for measuring the topographical profile of a surface.

3.3.60 *rms microroughness* (R_q) — the root mean square of the surface profile height deviations Z(x) from the mean line taken within the evaluation Length L.

3.3.60.1 Discussion: *rms microroughness,* R_q is one of several statistical metrics which can be used to describe a surface profile; definitions for other metrics and for such concepts as mean line, evaluation length, and power spectral density function, may be found in ANSI/ASME B46.1 and ISO 4287/1.

3.3.60.2 The function R_q is related to a one-dimensional measurement of the surface profile as follows:

$$R_q = \left[\frac{1}{L} \int_0^L Z(x)^2 dx \right]^{1/2}$$

3.3.60.3 The digital approximation of R_q for a profile consisting of N equally spaced points is:

$$R_q = \left[\frac{1}{N} \sum_{i=1}^{N} Z_i^2 \right]^{1/2}$$

3.3.60.4 Experimentally, the profile is always limited by the spatial bandwidth of the measurement. For a profile of length L, consisting of N equally spaced points, the lower spatial frequency limit f_1 can never be less than $1/L$ and the upper spatial frequency limit f_2 can never be greater than the Nyquist limit, $N/2L$. In practical cases, $f_1 \approx 2/L$; the achievable value of f_2 depends on instrumental parameters.

3.3.60.5 R_q can also be estimated by integrating the one-dimensional power spectral density (PSD) function, *PSD(f)*, over the spatial frequency range between two spatial frequencies, f_1 and f_2, which lie within the bandwidth of the measurement:

$$R_q = \left[\int_{f_1}^{f_2} PSD(f) \mathrm{d}f \right]^{1/2}$$

3.3.60.6 In all cases, R_q must be reported together with the lower and upper limits, f_1 and f_2, respectively, of the spatial frequency bandwidth over which it has been determined. Alternatively, the spatial bandwidth may be expressed in terms of the upper and lower spatial wavelengths, λ2 (=1/f_2) and λ1 (=1/f_1), respectively.

3.3.61 *rms area microroughness,* (R_{qA}) — the root mean square of the topographic deviations of a surface Z(x,y) from the mean surface taken within the evaluation area A_e (=L_xL_y).

3.3.61.1 Discussion: The rms area microroughness is one of several statistical metrics which can be used to describe surface topography; definitions for other metrics and for such concepts as mean surface and evaluation area may be found in ANSI/ASME B46.1 and ISO 4287/1.

3.3.61.2 The function R_{qA} is related to a two-dimensional measurement of the surface profile as follows:

$$R_{qA} = \left[\frac{1}{A_e} \int_0^{L_x} \int_0^{L_y} Z(x,y)^2 \ \mathrm{d}x\mathrm{d}y \right]^{1/2}$$

3.3.61.3 The digital approximation of R_{qA} for a surface profile consisting of N by M data points equally spaced along the x and y directions, respectively, is:

$$R_{qA} = \left[\frac{1}{NM} \sum_{i=l}^{M} \sum_{j=l}^{N} Z_{ij}^2 \right]^{1/2}$$

3.3.61.4 Experimentally, the profile is always limited by the spatial bandwidth of the measurement. In the x direction, the profile length is Lx divided into N equally spaced points; the lower spatial frequency limit for fx can never be less than $1/L_x$ and the upper spatial frequency limit can never be greater than the Nyquist limit, $N/2L_x$. Similarly, in the y direction, the profile length is L_y divided into M equally spaced points; the lower frequency limit for f_y can never be less than $1/L_y$ and the upper spatial frequency limit can never be greater than the Nyquist limit, $M/2L_y$. Practical limits to the spatial bandwidth are governed by considerations similar to those for the one-dimensional case (see Discussion under *rms microroughness*).

3.3.61.5 R_{qA} can also be estimated by integrating the two-dimensional power spectral density (PSD) function, $PSD(f_x, f_y)$, over the spatial frequency range between spatial frequencies which lie within the bandwidth of the measurement:

$$R_{qA} = \left[\int_{f_{x1}}^{f_{x2}} \int_{f_{y1}}^{f_{y2}} PSD_A(f_x, f_y)\, df_x df_y \right]^{1/2}$$

3.3.61.6 If the surface is assumed to be isotropic and the instrument response function is neglected, the rms microroughness over the spatial frequency range between f_1 and f_2 can also be obtained by integrating the isotropic PSD function:

$$R_{qA} = \left[\int_{f_1}^{f_2} PSD_{iso}(f)\, df \right]^{1/2}$$

where $PSD_{iso}(f) = \int_0^{2\pi} PSD_A(f_x, f_y) f\, d\beta = 2\pi f\, PSD_A(f_x, f_y)$ and $f = (f_x^2 + f_y^2)^{1/2}$.

3.3.62 *radial gradient* — not preferred; see *resistivity variation*.

3.3.63 *reference plane* — a plane defined by one of the following:

1. Three points at specified locations on the front surface of the wafer, or
2. The least squares fit to the front surface of the wafer using all points within the FQA, or
3. The least squares fit to the front surface of the wafer using all points within a site, or
4. An ideal back surface (equivalent to the ideally flat chuck surface that contacts the wafer).

3.3.63.1 Discussion: The specified reference plane should be chosen with due regard for the capabilities of the imaging system. Front surface or back surface reference planes should be selected depending on the wafer mounting system. If the wafer cannot be gimbaled in the imaging system, a back surface reference plane should be specified.

3.3.64 *resistivity, (electrical)* — the measure of difficulty with which charged carriers flow through a material; the reciprocal of *conductivity*.

3.3.64.1 Discussion: the resistivity of a semiconductor or other material is the ratio of the potential gradient (electric field) parallel with the current to the current density. Symbol is σ and units are $(\Omega \bullet cm)^{-1}$.

3.3.65 *roughness* — the more narrowly spaced components of surface texture.

3.3.65.1 Discussion: These components are considered within defined limits of spatial wavelength (or frequency).

3.3.66 *scan direction* — the direction of successive subsites in a scanner site flatness calculation.

3.3.66.1 Discussion: The scanner site flatness value obtained for a site may depend on scan direction.

3.3.67 *scanner site flatness* — the maximum subsite TIR or the maximum subsite FPD, of a site. The subsite TIR is the TIR of the portion of the subsite that falls within the FQA and within the site; the subsite FPD is the maximum FPD of the portion of the subsite that falls within the FQA and within the site. The reference plane is calculated using all points within the subsite that fall within the FQA.

3.3.67.1 Discussion: Precise scanner site flatness measurement requires measurement points located closely enough to reveal the surface topography in detail. It is recommended that the scanner site flatness be measured using a data point array with adjacent points separated by 1 mm or less.

3.3.68 *secondary flat* — a flat of length shorter than the primary orientation flat, whose position with respect to the primary orientation flat identifies the type and orientation of the wafer.

3.3.69 *shape* — for wafer surfaces, the deviation of a specified wafer surface relative to a specified reference plane when the wafer is in an unclamped condition, expressed as the range or total indicator reading (TIR) or as the maximum reference plane deviation (maximum RPD) within the specified fixed quality area.

3.3.69.1 Discussion: This definition is analogous to the definition of flatness, which applies to the front surface geometry when the wafer is in the clamped condition.

3.3.70 *site* — a rectangular area, on the front surface of the wafer, whose sides are parallel and perpendicular to the primary orientation flat or to the notch bisector, and whose center falls within the FQA.

3.3.71 *site array* — a set of contiguous sites.

3.3.72 *site flatness* — the TIR or the maximum FPD of the portion of a site which falls within the FQA.

3.3.72.1 Discussion: Precise site flatness measurement requires measurement points located closely enough to reveal the surface topology in detail. It is recommended that site flatness be measured using a data point array with adjacent points separated by 2 mm or less. It is also recommended that the data set used to calculate site flatness have data at each site corner and along each site boundary. This makes the effective site measurement area equal to the site size.

3.3.73 *smudge* — dense local area of contamination usually caused by handling or fingerprints.

3.3.74 *sori* — the difference between the maximum positive and maximum negative deviations of the front surface of a wafer that is not chucked from a reference plane that is a least-squares fit to the front surface.

3.3.75 *subsite, of a site* — a rectangular area, Lss × Wss, on the front surface of a wafer, associated with a particular site. The center of the subsite must be within the site. Some part of the subsite must be within or on the FQA boundary. A subsite corresponds to the instantaneous area exposed by a scanning stepper (see Figures 8 and 9).

3.3.76 *surface texture* — the topographic deviations of a real surface from a reference surface.

3.3.76.1 Discussion: Surface texture includes roughness, waviness, and lay.

3.3.77 *total indicator reading (TIR)* — the smallest perpendicular distance between two planes, both parallel with the reference plane, which encloses all points on the front surface of a wafer within the FQA, the site, or the subsite, depending on which is specified.

3.3.78 *waves* — uneven contours in the surface of a wafer visible to the unaided eye under large-area diffuse illumination.

3.3.79 *waviness* — the more widely spaced component of surface texture.

3.3.79.1 Discussion: Waviness may be caused by such factors as machine or work piece deflections, vibration, and chatter. Roughness may be considered as superimposed on a wavy surface.

4 Wafer Ordering Information

4.1 Purchase orders for silicon wafers furnished to this specification shall include the following items:

4.1.1 Nominal diameter (see applicable polished silicon wafer standard).

4.1.2 Crystal growth method (see NOTE 4).

4.1.3 Surface orientation (see applicable polished silicon wafer standard).

4.1.4 Conductivity type (see applicable polished silicon wafer standard) and dopant (see NOTE 4).

4.1.5 Resistivity or resistivity range.

4.1.6 Lot acceptance procedures (see Section 8).

4.1.7 Certification (if required) (see Section 11).

4.1.8 Packing and marking (see Section 12).

4.1.9 Selection of test method to be used in evaluating those items for which alternate tests exist (see Section 9).

4.2 *Optional Criteria* — The following items may be specified optionally in addition to those listed above.

4.2.1 Doping method and thermal treatment (see NOTE 4).

4.2.2 Radial resistivity variation.

4.2.3 Crystal perfection.

4.2.4 Impurities other than common intentionally added dopant elements, such as interstitial atomic oxygen and substitutional carbon or in heavily doped n-type silicon, boron contamination.

4.2.5 Surface metal contaminants.

4.2.6 *Flatness* — The following conditions must be specified in connection with flatness measurement:

A. Type of Measurement
   1. Global flatness
   2. Maximum site flatness
   3. Percentage of sites within specification

B. Parameter: TIR or maximum FPD

C. Nominal Edge Exclusion: X

D. For site flatness (where specified):
   1. Site dimensions: x_{site} and y_{site} are relative to the SEMI M20 wafer coordinate system. The first site dimension listed in a site flatness specification shall be the x_{site} and the second dimension shall be the y_{site}.

2. Array offsets: x_{array} and y_{array} relative to FQA center and to the SEMI M20 wafer coordinate system.

NOTE 3: The array offsets are composed of the distance x_{array} and the distance y_{array} between the center of the wafer and the corner of the site that is nearest the wafer center.

E. Reference Plane:

1. Three point (also, specify point locations)
2. Least squares fit to the front surface within the FQA
3. Least squares fit to the front surface within a site
4. Ideal back surface

F. Focal Plane:

1. Global
2. Site

4.2.7 Edge contour

4.2.8 Hall or conductivity mobility (see NOTE 5).

4.2.9 Diffusion length (see NOTE 5).

4.2.10 Minority carrier lifetime (see NOTE 5).

NOTE 4: The dopant, crystal growth method (for example, Czochralski or floating zone), and doping method (for example, ion implantation or neutron transmutation) with subsequent heat treatment are difficult to ascertain in the finished wafers. Verification test procedures or certification of these characteristics (see Section 11) shall be agreed upon between the user and supplier.

NOTE 5: Items 4.2.7, 4.2.8, and 4.2.9 are less commonly specified than the others, but are included for completeness as parameters for which methods of evaluation have been developed.

5 Dimensions and Permissible Variations

5.1 The material shall conform to the dimensions and dimensional tolerances as specified in the polished silicon wafer standard applicable to the specified nominal diameter.

NOTE 6: Wafers of the same nominal diameter may typically have different dimensional configurations in different regions of the world. Many of these configurations are represented in this specification. In selecting the appropriate polished wafer standard, consideration should be given to compatibility with processes and equipment generally available in the region of use.

5.1.1 Sori is an attribute that may be specified between the user and supplier in lieu of bow or warp or both.

5.1.2 If bow is specified, a sign may be included in the specification to denote convex (positive) or concave (negative) curvature of the median surface of the wafer with the front surface up. If no sign is included in the specification, bow may vary between -a and +a, where “a” is the specified maximum magnitude of bow.

5.2 If edge-contoured wafers are specified on the purchase order, the profile shall conform to the following requirements at all points on the wafer periphery (except interior portions of notches, if present).

5.2.1 When the wafer is aligned with the SEMI Wafer Edge Profile Template (see Figure 4) so that the x-axis of the template is coincident with the wafer surface and the y-axis of the template is tangent with the outermost radial portion of the contour, the wafer edge profile must be contained within the clear region of the template. (See Figure 5 for examples of acceptable and unacceptable contours.)

5.2.2 No sharp points or protrusions are permitted anywhere on the wafer edge contour.

5.2.3 Cosmetic attributes of the edge contour are not covered by this specification. They shall be agreed upon between user and supplier.

5.3 Fiducial indications shall conform to the requirements of the appropriate polished silicon wafer standard.

5.3.1 Where secondary flats are specified, they shall be located as shown in Figure 6.

5.3.2 Where notches are specified, they shall conform to the dimensions in Figure 7.

5.4 Where alphanumeric marking is specified, the code character properties and code field location shall conform to SEMI M13 or to SEMI M12. Where back surface bar code marking is specified, the code symbol and its location shall conform to SEMI T1. Where two-dimensional matrix code marking is specified, the code symbol and its location shall conform to SEMI T2.

6 Materials and Manufacture

6.1 The material shall consist of wafers from ingots grown by the process specified in the purchase order or contract.

7 Physical Requirements

7.1 The material shall conform to the crystallographic orientation details as specified in the appropriate polished silicon wafer standard.

7.1.1 For ion implant applications, the following tolerance issues should be considered:

7.1.1.1 For general use where channeling is to be avoided, the current wafer orientation specification of ± 1.0° deviation from the [100] axis (perpendicular to the

(100) plane of the wafer) is adequate. This specification is suitable for minimum channeling applications, provided that the appropriate ion implant equipment angle settings are employed.

7.1.1.2 Uniform, maximum channeling along the [100] axis perpendicular to the (100) wafer surface is strongly dependent on strict adherence to a 0° tilt angle. To achieve maximum channeling, crystallography requires the orientation to be within ± 0.1° of a <100> direction. Also, the user must remove all overlying oxide, nitride, poly, etc., layers from the wafer prior to a channeling implant. The user must maintain very rigid control of the ion implant equipment angle setting in order to achieve maximum channeling across the wafer.

7.1.1.3 The tolerance of ± 0.1° is derived from experimental ion implant profile data and ion implant modeling activity for implants into (100) silicon wafers. The ranges for which data was obtained are:

Species	*Energy Range (keV)*
B	15–80
BF_2	15–65
As	15–180

7.2 The material shall conform to the details specified in the purchase order or contract, as follows:

7.2.1 Conductivity type and dopant (see NOTE 4),

7.2.2 Resistivity,

7.2.3 Doping methods and thermal treatment (see NOTE 4),

7.2.4 Radial resistivity variation,

7.2.5 Crystal perfection,

7.2.6 Amounts of impurities other than common dopants,

7.2.7 Hall or conductivity mobility,

7.2.8 Diffusion length, and

7.2.9 Minority-carrier lifetime.

7.3 The material shall conform to the limits on visually observable surface defects specified in Table 1. If surface metal contamination levels are specified on the purchase order, the maximum area densities shall be designated in units of atoms/cm^2 for specific individual elements (see Related Information 1).

8 Sampling

8.1 Unless otherwise specified, ASTM Practice E 122 shall be used to define the sampling plan. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) or lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

9 Test Methods

NOTE 7: Silicon wafers are extremely fragile. While the mechanical dimensions of a wafer can be measured by use of tools such as micrometer calipers and other conventional techniques, the wafer may be damaged physically in ways that are not immediately evident. Special care must, therefore, be used in the selection and execution of measurement methods.

9.1 *Diameter* — Determine in accordance with ASTM Test Method F 613 or DIN 50441/4.

9.2 *Thickness, Center Point* — Determine in accordance with ASTM Test Method F 533, ASTM Test Method F 1530, or DIN 50441/1.

9.3 *Flat Length* — Determine in accordance with ASTM Test Method F 671.

9.3.1 If flat diameter is specified instead of flat length, determine in accordance with Paragraph 6.2.1 of DIN 50441/4 or by a dial gauge method as agreed upon between the user and supplier.

9.4 *Bow and Warp* — Determine bow in accordance with ASTM Test Method F 534 and warp in accordance with ASTM Test Method F 1390 or Test Method F 657.

NOTE 8: ASTM has standardized two methods for measuring warp. ASTM Test Method F 1390 is an automated, noncontact method which provides for correction of the wafer deflection due to gravitational effects. The scan pattern covers the entire fixed quality area. ASTM Test Method F 657 is a manual, noncontact method which has a continuous, prescribed scan pattern which covers only a portion of the wafer surface. There is no provision for correction of the wafer deflection due to gravitational effects. As noted in Appendix 2, different reference planes are used for the two methods. Because Test Method F 657 employs a back surface reference plane, the measured warp may include contributions from thickness variation of the wafer. Test Method F 1390 employs a median surface reference plane and is not susceptible to interferences from thickness variations. In general, Test Method F 1390 is preferred, especially for wafers 150 mm in diameter and larger.

9.4.1 *Sori* — If sori is specified in lieu of bow or warp or both, determine in accordance with Test Method F 1451.

9.5 *Total Thickness Variation* — Determine in accordance with ASTM Test Method F 533, ASTM

Test Method F 657, ASTM Test Method F 1530, DIN 50441/1, or JIS H 0611.

NOTE 9: ASTM Test Method F 533, DIN 50441/1 and JIS H 0611 are all 5 point methods, while Test Method F 657 involves a continuous scan pattern over a portion of the wafer surface and Test Method F 1530 involves an automated continuous scan pattern over the entire wafer surface. JIS H 0611 differs from ASTM Test Method F 533 and DIN 50441/1, in that the measurements in JIS H 0611 are taken at the center and at 5 mm from the edge on diameters parallel and perpendicular to the primary orientation flat or notch bisector, while the measurements in ASTM Test Method F 533 and DIN 50441/1 are taken at the center and at the same radial distance ($R_{nominal}$ -6 mm) on diameters 30 degrees and 120 degrees counterclockwise from the bisector to the primary orientation flat or notch (with the wafer facing front surface up).

9.6 *Flat Orientation* — Determine in accordance with ASTM Test Method F 847.

9.7 *Surface Orientation* — Determine in accordance with ASTM Test Method F 26 or DIN 50433.

9.8 *Orthogonal Misorientation* — Determine by a method agreed upon between the user and supplier.

9.9 *Surface Defects and Contamination*

9.9.1 *Visually Observable Surface Defects* — Determine in accordance with ASTM Practice F 523. The following conditions shall be used:

a. Background light intensity: 8 ± 2 fc (86 ± 22 lux),

b. Angle (alpha): 45° ± 10°, and

c. Angle (beta): 90° ± 10°.

See Section 10 for surface defect minimal conditions or dimensions and Table 1 for allowable limits. In the event the wafers fail to meet these criteria, they may be conditioned according to a procedure as agreed upon between user and supplier and retested.

9.9.2 *Surface Metal Contamination* — Determine by a method or methods agreed upon between the supplier and the purchaser.

NOTE 10: ASTM Methods F 1526 and F1617 can be used to measure surface contamination levels of selected metals (see Related Information 1). ASTM Practices F 154 are useful guides for defining a variety of surface features found on silicon surfaces and for establishing commonly understood terms for describing them. It also gives detailed procedures for illumination and microscopical examination of surfaces. The presence of contaminating materials on silicon surfaces can be determined by ASTM Methods F 21 or F 22, as appropriate.

9.10 *Conductivity Type* — Determine in accordance with ASTM Test Method F 42 or DIN 50432.

9.11 *Resistivity* — Determine by methods agreed upon between the user and supplier.

NOTE 11: Resistivity of wafers is most appropriately determined for referee purposes by ASTM Method F 84 or DIN 50431. Under some circumstances these tests may be considered destructive, and an alternative means may be required. One nondestructive test is ASTM Test Method F 673, having a range from 0.0001 to 100 ohm cm. Another nondestructive test is ASTM Test Method F 398. This method is limited to carrier concentrations in the ranges from 1.5×10^{18} to 1.5×10^{21} cm^{-3} for *n*-type silicon and from 3×10^{18} to 5×10^{20} cm^{-3} for *p*-type, and has only moderate inter-laboratory precision. Other available methods include ASTM Test Method F 43 or DIN 50430 (referee methods requiring a bar-shaped sample) and ASTM Test Method F 419 (which is destructive, and of limited range).

9.12 *Radial Resistivity Variation* — Determine in accordance with ASTM Method F 81 or DIN 50435.

9.13 *Crystal Perfection* — Determine in accordance with ASTM Test Method F 47, DIN 50434, or JIS H 0609 (to determine grain boundaries, twinning, slip, dislocations, and lineage) and ASTM Test Method F 416 (to determine oxidation-induced defects).

9.14 *Other Impurities* — Determine by methods agreed upon between the user and supplier.

NOTE 12: ASTM Test Methods F 1188 and F 1619 and DIN 50438/1 are specific tests for oxygen in silicon, and ASTM Test Method F 1391 and DIN 50438/2 are specific tests for carbon in silicon; the test specimen cannot be heavily doped, and special thick test specimens may be necessary. ASTM Test Method F 1366 is a specific test for oxygen in heavily doped silicon. Radial variation of oxygen in silicon may be determined in accordance with ASTM Test Method F 951. Boron contamination in heavily doped *n*-type silicon can be determined in accordance with ASTM Test Method F 1528.

9.15 *Flatness* — Determine in accordance with ASTM Test Method F 1530 or by another method as agreed upon between the supplier and the purchaser.

9.15.1 For scanning site flatness, orient the wafer so the effective Scan Direction is along the wafer's Y-axis. For scanning site flatness, subsite width, Wss, shall be 8 mm.

9.16 *Edge Contour* — Determine in accordance with ASTM Test Methods F 928 or DIN 50441/2.

9.17 *Mobility* — If Hall mobility is specified, determine in accordance with ASTM Test Methods F 76; if conductivity mobility is specified, determine by a method agreed upon between the user and supplier.

9.18 *Diffusion Length* — Determine in accordance with ASTM Test Method F 391.

9.19 *Minority Carrier Lifetime* — Determine in accordance with ASTM Method F 28, ASTM Test Method F 1535, or DIN 50440/1.

NOTE 13: These test methods determine minority carrier lifetime only when the measurement is made in low injection conditions. ASTM Test Method F 28 and DIN 50440/1 both require the use of special test specimens; ASTM Test Method F 1535 is applicable to measurements on wafers but special surface passivation procedures may be required to obtain meaningful results. Minority carrier lifetime may also be inferred from measurements made in accordance with ASTM Test Method F 1388. This method yields generation lifetime if the measurements are made at or near room temperature and recombination lifetime if they are made at slightly elevated temperature (50 to 75°C). The test specimens required for Test Method F 1388 can be made by procedures which are compatible with typical wafer processing.

10 Standard Defect Limits

10.1 Minimal conditions or dimensions for surface defects are stated below. These limits shall be used for determining wafer acceptability; anomalies smaller than these limits shall not be considered defects.

10.1.1 *area contamination* — Any foreign matter on the surface in localized areas which is revealed under the inspection lighting conditions as discolored, mottled, or cloudy appearance resulting from smudges, stains, water spots, etc.

10.1.2 *crack* — Any anomaly conforming to the definition and greater than 0.010 inch (0.25 mm) in total length.

10.1.3 *crater* — Any individually distinguishable surface anomaly conforming to the definition and visible when viewed under diffused illumination.

10.1.4 *crow's foot* — Any anomaly conforming to the definition and greater than 0.010 inch (0.25 mm) in total length.

10.1.5 *dimple* — Any smooth surface depression greater than 3 mm in diameter.

10.1.6 *edge chip and indent* — Any edge anomaly including saw exit marks conforming to the definition and greater than 0.010 inch (0.25 mm) in radial depth and peripheral length.

10.1.7 *groove* — Any anomaly conforming to the definition and greater than 0.0005 inch (0.13 mm) wide or 0.030 inch (0.76 mm) in length.

10.1.8 *haze* — Haze is indicated when the image of a narrow beam tungsten lamp filament is detectable on the polished wafer surface. (Under some conditions, contamination may appear as haze.)

10.1.9 *mound* — Any anomaly conforming to the definition and greater than 0.010 inch (0.25 mm) in maximum dimension.

10.1.10 *orange peel* — Any visually detectable roughened surface conforming to the definition and observable under diffused illumination.

10.1.11 *particulate contamination* — Distinct particles resting on the surface which are revealed under collimated light as bright points.

10.1.12 *pit* — Any individually distinguishable nonremovable surface anomaly conforming to the definition and visible when viewed under intense illumination.

10.1.13 *scratch* — Any anomaly conforming to the definition and having a length-to-width ratio greater than 5:1.

10.1.14 *striation* — Any feature conforming to the definition and detectable under diffused lighting conditions.

11 Certification

11.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

11.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 9. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

12 Packing and Marking

12.1 Special packing requirements shall be subject to agreement between the user and supplier. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination and in accordance with the best industry practices to provide ample protection against damage during shipment.

12.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include as a minimum the nominal diameter, conductivity type, dopant, orientation, resistivity range, and lot number. The lot number, either (1) assigned by the original manufacturer of the wafers, or (2) assigned subsequent to wafer manufacture but providing reference to the original lot number, shall provide easy access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer's facility for at least one month after that particular lot has been accepted by the user.

Table 1 Polished Wafer Defect Limits

Item	*Characteristics*	*Maximum Defect Limit*	*AQL (See NOTE 5.)*	*Illumination Conditions (See NOTE 7.)*	*NOTES*
FRONT SURFACE					
1	SCRATCHES Maximum Number	None		High Intensity	1
2	PITS	None	1.0% Cum.	High Intensity	1
3	HAZE	None	1.0%	High Intensity	1
4	CONTAMINATION, PARTICULATE Maximum Number 2 inch Diameter Wafer 3 inch Diameter Wafer 100 mm Diameter Wafer 125 mm Diameter Wafer 150 mm Diameter Wafer	 4 6 10 10 15	1.0%	High Intensity	1
5	CONTAMINATION, AREA	None	1.0%	High Intensity or Diffuse	1
6	EDGE CHIPS AND INDENTS	None	See NOTE 4.	Diffuse	2, 4
7	CRACKS, CROW'S FEET	None		Diffuse	4
8	CRATERS	None		Diffuse	1
9	DIMPLES	None		Diffuse	1
10	GROOVES	None	1.0% Cum.	Diffuse	1
11	MOUNDS	None		Diffuse	1
12	ORANGE PEEL	None		Diffuse	1
13	SAW MARKS	None	1.0% Cum.	Diffuse	1
14	RESISTIVITY STRIATIONS	See NOTE 3.		Diffuse	3
BACK SURFACE					
15	EDGE CHIPS	None	See NOTE 4.	Diffuse	2, 4
16	CRACKS, CROW'S FEET	None		Diffuse	4
17	CONTAMINATION, AREA	None	1.0% Cum.	Diffuse	
18	SAW MARKS	None	1.0% Cum.	Diffuse	6
19	ALL LISTED CHARACTERISTICS (Items 1 through 18)		Total 2.5%		

NOTE 1: The outer 0.062 inch (1.57 mm) annulus is excluded from these criteria.

NOTE 2: Accept/reject criterion shall be agreed upon between user and supplier for wafers which are not mechanically edge-rounded.

NOTE 3: Striations may be visible on low resistivity wafers (less than 0.020 ½ ¥ cm).

NOTE 4: The cumulative AQL for both front surface and back surface of wafer is 1.0%.

NOTE 5: Single, Normal, Level II Sampling Plan as defined in ANSI/ASQC Z1.4.

NOTE 6: Accept/reject criterion shall be agreed upon between user and supplier for non-lapped wafers.

NOTE 7: See ASTM Practice F 523 for definition of Illumination Conditions.

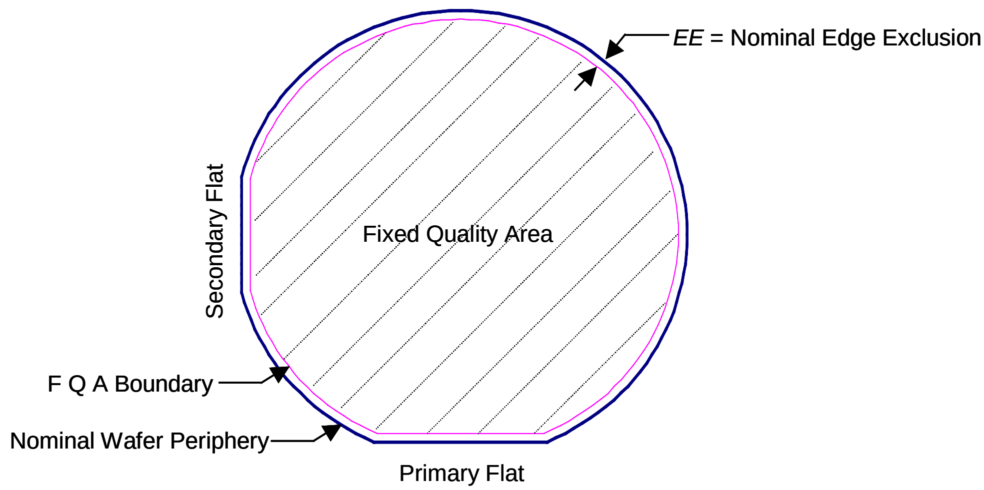


Figure 1a
Flatted Wafer

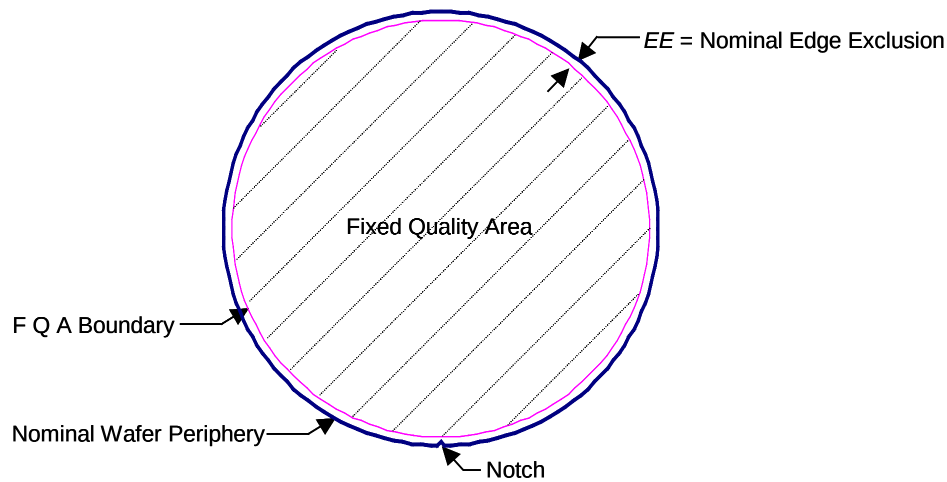


Figure 1b
Notched Wafer

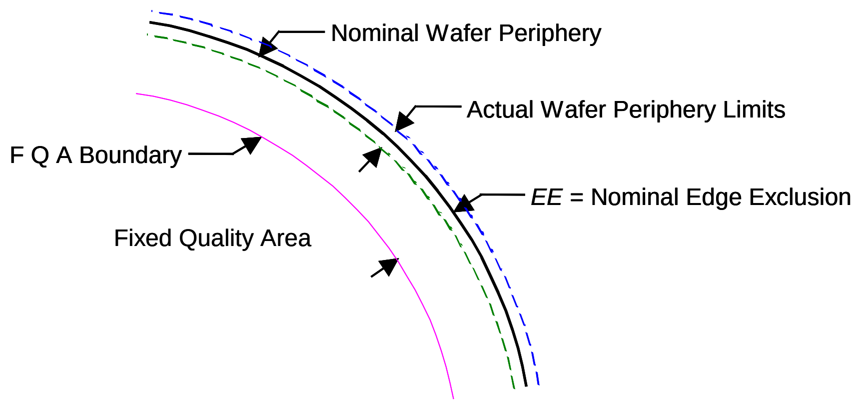


Figure 1c
Nominal and Actual Wafer Peripheries

Figure 1
Fixed Quality Area

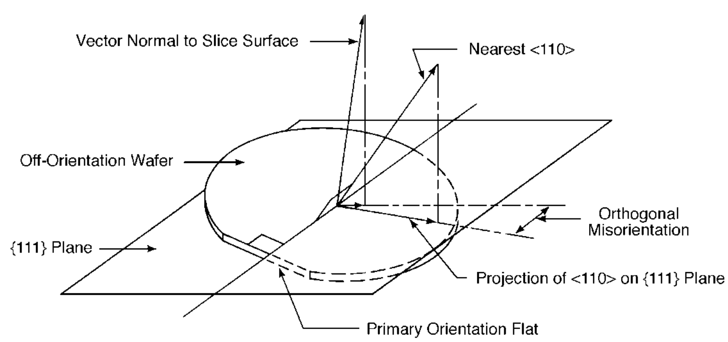


Figure 2
Orthogonal Misorientation

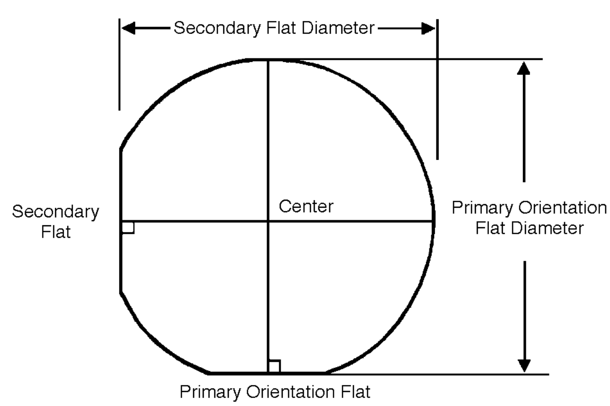
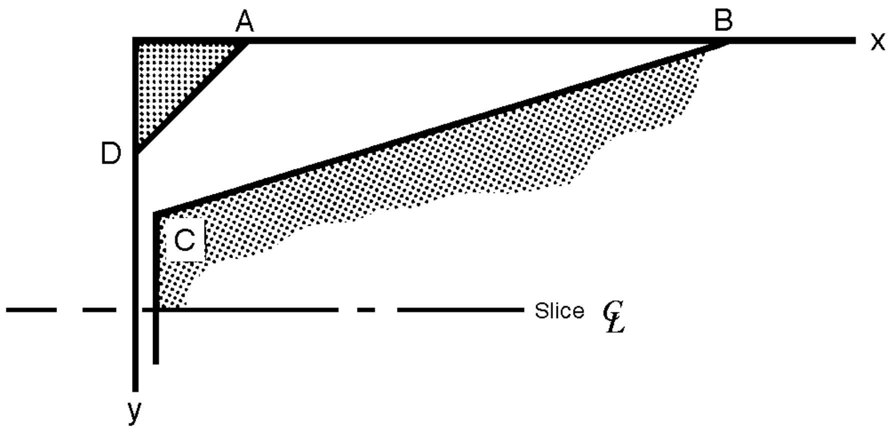


Figure 3
Primary Orientation Flat Diameter



NOTE: Figure 4 is not to scale.

Figure 4
SEMI Wafer Edge Profile Template

Table 2 Coordinates for "T/3" Wafer Edge Profile Template

Point	*x*		*y*	
	in.	*µm*	*in.*	*µm*
A	0.0030	76	0.00	0
B	0.0200	508	0.00	0
C	0.0020	50	1/3 Nominal Wafer Thickness (See NOTE 2.)	
D	0.00	0	0.0030	76

Table 3 Coordinates for "T/4" Wafer Edge Profile Template

Point	*x*		*y*	
	in.	*µm*	*in.*	*µm*
A	0.0047	120	0.00	0
B	0.0200	508	0.00	0
C	0.0040	100	1/4 Nominal Wafer Thickness (See NOTE 2.)	
D	0.00	0	0.0020	50

NOTE 1: For referee purposes, U.S. Customary units are to be used for 2 and 3 in. diameter wafers. SI units are to be used for all other diameters.

NOTE 2: See the appropriate polished silicon wafer standard for numerical values.

NOTE 3: Only one-half of the template is shown; the wafer surface is aligned with the *x*-axis, and the outermost radial portion of the edge contour is aligned with the *y*-axis. The template in Figure 4 is not intended for use in measuring wafer thickness.

NOTE 4: Constant radius profile with blended, tangential front and back surface intercepts is preferred for ease of manufacture and reduced particle and chip generation.

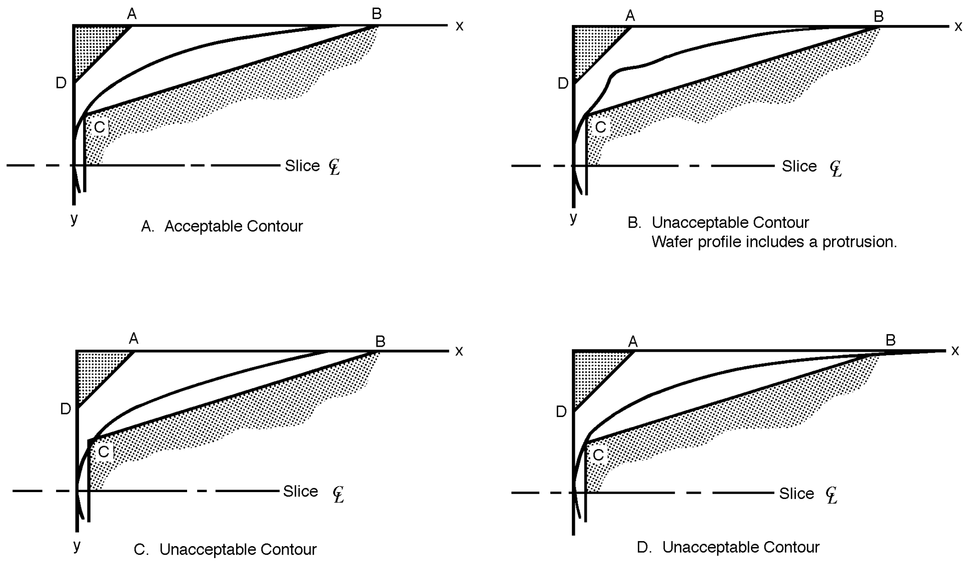


Figure 5
Examples of Acceptable and Unacceptable Wafer Edge Profiles

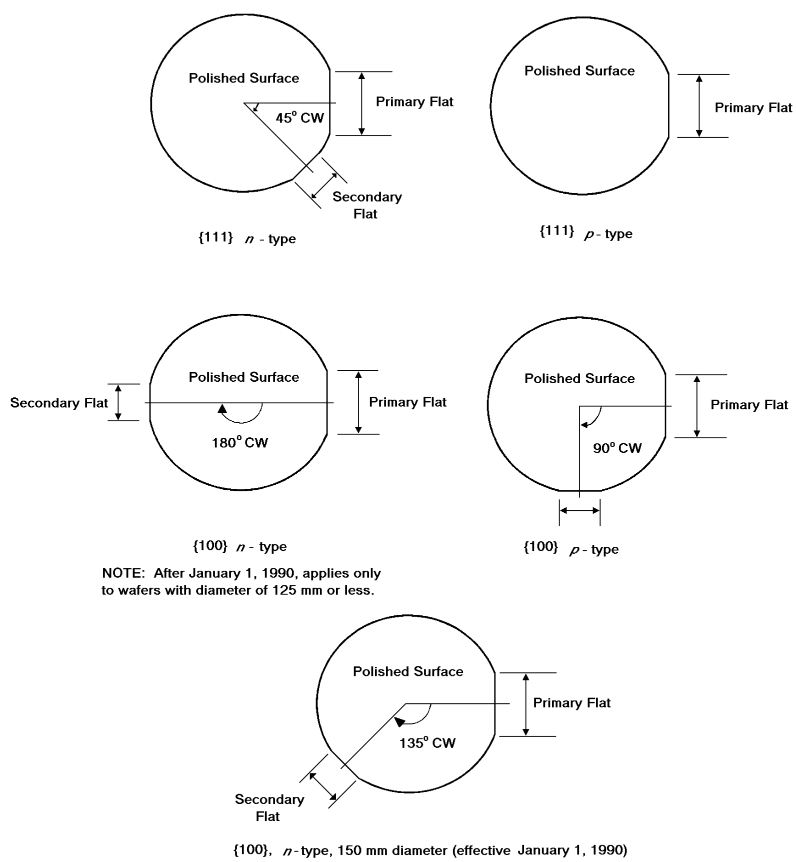


Figure 6
Secondary Flat Location

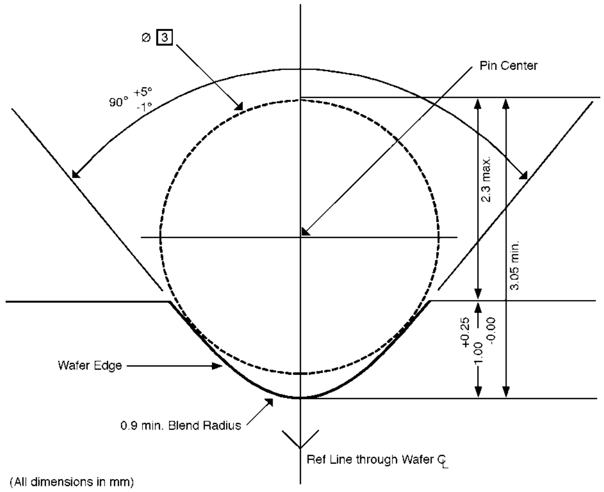


Figure 7
Notch Dimensions

12.3 For referee purposes, metric (SI) units apply. To ensure that the product shipped is within specification, any conversion to U.S. Customary Equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down, and the rightmost digit of the maximum values should be rounded up to avoid rejection of the material that is within the specification when measured by the referee system of units.

NOTE 14: The significance of the rightmost digit may vary depending on the quantity being measured and on the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

NOTE 15: The pin shown in the outline on this figure is used to align the notched wafer in a fixture during use. The pin is also used to reference the notched wafer during testing for notch dimensions and dimensional tolerances. The notch dimensions shown in the figure assume a 3 mm diameter for this alignment pin.

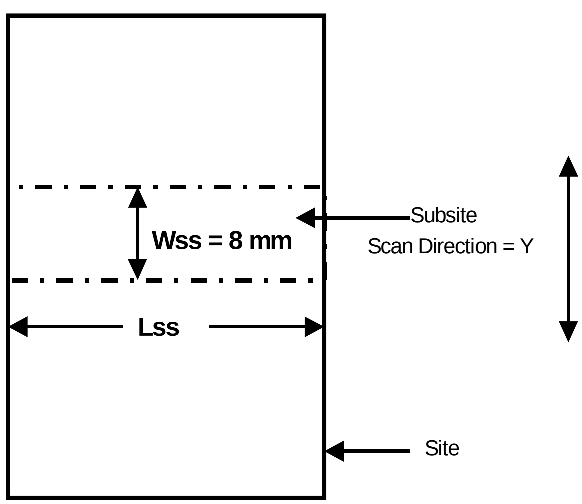


Figure 8
Scanner Site Flatness Elements

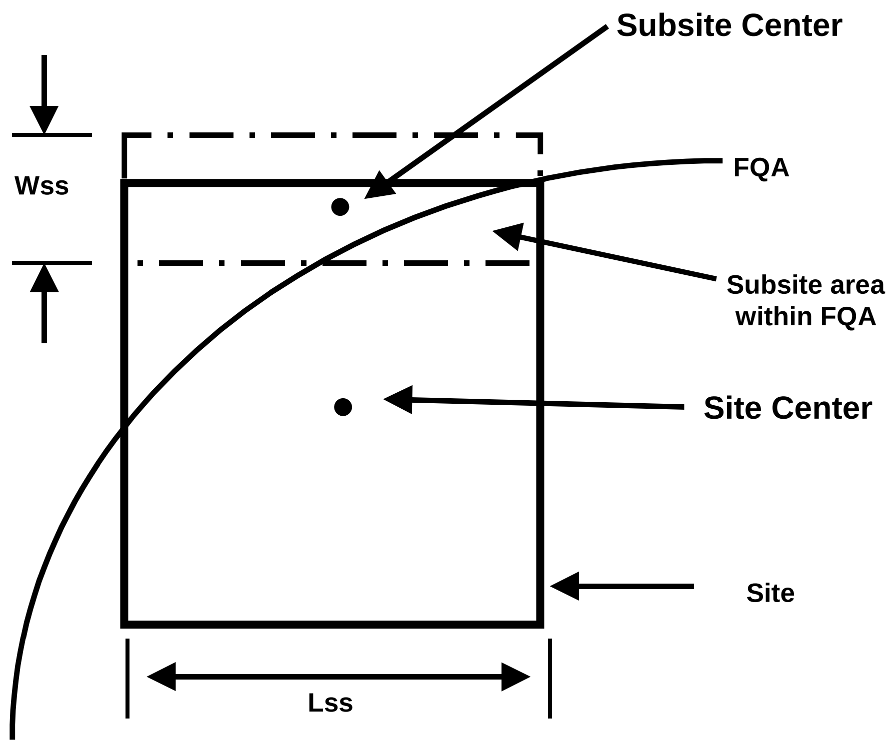


Figure 9
Scanner Site Flatness: Subsite Center Near Boundaries of Site and FQA

APPENDIX 1
FLATNESS DECISION TREE

NOTE: The material in this appendix is an official part of M1 and was approved by full letter ballot procedures on October 21, 1999 by the North American Regional Standards Committee.

A1-1 Scope

A1-1.1 The increasing complexity of integrated circuits and the reduction in design rule dimensions place new demands on the characterization of wafer surface geometry. Various high resolution optical lithographic systems have very limited depth of field and use a variety of methods to hold the wafer, to establish the focal plane, and to position the wafer relative to the focal plane during exposure. These varying focusing and location methods differ enough to make a single, simple flatness criterion (such as global TIR) ineffective in predicting successful or unsuccessful lithography in all cases.

A1-1.2 To clarify the requirements for wafer flatness characterization for the various classes of lithographic equipment, the decision tree depicted in Figure A1-1 has been developed. This tree gives an orderly procedure for selecting the various parameters outlined in Section 4.2.5.

A1-1.3 In this tree, it is assumed that the focal point is the site center for all parameters, except for SFQD, SFQR, SFSD, and SFSR, where the focal plane is identical to the reference plane. Most flatness characterization systems employ this convention. However, a number of photolithographic aligners use slightly different conventions for determining the focal plane. Currently, the difference between the centerpoint and other focusing conventions has not been quantified, but it is presumed to be insignificant for material characterization purposes.

A1-2 Use of the Flatness Decision Tree

A1-2.1 In the decision tree, there are decision blocks, shown as diamonds, whose use requires some knowledge of the lithographic tool to be used. The rectangular blocks require information to be furnished; this information is dependent on the device layout and the manufacturing procedures to be employed (such as dedicated or mixed aligner use).

A1-2.2 Step 1. Select the Fixed Quality Area (FQA): Decide on and specify the nominal edge exclusion, X, which defines the FQA. (See Figure 1.)

A1-2.3 Step 2. Choose the Measurement Method: Choose global flatness (G) if the lithographic tool uses a single, global exposure of the wafer, or choose site flatness (S) if the lithographic tool steps across the wafer, exposing only a portion of the wafer at a time.

A1-2.3.1 If global flatness is chosen, proceed to Step 3. If site flatness is chosen, it is also necessary to specify site size (related to exposure area dimensions) and site array (including (a) number of sites, (b) location of sites relative to the center of the FQA and to each other, as in an offset or bricklaying pattern, and (c) whether or not partial sites are to be excluded).

A1-2.4 Step 3. Choose the Reference Surface: Choose front surface (F) or back surface (B), depending on whether the lithographic tool is referenced to the front or back surface.

A1-2.5 Step 4. Choose the Reference Plane and Area:

A1-2.5.1 For global flatness measurements, a global reference plane is appropriate. If the lithographic tool is referenced to the back surface, an ideal plane (I) defined by the chuck which holds the wafer is appropriate. If the lithographic tool is referenced to the front surface, either a 3-point plane (3) defined by three points equally spaced about the edge of the front surface of the wafer or a plane defined by the least squares fit to the front surface (L) may be appropriate. The 3-point plane is appropriate if the lithographic tool holds the wafer in this fashion and does not allow interactive gimbaling of the wafer, while the least squares plane is appropriate if the lithographic tool allows interactive gimbaling of the wafer.

A1-2.5.2 For site flatness measurements, any of the above three planes [(1), (3), or (L)] may be suitable or, if the wafer is regimballed once at each site, a site least squares reference plane (Q) may be appropriate or, if the wafer is regimballed more than once at each site, a subsite least squares reference plane (S) may be appropriate.

A1-2.6 Step 5. Choose the Measurement Parameter: Choose either TIR, also known as range (R), or FPD, also known as deviation (D). In the case of site measurements, it is possible to specify the maximum value of (R) or (D) or the percentage of the sites (or FQA) which have an (R) or (D) less than some specified value.

A1-2.7 The codes in parentheses in Steps 2 through 5 may be used to form a code which uniquely defines the measurement technique as follows:

Position 1: Measurement Method (G) or (S), Position 2: Reference Surface (F) or (B),

Position 3: Reference Plane and Area (1), (3), (L), (Q), or (S), and

Position 4: Measurement Parameter (R) or (D).

A1-2.7.1 Stating this code, the numerical values for the FQA parameters (and, if required, information on site size and array), and the numerical limit for the measurement parameter provides enough information to describe the measurement and provide numerical limits.

A1-3 Future Developments

A1-3.1 As noted above, there may be specific systems which are not exactly described by one of the branch ends on this decision tree. This tree is an approximation of the more complete one which would describe all existing and possible lithographic technologies.

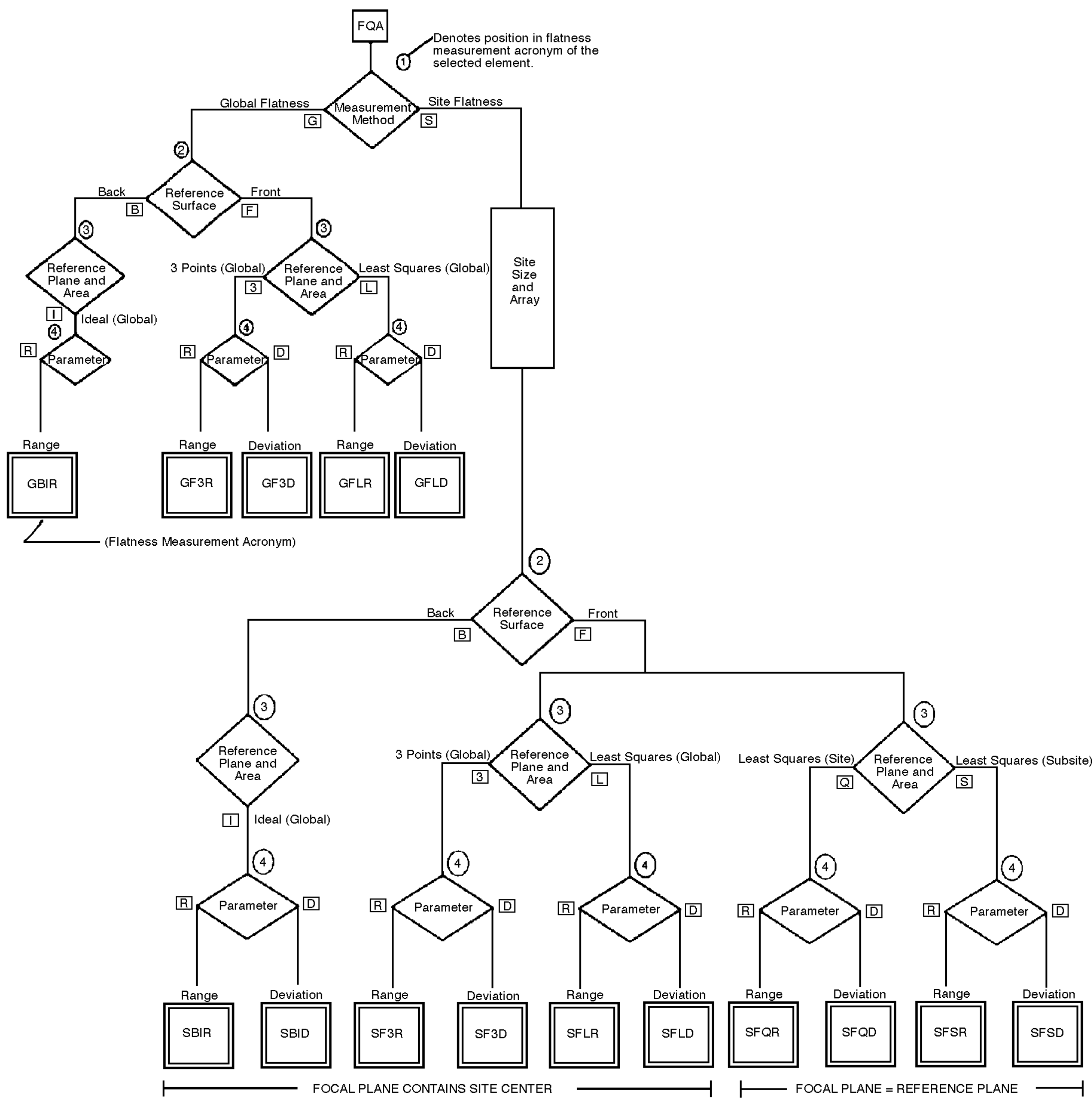


Figure A1-1
Flatness Decision Tree

APPENDIX 2
SHAPE DECISION TREE

NOTE: The material in this appendix is an official part of M1 and was approved by full letter ballot procedures on October 21, 1999 by the North American Regional Standards Committee.

A2-1 Scope

A2-1.1 In modern wafer fabrication processes, wafer surface geometry in the unclamped state can be a sensitive indicator of process effects. Larger wafer diameters and increasing complexity of processes and circuits have increased the need for accurate, standardized measurement of unclamped wafer geometry. The quantities that have historically been used, Bow and Back Surface Referenced Warp, may be inadequate to describe and quantify the geometries of interest in advanced processes. Additional surface geometry quantities, such as Sori and Median Surface Referenced Warp, have been introduced into standards.

A2-1.2 In addition, there is considerable confusion as to the precise meaning of these quantities, even though they are defined in the applicable ASTM test methods.

A2-1.3 The Shape Decision Tree was developed to provide an orderly method of identifying each of the variables involved in the quantities used to quantify unclamped wafer surface geometry. As such, the tree provides a concise and precise description of each shape quantity. A branch of the tree consists of a selection of one of the choices for each variable. The variables and the choices for each are listed in Table A2-1.

A2-1.4 Four branches of the tree, representing quantities for which standard measurement methods have been developed by ASTM, are depicted in Figure A2-1. There are many other branches of the tree, not all of which may represent practical combinations of variables.

A2-2 Use of the Shape Decision Tree

A2-2.1 Step 1. Select the value of the Nominal Edge Exclusion to define the Fixed Quality Area.

NOTE A2-1: This value must be provided whenever a shape quantity is specified.

A2-2.2 Step 2. Select the measurement method: global (over the entire fixed quality area) or local (over a site).

NOTE A2-2: At present, all shape quantities in common use are global measurements. The significance and use of local shape quantities have yet to be defined.

A2-2.3 Step 3. Select the reference surface: front, median, or back, to be used to establish the reference plane.

A2-2.4 Step 4. Select the type of reference plane: least-squares or 3-point.

NOTE A2-3: A measurement made with a least-squares reference plane is less affected by small changes in wafer position within the measurement apparatus than is a measurement made with a 3-point reference plane.

A2-2.5 Step 5. Determine whether the effects of gravitational sag on the wafer are accounted for (yes) or not (no).

NOTE A2-4: Gravitational effects may be accounted for by inverting the wafer during the measurement, by placing the wafer in a vertical or nearly vertical position during the measurement, or mathematically.

A2-2.6 Step 6. Select the measurement surface: front, median, or back, for which the deviations are to be measured.

A2-2.7 Step 7. Select the measurement pattern: full scan (a regular array of measurement points over the entire measurement area), partial scan (a specified pattern of measurement points covering only a portion of the measurement area), or centerpoint (measurement at the center of the wafer only).

A2-2.8 Step 8. Select the parameter to be determined: range (TIR) or maximum RPD.

A2-2.9 Step 9. Compare the branch thus obtained with the branches in Figure A2-1. If the branch obtained matches one of the branches illustrated in Figure A2-1, the resulting quantity is given by the code shown in the box at the bottom of the branch. The ASTM test method used for its measurement is also shown in the box. If the branch obtained does not match any of the branches illustrated in Figure A2-1, the quantity obtained has not been given a standardized term, nor has a standard test method been adopted for its measurement.

A2-2.9.1 These codes, which uniquely describe the various branches, are formed from the codes in Table A2-1. Stating this code together with the numerical value for the FQA exclusion distance provides enough information to describe the shape parameter and to establish numerical limits for it.

A2-2.9.2 Table A2-2 summarizes the shape parameters for which ASTM has developed test methods. This table lists the code, the term in common use for the parameter, the ASTM test method, and the expanded form of the code.

A2-2.9.3 If the branch obtained does not match any of the branches illustrated in Figure A2-1, the quantity obtained has not been formally defined nor has a standard test method been adopted for its measurement.

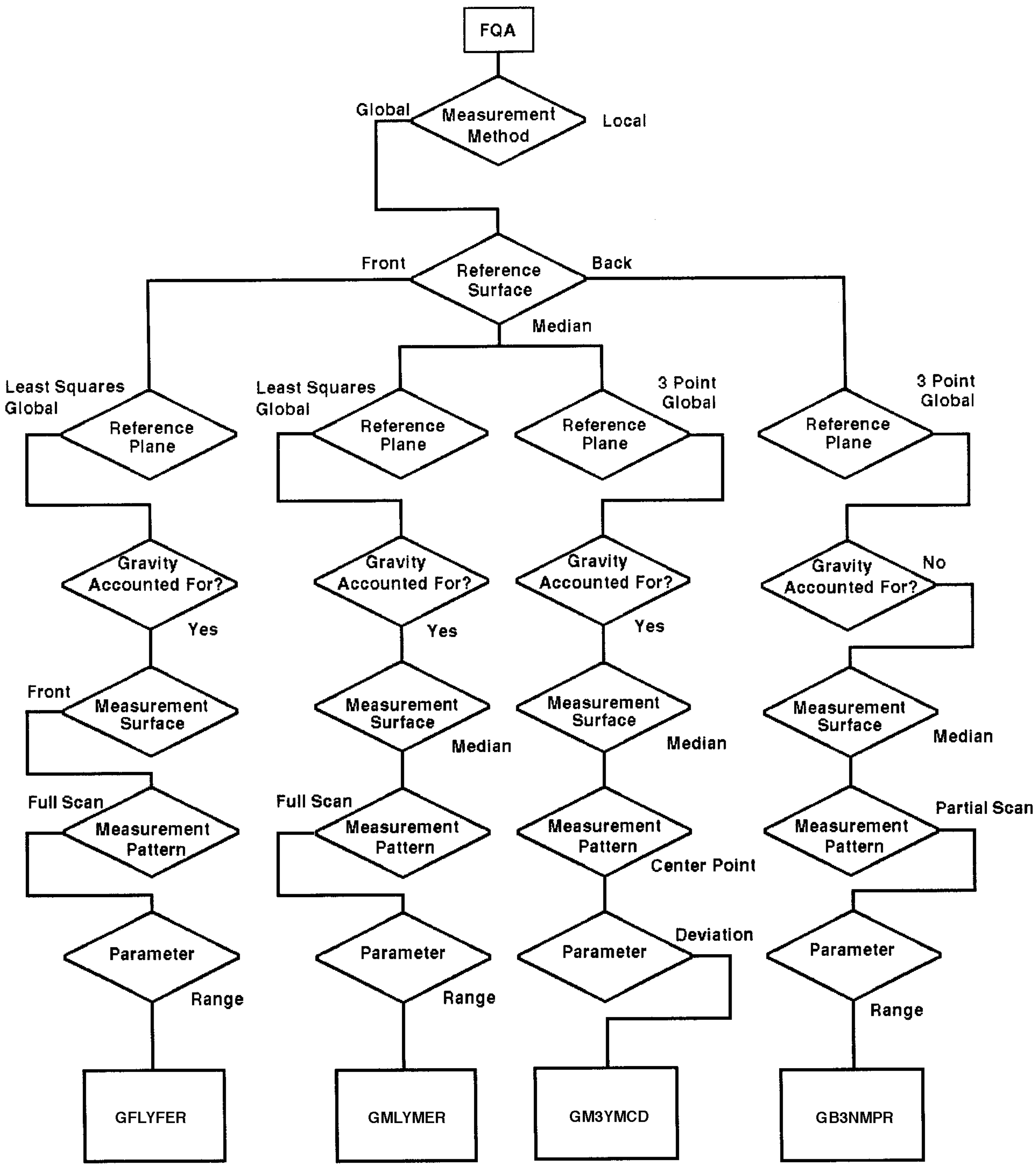


Figure A2-1
Four Branches of the Shape Decision Tree

Table A2-1 Variables in Shape Quantities

Variable	*Options*	*Code*
Measurement Method	Global	G
	Local (Site)	S
Reference Surface	Front	F
	Median	M
	Back	B
Reference Plane	Least-Square	L
	3-Point	3
Corrected for Gravitational Sag	Yes	Y
	No	N
Measurement Surface	Front	F
	Median	M
	Back	B
Measurement Pattern	Full Scan (Entire)	E
	Partial Scan	P
	Centerpoint	C
Parameter	Range (TIR)	R
	Maximum RPD	D

Table A2-2 Shape Code Summary

Code	*Term*	*ASTM Test Method*	*Expanded Form of Code*
GFLYFER	sori	F 1451	Global, Front-surface Least-squares reference plane, Yes (corrected for gravitational sag), Front-surface measurement, Entire surface scanned, Range
GMLYMER	warp	F 1390	Global, Median-surface Least-squares reference plane, Yes (corrected for gravitational sag), Median-surface measurement, Entire surface scanned, Range
GM3YMCD	bow	F 534	Global, Median-surface 3-point plane, Yes (corrected for gravitational sag), Median-surface measurement at Center point, Deviation
GB3NMPR	warp	F 657	Global, Back-surface 3-point reference plane, No (not corrected for gravitational sag), Median-surface measurement, Partial surface scanned, Range

RELATED INFORMATION 1
SURFACE METAL CONTAMINATION

NOTE: This related information is not an official part of SEMI M1 and is not intended to modify or supercede the official standard. Publication was authorized by full letter ballot procedure. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Scope

R1-1.1 Maximum allowable surface metal contamination levels generally depend upon the IC device density and upon the IC process design. In general, as the device density increases, the allowable surface metal contamination levels become lower.

R1-1.2 This related information is intended to provide guidance regarding allowable surface concentrations of metal contaminants which have been reported to be deleterious to circuit and device performance.

R1-2 Suggested Allowable Surface Metal Contamination Levels for 1 µm Geometries

R1-2.1 Table R1-1 lists suggested surface metal limits for circuits and devices with a minimum linewidth in the range of 0.8 µm to 1.2 µm for two alkali metals (Na, K), a light metal (Al), and five heavy metals (Cr, Fe, Ni, Cu, Zn).

R1-3 Test Methods

R1-3.1 Some commonly used test methods for each surface metal contaminant are also listed in Table R1-1. TXRF measurements should be made in accordance with ASTM Test Method F 1526 and SIMS measurements should be made in accordance with ASTM Test Method F 1617. Measurements involving vapor phase decomposition (VPD) have not yet been standardized. The following sections list some issues concerning application of the VPD methods.

R1-3.2 VPD is chemical preconcentration of the surface metals using vapor phase HF to decompose the surface native oxide and a water (or acid-spiked water) droplet to scan across the wafer dissolving the surface metals. The recovery rate of this preconcentration method is dependent upon the chemistry of the surface metals and upon the chemistry used for the preconcentration. An alternative preconcentration method to VPD is to scan an acid droplet across the wafer surface.

R1-3.3 VPD/AAS (vapor phase decomposition followed by graphite furnace atomic absorption spectroscopy) is a single element technique which is widely used in Japan: it is element-specific and very sensitive. VPD/ICP-MS (vapor phase decomposition followed by inductively coupled plasma mass spectrometry) is a rapid multi-element technique which is a more recent development: it is also very sensitive, but its reproducibility is dependent upon the injection process into the ICP-MS. VPD/TXRF (vapor phase decomposition followed by total reflection x-ray fluorescence) is a more recently developed multi-element technique. It is also very sensitive, but its reproducibility is dependent on the residue-drying process.

Table R1-1 Suggested Polished Wafer Surface Metal Contamination Limits Appropriate to Circuits and Devices with a Minimum Linewidth in the Range 0.8 µm to 1.2 µm

Element	*Contaminant Level*	*Test Method*
Na	10^{11} atoms/cm^2	SIMS, VPD/(AAS or ICP-MS)
Al	10^{11} atoms/cm^2	SIMS, VPD/(AAS or ICP-MS)
K	10^{11} atoms/cm^2	SIMS, VPD/(AAS, ICP-MS, or TXRF)
Cr	10^{11} atoms/cm^2	TXRF, VPD/(AAS, ICP-MS or TXRF)
Fe	10^{11} atoms/cm^2	TXRF, VPD/(AAS, ICP-MS or TXRF)
Ni	10^{11} atoms/cm^2	TXRF, VPD/(AAS, ICP-MS or TXRF)
Cu	10^{11} atoms/cm^2	TXRF, VPD/(AAS, ICP-MS or TXRF)
Zn	10^{12} atoms/cm^2	TXRF, VPD/(AAS, ICP-MS or TXRF)

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SEMI M1.1-89 (Reapproved 0299)
STANDARD FOR 2 inch POLISHED MONOCRYSTALLINE SILICON WAFERS

This standard was technically reapproved by the Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1980; previous published revision in 1989.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	2.000	± 0.015	in.
	50.80	± 0.38	mm
THICKNESS, CENTER POINT	0.0110	± 0.0010	in.
	279	± 25	µm
PRIMARY FLAT LENGTH	0.625	± 0.065	in.
	15.88	± 1.65	mm
SECONDARY FLAT LENGTH	0.315	± 0.065	in.
	8.00	± 1.65	mm
BOW, MAX	0.0015		in.
	38		µm
TOTAL THICKNESS VARIATION, MAX	0.0005		in.
	12		µm
EDGE PROFILE COORDINATE: C_y	0.0037		in.
(see Figure 4)	93		µm

[A] For referee purposes, the U.S. Customary units apply. Conversion to metric (SI) equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the metric equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{ 110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{ 111}*p*-type	No secondary flat
{ 100}*p*-type	(90° ± 5°) clockwise from primary flat
{ 111}*n*-type	(45° ± 5°) clockwise from primary flat
{ 100}*n*-type	(180° ± 5°) from primary flat
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent { 110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M1.2-89 (Reapproved 0299)
STANDARD FOR 3 inch POLISHED MONOCRYSTALLINE SILICON WAFERS

This standard was technically reapproved by the Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1978; previous published revision in 1989.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	3.000	± 0.025	in.
	76.20	± 0.63	mm
THICKNESS, CENTER POINT	0.0150	± 0.0010	in.
	381	± 25	µm
PRIMARY FLAT LENGTH	0.875	± 0.125	in.
	22.22	± 3.17	mm
SECONDARY FLAT LENGTH	0.440	± 0.060	in.
	11.18	± 1.52	mm
BOW, MAX	0.0016		in.
	40		µm
WARP, MAX	0.0016		in.
	40		µm
TOTAL THICKNESS VARIATION, MAX	0.0010		in.
	25		µm
EDGE PROFILE COORDINATE: C_y	0.0050		in.
(see Figure 4)	127		µm

[A] For referee purposes, the U.S. Customary units apply. Conversion to metric (SI) equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the metric equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{111}*p*-type	No secondary flat
{100}*p*-type	(90° ± 5°) clockwise from primary flat
{111}*n*-type	(45° ± 5°) clockwise from primary flat
{100}*n*-type	(180° ± 5°) from primary flat
SURFACE ORIENTATION[B]	
On-orientation for {111} and {100} wafers:	± 1°
Off-orientation {111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M1.5-89 (Reapproved 0699)
STANDARD FOR 100 mm POLISHED MONOCRYSTALLINE SILICON WAFERS (525 μm THICKNESS)

This standard was technically re-approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org February 1999; to be published June 1999. Originally published 1978; previously published 1989.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	100.00	± 0.50	mm
THICKNESS, CENTER POINT	525	± 20	μm
PRIMARY FLAT LENGTH	32.5	± 2.5	mm
SECONDARY FLAT LENGTH	18.0	± 2.0	mm
BOW, MAX	40		μm
WARP, MAX	40		μm
TOTAL THICKNESS VARIATION, MAX	10		μm
EDGE PROFILE COORDINATE: C_y (see Figure 4)	175		μm

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{111} *p*-type	No secondary flat
{100} *p*-type	(90° ± 5°) clockwise from primary flat
{111} *n*-type	(45° ± 5°) clockwise from primary flat
{100} *n*-type	(180° ± 5°) from primary flat
SURFACE ORIENTATION[B]	
On-orientation for {111} and {100} wafers:	± 1°
Off-orientation {111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

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SEMI M1.6-89 (Reapproved 0699)
STANDARD FOR 100 mm POLISHED MONOCRYSTALLINE SILICON WAFERS (625 μm THICKNESS)

This standard was technically re-approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org February 1999; to be published June 1999. Originally published 1978; previously published 1989.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	100.00	± 0.50	mm
THICKNESS, CENTER POINT	625	± 20	μm
PRIMARY FLAT LENGTH	32.5	± 2.5	mm
SECONDARY FLAT LENGTH	18.0	± 2.0	mm
BOW, MAX	40		μm
WARP, MAX	40		μm
TOTAL THICKNESS VARIATION, MAX	10		μm
EDGE PROFILE COORDINATE: C_y (see Figure 4)	208		μm

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{ 110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{ 111}*p*-type	No secondary flat
{ 100}*p*-type	(90° ± 5°) clockwise from primary flat
{ 111}*n*-type	(45° ± 5°) clockwise from primary flat
{ 100}*n*-type	(180° ± 5°) from primary flat
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent { 110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

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SEMI M1.7-89 (Reapproved 0699)
STANDARD FOR 125 mm POLISHED MONOCRYSTALLINE SILICON WAFERS

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org February 1999; to be published June 1999. Originally published 1978; previously published 1989.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	125.00	± 0.50	mm
THICKNESS, CENTER POINT	625	± 20	μm
PRIMARY FLAT LENGTH	42.5	± 2.5	mm
SECONDARY FLAT LENGTH	27.5	± 2.5	mm
BOW, MAX	40		μm
WARP, MAX	40		μm
TOTAL THICKNESS VARIATION, MAX	10		μm
EDGE PROFILE COORDINATE: C_y (see Figure 4)	208		μm

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{ 110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{ 111}*p*-type	No secondary flat
{ 100}*p*-type	(90° ± 5°) clockwise from primary flat
{ 111}*n*-type	(45° ± 5°) clockwise from primary flat
{ 100}*n*-type	(180° ± 5°) from primary flat
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent { 110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

SEMI M1.8-0699
STANDARD FOR 150 mm POLISHED MONOCRYSTALLINE SILICON WAFERS

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on March 4, 1999. Initially available at www.semi.org March 1999; to be published June 1999. Originally published 1979; previously published February 1998.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1 Dimension and Tolerance Requirements

Property		*Dimension*		*Tolerance*	*Units*[A]
DIAMETER		150.00		± 0.20	mm
THICKNESS, CENTER POINT		675		± 20	μm
PRIMARY FLAT LENGTH		57.5		± 2.5	mm
SECONDARY FLAT LENGTH		37.5		± 2.5	mm
BOW, MAX		60			μm
WARP, MAX		60			μm
TOTAL THICKNESS VARIATION, MAX		10			μm
EDGE PROFILE	Table	2 (T/3)	3 (T/4)[B]		
COORDINATE: (see Figure 4)	C_y	225	169		μm
	C_x	50	100		μm
EDGE PROFILE SURFACE FINISH		Not Specified[C]			

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded-up and the maximum values are rounded-down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded-down and maximum values rounded-up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION: The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

[B] Use of edge gripping or CMP (chemical-mechanical planarization) processing may necessitate edge profile restrictions, resulting in a generally blunter profile as required by the template in Figure 4 and Table 3 of SEMI M1.

[C] Surface finish shall be agreed upon between the supplier and purchaser. If polished, this term is meant to imply a surface condition and not a particular processing technique. If desired, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between supplier and purchaser.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{110} ± 1°
SECONDARY FLAT LOCATION (see Figure 6)	
{111}*p*-type	No secondary flat
{100}*p*-type	(90° ± 5°) clockwise from primary flat
{111}*n*-type	(45° ± 5°) clockwise from primary flat
{100}*n*-type	(135° ± 5°) clockwise from primary flat
SURFACE ORIENTATION[B]	
On-orientation for {111} and {100} wafers:	± 1°
Off-orientation {111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE: This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

NOTICE: – These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M1.9-0699
STANDARD FOR 200 mm POLISHED MONOCRYSTALLINE SILICON WAFERS (NOTCHED)

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on March 4, 1999. Initially available at www.semi.org March 1999; to be published June 1999. Originally published 1984; previously published February 1998.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1 Dimension and Tolerance Requirements

Property		*Dimension*		*Tolerance*	*Units*[A]
DIAMETER		200.00		± 0.20	mm
THICKNESS, CENTER POINT		725		± 20	µm
NOTCH (see Figure 7)					
Depth		1.00		+ 0.25, - 0.00	mm
Angle		90		+ 5, -1	Degrees
BOW, MAX		65			µm
WARP, MAX		75			µm
TOTAL THICKNESS VARIATION, MAX		10			µm
EDGE PROFILE	Table	2 (T/3)	3 (T/4)[B]		
COORDINATE: (see Figure 4)	C_y	242	181		µm
	C_x	50	100		µm
EDGE PROFILE SURFACE FINISH		Not Specified[C]			

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded-up and the maximum values are rounded-down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded-down and maximum values rounded-up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION: The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

[B] Use of edge gripping or CMP (chemical-mechanical planarization) processing may necessitate edge profile restrictions, resulting in a generally blunter profile as required by the template in Figure 4 and Table 3 of SEMI M1.

[C] Surface finish shall be agreed upon between the supplier and purchaser. If polished, this term is meant to imply a surface condition and not a particular processing technique. If desired, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between supplier and purchaser.

Table 2 Orientation Requirements

Property	*Requirement*
ORIENTATION OF NOTCH AXIS[A]	<110> ± 1°
SECONDARY FIDUCIAL LOCATION	No secondary fiducial
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane perpendicular to notch axis	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent <110> planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE: This standard was originated in the United States. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

NOTICE: – These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M1.10-0699
STANDARD FOR 200 mm POLISHED MONOCRYSTALLINE SILICON WAFERS (FLATTED)

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on March 4, 1999. Initially available at www.semi.org March 1999; to be published June 1999. Originally published 1989; previously published 1992.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1 Dimension and Tolerance Requirements

Property		*Dimension*		*Tolerance*	*Units*[A]
DIAMETER		200.00		± 0.20	mm
THICKNESS, CENTER POINT		725			µm
PRIMARY (ORIENTATION)FLAT DIAMETER		195.50		± .20	mm
BOW, MAX		65			µm
WARP, MAX		75			µm
TOTAL THICKNESS VARIATION, MAX		10			µm
EDGE PROFILE	Table	2 (T/3)	3 (T/4)[B]		
COORDINATE: (see Figure 4)	Cy	242	181		µm
	C_x	50	100		µm
EDGE PROFILE SURFACE FINISH		Not Specified[C]			

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded-up and the maximum values are rounded-down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded-down and maximum values rounded-up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION: The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

[B] Use of edge gripping or CMP (chemical-mechanical planarization) processing may necessitate edge profile restrictions, resulting in a generally blunter profile as required by the template in Figure 4 and Table 3 of SEMI M1.

[C] Surface finish shall be agreed upon between the supplier and purchaser. If polished, this term is meant to imply a surface condition and not a particular processing technique. If desired, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between supplier and purchaser.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{110} ± 1°
SECONDARY FLAT LOCATION[B]	No secondary flat
SURFACE ORIENTATION	
On-orientation for {111} and {100} wafers:	± 1°
Off-orientation {111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE - This standard was originated in Japan. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

NOTICE: – These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M1.11-90 (Reapproved 0299)
STANDARD FOR 100 mm POLISHED MONOCRYSTALLINE SILICON WAFERS WITHOUT SECONDARY FLAT (525 µm THICKNESS)

This standard was technically reapproved by the Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1990.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	100.00	± 0.20	mm
THICKNESS, CENTER POINT	525	± 15	µm
PRIMARY FLAT LENGTH	32.5	± 2.5	mm
BOW, MAX	40		µm
WARP, MAX	40		µm
TOTAL THICKNESS VARIATION, MAX	10		µm
EDGE PROFILE COORDINATE: C_y (see Figure 4)	175		µm

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{ 110} ± 1°
SECONDARY FLAT LOCATION	No secondary flat
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent { 110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in Japan. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

SEMI M1.12-90 (Reapproved 0299)
STANDARD FOR 125 mm POLISHED MONOCRYSTALLINE SILICON WAFERS WITHOUT SECONDARY FLAT

This standard was technically reapproved by the Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1990.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1. Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	125.00	± 0.20	mm
THICKNESS, CENTER POINT	625	± 15	µm
PRIMARY FLAT LENGTH	42.5	± 2.5	mm
BOW, MAX	40		µm
WARP, MAX	40		µm
TOTAL THICKNESS VARIATION, MAX	10		µm
EDGE PROFILE COORDINATE: C_y (see Figure 4)	208		µm

[A] For referee purposes, metric (SI) units apply. To ensure that the product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{ 110} ± 1°
SECONDARY FLAT LOCATION	No secondary flat
SURFACE ORIENTATION[B]	
On-orientation for { 111} and { 100} wafers:	± 1°
Off-orientation { 111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent { 110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE — This standard was originated in Japan. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

SEMI M1.13-0699
STANDARD FOR 150 mm POLISHED MONOCRYSTALLINE SILICON WAFERS WITHOUT SECONDARY FLAT (625 µm THICKNESS)

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on March 4, 1999. Initially available at www.semi.org March 1999; to be published June 1999. Originally published 1990.

The complete specification for this product includes all general requirements of SEMI M1.

Table 1 Dimension and Tolerance Requirements

Property		*Dimension*		*Tolerance*	*Units*[A]
DIAMETER		150.00		± 0.20	mm
THICKNESS, CENTER POINT		625		± 15	µm
PRIMARY FLAT LENGTH		47.5		± 2.5	mm
BOW, MAX		60			µm
WARP, MAX		60			µm
TOTAL THICKNESS VARIATION, MAX		10			µm
EDGE PROFILE	Table	2 (T/3)	3 (T/4)[B]		
COORDINATE: (see Figure 4)	C_y	208	156		µm
	C_x	50	100		µm
EDGE PROFILE SURFACE FINISH		Not Specified[C]			

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded-up and the maximum values are rounded-down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded-down and maximum values rounded-up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION: The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

[B] Use of edge gripping or CMP (chemical-mechanical planarization) processing may necessitate edge profile restrictions, resulting in a generally blunter profile as required by the template in Figure 4 and Table 3 of SEMI M1.

[C] Surface finish shall be agreed upon between the supplier and purchaser. If polished, this term is meant to imply a surface condition and not a particular processing technique. If desired, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between supplier and purchaser.

Table 2. Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION[A]	{110} ± 1°
SECONDARY FLAT LOCATION	No secondary flat
SURFACE ORIENTATION[B]	
On-orientation for {111} and {100} wafers:	± 1°
Off-orientation {111} wafers: Tilt angle of normal to wafer surface toward nearest <110> direction in a plane parallel to primary flat	2.5° ± 0.5°, or 4.0° ± 0.5°
ORTHOGONAL MISORIENTATION[C] (see Figure 2)	± 5° max

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

[B] Note that if the off-orientation angle is determined with the seed end up, the polished surface of the finished wafer must be the surface toward the seed end, and vice versa. Polishing of the incorrect wafer surface results in an incorrect wafer tilt which can cause unwanted pattern shifts and distortions during subsequent epitaxial growth.

[C] The contribution of 5° of orthogonal misorientation to the total off-orientation angle will be less than 0.5°.

NOTE - This standard was originated in Japan. Care should be taken applying this configuration to specific applications (see Note 15 in SEMI M1).

SEMI M1.14-96
GUIDELINE FOR 350 and 400 mm POLISHED MONOCRYSTALLINE SILICON WAFERS

The complete specification for this product includes all general requirements of SEMI M1.

Although 300 mm has been chosen as the next wafer diameter larger than 200 mm and separate 300 mm wafer specifications are being developed[1] , it may be appropriate to continue advanced research activities on larger wafers. This guideline is intended to provide guidance regarding the selection of dimensional and related characteristics of such wafers for the development of materials, equipment, and processes.

Table 1 Dimension and Tolerance Requirements

Property	*Target*	*Target*	*Tolerance*	*Units*[A]
DIAMETER	350.00	400.00	± 0.25	mm
THICKNESS, CENTER POINT	800	825	± 25	µm
NOTCH FIDUCIAL[B] (see Figure 7)				
Depth	1.00	1.00	+ 0.25, − 0.00	mm
Angle	90	90	+ 5, − 1	degrees
WARP, MAX	100	100		µm
NINE-POINT THICKNESSVARIATION, MAX	25	25		µm
BACK SURFACE FINISH[C]	BRIGHT ETCHED/POLISHED			
EDGE PROFILE COORDINATE: C_y (see Figure 4)	267	275		µm
EDGE PROFILE SURFACE FINISH[D]	POLISHED			
NOMINAL WAFER MASS[E]	179	242		g
	6.3	8.5		oz.

[A] For referee purposes, SI units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the specified range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded down, and maximum values rounded up, to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

[B] An alternative technique for crystal alignment to replace the notch could be an inscribed fiducial by laser marking.

[C] This term is not meant to imply any particular processing method for achieving the desired back surface finish, but rather to indicate a surface finish that is smoother than the usual finish achieved with caustic etching but not as smooth as the mirror polish typically obtained on front surfaces of wafers. Because the most appropriate magnitude of the back surface roughness is not yet established, wafer manufacturers are encouraged to report typical values of gloss or rms microroughness of the back surface finish of the wafers supplied, together with the method by which these values were determined, and, if rms microroughness is reported, the range of spatial frequencies (or spatial wavelengths) over which it was determined. Measurement procedures used to obtain this data are at the option of the wafer manufacturer. If necessary for a particular application, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or spatial wavelength) range. Because a standardized test method has not yet been developed for this measure, both values and test procedures shall be agreed upon between user and supplier.

[D] This term is meant to imply a surface condition and not a particular processing technique. If necessary for a particular application, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or spatial wavelength) range. Because a standardized test method has not yet been developed for this

[1] A specification for developmental 300 mm wafers has been approved as SEMI M28.

measure, values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between user and supplier.

E Note for material handling/processing: These wafers are heavy. The mass of a single wafer of nominal dimensions, taking the density of silicon as 2.33 g/cm3, is given in the table for information only.

Table 2 Orientation Requirements

Property	*Requirement*
ORIENTATION OF NOTCH AXIS[A]	<110> ± 1¡
SECONDARY FLAT LOCATION	No secondary flat
SURFACE ORIENTATION	{ 110} ± 1¡

A For (100) wafers, the allowable equivalent <110> directions are [011], [011], [011], and [011].

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M1.15-0302
STANDARD FOR 300 mm POLISHED MONOCRYSTALLINE SILICON WAFERS (NOTCHED)

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the European Regional Standards Committee on October 14,2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1997; previously published November 2001.

1 Referenced Standards

1.1 *SEMI Standard*

SEMI M12 — Specification for Alphanumeric Marking of the Front Surface of Silicon Wafers

SEMI T7 — Specification for Back Surface Marking of Double-Side Polished Wafers with a Two-Dimensional Matrix Code Symbol

1.2 *ASTM Standards*[1]

D 523 — Test Method for Specular Gloss

F 1530 — Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

1.3 *JIS Standard*[2]

Z 8741 — Method of Measurement for Specular Glossiness

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2 Requirements

2.1 The complete specification for this product includes all general requirements of SEMI M1 except for the following:

2.1.1 The exclusion of wafers polished on both sides in Section 1.3 of SEMI M1 is deleted.

2.1.2 Particulate contamination (localized light scatterer) requirements listed in Table 1 of SEMI M1 (Polished Wafer Defect Limits) do not apply to these wafers. Specification criteria and test methods for automated surface inspection of large wafers are under development.

2.1.3 Wafers shall be marked with a two-dimensional matrix code symbol on the back surface outside the fixed quality area as soon after slicing as practical in the manner specified in SEMI T7 in order to provide both identification of these wafers and traceability of each wafer back to the ingot from which it was cut. The back surface is identified as the wafer surface with the two-dimensional matrix code symbol.

2.1.4 Optionally, the user may specify that no mark be placed on the wafer.

NOTE 2: It is expected that the option of “no mark” will eventually become obsolete after or if experience with the SEMI T7 mark demonstrates success.

2.1.5 Optionally, the user may specify an additional back-surface mark (Note 3) that contains alphanumeric characters with

2.1.5.1 The same message characters as the SEMI T7 mark and appropriate checksum characters as defined by SEMI M12, and

2.1.5.2 Character string as specified in SEMI M12,

2.1.5.3 Single density dot matrix, 5 dots horizontal and 9 dots vertical, shall be used,

2.1.5.4 Dot diameter shall be the same as that used for the two-dimensional matrix code symbol (see Section 2.1.3).

2.1.5.5 Adjacent dots shall not touch.

2.1.5.6 Character dimensions shall be as defined in SEMI M12, Table 1 (nominal spacing = 1.42 mm, nominal width = 0.812 mm, nominal height = 1.624 mm).

2.1.5.7 Mark location (center of bottommost dot rows) relative to the reference point of the SEMI T7 mark shall be 1.40 ± 0.05 mm toward the wafer center, as shown in Figure 1,

2.1.5.8 Mark field height, as defined by the distance between the centers of the topmost and bottommost dot rows of the A/N characters, shall be 1.62 ± 0.03 mm (Note 4),

2.1.5.9 Mark field length , as defined by the distance between the centers of the leftmost and rightmost dot columns of the A/N characters, shall be 16.43 ± 0.07 mm (Note 4).

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Both Japanese editions and English translation available from Japan Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo 107, Japan

2.1.5.10 The mark-field shall be centered on the radius that passes through the reference point of the SEMI T7 mark as shown in Figure 1.

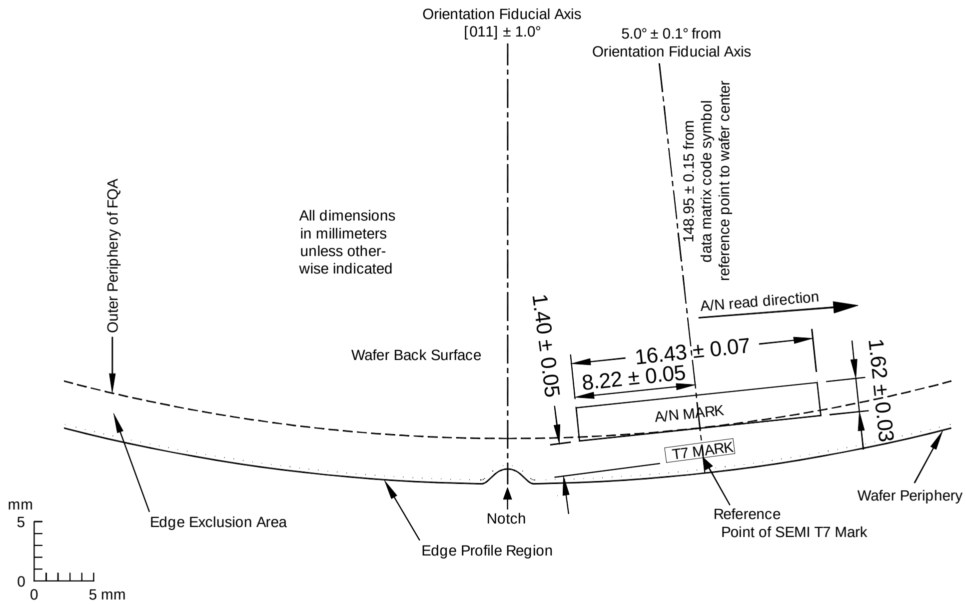
2.1.5.11 Character baseline shall be toward wafer OD and parallel with the row of the SEMI T7 mark that contains that mark's reference point.

NOTE 3: It is expected that this optional alphanumeric mark will not be used after users have developed successful experience with SEMI T7 mark usage.

NOTE 4: The overall length tolerance of the A/N mark is more stringent than that in SEMI M12. Also the height tolerance of the overall mark imposes tighter skew and offset tolerances than required in SEMI M12.

2.2 Dimension and tolerance requirements are given in Table 1.

2.3 Orientation requirements are given in Table 2.



NOTE: A/N mark field dimensions are defined by the centers of the topmost and bottommost dot rows and the center of the leftmost and rightmost dot columns of the A/N characters. The field dimensions are more tightly controlled than those of a field constructed using SEMI M12. This results from the availability of laser marking capabilities not available when SEMI M12 was developed. In addition, the tolerance on the field dimensions is not cumulative.

Figure 1
Optional A/N Code Field Location on Back Surface of Notched 300 mm Diameter Wafer

Table 1 Dimension and Tolerance Requirements

Property		*Dimension*	*Tolerance*	*Units*[A]
DIAMETER		300.00	± 0.20	mm
THICKNESS, CENTER POINT		775	± 20	µ m
NOTCH (see Figure 7)				
Depth		1.00	+ 0.25, -0.00	mm
Angle		90	+ 5, -1	degrees
WARP, MAX[B]		100		µ m
TOTAL THICKNESS VARIATION (GBIR), MAX[C]		10		µ m
BACK SURFACE GLOSS[D]		³ 0.80		
EDGE PROFILE SURFACE FINISH[E] POLISHED				
EDGE PROFILE COORDINATE:	Table 3 (T/4)[F]			
(see Figure 4)	C_y	194		µ m
	C_x	100		µ m

[A] For referee purposes, metric (SI) units apply. To ensure that product shipped is within specification, any conversion to U.S. Customary equivalents should be done following the maximum-minimum convention in which the minimum values are rounded-up and the maximum values are rounded-down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection, minimum values should be rounded-down and maximum values rounded-up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION: The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.
[B] Warp is corrected for gravitational effects. However, warp is not an adequate wafer shape specification for all applications.
[C] Full wafer scan as described in ASTM Test Method F 1530. However, a nine-point test pattern can be specified until full scan thickness measurement equipment is available.
[D] Gloss as measured in accordance with ASTM D 523 or JIS Z 8741 with visible illumination at a 60° angle of incidence referenced to a mirror polished silicon wafer front surface. This metric may not describe the back surface finish adequately to establish detectability of small localized light scatterers (LLSs). If it is necessary to detect LLSs smaller than 0.25 µm LSE, another quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures shall be agreed upon between supplier and purchaser.
[E] This term is meant to imply a surface condition and not a particular processing technique. If desired, a quantitative measure of surface finish may optionally be indicated by specifying the rms microroughness over a specified spatial frequency (or wavelength) range. Because a standardized test method has not yet been developed for this metric, both values and test procedures, including sampling plan and detrending procedures, shall be agreed upon between supplier and purchaser.
[F] Use of edge gripping or CMP (chem-mechanical planarization) processing may necessitate further edge profile restrictions, resulting in a generally blunter profile as required by the template in Figure 4 and Table 3 of SEMI M1.

Table 2 Orientation Requirements

Property	*Requirement*	
ORIENTATION OF NOTCH AXIS[A]	<110>	± 1°
SECONDARY FLAT LOCATION	No secondary flat	
SURFACE ORIENTATION	{100}	± 1°

[A] For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent <110> planes are [011], $[01\bar{1}]$, $[0\bar{1}\bar{1}]$, and $[0\bar{1}1]$.

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The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. RVSI Acuity CiMatrix has filed a statement with SEMI asserting that the patented or copyrighted item can be used by the public for the purpose of implementing this standard without specific license and without payment of royalty or other charge. Attention is also drawn to the possibility that some elements of this standard may be subject to patented technology or copyrighted items other than those identified above. Semiconductor Equipment and Materials International (SEMI) shall not be held responsible for identifying any or all such patented technology or copyrighted items. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights and the risk of infringement of such rights are entirely their own responsibility.

SEMI

SEMI M2-0997
SPECIFICATION FOR SILICON EPITAXIAL WAFERS FOR DISCRETE DEVICE APPLICATIONS

1 Purpose

1.1 This specification defines silicon epitaxial wafer requirements for discrete semiconductor device manufacture. It is restricted to wafers with device feature sizes in excess of 1 µm or wafers with epi layers thicker than 25 µm.

2 Scope

2.1 By defining inspection procedures and acceptance criteria, suppliers and consumers may uniformly define product characteristics and quality requirements.

2.2 The characteristics specified relate to the substrate (as specified in SEMl M1) and to the epitaxial layer, including handling and packaging. The primary standardized properties set forth in this specification relate to physical, electrical, and surface defect parameters.

2.3 A complete purchase specification requires that additional physical properties be specified along with suitable test methods for their measurement. SEMI M18 may be used for this purpose.

3 Limitations

3.1 This specification is specifically directed to silicon homoepitaxial deposits thicker than 25 µm on homogeneous silicon substrates or similar epitaxial wafers that are to be used to make discrete devices.

NOTE 1: Specifications for epitaxial wafers with greater uniformity and more stringent surface defect criteria are given in SEMI M11.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M17 — Specification for a Universal Wafer Grid

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M25 — Specification for Silicon Wafers for Calibration of Light Point Defect Wafer Inspection Systems with Respect to the Diameter of Polystyrene Latex Spheres

4.2 *ASTM Standards*[1]

F 47 — Test Method for Crystallographic Perfection of Silicon by Preferential Etch Techniques

F 80 — Test Method for Crystallographic Perfection of Epitaxial Deposits of Silicon by Etching

F 95 — Test Method for Thickness of Epitaxial Layers of Silicon on Substrates of the Same Type by Infrared Reflectance

F 110 — Test Method for Thickness of Epitaxial or Diffused Layers in Silicon by the Angle Lapping and Staining Technique

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 374 — Test Method for Sheet Resistance of Silicon Epitaxial, Diffused, and Ion-Implanted Layers Using a Colinear Four-Probe Array

F 398 — Test Method for Majority Carrier Concentration in Semiconductors by Measurement of Wavelength of the Plasma Resonance Minimum

F 419 — Test Method for Net Carrier Density in Silicon Epitaxial Layers by Diode Voltage-Capacitance of Gated and Ungated Diodes

F 522 — Test Method for Stacking Fault Density of Epitaxial Layers of Silicon by Interference-Contrast Microscopy

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 525 — Test Method for Measuring Resistivity of Silicon Wafers Using a Spreading Resistance Probe

F 672 — Test Method for Measuring Resistivity Profiles Perpendicular to the Surface of a Silicon Wafer Using a Spreading Resistance Probe

F 723 — Practice for Conversion between Resistivity and Dopant Density for Boron-Doped and Phosphorus-Doped Silicon

F 815 — Test Method for Detection of Epitaxial Spikes

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1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (All cited standards may be found in Volume 10.05 of the Annual Book of ASTM Standards.)

F 1241 — Terminology of Silicon Technology

F 1392 — Test Method for Determining Net Carrier Density Profiles in Silicon Wafer by Capacitance-Voltage Measurements with a Mercury Probe

F 1393 — Test Method for Determining Net Carrier Density in Silicon Wafers by Miller Feedback Profiler Measurements with a Mercury Probe

4.3 *Other Standards*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

5 Terminology

Many terms relating to silicon technology are defined in ASTM Terminology F 1241.

Definitions for the epitaxial wafer defects covered in Table 1 are given in ASTM Test Methods F 47, F 522, and F 815, and in ASTM Practices F 154.

Other terms are defined as follows:

5.1 *autodoping, of an epitaxial layer* — Incorporation of dopant originating from the substrate into the epitaxial layer. Also called *self-doping*.

NOTE 2: Sources of autodoping can be the back and front surfaces and edges of the substrate, other substrates in the reactor, the susceptor, or other parts of the deposition assembly.

5.2 *chemical vapor deposition, in semiconductor technology* — A process in which a controlled chemical reaction produces a thin surface film.

NOTE 3: Epitaxial growth is an example of a special case of chemical vapor deposition (CVD).

5.3 *edge crown* — The difference between the surface elevation 1/8 inch (3.2 mm) from the edge of the wafer and the elevation at the wafer edge.

5.4 *effective layer thickness, of an epitaxial layer* — The depth from the front surface in which the net carrier density is within the specified limits.

5.5 *epi profile slope, of an epitaxial layer* — The difference between the net carrier density at 0.75 of the layer thickness and the net carrier density at 0.25 of the layer thickness divided by one-half the layer thickness:

$$\text{epi profile slope} = \frac{N_{0.75t} - N_{0.25t}}{0.5t}$$

where :

N = net carrier density, cm^{-3}, and

t = layer thickness, μm.

5.6 *epitaxial layer* — A layer of single crystal semiconductor material grown on a host substrate which determines its orientation.

5.7 *epitaxy* — The growth of a single crystal layer on a substrate of the same material, homoepitaxy; or on a substrate of different material with a compatible crystal structure, heteroepitaxy.

5.8 *flat zone, of an epitaxial layer* — The depth from the front surface to the point where the net carrier density is 20% greater than or less than the average net carrier density (see Section 9.3.2) of the region between 0.25 and 0.75 of the layer thickness.

5.9 *thickness, of an epitaxial layer* — The distance from the surface of the wafer to the layer-substrate interface.

5.10 *transition width, of an epitaxial layer deposited on a more heavily doped substrate of the same conductivity type* — The difference between the layer thickness as determined by infrared reflectance (see Section 9.3.1) and the flat zone based on the same thickness measurement.

6 Ordering Information

6.1 Purchase orders for the epitaxial layer on substrates furnished to this specification shall include the following items:

6.1.1 Substrate characteristics,

6.1.2 Silicon source (if required) (see Note 4),

6.1.3 Conductivity type and doping source (see Note 4),

6.1.4 Etch removal (if required),

6.1.5 Center point thickness and thickness tolerances,

6.1.6 Radial thickness variation range,

6.1.7 Centerpoint net carrier density and net carrier density tolerances (see Note 5),

6.1.8 Radial net carrier density variation range,

6.1.9 Epitaxial wafer defect limits,

6.1.10 Methods of test and measurements (see Section 6),

6.1.11 Lot acceptance procedures (see Section 9),

[2] *American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202*

6.1.12 Certification (if required) (see Section 10),

6.1.13 Packing and marking (see Section 11).

NOTE 4: The dopant, doping method, and growth method are difficult to ascertain in the finished wafers. Verification test procedures or certification of these characteristics shall be agreed upon between the supplier and the purchaser (see Section 10).

NOTE 5: Care should be taken in converting between carrier density and resistivity using ASTM Practice F 723. Multiple conversions may introduce differences in values. For example, converting from carrier density (C_i) to resistivity and back to carrier density (C_f), may result in C_i not equaling C_f.

7 Requirements

7.1 The substrate shall conform to SEMI M1 and to the appropriate polished silicon wafer standard.

7.2 Epitaxial wafer defects shall not exceed the limits as given in Table 1.

NOTE 6: When an unetched wafer is observed for slip, it is impossible to differentiate between slip and linear misfit lines.

7.3 *Layer Thickness Variation* — Unless otherwise specified, the radial thickness variation shall be determined from values measured at the center and R/2 locations, on diameters both parallel and perpendicular to the primary flat, and shall be ≤ 6% defined as follows:

$$\text{Variation (\%)} = \frac{\left|\frac{R}{2} - C\right|_{max}}{C} \times 100$$

where R/2 denotes one of the values measured at R/2 and C denotes the value at the center.

7.4 *Net Carrier Density Variation*— The radial net carrier density variation shall be determined from values measured at the center and R/2 locations, on diameters both parallel and perpendicular to the primary flat, and shall be ≤ 10% for net carrier density ≥ 1×10^{15} cm^{-3} and≤ 15% for net carrier density < 1×10^{15} cm^{-3} defined as follows:

$$\text{Variation (\%)} = \frac{\left(\frac{R}{2} - C\right|_{max}}{C} \times 100$$

where R/2 denotes one of the values measured at R/2 and C denotes the value at the center.

8 Sampling

8.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot according to ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4. Inspection levels shall be agreed upon between supplier and purchaser.

8.2 Unless otherwise specified, the following AQL's shall be assigned:

8.2.1 Epitaxial layer thickness, 6.5%,

8.2.2 Epitaxial layer net carrier density, 6.5%,

8.2.3 Epitaxial wafer defects, cumulative, 4.0%.

9 Test Methods

9.1 Measurements shall be carried out in conformance with the specified ASTM methods. Where no methods are specified or where choices are given, the supplier and purchaser shall agree in advance on the means for making the measurement.

9.2 *Substrate* — Determine in accordance with methods defined in SEMI M1.

9.3 Epitaxial Layer

9.3.1 *Thickness* — Determine in accordance with ASTM Test Methods F 95 or F 110.

NOTE 7: There is a possibility that various types of infrared reflectance instrumentation may result in different values of epitaxial layer thickness. Therefore, the instrumentation used shall be agreed upon between supplier and purchaser.

9.3.2 *Net Carrier Density* — Determine by method(s) agreed upon between supplier and purchaser.

NOTE 8: ASTM Test Method F 419 is a standardized differential-capacitance method for net carrier density, but it requires fabrication of a p-n junction. ASTM Test Methods F 1392 and F 1393 are methods for measuring net carrier density using a mercury probe contact. If resistivity is measured, as by ASTM Test Methods F 374 or F 525, conversion to dopant density shall be made using ASTM Practice F 723. Net carrier density of very heavily doped layers (or substrates) may be found using ASTM Test Method F 398. Net carrier density profiles may be determined directly in accordance with ASTM Test Method F 419, F 1392, or F 1393 or indirectly in accordance with ASTM Test Method F 672, with conversion from resistivity to net carrier density in accordance with ASTM Practice F 723. If the method used for determining the net carrier density profile is not the same as that used to determine the centerpoint net carrier density, correlation between the two methods used shall be established.

9.3.3 *Epitaxial Wafer Defects* — Determine in accordance with the methods given in Table 1.

9.3.3.1 Surface inspection shall be performed before any other testing. Wafers may be cleaned prior to inspection to minimize difficulty in the visual inspection of defects other than foreign matter.

9.3.3.2 Inspection for slip shall be done using grid elements constructed in accordance with SEMI M17. An element is defective if it contains one or more slip lines. The total number of defective elements shall be less than or equal to *n*, where *n* is listed in Table 1.

9.4 If substrates of different type and net carrier density than the product substrates are to be used for deposition control, their type, net carrier density, and quantity per run or lot shall be agreed upon between supplier and purchaser.

10 Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

10.2 The user and supplier may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 9; however, if the user performs the test and the material fails to meet the requirement, the material may be subject to rejection.

11 Packing and Package Labeling

11.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide protection against damage during shipment.

11.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or container, and each subdivision thereof, in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include supplier's name and reference number, purchaser's p.o. number, quantity, dopant, orientation, conductivity type of substrates and epitaxial layers, carrier density, and thickness of the epitaxial layer. The reference number assigned by the supplier shall provide ready access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer's facility for at least one year after the particular lot has been shipped.

Table 1 Discrete Epitaxial Wafer Defect Limits

Item	*Characteristics*	*Maximum Limit*				*Test Method*	*Notes*
1	Stacking Faults	15 per cm^2				Nomarski Interference Contrast Microscopy ASTM F 522	1
2	Slip	*n* = 36 grid elements				SEMI M17, F 523, or F 80	1, 2, 3
3	Haze	NONE				F 523 Section 12.2	1, 4, 5
4	Scratches	NONE				F 523 Section 12.2	1, 5, 6
5	Edge Chips	NONE				F 523 Section 12.2	7
6	Edge Crown	Projection above wafer surface not to exceed 1/3 of epi layer thickness				To be defined	2, 8
7	Foreign Matter	NONE				F 523 Section 12.3	1, 4
8	Back Surface Contamination	NONE				F 523 Section 12.4	1, 4
Front Surface Characteristics Dependent on Layer Thickness		Epitaxial Layer Thickness					
		< 25 µm	25–50 µm	50–100 µm	> 100 µm		
9	Large Point Defects (Density per m^2)	700	900	1200	1500	F 523 or ≥ 20 µm LSE, based on calibration of surface scanning inspection systems with polystyrene latex spheres, 90% capture rate	1, 2, 5, 9
10	Total Localized Light Scatterers (Density per m^2)	2000	2400	2700	3000	F 523 or ≥ 0.5 µm LSE, based on calibration of surface scanning inspection systems with polystyrene latex spheres, 90% capture rate	1, 2, 5, 9

Notes:

1. Defect limits shall apply to quality area, which is defined as the entire wafer surface except a defined outer annulus: 2 inch and 3 inch = 2 mm; 100 mm and 125 mm = 3 mm; 150 mm and 200 mm = 4 mm and any are included in a window where there is a laser indentification mark.

2. Test method(s) to be agreed upon between supplier and purchaser.

3. For observation of gross slip, examine the epi layer under illumination conditions specified in Section 12.2 of ASTM Practice F 523. For more demanding applications, it may be desirable to etch the surface in accordance with ASTM Method F 80 prior to the visual inspection.

4. Any adherent contaminants, such as stains, glovemarks, dirt, smudges, and solvent residues. This characteristic does not include point defects. Any nonadherent contaminant or particulate matter easily removed by industry accepted cleaning techniques shall not constitute foreign matter or haze.

5. In today's technology, it may be possible to do this inspection using automated laser scanning systems; however, a standard test procedure has yet to be developed. Application of automated inspection must be agreed upon between supplier and user.

6. The cumulative AQL for both front surface and back surface of wafer is 2.5%.

7. The cumulative AQL for both front surface and back surface of wafer is 1.0%. Maximum radial penetration, 1.0 mm; maximum single chip peripheral length, 6.3 mm; maximum cumulative peripheral length, 6.3 mm.

8. Edge crowning may be reduced by pre-epitaxy edge rounding, or removed by post-epitaxy edge rounding.

9. See Table 2 in SEMI M25.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M3-1296
SPECIFICATIONS FOR POLISHED MONOCRYSTALLINE SAPPHIRE SUBSTRATES

1 Preface

1.1 These specifications cover requirements for four sizes of monocrystalline high-purity polished sapphire substrates used for silicon growth and subsequent semiconductor device manufacture. Dimensional and crystallographic orientation characteristics are the only standardized properties set forth below. A purchase specification may require that additional physical properties and allowable levels of bulk and surface defects be defined. These properties are listed, together with test methods suitable for determining their magnitude.

1.2 These specifications are directed specifically to sapphire substrates with one polished surface. Substrates polished on both sides, or unpolished, or with epitaxial deposits, are not covered; however, purchasers of such substrates may find this specification to be a useful guide in defining their requirements.

1.3 For referee purposes, U.S. customary units shall be used for substrates of 2.0 and 3.0 in. nominal diameters, and SI (System International, commonly called metric) units for 100 mm and larger diameter substrates.

2 Applicable Documents

2.1 *ASTM Standards*[1]

E 122 — Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

F 21 — Test Method for Hydrophobic Surface Films by the Atomizer Test

F 22 — Test Method for Hydrophobic Surface Films by the Water-Break Test

F 24 — Method for Measuring and Counting Particulate Contamination on Surfaces

F 26 — Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 533 — Test Method for Thickness and Thickness Variation of Silicon Slices

F 534 — Test Method for Bow of Silicon Slices

2.2 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

3 Selected Definitions

3.1 *Lot* — For the purposes of this document, (a) all of the substrates of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of substrates as (a) above which have been identified by the supplier as constituting a lot.

3.2 *Sapphire* — Single crystal Al_2O_3 having a definite orientation that allows epitaxial deposition.

3.3 *Substrate* — The polished sapphire slice upon which the epitaxial layer of silicon is grown.

4 Ordering Information

4.1 Purchase orders for sapphire substrates furnished to these specifications shall include the following items:

4.1.1 Nominal diameter (see applicable SEMI Standard for Sapphire Substrates),

4.1.2 Crystal growth method (see Note 1),

4.1.3 Surface orientation (see Figures 1 and 2),

4.1.4 Lot acceptance procedures (see Section 8),

4.1.5 Certification (if required) (see Section 14),

4.1.6 Packing and marking (see Section 15).

4.2 The following items may be specified optionally in addition to those listed in Paragraph 4.1:

4.2.1 Crystal perfection,

4.2.2 Surface defect and contaminant levels,

4.2.3 Impurities other than common doping elements,

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

4.2.4 Surface finish quality level (see Figures 5 through 8),

4.2.5 Back surface finish,

4.2.6 Secondary flat (see Figure 3, Section 10),

4.2.7 Flatness (see Table 1, Section 11).

NOTE 1 The crystal growth method (for example, Czochralski or EFG ribbon) is difficult to ascertain in the finished substrates. Verification test procedures or certification of these characteristics (see Section 14) shall be agreed upon between the supplier and the purchaser.

NOTE 2 Items in Paragraph 4.2 are less commonly specified than the others but are included for completeness as parameters for which methods of evaluation have been developed.

5 Dimensions and Permissible Variations

5.1 The material shall conform to the dimensions and dimensional tolerances as specified in the appropriate sapphire substrate standard.

6 Materials and Manufacture

6.1 The material shall consist of slices from sapphire grown by the process specified in the purchase order or contract.

7 Physical Requirements

7.1 The material shall conform to the crystallographic orientation details of the appropriate sapphire substrate standard (see Figure 1).

7.2 The following items, if included, shall conform to the requirements specified in the purchase order or contract:

7.2.1 Crystal perfection,

7.2.2 Surface defect and contaminant levels,

7.2.3 Amount of impurities other than common dopants,

7.2.4 Surface finish quality level,

7.2.5 Back surface finish.

8 Sampling

8.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4-1993. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4-1993 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

9 Test Methods

9.1 *Dimensions* — Measure as follows:

9.1.1 *Diameter* — Determine in accordance with ASTM Test Method F 613.

NOTE 3 Sapphire substrates are susceptible to surface damage. While the mechanical dimensions of a slice can be measured by use of tools such as micrometer calipers and other conventional techniques, the substrate may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement methods. Figure 2 of Section 12 illustrates the standard measurement location convention.

9.1.2 *Thickness, Center Point* — Determine in accordance with ASTM Test Method F 533.

9.1.3 *Flat Length* — Determine in accordance with ASTM Test Method F 671.

9.1.4 *Bow* — Determine in accordance with ASTM Test Method F 534.

9.1.5 *Total Thickness Variation* — Determine in accordance with ASTM Test Method F 533.

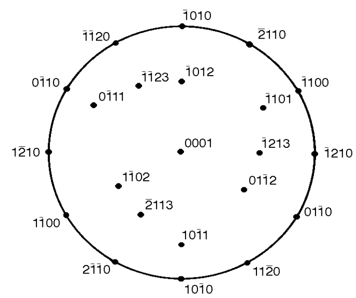
9.2 *Flat Orientation* — Determine by a method agreed upon between the supplier and the purchaser.

9.3 *Surface Orientation* — Determine in accordance with ASTM Test Methods F 26.

9.4 *Crystal Perfection* — Determine by a method agreed upon between the supplier and the purchaser.

9.5 *Surface Defects and Contamination* — Determine defects in accordance with ASTM Practice F 523. See Section 13 for surface defect definitions and Table 3 for allowable levels of defects. In the event the substrates fail to meet these criteria, they shall be conditioned according to ASTM Practice F 612 and retested.

Structural Indices	Mineralogical Symbols
$1\bar{1}02$	r
$01\bar{1}2$	r
$\bar{1}012$	r
0001	c
1010	m
$11\bar{2}0$	a
$10\bar{1}1$	s
$2\bar{1}\bar{1}3$	n



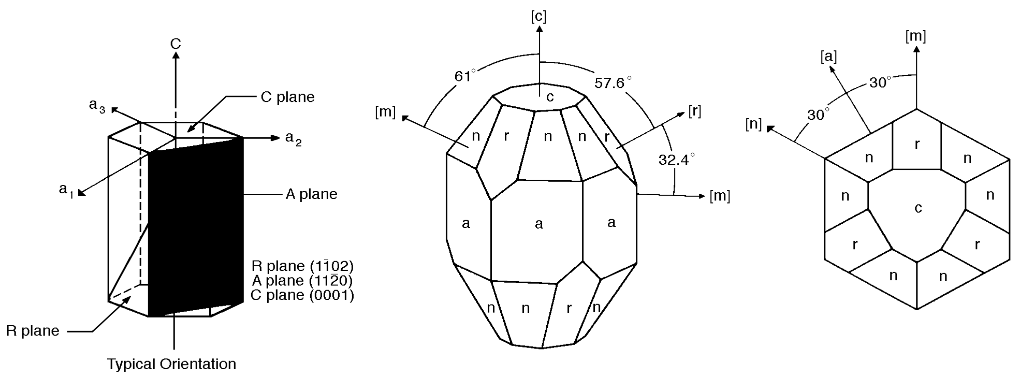


Figure 1
Sapphire Crystallographic Diagrams

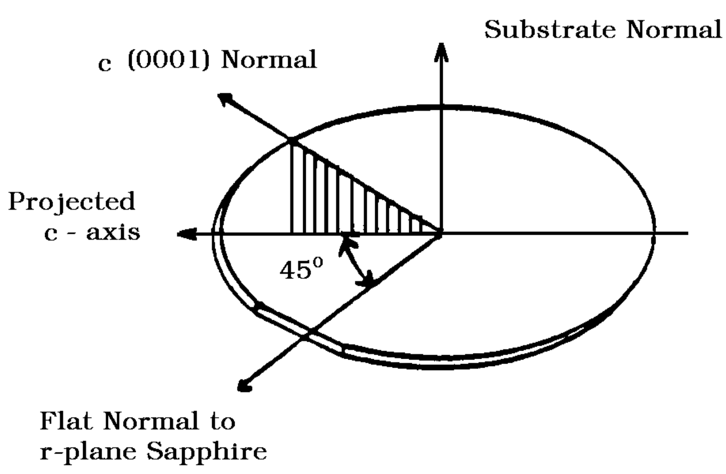


Figure 2
Sapphire Surface Orientation

NOTE 4 — ASTM Practices F 154 is a useful guide for defining a variety of surface features found on silicon slice surfaces and for establishing commonly understood terms for describing them. It also gives detailed procedures for illumination and microscopical examination of surfaces. The presence of contaminating materials on silicon surfaces can be determined by ASTM Test Methods F 21, F 22, or F24, as appropriate.

9.6 *Other Impurities* — Determine by methods agreed upon between the supplier and the purchaser.

9.7 *Surface Finish* — Determine by methods agreed upon between the supplier and the purchaser. Limits are given in the individual specifications.

9.8 *Backside Finish* — Determine by methods agreed upon between the supplier and the purchaser.

9.9 *Secondary Flat* — Standard location is determined as described in Section 10. Flat length is determined as described in Paragraph 9.1.3.

9.10 *Flatness* — Determine by a method agreed upon between the user and supplier.

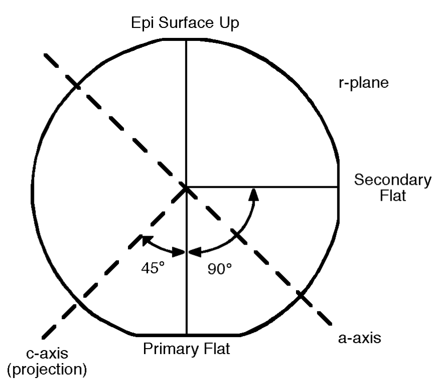


Figure 3

10 Flat System

10.1 Figures 2 and 3 describe the primary and secondary flat system.

Primary Flat: 45° ± 2° in the counter-clockwise direction from the projection of the c-axis along an r-plane.

Secondary Flat (Optional): 90° ± 2° in the counter-clockwise direction from the primary flat, along an r-plane.

The a-axis lies between the two flats bisecting the 90° angle. Projection of the c-axis lies 45° in the clockwise direction from the primary flat and 90° in the clockwise direction from the a-axis.

11 Flatness

Specifications for flatness of polished monocrystalline sapphire substrates shall be as given in Table 1.

Table 1

Class	*Sapphire Substrate ((TIR), μm)*
I	25 max
II	14 max
III	10 max
IV	8 max
V	6 max

12 Measurement Location Convention

12.1 Figure 4 illustrates the standard measurement location convention.

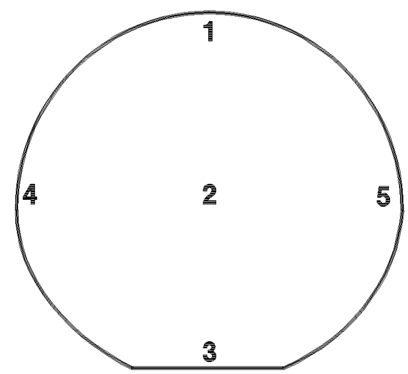


Figure 4

13 Standard Defect Limits

Definitions for surface defects are found in ASTM Practice F 523, where defects commonly found on silicon slices are defined. Some of these terms do not apply to sapphire substrates, but are present in Table 2 for a convenient reference point to the silicon slice standards.

Minimal Conditions and/or Dimensions — Minimal conditions or dimensions for defects are stated below and shall be used for determining substrate acceptability unless other minimal limiters are agreed upon by the interested parties. Anomalies less than these limits shall not be considered defects.

Area Contamination — Foreign matter on the surface in localized areas which is revealed as discolored, mottled, or cloudy appearance resulting from smudges, stains, water spots, etc.

Contamination — Any foreign matter detectable under the inspection lighting conditions.

Edge Chips and Indents — Any edge or surface anomaly conforming to the accepted definition greater than .010 inch in radial depth and peripheral length.

Cracks — Any anomaly conforming to the accepted definition greater than 0.010 inch (0.25 mm) in total length.

Craters — Any individually distinguishable surface anomaly conforming to the accepted definition visible when viewed under diffuse illumination.

Crow's Feet — N.A.

Grooves — N.A.

Haze — Haze is indicated when the image of a narrow beam tungsten lamp filament is detectable on the epi silicon surface. (Under some conditions, contamination may appear as haze.)

Mounds — N.A.

Orange Peel — Any visually detectable roughened surface conforming to the accepted definition observable under diffuse illumination.

Pits — Any individually distinguishable nonremovable surface anomaly conforming to the accepted definition visible when viewed under intense illumination.

Saw Exit Mark — N.A.

Scratch — Any anomaly conforming to the definition with a length-to-width ratio greater than 5:1.

Striation — Any feature conforming to the accepted definition detectable under background lighting conditions.

14 Certification

Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 9. However, if the purchaser performs the test and the material fails to meet the requirements, the material may be subject to rejection.

15 Packing and Marking

Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise all slices shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide ample protection against damage during shipment.

The substrates supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container, and each subdivision thereof, in which it may reasonably be expected that the substrates will be stored prior to further processing. Identification shall include, as a minimum, the nominal diameter, orientation, and lot number. The lot number, either (1) assigned by the original manufacturer of the substrates, or (2) assigned subsequent to substrate's manufacture, but providing reference to the original lot number, shall provide ready access to information concerning the fabrication history of the particular substrates in that lot. Such information shall be retained on file at the manufacturer's facility for at least one month after that particular lot has been accepted by the purchaser.

Table 2 Sapphire Substrate Defect Limits

ITEM	*CHARACTERISTICS*	*MAX DEFECT LIMIT*	*AQL (see NOTE 6)*	*ILLUMINATION*	*NOTES*
1	SCRATCHES Maximum Number Maximum Length	3 R/2		High Intensity	1
2	PITS Maximum Number 2" Diameter Substrate 3" Diameter Substrate 100 mm Diameter Substrate	4 9 15	4% Cum.		1, 2
3	HAZE	None — see Note 4	4% Cum.		4
4	CONTAMINATION/PARTICULATE Maximum Number 2" Diameter Substrate 3" Diameter Substrate 100 mm Diameter Substrate	4 9 15	4% Cum.	Diffuse	1, 2
5	CONTAMINATION/AREA	None			
6	EDGE CHIPS Maximum Number Maximum Radial Penetration Maximum Single Chip Peripheral Length Maximum Cumulative Peripheral Length	see Note 3 2 0.12" (3 mm) 0.250" (6.35 mm) 0.250" (6.35 mm)	4% Cum.	Diffuse	3
7	CRACKS,CROW'S FEET		see Note 6		6
8	CRATERS	None			1, 5
9	DIMPLES	None			1
10	GROOVES	None	4% Cum.		1, 5
11	MOUNDS	None			1, 5
12	ORANGE PEEL	None		Diffuse	1
13	SAW MARKS	None			1, 5
14	STRIATIONS				
SLICE BACK SURFACE					
15	CHIPS	see Note 3	see Note 3	Diffuse	3
16	CRACKS, CROW'S FEET	None	see Note 6		6
17	CONTAMINATION/AREA	None			
18	SAW MARKS Incidence Maximum Depth	N.A.	see Note 5		5

Notes:

1. The outer 4 mm annulus is excluded from these criteria.
2. Ninety percent of substrate shall be free of contaminants after pre-inspection treatment. Balance of substrate may have light-reflecting particles up to the limit established for Item 2 — Pits.
3. All chips shall be beveled. Chips less than 0.4 mm should not be counted.
4. Haze refers to epitaxial silicon appearance only, not to condition of polished sapphire substrate.
5. These defects are not observed in SOS wafers. Terms remain for convenient reference to silicon specification.
6. Cracks are observed in sapphire substrates as fractures or as surface separations along cleavage planes. The cumulative AQL for both front surface and back surface of substrate is 4% for both. Crow's feet.

Figure 5 *Figure 6*

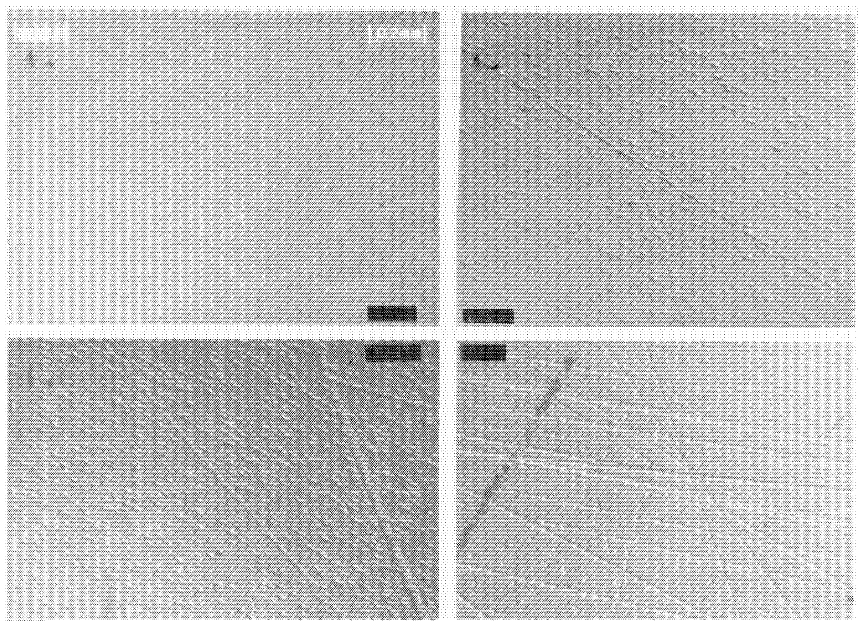


Figure 7 *Figure 8*

Figures 5 - 8

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SEMI M3.2-91
STANDARD FOR 2 inch SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[D]
DIAMETER	50.55	51.05	mm
	1.990	2.010	in.
THICKNESS, CENTER POINT	280	380	µm
	0.011	0.015	in.
PRIMARY FLAT LENGTH	14.23	17.52	mm
	0.56	0.69	in.
SECONDARY FLAT LENGTH	6.35	9.65	mm
	0.25	0.38	in.
BOW		38	µm
		0.0015	in.
TOTAL THICKNESS VARIATION		51	µm
		0.002	in.

SURFACE ORIENTATION[A]	(1102) ± 2.0°
FLAT LOCATION[B]	See Section 10 of SEMI M3.
BACK SURFACE FINISH	Approximately 32 µin
FRONT SURFACE FINISH[C]	The substrate shall be polished on one side suitable for the epitaxial growth of silicon. The quality of this surface may be determined by optical examination at 70× using Nomarski interference contrast microscopy after etching the substrate in potassium hydroxide at 310°C for one to three minutes. Using the photographs as a guide, Figure 5 shall be considered acceptable, while Figure 8 is unacceptable. Figure 6 and Figure 7 are questionable surfaces and subject to individual evaluation.

[A] See Figure 1 for orientation diagrams.

[B] See Figure 3 for flat diagram.

[C] See Figures 5 through 8 for surface finish quality levels.

[D] For referee purposes, the U.S. Customary units apply. Conversion to metric (SI) equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the metric (SI) equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

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SEMI M3.4-91
STANDARD FOR 3 inch SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[D]
DIAMETER	75.95	76.45	mm
	2.990	30.010	in.
THICKNESS, CENTER POINT	380	480	µm
	0.015	0.019	in.
PRIMARY FLAT LENGTH	19	25	mm
	0.75	1.00	in.
SECONDARY FLAT LENGTH	9.6	12.7	mm
	0.38	0.50	in.
BOW		51	µm
		0.0020	in.
TOTAL THICKNESS VARIATION		76	µm
		0.0030	in.

SURFACE ORIENTATION[A]	(1102) ± 2.0°
FLAT LOCATION[B]	See Section 10 of SEMI M3.
BACK SURFACE FINISH	Approximately 32 µin.
FRONT SURFACE FINISH[C]	The substrate shall be polished on one side suitable for the epitaxial growth of silicon. The quality of this surface may be determined by optical examination at 70× using Nomarski interference contrast microscopy after etching the substrate in potassium hydroxide at 310°C for one to three minutes. Using the photographs as a guide, Figure 5 shall be considered acceptable, while Figure 8 is unacceptable. Figure 6 and Figure 7 are questionable surfaces and subhect to individual evaluation.

[A] See Figure 1 for orientation diagrams.

[B] See Figure 3 for flat location diagram.

[C] See Figures 5 through 8 for surface finish quality levels.

[D] For referee purposes, the U.S. Customary units apply. Conversion to metric (SI) equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the metric equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

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SEMI M3.5-92
STANDARD FOR 100 mm SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[D]
DIAMETER	99.0	101.0	mm
	3.90	3.97	in.
THICKNESS, CENTER POINT	500	550	µm
	0.0197	0.0216	in.
PRIMARY FLAT LENGTH	30.0	35.0	mm
	1.182	1.377	in.
SECONDARY FLAT LENGTH	16.0	20.0	mm
	0.630	0.787	in.
BOW		40	µm
WARP		40	µm
TOTAL THICKNESS VARIATION		50	µm
		0.0019	in.

SURFACE ORIENTATION[A]	$(1\bar{1}02) \pm 2.0°$
FLAT LOCATION[B]	See Section 10 of SEMI M3.
BACK SURFACE FINISH	Approximately 32 µin.
FRONT SURFACE FINISH[C]	The substrate shall be polished on one side suitable for the epitaxial growth of silicon. The quality of this surface may be determined by optical examination at 70× using Nomarski interference contrast microscopy after etching the substrate in potassium hydroxide at 310°C for one to three minutes. Using the photographs as a guide, Figure 5 shall be considered acceptable, while Figure 8 is unacceptable. Figure 6 and Figure 7 are questionable surfaces and subhect to individual evaluation

[A] See Figure 1 for orientation diagrams.

[B] See Figure 3 for flat location diagram.

[C] See Figures 5 through 8 for surface finish quality levels.

[D] For referee purposes, the metric (SI) units apply. Conversion to U.S. Customary equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

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SEMI M3.6-88
STANDARD FOR 3 inch RECLAIMED SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[B]
DIAMETER	As received for reclamation.		
THICKNESS, CENTER POINT[A]	0.014	0.019	in.
FLAT LENGTH	As received for reclamation		
BOW		0.002	in.
FLATNESS[A]		25	µm
		14	µm
		10	µm
		8	µm
		6	µm

SURFACE ORIENTATION	As received for reclamation
FLAT LOCATION	As received for reclamation
BACK SURFACE FINISH	As received for reclamation
FRONT SURFACE FINISH	To SEMI M3

A: Amount of surface damage and flatness of as-received substrate determines final flatness and substrate thickness.

B: For referee purposes, the U.S. Customary units apply. To ensure that product shipped is within specification, any conversion to metric (SI) equivalents should be done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the metric (SI) equivalents are used for incoming inspection measurements, minimum values should be rounded down and maximum values rounded up to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

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SEMI M3.7-91
STANDARD FOR 125 mm SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[D]
DIAMETER	124.0	126.0	mm
THICKNESS, CENTER POINT	600	650	µm
PRIMARY FLAT LENGTH	40.0	45.0	mm
SECONDARY FLAT LENGTH	18.0	22.0	mm
BOW		60	µm
WARP		60	µm
TOTAL THICKNESS VARIATION		50	µm

SURFACE ORIENTATION[A]	(1102) ± 2.0°
FLAT LOCATION[B]	See Section 10 of SEMI M3.
BACK SURFACE FINISH	Approximately 32µin.
FRONT SURFACE FINISH[C]	The substrate shall be polished on one side suitable for the epitaxial growth of silicon. The quality of this surface may be determined by optical examination at 70× using Nomarski interference contrast microscopy after etching the substrate in potassium hydroxide at 310°C for one to three minutes. Using the photographs as a guide, Figure 5 shall be considered acceptable, while Figure 8 is unacceptable. Figure 6 and Figure 7 are questionable surfaces and subhect to individual evaluation.

[A] See Figure 1 for orientation diagrams.

[B] See Figure 3 for flat location diagram.

[C] See Figures 5 through 8 for surface finish quality levels.

[D] For referee purposes, the metric (SI) units apply. Conversion to U.S. Customary equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

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SEMI M3.8-91
STANDARD FOR 150 mm SAPPHIRE SUBSTRATES

The complete specification for this product includes all general requirements of SEMI M3.

Property	*Min*	*Max*	*Units*[D]
DIAMETER	149.0	151.0	mm
THICKNESS, CENTER POINT	650	700	µm
PRIMARY FLAT LENGTH	55.0	60.0	mm
SECONDARY FLAT LENGTH	35.0	40.0	mm
BOW		60	µm
WARP		60	µm
TOTAL THICKNESS VARIATION		60	µm

SURFACE ORIENTATION[A]	(1102) ± 2.0°
FLAT LOCATION[B]	See Section 10 of SEMI M3.
BACK SURFACE FINISH	Approximately 32 µin.
FRONT SURFACE FINISH[C]	The substrate shall be polished on one side suitable for the epitaxial growth of silicon. The quality of this surface may be determined by optical examination at 70× using Nomarski interference contrast microscopy after etching the substrate in potassium hydroxide at 310°C for one to three minutes. Using the photographs as a guide, Figure 5 shall be considered acceptable, while Figure 8 is unacceptable. Figure 6 and Figure 7 are questionable surfaces and subhect to individual evaluation.

[A] See Figure 1 for orientation diagrams.

[B] See Figure 3 for flat location diagram.

[C] See Figures 5 through 8 for surface finish quality levels.

[D] For referee purposes, the metric (SI) units apply. Conversion to U.S. Customary equivalents was done following the maximum-minimum convention in which the minimum values are rounded up and the maximum values are rounded down to ensure that the equivalent range is always inside the referee range. If the U.S. Customary equivalents are used for incoming inspection measurements, the rightmost digit of the minimum values should be reduced by 1 and the rightmost digit of the maximum values should be increased by 1 to avoid rejection of material that is within the specification when measured by the referee system of units. CAUTION — The significance of the rightmost digit may vary, depending on the quantity being measured and the precision of the test procedure. Refer to the relevant test method for precision data which can be used to construct appropriate guard bands.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M4-1296
SPECIFICATIONS FOR SOS EPITAXIAL WAFERS

1 Preface

1.1 These specifications cover requirements for monocrystalline silicon epitaxial layers on sapphire substrates, used for semiconductor device manufacture. By outlining an inspection process and defining various reject criteria, both users and suppliers can uniformly define epitaxial layer quality.

1.2 The defects discussed originate from two sources: those which are caused by imperfection in the sapphire substrate and those related to the epitaxial layer, including handling and packaging.

2 Applicable Documents

2.1 *SEMI Standard*

SEMI M3 — Specifications for Polished Monocrystalline Sapphire Substrates

2.2 *ASTM Standards*[1]

E 122 — Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

F 95 — Test Method for Thickness of Epitaxial Layers of Silicon on Substrates of the Same Type by Infrared Reflectance (Modifications to this procedure are required for use on SOS wafers.)

F 110 — Test Method for Thickness of Epitaxial or Diffused Layers in Silicon by the Angle Lapping and Staining Technique

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 374 — Test Method for Sheet Resistance of Silicon Epitaxial Layers Using a Colinear Four-Probe Array

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

2.3 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

3 Terminology

3.1 *Deposition* — The technique involved in the vapor deposition of single-crystal silicon on oriented sapphire substrates.

3.2 *Dopant* — A chemical element, usually from the third or fifth columns of the periodic table (typically phosphorous, arsenic, or boron), incorporated in trace amounts in the epitaxial layer to establish its conductivity type and resistivity.

3.3 *Doping* — The process of incorporation of a dopant into the epitaxial layer while the film is growing.

3.4 *Epitaxial Layer* — The layer of semiconductor material that is grown on the substrate.

3.5 *Lot* — For the purpose of this document, (a) all of the wafers of nominally identical specification and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of epitaxial wafers as above which have been identified by the supplier as constituting a lot.

3.6 *Pre-Epitaxial Treatment* — The process of etching an amount of material from the sapphire substrate in situ prior to deposition. H_2 is commonly used for this purpose.

3.7 *Resistivity (ohm-cm)* — For the purpose of this method, the volume resistivity which is defined as the ratio of the potential gradient parallel to the current in the material to the current density.

3.8 *Silicon Source* — Volatile or gaseous silicon compounds; silane (SiH_4) is commonly used for this purpose.

3.9 *Substrate* — The polished sapphire slice upon which the epitaxial layer is deposited.

3.10 *Surface Defects* — Refers to mechanical imperfections, SiO_2 residual dust, and other imperfections visible on the wafer surface. Some examples of surface defects are: dimples, pits, particulates, spots, scratches, smears, hillocks, and polycrystalline regions. Definitions given in ASTM Practices F 154 shall be used.

3.11 *Wafer, SOS Epitaxial Wafer* — The combined sapphire substrate with the deposited epitaxial layer.

4 Ordering Information

4.1 Purchase orders for sapphire substrates furnished to this specification shall refer to SEMI M3, Specifications for Polished Monocrystalline Sapphire Substrates.

4.2 Purchase orders for the epitaxial layer on sapphire substrates furnished to this specification shall include the following additional items:

4.2.1 Silicon source (if required),

4.2.2 Conductivity type and doping source,

4.2.3 Pre-epitaxial treatment (if required),

4.2.4 Thickness,

4.2.5 Resistivity,

4.2.6 Surface defects,

4.2.7 Methods of test and measurements (see Section 6),

4.2.8 Lot acceptance procedures (see Section 7),

4.2.9 Certification (if required) (see Section 8),

4.2.10 Packing and marking (see Section 9).

NOTE 1 Correlation of these characteristics (see Section 4) and verification test procedures or certification of these characteristics (see Section 8) shall be agreed upon between the user and supplier.

5 Requirements

5.1 The substrate material shall conform to the requirements of SEMI M3.

5.2 The epitaxial layer shall meet the requirements specified in the purchase order or contract.

5.3 *Layer Thickness Variation* — Unless otherwise specified, the radial thickness variation shall be determined from values measured at the center and edge locations, as shown in Figure 1. Point 2, at wafer center, is the nominal film thickness for the wafer. Points 1, 3, 4, and 5 are located 6 mm in from the wafer periphery and define the edge measurements. All thickness values must be within the specified range. For example, for a film specified at 0.50 10% µm, all readings at points 1–5 must range from 0.45 to 0.55 µm.

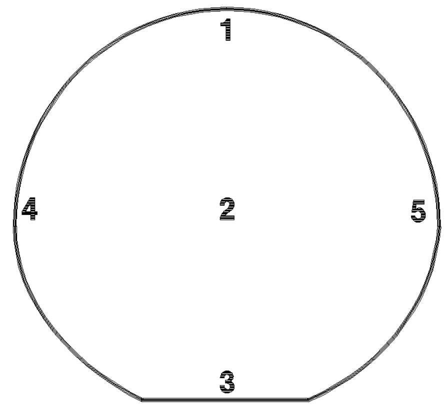

Figure 1

5.4 *Film Crystallinity* — SOS films can display varying degrees of haze due to polycrystalline silicon deposits in the film. These polycrystalline deposits can result from improper deposition temperatures, substrate surface contaminants, or contaminants in the reactor or reactor gases. Haze can be seen visually and can be quantitatively measured by ultraviolet light reflectance spectroscopy or by x-ray diffraction (pole figure) measurements. The ultraviolet light reflectance (UVR) value is commonly measured to determine the film crystalline quality. In this technique, the reflectance at two wavelengths, 280 and 440 nm, is measured using a clean, polished (100) silicon substrate as a reference. The difference between the two reflectance values, R_{280}–R_{440}, is recorded as the UVR value. For films in the thickness range 0.5 to 0.8 mm, the R_{280}–R_{440} value shall be less than 15 units. This value is an average of 5 points measured in the wafer as shown in Figure 1. The edge measurements are located at 12.5 mm in from the wafer periphery. For thinner films at 0.2 to 0.6 µm, the reflectance value at the single wavelength of 280 nm can be used. X-ray pole figure analysis measures the volume concentration of microtwins, as % (111), in the silicon film. The ultraviolet reflectance values and pole figure values are dependent on film thickness, so specified limits are listed for each film thickness in Table 1.

Table 1 Ultraviolet Reflection and X-Ray Pole Figure Values

Film Thickness	*Average Value, (MAX)*		*1 Peripheral Value, (MAX)*	
μm	ΔR_{280}	*%(111)*	ΔR_{280}	*%(111)*
0.20	15	7.0	23	11.5
0.30	17	5.5	28	9.5
0.40	21	5.0	33	8.0
0.50	27	4.5	42	7.0
0.60	32	4.0	51	6.5

$$\Delta R_{280} = \frac{|R_{ref} - R_{SOS}|}{R_{ref}}$$

NOTE 2 Currently, there is no ASTM method for this procedure. The procedure is described in the following references: M.T. Duffy, et al, National Institute of Standards and Technology Report No. NBS SP400-62, Semiconductor Measurement Technology, Contract NBS 5-35915 August 1980. M.T. Duffy, et al, J. Crystal Growth 58 (1982) 10.

5.5 *Microparticulate Density* — SOS films can display varying degrees of surface cleanliness as viewed with a microscope. Small particles trapped in the film can cause yield losses in some devices. The density of small particles can be determined by counting the particles observed during an X-Y scan across the wafers using Normarski Interference contrast at 100×. For particles greater than 2 mm in diameter, the particle density shall be less than 2 defects per square centimeter, excluding the outer 6 mm of the wafer periphery.

6 Methods of Test and Measurement

6.1 *Substrates* — Determined by methods agreed upon between the user and supplier. For measurement methods, see SEMI M3.

6.2 *Epitaxial Layer*

6.2.1 *Thickness* — Determine by method agreed upon between user and supplier. Recommended: ASTM Test Method F 95.

6.2.2 *Resistivity* — Determine by method(s) agreed upon between user and supplier. Recommended: ASTM Test Method F 374.

6.2.3 *Surface Defects and Contamination* — Determine by methods agreed upon between user and supplier. ASTM Practices F 154 is a useful guide for defining a variety of surface features and establishing commonly understood terms for describing surface defects and contamination. ASTM Practice F 523 is also recommended.

NOTE 3 SOS wafers are susceptible to surface damage. The thin film on the hard sapphire substrate may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement procedures.

NOTE 4 In this practice, defects commonly found in silicon slices are defined. Some of these terms do not apply to SOS wafers, but are present in Table 2 to provide a convenient reference point to the silicon wafer and epitaxial wafer standards.

7 Sampling

7.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot according to ANSI/ASQC Z1.4-1993. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4-1993 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between user and supplier.

8 Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

8.2 In the interest of controlling inspection costs, the supplier and purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 6; however, if the purchaser performs the test and the material fails to meet the requirements, the material may be subject to rejection.

9 Packing and Marking

9.1 Special packing requirements shall be subject to agreement between the user and supplier. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide protection against damage during shipment.

9.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or container, and each subdivision thereof, in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include supplier's name and reference number, purchaser's part number, purchaser order number, quantity, dopant, conductivity type of epitaxial layers, resistivity and thickness of the epitaxial layer; the reference number assigned by the supplier shall provide ready access to information concerning the fabrication history of the particular substrates in that lot. Such information shall be retained on file at the manufacturer's facility for at least one month after that particular lot has been accepted by the purchaser.

10 Specification Limits

10.1 *Sampling Methods*

Epi layer thickness — As specified

Epi layer resistivity — As specified

General surface — As specified

10.2 *Surface Conditions*

10.2.1 Surface inspection shall be done before any other testing is to be done. Wafers may be cleaned prior to inspection to minimize difficulty in the visual inspection of defects other than foreign matter. Requirements shall apply to the entire surface, excepting the region 4 mm from the periphery.

10.2.2 Most of the following surface defects are defined in ASTM Practices F 154. Limits are defined in Table 2.

10.2.2.1 *Appearance* — Film shall be specular in appearance.

10.3 *Thickness*

10.3.1 Epitaxial layer thickness shall be as specified when determined by the method agreed upon between user and supplier. Standard test methods, correction factors, and correlation of these characteristics shall be agreed upon between user and supplier.

10.3.2 Layer thickness variation shall be specified as described in Section 5.3.

10.4 *Resistivity*

10.4.1 Resistivity range of the epitaxial layer shall be as specified, determined by the method agreed upon between user and supplier. Standard test methods, correction factors, and correlation of these characteristics shall be agreed upon and verified between user and supplier.

10.4.2 The radial resistivity gradient shall be measured at the center and R/2, and shall be as specified.

10.5 *Film Crystallinity*

10.5.1 Film crystallinity shall be as specified when determined by the method agreed upon between user and supplier. Common practice is described in Section 5.4.

10.6 *Microparticulate Density*

10.6.1 Microparticulate density shall be as specified when determined by the method agreed upon between user and supplier. Common practice is described in Section 5.5.

Table 2 Surface Defects by Non-Destructive Means

ITEM	*CHARACTERISTICS*	*MAX ACCEPTABLE LIMIT*	*TEST METHOD*	*DEFECT DEFINITION PER*	*NOTES*
1	STACKING FAULTS	N.A.			2
2	SLIP	N.A.			2
3	PROTRUDING DEFECTS (Including spikes, hillocks, pyramids, and inclusions)	N.A.			2
4	PITS	Diameter No. 2" 4 3" 9 100 mm 15	F 523	F 154	1, 3
5	SCRATCHES	Cumulative L 1/2 wafer radius	F 523	F 154	1, 3
6	CRACKS, FRACTURES	None	F 523	F 154	5
7	ORANGE PEEL	N.A.			2
8	EDGE CHIPS	Max No. 2	F 523	F 154	2
9	EDGE CROWN	N.A.			2
10	HAZE	None	F 523	F 154	1, 6
11	FOREIGN MATTER FINGER PRINTS	None	F 523	F 154	1, 7

Notes:

1. The outer 4 mm annulus is excluded from these criteria.
2. These defects are not observed in SOS wafers. Terms remain for convenient reference to epitaxial silicon wafer specification.
3. Ninety percent of the wafers shall be free of these defects. Balance of wafer may have defects at these limits.
4. All chips shall be beveled. Maximum penetration 3 mm. Pointed apex chips none. Chips less than 0.4 mm (0.015 in.) shall not be counted. See SEMI M3, Table 3.
5. Cracks are observed in sapphire as fractures or as surface separations along cleavage planes.
6. Haze refers to the presence of polycrystalline silicon deposits in the film, as described in Section 5.4. Haze shall not be visible under lighting conditions of ASTM F 154.
7. Particulate matter easily removed by industry-accepted cleaning techniques shall not constitute foreign matter.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M6-1000
SPECIFICATION FOR SILICON WAFERS FOR USE AS PHOTOVOLTAIC SOLAR CELLS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the European Materials Committee. Current edition approved by the European Regional Standards Committee on July 28, 2000. Initially available at www.semi.org September 2000; to be published October 2000. Originally published in 1981; previously published in 1985.

NOTE: This document replaces the previous version of SEMI M6 and M6.1, M6.2, M6.3, M6.4, and M6.5 in their entirety.

1 Purpose

1.1 This specification covers the requirements for silicon wafers for use in photovoltaic (PV) solar cell manufacture.

2 Scope

2.1 The dimensional characteristics, crystalline defects and commonly used wafer electronic properties are described. Two classes of crystalline silicon materials are recognized: monocrystalline and multicrystalline.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.3 SI (System International) units are used throughout.

3 Referenced Standards

NOTE 1: The specification recognizes only two discrete material forms monocrystalline and multicrystalline. In the monocrystalline form one crystallographic orientation describes the whole wafer and in the multicrystalline case there is more than one crystallographic orientation present.

3.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

3.2 *ASTM Standards*[1]

E 122 — Standard Practice for Choice of Sample Size to Estimate the Average for a Characteristic of a Lot or Process

F 26 — Standard Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 28 — Standard Test Methods for Minority-Carrier Lifetime in Bulk Germanium and Silicon by Measurement of Photoconductivity Decay

F 42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 43 — Standard Test Methods for Resistivity of Semiconductor Materials

F 84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

F 391 — Standard Test Methods for Minority Carrier Diffusion Length in Extrinsic Semiconductors by Measurement of Steady-State Surface Photovoltage

F 398 — Standard Test Method for Majority Carrier Concentration in Semiconductors by Measurement of Wavenumber or Wavelength of the Plasma Resonance Minimum

F 533 — Standard Test method for Thickness and Thickness Variation of Silicon Wafers

F 613 — Standard Test Method for Measuring Diameter of Semiconductor Wafers

F 657 — Standard Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Noncontact Scanning

F 673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

F 1188 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F 1391 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

F 1535 — Standard Test Method for Carrier Recombination Lifetime in Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

F 1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at the Brewster Angle

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

3.3 *DIN Standards*[2]

50430 — Messung des spezifischen elektrischen Widerstandes von stabformigen Einkristallen aus Silicium oder Germanium mit dem Zwei-Sonden-Gleichstrom-Verfahren (Measurement of the Electrical Resistivity of Silicon or Germanium single Crystals in Bars by means of the Two-Point-Probe Direct Current Method)

50431 — Messung des spezifischen elektrischen Widerstandes von Einkristallen aus Silicium oder Germanium mit dem Vier-Sonden-Gleichstrom-Verfahren bei linearer Anordnung der Sonden (Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals by Means of the Four-Point-Probe Direct Current method with collinear Four Probe Array)

50432 — Bestimmung des Leitungstyps von Silicium oder Germanium mittels Richttest oder Thermosonde (Determination of the Conductivity Type of Silicon or Germanium by Means of Rectification Test or Hot-Probe)

50433-1 — Bestimmung der Orientierung von Einkristallen mit einem Roentgengoniometer (Determining the orientation of Single Crystals by Means of X-Ray Diffraction)

50433-2 — Bestimmung der Orientierung von Einkristallen nach der Lichtfigurenmethode (Determining the orientation of Single crystals by Means of Optical Reflection Figure)

50433-3 — Bestimmung der Orientierung von Einkristallen mittels Laue-Rueckstrahl-Verfahren (Determination of the Orientation of Single Crystals by Means of Laue Back Scattering)

50438-1 — Bestimmung des Verunreinigungsgehaltes in Silicium mittels lnfrarot-Absorption - Teil 1: Sauerstoff (Determination of impurity Content in silicon by Infrared Absorption - Part 1: oxygen)

50438-2 — Bestimmung des Verunreinigungsgehaltes in Silicium mittels Infrarot-Absorption; Kohlenstoff (Determination of Impurity Content in Silicon by infrared Absorption; Carbon)

50441-1 — Messung der geometrischen Dimensionen von Halbleiterscheiben - Teil 1: Dicke und Dickenvariation (Determination of the Geometric Dimensions of Semiconductor Wafers; Part 1: Measurement of Thickness)

2 Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

3.4 *ASQC standard*[3]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.5 *JEIDA standard*[4]

JEIDA-53 — Test Method for Carrier Recombination Lifetime in Silicon Wafers by Measurement of Photoconductivity Decay by Microwave Reflectance

NOTE 2: As listed or revised, all documents shall be the latest publications of adopted standards.

4 Terminology

4.1 *dopant* — A chemical element, usually from the third or fifth columns of the periodic table, incorporated in trace amounts in a semiconductor crystal to establish its conductivity type and resistivity. Common doping elements are boron and phosphorous.

4.2 *lot* — For the purposes of this document, (a) all of the wafers of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of wafers as listed above which have been identified by the supplier as constituting a lot.

4.3 *monocrystalline* — (synonym: single crystal) A body of crystalline material that contains no large-angle boundaries or twin boundaries.

4.4 *multicrystalline* — A body of crystalline material that contains large-angle boundaries or twin boundaries. Most crystals of this body have dimensions in the millimeter up to centimeter range.

5 Ordering Information

5.1 Purchase orders for silicon wafers furnished to this specification shall include the following items:

5.1.1 Nominal dimensions,

5.1.2 Either monocrystalline or multicrystalline,

5.1.3 Crystal growth method,

5.1.4 Surface orientation, crystal planes for monocrystalline wafers

5.1.5 Conductivity type and dopant,

NOTE 3: The dopant is difficult to ascertain in the finished wafers. Verification test procedures or certification (see Section 9) shall be agreed upon between the supplier and the purchaser.

5.1.6 Resistivity or resistivity range,

3 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

4 Japan Electronic Industry Development Association, 3-5-8 Shibakoen, Minato-ku, Tokyo 105, Japan

5.1.7 Lot acceptance procedures (see Section 6.4),

5.1.8 Certification (if required) (see Section 8),

5.1.9 Packing and marking (see Section 9),

5.1.10 Selection of test method to be used in evaluating those items for which alternate tests exist (see Section 7), and

5.1.11 Carbon and oxygen content.

5.2 Optional criteria. The following items may be specified optionally in addition to those listed above:

NOTE 4: Items in Paragraph 5.2 are less commonly specified than the others, but are included for completeness as parameters for which methods of evaluation have been developed.

5.2.1 Impurities other than common doping elements,

5.2.2 Diffusion length, and

5.2.3 Minority carrier lifetime.

NOTE 5: Up to now diffusion length and minority carrier lifetime cannot be measured with sufficient inter-laboratory accuracy. Subsequent recommendations, following lifetime round robin experiments, will be available in the future and will be presented in an addendum to this standard.

Even in the case of comparable and reproducible lifetime and diffusion length measurements, the measured characteristics must be regarded as an indication for solar cell efficiency. There is no general relation between initial minority carrier lifetime and solar cell efficiency as other parameters such as carbon or oxygen content will also influence the wafer in the solar cell process. However, in practical cases a dependence between minority carrier lifetime and solar cell efficiency can be found for a fixed solar cell process and a certain silicon wafer material. If one of them is changed the relation between them is suspect to change too.

6 Requirements

6.1 *Dimensions and Permissible Variations*

6.1.1 *Wafer Thickness and Variation*

6.1.1.1 Wafer thickness is typically 330 micrometer in 1999. In the future wafers should be specified in 50 micrometer intervals in the range between 150 and 400 micrometers.

6.1.1.2 The variation of wafer thickness in a lot as measured according to 7.2 at the center point of each wafer will be less than 15% of the specified wafer thickness.

6.1.2 *Rectangular Mainly Square Wafer Dimensions* — Depending upon the wafer type, one of the sections 6.1.2.1, 6.1.2.2 or 6.1.2.3 applies.

6.1.2.1 *Square Crystalline Silicon Wafer Dimensions*

6.1.2.1.1 *Physical dimensions* — See Figure 1, Table 2

Rectangular cells are permitted as long as the measures of A and B are according to the nominal size measures in Table 2.

Example: A = 100 mm, B = 150 mm.

Dimension D (identical for all sizes) min = 0.5 mm, max = 2.0 mm. By bilateral agreement, one corner can be of different angle and size to indicate the orientation of the wafer.

Squareness: The wafer will fit inside a square of the maximum dimension A and contain a square of the minimum dimension A.

6.1.2.1.2 TTV: 50 micrometer.

6.1.2.2 *Circular Monocrystalline Photovoltaic Solar Cell Silicon Wafers*

6.1.2.2.1 Diameters (mm): 100, 125, 150, 175, 200: Variation in diameter: ± 1 mm all sizes

6.1.2.2.2 TTV: 30 micrometer.

6.1.2.2.3 Warp: 75 micrometer.

6.1.2.3 *Pseudo-Square Monocrystalline Photovoltaic Solar Cell Silicon Wafers*

6.1.2.3.1 Physical dimensions: See Figure 2, Table 3

6.1.2.3.2 TTV: 30 micrometer.

6.1.2.3.3 Warp: 75 micrometer.

6.2 *Materials and Manufacture*

6.2.1 The material shall consist of wafers conforming to the structural class specified in the purchase order or contract.

6.3 *Physical Parameters*

6.3.1 The material shall conform to the crystallographic orientation details as specified in the purchase order or contract.

6.3.2 The material shall conform to the details specified in the purchase order or contract, as follows:

6.3.2.1 Conductivity type and dopant (see Note 3),

6.3.2.2 Resistivity,

6.3.2.3 Amounts of impurities other than common dopants (such as phosphorous, boron), especially oxygen and carbon content (optional),

6.3.2.4 Diffusion length (optional), and

6.3.2.5 Minority-carrier lifetime (optional).

6.4 *Wafer defect limits* — See Table 1.

Table 1 Wafer Defect Limits

Item	*Characteristics**	*Max Defect Limits*	*Notes*
1	Saw Marks	20 µm TIR	1
2	Area Contamination	To be determined	
3	Edge Chips/Indents	2 per wafer max up to l mm wide and l mm deep	2
4	Cracks/crow's feet	None	

* Characteristics are defined in SEMI M1, Section 10.

NOTE 1: The outer l mm (0.040") is excluded from these criteria.

NOTE 2: Excluding conchoidal chips.

6.5 *Sampling*

6.5.1 Unless otherwise specified, Practice E 122 shall be used.

6.5.1.1 When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

7 Test Methods

NOTE 6: Silicon wafers are extremely fragile. While the mechanical dimensions of a wafer can be measured by use of tools such as micrometer calipers and other conventional techniques, the wafer may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement methods.

7.1 *Length, Width, or Diameter* — Determine the diameter of circular wafers in accordance with ASTM Test Method F 613. Determine the side length of square wafers by a method agreed upon between the supplier and the purchaser.

7.2 *Thickness, Center Point* — Determine in accordance with ASTM Test Methods F 533 or DIN 50441-1.

7.3 *Thickness Variation* — Determine in accordance with ASTM Test Methods F 533 or F 657.

7.4 *Structural Class* — Determine the structural class by a method agreed upon between the supplier and the purchaser.

7.5 *Surface Orientation* — Determine in accordance with ASTM Test Methods F 26 or DIN 50433-1, DIN 50433-2 and DIN 50433-3.

7.6 *Conductivity Type* — Determine in accordance with ASTM Test Methods F 42 or DIN 50432.

7.7 *Resistivity* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 7: Resistivity of wafers is most appropriately determined for referee purposes by ASTM Method F 84 or DIN 50431. Reliable measurements with these methods can only be made in regions of a wafer which contain no grain boundaries; these methods are therefore not appropriate for multicrystalline material. Under some circumstances these tests may be considered destructive, and an alternative means may be required. One non-destructive test is ASTM Test method F 673, having a range from 0.001 to 100 Ω-cm. This method is relatively insensitive to the presence of grain boundaries and is recommended for all material types. Another nondestructive test is ASTM Test Method F 398. This method is limited to carrier concentrations in the ranges from 1.5×10^{18} cm^{-3} to 1.5×10^{21} cm^{-3} for n-type silicon and from 3×10^{18} cm^{-3} to 5×10^{20} cm^{-3} for p-type, and has only moderate inter-laboratory precision. Other available methods include ASTM Test methods F 43 or DIN 50430 (referee methods requiring a bar-shaped sample).

7.8 *Other Impurities* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 8: ASTM Test Methods F 1188, F 1619 and DIN 50438-1 are specific tests for oxygen. ASTM F 1391 and DIN 50438-2 are specific tests for carbon; special thick test specimens are necessary.

7.9 *Minority Carrier Diffusion Length* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 9: Methods for minority carrier diffusion length are listed in ASTM F 391.

7.10 *Minority Carrier Lifetime* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 10: Methods for minority carrier lifetime measurements are given in ASTM F 28 (bulk material), ASTM F 1535 (wafers) and JEIDA-53 (wafers). As the wafer methods measure an effective lifetime, the sample preparation (surface passivation) and measurement conditions will influence the results and must be considered.

8 Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

8.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as ‘capable of meeting’ certain requirements. In this context, ‘capable of meeting’ shall signify that the supplier is not required to perform the appropriate tests in Section 7. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

9 Packing and Package Labeling

9.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide ample protection against damage during shipment.

9.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include as a minimum the nominal diameter, conductivity type, dopant, orientation, resistivity range, and lot number. The lot number, either (1) assigned by the original manufacturer of the wafers, or (2) assigned subsequent to wafer manufacture but providing reference to the original lot number, shall provide easy access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer’s facility for at least one year after that particular lot has been accepted by the purchaser.

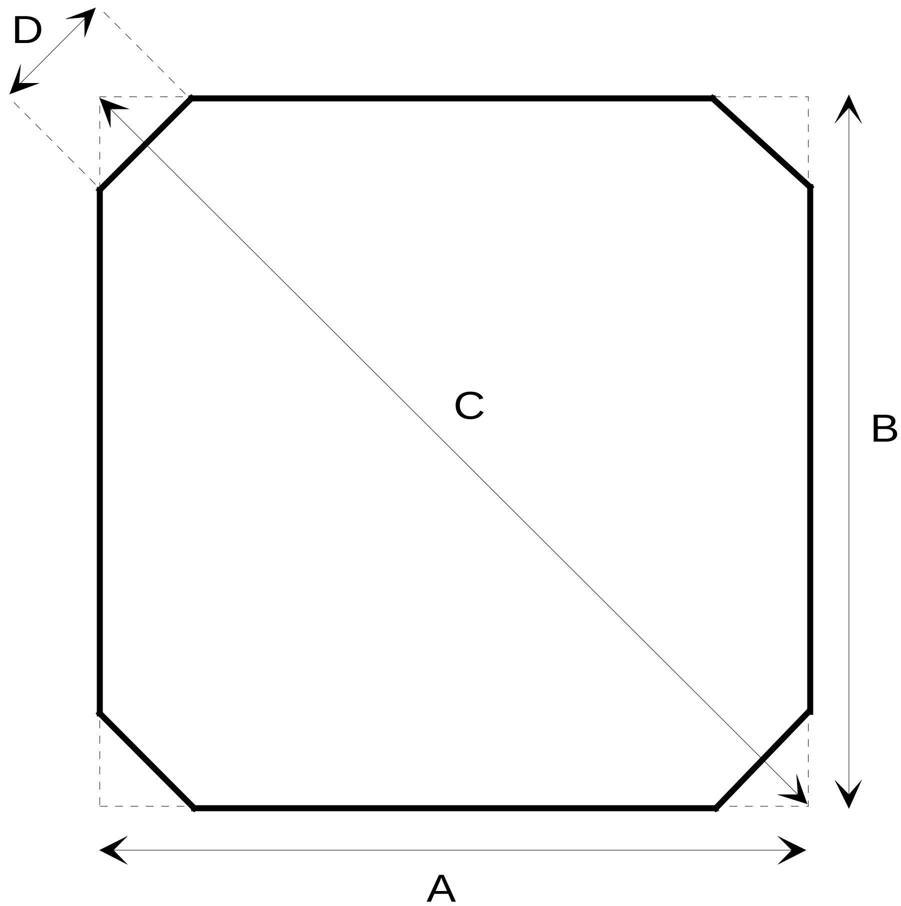

Figure 1
Rectangular Mainly Square Photovoltaic Solar Cell Silicon Wafer Dimensions

Table 2 Rectangular Mainly Square Photovoltaic Solar Cell Silicon Wafer Dimensions (letters as in Figure 1)

Nominal Size (mm)	*Dimensions (mm)*							
	A		*B*		*C*		*D*	
	Max.	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*
100	101	99	101	99	142.8	140.0	2.0	0.5
125	126	124	126	124	187.2	175.4	2.0	0.5
150	151	149	151	149	213.5	210.7	2.0	0.5
200	201	199	201	199	284.3	281.4	2.0	0.5

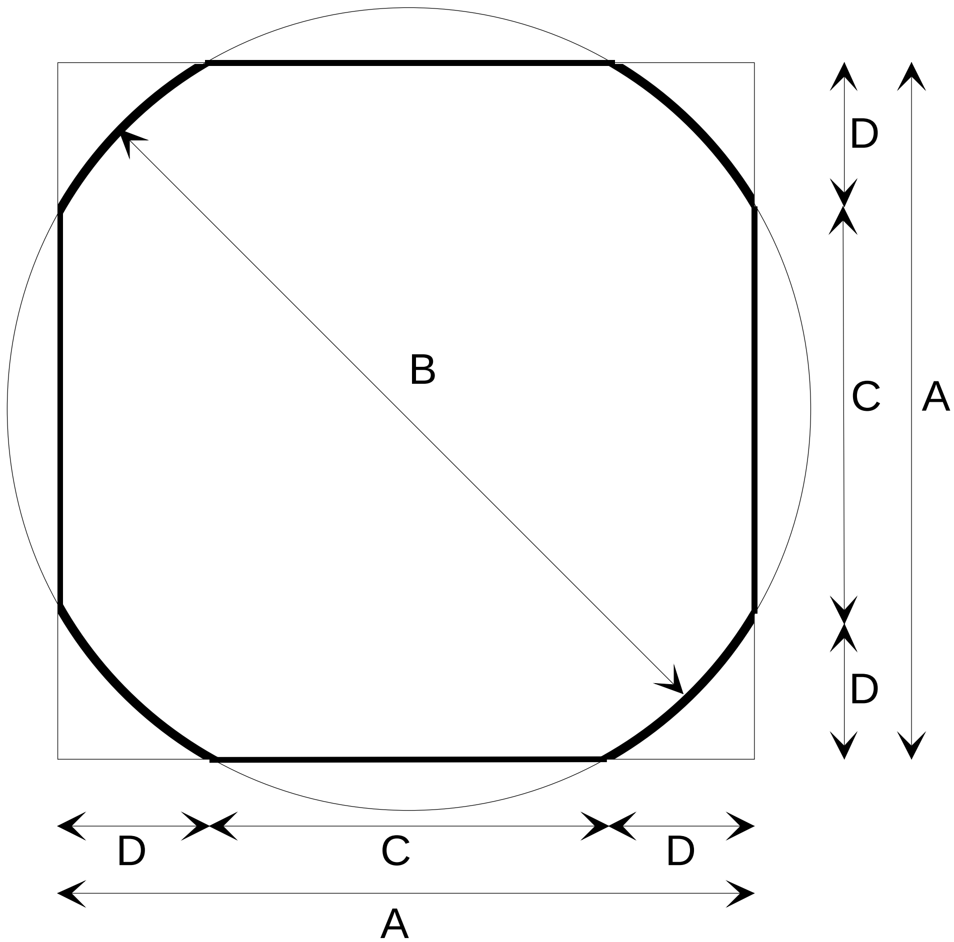

Figure 2
Pseudo-Square Monocrystalline Photovoltaic Solar Cell Silicon Wafer Dimensions

Table 3 Pseudo-Square Monocrystalline Photovoltaic Solar Cell Silicon Wafer Dimensions (letters as in Figure 2)

Nominal size (mm)	*Dimensions (mm)*							
	A		*B*		*C*		*D*	
	Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
100	99	101	124	126	71.9	77.9	10.6	14.6
125	124	126	149	151	79.5	86.2	23.2	28.9
150	149	151	174	176	86.4	93.7	27.6	32.3

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI M6 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A1-1 *Crystal Orientation of Monocrystalline silicon wafers*

A1-1.1 A typical crystal orientation for monocrystalline silicon wafers is <100>.in the plane of the wafer.

A1-2 *Wafer resistivity*

A1-2.1 Typical wafer resistivity is between 0.5 Ω-cm and 2 Ω-cm.

A1-3 *Oxygen and Carbon Contents*

A1-3.1 Typical values.

A-1.3.1.1 Interstitial oxygen < 1×10^{18} at/cm^3 for CZ material and less than 8×10^{17} at/cm^3 for multicrystalline wafers.

A-1.3.1.2 Substitutional carbon < 5×10^{17} at/cm^3 for CZ and 1×10^{18} at/cm^3 for multicrystalline material.

A1-4 *Lifetime and Minority Carrier Diffusion Length*

A1-4.1 Typical minority carrier lifetime values for wafers used in the solar cell manufacturing process lie in a range between 1 µs and 20 µs.

NOTICE: SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of these guidelines is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These guidelines are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M8-0301
SPECIFICATION FOR POLISHED MONOCRYSTALLINE SILICON TEST WAFERS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1984; previously published September 1999.

1 Purpose

1.1 This specification covers requirements for virgin silicon test wafers to be used for testing and process monitoring in semiconductor manufacturing.

2 Scope

2.1 Dimensional and crystallographic orientation characteristics and limits on surface defects are the only standardized properties included in this specification.

2.2 A complete purchase specification requires that additional physical properties be defined. These properties are listed, together with test methods suitable for determining their magnitude.

2.3 This specification is directed specifically to silicon wafers with one polished surface. Wafers polished on both sides, or unpolished, or with epitaxial deposits are not covered; however, purchasers of such wafers may find this specification to be a useful guide in defining their requirements.

2.4 This specification classifies test wafers according to surface condition defect levels and dimensional tolerances. Test wafer classifications are summarized in Tables 1 and 2.

2.5 For applications placing higher demands on silicon wafers such as particle counting, measuring particle resolution in a photolithography process, or surface ion contamination monitoring, the user may reference the SEMI M1 or M24 standards.

2.6 For referee purposes, U.S. customary units shall be used for wafers of 2- and 3-inch nominal diameter and SI (System International), commonly called metric units, for 100 mm and larger diameter wafers.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M24 — Specification for Polished Monocrystalline Silicon Premium Wafers

SEMI M25 — Specification for Silicon Wafers for Calibration of Light Point Defect Wafer Inspection Systems with Respect to the Diameter of Polystyrene Latex Spheres

3.2 *ANSI/ASQC Standards*[1]

For a comprehensive list of applicable ANSI/ASQC Standards, see those listed in Table 1 of SEMI M18.

3.3 *ASTM Standards*[2]

For a comprehensive list of applicable ASTM Standards, see those listed in Table 1 of SEMI M18.

3.4 *DIN Standards*[3]

For a comprehensive list of applicable DIN Standards, see those listed in Table 1 of SEMI M18.

3.5 *JIS Standards*[4]

For a comprehensive list of applicable JIS Standards, see those listed in Table 1 of SEMI M18.

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

1 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

4 Japanese Standards Association, 1-24, Akasaka, 4-Chome, Minato-ku, Tokyo 107 Japan

4 Terminology

4.1 Definitions of terms related to silicon wafer technology are given in ASTM Terminology F 1241.

4.2 Definitions for some additional terms are given in SEMI M1.

4.3 The following definitions apply in the context of this specification:

mechanical test wafer — silicon wafer suitable for testing equipment with emphasis on dimensional and structural characteristics only.

process test wafer — silicon wafer suitable for processes as well as area and process cleanliness (higher grade than mechanical test).

test wafer — silicon wafer suitable for process monitoring in semiconductor manufacturing. Also called *monitor wafer*.

virgin test wafer — test wafer that has not been used previously in semiconductor manufacturing.

5 Ordering Information

5.1 Purchase orders for 2", 3", 100 mm and 125 mm silicon test wafers furnished to this specification shall include the items from the appropriate specification groups listed in Table 1.

Table 1 Wafer Classifications

Classification	*Applicable Specification Groups*
A	1, 2, 3
B	1, 2
C	1

5.2 Items which may be specified when ordering silicon wafers are listed in SEMI M18. Not all of these items are required for ordering test wafers. The following items are included in the three specification groups; numbers in square brackets following the item are the item numbers in SEMI M18:

5.2.1 *Group 1*, *General and Geometrical* — Growth method [1.1], diameter [6.1], surface orientation [6.9], thickness [6.7], orientation fiducials (flats and notches) [6.2–6.5], and edge profile [6.6].

5.2.2 *Group 2, Surface Characteristics* — Surface defects as listed in Tables 3 and 4 [7.1–7.2, 8.1–8.16].

5.2.3 *Group 3, Basic Intrinsic Properties* — Conductivity type [1.3], dopant [1.4], and resistivity [2.1].

5.3 Not all of the above items must be specified explicitly; the specifications for many of the items are determined by the combination of wafer classification and nominal diameter. In all cases, the following must be specified on the purchase order for all classes of 2", 3" 100 mm and 125 mm test wafers.

5.3.1 Wafer Classification (A, B or C)

5.3.2 Nominal diameter and surface orientation

5.3.3 Growth method (see Section 7)

5.3.4 Lot acceptance procedures (see Section 9)

5.3.5 Certification (if required) (see Section 12)

5.3.6 Packing and Marking (see Section 13)

5.4 For Class A and B test wafers, that require controlled surface characteristics (see Section 11), in addition to the items listed in Section 5.3, see Table 4, Sections 8.1–8.16.

5.5 For Class A wafers, the following must be specified in addition to the items listed in Sections 5.3 and 5.4 (see Section 8):

5.5.1 Conductivity type

5.5.2 Resistivity

5.6 Purchase Orders for 150 mm, 200 mm, and 300 mm silicon test wafers shall include the items from the appropriate specification groups listed in Table 2.

Table 2 Wafer Classifications

Classifications	*Applicable Specification Groups*
Mechanical	1
Process	1, 2

5.6.1 *Group 1, General and Geometrical* — Growth method [1.1], diameter [6.1], surface orientation [6.9], thickness [6.7], orientation fiducials (flats and notches) [6.2–6.5], and edge profile [6.6].

5.6.2 *Group 2, Surface and Intrinsic Properties* — Surface defects as listed in Table 3 [7.1–7.2, 8.1–8.16], conductivity type [1.3], dopant [1.4], and resistivity [2.1].

5.7 Not all the specifications must be specified explicitly; the specifications for many of the items are determined by wafer classification and nominal diameter. In all cases the following must be specified on the purchase order for all classes of 150 mm, 200 mm, and 300 mm test wafers:

5.7.1 Wafer Classification (*Mechanical* or *Process)*

5.7.2 Nominal diameter and surface orientation

5.7.3 Growth method (see Section 7)

5.7.4 Lot acceptance procedures (see Section 9)

5.7.5 Certification (if required) (see Section 12)

5.7.6 Packing and Marking (see Section 13)

6 Dimensions and Permissible Variations

6.1 The material shall conform to the parameters as specified in Tables 3 or 4.

6.2 If test wafers are specified to be edge contoured, the profile shall conform to the requirements in Section 5.2 of SEMI M1 and to the dimension C_y in the associated polished silicon wafer standard applicable to the same nominal diameter and thickness. If edge profiling is not specified explicitly, there is no specification for the geometrical dimensions of any profiles which may exist on the wafers.

6.3 The material shall conform to the crystallographic orientation details as listed in the tables.

7 Materials and Manufacture

7.1 The material shall consist of wafers from crystals grown by the process specified in the purchase order or contract.

8 Electrical Requirements

8.1 The material shall conform to the details specified in the purchase order or contract, as follows:

8.1.1 Conductivity type

8.1.2 Resistivity

9 Sampling

9.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

10 Test Methods

NOTE 2: Silicon wafers are extremely fragile. While the mechanical dimensions of a wafer can be measured by use of tools such as micrometer calipers and other conventional techniques, the wafer may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement methods.

NOTE 3: The crystal growth method (for example, Czochralski or Float Zone) and dopant (for example, boron, phosphorous or antimony) used are difficult to ascertain in finished wafers. Verification test procedures for certification of these characteristics shall be agreed upon between the supplier and the purchaser.

10.1 *Diameter* — Determine in accordance with ASTM Test Method F 613.

10.2 *Thickness, Center Point* — Determine in accordance with ASTM Test Method F 533 or DIN 50441/1, or JIS H 0611.

10.3 *Flat Length* — Determine in accordance with ASTM Test Method F 671.

10.4 *Flat Orientation* — Determine in accordance with ASTM Test Methods F 847.

10.5 *Surface Orientation* — Determine in accordance with ASTM Test Methods F 26 or DIN 50433.

10.6 *Surface Defects and Contamination* — Determine in accordance with ASTM Practice F 523. The following conditions shall be used (unless otherwise specified in the purchase or contract):

a. Background light intensity: 8 ± 2 fc (86 ± 22 lux)

b. Angle α (alpha): 45° ± 10°

c. Angle β (beta): 90° ± 10°

See Section 11 for surface defect criteria and Table 2 for allowable levels of defects. In the event the wafers fail to meet these criteria, they shall be conditioned according to ASTM Practice F 612 or other cleaning procedure as agreed upon between supplier and user and retested.

NOTE 4: ASTM Practices F 154 is a useful guide for defining a variety of surface features found on silicon surfaces and for establishing commonly understood terms for describing them. It also gives detailed procedures for illumination and microscopical examination of surfaces.

10.7 *Conductivity Type* — Determine in accordance with ASTM Test Methods F 42 or DIN 50432.

10.8 *Resistivity* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 5: Resistivity of wafers is most appropriately determined for referee purposes by ASTM Method F 84 or DIN 50431. Under some circumstances these tests may be considered destructive, and an alternative means may be required. A widely used nondestructive test is ASTM Test Methods F 673, having a range from 0.0001 to 200 Ω • cm.

10.9 *Radial Resistivity Variation* — Determine in accordance with ASTM Test Methods F 81 or DIN 50435.

10.10 *Crystal Perfection* — Determine in accordance with ASTM Test Method F 47 or DIN 50434 (to determine grain boundaries, twinning, slip, dislocations, and lineage).

10.11 *Edge Profile* — Determine in accordance with ASTM Test Methods F 928 or DIN 50441/2.

11 Surface Defect Criteria

11.1 *Minimal Conditions or Dimensions* — The minimal conditions or dimensions for defects stated below shall be used for determining wafer acceptability. Anomalies smaller than these limits shall not be considered defects.

11.2 *area contamination* — any foreign matter on the surface in localized areas which is revealed under the inspection lighting conditions as discolored, mottled, or cloudy appearance resulting from smudges, stains, water spots, etc.

11.3 *crack* — any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.4 *crow's foot* — any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.5 *dimple* — any smooth surface depression greater than 3 mm in diameter.

11.6 *edge chip and indent* — any edge anomaly including saw exit marks conforming to the definition and greater than 0.25 mm (0.010 inch) in radial depth and peripheral length.

11.7 *hand scribe mark* — any mark such as that caused by a diamond scribe that is visible under diffuse illumination.

11.8 *haze* — haze is indicated when the image of a narrow beam tungsten lamp filament is detectable on the polished wafer surface. (Under some conditions contamination may appear as haze.)

11.9 *orange peel* — any roughened surface conforming to the definition that is observable under diffuse illumination.

11.10 *particulate contamination* — distinct particles resting on the surface which are revealed under collimated light as bright points.

11.11 *pit* — any individually distinguishable non-removable surface anomaly conforming to the definition and visible when viewed under high intensity illumination.

11.12 *saw marks* — any surface irregularities conforming to the definition that is observable under diffuse illumination.

11.13 *scratch* — any anomaly conforming to the definition and having a length-to-width ratio greater than 5:1.

11.14 *slip* — any pattern of short ridges aligned along <110> directions and visible under diffuse illumination.

11.15 *striations* — any helical features conforming to the definition and visible under diffuse illumination.

12 Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

12.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 10. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

13 Packing and Marking

13.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices, to provide ample protection against damage during shipment.

13.2 The wafers supplied under this specification shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing.

Table 3 Format for 150 mm, 200 mm, and 300 mm Silicon Test Wafer Form for Order Entry

EDI Code		*Item*	*Specification*	
			CLASSIFICATION **PROCESS**	**MECHANICAL**
	1.0	**General Characteristics**		
	1.1	Growth Method	CZ or MCZ	CZ or MCZ
	1.2	Crystal Orientation	User specified	Unspecified
	1.3	Conductivity Type	[ ]P or [ ]N	Unspecified
	1.4	Dopant	[ ]Boron [ ]Phos	Unspecified
	1.5	Nominal Edge Exclusion Distance for FQA	3 mm	3 mm
	2.0	**Electrical Characteristics**		
	2.1	Resistivity	> 1 ohm-cm	Unspecified
	2.2	Radial Resistivity Variation (RRG)	Unspecified	Unspecified
	2.3	Resistivity Striations	Unspecified	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified	Unspecified
	3.0	**Chemical Characteristics**		
	3.1	Oxygen Concentration	Unspecified	Unspecified
	3.2	Radial Oxygen Variation	Unspecified	Unspecified
	3.3	Carbon Concentration	Unspecified	Unspecified
	4.0	**Structural Characteristics**		
	4.1	Dislocation Etch Pit Density	$\leq 500/cm^2$	Unspecified
	4.2	Slip	None	Unspecified
	4.3	Lineage	None	Unspecified
	4.4	Twins	None	Unspecified
	4.5	Swirl	Unspecified	Unspecified
	4.6	Shallow Pits	Unspecified	Unspecified
	4.7	OISF	Unspecified	Unspecified
	4.8	Oxide Precipitates	Unspecified	Unspecified
	5.0	**Wafer Preparation Characteristics**		
	5.1	Wafer ID Marking	Optional	Optional
	5.2	Front Surface Thin Films	Unspecified	Unspecified
	5.3	Denuded Zone	Unspecified	Unspecified
	5.4	Extrinsic Gettering	Unspecified	Unspecified
	5.5	Backseal	Unspecified	Unspecified
	5.6	Annealing	Unspecified	Unspecified
	6.0	**Mechanical Characteristics**		
	6.1	Diameter		
		150 mm ±	SEMI M1	SEMI M1
		200 mm ±	SEMI M1	SEMI M1
		300 mm ±	SEMI M1	SEMI M1
	6.2	Primary Flat Dimension (or Notch Depth)		
		150 mm (flat length — option #1)	SEMI M1	SEMI M1

EDI Code		*Item*	*Specification*	
			CLASSIFICATION	
			PROCESS	**MECHANICAL**
		150 mm (flat length — option #2)	SEMI M1	SEMI M1
		200 mm (notch depth)	SEMI M1	SEMI M1
		200 mm (flat diameter)	SEMI M1	SEMI M1
		300 mm (notch depth)	SEMI M1	SEMI M1
	6.3	Primary Flat/Notch Orientation (See NOTE 1.)	SEMI M1	SEMI M1
	6.4	Secondary Flat Length (all diameters up to 200 mm)	SEMI M1	SEMI M1
		Secondary Flat Length (300 mm)	None	None
	6.5	Secondary Flat Location	SEMI M1	SEMI M1
	6.6	Edge Profile	SEMI M1	SEMI M1
	6.7	Thickness		
		150 mm (SEMI M1)	SEMI M1	SEMI M1
		150 mm (SEMI M1.13)	SEMI M1	SEMI M1
		200 mm (notched or flatted)	SEMI M1	SEMI M1
		300 mm	SEMI M1	SEMI M1
	6.8	Thickness Variation (TTV)	Unspecified	Unspecified
	6.9	Surface Orientation (for all diameters up to 200 mm)	Unspecified	Unspecified
		Surface Orientation (for 300 mm)	Unspecified	Unspecified
	6.10	Bow	Unspecified	Unspecified
	6.11	Warp	Unspecified	Unspecified
	6.12	Sori	Unspecified	Unspecified
	6.13	Flatness/Global	Unspecified	Unspecified
	6.14	Flatness/Site	Unspecified	Unspecified
	7.0	**Front Surface Chemistry**		
	7.1	Surface Metal Contamination		
		Sodium	$< 1 \times 10^{11}/cm^2$	Unspecified
		Aluminum	$< 1 \times 10^{11}/cm^2$	Unspecified
		Chromium	$< 1 \times 10^{11}/cm^2$	Unspecified
		Iron	$< 1 \times 10^{11}/cm^2$	Unspecified
		Nickel	$< 1 \times 10^{11}/cm^2$	Unspecified
		Copper	$< 1 \times 10^{11}/cm^2$	Unspecified
		Zinc	$< 1 \times 10^{11}/cm^2$	Unspecified
		Calcium	$< 1 \times 10^{11}/cm^2$	Unspecified
	8.0	**Front Surface Visual Characteristics**		
	8.1a	Scratches (macro) – total length	None	Unspecified
	8.1b	Scratches (micro) – total length	< 0.10 × Diameter	Unspecified
	8.2	Pits	None	Unspecified
	8.3	Haze	None	Unspecified
	8.4	Localized Light Scatterers		
		150 mm	$< 0.20/cm^2$ @ ≥ 0.20 µm	Unspecified
		200 mm	$< 0.20/cm^2$ @ ≥ 0.20 µm	Unspecified
		300 mm	$< 0.20/cm^2$ @ ≥ 0.20 µm	Unspecified
	8.5	Contamination/area	None	Unspecified

EDI Code		*Item*	*Specification*	
			CLASSIFICATION	
			PROCESS	**MECHANICAL**
	8.6	Edge Chips	None	Unspecified
	8.7	Edge Cracks	None	Unspecified
	8.8	Cracks, Crow’s feet	None	Unspecified
	8.9	Craters	None	Unspecified
	8.10	Dimples	None	Unspecified
	8.11	Grooves	None	Unspecified
	8.12	Mounds	None	Unspecified
	8.13	Orange Peel	None	Unspecified
	8.14	Saw Marks	None	Unspecified
	9.0	**Back Surface Characteristics**		
	9.1	Edge Chips	None	Unspecified
	9.6	Roughness	Unspecified	Unspecified
	9.7	Brightness (gloss)		
		150 mm/200 mm	Unspecified	Unspecified
		300 mm	> 80%	> 80%
	TBD	Localized Light Scatterers (LLS’s)	Unspecified	Unspecified
	TBD	Scratches (macro)	< 0.25 × Diameter	Unspecified
	TBD	Scratches (micro)	Unspecified	Unspecified
	10.0	**Other Characteristics**		
	TBD	Edge Condition		
		150 mm/200 mm	Unspecified	Unspecified
		300 mm	Polished	Unspecified

NOTE 1: For (111) wafers, the $(1\bar{1}0)$, $(01\bar{1})$, and $(\bar{1}01)$ planes are equivalent, allowable planes. For (100) wafers, the allowable equivalent {110} planes are $(01\bar{1})$, (011), $(0\bar{1}1)$, and $(0\bar{1}\bar{1})$.

Table 4 Format for 2", 3", 100 mm, and 125 mm Silicon Test Wafer Form for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	User specified
	1.2	Crystal Orientation	User specified
	1.2.1	Crystal Orientation	User specified
	1.3	Conductivity Type	User specified
	1.4	Dopant	User specified
	1.5	Nominal Edge Exclusion Distance for FQA	Not specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Optional
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified

EDI Code		*Item*	*Specification*		
	3.2	Radial Oxygen Variation		Unspecified	
	3.3	Carbon Concentration		Unspecified	
	4.0	**Structural Characteristics**		**CLASSIFICATION**	
			A	**B**	**C**
	4.1	Dislocation Etch Pit Density	None	Optional	Unspecified
	4.2	Slip	None	Optional	Unspecified
	4.3	Lineage	None	Optional	Unspecified
	4.4	Twins	None	Optional	Unspecified
	4.5	Swirl	None	Optional	Unspecified
	4.6	Shallow Pits	None	Optional	Unspecified
	4.7	OISF	Optional	Optional	Unspecified
	4.8	Oxide Precipitates	Unspecified	Unspecified	Unspecified
	5.0	**Wafer Preparation Characteristics**			
	5.1	Wafer ID Marking	Optional	Optional	Unspecified
	5.2	Front Surface Thin Films	Optional	Optional	Unspecified
	5.3	Denuded Zone	Optional	Optional	Unspecified
	5.4	Extrinsic Gettering	Optional	Optional	Unspecified
	5.5	Backseal	Optional	Optional	Unspecified
	5.6	Annealing	Optional	Optional	Unspecified
	6.0	**Mechanical Characteristics**			
	6.1	Diameter			
		2.00 inch ±	0.015 in	0.020 in	0.030 in
		3.00 inch ±	0.020 in	0.025 in	0.050 in
		100 mm ±	0.20 mm	0.50 mm	1.00 mm
		125 mm ±	0.20 mm	0.50 mm	1.00 mm
	6.2	Primary Flat Dimension			
		2.00 inch (flat length)	0.500–0.750 in	0.500–0.750 in	0.500–0.750 in
		3.00 inch (flat length)	0.750–1.00 in	0.750–1.00 in	0.750–1.00 in
		100 mm (flat length)	30–35 mm	28–37 mm	28–37 mm
		125 mm (flat length)	40–45 mm	38–47 mm	38–47 mm
	6.3	Primary Flat Orientation	1-1-0 ± 2°	1-1-0 ± 2°	1-1-0 ± 2°
	6.4	Secondary Flat Length	Unspecified	Unspecified	Unspecified
	6.5	Secondary Flat Location	Unspecified	Unspecified	Unspecified
	6.6	Edge Profile	SEMI M1	SEMI M1	Optional
	6.7	Thickness			
		2 inch	0.0095–0.0125 in	0.0090–0.013 in	0.0080–0.0130 in
		3 inch	0.0135–0.0165 in	0.013–0.017 in	0.012–0.018 in
		100 mm (SEMI M1.5)	505–545 µm	500–550 µm	475–575 µm
		100 mm (SEMI M1.6)	605–645 µm	600–650 µm	575–675 µm
		125 mm	605–645 µm	600–650 µm	575–675 µm
	6.8	Thickness Variation (TTV)	Unspecified	Unspecified	Unspecified
	6.9	Surface Orientation	User specified	Optional	Unspecified
	6.10	Bow	Unspecified	Unspecified	Unspecified
	6.11	Warp	Unspecified	Unspecified	Unspecified
	6.12	Sori	Unspecified	Unspecified	Unspecified

EDI Code		*Item*	*Specification*		
	6.13	Flatness/Global	Unspecified	Unspecified	Unspecified
	6.14	Flatness/Site	Unspecified	Unspecified	Unspecified
	7.0	**Front Surface Chemistry**			
	7.1	Surface Metal Contamination			
		Sodium	Optional	Unspecified	Unspecified
		Aluminum	Optional	Unspecified	Unspecified
		Potassium	Optional	Unspecified	Unspecified
		Chromium	Optional	Unspecified	Unspecified
		Iron	Optional	Unspecified	Unspecified
		Nickel	Optional	Unspecified	Unspecified
		Copper	Optional	Unspecified	Unspecified
		Zinc	Optional	Unspecified	Unspecified
	7.2	Surface Organics	Optional	Unspecified	Unspecified
	8.0	**Front Surface Visual Characteristics**			
	8.1	Scratches (# of)	User specified	User specified	Unspecified
		(cumulative length)	R/5	R/2	Unspecified
	8.2	Pits	None	None	Unspecified
	8.3	Haze	None	None	Unspecified
	8.4	Localized Light Scatterers (density per sq. meter)	(Density per square meter with 4 mm edge exclusion)		
		2 inch	< 1900	< 5000	Unspecified
		3 inch	< 1900	< 5000	Unspecified
		100 mm	< 1900	< 5000	Unspecified
		125 mm	< 1900	< 5000	Unspecified
	8.5	Contamination/area	None	None	Unspecified
	8.6	Edge Chips	None	None	Unspecified
	8.7	Edge Cracks	None	None	Unspecified
	8.8	Cracks, Crow's feet	None	None	Unspecified
	8.9	Craters	None	None	Unspecified
	8.10	Dimples	None	None	Unspecified
	8.11	Grooves	None	None	Unspecified
	8.12	Mounds	None	None	Unspecified
	8.13	Orange Peel	None	None	Unspecified
	8.14	Saw Marks	None	None	Unspecified
	8.15	Dopant Striation Rings	None	None	Unspecified
	8.16	Stains	None	None	Unspecified
	9.0	**Back Surface Characteristics**			
	9.1	Edge Chips	None	None	Unspecified
	9.2	Cracks, Crow's feet	None	None	Unspecified
	9.3	Contamination/Area	None	None	Unspecified
	9.4	Saw Marks	None	None	Unspecified
	9.5	Stains	None	None	Unspecified
	9.6	Roughness	Unspecified	Unspecified	Unspecified
	9.7	Brightness (gloss)	Unspecified	Unspecified	Unspecified
	TBD	Back Surface Finish	Unspecified	Unspecified	Unspecified

Table 5 Guide For The Specification Of 0.18 µm Design Rule 200 mm Polished Silicon Test Wafers

EDI Code		*Item*	*P- Test Wafer*
	1.0	**GENERAL CHARACTERISTICS**	
	1.1	Growth Method	CZ or MCZ
	1.2	Crystal Orientation	1-0-0
	1.3	Conductivity Type	P
	1.4	Dopant	Boron
	1.5	Nominal Edge Exclusion	3 mm
	2.0	**ELECTRICAL CHARACTERISTICS**	
	2.1	Resistivity	0.5–50.0 ohm-cm (See NOTE 1.)
	2.2	Radial Resistivity Variation	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Recombination Lifetime	Unspecified
	3.0	**CHEMICAL CHARACTERISTICS**	
	3.1.1	Oxygen Concentration	$\leq$ 32 ppma (old ASTM F121-79)
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**STRUCTURAL CHARACTERISTICS**	
	4.2	Slip	none
	4.3	Lineage	none
	4.4	Twins	none
	4.5	Swirl	Unspecified
	4.6	Shallow pits	Unspecified
	4.7	Oxidation-Induced Stacking Faults (OISF)	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**WAFER PREPARATION CHARACTERISTICS**	
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	None
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	6.0	**MECHANICAL CHARACTERISTICS**	
	6.1	Diameter	200 ± 0.2 mm
	6.2	Primary Fiducial Location	SEMI M1
	6.3	Primary Fiducial Dimension	SEMI M1
	6.6	Edge Profile	SEMI M1
	6.7	Thickness	725 ± 25 µm
	6.8	Thickness Variation (TTV)	5 µm max.
	6.9	Wafer Surface Orientation	1-0-0 + 1°
	6.11	Warp	50 µm max.
	6.12	Sori	Unspecified
	6.14	Flatness/Site	Unspecified

EDI Code		Item	P- Test Wafer
	7.0	**FRONT SURFACE CHEMISTRY**	
	7.1	Surface Metal Contamination	
		Sodium	≤ 1 x 10^{11}/cm^2
		Aluminum	≤ 1 x 10^{11}/cm^2
		Chromium	≤ 1 x 10^{11}/cm^2
		Iron	≤ 1 x 10^{11}/cm^2
		Nickel	≤ 1 x 10^{11}/cm^2
		Copper	≤ 1 x 10^{11}/cm^2
		Zinc	≤ 1 x 10^{11}/cm^2
		Calcium	≤ 1 x 10^{11}/cm^2
	8.0	**FRONT SURFACE CRITERIA**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	< 0.10 × Diameter
	8.2	Pits	None
	8.3	Haze	None
	8.4	Localized Light Scatterers	< 0.20/cm^2 @ ≥ 0.20 µm
	8.5	Contamination/Area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Crack, crows feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**BACK SURFACE CRITERIA**	
	9.1	Edge Chips	none
	9.6	Roughness	Unspecified
	9.7	Brightness (Gloss)	Unspecified
	TBD	Localized Light Scatterers	Unspecified
	TBD	Scratches (macro) – total length	< 50 mm
	TBD	Scratches (micro) – total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge Condition	Polished

NOTE 1: For implant controls and sheet resistivity measurements, a narrower resistivity range may be preferable.

Table 6 Guide For The Specification Of 0.13 µm Design Rule 300 mm Polished Silicon Test Wafers

EDI Code		Item	P- Test Wafer
	1.0	**GENERAL CHARACTERISTICS**	
	1.1	Growth Method	CZ or MCZ
	1.2	Crystal Orientation	1-0-0
	1.3	Conductivity Type	P

EDI Code		*Item*	*P- Test Wafer*
	1.4	Dopant	Boron
	1.5	Nominal Edge Exclusion	3 mm
	2.0	**ELECTRICAL CHARACTERISTICS**	
	2.1	Resistivity	0.5–50 ohm-cm
	2.2	Radial Resistivity Variation	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Recombination Lifetime	Unspecified
	3.0	**CHEMICAL CHARACTERISTICS**	
	3.1.1	Oxygen Concentration	≤ 32 ppma (old ASTM F121-79)
	3.2	Radial Oxygen Variation	Unspecified
	4.0	**STRUCTURAL CHARACTERISTICS**	
	4.1	Dislocation Etch Pit Density	See NOTE 1.
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	none
	4.5	Swirl	Unspecified
	4.6	Shallow pits	Unspecified
	4.7	Oxidation-Induced Stacking Faults (OISF)	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**WAFER PREPARATION CHARACTERISTICS**	
	5.1	Wafer ID Marking	See NOTE 2.
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	None
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	6.0	**MECHANICAL CHARACTERISTICS**	
	6.1	Diameter	300 ± 0.2 mm
	6.2	Primary Fiducial Location	See SEMI M1.
	6.3	Primary Fiducial Dimension	See SEMI M1.
	6.6	Edge Profile	See SEMI M1.
	6.7	Thickness	775 ± 25 µm
	6.8	Thickness Variation (TTV)	10 µm max.
	6.9	Wafer Surface Orientation	1-0-0 ± 1°
	6.11	Warp	User Specified
	6.14	Flatness/Site	See NOTE 3.
	7.0	**FRONT SURFACE CHEMISTRY**	
	7.1	Surface Metal Contamination	
		Sodium	≤ 5 x 10^{10}/cm^2
		Aluminum	≤ 5 x 10^{10}/cm^2
		Chromium	≤ 1 x 10^{10}/cm^2
		Iron	≤ 1 x 10^{10}/cm^2
		Nickel	≤ 1 x 10^{10}/cm^2

EDI Code		*Item*	*P- Test Wafer*
		Copper	≤ 1 x 10^{10}/cm^2
		Zinc	≤ 5 x 10^{10}/cm^2
		Calcium	≤ 5 x 10^{10}/cm^2
	8.0	**FRONT SURFACE CRITERIA**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	< 0.10 × Diameter
	8.2	Pits	None
	8.3	Haze	None
	8.4	Localized Light Scatterers	See NOTE 4.
	8.5	Contamination/Area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Crack, crows feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**BACK SURFACE CRITERIA**	
	9.1	Edge Chips	None
	9.6	Roughness	Unspecified
	9.7	Brightness (Gloss)	Unspecified
	TBD	Visual Defects	≤ 25 defects/wafer
	TBD	Scratches (macro) – total length	None
	TBD	Scratches (micro) – total length	≤ 150 mm
	10.0	**Other Characteristics**	
	TBD	Edge Condition	Polished

NOTE 1: Dislocation etch pit density is not specified. Wafers are permitted to be vacancy-rich or self-interstitial rich, and "ring" structures are allowable (V-I boundary within the FQA).

NOTE 2: Backside T7 per SEMI M1.15; backside M12 OCR mark per SEMI M1.15 may be optionally added but is expected to be used only on a temporary basis and to become obsolete after experience with the T7 mark demonstrates success.

NOTE 3: Site flatness specified as SFQR, 25 mm × 25 mm site size, x-offset=y-offset=ø, 112 sites. 100% inspection for site flatness is not recommended — process capability of 100% usable area @ ≤ 0.4 µm or 99% usable area @ ≤ 0.18 µm should be demonstrated.

NOTE 4: The number of Localized Light Scatterers (LLS) per wafer is to be determined by user/supplier agreement; the LLS size in PSL equivalents is specified as ≥ 0.16 µm with a goal of decreasing to 0.12 µm.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M9-0999
SPECIFICATIONS FOR POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE SLICES

NOTE: This specification was modified in September 1999 to correct an editorial error present in Figure 4A. A Publication Improvement Proposal (PIP) form was submitted in August 1999.

1 Preface

1.1 These specifications cover two groups of substrate requirements for monocrystalline high-purity gallium arsenide wafers used in semiconductor and electronic device manufacture. Dimensional and crystallographic orientation characteristics and limits on surface defects are the only standardized properties set forth below.

1.2 A complete purchase specification may require that additional physical, electrical, and bulk properties be defined. These properties are listed, together with test methods suitable for determining their magnitude where such procedures are documented.

1.3 These specifications are directed specifically to gallium arsenide wafers with one or both sides polished. Unpolished wafers or wafers with epitaxial films are not covered; however, purchasers of such wafers may find these specifications helpful in defining their requirements.

1.4 The material is Single Crystal Gallium Arsenide (GaAs) having a cubic zinc blende structure and having the following properties. The following properties are for use as guidelines:

Density	5.316 gm/cm^3
Melting Point	1238°C
Dielectric Constant	13.1
Lattice Parameter	5.654 Å
Energy Gap	1.42 eV

1.5 For reference purposes, SI (System International, commonly called metric) units shall be used.

2 Applicable Documents

2.1 *ASTM Standards*[1]

E 122 — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

F 26 — Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 76 — Test Methods for Measuring Hall Mobility and Hall Coefficient in Extrinsic Semiconductor Single Crystals

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 533 — Test Method for Thickness and Thickness Variation of Silicon Slices

F 534 — Test Method for Bow of Silicon Slices

F 613 — Test Method for Measuring Diameter of Silicon Slices and Wafers

F 657 — Test Method for Measuring Warp and Total Thickness Variation on Silicon Slices and Wafers by a Non-Contact Scanning Method

F 671 — Test Method for Measuring Fiducial Flat Length and Deviation

F 928 — Test Method for Edge Contour of Silicon Wafers

2.2 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

3 Definitions

3.1 *Bow* — of a semiconductor slice or wafer, a measure of concave or convex deformation of the median surface of a slice or wafer, independent of any thickness variation which may be present. Bow is a bulk property of the test specimen, not a property of an exposed surface. Generally, bow is determined with a test specimen in a free, unclamped condition. Units of bow are generally micrometers or inches.

3.2 *Dopant* — a chemical element, usually from the second, fourth, or sixth columns of the periodic table for the case of III-V compounds, incorporated in trace amounts in a semiconductor crystal to establish its conductivity type and resistivity.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

3.3 *Lot* — for the purpose of this document, (a) all of the wafers of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of wafers as above which have been identified by the supplier as constituting a lot.

3.4 *Flat Diameter* — the linear dimension across the surface of a semiconductor wafer from the center of the flat through the wafer center to the circumference of the wafer on the opposite edge along the diameter perpendicular to the flat. (See Figure 6.)

NOTE 4 — The flat diameter may be associated with the primary orientation flat, with a secondary flat, if present, or with any other flat, if present. In such cases, the terms may be modified as primary orientation flat diameter, secondary flat diameter, etc.

3.5 *Orthogonal Misorientation* — in { 100} wafers cut intentionally "off-orientation," the angle between the projection of the vector normal to the slice surface onto the { 100} plane and the projection on that plane of the nearest direction. (See Figure 5.)

3.6 *Total Thickness Variation* — (TTV) the difference between the maximum and minimum thickness values of a slice or wafer encountered during a scan pattern or a series of point requirements. TTV is generally expressed in micrometers or mils (thousandths of an inch).

3.7 *Warp* — of a semiconductor slice or wafer, the difference between the maximum and minimum distances of the median surface of the slice or wafer from a reference plane, encountered during a scan pattern. Warp is a bulk property of the test specimen, not a property of an exposed surface. Warp is generally expressed in micrometers or mils (thousandths of an inch).

3.8 *Edge Contouring* — on slices whose edges have been shaped by mechanical and/or chemical means, a description of the profile of the boundary of the slice joining the front and back sides.

4 Ordering Information

4.1 Purchase orders for gallium arsenide wafers furnished to this specification shall include the following items:

4.1.1 Nominal diameter (see applicable SEMI Standard for polished GaAs wafers),

4.1.2 Thickness (see applicable SEMl Standard for polished GaAs wafers),

4.1.3 Total Thickness Variation (see applicable SEMI Standard for polished GaAs wafers),

4.1.4 Surface orientation (see applicable SEMI Standard for polished GaAs wafers). There are two options of flat location for 2" and 3" diameter polished mono-crystalline GaAs wafers for integrated circuit and optoelectronic applications. They are V-Groove (as illustrated in Figures 1 and 3) and Dove-Tail (as illustrated in Figures 2 and 4). These designations describe the shape of groove that can be etched perpendicular to the primary flat.

The following are the options of wafer surface orientation:

A. (100) ± 0.5° as shown in Figures 1 and 2

B. For V-Groove option:

(100) off 2° toward the (110) plane which is located between the primary and secondary flats as shown in Figure 3. Figure 5 illustrates orthogonal misorientation.

For Dove-Tail option:

(100) off 2° toward any of the nearest (110) planes as shown in Figure 4. Figure 5 illustrates orthogonal misorientation.

4.1.5 Lot Acceptance Procedures (see Section 8),

4.1.6 Certification (see Section 11),

4.1.7 Packing and Marking (see Section 12).

4.2 *Optional Criteria* — The following items may be specified optionally in addition to those listed above:

4.2.1 Crystal Growth Method,

4.2.2 Etch Pit Density (EPD) of Crystal,

4.2.3 Crystal Growth Perfection,

4.2.4 Impurity Type,

4.2.5 Surface Condition of Wafer,

4.2.6 Edge Contour,

4.2.7 Mobility,

4.2.8 Resistivity,

4.2.9 Carrier Concentration,

4.2.10 Thermal Conversion Characteristics.

5 Dimensions and Permissible Variations

5.1 The material shall conform to the dimensions and dimensional tolerances as specified in the applicable polished gallium arsenide slice standard.

5.2 If edge contoured wafers are specified on the purchase order, the profile shall conform to the following requirements at all points on the wafer periphery.

5.2.1 When the wafer is aligned with the SEMI Wafer Edge Profile Template (see Figure 6) so that the x-axis of the template is coincident with the wafer surface and the y-axis of the template is tangent with the outermost radial portion of the contour, the wafer edge profile must be contained within the clear region of the template. (See Figure 7 for example of acceptable and unacceptable contours.)

5.2.2 No sharp points or protrusions are permitted anywhere on the wafer edge contour.

5.2.3 Cosmetic attributes of the edge contour are not covered by this specification. They shall be agreed upon between supplier and purchaser.

6 Materials and Manufacture

6.1 The material shall consist of wafers from ingots grown to the material definition specified in the purchase order or contract.

7 Physical Requirements

7.1 The material shall conform to the crystallographic orientation details as specified in the applicable polished gallium arsenide slice standard.

7.2 The material shall conform to the details specified in the purchase order or contract as follows:

7.2.1 Conduction Type,

7.2.2 Dopant,

7.2.3 Carrier Concentration,

7.2.4 Resistivity,

7.2.5 Thermal Conversion Characteristics,

7.2.6 Etch Pit Density,

7.2.7 Mobility,

7.2.8 Surface Characteristics,

7.2.9 Growth Methods.

8 Sampling

8.1 Unless otherwise specified, Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) or lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

9 Test Methods

9.1 *Diameter* — Determine by ASTM Test Method F 613.

9.2 *Thickness, Center Point* — Determine by ASTM Test Method F 533.

NOTE 2 — GaAs wafers are extremely fragile. While the mechanical dimensions of a slice can be measured by use of tools such as a micrometer calipers and other conventional techniques, the slice may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement methods.

9.3 *Flat Length* — Determine by ASTM Test Method F 671.

9.4 *Flat Orientation* — Determine by etching method identified in the appropriate polished GaAs wafer standard.

9.5 *Bow and Warp* — Determine bow in accordance with ASTM Test Method F 534 and warp in accordance with ASTM Test Method F 657.

9.6 *Total Thickness Variation* — Determine by ASTM Test Method F 533 or F 657.

9.7 *Surface Orientation* — Determined by ASTM Test Methods F 26.

9.8 *Orthogonal Misorientation* — Determined by a method agreed upon between the supplier and purchaser.

9.9 *Surface Defects and Contamination* — Determined by a method agreed upon between the supplier and purchaser.

9.10 *Mobility* — Determined by ASTM Test Methods F 76.

9.11 *Crystal Perfection* — Determined by a method agreed upon between the supplier and purchaser.

10 Standard Defect Limits

10.1 Determined by agreement between supplier and purchaser as to limits.

11 Certification

11.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification together, with a report of the test results, shall be furnished at the time of shipment.

11.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as “capable of meeting” certain requirements. In this context, “capable of meeting” shall signify that the supplier is not required to perform the appropriate tests in Section 9. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

12 Packing and Marking

12.1 Special packing and marking requirements shall be subject to agreement between the supplier and the purchaser. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination in accordance with the best industry practices to provide ample protection against damage during shipment.

12.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include as a minimum the nominal diameter, conductive dopant, orientation, resistivity range, and lot number.

12.3 The lot number, either (1) assigned by the original manufacturer of the wafers, or (2) assigned subsequent to slice manufacture but providing reference to the original lot number, shall provide easy access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer’s facility for at least one month or as negotiated between vendor and user after that particular lot has been accepted by the purchaser.

Table 1. Equivalent Orientations — V-Groove Option

Surface orientation:	(100)	(100)	$(\bar{1}00)$	$(\bar{1}00)$
Primary flat location:	$(01\bar{1})$	$(0\bar{1}1)$	$(0\bar{1}\bar{1})$	(011)
Secondary flat location:	(011)	$(0\bar{1}\bar{1})$	$(0\bar{1}1)$	$(01\bar{1})$
For Surface orientation B, the off-orientation tilt direction is toward:	(110)	$(1\bar{1}0)$	$(\bar{1}\bar{1}0)$	$(\bar{1}10)$

Table 2. Equivalent Orientations — Dove-Tail Option

Surface orientation:	(100)	(100)	$(\bar{1}00)$	$(\bar{1}00)$
Primary flat location:	$(0\bar{1}\bar{1})$	(011)	$(01\bar{1})$	$(0\bar{1}1)$
Secondary flat location:	$(0\bar{1}1)$	$(01\bar{1})$	(011)	$(0\bar{1}\bar{1})$
For Surface orientation B, the off-orientation tilt direction is toward:	$(1\bar{1}0)$	(110)	$(\bar{1}10)$	$(\bar{1}\bar{1}0)$

The symmetry of GaAs crystal structure allows other Miller indices to be used for identifying surface and flat orientations. This table lists various possibilities which meet the requirements for the above two options.

NOTE: For V-Groove Option, the relative directions in a single column must be maintained. For Dove-Tail Option, any of the 110 tilt directions are considered equivalent.

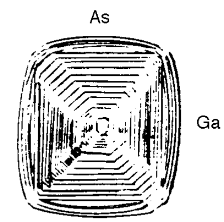
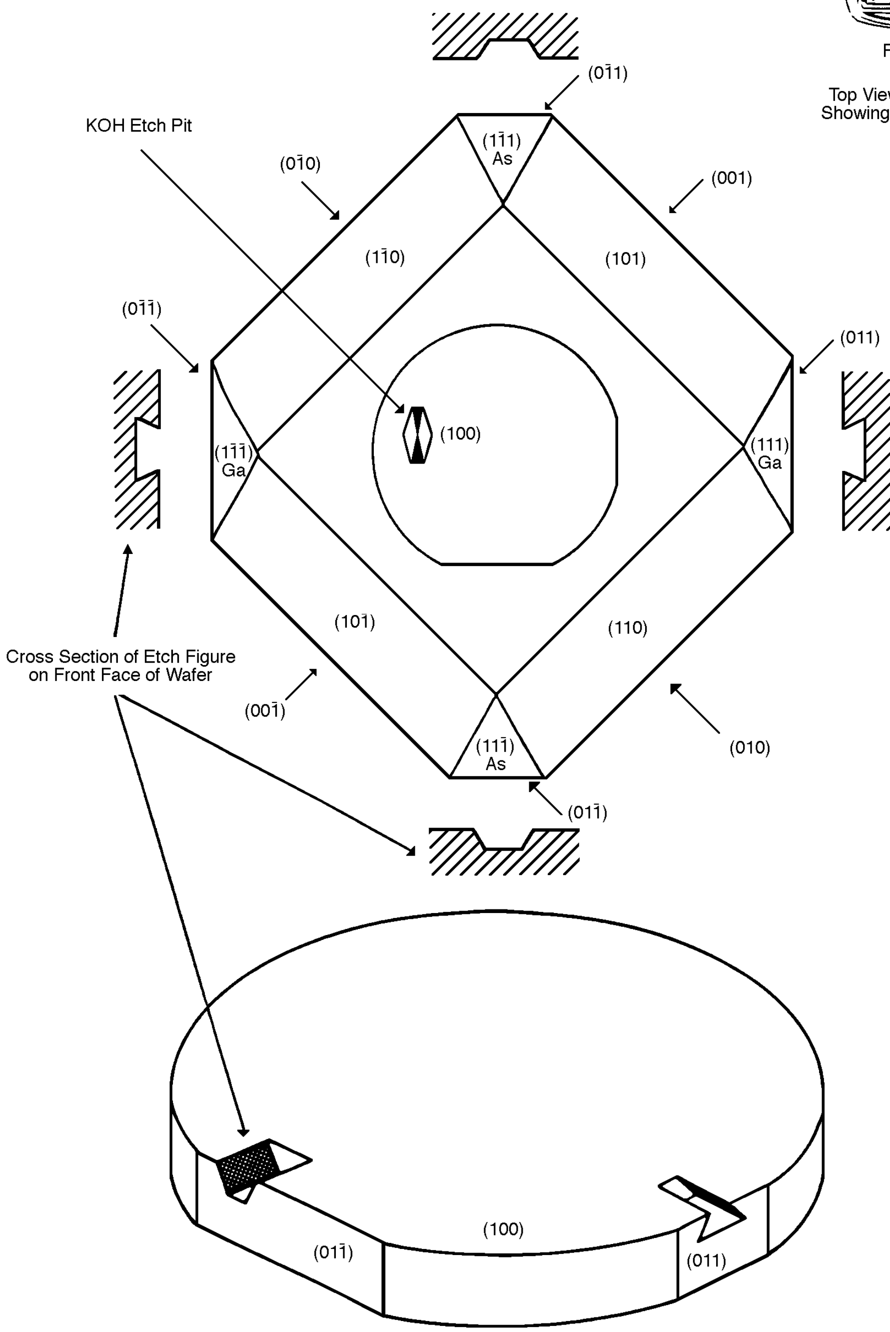


Figure 1B

Top View of LEC Crystal
Showing As and Ga Facet



Figures 1A and 1B
Both Diagrams Show a GaAs Wafer with Surface Orientation A and Flat Option V-Groove

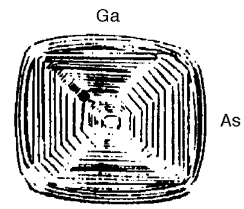
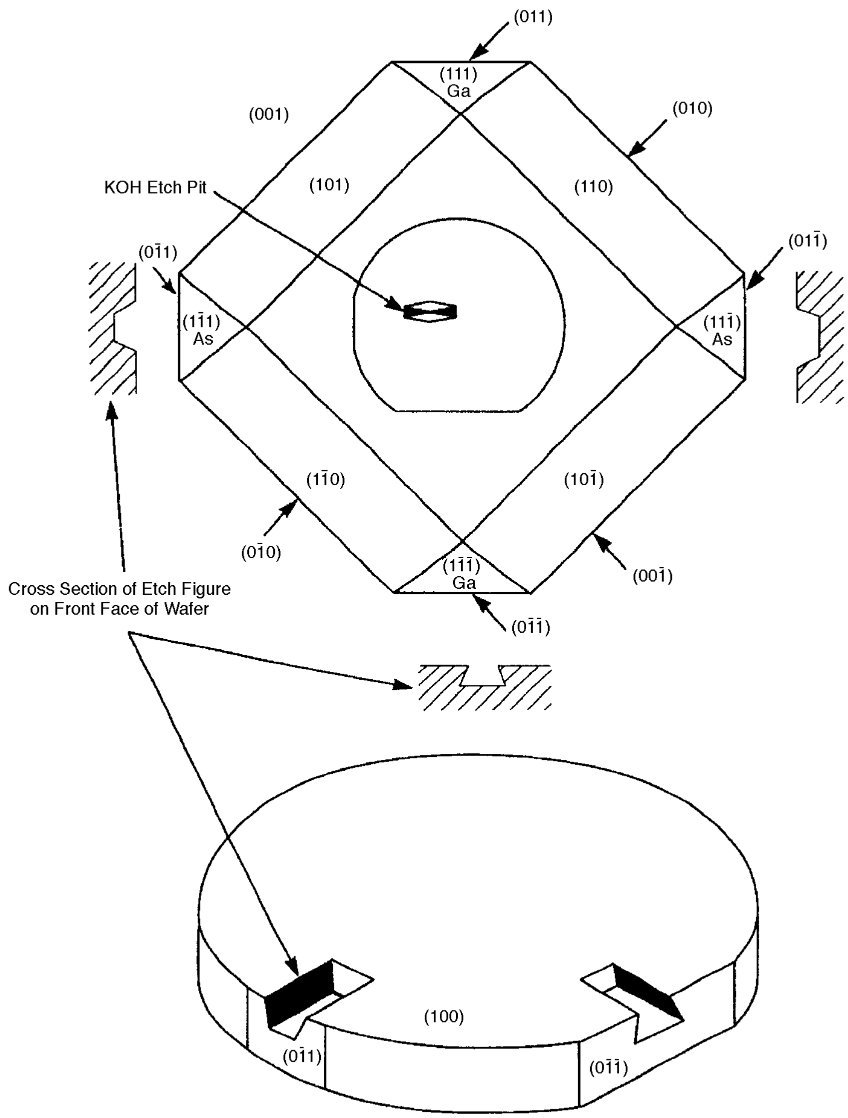
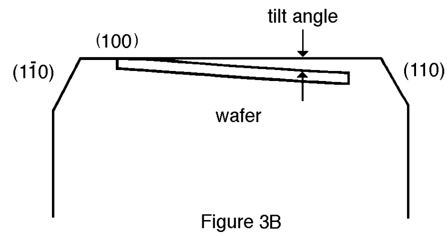


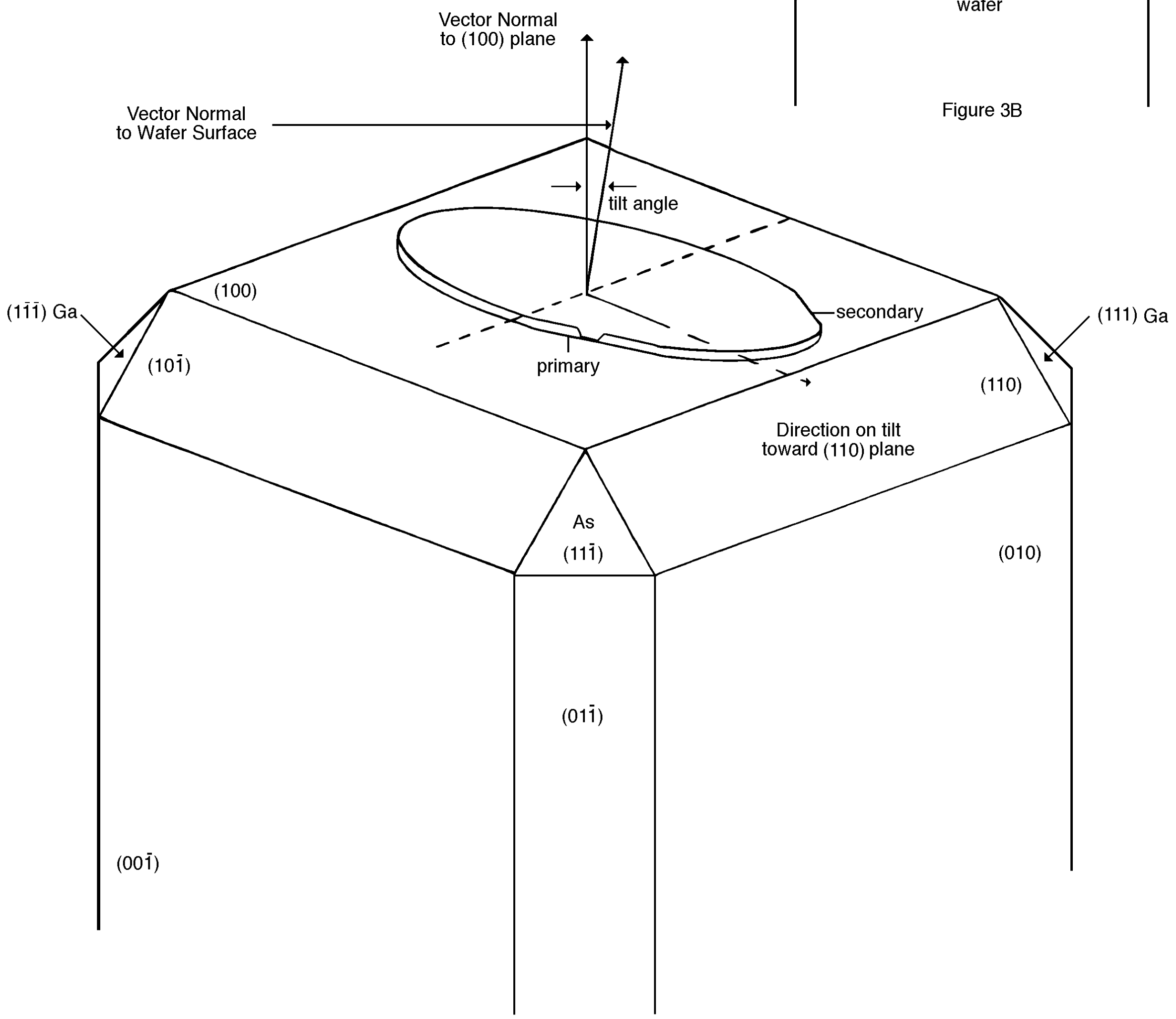
Figure 2B

Top View of LEC Crystal
Showing Ga and As Facets

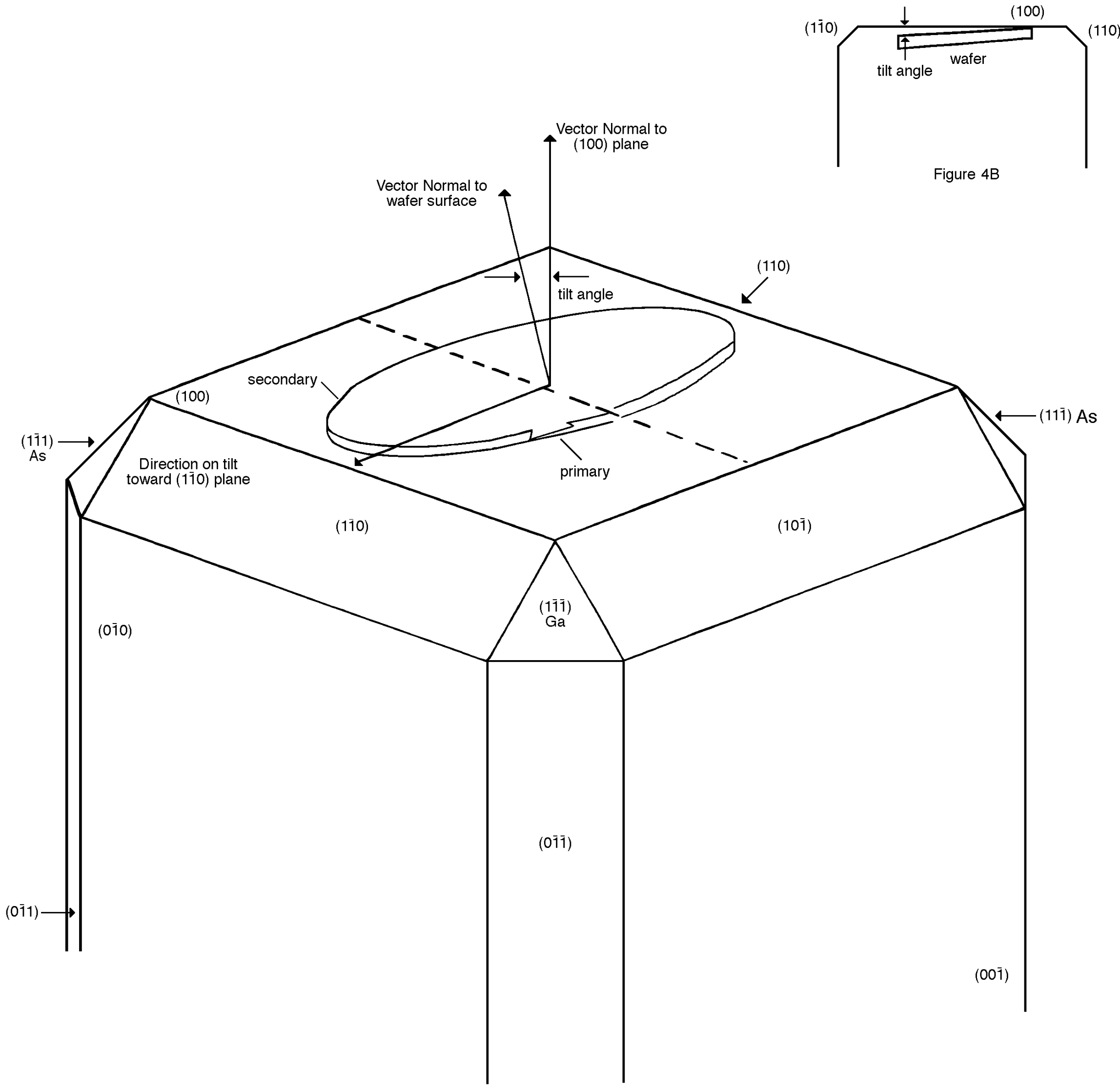


Figures 2A and 2B
Both Diagrams Show a GaAs Wafer with Surface Orientation A and Flat Option Dove-Tail





Figures 3A and 3B
Both Diagrams Show a GaAs Wafer with Surface Orientation B and Flat Option V-Groove



Figures 4A and 4B
Both Diagrams Show a GaAs Wafer with Surface Orientation B and Flat Option Dove-Tail

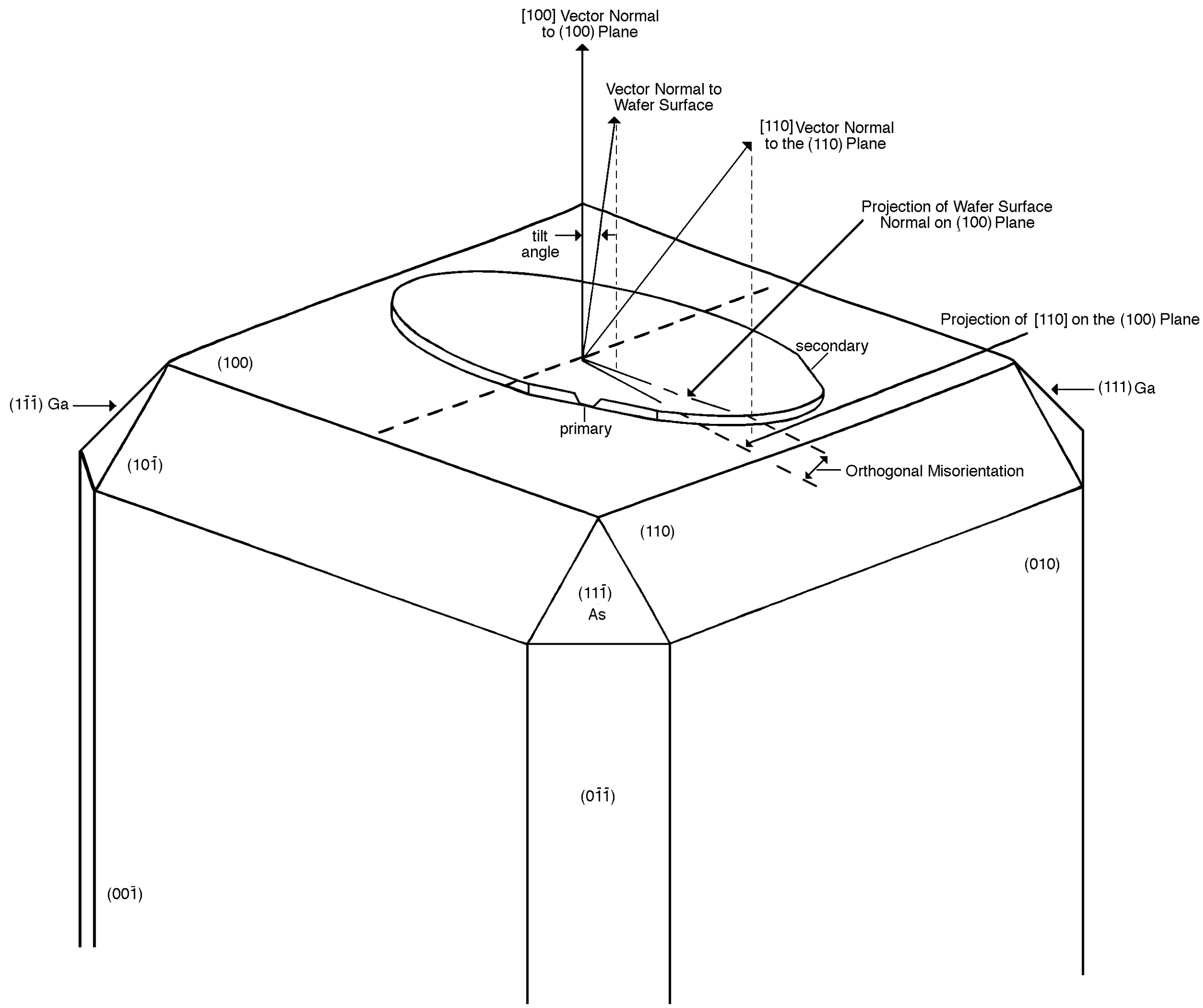


Figure 5
A GaAs Wafer with the Same Orientation as Figure 3, but with a Few Degrees of Orthogonal Misorientation

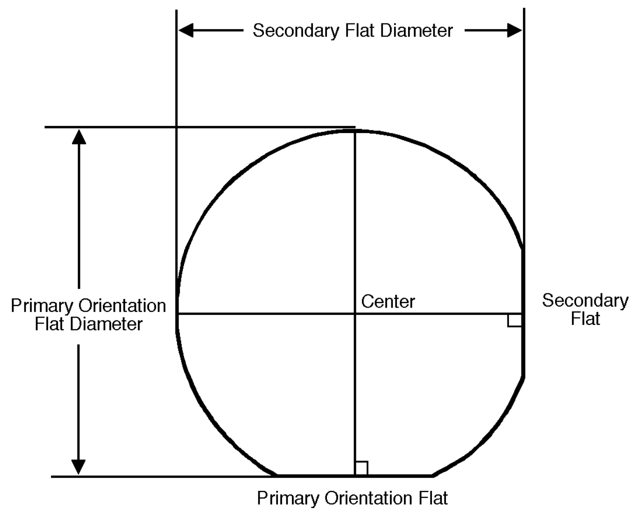


Figure 6
Flat Diameter on Wafer with Primary Orientation Flat and Secondary Flat

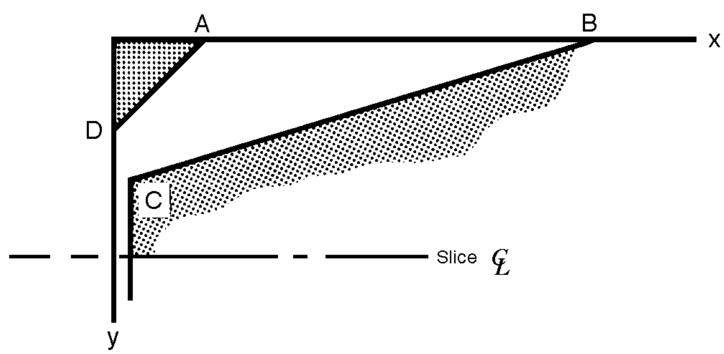


Figure 7
SEMI Wafer Edge Profile Template

Point	*x*		*y*	
	in.	*μm*	*in.*	*μm*
A	0.0030	76	0.00	0
B	0.0200	508	0.00	0
C	0.0020	51	(See Note 2)	(See Note 2)
D	0.00	0	0.0030	76

NOTE 1: For referee purposes, U.S. customary units are to be used for 2 and 3 in. diameter wafers and SI units otherwise.

NOTE 2: The y-coordinate of point C is 1/3 the nominal wafer thickness.

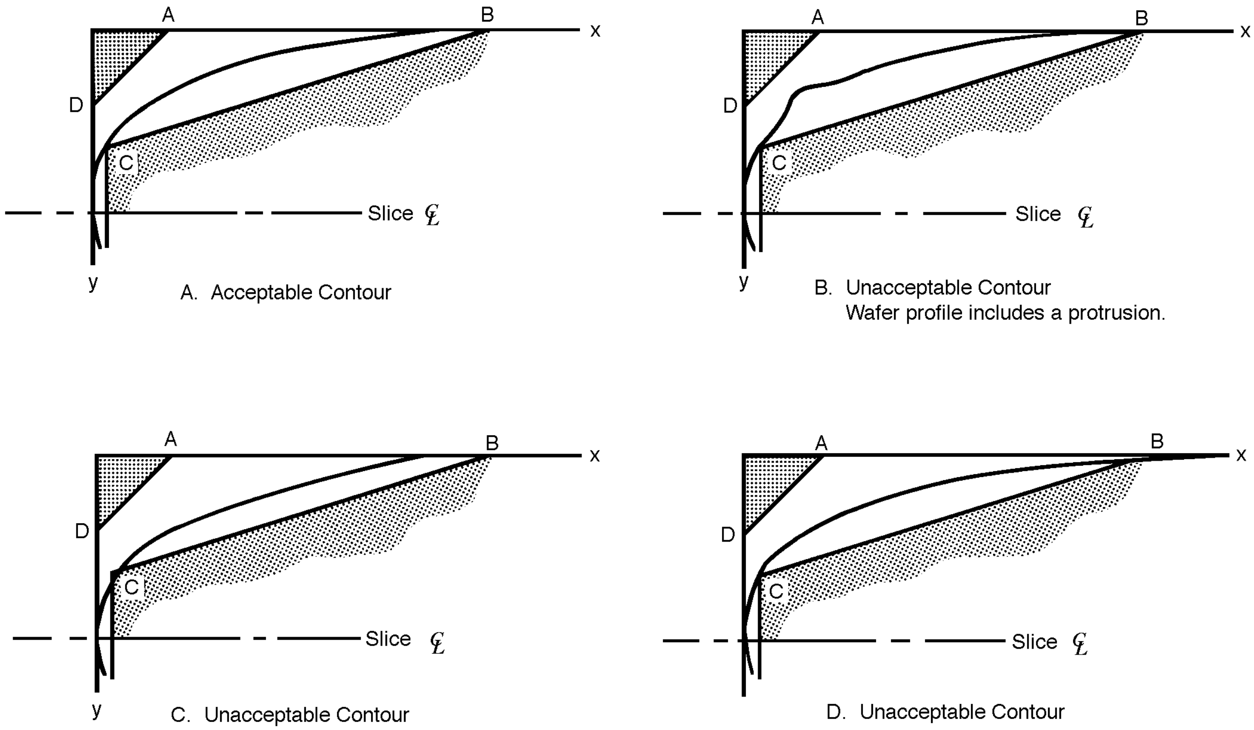


Figure 8
Examples of Acceptable and Unacceptable Wafer Edge Profiles

SEMI M9.1-96
STANDARD FOR ROUND 50.8 mm POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE WAFERS FOR ELECTRONIC DEVICE APPLICATIONS

NOTE: This entire document was rewritten in 1995.

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER[A]	50.8	± 0.5	mm
THICKNESS, CENTER POINT	450	± 25	µm
PRIMARY FLAT LENGTH	16	± 2	mm
SECONDARY FLAT LENGTH	8	± 2	mm

[A] The diameter standard means that the dimension is centered to this value.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION	$(01\bar{1})$ ± 0.5° [A], under an Arsenic facet. The primary flat shall be perpendicular to the "V" etch figure.[B]
SECONDARY FLAT ORIENTATION	90° ± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION[C]	(100) ± 0.5°
A.	(See Figure 1 in SEMI M9.)
B.	(100) off 2° ± 0.5° toward the (110) plane which is between the primary and secondary flats (see Figure 3 in SEMI M9.)
ORTHOGONAL MISORIENTATION	± 5° (See Figure 5 in SEMI M9.)

[A] See Table 1 in SEMI M9.

[B] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 and 3 in SEMI M9. Figure 1 also shows the orientation of the V-groove figures relative to KOH etch pits.

[C] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted toward the (110) plane of the crystal.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M9.2-96
STANDARD FOR ROUND 76.2 mm POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE WAFERS FOR ELECTRONIC DEVICE APPLICATIONS

NOTE: This entire document was revised in 1995.

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER[A]	76.2	± 0.5	mm
THICKNESS, CENTER POINT	625	± 25	µm
PRIMARY FLAT LENGTH	22	± 2	mm
SECONDARY FLAT LENGTH	11	± 2	mm

[A] The diameter standard means that the dimension is centered to this value.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION	($(01\bar{1})$) ± 0.5° [A], under an Arsenic facet. The primary flat shall be perpendicular to the "V" etch figure.[B]
SECONDARY FLAT ORIENTATION	90° ± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION[C]	(100) ± 0.5°
A.	(See Figure 1 in SEMI M9.)
B.	(100) off 2° ± 0.5° toward the (110) plane which is between the primary and secondary flats (see Figure 3 in SEMI M9.)
ORTHOGONAL MISORIENTATION	± 5° (See Figure 5 in SEMI M9.)

[A] See Table 1 in SEMI M9.

[B] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 and 3 in SEMI M9. Figure 1 also shows the orientation of the V-groove figures relative to KOH etch pits.

[C] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted toward the (110) plane of the crystal.

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SEMI M9.3-89
STANDARD FOR ROUND 2 inch DIAMETER POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE SLICES FOR OPTOELECTRIC APPLICATIONS

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Min*	*Max*	*Units*[A]
DIAMETER	50.42	51.18	mm
	1.985	2.015	in.
THICKNESS, CENTER POINT	350	400	mm
	0.0138	0.0158	in.
PRIMARY FLAT LENGTH	14.23	17.52	mm
	0.560	0.690	in.
SECONDARY FLAT LENGTH	6.35	9.65	mm
	0.250	0.380	In.
BOW		20	µm
		0.0008	in.
A.		50	µm
		0.0019	in.
B.		30	µm
		0.0011	in.
C.		10	µm
		0.0039	in.
TOTAL THICKNESS VARIATION SCHEDULE			
A.		24	µm
		0.0009	in.
B.		12	µm
		0.0005	in.
C.		8	µm
		0.0003	in.
D.		4	µm
		0.0002	in.

[A] For referee purposes, metric (SI) units apply.

Table 2 Orientation and Flat-Location Requirements

Property	*Requirement*	
Option	V-Groove (See Figures 1 and 3.)	Dove-Tail (See Figures 2 and 4.)
PRIMARY FLAT ORIENTATION	(011) ± 0.5° [B], under an Arsenic facet. The primary flat shall be perpendicular to the “V” etch figure.[C]	(011) ± 0.5° [B], under a Gallium facet. The primary flat shall be perpendicular to the “Dove-tail” etch figure.[C]
SECONDARY FLAT LOCATION	90° ± 5° counterclockwise from the primary flat.	90° ± 5° clockwise from the primary flat.
SURFACE ORIENTATION[A]		
A.	(100) ± 0.5° (See Figure 1.)	(100) ± 0.5° (See Figure 2.)
B.	(100) off 2° ± 0.5° towards the (110) plane which is between the primary and secondary flats (See Figure 3).	(100) off 2° ± 0.5° towards any (110) plane (See Figure 4).
ORTHOGONAL MISORIENTATION	± 5° (See Figure 5.)	± 5° (See Figure 5.)

[A] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted towards the (110) plane of the crystal.

[B] See Table 1.

[C] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 through 4. Figures 1 and 2 also show the orientation of the V-groove and Dove-tail figures relative to KOH etch pits.

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SEMI M9.4-89
STANDARD FOR ROUND 3 inch DIAMETER POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE SLICES FOR OPTOELECTRIC APPLICATIONS

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Min*	*Max*	*Units*[A]
DIAMETER	75.82	76.58	mm
	2.985	3.015	in.
THICKNESS, CENTER POINT	475	525	µm
	0.0187	0.0207	in.
PRIMARY FLAT LENGTH	19.05	25.40	mm in.
	0.750	1.000	mm
SECONDARY FLAT LENGTH	9.66	12.70	mm
	0.380	0.500	in.
BOW		20	µm
		0.0008	in.
A.		50	µm
		0.0019	in.
B.		30	µm
		0.0011	in.
C.		10	µm
		0.0039	in.
TOTAL THICKNESS VARIATION SCHEDULE:			
A.		24	µm
		0.0009	in.
B.		12	µm
		0.0005	in.
C.		8	µm
		0.0003	in.
D.		4	µm
		0.0002	in.

[A] For referee purposes, metric (SI) units apply.

Table 2 Orientation and Flat-Location Requirements

Property	*Requirement*	
Option	V-Groove (see Figures 1 and 3)	Dove-Tail (see Figures 2 and 4)
PRIMARY FLAT ORIENTATION	(011) ± 0.5° [B], under an Arsenic facet. The primary flat shall be perpendicular to the “V” etch figure.[C]	(011) ± 0.5° [B], under a Gallium facet. The primary flat shall be perpendicular to the “Dove-tail” etch figure.[C]
SECONDARY FLAT LOCATION	90° ± 5° counterclockwise from the primary flat.	90° ± 5° clockwise from the primary flat.
SURFACE ORIENTATION[A]		
A.	(100) ± 0.5° (see Figure 1.)	(100) ± 0.5° (see Figure 2.)
B.	(100) off 2° ± 0.5° towards the(110) plane which is between the primary and secondary flats (see Figure 3.)	(100) off 2° ± 0.5° towards any nearest (110) plane (see Figure 4.)
ORTHOGONAL MISORIENTATION	± 5° (see Figure 5.)	± 5° (see Figure 5.)

[A] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted towards the (110) plane of the crystal.

[B] See Table 1.

[C] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 through 4. Figures 1 and 2 also show the orientation of the V-groove and Dove-tail figures relative to KOH etch pits.

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SEMI M9.5-96
STANDARD FOR ROUND 100 mm POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE WAFERS FOR ELECTRONIC DEVICE APPLICATIONS

NOTE: This entire document was revised in 1995.

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER[A]	100.0	± 0.5	mm
THICKNESS, CENTER POINT	625	± 25	µm
PRIMARY FLAT LENGTH	32.5	± 2	mm
SECONDARY FLAT LENGTH	18	± 2	mm

[A] The diameter standard means that the dimension is centered to this value.

Table 2 Orientation and Flat- Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION	$(01\bar{1})$ ± 0.5° [A], under an Arsenic facet. The primary flat shall be perpendicular to the "V" etch figure.[B]
SECONDARY FLAT ORIENTATION	90° ± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION[C]	(100) ± 0.5°
A.	(See Figure 1 in SEMI M9.)
B.	(100) off 2° ± 0.5° toward the (110) plane which is between the primary and secondary flats (See Figure 3 in SEMI M9.)
ORTHOGONAL MISORIENTATION	± 5° (See Figure 5 in SEMI M9).

[A] See Table 1 in SEMI M9.

[B] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 and 3 in SEMI M9. Figure 1 also shows the orientation of the V-groove figures relative to KOH etch pits.

[C] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted toward the (110) plane of the crystal.

SEMI M9.6-95
STANDARD FOR ROUND 125 mm DIAMETER POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE WAFERS

The complete specification for this product includes all general requirements of SEMI M9.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER	125.0	± 0.3	mm
THICKNESS, CENTER POINT	625	± 25	µm
PRIMARY ORIENTATION FLAT DIAMETER[A]	121.0	± 0.3	mm
SECONDARY FLAT DIAMETER[B]	123.5	± 0.3	mm

[A] Actual Primary Orientation Flat Length depends on allowed variation in the wafer diameter and the orientation flat diameter. Variation in Primary Orientation Flat Length is calculated assuming that the end points of Primary Orientation Flat will have curvature of a circle of radius R = 0 or R = 3 mm; this circle will be tangent to the orientation flat and also tangent to the wafer circumference. Calculated nominal linear length of Primary Orientation Flat (the straight part of the flat) are 44.00 mm in a case of R = 0 mm and 42.90 respectively on a case of R = 3 mm.

[B] Actual Secondary Flat Length also depends on allowed variation in the wafer diameter and the Secondary Flat Diameter. Variation in Secondary Flat Length is calculated. Calculated nominal linear lengths of the Secondary Flat (the straight part of the flat) are 27.22 mm in the case of R = 0 mm, and 26.25 mm, respectively, in the case of R = 3 mm.

Table 2 Orientation and Flat-Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION	(011) ± 1.0°, under an Arsenic facet. The primary flat shall be perpendicular to the "V" etch figure.[C]
SECONDARY FLAT ORIENTATION	90° ± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION	
A.	(100) ± 0.5° (see Figure 1 in M9.)
B.	(100) off 2° ± 0.5° towards the (110) plane which is between the primary and secondary flats (see Figure 3 in M9.)
ORTHOGONAL MISORIENTATION	± 5° (see Figure 5 in M9.)

[A] The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted towards the (110) plane of the crystal.

[B] See Table 1.

[C] Using A-B, bromine-methanol, ammonium hydroxide: hydrogen peroxide etch. See Figures 1 through 4. Figure 1 also shows the orientation of the V-groove figure relative to the KOH etch pits.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M9.7-0200
SPECIFICATION FOR ROUND 150 mm POLISHED MONOCRYSTALLINE GALLIUM ARSENIDE WAFERS (NOTCHED)

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the North American Compound Semiconductor Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org January 2000; to be published February 2000. Originally published in 1995; previously published in 1996.

NOTE: This document was rewritten in its entirety in February 2000.

1 Purpose

1.1 This specification defines properties of 150 mm monocrystalline GaAs substrates, in agreement with presently established industry practice. It uniquely defines those mechanical parameters that do not need, for technical reasons, a choice of different values.

2 Scope

2.1 The parameters defined include the values and tolerances of wafer diameter, thickness and surface orientation. The position and depth of the notch and laser marking are also specified.

2.2 The complete specification of this product includes the requirements of SEMI M9, excluding those that are not relevant to this specification (e.g., flat positions).

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

4 Physical Requirements

Table 1 Physical Requirements

Property	*Specification*	*Tolerance*	*Unit*	*Reference*
WAFER				
Diameter	150.0	± 0.5	mm	
Thickness, center point	675	± 25	µm	
Surface orientation A	(100)	0.5 max.	degrees	Figure 2
Surface orientation B				
Tilt	2 off (100) towards (110)	± 0.5	degrees	Figure 3
Orthogonal misorientation	0	± 5 max.	degrees	Figure 4
NOTCH				
Orientation	[010]	± 2	degrees	Figure 1
Depth	1.0	+ 0.25, -0.0	mm	Figure 5
Opening angle	90	+ 5, -1	degrees	Figure 5
LASER MARKING				
Surface	front side			
Position	adjacent to notch			Figure 6
Mandatory content	check characters			SEMI M12

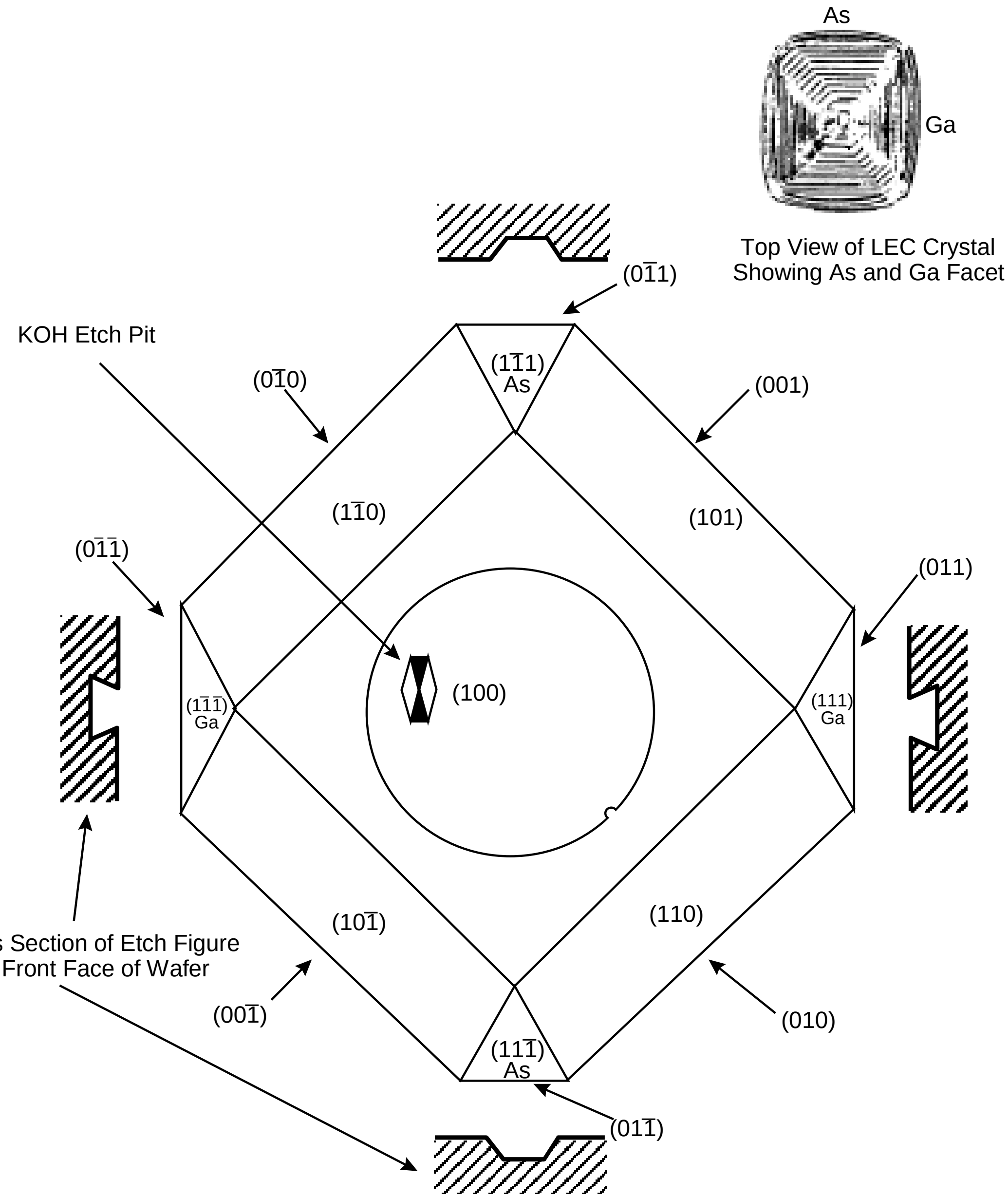

Figure 1
Diagram Shows a GaAs Wafer with Notch

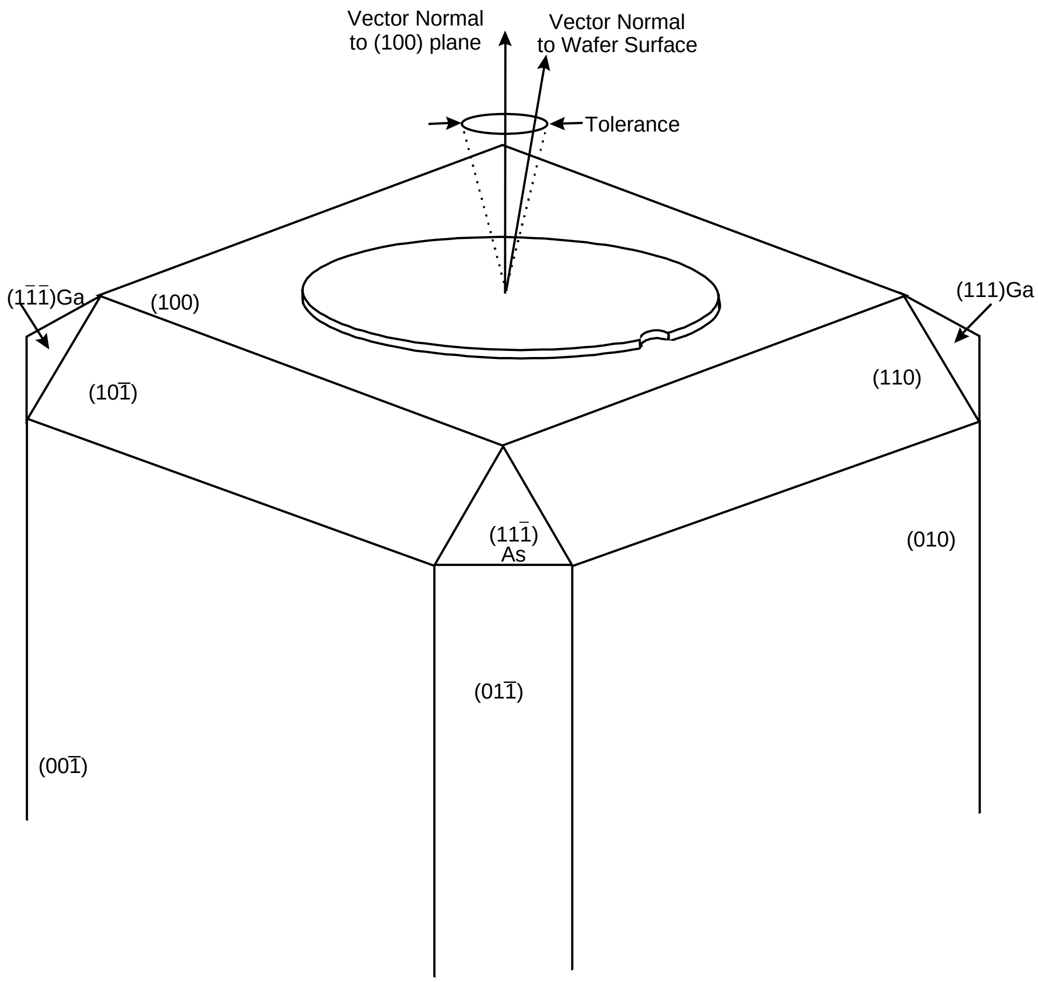

Figure 2
Notched GaAs Wafer Illustrating Surface Orientation A

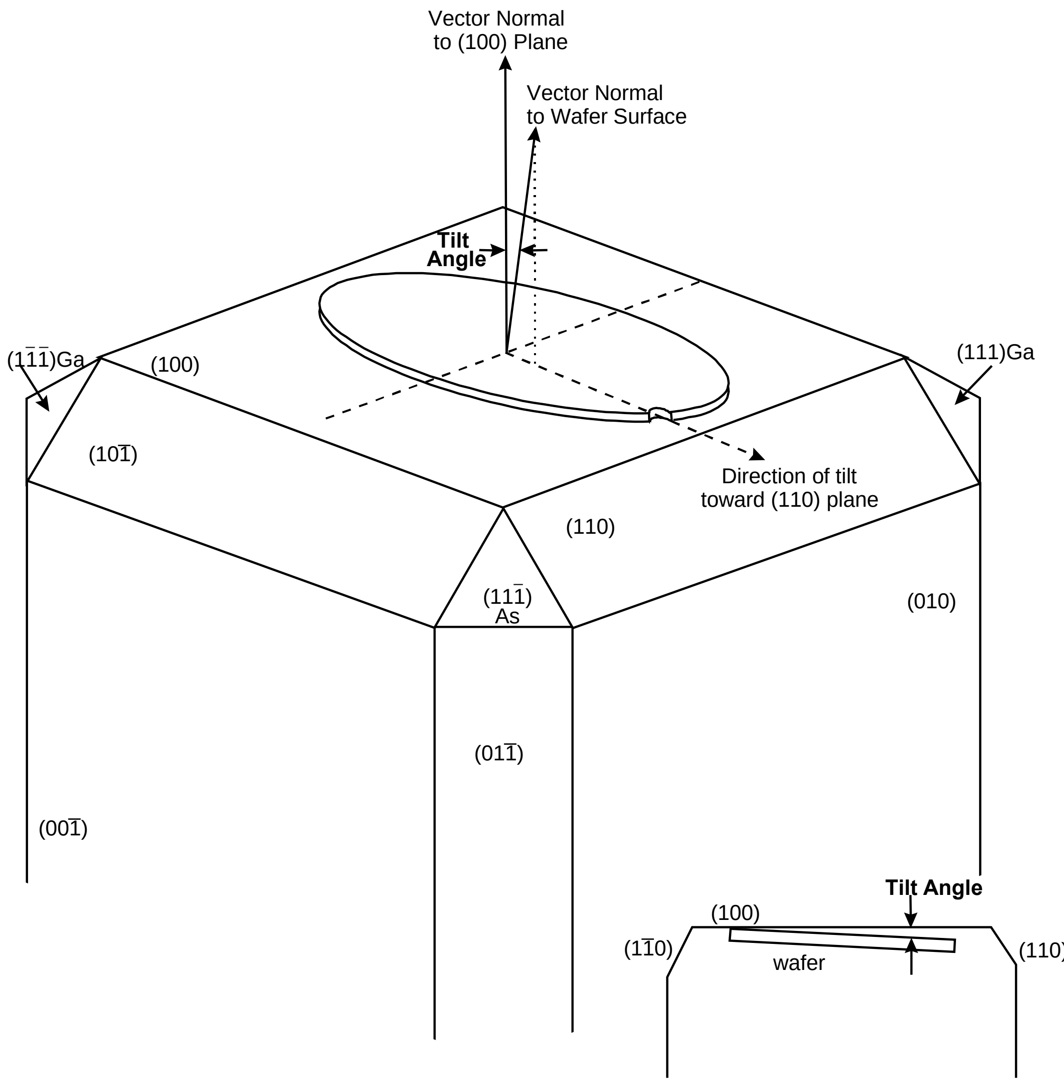

Figure 3
Notched GaAs Wafer Illustrating Surface Orientation B, with Tilt

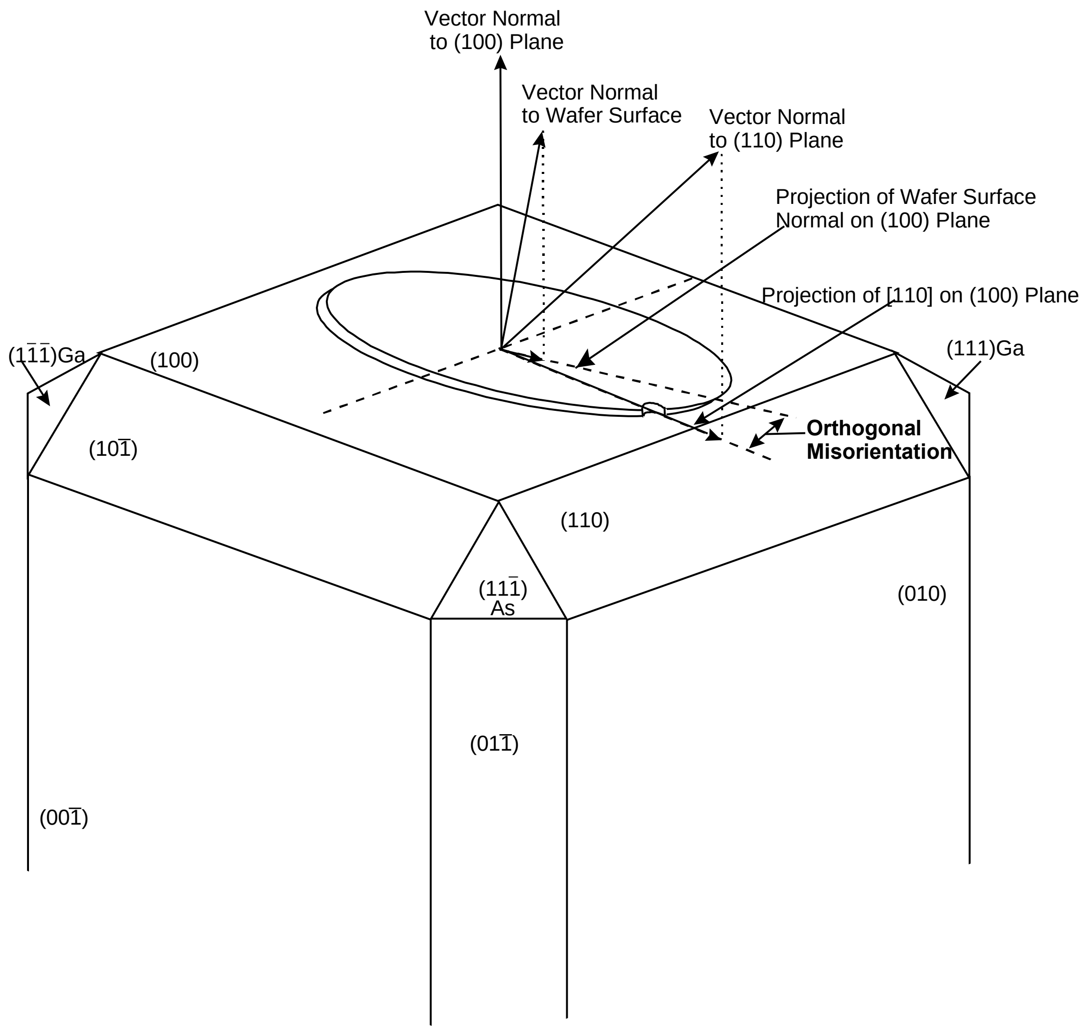

Figure 4
Notched GaAs Wafer Illustrating Surface Orientation B, with Tilt and Orthogonal Misorientation

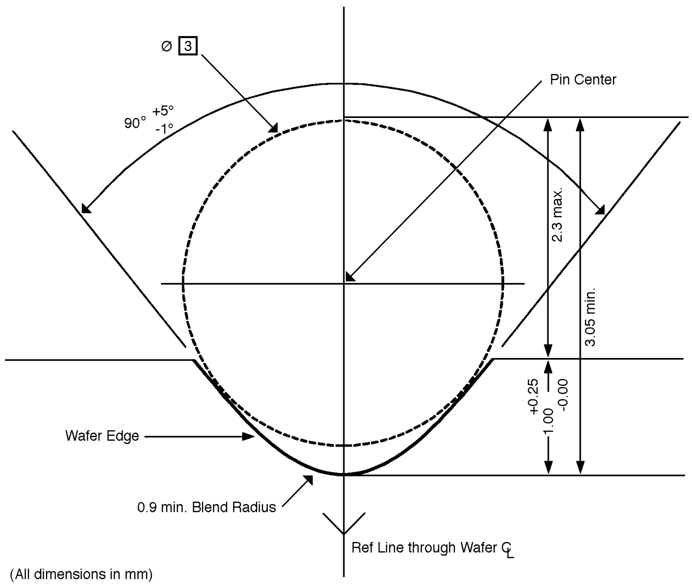

Figure 5
Notch Dimensions

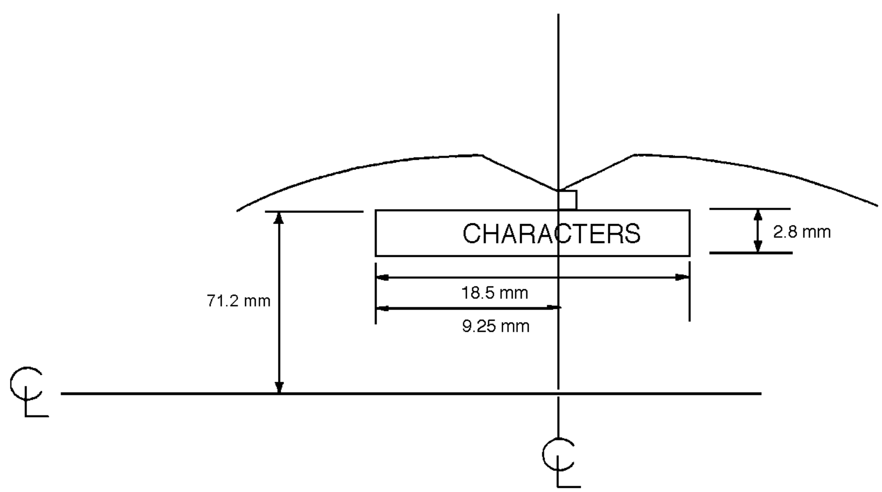

Figure 6
Character Window Location

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SEMI M10-1296
STANDARD NOMENCLATURE FOR IDENTIFICATION OF STRUCTURES AND FEATURES SEEN ON GALLIUM ARSENIDE WAFERS

1 Scope

1.1 The purpose of this document is to list, illustrate, and define various characters, features, and contaminants that are seen on highly polished GaAs wafers and present recommended practices for observation of these defects. These occurrences are frequently referred to as surface defects. The defects and common synonyms are arranged alphabetically in Section 4, and each structure is referred to by its most common name and, in some cases, probably origins.

1.2 Two cases of surface preparations are considered in this document: (1) surfaces after chemical polishing, and (2) mechanically and chemically polished surfaces.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Applicable Documents

2.1 *SEMI Standard*

SEMI M9 — Specifications for Round Polished Monocrystalline Gallium Arsenide Slices

2.2 *ASTM Standard*[1]

F 47 — Crystallographic Perfection of Silicon by Preferential Etch Techniques

2.3 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

3 Significance and Use

3.1 This document contains a compilation of the most commonly observed singularly discernable structures on polished GaAs surfaces. Ambiguities and uncertainties regarding surface defects may be resolved by reference to this document.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (The cited standard may be found in Volume 10.05 of the Annual Book of ASTM Standards.)

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

4 Definitions and Descriptions of Terms

cell structure — (block structure): Malformations attributable to crystal inhomogeneities and that have their origins in the crystal growth process.

chips — (edge chips, peripheral chips, peripheral indents, surface chips): Areas of material mechanically removed from the surface or edge of a wafer.

> Chips indicate crystallographic damage in the adjacent material. The origins of some chips are in the handling of wafers arising from the physical transfer or placement of the specimen for process, measurement, or inspection purposes. The size of a chip is defined by its maximum radial depth and peripheral chord length as measurable on an orthographic shadow projection of the specimen outline.

apex chip —Any material missing from the edge of a wafer having at least 2 distinct interior boundaries which form one or more distinct intersections.

chuck marks — Any physical mark on either surface of a wafer caused by a chuck or wand.

contaminant — (solvent residue, wax residue, film, mottled surface, smudge): Surface feature that cannot be removed by the pre-inspection (non-etching) cleaning.

NOTE Contaminant may be foreign matter on the surface such as localized areas which are smudged, stained, discolored, mottled, etc., or larger areas exhibiting a hazy or cloudy appearance resulting from a film of foreign material.

> Solvent residue: type of film found on wafer surfaces after solvent evaporation from the surface. Note: The residue comes from either the solvent itself or material that the solvent has removed from the surface and redeposited. Wax residue: film of wax that migrated onto the wafer surface from several possible sources.

NOTE The wax originally may have been used to hold the crystal in place during slicing or polishing. Excessive heat used in mounting or demounting, during lapping or polishing processes, may cause the wax to polymerize.

crack — Cleavage or fracture that extends to the surface of a slice. It may or may not pass through the entire thickness of the slice. Often cracks are caused by the improper handling of wafers.

NOTE Some crack-defect structures can be traced to process related events.

cavity — (void) A vacancy or hole in the wafer.

NOTE Usually left by dissolved precipitates and Ga inclusions, As disassociation or created by excess vapor pressure.

Dimple — Deformation appearing in mechanically polished GaAs wafers.

NOTE This surface texture can be induced by floating the wafers during the initial stages of polishing.

Dislocation — See *slip, lineage, pit*.

edge chip — See *chip*.

Embedded — abrasive grains Abrasive particles mechanically forced into the surface of the wafer.

etch pi t — See *pit*.

film — See *contaminant*.

flake — Material missing from one, but not the other, side of a wafer, whose sole interior boundary is one distinct line or arc not exceeding 2 mm in length, nor projecting into the wafer beyond the specified edge exclusion.

gallium inclusion — A segregated Ga-rich droplet incorporated into the surface structure.

NOTE Normally caused by insufficient As vapor pressure at the termination of the crystal growth process or by Ga complexing with some dopants near saturation.

grain boundary — See *lineage*.

haze — (cloud, nebula): Attributable to light scattering by concentrations of microscopic surface irregularities such as pits, oxides, small ridges or scratches, particles, etc. The light reflection from an individual irregularity probably could not be readily detected by the unaided eye, so haze is a mass effect. It is seen as a high density of tiny reflections.

NOTE This type of contamination may occur during slicing, lapping, or polishing.

lamella — A special case of the twin. A multiple twin, extremely thin and relatively long, which may intersect more than one plane.

lineage — (dislocation pits, grain boundary): Low-angle grain boundary resulting from an array of dislocations. This angle may vary from a fraction of a second to a minute of arc difference in orientation from one part of the crystal to another. The array of dislocations will appear as rows of pits on a preferentially etched surface.

NOTE Lineage can be induced into the material in crystal growth or in subsequent thermal or epitaxial processes. Lineage will be visible to the unaided eye only after preferential etching.

macroscratch —See *scratch*.

microscratch — See *scratch*.

microtwin — See *twin*.

orange peel — (roughness, texture): Large featured roughened type of surface visible to the unaided eye, occasionally seen on all types of polished wafers.

NOTE Orange peel is usually symptomatic of a process control problem. In the case of chemical polishing for instance, an excessively fast polishing rate, or nonuniform flow of oxidizer during polishing, can result in orange peel. Conversely, it can also be caused by insufficient stock removal.

particulate — (dust): Discrete particle of material which can usually be removed by (non-etching) cleaning.

pit — (dislocation, etch pit): Depression in the wafer surface which has a definite and distinguishable shape, that is, a place where the sloped sides of the pit meet the wafer surface.

NOTE Pits can be caused by the various growths or polishing processes.

Preferential etch pits result where dislocations intersect the wafer surface after treatment with a preferential etch. These pits so formed usually have a characteristic shape related to the surface and bulk crystallographic orientation.

polycrystalline — (poly): Body of semiconductor materials that contain large-angle grain boundaries, twin boundaries, or both.

precipitates — A localized concentration of dopant at its solubility limit formed during crystal growth.

probe damage — Any damage to the wafer surface caused by mechanical probing or measurement.

roughness — see *orange peel*.

saw blade defects —A depression in the wafer surface made by the blade, which may not be visible before polishing.

saw exit chip —A particular kind of edge chip, found at the point where the saw blade completed its cut of the wafer. It is typically flat or arc shaped instead of irregular in shape, and can sometimes be confused with the orientation flats.

scratch — (macroscratch, microscratch): Long, narrow, shallow groove or cut below the established plane of the surface, seen either before or after etching. The ratio of the length of the figure to the width of the figure must be greater than 5:1 in order to be defined as a scratch.

Macroscratches are visible to the unaided eye under high intensity illumination.

Microscratches are not visible to the unaided eye under high intensity illumination.

slip — (dislocation pit, preferential etch pits, stress effect) (see also *pit*): Process of plastic deformation in which one part of a crystal undergoes a shear displacement relative to another in a fashion which preserves the crystallinity of the material. Slip is evidenced by a pattern of one or more straight lines of 10 or more dislocation etch pits per millimeter which do not necessarily touch each other.

striations — Striations appear in Czochralski grown crystals regardless of their resistivity.

tweezer mark — Any mark on the wafer caused by handling with tweezers.

twin — A body of crystal within the wafer in which the lattice is of two parts, related to each other in orientation as mirror images, across a coherent planar interface known as the twinning plane or twin boundary.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M11-0702
SPECIFICATIONS FOR SILICON EPITAXIAL WAFERS FOR INTEGRATED CIRCUIT (IC) APPLICATIONS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1988; previously published March 2001.

1 Purpose

1.1 This specification defines and provides examples of silicon epitaxial wafer requirements for integrated circuit device manufacture. It is restricted to wafers of diameters 100 mm or greater with epitaxial layer thicknesses less than or equal to 25 µm. By defining inspection procedures and acceptance criteria, both suppliers and consumers may uniformly define product characteristics and quality requirements.

1.2 The characteristics specified relate to the substrate (as specified in SEMI M1) and to the epitaxial layer, including handling and packaging. The primary standardized properties set forth in this specification relate to physical, electrical, and surface defect parameters.

1.3 A complete purchase specification requires that additional physical properties be specified along with suitable test methods for their measurements. SEMI M18 may be used for this purpose.

1.4 These specifications are specifically directed to silicon homoepitaxial deposits on homogeneous silicon substrates only, for which more stringent uniformity and surface defect criteria are required than specified in SEMI M2.

1.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Standards

2.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specification for Silicon Epitaxial Wafers for Discrete Device Applications

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

2.2 *ASTM Standards*[1]

F 47 — Test Method for Crystallographic Perfection of Silicon by Preferential Etch Techniques

F 80 — Test Method for Crystallographic Perfection of Epitaxial Deposits of Silicon by Etching Techniques

F 95 — Test Method for Thickness of Epitaxial Layers of Silicon on Substrates of the Same Type by Infrared Reflectance

F 110 — Test Method for Thickness of Epitaxial or Diffused Layers in Silicon by the Angle Lapping and Staining Technique

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 374 — Test Method for Sheet Resistance of Silicon Epitaxial Layers Using a Colinear Four-Probe Array

F 398 — Test Method for Majority Carrier Concentration in Semiconductors by Measurement of Wavelength of the Plasma Resonance Minimum

F 419 — Test Method for Net Carrier Density in Silicon Epitaxial Layers by Diode Voltage-Capacitance

F 522 — Test Method for Stacking Fault Density of Epitaxial Layers of Silicon by Interference-Contrast Microscopy

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 525 — Measuring Resistivity of Silicon Wafers Using a Spreading Resistance Probe

F 672 — Test Method for Measuring Resistivity Profiles Perpendicular to the Surface of a Silicon Wafer Using a Spreading Resistance Probe

F 723 — Practice for Conversion between Resistivity and Dopant Density for Boron-Doped and Phosphorus-Doped Silicon

F 815 — Test Method for Detection of Epitaxial Spikes

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

F 1241 — Terminology of Silicon Technology

F 1392 — Test Method for Determining Net Carrier Density Profiles in Silicon Wafers by Capacitance-Voltage Measurements with a Mercury Probe

F 1393 — Test Method for Determining Net Carrier Density in Silicon Wafers by Miller Feedback Profiler Measurements with a Mercury Probe

F1727 — Practice for Detection of Oxidation Induced Defects in Polished Silicon Wafers

2.3 *Other Standard*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3 Terminology

3.1 Many terms relating to silicon technology are defined in ASTM Terminology F 1241.

3.2 Definitions for the epitaxial wafer defects covered in Table 1 are given in ASTM Test Methods F 47, F 522, and F 815, and in ASTM Practices F 154.

3.3 Definitions of selected epi wafer defects, extended to consider automatic surface inspection are given below.

3.3.1 *mound (epi)* — a rounded protrusion on a semiconductor wafer surface, which may have one or more partially developed facets (see Figure 1).

NOTE 2: Scattering event size reported by SSIS will differ from the physical size of the object. The figure captions in the examples highlight this fact. No useful method exists at the present time to quantify this relationship (see Section 6.3.3.3)

3.3.1.1 *Discussion* — Related characteristics include the following:

- *Device characteristics that may be affected* — critical feature dimensions, lithographic equipment focus, gate oxide integrity.
- *Detection characteristics used for characterization* — mound height, diameter at 50% height.
- *Discrimination characteristics used for characterization* — positive height: 10–100 nm, or approximately 20% of the epi layer thickness; diameter: 0.1–6 µm; circular symmetry.
- *Specification characteristics used for wafer qualification* — number per wafer, mound height, height to diameter.

3.3.2 *epi stacking fault* — a two dimensional effect that results from a deviation from the normal stacking sequence of atoms in a crystal. [ASTM F 154, F 522, F1727]

NOTE 3: Discrimination and specification characteristics are given in this section to facilitate equipment development (see Section 6.3.3.3) and are not intended for use in commercial wafer specifications.

3.3.2.1 *Discussion* — Epi stacking faults are typically linked together into squares in the case of {100} oriented wafers, and triangles in the case of {111} oriented wafers. Most stacking faults are nucleated at the epi layer substrate boundary, though some have been observed being nucleated further into the epi growth process. Faults are aligned along specific crystallographic directions. For {100} wafer the sides of the faults are aligned along <110> directions. The length of a side is typically proportional to the epi layer thickness and related to the crystallographic orientation. In order to minimize the strain around a stacking fault contaminants may diffuse to these defects. Some stacking faults may have an effect on the local growth rate giving the stacking fault a three dimension aspect. This three dimensional aspect changes their light scattering cross section when observed by an SSIS (see Figures 3 through 7). Still more complicated are overlapping stacking faults which scatter even more than a single stacking fault of the same size (see figure 4). Other types of defects may be composites of stacking faults and polysilicon growth which can also appear larger than a single stacking fault of the same lateral dimensions (see Figures 5 and 6). Related characteristics include the following:

- *Device characteristics that may be affected* — leakage and gate oxide integrity, from crystallographic changes.
- *Detection characteristics used for characterization* — side length and depth, orientation parallel to a <110> direction.
- *Discrimination characteristics used for characterization* — shape, length ~ epi layer thickness: 1–10 µm. Stacking faults may cluster (see Figure 7) and scatter more than a single stacking fault.

[2] American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

- *Specification characteristics used for wafer qualification* — Number per wafer. Since certain types of epi stacking faults have no observed impact on device performance while others are killer defects no number can be assigned without a clear identification of the type of epi stacking fault that is involved.

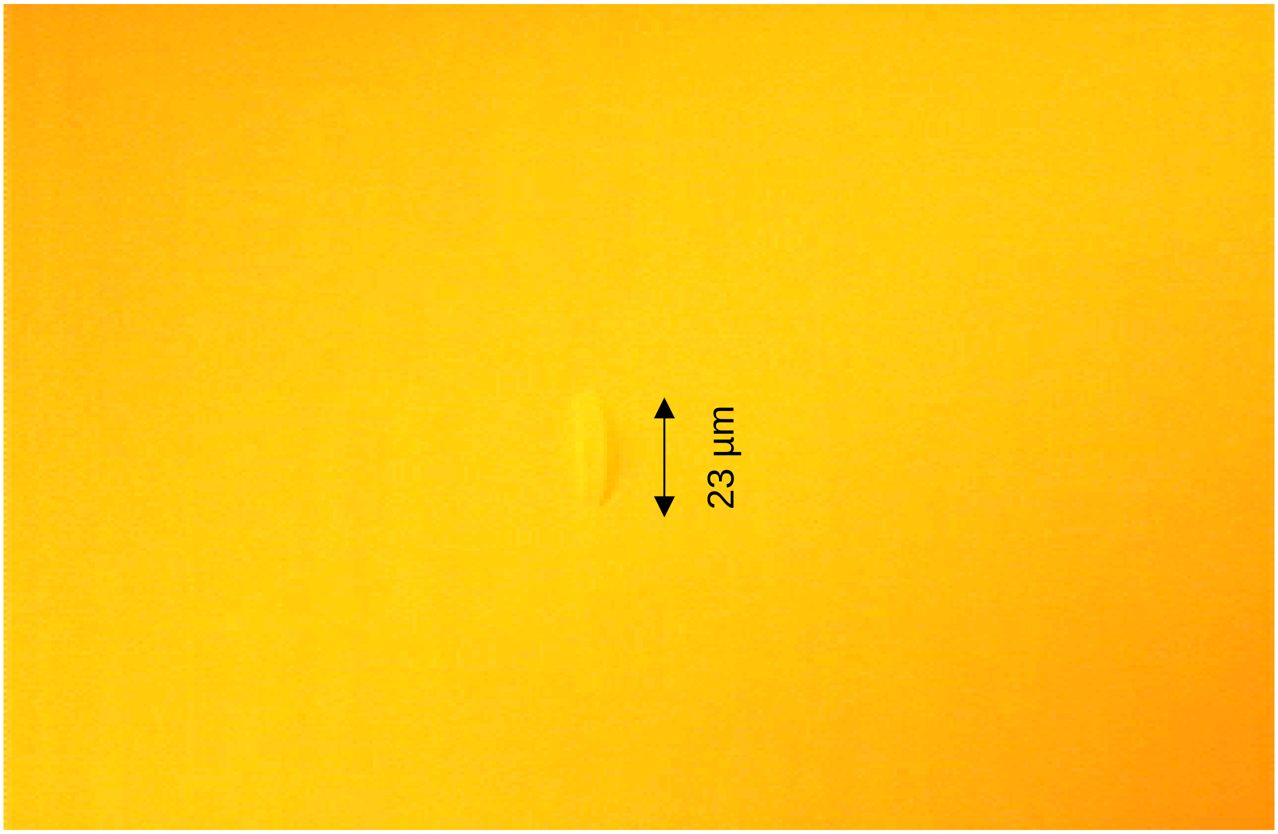


Figure 1
A Mound. Magnification 1000 times using Nomarksi Interference Microscopy. Approximate SSIS scattering event size 0.22 µm.

Figure 2
This is a mound that does not have the sharp edges of an Epitaxial Stacking Fault, but is not as high as a Bump. They are typically sized much smaller in a SSIS than their actual size, but some have facets that scatter enough light to be more easily detected. Some people refer to this feature as a hillock which is a type of mound. The shape can be either circular or square. Magnification 500 times using Nomarski Interference Microscopy. Approximate SSIS event size: 0.15 µm

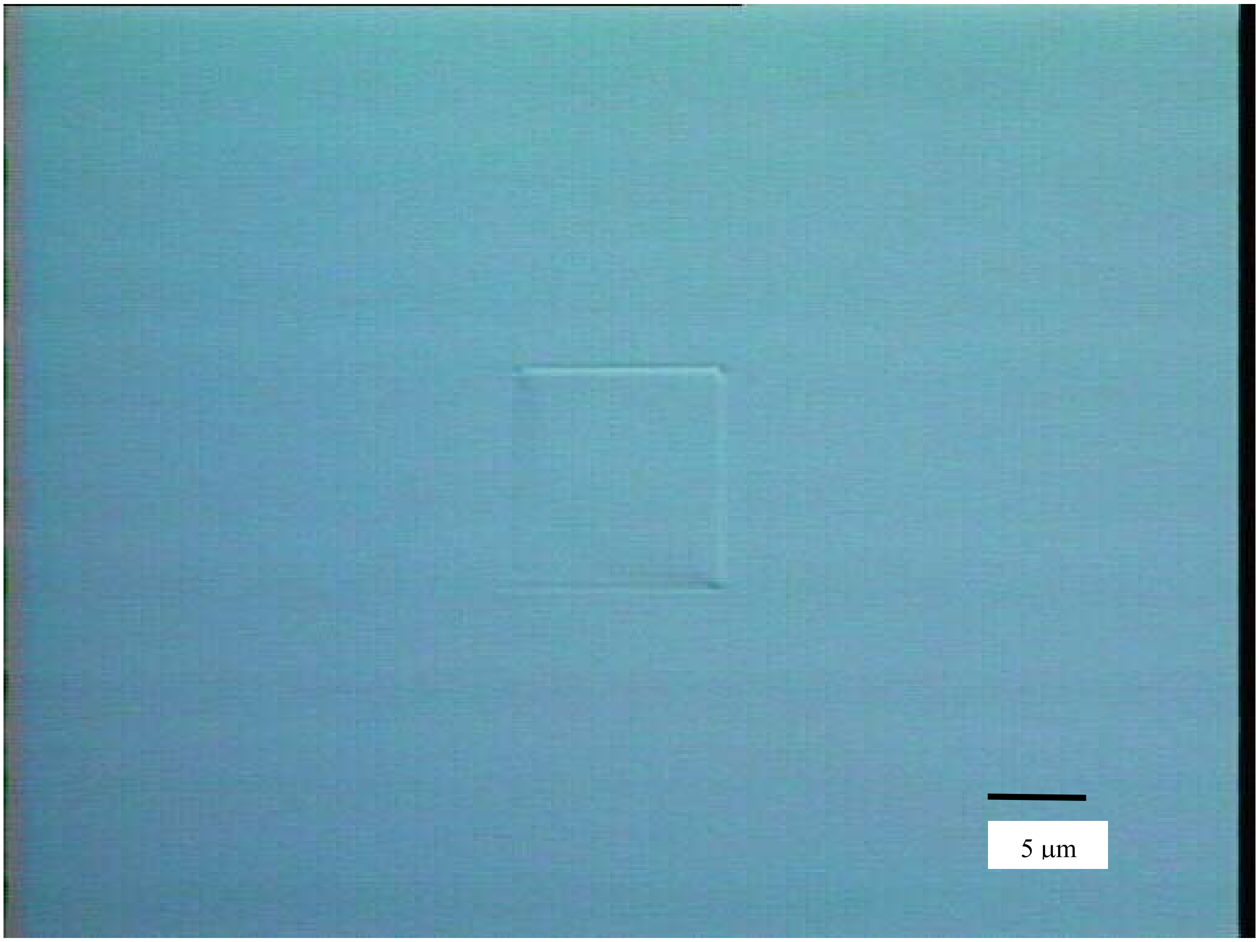


Figure 3
The Epi Stacking Fault (ESF) defect is a grown-in defect with 1 to 4 sides of a square visible. Magnification 1500 times using Nomarski Interference Microscopy. Approximate SSIS event size: 0.165 µm

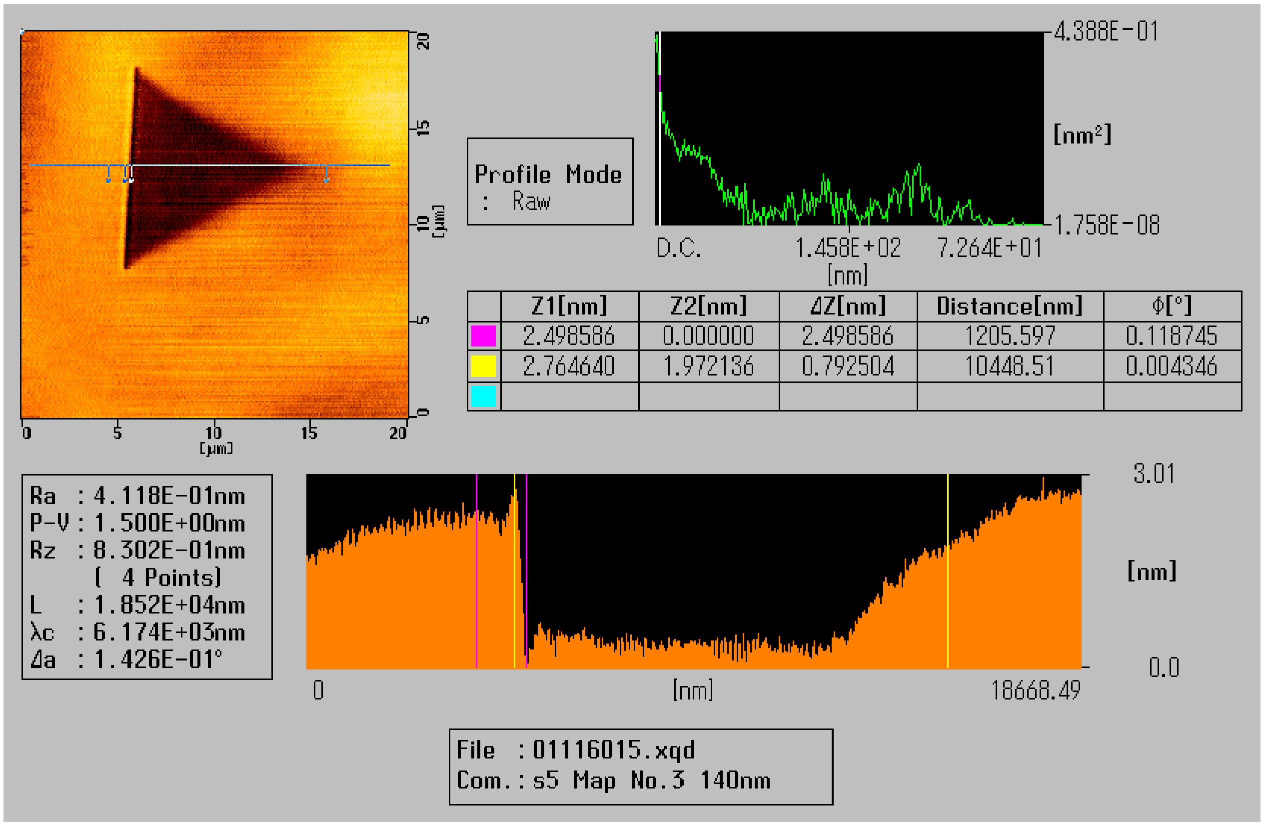


Figure 4
Epitaxial Stacking Fault. Atomic Force Microscope (AFM) Image. Approximate SSIS scattering event size 0.12 µm.

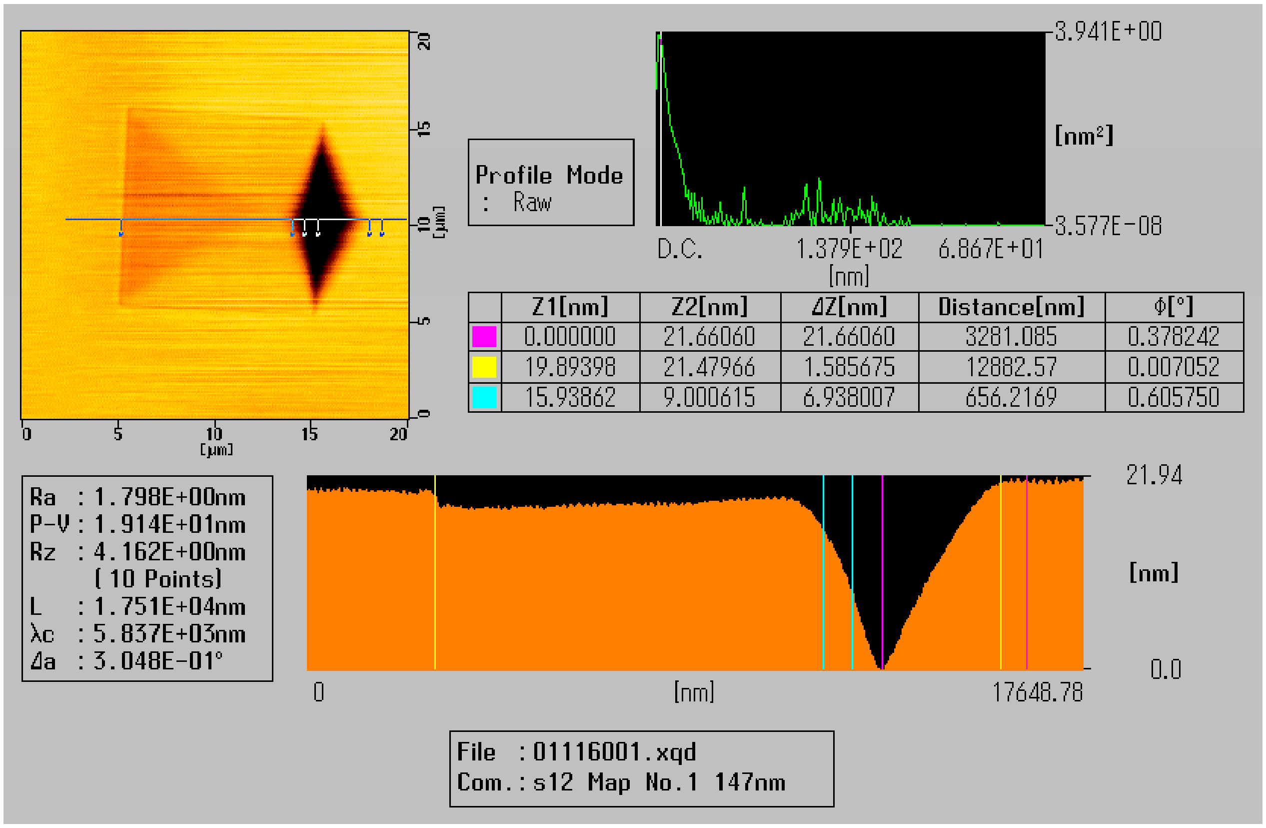


Figure 5
Epitaxial Stacking Fault showing four sides and a deep depression on on side of about 20 nm. Atomic Force Microscope Image. Approximate SSIS scattering event size, 0.30 µm.

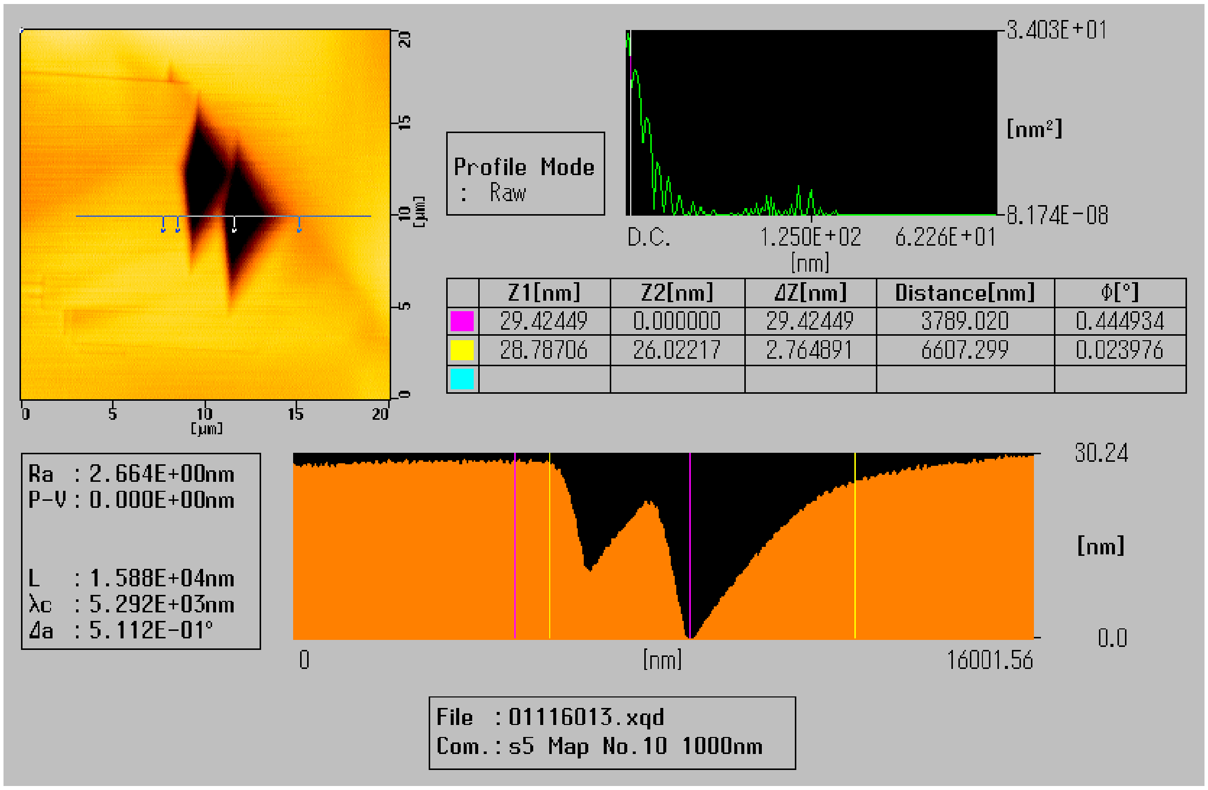


Figure 6
Double Epi taxial Stacking Fault. Atomic Force Microscope image. Approximate SSIS event scattering size 1.05 µm

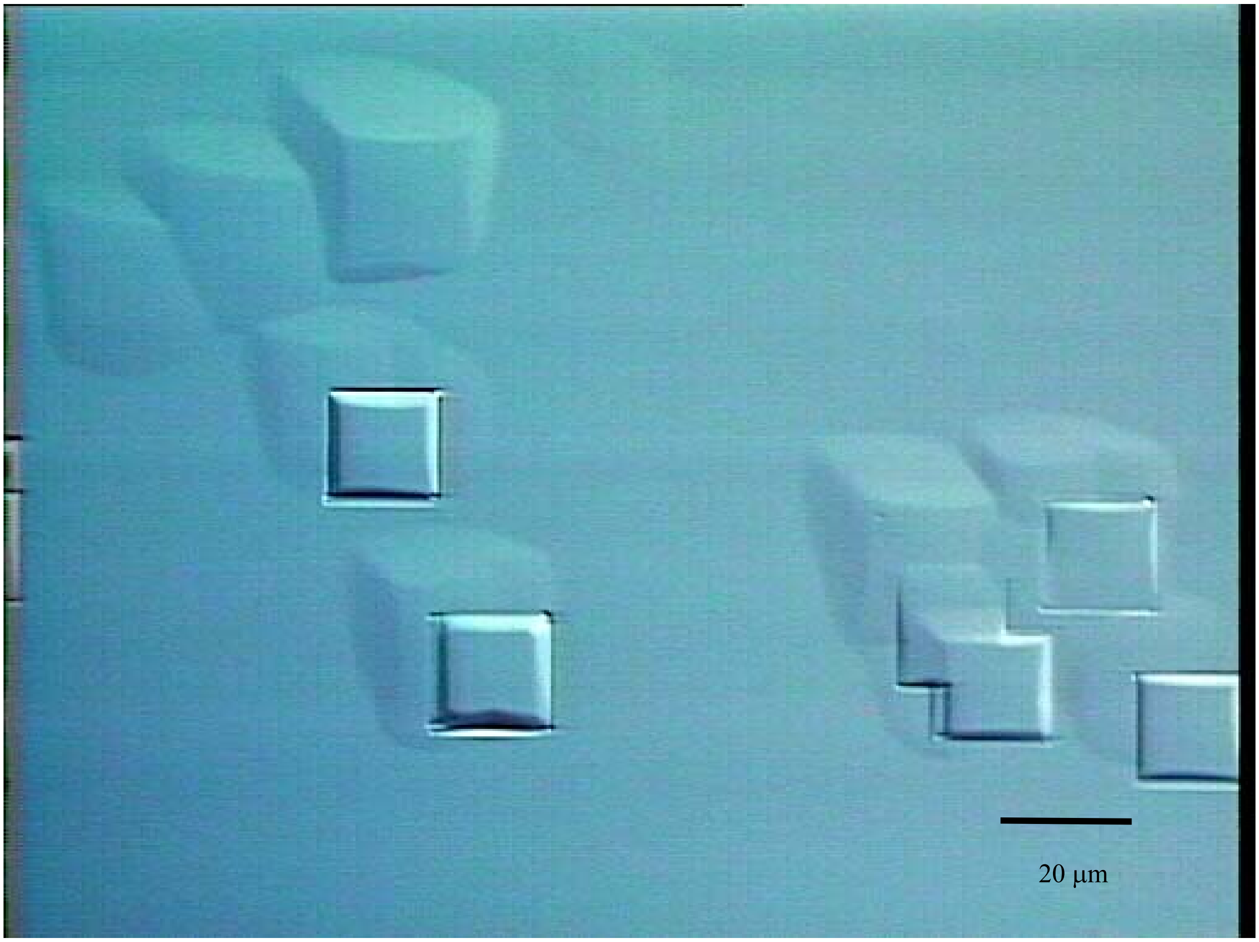


Figure 7
The Epitaxial Stacking Fault Cluster classification is used to define a group of ESFs in close proximity on the wafer surface. The group can either be overlapping or in a line (except when the line appears to be part of a Pre-Epi Scratch). Magnification 500 times using Nomarski Interference Microscopy. Approximate SSIS event size, 0.20 µm

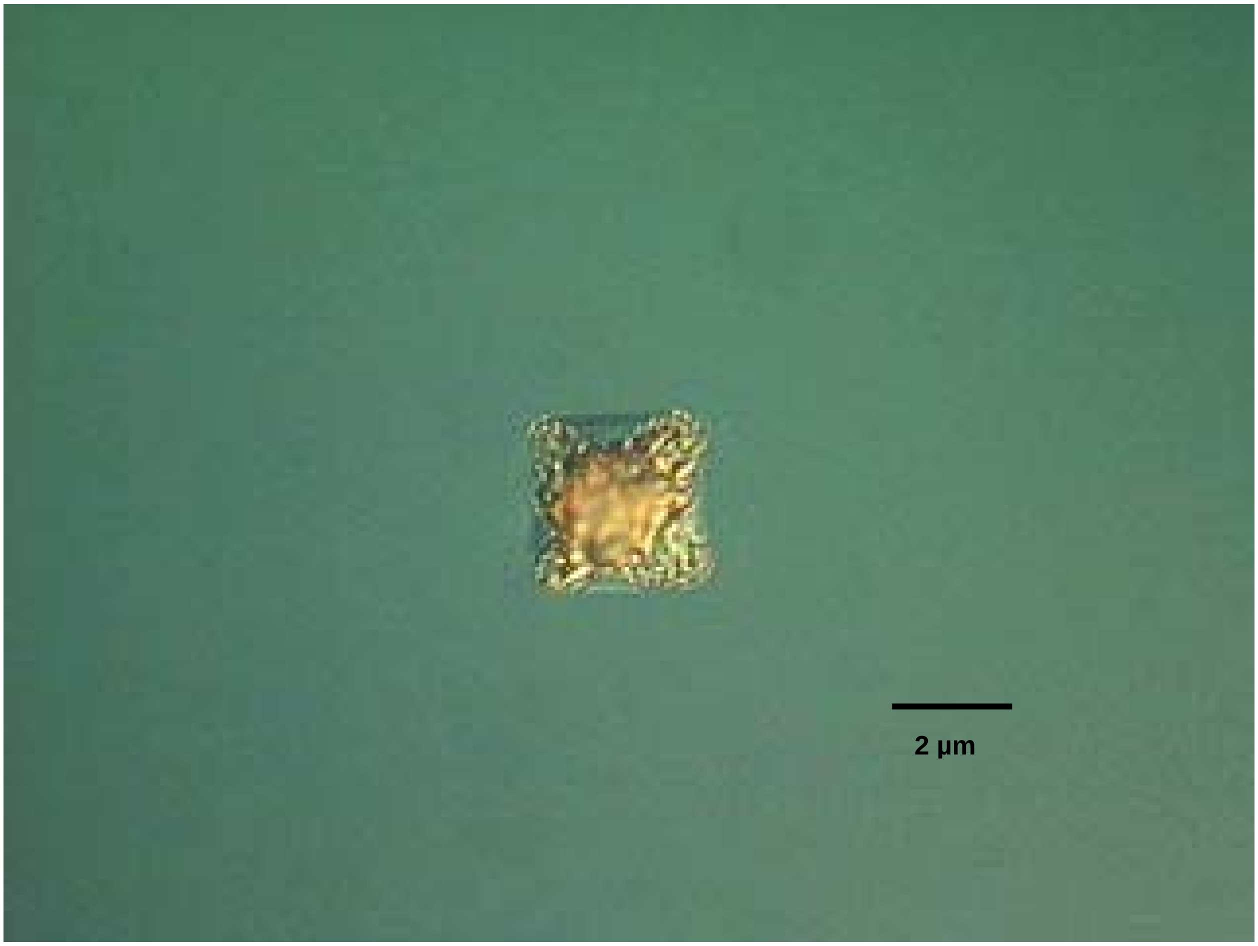


Figure 8
Composite Defect of polysilicon growth and stacking faults. Magnification 1000 times by Nomarksi Interference Microscopy. Approximate SSIS image event size >>1.0 µm

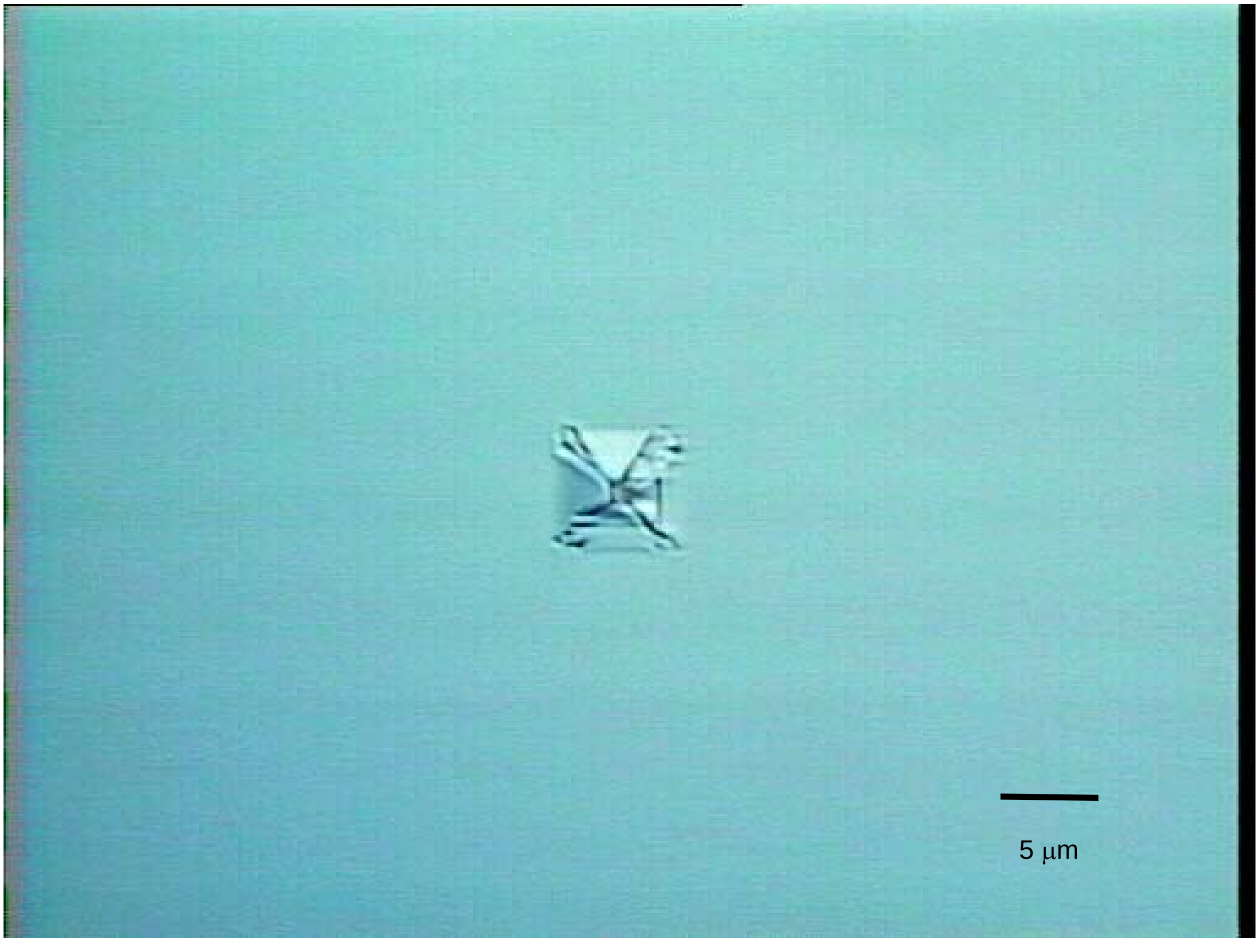


Figure 9
The Compound ESF defect is an epi stacking fault that has a broken surface, but maintains the square shape of an ESF. It typically scatters more light than a normal ESF because of the extra facets, so it is sized larger in a SSIS. Magnification 500 times using Nomarski Interference Microscopy. Approximate SSIS event size: 280 µm

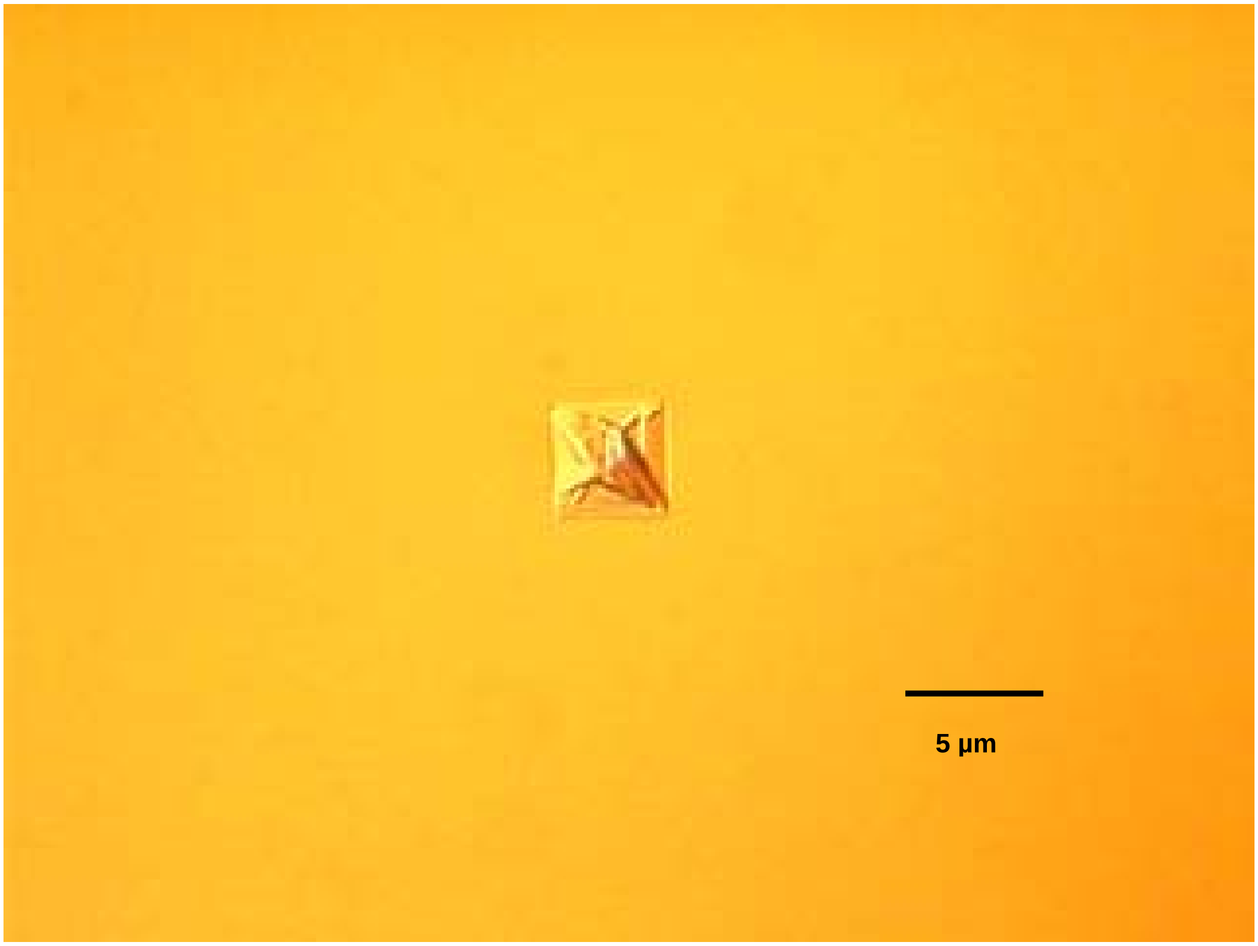


Figure 10
Composite Defect of polysilicon growth and stacking faults. Magnification 500 times by Nomarksi Interference Microscopy. Approximate SSIS image event size >>1.0 µm

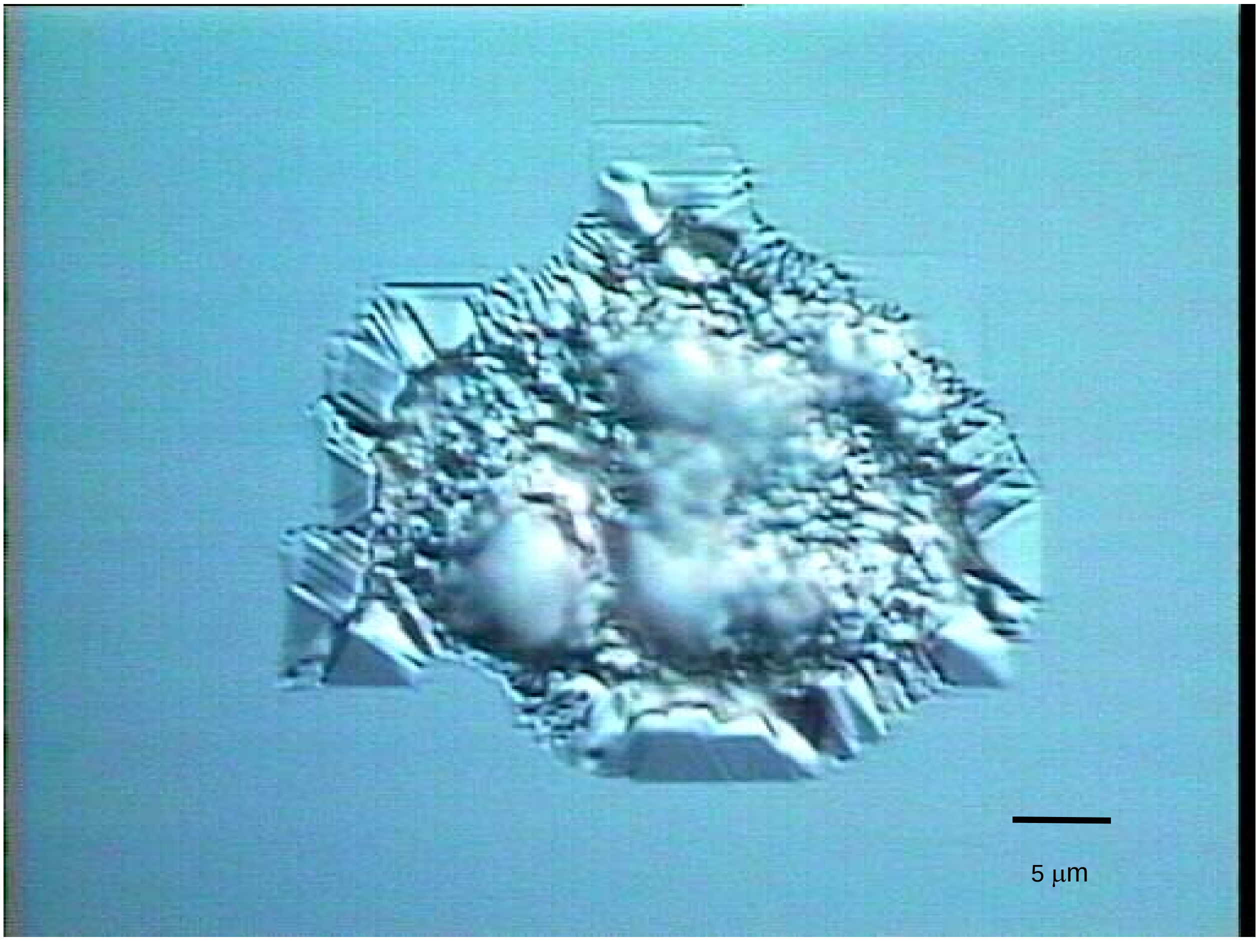


Figure 11
A Polysilicon Epitaxial Stacking Fault is a defect that covers a large area and is covered or surrounded by ESFs. This classification is used when the surface appears to be poly-crystalline rather than single crystal. It is almost always a Large Area Defect and is caused by a large particle that may still be visible (see Buried Particle). Magnification 1500 times using Nomarski Interference Microscopy. Approximate SSIS event size, 440 µm

3.4 Other terms are defined as follows:

3.4.1 *autodoping, of an epitaxial layer* — incorporation of dopant originating from the substrate into the epitaxial layer. Also called *self-doping*.

NOTE 4: Sources of autodoping can be the back and front surfaces and edges of the substrate, other substrates in the reactor, the susceptor, or other parts of the deposition assembly.

3.4.2 *chemical vapor deposition, in semiconductor technology* — a process in which a controlled chemical reaction produces a thin surface film.

NOTE 5: Epitaxial growth is an example of a special case of chemical vapor deposition (CVD).

3.4.3 *edge crown* — the difference between the surface elevation 1/8 inch (3.2 mm) from the edge of the wafer and the elevation at the wafer edge.

3.4.4 *effective layer thickness, of an epitaxial layer* — the depth from the front surface in which the net carrier density is within the specified limits.

3.4.5 *epi profile slope, of an epitaxial layer* — the difference between the net carrier density at 0.75 of the layer thickness and the net carrier density at 0.25 of the layer thickness divided by one-half the layer thickness:

$$\text{epi profile slope} = \frac{N_{0.75t} - N_{0.25t}}{0.5t}$$

where :

N = net carrier density, cm^{-3}, and

t = layer thickness, μm.

3.4.6 *epitaxial layer* — a layer of single crystal semiconductor material grown on a host substrate which determines its orientation.

3.4.7 *epitaxy* — the growth of a single crystal layer on a substrate of the same material, homoepitaxy; or on a substrate of different material with a compatible crystal structure, heteroepitaxy.

3.4.8 *flat zone, of an epitaxial layer* — the depth from the front surface to the point where the net carrier density is 20% greater than or less than the average net carrier density (see Section 6.3.2) of the region between 0.25 and 0.75 of the layer thickness.

3.4.9 *laser light scattering event* — a signal pulse that exceeds a preset threshold, generated by the interaction of a laser beam with a discrete scatterer at a wafer surface as sensed by a detector.

3.4.10 *thickness, of an epitaxial layer* — the distance from the surface of the wafer to the layer-substrate interface.

3.4.11 *transition width, of an epitaxial layer deposited on a more heavily doped substrate of the same conductivity type* — the difference between the layer thickness as determined by infrared reflectance (see Section 6.3.1) and the flat zone based on the same thickness measurement.

4 Ordering Information

4.1 Purchase orders for the epitaxial layer on substrates furnished to this specification shall include the following items:

4.1.1 *Substrate Characteristics*

4.1.2 *Epitaxial Layer Characteristics*

4.1.2.1 Silicon Source for Epitaxial Growth (if required) (see Note 4)

4.1.2.2 Epitaxial Layer Conductivity Type and Doping Source (see Note 4)

4.1.2.3 Etch Removal (if required)

4.1.2.4 Epitaxial Layer Center Point Thickness and Thickness Tolerances

4.1.2.5 Epitaxial Layer Thickness Variation Range

4.1.2.6 Epitaxial Layer Centerpoint Net Carrier Density and Net Carrier Density Tolerances (see Note 5)

4.1.2.7 Epitaxial Layer Net Carrier Density Variation Range

4.1.2.8 Epitaxial Layer Defect Limits

4.1.3 Methods of Test and Measurements (see Section 6)

4.1.4 Lot Acceptance Procedures (see Section 7)

4.1.5 Certification (if required) (see Section 8)

4.1.6 Packing and Marking (see Section 9)

NOTE 6: The dopant, doping method, and growth method are difficult to ascertain in the finished wafers. Verification test procedures or certification of these characteristics shall be agreed upon between the supplier and the purchaser. (See Section 8.)

NOTE 7: Care should be taken in converting between carrier density and resistivity using ASTM Practice F 723. Multiple conversions may introduce differences in values. For example, converting from carrier density (C_i) to resistivity and back to carrier density (C_f), may result in C_i not equaling C_f.

5 Requirements

5.1 As a minimum, the substrate shall conform to SEMI M1 and the appropriate individual polished monocrystalline silicon wafer standard.

5.2 Epitaxial wafer defects shall not exceed the limit as given in Table 1.

5.2.1 Limits for slip, which may require destructive testing, shall be specified in a purchase order together with an appropriate test method. In the absence of another specification, the wafer will contain no slip lines within the quality area. (See Table 1, Note 1.)

NOTE 8: When an unetched wafer is observed for slip it is impossible to differentiate between slip and linear misfit lines.

5.3 *Layer Thickness Variation* — Unless otherwise specified, the thickness variation shall be determined from value measured at the center and locations centered 12 mm ± 1 mm from the periphery, on diameters both parallel and perpendicular to the primary flat,

$$\text{Variation}(\%) = \frac{t_{max} - t_{min}}{t_{max} + t_{min}} \times 100$$

where t_{max} and t_{min} denote the maximum and minimum thickness values measured. The 12 mm locations have been defined based on instrument processing and fixturing considerations.

5.4 *Layer Net Carrier Density Variation* — The net carrier density variation shall be determined from values measured at the center and locations with center of the probe at 12 mm ± 1 mm from the periphery, on diameters both parallel and perpendicular to the primary flat,

$$\text{Variation}(\%) = \frac{N_{max} - N_{min}}{N_{max} + N_{min}} \times 100$$

where N_{max} and N_{min} denote the maximum and minimum values measured. The 12 mm locations have been defined based on instrument processing and fixturing considerations.

6 Test Methods and Measurements

6.1 Measurements shall be carried out in conformance with the specified ASTM Test Methods. Where no methods are specified or where choices are given, the supplier and purchaser shall agree in advance on the means for making the measurement.

6.2 *Substrates* — Determine in accordance with methods specified in SEMI M1.

6.3 *Epitaxial Layer*

6.3.1 *Thickness* — Determine in accordance with ASTM Test Method F 95 or F 110.

NOTE 9: In the case of thin layers and graded doping transitions, ASTM Test Methods F 95 and F 110 may not be suitable. See the scopes of these test methods to determine their limitations. In all cases, there is a possibility that various types of infrared reflectance instrumentation may result in different values of epitaxial layer thickness. Therefore, the instrumentation used shall be agreed upon between supplier and purchaser.

6.3.2 *Net Carrier Density* — Determine by method(s) agreed upon between supplier and purchaser.

NOTE 10: ASTM Test Method F 419 is a standardized differential-capacitance method for net carrier density, but it requires fabrication of a *p-n* junction. ASTM Test Methods F 1392 and F 1393 are methods for measuring net carrier density using a mercury probe contact. If resistivity is measured, as by ASTM Test Method F 374 or F 525, conversion to dopant density shall be made using ASTM Practice F 723. Net carrier density of very heavily doped layers (or substrates) may be found using ASTM Test Method F 398. Net carrier density profiles may be determined directly in accordance with ASTM Test Method F 419, F 1392, or F 1393 or indirectly in accordance with ASTM Test Method F 672, with conversion from resistivity to net carrier density in accordance with ASTM Practice F 723. If the method used for determining the net carrier density profile is not the same as that used to determine the centerpoint net carrier density, correlation between the two methods used shall be established.

6.3.3 *Epitaxial Wafer Defects* — Determine in accordance with the methods given in Table 1.

6.3.3.1 Surface inspection shall be performed before any other testing. Wafers may be cleaned prior to inspection to minimize difficulty in the visual inspection of defects other than foreign matter.

6.3.3.2 *Slip* — Determine by methods agreed upon between supplier and purchaser.

6.3.3.3 Automatic surface inspection technology is being developed to detect and discriminate surface defects. The extended definitions in Section 3.3 are intended to facilitate this development.

NOTE 11: For observation of gross slip, examination of the epitaxial layer under the illumination conditions specified in Section 12.2 of ASTM Practice F 523 may suffice. For more demanding applications, it may be desirable to etch the surface in accordance with ASTM Test Method F 80 prior to the visual inspection.

6.4 If substrates of different type and net carrier density than the product substrates are to be used for deposition control, their type, resistivity, and quantity per run or lot shall be agreed upon between supplier and purchaser.

Table 1 IC Epitaxial Wafers - Basic Surface Criteria

Item	*Characteristics*	*Maximum Acceptability Limits*	*Test Method*	*Notes and Reference Documents*
1	Stacking Faults	1 per cm^2	ASTM F 522	1
2	Slip	None	ASTM F 523 or F80	1, 5, 6
3	Dislocations	None	ASTM F 80	1
4	Total Localized Light Scatterers	2000 per m^2	≥ 0.5 µm LSE, based on calibration of surface scanning inspection systems with latex spheres, 90% capture rate	1, 7, SEMI M25 Table 2
5	Haze	None	ASTM F 523 Section 12.2	4, 7
6	Scratches	None	ASTM F 523 Section 12.2	2, 7
7	Edge Chips	None	ASTM F 523 Section 12.2	
8	Foreign Matter	None	ASTM F 523 Section 12.3	4
9	Back Surface Contamination	None	ASTM F 523 Section 12.4	4

NOTE 1: Defect limits shall apply to quality area, which is defined as the entire wafer surface except a defined outer annulus of 4 mm and any area included in a window where there is a laser identification mark.
NOTE 2: The cumulative AQL for both front surface and back surface of wafer is 2.5.
NOTE 3: The cumulative AQL for both front surface and back surface of wafer is 1.0.
NOTE 4: Any adherent contaminants, such as stains, glovemarks, dirt, smudges, warps, and solvent residues. This characteristic does not include point defects. Any nonadherent contamination or particulate matter easily removed by industry-accepted cleaning techniques shall not constitute foreign matter or haze.
NOTE 5: Test method(s) to be agreed upon between supplier and purchaser.
NOTE 6: For observation of gross slip, examine the epitaxial layer under illumination conditions specified in Section 12.2 of ASTM Practice F 523. For more demanding applications, it may be desirable to etch the surface in accordance with ASTM Test Method F 80.
NOTE 7: In today's technology, it may be possible to do this inspection using automated laser scanning systems; however, a standard test procedure has yet to be developed. Application of automated inspection must be agreed upon between supplier and user.

7 Sampling

7.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot according to ANSI/ASQC Z1.4-1993. Quality characteristics shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4-1993. Inspection levels shall be agreed upon between supplier and purchaser. Accept and reject criteria are to be based on defective wafers, not on defective characteristics.

7.2 Unless otherwise specified, the following AQL's shall be assigned:

7.2.1 Epitaxial Layer Center Thickness and Variation, 1%;

7.2.2 Epitaxial Layer Center Net Carrier Density and Variation, 1%;

7.2.3 Epitaxial Wafer Defects, Cumulative, 2.5%.

8 Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

8.2 The supplier and purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 6; however, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

9 Packing and Marking

9.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide protection against damage during shipment.

9.2 The wafers supplied under this specification shall be identified by appropriately labeling the outside of each box or container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include supplier's name and reference number, purchaser's p.o. number, quantity, dopant, orientation, conductivity type of substrates and epitaxial layers, carrier density, and thickness of the epitaxial layer. The reference number assigned by the supplier shall provide ready access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer's facility for at least one year after that particular lot has been shipped.

10 Guides

10.1 The specifications in the epitaxial guides are examples which were formed by a consensus of viewpoints. They may or may not be used as a foundation to specify an epitaxial wafer for use in device manufacture. Their usefulness can be increased by considering the guides prior to developing a device design or process. The required specification is deter-mined by the device and the process design, the guides are suggestions from which a specification can evolve.

10.2 An epitaxial guide can be viewed as a generic epitaxial wafer specification or as an example of a specification. These tables provide common epitaxial wafer characteristics which describe starting wafers useful for the manufacture of some twin tub CMOS devices.

10.3 The guides in Tables 3, 4, 5, 6, 7, 8 and 9 provide a series of options intended to increase the awareness of epitaxial specifications and to provide information from which a specification can be formulated.

10.4 SEMI M18 was used as a template for formulating these tables. When suitable to the application, the guides can be used intact, reducing the proliferation of specifications and formats.

10.4.1 Table 3 is representative of 1.0 µm design rule epitaxial wafer criteria.

10.4.2 Table 4 is typical of an epitaxial wafer criteria for custom twin tub CMOS, 0.35 µm design rule devices, such as, but not limited to ASIC's, FPGA's, linears, DSP's, and microprocessors.

10.4.3 Table 5 is typical of an epitaxial wafer criteria for 0.35 µm design rule devices such as 64 megabit DRAM's.

10.4.4 Table 6 is typical of epitaxial wafer criteria for twin tub CMOS, 0.25 µm design rule devices, such as, but not limited to ASIC's, FPGA's, linears, DSP's, and microprocessors.

10.4.5 Table 7 is typical of epitaxial wafer criteria for twin tub CMOS, 0.18 µm design rule devices.

10.4.6 Table 8 is typical of epitaxial wafer substrate criteria for a wafer pre-epitaxial that will be used in twin tub CMOS, 0.25 µm design rule devices.

10.4.7 Table 9 is typical of epi wafer criteria for twin tub CMOS, 0.13 µm design rule devices.

Table 2 Equivalent Units for Localized Light Scatterers

	Diameter[1]					
Density per m^2	*100*	*125*	*150*	*200*	*300*	*Density per cm*^{2}
	Localized Light Scatterers per Wafer					
100	1	1	2	3	7	0.01
200	1	2	3	6	13	0.02
300	2	3	5	9	20	0.03
400	3	4	6	12	27	0.04
500	3	5	8	14	33	0.05
600	4	6	10	17	40	0.06
700	5	8	11	20	47	0.07
800	5	9	13	23	54	0.08
900	6	10	14	26	60	0.09
1000	7	11	16	29	67	0.10

Diameter[1]						
Density per m²	*100*	*125*	*150*	*200*	*300*	*Density per cm²*
	Localized Light Scatterers per Wafer					
1100	7	12	17	32	74	0.11
1200	8	13	19	35	80	0.12
1300	9	14	21	38	87	0.13
1400	9	15	22	41	94	0.14
1500	10	16	24	43	100	0.15
1600	11	17	25	46	107	0.16
1700	11	18	27	49	114	0.17
1800	12	19	29	52	121	0.18
1900	13	20	30	55	127	0.19
2000	13	22	32	58	134	0.20
2100	14	23	33	61	141	0.21
2200	15	24	35	64	147	0.22
2300	15	25	36	67	154	0.23
2400	16	26	38	69	161	0.24
2500	17	27	40	72	167	0.25
2600	17	28	41	75	174	0.26
2700	18	29	43	78	181	0.27
2800	19	30	44	81	188	0.28
2900	19	31	46	84	194	0.29
3000	20	32	48	87	201	0.30
3100	21	33	49	90	208	0.31
3200	21	34	51	93	214	0.32
3300	22	35	52	96	221	0.33
3400	23	37	54	98	228	0.34
3500	23	38	55	101	234	0.35
3600	24	39	57	104	241	0.36
3700	25	40	59	107	248	0.37
3800	25	41	60	110	254	0.38
3900	26	42	62	113	261	0.39
4000	27	43	63	116	268	0.40
4100	27	44	65	119	275	0.41
4200	28	45	67	122	281	0.42
4300	29	46	68	124	288	0.43
4400	29	47	70	127	295	0.44
4500	30	48	71	130	301	0.45
4600	31	49	73	133	308	0.46
4700	31	51	74	136	315	0.47
4800	32	52	76	139	321	0.48
4900	33	53	78	142	328	0.49
5000	33	54	79	145	335	0.50

Table 3 Guide for Specification of 1.0 µm Design Rule, Twin-Tub CMOS, Epitaxial Wafers

CUSTOMER:		*PART NUMBER: REVISION:*	*DATE:*			
M18 ITEM #		*SPECIFICATION*	*TESTING LEVEL*			
			WAFER		*TEST PIECE*	
			100%	*SAMPLE*	*100%*	*SAMPLE*
11. GENERAL EPITAXIAL WAFER AND LAYER CHARACTERISTICS						
11.1	Conductivity Type/ Structure	p/p+				
11.2	Primary Dopant	Boron				
11.3	Silicon Source Gas	Fixed				
11.4	Reactor Type	Fixed				
11.5	Carrier Density (Center)	$2.00 \pm 1.0 \times 10^{15}$				
	Units	carriers per cm^3				
	Test Method	Mercury Probe ASTM F 1392				
11.6	Carrier Density Variation	10% max per SEMI M11				
11.7	Thickness (Center)	Target ± 10%				
11.8	Thickness Variation	10% per SEMI M11				
11.11	Phantom Layer	none				
12. MECHANICAL CHARACTERISTICS: POST EPI						
12.5	Flatness/Site	95% of the 18 mm × 18 mm sites ≤ 0.5 µm (SFQD) includes partial sites				
13. FRONT SURFACE CHARACTERISTICS						
13.1	Stacking Faults	1 per cm^2 maximum				
13.2	Slip/Dislocations	none per ASTM F 80				
13.14	Localized Light Scatterers	2000 per m^2 max. ≥ 0.5 µm LSE, based on calibration of surface scanning inspection systems with latex spheres, 90% capture rate				
13.5	Scratches	none per ASTM F 523, Section 12.2				
13.6	Dimples	none per ASTM F 523, Section 12.3				
13.7	Orange Peel	none per ASTM F 523, Section 12.3				
13.8	Cracks/Fractures	none per ASTM F 523, Section 12.3				
13.9	Crow's Feet	none per ASTM F 523, Section 12.3				
13.10	Edge Chips	none per ASTM F 523, Section 12.3				
13.12	Haze	none per ASTM F 523, Section 12.2				
12.13	Foreign Matter	none per ASTM F 523, Section 12.3				
13.15	Nominal Edge Exclusion	4 mm				
	Surface Metals	$\leq 1 \times 10^{12}$ per cm^2 for Zn, Al, Ni $\leq 2 \times 10^{11}$ per cm^2 for each element: Na, Cr, K, Fe, Cu				
14. BACK SURFACE CHARACTERISTICS						
14.1	Contamination	none per ASTM F 523, Section 12.4				
15. OTHER CHARACTERISTICS - POLISHED WAFER: EPITAXIAL SUBSTRATE — MEETS SEMI M1						
15.1	Resistivity	0.005–0.020 Ω-cm				
15.2	Back Seal	polysilicon [ ], silicon oxide [ ], silicon nitride [ ], combination and thickness as required, none [ ]				
15.3	Nominal Diameter	125 mm [ ], 150 mm [ ], 200 mm [ ], 300 mm [ ]				

Table 4 Guide for the Specification of 0.35 µm Design Rule, Twin-Tub CMOS, Epitaxial Wafers

CUSTOMER:		PART NUMBER: REVISION:	DATE:			
M18 ITEM #		SPECIFICATION	TESTING LEVEL			
			WAFER		TEST PIECE	
			100%	SAMPLE	100%	SAMPLE
11. GENERAL EPITAXIAL WAFER AND LAYER CHARACTERISTICS						
11.1	Conductivity Type/ Structure	*p/p+*				
11.2	Primary Dopant	Boron				
11.3	Silicon Source Gas	Fixed				
11.4	Reactor Type	Fixed				
11.5	Net Carrier Density (Center)	$2.00 \pm 0.5 \times 10^{15}$				
	Units	carriers per cm^3				
	Test Method	Mercury Probe ASTM F 1392 or F 1393				
11.6	Net Carrier DensityVariation	10% max per SEMI M11				
11.7	Thickness (Center)	Target ± 5% (1σ)				
11.8	Thickness Variation	10% per SEMI M11				
11.11	Phantom Layer	none				
12. MECHANICAL CHARACTERISTICS: POST EPI						
12.5	Flatness/Site	95% of the 22 mm × 22 mm ≤ 0.23 um (SFQD) includes partial sites				
13. FRONT SURFACE CHARACTERISTICS						
13.1	Stacking Faults	0.1 per cm^2 maximum				
13.2	Slip/Dislocations	none per ASTM F 80				
13.5	Scratches	none per ASTM F 523, Section 12.2				
13.6	Dimples	none per ASTM F 523, Section 12.3				
13.7	Orange Peel	none per ASTM F 523, Section 12.3				
13.8	Cracks/Fractures	none per ASTM F 523, Section 12.3				
13.9	Crow’s Feet	none per ASTM F 523, Section 12.3				
13.10	Edge Chips	none per ASTM F 523, Section 12.3				
13.12	Haze	none per ASTM F 523, Section 12.2				
13.13	Foreign Matter	none per ASTM F 523, Section 12.3				
TBD	Localized Light Scatterers	2000 per m^2 max. ≥ 0.2 µm size, based on calibration of surface scanning inspection systems with latex spheres, 90% capture rate				
13.15	Nominal Edge Exclusion	4 mm for all front surface characteristics except cracks/fractures, edge chips, crow’s feet, and foreign matter				
7.1	Surface Metals	$\leq 1 \times 10^{11}$ atoms per cm^2 for each element: Na, Al, Cr, K, Fe, Ni, Cu, Zn				
14. BACK SURFACE CHARACTERISTICS						
14.1	Contamination	none per ASTM F 523, Section 13.4				
TBD	Back Seal	user specified				
15. OTHER CHARACTERISTICS: POLISHED WAFER-EPITAXIAL SUBSTRATE — MUST MEET SEMI M1 EXCEPT AS NOTED						
2.1	Resistivity	0.005–0.010 Ω-cm				
TBD	Bulk Micro Defects	user specified				

CUSTOMER:		PART NUMBER: REVISION:	DATE:			
M18 ITEM #		SPECIFICATION	TESTING LEVEL			
			WAFER		TEST PIECE	
			100%	SAMPLE	100%	SAMPLE
TBD	Denuded Zone	user specified				
TBD	Back Seal	polysilicon [ ], silicon oxide [ ], silicon nitride [ ], combination and thickness as required, none [ ]				
6.1	Diameter	125 mm [ ], 150 mm [ ], 200 mm [ ], 300 mm [ ]				

Table 5 Guide for the Specification of 0.35 μm Design Rule Epitaxial Wafers for DRAM Applications

CUSTOMER:		PART NUMBER: REVISION:	DATE:			
M18 ITEM #		SPECIFICATION	TESTING LEVEL			
			WAFER		TEST PIECE	
			100%	SAMPLE	100%	SAMPLE
11. GENERAL EPITAXIAL WAFER AND LAYER CHARACTERISTICS						
11.1	Conductivity Type/ Structure	p/p+				
11.2	Primary Dopant	Boron				
11.3	Silicon Source Gas	not specified				
11.4	Growth Method	not specified				
11.5	Net Carrier Density(Center)	Target must be $\geq 1.34 \times 10^{15}$ Tolerance ± 25% of target				
	Units	Carriers per cm^3				
	Test Method	ASTM F 419, F 1392, or F 1393				
11.6	Net Carrier DensityVariation	± 20% per SEMI M11				
11.7	Thickness (Center)	Target must be ≤ 5 μm, Tolerance ± 5 % (1σ) or target				
11.8	Thickness Variation	10% per SEMI M11				
11.9	Transition Width	user specified				
11.11	Phantom Layer	none				
6. MECHANICAL CHARACTERISTICS: PRE EPI						
6.11	Warp	user specified				
6.13	Global Flatness	3 μm max. (GFLR)				
6.8	Total Thickness Variation (TTV)	5 μm max. (GBIR)				
6.14	Flatness/Site	95% of the 22 mm × 22 mm sites ≤ 0.35 μm (SFQD), partial sites not included, substrate form				
13. FRONT SURFACE CHARACTERISTICS						
13.1	Stacking Faults	0.1 per cm^2 maximum				
13.2	Slip/Dislocations	total length ≤ diameter/2 per ASTM F 80				
13.10	Edge Chips	none per ASTM F 523, Section 12.3				
13.14	Localized Light Scatters including haze, stacking faults and scratches	2000 per m^2 max. ≥ 0.16 μm size, based on calibration of surface scanning inspection systems with latex spheres, 90% capture rate				
13.15	Nominal Edge Exclusion	4 mm for all front surface characteristics except cracks/fractures, edge chips, crow's feet, and foreign matter				

CUSTOMER:		PART NUMBER: REVISION:		DATE:			
M18 ITEM #		SPECIFICATION		TESTING LEVEL			
				WAFER		TEST PIECE	
				100%	SAMPLE	100%	SAMPLE
7.1	Surface Metals	$\leq 1 \times 10^{11}$ atoms per cm^2 for each element: Na, Al, Cr, K, Fe, Ni, Cu, Zn					
14. BACK SURFACE CHARACTERISTICS							
14.1	Contamination	none per ASTM F 523, Section 12.4					
14.2	Back Seal	Silicon Oxide [ ], None [ ]					
15. OTHER CHARACTERISTICS: POLISHED WAFER, EPITAXIAL - SUBSTRATE - MUST MEET SEMI M1 EXCEPT AS NOTED							
2.1	Resistivity	0.005–0.010 Ω-cm or 0.010–0.020 Ω-cm					
		Substrate Resistivity	Backseal Required				
		0.005–0.010 Ω-cm	yes				
		0.010–0.020 Ω-cm	user specified				
TBD	Bulk Micro Defects	user-specified					
TBD	Denuded Zone	user-specified					
6.1	Nominal Diameter	200 mm only					
6.3	Primary Flat/Notch	Notch Only					
TBD	Extrinsic Getter	user-specified					
5.1	Laser Mark Identification	SEMI M13					
3.1	Oxygen Concentration	$\leq 1.5 \times 10^{18}$ atoms/cm^3 (per in-process monitoring only) correlated to ASTM F 121-79 equivalent					
TBD	Inspection Sheet	Certificate required in a standard format to be determined					

NOTE 1: TBD - Number to be determined by M18 Task Force, which will also develop EDI coding.

Table 6 Guide for the Specification of 0.25 Micron Design Rule, Twin-Tub CMOS, Epitaxial Wafers

CUSTOMER:		PART NUMBER: REVISION:	DATE:			
M18 ITEM #		SPECIFICATION	TESTING LEVEL			
			WAFER		TEST PIECE	
			100%	SAMPLE	100%	SAMPLE
11. GENERAL EPITAXIAL WAFER AND LAYER CHARACTERISTICS						
11.1	Conductivity Type/ Structure	*p/p+*				
11.2	Primary Dopant	Boron				
11.3	Silicon Source Gas	fixed by agreement				
11.4	Reactor Type	fixed by agreement				
11.5	Net Carrier Density (Center)	2.00×10^{15} target $\pm$ 25% (2σ) tolerance 1.34×10^{15} minimum				
	Units	carriers per cm^3				
	Test Method	Mercury Probe ASTM F 1392 or F 1393 or V-C Diode by F 419				

CUSTOMER:		PART NUMBER: REVISION:	DATE:			
M18 ITEM #		SPECIFICATION	TESTING LEVEL			
			WAFER		TEST PIECE	
			100%	SAMPLE	100%	SAMPLE
11.6	Net Carrier DensityVariation	10% maximum per SEMI M11				
11.7	Thickness (Center)	target by agreement within 2–5 µm range ± 5% (1σ) tolerance				
11.8	Thickness Variation	10% per SEMI M11				
11.11	Phantom Layer	none				
12. MECHANICAL CHARACTERISTICS: POST EPI						
12.5	Flatness/Site	≤ 0.25 um (SFQR), site size 22 mm × 22 mm including partial sites, PUA to be negotiated (See NOTE 1.)				
13. FRONT SURFACE CHARACTERISTICS						
13.1	Stacking Faults	0.03/cm^2 maximum (See NOTE 2.)				
13.2	Slip/Dislocations	none per ASTM F 80, slip with a depth < 0.1 µm acceptable				
13.5	Scratches	none per ASTM F 523, Section 12.2				
13.6	Dimples	none per ASTM F 523, Section 12.3				
13.7	Orange Peel	none per ASTM F 523, Section 12.3				
13.8	Cracks/Fractures	none per ASTM F 523, Section 12.3				
13.9	Crow's Feet	none per ASTM F 523, Section 12.3				
13.10	Edge Chips	none per ASTM F 523, Section 12.3				
13.12	Haze	none per ASTM F 523, Section 12.2				
13.13	Foreign Matter	none per ASTM F 523, Section 12.3				
TBD	Localized Light Scatterers	0.36 per cm^2 maximum ≥ 0.16 µm LSE (See NOTE 3.)				
		calibrate using ASTM F 1620				
13.15	Nominal Edge Exclusion	4 mm for all front surface characteristics except cracks/fractures, edge chips, crow's feet, and foreign matter.				
7.1	Surface Metals	≤ 5×10^{10} atoms per cm^2 for each of the following elements: Ca, Cr, Co, Cu, Fe, K, Mn, Mo, Na, Ni, Ti.				
		≤ 1×10^{11} atoms per cm^2 for each of the following elements: Al, V, Zn.				
14. BACK SURFACE CHARACTERISTICS						
14.1	Contamination	none per ASTM F 523, Section 13.4				
TBD	Back Seal	user specified				
15. OTHER CHARACTERISTICS: POLISHED WAFER-EPITAXIAL SUBSTRATE – MUST MEET SEMI M1 (except when noted)						
2.1	Resistivity	0.005–0.010 Ω-cm [ ], 0.010–0.020 Ω-cm [ ]				
TBD	Bulk Micro Defects	by agreement				
TBD	Denuded Zone	by agreement				
TBD	Back Seal	polysilicon [ ], silicon oxide [ ], combinations and thickness by agreement, none [ ]				
6.1	Diameter	125 mm [ ], 150 mm [ ], 200 mm [ ], 300 mm [ ]				

NOTE 1: Based on 1997 process capability. PUA is estimated to be 90%.

NOTE 2: Based on 1997 process capability.

NOTE 3: This requirement is mathematically consistent with the SIA Roadmap value of 0.6 per cm^2 maximum ≥ 0.12 µm LSE. The SIA Roadmap value was transformed using draft international standard ISO/DIS 14644-1 which follows the equation: 0.36 per cm^2 = 0.60 per cm^2 /(0.16 µm /0.125 µm)$^{2.1}$.

NOTE 4: TBD — Number to be determined by M-18 Task Force which will also develop EDI coding.

Table 7 Guide For The Specification Of 0.18 Micron Design Rule

ITEM		*p/p⁻ EPITAXIAL CIRCUIT WAFER (DRAM)*	*p/p⁺ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)*	*p/p⁺⁺ EPIAXIAL CIRCUIT WAFER (Logic)*
1.0 GENERAL CHARACTERISTICS				
1.1	Growth Method	Cz or MCz *	Cz or MCz *	Cz or MCz *
1.2	Crystal Orientation/Tolerance	{100} ± 1°	{100} ± 1°	{100} ± 1°
1.3	Conductivity Type	*p/p⁻*	*p/p⁺*	*p/p⁺⁺*
1.4	Dopant	Boron	Boron	Boron
1.5	Nominal Edge Exclusion	3 mm	3 mm	3 mm
2.0 ELECTRICAL CHARACTERISTICS				
2.1.1	Resistivity (Center Point)	0.8–15 Ω-cm* (match epi layer)	0.01–0.02 Ω-cm*	0.005–0.010 Ω-cm*
2.1.2	Resistivity (Tolerance)	(see row 2.1.1)	(see row 2.1.1)	(see row 2.1.1)
2.2	Radial Resistivity Variation (RRG)	< 20% *	< 20% *	< 20% *
2.3	Resistivity Striations	NS * (See Note 2.)	NS * (See Note 2.)	NS * (See Note 2.)
2.4	Minority Carrier Recombination Lifetime	NS * (See Note 2.)	NS * (See Note 2.)	NS * (See Note 2.)
3.0 CHEMICAL CHARACTERISTICS				
3.1.1	Oxygen Concentration (Nominal)	user/supplier	user/supplier	user/supplier
3.1.2	Oxygen Concentration (Tolerance: within shipment variation)	± 1.5 ppma *	± 2.0 ppma * (See Note 3.)	± 2.0 ppma * (See Note 3.)
3.2	Radial Oxygen Variation	≤ 10% * 10 mm from Edge	≤ 10% * 10 mm from Edge	≤ 10% * 10 mm from Edge
3.3	Carbon Concentration	≤ 0.5 ppma *	See Note 3	See Note 3
4.0 STRUCTURAL CHARACTERISTICS				
4.1	Dislocation Etch Pit Density	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
4.2	Slip	none	none	none
4.3	Lineage	none	none	none
4.4	Twin	none	none	none
4.5	Swirl	none	none	none
4.6	Shallow Pits	none	none	none
4.7	Oxidation-Induced Stacking Faults (OSF)	NS * (See Note 2.)	NS * (See Note 2.)	NS * (See Note 2.)
4.8	Oxide Precipitates (BMD) O_i Reduction (ΔO_i)	user/supplier	user/supplier	user/supplier
5.0 WAFER PREPARATION CHARACTERISTICS				
5.1	Wafer ID Marking	Per SEMI M1	Per SEMI M1	Per SEMI M1
5.2	Front Surface Thin Film(s)			
5.3	Denuded Zone	user/supplier	user/supplier	user/supplier
5.4	Extrinsic Gettering Treatment	user/supplier	user/supplier	user/supplier
5.5	Backseal	none	None or as user/ supplier agreement	None or as user/ supplier agreement
5.6	Annealing	None or as user/ supplier agreement	None or as user/ supplier agreement	None or as user/ supplier agreement
6.0 MECHANICAL CHARACTERISTICS				
6.1	Diameter	300 ± 0.2 mm or 200 ± 0.2 mm	300 ± 0.2 mm or 200 ± 0.2 mm	300 ± 0.2 mm or 200 ± 0.2 mm
6.2	Diameter Notch Dimensions	Per SEMI M1	Per SEMI M1	Per SEMI M1
6.2.1	Notch Depth	1 + 0.25, -0.00 mm	1 + 0.25, -0.00 mm	1 + 0.25, -0.00 mm

ITEM		*p/p^- EPITAXIAL CIRCUIT WAFER (DRAM)*	*p/p^+ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)*	*p/p^{++} EPIAXIAL CIRCUIT WAFER (Logic)*
6.2.2	Notch Angle	90 +5, -1 degrees	90 +5, -1 degrees	90 +5, -1 degrees
6.3	Notch Orientation	<110> ± 1°	<110> ± 1°	<110> ± 1°
6.6	Edge Profile*	Per SEMI M1	Per SEMI M1	Per SEMI M1
6.6.1	Edge Surface Finish	Polished *	Polished *	Polished *
6.7	Thickness	300 mm per SEMI M1	300 mm per SEMI M1	300 mm per SEMI M1
6.7.1	Thickness Variation (9-Point TTV)	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
6.7.2	Thickness Variation (GBIR)	≤ 3 µm	≤ 3 µm	≤ 3 µm
6.10	Bow	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
6.11	Warp (only process control data required)	≤ 50 µm	≤ 50 µm for wafers without backseal ≤ 100 µm for wafers with backseal	≤ 50 µm for wafers without backseal ≤ 100 µm for wafers with backseal
6.12	Sori	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
6.13	Flatness/Global	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
6.14 B	Flatness/Site (See NOTE 4)	SFSR ≤ 0.18 µm	SFSR ≤ 0.18 µm	SFSR ≤ 0.18 µm
7.0 FRONT SURFACE CHEMISTRY				
7.1	Surface Metal Contamination			
	Sodium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Aluminum	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$
	Potassium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Chromium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Iron	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Nickel	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Copper	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Zinc	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$
	Calcium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
8.0 FRONT SURFACE CRITERIA				
8.1A	Scratches (macro)	none	none	none
8.1B	Scratches (micro)	≤ 10 mm (total length)	≤ 10 mm (total length)	≤ 10 mm (total length)
8.3	Localized Light Scatterers – Only particles for epitaxial wafers – Sizes are PSL equivalents	≤ 60 @ ≥ 0.09 µm (300 mm) ≤ 27 @ ≥ 0.09 µm (200 mm) or (See NOTE 5) ≤ 34 @ ≥ 0.12 µm (300 mm) ≤ 15 @ ≥ 0.12 µm (200 mm)	≤ 60 @ ≥ 0.09 µm (300 mm) ≤ 27 @ ≥ 0.09 µm (200 mm) or (See NOTE 5) ≤ 34 @ ≥ 0.12 µm (300 mm) ≤ 15 @ ≥ 0.12 µm (200 mm)	≤ 60 @ ≥ 0.09 µm (300 mm) ≤ 27 @ ≥ 0.09 µm (200 mm) or (See NOTE 5) ≤ 34 @ ≥ 0.12 µm (300 mm) ≤ 15 @ ≥ 0.12 µm (200 mm)
8.4	Edge Chips	none	none	none
8.5-8.16	OTHER	none	none	none
9.0 BACK SURFACE CRITERIA				
9.1	Edge Chips	none	none	none

ITEM		p/p^- EPITAXIAL CIRCUIT WAFER (DRAM)	p/p^+ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)	p/p^{++} EPIAXIAL CIRCUIT WAFER (Logic)
9.2-9.5	OTHER	none	none	none
9.6	Roughness	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
9.7	Brightness (Gloss) 60° angle of incidence, referenced to a mirror polished wafer. NOTE: Double-side polish process preferred	≥ 80%	≥ 80% Applies to wafers without backseal only.	≥ 80% Applies to wafers without backseal only.
9.X	Localized Light Scatterers (See Note 6)	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
9.YA	Scratches (Macro)	none	none	none
9.YB	Scratches (Micro)	≤ 25 mm (total length)	≤ 25 mm (total length)	≤ 25 mm (total length)
11.0 ADDITIONAL EPITAXIAL LAYER CHARACTERISTICS				
11.1	Conductivity Type/Structure	p/p^-	p/p^+	p/p^{++}
11.2	Primary Dopant	Boron	Boron	Boron
11.3	Silicon Source Gas	NS (See Note 2.)	NS (See Note 2.)	NS (See Note 2.)
11.4	Epitaxial Growth Method	NS (See Note 2.) (see Item 5.3)	NS (See Note 2.) (see Item 5.3)	NS (See Note 2.) (see Item 5.3)
11.5	Net Carrier Density Target Variation (Center of wafer)	user/supplier	user/supplier	user/supplier
11.6	Net Carrier Density Variation	± 5%	± 5% with backseal ± 10% without backseal	± 5% with backseal ± 10% without backseal
11.7	Thickness Target Variation	± 5%	± 5%	± 5%
11.8	Thickness Variation	± 10%	± 10%	± 10%
11.9	Transition Width	user/supplier	user/supplier	user/supplier
11.X	Layer Flat Zone	user/supplier	user/supplier	user/supplier
13.1	Stacking Faults (See Note 7)	< 2 per wafer	< 2 per wafer	< 2 per wafer
13.2	Slip/Dislocations (See Note 8)	none	none	none
13.5-13.13	OTHER	(see Item 13.1)	(see Item 13.1)	(see Item 13.1)

NOTE 1: * indicates substrate specification.
NOTE 2: NS is the abbreviation for Not Specified.
NOTE 3: Practical non-destructive metrology did not exist at the time this document was approved.
NOTE 4: The site size is 32 mm × 25 mm. Partial sites are included. The metrology was being developed at the time this document was being balloted.
NOTE 5: These values are mathematically consistent. The 0.09 µm count limit was transformed using draft international standard: ISO/DIS 14644-1 which follows the equation: 34 counts per wafer = 60 counts per wafer /(0.12 µm/ 0.09 µm)2.
NOTE 6: The process control capability is expected to be: ≤ 500 @ ≥ 0.25 µm.
NOTE 7: The lot average density is < 0.0029/cm2.
NOTE 8: Tested per ASTM F80; a depth < 100 nm is acceptable.

Table 8 Guide for the Specification of Polished Wafer, P+ Substrate for 0.25 μm Design Rule Epitaxial

CUSTOMER			*PART NUMBER:* *REVISION*	*DATE:*			
REQ.	*M18 ITEM #*		*SPECIFICATION*	*TESTING LEVEL*			
				WAFER		*TEST PIECE*	
				100%	*SAMPLE*	*100%*	*SAMPLE*
POLISHED WAFER, EPITAXIAL SUBSTRATE - MUST MEET SEMI M-1							
	15.1	Resistivity	0.005-0.010 Ω-cm or 0.010-0.020 Ω-cm				
			Substrate Resistivity / **Backseal Required**				
			0.005–0.010 Ω–cm / yes				
			0.010–0.020 Ω–cm / user specified				
	15.2	Bulk Micro Defects	user specified				
		Dopant	Boron				
	15.4	Nominal Diameter	150 mm [ ] 200 mm [ ]				
	15.5	Primary Flat/ Notch	User specified per SEMI M1				
	15.6	Extrinsic Getter	User specified				
		Intrinsic Getter	User specified				
	15.7	Laser Mark Identification	SEMI M13 [ ] SEMI M12 [ ] SEMI T1 [ ]				
	15.8	Oxygen Concentration	maximum 30 ppma, Old ASTM				
		Inspection Sheet	Certificate required in a standard format to be determined.				
		SQC Data Sheet	SQC required in a standard format to be determined.				
12. MECHANICAL CHARACTERISTICS: PRE EPITAXIAL							
		Total Thickness Variation (TTV)	5 μm (GBIR)				
	12.5	Flatness/Site	≤ 0.25 μm (SFQR), site size 22 mm × 22 mm including partial sites, PUA to be negotiated				
13. FRONT SURFACE CHARACTERISTICS							
	13.2	Slip/Dislocations	none				
	13.10	Edge Chips	none per ASTM F 523, Section 12.3				
	13.14	Localized Light Scatterers and	0.23 per cm^2 maximum ≥ 0.12 μm LSE and 0.0 per cm^2 ≥ 1 μm LSE, calibrate using ASTM F 1620				
		Scratches	none				
	13.15	Nominal Edge Exclusion	3 mm for all front surface characteristics except cracks/fractures, edge chips, crow's feet, and foreign matter				
		Surface Metals	≤ 1 E 11 atoms per cm^2 for each element: Na, Al, Cr, K , Fe, Ni, Cu, Zn				
14. BACK SURFACE CHARACTERISTICS							
	14.1	Contamination	none per ASTM F 523, Section 12.4				

CUSTOMER			PART NUMBER: REVISION	DATE:
	14.2	Back Seal	[ ] Silicon Oxide: 5000 ± 1000 Angstroms, [ ] Polysilicon: 10,000 ± 2000 Angstroms, [ ] Backside Damage, [ ] None, [ ] Combination of: 3000 ± 1000 Angstroms Silicon Oxide on top of 8000 ± 2000 Angstroms Polysilicon	

Table 9 Guide For The Specification Of 0.13 Micron Design Rule Silicon Epitaxial Wafers

ITEM		*p/p^- EPITAXIAL CIRCUIT WAFER (DRAM)*	*p/p^+ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)*	*p/p^{++} EPITAXIAL CIRCUIT WAFER (Logic)*
1.0 GENERAL CHARACTERISTICS				
1.1	Growth Method	Cz or MCz *	Cz or MCz *	Cz or MCz *
1.2	Crystal Orientation	{100}	{100}	{100}
1.3	Crystal Orientation/Tolerance	± 1°	± 1°	± 1°
1.4	Conductivity type	p/p-	p/p+	p/p++
1.5	Dopant	Boron	Boron	Boron
1.6	Nominal Edge Exclusion	3 mm	3 mm	3 mm
2.0 ELECTRICAL CHARACTERISTICS				
2.1.1	Resistivity (Center Point)	0.8–15 Ω-cm *	0.01–0.02 Ω-cm *	0.005–0.010 Ω-cm *
2.2	Radial Resistivity Variation (See Note 9.)	< 20% *	< 20% *	< 20% *
2.3	Resistivity Striations	NS *	NS *	NS *
3.0 CHEMICAL CHARACTERISTICS				
3.1.1	Nominal Oxygen Concentration (Center)	user/supplier	user/supplier	user/supplier
3.1.2	Oxygen Concentration Tolerance Per ASTM F121-79	± 2.0 ppma *	± 2.0 ppma * (See Note 3.)	± 2.0 ppma * (See Note 3.)
3.2	Radial Oxygen Variation Per ASTM F951	≤ 10% * 10 mm from Edge	≤ 10% * 10 mm from Edge (See Note 3.)	≤ 10% * 10 mm from Edge (See Note 3.)
3.3	Carbon Concentration (See Note 9.)	≤ 0.5 ppma *	≤ 0.5 ppma (See Note 3.) *	≤ 0.5 ppma (See Note 3.) *
4.0 STRUCTURAL CHARACTERISTICS				
4.1	Dislocation Etch Pit Density	NS	NS	NS
4.2	Slip	none	none	none
4.3	Lineage	none	none	none
4.4	Twin	none	none	none
4.5	Swirl	none	none	none
4.6	Shallow pits	none	none	none
4.7	Oxidation-Induced Stacking Faults (OSF)	NS *	NS *	NS *
4.8	Oxide Precipitates (BMD) O_i Reduction (ΔO_i)	user/supplier	user/supplier	user/supplier
5.0 WAFER PREPARATION CHARACTERISTICS				
5.1	Wafer ID Marking	per M1	per M1	per M1
5.2	Front Surface Thin Film(s)	NS	NS	NS
5.3	Denuded Zone	user/supplier	user/supplier	user/supplier
5.4	Extrinsic Gettering Treatment	user/supplier	user/supplier	user/supplier

ITEM		*p/p⁻ EPITAXIAL CIRCUIT WAFER (DRAM)*	*p/p⁺ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)*	*p/p⁺⁺ EPITAXIAL CIRCUIT WAFER (Logic)*
5.5	Backseal	none	None or as user/supplier agreement	None or as user/supplier agreement
5.6	Annealing	None or as user/supplier agreement	None or as user/supplier agreement	None or as user/supplier agreement
6.0 MECHANICAL CHARACTERISTICS				
6.1	Diameter	300 ± 0.2 mm or 200 ± 0.2 mm	300 ± 0.2 mm or 200 ± 0.2 mm	300 ± 0.2 mm or 200 ± 0.2 mm
6.2	Diameter Notch Dimensions			
6.2.1	Notch Depth	1 +0.25,-0.00 mm	1 +0.25,-0.00 mm	1 +0.25,-0.00 mm
6.2.2	Notch Angle	90 +5,-1 degrees	90 +5,-1 degrees	90 +5,-1 degrees
6.3	Notch Orientation	<110> ± 1°	<110> ± 1°	<110> ± 1°
6.61	Edge Profile*	per SEMI M1	per SEMI M1	per SEMI M1
6.6.2	Edge Surface Finish	Polished *	Polished *	Polished *
6.7	Thickness	775 ± 25 µm* [300 mm diameter] or 725 ± 20 µm* [200 mm diameter]	775 ± 25 µm* [300 mm diameter] or 725 ± 20 µm* [200 mm diameter]	775 ± 25 µm* [300 mm diameter] or 725 ± 20 µm* [200 mm diameter]
6.7.1	Thickness Variation (9-Point TTV)	NS	NS	NS
6.72	Thickness Variation (GBIR)	≤ 3 µm	≤ 3 µm	≤ 3 µm
6.9	Surface Orientation	100	100	100
6.10	Bow	NS	NS	NS
6.11	Warp (only process control data required)	≤ 50 µm	≤ 50 µm for wafers without backseal ≤ 100 µm for wafers with backseal	≤ 50 µm for wafers without backseal ≤ 100 µm for wafers with backseal
6.12	Sori	NS	NS	NS
6.13	Flatness/Global	NS	NS	NS
6.14B	Flatness/Site (See Note 4)	SFSR ≤ 0.13 µm	SFSR ≤ 0.13 µm	SFSR ≤ 0.13 µm
7.0 FRONT SURFACE CHEMISTRY				
7.1	Surface Metal Contamination See Note 9			
	Sodium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Aluminum	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$
	Potassium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Chromium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Iron	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Nickel	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Copper	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
	Zinc	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$	$\leq 1 \times 10^{11}/cm^2$
	Calcium	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$	$\leq 1.3 \times 10^{10}/cm^2$
8.0 FRONT SURFACE CRITERIA				
8.1A	Scratches (macro)	none	none	none
8.1B	Scratches (micro)	≤ 10 mm (total length)	≤ 10 mm (total length)	≤ 10 mm (total length)

	ITEM	*p/p⁻ EPITAXIAL CIRCUIT WAFER (DRAM)*	*p/p⁺ EPITAXIAL CIRCUIT WAFER (Logic/DRAM)*	*p/p⁺⁺ EPITAXIAL CIRCUIT WAFER (Logic)*
8.3	Localized Light Scatterers - Only particles for epitaxial wafers - Sizes are PSL equivalents	300 mm: ≤ 200 @ ≥ 0.09 µm or ≤ 112 @ ≥ 0.12 µm (See note 5.)	300 mm: ≤ 200 @ ≥ 0.09 µm or ≤ 112 @ ≥ 0.12 µm (See note 5.)	300 mm: ≤ 200 @ ≥ 0.09 µm or ≤ 112 @ ≥ 0.12 µm (See note 5.)
		200 mm: ≤ 89 @ ≥ 0.09 µm or ≤ 50 @ ≥ 0.12 µm (See note 5.)	200 mm: ≤ 89 @ ≥ 0.09 µm or ≤ 50 @ ≥ 0.12 µm (See note 5.)	200 mm: ≤ 89 @ ≥ 0.09 µm or ≤ 50 @ ≥ 0.12 µm (See note 5.)
8.4	Edge Chips	none	none	none
8.5-8.16	OTHER	none	none	none
9.0 BACK SURFACE CRITERIA				
9.1	Edge Chips	none	none	none
9.2-9.5	OTHER	none	none	none
9.6	Roughness	NS	NS	NS
9.7	Brightness (Gloss) 60° angle of incidence, referenced to a mirror polished wafer. NOTE: Double-side polish process preferred	≥ 80%.	≥ 80% Applies to wafers without backseal only.	≥ 80% Applies to wafers without backseal only.
TBD	Localized Light Scatterers (See Note 6.)	NS	NS	NS
TBD	Scratches (Macro)	none	none	none
TBD	Scratches (Micro)	Cumulative Length ≤ 10% of the Wafer Diameter	Cumulative Length ≤ 10% of the Wafer Diameter	Cumulative Length ≤ 10% of the Wafer Diameter
11.0 ADDITIONAL EPITAXIAL LAYER CHARACTERISTICS				
11.1	Conductivity Type/Structure	p/p-	p/p+	p/p++
11.2	Primary Dopant	Boron	Boron	Boron
11.3	Silicon Source Gas	NS	NS	NS
11.4	Epi Growth Method	NS (see item 5.3)	NS (see item 5.3)	NS (see item 5.3)
11.5	Carrier Density Range - Must be met at all points on the wafer surface inside the edge exclusion (See Note 11.)	User/supplier agreement	User/supplier agreement	User/supplier agreement
11.6	Layer Thickness (Target Value at Wafer Center and Tolerance)	Target: user/supplier agreement Tolerance: ± 5%	Target: user/supplier agreement Tolerance: ± 5%	Target: user/supplier agreement Tolerance: ± 5%
11.7	Thickness Variation (within wafer per SEMI M11)	10%	10%	10%
11.8	Transition Width	User/supplier agreement	User/supplier agreement	User/supplier agreement
11.9	Layer Flat Zone	User/supplier agreement	User/supplier agreement	User/supplier agreement
13.1	Stacking Faults (See Note 7.)	$< 0.012/cm^2$	$< 0.012/cm^2$	$< 0.012/cm^2$
TBD	Large Area Defects (LAD's) (See Note 7.)	$< 0.006/cm^2$	$< 0.006/cm^2$	$< 0.006/cm^2$
13.2	Slip/Dislocations (See Note 8.)	none	none	none
13.5 - 13.13	OTHER	(see 13.1)	(see 13.1)	(see 13.1)

NOTE 1: * indicates substrate specification.
NOTE 2: NS is the abbreviation for Not Specified.
NOTE 3: Non-destructive metrology did not exist at the time this document was approved.
NOTE 4: The site size is 25 mm × 32 mm. Partial sites are included. The metrology was being developed at the time this document was being balloted.
NOTE 5: These values are mathematically consistent. The 0.09 µm count limit was transformed using draft international standard: ISO/DIS 14644-1 which follows the equation: 112 counts per wafer = 200 counts per wafer $/(0.12\mu m/0.09\mu m)^2$.
NOTE 6: The process control capability is expected to be: ≤ 500 @ ≥ 0.25 µm.
NOTE 7: Large Area Defects (LAD's) are surface imperfections or particles that have geometry with at least one side or diameter that is a minimum of 1 micron in length .
NOTE 8: Tested per ASTM F80; a depth < 100nm is acceptable.
NOTE 9: Only process control data is required. Data not required on Certificate of Compliance.
NOTE 10: The first column under item references SEMI M18. M18 was in the process of substantial revision at the time this documented was balloted. Many M18 line references remain to be determined. TBD is the abbreviation for "to be determined".
NOTE 11: The intent in specifying carrier density using a range, rather than the center nominal with tolerance accompanied by a wafer variation limit, is to minimize the importance of edge variations and to emphasize meeting the range of carrier density as it is allowed by the process and the designers.

SEMI M12-0998[E]
SPECIFICATION FOR SERIAL ALPHANUMERIC MARKING OF THE FRONT SURFACE OF WAFERS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Silicon Wafer Committee on July 12, 1998. Initially available at www.semi.org May 1999; to be published June 1999. Originally published in 1988.

[E] This document was modified by the Global Traceability Committee in April 1999 to reflect the creation of SEMI AUX1 as the source for vendor identification codes. Changes were made to numerous sections.

1 Scope

1.1 This specification defines the geometric and spatial limits of the alphanumeric code, specifically for serial identification of flatted and notched silicon wafers. It also defines the basic code used to characterize the individual wafer, using database systems. This specification will ensure the consistency of all wafer marking performed by wafer manufacturers. This will allow simplification of the performance requirements of Automatic Optical Character Reading (OCR) equipment, provide unassisted and immediate human readability without wafer handling, and facilitate resolution of wafer level process variations. This document does NOT address the marking techniques that may be employed when complying with this standard. The marking code is intended to be valid for a broad range of wafer products (i.e., epi, SOI, processed polished wafers).

2 Referenced Documents

2.1 *SEMI Standards*

SEMI AUX1 — List of Vendor Identification Codes

2.2 *ANSI Standard*[1]

ANSI X 3.17 — Character Set and Print Quality for Optical Character Recognition (OCR-A).

3 Selected Definitions

3.1 *adjacent character misalignment* — the vertical distance, R, between the character baselines of two adjacent characters on the same line (see Figure 6a).

3.2 *character separation* — the horizontal distance between the adjacent boundaries of any characters (see Figure 1).

3.3 *character spacing* — the horizontal distance between the character centerlines of the adjacent characters (see Figure 1).

3.4 *character window* — the rectangular window within which all characters must be contained as shown on Figures 3 and 4 with dimensions of 18.5 mm long and 2.8 mm high as located on these figures.

3.5 *front surface of the wafer* — the exposed surface upon which active semiconductor devices have been or will be fabricated.

3.6 *line character misalignment* — the vertical distance, R, between the character baselines of two characters on the same line (see Figure 6b).

4 Shape and Size of Marking

4.1 Solid line or dot matrix method may be used to write characters. The minimum matrix shall be 5 dots horizontal and 9 dots vertical. More dots may be used, up to and including a solid line. Higher density is recommended to achieve improved read reliability (see Related Information 1).

4.2 *Character Dimensions and Spacing* — (see Table 1 and Figure 1)

Table 1 Character Dimensions

Character	*mm*
Height	1.624 ± 0.025
Width	0.812 ± 0.025
Thickness (See NOTE 1)	0.200 + 0.050/-0.150
Spacing	1.420 ± 0.025

NOTE 1: The thickness of the diagonal in the letter "N" is 0.138 ± 0.05 mm for single density dot matrix.

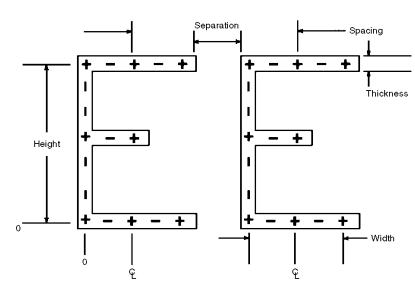


Figure 1

Character Outline

[1] *American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel 212.642.4900, fax 212.398.0023*

Table 2 Code

Character Location	*CharacterStyle*	*Parameter*	*Code*	*Definition*
1	Alpha/Numeric	IDENTIFICATION NUMBER	A through Z and 0 through 9	Vendor-Assigned (see NOTE 1)
2	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
3	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
4	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
5	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
6	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
7	Alpha/Numeric	IDENTIFICATION NUMBER		Vendor-Assigned (see NOTE 1)
8	Numeric Only	IDENTIFICATION NUMBER	0 through 9	Vendor-Assigned (see NOTE 1)
9	Alpha Only	VENDOR IDENTIFICATON CODE	A through Z	(see SEMI AUX1 and NOTE 1)
10	Alpha Only	VENDOR IDENTIFICATION CODE		(see SEMI AUX1 and NOTE 1)
11	Alpha Only	CHECK CHARACTERS	A through H	Error-Detecting Method (see Section 13)
12	Numeric Only	CHECK CHARACTERS	0 through 7	Error-Detecting Method (see Section 13)

NOTE 1: In the absence of information at any assigned location, a dash (-) must be used.

5 Alphanumeric Code

5.1 The code consists of one line of 12 characters. The first eight characters are an identification number which is unique to the wafer for a given vendor. These characters may be alphanumeric except character 8 which must be numeric (see Table 2). Characters 9 and 10 are the vendor identification codes (see SEMI AUX1). Characters 11 and 12 are check characters (see Sections 8 through 13). These check characters are machine generated for code acceptance.

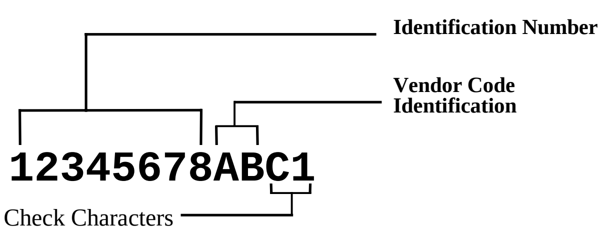


Figure 2

Example of Code

5.2 In the absence of a character at any assigned location, a dash (-) must be used.

5.3 An example of the code is given in Figure 2.

5.4 *SEMI-OCR Standard Character Set* — See Table 3 and Appendix 1.

Table 3 Standard Character Set

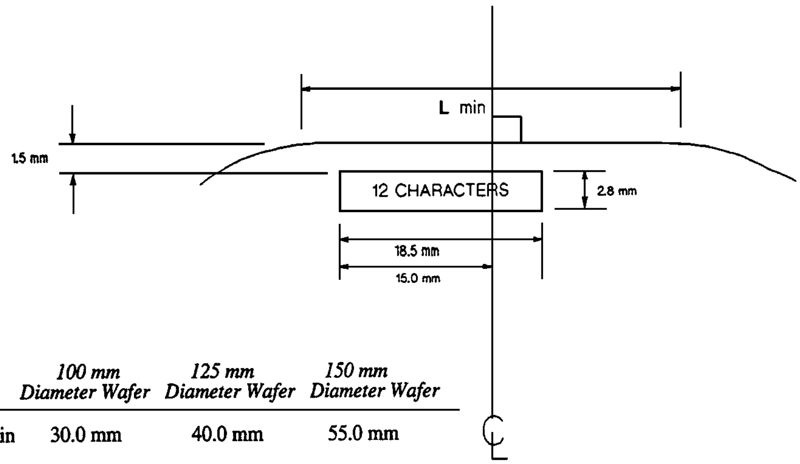
ABCDEFGHIJKLMNO
PQRSTUVWXYZ-
0123456789.

6 Character Window

6.1 Character window must be located on the front surface of the wafers.

6.2 All characters must be contained within the character window dimensions specified in Figures 3 and 4 (dashed lines).

6.3 The top of the characters is toward the side of the character window nearest to the flat or notch.

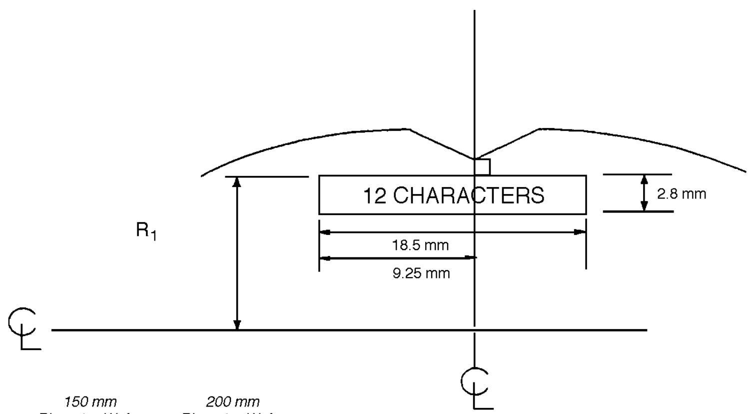


	100 mm Diameter Wafer	125 mm Diameter Wafer	150 mm Diameter Wafer
L min	30.0 mm	40.0 mm	55.0 mm

Figure 3

Character Window Location for Flatted Wafers

NOTE: The vertical center line referenced in Figure 3 is the bisector of the primary fiducial (flat).



	150 mm Diameter Wafer	200 mm Diameter Wafer
R_1	71.2 mm	96.5 mm

Figure 4

Character Window Location for Notched Wafers

NOTE: The vertical center line referenced in Figure 4 is the bisector of the primary fiducial (notch).

7 Character Alignment

7.1 *Character Skew* — the maximum angle between the character baseline and a line parallel with the bottom of the character window is 3 (see Figure 5).

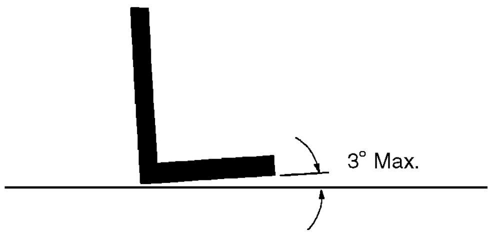


Figure 5

Character Skew

NOTE: This line is parallel to the bottom of the character window.

7.2 *Maximum Character Misalignment* — the maximum misalignment between adjacent characters is 0.23 mm (see Figure 6a), and the maximum line character misalignment is 0.46 mm (see Figure 6b).

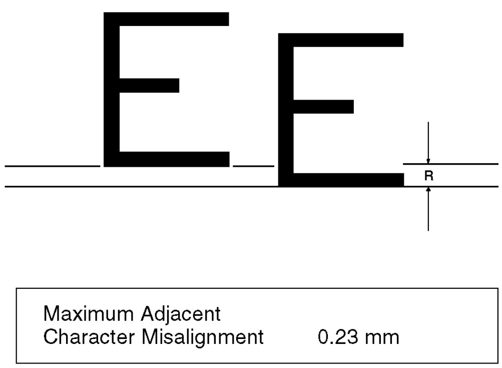


Figure 6A

Character Misalignment

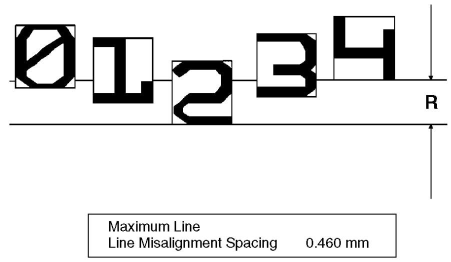


Figure 6B

Line Spacing Misalignment

8 Alphanumeric Error-Detecting Method

8.1 The alphanumeric check characters in character locations 11 and 12 are a required part of the Vendor Code.

8.2 All single-character substitution errors are detected.

8.3 All two-character transposition errors are detected for any message up to 58 characters in length.

8.4 The character set may be expanded to include the first 59 characters of the ASCII 64-character set.

8.5 There exist simple recursive algorithms for error detection and check character generation that do not require the use of multiplication or division.

9 Definition of the Error-Detecting Method

9.1 For the purpose of describing the error-detecting method, we define the following symbols:

A_i represents the ith ASCII character.

a_i represents the numerical value assigned to A_i.

9.2 The characters are numbered from left to right, so that the message is given by

$$A_1A_2A_3\ldots A_{12}$$

9.3 A complete description of the error-detecting method is given by the following seven rules:

9.3.1 The numerical value a_i is found by subtracting 32 from the ASCII decimal representation of A_i (refer to Table 4 — Character Values).

9.3.2 An ASCII character A_i is allowed only if its numerical value a_i is one of

$$0,1,2,\ldots 58.$$

9.3.3 The check character A_{11} must be one of the ASCII characters A,B,C,D,E,F,G,H.

9.3.4 The check character A_{12} must be one of the ASCII characters 1,2,3,4,5,6,7.

9.3.5 The check character pair $A_{11}A_{12}$ may not be one of the combinations H3, H4, H5, H6, H7.

9.3.6 When the message is written, the check characters A_{11} and A_{12} are chosen such that 59 divides the expression

$$8^{11}a_1 + 8^{10}a_2 \ldots + 8^2 a_{10} + 8a_{11} + a_{12}$$

without a remainder.

9.3.7 If, on reading the message, 59 does not evenly divide the expression given above, an error has occurred.

Table 4 Character Values

ASCII Character	*ASCII Decimal Value*	*Numerical Value*
–	45	13
.	46	14
0	48	16
1	49	17
2	50	18
3	51	19
4	52	20
5	53	21
6	54	22
7	55	23
8	56	24
9	57	25
A	65	33
B	66	34
C	67	35
D	68	36
E	69	37
F	70	38
G	71	39
H	72	40
I	73	41
J	74	42
K	75	43
L	76	44
M	77	45
N	78	46
O	79	47
P	80	48
Q	81	49
R	82	50
S	83	51
T	84	52
U	85	53
V	86	54
W	87	55
X	88	56
Y	89	57
Z	90	58

10 Suggestions for Implementation

10.1 The error-detecting method can be implemented directly by calculating the expression given above, and the check characters can be found by exhaustive search. However, this approach is unnecessarily complex; a decrease in complexity can be made by taking advantage of three simple observations.

10.2 First, since we are interested only in the remainder of the final expression after dividing it by 59, we can avoid working with large numbers by subtracting 59 repeatedly after each operation until the result is less than 59.

10.3 Second, we can rearrange the error-detecting expression, using Horner's Rule, to form

$$a_{12} + 8\left(a_{11} + \ldots 8\left(a_3 + 8\left(a_2 + 8a_1\right)\right)\ldots\right)$$

which can be calculated recursively from the inside out by successive multiplication and addition.

10.4 Third, multiplication by eight can be accomplished by adding a quantity to itself three times in succession.

11 An Algorithm for Error Detection [2]

11.1 When implementing error detection, it is convenient to imagine a checksum for each individual character position. This partial checksum forms a check on all preceding characters, as well as the present character. Then using Horner's Rule, one can calculate a running checksum (that is, calculate each partial checksum in order). This leads to the following algorithm.

11.2 Add the checksum (or the previous character position to itself. (For the first character position, the

[2] *Formal proofs of the properties of the error detecting method (as well as descriptive notes and other reference materials) are on file at SEMI, and are available upon request.*

value of the previous checksum is zero.) If the result is 59 or greater, subtract 59. This leaves a value in the range 0-58.

11.3 Add the result of step 1 to itself. If the result is 59 or greater, subtract 59.

11.4 Add the result of step 2 to itself. If the result is 59 or greater, subtract 59. The result of this step is eight times the previous position checksum, modulo 59.

11.5 Add the result of step 3 to the numerical value of the character in the present position. If the result is 59 or greater, subtract 59. The result of this step is the checksum for the present character position.

11.6 Repeat steps 1 through 4 for each character position. If the checksum for the final character position is nonzero, an error has occurred.

12 An Algorithm for Generating the Check Characters

12.1 The check characters can be generated as follows:

12.2 Initially, assume that the check characters are A0 (the first check character is the letter A, the second is the digit 0).

12.3 Calculate the final checksum in the manner described above for error detection. If the result is zero, the check characters are correct, and the algorithm terminates.

12.4 If the result of step 2 is nonzero, subtract it from 59, yielding a number in the range 1-58.

12.5 Convert the result of step 3 to binary.

12.6 Add the least significant three bits of the binary number to the numerical value of the second assumed check character 0 (zero). This will yield a value that corresponds to an ASCII character in the range 0-7.

12.7 Add the next higher three bits of the binary number to the numerical value of the first assumed check character A. This will yield a numerical value that corresponds to an ASCII character in the range A-H.

13 An Illustrative Example

13.1 For the purpose of illustrating the check character generating algorithm, assume that the message consists of only two characters, the digits 2 and 3. Initially, assume that the check characters are A and 0 (zero) yielding the composite message 23A0.

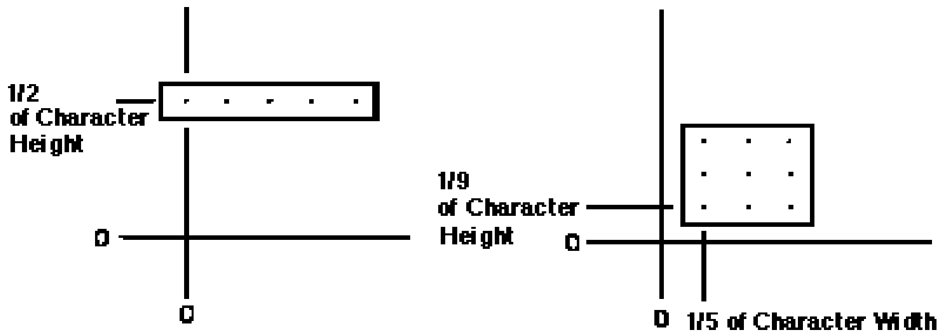
13.2 Using the algorithm described above, the final checksum is found to be 33. Since this is nonzero, it is subtracted from 59, yielding 26 in decimal, or 011010 in binary.

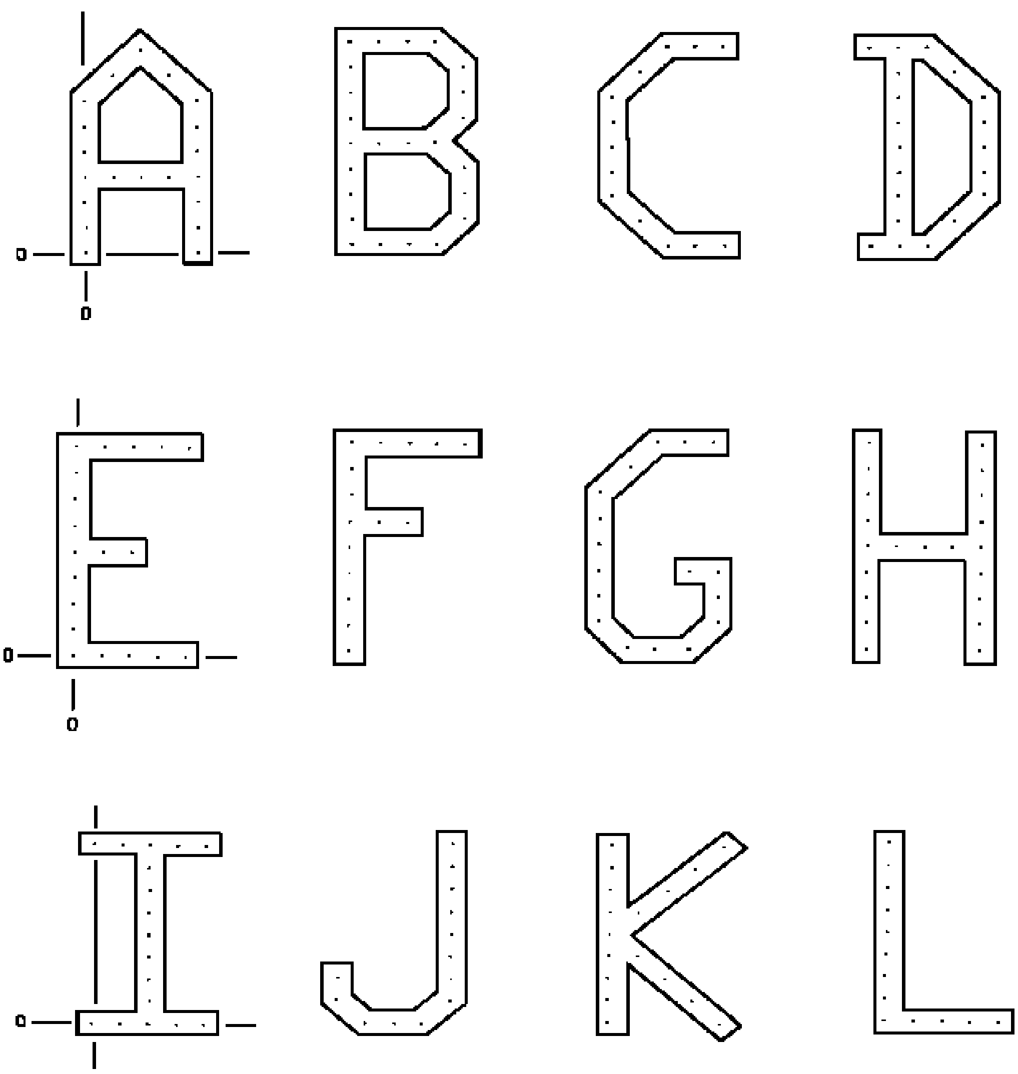
13.3 The least significant three bits 010 (decimal value 2) added to the numerical value of the ASCII character 0 (zero), which is 16, yields 18 (the numerical value of the ASCII character 2).

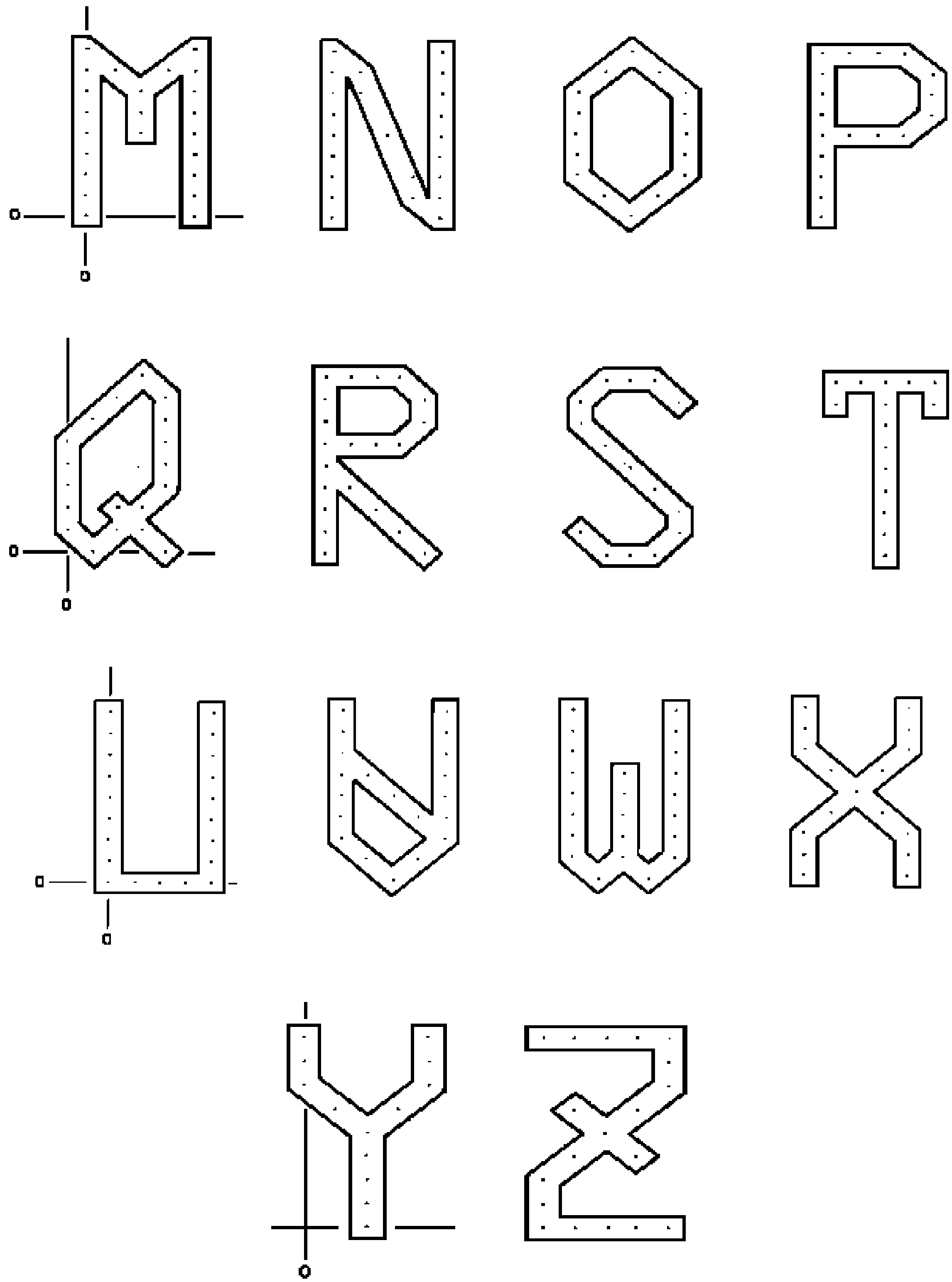
13.4 The next higher three bits 011 (decimal value 3) added to the numerical value of the ASCII character A, which is 33, yields 36 (the numerical value of the ASCII character D). The final composite message is 23D2.

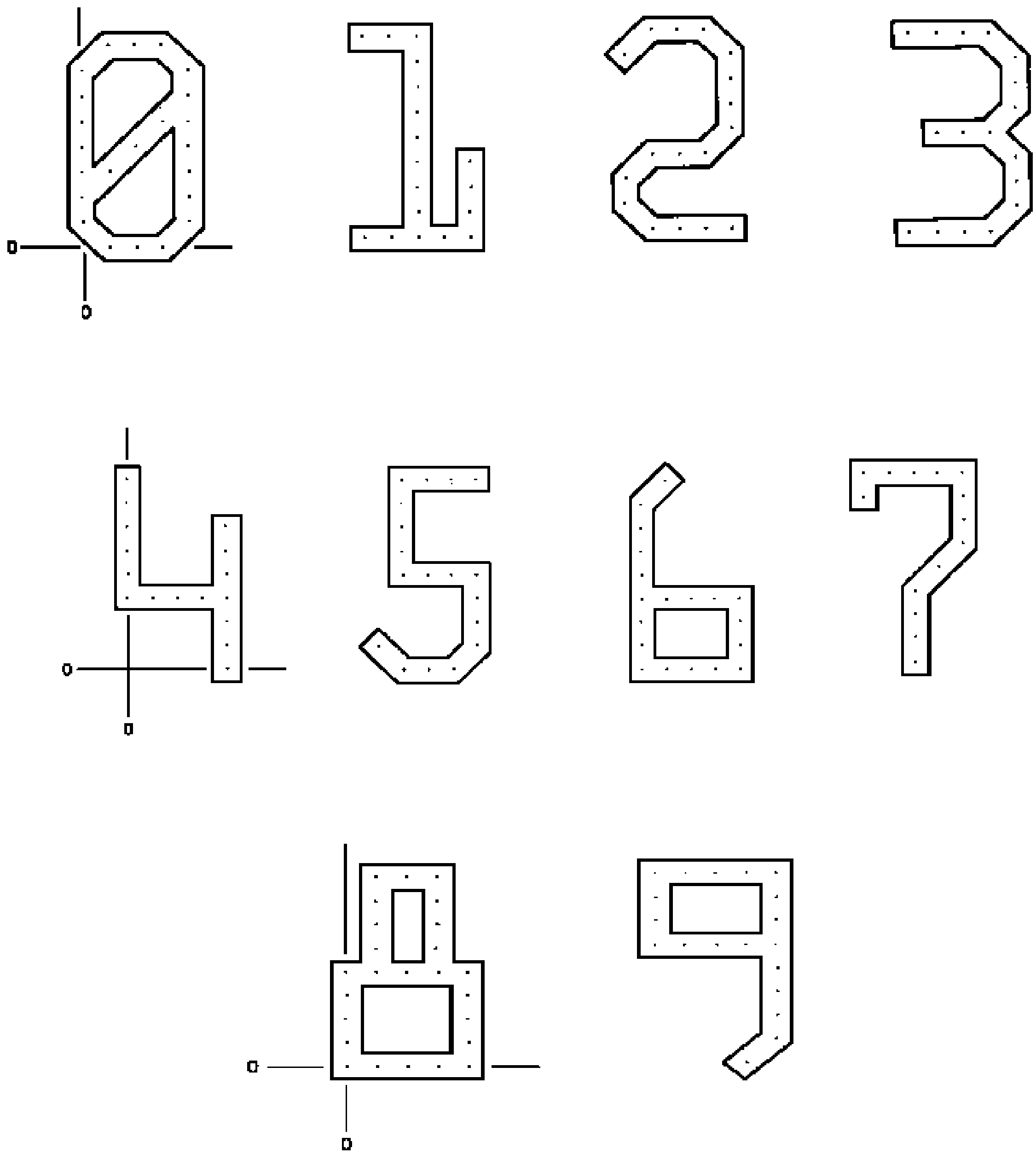
APPENDIX 1
SEMI OCR CHARACTER OUTLINES

NOTE: The material in this appendix is an official part of SEMI M12 and was approved by full letter ballot procedures on July 12, 1998.









RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI M12 but was approved for publication on July 12, 1998.

R1-1 Considerations for Reliable Automatic Reading of the Marking

R1-1.1 The following suggestions are offered to assist in assuring the most reliable automatic reading of the alphanumeric marking.

R1-1.2 *Character Stroke Thickness* — If a 5 × 9 dot matrix is chosen for marking, it is recommended that the minimum dot size be 0.100 mm. Double or higher density dot matrix is recommended — when used, smaller dot diameters may be employed. Stroke thickness should be constant within 20% over the entire character set so that the reader settings may be optimized for the specific wafer run.

R1-1.3 *Contrast* — The character should have sufficient contrast to be legible. Contrast may be affected by depth and other conditions.

R1-1.4 *Clear Zone* — It is recommended that the area immediately beneath and a minimum of 0.500 mm around the marking characters be of uniform reflectivity and free of any lithography and process overlay edges.

R1-2 Considerations for the Use of Front Surface Markings

R1-2.1 Marks can impinge upon areas where devices may be printed. Since mask geometries are varied, considerations of the mark area should be made in mask design and also when applying the mark specifications to existing mask designs.

R1-2.2 When the mark is applied prior to epitaxial deposition, a crown or epi may grow along the mark edge. The height of this crown will depend upon the epi thickness and the deposition process.

SEMI M13-0998[E]
SPECIFICATION FOR ALPHANUMERIC MARKING OF SILICON WAFERS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Silicon Wafer Committee on July 12, 1998. Initially available at www.semi.org May 1999; to be published June 1999. Originally published in 1988; previously published in September 1998.

[E] This document was modified by the Global Traceability Committee in April 1999 to reflect the creation of SEMI AUX1 as the source for vendor identification codes. Changes were made to numerous sections.

1 Scope

1.1 This specification defines the geometric and spatial limits of the alphanumeric code, specifically for flatted and notched silicon wafers. It also defines the basic code used to characterize the individual wafer, thereby providing practical operator interpretation. This specification will ensure the consistency of all wafer marking performed by silicon manufacturers. This will allow simplification of the performance requirements of Automatic Optical Character Reading (OCR) equipment. This document does NOT address the marking techniques that may be employed when complying with this standard.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI AUX1 — List of Vendor Identification Codes

2.2 *ANSI Standard*[1]

ANSI X 3.17 — Character Set and Print Quality for Optical Character Recognition (OCR-A).

3 Selected Definitions

3.1 *character misalignment* — the vertical distance, R, between the character baselines of two adjacent characters on the same line (see Figure 6a.).

3.2 *character separation* — the horizontal distance between the adjacent boundaries of any characters (see Figure 1).

3.3 *character spacing* — the horizontal distance between the character spacing reference lines of the adjacent characters (see Figure 1).

3.4 *line spacing misalignment* — the vertical distance, R, between the character baselines of two characters on the same line (see Figure 6b).

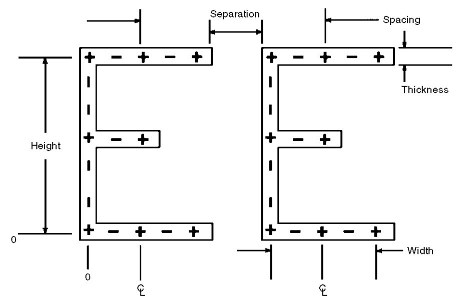


Figure 1

Character Outline

4 Method of Marking

4.1 Solid line or dot matrix method may be used to write characters. The minimum matrix shall be 5 dots horizontal and 9 dots vertical as shown in Figure 1.

NOTE 1: The 5 × 9 dot matrix shown in Figure 1 is the minimum number of dots allowed. More dots may be used, up to and including a solid line.

NOTE 2: The diagonal thickness of the letter "N" is 0.138 + 0.05 mm.

4.2 *Character Dimensions and Spacing* — See Table 1 and Figure 1.

4.3 *SEMI OCR Standard Character Set* — See Table 2 and Appendix 1.

5 Alphanumeric Code

5.1 *Vendor Code* — Limited to one line of 18 characters (See Figure 2 and Table 3.)

NOTE 3: In the absence of a character at any assigned location, a dash (-) must be used.

---

[1] *American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel 212.642.4900, fax 212.398.0023*

Table 1 Character Dimensions

Character	*100 mm, 125 mm, and 150 mm Flatted Wafers mm*	*150 mm and 200 mm Notched Wafers mm*
Height	0.812 ± 0.025	1.624 ± 0.025
Width	0.406 ± 0.025	0.812 ± 0.025
Thickness	0.100 ± 0.050	0.200 + 0.025 or - 0.150
Spacing	0.710 ± 0.025	1.420 ± 0.025
Minimum Separation	0.104	0.308

6 Code Field Location

6.1 Vendor Code Field to be located on the polished and/or front surface of wafers (see SEMI AUX1 for a list of codes).

6.2 All characters must be contained within field (dashed lines).

6.3 *Dimensions* — See Figures 3 and 4.

7 Character Alignment

7.1 *Character Skew* — 3 maximum allowable (See Figure 5.)

7.2 Maximum Character Misalignment — See Figures 6a and 6b.

Table 2 Standard Character Set

ABCDEFGHIJKLMNO
PQRSTUVWXYZ-
0123456789.

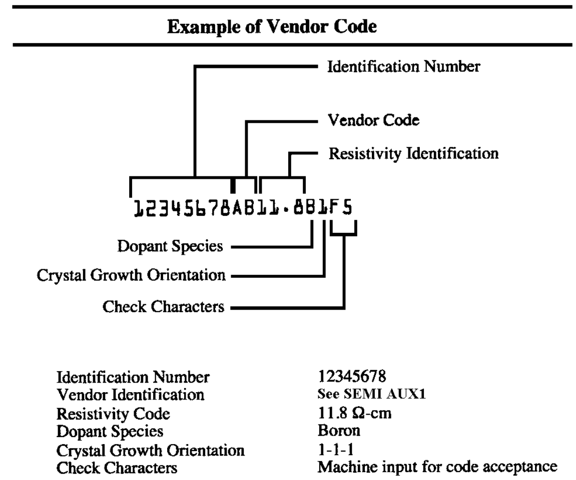
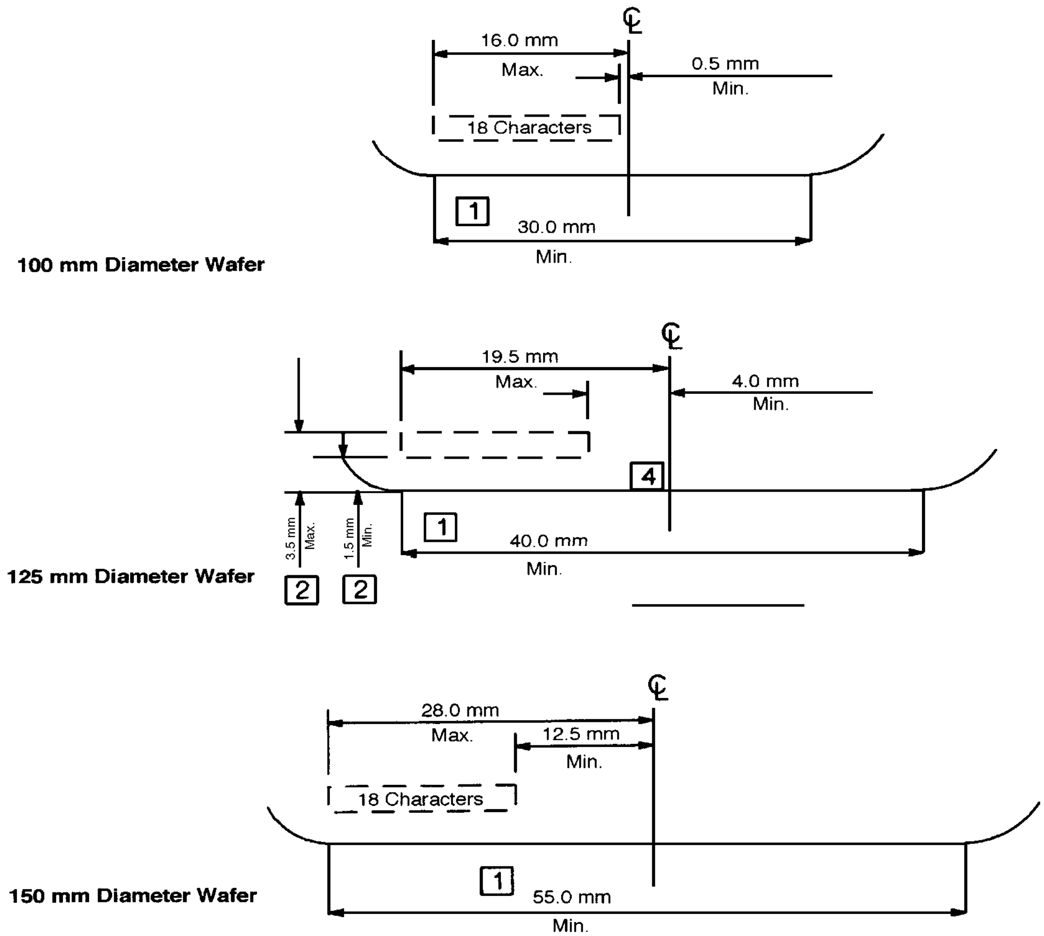


Figure 2

Example of Vendor Code

Table 3 Vendor Code

Character Location	*CharacterStyle*	*Parameter*	*Code*	*Definition*
1	Alpha/Numeric	IDENTIFICATION NUMBER	ABCDEFG	Vendor-Assigned
2	Alpha/Numeric	IDENTIFICATION NUMBER	HIJKLMN	Vendor-Assigned
3	Alpha/Numeric	IDENTIFICATION NUMBER	OPQRSTU	Vendor-Assigned
4	Alpha/Numeric	IDENTIFICATION NUMBER	VWXYZ	Vendor-Assigned
5	Alpha/Numeric	IDENTIFICATION NUMBER	0123	Vendor-Assigned
6	Alpha/Numeric	IDENTIFICATION NUMBER	4567	Vendor-Assigned
7	Alpha/Numeric	IDENTIFICATION NUMBER	89	Vendor-Assigned
8	Numeric Only	IDENTIFICATION NUMBER	-	Vendor-Assigned
9	Alpha Only	VENDOR IDENTIFICATION	A through Z	(see SEMI AUX1)
10	Alpha Only	VENDOR IDENTIFICATION	A through Z	Resistivity (ohm-cm) identification is assigned by vendor in whole or partial numbers. No accuracy is implied.
11	Numeric Only	RESISTIVITY IDENTIFICATION	012	Resistivity (ohm-cm) identification is assigned by vendor in whole or partial numbers. No accuracy is implied.
12	Numeric Only	RESISTIVITY IDENTIFICATION	345	Resistivity (ohm-cm) identification is assigned by vendor in whole or partial numbers. No accuracy is implied.
13	Numeric Only	RESISTIVITY IDENTIFICATION	678	Resistivity (ohm-cm) identification is assigned by vendor in whole or partial numbers. No accuracy is implied.
14	Numeric Only	RESISTIVITY IDENTIFICATION	9.	Resistivity (ohm-cm) identification is assigned by vendor in whole or partial numbers. No accuracy is implied.
15	Alpha Only	DOPANT SPECIES	B	Boron
			F	Phosphorous
			A	Arsenic
			S	Antimony
16	Numeric Only	CRYSTAL GROWTH ORIENTATION	0	1-0-0
			1	1-1-1
			2	1-1-0
			3	0-1-1
			5	5-1-1
			-	
17	Alpha Only	CHECK CHARACTERS	A through H	Error-Detecting Method
18	Numeric Only	CHECK CHARACTERS	0 through 7	(see Sections 8 - 13)



1 Minimum flat length shown for 100 mm, 125 mm, and 150 mm diameter wafers.

2 This dimension applies to 100 mm, 125 mm, and 150 mm diameter wafers.

Figure 3
Vendor Code Field Location for Flatted Wafers

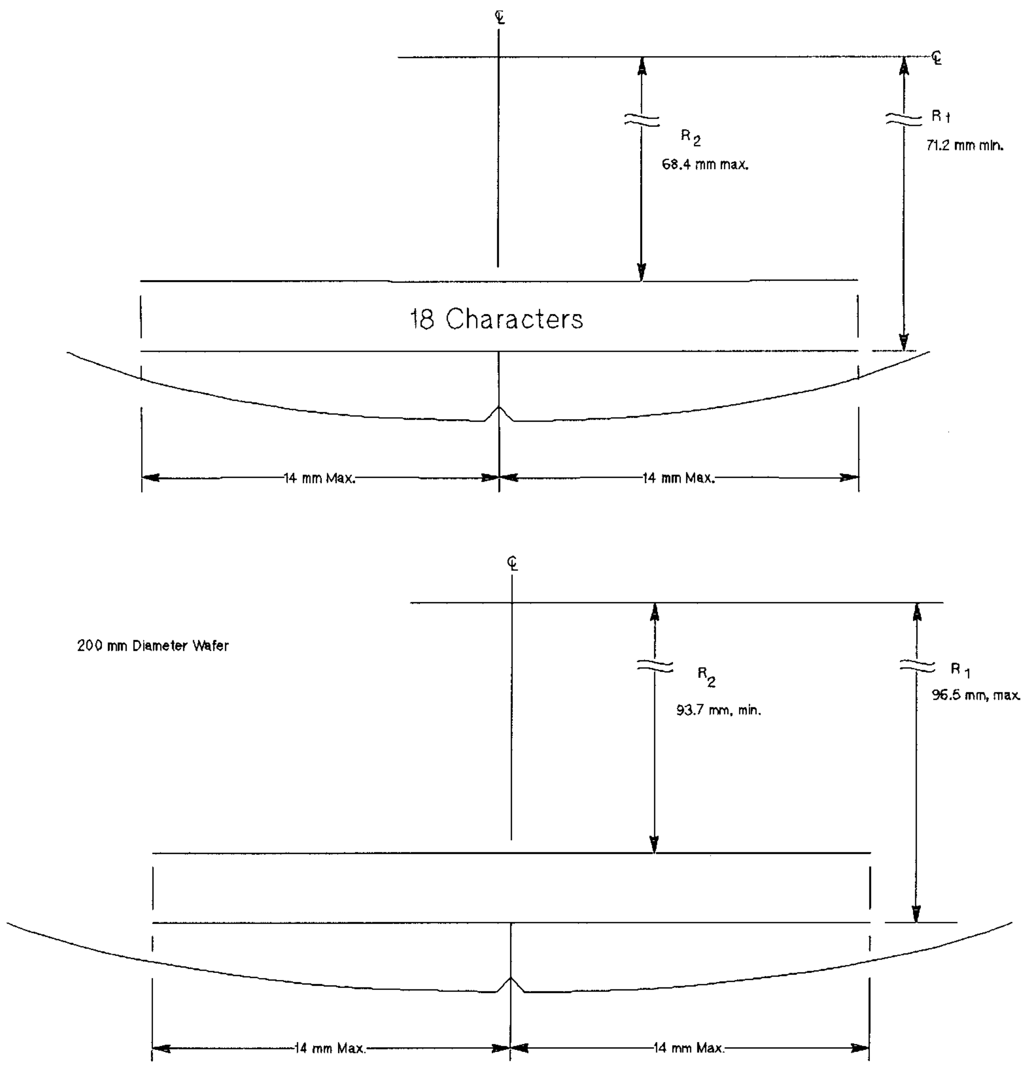


Figure 4
Vendor Field Location for Notched Wafers

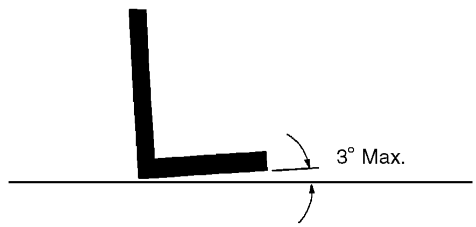


Figure 5

Character Skew

NOTE: This line is parallel to the bottom of the code field window.

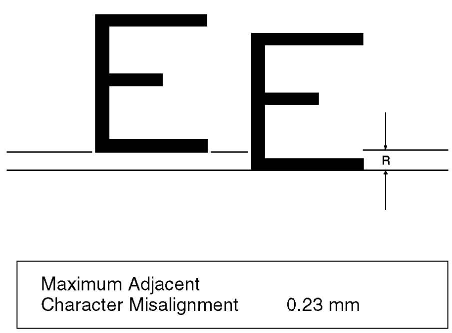


Figure 6A

Character Misalignment

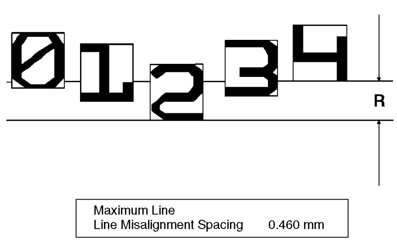


Figure 6B

Line Spacing Misalignment

8 Alphanumeric Error-Detecting Method[2]

8.1 The alphanumeric check characters in character locations 17 and 18 are a required part of the Vendor Code.

8.2 All single-character substitution errors are detected.

8.3 All two-character transposition errors are detected for any message up to 58 characters in length.

8.4 The character set may be expanded into the first 59 characters of the ASCII 64-character set.

8.5 There exist simple recursive algorithms for error detection and check character generation that do not require the use of multiplication or division.

9 Definition of the Error-Detecting Method

9.1 For the purpose of describing the error-detecting method, we define the following symbols:

A_i represents the i^{th} ASCII character.
a_i represents the numerical value assigned to A_i.

9.2 The characters are numbered from left to right, so that the message is given by

$$A_1A_2A_3...A_{18}.$$

9.3 A complete description of the error-detecting method is given by the following seven rules:

9.3.1 The numerical value a_i is found by subtracting 32 from the ASCII decimal representation of A_i (refer to Table 4 — Character Values).

9.3.2 An ASCII character A_i is allowed only if its numerical value a_i is one of

$$0, 1, 2, ..., 58.$$

9.3.3 The check character A_{17} must be one of the ASCII characters A,B,C,D,E,F,G,H.

9.3.4 The check character A_{18} must be one of the ASCII characters 0,1,2,3,4,5,6,7.

9.3.5 The check character pair A_{17} A_{18} may not be one of the combinations H3, H4, H5, H6, H7.

9.3.6 When the message is written, the check characters A_{17} and A_{18} are chosen such that 59 divides the expression

$$8^{17}a_1 + 8^{16}a_2 ... + 8^2a_{16} + 8a_{17} + a_{18}$$

without a remainder.

[2] *Formal proofs of the properties of the error-detecting method (as well as descriptive notes and other reference materials) are on file at SEMI, and are available upon request.*

9.3.7 If, on reading the message, 59 does not evenly divide the expression given above, an error has occurred.

10 Suggestions for Implementation

10.1 The error-detecting method can be implemented directly by calculating the expression given above, and the check characters can be found by exhaustive search. However, this approach is unnecessarily complex; a decrease in complexity can be made by taking advantage of three simple observations.

10.2 First, since we are interested only in the remainder of the final expression after dividing it by 59, we can avoid working with large numbers by subtracting 59 repeatedly after each operation until the result is less than 59.

10.3 Second, we can rearrange the error-detecting expression, using Horner's Rule, to form

$$a_{18} + 8(a_{16} + ...8(a_3 + 8(a_2 + 8a_1))...)$$

which can be calculated recursively from the inside out by successive multiplication and addition.

10.4 Third, multiplication by eight can be accomplished by adding a quantity to itself three times in succession.

11 An Algorithm for Error Detection

11.1 When implementing error detection, it is convenient to imaging a checksum for each individual character position. This partial checksum forms a check on all preceding characters, as well as the present character. Then, using Horner's Rule, one can calculate a "running" checksum (that is, calculate each partial checksum in order). This leads to the following algorithm.

11.2 Add the checksum for the previous character position to itself. (For the first character position, the value of the previous checksum is zero.) If the result is 59 or greater, subtract 59. This leaves a value in the range 0-58.

11.3 Add the result of Step 1 to itself. If the result is 59 or greater, subtract 59.

11.4 Add the result of Step 2 to itself. If the result is 59 or greater, subtract 59. The result of this step is eight times the previous position checksum, modulo 59.

11.5 Add the result of Step 3 to the numerical value of the character in the present position. If the result is 59 or greater, subtract 59. The result of this step is the checksum for the present character position.

11.6 Repeat Steps 1 through 4 for each character position. If the checksum for the final character position is nonzero, an error has occurred.

12 An Algorithm for Generating the Check Characters

12.1 Initially, assume that the check characters are A0 (the first check character is the letter A, the second is the digit 0).

12.2 Calculate the final checksum in the manner described above for error detection. If the result is zero, the check characters are correct, and the algorithm terminates.

12.3 If the result of Step 2 is nonzero, subtract it from 59, yielding a number in the range 1-58.

12.4 Convert the result of Step 3 to binary.

12.5 Add the least significant three bits of the binary number to the numerical value of the second assumed check character 0 (zero). This will yield a value that corresponds to an ASCII character in the range 0-7.

12.6 Add the next higher three bits of the binary number to the numerical value of the first assumed check character A. This will yield a numerical value that corresponds to an ASCII character in the range A-H.

13 An Illustrative Example

13.1 For the purpose of illustrating the check character generating algorithm, assume that the message consists of only two characters, the digits 2 and 3. Initially, assume that the check characters are A and 0 (zero) yielding the composite message 23A0.

13.2 Using the algorithm described above, the final checksum is found to be 33. Since this is nonzero, it is subtracted from 59, yielding 26 in decimal, or 011010 in binary.

13.3 The least significant three bits 010 (decimal value 2) added to the numerical value of the ASCII character 0 (zero), which is 16, yields 18 (the numerical value of the ASCII character 2).

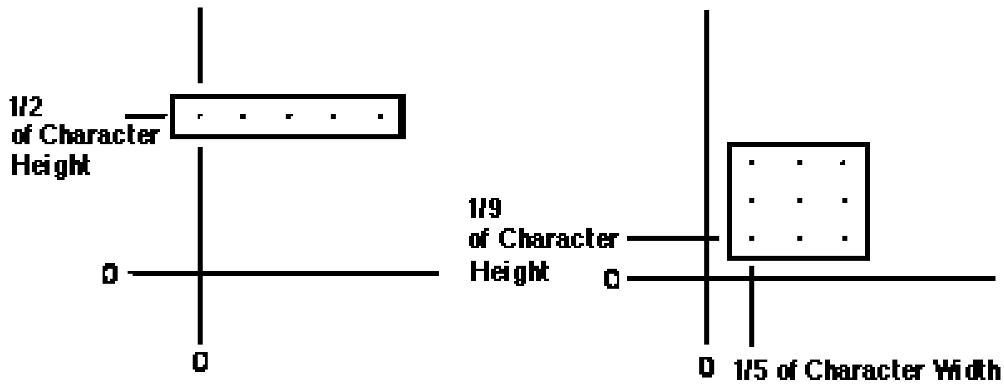
13.4 The final composite message is 23D2. The next higher three bits (011) (decimal value 3) added to the numerical value of the ASCII character A, which is 33, yields 36 (the numerical value of the ASCII character D).

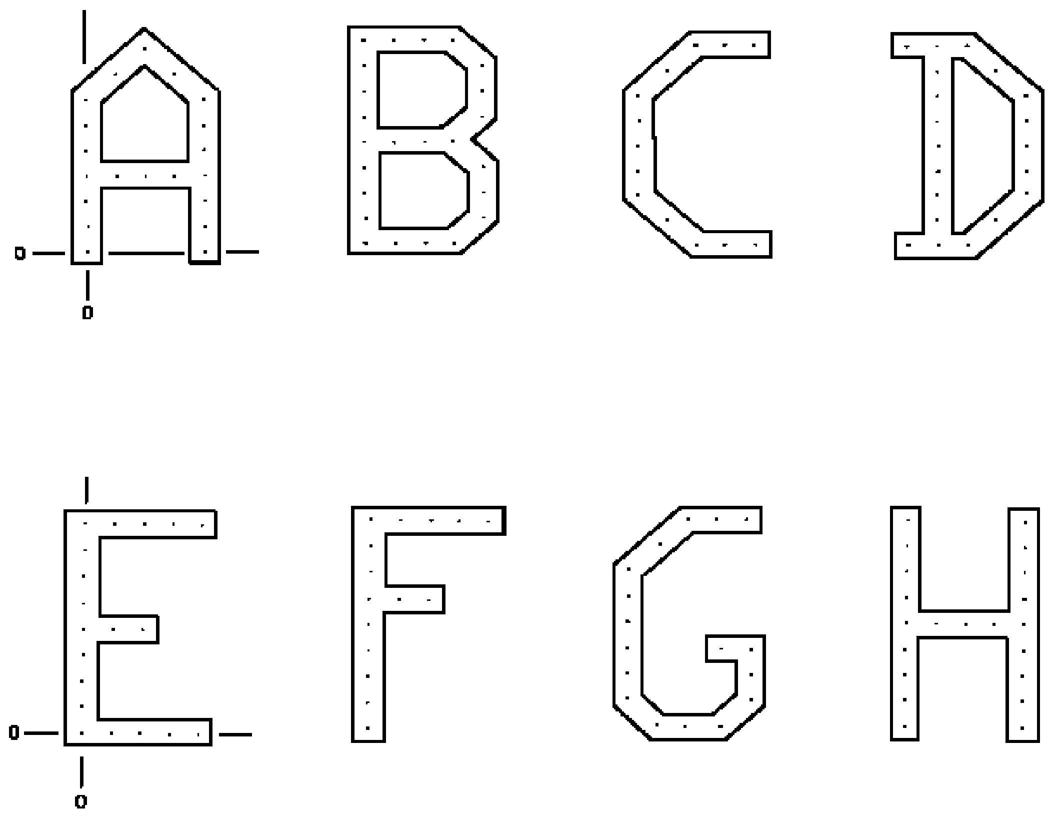
Table 4 Character Values

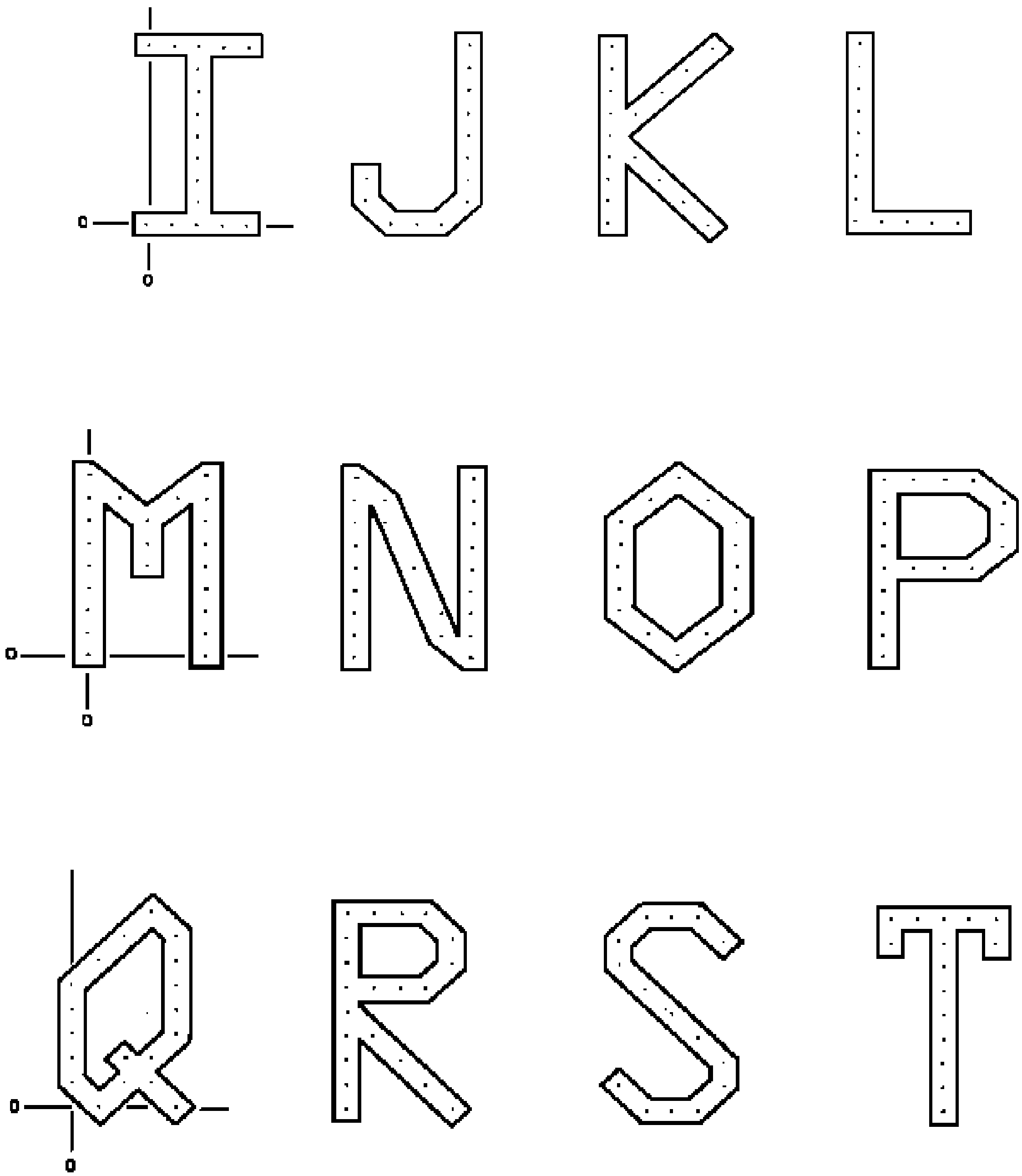
ASCII Character	*ASCII Decimal Value*	*Numerical Value*
–	45	13
.	46	14
0	48	16
1	49	17
2	50	18
3	51	19
4	52	20
5	53	21
6	54	22
7	55	23
8	56	24
9	57	25
A	65	33
B	66	34
C	67	35
D	68	36
E	69	37
F	70	38
G	71	39
H	72	40
I	73	41
J	74	42
K	75	43
L	76	44
M	77	45
N	78	46
O	79	47
P	80	48
Q	81	49
R	82	50
S	83	51
T	84	52
U	85	53
V	86	54
W	87	55
X	88	56
Y	89	57
Z	90	58

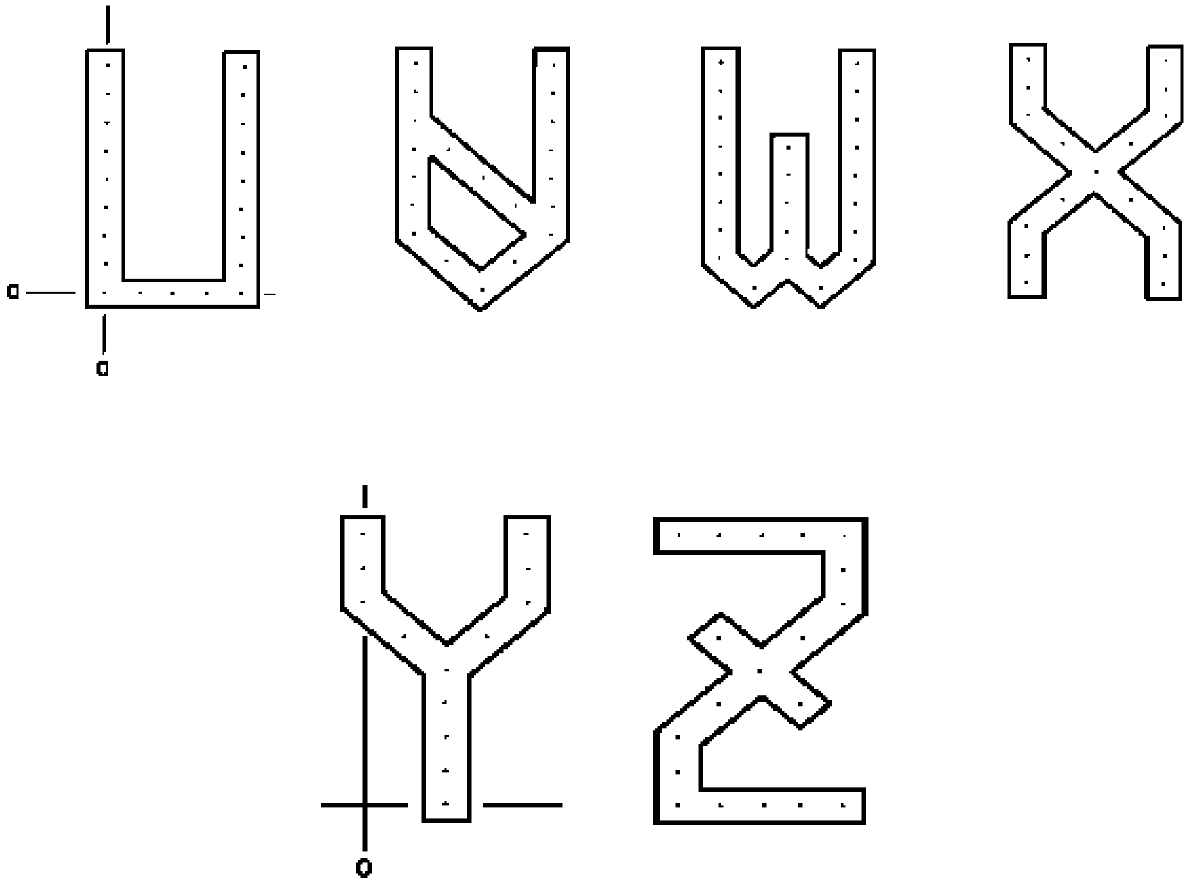
APPENDIX 1
SEMI OCR CHARACTER OUTLINES

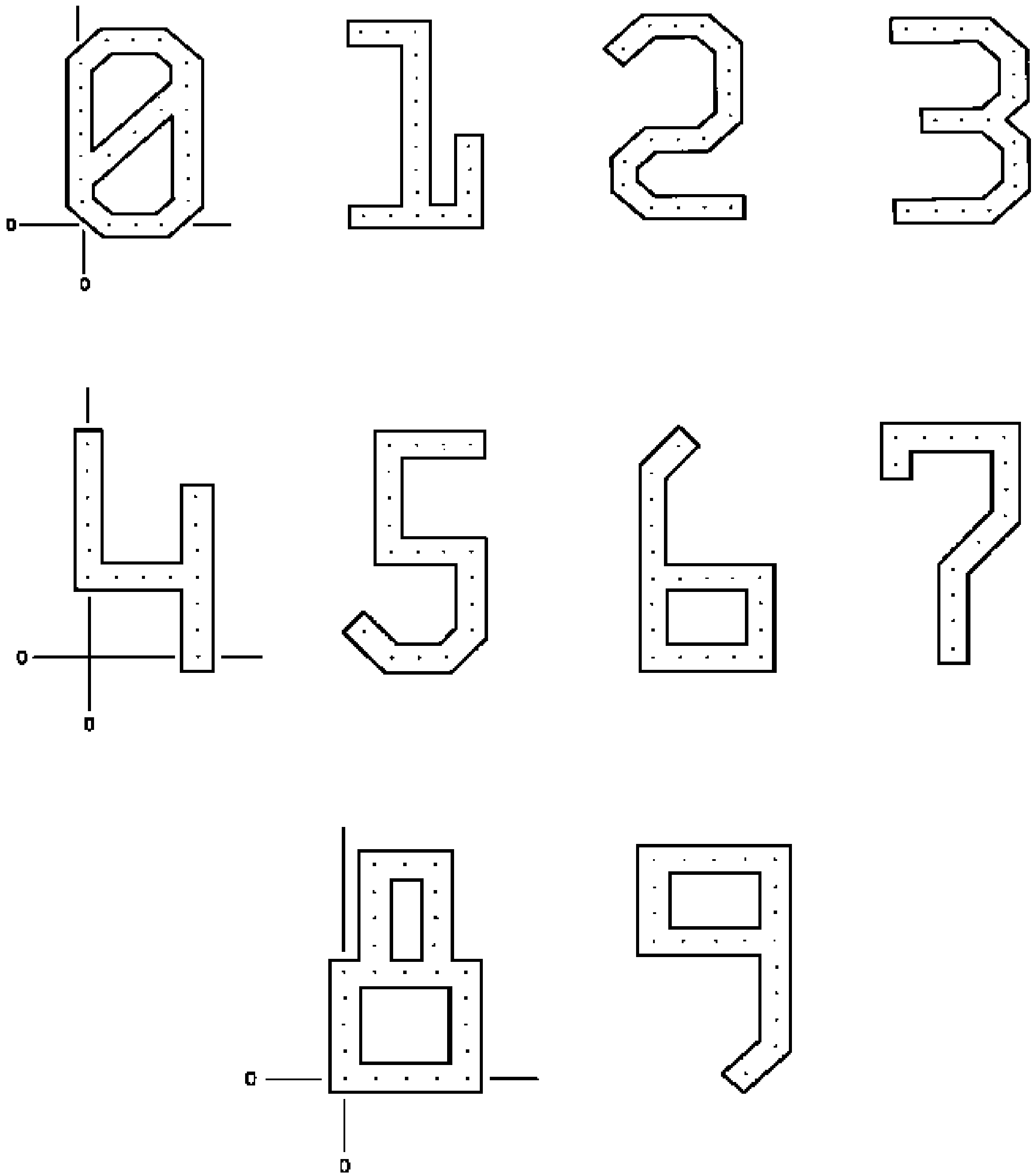
NOTE: The material in this appendix is an official part of SEMI M13 and was approved by full letter ballot procedures on July 12, 1998.







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RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI M13 and is not intended to modify or supercede the official standard. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

R1-1 Consideration for Reliable Automatic Reading of the Marking

R1-1.1 The following suggestions are offered to assist in assuring the most reliable automatic reading of the alphanumeric marking.

R1-1.2 *Character Stroke Thickness* — If a 5 × 9 dot matrix is chosen for marking, it is recommended that the minimum dot size be 0.100 mm. With a higher density dot matrix format, smaller dot diameters may be employed. Stroke thickness should be constant within 20% over the entire character set so that the reader settings may be optimized from the specific wafer run.

R1-1.3 *Contrast* — The character should have sufficient contrast to be legible. Contrast may be affected by depth and other conditions.

R1-1.4 *Clear Zone* — It is recommended that the area immediately beneath, and a minimum of 0.500 mm around, the marking characters be of uniform reflectivity and free of any lithography and process overlay edges.

SEMI M14-89
SPECIFICATION FOR ION IMPLANTATION AND ACTIVATION PROCESS FOR SEMI-INSULATING GALLIUM ARSENIDE SINGLE CRYSTALS

1 Scope

The purpose of this document is to present a process for ion implantation, activation, and measurement of the resulting layers so that meaningful comparisons can be made between various lots of semi-insulating GaAs. This test will be performed by the supplier so that product may be represented in a standard way.

NOTE: This is intended to be an interim procedure for use until a standard test method is developed by ASTM.

2 Process

2.1 Candidate lots must pass SEMI GaAs specifications for resistivity, mobility, and thermal stability using standard ASTM referee techniques.

2.2 *Implantation Process*

2.2.1 *Surface Preparation* — The surface treatment shall be designed to remove residual oxide.

2.2.2 *Implant Angle Energy Species and Dose* — An energy of 150 keV using Si_{29} to a dose of $2 \times 10^{12}/cm^2$ and a tilt of 11° to 13° from the (100) toward the (110).

2.3 *Activation Process*

2.3.1 *Surface Preparation* — No chemical treatment should be performed prior to activation.

2.3.2 *Activation* — The samples shall be subjected to a temperature of 850°C for 10 minutes with a second proximity wafer directly in contact with the implanted surface. The proximity wafer shall be identical to the subject wafer except not subjected to ion implantation. The ambient of the furnace shall be a gas such as nitrogen or argon.

2.4 *Layer Evaluation*

2.4.1 Evaluation of the activated samples shall be based upon CV profiling, mobility, and resistivity as specified according to standard ASTM techniques.

SEMI M15-0298
POLISHED WAFER DEFECT LIMITS TABLE FOR SEMI-INSULATING GALLIUM ARSENIDE WAFERS

NOTE: This entire document was revised in 1998.

1 Purpose

1.1 This document defines the maximum number of defects, by type, that an acceptable polished Semi-Insulating Gallium Arsenide (GaAs) wafer may exhibit.

2 Scope

2.1 This document, established separately from SEMI M15, in accordance with the latest requirements for the material in advanced applications, covers polished semi-insulating GaAs wafers. The defect limits table can also be applied to conducting GaAs wafers, except for the specification of Light Point Defects (LPD) mentioned hereinafter. “Polished” shall refer to those wafers which have a specular chemical or chemical/mechanical finish applied to one side of the wafer, with the backside being as cut and etched, lapped and etched, ground and etched, or polished. The definition of defects is covered in ASTM Practices F 523 and F 154.

3 Referenced Documents

3.1 *ASTM Standards*[1]

F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

Table 1 Polished Wafer Defect Limits

Item #	*Characteristics — Front Surface*	*Maximum Defects Limits Prime Wafer*	*Maximum Defects Limits Test Wafer*	*Notes*
1	Scratches			
	Macroscratches	None		#1
	Maximum Number	----	3	
	Maximum Length	----	Radius/2	
	Microscratches	None	Not Specified	#1, 2
2	Pits			#1, 2
	2" Diameter Slices	None	5	
	3" Diameter Slices	None	15	
	4" Diameter Slices	None	30	
3	Haze	None	None	#1, 2
4	Cavity/Voids	None	None	#1
5	Contamination	None	None	#1, 2
6	Light Point Defects ≥ ϕ 2.0 µm			
	2" Diameter Slices	10	20	#2, 3
	3" Diameter Slices	15	30	#2, 3
	4" Diameter Slices	20	40	#2, 3
	Light Point Defects ≥ ϕ 3.0 µm			
	2" Diameter Slices	50	100	#2, 3
	3" Diameter Slices	100	200	#2, 3

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

18				
	4" Diameter Slices	200	400	#2, 3
7	Chips (≥ 0.5 mm × 0.3 mm)	None	None	#1
8	Cracks	None	None	#1
9	Dimples	None	None	#1, 2
10	Gallium Inclusions/Precipitates	None	None	#1, 2
11	Orange Peel	None	None	#1, 2
12	Saw Marks	None	None	#1
13	Striations	None	None	#1, 2
14	Twins	None	None	#1, 2

Item #	*Characteristics – Back Surface*	*Maximum Defect LimitsPrime Wafer*	*Maximum Defect LimitsTest Wafer*	*Notes*
15	Stain	None	None	#2, 4
16	Saw Marks	None	None	#1, 5
17	Chips (≥ 0.5 mm × 0.3 mm)	None	None	#1
18	Cracks	None	None	#1
19	Listed Defects #10, 14	None	None	#1, 2
20	Listed Defects #1, 2, 6			#6

NOTES:

1. These defect limits are meant to apply only to those characteristics which can be seen with the unaided eye under high-intensity illumination according to ASTM Practice F 523. Limits for other defects listed and defined in this section which require the aid of a microscope, preferential etching, or other apparatus must be agreed upon between supplier and user.

2. Peripheral Edge Allowance — The outer edge exclusion for observation shall be determined from the following tabe:

Diameter	*Outer Edge Exclusion for Observation*
2 inch	2 mm
3 inch	3 mm
4 inch	3 mm

3. LPD shall be counted by measuring equipment designed for detecting laser light scatter. Selection of the measuring equipment and the requirement for the precision are to be agreed upon between supplier and user.

4. Back Surface Stain — An area of undercutting, texturing, or oxidation, common in waxless polished wafers.

5. The depth of allowed saw marks is to be no greater than 5 µm. The measuring method is to be agreed upon between supplier and user.

6. Item #20 — To be agreed upon between supplier and user.

SEMI M16-1296
SPECIFICATION FOR POLYCRYSTALLINE SILICON

1 Preface

1.1 This specification covers requirements for polycrystalline silicon (poly) used to produce single crystal silicon by the Czochralski (Cz) crystal growth technique for applications in the semiconductor device industry. Form and dimensional characteristics are the only standardized properties set forth below.

1.2 A purchase specification may require that additional physical properties be defined. These properties are listed, together with test methods suitable for determining their magnitude.

2 Applicable Documents

2.1 *ASTM Standards*[1]

E 122 — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

F 574 — Test Method for Evaluation of Polysilicon (In Revision)

P 213 — Proposed Test Method for Photoluminescence Analysis of Single Crystal Silicon for III-V Impurities

2.2 *Other Standards*

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes[2]

AQAP-4 — NATO Inspection System Requirements for Industry

3 Terminology

etched polysilicon — polysilicon that has been etched with acid to remove surface contamination.

lot — all of the material of nominally identical purity and characteristics contained in a single shipment, manufactured with similar processing conditions, and traceable to the manufacturing conditions. A lot may be further defined as the polysilicon produced from one reactor run.

polycrystalline silicon — (Poly, polysilicon) silicon, formed by chemical vapor deposition from a silicon source gas, having a structure which contains large angle grain boundaries, twin boundaries, or both.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

4 Ordering Information

4.1 Purchase orders for polysilicon furnished to this specification shall include the following items:

4.1.1 Form

4.1.2 Size

4.1.3 Purity

4.1.4 Surface Texture

4.1.5 Surface Condition

4.1.6 Appearance

4.1.7 Lot Acceptance Procedures

4.1.8 Certification (if required)

4.1.9 Packing and Marking

5 Dimensions and Permissible Variations

5.1 The material shall conform to the dimensions and dimensional tolerances as specified in the appropriate polysilicon standard.

6 Materials and Manufacture

6.1 The material shall consist of polysilicon with the form specified in the purchase order or contract.

7 Physical Requirements

7.1 The material shall conform to the properties specified in the purchase order or contract, as follows:

7.1.1 Purity

7.1.2 Size

7.1.3 Surface Texture

7.1.4 Surface Condition

7.1.5 Appearance

8 Sampling

8.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4-1993. Inspection levels shall be agreed upon between the supplier and the purchaser. Alternately AQAP-4 may be used to determine sampling plan.

9 Test Methods

9.1 *Size* — Determine by a method agreed upon by the purchaser and the supplier.

9.2 *Purity* — Determine in accordance with ASTM Test Method F 574.

NOTE 1: Newer test methods are being developed, including photoluminescence (ASTM Proposed Test Methods P 213) and low temperature FTIR.

9.3 *Surface Texture* — Determine by a method agreed upon by the purchaser and the supplier. Visual limit standards shall be used to describe acceptable limits.

10 Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with the specification shall be furnished at the time of shipment (Certificate of Compliance). Upon request, a report of the test results may also be required (Certificate of Analysis).

10.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate test in Section 9. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

11 Packing and Marking

11.1 Special packing requirements shall be subject to agreement between the supplier and purchaser. Otherwise all poly shall be handled, inspected, and packed in bags and boxes in such a manner as to minimize abrasion, chipping, and contamination, and in accordance with the best industry practices to provide ample protection against damage during shipment.

11.2 The poly supplied under the specification shall be identified by appropriately labeling the outside of each box and each bag therein. Identification shall include, as a minimum, the weight and lot number of the polysilicon. The lot number shall provide traceability to information concerning the manufacturing history of the particular poly in that lot. Such information shall be kept on file at the manufacturer's facility for at least three years after that particular lot has been accepted by the purchaser.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M16.1-89
STANDARD FOR NUGGET-FORM POLYCRYSTALLINE SILICON

The complete specification for this product includes all general requirements of SEMI M16.

1 Purity

1.1 Values to be determined by the purchase order are listed as follows:

Acceptor, max = Maximum allowable content of acceptor impurities to be specified as parts per billion, atomic (ppba).

Donor, max = Maximum allowable content of donor impurities to be specified as parts per billion, atomic (ppba).

Carbon, max = Maximum allowable content of carbon impurity to be specified as parts per million, atomic (ppma).

2 Size Distribution

2.1 Nuggets shall have irregular shape and a random size distribution resulting from the breaking of rod-form poly. The minimum linear dimension of a nugget shall be 6 mm, the maximum linear dimension 100 mm.

2.2 Size distribution shall be:

< 6 mm size	1% by weight, maximum
< 12 mm size	2% by weight, maximum
12 –25 mm size	10% by weight, maximum
25–50 mm size	15–35% by weight
50–100 mm size	65% by weight, minimum

3 Surface Texture

3.1 Visual limit standards shall be agreed upon between the purchaser and the supplier.

4 Surface Condition

4.1 All polysilicon shall be identified as to its surface condition, whether or not it has been etched.

5 Appearance

5.1 Surface of nuggets shall be clean, with no stains, discolorations, or visible contaminants.

SEMI M17-0998
SPECIFICATION FOR A UNIVERSAL WAFER GRID

1 Scope

1.1 This document defines a grid pattern which is useful for quantifying surface defects on a nominally circular semiconductor wafer. The grid is defined such that it contains 1000 elements of approximately equal area. Each grid element thus contains 0.1 percent of the total quality area of the surface being inspected. Defects which are non-uniformly distributed (for example, slip) can be quantified in terms of the percent defective (or percent useful) area on the wafer surface.

1.2 The quantification of defective area is done by overlaying a transparency of the grid onto a map of wafer defects or by mapping observed defects onto the grid. The number of grid elements which contain defects is counted. The element count divided by 10 corresponds to the percent of defective area. This grid could also be superimposed onto a CRT display, photograph, or computer generated map, where applicable. In use, grid pattern diameters must be scaled to the size of the map or image of the wafer to be overlaid.

1.3 The grid described is referenced to the center of the wafer. A concept of a "Fixed Quality Area" is used, based on nominal wafer diameter, such as is specified in SEMI M1.

1.4 Maximum allowable slip and other non-uniformly distributed defects on epitaxial layers are specified in SEMI M2 and SEMI M11, and are observed in accordance with ASTM Test Methods F 80 or F 523.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specifications for Silicon Epitaxial Wafers

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Advanced Applications

2.2 *ASTM Standards*[1]

F 47 — Test Method for Crystallographic Perfection of Silicon by Preferential Etch Techniques

F 80 — Test Method for Crystallographic Perfection of Epitaxial Deposits of Silicon by Etching Techniques

F 154 — Standard Practice and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

F 1241 — Terminology for Silicon Technology

3 Terminology

3.1 Selected definitions (for information only) are listed in the glossary, Definitions for Semiconductor Materials, at the end of this volume.

3.2 Definitions for many surface defects are given in ASTM Terminology F 1241. Additional information is provided in ASTM Test Method F 47 and ASTM Practices F 154.

4 Grid Element Layout

4.1 *Grid Element Scheme*

4.1.1 Two types of grids are defined: one for wafers without a primary flat (for example, wafers where the primary fiducial is a notch), and one for wafers with a primary flat. The grid is divided by 18 concentric circles containing radial divisions which are assigned according to the diameter of each circle (see Table 1). The relative diameters of the concentric circles are established by the areas of each annulus. To find the actual diameter of any circle, multiply the relative diameter by the outer diameter of the grid.

4.1.2 The outer diameter of the grid is chosen to be the size appropriate for a particular application. This diameter would normally be chosen to be the nominal diameter of the fixed quality area to allow for such things as an edge exclusion, tolerance variations in the wafer diameter, and edge rounding. Table 2 shows (as an example) the circle diameters for a series of grids which have a fixed quality area radius 3 mm smaller than the nominal radius of selected wafers specified in SEMI M1.

4.1.3 Identification of each grid element is done by referring to a circle number and a division number on that circle. Circles are numbered from the center out, with the center circle being number 01 and the outermost circle being number 18. The divisions are numbered starting with the first division counterclockwise from the horizontal line which starts

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

at the center of the grid and extends to the right, when the primary fiducial (flat or notch) is placed at the bottom of the grid. Divisions are progressively numbered counterclockwise from 01 to n, where n equals the total number of divisions on the circle. An element's address is given by two sets of numbers separated by a comma: circle (0 –18), division (01–n). Elements 18, 01 and 18, 100 are identified in Figure 1.

4.2 *Wafers without a Primary Flat*

4.2.1 The grid elements for wafers without a primary flat are illustrated in Figure 1. This pattern is generated by making concentric circles with relative diameters and radial divisions as specified in Table 1. In this table the circle number is given in the leftmost column. The number of divisions and the included angle of each division in the circle are given in the second and third columns. The total number of divisions (from the center outward) is given in the fourth column. The included area ratio, given in the fifth column, is the total number of divisions included within a circle divided by 1000, the total number of divisions in the grid. The relative diameter, given in the rightmost column, is the square root of the included area ratio.

4.3 *Wafers with a Primary Flat*

4.3.1 For wafers with a primary flat, a standard included angle of 43.2° is used for all wafer sizes. This angle was chosen because it lies between the maximum and minimum included angles of the primary flats specified in SEMI M1 for 100 mm, 125 mm, 150 mm, and 200 mm diameter wafers. In addition, if a fixed quality area of radius 3 mm less than the nominal wafer radius is used, the grid will not in any case extend beyond the edge of the wafer in the region of the primary flat.

4.3.2 This flat is propagated into the wafer as illustrated in Figure 2. The diameter of each circle is the same as for wafers without a primary flat. The flat is propagated vertically downward (starting with circle number 3) by the intersection of the circle with a horizontal chord which subtends 43.2°.

4.3.3 The areas of the grid elements within the propagated flat region are slightly smaller than the areas of the regular grid elements. This difference is ignored when counting grid elements for wafers with a primary flat. All grid elements are assumed to be 0.001 of the total fixed quality area.

4.4 *Secondary Flats*

4.4.1 The grid ignores secondary flats. These are shallow enough that the outer circle does not extend beyond the wafer edge if a fixed quality area of radius 3 mm less than the nominal wafer radius is used.

NOTE In this sense, the fixed quality area used by the Universal Wafer Grid deviates somewhat from the formal definition in SEMI M1 which embodies an edge exclusion of constant width around the entire periphery of the wafer including the region of the secondary flat.

Table 1 Grid Element Scheme

Circle Number	*Number of Divisions*	*Included Angle*	*Total Number of Divisions*	*Included Area Ratio*	*Relative Diameter*
01	4	90.0°	4	0.004	0.0632
02	8	45.0°	12	0.012	0.1095
03	16	22.5°	28	0.028	0.1673
04	24	15.0°	52	0.052	0.2280
05	30	12.0°	82	0.082	0.2864
06	36	10.0°	118	0.118	0.3435
07	40	9.0°	158	0.158	0.3975
08	48	7.5°	206	0.206	0.4539
09	50	7.2°	256	0.256	0.5060
10	60	6.0°	316	0.316	0.5621
11	72	5.0°	388	0.388	0.6229
12	72	5.0°	460	0.460	0.6782
13	80	4.5°	540	0.540	0.7348
14	80	4.5°	620	0.620	0.7874
15	90	4.0°	710	0.710	0.8426
16	90	4.0°	800	0.800	0.8944
17	100	3.6°	900	0.900	0.9487
18	100	3.6°	1000	1.000	1.0000

Table 2 Grid Circle Diameters (in mm) for Various Standard Wafer Sizes with Fixed Quality Area Radius 3 mm Smaller Than Nominal Wafer Radius

			Nominal Wafer Diameter		
Circle Number	*Relative Diameter*	*100 mm*	*125 mm*	*150 mm*	*200 mm*
01	0.0632	5.94	7.52	9.10	12.26
02	0.1095	10.29	13.03	15.77	21.24
03	0.1673	15.73	19.91	24.09	32.46
04	0.2280	21.43	27.13	32.83	44.23
05	0.2864	26.92	34.08	41.24	55.56
06	0.3435	32.29	40.88	49.46	66.64
07	0.3975	37.37	47.30	57.24	77.12
08	0.4539	42.67	54.01	65.36	88.06
09	0.5060	47.56	60.21	72.86	98.16
10	0.5621	52.84	66.89	80.94	109.05
11	0.6229	58.55	74.13	89.70	120.84
12	0.6782	63.75	80.71	97.66	131.57
13	0.7348	69.07	87.44	105.81	142.55
14	0.7874	74.02	93.70	113.39	152.76
15	0.8426	79.20	100.27	121.33	163.46
16	0.8944	84.07	106.43	128.79	173.51
17	0.9487	89.18	112.90	136.61	184.05
18	1.0000	94.00	119.00	144.00	194.00

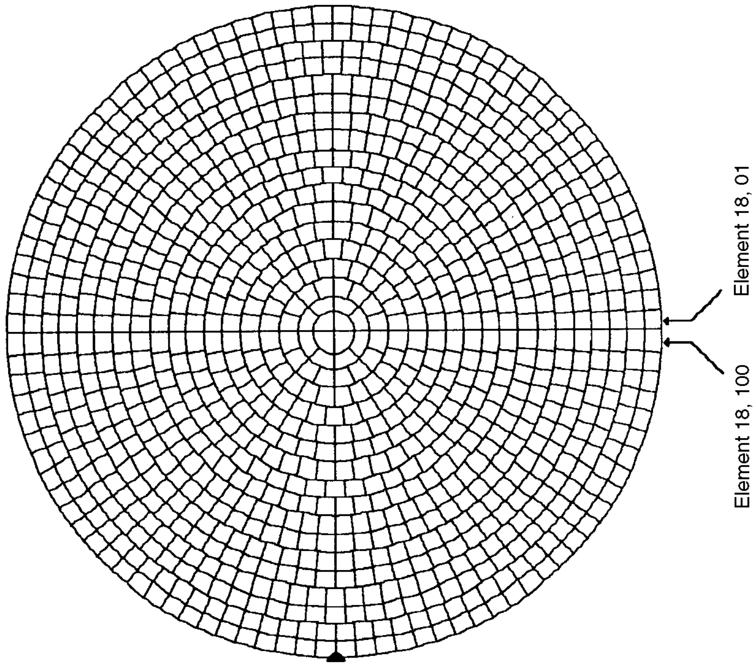

Figure 1
Grid Layout for Wafers Without a Primary Flat

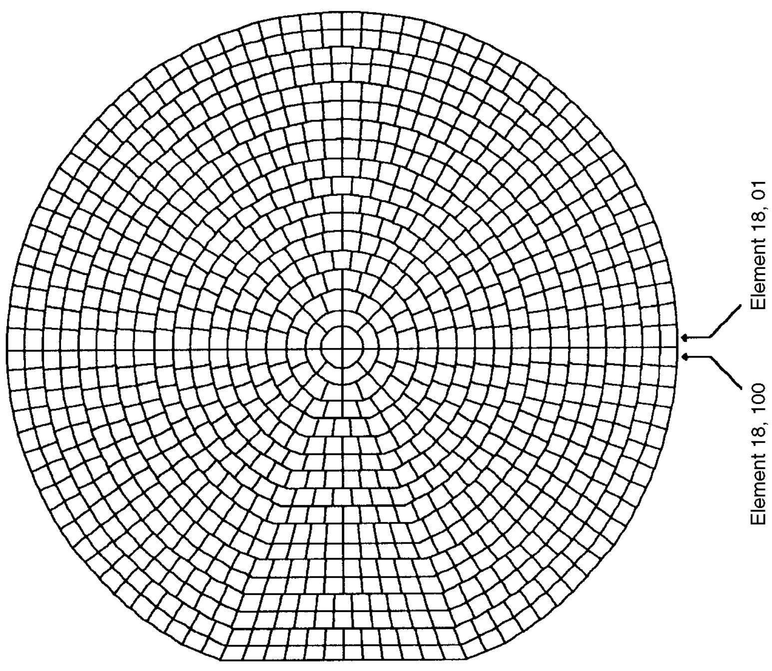

Figure 2
Grid Layout for Wafers With a Primary Flat

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M18-0702
FORMAT FOR SILICON WAFER SPECIFICATION FORM FOR ORDER ENTRY

This format was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published in 1990; previously published March 2002.

1 Purpose

1.1 This format provides a standard form for specifying several classifications of silicon wafers, as follows:

1.1.1 Polished Silicon Wafers.

1.1.2 Epitaxial Silicon Wafers.

1.1.3 Epitaxial Silicon Wafers with Buried Layer.

1.1.4 Annealed Silicon Wafer.

1.2 This format also lists the Electronic Data Interchange (EDI) codes used in SEMI T6 to identify the type of data being reported in the EDI message.

2 Scope

2.1 The form is designed to be used in conjunction with other SEMI specifications where details of the dimensional, physical, electrical, and chemical properties are defined or specified. However, the form includes many items that are not currently included in the SEMI specifications. Also, many items are not now commonly specified, but may find increased importance in the future. The intention is to provide for flexibility and expansion of the technology.

2.2 This format provides for specifying and ordering silicon wafers with varying levels of complexity. The minimum level of completeness is shown in each case, with additional options included to allow for customization of the wafer to the specific processing requirements of the user. If a particular item is not of interest, no entry is required. The only required entries are those marked as such for the purpose of minimal specification (diameter, orientation, dopant, resistivity, etc.).

2.3 Values for many items are listed either in the polished silicon wafer standards in SEMI M1 or in the defect limits tables in SEMI M1, SEMI M2, or SEMI M11. If these standard specifications are sufficient for defining the wafers, only a single entry is required in each section of the form.

2.4 This format also lists the codes required by SEMI T6 to identify the parameter being reported in the EDI message. Where necessary, secondary characteristics or identifier codes are listed within a generalized characteristic.

2.5 For referee purposes, U.S. Customary units shall be used for wafers of 2- and 3-inch diameters, and SI (System International, commonly called metric) units for 100 mm and larger diameter wafers.

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specifications for Silicon Epitaxial Wafers for Discrete Device Applications

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specifications for Alphanumeric Marking of Silicon Wafers

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M25 — Specification for Silicon Wafers for Calibration of Light Point Defect Wafer Inspection Systems with Respect to the Diameter of Polystyrene Latex Spheres

SEMI M28 — Specification for Developmental 300 mm Diameter Polished Single Crystal Wafers

SEMI M33 — Test Method for the Determination of Residual Surface Contamination on Silicon Wafers by Means of Total Reflection X-Ray Fluorescence Spectroscopy (TXRF)

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

SEMI T2 — Specification for Marking of Wafers with a Two-Dimensional Matrix Code Symbol

SEMI T6 — Procedure and Format for Reporting of Test Results by Electronic Data Interchange (EDI)

SEMI T7 — Specification for Back Surface Marking of Double-Side Polished Wafers with a Two-Dimensional Matrix Code Symbol

3.2 *ANSI Standard*[1]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.3 *ASTM Standards*[2]

D 523 — Standard Test Method for Specular Gloss

E 122 — Standard Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

F 26 — Standard Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 28 — Test Method for Minority-Carrier Lifetime in Bulk Germanium and Silicon by Measurement of Photoconductive Decay

F 42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 81 — Method for Measuring Radial Resistivity Variation on Silicon Wafers

F 84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Probe Array

F 95 — Test Method for Thickness of Lightly Doped Silcon Epitaxial Layers on Heavily Doped Silicon Substrates Using an Infrared Dispersive Spectrophotometer

F 110 — Test Metod for Thickness of Epitaxial or Diffused Layers in Silicon by the Angle Lapping and Staining Technique

F 154 — Standard Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 374 — Test Method for Sheet Resistance of Silicon Epitaxial, Diffused, Polysilicon, and Ion-implanted Layers Using and In-Line Four-Point Probe

1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

F 391 — Standard Test Methods for Minority-Carrier Diffusion Length in Extrinsic Semiconductors by Measurement of Steady-State Surface Photovoltage

F 398 — Test Method for Majority Carrier Concentration in Semiconductors by Measurement of Wave Number or Wavelength of the Plasma Resonance Minimum.

F 416 — Standard Test Method for Detection of Oxidation Induced Defects in Polished Silicon Wafers

F 419 — Test Method for Determining Carrier Density in Silicon Epitaxial Layers by Capacitance-Voltage Measurement on Fabricated Junction of Schottky Diodes

F 523 — Standard Practice for Unaided Visual Inspection of Polished Silicon Wafer Surface

F 525 — Test Method Measuring Resistivity of Silicon Wafers Using a Spreading Resistance Probe

F 533 — Standard Test Method for Thickness and Thickness of Variation of Silicon Wafers

F 534 — Standard Test Method for Bow of Silicon Wafers

F 672 — Test Method for Measuring Resistivity Profiles Perpendicular to the Surface of a Silicon Wafer Using a Spreading Resistance Probe

F 613 — Standard Test Method for Measuring Diameter of Semiconductor Wafers

F 657 — Standard Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Noncontact Scanning

F 671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Material

F 673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

F 723 — Practice for Conversion Between Resisitivity and Dopant Density for Boron-Doped, Phosphorus-Doped, and Arsenic-Doped Silicon.

F 847 — Standard Test Methods for Measuring Crystallographic Orientation of Flats on Single Crystal Silicon Wafers by X-Ray Techniques

F 928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F 951 — Test Method for Radial Interstitial Oxygen Variation in Silicon Wafers

F 978 — Standard Test Method for Characterizing Semiconductor Deep Levels by Transient Capacitance Techniques

F 1049 — Standard Practice for Shallow Pit Detection on Silicon Wafers

F 1152 — Standard Test Method for Dimensions of Notches on Silicon Wafers

F 1188 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F 1239 — Standard Test Methods for Oxygen Precipitation Characterization of Silicon Wafers by Measurement of Interstitial Oxygen Reduction

F 1241 — Standard Terminology of Silicon Technology

F 1366 — Test Method for Measuring Oxygen Concentration in Heavily Doped Silicon Substrates by Secondary Ion Mass Spectroscopy

F 1388 — Test Method for Generation Lifetime and Generation Velocity of Silicon Material by Capacitance-Time Measurements of Metal-Oxide-Silicon (MOS) Capacitors

F 1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

F 1391 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

F 1392 — Test Method for Determining Net Carrier Density Profiles in Silicon Wafers by Capacitance-Voltage Measurements with a Mercury Probe

F 1393 — Test Metod for Determining Net Carrier Density Profile in Silicon Wafers by Capacitance-Voltage Measurements with a Mercury Probe

F 1451 — Standard Test Method for Measuring Sori on Silicon Wafers by Automated Noncontact Scanning

F 1526 — Standard Test Method for Measuring Surface Metal Contamination on Silicon Wafers by Total Reflection X-ray Fluorescence Spectroscopy

F 1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F 1528 — Test Method for Measuring Boron Contamination in Heavily Doped N-Type Silicon Substrates by Secondary Ion Mass Spectrometry

F 1535 — Standard Test Method for Carrier Recombination Lifetime in Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

F 1617 — Standard Test Method for Measuring Surface Sodium, Aluminum, and Potassium on Silicon and EPI Substrates by Secondary Ion Mass Spectroscopy

F 1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at the Brewster Angle

F 1620 — Standard Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Surfaces

F 1621 — Standard Practice for Determining Positional Accuracy Capabilities of a Scanning Surface Inspection System

F 1725 — Standard Guide for Analysis of Crystallographic Perfection of Silicon Ingots

F 1726 — Standard Guide for Analysis of Crystallographic Perfection of Silicon Wafers

F 1727 — Practice for Detection of Oxidation Induced Defects in Polished Silicon Wafers

F 1809 — Guide for Selection and Use for Etching Solutions to Delineate Structural Defects in Silicon

F 1810 — Test Method for Counting Preferentailly Etched or Decorated Structural Defects on Silicon Wafers

F 1982 — Test Method for Analyzing Organic Contamination on Silicon Wafers Surfaces by Thermal Desporption Gas Chromatography

3.4 *DIN Standards*[3]

NOTE 1: DIN Standards are available in both German and English editions. ASTM equivalents are given in square brackets following the title.

50431 — Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals by Means of the Four-Point-Probe Direct Current Method with Colinear Four-Probe Array

50432 — Determination of the Conductivity Type of Silicon or Germanium by Means of Rectification Test or Hot-Probe

50433/1 — Determination of the Orientation of Single Crystals by Means of X-Ray Diffraction

50433/2 — Determination of the Orientation of Single Crystals by Means of Optical Reflection Figure

3 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, website: www.din.de

50433/3 — Determination of the Orientation of Single Crystals by Means of Laue Back Scattering

50434 — Determination of Crystal Defects in Monocrystalline Silicon Using Etching Techniques on {111} and {100} Surfaces

50435 — Determination of the Radial Resistivity Variation of Silicon or Germanium Slices by Means of a Four-Point-DC-Probe

50436 — Measurement of Metallurgical Thicknes of Epitaxial Layers of Silicon by the Stacking Fault Method

50437 — Measuring the Thickness of Silicon Epitaxial Layers of Silicon by Infrared Intereference Method [F95]

50438/1 — Determination of Impurity Content in Silicon by Infrared Absorption: Oxygen

50438/2 — Determination of Impurity Content in Silicon by Infrared Absorption: Carbon

50439 — Determination of the Dopant Concentration Profile of Single Crystalline Semiconductor Material by Means of the Capacitance-Voltage Method and Mercury Contact [F 1392, F 1393]

50438/3 — Determination of Impurity Content in Silicon by Infrared Absorption: Boron and Phosphorus

50440/1 — Measurement of Recombination Carrier Lifetime in Silicon Single Crystals by Means of Photoconductive Decay Method; Measurement on Bar-Shaped Test Samples [F28]

50441/1 — Determination of the Geometric Dimensions of Semiconductor Slices: Measurement of Thickness

50441/2 — Determination of the Geometric Dimensions of Semiconductor Slices: Testing of Edge Rounding

50441/3 — Measurement of the Geometric Dimensions of Semiconductor Slices; Determination of Flatness Deviation of Polished Slices by Means of Multiple Beam Interference

50441/4 — Determination of the Geometrical Dimensions of Semiconductor Slices: Diameter and Flat Depth of Slices

50443/1 — Recognition of Defects and Inhomogenities in Semiconductor Single Crystals by X-Ray Topography: Silicon

50444 — Conversion Between Resistivity and Dopant Density; Silicon [F723 (phosphorous and boron only)]

50445 — Contactless Determination of the Electrical Resistivity of Semiconductor Wafers with the Eddy Current Method

50446 — Determination of Defect Types and Defect Densities of Silicon Epitaxial Wafers [no direct ASTM equivalent, compare F 1726 and associated standards]

3.5 *ISO Standards*[4]

ISO 4287/1 — Surface Roughness – Terminology – Part 1: Surface and its Parameters

ISO 14644/1-7 — Clean Room and Associated Controlled Environments

3.6 *JEITA (formerly JEIDA) Standards*[5]

18 — Determining the Orientation of a Semiconductor Silicon Single Crystal

27 — Standard Specification for Dimensional Properties of Silicon Wafers with Specular Surface

43 — Terminology of Silicon Wafer Flatness

53 — Test Method for Recombination Lifetime in Silicon Wafers by Measurement of Photoconductivity Decay by Microwave Reflectance

56 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

61— Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

3.7 *JIS Standards*[6]

NOTE 2: ASTM equivalents are given in square brackets following the title.

H 0602 — Testing Method of Resistivity for Silicon Crystals and Silicon Wafers with Four-Point Probe

H 0604 — Measurement of Minority Carrier Life Time in Silicon by Photoconductive Decay Method [F 28]

H 0607 — Testing Methods for Conductivity Type of Semiconductor Materials

H 0609 — Test Methods of Crystalline Defects in Silicon by Preferential Etch Techniques

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4 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

5 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: www.jeita.or.jp

6 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

H 0611 — Methods of Measurement of Thickness, Taper, and Bow of Silicon Wafers

H 0612 — Testing Method of Resistivity for Single Crystal Silicon Wafers (with Four Point Probe) [F 84]

H 0614 — Visual Inspection for Silicon Wafers with Specular Surfaces

Z 8741 — Method of Measurement for Specular Glossiness

3.8 *Other Standard*[7]

ANSI/ASME B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

NOTE 3: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 The items listed in the form are referenced and defined in various documents. A reference for most items in Parts 2 and 3 of the form is listed in Table 1. The entries in the table are keyed to the form by item number. Because terms related to epitaxial wafers with buried layer are defined in this standard and because no standardized test methods for the buried layer parameters exist, Table 1 does not include line items from Part 4 of the form.

4.2 General term used in this standard:

4.2.1 *required (req. or req'd)* — when applied to a parameter listed in the order form, a user-supplied value is necessary to minimally define the material for manufacture.

4.3 Terms related to epitaxial wafers with buried layers:

4.3.1 *buried layer* — a diffused region in a substrate that is, or is intended to be, covered with an epitaxial layer.

4.3.2 *alignment precision* — pattern displacement in first mask photolithography process.

NOTE 4: Alignment precision is specified by maximum values of X and Y, the displacement of the center of the pattern from a reference position defined in the wafer specification in terms of the wafer coordinate system defined in SEMI M20, and the maximum value of θ, the angle between the x-axis of the pattern and the primary orientation flat (see Figure 1).

4.3.3 *pattern distortion ratio* — absolute magnitude of the quotient of the (1) difference between the width of the pattern on the substrate and the width of the pattern on the top surface of the epitaxial layer and (2) the thickness of the epitaxial layer.

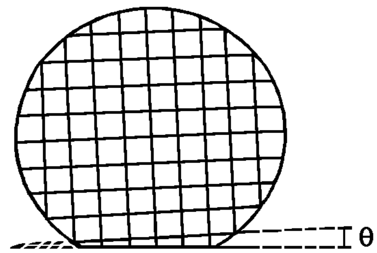

Figure 1
First Mask Showing Angular Displacement *θ*

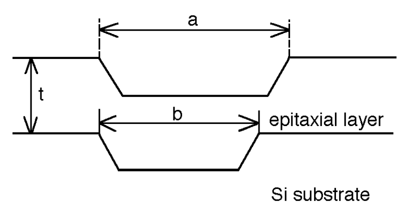

Figure 2
Cross-Section View of Epitaxial Layer Showing the Pattern Widths, *a*, at the Epi Surface, and *b*, at the Layer-Substrate Interface

4.3.4 *pattern shift ratio* — lateral distance between the center point of the pattern on the surface of the substrate and the center point of the pattern on the surface of the epitaxial layer divided by the epitaxial layer thickness.

NOTE 5: Pattern shift ratio, *d/t* (see Figure 4), is specified in terms of a nominal value, *X*, and a tolerance, ± *Y*, both of which are dimensionless because both *d* and *t* are in µm.

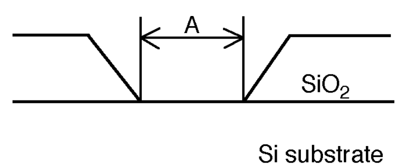

Figure 3
Schematic Diagram Showing Line Width, *A*, of Pattern on Substrate Wafer

7 The Amercan Society of Mechanical Engineers, United Engineering Center, 345 E. 47th St., New York, NY 10017.

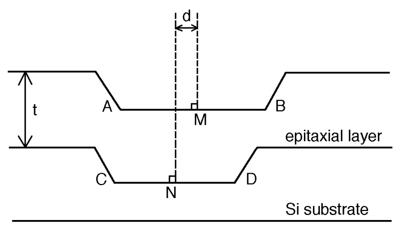

Figure 4
Cross-Section View of Epitaxial Wafer Showing the Pattern Shift, *d*. Not to scale: AM = MB and CN = ND

4.3.5 *pattern step height* — difference in vertical position of the diffused (buried layer) surface and the original substrate surface, after removal of oxide.

NOTE 6: Pattern step height, *A*, is specified as a nominal value, *X*, and a tolerance ± *Y*, both in nm. See Figure 5.

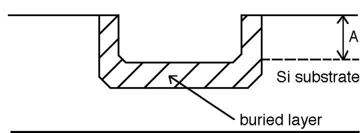

Figure 5
Cross-Sectional View of Epitaxial Substrate After Oxide Removal but Before Deposition of the Epitaxial Layer Showing the Pattern Step Height, *A*

4.4 *Terms Related to Annealed Wafers*

4.4.1 *Annealed wafer* — Wafer that has defects (COP) free zone near the surface produces by high temperature annealing.

4.4.1.1 *Hydrogen annealed wafer* — Annealed wafer produced under hydrogen atmosphere.

4.4.1.2 *Argon annealed wafer* — Annealed wafer produced under argon atmosphere.

5 Use of the Form

5.1 For annealed wafer, parts 1, 2 and 5 shall be completed.

5.2 If this form is used in conjunction with purchase orders for silicon wafers, Parts 1 and 2 shall be completed. For epitaxial wafers, Parts 1, 2, and 3 shall be completed. For epitaxial wafers with buried layer, Parts 1, 2, 3, and 4 shall be completed.

5.3 In all cases, items listed as required must have a value or choice indicated to minimally specify the material.

5.4 Certain required dimensional items may be specified as a group according to the standard values presented in the applicable SEMI specification, or they may be specified individually.

5.5 Visual inspection criteria may be specified as a group according to the standard values listed in the applicable SEMI specification, or they may be specified individually.

5.6 For either dimensional values or visual inspection criteria, the appropriate SEMI specification may be marked and an optional line item (or items) marked as well. In this case, the value marked on each individual line item takes precedence over the standard value.

5.7 If the suggested form included in this format is not reproduced and used as a fill-out form, the items and responses must be adequately identified so that the information and requirements are clear to all parties.

6 Test Methods

6.1 Measurements shall be made or certifiable to the ASTM, JEIDA, JIS, or DIN standard test method as cited in Table 1.

6.2 When standard test methods from different geographic regions are available, the default method shall be the method in common usage for the region of the purchaser of the wafer.

6.3 If several different standard test methods for an item are commonly used within a region, a specific entry must be made to identify which method of test is applicable.

6.4 If no standard test method for an item is available, the test procedure must be specified.

7 Testing Level and Certification

7.1 Material ordered using this format shall be tested and/or certified to the limits set forth in the individual criteria.

7.2 The actual testing level, whether the test is performed on all wafers, a sample of the wafers, special test pieces representing all portions of the material, or a sample of the test pieces, may be specified using this format.

7.3 In some cases, the material may be certified as “capable of meeting” certain requirements. In this context, the supplier is not required to perform the tests outlined in this format. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

8 EDI Codes and Sub-Parameter Codes

8.1 The EDI Codes for each parameter are listed in the following Table. Where necessary for clarity, additional sub-parameters are listed. These sub-parameter identify a specific measurement technique or method to be used.

8.2 If additional codes are required in the future, they will be added to the table, beginning with the next available EDI code identifier. This will allow the table to be rearranged for clarity while maintaining unique and consistent EDI codes for existing parameters. Table 2 provides a numerically sorted list of the EDI Codes.

SEMI Silicon Wafer Specification Form For Order Entry (Page 1)

Part 1 General Information

ITEMS	*INFORMATION*	*Date:*
Customer Name		
Purchase Order Number		
Line Number		
Item Number		
General Specification Number		
Revision Level		
Part Number/Revision		

Part 2 Polished Wafer

CUSTOMER:			*PART NUMBER:* *REVISION*	*DATE:*					
REQUIRED		*ITEM*	*SPECIFICATION*	*TESTING LEVEL*				*EDI Code ID*	*Sub Param ID*
				WAFER		*TEST PIECE*			
				100%	*SAMPLE*	*100%*	*SAMPLE*		
		1. GENERAL CHARACTERISTICS							
♦	1.1	Growth Method	[ ]Cz [ ]FZ [ ]MCz					100001	
♦	1.2	Crystal Orientation	[ ](100) [ ] (111) [ ] ( )					100002	
♦	1.3	Conductivity Type	[ ]p [ ]n					100003	
♦	1.4	Dopant	[ ]B [ ]Phos [ ]Sb [ ]As [ ]NTD					100004	
	1.5	Nominal Edge Exclusion Distance for Fixed Quality Area	Applies to Sections 6.10–6.14; 11 [ ]3 mm; [ ]5 mm; [ ]Other__mm Applies to Sections 7, 8, 12, 13 [ ]3 mm; [ ]5 mm; [ ]Other__mm (except edge defects)					100005	
		2. ELECTRICAL CHARACTERISTICS							
♦	2.1	Resistivity	Nominal [ ] ± Tolerance [ ] Ω–cm					100006	
		Measurement Position	[ ]Center Point; [ ]Other:						
		Measurement Method	[ ]ASTM F81; [ ]ASTM F673; [ ]JIS H 612; [ ]JEIDA 18; [ ]DIN 50431						
	2.2	Radial Resistivity Variation (RRG)	Not greater than [ ]%					100007	
		Measurement Position	ASTM F81 Fig. 1 - [ ]A, [ ]B, [ ]C, [ ]D; [ ] JEIDA 18; [ ]DIN 50435						
		Calculation Method	[ ]ASTM F81; [ ]JEIDA 18; [ ]DIN 50435; [ ]Other:						
	2.3	Resistivity Striations	Not greater than [ ]%					100008	
	2.4	Minority Carrier Lifetime	Greater than [ ]µs					100009	

		Test Method	ASTM F28 [ ]A, [ ]B; ASTM F391 [ ]A, [ ]B; [ ]ASTM F1388; [ ]ASTM F1535; [ ]JEIDA 53; [ ]JIS H604; [ ]DIN 50440; [ ]Other						
		3. CHEMICAL CHARACTERISTICS							
	3.1	Oxygen Concentration	Nominal [ ] ± Tolerance [ ]; [ ] $\times 10^{17}$ cm^{-3}; [ ]ppma					100010	
		Calibration Factor	[ ]ASTM F1188; [ ]ASTM F121(79); [ ]ASTM F121(83); [ ] JEIDA 61; [ ]DIN 50438/1; [ ]Other ____						
		Measurement Method	IR (Interstitial): [ ] ASTM F1188; [ ] ASTM F1619; [ ] JEIDA 61; [ ] DIN 50438-1 SIMS (Total): [ ]ASTM F1366 [ ]GFA (Total)						
	3.2	Radial Oxygen Variation	Not greater than [ ]%					100011	
		Measurement Position	ASTM F951 Plan [ ]A, [ ]B, [ ]B1, [ ]C, [ ]D; [ ]Other:__						
		Calculation Method	ASTM F951 Plan [ ]A, [ ]B, [ ]B1, [ ]C, [ ]D; [ ] Other:__						
	3.3	Carbon Concentration	Not greater than [ ] [ ]ppma; [ ] $\times 10^{16} cm^{-3}$					100012	
		Measurement Method	[ ]ASTM F1391; JEIDA 56; [ ]DIN 50438/2; [ ]Other:____						
	3.4	Boron Concentration in Heavily Doped n-type Si	Not greater than [ ] ppba					100013	
		4. STRUCTURAL CHARACTERISTICS							
	4.1	Dislocation Etch Pit Density	[ ]Not greater than [ ]/cm^2					100014	
	4.2	Slip	[ ]None [ ]Other ___					100015	
	4.3	Lineage	[ ]None [ ]Other ___					100016	
	4.4	Twin	[ ]None [ ]Other ___					100017	
	4.5	Swirl	[ ]Not greater than [ ]% of wafer area					100018	
	4.6	Shallow Pits	Not greater than [ ]/cm^2					100019	
	4.7	Oxidation Induced Stacking Faults (OSF)	Not greater than [ ]/cm^2					100020	
		Test Cycle	ASTM F 416 Cycle-[ ]1 [ ]2 [ ]3; [ ] ASTM F 1727; [ ]Other:__						
	4.8	Oxide Precipitates (BMD)	Range: [ ] to [ ] Unit: [ ] cm^2 [ ] cm^3					100021	
		Test Cycle	ASTM F1239 [ ]A, [ ]B; [ ] Other:_____						
	4.9	Interstitial Oxygen Reduction (ΔO_I)	Range: [ ] to [ ] [ ]ppma, [ ] $\times 10^{17} cm^{-3}$					100162	
		Test Cycle	ASTM F1239 [ ]A, [ ]B; [ ] Other:_____						
		5. WAFER PREPARATION CHARACTERISTICS							
	5.1	Wafer ID Marking	[ ]None; [ ]SEMI M12; [ ]SEMI M13; [ ]SEMI T1; [ ]SEMI T2; [ ] SEMI T7; [ ]Other:_____					100022	
	5.2	Front Surface Thin Film(s) Appl	[ ]None [ ]Description:					100023	
	5.3	Denuded Zone	[ ]None [ ]Description:					100024	
	5.4	Extrinsic Gettering Treatment	[ ]None [ ]Description:					100025	
	5.5	Backseal	[ ]None [ ]Description:					100026	
	5.6	Annealing	[ ]None [ ]Description:					100027	

		6. MECHANICAL CHARACTERISTICS							
		THE ITEMS LISTED IN THIS SECTION MAY BE							
	6.01	[ ] Specified According to SEMI M1_____						100028	
		OR SPECIFIED INDIVIDUALLY							
♦	6.1	Diameter[1]	Nominal [ ] ± Tolerance [ ] mm					100029	
♦	6.2	Primary Flat Length/Diameter Notch Dimensions[1]	[ ]SEMI M1._______; [ ]Other:___mm					100030	
♦	6.3	Primary Flat/Notch Orientation[1]	[ ]SEMI M1._______; [ ]Other:					100031	
♦	6.4	Secondary Flat Length[1]	[ ]SEMI M1._______; [ ]Other:___mm; [ ]None					100032	
♦	6.5	Secondary Flat Location[1]	[ ]SEMI M1._______; [ ]Other:___; [ ]None					100033	
♦	6.6	Edge Profile[1]	[ ]SEMI Standard [ ]Other:_____					100034	
♦	6.7	Thickness[1]	Nominal [ ] ± Tolerance [ ] µm					100035	
		Method	[ ]ASTM F533; [ ]ASTM F1530; [ ]JIS H 611; [ ]DIN 50441/1; [ ]Other						
	6.8	Thickness Variation (TTV)[1]	[ ]SEMI M1._______; [ ]Other: [ ] µm					100036	
		Measurement Position	[ ]ASTM F533; [ ]ASTM F657; [ ]ASTM F1530; [ ]JIS H 611; [ ]DIN 50441/1; [ ]Other:_____						
♦	6.9	Surface Orientation	[ ]0.00 ± 0.50; [ ]2.50 ± 0.50; [ ]4.00 ± 0.50; [ ] Other:_____					100037	
		Method	[ ]ASTM F26; [ ]JEIDA 18; [ ]DIN 50433; [ ]Other:_____						
	6.10	Bow[1]	[ ]SEMI M1._______; [ ]Other:___ µm					100038	
		Method	[ ]ASTM F534; [ ]JIS H 611; [ ]Other:_____						
	6.11	Warp[1]	[ ]SEMI M1._______; [ ]Other: ___ µm						
		Method	[ ]ASTM F657; [ ]ASTM F1390; [ ]Other:_____					100039 100040	ASTM F657 ASTM F1390
	6.12	Sori	[ ]_______µm					100041	
		Method	[ ] ASTM F1451; [ ] JEIDA 43						
	6.13	Flatness/Global	Acronym:[2][ ] [ ] [ ] [ ] Value: [ ]µm					100042	
		Method	[ ]ASTM F1530; [ ]DIN 50441/3; [ ]Other:_____						
	6.14	Flatness/Site	Acronym:[2] [ ] [ ] [ ] [ ] Value: [ ]µm Site Size ___×___ mm Total Sites___ % Usable Area___ [ ] Include partial sites [ ] Offset: x = [ ] mm, y = [ ] mm					100043 100044 100045 100046 100047 100048 100049 100050 100221	SF3R SF3D SFLR SFLD SFQR SFQD SBIR SBID SFSD
	6.15	Fixed Quality Area	Value: [ ]mm dia					100164	
		7. FRONT SURFACE CHEMISTRY							
	7.1	Surface Metal Contamination							
		Sodium	[ ]Not greater than [ ]atoms/cm^2; [ ]Other					100051	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1617 (SIMS); [ ]Other:_____						
		Aluminum	[ ]Not greater than [ ]atoms/cm^2; [ ]Other					100052	

		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1617 (SIMS); [ ]Other:_____							
		Potassium	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100053	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1617 (SIMS); [ ]SEMI M33 (TXRF); [ ]Other:_____							
		Chromium	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100054	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
		Iron	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100055	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]ASTM F1617 (SIMS); [ ]Other:_____							
		Nickel	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100056	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]Other:_____							
		Copper	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100057	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]Other:_____							
		Zinc	[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100058	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]Other:_____							
		Others (List Separately)								
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100059	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100060	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100061	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100062	
		Method	[]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100063	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
			[ ]Not greater than [ ]atoms/cm^2; [ ]Other						100064	
		Method	[ ]ICP/MS; [ ]AAS; [ ]ASTM F1526 (TXRF); [ ]SEMI M33 (TXRF); [ ]SIMS; [ ]Other:_____							
	7.2	Surface Organics	[ ]Not greater than [ ]ngrams/cm^2						100065	
		Method	[ ]ASTM F1982; [ ]Other:_____							
		8. FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS								
		THE ITEMS LISTED IN THIS SECTION MAY BE								
	8.01	[ ] Specified According to SEMI M1 Table 1							100066	
		OR SPECIFIED INDIVIDUALLY								

	8.1	Scratches[3]	[ ]SEMI M1 Table 1 [ ]Other:					100067	
	8.2	Pits[3]	[ ]SEMI M1 Table 1 [ ]Other:					100068	
	8.3	Haze[3]	[ ]SEMI M1 Table 1 [ ]Other:					100069	
	8.4	Localized Light Scatterers (LLS)[3]	[ ]SEMI M1 Table 1 [ ]Other: Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ]					100070 100071 100072 100073 100074 100075 100076 100077 100078 100079 100080 100081 100082 100083 100084 100085 100086 100087 100088 100089 100090	≥0.50µ ≥0.30µ ≥0.20µ ≥0.19µ ≥0.18µ ≥0.17µ ≥0.16µ ≥0.15µ ≥0.14µ ≥0.13µ ≥0.12µ ≥0.11µ ≥0.10µ ≥0.09µ ≥0.08µ ≥0.07µ ≥0.06µ ≥0.05µ ≥0.04µ ≥0.03µ ≥0.02µ
		Method	[ ]ASTM F523; [ ]ASTM F1620; [ ]JIS H 614; [ ]JEIDA 24; [ ]Other:______						
	8.5	Contamination/Area[3]	[ ]SEMI M1 Table 1 [ ]Other:					100091	
	8.6	Edge Chips[3]	[ ]SEMI M1 Table 1 [ ]Other:					100092	
	8.7	Edge Cracks[3]	[ ]SEMI M1 Table 1 [ ]Other:					100093	
	8.8	Cracks, Crow's Feet[3]	[ ]SEMI M1 Table 1 [ ]Other:					100094	
	8.9	Craters[3]	[ ]SEMI M1 Table 1 [ ]Other:					100095	
	8.10	Dimples[3]	[ ]SEMI M1 Table 1 [ ]Other:					100096	
	8.11	Grooves[3]	[ ]SEMI M1 Table 1 [ ]Other:					100097	
	8.12	Mounds[3]	[ ]SEMI M1 Table 1 [ ]Other:					100098	
	8.13	Orange Peel[3]	[ ]SEMI M1 Table 1 [ ]Other:					100099	
	8.14	Saw Marks[3]	[ ]SEMI M1 Table 1 [ ]Other:					100100	
	8.15	Dopant Striation Rings	[ ]					100101	
	8.16	Stains	[ ]					100102	
		9. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS							
		THE ITEMS LISTED IN THIS SECTION MAY BE							
	9.01	[ ] Specified According to SEMI M1 Table 1						100103	
		OR SPECIFIED INDIVIDUALLY							
	9.1	Edge Chips[3]	[ ]SEMI M1 Table 1 [ ]Other:					100104	
	9.2	Cracks, Crow's Feet[3]	[ ]SEMI M1 Table 1 [ ]Other:					100105	
	9.3	Contamination/Area[3]	[ ]SEMI M1 Table 1 [ ]Other:					100106	
	9.4	Saw Marks[3]	[ ]SEMI M1 Table 1 [ ]Other:					100107	
	9.5	Stains	[ ]					100108	
	9.6	Roughness	[ ]					100109	
	9.7	Brightness	[ ]					100110	
	9.8	Scratches – macro	[ ]None; [ ]Cum Length =[ ]mm					100165	
	9.9	Scratches – micro	[ ]None; [ ]Cum Length =[ ]mm					100166	
	9.10	Localized Light Scatterers	Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ]					100167 100168	

	10. OTHER CHARACTERISTICS								
	10.1	Bulk defects by X-ray topography	[ ]Value:_____					100169	
		Method	[ ]DIN 50443/1; [ ]Other:_____						

Part 3 Epitaxial Wafer

CUSTOMER:			*PART NUMBER:* *REVISION*	*DATE:*					
REQUIRED	*ITEM*		*SPECIFICATION*	*TESTING LEVEL*				*EDI*	*Sub*
				WAFER		*TEST PIECE*		*Code*	*Param*
				100%	*SAMPLE*	*100%*	*SAMPLE*	*ID*	*ID*
	11. GENERAL EPITAXIAL WAFER AND LAYER CHARACTERISTICS								
	THE ITEMS LISTED IN THIS TABLE MAY BE								
	11.01	[ ] Specified According to SEMI M11 Table [ ]						100170	
	OR SPECIFIED INDIVIDUALLY								
♦	11.1	Conductivity Type/Structure	[ ]n/n+ [ ]p/p+ [ ]Other:_____					100111	
♦	11.2	Dopant	[ ]B [ ]Phos [ ]As					100112	
	11.3	Silicon Source Gas	[ ]SiH_4; [ ]SiH_2Cl_2; [ ]$SiHCl_3$; [ ]$SiCl_4$					100113	
	11.4	Growth Method	Reactor Type [ ] Pressure [ ]					100114	
♦	11.5	Net Carrier Density (Resistivity)	Nominal [ ] ± Tolerance [ ] (check unit below)					100115	
		Units	[ ]10[ ]atoms/cm^3; [ ]Ωcm						
		Test Method	[ ]ASTM F419 - [ ]Gated, [ ]Ungated, [ ]Schottky; [ ]ASTM F374 (4-Pt); [ ]ASTM F525 (SRP); [ ]ASTM F1392 (Hg-CV); [ ] ASTM F1393; [ ]DIN 50439; [ ]DIN 50444; [ ]DIN 50447; [ ]Other ____						
♦	11.6	Net Carrier Density Variation	[ ]Not greater than [ ]% [ ]SEMI M2; [ ]SEMI M11 Table [ ]					100116	
		Measurement Position	[ ]SEMI M2; [ ]SEMI M11; [ ]Other:_____						
		Calculation	[ ]SEMI M2; [ ]SEMI M11; [ ]Other:_____						
♦	11.7	Thickness	Nominal [ ] ± Tolerance [ ]µm					100117	
		Test Method	[ ]ASTM F95; [ ]ASTM F110; [ ]FT-IR; [ ]ASTM F 672(SRP); [ ]DIN 50436; [ ]DIN 50437; [ ]Other:_____						
♦	11.8	Thickness Variation	[ ]Not greater than [ ]% [ ]SEMI M2; [ ]SEMI M11 Table [ ]					100118	
		Measurement Position	[ ]SEMI M2; [ ]SEMI M11; [ ]Other:______						
		Calculation	[ ]SEMI M2; [ ]SEMI M11; [ ]Other:______						
	11.9	Transition Width	Not greater than [ ]µm					100119	
		Measurement Position							
		Calculation							
	11.10	Flat Zone	Not less than [ ]µm					100120	
		Measurement Position							
		Calculation							
	11.11	Phantom Layer	[ ]None					100121	
	12. MECHANICAL CHARACTERISTICS								
	THE ITEMS LISTED IN THIS SECTION MAY BE								

	12.01	[ ] Specified According to SEMI M11 Table [ ]						100135	
OR SPECIFIED INDIVIDUALLY									
	12.1	Bow	Not greater than [ ] µm					100122	
		Method	[ ]ASTM F534; [ ]JIS H 611; [ ]Other:_____						
	12.2	Warp	Not greater than [ ] µm						
		Method	[ ] ASTM F657; [ ] ASTM F1390; [ ]Other:______					100123 100124	ASTM 657 ASTM 1390
	12.3	Sori	Not greater than [ ] µm					100125	
	12.4	Flatness/Global	Acronym[2]: [ ][ ][ ][ ] Value _____µm					100126	
		Method	[ ]ASTM F1530 [ ]DIN 50441/3 [ ]Other						
	12.5	Flatness/Site	Acronym[2]:[ ][ ][ ][ ] Value ____µm Site Size __×__ mm Total Sites __ % Usable Area __ [ ] Include partial sites [ ] Offset: x = [ ] mm, y = [ ] mm					100127 100128 100129 100130 100131 100132 100134 100161 100222 100223	SF3R SF3D SFLR SFLD SFQR SFQD SBIR SFSR SFSD SBID
	12.6	Fixed Quality Area	Value: [ ]mm dia					100172	
13. FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS									
THE ITEMS LISTED IN THIS SECTION MAY BE									
	13.01	[ ] Specified According to [ ]SEMI M2 Table 1 or [ ]SEMI M11 Table [ ]						100135	
OR SPECIFIED INDIVIDUALLY									
	13.1	Stacking Faults[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100136	
		Method	[ ] ASTM F522 [ ] DIN 50446 [ ]Other						
	13.2	Slip[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100137	
		Method	[ ] ASTM F47 [ ] ASTM F80 [ ] ASTM F523 [ ]DIN 50446 [ ]Other						
	13.3	Large Point Defects[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100138	
		Method	[ ] ASTM F523 [ ] ASTM F815 [ ] DIN 50446 [ ] Other: _______						
	13.4	Total Points Defects[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100139	
		Method	[ ] ASTM F523 [ ] ASTM F815 [ ] DIN 50446 [ ] Other: _______						
	13.5	Scratches[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100140	
		Method	[ ] ASTM F523 [ ]Other						
	13.6	Dimples[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100141	
		Method	[ ] ASTM F523 [ ]Other						
	13.7	Orange Peel[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100142	

		Method	[ ] ASTM F523 [ ]Other						
	13.8	Cracks/Fractures[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: _______					100143	
		Method	[ ] ASTM F523 [ ]Other						
	13.9	Crow's Feet[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: ________					100144	
		Method	[ ] ASTM F523 [ ]Other						
	13.10	Edge Chips[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: ________					100145	
		Method	[ ] ASTM F523 [ ]Other						
	13.11	Edge Crown[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: ________					100146	
		Method	[ ] DIN 50446 [ ]Other						
	13.12	Haze[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: ________					100147	
		Method	[ ] ASTM F523 [ ]Other						
	13.13	Foreign Matter[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other: ________					100148	
		Method	[ ] ASTM F523 [ ]Other						
	13.14	Localized Light Scatterers (LLS)[4]	[ ]SEMI M11 Table 1 [ ]Other: Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ] Size: [ ] µm Count: ≤ [ ]					100173 100174 100175 100176 100177 100178 100179 100180 100181 100182 100183 100184 100185 100186 100187 100188 100189 100190 100191 100192 100193	≥0.50µ ≥0.30µ ≥0.20µ ≥0.19µ ≥0.18µ ≥0.17µ ≥0.16µ ≥0.15µ ≥0.14µ ≥0.13µ ≥0.12µ ≥0.11µ ≥0.10µ ≥0.09µ ≥0.08µ ≥0.07µ ≥0.06µ ≥0.05µ ≥0.04µ ≥0.03µ ≥0.02µ
		Method	[ ]ASTM F523; [ ]ASTM F1620; [ ]JIS H 614; [ ]JEIDA 24; [ ]Other:______						
	13.15	Surface Edge Exclusion	[ ]2 mm; [ ]3 mm; [ ]4 mm; [ ]5 mm ; [ ]Other:____					100194	
14. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS									
THE ITEMS LISTED IN THIS SECTION MAY BE									
	14.01	[ ] Specified According to SEMI M11 Table [ ]						100195	
OR SPECIFIED INDIVIDUALLY									
	14.1	Contamination[4]	[ ]SEMI M2 Table 1; [ ]SEMI M11 Table [ ]; [ ]Other:_____					100149	
	14.2	Scratches -- macro	[ ]None; [ ]Cum Length =[ ] mm					100196	
	14.3	Scratches -- micro	[ ]None; [ ]Cum Length =[ ] mm					100197	

	14.4	Localized Light Scatterers	[ ]SEMI M11 Table [ ]; [ ]Other:_____ Size: [ ] μm Count: ≤ [ ] Size: [ ] μm Count: ≤ [ ]					100198 100199	
		15. OTHER CHARACTERISTICS							

Part 4 Epitaxial Wafer with Buried Layer

CUSTOMER:			*PART NUMBER: REVISION*	*DATE:*					
REQUIRED		*ITEM*	*SPECIFICATION*	*TESTING LEVEL*				*EDI*	*Sub*
				WAFER		*TEST PIECE*		*Code*	*Param*
				100%	*SAMPLE*	*100%*	*SAMPLE*	*ID*	*ID*
		16. PHOTOLITHOGRAPHY CHARACTERISTICS							
	16.1	Mask ID	[ ] Number: [ ]; [ ]None					100150	
	16.2	Alignment Precision	X max [ ] μm, Y max [ ] μm, Θ max[ ]; Reference Point (Wafer Coordinate System): x [ ] mm, y [ ] mm					100151	
	16.3	Pattern Line Width Tolerance	Tolerance ± [ ] μm					100152	
		17. BURIED LAYER CHARACTERISTICS							
	17.1	Dopant	[ ]B; [ ]Phos; [ ]Sb; [ ]As					100153	
	17.2	Diffusion Depth (x_j)	Nominal [ ] ± Tolerance [ ] μm					100154	
	17.3	Sheet Resistance	Nominal [ ] ± Tolerance [ ] Ω/sq					100155	
	17.4	Pattern Step Height	Nominal [ ] ± Tolerance [ ] nm					100156	
	17.5	Defect Density (Before Epi)	Not greater than [ ]/cm^2					100157	
		18. BURIED LAYER PATTERN CHARACTERISTICS AFTER EPI							
	18.1	Pattern Shift Ratio	Nominal [ ] ± Tolerance [ ]					100158	
	18.2	Pattern Distortion Ratio	Max. [ ]					100159	
		19. OTHER CHARACTERISTICS							

Part 5 Annealed Wafer

CUSTOMER:			PART NUMBER: REVISION	DATE:					
REQUIRED	*ITEM*		*SPECIFICATION*	*TESTING LEVEL*				*EDI*	*Sub*
				WAFER		*TEST PIECE*		*Code*	*Param*
				100%	*SAMPLE*	*100%*	*SAMPLE*	*ID*	*ID*
		20. GENERAL ANNEALED WAFER CHARACTERISTICS							
♦	20.1	Annealing Atmosphere	[ ]Hydrogen [ ]Argon [ ]Other: ____________					100200	
♦	20.2	Co-dopant in Crystal	[ ]N [ ]C [ ]Other:					100201	
		21. MECHANICAL CHARACTERISTICS							
	21.1	Bow	Not greater than [ ] µm					100202	
		Method	[ ]ASTM F534; [ ]JIS H 611; [ ]Other:_____						
	21.2	Warp	Not greater than [ ] µm						
		Method	[ ] ASTM F657; [ ] ASTM F1390; [ ]Other:__________					100203 100204	ASTM 657 ASTM 1390
	21.3	Sori	Not greater than [ ] µm					100205	
	21.4	Flatness/Global	Acronym[2]: [ ][ ][ ][ ] Value _____µm					100206	
		Method	[ ]ASTM F1530 [ ]DIN 50441/3 [ ]Other						
	21.5	Flatness/Site	Acronym[2]:[ ][ ][ ][ ] Value ____µm Site Size __×__ mm Total Sites __ % Usable Area __ [ ] Include partial sites [ ] Offset: x = [ ] mm, y = [ ] mm					100207 100208 100209 100210 100211 100212 100213 100214 100224 100225	SF3R SF3D SFLR SFLD SFQR SFQD SBIR SFSR SFSD SBID
	21.6	Fixed Quality Area	Value: [ ] mm					100215	
		22. FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS							
		THE ITEMS LISTED IN THIS SECTION MAY BE							
	22.01	[ ] Specified According to [ ]SEMI M2 Table 1 or [ ]SEMI M11 Table 1							
		OR SPECIFIED INDIVIDUALLY							
	22.1	Stacking Faults[4]	[ ]SEMI M() Table 1 [ ]Other:					100216	
	22.2	Slip[4]	[ ]SEMI M() Table 1 [ ]Other:					100217	
	22.3	Other Defect[5]	[ ]SEMI M() Table 1 [ ]Other:						
		23. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS							
	23.1	Contamination[4]	[ ]SEMI M( ) Table 1; [ ]Other:_____					100218	
	23.2	Other[6]							
		24. OTHER CHARACTERISTICS							
	24.1	Depth of BMD Denuded Zone						100219	

CUSTOMER:		PART NUMBER: REVISION	DATE:					
REQUIRED	ITEM	SPECIFICATION	TESTING LEVEL				EDI Code ID	Sub Param ID
			WAFER		TEST PIECE			
			100%	SAMPLE	100%	SAMPLE		
	24.2 BMD Density						100220	
	24.3 Other[7]							

1. Individual value is not required if wafer is specified according to SEMI M1. ______.
2. Flatness Acronyms are determined from the Flatness Decision Tree in SEMI M1, Appendix 1.
3. Individual value is not required if wafer is specified according to SEMI M1, Table 1.
4. Individual value is not required if wafer is specified according to Table 1 of SEMI M2 or SEMI M11.
5. Haze, Teracing, Surface micro-roughness, Nanotopography, and other attributes may be discussed between supplier and user.
6. Support-related backside defects may be discussed between supplier and user
7. Surface boron depletion, dissolved hydrogen in the case of hydrogen annealed wafer, Post-annealed oxygen, and Silicon nitride precipitates and defects in the case of nitrogen-doped silicon may be discussed between supplier and user.

Table 1 Industry Standard References

Polished Wafer

ITEM		VALUE		STANDARD REFERENCE[A]		STANDARD TEST METHODS		
		IS IN SEMI	IS REQ'D[B]	SEMI	JEIDA	ASTM	JIS JEIDA	DIN
1.	GENERAL CHARACTERISTICS							
1.1	Growth Method	NO	YES	M1 Note 5				
1.2	Crystal Orientation	NO	YES			F 26	18	50433/1 50433/2 50433/3
1.3	Conductivity Type	NO	YES	M1 Note 5		F 42	H 607	50432
1.4	Dopant	NO	YES	M1 Note 5				50438/3
1.5	Nominal Edge Exclusion Distance for Fixed Quality Area	NO	NO	M1 Fig 1				
2.	ELECTRICAL CHARACTERISTICS							
2.1	Resistivity	NO	YES	M1 Sec 9		F 84, F 673	H 602 18 H 612	50431, 50447
2.2	Radial Resistivity Variation (RRG)	NO	NO	M1 Sec 9		F 81	18	50435
2.3	Resistivity Striations	NO	NO			F 154, F 525		
2.4	Minority Carrier Lifetime	NO	NO			F 28, F 391, F 1388, F 1535	H 604 53	50440
3.	CHEMICAL CHARACTERISTICS							
3.1	Oxygen Concentration	NO	NO			F 1188, F 1366, F 1619	61	50438/1
3.2	Radial Oxygen Variation	NO	NO			F 951		
3.3	Carbon Concentration	NO	NO			F 1391	56	50438/2
3.4	Boron Concentration in Heavily Doped n-type Si	NO	NO			F 1528		
4.	STRUCTURAL CHARACTERISTICS							
4.1	Dislocation Etch Pit Density	NO	NO			F 47	H 609	50434
4.2	Slip	NO	NO			F 47, F 416	H 609	50434
4.3	Lineage	NO	NO			F 47	H 609	50434

	ITEM	VALUE		STANDARD REFERENCE[A]		STANDARD TEST METHODS		
		IS IN SEMI	IS REQ'D[B]	SEMI	JEIDA	ASTM	JIS JEIDA	DIN
4.4	Twin	NO	NO			F 47	H 609	50434
4.5	Swirl	NO	NO			F 416	H 614 24	
4.6	Shallow Pits	NO	NO			F 416, F 1049	H 614 24	
4.7	Oxidation Induced Stacking Faults (OSF)	NO	NO			F 416, F 1727, F 1809, F 1810		
4.8	Oxide Precipitates (BMD) Interstitial Oxygen Reduction (ΔO_i)	NO NO	NO NO			F 1239, F 1809, F 1810		
5.	WAFER PREPARATION CHARACTERISTICS							
5.1	Wafer ID Marking	YES	NO	M12, M13				
5.2	Front Surface Thin Film(s) Applied	NO	NO					
5.3	Denuded Zone	NO	NO					
5.4	Extrinsic Gettering Treatment	NO	NO					
5.5	Backseal	NO	NO					
5.6	Annealing	NO	NO					
6.	MECHANICAL CHARACTERISTICS							
6.1	Diameter	YES	YES[C]	M1 Sec 9	27	F 613		50441/4
6.2	Primary Flat Length/Diameter Notch Dimensions	YES	YES[C]	M1	27	F 671, F 1152		50441/4
6.3	Primary Flat/Notch Orientation	YES	YES[C]	M1 Sec 9	27	F 847		
6.4	Secondary Flat Length	YES	YES[C]	M1 Sec 9		F 671		50441/4
6.5	Secondary Flat Location	YES	YES[C]	M1 Sec 9		F 847		
6.6	Edge Profile	YES	YES[C]	M1 Sec 5		F 928		50441/2
6.7	Thickness	YES	YES[C]	M1 Sec 9	27	F 533, F 1530	H 611	50441/1
6.8	Thickness Variation (TTV)	YES	NO	M1 Sec 9	27	F 533, F 657, F 1530	H 611	50441/1
6.9	Surface Orientation	YES	YES	M1 Sec 9	27	F 26	18	50433
6.10	Bow	YES	NO	M1 Sec 9		F 534	H 611	
6.11	Warp	YES	NO	M1 Sec 9		F 657, F 1390		
6.12	Sori	NO	NO	M1 Sec 9		F 1451	43	
6.13	Flatness	NO	NO	M1 Sec 9		F 1530		50441/3
7.	FRONT SURFACE CHEMISTRY							
7.1	Surface Metal Contamination							
	Sodium	NO	NO			F 1617		
	Aluminum	NO	NO			F 1617		
	Potassium	NO	NO	M33		F 1617		
	Chromium	NO	NO	M33		F 1526		
	Iron	NO	NO	M33		F 1526		
	Nickel	NO	NO	M33		F 1526		
	Copper	NO	NO	M33		F 1526		
	Zinc	NO	NO	M33		F 1526		
7.2	Surface Organics					F 1982		
8.	FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS[D]							
8.1	Scratches	YES	NO	M1 Table 1	26	F 523	H 614	
8.2	Pits	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.3	Haze	YES	NO	M1 Table 1	26	F 523	H 614 24	

ITEM		VALUE		STANDARD REFERENCE[A]		STANDARD TEST METHODS		
		IS IN SEMI	IS REQ'D[B]	SEMI	JEIDA	ASTM	JIS JEIDA	DIN
8.4	Light Scattering Defects(Particulate Contamination)	YES	NO	M1 Table 1	26	F 523, F 1620	H 614 24	
8.5	Contamination/Area	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.6	Edge Chips	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.7	Edge Cracks	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.8	Cracks, Crow's Feet	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.9	Craters	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.10	Dimples	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.11	Grooves	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.12	Mounds	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.13	Orange Peel	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.14	Saw Marks	YES	NO	M1 Table 1	26	F 523	H 614 24	
8.15	Dopant Striation Rings	NO	NO		26	F 523	H 614 24	
8.16	Stains	NO	NO		26	F 523	H 614 24	
9.	BACK SURFACE VISUAL INSPECTION CHARACTERISTICS							
9.1	Edge Chips	YES	NO	M1 Table 1		F 523		
9.2	Cracks, Crow's Feet	YES	NO	M1 Table 1		F 523		
9.3	Contamination/Area	YES	NO	M1 Table 1		F 523		
9.4	Saw Marks	YES	NO	M1 Table 1		F 523		
9.5	Stains	NO	NO					
9.6	Roughness	NO	NO					
9.7	Brightness	NO	NO					
10.	OTHER CHARACTERISTICS							
10.1	Bulk defects by X-ray topography							50443/1

Epitaxial Wafer

ITEM		VALUE			STANDARD REFERENCE[A]			STANDARD TEST METHODS		
		IS IN M2	IS IN M11	IS REQ'D[B]	SEMI M2	SEMI M11	JEIDA	ASTM	JIS JEIDA	DIN
11.	GENERAL EPITAXIAL LAYER CHARACTERISTICS									
11.1	Conductivity Type/Structure	NO	NO	YES	Sec 3	Sec 3				
11.2	Dopant	NO	NO	YES	Sec 3	Sec 3				
11.3	Silicon Source Gas	NO	NO	NO	Sec 3	Sec 3				
11.4	Growth Method	NO	NO	NO	Sec 3	Sec 3				
11.5	Net Carrier Density (Resistivity)	NO	NO	YES	Sec 3	Sec 3		F 419, F 1392, F 1393 (F 374, F 398, F 525, F 723)		50439 (50444, 50447)
11.6	Net Carrier Density Variation (Resistivity Variation)	YES	NO	YES	Sec 3, 5	Sec 3, 5				50439

ITEM		VALUE			STANDARD REFERENCE[A]			STANDARD TEST METHODS		
		IS IN M2	IS IN M11	IS REQ'D[B]	SEMI M2	SEMI M11	JEIDA	ASTM	JIS JEIDA	DIN
11.7	Thickness	NO	NO	YES	Sec 3	Sec 3		F 95, F 110, F 672		50436, 50437
11.8	Thickness Variation	YES	NO	YES	Sec 3, 5	Sec 3, 5				
11.9	Transition Width	NO	NO	NO						
11.10	Flat Zone	NO	NO	NO						
11.11	Phantom Layer	NO	NO	NO						
12.	MECHANICAL CHARACTERISTICS[D]									
12.1	Bow	NO	NO	NO	M1 Sec 9	M1 Sec 9		F 534	H 611	
12.2	Warp	NO	NO	NO	M1 Sec 9	M1 Sec 9		F 657, F 1390		
12.3	Sori	NO	NO	NO	M1 Sec 9	M1 Sec 9				
12.4	Flatness/Global	NO	NO	NO	M1 Sec 9	M1 Sec 9	DEF 43	F 1530		50441/3
12.5	Flatness/Site	NO	NO	NO	M1 Sec 9	M1 Sec 9		F 1530		
12.6	Fixed Quality Area	NO	NO	NO	M1 Sec 9	M1 Sec 9		F 1530		
13.	EPITAXIAL LAYER VISUAL INSPECTION CHARACTERISTICS[D]									
13.1	Stacking Faults	YES	YES	NO	Table 1	Table 1		F 522		50446
13.2	Slip	YES	YES	NO	Table 1	Table 1		F 47, F 80, F 523		50446
13.3	Large Point Defects	YES	YES	NO	Table 1	Table 1		F 523, F 815		50446
13.4	Total Point Defects	YES	YES	NO	Table 1	Table 1		F 523, F 815		50446
13.5	Scratches	YES	YES	NO	Table 1	Table 1		F 523		
13.6	Dimples	YES	YES	NO	Table 1	Table 1		F 523		
13.7	Orange Peel	YES	YES	NO	Table 1	Table 1		F 523		
13.8	Cracks/Fractures	YES	YES	NO	Table 1	Table 1		F 523		
13.9	Crow's Feet	YES	YES	NO	Table 1	Table 1		F 523		
13.10	Edge Chips	YES	YES	NO	Table 1	Table 1		F 523		
13.11	Edge Crown	YES	YES	NO	Table 1	Table 1				50446
13.12	Haze	YES	YES	NO	Table 1	Table 1		F 523		50446
13.13	Foreign Matter	YES	YES	NO	Table 1	Table 1		F 523		
14.	BACK SURFACE VISUAL INSPECTION CHARACTERISTICS									
14.1	Contamination	YES	YES	NO	Table 1	Table 1		F 523		
15.	OTHER CHARACTERISTICS									

Annealed Wafer

ITEM		VALUE		STANDARD REFERENCE[A]		STANDARD TEST METHODS		
		IS IN SEMI	IS REQ'D[B]	SEMI	JEIDA	ASTM	JIS JEIDA	DIN
20.	GENERAL ANNEALED WAFER CHARACTERISTICS							
20.1	Annealing Atmosphere	NO	YES					
20.2	Co-Dopant in Crystal	NO	YES					
21.	MECHANICAL CHARACTERISTICS[D]							
21.1	Bow	YES	NO	M1 Sec 9		F 534	H 611	
21.2	Warp	YES	NO	M1 Sec 9		F 657, F 1390		
21.3	Sori	NO	NO	M1 Sec 9		F 1451	43	
21.4	Flatness/Global	NO	NO	M1 Sec 9		F 1530		50441/3
21.5	Flatness/Site	NO	NO	M1 Sec 9		F 1530		
21.6	Fixed Quality Area	NO	NO	M1 Sec 9		F 1530		
22.	FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS[D]							
22.1	Stacking Faults	YES	NO	M2 Table 1		F 1810		50446
22.2	Slip	YES	NO	M2 Table 1		F 523, F 1726		50446
22.3	Other Defect	YES	NO	M2 Table 1		F 523, F 1726		50446
23.	BACK SURFACE VISUAL INSPECTION CHARACTERISTICS							
23.1	Contamination	YES	NO	M1 Table 1		F 523		
23.2	Other							
24.	OTHER CHARACTERISTICS							
24.1	Depth of BMD Denuded Zone	NO	NO					
24.2	BMD Density	NO	NO			F 1239		
24.3	Other							

[A] Item is defined or described and/or a test procedure applicable to the item is included in the cited reference.
[B] Value is/is not required to minimally specify a wafer.
[C] Individual value is not required if wafer is specified according to SEMI M1.
[D] In today's technology, it may be possible to inspect for some of these items using automated laser scanning systems; however, a standard test procedure has yet to be developed. Application of automated inspection must be agreed upon between supplier and user.

Table 2 EDI Code List

Line	*Item*	*EDI Code ID*	*Sub Param ID*
1.1	Growth Method	100001	
1.2	Crystal Orientation	100002	
1.3	Conductivity Type	100003	
1.4	Dopant	100004	
1.5	Nominal Edge Exclusion Distance for Fixed Quality Area	100005	
2.1	Resistivity	100006	
2.2	Radial Resistivity Variation (RRG)	100007	
2.3	Resistivity Striations	100008	
2.4	Minority Carrier Lifetime	100009	
3.1	Oxygen Concentration	100010	
3.2	Radial Oxygen Variation	100011	
3.3	Carbon Concentration	100012	
3.4	Boron Concentration in Heavily Doped n-type Si	100013	
4.1	Dislocation Etch Pit Density	100014	

Line	Item	EDI Code ID	Sub Param ID
4.2	Slip	100015	
4.3	Lineage	100016	
4.4	Twin	100017	
4.5	Swirl	100018	
4.6	Shallow Pits	100019	
4.7	Oxidation Induced Stacking Faults (OSF)	100020	
4.8	Oxide Precipitates (BMD)	100021	
5.1	Wafer ID Marking	100022	
5.2	Front Surface Thin Film(s) Appl	100023	
5.3	Denuded Zone	100024	
5.4	Extrinsic Gettering Treatment	100025	
5.5	Backseal	100026	
5.6	Annealing	100027	
6.01	Dimensions Specified According to SEMI M1.xx	100028	
6.1	Diameter	100029	
6.2	Primary Flat Length/Diameter Notch Dimensions	100030	
6.3	Primary Flat/Notch Orientation	100031	
6.4	Secondary Flat Length	100032	
6.5	Secondary Flat Location	100033	
6.6	Edge Profile	100034	
6.7	Thickness	100035	
6.8	Thickness Variation (TTV)	100036	
6.9	Surface Orientation	100037	
6.10	Bow	100038	
6.11	Warp Method	100039	ASTM F657
6.11	Warp Method	100040	ASTM F1390
6.12	Sori	100041	
6.13	Flatness/Global	100042	
6.14	Flatness/Site	100043	SF3R
6.14	Flatness/Site	100044	SF3D
6.14	Flatness/Site	100045	SFLR
6.14	Flatness/Site	100046	SFLD
6.14	Flatness/Site	100047	SFQR
6.14	Flatness/Site	100048	SFQD
6.14	Flatness/Site	100049	SBIR
6.14	Flatness/Site	100050	SBID
7.1	Surface Metal Contamination -- Sodium	100051	
7.1	Surface Metal Contamination -- Aluminum	100052	
7.1	Surface Metal Contamination -- Potassium	100053	
7.1	Surface Metal Contamination -- Chromium	100054	
7.1	Surface Metal Contamination -- Iron	100055	
7.1	Surface Metal Contamination -- Nickel	100056	
7.1	Surface Metal Contamination -- Copper	100057	
7.1	Surface Metal Contamination -- Zinc	100058	
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100059	
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100060	

Line	Item	EDI Code ID	Sub Param ID
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100061	
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100062	
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100063	
7.1	Surface Metal Contamination -- (Producer-User Defined Metal)	100064	
7.2	Surface Organics	100065	
8.01	Front Surface Visual Inspection Specified According to SEMI M1 Table 1	100066	
8.1	Scratches	100067	
8.2	Pits	100068	
8.3	Haze	100069	
8.4	Localized Light Scatterers (LLS)	100070	≥0.50µ
8.4	Localized Light Scatterers (LLS)	100071	≥0.30µ
8.4	Localized Light Scatterers (LLS)	100072	≥0.20µ
8.4	Localized Light Scatterers (LLS)	100073	≥0.19µ
8.4	Localized Light Scatterers (LLS)	100074	≥0.18µ
8.4	Localized Light Scatterers (LLS)	100075	≥0.17µ
8.4	Localized Light Scatterers (LLS)	100076	≥0.16µ
8.4	Localized Light Scatterers (LLS)	100077	≥0.15µ
8.4	Localized Light Scatterers (LLS)	100078	≥0.14µ
8.4	Localized Light Scatterers (LLS)	100079	≥0.13µ
8.4	Localized Light Scatterers (LLS)	100080	≥0.12µ
8.4	Localized Light Scatterers (LLS)	100081	≥0.11µ
8.4	Localized Light Scatterers (LLS)	100082	≥0.10µ
8.4	Localized Light Scatterers (LLS)	100083	≥0.09µ
8.4	Localized Light Scatterers (LLS)	100084	≥0.08µ
8.4	Localized Light Scatterers (LLS)	100085	≥0.07µ
8.4	Localized Light Scatterers (LLS)	100086	≥0.06µ
8.4	Localized Light Scatterers (LLS)	100087	≥0.05µ
8.4	Localized Light Scatterers (LLS)	100088	≥0.04µ
8.4	Localized Light Scatterers (LLS)	100089	≥0.03µ
8.4	Localized Light Scatterers (LLS)	100090	≥0.02µ
8.5	Contamination/Area	100091	
8.6	Edge Chips	100092	
8.7	Edge Cracks	100093	
8.8	Cracks, Crow's Feet	100094	
8.9	Craters	100095	
8.10	Dimples	100096	
8.11	Grooves	100097	
8.12	Mounds	100098	
8.13	Orange Peel	100099	
8.14	Saw Marks	100100	
8.15	Dopant Striation Rings	100101	
8.16	Stains	100102	
9.01	Back Surface Visual Inspection Specified According to SEMI M1 Table 1	100103	
9.1	Edge Chips	100104	
9.2	Cracks, Crow's Feet	100105	
9.3	Contamination/Area	100106	

Line	*Item*	*EDI Code ID*	*Sub Param ID*
9.4	Saw Marks	100107	
9.5	Stains	100108	
9.6	Roughness	100109	
9.7	Brightness	100110	
11.1	Conductivity Type/Structure	100111	
11.2	Dopant	100112	
11.3	Silicon Source Gas	100113	
11.4	Growth Method	100114	
11.5	Net Carrier Density (Resistivity)	100115	
11.6	Net Carrier Density Variation	100116	
11.7	Thickness	100117	
11.8	Thickness Variation	100118	
11.9	Transition Width	100119	
11.10	Flat Zone	100120	
11.11	Phantom Layer	100121	
12.1	Bow	100122	
12.2	Warp Method	100123	ASTM 657
12.2	Warp Method	100124	ASTM 1390
12.3	Sori	100125	
12.4	Flatness/Global	100126	
12.5	Flatness/Site	100127	SF3R
12.5	Flatness/Site	100128	SF3D
12.5	Flatness/Site	100129	SFLR
12.5	Flatness/Site	100130	SFLD
12.5	Flatness/Site	100131	SFQR
12.5	Flatness/Site	100132	SFQD
12.5	Flatness/Site	100134	SBIR
13.01	Epi Front Surface Visual Inspection Specified According to SEMI M2 Table 1 or SEMI M11 Table 1	100135	
13.1	Stacking Faults	100136	
13.2	Slip	100137	
13.3	Large Point Defects	100138	
13.4	Total Points Defects	100139	
13.5	Scratches	100140	
13.6	Dimples	100141	
13.7	Orange Peel	100142	
13.8	Cracks/Fractures	100143	
13.9	Crow's Feet	100144	
13.10	Edge Chips	100145	
13.11	Edge Crown	100146	
13.12	Haze	100147	
13.13	Foreign Matter	100148	
14.1	Contamination	100149	
16.1	Mask ID	100150	
16.2	Alignment Precision	100151	
16.3	Pattern Line Width Tolerance	100152	

Line	*Item*	*EDI Code ID*	*Sub Param ID*
17.1	Dopant	100153	
17.2	Diffusion Depth (xj)	100154	
17.3	Sheet Resistance	100155	
17.4	Pattern Step Height	100156	
17.5	Defect Density (Before Epi)	100157	
18.1	Pattern Shift Ratio	100158	
18.2	Pattern Distortion Ratio	100159	
6.14	Flatness/Site	100160	SFSR
12.5	Flatness/Site	100161	SFSR
4.9	Interstitial Oxygen Reduction (ΔOi)	100162	
6.15	Fixed Quality Area	100164	
10.1	Bulk defects by X-ray topography	100169	
12.6	Fixed Quality Area	100172	
9.8	Scratches – macro	100165	
9.9	Scratches – micro	100166	
9.10	Localized Light Scatterers (LLS)[4]	100167	
9.10	Localized Light Scatterers (LLS)[4]	100168	
11.01	[ ] Specified According to SEMI M11 Table [ ]	100170	
12.01	[ ] Specified According to SEMI M11 Table [ ]	100171	
13.14	Localized Light Scatterers (LLS)[4]	100173	≥0.50µ
13.14	Localized Light Scatterers (LLS)[4]	100174	≥0.30µ
13.14	Localized Light Scatterers (LLS)[4]	100175	≥0.20µ
13.14	Localized Light Scatterers (LLS)[4]	100176	≥0.19µ
13.14	Localized Light Scatterers (LLS)[4]	100177	≥0.18µ
13.14	Localized Light Scatterers (LLS)[4]	100178	≥0.17µ
13.14	Localized Light Scatterers (LLS)[4]	100179	≥0.16µ
13.14	Localized Light Scatterers (LLS)[4]	100180	≥0.15µ
13.14	Localized Light Scatterers (LLS)[4]	100181	≥0.14µ
13.14	Localized Light Scatterers (LLS)[4]	100182	≥0.13µ
13.14	Localized Light Scatterers (LLS)[4]	100183	≥0.12µ
13.14	Localized Light Scatterers (LLS)[4]	100184	≥0.11µ
13.14	Localized Light Scatterers (LLS)[4]	100185	≥0.10µ
13.14	Localized Light Scatterers (LLS)[4]	100186	≥0.09µ
13.14	Localized Light Scatterers (LLS)[4]	100187	≥0.08µ
13.14	Localized Light Scatterers (LLS)[4]	100188	≥0.07µ
13.14	Localized Light Scatterers (LLS)[4]	100189	≥0.06µ
13.14	Localized Light Scatterers (LLS)[4]	100190	≥0.05µ
13.14	Localized Light Scatterers (LLS)[4]	100191	≥0.04µ
13.14	Localized Light Scatterers (LLS)[4]	100192	≥0.03µ
13.14	Localized Light Scatterers (LLS)[4]	100193	≥0.02µ
13.15	Surface Edge Exclusion	100194	
14.01	[ ] Specified According to SEMI M11 Table [ ]	100195	
14.2	Scratches -- macro	100196	
14.3	Scratches -- micro	100197	
14.4	Localized Light Scatterers	100198 100199	

Line	*Item*	*EDI Code ID*	*Sub Param ID*
20.1	Annealing Atmosphere	100200	
20.2	Other Dopant in Crystal	100201	
21.1	Bow	100202	
21.2	Warp	100203	ASTM 657
21.2	Warp	100204	ASTM 1390
21.3	Sori	100205	
21.4	Flatness/Global	100206	
21.5	Flatness/Site	100207	SF3R
21.5	Flatnes/Site	100208	SF3D
21.5	Flatness/Site	100209	SFLR
21.5	Flatness/Site	100210	SFLD
21.5	Flatness/Site	100211	SFQR
21.5	Flatness/Site	100212	SFQD
21.5	Flatness/Site	100213	SBIR
21.5	Flatness/Site	100214	SFSR
21.6	Fixed Quality Area	100215	
22.1	Stacking Faults	100216	
22.2	Slip	100217	
23.1	Contamination	100218	
24.1	Depth of BMD Denuded Zone	100219	
24.2	BMD Density	100220	
6.14	Flatness/Site	100221	SFSD
12.5	Flatness/Site	100222	SFSD
12.5	Flatness/Site	100223	SBID
21.5	Flatness/Site	100224	SFSD
21.5	Flatness/Site	100225	SBID

SEMI M19-91
SPECIFICATION FOR ELECTRICAL PROPERTIES OF BULK GALLIUM ARSENIDE SINGLE CRYSTAL SUBSTRATES

1 Introduction

For the specification, three principal types of material were identified: semi-insulating, n-type, and p-type. This encompasses the full range of conductivity characteristics for Gallium Arsenide (GaAs). Section 3 considers subclasses of these characteristics defining the species which may be used for producing the conductivity type. For semi-insulating material, special cases have been isolated.

Undoped, Grade A1 represents those materials which are of high resistivity and stable following growth, without necessitating any additional annealing or processing. The Grade A2 material, "high purity", requires additional thermal processing following growth to bring the resistivity to a level > 10^7 Ω-cm. At this time, most producers have indicated that the majority of the Grade A2 ingots have resistivity characteristics which rise into the acceptable range after an appropriate thermal cycle. However, this phenomenon is sensitive to the details of the time-temperature cycle, and thus, such an increase cannot be guaranteed in every application. Thus, the label "Grade A2" is used to denote this material.

Chromium doping produces a high resistivity material. However, due to the rapid diffusion of Cr during processing and the propensity for surface accumulation, it is not as well suited to processing as grades 3.A.1 and 3.A.2, thus we assign this material "grade A".

Iso-electric dopant additions do not appear to affect the resistivity significantly, but rather, permit the reduction of dislocation generation in the final product. Thus, this material is classified Grade A. While In is the most effective hardening agent, Al, P, and Sb are also viable species. They are included for completeness and to reduce the likelihood of document revision at a later date. The Grade B specification encompasses those materials where the impurity and point defect densities are not quite in the proper balance, but the resistivity is suitable for less-stringent applications.

For conducting material, the best characterized, non-transition metal species have been included as n-type dopants; for p-type, a broader range of species has been included, as transition metals are useful acceptor impurities.

Section 4 defines the resistivity and stability of semi-insulating material as specified in Section 3. A stringent limit was placed on the Grade A2 material to minimize the likelihood that this material converts to low resistivity upon annealing. The issue of surface conversion in Cr-doped material was dealt with by eliminating a requirement for n-type characteristics following annealing.

The resistivity ranges for n-type conducting material were determined from the carrier concentration table (Section 5) and mobility values, using the analysis of Walukiewicz et al, J. Appl. Phys. 50 (1979) 899. This places a constraint on the permissible compensation ratio, selected to be in the range of approximately 0.0 to 0.7. The specification was designed then to exclude abnormally poor crystals. As limited data and demand exist for p-type material, there are no ranges specified at this writing. Should a significant body of data evolve, this specification may be designed and balloted as appropriate.

Section 5 deals with impurity concentrations, net electron yields and implicitly, with point defect concentrations. For semi-insulating material of high quality, the impurities are, at the present time, not reliably measurable (carbon is the notable exception). Thus the "unspecified" nomenclature. For types A-3 and A-4, the determination of the amount of the relevant impurity species is given to the appropriate party, the user, and producer, respectively.

For n-type materials, the ranges were selected to define a high purity regime ($n \leq 4 \times 10^{16}$ cm^{-3}), an intermediate regime where donor density is not more than ~10 times the typical deep level density; the transition region wherein deep levels are suppressed (range B-3); a highly doped range (> 10 ppm net electron concentration yield); and "saturation" doping range where the crystal growth process and thermodynamics determine the limits of impurity incorporation and electron yield.

In Section 6, the electron mobility values and ranges are stated. For semi-insulating materials, the values that have been determined by consensus are 5000 cm^2/V-s for Grade A1 and 6000 cm^2/V-s. In the interest of harmony, and to prevent further debilitating discussions, the authors and participants at the SEMI meetings, and responses from producers have been used to set this value at 5000 cm^2/V-s. The producers indicated that the Grade A2 material nearly always exceeds 6000 cm^2/V-s, and thus this value was adopted. For chromium doped materials, the mobility is less predictable and, therefore, is negotiated between the user and producer. In-doped materials have consistently lower mobilities, resulting from strain-effects, scattering, and other related phenomena. Thus, based on producer experience, the minimum value was set at 3500 cm^2/V-s.

For n-type materials, the mobility ranges were selected to represent compensation ratios in the range of approximately 0.0 to 0.7 for a given net electron concentration. P-type material is not yet characterized sufficiently to warrant a specification.

2 Scope

This document specifies the characteristics and ranges of electrical properties for bulk GaAs crystals and substrate wafers. For high resistivity and n-type conducting materials, the permissible growth conditions or impurity species are stated; the electrical properties corresponding to the appropriate range(s) are noted. Due to the limited understanding, experience and demand for p-type materials only guidelines are provided in this specification at the present writing.

3 Conductivity Type

A. Semi-insulating, n-type

B. Conducting, n-type

C. Conducting, p-type

4 Dopant Species

A. 1. Undoped; Grade A1

2. Undoped; Grade A2

3. Chromium; Grade A

4. Isoelectronic impurity; Grade A Dopant specified by producer: In, Al, P, Sb

5. Undoped; Grade B

B. Dopant specified by user: Si, S, Se, Te, Sn

C. Dopant specified by user: Zn, Cd, Be, Mn, Fe, Co, Mg

NOTE See Sections 4 and 5 below for grade definition.

5 Resistivity at 300K

A. Semi-insulating, n-type*

B. 1. $\geq 1 \times 10^7$ Ω-cm, n-type before and after anneal

2. $\geq 5 \times 10^6$ Ω-cm becoming $\geq 1 \times 10^7$ Ω-cm after anneal n-type before and after anneal

3. $\geq 1 \times 10^7$ Ω-cm, n-type before anneal

4. $\geq 1 \times 10^7$ Ω-cm, n-type before and after anneal

5. $\geq 5 \times 10^6$ Ω-cm, n-type before and after anneal

1×10^7 Ω-cm = 1.6×10^8 Ω/❐; 5×10^6 Ω-cm = 8×10^7 Ω/❐;

* 1×10^6 Ω-cm = 1.6×10^7 Ω/❐ based on 625 µm wafer thickness

C. Conducting, n-type

D. 1. ≥ 0.0026 Ω-cm (at $n - 4 \times 10^{16}$ cm^{-3}; $\mu = 6000$ cm^2/V-s

2. ≤ 0.06 Ω-cm

3. ≤ 0.042 Ω-cm

4. ≤ 0.012 Ω-cm

5. $< 5.2\ 10^{-3}$ Ω-cm

6. to be determined between user and producer

NOTE Ranges overlap due to the interrelationship of ρ, n, and µ.

E. Ranges to be determined between the user and producer.

6 Free Carrier or Impurity Concentration

A. 1. Unspecified impurity concentration

2. Unspecified impurity concentration

3. Cr concentration range in atomic ppm specified by user

4. Isoelectronic impurity concentration range in atomic ppm specified by producer

5. Unspecified impurity concentration

6. To be determined between user and producer

B. 1. $\leq 4 \times 10^{16}$ cm^{-3}

2. $> 4 \times 10^{16} - 1 \times 10^{17}$ cm^{-3}

3. $> 1 \times 10^7 - 5 \times 10^{17}$ cm^{-3}

4. $> 5 \times 10^7 - 3 \times 10^{18}$ cm^{-3}

5. $> 3 \times 10^{18}$ cm^{-3}

C. Carrier concentration agreed upon between user and producer

7 Electron Mobility, 300K (determined by Hall Effect)

A. 1 ≥ 5000 cm^2/V-s

2. ≥ 6000 cm^2/V-s

3. Concentration dependent: to be agreed upon between user and producer
4. $\geq$ 3500 cm^2/V-s
5. Unspecified

B. 1. $\geq$ 4000 cm^2/V-s
2. $\geq$ 2500 cm^2/V-s
3. $\geq$1500 cm^2/V-s
4. $\geq$ 1000 cm^2/V-s
5. $\geq$ 400 cm^2/V-s
6. to be determined between user and producer

C. To be agreed upon between user and producer

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SEMI M20-0998
SPECIFICATION FOR ESTABLISHING A WAFER COORDINATE SYSTEM

1 Scope

1.1 This specification defines a wafer coordinate system which can be used to locate uniquely any point on a wafer using the wafer center as the origin and either polar (r-θ-z) or Cartesian (x-y-z) coordinates.

1.2 For unpatterned wafers, this wafer coordinate system can be used directly or in conjunction with a rectangular or polar overlay array.

1.3 This wafer coordinate system can also be used to locate the origins or other reference points of other coordinate systems used to define or report position data of site, die, or map arrays on a patterned or unpatterned wafer. In this way, the array coordinate system may be referenced to the physical geometry of the wafer.

2 Referenced Documents

2.1 *SEMI Standards*

SEMI E5 — Equipment Communications Standard 2, Message Content (SECS II)

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M12 — Specifications for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M17 — Specification for a Universal Wafer Grid

3 Interferences

3.1 Mask alignment conventions are not necessarily consistent with the wafer coordinate system.

3.2 In SEMI M1, the position of the secondary flat on silicon wafers is defined by the clockwise rotation from the primary flat. This is opposite to the convention used for the polar angle in the wafer coordinate system.

3.3 In SEMI E5, the "normal" position of the wafer is defined similarly to that in the wafer coordinate system; that is, the primary fiducial is downward and its bisector is the negative y-axis. However, the rotational position of the wafer is defined by its clockwise rotation from the "normal" position, again opposite to the convention used for the polar angle in the wafer coordinate system. Further, in SEMI E5, the coordinate system axes do not rotate; the wafer rotates with respect to these axes. In the wafer coordinate system, the coordinate axes are referenced to the wafer itself, independent of the physical position of the wafer in space.

3.4 SEMI M12 and SEMI M13 specify the mark field location for 100 mm, 125 mm, or 150 mm diameter flatted wafers relative to the flat rather than the wafer center. Thus, the mark field location may vary with respect to the wafer center and the coordinates of the corners of the mark field location (in the wafer coordinate system) may vary from wafer to wafer. However, the mark field location for notched wafers 150 and 200 mm in diameter is referenced to the wafer center.

3.5 There are some circumstances in which the front surface of an unpatterned wafer is not readily distinguished from the back surface.

4 Procedure for Establishing the Wafer Coordinate System

4.1 Position the wafer front surface up.

4.2 Find the center of the wafer. For purposes of this document, the periphery of a wafer is assumed to be the smallest circle enclosing the wafer, disregarding fiducials and all other edge anomalies. The center of this circle is to be used as the center of the wafer.

4.3 Erect a right-handed Cartesian coordinate system with:

4.3.1 its origin at the geometric center of the wafer,

4.3.2 the y-axis on the diameter in the plane of the front surface which bisects the primary fiducial (flat or notch), and

4.3.3 the x-axis on the diameter in the plane of the front surface which is perpendicular to the bisector of the primary fiducial.

4.4 Orient the wafer so the primary fiducial is in the negative y-direction (see Figure 1).

NOTE 1 The usual convention is that the negative y-direction is pointing downward (on a page) or toward the operator (on a table or chuck).

4.5 Reference the polar coordinates, r and θ to the positive x-axis.

4.6 Choose Cartesian or polar coordinates according to the application.

5 Applications of the Wafer Coordinate System

5.1 Many, though not all, processing systems now employed in advanced device manufacturing use aligning mechanisms to position the wafer rotationally and in *x-y* prior to processing. Many of these scan the wafer periphery and determine the geometric center of the wafer. This is most often seen on stepping aligners, to minimize the effects of wafer-to-wafer diameter variation in mixed aligner type fabs. Similar center-referencing subsystems are found on many characterization systems. The wafer coordinate system provides a method for referencing any other coordinate system, such as a site, pattern, or mapping array, to the physical geometry of the wafer. If the points of the array lie on the front surface of the wafer, only the *x* and *y* (or *r* and θ) coordinates are relevant. If the point or points lie above or below the front surface, the *z* coordinate must also be used.

5.2 It has become increasingly important in semiconductor material and device manufacturing to describe, in unambiguous terms, the position of a point on a wafer that automatic processing, test, or characterization equipment can recognize and locate. For example, characterization equipment needs to report the precise locations of defects and anomalies discovered in wafers before or after processing in order to relate the presence or absence of such defects and anomalies to device yield variations. The wafer coordinate system can be used to establish the coordinates of each point of interest, and, through transformation to the yield analysis coordinate system, relate them to the die yield map.

5.3 SEMI E5, in Stream 12 - Wafer Mapping, delineates how a coordinate system for reporting position data may be communicated. The origin of this coordinate system, which is specified by the equipment when generating the wafer map, may be the site at any of the four corners of the array or at the array center. In addition, the stream provides for transmission of an arbitrary number of reference points to relate the map coordinate system to the physical wafer. The wafer coordinate system may be used to establish the locations of these reference points and of the origin of the map coordinate system.

5.4 SEMI M17 defines a polar array of 1000 elements which can be used to identify the locations on a wafer of extended defects such as slip. This array is consistent with the wafer coordinate system.

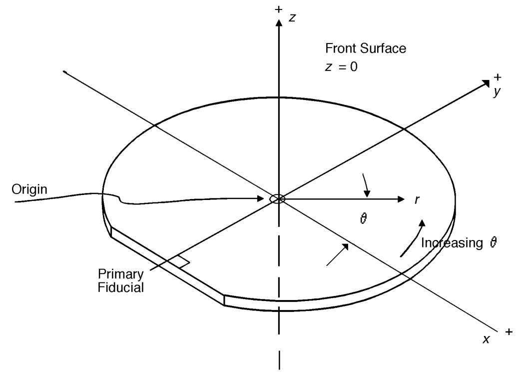

Figure 1
Wafer Coordinate System

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SEMI M21-0998
SPECIFICATION FOR ASSIGNING ADDRESSES TO RECTANGULAR ELEMENTS IN A CARTESIAN ARRAY

NOTE: This specification reflects input from equipment producers and users; from SEMI Standards groups in the U.S. and Japan with interest in silicon wafers (including epi), equipment automation, and micropatterning metrology; and from individuals in the U.S., Japan, and Europe.

1 Scope

1.1 This specification defines an element addressing convention which can be used to locate and identify rectangular elements in a Cartesian array. The array may be regular or tiled in one direction. Such arrays are useful in locating sites for site flatness characterization, defect mapping, determination of parametric distributions, etc. on unpatterned semiconductor wafers. The position of the array on the wafer may be established through use of the wafer coordinate system defined in SEMI M20. For complex patterns, more than one array on a wafer may be defined and related to the same coordinate axes.

1.2 This specification provides a unique identification (address) for each element in the array.

1.3 The element addressing convention in this specification is consistent with that of the polar array specified in SEMI M17. In addition, element addresses can be readily transformed to addresses in other types of addressing conventions for cartesian arrays.

1.4 The element addressing convention in this specification provides an orderly progression along perpendicular directions with addresses of adjacent elements in any direction differing by 1. Consequently, distances may be calculated in a unified way.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specification for Silicon Epitaxial Wafers

SEMI M11 — Specification for Silicon Epitaxial Wafers for Advanced Applications

SEMI M17 — Specification for a Universal Wafer Grid

SEMI M20 — Specification for Establishing a Wafer Coordinate System

2.2 *ASTM Standard*[1]

F 1241 — Terminology of Silicon Technology

3 Terminology

3.1 Many terms used in silicon wafer technology are defined in ASTM Terminology F 1241.

3.2 Definitions of additional terms may be found in SEMI M1, SEMI M2, or SEMI M11.

3.3 Selected definitions are also listed (for information only) in the glossary, Definitions for Semiconductor Materials, at the end of this volume.

4 Array Element Layout

4.1 The array is constructed from m vertical columns and n horizontal rows of identical elements of dimension a horizontally and b vertically. The number of elements in different rows and columns may vary to suit the application.

4.2 The address of an element is given by two numbers separated by a comma: (i,j). The first number, i, indicates the column and the second, j, the row.

4.3 The longest row and the longest column are used in identifying the Starting Element, which is assigned the address (0,0).

4.4 The array may have a tiled appearance, either with one or more rows offset relative to the row containing the Starting Element (row tiling) or with one or more columns offset relative to the column containing the Starting Element (column tiling).

4.4.1 For row tiling, the offset, t_r, is a fraction (p_r/q_r) of the horizontal element dimension, a, where p_r and q_r are small whole numbers.

4.4.2 For column tiling, the offset, t_c, is a fraction (p_c/q_c) of the vertical element dimension, b, where p_c and q_c are small whole numbers.

4.4.3 In either case, the offset may be constant or it may vary from row to row or column to column. When the offset is constant, the array pattern is repeated every q_r rows or q_c columns.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

5 Element Addresses

5.1 Define the array center as the intersection of the vertical and horizontal array centerlines, found as follows:

5.1.1 If the array is regular (not tiled):

5.1.1.1 Count the number of elements, *m*, in the longest row.

5.1.1.2 If *m* is even, start at the leftmost element, count *m*/2 elements to the right, and construct a line along the right vertical boundary of this element. This line is the vertical array centerline (see Figure 1a).

5.1.1.3 If *m* is odd, start at the leftmost element, count the integer of *m*/2 elements to the right, continue to the next element to the right, and construct a line through the center of this element. This line is the vertical array centerline (see Figure 1b).

5.1.1.4 Count the number of elements, *n*, in the longest column.

5.1.1.5 If *n* is even, start at the topmost element, count down *n*/2 elements, and construct a line along the bottom horizontal boundary of this element. This line is the horizontal array centerline (see Figure 1c).

5.1.1.6 If *n* is odd, start at the topmost element, count down the integer of *n*/2 elements, continue down to the next element, and construct a line through the center of this element. This line is the horizontal array centerline (see Figure 1d).

5.1.2 If the columns of the array are tiled (see Figure 2a):

5.1.2.1 Count the number of columns, *m*, in the widest part of the array from left to right.

5.1.2.2 If *m* is even, start at the leftmost column, count *m*/2 columns to the right, and construct a line along the right vertical boundary of this column. This line is the vertical array centerline.

5.1.2.3 If *m* is odd, start at the leftmost column, count the integer of *m*/2 columns to the right, continue to the next column to the right, and construct a line through the center of this column. This line is the vertical array centerline.

5.1.2.4 Count the number of elements, *n'*, in the column which contains or is immediately to the right of the vertical array centerline, depending on whether *m* is odd or even, respectively.

NOTE 1 The number, *n'*, is usually equal to but may be less than *n*.

5.1.2.5 If *n'* is even, start at the topmost element, count down *n'*/2 elements, and construct a line along the bottom horizontal boundary of this element. This line is the horizontal array centerline.

5.1.2.6 If *n'* is odd, start at the topmost element, count down the integer of *n'*/2 elements, continue down to the next element, and construct a line through the center of this element. This line is the horizontal array centerline.

5.1.3 If the rows of the array are tiled (see Figure 2b):

5.1.3.1 Count the number of rows, *n*, in the widest part of the array from top to bottom.

5.1.3.2 If *n* is even, start at the topmost row, count down *n*/2 rows, and construct a line along the bottom horizontal boundary of this row. This line is the horizontal array centerline (see Figure 1c).

5.1.3.3 If *n* is odd, start at the topmost row, count down the integer of *n*/2 rows, continue down to the next row, and construct a line through the center of this row. This line is the horizontal array centerline (see Figure 1d).

5.1.3.4 Count the number of elements, *m'*, in the row which contains or is immediately above the vertical array centerline, depending on whether *n* is odd or even, respectively.

NOTE 2 The number, *m'*, is usually equal to but may be less than *m*.

5.1.3.5 If *m'* is even, start at the leftmost element, count *m'*/2 elements to the right, and construct a line along the right vertical boundary of this element. This line is the vertical array centerline.

5.1.3.6 If *m'* is odd, start at the leftmost element, count the integer of *m'*/2 elements to the right, continue to the next element to the right, and construct a line through the center of this element. This line is the vertical array centerline.

5.2 Locate the Starting Element (0,0) as follows:

5.2.1 If the array center falls within an element, designate that element as the Starting Element (see Figure 3a).

5.2.2 If the array is regular and the array center lies at an element corner, designate the element to the right and immediately above the array center as the Starting Element (see Figure 3b).

5.2.3 If the array is regular and the array center lies on a vertical element boundary, designate as the Starting Element that element which contains the horizontal array centerline and is immediately to the right of the vertical array centerline (see Figure 3c).

5.2.4 If the array is regular and the array center lies on a horizontal element boundary, designate as the Starting

Element that element which contains the vertical array centerline and is immediately above the horizontal array centerline (see Figure 3d).

5.2.5 If columns of the array are tiled and the array center lies on a vertical boundary between columns, designate that element immediately to the right of the vertical centerline and containing the horizontal array centerline as the Starting Element. If the horizontal array centerline also falls on an element boundary in the column immediately to the right of the vertical array centerline, designate the element in this column and immediately above the horizontal array centerline as the Starting Element (see Figure 4a).

5.2.6 If rows of the array are tiled and the array center lies on a horizontal boundary between rows, designate that element immediately above the horizontal array centerline and containing the vertical array centerline as the Starting Element. If the vertical array centerline also falls on an element boundary in the row immediately above the horizontal array centerline, designate the element in this row and immediately to the right of the vertical array centerline as the Starting Element (see Figure 4b).

5.3 Assign addresses to the array elements as follows:

5.3.1 Elements along the horizontal array centerline:

5.3.1.1 If the horizontal array centerline passes through an element, assign that element the address (*i*,0), where *i* is the column number. The first column to the right of the vertical array centerline is numbered 1, the next column to the right is numbered 2, the next column to the right is numbered 3, etc. Similarly, the first column to the left of the vertical array centerline is numbered -1, the next column to the left is numbered -2, the next column to the left is numbered -3, etc. (see Figure 3a).

5.3.1.2 If the horizontal array centerline falls along an element boundary in any column, *i*, assign the address (*i*,0) to the element in that column which lies immediately above the horizontal array centerline (see Figure 3b).

5.3.2 Elements along the vertical array centerline:

5.3.2.1 If the vertical array centerline passes through an element, assign that element the address (0,*j*), where *j* is the row number. The first row above the horizontal array centerline is numbered 1, the next row up is numbered 2, the next row up is numbered 3, etc. Similarly the first row below the horizontal array centerline is numbered -1, the next row down is numbered -2, the next row down is numbered -3, etc. (see Figure 3a).

5.3.2.2 If the vertical array centerline falls along an element boundary in any row, *j*, assign the address (0,*j*) to the element in that row which lies immediately to the right of the vertical array centerline (see Figure 3b).

5.3.3 Remaining elements:

5.3.3.1 Assign addresses (*i*,*j*) to the remaining elements based on their position relative to the elements along the horizontal and vertical array centerlines. For example the address of the element immediately above (1,0) is (1,1) and the element immediately below (1,0) is (1,-1) (see Figure 5).

6 An Example

6.1 An example of a regular 29-column by 9-row array, truncated for application to a wafer, is shown in Figure 6. The Starting Element includes the array center because there are odd numbers of both columns and rows. In addition, Figure 6 shows the element addresses for elements along the right half of the horizontal array centerline, for elements along column 1, and for selected other elements in the array. Also shown are the left hand corner elements (which lie outside the truncated array).

6.2 Figure 7 shows the same truncated array fitted onto a wafer. Because the truncation is not symmetrical around the vertical array centerline, the array center is located to the left of the wafer center.

7 Extensions to Other Element Addressing Conventions

7.1 Element addressing conventions other than that covered by this specification are also widely used in engineering. Two of these are illustrated in Figure 8 with the use of the same truncated array discussed in the previous section.

7.2 *First-Quadrant Convention*

7.2.1 Addresses in this convention start at the lower left corner of the array and increase to the right and upward in the same way as in the convention covered by this specification. The lower left corner of the array is defined by the intersection of the bottom boundary of the lowest row and the left boundary of the leftmost column. In the case of tiling, the boundaries are those of the lowest elements and the leftmost elements in the array. The lower left corner may fall outside the useful portion of the array. The lower left element of the array is the element immediately to the right and above the lower left corner of the array.

7.2.2 The First-Quadrant Convention uses a column, row address but does not have a zero row or a zero column.

7.2.3 The addresses of the corners of an array with *m* columns and *n* rows in the First-Quadrant Convention are as follows:

lower left (Starting Element)	(1,1)
lower right	(*m*,1)
upper left	(1,*n*)
upper right	(*m*,*n*)

7.2.4 The general formulas for obtaining the addresses of any element (i_f,j_f) in the First-Quadrant Convention from the addresses (i,j) in the convention covered by this specification are as follows:

$$i_{\mathrm{f}} = i + \mathrm{integer}(m/2) + 1$$
$$j_{\mathrm{f}} = j + \mathrm{integer}(n/2) + 1$$

7.2.5 These equations also apply to arrays with column or row tiling if $n' = n$ or $m' = m$, respectively. If this condition is not met, the displacement of the row or column which defines the array centerline with respect to the boundary of the array must be known to transform the addresses.

7.3 *Row, Column (Matrix) Convention*

7.3.1 Addresses in this convention start at the upper left corner of the array and increase to the right and downward. The upper left corner of the array is defined by the intersection of the top boundary of the highest row and the left boundary of the leftmost column. In the case of tiling, the boundaries are those of the highest elements and the leftmost elements in the array. The upper left corner may fall outside the useful portion of the array. The upper left element of the array is the element immediately to the right and below the upper left corner of the array.

7.3.2 The Row, Column (Matrix) Convention uses a row, column address and, like the First-Quadrant Convention, does not have a zero row or a zero column.

7.3.3 The addresses of the corners of an array with *m* columns and *n* rows in the Row, Column (Matrix) Convention are as follows:

upper left (Starting Element)	(1,1)
upper right	(1,*m*)
lower left	(*n*,1)
lower right	(*n*,*m*)

7.3.4 The general formulas for obtaining the addresses of any element (i_m,j_m) in the Row, Column (Matrix) Convention from the addresses (i,j) in the convention covered by this specification are as follows:

$$i_{\mathrm{m}} = \mathrm{integer}(n/2) + 1 + j$$
$$j_{\mathrm{m}} = \mathrm{integer}(m/2) + 1 + i$$

7.3.5 These equations also apply to arrays with column or row tiling if $n' = n$ or $m' = m$, respectively. If this condition is not met, the displacement of the row or column which defines the array centerline with respect to the boundary of the array must be known to transform the addresses.

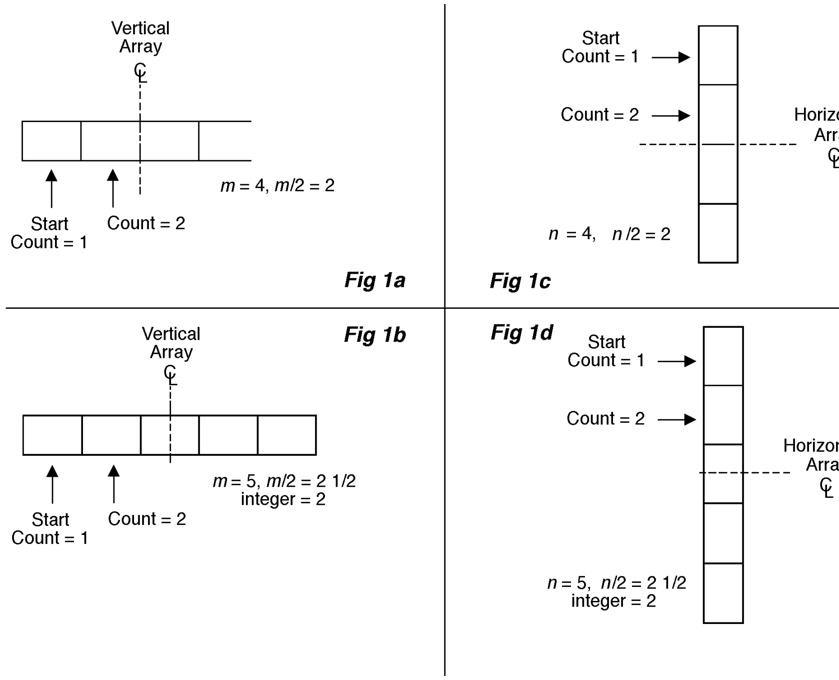

Figure 1
Array Centerlines

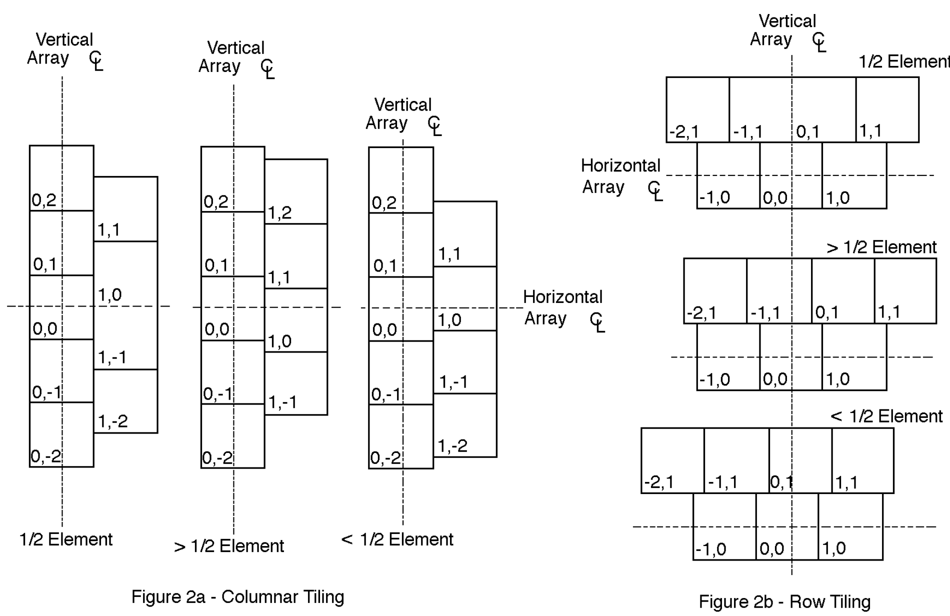

Figure 2
Tiling

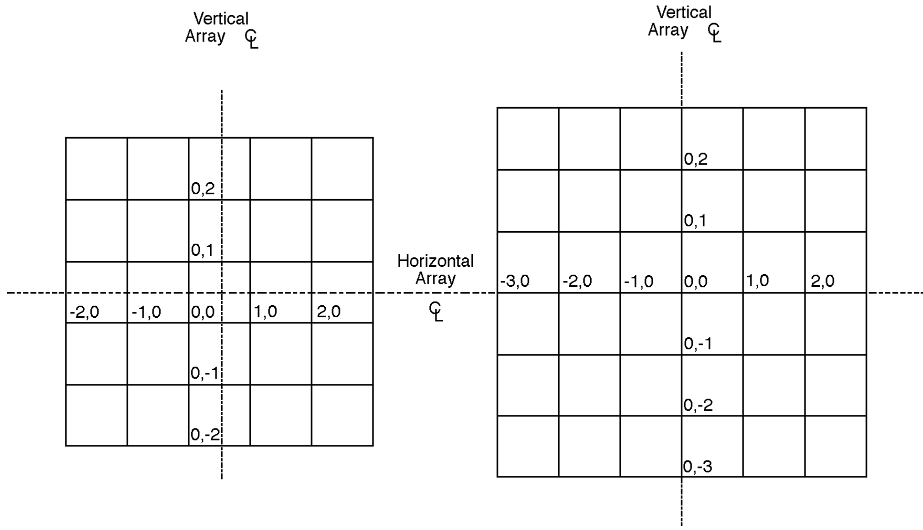

Figure 3a - Array Center within an Element

Figure 3b - Array Center on Element Corner

Figures 3a & 3b
On-Centerline Element Numbering

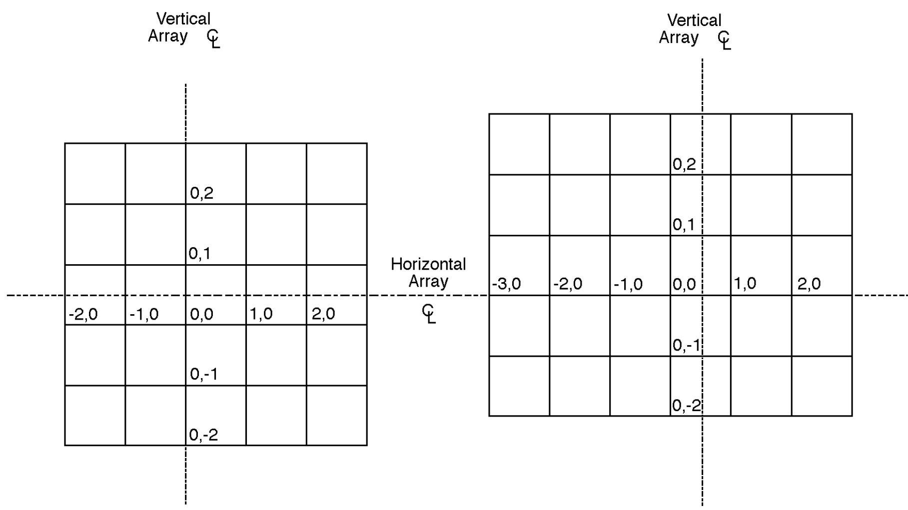

Figure 3c - Array Center along Element Vertical Edge

Figure 3d - Array Center along Element Horizontal Edge

Figures 3c & 3d
On-Centerline Element Numbering

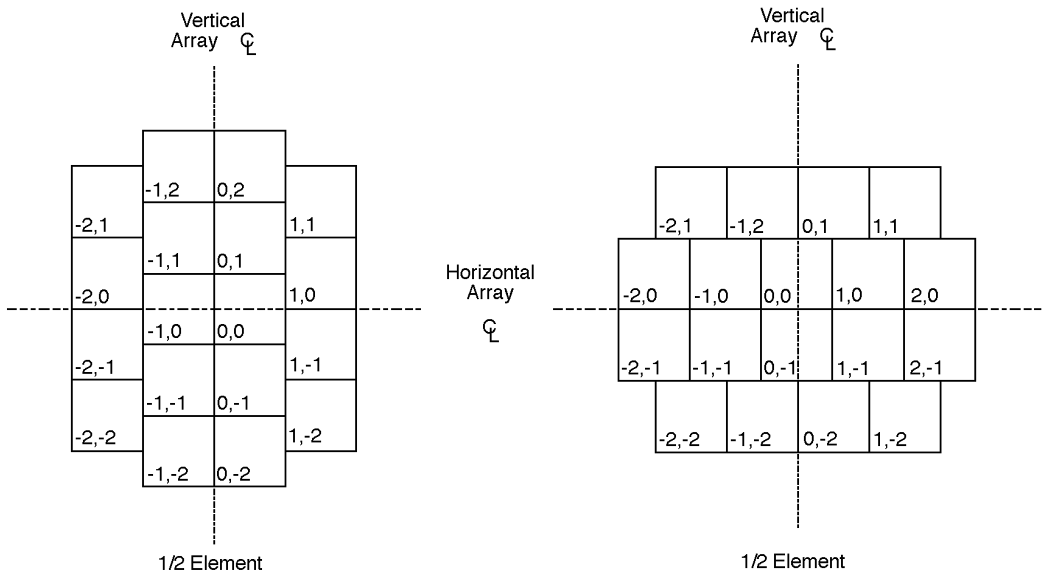

Figure 4a - Columnar Tiling

Figure 4b - Row Tiling

Figures 4a & 4b
Tiled Element Numbering

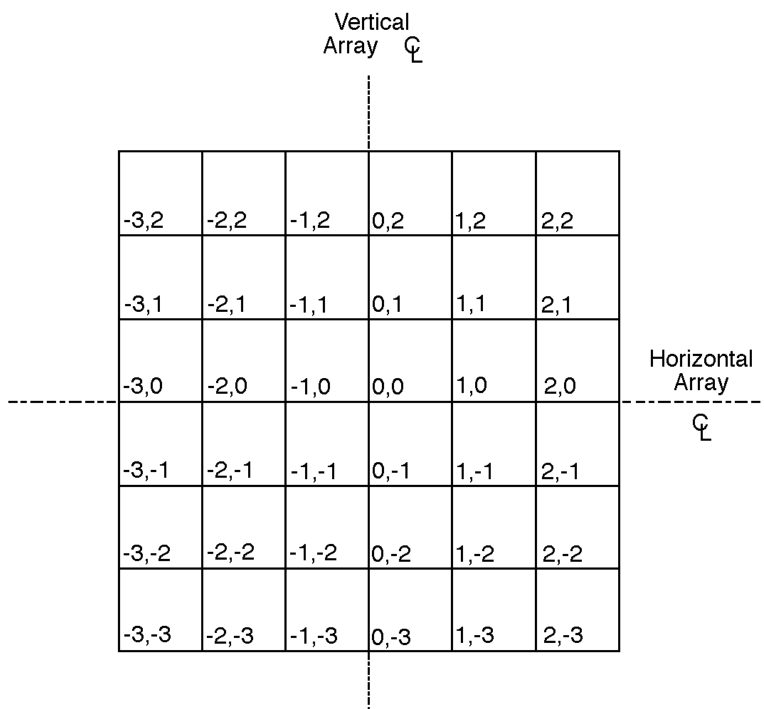

Figure 5
All Elements Numbered

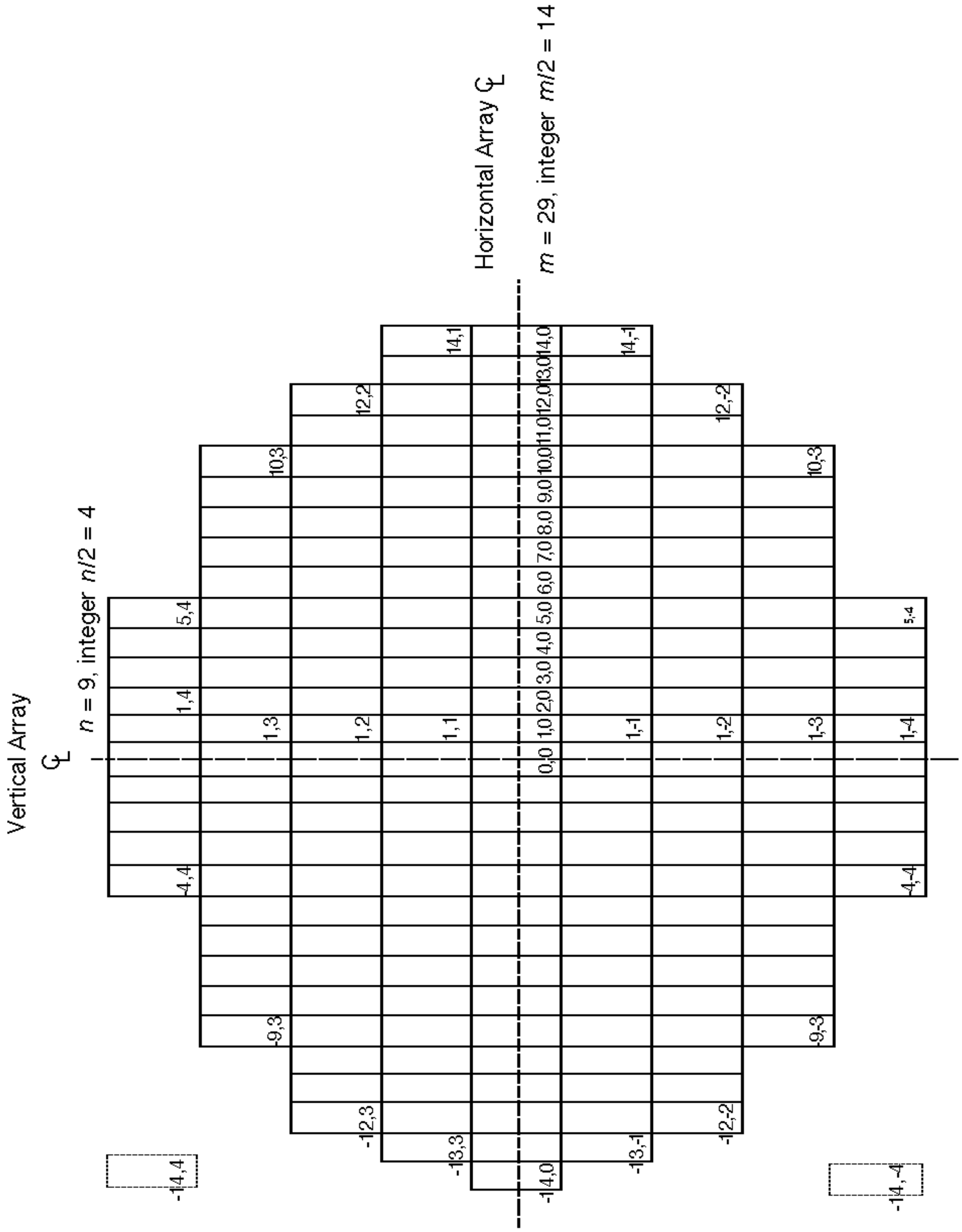

Figure 6
Array, Truncated for Application to a Wafer

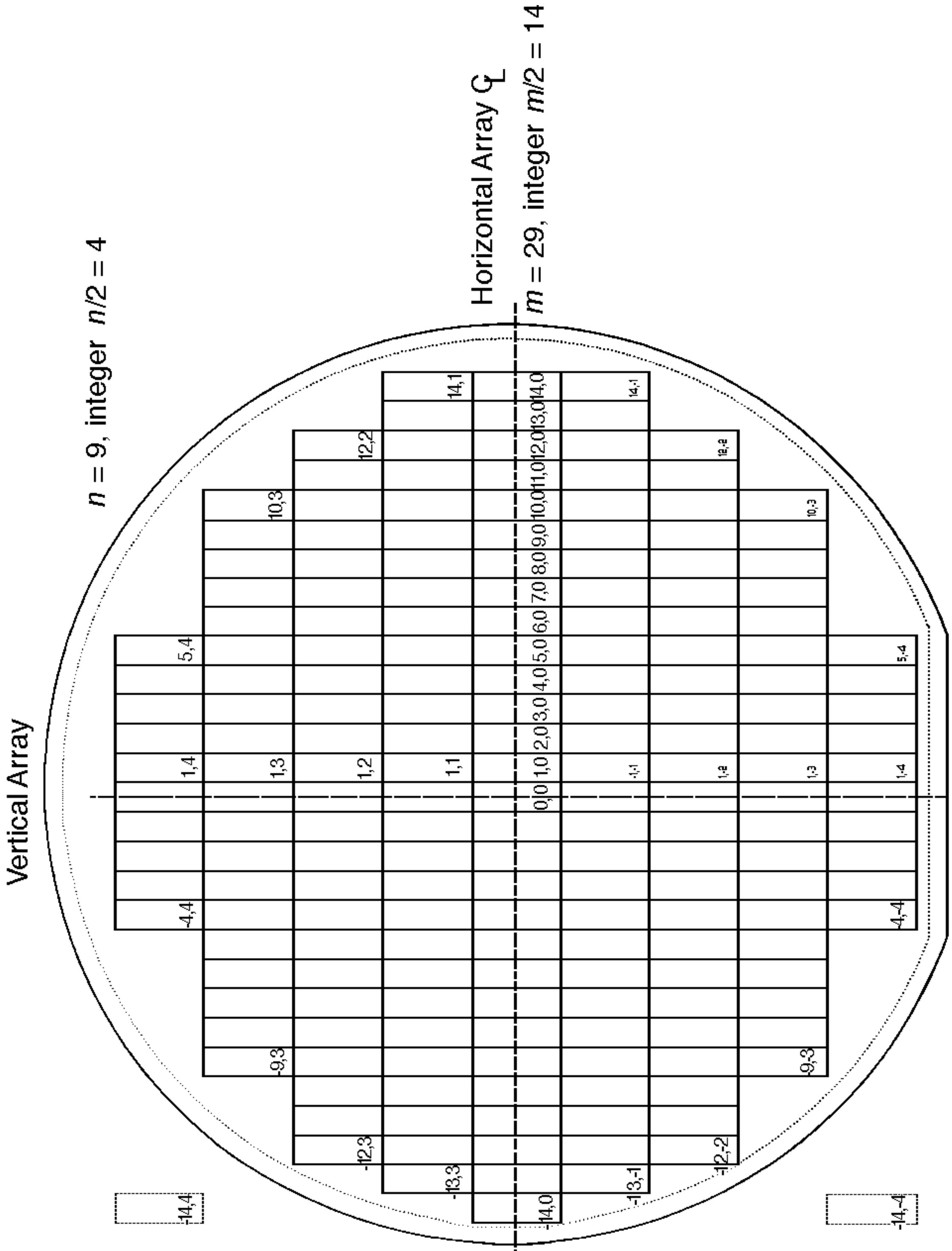

Figure 7
Truncated Array on the Wafer

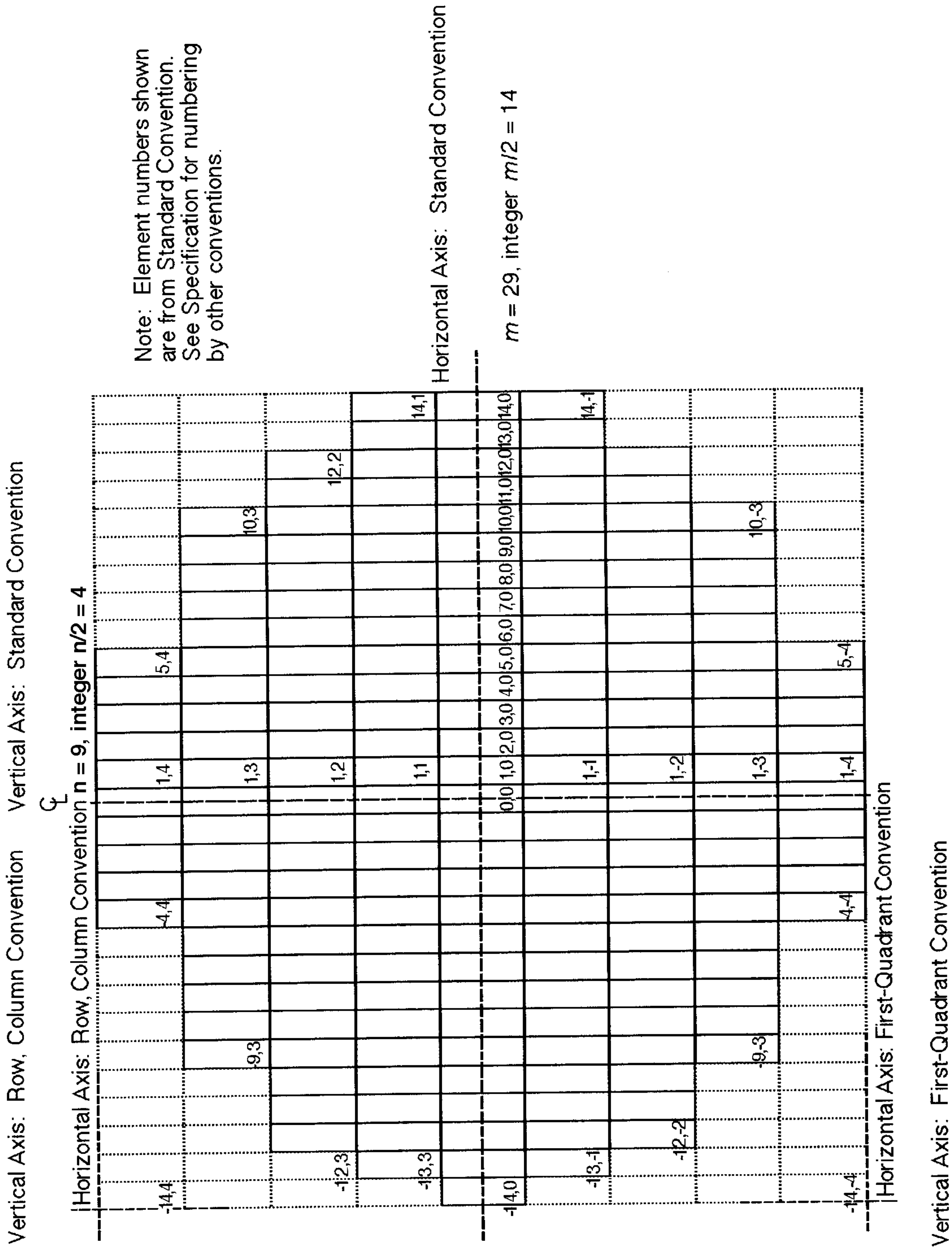

Figure 8
Comparison of Array Addressing Conventions

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SEMI M22-1296
SPECIFICATION FOR DIELECTRICALLY ISOLATED (DI) WAFERS

1 Scope

1.1 These specifications define requirements for dielectrically isolated (DI) wafers used for semiconductor device manufacture. By defining inspection procedures and acceptance criteria, both suppliers and consumers may uniformly define product characteristics and quality requirements.

NOTE This document currently applies to 100 mm nominal diameter DI wafers.

1.2 The primary standardized properties set forth in this specification relate to physical, electrical, and surface defect parameters of DI wafers.

1.3 A complete purchase specification requires that additional physical properties be specified along with suitable test methods for their measurements.

2 Applicable Documents

2.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

2.2 *ASTM Standard*[1]

F 523 — Practice for Unaided Visual Inspection of Polished Silicon Slices

2.3 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

3 Terminology

connected tubs — Adjacent tubs which are not completely surrounded by an oxide but are connected by silicon (see Figure 1).

concentricity — The distance between the centerpoint of the DI wafer and the centerpoint of the photolithographic pattern.

DI wafer — A wafer consisting of polysilicon, oxide, and single crystal silicon regions. A typical cross-section is shown in Figure 2.

edge indent — An edge defect on a DI wafer that extends from the front surface to the back surface.

pattern deformation — A microscopic defect associated with missing or indented tub features of 4 microns or more (see Figure 3).

layer of polycrystalline silicon — The thick matrix material of a DI wafer in which the silicon tubs reside.

void in the polycrystalline silicon — A microscopic depression on the surface of polysilicon areas in DI wafers (see Figure 4).

rotation — The angle of deviation between the primary flat of the DI wafer and the x-axis of the photolithography pattern.

tub — A single crystal silicon region in a DI wafer which is surrounded by an oxide layer on the sides and bottom.

tub depth — The thickness of the tub as measured from the wafer surface to the buried oxide layer parallel to the wafer surface (see Figure 2).

electrical die — An identifiable repetitive monolithic combination of tubs and polysilicon areas in a DI wafer surrounded by a grid border which as packaged becomes a component.

4 Ordering Information

4.1 Purchase orders for dielectrically isolated wafers shall include the following items:

4.1.1 Tub Characteristics

A. Resistivity

B. Conductivity and Dopant Type

C. Crystal Growth Method (Czochralski or Float Zone)

4.1.2 Tub Diffused Layers (if required)

A. Sheet Resistance

B. Junction Depth

C. Dopant Type

4.1.3 Polysilicon Resistivity

4.1.4 Nominal Tub Depth

4.1.5 Method of Pattern Transfer from User to Supplier

The pattern transfer of electrical die information may be accomplished through a physical exchange of photomasks or through a data exchange. Issues such as corner compensations, design rules, and alignment

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2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

features shall be agreed upon between the supplier and purchaser.

4.1.6 Oxide Thickness of Isolation Layer

4.1.7 Methods of Test and Measurements (see Section 6)

4.1.8 Lot Acceptance Procedures (see Section 7)

4.1.9 Certification (if required) (see Section 8)

4.1.10 Packing and Marking (see Section 9)

5 Requirements

5.1 The complete specification for the starting substrates to produce DI wafers includes all general requirements of SEMI M1.

5.2 The Dimension and Tolerance Requirements for 100 mm DI wafers are listed in Table 1.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
Diameter	100	± 0.50	mm
Thickness, Center Point	508	± 25	mm
Surface Orientation, referenced to tub crystal axes	{ 100}	± 1	deg
Primary Flat Orientation, referenced to tub crystal axes	{ 110}	± 1	deg
Primary Flat Length	32.5	± 2.5	mm
Secondary Flat Location, optional			
Secondary Flat Length	18.0	± 2.0	mm
Bow, Max.	+380		µm
Total Thickness Variation, Max.	25		µm
Concentricity, Max.	3		mm
Rotation, Max.	2		deg
Edge Profile Coordinate, Cy[B]	170		µm

[A] For referee purposes the metric (SI) units apply.

[B] See Figure SEMI M1, Figure 3.

5.3 Visual defects on a wafer shall not exceed the limits is established in Table 2, Part A.

Table 2 DI Wafer Defect Limits
A. Visual

Item	*Characteristics*	*Defect Limit*	*Illumination See Note #3*	*Notes*
1	Edge Chips Maximum Number Maximum Size	3 6.35 mm^2	Diffused	
2	Contamination, Area Minimum % of clean surface area	95%	High Intensity	1, 2
3	Cracks	None	Diffused	
4	Fractures	None	Diffused	
5	Holes	None	High Intensity	
6	Scratches Total Cumulative Length Not to Exceed	1/2 Diameter	High Intensity	1, 2
7	Pits Maximum Number Maximum Size	5 0.1 mm^2	High Intensity	1, 2

Table 2 DI Wafer Defect Limits
B. Microscopic

Item	*Characteristics*	*Defect Limit (per die)*	*Defect Limit (per wafer)*	*Notes*
8	Connected Tubs	None	"	
9	Pattern Deformation	None	"	
10	Polysilicon Voids	None	"	
11	Tub Depth (> +5% or < -5% from nominal value)	None	"	
12	Defective Die		25%	4

Notes:

1. The outer 5 mm annulus is excluded from these criteria.
2. These criteria are concerned only with polished front surfaces of DI wafers.
3. See ASTM F 523 for definition of Illumination Conditions.
4. The number of defects per die is not cumulative; an electrical die with one or more defects is counted as a single defective die.

5.4 Microscopic defects on a die and defective die on a wafer shall not exceed the limits as established in Table 2, Part B. To meet these specifications, at least 75% of the die on a wafer must be defect free.

6 Test Methods and Measurements

6.1 The supplier and purchaser shall agree in advance on the means for making all measurements (see Section 8).

6.2 *DI Wafer Characteristics*

6.2.1 *Tub Characteristics* — The resistivity, conductivity, dopant type, and crystal growth method are difficult to ascertain in the finished DI wafers. Verification test procedures or certification of these characteristics shall be agreed upon between the supplier and the purchaser (see Section 8).

6.2.2 *Tub Diffused Layers* — The test procedures to measure the sheet resistance, junction depth, and dopant type shall be agreed upon between supplier and purchaser (see Section 8).

6.2.3 *Visual Surface Defects and Contamination* — Determine in accordance with ASTM Practice F 523.

6.2.4 *Microscopically Observed Die Defects* — Examine a representative sampling of die (see 7.2) with an optical microscope with magnification such that one complete electrical die fills the field of view. If necessary for verification of defects, move to higher magnifications as required. Due to the extensive microscopic inspections required, verification test procedures or certification of these characteristics shall be agreed upon between the supplier and the purchaser (see Section 8).

7 Sampling

7.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot according to ANSI/ASQC Z1.4-1993. Each quality characteristic shall be an assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4-1993. Inspection levels shall be agreed upon between supplier and purchaser.

7.2 The sampling plan for microscopic inspection of die on the wafer, including number and location of inspected die, shall be agreed upon between supplier and purchaser.

8 Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of test results, shall be furnished at the time of shipment.

8.2 The supplier and purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 6; however, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

9 Packing and Marking

9.1 Special packing requirements shall be subject to agreement between the supplier and purchaser. Otherwise all wafers shall be handled, inspected, and packed in such a manner to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide protection against damage during shipment.

9.2 The wafers supplied under this specification shall be identified by appropriately labeling the outside of each box or container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include supplier's name and reference no., date, quantity, DI wafer diameter, DI wafer thickness, and customer code no. The reference number assigned by the supplier shall provide ready access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the manufacturer's facility for at least one year after the particular lot has been shipped.

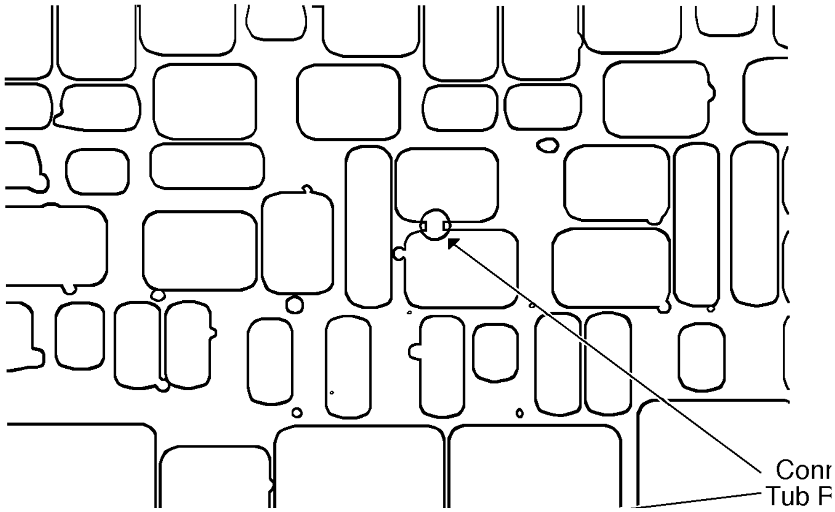

Figure 1
Connected Tubs

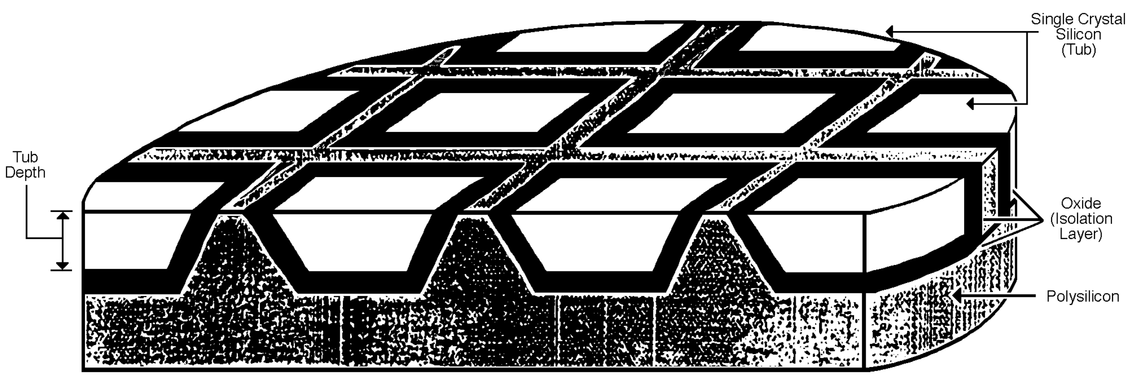

Figure 2
Cross-Section of DI Wafer

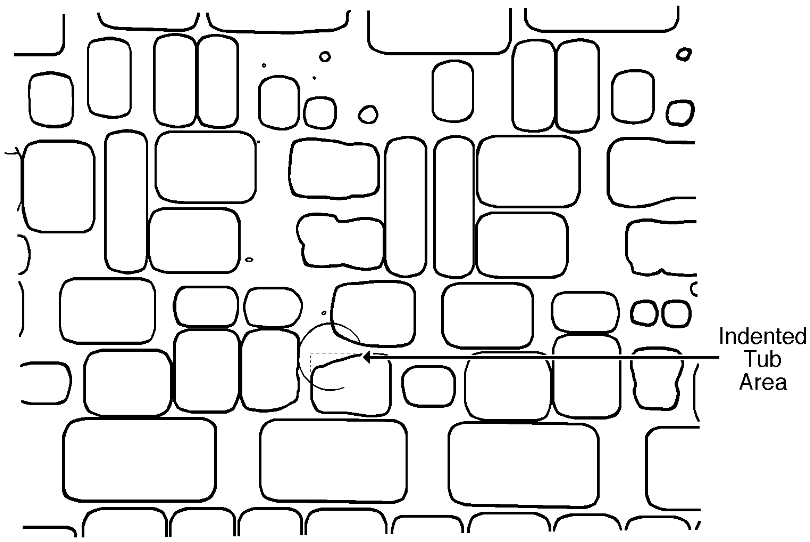

Figure 3
Pattern Deformation

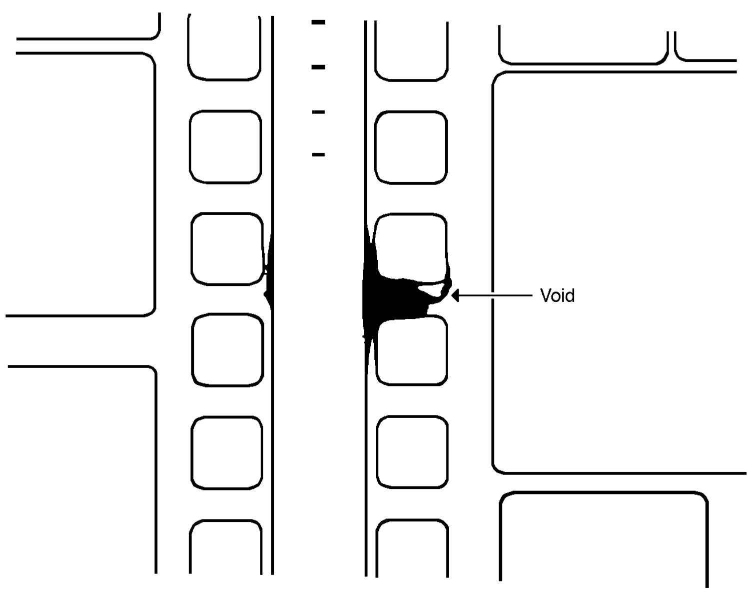

Figure 4
Void in the Polycrystalline Silicon

SEMI M23-0302
SPECIFICATION FOR POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the North American Compound Semiconductor Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1993; previously published October 2000.

1 Purpose

1.1 These specifications cover the substrate requirements for monocrystalline high-purity indium phosphide wafers used in semiconductor and electronic device manufacturing. Dimensional and crystallographic orientation characteristics are the only standardized properties set forth below.

1.2 A complete purchase specification may require that additional physical, electrical, and bulk properties be defined. These properties are listed together with test methods suitable for determining their magnitude where such procedures are documented.

2 Scope

2.1 These specifications are directed specifically to indium phosphide wafers with one or both sides polished. Unpolished wafers or wafers with epitaxial films are not covered; however, purchasers of such wafers may find these specifications helpful in defining their requirements.

2.2 The material is Single Crystal Indium Phosphide (InP) having a cubic zinc blende structure and the following properties:

Density	4.787 g/cm^3
Melting Point	1062°C
Dielectric Constant	12.4
Lattice Parameter	5.869 A at 27°C
Energy Gap	1.351 eV at 27°C

2.3 For reference purposes SI (System International, commonly called metric) units shall be used.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M39 — Test Method for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility on Semi-Insulating GaAs Single Crystals

3.2 *ASTM Standards*[1]

ASTM E 122 — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

ASTM F 26 — Test Methods for Determining the Orientation of a Semiconductive Single Crystal

ASTM F 42 — Test Method for Conductivity Type of Extrinsic Semiconducting Materials

ASTM F 76 — Test Methods for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility in Single Crystal Semiconductors

ASTM F 84 — Test Methods for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

ASTM F 154 — Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

ASTM F 523 — Practice for Unaided Visual Inspection of Polished Silicon Wafer Surfaces

ASTM F 533 — Test Method for Thickness and Thickness Variation of Silicon Wafers

ASTM F 534 — Test Method for Bow of Silicon Wafers

ASTM F 613 — Test Method for Measuring Diameter of Semiconductor Wafers

ASTM F 657 — Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Non-Contact Scanning

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 (All cited standards except for E 122 may be found in Volume 10.05 of the Annual Book of ASTM Standards; E 122 may be found in Volume 14.02.)

ASTM F 671 — Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Materials

ASTM F673 — Test Method for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

ASTM F 928 — Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

ASTM F1241 — Terminology of Silicon Technology

ASTM F 1392 — Test Method for Determining Net Carrier Density Profiles in Silicon Wafers by Capacitance-Voltage Measurements with a Mercury Probe

ASTM F 1393 — Test Method for Determining Net Carrier Density in Silicon Wafers by Miller Feedback Profiler Measurements with a Mercury Probe

3.3 *Other Standards*

ANSI/ASQC[2] Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

DIN[3] Standard Test Method 50454-2 — Determination of the Dislocation Etch Pit Density in Monocrystals of III-V Compound Semiconductors - Part 2: Indium Phosphide.

DIN Test Method 50448 — Testing of Materials for Semiconductor Technology – Contactless Determination of the Electrical Resistivity of Semi-Insulation Semiconductor Slices using a Capacitive Probe

4 Terminology

4.1 *Definitions*

NOTE 1: The selected terminology defined here has been adopted from ASTM Standard F 1241. Updates to this section are dependent on information exchange between ASTM and SEMI. Definitions are included for the benefit of the user, however, for a complete list, please refer to ASTM Standard F 1241.

4.1.1 *bow (of a semiconductor wafer)* — the deviation of the center point of the median surface of a free, unclamped wafer from a median-surface reference plane established by three points equally spaced on a circle with diameter a specified amount less than the nominal diameter of the wafer. Contrast flatness. Also see warp.

4.1.2 *dopant* — a chemical element, usually from the second, fourth, or sixth column of the periodic table for the case of III-V compounds, incorporated in trace amounts in a semiconductor crystal to establish its conductivity type and resistivity.

4.1.3 *edge profile* — on wafers whose edges have been rounded by mechanical and/or chemical means, a description of the contour of the boundary of the wafer that joins the front and back surfaces.

4.1.4 *lot* — for the purpose of this document, (a) all of the wafers of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of wafers as above which have been identified by the supplier as constituting a lot.

4.1.5 *orthogonal misorientation* — in { 100} wafers cut intentionally "off-orientation," the angle between the projection of the vector normal to the wafer surface onto the { 100} plane and the projection on that plane of the nearest direction (see Figure 5).

4.1.6 *TIR* — on a wafer surface, the smallest perpendicular distance between two planes, both parallel with the reference plane, which enclose all points on the front surface of a wafer within the flatness quality area or the site, depending on which is specified.

4.1.7 *TTV, total thickness variation* — of a semiconductor wafer, the difference between the maximum and minimum values of the thickness of the wafer.

4.1.8 *warp* — of a semiconductor wafer, the difference between the maximum and minimum distances of the median surface of a free, unclamped wafer from a reference plane, encountered during a scan pattern.

5 Ordering Information

5.1 Purchase orders for indium phosphide wafers furnished to this specification shall include the following items:

5.1.1 Nominal diameter (see applicable SEMI Standard for Polished InP wafers),

5.1.2 Thickness (see applicable SEMI Standard for polished InP Wafers),

5.1.3 Total Thickness Variation, TIR, warp and bow (determined by agreement between supplier and purchaser as to limits),

5.1.4 Surface orientation (see applicable SEMI Standard for polished InP wafers). There is only one option of flat location for 2" diameter polished monocrystalline InP wafers. The Dove-Tail option as

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

3 Deutsches Institut fur Normung e.v., available from Beuth Verlag, Burggrafenstrasse 6, D-10787 Berlin, Germany

illustrated in Figures 1 and 3 is used for 2" diameter InP. There is a choice of dovetail or V-Groove options for 3" and 100mm diameter wafers. These designations describe the shape of groove that can be etched perpendicular to the primary flat. The following are the options of wafer surface orientation:

A. (100) ± 0.5° as shown in Figures 1 and 2

B. (100) off 2° toward any of the nearest (110) planes. Examples shown in Figures 3 and 4.

Direction of off-orientation can be designated by α angle. (See Figure 5)

Figure 5 illustrates orthogonal misorientation.

5.1.5 Lot acceptance procedures (see Section 8),

5.1.6 Certification (see Section 11),

5.1.7 Packing and Marking (see Section 12).

5.2 *Optional Criteria* — The following items may be specified optionally in addition to those listed above:

5.2.1 Crystal growth method,

5.2.2 Etch Pit Density (EPD) of Crystal,

5.2.3 Crystal Growth Perfection,

5.2.4 Impurity Type,

5.2.5 Surface Condition of Wafer,

5.2.6 Edge Profile (see Figures 6 and 7),

5.2.7 Mobility,

5.2.8 Resistivity, and

5.2.9 Carrier Concentration.

6 Materials and Manufacture

6.1 The material shall consist of wafers from ingots grown to the material defined in the purchase order or contract.

7 Physical and Electrical Requirements

7.1 The material shall conform to the crystallographic orientation details as specified in the applicable polished indium phosphide wafer standard.

7.2 The material shall conform to the details specified in the purchase order or contract as follows:

7.2.1 Conduction Type,

7.2.2 Dopant,

7.2.3 Carrier Concentration,

7.2.4 Resistivity,

7.2.5 Etch Pit Density,

7.2.6 Mobility,

7.2.7 Surface Characteristics, and

7.2.8 Growth Methods.

8 Sampling

8.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4-1993. Each quality characteristic shall be assigned an acceptable quality level (AQL) or lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4-1993 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

9 Test Methods[4]

9.1 *Diameter* — Determined by ASTM Test Method F 613.

9.2 *Thickness, Center Point* — Determined by ASTM Test Method F 533.

9.3 *Flat Length* — Determined by ASTM Test Method F 671.

9.4 *Flat Orientation*[5] — Determined by etching method identified in the appropriate InP wafer standard.

9.5 *Total Thickness Variation* — Determined by ASTM Test Method F 533 or F 657.

9.6 *Surface Orientation* — Determined by ASTM Test Method F 26.

9.7 *Orthogonal Misorientation* — Determined by a method agreed upon between the supplier and purchaser.

9.8 *Surface Defects and Contamination* — Determined by ASTM Test Methods F154, F523 or a method agreed upon between the supplier and purchaser.

9.9 *Mobility* — Determined by ASTM Test Methods F 76 or SEMI M39.

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4 InP wafers are extremely fragile. While the mechanical dimensions of a wafer can be measured by use of tools such as a micrometer calipers and other conventional techniques, the wafer may be damaged physically in ways that are not immediately evident. Special care must, therefore, be used in the selection and execution of measurement methods.

5 Relating to the etchant used for identifying V-groove and/or dovetail direction, see reference: “HBr-K2 Cr2O7 – H2O etching system for indium phosphide” J.L. Weyher, et al. Materials Science and Engineering B28 (1994) 488-492.

9.10 *Resistivity of Semi-insulating Wafers* — Determined by ASTM Test Method F76 or SEMI M39 or DIN 50448.

9.11 *Conductivity or Resistivity of Doped Wafers* — Determined by ASTM Test Method F76 or F84 or F673.

9.12 *Carrier concentration* — Determined by ASTM Test Method F76 or F1392 or F1393 or Electrochemical CV[6].

9.13 *Conductivity Type* — Determined by ASTM Test Method F42 or F76.

9.14 *Crystal Perfection* — Determined by a method agreed upon between the supplier and purchaser.

9.15 *Edge Contouring* — Determined by ASTM Test Method F 928.

9.16 *Bow* — Determined by ASTM Test Method F534 or a method agreed upon between the supplier and purchaser.

9.17 *Etch Pit Density* (*EPD*) — Determined by DIN Standard Test Method 50454-2

10 Standard Defect Limits

10.1 Limits are determined by an agreement between supplier and purchaser.

11 Certification

11.1 A manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results. A certification shall be furnished at the time of shipment, upon the request of the purchaser in the contract or order.

12 Packing and Marking

12.1 Special packing and marking requirements shall be subject to agreement between the supplier and the purchaser. Otherwise, all wafers shall be handled, inspected, and packed with the best industry practices to provide ample protection against damage during shipment.

12.2 The wafers supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container and each subdivision that the wafers will be stored prior to further processing. Identification shall include lot number and wafer number. Per the agreement between the supplier and purchaser, the following must be accessible from the lot and wafer numbers: nominal diameter, conductive dopant, orientation, resistivity, and EPD. Such information shall be retained on file at the manufacturer's facility for at least one month or as negotiated between vendor and user after that particular lot has been accepted by the purchaser.

13 Related Documents

"HBr-$K_2Cr_2O_7$ – H_2O etching system for indium phosphide" J.L. Weyher, et al. Materials Science and Engineering B28 (1994) 488-492.

6 NOTE: Electrochemical CV test method has not been completed but is in the process of being developed by the industry.

Table 1 Equivalent Orientations — Dove-Tail Option

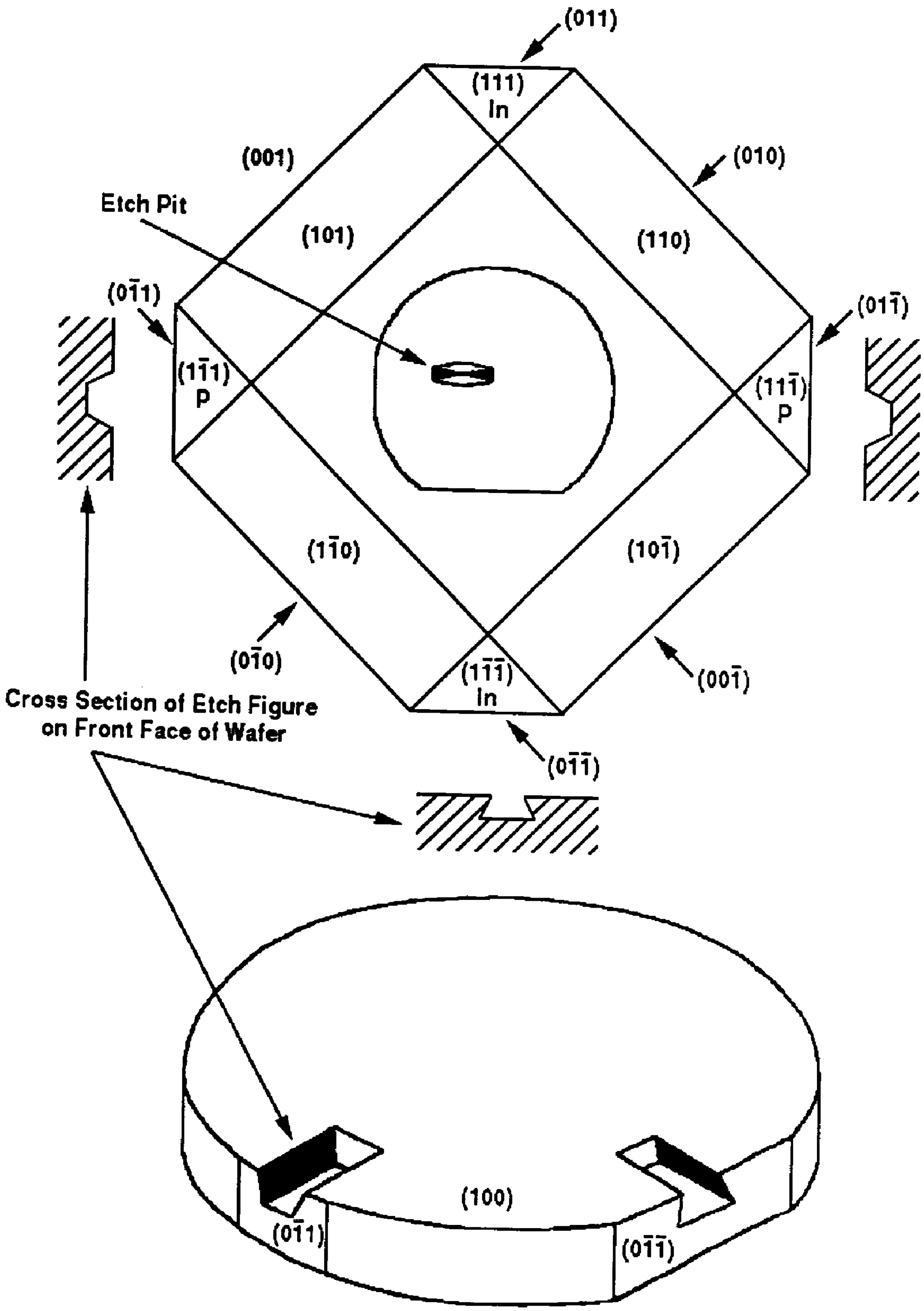
Surface orientation:	(100)	(100)	$(\bar{1}00)$	$(\bar{1}00)$
Primary flat location:	$(0\bar{1}\bar{1})$	(011)	$(01\bar{1})$	$(0\bar{1}1)$
Secondary flat location:	$(0\bar{1}1)$	$(01\bar{1})$	(011)	$(0\bar{1}\bar{1})$
For Surface orientation B, the off-orientation tilt direction is toward: (See NOTE 1)	$(1\bar{1}0)$	(110)	$(\bar{1}10)$	$(\bar{1}\bar{1}0)$

Table 2 Equivalent Orientation — V-Groove Option

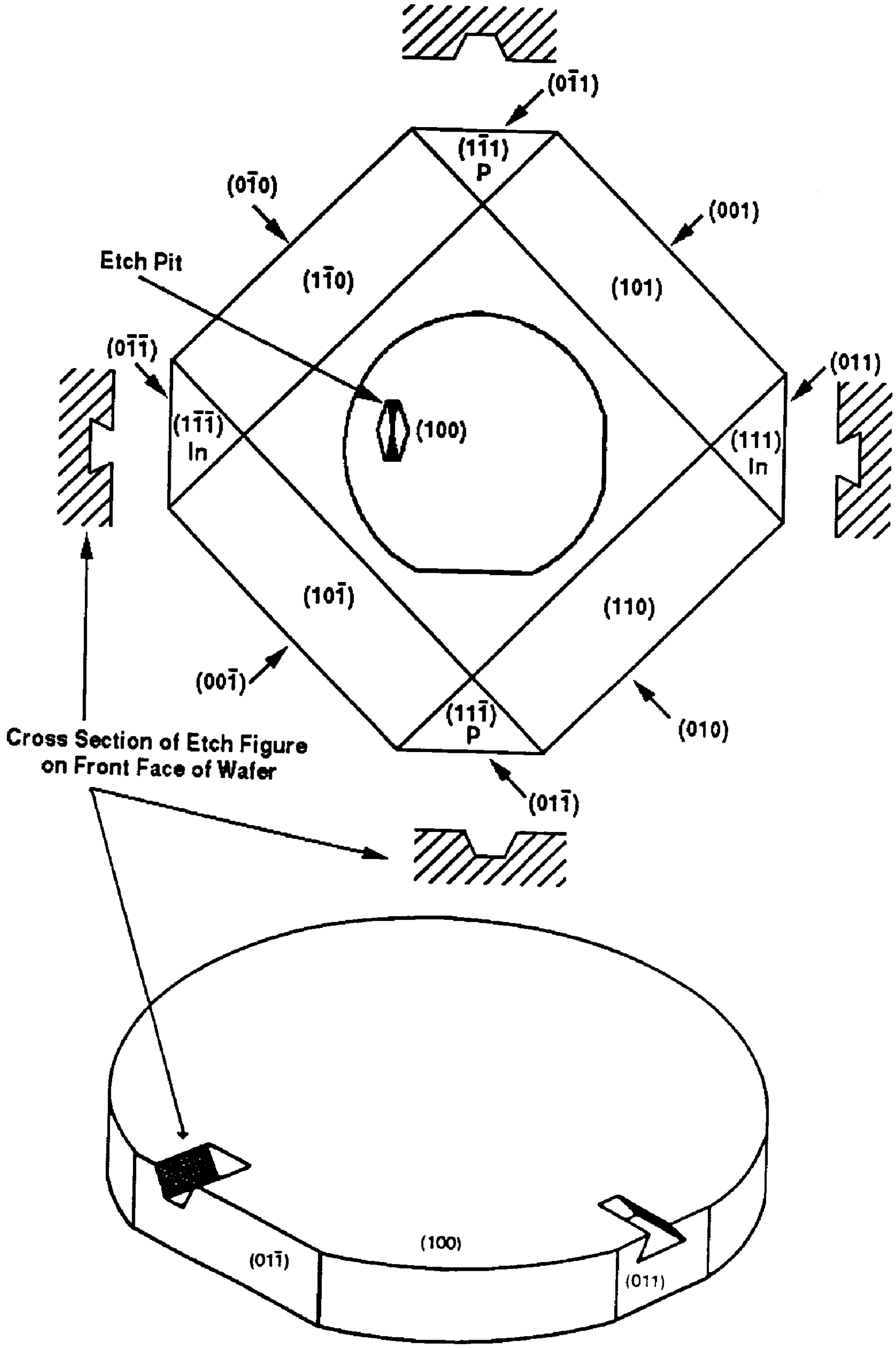
Surface orientation:	(100)	(100)	$(\bar{1}00)$	$(\bar{1}00)$
Primary flat location:	$(01\bar{1})$	$(0\bar{1}1)$	$(0\bar{1}\bar{1})$	(011)
Secondary flat location:	(011)	$(0\bar{1}\bar{1})$	$(0\bar{1}1)$	$(01\bar{1})$
For Surface orientation B, the off-orientation tilt direction is toward:	(110)	$(1\bar{1}0)$	$(\bar{1}\bar{1}0)$	$(\bar{1}10)$

The Symmetry of InP crystal structure allows other Miller indices to be used for identifying surface and flat orientations. This table lists various possibilities that meet requirements for the above specific option.

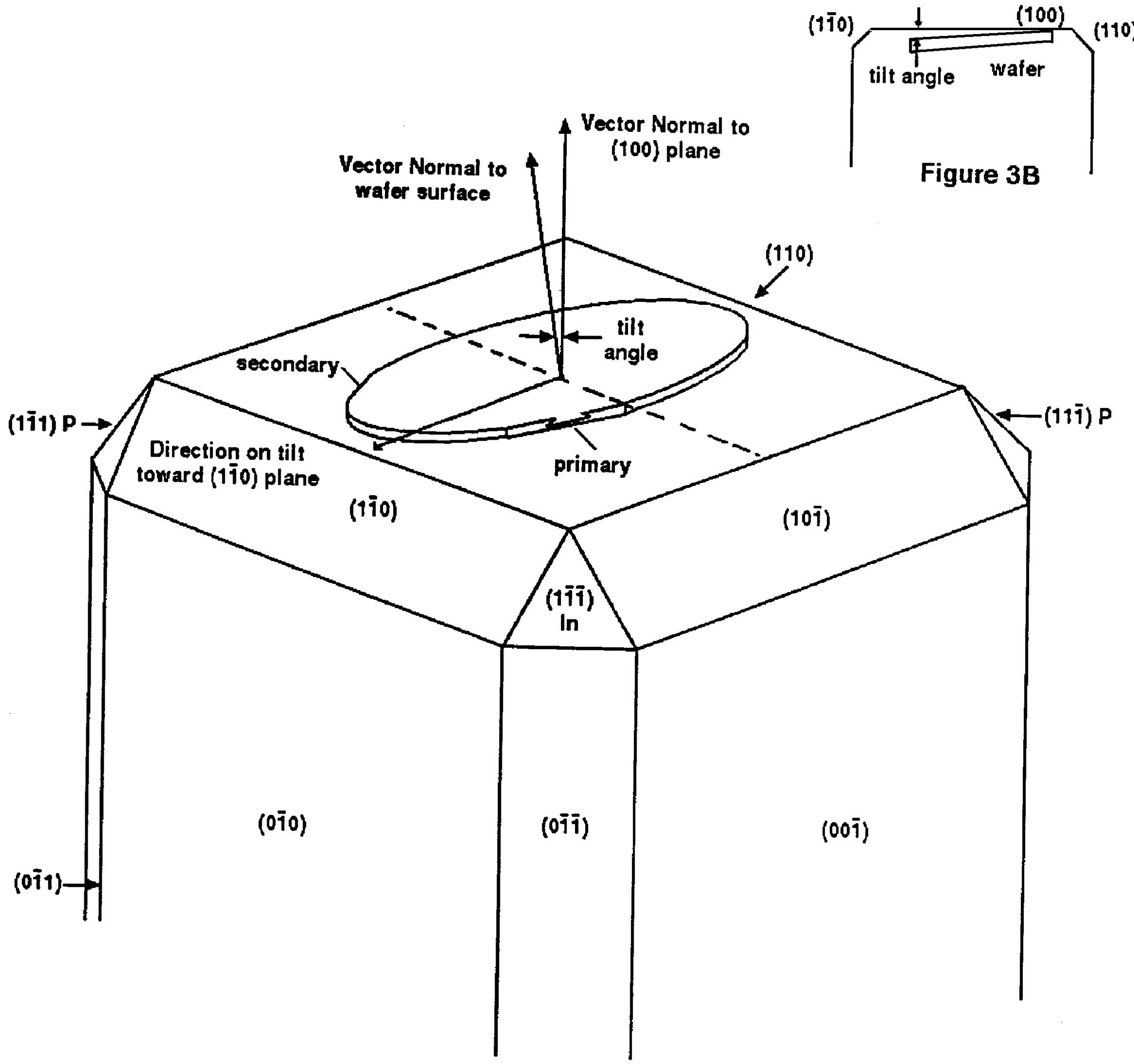
NOTE 1: For Dove-Tail Option, any of the 110 tilt directions are considered equivalent.



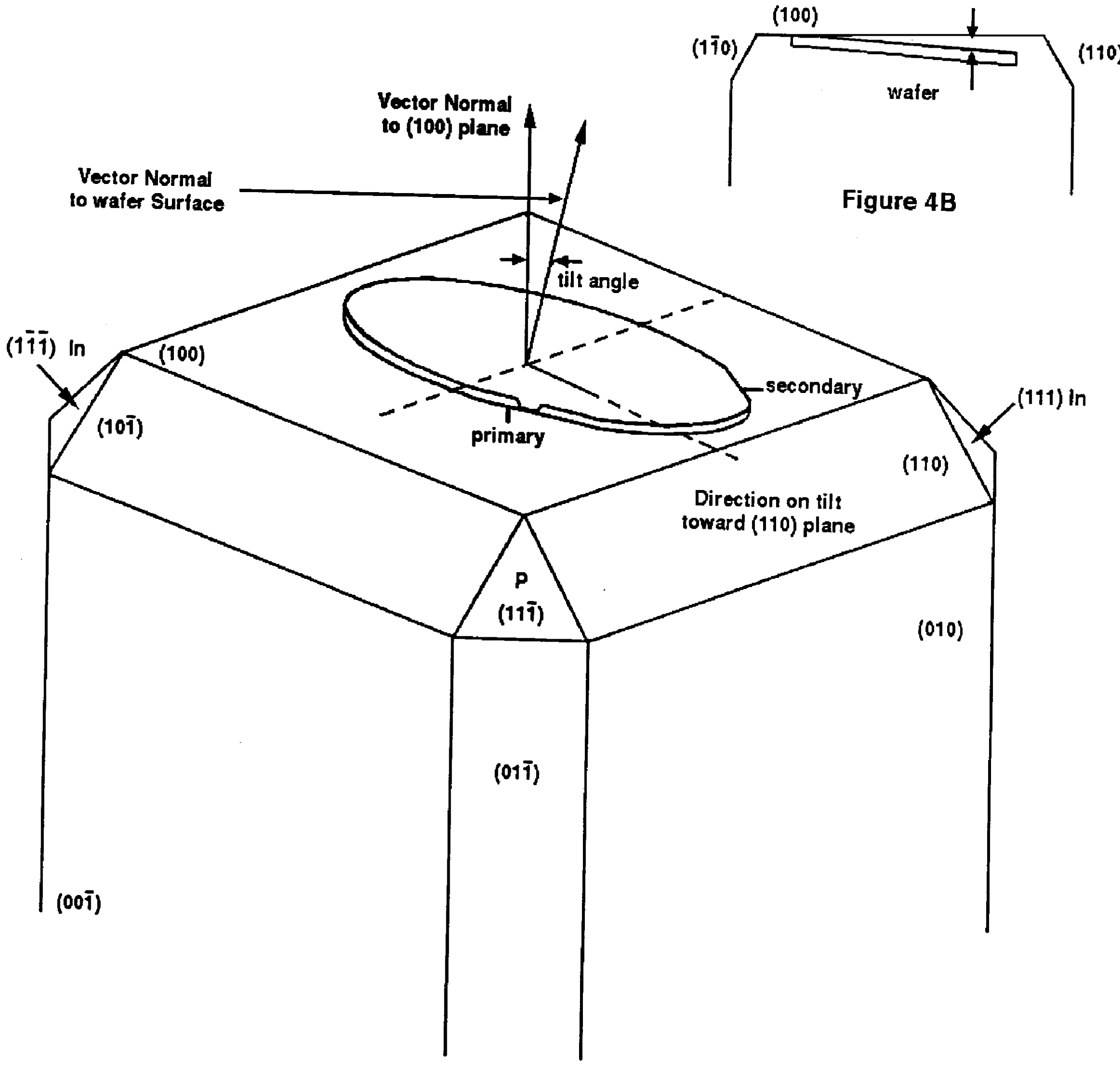
Figures 1A and 1B
Both Diagrams show an InP Wafer with Surface Orientation A and Flat Option Dove-Tail



Figures 2A and 2B
Both Diagrams show an InP Wafer with Surface Orientation A and Flat Option V-Groove



Figures 3A and 3B
Both Diagrams Show an InP Wafer with Surface Orientation B and Flat Option Dove-Tail



Figures 4A and 4B

Both Diagrams Show an InP Wafer with Surface Orientation B and Flat Option V-Groove

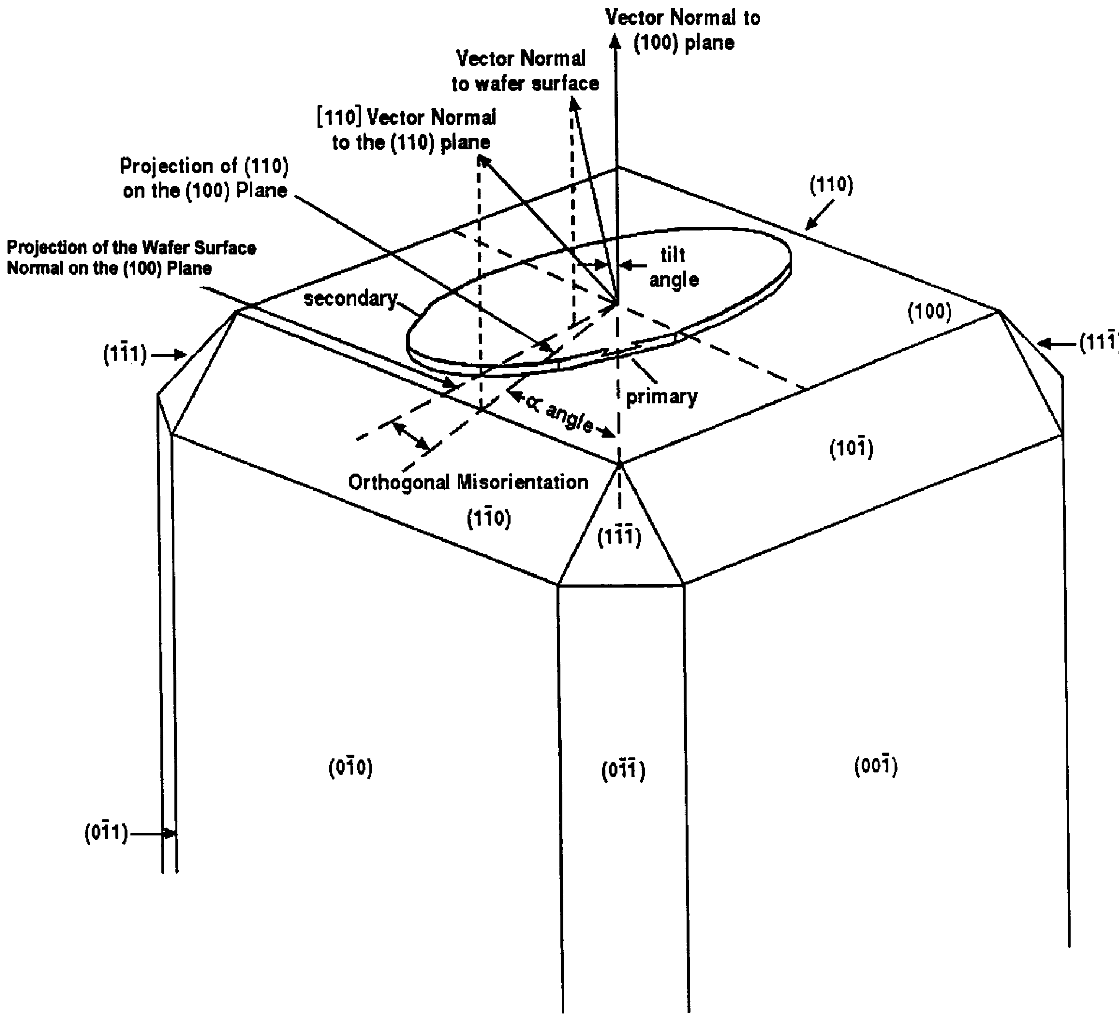


Figure 5
Diagram Shows an InP Wafer with the Same Orientation as Figure 3, but with a Few Degrees of Orthogonal Misorientation from the Intended Off-Orientation. The α angle is also shown.

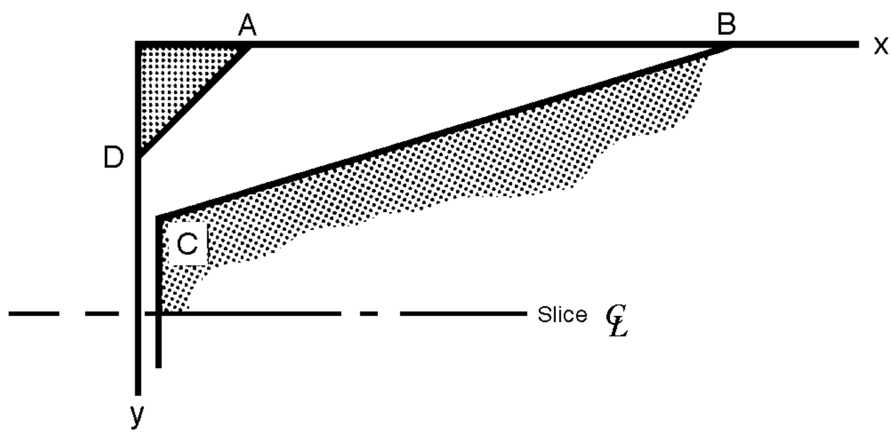


Figure 6
SEMI Wafer Edge Profile Template

Table 3 Edge Profile — Dimension and Tolerance Requirements

Property	*Dimensions*		*Units*
Edge Profile Coordinate:	x-coordinate	y-coordinate	
Point A	75	0	µm
Point B	510	0	µm
Point C	50	(See NOTE 1.)	µm
Point D	0	75	µm

NOTE 1: The y-coordinate of point C is 1/3 the nominal wafer thickness.

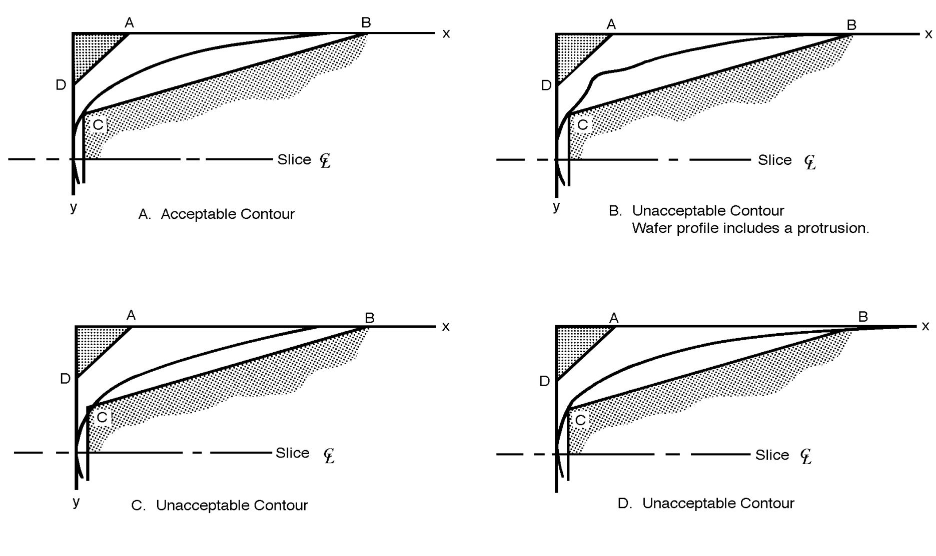


Figure 7
Example of Acceptable and Unacceptable Wafer Edge Profiles

SEMI M23.1-0600
STANDARD FOR ROUND 50 mm DIAMETER POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS

This standard was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Committee. Current edition approved by the Japanese Regional Standards Committee on April 28, 2000. Initially available at www.semi.org May 2000; to be published June 2000. Originally published in 1993; previously published in 1996.

The complete specification for this product includes all general requirements of SEMI M23.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
DIAMETER	50.0	± 0.5	mm
THICKNESS, CENTER POINT			
A	350	± 25	µm
B	450	± 25	µm
PRIMARY FLAT LENGTH	16	± 2	mm
SECONDARY FLAT LENGTH	8	± 2	mm
BOW	to be specified		
TOTAL THICKNESS VARIATION	to be specified		

[A]: For reference purposes, the metric (SI) units apply.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
OPTION	Dove-Tail
PRIMARY FLAT ORIENTATION	$(0\bar{1}1)$ ± 0.5°, under an indium facet. The primary flat shall be perpendicular to the “Dove-tail” etch figure.
SECONDARY FLAT ORIENTATION	90 ± 5° clockwise from the primary flat.
SURFACE ORIENTATION	
A	{ 100} ± 0.5°
B	{ 100} off 2° ± 0.5° toward any { 110} plane
ORTHOGONAL MISORIENTATION	± 5°

SEMI M23.2-1000
STANDARD FOR ROUND 3 inch (76.2 mm) DIAMETER POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the North American Compound Semiconductor Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available on SEMI OnLine September 2000; to be published October 2000.

NOTE: The complete specification for this product includes all requirements of SEMI M23.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units (See NOTE 1.)*
DIAMETER	76.2	± 0.5	mm
THICKNESS, CENTER POINT	600	± 25	µm
PRIMARY FLAT LENGTH	22	± 2	mm
SECONDARY FLAT LENGTH	11	± 2	mm
BOW	to be specified		
TOTAL THICKNESS VARIATION	to be specified		

NOTE 1: For reference purposes, the metric (SI) units apply.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*	
Option	*Dove-Tail*	*V-Groove*
PRIMARY FLAT ORIENTATION	$(0\overline{11})$ ± 0.5°, (see NOTE 1) under an indium facet. The primary flat shall be perpendicular to the “Dove-tail” etch figure. (See NOTE 2.)	$(01\bar{1})$ ± 0.5°, (see NOTE 1) under a phosphorus facet. The primary flat shall be perpendicular to the “V-Groove” etch figure. (See NOTE 2.)
SECONDARY FLAT ORIENTATION	90 ± 5° clockwise from the primary flat.	90 ± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION (See NOTE 3.)		
A	{ 100} ± 0.5° (see Figure 1, SEMI M23)	{ 100} ± 0.5° (see Figure 2, SEMI M23)
B	{ 100} off 2° ± 0.5° toward any { 110} plane (see Figure 3)	{ 100} off 2° ± 0.5° toward the { 110} plane which is between the primary and secondary flats (see Figure 4)
ORTHOGONAL MISORIENTATION	± 5° (see Figure 5)	± 5° (see Figure 5)

NOTE 1: See Table 1 in SEMI M23.

NOTE 2: See Figures 1 and 2 in SEMI M23, which show the orientation of the Dovetail and V-groove figures relative to crystallographically anisotropic pits (see NOTE 4).

NOTE 3: The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted towards the (110) plane of the crystal.

NOTE 4: Relating to the etchant used for identifying V-groove and/or dovetail direction, see reference: “HBr-$K_2Cr_2O_7$ - H_2O etching system for indium phosphide” J.L.Weyher, et al. Materials Science and Engineering B28 (1994) 488-492.

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SEMI M23.3-0600
STANDARD FOR RECTANGULAR POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS

This standard was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Committee. Current edition approved by the Japanese Regional Standards Committee on April 28, 2000. Initially available at www.semi.org May 2000; to be published June 2000. Originally published in 1994; previously published in 1996.

The complete specification for this product includes all general requirements of SEMI M23.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*[A]
IA-1			
LONGITUDINAL SIDE LENGTH	32.6	± 0.3	mm
LATERAL SIDE LENGTH	23.1	± 0.3	mm
THICKNESS, CENTER POINT	350	± 25	µm
IA-2			
LONGITUDINAL SIDE LENGTH	23.1	± 0.3	mm
LATERAL SIDE LENGTH	16.3	± 0.3	mm
THICKNESS, CENTER POINT	350	± 25	µm
IB-1			
LONGITUDINAL SIDE LENGTH	53.0	± 0.3	mm
LATERAL SIDE LENGTH	37.5	± 0.3	mm
THICKNESS, CENTER POINT	600	± 25	µm
IB-2			
LONGITUDINAL SIDE LENGTH	37.5	± 0.3	mm
LATERAL SIDE LENGTH	26.5	± 0.3	mm
THICKNESS, CENTER POINT	600	± 25	µm

[A] For reference purposes, the metric (SI) units apply.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
LONGITUDINAL SIDE ORIENTATION	$(01\bar{1})$ ± 0.5°, under a phosphorus facet.
LATERAL SIDE ORIENTATION	$(0\overline{11})$ ± 0.5°, under an indium facet.
SURFACE ORIENTATION	{ 100} ± 0.5°
FRONT SURFACE FINISH	Polished
BACK SURFACE FINISH	Lapped and etched
WAFER EDGE PROFILE	Cleaved face

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI M23.3 and was approved by full letter ballot procedures on April 21, 2000 by the Japanese Regional Standards Committee.

A1-1 InP is a promising material for photonic devices such as LDs, LEDs, and photodetectors for fiber communications. The consumption of InP wafers is increasing year by year due to the fiber communication systems such as LAN, ISDN, and others.

A1-2 In order to fabricate these devices, many rectangular wafers with more than 30 different sizes are industrially used but most of the sizes are not reasonably determined. From the viewpoint of material yield as explained below, the standardization of rectangular InP wafers is useful not only for InP wafer manufacturers, but also for device manufacturers.

A1-3 Figure A1-1 shows the effective area (A) as a function of ratio of longitudinal length (a) and of lateral length (b). It is a fact that the largest area can be obtained when the shape is square. However, it is difficult to distinguish V-Groove and Dove-Tail Groove orientations when the shape is square. It is, therefore, necessary to make the shape rectangular in a way that one can distinguish the orientations. It is however, noted that if the length ratio becomes too large, the effective area is dramatically decreased as seen in Figure A1-1. For instance, rectangular wafers at the point P have very little area, and most of wafer is cut off in vain. It is, therefore, very reasonable to select the length ratio at which the effective area is not largely decreased. When the length ratio (a/b ratio) is √2, the area decrease is only 5.7% as seen in Table A1-1 and Figure A1-1. It is also interesting to note that if the length ratio is determined as √2, each half of the rectangular wafer again gives a similar shape with the same ratio. In fact, this length ratio is used for paper standardization as A3/A4 or B3/B4. Rectangular wafers are therefore determined SEMI M23.3.

A1-4 Since there are already standardized 50 mm and 75 mm round wafers, the standardization is made in a way that large rectangular wafers can be obtained from these standardized wafers by removing 5 mm from the periphery as seen in Figure A1-2. Removing of 5 mm is due to EPD measurement specifications in which 5 mm periphery is excluded from the measurement.

A1-5 As explained above, it is highly recommended to use the standardized rectangular wafers because this standardization is very important in preventing proliferation of various sizes of rectangular wafers in the future.

Table A1-1

a/b Ratio	*A (mm^2)*	*A/square*
1.000	800.0	100%
1.414	754.2	94.3%
2.000	640.0	80.0%

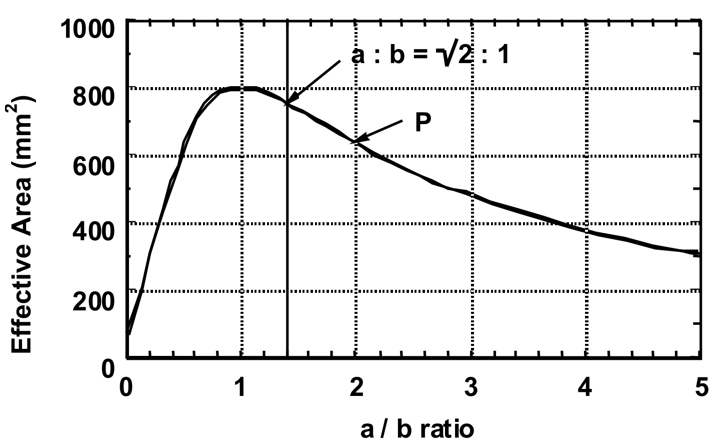

Figure A1-1
Effective Area as a Function of a/b Ratio

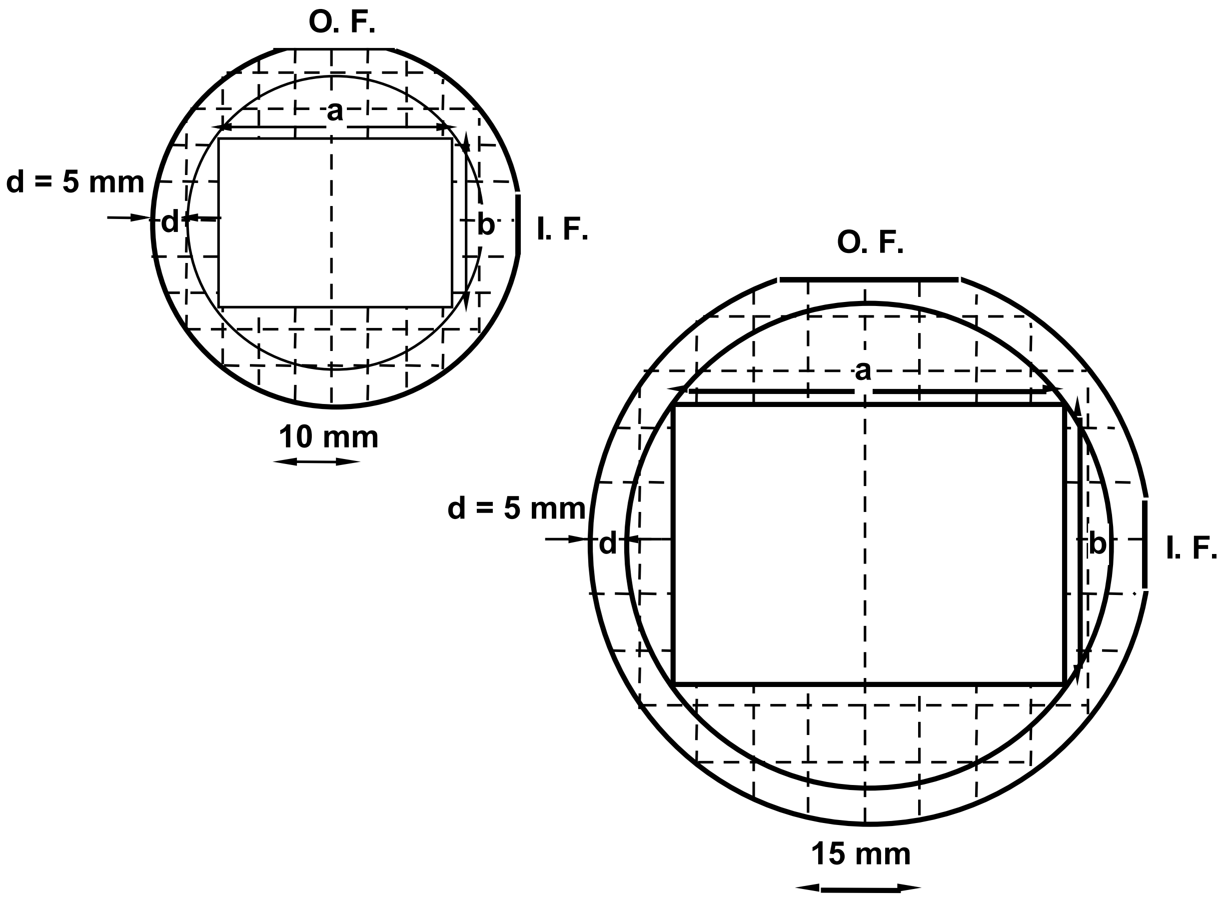

Figure A1-2
Rectangular Wafers Which can be Obtained from 50 and 75 mm Round Wafers

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SEMI M23.4-0999
SPECIFICATION FOR ROUND 100 mm POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS FOR ELECTRONIC AND OPTOELECTRONIC DEVICE APPLICATIONS (DOVE-TAIL TYPE)

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Committee. Current edition approved by the Japanese Regional Standards Committee on June 1, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

NOTE: The complete specification for this product includes all general requirements of SEMI M23.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER (See NOTE 1.)	100.0	± 0.5	mm
THICKNESS, CENTER POINT	625.0	± 25	µm
PRIMARY FLAT LENGTH	32.5	± 2	mm
SECONDARY FLAT LENGTH	18.0	± 2	mm

NOTE 1: The diameter standard means that the dimension is centered to this value.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
OPTION	Dove-Tail
PRIMARY FLAT ORIENTATION	$(0\bar{1}\bar{1})$ ± 0.5 (see Figure 1 in SEMI M23) under an indium facet. The primary flat shall be perpendicular to the "Dove-Tail" etch figure (see NOTE 1).
SECONDARY FLAT ORIENTATION	$(0\bar{1}1)$ 90° ± 5° clockwise from the primary flat.
SURFACE ORIENTATION	
A.	(100) ± 0.5° (See Figure 1 in SEMI M23.)
B.	(100) off 2° ± 0.5° toward the $(1\bar{1}0)$ plane (see NOTE 2). (See Figure 2 in SEMI M23.)
ORTHOGONAL MISORIENTATION	± 5° (See Figure 3 in SEMI M23.)

NOTE 1: Since there are various etchants, the appropriate etching method for revealing etch pits can be determined by each manufacturer. For example, see reference "HBr-$K_2Cr_2O_7$-H_2O etching system for indium phosphide" J.L. Weyher *et al.*, *Materials Science and Engineering*, B28 (1994) 488-492.

NOTE 2: The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted toward the $(1\bar{1}0)$ plane of the crystal.

SEMI M23.5-1000
SPECIFICATION FOR ROUND 100 mm POLISHED MONOCRYSTALLINE INDIUM PHOSPHIDE WAFERS FOR ELECTRONIC AND OPTOELECTRONIC DEVICE APPLICATIONS (V-GROOVE OPTION)

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the North American Compound Semiconductor Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available at www.semi.org September 2000; to be published October 2000.

NOTE: The complete specification for this product includes all requirements of SEMI M23.

Table 1 Dimension and Tolerance Requirements

Property	*Dimension*	*Tolerance*	*Units*
DIAMETER (See NOTE 1.)	100.0	± 0.5	mm
THICKNESS, CENTER POINT	625	± 25	µm
PRIMARY FLAT LENGTH	32.5	± 2	mm
SECONDARY FLAT LENGTH	18	± 2	mm

NOTE 1: The diameter standard means that the dimension is centered to this value.

Table 2 Orientation and Flat Location Requirements

Property	*Requirement*
PRIMARY FLAT ORIENTATION	$(01\bar{1})$ ± 0.5° (see NOTE 1) under a Phosphorus facet. The primary flat shall be perpendicular to the "V" etch figure. (See NOTE 2.)
SECONDARY FLAT ORIENTATION	(011), 90°± 5° counterclockwise from the primary flat.
SURFACE ORIENTATION (See NOTE 3.)	
A.	{ 100} (see NOTE 1) ± 0.5° (See Figure 2 in SEMI M23.)
B.	{ 100} (see NOTE 1) off 2° ± 0.5° toward the (110) plane which is between the primary and secondary flats (See Figure 4 in SEMI M23.)
ORTHOGONAL MISORIENTATION	± 5° (See Figure 5 in SEMI M23.)

NOTE 1: See Table 1 in SEMI M23.

NOTE 2: See Figure 2 in SEMI M23, which shows the orientation of the V-groove figure relative to crystallographically anisotropic pits (see NOTE 4).

NOTE 3: The frame of reference is the (100) plane of the crystal. It is the wafer normal that is tilted toward the (110) plane of the crystal.

NOTE 4: Relating to the etchant used for identifying V-groove and/or dovetail direction, see reference: "HBr-$K_2Cr_2O_7$ - H_2O etching system for indium phosphide" J.L.Weyher, et al. Materials Science and Engineering B28 (1994) 488–492.

SEMI M24-1101
SPECIFICATION FOR POLISHED MONOCRYSTALLINE SILICON PREMIUM WAFERS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the Japanese Silicon Wafer Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; published November 2001. Originally published in 1994; previously published March 2001.

1 Purpose

1.1 This document specifies requirements for virgin silicon premium wafers with nominal diameter from 150 mm to 300 mm used for particle counting, metal contamination monitoring, and measuring pattern resolution in the photolithography process in semiconductor manufacturing. The premium wafer has tighter specification values in some specific items for the specific usage, and looser or equal specification values in other items than a prime wafer has.

2 Scope

2.1 This specification classifies premium wafers according to surface condition and dimensional tolerances. Premium wafer classifications are summarized in Table 1.

2.2 Specification values are determined by the use for which the wafers are intended.

2.3 This specification provides premium wafers that can be used to test and evaluate leading edge device process.

2.4 For referee purposes, SI (System International) units shall be used.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M20 — Specification for Establishing a Wafer Coordinate System

SEMI M25 — Specification for Silicon Wafers for Calibration of Light Point Defect Wafer Inspection Systems with Respect to the Diameter of Polystyrene Latex Spheres

3.2 *ANSI Standard*[1]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.3 *ASTM Standards*[2]

D 523 — Standard Test Method for Specular Gloss

E 122 — Standard Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

F 26 — Standard Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F 42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 47 — Standard Test Method for Crystallographic Perfection of Silicon by Preferential Etch Techniques

F 84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Probe Array

F 154 — Standard Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 391 — Standard Test Methods for Minority-Carrier Diffusion Length in Extrinsic Semiconductors by Measurement of Steady-State Surface Photovoltage

F 416 — Standard Test Method for Detection of Oxidation Induced Defects in Polished Silicon Wafers

F 523 — Standard Practice for Unaided Visual Inspection of Polished Silicon Wafer Surface

F 533 — Standard Test Method for Thickness and Thickness of Variation of Silicon Wafers

F 534 — Standard Test Method for Bow of Silicon Wafers

F 613 — Standard Test Method for Measuring Diameter of Semiconductor Wafers

1 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

F 657 — Standard Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Noncontact Scanning

F 671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Material

F 673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

F 847 — Standard Test Methods for Measuring Crystallographic Orientation of Flats on Single Crystal Silicon Wafers by X-Ray Techniques

F 928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F 978 — Standard Test Method for Characterizing Semiconductor Deep Levels by Transient Capacitance Techniques

F 1049 — Standard Practice for Shallow Pit Detection on Silicon Wafers

F 1152 — Standard Test Method for Dimensions of Notches on Silicon Wafers

F 1188 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F 1239 — Standard Test Methods for Oxygen Precipitation Characterization of Silicon Wafers by Measurement of Interstitial Oxygen Reduction

F 1241 — Standard Terminology of Silicon Technology

F 1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

F 1391 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

F 1451 — Standard Test Method for Measuring Sori on Silicon Wafers by Automated Noncontact Scanning

F 1526 — Standard Test Method for Measuring Surface Metal Contamination on Silicon Wafers by Total Reflection X-ray Fluorescence Spectroscopy

F 1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F 1535 — Standard Test Method for Carrier Recombination Lifetime in Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

F 1617 — Standard Test Method for Measuring Surface Sodium, Aluminum, and Potassium on Silicon and EPI Substrates by Secondary Ion Mass Spectroscopy

F 1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at the Brewster Angle

F 1620 — Standard Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Surfaces

F 1621 — Standard Practice for Determining Positional Accuracy Capabilities of a Scanning Surface Inspection System

3.4 *DIN Standards*[3]

50431 — Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals by Means of the Four-Point-Probe Direct Current Method with Colinear Four-Probe Array

50432 — Determination of the Conductivity Type of Silicon or Germanium by Means of Rectification Test or Hot-Probe

50433/1 — Determination of the Orientation of Single Crystals by Means of X-Ray Diffraction

50433/2 — Determination of the Orientation of Single Crystals by Means of Optical Reflection Figure

50433/3 — Determination of the Orientation of Single Crystals by Means of Laue Back Scattering

50434 — Determination of Crystal Defects in Monocrystalline Silicon Using Etching Techniques on {111} and {100} Surfaces

50435 — Determination of the Radial Resistivity Variation of Silicon or Germanium Slices by Means of a Four-Point-DC-Probe

50438/1 — Determination of Impurity Content in Silicon by Infrared Absorption: Oxygen

50438/2 — Determination of Impurity Content in Silicon by Infrared Absorption: Carbon

50438/3 — Determination of Impurity Content in Silicon by Infrared Absorption: Boron and Phosphorus

50441/1 — Determination of the Geometric Dimensions of Semiconductor Slices: Measurement of Thickness

3 Deutsches Institut für Normung e.v., available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

50441/2 — Determination of the Geometric Dimensions of Semiconductor Slices: Testing of Edge Rounding

50441/4 — Determination of the Geometrical Dimensions of Semiconductor Slices: Diameter and Flat Depth of Slices

50443/1 — Recognition of Defects and Inhomogenities in Semiconductor Single Crystals by X-Ray Topography: Silicon

50445 — Contactless Determination of the Electrical Resistivity of Semiconductor Wafers with the Eddy Current Method

3.5 *JEITA Standards*[4]

JEIDA 18 — Determining the Orientation of a Semiconductor Silicon Single Crystal

JEIDA 27 — Standard Specification for Dimensional Properties of Silicon Wafers with Specular Surface

JEIDA 43 — Terminology of Silicon Wafer Flatness

JEIDA 53 — Test Method for Recombination Lifetime in Silicon Wafers by Measurement of Photoconductivity Decay by Microwave Reflectance

JEIDA 56 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

JEIDA 61 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

3.6 *JIS Standards*[5]

H 0602 — Testing Method of Resistivity for Silicon Crystals and Silicon Wafers with Four-Point Probe

H 0607 — Testing Methods for Conductivity Type of Semiconductor Materials

H 0609 — Test Methods of Crystalline Defects in Silicon by Preferential Etch Techniques

H 0611 — Methods of Measurement of Thickness, Taper, and Bow of Silicon Wafers

H 0614 — Visual Inspection for Silicon Wafers with Specular Surfaces

Z8741 — Method of Measurement for Specular Glossiness

4 Japan Electronics and Information Technology Industries Association, 3rd Floor Mitsui Kaijo Bldg. Annex 11, Kanda Surugadai 3-chome, Chiyoda-ku, Tokyo 101-0062, Japan

5 Japanese Standard Association 1-24, Akasaka 4 Chome, Minato-ku, Tokyo 107-0000, Japan

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 Definitions of terms related to silicon wafer technology are given in ASTM Terminology F 1241.

4.2 Definitions for some additional terms are given in SEMI M1.

4.3 The following definitions apply in the context of this specification:

4.3.1 *furnace and thermal processes* — wafers intended for use in evaluating metal contamination in thermal process.

4.3.2 *hand scribe mark* — any marking, usually on the back surface of a wafer, scratched manually into the silicon surface, as with a diamond-tipped scribe, for purposes of wafer identification.

4.3.3 *lithography and patterning* — wafers intended for use in evaluating pattern resolution.

4.3.4 *particle counting* — wafers intended for use in evaluating the particulate contamination added by a process tool. LLSs (Localized Light Scatterers) include particles and COP (Crystal Originated Pits).

4.3.5 *premium wafer* — a silicon wafer suitable for particle counting, metal contamination monitoring, and measuring pattern resolution in the photolithography process. The premium wafer has tighter specification values in some specific items for the specific usage, and looser or equal specification values for other items than a prime wafer has.

5 Ordering Information

5.1 Purchase orders for silicon premium wafers furnished to this specification shall include the items from the appropriate specification groups listed in Table 1.

Table 1 Wafer Classifications

Classification	*Application*
Particle Counting	Particle counting
Furnace and Thermal Process	Metal contamination monitoring
Lithography and Patterning	Measurement of pattern resolution in photolithography

5.2 Items which may be specified when ordering silicon wafers are listed in attached specification tables. Not all of these items are required for ordering premium wafers.

6 Dimensions and Permissible Variations

6.1 The material shall conform to the dimensions and dimensional tolerances in attached specification tables.

7 Materials and Manufacture

7.1 The material shall consist of wafers from crystals grown by the process specified in the purchase order or contract.

8 Physical Requirements

8.1 The material shall conform to the details specified in the purchase order.

9 Sampling

9.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

10 Test Methods

10.1 Table 1 of SEMI M18 contains a complete listing of ASTM, DIN, and JEIDA/JIS test methods that may apply to the testing of specified premium silicon wafers. These attributes are listed in the order they are found in the specification (which corresponds to the order in SEMI M18).

10.2 *Conductivity Type* — Use any of the methods in ASTM Test Methods F 42, JIS H 0607, or DIN 50432 for confirming the conductivity type of silicon wafers covered by this specification.

10.3 *Dopant* — Confirm the dopant of high resistivity silicon by the photoluminescence method of ASTM Test Method F 1389 or by the low-temperature infrared method of ASTM Test Method F 1630 or DIN 50438/3.

10.4 *Resistivity* — Determine the electrical resistivity of the wafer in accordance with ASTM Test Method F 673 or DIN 50445 (eddy current), or ASTM Test Method F 84, JIS H 0602, or DIN 50431 (four point probe) using a suitable fixture to hold the wafer.

10.5 *Carrier Recombination Lifetime* — Determine in accordance with F 1535 or JEIDA 53.

10.6 *Oxygen Content* — Determine the interstitial oxygen content of wafers with resistivity greater than a few ohm-cm by infrared absorption. ASTM Test Method F 1188 is the method that was used in analyzing the results of the international round robin experiment that established the IOC-88 conversion coefficient. DIN 50438/1 provides improved procedures of correcting for back surface roughness and multiple internal reflections. ASTM Test Method F 1619, based on work carried out in JEIDA (JEIDA 61) and SEMI Japan, is an alternative procedure for significantly reducing errors associated with these two phenomena.

10.7 *Carbon Content* — For all but very heavily doped epitaxial substrates, establish the carbon content in accordance with ASTM Test Method F 1391, JEIDA 56, or DIN 50438/2.

10.8 *Total Bulk Iron* — No standardized test method exists for direct determination of total bulk iron content in silicon. ASTM Test Method F 978 can be used for direct determination of the electrically active iron. Extensions of the surface photovoltage method (ASTM Test Method F 391) and of the microwave lifetime method (ASTM Test Method F 1535) have been reported in the literature to provide information on total bulk iron content of boron-doped silicon; both these extensions are based on the iron-boron pairing process.

10.9 *Structural Characteristics* — When feasible observe crystal defects such as dislocation etch pits, slip, lineage, twins, etc., in accordance with ASTM Test Method F 47, JIS H 0609, or DIN 50434. These methods are destructive, and with the exception of JIS H 0609 are based on chromium-containing etchants. Some structural defects, especially slip, can be determined nondestructively by means of X-ray topographic analysis in accordance with DIN 50443/1. Swirl and oxidation induced stacking faults (OSFs) are best observed after heat treatment such as those specified in ASTM Practice F 416. However, the heat cycles in this practice were developed for 100 mm wafers and are not suitable for 300 mm wafers. Accordingly, thermal cycles used shall be agreed upon between supplier and purchaser. For observation of OSFs, a 2-hour heat treatment at 1100°C in steam is recommended. Observe shallow pits in accordance with ASTM Practice F 1049.

10.10 *Diameter* — Diameter may be determined in accordance with ASTM Test Method F 613 or DIN 50441/4. Because notched wafers do not have flats, it is not necessary to make the measurements along the particular diameters identified in ASTM Test Method F 613; rather it is suggested that measurements be made along the diameter perpendicular to the <100> orientation fiducial axis (0° in the coordinate system specified in SEMI M20), the diameter 120° counter-clockwise, and the diameter 240° counterclockwise. However, a more precise method of determining the diameter is to find the circle that best fits the circumference of the wafer by a least squares method; the diameter of the wafer is twice the radius of this circle.

10.11 *Flat Orientation* — Determine in accordance with ASTM Test Method F 847.

10.12 *Flat Length* — Determine in accordance with ASTM Test Method F 671.

10.12.1 If flat diameter is specified instead of flat length, determine in accordance with Section 5.2.1 of DIN 50441/4 or by a dial gauge method (see NOTE 8) as agreed upon between supplier and purchaser.

10.13 *Notch Dimension* — Determine the depth and angle of the fiducial notch in accordance with ASTM Test Method F 1152 with the use of a wafer holding fixture appropriate for silicon wafers.

10.14 *Notch Orientation* — No test method for verifying the crystal axis of the orientation fiducial axis of notched wafers has yet been standardized. Accordingly, test procedures for making this determination shall be agreed upon between supplier and purchaser. A starting point may be an extension of ASTM Test Method F 847 with fixturing appropriate to notched wafers.

10.15 *Edge Profile Shape* — Determine the suitability of the edge profile in accordance with ASTM Test Method F 928 or DIN 50441/2.

10.16 *Edge Surface Finish* — Establish the surface finish of the edge region of the wafer by a method agreed upon between supplier and purchaser.

10.17 *Thickness, Center Point* — Determine thickness, center point may in accordance with ASTM Test Method F 533, JIS H 0611, or DIN 50441/1; special jigs or fixtures may be needed to allow the probe to reach the center point of the wafer.

10.18 *Total Thickness Variation* — Determine in accordance with ASTM Test Method F 533, ASTM Test Method F 657, DIN 50441/1, and JIS H 0611.

NOTE 2: ASTM Test Method F 533, DIN 50441/1, and JIS H 0611 are all 5-point methods, while Test Method F 657 involves a continuous scan pattern. JIS H 0611 differs from ASTM Test Method F 533 and DIN 50441/1 in that the measurements in JIS H 0611 are taken at the center and at 5 mm from the edge on diameters parallel and perpendicular to the major flat, while the measurements in the latter two test methods are taken at the center and at the same radial distance (R nominal - 6 mm) on diameters 30 degrees and 120 degrees counterclockwise from the bisector to the primary flat or notch (with the wafer facing front surface up).

10.19 *Surface Orientation* — Determine the crystallographic orientation of the wafer surface in accordance with ASTM test methods F 26, JEIDA Method 18, or DIN 50433 using a suitable fixture to hold wafer.

10.20 *Bow and Warp* — Determine bow in accordance with ASTM Test Method F 534 and warp in accordance with ASTM Test Method F 1390 or Test Method F 657.

NOTE 3: ASTM has standardized two methods for measuring warp. ASTM Test Method F 1390 is an automated, non-contact method which provides for correction of the wafer deflection due to gravitational effects. The scan pattern covers the entire fixed quality area. ASTM Test Method F 657 is a manual, non-contact method which has a continuous, prescribed scan pattern which covers only a portion of the wafer surface. There is no provision for correction of the wafer deflection due to gravitational effects. As noted in Appendix 2, different reference planes are used for the two methods. Because Test Method F 657 employs a back surface reference plane, the measured warp may include contributions from thickness variation of the wafer. Test Method F 1390 employs a median surface reference plane and is not susceptible to interferences from thickness variations. In general, Test Method F 1390 is preferred, especially for wafers 150 mm in diameter and larger, although ASTM Test Method F 1530 may also be used for this determination.

10.21 *Sori* — If sori is specified in lieu of bow or warp or both, determine by a method agreed upon between the supplier and the purchaser.

NOTE 4: Because sori is a property of the top surface of an unclamped wafer, it may be measured on many types of flatness measuring instruments. ASTM Test Method F 1451 may, in principle, be used for determination of sori.

10.22 *Flatness* — Determine by a method agreed upon between the supplier and the purchaser. It is recommended that site flatness is determined in accordance with ASTM Test Method F 1530 using a site-by-site front surface reference (indicated by the acronym SFQR in the Flatness Decision tree (see SEMI M1, Figure A1-1)). The percent usable area (PUA) shall be calculated as the percentage of the total number of full sites within the FQA that meet the specification.

10.23 *Surface Metal Contamination* — Determine surface metal contamination by a method agreed upon between supplier and purchaser; ASTM Test Method F 1617 is suitable for sodium and aluminum, and ASTM Test Method F 1526 is suitable for chromium, iron, nickel, copper, and zinc at the specified levels. Other, more sensitive methods may also be utilized by agreement between supplier and purchaser.

10.24 *Back Surface Gloss* — Determine test method in accordance with ASTM D523 or JIS Z8741 using a 60 degree of incidence and referencing the zero to a mirror polished wafer front surface instead of reference gloss surface as described in these feat method.

11 Surface Defect Criteria

11.1 Front surface defect criteria are shown in Item 8 in attached specification tables.

11.2 *Minimal Conditions or Dimensions* — The minimal conditions or dimenions for defects stated below shall be used for determining wafer acceptability. Anomalies smaller than these limits shall not be considered defects.

11.2.1 *area contamination* — Any foreign matter on the surface in localized areas which is revealed under the inspection lighting conditions as discolored, mottled, or cloudy appearance resulting from smudges, stains, water spots, etc.

11.2.2 *crack* — Any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.2.3 *crow's foot* — Any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.2.4 *dimple* — Any smooth surface depression greater than 3 mm in diameter.

11.2.5 *edge chip and indent* — Any edge anomaly, including saw exit marks, conforming to the definition and greater than 0.25 mm (0.010 inch) in radial depth and peripheral length.

11.2.6 *hand scribe mark* — Any mark such as that caused by a diamond scribe that is visible under diffuse illumination.

11.2.7 *haze* — Haze is indicated when the image of a narrow beam tungsten lamp filament is detectable on the polished wafer surface. (Under some conditions, contamination may appear as haze.)

11.2.8 *orange peel* — Any roughened surface conforming to the definition that is observable under diffuse illumination.

11.2.9 *particulate contamination* — Distinct particles, resting on the surface, which are revealed under collineated light as bright points.

11.2.10 *pit* — Any individually distinguishable non-removable surface anomaly conforming to the definition and visible when viewed under high intensity illumination.

11.2.11 *saw marks* — Any surface irregularities conforming to the definition that are observable under diffuse illumination.

11.2.12 *scratch* — Any anomaly conforming to the definition and having a length-to-width ratio greater than 5:1.

11.2.13 *slip* — Any pattern of short ridges aligned along <111> directions and visible under diffuse illumination.

11.2.14 *striations* — Any helical features conforming to the definition and visible under diffuse illumination.

11.3 Back surface defect criteria are specified in attached specification tables.

12 Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

12.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 10. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

13 Packing and Marking

13.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices, to provide ample protection against damage during shipment.

13.2 The wafers supplied under this specification shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification shall include, as a minimum, wafer classification, nominal diameter, surface orientation, growth method, lot number, and origin. In addition, identification of premium wafers shall include conductivity type and resistivity range of the lot. The lot number, either (1) assigned by the original manufacturer of the wafer, or (2) assigned subsequent to wafer manufacture but providing reference to the original lot number, shall provide easy access to information concerning the fabrication history of the particular wafers in that lot. Such information shall be retained on file at the vendor's facility for at least one month after that particular lot has been accepted by the purchaser.

Table 2 Specification for Polished Monocrystaline Silicon Premium Wafers for 250 nm Design Rule Usage

	CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
1.	GENERAL CHARACTERISTICS				
1.1	Growth Method	CZ or MCz	CZ or MCz	Cz or MCz	
1.2	Crystal Orientation	(100) ± 1°	(100) ± 1°	(100) ± 1°	ASTM F 26, DIN 50433
1.3	Conductivity Type	*n* or *p*	*n* or *p*	*n* or *p*	ASTM F 42, JIS H 607, DIN 50432
1.4	Dopant	P or B	P or B	P or B	ASTM F 1389, F 1630, DIN 50438/3
1.5	Nominal Edge Exclusion (Distance for Fixed Quality Area)	3 mm	3 mm	3 mm	
2.	ELECTRICAL CHARACTERISTICS				
2.1	Resistivity, Center Point	NS	≥ 1 Ω-cm	NS	ASTM F 84, F 673, JIS H 602, DIN 50431, 50445
2.2	Radial Resistivity Variation	NS	NS		ASTM F 81, DIN 50435
2.4	Carrier Recombination Lifetime (see NOTE 1)	NS	≥ 200 µs		JEIDA 53, F 1535
3.	CHEMICAL CHARACTERISTICS				
3.1	Oxygen Concentration: Spec. Range of Center Point: Target	NS	$\leq 1.2 \times 10^{18}/cm^3$	NS	ASTM F 1188, F 1619, DIN 50438/1, JEIDA 61
3.1.1	Oxygen Concentration: Tolerance Around Center Point: Target		≤ 10%		
3.2	Radial Oxygen Variation		NS		
3.3	Carbon Concentration		≤ 0.2 ppma		ASTM F 1391, DIN 50438/2, JEIDA 56
3.-	Total Bulk Iron Concentration (see NOTE 2)		$\leq 5 \times 10^{10}/cm^3$		ASTM F 987
4.	STRUCTURAL CHARACTERISTICS				
4.1	Dislocation Etch Pit Density	NS	$\leq 500/cm^2$	NS	ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.2	Slip		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.3	Lineage		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.4	Twin		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.5	Swirl	NS	None	NS	ASTM F 416, JIS H 614, DIN 50443/1
4.6	S-pits		None		ASTM F 416, F 1049
4.7	Oxidation-Induced Stacking Faults (OSF) (see NOTE 3)		User/Vendor		ASTM F 416 User/Vendor mutual agreement
4.8	Oxide Precipitates (BMD) Interstitial Oxygen Reduction (Δ O_i) (see NOTE 4)		User/Vendor		ASTM F 1239 User/Vendor mutual agreement
5.	WAFER PREPARATION CHARACTERISTICS				
5.1	Wafer ID Marking	Optional	Optional	Optional	
5.3	Denuded Zone	NS	NS	NS	
5.4	Extrinsic Gettering Treatment	None	None	None	

CLASSIFICATION ITEMS (SEMI M18)		*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
5.5	Backseal	NS	None	NS	
5.6	Annealing	NS	Donor Annihilation Only	NS	
6.	MECHANICAL CHARACTERISTICS				
6.1	Diameter	150, 200, and 300 mm	150, 200, and 300 mm	150, 200, and 300 mm	ASTM F 613,DIN 50441/4, JEIDA 27
6.2	Primary Flat Length/Diameter Notch Dimensions	SEMI M1	SEMI M1	SEMI M1	ASTM F 671, F 1152, DIN 50441/4 JEIDA 27
6.3	Primary Flat/Notch Orientation				ASTM F 847
6.4	Secondary Flat Length				ASTM F 671, DIN 50441/4
6.5	Secondary Flat Location				ASTM F 847
6.6	Edge Profile	SEMI M1	SEMI M1	SEMI M1	ASTM F 928, DIN 50441/2
6.-	Edge Surface Finish	Polished	Polished	Polished	
6.7	Thickness, Center Point	SEMI M1	SEMI M1	SEMI M1	ASTM F 533, JIS H 611, DIN 50441/1
6.-	Nine-point Thickness Variation	-	-	-	
6.8	Total Thickness Variation, GBIR	≤ 10 µm	≤ 10 µm	≤ 10 µm	ASTM F 533, F 657, JIS H 611, DIN 50441/1
6.9	Surface Orientation	-	-	-	ASTM F 26, JEIDA 18, DIN 50433
6.10	Bow	-	-	-	ASTM F 534, JIS H 611
6.11, 12	Warp, Sori	NS	NS	300	ASTM F 657, F 1390, F 1451
6.13	Flatness/Global, GFLR	NS	NS	NS	ASTM F 1530, JEIDA 43
6.14	Flatness/Site, SFQR (25 × 25 mm, PUA 90%)			≤ 0.2 µm	
7.	FRONT SURFACE CHEMISTRY				
7.1	Surface Metal Concentration (see NOTE 5)				User/Vendor Mutual Agreement, ASTM F 1526, ASTM F 1617
	Sodium	$\leq 5.0 \times 10^{10}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 5.0 \times 10^{10}/cm^2$	
	Aluminum	$\leq 1.0 \times 10^{11}/cm^2$	$\leq 1.0 \times 10^{11}/cm^2$	$\leq 1.0 \times 10^{11}/cm^2$	
	Chromium	$\leq 5.0 \times 10^{10}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 5.0 \times 10^{10}/cm^2$	
	Iron	$\leq 5.0 \times 10^{10}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 5.0 \times 10^{10}/cm^2$	
	Nickel	$\leq 5.0 \times 10^{10}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 5.0 \times 10^{10}/cm^2$	
	Copper	$\leq 5.0 \times 10^{10}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 5.0 \times 10^{10}/cm^2$	
	Zinc	$\leq 1.0 \times 10^{11}/cm^2$	$\leq 1.0 \times 10^{11}/cm^2$	$\leq 1.0 \times 10^{11}/cm^2$	
	Calcium	$\leq 1.0 \times 10^{11}/cm^2$	$\leq 2.5 \times 10^{10}/cm^2$	$\leq 1.0 \times 10^{11}/cm^2$	
8.	FRONT SURFACE INSPECTION CHARACTERISTICS				
8.1A	Scratches, Macro	None	None	None	ASTM F 154, F 523, JIS H 614
8.1B	Scratches, Micro	None	≤ 1/10 × D mm	≤ 1/10 × D mm	ASTM F 154, JIS H 614
8.2	Pits	None	None	SEMI M1	ASTM F 154, F 523, JIS H 614
8.3	Haze	None	None	SEMI M1	ASTM F 154, F 523, JIS H 614

CLASSIFICATION ITEMS (SEMI M18)		Particle Counting	Furnace & Thermal Process	Lithography & Patterning	Test Method
8.4	Localized Light Scatterers (LLSs) (≥ 0.125 µm)	≤ 0.6/cm^2	NS	NS	SEMI M25, ASTM F 523, F 1620, F 1621
	(≥ 0.25 µm)	≤ 0.15/cm^2	≤ 0.15/cm^2	≤ 0.15/cm^2	
8.5	Contamination/Area	None	None	None	ASTM F 154, F 523, JIS H 614
8.6	Edge Chips	None	None	None	ASTM F 154, F 523, JIS H 614
8.7	Cracks, Crow's Feet	None	None	None	ASTM F 154, F 523, JIS H 614
8.8	Craters	None	None	None	ASTM F 154, F 523, JIS H 614
8.9	Dimples	None	None	None	ASTM F 154, F 523, JIS H 614
8.10	Grooves	None	None	None	ASTM F 154, F 523, JIS H 614
8.11	Mounds	None	None	None	ASTM F 154, F 523, JIS H 614
8.12	Orange Peel	None	None	None	ASTM F 154, F 523, JIS H 614
8.14	Saw Marks	None	None	None	ASTM F 154, F 523, JIS H 614
8.15	Dopant Striation Ring	None	None	None	ASTM F 154, F 523, JIS H 614
8.-	Microroughness	NS	NS	NS	
9.	BACK SURFACE VISUAL INSPECTION CHARACTERISTICS				
9.1	Edge Chips	None	None	None	ASTM F 154, F 523, JIS H 614
9.6	Roughness, rms	NS	NS	NS	
9.7	Brightness (Gloss) (see NOTE 6)	300 mm ≥ 80% 150, 200 mm NS	300 mm ≥ 80% 150, 200 mm NS	≥ 80% 150, 200 mm NS	ASTM D 523, JIS Z 8741
9.8	Localized Light Scatters (LLSs)	NS	NS	NS	ASTM F 523, F 1620, F 1621, JIS H 614
9.9	Scratches, Macro	≤ 0.25 × D mm	≤ 0.25 × D mm	≤ 0.25 × D mm	ASTM F 154, F 523, JIS H 614
9.10	Scratches, Micro	NS	NS	NS	ASTM F 154, JIS H 614

NOTE 1: Carrier recombination lifetime is well known to be dependent on dopant concentration. If there exist any difficulties to realize resistivity of 1 ohm-cm and recombination lifetime of 200 ms simultaneously, it is advised that specification of those two items be determined based upon user-supplier mutual agreement.

NOTE 2: Specification of bulk iron requires mutual agreement between supplier and purchaser as to both the specification limit and test procedure.

NOTE 3: Specification of OSFs requires mutual agreement between supplier and purchaser.

NOTE 4: Specification of BMDs requires mutual agreement between supplier and purchaser.

NOTE 5: Surface metal contamination should be determined by a method agreed upon between supplier and purchaser; ASTM Test Method F 1617 is suitable for sodium and aluminum, and ASTM Test Method F 1526 is suitable for chromium, iron, nickel, copper, and zinc at the specified levels. More sensitive methods may also be utilized with agreement between supplier and purchaser. Surface Metal Contamination specifications for "Furnace & Thermal Process" wafer are based on NTRS 1997.

NOTE 6: Gloss: As measured with visible light at an incident angle of 60°, referenced to a mirror polished silicon wafer front surface.

Table 3 Specification for Polished Monocrystalline Silicon Premium Wafers for 180 nm Design Rule Usage

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
1. GENERAL CHARACTERISTICS				
1.1 Growth Method	Cz or MCz	Cz or MCz	Cz or MCz	
1.2. Crystal Orientation	(100) ± 1°	(100) ± 1°	(100) ± 1°	ASTM F 26, DIN 50433
1.3 Conductivity Type	n or p	n or p	n or p	ASTM F 42, JIS H607 DIN 50432
1.4 Dopant	P or B	P or B	P or B	ASTM F 1389, F 1630, DIN 50438/3
1.5 Nominal Edge Exclusion (Fixed Quality Area) (See NOTE 1)	300 mm: 2 mm 200 mm: 3 mm	300 mm: 2 mm 200 mm: 3 mm	300 mm: 2 mm 200 mm: 3 mm	
2. ELECTRICAL CHARACTERISTICS				
2.1 Resistivity, Center Point	NS	≥ 1 Ω-cm (See NOTE 4)	NS	ASTM F 84, F 673, JIS H 602, DIN 50431, 50445
2.2 Radial Resistivity Variation	NS	NS		ASTM F 81, DIN 50435
2.4 Minority Carrier Lifetime (Carrier Recombination Lifetime)	NS	≥ 325 µs (See NOTE 4)		JEIDA 53, F 1535
3. CHEMICAL CHARACTERISTICS				
3.1 Oxygen Concentration: Spec. Range of Center Point: Target	NS	$\leq 1.2 \times 10^{18}$ /cm^3	NS	ASTM F 1188, F 1619 DIN 50438/1, JEIDA 61
3.1.1 Oxygen Concentration: Tolerance Around Center Point: Target		≤ 10%		
3.2 Radial Oxygen Variation		NS		
3.3 Carbon Concentration		≤ 0.2 ppma		ASTM F 1391, DIN 50438/2, JEIDA 56
3.- Total Bulk Iron Concentration		$\leq 5 \times 10^{10}$ /cm^3		ASTM F 978
4. STRUCTURAL CHARACTERISTICS				
4.1 Dislocation Etch Pit Density	NS	≤ 500/cm^2	NS	ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.2 Slip		None		ASTM F 47 JIS H 609, DIN 50434, 50443/1
4.3 Lineage		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.4 Twin		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.5 swirl		None		ASTM F 416, JIS H 614, DIN 50443/1
4.6 S-pits		None		ASTM F 416, F 1049

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
4.7 Oxidation Induced Stacking Faults (OSF)		User/Vendor		ASTM F 416, User/Vender mutual agreement
4.8 Oxide Precipitates (BMD) Interstitial Oxygen Reduction (Δ Oi)		User/Vendor		ASTM F 1239, User/Vender mutual agreement
5.WAFER PREPARATION CHARACTERISTICS				
5.1 Wafer ID Marking (See NOTE 2)	Optional	Optional	Optional	
5.3 Denuded Zone	NS	NS	NS	
5.4 Extrinsic Gettering Treatment	None	None	None	
5.5 Backseal	NS	None	NS	
5.6 Annealing	NS	Donor Annih. Only	NS	
6. MECHANICAL CHARACTERISTCS				
6.1 Diameter	200 and 300 mm	200 and 300 mm	200 and 300 mm	ASTM F 613, DIN 50441/4, JEIDA27
6.2 Primary Flat Length/Diameter Notch Dimensions	SEMI M1	SEMI M1	SEMI M1	ASTM F 671, F 1152, DIN 50441/4 JEIDA 27,
6.3 Primary Flat/ Notch Orientation				ASTM F 847
6.4 Secondary Flat Length				ASTM F 671, DIN 50441/4
6.5 Secondary Flat Location				ASTM F 847
6.6 Edge Profile	SEMI M1	SEMI M1	SEMI M1	ASTM F 928, DIN 50441/2
6.- Edge Surface Finish	Polished	Polished	Polished	
6.7 Thickness, Center Point	SEMI M1	SEMI M1	SEMI M1	ASTM F 533, JIS H 611, DIN 50441/1
6.- Nine-point Thickness Variation	-	-	-	
6.8 Total Thickness Variation, GBIR	≤ 10 µm	≤ 10 µm	≤ 5 µm	ASTM F 533, F 657, JIS H 611, DIN 50441/1
6.9 Surface Orientation	-	-	-	ASTM F 26, JEIDA 18, DIN 50433
6.10 Bow	-	-	-	ASTM F 534, JIS H 611
6.11, 12 Warp, Sori	NS	NS	300 ≤ 100 µm 200 ≤ 75 µm	ASTM F 657, F 1390, F 1451
6.13 Flatness/Global, GFLR	NS	NS	NS	ASTM F 1530, JEIDA 43
6.14 Flatness/Site, SFQR (25 × 25 mm, PUA 90%) SFSR (25 mm × 32 mm)			≤ 180 nm ≤ 150 nm	
7. FRONT SURFACE CHEMISTRY				

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
7.1 Surface Metal Concentration (atoms/cm^2)	(See NOTE 6)	(See NOTE 5)	(See NOTE 6)	User/Vendor
Sodium	$\leq 5.0 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 5.0 \times 10^{10}$ /cm^2	Mutual Agreement,
Aluminum	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	ASTM F 1526,
Chromium	$\leq 5.0 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 5.0 \times 10^{10}$ /cm^2	ASTM F 1617
Iron	$\leq 5.0 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 5.0 \times 10^{10}$ /cm^2	
Nickel	$\leq 5.0 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 5.0 \times 10^{10}$ /cm^2	
Copper	$\leq 5.0 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 5.0 \times 10^{10}$ /cm^2	
Zinc	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	
Calcium	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	
8. FRONT SURFACE INSPECTION CHARACTERISTICS				
8.1 A Scratches, Macro	None	None	None	ASTM F 154, F 523, JIS H 614
8.1 B Scratches, Micro	None	$\leq 1/10 \times$ D mm	$\leq 1/10 \times$ D mm	ASTM F 154, JIS H 614
8.2 Pits	None	None	SEMI M1	ASTM F 154, F 523, JIS H 614
8.3 Haze	None	None	SEMI M1	ASTM F 154, F 523, JIS H 614
8.4 Localized Light Scatterers (LLSs)				
($\geq$ 90 nm) (See NOTE 3)	$\leq$ 0.29/cm^2	NS	NS	SEMI M25,
($\geq$ 180 nm) (See NOTE 7)	-	$\leq$ 0.15/cm^2	$\leq$ 0.15/cm^2	ASTM F 523, F 1620, F 1621
8.5 Contamination/Area	None	None	None	ASTM F 154, F 523, JIS H 614
8.6 Edge chips	None	None	None	ASTM F 154, F 523, JIS H 614
8.7 Cracks, Crow's Feet	None	None	None	ASTM F 154, F 523, JIS H 614
8.8 Craters	None	None	None	ASTM F 154, F 523, JIS H 614
8.9 Dimples	None	None	None	ASTM F 154, F 523, JIS H 614
8.10 Grooves	None	None	None	ASTM F 154, F 523, JIS H 614
8.11 Mounds	None	None	None	ASTM F 154, F 523, JIS H 614
8.12 Orange Peel	None	None	None	ASTM F 154, F 523, JIS H 614
8.14 Saw Marks	None	None	None	ASTM F 154, F 523, JIS H 614
8.15 Dopant Striation Ring	None	None	None	ASTM F 154, F 523, JIS H 614
8.- Microroughness	NS	NS	NS	
9. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS				
9.1 Edge Chips	None	None	None	ASTM F 154, F 523, JIS H 614
9.6 Roughness, rms	NS	NS	NS	
9.7 Brightness (Gloss)	300 mm $\geq$ 80% 200 mm NS	300 mm $\geq$ 80% 200 mm NS	300 mm $\geq$ 80% 200 mm NS	ASTM D 523, JIS Z8741

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
9.8 Localized Light Scatterers (LLSs)	NS	NS	NS	ASTM F 523, F 1620, F 1621, JIS H 614
9.9 Scratches, Macro	≤ 0.25 × D mm	≤ 0.25 × D mm	≤ 0.25 × D mm	ASTM F 154, F 523, JIS H 614
9.10 Scratches, Micro	NS	NS	NS	ASTM F 154

NOTE 1: Nominal Edge Exclusion: 2 mm can be achievable in new 300 mm equipment; however, it will be difficult in conventional 200 mm equipment. Edge Exclusion Task Force is now making activities for developing a guide containing definition of edge exclusion when a measurement is made over a finite sampling area.

NOTE 2: Wafer ID Marking: SEMI M1 specification shall be applied, if ID mark is applied.

NOTE 3: LLSs: LLSs for particle counting wafer is specified only by the half size of design rule. These specification values shall be reviewed when the evaluation techniques for distinguishing particle and COP are established. The nominal particle size can be transferred to another particle size using coefficient value and the latter can be applicable for the usage.

NOTE 4: Carrier Recombination Lifetime: Carrier recombination lifetime is affected by carrier concentration (resistivity) and metallic impurities. Specified resistivity and bulk iron concentration are only necessary conditions for obtaining the specified carrier recombination lifetime.

NOTE 5: Surface Metal Contamination for Furnace and Thermal Process: The proposed specification values are recommended ones considering NTRS 1997 and current measuring technology and accuracy.

NOTE 6: Surface Metal Contamination for Particle Counting and Lithography & Patterning: The values are proposed considering current process capabilities and the necessary level for their usage.

NOTE 7: LLSs for Furnace & Thermal Process and Lithography & Patterning: The values are proposed considering current process capabilities and the necessary level for their usage.

NOTE 8: The nominal particle size can be transferred to another particle size using coefficient value and the latter can be applicable for the usage.

Table 4 Specification Guide for Polished Monocrystalline Silicon Premium Wafers for 130 nm Design Rule Usage

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
1. GENERAL CHARACTERISTICS				
1.1 Growth Method	Cz or MCz	Cz or MCz	Cz or MCz	
1.2. Crystal Orientation	(100)	(100)	(100)	ASTM F 26, DIN 50433
1.3 Conductivity Type	n or p	n or p	n or p	ASTM F 42, JIS H607 DIN 50432
1.4 Dopant	P or B	P or B	P or B	ASTM F 1389, F 1630, DIN 50438/3
1.5 Nominal Edge Exclusion (See NOTE 1) (Fixed Quality Area)				
300 mm	2 mm	2 mm	2 mm	
200 mm	3 mm	3 mm	3 mm	
2. ELECTRICAL CHARACTERISTICS				
2.1 Resistivity, Center Point	NS	≥ 1 Ω-cm	NS	ASTM F 84, F 673, JIS H 602, DIN 50431, 50445
2.2 Radial Resistivity Variation	NS	NS		ASTM F 81, DIN 50435
2.4 Minority Carrier Lifetime (Carrier Recombination Lifetime)	NS	≥ 325 µs		JEIDA 53, ASTM F 1535
3. CHEMICAL CHARACTERISTICS				

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
3.1 Oxygen Concentration	NS	$\leq 1.2 \times 10^{18}$ /cm^3	NS	ASTM F 1188, F 1619 DIN 50438/1, JEIDA 61
3.1.1 Oxygen Concentration Tolerance: Tolerance around Center Point		≤ 10%		
3.2 Radial Oxygen Variation		NS		
3.3 Carbon Concentration		≤ 0.2 ppma		ASTM F 1391, DIN 50438/2, JEIDA 56
3.- Total Bulk Iron Concentration		$\leq 5 \times 10^{10}$ /cm^3		ASTM F 978
4. STRUCTURAL CHARACTERISTICS				
4.1 Dislocation Etch Pit Density	NS	≤ 500/cm^2	NS	ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.2 Slip		None		ASTM F 47 JIS H 609, DIN 50434, 50443/1
4.3 Lineage		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.4 Twin		None		ASTM F 47, JIS H 609, DIN 50434, 50443/1
4.5 swirl		None		ASTM F 416, JIS H 614, DIN 50443/1
4.6 S-pits		None		ASTM F 416, F 1049
4.7 Oxidation Induced Stacking Faults (OSF)		User/Vendor		ASTM F 416, User/Vender mutual agreement
4.8 Oxide Precipitates (BMD) Interstitial Oxygen Reduction (Δ Oi)		User/Vendor		ASTM F 1239, User/Vender mutual agreement
5.WAFER PREPARATION CHARACTERISTICS				
5.1 Wafer ID Marking (See NOTE 2)	Optional	Optional	Optional	
5.3 Denuded Zone	NS	NS	NS	
5.4 Extrinsic Gettering Treatment	None	None	None	
5.5 Backseal	NS	None	NS	
5.6 Annealing	NS	Donor Annih. Only	NS	
6. MECHANICAL CHARACTERISTCS				
6.1 Diameter	200 and 300 mm	200 and 300 mm	200 and 300 mm	ASTM F 613, DIN 50441/4, JEIDA27
6.2 Primary Flat Length/Diameter Notch Dimensions	SEMI M1	SEMI M1	SEMI M1	ASTM F 671, F 1152, DIN 50441/4 JEIDA 27,

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
6.3 Primary Flat/ Notch Orientation				ASTM F 847
6.4 Secondary Flat Length				ASTM F 671, DIN 50441/4
6.5 Secondary Flat Location				ASTM F 847
6.6 Edge Profile	SEMI M1	SEMI M1	SEMI M1	ASTM F 928, DIN 50441/2
6.- Edge Surface Finish	Polished	Polished	Polished	
6.7 Thickness, Center Point	SEMI M1	SEMI M1	SEMI M1	ASTM F 533, JIS H 611, DIN 50441/1
6.8 Total Thickness Variation, GBIR	≤ 5µm	≤ 5 µm	≤ 3 µm	ASTM F 533, F 657, JIS H 611, DIN 50441/1
6.9 Surface Orientation	0 ± 1.0°	0 ± 1.0°	0 ± 1.0°	ASTM F 26, JEIDA 18, DIN 50433
6.11, 12 Warp, Sori 300 mm 200 mm	 NS NS	 NS NS	 ≤ 100 µm ≤ 75 µm	ASTM F 657, F 1390, F 1451
6.13 Flatness/Global, GFLR	NS	NS	NS	ASTM F 1530, JEIDA 43
6.14 Flatness/Site, SFSR (25 × 32 mm, PUA 90%)			≤ 130 nm	
7. FRONT SURFACE CHEMISTRY				
7.1 Surface Metal Concentration (atoms/cm^2)	(See NOTE 4)	(See NOTE 3)	(See NOTE 4)	User/Vendor
Sodium	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	
Aluminum	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	Mutual Agreement,
Chromium	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	ASTM F 1526,
Iron	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	ASTM F 1617
Nickel	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	
Copper	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	
Zinc	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	$\leq 1.0 \times 10^{11}$ /cm^2	
Calcium	$\leq 1.8 \times 10^{10}$ /cm^2	$\leq 0.88 \times 10^{10}$ /cm^2	$\leq 1.8 \times 10^{10}$ /cm^2	
8. FRONT SURFACE INSPECTION CHARACTERISTICS				
8.1 A Scratches, Macro (See Note 5)	None	None	None	ASTM F 154, F 523, JIS H 614
8.1 B Scratches, Micro (See Note 5)	None	≤ 1/10 × D mm	≤ 1/10 × D mm	ASTM F 154, JIS H 614
8.2 Pits	None	None	None	ASTM F 154, F 523, JIS H 614
8.3 Haze (See Note 5)	None	None	None	ASTM F 154, F 523, JIS H 614

CLASSIFICATION ITEMS (SEMI M18)	*Particle Counting*	*Furnace & Thermal Process*	*Lithography & Patterning*	*Test Method*
8.4 Localized Light Scatterers (Particulate 90 nm Contamination; LLSs) (See NOTE 6) 300 mm 200 mm	≤ 60/wf ≤ 27/wf	NS NS	NS NS	SEMI M25, ASTM F 523, F 1620, F 1621
(Particulate 0.13 µm Contamination; LLSs) (See NOTE 7)	-	≤ 0.15/cm^2	≤ 0.15/cm^2	
8.5 Contamination/Area	None	None	None	ASTM F 154, F 523, JIS H 614
8.6 Edge chips	None	None	None	ASTM F 154, F 523, JIS H 614
8.7 Cracks, Crow's Feet	None	None	None	ASTM F 154, F 523, JIS H 614
8.8 Craters	None	None	None	ASTM F 154, F 523, JIS H 614
8.9 Dimples	None	None	None	ASTM F 154, F 523, JIS H 614
8.10 Grooves	None	None	None	ASTM F 154, F 523, JIS H 614
8.11 Mounds	None	None	None	ASTM F 154, F 523, JIS H 614
8.12 Orange Peel	None	None	None	ASTM F 154, F 523, JIS H 614
8.14 Saw Marks	None	None	None	ASTM F 154, F 523, JIS H 614
8.15 Dopant Striation Ring	None	None	None	ASTM F 154, F 523, JIS H 614
8.- Microroughness	NS	NS	NS	
9. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS				
9.1 Edge Chips	None	None	None	ASTM F 154, F 523, JIS H 614
9.6 Roughness, rms	NS	NS	NS	
9.7 Brightness (Gloss) 300 mm 200 mm	≥ 80% User/Vendor	≥ 80% User/Vendor	≥ 80% User/Vendor	ASTM D 523, JIS Z8741
9.8 Localized Light Scatterers (LLSs)	NS	NS	NS	ASTM F 523, F 1620, F 1621, JIS H 614
9.9 Scratches, Macro	≤ 0.25 × D mm	≤ 0.25 × D mm	≤ 0.25 × D mm	ASTM F 154, F 523, JIS H 614
9.10 Scratches, Micro	NS	NS	NS	ASTM F 154

NOTE 1: Nominal Edge Exclusion is proposed as the same as in Table2 and as in Table3, however, more discussion will be necessary. Edge Exclusion Task Force is now making activities for developing a guide containing definition of edge exclusion when a measurement is made over a finite sampling area.
NOTE 2: Wafer ID Marking: SEMI M1 specification shall be applied, if ID mark is applied.
NOTE 3: Surface Metal Contamination for Furnace and Thermal Process: The specification values are based on ITRS '99 Roadmap.
NOTE 4: Surface Metal Contamination for Particle Counting and Lithography & Patterning: The specified values are based on 180 nm process requirement in ITRS 1999.
NOTE 5: Visual techniques are neither sufficient nor appropriate for 0.13 µm design rules. Automatic surface inspection tools can be used for reporting values such as scratches and haze. Test method and standardization for automatic surface inspection tools is under development, visual inspection is now used as a supplemental method.

NOTE 6: LLSs (Localized Light Scatterers: 90 nm): These specification values shall be reviewed when the evaluation techniques for distinguishing particle and COP are established. Critical surface LLS size should be the half of CD, however, tools are not well established. 65 nm count limit was transferred to 90 nm count limit using draft international standard: ISO/DIS 14644-1 which follows the equation: 90 nm LLS counts per wafer = 65 nm LLS counts per wafer /$(90 \text{ nm} /65 \text{ nm})^2$.

NOTE 7: LLSs for Furnace & Thermal Process and Lithography & Patterning: New concept is proposed for LLSs for Furnace and Thermal Process. The critical surface LLS size for prime wafer is proposed as a half size of CD in IRTS Roadmap. The half of CD is not necessarily requested for monitor test wafers. In actual business, an additional specification of LLS, the size of which is around CD is used, however, the size is not standardized. TF proposes the additional LLS size as the same size as CD. This size is used for specifying LLS for Furnace & Thermal Process.

SEMI M25-95
SPECIFICATION FOR SILICON WAFERS FOR CALIBRATION OF LIGHT POINT DEFECT WAFER INSPECTION SYSTEMS WITH RESPECT TO THE DIAMETER OF POLYSTYRENE LATEX SPHERES

1 Purpose

1.1 This document describes the specifications to be met by bare silicon wafers used for calibrating surface inspection systems with respect to the diameter of polystyrene latex spheres. This document does not intend to establish manufacturing procedures for calibration wafers.

Note 1: This specification might be used as the basis for making calibration substrates with other materials and/or surfaces.

2 Scope

2.1 Bare silicon wafers on which latex-spheres of a known diameter are deposited are used as standards for the calibration of bare wafer inspection systems. The response curve of the systems is generated for the calibration of the systems with respect to the sizing of polystyrene latex (PSL) spheres, not for counting them.

3 Referenced Documents

3.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

4 Terminology

4.1 *Light-Point Defect (LPD)* — An isolated, localized effect on the wafer surface or in the substrate wafers resulting in increased light scattering intensity above a threshold (unit LSE).

Note 2: LPD is a general term and it includes for example latex spheres and other localized surface irregularities.

4.2 *Latex-Sphere Equivalent (LSE)* — The size unit of an LPD expressed as the diameter of a latex-sphere which scatters the same amount of light as the LPD. This is indicated by adding “LSE” to the length unit used, e.g., 0.2 µm LSE.

Note 3: Sizing may be different for other materials and shapes than PSL spheres because of the different optical designs of inspection systems.

4.3 *Response Curve (RC)* — The relation between measured scattered light intensity and latex-sphere diameters for a calibration surface inspection system. The RC depends on the light source used and may contain non-monotonic regions.

4.4 *LPD histogram* — The distribution of the counts of LPD’s per unit length over their size as expressed in LSE.

5 Requirements

5.1 *Substrates* — The wafers used as substrates for the deposition of latex-spheres must be bare silicon with a native oxide surface and they have to meet the requirements of SEMI M1. In addition to the M1 specification, the surface conditions (for example, roughness) must be in compliance with Section 5.5.2.

Note 4: The substrate wafer must be measured before latex sphere deposition with the same type of instrument to ensure that the conditions of 5.5.2 are fulfilled.

5.2 *Latex-Spheres* — The latex-spheres used must be certified with respect to their diameter and they must be traceable to the Standard Reference Materials (SRM) of the National Institute of Standards and Technology (NIST), former National Bureau of Standards (NBS). The certification methodology must be in accordance with the technologies used by NIST.

Note 5 : If the PSL are not traceable to NIST, the certification method should be fully documented.

5.3 *Range of Latex-Sphere Diameters* — The diameters of the latex-spheres used for calibration must be selected so that the measurement range for the intended application is covered. Sufficient latex-sphere diameters must be used to achieve the required accuracy of the RC.

Note 6: For surface inspection systems using laser light source(s), it is recommended to avoid latex-sphere diameters corresponding approximately to the wavelength of the laser used and its multiples of the laser used.

5.4 *Density of Latex-Spheres Deposited* — The density of the deposited latex-spheres, full or partial wafer coverage, must be selected in such a way that the peak of the histogram of the latex-sphere diameters is at least 100% above the background counts. It has to be verified that the indicated (relevant) peak in the histogram is generated by single, isolated latex-spheres of the specified diameter. A density of 5–15 latex-spheres per square centimeter is recommended.

5.5 *Background Contamination*

5.5.1 Calibration wafers must be handled and stored with great care to avoid contamination and damage.

5.5.2 The bell-shaped peak in the LPD histogram of a calibration wafer which is generated by the latex-spheres must be well-defined and must be well above the background level. The bell-shaped curve has to go down to less than 50% of its peak value on both sides of the maximum within a diameter range of ± 15% as referred to the nominal latex-sphere diameter.

5.6 *Multiple Deposition of Latex-Spheres* — Deposition of latex-spheres with different, well-defined diameters on a calibration wafer is allowed if all the conditions of this specification are met for each kind of deposited latex-sphere size.

6 Packaging

6.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices to provide ample protection against damage during shipment.

7 Data to Accompany Calibration Wafers

7.1 Certificate for average and standard deviation of the diameter of the latex spheres used, including the production lot number of latex-spheres used.

7.2 Date of production and certification of calibration wafer.

7.3 Histogram, as defined above.

7.4 Approximate number of deposited latex-spheres in a specified area.

7.5 Wafer identification.

7.6 Name and address of the originator of the calibration wafers.

7.7 LPD's wafer map.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI M26-96
GUIDE FOR THE RE-USE OF WAFER BOXES AND CASSETTES USED TO TRANSPORT WAFERS

1 Purpose

This document is a guide for box cleaning services, wafer suppliers, and wafer users for the re-use of boxes and cassettes. Its purpose is to encourage the re-use of wafer boxes and cassettes, thereby reducing waste.

2 Scope

None.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI E1 — Specification for 3", 100 mm, 125 mm, and 150 mm Plastic and Metal Wafer Carriers

SEMI T3 — Specification for Semiconductor Wafer Box Labels

3.2 *ANSI Document*[1]

ANSI/EIA - 556-A — Outer Shipping Container Bar Code Label Standard

4 Terminology

4.1 *box wrap* — The wrapping or bagging applied over the wafer box to comprise the product package.

4.2 *cassette* — A device to hold wafers during transport or processing. Also called *wafer carrier*.

Note: In this guide, the emphasis is on the cassette for holding wafers in transport, not in processing. Cassettes for re-use inside the wafer boxes should not be exposed to processing chemicals nor metal contaminants. (Compare SEMI E1 in which the emphasis is on cassettes to hold wafers during processing.)

4.3 *recycle* — To pass through a cycle or process for the purpose of recovering any useful substances from waste material. Compare with *re-use*.

4.4 *re-use* — To re-employ an article in its original form for a purpose which is the same or similar to its initial purpose.

4.5 *seam tape* — Adhesive-coated tape employed to seal the seam between the cover and the base of a box.

4.6 *secondary packaging* — Packaging materials, molded or unmolded, inside the shipping container, which serve to protect the wafer package from damage during transportation.

4.7 *shipping container* — A carton used to transport wafer boxes; it is typically constructed of corrugated cardboard.

4.8 *wafer box* — A sealable container, consisting of a base and a cover, used for storing or transporting wafers. Compare with transport package in ANSI/EIA 556-A.

4.9 *wafer box label* — The label on the box identifying the product and its manufacturer (see SEMI T3).

5 Suitability for Re-Use

5.1 The ability to re-use wafer boxes and cassettes is adversely affected by certain characteristics. Some of these characteristics also impact on the ability to recycle.

5.1.1 The following characteristics are recommended:

5.1.1.1 generic embossed markings (e.g., model name, model number, manufacturer's information, such as name and location),

5.1.1.2 embossed recycle symbol, trademark symbol, mold markings,

5.1.1.3 embossed instructions,

5.1.1.4 removable labels with low residue, low tack adhesives,

5.1.1.5 removable seam tape with low residue, low tack adhesives,

5.1.1.6 removable methods of identification,

5.1.1.7 stackable wafer box bases and covers,

5.1.2 The following characteristics are not recommended:

5.1.2.1 “custom” embossed markings,

5.1.2.2 end-user specific logos, symbols, and markings,

5.1.2.3 high residue tape and labels,

5.1.2.4 labels which are difficult to remove or are non-removable,

5.1.2.5 non-removable marks such as inks and other coloring.

1 American National Standards Institute, 1430 Broadway, New York, NY 10018

6 Procedural Guidelines

6.1 *Collection Method at the Wafer User Facility*

6.1.1 Unpack shipping containers and save for re-use or recycle.

6.1.2 Remove box wrap and seam tape from boxes under a clean air module or in a cleanroom. Exercise care when removing the box wrap; avoid scuffing or cutting the box surface. If recyclable, collect box wrap material and seam tape in designated containers.

6.1.3 Remove wafers from box in cleanroom area. Remove all labels from the box.

6.1.4 Place boxes and cassettes for re-use in a designated collection container or collection area.

6.1.5 Maintain the cassettes and boxes for re-use in an environment free from contact with metal contaminants and process chemicals.

6.1.6 Periodically return boxes and cassettes for reclean to the reclean service location or the wafer supplier.

6.1.7 Whenever possible, cycle cassettes and boxes between the same wafer user and wafer supplier.

6.2 *Box and Cassette Cleaning at the Reclean Service Location*

6.2.1 The supplier of the reclean service must engineer the reclean process.

6.2.2 At the service supplier's option, visually inspect the boxes and cassettes prior to cleaning. The wafer supplier and wafer user should agree to acceptable and unacceptable levels of defects, recognizing that there will be some normal wear. These levels should be provided to the service supplier. Inspect for the following defects:

6.2.2.1 deformation or warp,

6.2.2.2 razor cuts, scuffs, breaks, cracks, voids, and fractures,

6.2.2.3 contamination and imbedded silicon,

6.2.2.4 damage to tension springs or other wafer retention mechanisms,

6.2.2.5 markings and labels.

6.2.3 Collect defective parts for recycle, and clean acceptable parts as follows:

6.2.3.1 Clean using an aqueous-based or non-aqueous-based chemistry,

6.2.3.2 Chlorofluorocarbon chemistries are not permitted.

6.2.3.3 Confirm the compatibility of the box and cassette materials with the cleaning method and drying conditions.

6.2.4 Visually inspect the boxes and cassettes after cleaning using a high intensity or an ultraviolet light. The wafer user and the wafer supplier should agree to acceptable and unacceptable levels of defects, recognizing that there will be some normal wear. Inspect for all the defects noted in 5.2.2.2 and, in addition, for:

6.2.4.1 residues from labels, markings, or tape,

6.2.4.2 failure of the box halves to seat and seal together.

6.2.5 Collect defective parts for recycle.

6.2.6 Return acceptable boxes and cassettes to the wafer supplier using box wrap, nesting material, and shipping containers as required to maintain cleanliness and mechanical integrity.

6.3 *Maximum Number of Re-Use Cycles*

6.3.1 Base the total number of re-use cycles on the ability to maintain both mechanical integrity and cleanliness.

Note: By following this guide, some users have found that boxes and cassettes processed through more than four re-use cycles were still satisfactory.

SEMI M27-96
PRACTICE FOR DETERMINING THE PRECISION OVER TOLERANCE (P/T) RATIO OF TEST EQUIPMENT

1 Purpose

1.1 This practice covers a procedure for estimating the capability of a test instrument with respect to the tolerance (specification) of a parameter.

NOTE 1: If the variability associated with the measurement of the parameter by this instrument is very small compared with the width of the specification range, the chances of obtaining a test result outside the specification limits when the parameter actually lies within the specification limits (or conversely) is quite small. On the other hand, if this variability is too large, the probability of obtaining a false test result is much greater.

2 Scope

2.1 This practice provides a standardized method for determining the relationship between the measurement precision of a single instrument and the specification range.

2.2 The ratio of precision to tolerance *(P/T)* can be used as a measure of the suitability of a measurement process to evaluate a specific parameter against a given specification. Calculation of the *P/T* ratio requires knowledge both of the precision of the measurement process and of the specification range or tolerance of interest.

NOTE 2: If the tolerance has been arbitrarily defined without regard to process variability or other considerations, the *P/T* ratio might be meaningless.

NOTE 3: Another metric for the suitability of test equipment is the signal to noise *(S/N)* ratio, which relates the process variability to the measurement variability; consideration of this metric is beyond the scope of this practice.

NOTE 4: The *P/T* ratio does not provide any information about the bias of the test instrument being evaluated; hence, it is not a suitable metric for test instrument accuracy.

2.2.1 A procedure is given for estimating the overall measurement precision of the measurement process as carried out by an automated (self-calibrating) or non-automated (non-self calibrating) test instrument under the conditions normally encountered in applying the instrument. No information is developed concerning the components of the precision; consequently, this practice cannot be used to determine the origins of measurement variability. Such information can be developed through the use of a full measurement capability analysis such as a properly designed gauge repeatability and reproducibility study.[1]

2.2.2 Both double-sided and single-sided specifications are covered by this practice.

NOTE 5: It is not meaningful to compare *P/T* ratios between single-sided and double-sided specifications of the same parameter.

3 Referenced Documents

3.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

4 Terminology

4.1 *accuracy* — The closeness of agreement between a test result or the mean of a group of test results and the true value (accepted reference value).

DISCUSSION — Accuracy depends on both precision and bias of the measurement process. Since in routine use, random components of error (resulting in imprecision) and systematic components of error (resulting in bias) cannot be completely separated, the reported accuracy must be interpreted as a combination of these two elements. In part, because of the inability to separate the random and systematic components of error, the ISO Guide to the Expression of Uncertainty in Measurement[2] separates uncertainty components of a measurement result into two categories (Type A and Type B) based on their method of evaluation. Type A uncertainties are those that are evaluated by the statistical analysis of a series of observations. Type B uncertainties are those that are evaluated by other (non-statistical) means.

4.2 *bias* — The systematic difference between the population mean of the test results from a measurement process and the accepted reference value of the property being measured.

1 Steven A. Eastman, "Evaluating Automated Wafer Measurement Instruments," in Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A. C. Diebold, eds. (AIP Press, Woodbury, NY, 1995) pp. 248 - 251.

2 ISO/TAG 4/WG 3 Guide to the Expression of Uncertainty in Measurement (October 1993), available from ISO Central Secretariat, C. P. 56, CH-1211 Genève 20, Switzerland, or (in the U.S.) from American National Standards Institute, 11 West 42nd Street, 13th floor, New York, NY 10036. Also see: Barry Taylor and Chris Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, 1994 Edition, NIST Technical Note 1297 (September 1994).

DISCUSSION — One or more systematic error components may contribute to the bias. Because the population mean involves the totality of all possible test results, it cannot be determined directly. The sample mean, x is an unbiased estimator of the population mean.

4.3 *precision* — A measure of the variability of a measurement process about the mean value of the test results obtained.

DISCUSSION — For purposes of this practice, the precision of the test instrument is quantified as 6 times the sample standard deviation of a set of individual test results made under conditions typical of those encountered in the normal use of the measurement equipment being evaluated. Among other factors, drift between instrument calibrations and known and unknown variabilities caused by ambient conditions must be considered. If the data set consists only of a small number of samples, the estimate of precision may be in error.

4.4 *tolerance* — The absolute magnitude of the range of the product specification.

DISCUSSION — Tolerance and specification are sometimes used interchangeably. Certain industries prefer one term to the other. In some cases, in particular in SEMI M1, the tolerance is given in terms of the deviation from the mean. For the purpose of this practice, the tolerance is always the full range of the specification.

5 Procedure

5.1 *Determine the Tolerance (T)*

5.1.1 For a double-sided specification, calculate T from:

$$T = USL - LSL$$

where USL is the upper specification limit and LSL is the lower specification limit ($USL > LSL$). If the specification is given as "DIMENSION," $T = 2a$.

5.1.2 For a single-sided specification with only an LSL or USL, take T as the magnitude of the LSL or USL.

5.2 *Determine the Precision (P)*

5.2.1 Ensure that the test instrument being evaluated is under acceptable statistical control by the methods customarily employed to evaluate the state of control of test instrumentation in the laboratory carrying out the evaluation.

5.2.2 Make a series of measurements of the desired parameter on a test specimen with the test instrument being evaluated under conditions and for a period of time typical of those encountered in use of the test instrument. Record each individual test result as x_i, where i ranges from 1 to n, the total number of test results in the set. Note and record the range of operating conditions (operator, temperature, humidity, automatic recalibration, loading and unloading of the test specimen, repositioning, illumination, etc., as appropriate) encountered while the set of test results is being collected.

NOTE 6: The test specimen should have characteristics including uniformity that are typical of test specimens to be measured in practice. If evaluation of the test instrument is desired over a range of parameter values (levels), the procedure may be carried out at each level of interest.

NOTE 7: Specification of sampling plans is beyond the scope of this practice. Related Information 1 gives examples of what constitutes a test result for several different types of automated measurement instrumentation.

5.2.3 Estimate the overall standard deviation, $\hat{\sigma}$, of the test results as follows:

$$\hat{\sigma} \approx s = \left| \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n - 1} \right|^{1/2}$$

where:

s = the sample standard deviation of the set of n test results, and

$\bar{x}$ = the sample mean $\left(\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \right)$.

5.2.4 Take as the precision, P, the quantity

$$P = 6\hat{\sigma}$$

5.2.5 Calculate the P/T ratio, in percent, as follows:

$$P/T(\%) = \frac{P}{T} \times 100$$

and round to the nearest percent.

6 Interpretation

6.1 The value against which the P/T ratio is judged depends upon the application. In general, one prefers that the value of the measurement precision, P, be much smaller than the specification range, T. A test instrument is usually deemed to be suitable for the purpose if P/T lies below 10%. If P/T is greater than 30%, the test instrument is not likely to be suitable for the purpose. Cases for which P/T lies between 10% and 30% must be judged on an individual basis, depending on the requirements being placed on the measurement system.

6.2 Evaluation of the risk of erroneously obtaining a measurement result outside the specification range is dependent upon the instrument response function and the shape of the process distribution, neither of which is determined by the procedures of the practice.

NOTE 8: This practice cannot determine the suitability of the measurement instrument for evaluating the process variation (see NOTE 3).

7 Report

7.1 Report the following information:

7.1.1 Description of the test instrument being evaluated,

7.1.2 Parameter being measured,

7.1.3 Level or levels of the parameter being measured,

7.1.4 A description of the range of measurement conditions used in the evaluation experiments,

7.1.5 Specification range of interest (or the *LSL* and *USL*), and

7.1.6 The *P/T* ratio, in percent.

RELATED INFORMATION 1
EXAMPLES OF TEST RESULTS

NOTE: This related information is not an official part of SEMI M27 and is not intended to modify or supercede the official standard. The standard should be referred to in all cases; this information is provided to illustrate the types of test results anticipated to be used with this standard. This related information accompanied the standard through the consensus balloting process. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

R1-1 Scope

R1-1.1 This related information illustrates the concept of a test result for several types of automated measurements commonly encountered in evaluating silicon materials in the semiconductor industry.

R1-2 Referenced Documents

R1-2.1 *ASTM Standards*[3]

F 673 — Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy-Current Gage

F 1392 — Test Method for Determining Net [sic] Carrier Density Profiles in Silicon Wafers by Capacitance-Voltage Measurements with a Mercury Probe

F 1530 — Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F 1618 — Practice for the Determination of Uniformity of Thin Films on Silicon Wafers

F 1619 — Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with P-Polarized Radiation Incident at the Brewster Angle

R1-2.2 *DIN Standard*[4]

50438, Part 1 — Testing Materials for Semiconductor Technology: Determination of Impurity Content in Semiconductors by Infrared Absorption — Oxygen in Silicon

R1-3 Illustrative Examples

R1-3.1 *Single Reading per Test Result: Flatness, Thickness, or Thickness Variation by Noncontact Scanning* — Consider each reported determination of the desired parameter in accordance with ASTM Test Method F 1530 to be an individual test result; this is the simplest situation likely to be encountered in practice. Note, however, that substantial internal computation may be required to generate the reported determination and that the gauge may or may not be recalibrated or restandardized between individual determinations. Figure R1-1 illustrates an example of flatness (GFLR or TIR) data taken over a period of 261 days. Note that the reported values are discrete, limited by the resolution of the test instrument. The inset shows a histogram of the data, together with a fitted normal distribution with the same mean (0.9693 µm) and standard deviation (0.02657 µm). Note that if a smaller data set had been used, the fit of the normal curve to the actual data would be expected to be much worse than in this example.

3 Annual Book of ASTM Standards, Volume 10.05, published annually by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

4 DIN Standards, Deutsches Institut fur Normung e.v., available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000 Berlin 30, Germany. An English translation is available in Reference 3.

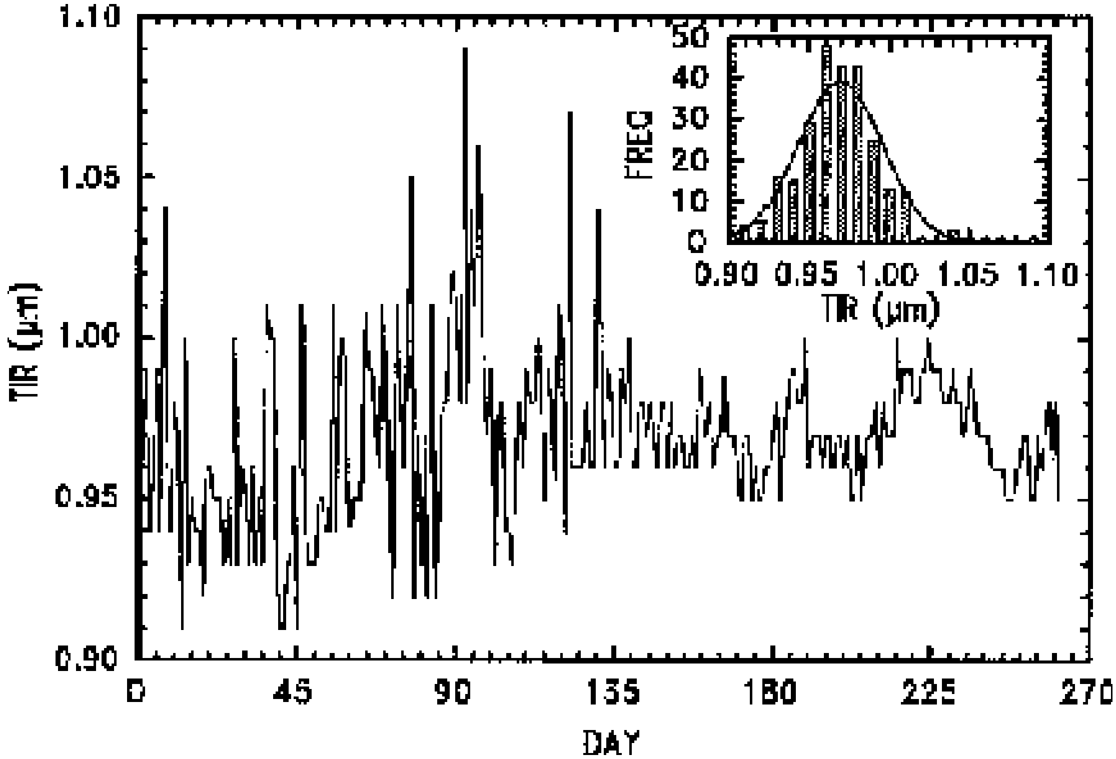

Figure R1-1
Flatness (GFLR) Data Taken on a Wafer Once per Day for a Period of 261 Days

NOTE 9: The resolution of the measurement system is 0.01 µm, so the data have discrete values on the scale shown. The inset shows a histogram of the measured data, together with a normal distribution, having the same mean (0.9693 µm) and standard deviation (0.02657 µm) as the measured data distribution.

R1-3.2 *Single Reading (of an attribute explicitly dependent on the value of another attribute) per Test Result: Resistivity by Eddy Current Gauge* — Consider each determination of the resistivity in accordance with ASTM Test Method F 673 at a given location on the test specimen to be an independent test result; note, however, that although a thickness value is required for each test result, the thickness may or may not be determined for each determination of the resistivity. The choice should be made based on the practice usually used when making measurements with the test instrument being evaluated.

R1-3.3 *Average Reading (of repetitive measurements) per Test Result: Interstitial Oxygen Content by Fourier Transform Infrared Spectroscopy* — In the case of measurements of interstitial oxygen content with FTIR spectrometers in accordance with ASTM Test Method F 1619 or DIN Method 50438/1, each determination reported by the instrument is found by averaging n scans; consider each reported average determination as a test result, and also report the number of scans used in evaluating the test instrument. Note that this number of scans should remain constant throughout the evaluation.

R1-3.4 *Average Reading (of a linear spatial distribution) per Test Result: Average Carrier Density by Mercury Probe C-V* — In the case of measurements of average carrier density in accordance with ASTM Test Method F 1392, a series of measurements of carrier density as a function of depth into the semiconductor is averaged to obtain the average carrier density in the test specimen; consider the average value as a test result. Note that the same depth range should be used throughout the evaluation.

R1-3.5 *Mean Value and Sample Standard Deviation (of an area spatial distribution) per Test Result: Wafer Mapping* — Frequently film thickness, sheet resistance, or other data obtained from wafer maps in accordance with Practice F 1618 is reported as a mean and sample standard deviation in order to facilitate comparisons of one wafer with another. In the context of this practice, the mean and standard deviation each may be treated as a test result. Alternatively, data from each measurement location (or a subset of the measurement locations) may be treated individually.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M28-0997 (Withdrawn 1000)
SPECIFICATION FOR DEVELOPMENTAL 300 mm DIAMETER POLISHED SINGLE CRYSTAL SILICON WAFERS

This document was balloted and approved for withdrawal in 2000.

1 Purpose

1.1 The developmental wafers covered by this specification are intended for use in research on and development of process and metrology equipment and fabrication processes required to manufacture high-density integrated circuits on 300 mm diameter single crystal silicon wafers. They can also be used to establish the techniques and metrology necessary to support a dimensional specification for 300 mm diameter circuit-quality (prime) wafers.

SEMI M29-1296
SPECIFICATION FOR 300 mm SHIPPING BOX

1 Purpose

This specification defines a container for safe transportation of 300 mm wafers from a wafer maker to a receiving dock of an IC maker site.

2 Scope

2.1 This specification additionally defines the parts necessary for a shipping box among cassettes specified in SEMI E57 and SEMI E1.9, within the range of the specifications in SEMI E57 and SEMI E1.9.

2.2 This specification also defines the size of a box containing a shipping cassette containing 300 mm wafers.

2.3 Although, as for material, use of plastic is a premise, actual material names are not defined for free selection based on progress of maker's technologies.

2.4 Although this specification directs a high-performance shipping box, this does not concretely define the performance on particle generation and sealing capability.

2.5 As for the count of contained wafers, this defines two sorts, that is, 13 and 25 wafers.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

4 Terminology

4.1 *box bottom* — A lower half of an outer box.

4.2 *box top* — An upper half of an outer box.

4.3 *cassette* — A cassette defined in SEMI E57 and SEMI E1.9.

4.4 *clamp* — A part to fix a box top and a box bottom mutually.

4.5 *clamping indent* — A groove formed with a box top and a box bottom. The groove which a clamp hooks for setting.

4.6 *front retainer* — A retainer which is attached in a front side of a cassette, the front side which is defined in SEMI E1.9.

4.7 *gasket area* — An area where gaskets are attached so as to reduce air flow in a shipping box which is generated by the difference between internal pressure and external pressure.

4.8 *orientation mark* — A mark expressed on a part for confirmation of cassette direction.

4.9 *outer box* — A container part of a shipping box, surrounding the whole objects so as to protect a shipping cassette, except gasket and clamps.

4.10 *poka-yoke* — A device applied to a rib so as not to be set in an incorrect direction in order to avoid an orientation failure when the part is set.

4.11 *rear retainer* — A retainer which is attached in a rear side of a cassette, the rear side which is defined in SEMI E1.9.

4.12 *retainer* — A part to be attached to a shipping cassette for retaining wafers in transportation so that the wafers do not move. There are two types, that is, a front retainer and a rear retainer.

4.13 *retainer hook* — A projection formed on a shipping cassette for attaching a retainer.

4.14 *setting hole* — A hole formed in a retainer for attaching the retainer. This makes a pair with a retainer hook.

4.15 *shipping box* — A whole container containing a shipping cassette. This is composed of a shipping cassette, an outer box, retainers, gasket, and clamps.

4.16 *shipping cassette* — A cassette additionally defined herein for shipping among cassettes.

4.17 *stacking rib* — A rib formed on a top surface of a box top and on a bottom surface of a box bottom so as not to collapse when shipping boxes are stacked. A rib positioned on the top is called a top rib, and a rib on the bottom a bottom rib.

4.18 *supporting rib* — A rib inside an outer box for supporting a cassette.

5 Requirements

5.1 *Part Construction* — A shipping box defined herein is composed of the parts shown in Figure 1.

The appearance of this part is one of embodiments of this definition.

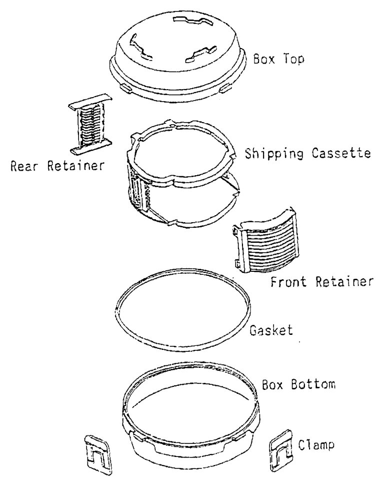

Figure 1
Components

5.2 *Shipping Cassette*

5.2.1 *Additional Dimensions* — Dimensions of a shipping cassette should conform to SEMI E57 and SEMI E1.9. However, in the above documents, there are many Max. or Min. notations, and hence, they are not sufficient to design a shipping box. Therefore, in Figure 2 and Table 1, necessary dimensions are added within the ranges defined in the above documents.

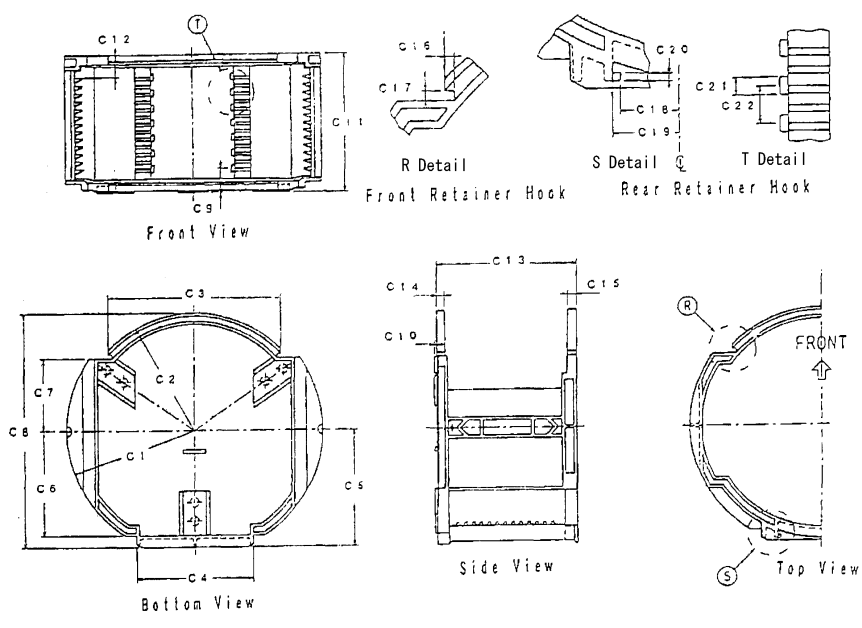

Figure 2
Additional Definition of Shipping Cassette

5.2.2 *Orientation Mark* — The orientation mark indicating the front side of a cassette is shown in Figure 3 and Table 1. This supports a user to manually set a cassette on a box bottom or a platform of equipment.

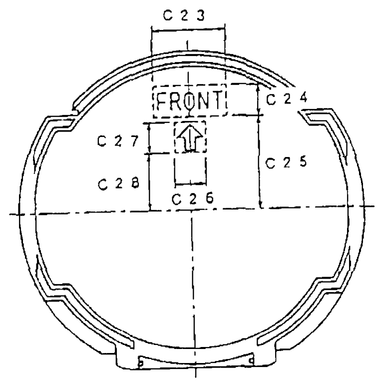

Figure 3
Orientation Mark of Shipping Cassette

Table 1 Dimensions of Shipping Cassette

Unit: mm

Location	*Standardized Dimension*		*Corresponding to SEMI E1.9*
	13 Wafers	*25 Wafers*	
C1	166 ± 0.5	←	r5
C2	153.5 ± 0.5	←	r6
C3	224 ± 1	←	x6 + x6
C4	152 ± 0.5	←	x5 + x5
C5	155 ± 0.5	←	y16
C6	139.5 ± 0.5	←	y23
C7	94 ± 0.5	←	y15
C8	308.5 ± 1	←	r6 + y16
C9	31 ± 0.5	←	z8 - z1
C10	3 ± 0.5	←	
C11	182 ± 1	302 ± 1.5	
C12	29.5 ± 0.5	←	z18
C13	179 ± 3	299 ± 4	
C14	10 ± 1	←	
C15	11 ± 1	←	
C16	5 ± 0.5	←	
C17	5 ± 0.5	←	
C18	51 ± 0.5	←	x1
C19	55 ± 0.5	←	
C20	4 ± 0.5	←	
C21	9 ± 0.5	←	
C22	20 ± 0.5	←	
C23	70 ± 10	←	
C24	30 ± 10	←	
C25	90 ± 10	←	
C26	30 ± 10	←	
C27	30 ± 10	←	
C28	55 ± 10	←	

5.3 *Box Top*

5.3.1 *Outer Dimensions* — Outer dimensions of a box top are shown in Figure 4 and Table 2.

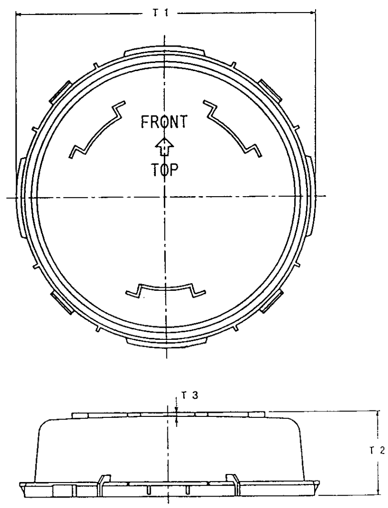

Figure 4
Outer Dimensions of Box Top

5.3.2 *Supporting Rib and Poka-yoke Rib* — Positions of a supporting rib for supporting a shipping cassette inside a box top and a poka-yoke (fool-proof) rib for avoiding setting the box top in a wrong orientation are shown in Figure 5 and Table 2.

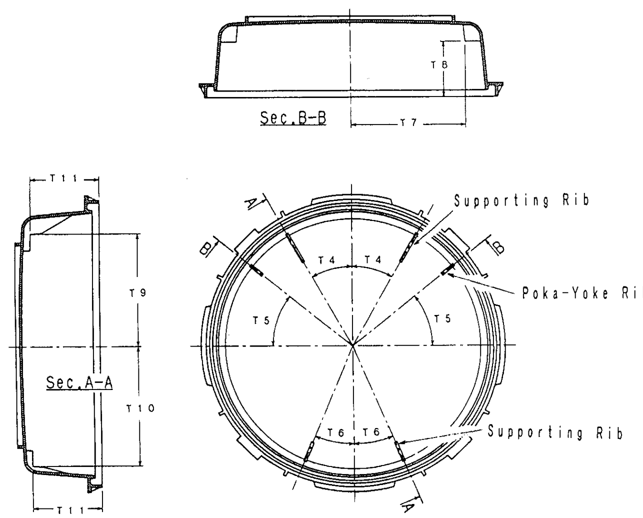

Figure 5
Supporting Rib and Poka-yoke Rib of Box Top

5.3.3 *Gasket Area* — It is required to provide a gasket in an area shown in Figure 6 and Table 2 if the gasket is provided.

5.3.4 *Clamping Indent* — Figure 7 and Table 2 show dimensions of a concave part for receiving a clamp. Refer to Figure 8 and Table 2 for horizontal positions.

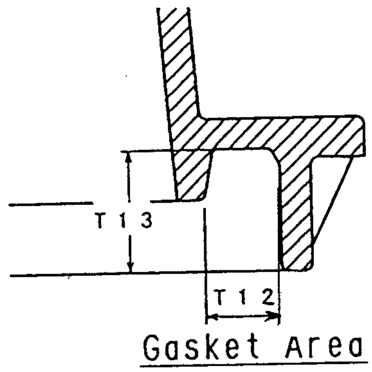

Figure 6
Gasket Area

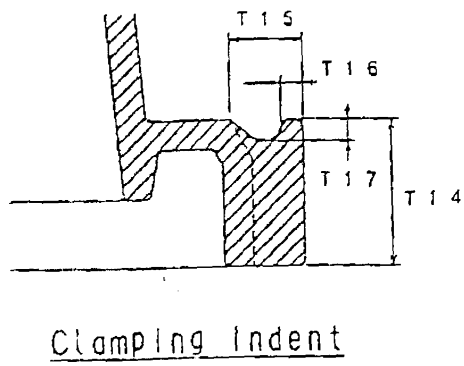

Figure 7
Clamping Indent

5.3.5 *Top Rib and Orientation Mark* — Dimensions of a top rib to avoid collapsing when shipping boxes stacked, and the position of an orientation mark are shown in Figure 8 and Table 2. In addition, since this rib makes a pair with a bottom rib, and is a poka-yoke rib, the shipping boxes can be stacked in a correct direction.

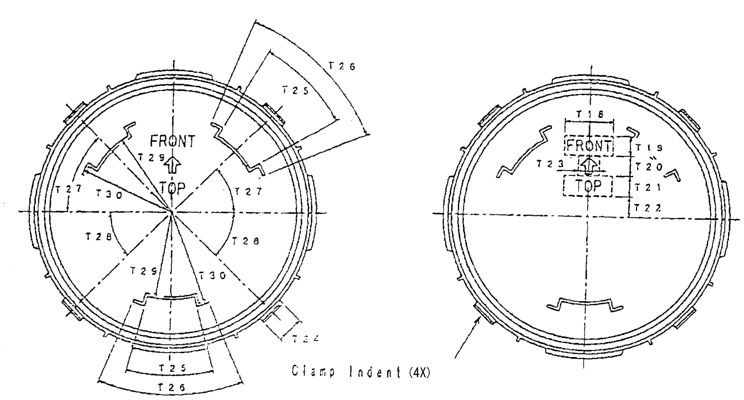

Figure 8
Top Rib and Orientation Mark

Table 2 Dimensions of Box Top

Unit: mm

Location	*Standardized Dimension*	
	13 Wafers	*25 Wafers*
T1	ø 430 max	ø 450 max
T2	116.5 ± 1	176.5 ± 1
T3	5 min	←
T4	30°	←
T5	38.5°	←
T6	22.5°	←
T7	158 ± 1	←
T8	80 ± 1	140 ± 1
T9	156.5 ± 0.5	←
T10	171.5 ± 0.5	←
T11	95.5 ± 0.5	155.5 ± 1
T12	10 max	←
T13	18 max	←
T14	20.5 ± 0.5	←
T15	10 max	←
T16	3 ± 0.5	←
T17	3 ± 0.5	←
T18	70 ± 10	←
T19	30 ± 5	←
T20	30 ± 5	←
T21	30 ± 5	←
T22	30 ± 10	←
T23	30 ± 5	←
T24	40 ± 1	←
T25	30°	←
T26	45° min	←
T27	45°	←
T28	45°	←
T29	130 ± 1	←
T30	145 ± 1	←

5.4 *Box Bottom*

5.4.1 *Outer Dimensions of Box Bottom* — Outer dimensions of a box bottom are shown in Figure 9 and Table 3.

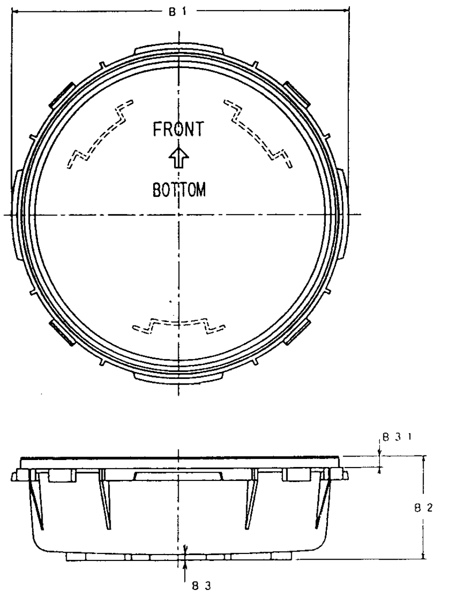

Figure 9
Outer Dimensions of Box Bottom

5.4.2 *Supporting Rib and Poka-yoke Rib* — Positions of a supporting rib for supporting a shipping cassette inside a box bottom and a poka-yoke rib provided for avoiding setting the cassette in a wrong orientation are shown in Figure 10 and Table 3.

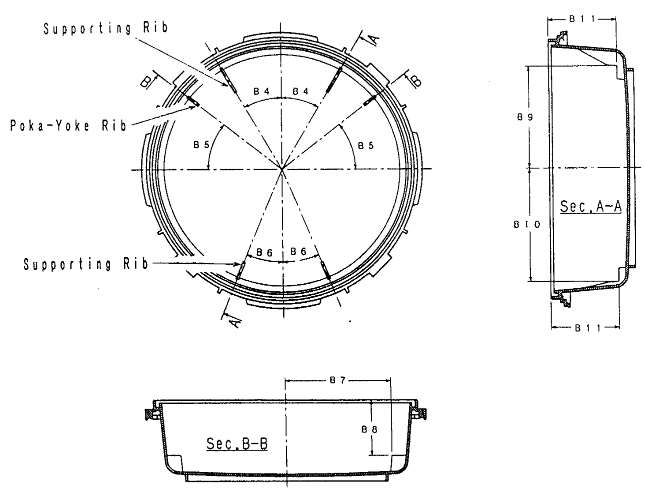

Figure 10
Supporting Rib and Poka-yoke Rib

5.4.3 *Gasket Area* — It is required to provide a gasket in an area shown in Figure 6 and Table 2 if the gasket is provided.

5.4.4 *Clamping Indent* — Figure 12 and Table 3 show dimensions of a concave part for receiving a clamp. Refer to Figure 13 and Table 3 for horizontal positions.

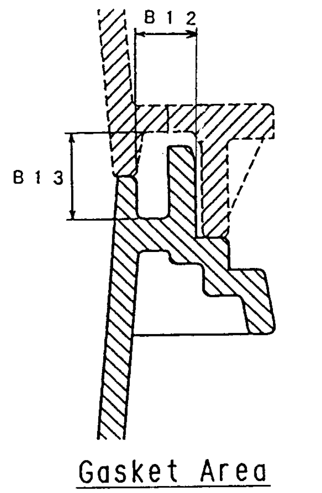

Figure 11
Gasket Area

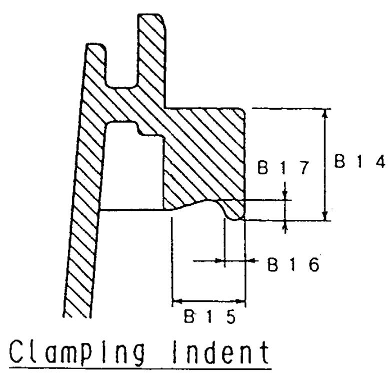

Figure 12
Clamping Indent

5.4.5 *Bottom Rib and Orientation Mark* — The position of a bottom rib and the position of an orientation mark are shown in Figure 13 and Table 3. In addition, since this rib makes a pair with a top rib, this avoids slipping of stacked shipping boxes, and becomes a datum for positioning the box bottom to equipment.

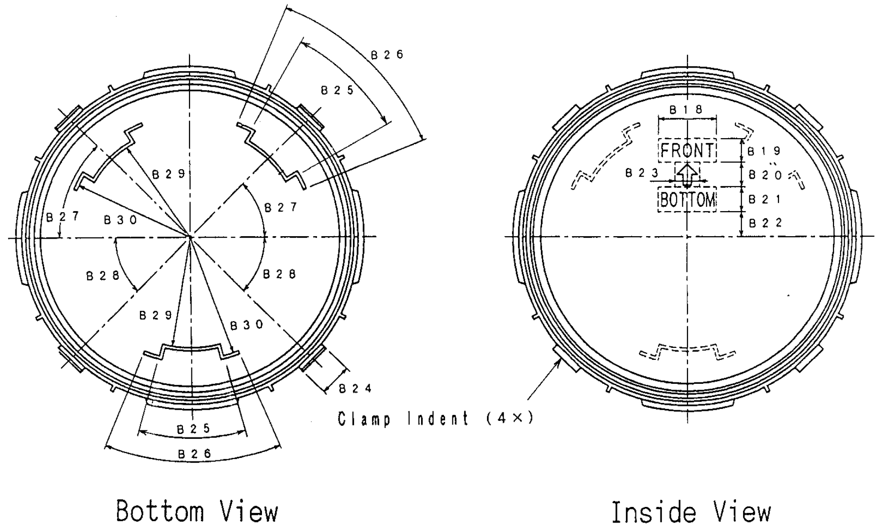

Figure 13
Bottom Rib and Orientation Mark

Table 3 Dimensions of Box Bottom

Unit: mm

Location	*Standardized Dimension*	
	13 Wafers	*25 Wafers*
B1	ø 430 max	ø 450 max
B2	126.5 ± 1	186.5 ± 1
B3	7 min	←
B4	30°	←
B5	38.5°	←
B6	22.5°	←
B7	158 ± 1	←
B8	86 ± 1	146 ± 1
B9	156.5 ± 0.5	←
B10	171.5 ± 0.5	←
B11	101.5 ± 0.5	161.5 ± 1
B12	10 max	←
B13	18 max	←
B14	16.5 ± 0.5	←
B15	12 max	←
B16	3 ± 0.5	←
B17	3 ± 0.5	←
B18	70 ± 10	←
B19	30 ± 10	←
B20	90 ± 10	←
B21	30 ± 10	←
B22	30 ± 10	←
B23	55 ± 10	←
B24	40 ± 1	←
B25	27°	←
B26	45° min	←

Unit: mm

Location	Standardized Dimension	
	13 Wafers	*25 Wafers*
B27	45°	←
B28	45°	←
B29	133 ± 1	←
B30	148 ± 1	←
B31	14 ± 1	←

5.5 *Retainer*

5.5.1 *Front Retainer* — Dimensions of a front retainer are shown in Figure 14 and Table 4.

NOTE: Usually, this part is made of an elastic material, and hence, it is difficult to show its form or to measure it. Here, the front view of this part shows the dimensions in the status fitted with a cassette.

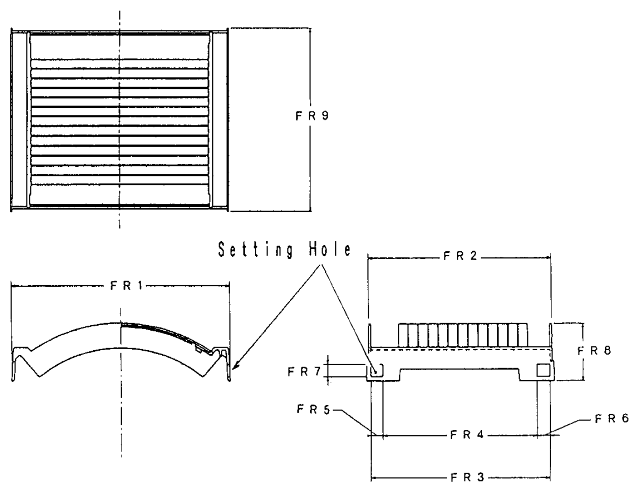

Figure 14
Front Retainer

Table 4 Dimensions of Front Retainer

Unit: mm

Location	Standardized Dimension	
	13 Wafers	*25 Wafers*
FR1	220 ± 1	←
FR2	183 ± 1	303 ± 1.5
FR3	178 ± 1	298 ± 1.5
FR4	153.5 ± 1	273.5 ± 1.5
FR5	11 ± 0.5	←
FR6	13 ± 0.5	←
FR7	12.5 ± 0.5	←
FR8	59 ± 2	←
FR9	187 ± 1	307 ± 1.5

5.5.2 *Rear Retainer* — Dimensions of a rear retainer are shown in Figure 15 and Table 5.

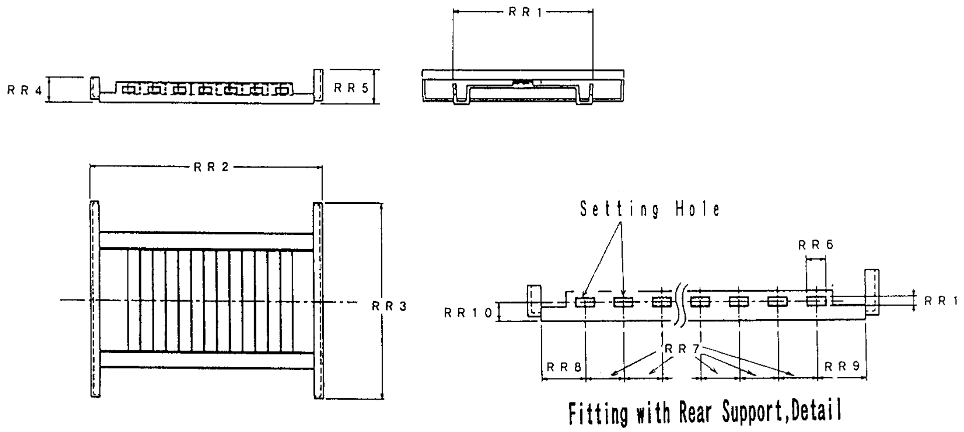

Figure 15
Rear Retainer

Table 5 Dimensions of Rear Retainer

Unit: mm

Location	*Standardized Dimension*	
	13 Wafers	*25 Wafers*
RR1	110 ± 1	←
RR2	184 ± 2	304 ± 3
RR3	157 ± 2	←
RR4	19.5 ± 1	←
RR5	27 ± 1	←
RR6	10 ± 0.5	←
RR7	20 ± 0.5	←
RR8	23 ± 2	←
RR9	25 ± 1	←
RR10	15 ± 5	←
RR11	5 ± 0.5	←

5.6 *Clamp* — Dimensions of a clamp are shown in Figure 16 and Table 6.

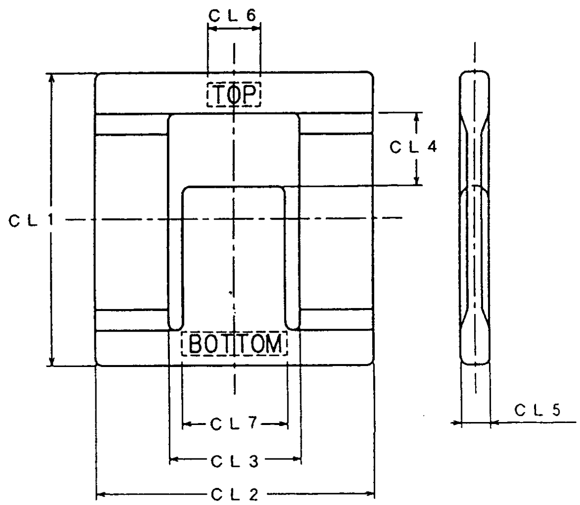

Figure 16
Clamp

Table 6 Dimensions of Clamp

Unit: mm

Location	*Standardized Dimension*	
	13 Wafers	*25 Wafers*
CL1	100 ± 10	←
CL2	95 ± 2	←
CL3	45 ± 2	←
CL4	25 ± 1	←
CL5	10 max	←
CL6	20 ± 5	←
CL7	40 ± 10	←

5.7 *Gasket* — A gasket is a part to be mainly designed with maker's know-how regarding its material and form. In addition, this is frequently revised for increase of quality.

Since there is no practical problem so long as its position is decided, the gasket is not defined. However, it should be provided in the area defined in Sections 5.3.3 and 5.4.3.

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix was approved as a part of SEMI M29 by full letter ballot procedure.

A1-1 Heat-Resistant Temperature

Parts defined herein are not considered to be used under high temperature because it is assumed to be used under the usual conditions. As for operating temperature of each part, information from its maker should be confirmed.

A1-2 Orientation of Wafers in Transportation

It is necessary to vertically keep wafers in transportation. Therefore, it is necessary to clarify vertical holding indicated on buffering material and carton boxes.

A1-3 Using Procedure

The procedure for using a shipping box defined in this document is shown in Figure 17.

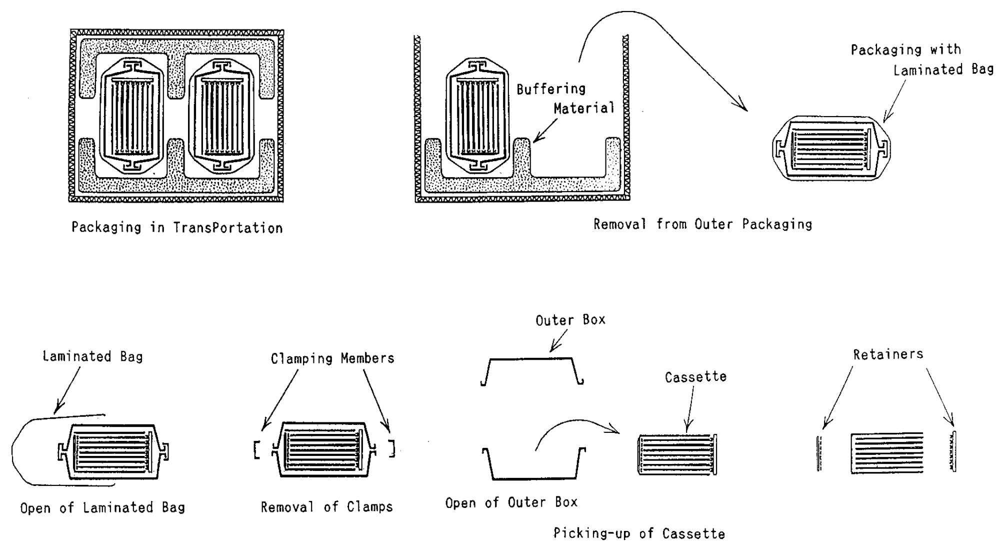

Figure 17
Example of Procedure for Using a Shipping Box

A1-4 Maximum Dimensions and Attached Location of Label

In case it is necessary to attach a label on a shipping box, the label should be attached in the area shown in Figure 18 and Table 7, and hence, a designer of a shipping box should not provide a projection in this area.

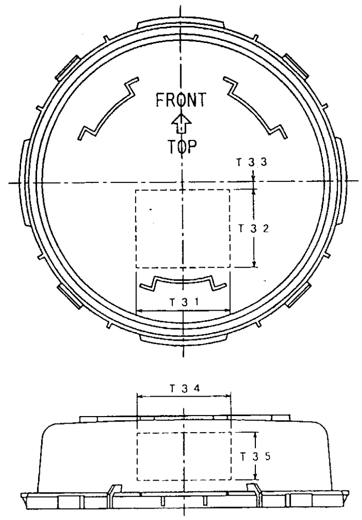

Figure 18
Label Area

Table 7 Dimensions of Label Area

Unit: mm

Location	*Standardized Dimension*	
	13 Wafers	*25 Wafers*
T31	120 max	←
T32	100 max	←
T33	10 min	←
T34	120 max	←
T35	60 max	←

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M30-0997
STANDARD TEST METHOD FOR SUBSTITUTIONAL ATOMIC CARBON CONCENTRATION IN GaAs BY FOURIER TRANSFORM INFRARED ABSORPTION SPECTROSCOPY

1 Purpose

The purpose of this document is to test substitutional atomic carbon concentration in GaAs by Fourier Transform Infrared Absorption Spectroscopy (FT-IR).

2 Scope

2.1 This referee test method covers the determination of substitutional carbon concentration in single crystal GaAs.

2.2 The useful range of carbon concentration measurable at room temperature by this test method is from the maximum amount of substitutional carbon soluble in GaAs to 1×10^{15} cm^{-3}. The detection limit depends on the equipment and measurement conditions. It is expected that many users of this test method can reduce the detection limit to 10^{14} cm^{-3} level. 77K measurement is effective to reduce the detection limit. In the case of 77K measurement, the upper limit is 1.3×10^{16} cm^{-3}, as described in the following article:

T.Arai et al : J. Electronic Industry, Vol. 30, 9 (1988) 38

2.3 The test method utilizes the relationship between carbon concentration and absorption coefficient at 580 cm^{-1} for room temperature measurement (around 582 cm^{-1} for 77K measurement), the infrared absorption band is associated with substitutional carbon in GaAs. These specific absorption bands in GaAs have been associated with the local vibration mode of C_{as}.

2.4 The method is applicable to Semi-Insulating (SI) GaAs. Slices can be any crystallographic orientation and should be polished or lapped and etched on both surfaces.

2.5 This test method is intended to be used with FT-IR spectrometers that are equipped to operate in the region including the wave number range from 700 to 500 cm^{-1}.

2.6 This standard may involve hazardous materials, operation, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Documents

3.1 *ASTM Standards*[1]

E 131 — Definitions of Terms and Symbols Relating to Molecular Spectroscopy

E 168 — Recommended Practices for General Techniques of Infrared Quantitative Analysis

E 177 — Practice for Use of the Terms Precision and Bias in ASTM Test Methods

F 120 — Practice for Infrared Absorption Analysis of Impurities in Single Crystal Semiconductor Materials

F 133 (A 894) — Test Method for Thickness and Thickness Variation of GaAs Slices

3.2 *Other Document*[2]

DIN 50449-1 — Bestimmung des Verunreinigungsgehaltes in III-V-Verbindungshalbleitern mittels Infrarotabsorption/Teil 1: Kohlenstoff in Galliumarsenide (Determination of Impurity Content in Semiconductors by Infrared Absorption Part 1: Carbon in Gallium Arsenide)

4 Terminology

4.1 *Acronyms*

4.1.1 *CPAA* — Charged particle activation analysis

4.1.2 *FWHM* — Full width at half maximum, the width of the absorption band at half its magnitude as measured from the baseline.

4.1.3 *MCT* — Mercury cadmium telluride

4.1.4 *TGS* — Triglycine sulfate

4.2 Many of the terms associated with this test method can be found in ASTM Definitions E 131.

4.2.1 *baseline* — A linearly interpolated pattern over a limited spectral region of the ratio recording used to derive an absorption coefficient (see Figure 1 and refer to ASTM Practice E 168).

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Deutches Institut fur Normung, e.v., Beuth Verlag GmbH, Burggrafstrasse 4-10, D-1000 Berlin 30, Germany

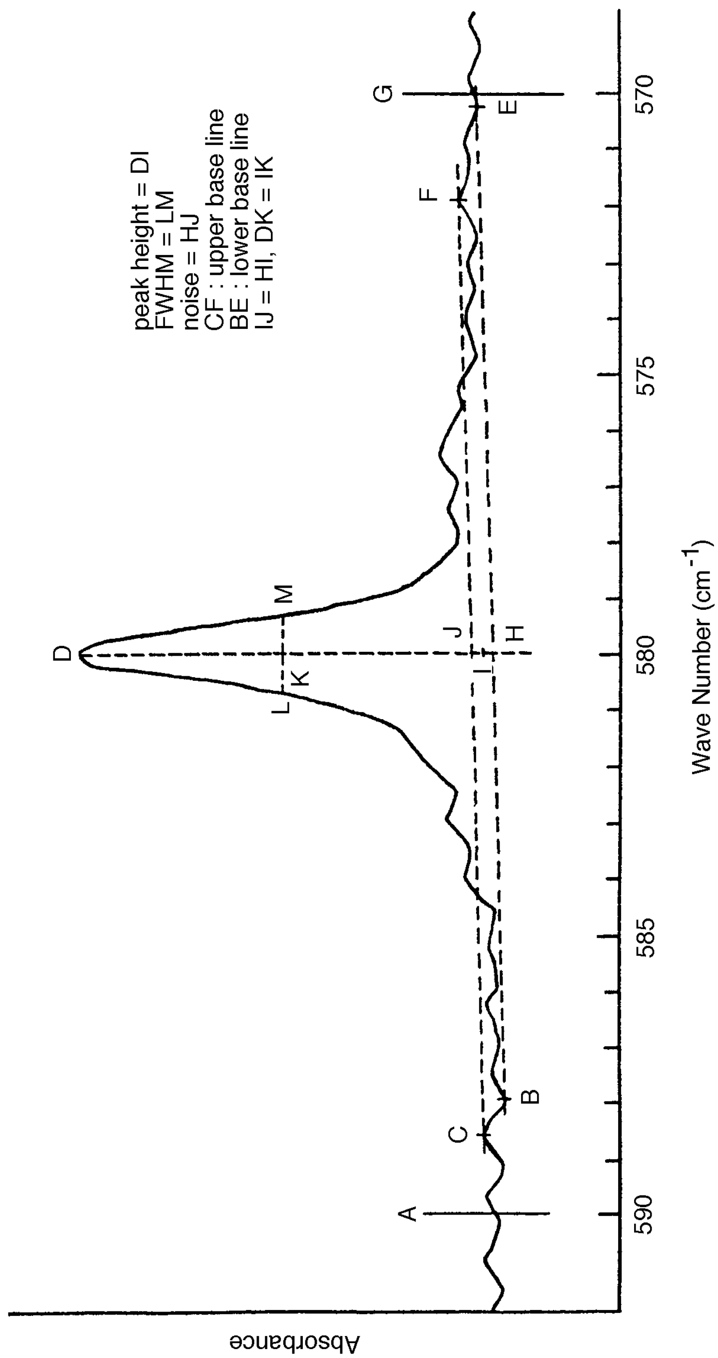

Figure 1
FT-IR Spectrum of C_{as} Local Mode Absorption in GaAs

4.2.2 *calibration coefficient* — Conversion factor to carbon concentration from absorbance or absorption coefficient of each FT-IR instrument.

4.2.3 *carbon concentration* — For purposes of this test method, the volume density of atomic carbon incorporated in the crystal lattice at substitutional positions. It is proportional to the absorption coefficient following Beer's law. Units are atoms per cubic centimeter.

4.2.4 *primary standard samples* — Samples where the carbon concentration is already known, as measured by the CPAA method (see Section 4.1.1). A set of primary standard samples is composed of 4 specimens with each carbon concentration as follows:

No.	*Thickness (mm)*	*Carbon Concentration* (cm^{-3})
#3	5.103	1.4×10^{15}
#5	5.013	12.0×10^{15}
#7	5.015	2.4×10^{15}
#15	4.994	3.2×10^{15}

These samples are preserved at SEMI Japan. Details (actual measured values and measurement errors, etc.) for these samples are described in the following article:

T.Arai et al : J. Electronic Industry, Vol. 30, 9 (1988) 38

4.2.5 *reference sample* — The nearly carbon-free GaAs sample used for calculating the subtracted spectrum which are used for determination of carbon concentration. The reference sample is used for room temperature measurement. It is recommended that the carbon concentration of the reference sample is $< 3 \times 10^{14}$ cm^{-3}.

4.2.6 *secondary standard samples* — The samples of which the carbon concentration was determined in a round-robin test by the FT-IR method using the primary standard samples. More than 3 samples covering the carbon concentration range from 1.5×10^{15} to 10.0×10^{15} cm^{-3} must be used. These samples are preserved as SEMI Japan, and will be lent out for determination of the calibration coefficient for specific FT-IR spectrometers.

5 Summary of Test Method

5.1 Test slices are prepared that are polished or lapped and etched on both sides to a thickness from 3 to 6 mm.

5.2 Apparatus should be calibrated by using the primary standard samples or secondary standard samples. This calibration coefficient is used to calculate the carbon concentration of specimens.

5.3 For room temperature measurement, a baseline is drawn in the differential spectrum (after subtraction of the reference sample spectrum) from which an absorption coefficient is derived. The range of baseline should be wider than ± 10 cm^{-1}. The baseline has to be determined in an interval of the spectra which is neither influenced by main peak at 580 cm^{-1} nor the side peak at 576 cm^{-1}. For 77K measurement, the range of baseline should be wider than ± 1.5 cm^{-1}.

6 Significance and Use

6.1 Carbon plays an important role in the determination of the compensation mechanism which determines the semi-insulating behavior of GaAs. As such the concentration is critical in determining the substrate resistivity.

6.2 As a dominant acceptor in SI-GaAs substrates, carbon could, potentially impact ion implantation activation.

7 Interferences

7.1 Stray light that reaches the detector will tend to reduce the calculated absorption coefficient value and thereby reduce the reported carbon concentration.

7.2 FT-IR instrument instruction manuals should be consulted if problems with the technique are suspected.

7.3 The carbon absorption band half width at room temperature must be less than 2 cm^{-1} for acceptable measurement results. Excessive width can be due to improper thickness matching or stress.

7.4 Specimens that do not exceed the instrument beam size will cause error. Use of apertures, or preferably beam condensers, can correct this problem.

7.5 The minimum detection level of this method is limited by the signal-to-noise ratio of the recording.

8 Apparatus

8.1 FT-IR with an operating range that includes the region of 700 to 500 cm^{-1}. Instrument resolution or spectral resolution at the carbon absorption band of 580 cm^{-1} for room temperature measurement and around 582 cm^{-1} for 77K measurement must not exceed 0.5 cm^{-1}, which means the effective resolution after apodization must not exceed 1.0 cm^{-1}.

8.1.1 Beam sizes and sample holder active areas for both the specimen and the reference must be within 10% of each other.

8.2 Instrument suitable for thickness measurement to an accuracy of 0.0025 mm.

8.3 Holders for these test and reference specimens that prevent any source of infrared radiation from bypassing the specimen.

8.4 For use at 77K, low-temperature cryostat capable of maintaining the specimen and reference at 77K temperature with suitable window materials (refer to ASTM Practice F 120).

8.5 Equipment and materials for slicing and polishing GaAs to a final thickness tolerance of 0.005 mm or less, and a total thickness variation of 0.01 mm or less.

9 Sampling

Unless otherwise specified, a GaAs slice used for the carbon test is to be measured at the nominal slice center. And if a slice is to be reduced in area prior to test, it is shaped such that the original slice center area is that which is tested.

10 Test Specimens

10.1 A single crystal slice of GaAs with a thickness from 3 to 6 mm must be used for carbon determination.

10.2 The test specimen must be carefully shaped to the following criteria:

10.2.1 Thickness variation over the measurement area of 0.005 mm or less.

10.2.2 Same surface preparation on both front and back surfaces. For room temperature measurement, surface preparation of specimen should be same with reference sample. For 77K measurement, mirror polishing on both surface or same surface preparation with standard sample is recommended.

10.2.3 Final thickness agreement between specimen and reference samples of 0.1 mm.

10.2.4 Surface area large enough such that with respect to the holders no incident radiation can bypass either specimen or reference.

11 Procedure

11.1 Prepare FT-IR in accordance with the manufacture's instructions.

11.2 Determine the differential transmission spectrum from 700 to 500 cm^{-1} in accordance with of ASTM Practice F 120.

11.2.1 The FWHM must not exceed 2 cm^{-1} to achieve reliable results. If this is not met, recheck test and reference specimen mechanical properties, use slower scan speed, or longer measuring time, and reverify FT-IR operating conditions.

11.2.2 Reference to Figure 1 and Recommended ASTM Practice E 168, Section 7, for assistance in establishing a baseline on the finished spectrogram. Baseline determination is very important to this method, and becomes more critical as the measured carbon level decreases (refer to ASTM Practice E 168).

11.2.3 For room temperature meansurement, the following conditions are recommended:

- Detector : Broadband MCT (or TGS) (see Sections 4.1.3 and 4.1.4)
- Resolution : 0.5 cm^{-1}
- S/N ratio : > 3
- Range of wave number : including 700 – 500 cm^{-1}
- Aperture : Optimum for each FT-IR
- Apodization function : Triangle
- Smoothing : Not applicable
- Reference : Air, reference sample
- Temperature : 290 ~ 300K

11.2.4 Make the determination at low temperature (77K) if increased sensitivity is required. Follow the same test conditions as described in Sections 11.1 and 11.2 except reference and temperature.

11.3 Determination of the calibration coefficient should be done once or more times per year. Four or more secondary standard samples should be used for this calibration. The user of this method can have and use the internal standard samples to check the spectrometer frequently.

12 Calculations

12.1 Calculate the absorption coefficient, α, using the expression:

$$\alpha = 1X \cdot 1n\,(I_0/I) = 1/X \cdot 2.303 \cdot (\text{peak height of absorption})$$

where :

α = absorption coefficient

X = specimen thickness, cm,

I = transmitted intensity at peak absorption (580 cm^{-1} for room temperature, 582 cm^{-1} for 77K, and

I_0 = baseline intensity at peak absorption, I.

12.2 Determine the calibration coefficient of each FT-IR using the least square method in the following equations:

$$[C_0] = \beta \cdot \alpha_0 \cdot \Delta_0 \text{ or } [C_0] = \beta \cdot \alpha_0$$

where :

$[C_0]$ = already known carbon concentration in standard samples

α_0 = absorption coefficient of standard samples

Δ_0 = FWHM of standard samples

β = calibration coefficient of each FT - IR

12.3 Calculate the concentration of substitutional carbon in atoms/cm^3 with the use of the following equations:

$$[C] = \beta \cdot \alpha \cdot \Delta \text{ or } [C] = \beta \cdot \alpha$$

where :

[C] = carbon concentration in test specimen

α = absorption coefficient of test specimen

Δ = FWHM of test specimen

β = calibration coefficient of each FT - IR, determined in 12.2

13 Report

13.1 The following information shall be included in the report for referee and research measurements:

13.1.1 Instruments used, detector, resolution, measurement time, range of wave number, aperture, apodization function, smoothing, specimen measurement temperature (room temperature or 77K).

13.1.2 Specimen thickness, and identification.

13.1.3 Calibration coefficient of FT-IR used, width of base line.

13.1.4 FWHM in cm^{-1}, calculated absorption coefficient or absorption, and carbon concentration.

13.1.5 Date of measurement, organization performing test, and location.

13.1.6 Use of any special techniques, such as beam condenser, scale expansion, scan suppression, etc.

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SEMI M31-0999
PROVISIONAL MECHANICAL SPECIFICATION FOR FRONT-OPENING SHIPPING BOX USED TO TRANSPORT AND SHIP 300 mm WAFERS

This provisional specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on July 15, 1999. Initially available at www.semi.org August 1999; to be published September 1999. Originally published in 1998; previously published June 1999.

1 Purpose

1.1 This standard partially specifies the front-opening shipping box (FOSB) used to ship 300 mm wafers from wafer suppliers to their customers (typically IC manufacturers).

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Only the physical interfaces for FOSB are specified; no materials requirements or micro-contamination limits are given. However, this standard has been written so that both metal and injection-molded plastic FOSBs can be manufactured in conformance with it.

2.2 This standard assumes that the FOSB is used in the last process in wafer manufacturing, in acceptance and inspection, and in transferring the wafers from the FOSB to a FOUP or open cassette inside an IC manufacturing facility. The FOSB is not intended to be used in IC manufacturing processes. It is recommended that wafers be transferred from the FOSB to a FOUP or open cassette using automated methods. As described in Section 5.3, the purchaser needs to specify which type of shipper door is required:

1) Manual door as described in Section 5.3.1; or

2) Automated door as described in Section 5.3.2.

2.3 This standard (as well as other 300 mm standards) is provisional. Once FOSB testing and initial volume production is done (or any change related to the FOSB is made to a document listed in Section 3 below), this standard should be modified and upgraded from provisional status. Where possible, the specified design features are in accord with like features in SEMI E1.9 and SEMI E47.1.

2.4 This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E44 — Guide for Procurement and Acceptance of Minienvironments

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

bilateral datum plane — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

box — a protective portable container for a carrier and/or substrate(s) (as defined in SEMI E44).

carrier — an open structure that holds one or more substrates.

carrier bottom domain — volume (below *z*6 above the horizontal datum plane) that contains the bottom of the carrier (as defined in SEMI E1.9).

carrier capacity — the number of substrates that a carrier holds (as defined in SEMI E1.9).

carrier sensing pads — surfaces on the bottom of the carrier for triggering optical or mechanical sensors (as defined in SEMI E1.9).

carrier side domains — volumes (from *z*6 above the horizontal datum plane to *z*15 above the top nominal wafer seating plane) that contain the mizo teeth or slots that support the wafer and the supporting columns on the sides and rear of the carrier (as defined in SEMI E1.9).

carrier top domain — volume (higher than *z*15 above the top wafer) that contains the top of the carrier (as defined in SEMI E1.9).

facial datum plane — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

front-opening shipping box (FOSB) — a shipping box with a front-opening interface.

front-opening unified pod (FOUP) — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62) (as defined in SEMI E47.1).

horizontal datum plane — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

minienvironment **—** a localized environment created by an enclosure to isolate the product from contamination and people (as defined in SEMI E44).

nominal wafer centerline — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling) (as defined in SEMI E57).

optical wafer sensing paths — lines of sight for optically sensing the positions of the wafers. Several horizontal optical wafer sensing paths are present in between the carrier side domains. In addition, two vertical optical wafer sensing paths are created by rectangular exclusion zones in the front of the carrier top and bottom (as defined in SEMI E1.9).

shipping box — a protective portable container for a carrier and/or wafer(s) that is used to ship wafers from the wafer suppliers to their customers.

shipping-box front-opening mechanical interface (SFMI) — optional automated door style for a shipping box that is compatible with SEMI E62, with exceptions as noted in Section 5.3.2.

virtual tracking unit — an entity (which could be a number of substrates or an individual die or mask group) that the factory floor control system treats as a single unit for tracking purposes (as defined in SEMI E1.9).

wafer carrier — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

wafer extraction volume — the open space for extracting a wafer from the carrier (as defined in SEMI E1.9).

wafer pick-up volume — the space that contains entire bottom of a wafer if the wafer has been pushed to the rear of the carrier (as defined in SEMI E1.9).

wafer set-down volume — the open space for inserting and setting down a wafer in the carrier (as defined in SEMI E1.9).

5 Requirements

The shipping box has the following components and sub-components:

Key:

- Required feature

◊ Optional feature

- Door on front
  - ◊ Manual door (optional)
  - ◊ Automated door (optional)
  - Holes for latch keys that lock the door to the SFMI interface when the door is unlatched from the box
  - Holes for registration pins
  - Door presence sensing areas
- Top
  - ◊ Top robotic handling flange (optional)
- Interior
  - Non-removable cassette with supports for 13 or 25 wafers
  - Wafer capture mechanism
  - 2 end effector exclusion zones

- Sides
  - ◊ Ergonomic manual handles (optional)
- Bottom
  - 5 carrier sensing pads
  - 4 Info pads
  - 3 features that mate with kinematic coupling pins and provide a 10 mm lead-in
  - ◊ 3 features that mate with kinematic coupling pins and provide a 15 mm lead-in (optional)

5.1 *Kinematic Couplings* — The physical alignment mechanism from the FOSB to the tool load-port (or a nest on a vehicle or in a stocker) consists of features (not specified in this standard) on the top entity that mate with three or six pins underneath as defined in SEMI E57. The three features that mate with the kinematic coupling pins must provide a lead-in capability that corrects a FOSB misalignment of up to *r*69 in any horizontal direction.

5.2 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the FOSB supplier. Note also that this radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the FOSB supplier. Note also that this radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the FOSB specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

5.3 *Door* — It is recommended that the FOSB not be vertical when it is opened or closed. When the FOSB is in a vertical orientation with the door removed, the wafers must be restrained from touching each other by appropriate wafer support design or other retaining techniques.

5.3.1 *Manual Door* — If chosen, the manual door option requires no automation to open the door. An exclusion zone surrounding the manual door area is specified in the standard. There are several possible techniques for sealing and clamping the manual door that meet user requirements. Therefore, only an exclusion zone surrounding the manual door area is specified in this standard. All features of the door and door retaining mechanism must lie within the exclusion zone illustrated in Figure 1 and must not interfere with other specified features (including the kinematic couplings). Figure 1 and dimensions *x*81, *y*81, *y*82, *z*82, and *z*83 define the manual door area and therefore apply only to the manual door option as described in this section.

5.3.2 *Automated Door* — If chosen, the SFMI automated door must be designed to mate with a port that conforms to SEMI E62. Note the following exceptions: the maximum required latch torque is 4.4 N-m instead of 1.7 N-m. It is recommended then that the automated door opener provide at least 4.5 N-m to open or close the automated door in conjunction with the increased torque. If the increased torque does not allow for the FOSB to be clamped solely using the front clamping feature, the FOSB might need to be supported with additional devices attached to the equipment load port.

5.3.2.1 Since the FOSB has a $y51 \geq 50$ mm, instead of 140 mm as in SEMI E47.1, a longer stroke is required to remove the door. Note that there must be a provision for opening the automated door without a loadport.

5.4 *Seal Zones for Door* — On the exterior side of the port (at a distance *y*33 from FOSB facial datum plane) are areas for sealing to the FOSB. It is recommended that FOSBs be designed with surfaces opposite these seal zones that are at a distance of *y*33 from the facial datum plane (where *r*38 and *y*33 are specified in SEMI E62) and that have a flatness of *y*42. The frame seal zone is on the frame of the port door in the area between *x*34 and *x*35 from the facial datum plane and between *z*34 and *z*35 from the vertical centerline of the port (see Figure 2). Table 2 defines the dimensions.

5.5 *Wafer Capture and Centering* — When the FOSB is closed, the wafers must be captured in the FOSB to prevent movement during subsequent handling, including shipping. It should be noted that wafers are typically shipped in a vertical orientation and generally require support from a secondary package. It is recommended that this secondary package be designed to allow for easy removal of the FOSB from the secondary package.

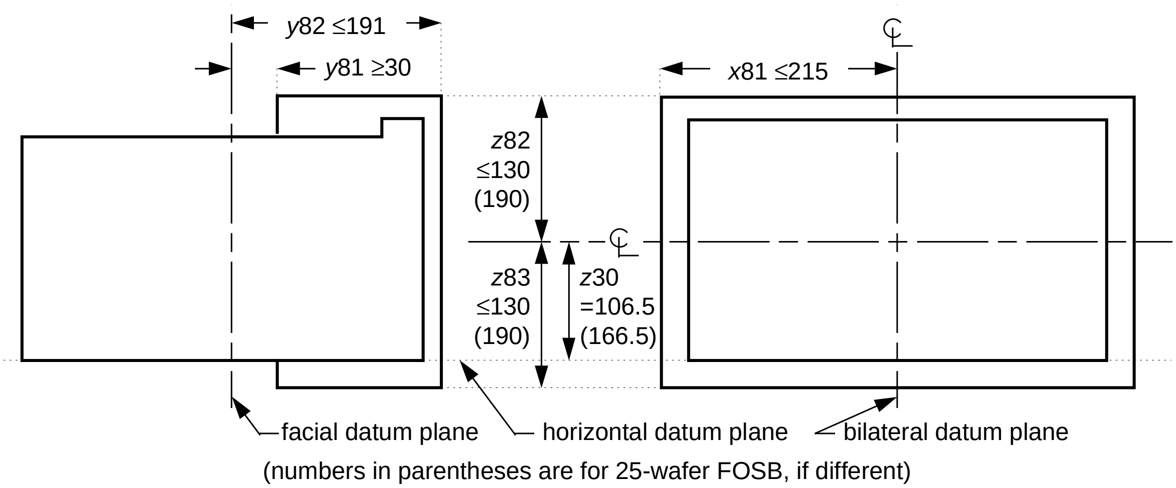


Figure 1
Manual Door Area

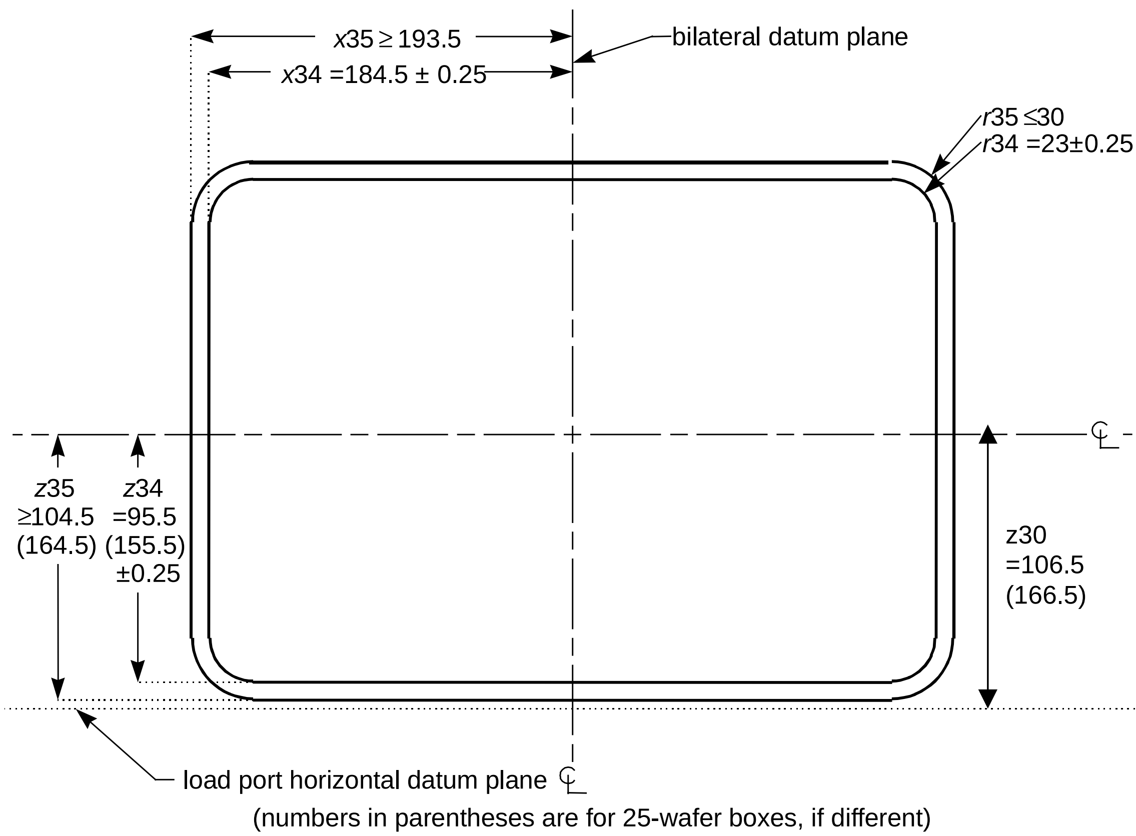


Figure 2
Dimensions for Front-Opening Interface

5.6 *Wafer Orientation and Numbering* — The wafers must be horizontal when the FOSB is placed on the coupling, and the wafers slots are numbered in increasing order from bottom to top (so the bottom wafer is wafer number 1, the next wafer up is wafer number 2, etc.).

5.7 *Internal Horizontal Dimensions* — Figure 3 shows a cross-section of the horizontal boundaries of the FOSB side domains (which contain the parts of the FOSB higher than *z*6 above the horizontal datum plane and lower than *z*15 above the top wafer). In this and following figures, the most heavy lines are used for surfaces that have tolerances (not surfaces that have only maximum or minimum dimensions). Table 2 defines the dimensions shown in this and following figures.

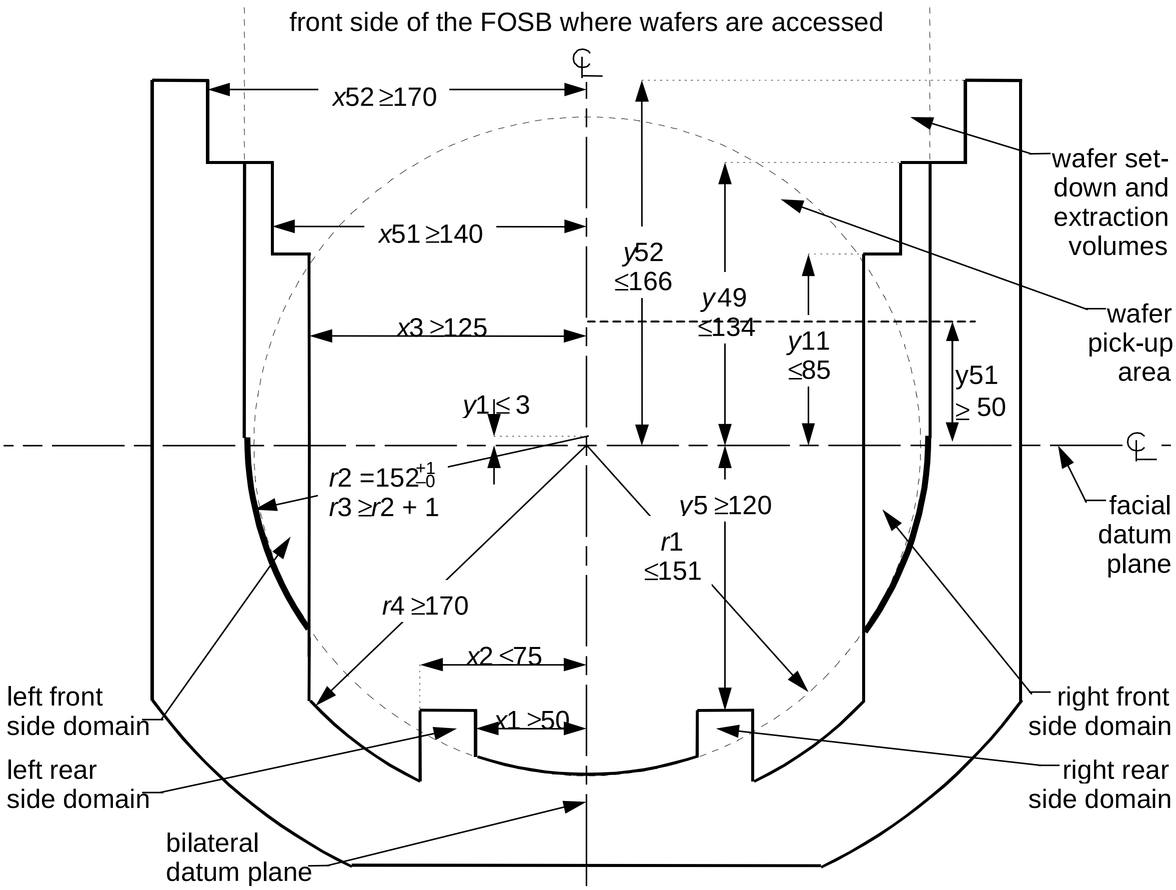


Figure 3
Top View of FOSB Internal Dimensions

5.8 *Internal Vertical Dimensions* — Figures 4 through 8 show the vertical dimensions of the internal FOSB. Note that *z*8 (the height of the bottom nominal wafer seating plane above the horizontal datum plane) and *z*12 (the distance between adjacent nominal wafer seating planes) are given as absolute distances with no tolerance. This means that the sum of actual height variations in the FOSB from the kinematic coupling to the supporting features holding each wafer must be contained within the tolerance of *z*10 with no further stack-up at each higher wafer. The method for meeting this requirement is left up to the FOSB supplier. Table 2 defines all dimensions for Figures 4 through 8.

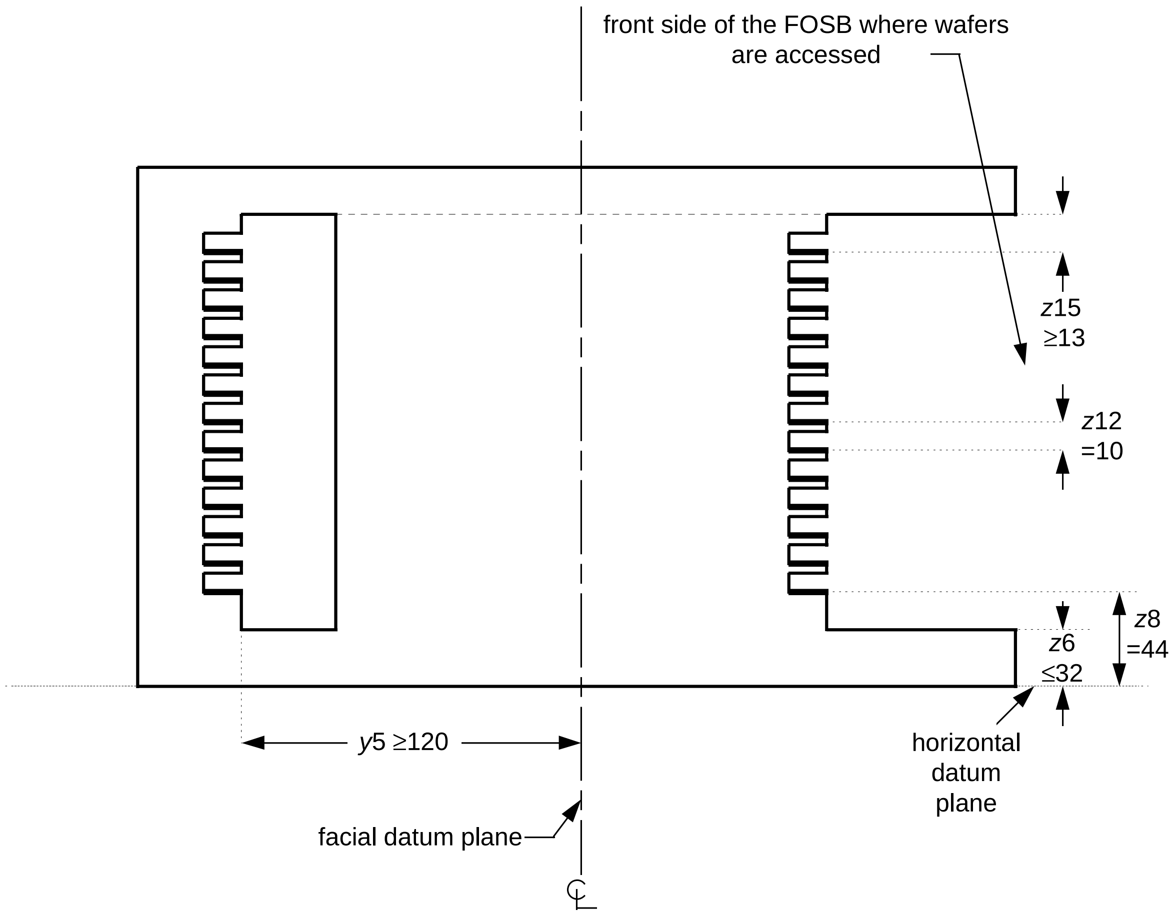


Figure 4
Side View of FOSB Internal Dimensions

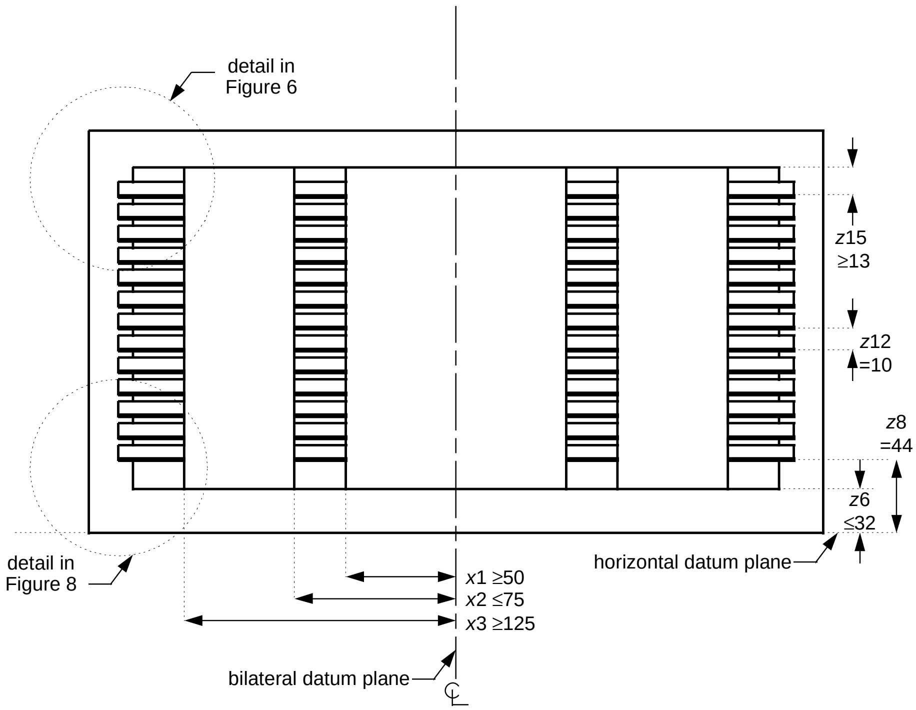


Figure 5
Front View of FOSB Internal Dimensions

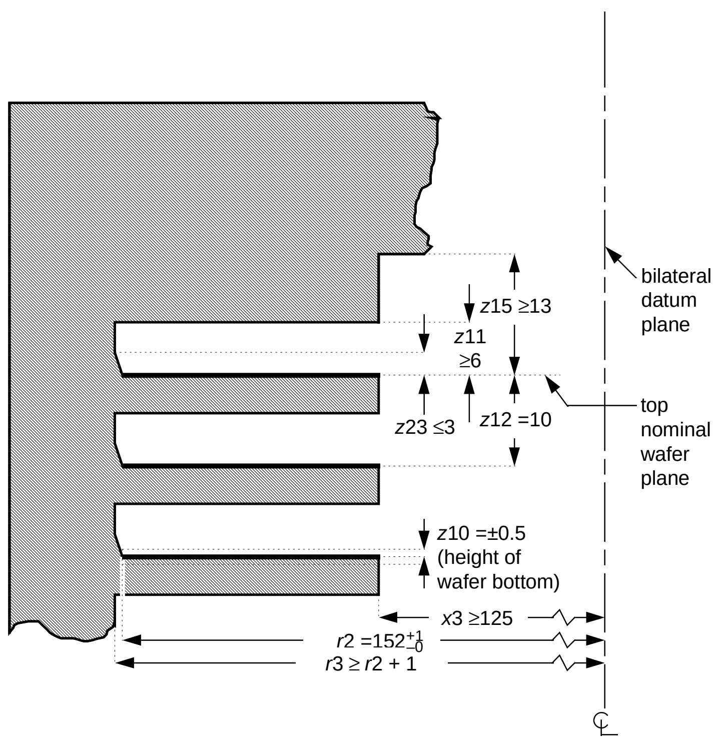


Figure 6
Upper Cross-Section at Facial Datum Plane

5.8.1 *Wafer Set-Down Volume* — The open space for the wafer set-down volume consists of a cylindrical section with radius *r*2 and a main axis parallel to and *y*1 in front of the nominal wafer centerline. The top of this cylindrical section is *z*11 above the nominal wafer seating plane and its bottom is *z*10 above the nominal wafer seating plane. The implications for wafer positioning of the tolerance on *r*2 are as follows. The wafers should be placed in the FOSB within a circle of radius corresponding to the smaller bound on *r*2 to avoid touching the edge of the wafer to the side of the FOSB. Once the wafer has been placed, the FOSB must not allow a wafer to move outside of a circle of radius corresponding to the larger bound on *r*2. There are two exceptions to this limit on wafer movement. When the wafer is pushed toward the rear of the FOSB, the location of the wafer is defined by the wafer pick-up volume (see Section 5.8.3). When the FOSB is gently tilted forward up to 45°, the wafers may slide forward, but it is recommended that they not extend further than *y*20 from the facial datum plane. This may be accomplished by designing the teeth supporting the wafers to include a "wafer stopper" at the front that is outside of *r*2 and under *z*29 as illustrated in Figure 7.

5.8.2 *Wafer Extraction Volume* — The open space for the wafer extraction volume includes a cylindrical section with radius *r*3 and a main axis parallel to and *y*1 in front of the nominal wafer center line. The top of this cylindrical section is *z*11 above the nominal wafer seating plane and its bottom is *z*23 above the nominal wafer seating plane. The wafer extraction volume also includes the extrusion out the front of the FOSB of this cylindrical section and the portion of the wafer set-down volume above *z*29. The implications for wafer extraction of the definition of dimension *r*3 ($r3 \geq r2 + 1$) are as follows. The FOSB must give an extra 1 mm (0.04 in.) of horizontal clearance once the wafer is picked up from wherever it ends up (within the bounds of *r*2) after transport in the FOSB.

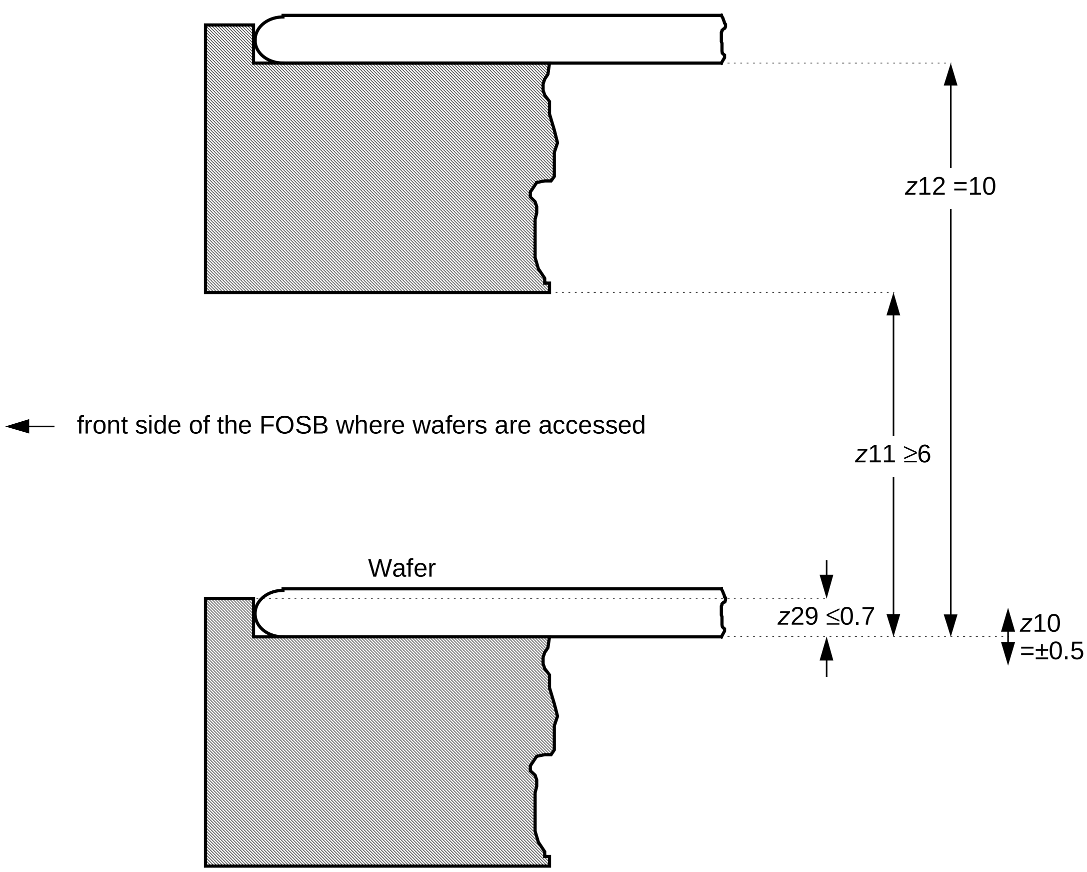


Figure 7
Features That Prevent Wafer Creep-Out

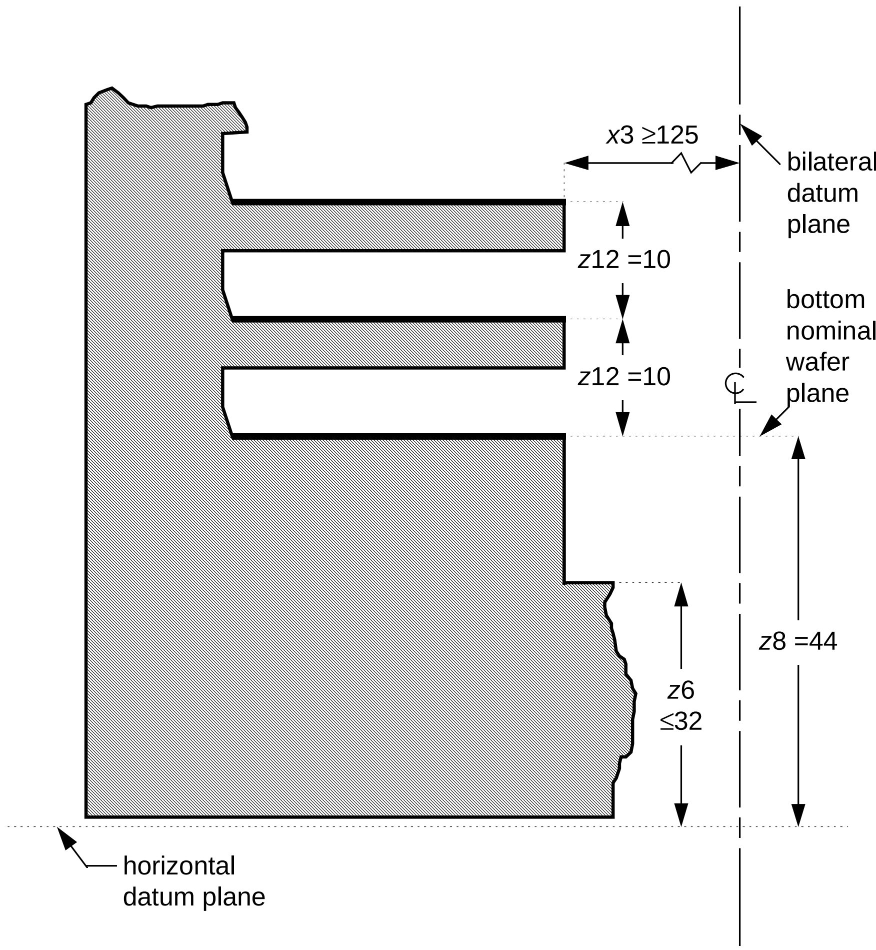


Figure 8
Lower Cross-Section at Facial Datum Plane

5.8.3 *Wafer Pick-Up Volume* — If a wafer is placed in the wafer set-down volume and is then pushed toward the rear of the FOSB, then the entire bottom of the wafer must be contained in the wafer pick-up volume. However, if the wafer is not pushed toward the rear of the FOSB, then the wafer may only be somewhere within the wafer extraction volume. The wafer pick-up volume is defined by a cylindrical section with radius *r*1 and a main axis at the nominal wafer centerline. Its top and bottom are the upper and lower tolerance of *z*10 around the nominal wafer seating plane.

5.9 *Pitch and Capacity* — Table 1 shows the different options with regard to the wafer pitch (spacing) and the FOSB capacity. Again, no tolerance is given on the wafer pitch (*z*12), for reasons given in Section 5.8.

Table 1 Pitch and Capacity Options

Option Number	*FOSB Capacity (c)*	*Wafer Pitch (z12)*	*Wafer Clearance (z11)*
1	13 wafers	10 mm (0.39 in.)	6 mm (0.24 in.) minimum
2	25 wafers	10 mm (0.39 in.)	6 mm (0.24 in.) minimum

Table 2 Internal FOSB Dimensions (Figures 2–8)

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Boundary or Feature Measured to*
*r*1	3	151 mm (5.94 in.) maximum	nominal wafer centerline	outer edge of wafer pick-up volume
*r*2	3, 6	152 = 1 – 0 mm (5.99 + 0.03 – 0 in.)	*y*1 in front of nominal wafer centerline	encroachment of FOSB side domains on wafer set-down volume
*r*3	3, 6	*r*2 + 1 mm (0.04 in.) minimum	*y*1 in front of nominal wafer centerline	encroachment of FOSB side domains on wafer extraction volume
*r*4	3	170 mm (6.69 in.) minimum	nominal wafer centerline	encroachment of FOSB on end effector exclusion zone between front and rear FOSB side domains
*x*1	3, 5	50 mm (1.97 in.) minimum	bilateral datum plane	inside of rear FOSB side domains
*x*2	3, 5	75 mm (2.95 in.) maximum	bilateral datum plane	outside of rear FOSB side domains
*x*3	3, 5, 6, 8	125 mm (4.92 in.) minimum	bilateral datum plane	inside of front FOSB side domains
*x*51	3	140 mm (5.51 in.) minimum	bilateral datum plane	interior of FOSB sides between *y*11 and *y*49
*x*52	3	170 mm (6.69 in.) minimum	bilateral datum plane	interior of FOSB sides between *y*49 and *y*52
*y*1	3	3 mm (0.12 in.) maximum	facial datum plane	origin of *r*2 and *r*3 on bilateral datum plane
*y*5	3, 4	120 mm (4.72 in.) minimum	facial datum plane	front of rear FOSB side domains
*y*11	3	85 mm (3.35 in.) maximum	facial datum plane	interior of FOSB sides between *x*3 and *x*51
*y*20‡	None	158 mm (6.22 in.)	facial datum plane	maximum protrusion of wafers toward the front of the FOSB
*y*49	3	134 mm (5.28 in.) maximum	facial datum plane	interior of FOSB sides between *x*51 and *x*52
*y*51	3	50 mm (1.97 in.) minimum	facial datum plane	rear of door
*z*6	4, 5, 8	32 mm (1.26 in.) maximum	horizontal datum plane	top of FOSB bottom domain
*z*8	4, 5, 8	44 mm (1.73 in)	horizontal datum plane	bottom nominal wafer seating plane
*z*10	6, 7	0 ± 0.5 mm (0.00 ± 0.02 in.)	each nominal wafer seating plane	entire bottom of the wafer
*z*11	6, 7	See Table 1.	each nominal wafer seating plane	encroachment of FOSB side domains on clearance above the wafer
*z*12	4, 5, 6, 7, 8	See Table 1.	each nominal wafer seating plane	adjacent nominal wafer seating planes
*z*15	4, 5, 6	13 mm (0.51 in.) minimum	top nominal wafer seating plane	bottom of FOSB top domain
*z*23	6	3 mm (0.12 in.) maximum	each nominal wafer seating plane	bottom of wafer extraction volume
*z*29	7	0.7 mm (0.028 in.) maximum	each nominal wafer seating plane	encroachment of FOSB side domains under wafer extraction volume

‡ These dimensions are for optional features.

5.10 *External Dimensions* — Figures 9 through 13 respectively show the side view, rear view, top view, robotic flange, and bottom view for the front-opening FOSB. Table 3 defines all of the dimensions. If an identification tag is used, it must be located at the bottom rear centered on the bilateral datum plane and must be contained within the maximum outer dimensions of the FOSB.

5.11 *Human Handles* — All handles for use by humans must either be contained within the maximum outer dimensions of the FOSB, be detached when not in use, or be retractable into the maximum outer dimensions when not in use. Although such handles may extend past *x*53, they must still be contained within *x*50, *y*40, and *r*67. Handles for use by humans (if present) must follow SEMI S8, and they must require the use of both hands (each using a full wrap-around grip, given the minimum clearance requirement in SEMI E15.1). Automation handling features shall not be considered dual purpose unless they are designed to meet SEMI S8 guidelines.

5.12 *Automation Handling* — On the top of the FOSB, there is an optional robotic handling flange for manipulating the FOSB as illustrated in Figure 12. On the bottom of the FOSB, there are optional rails for use with roller conveyors or forklifts. Although they are only required to extend *y*58 to the left and right, it is recommended that they be as long as possible. Beyond *y*58, only the lower bound on *z*43 apply. These optional conveyor rails (defined by *x*56, *x*57, and *z*43) are located on the left and right bottom edges of the front-opening shipping box. The conveyor rails also have vertical cylindrical pin holes for fork lift centering (defined by *d*65).

(numbers in parentheses are for 25-wafer FOSB, if different)

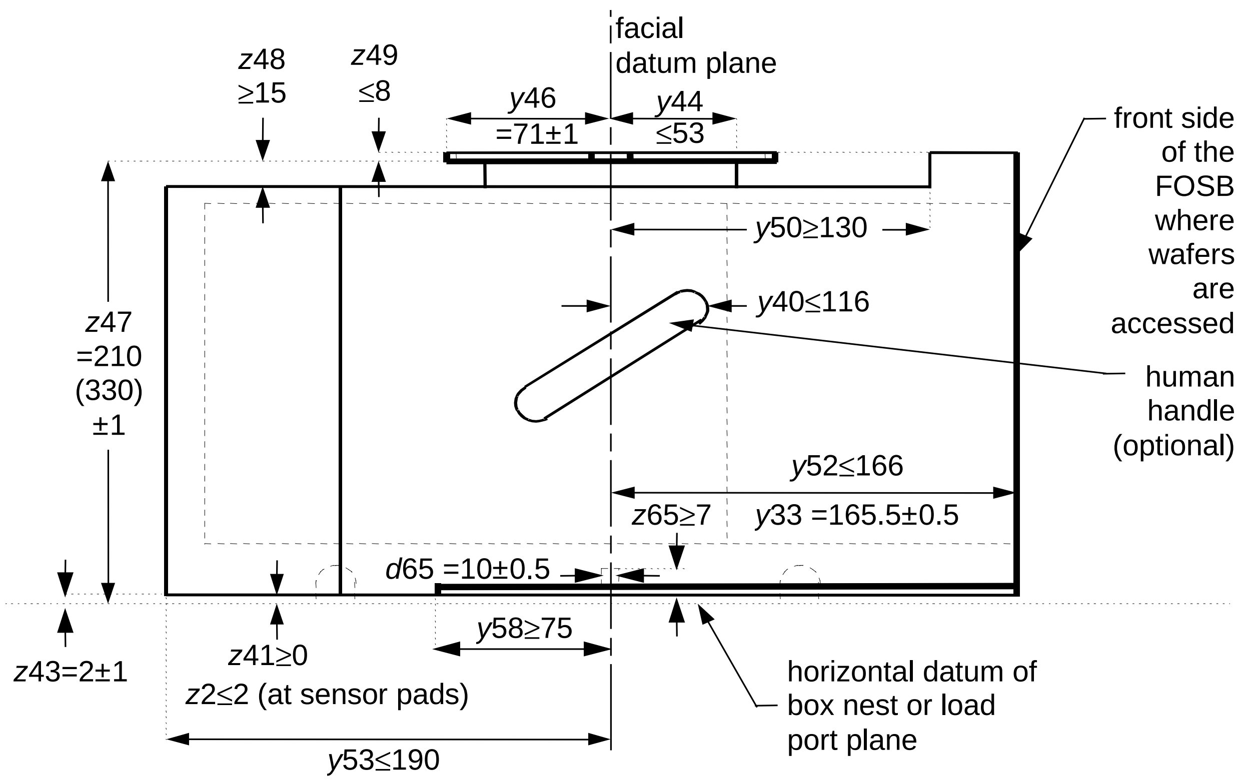


Figure 9
Side View of FOSB

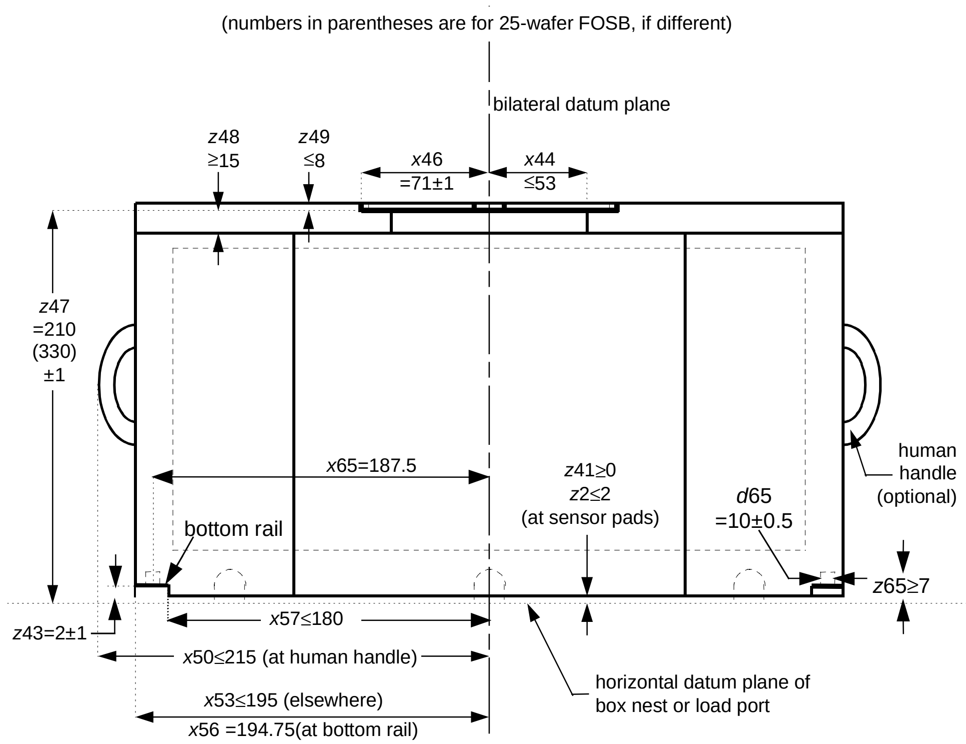


Figure 10
Rear View of FOSB

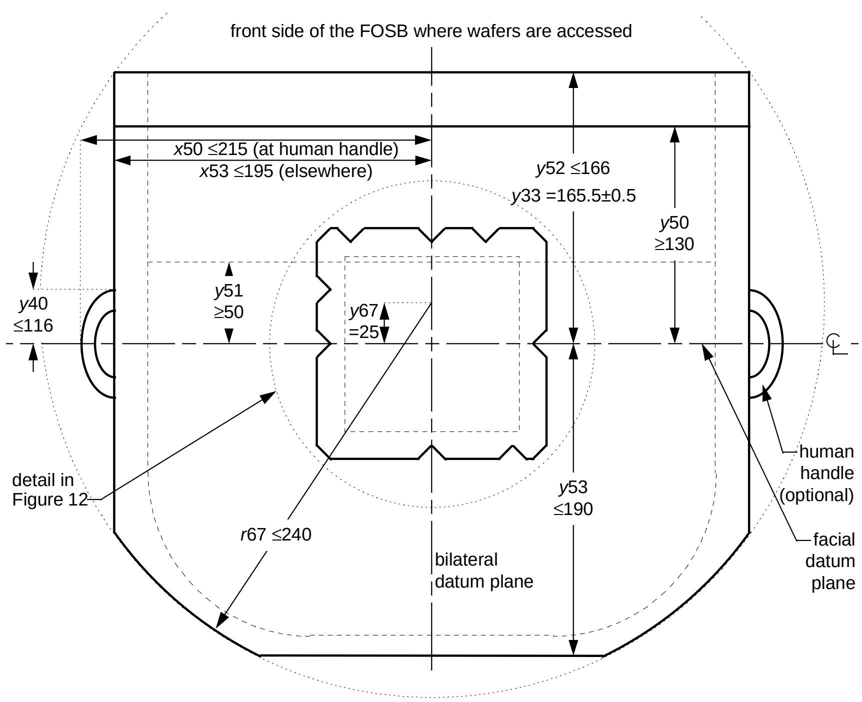


Figure 11
Top View of FOSB

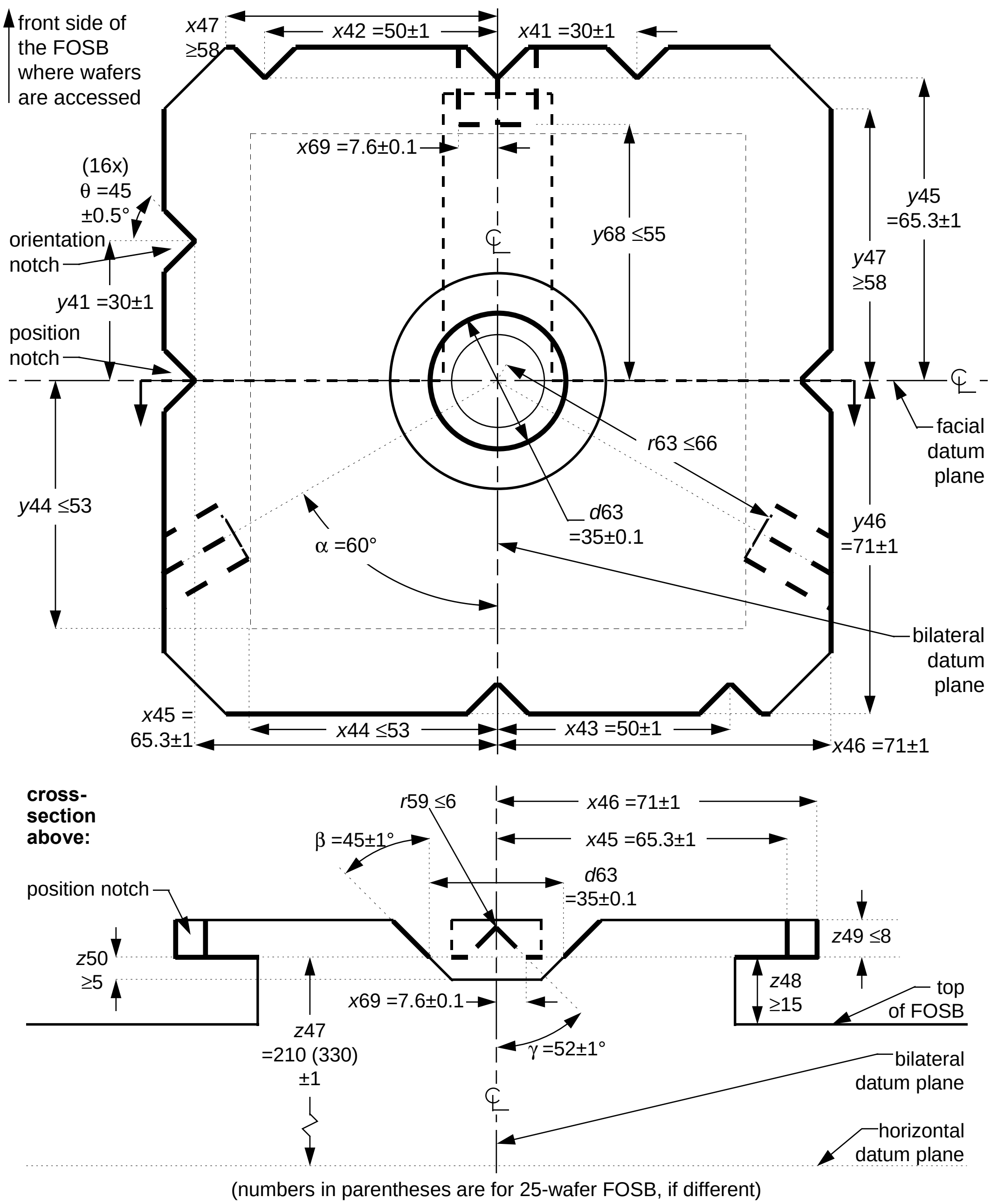


Figure 12
Top Robotic Handling Flange

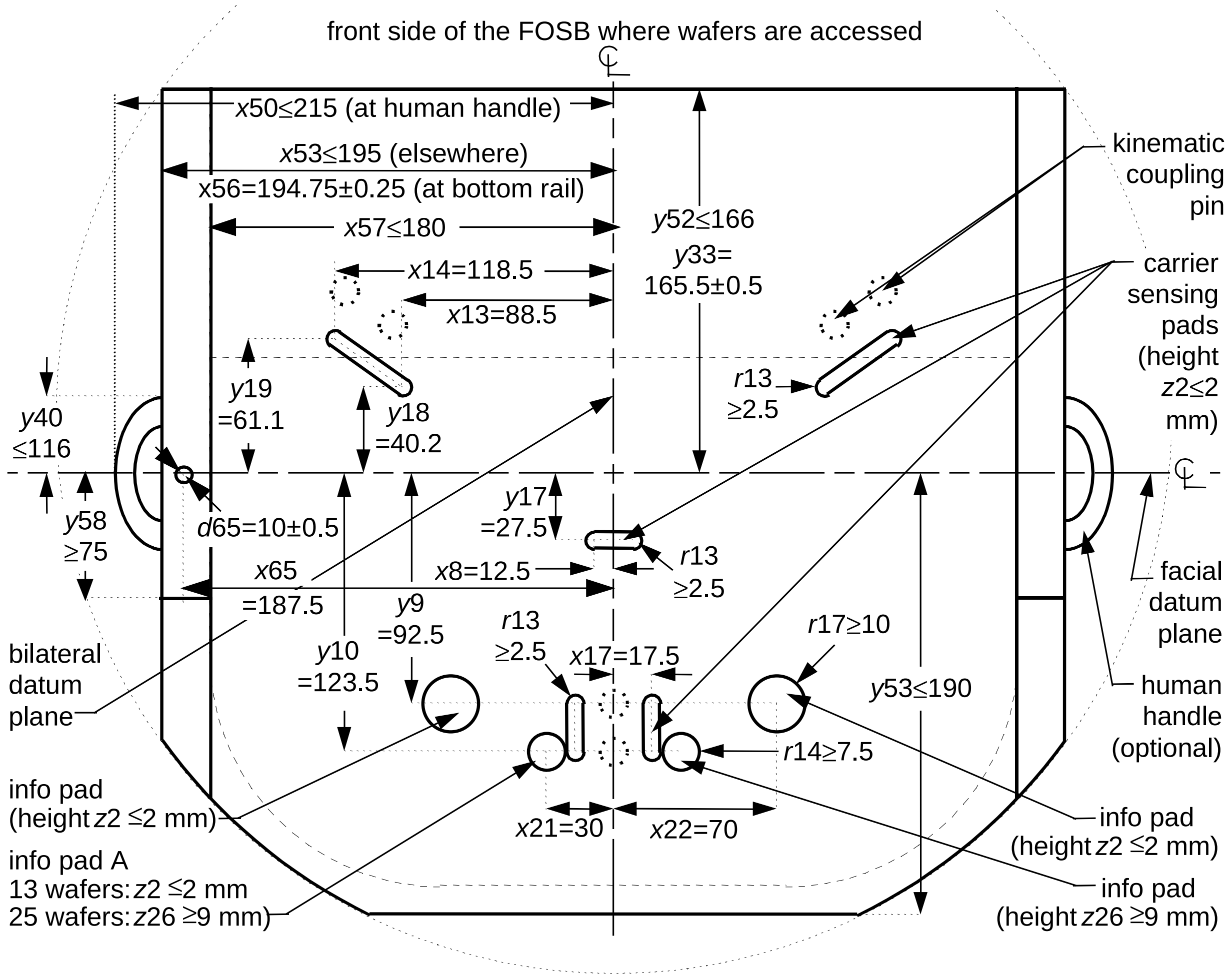


Figure 13
Bottom View of FOSB

5.13 Sensing Pads — As shown in Figure 13, when the FOSB is fully down on the kinematic coupling, the carrier sensing pads must be z2 above horizontal datum plane. It is recommended that the areas surrounding all of the carrier sensing pads be designed in conjunction with the features that mate with kinematic coupling pins so that a mechanical sensor pin cannot interfere with the lead-in function of the kinematic couplings. Other sensing pads (called info pads and given letter names) communicate information about the carrier. Note that since this is a bottom view, the positions of sensors on a load port will be switched, with the sensor for info pad A on the right and the sensor for info pad B on the left as one faces the tool from the front. Info pad A (on the lower left in Figure 13) indicates the FOSB capacity (the number of wafers). Info pad A must be in the down position (at z2 above horizontal datum plane) if the FOSB holds 13 wafers and must be in the up position (at z26 above horizontal datum plane) if the FOSB holds 25 wafers. Info pad B is allowed to be at either height (up or down) as specified by the purchaser. If such information is not required by the purchaser, info pad B must be up. Info pads C and D (slightly forward and to the outside of info pads A and B) are allowed to be at either height (up or down) as specified by the purchaser. If such information is not required by the purchaser, info pads C and D must both be up. Table 3 defines all dimensions.

Table 3 External FOSB Dimensions (Figures 9–13)

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Feature Measured to*
α‡	12	60°	bilateral datum plane	centerline of the right and left kinematic grooves in the top robotic handling flange
β‡	12	45 ± 1°	nominal wafer centerline	surface of the center hole in the top robotic handling flange
γ‡	12	52 ± 1°	bilateral datum plane or vertical plane rotated α away from it about nominal wafer centerline	angled surface of the kinematic grooves in the top robotic handling flange
θ‡	12	45 ± 0.5°	either vertical datum plane	sides of position and orientation notches
*d*63‡	12	35 ± 0.1 mm (1.378 ± 0.004 in.)	diameter centered on the nominal wafer centerline	sides the center hole in the top robotic handling flange at height *z*47
*d*65	9, 10, 13	10 ± 0.5 mm (0.39 ± 0.02 in.)	diameter centered on the intersection of *x*65 and the facial datum plane	surface of cylindrical fork-lift pin holes in left and right bottom conveyor rails
*r*13	13	2.5 mm (0.10 in.) minimum	line segment along center of carrier sensing pad	edge of carrier sensing pad
*r*14	13	7.5 mm (0.30 in.) minimum	intersection of *x*21 and *y*10	edge of info pads A and B
*r*17	13	10 mm (0.39 in.) minimum	intersection of *x*22 and *y*9	edge of info pads C and D
*r*34	2	23 ± 0.25 mm (0.906 ± 0.010 in.)	not applicable	inside corner of frame seal zone
*r*35	2	30 mm (1.18 in.) maximum	not applicable	outside corner of frame seal zone
*r*59‡	12	6 mm (0.24 in.) maximum	not applicable	radius on peak of kinematic grooves in the top robotic handling flange
*r*63‡	12	66 mm (2.60 in.) maximum	nominal wafer centerline	near end of the right and left kinematic grooves in the top robotic handling flange
*r*65	None	1 mm (0.04 in.) maximum	not applicable	all concave features (radius)
*r*66	None	2 mm (0.08 in.) maximum	not applicable	all required convex features (radius)
*r*67	11	240 mm (9.45 in.) maximum	*y*67 in front of nominal wafer centerline	any part of FOSB
*r*69	None	10 mm (0.4 in.) minimum (required) 15 mm (0.6 in.) (recommended for ergonomic reasons)	not applicable	correctable FOSB misalignment in any horizontal direction
*x*8	13	12.5 mm (0.49 in.)	bilateral datum plane	end of the line segment along center of center carrier sensing pad
*x*13	13	88.5 mm (3.48 in.)	bilateral datum plane	near end of the line segment along center of front carrier sensing pads
*x*14	13	118.5 mm (4.67 in.)	bilateral datum plane	far end of the line segment along center of front carrier sensing pads
*x*17	13	17.5 mm (0.69 in.)	bilateral datum plane	line segment along center of rear carrier sensing pads

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*x*21	13	30 mm (1.18 in.)	bilateral datum plane	origin of radius *r*14 at center of info pads A and B
*x*22	13	70 mm (2.76 in.)	bilateral datum plane	origin of radius *r*17 at center of info pads C and D
*x*34	2	184.5 ± 0.25 mm (7.264 ± 0.010 in.)	bilateral datum plane	inside edge of frame seal zone
*x*35	2	193.5 mm (7.62 in.) minimum	bilateral datum plane	outside edge of frame seal zone
*x*41‡	12	30 ± 1 mm (1.18 ± 0.04 in.)	bilateral datum plane	front right orientation notch on robotic handling flange
*x*42‡	12	50 ± 1 mm (1.97 ± 0.04 in.)	bilateral datum plane	front left orientation notch on robotic handling flange
*x*43‡	12	50 ± 1 mm (1.97 ± 0.04 in.)	bilateral datum plane	rear orientation notch on robotic handling flange
*x*44‡	10, 12	53 mm (2.09 in.) maximum	bilateral datum plane	encroachment of FOSB underneath robotic handling flange
*x*45‡	12	65.3 ± 1 mm (2.57 ± 0.04 in.)	bilateral datum plane	nearest point of side position and orientation notches on robotic handling flange
*x*46‡	10, 12	71 ± 1 mm (2.80 ± 0.04 in.)	bilateral datum plane	sides of robotic handling flange
*x*47‡	12	58 mm (2.28 in.) minimum	bilateral datum plane	end of robotic handling flange front and rear
*x*50	10, 11, 13	215 mm (8.46 in.) maximum	bilateral datum plane	furthest reach of human handles
*x*53	10, 11, 13	195 mm (7.68 in.) maximum	bilateral datum plane	FOSB sides (apart from human handles)
*x*56	10, 13	194.75 ± 0.25 mm (7.667 ± 0.010 in.)	bilateral datum plane	outside edge of bottom conveyor rails
*x*57	10, 13	180 mm (7.09 in.) maximum	bilateral datum plane	FOSB sides underneath bottom conveyor rails
*x*65	10, 13	187.5 mm (7.38 in.)	bilateral datum plane	vertical axis of cylindrical fork-lift pin holes in left and right bottom conveyor rails
*x*69‡	12	7.6 ± 0.1 mm (0.299 ± 0.004 in.)	bilateral datum plane or vertical plane rotated α away from it about nominal wafer centerline	beginning of angled surface of the kinematic grooves in the top robotic handling flange
*x*81†	1	215 mm (8.46 in.) maximum	bilateral datum plane	outer edge of manual door
*y*9	13	92.5 mm (3.64 in.)	facial datum plane	front end of the line segment along center of rear carrier sensing pads and origin of radius *r*17 at center of info pads C and D
*y*10	13	123.5 mm (4.86 in.)	facial datum plane	rear end of the line segment along center of rear carrier sensing pads and origin of radius *r*14 at center of info pads A and B
*y*17	13	27.5 mm (1.08 in.)	facial datum plane	line segment along center of center carrier sensing pad
*y*18	13	40.2 mm (1.58 in.)	facial datum plane	near end of the line segment along center of front carrier sensing pads

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*y*19	13	61.1 mm (2.41 in.)	facial datum plane	far end of the line segment along center of front carrier sensing pads
*y*33	9, 11, 13	± 0.5 mm (6.52 ± 0.02 in.)	facial datum plane	surface of seal zones
*y*40‡	9, 11, 13	116 mm (4.57 in.) maximum	facial datum plane	furthest extent of human handles toward the front
*y*41‡	12	30 ± 1 mm (1.18 ± 0.04 in.)	facial datum plane	left orientation notch on robotic handling flange
*y*42	None	± 0.5 mm (± 0.02 in.) flatness over each area	facial datum plane	surfaces that mate with the seal zones
*y*44‡	9, 12	53 mm (2.09 in.) maximum	facial datum plane	encroachment of supports under the outer edge of the robotic handling flange
*y*45‡	12	65.3 ± 1 mm (2.57 ± 0.04 in.)	facial datum plane	nearest point of front and rear position and orientation notches on robotic handling flange
*y*46‡	9, 12	71 ± 1 mm (2.80 ± 0.04 in.)	facial datum plane	front and rear edge of robotic handling flange
*y*47‡	12	58 mm (2.28 in.) minimum	facial datum plane	end of robotic handling flange sides
*y*49	None	134 mm (5.28 in.) maximum	facial datum plane	interior of FOSB sides between *x*51 and *x*52
*y*50	9, 11	130 mm (5.12 in.) minimum	facial datum plane	rear of upper door frame volume
*y*52	3, 9, 11, 13	166 mm (6.54 in.) maximum	facial datum plane	FOSB front
*y*53	9, 11, 13	190 mm (7.48 in.) maximum	facial datum plane	FOSB rear
*y*58	9, 13	75 mm (2.95 in.) minimum	facial datum plane	end of left and right conveyor rails
*y*67	11	25 mm (0.98 in.)	facial datum plane	origin of *r*67 on bilateral datum plane
*y*68‡	12	55 mm (2.17 in.) maximum	facial datum plane	near end of the front kinematic groove in the top robotic handling flange
*y*81†	1	30 mm (1.18 in.) minimum	facial datum plane	rear edge of manual door
*y*82†	1	191 mm (7.52 in.) maximum	facial datum plane	front surface of manual door
*z*2	9, 10, 13	2 mm (0.08 in.) maximum	horizontal datum plane	bottom of carrier sensing pads and info pads (when down)
*z*26	13	9 mm (0.35 in.) minimum	horizontal datum plane	bottom of info pads (when up)

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*z*30	2	106.5 ± 0 mm (4.19 ± 0 in.) for non-removable 13-wafer cassette and 166.5 ± 0 mm (6.56 ± 0 in.) for non-removable 25-wafer cassette and 128 ± 0 mm (5.04 ± 0 in.) for removable 13-wafer cassette and 188 ± 0 mm (7.40 ± 0 in.) for removable 25-wafer cassette	horizontal datum plane	vertical centerline of port
*z*34	2	95.5 ± 0.25 mm (3.760 ± 0.010 in.) for 13-wafer FOSB and 155.5 ± 0.25 mm (6.122 ± 0.010 in.) for 25-wafer FOSB	*z*30 above horizontal datum plane	inside edge of frame seal zone
*z*35	2	104.5 mm (4.11 in.) minimum for 13-wafer FOSB and 164.5 mm (6.48 in.) minimum for 25-wafer FOSB	*z*30 above horizontal datum plane	outside edge of frame seal zone
*z*41	9, 10	0 mm (0 in.) minimum	external horizontal datum plane	bottom of FOSB
*z*43	9, 10	2 ± 1 mm (0.08 ± 0.04 in.)	external horizontal datum plane	bottom conveyor rails
*z*47‡	9, 10, 12	210 ± 1 mm (8.27 ± 0.04 in.) for 13-wafer FOSB and 330 ± 1 mm (12.99 ± 0.04 in.) for 25-wafer FOSB	external horizontal datum plane	bottom of robotic handling flange
*z*48‡	9, 10, 12	15 mm (0.59 in.) minimum	bottom of robotic handling flange	encroachment of FOSB top underneath robotic handling flange
*z*49‡	9, 10, 12	8 mm (0.31 in.) maximum	bottom of robotic handling flange	top of robotic handling flange and upper door frame volume
*z*50‡	12	5 mm (0.20 in.) minimum	bottom of robotic handling flange	encroachment of FOSB top underneath the center hole in the top robotic handling flange
*z*65	9, 10	7 mm (0.28 in.) minimum	horizontal datum plane	upper boundary of cylindrical fork-lift pin holes in left and right bottom conveyor rails

Symbol Used	*Figure Number*	*Value Specified*	*Datum Measured from*	*Feature Measured to*
*z*82†	1	130 mm (5.12 in.) maximum for 13-wafer FOSB and 190 mm (7.48 in.) maximum for 25-wafer FOSB	*z*30 above horizontal datum plane	top edge of manual door
*z*83†	1	130 mm (5.12 in.) maximum for 13-wafer FOSB and 190 mm (7.48 in.) maximum for 25-wafer FOSB	*z*30 above horizontal datum plane	bottom edge of manual door

‡ These dimensions are for optional features.

† These dimensions pertain to the manual door only.

6 Related Documents

6.1 *SEMI Standards*

SEMI E19.5 — Specification for 300 mm Bottom-Opening Standard Mechanical Interface (SMIF)

SEMI E22.1 — Cluster Tool Module Interface 300 mm: Transport Module End Effector Exclusion Volume Standard

SEMI E63 — Provisional Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI M28 — Specification for Developmental 300 mm Diameter Polished Single Crystal Silicon Wafers

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

APPENDIX 1
APPLICATION NOTES

NOTE: This appendix is an official part of SEMI M31 and was approved by full letter ballot procedures on July 15, 1999.

A1-1 Although FOSB parameters supporting effective reuse and cleaning (washing/drying) are not defined in this document, it is essential that these capabilities be considered for a successful overall shipping box design.

A1-2 It is important to note that shipping boxes containing wafers are typically bagged for shipment to the IC manufacturer. It is therefore important to design the outer surfaces of the shipping box to be compatible with this common practice.

SEMI M32-0998
GUIDE TO STATISTICAL SPECIFICATIONS

1 Purpose

1.1 Specifications are based on requirements negotiated between trading partners. This document describes an explicit specification form that defines the risk level as a part of parametric specifications. This approach uses process capability information to focus quality improvement efforts, reduce sampling, and maintain low risks. It is based on the fundamental belief that specifications should facilitate the movement toward processed-in quality instead of inspected-in quality.

1.2 It is important for users and suppliers to acknowledge and mutually agree on quality levels so the methods employed will satisfy their expectations. Statistical specifications provide a convenient way to do this.

1.3 Statistical specifications are designed to facilitate the movement toward processed-in quality. They are most appropriate for processes that have been statistically characterized. This means the shape of the statistical distribution that created the product is known, or can be approximated to the satisfaction of the user and the supplier. It also implies that the statistical control of the process and the measurement systems are defined to the level that is necessary to meet the current needs.

2 Scope

2.1 This guide may be used when changing or adding specifications to SEMI M18.

2.2 Statistical specifications apply to all processes that have been statistically characterized. Solutions are given for two product distribution shapes (normal & lognormal), and the advantages of these solutions are explained. Appendix 3 shows the statistically characterized shape for many common silicon wafer processes.

2.3 This guide applies to processes related to the production and use of silicon wafers. It may also be applied to the production and use of other materials.

2.4 This approach implies that the quality level shipped is the same as the quality level produced.

2.5 This methodology can be an effective tool for driving quality improvement.

2.6 This procedure can be coupled with other techniques for centering the mean and reducing the variation within the process distribution as deemed necessary by the user and supplier.

2.7 Appendix 4 further explains the rationale for this approach.

3 Limitations

3.1 Outlier effects are beyond the scope of this document.

4 Referenced Documents

NOTE: As listed or revised, the document cited shall be the latest publication of the adopted standard.

4.1 *SEMI Standard*

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

5 Terminology

5.1 *Acronyms*

5.1.1 *Cpk* — Process capability index

5.1.2 *ppm* — Parts per million

5.2 *Definitions*

5.2.1 *capability based sampling* — Any method that uses the process capability as a factor in determining the required sampling.

5.2.2 *ECPK* — Process capability index on a non-normal process which is corrected for non-normality.

5.2.3 *error* — The difference between the quality level committed to a user and the level that could be received.

5.2.4 *process capability index (Cpk)* — The smaller of (upper spec limit - mean) ÷ 3 sigma, or (mean - lower spec limit) ÷ 3 sigma.

5.2.5 *quality level* — The maximum defect level agreed upon by the user and the supplier.

5.2.6 *supplier risk* — The risk of rejecting material that is within the user specifications.

5.2.7 *user risk* — The risk of accepting material that is outside the user specifications.

6 Solutions

6.1 The following are examples of statistical specifications for normal and lognormal distributions.

6.1.1 *Normal* — The normal distribution describes processes that target a specific value and have symmetric random variation about that value. The first portion of the normal statistical specification is the familiar tolerance. It uses an upper specification limit (USL) and a lower specification limit (LSL), or the target plus and/or minus a value. The second portion, after the @ sign below, is a measure of the quality level, in ppm.

LSL to USL @ yy ppm, or

Target ± xx @ yy ppm

6.1.2 *Lognormal* — The lognormal function describes many of the one-sided distributions that are encountered in the silicon industry. It applies to those parameters such as flatness and warp that are bounded by zero. For lognormal processes, the value of a parameter could be specified as:

≤ xx @ yy ppm

6.2 More details, and examples of use, are shown in Appendix 1 for normal applications and Appendix 2 for lognormal applications.

6.3 For process distributions not following normal or lognormal forms, Pearson or other distributions may be used.

APPENDIX 1
USING STATISTICAL SPECIFICATIONS FOR NORMAL PROCESSES

NOTE: This appendix was approved as an official part of SEMI M32 by full letter ballot procedure.

A1-1 Statistical Specification Format for Normal Distributions

A1-1.1 The normal distribution is quite well-known. It describes processes that target a specific value and have symmetric random variation about that value. Below are examples of statistical specifications for normal processes. The first portion is the familiar tolerance, and the second portion is a measure of the quality level.

LSL to USL @ yy ppm, or

Target ± xx @ yy ppm

Other standard tolerance definitions could be substituted, or other definitions of the quality level such as Cpk, Z-value, or percent could be used.

A1-1.2 Adding the quality level removes the potential for misunderstanding and makes the specification more meaningful.

A1-2 Example of Use

A1-2.1 Functionally, statistical specifications are similar to conventional tolerances, except that the quality level is stated rather than just implied. They can be directly substituted for tolerances or other forms of specifications. Statistical specifications are especially useful for focusing quality improvement efforts, achieving ship-to-stock relationships, promoting processed in quality, and reducing after the fact inspection. In this environment they could be used as follows:

A1-2.1.1 Through audits and capability reporting a particular parameter is targeted for improvement or chosen as a ship-to-stock candidate.

A1-2.1.2 The control methods, distribution shape, and statistical specification are agreed upon. The tolerance and quality level defined in the statistical specification completely define the needed process capability.

A1-2.1.3 Once it is shown that the required capability is consistently exceeded then reduced inspection sampling can be implemented without increasing the risk to the customer or supplier. In this way the process controls can gradually become the guarantee for quality, and after the fact inspection can be gradually reduced to the level that is needed for outgoing quality reporting.

A1-3 Discussion

A1-3.1 Statistical specifications remove ambiguity, allow small risks, and promote the movement toward better process controls and less after the fact inspection. The quality level (i.e., the yy portion) is often misunderstood. Some people say they want ppm level quality but introduce methods that allow 50,000 to 200,000 ppm in error. This causes confusion.

A1-3.2 Many people have the misconception that tolerances are goal posts that require 100% of the material to fall inside. Processes are usually described by statistical distributions, so specifications have little meaning if a quality level is not defined. For many years, 99.73% (i.e., ± 3 sigma) was considered to be satisfactory. "Within tolerance" was understood to mean within tolerance with a 99.73% confidence, or a 0.27% quality level. Later the 99.73% process was defined as "cruel". 0.27% was no longer an acceptable quality level, and process drift was understood to cause even higher reject rates. This led to the demand for better process capabilities (i.e., higher Cpk's), which demanded corresponding improvements in process characterization and control methodologies. At the same time other users tightened their tolerances to the point that led to over-control. Either extreme can cause a mismatch between expectations and capabilities if the risks are not carefully evaluated.

A1-3.3 Capability-based sampling is perhaps the only way to rigorously transfer from inspection-based quality to process control-based quality, without incurring high risks. Statistical specifications create the environment for this to work. Once the specification is clearly defined, it can be clearly achieved. The details of capability based sampling are beyond the scope of this document, but the basic concept is easy to understand. If a process is very capable and controlled, then the system can be relied upon to create the necessary quality level with less after the fact inspection. This is good for both sides. Users get more reliable quality, and suppliers get the information needed to focus quality improvement efforts and direct resources at the most critical processes.

A1-3.4 Once a process has been statistically characterized, everything becomes much easier. Calculations can be done in milliseconds instead of minutes. This includes spec acceptance, comparisons, and many forms of analysis. Multiple levels like % < A, % < B, and % < C are also clearly unnecessary if the distribution shape is known. This prevents a large amount of duplicate work.

APPENDIX 2
USING STATISTICAL SPECIFICATIONS FOR LOGNORMAL PROCESSES

NOTE: This appendix was approved as an official part of SEMI M32 by full letter ballot procedure.

A2-1 Statistical Specification Format for Lognormal Distributions

A2-1.1 The lognormal probability distribution function describes many of the one-sided distributions encountered in the silicon industry. It applies to those one-sided parameters like flatness and warp that are bounded by zero. Below is an example of a statistical specification for a lognormal process.

$$\leq \text{ xx @ yy ppm}$$

A2-1.2 Other standard tolerance definitions could be substituted, or other quality level definitions such as ECPK, Z-value, or percent could be used. Again, ECPK is the Equivalent normal Cpk that corrects for non-normality. More information on the Equivalent Cpk is shown at the end of this appendix.

A2-1.3 As with the normal distribution, adding the quality level removes the potential for misunderstanding and makes the specification more meaningful.

A2-2 Example of Use

A2-2.1 Again, the major objectives are to focus quality improvement efforts, achieve ship-to-stock relationships, promote processed in quality, and reduce after the fact inspection. The steps are the same as shown in Paragraph A1-2 for the normal distribution. The major difference is that only the upper tail needs to be considered. However, since the lognormal tail goes so much farther out, it might be necessary to accept a less critical quality level.

A2-3 Discussion

A2-3.1 Statistical specifications work very well for processes with lognormal distributions. They have all the benefits described for normal distributions, and in some respects, they are even easier. Since lognormal processes only have one tail, checking each tail to decide which is the most critical is not necessary. Also, it has been empirically observed that lognormal processes are not as prone to mean drifting, so they tend to be more stable. The main hurdle is realizing how much error is introduced if the distribution shape is assumed to be normal when it is not.

A2-3.1.1 Figure A2-1 illustrates the difference between a lognormal and a normal process. The curve which has a solid line (and is clearly not symmetrical) is the lognormal distribution. The curve with the dashed line is the normal distribution. The error when mistakenly using a normal distribution to characterize a lognormal process is shown in Table A2-1. For values that increment by 1 sigma from the mean, the ppm greater than that value is given for each curve, and the difference (or error) is calculated. To make it easier to visualize, increments of the simple normal mean and sigma (1.8263 and 0.7568 respectively) are used in the "value" column. For calculating the lognormal statistics the correct lognormal geometric mean of 1.8258 and the lognormal geometric sigma of 0.7550 are used. The error between the curves increases as the point of interest moves toward the center of the distribution, but the most important issue is the length of the tail. The right tail of the lognormal distribution extends along with the histogram, but the normal distribution is much shorter. Visually, the significance might be overlooked in Figure A2-1, but when the tail probabilities are shown in ppm (Table A2-1) the difference is very apparent.

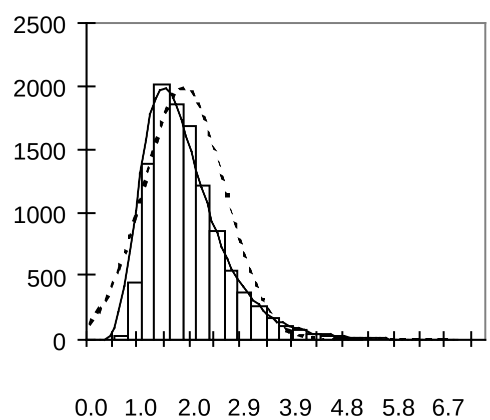


Figure A2-1
Lognormal vs. Normal Curves

Table A2-1 Lognormal vs. Normal Data

Value	*Value Description*	*Normal ppm >*	*Lognormal ppm >*	*Error*
1.8263	mean	500000	420997	79003
2.5831	+ 1 s	158655	141869	16786
3.3399	+ 2 s	22750	42836	20086
4.0967	+ 3 s	1350	12783	11433
4.8535	+ 4 s	32	3914	3882
5.6103	+ 5 s	0.3	1247	1247
6.3671	+ 6 s		415	415
7.1239	+ 7 s		144	144
7.8807	+ 8 s		52	52
8.6375	+ 9 s		20	20
9.3943	+ 10 s		8	8
10.1511	+ 11 s		3	3
10.9079	+ 12 s		1	1

A2-3.2 Lognormal distributions can be handled mathematically as easily as normal distributions, if the formulas are known. The difficulty in the past was that many of the calculations developed for the normal distribution were not available for lognormal. The equivalent normal Cpk (ECPK) was developed to address this issue. For the lognormal distribution, ECPK is calculated as shown below. It is an exact mathematical derivation with no estimations or assumptions. It was designed to allow people to see real data and keep all transformations and conversions inside the computer where they are totally invisible. Two cases are presented. Section A2-3.3 describes the case where a statistical software is available, and Section A2-3.4 describes a shortcut that may be used when the computation is derived from scratch. In both cases, it is important to remember that only the computer will see these formulas.

A2-3.3 Statistical software packages will usually output the geometric mean and geometric sigma. If μ is the lognormal geometric mean, σ is the lognormal geometric sigma, and 1n is the natural log function, then ECPK is calculated as:

$$\mathrm{ECPK} = \frac{1\mathrm{n}\,[\mathrm{USL}] - 1\mathrm{n}\left|\dfrac{\mu^2}{\sqrt{\mu^2+\sigma^2}}\right|}{3\left(\sqrt{1\mathrm{n}\left(\dfrac{\mu^2+\sigma^2}{\mu^2}\right)}\right)}$$

For the example in Figure A2-1 the lognormal geometric mean is 1.826 and the lognormal geometric sigma is 0.755. If an upper spec limit (USL) of 6 is applied, then the ECPK is 1.06. This will usually be done in a computer. A programming version of this formula is written as:

$$\mathrm{ECPK} = ((\log\,(\mathrm{USL})) - \log\,(\mathrm{Gmean}**2 \,/\, (\mathrm{sqrt}\,(\mathrm{Gmean}**2 + \mathrm{Gsigma}**2)))) \,/\, (3 * \mathrm{sqrt}\,(\log\,((\mathrm{Gmean}**2 + \mathrm{Gsigma}**2) \,/\, \mathrm{Gmean}**2)))$$

A2-3.4 If the computation is programmed from scratch for raw data, it may be convenient to take the natural log of each data point (i.e., do a log transformation) then compute the mean of the transformed data (Tmean) and sigma of the transformed data (Tsigma). Again, ln is the natural log function. In this case, the ECPK formula can be written as:

$$\mathrm{ECPK} = (1\mathrm{n}(\mathrm{USL}) - \mathrm{Tmean})/(3 * \mathrm{Tsigma})$$

The geometric mean and geometric sigma could then be calculated as follows:

$$\mathrm{Gmean} = \exp(\mathrm{Tmean} + (\mathrm{Tsigma}**2)/2)$$

$$\mathrm{Gsigma} = \mathrm{sqrt}((\exp((2*\mathrm{Tmean}) + (\mathrm{Tsigma}**2)))*(\exp((\mathrm{Tsigma}**2)) - 1))$$

A2-4 Conclusion

Lognormal calculations can be as easy as normal calculations. Again, the formulas reside only in the computer where they are never seen by the user. They allow the user to view the actual measures and the actual distributions.

APPENDIX 3
CURRENT STATISTICAL CHARACTERIZATION OF SILICON PROCESS PARAMETERS

NOTE: This appendix was approved as an official part of SEMI M32 by full letter ballot procedure.

A3-1 Statistical Characterization of Silicon Process Parameters

A3-1.1 The following table describes the statistical characterization on a number of silicon wafer processes. The comments column indicates the level of characterization that has been achieved. “Characterized” means that the process should, under usual conditions, display the distribution shape shown. “Conditional” means that there are conditions that might need to be considered before deciding if the shape shown is satisfactory. The chi-square goodness of fit test was used to characterize the distribution shapes. Actual chi-square goodness of fit values will typically be proprietary information that is shared only between a given supplier and user.

Table A3-1 Characterization of Silicon Processes

Process or Parameter Description	*Distribution Shape*	*Comments*
Diameter	Normal	Characterized
Flatness/Global (GBIR, GF3R, GF3D, GFLR, or GFLD)	Lognormal	Characterized
Flatness/Site (SF3R, SF3D, SFLR, SFLD, SFQR, SFQD, SBIR, or SBID)	Lognormal	Characterized
Oxygen Concentration	Normal	*Conditional* — Non-normalities are mostly attributed to measurement error, so the normal distribution is usually satisfactory.
Shape, Bow (Reference SEMI M1, Figure A2-1.)	Normal	Characterized
Shape, Warp, or Sori (Reference SEMI M1, Figure A2-1.)	Lognormal	Characterized
Thickness (Polished or EPI)	Normal	Characterized

APPENDIX 4
RATIONALE FOR STATISTICAL SPECIFICATIONS

NOTE: This appendix was approved as an official part of SEMI M32 by full letter ballot procedure.

A4-1 Introduction

A4-1.1 The purpose of a specification is either to define acceptance criteria or to assist in quality improvement planning. The basic intent is to quantify user need so suppliers can accommodate that need. Developing a clear link between user needs and the control methods used on the production floor is one of the most critical steps for creating a Total Quality Management (TQM) environment. Following are some key background concepts that allow the reader to understand the conclusions drawn in this document.

A4-1.2 For most manufacturing processes there is no such thing as “zero defects”. Processes are described by statistical probability distributions, and the tails of these functions can go all the way to infinity. For many years, 99.73% (i.e., ± 3 sigma) was used as the basis for tolerances. “Within tolerance” was understood to mean within tolerance with a 99.73% confidence, or a 0.27% quality level. When users requested better levels, then new standards such as 33 ppm or 3.4 ppm were made. In any case, this quality level needs to be agreed upon for a specification method to have meaning. It can be measured in terms of ppm, Z, Cpk (which is equal to Z divided by 3), or percent. Z tables or Cpk tables can be obtained which provide this information.

A4-1.3 Errors in the 10% or higher range can be generated if a percentile specification is based on the central portion of the distribution. An example of such a specification is “50% ≤ 1.2 microns”. These errors are not obvious and require careful statistical analysis based upon real process variation. Multiple percentile specifications are also difficult to apply. Paragraph A4-3 provides more details on these issues.

A4-1.4 Conversely, if specifications get too far out on the tail, they tend to become abstract and are not used as the primary factor driving quality improvements. This is especially true for non-normal processes where the tail of the distribution goes out much farther than expected from a normal distribution. Figure A4-1 shows where a 3.4 ppm specification would be on a lognormal process. Users usually will not allow that much tolerance. However, if the specification is tightened while the process capability remains the same, then the consequence is a degradation in the quality level.

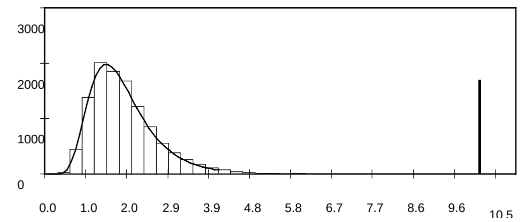


Figure A4-1
Lognormal Tolerance for 3.4 ppm Quality Level

A4-1.5 The mean and sigma specification is another proposed approach. Intuitively, this seems promising, but it has many of the same problems as multiple percentile specifications. More details are given in Paragraph A4-4.

A4-1.6 Errors in the 5% to 10% range can also be generated if process distributions are assumed to be normal when they are not. Knowing the actual distribution shape is a key factor that opens up a tremendous amount of knowledge. Figure A4-2 shows an example of real data that illustrates a lognormal process. In the past, this was considered to be difficult because non-normal distributions were only supported by high-level statistical software. Now even spreadsheets have them. It should also be noted that once the process characterization has been done, the shape of the distribution typically does not change, so this knowledge can be shared throughout the industry. Regularly monitoring the process by overlaying the distribution on the process histogram or cumulative frequency plot is extremely valuable to confirm that the process is not taking on unnatural bimodal or outlier effects. One-sided distributions such as flatness and warp are so well-characterized by the lognormal distribution that “goodness-of-fit” results are very close to 100%. Again, the error gets larger as the point-of interest moves toward the “center” of the distribution, but the major concern is the length of the tail. The lognormal distribution in Figure A4-2 (the curve with a solid line which is clearly not symmetrical) has a tail that extends much farther to the right than the normal distribution which is shown with a dashed line. This effect, and the impact, is shown in more detail in Appendix 2.

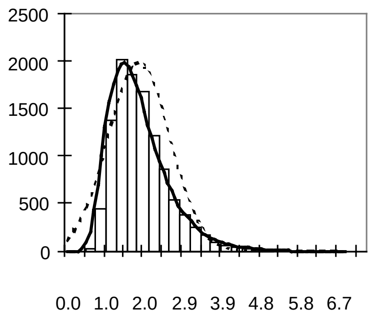


Figure A4-2
Normal vs. Lognormal Shape

A4-1.7 Statistical specifications quantify the quality level so it is not an abstract assumption left to conjecture. This allows both the user and supplier to optimize their control systems to that level. Capability based sampling is one example. Simply put, this means to use process capability information to help define the sampling plan for a process. A detailed discussion of this subject is beyond the scope of this document, but the basic concept is easy to understand. If a process is very capable and controlled it does not need as much sampling as one that is not. Implementing this strategy is a big step ahead of standard sampling theory. It might be the only way to rigorously transfer from inspection based quality to process control based quality, without incurring high risks. Statistical specifications create the environment which facilitates this improved strategy. Hopefully, the quality levels would be defined in ppm, but any level agreed upon by both the user and the supplier would work.

A4-2 Tolerance Specifications

LSL to USL, or Target ± xx

A4-2.1 The main problem with a conventional tolerance is that many people perceive it as a goal post that requires 100% of the material to fall inside. This document has shown in detail that this is simply a wrong perception. Stating the quality level in the specification, instead of just implying it, corrects this problem.

A4-2.2 Another common misconception is that tolerances and tail probabilities divert attention away from centering the process. Of course, centering is important. Considering the impact of poor quality on all customers, it is clear that a well centered process is far more efficient than one that is not. It is also generally true that the suitability of the product is not significantly different immediately on one side of a tolerance line compared to the other. However, there are a number of issues that warrant discussion.

A4-2.2.1 First, centering is usually not difficult, so it usually does not need a major emphasis. Those who are experienced in quality improvement techniques would certainly not forget to center the process. Simply monitoring the mean trend gives an excellent measure of centering, and it keeps the focus on the process rather than the specification. Industry carries a long history where specifications prevented the attainment of good process control. Many of the issues have been explained earlier in this document. To summarize, process controls are the only way to truly maintain a centered process, and these controls can only work if there is enough tolerance in the specification to accommodate the sensitivity limitations of the control methods.

A4-2.2.2 The second issue is that it might not be possible to center. This is clearly the case in one-sided processes that are bounded by zero. Optimizing multiple parameters might also dictate that some parameters get worse.

A4-2.2.3 The final, and most important, issue is the challenge of teaching statistical methods to the factory population. It is very easy to teach averages and centering since they tend to be well understood already. It is not as easy to teach sigma and the fact that sigma trends must be thoroughly understood before much of anything can be said about averages. Confirming that the R or S chart is controlled before studying the Xbar chart and doing an F-test before doing a t-test are just two examples. These are very important concepts that must be fully understood in order to apply statistical methods. Over-stressing centering de-emphasizes sigma and creates an environment where it is not appreciated. Thinking in terms of sigma is the most important concept that most people will learn about process control methods. It deserves a major emphasis.

A4-2.2.4 Of course, centering would be a concern if mixing and matching of lots is the control method, but this can be easily spotted in the statistical characterization process. The fact that some of the alternatives to tolerances are much more likely to cause this practice will be further explained in Paragraphs A4-3 and A4-4.

A4-3 Multiple Distributional Percentile Specifications

$\% \leq A$, $\% \leq B$, and $\% \leq C$

A4-3.1 Errors in the 10% or higher range can be generated if a specification in the central portion of the distribution is used. An example of such a specification is “50% ≤ 1.2 microns”.

A4-3.2 No control method can hold a process perfectly still. Even the best real-time control methods can allow a process to drift as much as ± 1.5 sigma. For this reason, a 6-sigma design was defined as 4.5 sigma to the nearest tolerance.

A4-3.3 Sampling issues are a major concern. Many kinds of variation can be quantified by rigorously studying the appropriate samplings (within batch samples for batch-to-batch variation, monthly samples for month-to-month variation, etc.). However, there are practical limits on how many kinds of variation can be continuously monitored. There is a large amount of work involved, and there are hundreds of potential sources of variation. Resource restrictions regularly force suppliers to concentrate on the known key variables and leave the rest as error in the system (at least for now). As sample periods get longer, there is more statistical sensitivity, but also more probability that the drift will be confounded with user-driven process improvements. For example, month-to-month random drift is hard to quantify because production processes are often improved before many months of data can be observed. Measurement error is another main contributor which further complicates the other sensitivity issues. These factors all combine to allow a certain amount of undetectable process drift. This process drift needs to be considered when defining the specification approach.

A4-3.4 These variations cannot be detected because of statistical sensitivity limitations. Table A4-1 shows the sample sizes needed to detect different levels of process shift. Delta will be defined as the number of sigma of undetectable mean drift. For simplicity, a one-way shift is shown, but in most practical cases, the shift could go plus or minus. Using the old standard of 5% supplier risk and 10% user risk, 72 samples are needed to detect a delta of 0.25 sigma. This example (0.25 sigma of mean drift) has been used throughout this document. Since most of the discussion will relate to process drift, the terms “drift” and “shift” will be used interchangeably. Clearly, 72 is too large a sampling for most real-time control systems, but it is still an understatement of the problem. Most users currently expect their risk to be much smaller than 10%. The last row shows that the sample size would need to be 311 to reach 0.1% user and supplier risks. It is generally agreed that 0.1% (i.e., 1000 ppm) is the lowest level that is feasible using standard probability theory. For lower levels, it is necessary to move farther out on the distribution tails where it is necessary to rely on more than just stndard sampling probabilities.

Table A4-1 Sampling Requirements

(a = supplier risk, b = user risk)

Detectable Mean Shift (in Sigma)	*0.125*	*0.25*	*0.50*	*0.75*	*1.0*
Min N a = 20% b = 20%	92	24	7	4	4
Min N a = 5% b = 10%	280	72	20	10	7
Min N a = 1% b = 1%	696	177	47	23	15
Min N a = 0.1% b = 0.1%	1228	311	82	40	25

A4-3.5 Figures A4-3a, A4-3b, and A4-3c show the error generated by 0.25 sigma of undetectable mean drift. Again, the number of sigma of undetectable mean drift will be defined as delta. Notice how the error grows as the point of interest moves toward the center of the distribution. At the four sigma point (out on the tail) there is very little error, so suppliers can be generous with internal buffer specifications to protect the user. This is not as feasible in the center of the distribution because there is so much material at stake. A percentile specification in the center of the process shown would have about 1000 times more undetected, out-of-spec product than a specification at the 4 sigma point. Since the shift could go either way, this could also be 1000 times more material that was rejected and should not have been.

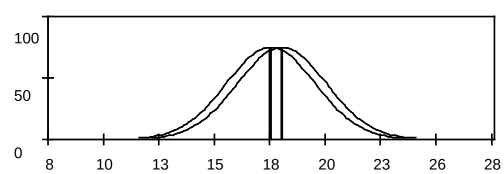


Figure A4-3a
Error at 0 Sigma

A4-3.6 The left curve in Figure A4-3a shows a distribution with an expected mean of 18. The right curve shows the same distribution with an undetectable drift of 0.25 sigma. If a specification limit is placed at 18, then 50% of the material is below the specification for the nominal distribution. However, only 40.13% is below the specification for the distribution that has drifted. The error, shown by the area between the vertical lines and below the right curve, is 9.87% or 98,700 ppm.

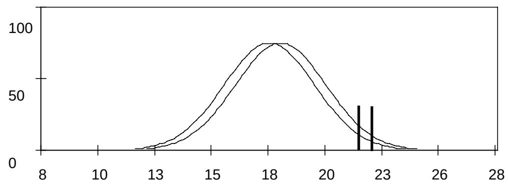


Figure A4-3b
Error at 2 Sigma

A4-3.7 The error when the specification is 2 sigma from the mean, shown in Figure A4-3b as the area between the vertical lines and below the right curve, is 1.73% or 17,300 ppm.

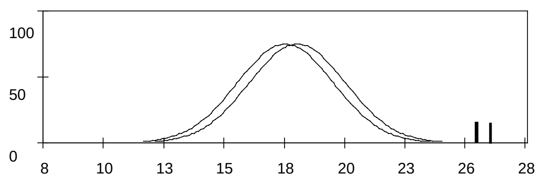
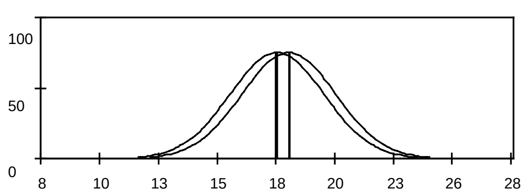


Figure A4-3c
Error at 4 Sigma

A4-3.8 The error when the specification is 4 sigma from the mean, shown in Figure A4-3c as the area between the vertical lines and below the right curve (but indistinguishable), is 0.01% or 100 ppm.

A4-3.9 Figure A4-4 further quantifies this error. Percent-less-than calculations are shown for each curve at increments of 1 sigma from the mean. The starting mean is 18, and the sigma is 2.



Value	*Value Description*	*Left Curve %*	*Right Curve %*	*Error %*
10	- 4 s	0.01	0.00	0.01
12	- 3 s	0.13	0.06	0.07
14	- 2 s	2.28	1.22	1.06
16	- 1 s	15.87	10.56	5.31
18	mean	50.00	40.13	9.87
20	+ 1 s	84.13	77.34	6.79
22	+ 2 s	97.72	95.99	1.73
24	+ 3 s	99.87	99.70	0.17
26	+ 4 s	100.00	99.99	0.01

Figure A4-4
Percentage Error

A4-3.10 Please note that this is a very conservative example. The delta and the resulting error can get much larger.

A4-3.11 A major concern is what to do when the specification is not met. Users would certainly not want suppliers to reject material in the center of the distribution. Alternatives are to (1) reject the whole shipment, (2) reject nearby lots, (3) mix and match lots, or (4) translate the percentage hypothetically lost in the center back out to the tail in order to reject the worst material. The first two alternatives are really more like penalties and would lead to unnecessary loss of good material. The third is the worst form of inspecting in quality. It is generally agreed that this is the main thing to avoid. Translating the error back to the tail is possible but not necessarily a good approach. This would involve translating a reject percentage with a large potential error back out to a region that would have had a very small error. A multiple percentile specification can also be quite difficult in a production environment. Each of the percentile criteria must be evaluated to determine which one requires the highest reject rate. That reject rate must then be translated back to the tail, and 100% sample data must be used to determine which actual pieces to reject. If the statistical distribution is defined, one specification would give the same amount of information with much less work. If only one criterion is used, and it is well out on the tail (hopefully in the ppm range) then this method is very similar to a statistical specification.

A4-3.12 A commonly stated goal of multiple percentile specifications is to focus on centering rather than distribution tails. All of the discussion in Section A4-2.2 concerning centering is equally applicable here. Multiple percentile specifications are more likely to cause inspected-in quality which detracts from process control based centering.

A4-3.13 Ease of use is another stated goal, but for all of the reasons stated above, this method is one of the most difficult to use. Statistical calculations can be done in milliseconds while the potential of large samplings, raw data manipulation, and duplicate effort associated with multiple distributional percentile specifications create much more work. Characterizing with percentiles is an alternative for processes that have not yet been statistically characterized, but once that hurdle is crossed, everything gets many times easier.

A4-4 Mean and Sigma Specifications

Mean ≤ Value, Sigma ≤ Value, or

Low to High Mean, Sigma ≤ Value

A4-4.1 First, please note that the term "sigma" is intentionally used, rather than "standard deviation". This does not in any way imply 100% sampling. Instead, the implication is that the process would need to be monitored long enough to understand the "process sigma" (i.e., the state at which the process can be controlled).

A4-4.2 Mean and sigma specifications intuitively seem very promising, but they have many of the same problems as multiple distributional percentile specifications. Here, the issue of statistical sensitivity is particularly important. Table A4-1, and the discussion in Section A4-3.4 concerning sampling requirements, explain the central issue. The sample sizes required to detect smaller mean shifts are very large, so they usually are not feasible at the process control point. As a result, mean and sigma specifications could lead to much more sampling in an inspection area or in the warehouse, where larger quantities are available. To keep the sample sizes small, it is necessary to allow a specified amount of process drift. Therefore, some form of tolerance is necessary.

A4-4.3 Another factor that needs careful consideration is the movement toward controlling surrogate variables instead of outgoing parameters. Many types of variation can be controlled by carefully applying the appropriate samplings (within batch samples for batch-to-batch variation, within lot samples for lot-to-lot variation, etc.). However, there are practical limitations on how many types of variation can be continuously monitored. There is a large amount of work involved, and there are hundreds of potential sources of variation. Resource restrictions regularly force suppliers to concentrate on the known key variables and leave the rest as error in the system (at least for now). This practice, called homogeneous sampling, is designed to continuously home in on the variables that have the greatest impact on the distribution. Strictly speaking, for characterizing process capability, a random and over-time sampling which covers all sources of variation should be used. In practice, this is difficult to do, so engineering judgment is needed to select the most appropriate homogeneous sampling. This is yet another issue that could generate significant errors if it is not fully understood.

A4-4.4 From an ease-of-use standpoint, mean and sigma specifications have many of the same issues as multiple distributional percentile specifications. Mixing and matching of lots would be especially tempting with this approach because it might be the only practical alternative.

SEMI M33-0998
TEST METHOD FOR THE DETERMINATION OF RESIDUAL SURFACE CONTAMINATION ON SILICON WAFERS BY MEANS OF TOTAL REFLECTION X-RAY FLUORESCENCE SPECTROSCOPY (TXRF)

1 Purpose

1.1 The test provides the analytical procedure to determine the trace level of contaminating elements of an atomic number higher than 15 on polished or epitaxial silicon wafer surfaces in native or thermally grown or tetraethylorthosilicate (TEOS) oxide or in residues of microdroplets of process chemicals or media as analyzed with TXRF on silicon wafer surfaces as described in Sections 15.1 and 15.2.

2 Scope

2.1 This document specifies a VPD-TXRF (Vapor Phase Decomposition Total Reflection X-Ray Fluorescence Spectroscopy) method to analyze the elemental composition and areal density of impurities, that include cations and anions with atomic numbers between 16 (S) and 92 (U) independent of their chemical state, with the exception of the X-ray source material, on polished or epitaxial silicon wafer surfaces in native or thermally grown oxide or in residues of microdroplets of process chemicals or media as analyzed with TXRF on silicon wafer surfaces.

2.2 This test is especially useful for analyzing metallic elements such as K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, (Mo), Pd, Ag, Sn, Sb, Ta, (W), Pt, (Au), Hg, and Pb and non-metallic elements such as S, Cl, As, Br, and I through their characteristic K and L lines. (Elements in brackets are usual X-ray sources.) For limitations in the nature of analytes refer to the note in Section 14.7.

2.3 This test method can be used to analyze areal surface contamination that can be collected in a microdroplet during the specified VPD preparation and the collection of the digested surface contamination in the range of 5×10^8 through 5×10^{12} atoms/cm^2.

2.4 Theoretically, the detection limit (LOD) of each analyte depends upon its atomic number. As defined by DIN 32645 "Limit of detection, determination and quantification" the LOD of TXRF is also depending upon many parameters, such as:

- excitation energy,
- intensity of incident X-ray,
- instrumental background,
- crystallographic interferences, such as Bragg diffraction conditions,
- impurities in the beam path,
- contamination of the blank scanning solution (see Section 4.5),
- contamination level in the analytical ambient,
- surface microroughness of wafer at the microdroplet (see Section 6.7), and
- integration time.

2.5 Concerning the surface conditions to be analyzed, the VPD-TXRF method is invasive. Nevertheless, the TXRF analysis of the microdroplet residue can be repeated many times provided that the prepared specimen is stored in a clean environment. The substrate and/or surrogate wafers can be recycled for monitoring purposes.

2.6 The user of this test method must assure that the metrology equipment is under control by the procedures commonly utilized in the performing laboratory. In the absence of established control procedures the use of 4.11.2 EN-ISO 9001 is recommended.

NOTICE SAFETY PRECAUTIONS — This standard does not purport to address the safety concerns, associated with its use. It is the responsibility of the user of this standard to establish and maintain appropriate safety and health practices and comply with the local regulatory ordinance. X-ray irradiation and handling of HNO_3, HF and H_2O_2 are dangerous. Operators must comply with X-ray safety regulations and be trained to wear protective garments and glasses when handling HNO_3, HF and H_2O_2. These chemicals should be handled in a ventilated area (under exhaust.)

3 Referenced Documents

3.1 *SEMI Standards*

SEMI C7.3 — Standard for Hydrofluoric Acid, Grade 2

SEMI C7.5 — Standard for Hydrogen Peroxide, Grade 2

SEMI C7.6 — Standard for Nitric Acid, Grade 2

SEMI C10.1 — Guide for Determination of Method Detection Limits for Trace Metal Analysis by Plasma Spectroscopy

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M20 — Specification for Establishing a Wafer Coordinate System

3.2 *ASTM Specifications*[1]

ASTM D 5127 — Standard Guide for Electronic Grade Water (Type E-1)

ASTM E 691 — Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

ASTM F 1526 — Test Method for Surface Metals/TXRF

3.3 *DIN Specifications*[2]

DIN-ISO 5725 — Precision of Test Methods, Evaluation of Round-robins

DIN 12650 Part 6 — Gravimetrical Test for Piston Operated Volumetric Apparatus

DIN 12650 Part 6 (Apr. 1983) — Gravimetrical Test for Piston Operated Volumetric Apparatus

DIN 32645 — Limit of Detection and of Quantification

3.4 *ISO Specifications*[3]

EN-ISO-DIN 9001 — Quality Systems; Quality Assurance

3.5 *Other Specification*[4]

U.S. Federal Standard 209 — Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

4 Terminology

4.1 *anglescan* — A measurement of the emitted fluorescene signal as a function of the glancing angle of incident X-ray beam.

4.2 *areal density* — Amount of impurities in a unit area of native or thermally grown silicon oxide as converted from the detected amount of analytes into the whole analyzed (i.e., scanned surface area).

4.3 *as-polished wafer* — Mirror-finished wafer planarized by chemi-mechanical polishing.

4.4 *azimuthal position* — Orientation around the z-crystal/ingot axis as specified in SEMI M20.

4.5 *contamination collection* — Microanalytical method to collect the VPD decomposition products from the silicon surface by rolling a scanning microdroplet on the hydrophobic silicon wafer surface after VPD preparation as originally described in Sections 15.2, 15.4, and 15.5 (also see Section 8.3 of this document).

4.6 *critical angle* — The incident X-ray glancing angle below which total reflection of the incident X-ray occurs. At the critical angle the X-ray reflection equals 0.5.

4.7 *detection spot area* — The surface area where above the fluorescence counts are integrated.

4.8 *epitaxial wafer* — As-polished wafer covered with a layer of monocrystalline silicon deposited from a heterogeneous phase.

4.9 *glancing angle* — Incidence angle of X-ray excitation.

4.10 *hydrophobic surface* — Contact angle of wafer > 60° (e.g., virgin epitaxial or HF- or HMDS (hexamethyldisilazane) -treated surface as described in Section 15.3).

4.11 *impurities* — Elements in/on the specimen other than silicon or elements in ultra pure process media as listed in Section 2.2.

4.12 *native oxide* — Compound of silicon, oxygen, and water on as-polished or epitaxial wafer, grown in air or in cleaning solutions.

4.13 *recovery rate* — The ratio of analytes found after the first VPD and contamination collection procedure to the sum of the analytes found after two or more repeated scanning with unused scanning droplet of unchanged chemical composition.

NOTE: Recent efforts of the Statistical Task Force of the SEMI Chemicals and Gases Committee may result in a new definition (see Section 14.2 of this document).

4.14 *spurious peaks* — Peaks that are detected but not originated from impurities of the silicon wafer (c.f., 6.1).

4.15 *thermally grown oxide* — SiO_2 up to 1000 nm thickness deposited or grown in thermal processing in oxygen containing atmosphere.

4.16 *vapor phase decomposition (VPD)* — Vapor phase decomposition of silicon oxides using HF vapor at room temperature as a surface preparation method for

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Deutches Institut fur Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin 30, Germany

3 ISO Central Secretariat, C2.P2 56 Clf-1211 Geneve 20, Switzerland, available in the U.S. from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

4 Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Attn: NPODS

microanalysis, as originally described in Sections 15.2, 15.4, or 15.5 (also see Sections 5.1 and 11 of this document).

5 Summary of Method

5.1 The native or thermally grown oxide layer of the silicon surface is converted with HF vapor into fluid droplets that contain the impurities of the oxide layer. With a scanning droplet the fluid reaction products are collected in one microdroplet. That microdroplet is dried on the wafer under controlled conditions and analyzed with TXRF.

5.2 Similarly, a microdroplet of process chemicals or media can be dried on hydrophobic polished or epitaxial silicon wafer under controlled conditions and analyzed with TXRF.

5.3 Preferably, monochromatic and collimated X-rays irradiate a planarized and chemi-mechanically polished, monocrystalline silicon wafer surface. The X-rays impinge the surface at a glancing angle that is below the angle for total reflection of the X-rays, preferably, at an incident angle 70% of the angle of total reflection [1.3 mrad (or 0.07 degrees) for Mo target and 2.0 mrad (or 0.11 degrees) for W target].

5.4 The evanescent waves excite the fluorescence energy levels of the surface atoms, which then emit fluorescence X-rays characteristic of their atomic number. The emitted X-rays are detected by a solid state detector that is an energy dispersive spectrometer. In the range of specified areal density (compare with Section 2.3 of this document) the integrated count rate (cps) is linearly proportional to the elemental areal density.

5.5 For quantification, the linear regression must be established (c.f., Section 15.6) or a linear proportionality is anticipated between the cps data that are measured above the certified reference microdroplet(s) and the cps data that are measured above the microdroplet of the unknown analytes without changing the anglescan conditions, according to Sections 9.1, 13.6, and 15.7.

6 Interferences

6.1 The known interferences in X-ray fluorescence spectroscopy also affect TXRF. Thus, overlapping fluorescence lines, escape peak, energy gain drift, X-ray source stability, beam path background contamination must be evaluated according to Section 15.7 of this document.

6.2 Baseline corrections due to varying background contamination must be controlled by the rules of statistical analysis (e.g., as described in Section 15.8 of this document).

6.3 Under the specified conditions, no corrections are required for secondary fluorescence or for oscillations or for matrix absorption as described in Sections 15.9–15.11 of this document.

6.4 Accuracy of the standard reference specimen and positioning accuracy and precision of the detector define the bias in the assigned areal density.

6.5 Mechanical vibration may degrade the detector resolution and it can also decrease the selectivity.

6.6 Multielement contamination degrades the LOD compared with monoelement contamination.

6.7 Increased surface microroughness and/or high-total signal count rates result in high deadtime and can lead to non-linearity of detected fluorescence signal versus areal density (i.e., to degradation of LOD).

6.8 Under optical conditions satisfying the Bragg reflections the background noise depends upon the azimuthal orientation of the sample. Before quantification, a determination of the azimuthal angular range, that shows minimum Bragg reflection background, is recommended. Otherwise the LOD may degrade due to high background and spurious peaks.

6.9 During handling and measurement particles or volatile contamination (e.g., NH_3) from the analytical environment must be controlled and avoided.

6.10 During measurement Ar must be excluded from the analytical ambient (e.g., by evacuating the chamber or flushing it with He).

6.11 Curve smoothing and evaluation algorithms with controlled Fourier parameters or Digital Filtering are preferred to direct count rate evaluation because these algorithms provide a higher level of statistical confidence than a software that directly quantifies cps as described in Section 15.12 of this document.

6.12 Recovery rates as defined in Section 4.13 of this document depend upon the distribution of the analytes between the scanning solution (solubility) and silicon surface (adsorption and plating). Therefore, recovery rates depend on the:

- applied scanning solution (Sections 4.5, 8.3),
- chemical nature of the different analytes/elements, and
- physical and physicochemical state of the silicon surface.

6.13 Automated contamination collection procedure (scanning) increases the wafer-to-wafer reproducibility of the described method as reported in Section 15.13 of this document.

7 Apparatus

7.1 The VPD treatment and contamination collection particularly, but also the handling and measurement of the specimen wafer is to be carried out in a specified and controlled ambient (e.g., Cl. 10 (U.S. Federal Standard 209)).

7.2 TXRF system equipped with:

— an X-ray source,

— a monochromator (preferable),

— a sample stage capable of manipulating in the x-, y-, and z-direction,

— automated test specimen handling,

— an energy-dispersive spectrometer X-ray detector,

— software sub-routine for glancing angle calibration,

— software for baseline setting and for peak-fitting and/or range-of-interest (ROI) peak finding identification and evaluation, and

— analysis ambient without Ar background (see Sections 6.10 and 7.1 of ASTM F 1526). The system is preferably equipped with a flat/notch-finder and quick-search option. For details, see Section 6.10 of this document and Section 7.1 of ASTM F 1526.

7.3 The VPD and the advisable drying chamber(s) will have opening(s) made of polyvinylidenfluoride (PVDF), polyfluoroalkoxyethylene (PFA), polyfluoro-ethylene (PTFE) or similar resistant and pure polymer materials that will not be attacked by HF. The chamber(s) may contain one or more wafers on stacks. The use of a drying chamber is advisable for the preparation of the calibration reference microdroplet (c.f., Section 10.1), but optional for the analysis procedure. When a drying chamber is used, it must be evacuable to below 1 kPa. After evacuation the chamber is to be flushed with filtered N_2 until the complete drying of the microdroplet residue is achieved (see Section 9.1 of this document).

7.4 For the aliquots of standard stock and scanning solutions validated micropipettes must be used. Validation procedure can follow the requirements of DIN 12650 Part 6.

8 Reagents and Materials

SAFETY PRECAUTIONS — Handling HNO_3, HF and H_2O_2 is dangerous. Operators must comply with X-ray safety regulations and be trained to wear protective garments and glasses when handling HNO_3, HF and H_2O_2 under efficient exhaust.

8.1 *Ultra Pure Water, HNO_3, HF, H_2O* — As specified in ASTM D 5127, SEMI C7.3, C7.5, and C7.6, respectively.

8.2 *Standard Stock Solution* — Certified and traceable standard reference “stock” solution with known amount(s) of nitrate salt of the metals and sodium salt of the non-metallic elements to be analyzed. Dilutions have to be acidified with HNO_3 at pH ≤ 2. Note that the shelf life of diluted solutions in the ppb-range of µg/L or ng/L is less than 2 days.

8.3 *Tested Scanning Droplet (Sections 4.5 and 6.12)* — 50 to 100 µL of ultra pure water or other scanning solutions (e.g., aqueous HF (1 volume %) and H_2O_2 (30 volume %)). The composition of the scanning droplet must provide a controlled recovery rate above 90% for each analyte, including Cu.

8.4 *Blank Scanning Solution* — The composition and the amount of a scanning droplet without surface impurities.

8.5 *Microdroplet Residue* — Microdroplet calibration standard reference solution and/or scanning or microdroplet of a liquid process medium dried at room temperature under controlled conditions according to Section 7.3. Above the microdroplet residue the fluorescence count rate remains independent of azimuthal position and of varying incident angle for angles below 80% of the critical angle as described in Section 15.6 of this document.

8.6 *Surrogate Wafers* — Polished or epitaxial wafers used as carrier plates for scanning droplets collected from other specimen wafers.

9 Preparation of Certified Reference Microdroplet for Calibration Standard

9.1 *Tested Preparation Conditions* — Deposit microdroplets containing 0.01 ng, 0.1 ng and 1 ng Ni in Ni $(NO_3)_2$ in 100 µL of a diluted standard stock solution onto (a) hydrophobic (see Section 4.12 of this document) polished or epitaxial wafer(s). Dry it (them) under controlled conditions (e.g., in a drying chamber at room temperature). When a drying chamber is used, flush the chamber with a slow flow of N_2 for 20 minutes, then evacuate it (see Section 7.3 of this document). The droplets must not explode or extend during drying. They should not exceed an areal dimension of 1 mm in any direction. Elements forming volatile compounds must not be applied (see the note in Section 14.7).

10 Calibration Procedure

SAFETY PRECAUTIONS — X-ray irradiation is dangerous. It is the responsibility of the user of this standard to establish and maintain appropriate safety and health practices and comply with the local regulatory ordinance. The X-ray source must be inactivated when beam path is unshielded. Operators must be trained to avoid exposure to X-ray irradiation.

10.1 The calibration standard is a microdroplet of 100 µL of a diluted certified standard reference "stock" solution. Note that the shelf life of diluted solutions in the sub-ppb-range of µg/L or ng/mL is less than 2 days.

10.2 Locate the calibration standard microdroplet residue and place it under the detector. Adjust the glancing angle into the range where the fluorescence count rate is independent of varying incidence angle (see Section 8.5 of this document).

10.3 Position the detector window as follows. Set mapping or quick search parameters for covering the residue(s) with 3 × 3 detection spots (see Figure 1), which are placed around the residue(s) as described in Section 15.6 of this document. The mapped surface must cover at least 95% of the square around the residue(s) that is lying about in the center of the detection spot. The analyzed part of microdroplet residue under the detection spot must be higher than 95%.

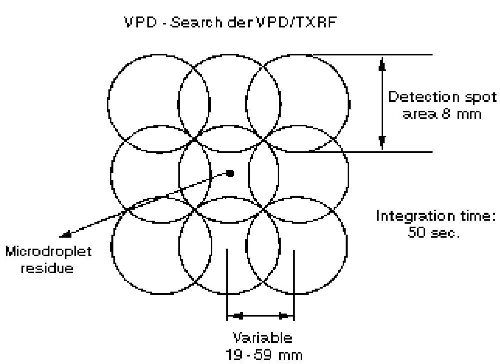


Figure 1
VPD-Search VPD/TXRF

10.4 Set for mapping around the microdroplet residue with a 50-sec integration time program at each detection spot. Integrate at the maximum position(s) for at least 1000 sec. These data provide the final result of calibration due to the algorithm given in Section 13.6 of this document.

10.5 Repeat calibration cycle (load-analyze-unload) at least 3-times.

10.6 In order to distinguish relevant results from particle contamination from the environment and from inefficient contamination collection, repeat measurement on blank surface adjacent to the microdroplet solution. The data are to be considered as background data in the quantification algorithm (see Section 15.12 of this document). For valid calibration, background fluorescence counts must remain less than 20% of the fluorescence counts of microdroplet residues, particularly, at lower areal densities ($< 1 \times 10^9$ atoms/cm^2).

10.7 The integrated fluorescence counts measured with the specified Ni calibration standard can be converted by known sensitivity factors into other elements of interest as described in the References section (see Sections 15.14 and 15.15 of this document).

10.8 Keep the calibration standards in closed, identifiable wafer holders in a clean room at room temperature under conditions that will not change the fluorescence reproducibility.

10.9 Optional linearity tests should deploy the methods described in References section (see Section 15.16 of this document). Similar statistical linearity tests can also be applied.

10.10 Upon the users request, the absolute instrumental calibration factor can be obtained. Due to the Fresnel theory of X-ray absorption and enhancement on pure metal (Ni) surfaces, the absolute calibration can be carried out under specific optical conditions. (See Referenced Documents section and specifically Section 15.17.). Then, that absolute calibration can be correlated to the external microdroplet calibration.

11 Preparation Procedure

11.1 VPD treatment of the wafer surface (Section 4.16) and the collection of contamination collection with a scanning microdroplet (Section 4.5).

SAFETY PRECAUTIONS — Handling HF is dangerous. It is the responsibility of the user of this standard to establish and maintain appropriate safety and health practices and comply with the local regulatory ordinance. Operators must be trained to wear protective garments and glasses when handling HF under efficient exhaust.

11.2 In the VPD chamber wafers are treated with HF vapor (e.g., isothermally distilled at room temperature from an aqueous solution (20–50 volume %) within the VPD chamber). The analytical specimen, the calibration droplet and the scanning droplet must be handled, prepared and dried under specified and controlled conditions. Drying means the evaporation of the solvents on the wafer surface in a clean and controlled environment without loosing analytes from the microdroplet residue.

11.3 The wafers are exposed to the HF vapor in the VPD chamber at room temperature. The exposure time depends on the concentration of the HF used and on the preceeding wafer treatment. The time has to be long enough to ensure that the wafer surface will become hydrophobic. After the HF treatment the solubilized reaction products are collected by scanning a microdroplet over the whole surface. Automatic scanning is preferable (see Section 6.13 of this document). The composition of the scanning solution is optional but its volume and drying conditions should be the same as under the preparation of calibration standards (see Sections 8 and 15.18 of this document).

11.4 An example for tested preparation conditions according to Section 15.18 of this document. A PTFE or PFA petri dish of a diameter > 25 cm is filled with 20 volume % HF by mixing DI ultra pure water and 40 volume % HF of ULSI grade in a clean room ambient of Cl 10 by U.S. Federal Standard 209. The petri dish is positioned in the bottom of the VPD chamber, loaded with specimen wafers. The wafers are exposed to the HF wafer at room temperature. Exposure time is between 30 minutes and 6 hours. Longer exposure times can lead to deliberate etching. After the HF treatment the solubilized, reaction products are collected by rolling a scanning microdroplet over the whole surface. Automatic scanning is preferable. Please refer also to Section 4.5 and Section 8.3 of SEMI E45.

11.5 Rinse the validated micropipette at least 5 times with ultra pure water or with the selected scanning solution. Then fill the micropipette with the required amount of ultra pure water or with the scanning solution. For scanning surfaces with thicker silicon oxide (> 300 nm) only about 50 µL of scanning solution is sufficient. The microdroplet to be dried for analysis should not extensively (+10%) exceed 100 µL together with the VPD reaction products.

11.6 Put the scanning microdroplet on the wafer surface and roll the scanning microdroplet around the wafer edge 2 times and then over the whole surface in a zigzag pattern. Automatic equipment can scan in a spiral pattern with overlapping paths (see Section 6.13). An edge exclusion of less than 1 mm is attainable for manual or automatic scanning. Edge exclusion is well below 1 mm at automatic scanning.

11.7 Position the scanning microdroplet in the center of the wafer.

11.8 For monitoring the cleanliness of the VPD preparation and contamination collection and that of the analytical ambient, put the same volume of the blank scanning solution, as applied to the preparation of the calibration standard (100 µL under tested preparation conditions), with the validated micropipette onto the scanned specimen surface at least 3 cm off the position of the scanning solution. For valid results fluorescence counts above the blank must remain less than 20% of the fluorescence counts above the droplet residues. Use ultra pure water (100 µL) for blanks of process chemical and media samples. If the scanning solution consists only of ultra pure water of controlled quality, no blanks are required.

NOTE: In the absence of oxidation agent(s), Cu recovery rates can be reduced (see Section 15.18).

11.9 Dry the wafers as specified in Sections 7.3, 9.1, and 11.2 of this document.

12 Analysis Procedure

12.1 Localize the microdroplet residues of the collected scanning solution or the microdroplet residues of the liquid process medium and the microdroplet residue of the blank scanning solution. Detect fluorescence counting rates above these microdroplet residues and above the scanned blank surface under the instrumental parameter adjusted for calibration. The quantification algorithm is given in Section 13.6. Integrated counts above both the blanks and the VPD prepared surface must not exceed 20% of the integrated counts above the microdroplet residue of the collected scanning solution (see Section 9.6 of this document).

13 Quantification Procedure

13.1 The instrument must run under established statistical process control (e.g., as described in Section 15.19 of this document).

13.2 Before releasing results, quote instrumental parameters such as:

- rotating or sealed anode,
- voltage and current applied to the X-ray source,
- characteristic excitation line(s) of the incident X-ray,
- glancing angle(s),
- type of monochromator,
- amount [ng] or [number of atoms] of e.g., Ni in the calibration standard reference microdroplet,
- location of the microdroplet(s) analyzed,
- peak evaluation technique (ROI or peak-fitting),

- measurement time,
- analysis results on the blank microdroplet,
- compositions and amount of the scanning droplet,
- running time since last calibration or frequency of SPC measurement,
- lab environment classification by U.S. Federal Standard 209,
- edge exclusion, if any (c.f., Sections 4.2 and 11.6).

13.3 Quantification of areal density is in units of 10^{10} atoms/cm^2.

13.4 Detection spot area is the surface area where above the fluorescence counts are integrated.

13.5 Scanned surface area is the surface area where the impurities are collected from, according to Section 9.1.

13.6 Calculate the areal density of impurity i according to the following algorithm:

$$c_{i,VPD} = \frac{c_i}{\frac{A_w}{A_m} \cdot R_i} \text{ (atoms/cm}^2\text{)}$$

$$= \frac{n_i}{A_w \cdot R_i} \text{ (atoms/cm}^2\text{)}$$

where;

$c_{i,VPD}$ = density of impurity (i) at scanned area of wafer surface in [atoms/cm ^{2}]

c_i = measured concentration of impurity i at measured spot [atoms/cm ^{2}]

A_w = VPD - scanned wafer area in [cm ^{2}]

A_m = measuring spot area in [cm ^{2}]

R_i = recovery rate of the collected impurity ($0 < R_i < 1$) c.f., Section 4.13

n_i = measured number of atoms of analyte i

The measured concentration c_i of impurity (i) can be related to the reference standard by means of the following expression.

NOTE: The reference standard element is assumed to be Ni in this section.

$$ci = RSF_i \cdot c_{\text{Ni}} / I_{\text{Ni}} \cdot I_i \text{ [atoms/cm}^2\text{]}$$

where;

$c_{\text{Ni}} = n_{\text{Ni}} / A_m$

n_{Ni} = number of impurity atoms (Ni) in the standard reference specimen

I_i = measured fluorescence intensity of impurity (i) in counts per second [cps]

I_{Ni} = measured fluorescence intensity of the standard reference specimen (Ni) in counts per second [cps]

RSF_i = instrumental sensitivity factor of the analyte i relative to the standard element (Ni)

This formula provides the areal density for the impurity of interest with LOD as given in Section 13.7.

13.7 Calculation of LOD_i, the lowest detectable number of impurity atoms i from a scanned surface, is:

$$LOD_i(t) \equiv 3 \cdot c_{i,VPD} \cdot \frac{\sqrt{N_{bg}(t)}}{N_{netto,i}(t)}$$

where;

$N_{bg}(t)$ denotes the background fluorescence cps, integrated over time (t)

$N_{bg}(t) = I_{bg} \cdot t$,

with

I_{bg} = intensity of the background in cps, and

where;

$N_{netto,i}(t)$ denotes the netto number of the impurity fluorescence [cps], integrated over the time,

$N_{netto,i}(t) = I_i \cdot t$

The equation for the $LOD_i(t)$ can be rewritten as :

$$LODi(t) = 3 \cdot \frac{c_{i,VPD}}{I_i} \cdot \sqrt{\frac{I_{bg}}{t}}$$

14 Bias and Precision

14.1 Relative error of the described VPD-TXRF method must be assessed according to Section 15.11 of this document. Under the given measurement conditions the accuracy of the results is limited by the error summarized in Section 14.2.

14.2 Under given solute amounts and measurement conditions the accuracy of the results is limited only by the recovery rate of the VPD treatment and the scanning solution as described in Section 15.19 of this document. The relative error is to be calculated by:

$$\frac{dc_{i,VPD}}{c_{i,VPD}} = \left(\left(\frac{dR_i}{R_i}\right)^2 + \left(\frac{dRSF_i}{RSF_i}\right)^2 + \left(\frac{dA_w}{A_w}\right)^2 + \left(\frac{dn_{Ni}}{n_{Ni}}\right)^2 + \left(\frac{dI_i}{I_i}\right)^2 + \left(\frac{dI_{Ni}}{I_{Ni}}\right)^2 \right)^{1/2}$$

14.3 Relative error of the reference droplet standard is determined by the error of the micropipette aliquot (V) and of the stock solution (c_S).

$$\frac{dn_{Ni}}{n_{Ni}} = \left(\left(\frac{dV}{V}\right)^2 + \left(\frac{dc_S}{c_S}\right)^2 \right)^{1/2}$$

14.4 The relative error of areal concentrations below the concentration of the calibration standard reference are strongly dependent upon the relative error of the micropipette aliquots. In the given range bias due to crystallization and/or mass absorption can be anticipated to be less than 1% as described in Sections 15.6 and 15.11 of this document.

14.5 Reproducibility of the measurement system must be tested with calibration standard reference in five complete analysis cycles (load-analyze-unload). The standard deviation of the 5 results shall not exceed more than 10% of the theoretical value of the standard deviation of the respective Poisson statistics *Nx*. For long term reproducibility, please refer to Section 2.6.

14.6 The minimum sample size for controlling the wafer-to-wafer reproducibility of the complete procedure must consist of a group of 3 wafers of the very same polishing and/or cleaning batch as described in Section 15.20 of this document. Tolerated standard deviation of 3 groups should be defined by the interested parties.

14.7 In interlaboratory tests (round robin), the reproducibility of the method can preferably be evaluated in accordance with DIN ISO 5725 or ASTM E 691.

NOTE: Report reproducibility in accordance with this document. Calibration accuracy was found to be within 10% relative standard deviation for K, Ca, Ti, Cr, Fe, and Cu among five TXRF stations as stated in Section 15.21 of this document. W and other compounds forming volatile fluorides shall not be analyzed after VPD because of low recovery rates.

15 References

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SEMI M34-0299
GUIDE FOR SPECIFYING SIMOX WAFERS

1. Purpose

1.1 This guide is for specification of SIMOX (separation by implantation of oxygen) wafers with less than 0.5 μm silicon film thickness used for semiconductor device manufacture. These specifications define the generic characteristics of SIMOX SOI wafers; the specific values for measured parameters will be determined by agreement between the user and supplier for the application. By defining parameters, inspection procedures, and acceptance criteria, both users and suppliers may uniformly define product characteristics and quality requirements.

2. Scope

2.1 The primary standardized properties set forth in this specification relate to physical and electrical characteristics of SIMOX wafers.

3. Referenced Documents

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M22 — Specification for Dielectrically Isolated (DI) Wafers

3.2 *ASTM Documents*[1]

Practice E 122 (vol. 14.02) — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

F 154 (vol. 10.05) — Standard Practices and Nomenclature for Indentification of Structures and Contaminants Seen on Specular Silicon Surfaces

F 523 (vol. 10.05) — Standard Practice for Unaided Visual Inspection of Polished Silicon Slices

3.3 *Other Standards*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

4. Terminology

4.1 *Acronyms*

4.1.1 *BOX* — Buried Oxide

4.1.2 *SIMOX* — Separation by Implantation of Oxygen

4.1.3 *SOS* — Silicon on Sapphire

4.2 *Definitions*

4.2.1 *buried oxide* — The oxide layer that is formed by the oxygen implant.

4.2.2 *SIMOX layer* — The thin silicon, layer above the BOX. This is also referred to as top silicon or superficial silicon.

4.2.3 *substrate* — The supporting material: silicon for SIMOX.

5. Requirements

5.1 The complete specification for the starting substrate to produce SOI wafers includes all general requirements of SEMI M1 or SEMI M3, as applicable.

5.2 In addition, the parameters listed in Table 1 shall be specified, as applicable. For example, specification of BOX thickness is not applicable for SOS. The specific values for parameters listed are to be specified by agreement between user and supplier for specific uses and specific wafer technologies.

5.3 The parameters of Table 1 apply to the final SOI wafer. Parameters for the starting material may be specified by agreement between user and supplier using other standards (e.g., SEMI M1 or SEMI M3, as appropriate). Additional parameters shall be negotiated between user and supplier, as needed.

6. Sampling Plan

6.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) of lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values.

Inspection levels shall be agreed upon between the user and supplier.

7. Test Methods - Dimensions

7.1 *SIMOX Layer Thickness Measurements*

7.1.1 *Measurements Methods* — Two non-contact, non-destructive optical characterization techniques, spectroscopic reflectometry and spectroscopic ellipsometry, have proven useful for SIMOX layer thickness measurements. Both techniques use reflected light to allow deduction of the thickness and refractive index of thin film layers. In both cases, film thickness and index of refraction data must be "backed out" of the measured optical data by a process of successive approximation. In both cases, the fitting procedure is more straightforward and more accurate the as-annealed SIMOX wafers with abrupt silicon/oxide interfaces than for the implanted SIMOX wafers with extended interface zones. Silicon islands and interface nonuniformities make these techniques problematic for SIMOX wafers with oxygen implant doses below the "stoichiometric dose", roughly 1.6×10^{18} O^+/cm^2 for a 375 nm oxide layer.

7.1.1.1 The measurement strategy is to make a detailed measurement with an accurate fit on at least five wafer sites, including the center as illustrated in Figure 1. The number of wafer sites to be monitored should be agreed on between customer and vendor. Generally, the greater the variability relative to the mean, the larger the number of sites that should be monitored. In each case, the measurement system supplies a "goodness-of-fit" parameter which indicates a level of confidence in the fit to the measured data.

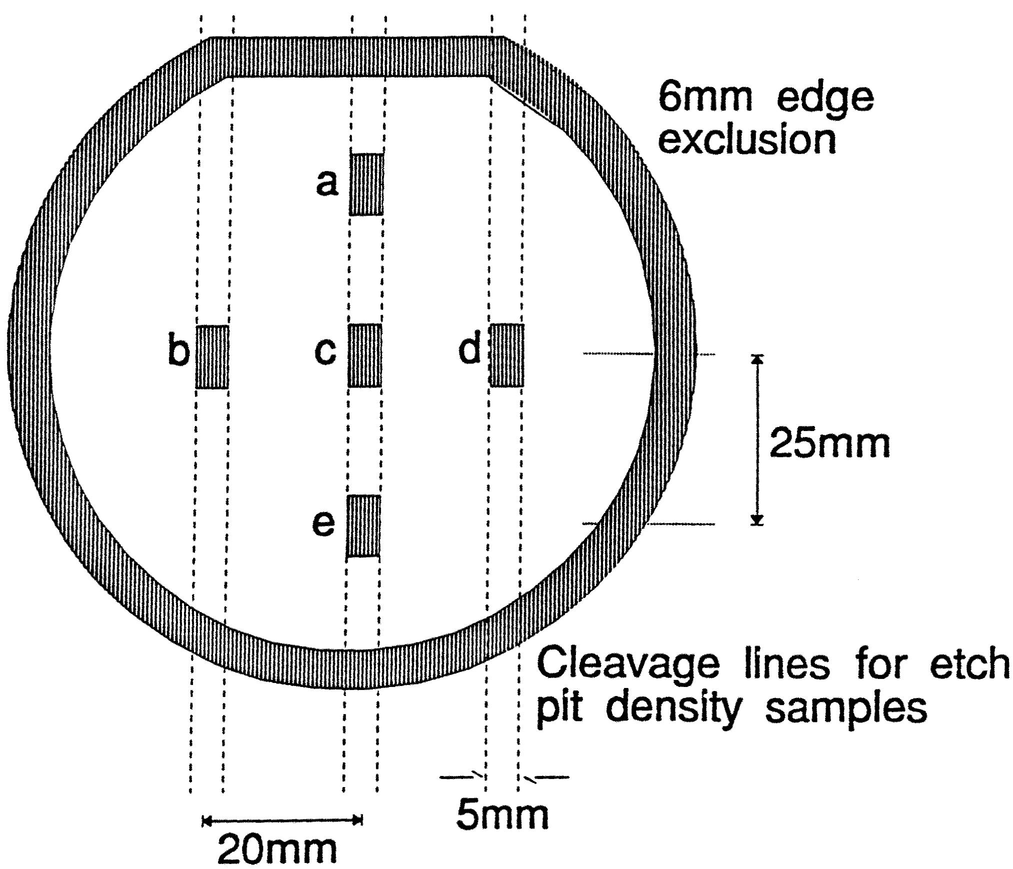

Figure 1
Schematic of Measurement Sites, Cleavage Lines, and Edge Exclusion for 100 mm SIMOX Wafer Inspection

7.1.2 *Spectroscopic Ellipsometry Measurement* — In this measurement, white light from a xenon arc lamp passes through a polarizing rotating filter and illuminates the sample site under study; reflected light passes through an analyzer to a monochromator and photomultiplier detector. For each wavelength, reflectivity oscillates with polarizer rotation; the magnitude and phase of reflectivity changes are measured to determine ellipsometric angles, δ and ψ. The two measured spectra are fit by successive approximation to allow determination of the silicon and oxide layer thickness and oxide composition. Ellipsometry measurements are only specified for the annealed SIMOX wafers. For spectroscopic ellipsometry, the choice of instrument and associated model and fitting parameters affect the confidence-of-fit, so they should be taken into account in the user/supplier agreement. For example, with the SOPRA SE system, the goodness-of-fit error estimator shall be less than 0.025 for accurate structural models.

7.1.3 *Optical Reflectance Measurements* — In this measurement, light from a xenon arc lamp passes through a grating monochromator and illuminates the sample site under study; reflected light is gathered by an intrinsic silicon detector. Specular reflectivity is plotted as a function of wavelength from 0.4 micron to 1.1 micron. The analysis proceeds by making successively better approximations to the oxygen content, index of refraction, and absorption of each layer until an acceptable fit is achieved. Measurements are made with a reflectance mode optical interferometer.

7.1.4 *Optical Model Fitting and Correlation* — There are slight, systematic differences between layer thickness measured by reflectance and by spectroscopic ellipsometry (SE). Because of this, user and supplier should specify the actual measurement method to be used. The two methods offer results which are reproducible and well-correlated with each other over a wide range of conditions. If both measurement techniques are used, it is recommended that the reflectance system measurements be calibrated to fit the results of the SE. Figure 2 shows conversion curves for top silicon and oxide layer thickness measurements made with the two measurement techniques.

7.1.5 *Top Silicon Layer Thickness* — See Section 7.1.4 on correlation of reflectance and spectroscopic ellipsometry (SE) measurements. Optical measurements will be made on five wafer sites as shown in Figure 1. Spectra for each site will be fit independently with both the top silicon and oxide layer thickness as adjustable parameters. Both the mean thickness and the uniformity should be specified. Depending on the type of SIMOX wafer being specified, the mean thickness of the top silicon layer will be from 50 nm to 500 nm. Following is an example specification: Mean top silicon layer thickness for the five sites will be 215 ± 10 nm with acceptable goodness-of-fit at all five sites. Top silicon non-uniformity will be less than ± 5 nm.

7.1.6 *Buried Oxide Layer Thickness* — See Section 7.1.4 on correlation of reflectance and spectroscopic ellipsometry (SE) measurements. Optical measurements will be made on five wafer sites as shown in Figure 1. Spectra for each site will be fit independently with both the top silicon and the buried oxide layer thickness as adjustable parameters. Both the mean thickness and the uniformity should be specified. Depending on the type of SIMOX wafer being specified, the mean thickness of the buried oxide layer is from 50 nm to 500 nm. Following is an example specification: Mean buried oxide layer thickness for the five sites will be 380 nm ± 20 nm with acceptable goodness-of-fit at all five sites. Buried oxide uniformity will be less than ± 10 nm.

7.2 *Crystallographic Defect Measurements - Test Methods* — The evaluation of threading dislocation density in the top SI layer will be made by destructive chemical etching and microscopic etch pit density measurements. The appropriate evaluation procedure for given SIMOX wafer, which depends on the threading dislocation density and the thickness of top Si and buried oxide layers, will be determined by the agreement between user and supplier.

7.2.1 Optionally, other crystallographic defects which may be formed in the top Si layer of SIMOX wafers, such as oxide precipitates or micro stacking faults, silicon crystal defects induced by surface particles prior to epi growth when epi is used to increase the thickness of the top silicon. A sampling plan should be established based on experience with the supplier.

7.2.2 Following are examples of the evaluation of threading dislocations in two kinds of SIMOX wafers:

7.2.2.1 Example 1. Threading dislocation evaluation in SIMOX wafers with 200 nm thick top Si layer and 400 nm thick buried oxide: Samples are handled with plastic tweezers throughout the etching procedure. Samples are first stripped of native oxide by dipping in Bell 2 or HF stripping solutions. Immediately after stripping, wafers are dipped in freshly prepared standard Secco Etch: one part (by volume) of a 0.15 molar solution of $K_2Cr_3O_7$ in distilled water and two parts HF (49%). Samples are dipped in the Secco etch until 50 nm of silicon remains, and then they are rinsed thoroughly in distilled water and blown dry. The thickness of the remaining silicon ensures that stacking fault pyramids found in multiple implant material are counted. The threading dislocation density may vary over a wide range, depending on the type of material. The Secco Etch, as described, creates etch pits that appear as dark circles roughly 50 nm in diameter, and pictures should be taken at 2500X to 20,000X magnification in order to unambiguaously identify and count the etch pits. This is suitable for high density defect samples. For lower dislocation densities typical of recent SIMOX material, a third etch in buffered HF (1 HF (49%): 6 NH_4F (40%)) for 10 minutes will etch the buried oxide under each Secco etch pit, creating a characteristic circular shape 2 µm in diameter that can be seen at 500X magnification.

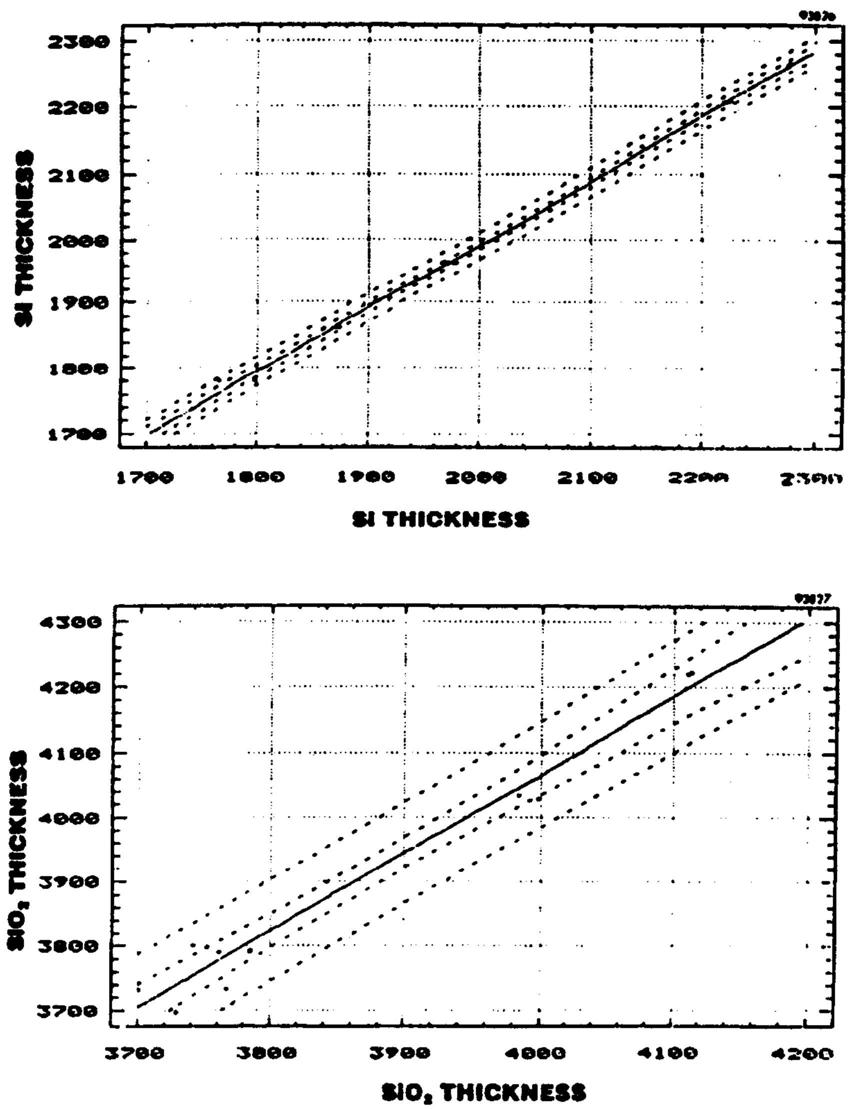

Figure 2
Calibration Curves Relating Reflectance Measurements to Ellipsometry Measurements for Top Silicon and Buried Oxide Layer Thickness

NOTE: Dashed lines are at ± 1 sigma and ± 3 sigma.

7.2.2.2 Example 2. Threading dislocation evaluation in SIMOX wafers with 170 nm thick top Si layer and 100 nm thick buried oxide: Samples are first immersed in HF to remove oxide from the surface. Then the samples are etched for 30 seconds in the solution:[3] 50 ml of HF (49%) plus 80 ml of HNO_3 (61%) plus 160 ml of H_2O [$K_2Cr_2O_7$ 1g + $Cu(NO_3)_2 \cdot 3H_2O$ 4g]. The thickness of removed silicon is about 1/3 of the initial top Si layer thickness, i.e., about 60 nm. After rinsing in water, samples are dipped in HF (49%) for 5 minutes. The HF etches the buried oxide and creates cavities under the etch pits. The cavities are around 10 μm in diameter. Each cavity corresponds to one dislocation threading the top Si layer. The cavities can be seen at 50X magnification.

7.2.2.3 A recommended protocol for the microscopic etch pit density measurement is to take enough pictures to count at least 50 etch pits, and then divide the number counted by the area scanned to get the defect density. The pictures taken should be non-overlapping areas of the sample far from the tweezer marks and far from the edges of the sample. Following is an example specification: Of the five samples prepared from the test wafers, none should have threading dislocation densities higher than 1×10^7 cm $^{-2}$.

7.3 *Buried Oxide*

7.3.1 *Buried Oxide Pinhole Measurements* — Buried oxide pinhole evaluations shall be made by $CuS0_4$ plating or copper decoration methods.

7.3.1.1 In the evaluation done by $CuSO_4$ plating method the wafer under study is placed (front face down) on a paper towel soaked in 20% $CuSO_4$ solution on top of a copper plate. An aluminum plate is placed on the back of the wafer. The copper plate is grounded, and -25 VDC is applied to the aluminum plate. Small (sub-micro Angstrom) leakage currents through pinholes in the insulator cause copper to plate out onto the towel at the pinhole density.

7.3.1.2 In the evaluation done by copper decoration method the top Si layer is first etched off by KOH solution to expose the buried oxide layer. Then the wafer is immersed in methanol and brought downward into direct contact with the gold-coated cathode. A copper mesh as an anode is immersed in the liquid 5 mm above the wafer. Required voltage is applied, such as the electric field in the buried oxide layer is 1MV/cm. The voltage is measured at the oxide surface with a surface voltage probe. Localized copper decorations at pinhole sites in the oxide are observed with a low power optical microscope.

7.3.1.3 Allowable pinhole density depends on the application for SIMOX wafer and will be determined by the agreement between user and vendor. Typical allowable pinhole density is 0.1/cm^2.

7.4 *SIMOX Wafer Surface Inspection*

7.4.1 *Total Reflectance X-Ray Fluorescence Measurements* — The preferred test methodology is described in ASTM F 1526.

7.4.1.1 The instrument provides a map of impurity element distribution. As an example specification, surface contamination for elements within the detection limits (typically S to Zn) shall be less than 10^{10} cm^{-2} per element or < 10^{11} cm^{-2} total.

7.4.1.2 The customer and vendor should be aware that most TXRF systems will contaminate a wafer - slightly on front and significantly on the back. (Reference: DXRC, Denver CO, July 1996, abstract 5.1 "Particulate Contamination from TXRF Instrumentation", Dennis Werho, et al.)

7.4.2 *Automated Particle Counter Measurements* — Automatic production tools are available for accurate particle counting on fully processed SIMOX wafers for particles greater than 0.25 micron. Alternatively, particles down to 0.1 micron can be detected on as-implanted SIMOX wafers prior to anneal. Any specification of particle count should include the point in the process at which the measurement is to be made. Following is an example specification:

7.4.2.1 Instrument settings shall allow detection of particles from 0.3–10 micron size. Maximum allowable particle count, with a 6 mm edge exclusion, is 20 particles greater than 0.25 micron size per 150 mm wafer, or 0.1 particles/cm^2, just prior to shipping.

7.4.3 *Visual and Microscopic Inspection* — Visual inspection techniques will be in accordance with ASTM F 523, when possible, by automatic inspection equipment. Alternatively, slices will be inspected visually under fluorescent light for chips, fractures, scratches, fragmentation, saw marks, grinder marks, and dimples and also under a narrow beam high intensity light (> 6000 footcandles), for fractures, film haze, contamination, and scratches. SIMOX wafers typically exhibit uniform light haze due to light scattering from the rough silicon/oxide interface and from silicon precipitates in the BOX. A light, uniform haze is typically acceptable, while patches of moderate or heavy haze typically are not acceptable.

7.4.3.1 Standards for specification of haze are being developed for bulk silicon. A modification of that

3 Refer to L. F. Giles, A. Nejim, and P. L. F. Hemment, Materials Chemistry and Physics, 1993, vol. 35, p. 129 specification will be required for SIMOX material. It may be necessary to iterate between customer and vendor to agree on specification of acceptable haze.

7.4.4 *Surface Roughness* — Surface roughness is a measure of the microscopic topology of the wafer surface. The effect of this parameter may be in Gate Oxide Integrity (GOI) on MOS devices, depending on the design and process. The measurement of surface roughness is done on an atomic scale by an Atomic Force Microscope (AFM). With AFM, it is suggested that four measurement areas of greater than 2 μm^2 be measured at each of five measurement locations, with the measurement locations distributed as in Figure 1. Because of the expense of this measurement, a sampling plan should be established with the supplier.

7.4.4.1 Standards for specification of surface roughness are being developed for bulk silicon and shall be applicable here when adopted.

7.4.5 *HF Defect Measurements - Test Methods* — Measurement of the microscopic etch pit density following an HF etch is a method commonly used to disclose defects in SOI material. Pitting of the top silicon surface may be present before the HF etch or be caused by HF etching. For this destructive measurement, at least one quarter of a wafer should be used and preferably a whole wafer. The sample is placed in concentrated (49%) HF for 10 to 15 minutes, then removed, rinsed and dried. If there are pits in the SI surface, metal particles embedded in the surface or silicides formed in the top Si layer, the HF will etch the metals/silicides and then etch the buried oxide. This results in a section of the buried oxide being etched out that is 25–50 μm diameter (depending on the etch time) centered on the original pit or particle. The defect density is then measured in an optical microscope using a 5X objective and 10X eyepiece or comparable setup. The sample should be scanned 2–3 times near the center of the wafer if a whole wafer is used to get sufficient statistics. If a piece of a wafer is used, the scan should be adjusted accordingly. The total area scanned should be at least 10 cm^2. Care should be taken to exclude edge density depending on the expected impact on yield versus material cost. A typical specification is that the HF defect density should be less than 1/cm^2.

Table 1. Specification Summary

Parameter	*Reference*	*Example Values*	*Method*
Wafer diameter (D)	ASTM 613	150 mm, 200 mm	Optical comparitor
Wafer thickness	ASTM 533		Thickness gauge
Thickness variation	ASTM 533	< 3 µm	Thickness gauge
Wafer warp	ASTM F 657, F 1390	≤ 30 µm for D = 150 mm	Jig + gauge
Crystal orientation	ASTM 26		X-ray diffraction
a) front surface		(100) ± 1°	
b) back surface			
Substrate type/dopant	ASTM 42		Hot point probe
Substrate resistivity	ASTM 84		4-point probe
Substrate RRG	ASTM 84		4-point probe
Surface Si thickness	Section 7.1.5	50 nm to 500 nm	SE/optical reflectance
Surface Si uniformity	Section 7.1.3	± 5 nm	SE/optical reflectance
Buried oxide thickness	Section 7.1.6	50 nm to 500 nm	SE/optical reflectance
Buried OX uniformity	Section 7.1.3	± 10 nm	SE/optical reflectance
Crystal defect (EPD)	Section 7.2	< 10 E7/cm^2	SEM examination
			Secco etch
Buried OX pinholes		< 0.1/cm^2	a) $CuSO_4$ plating
			b) BOX capacitor @ 1 nA
Metal contamination	Section 7.4.1	total < 10^{11} atoms /cm^2	TXRF
a) per unit area			
b) per unit volume			
Particles	Section 7.4.2	≤ 20 (> 0.25 µm) / wafer	Automated particle counter
Haze	Section 7.4.3	See Table 2.	Visual inspection
Slip	ASTM F 523*	See Table 2.	Visual inspection
Scratches	ASTM F 523*	None	Visual inspection
Chips	ASTM F 523*	See Table 2.	Visual inspection
Surf Spot Discolor	ASTM F 523	See Table 2.	Visual inspection
Foreign matter	ASTM F 523	See Table 2.	Visual inspection
Backside contamination	ASTM F 523		Visual inspection
Surface roughness	Section 7.4.4	5	Atomic force microscope (AFM)
Inclusions	Section 7.4.5		

* The user and supplier may agree on an edge exclusion for these specifications. For example, the area within 6 mm proximity of the wafer edge may be excluded.

Table 2. Example SIMOX Wafer Surface Inspection Criteria

Criterion	*Allow Quantity*	*Description*
Slip	0.3 mm: NONE 0.1–0.3 mm: < 15 mm total < 0.1 mm: OVERLOOK	6 mm edge exclusion
Scratch	NONE	6 mm edge exclusion
Contamination	NONE	Backside
Stain	< 5 spots	< 0.05 cm^2 total area
Edge Chips/Cracks	< 1.5 mm circumferential < 1.8 mm radial	combined length 1 × bright light
Pits and Dimples	< 0.5 mm - 10/wafer > 0.5 mm - NONE	1 × bright light
Haze	Moderate haze - NONE Heavy haze - NONE Non-uniform haze - NONE	Light uniform haze is acceptable. (Iterate between user and vendor.)
Foreign Matter (embedded particles)	< 0.05/cm^2	< 3 embedded particles per 150 mm wafer

Table 3. SIMOX Electrical Parameters

Parameters	*Reference*	*Value*	*Method*
Photoconductivity Lifetime (Backside)	Section 8.1	> 1 msec.	microwave
Photoconductivity Lifetime (Front side)	Section 8.1	TBD	microwave
BOX Breakdown	Section 8.2	> 5 MV/cm	I-V
BOX Pinholes	Section 8.3	< 0.2 cm^2	I-V
BOX Charge	Section 8.4	<	C-V
BOX Surface States	Section 8.5	$< 5 \times 10^{10}/cm^2$	C-V
Doping Density Sub, Surface	Section 8.6	TBD	4-point probe

8. Electrical Parameters

8.1 *Photoconductivity Lifetime* — This is measured by creating an excess of carriers (typically by using a light source) and measuring the slope of the decay curve. Several pieces of commercial equipment are available for this purpose. This requires that polysilicon is not deposited on the backside, as is sometimes done for gettering. Also, surface passivation may be needed for lifetime measurements. Backside measurements indicate the quality of the substrate and can be performed by traditional methods. Frontside measurements are more difficult and must be performed using incident light which can be entirely absorbed before reaching the underlying substrate.

8.1.1 Typically, the sample is placed on a micro-wave wave guide post, forming part of a transmission line circuit. The microwave reflection is determined by the total conductivity of the sample and the conductivity is modulated by an intense light pulse. When the light is turned off, the microwave detects an exponential decay in conductivity from which a decay constant is determined. The photoconductivity lifetime is a result of the recombination velocity at the surfaces, volume recombination in the silicon layer, and any trapping. Measurements are made independently on the front and back sides of the wafer. The mean value on the backside of the wafer will typically be at least 10 microseconds for N-type material and 3 microseconds for P-type material. These values correspond to about a 100 micron diffusion length (SPV value).

8.1.2 The relevance of photoconductivity lifetime to the users requirement should be discussed. The use of this measurement should be negotiated between customer and vendor.

8.2 *BOX Breakdown* — This parameter can be measured with a buried oxide capacitor (BOX-CAP). The buried oxide thickness and the intended application will affect both the test procedure (such as capacitor area and voltage criterion) and the allowable values of measured parameters. These should be determined by agreement between the user and vendor. Example procedure and values for standard evaluation of 400 nm thick buried oxide are given in the following paragraphs.

8.2.1 *Test Structure* — Buried oxide capacitor (BOX-CAP) having an area of 0.01 cm^2 for standard (400 nm) BOX. The electrode material and thickness affect the breakdown phenomena due to thermal effects, and so should be included in the agreement between customer and vendor.

8.2.2 *Test Method: Staircase I-V Measurement* — Voltage is stepped in one-volt increments from zero to 400 volts, or until destructive breakdown is sensed. Tests are done for both bias polarities. The test detects the onset of high field conduction, as well as the point of destructive or massive charge injection and trapping.

8.2.3 *Typical Values*

$J_{ox} < 10^{-8}$ A/cm^2 at $E_{ox} = \pm 2$ MV/cm [onset of hi-E regime]

$E_{ox} > 5$ MV/cm at $J_{ox} = 0.01$ A/cm^2 [break-down/injection]

8.3 *BOX Pinhole Density* — This parameter can be measured with a buried oxide capacitor (BOX-CAP). The buried oxide thickness and the intended application will affect both the test procedure (such as capacitor area and voltage criterion) and the allowable values of measured parameters. These should be determined by agreement between the user and vendor. Example procedure and values for standard evaluation of 400 nm thick buried oxide are given in the following paragraphs.

8.3.1 *Test Structure* — Buried oxide capacitor having an area equal to or greater than 0.05 cm^2.

8.3.2 *Test Method: Staircase I-V* — Measurement testing can be done for both Type I and Type II defects where Type I defects are silicon pipes traversing the buried oxide, and Type II defects are local regions of thin buried oxide. If Type II defect density is sought, capacitors are subjected to a series of 30 voltage steps of 3.3 volts, with current monitored after each step, using a failure criterion of 1 nA.

8.3.2.1 Arrays of at least 200 capacitors per wafer are tested. Bias polarity of the voltage ramp is chosen so as to accumulate the substrate portion of the capacitor (positive for *n*-silicon, negative for *p*-silicon).

8.3.2.2 Type I defect density is determined using the same test procedure, except that the failure current criterion is 1 µA.

8.3.2.3 Any capacitor displaying the failure current or more for voltages less than 100 volts is considered defective. Defect density of either type is calculated from the yield of good capacitors, (Y = 1 – # failed/# tested), using Poisson statistics;

$$D = -1n (Y)/A,$$

where A is the total area of the capacitors tested.

8.3.2.4 For thin buried oxide (films less than 360 nm), the voltage criteria above need to be adjusted to account for the onset of high field conduction in defect-free capacitors.

8.3.3 *Values*

$$D \text{ (Type I)} < = 0.2 \text{ defects/cm}^2$$

8.3.3.1 No standardized criterion for Type II defects has been established.

8.4 *Buried Oxide Charge* — This parameter can be measured with a buried oxide capacitor (BOX-CAP). The buried oxide thickness and the intended application will affect both the test procedure (such as capacitor area and voltage criterion) and the allowable values of measured parameters. These should be determined by agreement between the user and vendor. Example procedure and values for standard evaluation of 400 nm thick buried oxide are given in the following paragraphs.

8.4.1 *Test Structure* — Buried oxide capacitor having an area of 0.01 cm^2.

8.4.2 *Test Method* — MOS high frequency C-V measurement of a buried oxide capacitor normally yields a flat band voltage less than one volt in magnitude. For a previously untested 400 nm film, this implies an effective fixed charge density of less than 5 Ξ 10^{10} charges/cm^2.

8.4.3 *Values*

$$Qf/q <= 5 \times 10^{10}/cm^2$$

8.5 *Buried Oxide Fast Interfaces State Density* — This parameter can be measured with a buried oxide capacitor (BOX-CAP). The buried oxide thickness and the intended application will affect both the test procedure (such as capacitor area and voltage criterion) and the allowable values of measured parameters. These should be determined by agreement between the user and vendor. Example procedure and values for standard evaluation of 400 nm thick buried oxide are given in the following paragraphs.

8.5.1 *Test Structure* — Buried oxide capacitor having an area of 0.01 cm^2.

8.5.2 *Test Method* — High-Low Frequency MOS C-V. If care is taken in their fabrication to minimize oxide surface damage and contamination during silicon etching, good quality quasi-static MOS C-V curves can be measured on BOX-CAP's. From comparison of high and low frequency C-V curves, midgap interface state density can be determined exactly as for normal MOS capacitors.

8.5.3 *Values*

$$Dit (0) <= 5 \times 10^{10} \text{ states/ /cm}^2\text{-eV}$$

8.6 *Doping Density in the SIMOX Layer*

8.6.1 *Test Structure* — The untreated SIMOX wafer.

Substrate: Buried oxide capacitor, area = 0.01 cm^2

8.6.2 *Test Method* — Spreading Resistance Probing (SRP) offers a way of determining the resistance profile in the Si layer as a function of distance from the top surface. The carrier concentration can be calculated directly from this data.

8.6.2.1 The four point probe method of SIMS can also be used. The four point probe test is liable to punch through and should be considered a destructive test as is SIMS. SIMS will allow for an understanding of compensation effects, if any.

8.6.3 *Values* — The acceptable dopant values are to be determined by agreement between the user and vendor.

8.7 *Doping Density in the Substrate*

8.7.1 *Test Structure* — A buried oxide capacitor (BOX-CAP) area = 0.01 cm^2.

8.7.2 *Test Method* — The electrically active dopant concentration in the substrate immediately beneath the buried oxide can be determined from the standard analysis of high frequency MOS C-V curves measured on BOX-CAPs, dependent on oxide charge and interface properties.

Values — The acceptable dopant values are to be determined by agreement between the user and vendor.

9. Packing and Marking

9.1 Special packing requirements shall be subject to agreement between the user and supplier. Otherwise, all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination and in accordance with the best industry practices to provide ample protection against damage during shipment.

9.2 The wafer supplied under these specifications shall be identified by appropriately labeling the outside of each box or other container, and each subdivision thereof, in which it may reasonably be expected that the wafers will be stored prior to further processing. Identification marks, codes, symbols and content shall be agreed upon between user and supplier.

NOTICE: These guidelines do not purport to address all of the safety issues associated with their use. It is the responsibility of the users of these guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the guidelines set forth herein for any particular application. The determination of the suitability of these guidelines is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These guidelines are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M35-0299^E
GUIDE FOR DEVELOPING SPECIFICATIONS FOR SILICON WAFER SURFACE FEATURES DETECTED BY AUTOMATED INSPECTION

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on October 18, 1998. Initially available at www.semi.org February 1999; to be published February 1999.

E This document was editorially modified in March 2000. A change was made to Section 2.1.

1. Purpose

1.1 This guide provides a specification framework for reporting measurements of silicon wafer surface features through the use of scanning (or automated) surface inspection tools, also called SSIS's.

2. Scope

2.1 XLS's are scratches and regions of high roughness. This guide addresses specifications related to localized light scatterers (LLS's) as well as extended light scatterers (XLS's). Examples of LLS's are particles and pits. Examples of XLS's are scratches and regions of high roughness.

2.2 Surface scanners, which have discriminated between XLS's and LLS's for several years, are now discriminating (and selectively reporting) between different types of LLS's (for example: pits and particles).

2.3 Specific numbers limiting feature levels and/or densities are to be agreed upon between suppliers and users. This guide provides a framework for that communication.

2.4 The resulting specifications will be flexible enough to accommodate variations in measurement due to different scanning tools.

3. Discussion

3.1 *Discussion of LLS Measurement Issues*

3.1.1 Because there is considerable variation in the scatter characteristics of different LLS's, they have been historically sized in polystyrene latex sphere (PSL) equivalents. In other words, the signal received from an unknown LLS is equivalent to that which would be obtained from a PSL of known size.

3.1.2 Automated scanning systems typically display a map of LLS location as well as a histogram of (equivalent) PSL size.

3.1.3 The instrumentation industry is working on building scanning tools that will discriminate some LLS's from others based on differences in measured scatter that depend on feature size, shape and material. This raises the question of whether identified LLS's should be sized using PSL equivalents, or if some new (more accurate) standard would be more acceptable. For example, if an LLS signal could be identified as coming from a pit, then it might become appropriate to develop a standard pit wafer. In this case, pits (either manufactured or found naturally) could be measured via atomic force microscope (AFM) and be made available on a calibration wafer to size pits via their measured scatter. Another option, would be to use a model based standard that resides in the SSIS software.

3.2 *Discussion of XLS Measurement Issues*

3.2.1 Identification of scratches is typically done (in part) through software that identifies a string of connected LLS signals. Defects with dimensions such that the length is at least five times the width are defined as scratches. Users and suppliers may agree on scratch aspect ratios different from 5:1. SSIS software often provides a user-settable aspect ratio, as well as a minimum overall length, as criteria for classification of an SSIS defect or group of defects as a scratch. Currently, scratch signals are calibrated in PSL equivalents; however, in the future it may become useful to calibrate scratch signals with a standard obtained from a scratch that has been either manufactured to a known size, or has been measured via AFM.

3.2.2 Haze is specified as parts per million (ppm) of measured scattered optical power relative to the incident optical power on the surface. All of the associated measurement conditions must be given (or implied) with the specified haze value. These conditions include: source incident angle (measured as a polar angle from surface normal), source polarization (S, P, other), source wavelength (or wavelength band), nominal source spot size at the wafer, haze collection angles (given as solid angles with directions). All of these quantities must be part of a haze specification, either by description, or by implication to specific instrumentation (with known or fixed parameters).

3.2.3 Haze is quantified by measuring scattered light power over one or more solid angles and then normalizing by the light power incident on the surface. It is nothing more than the diffuse reflectance of a surface in specified directions for a known source (incident angle, polarization, spot size, wavelength band) and receiver (or detector) configuration (solid angles and locations). Measured haze can be expected to change if the surface is changed, or if any of the measurement parameters change.

3.2.4 Under special conditions, where the source of the haze is known, it may be possible to use a model to predict the haze reading on one instrument from the haze reading on another. For example, if on the basis of product experience and measurements on a few wafers, the surface power spectral density function can be determined, then the haze due to surface roughness can be calculated for an instrument with different parameters. This is the basic idea behind the standard haze wafer (and software) being commercially developed. Haze caused by a large number of small particles and/or film contamination is more difficult to model.

3.2.5 SSIS equipment often reports haze as the arithmetic average of a grid of local haze measurements taken over the FQA. This average can be, and often is, biased by wafer haze distributions that exhibit long, positively skewed tails. SSIS equipment software is being developed that will automatically calculate other haze statistics, such as the median haze value, the standard deviation of the haze distribution and so on.

4. Limitations

4.1 The following measurement considerations impose limitations on the guidelines.

4.1.1 The histograms (currently) calculated in PSL equivalents may be distorted, because a given surface will in general have LLS's of different size, shape and material.

4.1.2 Measurement results do not always compare well between systems, because different tool designs employ different geometries and gather light scattered in different directions. Haze maps may have different levels and localized surface features may have different calculated sizes.

4.1.3 All scanning systems have a minimum (PSL equivalent) LLS size that can be reliably mapped and sized. The limitation is due to a combination of system electrical noise and the detection of non-particle light scatter signals, such as those created by Rayleigh scatter, surface roughness and system optics. Operation near this noise floor limits the utility of this guide for those size LLS's.

4.1.4 Measurements made near the wafer edge often result in large numbers of false counts called edge blast. These counts are caused by small amounts of stray light propagating near the incident beam that scatter from the relatively rough wafer edge back into the detector optics. Under certain combinations of sensitivity and edge exclusion, light scattered from these effects may cause false counts within the FQA.

4.1.5 Types of LLS signals that may be mis-identified as scratches include lines of particles, pits, false counts, stacking faults, slip and spin dry residue.

4.1.6 Closely spaced features may be counted as a single scattering event because the scanning spot size is generally much larger than the feature diameter.

4.1.7 Scratch orientation may affect scanner response. Thus the minimum detectable scratch cross-section may vary with orientation.

5. Referenced Documents

5.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Polished Silicon Wafers

5.2 *ASTM Standards*[1]

F 1620 — Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Latex Spheres Deposited on Polished or Epitaxial Surfaces.

5.3 *SEMATECH*[2]

*Glossary of Term*s, SEMATECH Technology Transfer Document # 95082941A-TR

6. Terminology

6.1 *edge exclusion* — The width of a narrow band of wafer surface, located just inside the wafer edge, over which the values of the specified parameter do not apply. See the definition for fixed quality area below.

6.2 *extended light scatterer (XLS)* — A feature larger than the spatial resolution of the inspection equipment, on or in a wafer surface, resulting in increased light scattering intensity relative to that of the surrounding wafer, sometimes called an *area defect* (see SEMATECH # 95082941A-TR).

6.3 *fixed quality area (FQA)* — That portion of the area of a wafer surface, defined by a nominal, or specified, edge exclusion, E, over which the specified

1 Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, tel.: 610.832.9585, fax: 610.832.9555, website: www.astm.org

2 Available from SEMATECH, 2706 Montopolis, Austin, TX, tel.: 512.356.3500, fax: 512.779.2826 values of a parameter apply. The FQA lies within and is at all points at least the distance E (the nominal edge exclusion) away from the periphery of a wafer of nominal dimensions (see SEMI M1).

6.4 *haze* — Non-localized light scattering resulting from surface topography (microroughness) or from dense concentrations of surface or near surface imperfections. See *laser light scattering event* and the related Discussion to this definition in SEMI M1.

6.5 *localized light scatterer (LLS)* — An isolated feature, such as a particle or pit, on or in the wafer surface, resulting in increased light scattering intensity relative to that of the surrounding wafer surface; sometimes called *light point defect (LPD)* (see SEMI M1).

6.6 *particle* — A small, discrete piece of foreign material or silicon not connected crystallographically to the wafer (see SEMI M1). Also, see the Discussion related to this definition in SEMI M1.

6.7 *pit* — A depression in a wafer surface that has steeply sloped sides that meet the surface in a distinguishable manner in contrast to the rounded sides of a dimple (see SEMATECH # 95082941A-TR).

6.8 *power spectral density function* — The Fourier decomposition of the surface profile into its component spatial frequencies (see SEMATECH # 95082941A-TR). A statistical function that shows how the mean-square of profile height deviations are distributed among the various surface spatial frequencies inherent in the profile.

NOTE: Similar to the definition found in ASTM Standard F 1811.

6.9 *roughness* — The more narrowly spaced components of surface texture (see SEMI M1.) Also, see the Discussion related to this definition in SEMI M1.

6.10 *scanning surface inspection system (SSIS)* — An instrument for rapid examination of the entire quality area on a wafer to detect the presence of localized light scatterers or haze or both, also called *particle counter* and *laser surface scanner* (see ASTM F 1620).

6.11 *scratch* — A shallow groove or cut below the established plane of the wafer surface, with a length to width ratio greater than 5:1 (see SEMATECH # 95082941A-TR).

7. Specifications

7.1 Specification guidelines are given below for several different LLS's and XLS's.

7.1.1 *Generic LLS* — There shall be no more than N LLS's (particles or pits) of size greater than or equal to D nm in effective PSL diameter on the wafer within an edge exclusion of E mm from the edge.

7.1.1.1 Options: Size ranges and counts may be specified within the FQA.

7.1.2 *Particles* — There shall be no more than N particles of size greater than or equal to D nm in effective PSL diameter on the wafer within an edge exclusion of E mm from the edge. Size ranges and counts may be specified.

7.1.2.1 Options: Size ranges and counts may be specified within the FQA.

7.1.3 *Pits* — There shall be no more than N pits of size greater than or equal to D nm in effective pit diameter on the wafer within an edge exclusion of E mm from the edge. Size ranges and counts may be specified.

7.1.3.1 Options: Size ranges and counts may be specified within the FQA.

7.1.4 *Scratches* — There shall be no more than N scratches of length greater than or equal to L nm on the wafer within an edge exclusion of E mm from the edge.

7.1.4.1 Options: Size ranges and counts may be specified within the FQA.

7.1.4.2 Scratch aspect ratios different than 5:1 and minimum lengths may be used by agreement of user and supplier.

7.1.5 *Generic XLS* — There shall be no generic XLS's of N ppm or greater in an area larger than A mm^2 within an edge exclusion of E mm from the edge.

7.1.6 *Haze (Using Defined Conditions*) — Either local haze or average haze may be specified in the following way. The haze shall not exceed N ppm over the wafer surface when measured under the following conditions:

a. A $\underline{\lambda}$ nm S polarized laser source incident on the sample at $\underline{\theta}$ degrees.

b. Haze measured over a solid angle of $\underline{\Omega}$ sr of circular cross-section centered about the surface normal.

Users and suppliers may agree to use other statistics of the wafer haze distribution in haze specifications.

NOTE: For example: the median wafer haze shall not exceed M ppm; the standard deviation of wafer haze shall not exceed S ppm; the inter-quartile range of wafer haze shall not exceed IQR ppm. Statistics based on the log of the haze distribution may also be used.

7.1.7 *Haze (Using an Instrument Definition)* — Either local haze or average haze may be specified in the following way. The haze shall not exceed N ppm over the wafer surface when measured with a model XXX particle scanner under YYY operating conditions. Users and suppliers may agree to use other statistics of the wafer haze distribution in haze specifications.

NOTE: For example: the median wafer haze shall not exceed M ppm; the standard deviation of wafer haze shall not exceed S ppm; the inter-quartile range of wafer haze shall not exceed IQR ppm. Statistics based on the log of the haze distribution may also be used.

7.2 Specifications may be selected from the following table:

Table 1 Specification Elements Related to Automatic Inspection of Silicon Wafer Surfaces

Parameter	*Specification Elements*	*Specified Measurement Conditions*
1. Generic LLS	___, max number	with equivalent PSL dia ≥ __nm, edge exclusion of __ mm
2. Particles	___, max number	with equivalent PSL dia ≥ __nm edge exclusion of __ mm
3. Pits	___, max number	with equivalent PSL dia ≥ __nm edge exclusion of __ mm
4. Scratches	___, max number	length ≥ __ µm edge exclusion of __ mm
5. Generic XLS	__ ppm, max	with area ≥ __ mm^2 edge exclusion of __ mm
6. Haze (conditions)	__ ppm, max	with __ degree incident angle, at __ nm wavelength, at __ polarization, over __ sr solid collection angle, in __degree polar direction and __ degree azimuthal direction, edge exclusion of __ mm
7. Haze (instrument)	__ ppm, max (or other statistics)	with model XXX SSIS under YYY conditions

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SEMI M36-0699
TEST METHOD FOR MEASURING ETCH PIT DENSITY (EPD) IN LOW DISLOCATION DENSITY GALLIUM ARSENIDE WAFERS

This test method was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Materials Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available at www.semi.org April 1999; to be published June 1999.

1 Purpose

1.1 This document provides a method to measure etch pit density (EPD) in low dislocation density GaAs wafers.

2 Scope

2.1 This test method describes a procedure to measure EPD of 50 mm and 76 mm diameter round GaAs wafers with an EPD of less than $5000/cm^2$.

2.2 This test method does not include GaAs wafer preparation, such as wafer slicing, polishing and pit etching. The preparation of GaAs wafer can be found in a Referenced Document.

2.3 This standard does not purport to address all of the safety issues. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulations prior to use of the test method.

3 Referenced Document

3.1 *ASTM Standard*

F 140-92 — Test Method for Crystallographic Perfection of Gallium Arsenide by Molten Potassium Hydroxide (KOH) Etch Technique.

4 Apparatus

4.1 Microscope - Measuring field should be 1 mm^2 or larger.

NOTE: For accurate EPD measurement, accurate area of the measuring field should be measured by a standard scale.

5 Procedure

5.1 The counting positions for 50 mm diameter wafers and for 76 mm diameter wafers are shown in Figure 1 and Figure 2 respectively. The counting points are located in the center of each mesh. In the case of a 50 mm diameter wafer the mesh size is 5 mm. The total number of counting positions is 69 and position 35 is located at the center of the wafer. In the case of 76 mm diameter wafer the mesh size is 10 mm, and the total number of counting position is 37. Position 19 is located at the center of the wafer.

5.2 Count and record the number of etch pits for which the cores are in the measuring field. If the pits are crowded and are difficult to count, increase the magnification. After that count the etch pits and record the results as well as the microscope magnification.

5.3 Repeat Section 5.3 for all other positions, 2 through 69 positions in the case of 50 mm diameter wafers and 2 through 37 positions in the case of 76 mm diameter wafers.

6 Calculations

6.1 The EPD in each measuring field is the number of pits counted divided by the area.

$$EPD = (\text{Number of pits}) / \text{Area}$$

For example, if the size of measuring field is exactly 1 mm × 1 mm, the area is 0.01 cm^2.

7 Report

7.1 There are several forms that are possible for reporting the EPD, for example the average EPD of all the positions or the area less than some specified value or map of EPD for the entire wafer, etc. An appropriate report form should be decided between the supplier and the user.

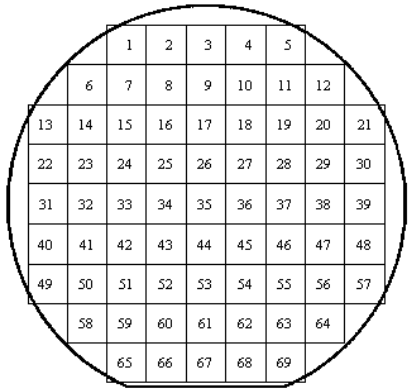

Figure 1

Counting positions for a 50 mm diameter wafer

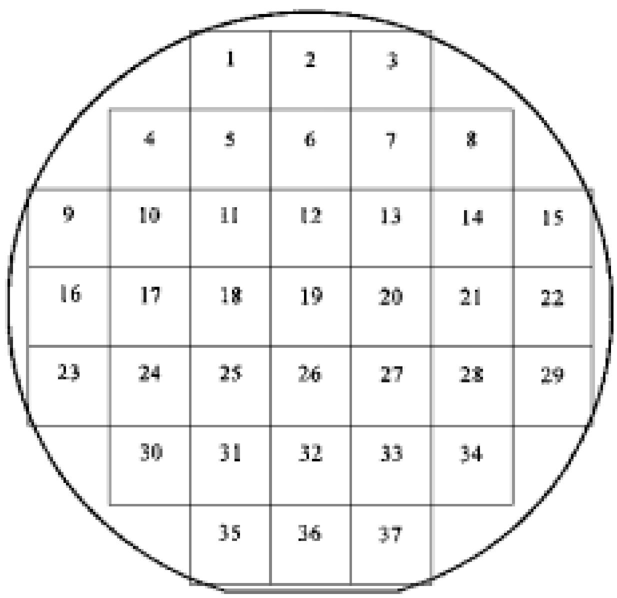

Figure 2

Counting positions for a 76 mm diameter wafer

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SEMI M37-0699
TEST METHOD FOR MEASURING ETCH PIT DENSITY (EPD) IN LOW DISLOCATION DENSITY INDIUM PHOSPHIDE WAFERS

This test method was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Materials Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available at www.semi.org April 1999; to be published June 1999.

1 Purpose

1.1 This document provides a method to measure etch pit density (EPD) in low dislocation density InP wafers.

2 Scope

2.1 This test method describes a procedure to measure EPD of 50 mm diameter round InP wafers with an EPD of less than 5000/cm^2.

2.2 This standard does not purport to address all of the safety issues. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulations prior to use of the test method.

3 Referenced Document

3.1 *ASTM Standard*

F 140-92 — Test Method for Crystallographic Perfection of Gallium Arsenide by Molten Potassium Hydroxide (KOH) Etch Technique.

4 Apparatus

4.1 Microscope — Measuring field should be 1 mm^2 or larger.

NOTE: For accurate EPD measurement, accurate area of the measuring field should be measured by a standard scale.

5 Procedure

5.1 Orient the ingot so that the front surface normal direction of the sample is parallel to the <100> within 5°, and then cut a wafer from the ingot.

5.2 Polish the wafer to form a mirror finish. Afterwards, the wafer must be cleaned and dried.

5.3 Mix phosphoric acid (H_3PO_4) and hydrobromic acid (HBr) in a beaker. The ratio of each acid is H_3PO_4: HBr=2:1.

5.4 Immerse the wafer in the mixed acid for 3 minutes at room temperature.

5.5 Rinse the wafer with deionized water and then dry.

5.6 The counting positions are shown in Figure 1. The counting points are located in the center of each mesh. The mesh size is 5 mm and the total number of counting positions is 69. Position 35 is located at the center of the wafer.

5.7 Count and record the number of etch pits for which the cores are in the measuring field. If the pits are crowded and are difficult to count, increase the magnification. After that count the etch pits and record the results as well as the microscope magnification.

5.8 Repeat Section 5.8 for all other positions, 2 through 69.

6 Calculations

6.1 The EPD in each measuring field is the number of pits counted divided by the area.

$$EPD = (\text{Number of pits}) / \text{Area}$$

For example, if the size of measuring field is exactly 1 mm × 1 mm, the area is 0.01 cm^2.

7 Report

7.1 There are several forms that are possible for reporting the EPD, for example the average EPD of all the positions or the area less than some specified value or map of EPD for the entire wafer, etc. An appropriate report form should be decided between the supplier and the user.

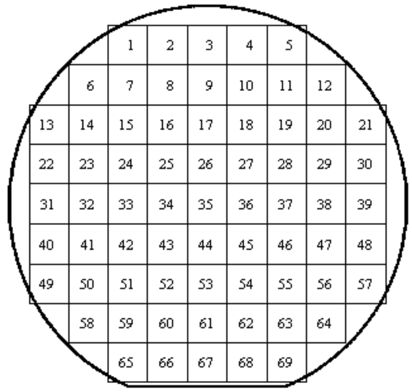

Figure 1

Counting positions for a 50 mm diameter wafer

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SEMI M38-1101
SPECIFICATION FOR POLISHED RECLAIMED SILICON WAFERS

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published September 1999; previously published March 2001.

1 Purpose

1.1 This specification covers requirements for reclaimed silicon wafers to be used for testing and process monitoring in semiconductor manufacturing. A reclaimed wafer is a silicon wafer which has been re-conditioned for subsequent utilization.

2 Scope

2.1 A complete purchase specification requires that additional physical properties be defined. These properties are listed, together with test methods suitable for determining their magnitude.

2.2 This specification is directed specifically to silicon wafers with one or both polished surfaces, unpolished, or with epitaxial deposits.

2.3 This specification covers reclaim wafers that are either customer-supplied or third party-sourced. The user should exercise caution when sourcing materials with unknown thermal histories, unknown bulk contamination or unknown deposits, such as gold (Au) films.

2.4 Reclaimed silicon has been divided into four "use" categories: Mechanical, Furnace, Particle, and Lithography. The intent is that a prospective purchaser or reclaimed silicon needs to know which application matches his requirements and which wafer attributes are important for that application.

2.5 For applications placing higher demands on silicon wafers such as particle counting, measuring pattern resolution in a photolithography process, or surface ion contamination monitoring, the user may want to reference SEMI M1, M8, or M24.

2.6 For referee purposes, U.S. customary units shall be used for wafers of 2- and 3-inch nominal diameter and SI (System International), commonly called metric units, for 100 mm and larger diameter wafers.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

SEMI M8 — Specification for Polished Monocrystalline Silicon Test Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M24 — Specification for Polished Monocrystalline Silicon Premium Wafers

3.2 *ANSI Standard*[1]

For a comprehensive list of applicable ANSI Standards, see those listed in Table 1 of SEMI M18.

3.3 *ASTM Standards*[2]

For a comprehensive list of applicable ASTM Standards, see those listed in Table 1 of SEMI M18.

3.4 *DIN Standards*[3]

For a comprehensive list of applicable DIN Standards, see those listed in Table 1 of SEMI M18.

3.5 *JIS Standard*[4]

For a comprehensive list of applicable JIS Standards, see those listed in Table 1 of SEMI M18.

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

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1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

3 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany, website: www.din.de

4 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

4 Terminology

4.1 Definitions of terms related to silicon wafer technology are given in ASTM Terminology F 1241.

4.2 Definitions for some additional terms are given in SEMI M1.

4.3 The following definitions apply in the context of this specification:

4.3.1 *furnace wafer* — a silicon wafer which can be used for monitoring thermal processes or as an implant monitor and is usually only used in a cleanroom.

4.3.2 *hand scribe mark* — any marking, usually on the back surface of a wafer, scratched manually into the silicon surface, as with a diamond tipped scribe, for purposes of wafer identification.

4.3.3 *lithography wafer* — a silicon wafer used specifically for testing lithography equipment wherein surface flatness is key to process monitoring. This wafer is usually only used in a cleanroom environment.

4.3.4 *mechanical wafer* — a silicon wafer suitable for equipment or process testing which is usually only used outside of a cleanroom environment.

4.3.5 *particle wafer* — a silicon wafer which can be used for monitoring area or process cleanliness and is only used in a cleanroom environment.

4.3.6 *reclaimed wafer* — a silicon wafer which has been reconditioned for subsequent utilization.

4.3.7 *test wafer* — a silicon wafer suitable for process monitoring in semiconductor manufacturing. Also called *monitor wafer*.

5 Ordering Information

5.1 Purchase orders for reclaimed silicon wafers furnished to this specification shall minimally include the following items:

5.1.1 Customer-supplied or third-party sourced, and

5.1.2 Nominal diameter, conductivity type, resistivity, and surface orientation.

5.2 Following are the optional criteria to include in a prospective purchase order:

5.2.1 Lot acceptance criteria,

5.2.2 Certification,

5.2.3 Packing and Marking,

5.2.4 Minimum removal requirements (if any), and

5.2.5 Lot traceability and lot integrity maintenance requirements.

5.3 This specification is divided into four application categories or tables: Mechanical, Furnace, Particle, and Lithography. For ordering purposes, attributes applicable to each use are listed in the appropriate table.

6 Dimensions and Permissible Variations

6.1 The material shall conform to the parameters as specified in Tables 1 through 9.

6.2 The material shall conform to the crystallographic orientation details as listed in the tables.

7 Materials and Manufacture

7.1 The material shall consist of silicon wafers which are capable of being reconditioned for use.

8 Electrical Requirements

8.1 The material shall conform to the details specified in the purchase order or contract, as follows:

8.1.1 Conductivity type

8.1.2 Resistivity

9 Sampling

9.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z 1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z 1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the purchaser.

10 Test Methods

NOTE 2: Silicon wafers are extremely fragile. While the mechanical dimensions of a wafer can be measured by use of tools such as micrometer calipers and other conventional techniques, the wafer may be damaged physically in ways that are not immediately evident. Special care must therefore be used in the selection and execution of measurement methods.

NOTE 3: The kind of dopant used is difficult to ascertain in finished wafers. Verification test procedures for certification of these characteristics shall be agreed upon between the supplier and the purchaser.

10.1 *Diameter* — Determine in accordance with ASTM Test Method F 613.

10.2 *Thickness, Center Point* — Determine in accordance with ASTM Test Method F 533 or DIN 50441/1, or JIS H 0611.

10.3 *Flat Length* — Determine in accordance with ASTM Test Method F 671.

10.4 *Flat Orientation* — Determine in accordance with ASTM Test Methods F 847.

10.5 *Surface Orientation* — Determine in accordance with ASTM Test Methods F 26 or DIN 50433.

10.6 *Surface Defects and Contamination* — Determine in accordance with ASTM Practice F 523. The following conditions shall be used (unless otherwise specified in the purchase or contract):

a. Background light intensity:

8 ± 2 fc (86 ± 22 lux)

b. Angle α (alpha): 45° ± 10°

c. Angle β (beta): 90° ± 10°

10.6.1 See Section 10 for surface defect criteria and Table 2 for allowable levels of defects. In the event the wafers fail to meet these criteria, they shall be conditioned according to ASTM Practice F 612 or other cleaning procedure as agreed upon between supplier and user and retested.

NOTE 4: ASTM Practices F 154 is a useful guide for defining a variety of surface features found on silicon surfaces and for establishing commonly understood terms for describing them. It also gives detailed procedures for illumination and microscopical examination of surfaces.

10.7 *Conductivity Type* — Determine in accordance with ASTM Test Methods F 42 or DIN 50432.

10.8 *Resistivity* — Determine by methods agreed upon between the supplier and the purchaser.

NOTE 5: Resistivity of wafers is most appropriately determined for referee purposes by ASTM Method F 84 or DIN 50431. Under some circumstances these tests may be considered destructive, and an alternative means may be required. A widely used nondestructive test is ASTM Test Methods F 673, having a range from 0.0001 to 200 Ω • cm.

10.9 *Radial Resistivity Variation* — Determine in accordance with ASTM Test Methods F 81 or DIN 50435.

10.10 *Crystal Perfection* — Determine in accordance with ASTM Test Method F 47 or DIN 50434 (to determine grain boundaries, twinning, slip, dislocations, and lineage).

10.11 *Edge Profile* — Determine in accordance with ASTM Test Methods F 928 or DIN 50441/2.

11 Surface Defect Criteria

11.1 *Minimal Conditions or Dimensions* — The minimal conditions or dimensions for defects stated below shall be used for determining wafer acceptability. Anomalies smaller than these limits shall not be considered defects.

11.2 *area contamination* — any foreign matter on the surface in localized areas which is revealed under the inspection lighting conditions as discolored, mottled, or cloudy appearance resulting from smudges, stains, water spots, etc.

11.3 *crack* — any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.4 *crow's foot* — any anomaly conforming to the definition and greater than 0.25 mm (0.010 inch) in total length.

11.5 *dimple* — any smooth surface depression greater than 3 mm in diameter.

11.6 *edge chip and indent* — any edge anomaly including saw exit marks conforming to the definition and greater than 0.25 mm (0.010 inch) in radial depth and peripheral length.

11.7 *hand scribe mark* — any mark such as that caused by a diamond scribe that is visible under diffuse illumination.

11.8 *haze* — haze is indicated when the image of a narrow beam tungsten lamp filament is detectable on the polished wafer surface. (Under some conditions contamination may appear as haze.)

11.9 *orange peel* — any roughened surface conforming to the definition that is observable under diffuse illumination.

11.10 *particulate contamination* — distinct particles resting on the surface which are revealed under collimated light as bright points.

11.11 *pit* — any individually distinguishable non-removable surface anomaly conforming to the definition and visible when viewed under high intensity illumination.

11.12 *saw marks* — any surface irregularities conforming to the definition that is observable under diffuse illumination.

11.13 *scratch* — any anomaly conforming to the definition and having a length-to-width ratio greater than 5:1.

11.14 *slip* — any pattern of short ridges aligned along <110> directions and visible under diffuse illumination.

11.15 *striations* — any helical features conforming to the definition and visible under diffuse illumination.

12 Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

12.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 9. However, if the purchaser performs the test and the material fails to meet the requirement, the material may be subject to rejection.

13 Packing and Marking

13.1 Special packing requirements shall be subject to agreement between the supplier and the purchaser. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches, and contamination, and in accordance with the best industry practices, to provide ample protection against damage during shipment.

13.2 The wafers supplied under this specification shall be identified by appropriately labeling the outside of each box or other container and each subdivision thereof in which it may reasonably be expected that the wafers will be stored prior to further processing.

14 Tables

14.1 Please note the following terminology for the tables:

unspecified — an attribute which is not specified,

user specified — an attribute which may be specified, and

as-supplied — an attribute which is pre-established in the as-delivered wafer for reclaim.

Table 1 Format for 150 mm, 200 mm, and 300 mm Silicon Reclaim Wafer – Mechanical for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	Unspecified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	Unspecified
	4.3	Lineage	Unspecified
	4.4	Twins	Unspecified
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified

EDI Code		*Item*	*Specification*
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Mechanical Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	Unspecified
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	Unspecified
	5.5	Backseal	Unspecified
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		150 mm ±	0.50 mm
		200 mm ±	0.50 mm
		300 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		150 mm (SEMI M1.8)	As-supplied
		150 mm (SEMI M1.13)	As-supplied
		200 mm	As-supplied
		300 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		150 mm (SEMI M1.8)	533–675 µm
		150 mm (SEMI M1.13)	585–725 µm
		200 mm	600–775 µm
			Mechanical Wafer
		300 mm	650–800 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp (for diameters other than 300 mm)	Unspecified
		Warp (for 300 mm only)	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified

EDI Code		Item	Specification
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1A	Scratches (macro) – total length	Unspecified
	8.1B	Scratches (micro) – total length	Unspecified
	8.2	Pits	Unspecified
	8.3	Haze	Unspecified
			Mechanical Wafer
	8.4	Localized Light Scatterers	Unspecified
	8.5	Contamination/area	Unspecified
	8.6	Edge Chips	Unspecified
	8.7	Edge Cracks	Unspecified
	8.8	Cracks, Crow's feet	Unspecified
	8.9	Craters	Unspecified
	8.10	Dimples	Unspecified
	8.11	Grooves	Unspecified
	8.12	Mounds	Unspecified
	8.13	Orange Peel	Unspecified
	8.14	Saw Marks	Unspecified
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	Unspecified
	9.6	Roughness	Unspecified
	9.7A	Brightness (gloss) (150 & 200 mm)	Unspecified
	9.7B	Brightness (gloss) (300 mm)	$\geq$ 80%
	9.8	Localized Light Scatterers	Unspecified
	9.9A	Scratches (macro)	Unspecified
	9.9B	Scratches (micro)	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge condition (for 200 mm and 300 mm only)	Unspecified

Table 2 Format for 150 mm, 200 mm, and 300 mm Silicon Reclaim Wafer – Furnace for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified

EDI Code		*Item*	*Specification*
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	As-supplied
	3.2	Radial Oxygen Variation	As-supplied
	3.3	Carbon Concentration	As-supplied
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Furnace Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		150 mm ±	0.50 mm
		200 mm ±	0.50 mm
		300 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		150 mm (SEMI M1.8)	As-supplied
		150 mm (SEMI M1.13)	As-supplied
		200 mm	As-supplied
		300 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		150 mm (SEMI M1.8)	533–675 µm
		150 mm (SEM M1.13)	585–725 µm
		200 mm	600–775 µm
			Furnace Wafer
		300 mm	650–800 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied

EDI Code		*Item*	*Specification*
	6.10	Bow	Unspecified
	6.11	Warp (for diameters other than 300 mm)	Unspecified
		Warp (for 300 mm only)	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	User specified
		Aluminum	User specified
		Potassium	User specified
		Chromium	User specified
		Iron	User specified
		Nickel	User specified
		Copper	User specified
		Zinc	User specified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	$\leq$ 0.10 × Diameter
	8.2	Pits	Unspecified
	8.3	Haze	Unspecified
			Furnace Wafer
	8.4	Localized Light Scatterers	
		150 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm
		200 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm
		300 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7A	Brightness (gloss) (150 & 200 mm)	Unspecified
	9.7B	Brightness (gloss) (300 mm)	$\geq$ 80%
	9.8	Localized Light Scatterers	User specified
	9.9A	Scratches (macro) – total length	$\leq$ 0.25 × Diameter

EDI Code		*Item*	*Specification*
	9.9B	Scratches (micro) – total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge condition (for 200 mm and 300 mm only)	User specified

Table 3 Format for 150 mm, 200 mm, and 300 mm Silicon Reclaim Wafer – Particle for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Particle Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	Unspecified
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	Unspecified
	5.5	Backseal	Unspecified
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		150 mm ±	0.50 mm
		200 mm ±	0.50 mm

EDI Code		*Item*	*Specification*
		300 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		150 mm (SEMI M1.8)	As-supplied
		150 mm (SEMI M1.13)	As-supplied
		200 mm	As-supplied
		300 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		150 mm (SEMI M1.8)	533–675 µm
		150 mm (SEMI M1.13)	585–725 µm
		200 mm	600–775 µm
			Particle Wafer
		300 mm	650–800 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp (for diameters other than 300 mm)	Unspecified
		Warp (for 300 mm only)	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (macro) – total length	$\leq$ 0.10 × Diameter
	8.2	Pits	User specified
	8.3	Haze	User specified
			Particle Wafer
	8.4	Localized Light Scatterers	
		150 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm
		200 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm
		300 mm	$\leq 0.20/cm^2$ @ $\geq$ 0.20 µm

EDI Code		*Item*	*Specification*
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7A	Brightness (gloss) (150 & 200 mm)	User specified
	9.7B	Brightness (gloss) (300 mm)	$\geq$ 80%
	9.8	Localized Light Scatterers	User specified
	9.9A	Scratches (macro) – total length	$\leq$ 0.25 × Diameter
	9.9B	Scratches (micro) – total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge condition (for 200 mm and 300 mm only)	User specified

Table 4 Format for 150 mm, 200 mm, and 300 mm Silicon Reclaim Wafer – Lithography for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	None
	4.2	Slip	None
	4.3	Lineage	None

EDI Code		*Item*	*Specification*
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Lithography Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		150 mm ±	0.50 mm
		200 mm ±	0.50 mm
		300 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		150 mm (SEMI M1.8)	As-supplied
		150 mm (SEMI M1.13)	As-supplied
		200 mm	As-supplied
		300 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		150 mm (SEMI M1.8)	533–675 µm
		150 mm (SEMI M1.13)	585–725 µm
		200 mm	600–775 µm
			Lithography Wafer
		300 mm	650–800 µm
	6.8	Thickness Variation (TTV)	User specified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp (for diameters other than 300 mm)	Unspecified
		Warp (for 300 mm only)	Unspecified
	6.12	Sori	User specified
	6.13	Flatness/Global	User specified
	6.14	Flatness/Site	User specified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified

EDI Code		*Item*	*Specification*
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	$\leq$ 0.10 × Diameter
	8.2	Pits	User specified
	8.3	Haze	User specified
			Lithography Wafer
	8.4	Localized Light Scatterers	
		150 mm	$\leq 0.20/cm^2$ @ $\geq 0.20\ \mu m$
		200 mm	$\leq 0.20/cm^2$ @ $\geq 0.20\ \mu m$
		300 mm	$\leq 0.20/cm^2$ @ $\geq 0.20\ \mu m$
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7A	Brightness (gloss) (150 & 200 mm)	User specified
	9.7B	Brightness (gloss) (300 mm)	$\geq$ 80%
	9.8	Localized Light Scatterers	User specified
	9.9A	Scratches (macro) – total length	$\leq$ 0.25 × Diameter
	9.9B	Scratches (micro) – total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge condition (for 200 mm and 300 mm only)	User specified

Table 5 Format for 2", 3", 100 mm, and 125 mm Silicon Reclaim Wafer – Mechanical for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	Unspecified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	Unspecified
	4.3	Lineage	Unspecified
	4.4	Twins	Unspecified
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Mechanical Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	Unspecified
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	Unspecified
	5.5	Backseal	Unspecified
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		2.00 inch ±	0.020 inch
		3.00 inch ±	0.025 inch
		100 mm ±	0.50 mm
		125 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		2.00 inch	As-supplied
		3.00 inch	As-supplied
		100 mm	As-supplied

EDI Code		*Item*	*Specification*
		125 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		2.00 inch	0.008–0.013 in
		3.00 inch	0.012–0.018 in
			Mechanical Wafer
		100 mm (SEMI M1.5)	432–575 µm
		100 mm (SEMI M1.6)	533–675 µm
		125 mm	533–675 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1	Scratches	Unspecified
	8.2	Pits	Unspecified
	8.3	Haze	Unspecified
			Mechanical Wafer
	8.4	Localized Light Scatters	Unspecified
	8.5	Contamination/area	Unspecified
	8.6	Edge Chips	Unspecified
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	Unspecified
	8.10	Dimples	Unspecified
	8.11	Grooves	Unspecified
	8.12	Mounds	Unspecified
	8.13	Orange Peel	Unspecified

EDI Code		Item	Specification
	8.14	Saw Marks	Unspecified
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	Unspecified
	9.6	Roughness	Unspecified
	9.7	Brightness (gloss)	User specified
	9.8	Localized Light Scatterers	Unspecified
	9.9	Scratches (# of)	Unspecified
		Cumulative length	Unspecified

Table 6 Format for 2", 3", 100 mm, and 125 mm Silicon Reclaim Wafer – Furnace for Order Entry

EDI Code		Item	Specification
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	As-supplied
	3.2	Radial Oxygen Variation	As-supplied
	3.3	Carbon Concentration	As-supplied
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	User specified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Furnace Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	5.6	Annealing	Unspecified

EDI Code		*Item*	*Specification*
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		2.00 inch ±	0.020 in
		3.00 inch ±	0.025 in
		100 mm ±	0.50 mm
		125 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		2.00 inch	As-supplied
		3.00 inch	As-supplied
		100 mm	As-supplied
		125 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		2.00 inch	0.008–0.013 in
		3.00 inch	0.012–0.018 in
			Furnace Wafer
		100 mm (SEMI M1.5)	432–575 µm
		100 mm (SEMI M1.6)	533–675 µm
		125 mm	533–675 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	User specified
		Aluminum	User specified
		Potassium	User specified
		Chromium	User specified
		Iron	User specified
		Nickel	User specified
		Copper	User specified
		Zinc	User specified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1	Scratches (# of)	2
		Cumulative length	20 mm
	8.2	Pits	Unspecified

EDI Code		*Item*	*Specification*
			Furnace Wafer
	8.3	Haze	Unspecified
	8.4	Localized Light Scatterers	
		2.00 inch	≤ 0.19/cm² @ User specified size
		3.00 inch	≤ 0.19/cm² @ User specified size
		100 mm	≤ 0.19/cm² @ User specified size
		125 mm	≤ 0.19/cm² @ User specified size
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7	Brightness (gloss)	User specified
	9.8	Localized Light Scatterers	User specified
	9.9	Scratches (# of)	User specified
		Cumulative length	User specified

Table 7 Format for 2", 3", 100 mm, and 125 mm Silicon Reclaim Wafer – Particle for Order Entry

EDI Code		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	

EDI Code		*Item*	*Specification*
	4.1	Dislocation Etch Pit Density	Unspecified
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Particle Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	Unspecified
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	Unspecified
	5.5	Backseal	Unspecified
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		2.00 inch ±	0.020 in
		3.00 inch ±	0.025 in
		100 mm ±	0.50 mm
		125 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		2.00 inch	As-supplied
		3.00 inch	As-supplied
		100 mm	As-supplied
		125 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		2.00 inch	0.008–0.013 in
		3.00 inch	0.012–0.018 in
			Particle Wafer
		100 mm (SEMI M1.5)	432–575 µm
		100 mm (SEMI M1.6)	533–675 µm
		125 mm	533–675 µm
	6.8	Thickness Variation (TTV)	Unspecified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp	Unspecified
	6.12	Sori	Unspecified
	6.13	Flatness/Global	Unspecified
	6.14	Flatness/Site	Unspecified

EDI Code		*Item*	*Specification*
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1	Scratches (# of)	2
		Cumulative length	20 mm
	8.2	Pits	User specified
			Particle Wafer
	8.3	Haze	User specified
	8.4	Localized Light Scatterers	
		2.00 inch	$\leq$ 0.19/cm^2 @ User specified size
		3.00 inch	$\leq$ 0.19/cm^2 @ User specified size
		100 mm	$\leq$ 0.19/cm^2 @ User specified size
		125 mm	$\leq$ 0.19/cm^2 @ User specified size
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7	Brightness (gloss)	User specified
	9.8	Localized Light Scatterers	User specified
	9.9	Scratches (# of)	User specified
		Cumulative length	User specified

Table 8 Format for 2", 3", 100 mm, and 125 mm Silicon Reclaim Wafer – Lithography for Order Entry

EDI Codes		*Item*	*Specification*
	1.0	**General Characteristics**	
	1.1	Growth Method	As-supplied
	1.2	Crystal Orientation	As-supplied
	1.3	Conductivity Type	As-supplied
	1.4	Dopant	As-supplied
	1.5	Nominal Edge Exclusion Distance for FQA	User specified
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	User specified
	2.2	Radial Resistivity Variation (RRG)	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.1	Dislocation Etch Pit Density	None
	4.2	Slip	None
	4.3	Lineage	None
	4.4	Twins	None
	4.5	Swirl	Unspecified
	4.6	Shallow Pits	Unspecified
	4.7	OISF	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	**Lithography Wafer**
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	Unspecified
	5.3	Denuded Zone	Unspecified
	5.4	Extrinsic Gettering	Unspecified
	5.5	Backseal	Unspecified
	5.6	Annealing	Unspecified
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	
		2.00 inch ±	0.020 in
		3.00 inch ±	0.025 in
		100 mm ±	0.50 mm
		125 mm ±	0.50 mm
	6.2	Primary Flat/Notch Dimension	
		2.00 inch	As-supplied
		3.00 inch	As-supplied
		100 mm	As-supplied

EDI Codes		*Item*	*Specification*
		125 mm	As-supplied
	6.3	Primary Flat/Notch Orientation	As-supplied
	6.4	Secondary Flat Dimension (if applicable)	As-supplied
	6.5	Secondary Flat Location (if applicable)	As-supplied
	6.6	Edge Profile	Unspecified
	6.7	Thickness	
		2.00 inch	0.008–0.013 in
		3.00 inch	0.012–0.018 in
			Lithography Wafer
		100 mm (SEMI M1.5)	432–575 µm
		100 mm (SEMI 1.6)	533–675 µm
		125 mm	533–675 µm
	6.8	Thickness Variation (TTV)	User specified
	6.9	Surface Orientation	As-supplied
	6.10	Bow	Unspecified
	6.11	Warp	Unspecified
	6.12	Sori	User specified
	6.13	Flatness/Global	User specified
	6.14	Flatness/Site	User specified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	Unspecified
		Aluminum	Unspecified
		Potassium	Unspecified
		Chromium	Unspecified
		Iron	Unspecified
		Nickel	Unspecified
		Copper	Unspecified
		Zinc	Unspecified
	7.2	Surface Organics	Unspecified
	8.0	**Front Surface Visual Characteristics**	
	8.1	Scratches (# of)	2
		Cumulative length	20 mm
	8.2	Pits	User specified
			Lithography Wafer
	8.3	Haze	User specified
	8.4	Localized Light Scatterers	
		2.00 inch	$\leq$ 0.19/cm^2 @ User specified size
		3.00 inch	$\leq$ 0.19/cm^2 @ User specified size
		100 mm	$\leq$ 0.19/cm^2 @ User specified size
		125 mm	$\leq$ 0.19/cm^2 @ User specified size
	8.5	Contamination/area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Cracks, Crow's feet	None

EDI Codes		Item	Specification
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Characteristics**	
	9.1	Edge Chips	None
	9.6	Roughness	User specified
	9.7	Brightness (gloss)	User specified
	9.8	Localized Light Scatterers	User specified
	9.9	Scratches (# of)	User specified
		Cumulative length	User specified

Table 9 Guide For The Specification Of 0.18 µm Design Rule 200 mm Polished Reclaimed Wafers

EDI Code		Item	P- Reclaim Wafer
	1.0	**General Characteristics**	
	1.1	Growth Method	CZ or MCZ
	1.2	Crystal Orientation	1-0-0
	1.3	Conductivity Type	P
	1.4	Dopant	Boron
	1.5	Nominal Edge Exclusion	3 mm (See NOTE 1.)
	2.0	**Electrical Characteristics**	
	2.1	Resistivity	0.5–50.0 ohm
	2.2	Radial Resistivity Variation	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Recombination Lifetime	Unspecified
	3.0	**Chemical Characteristics**	
	3.1.1	Oxygen Concentration	≤ 32 ppma (old ASTM F121-79)
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**Structural Characteristics**	
	4.2	Slip	none
	4.3	Lineage	none
	4.4	Twins	none
	4.5	Swirl	Unspecified
	4.6	Shallow pits	Unspecified
	4.7	Oxidation-Induced Stacking Faults (OISF)	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**Wafer Preparation Characteristics**	
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None

EDI Code		*Item*	*P- Reclaim Wafer*
	5.3	Denuded Zone	None
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	6.0	**Mechanical Characteristics**	
	6.1	Diameter	200 ± 0.2 mm
	6.2	Primary Fiducial Location	See SEMI M1
	6.3	Primary Fiducial Dimension	See SEMI M1
	6.7	Thickness	> 650 µm (See NOTE 2.)
	6.8	Thickness Variation (TTV)	10 µm max.
	6.9	Wafer Surface Orientation	1-0-0 + 1°
	6.11	Warp	User specified
	6.12	Sori	Unspecified
	6.14	Flatness/Site	Unspecified
	7.0	**Front Surface Chemistry**	
	7.1	Surface Metal Contamination	
		Sodium	δ 1 x 10^{11}/cm^2
		Aluminum	δ 1 x 10^{11}/cm^2
		Chromium	δ 1 x 10^{11}/cm^2
		Iron	δ 1 x 10^{11}/cm^2
		Nickel	δ 1 x 10^{11}/cm^2
		Copper	δ 1 x 10^{11}/cm^2
		Zinc	δ 1 x 10^{11}/cm^2
		Calcium	δ 1 x 10^{11}/cm^2
	8.0	**Front Surface Criteria**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	< 0.10 × Diameter
	8.2	Pits	None
	8.3	Haze	None
	8.4	Localized Light Scatterers	< 0.20/cm^2 @ $\geq$ 0.20 um
	8.5	Contamination/Area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Crack, crows feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**Back Surface Criteria**	
	9.1	Edge Chips	None
	9.6	Roughness	Unspecified
	9.7	Brightness (Gloss)	Unspecified

EDI Code		Item	P- Reclaim Wafer
	TBD	Localized Light Scatterers	Unspecified
	TBD	Scratches (macro)-total length	< 50 mm
	TBD	Scratches (micro)-total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge Condition	Polished

NOTE 1: For edge exclusion, laser-marked areas are to be given special consideration.
NOTE 2: Minimum thickness may be limited by equipment constraints.

Table 10 Guide For The Specification Of 0.13 µm Design Rule 300 mm Polished Reclaimed Wafers

EDI Code		*ITEM*	*P⁻ Reclaim Wafer*
	1.0	**GENERAL CHARACTERISTICS**	
	1.1	Growth Method	CZ or MCZ
	1.2	Crystal Orientation	{100}
	1.3	Conductivity Type	*p*
	1.4	Dopant	Boron
	1.5	Nominal Edge Exclusion	3 mm (See NOTE 1.)
	2.0	**ELECTRICAL CHARACTERISTICS**	
	2.1	Resistivity	0.5–50.0 Ω•cm
	2.2	Radial Resistivity Variation	Unspecified
	2.3	Resistivity Striations	Unspecified
	2.4	Minority Carrier Recombination Lifetime	Unspecified
	3.0	**CHEMICAL CHARACTERISTICS**	
	3.1.1	Oxygen Concentration	Unspecified
	3.2	Radial Oxygen Variation	Unspecified
	3.3	Carbon Concentration	Unspecified
	4.0	**STRUCTURAL CHARACTERISTICS**	
	4.2	Slip	none
	4.3	Lineage	none
	4.4	Twins	none
	4.5	Swirl	Unspecified
	4.6	Shallow pits	Unspecified
	4.7	Oxidation-Induced Stacking Faults (OISF)	Unspecified
	4.8	Oxide Precipitates	Unspecified
	5.0	**WAFER PREPARATION CHARACTERISTICS**	
	5.1	Wafer ID Marking	User specified
	5.2	Front Surface Thin Films	None
	5.3	Denuded Zone	None
	5.4	Extrinsic Gettering	None
	5.5	Backseal	None
	6.0	**MECHANICAL CHARACTERISTICS**	
	6.1	Diameter	300 ± 0.2 mm
	6.2	Primary Fiducial Location	See SEMI M1.
	6.3	Primary Fiducial Dimension	See SEMI M1.
	6.7	Thickness	> 650 µm (See NOTE 2.)
	6.8	Thickness Variation (TTV)	25 µm max.

EDI Code		*ITEM*	*P⁻ Reclaim Wafer*
	6.9	Wafer Surface Orientation	{100} ± 1°
	6.11	Warp	User specified
	6.12	Sori	Unspecified
	6.14	Flatness/Site	(See NOTE 3.)
	7.0	**FRONT SURFACE CHEMISTRY**	
	7.1	Surface Metal Contamination	
		Sodium	$\leq 1 \times 10^{11}/cm^2$
		Aluminum	$\leq 1.8 \times 10^{11}/cm^2$
		Chromium	$\leq 1 \times 10^{11}/cm^2$
		Iron	$\leq 1 \times 10^{11}/cm^2$
		Nickel	$\leq 1 \times 10^{11}/cm^2$
		Copper	$\leq 1 \times 10^{11}/cm^2$
		Zinc	$\leq 1 \times 10^{11}/cm^2$
		Calcium	$\leq 1 \times 10^{11}/cm^2$
	8.0	**FRONT SURFACE CRITERIA**	
	8.1A	Scratches (macro) – total length	None
	8.1B	Scratches (micro) – total length	< 0.50 × Diameter
	8.2	Pits	None
	8.3	Haze	None
	8.4	Localized Light Scatterers	(See NOTE 4.)
	8.5	Contamination/Area	None
	8.6	Edge Chips	None
	8.7	Edge Cracks	None
	8.8	Crack, crows feet	None
	8.9	Craters	None
	8.10	Dimples	None
	8.11	Grooves	None
	8.12	Mounds	None
	8.13	Orange Peel	None
	8.14	Saw Marks	None
	9.0	**BACK SURFACE CRITERIA**	
	9.1	Edge Chips	none
	9.6	Roughness	Unspecified
	9.7	Brightness (Gloss)	Unspecified
	TBD	Localized Light Scatterers	Unspecified
	TBD	Scratches (macro)-total length	< 150 mm
	TBD	Scratches (micro)-total length	Unspecified
	10.0	**Other Characteristics**	
	TBD	Edge Condition	Polished
	TBD	Packaging	See SEMI M31 and M45.

NOTE 1: For edge exclusion, laser-marked areas are to be given special consideration.
NOTE 2: Minimum thickness may be limited by equipment constraints.
NOTE 3: To be negotiated between user/supplier.
NOTE 4: The nµmber of Localized Light Scatterers (LLS) per wafer is to be determined by user/supplier agreement; the LLS size in PSL equivalents is specified as ≥ 0.16 µm with a goal of decreasing to 0.12 µm. A recommended value is ≤ 200 @ ≥ 0.16 µm (interpreted as particles + COP's) or ≤ 50 @ ≥ 0.16 µm (for particles only – which may be distinguished from COP's by metrology with user/supplier agreement on the tool and methodology.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI M39-0999
TEST METHOD FOR MEASURING RESISTIVITY AND HALL COEFFICIENT AND DETERMINING HALL MOBILITY IN SEMI-INSULATING GaAs SINGLE CRYSTALS

This test method was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Committee. Current edition approved by the Japanese Regional Standards Committee on June 1, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 The purpose of this document is to specify a method to measure resistivity and determine Hall mobility of semi-insulating GaAs single crystals by the Van der Pauw method. Especially, this document specifies a simple and practical method for commercial semi-insulating GaAs single crystals.

2 Scope

2.1 This test method covers a procedure for measuring the resistivity and determining Hall mobility of semi-insulating GaAs single crystals by the van der Pauw method. This method requires a singly connected test specimen without any isolated holes, of homogeneous thickness and with a square shape. In this method, contacts must be sufficiently small and located at the corners of the specimen.

2.2 This standard may involve hazardous materials, operation, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ASTM Standards*

F 76-73 — Standard Method for Measuring Hall Mobility and Hall Coefficient in Extrinsic Semiconductor Single Crystals

F 76-86 — Standard Test Methods for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility in Single-Crystal Semiconductors

F 43-93 — Standard Test Methods for Resistivity of Semiconductor Materials

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

NOTE 2: Many of the terms associated with this test method can be found in ASTM Definitions F 76-86.

hall mobility — the ratio of the magnitude of the Hall coefficient to the resistivity; it is readily interpreted only in a system with carriers of one charge type.

resistivity — the ratio of the potential gradient parallel to the current in the material to the current density. For the purpose of this method, the resistivity shall always be determined for the case of zero magnetic flux.

5 Summary of Test Method

5.1 In this method, the thickness of a specimen cut from a semi-insulating GaAs single crystal is measured.

5.2 Ohmic contacts are formed on the specimen.

5.3 The temperature near the specimen is measured.

5.4 Hall-effect measurement is performed and data are taken.

5.5 From the measured data, the resistivity and Hall mobility are calculated and corrected for temperature.

6 Interferences

6.1 Light could cause an error due to photo-conductivity, so the specimen must be placed in a dark environment.

6.2 Temperature fluctuation gives significant error. Specimen itself could be at higher temperature than the environment if one does not take sufficient time after soldering the contacts.

6.3 The current-voltage conditions must be ohmic.

6.4 The damaged layer due to the sawing must be removed by etching the specimen, for example by using mixture of sulfuric acid (H_2SO_4), hydrogen peroxide (H_2O_2) and water (H_2SO_4:H_2O_2:H_2O = 3:1:1).

7 Apparatus

7.1 *Measurement of Specimen Thickness* — Dial gauge, micrometer, or electronic thickness gauge capable of measuring the specimen thickness within ± 1% must be used.

7.2 *Magnet* — A calibrated magnet capable of providing a magnetic flux density uniform within ± 1% over the area in which the test specimen is to be located. Flux densities must be between 3,000–10,000 gauss (0.3T–1.0T).

7.3 *Instrumentation*

7.3.1 *Current Source* — Capable of maintaining current through the specimen constant to ± 1% during the measurement. The current source is accurate to ± 1% on all ranges used in the measurement.

7.3.2 *Electrometer or Voltmeter* — With which voltage measurements can be made to an accuracy of ± 1%. The input resistance of the electrometer (or voltmeter) must be greater than 1E13 Ω. In addition to the Electrometer, the input resistance greater than 1E13 Ω must be kept in the Hall measurement system.

7.4 *Specimen Holder*

7.4.1 *Container* — Used to hold the specimen, to isolate it from surroundings and shield it from light.

7.4.2 *Thermometer* — Located in close proximity to the test specimen and associated instruments for monitoring temperature to an accuracy of ± 0.1°C during the measurement. This may include, for example, a thermocouple.

8 Reagents and Materials

8.1 *Purity of Reagents* — All chemicals for which such specifications exist shall conform to SEMI C1.

8.2 *Purity of Water* — When water is used, it is either distilled water or deionized water having a resistivity greater than 2MΩcm at 25°C as determined by the Non-Referee Test of Test Methods D 1125.

9 Test Specimen Preparation

9.1 Regardless of the specimen preparation process used, high-purity reagents and water are required.

9.2 *Material* — The test specimen is prepared from a sliced wafer of a GaAs single crystal.

9.3 *Specimen Cutting*

9.3.1 Cut wafers which have a thickness ranging from 0.3 to 1.0 mm from a GaAs single crystal.

9.3.2 Clean and etch them, for example by a sulfuric acid/peroxide solution (H_2SO_4:H_2O_2:H_2O = 3:1:1), in order to remove surface damage and to obtain smoother surfaces. Polishing can be used instead of etching.

9.3.3 Cleave or dice the test specimen into a square shape with each side length from 3 mm to 10 mm. The thickness variation over the specimen should be in ± 1%.

9.4 *Contact Formation*

9.4.1 Ohmic contact materials can be In, AuGe/Au or AuGe/Ni.

9.4.2 Place the contacts on four corners of the specimen.

9.4.3 Maintain the contact dimensions as small as possible relative to the peripheral length of the specimen. Recommended dimension of the contact is not greater than 1/10 of the side length of the specimen.

10 Measurement Procedure

10.1 *Thickness Measurement* — Measure the specimen thickness, t[cm] with a precision of ± 1%.

10.2 *Contact Evaluation* — Verify that all combinations of contact pairs in both polarities have linear current-voltage characteristics, without noticeable curvature, about the actual value of current to be used and at the measurement temperature.

10.3 *Specimen Placement* — Place the clean and contacted specimen in its container. If a permanent magnet is used to provide the magnetic flux, keep the magnet and the specimen separate during the measurement of resistivity. If an electromagnet is used, be certain that the residual flux density is small enough not to affect the resistivity measurement.

10.4 *Resistivity Measurement (see Figure 1)* — Measure the temperature, T_1, of the specimen. Set the current magnitude, I, to the desired value in a linear region. Measure the voltages V_1 at I_1 and V_2 at I_2. T_1 shall be 25 ± 5°C and the fluctuation of T_1 shall be maintained to ± 1°C during the resistivity measurement.

10.5 *Hall Mobility Measurement (see Figure 2)*

10.5.1 Position the specimen between the magnet-pole pieces so that the magnetic flux is perpendicular to the two flat faces of the specimen.

10.5.2 Measure the temperature, T_2, of the specimen. Set the current magnitude, I, to the desired value. Measure the voltage V_3 with the magnetic flux and V_4 without the magnetic flux.

10.5.3 T_2 shall be 25 ± 5°C and the fluctuation of T_2 shall be maintained to ± 1°C during Hall mobility measurement.

11 Calculations

11.1 *Resistivity*

$\rho = (\pi \times t/2 \ln 2) \times (R_1 + R_2) \times f(R_1/R_2)$ [Ω·cm]

where:

t is the specimen thickness,

R_1 and R_2 are the equivalent resistances

for two opposite sides as follows:

$R_1 = V_1/I_1$

$R_2 = V_2/I_2$

$f(R_1/R_2)$ is the correction factor for specimen shape.

In the case of $R_1/R_2 < 10$,

$f(R_1/R_2) = 1 - 0.34657A - 0.09236A^2$

where: $A = [(R_1/R_2 - 1)/(R_1/R_2 + 1)]^2$

11.2 *Hall Mobility*

$\mu = (t/B) \times R_3/\rho$ [cm^2 / V·s]

where:

B is the magnetic flux density,

$R_3 = V_3 - V_4$ / I

where:

V_3 is the voltage when the current is I under magnetic flux

V_4 is the voltage when the current is I without magnetic flux.

11.3 *Temperature Conversion*

11.3.1 *Resistivity*

$\rho_T = \rho_{T1} \cdot \exp[-Ea/k \cdot (1/T_1 - 1/T)]$

where:

Ea is the activation energy (= 0.75eV)

k is the Boltzman constant (= 8.61E – 5 eV/K)

ρ_T is the resistivity at T(K)

11.3.2 *Hall Mobility*

$\mu_T = \mu_{T2}(T/T_2)^{-3/2}$

where: μ_T is the Hall mobility at T(K)

12 Report

12.1 The following information shall be included in the report for referee and research measurement:

12.1.1 Identification of test specimen,

12.1.2 Test temperature,

12.1.3 Specimen shape used, orientation, and corresponding dimensions,

12.1.4 Magnitude of magnetic-flux density, and

12.1.5 Calculated resistivity and Hall mobility.

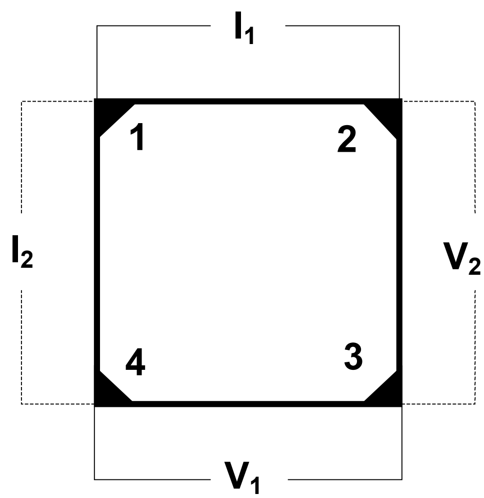

Figure 1
Block Diagram of Resistivity Measurement

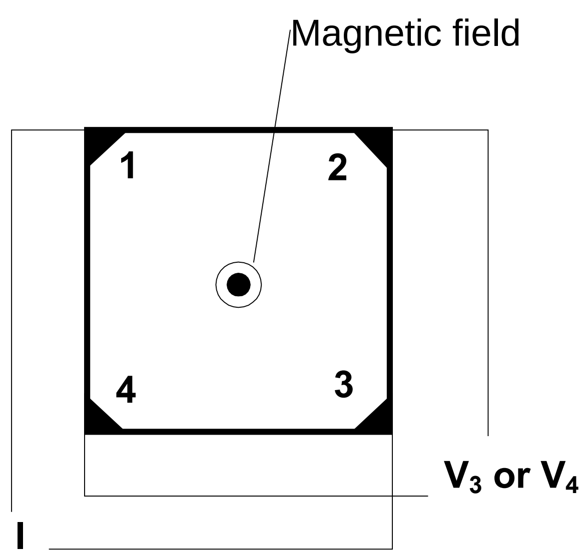

Figure 2
Block Diagram of Hall Mobility Measurement

SEMI M40-0200
GUIDE FOR MEASUREMENT OF SURFACE ROUGHNESS OF PLANAR SURFACES ON SILICON WAFER

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org February 2000; to be published February 2000.

1 Purpose

1.1 This guide provides procedures for specifying the measurements to be used in characterizing and reporting roughness of the planar surfaces of silicon wafers. It may also be applicable to other types of planar wafer materials.

1.2 This guide provides nomenclature and procedures for roughness determination that employ three key methodologies:

1.2.1 Standardized scan site patterns,

1.2.2 Roughness abbreviations, and

1.2.3 Reference test methodologies with respect to identifying specific roughness measurements.

2 Scope

2.1 This guide incorporates the following methodologies:

2.1.1 Standardized scan patterns for both local and full-area surface characterization,

2.1.2 A set of roughness abbreviations that describe measurement conditions in a short-hand code, and

2.1.3 Reference test methodologies for three generic types of roughness measuring instruments. These general categories may include, but are not limited to:

- Profilometers — AFM and other scanning probe microscopes; optical profilometers; high-resolution mechanical stylus systems,
- Interferometers — interference microscopes, and
- Scatterometers — Total integrating scatterometers (TIS), angle-resolved light scatterometers (ARLS), scanning surface inspection systems (SSIS).

2.2 Procedures to obtain a representative value of roughness for a surface are specified.

2.3 Roughness nomenclature is intended to remove ambiguities with respect to identifying the roughness measurements used and the results achieved.

2.4 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This guide does not apply to measurements in the edge region of wafers.

3.2 This guide does not apply to spatial wavelengths ≤ 10 nm.

3.3 This guide is not intended to define specific roughness parameters; these can be found in other documents.

3.4 The bandwidth of the measurement tool and the bandwidth used can severely influence the result of roughness measurements.

3.4.1 Differences in either long or short bandwidths used between two instruments can produce significantly different results.

3.4.2 The codes listed in Table 1 of this guide do not identify instrument transfer functions.

3.5 The presence of films may affect light scattering measurements.

4 Discussion

4.1 Roughness of silicon wafer surfaces is becoming frequently specified for bare silicon wafers (cf. the SIA International Technology Roadmap for Semiconductors). These specifications refer to the roughness of both the final polished front and the back surfaces of a wafer. Various techniques are currently used to measure the surface roughness of silicon wafers. These techniques include AFM scanning probes, mechanical and optical profiling, interferometric microscopes, and light (electromagnetic radiation) scattering. Mechanical profiling techniques are widely used in other industries and are well standardized. Profiling techniques are generally limited to line scans and therefore provide information of only a very small part of a surface. Interferometric techniques for roughness measurements are similarly limited, whereas light scattering techniques can scan the entire wafer surface.

4.2 Historically a variety of roughness parameters for profiling techniques have evolved and have been standardized, including rms roughness (R_q) and average roughness (R_a). Profiling instruments measure the surface topography and derive roughness statistics, such as R_q, from a series of height data. Light scattering techniques measure R_q from the angular dependence of scattering; some light scattering systems derive other parameters through interpretation and estimation.

4.3 A roughness value representative of an entire wafer surface, or a large portion of the surface, cannot be based on data obtained at a single point. Yet, specifications often describe a single value for a wafer. Therefore, this guideline suggests and defines standardized patterns of scan sites that can be described and used unambiguously. A model describing the relationship between several types of roughness variation, scan patterns, and reported results is included in the attached Related Information to assist users in specifying and interpreting these variables.

4.4 A common feature of all roughness measurements is their dependence on the bandwidth and transfer function of the tool used. In addition, high or low spatial frequency software filters are common and affect reported results. Widely different numbers can be reported for the same surface by two measurement instruments. This guideline includes suggestions on specifying and reporting the instrument bandwidth and transfer function.

5 Referenced Standards

5.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M20 — Specification for Establishing a Wafer Coordinate System

5.2 *ASME Standard* [1]

ASME B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

5.3 *ASTM Standards* [2]

E 1392 — Practice for Angle Resolved Optical Scatter Measurements on Specular or Diffuse Surfaces

F 1048 — Test Method for Measuring the Effective Surface Roughness of Optical Components by Total Integrated Scattering

F 1620 — Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Surfaces

F 1811 — Estimating the Power Spectral Density Function and Related Finish Parameters from Surface Profile Data

5.4 *DIN Standards* [3]

DIN 4760 — Form Deviation, Waviness, Surface Roughness; System of Order, Terms and Definitions

DIN 4768 — Determination of Values of Surface Roughness Parameters Ra, Rz, Rmax by Means of Electrical Contact (Stylus) Instruments; Terminology, Measuring Conditions

DIN 4777 — Metrology of Surfaces; Profile Filters for Electrical Contact Stylus Instruments; Phase-Corrected Filters

5.5 *ISO Standards* [4]

ISO 468 — Surface Roughness – Parameters, Their Values and General Rules for Specifying Requirements

ISO 1879 — Instrument for the Measurement of Surface Roughness by the Profile Method - Vocabulary

ISO 1880 — Instruments for the Measurement of Surface Roughness by the Profile Method - Contact (Stylus) Instruments of Progressive Profile Transformation - Profile Recording Instruments

ISO 3274 — Instruments for the Measurement of Surface Roughness by the Profile Method – Contact (Stylus) Instrument of Consecutive Profile Transformation – Contact Profile Meters, System M

ISO 4287/1 — Surface roughness – Terminology – Part 1: surface and its parameters

ISO 4288 — Rules and Procedures for the Measurement of Surface Roughness Using Stylus Instruments

5.6 *JIS Standards* [5]

JIS B 0601 — Surface Roughness - Definitions And Designation

JIS B 0652 — Instruments For The Measurement Of Surface Roughness By The Interferometric Method

JIS B 0659 — Roughness Comparison Specimens

1 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

3 Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

4 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

5 Japanese Standards Association, 1-24, Akasaka, 4-Chome, Minato-ku, Tokyo 107 Japan

5.7 *Other Documents*

International Technology Roadmap for Semiconductors[6]

Optical Scattering in the Optics, Semiconductor, and Computer Disk Industries, Second Edition 1995, J C Stover, Editor[7]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

6 Terminology

6.1 *autocorrelation function* — the Fourier transform of the Power Spectral Density function. It expresses the similarity between a surface profile and the same profile that is slipped, or moved laterally, with respect to itself.

6.2 *autocorrelation length* — the lateral slip required to reduce the Autocorrelation function to a value equal to e-1 times its zero slip value. Sometimes 10% or even 0 value definitions are used instead of e-1.

6.3 *average roughness* (R_a) — the average of the surface profile height deviations Z(x) from the mean line taken within the evaluation length (ASME B46.1).

6.4 *bi-directional reflectance distribution function, BRDF* — a description of the distribution of light scattered by a surface, it is the differential radiance normalized by the differential irradiance, and is approximated by the scattered power per unit projected solid angle divided by the incident power (Stover).

6.5 *fixed quality area (FQA)* — the central area of a wafer surface, defined by a nominal edge exclusion, *X*, over which the specified values of a parameter apply (SEMI M1). See also the discussion immediately following this definition in SEMI M1.

6.6 *haze* — non-localized light scattering resulting from surface topography (microroughness) or from dense concentrations of surface or near-surface imperfections (SEMI M1).

DISCUSSION — Haze due to the existence of a collection of imperfections is a mass effect; individual imperfections of the type which result in haze cannot be readily distinguished by the eye or other optical detection systems without magnification. In a particle counter (SSIS), haze results in a background signal and laser light-scattering events together comprise the signal due to light-scattering from a wafer surface. (SEMI M1). It is the total scattered optical flux collected by an optical system normalized by the incident flux.

NOTE 2: Different SSIS instrument types may give significantly different haze values on a given sample.

6.7 *illumination source incidence angle* — the angle of the incoming beam, measured from surface normal.

6.8 *kurtosis (Rku)* — a measure of the sharpness of the histogram of surface profile height deviations *Z(x)* from the mean line within the evaluation length. A complete random surface will have a Gaussian histogram and *Rku* = 3 (ASME B46.1).

6.9 *laser light-scattering event* — a signal pulse that exceeds a preset threshold, generated by the interaction of a laser beam with a discrete scatterer at a wafer surface as sensed by a detector; see also *haze* (SEMI M1). See also the discussion that follows this definition in SEMI M1.

6.10 *lay* – the predominant direction of the surface pattern, ordinarily determined by the production method used (ASME B46.1).

6.11 *microroughness* — surface roughness components with spacing between irregularities (spatial wavelength) less than about 100 µm (SEMI M1).

6.12 *Nyquist Criterion* — the shortest spatial wavelength detected. It is twice the sample spacing.

6.13 *one-dimensional grating equation* — in its most common form, it is an expression that gives the positions of diffracted orders from a one-dimensional sinusoidal grating (Stover).

6.14 *peak to valley* (R_t) — the highest to lowest value of the surface profile height deviations *Z(x)* from the mean line taken within the evaluation Length *L* (ASME B46.1).

6.15 *power spectral density (PSD) function* — a surface characterization function that is proportional to the square of the modulus of the Fourier transform of the surface and may be considered as a roughness power per unit of spatial frequency (ASTM F 1811).

6.16 *Rayleigh Criterion (of resolving power)* — a condition for distinguishing a pair of diffraction patterns whereby the maximum of one pattern overlaps with the minimum of the other.

DISCUSSION — When a lens is free from aberrations, the images of point objects appear as diffraction patterns. When the principle maximum of one pattern strikes the first minimum of another, the images are described as being resolved. With respect to circular optics, this criterion applies when the distance between resolvable point objects, viewed from the objective lens of the instrument, is

6 Semiconductor Industry Association (SIA), 181 Metro Drive, Suite 450, San Jose, CA

7 SPIE, P.O. Box 10, Bellingham, WA 98227-0010

$$\frac{0.61\lambda}{NA}$$

where NA is the numerical aperture of the objective lens and λ is the illumination wavelength.[8]

6.17 *rms area microroughness* (R_qA) — the root mean square of the topographic deviations of a surface $Z(x,y)$ from the mean surface taken within the evaluation Area ($=L_xL_y$) (SEMI M1). See also the extended discussion that follows this definition in SEMI M1.

6.18 *rms microroughness* (R_q) — the root mean square of the surface profile height deviations $Z(x)$ from the mean line taken within the evaluation Length L (SEMI M1). See also the extended discussion that follows this definition in SEMI M1.

6.19 *rms slope (mq)* — the root-mean-square value of the rate of change of profile departures within the evaluation length (Adapted from ISO 4271/1).

6.20 *roughness* — the more narrowly spaced components of surface texture (SEMI M1). Compare with *waviness*.

6.21 *skewness (Rsk)* — a measure of the asymmetry of the surface topographic deviations of a surface $Z(x,y)$ about the mean line. A perfect random surface will have $Rsk = 0$ (*ASME B46.1*).

6.22 *spatial bandwidth* — the range of wavelengths in which a given instrument operates (Stover).

6.23 *spatial frequency* — spatial frequency ($F_{spatial}$) is the inverse of spatial wavelength ($\lambda_{spatial}$).

6.24 *spatial wavelength* — the spacing between adjacent peaks of a purely sinusoidal profile (*ASME B46.1*).

6.25 *ten point roughness height* (R_z) — the average value of the absolute values of the heights of the five highest profile peaks and the depths of the five lowest profile valleys from the mean line taken within the evaluation length. (Adapted from ISO 4281/1.)

6.26 *transfer function* — the response of an instrument over all measured spatial wavelengths.

DISCUSSION — A perfect instrument would have a 100% response over all spatial wavelengths. Every measuring instrument will have some deviation from a perfect response especially at the low spatial frequency limit (the traversing length) and at the high spatial frequency limit. The power spectrum can be used to examine this limit near the high spatial frequency response. Contact the instrument supplier for this information.

6.27 *traversing length* — the maximum distance sampled in a given direction. The maximum measurable spatial wavelength is always less then the traversing length.

6.28 *wavelength scaling* — a surface is said to wavelength scale if the scatter measurements at one wavelength may be used to predict scatter measurements at another wavelength (Stover).

6.29 *waviness* — the more widely spaced (spatial wavelength) components of surface texture (SEMI M1). Compare with *roughness*.

7 Instruments and Capabilities

7.1 *Profilometers*

7.1.1 The high spatial frequency limit of AFM, mechanical and optical profilers can be approximated by the radius of the mechanical tip or by the diameter and intensity profile of the laser spot, respectively. Their response functions are complicated, and in some cases are a combined effect of the probe and the measured surface. The high spatial frequency limit of such tools has to be set or selected reasonably removed from that limit in order to achieve reasonable, comparable, and repeatable measurements.

7.2 *Interference Microscope*

7.2.1 The high spatial frequency limit of these instruments is defined by the focusing optics or in some cases by the pixel spacing of the detector array. The high spatial frequency limit of such tools has to be set or selected reasonably removed from that limit in order to achieve reasonable, comparable, and repeatable measurements.

7.3 *Scattering Instruments*

7.3.1 A straightforward relation between scattered light intensity and roughness exists only for sufficiently smooth surfaces. The Rayleigh smooth-surface criterion, given below, is frequently used for estimating the smooth-surface limit (Stover).

$$\frac{1}{2}\left(\frac{4\pi a\cos\theta_i}{\lambda}\right)^2 << 1 \quad (1)$$

$$m << 1 \quad (2)$$

where: m = profile slope,

λ = wavelength of incident light,

a = amplitude of sample profile (half of the peak-to-valley height), and

8 Optics, Eugene Hecht, et al; 3rd edition (August 1997); Addison-Wesley Publishing Co; ISBN: 0201838877

θ_i = incidence angle of light.

7.3.2 Corresponding amplitude examples assuming a limit of 0.1 result in

$a \leq 23$ nm for $\lambda = 633$ nm, $\theta_i = 0°$ and

$a \leq 51$ nm for $\lambda = 488$ nm, $\theta_i = 70°$

7.3.3 The equivalent rms-roughness values for a sinusoidal profile and for a limit of 0.1 are

$R_q \leq 16$ nm for $\lambda = 633$ nm, $\theta_i = 0°$ and

$R_q \leq 36$ nm for $\lambda = 488$ nm, $\theta_i = 70°$

7.3.4 Light scattering tools can be applied to rougher surfaces than those surfaces identified in equations 1 and 2, but then other mathematical approaches as compared to PSD curves have to be applied to calculate roughness or slope values. Also, the slope of the PSD curve can be important in certain situations (Stover).

7.3.5 There is a basic high spatial frequency (short spatial wavelength) limit for light scattering tools which cannot be exceeded. This limit is:

a) twice the inverse wavelength, $\frac{2}{\lambda}$, of the light used in case of grazing incidence ($\theta_i = 90°$), and

b) one inverse wavelength, $\frac{1}{\lambda}$, in the case of normal incidence ($\theta_i = 0°$).

These conditions follow directly from the one-dimensional grating equation

$$f_x = \frac{\sin\theta_s \cos\phi_s - \cos\theta_i}{\lambda}$$

where: θ_s = scattering angle in the incident plane, and

ϕ_s = scattering angle out of the plane-of-incidence.

NOTE 3: f_x becomes -1 when the light is scattered back in the direction of the incoming light in the incident plane (ϕ_s = 180°).

7.4 *Total Integrating Scatterometers (TIS)*

7.4.1 These instruments most often use an incidence angle close to zero. The low and high frequency limits of the accessible spatial bandwidth are defined by the design of the optical system. An appropriately designed system may be able to access a spatial bandwidth from about 0.8 µm to about 40 µm. These systems may also be designed so that the scattered signal can be broken into low spatial frequency (near specular) and high spatial frequency (large scatter angle) bands.

7.5 *Angle-resolved Light Scatterometers (ARLS)*

7.5.1 The high spatial frequency limit of this technique is defined by incident and scattering angles and the illumination wavelength used.

7.5.2 The low spatial frequency limit is given by

- the above equations (for incidence angle),
- the diameter of the incident illumination spot at the wafer surface,
- the solid collection angle of the optical system, and
- the smallest angular distance allowed by the instrument between specular reflected light and the detector.

7.5.3 The roughness may be measured by using a fixed incidence angle and by recording the intensity of scattered light at various scattering angles in the plane of incidence. The two-dimensional PSD curve of the surface can then be calculated from the angular spectrum of the scattered light (BRDF). R_q as well as mq may be calculated from a one-dimensional or isotropic PSD curve for a given spatial bandwidth as long as the above mentioned limits are accommodated.

7.5.4 Such tools may be able to access a spatial bandwidth range of about one-half the wavelength of the illuminating light up to several hundred µm.

7.6 *Scanning Surface Inspection Systems (SSIS)*

7.6.1 SSIS measurements are integrated scatter measurements similar to those made by TIS systems, in that they gather light over large solid angles; however, there are some significant differences. In general, most SSIS avoid light collection within five to ten degrees of the specular beam, because in this region the scatter tends to be dominated by surface roughness scatter (which becomes background noise) competing with the signal from laser light scattering events. The early (older) scanners generally had one detector measuring light from a very large solid angle collector. Later systems tend to use several smaller collection angles, each with their own detector. Whatever the arrangement, each collection angle can be defined in terms of its spatial frequency band pass region, and each detector will have some background haze component (or threshold) that is caused by surface roughness. Thus, in the absence of laser light scattering events, measured haze may be converted to an rms roughness for the defined spatial frequencies. This conversion assumes that the surface meets the necessary (smooth, clean, front surface reflective) conditions required for roughness calculations, and that other noise sources, such as background electronic noise and Rayleigh air scatter, are not issues.

8 Roughness Measurements

8.1 *Parameters*

8.1.1 R_q and R_a are generally used for silicon wafer surfaces. Other roughness measurement parameters may also prove useful. This guideline does not suggest which parameters to use, rather it suggests how to incorporate any parameter into a standardized measurement specification.

8.2 *Measurement Sites*

8.2.1 Roughness can vary considerably across a wafer surface. It may also have a preferential direction or anisotropy, often called "lay" (ASME B46.1). Many measurement techniques are limited to a very small measurement area and to one or two scan directions. Therefore specific measurement patterns must be defined to obtain representative and reproducible results. These patterns should correspond to effects observed on wafers in different manufacturing steps. These processing steps can generate features on a wafer surface with rotational symmetries ranging from mirror to infinite. The wafer slicing process may produce low symmetry, while single-wafer polishing can produce high symmetry.

8.2.2 In cases where only a small number of spots is measured, the spot pattern and the scan orientation have to be identified. See Figure 1 for some patterns and orientations; others may be agreed upon between interested parties.

8.3 *Site Patterns*

8.3.1 One-point — This can be useful for rapidly reviewing results of a quantity of wafers. This is often at the wafer centerpoint.

8.3.2 In applications where only a small number of locations are to be measured, the pattern and orientation of the local scans have to be identified. Measurements are performed at locations as outlined in Figure 1. For each local scan, a representative roughness is calculated. The wafer's representative roughness is then a function of the *n* individual representative scan values. The roughness variation can be calculated by the average, the standard deviation, the maximum or the range (Max-Min) of the individual scan values. Other statistical approaches may be employed.

8.3.3 Standard patterns include:

a. 1-point Wafer center,

b. 5-point Wafer Center plus four points at 2r/3 from the wafer center, and

c. 9-point Wafer Center plus four points at 2r/5 and four at 4r/5 from the wafer center.

NOTE 4: These patterns have been shown to be useful with a range of symmetries and values. See Related Information.

8.3.4 Standard measurement orientation patterns include:

a. Type A - linear scans parallel and perpendicular to the fiducial bisector, and

b. Type B - linear scans at 45° relative to the fiducial bisector.

NOTE 5: Type A is generally used for all surfaces. Type B has been reported to be useful for some surface conditions on (111) wafers.

8.4 *Bandwidth*

8.4.1 Two issues affect the bandwidth of the roughness results. The first is the bandwidth of the roughness measuring tool, which is discussed in Section 7. The second bandwidth effect is from the analysis software, which is user selected to emphasize certain spatial frequencies. Both long and short spatial wavelength (or frequency) limits must be defined in µm (or μm^{-1}). When entering this information into a measurement, specification wavelength units shall be used. Profiling instruments should have scan length and bandwidth adjusted according to DIN 4768 and 4777 or ASME B46.1.

8.5 *Precision*

8.5.1 The precision of the roughness measuring instrument (*P*) is important. The relationship between *P* and the tolerance of the parts to be characterized (*T*) is often called the *P/T* Ratio. SEMI M27 describes how to determine and interpret the factors: "A test instrument is usually deemed to be suitable for the purpose if P/T lies below 10%. If *P/T* is greater than 30%, the test instrument is not likely to be suitable for the purpose. Cases for which *P/T* lies between 10% and 30% must be judged on an individual basis, depending on the requirements being placed on the measurement system."

9 Roughness Measurement Specifications

9.1 The process of defining the measurements to be taken involves several distinct steps. The definition sequence below represents one logical sequence; others may be equally useful. See Table 1 for measurement abbreviations.

9.2 First, select the type of instrument to be used, including ALL of the following:

9.2.1 Generic instrument type

9.2.1.1 Interferometer

a. Interference microscope

9.2.1.2 Profilometer

a. AFM

b. Other scanning probe microscopes

c. Optical profilometer

d. Mechanical stylus

9.2.1.3 Scatterometer

a. Total Integrating (TIS)

b. Angle-resolved light (ARLS)

c. Scanning Surface Inspection System (SSIS)

9.3 Next, select the roughness parameter to by calculated.

9.4 Select the measurement pattern (Figure 1):

a. Center point

b. 5-point

c. 9-point

d. Full-FQA raster scan

e. Full-FQA R-theta scan

9.5 Select the pattern orientation (Figure 1)

a. Type A

b. Type B

9.6 Select the local measuring condition

a. Point

b. Line

c. Area

9.7 Specify the measurement calculations to be reported

a. Average (A)

b. Range (R)

c. Maximum (M)

d. Standard Deviation, 1 sigma (S_{n-1})

9.8 Specify the bandwidth and scan length limits within which data is to be gathered.

9.9 Lastly, record the abbreviations describing these selections (see Appendix 1 for examples), separating adjacent abbreviations with a comma and using periods for decimal notation. This creates a seven-field abbreviation. The field sequence described above follows the order of elements in Table 1.

10 Measurement Reporting Sequence

10.1 In general, one value is reported for a wafer. Where more than one pattern is specified the calculated values are reported in the order in which they are listed in Table 1.

Table 1 Roughness Measurement Codes

Element	*Abbreviation Item*					
Instrument	A Profilometer	1 AFM	2 SPM	3 OPR	4 MPR	
	B Interferometer	1 IM				
	C Scatterometer	1 TIS	2 ARLS	3 SSIS		
Pattern (See NOTE 1.)	1 Center	5 5-point	9 9-point	R FQA/Raster scan	C FQA/Concentric R-theta scan	S FQA/Spiral R-theta scan
Pattern Orientation	A A	B B				
Local Measurement Condition	P Point	L Line	A Area			
Parameter (See NOTE 1.)	Q Rq	A Ra	Z Rz	T Rt	K Kurtosis	S Skewness
Calculation (See NOTE 1.)	A Average	R Range	M Maximum	D Std. Deviation (1 sigma $_{n-1}$)		
Bandwidth, µm	[__]/[__] (fill in blanks to two significant figures) Long wavelength (µm)/Short wavelength (µm)					

NOTE 1: If more than 1 element is specified, the representative letters are concatenated in the relevant field, in the order specified. See Appendix 1 for examples.

Table 2 Scan Pattern Locations

Location		*X, Y Coordinates (per SEMI M20)*	*Scan Direction (for line and area tools), parallel to:*
Center Point		0, 0	Y-axis
5-point Pattern			
Point #	Location		
1	Center Point	0, 0	Y-axis
2	2r/3	0, 2r/3	Y-axis
3	2r/3	-2r/3, 0	X-axis
4	2r/3	0, -2r/3	Y-axis
5	2r/3	2r/3, 0	X-axis
9-point Pattern			
1	Center	0, 0	Y-axis
2	4r/5	0, 4r/5	Y-axis
3	4r/5	-4r/5, 0	X-axis
4	4r/5	0, -4r/5	Y-axis
5	4r/5	4r/5, 0	X-axis
6	$(r\sqrt{2})/5$	$(r\sqrt{2})/5, (r\sqrt{2})/5$	Y-axis
7	$(r\sqrt{2})/5$	$-(r\sqrt{2})/5, (r\sqrt{2})/5$	X-axis
8	$(r\sqrt{2})/5$	$-(r\sqrt{2})/5, -(r\sqrt{2})/5$	Y-axis
9	$(r\sqrt{2})/5$	$(r\sqrt{2})/5, -(r\sqrt{2})/5$	X-axis
Full FQA Scan			
Raster Scan		Full FQA	X-axis
Concentric Circles or Spiral		Full FQA	R – Theta

NOTE 1: r = nominal wafer radius

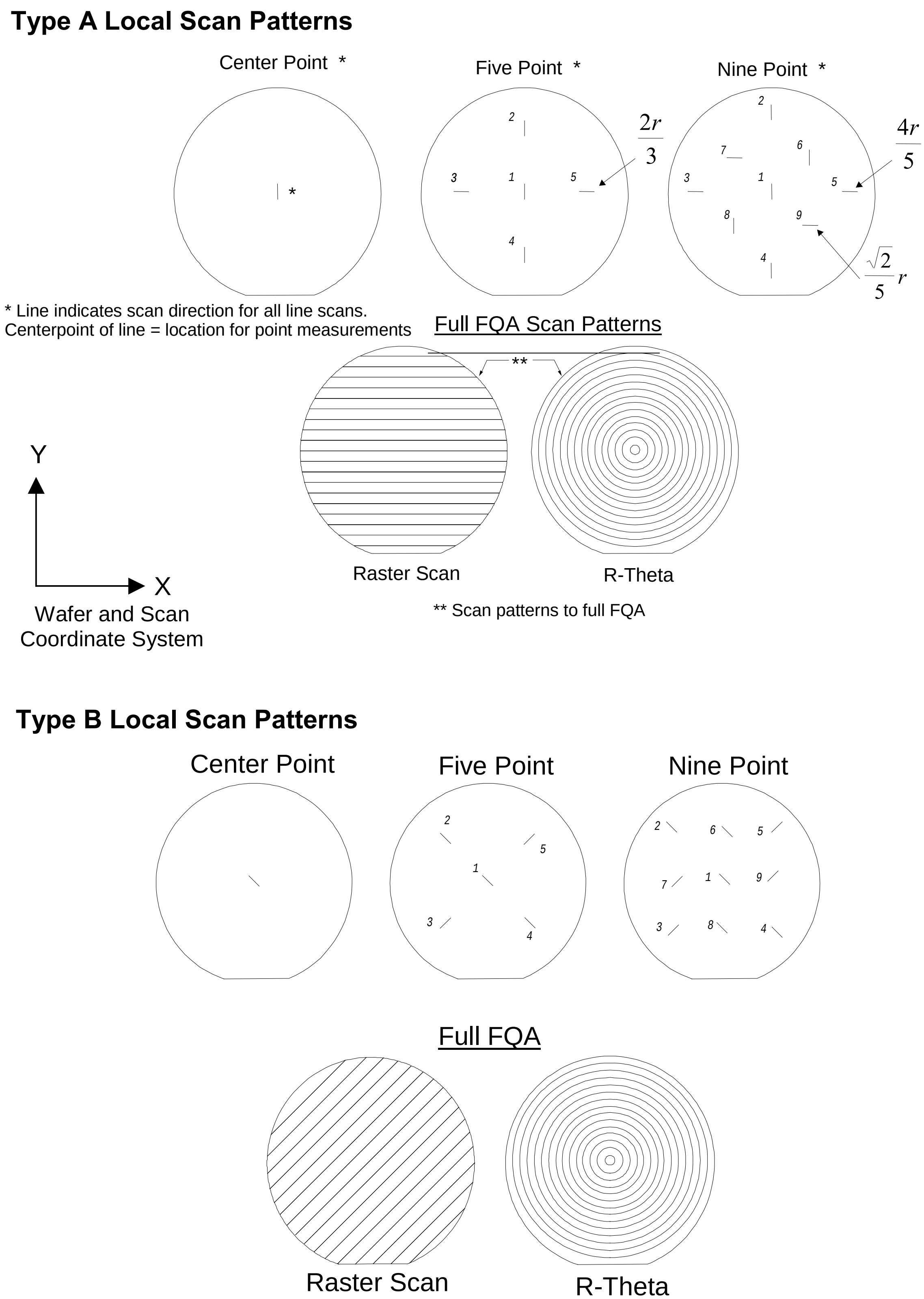

Figure 1
Patterns of Locations on a Silicon Wafer Surface for Measuring
(NOTE: R-Theta scan may be implemented in either a circular or a spiral pattern.)

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI M40 and was approved by full letter ballot procedures on December 15, 1999 by the North American Regional Standards Committee.

A1-1 Examples of Roughness Measurement Specifications and Related Output

The construction of typical measurement specifications and reported results are shown below. These could be the input to and output from a suitably equipped metrology tool, or directions for manual execution and reporting of the measurement and calculation sequence. The elements and codes are listed only in the first example. The quantitative data below is presented for illustration only, it does not represent actual instrument or sample measurements.

1. Mechanical Profiler

   The Mechanical profiler measurement was specified as MPR,5,L,A,A,A,250/10. This corresponds to measuring a 5-point pattern with a local line-scan and with pattern orientation A, and reporting Ra average value over a bandwidth from 250 to 10 µm.

Elements	Profiler, Mechanical;	5-point;	line-scan;	orient A;	Ra;	average;	250/10 µm
Codes	MPR	5	L	A	A	A	250/10
Output Example	MPR,5,L,A,A,A,250/10 = 0.53 nm						

2. Angle-Resolved Light Scattering

   The Angle-resolved light scattering instrument measurement was specified as ARLS,9,B,P,Q,A,40/2.0. This corresponds to measuring a 9-point pattern with a single spot and with pattern orientation B, reporting rms (Rq) average value over a bandwidth from 40 to 2 µm.

   Output Example ARLS,9,B,P,Q,A,40/2.0 = 0.15 nm

3. Interference Microscope

   The Interference microscope measurement was specified as IM,5,A,A,T,D,250/10. This corresponds to measuring a 5-point pattern with a local area and with pattern orientation A, reporting peak-to-valley (Rt) standard deviation over a bandwidth from 250 to 10 µm.

   Output Example IM,5,A,A,T,D,250/10 = 0.05 nm

4. Total Integrated Scattering

   The Total Integrated Scattering system (TIS) measurement was specified as TIS,S,P,A,Q,D,38/0.50. This corresponds to measuring a full FQA/spiral scan with a local spot and with pattern orientation A, reporting rms (Rq) standard deviation over a bandwidth from 38 to 0.5 µm.

   Output Example TIS,S,P,A,Q,D,38/0.50 = 0.02 nm

5. Optical Profiler

   The Optical Profiler measurement was specified as OPR,9,L,B,A,AD,80/0.50. This corresponds to measuring a 9 point pattern with a local line-scan and with pattern orientation B, reporting Ra average value and standard deviation over a bandwidth from 80 to 0.5 µm.

   Output Example OPR,9,L,B,A,AD,80/0.50 = 0.17nm (Ra average), 0.02 nm (Ra, standard deviation)

6. AFM

   The AFM measurement was specified as AFM,5,A,A,Z,A,20/0.04. This corresponds to measuring a 5 point pattern with local area and with pattern orientation A, reporting Rz average value over a bandwidth from 20 to 0.040 µm.

   Output Example AFM,5,A,A,Z,A,20/0.04 = 0.43 nm

RELATED INFORMATION 1
EXPERIMENTS AND MODELS RELATING TO ROUGHNESS DISTRIBUTION OF SILICON WAFERS

NOTE: This related information is not an official part of SEMI M40 but was approved for publication by full letter ballot procedures.

R1-1 Executive Summary

R1-1.1 Roughness is measured traditionally only on selected spots on a surface and only a few methods, such as light scattering, are practical for a complete surface scan. Therefore a systematic, standardized approach is required for defining the roughness of the entire surface of a silicon wafer. This can be done by defining one or several patterns of measurement spots which represent the entire surface so that the deviation of the average roughness and its standard deviation from the "true" values are small. The task of finding such patterns and verifying that they represent the entire surface was approached in two steps: 1. by investigating various patterns on various wafer surfaces experimentally, and 2. by simulating the roughness map of surfaces and by applying the selected patterns to them.

R1-1.2 Five different site patterns were used for the experimental investigation of silicon wafer surfaces which were final polished, stock removal polished and acid etched. The patterns consist of one, five, nine, ten and thirteen points (thirteen being the sum of a five and nine point pattern), respectively, and the measurements were performed with 10, 30, 80 and 250 µm filter lengths. Therefore 20 average roughness values and corresponding standard deviations were obtained for every wafer investigated, five for any filter length.

R1-1.3 Haze maps of these surfaces either displayed no variation, variations with an approximately rotational symmetry or a gradient across the surface, respectively. The average roughness of the surfaces measured with the various site patterns varied over four and a half orders of magnitude for the set of wafers used and the filter settings selected. The corresponding standard deviations were found to be <10% of the average roughness with the exception of four 200 mm final polished wafers where standard deviations up to 50-60% occurred. The 5-, 9- and 10-point site patterns were compared with respect to the average roughness and the corresponding standard deviation for every wafer. The variation (standard deviation) of the average roughness and the standard deviations as measured were found to be smaller than or approximately 10% in any case when normalized to the total average roughness of the corresponding wafer (average over all points of all patterns for a wafer).

R1-1.4 Roughness maps were generated for the simulation according to three different models: maps with a roughness pattern with rotational symmetry, with a linear gradient and with mirror symmetry. Two maps with a pixel size of 1 mm^2 were generated for each surface to take into account any anisotropy of the roughness, and center roughness and edge roughness, respectively, were used as free parameters for both maps. These parameters were varied between two level (0.1 and 0.2) for both maps resulting in a 2^5 factorial design of "experiment" where the symmetry was considered as 5^{th} parameter. The 1-, 5- and 9-point site patterns were applied to the various maps and the average roughness and standard deviation of roughness were calculated as well as the true values using all points of a map. Strong effects were observed for the 1-point pattern. As expected one point in the wafer center does in general not represent the average roughness of the entire surface reasonably well. The 5-point measurement provides the correct average ± 6%, the 9-point measurement is ± 2.5%. Similarly, the 5-point standard deviation is correct ± 1.6% and the 9-point one is ± 1%. Second order effects were found to be smaller than the main effects. Therefore it is concluded that the suggested five and nine point measurement patterns provide a good estimate of the roughness of an entire surface and its variations for reasonably homogeneous Si wafer surfaces.

R1-2 Introduction

R1-2.1 Roughness measurement of surfaces is performed with a variety of techniques, the most common ones being mechanical or optical profiling in real space or light scattering in reciprocal space (1,2,3). The numerical result of a roughness measurement process depends significantly on several parameters such as spatial bandwidth of the response function of the tool used including filtering, scan length, probe diameter, scanning speed etc. These parameters are not independent of each other and have been standardized only for mechanical profilers (e.g.4,5). The roughness values reported by different types of tools usually do not agree but they correlate provided their parameters were set up not too differently (6). The standardized roughness metrics such as average roughness R_a or root-mean-square roughness R_q refer mainly to line scans as performed by profiling techniques (e.g. 7). Area scans performed by profiling tools by aligning a series of line scans are usually very slow. Scanning the entire surface of a Si wafer with a profiler therefore would consume many hours, in the case of AFM (Atomic Force Microscope) many years.

R1-2.2 Techniques based on light scattering are capable of scanning the entire wafer surface quite rapidly, in about 1-2 min. Their response function, however, has a limited spatial bandwidth ranging approximately from 0.5 to 40 µm. Standards for light scattering measurements are now emerging (8,9).

R1-2.3 The obvious solution for obtaining a standardized roughness value of an entire surface is a) to define a pattern of sites where one- or two-dimensional scans are performed and b) to report the significant parameters along with the measurement (roughness) result. The second task can be solved theoretically by collecting the important parameters and by designing an appropriate abbreviation code. The first task requires experiments to collect data about the variation of roughness across a typical, real wafer surface and numerical simulations to find a set of sites the roughness of which agrees sufficiently well with the roughness of the entire surface.

R1-2.4 This appendix reports the results of corresponding roughness measurements as well as of a numerical simulation using a virtual design-of-experiment (DOX).

R1-3 Roughness Definitions

R1-3.1 A variety of definitions for roughness have been standardized by national and international institutions in the US, Japan and Europe. Corresponding standards are listed in section 5 of the main document and some selected ones again in reference 7. Most widely used are average roughness R_a and root-mean-square roughness R_q. Both refer to the average deviation of a profile from a reference line.

R1-4 Roughness Measurements

R1-4.1 *Experimental Details*

R1-4.1.1 Four groups of four wafers each were investigated to collect data about the variation of roughness across the wafer surface. The wafers were selected to represent different process steps and polishing techniques:

a) final polished wafers, 150 mm, #1-4
b) final polished wafers, 200 mm, #4-8
c) pre-polished wafers, 200 mm, #9-12
d) acid-etched wafers, 200 mm, #13-16.

R1-4.1.2 The wafers were characterized for haze with an SSIS (Censor ANS-100) and the roughness measurements were performed with an optical non-contact profiler (Chapman MP-2000+). The roughness data were taken by performing scans of length 3 mm and were evaluated using filters of 19, 30, 80 and 250 µm, respectively. The scans were performed at a variety of sites according to four different site patterns as displayed in Figure R1-1 where also the directions of the various scans are indicated:

i) center of wafer, one scan
ii) five points, center of wafer plus four points at 2/3 of radius
iii) nine points, center of wafer plus four points at 2/5 of radius plus four points at 4/5 of radius
iv) ten points, two in the center of wafer plus four points at ½ of radius and four points at radius minus 10 mm.
v) thirteen points, combination of pattern ii and iii.

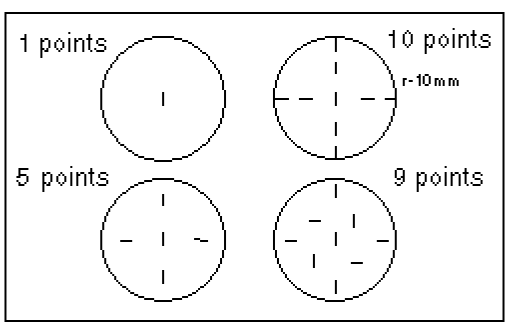

Figure R1-1
Site Patterns

R1-4.2 *Results*

R1-4.2.1 The average values of each site pattern is reported here together with the corresponding standard deviation. The average might be considered as the characteristic roughness of the entire surface whereas the standard deviation is a measure of roughness inhomogeneity. The results are summarized in Tables R1-1 and R1-3. These averages and standard deviations are called site average or site standard deviation for the respective site patterns for each wafer and each filter length applied.

R1-4.2.2 The variation in average values obtained with the different site patterns employed can be obtained by calculating 1) the average ofthe individual site averages and the standard deviation for each wafer and 2) the average of the individual site standard deviations and the corresponding standard deviation. These averages are called wafer average and wafer standard deviation, respectively. The corresponding standard deviations are called standard deviation of wafer average and standard deviation of wafer standard deviation. They are reported in Table R1-3 and Table R1-5 and in Figure R1-2 and Figure R1-3.

R1-4.2.3 The site average roughness values found range from 0.09 A for final polished wafers to 350 A for acid etched wafers for a 10 µm filter and from about 5 A to 2200 A, respectively, for a 250 µm filter. In total, a range of about four and a half orders of magnitude is covered. The site standard deviation for the different site patterns is around 10-15% of the average roughness of the wafer indicating a homogeneous roughness of the wafer surfaces. The difference between the site patterns ii, iii, iv and v for the relative site standard deviation is small, typically about 1-2 %. Exceptions are for the 200 mm final polished wafers with standard deviations of about 50-60% for the 10 µm filter.

R1-4.2.4 According to the values in Tables R1-3 & R1-5, the standard deviations of the wafer averages are less than 10 % in any case (Figure RI). The standard deviations of the various site standard deviations (Figure A3) are also smaller than or about 10 % with respect to the wafer average. This indicates that in the present case any site pattern —with the exception of the single site measurement at the wafer center—represents the “true” mean roughness of the entire surface and its standard deviation reasonably well.

Table R1-1 Results of Roughness Measurements, 10 and 30 µm Filters

	Wfr #	*Average/Standard Deviation, A 10 µm Filter*					*Average/Standard Deviation, A 30 µm Filter*				
Site pattern		i	ii	iii	iv	v	i	ii	iii	iv	v
Final polished, 150 mm	1	0.08	0.086/ 0.005	0.089/ 0.009	0.090/ 0.007	0.086/ 0.008	0.36	0.390/ 0.020	0.396/ 0.030	0.389/ 0.028	0.396/ 0.025
	2	0.09	0.090/ 0.007	0.094/ 0.010	0.090/ 0.005	0.093/ 0.009	0.43	0.408/ 0.037	0.413/ 0.035	0.410/ 0.028	0.410/ 0.035
	3	0.09	0.090/ 0.000	0.092/ 0.008	0.090/ 0.005	0.092/ 0.007	0.41	0.404/ 0.018	0.401/ 0.030	0.387/ 0.022	0.402/ 0.027
	4	0.09	0.090/ 0.000	0.097/ 0.010	0.090/ 0.004	0.095/ 0.009	0.40	0.402/ 0.015	0.420/ 0.025	0.414/ 0.016	0.415/ 0.024
Final polished, 200 mm	5	0.23	0.14/ 0.05	0.15/ 0.06	0.15/ 0.06	0.14/ 0.06	1.17	0.746/ 0.35	0.827/ 0.33	0.795/ 0.32	0.769/ 0.29
	6	0.26	0.13/ 0.07	0.15/ 0.06	0.15/ 0.06	0.14/ 0.06	1.36	0.746/ 0.35	0.846/ 0.36	0.801/ 0.33	0.768/ 0.32
	7	0.10	0.13/ 0.03	0.12/ 0.04	0.13/ 0.06	0.13/ 0.04	0.53	0.736/ 0.23	0.699/ 0.23	0.752/ 0.32	0.726/ 0.22
	8	0.09	0.12/ 0.02	0.11/ 0.02	0.12/ 0.03	0.12/ 0.02	0.50	0.648/ 0.15	0.626/ 0.14	0.636/ 0.18	0.644/ 0.13
Pre-polished, 200 mm	9	2.64	2.41/ 0.25	2.45/ 0.32	2.39/ 0.39	2.42/ 0.29	7.21	6.398/ 0.77	6.538/ 0.83	6.387/ 0.91	6.432/ 0.78
	10	2.64	2.56/ 0.36	2.69/ 0.19	2.37/ 0.41	2.64/ 0.27	6.84	6.760/ 0.95	7.147/ 0.50	6.419/ 1.00	7.022/ 0.27
	11	2.75	2.77/ 0.07	2.78/ 0.10	2.46/ 0.45	2.78/ 0.09	7.30	7.310 0.19	7.302/ 0.30	6.545/ 1.05	7.305/ 0.27

	12	2.76	2.48/ 0.32	2.50/ 0.32	2.43/ 0.42	2.47/ 0.31	7.30	6.566/ 0.91	6.521/ 0.75	6.146/ 1.05	6.478/ 0.77
Acid etched, 200 mm	13	327.2	332.0/ 6.73	335.0/ 16.25	352.6/ 12.37	334.5/ 13.76	826.2	873.5/ 43.16	869.5/ 50.22	906.5/ 28.56	874.4/ 46.13
	14	337.9	344.9/ 18.74	344.7/ 9.19	353.1/ 12.11	345.3/ 13.00	876.8	899.9/ 60.49	915.5/ 24.15	930.0/ 43.19	912.5/ 39.69
	15	339.5	340.5 8/13.4 2	335.2/ 6.07	363.4/ 7.22	337.0/ 9.58	887.7	913.7/ 68.10	879.1/ 24.64	966.1/ 30.75	891.7/ 47.65
	16	337.6	331.8/ 8.84	337.6/ 13.37	348.7/ 9.26	335.4/ 12.41	922.8	886.1/ 37.57	896.0/ 38.04	921.8/ 27.16	890.2/ 37.14

Table R1-2 Results of Roughness Measurements, 80 and 250 µm Filters

	Wfr. #	*Average/Standard Deviation, A 80 µm filter*					*Average/Standard Deviation, A 250 µm filter*				
Site pattern		i	ii	iii	iv	v	i	ii	iii	iv	v
Final polished, 150 mm	1	1.33	1.426/ 0.075	1.416/ 0.134	1.434/ 0.108	1.426/ 0.115	4.34	4.678/ 0.484	4.836/ 0.632	4.786/ 0.435	4.813/ 0.578
	2	1.57	1.470/ 0.112	1.482/ 0.147	1.444/ 0.112	1.471/ 0.133	5.34	4.944/ 0.312	5.441/ 0.613	4.592/ 0.434	5.258/ 0.591
	3	1.49	1.460/ 0.025	1.472/ 0.131	1.357/ 0.080	1.466/ 0.108	4.81	4.788/ 0.403	5.164/ 0.823	4.353/ 0.507	5.047/ 0.735
	4	1.33	1.394/ 0.089	1.446/ 0.115	1.461/ 0.069	1.435/ 0.106	4.09	4.528/ 0.619	4.814/ 0.584	4.934/ 0.503	4.760/ 0.585
Final polished, 200 mm	5	3.29	2.582/ 0.45	2.638/ 0.71	2.531/ 0.65	2.566/ 0.60	7.33	6.676/ 0.45	6.627/ 0.99	6.560/ 0.95	6.592/ 0.82
	6	3.65	2.560/ 0.65	2.724/ 0.79	2.510/ 0.67	2.590/ 0.69	7.49	6.804/ 0.57	6.834/ 0.93	6.443/ 0.92	6.772/ 0.80
	7	2.02	2.682 /0.72	2.493/ 0.56	2.641/ 0.81	2.602/ 0.61	5.45	6.914/ 1.37	6.601/ 0.81	7.057/ 1.47	6.810/ 0.97
	8	1.97	2.400/ 0.45	2.317/ 0.40	2.279/ 0.54	2.375/ 0.40	5.56	6.268/ 0.59	6.342/ 0.69	6.232/ 1.08	6.374/ 0.62
Pre-polished, 200 mm	9	11.12	9.94/ 1.06	10.19/ 1.09	10.10/ 1.27	10.02/ 1.04	15.15	14.25/ 1.31	14.50/ 1.18	14.47/	14.36/ 1.22
	10	10.13	10.54/ 1.34	11.05/ 0.78	10.27/ 1.35	10.92/ 1.03	14.40	15.44/ 2.01	15.58/ 0.77	14.59/ 1.88	15.62/ 1.28
	11	11.29	11.35/ 0.31	11.26/ 0.45	10.13/ 1.23	11.29/ 0.41	15.75	16.56/ 0.59	16.27/ 0.81	14.83/ 1.26	16.42/ 0.74
	12	10.60	10.11/ 1.10	9.86/ 0.95	9.92/ 1.12	9.90/ 0.99	14.42	14.33/ 1.31	14.10/ 1.14	14.41/ 1.26	14.17/ 1.21
Acid etched, 200 mm	13	1257.0	1404/ 140.8	1391/ 123.44	1439/ 88.10	1406/ 122.83	1789.6	2127/ 331.59	2118/ 295.83	2185/ 270.70	2147/ 291.78
	14	1421.9	1460/ 109.9	1514/ 53.27	1497/ 95.92	1501/ 78.94	2154.6	2256/ 154.21	2366/ 222.41	2322/ 216.72	2349/ 203.72
	15	1374.7	1500/ 199.2	1396/ 94.33	1549/ 95.25	1438/ 147.56	1970.4	2350/ 508.52	2071/ 257.41	2348/ 198.70	2186/ 384.36
	16	1478.4	1421/ 109.9	1450/ 108.89	1477/ 104.51	1437/ 109.71	2006.4	2075/ 186.85	2219/ 297.40	2264/ 252.44	2180/ 271.75

R1-4.2.5 The five-point site pattern appears to represent the average surface reasonably well for wafers where the roughness does not vary more than by a factor of about two across the entire surface. Patterns with a higher number of sites are recommended for problematic surfaces.

Table R1-3 Average Over Site Patterns ii, iii and iv (wafer average) and Corresponding Relative Standard Deviation for Each Wafer

	Wfr #	*Avg. of Averages, A*				*Relative Std. Dev. of Averages, %*			
Filter		10 µm	30 µm	80 µm	250 µm	10 µm	30 µm	80 µm	250 µm
Final polished, 150 mm	1	0.088	0.392	1.425	4.767	2.34	0.90	0.65	1.69
	2	0.091	0.410	1.465	4.992	2.80	0.66	1.33	8.55
	3	0.091	0.397	1.430	4.768	1.41	2.29	4.43	8.52
	4	0.092	0.412	1.434	4.759	4.17	2.22	2.45	4.38
Final polished, 200 mm	5	0.146	0.789	2.584	6.606	6.09	5.15	2.07	1.24
	6	0.145	0.798	2.598	6.694	7.79	6.25	4.32	3.25
	7	0.128	0.729	2.605	6.857	4.16	3.74	3.81	3.40
	8	0.116	0.637	2.332	6.281	3.35	1.76	2.66	0.89
Pre-polished, 200 mm	9	2.418	6.441	10.08	14.41	1.35	1.31	1.23	0.96
	10	2.541	6.775	10.59	15.21	6.30	5.37	4.18	3.54
	11	2.669	7.052	10.91	15.89	6.89	6.23	6.20	5.83
	12	2.469	6.411	9.96	14.28	1.54	3.60	1.30	1.13
Acid etched, 200 mm	13	339.87	883.15	1411.66	2143.24	3.27	2.30	1.78	1.68
	14	347.57	915.12	1490.70	2314.67	1.37	1.64	1.87	2.40
	15	346.41	919.62	1481.90	2256.45	4.32	4.77	5.29	7.13
	16	339.38	901.30	1449.77	2185.77	2.52	2.04	1.93	4.52

Table R1-4 Average Over the Standard Deviations of the Site Patterns ii, iii and iv (wafer standard deviation) and the Corresponding Relative Standard Deviations for Each Wafer Normalized to the Wafer Average

	Wfr #	*Avg. of Std. Deviations, A*				*Relative Std. Dev. of Std. Devs, %*			
Filter		10 µm	30 µm	80 µm	250 µm	10 µm	30 µm	80 µm	250 µm
Final polished, 150 mm	1	0.007	0.026	0.106	0.517	2.2	1.4	2.1	2.2
	2	0.007	0.033	0.123	0.453	2.8	1.2	1.4	3.0
	3	0.004	0.023	0.079	0.578	4.6	1.6	3.7	4.6
	4	0.005	0.019	0.091	0.569	5.5	1.4	1.6	1.3
Final polished, 200 mm	5	0.059	0.302	0.603	0.797	3.8	6.2	5.3	4.6
	6	0.065	0.347	0.703	0.807	4.0	1.8	2.9	3.1
	7	0.042	0.261	0.699	1.219	10.4	7.3	4.9	5.2
	8	0.025	0.156	0.463	0.789	4.7	4.0	3.1	4.1
Pre-polished, 200 mm	9	0.320	0.834	1.14	1.397	3.1	1.1	1.1	1.8
	10	0.321	0.816	1.17	1.553	4.4	4.0	3.2	4.5
	11	0.205	0.516	0.663	0.889	7.9	6.6	4.5	2.2
	12	0.353	0.901	1.06	1.234	2.2	2.3	0.9	0.6
Acid etched, 200 mm	13	11.78	40.65	117.5	299.4	1.4	1.3	1.9	1.4
	14	13.35	42.61	86.4	197.8	1.4	2.0	2.0	1.6
	15	8.90	41.16	129.6	321.5	1.1	2.6	4.1	7.3
	16	10.49	34.25	107.8	245.6	0.7	0.7	0.2	2.5

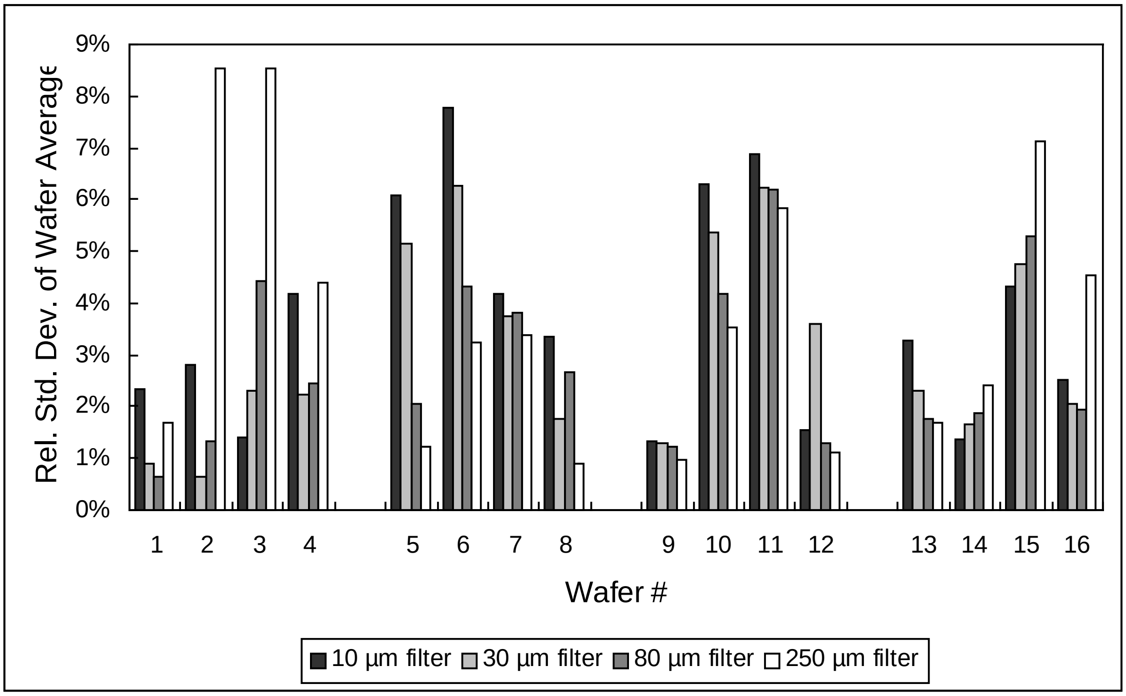

Figure R1-2
The Relative Standard Deviations of the Wafer Averages Normalized to the Wafer Averages for Site Patterns ii, iii and iv, for All Wafers Investigated and for Filter Lengths of 10, 30, 80 and 250 µm

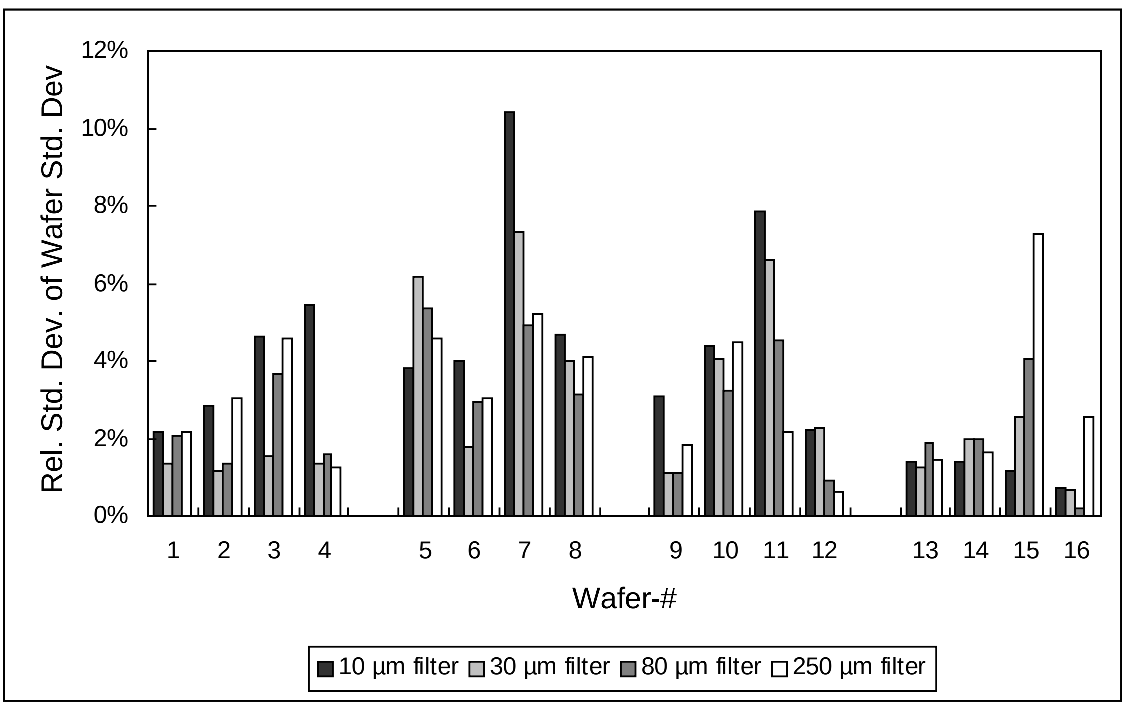

Figure R1-3
The Relative Wafer Standard Deviations of the Wafer Standard Deviations Normalized to the Wafer Averages for the Site Patterns ii, iii and iv, for All Wafers and for Filter Lengths of 10, 30, 80 and 250 µm

R1-5 Models of Roughness Distribution and their Evaluation with a Virtual Experiment of Factorial Design

R1-5.1 *Goal of the Simulation*

R1-5.1.1 Roughness is measured on the entire wafer surface only in rare cases. Therefore approximations have to be found which represent the roughness of an entire wafer surface with appropriate accuracy. Three discrete site patterns were defined in section 9 of SEMI M40, which are thought to provide such approximations. Performing many measurements using these site patterns is one approach to assess these site patterns with respect to their validity. Another approach is to simulate roughness variations across a wafer surface and apply the site patterns to them. This allows easy and systematic variations of the surface roughness properties and maps. The assessment of the results again has to be performed in a systematic way. An appropriate tool for doing this is to utilize a factorial design for the variables in the various surface models used. The goal of finding a site pattern which represents the entire surface is considered to be achieved when the variations of the variables of the different surface models result in a non-significant effect in the evaluation of the factorial design.

R1-5.2 *Simulation of Roughness Maps*

R1-5.2.1 The measurement results that are reported in section 3 provide some insight into the variation of roughness that occurs across actual, typical wafer surfaces. The variation observed on the different wafers is related to the specific polishing technique (wax mount polishing, wax free polishing) and to the polishing parameters used. Examination of haze maps reveals three basic patterns of variation:

a) a circularly symmetric haze variation
b) a haze variation approximately symmetric with respect to a diameter across the wafer
c) a linear gradient of haze from one wafer edge to the opposite one.

R1-5.2.2 The following relations were used to simulate the variation of roughness according to these three basic models a)-c) with e and c being the roughness values near the edge and at the center of a wafer, respectively:

model a: a parabolic relation
$z(x,y) = (x^2+y^2)\,(e-c)/r^2 + c$ (equ. 1)

model b: a semi-cylindrical relation
$z(x,y) = (r^2-(y \cos a - x \sin a)^2)^{1/2}\,(e-c)/r + e$

(equ. 2)

model c: a linear gradient
$z(x,y) = (y \cos a - x \sin a)\,(e-c)/r + c$ (equ. 3)

with wafer radius r and angle α corresponding to the angle between the symmetry plane and the x-direction (model b) or the direction of the gradient and the y-direction (model c).

R1-5.2.3 Using equations 1-3, roughness maps of wafer surfaces can be generated with a roughness value assigned to each site. This was performed by using MathCad® software and by assuming 200 mm wafers, the area of each being partitioned into sites of 1 mm^2 size.

R1-5.2.4 Roughness is not necessarily an isotropic property of a surface. Different roughness values are in general obtained when e.g. two scans are performed at the same spot on a wafer surface but in perpendicular directions. Therefore two maps representing the roughness anisotropy were generated in each case by assuming two sets of the parameters e and c – e1, c1, e2, and c2, per wafer surface.

R1-5.3 *Factorial Design*

R1-5.3.1 A factorial design at two levels was selected in order to compare the various wafer maps generated (10). The parameters ei and ci (i = 1,2) were used as variables and were varied between two levels, 0.1 and 0.2, in arbitrary units. In addition the patterns (models a – c) were also used as a variable and the values –1 and +1 were correspondingly assigned resulting in a 2^5 factorial design. The complete set of parameters used is displayed in Table R1-5.

Table R1-5 Complete Set of Parameters Used in the 2^5 Factorial Design

Variable	*e1*	*c1*	*e2*	*C2*	*Model*
High level	0.2	0.2	0.2	0.2	+1 (model b or c)
Low level	0.1	0.1	0.1	0.1	-1 (model a)

Table R1-6 Results of Roughness Simulation for Models a (variable = -1) and b (variable = 1)

Variable Set #	*c1*	*e1*	*c2*	*e2*	*Sym.*	*avg1*	*avg5*	*avg9*	*avgtrue*	*stdabw5*	*stdabw9*	*stdabwtrue*
1	0.1	0.1	0.1	0.1	-1	0.1	0.1	0.1	0.1	0	0	0
2	0.2	0.1	0.1	0.1	-1	0.2	0.143	0.127	0.125	0.038	0.031	0.014
3	0.1	0.2	0.1	0.1	-1	0.1	0.117	0.129	0.125	0.021	0.032	0.014
4	0.2	0.2	0.1	0.1	-1	0.2	0.16	0.156	0.15	0.049	0.05	0
5	0.1	0.1	0.2	0.1	-1	0.1	0.123	0.116	0.125	0.028	0.018	0.014
6	0.2	0.1	0.2	0.1	-1	0.2	0.165	0.143	0.15	0.017	0.02	0.029
7	0.1	0.2	0.2	0.1	-1	0.1	0.14	0.144	0.15	0.021	0.021	0
8	0.2	0.2	0.2	0.1	-1	0.2	0.183	0.171	0.175	0.021	0.032	0.014
9	0.1	0.1	0.1	0.2	-1	0.1	0.117	0.129	0.125	0.021	0.032	0.014
10	0.2	0.1	0.1	0.2	-1	0.2	0.16	0.156	0.15	0.021	0.021	0
11	0.1	0.2	0.1	0.2	-1	0.1	0.135	0.157	0.15	0.017	0.02	0.029
12	0.2	0.2	0.1	0.2	-1	0.2	0.177	0.184	0.175	0.028	0.018	0.014
13	0.1	0.1	0.2	0.2	-1	0.1	0.14	0.144	0.15	0.049	0.05	0
14	0.2	0.1	0.2	0.2	-1	0.2	0.183	0.171	0.175	0.021	0.032	0.014
15	0.1	0.2	0.2	0.2	-1	0.1	0.157	0.173	0.175	0.038	0.031	0.014
16	0.2	0.2	0.2	0.2	-1	0.2	0.2	0.2	0.2	0	0	0
17	0.1	0.1	0.1	0.1	1	0.1	0.1	0.1	0.1	0	0	0
18	0.2	0.1	0.1	0.1	1	0.2	0.158	0.153	0.142	0.047	0.048	0.009
19	0.1	0.2	0.1	0.1	1	0.1	0.102	0.102	0.108	0.003	0.003	0.009
20	0.2	0.2	0.1	0.1	1	0.2	0.16	0.156	0.15	0.049	0.05	0
21	0.1	0.1	0.2	0.1	1	0.1	0.133	0.13	0.142	0.04	0.034	0.009
22	0.2	0.1	0.2	0.1	1	0.2	0.191	0.183	0.185	0.007	0.015	0.017
23	0.1	0.2	0.2	0.1	1	0.1	0.135	0.132	0.15	0.038	0.032	0
24	0.2	0.2	0.2	0.1	1	0.2	0.193	0.185	0.192	0.009	0.016	0.009
25	0.1	0.1	0.1	0.2	1	0.1	0.107	0.114	0.108	0.009	0.016	0.009
26	0.2	0.1	0.1	0.2	1	0.2	0.165	0.168	0.15	0.038	0.032	0
27	0.1	0.2	0.1	0.2	1	0.1	0.109	0.117	0.115	0.007	0.015	0.017
28	0.2	0.2	0.1	0.2	1	0.2	0.167	0.17	0.158	0.04	0.034	0.009
29	0.1	0.1	0.2	0.2	1	0.1	0.14	0.144	0.15	0.049	0.05	0
30	0.2	0.1	0.2	0.2	1	0.2	0.198	0.198	0.192	0.003	0.003	0.009
31	0.1	0.2	0.2	0.2	1	0.1	0.142	0.147	0.158	0.047	0.048	0.009
32	0.2	0.2	0.2	0.2	1	0.2	0.2	0.2	0.2	0	0	0
	Average					0.15	0.15	0.1499	0.15	0.0241	0.0247	0.0066
	Std. Dev.					0.05	0.0335	0.0314	0.0303	0.0198	0.0179	0.0057

Table R1-7 Normalized values of Table R1-6

Variable Set #	*ravg1*	*ravg5*	*ravg9*	*rstdabw5*	*rstdabw9*
1	1.0000	1.0000	1.0000	0.0000	0.0000
2	1.6000	1.1440	1.0160	0.1920	0.1360
3	0.8000	0.9360	1.0320	0.0560	0.1440
4	1.3333	1.0667	1.0400	0.3267	0.3333
5	0.8000	0.9840	0.9280	0.1120	0.0320
6	1.3333	1.1000	0.9533	0.0800	0.0600
7	0.6667	0.9333	0.9600	0.1400	0.1400
8	1.1429	1.0457	0.9771	0.0400	0.1029
9	0.8000	0.9360	1.0320	0.0560	0.1440
10	1.3333	1.0667	1.0400	0.1400	0.1400
11	0.6667	0.9000	1.0467	0.0800	0.0600
12	1.1429	1.0114	1.0514	0.0800	0.0229
13	0.6667	0.9333	0.9600	0.3267	0.3333
14	1.1429	1.0457	0.9771	0.0400	0.1029
15	0.5714	0.8971	0.9886	0.1371	0.0971
16	1.0000	1.0000	1.0000	0.0000	0.0000
17	1.0000	1.0000	1.0000	0.0000	0.0000
18	1.4085	1.1127	1.0775	0.2676	0.2746
19	0.9259	0.9444	0.9444	0.0556	0.0556
20	1.3333	1.0667	1.0400	0.3267	0.3333
21	0.7042	0.9366	0.9155	0.2183	0.1761
22	1.0811	1.0324	0.9892	0.0541	0.0108
23	0.6667	0.9000	0.8800	0.2533	0.2133
24	1.0417	1.0052	0.9635	0.0000	0.0365
25	0.9259	0.9907	1.0556	0.0000	0.0648
26	1.3333	1.1000	1.1200	0.2533	0.2133
27	0.8696	0.9478	1.0174	0.0870	0.0174
28	1.2658	1.0570	1.0759	0.1962	0.1582
29	0.6667	0.9333	0.9600	0.3267	0.3333
30	1.0417	1.0313	1.0313	0.0313	0.0313
31	0.6329	0.8987	0.9304	0.2405	0.2468
32	1.0000	1.0000	1.0000	0.0000	0.0000
average	0.9968	0.9987	1.0001	0.1287	0.1254
standard deviation	0.2700	0.0682	0.0521	0.1106	0.1080
maximum	1.6000	1.1440	1.1200	0.3267	0.3333
minimum	0.5714	0.8971	0.8800	0.0000	0.0000

R1-5.3.2 Wafer roughness maps with 1 mm^2 pixel size were generated using all possible 32 combinations of the parameters in Table R1-5. Average roughness and standard deviation were calculated by using all pixels of a map (avgtrue, stdabwtrue) as well as by using the three discrete site patterns displayed in Figure 1 of the main part of this document (avg1, avg5, avg9, stdabw5, stdabw9). Corresponding results for comparing models a and b are displayed in Table R1-6. These values were normalized for further evaluation, the averages with respect to avgtrue (ravgi=avgi/avgtrue, i=1,5,9), the standard deviations with respect to their difference to the "true" value ((rstdabwi=stdabwi.-stdabwtrue) / stdabwtrue, i=5,9) (Table R1-7). Results for comparing models a and c are similar and are not reported here in detail.

R1-5.3.3 The averages for ravg1,5,9 over the various variable sets differ by less than 1% from unity. The corresponding standard deviations decrease from 27% to 5% going from ravg1 to ravg9, respectively, indicating — as one would expect — that ravg9 is a much more precise value for the roughness of the entire surface as compared to ravg1 or ravg5. The relative standard deviations rstdabw5,9 deviate in the average by about 12% from the true value. The corresponding standard deviations differ not much for rstdabw5 and rstdabw9.

R1-5.3.4 More detailed information is obtained when the results are evaluated according to the factorial design used. The 1st to 5th order effects of varying the variables were calculated by applying using a table of contrast coefficients /10/ to the normalized results of the simulation. The 1st order — or main — effects are the difference of the observations for both levels of one parameter and averages over all other observations. They measure the average effect of a variable over all conditions of the other variables. The 2nd order effects are a measure for the interaction of variables and are obtained by calculating one half of the difference of the average effect of variable 1 with variable 2 at level 1 and variable 1 with variable 2 at level 2. 3rd order and higher effects are not considered in the present work. They are assumed to be negligible and are used to calculate the variance of an effect (=square root of the average of the squares of 3rd to 5th order effects).

R1-5.3.5 The result of this evaluation is displayed in Table R1-8 and Table R1-9 for the main (1st order) and 2nd order effects, respectively.

Table R1-8 Average (over all sets of variables) and Main Effects of the Various Variables on the Observables (The variance as calculated from the 2nd to 5th order effects is displayed in the last column.)

	Average	*c1*	*e1*	*c2*	*e2*	*Sym.*	*Variance*
ravg1	0.9968	0.4482	-0.1111	-0.2237	-0.1111	-0.0064	4.16E-05
ravg5	0.9987	0.1134	-0.0460	-0.0377	-0.0287	-0.0027	3.69E-06
ravg9	1.0001	0.0439	-0.0067	-0.0734	0.0356	-0.0001	4.37E-06
rstdabw5	0.1287	-0.0038	-0.0049	-0.0073	-0.0080	0.0315	3.43E-04
rstdabw9	0.1254	-0.0064	-0.0057	-0.0113	-0.0052	0.0198	4.87E-04

Table R1-9 2nd Order Effects (The variance as calculated from the 2nd to 5th order effects is displayed in the last column.)

	c1/e1	*c1/c2*	*c1/e2*	*c1/sym*	*e1/c2*	*e1/e2*	*e1/sym*	*c2/e2*	*c2/sym*	*e2/sym*	*Variance*
ravg1	-0.0157	-0.0221	-0.0157	-0.0590	0.0218	0.0160	0.0579	0.0218	-0.0547	0.0579	4.16E-05
ravg5	-0.0015	-0.0079	-0.0040	-0.0067	0.0065	0.0054	0.0064	0.0039	-0.0225	0.0238	3.69E-06
ravg9	-0.0003	0.0023	-0.0057	0.0304	0.0049	-0.0015	-0.0304	-0.0005	-0.0092	0.0119	4.37E-06
rstdabw5	-0.0062	-0.1848	-0.0603	-0.0027	-0.0423	-0.0392	0.0059	0.0335	-0.0005	0.0029	3.43E-04
rstdabw9	0.0080	-0.1471	-0.0722	0.0002	-0.0247	-0.0894	0.0003	0.0518	0.0027	0.0008	4.87E-04

R1-5.3.6 The behavior of the main effects is also illustrated in Figure R1-5, where the variation of ravg1,5,9 and stdabw5,9 are plotted vs. the variables. The clear effect, on ravg1, of varying center1 between 0.1 and 0.2 is easy to understand as ravg1 consists only of one measurement point in the center of the wafer surface. Similar but less pronounced effects are observed for ravg5 and 9. Note that the opposite effect occurs for center 2 as this point is not included in calculating ravg1,5 or 9. Also note that the influence of the variables edge1 or edge2 is much less pronounced. In any case, the 5-point measurement provides the correct average ± 6%, the 9-point measurement ± 2.5%. In a similar way, the 5-point standard deviation is correct ± 1.6% and the 9-point standard deviation ± 1%.

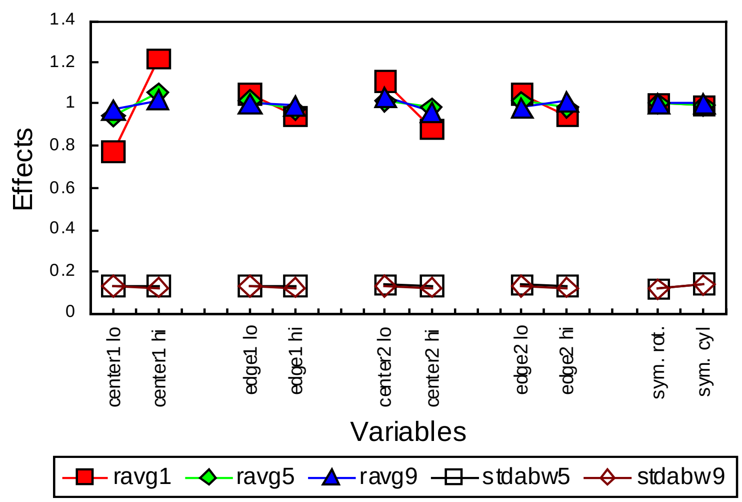

Figure R1-5
Main Effects of the 2^5 Factorial Design for Models a and b

R1-5.3.7 The significance of numbers given in Table R1-8 and Table R1-9 can be estimated only in relation to the noise or variance of the observables which is also displayed in both tables. The signal-to-noise ratio S/N is obtained by using a logarithmic measure:

$$S/N = 10 \log (\text{effect}^2/\text{variance})$$

R1-5.3.8 The corresponding S/N values for the main and for the second order effects are listed in Table R1-10 and Table R1-11.

R1-5.3.9 A linear signal-to-noise ratio of 3:1 is commonly used to distinguish significant data from insignificant data. This linear ratio corresponds to a S/N of about 10 in the present case of a logarithmic signal-to- noise ration. The S/N ratios > 10 are shaded lightly gray in Table R1-10 and Table R1-11. The variables center1,2 and edge1,2 have a significant effect on the relative averages ravg1,5,9. Mainly the interactions of the model selected with the other variables are significant for the relative averages ravg1,5,9 and the interaction of center1 and center2 for the relative standard deviations rstdabw5,9. The other cases emphasized in Table R1-11 by shading have a S/N ratio only slightly larger than 10.

Table R1-10 S/N Ratios for the Main Effects of Table R1-8

	average	*c1*	*e1*	*c2*	*e2*	*Sym*
ravg1	43.7817	36.8384	24.7251	30.8046	24.7251	-0.0364
ravg5	54.3215	35.4230	27.5959	25.8609	23.4801	2.9416
ravg9	53.5959	26.4387	10.1741	30.9124	24.6260	-26.2612
rstdabw5	16.8383	-13.6750	-11.4959	-8.0646	-7.3246	4.6154
rstdabw9	15.0934	-10.7996	-11.7656	-5.7926	-12.5745	-0.9359

Table R1-11 S/N Ratios for the 2nd Order Effects of Table R1-9

	c1/e1	*c1/c2*	*c1/e2*	*c1/sym*	*e1/c2*	*e1/e2*	*e1/sym*	*c2/e2*	*c2/sym*	*e2/sym*
ravg1	7.7045	10.7110	7.7045	19.2237	10.5897	7.8732	19.0682	10.5897	18.5684	19.0682
ravg5	-2.3106	12.2743	6.3820	10.8291	10.5529	9.0162	10.4414	6.2417	21.3820	21.8517
ravg9	-17.0034	0.7278	8.7438	23.2512	7.3954	-3.1738	23.2558	-11.9623	12.8618	15.1361
Rstdabw5	-9.5587	19.9853	10.2575	-16.7484	7.1802	6.5178	-9.8910	5.1594	-32.1153	-16.1308
Rstdabw9	-8.8505	16.4782	10.2932	-40.5530	0.9730	12.1486	-37.1733	7.4191	-18.3336	-28.6846

R1-5.3.10 The interactions are discussed for two examples, ravg9 and rstdabw5 (Table R1-12). Going from sym lo (model a, parabolic symmetry) to sym hi (model b, cylindrical symmetry) and keeping c1 fixed at the lo level decreases ravg9 from 0.993 to 0.963 whereas it increases from 1.007 to 1.037 when c1 is kept fixed at the lo level. This change in opposite directions indicate an interaction between c1 and sym. c1 and c2 interact in a similar way with respect to rstdabw5.

Table R1-12 2nd Order Effects or Interactions

C1 lo/sym hi	0.963		1.037	c1 hi/sym hi
		ravg9		
C1 lo/sym lo	0.993		1.007	c1 hi/sym lo
c1 lo/c2 hi	0.219		0.031	c1 hi/c2 hi
		stdabw5		
c1 lo/c2 lo	0.132		0.223	c1 hi/c2 lo

R1-5.4 *Summary and Conclusions*

R1-5.4.1 Three different models for surface roughness distribution (roughness maps) were investigated and three different site patterns for measuring the roughness were applied to them. The parameters of the models – roughness in the center and near the edge of the wafer – were used as variables in a factorial design and varied between two levels. Average roughness and the corresponding standard deviations calculated for the site patterns were compared with the "true" values obtained by evaluating all points of the roughness map.

R1-5.4.2 The patterns where the roughness is measured at five or nine points exhibit a standard deviation of 7 and 5 %, respectively, from the true average value for all possible combinations of the variables. The average of the standard deviations of the roughness distribution of the single variable sets differs by about 13% from the true value for the five- as well as nine-point site pattern. A standard deviation of the standard deviations of about 11% is obtained by averaging over the 32 different variables sets.

R1-5.4.3 The evaluation of the factorial design outlines that the variation of the variables c1, c2, e1, and e2 has a significant effect – with respect to "noise" – on the average roughness values but not on the corresponding standard deviations. Varying the surface model does not significantly affect the averages and standard deviations. Some second order effects or interactions are also significant but less pronounced than the main effects. A pronounced interaction of the variables c1 and c2 occurs e.g. for the five point standard deviation rstdabw5. This interaction could be reduced by introducing an additional site for measuring roughness in the center of the wafer with a direction perpendicular to the present one.

R1-5.4.4 The goal of finding a site pattern which results only in non-significant effects is not completely achieved by the five and nine point patterns utilized in the present work. However, they allow to measure the average roughness of wide variety of surface roughness distributions with a one sigma deviation of 5-7 %, or a three sigma deviation of 15-21 %. These values are certainly more than sufficient for present wafer surfaces.

R1-6 Related Documents

ASTM E 1392 — *Practice for Angle Resolved Optical Scattering Measurements on Specular or Diffuse Surfaces*

ASTM F 1048 — T*est Method for Measuring the Effective Surface Roughness of Optical Components by Total Integrated Scattering*

J.M. Bennett, L. Mattson, *Introduction to Surface Roughness and Scattering*, Optical Society of America, Washington, D.C., 1989

G.E.P. Box, W.G. Hunter, J.S. Hunter, *Statistics for Experiments, An Introduction to Design, Data Analysis, and Model Building*, John Wiley, N.Y.

ISO 1879 — *Instruments for the measurement of surface roughness by the profile method -- Vocabulary*

ISO 3274 — *Instruments for the measurement of surface roughness by the profile method – Contact (stylus) instruments of consecutive profile transformation – Contact profile meters, system M*

ISO 4287/1 — *Surface roughness – Terminology – Part 1: Surface and its parameters*

J.A. Ogilvy, *Theory of Wave Scattering from Random Rough Surfaces*, IOP Publishing, Bristol, 1991

J.C. Stover, *Optical Scattering, Measurement and Analysis*, Second Edition, McGraw-Hill, Inc., N.Y. 1995

P. Wagner, H.A. Gerber, in *Particles, Haze and Microroughness on Silicon Wafers*, SEMICON Europe 1995, W. Baylies, P. Wagner, Eds.

SEMI M41-1101
SPECIFICATION OF SILICON-ON-INSULATOR (SOI) FOR POWER DEVICE/ICs

This specification was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the Japanese Silicon Wafer Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org August 2001; to be published November 2001. Originally published June 2000; previously published July 2001.

1 Purpose

1.1 This specification covers requirements for silicon-on-insulator (SOI) for semiconductor power-device/IC manufacture. By defining inspection procedures and acceptance criteria, both users and suppliers may define product characteristics and quality requirements.

2 Scope

2.1 This specification provides requirements of SOI wafers, which are used for power devices/ICs of specific voltage applications. The voltage ranges cover low voltage (40–60V), medium voltage (150–250V) and high voltage (500–600V). The specification covers physical, electrical, and surface parameters pertinent to bonded wafers.

2.2 Included in this document is a list of goals for inspection of these wafers which need to be negotiated between the users and suppliers of bonded wafers.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specifications for Silicon Epitaxial Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

SEMI M34 — Guide for Specifying SIMOX Wafers

3.2 *ASTM Standards*[1]

F26 — Standard Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F43 — Standard Test Methods for Resistivity of Semiconductor Materials

F81 — Standard Test Method for Measuring Radial Resistivity Variation on Silicon Wafers

F84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

F110 — Standard Test Method for Thickness of Epitaxial or Diffused Layers in Silicon by the Angle Lapping and Staining Technique

F154 — Standard Practices and Nomenclature for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces

F399 — Standard Test Method for Thickness of Heteroepitaxial or Polysilicon Layers

F523 — Standard Practice for Unaided Visual Inspection of Polished Silicon Wafer Surfaces

F533 — Standard Test Method for Thickness and Thickness Variation of Silicon Wafers

F576 — Standard Test Method for Measurement of Insulator Thickness and Refractive Index on Silicon Substrates by Ellipsometry

F613 — Standard Test Method for Measuring Diameter of Semiconductor Wafers

F671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Materials

F847 — Standard Test Methods for Measuring Crystallographic Orientation of Flats on Single Crystal Silicon Wafers by X-Ray Techniques

F928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F1152 — Standard Test Method for Dimensions of Notches on Silicon Wafers

F1153 — Standard Test Method for Characterization of Metal-Oxide-Silicon (MOS) Structures by Capacitance-Voltage Measurements

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

F1188 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F1241 — Standard Terminology of Silicon Technology

F1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

F1391 — Standard Test Method for Substitutional Atomic Carbon Content of Silicon by Infrared Absorption

F1526 — Standard Test Method for Measuring Surface Metal Contamination on Silicon Wafers by Total Reflection X-Ray Fluorescence Spectroscopy

F1527 — Standard Guide for Application of Silicon Standard Reference Materials and Reference Wafers for Calibration and Control of Instruments for Measuring Resisitivity of Silicon

F1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F1535 — Standard Test Method for Carrier Recombination Lifetime in Silicon Wafers by Noncontact Measurement of Photoconductivity Decay by Microwave Reflectance

F1617 — Standard Test Method for Measuring Surface Sodium, Aluminum, Potassium, and Iron on Silicon and EPI Substrates by Secondary Ion Mass Spectroscopy

F1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at Brewster Angle

F1620 — Standard Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Wafer Surfaces

F1726 — Standard Guide for Analysis of Crystallographic Perfection of Silicon Wafers

F1727 — Detection of Oxidation Induced Defects in Polished Silicon Wafers

3.3 *ANSI Standard*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

3.4 *JEITA Standard*[3]

JEIDA 50 — Standard Specification for SOI Wafers

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 Many terms relating to silicon technology are defined in ASTM Terminology F1241, "Terminology of Silicon Technology."

4.2 Other terms are defined as follows:

4.2.1 *base silicon wafer* — the silicon wafer below the insulator layer, supporting the top silicon film.

4.2.2 *bonded wafers* — defined as two silicon wafers bonded together with an insulating layer. This insulator layer is typically thermally grown silicon-dioxide.

4.2.3 *bonding interface* — the plane where the bonding between the two wafers takes place.

4.2.4 *buried oxide layer (BOX)* — the insulator layer between the two wafers when the insulator layer is silicon-dioxide.

4.2.5 *non-SOI edge area* — an annulus between the nominal radius of the surface silicon layer and the nominal radius of the base silicon wafer (for bonded SOI wafers). The annulus which implies an area is determined by its width as one dimension. It is the difference in the nominal radius of the surface silicon layer and that of the base silicon wafer.

4.2.6 *thickness of top silicon film* — the distance between the surface of the top silicon film and the top silicon film-buried oxide interface.

4.2.7 *top silicon film* — the silicon layer on top of the insulator film in which the semiconductor active devices are fabricated.

4.2.8 *void* — the absence of a chemical bond at the bonding interface.

5 Ordering Information

5.1 Purchase orders for bonded wafers furnished to this specification shall include the following items:

5.1.1 Substrate Characteristics for the device layer (*diameter, dopant, orientation, resistivity, Oi, etc.*)

5.1.2 Substrate Characteristics for the base wafer (*diameter, thickness, dopant, orientation, resistivity, etc.*)

3 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: www.jeita.or.jp

5.1.3 Buried oxide thickness and thickness tolerances

5.1.4 Top silicon film thickness and thickness tolerances

5.1.5 Warp limits

5.1.6 Top silicon film OSF defect limits

5.1.7 Top silicon film carrier life time limits

5.1.8 Buried oxide defect limits

5.1.9 Edge profile of the top silicon film and non-SOI edge area

5.1.10 Rotation alignment between top silicon film and the base silicon

5.1.11 Position of the bonding interface

5.1.12 Methods of test and measurements (see Sections 8 and 9)

5.1.13 Lot acceptance procedures (see Section 7)

5.1.14 Certification (if required)

5.1.15 Packing and marking (see Section 10)

NOTE 2: Verification test procedures of certification of these items shall be agreed upon between the users and the supplier (see Sections 8 and 9).

6 Requirements

6.1 The complete specifications for Overall Wafer, Top Silicon Film, Buried Oxide (BOX) and Base Silicon Wafer are listed in Tables 1 to 5.

Table 1 Silicon-on-Insulator (SOI) Specifications for Low Voltage (45–60V) Power Device (1)

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Wafer(Overall)			
Diameter (mm)	125, 150, 200	F613-93	Note A
Thickness (µm)	(Value of regular silicon wafer) + (SOI thickness) + (Box thickness)	F533-96, F1530-94	Note A
Total Thickness Variation (µm)	Note C	F1530-94	Note C
LTV (µm)	Note C	F1530-94	Note C
Warp (µm)	≤ 100 (Note B, C, F)	F1390-92	Note C, or Certified by Wafer Manufactures
Non-SOI Edge Area (mm)	≤ 3 (Note C)	Optical Metrology	Note C, or Certified by Wafer Manufactures
Edge Profile/Edge Profile Surface Finish	Note C	F928-93	Note C, or Certified by Wafer Manufactures
Top Silicon Film			
Thickness (µm)	2–12	Note D (F399-88)	Note C, E, Must be measured on each wafer
Surface Orientation	Note C	X-ray Diffraction (F26-87a)	Note C, or Certified by Wafer Manufactures
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C, or Certified by Wafer Manufactures
Conductivity Type	Note C	F42-93	Note C, or Certified by Wafer Manufactures
Oxygen Concentration (/cm^3)	Note C	F1188-93a, F1619-95	Note C, or Certified by Wafer Manufactures
Carbon Concentration (/cm^3)	Note C	F1391-93	Note C, or Certified by Wafer Manufactures
Surface Cleanliness: Metal Contamination (/cm^2)	Note A, C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note A, C
Surface Cleanliness: Particle Density (/wafer)	Note A, C	Light Scattering Tomography (F1620-96) (SEMI M34)	Note A, C

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Surface Roughness (nm)	Note A, C	AFM (SEMI M34)	Note A, C
Carrier Lifetime (μsec)	Note C	μ-PCD Method (F1535-94)	Note C
Crystalline Alignment of Top Silicon Film to Base Wafer (°)	Note C	X-ray diffraction (F847-94)	Note C
Surface Feature (Haze, Scratch, etc)	None	F154-94, F523-93, F1726-97	Must be measured on each wafer
OSF Density (/cm^2)	Note C	Optical Metrology (F1727-97)	Note C, or Certified by Wafer Manufactures
Buried Oxide (BOX)			
Thickness (μm)	0.5–2	Ellipsometry (F576-95) or Reflective Spectroscopy (SEMI M34)	Tolerance is ± 5%; Note C, or Certified by Wafer Manufactures
Location of Bonded Interface	Lower Surface (Note C)	TEM	Certified by Wafer Manufactures
Void Density (/cm^2)	None	Scanning Acoustic Tomography, Optical Defect Inspection	Note C
Oxide Defect Density (/cm^2)	Note C	I-V on Capacitor, Cu Decoration (SEMI M34)	Note C
Dielectric Breakdown Voltage (V)	Note C	I-V on Capacitor	Note C
Interface States (/cm^2)	Note C, H	C-V Technique	Note C
Fixed Charge Density (/cm^2)	Note C, H	C-V Technique (F1153-92)	Note C
Bonding Strength (kg/cm^2)	Note C	Tensile Strength	Note C, or Certified by Wafer Manufactures
Base Silicon Wafer			
Crystalline Orientation	Note C	F26-87a	Note C
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C
Conductivity Type	Note C	F42-93	Note C
Fiducial Axis Orientation (Flat/Notch)	Note C	F671-90, F1152-93	Note C
To-be-bonded Surface Cleanliness: Metals (/cm^2)	Note C	AAS, ICP-MS, XRF (F1526-95), SIMS (F1617-98)	Note C
Back Surface Finish	Note C	Optical Metrology	Note C

Table 2 Silicon-on-Insulator (SOI) Specifications for Low Voltage (45–60V) Power Device (2)

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Wafer(Overall)			
Diameter (mm)	125, 150, 200	F613-93	Note A
Thickness (μm)	Note A	F533-96, F1530-94	Note A
Total Thickness Variation (μm)	Note C	F1530-94	Note C
LTV (μm)	Note C	F1530-94	Note C
Warp (μm)	≤ 50 (Note B, C, F)	F1390-92	Note C, or Certified by Wafer Manufactures
Non-SOI Edge Area (mm)	≤ 3 (Note C)	Optical Metrology	Note C, or Certified by Wafer Manufactures
Edge Profile / Edge Profile Surface Finish	Note C	F928-93	Note C, or Certified by Wafer Manufactures
Top Silicon Film			
Thickness (μm)	0.1–0.5	Note D	Note C, E, Must be measured on each wafer
Surface Orientation	Note C	X-ray Diffraction (F26-87a)	Note C, or Certified by Wafer Manufactures
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C, or Certified by Wafer Manufactures
Conductivity Type	Note C	F42-93	Note C, or Certified by Wafer Manufactures
Oxygen Concentration (/cm^3)	Note C	F1188-93a, F1619-95	Note C, or Certified by Wafer Manufactures
Carbon Concentration (/cm^3)	Note C	F1391-93	Note C, or Certified by Wafer Manufactures
Surface Cleanliness: Metal Contamination (/cm^2)	Note A, C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note A, C
Surface Cleanliness: Particle Density (/wafer)	Note A, C	Light Scattering Tomography (F1620-96) (SEMI M34)	Note A, C
Surface Roughness (nm)	Note A, C	AFM (SEMI M34)	Note A, C
Carrier Lifetime (μsec)	Note C	μ-PCD Method (F1535-94)	Note C
Crystalline Alignment of Top Silicon Film to Base Wafer (°)	Note C	X-ray Diffraction (F847-94)	Note C
Surface Feature (Haze, Scratch, etc)	None	F154-94, F523-93, F1726-97 (SEMI M34)	Must be measured on each wafer
Buried Oxide (BOX)			
Thickness (μm)	0.4–1.0	Ellipsometry (F576-95) or Reflective Spectroscopy (SEMI M34)	Tolerance is ± 5%; Note C, or Certified by Wafer Manufactures
Location of Bonded Interface	Lower Surface (Note C)	TEM	Certified by Wafer Manufactures
Void Density (/cm^2)	None	Scanning Acoustic Tomography, Optical Defect Inspection	Note C

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Oxide Defect Density (/cm^2)	Note C	I-V on Capacitor, Cu Decoration (SEMI M34)	Note C
Dielectric Breakdown Voltage (V)	Note C	I-V on Capacitor	Note C
Interface States (/cm^2)	Note C, H	C-V Technique	Note C
Fixed Charge Density (/cm^2)	Note C, H	C-V Technique (F1153-92)	Note C
Bonding Strength (kg/cm^2)	Note C	Tensile Strength	Note C, or Certified by Wafer Manufactures
Base Silicon Wafer			
Crystalline Orientation	Note C	F26-87a	Note C
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C
Conductivity Type	Note C	F42-93	Note C
Fiducial Axis Orientation (Flat/Notch)	Note C	F671-90, F1152-93	Note C
To-be-bonded Surface Cleanliness: Metals (/cm^2)	Note C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note C
Back Surface Finish	Note C	Optical Metrology	Note C

Table 3 Silicon-on-Insulator (SOI) Specifications for Low Voltage (45–60V) Power Device with N+ Buried layer

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Wafer(Overall)			
Diameter (mm)	125, 150, 200	F613-93	Note A
Thickness (µm)	(Value of regular silicon wafer) + (SOI thickness) + (Box thickness)	F533-96, F1530-94	Note A
Total Thickness Variation (µm)	Note C	F1530-94	Note C
LTV (µm)	Note C	F1530-94	Note C
Warp (µm)	≤ 100 (Note B, C, F)	F1390-92	Note C, or Certified by Wafer Manufactures
Non-SOI Edge Area (mm)	≤ 3 (Note C)	Optical Metrology	Note C, or Certified by Wafer Manufactures
Edge Profile/Edge Profile Surface Finish	Note C	F928-93	Note C, or Certified by Wafer Manufactures
Top Silicon Film			
Thickness (µm)	8–16	Note D (F399-88)	Note C, E, Must be measured on each wafer
Surface Orientation	Note C	X-ray Diffraction (F26-87a)	Note C, or Certified by Wafer Manufactures
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C, or Certified by Wafer Manufactures
Conductivity Type	Note C	F42-93	Note C, or Certified by Wafer Manufactures

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Oxygen Concentration (/cm^3)	Note C	F1188-93a, F1619-95	Note C, or Certified by Wafer Manufactures
Carbon Concentration (/cm^3)	Note C	F1391-93	Note C, or Certified by Wafer Manufactures
Surface Cleanliness: Metal Contamination (/cm^2)	Note A, C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note A, C
Surface Cleanliness: Particle Density (/wafer)	Note A, C	Light Scattering Tomography (F1620-96) (SEMI M34)	Note A, C
Surface Roughness (nm)	Note A, C	AFM (SEMI M34)	Note A, C
Carrier Lifetime (µsec)	Note C	µ-PCD Method (F1535-94)	Note C
Crystalline Alignment of Top Silicon Film to Base Wafer (°)	Note C	X-ray Diffraction (F847-94)	Note C
Surface Feature (Haze, Scratch, etc)	None	F154-94, F523-93, F1726-97	Must be measured on each wafer
OSF Density (/cm^2)	Note C	Optical Metrology (F1727-97)	Note C, or Certified by Wafer Manufactures
Buried Layer	Note C	F110-88	Note C
Buried Oxide (BOX)			
Thickness (µm)	0.5–2	Ellipsometry (F576-95) or Reflective Spectroscopy (SEMI M34)	Tolerance is ± 5%; Note C, or Certified by Wafer Manufactures
Location of Bonded Interface	Note C	TEM	Certified by Wafer Manufactures
Void Density (/cm^2)	None	Scanning Acoustic Tomography, Optical Defect Inspection	Note C
Oxide Defect Density (/cm^2)	Note C	I-V on Capacitor, Cu Decoration (SEMI M34)	Note C
Dielectric Breakdown Voltage (V)	Note C	I-V on Capacitor	Note C
Interface States (/cm^2)	Note C, H	C-V Technique	Note C
Fixed Charge Density (/cm^2)	Note C, H	C-V Technique (F1153-92)	Note C
Bonding Strength (kg/cm^2)	Note C	Tensile Strength	Note C, or Certified by Wafer Manufactures
Base Silicon Wafer			
Surface Orientation	Note C	F26-87a	Note C
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C
Conductivity Type	Note C	F42-93	Note C
Fiducial Axis Orientation (Flat/Notch)	Note C	F671-90, F1152-93	Note C
To-be-bonded Surface Cleanliness: Metals (/cm^2)	Note C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note C
Back Surface Finish	Note C	Optical Metrology	Note C

Table 4 Silicon-on-Insulator (SOI) Specifications for Medium Voltage (150–250V) Power Device

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Wafer(Overall)			
Diameter (mm)	125, 150, 200	F613-93	Note A
Thickness (µm)	(Value of regular silicon wafer) + (SOI thickness) + (Box thickness)	F533-96, F1530-94	Note A
Total Thickness Variation (µm)	Note C	F1530-94	Note C
LTV (µm)	Note C	F1530-94	Note C
Warp (µm)	≤ 100 (Note B, C, G)	F1390-92	Note C, or Certified by Wafer Manufactures
Non-SOI Edge Area (mm)	≤ 3 (Note C)	Optical Metrology	Note C, or Certified by Wafer Manufactures
Edge Profile/Edge Profile Surface Finish	Note C	F928-93	Note C, or Certified by Wafer Manufactures
Top Silicon Film			
Thickness (µm)	2–10	Note D (F399-88)	Note C, E, Must be measured on each wafer
Surface Orientation	Note C	X-ray Diffraction (F26-87a)	Note C, or Certified by Wafer Manufactures
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C, or Certified by Wafer Manufactures
Conductivity Type	Note C	F42-93	Note C, or Certified by Wafer Manufactures
Oxygen Concentration ($/cm^3$)	Note C	F1188-93a, F1619-95	Note C, or Certified by Wafer Manufactures
Carbon Concentration ($/cm^3$)	Note C	F1391-93	Note C, or Certified by Wafer Manufactures
Surface Cleanliness: Metal Contamination ($/cm^2$)	Note A, C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note A, C
Surface Cleanliness: Particle Density (/wafer)	Note A, C	Light Scattering Tomography (F1620-96) (SEMI M34)	Note A, C
Surface Roughness (nm)	Note A, C	AFM (SEMI M34)	Note A, C
Carrier Lifetime (µsec)	Note C	µ-PCD Method (F1535-94)	Note C
Crystalline Alignment of Top Silicon Film to Base Wafer(°)	Note C	X-ray Diffraction (F847-94)	Note C
Surface Feature (Haze, Scratch, etc)	None	F154-94, F523-93, F1726-97	Must be measured on each wafer
OSF Density ($/cm^2$)	Note C	Optical Metrology (F1727-97)	Note C, or Certified by Wafer Manufactures
Buried Oxide (BOX)			
Thickness (µm)	0.5–3	Ellipsometry (F576-95) or Reflective Spectroscopy (SEMI M34)	Tolerance is ± 5%; Note C, or Certified by Wafer Manufactures

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Location of Bonded Interface	Lower Surface, or Inside Oxide	TEM	Certified by Wafer Manufactures
Void Density (/cm^2)	None	Scanning Acoustic Tomography, Optical Defect Inspection	Note C
Oxide Defect Density (/cm^2)	Note C	I-V on Capacitor, Cu Decoration (SEMI M34)	Note C
Dielectric Breakdown Voltage (V)	Note C	I-V on Capacitor	Note C
Interface States (/cm^2)	Note C, H	C-V Technique	Note C
Fixed Charge Density (/cm^2)	Note C, H	C-V Technique (F1153-92)	Note C
Bonding Strength (kg/cm^2)	Note C	Tensile Strength	Note C, or Certified by Wafer Manufactures
Base Silicon Wafer			
Surface Orientation	Note C	F26-87a	Note C
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C
Conductivity Type	Note C	F42-93	Note C
Fiducial Axis Orientation (Flat/Notch)	Note C	F671-90, F1152-93	Note C
To-be-bonded Surface Cleanliness: Metals (/cm^2)	Note C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note C
Back Surface Finish	Note C	Optical Metrology	Note C

Table 5 Silicon-on-Insulator (SOI) Specifications for High Voltage (500–600V) Power Device

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Wafer(Overall)			
Diameter (mm)	125, 150, 200	F613-93	Note A
Thickness (μm)	(Value of regular silicon wafer) + (SOI thickness) + (Box thickness)	F533-96, F1530-94	Note A
Total Thickness Variation (μm)	Note C	F1530-94	Note C
LTV (μm)	Note C	F1530-94	Note C
Warp (μm)	≤ 100 (Note B,C,G)	F1390-92	Note C, or Certified by Wafer Manufactures
Non-SOI Edge Area (mm)	≤ 3 (Note C)	Optical Metrology	Note C, or Certified by Wafer Manufactures
Edge Profile / Edge Profile Surface Finish	Note C	F928-93	Note C, or Certified by Wafer Manufactures
Top Silicon Film			
Thickness (μm)	3–17	Note D (F399-88)	Note C, E, Must be measured on each wafer
Surface Orientation	Note C	X-ray Diffraction (F26-87a)	Note C, or Certified by Wafer Manufactures

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C, or Certified by Wafer Manufactures
Conductivity Type	Note C	F42-93	Note C, or Certified by Wafer Manufactures
Oxygen Concentration (/cm^3)	Note C	F1188-93a, F1619-95	Note C, or Certified by Wafer Manufactures
Carbon Concentration (/cm^3)	Note C	F1391-93	Note C, or Certified by Wafer Manufactures
Surface Cleanliness: Metal Contamination (/cm^2)	Note A, C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note A, C
Surface Cleanliness: Particle Density (/wafer)	Note A, C	Light Scattering Tomography (F1620-96) (SEMI M34)	Note A, C
Surface Roughness (nm)	Note A, C	AFM (SEMI M34)	Note A, C
Carrier Lifetime (µsec)	Note C	µ-PCD Method (F1535-94)	Note C
Crystalline Alignment of Top Silicon Film to Base Wafer (^{o})	Note C	X-ray Diffraction (F847-94)	Note C
Surface Feature (Haze, Scratch, etc)	None	F154-94, F523-93, F1726-97	Must be measured on each wafer
OSF Density (/cm^2)	Note C	Optical Metrology (F1727-97)	Note C, or Certified by Wafer Manufactures
Buried Oxide (BOX)			
Thickness (µm)	3–5	Ellipsometry (F576-95) or Reflective Spectroscopy (SEMI M34)	Tolerance is ± 5%; Note C, or Certified by Wafer Manufactures
Location of Bonded Interface	Inside Oxide (Lower Surface)	TEM	Certified by Wafer Manufactures
Void Density (/cm^2)	None	Scanning Acoustic Tomography, Optical Defect Inspection	Note C
Oxide Defect Density (/cm^2)	Note C	I-V on Capacitor, Cu Decoration (SEMI M34)	Note C
Dielectric Breakdown Voltage (V)	Note C	I-V on Capacitor	Note C
Interface States (/cm^2)	Note C, H	C–V Technique	Note C
Fixed Charge Density (/cm^2)	Note C, H	C–V Technique (F1153-92)	Note C
Bonding Strength (kg/cm^2)	Note C	Tensile Strength	Note C, or Certified by Wafer Manufactures
Base Silicon Wafer			
Surface Orientation	Note C	F26-87a	Note C
Resistivity (ohm-cm)	Note C	F43-93, F84-93, F1527-94	Note C
Conductivity Type	Note C	F42-93	Note C
Fiducial Axis Orientation (Flat/Notch)	Note C	F671-90, F1152-93	Note C

Parameters (Units)	*Value*	*ASTM Test Method or Measurement Procedure*	*Acceptance*
To-be-bonded Surface Cleanliness: Metals (/cm^2)	Note C	AAS, ICP-MS, TXRF (F1526-95), SIMS (F1617-98)	Note C
Back Surface Finish	Note C	Optical Metrology	Note C

Note A: Same as the standard of regular silicon wafer
Note B: The value is of 150 mm wafers, and is determined according to wafer diameter.
Note C: To be determined by negotiation between wafer users and suppliers
Note D: Reflective spectroscopy or FT-IR is recommended for top silicon film of less than several µm (about 7 µm), and FT-IR for top silicon film of more than several µm (about 7 µm).
Note E: Tolerance of ± 0.5 µm is recommended for top silicon film of less than several µm (about 7 µm), and ± 1.0 µm for top silicon film of more than several µm (about 7 µm).
Note F: The value is without the compensation method by backside oxide.
Note G: The value is with the compensation method by backside oxide.
Note H: This item can be neglected if the bonding interface is between BOX and base wafer.

7 Sampling Plan

7.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) of lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contact or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between the users and the suppliers.

8 Test Methods - Dimensions

NOTE 3: Detailed test procedures of each item should be determined between the users and the suppliers.

8.1 *Thickness of Top Silicon Film* — The following two methods are available for thickness measurement.

8.1.1 *Reflective Spectroscopy* — The light of visual wavelength (400–800 nm) is introduced into top silicon film by varying its wavelength continuously, and then the reflective spectra is measured. When the light is introduced into multi-layers of SOI wafers, reflection occurs on the surface of top silicon film and the front and backside of BOX. In such a case, the phase varies. The final intensities of the light that reflects from top silicon film surface are the sum of the intensity of light that reflects from each layer. The thickness of top silicon film and BOX makes optical path difference and then results in phase difference that is dependent on its wave length. The reflective light intensities, depending on its wavelength, are measured. The reflective spectra are defined as the ratio of reflective light intensity to incident intensity. This spectra curve varies by the thickness of top silicon film and BOX. The top silicon film thickness is derived from the obtained spectra curve by approximate calculation based on simulation or by comparing with the database.

8.1.1.1 Reference: J.-P. Colinge, “Silicon-On-Insulator Technology”, Kluwer Academic Publisher, 1991.

NOTE 4: Thickness of top silicon film and BOX layer are limited to measure because of using visual light.

Example: Nanospec/AFT model : 210LCW, SP-FSC15

Top silicon film thickness: 0.01–15 µm

BOX thickness: 0.004–3 µm

NOTE 5: Optical constant is already known in each of multilayers, and it should be constant in the whole layer.

8.1.2 *FT-IR (Fourier Transform Infra-Red Spectrometry)* — The reflectance spectrum of the specimen, which exhibits successive maxima and minima characteristics of optical interference phenomena, is measured as a function of wavelength using an infrared spectrophotometer. These maxima and minima are observed when the optical path lengths of the infrared beam, reflected from both the top silicon film surface and the top silicon film–buried oxide interface, differ by an integral number of half wavelengths. Consequently, the thickness of top silicon film is calculated using the wavelength of the extreme maximum and minimum in reflectance spectrum, the refractive index of Silicon and Silicon dioxide, and the angle of incidence of the infrared beam upon the SOI wafer.

Reference: F95 – Standard Test Method for Thickness of Lightly Doped Silicon Epitaxial Layers on Heavily Doped Silicon Substrates Using an Infrared Dispersive Spectrophotometer

8.1.3 *Definition of top silicon film thickness tolerance* — Thickness tolerance is defined below.

8.1.3.1 After top silicon film thickness is measured at predetermined number of points within an SOI wafer, the maximum and the minimum values are chosen, and then the tolerance is defined as;

Tolerance = Maximum value – Minimum value

NOTE 6: The location and numbers of measuring points should be determined between users and suppliers.

8.1.3.2 In case of multi-points measurements (ex. a few hundreds) within an SOI wafer, the tolerance is defined as;

Tolerance = 3σ (3 times of the standard deviation)

8.1.3.3 Measurement exclusion area such as wafer edge should be determined between users and suppliers.

NOTE 7: Recommendable metrology

a) Reflective spectroscopy or FT-IR is recommended

- for top silicon film of less than several μm (about 7 μm),
- and FT-IR for top silicon film of more than several μm (about 7 μm)

b) Tolerance is defined as the difference between the maximum and the minimum value after measuring several (ex. 9) points.

c) It is not necessary to measure the BOX thickness of SOI wafer after bonding. It is OK to measure it before wafer bonding.

d) In case of the above 1) ~ 3), the number of measurement points and their location should be specified in case of several points measuring, and the measurement exclusion area should be specified in case of multi-points measuring.

8.2 *Crystal Defect of Top Silicon Film*

8.2.1 *OSF (Oxidation induced Stacking Fault)* — This technique is applicable to the top silicon film of thicker than 1.5 μm. OSF density is measured by preferential chemical etching and microscopic observation. Preparation of samples and measurement of OSF density are as follows:

8.2.1.1 *Sample Preparation* — SOI wafers are oxidized at 1,100°C, 1 h, in H_2 / O ambient after the SC-1 and SC-2 cleaning. Oxide is removed by ca. 25 % HF and then the SOI wafers are preferentially etched by 1 μm, applying JIS H 0609:1994(B), and then rinsed thoroughly in distilled water and blown dry. JIS H 0609 defines the chromium-free preferential solution, which is composed of HF, HNO_3, CH_3COOH and H_2O.

8.2.1.2 *Measurement of OSF Density* — Samples are examined by an optical microscope. The sample surface is observed by magnification of 200 X, and OSF is counted on SOI wafer within the scope along the two lines, which are parallel and perpendicular to the orientation flat (so called cross scanning). OSF density is calculated from the count number and scanning area.

8.3 *Buried Oxide Defect*

8.3.1 *Cu Decoration Method* — In case of Bonded SOI, the buried oxide is usually formed by thermal oxidation. Therefore, the defect of buried oxide is taken into consideration only for the thin oxide cases. Buried oxide defect such as pinholes can be evaluated by Cu decoration method. This method has been applied to the buried oxide film of less than 400 nm thickness. Sample preparation and Cu decoration are conducted by the following procedure. The top silicon film on the buried oxide is removed by KOH solution, and then cleaned and rinsed. The sample is set on a gold-plated brass (Cathode) in the methanol solution. On the other side, a copper plate (Anode) is placed 5 mm above the sample surface. Positive constant bias of 1–3 MV/cm (ex. 40–120 V for 400 nm oxide) is applied to the copper plate for 5 minutes. Small leakage current passes through the buried oxide defect, and consequently copper precipitates on the defects. Typical allowable defect density is < 0.1/cm^2.

8.4 *Metal Contamination*

8.4.1 The surface metal contamination can be measured by TXRF, AAS and ICP-MS methods.

8.4.2 *TXRF (Total X-Ray Fluorescence)* — Total X-ray Fluorescence uses a low angle incident, and a tightly collimated X-ray beam excites the characteristic X-rays from impurity atoms near the sample surface. Usually, the angle of X-ray incident is less than 0.1 degree. The element identification and the amount of the element can be obtained by measuring energy and intensities of fluorescence X-ray. The instrument provides a map of impurity element distribution. The surface metal contamination (typically from Na to Zn) shall be less than 10^{11} cm^{-2} in total.

NOTE 8: This TXRF method is conveniently used to detect the metals on the SOI wafer surface.

8.4.3 *AAS (Atomic Absorption Spectrophotometry)* — The elemental characteristic absorption of the atom is measured by introducing sample solution as aerosol into the flame and then spectral absorption through the flame from the light source is detected by the spectroscope. The flameless method, superior to the flame method in the sensitivity, is now broadly used.

8.4.3.1 *Sample Preparation* — Careful sample preparation is necessary for the precise measurement. SOI wafer surface is exposed to HF vapor, and the metals on the surface are collected as droplet. To improve the sensitivity, the volume of collective solution should be as tiny as possible and the HF drops are rolled all over the surface in collective operation. In case of precious metals, it is better to use other kinds of collective solutions instead, since they are not dissolved or collected by HF solution itself.

Examples:

For Cu; HF-H_2O_2 (HF : H_2O_2: H_2O = 1 : 17 : 82)

For Au and Pt; aqua regia (HNO_3 : HCl = 1 : 3)

8.4.4 *ICP-MS (Inductively Coupled Plasma Mass Spectrometry)* — ICP-MS is composed of ICP (Inductively Coupled Plasma) part as an ion source and MS (Mass Spectrometer) part, which measures the ions generated at ICP part. Usually, sample solution is vaporized in the nebulizer and then finally introduced into Argon plasma in the silica tube called torch through the spray chamber. The sample is decomposed, evaporated, atomized and then ionized in the Argon plasma. Except for few atoms that have relatively high ionization potential, most of the elements (> 90%) can be ionized. Ions are identified and measured in amount by the mass spectrometer.

8.4.4.1 *Sample Preparation* — The same method as AAS method is applicable. In case of quantitative measurement of Fe, since its mass weight is close to that of ArO^+, it is necessary to pay attention to the degradation of detection sensitivity.

8.5 *Particle Density (LPD : Light Point Defect)*

8.5.1 *Light Scattering Tomography* — The particle larger than 0.2 μm on the thick SOI wafers is counted by Automated particle counter. The particles in the order of 0.1 μm can be detected if top silicon film is sufficiently thick.

8.5.2 *Principle of measurement* — By scanning the laser beam on the wafer surface, the light scattered by the particles on the wafer is detected. The scattered light and the noise from the wafer surface is detected as a direct current, on the other hand, the scattered light by the particles can be detected as pulse components. The particle size can be calibrated with standard polystyrene latex spheres. Multi-layers of SOI wafers usually have scattering noise from the layer interface. In case of less than 1 μm of the top silicon film thickness, it is necessary to reduce incident angle of the laser beam to increase the reflective component from the surface. For example, S/N ratio is improved when using S-polarized light of 10 degree incident, 85% of its component is reflected from silicon surface.

NOTE 9: In case of SOI wafer (Thickness > 1 μm)

Particle counter with a vertical incident laser, which is the same one used for the bulk wafer, is applied. It should be noted that bypass filter to erase the interference signals due to thickness dispersion, and adjustment of photo-multiplier sensitivity are necessary. By this technique, it is capable of detecting particles (> 0.1μm) as much as on the bulk wafer.

NOTE 10: In case of SOI wafer (Thickness < 0.5 μm)

It is recommended to use S - polarized light or normal light with low incident angle because of high scattering noise. However, the adjustment of photo-multiplier sensitivity is necessary to reduce the noise component. The sensitivity depends on the magnitude of the noise and it is usually possible to detect particles of around more than 0.5μm (in bulk wafer, > 0.2 μm).

8.5.3 *Visual Inspection* — SOI wafer can be visually inspected in accordance with ASTM F523. The automatic inspection equipment is also used when available. For visual inspection, the collimated high intensity bright light (ex. 500,000 lux) is used. Under using this light, SOI wafer is inspected for haze, slip, scratches, chips, cracks, pits, dimples, mound, orange peel, LPD and contamination.

8.6 *Surface Roughness*

8.6.1 *AFM (Atomic Force Microscope)* — By contacting the probe equipped with the cantilever onto the wafer surface of the sample, and by scanning the cantilever and detecting the variation by i.e., optical method, the roughness information is obtained.

NOTE 11: It is expected to set the observation area as > 20 μm × 20 μm to increase reliability of the data.

NOTE 12: Height calibration of concave and convex: Refer to UC standard ("Calibration method of 1 μm order height in AFM", [Ultra Clean Technology, Vol. 7, No. 2, pp. 43, 1995]).

8.7 *Inclusions*

8.7.1 In bonded SOI wafer, there exists the contaminants at the bonding Si/SiO_2 or SiO_2/SiO_2 interface such as particles, metals, boron, and hydrocarbon. Here, inclusions means the contaminants. Although there has been no report on the influence of contaminants to the device characteristics, the improvement of the contamination level is required.

8.8 *Void*

8.8.1 *Scanning Acoustic Topography* — The void can be detected by means of the traveling time difference of the acoustic waves. The void mapping can be made by scanning an ultrasonic wave and detecting the reflecting wave from the both surfaces of the void. Measuring in water improves the resolving power of location since the ultrasonic wave can be tightened by acoustic lenses.

NOTE 13: It is not suitable to measure SOI wafer that is not bonded firmly because measurement is conducted in water.

NOTE 14: It is not suitable to measure top silicon film (< 7 μm) because it is impossible to separate reflective waves both from top silicon film surface and the bonding interface.

NOTE 15: Detectable void gap depends on acoustic wave frequency. Detectable void diameter depends on the size of the acoustic source and the receiver. For example, if using 75

MHz frequency, 5 nm void gap and 50 µm void diameter can be detected.

NOTE 16: Void is defined as “empty space” that is due to the imperfect bonding at Si/SiO_2 and SiO_2/ SiO_2 interface. This void should be discriminated from the splitting at bonding strength test.

NOTE 17: Void can be only evaluated during SOI wafer processing, not at the shipping.

8.9 *Bonding Strength*

8.9.1 *Tensile Testing Method* — Bonding strength is defined and evaluated by tensile strength (kgf/cm^2) which is needed to split the bonding interface vertically. Details of the test structure and the test method should be determined by negotiation between wafer users and wafer suppliers.

Table 6 Test Summary Table

Parameter	*Reference*	*Method*
Wafer Diameter	F613-93	Optical Comparator
Wafer Thickness	F533-96, F1530-94	Thick. Gage, Auto. Noncontact Scan.
Total Thickness Variation LTV	F1530-94	Automated Noncontact Scanning
Warp	F1390-92	Automated Noncontact Scanning
Crystal Orientation Top Silicon Film (SOI) Base Wafer	F26-87a (1993)	X-ray Diffraction
Substrate Type / Dopant	F42-93	Hot-Probe (Test Method A)
Substrate Resistivity	F43-93, F84-93, F1527-94	4 Point Probe
Substrate RRG	F81-95	4 Point Probe
Top Si Film Thickness	Section 8.1	Reflective Spectroscopy or FTIR
Crystal Defect (OSF)	Section 8.2, (JIS H 0609 :1994 B)	Cr-free Etch / Optical Microscopy
Buried Ox defects	Section 8.3, (SEMI M34)	(a) Cu Decoration, (b) BOX Capacitor
Metal Contamination (per unit area)	Section 8.4, (F1526-95)	TXRF, AAS/ICP-MS
Particle Density (LPD)	Section 8.5 (F1620-96)	Light Scattering Tomography (Automated Particle Counter)
Haze	F523-93 (see NOTE 1), F154-94	Visual Inspection
Slip	F523-93 (see NOTE 1), F154-94	Visual Inspection
Scratches	F523-93 (see NOTE 1), F154-94	Visual Inspection
Chips / Cracks	F523-93 (see NOTE 1), F154-94	Visual Inspection
Pits and Dimples	F523-93 (see NOTE 1), F154-94	Visual Inspection
Mounds	F523-93 (see NOTE 1), F154-94	Visual Inspection
Orange peel	F523-93 (see NOTE 1), F154-94	Visual Inspection
Particle Density (LPD)	F523-93 (see NOTE 1), F154-94	Visual Inspection
Contamination (Both Side)	F523-93 (see NOTE 1), F154-94	Visual Inspection
Surface Roughness	Section 8.6	AFM
Inclusions	Section 8.7	SIMS
Voids	Section 8.8	Scanning Acoustic Tomography
Bonding Strength	Section 8.9	Tensile Strength

NOTE 1: Users and suppliers may agree on the non-SOI edge area for these specifications. For example the area within 6 mm proximity of the wafer edge may be excluded.

Table 7 Example: Soi Wafer Surface Visual Inspection Criteria

Criterion Items	*Allowed Quantity (Per 150 mm Wafer)*	*Description*
Haze	NONE	
Slip	< 4 2 mm width and < 15 mm length	
Scratches	NONE	
Chips / Cracks	< 3 for @ 0.5 mm circumferential x 0.3 mm length	Edge : Base Wafer
Pits and Dimples	NONE	
Particle Density (LPD)	< 30 for @ > 0.2 µm	<0.17 / cm^2 for 150 mm Wafer
Contamination	NONE	Both Surface and Backside

NOTE 1: The surface visual inspection is conducted under the collimated bright light.
NOTE 2: Non-SOI edge area (E.E.) of 6 mm is applied to the criterion items except for edge chips/cracks.
NOTE 3: The whole wafer (Top silicon film and Base wafer) is inspected except for edge chips/cracks.

Table 8 Soi Electrical Parameters

Parameters	*Reference*	*Value*	*Method*
Photo-conductivity Lifetime	Section 9.1	To be determined	µ-PCD
BOX Breakdown	Section 9.2	To be determined	I-V
BOX Charge	Section 9.3	To be determined	C-V
BOX Surface States	Section 9.4	To be determined	C-V
Doping Density Top silicon film, Base wafer	Section 9.5	To be determined	SIMS or 4 pt. probe

9 Electrical Parameters

9.1 *Photo-conductivity Lifetime*

9.1.1 *Test Method: µ-PCD method*

9.1.1.1 Excess carriers that are created in the wafer by a light pulse increases the conductivity of the sample. When the light is turned off, the conductivity is decreased by the carrier recombination. This phenom-enon is monitored by means of microwave reflectance. The microwave detects an exponential decay in conduc-tivity, from which a decay constant is determined.

9.1.2 The effective recombination lifetime τ_{eff} is given by the following expression:

$$1/\tau_{eff} = 1/\tau_B + 1/(\tau_S + \tau_D)$$

$$\tau_S = d/(S_{Si/Box} + S_{Si}),\ \tau_D = d/\pi^2 D$$

Where τ_B is bulk recombination lifetime, τ_S is surface recombination lifetime, τ_D is diffusion lifetime, $S_{Si/Box}$ is recombination velocity at the Box interface, S_{Si} is recombination velocity at the silicon surface, D is diffusion coefficient and d is top silicon film thickness.

9.1.3 The wavelength of the light has to be selected, depending on the top silicon film thickness (see Table 9).

9.2 *Box Breakdown Voltage*

9.2.1 *Test Structure* — Box capacitor having an area (Ex. 1 cm^2).

9.2.2 *Test Method: Staircase I-V Measurement* — Voltage is stepwise increased in one-volt increments from zero to the (+/-) specified voltage. Details of the test structure and the test method are determined by negotiation between wafer users and wafer suppliers.

9.3 *Box Charge*

9.3.1 *Test Structure* — Box capacitor having an area (Ex. 1 cm^2).

9.3.2 *Test method* — MOS high-frequency C-V measurement of a Box capacitor normally yields a flat band voltage. Details of the test structure and the test method are determined by negotiation between wafer users and wafer suppliers.

9.4 *Buried Oxide Fast Interfaces State Density*

9.4.1 *Test Structure* — Box capacitor having an area. (Ex. 1 cm^2)

9.4.2 *Test Method* — High-Low Frequency MOS C-V.

9.4.3 If care is taken in their fabrication to minimize oxide surface damage and contamination during silicon etching, good quality quasi-static MOS C-V curves can be measured. From comparison of high and low frequency C-V curves, midgap interface state density can be determined. Details of the test structure and the test method are determined by negotiation between wafer users and wafer suppliers.

9.5 *Doping Density*

9.5.1 *Test Method* — SIMS

9.5.1.1 Be careful of electrical charging up of test pieces due to the existence of BOX, the difference of detecting sensitivity between silicon and silicon dioxide, and the existence of disturbance ions such as $Si^{30}H^{1}$ in case of P^{31} measurement.

Table 9 Relationship Between Wavelength of the Light and Penetration Depth

Wavelength [nm]	450	532	635	670	780	820	850
Depth [μm]	~ 0.8	~ 1.4	~ 3.0	~ 4.0	~ 10.0	~ 14.0	~ 18.0

9.5.2 *Test Method* — Four point probe

9.5.2.1 By contacting the equally spaced four point probes with a wafer and by supplying current between the outer two probes, the voltage difference between the inner two probes is measured. The silicon resistivity ρ is determined by the following equation (JIS H0602):

$$\rho = \pi V/\ln 2 \bullet I \bullet d[\Omega cm] \quad \text{if probe interval} >> \text{top silicon film thickness: d}$$

9.5.3 The specific test method should be determined between wafer users and wafer suppliers.

10 Packing and Marking

10.1 Special packing requirements shall be subject to agreement between the users and the suppliers. Otherwise all wafers shall be handled, inspected, and packed in such a manner as to avoid chipping, scratches and contamination, and in accordance with the best industry practices to provide sample protection against damage during shipment.

10.2 The wafer supplied under these specifications shall be identified by appropriately labeling on the outside of each box or other container and each subdivision thereof in which it may be reasonably expected that the wafers will be stored prior to further processing. Identification marks, codes, symbols and content shall be agreed upon between users and suppliers.

SEMI M42-1000
SPECIFICATION FOR COMPOUND SEMICONDUCTOR EPITAXIAL WAFERS

This specification was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the North American Compound Semiconductor Committee. Current edition approved by the North American Regional Standards Committee on August 28, 2000. Initially available at www.semi.org September 2000; to be published October 2000.

1 Purpose

1.1 Compound semiconductor epitaxial layers have been extensively used for many years as the basis of high speed electronics and optoelectronic devices. There are suppliers of epitaxial layers who will grow material to the customer's specification. There is a need to define standardized descriptive terms, tolerance schedules and recommended test methods to reduce ambiguity in the interpretation of specifications for such wafers. Special emphasis is placed on the definitions pertaining to uniformity. This proposed document addresses only the basic requirements. Further clarification may be required between supplier and purchaser for the particular layers required.

2 Scope

2.1 These specifications cover the requirements for epitaxial layers of the generic composition $A_aB_bC_c...N_n$ grown on monocrystalline wafers of GaAs or InP (other substrates may be considered where appropriate documents exist to describe the specification of the substrate). This document may only cover a portion of the properties considered to be part of the purchase specification.

2.2 This specification does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standard*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

3.2 *ASTM Test Methods*[1]

ASTM F76 — Standard Test Methods for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility in Single-Crystal Semiconductors.

ASTM F673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Noncontact Eddy Current Gage.

3.3 *DIN Standard*[2]

DIN 50447 — Contactless Determination of the Electrical Sheet Resistance of Semiconductor Layers with the Eddy Current Method

4 Terminology

4.1 *epitaxy* — the growth of a single crystal layer on a substrate of the same material, homoepitaxy; or on a substrate of different material with compatible crystal structure, heteroepitaxy

4.2 *fixed quality area (FQA)* — (refer to Figure 1 of SEMI M1) the central area of the wafer surface, defined by a nominal edge exclusion, X, over which the specified values of a parameter apply.

4.3 *mismatch* — the ratio, m_c, defined by the lattice constant of the epitaxial layer perpendicular to the surface, c, minus that of the substrate, a_o divided by the substrate lattice constant.

$m_c = (c - a_o)/a_o$

4.4 *mole fraction* — the normalized fraction of a particular element occupying the same lattice site in a compound. E.g. in the compound $A_aB_bC_cD_d$, a, b, c and d are the mole fractions of the elements A, B, C and D respectively. If, in this example, A and B share the same lattice site, and C and D share the other lattice site, then by definition the sum of a and b, and the sum of c and d each must be 1.

4.5 *graded layer* — a layer whose properties vary smoothly in the direction perpendicular to the surface. The properties of a graded layer are specified in terms of the parameters at the top (last to grow surface) and bottom (first to grow surface) of the layer and unless otherwise specified, are expected to vary linearly between these two end values.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

2 Deutsches Institut für Normung e.V., available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

5 Wafer Ordering Information

5.1 Purchase orders for epitaxial layers must include the following items:

5.1.1 The substrate (as described by the relevant SEMI Standard).

5.1.2 The epitaxy growth method.

5.1.3 The nominal edge exclusion used to define the FQA.

5.1.4 The composition of each layer in terms of mole fraction(s) and a description of the test method used to measure it and/or calibrate the growth conditions of that layer. Note that in the case of a ternary compound, the purchaser may require that the specification for mismatch or bandgap energy take precedence over that for nominal composition. Similarly in the case of a quaternary compound, a specification of mismatch and bandgap energy may be preferred. This is because the mismatch and bandgap energy, which depend on the composition, are often easier to measure than the composition directly.

5.1.5 The thickness of each layer and a description of the test method used to measure it and/or calibrate the growth conditions of that layer.

5.1.6 The dopant used for each layer.

5.1.7 The carrier concentration of each layer and a description of the test method used to measure it and/or calibrate the growth conditions of that layer. In the case of layers with significant interface or surface depletion, the carrier concentration refers to the value that would be observed in thicker layers, once the appropriate correction is applied for interface and surface depletion effects.

5.1.8 *Optional Criteria* — The following items may also be specified in addition to those listed above.

5.1.8.1 The mobility of each layer.

5.1.8.2 The sheet resistance of the epitaxial layers.

5.1.8.3 The mismatch for each layer. The test method must be described.

5.1.8.4 The bandgap energy for each layer. The test method must be described.

5.1.8.5 The sheet carrier concentration and mobility of the whole structure. This is relevant to those structures where the carriers are expected to redistribute to an adjacent material or interface.

5.1.8.6 The surface defect density.

5.1.8.7 The end values and thickness of each graded layer.

5.1.8.8 The surface roughness. The test method must be described.

5.1.8.9 The growth and test methods of a calibration structure along with a schedule for the growth of such a structure.

6 Tolerance Requirements

6.1 The tolerance requirements for the specified parameter, unless otherwise agreed to between the supplier and purchaser, are as in Table 1. Tolerance is defined as the allowed range of values permissible within the FQA and includes variations due to non-uniformity and deviation from the customer's target value. The measurement point schedule (map of measurement points) should be agreed upon between the supplier and purchaser. Three classifications are given for products of varying control needs.

Table 1 Parameter and Tolerance Requirements

Parameter	*Tolerance A*	*Tolerance B*	*Tolerance C*
composition [mole fraction (s)]	± 0.05	± 0.01	± 0.005
thickness [percent of nominal]	± 20%	± 10%	± 5%
carrier concentration [percent of nominal]	± 20%	± 10%	± 5%
sheet resistance [percent of nominal]	± 20%	± 10%	± 5%

Table 2 Parameter and Recommended Measurement Technique

Parameter	*Technique*	*Test Method*
composition	infer from bandgap energy measured by photoluminescence, or photo reflectance and/or from mismatch measured by high resolution X-ray diffractometry	under development none as yet
thickness	cleaved cross sections measured by optical or scanning electron microscopy and/or profilometry of selectively etched layers	needs revision none as yet
carrier concentration	Hall effect or C-V profiling (electrochemical or mercury probe)	ASTM F 76- needs revision none as yet
sheet resistance	Van der Pauw technique and/or eddy current	ASTM F 76 ASTM F 673 or DIN 50447
mobility	Hall effect	ASTM F 76

7 Test Methods

7.1 Measurements shall be carried out according to the methods outlined in Table 2. Where no methods are specified, or where choices are given, the supplier and purchaser shall agree in advance on the means for making the measurement.

7.2 Given the state of development for the recommended test methods and the lack of standard reference materials, it is advisable that the vendor and purchaser exchange samples to cross calibrate their measurement instruments and procedures.

8 Marking

8.1 In addition to the requirements set out in the specification for the substrates, a unique number traceable to the growth run shall be identified on the supplier's certificate.

9 Certification

9.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

9.2 The user and supplier may agree that the material shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests in Section 7; however, if the user performs the test and the material fails to meet the requirement, the material may be subject to rejection.

SEMI M43-0301
GUIDE FOR REPORTING WAFER NANOTOPOGRAPHY

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001.

1 Purpose

1.1 This guide provides a framework for reporting of nanotopography surface features on silicon wafers.

2 Scope

2.1 This guide addresses reporting the characterization of nanotopography surface features found on wafer surfaces. Nanotopography is the non-planar deviation of the whole front wafer surface within a spatial wavelength range of approximately 0.2 to 20 mm and within the fixed quality area (FQA). Typical examples include dips, bumps or waves on the wafer surface that vary in peak to valley height from a few nanometers to a several hundred nanometers.

2.2 This guide provides a framework for communicating specific values limiting feature levels and/or densities as agreed upon between suppliers and users.

2.2.1 *Discussion* — Nanotopography measurements have not been needed for 0.25 µm generation devices, but are expected to be required for smaller feature sizes to meet CMP requirements. Nanotopography on a wafer surface prior to CMP processes can result in variations in post-CMP dielectric thickness with potential negative consequences for circuit performance and yield; features as small as 20 nm (peak to valley) can result in post CMP discoloration of dielectrics as a result of local thickness variation of the remaining dielectric[1]. Height variations over specified distances (determined by CMP issues and/or lithography systems) need to be properly controlled to assure that wafers are acceptable for selected process steps. In the case of CMP, the issue is control of film thickness variation introduced by nanotopography. The metrology industry is building tools that will measure and map surface features at nanotopography amplitudes and spatial wavelengths. Nanotopography features are characterized by their height variation within an area, and are discriminated from other features of similar height by their spatial wavelength range.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 The reported surface features will be influenced by limitations and parameters of the measurement tool. These include:

3.1.1 The finite surface spatial bandwidth of the tool and the applied filtering will prevent surface variations outside the bandwidth of operation from being measured. Also, the finite bandwidth of filtering produces non-physical artifacts that may be apparent in regions where the power in the rejected bands is high.

3.1.2 Bandwidth edges are not always well defined. Measurement results do not always agree well between systems, because different tool designs employ different geometries and operate them over different spatial bandwidths.

3.1.3 All surface profiling measurement systems have a minimum height variation sensitivity that will distort signals near the noise floor.

3.1.4 The reported shape of some features may also depend on the pixel grid orientation employed by the instrument.

3.1.5 The pixel size and sampled area will affect the bandwidth limits.

3.2 Reported profiles also vary with interactions between wafer and tool. These limitations include:

3.2.1 Measurements made near the wafer edge may result in false readings. Under certain conditions, this may cause incorrect height measurement within the FQA.

3.2.2 Closely spaced features may be counted as a single feature, or as no feature, if the pixel size is larger than the feature, or is larger than the spacing between features. Reported features may result from the combination of the actual surface features, the manner in which the wafer is chucked, or be caused by particles trapped between the wafer back surface and the chuck.

3.2.3 High-pass (spatial frequency) filtering is typically used with these measurements to remove the (long-spatial wavelength) effects of wafer shape (such

1 K. V. Ravi, "Wafer Flatness Requirements for Future Technologies," Future Fab International, July 1999.

as bow, warp and sori). This filtering may affect the reported results.

3.3 Nanotopography characterization does not include microroughness, which applies to a shorter spatial wavelength range.

3.4 The location of defective areas as calculated in section 6 may not coincide with the location of the surface features that lead to those values. This may cause lack of spatial correlation between reported defective areas and device process defect areas.

3.5 The height map used to create nanotopography reports may be affected by wafer shape and measurement chuck effects.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI M1 — Specification for Monocrystalline Polished Silicon Wafers

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *fixed quality area (FQA)* [SEMI M1] — the central area of a wafer surface, defined by a nominal edge exclusion, X over which the specified values of a parameter apply.

Discussion: The boundary of the FQA is at all points the distance X away from the periphery of a wafer of nominal dimensions. (See Figure 1). The size of the FQA is independent of the wafer diameter and flat length tolerances. For the purpose of defining the FQA, the wafer periphery at locations with notch fiducials is assumed to follow the circumference of a circle with diameter equal to the nominal wafer diameter.

5.2 *nanotopography, of a wafer surface* — the non-planar deviation of a surface within a spatial wavelength range of approximately 0.2 to 20 mm.

5.3 *nanotopology, of a wafer surface* — see *nanotopography*.

5.4 *roughness* [SEMI M1] — the more narrowly spaced components of surface texture.

Discussion: These components are considered within defined limits of spatial wavelength (or frequency).

5.5 *spatial wavelength* — the spacing between adjacent peaks of a purely sinusoidal profile.

6 Measurements

6.1 The height map is obtained from a front-surface measurement. An explicit reference plane is not used for calculating and assigning values.

NOTE 2: Other methods of analyzing nanotopography may require the use of an explicit reference plane.

6.2 The high-pass filter removes long spatial wavelength wafer tilt and topography effects, effectively creating a global reference surface.

6.3 *Calculation* — The calculation determines the peak to valley height (P-V) variation among the pixels included in the analysis area, and assigns that variation in nanometers to the center of the analysis area. The calculation is performed for every analysis area within the FQA of the wafer. These calculations may be repeated for analysis areas of different dimension D.

NOTE 3: This calculation describes the "full-analysis area" method. There is another calculation, the "partial analysis area" method, where the calculation is performed for every analysis area whose center pixel is within the FQA of the wafer. The partial analysis area method, not defined in this document, is being addressed by SEMI for inclusion in a standard.

6.4 The following measurement elements should be reported:

6.4.1 *Filtering*

a) Spatial cutoff of high pass filter

b) Type of Filter

c) Pixel spacing

Filtering is used to remove long wavelength shape components from the raw height data.

6.4.2 *Analysis Area* — Specify this analysis area's:

a) Shape, e.g., square, circle, and

b) Dimension *D* of the analysis area

An analysis area contains a pixel at its center (Figure 1). The pixels within the surrounding analysis area of dimension *D*, and within the FQA, are used to determine the value assigned to the center pixel location.

6.4.3 *Data Report* — Report one or more of the following:

6.4.3.1 *Statistical Representation by Threshold Curve* — Plot, for each D, % area vs. threshold T, in nanometers, where % area is the ratio of

a) the number of analysis areas whose assigned value (calculated per Section 6.3) exceeds the threshold T, to

b) the number of pixels within the FQA.

The ratio is expressed as a percentage.

6.4.3.2 *Tabular Representation by % Area Sorted* — Specify a threshold T for each D and report the % area.

6.4.3.3 *Tabular Representation by Threshold* — Specify a % area for each D and report the Threshold, T.

6.4.3.4 *Spatial Representation by Height Map* — Generate a whole wafer height map of the surface.

6.4.3.5 *Spatial Representation by Defect Map* — Generate a whole wafer height map of the surface. Analysis areas whose assigned values (calculated per Section 6.3) exceed the threshold in Section 6.4.3.2 are flagged for each D.

6.4.3.6 *Spatial Representation by PV Analysis Map* — Generate a whole wafer map of the values assigned in Section 6.3.

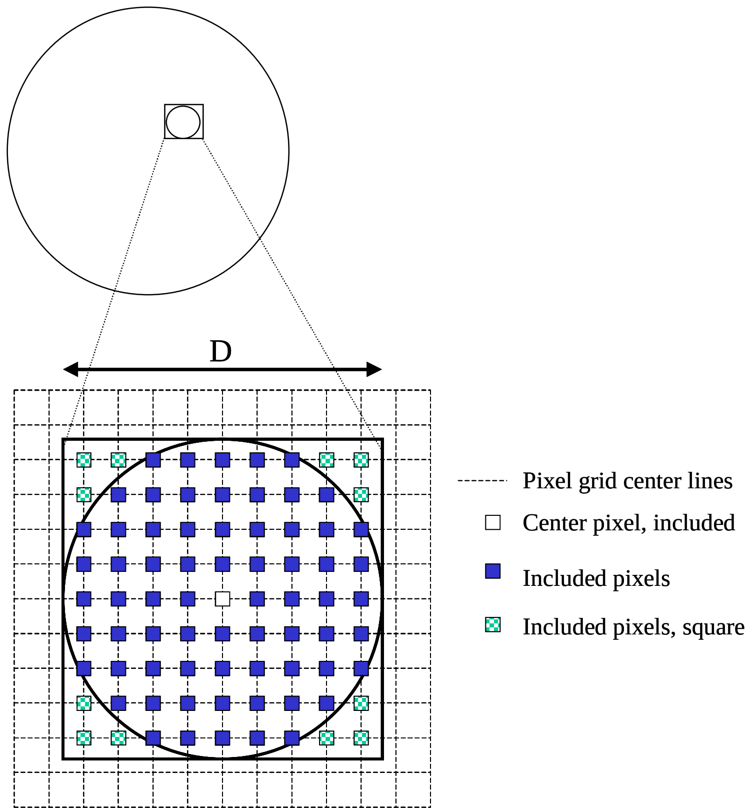

Figure 1
The Analysis Area Of Dimension D, Center And Included Pixels Are Indicated

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI M43 and is not intended to modify or supercede the proposed standard. It is provided for information purposes. The proposed standard should be referred to in all cases.

R1-1 SEMI M43 describes reporting wafer nanotopography. The figure below illustrates the flow of data from measurement through reporting referenced to the document sections.

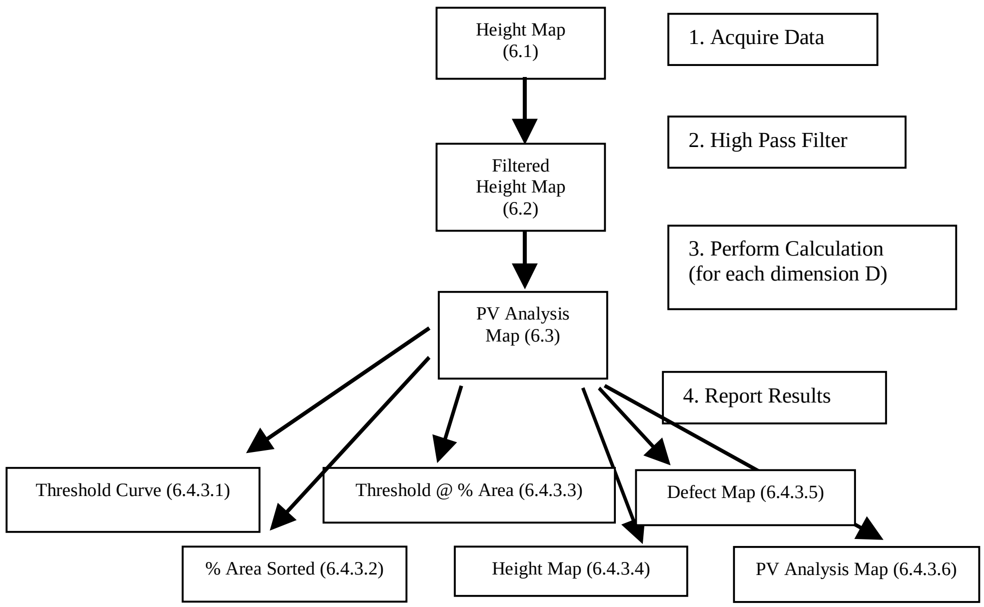

Figure R1-1
Nanotopography Reporting Flow

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SEMI M44-0702
GUIDE TO CONVERSION FACTORS FOR INTERSTITIAL OXYGEN IN SILICON

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on April 30, 2002. Initially available at www.semi.org June 2002; to be published July 2002. Originally published March 2001.

1 Purpose

1.1 This guide is a compilation of the conversion and calibration factors used by different standards established for the measurement of interstitial oxygen in silicon.

2 Scope

2.1 This guide allows the user of the guide to convert quantitative values obtained from one standard to another.

2.2 This guide does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

3.2 *ASTM Standards* [1]

F121-79 — Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F121-83 — Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F1188 — Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption (refers to IOC-88[2])

F1241 — Standard Terminology of Silicon Technology

3.3 *DIN Standard* [3]

DIN 50438-1[1994, 1995] — Determination of Impurity Content in Silicon by Infrared Absorption; Part 1 Oxygen[4] (refers to IOC-88[2])

DIN 50438 Part 1 [1978] — Determination of Impurity Content in Silicon by Infrared Absorption: Oxygen

3.4 *JEITA Standard* [5]

JEIDA 61 — Standard Test Method for Atomic Oxygen Content of Silicon by Infrared Absorption (refers to IOC-88[2])

4 Terminology

4.1 Many terms relating to silicon technology are defined in ASTM Terminology F 1241.

5 Other Techniques

5.1 Other measurement techniques for measuring oxygen in silicon (e.g., SIMS or GFA) measure total oxygen whereas the referenced methods measure interstitial oxygen only. For details, refer to Volume 10.05 of *Annual Book of ASTM Standards*.

6 Conversion Factors Among International Standards

6.1 Table 1 gives the conversion factors to convert oxygen concentration of one standard to oxygen concentration of another standard.

6.2 Table 2 gives the calibration factors to relate peak absorption coefficient (cm^{-1}) to interstitial oxygen content in both parts per million atomic (ppma) and $atoms/cm^3$ for various standards that have been replaced by newer revisions.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 A. Baghdadi, W. M. Bullis, M. C. Croarkin, Y.-Z. Li, R. I. Scace, R.W.Series, P.Stallhofer, M.Watanabe, “Interlaboratory Determination of the Calibration Factor for the Measurement of the Interstitial Oxygen Content of Silicon by Infrared Absorption,” *J. Electrochem. Soc.,* Vol. 136, p. 2015 (1989)

3 Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany

4 In German – 1995 English edition available. DIN 50438-1 [1995] – Determination of Interstitial Oxygen Content of Silicon Intended for Use in Semiconductor Technology by Infrared Absorption spectroscopy (refers to IOC-882)

5 Japan Electronics and Information Technology Industries Association, 3rd Floor Mitsui Kaijo Bldg. Annex 11, Kanda Surugadai 3-chome, Chiyoda-ku, Tokyo 101-0062, Japan

6.3 Irrespective of a standard, to convert oxygen density (atoms/cm^3) to oxygen concentration (ppma), within the same standard, divide the value by:

$$5 \times 10^{16} \text{ (atoms per cm}^3\text{ / ppma)}, \qquad (1)$$

and, to convert ppma to concentration (atoms/cm^3), within the same standard, multiply the value by (1).

Table 1 Conversion Factors

TO: → / *Convert From: ↓*	*ASTM F121-79[A] (Old ASTM)*	*ASTM F121-83[B] (New ASTM) or DIN 50438 Part 1 (1978)*	*ASTM F1188[C] or DIN 50438-1[C] [1994, 1995] or JEIDA 61[C]*	*"JEIDA Coefficient (Original)"[D]*
ASTM F121-79[A] (Old ASTM)	1	0.509	0.652	0.629
ASTM F121-83[B] (New ASTM) or DIN 50438 Part 1 (1978)	1.965	1	1.282	1.237
ASTM F1188[C] or DIN 50438-1[C] [1994, 1995] or JEIDA 61[C]	1.533	0.780	1	0.965
"JEIDA Coefficient (Original)"[D]	1.589	0.809	1.036	1

A. All ASTM F 121 from 1970 to 1979.
B. All ASTM F 121 at or later than 1980.
C. Each of these standards refers to IOC-88.
D. T. Iizuka, S. Takasu, M. Tajima, T. Arai, T. Nozaki, N. Inoue, and M. Watanabe, "Determination of Conversion Factor for Infrared Measurement of Oxygen in Silicon," *J. Electrochemical Society,* Vol 132, pp 1707-1713 (1985).

Table 2 Calibration Factors

Calibration Factor	*Value to Obtain Oxygen Content in ppma*	*Value to Obtain Oxygen Content in atoms/cm³*
ASTM F121-79[A] (Old ASTM)	9.63	4.815×10^{17}
ASTM F121-83[B] (New ASTM) or DIN 50438 Part 1 (1978)	4.90	2.45×10^{17}
ASTM F1188[C] or DIN 50438-1[C] [1994, 1995] or JEIDA 61[C]	6.28	3.14×10^{17}
"JEIDA Coefficient (Original)"[D]	6.06	3.03×10^{17}

A. All ASTM F 121 from 1970 to 1979.
B. All ASTM F 121 at or later than 1980.
C. Each of these standards refers to IOC-88.
D. T. Iizuka, S. Takasu, M. Tajima, T. Arai, T. Nozaki, N. Inoue, and M. Watanabe, "Determination of Conversion Factor for Infrared Measurement of Oxygen in Silicon," *J. Electrochemical Society,* Vol 132, pp 1707-1713 (1985).

NOTICE: SEMI makes no warranties or representation as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacture's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

By publications of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position respecting the validity of any patent rights or copyrights asserted in connection with any items mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights are entirely their own responsibility.

SEMI M45-0301
PROVISIONAL STANDARD FOR 300 mm WAFER SHIPPING SYSTEM

This standard was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the Japanese Silicon Wafer Committee. Current edition approved by the Japanese Regional Standards Committee on December 1, 2000. Initially available at www.semi.org January 2001; to be published March 2001.

1 Purpose

1.1 This standard stipulates transport related materials and systems to minimize the total cost relating to transport of 300 mm wafers from the wafer supplier to the customer.

2 Scope

2.1 This standard stipulates materials relating to transport of 300 mm wafers using Shipping Boxes (FOSB) regulated by SEMI M31, and includes wafer shipping boxes, bags, labels, cushions, secondary containers, pallets, and shipping documentation.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

NOTE 1: This standard is provisional because some technical issues are not implemented. Once these issues are addressed, this standard should be modified and upgraded from provisional status.

3 Referenced Standards

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Standards*

SEMI M31 — Provisional Mechanical Specifications for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI T3 — Specification for Wafer Box Labels

3.2 *ANSI Standards*

ASNI/EAI-556-B — Outer Shipping Container Label Standard[1]

4 Terminology

4.1 *bag* — a package used for sealing the outside of the wafer shipping box. Typically two or three types of different plastic film and aluminum film are laminated, and these are usually heat-sealed.

4.2 *cushions* — materials placed between the wafer shipping box and secondary container in order to absorb shock during shipping and to stabilize the wafer shipping box within the secondary container.

4.3 *label* — the label on the wafer shipping box or items such as bags identifying the product and its manufacturer.

4.4 *pallet* — a flat container used for collecting and holding a suitable amount of secondary containers that hold wafers, to make handling with forklifts easier.

4.5 *recycle* — to use an already used item for some other useful purpose.

4.6 *reuse* — to repeat use of an item in its original shape for the same purpose as initially intended.

4.7 *secondary container* — the outermost box of the smallest transport unit. Typically cardboard boxes or similar boxes are used.

4.8 *shipping document* — documents required when shipping.

4.9 *wafer shipping box* — a box that directly holds the wafers. In this standard, this box is specified by SEMI M31.

5 Requirements

5.1 *Wafer Shipping Box*

5.1.1 Wafer shipping boxes that comply with SEMI M31 must be used.

5.1.2 There are no grounding or ESD requirements for wafer shipping box.

5.1.3 To make sure raw materials are traceable, the product number, revision number, and manufacturing period (year, week) must be displayed on the wafer shipping box main device and door by molding or by a method that cannot be easily erased.

5.1.4 The wafer shipping box door must be designed so that it can be automatically as well as manually opened and closed.

5.1.5 Optional top robotic handling flange or side mounted human handles will not be attached during transport of the wafer shipping box. If required, these items will be applied at the receiving site. The design of

1 Available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112-5704.

these features will allow for quick, lockable attachment to the wafer shipping box.

5.1.6 Wafers must be visible inside when the wafer shipping box is closed.

5.1.7 No tape may be used to seal the wafer shipping box.

5.1.8 The only environment in which wafers can be placed into or taken out of a wafer shipping box bag, as well as the surrounding environment thereafter, is clean room air.

5.1.9 The body and door of the wafer shipping box must be designed to allow for multiple reuse cycles without compromising wafer quality.

5.1.10 After a customer has transferred an accepted wafer to a fab carrier, the wafer shipping box must be returned to the supplier without having used it for any other purpose. The wafer shipping box will be inserted into a bag sealed prior to return to the wafer supplier using the same type bag (agreed upon by supplier and customer).

5.1.11 Each wafer shipping box must be returned only to the supplier that delivered the wafers for which the wafer shipping box was used. A display for the supplier showing the number of times a wafer shipping box was used is optional.

5.1.12 The property rights of wafer shipping box used to deliver wafers and to be returned after unloading belong to the wafer manufacturers.

5.1.13 The wafer shipping box will maintain its dimensional stability throughout its lifetime.

5.1.14 Wafer shipping box materials must be recyclable after useful life.

5.2 *Wafer Shipping Box Bagging System*

5.2.1 It is preferable that the bag material is recyclable, but until a technical solution is found, bags should be easily disposable.

5.2.2 The bagging system must consist of two or more layers of bags. At least one layer must be a moisture barrier.

5.2.3 The use of desiccant between the bag layers is currently optional. Its use must not negatively impact the cleanliness of the bagging system.

5.2.4 Bags may be evacuated optionally. The initial bag ambient, prior to evacuation and sealing, may be temperature/humidity controlled clean room air, clean dry air (CDA), or nitrogen (N2).

5.3 *Wafer Shipping Box and Bag Labeling*

5.3.1 Prepare and apply two identical labels that are in accordance with SEMI T3, with additional requirements as noted below.

5.3.1.1 Label size may be as large as 120 mm x 120 mm.

5.3.1.2 Label data content shall include all the data specified in SEMI T3, including wafer ID and FOSB slot #. Additional data may be added optionally, as agreed to between supplier and user.

5.3.1.3 Apply one label to the center of the rear surface of the FOSB. The long axis of the label shall be parallel to the FOSB base.

5.3.1.4 Apply the other label to the shipping bag, on the door side of the FOSB.

5.3.2 The wafer shipping box and outer bag labels should use the same peelable, cleanroom compatible label stock. The labels must not leave residual adhesive or backing material on the wafer shipping box when removed.

5.4 *Secondary Container Labeling*

5.4.1 Labels shall be placed in accordance with EIA-556-B.

5.4.2 Prepare labels in accordance with EIA-556-B. Information shall include at least the following [Items below marked by an asterisk (*) are mandatory EIA-556-B data fields]:

5.4.2.1 *Bar Code Data Fields*

- Transport unit License Plate number*
- Transaction identification (Purchase Order number)*
- Total Quantity of Wafers*
- Total Quantity of Cartons
- Customer Part number*

5.4.2.2 *Non-Bar Code Data Fields*

- Ship-to address (including Customer name)*
- Ship-from address (including Supplier name)*

5.4.2.3 Optional information, as agreed to between supplier and user, may be included.

5.5 *Secondary Container*

5.5.1 Whether the secondary container material is a single use material or a material that can be reused multiple times should be decided by considering the transport environment to minimize the packaging cost.

The same is true for the secondary container sealing system.

5.5.2 The secondary container should be collapsible for efficient storage and empty transport.

5.5.3 The materials for the secondary container should be recyclable after the designated number of uses is completed.

5.5.4 The design and size of the secondary container should have an optimal fit with the standard pallet noted in Section 5.7.2, and should have the strength to be stacked in four layers.

5.5.5 The number of wafer shipping boxes per secondary container must allow for optimal transportation costs.

5.5.6 Ergonomic considerations should be made for the secondary container, and should be compatible with manual handling. When handling very large quantities, a supplemental handling system is necessary.

5.5.7 The secondary container design is not required to provide specific weather protection. The storage environment should not be affected by the weather.

5.6 *Cushions*

5.6.1 Whether the cushion material is a single use material or a material that can be reused multiple times should be decided by considering the transport environment to minimize the packaging cost.

5.6.2 For the sake of efficiency during holding and transport, it is preferable to have only one or two cushions per secondary container.

5.6.3 The materials for the cushions should be recyclable after the designated number of uses is completed.

5.7 *Pallet*

5.7.1 Pallets must be stand-alone components and are not integrated with secondary containers.

5.7.2 Considering space efficiency of ocean freight containers, it is preferable that the pallet size be 1130 mm max on at least one side.

5.7.3 Palletized containers must be banded and film-wrapped.

5.7.4 Pallet material must meet transportation industry requirements and allow for reuse and recycle after end of useful life.

5.7.5 Pallets must be able to be accessed by a forklift from at least two directions.

5.8 *Shipment Documentation*

5.8.1 English should be used for all international shipment documentation. The local language may be used only for domestic shipments only.

5.8.2 Packing list and customs invoice (if required) should be located on the outside of container number 1 with a sufficient number of copies to ensure the customer receives one copy.

5.8.3 Customs invoices must meet appropriate government regulations. Key content items are: PO number, product description, price, shipping address, and cross-reference to packing list.

5.8.4 The packing list must contain: date, customer shipping address, supplier name, country of origin, PO number, customer part number, shipment quantity, total number of cartons, carton identifiers.

5.8.5 The certificate of analysis or conformance should be electronically transmitted from wafer supplier to customer. Electronic transmission format must be flexible to allow for future content changes.

5.9 *Transportation Logistics*

5.9.1 Small quantity shipments or expedited shipments may require a special secondary container size.

5.9.2 The 300 mm wafer shipping system design must comprehend both surface and air transportation.

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI M45 by full letter ballot procedure, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1.1 The 300 mm Wafer shipping box must be re-usable in view of the wafer manufacturing cost and environmental concerns.

A1-1.2 When the shipping box is re-used, the customer who received wafers must keep the shipping box in good condition after opening the package and return to the wafer supplier.

A1-1.3 The box cleaning process of the supplier can not remove ink, adhesive, and excessive metal contamination of the returned shipping box.

A1-1.4 The customers must avoid contaminating the shipping boxes in this way. The customers must keep the shipping box separate from those contaminated conditions. Contaminated shipping boxes must not be returned to the supplier.

SEMI M46-1101^{E}
TEST METHOD FOR MEASURING CARRIER CONCENTRATIONS IN EPITAXIAL LAYER STRUCTURES BY ECV PROFILING

This test method was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the European Compound Semiconductor Materials Committee. Current edition approved by the European Regional Standards Committee on June 29, 2001. Initially available at www.semi.org December 2001; to be published March 2002.

^{E} This document was editorially modified in November 2001 to correct a typographical error. A change was made to Section 7.3.3.

1 Purpose

1.1 The purpose of this document is to specify a method to measure the carrier concentration and carrier concentration vs. depth profile of epitaxial layers by Electrochemical Capacitance Voltage ECV profiling.

2 Scope

2.1 This test method covers a procedure for measuring the carrier concentration of epitaxial layers by ECV profiling. This method focuses on improving the accuracy and repeatability of the measurement by standardizing the test conditions and reporting and by routine calibration of the measurement.

2.2 This test method is intended to cover the majority of routine samples measured. However, because of the number of different materials encountered it cannot cover every contingency.

2.3 This standard may involve hazardous materials. This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

3.2 *ASTM Standards*

D1125-95 (1999) — Standard Test Methods for Electrical Conductivity and Resistivity of Water

4 Terminology

4.1 *bias* — the potential applied to the sample with respect to a reference electrode.

4.2 *capacitance voltage CV measurements* — electrical measurements where the capacitance of a rectifying barrier is measured as a function of applied bias and is a measure of the net fixed ionized charge per unit volume.

4.3 *carrier concentration* — the net fixed ionized charge per unit volume. Equal to the free carrier concentration if the dopant is fully ionized and the material is free of traps.

4.4 *current voltage IV measurements* — electrical measurements where the current through the rectifying barrier is measured as a function of applied bias.

4.5 *dissipation factor* — the ratio of the real part to the imaginary part of the complex admittance. It is a measure of the non-ideality of the barrier.

4.6 *electrochemical* — chemical reaction in which charge transfer takes place via an external circuit.

4.7 *epitaxial layer* — a layer of single crystal semiconductor material grown on a host substrate which determines its orientation.

4.8 *excess area* — the difference between the wetted and illuminated areas.

4.9 *flatband potential* — the intercept on the voltage axis of the $1/C^2$ vs V plot. A measure of the built in field or barrier height.

4.10 *illuminated area* — the area of the sample which can be illuminated during electrochemical etching.

4.11 *rectifying barrier* — a potential gradient formed at the junction between two materials which permits the flow of charge in one direction only.

4.12 *reference electrode* — half cell which has a constant electrode potential, such as a saturated calomel electrode, SCE.

4.13 *rest potential* — the open circuit potential of the sample with respect to the reference electrode.

4.14 *wetted area* — the area of contact between the electrolyte and the sample.

5 Summary of Method

5.1 In this method, the carrier concentration of the epitaxial layer is measured by the CV method.

5.1.1 Ohmic contacts are formed on the sample.

5.1.2 A rectifying barrier, of known contact area, is formed by placing the sample in contact with an electrolyte.

5.1.3 The quality of the barrier is assessed using I-V and C-V measurements.

5.1.4 From the measured C-V data the carrier concentration of the layer is determined.

5.1.5 The sample is anodically etched to produce a new barrier deeper in the material. The etch depth is determined using Faraday's law of electrolysis.

5.1.6 Sections 5.1.4 and 5.1.5 are repeated to generate a carrier concentration vs. depth profile.

6 Interferences

6.1 *Thin Layers* — Diffusion of carriers into adjacent regions set a fundamental resolution limit to the measurement. In addition if the layer has a high sheet resistivity this can also affect the value obtained.

6.2 Double Layer Capacitance — A limitation imposed by the physical nature of the electrolyte/semiconductor barrier which sets an upper limit to the measured carrier concentration, for accurate measurements, of 1×10^{19} cm^{-3}. The technique can be used beyond this value, but with progressive degradation.

6.3 *Etch Well Uniformity*

6.3.1 *Etch Well Flatness* — Non-uniformity increases the effective area and may result in the measurement not being wholly made in the layer of interest. The main causes of non-uniformity are gas bubbles, inadequate electrolyte circulation and uneven illumination.

6.3.2 *Etch Well Roughness* — indicates poor etching and has a deleterious effect on the measurements. Generally overcome by selecting a more appropriate electrolyte and/or etching conditions.

6.4 *Non-Ideal Electrical Characteristics*

6.4.1 *Series Resistance* — From the contacts, sample and electrolyte affect the accuracy of the measurements. This effect is minimized by using a highly conductive electrolyte, making large area ohmic contacts and by employing a low measurement frequency.

6.4.2 *Leakage Currents* — Parallel conduction can affect the accuracy of the measurement. Its influence is reduced by employing a high measurement frequency.

6.4.3 *Large Excess Area* — Can give rise to errors on n-type material particularly when profiling Hi-Lo structures. The excess area is electrolyte dependent but is mainly affected by the quality of the seal used to define the area. Large excess areas indicate a poor seal and are corrected by replacing the seal.

6.5 *Hi-Lo Structures* — Measurement is subject to inaccuracy due to carrier diffusion and excess area errors. For accurate measurements, chemically etch to the layer of interest before measurement.

6.6 *Contact Quality* — Non-Ohmic or high resistance contacts have a deleterious effect on the measurement. Contacts should be checked by measuring the resistance between two similar contacts and then reversing the current direction and repeating the measurement.

6.7 *Surface and Deep States* — Cause the measured capacitance to be frequency dependent and/or dependent on the rate at which the bias is changed. Usually resolved by using a high measurement frequency. This should not be confused with the frequency dependence which is more usually attributed to high series resistance.

6.8 *Surface Films* — Have a deleterious effect on the capacitance measurement. Film formation should be avoided by using an appropriate electrolyte, control of the etching bias and time and by electrolyte circulation.

6.9 Surface Roughness — The surface of the sample should be smooth and free of features that would affect the action of the seal.

6.10 *Light* — Light can affect the capacitance measurement, so the sample must be placed in a dark environment during the measurement.

6.11 *Sample Loading* — The accuracy of the measurement depends on the repeatability of the area. If a compliant seal is involved, such as a plastic ring, the sample should be held in contact with the seal by applying a controlled and constant force. No relative lateral movement should take place during the loading process.

6.12 *Ring Variability* — The condition of the ring has a large effect on the measurement. Good seals will have a small to zero excess area and exhibit a well defined and reproducible contact area.

7 Apparatus

7.1 *Measurement of Etch Well and Ring Areas* — Measuring microscope with either an XY stage, with a linear resolution of 0.01 mm or better, or a camera and image processing system capable of measuring an area of 0.1 cm^2 to better than 0.5%.

7.2 *Measurement of Etch Well Flatness* — (Optional) A means such as a stylus profiler for checking the flatness and roughness of the etch well. In most cases visual inspection of the etch well, for a mirror like appearance, is sufficient indication of low roughness.

7.3 *Instrumentation*

7.3.1 *Capacitance Meter* — Capable of measuring values up to 300 nF, employing a test signal of amplitude less than 100 mV RMS. The measurement frequency should be typically between 1 and 100 kHz.

7.3.2 *Equivalent Circuit Model* — The meter should assume a parallel circuit model for the electrolyte/semiconductor interface and provision should be made to compensate for the large series resistance of the electrolyte and contacts.

7.3.3 *Potentiostat* — Capable of maintaining the potential of the sample with respect to a reference electrode constant to ±5mV during the measurement and with a reference input impedance of > 10^{13} Ohms.

7.3.4 *Light Source* — A source of uniform illumination of above band gap energy for etching n-type materials.

7.4 *Sample Holder*

7.4.1 *Electrochemical Cell* — Used to hold the sample, contain the electrolyte and support the sealing ring and other electrodes, see Figure 1.

7.4.1.1 *Sealing Ring* — A corrosion resistant ring which forms a seal between the electrolyte and the sample. This ring defines the measurement area which should be reproducible and well defined. The ring area should not be less than 0.008 cm^2 and the reproducibility between runs should be better than ± 3%. Large ring areas (typically ≥ 0.1 cm^2) are preferred for more accurate measurements.

7.4.1.2 *Reference Electrode* — Used to control the sample bias via a potentiostat.

7.4.1.3 *Counter Electrode* — The bias and test signals are applied between this electrode and the sample.

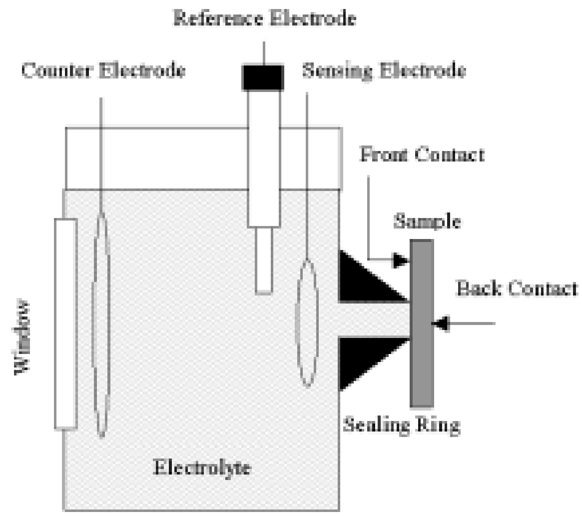


Figure 1
Electrochemical Cell

7.4.1.4 *Sensing Electrode* — Placed close to the sample-electrolyte interface and used to measure the admittance of the sample.

7.4.1.5 *Sample Contacts* — Ohmic contacts to the front and/or back surface of the sample for the purpose of applying bias.

8 Reagents and Materials

8.1 *Purity of Reagents* — All chemicals for which such specifications exist shall conform to SEMI C1.

8.2 *Purity of Water* — Use either distilled or de-ionized water having a resistivity greater than 2 MOhm•cm at 25°C as determined by the Non-Referee Test of Test Methods D 1125.

8.3 *Selection of Electrolyte* — The choice of electrolyte is not defined by this standard and is up to the discretion of the user or by agreement between the customer and the supplier.

8.3.1 *InP, GaAs and Related Compounds* — Preferred electrolyte, Na_2.EDTA (0.1 M) basified with ethylenediamine to a pH of 10, although other electrolytes can be satisfactorily used.

NOTE 1: Preferred electrolyte, see reference “Electrochemical C-V Profiling of Heterojunction Device Structures” A.C.Seabaugh et al. IEEE Trans on Electron Dev 36 No 2 (1989) 309-313.

9 Safety Precautions

9.1 The electrolytes used are potentially hazardous. Read the Materials Safety Data Sheets before attempting to prepare the electrolytes. Use safety eyewear, rubber gloves and protective clothing. Prepare all electrolytes in a fume hood.

9.2 Ensure that all electrolytes are correctly labeled.

10 Specimen Preparation

10.1 The sample should be free from surface debris and scratches. The sample should be cleaned with deionized (DI) water and dried.

10.2 To measure a single layer or upper layer of a multilayered structure, no additional sample preparation is required.

10.3 For a buried layer in a multilayered structure, measurement accuracy is improved by removing the overlaying layers by either the use of selective or controlled chemical etches.

10.4 If the upper layers cannot be removed by chemical etching then the sample can be profiled electrochemically but in some cases this may reduce the accuracy of the method.

10.5 For conducting substrates Ohmic contacts should be made to either the front or back of the wafer. For insulating substrates an Ohmic contact should be made to the front of the epilayer. Contacts are formed electrically, by alloying or by any other suitable method. The quality of the contact should be verified electrically.

11 Calibration and Standardization

11.1 *Sealing Ring* — Calibration of the sealing ring areas is performed using a "blue slice", made by growing an anodic oxide film on a polished n-type substrate.

11.1.1 The "blue slice" is profiled according to this test method. Etch only the minimum amount necessary to see the illuminated area (typically 0.5 μm). Flush the cell several times with DI water before removing the sample. Wash and measure the sample as soon as possible.

11.1.2 *Wetted Area* — The wetted area is observed due to chemical attack of the oxide film and is measured using a measuring microscope with cross hair eye-pieces and micrometer XY stage or by using a zoom camera and image processing system.

11.1.3 *Illuminated Area* — Etches in the light and forms a well defined etch well, which is measured as per the wetted area.

11.1.4 *Calibration Interval* — Regularly check the area and condition of the sealing ring. For daily use, the ring areas should be calibrated at least three times a week.

11.1.5 *Replacement* — Rings should be replaced if the excess area exceeds 10% for rings of area ≤ 0.05 cm^2 or 5% for rings of area > 0.05 cm^2 or if the perimeter is not uniform.

11.1.6 *Alternative Calibration Method* — The areas can be measured using known n and p-type test samples. This method is best suited for continual monitoring of the ring area between "blue slice" calibrations.

11.2 *Instrumentation* — The bias voltage, measurement frequency and capacitance measurement should be checked annually.

11.2.1 *Bias* — The bias voltage should be checked with a DVM with an input impedance > 1 MOhm.

11.2.2 *Capacitance* — The capacitance measurement should be checked using calibrated fixed value capacitors covering the expected sample capacitance range or from 1–100 nF.

11.2.3 *Frequency* — The measurement frequency should be checked with a frequency counter.

12 Measurement Procedure

12.1 *Choice of Electrolyte* — An electrolyte should be selected that forms a rectifying barrier with the sample, gives a flat, mirror finish etch well and generates only a small excess area.

12.2 *Sample Mounting* — A region of the sample should be defined which will form the rectifying contact with the electrolyte. This area can be defined by some form of sealing ring or mask, but it is important that the area of contact between the electrolyte and the sample be precisely known and remain constant during the measurement.

12.2.1 *Sealing Ring* — If the sample is pressed against a sealing ring, the seal must be cleaned with DI water and dried before positioning the sample. If the sample needs repositioning, the sample and sealing ring should be recleaned and dried.

12.2.2 *Ring Loading* — As the mounting pressure may effect the reproducibility of the measurement and the lifetime of the sealing ring, it must be controlled (e.g. by the reproducible use of a suitable compression spring).

12.3 *Cell Filling and Debubbling* — Fill the cell, which holds the sealing ring and other measurement electrodes, with the electrolyte. The process of filling the cell frequently traps bubbles of air on the surface of the sample. These bubbles must be removed before a measurement can be made.

12.4 *Contact Evaluation* — Verify that the contacts, for both directions of current flow have low and approximately equal resistance.

12.5 *Rest Potential* — Measure the sample's rest potential to verify that the reference electrode and sample are electrochemically stable. Its value usually lies between 0 and −1 V (respective to a SCE reference electrode). Values outside this range can indicate a problem with the sample or reference electrode.

12.6 *Cable Compensation* — Determine any stray capacitance or additional resistance associated with the cell and test leads that would impact the measurement.

12.7 *Current vs. Voltage (I-V)* — Used to select the bias for measurement and etching and as a general test of material quality.

12.7.1 *Measurement Bias* — is set in the reverse bias, low dark current region.

12.7.2 *Etching Bias (p-type material)* — is set in the forward bias region. The abruptness of the forward bias breakdown is indicative of the ohmic nature of the contacts. No or shallow forward breakdown often indicates unsuitable ohmic contacts.

12.7.3 *Etching Bias (n-type material)* — is set in the reverse bias, low dark current region. Illumination should result in a significant increase in current (photo-current).

12.8 *Capacitance vs. Voltage (C-V)* — Used to evaluate the quality of the electrochemical diode and to select a range of possible measurement voltages. The measured flatband potential (respective to a SCE reference electrode) should lie between −0.5 and −2.5 V for n-type semiconductors and between –1 and +1 V for p-type semiconductors.

12.8.1 *Measurement Bias* — is set in a region of low dissipation, where the $1/C^2$ vs V plot is linear. For layers grown with concentration gradients, the latter condition cannot be strictly adhered to and in such cases the amplitude of the test signal, used for capacitance measurement, should be kept as small as possible.

12.8.2 *Dissipation* — The normally accepted safe level is < 0.4.

12.8.3 *Excess Area Capacitance* — For n-type surface layers the capacitance of the electrolyte/semiconductor interface is measured prior to etching and the capacitance associated with the excess area is computed by multiplying the measured capacitance by the ratio of the excess area to the wetted area.

12.9 *Carrier Concentration Profiling* — Profile the sample using the etching and measurement conditions determined from the I-V and C-V data.

12.9.1 *Carrier Concentration* — The carrier concentration is determined from the C-V data.

12.9.2 *Excess Area Correction* — For n-type material the capacitance associated with material in the excess area should be subtracted from the measured capacitance.

12.9.3 *Etching* — The sample is anodically etched at the etching bias. The depth of the etch well is determined from the time integral of the current using Faraday's law of electrolysis.

12.9.4 *Profiled Depth* — The profile assumes that the measured carrier concentration lies at a depth equal to the sum of the etch and the depletion depths.

12.10 *Ring Area* — It is advised to measure the etch well area after profiling and to use this value to recalculate the carrier concentration vs. depth profile.

13 Calculations and Interpretation of Results

13.1 *Carrier Concentration,* N

The principle of this method is based on measuring the slope of $1/C^2$ vs V.

$$N = \frac{-2}{q\varepsilon_0\varepsilon_r A^2}\cdot\left[\frac{d\left(1/C^2\right)}{dV}\right]^{-1} \qquad [\mathrm{cm}^{-3}]$$

where

C is the measured capacitance (for n-type material the capacitance associated with the excess area should be subtracted from the measured capacitance),
V is the applied bias,
q is the electronic charge,
ε_r is the relative permittivity of the sample,
ε_o is the permittivity of free space
(= 8.854×10^{-12} Fm^{-1})
A is the area of the etch well

It is also possible to measure dC/dV by modulating the bias with a low frequency (secondary signal). The $d(1/C^2)/dV$ of the upper equation may be evaluated to result in the following formula.

$$N = \frac{1}{q\varepsilon_0\varepsilon_r A^2}\cdot\frac{C^3}{dC/dV} \qquad [\mathrm{cm}^{-3}]$$

13.1.1 *Excess Area Capacitance*, C_{excess}

$$C_{excess} = C.\frac{A_w - A_i}{A_w} \qquad [F]$$

Where

C_{excess} is the capacitance of material in the excess area,

A_w is the wetted area,

A_i is the illuminated area

13.2 *Depletion Depth*, W_d, — calculated from the parallel plate capacitor equation.

$$W_d = \frac{\varepsilon_0 \varepsilon_r A}{C} \qquad [\mu m]$$

13.3 *Etched depth*, W_e, — calculated from the charged passed through the cell using Faraday's law for electrolysis.

$$W_e = \frac{M}{zFDA} \int I dt \qquad [\mu m]$$

Where

z is the effective dissolution valency,
F is the Faraday constant,
(= 9.65×10^4 $Cmol^{-1}$)
D is the density of the semiconductor,
M is the molecular weight of the semiconductor
I is the etch current

13.4 *Total depth*, W, — the sum of the depletion and etch depths and is the depth at which the measurement is made.

$$W = W_d + W_e \qquad [\mu m]$$

14 Reporting Results

14.1 The following information shall be included in the report:

14.1.1 *Identification of Specimen* — including details of any pretreatment such as the use of a selective etch to chemically etch the sample to the layer of interest.

14.1.2 *Sealing Ring Area* — both the wetted and illuminated areas should be reported.

14.1.3 *Electrolyte* — the composition of the electrolyte should specify the molecular concentration.

14.1.4 *Material Constants* — The relative permittivity of the sample, ε_r and the effective dissolution valency, z.

14.1.5 *Primary Measurement Signal* — the frequency and amplitude of the signal used for the capacitance measurement.

14.1.6 *Secondary (bias) Signal* — If the measurement is made using a secondary modulation component its frequency and amplitude should be reported. If the measurement is made by changing the bias, its minimum and maximum value should be specified.

14.1.7 *Measurement Bias* — The average value (DC component) of the bias used during the capacitance measurement.

14.1.8 *Electrochemical Etching Bias* — The bias used to etch the sample including whether or not the sample was illuminated. If etched at a constant current this should be stated. Then it is not necessary to report the bias.

14.1.9 *Electrochemical Etching Current* — If etched at constant bias the average value of current measured during electrochemical etching. If etched at a constant current the value used.

SEMI M47-0302
SPECIFICATION FOR SILICON-ON-INSULATOR (SOI) WAFERS FOR CMOS LSI APPLICATIONS

This safety guideline was technically approved by the Silicon Wafer Committee and is the direct responsibility of the Japanese Silicon Wafer Committee. Current edition approved by the Japanese Regional Standards Committee on January 11, 2002. Initially available at www.semi.org January 2002; to be published March 2002. Previously published November 2001.

1 Purpose

1.1 This specification defines thin-layer silicon-on-insulator (SOI) wafer requirements for CMOS large scale integrated circuit (LSI) devices. In another aspect, this specification defines the generic characteristics of SIMOX and bonded silicon-on-insulator wafers having typically no more than 0.2 μm SOI layer thickness. By defining parameters, inspection procedures and acceptance criteria, both users and suppliers may uniformly define product characteristics and quality requirements.

2 Scope

2.1 This specification is specifically directed to SIMOX and bonded silicon-on-insulator wafers, which are exclusively used for LSI applications made up of CMOS devices.

2.2 A complete purchase specification requires the base silicon wafer, SOI surface and layer, and buried oxide layer properties detailed in this standard, suitable test methods for their characterization. SEMI M18 may be for purchase specification purpose.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M18 — Format for Silicon Wafer Specification From for Order Entry

SEMI M22 — Specifications for Dielectrically Isolated (DI) Wafers

SEMI M34 — Guide for Specifying SIMOX Wafers

SEMI M35 — Guide for Developing Specifications for Silicon Wafer Surface Features Detected by Automated Inspection

SEMI M41 — Specification of Silicon-on Insulator (SOI) for Power Device/ICs

3.2 *ASTM Standards*[1]

E122 — Practice for Choice of Sample Size to Estimate Average Quality of a Lot or Process

F26 — Standard Test Methods for Determining the Orientation of a Semiconductive Single Crystal

F42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconductor Materials

F84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

F523 — Standard Practice for Unaided Visual Inspection of Polished Silicon Wafer Surfaces

F533 — Standard Test Method for Thickness and Thickness Variation of Silicon Wafers

F671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Materials

F928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F1152 — Standard Test Methods for Dimensions of Notches on Silicon Wafers

F1188 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

F1241 — Standard Test Methods for Terminology of Silicon Technology

F1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

F1526 — Standard Test Method for Measuring Surface Metal Contamination on Silicon Wafers by Total Reflection X-Ray Fluorescence Spectroscopy

F1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F1619 — Standard Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at Brewster Angle

F1620 — Standard Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Wafer Surfaces

F2074 — Standards Guide for Measuring Diameter of Silicon and Other Semiconductor Wafers

3.3 *JEITA Standards* [2]

JEIDA 27 — Standard Specification for Dimensional Properties of Silicon Wafers with Specular Surface

JEIDA 61 — Standards Test Method for Interstitial Atomic Oxygen of Silicon by Infrared Absorption

3.4 *ANSI Standard* [3]

ANSI/ASQCZ1.4 — Sampling Procedure and Tables for Inspection

4 Terminology

4.1 Many terms relating to silicon technology are defined in ASTM Terminology F 1241. Other terms are defined as below.

4.2 *Abbreviations and Acronyms*

4.2.1 *BOX* — buried oxide layer

4.2.2 *SIMOX* — separation by implanted oxygen

4.3 *Definitions*

4.3.1 *bonded interface* — the plane where the bonding between handle and device wafers takes place.

4.3.2 *bonded wafer* — an SOI wafer made by bonding two silicon wafers with an insulating layer between them. The insulating layer is typically thermally grown oxide.

4.3.3 *BOX pin-hole* — electrically conductive path through the BOX.

4.3.4 *buried oxide layer* — the silicon dioxide layer between SOI layer and base silicon substrate.

4.3.5 *handle wafer or base silicon wafer or base silicon substrate* — the substrate which structurally supports the BOX and the SOI layer.

4.3.6 *HF defect* — defect in the SOI layer decorated by immersing the wafer in HF for a certain time.

4.3.7 *non-SOI edge area* — an annulus between the nominal radius of the surface silicon layer and the nominal radius of the base silicon wafer (for bonded SOI wafers). The annulus which implies an area is determined by its width as one dimension. It is the difference in the nominal radius of the surface silicon layer and the base silicon wafer.

4.3.8 *SIMOX wafer* — SOI wafer made by oxygen implantation technology

4.3.9 *SOI etch pit* — defect in an SOI layer decorated by immersing the wafer in Secco etch solution.

4.3.10 *SOI layer or surface silicon layer* — the silicon layer on the BOX of the SOI wafer.

4.3.11 *void* — local absence of SOI layer and/or BOX in bonded wafer.

5 Ordering Information

5.1 Purchase orders for SIMOX or bonded silicon-on-insulator wafers furnished to this specification shall include the following items:

- Characteristics for the SOI layer (thickness, crystal orientation, dopant, etc.)
- Characteristics for the base silicon substrate (thickness, crystal orientation, dopant, etc.)
- Characteristics of the buried oxide (thickness, dielectric breakdown voltage, etc.)
- Misalignment of wafer orientation between the SOI layer and the handle wafer
- Sampling plan and lot acceptance procedures (see Section 7)
- Methods of test and measurements (see Section 8)

6 Requirement

6.1 Requirements of SOI wafers consists of a base silicon wafer specification part and an SOI wafer specification part. A base silicon wafer is specified based on a SEMI M18 format. A similar format is applied for the specification of an SOI wafer.

2 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: www.jeita.or.jp

3 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

6.2 As a minimum, the base silicon wafer shall conform to SEMI M1 and the appropriate individual polished monocrystalline silicon wafer standard; i.e. JEIDA 27.

6.3 SOI wafer specified items and test methods are listed in Table 1 and shall not exceed the limits as given in Table 1.

Table 1 Specification of SOI Wafers for CMOS LSI Applications

	Item	*Specification Units*		*Standard reference*	*Test method*
		SIMOX	*Bonded*		
Base Silicon Wafer					
1. GENERAL CHARACTERISTICS					
1.1	Growth Method	CZ	CZ		
1.2	Crystal Orientation	(100) ± 1°	(100) ± 1°	ASTM F 26	X-ray diffraction
1.3	Conductivity Type	P-type	P-type	ASTM F 42	Hot point probe
1.4	Dopant	Boron	Boron		
1.5	Edge Exclusion, Nominal	3 (mm)	3 (mm)		
2. ELECTRICAL CHARACTERISTICS					
2.1	Resistivity (Center Point)	See NOTE 1.	See NOTE 1.	ASTM F 84	4-point probe
3. CHEMICAL CHARACTERISTICS					
3.1	Oxygen Concentration	See NOTE 1.	See NOTE 1.	ASTM F 1188, F 1619, JEIDA 61	IR absorption
4. STRUCTURAL CHARACTERISTICS					
4.2	Slip	None	None	ASTM F 523	Visual inspection
4.3	Lineage	None	None	ASTM F 523	Visual inspection
4.4	Twin	None	None	ASTM F 523	Visual inspection
4.5	Swirl	None	None	ASTM F 523	Visual inspection
4.6	Shallow Pits	None	None	ASTM F 523	Visual inspection
5. WAFER PREPARATION CHARACTERISITICS					
5.1	Wafer ID	See NOTE 1.	See NOTE 1.		
5.4	Extrinsic Gettering Treatment	See NOTE 1.	See NOTE 1.		
6. MECHANICAL CHARACTERISTICS					
6.1	Nominal Diameter	150 / 200 (mm)	150 / 200 (mm)	ASTM F 2074	
	Diameter Tolerance	≤ ± 0.2 (mm)	≤ ± 0.2 (mm)	ASTM F 2074	
6.2	Primary Flat Length/Notch Dimension	SEMI M1 or JEIDA 27	SEMI M1 or JEIDA 27		
6.3	Primary Flat/Notch Orientation	[011] ± 1°	[011] ± 1°	ASTM F 671, F 1152	
6.6	Edge Profile	SEMI M1	SEMI M1	ASTM F 928	
6.6.1	Edge Surface Finish	See NOTE 1.	See NOTE 1.	ASTM F 928	
6.7	Thickness	SEMI M1 or JEIDA 27	SEMI M1 or JEIDA 27	ASTM F 533	Thickness gauge
6.8	Thickness Variation (TTV)	SEMI M1	SEMI M1	ASTM F 533	Thickness gauge
6.14	Flatness Site	See NOTE 1. (Refer to SEMI M18.)	See NOTE 1. (Refer to SEMI M18.)		
8. FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS					
8.01	Specified according to SEMI M1 Table 1			ASTM F 523	Visual inspection
9. BACK SURFACE VISUAL INSPECTION CHARACTERISTICS					

	Item	*Specification Units*		*Standard reference*	*Test method*
		SIMOX	*Bonded*		
9.01	Specified according to SEMI M1 Table 1			ASTM F 523	Visual inspection
SOI Wafer					
20. SOI LAYER CHARACTERISTICS					
20.1	Growth Method	CZ	See NOTE 1.		
20.2	Surface Silicon Thickness	≤ 0.2 (µm) See NOTE 1.	≤ 0.2 (µm) See NOTE 1.		Spectroscopic ellipsometry, Spectroscopic reflectometry
20.3	Surface Silicon Thickness Mean Value Variation	≤ ± 5 (nm)	≤ ± 5 (nm) See NOTE 2.		Spectroscopic ellipsometry, Spectroscopic reflectometry
20.4	Surface Silicon Thickness Variation in Wafer	≤ ± 3 (nm)	≤ ± 7.5 (nm) See NOTE 2.		
20.5	Crystal Orientation	(100) ± 1°	(100) ± 1°	ASTM F 26	X-ray diffraction
20.6	Rotation Misalignment	NA	≤ ± 1°		Visual
20.7	Edge Exclusion, Nominal	5 (mm) See NOTE 3.	5 (mm) See NOTE 3.		
20.8	Non-SOI Edge Area	NA	≤ 3 (mm)		Visual
20.9	Conductivity Type	P-type	P-type	ASTM F 42	
20.10	Dopant	Boron	Boron		Secondary ion mass spectroscopy
20.11	Dopant Concentration	See NOTE 1.	See NOTE 1.		Secondary ion mass spectroscopy
20.12	SOI Etch Pit	$< 1 \times 10^6$ (/cm^2)	$< 1 \times 10^4$ (/cm^2)		Secco's etching
20.13	Threading Dislocation	$< 5 \times 10^4$ (/cm^2) (LD) $< 5 \times 10^5$ (/cm^2) (HD)	NA		Secco's etching
20.14	HF Defect	< 0.5 (/cm^2)	< 0.5 (/cm^2) (150 mmϕ) < 0.3 (/cm^2) (200 mmϕ)		HF etching
20.15	Void	NA	See NOTE 1.		Visual, Automated particle counter
20.16	Roughness (Si surface) rms @ 2 × 2µm	< 0.4 (nm)	< 0.2 (nm)	See NOTE 4.	Atomic force microscope
20.17	Surface Metal Contamination (Fe, Cr, Ni, Cu)	$< 5 \times 10^{10}$ (/cm^2) for each atom	$< 5 \times 10^{10}$ (/cm^2) for each atom	ASTM F 1526	TXRF AAS, ICP-MS
21. BOX CHARACTERISTICS					
21.1	BOX Thickness	≤ 0.4 (µm) See NOTE 1.	≤ 0.4 (µm) See NOTE 1.		Spectroscopic ellipsometry, Spectroscopic reflectometry
21.2	BOX Thickness Variation	≤ ± 5 (%)	≤ ± 5 (%)		Spectroscopic ellipsometry, Spectroscopic reflectometry
21.3	Bonded Interface Location	NA	See NOTE 1.		

	Item	Specification Units		Standard reference	Test method
		SIMOX	Bonded		
21.4	BOX Pinholes	< 0.5 (/cm^2) (LD) < 0.1 (/cm^2) (HD)	< 0.1 (/cm^2)		Cu plating, BOX capacitor
21.5	Dielectric Breakdown	> 5 (MV/cm)	> 6 (MV/cm)		BOX capacitor
22. MECHANICAL CHARACTERISTICS					
22.1	Warp	< 40 (μm) (LD) < 50 (μm) (HD)	< 40 (μm)	ASTM F 1390	Automated noncontact scanning
22.2	Flatness-site	See NOTE 1. (Refer to SEMI M18.)	See NOTE 1. (Refer to SEMI M18.)		
23. FRONT SURFACE VISUAL INSPECTION CHARACTERISTICS					
23.1	Scratch	None	None	ASTM F 523	Visual inspection
23.2	Haze	None	None	ASTM F 523	Visual inspection
23.3	LLS @particle size	≤ 0.3 (/cm^2) @ > 0.25 μm	≤ 0.3 (/cm^2) @ > 0.2 μm	SEMI M35	Automated particle counter
23.4	Slip	See NOTE 1.	See NOTE 1.	ASTM F 523	Visual inspection
23.5	Edge Chip	SEMI M1	SEMI M1	ASTM F 523	Visual inspection
23.6	Edge Crack	SEMI M1	SEMI M1	ASTM F 523	Visual inspection
23.7	Foreign Matter	See NOTE 1.	See NOTE 1.	ASTM F 523	Visual inspection
24. BACK SURFACE CHARACTERISTICS					
24.1	Backside Metal Contamination (Fe, Cr, Ni, Cu)	< 1 × 10^{11} (/cm^2) for each atom	< 1 × 10^{11} (/cm^2) for each atom	ASTM F 1526	TXRF AAS, ICP-MS

NOTE 1: to be specified or discussed between users and suppliers
NOTE 2: typically 0.1 μm and thicker SOI are specified. Thinner SOI is to be discussed between users and suppliers.
NOTE 3: It is specified by a distance from the FQA boundary to the periphery of a base wafer of nominal dimensions. It is not a distance from an edge of an SOI layer.
NOTE 4: JEITA Standards "One-Nanometer-Order Z-Axis Calibration Height of AFM" will be available in April 2002.
NA: not applicable
LD: Low dose SIMOX with BOX thickness ≤ 200 nm
HD: High dose SIMOX with BOX thickness > 200 nm

7 Sampling Plan

7.1 Unless otherwise specified, ASTM Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned with an acceptable quality level (AQL) of lot tolerance percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL or LTPD values. Inspection levels shall be agreed upon between users and suppliers.

8 Test Methods

8.1 *Thickness of Surface Silicon Layer and Buried Oxide Layer*

8.1.1 *Measurement Methods* — Two non-contact, non-destructive optical characterization techniques, spectroscopic ellipsometry (SE) and spectroscopic reflectometry, have proven useful both for surface silicon layer and buried oxide (BOX) layer thickness measurements. Both techniques use reflected light to allow deduction of the thickness and refractive index of thin layers. In both cases, layer thickness and index of refraction data must be "backed out" of the measured optical data by a process of successive approximation. Silicon islands in the BOX layer of SIMOX and interface non-uniformity make these techniques less reliable.

8.1.1.1 *Spectroscopic Ellipsometry (SE) Measurement* — In this measurement, white light from a xenon arc lamp passes through a polarizing rotating filter and illuminates the sample site under study; reflected light passes through an analyzer to a monochrometer and photomultiplier detector. For each wavelength, reflectivity oscillates with polarizer rotation; the magnitude and phase of reflectivity changes are measured to determine ellipsometric angles, δ and Ψ. The two measured spectra are fit by successive approximation to allow determination of the surface silicon layer and BOX layer thickness and oxide composition. For SE, the choice of instrument and associated model and fitting parameters affect the confidence-of-fit, so they should be taken into account in the user-supplier agreement.

8.1.1.2 *Spectroscopic Reflectometry Measurement* — In this measurement, light from a xenon arc lamp passes through a grating monochrometer or optical band-pass filters and illuminates the sample site under study; reflected light is gathered by a detector. Specular reflectivity is plotted as a function of wavelength from 0.4 µm to 1.1 µm. The analysis proceeds by making successively better approximations to index of refraction and absorption of each layer until an acceptable fit is achieved. Measurements are made with a reflectance mode optical interferometer.

8.1.1.3 *Optical Model Fitting and Correlation* — There are slight, systematic differences between layer thickness measured by SE and spectroscopic reflectometry. Because of this, users and suppliers should specify the actual measurement method to be used. The two methods offer results which are reproducible and well-correlated with each other over a wide range of conditions. If both measurement techniques are used, it is recommended that the reflectance system measurements should be calibrated to fit the results of the SE.

8.1.2 *Measurement Positions* — The measurement strategy is to make a detailed measurement with an accurate fit on at least nine wafer sites, for example, the wafer center, four points at half of the wafer radius and four points at 10 mm from the wafer edge. The number and position of wafer sites to be monitored should be agreed on between users and suppliers. Generally, the greater the variability relative to the mean, the larger the number of sites that should be monitored. In each case, the measurement system supplies a "goodness-of-fit" parameter that indicates a level of confidence in the fit to the measured data.

8.1.3 *Surface Silicon Layer and Buried Oxide (BOX) Layer Thickness* — Spectra for each site are fit independently with both the surface silicon and BOX layer thickness as adjustable parameters. Both the mean thickness and the uniformity should be specified.

8.1.4 *Surface Silicon Thickness Mean Value Variation*

8.1.4.1 After surface silicon layer thickness is measured for predetermined number of wafers and mean value of surface silicon thickness is derived for each wafer, the maximum and the minimum values are chosen, and then the variation (nm) is calculated as;

$$\pm \text{(Maximum mean value – Minimum mean value)} / 2$$

8.1.4.2 In case of quite large number of wafers (ex. a few hundreds), the variation (mm) can be calculated as;

$$\pm 3\sigma \text{ (3 times of the standard deviation)}$$

under agreement between users and suppliers.

8.1.5 *Surface Silicon Thickness Variation in Wafer*

8.1.5.1 After surface silicon layer thickness is measured at predetermined number of points within an SOI wafer, the maximum and the minimum values are chosen, and then the variation (nm) is calculated as ;

$$\pm \text{(Maximum value – Minimum value)} / 2$$

8.1.5.2 In case of multi-points measurements (ex. a few hundreds) within an SOI wafer, the variation (nm) can be calculated as;

$$\pm 3\sigma \text{ (3 times of the standard deviation)}$$

under agreement between users and suppliers.

8.1.6 *Buried Oxide (BOX) Thickness Variation*

8.1.6.1 After BOX thickness is measured for predetermined number of points on predetermined number of wafers, the maximum and the minimum values are chosen, and then the variation (%) is calculated as;

$$\pm \text{(Maximum value – Minimum value)} \times 100 / (2 \times \text{mean value})$$

8.1.6.2 In case of multi-points measurements (ex. a few hundreds) within an SOI wafer or quite large number of wafers (ex. a few hundreds), the variation (%) can be calculated as;

$$\pm 3\sigma \text{ (3 times of the standard deviation)} \times 100 / \text{(mean value)}$$

under agreement between users and suppliers.

8.2 *Dopant Concentration*

8.2.1 Secondary Ion Mass Spectroscopy (SIMS) is utilized to determine dopant concentration in surface silicon layer.

8.2.2 The acceptable dopant concentrations are to be determined by agreement between users and suppliers.

8.3 *Defects in Surface Silicon Layer*

8.3.1 *SOI Etch Pit*

8.3.1.1 Defects in surface silicon layer including stacking faults, threading dislocations and other crystal defects are evaluated by destructive chemical etching and microscopic etch pit density measurements. The appropriate evaluation procedure for SOI wafers, which depends on type of defects targeted and thickness of surface silicon layers, is determined by agreement between users and suppliers.

8.3.1.2 Following are examples of the evaluation on SIMOX wafers and bonded wafers.

8.3.1.3 *Example 1* — SOI etch pit evaluation in SIMOX wafers: Samples are first immersed in HF to remove oxide from the surface. Then the samples are etched by Secco etch. In the case of a relatively thick SOI layer such as 170–200 nm, freshly prepared standard Secco Etch can be used: one part (by volume) of a 0.15 molar solution of $K_2Cr_3O_7$ in distilled water and two parts HF (49%). In the case of a thin SOI layer below 100 nm, the samples are etched for 30 seconds in the solution[4]: 50 ml of HF (49%) plus 80 ml of HNO_3 (61%) plus 160 ml of H_2O [$K_2Cr_2O_7$ 1g + $Cu(NO_3)_2 \cdot 3H_2O$ 4g] (a sort of diluted Secco etch). For both cases, the etching should continue until 50 nm of the surface Si remains. After the etching and rinsing in water, samples are dipped in HF (49%) for 5 minutes. The HF etches the buried oxide and creates cavities under the etch pits. The number of etch pits is counted through optical microscope. The etch pits include various defects such as threading dislocations and stacking fault pyramid.

8.3.1.4 *Example 2* — SOI etch pit evaluation in bonded SOI wafers fabricated by delamination followed by CMP: SOI etch pit density increases when remaining SOI thickness after Secco etching is thinner and thinner. SOI layers thicker than 150 nm are usually etched down to 50 nm by Secco etching before SOI etch pits are counted. These pits are detected when selectively etched depth or the size of defects is larger than SOI layer thickness remaining after Secco etching. Thus, damages deeper than 50 nm or defects larger than 50 nm can be detected. These pits come from defects contained in original silicon material and/or damages or defects induced in SOI fabrication process. The former includes COP, bulk micro defects, oxygen precipitates, and so on. The latter includes CMP damages, defects induced by heat cycles and so on, as possibility. To define origins of SOI etch pits, their distribution in depth of SOI layers and/or that on a wafer should be evaluated. For example, CMP damages may be localized on surface of SOI layers. By etching SOI surfaces up to desired depth with using non-selective etching such as KOH followed by Secco etching, etch pits due to CMP damages disappear. The depth distribution of defects or damages can be evaluated in this manner.[5]

8.3.1.5 *Example 3* — SOI etch pit evaluation in bonded SOI wafers formed by epitaxial layer transfer technology: In this case, there is no COP, bulk micro defects, and oxygen precipitates in the SOI layer because it is made of epitaxially grown Si on porous Si. In addition, mechanical damage related defect is not introduced, since the SOI surface is smoothed out by hydrogen annealing instead of polishing. The major defect in this type of SOI wafers is same sided pyramidal stacking fault, that is induced at the initial stage of the epitaxy, and is grown through the epitaxy with upside-down pyramidal shape[6], and then is turned upside-down again by bonding. This defect is decorated as the etch pit by standard or diluted Secco's etching as described in Example 1 in conjunction with HF dipping. It is enough to etch until 50 nm of the SOI layer remaining to etch the defect portion through the SOI layer selectively by the defect etching such as Secco etching because the stacking fault penetrates through the SOI layer. The following HF dipping etches the BOX through the etch pit to form large cavity. It helps to count low density of defects in a wide observation area with low magnification microscope.

8.3.2 *Threading Dislocation*

8.3.2.1 The etching of the SIMOX sample shown above in Section 8.3.1.3 (Example 1) is terminated when the remaining surface silicon layer thickness is 1/3–1/2 of the initial thickness and then dipped in HF as the same manner as Example 1. In this case the etch pits include mainly threading dislocations only which can be counted through optical microscope.

8.3.3 *HF Defect*

8.3.3.1 Measurement of the microscopic etch pit density following an HF etch is commonly used to disclose defects in SOI material. Pitting of surface silicon may be present before the HF etch or be caused by HF etching. For this destructive measurement, a whole wafer or at least one quarter of a wafer should be used. The sample is placed in concentrated (49%) HF for 10 to 15 minutes or diluted (e.g. 25%) HF for longer time (e.g. 3 to 4 hours), then removed, rinsed and dried. If there are pits or voids and/or metal particles or silicides formed in the surface silicon layer, the HF etches the metals/silicides and then etch the buried oxide. This results in local etching of BOX with 25–50 μm diameter (depending on the HF concentration and the etch time) centered on the original defects. The defect density is then measured in an optical microscope using a 5× objective and 10× eyepiece or comparable setup. The samples should be scanned for whole surface within edge exclusion boundary.

8.3.4 *Void*

8.3.4.1 Voids are determined as an unbonded area on bonded SOI wafers. See SEMI M41. Because SOI layer in thin bonded SOI wafers are typically 0.2 μm thick or

4 L. F. Giles, A. Nejim, and P. L. F. Hemment, *Materials Chemistry and Physics*, vol.35, p. 129, 1993.

5 K. Mitani, H. Aga, and M. Nakano, *Jpn. J. Appl. Phys.* vol.36, p. 1646 1997.

6 N. Sato, K. Sakaguchi, K. Yamagata, Y. Fujiyama, J. Nakayama, and T. Yonehara, *Jpn. J. Appl. Phys.* vol.35, p. 973 (1996).

thinner, void areas are broken and SOI layers as well as BOX are usually absent. By this reason, voids are specified as local absence of SOI layers and/or BOX in bonded wafers in this specification.

8.3.4.2 *Visual inspection* — Under visible light, the edge of voids is detected because the edge area is step-shaped due to absence of SOI layers and/or BOX layers. See Section 8.8 for inspection conditions.

8.3.4.3 *Detection as large LLS* — The edge of local absence of SOI layer and/or BOX scatters light. Therefore, voids are detected as large LLS. See Section 8.7.2 for the principle. A size of LLS corresponding to various sizes of voids should be calibrated or correlated by comparison of defects one by one using a microscope.

8.4 *Surface Roughness*

8.4.1 *AFM (Atomic Force Microscope)* — By contacting the probe equipped with the cantilever onto the wafer surface of the sample, and by scanning the cantilever and detecting the variation by optical method, the roughness information is obtained. A tapping mode is commonly used.

8.5 *Metal Contamination*

8.5.1 The surface metal contamination can be measured by TXRF, AAS and ICP-MS methods.

8.5.2 *TXRF (Total X-Ray Fluorescence)* — Total X-ray Fluorescence uses a low angle incident, and a tightly collimated X-ray beam excites the characteristic X-rays from impurity atoms near the sample surface. Usually, the angle of X-ray incidence is less than 0.1 degree. The element identification and the amount of the element can be obtained by measuring energy and intensities of fluorescence X-ray. The instrument provides a map of impurity element distribution. Surface roughness may change metal detection sensitivity. Thus, calibration is suggested before samples with deferent level of roughness, e.g. back surface, are measured. A reference for details is ASTM F1526.

8.5.3 *AAS (Atomic Absorption Spectroscopy)*

8.5.3.1 The elemental characteristic absorption of the atom is measured by introducing sample solution as aerosol into the flame and then spectral absorption through the flame from the light source is detected by the spectrometer. The flameless method, superior to the flame method in the sensitivity, is now broadly used.

8.5.3.2 *Sample Preparation* — Careful sample preparation is necessary for the precise measurement. SOI wafer surface is exposed to HF vapor, and metals on the surface are collected as droplet. To improve sensitivity, the volume of collective solution should be as small as possible and HF drops are rolled all over the surface in collective operation. In case of precious metals, it is better to use other kinds of collective solutions instead, since they are not dissolved or collected by HF solution itself.

Examples:

1. For Cu ; HF-H_2O_2 (HF (50 wt.%) : H_2O_2 (31 wt.%): H_2O = 1 : 17 : 82 volume ratio)
2. For Au and Pt ; aqua regia (HNO_3 (68 wt.%) : HCl (36 wt.%) = 1 : 3 volume ratio)

8.5.4 *ICP-MS (Inductively Coupled Plasma Mass Spectroscopy)*

8.5.4.1 ICP-MS is composed of ICP (Inductively Coupled Plasma) part as an ion source and MS (Mass Spectrometer) part, which measures the ions generated at ICP part. Usually, sample solution is vaporized in the nebulizer and then finally introduced into Argon plasma in the silica tube called torch through the spray chamber. The sample is decomposed, evaporated, atomized and then ionized in the Argon plasma. Except for few atoms that have relatively high ionization potential, most of the elements (> 90%) can be ionized. Ions are identified and measured in amount by the mass spectrometer.

8.5.4.2 *Sample Preparation* — The same method as AAS method is applicable. In case of quantitative measurement of Fe, since its mass weight is close to that of ArO^+, it is necessary to pay attention to degradation of detection sensitivity.

8.6 *BOX Defect*

8.6.1 *BOX Pinhole Measurement-1 (by $CuSO_4$ plating or copper decoration)*

8.6.1.1 BOX pinhole evaluations shall be made by $CuSO_4$ plating or copper decoration methods. They can be also evaluated by BOX capacitor dielectric breakdown, the details of which are explained later in *BOX Pinhole Measurement-2*.

8.6.1.2 In evaluation by $CuSO_4$ plating method, the sample wafer is placed (front face down) on a paper towel soaked in 20% $CuSO_4$ solution on top of a copper plate. An aluminum plate is placed on the back of the wafer. The copper plate is grounded, and −25 V_{DC} is applied to the aluminum plate. Small leakage currents (sub-µA) through pinholes in the BOX cause copper to plate out onto the towel with the density same as BOX pinhole density.

8.6.1.3 In evaluation by copper decoration method, an SOI layer is first etched off by KOH solution to expose a BOX layer. Then the wafer is immersed in methanol and brought downward into direct contact with the gold-coated cathode. A copper mesh as an anode is immersed in the liquid 5 mm above the wafer. Required voltage is applied, such as the electric field in the buried oxide layer is 1 MV/cm. The voltage is measured at the oxide surface with a surface voltage probe. Localized copper decorations at pinhole sites in the oxide are observed with a low power optical microscope.

8.6.2 *BOX Capacitor Dielectric Breakdown* — This parameter can be measured with BOX capacitor. The BOX thickness affects both the test procedure (such as capacitor area and voltage criterion) and the allowable values of measured parameters. These should be determined by agreement between users and suppliers.

8.6.2.1 *Test Structure* — BOX capacitor utilizing mesa-etched SOI layers and Si substrates for both electrodes to apply electric field to the embedded buried oxide is used. The area of capacitor, which affects the breakdown voltage, should be determined by agreement between users and suppliers. Typical capacitor area is 0.01–0.1 cm^2. The electrode material and thickness affect the breakdown phenomena due to thermal effects, and so should be included in the agreement.

8.6.2.2 *Test Method: Staircase I-V Measurement* — Voltage is stepped in one-volt increments from zero to until destructive breakdown is sensed. The test detects the onset of high field conduction, as well as the point of destructive or massive charge injection and trapping.

8.6.3 *BOX Pinhole Measurement-2 (by Dielectric Breakdown)*

8.6.3.1 Buried oxide pinhole can be detected also by BOX capacitor.

8.6.3.2 *Test Structure* — BOX capacitor having an area equal to or greater than 0.05 cm^2.

8.6.3.3 *Test Method: Staircase I-V* — Measurement testing can be done for both Type I and Type II defects where Type I defects are silicon pipes traversing the buried oxide, and Type II defects are local regions of thin buried oxide. If Type II defect density is sought, capacitors are subjected to a series of 30 voltage steps of 3.3 volts, with current monitored after each step, using a failure criterion of 1 nA.

8.6.3.4 Any capacitor displaying the failure current or more for applied field less than 2 MV/cm is considered defective. Defect density of either type is calculated from the yield of good capacitors, (Y = 1 − # failed/# tested), using Poisson statistics;

$$D = -\ln(Y)/A,$$

where A is the total area of the capacitors tested.

8.7 *Particle (LLS : Localized Light Scatterer)*

8.7.1 *Light Scattering Tomography* — The particle larger than predetermined threshold size is counted by an automated particle counter.

8.7.2 *Principle of Measurement* — By scanning the laser beam on the wafer surface, the light scattered by particles on a wafer is detected. The scattered light and the noise from the wafer surface is detected as a direct current, on the other hand, the scattered light by the particles can be detected as pulse components. The particle size can be calibrated with standard polystyrene latex spheres. SOI wafers usually have scattering noise from the layer interface. It is necessary to reduce incident angle of the laser beam to increase the reflective component from the surface. For example, S/N ratio is improved when using S-polarized light of 10 degree incident, 85% of its component is reflected from silicon surface.

NOTE 1: Detailed procedure of size calibration with standard polystyrene latex spheres: Refer to ASTM F1620.

NOTE 2: Measurement procedure should be determined by agreement between users and suppliers.

8.8 *Visual Inspection* — SOI wafer can be visually inspected in accordance with ASTM F523. The automatic inspection equipment is also used when available. For visual inspection, the collimated high intensity bright light (e.g. 500,000 lux) is used. Under using this light, SOI wafer is inspected for haze, slip, scratches, chips, cracks, pits, dimples, mound, orange peel, voids, LLS and contamination.

SEMI M48-1101
GUIDE FOR EVALUATING CHEMICAL-MECHANICAL POLISHING PROCESSES OF FILMS ON UNPATTERNED SILICON SUBSTRATES

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this document is to provide a guide for evaluation of chemical-mechanical polishing (CMP) processes of thin films on unpatterned silicon substrates. This includes recommended procedures for process testing and reporting formats.

1.2 This guide is intended for use by both suppliers and end users.

2 Scope

2.1 This document provides a guide for evaluating a CMP process for films deposited or grown on an unpatterned silicon substrate. These evaluations could include tests with fixed polishing time, fixed removal rate, fixed ending thickness, time-dependent material removal, and others.

2.2 Recommended procedures for characterizing a CMP process are discussed in this guide.

2.3 This guide suggests selected parameters and values of the properties of the starting monitor wafer.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 The guide does not address evaluation of CMP processes for films on patterned substrates.

3.2 Evaluation of surface quality or surface contamination is not addressed in this document. Surface quality and surface contamination are important aspects of the CMP process evaluation but they are beyond the scope of this guide.

3.3 This guide employs sample standard deviation to estimate variation.

3.4 Wafer positioning precision on a metrology tool can affect the precision of the polishing evaluation. This issue is not addressed in this standard.

3.5 The values derived from the calculations in this guide are sample-dependent. They are affected by measurement location and number of observations.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E89 — Guide for Measurement System Capability Analysis

SEMI M1 — Specifications For Polished Monocrystalline Silicon Wafers

SEMI M11 — Specifications For Silicon Epitaxial Wafers For Integrated Circuit (IC) Applications

SEMI M20 — Specification for Establishing a Wafer Coordinate System.

4.2 *ASTM Standards*[1]

F 534 — Test Method for Bow of Silicon Slices

F 1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

F 1530 — Test Method for Measuring Flatness, Thickness and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning

F 1618 — Standard Practice for Determination of Uniformity of Thin Films on Silicon Wafers.

4.3 *DIN Standards*[2]

DIN 50441/4 — Prüfung von Materialen für die Halbleitertechnologie; Messung der geometrischen Dimensionen von Halbleiterscheiben; Scheibendurchmesser und Flattiefe. (Measurement Determination of the Geometric Dimensions of Semiconductors Slices [including] Diameter and Flat Depth)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 DIN Standards, Deutsches Institut fur Normung e.v., available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000 Berlin 30, Germany

5 Terminology

5.1 *blanket polish* — polishing of material deposited on an unpatterned silicon substrate.

5.2 *diameter scan* — measurements of material on a wafer taken along a specified diameter. The diameter scan is useful in determining the thickness profile of the material on the wafer surface.

5.3 *edge scan* — measurements of material taken along a specified radial segment in the edge region of the wafer. A series of edge scans can be employed to determine circumferential thickness profile.

5.3.1 *Discussion* — the data density for edge scan measurements is generally higher than for other measurements. Combining a low-density diameter scan in the central region of the wafer with a higher-density edge scan, taken along the same scan line, can improve throughput with appropriate local measurement data density.

5.4 *film total thickness variation (film TTV)* — the total thickness variation ($Thk_{max} - Thk_{min}$) of film material among a set of measurement points.

5.4.1 *Discussion* — The variation may pertain to a region within a wafer, a complete wafer or multiple wafers with a single polish head, or multiple wafers with multiple polish heads. These wafer and head combinations must be considered in planning and comparing measurements. If one assumes that a given wafer is polished by a subset of the tool heads (typically one), a hierarchical relationship exists such that wafers must be associated with the (tool head) subsets used to polish them. Another way to look at this is, if *head* is considered an experimental treatment, then a wafer polished by one head will be assumed to be treated differently than a wafer polished by a different head. This relationship leads to what is known as a hierarchic or nested model. (In this case, one says that wafer is nested within *head*). A more complete model would also treat *head* as a fixed effect, *wafer* random and nested within *head*, and error as nested with *head* and *wafer*. A random effect indicates that the observation comes from a random sample of a larger population. *Head* is a fixed effect because the entire population of heads (i.e., all the heads on the tools) constitutes the entire population of interest. Given this model, variance components would be used to estimate the different sources of variation. In this case, the sample standard deviation underestimates the population standard deviation. Historically, the expected value of the variance components is equal to the population standard deviation. This is not the case for the sample standard deviation.

5.5 *head to head removal rate non-uniformity (HTHNU)* — this metric is useful when evaluating polishing processes on a multi-head tool configuration. It is the standard deviation (1σ) of the removal rate variation from polish head (HTH) to polish head for a fixed number of wafers where the number of wafers run for each head must be equal. It is expressed as follows:

$$HTHNU = \sqrt{\frac{\sum_{k=1}^{p}\left(\overline{RR_k} - \overline{\overline{RR_{HTH}}}\right)^2}{p-1}} \quad 1)$$

Where k is the head indexer and p is the total number of heads. $\overline{RR_k}$ is the average within wafer removal rate of head k. $\overline{\overline{RR_{HTH}}}$ is the head to head wafer removal rate averaged across all wafers and all heads. The measurement site locations on each wafer must be identical for all wafers sampled.

It may also be expressed as a percentage of the average head to head removal rate:

$$\%\ HTHNU = \frac{\sqrt{\frac{\sum_{k=1}^{p}\left(\overline{RR_k} - \overline{\overline{RR_{HTH}}}\right)^2}{p-1}}}{\overline{\overline{RR_{HTH}}}} \times 100 \quad 2)$$

5.6 *removal rate (RR)* — the amount of material removed per unit time during the polish process. At any given point i on the wafer, the removal rate is expressed by

$$RR_i = \frac{Thk_{pre_i} - Thk_{post_i}}{\text{Polish time}} \quad 3)$$

5.7 *thickness, prepolish (Thk_{pre})* — the thickness of material on an incoming blanket film wafer prior to polish.

5.8 *thickness, post-polish (Thk_{post})* — the thickness of material remaining at a measurement site on a silicon substrate after completion of the polish process.

5.9 *wafer to wafer (WTW) variation* — the variation across multiple wafers at site locations where the locations on each wafer are identical for all wafers sampled.

5.10 *wafer to wafer removal rate nonuniformity (WTWNU)* — a measure of the wafer to wafer removal rate variation. It is the standard deviation (1σ) of the removal rate variation wafer to wafer over a polish run that employs a single polishing head. The average removal rate for such a group of wafers is expressed as:

$$\text{Average WTW RR} \Rightarrow \overline{\overline{RR}}_{WTW} = \sum_{j=1}^{m} \frac{\overline{RR_j}}{m} \qquad 4)$$

where *j* is the wafer indexer and *m* is the total number of wafers within the group. A typical number for m is ≥ 25.

The measurement site locations on each wafer must be identical for all wafers sampled. The wafer-to-wafer removal non-uniformity is expressed as follows:

$$WTWNU = \sqrt{\frac{\sum_{j=1}^{m} \left(\overline{RR}_{WIW} - \overline{\overline{RR}}_{WTW}\right)^2}{m-1}} \qquad 5)$$

It may also be expressed as a percentage of the average wafer to wafer removal rate:

$$\% \, WTWNU = \frac{\sqrt{\frac{\sum_{j=1}^{m} \left(\overline{RR}_{j_{WIW}} - \overline{\overline{RR}}_{WTW}\right)^2}{m-1}}}{\overline{\overline{RR}}_{WTW}} \times 100 \qquad 6)$$

5.11 *within wafer average removal rate* — the average removal rate within a wafer. It is given as

$$\text{Average WIW RR} \Rightarrow \overline{RR}_{WIW} = \sum_{i=1}^{n} \frac{RR_i}{n} \qquad 7)$$

where *i* is the site indexer and *n* is the total number of measurement sites within the wafer, and RR_i is within wafer removal rate.

5.12 *within wafer removal rate nonuniformity (WIWNU)* — a measure of removal rate variation. It is the standard deviation (1σ) of the removal rate within the wafer and is expressed as follows:

$$WIWNU = \sqrt{\frac{\sum_{i=1}^{n} \left(RR_i - \overline{RR}_{WIW}\right)^2}{n-1}} \qquad 8)$$

where *i* is the site indexer, *n* is the total number of measurement sites on the wafer and $\overline{RR_{WIW}}$ is the average within wafer removal rate. It may also be expressed as a percentage of the average removal rate:

$$\% \, WIWNU = \frac{\sqrt{\frac{\sum_{i=1}^{n} \left(RR_i - \overline{RR}_{WIW}\right)^2}{n-1}}}{\overline{RR}_{WIW}} \times 100 \qquad 9)$$

5.13 *within wafer (WIW) variation* — the variation in measurement values obtained at defined locations within a single wafer.

6 CMP Process Test

6.1 *Introduction*

6.1.1 The CMP process test should be performed with attention to the quality of both the substrate and the incoming film material, and the relative condition of the consumables and polishing system being utilized.

6.1.2 The number of wafers within the group should be specified.

6.2 *Monitor Wafer*

6.2.1 Monitor wafer specifications should be per SEMI M1 for incoming bow, warp, total thickness variation (TTV), and edge profile.

6.2.2 The geometry of the wafer may influence the CMP process results. Tables R-1 and R-2 in Related Information 1 recommend specifications for wafer geometry that can minimize the effects of such geometry on the CMP process test.

6.2.3 Record bow, warp and other wafer geometry characteristics.

6.2.4 Wafers can be laser-marked for ease of tracking. Data taken in this mark area should be excluded from the process analysis. It is desirable that all wafers in an evaluation lot contain marks at the same nominal locations.

6.3 *Incoming Film Properties*

6.3.1 Record the incoming film type and deposition tool and, where applicable, the deposition process conditions.

6.3.2 Ascertain that the incoming film thickness is sufficient to prevent polishing through to the substrate. See Tables R-1 and R-2 in Related Information 1 for recommended values for incoming film thickness.

6.4 *Post-process Measurements*

6.4.1 Record bow, warp and the same other wafer geometry characteristics determined in Section 6.2.3.

NOTE 2: These post-process measurement values may vary arbitrarily relative to the pre-process values.

6.4.2 Record final film thickness in the same locations employed for the starting film.

6.4.3 Calculate global and local film thickness changes appropriate for the application of interest.

6.5 *Metrology tools*

6.5.1 Select a film thickness measurement system suitable for the film and sampling pattern to be characterized.

6.5.1.1 Perform a gauge study on each metrology tool accordance with SEMI E89 to determine its effectiveness for the films to be measured.

6.5.2 Ascertain that the metrology tool is operating properly under Statistical Process Control prior to use in the CMP process test.

6.5.3 Perform tool calibration in accordance with the tool supplier's instructions.

6.6 *CMP Consumables*

6.6.1 Identify all consumables including pad, insert film, slurry type, and conditioning end effector.

6.6.2 Record the manufacturer's part number and lot number (if available) of each consumable item.

6.6.3 Record the status and history of each consumable prior to starting the process test.

NOTE 3: The history of consumables can affect the CMP process test.

6.6.4 Perform break-in procedures for pad and carrier film as required to ensure stable operation. Base these break-in procedures on recommendations from the consumable supplier.

6.7 *Polishing Tool*

6.7.1 Calibrate and record polish downforce, alignment tolerances, velocity, fluid dispense rates and other operational parameters based on recommended procedures from the equipment manufacturer.

6.7.2 Polish the samples.

7 Measurement Locations on the Wafer

7.1 The number and location of measurement sites are specific to the process test. In general, locations should be evenly spaced. Data extrapolation beyond the boundary of the measurement site population should not be performed.

7.2 ASTM F 1618 covers a set of site distribution patterns for measuring the uniformity of a thin film on a silicon wafer, similar to Figures 2 – 5, as well as simple procedures for analyzing and reporting the results of those measurements. For edge-scan measurements, see Section 7.3.6 below. For spiral-scan measurements, see Section 7.3.7 below. For full-wafer, high-density measurements, see Section 7.3.10 below.

7.3 Select one of these patterns for CMP process analysis on unpatterned wafers, unless otherwise agreed to.

7.3.1 Sampling plans are based on concentric circles, spirals, Cartesian sites, partial-radius, and partial and single-diameter sites.

7.3.2 Measurements are made at the sites specified in the chosen sampling plan, using the appropriate instrumentation and measurement procedure for the film parameter of interest.

7.3.3 Measures of the dispersion of the values are obtained by simple statistics specified for the sampling plans.

7.3.4 For diagonal scan measurements, refer to Figure 1. Select values for each of the following scan parameters:

- Scan Angle, θ
- Scan Radius Start/Stop, r_1 / r_2
- Number of Measurement Points, n, across the diameter.

7.3.5 For edge scan measurements, refer to Figure 6. Select values for each of the following scan parameters:

- Scan Angle, θ
- Inner Scan Radius, r_1
- Outer Scan Radius, r_2
- Number of Measurement Points, n, between r_1 and r_2.

NOTE 4: These n measurement sites are uniformly distributed.

7.3.5.1 *Discussion* — the data density for edge scan measurements is generally higher than for other measurements. Combining a low-density diameter scan in the central region of the wafer with a higher-density edge scan, taken along the same scan line, can improve throughput with appropriate local measurement data density.

7.3.6 For spiral scan measurements, refer to Figure 7. In such scans, the measurements are evenly distributed from near the center (r = 0) to near the edge exclusion boundary (r = 1 – EE). For each successive point, both the radius and the angle θ are systematically changed. For the 200 mm example with 3 mm edge exclusion shown in Figure 7, the 81 measurement points start at

R_1 = 0.10 mm and θ_1 = 0.52°. Successive points are incremented with ΔR = 1.21 mm and $\Delta\theta$ = 1.16°.

NOTE 5: Spiral scans uniformly sample properties that are radially symmetrical. These scans apply equal weight to all measurement sites. They also provide radial information, similar to diameter scans, as well as additional theta-related information that may not be provided by diameter scans.

7.3.7 For concentric circle scans, refer to Figures 2 and 3. In these scans, the inner circles lie on a fraction of the nominal radius. For notched wafers, the outer circle lies on a radius equal to the nominal radius less the edge exclusion, which is conformal with the notch on notched wafers. For flatted wafers the outer circle lies on a radius equal to the nominal radius less the sum of the flat depth plus the edge exclusion.

7.3.8 For Cartesian measurement scans, refer to Figure 4.

7.3.9 For full-wafer measurements, the measurements sites are evenly spaced over the entire area being examined. Typically, the first point is the wafer center, and the remaining measurement sites are equally spaced about the wafer center in X and Y. This X-Y grid is similar to Figure 4, but with significantly higher spatial density.

7.4 Record and identify the measurement site locations in accordance with SEMI M20.

7.4.1 Include an illustration of these locations with the test setup and with the recorded data set.

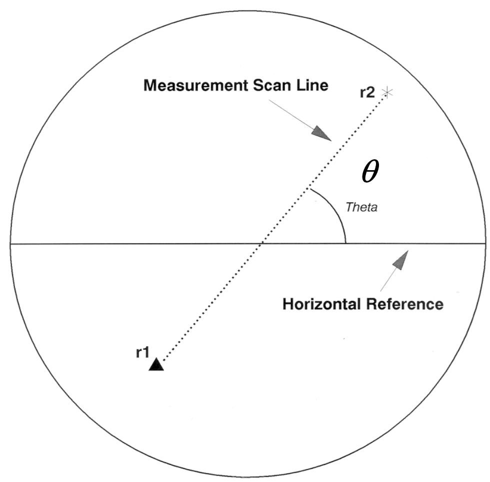


Figure 1
Diameter Scan
θ = scan orientation; r_1, r_2 = scan start/stop

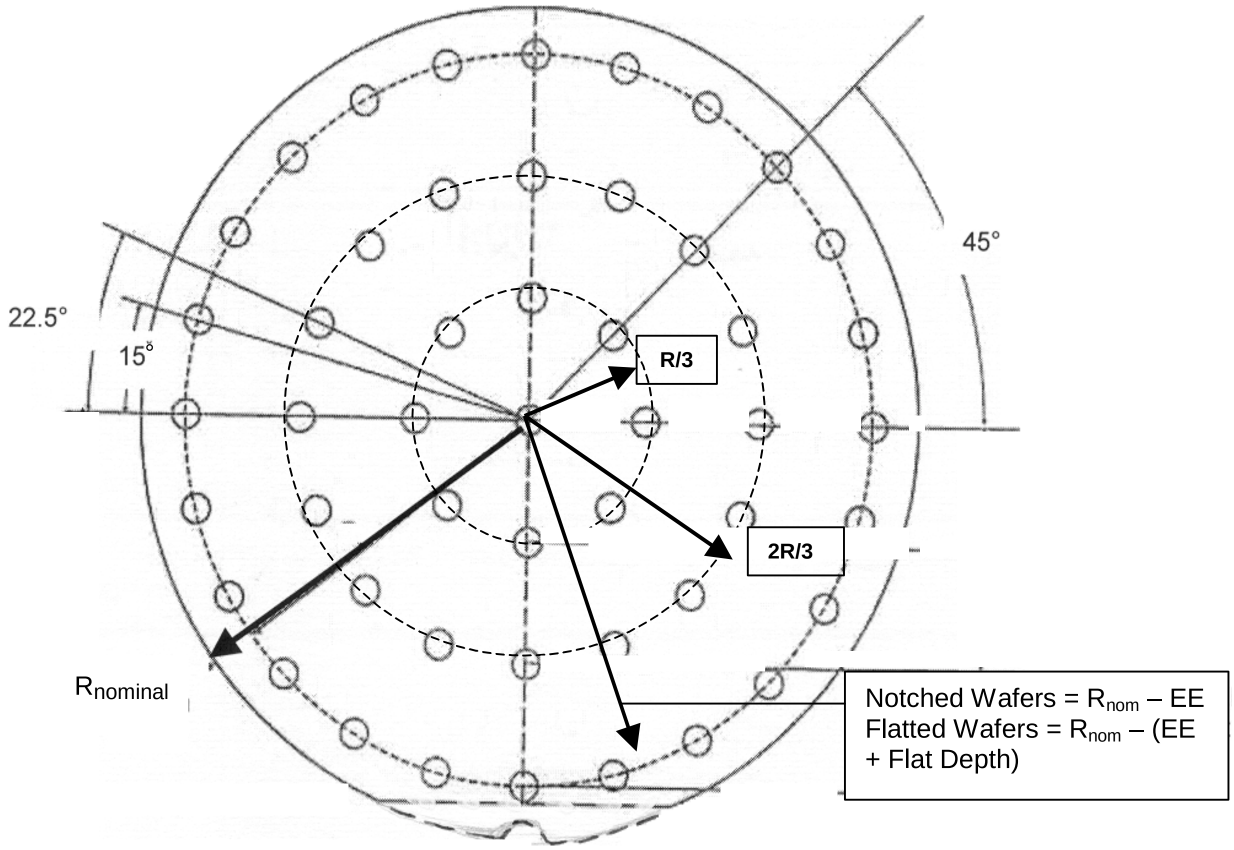


Figure 2
Three Concentric Circles

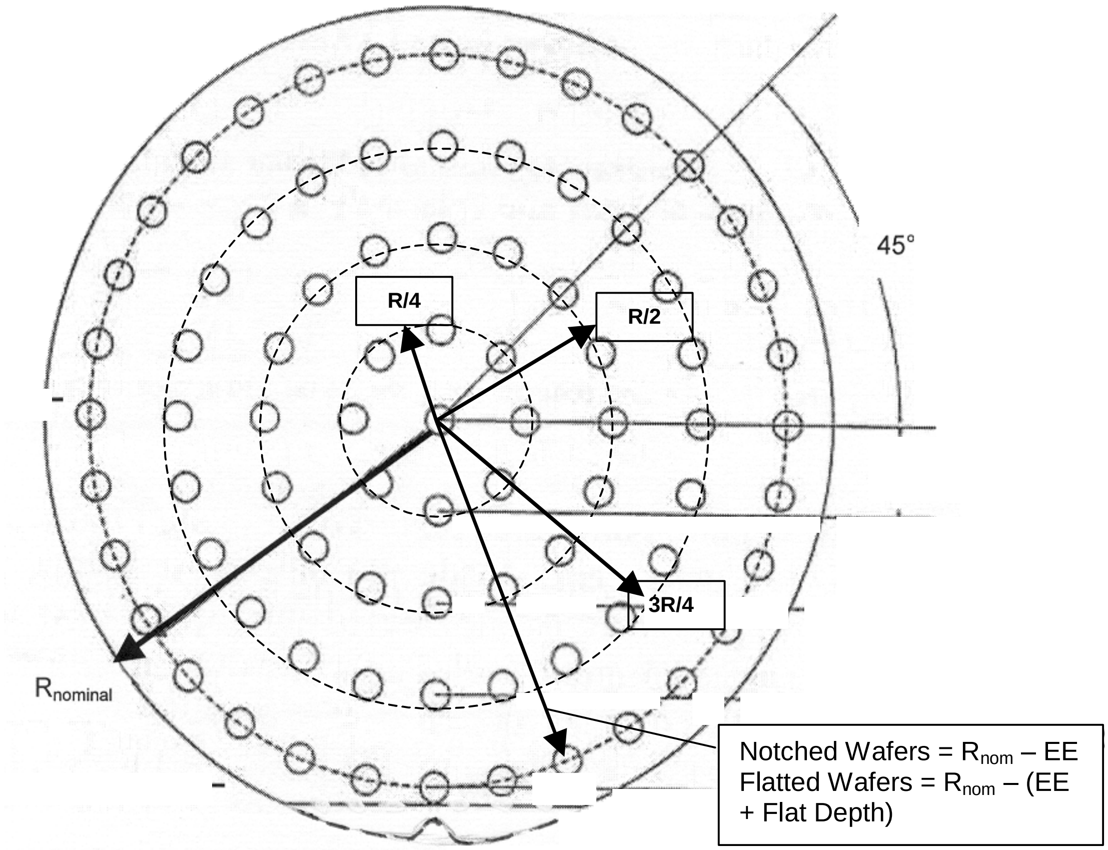


Figure 3
Four Concentric Circles

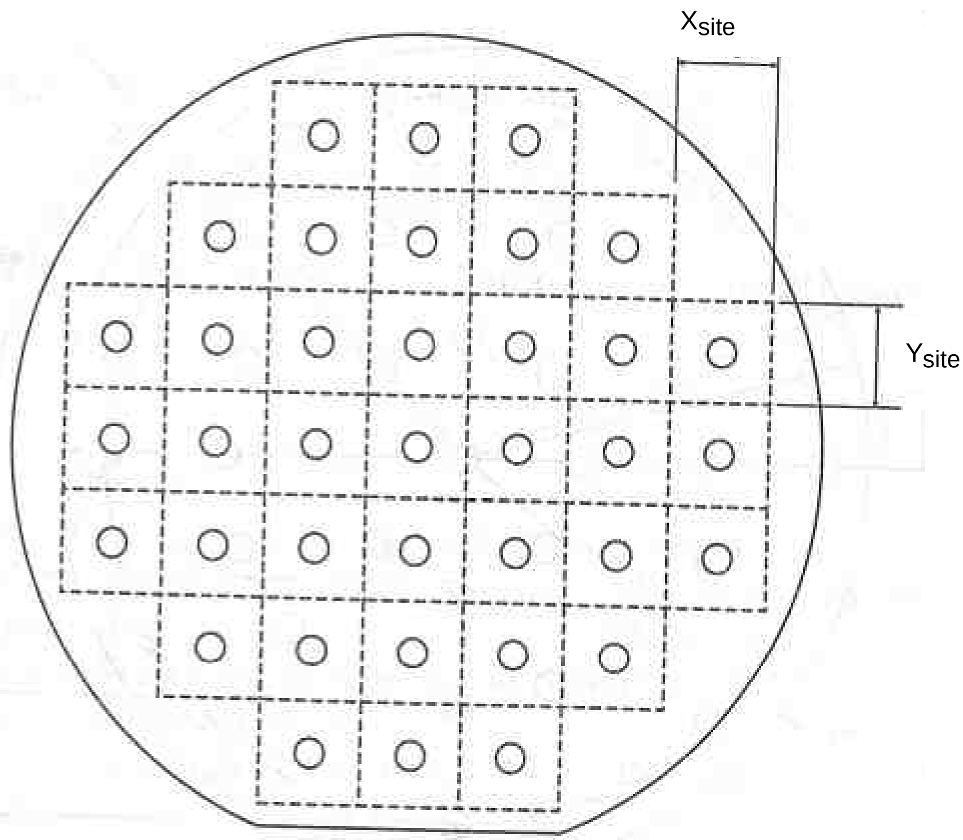


Figure 4
Cartesian Measurement Site Patterns

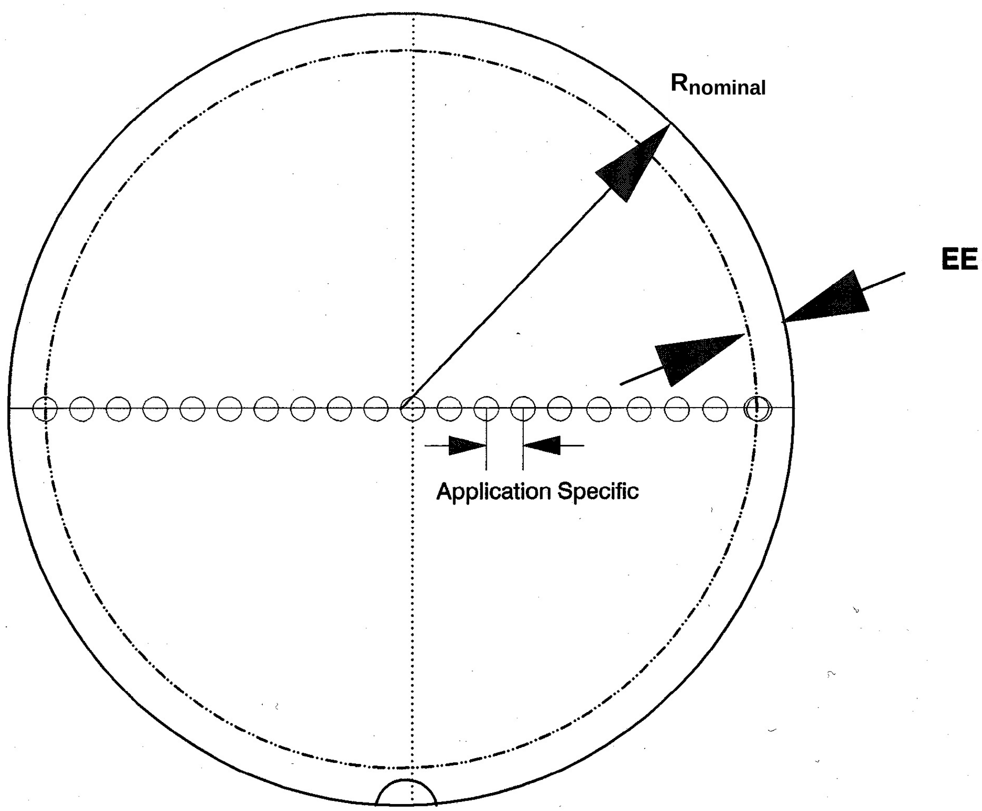


Figure 5
Single-Diameter High-Density Measurement Sites

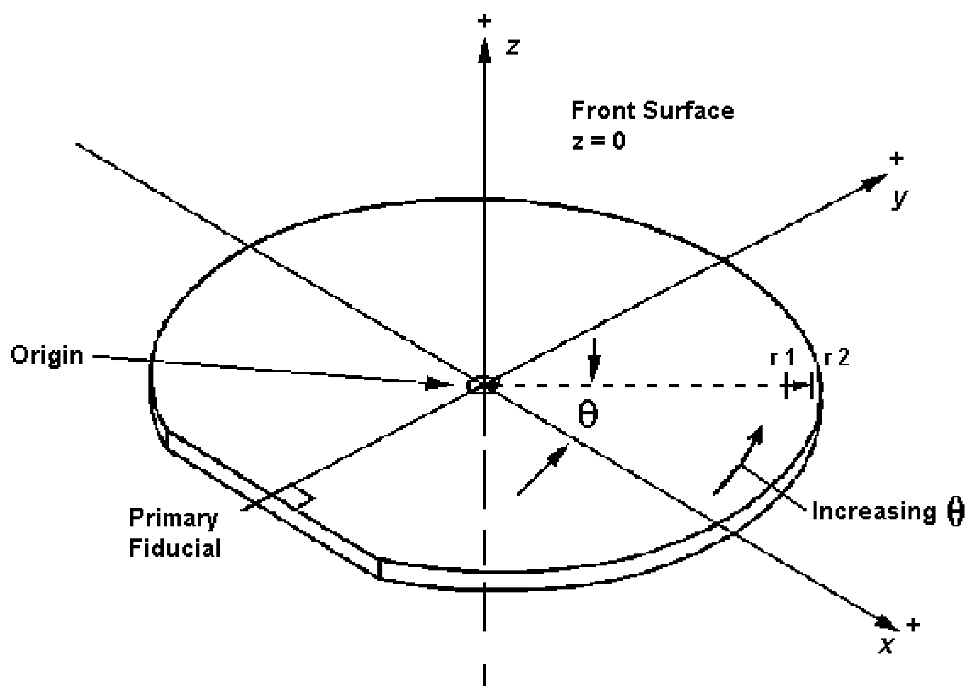


Figure 6
Edge Scan Location

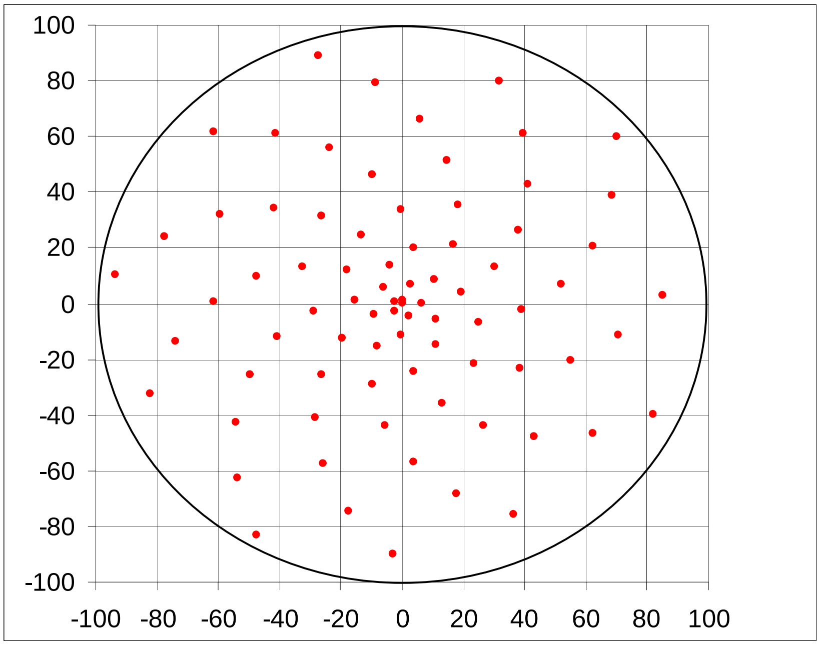


Figure 7
Spiral Scan Example - 200 mm Diameter Wafer, 81 Points

RELATED INFORMATION 1
CMP PROCESS TEST GUIDE

NOTE: This related information is not an official part of SEMI M48, and is not intended to modify or supercede the proposed standard. It is provided for information purposes.

Table R1-1 Recommended Values for Wafer and Insulating Film Thickness for CMP Process Test

Item		*Guideline*
Wafer (See NOTE 1.)	Bow	–25 µm to +25 µm
	Warp	≤ 25 µm
	GBIR (previously called TTV)	≤ 4 µm
	SBIR (20 × 20 mm site)	≤ 0.5 µm
Starting Insulating Film Thickness		1000 – 1500 nm
Starting % WIWNU		≤ 2% of mean thickness
Final Insulating Film Thickness		50% of starting film thickness

NOTE 1: See SEMI M1 for definitions of listed wafer parameters.

Table R1-2 Recommended Values for Wafer and Metal Film Thickness for CMP Process Test

Item		*Guideline*
Wafer (See NOTE 1.)	Bow	–25 µm to +25 µm
	Warp	≤ 25 µm
	GBIR (previously called TTV)	≤ 4 µm
	SBIR (20 × 20 mm site)	≤ 0.5 µm
	Insulating Film Thickness	≤ 600–1000 nm
W Stack	Starting TiN Film Thickness	25–30 nm
	Starting W Film Thickness	800 nm
	Final W Thickness	50% of starting W film thickness
	W Stack % WIWNU	≤ 2% of mean thickness
Cu Stack	Starting Glue Layer (Ta or TaN) Thickness	20–50 nm
	Starting Cu Seed Layer Thickness	100–150 nm
	Plated Cu Film Thickness	As required by application
	Final Cu Film Thickness	50% of plated Cu film thickness
	Cu Stack % WIWNU	≤ 8% of mean thickness

NOTE 1: See SEMI M1 for definitions of listed wafer parameters.

SEMI M49-1101
GUIDE FOR SPECIFYING GEOMETRY MEASUREMENT EQUIPMENT FOR SILICON WAFERS FOR 130 nm TECHNOLOGY GENERATION

This guide was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This document provides a guide for specifying measurement equipment for geometry and flatness of silicon wafers of the 130 nm technology generation as anticipated by the International Technology Roadmap for Semiconductors (ITRS), 1999 edition and in the forecasts of the major manufacturers of semiconductor devices. Wafer parameters as defined by SEMI M1, M24 or M38 are specified by customers of Si wafer suppliers and are usually part of Certificates of Compliance. Suppliers of Si wafers and their customers might measure these parameters using equipment provided by different manufacturers of such equipment or using different generations of equipment of one supplier. Agreement on basic features and capability of such measurement equipment improves data exchange and interpretation of data as well as procurement of appropriate tools.

2 Scope

2.1 This guide outlines and recommends basic specifications for equipment for measuring geometry and flatness of Si wafers of 130 nm technology generation.

NOTE 1: Future revisions of this guide are expected to reflect changed requirements for the 130 nm node as well as requirements of other nodes.

2.2 The guide applies to measurement equipment used for verifying the quality parameters geometry and flatness in large scale production of bare polished or epitaxial Si wafers the backside of which may be acid etched and/or covered by unpatterned, homogeneous layers of e.g. poly-Si or LTO (low temperature oxide). Artifacts (e.g., reference materials) for calibrating measurement equipment might have different properties.

2.3 The guide also applies to measurement equipment that provides only a subset of the measurement features outlined in Table 3.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 The document does not apply to measurement equipment used to control intermediate process steps during Si wafer manufacturing. However, it may be completely or partly used for measurement equipment for those applications provided corresponding constraints are appropriately identified.

3.2 The document also does not apply to measurement equipment for SOI wafers or patterned wafers.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E10 — Standard for Definition and measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E14 — Measurement of Particle Contamination Contributed the Product from the Process or Support Tool

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, behavior, and Services

SEMI E89 — Guide for Measurement System Capability Analysis

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

SEMI M1.15 — Standard for 300 mm Polished Monocrystalline Silicon Wafers (Notched)

SEMI M8 — Specification for Polished Monocrystalline Test Wafers

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of silicon Wafers

SEMI M24 — Specification for Polished Monocrystalline Silicon Premium Wafers

SEMI M27 — Practice for Determining the Precision over Tolerance (P/T) Ratio of Test Equipment

SEMI M38 — Specification for Polished Reclaim Silicon Wafers

SEMI M43 — Guide for Reporting Wafer Nanotopography

SEMI T7 — Specification for Back Surface Marking of Double-Side Polished Wafers with a Two-dimensional Matrix Code Symbol

4.2 *ASTM Standards*[1]

F 42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

F 534 — Standard Test Method for Bow of Silicon Wafers

F 657 — Standard Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Non-contact Scanning

F 671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Materials

F 673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Non-contact Eddy-Current Gage

F 928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F 1152 — Standard Test Method for Dimensions of Notches on Silicon Wafers

F 1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Non-contact Scanning

F 1451 — Standard Test Method for Measuring Sori on Silicon Wafers by Automated Non-contact Scanning

F 1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Non-contact Scanning

F 2074 — Standard Guide for Measuring Diameter of Silicon and Other Semiconductor Wafers

4.3 *ISO Standards*[2]

ISO 9000 — Quality management systems - Fundamentals and vocabulary

ISO 9001 — Quality management systems - Requirements

4.4 *JEITA Standards*[3]

JEIDA 43 — Terminology of silicon wafer flatness

4.5 *DIN Standards*[4]

50431 — Measurement of the electrical resistivity of silicon or germanium single crystals by means of the four-point-probe direct current method with collinear probe array

50432 — Determination of the conductivity type of silicon or germanium by means of rectification test or hot-probe

50441-1 — Determination of the geometric dimensions of semiconductor slices; measurement of thickness

50441-2 — Determination of the geometric dimensions of semiconductor slices; testing of edge rounding

50441-4 — Determination of the geometric dimensions of semiconductor slices; diameter and flat depth of slices

50441-5 — Determination of the geometric dimensions of semiconductor wafers; terms of shape and flatness deviation

50445 — Contactless determination of the electrical resistivity of semiconductor wafers with the eddy current method

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ARAMS* — Automated Reliability, Availability, and Maintainability Standard

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

3 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: www.jeita.or.jp

4 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany. Website: www.din.de

5.1.2 *ASCII* — American Standard Code for Information Interchange

5.1.3 *FTP* — File Transfer Protocol

5.1.4 *GEM* — Generic Equipment Model

5.1.5 *HSMS* — High Speed SECS Messaging Service

5.1.6 *IEEE* — The Institute of Electrical and Electronics Engineers, Inc.

5.1.7 *JPEG* — Joint Photographics Expert Group

5.1.8 *SECS* — SEMI Equipment Communications Standard

5.1.9 *XML* — Extensible Markup Language

5.2 *Definitions*

5.2.1 *bias* — the difference between the average of measurements made on the same object and its true value. Sufficient measurements are needed to mitigate the effects of variability. (SEMI E89)

5.2.2 *calibration* — calibration is a measurement process that assigns value to the property of an artifact or to the response of an instrument relative to reference standards or to a designated measurement process.

NOTE 3: The purpose of calibration is to eliminate or reduce bias in the user's measurement system relative to the reference base. The calibration process compares an unknown or test item or instrument with reference standards according to a specific algorithm, often in the form of a specific calibration curve. (SEMI E89)

5.2.3 *compatibility* — the capability of measurement equipment to emulate the measurement process of other tools. Downward compatibility refers to former generation(s) of the same or similar type of equipment of an equipment supplier.

NOTE 4: Compatibility can be provided by a measurement mode in which filtering, spatial resolution, etc. of another, older, tool is imitated.

5.2.4 c*orrelation* — the relation of measurement results obtained by repeated measurements with the same set of test specimen(s) and any two measurement tools expressed in terms of a regression curve.

5.2.5 *matching tolerance* (Δ_m) — the difference in bias for any two measurement tools of the same kind. Otherwise matching tolerance tests are performed under the conditions of σ_3 tests.

NOTE 5: In the absence of certified or standard reference materials matching may be tested by using appropriate wafers complying with 130 nm technology node specifications. It is recommended to test for matching with a set of samples covering the parameter range of interest.

5.2.6 *precision over tolerance (P/T) ratio* — the ratio of the precision of measurement equipment and a product's tolerance. (SEMI M27)

5.2.7 *level 1 variability* (σ_1) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool under nominally identical conditions without replacing the test specimen between subsequent measurement runs. σ_1 tests are performed with a single calibration in the shortest possible time interval.

5.2.8 *level 2 variability* (σ_2) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool with replacing the test specimen between subsequent measurement runs but otherwise under nominally identical conditions. σ_2 tests are performed with a single calibration in the shortest possible time interval.

5.2.9 *level 3 variability* (σ_3) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool with replacing the test specimen between subsequent measurement runs but otherwise under nominally identical conditions. σ_3 tests are performed over a time period greater than σ_2 tests without operator induced adjustment.

5.2.10 *sorting* — real and virtual separation of test specimens in different categories specified by one or multiple parameters.

5.2.11 *tolerance* — the absolute magnitude of the range of the product specification. (SEMI M27)

6 Specification for Measurement Equipment for Silicon Wafers of 130 nm Technology Generation

6.1 The specification is structured in three sections (Tables 1–3):

- Generic Equipment Characteristics (Table 1)
- Materials to be measured (Table 2)
- Metrology Specific Equipment Characteristics (Table 3)

6.2 Tables 1–3 contain the specifications, referenced documents, test methods, and comments. Additional explanations and discussions are provided in this section.

6.3 Generic Equipment Characteristics (Table 1)

6.3.1 The section "Generic Equipment Characteristics" consists of five subsections:

- Wafer handling
- Reliability
- Procedural
- Documentation
- Computer/User Interface/Connectivity

6.3.2 Subsections covering “Facilities Requirements” and “Safety/Legal/Regulatory” are not included in the present document as these issues are highly user specific and dependent on national regulations.

6.4 *Materials to be measured (Table 2)*

6.4.1 Table 2 specifies the parameters of Si wafers that the measurement equipment must be capable to handle and to measure.

6.5 *Metrology Specific Equipment Characteristics (Table 3)*

6.5.1 This section specifies the dimensional parameters of Si wafers to be measured and to be reported by equipment for measuring the geometry and flatness of wafers as well as the required spatial resolution, precision and accuracy of the measurement equipment.

6.5.2 The ability of a metrology tool to properly measure surface features of different spatial wavelengths is affected by the spatial bandwidth of the tool's response function. Spatial bandwidth can be defined in many ways and is influenced by many factors beyond the scope of this document. Some of these need to be standardized.

6.5.3 Spatial resolution is defined by the high spatial frequency limit of the bandwidth of the tool's response function.

6.5.4 Low and high cut-off frequency f_{min} and f_{max} define the bandwidth of the response function of measurement equipment. The cut-off frequencies correspond to an attenuation of 0.5 for the amplitude of a sinusoidal surface feature with the exception of a low pass filter ($f_{min} = 0$) for which the attenuation remains 1 at f_{min}.

6.5.5 The rate of change of the attenuation approaching the cut-off frequencies has to be larger than the rate of a Gaussian filter with the corresponding cut-off frequency.

6.5.6 The present document recommends f_{max} and f_{min} that must be measured by the instrument.

6.5.7 Any variations in filtering procedures applied near the FQA boundary must be described by the supplier of the equipment.

6.5.8 The bandwidth as specified in Table 3 is a nominal value.

6.5.9 In the present document a hierarchy of variability levels is used to describe the performance of measurement equipment which is calibrated and adjusted/aligned according to the supplier's procedures. The various terms are defined in section 5. These variability levels are consistent with terms defined in SEMI E89 but not fully interchangeable. Their relation is indicated in parentheses.

6.5.9.1 Level 1 variability: standard deviation σ_1 (SEMI E89 static repeatability)

6.5.9.2 Level 2 variability: standard deviation σ_2 (SEMI E89 dynamic repeatability)

6.5.9.3 Level 3 variability: standard deviation σ_3 (SEMI E89 reproducibility)

6.5.10 In addition two levels of systematic off-set between different tools are defined:

6.5.10.1 matching tolerance (difference of means Δ_m)

6.5.10.2 correlation (regression curve)

6.5.11 Explicitly specified in the present document are only level 3 variability σ_3 and matching tolerance Δ_m as they correspond to the utilization of measurement equipment for wafer manufacturing most closely. The supplier of a specific tool may optionally provide specifications for level 1 and/or level 2 variability, respectively.

6.5.12 Level 3 variability σ_3 and matching tolerance Δ_m are specified with respect to anticipated specifications for wafer geometry and flatness as given in Table 3 for a reference wafer.

6.5.13 In the present document P/T-ratios are used for specifying level 3 variability σ_3.

6.5.13.1 A precision-to-tolerance ration P/T less than 10% at 6σ is recommended in SEMI M27 for metrology equipment. This would be an extremely demanding specification for flatness and geometry measurement tools. In addition, flatness characterisitics of Si wafers are typically described by a single sided distribution with the median approaching zero, the lower specification boundary. Therefore two grades that are based on 3σ criteria, instead on 6σ, are recommended for such tools in the present document:

- grade A: P/T < 10%, $3\sigma_3$
- grade B: P/T < 20%, $3\sigma_3$

6.5.13.2 The individual measurement features a tool provides may be graded differently, e.g. SFQR might meet grade A, but SBIR only grade B. This has to be indicated appropriately in the tools' technical specifications.

6.5.14 Matching tolerance is specified to be less or equal to $1.5\sigma_3$ of level 3 variability. This corresponds to a greater than 99% probability that the difference of any individual measurement results obtained with two different tools is smaller or equal to $5\sigma_3$.

6.5.15 The target for bias is a range of $\pm 1.5\sigma_3$ with respect to a certified value provided appropriate reference materials are available. This corresponds to a greater than 99% probability that any individual measurement is in the range of $\pm 4\sigma_3$ around the certified value when a reference material is tested.

6.5.16 Reference material with a series of surface features with appropriate height and half width is required to verify bandwidth of a measurement tool. The height of the features corresponds to the wafer specification as outlined in Table 3.

6.5.17 The specifications of the measurement equipment are verified by using wafers the parameters of which are in a range, the upper limit of which corresponds to 1.5 times anticipated wafer specification, the lower limit to 0.5 of anticipated wafer specification. These are listed in Table 3 as Reference Wafer Specifications.

NOTE 6: The edge region of wafers represents the most challenging area for meeting the desired performance characteristics. This is because of the larger surface geometry variations in the region near the edge, e.g. from polishing roll-off.

6.5.18 Reference Wafers that meet all requirements of Table 3 are not readily available (in 2000). Therefore it might be difficult to properly characterize and separate all contributions to measurement error.

6.5.19 Verification of bias, matching tolerance and the various levels of variability are performed with equipment which is calibrated according to the supplier's procedures and which is under statistical process control.

6.5.20 Compatibility of two tools is considered to be satisfactory when the specifications of the older tool are met with the newer tool operating in the emulation mode.

6.5.21 The quality of a correlation between different measurement equipment is not specified in the present document.

7 Related Documents

7.1 *ASTM Documents*

E 177 — Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 456 — Standard Terminology for Relating to Quality and Statistics

7.2 *Other Documents*

Evaluating Automated Wafer Measurement Instruments, SEMATECH[5], Technology Transfer 94112638A-XFR

Metrology Tool Gauge Study Procedure for the International 300 mm Initiative (I300I), International 300 mm Initiative[5], Technology Transfer #97063295A-XFR

International Technology Roadmap for Semiconductors: 1999 edition[6,7]

ISO 3274: 1996 — Geometrical Product Specifications (GPS) – Surface Texture: Profile method – Nominal characteristic of contact (stylus) instruments[2]

5 International Sematech, 2706 Montopolis Drive, Austin, Tx. 78741-6499, USA

6 SEMATECH, 3101 Industrial Terrace Suite 106, Austin TX 78758

7 More recent versions of the ITRS are available from the homepage of International Sematech: www.sematech.org

Table 1 Generic Equipment Characteristics

Item	*Recommended Specification*	*Comment*	*Test Method/Reference*
1 WAFER HANDLING			
1.1 Robot End-Effector	optional wafer edge or backside contact	edge as defined by SEMI M1	
1.2 Scan Stage	optional wafer edge or backside contact	edge as defined by SEMI M1	
1.3 Wafer Contact Materials	contact materials to leave metals and organics on wafers < as defined in ITRS 99		
1.4 Wafer Detection	protection of accidental contact due to e.g., cross-slotting double slotting, protrusions, etc.		
1.5 Wafer Rotational Alignment	random in, aligned out		
1.6 Number of Cassette Stations	2–4, arbitrary sender/receiver assignment		
1.7 Type of Cassettes	open, FOUP/SMIF, FOSB	to be specified alternatively	
1.8 Cassette Loading	manual/guided vehicle, conveyor belt		
1.9 Automatic Cassette ID	user specific		
1.10 Wafer Seating	vertical or off-horizontal	during setting cassette on station by operator	
1.11 Cassette Filling Modes	random access and loading, programmable empty slot filling		
1.12 Automatic Wafer ID reading	user specific		
1.13 Particulate Contamination	< 0.001 PWP per cm^2, > 90 nm LSE front, and > 120 nm LSE backside (See NOTE 1.)	verify with mirror polished wafer surfaces	SEMI E14
2 RELIABILITY			
2.1 MTBF	> 2000 h		SEMI E10
2.2 MTTA	> 4 h		SEMI E10
2.3 MTTR	according to service contract		SEMI E10
2.4 Availability	> 98%	per year	
2.5 Uptime	> 160 h/w		
2.6 Response Time	according to service contract		
2.7 Statistical Process Control (SPC) performance	automated		
2.8 Statistical Process Control (SPC) machine parameters	automated		
3 PROCEDURAL			
3.1 Acceptance Testing	user specific		
3.2 Transport and Assembly	user specific		
3.3 Quality Assurance	supplier conforming with ISO 9000/9001		ISO 9000/9001
3.4 Warranty	> 1 y		
3.5 Test Certificates	user specific		
3.6 Spares Availability	> 10 y		
3.7 Change Control	supplier conforming with ISO 9000/9001		ISO 9000/9001
4 DOCUMENTATION			
4.1 Installation	tbd		

Item	*Recommended Specification*	*Comment*	*Test Method/Reference*
4.2 Operation	tbd		
4.3 Service	tbd		
5 COMPUTER, USER INTERFACE, CONNECTIVITY			
5.1 Computer Operating System	- Microsoft Windows NT 4.0 or higher, or - Unix		
5.2 Display	cleanroom compatible, class 10		
5.3 Keyboard	cleanroom compatible, class 10		
5.4 Pointing Device	cleanroom compatible, class 10		
5.5 Printer	cleanroom compatible, class 10		
5.6 Data Processing	- reprocessing of data - parallel processing in different modes during measurement including sorting - multiprocessing: e.g. recipe editing, up/downloading during measurements	different modes refer to data evaluation e.g. for two different site patterns, or different emulation modes	
5.7 Data Access	- access to basic measurement results: e.g thickness map, height map - data available at SECS/GEM/HSMS interface in real time	refers to all functions as defined in Table 3	
5.8 Data Analysis (Online/Offline)	on-line/off-line		
5.9 Recipe Control	- complete recipe generation off-line without machine specific data (calibration curves) - off-line recipe editing - remote recipe control by host computer - recipes are compatible between different software versions		
5.10 Operating Sequence	complete remote control : recipe download, start, stop, define data evaluation via SECS/GEM		
5.11 Data Interfaces	- SECS/GEM - optional additionally a mass data standard transfer protocol (e.g. FTP)		
5.12 Material Tracking System Support	required, details user specific		
5.13 Output File Format	standardized formats: - ASCII or XML for measurement results - IEEE for raw data (floating point) - JPEG (or equivalent) for raw data (image data)		
5.14 Network Communications Standards Support	Ethernet, Fast Ethernet		
5.15 SECS/GEM	required		
5.16 ARAMS	required		SEMI E58

NOTE 1: The particulate contamination PWP value given for the backside has not been established in commercial practice and is under further consideration by the SEMI Silicon Wafer Committee.

Table 2 Materials to be measured

Item	*Recommended Specification*	*Comments*	*Test method/references*
1 WAFERS			
1.1 Kind of Wafers	monocrystalline, unpatterned silicon wafers with layers as specified in Table 2, Item 1.3.4		SEMI M1 (SEMI M8) (SEMI M11)
1.2 Wafer Characteristics – dimensional			
1.2.1 Wafer Diameter	200 or 300 or 200+300 mm nominal		SEMI M1 ASTM F 2074 DIN 50441-4
1.2.2 Wafer Thickness	700–850 µm	For reclaim wafers (performance as outlined in Tab3 might be reduced): 200 mm: 600–850 µ 300 mm: 650–850 µm	ASTM F 1530 DIN 50441-1
1.2.3 Edge Shape	rounded		SEMI M1 DIN 50441-2 ASTM F 928
1.2.4 Wafer Shape Range	200 mm wfrs: warp <= 100 µm, 300 mm wfrs: warp <= 200 µm		SEMI M1 ASTM F 1390 DIN 50441-5
1.2.5 Fiducial	200 mm wfrs:notch or flat 300 mm wfrs: notch		SEMI M1 ASTM F 671 ASTM F 1152 (DIN 50441-4)
1.2.6 ID Mark(s)	200 mm wfrs: user specific 300 mm wfrs: according to SEMI standards	content, type location of ID mark to be specified	SEMI M1.15 SEMI M12 SEMI M13 SEMI T7
1.3 Wafer Characteristics – electrical, optical			
1.3.1 Electrical Resistivity of Wafers, Conductivity Type	0.5 mΩcm – intrinsic, p-, n-type		Res: ASTM F 673 DIN 50445 ASTM F 84 DIN 50431 Type: ASTM F 42 or DIN50432
1.3.2 Thermal Donors	annealed and not annealed		
1.3.3 Wafer Charge	no effect with respect to measurement		
1.3.4 Layers (LTO, poly-Si), Epi	LTO: thickness: 150 – 900 nm uniformity: ≤ 10% poly-Si: thickness: ≤ 2 µm uniformity: < 20% Epitaxial layer: customer specific		
1.3.5 Wafer Surface Conditions	front surface: polished, epitaxial layer back surface: polished, acid and/or caustic etched, layers according to Item 1.3.4	optional conditions of both surfaces: etched, lapped, as cut	

Table 3 Metrology Specific Equipment Characteristics

Item	*Recommended Specification*		*Comments*	*Test Methods/References*
	Grade A	*Grade B*		
1 MEASUREMENT FUNCTIONS				
1.4 Geometry (SEMI M1)			these parameters refer to thickness and shape measurement of wafer	SEMI M1 Appendix 1 - Flatness Decision Tree, Appendix 2 - Shape Decision Tree
1.4.1 Thickness (Center Thickness)				
1.4.1.1 Reference Wafer Specification	725 µm for 200 mm wfrs, 775 µm for 300 mm wfrs		nominal thickness, tolerances according to SEMI M1	SEMI M1 ASTM F 1530
1.4.1.2 Level 3 Variability σ_3	≤ 1 µm, 1σ	≤ 2 µm, 1σ		
1.4.1.3 Matching Tolerance Δ_m	≤ 1.5 µm	≤ 3 µm		
1.4.1.4 Bias	± 1.5 µm	± 3 µm	target until certified reference materials are available	
1.4.1.5 Spatial Bandwidth	$f_{min} = 0\ mm^{-1}$ $f_{max} = 1\ mm^{-1}$		nominal value, tolerance ± 5%	
1.4.2 Global Flatness (GBIR)				SEMI M1 Appendix 1 - Flatness Decision Tree JEIDA 43 ASTM F 1530
1.4.2.1 Reference Wafer Specification	1 µm			
1.4.2.2 Level 3 Variability σ_3	≤ 30 nm, 1σ	≤ 65 nm, 1σ		
1.4.2.3 Matching Tolerance Δ_m	≤ 50 nm	≤ 100 nm		
1.4.2.4 Bias	± 50 nm	± 100 nm	target until certified reference materials are available	
1.4.2.5 Spatial Bandwidth	$f_{min} = 0\ mm^{-1}$ $f_{max} = 1\ mm^{-1}$		nominal value, tolerance ± 5%	
1.4.3 Local Flatness (SBIR)			specifications apply on a site-by-site basis	SEMI M1 Appendix 1 - Flatness Decision Tree, ASTM F 1530 DIN 50441-5 JEIDA 43
1.4.3.1 Reference Wafer Specification	0.25 µm		site size 25×25 mm^2, partial sites included	
1.4.3.2 Level 3 Variability σ_3	≤ 8 nm, 1σ	≤ 17 nm, 1σ		
1.4.3.3 Matching Tolerance Δ_m	≤ 13 nm	≤ 25 nm		
1.4.3.4 Bias	± 13 nm	± 25 nm	target until certified reference materials are available	
1.4.3.5 Spatial Bandwidth	$f_{min} = 0\ mm^{-1}$ $f_{max} = 1\ mm^{-1}$		nominal value, tolerance ± 5%	

Item	*Recommended Specification*		*Comments*	*Test Methods/References*
	Grade A	*Grade B*		
1.4.4 Local Flatness (SFQR)			specifications apply on a site-by-site basis	SEMI M1 Appendix 1 - Flatness Decision Tree, ASTM F 1530 DIN 50441-5 JEIDA 43
1.4.4.1 Reference Wafer Specification	130 nm		site size 25×25 mm^2, partial sites included	
1.4.4.2 Level 3 Variability σ_3	≤ 4 nm, 1σ	≤ 9 nm, 1σ		
1.4.4.3 Matching Tolerance Δ_m	≤ 7 nm	≤ 13 nm		
1.4.4.4 Bias	± 7 nm	± 13 nm	target until certified reference materials are available	
1.4.4.5 Spatial Bandwidth	$f_{min} = 0\ mm^{-1}$ $f_{max} = 1\ mm^{-1}$		nominal value, tolerance ± 5%	
1.4.5 Shape (Warp, GMLYMER)				SEMI M1 Appendix 2 - Shape Decision Tree, ASTM F 1390 JEIDA 43 DIN 50441-5
1.4.5.1 Reference Wafer Specification	30 µm			
1.4.5.2 Level 3 Variability σ_3	≤ 1 µm, 1σ	≤ 2 µm, 1σ		
1.4.5.3 Matching Tolerance Δ_m	≤ 1.5 µm	≤ 3 µm		
1.4.5.4 Bias	± 1.5 µm	± 3 µm	target until certified reference materials are available	
1.4.5.5 Spatial Bandwidth	$f_{min} = 0\ mm^{-1}$ $f_{max} = 1\ mm^{-1}$		nominal value, tolerance ± 5%	
1.4.6 Other Global Flatness Parameters				SEMI M1 Appendix 1 - Flatness Decision Tree, JEIDA 43 DIN 50441-5
1.4.6.1 GFLR, GFLD	required			
1.4.7 Other Local Flatness Parameters				SEMI M1 Appendix 1 - Flatness Decision Tree, JEIDA 43 DIN 50441-5
1.4.7.1 SBID, SFLR, SFLD, SFQD, SFSR, SFSD	required			
1.4.8 Other Shape Parameters				SEMI M1 Appendix 2 - Shape Decision Tree ASTM F 1390 ASTM F 1451 ASTM F 534 ASTM F 657 JEIDA 43 DIN 50441-5
1.4.8.1 Sori (GFLYFER), Bow (GM3YMCD), Warp (GB3NMPR)	required			

Item	*Recommended Specification*		*Comments*	*Test Methods/References*
	Grade A	*Grade B*		
1.5 Nanotopography			these parameter refer to flatness measurement of individual surfaces	SEMI M43
1.5.1 2 mm Analysis Area Size				
1.5.1.1 Reference Wafer Specification	20 nm PV		in window (site) with specified dimensions	
1.5.1.2 Level 3 Variability σ_3	≤ 0.7 nm, 1σ	≤ 1.3 nm, 1σ		
1.5.1.3 Matching Tolerance Δ_m	≤ 1 nm	≤ 2 nm		
1.5.1.4 Bias	± 1 nm	± 2 nm	target until certified reference materials are available	
1.5.1.5 Spatial Bandwidth	f_{min} = 0.05 mm^{-1} f_{max} = 2.5 mm^{-1}		nominal value, tolerance ± 5% optionally a range of f_{min} = 0.25 mm^{-1} f_{max} = 2.5 mm^{-1} may be used	
1.5.2 10 mm Analysis Area Size			in window (site) with specified dimensions	
1.5.2.1 Reference Wafer Specifiation	70 nm PV			
1.5.2.2 Level 3 Variability σ_3	≤ 2.5 nm, 1σ	≤ 4.7 nm, 1σ		
1.5.2.3 Matching Tolerance Δ_m	≤ 3.5 nm	≤ 7 nm		
1.5.2.4 Bias	± 3.5 nm	± 7 nm	target until certified reference materials are available	
1.5.2.5 Spatial Bandwidth	f_{min} = 0.05 mm^{-1} f_{max} = 2.5 mm^{-1}		nominal value, tolerance ± 5% optionally a range of f_{min} = 0.05 mm^{-1} f_{max} = 0.5 mm^{-1} may be used	
1.6 Other parameters				
1.6.1 Waviness	user specific			
1.6.2 Height (individual wafer surfaces)	user specific			
1.6.3 Slope	user specific			
1.6.4 Curvature	user specific			
1.6.5 Line Scans	user specific			
1.6.6 Contour Maps	user specific			
1.6.7 Data Histogram	10 or more bins per channel, arbitrarily defineable, cumulative, differential			
1.6.8 Additional Parameters	user specific			
2 SETUP PARAMETERS				
2.1 FQA/Edge Exclusion	EE ≥ 1 mm, 200 and 300 mm wafers FQA 200 mm wfrs: ≤ 198 mm FQA 300 mm wfrs: ≤ 298 mm		performance parameters to be verified with EE ≥ 2 mm	

Item	*Recommended Specification*		*Comments*	*Test Methods/References*
	Grade A	*Grade B*		
2.2 Site Patterns	for local flatness according to Section 1.1: any compatible with SEMI M1 for nanotopography: floating sites		recommended range for site size: 5–40 mm, arbitrary combination of length of rectangular sides	SEMI M1 SEMI M43
2.3 Sorting Criteria	sorting is performed by using logical "and/or" combinations of multiple parameters			
2.4 Exclusion Windows	a) >3, curved/linear boundaries, arbitrary position on entire wafer surface b) perimeter exclusion windows: N zones with total area covered ≤ 0.001 of total wafer area in the radial range R-2 mm to R, total perimeter excluded at R-1 mm ≤ 4% of total wafer circumference, no single zone longer than 5 mm.		a) e.g. laser mark exclusion b) e.g. edge gripping exclusion	
3 PERFORMANCE				
3.1 Throughput				
3.1.1 200 mm Wafers	> 60 wph			
3.1.2 300 mm Wafers	> 40 wph			
3.2 Downward Compatibility	at least one previous tool generation of supplier		specific tools involved need to be identified	
3.3 Calibration	automated method, Certified Reference Material (CRM) to be provided by equipment supplier			
3.3.1 Level 3 Variability Test Interval	user specific		to be recommended by supplier of measurement equipment	
3.4 Dependence of Results on Wafer Orientation	$< 1\sigma_3$			

SEMI M50-1101
TEST METHOD FOR DETERMINING CAPTURE RATE AND FALSE COUNT RATE FOR SURFACE SCANNING INSPECTION SYSTEMS BY THE OVERLAY METHOD

This test method was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the North American Silicon Wafer Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This test method provides a framework for the calculation of the capture rate (CR), false count rate (FCR) and cumulative false count rate (CFCR) of a scanning surface inspection system (SSIS) as a function of latex sphere equivalent (LSE) size of localized light scatterers (LLS).

NOTE 1: In the context of this document the term "size" refers to the LSE diameter.

2 Scope

2.1 This test method defines the SSIS capture rate and discusses its usage in industry specifications.

2.2 This test method addresses calculating and reporting SSIS capture rate from measurements of either PSL depositions or other LLS on wafers in LSE units.

2.3 Specific wafer surfaces (by wafer product, type of film or type of polish) that may affect the measured capture rate and false count rate of an SSIS are to be agreed upon between suppliers and users.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 This test method is limited to use on unpatterned wafers.

3.2 This test method is limited to use on calibrated scanners operated in a production mode.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI M1 — Specification for Monocrystalline Polished Silicon Wafers

4.2 *ASME Standards*[1]

ASME B46.11-1995 — Surface Texture (Surface Roughness, Waviness and Lay)

4.3 *ASTM Standards*[2]

F 1527 — Standard Guide for Application of Silicon Standard Reference Materials and Reference Wafers for Calibration and Control Instruments for Measuring Resistivity of Silicon

F 1620 — Standard Practice for Calibrating a Scanning Surface Inspection System Using Monodisperse Polystyrene Latex Spheres Deposited on Polished or Epitaxial Wafers

F 1621 — Standard Practice for Determining the Positional Accuracy Capabilities of a Scanning Surface Inspection System

4.4 *ISO Standard*[3]

ISO Guide 30:1992 — Terms and Definitions Used in Connection with Reference Materials

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *capture rate (CR)* — the probability that an SSIS detects an LLS of latex sphere equivalent (LSE) signal value at some specified SSIS operational setting.

5.2 *certified reference material (CRM)* — A reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes its traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is

1 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

3 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

accompanied by an uncertainty at a stated level of confidence. [ISO Guide 30:1992]

5.3 *cumulative false count rate* (CFCR) — the number of false counts of size S_f, or larger, that are expected to be recorded by an SSIS at some specified operational setting as a function of S_f. CFCR may be found by averaging false counts over multiple scans.

5.4 *false count (FC)* — a laser-light scattering event that arises from instrumental causes rather than from any feature on or near the wafer surface; also called false positive; compare nuisance count. [ASTM Practice F 1620]

5.4.1 *Discussion* — False counts would not be expected to occur at the same point on the wafer surface during multiple inspection scans, and hence they could be considered as random "noise" that could be identified by examining the results of repeated scans.

5.5 *false count rate (FCR)* — the mean total number of false counts per wafer that an SSIS reports at some specified SSIS operational setting.

5.6 *repeat counts* — LLSs that are found in a later scan within the scanner *XY* uncertainty distance of their location as found on an earlier scan.

5.6.1 *Discussion* — The implication is that if defect density is low enough, then a repeat count results from detecting the same LLS event again and is not the result of SSIS noise. Besides the absolute position of the LLS, an additional matching condition may be the LSE signal of the LLS.

5.7 *scanner* XY *uncertainty* — The quadrature sum of the one-sigma uncertainties in the *X* and *Y* location uncertainties of the SSIS under test.

5.7.1 *Discussion* — In ASTM Practice F 1621, this quantity is called positional accuracy and is determined under a variety of experimental conditions. For purposes of the present test method, the scanner *XY* uncertainty should be determined under static repeatability condition, i.e., without removing the wafer from the stage between scans.

5.8 *standard reference material (SRM®)* — A certified reference material (CRM) issued by the U.S. National Institute of Standards and Technology (ASTM Guide F 1527).

5.9 *true count* — a laser-light scattering event that arises from the localized light scatterers (LLS) being investigated. [ASTM Practice F 1620]

6 Summary of Method

6.1 The *XY* coordinate uncertainty of the scanner is determined under static repeatability conditions.

6.2 The reference wafer to be used in this test is selected.

6.3 The selected wafer is scanned *Z* times on the SSIS under test. The first two scans are used to qualify the reference wafer before continuing with the remaining *Z*–2 scans.

NOTE 3: Typical values for *Z* are between 30 and 100 scans.

6.4 The scans are analyzed to determine and record the number of times each LLS event occurs in each location (to within a distance approximately six times the scanner *XY* uncertainty) during the *Z* scans. The capture rate, standard size deviation, false count rate, and cumulative false count rate are determined from this data set.

7 Apparatus

7.1 *The SSIS under test* should be installed in its position of use with clean room rating recommended by the manufacturer

7.2 *Off-line analysis software program* — to track each observed count and determine the capture rate, standard size deviation, the number of false counts at each LLS size, the false count rate, and the cumulative false count rate.

NOTE 4: The analysis software may be incorporated into the SSIS, if desired.

8 Test Specimens

8.1 Use any wafer with (1) natural LLS with density of LLS < 10 LLS/cm^2 and (2) a surface roughness typical of the wafers to be measured in production (see Section 2.3).

8.1.1 The minimum distance between any two LLS found during any one scan and used in the data set to be analyzed shall be larger than six times the scanner *XY* uncertainty. Clusters of LLS (found in any one scan and closer together than six times the scanner *XY* uncertainty) and scratches must be excluded during the analysis.

8.1.2 Determine the scanner *XY* uncertainty from previous knowledge, from the scanner manufacturer specifications, or from the positional accuracy determined under static repeatability conditions in accordance with ASTM Practice F 1621.

8.2 Alternatively, a wafer with deposited polystyrene latex spheres can be used to more accurately evaluate the capture rate at a specific particle size. The same particle density, particle spacing, and defect cluster conditions as in Section 8.1 should be observed.

NOTE 5: The wafer with deposited PSL spheres may or may not be an SRM or other certified reference material.

9 Procedure

9.1 Qualify the wafer for appropriate LLS number (see Section 8.1) prior to taking CR and CFCR data as follows:

9.1.1 Scan the wafer once and determine position, P_m, and size, $S_{m,}$ of each of the M_1 detected LLS_m events with $m = [1, M_1]$.

9.1.2 Scan the wafer a second time and compare the detected LLS events with respect to the positions of those detected during the first scan. The total number of LLS events that repeat their position in the first scan to within six times the scanner *XY* uncertainty is defined as M_2. To qualify the wafer, the share of repeat LLS events on the wafer, M_2, shall be larger than 0.75 M_1. The conditions of Sections 8.1 and 8.1.1 must be fulfilled for both wafer scans. The purpose of this scan is to determine that there are enough repeating LLS events to make the CR calculation meaningful.

9.2 Scan the wafer a total of *Z* times to obtain CR, FCR, and CFCR data. (See NOTE 3.) The two scans of Section 9.1 can be used as part of this data set; however, the wafer must remain on the scan stage during the entire set of *Z* scans to perform a static measurement sequence. Record each LLS event detected during the *Z* scans according to its position, *P* and size, *S*.

10 Analysis

10.1 *Initial Analysis*

10.1.1 Determine the locations on the wafer where an LLS event has been detected at least once by comparing all recorded positions (within the constraint of the six-sigma *XY* uncertainty) of the multiple scans as reported by the SSIS. These locations, L_i, with $i=[1,N]$ represent the complete set of LLS events which will be used in the further analysis. Each location is characterized by the number of scans H_i, in which the LLS event at that position has been detected, and by the H_i reported sizes S_{ih}, where $h=[1,H_i]$, for the LLS event.

10.1.2 Consider those of the *N* events with $H_i = 1$, (i.e., events seen only once) as false counts. Order these events by decreasing size, S_i. Index them by $f = [1,F]$, with $f = 1$ representing the largest size and $f = F$ representing the smallest.

10.1.3 Consider those events that were seen at least twice during the Z scans ($H_i \geq 2$) to be true counts.

NOTE 6: The sequence of analysis steps given below is intended to be representative and illustrative. The actual algorithms used in the analysis software may differ from these as long as the same result is achieved.

10.2 *Analysis of True Counts*

10.2.1 Determine the average size $<S_i>$ of each true count ($H_i \geq 2$) as follows:

$$< S_i > = \frac{1}{H_i} \sum_{h=1}^{H_i} S_{ih}$$

10.2.2 Calculate the size dependent capture rate, $CR(<S_i>)$, for every true count as follows:

$$CR(< S_i >) = \frac{H_i}{Z}$$

10.2.3 Plot $CR(<S_i>)$ versus $<S_i>$ as in the example in Figure 1, and interpolate or fit the data to discriminate against outlying points.

NOTE 7: The following equation for $c_{s,}$ in percent,

$$c_s = 100 \left[1 - \exp\left(\frac{s_0 - s}{c_0}\right)\right],$$

may be used to fit the plotted $CR(<S_i>)$ data. Here, c_s is the fitted value of $CR(<S_i>)$, s is the size ($<S_i>$), s_0 is the size at zero probability of capture, and c_0 is a curvature factor that determines the point at which the probability of capture approaches 100%. As c_0 and s_0 constitute a sufficient parameter set to describe completely $CR(<S_i>)$, they can be used for reporting, together with the chi-square goodness of the fit test statistic result.

10.2.4 Calculate the standard deviation of size, S_i for all true counts as follows:

$$\sigma(S_i) = \sqrt{\frac{1}{H_i - 1} \sum_{h=1}^{H_i} (S_{ih} - < S_i >)^2}$$

10.2.5 Plot the standard deviation of size, $\sigma(S_i)$, versus the mean size, $<S_i>$, for all true counts as shown in the example in Figure 2.

10.3 *Analysis of False Counts*

10.3.1 Divide the total number of false counts, *F*, by the number of scans, *Z*, to get the false count rate, *FCR*:

$$FCR = \frac{F}{Z}$$

10.3.2 Analyze the false count rate as a function of size to determine the cumulative false count rate, $CFCR(S_i)$, at each size, S_i, by taking the total number of false counts of size equal to or greater than S_i, and dividing by the number of scans, *Z*:

$$CFCR(S_i) = \frac{F_i}{Z},$$

where F_i is the largest value of the index associated with the count (or counts) of size S_i.

10.3.3 Plot $CFCR(S_i)$ as a function of S_i as shown in the example in Figure 3.

11 Report

11.1 Report the following information:

11.1.1 Operator identification;

11.1.2 Date of test;

11.1.3 Manufacturer, model, serial number, and software version of the SSIS being tested,

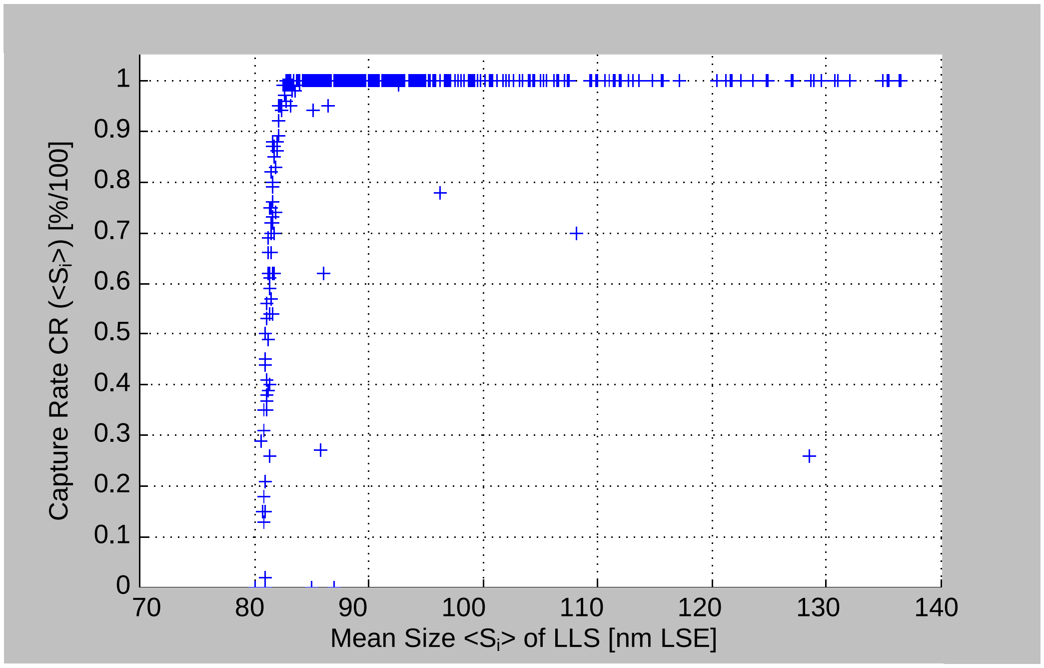
11.1.4 Description of the reference wafer used in the test.

11.1.5 Plot of the capture rate, $CR(<S_i>)$, *vs.* the mean size, $<S_i>$, similar to the example in Figure 1.

11.1.6 Plot of the standard deviation, $\sigma(S_i)$, of the LLS mean size, $<S_i>$, similar to the example in Figure 2.

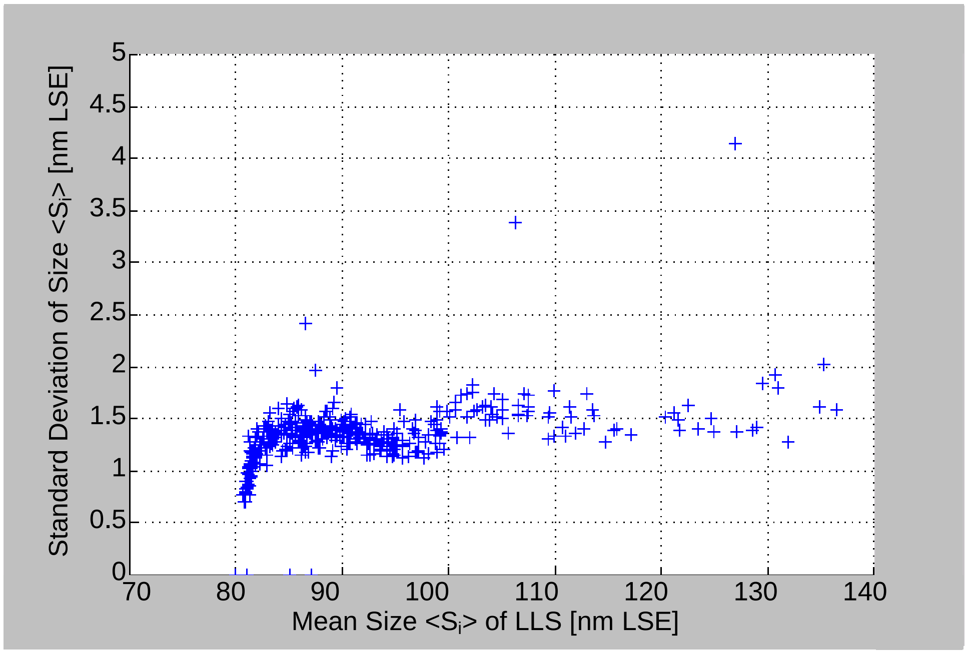
11.1.7 Calculated false count rate, *FCR*, as described in Section 10.3.2.

11.1.8 Plot of the cumulative false count rate, $CFCR(S_i)$, similar to the example in Figure 3.



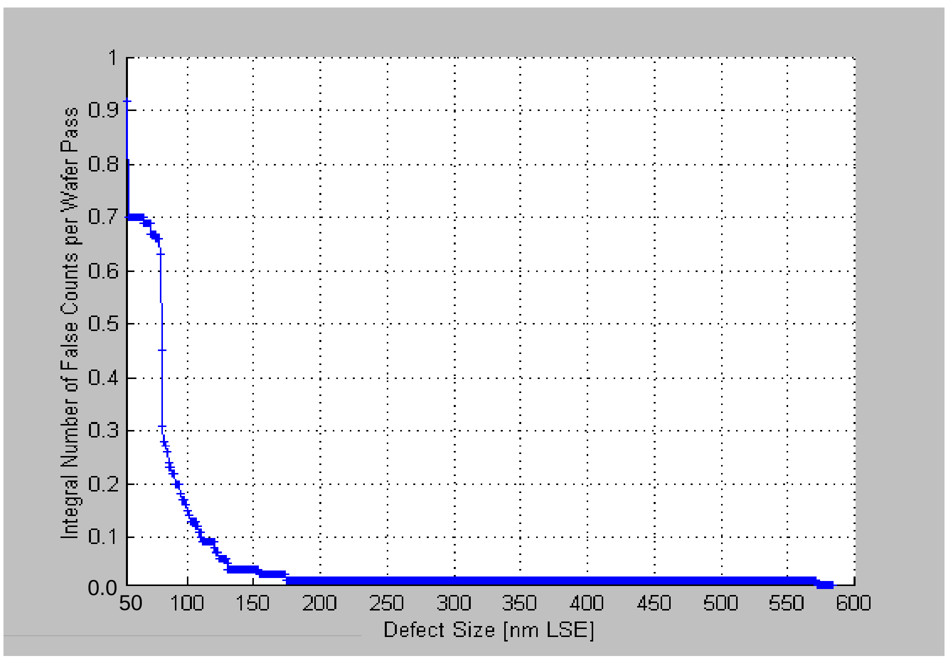
NOTE 1: This figure is an example plot of capture rate as determined in Sections 10.2.1 through 10.2.3. The measurements in this example are the result of 100 scans on a wafer with several natural LLS sites of different sizes. The SSIS noise floor was set at 80 nm LSE.

Figure 1
Capture Rate



NOTE 1: This figure is an example plot of the standard deviation of true count size as determined in Sections 10.2.4 and 10.2.5.

Figure 2
Standard Size Deviation



NOTE 1: This figure is an example plot of cumulative false count rate as determined in Sections 10.3.1 through 10.3.4 This is the same data set used for Figures 1 and 2; however, the horizonatal scale has been expanded.

Figure 3
Cumulative False Count Rate (CFCR)

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SEMI M51-0702
TEST METHOD FOR CHARACTERIZING SILICON WAFER BY GATE OXIDE INTEGRITY

This test method was technically approved by the Global Silicon Wafer Committee and is the direct responsibility of the Japan Silicon Wafer Committee. Current edition approved by the Japan Regional Standards Committee on April 26, 2002. Initially available at www.semi.org June 2002; to be published July 2002.

1 Purpose

1.1 Technique outlined in this standard is for the purpose of standardizing silicon wafer characterization by Gate Oxide Integrity (GOI). For a more detailed discussion of the general characterizing methods for this test, the reader is referred to Section 3. This test method is effective to evaluating Crystal Originated Particles in polished Si wafers that influence GOI.

2 Scope

2.1 This standard is for the purpose of characterization method of silicon wafer by GOI. This characterization method outline is below.

1) MOS (Metal-Oxide-Semiconductor) – capacitors fabrication: On the silicon wafer surface, a gate oxide film is thermally grown. Next, poly-Si electrodes are formed on the gate oxide film.

2) Electrical characterization: TZDB (Time Zero Dielectric Breakdown) characteristics of the MOS capacitors are measured. The presence of COP (Crystal Originated Particles) in the polished Si substrates gives an influence of the TZDB histogram of the gate oxide. That is, the silicon wafer is characterized by such GOI methods. The technique outlined in this standard is for the purpose of standardizing the procedure of MOS fabrication, measurement, analysis, and reporting of GOI data to interested parties. This standard is based on round robin results among the silicon wafer manufacturers. In general, this GOI test strongly depends on wafer surface/near–surface crystal defects, contaminations, particles, fabrication processes, and so on. Clean environment in which the MOS capacitors are fabricated shall be evaluated to be acceptable (see Section 5.2.1 and Related Information 1).

2.2 A target of this standard is to characterize silicon wafer. A proper gate oxide thickness of the MOS sample is 20–25 nm. Discussion of the gate oxide thickness is given in later section. It is well known that oxygen precipitate is also one of the gate oxide defect origins[1]. But, this is out of discussion of this standard, because the as-received wafers contain only a little oxygen precipitate.

2.3 The poly-Si film is used as a gate electrode of measured MOS capacitors. The poly-Si film can make standard test results fitter in actual integrated circuits than other metal electrodes because the poly-Si electrode is quite commonly used in most of the actual devices. It is advisable that a poly-Si electrode thickness range is from 200 to 400 nm, and a sheet resistivity range is less than 50 ohm/sq. (These poly-Si condition is discussed in later section.)

2.4 For a detailed discussion of sample structures for this test method, the reader is referred to EIA/JEDEC Standard 35-1. In general, the three most likely sample structures are simple planner metal-oxide semiconductor (MOS) capacitors, various isolation structures (for example, local oxidation of silicon (LOCOS), shallow trench isolation (STI)), and field effect transistors (FET). For the purpose of silicon wafer characterization, the simple planner MOS capacitor structure is most desirable. In the case of the various isolation structures and FET, the silicon wafer receives thermal treatments some times in the complicated sample fabrication process. Therefore, it is questionable that we look upon this measurement as the starting Si wafer characterization.

2.5 This TZDB method measure oxide breakdown electric fields using MOS capacitors. (The measurement condition gives the details later.) The COP influence on the oxide breakdown can be estimated by histogram of breakdown electric field.

2.6 The gate voltage is negatively biased so as to be in accumulation the Si surface and be effectively applied to the gate oxide. The applied electric field is stepwise increased from 0 to 15 MV/cm (in case of 25 nm gate oxide thickness: actual applied voltage is from 0 to 37.5 V).

1 K.Yamabe and K.Taniguchi, "Time-Dependent Dielectric Breakdown of Thin Thermally Grown SiO_2 Films", J. Solid St. Circuits, SC-20, 343(1983).

2.7 This test method is applicable to p-type CZ polished Si wafers. In the case of n-type Si wafer, the applied voltage polarity is reversed.

2.8 This standard does not purport to address safety concerns, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

3.1 *SEMI Standards*

SEMI C3.6 — Standard for Phosphine (PH_3) in Cylinders, 99.98% Quality

SEMI C3.21 — Standard for Carbon Tetrafluoride (CF_4) in Cylinders (Provisional)

SEMI C3.22 — Standard for Oxygen (O_2), 99.5% Quality

SEMI C3.23 — Standard for Oxygen (O_2), 99.98% Quality

SEMI C3.28 — Standard for Nitrogen (N_2), VLSI Grade in Cylinders, 99.9996% Quality

SEMI C3.41 — Standard for Oxygen (O_2), Bulk, 99.9998% Quality (Provisional)

SEMI C3.49 — Standard for Bulk Nitrogen (N_2), 99.99999% Quality

SEMI C3.54 — Gas Purity Guideline for Silane (SiH_4)

SEMI C21 — Specifications and Guideline for Ammonium Hydroxide

SEMI C27 — Specifications and Guidelines for Hydrochloric Acid

SEMI C28 — Specifications and Guidelines for Hydroflouric Acid

SEMI C30 — Specifications and Guidelines for Hydrogen Peroxide

SEMI C35 — Specifications and Guideline for Nitric Acid

SEMI C38 — Guideline for Phosphorus Oxychloride

SEMI C41 — Specifications and Guidelines for 2-Propanol

SEMI C44 — Specifications and Guidelines for Sulfuric Acid

3.2 *ASTM Standards*[2]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor for Industry.

ASTM F1241 — Terminology of Silicon Technology

ASTM F1771 — Standard Test Method for Evaluating Gate Oxide Integrity by Voltage Ramp Technique.

3.3 *EIA/JEDEC Standards*[3 4]

EIA/JEDEC 35 — Procedure for the Wafer-Level Testing of Thin Dielectrics

EIA/JEDEC 35-1 — General Guidelines for Designing Test Structures for the Wafer-Level Testing of Thin Dielectrics

EIA/JEDEC 35-2 — Test Criteria for the Wafer-Level Testing of Thin Dielectric

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *COP* — Crystal Originated Particles

4.1.2 *GOI* — Gate Oxide Integrity

4.1.3 *LOCOS* — Local Oxidation of Silicon

4.1.4 *MOS* — Metal Oxide Semiconductor

4.1.5 *STI* — Shallow Trench Isolation

4.1.6 *TZDB* — Time Zero Dielectric Breakdown

4.2 *Definitions*

4.2.1 Many terms relating to silicon technology are defined in ASTM Terminology F 1241.

4.2.2 Definitions for some additional terms are given in SEMI M1 and ASTM F1771.

4.2.3 Other terms are defined as follows:

4.2.3.1 *crystal originated particles*[5] *(COP)* — This is the one of grown-in defects in the CZ Si wafers with an octahedral structure. This was found as particles

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

3 Electronic Industries Alliance, EIA Engineering Department, Standards Sales Office, 2001 Eye Street, NW, Washington, D.C. 20006, USA. Website: www.eia.org

4 Joint Electron Device Engineering Council, 2500 Wilson Blvd., Arlington, VA 22201, website: www.jedec.org

5 J. Ryuta, E. Morita, T. Tanaka and Y. Shimanuki, “Crystal – Originated Singularities on Si Wafer Surface after SC1 Cleaning”, *Jpn. J. Appl. Phys*. 29(1990) L947.

appeared on the silicon surface by repetition SC-1[6] of RCA cleaning.

4.2.3.1.1 *Discussion* — It has been thought that the COP is one of the main origins of the GOI degradation. The gate oxide formed on the Si surface at which the COP appears easily breaks down at the corner of the octahedral shape like at a Si trench corner[7,8]. This corner of octahedral structures is thinning the oxide films. The oxide electric field enhances at that place. The breakdown electric field is decreased.

4.2.3.2 *failure modes* — The breakdown failure results are summarized in terms of ranges of oxide electric field in which the breakdown occurred. One set of categories (A, B and C for TZDB) widely used[9, 10] is as follows:

- *A mode failure*: 0 MV/cm $\leq E_{bd} <$ 3 MV/cm
- *B mode failure*: 3 MV/cm $\leq E_{bd} <$ 8MV/cm
- *C mode failure*: 8 MV/cm $\leq E_{bd}$

4.2.3.2.1 *Discussion*

- *A mode failure*: Initial short

  This failure mode is caused by pinholes of oxide films formed in the gate oxide process. The COP does not cause these oxide pinholes.

- *B mode failure*: Accidental breakdown

  The COP is a main origin of this failure. This failure mode gives influence on MOS devices or MOS integrated circuits.

- *C mode failure*: Fatigue breakdown

  This failure mode is partly caused by the COP, but is almost wearout breakdown. These categories have traditionally been used for oxide thickness about 20–25 nm. For thinner films, care must be taken in their use and in proper derivation of the oxide filed strength as described in RELATED INFORMATION 1.

4.2.3.3 *Time Zero Dielectric Breakdown (TZDB)* — This is one of the electrical characteristics of dielectric films. This characteristic is contrasted with time dependent dielectric breakdown[11,12].

4.2.3.3.1 *Discussion* — An applied bias, for which the oxide leakage current goes over a predetermined I_{bd}, is measured as a breakdown gate voltage. The breakdown electric filed is defined by the gate breakdown voltage normalized by the gate oxide thickness.

5 Summary of Method

5.1 *Overview* — This test method are fabricating array of the many similar MOS capacitors on silicon wafers, measuring the TZDB voltage histogram by applying step voltage to the MOS capacitors with monitoring the oxide leakage current, estimating the dielectric breakdown defect density which is caused by silicon wafers. The defect density is estimated from the B-mode failure fraction. This test method is to characterize the Si wafer and is very useful in the crystal defect (mainly COP) evaluation of mirror polished CZ Si wafer.

5.2 *MOS Capacitor Fabrication Process* — Many MOS capacitors are formed on the test wafer. The MOS fabrication process consists of wafer cleaning, thermal oxidation, poly-Si deposition, phosphorous doping, activation heat treatment, photolithography and etching.

5.2.1 *Fabrication Environment* — It is necessary to fabricate MOS capacitors in the clean room environment of 1000 or better class in total quality. That is, it needs to be confirmed that the A mode failure rate is 10% or less. The A mode failure depends not only on the particle of work environment atmosphere but also on the ultra pure water, fixtures, process apparatus, clean cloths, operation rules etc. Heavily contamination such as alkaline or heavy metal has an important effect on the TZDB of the oxide.

5.2.2 *Wafer Cleaning* — To characterize the as-received Si wafers, the wafers shall not be cleaned. If it might contaminate a furnace, the wafers shall be cleaned before oxidation. In these cases, the wafers are cleaned by a modified RCA method[6], in general. The cleaning method shall be confirmed in advance that the previously mentioned condition for the A mode failure is met.

6 W. Kern and D. Puotinen, "Clean Solution Based on Hydrogen Peroxide for Use in Silicon Semiconductor Technology", *RCA Rev*., 31, 187(1970).

7 T. Mera, J. Jablonski, K. Nagai, and M. Watanabe, "Grown-in defects in silicon crystals responsible for gate oxide integrity deterioration", *Ohyo-Buturi*, 66(7), 728 (1997).

8 K.Yamabe and K.Imai, "Nonplanar Oxidation and Reduction of Oxide Leakage Currents at Silicon Corners by Rounding-off Oxidation", IEEE Trans. Electron Devices, ED-34,1681 (1987) .

9 K. Yamabe, K. Taniguchi, and Y. Matsushita, "Thickness Dependence of Dielectric Breakdown Failure of Thermal SiO_2 Films", *Reliability Physics – 21st Annual Proceedings*, 1983, p.184.

10 K. Yamabe, Y. Ozawa, S. Nadahara, and K. Imai, "Thermally Grown Silicon Dioxide with High Reliability", in "Semiconductor Silicon 1990", Proceedings of the 1990 Spring Meeting of The Electrochemical Society, P.349.

11 D. L. Crook, "Method of Determining Reliability Screens for Time Dependent Dielectric Breakdown", Proc. *Int. Reliability Physics Symposium*, 1979, p.1

12 E. S. Anolick and G. R. Nelson, "Low Field Time Dependent Dielectric Integrity", Proc. *Int. Reliability Physics Symposium*, 1978, p.8

5.2.3 *Thermal Oxidation* — The gate oxide of the MOS capacitor is thermally grown. It is desirable to fix the oxidation conditions. Because the oxidation rate is influenced to oxidation temperature[13] and the gate oxide quality is depend on the oxide film thickness[9] and, strictly speaking, oxidation condition (ambient, temperature etc.). It is recommended that the gate oxide of about 20–25 nm thick is grown in dry oxygen ambient at 850–950°C. It is possible that addition of HCl or water vapor to the oxidation ambient leads to underestimate the oxide defect density. As the result, one evaluation result of the gate oxide formed in a special oxidation condition cannot be compared with that in the standard oxidation condition. To measure an oxide film thickness, a monitor wafer is oxidized with sample wafers. An average value of 5 or more points on the monitor wafer is adopted as the oxide thickness.

5.2.4 *Electrode Formation* — The poly–Si layer with a thickness of 200 nm–400 nm and a sheet resistance of 20–50 Ω/sq is formed by low-pressure chemical vapor deposition (LPCVD). In general, there are two type phosphorous doping methods. One is ex-situ doping, and another is in-situ doping.

5.2.4.1 *Ex-situ Phosphorous Doping* — After the undoped poly-Si film is deposited by the LP-CVD method, phosphorus is diffused using $POCl_3$ as a phosphorous source.

5.2.4.2 *In-situ Phosphorous Doping* — The phosphorous-doped poly-Si is deposited using an in-situ doping LPCVD, following a heat treatment to activate the doped phosphorus.

5.2.5 *Discussion* — Too high resistance of the poly-Si electrode films leads a voltage drop within the electrode not to be neglected. That is, in the case, the oxide leakage current is decreased in the range of the higher electric field. On the other hand, too low resistivity of them caused by higher concentration phosphorous doping leads the gate oxide dielectric characteristics to degrade. Too thin poly Si electrode leads self-healing of the oxide weak spots to be easier[9]. The self-healing makes us underestimate the oxide breakdown defect density. Too thin poly-Si electrode leads the TZDB measurement to degrade for mechanical stress of an exploring probe such as tungsten. Too thick poly-Si electrode in the ex-situ doping technique is easy to induce a depletion layer of phosphorus near the poly-Si/SiO_2 interface that causes parasitic resistance and unnecessary voltage drop in a measurement circuit. It is desirable to monitor poly-Si thickness and sheet resistance of the poly-Si layers every processing batch using a monitor wafer.

13 B.E.Deal and A.S.Grove, "General relationship for the thermal Oxidation of Silicon", J.Appl.Phys., 36, 3770(1965).

5.2.6 *Photolithograph Process* — The electrodes of the MOS capacitors are formed by patterning in the photolithograph. EIA/JEDEC Standard 35-1 is referred to about this mask design. The appropriate area and the appropriate number of the MOS capacitors for each defect density shall be selected to detect the crystal defect with a high sensitivity. For the evaluation of COP, it is necessary to measure 100 or more MOS capacitors with a gate area of 10 mm^2 on a wafer. (See Table R1-3 in Related Information 1.) It is desirable to prepare the plural of MOS capacitors of the same area within each chip as a spare.

5.2.7 *Etching Processes* — The photo resist pattern formed by photolithograph technique is used as the mask of poly-Silicon etching. Generally a wet etching method or a dry etching method is applied for poly-Silicon etching. If the wet etching method is applied, the etching rate shall be controlled well. If the peripheral oxide of the electrode is removed, it is sometimes difficult to accurately measure the TZDB. If the dry etching method is applied, especially RIE, charging-up of MOS capacitor shall be cared. In the case that the A mode defect density is high, the MOS capacitors shall be confirmed to not be charged up during the etching process. If an ashing removal of the photo resist is applied, the charging-up of MOS capacitor shall be cared. Similarly to RIE, in the case that the A mode defect density is high, the MOS capacitors shall be confirmed to not be charged up during the ashing process. If there an oxide and the poly-Si film on the wafer backside surface, those shall be removed.

5.3 *Measurement of Electric Characteristic of MOS Capacitors*

5.3.1 The dielectric breakdown defect density of the silicon oxide is evaluated by the TZDB method for the MOS capacitors. In the TZDB method, the gate oxide electric field of MOS capacitor is kept increasing in step. The electric field applied to the gate oxide when the gate oxide leakage current exceeds the predetermined dielectric breakdown judgment value is defined as the oxide dielectric breakdown field. From a histogram of the breakdown field for the 100 or more MOS capacitors, the dielectric breakdown defect density is estimated.

5.3.2 We can see two characteristics of the formed MOS capacitors from the current-voltage (IV) plots. First, deviation of the gate oxide thickness appears in a loose distribution of the IV plots. Second, if the I-V curves bend suddenly and have gentle slope in the high voltage region, there may be the high parasitism resistance, for example, the high resistance of the poly-Si electrode. In such a case, the low reliable measurement demands the adjustment of the MOS preparation process.

5.3.3 *Applied Step Voltage*

5.3.3.1 For the reliable measurement, a voltage resource with well-defined output shape shall be used. An overshooting of the applied step voltage decreases the apparent oxide breakdown voltage as compared with a real breakdown voltage. In the TZDB measurement, the oxide leakage current is measured after holding the constant applied voltage during a predetermined time. After then, the applied voltage increases stepwise. This procedure is repeated. If the holding time is shorter than 100 ms, the stability of the voltage may be not enough for the current measurement. And if the hold time is longer than 800 ms, the stability of the voltage may be enough. Especially, in the high electric field region, the gate oxide may receive the electric stress similar to time dependent dielectric breakdown (TDDB). The holding time of 200 ms is recommended. Accordingly to the round robin result as described in RERATED INFORMATION 1, there are no problems in setting the holding time of 100–800 ms. A recommended step height of the applied voltage is between 0.1–0.5 MV/cm in electric field. The polarity of the voltage is selected for the Si surface so as to be in accumulation. That is, for P type silicon wafer, the gate oxide is negatively applied. The maximum electric field is 15 MV/cm. Even if the gate voltage corresponding to more than 15 MV/cm is applied, the voltage is not affectively applied to the gate oxide because of the voltage drop at the parasitic resistance.

5.3.4 *Breakdown Judgment*

5.3.4.1 The oxide dielectric breakdown is judged by the predetermined oxide leakage current. That is, when the gate oxide leakage current exceeds the dielectric breakdown judgment current, the applied voltage is defined as the breakdown voltage. The breakdown electric field is the value that the breakdown voltage is normalized by the gate oxide thickness.

5.3.4.2 *Discussion* — If the dielectric breakdown judgment current is too high (Ig > 10–3A), one part of proper A-mode failures can be counted as the B-mode failure because of the series resistance of the samples or measurement system. Otherwise, if the judgment current is too low (Ig < 10–7A), one part of proper C-mode failures that the gate oxide was not broken down is counted as the B-mode failure. In both cases, it will be done to take a mistake in classification of the failure mode categories, even if the measurement is accurately done and appropriate I–V curves is gotten. So the dielectric breakdown judgment current of 10–5A is recommended.

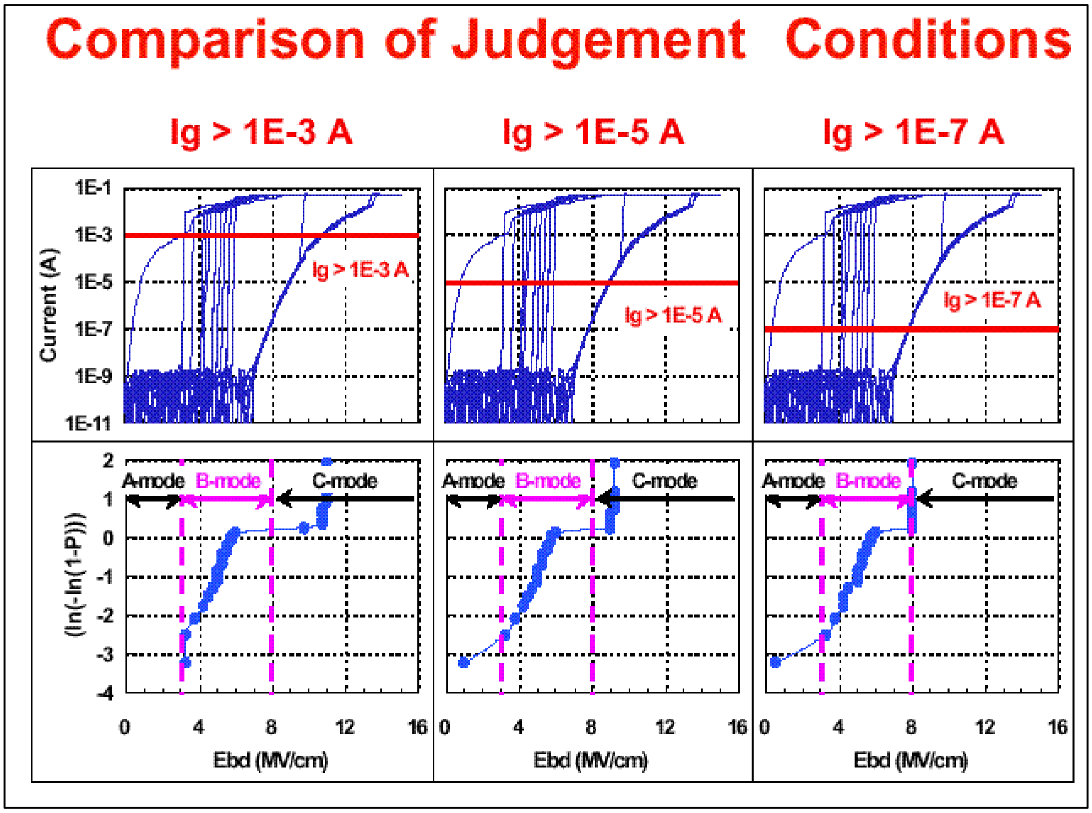

Figure 1
Comparison of Judgment Conditions

6 Significance and Use

6.1 This standard gives instructions for the procedure to characterize mirror polished CZ-grown p-type Si wafers by measuring the dielectric breakdown defect density in the thermally grown gate oxide film of the MOS capacitors. The MOS capacitors must be formed in accordance with the preparation process described in Section 5 that influences the oxide characteristics.

6.2 It is well known that both the Si surface morphology and the cross-sectional structure at the pattern edge of the active region/field isolation region of MOS devices influences the dielectric breakdown of the gate oxide. Various kinds of contaminations also influence the dielectric breakdown of the gate oxide. The contamination such as the alkaline or heavy metal and the organic particles increases with increasing sample fabrication process steps. Furthermore, the COP increases with SC-1 cleaning step numbers. These facts indicate that it is desirable to simplify the sample structure and its preparation processes to characterize the proper Si wafer by the TZDB of the gate oxide. Thermal process can cause oxygen precipitate growth in a Si wafer. This standard cannot be applied to Si wafers that might receive such a thermal process.

6.3 The appropriate area and the appropriate total number of the tested MOS capacitors shall be chosen so as to answer the purpose of this standard test. For example, as shown in Table R1-3 of RELATED INFORMATION, it is suitable to select the gate electrode area of 10 mm^2 and the total capacitor number of more than 100.

6.4 The electrode of the MOS capacitors has a great influence on the dielectric breakdown of the gate oxide. Poly-silicon is recommended as the electrode material in this standard. It is applicable to practical ultra large-scale integrated circuits (ULSI). The poly-Si electrode gives us test results highly consistent with the actual ULSI.

7 Interferences

7.1 Since this is a DC measurement, care must be taken to make sure that the Si wafer has a low resistance ohmic contact. There must be no dielectric film on the backside surface, e.g. silicon oxide, in order to effectively apply a voltage bias to the gate oxide. This is not necessary to be done with a metallic contact to the backside of the wafer under test.

7.1.1 However, when the vacuum chucking is weak, care must be taken on a possibility that the dielectric breakdown voltage of the gate oxide cannot be accurately measured due to the increase in the parasitic resistance.

7.2 It is strongly suggested that testing be done with a voltage polarity that the Si surface will be in accumulation underlying the gate oxide, that is, negative voltages for the p-type Si wafers. If the polarity of the voltage is chosen to be in the reverse direction, the accurate breakdown voltage may not be measured due to presence of a depletion layer below the gate electrode.

7.3 Evaluation and control of electrical noise in the current-voltage data as part of this test method are crucial to the proper identification of the failure criteria.

7.4 In the TZDB measurement, lowering of the electrical noise under low bias stress condition is made possible by averaging of measurement data using a sampling function of the measurement system. While the required 100-ms holding time may be set using a delay in the measurement loop, an additional, uncontrolled delay may be incurred due to autoranging of an electrometer. The effect is most pronounced for very low oxide leakage currents, where the measured value is several orders of magnitude below the minimum range set by the electrometer software.

7.5 Too high mechanical stress of the exploring probe can influence the measurement results, because the exploring probe is directly contacted to the gate electrode on the gate oxide.

7.6 The actual results obtained will depend somewhat on the sample fabrication process. Care must be taken to ensure a consistent processing.

7.7 Wafer temperature during testing shall be clearly defined. While the dielectric breakdown voltages are not strongly temperature-dependent, the oxide wearout mechanism is temperature-sensitive, and large temperature variations might have an impact on results.

7.8 Precaution: Since the voltage and currents involved are potentially dangerous, appropriate means of preventing the operator from coming into contact with the exploring probe or other charge surfaces shall be in place before testing.

7.9 This standard does not include any clauses relating to safety and sanitation of the environment. Those who intend to implement this standard shall consider appropriate means to prevent any accidents or disasters, as well as taking responsibility for maintaining a state of safety, health and hygiene for users.

8 Apparatus

8.1 The MOS capacitors shall be fabricated in an environment of 1000 or better class in total quality to prevent various contaminations. Contamination control in the processes from wafer cleaning step to poly-Si deposition step are especially important. The contaminations in those processes have been reported to degrade GOI. Therefore, attention must be paid particularly to these processes.

8.2 High purity deionized water and high purity chemicals of the electronics industry grades shall be used in the processes of wafer cleaning, wet etching, etc.

8.3 In thermal processes such as gate oxidation, poly-Si deposition and phosphorus doping, the fluctuation of process temperature may affect the uniformity of oxide thickness, poly-Si thickness and concentration and distribution of doped phosphorus ions. The temperature fluctuation of used furnaces shall be within ± 5°C at least.

8.4 Quartz is very stable for the strong acids excluding hydrofluoric acid or the strong alkalis used in the wet processes and at higher temperature than 1000°C. Therefore, quartz vessels and tubes, and so on are quite frequently used in the ULSI manufacturing processes. The quartz vessels and tubes with high purity of the electronics industry grades shall be also used in this MOS capacitor fabrication processes.

8.5 High purity gases of the electronics industry grades, such as N_2, O_2 and SiH_4, shall be used in the processes of the thermal oxidation, the poly-Si deposition, the phosphorous doping and so on to prevent contamination from the gases.

8.6 A criterion judging the validity of a clean room environment where the MOS samples is fabricated for this test method is that the A-mode failure fraction of the samples with 20–25 nm oxide is less than 10%. It is advisable that a cleanness level of the clean room environment where the tested MOS capacitors are fabricated is evaluated by the TZDB measurement of the MOS capacitors on an epitaxial wafer.

8.7 ASTM standard F1771 shall be applied for the measurement equipment such as voltage source units and manual probing machines.

9 Sampling

9.1 Sampling is the responsibility of the user of this test method. However, if testing is done as part of comparison or correlation, all participants shall agree upon sampling in advance.

NOTE 2: Refer to the appendix of JEDEC standard No.35 for good discussion of sampling plan statistics.

10 Procedure

10.1 *Fabrication of MOS Capacitor*

10.1.1 It shall be confirmed first that the environment for fabricating MOS capacitors is suitable for this test method. The environment includes clean room, chemicals, ultra pure deionized water, oxidation furnace, poly-Si deposition equipment, different kinds of quartz jigs, etc. As a criterion, A-mode failure fraction of MOS capacitors made in the environment shall be less than 10%.

10.1.2 To characterize the proper Si wafers, the wafers shall not be cleaned. If the wafers might contaminate a furnace, they shall be cleaned before oxidation. In these cases, the wafers are cleaned by a modified RCA method[6], in general.

10.1.3 Input oxidation parameters to a used furnace system. The parameters include oxidation temperature, ambient, gas flow rate, oxidation time, etc. A recommended oxidation temperature is 850–950°C. The appropriate parameters to obtain the recommended oxide thickness (20–25 nm) shall be found out in advance by preliminary tests.

10.1.4 Oxidize the wafers in dry oxygen ambient. Some reference wafers shall be treated with the sample wafers to monitor oxide thickness and sheet resistance of a poly-Si electrode later. The number of reference wafers shall be decided by user of this test method taking account of the quantity of the total wafers in the batch.

10.1.5 Measure an oxide thickness of the reference wafers by ellipsometry (or other optical method) to confirm a uniformity of the oxide thickness within a wafer. Average thickness shall be in 20–25 nm and the dispersion within a wafer shall be less than ± 3%.

10.1.6 Input deposition parameters of poly-Si to a used LP-CVD furnace system. The parameters include deposition temperature, pressure, gas flow rate, deposition time, etc. The appropriate condition to obtain the recommended poly-Si thickness (200–400 nm) shall be found out in advance by preliminary tests. If a doped poly-Si film will be deposited, corresponding deposition parameters shall be input.

10.1.7 Deposit a poly-Si film on the wafers oxidized. The recommended deposition temperature from this test method is 570–640°C. Some reference wafers with an oxide shall be treated with the sample wafers to monitor the poly-Si thickness later. The oxide thickness on the reference wafers shall be recommended by a vendor of equipment to measure a poly-Si film thickness. The number of reference wafers shall be decided by a user of this test method taking account of the total wafer quantity in the batch.

10.1.8 Measure poly-Si thickness on the reference wafers using spectroscopic reflectometer (or other optical film thickness measurement instruments) to confirm the uniformity of poly-Si film thickness within a wafer and within a batch. Average poly-Si film thickness shall be in 200–400 nm and dispersion within a batch shall be less than ± 10%. If doped poly-Si was deposited, proceed to Section 10.1.11.

10.1.9 Input the doping parameters to a phosphorus-doping furnace system. The parameters include doping temperature, ambient, phosphorous source, carrier gas flow rate, doping time, etc. $POCl_3$ is a well-known phosphorous source. Those process parameters will affect poly-Si resistance and its uniformity. The appropriate process parameters to obtain a recommended sheet resistance (20–50 Ω/sq) shall be found out in advance by preliminary tests.

10.1.10 Dope phosphorus into the poly-Si film on the Si wafers. The reference wafers shall be doped with the sample wafers to check the poly-Si film resistance.

10.1.11 Measure sheet resistance of reference wafers using resistance meter to confirm a uniformity of resistance within a wafer and within a batch. Average resistance shall be 20–50 Ω/sq and the dispersion within the batch shall be less than ± 10%.

10.1.12 Make a resist mask pattern using photolithography technique. The recommendation for gate electrode pattern of the MOS capacitors in this test method is to form more than 100 capacitors with an area of 10 mm^2 within a wafer.

10.1.13 Etch the poly-Si film to form MOS capacitors. At the same time, the backside poly-Si film shall be etched. If a dry etching method is used, care must be taken to avoid plasma damage on the formed MOS capacitors.

10.1.14 Etch the backside oxide. Care must be taken to prevent damage on MOS capacitors in the etching process. For example, a coating resist on the front surface can prevent the gate oxide from sustaining damage in NH_4F etching.

10.1.15 Remove the resist on the sample Si wafers. If a plasma ashing machine is used, attention must be paid because some kind of the ashing machine was reported to damage MOS capacitors.

10.2 *Measurement*

10.2.1 Before the measurement, record the following information for each sample: date, time, operator, sample ID, oxide thickness, gate area, gate material, oxidation condition, conductivity type (p or n), equipment ID, and comment.

10.2.2 Decide measurement parameters and record them. Stepwise voltage is applied in this test method. The parameters include maximum stress voltage (V_{max}), increment of step voltage (ΔV), step hold time (T_h), judgment current of breakdown (I_{bd}), measurement temperature, the number of capacitors to be measured and a map of the capacitors.

10.2.3 Set a tungsten-exploring probe at the starting position.

10.2.4 Set the exploring probe on a new MOS capacitor at the next position.

10.2.5 Bias the applied voltage to zero volts ($V_{app}(0) = 0$). Record the oxide leakage current and the voltage.

10.2.6 Increase the applied voltage by a step increment ($V_{app}(n) = V_{app}(n - 1) + \Delta V$). Measure the current I(n) and the voltage at the step after the hold time (T_h), and record them. Where "n" is the step number. At the first step, $V_{app}(1) = V_{app}(0) + \Delta V$.

10.2.7 If the applied voltage is equal to or large than the maximum stress voltage ($V_{app}(n) \geq V_{max}$), record the maximum stress voltage (V_{max}) as the breakdown voltage (V_{bd}) with MOS address, and proceed to Section 10.2.9. If V_{app} is less than V_{max}, proceed to next step.

10.2.8 Check to see if the current I(n) has reached the judgment current of breakdown (I_{bd}). If so, record the applied voltage (V_{app}) with each MOS address as the breakdown voltage (V_{bd}), and proceed to Section 10.2.9. If not, repeat from Section 10.2.6.

10.2.9 Check to see if there are any more MOS capacitors to be measured. If so, repeat from Section 10.2.4 until all MOS capacitors are tested.

10.2.10 Report the results.

10.2.11 The maximum stress electric field (E_{max}), increment of step field (ΔE) and applied field (E_{app}) can also be used as the measurement parameters. They can be obtained by calculation as shown in Section 10.2.

10.2.12 Figure 2 is a flow diagram outlining the procedure for this test method.

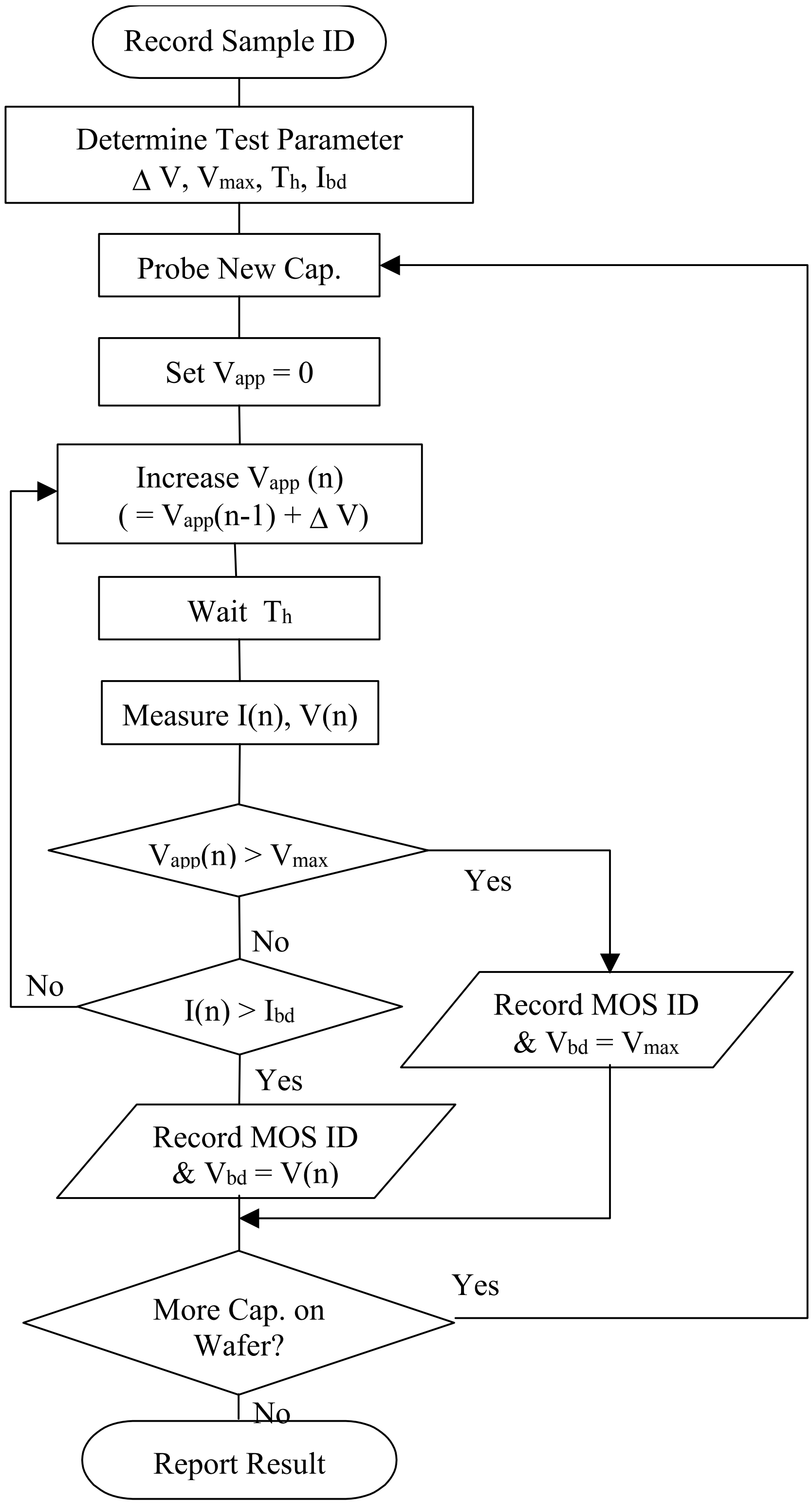

Figure 2
Flow Diagram Outline

11 Calculations

11.1 *Current and Current Density*

To calculate the oxide leakage current (I) from an oxide leakage current density (J), multiply the current density by the area of gate contact (S) as follows:

Symbolically: $I = J \times S$ (1)

Example: Given a current density (J) of 1 µA/cm^2 and a gate area (S) of 10 mm^2, the current would be 100 nA.

Similarly, compute current density (J, [A/cm^2]) from measured current (I, [A]) and area (S, [cm^2]) using.

$J = I / S$ [A/cm^2] (2)

11.2 *Voltage and Electric Field Strength*

To calculate voltage (V) from an electric field (E), multiply the electric field strength by the gate oxide thickness (T_{ox}) as follows:

Symbolically: $V = E \times T_{ox}$ (3)

Tox = gate oxide thickness, cm

Example: Given an electric field (E) of 15 MV/cm and a gate oxide thickness (Tox) of 25 nm, the voltage would be 37.5 V.

Similarly, compute electric field (E, [MV/cm]) from measured voltage (V, [V]) and gate oxide thickness (T_{ox}, [cm]) using.

$E = V / T_{ox}$ [MV/cm] (4)

11.3 *Oxide Voltage*

The applied voltage across an MOS capacitor has offset. The offset voltage due to gate-substrate work function difference [Φ_{ms}] and oxide fixed charge [Q_f]. Although it is better to consider this offset voltage, the influence of the offset voltage is small for the oxide film thickness in the range recommended in this test method and then it is not mandatory.

11.4 *Calculate of Defect Density*

The defect density calculation can be based on a Poisson relationship (see EIA/JEDEC 35) using the following equation:

$\rho_{ox} = -\ln(1 - F)/S$ (5)

ρ_{ox} = Defect density (defects/cm^2)

F = Failure fraction for each oxide breakdown mode

S = Capacitor gate area (cm^2)

Example: Given a total of 100 MOS capacitors tested with B mode failed 30 capacitors and a gate area of 10 mm^2, the defect density would be as follows:

$\rho_{ox} = -\ln(1-(30/100))/0.1 = 3.6$ defects/cm^2 (6)

11.5 *Weibull Distribution*

To convert cumulative percentages to Weibull format (sometimes referred to as "smallest extreme value probability distribution III"), use the following equation:

$\ln(-\ln(1 - F))$ (7)

When ln is the natural log operator and F is a fraction of cumulative failures. Care shall be taken so that F is never exactly 1 since this will be in an undefined situation.

12 Report

12.1 Report the following for each wafer, as appropriate for the test conditions and as agreed upon by the parties to the test.

12.2 *Test Description*

12.2.1 Date

12.2.2 Time

12.2.3 Operator

12.2.4 Measurement system ID

12.2.5 Sample lot ID

12.2.6 Wafer ID

12.2.7 Average oxide thickness

12.2.8 Gate area (cm^2)

12.2.9 Gate material

12.2.10 Oxidation parameters

12.2.11 Type of wafer (Ex: n or p)

12.2.12 Applied stress parameters

12.2.13 Test temperature

12.2.14 Process comment

12.3 Report the following for each capacitor.

12.3.1 Capacitor ID such as address

12.3.2 I–V character data

12.3.3 Breakdown voltage or Breakdown electric field

12.4 Report the following for each wafer.

12.4.1 Histogram and Weibull plot of breakdown electric field

12.4.2 Average of breakdown voltage, breakdown electric field

12.4.3 Breakdown mode yield (A-mode, B-mode and C-mode)

12.4.4 Breakdown mode map or E_{bd} map

12.4.5 Result of calculated defect density

RELATED INFORMATION 1
OUTLINE OF ROUND ROBIN

NOTE: This related information is not an official part of SEMI M51 and was derived from work by the originating task force. This related information was approved for publication by full letter ballot on April 26, 2002.

R1–1 MOS Structure

R1–1.1 *Gate Oxide Thickness*

R1–1.1.1 The gate oxide thickness of the MOS capacitors used to test in a round robin was 25 nm. In this round robin, we evaluated GOI of the MOS capacitors with the gate oxide film of 25 nm thick on the mirror-polished p–type CZ Si. In the TZDB evaluation, a negative electric field was raised step by step from 0 to 15MV/cm, and an oxide leakage current value was measured. When the oxide leakage current first exceeded the dielectric breakdown judgment value, we judged that the gate oxide film dielectrically broke down.

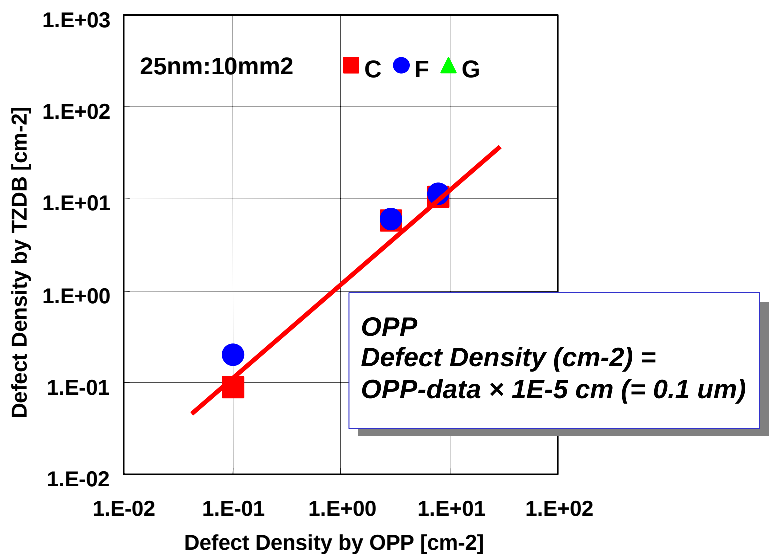

Figure R1–1
A Relationship between B-mode Defect Density in TZDB and Defect Density of OPP

R1–1.1.2 The graph above shows the relation between B-mode defect density by TZDB of 25 nm thick oxide and defect density by optical precipitate profiler (OPP). Here, based on an assumption that the dielectric breakdown defect is in conform with the Poisson distribution, the defect density by TZDB of 25 nm thick oxide, ρ, was calculated from the dielectric breakdown failure fraction of TZDB, F, as follows.

$\rho_{ox} = -\ln(1-F)/S$ (8)

Here, S is a gate electrode area of the evaluated MOS capacitors.

R1–1.1.3 The defect density was obtained by the B-mode failure fraction, F, of TZDB. On the other hand, estimation of the defect density by OPP was carried out as follows. The OPP defects were measured the wafers at the same position (ingot) of the same Si crystal as the sample wafers. The COP which appeared on the Si wafer surface was estimated from a volume defect density, n(cm^{-3}), and a diameter of the COP, L(cm) . The area density of the defects which appear at the Si surface can be estimated with n × L, assuming that the COP diameter, L, is almost uniform and the volume defect density, n, is uniformly distributed. Here, 0.1 μm as the L value[7] and the measurement results by the OPP technique as the n value were used. As a result, the OPP defect densities by which each three kinds of Si wafers, H, M, and L, was characterized became as follows.

H: $n = 7.83 \times 10^5 (cm^{-3}) \Rightarrow \rho_{ox} = 7.8 (cm^{-2})$

M: $n = 2.89 \times 10^5 (cm^{-3}) \Rightarrow \rho_{ox} = 2.9 (cm^{-2})$

L: $n \leq 1 \times 10^4 (cm^{-3}) \Rightarrow \rho_{ox} \leq 0.1 (cm^{-2})$

In the graph above, the sign of C, F, and G is measurement results for the MOS capacitors made in different three wafer vendors. The defect density by TZDB and the defect density by OPP can be seen the relation of almost 1:1 in this figure. These facts mean that the B-mode defect of the 25 nm-thick gate oxide is mainly attributed to the COP's that appear at the Si wafer surface. Moreover, these results indicate that this standard test method can gives us the evaluation of the oxide defect densities over the wide range of the COP defect density with excellent reproducibility.

R1–1.2 *Total Number and Electrode Area of Measured MOS Capacitors*

R1–1.2.1 To measure with high sensitivity of some defect density, the large number of the MOS capacitors with a large electrode area shall be measured. However, the measurement of too large area and too large number of the MOS capacitors leads to unnecessary evaluation load. Appropriate area size and a total number of the measurement MOS capacitors to evaluate the defect density at the Si wafer surface shall be selected depending on a foreseen defect density and a purpose of an evaluation. For instance, if you have a purpose to evaluate the conventional mirror polished CZ Si wafer with a defect density of 1-10/cm^2, you must measure about 100 MOS capacitors with an electrode area of 10–20 mm^2.

R1–1.2.2 When the Poisson's distribution is assumed as a defect distribution as mentioned above, the yield, Y, of the MOS capacitors with the electrode area of S and the defect density of ρ_{ox} is given by the following equation.

$Y = 1 - F = \exp(-\rho_{ox} S)$

R1–1.2.3 The failure fraction, F, is calculated using this expression. Here, the necessary MOS capacitor number, n, for the observation of one breakdown MOS capacitor is assumed to be 1/F. Thus, this n was calculated from the value of S and ρ_{ox} as shown in Table R1-1.

Table R1-1 Necessary Number for Observation of One Breakdown MOS Capacitor

1/F = Necessary number for observation of one breakdown MOS capacitor

S(mm^2)	*1*	*5*	*10*	*20*	*50*
$\rho_{ox} = 10\ cm^{-2}$	11	3	2	1	1
$\rho_{ox} = 1\ cm^{-2}$	101	21	11	6	3
$\rho_{ox} = 0.1\ cm^{-2}$	1001	201	101	51	21

R1–1.2.4 In the same way, the yield probability, Y, and necessary number, n, for observation of available MOS capacitors was calculated as indicated in Table R1-2.

Table R1-2 Necessary Number for Observation of Available MOS Capacitor

1/Y = Necessary number for observation of available MOS capacitor

S(mm^2)	*1*	*5*	*10*	*20*	*50*
$\rho_{ox} = 10\ cm^{-2}$	1	2	3	7	148
$\rho_{ox} = 1\ cm^{-2}$	1	1	1	1	2
$\rho_{ox} = 0.1\ cm^{-2}$	1	1	1	1	1

R1–1.2.5 The number of needed MOS capacitors is shown in Table R1-3 though both "1/F" and "1/Y" were done to one or more. If it wants to observe ten MOS capacitors or more respectively in an actual evaluation including reproducibility, the number of needed MOS capacitors for the measurement will be the multiplied ten and reaches the value of the Table R1-3 inside below.

Table R1-3 Necessary Number of MOS Capacitors (in the case of ρ_{ox} = 1 or 10)

S (mm²)	*1*	*5*	*10*	*20*	*50*
Confirmation of breakdown (ρ_{ox} = 1)	101	21	11	6	3
Confirmation of alive (ρ_{ox} = 10)	1	2	3	7	148
Necessary number (large one in above)	101	21	11	7	148
×10	1010	210	110	70	1480

In Table R1-3, the term of confirmation of breakdown (ρ_{ox} = 1) means the number of element necessary to confirm at least one breakdown in the case of ρ_{ox} = 1, and the term of confirmation of alive (ρ_{ox} = 10) means the number of element necessary to confirm at least one alive in the case of ρ_{ox} = 10.

R1–1.2.6 When the Si wafer with surface defect density of 10 /cm^2 is measured, if the MOS capacitors with an electrode area of 50 mm^2 are used, it breaks down surely. Therefore, we understand it is unsuitable in the comparative evaluation of the defect distribution as for this condition.

R1–1.2.7 If we want to confirm that 10 MOS capacitors are "alive" or "dead", it is necessary to measure 70 MOS capacitors of 20 mm^2, or 110 MOS capacitors with an electrode area of 10 mm^2, or 210 MOS capacitors of 5 mm^2.

R1–1.2.8 When the defect of sample wafer is 0.1 /cm^2, we can confirm broken 10 MOS capacitors of 50 mm^2 by measurement of only 210 MOS capacitors. For MOS capacitors of 1 mm^2, it will be necessary to measure about 10000, and this is not realistic.

R1–1.3 *Recommended Measurement Condition*

R1–1.3.1 An electric field step, E_{step}, and a hold time, T_{hold}, used in this round robin were shown in Figure R1-2.

TZDB(Step Voltage)

a) Group I: B,D,E b) Group II: A,F

T_{hold}(ms)	E_{step}(MV/cm) 0.1	0.25	0.5	1.0
100	I	I	-	-
200	II	I*, II	II	II
800	-	I	I	-

(* E measured T_{hold}=400ms)

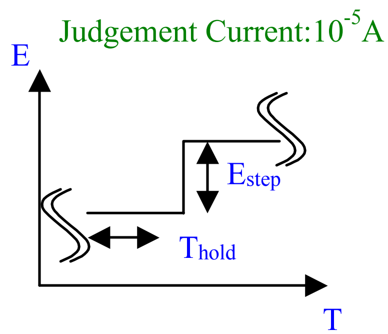

Figure R1-2
Applied Gate Electric Field Stress Condition in TZDB and Measurement Group Division.

R1–1.3.2 In the measurement of TZDB, the voltage is stepwise increased. Then, the electric current is measured after a constant hold time. This hold time is usually installed as a time for measurement stabilization. It is possible that the measurement result receives the influence of instability when the hold time is shorter than 100 ms.

R1–1.3.3 On the other hand, because too long hold time, that is, 800 ms or more, leads to a long total measurement time, the influence of TDDB becomes conspicuous in the high electrical field region, and it is a possible that the breakdown failure fraction of the MOS capacitors increases.

R1–1.3.4 In Figure R1-2, the B-mode failure fractions are shown as a function of the hold time of the applied electric field stress with a step height of 0.25 MV/cm. The hold time from100 ms to 800 ms did not especially have any influence in the measurement results of this round robin. Then, we proposed 200 ms as a practicable recommended hold time.

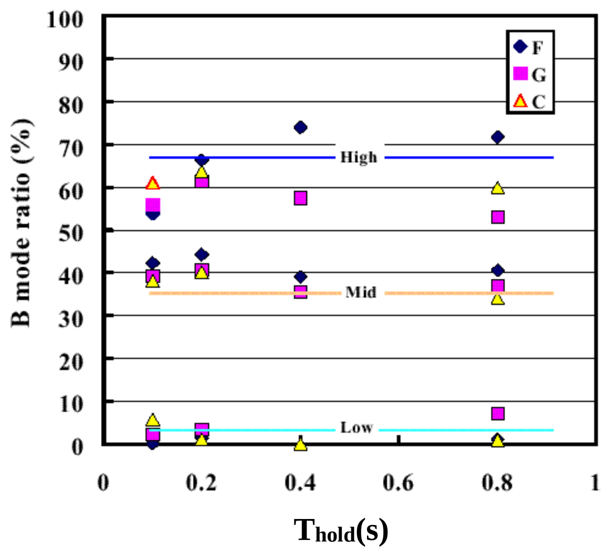

Figure R1-3
B-Mode Failure Fraction vs. Hold Time of Applied Electric Field Stress with a Step Height of 0.25 MV/cm in TZDB

R1–1.3.5 In this TZDB measurement, the applied electric field was stepwise increased directly after the current measurement. Too low step height of the applied electric field, ΔE, that is, 0.1 MV/cm or less, leads to unnecessary long measurement time, and the influence of TDDB becomes conspicuous in the high electrical field region.

R1–1.3.6 On the other hand, too high step of the applied electric field stress, for example, 1.0 MV/cm or more, leads to broadening of the dielectric breakdown electric field. That is, the reliability of the measurement result is decreased.

R1–1.3.7 In this round robin as shown in Figure R1-4, the B-mode failure fraction did not depend on the step height of the applied electric field stress with a hold time of 200 ms. The electric field step height of 0.1–0.5 MV/cm did not especially have any problem in the measurement results. In addition, considering the above practical factors, we recommend the step height range of 0.1–0.5 MV/cm, and especially, 0.25 MV/cm.

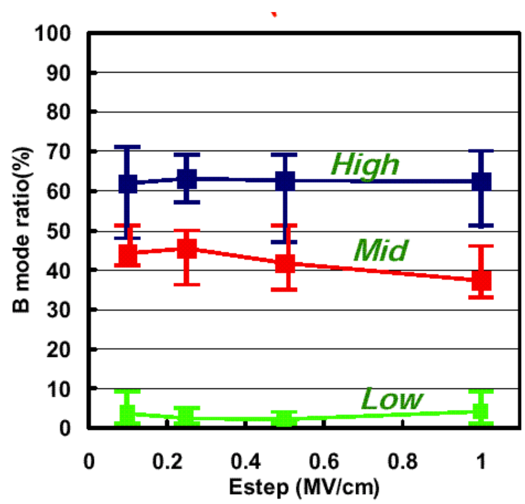

Figure R1-4
B-Mode Failure Fraction vs. Step Height of the Electric Field Stress with a Hold Time of 200 ms in TZDB

SEMI INTERNATIONAL STANDARDS

MICROLITHOGRAPHY

Semiconductor Equipment and Materials International

SEMI P1-1101
SPECIFICATION FOR HARD SURFACE PHOTOMASK SUBSTRATES

This specification was technically approved by the Global Micropatterning Committee and is the direct responsibility of the North American Micropatterning Committee. Current edition approved by the Japanese Regional Standards Committee on August 3, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1981; previously published February 1999.

1 Purpose

1.1 This specification covers the general requirements of the glass substrate for hard surface photomasks.

2 Scope

2.1 This document covers square photomasks up to 7 inches in length. 230 mm substrates are excluded from this standard and can be found in SEMI P33.

2.2 This document also gives specifications for the following materials:

- High Thermal Expansion (HTE),
- Medium Thermal Expansion (MTE),
- Low Thermal Expansion (LTE),
- Ultra Low Thermal Expansion (ULTE)
- Durable Fused Silica (DFS) glass for 193 nm wavelength
- Modified Fused Silica (MFS) glass for 157 nm wavelength.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI P33 — Provisional Specification for Developmental 230 mm Square Hard Surface Photomask Substrates

3.2 *ASTM Standards*[1]

ASTM E 228 — Test for Linear Thermal Expansion of Rigid Solids with a Vitreous Silical Dilatometer

3.3 *ANSI/ASQC Standards*[2]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.4 *ISO Standard*[3]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments Part 1: Classification of Air Cleanliness

4 Terminology

4.1 Selected terms relating to photomasking are given for information only in "Terms and Definitions Relating to the Microlithography Industry" found at the end of SEMI P33 "RELATED INFORMATION". Definitions may be found in what was ASTM F 127.

5 Ordering Information

5.1 Purchase orders for hard surface photomask substrates furnished to this specification shall include the following:

5.1.1 Nominal edge length, nominal thickness dimension, and edge criteria (see Section 6);

5.1.2 Material (see Section 7);

5.1.3 Flatness quality area and flatness (Total Indicated Reading, T.I.R.) see Section 8);

5.1.4 Visual quality area and defect limits (see Section 9); and

5.1.5 Lot acceptance criteria (see Section 10).

6 Dimensions and Permissible Variations

6.1 The square substrates shall conform to the dimensional tolerances appropriate to the nominal edge length and thickness as listed in Table 1. Dimensions are illustrated in Figure 1 and a fixture for measuring the diagonal dimensions is shown in Figure 2.

6.2 Substrates shall have chamfered or rounded edges. The edges shall conform to the dimensional tolerances

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202, USA

3 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

appropriate to the nominal thickness listed in Table 2. Dimensions are illustrated in Figures 3 and 4.

7 Material Specifications

7.1 Substrate materials shall be specified as high thermal expansion (HTE), medium thermal expansion (MTE), low thermal expansion (LTE), ultra low thermal expansion (ULTE), durable fused silica (DFS), or modified fused silica (MFS). Examples of HTE materials are white crown and soda lime glasses, of MTE materials are borosilicate and aluminosilicate glasses, of LTE materials are aluminosiliate glasses, and of ULTE, DFS, and MFS materials are quartz (silica).

7.2 Substrate materials shall conform to thermal expansion and optical transmittance characteristics specified in Table 3.

7.2.1 DFS shall maintain the transmittance given in Table 3 within 0.3% change at least accumulated dosage of 100 kJ/cm^2 of 193 nm wavelength irradiation.

7.3 Selected physical properties of HTE, MTE, LTE, ULTE, DFS, and MFS materials are provided for information only in Appendix 1.

8 Flatness Specifications

8.1 Substrates shall be supplied with one side having a flatness (TIR) of 0.25, 0.5, 1, 2, 5, 10, or 20 µm over a circular or square quality flatness area as defined in Figures 5 and 6.

9 Visual Criteria

9.1 A visual quality area, which may or may not correspond with the flatness area, shall be agreed upon between the user and supplier.

9.2 Each plate shall not have more defects than listed in Table 4. This table includes limits for the following types of defects:

9.2.1 Internal defects in the quality area,

9.2.2 Frontside surface defects,

9.2.3 Backside surface defects, and

9.2.4 Defects outside the quality area.

9.3 Glass substrates shall be identified with notches on the backside corner as shown in Figure 7. Soda lime and white crown (HTE) glasses are marked with one corner notch (Figure 7a). Borosilica and Aluminosilicate (MTE) glasses are marked with three corner notches (Figure 7b). Aluminosilica (LTE) glass is marked with two adjacent corner notches (Figure 7c). Quartz (ULTE) is marked with two diagonal corner notches (Figure 7d). Quartz (DFS) is marked with one corner notch (Figure 7e), that is the same as specified for HTE. Quartz (MFS) is marked with one non-isosceles triangle corner notch (Figure 7f). Dimensions of notches shall be as specified in Figure 8. If desired, and so specified in the contract or order, notches are positioned to identify the squareness origin corner.

10 Sampling

10.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired, and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL values. Inspection levels shall be agreed upon between user and supplier.

11 Test Methods

11.1 *Thermal Expansion* — Determine in accordance with ASTM E 228.

11.2 Transmission (to be agreed upon between user and supplier).

11.3 Irradiation durability (to be agreed upon between user and supplier).

11.4 Flatness (to be agreed up between user and supplier).

11.5 Visual (to be agreed upon between user and supplier).

12 Handling

12.1 Substrates are to be handled on the edges only. Substrates are to be handled with gloves approved for cleanroom use.

13 Certification

13.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

14 Packing and Marking

14.1 Substrates shall be packed in a class 100 environment as defined by ISO 14644-1. Containers shall be designed to prevent glass-to-glass contact, and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the acceptable flatness side toward the front of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable internal, national, state, and local laws and regulations required for shipping.

14.2 Containers shall be labeled “Warning: Open and Handle Under Cleanroom Conditions Only”: as well as identified by user purchase order number (if applicable), drawing number (if applicable), quantity, supplier lot number, and material identification.

Table 1 Specifications for Edge Length, Squareness, and Thickness for Square Substrates

Nominal Edge Length	*Edge Length Min.*	*Edge Length Max.*	*Squareness*	*Thickness Min.*	*Thickness Max.*	*Units*
2 1/2" Sq.	62.7	63.50	0.05/25.40	1.40	1.60	mm
3" Sq.	75.4	76.2	0.05/25.40	1.40	1.60	mm
3 1/2" Sq.	88.1	88.9	0.05/25.40	1.40	1.60	mm
4" Sq.	100.80	101.6	0.05/25.40	1.40	1.60	mm
				2.20	2.40	mm
5" Sq.	126.2	127.0	0.05/25.40	2.20	2.40	mm
				3.70	3.90	mm
				6.25	6.45	mm
6" Sq.	151.6	152.4	0.05/25.40	2.20	2.40	mm
				2.95	3.15	mm
				3.70	3.90	mm
				6.25	6.45	mm
7" Sq.	177.0	177.8	0.05/25.40	2.95	3.15	mm
				3.70	3.90	mm
				6.25	6.45	mm

NOTE: HTE squareness is 0.08/25.40

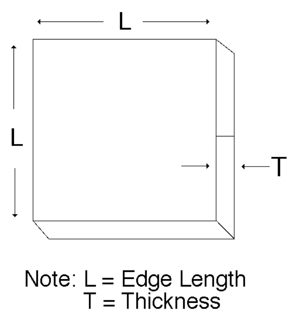

Figure 1
Square Hard Surface Photomask Substrate

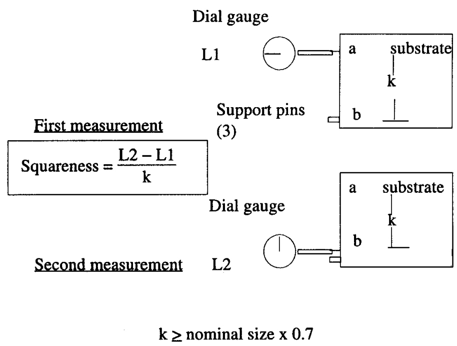

Figure 2
Measurements to Determine Substrate Squareness

Table 2 Specifications for Chamfered and Rounded Edge Dimensions

T	*A*	*A*	*B*	*B*	*C*	*C*	*D*	*D*	*E*	*E*	
Nominal	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Units*
1.50	0.20	0.50	0.20	0.50	0.30	0.70	2.00	3.00	0.25	0.60	mm
2.30	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
3.05	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
3.80	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
4.57	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm
6.35	0.20	0.60	0.20	0.60	0.30	0.70	2.00	3.00	0.25	0.60	mm

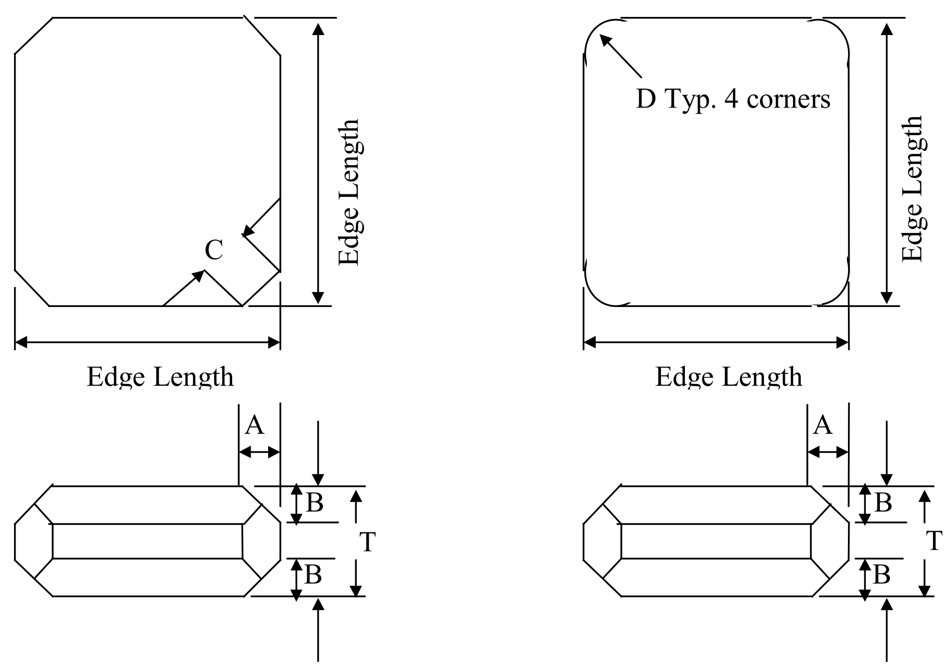

Figure 3
Chamfered Edge Dimensions

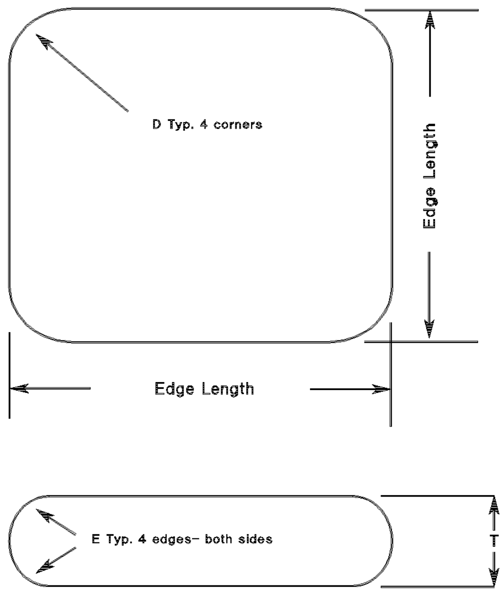

Figure 4
Rounded Edge Dimensions

Table 3 Substrate Material Characteristics

	Coefficient of Expansion (°C^{-1}) Between 0°C and 300°C	*Minimum Transmittance (%) of 1.5 mm Thick Substrate at Wavelengths of:*						
Glass Type		157 mm	193 mm	230 nm	254 nm	365 nm	405 nm	436 nm
HTE	80 to 100 × 10^{-7}	NA	NA	NA	NA	80	85	90
MTE	40 to 60 × 10^{-7}	NA	NA	NA	NA	80	85	90
LTE	30 to 39 × 10^{-7}	NA	NA	NA	NA	80	85	90
ULTE	< 7.5 × 10^{-7}	NA	NA	90	90	90	90	90
DFS	< 7.5 × 10^{-7}	NA	87	90	90	90	90	90
MFS	< 7.5 × 10^{-7}	82	87	90	90	90	90	90

Table 4 Glass Substrate Defect Limits per Plate

INTERNAL DEFECTS IN THE QUALITY AREA

	Opaque Spots	*Bubble*	*Total Defects (per cm.^{2})*	*Notes*
HTE Glass	> 10 µm	> 10 µm	0	1 and 2
	≤ 10 µm	≤ 10 µm	0.0465	
MTE Glass	> 5 µm	> 7 µm	0	
	≤ 5 µm	≤ 7 µm	0.0465	
LTE Glass	> 5 µm	> 5 µm	0	
	≤ 5 µm	≤ 5 µm	0.031	
ULTE Glass	> 2 µm	> 2 µm	0	
	≤ 2 µm	≤ 2 µm	0.0078	
DFS Glass	> 1.5 µm	> 1.5 µm	0	
	≤ 1.5 µm	≤ 1.5 µm	0.0078	
MFS Glass	> 1.2 µm	> 1.2 µm	0	
	≤ 1.2 µm	≤ 1.2 µm	0.0078	

SURFACE DEFECTS IN THE QUALITY AREA

Frontside	*Residue*	*Scratch Size*	*Total Scratch Defects*	*Sleek Size*	*Total Sleeks Defects (per cm^2)*	*Opaque Spot Size*	*Total Opaque Spot Defects (per cm^2)*
HTE Glass	None	> 1.0 µm	0	> 2 µm	0	> 5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–5 µm	0.0465
MTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.5 µm	0.0465
LTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.5 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.5 µm	0.0465
ULTE Glass	None	> 1.0 µm	0	> 2 µm	0	2.0 µm	0
		≤ 1.0 µm	no limit	1–2 µm	0.0465	1–2.0 µm	0.0155
DFS Glass	None	> 1.0 µm	0	> 1.5 µm	0	1.5 µm	0
		≤ 1.0 µm	no limit	1–1.5 µm	0.0310	1–1.5 µm	0.0110
MFS Glass	None	> 1.0 µm	0	> 1.2 µm	0	1.2 µm	0
		≤ 1.0 µm	no limit	1–1.2 µm	0.0155	1–1.2 µm	0.0052

Backside

HTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
MTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
LTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
ULTE Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
DFS Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit
MFS Glass		> 3.0 µm	0			> 10 µm	0.0465
		≤ 3.0 µm	no limit			≤ 10 µm	no limit

DEFECTS OUTSIDE THE QUALITY AREA

Edge Chips	*Defect Limit*	*Total Number*	
Radial Depth	≥ 0.76 mm	None	Note
Peripheral Cord	≥ 0.76 mm	None	
Other	Shall be negotiated between vendor and supplier	Shall be negotiated between vendor and supplier	

NOTE l: The size of internal defects shall be determined by 1/2 (long axis + short axis).

NOTE 2: This table is based on the assumption that defects < 3 µm will fail outside the focal depth of the lens systems and should not print.

NOTE 3: None of any size permitted that break the surface.

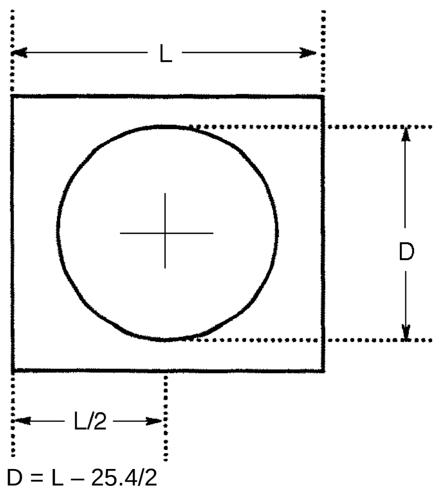

Figure 5
Circular Quality Area

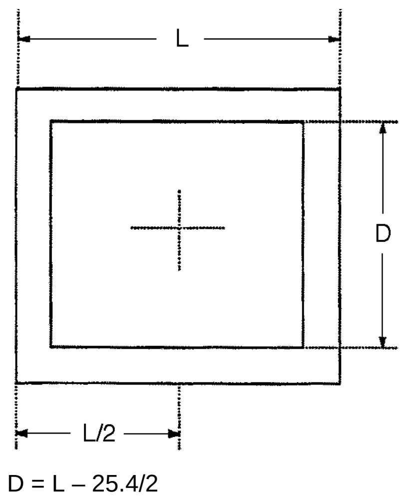

Figure 6
Square Quality Area

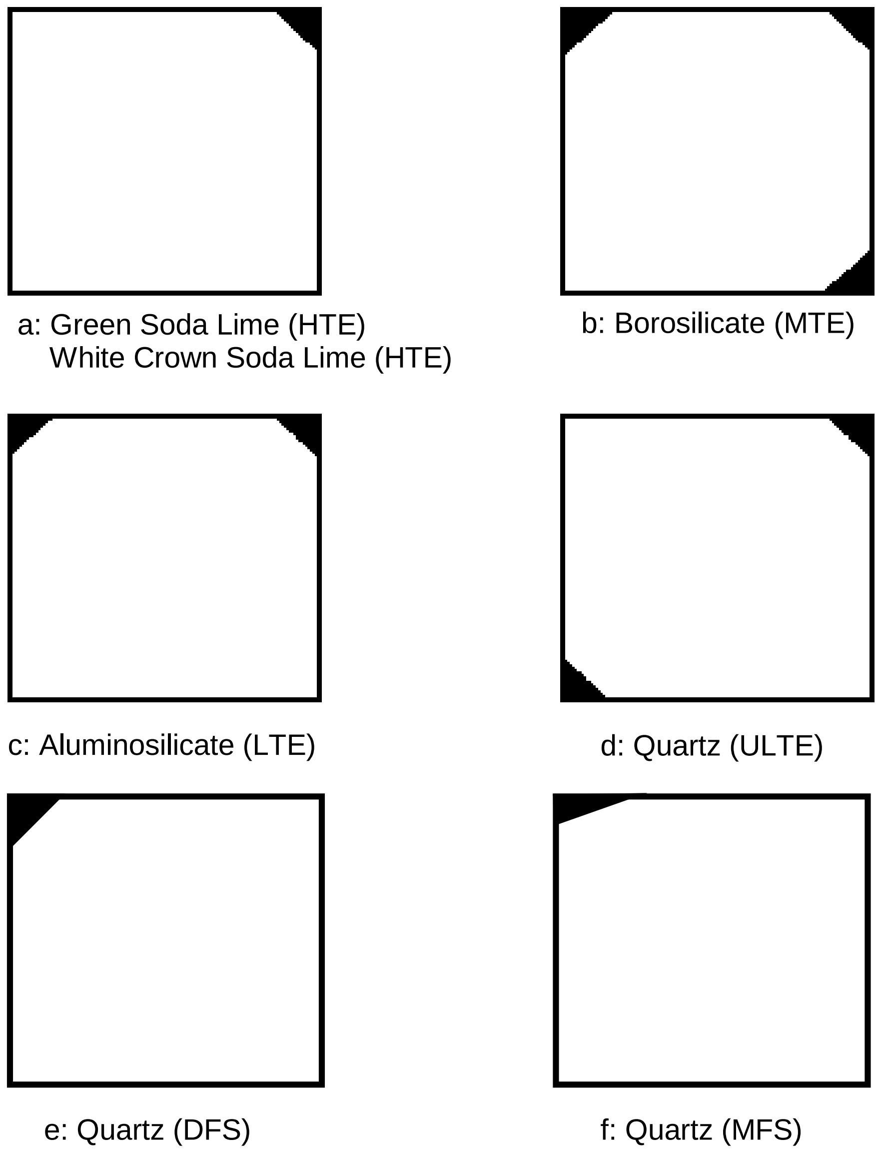

Figure 7
Glass Substrate Identification by Notches

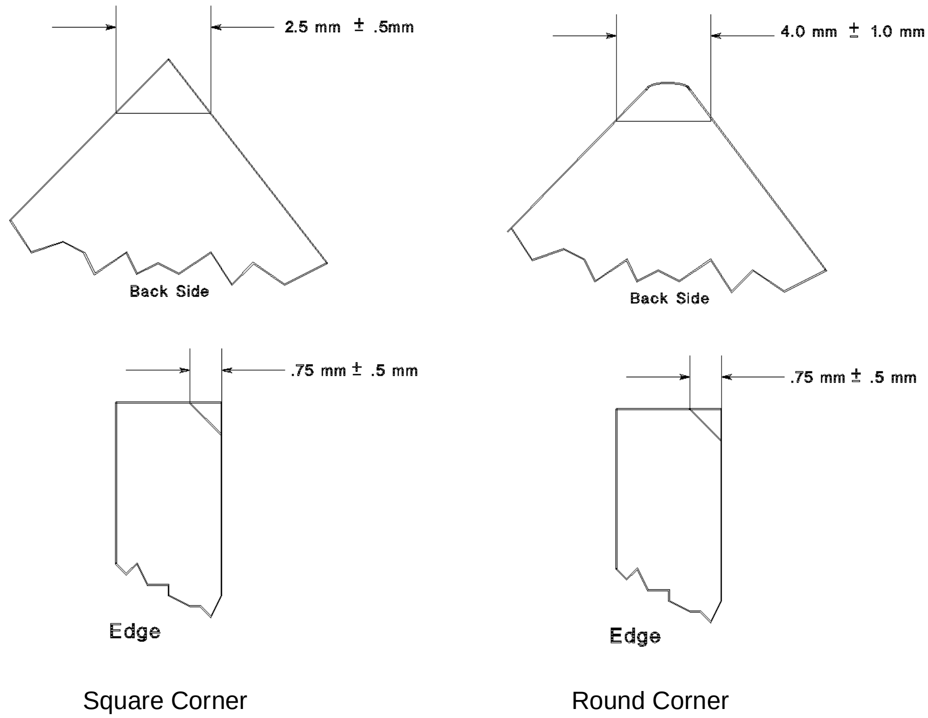

Figure 8a
Dimensions of Notches for HTE, MTE, LTE, ULTE, DFS

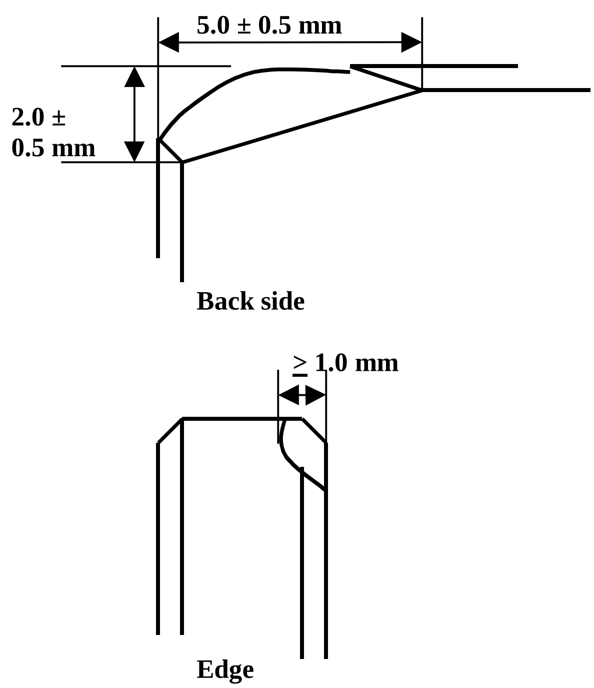

Figure 8b
Dimension of Notches for MFS

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI P1 and was approved by full letter ballot procedures on August 3, 2001.

A1-1 Hard Surface Photomask Glass Properties

GLASS PROPERTIES

Property	
HIGH THERMAL EXPANSION (HTE)	
Modulus of Elasticity	$7.0–7.3 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.22–0.23
Specific Gravity	2.50–2.56 g/cm^3
Index of Refraction	1.52
MEDIUM THERMAL EXPANSION (MTE)	
Modulus of Elasticity	$7.1–9.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.18–0.26
Specific Gravity	2.36–2.87 g/cm^3
Index of Refraction	1.49–1.57
LOW THERMAL EXPANSION (LTE)	
Modulus of Elasticity	$7.5–8.7 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.24
Specific Gravity	2.52–2.58 g/cm^3
Index of Refraction	1.53–1.56
ULTRA LOW THERMAL EXPANSION (ULTE)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	2.18–2.20 g/cm^3
Index of Refraction	1.46
DURABLE FUSED SILICA (DFS)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	2.18–2.20 g/cm^3
Index of Refraction	1.46
MODIFIED FUSED SILICA (MFS)	
Modulus of Elasticity	$6.7–7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	See NOTE 1.
Index of Refraction	See NOTE 1.

NOTE 1: Specific Gravity and Index of Refraction of MFS shall be agreed upon between user and supplier.
NOTE 2: Index of Refraction on this table is the value at 587 nm wavelength.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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SEMI P2-0298
SPECIFICATION FOR CHROME THIN FILMS FOR HARD SURFACE PHOTOMASKS

1 Purpose

This specification covers the general requirements of the chrome thin film for hard surface photomasks.

2 Referenced Documents

2.1 *SEMI Specification*

SEMI P1 — Specification for Hard Surface Photomask Substrates

2.2 *ASTM Standard*[1]

E 122 — Choice of Sample Size to Estimate the Average Quality of a Lot or Process

2.3 *Federal Standard*[2]

209D — Clean Room and Work Station Requirements, Controlled Environment

2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection by Attributes

3 Terminology

3.1 *defects, photomask* — Any flaw or imperfection in the opaque coating or functional pattern of a photomask that will reproduce itself in a photoresist film to such degree that it is pernicious to the proper functioning of the microelectric device being fabricated.

3.2 *fingerprint* — For the purposes of this practice, residual surface contamination deposited during handling.

3.3 *pinhole* — A small opening extending through a cover as a photoresist coating or an oxide layer.

4 Ordering Information

4.1 Purchase orders for hard surface photomasking substrates furnished to this specification shall include the following:

Optical Density	to be agreed upon by the user and supplier
Reflectivity	High reflective — Above 40% Medium Reflective — 2– 40% Low Reflective — Below 25%
Material	to be agreed upon by the user and supplier
Etchability	to be agreed upon by the user and supplier
Defects	to be agreed upon by the user and supplier
Lot Size	to be agreed upon by the user and supplier

5 Material Specifications

The material specifications are to be agreed upon by the user and supplier.

6 Visual Criteria

6.1 *Visual Quality Area*

6.1.1 *Circular Visual Quality Area* — (See SEMI P1, Figure 6, for available flatness limits of hard surface photomask substrates.)

6.1.2 *Square Visual Quality Area* — (See SEMI P1, Figure 7, for available flatness limits of hard surface photomask substrates.)

7 Defects

Definitons of defects and the allowable number of each type are listed in Table 1. The number of defects is indicated by plate size, chrome grades, and defect size.

8 Sampling

Unless otherwise specified, Recommended Practice ASTM E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105 definitions for critical. Major and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

9 Handling

Substrates are to be handled on the edges only.

10 Certification

Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 General Services Administrator, 4th and D Streets, SW, Room 6039, Washington, DC 20407

3 Military Standards, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

material was manufactured and tested shall be in accordance with this specification.

11 Packing and Marking

11.1 Substrates shall be packed in a Class 100 environment. Containers shall be designed to prevent glass-to-glass contact and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the coated side facing toward the same end of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable international, national, state laws, and local regulations required for shipping.

11.2 Containers shall be labeled, "Warning: Open and Handle Under Clean Room Conditions Only." Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, supplier lot number, and material identification.

Table 1 Total Allowable Defects for Unsensitized Photoplates

Defects in the Circular Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	2	0	0
4" B	3	1	0
4" C (Test)	N/A	N/A	10
5" AA	0	0	0
5" A (Master)	2	0	0
5" B	4	1	0
5" C (Test)	N/A	N/A	15
6" AA	0	0	0
6" A (Master)	3	0	0
6" B	6	2	0
6" C (Test)	N/A	N/A	20

Defects in the Square Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	2	0	0
4" B	4	1	0
4" C (Test)	N/A	N/A	10
5" AA	0	0	0
5" A (Master)	3	0	0
5" B	6	2	0
5" C (Test)	N/A	N/A	15
6" AA	0	0	0
6" A (Master)	4	0	0
6" B	8	2	0
6" C (Test)	N/A	N/A	20

SEMI P3-0298
SPECIFICATION FOR PHOTORESIST/E-BEAM RESIST FOR HARD SURFACE PHOTOPLATES

1 Purpose

1.1 This specification covers the general requirements on the photoresist and e-beam resist coating for hard surface photoplates. See SEMI P1 and SEMI P2 for requirements on physical characteristics of the photoplate substrate and the chrome coating on it.

2 Referenced Documents

2.1 *SEMI Specifications*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P2 — Specification for Chrome Thin Films for Hard Surface Photomasks

2.2 *ASTM Standard*[1]

ASTM E 122 — Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

2.3 *Federal Standard*[2]

209D — Clean Room and Work Station Requirements, Controlled Environments

2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection and Attributes

3 Terminology

3.1 *comets* — buildup of resist in the form of a comet, generated by a defect.

3.2 *defect, photomask* — any flaw or imperfection in the opaque coating or functional pattern of a photomask that will reproduce itself in a photoresist film to such a degree that it is pernicious to the proper functioning of the microelectric device being fabricated.

3.3 *fingerprint* — for the purposes of this practice, residual surface contamination deposited during handling.

3.4 *photoresist lifting* — the loss of adhesion of a photoresist coating to its substrate.

3.5 *pinhole* — a small opening extending through a cover as a photoresist coating or an oxide layer.

3.6 *residue* — any undesirable material remaining on a substrate after any process step.

3.7 *resist rings* — buildup of resist in round, multicolored rings, generated by particles or bubble bursts.

3.8 *stress marks* — radial, colored, thin lines starting in the center of the plate and extending out.

4 Ordering Information

4.1 Purchase orders for resist-coating for hard surface photoplate substrates furnished to this specification shall include the following in addition to the information called for in SEMI P1 and SEMI P2:

4.1.1 Resist Material

4.1.2 Resist Thickness and Tolerance in the Quality Area

4.1.3 Resist Uniformity across the Quality Area

4.1.4 Resist Consistency — from Plate to Plate

4.1.5 Resist Baking Time and Temperature

5 Visual Criteria

5.1 *Visual Quality Area*

5.1.1 *Circular Visual Quality Area* — (See SEMI P1, Figure 6, for Available Flatness Limits of Hard Surface Photomask Substrates.)

5.1.2 *Square Visual Quality Area* — (See SEMI P1, Figure 7, for Available Flatness Limits of Hard Surface Photomask Substrates.)

6 Defects

6.1 Definitions of defects and the allowable number of each type are noted in Table 1. The number of defects is indicated by plate size, chrome grades, and defect size.

7 Sampling

7.1 Unless otherwise specified, Recommended Practice ASTM E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105. Each quality

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characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105. Definitions for critical, major, and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

8 Handling

8.1 Resist-coated substrates are to be handled on the edges only with approved finger cots or gloves under clean room conditions.

9 Certification

9.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification shall be provided.

10 Packaging and Marking

10.1 Resist-coated substrates shall be packed in a Class 100 environment as defined in Federal Standard 209D. Containers shall be designed to prevent movement and glass-to-glass contact and to protect the substrates from contamination in handling and transit. Orientation of the coated side shall be indicated on each container. Packaging shall comply with the applicable international, national, state, and local laws and regulations required for shipping.

10.2 Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, supplier lot number, material identification, bake time and temperature, resist type, resist lot number, and date of applying resist.

10.2.1 *Photoresist* — Containers shall be labeled, "Warning: Open and Handle Under Safe Yellow Light in Clean Room Conditions Only."

10.2.2 *E-Beam Resist* — Containers shall be labeled, "Warning: Open and Handle Under Clean Room Conditions Only. DO NOT X-RAY."

Table 1 Total Allowable Defects for Unsensitized Photoplates

Defects in the Circular Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	4	0	0
4" B	6	2	0
4" C (Test)	N/A	N/A	20
5" AA	0	0	0
5" A (Master)	4	0	0
5" B	8	2	0
5" C (Test)	N/A	N/A	30
6" AA	0	0	0
6" A (Master)	6	0	0
6" B	12	4	0
6" C (Test)	N/A	N/A	40
Defects in the Square Quality Area			
Substrate Size	*Defect Size*		
Grade	*1–5.0 µm*	*5.1–10 µm*	*10 µm*
4" AA	0	0	0
4" A (Master)	4	0	0
4" B	8	2	0
4" C (Test)	N/A	N/A	20
5" AA	0	0	0
5" A (Master)	6	0	0
5" B	12	4	0
5" C (Test)	N/A	N/A	30
6" AA	0	0	0
6" A (Master)	8	0	0
6" B	16	2	0
6" C (Test)	N/A	N/A	40

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI P4-92 (Reapproved 0299)
SPECIFICATION FOR ROUND QUARTZ PHOTOMASK SUBSTRATES

This specification was technically reapproved by the Mask & Mask Equipment Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1983; previously published in 1996.

Editorial changes were made to the following: Sections: 2.2, 6.2, and 13.1, Tables 3, 4 and 5, and Figure 5.

General Requirements

1. Preface

This specification covers the general requirements of the quartz round substrate for hard surface photomasks.

2. Applicable Documents

2.1 *ASTM Standards*[1]

ASTM E 122 — Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

ASTM E 228 — Standard Test Method for Linear Thermal Expansion of Rigid Solids with a Vatreous Silical Dilatometer

2.2 *ISO Standard*[2]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments Part 1: Classification of Air Cleanliness

2.3 *Military Specifications*[3]

MIL-STD-105 — Sampling Procedure and Tables for Inspection and Attributes

3. Terminology

None.

4. Ordering Information

Purchase orders for hard surface photomask substrates furnished to this specification shall include the following:

Dimensions	(See Section 5)
Material	(See Section 6)
Flatness Criteria	(See Section 7)
Visual Criteria	(See Section 8)
Lot Acceptance	(See Section 9)

5. Dimensions and Permissible Variations

The material shall conform to the dimensions and dimensional tolerances as specified in Tables 1 and 5, Dimensions for Round Quartz Photomask Substrates.

6. Material Specifications (ULTE glass only)

6.1 *Thermal Characteristics 0–300°C*

6.1.1 *100% Quartz Material* — Coefficient of expansion 5.5×10^{-7}/°C.

6.1.2 *Less Pure Quartz* — Coefficient of expansion less than 7.5×10^{-7}/°C.

6.2 *Transmission Characteristics*[4]

Wave Lengths	*Minimum % @ 1.5 mm Thickness*
200 nm	To be agreed upon between user and supplier.
230 nm	To be agreed upon between user and supplier.
254 nm	To be agreed upon between user and supplier.
365 nm	To be agreed upon between user and supplier.
405 nm	To be agreed upon between user and supplier.

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2 ISO Central Secretariat, 1, rue de Varembé, C.P. 56, CH-1211 Genève 20, Switzerland

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

4 After correction for surface reflection

6.3 *Physical Properties* — Information on the following properties is provided for information only. (See Appendix 1.)

6.3.1 Poisson's Ratio

6.3.2 Density

6.3.3 Young's Modulus

6.3.4 Modulus of Elasticity

6.3.5 Index of Refraction

6.3.6 Volume Restivity

7. Flatness Area (for one side only)

7.1 *Flatness Quality Area*

7.1.1 *Circular Flatness Quality Area* — (See Tables 2 and 5.)

8. Visual Criteria (one side only)

8.1 *Quality Area* — (See Tables 2 and 5.)

Plate Diameter	*Quality Area (Diameter)*
125 mm	113 mm
150 mm	138 mm

8.2 *Defect Limits* — Defects and allowable number of each type are listed in Table 4.

8.2.1 *Terminology for SEMI P4* — Unless otherwise noted, the SEMI Terms and Definitions Relating to the Microlithography Industry shall be used.

8.2.2 *Minimal Conditions or Dimensions* — Minimal conditions or dimensions for defects are listed in Table 4 and shall be used for determining substrate acceptability unless other minimal limiters are agreed upon by the interested parties.

8.2.3 *Photomask Substrate Edge Criteria* — (See Table 3.)

8.3 *Identification* — To be agreed upon between the user and supplier.

9. Sampling

Unless otherwise specified, ASTM E 122 shall be used. When so specified, appropriate samples sizes shall be selected from each lot in accordance with MIL-STD-105D. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with MIL-STD-105D. Definitions for critical, major and minor classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

10. Test Methods

10.1 *Thermal Expansion* — Determine in accordance with ASTM E 228.

10.2 *Transmission* — (To be agreed upon between the user and supplier).

10.3 *Flatness* — (To be agreed upon between the user and supplier).

10.4 *Visual* — (To be agreed upon between the user and supplier.)

10.5 *Roundness* — 2 readings at 90° with appropriate tool such as Vernier Caliper or equivalent. Roundness values not specified at this time.

11. Handling

Substrates are to be handled on the edges only. Substrates are to be handled only with clean room approved gloves.

12. Certification

Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

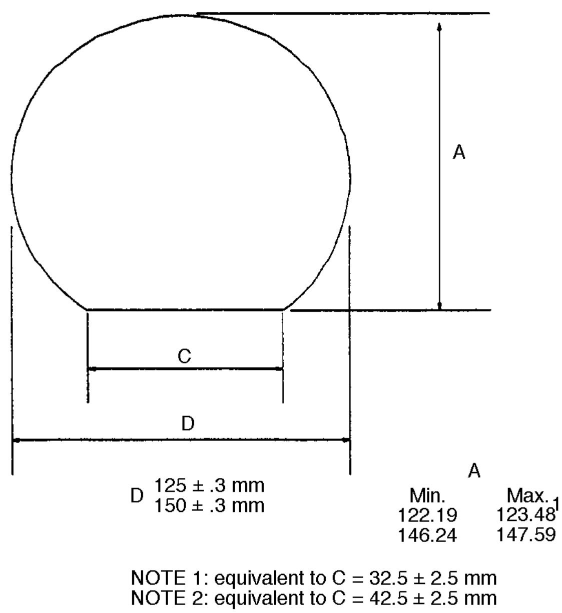
13. Packing and Marking

13.1 Substrates shall be packed in a class 100 environment as defined by ISO 14644-1. Containers shall be designed to prevent glass-to-glass contact and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the acceptable flatness side toward the front of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable international, national, state, and local laws and regulations required for shipping.

13.2 Containers shall be labeled "Warning: Open and Handle Under Clean Room Conditions Only." Each shipment shall be identified by user purchase order number, drawing number (if applicable), quantity, vendor lot number and material identification.

Table 1. Dimensions for Round Quartz Photomask Substrates

PLATE SIZE	*ROUNDNESS (T. B. A. Later Date)*	*PLATE THICKNESS*			
Dimension (D)		*Dimension*	*Tolerance Min.*	*Tolerance Max.*	*Units*
125 Diameter 125 ± .3	—	2.3	2.17	2.43	mm
150 Diameter 150 ± .3	—	2.3	2.17	2.43	mm
	—	3.0	2.87	3.13	mm



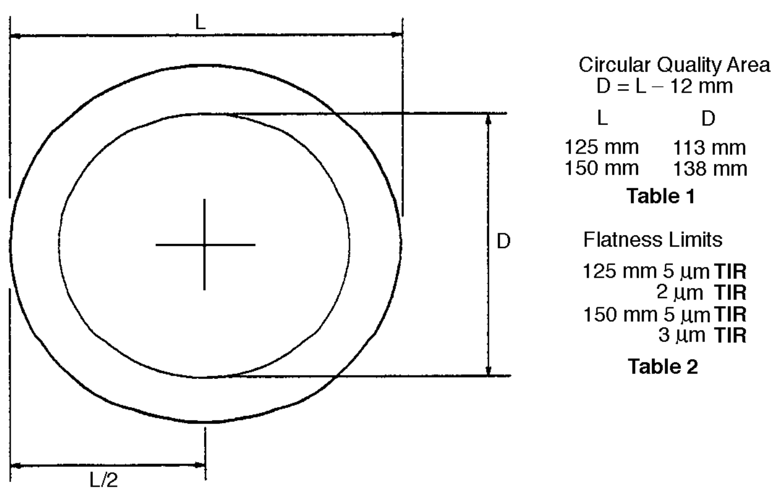
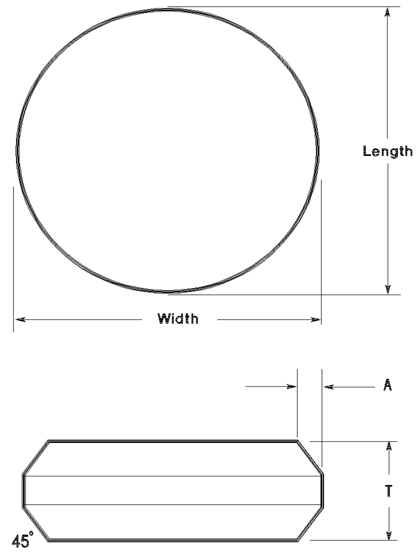


Table 2. Flatness Limits for Round Quartz Photomask Substrates

Chamfered Edge Criteria



T	A
2.3 mm (.090")	.10 mm (min.) - .6 mm (max.)
3.0 mm (.120")	.10 mm (min.) - .6 mm (max.)

Table 3. Edge Criteria for Round Quartz Photomask Substrates

Table 4. Glass Substrate Defect Limits per Plate — Internal Defects in the Quality Area

	OPAQUE SPOT	*BUBBLE*	*TOTAL DEFECTS (per inch^2)*	*NOTES*
ULTE Glass	≥ 2 µm	≥ 2 µm	0.05	1 & 2

Surface Defects in the Quality Area

	RESIDUE	*SCRATCH SIZE*	*TOTAL DEFECTS*	*SLEEK SIZE*	*TOTAL DEFECTS (per in.^{2})*	*OPAQUE SPOT SIZE*	*TOTAL DEFECTS (per in.^{2})*
FRONTSIDE — ULTE Glass	None	≥ 1.0 mm	0	≥ 2 µm	0	≥ 2.0 µm	0
		< 1.0 µm	No limit	1-2 µm	0.1	1-2.0 µm	0.1
BACKSIDE — ULTE Glass		≥ 3.0 µm	None	≥ 3.0 µm	None	≥ 10 µm	0.3

Defects Outside the Quality Area

EDGE CHIPS	*Defect Limit*	*Total Number*
Radial Depth	≥ .030"	None
Peripheral Cord	≥ .030"	None
Other	Shall be negotiated between vendor and supplier.	Shall be negotiated between vendor and supplier.

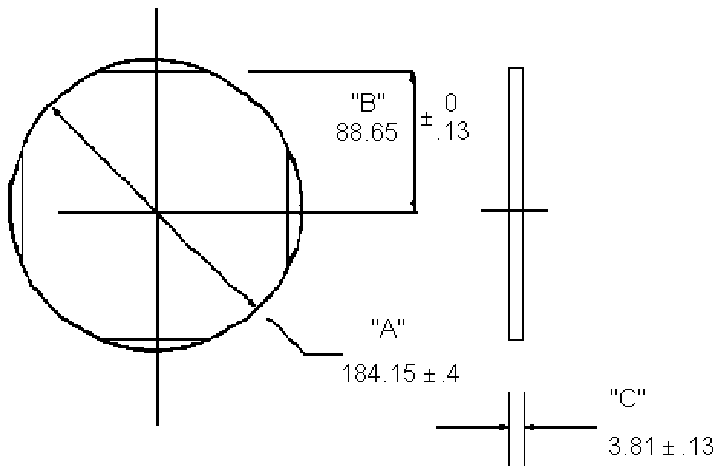
NOTES:

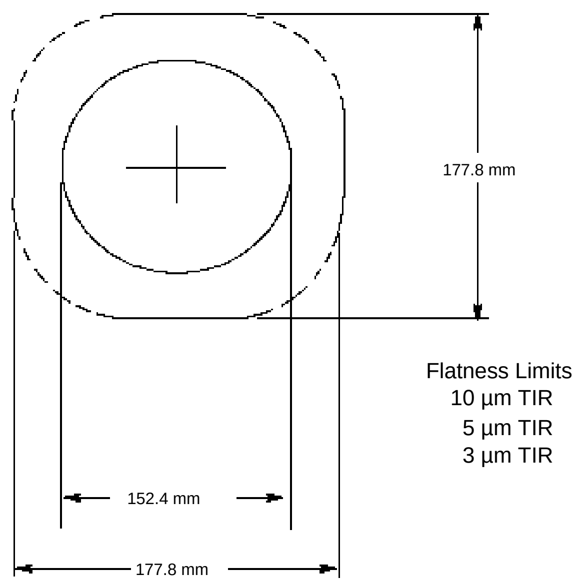
1. The size of internal defects is defined as 1/2 (long axis + short axis).

2. This table is based on the assumption that defects < 2 µm will fall outside the focal depth of the lens system and should not print.

Table 5. Specification for Diameter, Flat Depth, and Thickness for Round Substrates (proposed)

Nominal Diameter	*Diameter (A) Min.*	*Diameter (A) Max.*	*Flat Depth (B) Min.*	*Flat Depth (B) Max.*	*Nominal Thickness (C)*	*Thickness Min.*	*Thickness Max.*	*Units*
7 1/4"	183.75	184.55	88.52	88.65	3.81	3.69	3.94	mm
7 1/4"	7.234	7.266	3.485	3.490	0.150	0.145	0.155	in.





APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI P4 by full letter ballot procedure.

Hard Surface Photomask Glass Properties — Quartz Properties

Property

Ultra Low Thermal Expansion Ulte	
Modulus of Elasticity	$6.7\text{-}7.4 \times 10^3$ Kg/mm^2
Poisson's Ratio	0.18-0.19$^{(1)}$
Specific Gravity	2.18-2.20 g/cm^3
Index of Refraction	1.46

NOTE: These properties are not absolute requirements. For more specific information, contact your individual supplier.

SEMI P5-94
SPECIFICATION FOR PELLICLES

1 Preface

This specification covers requirements for pellicles used on photomasks or reticles in photolithographic exposure systems. This specification covers pellicles for use in either polychromatic or monochromatic exposure systems.

2 Applicable Documents

2.1 *ASTM Standard*[1]

2.2 *Federal Standard*[2]

209 D — Clean Room and Work Station Requirements, Controlled Environments

3 Definitions

3.1 Additional terms are listed for information only in the glossary, SEMI Terms and Definitions Relating to the Microlithography Industry.

3.2 *Selected Definitions*

3.2.1 *Pellicle* — A thin, optically transparent film, typically of nitrocellulose (cellulose nitrate), attached to and supported by a frame, and attached to a photomask (or reticle). Its purpose is to seal out contaminants and reduce printed defects caused by contamination in the image plane of an optical exposure system with a minimum decrease in the quality of optical transmission.

3.2.2 *Film Adhesive* — Adhesive between frame and film.

3.2.3 *Frame Adhesive* — Adhesive between frame and photomask.

3.2.4 *Mechanical Strength* — The physical condition a pellicle must meet to withstand a specified force from a blow-off gun without suffering any damage to the film due to stretching or breakage.

3.2.5 *Film Defects* — Inconsistencies in the integrity and planarity of the film, including particles, pinholes, scratches, dirt, and a minute quantity of solid.

3.2.5.1 *Particle* — Materials which can be distinguished from the film whether on the film surface or embedded in the film.

3.2.5.2 *Dirt* — Fingerprint; mark left behind after operator handling; stain from liquid.

3.2.5.3 *Pinhole* — A small opening completely through a polymer film.

3.2.5.4 *Scratch* — Long, narrow, shallow groove or cut below the established plane of the surface.

3.2.6 *Adhesive Stringer* — Any detectable protrusion from the edge of the adhesive.

4 Ordering Information

4.1 Purchase orders of pellicles furnished to this specification shall include the following:

4.1.1 Shape, Size, and Standoff of pellicles.

4.1.2 Film Characteristics

4.1.2.1 Type (i.e., AR–coated, non-AR–coated)

4.1.2.2 Exposure Range or Wavelength

4.1.2.3 Optical Transmission Rate

4.1.2.4 Thickness

4.1.2.5 Mechanical Strength

4.1.3 Defect Limits

4.2 In addition, the following items may also be specified:

4.2.1 Frame

4.2.1.1 Shape, Size, and Height

4.2.1.2 Materials or Type

4.2.2 Frame Adhesive

4.2.2.1 Materials or Type

4.2.2.2 Thickness and Width

5 Requirements

5.1 *Film Adhesive*

5.2 *Frame Adhesive*

5.3 *Frame*

5.4 *Light Resistance*

5.5 Other Characteristics — Other characteristics of pellicles are to be determined between the supplier and the user. The transmission of light for mask alignment is such a characteristic.

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2 General Service Administrator, 4th & D Streets, SW, Room 6039, Washington, DC 20407

6 Measurement Methods

6.1 Measurement methods are to be determined between the user and supplier. General and example methods are as follows:

Optical Transmission: by spectrophotometer

Optical Film Thickness: by spectrophotometer

Thickness Uniformity: by monochromatic (e.g., green) light

Width of Film Adhesive: Visual check by minimum defect sample

Defects: Visual check by maximum sample or particle detector

7 Sampling

7.1 Inspection levels shall be agreed upon between the user and supplier.

8 Handling

8.1 Pellicles are to be handled by the frame only.

9 Certification

9.1 Certification is to be determined between the user and supplier.

SEMI P5.1-94
STANDARD FOR PELLICLES FOR USE IN POLYCHROMATIC EXPOSURE SYSTEMS

1 Scope

This specification includes all characteristics of pellicles for use in polychromatic exposure systems.

2 Shape, Size, and Standoff of Pellicle

2.1 *Shape* — This is determined by agreement between the user and supplier.

2.2 *Size* — This is determined by agreement between the user and supplier, but expression of tolerance is as follows:

Outer diameter tolerance: +0, -x

Inner diameter tolerance: +x, -0

2.3 *Standoff* — This is determined by agreement between the user and supplier. But expression of tolerance is as follows:

Tolerance: +0, -x

3 Film Characteristics

3.1 *Polymer Films*

3.1.1 *Type* — AR-coated or non AR-coated.

3.1.2 *Exposure Range* — 360 nm–440 nm.

3.1.3 *Optical Transmission Rate* — There are the following two types depending on optical transmission rate at an incident angle of 90° from surface of pellicle.

Type	*Average*	*Minimum*
AR-Coated	≥98%	96%
Non-AR-Coated	≥91%	82%

3.1.4 *Thickness* — This is determined by agreement between the user and supplier.

3.1.4.1 *Thickness Conformity* — ± 0.2 µm maximum.

3.1.4.2 *Thickness Uniformity*

3.1.4.3 *Film Thickness*

3.1.5 *Mechanical Strength* — The requirements for air blow are determined within ranges shown below.

The air blow gun should be used;

Air pressure: ≤ 2.1 kgf/cm^2 (at input of the air blow gun)

Nozzle diameter of the air blow gun: ≤ 2 mm

Distance between the nozzle tip and the film: ≥ 25 mm

4 Defect Limits

4.1 Maximum defect limits based on the pellicle standoff and the numerical aperture of the given type of exposure system are given in Table 1. Any departure from these defect limits shall be agreed to between supplier and the user. Maximum defect limits are given in Table 1.

5 Requirements

5.1 *Film Adhesive* — Film must be sealed on the entire top of the frame with a minimum of 50% of the frame width at any location.

5.2 *Frame Adhesive* — Frame adhesive must be continuous and allow no gaps between pellicle frame and adhesive and between adhesive and photomask after attachment. No part of the frame adhesive may extend beyond the frame wall, and its edges must be free of visually detectable stringers (and particles). Adhesive should form a complete seal between the frame and the mask over a minimum of 60% of the width of the frame.

5.3 *Frame* — Pellicle frame must have no visually detectable machining burrs, discontinuities in anodization, or particles.

5.4 *Light Resistance* — This is expressed by total exposure energy value (mj/cm^2 or j/cm^2) on pellicle film until dropping 1% of optical transmission (rate) of one of the peak wavelengths between 360 nm–440 nm. Also the test conditions (special characteristics of exposure wavelength, exposure energy between 360 nm –440 nm, exposure conditions, and others) must be clear.

Table 1 Maximum Defect Limits

Characteristics	*Max. No. Allowable*	*Size counted for Max. No. Allowable*
Non-removable		≥45µm
Particles	None	
Pinholes	None	>limit of detection
Scratches	None	Width ≥45µm
Dirt	None	>limit of detection

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SEMI P5.2-94
STANDARD FOR PELLICLES FOR USE IN "G", "H", and "I" LINE EXPOSURE SYSTEMS

1 Scope

This specification includes the characteristics of pellicles for use in "g" (436 nm), "h" (405 nm), and "i" (365 nm) line exposure systems.

2 Shape, Size, and Standoff of Pellicle

2.1 *Shape* — This is determined by agreement between the user and supplier.

2.2 *Size* — This is determined by agreement between the user and supplier, but expression of tolerance is as follows:

Outer diameter tolerance: +0, -x

Inner diameter tolerance: +x, -0

2.3 *Standoff* — 6.3 mm and 4.0 mm should be standard.
Tolerance: +0, -x

3 Film Characteristics

3.1 Polymer Films

3.1.1 *Type* —AR-coated or non AR-coated.

3.1.2 *Exposure Wavelength* — "g", "h", and/or "i" lines.

3.1.3 *Optical Transmission Rate* — There are the following two types depending on optical transmission rate at incident angle of 90° from surface of pellicle at the specified wavelength(s).

Type	*Minimum*
AR Coated	99 percent
Non AR Coated	98 percent

3.1.4 *Thickness* — This is determined by agreement between the user and supplier.

3.1.4.1 *Thickness Conformity* — ± 0.2 µm maximum.

3.1.4.2 *Thickness Uniformity*

3.1.4.3 *Film Thickness*

3.1.5 *Mechanical Strength* — The requirements for air blow are determined within ranges shown below:

The air blow gun should be used.

Air pressure: ≤ 2.1 kgf/cm^2 (at input of the air blow gun).

Nozzle diameter of the air blow gun: ≤ 2 mm.

Distance between the nozzle tip and the film: ≥ 25 mm.

4 Defect Limits

4.1 Maximum defect limits based on the pellicle standoff and the numerical aperture of the given type of exposure system are given in Table 1. Any departure from these defect limits shall be agreed to between the user and supplier.

5 Requirements

5.1 *Film Adhesive* — Film must be sealed on the entire top of the frame. Seal with a minimum of 50% of the frame width at any location.

5.2 *Frame Adhesive* — Frame adhesive must be continuous and allow no gaps between pellicle frame and adhesive, and between adhesive and photomask after attachment. No part of the frame adhesive may extend beyond the frame wall, and its edges must be free of visually detectable stringers (and particles). Adhesive should form a complete seal between the frame and the mask over a minimum of 60% of the width of the frame.

5.3 *Frame* — Pellicle frame must have no visually detectable machining burrs, discontinuities in anodization, or particles.

5.4 *Light Resistance* — This is expressed by total exposure energy value (mj/cm^2 or j/cm^2) of specified wavelength on pellicle's film until dropping 0.5% of optical transmission (rate) at specified wavelength. Also, the test conditions (half bandwidth of exposure specified wavelength, energy of exposure specified wavelength, exposure conditions, and others) must be clear.

Table 1 Maximum Defect Limits

Characteristics	*Max. No. Allowable*	*Size Counted for Max. No. Allowable*
Non-removable		
Particles	None	>20 µm
Pinholes	None	>limit of detection
Scratches	None	Width >20 µm
Dirt	None	>limit of detection

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SEMI P6-88
SPECIFICATION FOR REGISTRATION MARKS FOR PHOTOMASKS

1 General Specification

1.1 *Scope*

1.1.1 This specification defines the shape, range of sizes, and general placement of a registration mark for use on all photomasks. Methods of use will be stated in accompanying application notes (to be furnished at a later date).

1.2 *Applicable Documents* — None.

2 Detail Specifications

2.1 *Introduction*

2.1.1 The complete specification for this registration mark is to be agreed upon by the circuit designer, mask maker, and the mask user.

2.2 *Requirements*

2.2.1 This specification covers a defined mark placed photolithographically on photomasks for the express purpose of determining the registration accuracy of one imaged photomask to another imaged photomask within the same set of photomasks.

2.3 *Other*

2.3.1 This mark is not intended to be used for the determination of overlay accuracy of an imaged layer of a photomask onto a maker to any subsequent imaged layers on the same wafer.

3 Guidelines for Shape and Sizes of Registration Mark

3.1 The shape of the mark shall be in the form of a cross (see Figure 1).

3.2 The area of intersection of the horizontal and vertical lines shall be "user-defined." The designer, mask maker, or user may define any shape of geometry within this area. The "user-defined" geometry used shall not exceed the width or height of the area of intersection (see Figure 2).

3.3 The width of both the horizontal and vertical lines shall be equal.

3.4 The length of both the horizontal and vertical lines shall be equal.

3.5 The width and length of the horizontal and vertical lines may vary due to design rules, scaling, process bias, etc. Table 1 lists the design dimensions for each type of photomask. Sections 3.3 and 3.4 are not superceded by this statement.

3.6 Any of the four quadrants created to the outside of the cross shall be defined as "No-Man's Land" and shall not have any geometry or marks placed within them (see Figure 3).

3.7 A field or registration mark (i.e., dark or clear) is user-definable.

3.8 The mark shall be placed as per attached application notes (to be furnished at a later date).

Table 1 Dimensions of Registration Mark For All Mask Types (all dimensions are in micrometers (μm))

Type of Photomask	*Width*	*Length*	*User Defined Area*	*Total Pattern Window*
1× Masters	4 – 8	10 – 15	min. 4 × 4 max. 8 × 8	min. 24 × 24 max. 38 × 38
1× Stepper Reticles	4 – 8	10 – 15	min. 4 × 4 max. 8 × 8	min. 24 × 24 max. 38 × 38
5× Stepper Reticles	8 – 40	20 – 75	min. 8 × 8 max. 40 × 40	min. 48 × 48 max. 190 × 190
10× Stepper Reticles	16 – 80	40 – 150	min. 16 × 16 max. 80 × 80	min. 96 × 96 max. 380 × 380

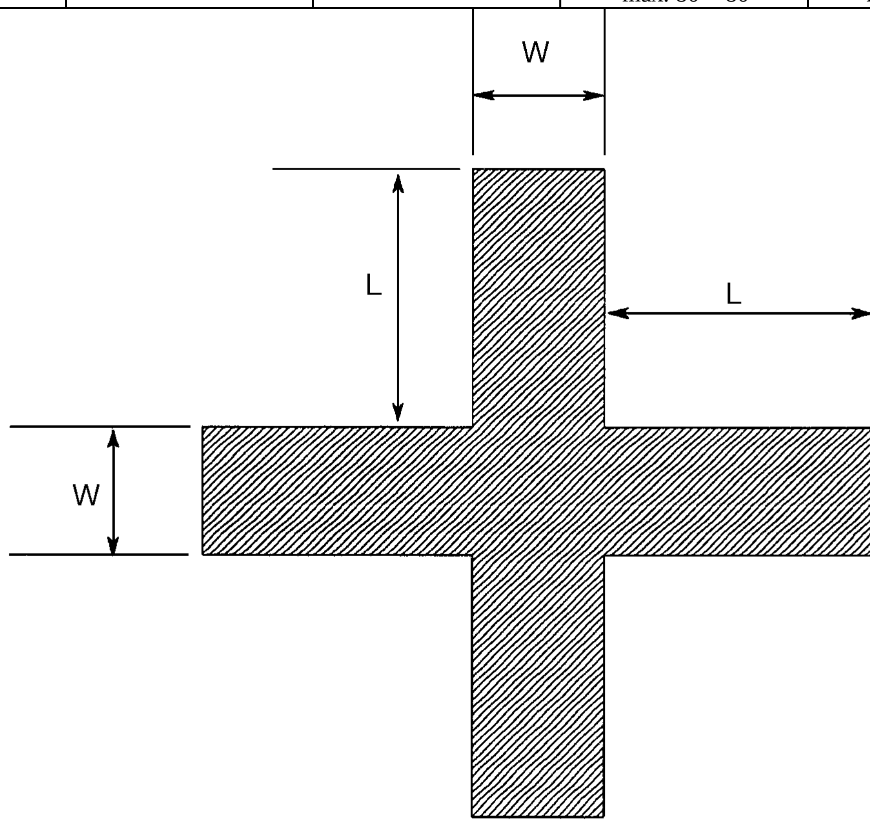

Figure 1
Shape of Registration Mark

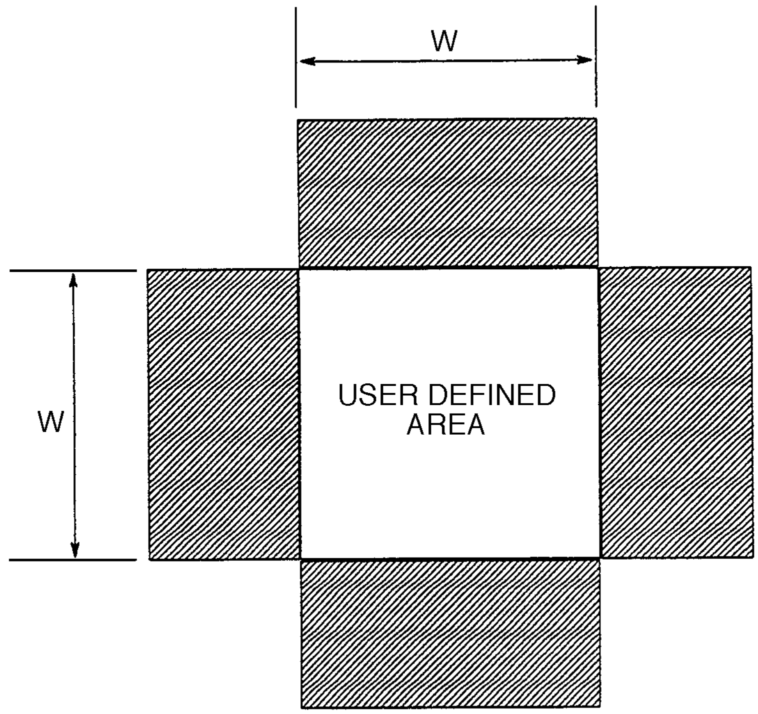

Figure 2
User-Defined Area

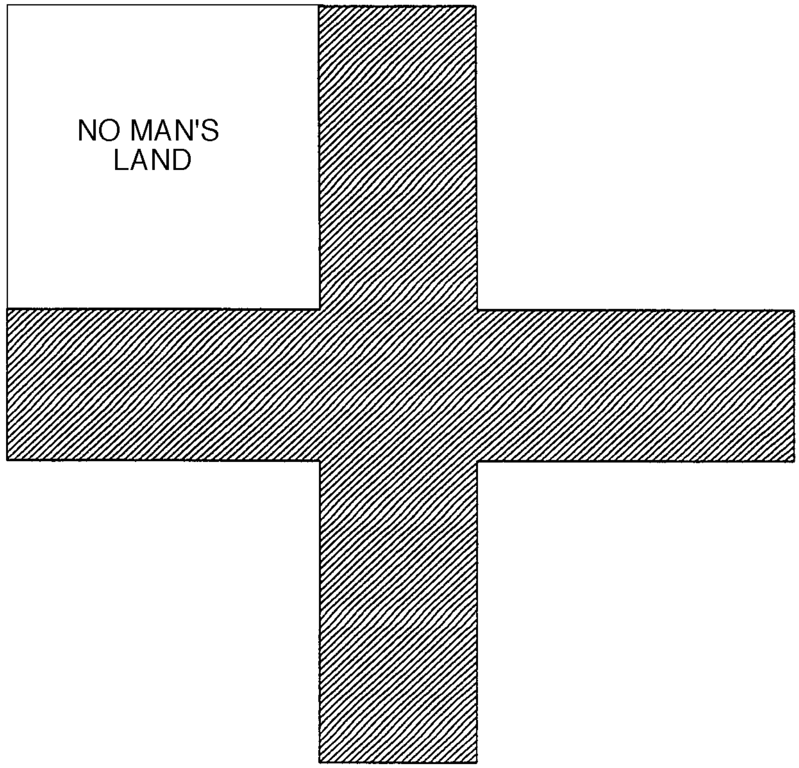

Figure 3
No Man's Land

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SEMI P7-0997
METHOD OF VISCOSITY DETERMINATION, METHOD A — KINEMATIC VISCOSITY

1 Scope

1.1 This method, a simplified version of ASTM D 445 and ASTM F 66 is intended for determining the kinematic viscosity of photoresists by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary at a fixed temperature. Efflux time is measured in seconds and multiplied by the calibration constant of the viscometer to obtain kinematic viscosity in units of centistokes (cSt). Optionally, kinematic viscosity may be multiplied by the density of the photoresist to obtain dynamic viscosity in units of centipoise (cP). Refer to ASTM D 445 and F 66 for additional information and definitions.

2 Referenced Documents

2.1 *ASTM Standard*[1]

D 445 — Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

F 66 — Photoresist Used in Microelectronic Fabrications

3 Apparatus

3.1 *Calibrated Viscometer* — Of the glass capillary type. (A listing of such viscometers is given in Table 1, ASTM D 445.)

3.2 *Constant Temperature Bath* — Equilibrated to 25.0 ± 0.1°C.

3.3 *Viscometer Clamp* — Adjustable to achieve vertical alignment.

3.4 *Thermometer* — Graduated in 0.1°C intervals and calibrated (see ASTM D 445 and ASTM F 66).

3.5 *Stopwatch* — Readable in 0.2 second intervals or better.

3.6 *Chemicals* — Acetone, chromic acid, methyl ethyl ketone, xylene.

4 Procedure

4.1 Confirm that the constant temperature bath is equilibrated to 25.0 ± 0.1°C.

4.2 Select a clean dry viscometer of appropriate viscosity range. Choose the proper tube size for the given viscosity so that the efflux time is greater than or equal to 200 seconds.

4.3 Charge the viscometer with photoresist in the manner dictated by the design of the viscometer and wipe clean.

4.4 Insert the viscometer into the clamp holder in the constant temperature bath. Vertical alignment of the viscometer is essential for proper flow measurement.

4.5 Allow 15 minutes for the sample temperature to equilibrate.

4.6 Use suction or pressure to adjust the level of the test sample to a position in the capillary arm about 5 mm ahead of the first timing mark.

4.7 With the sample flowing freely, measure the time for the meniscus to pass from the first timing mark to the second. Record the time in seconds.

4.8 Repeat the steps in Sections 4.6 and 4.7. (For reverse flow viscometers, use the same or another viscometer and begin with the step in Section 4.3 for the second measurement.)

4.9 The two measurements must agree within 0.5 seconds. If they do not agree, then reject the measurement results.

4.10 After the measurement, the viscometer should be flushed several times with a suitable solvent (methyl ethyl ketone or acetone for typical novolac positive resists or equivalent and xylene for rubber based negative resists or equivalent).

4.11 Dry the tube by blowing dry, filtered air through the viscometer for a few minutes.

4.12 The viscometer should periodically be cleaned with chromic acid to remove trace organic deposits.

5 Calculation

5.1 Average the flow measurements.

5.2 Kinematic viscosity in cTs = Viscometer constant × efflux time in seconds.

5.3 Dynamic viscosity in cP = Photoresist density at 25.0°C in g/mL × kinematic viscosity in cSt.

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SEMI P8-0997
METHOD FOR THE DETERMINATION OF WATER IN PHOTORESIST

1 Scope

1.1 This method is intended for the application of the Karl Fischer titration to the determination of water in photoresists. An electrometric method is used for determining the endpoint. The procedure is applicable to most resists that have polymer and solvent systems fully compatible with Karl Fischer reagent and diluent. The resist manufacturer should be consulted to determine if this procedure can be used with the resist in question.

2 Referenced Documents

2.1 *ASTM Standard*[1]

E 203 — Water by the Karl Fischer Method

2.2 *Reagent Chemicals* — Sixth Edition, American Chemical Society Specifications

3 Apparatus

3.1 Automatic titrator, equipped for Karl Fischer titrations. The titrator should be equipped with a titration vessel with a port for sample entry, desiccated vent tube, and a platinum versus platinum electrode. Mechanical stirring of the titration solvent should be provided for. The manufacturer's suggested operating procedure should be followed, and the endpoint timer set for 20 seconds.

3.2 Hypodermic syringes with lock tip, 0.25 mL and 10 mL.

3.3 Syringe needles, 5 to 8 cm length, 20 and 22 gauge.

3.4 Lint-free tissue.

3.5 Analytical balance, capable of weighing to 0.1 mg.

3.6 *Reagents*

3.6.1 Distilled water.

3.6.2 Methanol, ACS Reagent Grade.

3.6.3 Karl Fischer reagent with a titer of 3.0 (± 5.0) mg of water per ml of titrant. Typical preparation involves a one-to-one dilution of stabilized Karl Fischer reagent with Karl Fischer diluent from the same supplier.

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4 Procedure

4.1 *Standardization of Karl Fischer Reagent* — The Karl Fischer reagent should be standardized immediately before its use in water determinations.

4.1.1 Install Karl Fischer reagent in the titrator and flush all lines of the titration equipment at least three times.

4.1.2 Fill the titration vessel with enough methanol to cover the electrodes, and seal.

4.1.3 Titrate the methanol automatically with the Karl Fischer reagent to the endpoint (blank).

4.1.4 Draw 0.1 mL of distilled water into a 0.25 mL syringe equipped with a 22 gauge needle. Draw the water from the needle into the syringe by inverting the syringe (needle up) and drawing the plunger downward an additional 1 to 2 cm.

4.1.5 Wipe the needle with lint-free tissue.

4.1.6 Weigh the syringe assembly to the nearest 0.1 mg (W_1).

4.1.7 Inject the water into the titration vessel.

4.1.8 Titrate to the same endpoint used for the methanol blank.

4.1.9 Reweigh the syringe assembly to the nearest 0.1 mg (W_2).

4.1.10 Record the number of milliliters of titrant consumed (V_1).

4.1.11 Calculate the Karl Fischer factor (F):

$$F = \frac{\text{mg water injected}}{\text{mL KF titrant}} = \frac{W_1 - W_2}{V_1}$$

4.1.12 Repeat the standardizing titration twice and calculate the mean value for F from the three values (which should fall within a range of 0.02).

4.2 *Determination of Water*

4.2.1 Fill the titration vessel with enough methanol to cover the electrodes, and seal.

4.2.2 Titrate the methanol automatically with the Karl Fischer reagent to the endpoint (blank).

4.2.3 Flush a dry 10 mL syringe fitted with a 20 gauge needle several times with the sample to be tested. Fill the syringe with 3–5 mL of photoresist sample.

4.2.4 Wipe the needle with lint-free tissue.

4.2.5 Weigh the syringe assembly to the nearest 0.1 mg (W_3).

4.2.6 Inject the sample into the titration vessel.

4.2.7 Titrate to the same endpoint used for the methanol blank.

4.2.8 Reweigh the syringe assembly to the nearest 0.1 mg (W_4).

4.2.9 Record the number of milliliters of titrant used (V_2).

4.2.10 Calculate the water content of the sample.

$$\text{Weight \% } H_2O = \frac{\text{mL KF titrant} \times \text{F}}{\text{sample weight in mg}} \times 100$$

$$= \frac{V_2 \times F}{W_3 - W_4} \times 100$$

4.3 *Remarks* — Photoresists which contain interfering compounds (such as aldehydes and ketones) may require modification of the solvent or titration conditions. For further information, see Section 3.4 of ASTM Standard E 203. For some negative (polyisoprene) photoresists, solubility can be improved by substituting ethylene glycol as the solvent for methanol.

SEMI P9-0298
GUIDELINE FOR FUNCTIONAL TESTING OF MICROELECTRONIC RESISTS

1 Purpose

The purpose of this guideline is to provide a baseline program of test procedures needed to functionally test liquid-developed resists, resist developers, and rinses for microelectronic applications. It can also be used as a guide to evaluate process modifications to such systems. This guideline is intended to be applicable for photo, DUV, x-ray, and electron beam processes.

2 Background

Release of the information in this document was approved by the SEMI Photolithographic Chemicals Committee (Resist Committee) in May 1987. This committee plans to complete and revise the guideline as appropriate. Comments will be welcomed.

3 Scope

Virtually all lithographic fabrication processes vary in some way from location to location, even for the same type of resist. Consequently, it is impossible to provide a stringent evaluation program acceptable to most users. It is, therefore, the aim of this guideline to provide a program of tests and methods that allows variable, but controlled, process differences. In order to maintain a proper baseline control for each process, all tests should be run relative to some internal standard product whose functional characteristics are known and characterized. It is understood that each product is to be run at its own preferred or recommended conditions and that different products maybe evaluated under different conditions. It should also be understood that some properties, variables, or conditions, such as normality, are specific to resist type, such as positive photoresist, and are to be used only where applicable. Further, since this guide is directed to functional testing, it is assumed that any products to be evaluated have passed all relevant chemical and physical testing before such functional testing.

4 Priorities

This guideline has been divided into two separate groups. The first group, called “Sustaining Tests,” includes tests that are necessary for timely adjustments to coating and exposure conditions in order to maintain consistent image dimensions (Tables 1–3). The second group, called “Extended Testing,” includes tests that are required for full evaluation of the resist system (Tables 4–6). These tests may, or may not, be necessary for evaluation of each lot of product, depending on the individual requirements of the user.

5 Referenced Documents

5.1 *ASTM Standards*[1]

F 518 — Practice for Determining Effective Adhesion for Photoresist of Hard-Surface Photomask Blanks and Semiconductor Wafers during Etching

F 527 — Practice for Adjusting Photoresist Exposure Time

F 528 — Method for Measurement of Common-Emmiter D-C Current Gain of Junction Transistors

F 804 — Practice for Producing Spin Coating Resist Thickness Curves

F 863 — Practice for Detection of Defects in Spin-coated Resist

F 890 — Practice for Determining Pinhole Density in Photoresist Films Used in Microelectonics Device Processsing

F 1059 — Standard Practice for Calculating the Contrast and Threshold Sensitivity of a Positive Photoresist

6 Terminology

6.1 *test method* — A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

Table 1 Sustaining Tests — Resist Coating

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Thickness curve	Film thickness	Spin speed	Viscosity/Solids	ASTM F 804
			Substrate	
			Measurement method	
			Softbake	
			Coating program	
			Acceleration	
			Dispense volume	
			Exhaust rate	
			Environment	
Film uniformity	Film thickness	Across	As above	
		Wafer to wafer		
Striations	Fringes		As above	
	Film thickness variation		Before and after developing	
Cleanliness	Particles	In/On coating	Filtration	ASTM F 863
		On substrate after removal	Housekeeping	
			External sources	
			Defect size	
			Test method	
Film integrity	Pin holes	Film thickness	As above	ASTM F 890

Table 2 Sustaining Tests — Characteristic Information

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Threshold energy	Film thickness	Exposure energy	Measurement method	
			Calculation method	
			Exposure conditions	
			Developer type	
			Developer normality	
			Development time	
			Rinse type(s)	
			Agitation/Spray	
			Softbake	
			Environment	
Development rate	Film thickness	Exposure energy	As above	
		Development time		
Contrast	Film thickness	Exposure energy	As above	ASTM F 1059
			Film thickness	
Resist loss	Film thickness	Development conditions	As above	
Scum	Resist residue	Environment	As above	

Table 3 Sustaining Tests — Imaging

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Focus	Resolution	Focus	Substrate	
		Exposure energy	Film thickness	
			Exposure method	
			Exposure conditions	
			Measurement method	
			Developer type	
			Developer normality	
			Development time	
			Development method	
			Rinse type(s)	
			Agitation/Spray	
		Development time		
			Softbake	
			Environment	
Exposure requirements	Line width	Exposure energy	As above	ASTM F 527
		Image size		ASTM F 528

Table 4 Extended Testing — Resist Coating

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Planarization	Film thickness variation	Film thickness	Coating method	
		Topography	Spin speed	
			Softbake	
			Environment	
			Orientation of topography	

Table 5 Extended Testing — Imaging

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Focus latitude	Line width	Exposure energy	Substrate	
	Film thickness variation	Focus	Film thickness	
	Resolution		Exposure method	
			Exposure conditions	
			Line width	
			Developer type	
			Developer normality	
			Development time	
			Development method	
			Rinse type(s)	
			Agitation/Spray	
			Softbake	
			Environment	
Exposure latitude	As above	Exposure energy	As above	
Development latitude	As above	Development normality	Line width	
	Contrast	Development time	Exposure conditions	ASTM F 1059
	Threshold energy	Development temperature	Developer type	
		Exposure energy	Development method	

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
			Rinse type(s)	
			Agitation/Spray	
			Softbake	
			Environment	
Rinse latitude	As above	Composition	As above	
		Developer overlap		
		Rinse time		
Softbake latitude	As above	Softbake time	Line width	
		Softbake temperature	Exposure energy	
			Exposure conditions	
		Exposure energy	Film thickness	
			Ramp rate	
			Development conditions	
			Environment	
Thickness latitude	As above	Film thickness	As above	
		Exposed Energy	Substrate	
Resolution	As above	Exposure method	Substrate	
		Exposure energy	Exposure energy	
		Film thickness	Exposure conditions	
		Development conditions	Measurement method	
		Softbake conditions	Developer type	
			Development method	
			Rinse type(s)	
			Agitation/Spray	
			Focus	
			Softbake	
			Environment	
Resist profile	Wall angle	As above	As above	
	Corner rounding	Pre/Post treatment	Hardbake conditions	
	Shape			

Table 6 Extended Testing — Processing

Characteristic	*Measured Property*	*Variable*	*Fixed Conditions*	*Test Methods*
Thermal image stability	Shape	Temperature	Post exposure	
	Wall angle	Line width	Image hardening	
			Ramp rate	
	Corner rounding		Line width	
	Line width		Film thickness	
	Film integrity		Environment	
Wet etch adhesion (undercut/side)	Line width (top & bottom)	Etch time	Substrate	ASTM F 518
		Etch temp	Etch composition	
			Temperature	
			Resist treatment	
			Developer	
Wet etch adhesion (bias)	Line width etch-resist	As above	As above	
Dry etch resistance	Film thickness	Hardbake conditions	Ion	
	Line width	Image hardening	Process gases	
	Surface appearance		Process conditions	
Ion implant effects	Outgassing	Hardbake conditions	Ion	
	Film integrity	Image hardening	Power	
			Temperature	
			Film thickness	
Resist removal	Removal rate	Hardbake conditions	Stripping time	
	Residue	Post processing	Stripping temperature	
	Particles		Removal method	

SEMI P10-0301
SPECIFICATION OF DATA STRUCTURES FOR PHOTOMASK ORDERS

This specification was technically approved by the Global Mask & Mask Equipment Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1990; previously published February 1999.

This document was entirely rewritten in 2001.

1 Purpose

1.1 These data structure specifications are intended to facilitate the transmittal of mask order data between software systems to allow:

1.1.1 automated order placement by mask customers and to allow the automatic processing of such orders by mask shops, and

1.1.2 automated delivery of actual mask data by mask shops and to allow the automatic processing of such data by mask customers.

1.2 By using these standardized structures, software written independently for either mask customers or mask shops should be able to communicate unambiguously with software written by other parties.

2 Scope

2.1 This structure only defines the data format for the transmitted file. No particular database or programming language is specified by this standard. The data file is to be transmitted as an ASCII file. As such, it is compatible with the SECS-II standard.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 For a given customer, all pattern file names must be unique. (i.e., Pattern files which are different may not have the same name.)

3.2 For a given customer, all job file names must be unique. (i.e., Job files which are different may not have the same name.)

3.3 For a given customer, each mask set must have a unique identification.

3.4 For a given customer, each magnetic tape or other physical media delivered to the mask shop must have a unique identification.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P2 — Specification for Chrome Thin Films for Hard Surface Photomasks

5 Terminology

5.1 See Section 8.

6 Instructions and Conventions

6.1 Each record in the file will be composed of a specific keyword identifier followed by one or more data values, and will be terminated by a carriage return and/or linefeed.

6.2 Only records which are required to specify the order need to be included in the transmitted <mask_order> file, but each record included must appear in the sequence shown in the syntax specification.

6.3 Subsequent modifications or additions to the mask set require transmittal of all the information for the specific masks involved, including previously transmitted keywords and data fields if they still apply. Masks previously ordered which are not affected by the new order transmission may have their <mask_definition>, <mask_group> or <mask_set> omitted as appropriate.

6.4 Options are specified hierarchically such that those specified at a higher level are the default for all masks below, unless overridden at a lower level. The hierarchy is such that mask set options are overridden by mask group options, followed by mask definition, cell definition, cell instance, pattern group definition, and pattern definition.

6.5 Mask groups describe sets of masks which are similarly constructed. In simple cases there will be only one mask group per mask set. Multiple mask groups will be needed to describe mix-and-match sets, or for situations within a mask set where different features are required on some masks.

6.6 Pattern group definitions are intended for patterns which are similarly placed on all or most masks within a mask group (e.g., primary pattern files or test pattern files).

6.7 Cell definitions describe the construction of clusters of pattern groups and/or other cells. The PLACEMENT_TOP_CELL under a mask group describes the overall layout of the cells on all masks within the mask group.

6.8 Within a given mask set, each mask must have a unique identification (MASK_ID), independent of any titles on the mask.

6.9 Masks which require multiple writing operations (such as phase shift masks) will find those MASK_ID's identified with the same group number by the MULTIWRITE keyword.

6.10 The MASK_ID's defined under a mask group specify the masks to be built. The MASK_ID's also identify which patterns are to appear on the mask. A pattern is placed on the mask if and only if the MASK_ID matches the LEVEL_ID of a pattern referenced under the mask group's PLACEMENT_TOP_CELL.

6.11 <cell instance> and <pattern group instance> LOCATION's position the center of the patterns relative to the center of the CELL_ID referencing them. The cell referenced by the PLACEMENT_TOP_CELL is positioned at the center of the mask.

6.12 Job file data may be supplied in place of cell and pattern group data. In this case, the MASK_ID is understood to correspond to JOB_LEVEL in JOB_NAME.

6.13 Location of reference marks, mask titles and vendor-supplied barcodes are relative to the center of the mask. The coordinates and directions refer to right-handed, rectangular (Cartesian) coordinates, applied to the substrate being written.

6.14 All data in the structure will be in ASCII. The keyword in each record must include only upper case alphabetic characters and underscore.

6.15 Records (keyword, data value, comment and new line) may not exceed 256 characters. Some records may be repeated (e.g., BUSINESS_ADDRESS) in order to allow for longer field requirements; these are explicitly indicated in the syntax specification.

6.16 Comments may be included in records by preceding them with an exclamation point (!). Any data following an exclamation point and preceding a carriage return and/or linefeed will be ignored. Such comments are included in the 256 character record limit. If a record starts with an exclamation point, the entire record will be ignored. Only printable ASCII characters (plus spaces and tabs) are permitted in comments. Comments are for development and diagnostic purposes only. In commercial use, comments may always be ignored by the recipient without consequence. On the other hand, ADDITIONAL_..._INFO records must be evaluated by the recipient and applied to the masks being ordered, and may justify delay in mask delivery.

6.17 Spaces or tabs preceding the keyword will be ignored. At least one space or tab must precede the data field. Spaces and tabs imbedded in alphanumeric data fields will be preserved. Spaces or tabs may not be imbedded within numeric data values, but may be used to separate data values in multi-value data fields. At least one comma must appear between adjacent data values in multi-value data fields; more than one comma may not appear between adjacent data values. Spaces or tabs trailing the last data value in a data field will be ignored.

6.18 All numeric record values which require units will be in metric unless otherwise specified in Section 8. Units of length or position will be in microns unless otherwise specified.

6.19 Dates will be in the alphanumeric format DD-MMM-YYYY, where MMM will be the first 3 letters of the English spelling of the month. Times will be in the format HH:MM:SS OR HH:MM. Within the transmitted file, times and dates will always be Greenwich mean time.

6.20 Sizing to achieve a CD_TARGET from a CD_DATA must be applied to all pattern files hierarchically affected by the CD_TARGET record.

6.21 Since complex data manipulation operations are composed of simple binary and unary operations, intermediate files will need to be named. These names may be comprised of any printable ASCII characters, and must be unique within all revisions of the <mask_set>.

6.22 Binary data manipulation operations expect operands (input pattern files) to align center-to-center. This requires that DATA_PATTERN_WINDOW be defined for patterns which do not contain an explicit record of file extents.

6.23 All references to horizontal (or "x") and vertical (or "y") correspond to normal Cartesian coordinates and assume the rotational orientation of the glass when the mask was written.

6.24 All <shippable_data> keywords will be followed by <ship_to> specifying the destination and/or method of transmission for the transmitted data. Whenever applicable, the SEMI_MASK_DATA file (see Section 7.5) should be sent accordingly if electronic transmission is specified.

6.25 <shippable_data> keywords which require reference to specific mask feature locations will reference CD_SITE_ID and/or REGISTR_MARK_ID which must be unique for each location within all transmissions of <mask_order> for a given MASK_SET_ID.

7 Syntax Specification

The following specifies the syntax for the mask order structures. The record order is specific; records must appear in the sequence shown. Terminology for the individual records and their allowed data values are specified in Section 8.

7.1 *Syntax Symbol Definition* — The lower case syntactic names within < > are used to refer to collections of records. The use of { } around records or collections of records means an arbitrary number of repetitions of the records, including none at all. The use of [ ] around a record or collection of records means that the collection is optional.

7.2 *Record Syntax* — A keyword is followed by a data field which is followed by an optional comment. The record is terminated by a carriage return and/or linefeed. Each of these elements may be preceded by any combination of spaces or tabs, which will be ignored. At least one space or tab is required preceding the first data value in the record. An exclamation point (!) is required to initiate a comment. Exclamation points, carriage returns, and linefeeds are not allowed in keywords, data values or comments. Note that a record consisting of a comment only is also allowed. The syntax for individual records is defined as:

<record> = [{ <separator>} <keyword>

<separator> { <separator>} <data_field>]

[{ <separator>} ! <comment>]

{ <separator>} <new_line>

where “separator” is a space or a tab, “comment” is any string of printable ASCII characters (plus spaces and tabs), and “new_line” is a carriage return, linefeed or both.

7.3 *Multi-value Data Field Syntax* — When data_field is for (x,y) pairs or (x1,y1,x2,y2) double pairs (see Section 8), the individual values must be separated by a comma and any combination of spaces or tabs. One comma is required between each data_value, but not more than one comma. Two commas without an intervening data value are not permissible.

(x,y) = value { separator} comma { separator} value

(x1,y1,x2,y2) = (x1,y1) { separator} comma { separator} (x2,y2)

For data manipulation operations, three- and six- value data fields are also allowed:

(x,y,z) = (x,y) { separator} comma { separator} (z)

(x,y,x1,y1,x2,y2) = (x,y) { separator} comma { separator} (x1,y1,x2,y2)

7.4 *Mask Order Structure Syntax* — The following syntax definition uses the upper case keyword to represent the permissible applications of the corresponding data record within the mask order structure.

<mask_order> =	START_ORDER SEMI_REVISION CUSTOMER VENDOR
	FILE_DATE_TIME [OPERATOR_NAME]
	<mask_set> END_ORDER CHECKSUM
<mask_set> =	MASK_SET_ID <mask_set_options> END_MASK_SET_OPTIONS
	{ <mask_group>} END_MASK_SET
<mask_set_options> =	[BUSINESS_CONTACT] { BUSINESS_ADDRESS} { BUSINESS_PHONE}
	{ BUSINESS_FAX} [BUSINESS_EMAIL]
	[BILLING_CONTACT] { BILLING_ADDRESS}
	{ BILLING_PHONE} { BILLING_FAX} [BILLING_EMAIL]
	[DESIGN_RULE]
	[PRICE_UNITS]
	[SECURITY_CLASS]

[ENGINEERING_CONTACT] { ENGINEERING ADDRESS} { ENGINEERING_PHONE}
{ ENGINEERING_FAX} [ENGINEERING_EMAIL]
[SHIPPING_CONTACT] { SHIPPING_ADDRESS} { SHIPPING_PHONE}
{ SHIPPING FAX} [SHIPPING_EMAIL]
{ SHIPPING_METHOD}
[REPAIRS_AUTHORIZED]
[<shippable_data>]
{ <data>}
{ <standard_pattern>}
{ <data_manipulation>}
[MASK_SET_NAME [MASK_SET_VERSION]] [ORDER_ID]
{ ADDITIONAL_MASK_SET_INFO}

<data> = DATA_MEDIUM [DATA_LOCATION] [DATA_ID]
[DATA_FORMAT [DXF_ANGLE DXF_UNIT]]
[DATA_DENSITY] [DATA_FILE_SIZE]
[DATA_COMPRESSION] [DATA_CONSOLIDATION] [DATA_ENCRYPTION]
[DATA_CHECKSUM DATA_CHECKSUM_TYPE]
{ <pattern_data>} { <job_data>}
{ MEASURE_FILE_NAME [MEASURE_FILE_FORMAT] }
{ CD_MATRIX_FILE_NAME [CD_MATRIX_FILE_FORMAT] }
END_DATA_MEDIUM

<pattern_data> = DATA_PATTERN_NAME PATTERN_FORMAT [DATA_FILE_NUMBER]
[DATA_TOP_CELL] [DATA_LAYER_ID [DATA_DATATYPE]]
[DATA_PATTERN_WINDOW] [PATTERN_UNITS] [PATTERN_CHARACTER_SET]
END_ DATA_PATTERN_ NAME

<job_data> = DATA_JOB_NAME JOB_FORMAT

<standard_pattern> = STD_PATTERN_NAME PATTERN_FORMAT

<data_manipulation> = START_DATA_MANIPULATION [AND] [OR] [XOR] [NOT] [MINUS]
[SIZING [SIZING_RULE] [SIZING_BORDER_RULE]]
[FRACTURING_SCALE] [DATA_SCALE_FACTOR]
[PATTERN_ADDRESS_SIZE] [PATTERN_FORMAT]
[DARK_INTERNAL_WINDOW] [CLEAR_INTERNAL_WINDOW]
[EXTERNAL_WINDOW] [ROTATION] [MIRROR] END_ DATA_MANIPULATION

<mask_group> = MASK_GROUP_ID [<mask_options>] END_MASK_GROUP_OPTIONS
PLACEMENT_TOP_CELL { <mask_definition>}
{ <cell_definition>} { <pattern_group>} END_MASK_GROUP

<mask_options> = [BLANKET_PO_NUMBER] [PO_NUMBER] [SO_NUMBER] [ORDER_ID]
[RELEASE_NUMBER] [LINE_ITEM_NUMBER] [QUOTE_NUMBER]
[STATUS]
[DUE_DATE_TIME_REQUESTED]

[LAYER_PRIORITY [ELAPSED_TIME]]

[MILESTONES <ship_to>] [PERIODIC_UPDATES <ship_to>]

[ESTIMATED_ARRIVALS <ship_to>]

[BUSINESS_CONTACT] { BUSINESS_ADDRESS} { BUSINESS_PHONE}

{ BUSINESS_FAX} [BUSINESS_EMAIL]

[BILLING_CONTACT] { BILLING_ADDRESS}

{ BILLING_PHONE} { BILLING_FAX} [BILLING_EMAIL]

[PRICE]

[SECURITY_CLASS]

[SHIPPING_CONTACT] { SHIPPING_ADDRESS} { SHIPPING_PHONE}

{ SHIPPING FAX} [SHIPPING_EMAIL]

{ SHIPPING_METHOD}

[REPAIRS_AUTHORIZED]

[<shippable_data>]

{ MFG_SITE} { MFG_EQUIP} { MFG_MODEL}

{ PRODUCT_TYPE [PRODUCT_MAGNIFICATION] [PRODUCT_IMAGING_TYPE]

[QUANTITY] [PRODUCT_AS_CHECKPLATE] }

[MULTIWRITE]

{ WAFER_EXPOSURE_TOOL}

[JOB_NAME] [JOB_LEVEL]

[RETROFIT_JOB_NAME] [RETROFIT_JOB_LEVEL]

[RETROFIT_MASK_SET_ID] [RETROFIT_MASK_ID]

[RETROFIT_MASK_SET_NAME [RETROFIT_MASK_SET_VERSION]

[RETROFIT_MASK_NAME]]

{ <title_data>}

{ <barcode_data>}

{ APPROVAL_REQD} { REVIEW_REQD}

[SERIAL_NUMBER]

[MIRROR_MASK]

[GLASS_SIZE] [GLASS_TYPE]

[FLATNESS] [MASK_COATING]

[<phase_shift>]

[RESIST_TYPE] [UT1X_UNCUT] [PROCESS]

{ TOP_PELLICLE_TYPE [PRICE] } { BOTTOM_PELLICLE_TYPE [PRICE] }

[GUIDES_REQD [PRICE]]

[CENTRALITY]

{ <registration>}

[REGISTR_CLOSURE [REGISTR_CLOSURE_BEGIN REGISTR_CLOSURE_END]]

[BUTTING_ERROR [BUTTING_ERROR_METHOD]]

{ START_CD [<cd_definition>] [NUMBER_OF_CDS]

{ [CD_SITE_ID] MASK_CD_LOCATION} [CD_MATRIX_FILE_NAME]
[<cd_description>] END_CD}
[MIN_MASK_FEATURE_SIZE] [PERCENT_CLEAR]
{ <opc_definition>}
{ <defect_definition>}
[INSPECTION_REF_LOCATION]
<surface_definition>
[INSPECT_THROUGH_PELLICLE <defect_definition>]
[QUALITY_GROUP_ID]
[COMPACT_LABEL]
{ PACKAGE [MAX_MASKS_IN_PACKAGE] }
{ ADDITIONAL_MASK_INFO}

<title_data> = START_TITLE [TITLE_TEXT] [TITLE_TYPE] [TITLE_HEIGHT]
[TITLE_JUSTIFICATION] [TITLE_LOCATION] [MIRROR_TITLE]
[ROTATE_TITLE] [ROTATE_TITLE_CHARACTERS] END_TITLE

<barcode_data> = START_BARCODE [BARCODE_TYPE] [BARCODE_TEXT] [BARCODE_LOCATION]
[BARCODE_ROTATION] END_BARCODE

<array_plot> = SHIP_ARRAY_PLOT [QUANTITY]
[ARRAY_PLOT_SCALE]
[PRICE] [<ship_to>] END_SHIP_ARRAY_PLOT

<films> = SHIP_FILM [QUANTITY]
[FILM_SCALE] [FILM_SIZE] [FILM_COLOR] [FILM_NORMAL_TONE]
[PRICE] [<ship_to>] END_SHIP_FILM

<phase_shift> = START_PHASESHIFT [WAVELENGTH
[TRANSMISSION_TARGET [TRANSMISSION_TOLERANCE]
[TRANSMISSION_RANGE] [TRANSMISSION_ERROR]]
[PHASE_ANGLE_TARGET [PHASE_ANGLE_TOLERANCE]
[PHASE_ANGLE_RANGE] [PHASE_ANGLE_ERROR]]
[ETCH_DEPTH_TARGET [ETCH_DEPTH_TOLERANCE]
[ETCH_DEPTH_RANGE] [ETCH_DEPTH_ERROR]]]
END_PHASESHIFT

<registration> = START_REGISTR [REGISTR_ERROR] [REGISTR_SCALE] [REGISTR_RESIDUAL]
[REGISTR_RESIDUAL_THREE_SIGMA] [REGISTR_ORTHO] [REGISTR_RELATIVE]
[MULTIWRITE_OVERLAY_ERROR MULTIWRITE_REF_MASK_ID]
{ REGISTR_REF_MASK_ID REGISTR_REF_MASK_SET_ID}
{ REGISTR_REF_MASK_NAME REGISTR_REF_MASK_SET_NAME
[REGISTR_REF_MASK_SET_VERSION] }
{ REGISTR_EQUIP_REQD} [REGISTR_STD_GRID] { REGISTR_REF_METHOD}
[REGISTR_ALGORITHM]
{ [REGISTR_MARK_ID] MASK_REGISTR_MARK [MEASURE_FILE_NAME]

	[REGISTR_MARK_SEPARATION REGISTR_MARK_COUNT] }
	END_REGISTR
<cd_definition> =	[CD_DATA] [CD_DIGITIZED] [CD_TONE_CLEAR]
	[CD_ISOLATED] [CD_DENSE]
	[CD_TARGET] [CD_ORIENTATION]
	[CD_REFERENCE_ONLY]
	[CD_TOLERANCE] [CD_XY_TOLERANCE] [CD_XY_DEVIATION]
	[CD_RANGE] [CD_THREE_SIGMA]
	[CD_DEVIATION_FROM_TARGET] [CD_DEVIATION_FROM_MEAN]
	[CD_STD] [CD_CORRELATION_ID]
	{ CD_EQUIP_REQD}
<cd_description> =	[CD_FEATURE] [CD_LOCATION_DRAWING] [CD_DRAWING]
<opc_definition> =	START_OPC
	[OPC_TYPE [OPC_MINIMUM_FEATURE_SIZE] [OPC_MINIMUM_GAP]
	[OPC_PATTERN_SEPARATE] [OPC_PATTERN_MODIFIABLE]]
	END_OPC
<defect_definition> =	START_DEFECT_DEFINITION
	[VISUAL_INSPECTION_OK] [VISUAL_INSPECTION_REQD]
	[AUTO_INSPECTION_REQD] [DIE_TO_DIE_INSPECTION]
	[DEFECT_SIZE] [DEFECT_SIZE_CL] [DEFECT_SIZE_DK]
	[DEFECT_SIZE_CL_ADJ] [DEFECT_SIZE_CL_ADJ_REP]
	[DEFECT_SIZE_DK_ADJ] [DEFECT_SIZE_DK_ADJ_REP]
	[DEFECT_SIZE_CL_ISO] [DEFECT_SIZE_CL_ISO_REP]
	[DEFECT_SIZE_DK_ISO] [DEFECT_SIZE_DK_ISO_REP]
	[DEFECT_DENSITY] [DEFECT_COUNT] [DEFECT_COUNT_REP]
	[DEFECTIVE_DIE_DENSITY] [DEFECTIVE_DIE_COUNT]
	[DEFECTIVE_DIE_COUNT_REP]
	[PERCENT_DEFECTIVE_DIE]
	[EDGE_RAGGEDNESS] [EDGE_ROUGHNESS]
	[SCRATCH_SIZE_FRONT] [SCRATCH_SIZE_BACK]
	{ INSPECTION_AREA} { INSPECTION_AREA_EXCLUDE}
	[GOOD_FIELDS]
	{ DEFECT_EQUIP_REQD [DEFECT_INSP_MODE] [DEFECT_SETUP_FILE_NAME] }
	[<database_inspection>]
	END_DEFECT_DEFINITION
<database_inspection> =	DATABASE_INSPECTION [PRICE]
	[DATABASE_SOURCE]
	[DATABASE_TOP_CELL DATABASE_LAYER]
	[DATABASE_FILE_NAME]
	[DATABASE_UNIT] [USER_UNIT]

	[DATABASE_WITH_JOB [DATABASE_JOB_NAME DATABASE_JOB_LEVEL]]
	{ DATABASE_AREA}
<surface_definition> =	[SURFACE_INSPECTION] [SURF_INSP_METHOD] [SURF_INSP_AREA]
	[SURF_INSP_PELL_TOP] [SURF_INSP_PELL_BOTTOM]
	[SURF_INSP_GLASS_SIDE] [SURF_INSP_PATTERN_SIDE]
	[TRANSMISSION_DEFECT_CLEAR] [TRANSMISSION_DEFECT_DARK]
<mask_definition> =	MASK_ID [MASK_NAME] DELIVERABLE_MASK
	<mask_options> END_MASK
<cell_definition> =	CELL_ID <pattern_options> END_CELL_OPTIONS
	{ <cell_instance>} { <pattern_instance>} END_CELL
<pattern_group> =	PATTERN_GROUP_ID <pattern_options>
	END_PATTERN_GROUP_OPTIONS { <pattern_definitions>}
	END_PATTERN_GROUP
<pattern_definitions> =	LEVEL_ID
	[PATTERN_NAME] [PATTERN_VISUAL_ID] [FIGURE_COUNT]
	[MINIMUM_FEATURE_SIZE { MINIMUM_FEATURE_LOCATION}]
	{ <opc_definition>}
	[OPTICAL_MASK_SET_ID [OPTICAL_MASK_ID]]
	[OPTICAL_MASK_TITLE]
	<pattern_options>
	END_PATTERN_DEFINITION
<cell_instance> =	CELL_INSTANCE <pattern_options>
	END_CELL_INSTANCE_OPTIONS { <placement>}
	END_ CELL_INSTANCE
<pattern_instance> =	PATTERN_GROUP_INSTANCE <pattern_options> { <placement>}
	END_ PATTERN_GROUP_INSTANCE
<placement> =	START_PLACEMENT [LOCATION [STEPPING_DISTANCE STEPPING_COUNT]]
	[ARRAY_DIAMETER ARRAY_CENTER [ARRAY_DIAMETER_INCLUSIVE]]
	[DATA_OFFSET]
	{ DROPOUT [SCRIBE_TONE SCRIBE_INSIDE_CORNERS
	SCRIBE_OUTSIDE_CORNERS] }
	[LOCATION_SPEC] [CD_MEASURE_DIE]
	END_PLACEMENT
<pattern_options> =	START_PATTERN_OPTIONS [PATTERN_ADDRESS_SIZE] [SCALE_FACTOR]
	[DIGITIZED_DATA_DARK]
	[STRIPE_HEIGHT]
	[UNSCALED_PATTERN_SIZE]
	[SURROUNDING_TONE SURROUNDING_WIDTH SURROUNDING_HEIGHT]
	[MIRROR_PATTERN]
	[SHIP_PATTERN_PLOT [PRICE] [QUANTITY] [<ship_to>]]

[PATTERN_PLOT_SCALE] [PATTERN_PLOT_NORMAL_TONE]

[PATTERN_PLOT_APPR_REQD]

{ <films>}

{ [REGISTR_MARK_ID] CELL_REGISTR_MARK [MEASURE_FILE_NAME]

[REGISTR_MARK_SEPARATION REGISTR_MARK_COUNT] }

{ START_CD [<cd_definition>] [NUMBER_OF_CDS]

{ [CD_SITE_ID] PATTERN_CD_LOCATION} [CD_MATRIX_FILE_NAME]

[<cd_description>] END_CD }

[PERCENT_CLEAR]

[INSPECT_ALL_SITES]

{ <defect_definition>}

[BUTTING_ERROR]

[ADDITIONAL_PATTERN_INFO]

END_PATTERN_OPTIONS

<shippable_data> = START_SHIPPABLE_DATA

[SHIP_CD_DATA <ship_to>]

[SHIP_CD_PRINTOUT <ship_to>]

[SHIP_CD_UNIFORMITY_MAP <ship_to>]

[SHIP_DEFECT_DATA <ship_to>]

[SHIP_THRU_PELLICLE_DATA <ship_to>]

[SHIP_MANUAL_INSPECTION_FORM <ship_to>]

[SHIP_INSP_DATABASE_DATA [INSP_DATABASE_DATA_FORMAT] <ship_to>]

[SHIP_FIRST_PREPELL_DIE_DB_MSK_MAP <ship_to>]

[SHIP_FIRST_PREPELL_DIE_DB_PTN_MAP <ship_to>]

[SHIP_FIRST_PREPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FIRST_ROT_PREPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FINAL_PREPELL_DIE_DB_MSK_MAP <ship_to>]

[SHIP_FINAL_PREPELL_DIE_DB_PTN_MAP <ship_to>]

[SHIP_FINAL_PREPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FINAL_ROT_PREPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FIRST_POSTPELL_DIE_DB_MSK_MAP <ship_to>]

[SHIP_FIRST_POSTPELL_DIE_DB_PTN_MAP <ship_to>]

[SHIP_FIRST_POSTPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FIRST_ROT_POSTPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FINAL_POSTPELL_DIE_DB_MSK_MAP <ship_to>]

[SHIP_FINAL_POSTPELL_DIE_DB_PTN_MAP <ship_to>]

[SHIP_FINAL_POSTPELL_DIE_DIE_MAP <ship_to>]

[SHIP_FINAL_ROT_POSTPELL_DIE_DIE_MAP <ship_to>]

[SHIP_REPAIR_DATA <ship_to>]

[SHIP_REGISTR_DATA <ship_to>]

[SHIP_ARRAY_REGISTR_MAP <ship_to>]

[SHIP_DIE_FIT_MAP <ship_to>]

[SHIP_MEASURE_FILE_REGISTR_MAP <ship_to>]

[SHIP_PATTERN_PLACEMENT_MAP <ship_to>]

[SHIP_FIELD_FIT_MAP <ship_to>]

[SHIP_CENTRALITY_DATA <ship_to>]

[SHIP_CENTRALITY_MAP <ship_to>]

[SHIP_SURF_INSPECTION_MAP <ship_to>]

[SHIP_ SURF_INSP_PELL_TOP_MAP <ship_to>]

[SHIP_ SURF_INSP_PELL_BOTTOM_MAP <ship_to>]

[SHIP_ SURF_INSP_GLASS_SIDE_MAP <ship_to>]

[SHIP_ SURF_INSP_PATTERN_SIDE _MAP <ship_to>]

[SHIP_STARLIGHT_MAP <ship_to>]

[SHIP_PHASE_SHIFT_REPORT <ship_to>]

[SHIP_SEM_PHOTOS <ship_to>]

{ <array_plot>}

[SHIP_JOB_DATA_PLOT <ship_to>]

SHIP_BARCODE_PLOT <ship_to>]

{ <films>}

[SHIP_CERTIFICATE_OF_CONFORMANCE <ship_to>]

{ SHIP_CUSTOMER_QUALITY_FORM <ship_to>}

[SHIP_TRAVELER <ship_to>]

[PERCENT_CLEAR_REQUESTED <ship_to>]

{ SHIP_SPECIAL_REQUEST <ship_to>}

END_ SHIPPABLE_DATA

<ship_to> = START_SHIP_TO

{ EMAIL_ADDRESS} [<ftp_address>] { MAILING_ADDRESS} [SHIP_TO_FAX]

[DUE_DATE_TIME_REQUESTED]

END_SHIP_TO

<ftp_address> = FTP_HOST_NAME [FTP_LOGIN] [FTP_PASSWORD] [FTP_DIRECTORY]

[FTP_MODE] END_FTP_HOST

7.5 *Mask Data Structure Syntax* — The following syntax definition uses the upper case keyword to represent the permissible applications of the corresponding data record within the mask data structure. This structure allows the vendor to deliver to the customer actual data regarding masks being built.

<mask_data> = START_MASK_DATA SEMI_REVISION CUSTOMER VENDOR

FILE_DATE_TIME [OPERATOR_NAME]

MASK_SET_ID [<vendor_info>]

{ MASK_GROUP_ID[<vendor_info>]

{ MASK_ID <mask_data_options> END_MASK}
END_MASK_GROUP}
END_MASK_SET
END_MASK_DATA
CHECKSUM

<mask_data_options> = [<vendor_info>]
[MASK_NAME]
{ TITLES [TITLE_TYPE] }
[DUE_DATE_TIME_COMMITTED] [ELAPSED_TIME_COMMITTED]
[MILESTONE [ADDITIONAL_MILESTONE_INFO]]
[PERIODIC_UPDATE [ADDITIONAL_MILESTONE_INFO]]
[ESTIMATED_ARRIVAL [ADDITIONAL_MILESTONE_INFO]]
[MEASURED_PERCENT_CLEAR]
[MEASURED_CENTRALITY]
[<registration_measurements>]
{ <cd_measurements>}
[<defect_measurements>]
[THROUGH_PELLICLE_DEFECTS < defect_measurements>]

<vendor_info> = START_VENDOR_INFO
[VENDOR_CONTACT] [VENDOR_PHONE] { VENDOR_ADDRESS}
[VENDOR_FAX] [VENDOR_EMAIL]
END_VENDOR_INFO

<registration_measurements> = START_REGISTR_MEASUREMENTS
[REGISTR_ERROR] [REGISTR_SCALE] [REGISTR_RESIDUAL]
[REGISTR_RESIDUAL_THREE_SIGMA] [REGISTR_ORTHO] [REGISTR_RELATIVE]
[MULTIWRITE_OVERLAY_ERROR]
[MEASURED_REGISTR_ERROR] [MEASURED_REGISTR_SCALE]
[MEASURED_REGISTR_RESIDUAL]
[MEASURED_REGISTR_RESIDUAL_THREE_SIGMA]
[MEASURED_REGISTR_ORTHO] [MEASURED_REGISTR_RELATIVE]
[MEASURED_MULTIWRITE_OVERLAY_ERROR]
{ MEASURED_REGISTR_MARK_ID
MASK_REGISTR_MARK_LOCATION
MEASURED_REGISTR_MARK_LOCATION
END_MEASURED_REGISTR_MARK}
END_ REGISTR _MEASUREMENTS

<cd_measurements> = START_CD_MEASUREMENTS
[CD_TOLERANCE]
[CD_XY_TOLERANCE] [CD_XY_DEVIATION]

[CD_RANGE] [CD_THREE_SIGMA]
[CD_DEVIATION_FROM_TARGET]
[CD_DEVIATION_FROM_MEAN]
[CD_STD] [CD_CORRELATION_ID]
[MEASURED_CD_TOLERANCE]
[MEASURED_CD_XY_TOLERANCE] [MEASURED_CD_XY_DEVIATION]
[MEASURED_CD_RANGE] [MEASURED_CD_THREE_SIGMA]
[MEASURED_CD_DEVIATION_FROM_TARGET]
[MEASURED_CD_DEVIATION_FROM_MEAN]
{ MEASURED_CD_SITE_ID
MASK_CD_LOCATION
CD_TARGET
CD_TONE_CLEAR
[CD_ISOLATED] [CD_DENSE]
[CD_ORIENTATION]
[CD_REFERENCE_ONLY]
MEASURED_CD
END_MEASURED_CD_SITE}
END_ CD_MEASUREMENTS

<defect_measurements> = START_DEFECT_MEASUREMENTS
[MEASURED_DEFECT_DENSITY]
[MEASURED_DEFECT_COUNT]
[MEASURED_DEFECT_COUNT_REP]
[MEASURED_DEFECTIVE_DIE_DENSITY]
[MEASURED_DEFECTIVE_DIE_COUNT]
[MEASURED_DEFECTIVE_DIE_COUNT_REP]
[MEASURED_PERCENT_DEFECTIVE_DIE]
END_DEFECT_MEASUREMENTS

8 Terminology and Usage

8.1 Values in parentheses indicate the only acceptable alternative data values for the record and must be transmitted exactly as shown. (x,y) indicates the acceptable data value must be an ordered pair of dimensions, coordinates, repeat counts, filenames, or other parameters. (x,y,z) indicates an ordered triple. (x1,y1,z1) indicates a window with two ordered pairs, (x1,y1) and (x2,y2), describing the lower left and upper right corners respectively. Records without specified alternative values may have any appropriate data value.

ADDITIONAL_MASK_INFO

Any information necessary to specify the overall mask set which cannot be specified elsewhere in the order structure; must be brought to the attention of mask vendor personnel.

ADDITIONAL_MASK_SET_INFO

Any information necessary to specify the overall mask set which cannot be specified elsewhere in the order structure; must be brought to the attention of mask vendor personnel.

ADDITIONAL_MILESTONE_INFO

Text for the vendor to supply additional information regarding the status of the mask.

ADDITIONAL_PATTERN_INFO

Any information necessary to specify the pattern(s) which cannot be specified elsewhere in the order structure; must be brought to the attention of mask vendor personnel.

AND

(x,y,z) Name of file (x) to be formed by the logical intersection of the digitized geometries in file (y) and file (z). The extents of the pattern file (x) will be the same as for file (y).

APPROVAL_REQD

If present, indicates that no mask(s) are to be written until the approval is explicitly granted by the customer. The alphanumeric data field describes the items to be approved.

ARRAY_CENTER

Center of circular array limit, relative to the center of the mask.

ARRAY_DIAMETER

Diameter of circular array limit to be applied to pattern files.

ARRAY_DIAMETER_INCLUSIVE

(T or F) If T, then die which are at least partially included within the circular array limit must be included in the array. If F, then only die which are wholly included within the circular array limit may be included in the array.

ARRAY_PLOT_SCALE

Numeric scale of array map

AUTO_INSPECTION_REQD

(T or F) Automated inspection of the mask for defects is required.

BARCODE_LOCATION

(x,y) Location to place the center of the vendor-generated barcode.

BARCODE_ROTATION

(0,90,180, or 270) Degrees the barcode is to be rotated counterclockwise (before mirroring).

BARCODE_TEXT

Text to be used by the vendor to build the barcode.

BARCODE_TYPE

(ASM, ASET, CANON, GCA, NIKON_STD or NIKON_CUBE37, and others on request) Encoding system to be used by the vendor to build the required barcode.

BILLING_ADDRESS

Address for billing.

BILLING_CONTACT

Name of person to contact for billing purposes.

BILLING_EMAIL

Internet address for BILLING_CONTACT.

BILLING_FAX

Phone number for facsimile machine of BUSINESS_CONTACT.

BILLING_PHONE

Phone number for BILLING_CONTACT.

BLANKET_PO_NUMBER

Alphanumeric blanket purchase order number.

BOTTOM_PELLICLE_TYPE

Alphanumeric brand and model of acceptable pellicle for the glass side of the mask. If multiple pellicles are listed, they are listed with the most preferred first and then in declining preference.

BUSINESS_ADDRESS

Address of person placing the order.

BUSINESS_CONTACT

Name of person placing the order.

BUSINESS_EMAIL

Internet address for BUSINESS_CONTACT.

BUSINESS_FAX

Phone number for facsimile machine of BUSINESS_CONTACT.

BUSINESS_PHONE

Phone number for BUSINESS_CONTACT.

BUTTING_ERROR

Maximum misalignment of features due to stitching of adjacent fields in the segmented writing of a mask.

BUTTING_ERROR_METHOD

Alphanumeric description of the method to be used to measure butting error.

CD_CORRELATION_ID

Alphanumeric date or other identification of the vendor/customer correlation test to be used in measuring CDs.

CD_DATA

Size of critical dimension feature in data as supplied in the pattern file.

[CD_DENSE]

(T or F) Region surrounding cd feature is dense geometry.

CD_DEVIATION_FROM_MEAN

Maximum acceptable deviation of any of the customer-required CD measurements from the mean of those measurements.

CD_DEVIATION_FROM_TARGET

Maximum acceptable deviation of any of the customer-required CD measurements from the CD_TARGET.

CD_DIGITIZED

(T or F) If T, critical dimension in pattern is digitized data.

CD_DRAWING

The uniquely identified (for each customer) document which shows the CD structure itself, and may show the place within the CD which are to be measured.

CD_EQUIP_REQD

Alphanumeric identification of acceptable equip-ment for measuring critical dimensions.

CD_FEATURE

Text describing the feature to be used for CD measurement.

CD_ISOLATED

(T or F) CD feature has no other geometry nearby.

CD_LOCATION_DRAWING

The uniquely identified (for each customer) document which shows the location of the CD structure.

CD_MATRIX_FILE_NAME

Alphanumeric name of file to be used for critical dimension measurement locations. It is not to be used in conjunction with MASK_CD_LOCATION or PATTERN_CD_LOCATION within the same START_CD to END_CD set.

CD_MATRIX_FILE_FORMAT

(MF2, MF3, KMS and others on request)

CD_MEASURE_DIE

In combination with the associated <placement> definition, specifies the die to be used for CD measurement.

CD_ORIENTATION

(VERTICAL or HORIZONTAL) Direction in which the CD feature is to be scanned for measurement.

CD_RANGE

Maximum acceptable variation of all measured critical dimensions of same nominal size, same tone and same orientation, relative to each other.

CD_REFERENCE_ONLY

(T or F) If T, indicates that the CD location is to be measured and the data transmitted to the customer (if requested by SHIP_CD_DATA_), but that deviations in its measured value due to mask processing would NOT be cause for mask rejection. (This does not exempt mishandling of the data in pattern preparation from being a cause for mask rejection.)

CD_SITE_ID

Unique alphanumeric identifier of each critical dimension location within MASK_SET_ID to identify individual cd locations when using <mask_data>. If the same coordinates apply to locations on different masks within the mask set, they may have the same CD_SITE_ID, but it is not mandatory. If CD_SITE_ID is used with a PATTERN_CD_LOCATION, it will be associated with as many mask locations as the cell has instances. (See MEASURED_ CD_SITE _ID for more information.)

CD_STD

(NBS, NIST, ROGER_SHERMAN, CUSTOMER, and others on request) reference standard to be used to correlate critical dimension measurements.

CD_TARGET

Desired final size of critical dimension feature on mask.

CD_THREE_SIGMA

Maximum acceptable 3-sigma deviation of all measured critical dimensions to the the mean of all measured critical dimensions

CD_TOLERANCE

Maximum acceptable deviation of the mean of all measured critical dimensions to the CD_TARGET

CD_TONE_CLEAR

(T or F) If T, critical dimension feature on mask is clear.

CD_XY_DEVIATION

Maximum deviation, on a site-by-site basis, of a horizontal critical dimension to a vertical critical dimension. The two critical dimensions at each site must be the same size in the pattern data.

CD_XY_TOLERANCE

Maximum acceptable deviation of the mean of all measured horizontal critical dimensions to the mean of all measured vertical mask critical dimensions. Critical dimensions at all sites must be the same size in the pattern data.

CELL_ID

Name of the cell which follows; must be used in all references within this MASK_SET_ID to this cell definition.

CELL_INSTANCE

(text) Identifies CELL_ID to be placed by the following location information.

CELL_REGISTR_MARK

(x,y) Location of initial registration reference mark, relative to center of cell (before mirroring or scaling).

CENTRALITY

Maximum misplacement in millimeters of all patterns as a group, relative to the nominal center of the mask. The nominal center is determined using the bottom and left edges (chrome side up) and assumes nominal substrate dimensions. (See SEMI P1.)

CHECKSUM

For <mask_order>, an ASCII 16 bit crc checksum encompassing all records from START_ORDER through END_ORDER, inclusive. For <mask_data>, an ASCII 16 bit crc checksum encompassing all records from START_MASK_DATA through END_MASK_DATA, inclusive. (See COMPUTING THE CHECKSUM, Section 9.)

CLEAR_INTERNAL_WINDOW

(x,y,x1,y1,x2,y2) Name of file (x) to be formed from file (y) by removing all digitized data within the window described by (x1,y1,x2,y2). The extents of the pattern file (x) will be the same as for file (y).

COMPACT_LABEL

Identification of customer-supplied label to use on shipping compact.

CUSTOMER

The name of the company placing the order.

DARK_INTERNAL_WINDOW

(x,y,x1,y1,x2,y2) Name of file (x) to be formed from file (y) by completely digitizing the entire area within the window described by (x1,y1,x2,y2). The extents of the pattern file (x) will be the same as for file (y).

DATA_COMPRESSION

(ZIP, ZOO, GZIP, Z, NONE, BINHEX) Compression algorithm used for transmitted data.

DATA_CONSOLIDATION

(BACKUP, TAR, GNUTAR, ZIP, NONE Consolidation method used for transmitted data.

DATA_ENCRYPTION

(PGP, NETWIZARD, USER, HARDWARE, NONE) Encryption algorithm used for transmitted data.

DATA_CHECKSUM

(integer) To be used to verify integrity of transmitted data.

DATA_CHECKSUM_TYPE

(text) Algorithm used to generate DATA_CHECKSUM.

DATA_DATATYPE

(integer) Sublevel to a DATA_LAYER_ID for GDS-II data.

DATA_DENSITY

(800BPI, 1600BPI or 6250BPI for 9_TRACK_-TAPE DATA_MEDIUM; HIGH or LOW for 4MM_DAT or 8MM_DAT DATA_MEDIUM) for magnetic tape density.

DATA_FILE_NUMBER

For GDS-II, Mann or Electromask data, this is the file number on the physical medium.

DATA_FILE_SIZE

Size of the file in bytes.

DATA_FORMAT

(MEBES, MEBES_MODE_5, RDOS = RDOS dump, VAX = VAX backup, GDS-II = GDS-II stream, CIF = Cal Tech Intermediate Format, DXF = Autocad output, APPLICON, MANN_3000, MANN_3600, ELECTROMASK, DOS, UNIX, APPLE, TAR, and others on request) Physical medium format.

DATA_ID

The required identifying "name" for a physical volume of data. The name must match the label visible on the outside of the volume and must be unique among all physical volume names sent by a customer to a vendor.

DATA_JOB_NAME

For E-beam data, this is the name of the job file to be expected in DATA MEDIUM.

DATA_LAYER_ID

Layer to use within DATA_TOP_CELL.

DATA_LOCATION

Alphanumeric site where the data file may be found.

DATA_MEDIUM

(9_TRACK_TAPE, 4MM_DAT, 8MM_DAT, 1/4_INCH_CARTRIDGE, MODEM, FLOPPY, EMAIL, VPN, FTP, RCP, CDR, CDRW, HARDDRIVE ZIPDRIVE, JAZZDRIVE, FLOPPY100MB) Data transfer medium used for delivering pattern files, job files and measure files.

DATA_OFFSET

For optical masks only, the (x,y) shift to be applied to the data in building the mask.

DATA_PATTERN_NAME

For numbered files in a data volume, this is the pattern name to be applied to the file specified by the succeeding DATA_FILE_NUMBER and/or DATA_TOP_CELL and/or DATA_LAYER_ID. For E-beam, data, this is the name of the pattern file to be expected on the physical volume.

DATA_PATTERN_WINDOW

(x1,y1,x2,y2) Establishes the extents of the pattern file in the coordinate space as received. (x1,y1) identifies the lower-left corner; (x2,y2) identifies the upper-right corner.

DATA_SCALE_FACTOR

(x,y,z) Name of file (x) to be formed by (de)magnifying both the geometries and the overall pattern file extents of the file (y) by the positive, numeric (de)magnification factor (z).

DATA_TOP_CELL

Top cell or structure of the design.

DATABASE_AREA

(x1,y1,x2,y2) Unscaled, unmirrored coordinates of window for database inspection, lower left and upper right corners, relative to the center and coordinate system of the pattern or cell or, if a <mask_option>, relative to the center of the mask.

DATABASE_FILE_NAME

Name of database file to use for database inspection.

DATABASE_INSPECTION

(T or F) If T, database inspection is required.

DATABASE_JOB_LEVEL

Mask level of customer-supplied job file to use for database inspection.

DATABASE_JOB_NAME

Customer-supplied job file to use for database inspection. Should be omitted if customer does not supply job file.

DATABASE_LAYER

Layer to be used if DATABASE_SOURCE is GDS-II.

DATABASE_SOURCE

(MEBES, PG, GDS-II, KLARIS, UNDERIVED, and others on request) Data source to be used when database inspection is required. KLARIS indicates that KLARIS data was supplied by the customer. UNDERIVED indicates the customer-supplied data prior to vendor-performed data manipulation is to be used to produce the inspection data. GDS-II indicates that the GDS-II data is being supplied for database inspection, in addition to the customer-supplied MEBES or PG data to be used to write the mask.

DATABASE_TOP_CELL

Top cell to be used if DATABASE_SOURCE is GDS-II.

DATABASE_UNIT

Grid size to be used for fracturing DATABASE_-SOURCE into inspection data, as required by some inspection systems.

DATABASE_WITH_JOB

(T OR F) Database inspection must use job file (DATABASE_JOB_NAME and DATABASE_JOB_LEVEL if supplied by customer) to consolidate pattern files.

DEFECT_COUNT

Integer maximum allowable number of defects within the INSPECTION_AREA.

DEFECT_COUNT_REP

Integer maximum number of repeating defects within the INSPECTION_AREA.

DEFECT_DENSITY

Maximum allowable number of defects per square centimeter within the INSPECTION_AREA.

DEFECT_EQUIP_REQD

Alphanumeric identification of acceptable equip-ment for defect inspection.

DEFECT_INSP_MODE

Alphanumeric operating mode for DEFECT_-EQUIPMENT_REQD.

DEFECT_SETUP_FILE_NAME

Alphanumeric name of setup file for DEFECT_-EQUIP_REQD.

DEFECT_SIZE

Maximum dimension of smallest unacceptable defect—all types.

DEFECT_SIZE_CL

Maximum dimension of smallest unacceptable clear defect.

DEFECT_SIZE_CL_ADJ

Maximum dimension of smallest unacceptable clear, non-repeating edge defect.

DEFECT_SIZE_CL_ADJ_REP

Maximum dimension of smallest unacceptable clear, repeating edge defect.

DEFECT_SIZE_CL_ISO

Maximum dimension of smallest unacceptable clear, repeating isolated defect.

DEFECT_SIZE_CL_ISO_REP

Maximum dimension of smallest unacceptable clear, non-repeating isolated defect.

DEFECT_SIZE_DK

Maximum dimension of smallest unacceptable dark defect.

DEFECT_SIZE_DK_ADJ

Maximum dimension of smallest unacceptable dark, non-repeating edge defect.

DEFECT_SIZE_DK_ADJ_REP

Maximum dimension of smallest unacceptable dark, repeating edge defect.

DEFECT_SIZE_DK_ISO

Maximum dimension of smallest unacceptable dark, non-repeating isolated defect.

DEFECT_SIZE_DK_ISO_REP

Maximum dimension of smallest unacceptable dark, repeating isolated defect.

DEFECTIVE_DIE_DENSITY

Maximum allowable number of die with defects per square centimeter within the INSPECTION_AREA.

DEFECTIVE_DIE_COUNT

Integer maximum allowable number of die with defects within the INSPECTION_AREA.

DEFECTIVE_DIE_COUNT_REP

Integer maximum number of repeating defective die within the INSPECTION_AREA.

DELIVERABLE_MASK

(T or F) If F, the mask is to be held internally by the mask shop for the production of other deliverable masks. For a MASK_ID with MULTIWRITE, only the final write and process step MASK_ID within the multiwrite group may have DELIVERABLE_MASK = T.

DESIGN_RULE

Numeric data field indicates the nominal minimum dimension of wafer geometries.

DIE_TO_DIE_INSPECTION

(T or F) If T, die-to-die inspection is required.

DIGITIZED_DATA_DARK

(T or F) If T, the image of digitized data is to be opaque on the mask. If F, the image of digitized data is to be clear.

DROPOUT

(x,y) Row and column of pattern or cell placement which is to be omitted in the array. These array coordinates are rectangular (even if the actual written array is non-rectangular), with the origin at the lower left of the array (before mirroring).

DUE_DATE_TIME_COMMITTED

(date,time) For delivery (at customer) committed by vendor.

DUE_DATE_TIME_REQUESTED

(date,time) Requested for delivery (at customer).

DXF_ANGLE

(integer) To be used if DATA_FORMAT is DXF.

DXF_UNIT

(integer) To be used if DATA_FORMAT is DXF.

EDGE_RAGGEDNESS

The subjective impression of irregular deviations of a visual edge from an intended smooth curve or straight line. (See F127).

EDGE_ROUGHNESS

The (numeric) maximum value of edge roughness, based on physical measurements.

ELAPSED_TIME

Numeric hours between masking steps in the wafer fab. Used in conjunction with LAYER_PRIORITY, provides scheduled due dates based on the delivery of each previous mask. No mask may have both ELAPSED_TIME and DUE_DATE_REQUESTED. See LAYER_PRIORITY.

ELAPSED_TIME_COMMITTED

Numeric hours for delivery (at customer) committed by vendor.

EMAIL_ADDRESS

Internet address.

END_BARCODE

(text) must match data field of START_BARCODE.

END_CD

Alphanumeric data field must match data field of START_CD.

END_CD_MEASUREMENTS

(text) must match data field of START_ CD_MEASUREMENTS.

END_CELL

Must match data field of CELL_ID for which data is complete.

END_ CELL_INSTANCE

(text) must match data field of CELL_INSTANCE.

END_CELL_INSTANCE_OPTIONS

Must match data field of CELL_INSTANCE for which pattern options are complete.

END_CELL_OPTIONS

Must match data field of CELL_ID for which options are complete.

END_ DATA_MANIPULATION

(text) must match data field of START_DATA_MANIPULATION.

END_DATA_MEDIUM

Must match data field of DATA_MEDIUM for which data is complete.

END_ DATA_PATTERN_ NAME

Must match data field of DATA_PATTERN_NAME.

END_DEFECT_DEFINITION

(text) must match data field of START_DEFECT_DEFINITION

END_DEFECT_MEASUREMENTS

(text) must match data field of START_DEFECT_MEASUREMENTS.

END_FTP_HOST

Must match data field of FTP_HOST_NAME.

END_MASK

Must match data field of MASK_ID for which data is complete.

END_MASK_DATA

Must match data field of START_MASK_DATA.

END_MASK_GROUP

Must match data field of MASK_GROUP_ID for which data is complete.

END_MASK_GROUP_OPTIONS

Must match data field of MASK_GROUP_ID for which options are complete.

END_MASK_SET

Must match data field of MASK_SET_ID for which data is complete.

END_MASK_SET_OPTIONS

Must match data field of MASK_SET_ID for which options are complete.

END_MEASURED_CD_SITE

Must match data field of MEASURED_CD_SITE_ID.

END_MEASURED_REGISTR_MARK

Must match data field of MEASURED_REGISTR_MARK_ID.

END_OPC

Must match data field of START_OPC.

END_ORDER

Must match data field of START_ORDER for which data is complete.

END_PATTERN_DEFINITION

Must match data field of LEVEL_ID for which data is complete.

END_PATTERN_GROUP

Must match data field of PATTERN_GROUP_ID for which data is complete.

END_ PATTERN_GROUP_INSTANCE

Must match data field of PATTERN_GROUP_INSTANCE.

END_PATTERN_GROUP_OPTIONS

Must match data field of PATTERN_GROUP_ID for which options are complete.

END_PATTERN_OPTIONS

Must match data field of START_PATTERN_OPTIONS

END_PHASESHIFT

Must match data field of START_PHASESHIFT.

END_PLACEMENT

Must match data field of START_ PLACEMENT.

END_REGISTR

Must match data field of START_ REGISTR.

END_ REGISTR _MEASUREMENTS

Must match data field of START_REGISTR_MEASUREMENTS.

END_SHIP_ARRAY_PLOT

Must match data field of SHIP_ARRAY_PLOT.

END_SHIP_FILM

Must match data field of SHIP_ FILM.

END_SHIP_TO

Must match data field of START_SHIP_TO.

END_ SHIPPABLE_DATA

Must match data field of START_SHIPPABLE_DATA.

END_TITLE

(title number) Indicates end of keywords for a specific title. Must match data field of START_TITLE for which data is complete.

END_VENDOR_INFO

Must match data field of START_VENDOR_INFO.

ENGINEERING_ADDRESS

Address for delivery of shippable engineering data.

ENGINEERING_CONTACT

Name of person to contact for technical questions.

ENGINEERING_EMAIL

Internet address for ENGINEERING_CONTACT.

ENGINEERING_FAX

Phone number for facsimile machine of ENGINEERING_CONTACT.

ENGINEERING_PHONE

Phone number for ENGINEERING_CONTACT.

ESTIMATED_ARRIVAL

The date and time when the vendor predicts MASK_ID will be delivered to the customer, based on the MILESTONE most recently completed.

ESTIMATED_ARRIVALS

(T or F) If T, the vendor is requested to use <mask_data> to supply a prediction of the delivery date and time when MASK_ID will be delivered to the customer, based on the MILESTONE most recently completed. ESTIMATED_ARRIVAL will be transmitted each time <mask_data> is required by either MILESTONES or PERIODIC_UPDATES. If neither have been requested, then ESTIMATED_ARRIVAL should be transmitted daily.

ETCH_DEPTH_ERROR

Maximum allowable deviation (in angstroms) of any etch depth measurement from ETCH_DEPTH_TARGET.

ETCH_DEPTH_RANGE

Maximum acceptable variation (in angstroms) of all etch depth measurements, relative to each other.

ETCH_DEPTH_TARGET

Desired mean etch depth in angstroms.

ETCH_DEPTH_TOLERANCE

Maximum acceptable deviation (in angstroms) of the mean of all measured critical dimensions to the ETCH_DEPTH_TARGET.

EXTERNAL_WINDOW

(x,y,x1,y1,x2,y2) Name of file (x) to be formed from file (y) by removing all digitized data outside the window described by (x1,y1,x2,y2). The extents of the pattern file (x) are thus defined by the window.

FIGURE_COUNT

Total number of geometries which are expected in the pattern file. If this is incorrect, the mask will not be written until it is corrected.

FILE_DATE_TIME

(x,y) Date and time of transmission of mask order. Format will be as in Section 6.19.

FILM_COLOR

Color to be used for the mask film.

FILM_NORMAL_TONE

(T or F) If T, digitized data will be dark.

FILM_SCALE

Numeric scale of the film of the mask image.

FILM_SIZE

(x,y) Size in inches of the film.

FLATNESS

(2, 5, 10, or 20) Flatness within quality area (see SEMI P1).

FRACTURING_SCALE

For optical data (Mann or Electromask) only, this is the scale factor to use in fracturing the data to E-beam format.

FTP_HOST_NAME

Domain of the FTP host, either in the form n.n.n.n where n is an integer from 0 to 255, or in an equivalent text name if such is supported by the FTP site.

[FTP_LOGIN]

The login name for an FTP account. If an anonymous FTP is used, the data field will be "anonymous".

[FTP_PASSWORD]

Password for FTP account.

[FTP_DIRECTORY]

Name of target directory for FTP data.

[FTP_MODE]

(ASCII, BINARY or AUTO) Data type for FTP data. If absent, default is BINARY.

GLASS_SIZE

(2.5/60, 3/60, 3.5/60, 4/60, 4/90, 4/250, 5/60, 5/90, 5/250, 6/90, 6/120, 6/150, 6/250, 7/120, 7/150, 7/250, 7.25R/150 or 9/350) Nominal edge length (in inches) and thickness (in mils) of square substrate; 7.25R/150 is a round substrate. (See SEMI P1.)

GLASS_TYPE

(HTE, LTE, ULTE, WC, or SL) High-, low-, and ultralow thermal expansion glass (see SEMI P1.) WC and SL indicate White Crown and soda lime glass.

GOOD_FIELDS

Specifies the 1X reticle fields which must pass inspection criteria and is applied to the cells immediately instanced by the preceding CELL_ID. Fields are referenced by numbers assigned from left to right according to their position on the mask, chrome side up. For example, for a mask with 5 fields, the fields would be:

1 2 3 4 5

The required good fields are specified by any logical combination of field numbers, "AND", "OR", and parentheses. In the above example, "(1 OR 2) AND (3 OR 4) AND 5" would require that either 1 or 2 be good, and either 3 or 4 be good, and that 5 be good. No logical precedence is assumed; precedence is defined only by parentheses. This keyword applies only to 1X reticles.

GUIDES_REQD

(STANDARD, WIDE or BOTH) Applies to 1X reticles only.

INSPECT_ALL_SITES

If T, all placements of patterns under this <cell_instance> or <pattern_instance> require inspection, regardless of the number of inspection tool setups necessary to do so.

INSPECT_THROUGH_PELLICLE

(T or F) If T, the mask must be inspected through the pellicle and the <defect_definition> and <database_inspection> keywords to be used must follow the INSPECT_THROUGH_PELLICLE keyword. Unpellicized inspection may be separately defined and would precede the INSPECT_THROUGH_PELLICLE keyword.

INSPECTION_AREA

(x1,y1,x2,y2) Unscaled coordinates of window for defect inspection, lower left and upper right corners, relative to center of mask, pattern or cell (chrome side up for masks, unmirrored for patterns or cells).

INPECTION_AREA_EXCLUDE

(x1, y1, x2, y2) Unscaled coordinates of window to be excluded from defect inspection. (See INSPECTION_AREA.)

INSPECTION_SETUP_FILENAME

Alphanumeric name of setup file for defect inspection equipment.

INSP_DATABASE_DATA_FORMAT

Alphanumeric description of format for SHIP_-INSP_DATABASE_DATA.

INSPECTION_REF_LOCATION

(x,y) Location of reference mark for defect inspection, relative to the center of the the substrate (chrome side up).

JOB_FORMAT

(MEBES, EEBES, ATEQ, and others on request) Format of preceding job file.

JOB_LEVEL

Level of above JOB_NAME to be used to make mask.

JOB_NAME

Name of job file to be used to make mask(s).

LAYER_PRIORITY

Sequence number in which masks are needed. Together with ELAPSED_TIME determines the mask delivery schedule. The first mask (LAYER_PRIORITY=1) is due within its ELAPSED_TIME from the time it is ordered or released; the second mask is due within its ELAPSED_TIME from when the first mask was due, or from when the first mask was delivered, whichever is later; and so on.

LEVEL_ID

Numerical indicator of which masks within the mask set will include this pattern. When a MASK_ID in a MASK_GROUP, which references this PATTERN _GROUP_ID, matches this LEVEL_ID, this pattern will appear on the mask. When LEVEL_ID is “A”, the pattern will appear on all masks which reference the pattern group. A given LEVEL_ID value may appear only once in any pattern group. Appearance of “A” as a LEVEL_ID value precludes any other patterns from the pattern group.

LINE_ITEM_NUMBER

Integer line item number relative to PO_NUMBER.

LOCATION

(x,y) Location of the center of the initial pattern or cell, relative to center of the preceding CELL_ID (before mirroring).

LOCATION_SPEC

Alphanumeric identification of customer-supplied specification for pattern or cell placement.

MASK_CD_LOCATION

(x,y) Location of critical dimension feature relative to the center of the mask (chrome side up).

MASK_COATING

(HIGH_REFLECTIVE_CHROME, MEDIUM_RE-FLECTIVE_CHROME, LOW_REFLEC-TIVE_CHROME, SEE_THROUGH_CHROME, IRON_OXIDE, CHROME_OXIDE, EMULSION, MOSI, TISIN, ZRSI) or in the case of other coatings, an alphanumeric description. (See SEMI P2.)

MASK_GROUP_ID

Name of the mask group which follows; must be used in all references within this MASK_SET_ID to this mask group.

MASK_ID

Unique integer identifier of each mask within mask set. All patterns referenced by the MASK_-GROUP_ID's PLACEMENT_TOP_CELL whose LEVEL_IS's match this MASK_ID will appear on the mask. When LEVEL_IS is “A”, the pattern will appear on all masks whose PLACEMENT_-TOP_CELL references the pattern group.

MASK_NAME

Name used by customer for mask, to be used to cross-reference MASK_ID to customer's internal tracking system. This is for the customer's use only and will be completely ignored in the automatic processing of the mask order.

MASK_REGISTR_MARK

(x,y) Location of initial registration reference mark, relative to center of substrate (chrome side up).

MASK_REGISTR_MARK_LOCATION

(x,y) Location of individual registration mark, relative to center of substrate (chrome side up), based on <mask_order> information.

MEASURED_REGISTR_MARK_LOCATION

(x,y) Location of individual registration mark, relative to center of substrate (chrome side up), as measured by the vendor.

MASK_SET_ID

The “name” of the mask set, often the device name or number. This must be used in all future references to this mask set and must be unique among mask sets ordered by the customer.

MASK_SET_NAME

Name used by customer for mask set, to be used to cross-reference MASK_SET_ID to customer's internal tracking system. This is for the customer's use only and will be completely ignored in the automatic processing of the mask order.

MASK_SET_VERSION

Name used by customer for versions of the mask set, to be used to cross-reference MASK_SET_ID to customer's internal tracking system. This is for the customer's use only and will be completely ignored in the automatic processing of the mask order.

MAX_MASKS_IN_PACKAGE

Integer maximum number of masks to be shipped inside PACKAGE.

MEASURE_FILE_NAME

Alphanumeric name of file to be used for registration mark locations. When MEASURE_FILE_NAME follows MASK_REGISTR_MARK or CELL_REGISTR_MARK, the mark locates the origin of the measure file.

MEASURE_FILE_FORMAT

(MF2, MF3, MTX, IMP, and others on request.)

MEASURED_CD

The critical dimension measurement at the MASK_CD_LOCATION, as measured by the vendor.

MEASURED_CD_TOLERANCE

CD_TOLERANCE of the mask as measured by the vendor.

MEASURED_CD_XY_TOLERANCE

CD_XY_TOLERANCE of the mask as measured by the vendor.

MEASURED_CD_XY_DEVIATION

CD_XY_DEVIATION of the mask as measured by the vendor.

MEASURED_CD_RANGE

CD_RANGE of the mask as measured by the vendor.

MEASURED_CD_THREE_SIGMA

CD_THREE_SIGMA of the mask as measured by the vendor.

MEASURED_CD_DEVIATION_FROM_TARGET

CD_DEVIATION_FROM_TARGET of the mask as measured by the vendor.

MEASURED_CD_DEVIATION_FROM_MEAN

CD_DEVIATION_FROM_MEAN of the mask as measured by the vendor.

MEASURED_ CD_SITE_ID

Must match CD_SITE_ID in <mask_order> for site being measured. If the customer assigned no CD_SITE_ID for the required location (e.g., only CD_LOCATION_DRAWING was used), the vendor will assign a MEASURED_ CD_SITE_ID for each measurement location so that it is unique within the MASK_SET_ID. If REGISTR_MARK_ID was used as a <pattern_options> in <mask_order> for a pattern with multiple instances, then the vendor will add a suffix to CD_SITE_ID for each instance so that each MEASURED_ CD_SITE_ID in <mask_data> will be unique.

MEASURED_CENTRALITY

CENTRALITY as measured by the vendor.

MEASURED_DEFECT_DENSITY

DEFECT_DENSITY as measured by the vendor.

MEASURED_DEFECT_COUNT

DEFECT_COUNT as measured by the vendor.

MEASURED_DEFECT_COUNT_REP

DEFECT_COUNT_REP as measured by the vendor.

MEASURED_DEFECTIVE_DIE_DENSITY

DEFECTIVE_DIE_DENSITY as measured by the vendor.

MEASURED_DEFECTIVE_DIE_COUNT

DEFECTIVE_DIE_COUNT as measured by the vendor.

MEASURED_DEFECTIVE_DIE_COUNT_REP

DEFECTIVE_DIE_COUNT_REP as measured by the vendor.

MEASURED_PERCENT_DEFECTIVE_DIE

PERCENT_DEFECTIVE_DIE as measured by the vendor.

MEASURED_PERCENT_CLEAR

PERCENT_CLEAR as computed by the vendor.

MEASURED_REGISTR_ERROR

REGISTR_ERROR as measured by the vendor.

MEASURED_REGISTR_SCALE

REGISTR_SCALE as measured by the vendor.

MEASURED_REGISTR_RESIDUAL

REGISTR_RESIDUAL as measured by the vendor.

MEASURED_REGISTR_RESIDUAL_THREE_SIGMA

REGISTR_RESIDUAL_THREE_SIGMA as measured by the vendor.

MEASURED_REGISTR_ORTHO

REGISTR_ORTHO as measured by the vendor.

MEASURED_REGISTR_RELATIVE

REGISTR_RELATIVE as measured by the vendor.

MEASURED_MULTIWRITE_OVERLAY_ERROR

MULTIWRITE_OVERLAY_ERROR as measured by the vendor.

MEASURED_ REGISTR _MARK_ID

Must match REGISTR_MARK_ID in <mask_order> for site being measured. If the customer assigned no REGISTR_MARK_ID for the required location (e.g., only MEASURE_FILE_NAME was used), the vendor will assign a MEASURED_REGISTR_MARK_ID for each measurement location so that it is unique within the MASK_SET_ID. If REGISTR_MARK_ID was used as a <pattern_options> in <mask_order> for a pattern with multiple instances, then the vendor will add a suffix to REGISTR_MARK _ID for each instance so that each MEASURED_ REGISTR_MARK_ID in <mask_data> will be unique.

MFG_EQUIP

(EBEAM, OPTICAL, LASER) Acceptable equipment for writing product mask(s).

MFG_MODEL

Model of acceptable mask writing equipment, including (MEBES III, MEBES IV, MEBES_4000, MEBES_4500, MEBES_5000, ZBA_31, ZBA_320, ZBA_340, CORE_2000, CORE_2100, CORE_2500, CORE_2564, ALTA_3000, ALTA_3500, ALTA_3700, TRE_220, ULTRABEAM_V2000, MANN_3000, MANN_3600, HL_800, HL_900, JBX_7000, JBX_9000 and others on request).

MFG_SITE

Alphanumeric identification of qualified manufacturing sites.

MILESTONE

(ORDER_RECEIVED, ORDER_ACCEPTED, DATA_PREPARED, MASK_WRITTEN, CDS_MEASURED, REGISTR_MEASURED, DEFECTS_REPAIRED, PELLICLES_APPLIED, POST_PELLICLE_INSPECTION, SHIPPED, DELIVERED, ON_HOLD, OFF_HOLD) notifies the customer that the MASK_ID has passed the indicated processing step, or is on hold.

MILESTONES

(T or F) If T, the vendor is requested to use <mask_order> (see Section 7.5) to notify the customer each time the mask completes a significant processing step. Within this standard, these significant steps are limited to those defined under MILESTONE. MILESTONES may not be used in combination with PERIODIC_UPDATES for the same MASK_ID.

MIN_MASK_FEATURE_SIZE

Smallest (scaled) feature included in any customer-supplied pattern data on the mask.

MINIMUM_FEATURE_LOCATION

Location of a minimally sized feature within the pattern file, relative to the center of the pattern, unscaled and unmirrored.

MINIMUM_FEATURE_SIZE

Smallest (unscaled) feature included in pattern data, excluding OPC data which is identified under OPC_MINIMUM_FEATURE_SIZE.

MINUS

(x,y,z) Name of file (x) to be formed by logically removing from file (y) the portions of all digitized geometry which overlap with digitized geometry in file (z). The extents of file (x) are the same as the extents of file (y).

MIRROR

(x,y) Name of file (x) to be formed by mirroring the file (y) about its vertical centerline.

MIRROR_MASK

(T or F) All patterns and titles must be mirrored about the vertical axis, to be applied in addition to all other positioning information.

MIRROR_PATTERN

(T or F) If T, the pattern file (or cell) is to be mirrored about its vertical axis. If used in conjunction with MIRROR_MASK, the result will be unmirrored pattern data while all other data will be mirrored.

MIRROR_TITLE

(T or F) If T, TITLE_TEXT is to be mirrored about the vertical axis. If used in conjunction with

MIRROR_MASK, result will be an unmirrored title with all other data mirrored (chrome side up).

MULTIWRITE

(x,y) If present as a mask option, then the MASK_ID represents only one writing operation for a mask which requires multiple write and process cycles (defined within the <mask_group>) before the final mask is completed. All MASK_IDs used to make the final mask must have MULTIWRITE as a <mask_option> and must designate the same integer group number (x). Such a final mask will be built with a specified integer sequence (y) of MASK_IDs. Sequence numbers may never be less than 1 nor more than the number of write and process cycles specified in the order, except that zero may be used where the sequence is arbitrary. A sequence number within a group may not be repeated (except zero).

MULTIWRITE_OVERLAY_ERROR

Maximum allowable overlay error relative to the MULTIWRITE_REF_MASK_ID.

MULTIWRITE_REF_MASK_ID

Within the MULTIWRITE numerical group, this is the MASK_ID to which overlay error should be measured.

NOT

(x,y) Name of file (x) to be formed by the logical inversion of file (y). The resulting file is unbounded (i.e., has no extent limits).

NUMBER_OF_CDS

The integer number of CD locations to be measured. If sufficient specific sites are not explicitly identified by the customer, the vendor is free to select additional similar sites.

OPC_MINIMUM_FEATURE_SIZE

For the OPC_TYPE being described, the size of the smallest OPC feature in the pattern data.

OPC_MINIMUM_GAP

For the OPC_TYPE being described, the size of the smallest gap in the pattern data between OPC features of the same type.

OPC_PATTERN_MODIFIABLE

(T or F) If F, the pattern may not be modified (biased) by the mask shop for printability or CD linearity improvement. In this case, the need for such biasing must have been anticipated by the customer.

OPC_PATTERN_SEPARATE

(T or F) If T, then the pattern being described is only the OPC portion of what will be written on the mask. Depending upon the write tool methodology, the pattern may need to be merged off-line with other patterns. This may allow mask shop biasing for printability or CD linearity unless precluded by OPC_PATTERN_MODIFIABLE = F.

OPC_TYPE

(CLEAR_SERIF, CLEAR_HAMMERHEAD, CLEAR_ASSIST_BAR, OPAQUE_SERIF, OPAQUE_HAMMERHEAD, OPAQUE_ASSIST_BAR) (Linewidth biasing is not included as an OPC type.)

OPERATOR_NAME

Alphabetic name of the person entering the mask order.

OPTICAL_MASK_SET_ID

For optical stepping or contact printing, the “pattern” is to be obtained by using a reticle or mask from this MASK_SET_ID.

OPTICAL_MASK_ID

For optical stepping or contact printing, the “pattern” is to be obtained by using a reticle or mask built under this MASK_ID from the above-named MASK_SET_ID.

OPTICAL_MASK_TITLE

For optical stepping or contact printing, identifying title on reticle or mask. To be used in place of OPTICAL_MASK_SET_ID and OPTICAL_-MASK_ID when the reticle or mask was built without available <mask_order> data.

OR

(x,y,z) Name of file (x) to be formed by the logical union of file (y) and file (z). The extents of the pattern file (x) are described by the smallest rectangle which encloses both file (y) and file (z).

ORDER_ACCEPTED

Returns the exact FILE_DATE_TIME as in the file being accepted, thereby agreeing to process the order as received.

ORDER_RECEIVED

Returns the exact FILE_DATE_TIME as in the file being acknowledged, thereby confirming receipt of that file. This response is required each time a new transmission is received by the vendor.

ORDER_ID

Printable text of the customer's internal order identification to provide correlation with pre-existing order tracking systems. This is for customer cross-referencing only and will be ignored in automatic processing.

PACKAGE

Alphanumeric identification of brand and model of acceptable compact to be used for delivering masks.

PATTERN_ADDRESS_SIZE

Address unit of the (unscaled) pattern file. If this is incorrect, the mask will not be written until it is corrected. For data manipulation operations, this is the address to use in final fracturing to produce a pattern file for exposure.

PATTERN_CD_LOCATION

(x,y) Location of critical dimension feature within a pattern file or cell, relative to the center of the pattern, before mirroring or scaling.

PATTERN_CHARACTER_SET

(ASCII or EBCDID) ASCII is assumed unless otherwise specified.

PATTERN_FORMAT

(MEBES_I, MEBES_II, MEBES_EXTENDED, MEBES_RETICLE, MEBES_V, EEBES, HITACHI_700, HITACHI_800, JEOL_51, JEOL_52, ULTRABEAM, ZBA, ALF, MANN_3000, MANN_3600, ELECTROMASK, GDS-II, CIF, APPLICON, CATS_CFLT, CATS_CREF, AUTOCAD, KLARIS, FALCON, ORBOT and others on request) Format of preceding pattern file. For <data_manipulation> operations, this is the format to use for the output file resulting from the operation.

PATTERN_GROUP_ID

Name of the pattern group which follows; must be used in all references within this MASK_SET_ID to this pattern group.

PATTERN_GROUP_INSTANCE

Identifies PATTERN_GROUP_ID to be placed by the following location information.

PATTERN_NAME

Printable ASCII pattern file name. The file may be received intact, or may be derived through data manipulation.

PATTERN_PLOT_APPR_REQD

(T or F) If T, customer approval of the pattern plot is required before mask making is authorized.

PATTERN_PLOT_NORMAL_TONE

(T or F) If T, digitized data will be dark.

PATTERN_PLOT_SCALE

Numeric scale of the pattern plot.

PATTERN_UNITS

(METRIC, ENGLISH) Units of preceding pattern file.

PATTERN_VISUAL_ID

Optional, printable text to specify identification within the pattern file which must be visually confirmed as present before the mask may be written. If the feature is not present, the mask order should go on hold.

[PERCENT_CLEAR]

Percentage of the patterned area which will become transparent after the mask is processed. As a mask option it includes all the area within the scribe pattern limits. As a pattern option it includes the area within the individual pattern limits.

[PERCENT_CLEAR_REQUESTED]

(T or F) If T, the vendor is requested to calculate, using available CAD tools, the percentage of the patterned area on the mask which will become transparent after the mask is processed, and transmit this value to the customer.

PERCENT_DEFECTIVE_DIE

Maximum percentage of defective die among those required by the customer to meet defect criteria.

PERIODIC_UPDATE

notifies the customer that MASK_ID has passed the indicated processing step, or is on hold.

PERIODIC_UPDATES

(integer) If non-zero, the vendor is requested to use <mask_order> (see Section 7.5) to notify the customer on a periodic basis which significant processing step was last completed for MASK_ID. The value of the data field indicates the number of hours between updates. Within this standard, these significant steps are limited to those defined under MILESTONE. PERIODIC_UPDATES may not be used in combination with MILESTONES for the same MASK_ID.

PHASE_ANGLE_ERROR

Maximum acceptable deviation (in degrees) of any phase shift measurement from the PHASE_ANGLE_TARGET.

PHASE_ANGLE_RANGE

Maximum acceptable variation (in degrees) of phase shift measurements, relative to each other.

PHASE_ANGLE_TARGET

The required phase shift in degrees at the specified WAVELENGTH.

PHASE_ANGLE_TOLERANCE

The maximum acceptable deviation of the mean of all phase shift measurements (in degrees) to the PHASE_ANGLE_TARGET.

PLACEMENT_TOP_CELL

Name of CELL_ID which defines all pattern placements for this MASK_GROUP_ID. This referenced cell is centered on the mask.

PO_NUMBER

Alphanumeric purchase order number.

PRICE

Price (excluding freight and taxes) for preceding item (e.g., mask, pellicle, plot, database inspection).

PRICE_UNITS

(DOLLAR, POUND, SFRANC, FFRANC, GUILDER, LIRE, YEN) Monetary unit used in all references to PRICE with the <mask_set>.

PROCESS

Alphanumeric name of the special process to be used in making the masks.

PRODUCT_AS_CHECKPLATE

(T or F) If T, product mask is to be used for check-plate approval prior to making other product masks.

PRODUCT_IMAGING_TYPE

(BINARY, AAPSM, EAPSM, COMPLIMENTARY or BINARY_TRIM)

PRODUCT_MAGNIFICATION

(10X, 5X, 4X, 2.5X, 2X, 1X) Factor by which the exposure tool will reduce the image on the photomask (reticle) to form the image on the wafer.

PRODUCT_TYPE

(1X_FULL_FIELD, 1X_STD_FIELD_RETICLE, 1X_WIDE_FIELD_RETICLE, RETICLE, CONTACT, SUBMASTER, CHECKPLATE, PROBE_PLATE, REPELLICLIZE and REINSPECT)

QUALITY_GROUP_ID

Alphanumeric customer's label for a collection of mask quality specifications, to be used only in addition to explicit quality requirement keywords. This may not be used in the data structure in place of quality requirement keywords.

QUANTITY

Integer number of array plots, pattern plots and films. May also apply to masks only when PRODUCT_TYPE is contact masks.

QUOTE_NUMBER

Vendor's quotation number to be referenced in billing documents.

REGISTR_ALGORITHM

(ONE-POINT, TWO-POINT or MULTI-POINT, x1,y1,x2,y2) Specifies the method for analyzing registration reference marks. For ONE-POINT analysis, (x1,y1) is the fixed point and (x2,y2) is used for angular orientation only. For TWO-POINT analysis, (x1,y1) and (x2,y2) are both used for angular orientation and the fixed reference point is midway between the two. If MULTI-POINT, (x1, y1, x2, y2) is omitted. MULTI-POINT is the fit of all measured points resulting in zero mean error in x and zero mean error in y.

REGISTR_CLOSURE

Maximum positional error between patterns written at the beginning of writing the mask and the end of writing the mask.

REGISTR_CLOSURE_BEGIN

Identifies the CELL_ID or PATTERN_GROUP_ID to be used at the beginning of writing the mask for REGISTR_CLOSURE measurement.

REGISTR_CLOSURE_END

Identifies the CELL_ID or PATTERN_GROUP_ID to be used at the end of writing the mask for REGISTR_CLOSURE measurement.

REGISTR_EQUIP_REQD

Alphanumeric identification of acceptable equip-ment for measuring REGISTR_ERROR and REGISTR_ORTHO.

REGISTR_ERROR

Maximum allowable registration error, relative to the REGISTR_REF_MASK_ID or the reference grid of REGISTR_EQUIP_REQD.

REGISTR_MARK_COUNT

(x,y) For a rectangular array of registration marks, the number of rows (x) and columns (y).

REGISTR_MARK_ID

Unique alphanumeric identifier of each registration mark location within MASK_SET_ID to identify individual registration measurements when using <mask_data>. If the same coordinates apply to locations on different masks within the mask set, they may have the same REGISTR_MARK_ID, but it is not mandatory. If REGISTR_MARK_ID is used with a CELL_REGISTRATION_MARK, it will be associated with as many mask locations as the cell has instances. (See MEASURED_REGISTR_MARK_ID for more information.)

REGISTR_MARK_SEPARATION

(x, y) For an array of registration marks, the spacing between successive marks in the horizontal (x) and vertical (y) directions.

REGISTR_ORTHO

Maximum allowable non-orthogonality, in micro-radians, relative to the REGISTR_REF_MASK_ID or the reference grid of REGISTR_EQUIP_REQD.

REGISTR_REF_MASK_ID

MASK_ID of the reference mask for determining REGISTR_ERROR and REGISTR_ORTHO. If multiple masks are identified, the reference grid should be based on the mean of the measurements of the group of masks.

REGISTR_REF_MASK_NAME

To be used in place of REGISTR_REF_MASK_ID only to refer to those mask sets which were built outside the SEMI order standard and have no MASK_ID.

REGISTR_REF_MASK_SET_ID

MASK_SET_ID for the mask set containing REGISTR_REF_MASK_ID for determining REGISTR_ERROR and REGISTR_ORTHO.

REGISTR_REF_MASK_SET_NAME

To be used in place of REGISTR_-REF_MASK_SET_ID only to refer to those mask sets which were built outside the SEMI order standard and have no MASK_SET_ID.

REGISTR_REF_MASK_SET_VERSION

To be used in addition to REGISTR_-REF_MASK_SET_NAME only to refer to those mask sets which were built outside the SEMI order standard and have no MASK_SET_ID.

REGISTR_REF_METHOD

Alphanumeric description of the method and/or reference marks to use for measuring REGISTR_-ERROR and REGISTR_ORTHO (e.g., using a previously established reference, or the REGISTR_-EQUIP_REQD grid).

REGISTR_RELATIVE

If present, indicates that the START_REGISTR collection in which REGISTR_RELATIVE is contained is to be measured relative to another START_REGISTR collection, rather than to the grid of the registration measurement tool. The alphanumeric data field of REGISTR_RELATIVE must match the data field of START_REGISTR of the collection to which it is to be compared.

REGISTR_RESIDUAL (x,y)

The maximum acceptable deviation in each axis (in microns) of all registration measurements relative to the REGISTR_STD_GRID, with REGISTR_SCALE and REGISTR_ORTHO removed.

REGISTR_RESIDUAL_THREE_SIGMA (x,y)

The maximum acceptable 3 sigma deviation in each axis (in microns) of all registration measurements, with REGISTR_SCALE and REGISTR_ORTHO removed.

REGISTR_SCALE (x,y)

Maximum acceptable scale error in each axis in parts per million, relative to the REGISTR_STD_GRID.

REGISTR_STD_GRID

(NIST, PTB and others on request) reference standard to be used to correlate registration measurement. This keyword is not allowed in conjunction with REGISTR_REF_METHOD on the same mask.

RELEASE_NUMBER

Alphanumeric release number under BLANKET PO NUMBER.

REPAIRS_AUTHORIZED

(T or F) If F, customer approval is required before mask repairs can be made.

RESIST_TYPE

(POSITIVE or NEGATIVE) This data item is needed for <mask_order> only if overlapping patterns are required. (Overlapping patterns sometimes require the use of “blanking rectangles” to prevent exposure of areas which are to be exposed by another pattern.)

RETROFIT_JOB_LEVEL

Level in RETROFIT_JOB_NAME to which new mask(s) must retrofit.

RETROFIT_JOB_NAME

Name of job file to which mask(s) must retrofit.

RETROFIT_MASK_ID

MASK_ID in RETROFIT_MASK_SET_ID to which new mask(s) must retrofit.

RETROFIT_MASK_NAME

To be used in place of RETROFIT_MASK_ID only for retrofit to those mask sets which were built outside the SEMI order standard and have no MASK_SET_ID.

RETROFIT_MASK_SET_ID

MASK_SET_ID of mask set to which new mask(s) must retrofit.

RETROFIT_MASK_SET_NAME

To be used in place of RETROFIT_MASK_SET_ID only for retrofit to those mask sets which were built outside the SEMI order standard and have no MASK_SET_ID.

RETROFIT_MASK_SET_VERSION

To be used in addition to RETROFIT_-MASK_SET_NAME only for retrofit to those mask sets which were built outside the order standard and have no MASK_SET_ID.

REVIEW_REQD

If present, indicates that a review will be required but that it need not be completed prior to building and/or shipping the masks. The alphanumeric data field describes the items to be reviewed.

ROTATE_TITLE

(0, 90, 180 or 270) Title is to be rotated clockwise the indicated number of degrees, prior to any mirroring.

ROTATE_TITLE_CHARACTERS

(0, 90, 180 or 270) Characters within the title are to be rotated clockwise the indicated number of degrees, prior to any mirroring.

ROTATION

(x,y,z) Name of file (x) to be formed by rotating the file (y) counter-clockwise about its center by (z) in degrees. Allowable values for (z) are 0, 90, 180 or 270.

SCALE_FACTOR

(De)magnification factor to be multiplied with the PATTERN_ADDRESS_SIZE to get the effective address to be used to write the pattern file. Data value must be positive. 1.0 is assumed unless specified otherwise. SCALE_FACTOR alters both the size of individual geometries and the size of the pattern file.

SCRATCH_SIZE_BACK

Maximum dimension of smallest unacceptable scratch on glass side of mask.

SCRATCH_SIZE_FRONT

Maximum dimension of smallest unacceptable scratch on patterned side of mask.

SCRIBE_INSIDE_CORNERS

(X1,Y1,X2,Y2) The inner limits of the SCRIBE_-TONE frame to be built for the dropout by the vendor. It consists of two pairs of coordinates: the lower-left and upper-right.

SCRIBE_OUTSIDE_CORNERS

(X1,Y1,X2,Y2) The outer limits of the SCRIBE_-TONE frame to be built for the dropout by the vendor. It consists of two pairs of coordinates: the lower-left and upper-right.

SCRIBE_TONE

(CLEAR or DARK) Border surrounding DROP-OUT on mask is to be either clear or dark.

SECURITY_CLASS

(QML, SECRET, TOP_SECRET, CCI, or COMSEC) Security classification of mask set or individual mask.

SEMI_REVISION

Revision identification of the SEMI standard according to which the <mask_order> data structure was constructed. This revision is P10-0301.

SERIAL_NUMBER

(T or F) If T, a mask serial number must be included on the mask.

SHIP_ARRAY_PLOT

If present, array map must be sent to customer. Indicates beginning of <array_plot> collection. Alphanumeric data field identifies the collection to establish which collections are hierarchically affected by another. The appearance of a <array_plot> at a lower level in the hierarchy supercedes the <array_plot> at a higher level in the hierarchy if it has the same SHIP_ARRAY_PLOT data field.

SHIP_ARRAY_REGISTR_MAP

(T or F) If T, requires delivery of the registration map of the entire array to the customer.

SHIP_BARCODE_PLOT

(T or F) If T, the plot of the barcode must be sent to the customer.

SHIP_CD_DATA

(T or F) If T, requires delivery of all critical dimension measurements, criteria and evaluation data to the customer for all cd criteria specified.

SHIP_CD_PRINTOUT

(T or F) If T, requires delivery to the customer of the printout from the cd measurement tool.

SHIP_CD_UNIFORMITY_MAP

(T or F) If T, requires delivery to the customer of the uniformity map from the cd uniformity measurement tool.

SHIP_CENTRALITY_DATA

(T or F) If T, requires delivery of the centrality measurement to the customer.

SHIP_CENTRALITY_MAP

(T or F) If T, requires delivery of the centrality map to the customer.

SHIP_CERTIFICATE_OF_CONFORMANCE

(T or F) If T, requires delivery of a certificate of conformance to the customer.

SHIP_CUSTOMER_QUALITY_FORM

(text) If present, the data field specifies the form required by the customer to document the quality of the mask.

SHIP_DEFECT_DATA

(T or F) If T, requires delivery of defect inspection criteria and evaluation data to the customer for all defect criteria specified. This should be final inspection data unless SHIP_THRU_PELLICLE_DATA is specified, in which case it should be for final inspection prior to pelliclizing.

SHIP_DIE_FIT_MAP

(T or F) If T, requires delivery of a die fit map to the customer.

SHIP_FILM

If present, film(s) of mask(s) must be sent to customer. Indicates beginning of <films> collection. Alphanumeric data field identifies the collection to establish which collections are hierarchically affected by another. The appearance of a <films> at a lower level in the hierarchy supercedes the <films> at a higher level in the hierarchy if it has the same SHIP_FILM data field.

SHIP_FIELD_FIT_MAP

(T or F) If T, requires delivery of a field fit map to the customer.

SHIP_FINAL_POSTPELL_DIE_DB_MSK_MAP

(T or F) If T, requires delivery of the final run, post-pellicle die to database defect inspection map for the entire patterned area to be sent to customer.

SHIP_FINAL_POSTPELL_DIE_DB_PTN_MAP

(T or F) If T, requires delivery of the final run, post-pellicle die to database defect inspection map for the single pattern to be sent to customer.

SHIP_FINAL _POSTPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the final run, post-pellicle die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FINAL_PREPELL_DIE_DB_MSK_MAP

(T or F) If T, requires delivery of the final run, pre-pellicle die to database defect inspection map for the entire patterned area to be sent to customer.

SHIP_FINAL_PREPELL_DIE_DB_PTN_MAP

(T or F) If T, requires delivery of the final run, pre-pellicle die to database defect inspection map for the single pattern to be sent to customer.

SHIP_FINAL _PREPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the final run, pre-pellicle die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FINAL_ROT_POSTPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the final run, post-pellicle rotated die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FINAL_ROT_PREPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the final run, pre-pellicle rotated die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FIRST_POSTPELL_DIE_DB_MSK_MAP

(T or F) If T, requires delivery of the first run, post-pellicle die to database defect inspection map for the entire patterned area to be sent to customer.

SHIP_FIRST_POSTPELL_DIE_DB_PTN_MAP

(T or F) If T, requires delivery of the first run, post-pellicle die to database defect inspection map for the single pattern to be sent to customer.

SHIP_FIRST_POSTPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the first run, post-pellicle die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FIRST_PREPELL_DIE_DB_MSK_MAP

(T or F) If T, requires delivery of the first run, pre-pellicle die to database defect inspection map for the entire patterned area to be sent to customer.

SHIP_FIRST_PREPELL_DIE_DB_PTN_MAP

(T or F) If T, requires delivery of the first run, pre-pellicle die to database defect inspection map for the single pattern to be sent to customer.

SHIP_FIRST_PREPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the first run, pre-pellicle die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FIRST_ROT_POSTPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the first run, post-pellicle rotated die to die defect inspection map for the entire mask to be sent to customer.

SHIP_FIRST_ROT_PREPELL_DIE_DIE_MAP

(T or F) If T, requires delivery of the first run, pre-pellicle rotated die to die defect inspection map for the entire mask to be sent to customer.

SHIP_INSP_DATABASE_DATA

(T or F) If T, requires delivery of die-to-database inspection data to the customer.

SHIP_JOB_DATA_PLOT

(T or F) If T, requires delivering to the customer a plot of the entire patterned area of the mask, including the image of the pattern file data.

SHIP_MEASURE_FILE_REGISTR_MAP

(T or F) If T, requires delivering to the customer the measure file registration map.

SHIP_PATTERN_PLACEMENT_MAP

(T or F) If T, requires delivering to the customer a plot of the entire patterned area of the mask,, showing only an outline of each individual pattern file.

SHIP_PATTERN_PLOT

(T or F) If T, the pattern plot must be sent to customer.

SHIP_PHASE_SHIFT_REPORT

(T or F) If T, requires delivering to the customer a report of the phase shift characteristics of the mask.

SHIP_MANUAL_INSPECTION_FORM

(T or F) If T, requires delivering to the customer a copy of the manual inspection form.

SHIP_REGISTR_DATA

(T or F) If T, requires delivery of all registration measurements, criteria and evaluation data to the customer for all registration criteria specified.

SHIP_REPAIR_DATA

(T or F) If T, requires delivery of repair data to the customer.

SHIP_SEM_PHOTOS

(T or F) If T, requires delivery of SEM photos to the customer.

SHIP_SPECIAL_REQUEST

(text) If present, the data field specifies the special request of the customer.

SHIP_STARLIGHT_MAP

(T or F) If T, requires delivery of a defect map from the Starlight to the customer.

SHIP_ SURF_INSP_GLASS_SIDE_MAP

(T or F) If T, the final, post-pellicle, surface inspection map of the glass side of the mask must be sent to the customer.

SHIP_ SURF_INSP_PATTERN_SIDE _MAP

(T or F) If T, the final, post-pellicle, surface inspection map of the patterned side of the mask must be sent to the customer.

SHIP_ SURF_INSP_PELL_TOP_MAP

(T or F) If T, the final, post-pellicle, surface inspection map of the pellicle on the patterned side of the mask must be sent to the customer.

SHIP_SURF_INSP_PELL_BOTTOM_MAP

(T or F) If T, the final, post-pellicle, surface inspection map of the pellicle on the glass side of the mask must be sent to the customer.

SHIP_SURF_INSPECTION_MAP

(T or F) If T, the final, post-pellicle, surface inspection map(s) must be sent to the customer.

SHIP_THRU_PELLICLE_DATA

(T or F) If T, requires delivery of through-pellicle defect inspection criteria and evaluation data to the customer for all defect criteria specified. This should be final inspection data.

SHIP_TRAVELER

(T or F) If T, requires delivery of mask traveler document to the customer.

SHIPPING_ADDRESS

Address for delivery of masks.

SHIPPING_CONTACT

Name of person to receive masks.

SHIPPING_EMAIL

Internet address for SHIPPING_CONTACT.

SHIPPING_FAX

Phone number for facsimile machine of SHIPPING_CONTACT.

SHIPPING_PHONE

Phone number for SHIPPING_CONTRACT.

SHIPPING_METHOD

Transportation method for masks, including special arrangements for off-hours and weekends.

SIZING

(x,y,z) Name of file (x) to be formed by (de)increasing the width and height of all geometry within the file (y) by (z) in microns. Note that (z) results in a “one-sided” (de)increase in feature size.

SIZING_RULE

(SQUARE, PARAGON, EXTEND, OCTAGON and others on request) Describes methodology for applying SIZING around corners.

SIZING_BORDER_RULE

(FIT, INSIDE, OUTSIDE and others on request) Describes methodology for applying SIZING at the borders of the output file and the effect on the final dimensions of the output file.

SO_NUMBER

Alphanumeric sales order number.

START_BARCODE

(text) name of barcode.

START_CD

Indicates beginning of <cd_definition>. Defines separation between multiple <cd_definition>s. Alphanumeric data field identifies the collection to establish which collections are hierarchically affected by another. The appearance of a <cd definition> at a lower level in the hierarchy supercedes the *entire* <cd definition> at a higher level in the hierarchy *if and only if* it has the same START_CD data field.

START_CD_MEASUREMENTS

(text) name of cd measurement group.

START_DATA_MANIPULATION

(text) name of group of data manipulation commands.

START_DEFECT_DEFINITION

(text) name of <defect_definition> group.

START_DEFECT_MEASUREMENTS

(text) name of <defect_measurements> group.

START_MASK_DATA

Indicates the beginning of the file from the vendor to the customer containing actual mask data. Should match the data field of the START_ORDER to which it is responding AND the data field of END_MASK_DATA.

START_OPC

(text) name of <opc_definition> group.

START_ORDER

Indicates the beginning of order entry data file from the customer to the vendor. Should indicate the name(s) of the mask sets included.

START_PATTERN_OPTIONS

(text) name of <pattern_options> group.

START_PHASESHIFT

(text) name of <phase_shift> group.

START_PLACEMENT

(text) name of <placement> group.

START_REGISTR

Indicates beginning of <registration> collection. Defines separation between multiple <registra-tion>s. Alphanumeric data field identifies the collection to establish which collections are hierarchically superceded by another; also for reference by REGISTR_RELATIVE.

START_REGISTR_MEASUREMENTS

(text) name of <registration_measurements> group.

START_SHIP_TO

(text) name of <ship_to> group.

START_SHIPPABLE_DATA

(text) name of <shippable_data> group.

START_TITLE

(title number) Indicates the beginning keywords for a specific title.

STATUS

(NEW, OLD, CHANGE, CANCEL, STOP, RESTART, RETURNED, PROTESTED) Present status of mask(s); NEW = new mask which has not been ordered before. OLD = previously ordered mask whose data is included for reference only. CHANGE = previously ordered mask whose data is included because the order data has been changed since the last transmission. CANCEL = previously ordered mask whose order is being cancelled. STOP = previously ordered mask which is put on hold until further notice. RESTART = changes a previous STATUS of STOP from being on hold to being released for production. RETURNED = a previously delivered mask which has been rejected by the customer and is being returned to the vendor. A data entry transmittal which includes a RETURNED mask should also include a NEW mask if replacement is to be initiated. PRICE of the returned mask should be the negative of the original price in order to track credit. The NEW mask should also contain PRICE and a new schedule. PROTESTED = a RETURNED mask whose rejection is protested by the mask vendor. If a NEW mask accompanied the RETURNED mask to initiate replacement, the NEW mask should also have PROTESTED status.

START_VENDOR_INFO

(text) name of <vendor_info> group.

STD_PATTERN_NAME

Name of a standard pattern, on file at the vendor, previously supplied or authorized by the customer.

STEPPING_COUNT

(x,y) Count of successive pattern or cell placements.

STEPPING_DISTANCE

(x,y) Spacing between successive pattern or cell placements.

STRIPE_HEIGHT

Stripe height in address units of pattern file.

SURF_INSP_AREA

(x1,y1,x2,y2) Unscaled coordinates of window for surface inspection, lower left and upper right corners, relative to center of mask, pattern or cell (chrome side up for masks, unmirrored for patterns or cells).

SURF_INSP_GLASS_SIDE

If present, specifies the maximum dimension of the smallest unacceptable particle on the glass side of the mask.

SURF_INSP_METHOD

(LASER, VISUAL, PIXEL or MICROSCOPE) Methodology for detecting surface particles.

SURF_INSP_PATTERN_SIDE

If present, specifies the maximum dimension of the smallest unacceptable particle on the patterned side of the mask.

SURF_INSP_PELL_BOTTOM

If present, specifies the maximum dimension of the smallest unacceptable particle on the pellicle on the glass side of the mask.

SURF_INSP_PELL_TOP

If present, specifies the maximum dimension of the smallest unacceptable particle on the pellicle on the patterned side of the mask.

SURFACE_INSPECTION

If present, requires surface inspection and specifies the maximum dimension of the smallest unacceptable surface particles.

SURROUNDING_HEIGHT

Height of clear or dark border around pattern on mask.

SURROUNDING_TONE

(CLEAR or DARK) Border surrounding pattern on mask is to be either clear or dark.

SURROUNDING_WIDTH

Width of clear or dark border around pattern on mask.

THROUGH_PELLICLE_DEFECTS

Precedes <defect_measurements> when delivering defect data measured with pellicle applied.

TITLE_HEIGHT

(height) Height in microns of title characters.

TITLE_JUSTIFICATION

(L or R) Left or right justification within the writable field, before mirroring and before rotation.

TITLE_LOCATION

(x,y) Location of the lower left corner of the above-specified TITLE_TEXT (before mirroring or rotation).

TITLE_TEXT

(text) Alphanumeric contents of human-readable text to be written on mask.

TITLE_TYPE

(MASK, DEVICE, DATE_TIME, SOFTWARE, SERIAL_NUMBER, AUXILIARY)

TITLES

(text) TITLE_TEXT of title on the mask. This keyword should be repeated until each title appearing on the mask is listed.

TOP_PELLICLE_TYPE

Alphanumeric brand and model of acceptable pelli-cle for the patterned side of the mask. If multiple pellicles are listed, they are prioritized with the most preferred first and least preferred last.

TRANSMISSION_DEFECT_CLEAR

Maximum allowable percent transmission of light through a clear defect.

TRANSMISSION_DEFECT_DARK

Maximum allowable percent blocking of light through a dark defect.

TRANSMISSION_ERROR

For phase shift masks, the maximum acceptable deviation of any percent transmission measurement from the TRANSMISSION_TARGET.

TRANSMISSION_RANGE

For phase shift masks, the maximum acceptable variation of all percent transmission measurements, relative to each other.

TRANSMISSION_TARGET

For phase shift masks, the required percent transmission of light at the specified WAVELENGTH compared to quartz.

TRANSMISSION_TOLERANCE

For phase shift masks, the maximum acceptable deviation of the mean of all percent transmission measurements to the TRANSMISSION_TARGET.

UNSCALED_PATTERN_SIZE

(x,y) Unscaled size of the pattern file. If this is incorrect, the mask will not be written until it is corrected.

USER_UNIT

To be used for fracturing DATABASE_SOURCE into inspection data, as required by some inspection systems.

UT1X_UNCUT

(T or F) If T, indicates that the reticle is to be delivered uncut (i.e., 5 inch square) size. If F, or if the keyword is absent, the reticle is to be delivered in the 3 inch by 5 inch size.

VENDOR

The name of the company from which the masks are ordered.

VENDOR_ADDRESS

Address for VENDOR_CONTACT.

VENDOR_CONTACT

Name of person to contact regarding the mask.

VENDOR_EMAIL

Internet address for VENDOR.

VENDOR_FAX

Phone number for facsimile machine of VENDOR.

VENDOR_PHONE

Phone number for VENDOR_CONTACT.

VISUAL_INSPECTION_OK

(T or F) If T, the area of the preceding pattern may be inspected visually and/or automatically at the vendor's option. VISUAL_INSPECTION_OK is not allowed if either VISUAL_INSPECTION_REQD or AUTO_INSPECTION_REQD is T (true).

VISUAL_INSPECTION_REQD

(T or F) Visual, microscopic inspection of the mask for defects is required.

WAFER_EXPOSURE_TOOL

Alphanumeric brand and model of the stepper or aligner on which the mask is to be used.

WAVELENGTH

Wavelength in nanometers of the stepper or aligner on which the mask is to be used.

XOR

(x,y,z) Name of file (x) to be formed by the logical union of file (y) and file (z), excluding all areas in which they intersect.

9 Computing the Checksum

9.1 The cyclic checksum is computed as follows:

9.1.1 Initialize the 16 bit checksum value to zero. Consider all the records in the data file from START_ORDER through END_ORDER, inclusive. Consider each ASCII character up to and including the "new_line" character. Convert each character to its ASCII numeric equivalent (e.g., space is 32 decimal, "A" is 65 decimal, etc.) Use the value 10 decimal for the new_line function regardless of its internal representation (e.g., CR LF). Use only the 7 bit ASCII representation for each character (i.e., ignore the high order bit in an 8 bit byte).

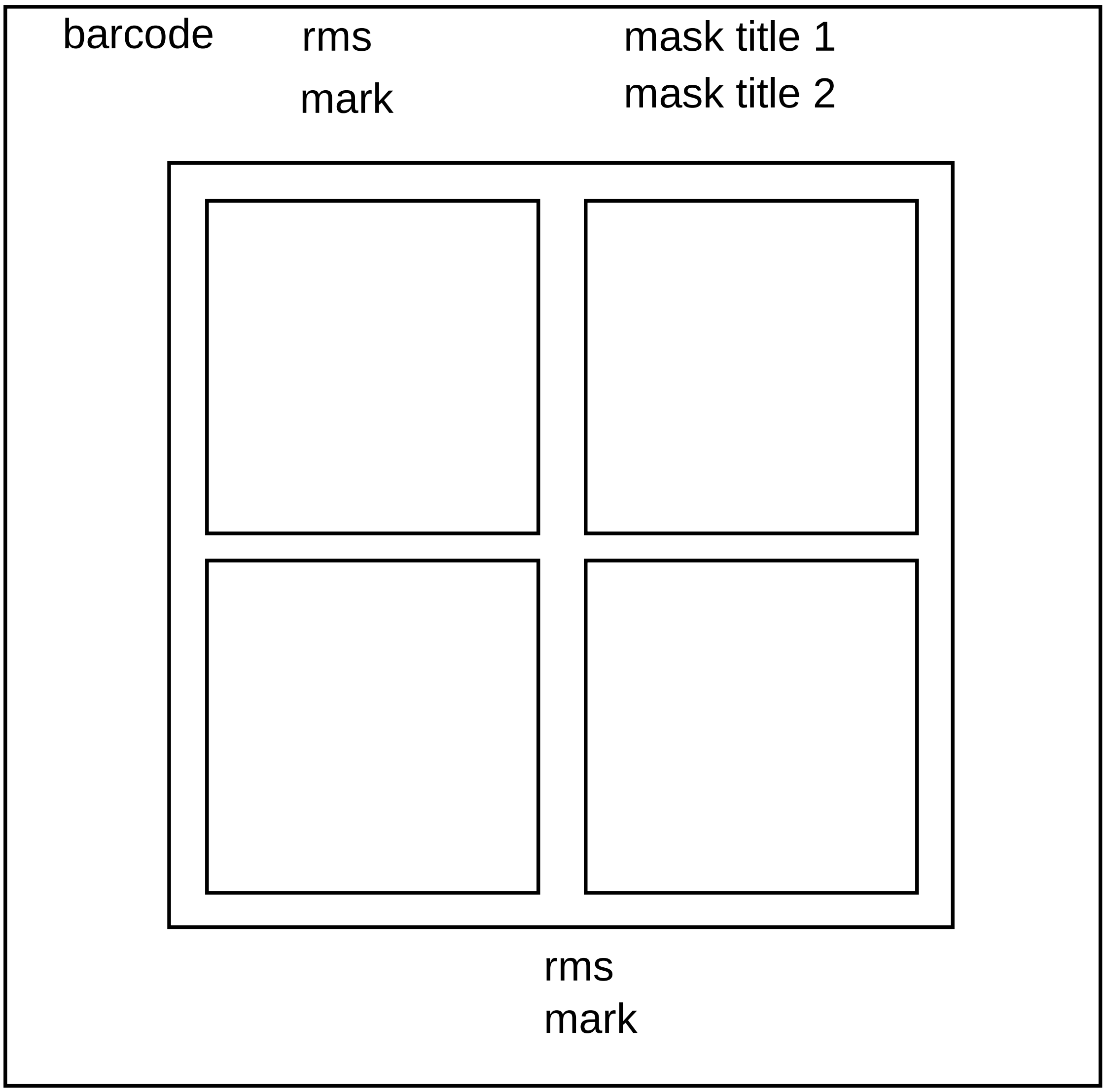
9.1.2 XOR each of the characters from each of the records in sequence, from the first character in the START_-ORDER record to the new_line character in the END_ORDER record. Before each character is XORed with the checksum, circularly rotate the previous value of the accumulated 16 bit checksum one bit to the left.

9.1.3 After all of the above characters have been accumulated into the checksum, convert it as an unsigned 16 bit integer into the ASCII representation of its decimal value. This ASCII string is the data field following the CHECKSUM keyword, the last record in the mask order structure.

RELATED INFORMATION 1
SEMI PHOTOMASK ORDER DATA FILE EXAMPLE

NOTE: The information contained in this related information is not an official part of SEMI P10, and it is not intended to modify or supercede the official standard. Rather, this example is offered as an aid to visualizing possible output from software which might implement the standard.

EXAMPLE: A pair of 4-die 5X reticles with separate scribe, barcode, and rms alignment marks.



```
START_ORDER             MS999
SEMI_REVISION           P10-0301                     ! <mask_order>
CUSTOMER                COMPANY NAME
VENDOR                  ULTIMATE MASK COMPANY
FILE_DATE_TIME          13-APR-1992, 13:00:00
MASK_SET_ID             9999                         ! <mask_set>
BILLING_CONTACT         Jean Doe, Accounts Payable   ! <mask_set_options>
BILLING_ADDRESS         Company Name
BILLING_ADDRESS         Street Address
BILLING_ADDRESS         City, State ZIP
BILLING_PHONE           4085551212
PRICE_UNITS             DOLLAR
SHIPPING_CONTACT        Joe Doe, Wafer Fab
SHIPPING_ADDRESS        Company Name
SHIPPING_ADDRESS        Street Address
SHIPPING_ADDRESS        City, State ZIP
SHIP_CD_DATA            T
SHIP_REGISTR_DATA       T
DATA_MEDIUM             TAPE
DATA_ID                 DEVICE 9999
DATA_FORMAT             MEBES
DATA_DENSITY            1600BPI
DATA_PATTERN_NAME       VT9999X-1A-26
PATTERN_FORMAT          MEBES_RETICLE
DATA_PATTERN_NAME       VT9999X-1A-10
PATTERN_FORMAT          MEBES_RETICLE
DATA_PATTERN_NAME       SC9999X-1A-26
PATTERN_FORMAT          MEBES_RETICLE
DATA_PATTERN_NAME       SC9999X-1A-10
PATTERN_FORMAT          MEBES_RETICLE
END_DATA_MEDIUM         TAPE
STD_PATTERN_NAME        GCARMSB-OX-AA
PATTERN_FORMAT          MEBES_RETICLE
END_MASK_SET_OPTIONS    9999
!
MASK_GROUP_ID           5X                           ! <mask_group>
BLANKET_PO_NUMBER       101055C
RELEASE_NUMBER          42
MILESTONES              T
START_TITLE             1
TITLE_TEXT              DEVICE 9999
TITLE_TYPE              DEVICE
TITLE_LOCATION          12500,58500
END_TITLE               1
```

START_TITLE	2	
TITLE_TYPE	MASK	
TITLE_LOCATION	12500,56500	
END_TITLE	2	
START_BARCODE	A	
BARCODE_TYPE	GCA	
BARCODE_LOCATION	-50000,57500	
END_BARCODE	A	
MIRROR_MASK	T	
PRODUCT_TYPE	RETICLE	
PRODUCT_MAGNIFICATION	5X	
PRODUCT_IMAGING_TYPE	BINARY	
GLASS_SIZE	5/90	
GLASS_TYPE	ULTE	
FLATNESS	2	
MASK_COATING	LOW_REFLECTANCE_CHROME	
RESIST_TYPE	POSITIVE	
REGISTR_ERROR	0.25	
REGISTR_REF_MASK_ID	2	
START_CD	SPECIFICATION	
CD_TOLERANCE	0.25	
CD_RANGE	0.3	
END_CD	SPECIFICATION	
START_DEFECT_DEFINITION	C	
DEFECT_SIZE	2.0	
DEFECT_COUNT	0	
INSPECTION_AREA	-30000,-35000,30000,35000	
END_DEFECT	C	
PACKAGE	H60-51-63A09	
END_MASK_GROUP_OPTIONS	5X	
!		
PLACEMENT_TOP_CELL	C1	
!		
MASK_ID	1	! <mask_definition>
DELIVERABLE_MASK	T	
LINE_ITEM_NUMBER	1	
STATUS	NEW	
DUE_DATE_REQUESTED	20-APR-1992	
PRICE	2000	
START_TITLE	2	
TITLE_TEXT	DIFFUSION	
END_TITLE	2	
START_BARCODE	A	
BARCODE_TEXT	9999-26	
END_BARCODE	A	

```
MIN_MASK_FEATURE_SIZE          10
END_MASK                       1
!
MASK_ID                        2                  ! <mask_definition>
DELIVERABLE_MASK               T
LINE_ITEM_NUMBER               2
STATUS                         NEW
DUE_DATE_REQUESTED             21-APR-1992
PRICE                          2000
START_TITLE                    2
TITLE_TEXT                     POLY
END_TITLE                      2
START_BARCODE                  A
BARCODE_TEXT                   9999-10
END_BARCODE                    A
MIN_MASK_FEATURE_SIZE          10
END_MASK                       2
!
CELL_ID                        C1                 ! <cell_definition>
END_CELL_OPTIONS               C1
CELL_INSTANCE                  C2                 ! MAIN ARRAY
END_CELL_INSTANCE              C2
LOCATION                       0,0
PATTERN_GROUP_INSTANCE         PG3                ! RMS ALIGNMENT KEYS
LOCATION                       0,-57500
LOCATION                       -11000,57500
END_CELL                       C1                 ! END TOP CELL DEFINITION
!
CELL_ID                        C2                 ! MAIN ARRAY DEFINITION
END_CELL_OPTIONS               C2
PATTERN_GROUP_INSTANCE         PG1                ! PRIMARY DIE
LOCATION                       -15000,-17500
STEPPING_DISTANCE              30000,35000
STEPPING_COUNT                 2,2
PATTERN_GROUP_INSTANCE         PG2                ! SCRIBE LINE
LOCATION                       0,0
END_CELL                       C2
!
PATTERN_GROUP_ID               PG1                ! PRIMARY PATTERN GROUP
PATTERN_ADDRESS_SIZE           0.5
SCALE_FACTOR                   1.0
STRIPE_HEIGHT                  1024
UNSCALED_PATTERN_SIZE          25000,30000
END_PATTERN_GROUP_OPTIONS      PG1
LEVEL_ID                       1
```

PATTERN_NAME	VT9999X-1A-26	
DIGITIZED_DATA_DARK	T	
END_PATTERN_DEFINITION	1	
LEVEL_ID	2	
PATTERN_NAME	VT9999X-1A-10	
DIGITIZED_DATA_DARK	F	
END_PATTERN_DEFINITION	2	
END_PATTERN_GROUP	PG1	
!		
PATTERN_GROUP_ID	PG2	! SCRIBE PATTERN GROUP
PATTERN_ADDRESS_SIZE	0.5	
SCALE_FACTOR	1.0	
STRIPE_HEIGHT	1024	
UNSCALED_PATTERN_SIZE	65000,75000	
START_CD	CD_SITES	
CD_SITE_ID	CD_1	
PATTERN_CD_LOCATION	-40000,0	
CD_SITE_ID	CD_2	
PATTERN_CD_LOCATION	0,-40000	
CD_SITE_ID	CD_3	
PATTERN_CD_LOCATION	0,40000	
CD_SITE_ID	CD_4	
PATTERN_CD_LOCATION	0,0	
END_CD	CD_SITES	
END_PATTERN_GROUP_OPTIONS	PG2	
LEVEL_ID	1	
PATTERN_NAME	SC9999X-1A-26	
DIGITIZED_DATA_DARK	T	
START_CD	DIMENSION	
CD_DATA	10	
CD_DIGITIZED	T	
CD_TARGET	10	
END_CD	DIMENSION	
END_PATTERN_DEFINITION	1	
LEVEL_ID	2	
PATTERN_NAME	SC9999X-1A-10	
DIGITIZED_DATA_DARK	F	
START_CD	DIMENSION	
CD_DATA	10	
CD_DIGITIZED	T	
CD_TARGET	10.5	
END_CD	DIMENSION	
END_PATTERN_DEFINITION	2	
END_PATTERN_GROUP	PG2	! END SCRIBE GROUP
!		

PATTERN_GROUP_ID	PG3	! RMS ALIGNMENT MARK
PATTERN_ADDRESS_SIZE	0.5	
SCALE_FACTOR	1.0	
STRIPE_HEIGHT	1024	
UNSCALED_PATTERN_SIZE	2000,2000	
INSPECTION_AREA	-3000,-3000,3000,3000	
END_PATTERN_GROUP_OPTIONS	PG3	
LEVEL_ID	A	
PATTERN_NAME	GCARMSB-OX-AA	
DIGITIZED_DATA_DARK	F	
END_PATTERN_DEFINITION	A	
END_PATTERN_GROUP	PG3	! END ALIGNMENT MARK
!		
END_MASK_GROUP	5X	
END_MASK_SET	9999	
END_ORDER	MS9999	
CHECKSUM	computed checksum	

RELATED INFORMATION 2
SEMI PHOTOMASK ORDER DATA FILE EXAMPLE EMPLOYING MULTIPLE WRITE AND PROCESS STEPS FOR A SINGLE MASK

NOTE: The information contained in this related information is not an official part of SEMI P10, and it is not intended to modify or supercede the official standard. Rather, this example is offered as an aid to visualizing possible output from software which might implement the standard.

EXAMPLE: One 4-die phase shift reticle requiring two write and process steps.

START_ORDER	MS999	
SEMI_REVISION	P10-0301	! <mask_order>
CUSTOMER	COMPANY NAME	
VENDOR	ULTIMATE MASK COMPANY	
FILE_DATE_TIME	06-JUL-2000, 01:06:00	
MASK_SET_ID	9999	! <mask_set>
END_MASK_SET_OPTIONS	9999	
!		
MASK_GROUP_ID	PSM	! <mask_group>
START_TITLE	1	
TITLE_TEXT	DEVICE 9999	
TITLE_TYPE	DEVICE	
TITLE_LOCATION	12500,58500	
END_TITLE	1	
START_TITLE	2	
TITLE_TEXT	PHASE SHIFT POLY	
TITLE_TYPE	MASK	
TITLE_LOCATION	12500,56500	
END_TITLE	2	
MIRROR_MASK	T	
PRODUCT_TYPE	RETICLE	
PRODUCT_MAGNIFICATION	5X	
PRODUCT_IMAGING_TYPE	EAPSM	
GLASS_SIZE	6/250	
GLASS_TYPE	ULTE	
FLATNESS	1	
MASK_COATING	MOSI	
RESIST_TYPE	POSITIVE	
START_CD	SPECIFICATION	
CD_TOLERANCE	0.05	
CD_RANGE	0.06	
END_CD	SPECIFICATION	
END_MASK_GROUP_OPTIONS	5X	
!		
PLACEMENT_TOP_CELL	C1	
!		

MASK_ID	1	! First write and process step
DELIVERABLE_MASK	F	
MULTIWRITE	(1,1)	
START_PHASESHIFT	1	
WAVELENGTH	248	
TRANSMISSION_TARGET	6	
TRANSMISSION_TOLERANCE	0.4	
TRANSMISSION_RANGE	0.8	
PHASE_ANGLE_TARGET	180	
PHASE_ANGLE_TOLERANCE	4	
PHASE_ANGLE_RANGE	8	
END_PHASESHIFT	1	
START_REGISTR	1	
REGISTR_ERROR	0.10	
END_REGISTR	1	
MIN_MASK_FEATURE_SIZE	0.8	
END_MASK	1	
!		
MASK_ID	2	! Second write and process step
DELIVERABLE_MASK	T	
MULTIWRITE	(1,2)	
START_PHASESHIFT	2	
WAVELENGTH	248	
TRANSMISSION_TARGET	6	
TRANSMISSION_TOLERANCE	0.4	
TRANSMISSION_RANGE	0.8	
PHASE_ANGLE_TARGET	180	
PHASE_ANGLE_TOLERANCE	4	
PHASE_ANGLE_RANGE	8	
END_PHASESHIFT	2	
TOP_PELLICLE_TYPE	CA627P-7043L	
MIN_MASK_FEATURE_SIZE	0.8	
START_DEFECT_DEFINITION	C	
DEFECT_SIZE	0.3	
DEFECT_COUNT	0	
INSPECTION_AREA	-30000,-35000,30000,35000	
END_DEFECT	C	
END_MASK	2	
!		
CELL_ID	C1	! <cell_definition>
END_CELL_OPTIONS	C1	
CELL_INSTANCE	C2	! MAIN ARRAY
END_CELL_INSTANCE	C2	
LOCATION	0,0	
PATTERN_GROUP_INSTANCE	PG3	! RMS ALIGNMENT KEYS

LOCATION	0,-57500	
LOCATION	-11000,57500	
END_CELL	C1	! END TOP CELL DEFINITION
!		
CELL_ID	C2	! MAIN ARRAY DEFINITION
END_CELL_OPTIONS	C2	
PATTERN_GROUP_INSTANCE	PG1	! PRIMARY DIE
LOCATION	-15000,-17500	
STEPPING_DISTANCE	30000,35000	
STEPPING_COUNT	2,2	
PATTERN_GROUP_INSTANCE	PG2	! SCRIBE LINE
LOCATION	0,0	
END_CELL	C2	
!		
PATTERN_GROUP_ID	PG1	! PRIMARY PATTERN GROUP
PATTERN_ADDRESS_SIZE	0.05	
SCALE_FACTOR	1.0	
STRIPE_HEIGHT	1024	
UNSCALED_PATTERN_SIZE	25000,30000	
END_PATTERN_GROUP_OPTIONS	PG1	
LEVEL_ID	1	
PATTERN_NAME	VT9999X-1A-26	
DIGITIZED_DATA_DARK	T	
END_PATTERN_DEFINITION	1	
LEVEL_ID	2	
PATTERN_NAME	VT9999X-1A-10	
DIGITIZED_DATA_DARK	F	
END_PATTERN_DEFINITION	2	
END_PATTERN_GROUP	PG1	
!		
PATTERN_GROUP_ID	PG2	! SCRIBE PATTERN GROUP
PATTERN_ADDRESS_SIZE	0.05	
SCALE_FACTOR	1.0	
STRIPE_HEIGHT	1024	
UNSCALED_PATTERN_SIZE	65000,75000	
START_CD	CD_SITES	
CD_SITE_ID	CD_1	
PATTERN_CD_LOCATION	-40000,0	
CD_SITE_ID	CD_2	
PATTERN_CD_LOCATION	0,-40000	
CD_SITE_ID	CD_3	
PATTERN_CD_LOCATION	0,40000	
CD_SITE_ID	CD_4	
PATTERN_CD_LOCATION	0,0	
END_CD	CD_SITES	

END_PATTERN_GROUP_OPTIONS	PG2	
LEVEL_ID	1	
PATTERN_NAME	SC9999X-1A-26	
DIGITIZED_DATA_DARK	T	
START_CD	DIMENSION	
CD_DATA	0.8	
CD_DIGITIZED	T	
CD_TARGET	0.8	
END_CD	DIMENSION	
END_PATTERN_DEFINITION	1	
LEVEL_ID	2	
PATTERN_NAME	SC9999X-1A-10	
DIGITIZED_DATA_DARK	F	
START_CD	DIMENSION	
CD_DATA	0.8	
CD_DIGITIZED	T	
CD_TARGET	0.8	
END_CD	DIMENSION	
END_PATTERN_DEFINITION	2	
END_PATTERN_GROUP	PG2	! END SCRIBE GROUP
!		
PATTERN_GROUP_ID	PG3	! RMS ALIGNMENT MARK
PATTERN_ADDRESS_SIZE	0.5	
SCALE_FACTOR	1.0	
STRIPE_HEIGHT	1024	
UNSCALED_PATTERN_SIZE	2000,2000	
INSPECTION_AREA	-3000,-3000,3000,3000	
END_PATTERN_GROUP_OPTIONS	PG3	
LEVEL_ID	A	
PATTERN_NAME	GCARMSB-OX-AA	
DIGITIZED_DATA_DARK	F	
END_PATTERN_DEFINITION	A	
END_PATTERN_GROUP	PG3	! END ALIGNMENT MARK
!		
END_MASK_GROUP	PSM	
END_MASK_SET	9999	
END_ORDER	MS9999	
CHECKSUM	computed checksum	

RELATED INFORMATION 3
SEMI PHOTOMASK ACTUAL DATA FILE EXAMPLE

NOTE: The information contained in this related information is not an official part of SEMI P10, and it is not intended to modify or supercede the official standard. Rather, this example is offered as an aid to visualizing possible output from software which might implement the standard.

EXAMPLE: The actual mask CD data sent by the vendor to the customer for a 4-die 5X reticle with SHIP_CD_DATA set to TRUE. (For reference, see Related Information 1, for MASK_ID = 1.)

START_MASK_DATA	MS999	
SEMI_REVISION	P10-0301	! <mask_order>
CUSTOMER	COMPANY NAME	
VENDOR	ULTIMATE MASK COMPANY	
FILE_DATE_TIME	13-APR-1992, 13:00:00	
MASK_SET_ID	9999	! <mask_set>
MASK_GROUP_ID	5X	
MASK_ID	1	
TITLES	DEVICE 9999	
TITLES	DIFFUSION	
START_CD_MEASUREMENTS	SPECIFICATION	
CD_TOLERANCE	0.25	
CD_RANGE	0.3	
MEASURED_CD_SITE_ID	CD_1	
MASK_CD_LOCATION	-40000,0	
CD_TARGET	10	
MEASURED_CD	9.95	
END_MEASURED_CD_SITE	CD_1	
MEASURED_CD_SITE_ID	CD_2	
MASK_CD_LOCATION	0,-40000	
CD_TARGET	10	
MEASURED_CD	10.01	
END_MEASURED_CD_SITE	CD_2	
MEASURED_CD_SITE_ID	CD_3	
MASK_CD_LOCATION	0,40000	
CD_TARGET	10	
MEASURED_CD	9.98	
END_MEASURED_CD_SITE	CD_3	
MEASURED_CD_SITE_ID	CD_4	
MASK_CD_LOCATION	0,0	
CD_TARGET	10	
MEASURED_CD	10.07	
END_MEASURED_CD_SITE	CD_4	
END_CD _MEASUREMENTS	SPECIFICATION	
END_MASK	1	
END_MASK_GROUP	5X	

END_MASK_SET	9999
END_ORDER	MS9999
CHECKSUM	computed checksum

SEMI P11-0997
DETERMINATION OF TOTAL NORMALITY FOR ALKALINE DEVELOPER SOLUTIONS

1 Scope

1.1 An acid-base potentiometric titration to single or multiple inflection points is performed on an automatic recording titrator using standardized hydrochloric acid as the titrant. The normality (meq/mL) is then calculated by the titrator using the data obtained.

2 Apparatus

2.1 Autotitrator

2.2 Glass combination electrode

2.3 Class A grade volumetric pipets in 1 to 25 mL sizes

2.4 250 mL beakers

3 Reagents

3.1 1.0 *N* Hydrochloric acid (from concentrate or ready to use 1.0 *N*)

3.2 *Primary Standard* — High-purity sodium carbonate is available from most chemical supply houses, but must be dried at 400 degree centigrade before use. TMAH (tris (hydroxymethyl) aminomethane) is also available from the National Institute of Standards and Technology (Standard Reference Material 723a) for this purpose.

3.3 Buffer solutions, pH 4.0, 7.0, 10.0.

4 Procedure

4.1 Standardize the 1.0 *N* Hydrochloric acid with the primary standard.

4.2 Standardize the titrator by performing a two point calibration with pH 4.0, 7.0, and 10.0 buffer.

4.3 Pipette an appropriate aliquot (1 to 25 mL) of sample into a 250 mL beaker containing a magnetic stir bar. Sample size should be determined according to the expected normality and the amount of titrant to be dispensed that will give the optimum precision and accuracy. Generally this is between one-half and three-quarters the capacity of the burette. (See the instrument manual for the recommended optimum range.)

4.4 Add deionized water to bring the volume to approximately 150 mL.

4.5 Without delay (to prevent carbon dioxide absorption), begin stirring without a vortex and titrate to beyond the inflection endpoint.

4.6 Determine the exact endpoint and record the volume of titrant consumed at the middle of the inflection endpoint. This will be done automatically on most newer digital titrators. On analog titrators, the inflection point can be determined by using the first derivative mode, or accurately determining the middle of the inflection.

5 Calculation

5.1 Calculate the normality of the sample by the following equation.

$$\text{Normality (N)} = \frac{\text{Volume of titrant (mL)} \times \text{Normality of titrant (N.HCL)}}{\text{Sample Volume (mL)}}$$

SEMI P12-0997

DETERMINATION OF IRON, ZINC, CALCIUM, MAGNESIUM, COPPER, BORON, ALUMINUM, CHROMIUM, MANGANESE, AND NICKEL IN POSITIVE PHOTORESISTS BY INDUCTIVELY COUPLED PLASMA EMISSION SPECTROSCOPY (ICP)

1 Scope

1.1 This procedure is an ICP plasma emission analysis for determination of iron, zinc, calcium, magnesium, copper, boron, aluminum, chromium, manganese, and nickel in photoresist. The applicable concentration range is 0.1 to 1 ppm when the sample is diluted 1 to 4. The precision was found to be within 0.1 ppm in a round robin analysis between four laboratories.

2 Spectrometer

2.1 A grating instrument with resolution sufficient to separate the analytical emission lines in Table 1 is required.

Table 1 Analytical Lines of the Elements

Elements	*Analytical Line, nm*	*Elements*	*Analytical Line, nm*
Aluminum	309.271	Magnesium	285.213
Calcium	317.933	Nickel	231.604
Copper	324.754	Zinc	213.856
Iron	239.562	Chromium	283.563
Boron	208.960	Manganese	257.610

3 Sample Preparation

3.1 The sample is diluted 1/4 (1 part of sample plus 3 parts of solvent weight/weight) in 2-methoxyethanol or another suitable solvent for positive resist. The solvent should contain less than 0.03 ppm of the above elements.

4 Standards

4.1 The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

4.2 The standards are prepared by diluting a concentrated standard of organic-soluble metals in 2-methoxyethanol or other suitable solvent. For example, a 500 ppm standard is diluted to 50 ppm with xylene. This solution is then diluted to 0.25 ppm with 2-methoxythanol.

5 Plasma Conditions

5.1 The sample is pumped on the region of 0.7 mL/min, usually with a perstaltic pump attached to the nebulizer. Choose a tubing that is not attacked by methyl cellosolve (for example, polytetrafluoro-ethylene). The argon plasma flow rate and RF power should be optimized for the sample using settings recommended in the manufacturer’s manual. Generally, a plasma gas flow rate of 16 1/min. is necessary to ionize organic solutions and an RF power of 1.7 watts is required.

6 Quantitation

6.1 The detector gain is set by measuring the 0.25 ppm standard. The background is measured with the solvent and several sample measures. The standard and blank should be run intermittently to satisfy reasonable precision. Standard and sample readings should be repeatable within 0.03 ppm. The effect of sample viscosity on delivery of diluted resist to the plasma was not found to be a factor for the resist tested for this procedure. This effect can be checked by adding an internal standard of an element known not to be present in the resist (such as Yttrium) at ppm and checking the emission response vs. external 1 ppm Yttrium standard in the diluting solvent.

7 Calculation

7.1 ppm element (mg/kg = ppm measured × delution factor (weight/weight)

7.2 *Detection Limit* — The detection limit is a function of the dilution factor and can vary by instrument. The dilution factor should be taken into account in calculation of detection limit.

7.2.1 Detection limit (ppm) = s × dilution factor where s = standard deviation of instrument readings in ppm.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI P13-91
DETERMINATION OF SODIUM AND POTASSIUM IN POSITIVE PHOTORESISTS BY ATOMIC ABSORPTION SPECTROSCOPY

1 Scope

This procedure is a flame atomic absorption analytical method for sodium and potassium analysis in photoresist. The applicable concentration range is 0.1 to 1 ppm when the sample is diluted one to four. The precision was found to be within 0.1 ppm in a round-robin analysis between four laboratories.

2 Atomic Absorption Spectrometer

The analytical wavelength for sodium is 589.0 nm and for potassium is 766.0 nm. The instrument conditions (i.e., slit width, burner gas flow rates) should be set according to the manufacturer's manual (the fuel flow should be set to approximately 1/2 the air flow to optimize for organic solvent). Optimize the nebulizer and lamp alignment to maximize the absorbance of the 1 ppm standard.

3 Sample Preparation

The sample should be diluted 1/4 (1 part resist and 3 parts of solvents weight/weight) in 2-methoxyethanol or another suitable solvent for positive resist. The solvent should contain less than 0.1 ppm of the element being analyzed.

4 Standards

The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

The standards are prepared by diluting a concentrated stock of organic-soluble sodium and potassium. For example, a 500 ppm standard of sodium is diluted to 50 ppm with reagent xylene. This solution is then diluted to 1 ppm with 2-methoxyethanol or another suitable solvent.

5 Procedure

Set the absorbance reading to zero with the flame ignited and no sample aspirating. Measure the absorbance of the solvent blank. It should not be more than 0.04. Measure the absorbance of the 1 ppm standard and samples. The absorbance of the standard should be in the region of 0.4. Duplicate sample and standard readings should be within 0.01 absorbance. A recovery of 88% was determined when a 1 ppm potassium internal standard was added to the resist tested. The effect of viscosity on delivery to the burner can be determined by adding 2 ppm of a potassium internal standard to the sample and checking the absorbance versus an external 2 ppm potassium standard in the diluting solvent. The potassium level in the resist, if any, should be subtracted.

6 Calculation

$$\text{ppm (mg/kg)} = \frac{\text{Abs. Sample} \times \text{ppm Standard} \times \text{dilution factor} \times \text{R}}{\text{Abs. Standard}}$$

R = Recovery factor due to sample viscosity if applicable, for example 1.136 in above example.

Detection Limit — The detection limit is a function of the dilution factor and can vary by instrument. The dilution factor should be taken into account in calculation of detection limit.

Detection limit (ppm) = s × dilution factor where s = standard deviation of instrument "readings" in ppm.

SEMI P14-0997
DETERMINATION OF TIN IN POSITIVE PHOTORESISTS BY GRAPHITE FURNACE ATOMIC ABSORPTION SPECTROSCOPY

1 Scope

1.1 This procedure is a graphite furnace atomic absorption analytical method for tin in photoresist. The applicable concentration range is 0.1 to 1 ppm when the sample is diluted one to ten. The precision was found to be within 0.1 ppm in a round robin analysis between four laboratories.

2 Instrument Conditions

2.1 An atomic absorption spectrometer equipped with a graphite furnace is used with graphite tubes equipped with pyrrolitically coated graphite platforms for sampling.

2.2 The 224.6 nm emission line from a hollow cathode tin lamp is used as the analytical absorption line.

Furnace Program*

	Dry Step	*Char Step*	*Atomization Step*
Temperature (°C)	110	800	2700
Ramp time (s)	20	20	0 +
Hold time (s)	20	20	5

+ Maximum power heating

* Argon flow rate of 50 mL/min

3 Sample Preparation

3.1 The sample is diluted 1/10 (1 part sample + 9 parts solvents weight/weight) in 2-methoxyethanol or another suitable solvent for positive resist. The solvent should contain less than 0.01 ppm of tin.

4 Standards

4.1 The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

4.2 A 50 ppm tin standard is prepared by diluting a 500 ppm tin standard in oil to 50 ppm with Xylene.

4.3 A 1 ppm standard is made by diluting the 50 ppm standard in 2-methoxyethanol or another suitable solvent.

5 Procedure

5.1 A 20 µL volume of 1 ppm tin standard is transferred to the platform by Eppendorf pipette. The furnace program is run and absorbance measured. The absorbance of the 1ppm tin standard should be in the range of 0.2 absorbance. Measure the absorbance of the solvent and sample in an identical manner.

6 Calculation

$$\text{ppm tin (mg/kg)} = \frac{\text{Abs. Sample} \times \text{ppm Standard} \times \text{dilution factor}}{\text{Abs. Standard}}$$

6.1 *Detection Limit* — The detection limit is a function of the dilution factor and can vary by instrument. The solution factor should be taken into account in calculation of the detection limit.

6.1.1 Detection limit (ppm) = s × dilution factor where s = standard deviation of instrument reading in PPM.

SEMI P15-92
DETERMINATION OF SODIUM AND POTASSIUM IN POSITIVE PHOTORESIST METAL ION FREE (MIF) DEVELOPERS BY ATOMIC ABSORPTION SPECTROSCOPY

1 Scope

This procedure is a flame atomic absorption analytical method for sodium and potassium analysis in photoresist MIF developers. The applicable concentration range is 20 to 1000 ppb.

2 Instrument Conditions

2.1 *Atomic Absorption Spectrometer* — The analytical wavelength for sodium is 589 nm and for potassium is 766 nm. The instrument conditions (i.e., slit width, burner gas flow rates) should be set according to the manufacturer's manual. Optimize the nebulizer and lamp alignment to maximize the absorbance of the 1 ppm standard.

3 Standards

The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

The standards are prepared by diluting a concentrated stock. For example, a 500 ppm standard of sodium is diluted to 50 ppm with de-ionized water. This solution is then diluted to 1 ppm.

4 Procedure

No sample preparation nor dilution is required.

Set the absorbance reading to zero with the flame ignited and no sample aspirating. Measure the absorbance of the 1 ppm standards and samples. The absorbance of the standard should be in the range of 0.2 absorbance. Duplicate sample and standard readings should be within 0.01 absorbance. The effect of viscosity on delivery to the burner can be determined by adding 2 ppm of a potassium internal standard to the sample and checking the absorbance versus an external 2 ppm potassium standard. The potassium level in the developer, if any, should be subtracted.

5 Calculation

$$\text{ppm (mg/kg)} = \frac{\text{Abs. Sample} \times \text{ppm Standard} \times \text{R}}{\text{Abs. Standard}}$$

R = Recovery factor due to sample viscosity if applicable.

SEMI P16-92
DETERMINATION OF TIN IN POSITIVE PHOTORESIST METAL ION FREE (MIF) DEVELOPERS BY GRAPHITE FURNACE ATOMIC ABSORPTION SPECTROSCOPY

1 Scope

This procedure is a graphite furnace atomic absorption analytical method for tin in photoresist MIF developers. The applicable concentration range is 20 to 1000 ppm.

2 Instrument Conditions

An atomic absorption spectrometer equipped with a graphite furnace is used with graphite tubes equipped with pyrolytic coated graphite platforms for sampling.

The 224.6 nm emission line from a hollow cathode tin lamp is used as the analytical absorption line.

Furnace Program*

	Dry Step	*Char Step*	*Atomization Step*
Temperature (°C)	110	800	2700
Ramp time (s)	20	20	0 +
Hold time (s)	20	20	5

\+ Maximum power heating
* Argon flow rate of 50 mL/min

3 Standards

The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

A 50 ppm tin standard is prepared by diluting a 500 ppm tin standard to 50 ppm with de-ionized water.

A 1 ppm standard is made by diluting the 50 ppm standard.

4 Procedure

No sample preparation nor dilution is required.

A 20 mL volume of 1 ppm tin standard is transferred to the platform by Eppendorf pipette. The furnace program is run and absorbance measured. The absorbance of the 1 ppm tin standard should be in the range of 0.2 absorbance. Measure the absorbance of the sample in an identical manner.

5 Calculation

$$\text{ppm tin (mg/kg)} = \frac{\text{Abs. Sample} \times \text{ppm Standard}}{\text{Abs. Standard}}$$

SEMI P17-92 (Reapproved 0299)
DETERMINATION OF IRON, ZINC, CALCIUM, MAGNESIUM, COPPER, BORON, ALUMINUM, CHROMIUM, MANGANESE, AND NICKEL IN POSITIVE PHOTORESIST METAL ION FREE (MIF) DEVELOPERS BY INDUCTIVELY COUPLED PLASMA EMISSION SPECTROSCOPY (ICP)

This standard was technically reapproved by the Resist Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee in October 1998. Initially available at www.semi.org February 1999; to be published February 1999. Originally published in 1992; previously published in 1996.

1 Scope

This procedure is an ICP plasma emission analysis for determination of iron, zinc, calcium, magnesium, copper, boron, aluminum, chromium, manganese, and nickel in photoresist MIF developers. The applicable concentration range and detection limit will depend upon the element and instrument.

2 Spectrometer

An instrument with resolution sufficient to separate the analytical emission lines in Table 1 is required.

Table 1. Analytical Lines of the Elements

Elements Analytical Line	*nm*
Aluminum	396.152
Calcium	317.933
Copper	324.754
Iron	239.562
Boron	208.960
Magnesium	285.213
Nickel	231.604
Zinc	213.856
Chromium	283.563
Manganese	257.610

3 Standards

The standards should be weight/weight (mg/kg) and should be diluted weight/weight since results will be expressed in mg/kg.

The standards are prepared by diluting a concentrated standard. For example, a 500 ppm standard is diluted to 50 ppm with deionized water. This solution is then diluted to 0.25 ppm.

4 Plasma Conditions

The sample is pumped in the region of 0.7 mL/min. usually with a peristaltic pump attached to the nebulizer. The argon plasma flow rate and RF power should be optimized for the sample using settings recommended in the manufacturer manual. Generally, a plasma gas flow rate of 12 L/min and an RF power of 1.25 kW is required.

5 Quantitation

No sample preparation nor dilution is required.

The detector gain is set by measuring the 0.25 ppm standard. The standard should be run intermittently to satisfy reasonable precision. Standard and sample readings should be repeatable within 0.03 ppm. The effect of sample viscosity on delivery of diluted sample to the plasma was not found to be a factor for this procedure. This effect can be checked by adding an internal standard of an element known not to be present in the sample (such as Yttrium) at 1 ppm and checking the emission response vs. an external 1 ppm Yttrium standard.

6 Calculation

$$\text{ppm element (mg/kg)} = \frac{Ix}{Is} \times 0.25 \text{ ppm}$$

Where Ix = emission intensity of sample

Is = emission intensity of 0.25 ppm standard

SEMI P18-92
SPECIFICATION FOR OVERLAY CAPABILITIES OF WAFER STEPPERS

1 Scope

1.1 Definitions for the overlay capabilities of wafer steppers are established, consistent with the primary application of wafer stepper (i.e., the manufacturing of very large-scale integrated circuits). Also included are definitions for associated parameters: registration, exposure field, good fields, and alignment.

2 Applicable Documents

2.1 Statistical methods shall be used in accordance with the procedures in NBS Handbook #91 (Experimental Statistics, by M.G. Natrella) and ASTM STD 15D (Manual on the presentation of data and control chart analysis).

3 Terminology

3.1 *overlay* — a vector quantity defined at every point on the wafer. It is the difference, O, between the vector position, P_1, of a substrate geometry, and the vector position of the corresponding point, P_2, in an overlaying pattern, which may consist of photoresist:

$$O = P_1 - P_2$$

3.2 *interfield overlay* (also referred to as field-to-field overlay) — The center of the lens is chosen to be a reference point. The overlay at the reference point in each exposure field is the interfield overlay.

3.3 *exposure field* — the area of a wafer covered by a single exposure.

3.4 *intrafield overlay* (also referred to as within-a-field overlay) — the overlay within an exposure field, relative to the overlay at the center of the lens reference location.

NOTE: From these definitions, it follows that the overlay at any point on the wafer is the vector sum of interfield and intrafield overlays.

3.5 r*egistration* — a vector quantity defined at every point on the wafer. It is the difference, R, between the vector position, P_1, of a substrate geometry, and vector position of the corresponding point, P_0, in a reference grid:

$$R = P_1 - P_0$$

3.5.1 The reference grid must be clearly specified in any specification of registration.

3.5.2 Interfield and intrafield registration are defined in a manner similar to interfield and intrafield overlay.

3.5.3 Overlay may be computed from registration measurements if the same reference standard is used on all systems for determining registration.

3.6 *alignment* — the mechanical positioning of reference points on the wafers ("alignment targets") to the corresponding points on the reticles. The measure of alignment is the overlay at the position on the wafer where the alignment targets are placed.

3.7 Registration and overlay vectors shall be decomposed into orthogonal components, X and Y, along the directions of the stepper stage motion.

3.8 *good fields* — exposure fields in which the magnitude of the overlay at every point within the field is less than a specified value, V, in both the X and Y directions, exclusive of contributions to overlay from the reticles and non-linear deformations of the wafers during non-stepper processing.

NOTE: It should be recognized that contributions from reticles are non-statistical in nature, and that a particular reticle will make the same contributions to overlay and registration in every exposure field in which it is imaged.

3.9 *fraction of good field* — the overlay capabilities of wafer steppers shall be quantified in terms of the fraction of good fields, F, out of the total number of fields on the wafer:

$$F = \frac{\text{Number of good fields}}{\text{Number of total fields}}$$

Good fields may also be quantified as a percentage (100 * F%).

3.10 Any specification of overlay must define the applicable exposure field size and the stepping patterns on the wafers over which the specification applies. From Sections 3.8 and 3.9 it follows that the specification of the overlay capability of wafer steppers consists of at least two additional numbers, the overlay value, V, and the fraction of good fields, F. It is consistent to characterize stepper overlay capability for multiple overlay values, V_1, V_2, ... with corresponding multiple fractions of good fields, F_1, F_2...

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SEMI P19-92
SPECIFICATION FOR METROLOGY PATTERN CELLS FOR INTEGRATED CIRCUIT MANUFACTURE

Purpose

This document defines several standard test patterns to provide consistent industrywide evaluation and testing of micropatterning equipment, metrology instruments, and processes used in integrated circuit manufacturing.

1 General Specification

1.1 *Scope*

1.1.1 This specification defines the shape, general size, and recommended placement and design rules (where appropriate) of several basic pattern cells for linewidth metrology, resolution testing, and proximity testing. These standard patterns include cells that can be used for optical microscopy, electron microscopy, and electrical probe testing.

1.1.2 This document does not attempt to specify the measurement techniques to be used in verifying critical dimensions for these test patterns on the reticle. Similarly, this document does not attempt to specify how the printed patterns are to be measured on the wafer. This document specifies only what the patterns are supposed to be; it is left to the user to ensure that the actual pattern conforms to this specification, subject to all other applicable SEMI specifications. A separate SEMI document will specify CD measurement conditions (see Section 1.2.1).

1.2 *Applicable Documents*

1.2.1 *SEMI Standards*

SEMI P24 — CD Metrology Procedures

1.3 *Definitions*

linewidth — In semiconductor technology, at a given cross-section of the line, the distance between the airline material boundaries at some specified height above the interface between the patterned layer in which the line is formed and the underlying layer (see Figure 1).

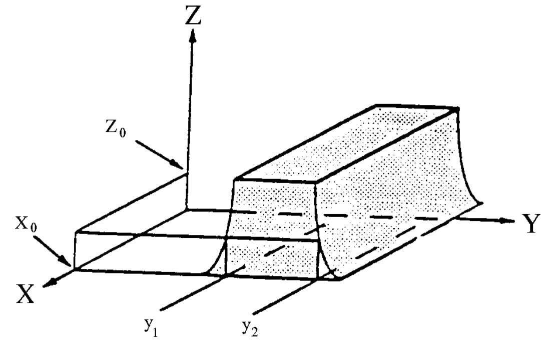

Figure 1
Linewidth (X_0, Z_0) = Y_2 - Y_1

NOTE: The physical basis for various methods of measuring linewidth may result in the measurements being carried out at differing heights for the same line at the same cross-section. For this reason, substantial method-dependent differences in measurement results may be expected and it is convenient to identify the method used in expressions such as "SEM linewidth," "optical linewidth," or "electrical linewidth" (ASTM F 127). Furthermore, the height at which the measurement is taken shall be qualitatively stated, even if it cannot be quantitively determined.

feature — areas within a single, continuous boundary (for example, an aggregate image) that have an optical-density value (gray-level range), that is distinct from the background area outside the feature (ASTM D 3849, D 24) (e.g., the simplest element of a pattern, such as a single line, space, or L-bar).

feature group — a small assembly of one or more similar features arranged together, such as three nested L-bars.

nominal feature dimension — the linear dimension of interest, such as the linewidth or contact hole width.

basic cell — an arrangement of features or groups, as defined by this document, based upon a specific, nominal-feature dimension.

composite cell — an arrangement of several basic cells.

isolated line — a clearfield, dark line as shown in Figure 2 (SYN: island).

Figure 2
Isolated Line

isolated space — A darkfield, clear line as shown in Figure 3 (SYN: window, trench, contact, opening).

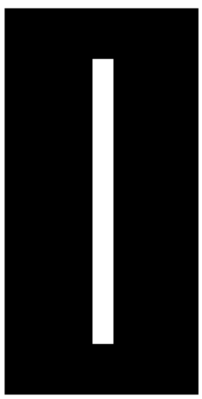

Figure 3
Isolated Space

2 Detail Specification

2.1 *Introduction*

2.1.1 This specification describes the pattern cells, which are illustrated in the figures at the end of this document. These cells are to be placed photolithographically or by other direct patterning methods onto wafer substrates at different masking levels during the IC manufacturing process.

2.1.2 Many details of the pattern cells, such as the orientation, magnitude, range of the linewidths, and polarity of tone (clearfield vs. darkfield) will be defined by the user, unless otherwise noted. When reporting results based on tests using these cells, details such as field polarity, orientation, and topographic considerations must be indicated.

2.1.3 All critical dimensions given in this document are the actual CAD values at 1X. For a given magnification, M, the target dimensions on the reticle should be exactly M times the dimension given in this specification. The reticle dimensions must not be sized to compensate for any wafer process-induced bias.

2.2 *Applications*

2.2.1 These cells are intended to be used in several applications. The following applications list some of the intended uses for the pattern cells.

2.2.1.1 *in-line process monitoring* — To establish patterns to determine if the layer has been processed to design specifications.

2.2.1.2 *process transfer* — To standardize the patterns for process monitoring within manufacturing fabrication sites and to facilitate process and technology transfers between sites.

2.2.1.3 *equipment evaluation* — To standardize the patterns used to evaluate semiconductor equipment.

2.2.1.4 *equipment characterization* — To standardize the patterns for the characterization process of different metrology equipment.

3 Guidelines for Applications

3.1 *General*

3.1.1 The cells described here represent a primary metrology set from which composite patterns may be constructed.

3.1.2 A composite pattern set meets this standard if it consists of any number of the basic cells described herein, provided all design rules for each cell are obeyed.

3.1.3 Each basic cell contains a fundamental design feature. This feature may be repeated at different (user-defined) dimensions within a modified metrology cell. The user will determine all appropriate dimensions for the feature as they apply to specific processing/equipment situations.

3.1.4 The figures provided within this document are intended to illustrate the proper layout of each pattern cell and to define the appropriate design elements used within each basic cell. The pattern cell dimensions are provided when appropriate.

3.1.5 All feature groups must be separated by at least five times the largest feature width. This proximity rule is defined in order to ensure that patterns intended to be independent are indeed non-coupled.

3.1.6 Labels, border lines, indicator marks, or any other adjacent feature will be separated by a minimum of 5 µm.

3.1.7 A label to indicate the nominal feature width must be placed near each basic cell, except the linearity cell, which has no user-defined features. The units of the CD labels must be micrometers and at least two significant figures must be used. The labels must be of a clearly printable size. Decimal points are optional. If decimal points are eliminated, digits to the left of the imaginary decimal point must be slightly larger than those digits to the right. Characters to the left of the decimal are optional. All CD labels that are printed with one size only will correspond to numbers less than 1.0 µm, and any number greater than 1.0 µm must contain at least one character to the right of the decimal place. If the cell includes a bias, a label to indicate this bias, including a "+" sign, must be placed near the basic cell. One significant figure may be used for bias labels if the bias is less than 1.0 µm and a multiple of 0.1 µm. (e.g., + 4 = + 0.4 µm).

3.1.8 It is recognized that there are design limitations dictated by the equipment used to generate the pattern (e.g., CAD grids, PG rectangles, E-beam spot sizes). It is permitted within this standard to modify these cells in order to meet these equipment limitations (e.g., stay on grid).

3.2 *Specific*

3.2.1 *L-Bar Cell* — (See Figure 4.)

3.2.1.1 The L-bar cell is designed to be a measurement site for isolated features as well as line and space groups in orthogonal axes. The cell can be used to measure the quality of pattern transfer and metrology of imaged features. The cell is also a qualitative visual test site for resolution of straight lines and lines bent at right angles.

3.2.1.2 The design elements are the nominal feature width, the inter-feature spacing, the minimum feature length, and the intergrouping linewidth difference (bias).

3.2.1.3 The basic cell consists of one or more groups of nested L-shaped lines at a specific pitch. The pitch is defined at twice the nominal feature width. (See Figure 5.)

W_0 = Nominal feature width

S = Interfeature spacing

L = Nominal feature length

W_0-W_1 = Intergrouping linewidth difference (bias)

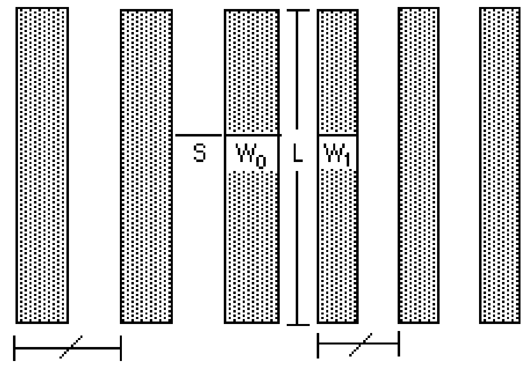

Figure 5

Table 1

Nominal Feature Width	*Number of Nested L-bars*	*Minimum Length*
>1 µm	3	10 W_0
≤1 µm	5	10 µm

The center L-bar of each group shall extend beyond the ends of the other L-bars by at least 10 µm. If these cells are to be used for cross-section analysis, the length of the L-bars may be designed considerably longer than the minimum length.

3.2.1.4 The L-bar basic cell consists of one, three, five, or seven feature groups. If the basic cell only consists of a single feature group, then the lines and spaces must both be equal to the nominal feature width. If the basic cell consists of three, five, or seven groups, then the groups are nested. For the middle group, the lines and spaces must both be equal to the nominal feature width. The feature widths in each successive feature group nested outside the middle group are incrementally increased by the bias. The feature widths in each successive feature group inside the middle group are incrementally decreased by the bias. The pitch for all L-bar groups within a basic cell must be held constant and equal to twice the nominal feature width.

3.2.2 *Straight-Line Cell* — (See Figure 6.)

3.2.2.1 The straight-line cell is a version of the L-bar cell, modified for tilted SEM inspection by removing the elbows.

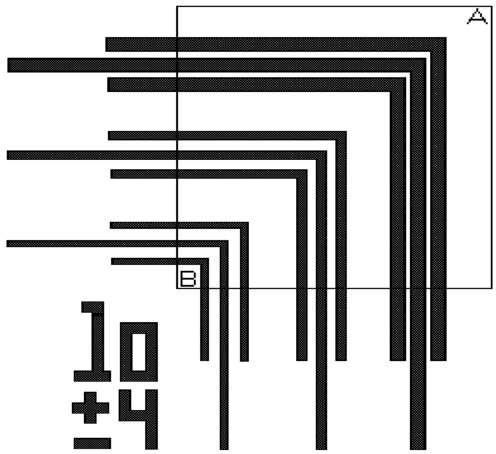

Figure 7
The square area, shown above, is removed to create straight-line cell.

3.2.2.2 To create the straight-line cell from the L-bar cell, the area removed will be a square defined by two diagonal corners referred to as "A" and "B" in Figure 7. Corner "A" is the outer edge of the outermost elbow. Corner "B" is a point inside the innermost elbow whose distance to the nearest edge is five times that of the smallest CD — or 5.0 µm if the smallest CD is less than 1.0 µm. This square area must remain unpatterned.

3.2.3 *Proximity Dagger Cell* — (See Figure 8.)

3.2.3.1 The proximity dagger cell is designed to provide information on the proximity effects of isolated lines/spaces in relation to large area blocks. This cell design allows clear and dark features to be measured simultaneously in one layout.

3.2.3.2 The design elements within the cell are the nominal feature linewidth, the nominal feature spacewidth, and the staircase stepwidth. The stepwidth is user-selected, but it is recommended to be at least 25% of the nominal feature pitch (i.e., pitch equals nominal linewidth plus nominal spacewidth).

3.2.3.3 The cell consists of a nine-tier staircase reproduced symmetrically in both clear and darkfields. A full description of the clearfield staircase (i.e., large chrome islands) is given. The same descriptions apply for the darkfield staircase except the polarities are reversed. Each tier is 10 microns tall. The full width of the cell is 40 microns and the full height is 180 microns. The first tier separates the nominal feature width symmetrically from the large chrome islands by an amount equal to the nominal width. Tiers 2–7 are successively wider by the indicated bias. The 8th and 9th tiers will be 5 and 10 times the nominal feature width respectively.

3.2.4 *Contact Array Cell* — (See Figure 9.)

3.2.4.1 The contact array cell is designed to provide resolution and proximity-effect information over a wide range of contact sizes.

3.2.4.2 The design elements are the nominal square contact dimension, the inter-contact dimension within the 5 × 5 and the 3 × 3 arrays. The latter dimension will be equal to the contact dimension.

3.2.4.3 The contact array cell will consist of three subgroups: a 5 × 5 contact array, a 3 × 3 contact array, and an isolated contact. The 5 × 5 array will produce the maximal proximity (i.e., dense printing) for the center contact. The center contact in the 3 × 3 array will exhibit proximal printing effects different from both the isolated contact and the dense contact.

3.2.5 *Staggered Contact Array* — (See Figure 10.)

3.2.5.1 The staggered contact array cell is designed to improve the probability of cross-sectioning small contacts for SEM metrology analysis.

3.2.5.2 The design elements are the square contact dimension, the column-to-column vertical offset — or staggering — and the contact-to-contact spacing. The contact-to-contact spacing will be equal to the square contact dimension.

3.2.5.3 The contacts are laid out using a minimum of three columns of contacts. The user-selected offset between columns should allow the contacts to remain on grid.

3.2.5.4 The lines (or spaces) shown on the left side of Figure 10 are optional. They have been placed to provide feature identification of pitch calibration. If the widths are to be submicron, 5 lines (or spaces) instead of 3 will be required.

3.2.6 *Linearity Cell* — (See Figure 11.)

3.2.6.1 The linearity cell is designed to test (1) the linearity of the measurement method, assuming the lithographical process is linear over all line sizes used, or (2) the linearity of the process, assuming that the metrological method is linear over all line sizes used.

3.2.6.2 The design elements of this cell are the linewidths, the interfeature spacing, and the minimum line lengths. Unlike the other cells, its elements are not adjusted to a nominal critical dimension, but rather are numerically specified as constants for all applications.

3.2.6.3 The cell consists of nine parallel lines, placed on a five-micron pitch. The linewidths are 1.2, 1.1, 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, and 0.4 microns. The line lengths are a minimum of ten microns. A two-micron top and bottom border (running orthogonal to the parallel lines, across the ends) is provided on the array to allow recognition of the cell as a unit.

3.2.7 *Electrical Cell* — (See Figure 12.)

3.2.7.1 The electrical cell is designed to provide very precise and relatively fast determinations of the average linewidth of a conductive film using an automated test system, but can also be used with a manual prober.

3.2.7.2 The design elements of this cell are the bridge resistor linewidth, W_b, the center-of-tap to center-of-tap bridge length, L_b, the sheet and bridge tap widths, W_c and W_t, the sheet and bridge tap lengths, L_c and L_t, the extension of the bridge resistor line to the nearest discontinuity in that line, L_e, and the size of the square sheet will be 35 – 100 µm. See Figure 13 for the labeling of these elements. The rules for these elements are as follows:

$W_t \leq W_b$ (for $L_b < 100\ W_b$)	(1)
$W_t \leq 1.2*W_b$ (for $L_b \geq 100\ W_b$ and W	(2)
$L_b \geq 15W_b$ for 80 µm, whichever is larger)	(3)
$L_t > 2W_t$	(4)
$L_e > 2W_b$	(5)
$L_c > 2W_c$	(6)

3.2.7.3 The cell consists of two types of four-point Kelvin structures: a van der Pauw sheet resistor and one or more bridge resisitors. The orientation of the individual bridge resistors is user-defined. The bridge resisitors also can be surrounded by dummy lines to measure the process bias due to proximity effect. On structures containing the dummy lines, the interconnects will hook up to the bridge resistor in a perpendicular fashion, as shown in Figure 14.

3.2.7.4 The pad labeled with a V in Figures 13 and 15 will be used for voltage measurement only, and will be used as the fourth point in the sheet resistivity measurements that will be used to make the linewidth determination.

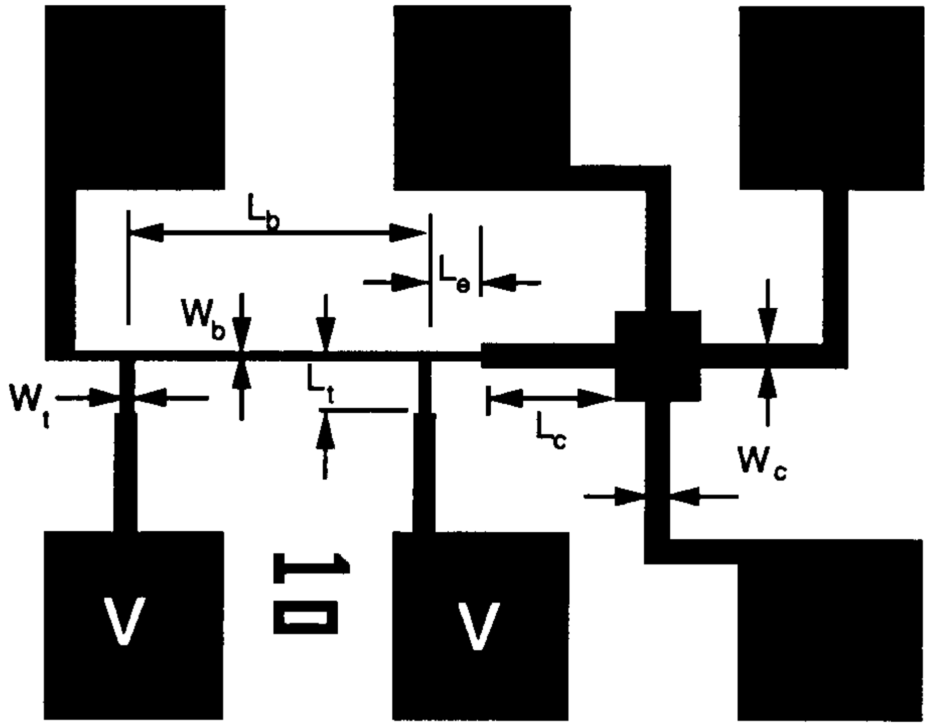

Figure 13
Electrical Cell, 2 × n Configuration with Labeling

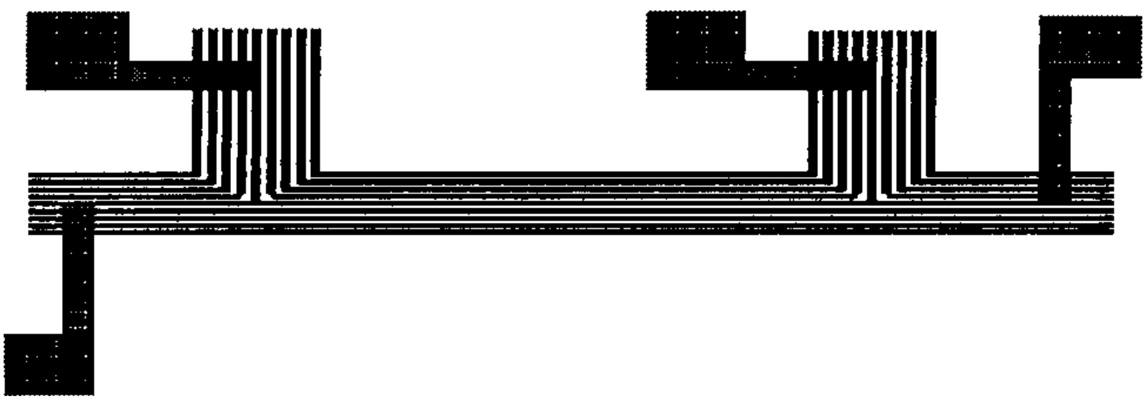

Figure 14
Blow-Up of Bridge Resistor with Proximity Lines

3.2.7.5 The pads can be arranged in a 1 × n layout for scribeline placement (see Figure 15), or the conventional 2 × n layout can be used if the spatial constraints are minimal. Pad size and pitch are user-defined. For automatic testing in a production environment, it is recommended that the pads be 80 – 100 mm per side.

3.3 *User Considerations*

3.3.1 *Target CD versus Resolved CD*

3.3.1.1 The desired size of a critical dimension (CD) on an integrated circuit can be considered its nominal value and is herein designated the "target CD." The size actually achieved (resolved CD) on the circuit may be different from this nominal value.

3.3.1.2 Measurements of the resolved CD may not be accurate because of the difficulty in determining the actual location of the edge in the optical or SEM image profile.

3.3.1.3 Even if inaccurate, measurement of the resolved CD can be valuable for comparison purposes if the measurement method has adequate precision and sensitivity to detect the dimensional changes of interest.

3.3.1.4 The traditional definition of resolution may not be adequate (e.g., ability to distinguish closely spaced points) for specifying the sensitivity to small dimensional changes.

4 References

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4.4 Buehler, M.G., Hershey, C.W., "The Split-Cross-Bridge Resistor for Measuring the Sheet Resistance, Linewidth, and Line Spacing of Conducting Layers," IEEE Transactions on Electron Devices, (1986), 1572.

4.5 Lin, Burn J., "Proximity and Astigmatism Tolerant Testsites for Electrical Linewidth Measurement," SPIE Proc., Vol. – (1989).

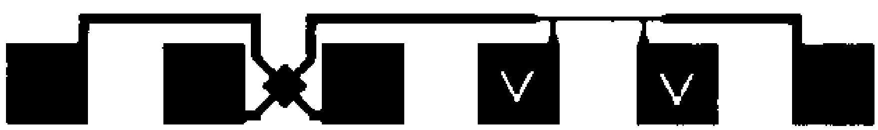

Figure 15
Electrical Cell, 1 × n Configuration

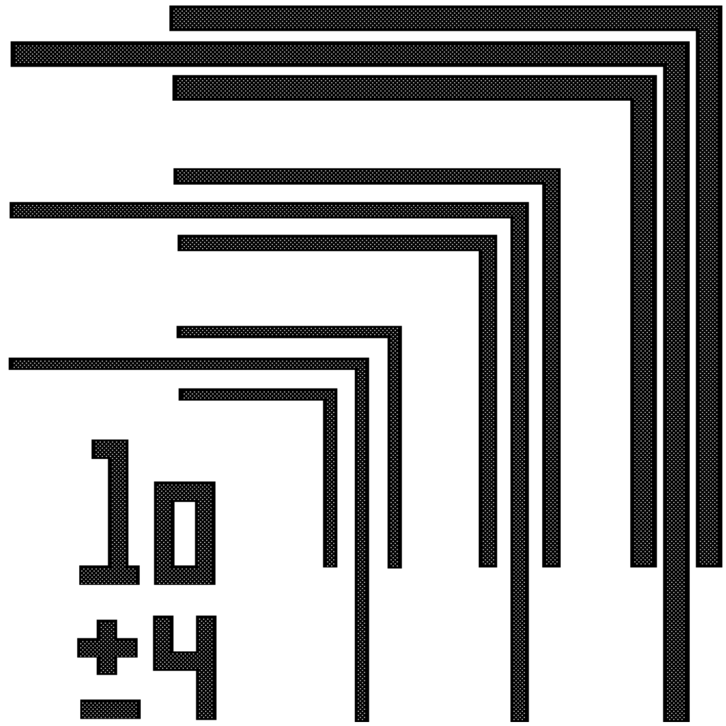

Figure 4
L-Bar Cell

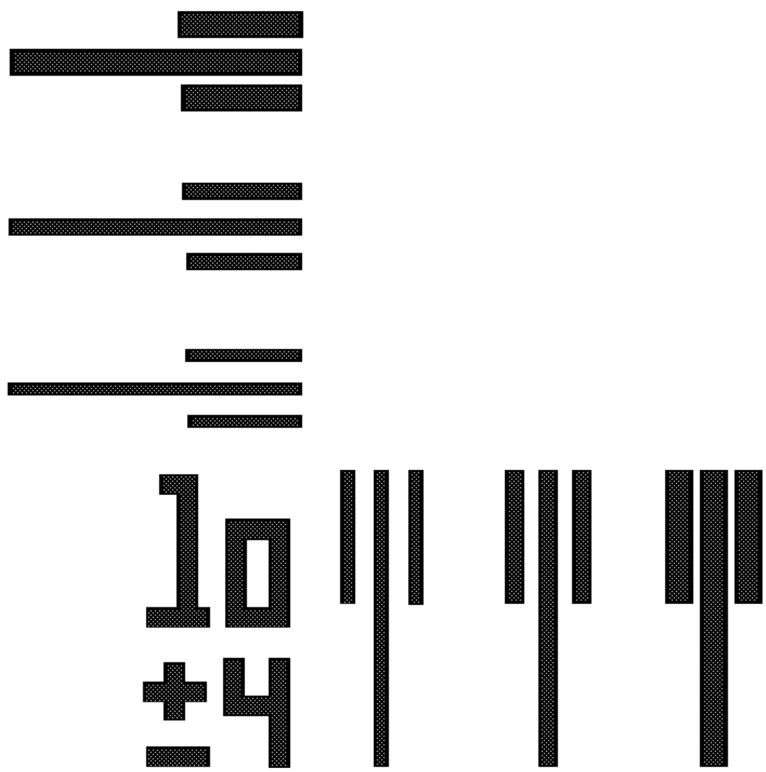

Figure 6
Straight Line Cell

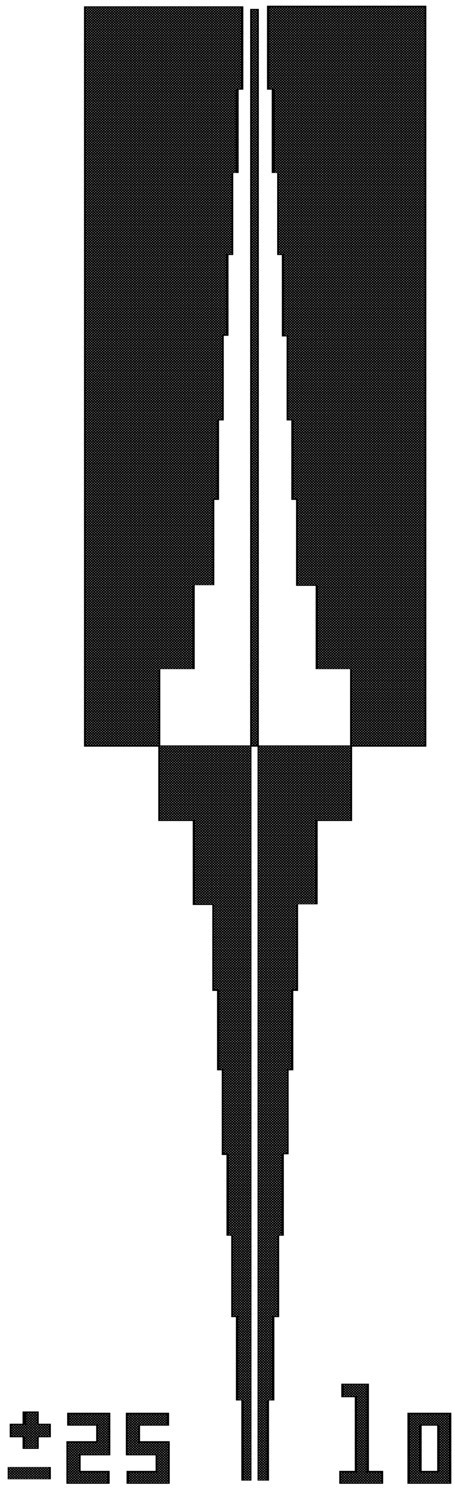

Figure 8
Proximity Dagger Cell

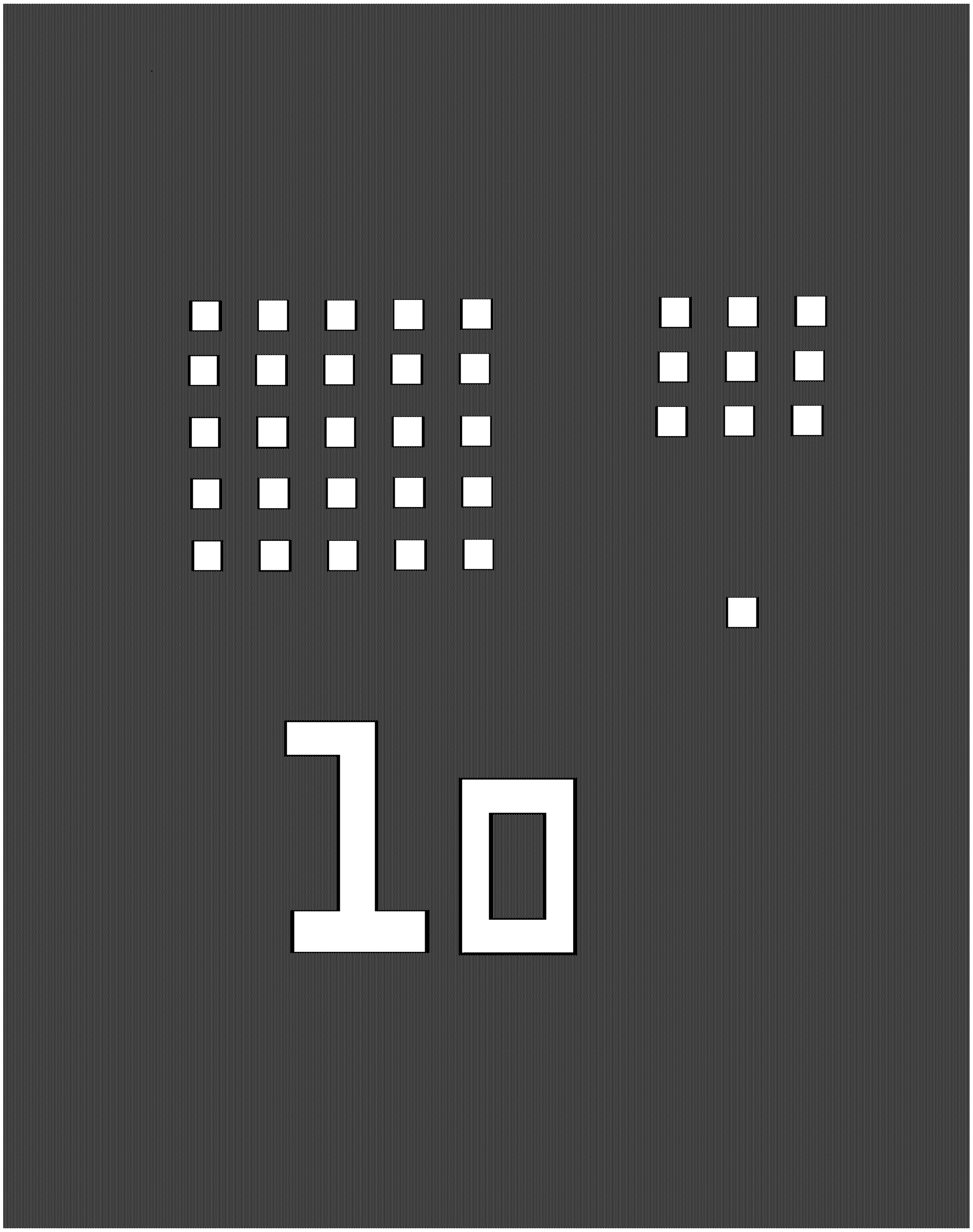

Figure 9
Contact Array Cell

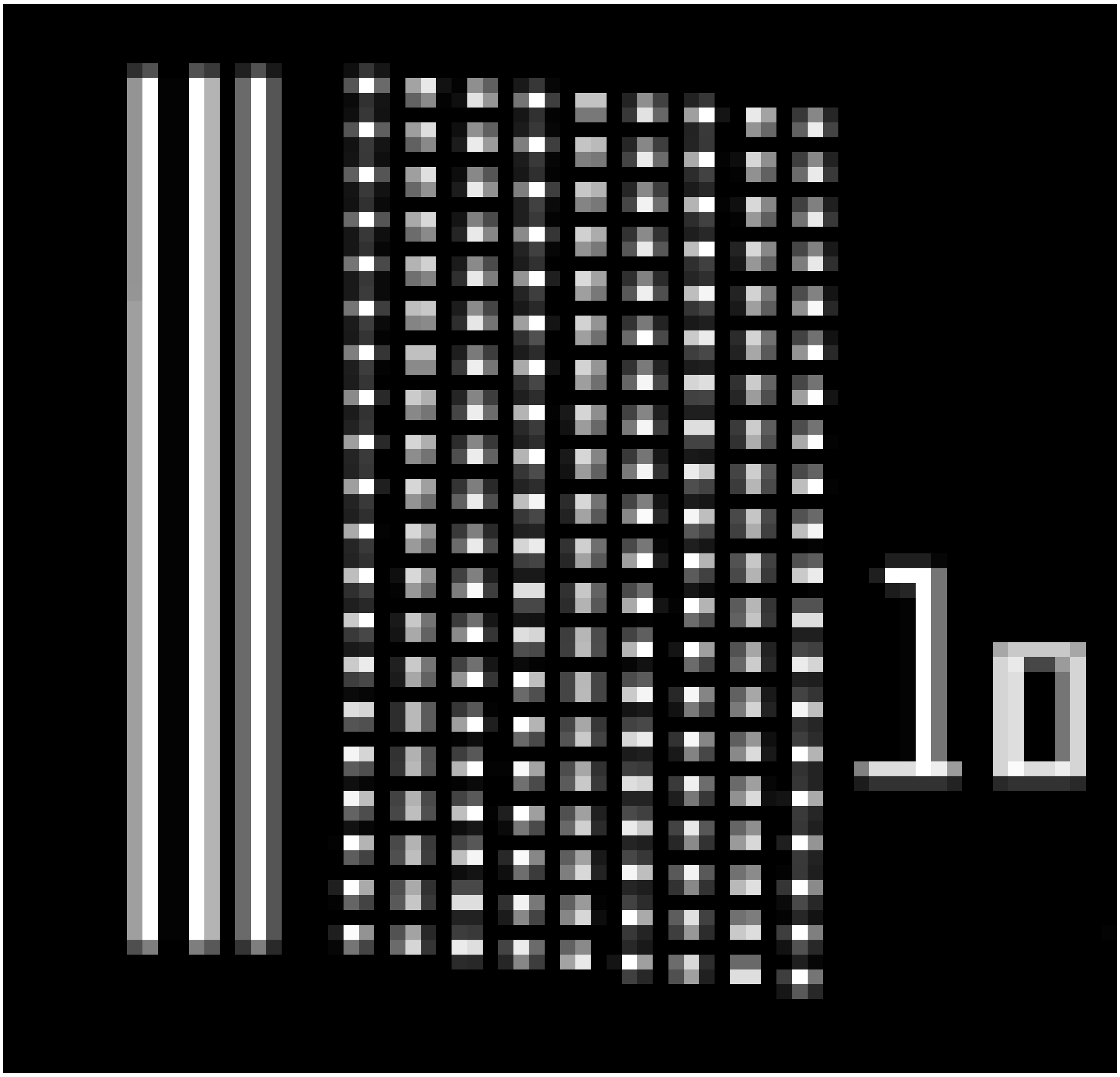

Figure 10
Staggered Contact Array

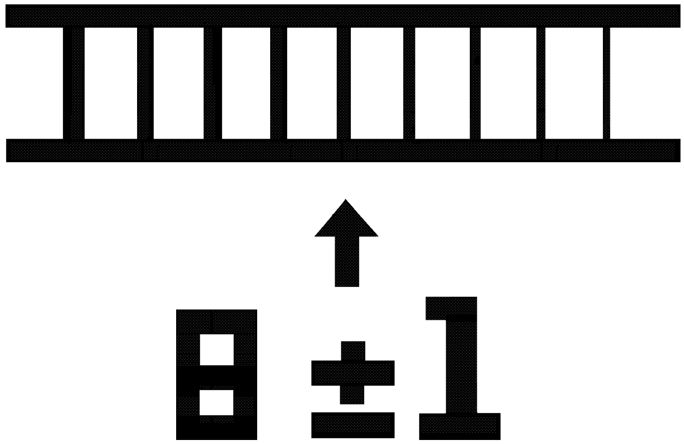

Figure 11
Linearity Cell

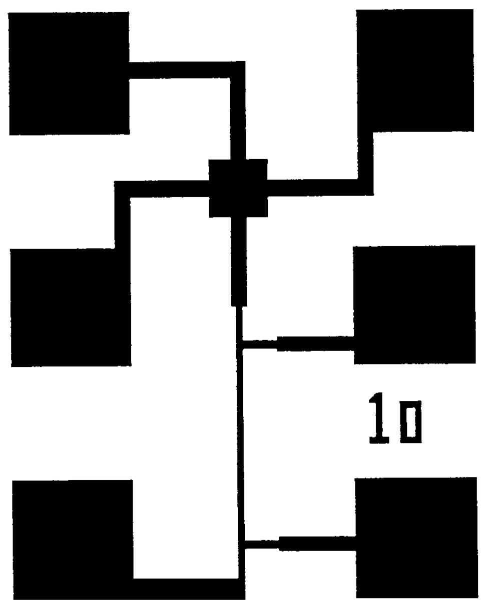

Figure 12
Electrical Cell, 2 × n Configuration

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The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI P20-92
GUIDELINE FOR CATALOG PUBLICATION OF EB RESIST PARAMETERS (PROPOSAL)

1 Purpose

The purpose of this guideline is to provide a baseline for publications of EB resist parameters. It can also be used as a guide to evaluate resist process parameters. This guideline is intended to be applicable for electron beam processes.

The parameters for EB Resist publication are discussed below.

2 Resist Commercial Name

Describe resist commercial name.

3 Resist Properties

3.1 *Polymer Properties*

3.1.1 *Components* — Describe resist components. Chemical structure is not necessarily required.

3.1.2 *Molecular Weight* — Describe M_w, Mn and M_w/Mn if known.

3.1.3 *Thermal Characteristics* — Describe Tg and Tm.

3.2 *Resist Solution Properties*

3.2.1 *Solvent* — Specify chemical names.

3.2.2 *Viscosity* — Solution viscosity, cP, 25°C.

3.2.3 *Solid Content* — Weight %.

4 Film Forming Properties

4.1 *Thickness Curves* — Plot film thickness T (µm or Å) after prebake versus spinning speed R (rpm). Here, x axis is log (R) and y axis is log (T).

4.2 *Conditions* — Specify following conditions.

4.2.1 *Substrate* — Silicon wafer or chrome mask blank. Specify its structure.

4.2.2 *Spinning Conditions* — Specify spinning conditions including coating sequence.

4.2.3 *Environmental Conditions* — Temperature (°C), relative humidity (%).

4.2.4 *Prebake Conditions* — Prebaking temperature (°C), time (sec), heating and cooling method and apparatus. Specify heating rate and cooling rate if monitored.

4.2.5 *Thickness Measurement Methods* — Thickness measurement instruments and measurement method. In case of a light interferance thickness measurement apparatus, specify the refractive index as a parameter used in the measurement.

5 Film Thicknesses

Defines resist thicknesses and measurement conditions for resist parameter descriptions in and after Section 9. Unit is µm or Å.

5.1 *Film Thickness Definitions*

5.1.1 *Ti* — Initial thickness after prebake prior to exposure.

5.1.2 *Te* — Exposed region thickness after development.

5.1.3 *Tu* — Unexposed region thickness after development, and after postbake if required.

5.1.4 *NTe* — Te/Ti. Normalized exposed region thickness.

5.1.5 *NTu* — Tu/Ti. Normalized unexposed region thickness.

5.2 *Thickness Measurement Conditions* — Thickness measurement conditions should be the same as described in Section 4.2.5. In case of measurements of exposed region thickness, exposed region area should be larger than 20 µm on all sides.

6 Sample Preparation

Defines sample preparation methods for resist parameter descriptions in and after Section 9.

6.1 *Film Thickness* — Ti. 0.50 ± 0.20 µm (5000 ± 200 Å) is recommended for a standard thickness.

6.2 *Conditions* — Specify conditions described in Sections 4.2.1 to 4.2.4.

7 Exposure

Defines exposure condition description methods for resist parameter descriptions in and after Section 9.

7.1 *Exposure Dosage Definition* — Quantity of electrical charge per unit area, $\mu C/cm^2$. Describe as D.

7.2 *Exposure Dosage Calculation* — Calculate as follows.

$D = I \times t/S \times 10^6$

Here, I is current (Å), t is exposure time (sec), S is exposure area (cm^2).

Specify these parameters.

7.3 *Acceleration Voltage* — In a range from 10 to 50 kV.

7.4 *Exposure System* — Specify exposure methods.

7.4.1 *Beam Scanning Methods* — For example, raster scanning or vector scanning. Specify beam scanning pitch if defined.

7.4.2 *Beam Shape* — Describe beam shape.

7.4.3 *Beam Conditions* — Specify beam size (µm or **A**) and current density (**A**/cm^2), if possible.

7.4.4 *Exposure Tool Manufacturer and System Name* — Specify exposure tool manufacturer and system name, if possible.

8 Processing and Developing Parameters

This section defines process condition descriptions in and after Section 9.

8.1 *Post Exposure Treatments* — Describe if any treatment is processed after exposure before development.

8.1.1 *Methods* — For example, post exposure bake.

8.1.2 *Conditions* — For example, treatment conditions such as temperature (°C), time (sec), atmosphere, heating method, cooling method and apparatus. Specify heating rate and cooling rate if monitored.

8.2 *Developing Parameters*

8.2.1 *Methods* — Specify spray, dip, or puddle.

8.2.2 *Solution Components* — Specify name of developer and rinse. (Chemical names and weight percent if possible.)

8.2.3 *Temperature* — °C

— For spray, bulk temperature. Processing chamber atmospheric temperature if monitored.
— For dip, solution temperature.
— For puddle, bulk temperature. Processing chamber atmospheric temperature and substrate temperature if monitored.

8.2.4 *Time* — sec.

8.2.5 *Relative Humidity* — %.

8.2.6 *Additional Processes* — Specify if applied.

8.3 *Post bake*

8.3.1 *Conditions* — Temperature (°C), time (sec), heating method, cooling method, and apparatus. Specify heating rate and cooling rate if monitored.

8.3.2 Describe treatment conditions before or after post baking, if applied.

9 Sensitivity Curves

9.1 *Curve Plotting* — Plot NTe as a function of D. Here, x axis is log (D), y axis is NTe.

9.2 *Exposure Dosage Range*

9.2.1 *Positive Resist* — Include dosages larger than a dose gives NTe of 0.

9.2.2 *Negative Resist* — Include dosages larger than a dose gives NTe of 0.7.

10 Sensitivity

A dose required to form a pattern larger than 20 µm on all sides.

10.1 *Positive Resist* — Describe as Dp^0. It gives NTe of 0.

10.2 *Negative Resist* — Describe as $Dn^{0.5}$. It gives NTe of 0.5.

11 Contrast

11.1 *Contrast Definition* — Describe as γ. Calculate from a slope of resist sensitivity curve.

11.2 *Positive Resist (Figure 1)* — Calculate using an angle given from a solid line between NTe of 0 and NTe of 0.8 and a solid line parallel to x axis. Here, NTu should be larger than 0.9.

$$\gamma_p 0-0.8 = \tan\theta = y/x = 0.8/\log\ (Dp^0/Dp^{0.8})$$

11.3 *Negative Resist (Figure 2)* — Calculate using an angle given from a solid line between NTe of 0.5 and NTe of 0.7 and a solid line parallel to x axis.

$$\gamma_n 0.5-0.7 = \tan\theta = y/x = 0.2/\log\ (Dn^{0.7}/Dn^{0.5})$$

12 Resolution

12.1 *Pattern Type and Feature Size* — Lines and spaces. Ratio of lines and spaces should be 1:1. Add hole pattern and isolated pattern if possible.

12.2 *Conditions* — Specify conditions in Sections 6, 7, and 8.

12.3 *Measurement Method* — Measure resolutions using a scanning electron microscope.

13 Nominal Exposure Dosage

13.1 *Nominal Exposure Dosage Definition* — A dose which gives lines and spaces of 3 µm at a ratio of 1:1 under conditions described in Sections 6, 7, and 8.

14 Others

Describe following items if known.

14.1 *Durability* — Wet etching, dry etching.

14.2 *Stability* — Shelf stability, spun film stability, post exposure stability, and post processing stability.

14.3 *Removability* — Describe resist removing method after processing.

14.4 *Remarks* — Describe special characteristics of the EB resist.

14.5 *Cautions* — Describe cautions for safety.

(Reference) G.N. Taylor, Solid State Technology, June (1984) 105.

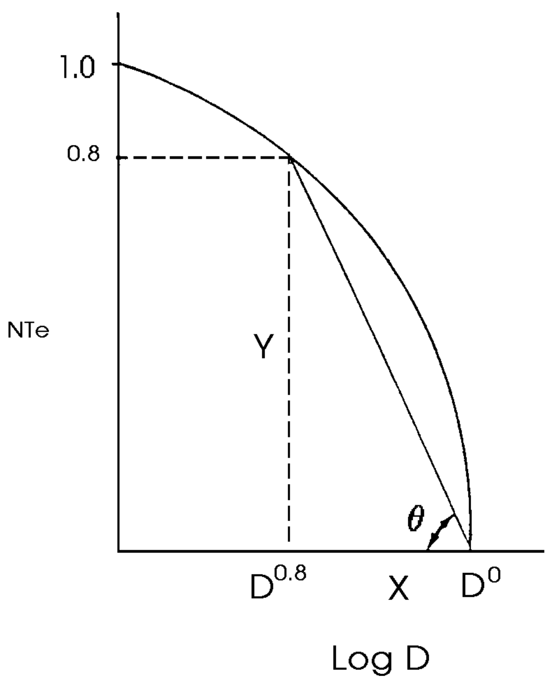

Figure 1
Positive Sensitivity Curve

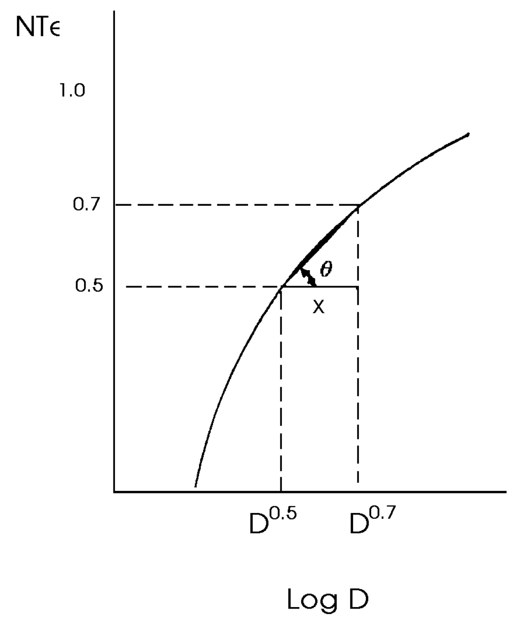

Figure 2
Negative Sensitivity Curve

SEMI P21-92
GUIDELINES FOR PRECISION AND ACCURACY EXPRESSION FOR MASK WRITING EQUIPMENT

1 Preface

This guideline describes general requirements concerning precision and accuracy expression of mask writing equipment. Writing accuracy of the mask writing equipment is evaluated by measuring a written mask, and is affected greatly by process conditions to be carried out. Therefore, the writing conditions are to be agreed upon by the user and supplier.

2 Precision and Accuracy Expression Items, Definitions, Measurement, and Requirements

2.1 *Minimum Pattern*

2.1.1 *Definition*

— The minimum line and space pattern and minimum pattern which is possible to be separated

2.1.2 *Expression*

— SEM photograph

2.1.3 *Measurement*

— SEM photograph of the resist pattern or the chrome pattern

2.2 *Pattern Dimension Precision and Accuracy*

2.2.1 *Definition*

— Critical Dimension (CD) variation and deviation of written pattern from designed value.

2.2.2 *Expression*

— Deviation of measured mean value to design value (Δl:μm) and variations (3 σ:μm)

— Measured area and number of sampling point should be clearly described.

2.2.3 *Measurement*

— Optical CD measurement

— Electron beam CD measurement

— CD measurement done by self diagnostic feature of writing equipment

2.2.4 *Requirement*

— Width of a long line pattern in X and Y direction should be measured.

— Pattern types are isolated pattern, 1:1 line and space pattern, or 1:2 line and space pattern.

— The line width to be measured is not specified, but at least three different line widths should be measured.

— Examples of patterns are shown in Figures 1 and 2.

2.3 *Overlay Accuracy*

2.3.1 *Definition*

— Relative deviation of pattern position between two masks

2.3.2 *Expression*

— 3σ:μm (X and Y direction separately)

— Measured area and number of sampling points should be clearly described.

2.3.3 *Measurement*

— Optical coordinates measurement

— Electron beam coordinates measurement

— Coordinates measurement done by self diagnostic feature of writing equipment

2.3.4 *Requirement*

— The pattern should be cross or L mark. Uniform rotation error in measurement should be subtracted from the measurement result.

— Overlay accuracy between different cassette should be clearly described. An example of a pattern is shown in Figure 3.

2.4 *Pattern Stitching Accuracy*

2.4.1 *Definition*

— Position errors at the stitching boundary of writing fields, stripes, and shots.

2.4.2 *Expression*

— |average value| 1 + 3 σμm (X and Y direction separately) measured area and number of sampling points should be clearly described.

2.4.3 *Measurement*

— Optical coordinates measurement

— Electron beam coordinate measurement

— Coordinates measurement done by self diagnostic feature of writing equipment

— Vernier measurement

— Boundary measurement by SEM image

2.4.4 *Requirement*

— The pattern should be cross or L marks in both sides adjacent to the stitching boundary for coordinate measurement

— When the optical microscope is used for measurement, the vernier pattern should be used.

3 Notice

The following subjects should be agreed upon beforehand between users and makers in order to evaluate the above mentioned writing precision and accuracy item.

1. Process Requirements

— Resist Materials

— Coating Condition

— Development Condition

— Process Sequence

— Mask Substrate and Chrome Thin Film Materials

2. Test Pattern

3. Measurement Procedure

4 Others

The following items are not specified in these guidelines, but it is preferable that these items are agreed upon beforehand between user and supplier.

1. Pattern coordinates
2. Pattern position accuracy
3. Long term stability of accuracy
4. Particles

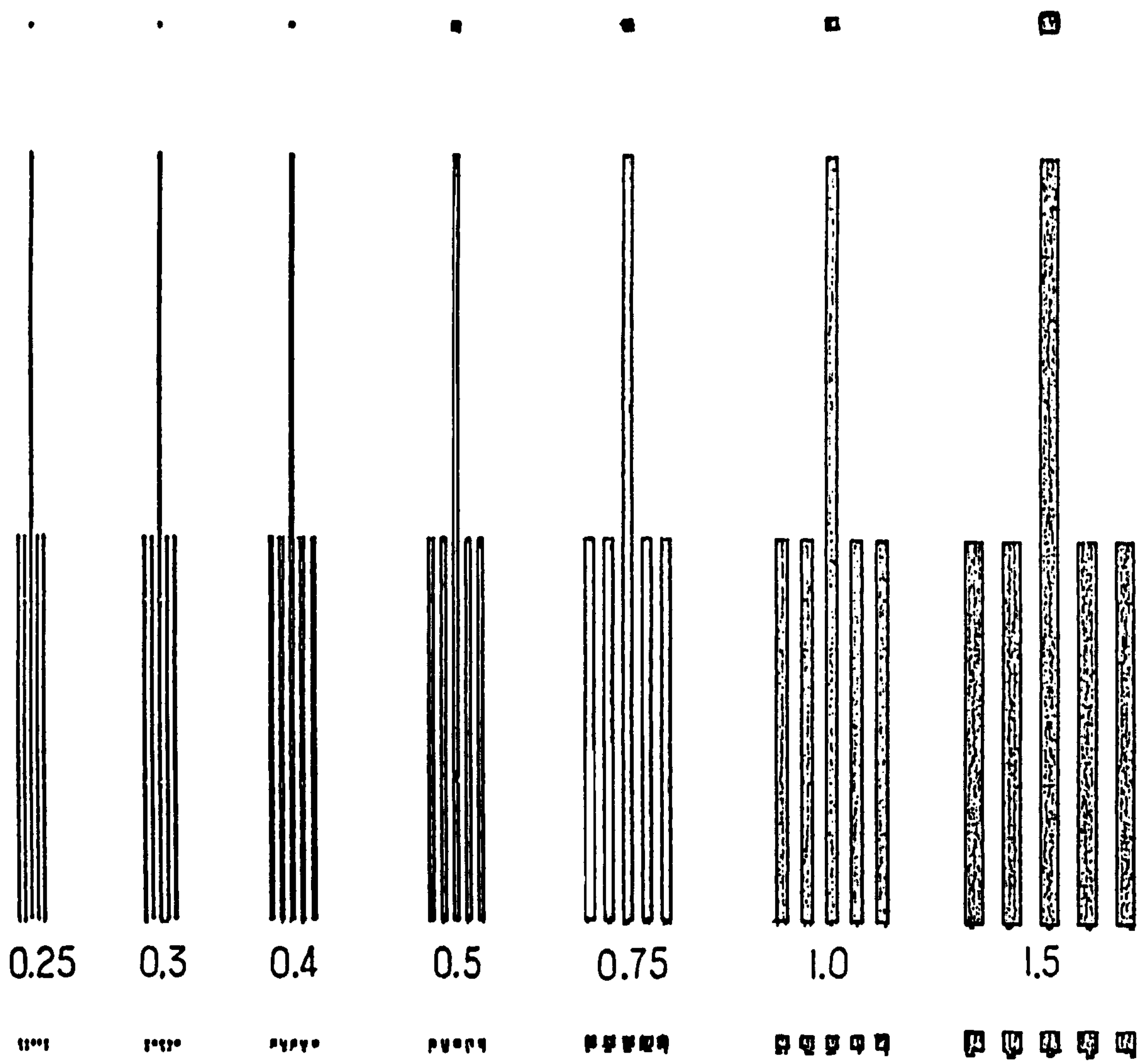

Figure 1

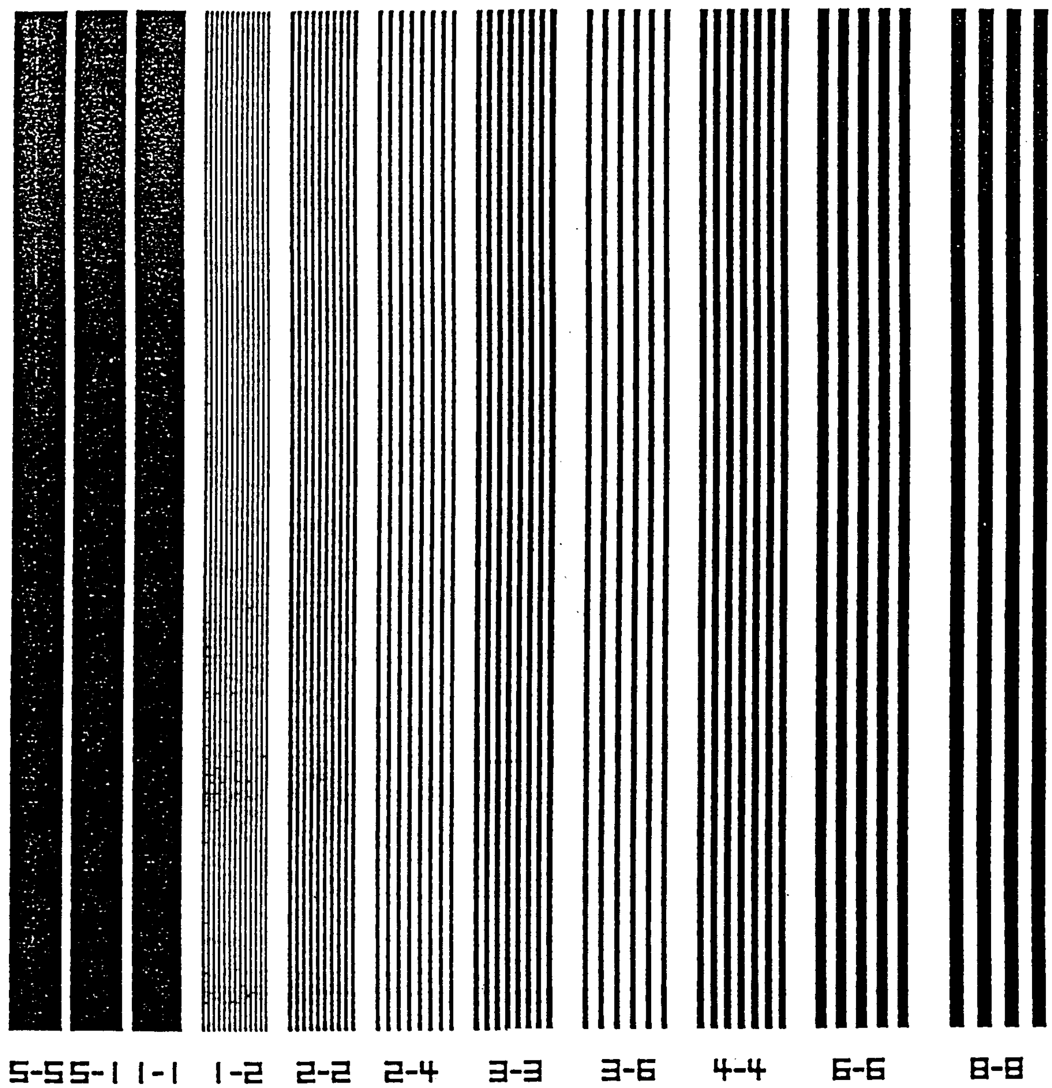

Figure 2

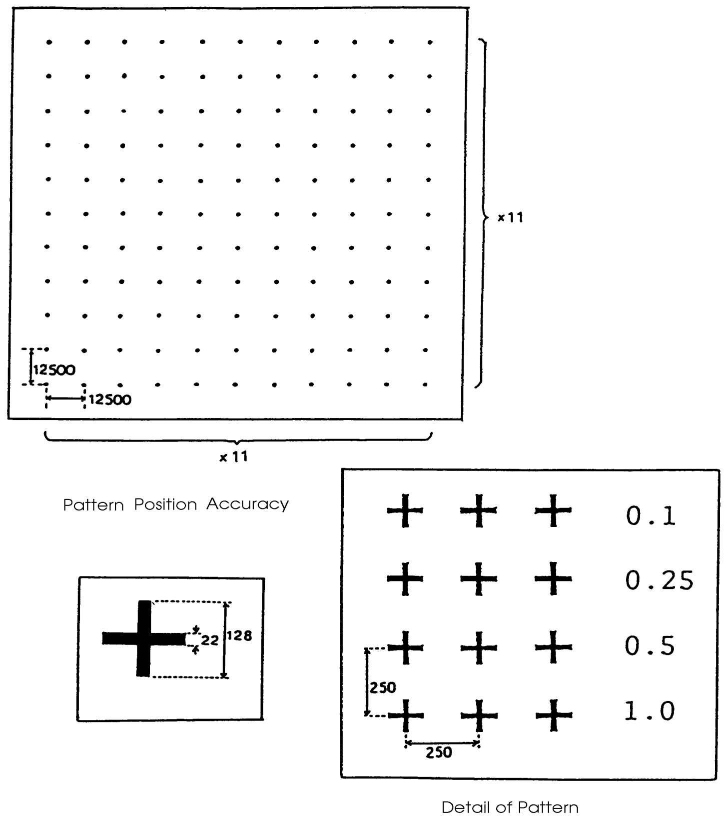

Figure 3

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI P22-0699
GUIDELINE FOR PHOTOMASK DEFECT CLASSIFICATION AND SIZE DEFINITION

This guideline was technically approved by the Global Mask & Mask Equipment Committee and is the direct responsibility of the Japanese Mask & Mask Equipment Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available at www.semi.org April 1999; to be published June 1999. Originally published in 1993.

1 Purpose

1.1 The purpose of this guideline is to establish standard nomenclature for photomask defect classifications, and to define defect sizing methods.

2 Scope

2.1 It is desirable to follow this guideline when discussing classification, nomenclature, and size of the photomask defects.

3 References

3.1 *SEMI Standard*

SEMI P33 — Provisional Specification For Developmental 230 mm Square Hard Surface Photomask Substrates.

4 Terminology

4.1 *design pattern* — pattern of intended design data.

4.2 *photomask pattern* — pattern on photomask surface.

4.3 Many terms relating to photomask technology can be found in SEMI P33.

5 Classification of the Mask Defect

5.1 *Mask Pattern Defects*

5.1.1 *Shape Defect* — a photomask pattern whose shape is different from its intended design pattern.

5.1.1.1 *Isolated Defect* — shape defects which are isolated from pattern.

1) Dot (See Figures 1, 23)

2) Hole (See Figure 2)

5.1.1.2 *Edge Defect* — shape defects which are adjacent to straight pattern edge.

1) Edge Extension (See Figures 3, 24)

2) Edge Intrusion (See Figure 4)

5.1.1.3 *Corner Defect* — shape defects which are adjacent to corners.

1) Corner Extension (See Figures 5, 27, 29)

2) Corner Intrusion (See Figures 6, 28, 30)

5.1.1.4 *Bridge* — shape defects which are adjacent to more than two edges.

1) Opaque Bridge (See Figures 7, 26)

2) Clear Bridge (See Figure 8)

5.1.2 *Size Defect* — a photomask pattern whose size is different from its intended design pattern.

1) Oversize (on opaque pattern) (See Figure 9)

2) Oversize (on clear pattern) (See Figure 10)

3) Undersize (on opaque pattern) (See Figure 11)

4) Undersize (on clear pattern) (See Figure 12)

5) Elongation (on opaque pattern) (See Figure 13)

6) Elongation (on clear pattern) (See Figure 14)

7) Truncation (on opaque pattern) (See Figure 15)

8) Truncation (on clear pattern) (See Figure 16)

5.1.3 *Misplacement Defect* — a photomask pattern whose placement is different from its intended design. (See Figures 17, 18, 25)

5.1.4 *Transmission Defect* — a photomask pattern whose transmission is different from its intended design.

1) Transmission Defect (on clear pattern) (See Figure 19)

2) Transmission Defect (on opaque pattern) (See Figure 20)

5.1.5 *Missing pattern defect* — a photomask pattern which is absent.

1) Missing opaque pattern (See Figure 21)

2) Missing clear pattern (See Figure 22)

5.2 *Glass Defect* — unwanted defect in (or on) a glass created by various undefined causes (e.g. sleek, pit, scratch, chip, striation, polishing mark, discolor, bubbles, etc.).

5.3 *Miscellaneous Defect* — unwanted clear or opaque spot created by various undefined causes (e.g., crystal growth, electrostatic damage, organic material deposit, Phase shift defect).

6 Definition of Size for Photomask Defects

6.1 The tools and conditions used to measure defect size should be clearly specified.

6.2 *Pattern Defects*

6.2.1 Shape Defects

6.2.1.1 *Isolated Defect* — defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the defect. (See Figures 1, 2, 23)

6.2.1.2 *Edge Defect* — defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the defect. (See Figures 3, 4, 24)

6.2.1.3 *Corner Defect* — defect size is expressed as the distance (S1) between the intersection point, formed by the bisection of the corner angle and the pattern, and the point designed. (See Figures 5, 6)

6.2.1.4 *Bridge* — defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the defect. (See Figures 7, 8, 26)

6.2.2 *Size Defects*

6.2.2.1 *Oversize and Undersize* — defect size is expressed as two dimensions (S1 and S2) representing the absolute value of the deviation from the intended design pattern.

S1 = | b - a |

S2 = | d - c |

"a" and "c" are intended value; "b" and "d" are actual measured value. (See Figures 9, 10, 11, 12)

6.2.2.2 *Elongation and Truncation* — defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the deviation from the intended design pattern. (See Figures 13, 14, 15, 16)

6.2.3 *Misplacement Defect* — defect size is expressed as the absolute value of X and Y displacement from its intended position. (See Figures 17, 18, 25)

6.2.4 *Transmission Defect* — transmission defects are evaluated by their transmissivity in addition to the size. The wavelength used for measurement should be clearly specified, as well as the transmissivity error (Te). Defect dimensions should be consistent with other definitions. (See Figures 19, 20)

Te = Td - Ti

where

Td = transmissivity of defect

Ti = intended transmissivity of design

6.2.5 *Missing Pattern Defect* — defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the intended design pattern. (See Figures 21, 22)

6.3 *Randomly Shaped Defects* — for the defects which all of above sizing method cannot be applied, defect size is expressed as two dimensions (S1 and S2) of the smallest rectangle that encloses the defect. (See Figures 23, 24, 27, 28, 29, 30)

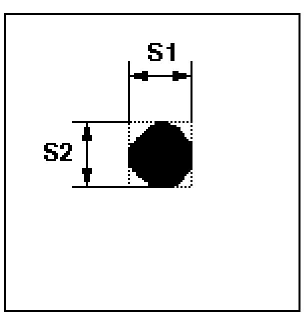

Figure 1

Dot

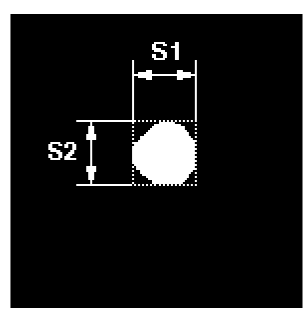

Figure 2

Hole

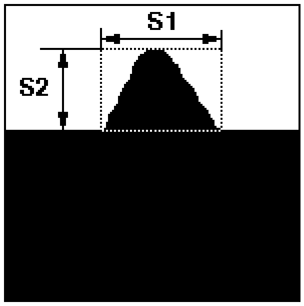

Figure 3

Edge Extension

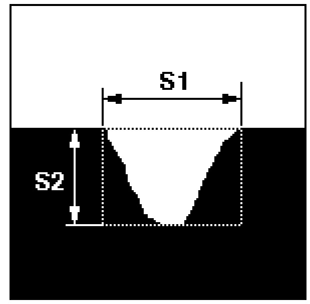

Figure 4

Edge Intrusion

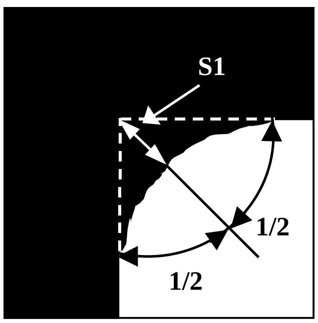

Figure 5

Corner Extension

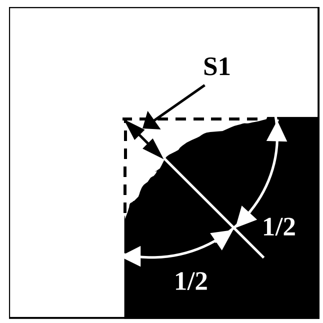

Figure 6

Corner Intrusion

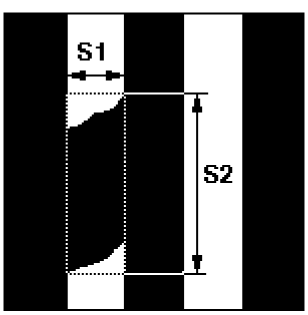

Figure 7

Opaque Bridge

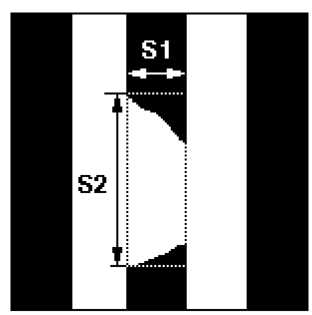

Figure 8

Clear Bridge

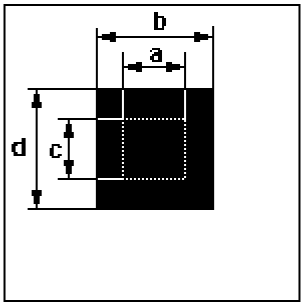

Figure 9

Oversize On Opaque Pattern

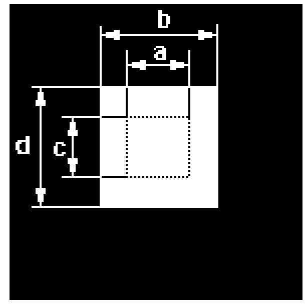

Figure 10

Oversize On Clear Pattern

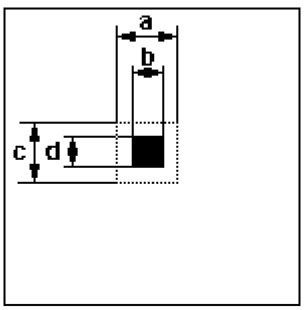

Figure 11

Undersize On Opaque Pattern

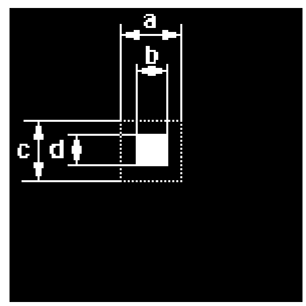

Figure 12

Undersize On Clear Pattern

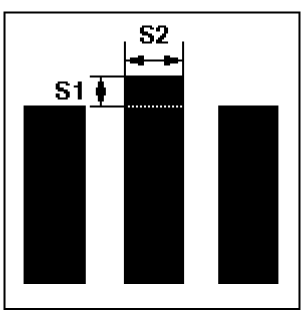

Figure 13

Elongation On Opaque Pattern

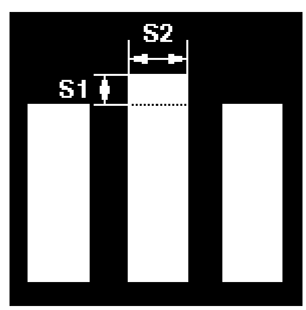

Figure 14

Elongation On Clear Pattern

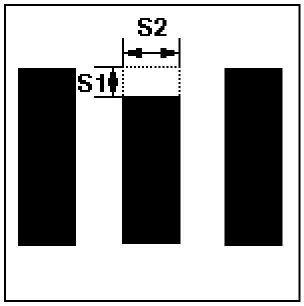

Figure 15

Truncation On Opaque Pattern

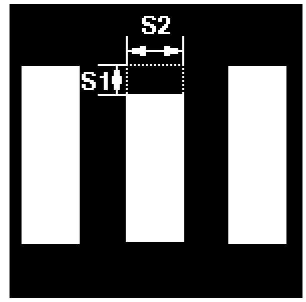

Figure 16

Truncation On Clear Pattern

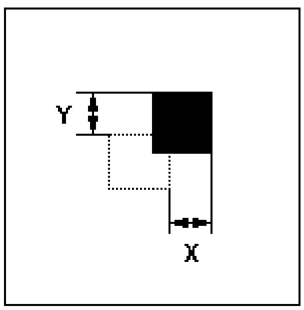

Figure 17

Misplacement On Opaque Pattern

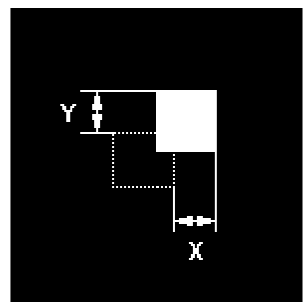

Figure 18

Misplacement On Clear Pattern

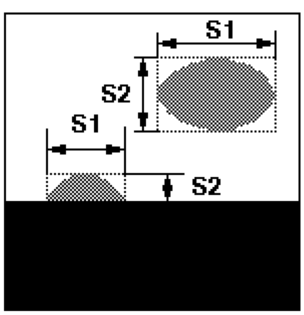

Figure 19

Transmission Defect On Clear Pattern

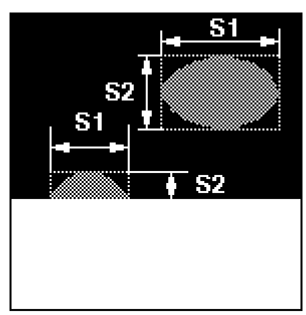

Figure 20

Transmission Defect On Opaque Pattern

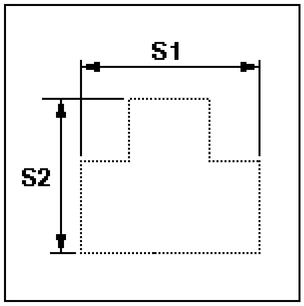

Figure 21

Missing Opaque Pattern

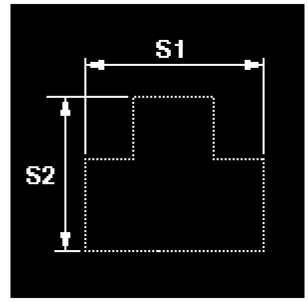

Figure 22

Missing Clear Pattern

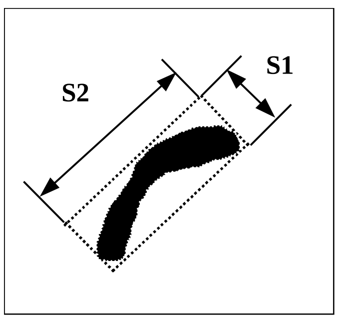

Figure 23

Dot Randomly Shaped

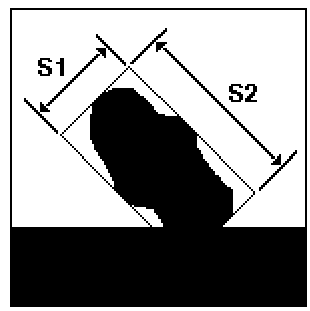

Figure 24

Edge Extension Randomly Shaped

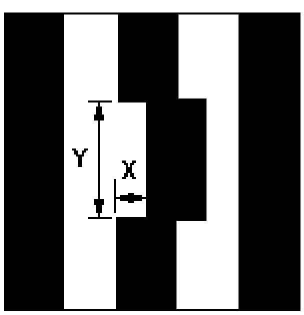

Figure 25

Misplacement On Opaque Pattern

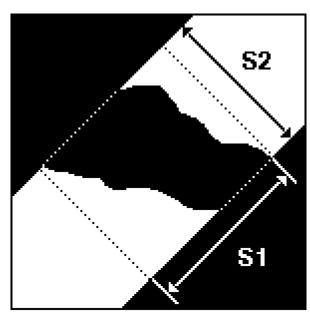

Figure 26

Opaque Bridge

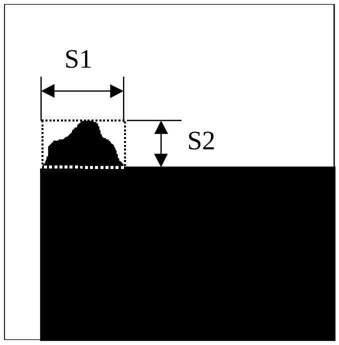

Figure 27

Corner Extension Randomly Shaped

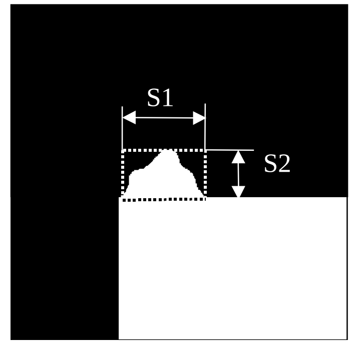

Figure 28

Corner Intrusion Randomly Shaped

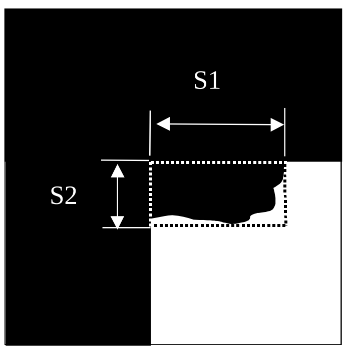

Figure 29

Corner Extension Randomly Shaped

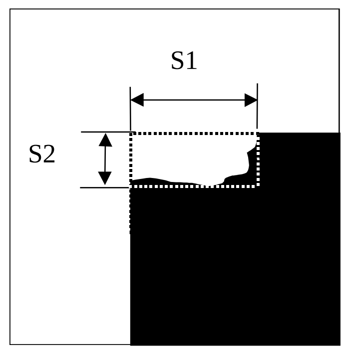

Figure 30

Corner Intrusion Randomly Shaped

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SEMI P23-0200
GUIDELINES FOR PROGRAMMED DEFECT MASKS AND BENCHMARK PROCEDURES FOR SENSITIVITY ANALYSIS OF MASK DEFECT INSPECTION SYSTEMS

These guidelines were technically approved by the Global Mask and Mask Equipment Committee and are the direct responsibility of the Japanese Mask and Mask Equipment Committee. Current edition approved by the Japanese Regional Standards Committee on September 10, 1999. Initially available at www.semi.org February 2000; to be published February 2000. Originally published in 1993; previously published in 1996.

NOTE: These guidelines were rewritten in their entirety in February 2000.

1 Purpose

1.1 The purpose of this guideline is to propose a test mask to be used for evaluation of the sensitivity of Mask Defect Inspection Systems. This test mask consists of test chips including programmed pattern defects and reference test chips without programmed defects. Since the test chip is an assembly of cells, the test chips are defined in this guideline by cell patterns, programmed defects in cell patterns, and the layout of the cells. Also, the test mask is defined by defining the test chips arrangement. Furthermore, the use of this mask is described. It is desirable that these test masks and benchmark procedures be used when the sensitivity of a Mask Defect Inspection System is evaluated.

1.2 *Background* — Different masks have been used by many equipment manufacturers and users in the past, and sensitivity has been tested by various methods decided independently by each manufacturer and user. In some cases, no common measurement methods or sensitivity analysis methods have been agreed upon. Therefore, confusion exists concerning the sensitivity comparison of equipment between manufacturers, the definition for specifications between users and suppliers, and the definition for specifications between users. Also, due to the fact that several problems were found when using the previous guideline in actual manufacturing, the document has been reviewed and content has been changed throughout. It was also the goal of this revision, while considering ease of manufacturing of test masks first, to fully cover the evaluation of mask defect inspection systems.

2 Scope

2.1 This guideline defines the content and methods for use of test masks used in the evaluation of mask defect inspection systems. Although it is possible to use this test mask to evaluate transcription of defects etc., this standard does not attempt to define these processes.

2.2 This guideline shall be revised when a new effective measurement technology for defect sizing becomes commonly available in the market.

2.3 This guideline does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition.

SEMI P33 — Provisional Specification for Developmental 230 mm Square Hard Surface Photomask Substrates

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *Definitions*

4.1.1 Many terms relating to photomask technology are defined in SEMI P22 and SEMI P33.

4.1.2 *design pattern* — pattern of intended design data.

4.1.3 *photomask pattern* — pattern on photomask surface.

5 Mask (See Figure 1)

5.1 Masks will be either 5" or 6" which meet SEMI P1; both the 5" and 6" will be the same layout.

5.2 Masks will be limited to two types, namely Conventional and Attenuated (Half Tone). Note that Levenson and Optical Proximity Correction (OPC) types will not be included.

5.3 There are two types of patterns: Wiring and Contact Hole pattern.

5.4 In one mask, there will be one type of pattern, either Wiring or Contact Hole.

5.5 One defect chip will be placed in the center of the mask.

5.6 Eight reference chips (non-defective) will be placed at 25,000 micron intervals to make sure that inspection can occur even if the mask is set in the inspection equipment in different directions (e.g., 0º, 90º, 180º, 270º).

5.7 *Mask Naming*

5.7.1 Wiring Pattern Mask is "SEMI STANDARD P23-0200-1500W".

5.7.2 Contact Hole Pattern Mask is "SEMI STANDARD P23-0200-1500C".

5.7.3 "P23-0200" is the registered number of this guideline.

5.7.4 "1500" expressed in nanometers, is the photomask pattern design rule. The following explanations in this guideline are based on a 1,500 nm (1.50 micron) design rule.

5.7.5 The mask naming should be written in characters which can be confirmed by the naked eye, and should be displayed in a place recognized by either the manufacturer or user of the mask.

5.8 Four light intensity adjustment patterns will be placed at 12,500 micron intervals from the center of the mask.

5.9 It is feasible to place stepper alignment marks and other patterns in such a way as not to effect the mask pattern described above.

6 Chip

See Figure 2 for illustration.

6.1 One chip of wiring patterns will be made up of 17 types of defects, each at 20 different defect sizes for a total of 340 cells.

6.2 One chip of contact hole patterns will be made up of 14 types of defects, each at 20 different defect sizes for a total of 280 cells.

6.3 Place defects changing types along the X-axis.

6.3.1 Display the defect type from the left side of the chip, toward the right, in capital English letters.

6.3.1.1 Wiring patterns are listed from A to Q.

6.3.1.2 Contact Hole patters are listed from A to N.

6.4 Place defects changing size along the Y-axis.

6.4.1 Place the defects, from top to bottom, in range of size from 0.05 microns to 1.00 microns at 0.05 micron intervals.

NOTE 2: Display all sizes as they pertain to the mask (on the mask).

7 Cell

7.1 One cell will be 250 microns square. (See Figure 3.)

7.2 Sub-cells will be placed 5 by 5 (Total=25).

7.3 Defects will be placed in the center of the cell (± 5.0 micron).

7.4 Cells will be broken up into 9 types, depending on the content of the pattern and defect.

7.4.1 Seven types are used for Wiring Patterns. (See Figures 4, 15 to 21.)

7.4.2 Two types are used for Contact Hole Patterns. (See Figures 6 and 7.)

8 Sub-cell

8.1 One sub-cell is 50 microns square.

8.2 Place a pattern which shows the boundaries of the cell at the sub-cell coordinates (x1,y1), (x5,y1), (x1,y5) and (x5,y5). (See Figures 8 to 12.)

8.2.1 Figure 13 shows an example of these patterns placed together.

8.2.2 The pattern placed at (x5,y1) should be a pattern from which coordinates can be measured.

8.3 Place the defect type ID (cell coordinates) and the abbreviated pattern for the defect type in sub-cell coordinates (x1,y5). (See Figures 8 and 12.)

8.3.1 Defect type ID (cell coordinates) are written as one capital English letter, representing the defect type and a two-digit number representing defect size. (Example: A01)

Character line width is set at 2.00 micron. (See Figure 14.)

8.3.2 The abbreviated pattern which denotes the defect content should keep the defect shape and direction consistent with the shape and direction of the program defect in the design.

8.4 The recommended values for pattern dimensions under the design rule (dimensions on mask) are as follows:

Dimension on Mask	*Mask Name*
5.00 micron	5000
3.00 micron	3000
2.50 micron	2500
2.00 micron	2000
1.50 micron	1500
1.00 micron	1000
0.80 micron	800
0.50 micron	500

8.4.1 The above list of design rule dimensions are recommended values, and it is feasible to use a different size.

8.4.2 When changing the design rule, chip spacing (25.0 mm) should not change.

8.5 For the Wiring Pattern Chip, place a pattern with uniform sub-cell coordinates: (x2,y1), (x4,y1), (x1,y2), (x2,y2), (x4,y2), (x5,y2), (x1,y4), (x2,y4), (x4,y4), (x5,y4), (x2,y5), (x4,y5). (See Figure 4.)

8.5.1 Patterns in a sub-cell using the uniform Wiring Pattern should be as follows:

Sub-cell Coordinates	*Pattern to Be Used*
(x2,y1) & (x4,y5)	Wiring Type A (Figure 15)
(x4,y1) & (x2,y5)	Wiring Type B (Figure 16)
(x1,y4) & (x5,y2)	Wiring Type A rotated 90º
(x1,y2) & (x5,y4)	Wiring Type B rotated 90º
(x2,y2)	Wiring Type C (Figure 17)
(x4,y2)	Wiring Type D (Figure 18)
(x2,y4)	Wiring Type E (Figure 19)
(x4,y4)	Wiring Type F (Figure 20)

8.5.2 Uniform patterns are placed inside a 50 micron-square sub-cell.

8.5.3 For patterns in the Wiring Pattern which change depending on the defect type ID, the same patterns should be placed, without borders, in sub-cell coordinates (x3,y1), (x3,y2), (x1,y3), (x2,y3), (x3,y3), (x4,y3), (x5,y3), (x3,y4) and (x3,y5).

8.5.4 Pattern content will change as follows, depending on the defect type ID:

Defect Type ID	*Pattern to Be Used*
A, B, C, D	Wiring Type A (Figure 15)
G, H, K, L, Q	Wiring Type C (Figure 17)
I, J	Wiring Type D (Figure 18)
E, F	Wiring Type E (Figure 19)
M, N	Wiring Type F (Figure 20)
O, P	Wiring Type G (Figure 21)

8.5.4.1 Adjust the pattern position so that the defect is placed in the center of sub-cell coordinates (x3,y3). There may be instances where the placement of the uniform patterns and the defect-inserted patterns vary slightly.

8.5.4.2 Figure 5 is an example of placement of a Type A Wiring Pattern.

8.6 For Contact Hole Pattern Chips, contact hole patterns should be placed at all sub-cells except coordinates (x1,y1), (x5,y1), (x1,y5) and (x5,y5). (See Figures 6 and 22.)

8.6.1 For misplacement defects, in order to be evaluated as an isolated field, place just one contact hole pattern in the center of sub-cell coordinates (x3, y3) and only in cells where the contact hole pattern defect type ID is “M”. (See Figure 7.)

8.6.2 Adjust the whole pattern for contact hole patterns so that the defect is placed in the center of sub-cell coordinates (x3,y3).

8.7 Use a common spacing for placement of wiring patterns and contact hole patterns.

8.7.1 For placement of patterns in design rule 1.50 microns (on mask), use a spacing of 14.0 microns in the X-direction and 7.0 microns in the Y-direction.

8.7.2 The values for spacing should change accordingly with a change in the design rule.

9 Defect

See Figures 23 and 24 for illustration.

9.1 *Defect Type*

9.1.1 Dot

9.1.2 Hole

9.1.3 Edge Extension

0 degree

45 degree

arctan (1/2) = 26.565 degree

9.1.4 Edge Intrusion

0 degree

45 degree

arctan (1/2) = 26.565 degree

9.1.5 Corner Extension

9.1.6 Corner Intrusion

9.1.7 Over size

9.1.8 Under size

9.1.9 Elongation

9.1.10 Truncation

9.1.11 Misplacement

9.1.12 Missing Pattern

9.2 *Defect Design Method*

9.2.1 Design the following defects, in squares, for wiring patterns and contact hole patterns. For edge defects on diagonal lines, use a pattern designed in a square and rotated to the angle of the diagonal. (In this case, the shape of the defect may change in the design data.) For corner defects, design using the edge length as a design dimension and not the diagonal.

9.2.1.1 Dot

9.2.1.2 Hole

9.2.1.3 Edge Extension

0 degree

45 degree

arctan (1/2) = 26.565 degree

9.2.1.4 Edge Intrusion

0 degree

45 degree

arctan (1/2) = 26.565 degree

9.2.1.5 Corner Extension

9.2.1.6 Corner Intrusion

9.2.2 The following defects change only in the pattern size along the Y-direction.

9.2.2.1 Wiring Pattern Over Size

9.2.2.2 Wiring Pattern Under Size

9.2.3 The following defects change in pattern size along both X and Y.

9.2.3.1 Contact Hole Pattern Over Size

9.2.3.2 Contact Hole Pattern Under size

9.2.4 The following defects change only in pattern length along the Y-direction in both wiring and contact hole patterns.

9.2.4.1 Elongation

9.2.4.2 Truncation

9.2.5 For the following defects, in both wiring and contact hole patterns, move the right half of the pattern in the Y-direction only to form a step.

9.2.5.1 Misplacement Defect with ID ”K”

9.2.6 In the following defects, the pattern shape and size are the same, with one whole isolated pattern moving only in the Y-direction.

9.2.6.1 Misplacement defects, in both wiring and contact hole patterns, which have the defect ID “L”.

9.2.6.2 Misplacement defects, in contact hole patterns, with the defect ID ”M”.

9.2.7 The following single isolated pattern is completely destroyed in both wiring and contact hole patterns.

9.2.7.1 Missing Pattern

9.3 *Fabricating Position for Program Defect*

9.3.1 Fabricate according to Figure detailed drawing.

10 Program Defect Size

10.1 According to SEMI P22, mainly, two values are to be used in defining size of defects. However, for the following reason, one value will be used to describe program defect size on this SEMI Standard P23 mask.

10.1.1 Defects used in evaluation are all program defects and mainly designed in square shape.

10.1.2 When describing the capabilities of mask defect inspection systems, it has become typical to describe defect size which one value.

10.2 Due to various reasons (influences) in mask manufacturing, it is not always possible to form all program defects with the shape and size described in the design.

10.3 SEMI Standard mask defect size is defined as follows. (See Figures 23 and 24.)

Follow SEMI P22 for the values used below (S1, S2, X, Y, a, b, c, d).

10.3.1 *Dot & Hole*

10.3.1.1 Defect Size is S1 or S2, whichever is larger.

10.3.2 *Edge Extension & Intrusion*

10.3.2.1 Defect Size is S2.

10.3.3 *Corner Extension*

10.3.3.1 Defect Size is the difference between the reference pattern S1[Reference] and the defect pattern S1[Defect]

(| S1[Reference] - S1[Defect] |).

10.3.4 *Corner Intrusion*

10.3.4.1 Wiring Pattern

10.3.4.1.1 Defect Size is the difference between the reference pattern S1[Reference] and the defect pattern S1[Defect]

(| S1[Reference] - S1[Defect] |).

10.3.4.2 Contact Hole Pattern

10.3.4.2.1 As with Edge Intrusion in 10.3.2, Defect Size is S2.

10.3.5 *Over Size*

10.3.5.1 Wiring Pattern

10.3.5.1.1 Since size only changes in the Y-direction, Defect Size is (d-c).

10.3.5.2 Contact Hole Pattern

10.3.5.2.1 With “a” and “c” as the reference pattern size, Defect Size is (b-a) or (d-c), whichever is larger.

10.3.6 *Under Size*

10.3.6.1 Wiring Pattern

10.3.6.1.1 Since size only changes in the Y-direction, Defect Size is (d-c).

10.3.6.2 Contact Hole Pattern

10.3.6.2.1 With “a” and “c” as the reference pattern size, Defect Size is (b-a) or (d-c), whichever is larger.

10.3.7 *Elongation & Truncation*

10.3.7.1 Since, in a program defect, the size only changes in the Y-direction (S1), Defect Size is S1.

10.3.8 *Misplacement*

10.3.8.1 Since the program defect is only moving along the Y-axis, Defect Size is Y.

10.3.9 *Missing Pattern*

10.3.9.1 With S1 and S2 as the reference pattern size, Defect Size is S1 or S2, whichever is larger.

11 Light Intensity Adjustment Pattern

11.1 Light intensity adjustment patterns will be placed in four areas in mask defect inspection systems. (See Figure 1.)

11.2 A glass pattern will be placed in the center.

11.3 Around the circumference of the glass pattern, a line and space pattern will be placed, 1 for 1, with the same line width as the design rule (dimensions on mask).

11.3.1 With 500 by 1,250 microns as one block, place horizontal patterns on the left and right sides, perpendicular patterns on the top and bottom. Also, place a horizontal pattern on the lower left corner. (See Figure 25.)

11.4 The circumference of the glass pattern and line & space pattern should have at least 6,000 microns of shade film.

12 Method for Use of Test Masks in Evaluating Mask Defect Inspection System

12.1 Inspect all defect cells, or a portion of them according to the inspection conditions of the mask defect inspection system to be evaluated.

12.2 Perform at least 20 inspections.

12.3 Perform the inspection at least with a set direction of 0º. It is also preferable that the inspection be performed after rotating the set at 90º, 180º, and 270º.

12.4 When displaying the defect inspection sensitivity for mask defect inspection system, display the defect size of the smallest defect of each type which was detected 100%. (See Figures 26 and 27.)

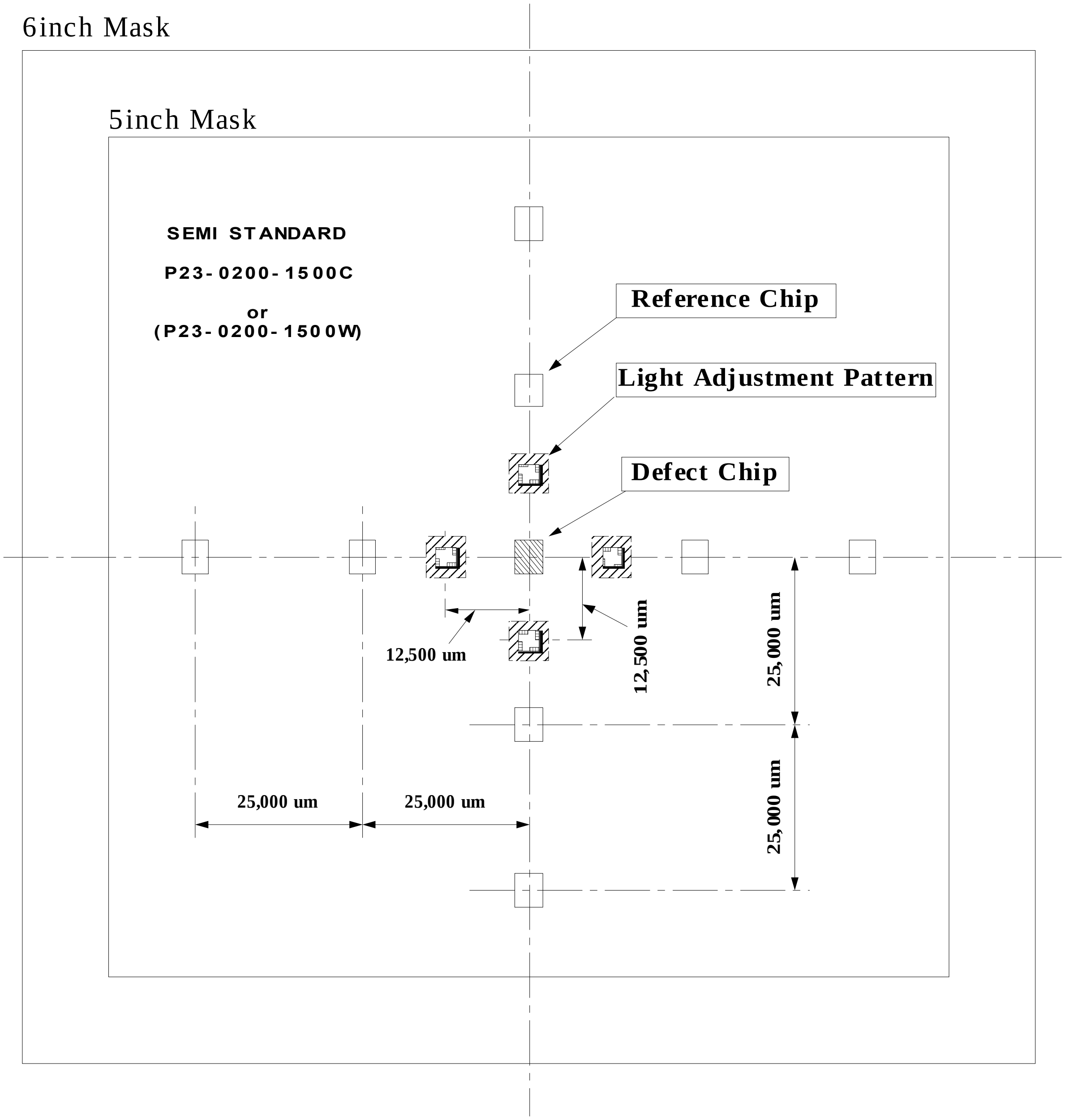


Figure 1
Mask

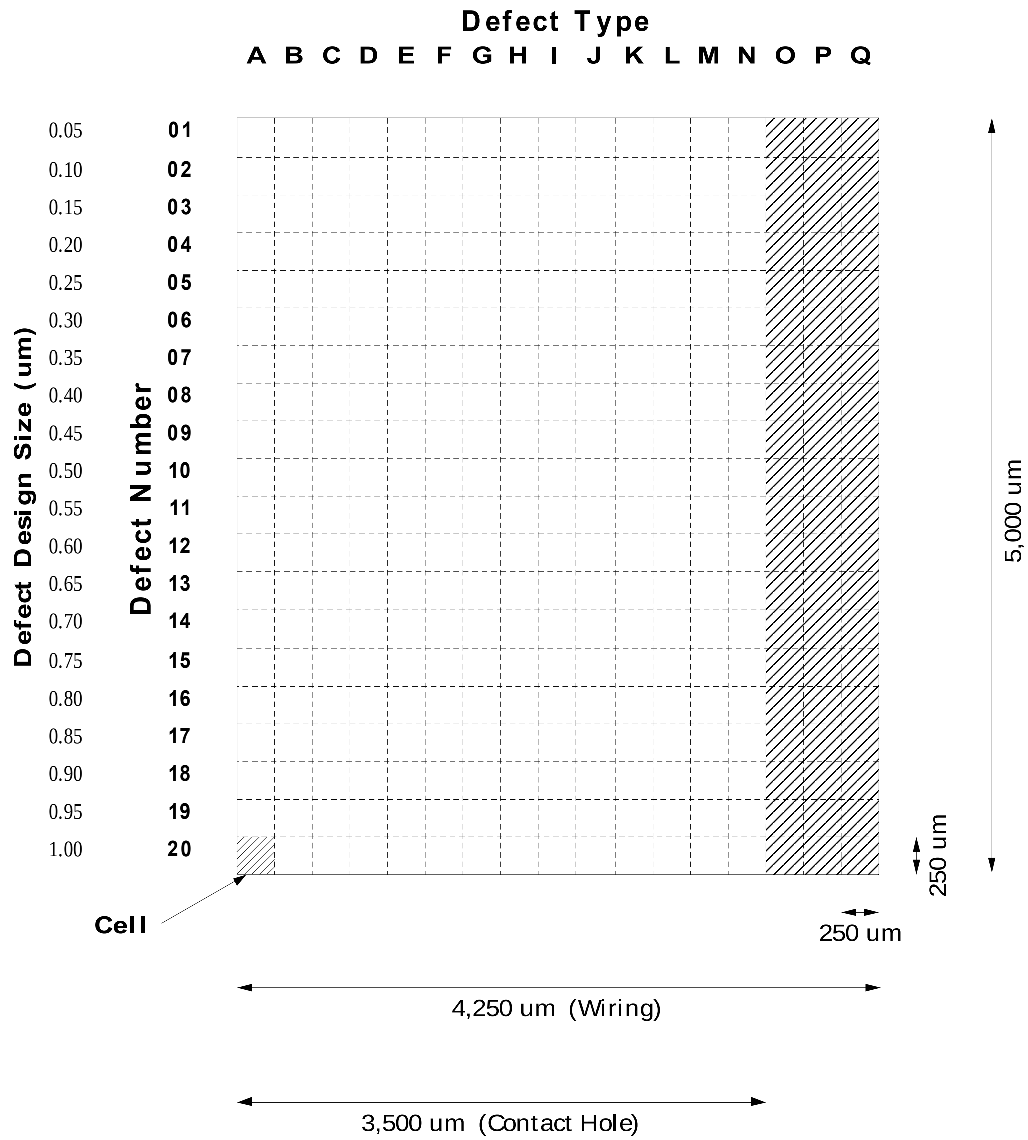


Figure 2
Chip
Wiring Chip; A to Q (#340 cell)
Contact Hole Chip; A to N (#280 cell)

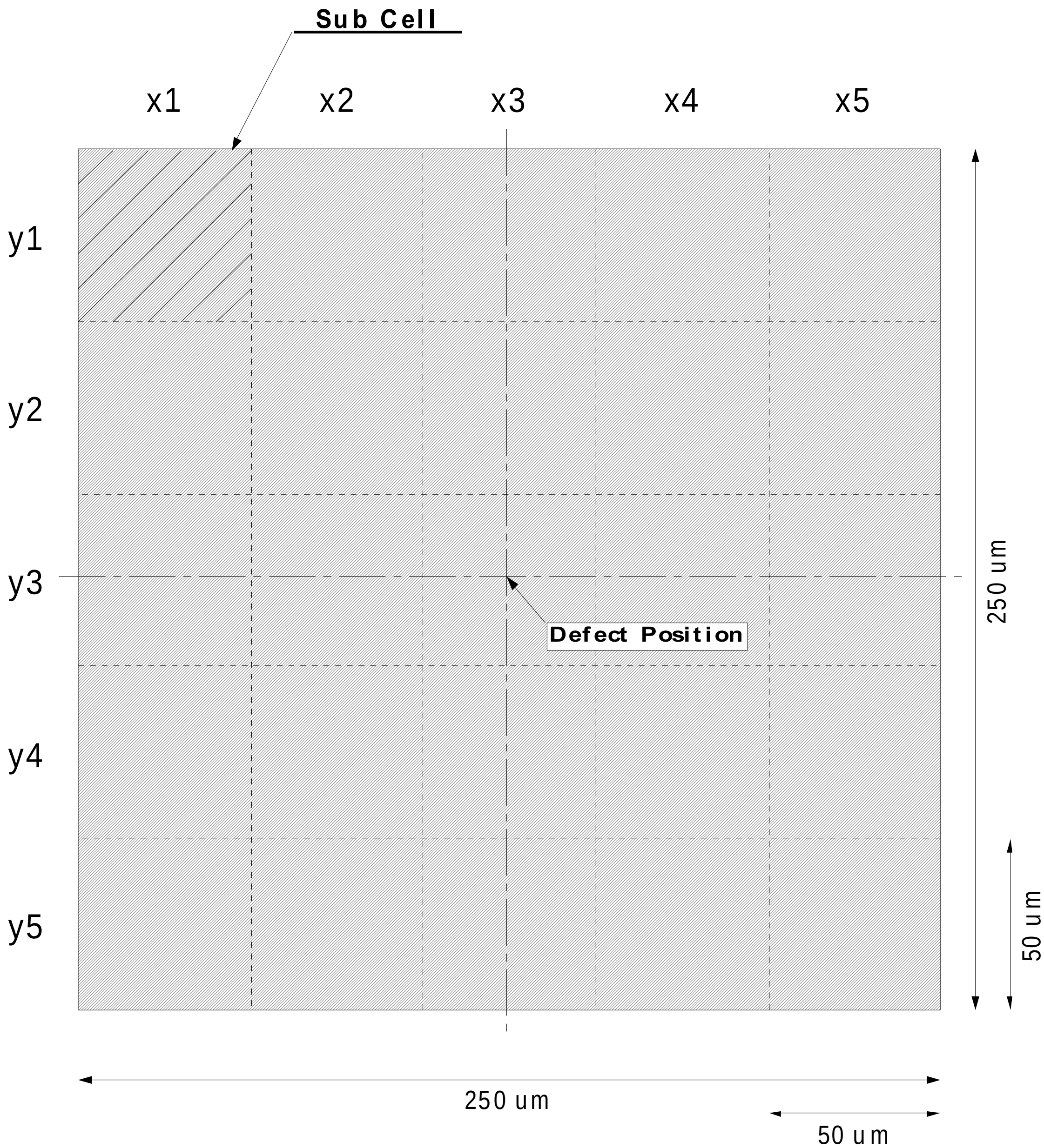


Figure 3
Cell

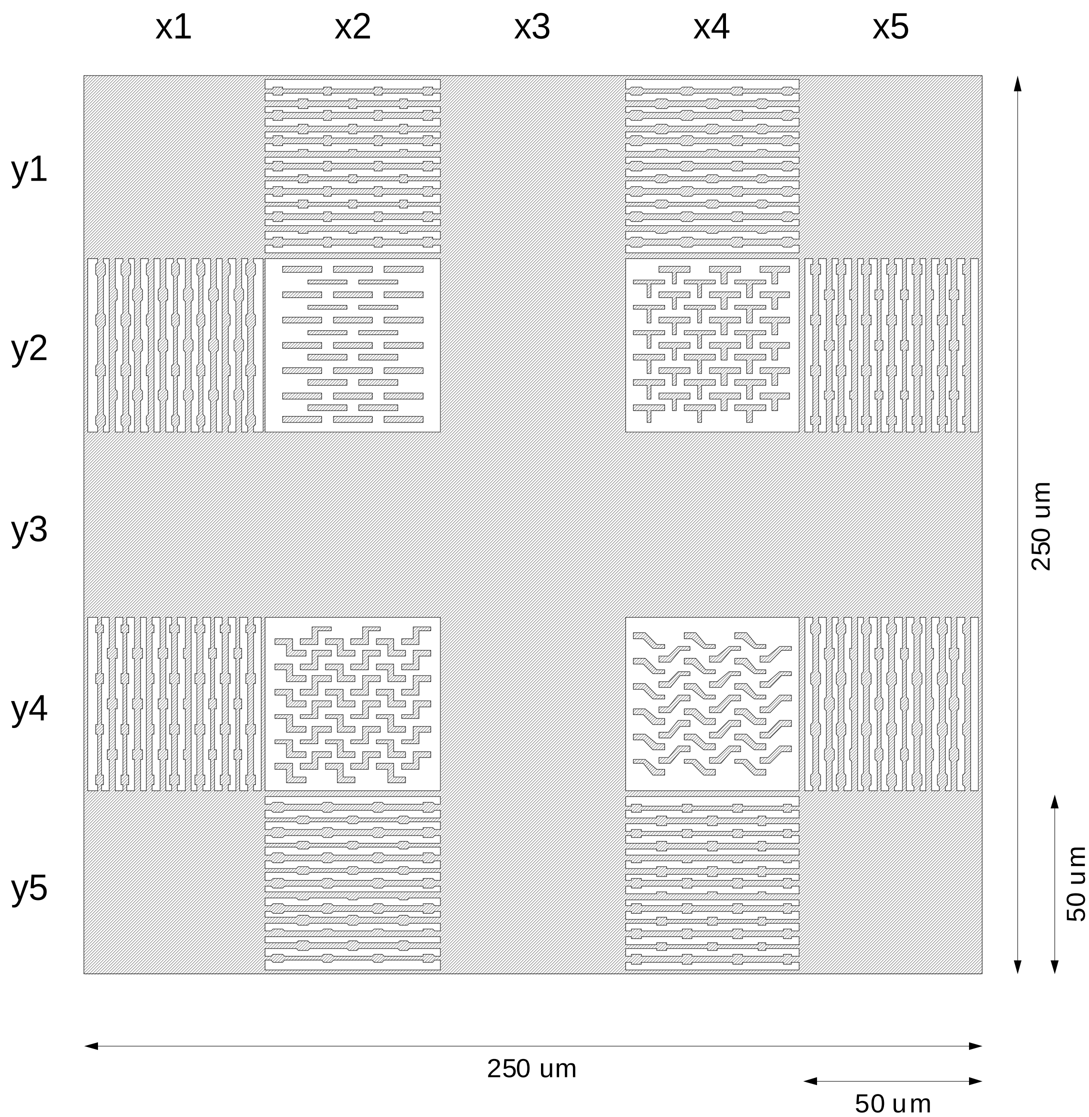


Figure 4
Cell
Wiring Standard Pattern

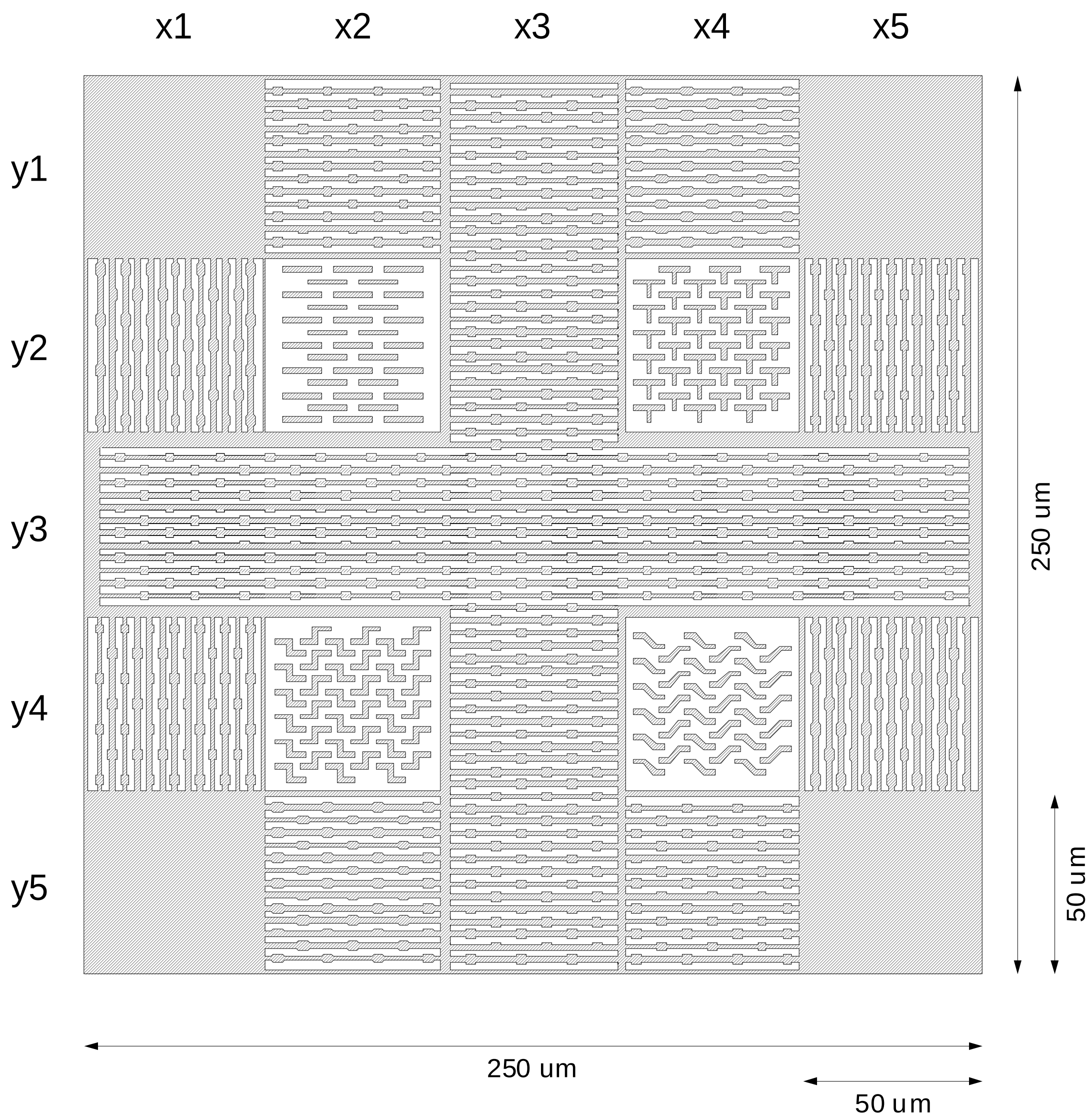


Figure 5
Cell
Sample; Wiring (Type A)
Defect ID; A, B, C, D

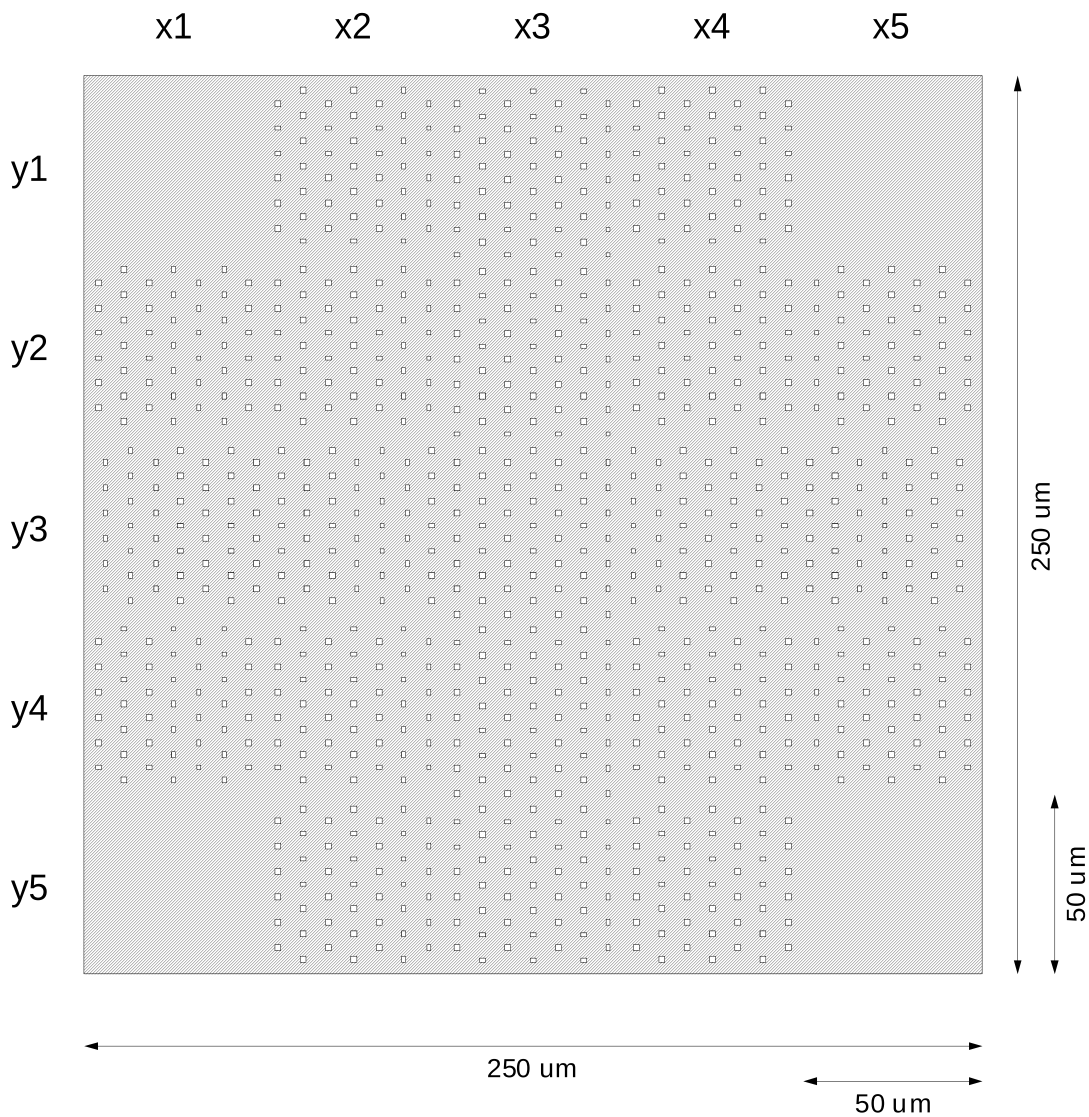


Figure 6
Cell
Contact Hole Pattern (Type A)
Defect ID; A to L, and N

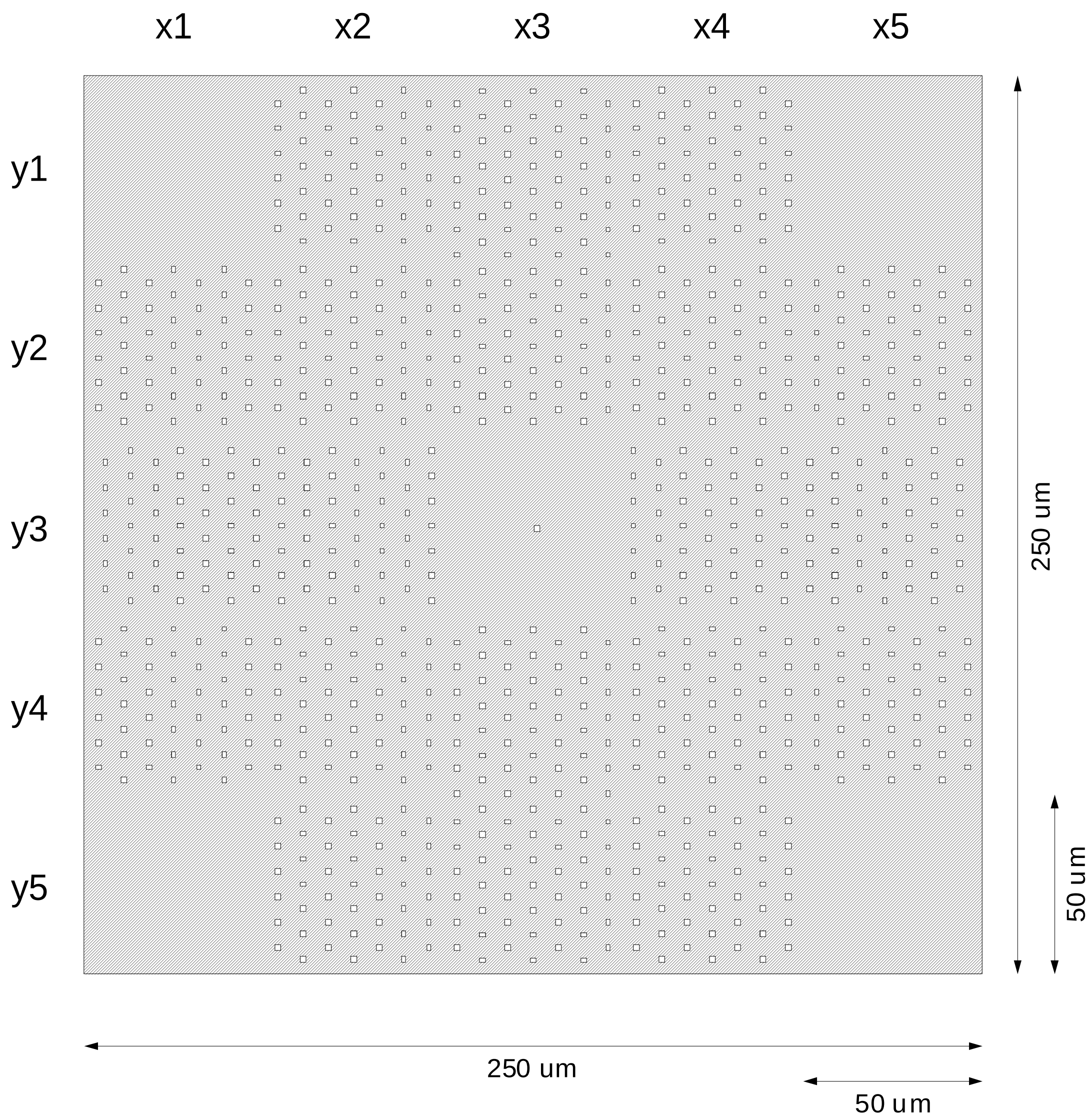


Figure 7
Cell
Contact Hole Pattern (Type B)
Defect ID; M

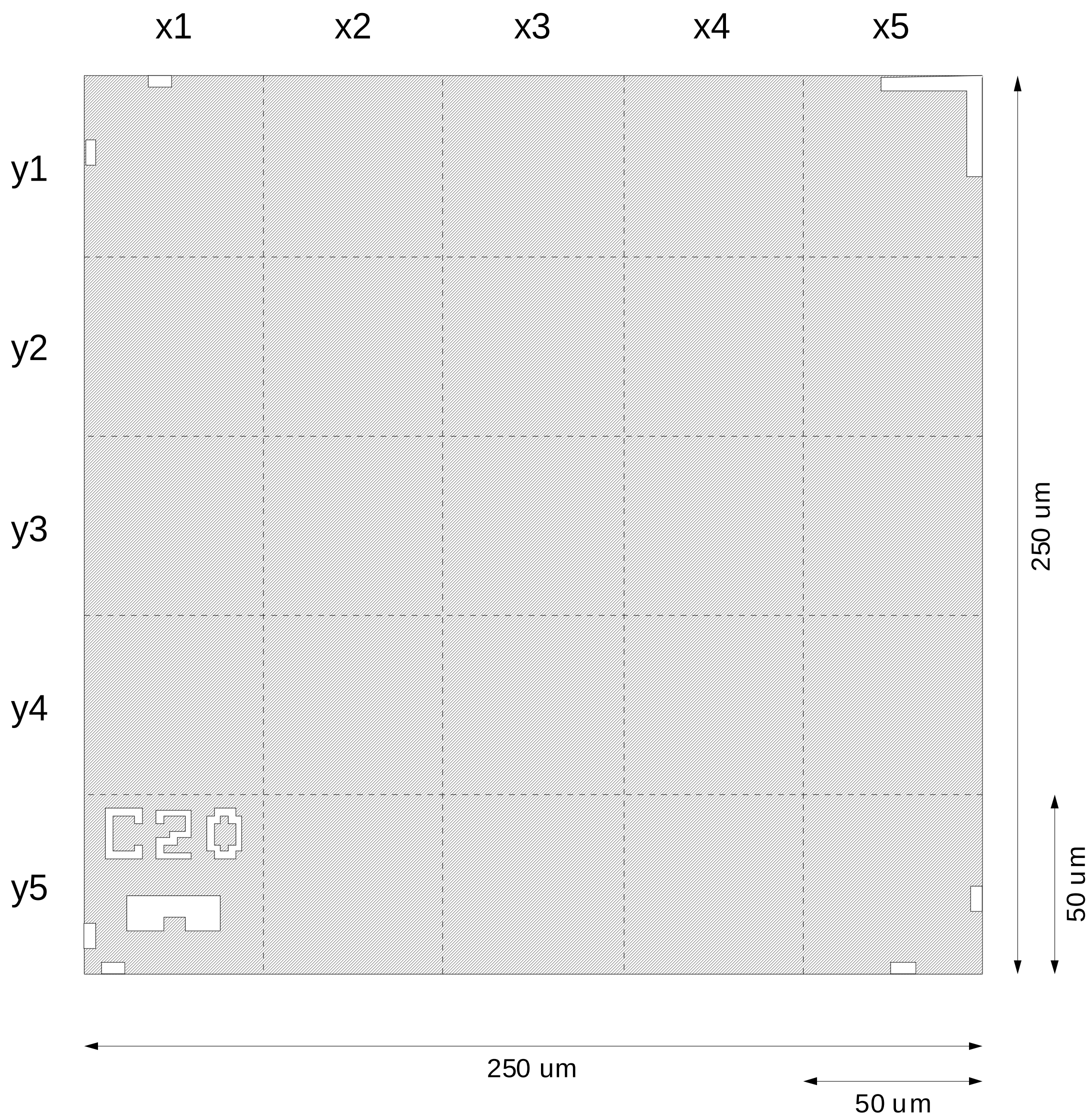
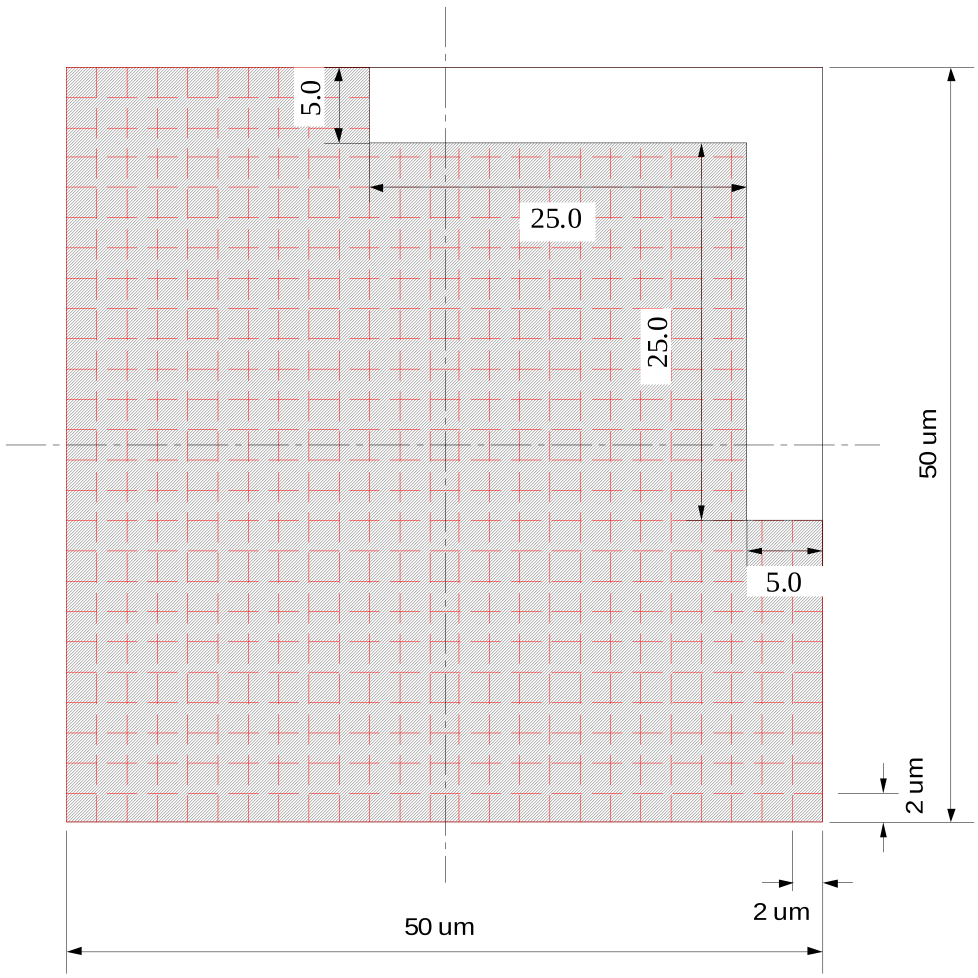


Figure 8
Cell



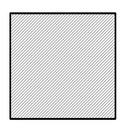
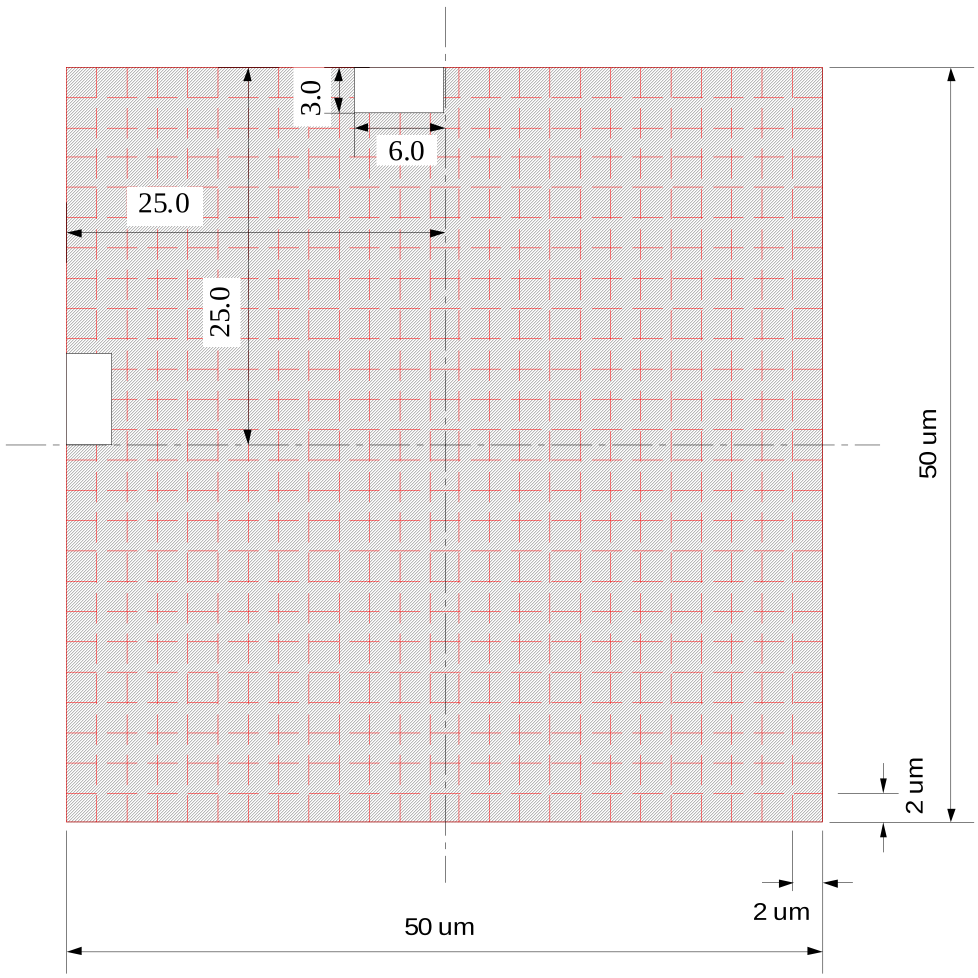
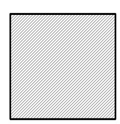


Figure 9
Sub Cell
Right Upper (x5, y1)
(Metrology Measurement Pattern)





; Film Pattern

Figure 10
Sub Cell
Left Upper (x1, y1)

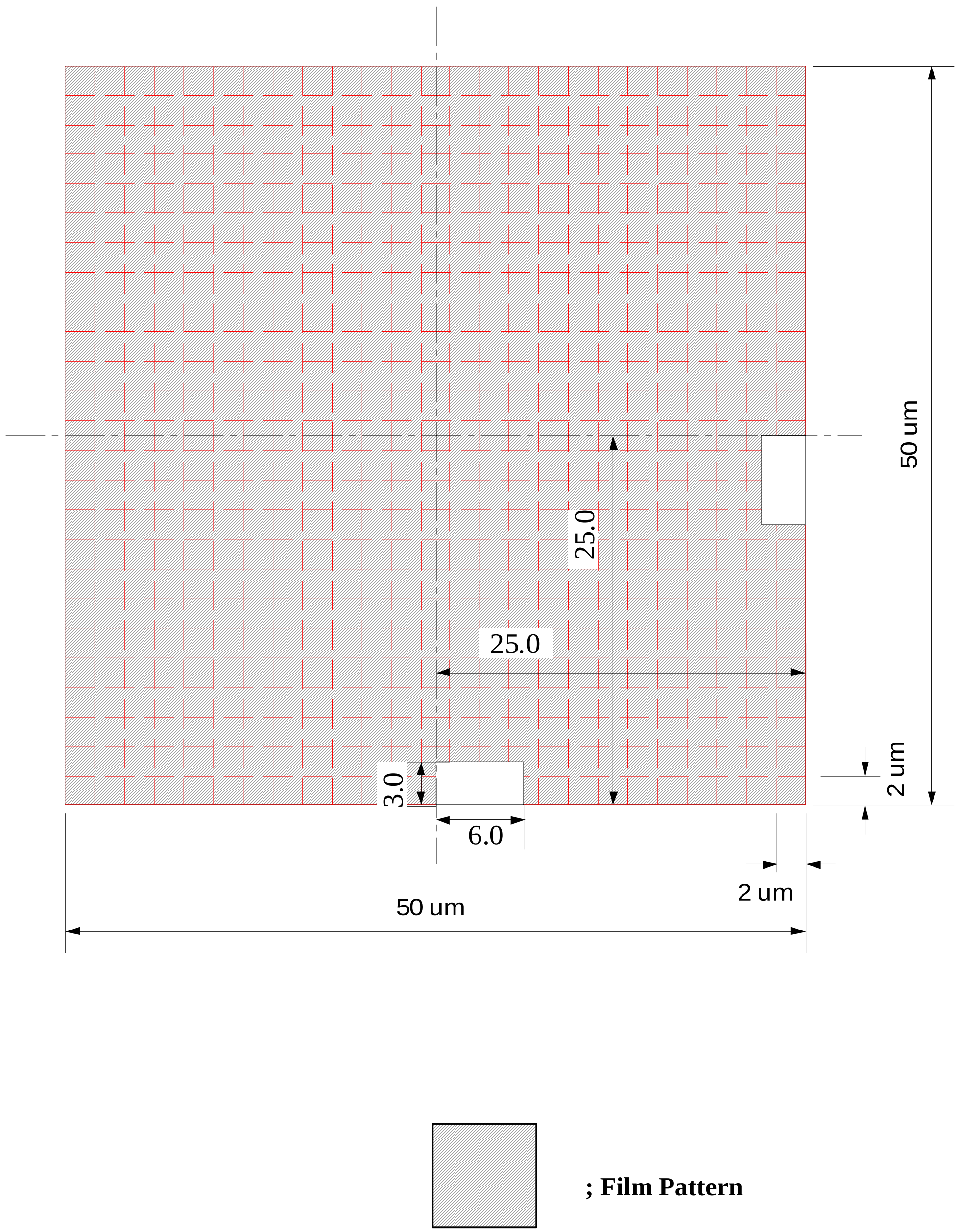
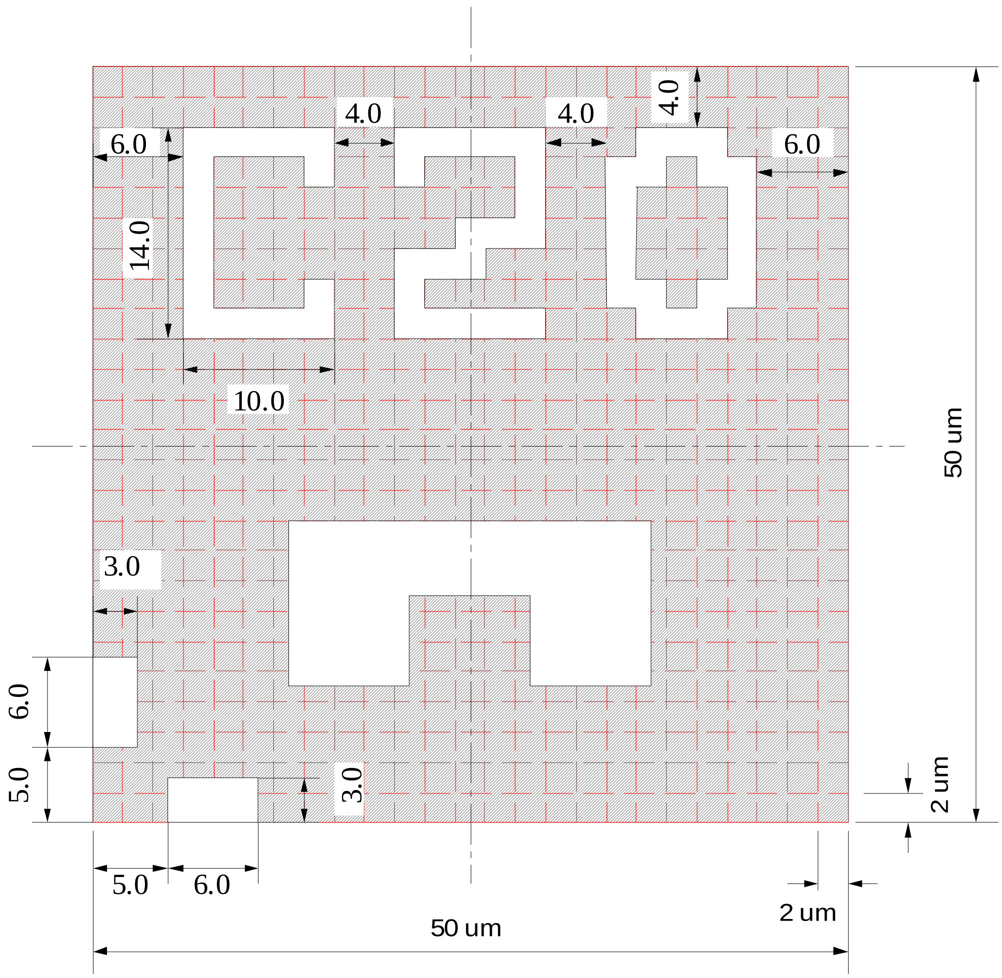


Figure 11
Sub Cell
Right Lower (x5, y5)



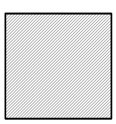
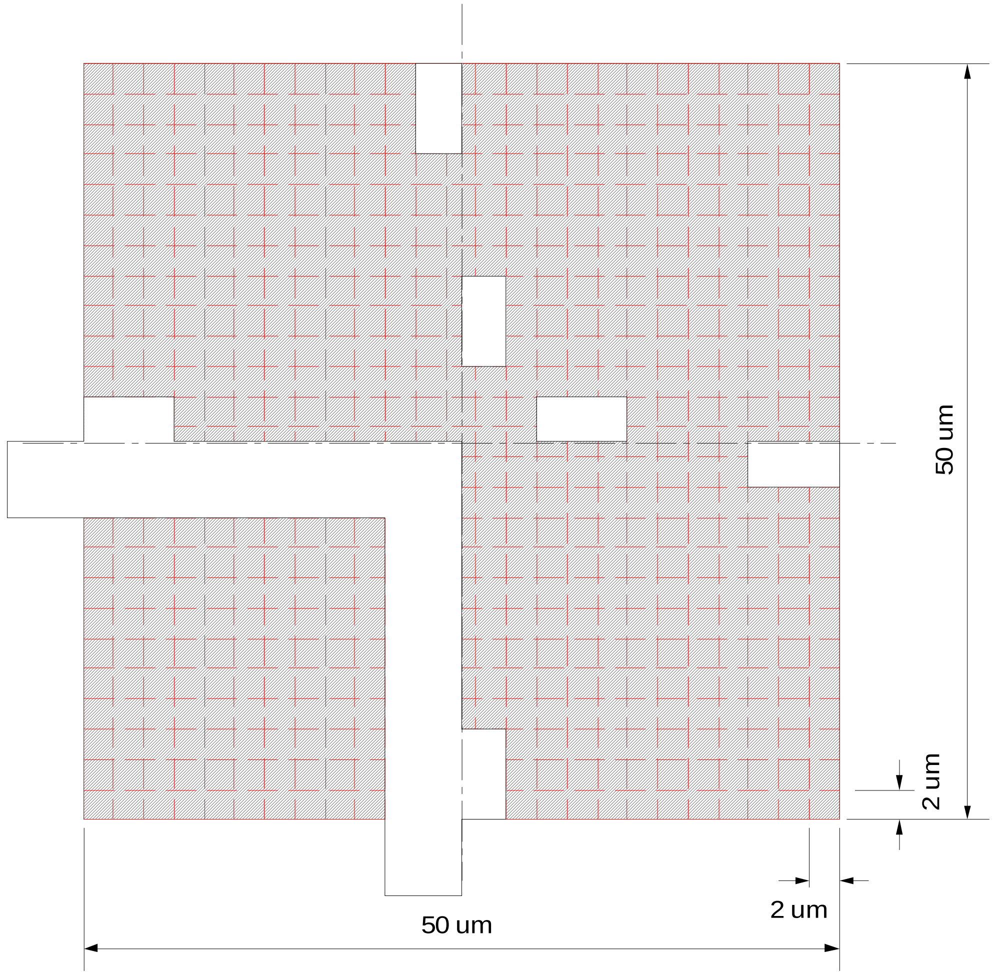


Figure 12
Sub Cell
Left Lower (X1, y5)
Defect ID & Defect Type



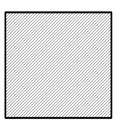


Figure 13
Sub Cell
Cell Corner Sample

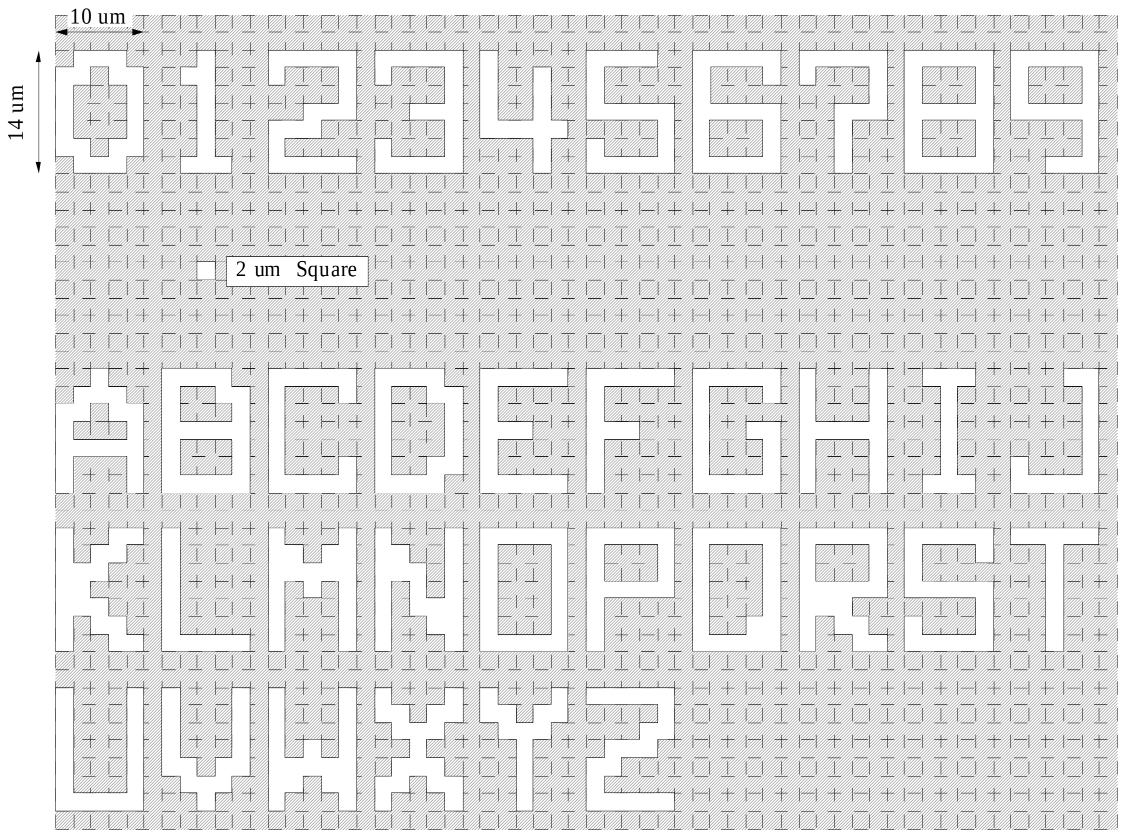
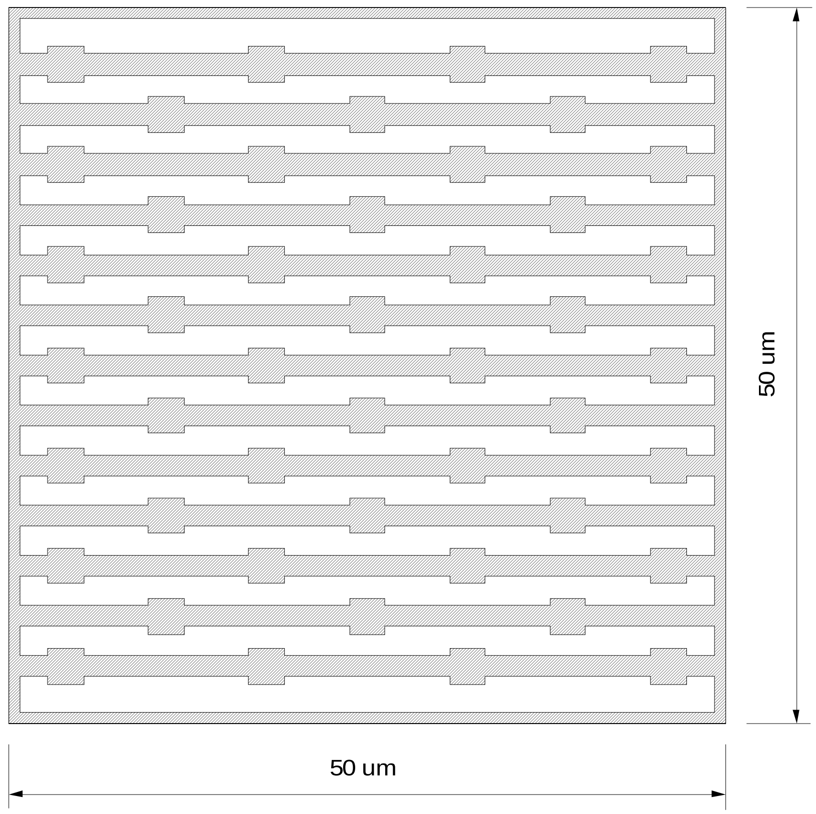


Figure 14
Letter
(Non False Defects Pattern)



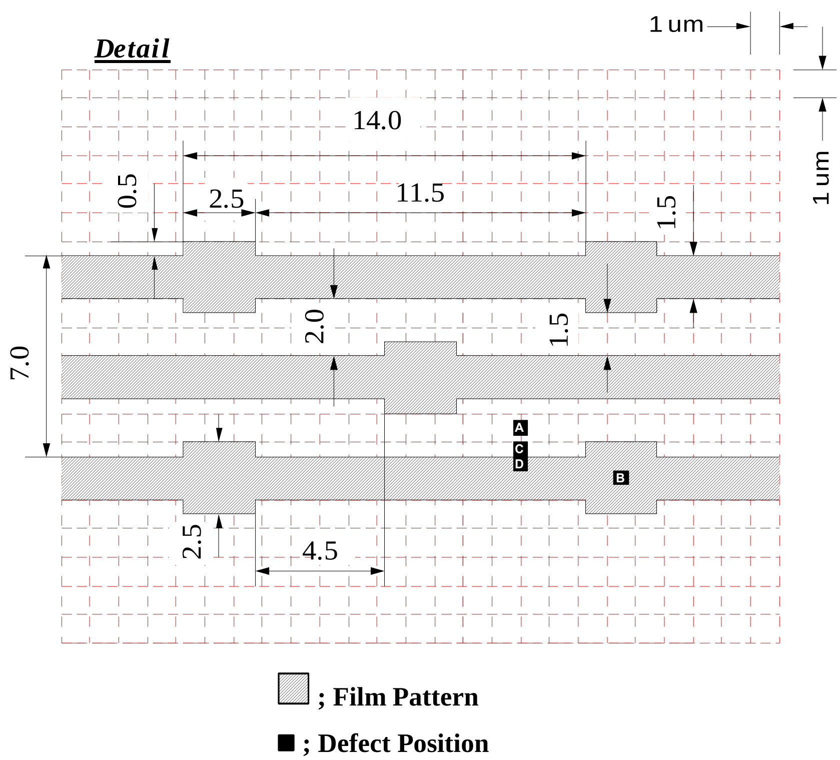
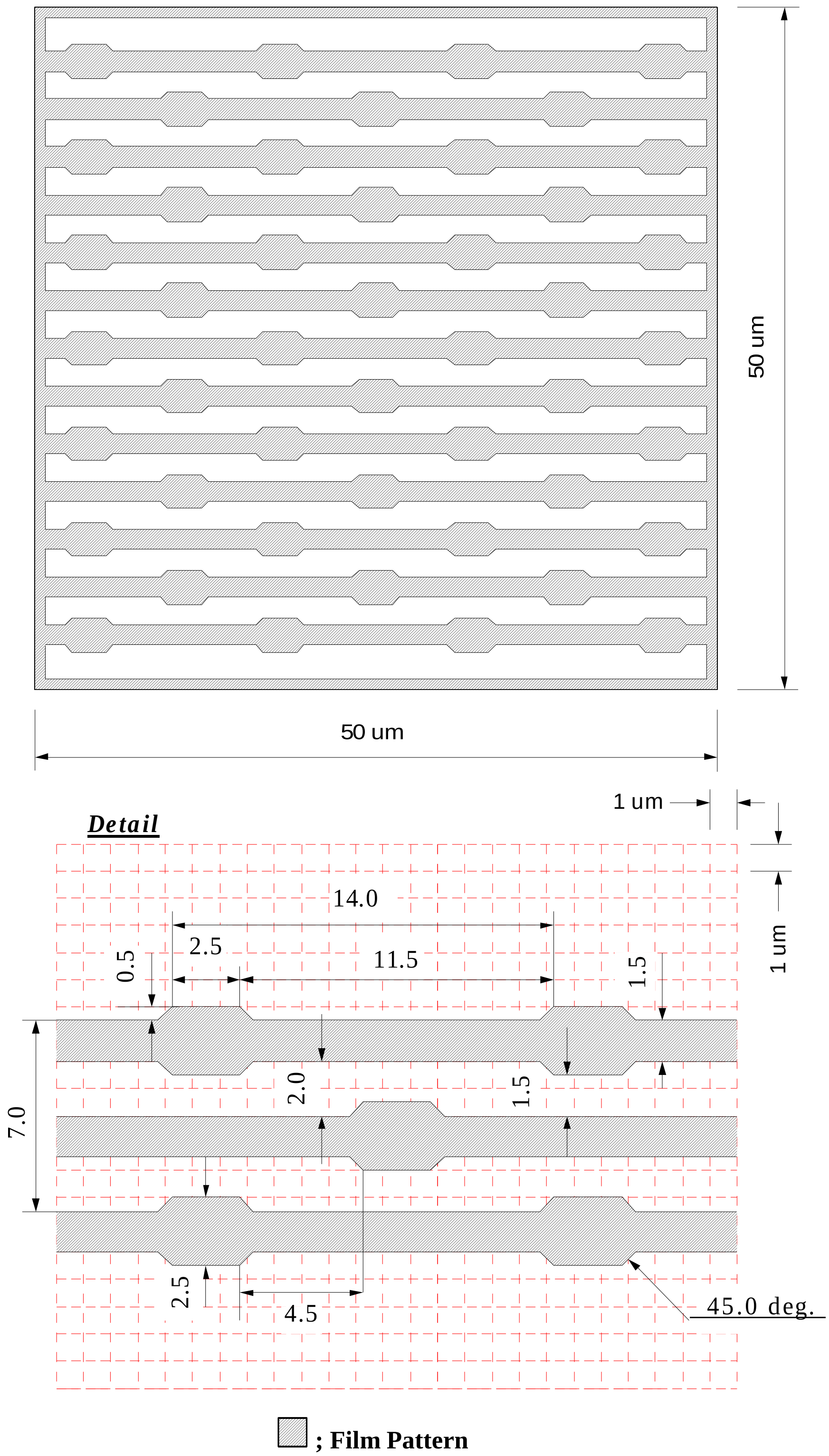
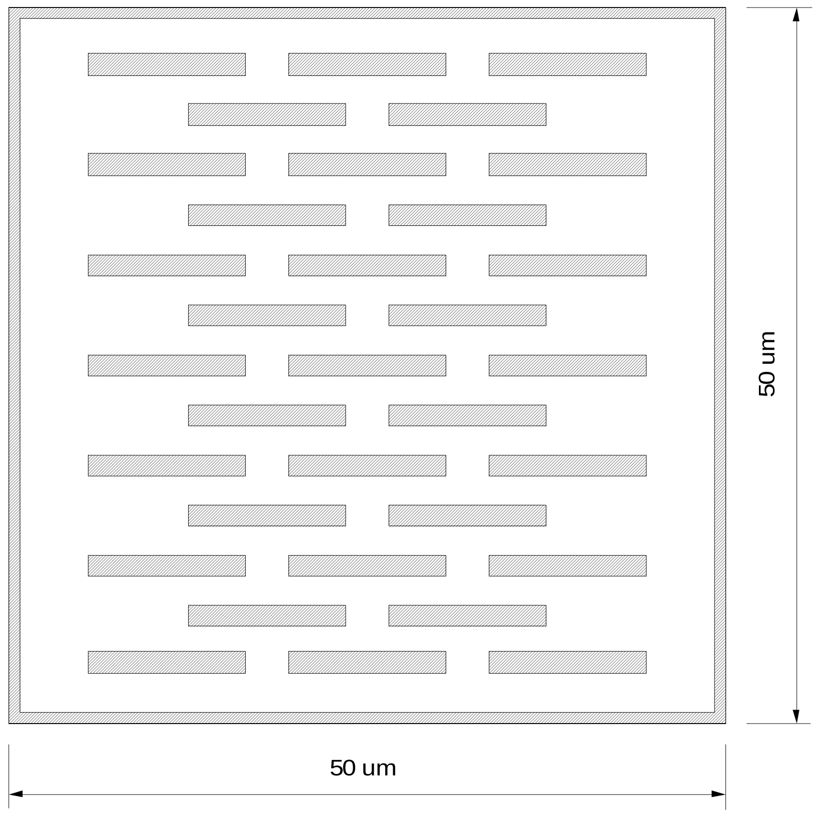


Figure 15
Sub Cell
Wiring (Type A)



; Film Pattern

Figure 16
Sub Cell
Wiring (Type B)



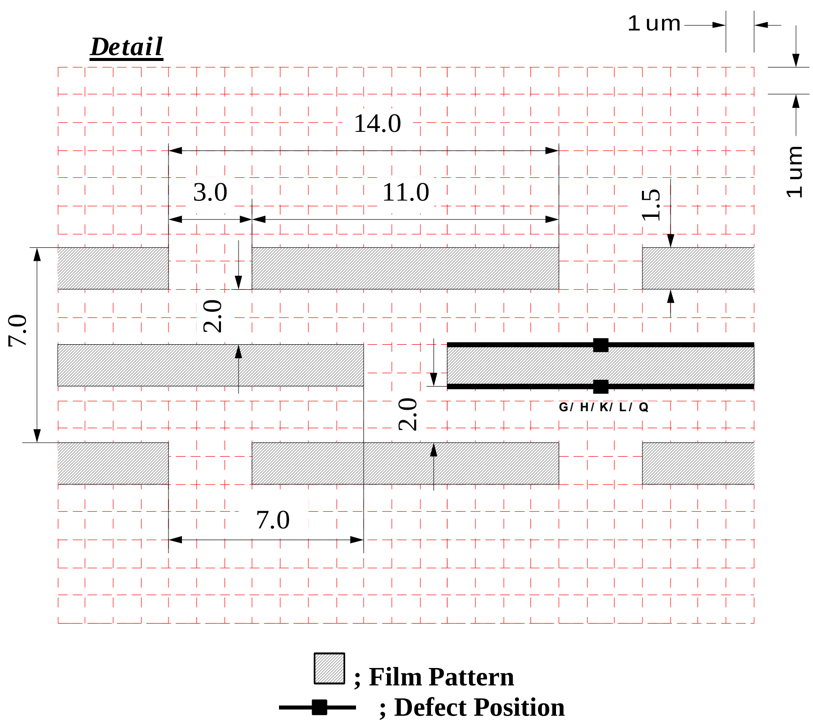


Figure 17
Sub Cell
Wiring (Type C)

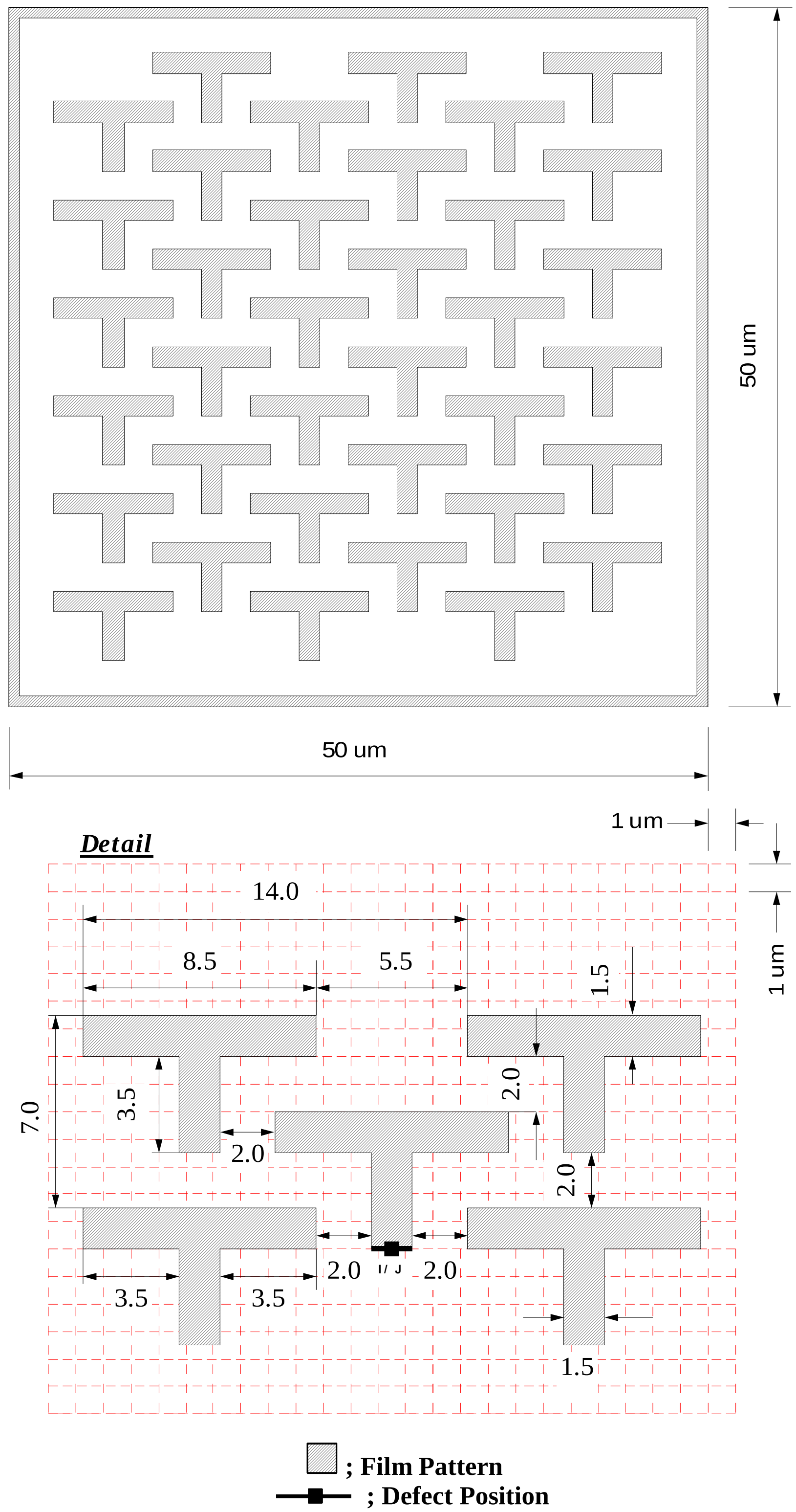


Figure 18
Sub Cell
Wiring (Type D)

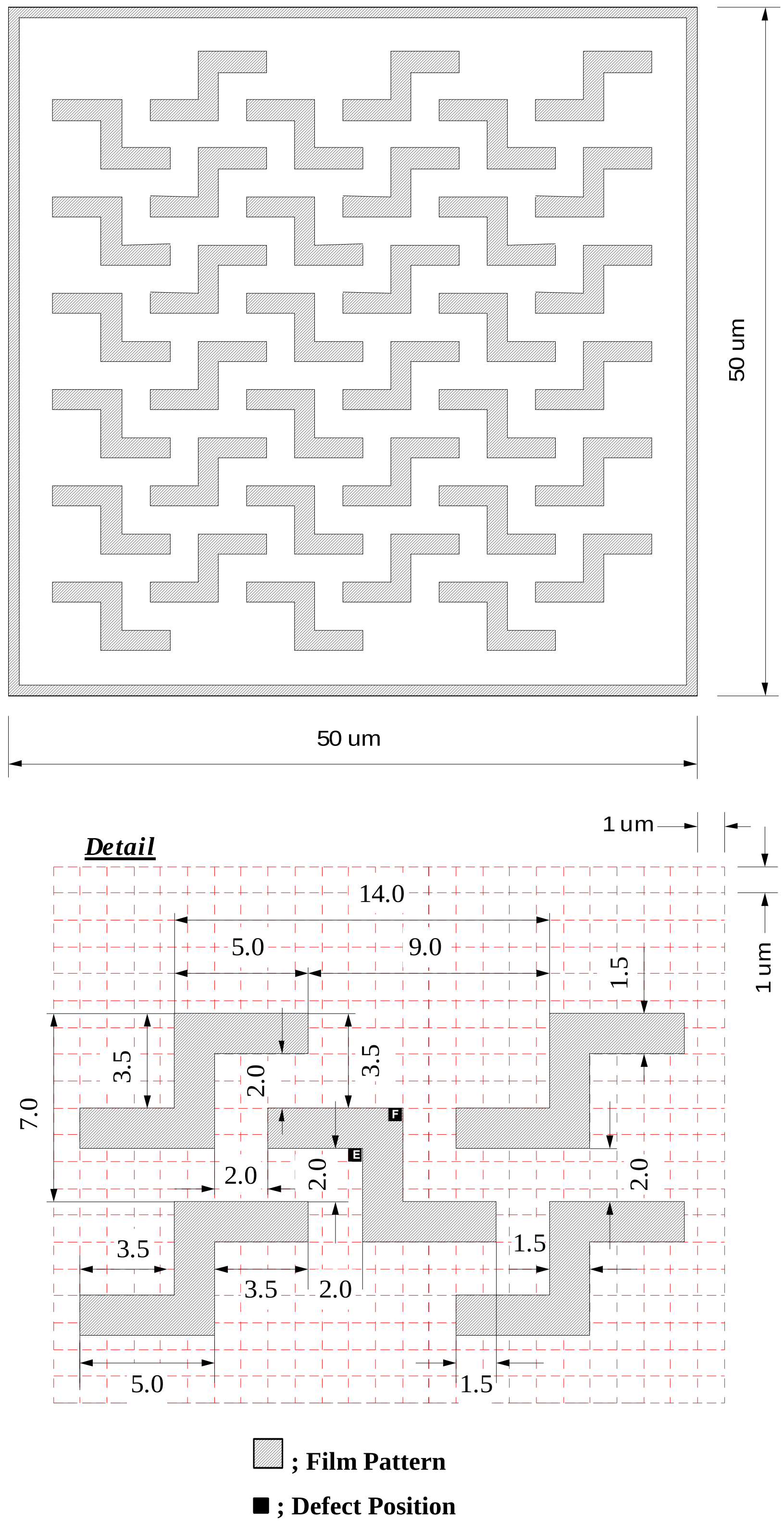
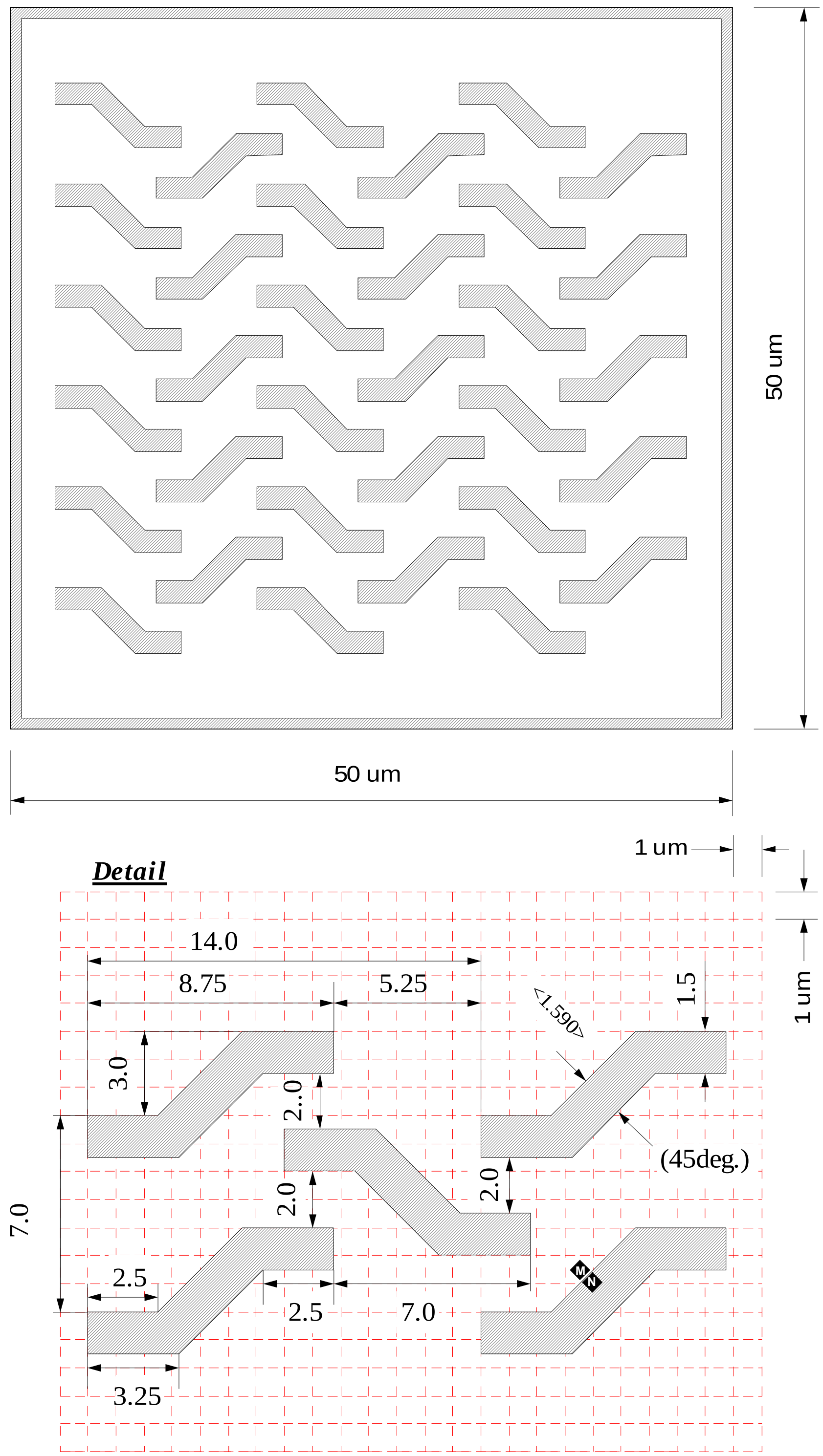


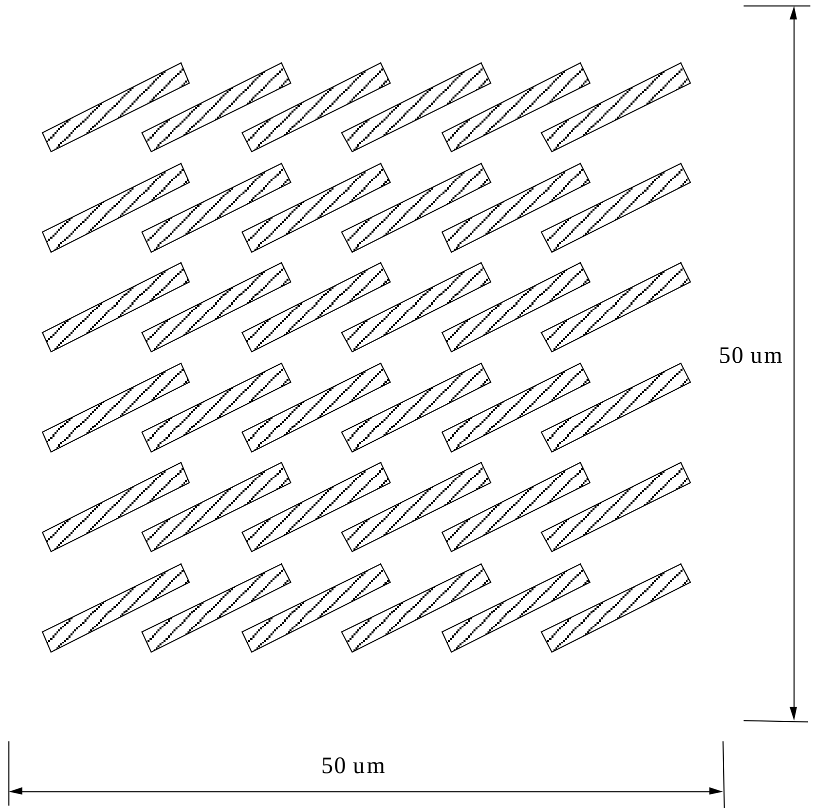
Figure 19
Sub Cell
Wiring (Type E)

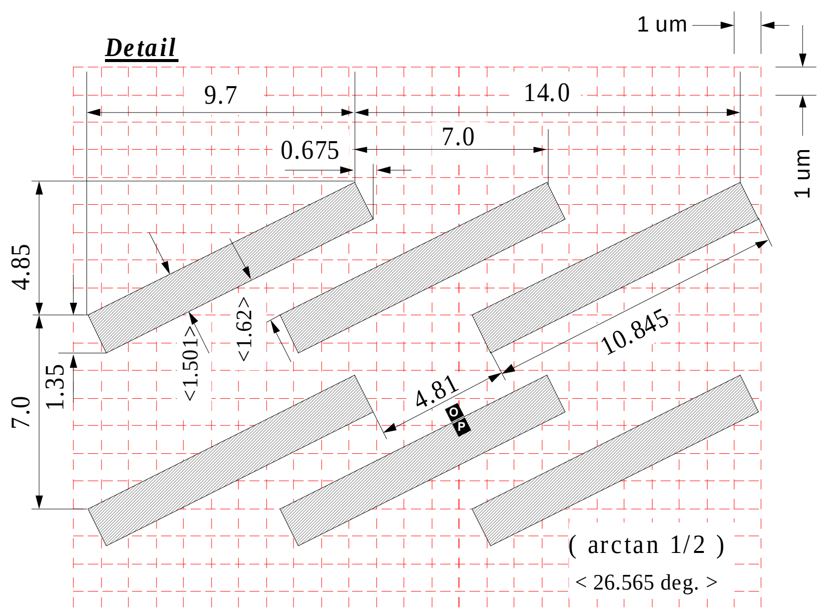


; Film Pattern

■ ; Defect Position

Figure 20
Sub Cell
Wiring (Type F)

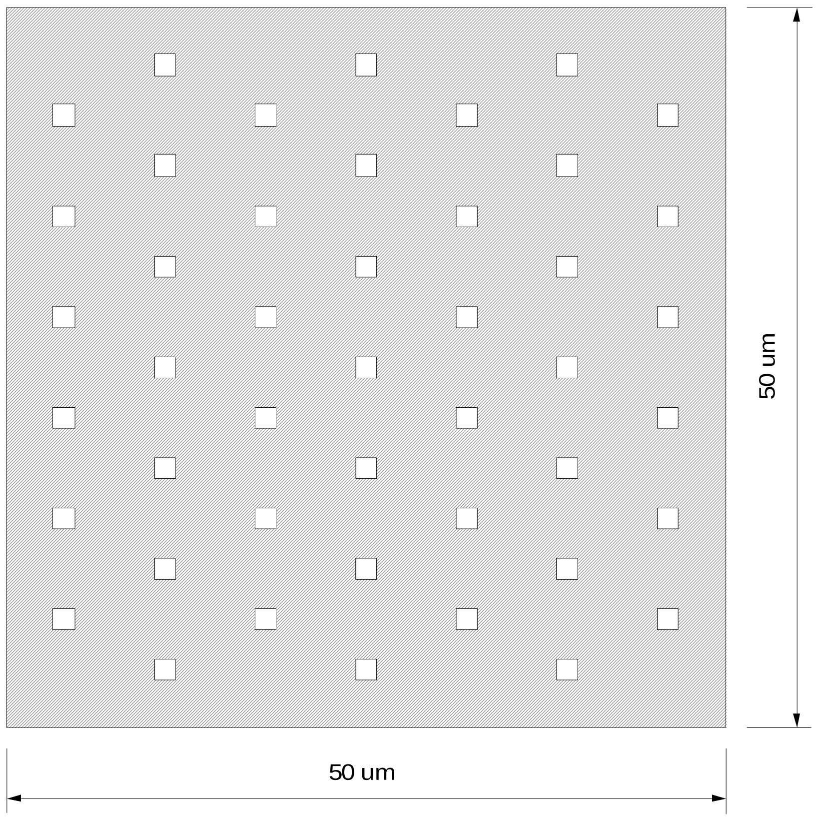


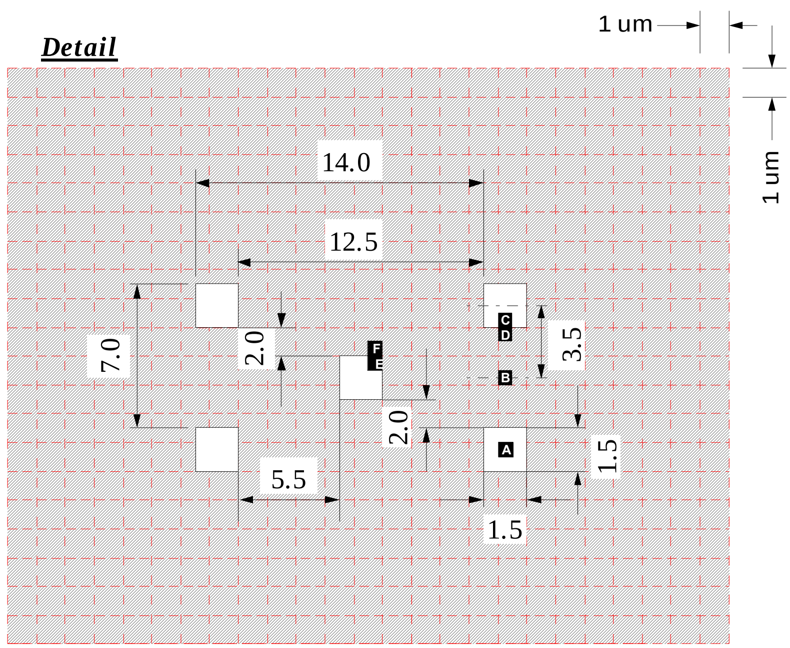


; Film Pattern

■ ; Defect Position

Figure 21
Sub Cell
Wiring (Type F)

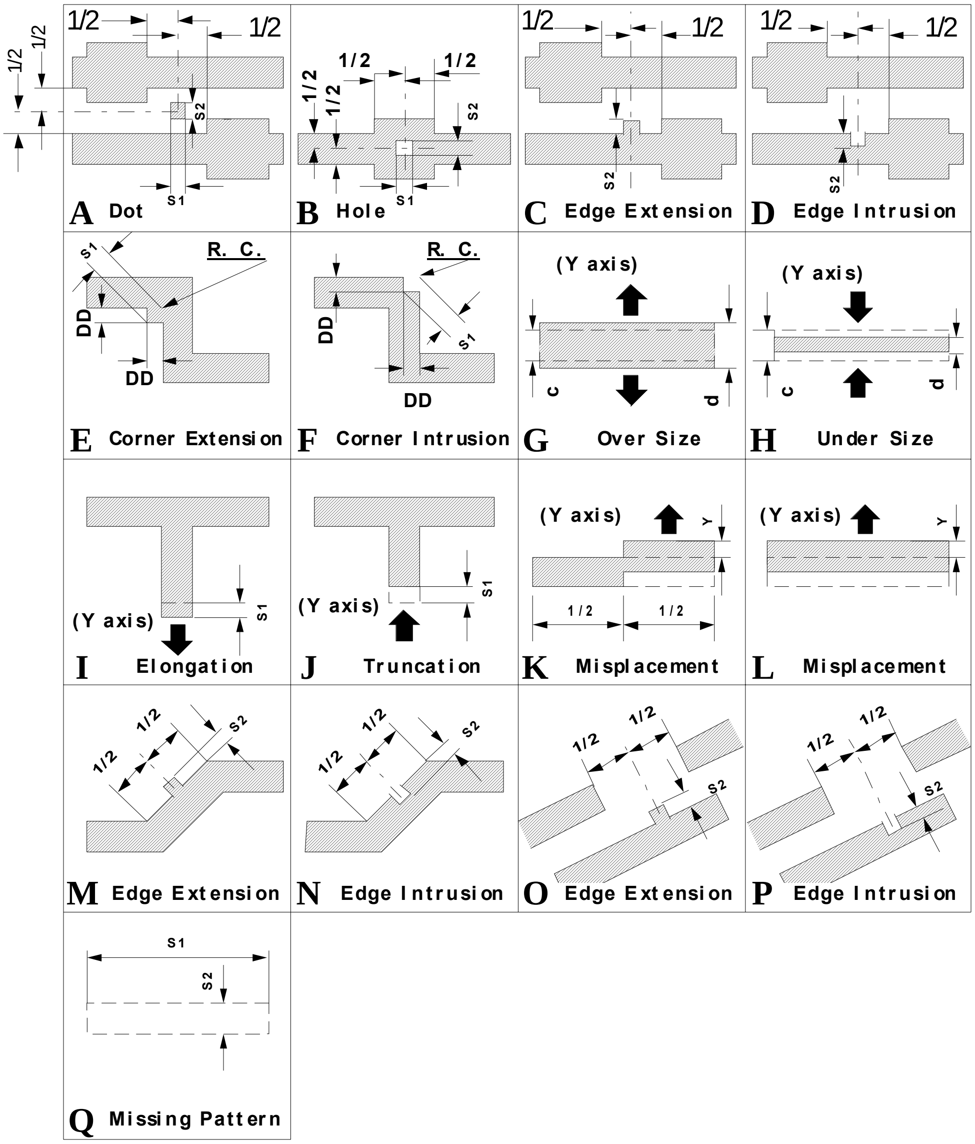




; Film Pattern

; Defect Position

Figure 22
Sub Cell
Contact Hole Pattern

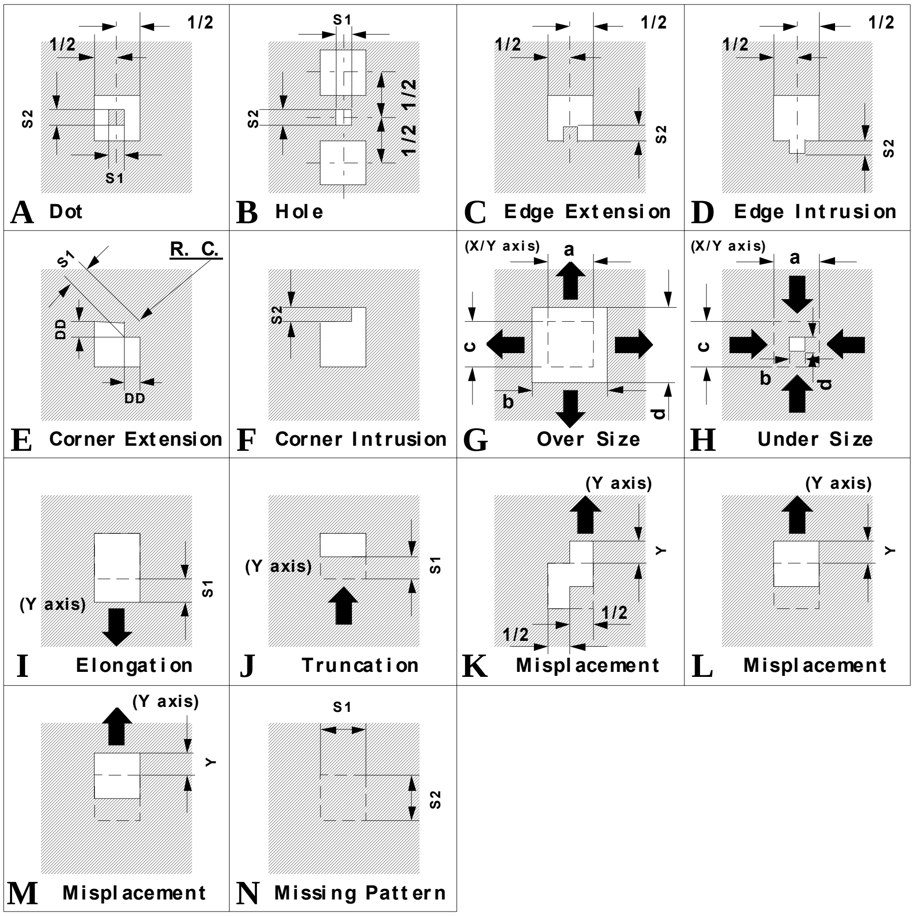


S1, S2 = Defect Size

DD = Defect Design Size

, R. C. = Reference Chip Pattern (or Design Pattern)

Figure 23
Defect
(Wiring Pattern)



S1, S2 = Defect Size

DD = Defect Design Size

[dashed box], R. C. = Reference Chip Pattern (or Design Pattern)

Figure 24
Defect
(Contact Hole Pattern)

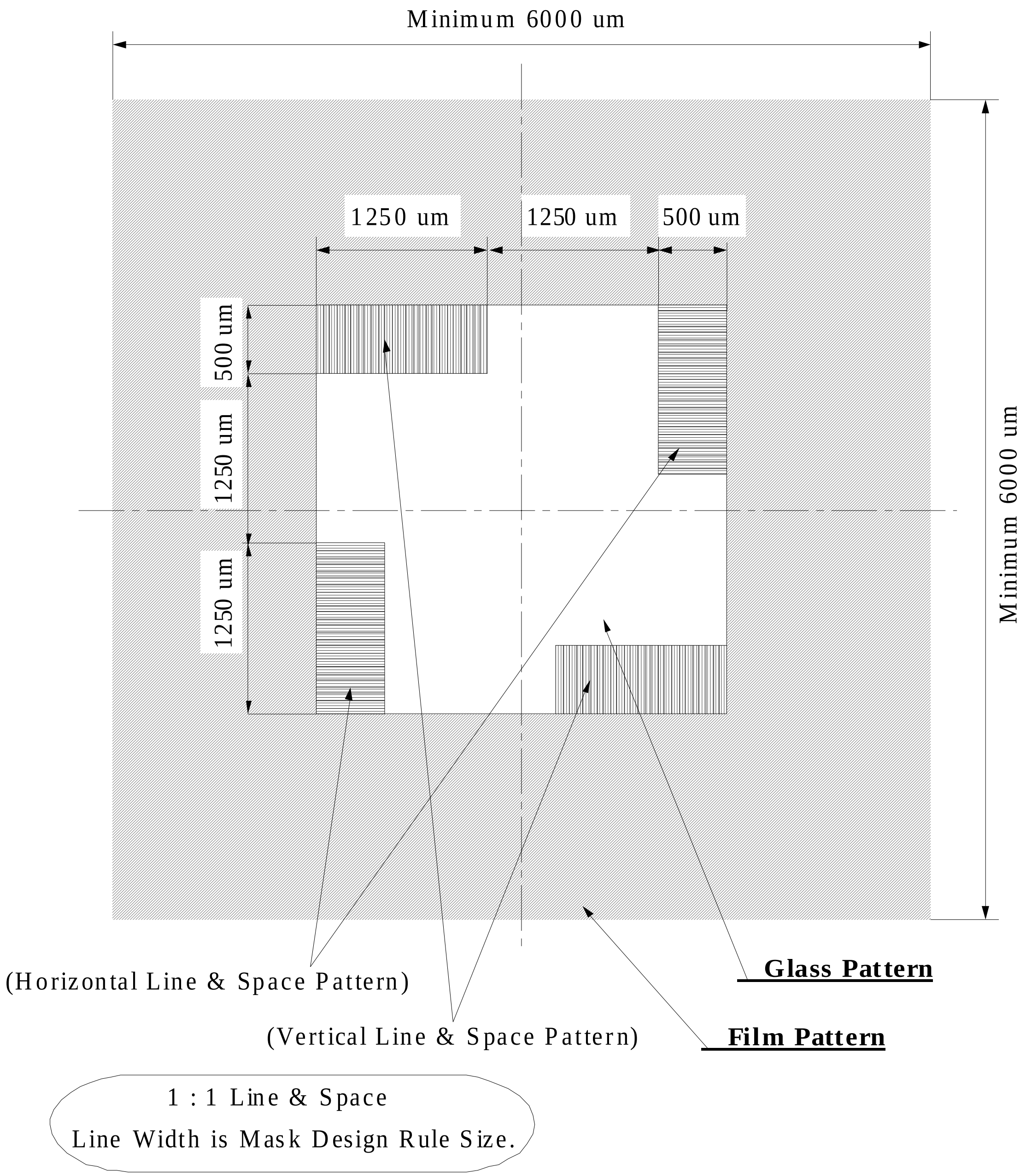
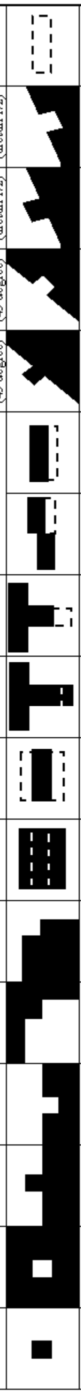


Figure 25
Light Intensity Adjustment Pattern



Defect Design Size (micron)		Isolated Defect: Dot	Hole	Edge Defect: Extension	Intrusion	Corner Defect: Extension	Intrusion	Size Defect: Over size	Under size	Elongation	Truncation	Misplacement Defect: Misplacement		Edge Defect: Extension (45 degree)	Intrusion (45 degree)	Extension (arctan 1/2)	Intrusion (arctan 1/2)	Missing
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
0.05	1																	
0.10	2																	
0.15	3																	
0.20	4																	
0.25	5																	
0.30	6																	
0.35	7																	
0.40	8																	
0.45	9																	
0.50	10																	
0.55	11																	
0.60	12																	
0.65	13																	
0.70	14																	
0.75	15																	
0.80	16																	
0.85	17																	
0.90	18																	
0.95	19																	
1.00	20																	

Figure 26
Sensitivity Check Sheet – Wiring Pattern

Defect	Isolated Defect		Edge Defect		Corner Defect		Size Defect				Misplacement Defect			Missing
Design Size	Dot	Hole	Extension	Intrusion	Extension	Intrusion	Over size	Under size	Elongation	Truncation	Misplacement	Dense	Isolated	
(micron)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
0.05 1														
0.10 2														
0.15 3														
0.20 4														
0.25 5														
0.30 6														
0.35 7														
0.40 8														
0.45 9														
0.50 10														
0.55 11														
0.60 12														
0.65 13														
0.70 14														
0.75 15														
0.80 16														
0.85 17														
0.90 18														
0.95 19														
1.00 20														

Figure 27
Sensitivity Check Sheet – Contact Hole Pattern

SEMI P24-94
CD METROLOGY PROCEDURES

Introduction

1.1 *Purpose* — The purpose of this document is to establish uniform procedures for metrology systems for the litho-metrology task. It does not address how these systems will be applied to solve problems, nor does it address other contributors to process variations such as thermal wafer processing, exposure tool focus control, materials, etc.

1.2 *Background* — Fundamental to manufacturing is the gauging or measurement process. It is required initially to develop a usable manufacturing capability and then to verify that what is being manufactured conforms to specification/expectation.

1.3 *Scope* — This document discusses determining the performance of gauging/measurement systems for a very specific application — the lithography section of integrated circuit wafer fabrication. This document in many cases, will be applicable to IC mask-making, in which case the word “mask” can be substituted for “wafer.”

It is acknowledged that the final measurement for a fabricated wafer is the electrical functionality. However, the intermediate lithographic measurements can be useful in prediction and control of final functionality. This document is intended to be useful for this litho-metrology application, irrespective of the technology employed.

Measurement results and system performance depend on the sample(s) used. Therefore, performance for different systems or the same system at different times can only be appropriately compared when the measurements are obtained with a sample of the same material composition.

The parameter addressed is precision. Additional important parameters are reliability and cleanliness, which have been addressed by other SEMI standards.

2 Applicable Documents

2.1 *SEMI Documents*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI P19 — Specification for Metrology Pattern Cells for Integrated Circuit Manufacture

2.2 *ASTM Standards*[1]

ASTM D 1129 — D-29

ASTM C 609 — C-21

ASTM D 4790 — D-16

ASTM E 180 — E-15

2.3 *Applications*

2.3.1 *Linewidth Measurement* — This task is to measure linewidths as defined by SEMI P19.

NOTE: Pitch is not addressed in this document.

2.3.2 *Contact Hole Measurement* — Contact and via hole area measurement is a different application which may use the same definitions and procedures as line-width measurement.

3 Precision

3.1 *Terminology*

3.1.1 *Precision* — The degree of agreement of repeated measurements of the same parameter expressed quantitatively as the standard deviation, computed from the results of a series of controlled determinations [ASTM D 1129, D-29].

A frequency plot of measurements taken with random error illustrates precision. The spread or variation of measurement in test A is smaller than that in test B. The results of test A are more precise than the results from test B. See Figure 1.

NOTE: Any test procedure used needs to differentiate between system and wafer contribution.

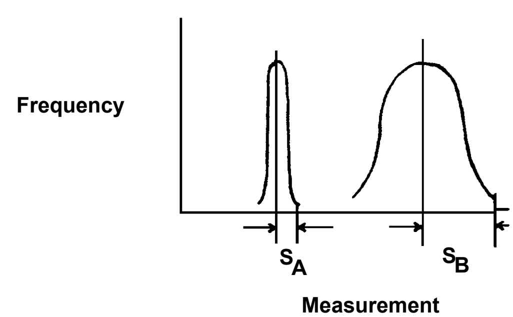


Figure 1
Generic Frequency Plot

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

3.1.2 *Repeatability* — The standard deviation of results obtained by the same operator using the same instrument in successive measurements [ASTM C 609, C-21]. The same system parameters need to be used. The degree to which the individual operator affects the measured result is a critical parameter and must be identified and benchmarked.

NOTE: The degree to which the individual operator affects the measured result may be a critical parameter and must be identified.

3.1.3 *Reproducibility* — The precision of a test method expressed in terms of agreement expected between measurements made in different laboratories using similar apparatus and the same procedure [ASTM D 4790, D-16].

3.1.4 *Stability* — The standard deviation of means of groups of measurements taken at specified intervals over an extended period of time.

NOTE: The means are used to avoid including the measurement precision. Stability is a characterization of the system independent of precision. It is important to use a stable sample so that system stability, independent of the sample, is determined.

3.1.5 *Standard Deviation* — A measure of the dispersion of a series of results around their average, expressed as the square root of the quantity, obtained by adding the squares of the deviations from the average of the results and dividing by the number of observations minus one. It is also the square root of the variance and can be calculated as follows:

$$s = \sqrt{\frac{(x_i = \bar{x})^2}{n-1}} \qquad (1)$$

Where:

s = estimated standard deviation of the series of results

X_i = each individual value

$\overline{X}$ = average (arithmetic mean) of all values, and

n = number of values

The following forms of this equation are more convenient for computation, especially when using a calculator:

$$s = \sqrt{\frac{x^2 - (\ x)^2 / n}{n-1}} \qquad (2)$$

or

$$s = \sqrt{\frac{n \quad x^2 - (\ x)^2}{n(n-1)}} \qquad (3)$$

where:

s = estimated standard deviation

x^2 = sum of the squares of all the individual values

$(\ x)^2$ = square of the total of the individual values, and

n = number of values

NOTE: Care must be taken in using either of these equations that a sufficient number of decimal places is carried in the sum of the values and in the sum of their square so that serious rounding errors do not occur. For best results, all rounding should be postponed until after a value has been obtained for s [ASTM E 180, E 15].

3.2 *Procedures to Benchmark Precision*

3.2.1 *Precision Types*

3.2.1.1 *Static Precision* — A series of measurements made of a single feature where, for each measurement, the information is reacquired and reprocessed. The minimal intervention required to repeat the measurement will be used. The standard deviation will be calculated based on the sample data.

3.2.1.2 *Z (Axis Adjustment) Precision* — A series of measurements is made of a single feature where it is necessary to refocus before each measurement (without intentional movement in the x and y axes before each measurement). The standard deviation will be calculated based on the sample data.

3.2.1.3 *Dynamic Precision* — Make one measurement of grouped line and space features at n number of sites on a focus/exposure matrix wafer, which includes typical size and side wall angle variations. Remove the wafer from the system, then reload and remeasure. Compute the dynamic precision, 3s, by the double sample method (see 2.3.1.3).

A total of 1 size × *n* sites × 2 repeates = 2*n* measurements per wafer × 3 passes = 6*n* measurements required.

10 is a minimum recommended value for *n*.

This may also be redone for different thicknesses of lines to be measured and repeated for each of the wafer types in the process.

3.3 *Precision Test*

3.3.1 *Test Methods*

3.3.1.1 *Stability Test Method* — Make a group of five measurements of a stable feature, such as etched polysilicon, at the same position, daily. Any system adjustment, maintenance, environment variation is allowed, but noted. Recalibration is optional, but is noted. Use a feature which doesn't change over time, or with repeated measurements. Plot the daily averages on an individual control chart with control limits based on the moving range of the daily averages.

3.3.1.2 *Sequence Test Method* — A series or sequence of measurements is taken of the same physical location. Any change between measurements determines the type of precision tested.

3.3.1.3 *Double Sample Test Method* — Two measurements are taken at separate times within the test run at a number of different physical locations. A series of sites is used which have: same nominal size, same proximity of other features, similar side wall angle, etc.

3.3.2 *Test Duration*

3.3.2.1 *Short Term* — No system calibration, adjustment, or maintenance will be done. The period should be short enough to minimize the effect of environmental variations. See R1-1.

3.3.2.2 *Long Term* — Any system adjustments, maintenance, environment variation is allowed. See R1-2. Recalibration is optional.

3.3.3 *Presentation of Results* — Some information, relative to the data, must be included to qualify the results. Graphical representation of the data is recommended.

3.3.3.1 The following must be included:

— The estimated (1, 2, or 3) standard deviation(s),

— Short or Long Term

— Confidence interval (see Application Note A.3)

— The number of measurements or sample size (*n*)

— Describe the feature film and substrate film

— Nominal or average measurement

— Feature Type: line or space or hole, grouped or isolated

— The frequency of recalibration

— Test identified as the type performed

Additional information which should also be included, particularly with unusual conditions, are:

— Metric units are recommended, such as nanometer [nm] or micrometer [µm]

— Feature characteristics, such as: sidewall angle, wall profile, corner radius, materials, thickness, index of refraction, edge waviness, edge roughness

— Duration of the test

— The sample frequency

— Significant parameters such as operator, system model, serial number, pertinent environmental conditions, etc.

APPENDIX 1
REFERENCES

NOTE: This appendix was approved as an official part of SEMI P24 by full letter ballot procedure.

"ASTM Compilation of ASTM Standard Definitions," American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428.

Nyyssonen, Dr. Robert D. Larrabee, "Submicrometer Linewidth Metrology for the Optical Microscope," (J. of Research of National Bureau of Standards, Vol. 92, No. 3, May/June 1987). National Institute of Standards and Technology (NIST), Bldg. 202, Room 204, Gaithersburg, MD 20899.

Dr. Robert D. Larrabee and Dr. Michael T. Postek, "Precision, Accuracy, Uncertainty and Traceability and Their Application to Submicrometer Dimensional Metrology" (Solid-State Electronics, Vol. 36, No 5, pp 673-684, 1993).

SEMASPEC #91090709A-ENG, "Introduction to Measurement Capabilities Studies," SEMATECH, Technology Transfer, 2706 Montopolis Drive, Austin, TX 78741.

RELATED INFORMATION 1

NOTE – The material contained in this related information is not an official part of SEMI P24 and is not meant to modify or supersede the standard in any way. This information is provided as a source of information to aid in the application of the standard. As such, it is to be considered as reference material only. The standard should be referred to in all cases.

R1-1 Short Term Test Duration

It is recommended the short term test duration be 30 measurements done in the shortest possible time under the most limited of conditions to eliminate extraneous sources of variation.

R1-2 Long Term Duration

Common practice requires about 30 degrees of freedom in the highest level of sources of variation. For example, one should continue a long term study over 30 working days, if days is the highest level of variation.

R1-3 Confidence Interval

This is one way in which confidence interval is calculated.

$$\sqrt{\left(\frac{vs^2}{x^2_{v.1-\alpha/2}}\right) \le \sigma^2 \le \left(\frac{vs^2}{x^2_{v.\alpha/2}}\right)}$$

where

v = df in the extimated standard deviation,

α/2 – the alpha risk accepted for the estimate (1-α) is the “confidence level”, and

X^2 refers to the “chi-square” distribution which fits variances. The equation is arranged such that the area under the chi-square distribution is to the right of the designated value.

The reference distribution looks something like Figure R1-1 — its shape depends on the degrees of freedom in the estimate.

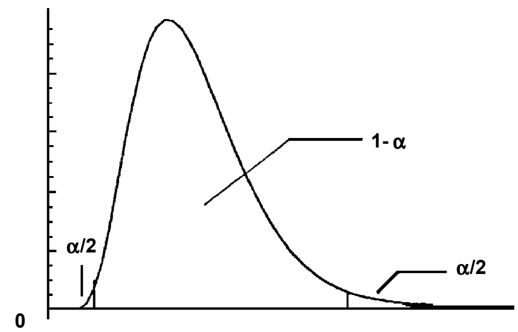


Figure R1-1
Example of a Chi-Square Distribution

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SEMI P25-94
SPECIFICATION FOR MEASURING DEPTH OF FOCUS AND BEST FOCUS

1 Purpose

This document provides a common descriptive vocabulary and outline of basic technique for use by photolithographers in the IC industry to gauge and report the depth of focus, astigmatism, and field curvature of IC photolithographic instruments (e.g., scanners, steppers). [Hereafter referred to as "instrument" or "instruments."]

2 Scope

This specification is limited to the measurement of focus and depth of focus for photolithography as used in the manufacture of integrated circuits and closely allied technologies. Because of the wide variation in equipment techniques, it is not possible to provide a definitive measurement procedure for these parameters. Rather, in this document, a basic guideline is offered.

Note: This technique has value in determining the best focus setting for a given application, however the main concern will be the determination for the depth of focus, astigmatism and field curvature for the purpose of comparing different instruments and processes.

3 Limitations

It must be emphasized that the values of depth of focus, astigmatism, and field curvature cannot be determined for a given instrument independent of the effects of the image geometries and the image transfer process. The values will have to be determined under the constraints of a practical application process, suitable for the instrument, illumination, process, object pattern, and environment. Thus, the process to be used for a fair measure of instrument performance must be one that is appropriate and has been optimized for the given instrument and application. Comparison of the performance of two different instruments will inherently be a comparison of the the total application, instrument specific processes included. A description of the process is a necessary part of the report of a depth of focus, astigmatism or field curvature measurement. Relying on values that were obtained under significantly different application conditions from the desired application will result in error and potential unexpected process failure.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI P19 — Metrology Pattern Cells for Integrated Circuit Manufacture

5 Terminology

NOTE: The scope of the following definitions does not necessarily cover application outside of the procedures discussed herein. For more universal definitions and discussion, the user is referred to any of the standard optical texts.

image (micropatterning) — Any single geometric form appearing in a layout: (1) drafting — as a part of a master drawing or layout; (2) optical — as projected on a screen or viewed, usually at some magnification or reduction; (3) oxide — as etched in the silicon dioxide layer on an oxidized silicon wafer; (4) photographic — as in a photomask or in the emulsion of a photographic film or plate; (5) as a photoresist, an exposed and developed coating on a substrate.

processed image (micropatterning) — Any single geometric form appearing in the realized pattern or topographical variation in a material surface or material constitution, obtained by a physical process of pattern transference from an optical image.

NOTE: This definition is intended to extend the discussion of depth of focus and focus to include both cases where the images are realized in photoresist films, per the image definition given above, and cases where there may not in fact be a photoresist film involved in the optical pattern transference process. Examples include photoactive chemical vapor deposition and photo ablation.

standard coordinates — A system of Cartesian coordinates with the z axis along the optical axis of the system and with the x and y axes in the flat plane perpendicular to the optical axis. The system user or the supplier will specify the x and y directions in this plane for any particular equipment studies.

NOTE: Upon occasion, cylindrical coordinates may be used for special discussions, for example, mapping astigmatism. The standard transform is used between the Cartesian (x,y) and the cylindrical (r,ø) is used.

NOTE: The x and y coordinates are taken as displacements from the optical axis along a flat plane. Thus, if the image plane is curved, the x and y coordinates are taken from the projection of the curved image plane onto a flat plane.

Consistently, r is taken as the distance along a perpendicular to the optical axis.

NOTE: A displacement along the z axis (and hence the optical axis) from a reference position will be negative for displacements toward midpoint of the optical system and positive for displacements away from the midpoint of the optical system, regardless of whether the reference position is on the object side or on the image side or coincident with some portion of the optical system.

NOTE: For folded optical systems, the coordinate system is allowed to rotate with position along the optical axis so that the above definition holds at any given position along the axis. Alternately, it may be assumed that for purposes of using this coordinate system, all optical paths are represented as unfolded.

image field — The extent of the image along the x and y axes. It may be defined by the limits of image quality, as a practical matter, for the intended application.

NOTE: Definitions 3.1 and 3.2 in combination with 3.4 define the drafting image field, the optical image field, the processed image field, etc. The term "image" refers to a single geometrical form. The term "field" refers to the complete set of forms.

practical use — The conditions of photoprocess, image geometries, etc. that are required for the intended use of the instrument. The practical use is specified by the following:

> *process* — Photoresist type and chemical processing, exposure conditions, and environmental conditions (temperature and humidty setpoints and stability).
>
> *pattern* — Description or diagram of the test structures, including the choice geometrical dimensions, orientations, positions.
>
> *substrate* — The substrate quality and specifications, including all pre-existing structures and layers on the substrate.
>
> *leveling* — The leveling mechanism used to hold the substrate at the desired position and angle with respect to the optical image plane.
>
> *site* — List or map of the image sites in the processed image field used for the tests.
>
> *criteria* — The acceptance criteria used in the evaluation of the processed images.

NOTE: Typically, the instrument vendor will indicate a range of practical use parameters and the instrument user will select from this range the actual conditions, as is appropriate to the user's needs.

resolution, practical — The minimum line width that reproduces the mask (or drafting) dimensions faithfully. [SEMI Micropatterning — Terms and Definitions Relating to the Microlithography Industry]

NOTE: The practical resolution is a number specified by the equipment vendor.

point-like object — A circular or square form in the image where the diameter or width is equal to the practical resolution.

evaluative line pattern — A pattern in the image constructed of 3 to 5 straight parallel lines where the lines are oriented at some specified angle with respect to the standard coordinates and where the width of the lines is equal to the practical resolution and the pitch of the lines is twice the practical resolution. (See SEMI P19.)

saggital lines — An evaluative line pattern where the lines lie along a radius to the optical axis. (See Figure 1.)

NOTE: Saggital lines are primarily formed from light rays that do not lie in planes containing the optical axis. For optical systems having cylindrical symmetry, such as some reduction steppers, the Saggital lines will be radial lines from some particular point of the image field. For other systems the lines may not be radial. For example, the Saggital direction for scanners is perpendicular to the direction of the scan throughout the image field.

tangential lines — An evaluative line pattern where the lines lie perpendicular to a radius to the optical axis. (See Figure 1.)

NOTE: Tangential lines are primarily formed from light rays that do lie in planes containing the optical axis. For systems having cylindrical symmetry, tangential lines lie upon circles about some particular point of the image field. For other systems, the lines may not be so arranged. For example, the tangential direction for scanners is parallel to the direction of the scan throughout the image field.

focus — A condition of geometric adjustment of the lens's object, the optical system and the image plane such that the optical image rays originating from a given point in the object converge to the smallest possible area at the corresponding point in the optical image. It is always given as a numerical displacement of the optical image point along the optical axis from some arbitrary reference such as an optical exit surface, optical center, conjugate plane, etc. Focus may vary across the image field and is properly given as a z axis value for a specified image site in the image field. (See the definition for Focal Surface.)

NOTE: Point-like objects will have the sharpest optical image at this z-axis position. The z-axis position for the sharpest processed image of point-like objects will usually have a constant offset from the z-axis position for the sharpest optical image for point-like objects. (See “mean focus” and “best focus” definitions that follow in the text.)

NOTE: This is also the position which yields the highest contrast in the photon flux at the given point in the optical image.

line focus — The z axis position where for evaluative lines in the image, the optical image has the highest contrast and the evaluative line pattern will consequently appear with the correct width and pitch. Line focus may vary across the image field and is properly given as a z axis value for a specified image site in the image field. It also varies with the line angle, and the line focus must, therefore, include a specification of the angle (e.g., Saggital, tangential, or some other angle).

focal surface — The surface determined by finding the focus for each point-like object in the optical image field, with the object fixed with respect to the lens. The focal surface is then the map of z axis displacements for the highest contrast at each point in the optical image field as a function of the (x,y) or (r,ø) coordinates.

NOTE: It is important to remember that the unqualified focal surface is determined using point-like objects, not lines or gratings. Separate determinations must be made for non-point-like objects.

field flatness — The difference between the maximum and the minimum z axis positions over the focal surface.

saggital focal surface — The focal surface determined by examining only Saggital lines.

tangential focal surface — The focal surface determined by examining only the tangential lines.

normal astigmatism — The difference in z axis position at each image site between the Saggital focal surface and the tangential focal surface. Astigmatism is a map of scalar values over the (x,y) coordinates of the image field.

rotated astigmatism — At each image site, the z axis difference for the line focus of two evaluative line sets, oriented at right angles to each other and at some specified angle to the coordinate system, where the specified angle is selected so that the z axis focus difference is a maximum at the given image site. The specified angle may vary from image site to image site.

NOTE: This is called “rotated” astigmatism because the specified angle is not necessarily the Saggital or tangential direction.

mean focus — The z axis position representing the area average focal surface for point-like objects in the optical image.

best focus — A position of the processed image surface such that the best compromise of focus across the whole of the processed image is obtained, as defined by the application requirements upon the processed image. The best focus is a single numerical value for the processed image surface displacement. The best compromise may be such as to optimize the possible defocus range or may optimize the line width variations or may minimize the deviation from some target width or may relate to some other processed image parameter.

NOTE: Because of processing effects, this may or may not correspond to an optical conjugate plane coincident with the photoresist film or other processed layer — top, middle, or bottom.

NOTE: Because the processed image surface will generally have a curvature that is not adjustable, it is not usual for the processed image surface to fully correspond to any of the focal surfaces. Focal surfaces are defined by determining the z-axis position for a given focus condition, as a function of the image position. A processed image surface is therefore set at a z axis position that provides the best compliance to the focal surface.

defocus — The distance, perpendicular to the image plane, between the processed image plane and the plane of best focus.

NOTE: A defocus of zero is the best focus position, a positive defocus places the optical image plane further from the lens, a negative defocus places the optical image plane closer to the lens.

focal range — Depth of focus — the total distance of defocus where over the whole of the processed image field, the processed image is sufficiently resolved for practical use.

depth of focus map — A plot, for each position in the image field, of the greatest defocus in the positive direction and the greatest defocus in the negative direction, where the processed image is sufficiently resolved for practical use.

NOTE: As stated previously, the focal range or the depth of focus are dependent on the process, upon the image geometries (especially the line width), and upon the permissible deviations. The depth of focus maps may be dependant, among other things, on the process, line width, and image geometry, especially the choice of point-like patterns or line-like patterns along the Saggital, tangential, or other directions. Several maps may be produced as part of a test, covering these variations.

6 Procedure

6.1 *Pattern* — See SEMI P19. A pattern and pattern dimensions are to be selected in accordance with the most reasonable correspondence to the intended application of the equipment. Typically, the pattern will consist of two sets of evaluative lines. A sequence of patterns of varying line widths may also be employed, in which case the depth of focus may be reported as a function of the line width. The pattern selection and dimensions must be included as part of the report.

6.2 *Test Sites* — The pattern is to be repeated at least nine times over the image field. The minimum of nine sites will include the four corners of the image, the four edge midpoints of the image field and the center of the image field. Whichever many sites are used, the sites must be distributed symmetrical and uniformly over the image field, giving no special weight to any portion of the image field. For examples, see Figure 2.

6.3 *Process* — A test image will be printed under the same conditions and processes to be used in the practical application (see Section 2) of the instrument (stepper, scanner, etc.). The process description will be included in the depth of focus and best focus report.

6.4 *Focus Steps* — The image will be printed several times, varying the defocus by a fixed amount between each print. The amount of variation of defocus between steps and the limits of the defocus will be selected so as to bracket the expected best focus position and to reach beyond the depth of focus at the extremes of the image series, as best as can be determined. The number and size of the defocus steps must be specified in the report.

6.5 *Image Array* — These multiple images can be a row of separate exposure fields on one substrate, multiple stepped displaced exposures of the test geometry within one image field region, or even exposures on entirely separate substrates. The particular strategy is usually constrained by the functions of the instrument under test.

6.6 *Test Measurements* — For each image site for both test pattern orientations and at each value of defocus, the processed image geometries will be examined and either accepted or rejected on the basis of image sharpness, image size or some related image characteristic. Usually this examination will use the line width as the acceptance criteria. The total number of the measurements will be twice the number of sites times the number of defocus steps.

6.7 *Quantitative Image Evaluation* — The photoresist image patterns will be examined or measured for deviation from the target, in a manner specified by the vendor or user of the instrument. An acceptable image is where the variation of the pattern is not outside the permissible deviation under the conditions of the intended use of the equipment. The defocus values for which the image is usable will be determined at each image site within the image field.

6.8 *Depth of Focus and Best Focus Determination* — The defocus variation over which there are usable images at simultaneously every test site within the field, by the above criteria, will be reported as the practical focal range. In accordance with the definition, the best focus will be the z axis position where some target specification is met or the possible defocus is maximized or the line deviation minimized, etc. If there is no common range of usable defocus across the the field, the depth of focus is zero and the best focus is undetermined. This can occur due to, among other things, a large plane tilt of substrate to the optical axis, high aerial image focus surface curvature, high astigmatism, and auto focus system instabilities.

6.9 *Focal Astigmatism Determination* — The test measurements are separated into two groups, one group for each of the two different orthogonal orientations of the test pattern. These groups are referred to as the “S” and “T” groups, however the Saggital and tangential orientations have not necessarily been used in accordance with the definition of “rotated astigmatism.”

For each group separately, the focal surface is determined by using for each site the midpoint of the defocus values where the processed image is found to be acceptable, in accordance with Section 4.7.

The difference in z position between these surfaces for each image site is calculated. These differences are plotted as a function of image position. This map of values is the astigmatism.

The maximum of the absolute values is the maximum astigmatism.

The average of the absolute values is the mean astigmatism.

6.10 *Field Flatness Determination* — Two alternative but essentially equivalent methods of determining the focal surface are allowed:

a. The focal surface which is the midpoint of the S and T focal surfaces is calculated.

b. Alternatively, if point-like objects are available in the image for evaluation, the focal surface may be obtained by finding the z displacement for the best processed point image at each image site.

This focal surface is reported as a map of z displacements as a function of image position. This map is the curvature of field.

The difference between the minimum z displacement in the focal surface and the maximum z displacement in the focal surface is the maximum curvature of field.

NOTE: This includes optical image curvature, wafer curvature, fixture curvature, etc. This procedure for the sake of simplicity does not separate these effects. It is an error to consider this measure of field flatness equivalent to a measure of the optical image focal surface.

7 Report

The depth of focus, best focus, etc. reports will include a description of the practical use, per definition 3.2.5. In addition, the report should include mention of any special mechanical considerations — in particular, among others, mention should be made if a chip leveling scheme is used and whether this scheme is site by site or global.

List of report contents:

Process: substrate and layer types and processing, exposure conditions

Pattern: description or diagram of the test structures, including the choice of S and T or X and Y orientations

Wafer: the wafer quality and specifications.

Leveling: leveling mechanism.

Sites: list or map of the image sites.

Criteria: the acceptance criteria used in the evaluation of the test structures.

Depth of Focus or Focal Range (single overall values)

Best Focus (single overall value)

Astigmatism map

Maximum Astigmatism

Mean Astigmatism

Field Flatness map

Maximum Curvature of Field

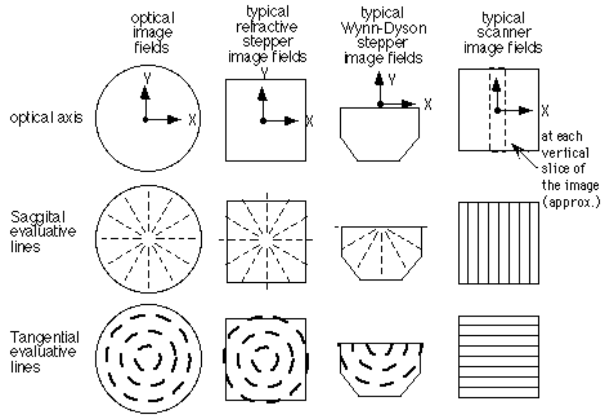

Figure 1
The Coordinate System and the Sagittal and Tangential Lines, Shown for the Optical Image Cylindrical Symmetry and for the Actual Processed Images of Steppers and Scanners

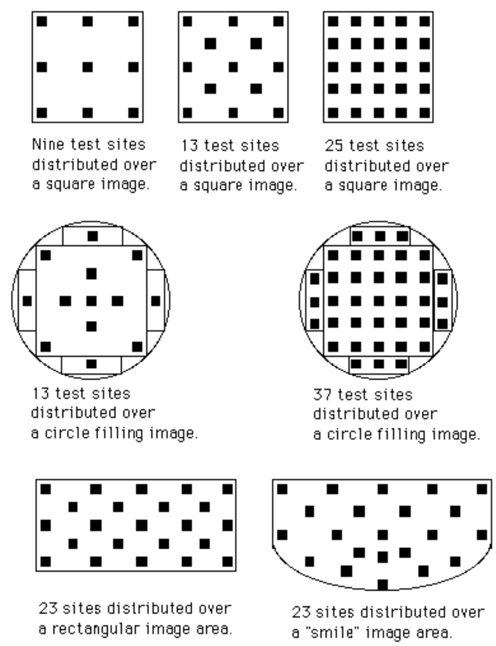

Figure 2
Typical Test Site Placements in Various Types of Image Fields

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SEMI P26-96
PARAMETER CHECKLIST FOR PHOTORESIST SENSITIVITY MEASUREMENT

1 Purpose

1.1 This checklist identifies the parameters for the measurement of photoresist sensitivity in order to avoid the variations between the supplier and users of photoresist.

2 Scope

2.1 The resists for which this guideline is intended are positive photoresist, excluding chemically amplified resists, for which the evaluation method of the sensitivity characteristics is not established.

2.2 In discussions between the supplier and the user of the resists, quantitative values should be provided for each parameter.

3 Referenced Documents

3.1 *SEMI Standard*

SEMI P27 — Parameter Checklist for Resist Thickness Measurement on a Substrate

ASTM[1]

ASTM F1059 — Practice for Calculating the Contrast and Threshold Sensitivity of a Positive Photoresist

4 Terminology

4.1 E_{th} *(threshold energy)* — The exposure energy where the remained thickness ratio becomes zero on the sensitivity curve.

4.2 E_{op} *(optimum energy)* — The exposure energy where the mask dimensions can be reproduced faithfully.

5 Parameters

5.1 *Substrate* — Silicon wafer

5.2 *Pre-Treatment of Substrate*

5.2.1 Removal of native oxide on silicon wafer is recommended.

5.2.2 Describe the process when the surface of silicon wafer has been treated with HMDS.

5.3 *Resist*

5.3.1 Trade-name of photoresist.

5.3.2 Film thickness after prebake. (Recommended thickness is 1.0–1.2 µm.)

5.4 *Prebake Condition*

5.4.1 Type of equipment for prebake; contact or proximity-bake.

5.4.2 Measuring position of the temperature in baking equipment and equipment for temperature measuring.

5.4.3 Baking time (sec).

5.4.4 Program sequence.

5.5 *Exposure*

5.5.1 Type of exposure machine; stepper or mirror projection.

5.5.2 Wavelength and half width (nm).

5.5.3 Light intensity of the exposed surface (mW/cm^2).

5.5.4 Numerical Aperture and sigma value.

5.6 *Post-Exposure Bake (if performed)*

5.6.1 Type of equipment for post-exposure bake; contact or proximity-bake.

5.6.2 Measuring position of the temperature in baking equipment and equipment for temperature measuring.

5.6.3 Baking time (sec).

5.6.4 Program sequence.

5.6.5 Film thickness after post-exposure bake.

5.7 *Development*

5.7.1 Type of developer; commercial name and chemical composition.

5.7.2 Concentration of developer (weight % or molar %).

5.7.3 Dilution factor.

5.7.4 Method; Spray (nozzle type, rotation speed, flow rate of developer), Puddle (program of sequence).

5.7.5 Temperature of developer, room temperature.

5.7.6 Development time (sec).

5.8 *Postbake*

5.8.1 Type of equipment for postbake; contact or proximity-bake.

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5.8.2 Measuring position of the temperature in baking equipment and equipment for temperature measuring.

5.8.3 Time (sec).

5.8.4 Program sequence.

5.9 *Measuring Equipment*

5.9.1 Specify the measurement system for the film thickness measurement.

5.9.2 Specify the measurement system for the pattern width measurement.

5.10 *Other* — Line-width of pattern in the reticle affects to E_{op}. The use of reticle with the width accuracy of ± 5/100 µm to the pattern, or co-share of reticle for the crosscheck is recommended for the purpose of this guideline.

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SEMI P27-96
PARAMETER CHECKLIST FOR RESIST THICKNESS MEASUREMENT ON A SUBSTRATE

1 Purpose

1.1 This checklist identifies the parameters for the thickness measurement of single layer resist on a substrate. Several methods are known for the thickness measurement of thin films, among them two methods are widely used for the thickness measurement of resist films.

1.2 They are the surface profilemeters which use mechanical contact method to detect the topology of a surface, and the light interference method which can be used only for transparent films.

1.3 The contacting method has more accuracy than light interference method, but the precision of the measurement is limited. The light interference method shows much more precision than the other but the results depend on measuring conditions.

2 Scope

2.1 This guideline describes on the parameters for the thickness measurement of single layer resist in lithography process.

2.2 For example, pre-expose resist thickness measurement on a bare silicon wafer for the QC of an optical resist, or the resist thickness measurement of partially exposed and fully exposed films after development for the determination of a characteristic curve of a resist.

3 Referenced Documents

3.1 *ASTM*[1]

ASTM F804-83 — Standard Practice for Producing Spin Coating Resist Curves, 7.4 Thickness Measuring Instrument

4 Parameters for Contact Type Measuring Instruments (Surface Profilometer)

1. Name of the instrument used for the measurement
2. Pressure of the stylus
3. Radius of curvature of the stylus tip
4. Type of substrate
5. The method of making a scratch on the surface of the resist
6. Temperature and relative humidity of the room

NOTE: The stylus pressure should be so adjusted that it does not leave a visible indented track mark on the resist surface at × 50 optical microscope magnification.

5 Parameters for Light Interference Thickness Measurement Apparatus

1. Name of the apparatus used for the measurement
2. Refractive index or Cauchy indexes of the resist used as the parameter of the measurement

$$n = A + \frac{B}{Y^2} + \frac{C}{Y^4}$$

where

A, B, C = Cauchy indexes

n = refractive index

Y = wave length

3. The range of wave length used for the measurement should be specified. Type of the substrate. Surface condition, cleaning method and the refractive index of the substrate if available.
4. Magnification setting
5. Type of optical filter
6. Temperature and relative humidity of the room

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SEMI P28-96
SPECIFICATION FOR OVERLAY-METROLOGY TEST PATTERNS FOR INTEGRATED-CIRCUIT MANUFACTURE

1 Purpose

1.1 This document defines several standard overlay-metrology patterns that are used by metrology equipment users to evaluate and test micropatterning equipment and processes in integrated circuit (IC) manufacturing. These overlay cells may be placed by optional patterning methods onto substrates during the manufacturing process. Usage of the standard overlay patterns is an attempt to provide consistent industrywide use of automated metrology equipment.

2 Scope

2.1 This specification defines general designs that describe the shape, size, design rules, and placement considerations (where appropriate) of several basic patterns for overlay metrology. These standard test patterns can be used for optical, scanning electron beam, and other types of metrology.

3 Limitations

3.1 The patterns described in this document represent the first pass at an industrywide commonality for the purpose of compatibility among various types of automated metrology equipment. It is not suggested, however, that these test patterns are a full complement or are optimal for all overlay-metrology applications. This document does not attempt to specify how the patterns are to be imaged or measured on the substrate.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI International Standards Handbook — Section E: Compilation of Terms

SEMI P6 — Specification for Registration Marks for Photomasks

SEMI P18 — Specification for Overlay Capabilities of Wafer Steppers

SEMI P19 — Specification for Metrology Pattern Cells for Integrated Circuit Manufacture

4.2 *ASTM Standard*[1]

F 127-84 — Definition of Terms Relating to Photomasking Technology for Microelectronics

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5 Terminology

5.1 *centerline* — a reference line that is equidistant from opposite edges of a feature.

5.2 *feature* — areas within a single continuous boundary (for example, an aggregate image) that have any physical property that is distinct from the background area outside the feature (e.g., the simplest element of a test pattern, such as a single line or bar). Some physical properties that may distinguish the feature are the refractive index, surface roughness, etc.

5.3 *feature dimension* — the dimension of interest; such as, the side of a box , bar width, and/or length.

5.4 *overlay (micropatterning)*

A vector quantity defined at every point on the wafer. It is the difference, O, between the vector position, P_1, of a substrate geometry, and the vector position of the corresponding point, P_2, in an overlaying pattern, which may consist of photoresist. [SEMI P18-92]

NOTE: All overlay test patterns are designed to provide both X and Y components of the vector overlay.

5.5 *pattern, overlay test* — a group of features for overlay metrology.

5.6 *pitch* — the distance between a point on an image and the corresponding point on the corresponding image in an adjacent functional pattern.

5.7 *substrate (materials)* — in semiconductor technology, a wafer that is the basis for subsequent processing operations in the fabrication of semiconductor devices or circuits. [ASTM F 1241-89] NOTE: The meaning of substrate is not limited to wafers.

6 General Specification

6.1 *Introduction*

6.1.1 This specification describes the overlay test patterns that are illustrated in the figures at the end of this document. The imaging means by which these test patterns are defined on the substrate may be selected by the user (see 6.2.1).

6.1.2 Characteristics of the overlay patterns, such as materials, topography, polarity, and method of pattern transfer will be defined by the user unless otherwise noted. When reporting measurements extracted from these overlay test patterns, the user should state the physical conditions (e.g., photoresist island on metal over an oxide window). The user should further state which features constitute the substrate geometry and which constitute the overlaying pattern (terms as used in the definition of overlay in 5.4). In general, the vectors P1 and P2 terminate at the geometrical centers of the substrate pattern and the overlaying pattern respectively.

6.2 *Applications*

6.2.1 The overlay test patterns are intended to be used in a variety of applications. The following applications list shows some uses for the overlay test patterns.

- Primary Pattern Generation
- Lithography & Metrology Equipment Characterization
- In-Line Process Overlay Monitoring
- Manufacturing Characterization
- Process Transfer Between Manufacturing Sites

6.3 *Guidelines*

6.3.1 The overlay test patterns described herein represent a basic metrology set from which composite patterns may be constructed.

6.3.2 Each overlay test pattern has a fundamental design. The user may adjust the dimensions appropriately as they apply to the user's specific processing/equipment situations.

6.3.3 It is required that labels, border lines, indicator marks, or any other adjacent features be avoided, or at least separated by a minimum of ten (10) micrometers from the overlay cell. This proximity guideline is defined to remind the user that patterns intended to be independent and symmetric be designed as circumstances permit. The user should determine actual spacing values, because spacing may be level-, process-, and/or tool-dependent.

6.3.4 It is recognized that there are design limitations dictated by the equipment and processes used to generate the pattern (e.g., computer aided graphics (CAD) grids, pattern generation (PG) rectangles, E-beam spot sizes). The user may modify the overlay test patterns in order to meet equipment limitations (e.g., stay on grid) provided that the resulting patterns or their representations retain the designed structures and symmetry.

7 Detailed Specification

7.1 *Introduction*

7.1.1 The figures provided within this document are intended to illustrate sample layouts of several overlay test patterns, and to define appropriate design elements used within each. The overlay test pattern dimensions are provided when appropriate. It is understood that, to optimize the test pattern's performance in a specific application, the user may deviate beyond this standard.

7.2 *Specific Overlay Patterns* — All patterns have 90° rotational symmetry.

7.2.1 *Box-in-Box (see Figure 1)*

7.2.1.1 The box-in-box test pattern is designed to be a test pattern for overlay measurement on metrology equipment. This is the simplest possible design presented.

7.2.1.2 The box-in-box test pattern consists of two square features. Each box is normally defined by a different imaging step; that is, one box corresponds to the substrate geometry and the other box corresponds to the overlaying pattern (5.4). The two boxes are designed to be concentric.

7.2.1.3 The design elements are the feature dimensions of the outer box, B_o, and of the inner box, B_i. The dimensions should follow these guidelines:

outer box: $B_o = 12 – 30$ micrometers (µm)

inner box: $B_i = B_o/2$

These specifications define a range of box sizes and their interfeature spacing. Users should modify the box-in-box dimensions as dictated by design rules, process, and/or measurement equipment requirements. The user should recognize that edges in close proximity may cause measurement errors.

7.2.2 *Frame-in-Frame (see Figure 2)*

7.2.2.1 The frame-in-frame test pattern is designed to be a test pattern for overlay measurement on metrology equipment. It has two designed edges per axis on each side of each imaged step. The additional information gained by having two features on each level, each with a centerline, may reduce the measurement uncertainty as compared to the box-in-box design.

7.2.2.2 The design elements are the pitch of opposite members of the outer frame (F_o), the pitch of opposite members of the inner frame (F_i), and the widths of the frames (W_o and/or W_i) as shown in Figure 2. Each frame is normally defined by a different imaging step; that is, one frame corresponds to the substrate geometry and the other box corresponds to the overlaying pattern (see 5.4). The frames are designed to be concentric.

7.2.2.3 The design elements are the outermost dimension of the outer frame (F_o), the outermost dimension for the inner frame (F_i), and the width(s) of the frames (W_o and/or W_i). The dimensions should follow these guidelines:

outer frame: F_o = 15–30 micrometers (µm)

inner frame: $F_i = F_o/2$

width: W = 1.0–1.5 µm for $F_o \leq 24$ µm, or 1.5–2.0 µm for $F_o \geq 24$ µm

NOTE: The width of the inner and outer bars may differ.

These specifications define a range of frame sizes and their interfeature spacing. Users may modify the frame-in-frame dimensions as dictated by design rules, process, and/or measurement equipment requirements.

7.2.3 *Bars-in-Bars (see Figure 3)*

7.2.3.1 The bars-in-bars test pattern is designed to be a test pattern for overlay measurement on metrology equipment. Each axis has two designed edges per axis on each side of each imaging step. The additional information gained by having two features on each level, each with a centerline, may reduce the measurement uncertainty as compared to the box-in-box design.

7.2.3.2 The overlay test pattern consists of two sets of bars, the outer set and the inner set. Each set of bars is arranged to form an overlay measurement frame as shown in Figure 3. Each bar-in-bar set is normally defined by a different imaging step; that is, the set of inner bars corresponds to the substrate geometry and the set of outer bars corresponds to the overlaying pattern (5.4), or vice versa. The two sets of bars are designed to be concentric.

7.2.3.3 The design elements are the pitch for the outer set of bars (B_o), the pitch for the inner set of bars (B_i), the length of the outer bars (L_o), the length of the inner bars (L_i), and the width(s) of the bars (W_o and/or W_i). The overlay test pattern dimensions should follow these guidelines:

outer bar set: B_o = 15–30 µm

inner bar set: $B_i = B_o/2$

outer bar length: L_o = 50%–70% B_o

inner bar length: L_I = 50%–70% B_i

width: W = 1.0–1.5 µm for $B_o \leq 24$ µm, or 1.5–2.0 µm for $B_o \geq 24$ µm

NOTE: The width of the inner and outer bars may differ.

These specifications define a range of box sizes and their interfeature spacing. Users may modify the box-in-box dimensions as dictated by design rules, process, and/or measurement equipment requirements. The user should recognize that edges in close proximity may cause measurement errors.

7.3 *User Considerations for Overlay-Metrology Equipment*

7.3.1 *Pattern Acquisition* — To ensure automatic acquisition of the desired overlay test pattern by an image-based automated overlay metrology equipment, one or more of the following may be required:

1. Separation of each overlay test pattern as required per metrology equipment specification.
2. Use of only one overlay test pattern in the measurement field-of-view.
3. Printing unique labels next to each overlay test pattern using the proximity guideline in Section 6.3.3.

7.3.2 *Feature Dimensions* — For each overlay test pattern, only a range of feature dimensions is defined (e.g., paragraph 7.2.2.3). The user and supplier together should determine that the dimensions of the overlay test patterns they select are those that consider design rules, the user's process capability, and limitations of the microlithography and measurement equipment.

7.3.2.1 *Width Dimensions* (frame-in-frame or bars-in-bars test patterns) — When all features of the overlay test pattern are imaged at the same process step, the widths of the inner and outer features are recommended to be equal, and of the same polarity, in order to minimize overlay-measurement errors.

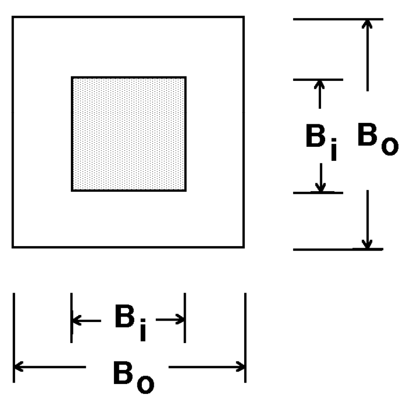


Figure 1
Box-in-Box

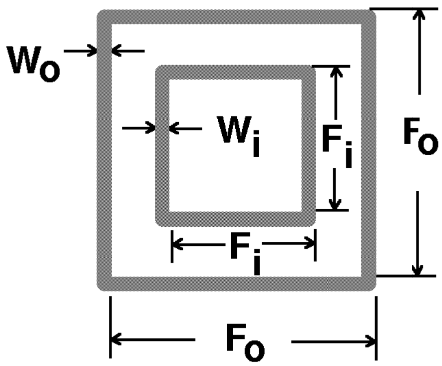


Figure 2
Frame-in-Frame

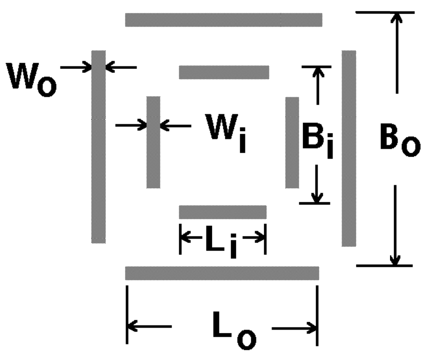


Figure 3
Bars-in-Bars

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI P29-0997
GUIDELINE FOR DESCRIPTION OF CHARACTERISTICS SPECIFIC TO HALFTONE/ATTENUATED PHASE SHIFT MASKS AND MASK BLANKS

1 Purpose

1.1 This guideline defines the characteristics specific to halftone/attenuated phase shift masks and mask blanks.

1.2 This guideline is intended to provide a baseline for specification of phase shift masks and mask blanks to be agreed between the supplier and user.

Because the phase shift mask is still under development, it may be needed to continue the research activity to standardize a final specification.

2 Scope

2.1 This guideline applies to halftone/attenuated phase shift masks and mask blanks for g-line, i-line, KrF, ArF, and/or DUV wavelengths.

2.2 These types of masks can be called either halftone or attenuated phase shift masks. This guideline uses “halftone phase shift masks” as the nomenclature.

2.3 Items not described in this guideline shall conform to SEMI P1.

3 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Documents*

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition

4 Terminology

4.1 *Terms for General Description*

4.1.1 *halftone phase shift mask* — a photomask designed to increase resolution through intentional control of light transmittance and phase against a transparent part by replacing a conventional opaque pattern with a thin, partially transmitting film (halftone shifter film) that controls light phase difference and transmittance.

4.1.2 *phase shift mask* — a photomask designed to increase resolution through intentional control of the exposure light phase.

4.2 *Terms for Structural Description*

4.2.1 *additional film type opaque ring* — an opaque ring composed of light shield materials other than the shifter.

4.2.2 *embedded shifter type opaque ring* — an opaque ring composed of small rectangles or line/space patterns in a shifter.

4.2.3 *multilayer halftone phase shift mask* — a halftone phase shift mask having multiple thin films of different material compositions to give a certain phase difference and transmittance. The layer that adjoins the substrate should be called the first layer.

4.2.4 *opaque ring* — an area of a certain width, adjacent to the periphery of the desired exposure area on a reticle, located in the non-exposure area of the reticle to obtain a dark portion required in a wafer lithography process.

4.2.5 *single-layer halftone phase shift mask* — halftone phase shift mask having a thin film of uniform material composition to give a certain phase difference and transmittance.

4.3 *Terms for Description of Optical Characteristics*

4.3.1 *glass side reflectivity* — a ratio of intensity of reflected light to intensity of incident light into the glass side that is the backside of the shifter film. The intensity of incident light is usually calculated by the intensity of reflected light measured using a reference mirror. (Figure 1 illustrates the glass side reflectivity.)

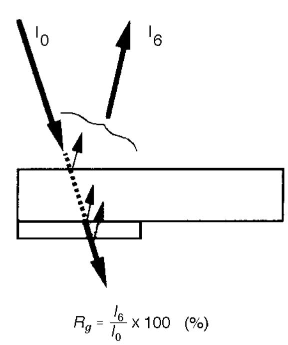
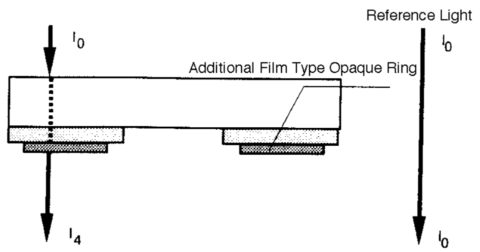


Figure 1
Glass Side Reflectivity

4.3.2 *opaque ring transmittance* — a ratio of intensity of light transmitted through the additional film type opaque ring area to intensity of incident light measured with air reference. (Figure 2 illustrates the opaque ring transmittance.)

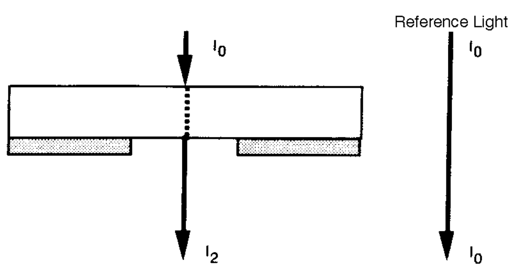
NOTE 1: For a halftone phase shift mask with embedded shifter type opaque ring, transmittance of the opaque ring area is not defined in this guideline because it depends heavily on the characteristics of the optical systems used.



$$T_4 = \frac{I_4}{I_0} \times 100 \quad (\%)$$

Figure 2
Opaque Ring Transmittance

4.3.3 *opening area transmittance* — a ratio of intensity of light transmitted through an opening area of a patterned halftone phase shift mask to intensity of vertical incident light measured with air reference. (Figure 3 illustrates the opening area transmittance.)

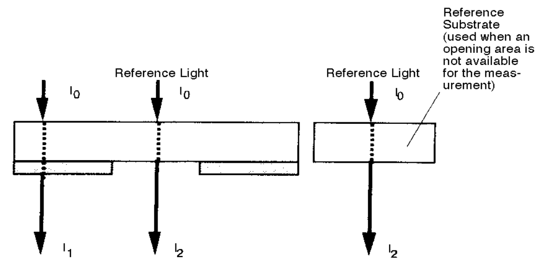


$$T_2 = \frac{I_2}{I_0} \times 100 \quad (\%)$$

Figure 3
Opening Area Transmittance

4.3.4 *phase difference* — a difference in phase of light generated by vertical transmission through a shifter area and an opening area with air equivalent to the shifter film in thickness.

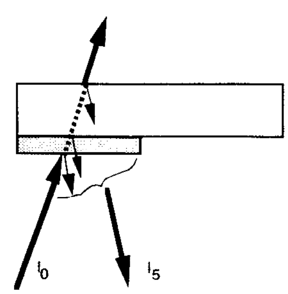
4.3.5 *relative transmittance* — a ratio of intensity of light transmitted through a shifter area to intensity of light transmitted through an opening area. (Figure 4 illustrates the relative transmittance.)



$$T_3 = \frac{T_1}{T_2} \times 100 \quad (\%) = \frac{\left(\frac{I_1}{I_0}\right)}{\left(\frac{I_2}{I_0}\right)} \times 100 = \frac{I_1}{I_2} \times 100 \quad (\%)$$

Figure 4
Relative Transmittance

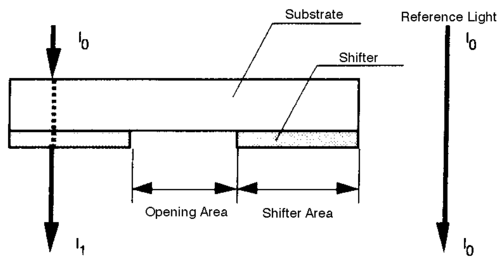
4.3.6 *shifter side reflectivity* — a ratio of intensity of reflected light to intensity of incident light onto the surface of a shifter film. The reflected light is the sum of the reflected light from the shifter surface and reflected light from the boundary between shifter and glass, and the boundary between glass and air. The reflectivity depends on the incident angle, the wavelength of the light, and the extent of polarization of the incident light. The intensity of incident light is usually calculated by the intensity of reflected light measured using reference mirror. (Figure 5 illustrates the shifter side reflectivity.)



$$R_s = \frac{I_5}{I_0} \times 100 \quad (\%)$$

Figure 5
Shifter Side Reflectivity

4.3.7 *shifter area transmittance* — ratio of intensity of light transmitted through a shifter area of a halftone phase shift mask (blank) to intensity of vertical incident light measured with air reference. (Figure 6 illustrates the shifter transmittance.)



$$T_1 = \frac{I_1}{I_0} \times 100 \quad (\%)$$

Figure 6
Shifter Area Transmittance

5 Mask Structure

5.1 Structure of a shifter shall be specified as single-layer type or multilayer type. A halftone shifter film whose components gradually change is classified into the multilayer type.

5.2 Structure of an opaque ring shall be specified as embedded shifter type or additional film type. In case of a mask blank, a light shield film may be added or not.

5.3 Addition of an electrically conductive layer, and/or a thin film for an etch-stop function shall be agreed upon by the supplier and user.

6 Film Thickness

6.1 For a mask blank, specifications such as film thickness of a shifter shall be agreed upon by the supplier and user. The film thickness may be described using a physical film thickness obtained from step height measurement, an optical film thickness obtained from ellipsometry or spectroscopy, and a controlled-film thickness obtained from rate method. Measuring method and measuring instrument shall be agreed upon by the supplier and user.

7 Film Materials

7.1 Specifications for materials and composition per layer in a shifter film and the opaque ring shall be agreed upon by the supplier and user.

8 Exposure Wavelength

8.1 As exposure wavelength, the center wavelength of g-line, i-line, KrF, ArF, and/or DUV shall be described in nm.

9 Transmittance

9.1 Specifications of transmittance shall be agreed upon by the supplier and user considering the selection of terms listed in Section 4.3 of this guideline.

9.2 A relative transmittance can also be obtained from the ratio of the shifter transmittance to the opening transmittance of a patterned halftone phase shift mask. In case the opening is not measurable, or it is a mask blank, a transmittance of a reference substrate should be used. The reference substrate shall be agreed upon by supplier and user beforehand.

9.3 Specifications of opening transmittance shall be agreed upon by the supplier and user considering its dependency to etching method.

9.4 Transmittance at the defect inspection wavelength, the dimension measurement wavelength, and/or the alignment wavelength shall be agreed upon by the supplier and user.

10 Phase Difference

10.1 Specifications of phase difference shall be agreed upon by the supplier and user giving attention to the measurement method. The unit should be degree. For a mask blank, the dependency of phase difference of a processed mask on the process method should be considered.

10.2 A measurement wavelength should be specified with its center value in nm. The measurement instrument and the bandwidth shall be agreed upon by the supplier and user.

11 Reflectivity

11.1 Shifter side reflectivity and glass side reflectivity should be described in percent, and its specification shall be agreed upon by the supplier and user. A measuring wavelength, a measuring instrument, a reference mirror, and an incident angle which are used for measurement shall be agreed upon by the supplier and user.

11.2 A defect inspection wavelength and an alignment wavelength shall be agreed upon by the supplier and user.

12 Opaque Ring Specification

12.1 Specification of an opaque ring shall be agreed upon by the supplier and user considering the type of opaque ring.

13 Etching Characteristics

13.1 Specifications of etching characteristics of a mask blank shall be agreed upon by the supplier and user.

14 Electrical Conductance

14.1 Electrical characteristics of a halftone phase shift mask blank should be represented by sheet resistance, and its specification and measuring method shall be agreed upon by the supplier and user.

15 Defects

15.1 Specific defects of a halftone phase shift mask and mask blank are phase defects and transmittance defects.

These defects are caused by halftone shifter dot, half-tone shifter hole, halftone shifter protrusion, halftone shifter intrusion, halftone shifter film thickness defect, halftone shifter film quality defect, and foreign materials.

15.2 Specifications for inspection and repair shall be agreed upon by the supplier and user.

15.3 Definition of defect sizes should conform to SEMI P22.

16 Ordering Information

16.1 It is recommended to agree mutually on the following items when ordering halftone phase shift masks. The other items should conform to SEMI P1.

Type of halftone structure	Single-layer type, or multilayer type
Type of opaque ring	Embedded shifter type, or additional film type
Film materials	To be agreed upon by the supplier and user
Exposure wavelength	To be agreed upon by the supplier and user
Transmittance	To be agreed upon by the supplier and user
Phase difference	To be agreed upon by the supplier and user
Reflectivity	To be agreed upon by the supplier and user
Defects, foreign materials, repair	To be agreed upon by the supplier and user

16.2 It is recommended to agree mutually on the following items when ordering halftone phase shift mask blanks. The other items should conform to SEMI P1.

Type of halftone structure	Single-layer type, or multilayer type
Light shield film	Added, or not
Film materials	To be agreed upon by the supplier and user
Exposure wavelength	To be agreed upon by the supplier and user
Transmittance	To be agreed upon by the supplier and user
Phase difference	To be agreed upon by the supplier and user
Reflectivity	To be agreed upon by the supplier and user
Etching characteristics	To be agreed upon by the supplier and user
Electrical conductivity	To be agreed upon by the supplier and user
Defects, foreign materials	To be agreed upon by the supplier and user

17 Sampling

17.1 Sampling should conform to SEMI P1.

18 Related Documents

SEMI P3 — Specification for Photoresist/E-Beam Resist for Hard Surface Photoplates

SEMI P30-0997
PRACTICE FOR CATALOG PUBLICATION OF CRITICAL DIMENSION MEASUREMENT SCANNING ELECTRON MICROSCOPES (CD-SEM)

1 Purpose

1.1 The purpose of this practice is to define terms listed in critical dimension-scanning electron microscopes (CD-SEM).

1.2 This document is designed to create a common understanding between suppliers and users.

2 Scope

2.1 This practice applies to terms listed in the CD-SEM catalog.

2.2 This practice also applies to terms listed in the estimate and purchasing specification.

3 Referenced Documents

None.

4 Terminology

4.1 *accelerating voltage* — the mean kinetic energy of primary electrons converted into voltage.

4.2 *alignment* — corrects coordinates for positions and specimen stage. Matching the coordinates of a wafer and a specimen stage in order to address measured patterns formed on a wafer.

4.3 *alignment error* — distance from the pattern center to screen center after alignment. This is the maximum distance between the screen center and a target pattern after addressing by its coordinates and completing alignment.

4.4 *Critical Dimension Measurement SEM (CD-SEM)* — selects fine patterns on a wafer and measure dimensions. Here, wafers include SEMI standards (defined sizes) only. The operation is normally in the following "sequence": Transport -> Stage Travel -> Positioning -> Measuring -> Transport.

4.5 *magnification* — the ratio of a deflection width on a display to that on a measurement pattern. Compares the deflection width on the screen and on the pattern.

4.6 *permissible floor loading capability* — the minimum floor loading capability where the equipment can be settled.

4.7 *permissible floor vibration* — the maximum floor vibration that can provide the guaranteed resolution.

4.8 *permissible air vibration* — the maximum air vibration that can provide the guaranteed resolution.

4.9 *permissible stray magnetic field* — the maximum change in the stray magnetic field that can provide the guaranteed resolution.

4.10 *measurable range* — measurement range to guarantee static and dynamic repeatability as well as linearity. Measuring dimensions guaranteed to be within the specification of static repeatability, dynamic repeatability, and linearity.

4.11 *measurement pattern determination method* — identifies the pattern to be measured. This method is used to identify the pattern to be measured. It is performed by automatic pattern recognition, or instructions from the operator.

4.11.1 *automatic pattern determination method* — the pattern selection method based on the automatic pattern recognition system.

4.11.2 *manual pattern determination method* — operator uses cursors, etc. The pattern selection method is accomplished by the operator placing cursors on the measurement pattern.

4.12 *measurement precision*

4.12.1 *static repeatability* — variations in average measurement values acquired in a sequence for a pattern. This is the closeness of agreement between the measured values obtained by measuring a pattern with wafer loading, wafer alignment, stage traveling to a measurement site, positioning of a measured pattern, measuring, and wafer unloading.

4.12.2 *dynamic repeatability* — variations between the nominal and measured dimensions. This is the maximum dispersion of measurements from the best approximate line defined between the nominal and measured dimensions.

4.12.3 *reproducibility* — variations in average measurement values acquired in a sequence during a certain period. This is the closeness of agreement between the mean values obtained by measuring a pattern repeatedly at stated period with wafer loading, wafer alignment, stage traveling to a measurement site, positioning of a measured pattern, measuring, and wafer unloading.

4.12.4 *linearity* — variations in measurement values without changing device and wafer conditions. This is the closeness of agreement between the measured values obtained by measuring a pattern repeatedly without any changes of measurement conditions.

4.13 *measurement target* — kind of measurement pattern. The measurement pattern, such as line, space, pitch, hole, box-in-box, etc.

4.14 *stage positioning range* — range on a wafer that can be measured by moving the wafer. This is the measurable range of a measured wafer placed on a specimen stage with stage moving.

4.15 *operation method* — the control method of operation sequence. There are three methods: auto, semi-auto, and manual.

4.15.1 *automatic operation method* — the operation method controlled by a computer automatically, after an operator sets a carrier on the equipment. The computer follows the commands written in a recipe. Uses a recipe on a computer.

4.15.2 *manual operation* — the operation method controlled by an operator without a recipe. Uses an operator.

4.15.3 *semi-auto operation* — the operating method controlled by a computer and an operator. The operator confirms the results of each command in a recipe using an automatic operation. Uses a recipe with an operator.

4.16 *pattern edge determination method* — uses a computer or an operator to look at the image. This is the method for determining the edge position of a given pattern, which is calculated by computer algorithm or by operator instructions.

4.16.1 *automatic pattern edge determination* — there are several methods, such as the threshold method, the linear approximation method, and the curve fitting method. This is the method used to determine the edge position automatically by calculating from the line profile signal of the secondary or back-scattered electrons. The calculations are performed using the aforementioned three algorithms.

4.16.2 *manual pattern edge determination method* — the operator measures the distance between cursors per image edge area. This method is used to determine the edge position manually by calculation based on the width between cursors, which are set to the measurement pattern edges by operator.

4.17 *pattern positioning error* — distance from the center of screen after positioning. This is the maximum distance between the screen center and a target pattern after pattern positioning.

4.18 *positioning of measured patterns* — moving pattern to the center screen (center of image field).

4.19 *image resolution* — resolution between two points. This is the minimum resolving distance between any two points in an image.

4.20 *stage positioning error* — variations when moving stage to a selected location repeatedly without correction. This is the positioning error of stage, which occurs when traveling to the same site repeatedly without electron beam deflection.

4.21 *throughput* — the number of processed wafers (per unit time, which is calculated from the time required for processing under pre-scheduled measurement sequence and conditions).

4.22 *transport* — transferring wafer from a wafer carrier to a specimen stage, or the reverse process.

4.23 *wafer size* — wafer diameter.

5 Listed Items

The following are desirable items and examples for listing in the CD-SEM catalog.

5.1	Equipment name			
5.2	Model			
5.3	Performance			
5.3.1	Throughput	___________	wafers/h	(Example: 30 wafers/h)
5.3.2	Image resolution	___________	nm	(Example: 5 nm)
5.3.3	Measurement precision			
5.3.3.1	Static repeatability	___________	nm (3 σ_{n-1})	(Example: 5 nm (3 σ_{n-1}))
5.3.3.2	Dynamic repeatability	___________	nm (3 σ_{n-1})	(Example: 5 nm (3 σ_{n-1}))
5.3.3.3	Reproducibility	___________	nm (3 σ_{n-1})	(Example: 5 nm (3 σ_{n-1}))
5.3.3.4	Linearity	___________	nm (3 σ_{n-1})	(Example: 5 nm (3 σ_{n-1}))
5.3.3.5	Precision guaranteed range	___________ µm ~	___________ µm	(Example: 0.2 µm ~ 10 µm, 5,000 ~ 200,000 x)
5.4	Function			
5.4.1	Wafer transport/Stage system			
5.4.1.1	Transport method	___________	(Example: double cassette support to C to C method)	
5.4.1.2	Stage stopping error	___________	µm (Example: ± µm)	
5.4.1.3	Wafer size	___________	mm (Example: 100, 125, 150, 200 mm)	
5.4.1.4	Positioning range	___________	(Example: whole wafer surface)	
5.4.2	Alignment system			
5.4.2.1	Alignment method	___________	(Example: uses optical image)	
5.4.2.2	Alignment precision	___________	± µm (Example: µm)	
5.4.2.3	Pattern positioning method	___________	(Example: moving cursor)	
5.4.2.4	Pattern positioning precision	___________	(Example: ± 0.1 µm)	
5.4.3	Electro-optical system			
5.4.3.1	Electron gun type	___________	(Example: LaB6/schottky/C-FE)	
5.4.3.2	Accelerating voltage	___________	(Example: 0.5–1.5 kV, 0.1 kV step)	
5.4.3.3	Probe current	___________	(Example: 0.2–10 pA)	
5.4.3.4	Magnification	___________	(Example: 100 ~ 200,000 times)	
5.4.4	Measurement			
5.4.4.1	Measurement pattern	___________	(Example: line/hole/overlay)	
5.4.4.2	Pattern determination method	___________	(Example: automatic (pattern recognition)/manual/cursor)	
5.4.4.3	Pattern edge determination method	___________	(Example: automatic (line approximation)/threshold method)	
5.4.4.4	Operation method	___________	(Example: auto/semiauto/manual)	
5.4.4.5	Communication protocol	___________	(Example: SECS)	
5.4.5	Vacuum exhaust system	___________	(Example: TMP (500 L/s) 1 unit, SIP (20 L/s) 2 units)	
5.5	Installation conditions			
5.5.1	Dimensions	width______mm,	depth______mm,	height______mm (May be included in the standard diagram.)
5.5.2	Standard layout diagram			
5.5.3	Mass	___________	kg	
5.5.4	Permissible environmental conditions			
5.5.4.1	Loading capability	___________	kg/m^2	
5.5.4.2	Stray magnetic field, maximum	___________	Tp-p	
5.5.4.3	Floor vibration, maximum	___________	dB	
5.5.4.4	Air vibration, maximum	___________	dB	
5.5.5	Electric power supply	___________ V/	___________ Φ/	___________ kVA
5.5.6	Water supply	___________	L/min.	
5.5.7	High-pressure gas supply	___________	(Example: Dry air, N_2)	
5.5.8	Reference standard		(Example: SEMI PXX-XX)	

6 Listed Items Guide (reference)

6.1 *Equipment Name* — List

6.2 *Model* — List

6.3 *Throughput* — To measure throughput, large-size wafers are generally used. List the number of processes per hour when 5-point measurement has been continuously processed. When wafers other than the maximum wafer sizes are used, list the wafer size. Also, list if the operator should intervene. The measurement position should be the center of wafer and the outside 4 points from 1/2 of the diameter on the diagonal line of the rectangle inscribing the wafer.

Please note that there are the following two methods:

6.3.1 The number of wafers that can be processed per hour for 1 wafer/lot processing.

6.3.2 The number of wafers that can be processed per hour for 25 wafers/lot continuous processing.

6.4 *Static Repeatability* — Use 3 σ_{n-1} and nm as the unit of measurement. When not listed, the sample should be the photoresist pattern and the number of measurement cycles should be 10.

6.5 *Dynamic Repeatability* — Use 3 σ_{n-1} and nm as the unit of measurement. When not listed, the sample should be the photoresist pattern, and the number of measurement cycles should be 10. In addition, one cycle of measurement should be just one cycle.

6.6 *Reproducibility* — Use 3 σ_{n-1} and nm as the unit of measurement. When not listed, the sample should be the photoresist pattern.

6.7 *Image Resolution* — The resolution should be listed in nm. In addition, the accelerating voltage acquired should be listed. When not listed, the sample should use gold deposition, and the conversion should be done from the photo image.

6.8 *Measurement Precision Warranty Range* — Should be listed in µm. When the precision depends on magnification, the listing of magnification is desirable.

6.9 *Operation Method* — List methods that can be used in auto, semi-auto, and manual.

6.10 *Transport Method* — List double-cassette supporting C to C method and/or SMIF supporting C to C method.

6.11 *Wafer Size* — List dimensions defined in SEMI M1. When creating guidelines, the dimensions are as follows: 2 inch, 3 inch, 100 mm, 125 mm, 150 mm, 200 mm, 300 mm, and 400 mm.

6.12 *Measurable Range* — List ranges that can be observed and measured through normal use in mm.

6.13 *Stage Stopping Error* — List the stopping error in mm when moving the maximum distance in both X and Y directions.

6.14 *Alignment Method* — List methods using optical microscopes, SEM images, and other.

6.15 *Alignment Precision* — List in µm.

6.16 *Measuring Pattern Identification Method* — List manual an auto and the content thereof.

6.17 *Pattern Edge Determination* — List manual an auto and the content thereof.

6.18 *Measuring Pattern Positioning Method* — List manual an auto and the content thereof.

6.19 *Measuring Pattern Positioning Accuracy* — List in µm.

6.20 *Magnification* — List range.

6.21 *Accelerating Voltage* — List range in V or kV units.

6.22 *Electron Gun* — List electron gun type.

6.23 *Vacuum Exhaust System* — List pump type, exhaust volume, and number of units.

6.24 *Communication Protocol* — List external computer and method of communication.

6.25 *Dimensions* — List block width, depth, and height per equipment block in mm. This may be listed in the standard layout diagram.

6.26 *Standard Layout Diagram* — List the standard layout when installing equipment. Equipment installation conditions can be listed in the diagram.

6.27 *Mass* — List in kg.

6.28 *Permissible Floor Weight* — List in kg/m^2.

6.29 *Permissible Stray Magnetic Field* — List in T, and list effective values or peak values separately.

6.30 *Permissible Floor Vibration* — List the maximum vibration level in dB in the 1~80 Hz frequency range. The vibration acceleration level La is found from the following equation:

$$La = 20\log(a/a_o)$$

Here,

a — Is the effective value of the vibration acceleration when the sensory vibration is not corrected:

a_o — (Standard vibration acceleration) (10^{-6} m/s^2)

6.31 *Permissible Air Vibration* — List the maximum sound level in dB in the 20 Hz ~ 8 kHz frequency range. The sound pressure level La is found from the following equation:

$La = 20\log(a/a_o)$

Here, a is the effective value for sound pressure in Pa units.

a_o (Standard sound pressure) (20 Pa)

6.32 *Reference Specification* — List guideline as the reference specification.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI P31-0997
PRACTICE FOR CATALOG PUBLICATION FOR CHEMICAL AMPLIFIED (CA) PHOTORESIST PARAMETER

1 Purpose

1.1 The purpose of this document is to provide a baseline for publication of chemical amplified (CA) photoresist parameters.

2 Scope

2.1 This document applies to CA photoresist used for semiconductor manufacturing.

2.2 This document is used as the guide to evaluate photoresist process parameters.

2.3 This document is not applicable for quality assurance.

3 Referenced Documents

None.

4 Terminology

4.1 *PEB* — post exposure bake

5 Description

NOTE: The following parameters for CA photoresist publication and test conditions should be described in the catalog.

5.1 Resist, overcoat and developer commercial name

5.2 Temperature and humidity

5.3 Environmental conditions (see Section 6)

5.4 Ammonia concentration measurement method (see Section 7)

5.5 Delay time dependency (see Section 8)

5.6 PEB temperature dependency (see Section 9)

5.7 PEB time dependency (see Section 10)

5.8 Substrate dependency (see Section 11)

5.9 *Measurement Conditions*

5.9.1 *Resist Coating and Development*

5.9.1.1 Resist baking method (contact baking or proximity baking)

5.9.1.2 Resist pre-baking temperature and time

5.9.1.3 Resist PEB temperature and time

5.9.1.4 Development time

5.9.1.5 Resist thickness

5.9.2 *Exposure*

5.9.2.1 Illumination conditions (NA, σ, etc.)

5.10 *Equipment Name*

5.10.1 Exposure equipment

5.10.2 SEM equipment

5.10.3 Ammonia concentration measurement equipment

6 Environmental Conditions

6.1 *Ammonia Concentration* — It is recommended to measure all CA photoresist parameters under the condition that the ammonia concentration is between 10–20 $\mu g/m^3$.

NOTE: CA photoresist is sensitive to the atmosphere, especially to ammonia. Acid from photoacid generator upon exposure is neutralized by the basic material in atmosphere like ammonia.

7 Ammonia Concentration Measurement Method

7.1 The ammonia concentration is measured by ion chromatography or another method which is capable to determine the ammonia concentration quantitatively in a range of 10–20 $\mu g/m^3$. The measurement equipment is calibrated with a standard ammonia solution.

8 Delay Time Dependency

NOTE: This section defines process conditions and procedures to obtain the delay time dependency.

8.1 *Resist Coating and Pre-baking* — Resist should be coated on the silicon substrate. After pre-baking, the resist thickness should be chose the bottom of swing curve of 0.7 μm. The actual thickness should be notified.

8.2 *Delay Time* — Delay time between resist coating and exposure, exposure and PEB, and PEB and development used for obtaining delay time dependency parameters are defined in Table 1.

Table 1 Delay Time Condition

Resist coating to exposure delay time						
0 min.			1 hour		6 hour	24 hour
NOTE: Normal sequential procedure without intentional delay between exposure and PEB as well as PEB and development.						
Exposure to PEB delay time						
0 min.	10 min.	30 min.	1 hour	2 hour		24 hour
NOTE: Normal sequential procedure without intentional delay between resist coating and exposure as well as PEB and development.						
PEB to development delay time						
0 min.	10 min.	30 min.	1 hour			24 hour
NOTE: Normal sequential procedure without intentional delay between resist coating and exposure time as well as exposure and PEB.						

NOTE: Zero minutes (0 min.) is defined as normal sequential procedure without intentional delay.

8.3 Measurement

8.3.1 After each time delay, fabricated 0.25 µm and 0.30 µm line and space patterns should be measured by SEM.

8.3.2 Record the measured pattern size.

8.3.3 Make the plotting of pattern size vs. delay time.

9 PEB Temperature Dependency

NOTE: This section defines process conditions and procedures to obtain the PEB temperature dependency.

9.1 *Resist Coating and Pre-baking* — Resist should be coated on the silicon substrate. After pre-baking, the resist thickness should be chose the bottom of the swing curve of 0.7 µm. The actual thickness should be notified.

9.2 *Measurement*

9.2.1 Ten points of temperature should be selected within ± 20 °C from the optimized PEB temperature. The fabricated 0.25 µm and 0.30 µm line and space patterns must be within the deviation of ± 20% from the optimized line width of 0.25 µm and 0.30 µm line and space patterns.

9.2.2 Record the measured pattern size.

9.2.3 Make the plotting of pattern width vs. PEB temperature. At least 6 to 8 points of pattern width should be plotted within the deviation of ± 10% from the optimized line width of 0.25 µm and 0.30 µm line and space patterns.

9.2.4 The cross section of resist patterns is observed and compared each other with standard sample. One should be selected from the optimized condition and the other one should be selected from the sample deviated around 10% from standard one.

10 PEB Time Dependency

NOTE: This section defines process conditions and procedures to obtain the PEB time dependency.

10.1 *Resist Coating and Pre-baking* — Resist should be coated on the silicon substrate. After pre-baking, the resist thickness should be chose the bottom of swing curve of 0.7 µm. The actual thickness should be notified.

10.2 *PEB Time* — PEB time should be selected from time 30 sec., 60 sec., 90 sec., 120 sec., 180 sec. on the optimized PEB temperature.

10.3 *Measurement*

10.3.1 Fabricated 0.25 µm and 0.30 µm line and space patterns should be measured by SEM.

10.3.2 Record the measured pattern size.

10.3.3 Make the plotting of pattern size vs. PEB time.

11 Substrate Dependency

11.1 *Resist Coating and Pre-baking* — Resist should be coated on a substrate. After pre-baking, the resist thickness should be chose the bottom of swing curve of 0.7 μm. The actual thickness should be notified.

11.2 *Observation* — Fabricated 0.25 μm and 0.30 μm line and space patterns and more than 1 μm isolated patterns should be observed by cross sectional SEM.

SEMI P32-0998
TEST METHOD FOR DETERMINATION OF TRACE METALS IN PHOTORESIST

1 Purpose

1.1 This document describes an outline of a quantitative analysis method on trace metal concentration. This standard is intended to promote communication between users and suppliers.

2 Scope

2.1 This document applies to a measurement of trace metal concentration in ppb level in photoresist by instrumental techniques, such as Atomic Absorption Spectrometry, Plasma Ion Source Mass Spectrometry, and Inductively Coupled Plasma Atomic Emission Spectrometry.

2.2 Object metals in this measurement are Al, Ca, Cr, Cu, Fe, Mg, Mn, Ni, K, and Na.

2.3 Either additional metals or fewer can be agreed upon between users and suppliers and are added to the measurement list.

2.4 The following method has given satisfactory results in determining trace metal impurities at the specified value for each of the target trace metals. Alternative methods or conditions may be used as long as appropriate studies demonstrate recovery between 75%–125% of a known sample spike for half the specification value. The results should be reported as within specification (below a certain value) or not in specification only (SEMI C1).

3 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *SEMI Standard*

SEMI C1 — Specifications for Reagents

3.2 *ASTM Standard*

ASTM D1193 — Standard Specification for Reagent Water

4 Summary of Method

4.1 Photoresist test solution is prepared by dry ashing method or direct method. Then trace metals in the test solution are measured by Atomic Absorption Spectrometry, Plasma Ion Source Mass Spectrometry, or Inductively Coupled Plasma Atomic Emission Spectrometry. The trace metal concentration is determined using a working curve, which is obtained by measuring a standard solution.

5 Terminology

5.1 *blank test* — a measurement without the subject photoresist, which is performed under the standard procedures.

5.2 *dilution factor* — numerical number that indicates final amount of solution divided by the initial amount of solution in the preparation of the photoresist process.

5.3 *direct method* — a sample preparation method for preparing samples for direct trace metal in photoresist. The materials are diluted with a solvent and then analyzed by the appropriate analytical instrument.

5.4 *dry ashing method* — a sample preparation method for preparing samples used in measuring trace metals in the photoresist. The photoresist is evaporated to dryness and decomposed to ash by heating. The ash is dissolved in a volumetric flask with acid and aqueous reagent, and then analyzed by the appropriate analytical instrument.

5.5 *plasma ion source mass spectrometry* — a method that isolates and measures quantitative metal element by mass spectrometer using plasma as excitation source. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Microwave Induced Plasma Mass Spectrometry (MIP-MS) belong to this category.

5.6 *working curve* — the relationship between known metal concentrations prepared by standard solutions and the observed values of instrumental analysis.

6 Apparatus

6.1 *Measurement Equipment*

6.1.1 Flame Atomic Absorption Spectrometer (F-AAS) and ICP-MS can use the dry ashing method.

6.1.2 Graphite Furnace Atomic Absorption Spectrometer (GF-AAS), Electrothermal Atomization Atomic Absorption Spectrometer (ETA-AAS), ICP-MS, MIP-MS, and Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) can use the direct method.

6.1.3 *Instrument Condition* — Recommended instrumental conditions are summarized in Table 1 for each target metal.

Table 1 Measurement Equipment and Metal Elements

Element	*Atomic Absorption Spectroscopy*	*Plasma Ion Source Mass Spectrometry*		*ICP-Atomic Emission Spectrometer*
		ICP-MS (Note 1)	*MIP-MS (Note 2)*	
Al	309.2 nm	^{27}Al	^{27}Al	396.2 nm
Ca	422.7 nm	^{40}Ca ^{44}Ca (Note 3)	^{40}Ca	393.4 nm
Cr	357.9 nm, 359.4 nm	^{52}Cr ^{53}Cr (Note 3)	^{52}Cr	267.7 nm 283.6 nm
Cu	324.7 nm	^{63}Cu ^{65}Cu	^{63}Cu ^{65}Cu	324.8 nm
Fe	248.3 nm	^{56}Fe ^{54}Fe (Note 3)	^{56}Fe ^{54}Fe	259.9 nm
Mg	285.2 nm	^{24}Mg ^{25}Mg ^{26}Mg	^{24}Mg ^{25}Mg ^{26}Mg	279.6 nm
Mn	279.5 nm	^{55}Mn (Note 3)	^{55}Mn	257.6 nm
Ni	232.0 nm, 341.4 nm	^{58}Ni ^{60}Ni (Note 3)	^{58}Ni ^{60}Ni	221.6 nm, 231.6 nm
K	766.5 nm	^{39}K ^{41}K (Note 3)	^{39}K ^{41}K	766.5 nm
Na	589.0 nm	^{23}Na	^{23}Na	589.0 nm

NOTE 1: *ICP-MS* — Ar is used as the plasma generation gas.

NOTE 2: *MIP-MS* — N_2 is used as the plasma generation gas.

NOTE 3: Beware of interfering ion (see Table 2).

Table 2 Interfering Ions

Object Metal	*Interfering Ion*
^{39}K	$^{38}Ar^{1}H$
^{41}K	$^{40}Ar^{1}H$
^{40}Ca	^{40}Ar
^{52}Cr	$^{40}Ar^{12}C$ $^{36}Ar^{16}O$ $^{38}Ar^{14}N$
^{55}Mn	$^{40}Ar^{14}C^{1}H$ $^{40}Ar^{15}N$ $^{38}Ar^{16}O^{1}H$
^{56}Fe	$^{40}Ar^{16}O$ $^{38}Ar^{18}O$
^{58}Ni	$^{40}Ar^{18}O$

7 Vessels, Reagents, and Environment

7.1 *Vessel*

7.1.1 Quartz glass volumetric flask

7.1.2 Quartz glass measuring pipette

7.1.3 Quartz glass beaker

7.1.4 PTFE vessel

7.1.5 Platinum crucible

7.2 *Reagents*

7.2.1 *DI Water* — Resistivity ≥ 18.0 MΩ cm at 25°C per ASTM D 1193.

7.2.2 *Organic Reagent* — Use commercially guaranteed reagent for trace metal analysis. Use the reagent of the same production lot for all measurements.

7.2.3 *Inorganic Reagent* — Use commercially guaranteed reagent for trace metal analysis. Use the reagent of the same production lot for all measurements.

7.2.4 *Standard Reagent* — Use the commercially guaranteed reagents which have certified trace metals concentration.

7.3 *Environment*

7.3.1 The measurement is recommended to be performed in a clean room or clean zone at constant temperature. The stability of temperature should be better than ± 2°C. Dry ashing method should be performed in a draft chamber with HEPA filter, if possible.

7.3.2 In the case of volumetric analysis, the measurement environment is set to the standard temperature of measuring tools such as volumetric flask and measuring pipette.

7.3.3 Record the number of particles at different sizes at the measuring point, if possible.

8 Procedures

8.1 *Flow Chart of Measurement* — See Figure 1.

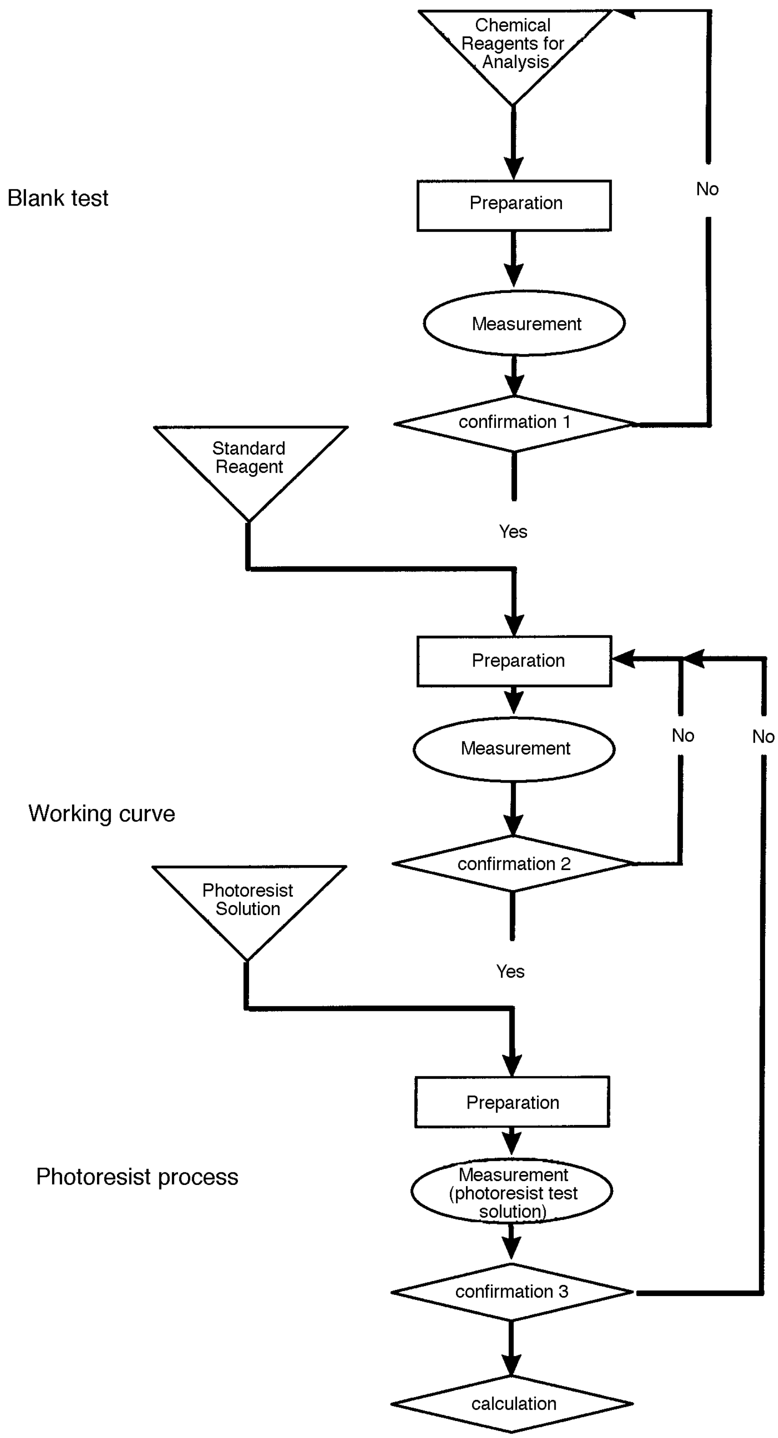


Figure 1
Flow Chart of Trace Metal Measurement

8.2 *Blank Test*

8.2.1 Prepare a blank test solution which is performed under the photoresist process without photoresist.

8.2.2 Measure each blank test solution for the same metals as measured in the photoresist.

8.2.3 The observed data should be adjusted for blank level and background corrections.

8.2.4 Determine the concentration of each metal element from the working curve (see Section 8.3).

8.2.5 *Confirmation 1* — Blank level should be equal or less than half the specification level in the photoresist.

8.3 *Working Curve*

8.3.1 The concentration range in the working curve should cover the anticipated concentration in photoresist test solution.

8.3.2 Prepare a standard solution with a known metal concentration using the reagents that are used in preparing the photoresist test solution. When checking for linearity (Section 8.3.6), more than three different concentrations should be used in preparing the standard curve.

8.3.3 Measure each metal element in the standard solution.

8.3.4 The observed data should be calibrated by the blank level correction and background correction.

8.3.5 Prepare a working curve for each metal element.

8.3.6 *Confirmation 2* — Working curve should be linear in the concentration range of standard solution.

8.4 *Measurement of Photoresist Test Solution*

8.4.1 *Dry Ashing Method*

8.4.1.1 Remove the solvent of photoresist by evaporation using Platinum crucible.

8.4.1.2 Ash the matrix by heating using Platinum crucible. Ashing temperature should be referred to Table 3. Resist cannot be ashed without possible loss of some elements, so loss of each element should be investigated before trace metal analysis.

Table 3 Recommended Ashing Temperature and Flame Component for F-AAS

Element	*Ashing Temperature (°C)*	*Flame Component*
Al	1000	N_2O-C_2H_2
Ca	800	Air-C_2H_2 N_2O-C_2H_2
Cr	800	Air-C_2H_2 N_2O-C_2H_2
Cu	800	Air-C_2H_2
F3 (NOTE 4)	600 300 (if $FeCl_3$ presents)	Air-C_2H_2 N_2O-C_2H_2
Mg	600	Air-C_2H_2 N_2O-C_2H_2
Mn	800	Air-C_2H_2 N_2O-C_2H_2
Ni	800	Air-C_2H_2
K (NOTE 5)	< 500	Air-C_2H_2 H_2-O_2
Na (NOTE 5)	< 500	Air-C_2H_2 H_2-O_2

NOTE 4: Iron can be present as ferric chloride and ferric chloride boils at 310°C.

NOTE 5: These elements tend to volatilize over 500°C.

8.4.1.3 Dissolve the ash in platinum crucible with acid.

8.4.1.4 Prepare a photoresist test solution in a volumetric flask with a constant volume of solvent.

8.4.1.5 In F-AAS analysis, analytical wavelength should be determined referring to Table 1. In ICP-MS analysis, analytical mass number should be determined referring to Table 1.

8.4.1.6 Measure each metal element in the photoresist test solution.

8.4.1.7 The observed data should be adjusted for blank level and background corrections.

8.4.1.8 Record the dilution factor, ashing temperature, acid, spike, and recovery for dry ashing. Record the analytical wavelength for F-AAS, or analytical atomic mass number for ICP-MS.

8.4.2 *Direct Method*

8.4.2.1 Prepare a photoresist test solution by diluting. Solvents such as PGMEA or EL are recommended.

8.4.2.2 Record the name of diluting solvent and dilution factor. Dilution factor is recommended to be in the range of 5 to 50.

8.4.2.3 In GF-AAS or ETA-AAS analysis, furnace program (step, temperature, lamp time, hold time) should be determined referring to Table 4 before trace metal analysis.

Table 4 Recommended Furnace Program for GF-AAS and ETA-AAS

Element	*Drying Temperature (°C)*	*Ashing Temperature (°C)*	*Atomization Temperature (°C)*
Al	130	1400	2700
Ca	130	1300	2600
Cr	130	1300	2700
Cu	130	900	1600
Fe	130	900	2500
Mg	130	900	2200
Mn	130	900	2600
Ni	130	1200	2700
K	130	800	2000
Na	130	800	2000

8.4.2.4 In GF-AAS, ETA-AAS, or ICP-AES analysis, analytical wavelength should be determined referring to Table 1. In ICP-MS or MIP-MS analysis, analytical mass number should be determined referring to Table 1.

8.4.2.5 Measure each metal element in the photoresist test solution.

8.4.2.6 The observed data should be calibrated by the blank level correction and background correction.

8.5 *Recommended Instrumental Conditions for Documentation*

8.5.1 Specify the equipment name.

8.5.2 Specify flame component and flow rate for F-AAS.

8.5.3 Specify carrier gas and flow rate for GF-AAS and ETA-AAS.

8.5.4 Specify plasma source gas and flow rate for ICP-MS, MIP-MS, and ICP-AES.

8.5.5 Specify furnace program (temperature for drying, ashing, atomization and cleaning, lamp time, hold time) for GF-AAS and ETA-AAS.

8.5.6 Specify analytical wavelength for F-AAS, GF-AAS, ETA-AAS, and ICP-AES.

8.5.7 Specify analytical atomic mass number for ICP-MS and MIP-MS.

8.6 *Concentration of Trace Metal in Photoresist*

8.6.1 The concentration of trace metal in a photoresist test solution is determined from the working curve. Determine the concentration of trace metal by multiplication of dilution factor to the observed concentration of a photoresist test solution. The unit of concentration should be represented in ppb.

8.6.2 The standard deviation should be calculated.

8.6.3 *Confirmation 3* — The observed concentration of photoresist test solution should be in the concentration range of working curve.

9 Suggested Reporting Information

9.1 Site

9.2 Test date

9.3 Company

9.4 Environment

9.4.1 Particle level

9.5 Sampling

9.5.1 Sample name (commercial name)

9.5.2 Lot No.

9.6 Results:

9.6.1 Element

9.6.2 Concentration (ppb)

9.6.3 Standard deviation 3 σ

9.6.4 Sample preparation method

9.6.4.1 Dry ashing method:

9.6.4.1.1 Ashing temperature

9.6.4.1.2 Dissolution acid

9.6.4.1.3 Dilution factor

9.6.4.2 Direct method:

9.6.4.2.1 Solvent name

9.6.4.2.2 Dilution factor

9.6.5 Measuring condition

9.6.5.1 Equipment name

9.6.5.2 Furnace program/temperature, lamp, and hold time for GF-AAS or ETA-AAS

9.6.5.3 Flame components and flow rate for F-AAS

9.6.5.4 Carrier gas and flow rate for GF-AAS or ETA-AAS

9.6.5.5 Plasma source gas for ICP-AES, ICP-MS, or MIP-MS

9.6.5.6 Analytical wavelength or analytical mass number

9.6.5.7 Blank level

9.6.5.8 Background correction

9.6.5.9 Correlation coefficient for working curve

10 Related Documents

10.1 *SEMI Standards*

SEMI P12 — Determination of Iron, Zinc, Calcium, Magnesium, Copper, Boron, Aluminum, Chromium, Manganese, and Nickel in Positive Photoresists by Inductively Coupled Plasma Emission Spectroscopy (ICP)

SEMI P13 — Determination of Sodium and Potassium in Positive Photoresists by Atomic Absorption Spectroscopy

SEMI P14 — Determination of Tin in Positive Photoresists by Graphite Furnace Atomic Absorption Spectroscopy

SEMI P33-0998
PROVISIONAL SPECIFICATION FOR DEVELOPMENTAL 230 mm SQUARE HARD SURFACE PHOTOMASK SUBSTRATES

1 Purpose

1.1 To define the dimensional requirements for nominally square hard surface photomask substrates of 230 mm nominal edge length for research on, and development of, process and manufacturing equipment, pellicles, carriers, other accessory materials, and any related mask designs.

2 Scope

2.1 This specification covers information pertaining to glass substrates for 230 mm square hard surface photomasks. This information includes, but is not limited to, physical dimensions, testing criteria, and measurement criteria.

3 Referenced Documents

3.1 *ANSI/ASQC Standard*[1]

Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.2 *ASTM Standard*[2]

E 228 — Test for Linear Thermal Expansion of Rigid Solids with a Vitreous Silical Dilatometer

3.3 *Federal Standard*[3]

209E — Clean Room and Work Station Requirements, Controlled Environments

4 Terminology

4.1 *230 mm* — the nominal edge length for the reticle generation defined in this specification. Also referred to as "9 inch" size.

4.2 *critical side* — major side intended for patterning. The critical side has no chamfered corner(s) (see Section 9.2), and has flatness equal to or better than the non-critical side (see Section 8.1).

4.3 *non-critical side* — major side not intended for patterning. Any and all chamfered corners are on the non-critical side (see Section 9.2, Figures 5 and 6).

1 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202

2 American Society for Testing & Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 General Services Administrator, 4th and D Streets, SW, Room 6039, Washington D.C. 20407

NOTE: Selected terms relating to photomasking are given for information only in Appendix 2, Related Information.

5 Ordering Information

5.1 Purchase orders for hard surface photomask substrates furnished to this specification shall include the following:

5.1.1 Nominal edge length, nominal thickness dimension, edge criteria, and parallelism of major sides (see Section 6);

5.1.2 Material (see Section 7);

5.1.3 Flatness quality area and flatness Total Indicated Reading (TIR; see Section 8);

5.1.4 Visual quality area (see Section 9); and

5.1.5 Lot acceptance criteria (see Section 10).

6 Dimensions and Permissible Variations

6.1 The substrates shall conform to the dimensional tolerances appropriate to the nominal edge length and thickness as listed in Table 1. Dimensions are illustrated in Figure 1, and a fixture for measuring the squareness dimensions is shown in Figure 2.

6.2 Substrates shall have beveled edges. The edges shall conform to the dimensional tolerances appropriate to the nominal thickness listed in Table 2. Dimensions are illustrated in Figure 3.

6.3 The major sides of square substrates shall be parallel within 5.0 µm along both major axes. Measurements are taken within the quality flatness area, along both major axes. Calculation of parallelism is illustrated in Figure 7.

7 Material Specifications

7.1 Substrate materials shall be specified "ultra low thermal expansion" (ULTE). An example of ULTE material is fused silica (quartz).

7.2 Selected physical properties of ULTE materials are provided for information only in Appendix 1.

8 Flatness Specifications

8.1 Substrates shall be supplied with two major sides having flatness (TIR) of 1, 2, or 5 µm over a square quality flatness area as defined in Figure 4. Sides are not required to have equivalent flatness. (NOTE: 0.5 µm is not yet available but is widely expected in the near future. Flatness of 0.5 µm is very desirable for semiconductor production, and equipment suppliers may want to consider this in their designs.)

9 Visual Criteria

9.1 A visual quality area, which may or may not correspond with the flatness area, shall be agreed upon between the user and supplier.

9.2 Fused silica (ULTE) substrates shall be identified with one corner chamfer as shown in Figure 5. Dimensions of the chamfer shall be as specified in Figure 6. The corner chamfer is made only on the non-critical side of the substrate.

10 Sampling

10.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired, and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL values. Inspection levels shall be agreed upon between user and supplier.

11 Test Methods

11.1 *Thermal Expansion* — Determine in accordance with ASTM E 228.

11.2 Flatness (to be agreed upon between user and supplier).

11.3 Visual (to be agreed upon between user and supplier).

11.4 Parallelism (to be agreed upon between user and supplier; non-contact methods are preferred).

12 Handling

12.1 Substrates are to be handled on the edges only. Substrates are to be handled with gloves approved for cleanroom use, when human handling is required.

13 Orientation

13.1 For ULTE substrates with a single corner chamfer (see Section 9.2), it is recommended that all orientation be performed referencing the corner of the substrate diagonally opposite the chamfer. See Figure 8 for more information.

14 Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15 Packing and Marking

15.1 Substrates shall be packed in a class 100 environment as defined by Federal Standard 209. Containers shall be designed to prevent glass-to-glass contact, and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the critical side toward the front or bottom of the shipping carrier, depending on carrier configuration. The substrate shipping position shall be indicated on each container. Packaging shall comply with the applicable internal, national, state, and local laws and regulations required for shipping.

15.2 Containers shall be labeled "Warning: Open and Handle Under Cleanroom Conditions Only" as well as identified by user purchase order number (if applicable), drawing number (if applicable), quantity, supplier lot number, and material identification.

16 Related Documents

16.1 *SEMI Standard*

SEMI P1 — Specification for Hard Surface Photomask Substrates

Table 1 Specifications for Edge Length, Squareness, and Thickness for Square Substrates

Nominal Edge Length	*Edge Length Minimum*	*Edge Length Maximum*	*Squareness*	*Thickness Minimum*	*Thickness Maximum*	*Units*
230 mm	229.6	230.0	0.186/213	8.90	9.10	mm

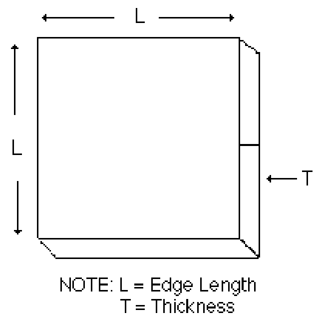


Figure 1
Square Hard Surface Photomask Substrate

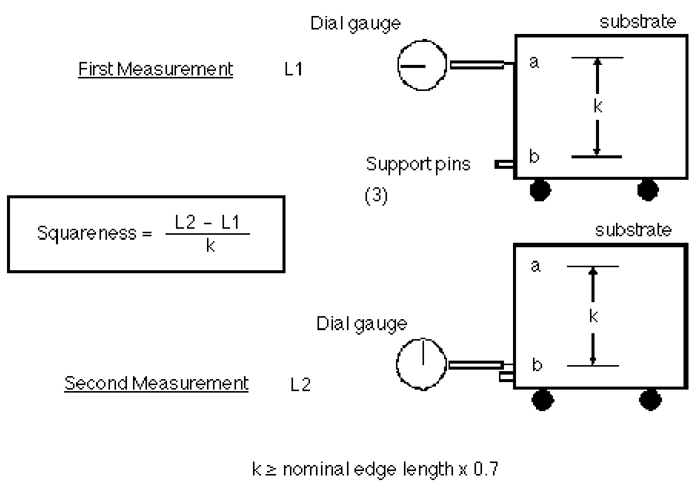


Figure 2
Measurement Fixture and Calculation to Determine Substrate Squareness

Table 2 Specifications for Beveled and Rounded Edge Dimensions

T	*A*	*A*	*B*	*B*	*C*	*C*	
Nominal	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*Units*
9.00	0.20	0.60	0.20	0.60	2.00	3.00	mm

NOTE: "D" is radius of curvature of concerns.

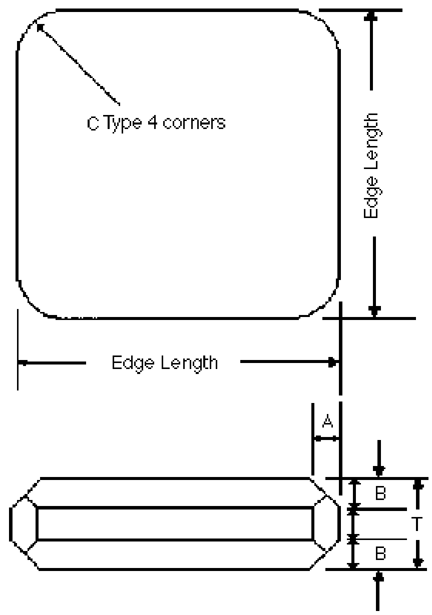


Figure 3
Beveled Edge Dimensions

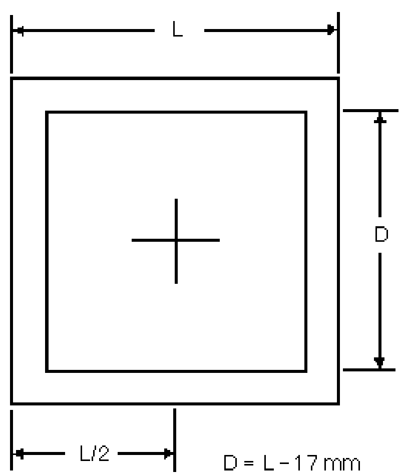


Figure 4
Square Quality Area

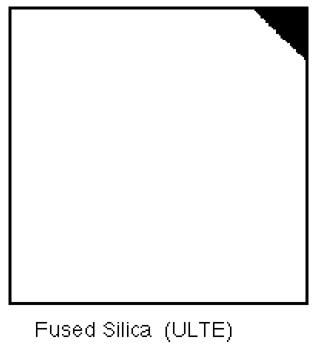


Figure 5
Substrate Identification by Corner Chamfer(Non-Critical Side)

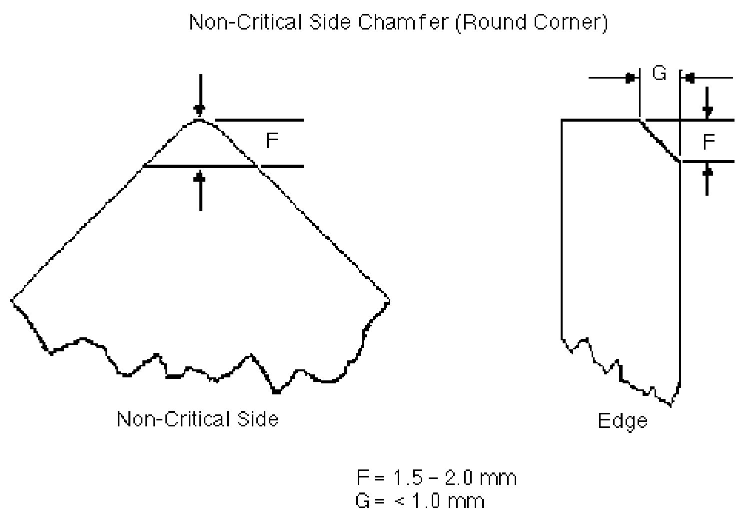


Figure 6
Dimension of Corner Chamfer

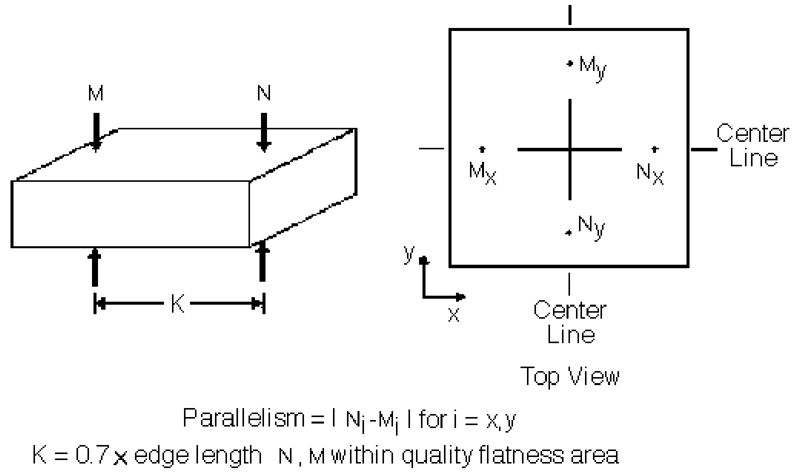


Figure 7
Measurements for Calculation of Parallelism with Approximate Positions

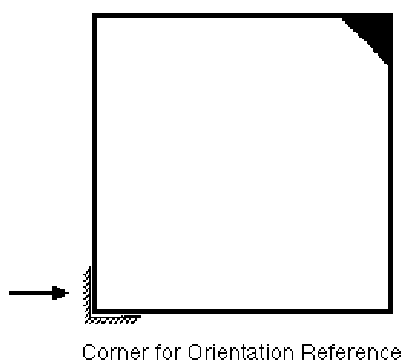


Figure 8
Corner Diagonally Opposite of Chamfer

APPENDIX 1
HARD SURFACE PHOTOMASK MATERIAL PROPERTIES

NOTE: This appendix was approved as an official part of SEMI P33 by full letter-ballot procedure.

Table A1-1 Material Properties

Property	
Ultra Low Thermal Expansion (ULTE)	
Modulus of Elasticity	6.7–7.4 × 10^3 kg/mm^2
Poisson's Ratio	0.16–0.19
Specific Gravity	2.18–2.20 g/cm^3

RELATED INFORMATION 1
TERMS AND DEFINITIONS

NOTE: This related information is not an official part of SEMI P33. The following terms and definitions are provided for information only. The Microlithography-related definitions identified herein were compiled from the Terminology sections of the Standards in the SEMI Microlithography Volume. The SEMI Microlithography Committee is currently updating all terminology through the Microlithography Terms and Definitions Task Force, and will eventually include the updated terminology in the SEMI Compilation of Terms.

SEMI makes no warranties or representations as to the suitability of the terms and definitions set forth herein for any particular application. The determination of the suitability of the terms and definitions is solely the responsibility of the user.

array rotation — the total array set rotated relative to substrate edges.

cavity — in pellicle technology, an unfilled space between the photomask and the optically transparent film within the mounted pellicle frame area.

coherence, spatial — the correlation of the electromagnetic fields at different points in space. Can be achieved with a non-monochromatic source.

coherence, temporal — the correlation of electromagnetic fields at different points in time but the same point in space (related to the non-monochromaticity of the source).

composite drawing — a large-scale drawing comprising all geometric forms required for a single device, arranged in proper relative positions. It is used as a guide for manual cutting by Rubylith, or for a digitizing guide for Computer Aided Design (see CAD). The set of colored overlay films made as work progresses to the reticle stage, can also be considered a composite, suitable for checking design errors. (SYN: Master Drawing, Engineering Drawing, Design Drawing.)

contact mask — in semiconductor fabrication, after the major diffusions, gates, and other active areas have been deposited, a glass insulating layer is placed over the whole die. Small holes are etched through this glass at points where the interconnecting metal conducts must ‘contact’ the active areas. The mask that defines these holes is characterized by many small squares (~0.2–0.4 mil) scattered throughout the die area.

contact printing — a process of reproducing an original by placing a photomask so that the coated side is in contact with the photoresist (or emulsion) surface of the area to be printed and then exposing the photoresist (or emulsion).

cure, photoresist — the process of eliminating undesirable properties of photoresists, such as tackiness, softness, the tendency to flow, lack of adhesion, etc.

dark area — an opaque area.

defect, gross photomask — a photomask defect that can be easily seen with the naked eye or under magnification no greater than 10×. Examples: large scratches, cracks in the glass substrate, drying marks, etc.

defect, photomask — any flaw or imperfection in the opaque coating or functional pattern of a photomask that will reproduce itself in a photoresist film to such a degree that it is pernicious to the proper functioning of the microelectronic device being fabricated.

degradation — reductions in image quality (measured as resolution, edge acuity, dimensional shifts, defect density, etc.) experienced in each generation of reproduction, as compared to the original or preceding generation. Generally, degradation increases with each generation, in a predictable manner.

diffraction pattern, spatial — intensity variations of light in the viewing plane caused by interference of waves undergoing diffraction.

element — a member of the set that makes up the photomask array; used either as a functional layer member for the fabrication of a single, integrated circuit or for test purposes. (Replaces chip, die, bar.)

emulsion — a suspension of a salt of silver in gelatin or collodion that is coated onto a photoplate and is exposed and developed to produce a photomask.

energy, minimum exposure — the energy corresponding to the total integrated energy of actinic radiation necessary to just completely render soluble a positive photoresist for a given replacement film thickness or just completely render insoluble a negative photoresist for a given single resist film thickness.

energy, optimum exposure — the energy per square centimeter corresponding to the total integrated energy of actinic radiation necessary to accurately reproduce photomask pattern dimensions in a photoresist of given thickness after exposure and development.

etch resistance — the ability of a photomask coating or protecting material, such as photoresist, in which the pattern is imaged or photoprinted.

etch time — the time required for the removal of a coating in an etching medium.

etchant — the chemically reactive solution used for removal of unwanted metallic coating from a substrate.

field — the background area of a device is defined as the area not being acted upon during the fabrication process. Thus, if a mask is to be used to produce metal interconnects, the area representing non-metal is the "field." The image polarity is named by the appearance of this field; thus, clear field, dark (opaque) field. This definition is very carefully stated because, in some devices, their gross appearance is very deceiving in that "field" cannot always be denoted as the major area. Some devices may have diffusion of buried layers, for instance, covering 80% of the area, the remaining 20% being the field. Some knowledge of the fabrication process is essential when determining field, as many of these ambiguous conditions exist where the field is less than 50% of the area. (ANT: active area; geometry; trace: diffusion area.)

film adhesive — adhesive between frame and film.

film thickness, dirt — fingerprint; mark touched by something; stain by liquid.

film thickness, particle — the particle state materials that can be distinguished from the film itself on the film surface or inside the film.

film thickness, pinhole — a small opening completely through a polymer film.

fixer — a chemical solution which makes an image permanent. In the case of silver emulsion processes, it dissolves and removes the unexposed/undeveloped silver halide crystals so that further darkening of the image cannot occur.

frame adhesive — adhesive between frame and photomask.

functional element — any contiguous fragment of a device that is necessary to the electrical operation of the finished device. Examples include diffused areas, traces, gates, contacts, etc.; excludes scribe lines, alignment marks, labels, etc. (SYN: active geometry.)

gel slug — a piece of clear, dried gelatin that has been trapped in a silver/gelatin emulsion during coating. A gel slug has the appearance, under a microscope, of a clear lens-like lump, generally 0.5 – 2 mils in size, and about twice as long as wide.

isolation layer — a partitioning, especially of bipolar devices, usually by diffusion, to electrically insulate functional components of an integrated circuit device. Isolation masks are usually layer 1 or 2, and characterized by thin lines defining open boxes all over the die area. (SYN: isolation mask.)

latent image — the invisible image formed on any photosensitive material after exposure. It requires some type of development to produce a useful, visible image.

layer — one of a sequential series of overlaying photomasks that make up a device series.

mask set — the complete series of masks for all layers, necessary to fabricate any given device.

master drawing — the original drawing from which the artwork is made.

master mask — original photomask, at 1× (final) scale, generated with a photorepeater from which submasters are printed. (SYN: master.)

matrix — the rectangular arrangement of die on a photomask. (SYN: array.)

mechanical strength — the physical condition a pellicle must meet to withstand a specified force from a blow-off gun without suffering any damage to the film.

mouse bite — see *mouse nip*.

mouse nip — in semiconductor imaging technology, a semicircular intrusion.

objective lens — in a microscope system, it is the lens closest to the test specimen (object). Usually provides the greatest amount of the total magnification and also limits system resolution. Most commonly several objectives, in typical powers of 10×, 20×, and 40×, are mounted on a turret for rapid magnification changes. See also *ocular*.

ocular — the set of microscope lenses closest to the observer's eye that produces final magnification of microscope. It usually contains graticules or filar-measuring apparatus. See also *objective lens*.

opacity — a direct measure of the light-stopping power of a semitransparent medium, as glass photographic emulsion or a thin chrome coating. Represented as the reciprocal of transmittance, O = 1/T. The common logarithm of opacity if used as Optical Density. $D = \text{Log}_{10}O$.

pellicle — a thin, optically transparent film, typically of nitrocellulose, attached to, supported by a frame, and attached to a photomask (or photomask reticle). NOTE: Its purpose is to seal out contaminants and reduce printed defects caused by contamination in the image plane of an optical exposure system.

photorepeater — a combination of a high-resolution reduction (usually 10× or 5×) camera and a programmable precision stage. The image from the camera is projected onto a photoplate, attached to the stage, and exposed in as many positions as required by moving the stage between exposures. The product of a photorepeater is the master mask. (SYN: image repeater; step-and-repeat camera.)

printing — the transfer of an image from one surface (substrate) onto another at 1× scale. Usually "printing" refers to the contact method, but it also can be accomplished using a 1-to-1 projection optical system. (SYN: contact printing.)

printing, contact — photoprinting photomask patterns by exposure of a photosensitive material coated on a supporting substrate to radiation passing through the photomask, which is in contact with the photosensitive material.

printing, off-contact — see *printing, proximity*.

printing, projection — a method of optically projecting an image onto a photosensitive material, thus eliminating the need for photomask/photosensitive-coating contact.

printing, proximity — photoprinting photomask patterns by exposure of photosensitive material coated on a supporting substrate to radiation passing through the photomask which is in the proximity of, but not in contact with, the photosensitive material being exposed.

reduction camera — a mechanism used to optically reduce the size of images and record them photographically. In two-step reduction, a copy camera is used for the range of 100× to 1000× reduced to 10×; the photorepeater reduces from 5× or 10× to 1×. Both are reduction cameras. See also *photorepeater.*

registration mark — a mark used to control placement of one layer relative to another.

repetitive defect — a defect (spot, pinhole, protrusion, or intrusion) introduced on the reticle so that in generating a master, it reproduces on every die.

reversal process — a photographic emulsion process that produces an image which is the same as the input image (i.e., clear areas remain clear, and opaque remain opaque). It is named 'reversal' because it yields the 'reverse' of the standard 'negative' process. Accomplished by developing the negative image, destroying this image by bleaching, and then subsequently developing all the original silver halide that represents the positive image. (SYN: positive-acting, process, positive process. ANT: negative acting process, normal process.)

rotation, of array — whole array is properly arranged (die relative to die), but placed on a blank which is rotationally mis-aligned. May occur during stepping or contact printing.

rotation, of die — on a master, misplacement of die by an angular displacement around the Z-axis. Usually caused by mispositioning of the reticle in a photorepeater so that it does not lie parallel to X- and Y-axis of stage travel.

run-in — a die placement error, where the die increment is less than the design dimension. This can occur during stepping, due to nonlinearity of miscalibration of the photorepeater stage scan scale, or during contact printing due to plate warpage.

shelf life — the period of time, at specified conditions of storage, in which the physical and chemical properties that affect a material's performance remain acceptable.

smear — a large area of partially removed coating or deposited foreign material.

space — area between image geometries; field between close-lying images. The space is often specified as the critical dimension. (SYN: field. ANT: digitized area; geometry.)

spinner — a device for holding a substrate and spinning it at a controlled rate of speed (usually 1000 to 6000 RPM), for applying extremely thin coating, as with photoresist.

submaster — a photomask printed in limited quantities from masters, and from which the working plates are printed. Used to reduce wear and tear on masters.

test device — a simplified, functional device (of the same process type as the majority die), inserted in several positions in any array, used for process control and monitoring during wafer fabrication.

torn image — image broken by movement of the image medium. Most often seen on emulsion images.

variable aperture — an aperture whose open area may be increased or decreased by movement of the elements forming the aperture.

visual defects — defects that can be identified by a skilled observer (with or without the aid of a microscope) without having to measure or compare (e.g., pinholes, slugs, spots, protrusions, etc.).

working plate — mask used selectively to expose photoresist on a wafer for IC fabrication. Usually printed from submasters or masters, thus preserving the master from excessive handling damage.

the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI P34-0200
SPECIFICATION FOR 230 mm SQUARE PHOTOMASK SUBSTRATES

This specification was technically approved by the Global Mask and Mask Equipment Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee on September 3, 1999. Initially available at www.semi.org November 1999; to be published February 2000.

1 Purpose

1.1 To define the standard requirements for nominally square photomask substrates of 230 mm nominal edge length.

2 Scope

2.1 This specification covers information pertaining to substrates for 230 mm square photomasks. This information includes, but is not limited to, physical dimensions, material properties, and testing and measurement criteria.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ANSI Standard*[1]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.2 *ASTM Standard*[2]

ASTM E228 — Standard Test Method For Linear Thermal Expansion of Solid Materials With a Vitreous Silica Dilatometer

3.3 *ISO Standard*[3]

ISO 14644-1 — Cleanrooms and associated controlled environments

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *230 mm* — the nominal edge length for the reticle generation defined in this specification. Also referred to as “9 inch” size.

4.2 *corner chamfer* — the bevel found in one corner of the substrate, in excess of the edge chamfer, as defined in Section 9.3 and Figure 6.

4.3 *critical side* — major side intended for patterning. The critical side has no chamfered corner(s) (see Section 9.3), and has flatness requirement equal or better than the non-critical side (see Section 8.1).

4.4 *edge chamfer* — the bevel found on all intersections between major and minor sides, as defined in Section 6.2 and Figure 3.

4.5 *non-critical side* — major side not intended for patterning. Any and all chamfered corners are on the non-critical side (see Section 9.3 and Figures 5 and 6).

5 Ordering Information

5.1 Purchase orders for photomask substrates furnished to this specification shall include the following:

5.1.1 Nominal edge length, nominal thickness, edge criteria including straightness and squareness, and parallelism of major sides (see Section 6); straightness shall be measured on all four minor sides;

5.1.2 Material (see Section 7);

5.1.3 Flatness quality area and flatness Total Indicated Reading (T.I.R.; see Section 8);

5.1.4 Visual quality area and defect limits (see Section 9); and

5.1.5 Lot acceptance criteria (see Section 10).

6 Dimensions and Permissible Variations

6.1 The substrates shall conform to the dimensional tolerances appropriate to the nominal edge length and thickness as listed in Table 1. Dimensions are illustrated in Figure 1 and a fixture for measuring the squareness dimensions is shown in Figure 2.

6.2 Substrates shall have chamfered edges between major and minor sides, and rounded corners between minor sides. The edges shall conform to the dimensional tolerances appropriate to the nominal thickness listed in Table 2. Dimensions are illustrated in Figure 3.

6.3 The major sides of substrates shall be parallel within 5.0 μm along both major axes. Measurements

1 American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

3 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland

are taken within the flatness quality area, along both major axes. Calculation of parallelism is illustrated in Figure 7.

7 Material Specifications

7.1 Substrate material shall be specified as fused silica (quartz). Fused silica is considered to be ultra low thermal expansion (ULTE) class material.

7.2 Substrate materials shall conform to thermal expansion and optical transmittance tolerances specified in Table 3.

7.3 Selected physical properties of fused silica are provided for information only in Appendix 1.

8 Flatness Specifications

8.1 Substrates shall be supplied with two major sides having a flatness (T.I.R.) of 1, 2, or 5 µm over a flatness quality area as defined in Figure 4a or Figure 4b. Sides are not required to have equivalent flatness.

NOTE 2: Flatness of 0.5 µm is very desirable for semiconductor production, and equipment suppliers may want to consider this in their designs.

9 Visual Criteria

9.1 A visual quality area, which may or may not correspond with the flatness quality area, shall be agreed upon between the user and supplier.

9.2 Each substrate shall not have more defects than listed in Table 4. This table includes limits for the following types of defects:

9.2.1 Internal defects in the visual quality area,

9.2.2 Critical side surface defects in the visual quality area,

9.2.3 Non-critical side surface defects in the visual quality area, and

9.2.4 Defects outside the visual quality area.

9.3 Fused silica substrates shall be identified with one corner chamfer as shown in Figure 5. Dimensions of the chamfer shall be as specified in Figure 6. The corner chamfer is made only on the non-critical side of the substrate.

NOTE 3: This configuration of corner chamfers is different than the configuration used for smaller ULTE class material substrates as defined in SEMI P1.

10 Sampling

10.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ANSI/ASQC Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ANSI/ASQC Z1.4 definitions for critical, major, and minor classifications. If desired, and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL values. Inspection levels shall be agreed upon between user and supplier.

11 Test Methods

11.1 Thermal Expansion — Determine in accordance with ASTM E228.

11.2 Transmission (to be agreed upon between user and supplier).

11.3 Flatness (to be agreed upon between user and supplier).

11.4 Visual (to be agreed upon between user and supplier).

11.5 Parallelism (to be agreed upon between user and supplier; non-contact methods are preferred).

12 Handling

12.1 Substrates are to be handled on the edges only. When human handling is required, substrates are to be handled with gloves approved for cleanroom use.

13 Orientation

13.1 For fused silica substrates with a single corner chamfer (see Section 9.3), it is recommended that all orientation be performed referencing the corner of the non-critical side diagonally opposite the corner chamfer. The corner for orientation signifies two orientation edges for positioning of the substrate. One edge shall be used for rotation baseline by two points. The other edge shall be used for positioning by one point. See Figure 8 for more information.

14 Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer’s or supplier’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15 Packing and Marking

15.1 Substrates shall be packed in a class 5 environment as defined by ISO 14644. Carriers shall be designed to prevent substrate-to-substrate contact, and to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the critical side toward the front or bottom of the shipping carrier, depending on carrier configuration. The substrate shipping position shall be indicated on each carrier. Packaging shall comply with the applicable international, national, state, and local laws and regulations required for shipping.

15.2 Containers shall be labeled "Warning: Open and Handle Under Cleanroom Conditions Only" as well as identified by user purchase order number (if applicable), drawing number (if applicable), quantity, supplier lot number, and material identification.

16 Related Documents

16.1 *SEMI Standard*

SEMI P1 — Specification for Hard Surface Photomask Substrates

Table 1 Specifications for Edge Length, Squareness, Straightness, and Thickness for Square Substrates

Nominal Edge Length	*Edge Length Minimum*	*Edge Length Maximum*	*Squareness*	*Straightness (T.I.R.)*	*Thickness Minimum*	*Thickness Maximum*	*Units*
230 mm (virgin)	229.6	230.0	0.186/213	0.050	8.90	9.10	mm
230 mm (repolished)	229.6	230.0	0.186/213	0.050	8.80	9.10	mm

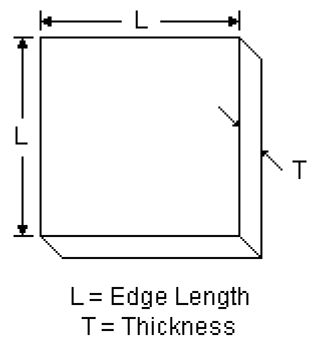


Figure 1
Square Photomask Substrate

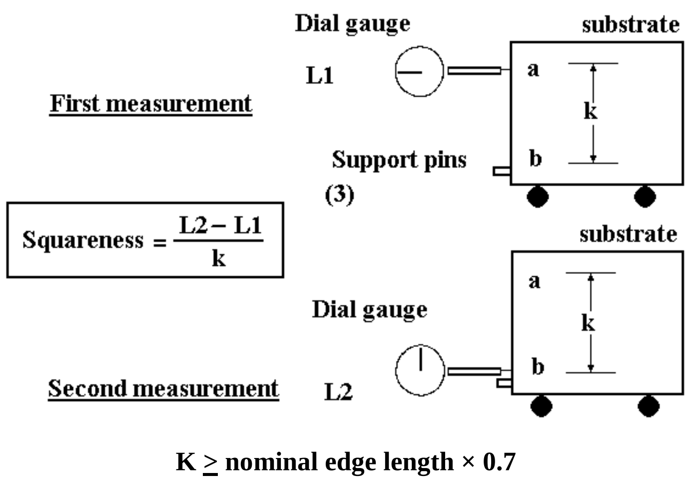


Figure 2
Measurement Fixture and Calculation to Determine Substrate Squareness

Table 2 Specifications for Chamfered Edge Dimensions

T	*A*	*A*	*B*	*B*	*C*	*C*	
Nominal	Min.	Max.	Min.	Max.	Min.	Max.	Units
9.00	0.20	0.60	0.20	0.60	2.00	3.00	mm

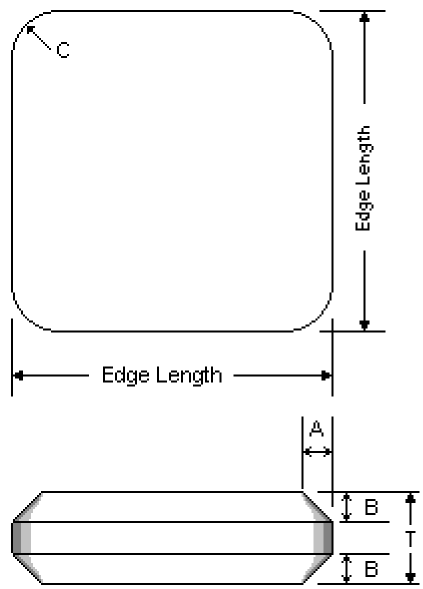


Figure 3
Dimensions for Chamfered Edge and Rounded Corners

Note: "C" is radius of curvature of corners.

Table 3 Substrate Material Characteristics

Fused Silica	*Coefficient of Expansion (°C^{-1}) between 0°C and 300°C*	*Minimum Transmittance (%) of 9 mm Thick Substrate at Wavelengths of:*					
		193 nm	248 nm	254 nm	365 nm	405 nm	436 nm
Virgin	$< 7.5 \times 10^{-7}$	90	90	90	90	90	90
Repolished	$< 7.5 \times 10^{-7}$	89	90	90	90	90	90

Table 4 Fused Silica Substrate Defect Limits

Bulk Defects Within the Visual Quality Area

Opaque Spots	*Bubble*	*Total Defects (per cm^2)*	*Notes*
> 1 µm	> 1 µm	0	1, 2
≤ 1 µm	≤ 1 µm	0.0078	

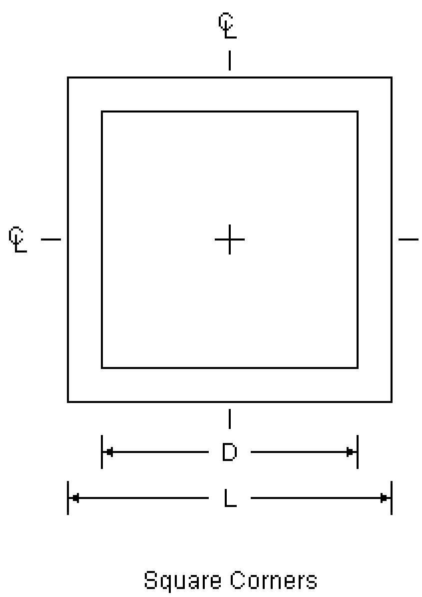
Surface Defects Within the Visual Quality Area

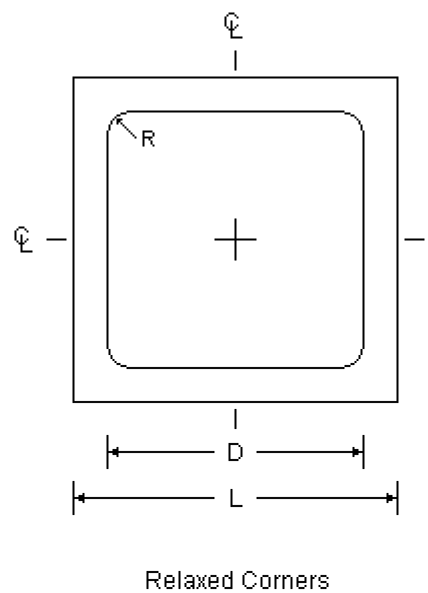
	Residue	*Scratch Size*	*Total Scratch Defects*	*Sleek Size*	*Total Sleek Defects (per cm^2)*	*Opaque Spot Size*	*Total Opaque Spot Defects (per cm^2)*
Critical side	None	> 1.0 µm	0	> 1.0 µm	0	> 1.0 µm	0
		≤ 1.0 µm	no limit	≤ 1.0 µm	0.0465	≤ 1.0 µm	0.0155
Non-critical side		> 1.0 µm	0			> 3.0 µm	0.0465
		≤ 1.0 µm	no limit			≤ 3.0 µm	no limit

Defects Outside the Visual Quality Area

		Defect Limit	*Total Number*	*Notes*
Edge Chips	Radial Depth	≥ 0.76 mm	0	3
	Peripheral Chord	≥ 0.76 mm	0	3
Other		Shall be negotiated between user and supplier.	Shall be negotiated between user and supplier.	

NOTES:
1. The size of internal defects is defined as 1/2 (long axis + short axis).
2. This table is based on the assumption that defects < 1 µm will fall outside the focal depth of the lens systems and should not print.
3. None of any size permitted that break the surface.

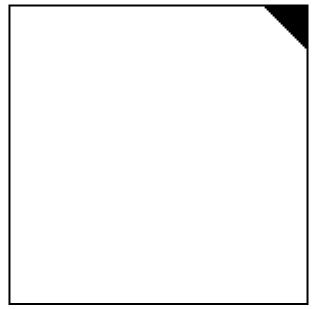




D ≥ 213 mm
R ≤ 6.5 mm (radius of curvature)

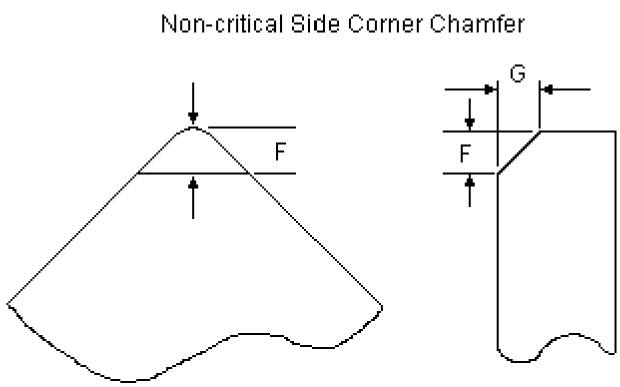
Figure 4a
Square Flatness Quality Area

Figure 4b
Relaxed Square Flatness Quality Area



Fused Silica

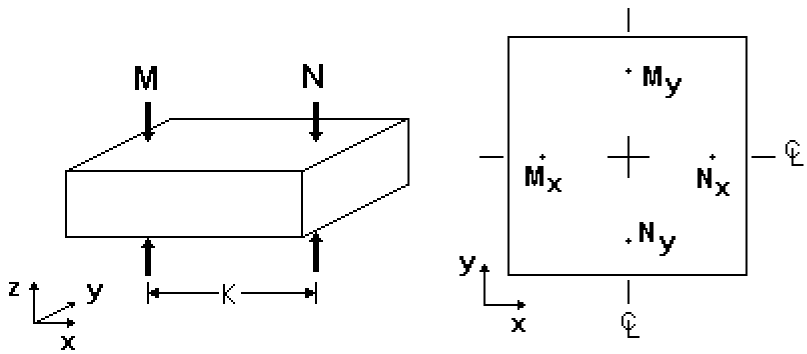
Figure 5
Substrate Identification by Corner Chamfer
(Non-critical Side)



F = 1.5–2.0 mm

G = 0.6–1.0 mm

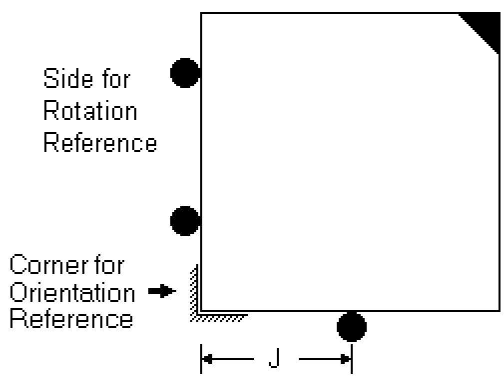
Figure 6
Dimension of Corner Chamfer
(Edge Chamfer Not Indicated)



Parallelism = | $N_i - M_i$ | for i = x, y

K = 0.7 × edge length   N, M within flatness quality area

Figure 7
Measurements for Calculation of Parallelism with Approximate Positions



J = 115 ± 15 mm

Figure 8
Corner Recommended for Orientation, Diagonally Opposite of Chamfer (Non-critical Side Shown)

APPENDIX 1
PHOTOMASK FUSED SILICA PROPERTIES

NOTE: The material in this appendix is an official part of SEMI P34 and was approved by full letter ballot procedures on September 3, 1999 by the North American Regional Standards Committee.

Table A1-1 Fused Silica Properties

Property	
ULTRA LOW THERMAL EXPANSION (ULTE)	
Modulus of Elasticity	65.7-72.6 GPa
Poisson's Ratio	0.16-0.19
Specific Gravity	2.18-2.20 g/cm^3
Index of Refraction @ λ = 436 nm	1.4667
Index of Refraction @ λ = 365 nm	1.4746
Index of Refraction @ λ = 248 nm	1.5086
Index of Refraction @ λ = 193 nm	1.5608
Thermal Optical Coefficient @ λ = 436 nm	10.6 ppm/°C @ 22°C
Thermal Optical Coefficient @ λ = 365 nm	11.2 ppm/°C @ 22°C
Thermal Optical Coefficient @ λ = 248 nm	14.2 ppm/°C @ 22°C
Thermal Optical Coefficient @ λ = 193 nm	20.6 ppm/°C @ 22°C

NOTE 1: Thermal Optical Coefficient is the same as Temperature Coefficient of Index of Refraction.

SEMI P35-0200^E
TERMINOLOGY FOR MICROLITHOGRAPHY METROLOGY

This terminology was technically approved by the Global Metrology Committee and is the direct responsibility of the North American Microlithography Committee. Current edition approved by the North American Regional Standards Committee on December 15, 1999. Initially available at www.semi.org January 2000; to be published February 2000.

E This document was editorially modified in March 2000. Changes were made to Sections 5.2.3, 5.4, 5.9, and the footnotes.

1 Purpose

1.1 Clear and commonly accepted definitions are needed for efficient communication and to prevent misunderstanding between buyers and vendors of metrology equipment. The purpose of this document is to provide a consistent terminology for the study and discussion of metrology issues important to microlithography.

2 Scope

2.1 The scope of this document is limited to the definitions of metrology terms used in microlithography. Every attempt is made to keep these definitions consistent with relevant international standards and common usage. This document is not intended to describe a measurement procedure, but an approach to defining a measurand in a useful and unambiguous way.

2.2 This document will grow as more terms are added in future revisions.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI P28 — Specification for Overlay-Metrology Test Patterns for Integrated-Circuit Manufacture

3.2 *ANSI/NCSL Standards*[1]

Z540-2 — US Guide to the Expression of Uncertainty in Measurement, ANSI/NCSL standard (the US version of Guide to the expression of uncertainty in measurement, ISO, 1995, 110 p., ISBN 92-67-10188-9)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Some Metrology Issues

4.1 *Measuring Linewidth* — Any measurement of length or position contains an unknown error whose influence on subsequent application of the measurement data is best described by the measurement uncertainty (reference Section 3.2). The problem of measuring feature size on photomasks or integrated circuit wafers (*e.g.*, linewidth) is complicated by the fact that a feature is a 3-dimensional object whose exact shape is generally not known. The metrology problem is further complicated when the object is microscopic and only its magnified image can be measured.

4.2 Feature measurement data are usually reduced to one or a few parameters because the additional data needed to describe the complex feature shape are seldom available and may be immaterial to the subsequent application of the measurement data.

4.3 The first rule of metrology is to define exactly what is to be measured. The approach used here, in light of the previous paragraphs, is to construct a simple idealized geometric shape, or model (Figure 1), which approximates a real object of complex shape. The model, whose size and center position are well defined, is substituted for the real feature in application of the measurement data. A model can be refined to better approximate the actual feature shape by adding degrees of freedom, requiring more parameters to describe the measurement. For example, a line might be represented by a rectangular cross section (with width and height) or better represented by a trapezoidal cross section (with base width, height, and two wall angles). The differences between the model and the actual shape of the feature contribute to the overall measurement uncertainty of the size or position of that feature.

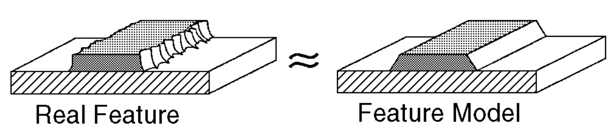


Figure 1
The Feature Model Approximates the Size and Shape of the Feature

1 American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, website: www.ansi.org

5 Definitions

Defined terms appearing in the definitions of other terms are *italicized*.

5.1 *bounding box* — a user-specified *feature model* with a planar face lying in the *reference plane* and with user-specified orientation in the *reference plane*, intended to represent the position and size of the *feature*. See Figure 2 for an example. The bounding box need not be rectangular.

5.1.1 *outer bounding box* — smallest *bounding box* encompassing the *feature*.

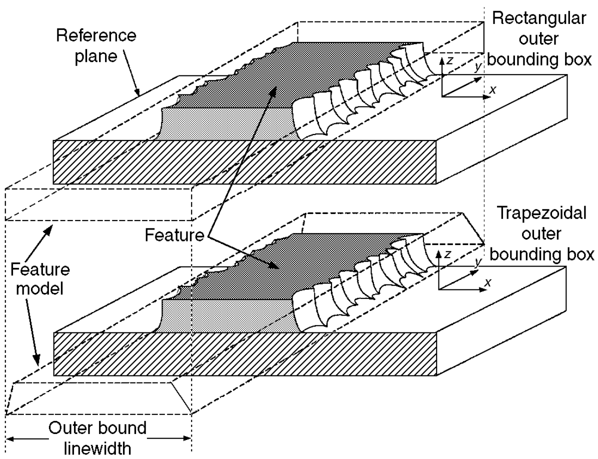


Figure 2
Two Possible Bounding Box Choices for a Line Feature

5.1.2 *best fit bounding box* — *bounding box* best fitting the *feature*, with user-defined criteria of best fit.

5.2 *feature (lithographic)* — region within a single continuous boundary, and attached to a *reference plane*, that has a physical property (parameter) that is distinct from the region outside the boundary. (Adapted from SEMI P28.)

NOTE 2: In general a feature is a 3-dimensional object, but some features can be adequately modeled as 2-dimensional objects.

5.2.1 *feature boundary* — surface defined by a user-specified property, such as a threshold, maximum gradient, *etc*., of the parameter distinguishing the *feature* from its surroundings. Open *features*, such as vias or spaces between lines, may be bounded in height by an additional plane parallel to the *reference plane*.

5.2.2 *feature height* — dimension of the specified *bounding box* perpendicular to the *reference plane*.

5.2.3 *feature model* — a solid geometrical shape, with well defined parameters: length, width, height, centroid, etc. (Figure 1), meant to approximate the actual shape of a *feature boundary*.

NOTE 3: A rectangular solid is often used to represent a line; a different extruded polygon may better represent the shape of the line. A hemisphere may best represent a solder bump. The more complex the model, more degrees of freedom are available to better fit the model to the feature, and more dimensional parameters are needed to describe the feature's size.

5.2.4 *feature placement* — coordinates describing the position of the centroid of the specified *bounding box* projected onto the *reference plane* relative to a coordinate system in that plane.

5.2.5 *feature size* — dimensions of the specified *bounding box*.

5.2.6 *nominal feature size* — the intended or specified dimension of a *feature*.

5.3 *linewidth* — (*a*) width of a specified rectangular *bounding box* constrained to the line *height* and bounding a specified line segment. Additional constraints, such as orientation parallel to the length direction, may be placed on the *bounding box*; (*b*) appropriate parameters describing the width of a different bounding box.

NOTE 4: Linewidth is sometimes referred to as critical dimension or CD.

5.3.1 *best fit linewidth* — width of constrained *best fit bounding box*.

5.3.2 *inner bound linewidth* — largest linewidth *bounding box* entirely inside the line segment.

5.3.3 *outer bound linewidth* — smallest linewidth *bounding box* encompassing the line segment.

5.3.4 *section linewidth* — width of the planar rectangle defining the intersection of a linewidth *bounding box* and a plane parallel to and a specified distance from the *reference plane*. See Section 5.3 (*b*).

5.4 *measurand* — particular quantity subject to measurement (reference Section 6.1).

5.5 *measurement uncertainty* — parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the *measurand*. Numerically, it is a stated factor chosen to represent the desired confidence interval (usually 2 for 95% or 3 for 99%) times the square root of the sum of the variances of the probability distributions of all the possible errors (both random and systematic), as described in *ANSI/NCSL Z540-2-1997* (reference Section 3.2).

5.6 *overlay* — vector distance between the *feature placements* of two corresponding *features* created at different processing levels, in the *reference plane* coordinate system.

5.7 *pattern* — set of one or more *features*.

5.7.1 *pattern placement* — coordinates describing the centroid of the set of *features* comprising the *pattern* in the *reference plane* relative to a coordinate system in that plane.

5.8 *reference plane* — in the context of this document, a user-defined plane approximating the surface of a substrate and containing a coordinate system.

NOTE 5: All dimensional measurement data are referred to the reference plane coordinate system.

5.9 *traceability* — property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated *uncertainties* (reference Section 6.1).

6 Related Documents

6.1 *ISO Document*[2]

International vocabulary of basic and general terms in metrology, ISO, 1993, 60 p., ISBN 92-67-01075-1

2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland, website: www.iso.ch (Also available from ANSI, 11 West 42nd Street, 13th Floor, New York, NY 10036, website: www.ansi.org)

SEMI P36-0600
GUIDELINE OF MAGNIFICATION REFERENCE FOR CRITICAL DIMENSION MEASUREMENT SCANNING ELECTRON MICROSCOPES (CD-SEMS)

This guideline was technically approved by the Global Metrology Committee and is the direct responsibility of the Japanese Metrology Committee. Current edition approved by the Japanese Regional Standards Committee on March 1, 2000. Initially available at www.semi.org May 2000; to be published June 2000.

1 Purpose

1.1 The purpose of this guideline is (1) to define common and important specifications of magnification references which are used for calibrating magnifications of critical dimension measurement scanning electron microscopes (CD-SEMs), and as the result (2) to provide magnification references which are easy for anyone to use.

2 Scope

2.1 It is preferable that design, manufacture and purchase specifications for CD-SEM magnification references conform to this guideline.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 None.

4 Terminology

4.1 *CD-SEM magnification reference* — a CD-SEM magnification reference is defined as a standard for calibrating magnifications of a said CD-SEM through mounting the standard on the specimen stage, measuring the dimensions of reference patterns formed on the standard, determining the difference between the measurement value and the true or reference value of the reference patterns, and adjusting the CD-SEM parameters to bring the difference zero.

4.1.1 There are two types of CD-SEM magnification references: one is a wafer on which reference patterns are formed; another is a chip on which reference patterns are formed. Hereinafter, the former will be referred to as “wafer-type magnification reference,” and the latter will be referred to as “chip-type magnification reference.”

4.2 *edge roughness* — Edge roughness refers to edge variations seen in the SEM images, and is defined as the distance, within a field of view, between the peak line and the valley line, where the peak line means the line which runs through the highest peak and is parallel to the pattern-edge mean line, the valley line means the line which runs through the lowest valley and is parallel to the pattern-edge mean line, and the pattern-edge mean line conforms to the expected pattern-edge line. Here, a peak is the tip of a convex section, and a valley is the deepest part of a concave section (See Figure 1).

5 Ordering Information

5.1 Specify whether a said CD-SEM magnification reference is a wafer-type magnification reference or a chip-type magnification reference.

6 Requirements

6.1 *CD-SEM Magnification References and Their Structure*

6.1.1 CD-SEM Magnification References are either wafer type or chip type. Chip types are composed of a chip (or chips) and a stub to hold the chip (or chips). Wafer type include a 'drop-in' wafer which is a wafer with a thinned section where a die with the reference calibration pattern can be dropped in.

6.2 *Shape, Size and Mounting Method of CD-SEM Magnification References*

6.2.1 Shape and size of wafer-type magnification references, and method of mounting them on the specimen stages in CD-SEMs must follow the shape, size and mounting method of product wafers.

6.2.2 Shape and size of chip-type magnification references, and method of mounting them on the specimen stages of CD-SEMs are defined as follows:

6.2.2.1 Size and shape of chip-type magnification references: See Figure 2.

6.2.2.2 Mounting method of chip-type magnification references:

6.2.2.2.1 A magnification reference should be mounted on a specimen stage as markers made on the stub fit in markers made on the specimen stage, and be fixed by using a screw. The markers made on the stub should show the direction of reference patterns at an accuracy of within ± 1°.

6.2.2.2.2 The markers made on the specimen stage should show the X- and Y-direction of specimen-stage movement, and the angle between the two markers should be 90° ± 0.1° (See Figures 2 and 3).

6.2.2.3 Chip surface height for chip-type magnification references:

6.2.2.3.1 The height of chip surface (or reference pattern surface) from the specimen stage surface should be 1.7 ± 0.05 mm as the magnification reference is mounted on the specimen stage.

6.3 *Materials for Magnification References* — Materials for magnification references must be non-magnetic and conductive.

6.3.1 Wafers for wafer-type magnification references and chips for chip-type magnification references are preferable to be silicon.

6.3.2 Materials of the stub for chip-type magnification references are preferable to be aluminum, copper, or carbon.

6.4 *Properties of Magnification Reference Pattern*

6.4.1 Reference patterns do not change or degrade in use.

6.4.2 The block area of reference patterns (or every block area, in the case where there are some reference pattern blocks) must be larger than 100 µm × 100 µm, and the block should be placed so that it is easily recognizable.

6.4.3 The pattern-edge roughness must be within the calibration uncertainty described in Section 6.5.5.

6.5 *Report*

6.5.1 Suppliers of CD-SEM magnification references must report the following to the purchaser.

6.5.2 Wafer material for wafer-type magnification references, or chip and stub materials for chip-type magnification references: e.g., silicon chip, aluminum stub, etc.

6.5.3 Type of reference patterns: e.g., dense lines, etc.

6.5.4 Figures and/or pictures of the reference patterns with pattern dimensions which show top and/or cross sectional view.

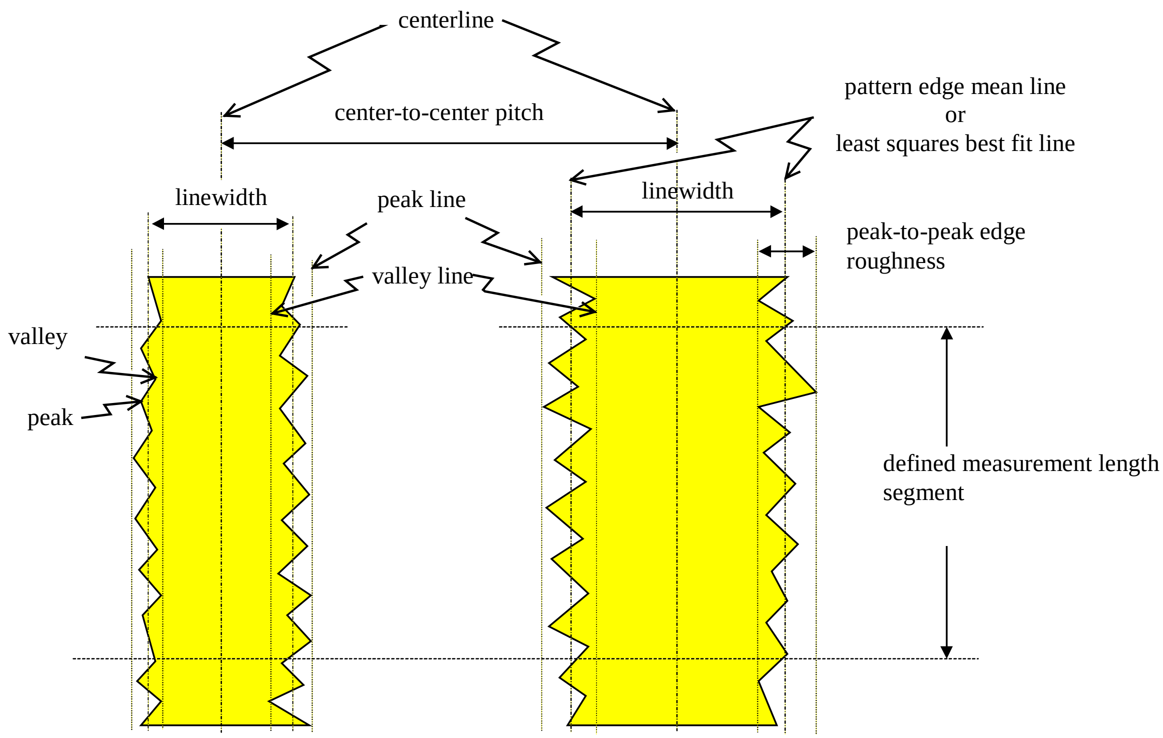
6.5.5 Calibration uncertainty of reference patterns: e.g., line pitch 180 ± 1 nm at 95% confidence level, etc.

6.5.6 Traceability and its certification organization, and measurement method used for deciding the calibration uncertainty of reference patterns: e.g., the uncertainty was decided in terms of mean value and variation obtained by means of a precise diffraction angle measurement using a He-Cd laser beam of a 2 mm spot diameter, and was certified by NMI (National Metrology Institute), etc.

NOTE 1: Traceability is the property of the calibration of the reference patterns whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparison of all having stated uncertainties. Refer to the international vocabulary of basic and general items in metrology, ISO, 1993, 60 p., ISEN 92-67 01075-1.

6.5.7 Applicable magnification range: e.g., 50k×–200k×, etc.

6.5.8 Notices of caution for cleaning and maintenance: e.g., whether cleaning is possible or not, and if possible, the process of cleaning, procedures for storage, etc.



NOTE 1: The figure ignores that fact that the SEM image is gray-scale and not black and white. Use the same intensity threshold setting for measuring pitch as for line width The center-to-center pitch averaged over the measurement length segment is to be certified and used for SEM magnification calibration

Figure 1
Definition of Edge Roughness

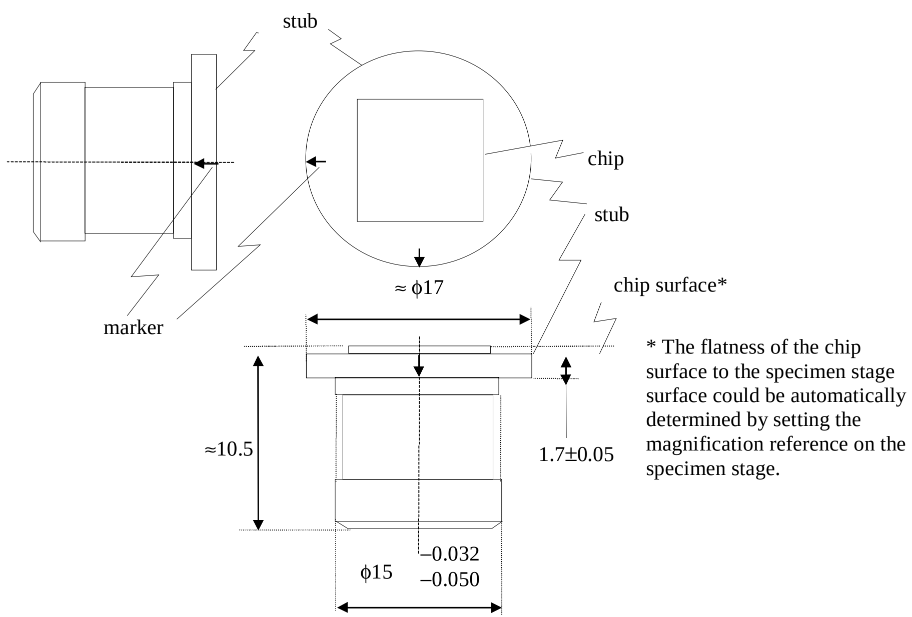


Figure 2
Shape and size of chip-type magnification reference: unit mm

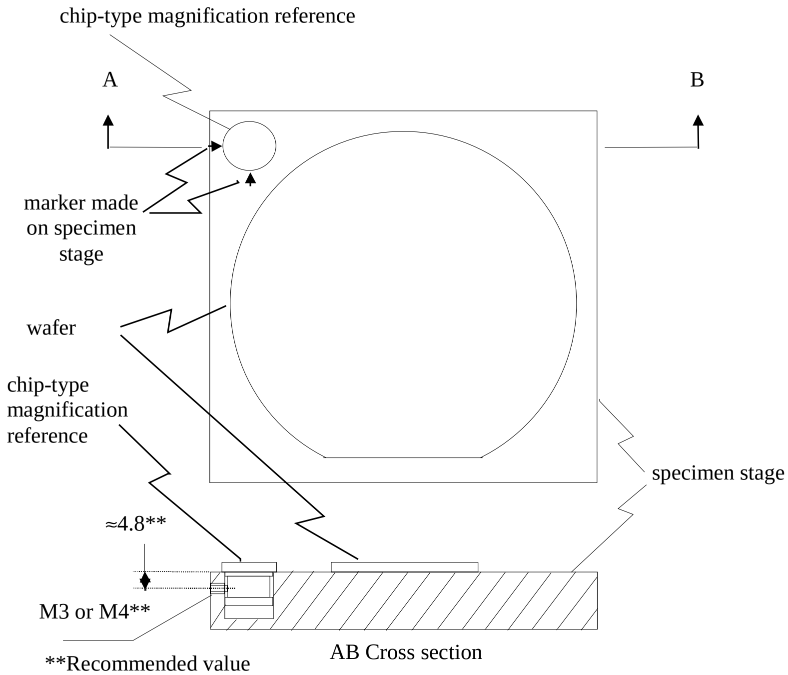


Figure 3
Chip-type magnification reference mounted on specimen stage: unit mm

APPENDIX 1
NOTES

NOTE: The material in this appendix is an official part of SEMI P36 and was approved by full letter ballot procedures on March 1, 2000 by the Japanese Regional Standards Committee.

A1-1 Reference patterns for adjusting CD-SEM magnification using their pitches and reference patterns for optimizing pattern-edge determination parameters using their widths

A1-2 The following procedures are generally applied to critical dimension measurements using CD-SEMs: an electron beam linearly scans across the measured pattern, secondary and/or reflected electrons emitted from every electron-beam incident point are collected to form its intensity profile, pattern edges are determined on the intensity profile using a designated pattern-edge determination method, and the measurement value of the width of the pattern is obtained from the distance between the two pattern edges.

A1-3 Therefore, measurement errors of CD-SEM measurements can be partitioned into two components: one is magnification error and another is pattern-edge determination error. Magnification error is caused by variation of the equipment conditions such as the sampling pitch and incident angle of electron beam. Pattern-edge determination error is affected by the manner of measurement such as pattern-edge determination algorithm used and pattern-edge determination parameters used, and the properties of the specimen such as pattern topography (e.g., pattern-edge slope) and pattern material.

A1-4 Magnification error, including inter-machine magnification error, can be detected and corrected through measuring pitches of reference patterns, and pattern-edge determination error could be detected and corrected through measuring widths of the reference patterns practical reference patterns are available for measuring their widths. However, it seems extremely difficult to produce practical reference patterns for measuring their widths; the source of the problem lies in the physics of electron beam image formation and not because the reference patterns are somehow inadequate because of the following reasons: (a) reference pattern can not be determined uniquely, since intensity profiles obtained are different from each other dependent on pattern topography and pattern materials even if the width of every reference pattern is the same, (b) it is technologically difficult to solve the problem of width change due to the contamination which changes the measurement value of pattern width dependent on measurement time.

SEMI P37-1101
SPECIFICATION FOR EXTREME ULTRAVIOLET LITHOGRAPHY MASK SUBSTRATES

This specification was technically approved by the Global Micropatterning Committee and is the direct responsibility of the North American Micropatterning Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This specification covers the general requirements of the substrate for Extreme Ultraviolet Lithography (EUVL) masks.

2 Scope

2.1 This standard details the physical characteristics required for EUVL mask substrates. The specific material is not specified to allow for innovation in materials and substrates.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *ISO Standard*[1]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments Part 1: Classification of Air Cleanliness

3.2 *ANSI Standard*[2]

ANSI/ASQC-Z1.4 — Sampling Procedures and Tables for Inspection by Attributes.

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 None.

5 Ordering Information

5.1 Purchase orders for EUVL mask substrates furnished to this specification shall include the following:

5.1.1 Material coefficient of thermal expansion (see Section 7);

5.1.2 Defect quality area dimensions and defect limits (see Section 9); and

5.1.3 Lot acceptance criteria (see Section 10).

6 Dimensions and Permissible Variations

6.1 The square substrates shall conform to the dimensional tolerances appropriate to the nominal edge length and thickness as listed in Table 1. Dimensions are illustrated in Figure 1.

6.2 Substrates shall have chamfered or rounded edges. The edges shall conform to the dimensional tolerances appropriate to the nominal thickness listed in Table 2. Dimensions are illustrated in Figure 1.

6.3 Substrates shall be identified with notches at three corners on the backside of the substrate as shown in Figure 1. Dimensions of notches shall be as defined in Figure 1.

6.4 Figure 2 shows three datum points on the edges of the mask substrate. Three datum points are also shown on the back surface of the mask substrate. These datum points serve as reference locations for all dimensional measurements listed in Table 1.

7 Material Specifications

7.1 Substrate materials shall be identified as near zero thermal expansion (NZTE). Examples of NZTE materials are titania doped silica glass or two phase glass ceramics.

7.2 Substrate materials shall conform to thermal expansion characteristics defined in Table 3 over the entire range of temperature listed and at all spatial points within the substrate.

7.2.1 The thermal expansion properties of the substrate are defined in four classes. The particular class of thermal expansion material used shall be agreed upon between user and supplier. The thermal expansion properties of the substrate are defined over the entire temperature range shown in Table 3.

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1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

2 American Society for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202, USA

7.2.2 Table 3 defines the permissible range of the mean and the permissible range of the coefficient of thermal expansion.

7.3 The substrate material shall have specific stiffness as defined in Table 3.

7.4 Selected physical properties of NZTE materials are provided for information only in Appendix 1.

7.5 The front, sides, and or back surfaces of the substrate may be coated with layers that are agreed upon between user and supplier. The substrate including these optional additional layers must meet all requirements outlined in this standard.

8 Flatness Specifications

8.1 Substrates shall be supplied with front and back sides having flatness as listed in Table 4 over a flatness quality area as defined in Figure 3. The flatness error is defined as the deviation of the surface from the plane that minimizes the maximum deviation, which is illustrated in Figure 4.

8.2 The global flatness requirement for the front and back sides, which includes the region excluded from the flatness quality area (defined in Figure 3), is shown in Table 4.

8.3 Substrates shall be supplied with wedge angle defined in Table 4 and defined in Figure 5.

8.4 Substrates shall be supplied with local slope angle as defined in Table 4 and defined in Figure 4.

8.5 A low order thickness variation (LOTV) requirement is defined over a range of spatial periods (shown in Table 4) composing the surface profile power spectral density. This thickness variation may be determined from the residual flatness error of the front and back surfaces after removing the wedge angle from the data.

8.6 The surface roughness requirements for the front and backside are listed in Table 4, and they are defined over a range of spatial periods.

9 Visual Criteria

9.1 A defect quality area, which may or may not correspond with the flatness area, shall be agreed upon between the user and supplier. Figure 6 shows the labeling of the dimensions of the defect quality area.

9.2 Each plate shall not have more defects than listed in Table 5 inside the defect quality area defined in Figure 6 on the front side. Dimensions of the quality area shall be agreed upon between user and supplier. Each plate shall not have more defects than listed in Table 5 outside the defect quality area defined in Figure 6 on the front side.

9.3 Each plate shall not have more defects than listed in Table 5 on the back side within the flatness quality area defined in Figure 3.

10 Sampling

10.1 Unless otherwise specified, appropriate sample sizes shall be selected from each lot in accordance with ASQC-Z1.4. Each quality characteristic shall be assigned an acceptable quality level (AQL) in accordance with ASQC-Z1.4 definitions for critical, major, and minor classifications. If desired, and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL values. Inspection levels shall be agreed upon between user and supplier.

11 Test Methods

11.1 *Thermal Expansion* — to be agreed upon between user and supplier.

11.2 *Flatness and Wedge Angle* — to be agreed upon between user and supplier.

11.3 *Visual* — to be agreed upon between user and supplier.

11.4 *Surface Roughness* — to be agreed upon between user and supplier.

12 Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

13 Packing and Marking

13.1 Substrates shall be packed in a class 1 environment as defined by ISO 14644-1. Containers shall be designed to protect the substrates from contamination in handling and transit. Substrates shall be shipped with the acceptable flatness side toward the front of the box. This orientation shall be indicated on each container. Packaging shall comply with the applicable internal, national, state, and local laws and regulations required for shipping.

13.2 Containers shall be labeled “Warning: Open and Handle Under Cleanroom Conditions Only” as well as identified by user purchase order number (if applicable), drawing number (if applicable), quantity, supplier lot number, and material identification.

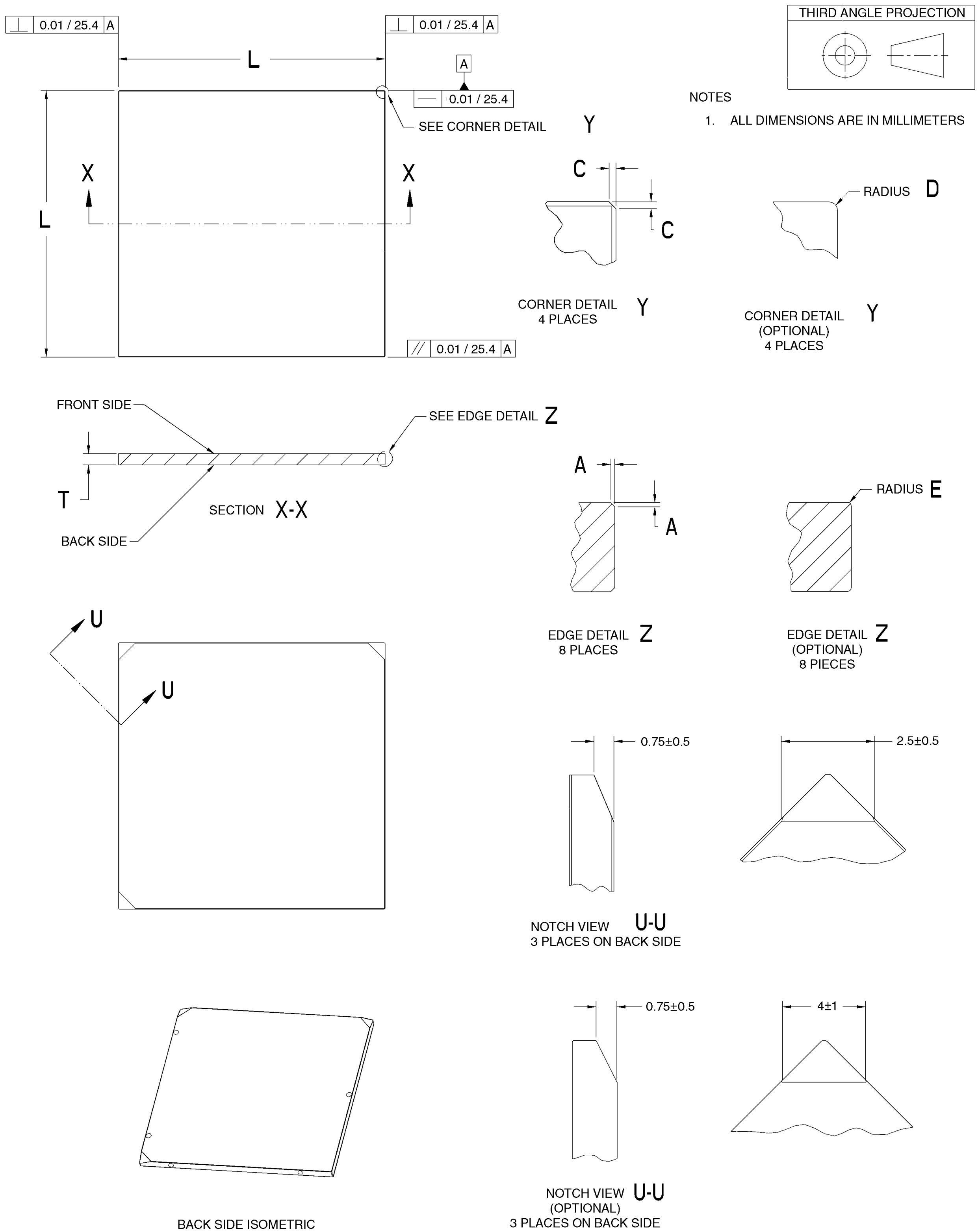

Figure 1
Dimensions of EUVL mask substrate

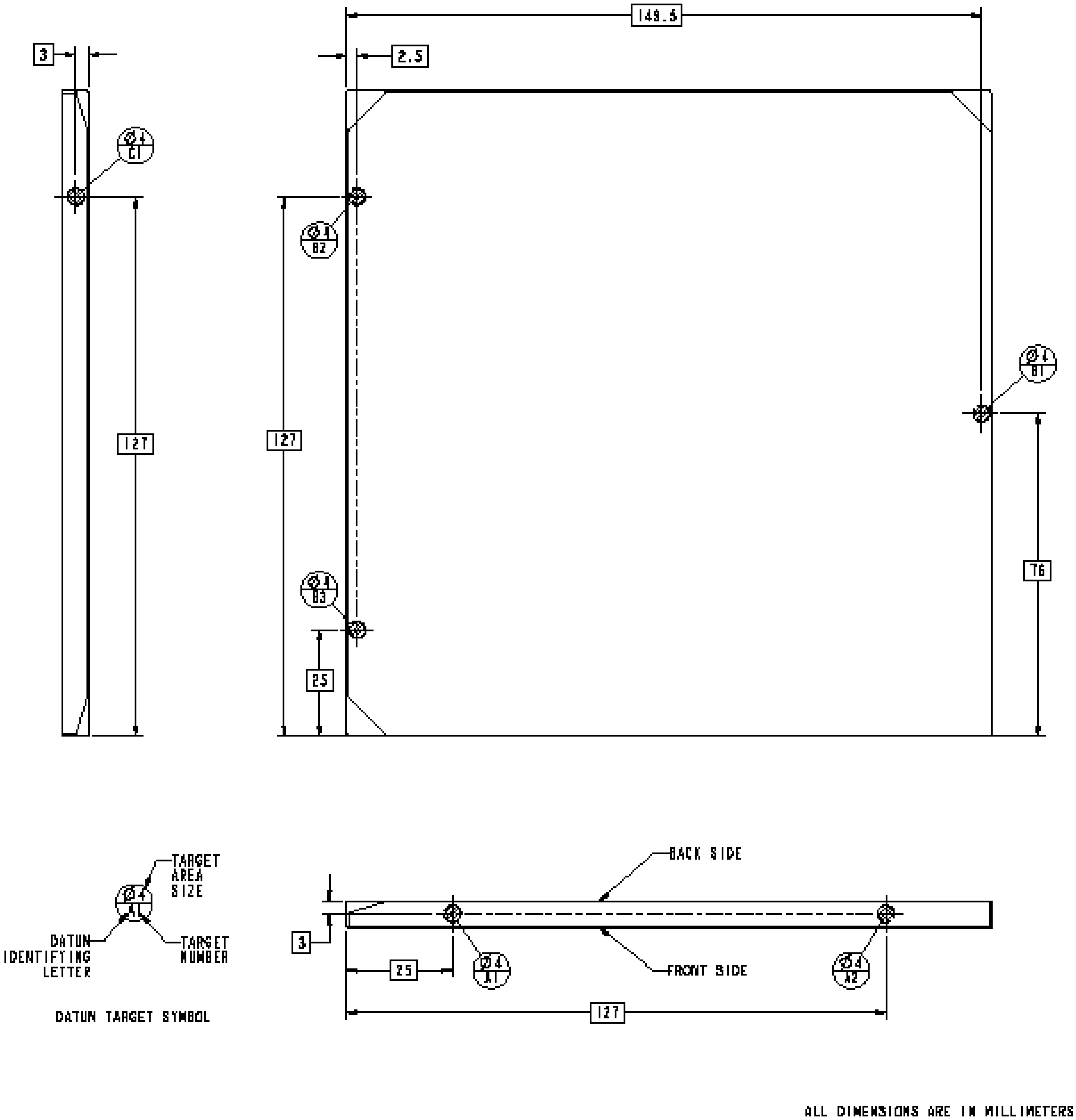

Figure 2
Datum locations on the EUVL mask substrate

Table 1 Specifications for Edge Length, Squareness, and Thickness for Square Substrates

Edge Length Min. L	*Edge Length Max.* L	*Squareness*	*Minimum Mean Thickness* T	*Maximum Mean Thickness* T	*Units*
151.9	152.1	0.01/25.40	6.25	6.45	mm

Table 2 Specifications for Chamfered and Rounded Edge Dimensions

T	*A*	*A*	*C*	*C*	*D*	*D*	*E*	*E*	
Nominal	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Units*
6.35	0.20	0.30	0.30	0.70	0.50	1.00	0.25	0.30	mm

Table 3 Substrate Material Characteristics

Property	*Symbol*	*Characteristic*
Temperature range for CTE requirement		19 to 25°C
Coefficient of Thermal Expansion	CTE (ppb/°C)	Class A: mean: 0 ± 5 ppb/°C 6 ppb/°C total spatial variation Class B: mean: 0 ± 10 ppb/°C 10 ppb/°C total spatial variation Class C: mean: 0 ± 20 ppb/°C 10 ppb/°C total spatial variation Class D: mean: 0 ± 30 ppb/°C 10 ppb/°C total spatial variation
Specific Stiffness (Young's elastic modulus divided by density)	E/ρ (m^2s^{-2})	$\geq 3 \times 10^7$

Note: ppb stands for parts per billion.

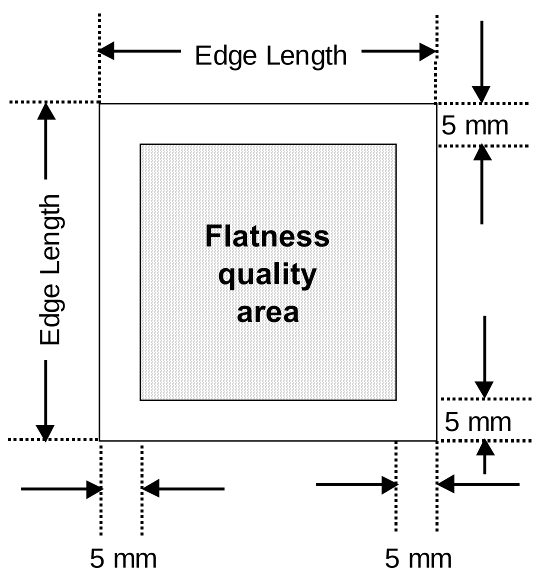

Figure 3
Front and Back Side Flatness Quality Area

Table 4 Flatness, Wedge and Surface Roughness

FLATNESS ERROR IN FLATNESS QUALITY AREA

Frontside Flatness, within Flatness Quality Area	*Backside Flatness, within Flatness Quality Area*	*Low Order Thickness Variation (LOTV), within Flatness Quality Area (See Note 2.)* $\lambda_{spatial} >$ *(edge length)*	*Units*
50 peak-to-valley	50 peak-to-valley	50	nm

NOTE 1: $\lambda_{spatial}$ is the spatial period of the flatness error.
NOTE 2: Evaluated after removing wedge angle.

FLATNESS OVER ENTIRE SURFACE

Frontside Flatness $\lambda_{spatial} \leq$ *(edge length)*	*Backside Flatness* $\lambda_{spatial} \leq$ *(edge length)*	*Units*
1000 peak-to-valley	1000 peak-to-valley	nm

NOTE 1: $\lambda_{spatial}$ is the spatial period of the flatness error.

WEDGE

Wedge angle	*Units*
≤ 100	microradians

LOCAL SLOPE OF FRONT SURFACE

Local slope angle $400\ nm \leq \lambda_{spatial} \leq 100\ mm$	*Units*
≤ 1.0	milliradians

FRONT SIDE SURFACE ROUGHNESS

Surface Roughness in Quality Area (Figure 6), $\lambda_{spatial} \leq 10\ \mu m$	*Units*
≤ 0.15 rms	nm

BACK SIDE SURFACE ROUGHNESS

Surface Roughness over entire back surface, $50\ nm \leq \lambda_{spatial} \leq 10\ \mu m$	*Units*
≤ 0.5 rms	nm

NOTE 1: rms is root mean square error. $\lambda_{spatial}$ is the spatial wavelength of the roughness.

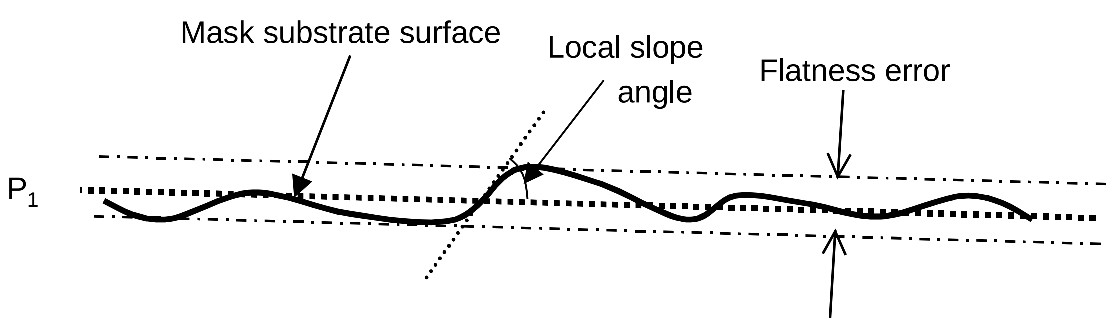

Figure 4
Definition of Flatness Error and Local Slope Angle
P1 is the plane that minimizes maximum deviation of the surface.

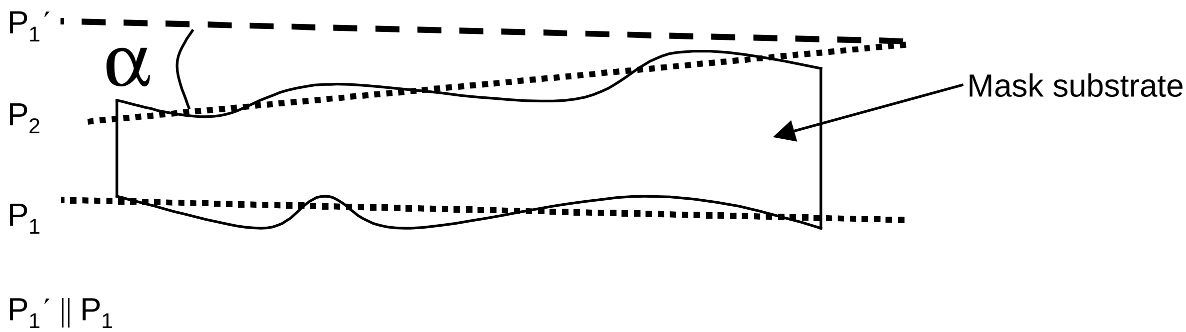

Figure 5
Definition of Wedge Angle, α
P_1 and P_2 are the planes that minimize the maximum deviation of the front and back surfaces, respectively.

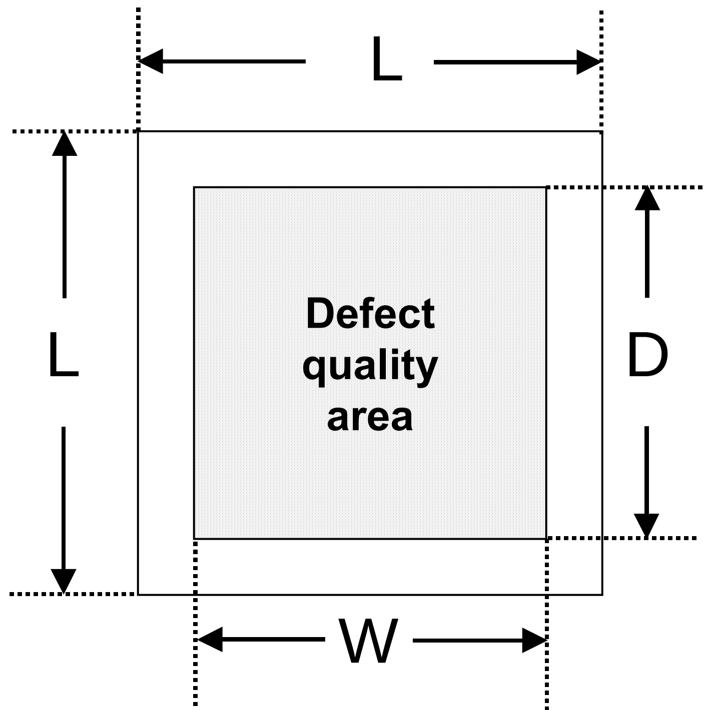

Figure 6
Definition of defect quality area on front side

Table 5 Substrate Defect Limits per Plate

FRONTSIDE SURFACE DEFECTS IN THE DEFECT QUALITY AREA

Frontside	*Residue*	*Total Scratch and Sleek Defects >1 nm in depth (See Note 1.)*	*Total Localized Light Scatterers > 50 nm PSL equivalent size (per cm^2) (See Note 2.)*	*Total Localized Light Scatterers < 50 nm PSL equivalent size (per cm^2) (See Note 2.)*
NZTE	None	0	0	To be agreed upon between user and supplier

NOTE 1: The maximum size for scratches and sleeks will be agreed upon between user and supplier.
NOTE 2: Localized light scatterers are any isolated features, such as particles or pits, on or in the substrate surface, resulting in increased light scattering intensity relative to that of the surrounding substrate surface. PSL equivalent size means the detected defect appears to be the same size as a polystyrene latex sphere examined under the same inspection conditions.

FRONTSIDE DEFECTS OUTSIDE THE DEFECT QUALITY AREA

Edge Chips	*Defect Limit*	*Total Number*
Radial Depth	≥ 0.76 mm	None
Peripheral Cord	≥ 0.76 mm	None
Other	Shall be negotiated between vendor and supplier	Shall be negotiated between vendor and supplier

BACKSIDE DEFECTS IN FLATNESS QUALITY AREA

Localized Light Scatterer Size (PSL equivalent) (See Note 2.)	*Total*	*Total Number of Backside Scratches (See Note 1.)*
> 1.0 µm	0	0
≤ 1.0 µm	no limit	

NOTE 1: The maximum size for scratches and sleeks will be agreed upon between user and supplier.
NOTE 2: Localized light scatterers are any isolated features, such as particles or pits, on or in the substrate surface, resulting in increased light scattering intensity relative to that of the surrounding substrate surface. PSL equivalent size means the detected defect appears to be the same size as a polystyrene latex sphere examined under the same inspection conditions.

RELATED INFORMATION 1
MATERIAL PROPERTIES

NOTE: This related information is not an official part of SEMI P37 and was derived from the work of the originating committee. This related information was approved for publication by full letter ballot procedures on August 27, 2001.

Table A1-1 Typical EUVL Mask Substrate Bulk Material Properties (for information only)

Property	*Symbol*	*NZTE*
Mean Specific Heat	C_p (J/kg-°C)	750–820
Thermal Conductivity	K (W/m-°C)	1.3–1.6
Density	ρ (g/cm^3)	2.1–2.6
Elastic Modulus	E (GPa)	65–91
Poisson's Ratio	ν	0.17–0.25
Index of refraction	n	1.4–1.6
Electrical conductivity at 20°C	σ (Siemens/m)	10^{-14}–10^{-18}
Dielectric constant	ε at 1 KHz	3.5–9.0

SEMI PR7-0302
PROPOSED PHOTOMASK QUALIFICATION TERMINOLOGY

This proposed terminology was technically approved by the Global Micropatterning Committee and is the direct responsibility of the European Micropatterning Committee. Current edition approved by the European Regional Standards Committee on December 20, 2001. Initially available at www.semi.org January 2002; to be published March 2002.

1 Purpose

1.1 This standard is aiming to define a unique language in the field of specification for, and qualification of, photomasks for use in optical lithography within the semiconductor industry.

2 Scope

2.1 At present only the International Technology Roadmap for Semiconductors (ITRS) serves as a universally accepted working document how to specify photomasks, however the definitions used are subject to interpretation. Different tool makers, mask makers and mask users are hindered in the communication with each other, as they first need to know and understand each others terminology. The lack of a common terminology complicates comparison of tools. A uniformly used, and universally accepted terminology, with a minimum of ambiguity, is required.

2.2 The definitions listed are for mask qualification, incorporating 3 possible types of value for a given qualification parameter:

- *<(true) qualification parameter>*, which would be the result of an ideal measurement of the total population of features of interest[1].
- *<measured qualification parameter>*, the result of a given population of measurements. It is hereby mentioned that a measured value (for example the mean, the standard deviation, the range) is always subject to the sample size of the measured population and the measurement method. Therefore both the sample size and the measurement method are mandatory information.
- *<qualification parameter spec(ification)>*, the maximum or minimum value that may not be exceeded for the selected population of measurements which must be defined as mandatory information.

2.2.1 The first two types of value for a given parameter will be defined in the present document.

2.2.2 The third parameter type will not be discussed here, since it is an upper limit to the measured qualification factor, and subject to the agreement between the individual parties of the mask qualification process.

2.3 *Restricted Scope For The First Version* — The present version of the document is restricted to the consideration of one-dimensional qualification in the mask pattern plane, i.e. parameters related to width measurement.

2.4 To assist users, the major differences in recommended default values between this standard and the ITRS mask table definitions are noted where applicable.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 The definitions listed are specific to state-of-the-art photomasks, with a focus on reduction reticles. They may therefore overrule any related terminology in other standards, with a more general scope. Application to other type of masks, e.g. for next generation lithography, may be feasible, but is NOT intended to be within the scope of the present document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI P10 — Specification of Data Structure for Photomask Order Entry

SEMI P19 — Specification for Metrology Pattern Cells for Integrated Circuit Manufacture

SEMI P21 — Guidelines for Precision and Accuracy Expression of Mask Writing Equipment

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition

SEMI P24 — CD Metrology Procedures

SEMI P35 — Terminology for Microlithography Metrology

SEMI Compilation of Terms

1 See reference document in Section 4.2.

4.2 *ISO Standards* [2]

International Vocabulary of Basic and General Terms in Metrology

4.3 *International Technology Roadmap for Semiconductors (ITRS)* [3]

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Interpretation of Related General Terminology

NOTE 2: This paragraph includes general terms, as a basis for the specific mask related terminology, which is the main subject of this document.

5.1 *feature* — as defined in SEMI P35.

5.2 *proximity range* — distance over which a feature influences another significantly (criterion to be stated). It applies to mask fabrication, mask metrology and/or printed wafer image, defining 3 types of proximity range (terminology for example *mask fabrication proximity range*). It is mandatory to state which of the 3 is referred to.

NOTE 3: Further in this document *proximity range* will refer by DEFAULT to the first type mentioned.

5.3 *line* — a clear field, dark feature of semi-infinite length (>> *proximity range*) determined by its width (called a 1D feature, see Figure 1). Such feature may also be called a line when it is shorter, insofar its length:width ratio is larger than 2 (called a 2D feature, as the width may be affected by the feature-ends)

5.4 *space* — in analogy to line, but dark field, clear feature (see Figure 1).

5.5 *contact* — a dark field, clear feature with length:width ratio ranging from 0.5 (1 is default) to 2 maximum (see Figure 1). The width of such feature may be measured 1D-wise, but for enhanced relevance it requires 2D or, more specifically, area assessment. A large contact can be called a *window*.

5.6 *dot* — in analogy to contact, but clear field, dark feature (see Figure 1). A large dot can be called a *pad*.

5.7 *isolated feature* — feature that has no neighbors within a distance smaller than the proximity range.

5.8 *dense features* — features that influence each other (all that are not isolated). Clarification is required to describe the proximity, either by detailing the feature pitch and number of lines, for regular arrays (pitch = design values of line width and space width added), or by describing the surrounding area (see Section 7). In absence of such clarification dense is regarded by default as equal lines and spaces (or “half pitch” in general) in a semi-infinite array size, insofar that the feature width does not exceed the proximity range.

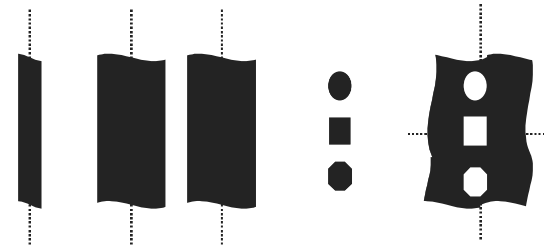

Figure 1
Nomenclature feature types (as designed)
Default contact (dot) is square.

6 Coordinate System

6.1 The coordinate system XYZ for this document is defined in Figure 2. It is defined with patterned mask side upwards and mask orientation as it was patterned. XY determines the mask plane. Z is the direction perpendicular to it. z = 0 for the absorber–substrate interface and z < 0 to the substrate side. Absorber is for example chrome or embedded material.

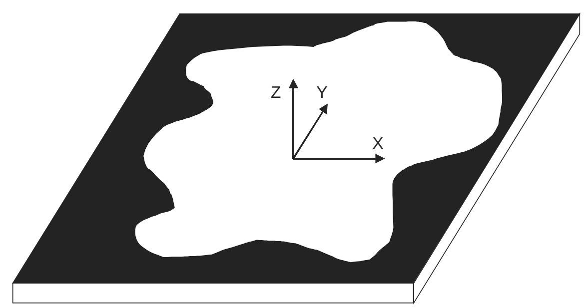

Figure 2
Mask coordinate system

6.2 Features are called vertical when their length is along Y. Feature width is then measured in X. This corresponds to Figure 2 of SEMI P35. Horizontal features have their length along X. Feature width is then measured in Y. See Figure 3.

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2 International Organization for Standardization 1, rue de Varembé Case Postale 56 CH-1211 Genève 20 Switzerland

3 International Technology Roadmap for Semiconductors, organized by International SEMATECH, 2706 Montopolis Drive, Austin, Texas 78741

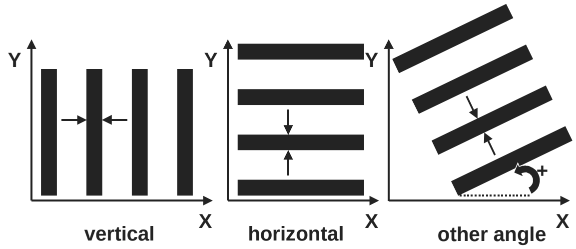

Figure 3
Orientation of Mask Features

7 Mask Qualification Terminology

7.1 *feature width* — Width of a cross section of a mask feature at a certain height defined by an appropriate bounding box model as described in SEMI P35, to be mentioned (see Figure 4). DEFAULT is at z = 0.

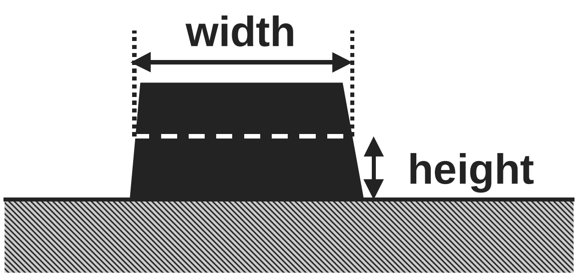

Figure 4
Cross section of a mask feature

7.2 *measured feature width* — Width determined from the measured signal obtained on the mask feature. For example width determined at a certain level of the signal.

To be stated as mandatory information:

- region of interest. For 1D features this corresponds to the specified line segment (SEMI P35),
- measurement method used (SEM, optical reflection, optical transmission, AFM, …),
- calibration and/or correlation used, and
- precision (SEMI P24).

and as optional information:

- measurement tool, and
- measurement algorithm used.

NOTE 4: The bounding box could be infinitely short as in the special situation of a measurement of a feature using a cross-section.

7.3 *feature edge* — Position of the material boundary of a mask feature at a certain height of the physical cross section (see Figure 2 of SEMI P35), to be stated as mandatory information. DEFAULT is feature/substrate interface.

7.4 *measured feature edge* — Position determined from the measured signal obtained on the mask feature edge. For example position determined at a certain level of the signal, as defined by the bounding box model of SEMI P35. Same mandatory/optional information must be stated as for *measured feature width.*

7.5 *critical dimension (abbreviated to CD)* — A user defined feature width of interest, mainly used for further qualification. Can be plural. DEFAULT is one width and one pitch. Mandatory information is width. (see *feature width uniformity*)

NOTE 5: The ITRS mask table assumes multiple pitches.

7.6 *feature width uniformity* — The spread of the distribution of the width of all mask features of a given design size selected as detailed hereafter. To be stated as mandatory information:

- its targeted feature width,
- all type and tone of features considered (line, contact, space, …as defined in SEMI P19),

  NOTE 6: Several could be combined, but the recommendation is one tone and one type, DEFAULT is lines for clearfield, spaces for darkfield.

- all orientations considered (adopting a pre-determined mask orientation), for example horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, …DEFAULT is horizontal and vertical together,
- the pitch of the feature (or in general: a description of the surrounding area, see further), e.g. equal lines and spaces, isolated line, …, or (if wished, but not recommended) an interval of pitches, and

  NOTE 7: In the latter case the defined feature width uniformity would not be proximity free. DEFAULT is one fixed pitch, to be mentioned. (The ITRS mask table assumes multiple pitches.)

- The considered area of interest on the mask.

7.7 *measured feature width uniformity* — Measured value of *feature width uniformity*, stating as mandatory information in addition to that of *measured feature width*:

- the number of measurement points used,
- the criterion used (range, 3-sigma, maximum deviation, ..), where sigma stands for standard deviation. Recommendation: Before 3-sigma is relevant, the distribution needs to be “normal” or

"near normal", and the number of measurements should be > 30, and

- the measured area on the mask.

and as optional information:

- the spatial distribution of measurement locations. DEFAULT is spread evenly over the measurement area.

7.8 *(measured) CD uniformity* is the special case of *feature width uniformity* where the selected feature is the *critical dimension*.

7.9 *mean-to-target* — The difference between the mean width of features, selected as detailed, and the targeted feature width, stating the same information as for *feature width uniformity*. (DEFAULT: selecting the same values as for *feature width uniformity*)

7.10 *measured mean-to-target* — The difference between the mean of measured feature widths and the targeted feature width, stating the same information as for *feature width uniformity* and in *measured feature width uniformity* (DEFAULT: selecting the same values as selected therein)

7.11 *(measured) CD mean-to-target* is the special case of *mean-to-target* where the selected feature is the *critical dimension*.

7.12 *maximum feature width deviation from target* — Maximum deviation from target in the total population of features considered, stating the same information as in *feature width uniformity*. (DEFAULT: selecting the same values as used therein)

7.13 *measured maximum feature width deviation from target* — Maximum deviation from target in the population of measurements, stating the same information as in *feature width uniformity* and in *measured feature width uniformity.* (DEFAULT: selecting the same values as used therein)

NOTE 8: (measured) maximum feature width deviation from target combines (measured) feature width uniformity and (measured) mean-to-target.

7.14 *mean X-Y deviation* — The difference between the mean of considered feature widths in X and Y directions (horizontal and vertical direction), stating the same information as *feature width uniformity*. (DEFAULT: selecting the same values)

7.15 *measured mean X-Y deviation* — The difference between the mean values of measured feature widths in X and Y directions, stating the same information as for *feature width uniformity* and in *measured feature width uniformity* (DEFAULT: selecting the same values as used therein)

7.16 *X-Y deviation uniformity* — The spread of the distribution of the difference between the width of all considered feature widths in X and Y directions (horizontal and vertical direction), stating the same information as *feature width uniformity*.

7.17 *measured X-Y deviation uniformity* — The spread of the distribution of the difference between the width of the measured feature widths in X and Y directions (horizontal and vertical direction), including/stating the same information as *feature width uniformity* and in *measured feature width uniformity*.

7.18 *feature linearity error* — Range of the deviations between the mask feature width and the respective target width on a range of feature widths, stating as mandatory information:

- the range of feature widths used (at mask level) (DEFAULT is the interval from the critical dimension to 5 times this).

  NOTE 9: The ITRS uses a wider interval.

- all type and tone of features considered, e.g. line, contact, space, …(see Section 5). It is a strong recommendation to fix on 1 tone/ 1 type to reach a useful number. DEFAULT is on lines ("*line linearity error*"). Contacts may be more challenging *("contact linearity error*"),

- all orientations considered, e.g. horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, …(see Figure 5)

- the pitch of the feature (or in general: a description of the surround(ing mask area), see further), e.g. equal lines and spaces, isolated line, …, or (if wished, but not recommended) an interval of pitches. DEFAULT is isolated features only, which is defined as *feature intra-proximity error.*

  NOTE 10: If a range of pitches is included, the resulting definition will include (inter)proximity effects. (The ITRS mask table assumes multiple pitches.)

7.19 *measured feature linearity error* — Measured value of *feature linearity error*, stating as mandatory information in addition to that of *measured feature width*:

- the number of measurement points used per feature width (which is recommended > 1. Then the mean value for each feature width is used).

and as optional information:

- the quality area, and
- the spatial distribution of measurement locations.

7.20 *feature inter-proximity error* — Range of the deviations between the mask feature width of a given size and the respective target width, on a variation of local pattern density and configuration (= of surround), stating as mandatory info:

- The nominal feature width at mask level,
- all type and tone of features considered, e.g. line, contact, space..(see Section 5). It is a strong recommendation to fix on 1 tone/ 1 type to reach a useful number. DEFAULT is on lines (*line inter-proximity error),*
- all orientations considered, e.g. horizontal and vertical together, horizontal only, vertical only, including other angles, horizontal-and-vertical separately, …
- range of feature pitches. DEFAULT is equal lines-and-spaces to isolated features. If only lines-and-spaces and isolated features themselves (and nothing in-between) also *iso-dense deviation* can be used, and
- In more general cases an alternative detailed description of the surround(ing mask area), preferably clarified with a drawing, will replace the pitch information.

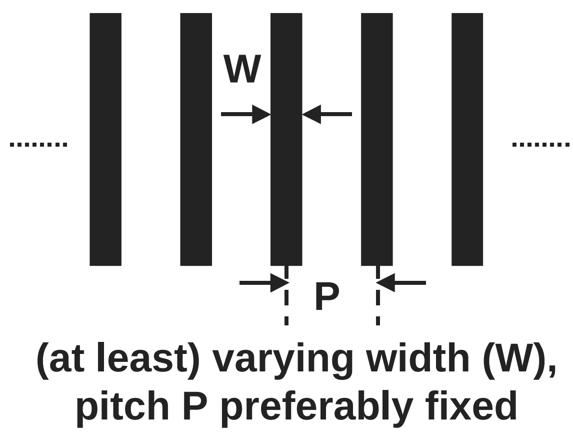

Figure 5
Feature Linearity

7.21 *measured feature inter-proximity error* — Measured value of *feature inter-proximity error*, stating as mandatory information in addition to that of *measured feature width*:

- the number of measurement points used per pitch or surrounding mask area (recommendation is > 1. Then the mean value is used).

and as optional information:

- the measured area on the mask, and
- the spatial distribution of measurement locations.

7.22 *feature proximity error* — Range of the deviations between the mask feature width and the respective target width on a range of feature widths and on a variation of local pattern density and configuration (= of surround), stating as mandatory info: … (to be adopted from linearity and inter-proximity)

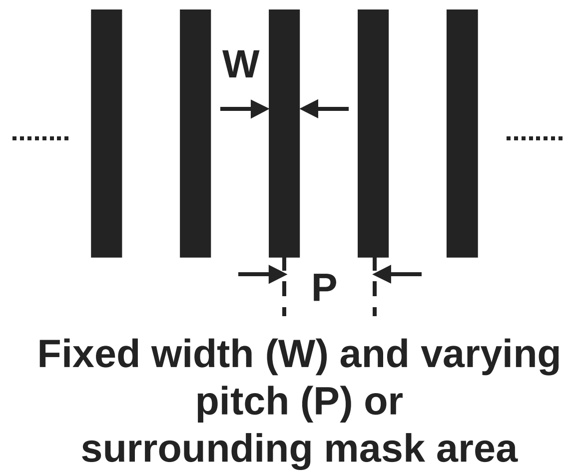

Figure 6
Feature Inter-proximity

7.23 *measured feature proximity error* — Measured value of *feature inter-proximity error*, stating as mandatory information in addition to that of *measured feature width*:

- the number of measurement points used per pitch or surrounding mask area (recommendation is > 1. Then the mean value is used).

and as optional information:

- the measured area on the mask, and
- the spatial distribution of measurement locations.

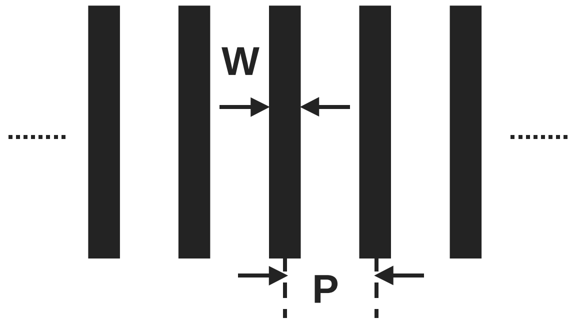

Figure 7
Feature Proximity

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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SEMI INTERNATIONAL STANDARDS

PACKAGING

Semiconductor Equipment and Materials International

SEMI G1-96
SPECIFICATION FOR CERDIP PACKAGE CONSTRUCTIONS

NOTE: This entire document was revised in 1996.

1 Purpose

This specification defines the materials and acceptance criteria for the components (bases, window frames, and caps) or sub-assemblies (leadframes mounted in a sandwich between bases and window frames) used for cerdip package constructions.

NOTE 1: Materials and acceptance criteria for leadframes, purchased separately for these constructions, are described in SEMI G2.

2 Scope

This specification applies to all cerdip (dual-in-line) packages which have either:

- A leadframe sandwiched between two ceramic pieces — the base and a window frame — and sealed by a solder glass layer, and a cap with a similar seal; or,
- A leadframe mounted into a solder glass layer on a ceramic base, and a cap with a similar glass seal layer.

NOTE 2: The base, leadframe, and, if required, the window frame may be purchased as separate components or as a sub-assembly.

3 Units

This specification uses U.S. Customary (inch pound) units as the prime unit.

4 Referenced Documents

4.1 *Order of Precedence*

To avoid conflicts, the order of precedence when ordering components or sub-assemblies for cerdip packages shall be as follows:

- Purchase order
- User's package drawings
- This specification
- Reference documents
- Related documents

4.2 *Referenced Documents*

4.3 *SEMI Specifications*

SEMI G2 — Specification Metallic Leadframes for Cer-Dip Packages

SEMI G20 — Specification Lead Finishes for Plastic Packages (Active Devices only)

SEMI G23 — Test Method Measuring the Inductance of Package Leads

SEMI G24 — Test Method Measuring the Lead-to-Lead and Loading Capacitance of Package Leads

SEMI G25 — Test Method Measuring the Resistance of Package Leads

SEMI G30 — Test Method Junction-to-Case Thermal Resistance Measurements of Ceramic Packages

4.4 *ANSI Specification*[1]

ANSI Y14.5M — Dimensioning and Tolerancing

4.5 *JEDEC Publication*[2]

JEDEC Publication 95 — Registered and Standard Outlines for Semiconductor Devices

4.6 *Military and Federal Specifications*[3]

MIL-STD-105D — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-1835 — Microcircuit Case Outlines

MIL-I-38535 — General Specifications for Microcircuits

5 Terminology

5.1 *blister (bubble) metallization* — An enclosed, localized separation of the metallization from its base material (such as ceramic or other metallization layer component) that does not expose the underlying layer.

5.2 *burr* — An adherent fragment of parent material at a component edge. In leadframes, the metal burr, due to the stamping operation, may be in the horizontal or vertical direction to the surface. In ceramic packages, this type of characteristic is called a fin.

1 American National Standards Institute, 1430 Broadway, New York, NY 10018

2 Joint Electronic Development Engineering Council, 2001 Eye Street, N.W., Washington, D.C. 20006

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

5.3 *camber (ceramic)* — Arching of a nominally flat ceramic body.

5.4 *chip* — A region of material missing from a component (e.g., ceramic from a package, or solder from a preform). The region does not progress completely through the component and is formed after the component is manufactured. Chip size is defined by its length, width, and depth from a projection of the design planform. Also called chipout (see Figure 1).

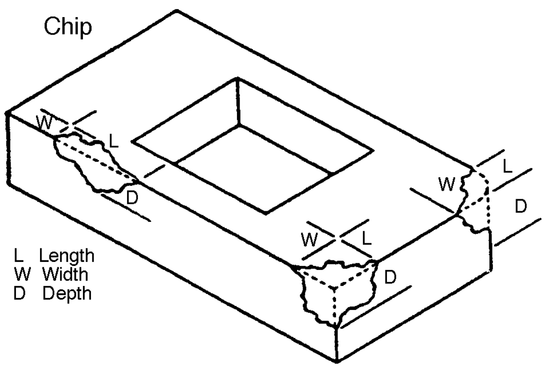


Figure 1

5.5 *crack* — A cleavage or fracture that extends to the surface of a semiconductor package or solder preform.The crack may or may not pass through the entire thickness of the package or preform.

5.6 *critical seal area* — On a semiconductor package, the area bounded by the shortest nominal design distance from the largest cavity, usually the wire bond cavity, to the edge of the package or ceramic layer forming the seal area (see Figure 2).

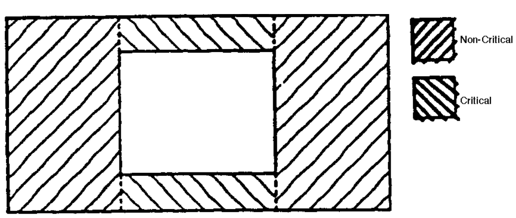


Figure 2
Critical and Non-Critical Seal Area

5.7 *fin* — On a ceramic package or cap, a fine feathery-edged projection of parent ceramic material on the corner of the ceramic body.

5.8 *foreign material* — An adherent particle that is not parent material of the component. Adherence means that the particle cannot be removed by an air or nitrogen blast at 20 psi.

5.9 *glass flow* — On a semiconductor package or cap, the heating process which just removes all the screen printing mesh marks in the sealing glass when viewed at 10× magnification.

5.10 *glass void* — The absence of a sealing glass layer from a designated area.

5.11 *metallization void* — The absence of a clad, evaporated, plated, or screen-printed metal layer or braze from a designated area.

5.12 *non-critical seal area* — On a semiconductor package that uses a lid, cap, or cover to effect the seal, the area of the sealing surface outside the critical sealing area (see Figure 2).

5.13 *overhang* — On a semiconductor package, the horizontal extension of the sealing glass past the vertical wall of a cavity cut into the ceramic layer on which the glass is printed (see Figure 3).

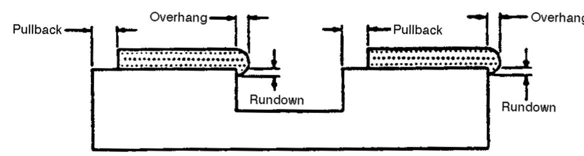


Figure 3
Glass Misalignment

5.14 *peeling (flaking)* — Any separation of a plated, vacuum-deposited, or clad metal layer from the base metal of a leadframe, pin heatsink, or seal ring, from an underplate or from a refractory metal on a ceramic package. Peeling exposes the underlying metal.

5.15 *projection* — On a semiconductor package (plastic or ceramic) leadframe or preform, an irregularly raised portion of a surface indigenous to the parent material.

5.16 *pullback* — On a semiconductor package, the linear distance between the edge of a cavity cut into a ceramic layer and the first measurable glass or metallization layer interface coated onto the top surface of that layer. The total pullback may be the result of the high-temperature processing required to manufacture the package or to coat the surface. It may also be the result of design considerations (see Figure 3).

5.17 *rundown* — On a semiconductor package, the linear distance from the upper surface of a ceramic cavity layer to the bottom point of the overhang into the cavity, of a sealing glass or metallization layer that has been screened onto that surface (see Figure 3).

5.18 *seal area* — On a semiconductor package, the area designated for sealing a cover or lid to a cofired ceramic package, to a cap to a cer-pack base.

5.19 *void* — An absence of metallization or glass from a designated metallized or glassed area on a ceramic surface.

6 Ordering Information

Purchase orders for cerdip components or sub-assemblies furnished to this specification shall include the following items:

6.1 Current drawing revision detailing:

6.1.1 All dimensions and tolerances per ANSI Y14.5M practices

6.1.2 Type and color of ceramic

6.1.3 Type and thickness of glass

6.1.4 Type and thickness of die pad metallization

NOTE 3: If sub-assemblies are purchased, the leadframe details shall be as described in SEMI G2. In some cases, unlike the frames described in SEMI G2, the leadframes may also have a die-attach pad. If required, the external lead plating requirements for these sub-assemblies shall also be specified. (See SEMI G20 for general details of lead finishes.) If sub-assemblies are purchased, leadframe inspection shall follow the requirements detailed in Section 9.

6.2 *Incoming Inspection and Functional Tests* — See Sections 9 and 10.

6.3 *Incoming Sampling Procedures* — See Section 11.

6.4 *Packaging and Marking Requirements* — See Section 12.

6.5 *Vendor Certification Requirements* — See Section 13.

6.6 Any additions to, or variations from, this specification.

7 Dimensions

The components or sub-assemblies described in this specification shall produce packaged devices that conform to the outline dimensions and lead numbering for cerdip package constructions detailed in:

— JEDEC Publication 95 and

— MIL-STD-1835.

Package manufacturing tolerances shall be agreed upon between user and supplier and detailed in the drawings.

Typical dimensions and tolerances for standard bases and caps are shown in the appendices at the end of this specification.

8 Materials

The definitions defect criteria and functional tests described in this specification relate to package components made with the following materials:

8.1 *Bases, Window Frames, and Caps*

8.1.1 *Material* — Ceramic with 90% alumina, minimum content.

8.1.2 *Color* — Black, dark brown, or dark violet.

8.2 *Sealing Material*

8.2.1 *Material* — Solder glass designed to seal metal (typically Iron-Nickel-Cobalt alloy per MIL-M-38150, Type A or Iron-Nickel alloy per MIL-M-38150 Type B) to ceramic.

8.3 *Die-Attach Pad*

8.3.1 *Material* — Thick film gold or other specified material.

8.4 *Leadframe*

8.4.1 Leadframes, whether purchased as component or in sub-assemblies, shall conform to the requirements of SEMI G2 as required.

9 Defect Limits

The following defects shall be cause for rejection if the limits shown are exceeded:

NOTE 4: The criteria apply to purchased components and pre-assemblies, as applicable, or, where applicable, to units assembled by the user to process conditions agreed upon between the user and supplier.

9.1 *Ceramic Components*

9.1.1 *Cracks* — Any crack.

9.1.2 *Chips* — See Figures 1 and 2.

9.1.2.1 *Corner Chips* — 0.030" (0.762 mm) × 0.030" (0.726mm) × 25% of the package element thickness.

9.1.2.2 *Edge Chips* — 0.100" (2.54 mm) × 0.030" (0.726mm) × 25% of the package element thickness.

9.1.2.3 *Critical Seal Area* — Chips shall not reduce the critical seal path, at any point, more than 30%. No more than four chips are allowed in this area, regardless of loss of seal length.

9.1.3 *Burrs, Projection (Fins), and Blisters*

9.1.3.1 *Bases, Caps, and Window Frames* — 0.005" (0.127 mm) maximum allowable dimension in the plane of the component, or greater than 0.003" (0.076 mm) in height.

9.1.3.2 *Die-Attach Surface (on Base Ceramic)* — 0.005" (0.127 mm) dimension in the plane of the component, or greater than 0.001" (0.254 mm) above the surface of the metallization excluding a zone, 0.010" (0.254 mm) wide, around the periphery of the cavity.

9.1.4 *Camber* — Shall be agreed upon between user and supplier and specified on the component or sub-assembly drawing. Standard limits shall be 0.003"/inch (0.003 mm/mm), maximum, with a minimum allowable camber of 0.002" (0.051 mm).

9.1.5 *Foreign Material* — 0.020" (0.508 mm) maximum allowable surface dimension or 0.005" (0.127 mm) in height. No more than three sites allowed and a minimum separation of 0.030" (0.762 mm) between sites.

9.2 *Glass Sealant*

9.2.1 *Chips and Voids* — 0.010" (0.025 mm) maximum allowable dimension. In the critical seal, there shall be no more than four acceptable chips or voids. In critical and non-critical seal areas, there shall be no voids after a glass flow cycle.

9.2.2 *Glass Misalignment* — (After glass flow on components, see Figure 3, or on sub-assemblies.)

9.2.2.1 *Glass Overhang* — 0.015" (0.381 mm) maximum extension from the ceramic edge.

9.2.2.2 *Glass Rundown* — 50% of the package element thickness.

9.2.2.3 *Glass Rundown into the Die-Attach Cavity* — 0.010" (0.254 mm) maximum extension from the ceramic surface into the cavity.

9.2.2.4 *Glass Pullback (After Glass Flow)* — See Table 1 and Figure 3.

Table 1 Maximum Allowable Pullback

Area of Package	*Package Row Spacing*	*Package Row Spacing*
	0.300" (7.500 mm) and 0.400"(10.16 mm)	0.600" (15.24 mm) and larger
Side external (critical seal area)	0.010" (0.254 mm)	0.015" (0.381 mm)
Side external (non-critical seal area)	0.015" (0.381 mm)	0.015" (0.381 mm)
End external	0.020" (0.508 mm)	0.020" (0.508 mm)
Side cavity	0.010" (0.254 mm)	0.015" (0.381 mm)
End cavity	0.010" (0.254 mm)	0.015" (0.381 mm)
Maximum allowable critical seal length reduction on any one side, as measured between the cavity and the external side	0.015" (0.381 mm)	0.020" (0.508 mm)

NOTE 5: Regardless of the maximum criteria noted in Table 1, the critical seal length at any point shall not be reduced any more than 30%.

9.2.2.5 *Foreign Material* — 0.020" (0.508 mm) maximum allowable surface dimension in the plane of the glass, but 0.010" (0.254 mm) in the critical seal area, with no more than three sites allowed and a minimum separation of 0.030" (0.762 mm) between sites.

9.3 *Die-Attach Cavity Metallization (0n Ceramic Base)* — Excluding a 0.010" (0.254 mm) wide zone around the periphery of the cavity, the following criteria shall apply:

9.3.1 *Foreign Material, Including Glass Splatters* — 0.005" (0.130 mm) maximum in the plane of the metallization or greater than 0.001" (0.025 mm) in height with no more than three sites allowed and a minimum separation of 0.030" (0.763 mm) between sites.

9.3.2 *Metallization Nodules* — No more than three allowed. If the metallization is gold and gold-silicon eutectic die attach is to be used, the bumps may not exceed 0.010" (0.254 mm) in the surface dimension or 0.005" (0.130 mm) in height. If silver glass or resin bonding is to be used, the nodules shall be treated as foreign material per Section 9.3

9.4 *Leadframe*

NOTE 6: The criteria described in this section generally apply to leadframe inspection for purchased sub-assemblies. Where appropriate, the criteria may be used for sub-assemblies manufactured in-house with purchased components. For information on the criteria for leadframes purchased separately, see SEMI G2.

9.4.1 *Lead Bond Areas* — The minimum lead bond area on the lead tip is defined in Figure 4.

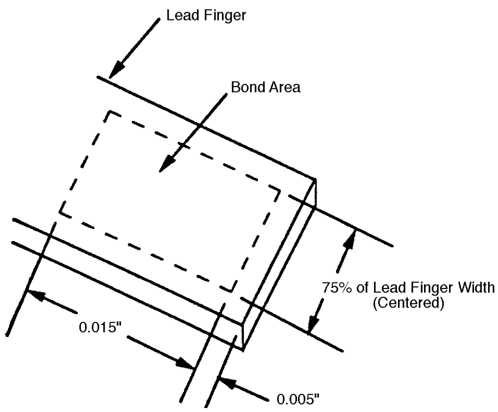


Figure 4

9.4.1.1 *Voids or Pits* — Exposure of base metal with any dimension greater than 0.001" (0.025 mm).

9.4.1.2 *Discoloration, Blistering, or Peeling of the Metallization*

9.4.1.3 *Scratches or Scrapes* — Any build-up of metallization or exposure of base metal.

9.4.1.4 *Foreign Material, Including Glass Splatter or Projections* — No more than three sites, each with a maximum dimension in any plane of 0.001" (0.025 mm).

9.4.1.5 *Glass Wetting or Cracking* — For purchased sub-assemblies, any lead finger which is not firmly embedded in the glass.

9.4.1.6 *Glass Pullback from the Lead Tip* — 0.010" (0.254 mm) maximum.

9.4.1.7 *Glass Bulge between Lead Fingers (Purchased or In-House Sub-Assemblies)* — 0.005" (0.127 mm) height above the fingers except as agreed upon between user and supplier for narrow pitch leads where this limit may cause wire bond interference problems.

9.4.1.8 *Lead Tip Coplanarity* — 0.006" (0.15 mm) maximum allowable difference in the position of the top surface of the lead from highest lead to lowest lead.

9.4.1.9 *Lead Tip Pitch* — ± 0.002" (0.508 mm) maximum allowable variation from true position.

9.4.2 *Internal Lead Areas, Excluding Lead Bond Areas*

9.4.2.1 *Burrs, Projections, and Pits* — 0.002" (0.508 mm) maximum allowable depth or height.

9.4.2.2 *Foreign Material, Including Plating Discoloration* — 0.015" (0.381 mm) maximum surface dimension or exceeding 0.002" (0.508 mm) in height.

9.4.2.3 *Voids* — Any exposure of base metal with a major dimension greater than 0.002" (0.508 mm).

9.4.2.4 *Blistering or Peeling of Metallization*

9.4.2.5 *Scratches and Scrapes* — Any build-up of metallization or exposure of base metal.

9.4.3 *External Lead Areas — Unplated*

NOTE 7: Non-functional areas of the leadframe, such as tie bars, shall not be subjected to inspection unless they interfere with handling equipment.

9.4.3.1 *Scratches* — Any scratch causing a loss of more than 25% of the leadframe thickness.

9.4.3.2 *Voids* — Any void which violates the criteria of Section 9.4.3.1 or causes a loss of more than 10% of the design width of a leadframe detail.

9.4.3.3 *Burrs* — In excess of 0.002" (0.051 mm) in height and 0.005" (0.127 mm) in the major dimension.

9.4.4 *External Leads — Plated*

NOTE 8: Non-functional areas of the leadframe, such as tie bars, shall not be subjected to inspection unless they interfere with handling equipment.

9.4.4.1 *Scratches* — Any scratch causing a loss of more than 25% of the leadframe thickness.

9.4.4.2 *Voids* — Any void which violates the criteria of Section 9.4.3.1 or causes a loss of more than 10% of the design width of leadframe detail.

9.4.4.3 *Burrs* — In excess of 0.002" (0.051 mm) in height and 0.005" (0.127 mm) in the major dimension.

9.4.4.4 *Scratches and Scrapes* — Any exposure of the base metal or loss of plating integrity over more than 5% of a lead finger.

9.4.4.5 *Voids* — Any exposure of base metal.

9.4.4.6 *Blistering or Peeling*

9.4.5 *Leadframe/Base/Window Assembly*

9.4.5.1 *Lead Tip Overhang* — 0.010" (0.254 mm) maximum from the cavity wall (see Figure 5).

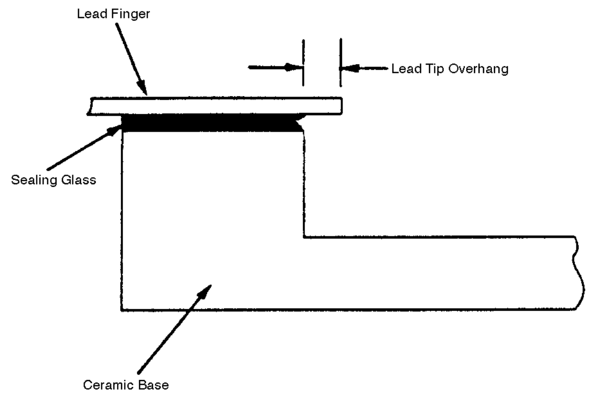
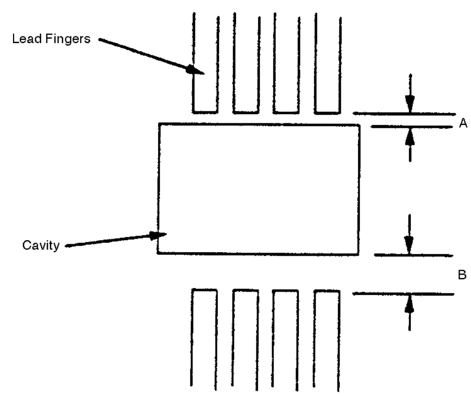


Figure 5

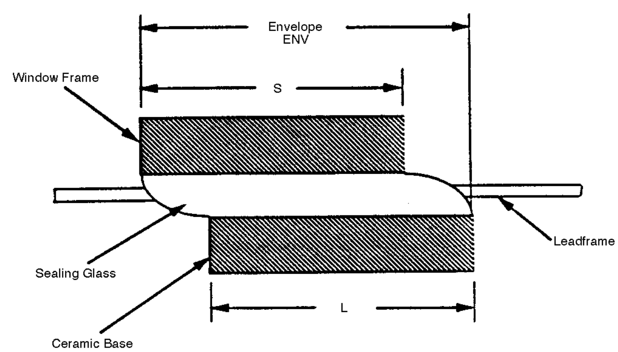
9.4.5.2 *Lead Misalignment to Ceramic Base* — 0.010" (0.254 mm) maximum (see Figure 6).



$\frac{A - B}{2} \leq 0.010"$

Figure 6

9.4.5.3 *Window Assembly Misalignment* — 0.015" (0.358 mm) maximum (see Figure 7).



$ENV - L + \frac{L - S}{2} \leq 0.015"$

Figure 7

9.4.6 *Die-Attach Pad (Leadframe)*

9.4.6.1 Flatness across the pad and parallelism to the base and window shall be agreed upon between user and supplier.

9.4.6.2 *Voids or Pits* — Exposure of base metal with any dimension greater than 0.001" (0.025 mm).

9.4.6.3 *Discoloration, Blistering, or Peeling of the Metallization*

9.4.6.4 *Scratches or Scrapes* — Any build-up of metallization or exposure of base metal.

9.4.6.5 *Foreign Material, Including Glass Splatter or Projections* — No more than three sites, each with a maximum dimension in any plane of 0.001" (0.025 mm).

9.4.7 *Mechanical Damage — Leads*

9.4.7.1 *Broken, Kinked, or Missing Leads*

9.4.7.2 *Twist* — Any lead twisted by more than 10° from the untwisted condition.

9.4.7.3 *Bottom-Formed Width* — Any sub-assembly with the bottom-formed width of the leadframe exceeding ± 0.010" (0.254 mm).

9.4.7.4 *Top-Formed Width* — Any sub-assembly with the top-formed width of the leadframe exceeding ± 0.010" (0.254 mm).

10 Incoming Inspection and Functional Tests

10.1 *Incoming Inspection*

10.1.1 Dimensional Inspection per Section 7.

10.1.2 Visual inspection per Section 9 at 10× magnification with vertical lighting.

10.1.3 *Metallization*

10.1.3.1 *Die-Attach Metallization* — Thickness shall be measured by standard cross-sectioning without smearing or by X-ray fluorescence.

10.1.3.2 *Lead Bond Metallization* — Thickness shall be measured by X-ray fluorescence.

10.1.3.3 *External Lead Plating (If Applicable)* — Thickness shall be measured by X-ray fluorescence.

10.1.4 *Lead Solderability (If Applicable)* — Tested in accordance with MIL-STD-883, Method 2003.

10.2 *Functional Testing*

NOTE 9: All procedures to functionally test the components or sub-assemblies shall be agreed upon between user and supplier.

The sequence of functional testing (and subsequent environmental testing) shall be as shown in Figure 8.

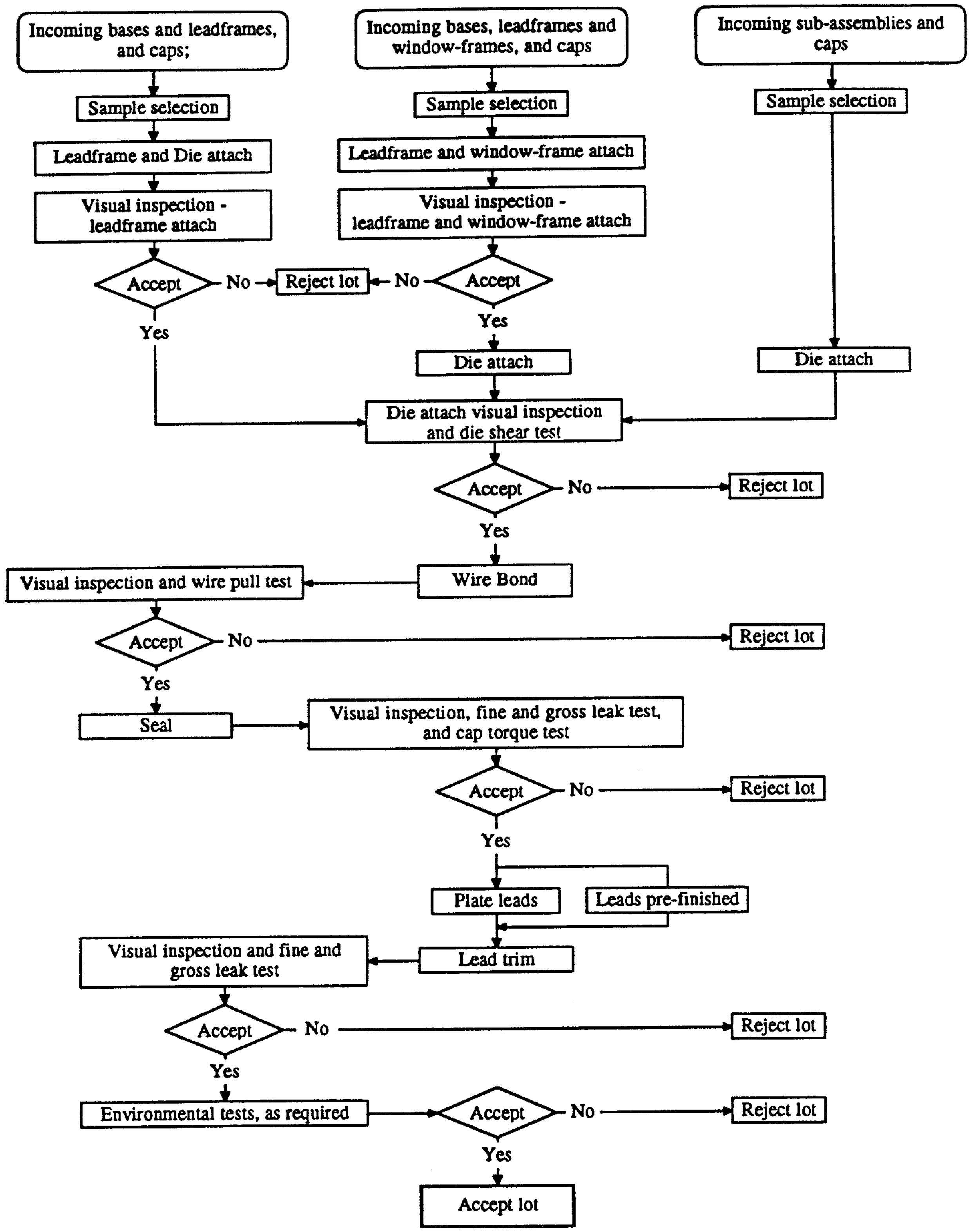

Incoming bases and leadframes, and caps;
Incoming bases, leadframes and window-frames, and caps
Incoming sub-assemblies and caps
Sample selection
Sample selection
Sample selection
Leadframe and Die attach
Leadframe and window-frame attach
Visual inspection - leadframe attach
Visual inspection - leadframe and window-frame attach
Accept
No
Reject lot
No
Accept
Yes
Yes
Die attach
Die attach
Die attach visual inspection and die shear test
Accept
No
Reject lot
Yes
Visual inspection and wire pull test
Wire Bond
Accept
No
Reject lot
Yes
Seal
Visual inspection, fine and gross leak test, and cap torque test
Accept
No
Reject lot
Yes
Plate leads
Leads pre-finished
Visual inspection and fine and gross leak test
Lead trim
Accept
No
Reject lot
Yes
Environmental tests, as required
Accept
No
Reject lot
Yes
Accept lot

Figure 8

10.2.1 *Die Attach*

10.2.1.1 *Visual Inspection*

- Eutectic Bonding — Visually inspect the alloy wet-out after die attach. The minimum wet out requirement shall be 100% of the die perimeter.
- Silver Glass or Resin Bonding — 100% die perimeter coverage shall be required.

NOTE 10: 100% coverage for silver glass or resin bonding is not a function of base acceptability but is required to standardize die shear testing. The inability of the resins to wet the surface of the die attach area due to contamination is cause for rejection.

10.2.1.2 *Die Shear Test* — Perform destructive testing in accordance with MIL-STD-883, Method 2019.

NOTE 11: Test may also be performed after environmental testing. In the case of very large die, this test may not be appropriate to fully evaluate the package. In these cases, die sizes agreed upon between user and supplier shall be used. Alternatively, die pull testing may be used by agreement between user and supplier. Inspection for die attach voids may be performed radiographically in accordance with Section 10.2.1.3 in order to ensure that the die attach process does not contribute to an incorrect evaluation of the shear or pull test results. In the case of eutectic die attach, the results from these methods may also be indicative of poor functionality of the gold die-attach metallization.

10.2.1.3 *Void Inspection* — Inspection for die-attach voids may be performed radiographically in accordance with MIL-STD-883. Method 2012 or ultrasonically in accordance with MIL-STD 883, Method 2030.

10.2.2 *Wire Bond* — On wire bonds which meet the requirements of MIL-STD-883, Method 2010, perform destructive pull testing in accordance with MIL-STD-883, Method 2011, Test Condition D.

NOTE 12: Bonds which cause lifted metallization from the lead fingers shall also be cause for rejection.

NOTE 13: This test may be performed at pre seal and post-seal.

10.2.3 *Seal*

10.2.3.1 *Visual Inspection* — The glass sealant appearance and flow shall be visually inspected for conformance to criteria agreed upon between user and supplier.

10.2.3.2 *Hermeticity* — Performed in accordance with MIL-STD-883, Method 1014, Test Condition A or B and C, the package must maintain hermetic integrity after each environmental test or sequence of tests.

NOTE 14: Internal water-vapor content may also be measured in accordance with MIL-STD-883, Method 1018.

10.2.3.3 *Cap Torque Test* — The failure criteria shall be agreed upon between user and supplier.

10.2.4 *Lead Finish* — Plate according to a process agreed upon between user and supplier.

10.2.5 *Lead Trim*

10.3 *Environmental Testing* — Environmental evaluation shall include, but not be limited to, the following tests:

NOTE 15: The sequence of testing and the sample sizes for each sub-group shall be agreed upon between user and supplier.

10.3.1 *Temperature Cycle* — In accordance with MIL-STD-883, Method 1010, Condition C.

10.3.2 *Thermal Shock* — Per MIL-STD-883, Method 1011, Condition B.

10.3.3 *Vibration Fatigue* — In accordance with MIL-STD-883, Method 2005, Test Condition B.

10.3.4 *Mechanical Shock* — In accordance with MIL-STD-883, Method 2002, Test Condition B.

10.3.5 *Constant Acceleration* — In accordance with MIL-STD-883, Method 2001, Test Condition A.

10.3.6 *Moisture Resistance* — In accordance with MIL-STD-883, Method 1004.

10.3.7 *Additional Testing* — Additional tests performed during package qualification may include evaluation of electrical and thermal characteristics, corrosion resistance and alpha particle emissions. These tests may be performed on a periodic basis to maintain package qualification. These tests may include, but are not limited to, the following:

10.3.7.1 *Insulation Resistance* — In accordance with MIL-STD-883, Method 1003, to test conditions agreed upon between user and supplier.

10.3.7.2 *Lead Inductance* — In accordance with SEMI G23 or using an impedance analyzer by a method agreed upon between user and supplier.

10.3.7.3 *Lead-to-Lead Capacitance* — Per SEMI G24.

10.3.7.4 *Lead Resistance* — Per SEMI G25.

10.3.7.5 *Junction-to-Case Thermal Resistance* — In accordance with SEMI G30 or a wind tunnel method agreed upon between user and supplier.

10.3.7.6 Alpha particle emission shall be tested by a method and to limits agreed upon between user and supplier.

10.3.7.7 *Salt Atmosphere (Corrosion) Testing* — In accordance with MIL-STD-883, Method 1009, 10.3.7.8 Condition A shall be performed to conditions agreed upon between user and supplier.

11 Sampling

The sampling plan used at incoming inspection shall be based on MIL-STD-105 and agreed upon between user and supplier (see Figure 8).

12 Packaging, Marking, and Packing List

12.1 *Packaging* — The shipping containers and materials shall be suitably designed to provide the components or sub-assemblies with protection against normal transportation damage risks which include crushing, spillage, and exposure to moisture and other corrosive gases.

The inner packaging materials must not cause particulate contamination of the components or sub-assemblies and shall be cleanroom compatible as defined by the user. The components or sub-assemblies, in packing trays, shall be vacuum-sealed in a bag with a desiccant.

12.2 *Marking*

12.2.1 *Internal Packages* — Each internal package shall be clearly marked with the following information, as appropriate:

- User's part number,
- User's purchase order number,
- Drawing number (user's and/or supplier's, as requested by user),
- Quantity, and
- Date of manufacture.

The package shall also contain any agreed upon certification data.

12.2.2 *External Packages* — The packing list on the outside of the external package shall contain the following information:

- User's part number,
- User's purchase order number,
- Quantity,
- Shipping date, and
- Any specific instructions for receiving dock personnel.

13 Certification

13.1 Upon request of the user in the contract or purchase order, a supplier's certification that the product was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment. However, if the user does perform inspection and test on a certified shipment, and the product fails to meet the requirements, the product shall be subject to rejection.

13.2 If the user and supplier agree, the product may be certified as capable of meeting this specification. In this context, capable of meeting signifies that the supplier is not required to perform all the inspections and tests. However, if the user does perform inspection and test on a certified shipment, and the product fails to meet the requirements, the product shall be subject to rejection.

APPENDIX 1
CERAMIC CERDIP BASE DIMENSIONS AND TOLERANCE REQUIREMENTS — STANDARD OUTLINES

Table 2 Ceramic Cerdip Base Dimensions and Tolerance Requirements

Lead Count	*Min. Length*	*Max. Length*	*Min. Width*	*Max. Width*	*Min. Cavity Length*	*Max. Cavity Length*	*Min. Cavity Length*	*Max. Cavity Length*	*Units*
8	0.380	0.400	0.248	0.288	0.140	0.220	0.120	0.380	in
	9.65	10.16	6.29	7.31	3.55	5.58	3.04	9.65	mm
14	0.760	0.750	0.248	0.288	0.140	0.250	0.110	0.150	in
	19.30	19.30	6.29	7.31	3.55	6.35	2.79	3.81	mm
16	0.760	0.760	0.248	0.288	0.140	0.400	0.110	0.193	in
	19.30	19.30	6.28	7.31	3.55	10.16	2.79	4.90	mm
18	0.890	0.890	0.268	0.288	0.140	0.400	0.110	0.193	in
	22.60	22.60	6.80	7.31	3.55	10.16	2.79	4.90	mm
20	0.950	0.970	0.268	0.288	0.250	0.330	0.140	0.193	in
	24.13	24.63	6.80	7.31	6.35	8.38	3.55	4.90	mm
22	1.070	1.070	0.288	0.380	0.200	0.410	0.170	0.230	in
	27.17	27.17	7.31	9.65	5.08	10.41	4.31	5.84	mm
24	1.193	1.250	0.275	0.577	0.198	0.440	0.130	0.380	in
	30.30	31.75	6.98	14.65	5.02	11.17	3.30	9.65	mm
28	1.450	1.450	0.520	0.577	0.250	0.500	0.170	0.340	in
	36.83	36.83	13.20	14.65	6.35	12.70	4.31	8.63	mm
32	1.650	1.650	0.577	0.577	0.370	0.710	0.325	0.380	in
	41.91	41.91	14.65	14.65	9.39	18.03	8.25	9.65	mm
40	2.050	2.050	0.520	0.577	0.260	0.800	0.250	0.415	in
	52.07	52.07	13.20	14.65	6.60	20.32	6.35	10.54	mm
48	2.450	2.450	0.588	0.588	0.250	0.300	0.250	0.300	in
	62.23	62.23	14.93	14.93	6.35	7.62	6.35	7.62	mm

NOTE 1: All categories in above table are min./max. tolerance requirements. In normal manufacturing specifications, tolerances and ± 1%.

NOTE 2: Ceramic body thickness range is 0.075 – 0.080 inches (1.88 - 2.03 mm).

NOTE 3: Cavity depth to be agreed upon between purchaser and supplier.

Table 3 Package Styles

Package Designation	*Definition*
LSI	Large scale integration
MSI	Medium scale integration
SD	Small (skinny) dual-in-line package
SSI	Small scale integration
SLSI	Super large scale integration
VLSI	Very large scale integration

APPENDIX 2
CERAMIC CERDIP CAP DIMENSIONS AND TOLERANCE REQUIREMENTS — STANDARD OUTLINES

Table 4 Ceramic Cerdip Cap Dimensions and Tolerance Requirements

Description	*Body Length*	*Body Width*	*Thickness Min. Max.*	*Cavity Length*	*Cavity Width*	*Cavity Depth (Measured at Cavity Bottom)*	*Units*
8SSI	0.380 ± 0.004	0.248 ± 0.003	0.050 - 0.055	0.260 ± 0.004	0.157 ± 0.003	0.018 ± 0.003	in
	9.65 ± 0.102	6.30 ± 0.076	1.27 - 1.40	6.60 ± 0.102	6.60 ± 0.102	3.99 ± 0.076	mm
8LSI	0.380 ± 0.004	0.288 ± 0.003	0.050 - 0.055	0.260 ± 0.004	0.185 ± 0.003	0.018 ± 0.003	in
	9.65 ± 0.012	7.32 ± 0.076	1.27 - 1.40	6.60 ± 0.102	4.70 ± 0.076	0.457 ± 0.076	mm
14/16SSI	0.760 ± 0.007	0.248 ± 0.004	0.050 - 0.055	0.350 ± 0.004	0.157 ± 0.003	0.018 ± 0.003	in
	19.30 ± 0.178	6.81 ± 0.076	1.27 - 1.40	8.89 ± 0.102	4.32 ± 0.076	0.457 ± 0.076	mm
16SLI/VLSI	0.760 ± 0.007	0.288 ± 0.003	0.050 - 0.055	0.450 ± 0.005	0.195 ± 0.003	0.018 ± 0.003	in
	19.30 ± 0.178	7.32 ± 0.076	1.27 - 1.40	10.67 ± 0.127	4.95 ± 0.076	0.457 ± 0.076	mm
18MSI	0.890 ± 0.008	0.268 ± 0.003	0.050 - 0.055	0.350 ± 0.004	0.170 ± 0.003	0.018 ± 0.003	in
	22.61 ± 0.203	6.81 ± 0.076	1.27 - 1.40	8.89 ± 0.102	4.32 ± 0.076	0.457 ± 0.076	mm
18LSI	0.890 ± 0.008	0.288 ± 0.003	0.050 - 0.055	0.350 ± 0.004	0.185 ± 0.003	0.018 ± 0.003	in
	22.61 ± 0.203	7.32 ± 0.076	1.27 - 1.40	8.89 ± 0.102	4.70 ± 0.076	0.457 ± 0.076	mm
18VLSI	0.890 ± 0.008	0.288 ± 0.003	0.050 - 0.055	0.420 ± 0.004	0.195 ± 0.003	0.018 ± 0.003	in
	22.61 ± 0.203	7.32 ± 0.076	1.27 - 1.40	10.67 ± 0.102	4.95 ± 0.076	0.457 ± 0.076	mm
20MSI	0.950 ± 0.010	0.268 ± 0.003	0.050 ± 0.055	0.300 ± 0.004	0.170 ± 0.003	0.018 ± 0.003	in
	24.13 ± 0.254	6.81 ± 0.076	1.27 - 1.40	7.62 ± 0.102	4.32 ± 0.076	4.57 ± 0.076	mm
20LSI/VLSI	0.950 ± 0.010	0.288 ± 0.003	0.050 - 0.055	0.380 ± 0.004	0.190 ± 0.003	0.018 ± 0.003	in
	24.13 ± 0.254	7.32 ± 0.076	1.27 - 1.40	9.65 ± 0.102	4.83 ± 0.076	0.457 ± 0.076	mm
22MSI/LSI/VLSI	1.070 ± 0.010	0.380 ± 0.004	0.050 - 0.055	0.370 ± 0.005	0.275 ± 0.004	0.018 ± 0.003	in
	27.17 ± 0.254	9.65 ± 0.102	1.27 - 1.40	9.40 ± 0.127	6.99 ± 0.102	0.457 ± 0.076	mm
24MSI/LSI	1.250 ± 0.010	0.520 ± 0.006	0.050 - 0.055	0.400 ± 0.005	0.330 ± 0.005	0.018 ± 0.003	in
	31.75 ± 0.254	13.21 ± 0.152	1.27 - 1.40	10.16 ± 0.127	8.38 ± 0.127	0.457 ± 0.076	mm
24VLSI	1.250 ± 0.010	0.577 ± 0.006	0.050 - 0.056	0.560 ± 0.006	0.380 ± 0.005	0.018 ± 0.003	in
	31.75 ± 0.254	14.65 ± 0.152	1.27 - 1.42	14.22 ± 0.152	9.65 ± 0.127	0.457 ± 0.076	mm
24SD3S	1.250 ± 0.010	0.288 ± 0.003	0.050 - 0.055	0.350 ± 0.004	0.190 ± 0.003	0.018 ± 0.003	in
	31.75 ± 0.254	7.32 ± 0.076	1.27 - 1.40	8.89 ± 0.102	4.83 ± 0.076	0.457 ± 0.076	mm
24SD3M	1.250 ± 0.010	0.288 ± 0.003	0.050 - 0.055	0.490 ± 0.005	0.195 ± 0.003	0.018 ± 0.003	in
	31.75 ± 0.254	7.32 ± 0.076	1.27 - 1.40	12.45 ± 0.127	4.95 ± 0.076	0.457 ± 0.076	mm
24SD4M	1.250 ± 0.010	0.380 ± 0.004	0.050 - 0.055	0.235 ± 0.004	0.235 ± 0.004	0.018 ± 0.003	in
	31.75 ± 0.254	9.65 ± 0.102	1.27 - 1.40	5.97 ± 0.102	5.97 ± 0.102	0.457 ± 0.076	mm
28MSI/LSI	1.450 ± 0.010	0.520 ± 0.006	0.050 - 0.055	0.400 ± 0.005	0.330 ± 0.005	0.018 ± 0.003	in
	36.83 ± 0.254	13.21 ± 0.152	1.27 - 1.40	10.16 ± 0.127	8.38 ± 0.127	0.457 ± 0.076	mm
28VLSI	1.450 ± 0.010	0.577 ± 0.006	0.050 - 0.056	0.560 ± 0.005	0.380 ± 0.005	0.018 ± 0.003	in
	36.83 ± 0.254	14.65 ± 0.152	1.27 - 1.42	14.22 ± 0.127	9.65 ± 0.127	0.457 ± 0.076	mm
40 MSI/LSI	2.050 ± 0.012	0.520 ± 0.006	0.050 - 0.055	0.475 ± 0.005	0.365 ± 0.005	0.018 ± 0.003	in
	52.07 ± 0.305	13.21 ± 0.152	1.27 - 1.40	12.07 ± 0.127	9.27 ± 0.127	0.457 ± 0.076	mm
48MSI	2.450 ± 0.015	0.577 ± 0.006	0.050 - 0.056	0.400 ± 0.005	0.400 ± 0.005	0.018 ± 0.003	in
	14.65 ± 0.152	14.65 ± 0.152	1.27 - 1.42	10.16 ± 0.127	10.16 ± 0.127	0.457 ± 0.076	mm

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G2-94
SPECIFICATION FOR METALLIC LEADFRAMES FOR CER-DIP PACKAGES

1 Preface

1.1 *Purpose* — This specification defines the materials and dimensions for the metallic leadframe (stamped or etched) used in the construction of Cer-DIP Package.

1.2 *Scope* — The criteria detailed in this document applies to the iron-nickel leadframe (MIL-M-38510 Type A or Type B) used in Cer-DIP packages.

1.3 *Units* — U.S. Customary (inch-pound) or metric (SI) units may be used at the customer's discretion. This specification uses the U.S. Customary units as the prime unit.

2 Referenced Documents[1]

2.1 This document specifically refers to:

MIL-I-23011 — Iron/Nickel Alloys for Sealing to Glasses and Ceramics

MIL-M-38510 — General Specifications for Microcircuits

MIL-STD-883 — Test Methods and Procedures for Microelectronics

2.2 Related information may also be found in:

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

3 Terminology

bonding area — Coined area on bond fingers within a distance of 0.762 mm (0.030") from lead tips.

bottom formed width — See Figure 3.

bow — Curvature of the leadframe strip in the vertical plane; see Figure 1.

burr — Fragment of excess parent material attached to the leadframe edges.

camber — Curvature of the leadframe strip edge in the horizontal plane; see Figure 2.

coined area — The area of the bond fingers planished to produce a flattened area for functional use; see Figure 3.

coplanarity — The total indicator reading difference of the lead tips in the Z direction.

datum plane — M is datum plane; see Figure 3.

discoloration — A darkening or staining of the aluminum (metallization).

foreign material — Any adhering residue which is not part of the leadframe composition.

pit — A shallow surface depression or crater with a visible edge.

planarity — Total indicator reading of the lead tips in the Z direction relative to datum M.

projection — A raised portion of the surface indigenous with the parent material, other than a burr.

slug marks — Random dents in the leadframe.

stamped leadframe terminology — See Figure 3.

tilt — The deviation of the plane of the coined area from a condition parallel to the plane on datum M.

top formed width — See Figure 3.

twist — The angular rotation of one end of the leadframe or strip with reference to the other end; see Figure 4.

void — An absence of aluminization from a designated area of the leadframe.

4 Ordering Information

Purchase order for Cer-DIP metallic leadframes furnished to this specification shall include the following items:

4.1 Current drawing of the leadframe showing all dimensions and tolerances, including the location of the metallization layer.

4.2 Material,

4.3 Number of leads,

4.4 Material tensile strength,

4.5 Metallization thickness and type,

4.6 Form of leadframes (i.e., singles, scored strips, or unscored strips),

4.7 Number of frames per strip; as applicable,

4.8 Material certification,

4.9 Packaging and marking.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

5 Dimensions

All Dimensioning and tolerancing shall conform to Y14.5. Table 1 presents standard leadframe dimensions.

6 Materials

6.1 *Leadframe Base Material* — Tensile strength shall be specified per MIL-I-23011.

6.1.1 *Chemical Composition* — Shall conform to the requirements of MIL-M-385l0, Type A or B.

6.1.2 *Material Tensile Strength* — Shall be supplied per MIL-I-23011.

6.2 *Metallization* — Aluminum

6.2.1 *Thickness* — 100 microinches minimum, 600 microinches maximum (micromin, micromaximum).

6.2.2 *Coverage* — 0.030" (0.762 mm) minimum; measured from lead tip. Maximum to be determined by ceramic size.

6.2.3 *Composition*

6.2.3.1 *Clad Material* — 99.4% minimum aluminum.

6.2.3.2 *Vapor Deposition* — 99.9% minimum aluminum.

NOTE: The two types of aluminum may exhibit different visual appearances and non-functional characteristics after processing.

7 Defect Limits

7.1 *Burrs*

7.1.1 *Horizontal*

7.1.1.1 *Bonding Area* — 0.001" (0.025 mm) max.

7.1.1.2 *Other Areas* — 0.002" (0.051 mm) max.

7.1.2 *Vertical*

7.1.2.1 *Bonding Area* — 0.001" (0.025 mm) max.

7.1.2.2 *Other Areas* — 0.002" (0.051 mm) max.

7.2 *Planarity/Coplanarity* — Shall not exceed the limits shown in Table 2.

7.3 *Foreign Materials* — Leadframes shall be clean and free from foreign material such as photoresist, lubricants, solvent residue, water marks, and rust spots. Protective coatings acceptable to both vendor and user are not considered foreign material.

7.4 *Pits and Slug Marks*

7.4.1.1 *Bonding Area* — 0.001" (0.025 mm) max. surface dimension × 0.0005" (0.013 mm) maximum depth.

7.4.1.2 *Other Areas* — 0.010" (0.254 mm) max. surface dimension × 0.0005" (0.013 mm) maximum depth.

7.5 *Projections*

7.5.1 *Bonding Area* — None allowed.

7.5.2 *Other Areas* — .010" (.254 mm) max. surface dimension × 0.002" (0.015 mm) maximum height.

7.6 *Scratches* — There shall be no scratches in the aluminum metallization that penetrate to the underlying base material.

7.7 *Voids* — All metallized areas of the leadframe within the bonding area shall have no voids larger than 0.001" (0.025 mm) in any dimension.

7.8 *Twist* (formed leadframe strip) — 0.004 inch per inch (0.102 mm).

7.9 *Coining*

7.9.1 *Coined Depth* — Minimum 0.0005" (0.013 mm); maximum 0.002" (0.051 mm). Minimum coined depth may be controlled by minimum flat area.

7.9.2 *Coined Flat Area* — Minimum of 80% of normal lead width; measured 0.005" (0.127 mm) back from lead tip.

7.9.3 *Coined Length* — Minimum 0.025" (0.635 mm) from lead tip.

7.10 *Lead Position*

7.10.1 *Lead Position* — A 0.007" (0.178 mm) diameter circle must be 100% within nominal lead position when centered at lead nominal centerline and 0.007" (0.178 mm) back from lead tip.

7.10.2 *Minimum Spacing* — 0.006" (0.152 mm) minimum.

7.11 *Bowing*

7.11.1 *Convex* — 0.0025 inch per inch (0.0025 mm per mm) maximum.

7.11.2 *Concave* — 0.0025 inch per inch (0.0025 mm per mm) maximum.

7.12 *Camber* — 0.005 inch per inch (0.005 mm per mm) maximum.

NOTE: Items 7.11 and 7.12 refer to scored strips only.

8 Sampling

Sampling will be determined between vendor and customer.

9 Test Methods

9.1 *Sequence of Events and Tests*

The sequence of testing should be:

9.1.1 Degrease

9.1.2 Metallurgical Bond Adhesion (Section 9.3.1)

9.1.3 Frame Attach

9.1.4 Die Attach

9.1.5 Bond

9.1.6 Pre-Seal Bond Pull (Section 9.3.2)

9.1.7 Seal

9.1.8 Mechanical Testing (Section 9.2)

9.1.9 Lead Trim

9.1.10 Post-Seal Bond Pull (Section 9.3.2)

NOTE: It is acknowledged that the leadframe manufacturer may not perform all these tests due to equipment and component limitations. Regardless, leadframes must fulfill these requirements, subject to the influence of the testing facility and associated components.

9.2 *Mechanical and Thermal*

9.2.1 *Temperature Cycling* — Per MIL-STD-883, Method 1010.4, Condition C.

9.2.2 *Thermal Shock* — Per MIL-STD-883, Method 1011.2, Condition C.

9.2.3 *Centrifuge* — Per MIL-STD-883, Method 2001.2, Condition E.

9.2.4 *Lead Integrity*

9.2.4.1 A 500°C ± 20° - 55% R.H. heat soak for 15 minutes ± 1 minute. Cooled at no more than 50°C per minute. Afterwards the frame is clamped between plates of a suitable size for the lead spacing (see Section 9.2.4.2). Then (3) 90° cycles are performed. Frames are examined at 20× magnification and if cracks are observed at the Apex A (Figure 3), then the frame is rejected.

9.2.4.2 Plate shall be of equivalent plan-form to the ceramic being employed for the particular frame. An edge radius equivalent to 2T, where T is the leadframe thickness, shall be on the contacting surface of the plate.

9.3 *Functional Test Methods*

9.3.1 *Metallurgical Bond Adhesion Aluminization* — The metallurgical bond between the aluminization and the base metal shall permit the leadframe to be heated in air to 525°C ± 10°C for five (5) minutes minimum without evidence of aluminum peeling, blistering, or discoloring when viewed at 20× magnification. (Discoloration must not jeopardize the user's standard part reliability.) Subsequently, the aluminized layer must pass the following two adhesion tests:

9.3.1.1 A cellophane type adhesive tape is firmly applied to the aluminization and removed toward the center of the cavity in a continuous rapid motion. This test is to be performed over the same area three times. No evidence of aluminum separation from the base metal shall be visible at 20× magnification

9.3.1.2 The aluminization shall be capable of passing a functional wirebond test without separating.

9.3.2 *Lead Bond Quality* — Minimum pre-seal and post-seal bond strength test per MIL-STD-883, Method 2011.2, Test Condition D. Applicable failure categories: A-4 and A-6.

10 Packaging and Marking

10.1 *Packaging* — The shipping containers and materials shall be suitably designed to provide the singulated components with protection against normal transportation damage risks which include crushing, abrasion and spillage, and exposure to moisture and other corrosive gases. The inner packing materials must not cause particulate contamination on the components and shall be clean-room compatible as defined by the customer. The components, in packing trays, shall be sealed in a vacuum bag with a dessicant.

10.2 *Packing List*

10.2.1 *Internal Packages* — Each internal package shall be marked as follows:

User Part Number

User Purchase Order Number

Drawing Number (User's and Supplier's, if appropriate)

Supplier Shipping Lot Number

Quantity

Date of Manufacture

10.2.2 *External Packages* — The Packing List, located on the outside of the container, shall provide the following information:

User's Part Number

User's Purchase Order Number

Quantity

Shipping Date

Any specific instructions for receiving dock personnel.

Table 1 Typical Ceramic Cer-DIP Metallic Leadframes Dimension and Tolerance Requirements

Description	*Cavity Length*	*Cavity Width*	*Lead-Formed Width, Top*	*Bond Finger Layout End vs. Side*		*Nominal Progression*	*Unit*
8SSI	-	0.120 ± 0.007	0.311 ± 0.003	0	4	0.945	in
		3.05 ± 0.178	7.90 ± 0.076			24.00	mm
8MSI	-	0.140 ± 0.007	0.311 ± 0.003	0	4	0.945	in
		3.56 ± 0.178	7.90 ± 0.076			24.00	mm
8LSI	-	0.160 ± 0.007	0.311 ± 0.003	0	4	0.945	in
		4.06 ± 0.178	7.90 ± 0.076			24.00	mm
14SSI	0.160 ± 0.007	0.120 ± 0.007	0.311 ± 0.003	4	3	0.945	in
	4.06 ± 0.178	3.05 ± 0.178	7.90 ± 0.076			24.00	mm
14MSI	0.260 ± 0.007	0.140 ± 0.007	0.311 ± 0.003	4	3	0.945	in
	6.60 ± 0.178	3.56 ± 0.178	7.90 ± 0.076			24.00	mm
16SSI	0.160 ± 0.007	0.120 ± 0.007	0.311 ± 0.003	4	4	0.945	in
	4.06 ± 0.178	3.05 ± 0.178	7.90 ± 0.076			24.00	mm
16MSI	0.260 ± 0.007	0.140 ± 0.007	0.311 ± 0.003	4	4	0.945	in
	6.60 ± 0.178	3.56 ± 0.178	7.90 ± 0.076			24.00	mm
16LSI	0.260 ± 0.007	0.170 ± 0.007	0.311 ± 0.003	4	4	0.945	in
	6.60 ± 0.178	4.32 ± 0.178	7.90 ± 0.076			24.00	mm
16SLSI	0.360 ± 0.007	0.170 ± 0.007	0.311 ± 0.003	4	4	0.945	in
	9.14 ± 0.178	4.32 ± 0.178	7.90 ± 0.076			24.00	mm
16VLSI	0.330 ± 0.007	0.180 ± 0.007	0.311 ± 0.003	6	2	0.945	in
	8.38 ± 0.178	4.57 ± 0.178	7.90 ± 0.076			24.00	mm
18MSI	0.260 ± 0.008	0.140 ± 0.008	0.311 ± 0.003	4	5	1.061	in
	6.60 ± 0.203	3.56 ± 0.203	7.90 ± 0.076			26.95	mm
18LSI	0.260 ± 0.008	0.170 ± 0.008	0.311 ± 0.003	6	3	1.061	in
	6.60 ± 0.203	4.32 ± 0.203	7.90 ± 0.076			26.95	mm
18VLSI	0.330 ± 0.008	0.180 ± 0.008	0.311 ± 0.003	6	3	1.061	in
	8.38 ± 0.203	4.57 ± 0.203	7.90 ± 0.076			26.95	mm
20MSI	0.210 ± 0.008	0.140 ± 0.008	0.311 ± 0.003	4	6	1.175	in
	5.33 ± 0.203	3.56 ± 0.203	7.90 ± 0.076			29.85	mm
20LSI	0.260 ± 0.008	0.170 ± 0.008	0.311 ± 0.003	6	4	1.175	in
	6.60 ± 0.203	4.32 ± 0.203	7.90 ± 0.076			29.85	mm
20VLSI	0.330 ± 0.008	0.175 ± 0.008	0.311 ± 0.003	6	4	1.175	in
	8.38 ± 0.203	4.45 ± 0.203	7.90 ± 0.076			29.85	mm
22MSI	0.270 ± 0.010	2.10 ± 0.010	0.411 ± 0.003	6	5	1.250	in
	6.86 ± 0.254	5.33 ± 0.254	10.44 ± 0.076			31.75	mm
22LSI	0.310 ± 0.010	0.240 ± 0.010	0.411 ± 0.003	6	5	1.250	in
	7.87 ± 0.254	6.10 ± 0.254	10.44 ± 0.076			31.75	mm
22VLSI	0.350 ± 0.010	0.260 ± 0.010	0.411 ± 0.003	8	3	1.250	in
	8.89 ± 0.254	6.60 ± 0.254	10.44 ± 0.076			31.75	mm
24MSI	0.260 ± 0.010	0.260 ± 0.010	0.611 ± 0.003	6	6	1.510	in
	8.38 ± 0.254	6.60 ± 0.254	15.01 ± 0.076			38.35	mm
24LSI	0.330 ± 0.010	0.285 ± 0.010	0.611 ± 0.003	6	6	1.510	in
	8.38 ± 0.254	7.24 ± 0.254	15.01 ± 0.076			38.35	mm
24VLSI	0.420 ± 0.010	0.290 ± 0.010	0.611 ± 0.003	6	6	1.510	in
	10.67 ± 0.254	7.37 ± 0.254	15.01 ± 0.076			38.35	mm
24SD3S	0.260 ± 0.010	0.170 ± 0.010	0.311 ± 0.003	6	6	1.510	in
	6.60 ± 0.254	4.32 ± 0.254	7.90 ± 0.076			38.35	mm

Description	*Cavity Length*	*Cavity Width*	*Lead-Formed Width, Top*	*Bond Finger Layout End vs. Side*		*Nominal Progression*	*Unit*
24SD3M	0.430 ± 0.010	0.180 ± 0.010	0.311 ± 0.003	8	4	1.510	in
	10.92 ± 0.254	4.57 ± 0.254	7.90 ± 0.076			38.35	mm
24SD4M	0.210 ± 0.010	0.210 ± 0.010	0.411 ± 0.003	6	6	1.510	in
	5.33 ± 0.254	5.33 ± 0.254	10.44 ± 0.076			38.35	mm
28MSI	0.260 ± 0.011	0.260 ± 0.011	0.611 ± 0.003	8	6	1.724	in
	6.60 ± 0.279	6.60 ± 0.279	15.01 ± 0.076			43.79	mm
28LSI	0.325 ± 0.011	0.275 ± 0.011	0.611 ± 0.003	8	6	1.724	in
	8.26 ± 0.279	6.99 ± 0.279	15.01 ± 0.076			43.79	mm
28VLSI	0.420 ± 0.011	0.280 ± 0.011	0.611 ± 0.003	8	6	1.724	in
	10.67 ± 0.279	7.11 ± 0.279	15.01 ± 0.076			43.79	mm
40MSI	0.270 ± 0.012	0.260 ± 0.012	0.611 ± 0.003	10	10	2.300	in
	6.86 ± 0.305	6.60 ± 0.305	15.01 ± 0.076			58.42	mm
40LSI	0.375 ± 0.012	0.295 ± 0.012	0.611 ± 0.003	12	8	2.300	in
	9.53 ± 0.305	7.49 ± 0.305	15.01 ± 0.076			58.42	mm

NOTE: While a 0.311 top form is still currently being used, numerous users have changed to a 0.314 top form to prevent interference between the Cer-DIP base and leadframe.

Table 2

Leads	*Planarity*		*Coplanarity*
8–14–16	+0.003"/–0.004"	(+ 0.076 mm/–0.102 mm)	0.004" (0.102 mm)
18	+0.004"/–0.005"	(+0.102 mm/–0.127 mm)	0.005" (0.127 mm)
20	+0.004"/–0.005"	(+0.102 mm/–0.127 mm)	0.006" (0.152 mm)
22	+0.004"/–0.006"	(+0.102 mm/–0.152 mm)	0.006" (0.152 mm)
24	+0.004"/–0.006"	(+0.102 mm/–0.152 mm)	0.007" (0.178 mm)
28	+0.005"/–0.007"	(+0.127 mm/–0.178 mm)	0.008" (0.203 mm)
40	+0.006"/–0.008"	(+0.152 mm/–0.203 mm)	0.010" (0.254 mm)

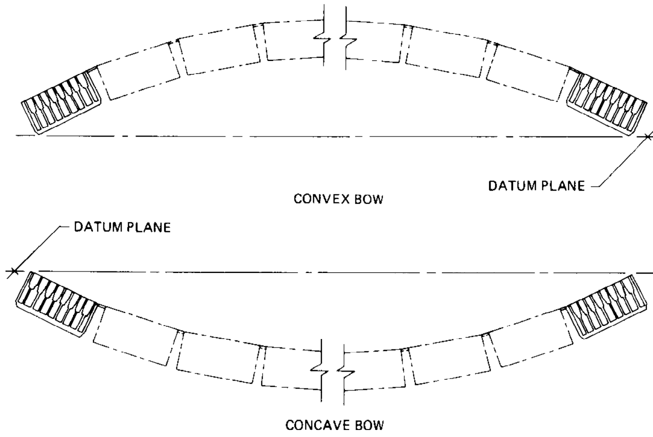

Figure 1
Bow

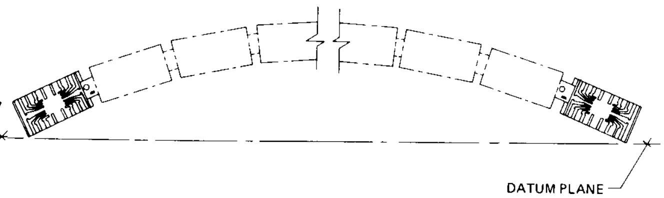

Figure 2
Camber

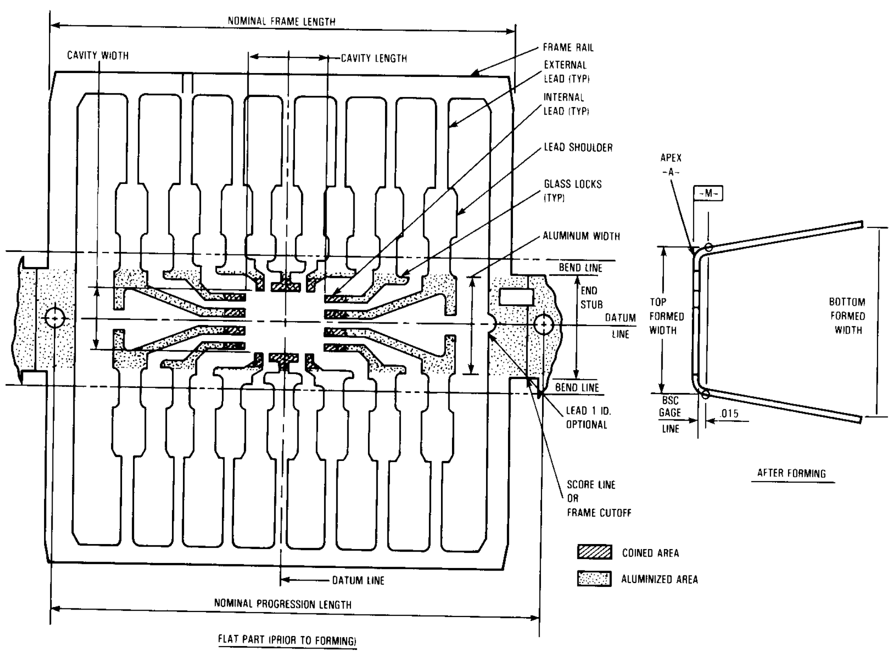

Figure 3
Stamped Leadframe Terminology

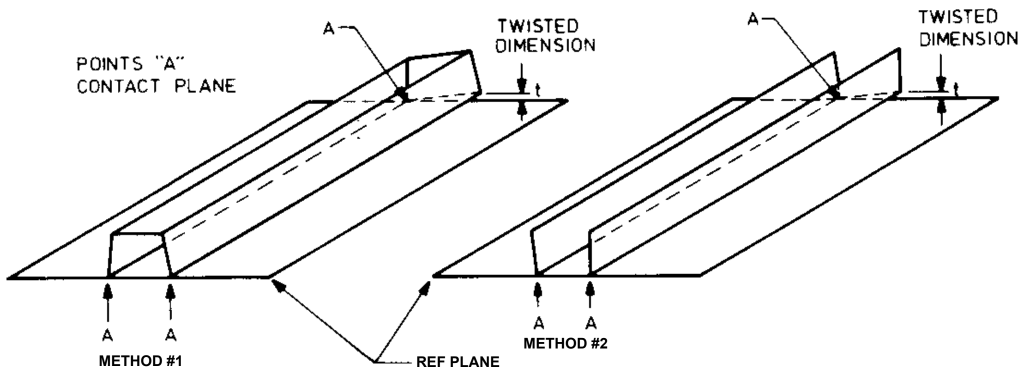

Figure 4
Twist Strip

Using surface plate, establish a reference plane the whole length of the frame strip. Place frame strip, either method 1 or 2, whichever method gives a 3 point contact with reference plane A, using thickness gauges to determine height between reference plane and 4th point noted as t. This measurement will determine frame twist over entire length.

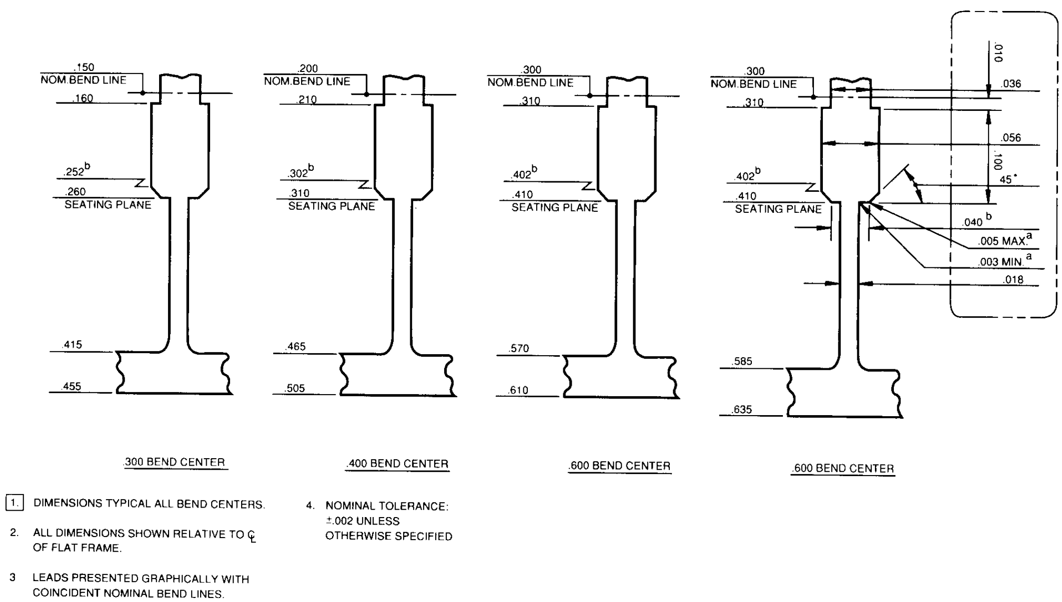

Figure 5
Standoff Lead Length

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SEMI G3-90
SPECIFICATION FOR SIDEBRAZED LAMINATES

1 Preface

This specification covers laminated ceramic sidebrazed packages of 7.62 mm (0.003"), 10.16 mm (0.400"), 15.24 mm (0.600") and 22.86 mm (0.900") nominal widths. The leadframe which is brazed to this type of package is included in this specification.

2 Applicable Documents[1]

2.1 This following applicable documents, of the revision currently in effect, are part of this specification to the extent referenced herein.

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-G-45204 — Gold Plating, Electro-Deposited

MIL-M-38510 — General Specification for Microcircuits

3 Selected Definitions

burr — An adherent fragment of excess parent material at the component edge.

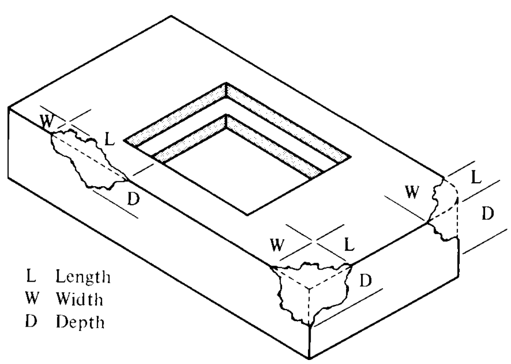
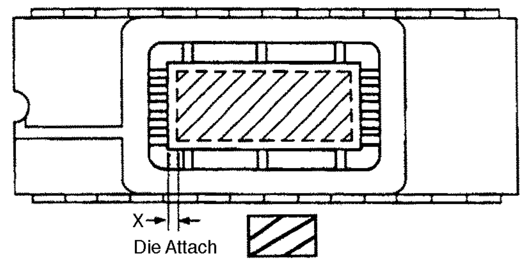


Figure 1
Chip Illustration

chip — A region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width and depth from a projection of the design plan-form. (See Figure 1.)

crack — A cleavage or fracture that extends to the surface of a package. It may or may not pass through the entire thickness of the package.

die attach surface — See Figure 2.



Package Row Spacing			
7.62 mm (.300")	10.16 mm (.400")	15.24 mm (.600")	22.86 mm (.900")
X = .203 mm (.008")	X = .254 mm (.010")	X = .381 mm (.015")	X = .508 mm (.020")

Figure 2
Die Attach Surface

discoloration — Any change in the color of the package plating as detected by the unaided eye after the application of heat per Section 9.1.1.

foreign material — An adherent particle other than parent material of that component.

LSI — Large scale integration.

layer — A ceramic or metallized layer that performs a discrete function as a part of the package. Should a layer be comprised of more than one ceramic laminate, all of those laminates shall be considered as comprising one layer if all are common in both plan-form and function. Leadframes shall not be considered as layers.

MSI — Medium scale integration.

projection — An adherent fragment of excess material on the component surface.

pullback — The linear distance between the edge of the ceramic and the first measurable metallization interface. (See Figure 3.)

rundown — See Figure 3.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

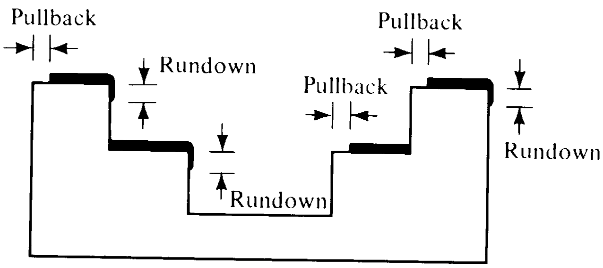


Figure 3
Metallization Misalignment

SSI — Small scale integration.

seal area — A dimensional outline area designated for either metallization or bare ceramic to provide a surface area for sealing. (See Figure 4.)

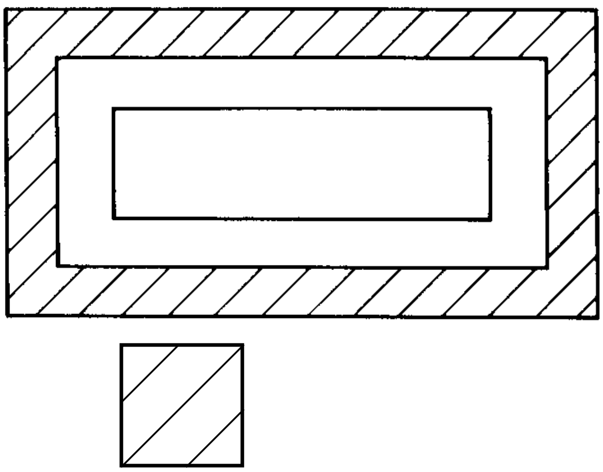
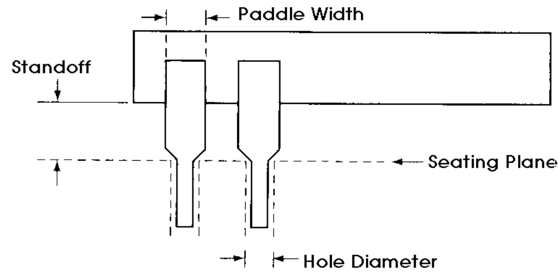


Figure 4
Seal Area

seating plane — See Figure 5.

standoff — Residual air gap after inserting the leads into a ground steel plate with a specific size hole and applying a specified downward pressure. (See Figure 5.)



NOTE: When determining the seating plane a downward of 10 grams is to be applied to the package.

Figure 5
Leadframe Paddle Width and Standoff

TIR — Total indicator reading.

VLSI — Very large scale integration.

void — An absence of metallization or plating from a designated area.

4 Ordering Information

Purchase orders for sidebrazed laminated packages furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Number of leads and lead series spacing
3. Type and color of ceramic
4. Type and thickness of plating
5. Description (See Table 1.)
6. Thickness of individual layers of ceramic
7. Internal finger bonding pattern layout
8. Minimum exposed metallized bond finger length and width
9. Leads common to die attach area and/or seal ring
10. Sealing dimensions and flatness
11. Certification
12. Method of test and measurements (See Section 9.)
13. Lot acceptance procedures (See Section 8.)
14. Packaging and Marking (See Section 10.)

5 Dimensions and Permissible Variations

The dimensions of the sidebraze laminate packages shall conform as specified in Table 1.

6 Materials

6.1 *Ceramic*

6.1.1 Alumina content 90% minimum.

6.1.2 *Color* — Opaque or white.

6.2 *Metallization*

6.2.1 Refractory metallization (provide adequate bond strength to ceramic).

6.2.2 Nickel plating (if designated).

6.2.3 Precious or noble metal plating.

6.2.4 Nickel/gold per MIL-M-38510 except gold plating shall conform to MIL-G-45204, Type III and have a thickness of 60 microinches minimum.

6.3 *Braze Material* — An alloy with a melting point equal to or greater than 750°C which will provide specified bond strength of the lead to the ceramic.

6.4 *Lead Material*

6.4.1 Iron nickel cobalt alloy per MIL-M-38510, Type A.

6.4.2 Iron nickel alloy per MIL-M-38510, Type B.

7 Defect Limits

7.1 *Ceramic*

7.1.1 *Cracks* — None allowed.

7.1.2 *Chips*

7.1.2.1 *Corner* — 0.762 mm (0.030") × 0.762 mm (0.030") × 0.762 mm (0.030") max.

7.1.2.2 *Edge* — 2.54 mm (0.100") × 0.762 mm (0.030") × 0.762 mm (0.030") max. (Chips can not be encroached or exposed any metallized area.)

7.1.2.3 *Seal Area*

7.1.2.3.1 7.62 mm (0.300") and 10.16 mm (0.400") Row Spacing Parts — .762 mm (0.030") × 2.54 mm (0.100")

7.1.2.3.2 *15.24 mm (0.600") Row Spacing Parts* — 1.27 mm (0.050") × 0.381 mm (0.015") × 0.381 mm (0.015") max.

7.1.2.3.3 *22.86 mm (0.900") Rowing Spacing Parts* — 1.52 mm (0.060") × 0.508 mm (0.020") × 0.508 mm (0.020") max.

7.1.2.3.4 Chips cannot reduce the seal width by more than 1/3 of the design width.

7.1.3 *Burrs and Projections*

7.1.3.1 *Top Plane Excluding Seal Area* — 0.102 mm (0.004") max.

7.1.3.2 *Seal Area* — 0.025 mm (0.001") max. above metallization.

7.1.3.3 *Wire Bond Finger Areas* — 0.025 mm (0.001") max. above metallization.

7.1.3.4 *Die Attach Surface* — 0.025 mm (0.001") max. above metallization excluding a 0.203 mm (0.008") perimeter on 7.62 mm (0.300") centerline packages, 0.254 mm (0.010") perimeter on 10.16 mm (0.400") centerline packages and 0.381 mm (0.015") perimeter on 15.24 mm (0.600") centerline packages, 0.508 mm (0.020") perimeter on 22.86 mm (0.900") row center package.

7.1.4 *Camber* — Ceramic-maximum of 0.004 inch/inch (mm/mm).

7.1.5 *Flatness*

7.1.5.1 *Seal Area* — 0.050 mm (0.002") TIR on 7.62 mm (0.300") row center packages, 0.0635 mm (0.0025") TIR on 10.16 mm (0.400") and 15.24 mm (0.600") row center packages.

7.1.5.2 *Die Attach* — Die attach pad to be flat to within 0.051 mm (0.002") TIR to exclude a 0.203 mm (0.008") perimeter on 7.62 mm (0.300") centerline packages, 0.254 mm (0.010") perimeter on 10.16 mm (0.400") centerline packages and 0.381 mm (0.015") perimeter on 15.24 mm (0.600") centerline packages.

7.2 *Metallization*

7.2.1 *Voids*

7.2.1.1 *Seal Area* — On the outer half of the seal area width, maximum of 3 voids no larger than 0.127 mm (0.005") in diameter are permissible. On the inner half, maximum of 3 voids no larger than 0.381 mm (0.015") in diameter or larger than 1/3 of the seal area width, whichever is the smaller. The distance between any 2 voids shall be at least 0.762 mm (0.030").

7.2.1.2 *Wire Bond Fingers* — A 0.254 mm (0.010") × 0.010" (0.254 mm) void free area within the specified wire bond finger area as defined be the procurement drawing.

7.2.1.3 *Die Attach Surface* — Maximum 0.010" (0.254 mm) diameter by a distance greater than 0.030" (0.762 mm) with no more than 3 voids.

7.2.2 *Metallization Misalignment* — See Figure 3.

7.2.2.1 *Seal Plane Rundown* — Internal cavity — not to exceed 25% of the cavity layer thickness. External cavity — not to be less than 0.010" (0.254 mm) outside the cavity.

7.2.2.2 *Wire Bond Finger Pullback* — A 0.010" (0.254 mm) maximum from the cavity edge and the minimum exposed wire bond lead length must meet the dimension on the procurement drawing or specification.

7.2.2.3 *Wire Bond Finger Rundown* — Not to exceed 25% of the ceramic layer thickness or 0.005" (0.127 mm), whichever is the smaller.

7.3 *Lead Attachment*

7.3.1 *Voids in Braze*

7.3.1.1 *Gold Plated Leadframes* — 75% of the braze fillet will be void free.

7.3.1.2 *Nickel or Bare Leadframes* — 75% of the braze fillet will be void free.

7.3.2 *Lead Alignment*

7.3.2.1 *Misalignment Leads to Braze Pads* — The leads shall not overhang the braze pads by more than 25% of the measured paddle width nor reduce the clearance between adjacent pad or lead to less than 50% of the clearance between adjacent metallizations.

7.3.2.2 *Lead Offset* — Lead centerlines must be aligned to within 0.015" (0.381 mm) relative to the position of the leads on the opposite side of the package.

7.3.2.3 *Lead-to-Lead Alignment* — 0.010" ± 0.010" (0.254 mm ± 0.254 mm) measured at the base of the ceramic on the same side.

8 Sampling

Sampling sizes must meet the requirements of MIL-STD-105; although single, double, or multiple samples may be used.

9 Test Methods

9.1 *Mechanical, Electrical and Thermal Test Methods*

9.1.1 *Gold Plating Quality*

9.1.1.1 Purity and adhesion of the gold plated package shall be tested by placing parts on a calibrated heater block at:

Condition A — 450°C ± 10°C for two minutes in air, or

Condition B — 470°C ± 10°C for one minute in nitrogen.

9.1.1.2 After cooling at room temperature the packages will be visually examined for the following criteria:

9.1.1.2.1 Blisters on the leadframe are acceptable only on the tie bar (that portion removed during trim). Blisters on the bonding fingers shall not exceed 0.003" (0.076 mm) diameter with a maximum of 1 blister per finger and 5 blisters per package of any size. Blisters on the seal ring shall not exceed 0.005" (0.127 mm) diameter. Blisters on the die attach pad shall not exceed 0.010" (0.254 mm) diameter with a maximum of 5 blisters per package greater than 0.005" (0.127 mm) diameter.

9.1.1.2.2 Slight discoloration of the gold at the die attach pad edges up to 0.025" (0.635 mm) from the cavity walls is acceptable. Discoloration of the bonding fingers, seal ring surface or external leads is not acceptable.

9.1.1.2.3 There shall be no flaking or peeling of the package plating when viewed at 15× magnification.

9.1.1.2.4 Superficial stains left during drying or prior operations is not cause for rejection.

9.1.2 *Lead Pull* — Four pounds (1.8 kg) minimum at a 45° angle from the lead's original plane.

9.1.3 *Lead Fatigue* — Test per MIL-STD-883, Method 2004.2, Test Condition B2, Section 3.2.

9.1.4 *Thermal Characteristics* — Test per MIL-STD-883, Method 1012, Test Conditions A, B, C, D, and E.

9.2 *Functional Test Methods*

9.2.1 *Die Attach Quality* — Perform destructive die shear test post environmental testing per MIL-STD-883, Method 2019.1, Section 3.2C.

9.2.2 *Wire Bond Quality* — Perform minimum pre-seal and post-seal bond strength test per MIL-STD-883, Method 2011.2, Test Condition D. Reject for bonds which cause plating to lift from the base metal of the die attach surface or bonding fingers.

9.2.3 *Solderability* — Test per MIL-STD-883, Method 2003.2.

9.2.4 *Insulation Resistance* — Test per MIL-STD-883, Method 1003.

9.2.5 *Hermetic and Environmental Testing*

9.2.5.1 The hermetic integrity of the package must be maintained after all environmental testing. Hermetic checks shall comply with MIL-STD-883, Method 1014.3, Test Condition A_1 or B and C.

9.2.5.2 Environmental testing shall include, but not be limited to, the following:

1. *Temperature Cycle* — MIL-STD-883, Method 1010.2 Condition C
2. *Thermal Shock* — MIL-STD-883, Method 1011.2, Condition C

3. *Centrifuge* — MIL-STD-883, Method 2001.2, Condition E
4. *Mechanical Shock* — MIL-STD-883, Method 2002.2, Condition B

9.2.6 *Sequence of Events and Incoming Testing* — During incoming inspection the sequence of testing shall be:

1. Die Attach
2. Wire Bond
3. Pre-Seal Bond Pull
4. Seal
5. Environmental Test
6. Fine Leak
7. Gross Leak
8. Trim
9. Post-Seal Bond Pull
10. Radiography
11. Die Shear
12. Solderability

NOTE: An initial vendor qualification on the thermal and electrical characteristics of the package may be performed. The characteristics tested will be:

1. *Insulation Resistance* — MIL-STD-883, Method 1003, Test Condition D
2. *Thermal Dissipation* — MIL-STD-883, Method 1012

10 Packaging and Marking

10.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents. Containers shall afford protection of the contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component parts with paper fibers or organic particles.

10.2 *Marking* — The outer containers shall be clearly marked to identify the user stock number, user purchase order number, drawing number, quantity, and vendor lot number.

11 Product Design

11.1 *Leadframe Paddle Width and Standoff* — (See Figure 5.)

NOTE: A geometric symbol adjacent to an identifying lead number 1 shall be considered appropriate for packages with all leads isolated from the die attach.

NOTE: Lead number 14 is common to die attach surface and is identified by placing this number where lead number 1 is located.

11.1.1 Leadframe paddle width shall be 1.14 mm (0.045") ± 0.178 mm (0.007").

11.1.2 Standoff shall be 1.02 mm ± 0.254 mm (0.040" ± 0.010").

11.1.3 Hole Diameter shall be 0.032" – 0.033" (0.813 mm – 0.838 mm).

11.2 *Substrate/Terminal Commonality on Sidebrazed Laminate Packages* — If no leads are common to the die attach surface, the lead one identification shall be a geometric symbol (Figure 6).

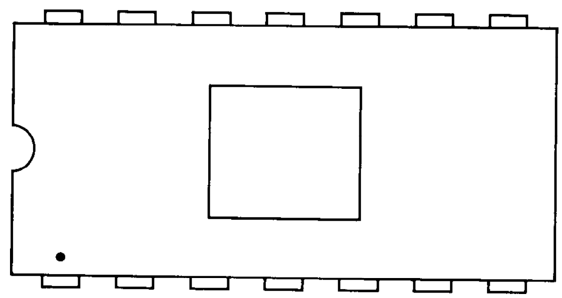


Figure 6
Lead Identification

Layers shall be designated by letter beginning with “A” as that layer nearest terminal insertion plane. Layers, regardless of function, shall be designated by succeeding letters, (B, C, D, etc.) as being progressively remote from the terminal insertion plane.

Should any lead be common to the die attach surface, that lead number will serve both as lead one identificationand as an indicator as to the lead that is common to the die attach surface (Figure 7).

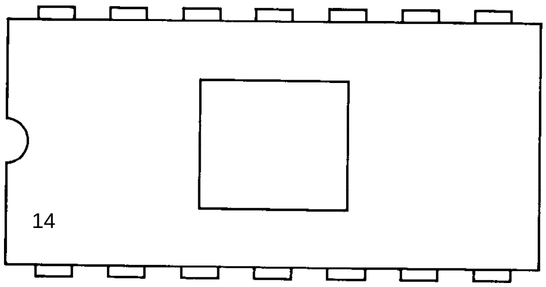


Figure 7
Lead Identification

11.3 *Sidebraze Ceramic Package Layer Design* — (See Figure 8).

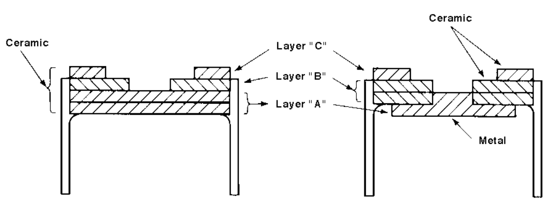


Figure 8
Layer Designation

Table 1 Sidebrazed Laminate Packages Dimensions and Tolerance Requirements

Desription	*Package Length*	*Package Width (Inc. Leadframe)*	*Package Thickness Min. Max.*	*Cavity Length (Measured at Cavity Bottom)*	*Cavity Width (Measured at Cavity Bottom)*	*Units*
8MSI	0.520 ± 0.008	0.310 + 0.010 - 0.015	0.076 – 0.094	0.180 ± 0.005	0.150 ± 0.005	in
	13.21 ± 0.203	7.87 + 0.254 - 0.381	1.93 – 2.39	4.57 ± 0.127	3.81 ± 0.127	mm
8LSI	0.520 ± 0.008	0.310 + 0.010 – 0.015	0.076 - 0.094	0.220 ± 0.005	0.175 ± 0.005	in
	13.21 ± 0.203	7.87 + 0.254 - 0.381	1.93 - 2.39	5.59 ± 0.127	4.45 ± 0.127	mm
8VLSI	0.520 ± 0.008	0.310 + 0.010 – 0.015	0.076 - 0.094	0.260 ± 0.005	0.175 ± 0.005	in
	13.21 ± 0.203	7.87 + 0.254 - 0.381	1.93 - 2.39	6.60 ± 0.127	4.45 ± 0.127	mm
14MSI	0.750 ± 0.010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.180 ± 0.005	0.150 ± 0.005	in
	19.05 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	4.57 ± 0.127	3.81 ± 0.127	mm
14LSI	0.750 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.220 ± 0.006	0.175 ± 0.005	in
	19.05 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	5.59 ± 0.152	4.45 ± 0.127	mm
14VLSI	0.750 ± .010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.260 ± 0.006	0.175 ± 0.005	in
	19.05 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	6.60 ± 0.152	4.45 ± 0.127	mm
16MSI	0.800 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.220 ± 0.006	0.175 ± 0.005	in
	20.32 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	5.59 ± 0.152	4.45 ± 0.127	mm
16LSI	0.800 ± 0.010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.240 ± 0.006	0.175 ± 0.005	in
	20.32 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	6.10 ± 0.152	4.45 ± 0.127	mm
16VLSI	0.800 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.320 ± 0.007	0.175 ± 0.005	in
	20.32 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	8.13 ± 0.178	4.45 ± 0.127	mm
18MSI	0.900 ± 0.010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.220 ± 0.006	0.175 ± 0.005	in
	22.86 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	5.59 ± 0.152	4.45 ± 0.127	mm
18LSI	0.900 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.265 ± 0.006	0.175 ± 0.005	in
	22.86 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	6.73 ± 0.152	4.45 ± 0.127	mm
18VLSI	0.900 ± 0.010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.320 ± 0.007	0.175 ± 0.005	in
	22.86 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	8.13 ± 0.178	4.45 ± 0.127	mm
20MSI	1.000 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.215 ± 0.005	0.175 ± 0.005	in
	24.89 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	5.46 ± 0.127	4.45 ± 0.127	mm
20LSI	1.000 ± 0.010	0.310 + 0.010 – 0.015	0.076 – 0.094	0.265 ± 0.006	0.175 ± 0.005	in
	24.89 ± 0.254	7.87 + 0.254 - 0.381	1.93 – 2.39	6.73 ± 0.152	4.45 ± 0.127	mm
20VLSI	1.000 ± 0.010	0.310 + 0.010 – 0.015	0.076 - 0.094	0.320 ± 0.007	0.175 ± 0.005	in
	24.89 ± 0.254	7.87 + 0.254 - 0.381	1.93 - 2.39	8.13 ± 0.178	4.45 ± 0.127	mm
22MSI	1.08 ± 0.011	0.410 + 0.010 – 0.015	0.076 – 0.094	0.250 ± 0.006	0.220 ± 0.006	in
	27.34 ± 0.279	10.41 + 0.254 - 0.381	1.93 – 2.39	6.35 ± 0.152	5.59 ± 0.152	mm
22LSI	1.08 ± 0.011	0.410 + 0.010 – 0.015	0.076 - 0.094	0.285 ± 0.006	2.20 ± 0.006	in
	27.34 ± 0.279	10.41 + 0.254 - 0.381	1.93 - 2.39	7.24 ± 0.152	5.59 ± 0.152	mm
22VLSI	1.08 ± 0.011	0.410 + 0.010 – 0.015	0.076 – 0.094	0.280 ± 0.006	0.260 ± 0.006	in
	27.34 ± 0.279	10.41 + 0.254 - 0.381	1.93 - 2.39	7.11 ± 0.152	6.60 ± 0.152	mm
24MSI	1.20 ± 0.012	0.610 + 0.010 – 0.015	0.076 - 0.094	0.250 ± 0.006	0.250 ± 0.006	in
	30.48 ± 0.305	15.49 + 0.254 - 0.381	1.93 - 2.39	6.35 ± 0.152	6.35 ± 0.152	mm
24LSI	1.20 ± 0.012	0.610 + 0.010 – 0.015	0.076 – 0.094	0.305 ± 0.010	0.305 ± 0.010	in
	30.48 ± 0.305	15.49 + 0.254 - 0.381	1.93 – 2.39	7.75 ± 0.254	7.75 ± 0.254	mm
24VLSI	1.20 ± 0.012	0.610 + 0.010 – 0.015	0.076 - 0.094	0.340 ± 0.008	0.340 ± 0.008	in
	30.48 ± 0.305	15.49 + 0.254 - 0.381	1.93 - 2.39	8.64 ± 0.203	8.64 ± 0.203	mm
28MSI	1.40 ± 0.014	0.610 + 0.010 – 0.015	0.076 – 0.094	0.250 ± 0.006	0.250 ± 0.006	in
	35.56 ± 0.356	15.49 + 0.254 - 0.381	1.93 – 2.39	6.35 ± 0.152	6.35 ± 0.152	mm
28LSI	1.40 ± 0.014	0.610 + 0.010 – 0.015	0.076 - 0.094	0.305 ± 0.010	0.305 ± 0.010	in

	35.56 ± 0.356	15.49 + 0.254 - 0.381	1.93 - 2.39	7.75 ± 0.254	7.75 ± 0.254	mm
28VLSI	1.40 ± 0.014	0.610 + 0.010 – 0.015	0.076 – 0.094	0.340 ± 0.008	0.340 ± 0.008	in
	35.56 ± 0.356	15.49 + 0.254 - 0.381	1.93 – 2.39	8.64 ± 0.203	8.64 ± 0.203	mm
40MSI	2.00 ± 0.020	0.610 + 0.010 – 0.015	0.076 - 0.094	0.250 ± 0.006	0.250 ± 0.006	in
	50.8 ± 0.508	15.49 + 0.254 - 0.381	1.93 - 2.39	6.35 ± 0.152	6.35 ± 0.152	mm
40LSI	2.00 ± 0.020	0.610 + 0.010 – 0.015	0.076 – 0.094	0.305 ± 0.010	0.305 ± 0.010	in
	50.8 ± 0.508	15.49 + 0.254 - 0.381	1.93 – 2.39	7.75 ± 0.254	7.75 ± 0.254	mm
40VLSI	2.00 ± 0.020	0.610 + 0.010 – 0.015	0.076 - 0.094	0.340 ± 0.008	0.340 ± 0.008	in
	50.8 ± 0.508	15.49 + 0.254 - 0.381	1.93 - 2.39	8.64 ± 0.203	8.64 ± 0.203	mm
48LSI	2.40 ± 0.025	0.610 + 0.010 – 0.015	0.076 – 0.094	0.305 ± 0.010	0.305 ± 0.010	in
	60.96 ± 0.635	15.49 + 0.254 – 0.381	1.93 – 2.39	7.75 ± 0.254	7.75 ± 0.254	mm
48VLSI	2.40 ± 0.025	0.610 + 0.010 - 0.015	0.076 - 0.094	0.340 ± 0.008	0.340 ± 0.008	in
	60.96 ± 0.635	15.49 + 0.254 – 0.381	1.93 - 2.39	8.64 ± 0.203	8.64 ± 0.203	mm

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SEMI G4-0302
SPECIFICATION FOR INTEGRATED CIRCUIT LEADFRAME MATERIALS USED IN THE PRODUCTION OF STAMPED LEADFRAMES

This specification was technically approved by the Gobal Assembly and Packaging Committtee and is the direct responsibility of the Japanese Assembly and Packaging Committee. Current edition approved by the Japanese Regional Standards Committtee on November 26, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1994.

1 Scope

1.1 This specification covers the special requirements for a metal strip to be used to fabricate integrated circuit leadframes by stamping.

2 Applicable Documents

Regional standards such as ANSI/ASTM,CEN, EN ISO, JIS, and MIL.

2.1 *ANSI*[1]*/ASTMStandard*[2]

ASTM B 193 — Test Method for Resistivity of Electrical Conductor Materials

ASTM B 601 — Standard Practice for Temper Designations for Copper and Copper Alloys — Wrought and Cast

ASTM E 8 — Standard Test Methods of Tension Testing of Metallic Materials

ASTM E 228 — Standard Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Delatometer

ASTM E 290 — Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

ASTM E 384 — Test Method for Microhardness of Materials

ASTM E 527 — Practice for Numbering Metals and Alloys (UNS)

2.2 *CES Standard*

CES M0002-5 — Method of W-Bend Test for Metallic Materials

2.3 *EN Standard*

EN 10 002 Part 1 — Metallic Materials, Tensile Testing, Part 1: Method of Testing (at ambient temperature)

EN 133/10 — Copper and Copper Alloys: Plate, Sheet, Strip, and Circles for General Purposes

EN 133/12 — Copper and Copper Alloys: Plate, Sheet, and Circles for Boilers, Pressure Vessels, and Hot Water Storage Units

2.4 *ISO Standard*[3]

ISO 197-3 — Copper and Copper Alloys, Terms, and Definitions, Part 3: Wrought Products

ISO 1190 Part 1 — Copper and Copper Alloys, Code of Designation, Part 1: Designation of Materials

ISO 4287 Part 1 — Surface Roughness, Terminology, Part 1: Surface and Its Parameters Trilingual Edition

ISO 6507 Part 1 — Metallic Materials, Hardness Test, Vickers Test, Part 1: HV 5 to HV 100

ISO 6507 Part 2 — Metallic Materials, Hardness Test, Vickers Test, Part 2: HV 0.2 to less than HV 5.

ISO 7438 — Metallic Materials, Bend Test

2.5 *JIS Standard*[4]

JIS B0601 — Definitions and Designation of Surface Roughness

JIS H0505 — Measuring Methods for Electrical Resistivity and Conductivity of Non-Ferrous Materials

JIS H3100 — Copper and Copper Alloy: Plates, Sheets, Strips

JIS H3110 — Phosphor Bronze and Nickel Silver: Plates, Sheets, Strips

JIS Z2201 — Test Pieces for Tensile Test for Metallic Materials

JIS Z2241 — Method of Tensile Test for Metallic Materials

JIS Z2244 — Method of Vickers Hardness Test

1 ANSI, 1430 Broadway, New York, NY 10018

2 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 ISO, 1 rue de Varembe, Case postale 56, CH01211 Geneva 20, Switzerland

4 JIS, 4-1-24 Akasaka Minato-ku Tokyo, Japan

JIS Z2251 — Method of Micro Hardness Test for Vickers and Knoop Hardness

3 Ordering Information

Orders for material under this specification shall include the following information:

1. Quantity of each size
2. Alloy name and number (see Section 4)
3. Temper or mechanical properties (see Section 4)
4. Dimensions: thickness and width (see Section 5)
5. How furnished: coils and coil size (see Section 10)
6. Special processing requirements
7. Certification or test report requirements (see Section 11).

4 Designations

4.1 Material designations shall be based on appropriate area standards based on country or area of material origin.

4.1.1 Europe ISO 1190 Part 1

4.1.2 Japan JIS H3100, JIS H3110

4.1.3 United States ASTM E 5.27

4.2 Temper designations shall be based on appropriate area standards based on country or area of material origin.

4.2.1 Europe EN133/10 and 133/12

4.2.2 Japan JIS H3100, JIS H 3110

4.2.3 United States ASTM B 601

5 Requirements

5.1 *General Requirements*

5.1.1 The materials covered by this specification shall conform to the requirements detailed herein, unless otherwise agreed upon by supplier and purchaser.

5.2 *Mechanical Properties*

5.2.1 The preferred method of designating mechanical properties of material covered under this specification is tensile strength. In addition to tensile strength, the 0.2% offset yield strength and percent elongation in 50 mm may be required if agreed between supplier and purchaser. The test shall conform to the appropriate area standards based on country or area of material origin.

5.2.1.1 Europe EN10 002 Part 1

5.2.1.2 Japan JIS Z2201, Z2241

5.2.1.3 United States ASTM E8

5.2.2 Should supplier and purchaser agree, microhardness may be used in lieu of tensile strength as the test for mechanical property. The test shall conform to the appropriate area standard based on country or area of material origin.

5.2.2.1 Europe ISO 6507 Part 1 and Part 2

5.2.2.2 Japan JIS Z2251, Z2244 (Test load shall be chosen from Table 1).

5.2.2.3 United States ASTM E 384

Table 1

Thickness of Metal Strip (mm)	*Test Load of Vickers Hardness*
0.100 to 0.160	1.961 N (200 gf)
over 0.160 to 0.500	4.903 N (500 gf)
over 0.500	9.807 N (1 Kgf)

5.3 *Thickness and Width Tolerance*

5.3.1 Thickness tolerance for material covered under this specification shall be chosen from Tables 2 and 3.

Table 2

Thickness	*Tolerance*
0.10 mm to 0.15 mm	± 0.005 mm
over 0.15 mm to 2.0 mm	± 3% of the ordered material thickness

Table 3

Thickness	*Tolerance*
0.10 mm up to 0.15 mm	± 0.005 mm
0.15 mm up to 0.3 mm	± 0.008 mm
0.3 mm up to 0.5 mm	± 0.010 mm
0.5 mm up to 0.8 mm	± 0.013 mm
0.8 mm up to 1.0 mm	± 0.015 mm
1.0 mm up to 1.5 mm	± 0.020 mm
1.5 mm up to 2.0 mm	±0.025 mm

* Table 3 is used in Europe.

5.3.2 Width tolerance shall be as shown in Tables 4 and 5.

Table 4

Width	*Thickness*	*Tolerance*
under 15 mm to 55 mm	0.1 mm to under 0.3 mm	± 0.05 mm
	0.3 mm to under 1.0 mm	± 0.08 mm
	1.0 mm to 2.0 mm	± 0.15 mm
over 55 mm to 100 mm	0.1 mm to under 0.3 mm	± 0.08 mm
	0.3 mm to under 1.0 mm	± 0.12 mm
	1.0 mm to 2.0 mm	± 0.15 mm

Table 5

Width	*Thickness*	*Tolerance*
under 15 mm	over 0.1 mm to 0.3 mm	± 0.05 mm
	over 0.3 mm to 1.0 mm	± 0.08 mm
	over 1.0 mm to 2.0 mm	± 0.15 mm
15 mm to 55 mm	over 0.1 mm to 0.3 mm	± 0.05 mm
	over 0.3 mm to 1.0 mm	± 0.08 mm
	over 1.0 mm to 2.0 mm	± 0.15 mm
Over 55 mm to 100 mm	over 0.1 mm to 0.3 mm	± 0.08 mm
	over 0.3 mm to 1.0 mm	± 0.12 mm
	over 1.0 mm to 2.0 mm	± 0.15 mm

* Table 5 is used in Europe.

5.4 *Surface Finish*

5.4.1 The material shall be commercially free of surface imperfections such as pits, nicks, dents, gouges, scratches, laminations, or inclusions.

5.4.2 The surface roughness of both sides shall be measured perpendicular to the direction of rolling and indicated as the arithmetic average height (R_a) and the maximum peak-to-valley roughness height (R_{max}).

5.4.2.1 Measurement and designations of surface roughness shall conform to appropriate area standards based on country or area of material origin.

5.4.2.1.1 Europe ISO 4287 Part 1

5.4.2.1.2 Japan JIS B0601

5.4.2.1.3 United States ANSI/ASME B46.1

5.4.2.2 Conditions for the measurement are shown in Table 6.

Table 6

Radius of Diamond Stylus: Less than 5mm	*(Record Actual Size)*
Cut Off:	0.8 mm
Stroke:	4 mm

5.4.2.3 Maximum acceptable values for surface roughness are shown in Table 7.

Table 7

Thickness	R_a	R_{max}
0.1 mm to under 0.3 mm	0.15 µm	1.0 µm (1.5 µm)
0.3 mm to 2 mm	0.20 µm	1.5 µm (2.0 µm)

* Values in parentheses are used in Europe.

5.5 *Camber (Edgewise Curvature)*

5.5.1 Camber is measured by placing a length of strip on a flat surface against the edge of a straight edge, as shown in Figure 1. The straight edge shall be of sufficient length to equal or exceed the length traditionally used in the area or country of origin of the material. The largest amount of separation of the strip sample from the straight edge shall be measured. Extreme care must be exercised with this test to ensure that the sample illustrates a uniform camber (no reverse curvature should be present in the sample), and also that it is not bent or kinked, as this could result in a grossly inaccurate measurement. The maximum camber per length allowable are shown in Table 8.

Table 8

Width	*Thickness*	*Max camber allowed in 1 meter*
Under 15 mm	0.1 mm to under 0.3 mm	1.8 mm (2.0 mm)
	0.3 mm to under 1.0 mm	2.2 mm (2.5 mm)
	1.0 mm to 2.0 mm	4.0 mm
15 mm to 55 mm	0.1 mm to under 0.3 mm	1.3 mm
	0.3 mm to under 1.0 mm	2.0 mm
	1.0 mm to 2.0 mm	3.0 mm
Over 55 mm to 100 mm	0.1 mm to under 0.3 mm	1.0 mm
	0.3 mm to under 1.0 mm	1.5 mm
	1.0 mm to 2.0 mm	2.5 mm

5.6 *Flatness*

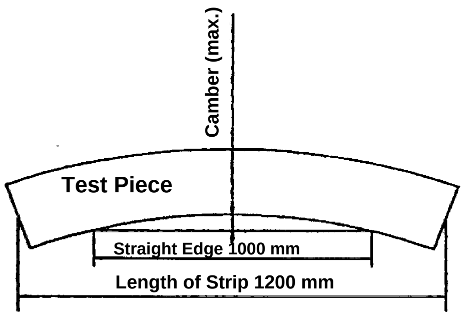


Figure 1
Camber

5.6.1 *Coil Set (Longitudinal Curl)*

5.6.1.1 Coil set shall be measured by attaching a length of strip, appropriate to the country or area of material origin, to a flat vertical surface as shown in Figure 2. The attachment shall be with a rigid block, wider than the strip. The block shall be so rigid as to ensure complete contact of the strip with the vertical surface. The distance between the flat surface and the free-hanging end of the strip (that is positioned for maximum distance from the flat vertical surface) shall be measured. The coil set shall be uniformly in the direction of coiling. Lengths shall be appropriate to the country or area of material origin. Maximum coil set for appropriate lengths are shown in Tables 9 and 10.

Table 9

Inside Diameter of Coil	*Thickness*	*Width*	*Max Coil Set in 1 m*
400 mm	under 0.3 mm	under 100 mm	100 mm

Table 10

Thickness	*Width*	*Max Coil Set in 0.3 m*
Under 0.3 mm	up to 15 mm	60 mm
	over 15 to 24 mm	50 mm
	over 24 to 55 mm	45 mm
	over 55 to 100 mm	40 mm
0.3 mm to 0.5 mm	up to 15 mm	70 mm
	over 15 to 24 mm	60 mm
	over 24 to 55 mm	55 mm
	over 55 to 100 mm	50 mm

* Table 10 is used in Europe.

5.6.2 *Crossbow (Dish)*

5.6.2.1 Crossbow shall be measured across the width of the strip, as shown in Figure 3. Burrs shall be removed or burr height excluded from this measurement. Crossbow shall be measured with a tool maker's microscope or equivalent. Crossbow maxima are listed in Tables 11 and 12.

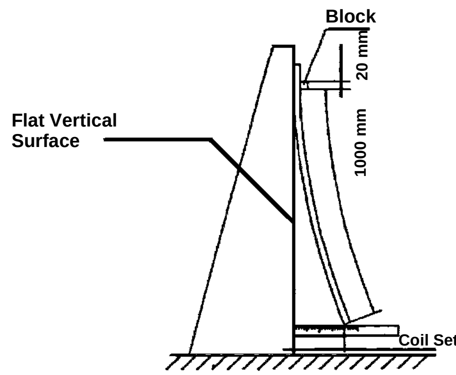


Figure 2
Coil Set

Table 11

Width	*Thickness*	*Crossbow Limit*
under 15 mm	0.1 mm to under 0.3 mm	0.5% of width
	0.3 mm to under 1.0 mm	1.0% of width
	1.0 mm to 2.0 mm	1.5% of width
15 mm to 55 mm	0.1 mm to under 0.3 mm	0.5% of width
	0.3 mm to under 1.0 mm	0.5% of width
	1.0 mm to 2.0 mm	0.5% of width
over 55 mm to 100 mm	0.1 mm to under 0.3 mm	0.4% of width
	0.3 mm to under 1.0 mm	0.4% of width
	1.0 mm to 2.0 mm	0.4% of width

Table 12

Width	*Thickness*	*Crossbow Limit*
from 15 mm to 24 mm	0.1 mm to under 0.3 mm	0.10 mm
	0.3 mm to under 1.0 mm	0.15 mm
	1.0 mm to 2.0 mm	0.20 mm
over 24 mm to 55 mm	0.1 mm to under 0.3 mm	0.15 mm
	0.3 mm to under 1.0 mm	0.20 mm
	1.0 mm to 2.0 mm	0.25 mm
over 55 mm to 100 mm	0.1 mm to under 0.3 mm	0.25 mm
	0.3 mm to under 1.0 mm	0.30 mm
	1.0 mm to 2.0 mm	0.35 mm

* Table 12 is used in Europe.

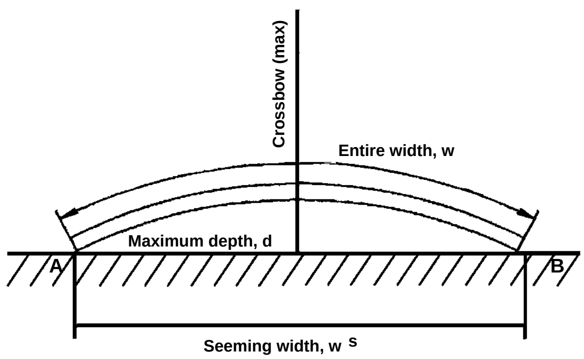


Figure 3
Crossbow

5.6.3 *Twist*

5.6.3.1 Twist shall be measured in a fashion similar to coil set, as shown in Figure 4A or Figure 4B. A length of strip, appropriate to the country or area of material origin, shall be attached at one end to a flat vertical surface. The attachment shall be with a rigid block, wider than the strip. The block shall be so rigid as to ensure complete contact of the strip with the vertical surface. At the free end of the strip, the distance from the vertical surface and both edges of the free strip end shall be measured. The maximum difference in these dimensions is shown in Table 13.

Table 13

Thickness	*Twist Maximum (Difference in Edge Distance)*
0.1 mm to 0.5 mm	Width × 0.2823 for 1000mm (Width × 0.2823 for 300mm)

* Value in parentheses is used in Europe.

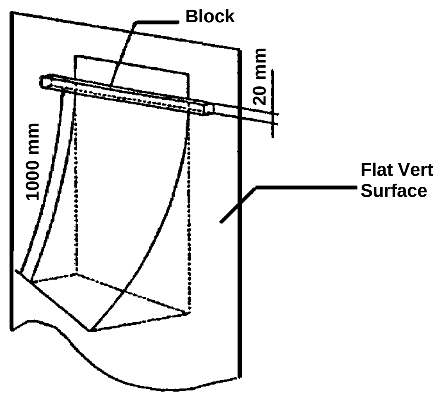


Figure 4
Twist Test

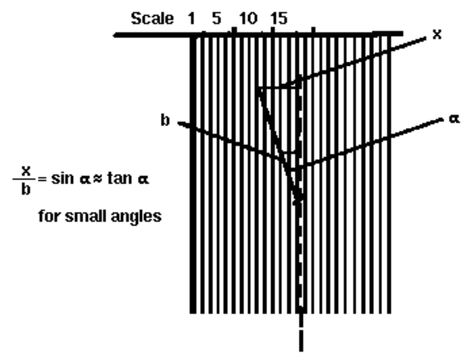


Figure 4B
Twist Test

5.7 *Burrs*

5.7.1 Edge burrs shall not exceed the values in Table 14 and 15. As shown in Figure 5, a-b shall be measured.

Table 14

Thickness	*Maximum Allowed Edge Burr*
0.1 mm to under 0.3 mm	Thickness x 10%
0.3 mm to under 1.0 mm	Thickness x 7%
1.0 mm to under 2.0 mm	Thickness x 5%

Table 15

Thickness	*Maximum Allowed Edge Burr Height*
0.1 mm to 0.3 mm	0.02 mm
Over 0.3 mm to 1.0 mm	0.03 mm
Over 1.0 mm to 2.0 mm	0.04 mm

* Table 15 is used in Europe.

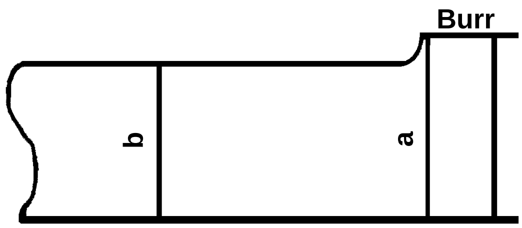


Figure 5
Burr

5.8 *Corrosion*

5.8.1 Visual inspection shall be performed within 60 days of receipt of material. The material shall be free of objectionable surface oxides which would render the product unusable for the intended application. The material shall have been stored for this period in the original supplier's package.

6 Bend Formability

6.1 When agreed between supplier and purchaser, a bend formability test shall be performed. This test shall be based on area standards based on country or area of material origin.

6.1.1 *Europe ISO 7438* — (Test jig is shown in Figure 2 of ISO 7438.)

6.1.2 *Japan CES M0002-5* — The test piece which shall be 10 mm wide and a minimum of 30 mm long will be put on the B type test jig with a bend radial of 0.15 mm and 0.25 mm and from 0–2.0 mm at interval of 0.2 mm. In this case, die pressure shall be 807N (1000Kgf) and over. The B type test jig is shown in Figure 2 of CES M0002-5.

6.1.3 *United States* — ASTM E 290.

7 Lead Bend Fatigue

7.1 When agreed between supplier and purchaser, a lead bend fatigue test shall be performed. This test shall be conform to the appropriate area standards based on the country or area of material origin.

7.1.1 *Europe* — MIL-STD-883.

7.1.2 *Japan* — Appendix 1

7.1.3 *United States* — MIL-STD-883.

8 Physical Properties

8.1 When agreed between supplier and purchaser, tests on physical properties shall be performed based on appropriate area standards based on country or area of material origin.

8.1.1 *Chemistry*

8.1.1.1 Chemical analysis of material shall be performed using accepted procedures such as X-Ray fluorescence spectroscopy, optical emission spectroscopy, and atomic absorption spectroscopy. These tests shall be performed based on appropriate area standards based on country or area of material origin.

8.1.1.1.1 *Europe* — ISO.

8.1.1.1.2 *Japan* — JIS.

8.1.1.1.3 *United States* — ASTM standards under preparation.

8.1.2 *Electrical Conductivity*

8.1.2.1 The test for electrical resistivity and conductivity shall be performed based on appropriate area standards based on country or area of material origin.

8.1.2.1.1 *Europe* — ASTM B193.

8.1.2.1.2 *Japan* — JIS H0505.

8.1.2.1.3 *United States* — ASTM B193.

8.1.2.2 Thermal conductivity shall be calculated from electrical conductivity using the law of Wiedemann and Franz, which is described as:

$k/\sigma T = L$, where:

k = thermal conductivity
σ = electrical conductivity
T = absolute temperature
L = Lorenz number = $2.44 \times 10^{-8} (V/K)^2$
where : V = voltage and K = Kelvin scale

8.1.3 *Coefficient of Thermal Expansion*

8.1.3.1 T he coefficient of thermal expansion shall be measured between 20°C and 300°C. The test shall be based on the appropriate area standard based on the country or area of material origin.

8.1.3.1.1 *Europe* — ASTM E 228.

8.1.3.1.2 *Japan* — ASTM E 228.

8.1.3.1.3 *United States* — ASTM E 228.

9 Silt Strain (Stress)

9.1 When agreed upon between supplier and purchaser, a test to determine internal stress distribution shall be performed. The test should be based on some form of chemical milling, sawing, or wire cutting to remove portions of the strip to form a pattern in the strip. As a guide to preparation of such tests, a procedure is shown in Appendix 2 or 3.

10 Coils

10.1 Unless otherwise specified, coils shall be supplied with an inside diameter that provides for good packing practice without resulting in excessive coil set.

10.2 All coils supplied shall be continuous, uniform lengths, and free of welds. Autogenous welds made at heavy gauge, prior to finish reductions that ultimately provide homogeneous structures, are allowed.

11 Certification or Test Reports

11.1 Requests for certifications or test reports shall be made at the time of order entry or contract agreement. They shall be furnished by the manufacturer within one week of date of shipment.

11.2 When certifications are required, the following information shall be supplied as a minimum:

1. Vendor name
2. Purchase order number
3. Vendor order number
4. Alloy name and number
5. Chemical analysis
6. Temper designation, reference only (for copper base alloys only)
7. Tensile strength
8. Elongation percent in 50 mm
9. Electrical conductivity % IACS (for copper base alloys only)

11.3 In the event of a disagreement between supplier and purchaser, an independent test shall be conducted on strip to verify the data provided in the certification.

12 Packaging and Marking

12.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by a common carrier for transportation at the lowest applicable rate.

12.2 The material shall be suitably packaged to protect from condensation, contamination, etc., and to afford protection from the normal hazards of transportation.

12.3 Each shipping unit shall be legibly marked with the purchase order number, alloy name or number, temper, size, gross and net weight, and name of the supplier. The specification number shall be shown when specified on the purchase order.

12.4 Any special packaging or shipping requirements shall be agreed upon between supplier and purchaser at the time of purchase.

13 Basis for Rejection

13.1 For the purposes of determining conformance with the requirements prescribed in the specifications, any measured value outside the specified limiting values shall be cause for rejection.

13.2 If objectionable material is found and rejected, samples of the questionable material, with the defects identified and marked, should be sent to the supplier along with information as to order number, quantity originally received, date received, and quantity rejected. Rejected material should be held with adequate protection and identification by the purchaser for a reasonable amount of time, pending investigation by the supplier.

APPENDIX 1
TEST METHOD FOR LEAD BEND FATIGUE OF METAL STRIPS

NOTE: The material in this appendix is an official part of SEMI G4.

A1-1 Preface

This is related to the test method for lead bend fatigue of metal strips of leadframe materials improving MIL-STD-883. Results of this test suggest the lead bend fatigue resistance of leadframes.

The following method is set up especially for the strips with the thickness of 0.25 mm ± 0.008 mm.

A1-2 Method of Measurement

A1-2.1 *Equipment* — Automatic or manual lead bend fatigue tester as shown in Figure A1-1.

A1-2.2 *Preparation of Specimen* — The specimen with the width of 0.5 mm ± 0.05 mm is made by either etching or stamping method. A wider portion on one end is recommended for a good grip as shown in Figure A1-2.

A1-2.3 *Procedure* — The specimen is clamped on both ends with clamp and weight as shown in Figure A1-3 and tested under the conditions listed in Table A1-1. The number of bending cycles (*) and other information (**) should be recorded.

*The number of bending cycles: The cycles until specimen breaks, and weight drops into pan.

0° – 90° – 0° bend on one side is counted as 1 cycle.

0° – 90° is counted as 0.5 cycle.

**Other information:

1. Rolling direction on the specimen.
2. Actually measured dimensional data of thickness and width.
3. Burr side related to bending corner (for stamped specimen only).

A1-3 Reference

SEMI G10 — Standard Method for Mechanical Measurement of Plastic Package Leadframes

Table A1-1

Bend Angle (set)	90° ± 2°
Rate of Cycle	2–5 sec/cycle
Weight	2.206–2.452N (225–250 gf)
Bend Radius: R (see Fig. A4)	0.15–0.20 mm

Note 1: In other cross sectional areas (thickness and width) of leads, the weight to be used shall be agreed upon between supplier and purchaser.

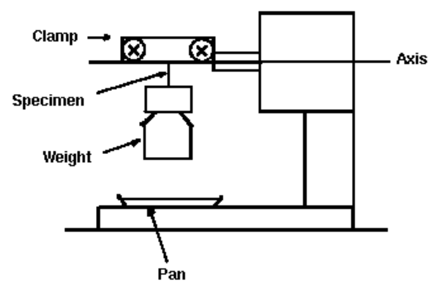


Figure A1-1
Lead Bend Fatigue Tester

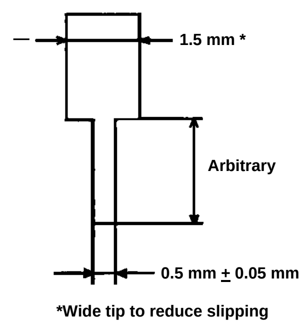


Figure A1-2
Shape of Specimen

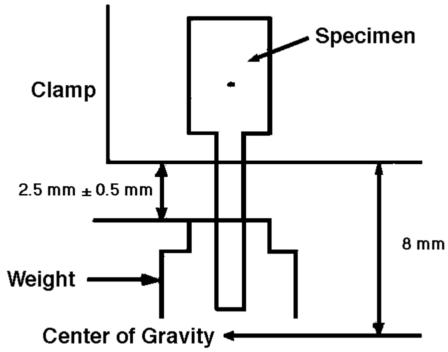


Figure A1-3
Clamping

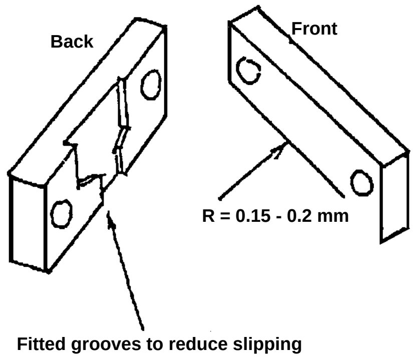


Figure A1-4
Inside of Clamp (Example)

APPENDIX 2
TEST METHOD FOR SLITTER STRAIN OF STRIPS USED FOR LEADFRAME STAMPING

NOTE: The material in this appendix is an official part of SEMI G4.

A2-1 Preface

This is related to the general evaluation method for slitter strain of strips used for leadframe stamping. Such distortion could result in adverse effects on leadframes, such as coil set, lead twist, and camber.

A2-2 Evaluation Method

A2-2.1 *Equipment* — Tool microscope (×100).

A2-2.2 *Procedure*

A2-2.2.1 Collect flat samples approximately 150 mm in length from strips in a way that residual distortion can be overlooked. (Collection methods include wire cutting, etching, refined cutting, etc.) Thickness of samples should be either 0.25 mm, 0.20 mm, or 0.15 mm.

A2-2.2.2 Fashion each sample to the shape shown in Figure A2-1 by etching or wire cutting. Measure with the tool microscope to obtain coordinates of the leg end corner. The reading accuracy is to 0.1 mm (see Note 1).

A2-2.2.3 Using the coordinates of the leg end corner, for each leg obtain longitudinal curvature “A”, lead twist “B”, and camber “C”, as shown in Figure A2-2 (see Note 2).

Note 1: Specify the direction of slit burr, and for legs in which the longitudinal curvature A is reversed, measure by reversing the sample itself.

Note 2: Measured values are marked as shown in Figure A2-2.

Note 3: This method should be applied to only slitter strain. Do not apply to any other kind of strain (e.g., thermal inner strain).

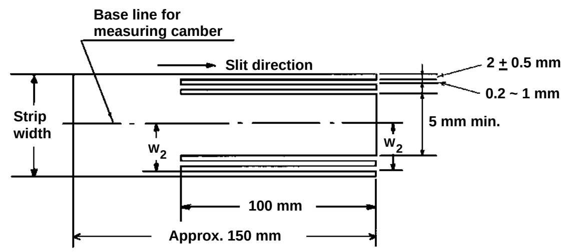


Figure A2-1
Shape for Evaluation of Slitter Strain

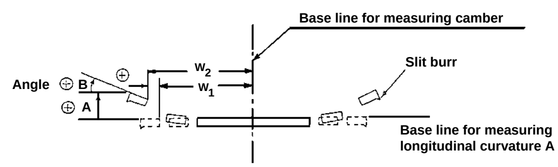


Figure A2-2
Evaluation Items

APPENDIX 3
TEST METHOD FOR SLIT STRAIN OF LEADFRAME STRIPS USED FOR STAMPING

NOTE: The material in this appendix is an official part of SEMI G4.

A3-1 Preface

A3-1.1 The method is used to evaluate the edge stress caused by slitting.

A3-1.2 This method is applied to thickness between 0.1 mm and 0.3 mm.

A3-2 Evaluation Method

A3-2.1 *Equipment* — Tool microscope (×100).

A3-2.2 *Procedure*

A3-2.2.1 A test piece of approximately 200 mm length is sawn, stamped, etched, wire cut, refined cut, etc., over a length of 100–150 mm parallel to the rolling direction of a distance of 2–5 mm from the edge of the strip. (See Figure A1-7.)

A3-2.2.2 The dislocation of the outer strips relative to the plane of the test piece measured as camber c, longitudinal curvature L, and twist T characterize the internal edge stress. (Note 1)

Note 1: The details of the test method and the maximum admissible values of c, L, and T shall be agreed between purchaser and supplier.

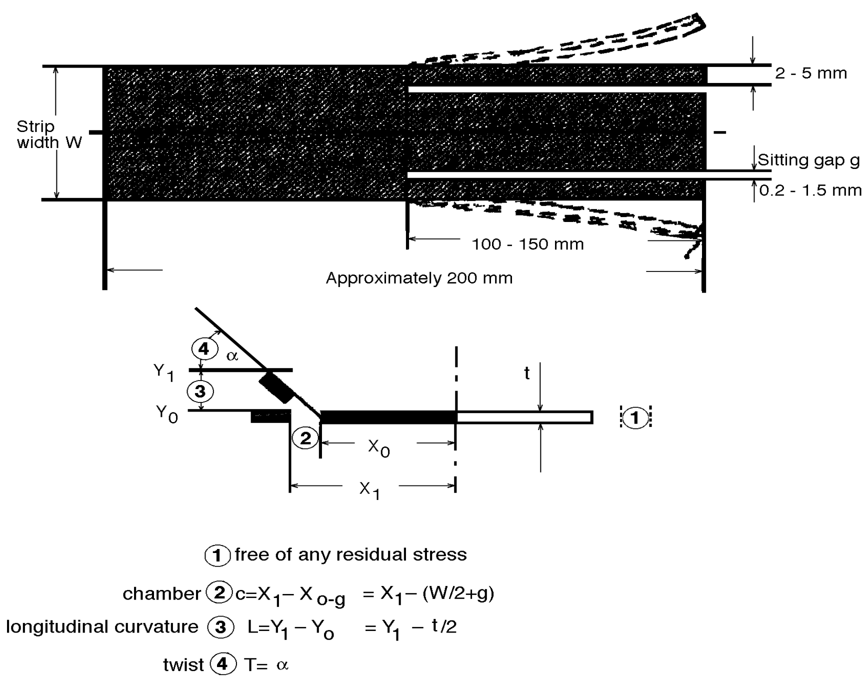


Figure A1-7
Test Method of Slit Stress

SEMI G5-87
STANDARD FOR CERAMIC CHIP CARRIERS

1 Scope

This specification defines the acceptance criteria for co-fired, ceramic chip carriers both leaded and lead-less.

2 Applicable Documents

2.1 *ANSI Specification*[1]

S Y 14.5 — Dimensioning and Tolerancing

2.2 *Federal Specification*[2]

QQ-N-290 — Nickel Plating

2.3 *JEDEC Specification*[3]

Pub. No. 95 — Registered and Standard Outline for Solid State Products

2.4 *Military Specifications*[4]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-7883 — Brazing

MIL-M-38510 — General Specification for Microcircuits

MIL-STD-45204 — Gold Plating, Electrodeposited

2.5 *SEMI Specifications*

SEMI G8 — Test Method for Gold Plating Quality

SEMI G25 — Test Method for Measuring the Resistance of Package Leads

SEMI G6 — Test Method for Seal Ring Flatness

3 Selected Definitions

braze — An alloy with a melting point equal to or greater than 600°C.

castellation — That series of ribs and metallized indentations that define edge contact regions (see Figure 1).

fired — A process or technology to manufacture products in which the ceramic and refractory metallization are fired simultaneously.

contact pad — That metallized pattern that provides mechanical or electrical connection to the external circuitry.

die attach surface — See Figure 3.

footprint — Contact pad pattern.

layer — A dielectric sheet with or without metallization that performs a discrete function as a part of the package.

lead offset — Alignment of leads across the package.

pullback — The linear distance between the edge of the ceramic and the first measurable metallization and/or glass interface (see Figures 4 and 5).

rundown — See Figures 4 and 5.

seal-area — A dimensional outline area designated for either metallization or bare ceramic to provide a surface area for sealing (see Figure 3).

terminal — Case outline at point of entry or exit of an electrical contact.

TIR — Total Indicator Reading.

4 Ordering Information

Purchase order for ceramic chip carriers furnished to this specification shall include the following items:

1. Quantity
2. Drawing — The drawing(s) for ceramic chip carriers shall specify the following information:
   a. Drawing number and revision level.
   b. Number of terminals and terminal center line spacing.
   c. Lead material and dimensions.
   d. Critical material properties.
   e. Type and thickness of plating.
   f. Package dimensions per ANSI Y14.5.
   g. Internal bonding patterns.
   h. Minimum exposed metallized bond finger length and width.

1 ANSI, 1430 Broadway, New York, NY 10018

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

3 JEDEC, 2001 Eye Street, N.W., Washington, D.C. 20006

4 General Services Administrator, 4th and D Streets, SW, Room 6039, Washington, D.C. 20407

i. Portion of external footprints connected to die attach area and/or seal ring.

j. Terminal #1 position, internal and external.

k. Certification (optional).

l. Method of test and measurements.

m. Electrical, mechanical, environmental requirements.

3. Reference to this specification

4. Any exception to print or specification

5 Dimensions and Permissible Variations

5.1 The dimensions of ceramic chip carriers shall conform to those specified in the customer drawing, and be within the outline of JEDEC Publication No. 95.

NOTE: A dimensioning scheme and measurement fixture are under task force review.

5.2 *Critical Material Parameters*

5.2.1 *Ceramic*

5.2.1.1 Alumina, content 90% minimum.

5.2.1.2 *Color* — Dark or white.

5.2.2 *Metallization*

5.2.2.1 Refractory metallization.

5.2.2.2 Plating (if designated) per MIL-M-38510.

5.2.2.3 Nickel per QQ-N-290

5.2.2.4 Gold per MIL-STD-45204, Type III.

5.2.2.5 Gold Plating Quality see SEMI G8.

5.2.3 Braze per MIL-STD-7883.

5.2.4 Lead per MIL-STD-23011.

5.2.4.1 Iron Nickel Cobalt alloy per MIL-M-38510, Type A.

5.2.4.2 Iron Nickel alloy per MIL-M-38510, Type B.

6 Functional Testing

The following tests are recommended for functional evaluation of ceramic chip carriers. (The conditions of acceptance to be negotiated between the customer and the vendor.)

6.1 *Die Attach*

6.2 *Pre-Seal Die Shear* — (See Section 10.1.6.)

6.3 *Wire Bond*

6.4 *Pre-Seal Bond Pull* — (See Section 10.1.7.)

6.5 *Seal*

6.6 *Environmental Test* — (See Sections 10.1.1 through 10.1.13.)

6.7 *Hermeticity* — (See Section 10.1.14) Lid Torque or Shear (for glass seal parts).

6.8 *Post-Seal Bond Pull* — (See Section 10.1.7.)

6.9 *Post-Seal Die Shear* — (See Section 10.1.6.)

7 Incoming Testing

7.1 *Visual* — (See Section 8.)

7.2 *Dimensions*

7.3 *Functional* — (See Section 6.)

7.4 *Standard Tests*

7.4.1 *Electrical* — (See SEMI G25.)

7.4.2 *Gold Plating Quality* — (See SEMI G8.)

7.4.3 *Trim*

7.4.4 *Lead Integrity* —(See Section 10.1.15.)

7.4.5 *Solderability* — (See Section 10.1.16.)

8 Visual

8.1 *Applicable Definitions*

blister (bubble) ceramic — Any separation within the ceramic which does not expose underlying ceramic material.

blister (bubble) metal — Any localized separation within the metallization or between the metallization and ceramic which does not expose underlying metal or ceramic material.

burr — An adherent fragment of excess parent material at the component edge.

chip — A region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width, and depth from a projection of the design plan-form (see Figure 2).

crack — A cleavage or fracture, internal or external.

die attach surface — See Figure 3.

discoloration — Any non-uniform color change of the package plating.

foreign material — An adherent particle other than parent material of that component.

LSI — Large scale integration.

void, dielectric — An absence of screen printed ceramic from a designated area greater than 0.76 mm (0.003") in diameter.

void, metallization — An absence of refractory metallization, braze, or plating material from a designated area greater than 0.076 mm (0.003") in diameter.

8.2 *Visual Criteria* — (10× magnification) (See Section 8.1.)

8.2.1 *Ceramic* — Unmetallized Surfaces

8.2.1.1 *Cracks* — None allowed per MIL-M-38510, Method 1014.

8.2.2 *Chips*

8.2.2.1 *Corner* — 0.762 mm (0.030") × 0.762 mm (0.030") × one tape layer thickness, maximum.

8.2.2.2 *Edge* — 2.54 mm (0.100") × 0.762 mm (0.030") × one tape layer thickness, maximum.

8.2.2.3 Chips cannot encroach upon seal area, or contact pad, or expose any buried metallization.

8.2.3 *Burrs, Projections, and Blisters*

8.2.3.1 *Top Plane, Excluding Seal Area* — 0.102 mm (0.004") maximum.

8.2.3.2 *Seal Area* — 0.025 mm (0.001") maximum.

8.2.3.3 *Heat Exchanger Attach Area* — 0.076 mm (0.003") maximum (if designated).

8.2.3.4 *Contact Surface* — 0.051 mm (0.002") maximum.

8.2.3.5 *Edges* — 0.152 mm (0.006")

8.2.3.6 Burrs, projections, and blisters must fit within the outline tolerances.

8.2.4 *Camber* — Ceramic of 0.1 mm/25.4 mm (0.004 inch/inch), maximum. None to be specified less than 0.076 mm (0.003") along any planar dimension of the part.

8.2.5 *Flatness* — See table below:

Table 1 Flatness

Flatness: Seal Area: Seal Ring Size	*Flatness (TIR)*
0–6.35 mm (0"–0.250")	0.051 mm max. (0.002")
6.37–12.7 mm (0.251"–0.500")	0.076 mm max. (0.003")
12.72 –25.4 mm (0.501"–1.000")	0.101 mm max. (0.004")
25.42 mm and up (1.001")	0.004 in/in

8.3 *Ceramic Metallized Surfaces*

8.3.1 *Voids*

8.3.1.1 *Seal Area* — maximum of 3 voids permitted. No more than two voids per side of 0.010" diameter maximum each. Any two voids must be separated by 0.030" (0.762 mm) minimum, not to degrade the seal width by more than 25%.

8.3.1.2 *Footprint* — Two voids per pad 0.254 mm (0.010") diameter maximum. A contiguous path must never be reduced by more than 1/3 the minimum design width.

8.3.1.3 *Wire Bond Fingers* — A void-free area 0.254 mm (0.010") × 0.254 mm (0.010") or as defined by the customer drawing.

8.3.1.4 *Heat Exchange Attach Area* — (if designated) The major dimension of a void shall not exceed 0.508 mm (0.020") and all voids must be separated by 0.762 mm (0.030"). Total void area to be equal or less than 10%.

8.3.1.5 *Die Attach Surface* — Three voids of 0.010" diameter are the maximum allowed separated by 0.030" minimum.

NOTE: Voids within 0.015" of a cavity wall 0.381 mm are excluded from this requirement.

Table 2 Die Attach Area Flatness Limits

Die Attach Pad Dimension	*TIR Flatness*
0-12.7 mm (0–0.500")	0.51 mm (0.002" max.)
12.72–19.5 mm (0.501"–0.750")	0.088 mm (0.0035" max.)

8.3.1.6 *Internal Metallization* — Voids shall not break continuity between wire bond fingers and the corresponding contact pad. The user may specify additional resistance and capacitance parameters for each application.

8.3.2 *Burrs and Projections* — Shall not exceed the specification of Table 3.

Table 3 Maximum Height of Burrs and Projections

	Maximum Inches	*Height mm*
Wire Bond Finger Area	0.001	(0.025)
Seal Area	0.001	(0.025)
Die Attach Surface	0.001	(0.025)
Contact Pad	0.002	(0.051)
Heat Exchanger Attach Area	0.003	(0.076)

8.3.3 Pattern Definitions (Cavity Packages) — (See Figure 4.)

8.3.3.1 *Seal Plane Rundown* — internal cavity — Not to exceed 25% of the cavity layer thickness.

8.3.3.2 *External to the Cavity* — Separation shall not be less than 0.254 mm (0.010") or 50% of the design width, whichever is less.

8.3.3.3 *Wire Bond Finger Pullback* — Not to exceed maximum from the cavity edge. The minimum exposed lead length must meet the dimension per applicable drawing.

8.3.3.4 *Wire Bond Finger Rundown* — Not to exceed 25% of the ceramic layer thickness or 0.127 mm (0.005"), whichever is smaller.

8.3.4 *Pattern Separation* — Minimum shall not be reduced by more than 50% of the design.

8.4 *Lead Attachment*

8.4.1 *Voids in Braze* — 66% of the braze fillet must be void-free.

8.4.2 *Lead Alignment* — Misalignment leads to braze pads — The leads shall not overhang braze pads.

8.4.2.1 *Lead Offset* — To be specified on user drawing. Lead center lines must be aligned to within .178 mm (.007").

8.4.2.2 *Lead-to-Lead Misalignment* — To exceed ± 10% of nominal lead spacing.

8.4.2.3 *Dimensional Criteria* — To be specified on user drawing.

9 Sampling

Sample sizes must meet requirements of MIL-STD-105 or MIL-M-38510 as agreed to between vendor and customer. Single, double, or multiple samples may be used.

10 Test Methods

10.1 *Mechanical, Electrical, and Thermal Test Methods* — Per MIL-STD-883, unless otherwise noted.

10.1.1 Gold plating thickness shall conform to MIL-STD-45204. Gold thickness may be determined using the Beta Backscatter Radiation Method or X-Ray Fluorescence.

10.1.2 Nickel plating shall conform to MIL-STD-45204. Nickel thickness may be determined using the Beta Backscatter Radiation Method.

10.1.3 *Seal Ring Flatness* — See SEMI G6.

10.1.4 *Electrical Trace Resistance* — See SEMI G25.

10.1.5 *Gold Plating Quality* — See SEMI G8.

10.1.6 *Die Shear* — Destructive — Method 2019.

10.1.7 *Wire Bond* — Method 2011, Condition D. Reject for bonds which cause plating to lift from the base metal of the die attach surface or bonding fingers.

10.1.8 *Temperature Cycle* — Method 1010, Condition C.

10.1.9 *Thermal Shock* — Method 1011, Condition C.

10.1.10 *Constant Acceleration* — Method 2001, Condition E.

10.1.11 *Mechanical Shock* — Method 2002, Condition B.

10.1.12 *Insulation Resistance* — Method 1003.

10.1.13 *Internal Water Vapor Content* — Method 1018.

10.1.14 *Hermeticity* — Method 1014, Conditions A, B, and C. The hermetic integrity of the package must be maintained after all environmental testing.

10.1.15 *Lead Integrity* — Method 2004, Condition B.

10.1.16 *Solderability* — 2003.

10.1.17 *Moisture Resistance Testing* — Method 1004.

11 Packaging and Marking

11.1 *Packaging* — Containers selected shall be strong enough, and suitably designed, to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents. Containers shall afford protection of the contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component parts with paper fibers or organic particles. Regardless of packaging, all parts should be cleaned before testing or use.

11.2 *Marking* — The outer containers shall be clearly marked identifying:

1. Vendor Part #
2. Customer Part #
3. Quantity
4. Date
5. Vendor Lot #
6. User P.O. number (optional)
7. Drawing number (optional)

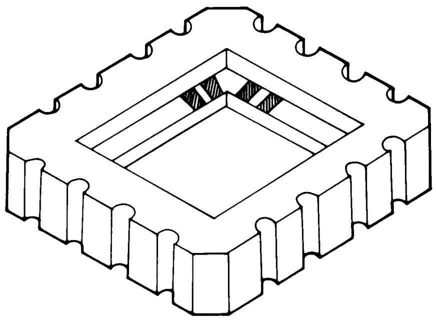


Figure 1
Castellations

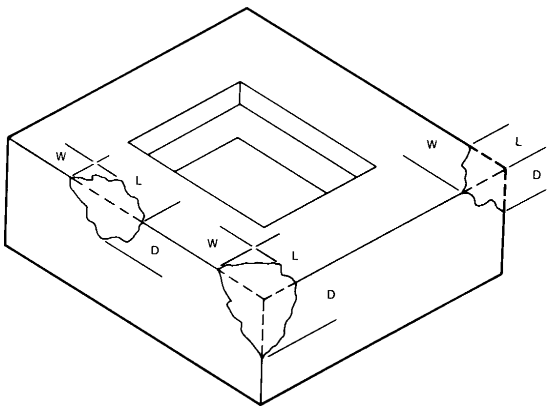


Figure 2
Chip Illustration

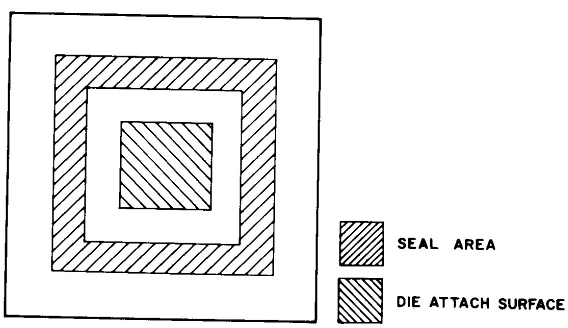


Figure 3
Die Attach Surface and Seal Area

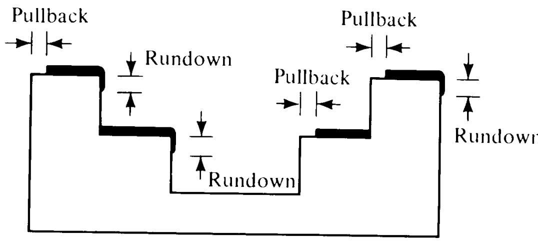


Figure 4
Metallization Misalignment

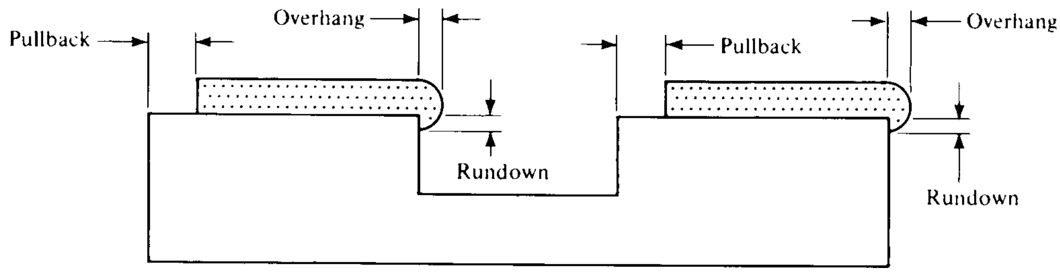


Figure 5
Glass Misalignment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G6-89
TEST METHOD FOR SEAL RING FLATNESS

1 Purpose

This specification covers the method for determining the maximum deviation between the seal ring and a reference plane defined by three fixed points on the seal ring. This method will not work on parts smaller than 0.330" × 0.330".

2 Equipment

2.1 Flat plate (black granite calibrated at ± 0.000025" (± 0.000835 mm) or equivalent).

2.2 *Fixture Clamps* — Three required (See Figure 1).

2.3 *Fixture Base* — (See Figure 1).

2.4 *Test Indicator* — (Hamilton Kwik Check or equivalent).

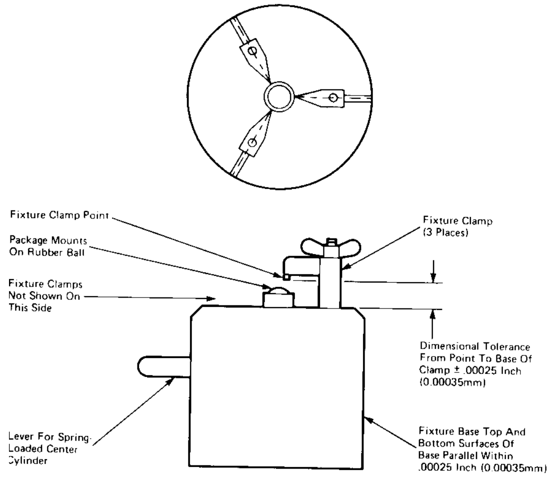


Figure 1
Fixture Base and Clamp Assembly

3 Preparation

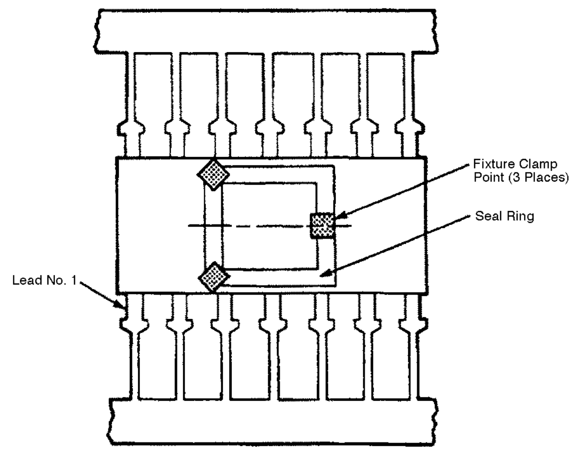
3.1 Fixture clamps shall be adjusted for part to be measured (see Figure 2).

3.2 The gaging fixture is to be calibrated with a precision ground gage block before each sample is measured.

3.2.1 Place gage block under the three fixture clamp points and release center cylinder to hold in place.

3.2.2 Position fixture base so the point of the test indicator is on the gage block.

3.2.3 Move fixture base so the point of the test indicator traverses the entire surface of the gage block. The total deviation read on the test indicator shall not exceed 0.0005" (0.013 mm).



Fixture clamp points aligned on seal ring diagonals on end closest to lead No. 1 and on ceramic center line opposite end.
Points aligned on diagonals shall not extend beyond the outside corners of the seal ring. Point aligned on the centerline shall not extend beyond the outside edge of the seal ring.

Figure 2
Fixture Clamp Orientation

4 Procedure

4.1 Place the package under the three fixture clamp points and release cylinder to hold in place (see Figure 2) for orientation of package seal ring and fixture clamp points.

4.2 Position fixture base so the point of the test indicator is on the package seal ring.

4.3 Move fixture base so the point of the test indicator traverses the length of the seal ring.

4.3.1 Move fixture base so the point of the test indicator stays in the middle of the seal ring.

4.3.2 Test indicator shall be relocated twice to get around fixture points.

5 Evaluation

If material buildup on the seal ring is visible with the unaided eye, the part shall not be used for this measurement.

SEMI G8-94
TEST METHOD FOR GOLD PLATING

1 Preface

1.1 *Purpose* — This test method describes procedures to determine gold plating quality.

1.2 *Scope* — These methods apply to gold plating on cofired ceramic or metal packages. The grade, hardness, and thickness of the gold plating shall be specified per MIL-G-45204 unless otherwise agreed between vendor and customer.

Note 1: The gold plate may be over refractory metal on cofired ceramic packages or over an underplate on metal packages.

2 Applicable Documents

2.1 *Referenced Documents*

2.1.1 *SEMI Specifications* — All SEMI package specifications

2.1.2 *ASTM Specifications*[1]

B 384 — Standard Test Method for Microhardness of Materials

B 487 — Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopic Examination of a Cross-Section

B 567 — Method for Measurement of Coating Thickness by the Beta Backscatter Method

B 568 — Method for Measuring Coating Thickness by X-Ray Spectrometry

F 1269 — Test Methods for Destructive Shear Testing of Ball Bonds

2.1.3 *Military and Federal Specifications*[2]

MIL-STD-750 — Test Methods for Semiconductor Devices

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-G-45204 — Gold Plating, Electrodeposited

2.2 *Related Documents*

Military and Federal Specifications

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-202 — Test Methods for Electronic and Electrical Componenet Parts

MIL-STD-19500 — General Specification for Semicondutor Devices

MIL-M-38510 — General Specification for Microcircuits

3 Summary of Method

Various test methods are described or referenced to determine gold plating quality for the following items:

- Visual Appearance
- Plating Thickness
- Plating Adhesion
- Functional tests
- Salt Atmosphere
- Hardness

4 Significance and Use

4.1 *Significance* — Poorly plated components result in lowered yields during package assembly operations or to reliability problems.

4.2 *Use* — The methods described in this document may be used by vendors to test gold plated components as part of their process control program, or by customers at incoming inspections.

The methods are to used in conjunction with individual component specifications.

5 Terminology

5.1 *blister (metal)* — An enclosed, localized separation of a metallization layer from its base material (such as ceramic or another metal layer) that does not expose the underlying layer.

5.2 *discoloration* — The change in color of any plated metallization, gold, silver, aluminum, etc., as detected by the unaided eye after the application of heat to the metallization. The metallization may be over base metal, another plated layer, or on refractory metal.

5.3 *peeling (flaking)* — Any separation of the plated, vacuum deposited or clad metal from the base metal of a leadframe, lead, pin, heatsink, or seal ring, from an underplate, or from refractory metal on a ceramic package. Peeling exposes the underlying material. Also called flaking.

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1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadepphia, PA 19120

5.4 *pitting (plated metal layer)* — Unspecified depressions in the plated layer, not the underlying layer(s). Such pits may be caused by incorrect plating conditions.

5.5 *resin bleed-out (die attach)* — The surface creep of a resin used for die attach beyond the outer perimeter of the bulk of the resin (filler). For a given resin formulation, the resin creep may be exacerbated by the microstructure and cleanliness of the die attach surface.

5.6 *scratch* — An abrasion in the surface of a metallization layer which exposes the base material.

6 Interferences

6.1 Avoid contaminating the gold plated surface (e.g., with finger oils), prior to performing the tests. Such contamination may effect visual appearance, and die attach, wire bond, and solderability functional tests.

7 Equipment

7.1 Beta Backscatter system

7.2 Die Attach equipment

7.3 Eutectic Die Attach heater block or lot plate capable of 450 °C ± 10 °C.

7.4 Microscope 10-30× magnification with vertical lighting.

7.5 Micro Cross-Section equipment

7.6 Wire Bond equipment

7.7 X-Ray Fluorescence System

8 Sampling

8.1 Sampling plans shall be agreed between vendor and customer.

9 Test Sequence

When the test methods are used at incoming inspection the sequence of test shall be as follows:

9.1 *Visual Appearance* — See Section 10.1.

9.2 *Plating Thickness* — See Section 10.2.

9.3 *Plating Adhesion* — See Section 10.3.

9.4 *Functional Tests (Die Attach, Wire Bond, and Lead Solderability)* — See Section 10.4.

9.5 *Salt Atmosphere Test* — See Section 10.5.

9.6 *Plating Hardness* — See Section 10.6.

10 Test Procedures

10.1 *Visual Inspection*

10.1.1 Components shall be visually inspected according to the appropriate component specification for plating requirements.

10.1.2 *Surface Structure* — The gold plate shall be smooth matte to semi-bright in appearance. Minor variations in color are not cause for failure at this stage unless there is evidence of corrosion, peeling, or pitting in the plating layer.

Note 2: For the purposes of this test method, particular attention shall be observed in relation to blisters and adhesion problems with the plating layer.

10.2 *Plating Thickness*

10.2.1 Plating thickness shall be measured at locations agreed upon between vendor and customer.

10.2.2 Plating thickness may be measured by one of the following techniques, which are listed in order of preference.

ASTM Method B 568

ASTM Method B 567

ASTM Method B 487

Note 3: Method B 487 shall only be used for thicknesses greater than 100 microinches (0.0025 mm).

10.3 *Plating Adhesion*

10.3.1 Submit samples to 450 °C ± 10°C for two (2) minutes in air on a die attach heater block or hot plate.

10.3.2 Visually inspect the plating under the microscope set at 10× magnification for blistering, peeling, and discoloration.

Note 4: Discoloration after the heat testing is only allowable if the gold plate thickness is less than 20 micro-inches (508 micro mm) by design. Amount and type of discoloration shall be agreed upon between vendor and customer.

Note 5: 30× magnification may be used for confirmation.

10.3.3 *Adhesion Tape Test — Flat Surface*

10.3.3.1 Place a strip of tape across the plated area. Press firmly with finger tips or another smooth object.

10.3.3.2 Peel the tape quickly off the plated surface. If there is any plating on the tape the component shall be rejected.

10.3.4 *Lead Finish Adherence — Bend Test*

10.3.4.1 Bend the leads once through a 90° angle on a diameter equal to the lead diameter or thickness.

10.3.4.2 Visually inspect the plating under the microscope set at 10× magnification for evidence peeling or cracking of the plated layer.

10.4 *Functional Tests*

10.4.1 *Die Attach and Wire Bond*

10.4.1.1 Die Attach and Wire Bond tests shall be performed using materials and conditions agreed between vendor and customer.

10.4.1.2 Die Attach shall be evaluated for shear strength per MIL-STD-883, Method 2019 or by a method agreed between vendor and customer.

Resin bleed-out shall also be evaluated when the extent of the bleed may affect subsequent wire bonding processes.

10.4.2 *Solderability*

10.4.2.1 Solderability testing, with or without aging, shall be agreed between vendor and customer. Solderability testing shall be performed per MIL-STD-883, Method 2003.

10.5 *Salt Atmosphere Test*

10.5.1 *Salt Atmosphere Testing Requirements* — Applicability and condition shall be agreed between vendor and customer. Salt atmosphere testing shall be performed per MIL-STD-883, Method 1009 or MIL-STD-750, Method 1041 as appropriate.

10.6 *Plating Hardness*

10.6.1 If specified, the plating hardness shall be determined by one of the following methods as appropriate:

ASTM B 384

ASTM E 10

Note 6: Hardness testing for thin plating is difficult and not very reliable. The hardness specification shall be agreed between user and supplier.

SEMI G9-89
SPECIFICATION FOR STAMPED LEADFRAMES FOR PLASTIC MOLDED DUAL-IN-LINE SEMICONDUCTOR PACKAGES

1 Preface

This specification is a guideline for the stamping manufacture of leadframes for plastic molded dual-in-line semiconductor packages. It is a design guideline for packaging engineers, leadframe stampers and mold manufacturers, and has been developed to meet the requirements of automatic bonding.

2 Applicable Documents

2.1 This document specifically refers to:

SEMI G4 — Specification for Integrated Circuit Leadframe Materials Used in the Production of Stamped Leadframes

SEMI G10 — Standard Method of Mechanical Measurement

SEMI G21 — Specification for Plating Integrated Circuit Leadframes

2.2 Related information may also be found in:

MIL-STD-105[1] — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

3 Selected Definitions

burr — A fragment of excess material either horizontal or vertical attached to the leadframe.

camber — Curvature of the leadframe strip edge (see Figure 1).

coil set — Longitudinal bowing of the leadframe strip length (see Figure 2).

coined area — Reference lead flat surface.

crossbow — Transverse bowing of the leadframe (see Figure 3.)

functional area — The die attach pad and the lead tips.

lead flat surface — Area on the lead tips that is suitable and available for wire bonding. This is generally achieved by coining on stamped leadframes and is also known as the coined area on such leadframes.

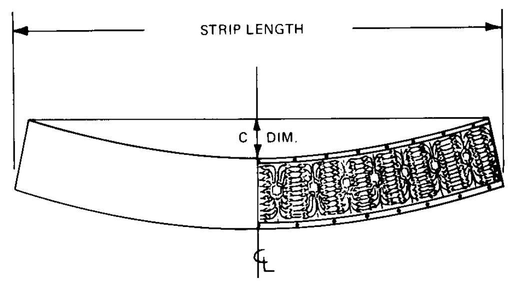

Figure 1
Camber

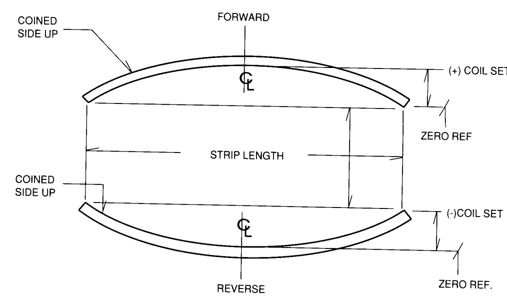

Figure 2
Coil Set

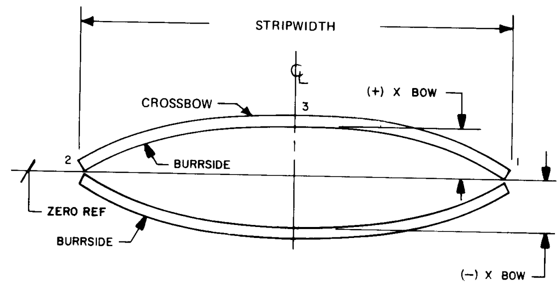

Figure 3
Crossbow

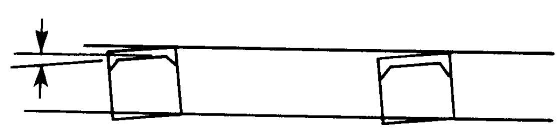

Figure 4
Lead Twist

1 Military Standards, Naval Publications and Form Center, 508 Tabor Ave., Philadelphia, PA 19120

(insert on received)

Figure 5
Stamped Leadframe Terminology

lead twist — Angular rotation on bonding fingers (see Figure 4).

pits — Shallow surface depressions or craters in the leadframe material.

slug marks — Random dents in the leadframe caused by foreign material in the stamping die.

stamped leadframe terminology — See Figure 5.

Z plane — Lead and pad planarity require a reference in the Z dimensions. The recommendation for the reference plane, hereafter called the "Z" plane, is the average of the two dambars when measured at their geometric center. This reference method is incorporated into SEMI G10.

4 Ordering Information

Purchase orders for leadframes for plastic molded dual-in-line semiconductor packages furnished to this specification shall include the following items:

1. Part Specification
2. Material
3. Number of Leads
4. Material Certification
5. Packaging and Marking (see Section 8)

5 Dimensions

See applicable part specification as referred to in Ordering Information, Section 4.

6 Defect Limits and Parameters(See SEMI G10 to Measure)

6.1 *Bond Targets*

6.1.1 Minimum area for bonding to allow placement of true position target of diameter taken (See Table below); 100% within the lead flat area and recommended to be 0.025" (0.63 mm) length from the tip, where plane geometry allows. (See SEMI G10, Section 14.)

Design Lead Width	*Design Lead Space*	*Minimum Lead Space*	*Minimum True Position Target*
≥ 0.011	≥ 0.011	0.006	0.007 Diameter
0.010	0.010	0.005	0.006 Diameter

NOTE: Tolerances for lead designs smaller than 0.010 should be negotiated between vendor and user.

6.1.2 Minimum metal to metal clearance to be as follows:

Material gage 0.010" (0.25 mm) – 0.006" (0.15 mm)

Material gage 0.008" (0.20 mm) – 0.004" (0.10 mm)

(See SEMI G10, Section 14)

6.1.3 Depth of coining on stamped leadframes to be no greater than 30% of material gage. (See SEMI G10, Section 15.)

6.1.4 Lead twist is not to exceed 3° 30' (0.0006" per 0.010" (0.016 mm per 0.25 mm)). (see SEMI G10, Section 3).

6.1.5 Lead tip will exhibit maximum 0.006" (0.15 mm) radius measured in the x-y plane at the lead flat surface (see Figure 6).

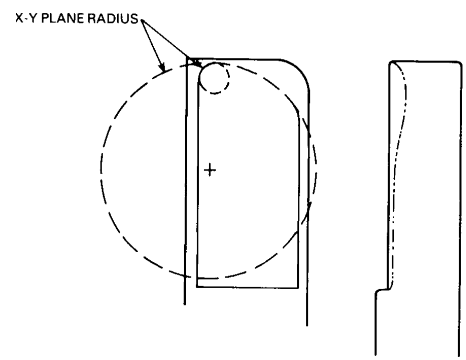

Figure 6
Lead Flat Radius

6.2 *Die Attach Pad Surface*

6.2.1 Die attach pad x-y axis location to be as follows:

rail-pad tie bar length	0.50" (12.5 mm) ± 0.002" (0.05 mm)
rail-pad tie bar length	0.50" (12.5 mm) ± 0.003" (0.08 mm)

from nominal drawing location. (See SEMI G10, Section 14.)

6.2.2 Die attach pad tilt to be as follows:

depressed pad — maximum 0.002" (0.05 mm) per 0.100" (2.5 mm)

undepressed pad — maximum 0.001" (0.025 mm) per 0.100" (2.5 mm) (see SEMI G10, Section 5)

6.2.3 Die attach pad flatness to be within 0.0002" (0.005 mm) T.I.R. per 0.100" (2.5 mm).

6.3 *Die Attach Pad Downset*

6.3.1 Die attach pad downset to be maximum ± 0.002" (0.05 mm) of nominal specified downset (see SEMI G10, Section 9).

6.4 *Lead and Die Attach Pad Planarity*

6.4.1 *Lead Planarity* — (See SEMI G10, Section 8)

6.4.1.1 Allowable tolerance is given by the following:

Strip Width	*Material Gage, 0.010" (0.25 mm)*	*Material Gage, 0.008" (0.20 mm)*
less than 1.000" (25.4 mm)	± 0.004" (0.10 mm)	± 0.003" (0.08 mm)
1.00" (25.4 mm) to 2.00" (50.8 mm)	± 0.005" (0.13 mm)	± 0.004" (0.10 mm)
greater than 2.00" (50.8 mm)	± 0.010" (0.25 mm)	± 0.008" (0.20 mm)

(See SEMI G10, Section 8.)

6.4.2 Die attach pad planarity (see SEMI G10, Section 11).

6.4.2.1 Allowable pad planarity tolerance, downset pad condition is given by the following:

Strip Width	*Tolerance*
Less than 0.75" (18.75 mm)	± 0.002" (0.05 mm)
0.75" (18.75 mm) to 1.00" (25.4 mm)	+0.003" (0.08 mm) to –0.005" (0.13 mm)
Greater than 1.00" (25.4 mm)	+0.006" (0.15 mm) to –0.003" (0.08 mm)

(See SEMI G10, Section 11.)

6.4.2.2 Allowable pad planarity tolerance, undepressed pad condition will not be specified in this document and is subject to vendor/customer negotiation.

6.5 *Material Tolerance*

6.5.1 Material dimensional tolerances are to be given by SEMI G4.

6.6 *Coil Set*

6.6.1 Coil set shall not exceed 0.020" over nominal length of the cut strip (see SEMI G10, Section 10).

6.7 *Crossbow*

6.7.1 Crossbow shall not exceed 0.5% of nominal strip width (see SEMI G10, Section 7).

6.8 *Camber*

6.8.1 Camber shall not exceed 0.002" (0.05 mm) over gage length of 6.00" (150 mm) (see SEMI G10, Section 6).

6.9 *Strip Pitch*

6.9.1 Strip pitch tolerance shall be ± 0.002" (0.05 mm) over the maximum measurable progression within the nominal strip length (see SEMI G10, Section 4).

6.10 *Burrs*

6.10.1 Burrs shall be firmly attached and able to withstand a probe force of 10 grams. Vertical burrs inside the dambar shall not exceed 0.001" (0.025 mm). Vertical burrs outside the dambar and horizontal burrs in any location shall not exceed 0.002" (0.051 mm) (see SEMI G10, Section 12).

6.11 *Pits (Indentations)*

6.11.1 Within function area and on external leads, there shall be no measurable slug marks. Pits shall not exceed 0.0003" (0.008 mm) in depth and 0.0005" (0.013 mm) in largest surface dimension in these areas (see SEMI G10, Section 13).

APPLICATION NOTE: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

6.11.2 In other areas, pits and imperfections shall not affect leadframe strength regardless of size and shall not exceed 0.002" (0.051 mm) in depth and 0.005" (0.127 mm) in largest surface dimensions (see SEMI G10, Section 13).

6.12 *Plating*

6.12.1 All plating related characteristics shall be specified by SEMI G21.

6.13 *Strip Length and Cutoff* — (See SEMI G10, Section 14.)

6.13.1 Strip cutoff location shall be ± 0.003" (0.08 mm) of specified nominal location.

6.13.2 Overall strip length shall be ± 0.003" (0.08 mm) of specified nominal length.

6.14 *Lead Fatigue* — Number of cycles to be determined between customer and supplier. (See SEMI G10, Section 16.)

7 Sampling

Sampling will be determined between supplier and purchaser.

8 Packaging and Marking

8.1 *Packaging* — Leadframes must be packaged in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided against foreseeable mechanical and environmental hazards.

8.2 *Marking* — The outer containers shall be clearly marked identifying the user stock number, user purchase order number, drawing number, and vendor lot numbers within the carton.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G10-96
STANDARD METHOD FOR MECHANICAL MEASUREMENT OF PLASTIC PACKAGE LEADFRAMES

1 Purpose

This method outlines standard mechanical measurement techniques for cut strip leadframes.

2 Scope

This method applies to all facilities that perform mechanical measurements on leadframes. Information is provided herein to enable the use of the following specifications: SEMI G9, SEMI G27, and SEMI G28.

3 Referenced Documents

None.

4 Terminology

None.

5 Equipment

1. Surface illuminated optical comparator with x-y grid
2. Toolmaker's microscope with depth ("z") reading capability, 100×, 400×, obtained with 10× objective, and 40× objective lens with 0.0002" resolution.
   a. Digital readout 0.0002" resolution on x-axis (optional)
   b. Closed circuit TV and camera (optional)
3. Surface plate
4. Gage pins
5. Universal leadframe fixture (see Figure 16)
   a. Fixture shall be perpendicular to optics within the resolution of the instrument and parallel to x and y travel axes.
   b. Leadframe strip shall be placed lead-flat surface up and clamped at rails to fixture base.
   c. The reference plane for measurement, hereinafter called the "z" plane, is the average of the height of the two dambars when measured at their geometric center.
   d. Z-plane cannot be established by this method if the dambar height measurement difference is greater than 0.003". Therefore, units that exhibit greater than 0.003" difference are not acceptable for z-axis measurement.
6. Leadframe camber fixture
   a. Nominal strip orientation defined in Figure 8.
7. Lead fatigue tester
8. Metal-to-metal clearance step gage (see Figure 13)
9. 0-1", 0.0001" reading micrometer
10. Overlay (see Figure 17)
    a. Overlay reference point shall be based on strip pilot holes. If pilot holes are off screen, x-y offsets of overlay pilot position to actual pilot position shall be specified.
    b. True position targets shall be placed on nominal lead center line 0.0065" (0.163 mm) back from nominal lead tip.
    c. Overlay will contain nominal pad location outline.
    d. Overlay will contain nominal strip cutoff position and required x-axis traverse for alignment.

6 Procedure for Lead Twist (Z-Axis) (See Figure 1)

Equipment — Toolmaker's microscope (400× magnification), leadframe fixture.

6.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

6.2 Focus microscope on the edge of the coined surface 0.010" back from the end of the lead tip on the lead to be measured. Ensure that the focus is done on the flat-coined surface and not on the rolled edge. Zero the focal height (z-axis).

6.3 Using the micrometer drum, move the stage the specified distance and refocus the microscope. Ensure that both focus points are on the flat-coined surface, and not on the rolled edge. Focal height difference is the lead twist measurement.

7 Procedure for Strip Pitch (X-Axis) (See Figure 2)

Equipment — Optical comparator (20× lens), piece part drawing.

7.1 All measurements will be taken from the pilot holes referred to on the piece part print unless otherwise noted.

7.2 Line up the pilot holes at each end of the strip so that they are in the same horizontal plane. Center the pilot hole by rotating the comparator screen 45° (Figure 3). Ensure that the vertical and horizontal lines (now at 45°) are tangent to the edge of the pilot hole. Zero the readout, move the stage (horizontal travel) to the proper pilot hole at the end of the strip. Center the specified pilot hole on the strip. Read the horizontal readout for the strip pitch measurement.

8 Procedure for Pad Tilt (Z-Axis) (See Figure 4)

Equipment — Toolmaker's microscope (100× magnification), leadframe fixture.

8.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

8.2 All targets are to be located .005" (.127 mm) in from cut edge, ensuring that the target is not located on the rolled edge.

8.3 Focus the toolmaker's microscope on one target crossbow (A), zero focal height (z-axis).

8.4 Use the barrel micrometer to move to the second target (B) of the die-attach pad. Note traverse distance for extrapolation of specification. Refocus the microscope. The focal height (z-axis) difference is the tentative pad tilt measurement.

8.5 Repeat at targets shown in Table 1.

Table 1 Measurement Targets

	A	B
2 Tie bars	1	2
	3	4
3 or more	1	2
Tie bars	3	4
	1	3
	2	4

8.6 Pad tilt is worst case of tentative measurements taken per Table 1.

9 Procedure for Camber (See Figure 5)

Equipment — Camber fixture

9.1 Place the part to be measured in the camber fixture on the comparator table. Ensure the strip rests against the gage pins.

9.2 Place the horizontal center line on the strip edge then down at the aperture.

9.3 This dimension, less gage distance, is the camber measurement. Traverse the stage to bring the horizontal center line to the reference edge.

10 Procedure for Crossbow (See Figure 6)

Equipment — Toolmaker's microscope (100× magnification), leadframe fixture.

10.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

10.2 Focus the toolmaker's microscope on the center of top rail above the dambar (1). Zero focal height (z-axis).

10.3 Move to the center of the opposite rail above the dambar (2) and refocus. Average these two focal heights to establish the base zero focal height.

10.4 Move to the center of the dambar (3) and refocus. Focal height difference to base zero focal height is the crossbow measurement.

11 Procedure for Lead Planarity (See Figure 7)

Equipment — Toolmaker's microscope (100× magnification), leadframe fixture.

11.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

11.2 Focus the toolmaker's microscope on the center of the dambar (1), then zero the focal height (z-axis).

11.3 Move to the center of the opposite dambar (2) and refocus. Average these two focal heights to establish the base zero focal height.

11.4 Move to subject lead (3) and refocus .010" (.254 mm) back from the lead tip. Note z-axis difference to base zero focal height. Subtract measured coin depth to give actual planarity measurement. Repeat above procedure for all leads to be measured. Be sure to record the plus (+) or minus (–) sign for each reading.

12 Procedure for Downset (See Figure 9)

12.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

12.2 Focus the toolmaker's microscope at the location numbered in Column A of Table 2 and zero the focal height (z-axis). Move the workholder so that the corresponding location from Column B is under the microscope and refocus. The difference in readings is the downsetmeasurement.

Table 2

	A	*B*	*Destination*
P-dip	1	2	Bottom
	3	4	Top
Quad	1	2	1st Quad
	3	4	2nd Quad
	5	6	3rd Quad
	7	8	4th Quad

12.3 Repeat this for all tie bars indicated in Table 2.

12.4 All measurements must fall within the specification that applies.

13 Procedure for Coil Set (See Figure 10)

Equipment — Surface plate, gage pins

13.1 Place the strip on the surface plate, bond target side down, depressed pad up.

13.2 Slip gage pins under until you find the largest size that will fit under freely at possible locations shown. Pin diameter is the coil set measurement, noting the + or designation of coil set direction per Figure l0.

14 Procedure for Pad Planarity (Z-Axis) (See Figure 11)

Equipment — Toolmaker's microscope (100× magnification), leadframe fixture.

14.1 Fixture leadframe and establish z-plane as described in Section 5.5.

14.2 Move to the center of the die-attach pad (3) and refocus. The focal height difference is the pad planarity measurement.

15 Procedure for Burrs (X, Y, Z-Axis)

15.1 *Vertical Burrs* — (See Figure 12.)

Equipment — Toolmaker's microscope (400× magnification), leadframe fixture.

15.1.1 Fixture leadframe lead flat down and establish z-plane as described in Section 5, items 5a and 5b.

15.1.2 Focus the toolmaker's microscope on point A. Zero the focal height (z-axis).

15.1.3 Move to the top of the burr (Point B) and refocus the toolmaker's microscope. The focal height difference is the height of the vertical burr.

15.2 *Horizontal Burrs (X, Y-Axis)* — (See B, Figure 12.)

Equipment — Toolmaker's microscope (400× magnification).

15.2.1 Measure the horizontal burrs using the toolmaker's microscope in a similar manner to that described in 15.1.2 and 15.1.3.

15.2.2 Line up the cut edge (Point C) with the 0 center line on the toolmaker's microscope. Record the number on micrometer drum.

15.2.3 Move the stage to align the centerline with the end of the burr (Point D). The lateral movement (difference between start/end micrometer reading) will be the burr dimension.

16 Procedure for Pits, Slug Marks, Tool Marks (X, Y, Z-Axis), and Horizontal Burrs (See Figure 14)

16.1 *Depth (Z-Axis)*

Equipment — Toolmaker's microscope (400× magnification), leadframe fixture.

16.1.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

16.1.2 Focus the toolmaker's microscope on the base of the material near the defect, then zero the focal height (z-axis).

16.1.3 Move to the pit, slug mark, or tool mark. Refocus on the deepest portion. The focal height difference (z-axis) is the depth of the pit, tool mark, or slug mark.

16.2 *Surface Dimension, Length, Width (X,Y-Axis)*

Equipment — Toolmaker's microscope (400× magnification), leadframe fixture.

16.2.1 Fixture leadframe and establish z-plane as described in Section 5, items 5a and 5b.

16.2.2 Line up to edge of the pit, slug mark, or tool mark on the cross hair. Note the micrometer drum reading.

16.2.3 Move to the opposite side of the pit, slug mark, or tool mark. The lateral movement (difference between start/end micrometer readings) is the pit, slug mark, or tool mark surface dimension.

17 Procedure for X-Y Dimensional Measurement

Equipment — Surface lit optical comparator, true position overlay, metal-to-metal step gage.

17.1 Align overlay to travel axes within the resolution of the instrument.

17.2 Position leadframe to overlay by optical methods.

17.3 Overlay targets will now be positioned to inspect lead-flat location.

17.4 Pad outline will be positioned to inspect pad location.

17.5 Metal-to-metal clearance is evaluated by use of step gage against leadframe image on comparator screen.

17.6 Traverse to specified distance to inspect cutoff position.

18 Method for Coin-Depth Measurement (See Figure 15)

18.1 Bend sample lead up for accessibility.

18.2 Measure material thickness beyond lead flat.

18.3 Measure material thickness within lead flat. Difference between two readings is depth of coining.

19 Procedure for Measuring Lead Fatigue

Equipment — Automatic or manual lead fatigue tester with 8 oz. ± .5 oz. weight.

19.1 Clamp leadframe strip on dambar of test frame (see Figure 18).

19.2 Clamp 8 oz. weight on bottom-half of lead (see Figure 19). Clamp must be at least L/2 from lead shoulder.

NOTE: If lead is clamped too close to shoulder, a reduction in measured lead strength will result, caused by twisting of weight.

19.3 Turn on lead fatigue machine and set all counters at zero.

19.4 Activate lead fatigue machine such that clamp arm rotates through 90° ± 5° (see Figures 20 and 21). This will result in actual bend of lead slightly less than 90°, depending on strength of metal.

19.5 Set machine to a two-to-five second cycle. One cycle defined to be a 90° rotation and back.

19.6 Count number of complete cycles until metal lead breaks and weight drops into pan.

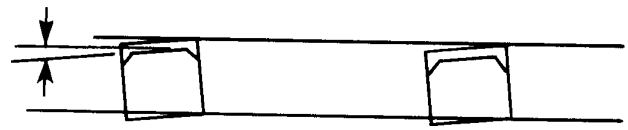


Figure 1
Lead Twist

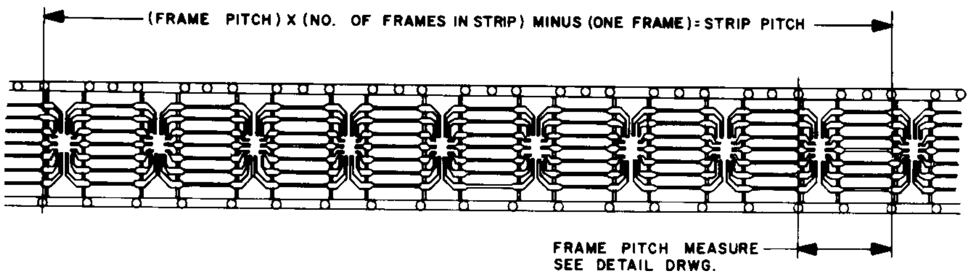


Figure 2
Strip Pitch

Strip Pitch

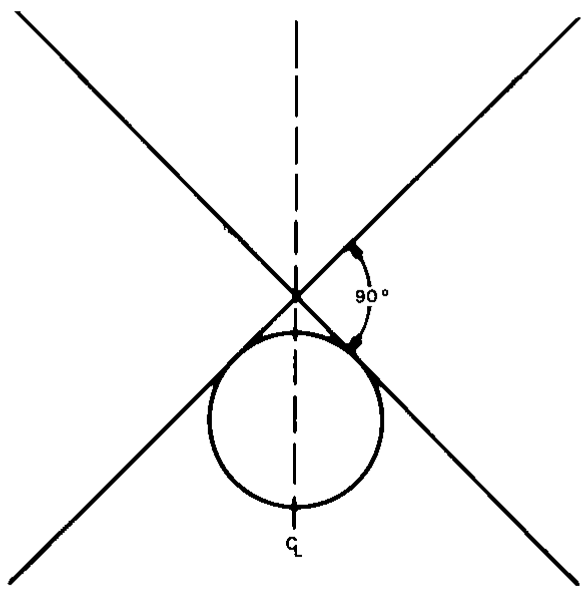


Figure 3
Pilot Hole

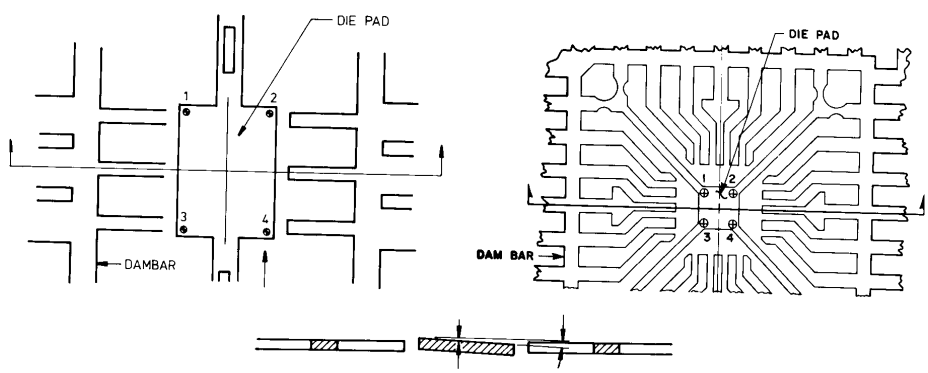
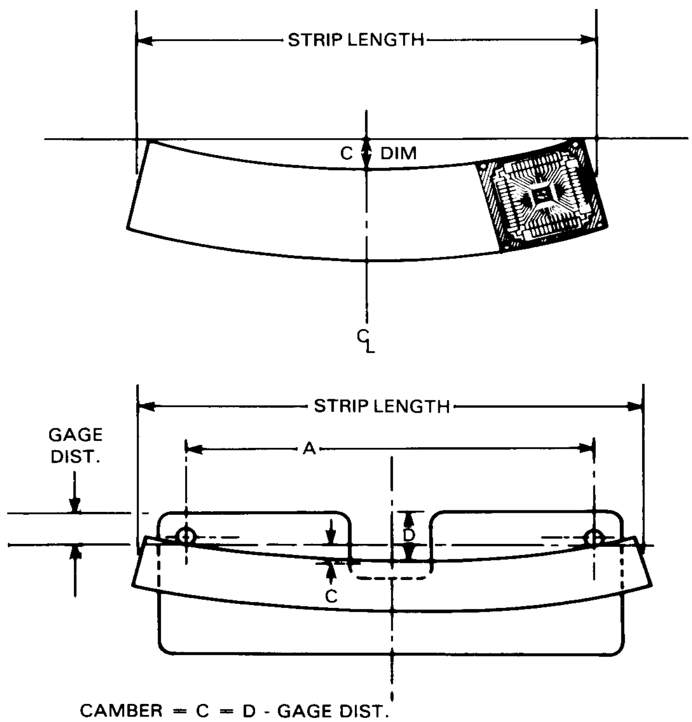


Figure 4
Pad Tilt



CAMBER IS REFERENCED TO DIMENSION A, NOT STRIP LENGTH.
STRIP LENGTH MUST BE LONGER THAN A.

Figure 5
Camber

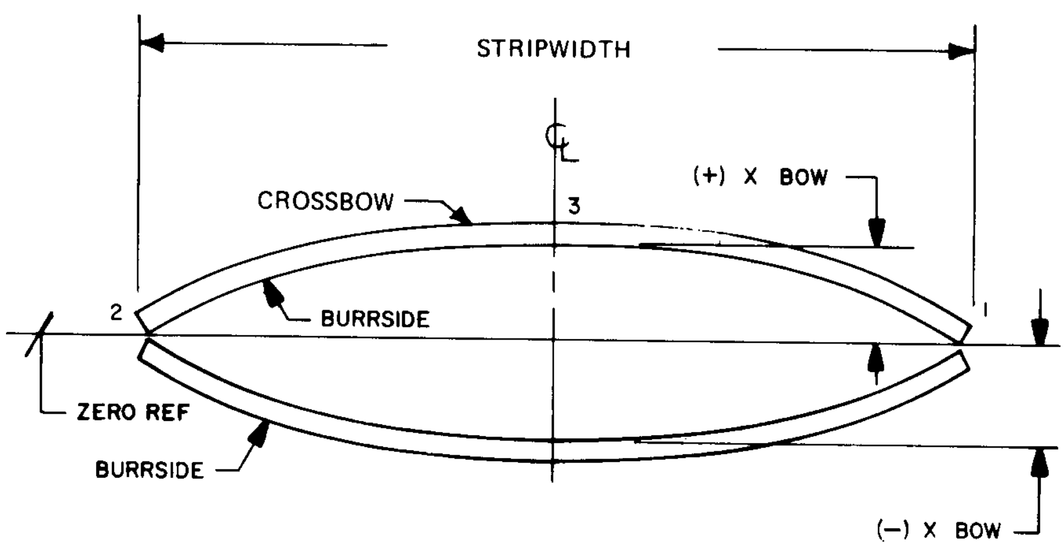


Figure 6
Crossbow

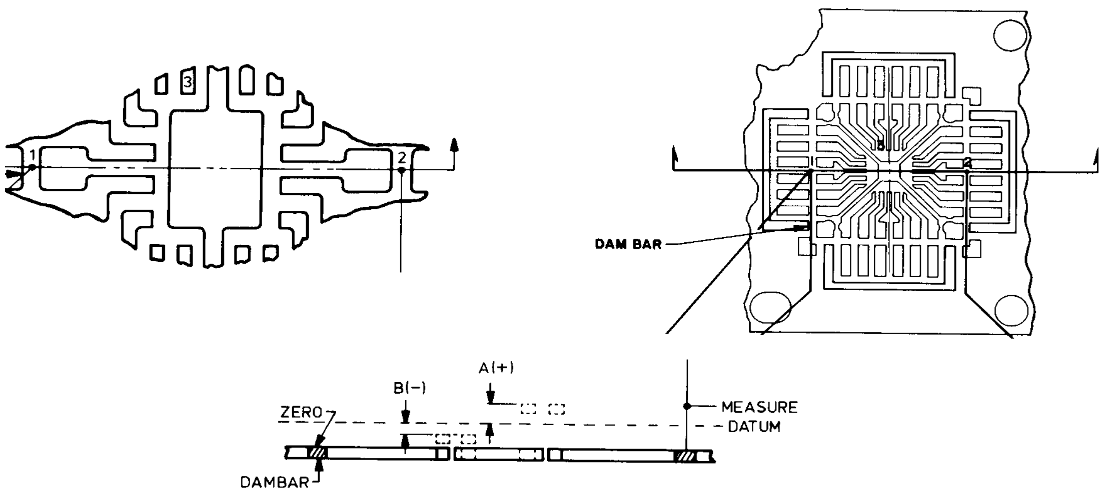


Figure 7
Lead Planarity

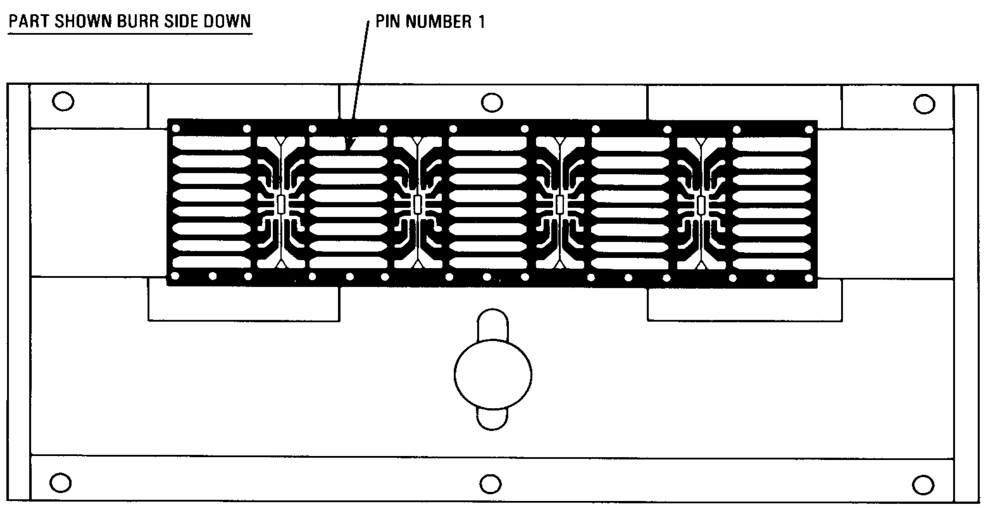


Figure 8
Strip Nominal Orientation

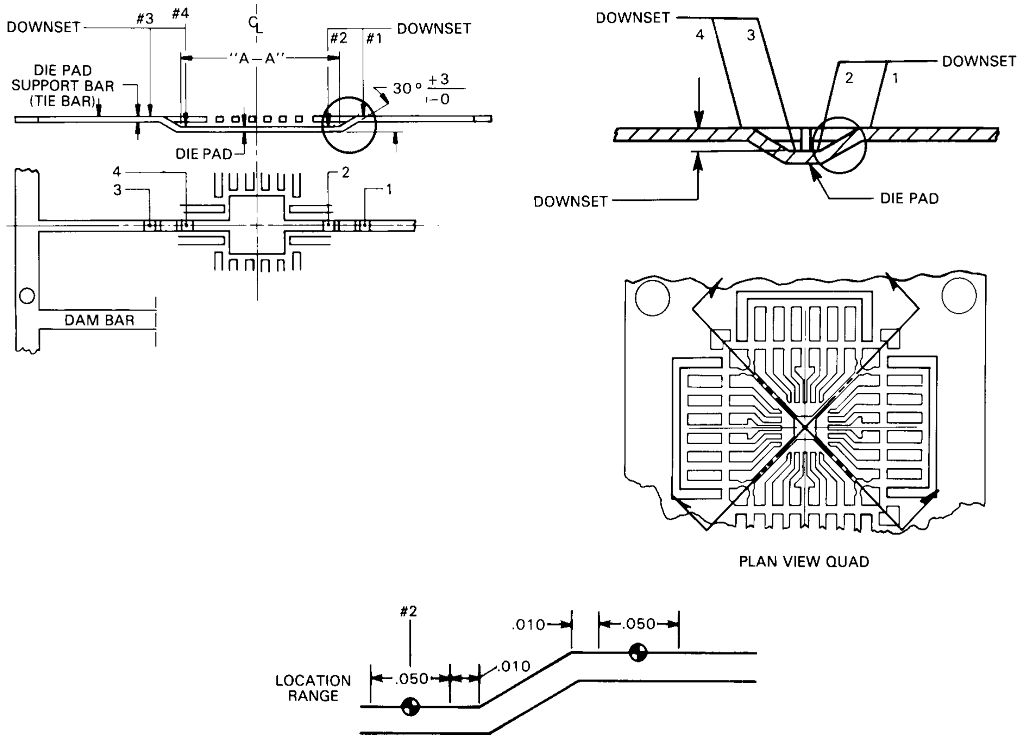


Figure 9
Downset

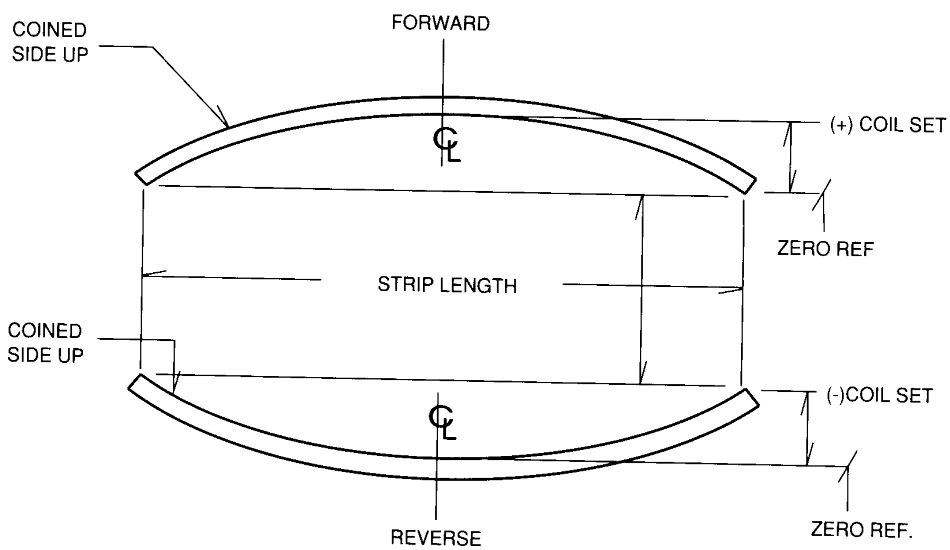


Figure 10
Coil Set

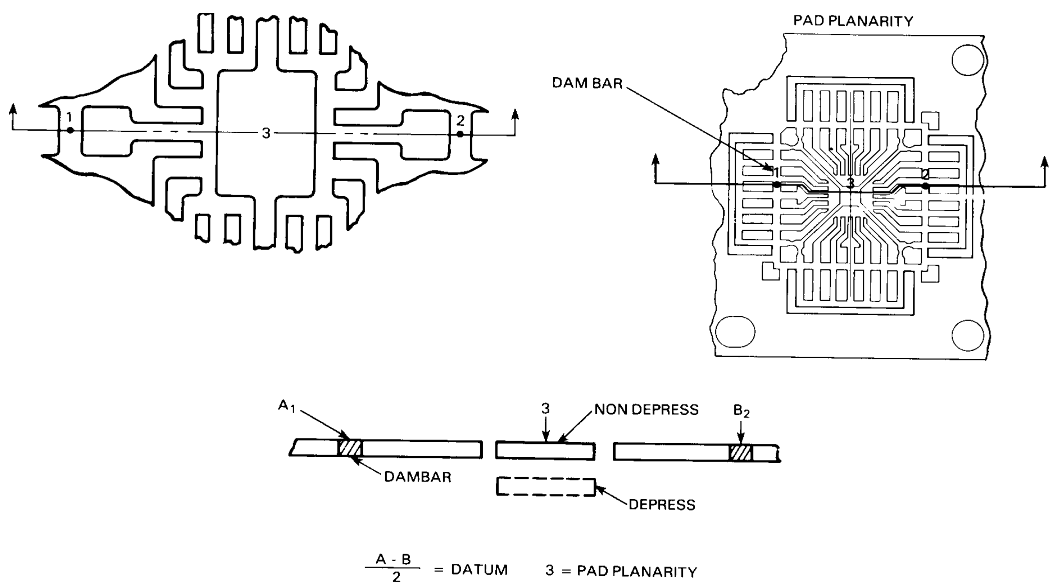


Figure 11
Pad Planarity

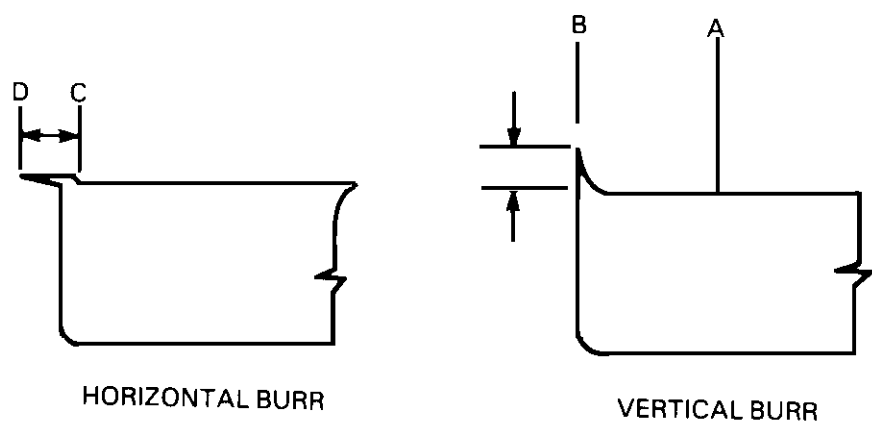


Figure 12
Cutting Burrs

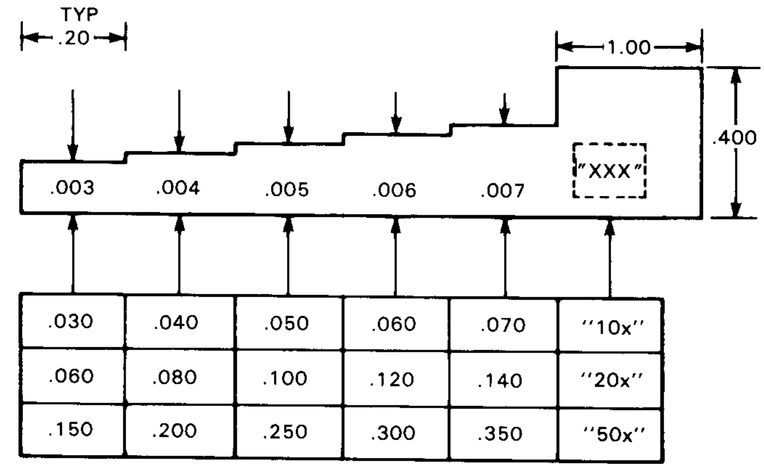


Figure 13
Step Gage

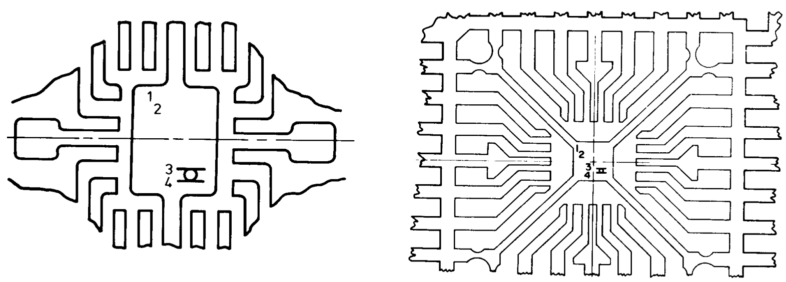


Figure 14
Pits, Slug Marks, Tool Marks

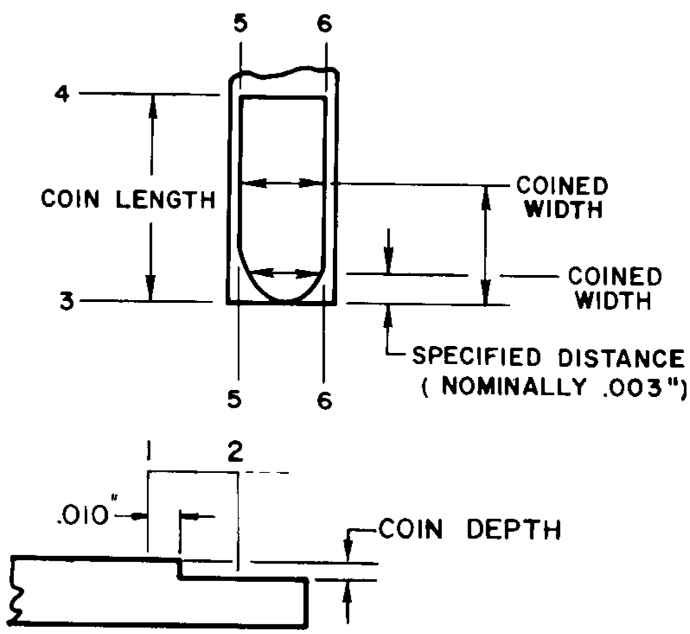


Figure 15
Coined Area

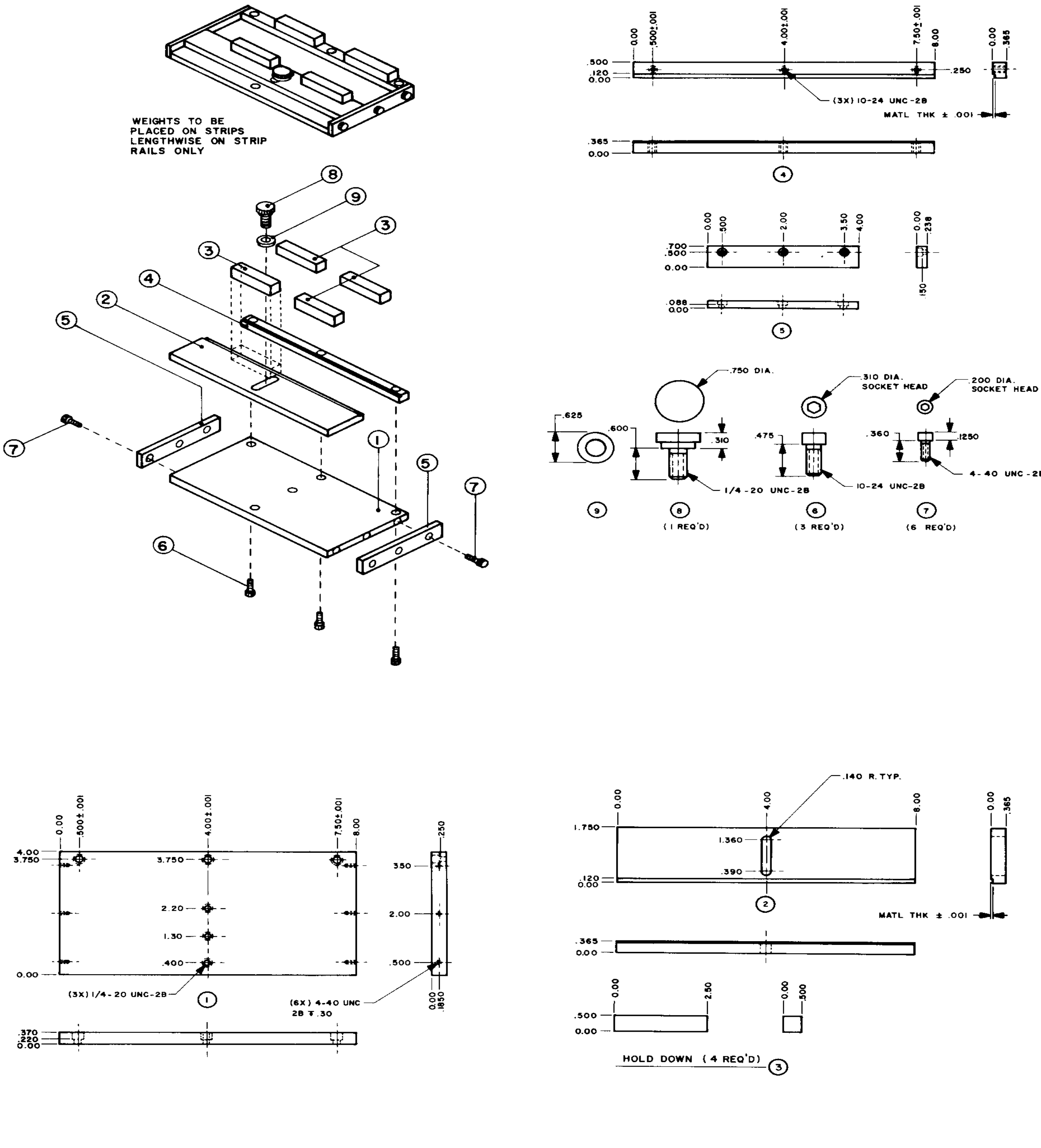


Figure 16
Universal Leadframe Fixture

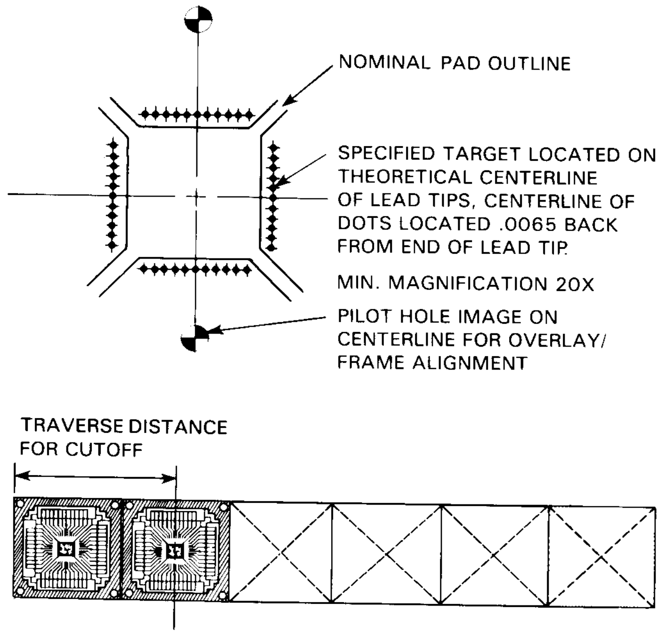


Figure 17
Lead Location

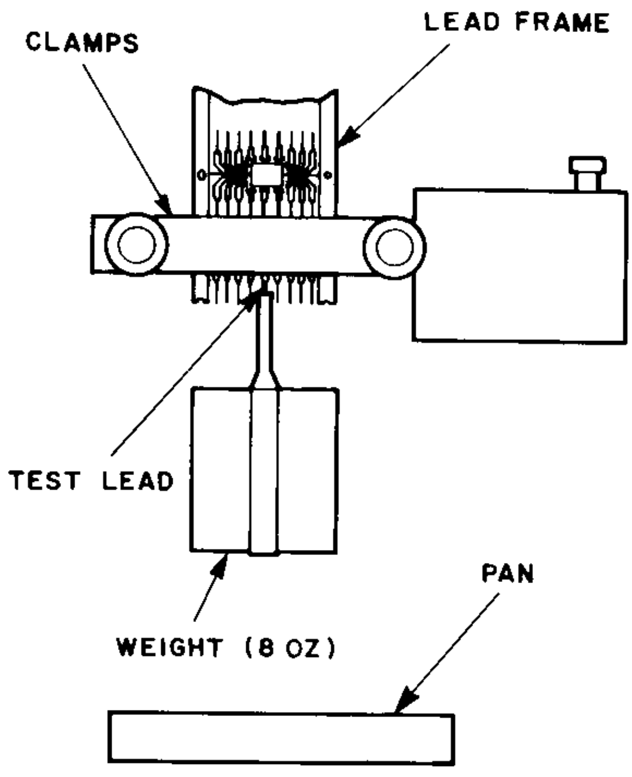


Figure 18
Frame Location on Lead Fatigue Testing Machine Front View

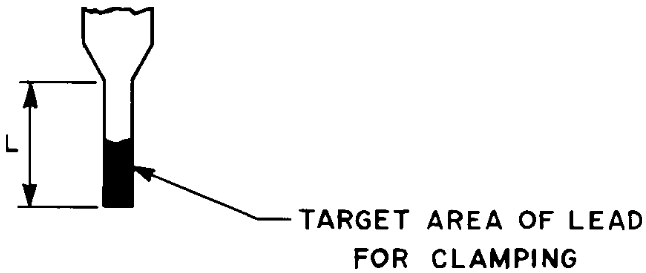


Figure 19
Frame Location on Lead Fatigue Testing Machine
Front View

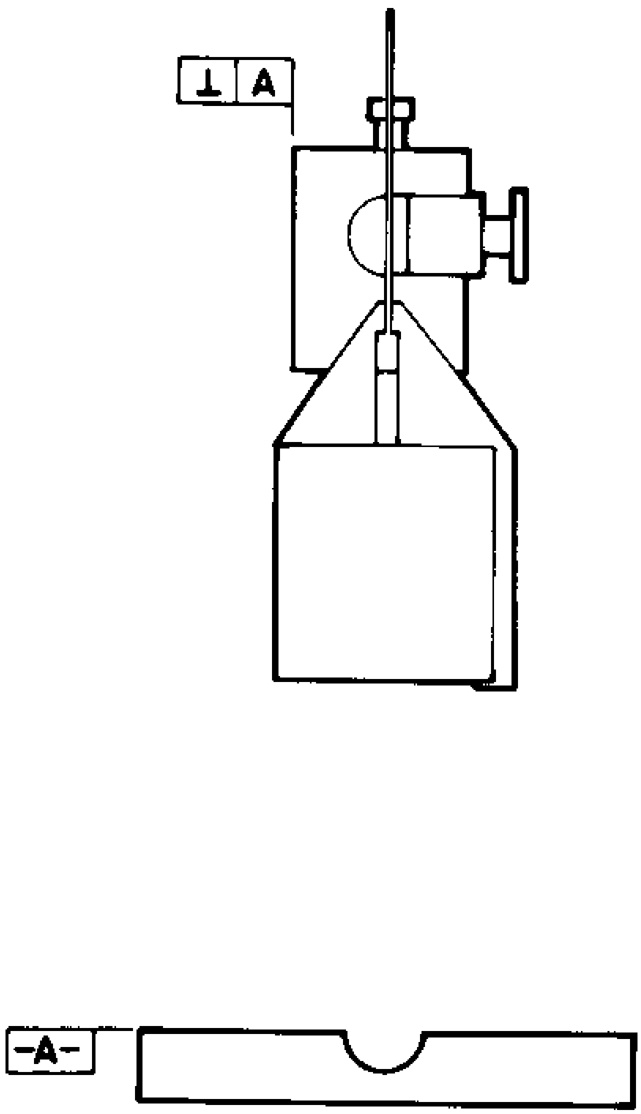


Figure 20
Frame Location on Lead Fatigue Testing Machine
Side View

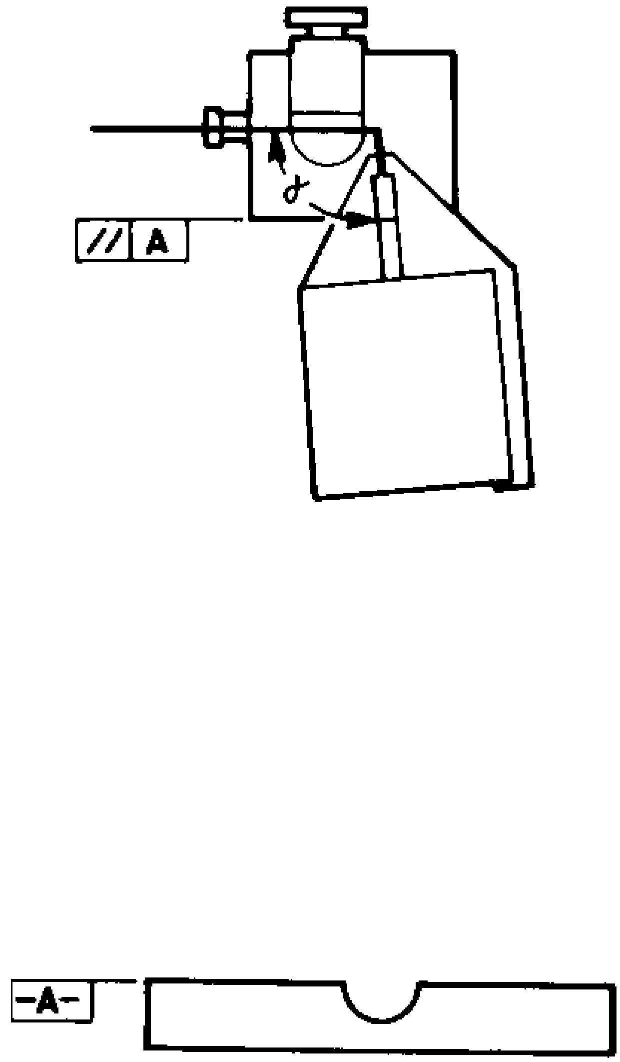


Figure 21
Frame Location on Lead Fatigue Testing Machine
Side View with 90° Rotation

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SEMI G11-88
RECOMMENDED PRACTICE FOR RAM FOLLOWER GEL TIME AND SPIRAL FLOW OF THERMAL SETTING MOLDING COMPOUNDS

1 Scope

This method describes a procedure for measuring the flow and gel characteristics of semiconductor grade transfer molding compounds using a ram follower device.

2 Applicable Documents[1]

ASTM D 3123 — Plastics, Molding, and Extrusions

3 Significance

3.1 The flow of a molding compound depends on the interaction of several variables, and is a measure of the combined characteristics of speed of gelation and melt viscosity of the particular compound under the specified conditions. The test is not a valid method for comparing the moldability of different compounds since a spiral flow test cannot duplicate actual molding conditions in different types of molds.

3.2 The moldability of thermosetting molding compounds has generally been defined by a single spiral flow number. The ram follower device follows graphically the molding compound as it melts and the rate of flow increases, as viscosity builds up due to resin polymerization, and as the flow of the compound ceases. Thus, it measures the gelation point of the compound, or the point where the material ceases to flow. This information can be an aid in characterizing the rheological behavior of the molding compound.

4 Apparatus

4.1 *Transfer Molding Press* — With a platen area sufficient to maintain a uniform mold temperature and having (1) a transfer piston pressure potential of 1000 psi on the material; (2) sufficient clamping pressure to prevent flashing of the molding compound; and (3) a minimum plunger speed of 25.4 mm (1 inch) per second without load. The pot diameter shall be 31.75 to 44.45 ± 0.635 mm (1.250 to 1.750 ± 0.025 inch) and the clearance between pot and ram shall be sufficiently small that flashing does not occur above the first sealing groove on the ram.

4.2 *Standard Spiral Flow Mold* — Per ASTM D 3123.

4.3 *Ram Following Apparatus* — Consisting of a displacement transducer attached to the transfer ram of the press in such a way as to accurately record its movement, suitable power supply for the displacement transducer, and a recorder capable of recording the signal from the displacement transducer and preferably having a chart speed of at least 10 mm per second. An optional velocity transducer can also be used as a means of directly measuring ram velocity and verifying the starting and ending of the flow process. In this case, a 2-channel recorder is needed.

4.4 *Thermocouple and Potentiometer* — Calibrated in the 149° to 177°C (300° to 350°F) range. (Calibration to be checked every six months.)

5 Test Conditions

5.1 *Molding Compound* — Refrigerated shipment and storage of some molding compounds is necessary. The molding compound is to be at room temperature before the container is opened. Once the compound has equilibrated to room temperature, the test should be run within 16 hours. Care must be taken to preserve the original moisture content. The material should be in powdered form, unless otherwise specified.

NOTE: Room temperature defined to be 23° ± 5°C.

NOTE: Refer to manufacturers' recommendations regarding shelf life differences which may exist between molding compounds.

5.2 *The Spiral Flow Mold* — Shall be clean and free from any mold release agents or lubricants. A standard mold cleaning compound can be used to insure mold cleanliness.

5.3 *Molding Conditions*

5.3.1 The temperature of the mold shall be measured using a thermocouple inserted in the mold. The ram shall be kept at the mold temperature. Molding temperature is to be as recommended by the material specification unless otherwise specified. Temperature must be maintained within ± 3°C (± 5°F) of the specified temperature.

NOTE: Flow duration is strongly influenced by temperature. For critical determinations, the temperature should be maintained as close to the nominal temperature as practical, preferably within ± 0.5°C (± 1°F).

5.3.2 The weight of the charge shall be adjusted to give a molded cull thickness of 3.302 ± 0.254 mm (0.130 ± 0.010 in.), excluding vertical flash.

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5.3.3 The free running ram speed shall be at least 25.4 mm/sec (1"/sec). Recommended speed is 100 ± 25 mm/sec into the pot and application of pressure on the charge shall not exceed 5 seconds.

5.3.4 The transfer pressure measured under the transfer plunger is to be 6.895 ± 0.177 mpa (1000 ± 25 psi) unless otherwise specified.

5.3.5 Unless otherwise specified, a minimum of 1.5 minutes close and cure time shall be used.

5.4 *Flow Length* — Read the spiral flow length directly from the molded specimen at the point of farthest continuous flow to the nearest 6.35 mm (0.25 in).

5.5 *Flow Duration* — The flow duration or gel time is defined as the time interval between the moment when the ram contacts the charge and the time the ram stops moving. The contact and gelation points are determined from the ram follower trace.

6 Procedure for Spiral Flow

6.1 Thoroughly clean the ram, pot, and mold of any cured compound, or other foreign matter.

6.2 Heat the mold and ram to within (± 3°C) of the specified temperature.

6.3 At the beginning of each series of tests and at each change of compound, check and set the transfer pressure using the force gage. The proper force gage setting can be determined from the formula:

$$F = \frac{\pi D^2 P}{4}$$

where F is the force in pounds, P is the desired pressure on the material in psi and D is the ram diameter in inches.

6.4 For each material change, make at least three “clean out” runs using the material to be tested before recording data. These runs may be used to determine the charge weight.

6.5 Weigh out the compound to the nearest 0.1 g as previously determined to yield a cull of 3.302 ± 0.254 mm (0.130 ± 0.010 in.).

6.6 Raise the ram, add the compound to the pot, and immediately activate the transfer cycle. If the recorder does not have a remote on-off that is activated by the cycle start, then it should be started before the cycle starts. After the ram motion ceases, the chart may be stopped.

6.7 Open mold and remove cured material. Measure cull thickness. If the cull is not within 3.302 ± 0.254 mm (0.130 ± 0.010 in.), discard run and repeat the test, adjusting the charge weight as necessary.

6.8 Read the flow length to the nearest 6.35 mm (0.5 in.).

6.9 Mark the point on the chart where the ram contacts the charge. This point is identified on the displacement trace as the point at which the rate of displacement initially changes.

6.10 Mark where the ram stopped moving. Caution should be exercised where significant flashing occurs. Count the number of divisions between the two points and divide by the chart speed. The result is the flow duration or gel time in seconds. Record this time to the nearest second.

6.11 If the optional velocity trace is available, mark point on the chart where the ram contacts the charge. This point is identified on the velocity trace as the point at which the transfer velocity transducer initially detects a significant reduction in velocity output.

6.12 Mark where the ram stopped moving. In order to detect the point of zero (0) velocity, the signal must be of sufficient magnitude. Count the number of divisions between the two points and divide by the chart speed. The result is the flow duration or gel time in seconds. Record this time to the nearest second.

6.13 If both displacement and velocity transducers are used, the starting and ending points should agree, therefore yielding the same gel time.

6.14 Repeat step 6.5 at least 3 times for repeatability.

7 Reporting of Results

7.1 Report the material designation and lot number.

7.2 Report the average and standard deviation of the flow length and gel time.

7.3 Report the temperature and pressure used for the tests.

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SEMI G13-88
STANDARD TEST METHOD FOR EXPANSION CHARACTERISTICS OF MOLDING COMPOUNDS

1 Scope

1.1 This specification describes the procedure for measuring the Coefficient of Thermal Expansion (CTE) and Glass Transition Temperature (T_g) of thermosetting molding compounds.

2 Apparatus

2.1 *Mold* — Producing 0.1–0.2" cubes or equivalent with an aspect ratio of 0.8–1.

2.2 *Transfer Press*

2.3 *Micrometer* — (0.0001 accuracy)

2.4 *Thermomechanical Analyzer* — (TMA) (Dupont Model 943, Perkin-Elmer TMS-1, or equivalent)

2.5 *Recorder and Power Supply* — (Dupont Model 990, Perkin-Elmer UUI, or equivalent)

2.6 *Oven* — (200° ± 5°C capability)

3 Materials

3.1 *Nitrogen (Gas)*

3.2 *Nitrogen (Liquid)*

4 Sampling

4.1 Mold samples according to product specifications.

4.2 Postcure the specimen in accordance with the material specification, and allow two (2) hours for cooling in a desiccator.

5 Procedure

5.1 Select a sample, making certain that all sides are flat and smooth. Measure the height of the sample with a micrometer to the nearest 0.0001 inch.

5.2 Place the sample into the TMA sample holder and bring the expansion probe down slowly until it just makes contact with the sample. Place sample on fixture per Instruction Manual. Add 3.0–5.0 grams to weight tray. Adjust the Linear Variable Differential Transformer (LVDT) to bring the recorder pen on scale. The LVDT is then zeroed with the zero switch. Readjust LVDT, if necessary, to bring pen on scale.

5.3 In a nitrogen atmosphere, heat the sample at a rate of 20°C/min. to its post-cure temperature.

5.4 Without changing LVDT or probe position, use liquid nitrogen to cool the sample to a temperature at least 100°C below the deviation from α_1.1.

5.5 Heat the sample at a rate of 5°C/min. to at least 200°C.

5.6 Calculate α(CTE), using the formula:

$$CTE = \left[\frac{(DL)(DY)}{(DT)(L)} \right]$$

where: $L_{(T+10°)}$=Length at Temperature 10° higher than temperature at which CTE is being measured. $L_{(T-10°)}$=Length at Temperature 10° lower than temperature at which CTE is being measured

ΔY = Y axis sensitivity in mils./in.

ΔT = change in temperature (20°C)

L = initial sample height (mils)

$$K = \frac{\text{LIT CTE}}{\text{EXP.CTE}} \text{ for aluminum standard}$$

5.7 Run two (2) samples for each lot and record the average.

5.8 An aluminum standard should be run to determine the calibration factor K for the Y (length) axis per 5.4 above, as necessary to insure the accuracy of the instrument's calibration.

5.9 Temperature readings should be calibrated periodically per manual instructions.

6 Report

6.1 Data is to include the orientation for which the sample is measured (e.g., perpendicular to flow).

6.2 CTE is reported as a function of temperature. CTE is to be reported every 10°C increments.

6.3 Report molding conditions and post-mold cure conditions.

6.4 Report specimen size.

NOTE: For many materials, the Glass Transition Temperature (Tg) may be determined by drawing tangents to the curve at the points of minimum and maximum slope. The point at which the tangents intersect is the T_g. The slopes of the lines are referred to as α 1 (below T_g) and α2 (above T_g).

7 References

ASTM D 696[1] — Coefficient of Linear Thermo Expansion Plastic

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SEMI G14-88
GUIDELINE FOR SPECIFYING THE DIMENSIONS AND TOLERANCES USED TO MANUFACTURE PLASTIC MOLDED DIP PACKAGE TOOLING

1 Preface

1.1 This document is a guideline for the ordering of tooling required to mold and form plastic molded DIP semiconductor packages. It is to be used by packaging engineers, mold manufacturers, and end-of-line tool makers as the basis for defining the limits of manufacturing tolerances.

2 Applicable Documents

2.1 This document specifically refers to:

JEDEC Publication No. 95[1] — JEDEC Registered and Standard Outline for Semiconductor Devices

2.2 Related information may also be found in:

MIL-STD-100[2] — General Engineering Drawing Practices

ANSI Y14.5[3] — Dimensioning and Tolerancing

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3 Selected Definitions — Product Criteria Tolerance Limits

3.1 *mismatch and offset* — Defined with respect to package only. All statements will be equally applicable in two (2) axes. All mismatch and offset measurements are made after molding and prior to trimming.

3.1.1 *cavity to frame offset* — Will be measured prior to any trimming operation. Offset will be defined as the difference in bottom cavity position with respect to a leadframe datum. The offset measurement will exclude leadframe tolerances. (See Figure 1.)

3.1.2 *top to bottom cavity mismatch* — Characterized by the fact that the top and bottom cavities in the mold are not aligned properly, causing a mismatch condition. The measurement shall be stated as the difference in the top cavity position relative to the bottom cavity position. (See Figure 2.)

3.2 *parting line protrusions* — Those plastic excesses which remain as a normal characteristic after normal trimming and molding operations. (See Figure 4.)

3.3 *top or bottom protrusions* — Those plastic excesses (includes ejector pin “crowns”) which remain as normal characteristics extending from the smooth surface of the molded package.

3.4 *variations in lead position* — Defined with respect to a 90° angle from the top or bottom of the smooth surface of the molded package as viewed on the end or side projections. (See Figure 4.)

3.5 *shoulder width intrusions/protrusions* — Any variations in straightness along the defined shoulder width caused by dambar removal. (See Figure 4.)

3.6 *package warpage* — Any non-linear dimensional change from the mold cavity characteristic, usually caused by incorrect package design or molding practices. (See Figure 5.)

3.7 *shoulder bend location* — Measured from the outermost point of the inner shoulder bend radius. (See Figure 6.)

4 Ordering Information

Purchase orders for tooling for plastic molded DIP semiconductor packages furnished to this specification shall include the following items:

1. A package tooling outline drawing showing all required dimensions listed in 5. Package surface finish to be included.
2. A list of any tolerance limits which differ from the SEMI standards detailed in 6.
3. The type of tooling steel required.
4. The type of leadframe material to be used, including a drawing.
5. The type of plastic to be molded (if proprietary, a statement of its shrinkage characteristics).
6. Sampling plan for compliance to 7.
7. The number of spare parts or expendable parts desired.
8. Type of molding press to be used, including power requirements.

1 JEDEC, 20001 Eye Street N.W., Washington, D.C. 20006

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

3 ANSI, 1430 Broadway, New York, NY 10018

9. Applicable leadframe drawing, showing all dimensions.

5 Dimensions

Drawing must show dimensions for the following items, if applicable:

1. Package length
2. Package width
3. Top cavity thickness
4. Bottom cavity thickness
5. Frame thickness
6. Top ejector pin locations from notch end
7. Bottom ejector pin locations from notch end
8. Ejector size (top and bottom)
9. Ejector depth (top and bottom), draft angle top side (bottom, side, and end)
10. End notch shape, depth, width, length
11. Pin 1 ID location from package center
12. Pin 1 ID shape and size
13. Corner radius on sides
14. Corner radius on ends
15. Lead spread (nominal) (see Figure 3)
16. Shoulder bend location
17. Shoulder width

6 Product Criteria Dimensional Tolerance Limits for DIPS

In recognition that every manufacturing process is subject to variation, the following list details the acceptable limits of this variation.

8 - 64 LEAD

(unless otherwise noted)

MISMATCH (see Figure 2)

	± 0.002"

PACKAGE/FRAME OFFSET (see Figure 1) (excludes leadframe tolerances)

8-64	± .002"

PROTRUSIONS (see Figure 4)

Parting line Side and End	0.006"(For reference use only)
Top Protrusion	0.001"
Bottom Protrusion	0.001"

INTRUSIONS (Ejector Pins)

	0.010" maximum

VARIATIONS IN LEAD POSITION (see Figure 4)

	0.007" True position non-accumulative

SHOULDER WIDTH PROTRUSIONS/INTRUSIONS (see Figure 4)

	+ 0.003"/- 0.002"

PACKAGE WARPAGE (see Figure 5)

Warp factor	2.5

SHOULDER BEND LOCATION (see Figure 6)

	JEDEC Publication No. 95 outline minus lead thickness. (Based on balanced plastic.)

LENGTH AND THICKNESS

	± 0.002" (see Figure 5) (Excluding protrusions)

7 Sampling

7.1 Samples used to determine compliance to Section 6 shall be determined between vendor and supplier.

8 Packaging

8.1 Tooling must be packaged in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided if tooling is to be shipped any great distance.

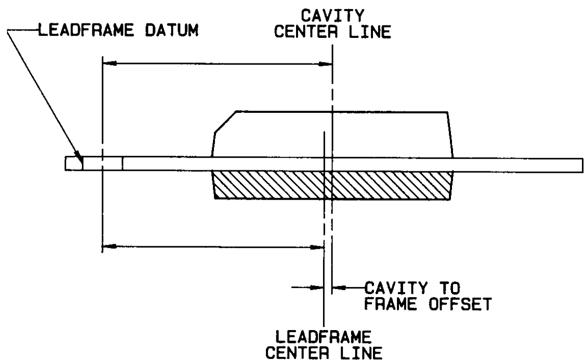

Figure 1

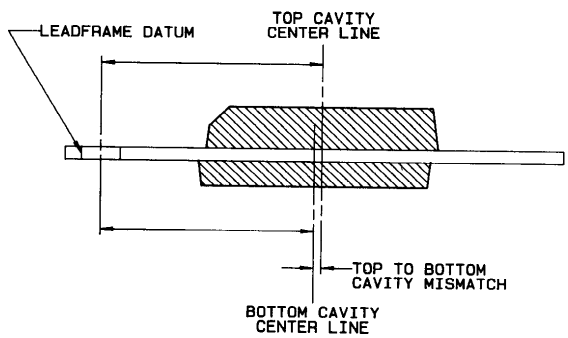

Figure 2

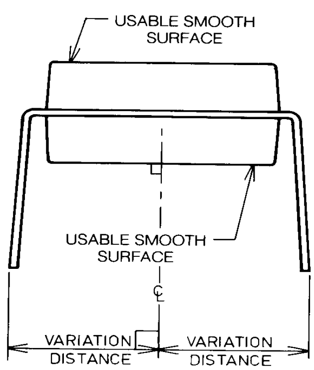

Figure 3
Variations from Nominal Lead Location

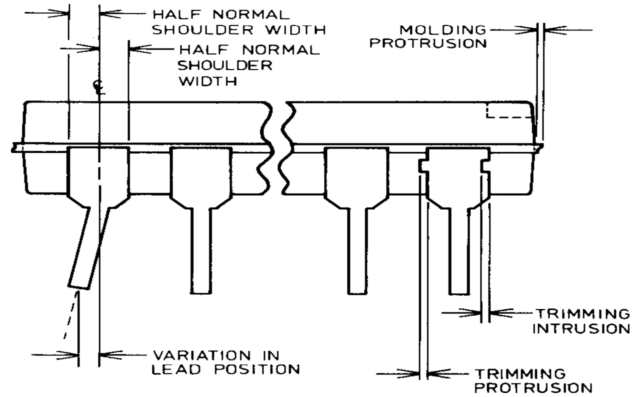

Figure 4
Parting Line Protrusions and Variation in Lead Position

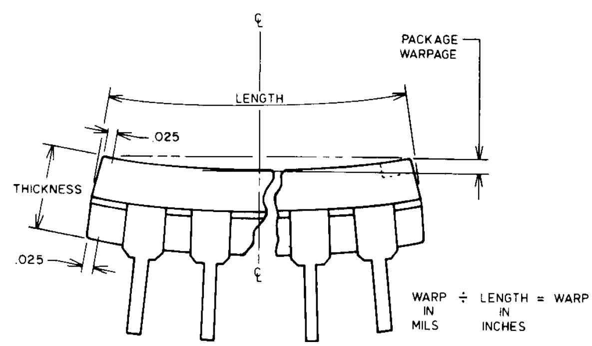

Figure 5
Package Warpage and Thickness

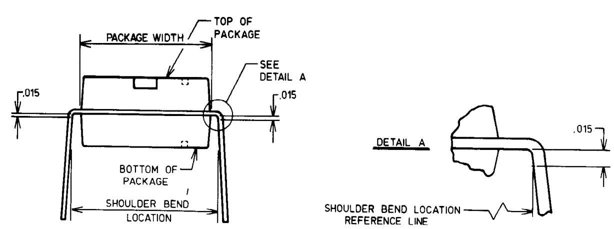

Figure 6
Shoulder Bend Location and Package Width

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SEMI G15-93
STANDARD TEST METHOD FOR DIFFERENTIAL SCANNING CALORIMETRY OF MOLDING COMPOUNDS

1 Preface

1.1 *Scope* — This document describes procedures for evaluating epoxy molding compounds by differential scanning calorimetry (DSC).

1.2 *Units* — This test method uses SI units.

2 Applicable Documents

2.1 *Reference Documents*

2.1.1 *ASTM Specifications*[1]

ASTM E 793 — Test Method for Heats of Fusion and Crystallization by Differential Scanning Calorimetry

ASTM E 967 — Practice for Temperature Calibration of Differential Scanning Calorimeters and Differential Thermal Analyzers

ASTM E 968 — Practice for Heat Flow Calibration of Differential Scanning Calorimeters

2.2 *Related Documents*

2.2.1 *ASTM Specifications*

ASTM E 473 — Standard Definitions of Terms Relating to Thermal Analyses

ASTM E 1269 — Test Method for Determining Specific Heat by Differential Scanning Calorimetry

3 Significance

3.1 DSC provides a rapid method at incoming inspection for evaluating molding compounds for consistency in subsequent molding processes.

4 Interferences

4.1 Very small quantities of material are used in the test. Lack of homogeneity may cause variable results.

4.2 *Gas Purge* — See Section 5.

4.3 *Sample Pans* — See Section 5.

5 Equipment

5.1 *Differential Scanning Calorimeter* — Capable of heating a sample from room temperature to 300°C with a controlled heating rate.

NOTE 1: Gas Purge Considerations — A reactive gas purge affects the material under test. A gas must be chosen that reflects the molding conditions normally used for that material (i.e., air or nitrogen).

5.2 *Sampling Pans for DSC Cell* — (Aluminum with crimping or hermetically sealed.) The pans must not be reactive to the sample under test.

5.3 *Process Controller* — Capable of collecting, calculating, and plotting the data resulting from the calorimeter.

5.4 *Analytical Balance* — Accuracy 0.001 mg.

5.5 *Tweezers and Microspatula*

6 Sampling

6.1 When the method is used to evaluate incoming molding materials, the sampling plan shall be agreed between supplier and customer.

6.2 Powdered or granular molding compounds shall be thoroughly mixed before sampling. If the compound is supplied in a preform, a small section may be cut off the preform with a blade.

7 Preparation of Samples

7.1 Protect samples from moisture absorption while awaiting test.

8 Equipment Setup and Calibration

8.1 *Temperature Calibration* — (Refer to ASTM E 967.)

8.1.1 Follow the manufacturer's operating manual to set up and run a calibration curve using indium (Melting Point 156.6°C) (see Figure 1).

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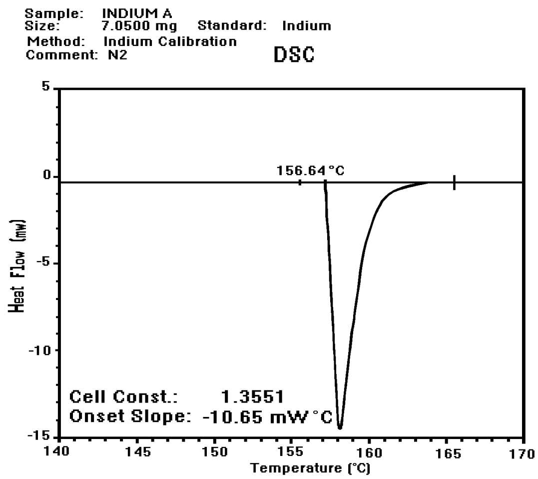

Figure 1

8.2 Determine the onset of melting and refer to the manual for the temperature correction method.

NOTE 2: There are other standard reference materials with higher melting points (see Table 1). Choose the standard which best matches the range of interest for the material under test.

Table 1

Reference Material	*Melting Point (°C)*
Indium	156.6
Tin	232.0
Zinc	419.6

8.2.1 Indium is also used to calibrate the Heat of Fusion for the DSC cell. Table 2 also lists the Standard Heat of Fusion for alternate materials that may be used.

Table 2

Reference Material	*Heat of Fusion (J/g)*
Mercury	11.44
Indium	28.42
Lead	23.16
Tin	59.23
Zinc	112.0

8.2.2 An area calculation of the indium melt provides the Heat of Fusion for DSC cell (see Figure 1).

8.2.3 Refer to the operating manual to obtain the cell constant and its correction.

9 Procedure

9.1 *Sample Size* — 2.000 to 12.000 mg may be used. 8.000 mg is commonly used. A small design of experiments exercise may be used to obtain the optimum sample size for the molding compound under test. Different compound chemistries may have an effect on the results if the sample size is not carefully chosen.

Place the sample in the sample pan.

9.2 Use an empty sample pan with its cover as a reference.

9.3 Carefully place the sample and reference pans onto their respective thermal sensors in the DSC cell. Seal the cell according to the manufacturer's instructions.

9.4 Set the heating rate to the optimum conditions determined for that instrument and the specific material under test. This rate will normally be between 5°C and 25°C per minute.

9.5 Activate the test sequence, and heat the sample from room-temperature to 300°C in order to obtain the DSC curve.

9.6 At the end of the run, remove the sample, and allow the DSC cell to cool to room-temperature in preparation for the next sample.

10 Results Report

10.1 The results report shall contain the following items:

10.1.1 Sample and equipment details

Molding material name/number

Sample weight

Equipment used

Heating rate

Calibration constant

Any pertinent information regarding material or equipment

10.1.2 *Scan Results* — The DSC curve shall indicate the following:

Maximum peak exotherm — units °C

Exotherm onset — units °C

Exotherm — units joules/gram

NOTE 3: The total exotherm is determined by an area calculation of the exotherm profile using a computer drawn baseline.

11 Accuracy and Precision (see ASTM E 968)

11.1 *Repeatability — Single Analyst* — The percent RSD over multiple days was determined to be 4.2%.

11.2 *Reproducibility — Multilaboratory* — The percent RSD was determined to be 8.2%.

12 Alternate Procedures

12.1 *Thermal Kinetic Modeling*

12.2 *Isothermal Differential Scanning Calorimetry* — There is a current lack of interlaboratory correlation to recommend this method.

NOTE 4: Manufacturers' literature may be used to obtain information on these methods.

SEMI G16-88
SPECIFICATION FOR DIMENSIONS AND TOLERANCES USED TO MANUFACTURE PLASTIC CHIP CARRIER TOOLING

1 Preface

This document is a guideline for the ordering of tooling required to mold and form plastic chip carriers. It is to be used by packaging engineers, mold manufacturers and end of line tool makers as the basis for defining the limits of manufacturing tolerances.

2 Applicable Documents

Related information may be found in:

MIL-STD-100[1] — Engineering Drawing Practices

ANSI Y14.5[2] — Dimensioning and Tolerancing

JEDEC Publication No. 95 [3] — Outline for Semiconductor Devices

3 Selected Definitions — Production Criteria Tolerance Limits

3.1 *mismatch and offset* — Defined with respect to package only. All statements will be equally applicable in two (2) axes. All mismatch and offset measurements are made after molding and prior to trimming.

3.1.1 *cavity to frame offset* — Will be measured prior to any trimming operation. Offset will be defined as the difference in bottom cavity position with respect to a leadframe datum. The offset measurement will exclude leadframe tolerances. (See Figure 1.)

3.1.2 *top to bottom cavity mismatch* — Characterized by the fact that the top and bottom cavities in the mold are not aligned properly, causing a mismatch condition. The measurement shall be stated as the difference in the top cavity position relative to the bottom cavity position. (See Figure 2.)

3.2 *Molded Protrusions*

3.2.1 *parting line protrusions* — Those plastic excesses which remain as a normal characteristic after normal molding, deflashing, trimming, and singulation. (See Figure 6.)

3.2.2 *top or bottom protrusions* — Those plastic excesses (includes ejector pin "crowns"), which remain as a normal characteristic extending from the smooth surface of the molded package.

3.3 *variations in lead location* — Defined with respect to a 90° angle from the top or bottom of the smooth surface of the molded package as viewed on the end or side projections. (See Figure 6.)

3.4 *lead shoulder protrusions and intrusions* — Any variations in straightness along the defined shoulder width caused by dambar removal. (See Figure 6.)

3.5 *package warpage* — Any non-linear dimensional change from the mold cavity characteristic, usually caused by incorrect package design or molding practices. (See Figure 3.)

3.6 *shoulder bend location* — Measured from the outermost point of the shoulder bend radius. (See Figure 4.)

3.7 *lead co-planarity* — Defined as the vertical lead position with respect to a reference plane measured after forming. (See Figure 5.)

4 Ordering Information

4.1 Purchase orders for tooling for plastic molded quad semiconductor packages furnished to this specification shall include the following items:

1. A package tooling outline drawing showing all required dimensions listed in Section 5. Package surface finish should be included.
2. A list of any tolerance limits which will differ from those detailed in Section 6.
3. The type of tooling steel required.
4. The type of leadframe material to be used.
5. The type of plastic to be molded (if proprietary, a statement of its shrinkage characteristics).
6. Sampling plan for compliance to Section 7.
7. The number of spare parts or expendable parts desired.
8. The type of molding press to be used, including power requirements.
9. Applicable leadframe drawing, including all dimensions.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

2 ANSI, 1430 Broadway, New York, NY 10018

3 JEDEC, 2001 Eye Street, N.W., Washington, D.C. 20006

5 Dimensions

5.1 Drawing must show dimensions for the following items, if applicable:

1. Package length
2. Package width
3. Top cavity thickness
4. Bottom cavity thickness
5. Frame thickness
6. Ejector top locations from cavity center line
7. Ejector bottom locations from cavity center line
8. Ejector size (top and bottom)
9. Ejector depth (top and bottom, draft angle top side, bottom side, and end)
10. End notch shape, depth, width, length
11. Pin 1 ID location from package center
12. Pin 1 ID shape and size
13. Corner radius or sides
14. Corner radius or ends
15. Lead spread (nominal)
16. Shoulder bend location
17. Shoulder width

6 Product Criteria Dimensional Tolerance Limits for PCCs

6.1 In recognizing that every manufacturing process is subject to variation, the following list details the acceptable limit of this variation:

CAVITY MISMATCH	0.004" (0.101 mm)

PACKAGE/FRAME OFFSET	0.002" (0.05 mm) (excluding leadframe tolerances)

MOLDED PROTRUSIONS

(see Figure 6)	
Parting line	0.006" (0.15 mm)
Top or bottom	0.001" (0.025 mm)

VARIATION IN LEAD POSITION

(see Figure 6)	0.004" (0.101 mm)

SHOULDER INTRUSIONS AND PROTRUSIONS

(see Figure 6) Intrusions	0.002" (0.05 mm)
Protrusions	0.003" (0.08 mm)

PACKAGE WARPAGE

Warp factor	2.5

LEAD CO-PLANARITY	0.003" (maximum)

EJECTOR PIN DEPTH	0.010" (maximum)

7 Sampling

7.1 Samples used to determine compliance to Section 6 shall be determined between vendor and supplier.

8 Packaging

8.1 Tooling must be packed in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided if tooling is to be shipped any great distance.

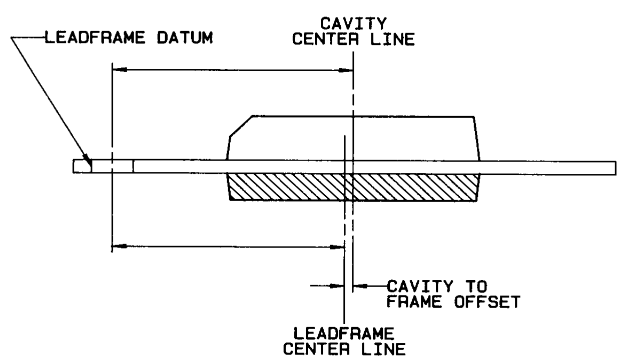

Figure 1

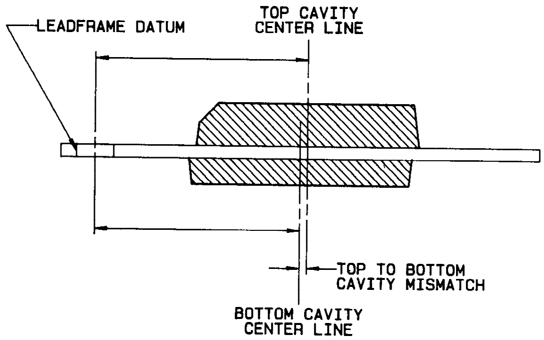

Figure 2

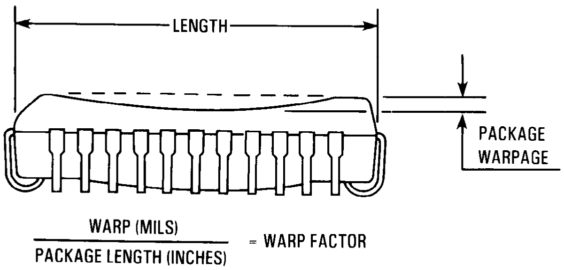

Figure 3

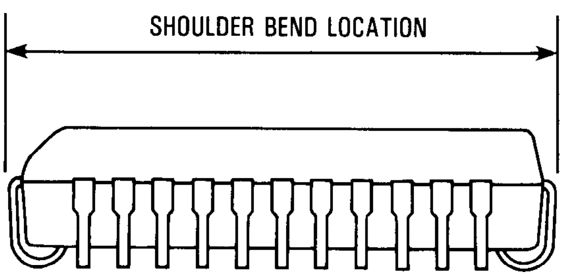

Figure 4
Shoulder Bend Location

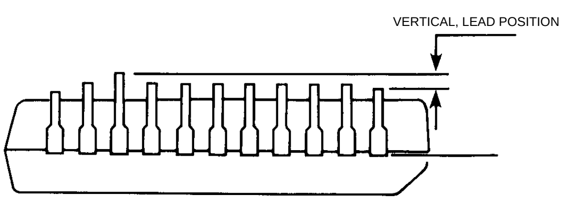

Figure 5
Coplanarity

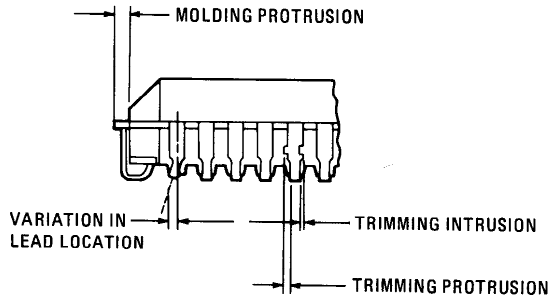

Figure 6
Parting Line Protrusion and Variation in Lead Locations — Vertical Lead Position

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G18-96
STANDARD FOR INTEGRATED CIRCUIT LEADFRAME MATERIAL USED IN THE PRODUCTION OF ETCHED LEADFRAMES

1 Purpose

This specification is for the leadframe material that will be shipped to an etch house. It is a leadframe specification, but deals with material aspects only.

2 Scope

This specification covers the special requirements for metal strip to be used to fabricate integrated circuit leadframes by etching.

3 Referenced Documents

3.1 *ASTM Specifications*[1]

ASTM B 601 — Recommended Practice for Temper Designations for Copper and Copper Alloys — Wrought and Cast

ASTM E 8 — Methods of Tension Testing of Metallic Materials

ASTM B 193 — Test Method for Resistivity of Electrical Conductor Materials

ASTM B 754 — Standard Test Method for Measuring and Recording the Deviations from Flatness in Copper and Copper Alloy Strip

4 Terminology

None.

5 Ordering Information

5.1 Orders for material under this specification shall include the following information:

1. Quantity of each size
2. Alloy name and number
3. Temper or mechanical properties
4. Dimensions: Thickness and width (see Section 7.3.)
5. How furnished: Coils and coil size or sheet size (see Section 10.)
6. Certification or test report requirements (see Section 11.)
7. Packaging and marking requirements (see Section 12.)

6 General Requirements

6.1 The materials covered by this specification shall conform to the requirements detailed in this specification, unless otherwise agreed upon by supplier and purchaser.

7 Dimension and Tolerances

7.1 The following tests shall be used to determine conformance or non-conformance to this specification.

7.2 *Etched Raw Materials Purchased in Coils* — Samples can be taken from the ID or OD of each coil. If the material does not conform to this specification, remove two wraps from the ID and OD of each coil and test for conformance again. Samples may also be taken from cut sheets.

7.3 *Thickness, Width, and Length* — The tolerances for thickness and width shall be as shown in Table 1. More restrictive tolerances than those shown in Table 1 or tolerances for other thicknesses and widths shall be agreed upon between user and supplier.

Table 1 Thickness and Width Tolerances

Thickness	*Tolerance*
0.005 - 0.010" (0.127 – 0.254 mm)	± 0.0003" (0.008 mm)
0.015" (0.381 mm)	± 0.0004" (0.010 mm)
0.020" (0.508 mm)	± 0.0005" (0.013 mm)
Width	*Tolerance*
2.000 - 8.000" (25.4 - 203.2 mm)	± 0.005" (0.127 mm)
> 8.000" (> 203.2 mm)	to ± 0.010" (0.254 mm)

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

7.4 *Camber (Edgewise Curvature)* — Camber is not critical for material used in the etching process provided the end product (leadframe strip) meets its requirements; ± 0.0625" (1.6 mm) in 36" (91 cm) is considered acceptable.

7.5 *Coil Set* — A three foot long sample shall be obtained from each coil supplied. The measured coil set shall not exceed 1.500" (38.1 mm).

7.6 *Edge Burrs* — Undesirable and, if present, their height shall not exceed 10% of the metal thickness.

7.7 *Crossbow (Dish)* — Crossbow is a function of slitting. Because material for the photo chemical process is generally about 16–20" wide, crossbow is not a critical problem. However, the final product (leadframe strips) must meet maximums, as suggested in Table 2, and crossbow in the sheet form, shall not be present to the extent that this specification cannot be met.

Table 2 Maximum Crossbow

Specified Strip Width	*Maximum Crossbow*
Up to 1.000" (25.4 mm), incl.	0.003" (0.076 mm)
Over 1.000" (25.4 mm)	0.005" (0.127 mm)

7.8 *Oil Can* — When any part of a sheet is pushed, but not bent, and it snaps into a different position or plane other than the original position with no further pressure, oil canning is present. Oil canning shall not be present on materials being used in the photo chemical process (etching) to the extent that the maximum crossbow specification on the finished product (see Table 2) cannot be met.

8 Surface Finish

8.1 The material shall be commercially free of surface imperfections such as pits, nicks, dents, gouges, scratches, laminations, or inclusions.

8.2 Surface defects less than 0.0003" (0.0076 mm) in depth will be acceptable unless otherwise agreed upon between the supplier and purchaser.

APPLICATION NOTE: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

9 Corrosion

9.1 Visual inspection shall be used to determine if objectionable surface oxides are present which would render the product unusable for the intended application. Objectionable conditions, if present, should be reported to the supplier within 60 days after receipt of the material.

9.2 There shall be no visible rust on the surface of Alloy 42 material.

10 Coils

10.1 Unless otherwise specified, coils shall be supplied with an inside diameter that provides for good packing practice without resulting in excessive coil set.

11 Certifications or Test Reports

11.1 Requests for certifications or test reports shall be made at the time of order entry or contract agreement. They shall be furnished by the manufacturer within one week of date of shipment.

11.2 When certifications are required, the following information shall be supplied as a minimum:

1. Vendor name
2. Purchase order number
3. Vendor order number
4. Alloy name and number
5. Chemical analysis
6. Temper designation (reference only)
7. Tensile strength
8. Elongation percent in 2"
9. Electrical conductivity % IACS (for copper base alloys only)

11.3 In the event of a disagreement between supplier and purchaser, an independent test shall be conducted on the strip to verify the data provided in the certification.

12 Packaging and Marking

12.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by a common carrier for transportation at the lowest applicable rate.

12.2 The material shall be suitably packaged to protect from condensation, contamination, etc., and to afford protection from the normal hazards of transportation.

12.3 Each shipping unit shall be legibly marked with the purchase order number, alloy name or number, temper, size, gross and net weight, and name of the supplier. The specification number shall be shown when specified on the purchase order.

12.4 Any special packaging or shipping requirements shall be agreed upon between supplier and purchaser at the time of purchase.

13 Basis for Rejection

13.1 For the purposes of determining conformance with the requirements prescribed in the specification, any measured value outside the specified limiting values shall be cause for rejection.

13.2 If objectionable material is found and rejected, samples of the questionable material, with the defects identified and marked, should be sent to the supplier along with information as to order number, quantity originally received, date received, and quantity rejected. Rejected material should be held with adequate protection and identification by the purchaser for a reasonable amount of time, pending investigation by the supplier.

SEMI G19-0997
SPECIFICATION FOR DIP LEADFRAMES PRODUCED BY ETCHING

1 Preface

This specification is a guideline for production of DIP leadframes for plastic molded semiconductor packages produced by the etching process. It is a design guideline for packaging engineers, etchers, and mold manufacturers and has been developed to meet the requirements of automatic bonders.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI G18 — Specification for Integrated Circuit Leadframe Material Used in the Production of Etched Leadframes

SEMI G10 — Standard Method for Mechanical Measurement of Plastic Package Leadframes

2.2 *Other Document*

PCM1 D-300[1] — Standard Specification

3 Selected Definitions

burrs and protrusions — Fragments of excess material, either horizontal or vertical, attached to the lead frame.

camber — Curvature of the leadframe strip edge (see Figure 1).

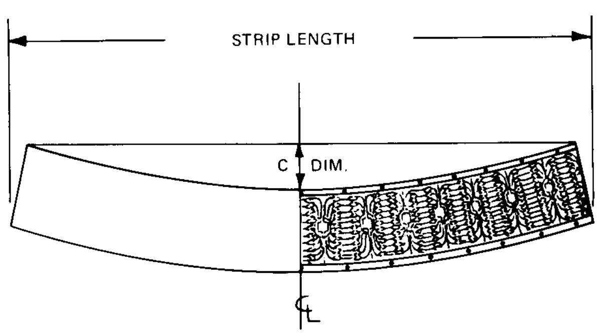

Figure 1
Camber

coil set — Longitudinal bowing of the leadframe (see Figure 2).

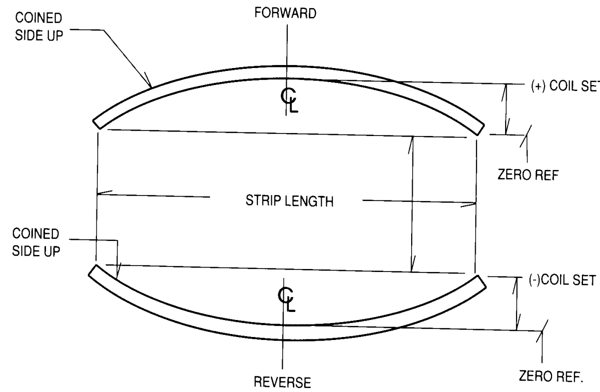

Figure 2
Coil Set

compensation — Changes made in the dimensions on the master artwork other than those specified on the engineering artwork that allow for the process variables (i.e., etch factor, undercut).

crossbow — Transverse bowing of the leadframe (see Figure 3).

(enter graphic when available)

Figure 3
Crossbow

etch factor — The ratio of etched depth to the lateral etch or undercut (see Figure 4).

1 Photochemical Machining Institute, 4113 Barberry, Lafayette Hills, PA 19444

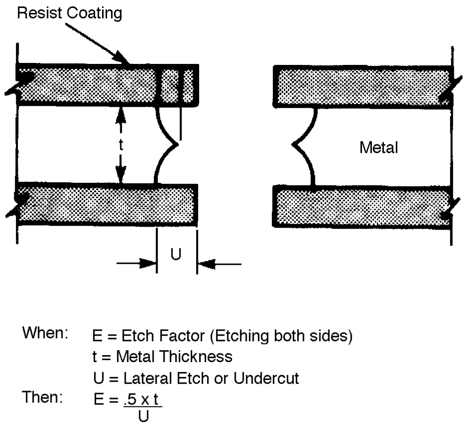

Figure 4
Undercut and Etch Factor

functional area — The die attach pad and wire bond (lead tip) area.

lateral etch or undercut — The allowable bevelled edge caused by the leadframe etchant attacking the metal laterally as well as vertically (see Figure 5).

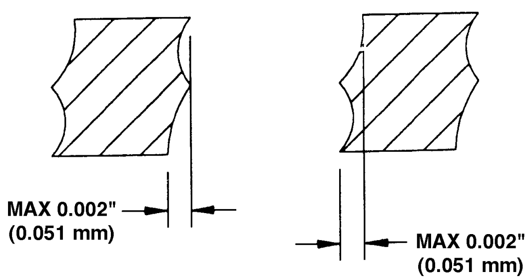

Figure 5
Overetching

lead twist — Angular rotation of the bond fingers (see Figure 6).

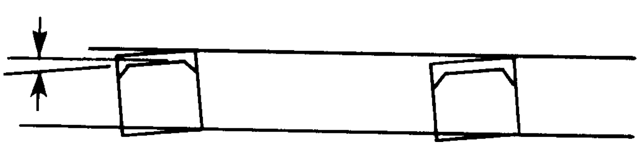

Figure 6
Lead Twist

offset alignment accuracy — The top to bottom alignment accuracy of the etched leadframe operation (see Figure 7).

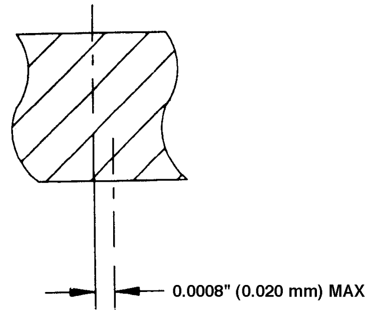

Figure 7
Etched Offset

pits — Shallow surface depressions or craters in the leadframe material (see Figure 8).

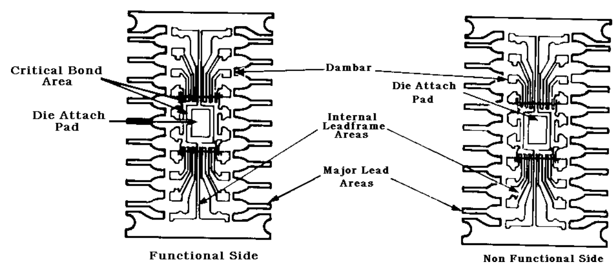

Figure 8
Pits

resist breakdown — Etching under the edges of the resist causing more than a standard undercut.

undercut — Bevelled edge caused by the etchant attacking the metal laterally as well as vertically (see Figure 4).

4 Ordering Information

Purchase orders for leadframes for plastic molded semiconductor packages furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Material
3. Number of leads
4. Material certification
5. Number of units/strip
6. Plating requirements
7. Packaging and marking (see Section 8)

5 Dimensions

See applicable leadframe drawing as referred to in the ordering information.

6 Defect Limits and Parameters (see SEMI G10 to Measure)

6.1 *Minimum Flat Wire Bonding Area* — 0.203 mm (0.008") or 80% of nominal lead width, whichever is greater in width and 0.635 mm (0.025") in length. Undercut is an unavoidable process of etching. The above parameters are applicable only so long as the flat surface area is obtainable using the formula of Figure 4. The "radiusing" effect of the etching process will round off the tips and, therefore, the length of the flat area should be measured by starting back from the tip 0.254 mm (0.010").

NOTE: 0.008" flat is desirable. In order to achieve 0.008" flat, on 0.010" thick material, it is necessary to have a design width of 0.022" center to center, giving a 0.012" wide lead and 0.010" wide space.

6.2 Horizontal Lead Spacing and Location

6.2.1 Spacing between leads to be 0.152 mm (0.006") minimum after plating.

6.2.2 Metal to metal clearance (Dimension "W" Figure 7) minimum clearance shall be the greater of 0.152 mm (0.006") or the drawing dimension "W" minus 0.102 mm (0.004"). In determining dimension "W," the tolerance limits (max. vs. min.) shown on the drawing shall be used in the calculation.

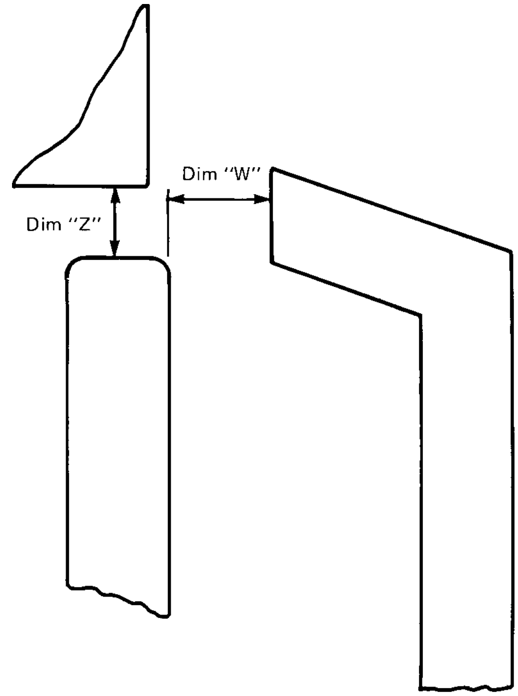

Figure 7
Metal to Metal Clearance

6.3 *Lead Twist* — Not to exceed 2° 30' or 0.0004" (0.010 mm) per 0.010" (0.254 mm) of lead width.

6.4 *Die Attach Pad Tilt & Flatness*

6.4.1 *Tilt* — 0.001" (0.025 mm) maximum per 0.100" (2.54 mm) of length or width in the undepressed state and 0.002" (0.050 mm) max per 0.100" (2.54 mm) of length or width in the depressed state when measuring from corner to corner. The corners are defined as 0.005" (0.127 mm) from each edge.

6.4.2 *Flatness* — 0.0004" (0.010 mm) maximum difference per 0.100" (2.54 mm) of length or width when measuring from center to average of four corners. The corners are defined as 0.005" (0.127 mm) from each edge.

6.5 *Die Attach Pad Offset or Depression* — (if applicable) — ± 0.002" (0.050 mm) as measured from the center of the pad to a point on the bar pad support strip. The nominal recommended offset is 0.015" (0.381 mm).

6.6 *Lead and Die Attach Pad Coplanarity* — See SEMI G10 for measurement procedure.

6.6.1 *Lead Planarity* — The lead tips as measured in the center of the flat wirebonding area must be within the following tolerances of the "Z" plane. Use Table 1 tolerances for untaped frames and Table 2 tolerances for taped frames.

Table 1 Tolerances for Untaped Frames

No. of Leads	*Strip Width*	*Lead Tip Coplanarity*
8 - 16	600"–1.000" (15.24 mm–25.4 mm)	+ 0.004"/-0.004" (0.101 mm)
18 - 22	1.070"– 1.020" (27.18 mm–25.91 mm)	+ 0.005"/-0.005" (0.127 mm)
22	1.270"–1.300" (32.26 mm– 33.02 mm)	+ 0.0065"/-0.0065" (0.165 mm)
24	1.470"–1.500" (37.34 mm–38.10 mm	+ 0.0075"/-0.0075" (0.191 mm)
28	1.670"–1.700" (42.42 m–43.18 mm)	+ 0.0085"/-0.0085" (0.216 mm)
40 & up	2.270"–2.300" (57.66 mm–58.42 mm)	+ 0.015"/-0.007" (+0.381 mm/-0.178 mm)

Table 2 Tolerances for Taped Frames

No. of Leads	*Strip Width*	*Lead Tip Coplanarity*
28	1.670"–1.700" (42.42 mm–43.18 mm)	+0.007"/-0.005" (+187 mm/-0.127 mm)
40 & up	2.270"–2.300" (57.66 mm–58.42 mm)	+0.010"/0.005" (+0.254 mm/-0.127 mm)

NOTE: It is recommended that 40 leads and more be taped prior to bonding.

6.6.2 *Die Attach Pad Planarity*

6.6.2.1 The die attach pad when measured at the center must be within the tolerances of the "Z" plane as shown in Table 3.

Table 3 Pad Planarity Tolerances

No. of Leads	*Pad Planarity*
8 - 16	+0.003"/-0.005" (+0.076 mm/-0.127 mm)
18 - 20	+0.006"/-0.003" (+0.152 mm/-0.076 mm)
22 - 40	+0.006"/-0.003" (+0.152 mm/-0.076 mm)
48	+0.006"/-0.003" (+0.152 mm/-0.076 mm)
64	+0.006"/-0.003" (+0.152 mm/-0.076 mm)

6.6.2.2 Die attach pads utilizing the four point tie design (support bars to both dambars) shall meet ± 0.002" (0.051 mm) of the "Z" plane.

6.7 *Material* — Thickness shall be as shown in Table 4.

Table 4 Material Thickness

Parameters	0.010" (0.254 mm)	0.015" (0.381 mm)	0.020" (0.508 mm)
Thickness	± 0.0003" (0.0076 mm)	± 0.0004" (0.0102 mm)	± 0.0005" (0.0127 mm)
Strip Width			
2.0" (50.8 mm)	± 0.002" (0.051 mm)	± 0.002" (0.051 mm)	± 0.002" (0.051 mm)
2.0" (50.8 mm)	± 0.003" (0.076 mm)	± 0.003" (0.076 mm)	± 0.003" (0.076 mm)

6.8 *Crossbow* — Shall not exceed the dimensions given in Table 5. If a certain width is not shown, 1% of the leadframe width shall apply.

Table 5 Maximum Crossbow Dimensions

No. of Leads	*Strip Width*	*Max. Crossbow*
8	0.600" (15.24 mm)	0.005" (0.127 mm)
14 - 16	0.970"/1.00" (24.64 mm/25.40 mm)	0.005" (0.127 mm)
18	1.070"/1.100" (27.18 mm/27.94 mm)	0.005" (0.127 mm)
20	1.170"/1.200"(29.72 mm/30.48 mm)	0.010" (0.254 mm)
22	1.270"/1.300"(32.26 mm/33.02 mm)	0.010" (0.254 mm)
24	1.470"/1.500"(37.34 mm/38.10 mm)	0.010" (0.254 mm)
28	1.670"/1.700"(42.42 mm/43.18 mm)	0.010" (0.254 mm)
40	2.270"/2.300"(56.66 mm/58.42 mm)	0.010" (0.254 mm)
48+	2.400"/2.670"(60.96 mm/67.82 mm)	0.010" (0.254 mm)

6.9 *Progression* — Progression over the (# of) steps in the strip should be within ± 0.051 mm (0.002") and non-cumulative.

6.10 *Pits (Indentations)* — Pits and imperfections cannot affect leadframe strength regardless of size (see Figure 6).

6.10.1 *Critical Bond Area* — 0.635 mm (0.025") of the finger tips + 0.508 mm (0.020") border of die attach pad; nothing greater than 0.0005" (0.0127 mm) diameter × 0.0076 mm (0.0003") in depth; not more than 1 pit.

Application Note: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

6.10.2 *Die Attach Pad* — Functional side inside 0.508 mm (0.020") border; nothing greater than 0.127 mm (0.005") diameter × 50% metal thickness in depth; not more than 2 pits.

6.10.3 *Die Attach Pad* — Nonfunctional side; nothing greater than .508 mm (0.020") × 50% of metal thickness in depth; not more than 3 pits; cannot affect leadframe strength regardless of size (i.e., pit cannot be located within 0.127 mm (0.50") of pad support bar attachments).

6.10.4 Internal leadframe areas where design width is 0.635 mm (0.025") or more, must be less than 0.381 mm (0.015") × 50% metal thickness in depth; if design width is less than 0.635 mm (0.025"), area must be 50% of design width. Cannot affect leadframe strength regardless of size.

6.10.5 *Major Lead Areas (outside dambar)* — Nothing greater than 0.127 mm (0.005") × 50% of metal thickness in depth; nothing greater than 0.254 mm (0.010") on shoulder above taper. Cannot affect leadframe strength regardless of size.

6.10.6 *Dambar* — Pit cannot extend all the way across the bar.

6.11 *Mold Locating Holes* — Conventional mold damage design dictates that gating is opposite pin #1; therefore, the mold locating holes must be in the rail adjacent to pin #1. In order to minimize gate flashing between the mold and the rail edge, a specific tolerance of ± 0.051 mm (0.002") is required from the centerline of the mold hole to the opposite rail edge.

6.12 *Strip Length* — Strip length cut off shall be within 0.005", lead tip to lead tip centerline (excluding rails). The rail cut off length shall be within + 0.635 mm (0.025") unless otherwise specified by the user.

7 Sampling

Sampling will be determined between supplier and purchaser.

8 Packaging and Marking

8.1 *Packaging* — Leadframes must be packaged in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided against crushing, exposure to moisture, and mixture gases.

8.2 *Marking* — The outer containers shall be clearly marked to identify the user stock number, user purchase order number, drawing number, supplier lot number, and reel numbers within the carton. Additional information required should be specified by the user.

SEMI G20-96
SPECIFICATION FOR LEAD FINISHES FOR PLASTIC PACKAGES (ACTIVE DEVICES ONLY)

1 Purpose

This specification defines lead finishes for plastic packages (e.g., single-in-line, dual-in-line, quad-in-line) utilizing leadframes with SEMI specified leadframe materials.

2 Scope

This specification defines the composition, properties, and limits and refers to the appropriate tests for utility.

3 Referenced Documents

Unless otherwise specified, the following standards and specifications, with appropriate issue letter at time of order entry, form a part of this specification to the extent, and for the purpose, specified herein.

3.1 *SEMI Specifications*

SEMI G4 — Specification for Integrated Circuit Leadframe Materials Used in the Production of Stamped Leadframes

SEMI G18 — Specification for Integrated Circuit Leadframe Material Used in the Production of Etched Leadframes

SEMI G55 — Test Method Measurement of Silver Plating Brightness

SEMI G56 — Test Method Measurement of Silver Plating Thickness

3.2 *ASTM Specifications*[1]

B 487 — Measuring Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

B 545 — Standard Specification for Electrodeposited Coatings of Tin

B 567 — Measurement of Coating Thickness by the Beta Backscatter Principle

B 568 — Measurement of Coating Thickness by X-Ray Spectrometry

E 1B 571 — Adhesion of Metallic Coatings

E 10 — Standard Test Method for Brinell Hardness for Metallic Materials

E 384 — Standard Test Methods for Microhardness of Materials

3.3 *Federal Specifications*[2]

QQ-S-365 — Silver Plating, Electrodeposited, General Requirements for

QQ-S-571 — Solder, Tin Alloy: Tin Lead Alloy, and Lead Alloy

3.4 *Military Specifications*[2]

MIL-G-45204 — Gold Plating, Electrodeposited

MIL-P-81728 — Plating, Tin Lead, Electrodeposited

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-T-10727 — Tin Plating; Electrodeposits or Hot-Dipped, for Ferrous and Non-Ferrous Metals

4 Application

4.1 Table 1 lists recommended finishes for copper and nickel/iron alloys.

4.1.1 Silver is approved as a lead finish for all alloys but only for internal processing. When shipped to a customer, silver must be removed and replaced by tin lead.

4.1.2 Gold plate is usable in socketed applications as well as in soldered applications. Hardness, grain size, and other properties shall be specified on the procurement drawing.

4.1.3 Solder, as used in this specification, refers to tin lead as 63/37 or 60/40 unless otherwise specified and agreed upon between user and supplier, and stated on procurement drawings.

4.1.4 “Tinning” is a generic term (primarily used in user industries) and means hot solder dip (near 60/40 tin lead) and not an application of tin.

4.2 Composition, limits, mechanical and physical properties, and dimensions and tolerances for leadframes are stated in SEMI G4 and SEMI G18.

4.3 Lead finish details are stated in Section 5.

1 American Society for Testing Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Military Standards, Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120

5 Lead Finish

5.1 Tin Electroplate

5.1.1 *Composition* — The tin shall not be less than 99.8% pure tin and shall not contain more than 0.1% carbon. The deposit is Type I as defined in MIL-T-10727.

Table 1 Alloys

	Finish Iron Alloys	*Finish Copper Alloys*
Tin MIL-T-10727		
Tin (over base metal)	X	X
Acceptable Undercoats		
1. Copper	X	X
2. Nickel	X	X
Tin Lead (Sn/Pb)		
MIL-P-81728		
Tin Lead (over base metal)	X	X
Sn/Pb		
Acceptable Undercoats		
1. Copper	X	X
2. Nickel	X	X
Solder Dip (Sn/Pb)		
QQ-S-571		
Solder Dip (over base metal)	X	X
Acceptable Undercoats		
1. Copper	X	X
2. Nickel	X	X
3. Silver	X	X
Gold MIL-G-45204		
Gold (over base metal)		X
Acceptable Undercoats		
1. Nickel	X	X
2. Copper Flash	X	
Silver QQ-S-365		
Silver (over base metal)	X	X
Acceptable Undercoats		
1. Copper	X	
2. Gold		X

5.1.2 *Characteristics* — The procedure used for evaluating the tin coating and the general requirements for the coating shall comply with ASTM B 545 or the latest current revision, except where noted below.

5.1.3 *Thickness* — The plated coating as measured on the major flat of the leads shall be a minimum of 5 micrometers (200 microinches).

5.1.4 *Appearance* — The surface texture of the tin shall be non-reflective matte finish.

5.1.5 *Hardness* — None specified.

5.1.6 *Preservation* — Preservation coating, if desired and agreed upon by user and supplier, is acceptable. (Example: Stearic acid solution in xylol as defined in MIL-T-10727.)

5.2 *Tin Lead (SnPb) Electroplate*

5.2.1 *Composition* — Major constituents shall be tin lead with minor impurities. Range of major constituents shall be:

Tin	60%—95%
Lead	5%—40%

5.2.2 *Purity and Application* — Per MIL-P-81728.

5.2.3 *Thickness* — Shall be a minimum of 5 micrometers (200 microinches) measured on the major flat of the leads.

5.2.4 The surface of the tin lead shall be non-reflective matte finish.

5.2.5 *Hardness* — None specified.

5.3 *Tin Lead Solder-Dip*

5.3.1 *Composition* — 60/40 or 63/37.

5.3.2 *Purity* — As per Federal Specification QQ-S-571.

5.3.3 *Thickness* — Shall be a minimum of 5 micrometers (200 microinches) as measured on the major flat of the leads.

5.3.4 *Process Conformance* — Solder coating is applicable as shown in Table 1. In addition, the coating is acceptable as follows:

1. Over the electroplated tin or tin lead as per Section 5.1 or 5.2.
2. Over the electroplated silver as per Section 5.4.
3. Over the electroplated gold as per Section 5.5.

5.3.5 *Appearance* — Surface shall be smooth and continuous.

5.3.6 *Hardness* — None specified.

5.4 *Silver Electroplate*

5.4.1 *Composition* — Silver electroplate shall be semi-bright, Type II as per Federal Specification QQ-S-365, Grade B, (without supplementary tarnish resistant treatment).

5.4.2 *Thickness* — Shall be a minimum of 1.25 micrometers (50 microinches) as measured on the major flat of the leads, in accordance with SEMI G56.

5.4.3 *Appearance* — Smooth and continuous and semi-bright with minimum discoloration as measured, in accordance with SEMI G55.

5.4.4 *Hardness* — Hardness shall be between 90 and 135 on the Brinell Hardness Scale, in accordance with ASTM E 10.

5.4.5 *Additional Processing*

5.4.5.1 Due to chemical reactions, silver electroplated surfaces should be protected from sulfur and sulfur bearing materials such as note paper, cardboard, and other like materials. Sulfur-free papers shall be used for packing.

5.4.5.2 Prior to shipment to a user, devices with silver electroplated leads shall have the silver removed and replaced with tin lead coated leads, unless accepted by contract.

5.5 *Gold Electroplate*

5.5.1 *Composition* — Gold plating shall be applied in accordance with MIL-G-45204 in any and all of the following grades depending on application.

Type I	- 99.7 Percent minimum
Type II	- 99.0 Percent minimum
Type III	- 99.9 Percent minimum

NOTE 1: Type II is suitable for socketing application only.

5.5.2 *Thickness* — Shall be a minimum of 1.25 micrometers (50 microinches) as measured on the major flat of the leads.

5.5.3 *Appearance* — Appearance of surface shall be smooth and continuous. Attributes and defects are specified in MIL-G-45204 (workmanship paragraph).

5.5.4 *Purity* — Composition limits are as specified in Section 5.5.1 above. Individual metallics in the deposit shall not exceed 0.1%. Metallic hardening agents, purposely added to adjust a plating bath to specified hardness, are not considered as impurities.

5.5.5 *Hardness* — Depending on Type and Application, hardness is specified, using Knoop indenter in the following categories (testing shall be in accordance with ASTM E 384):

Type	*Grade*	*Hardness (Knoop)*
I	A	90 max
	B	91—129
	C	130—200
II	B	91—129
	C	130—200
	D	201 and over
III	A	90 max

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SEMI G21-94
SPECIFICATION FOR PLATING INTEGRATED CIRCUIT LEADFRAMES

1 Preface

1.1 *Purpose* — This specification details the requirements for plating layers on leadframes intended for use in platic semiconductor packages. It is intended as a design guideline.

1.2 *Scope* — The specifications and test procedures detailed in this document apply to all plating applied to the internal section of leadframes. External leadframe finishes are not included.

1.3 *Units* — U.S. Customary (inch-pound) or SI units may be used at the customer's discretion. This specification uses U.S. Customary units as the prime unit.

2 Referenced Documents

2.1 *Applicable Documents* — To avoid conflicts, the order of precedence when ordering plated leadframes shall be as follows:

Purchase Order

Customer's Leadframe Drawing

This Specification

Referenced Documents

Related Documents

2.2 *Referenced Documents*

2.2.1 *SEMI Specifications*

SEMI G4 — Integrated Circuit Leadframe Materials used in the Production of Stamped Leadframes

SEMI G18 — Materials Used in the Production of Etched Leadframes for Semiconductor Devices

SEMI — All leadframe specifications

2.2.2 *ASTM Specifications*[1]

B 847 — Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopic Examination of a Cross-Section

B 567 — Method for Measurement of Coating Thickness by the Beta Backscatter Method

B 568 — Method for Measuring Coating Thickness by X-Ray Spectrometry

E 384 — Standard Test Method for Microhardness of Materials

F 1269 — Test Methods for Destructive Shear Testing of Ball Bonds

2.2.3 *Military and Federal Specifications*[2]

MIL-C-14550 — Copper Plating, Electrodeposited

MIL-G-45204 — Gold Plating, Electrodeposited

MIL-T-10727 — Tin Plating, Electrdeposits or Hot Dipped, for Ferrous and Non-Ferrous Metals

MIL-STD-883 — Test Methods and Procedures for Microelectronics

QQ-N-290 — Nickel Plating, Electrodeposited

QQ-S-3651 — General Requirements for Electrodeposited Silver Plating

2.3 *Related Documents*

2.3.1 *Military and Federal Specifications*

MIL-P-81728 — Plating Tin/Lead (Sn/Pb) Electrodeposited

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-202 — Test Methods for Electronic and Electrical Component Parts

MIL-S-19500 — General Specification for Semiconductor Devices

2.3.2 *ISO Standards*[3]

ISO-3497 — Metallic Coating Measurement of Coating Thickness, X-Ray Spectrometry Method

3 Terminology

3.1 *finish (plating)* — The final plating layer.

3.2 *resin bleed-out (die attach)* — The surface creep of a resin used for die attach beyond the outer perimeter of the bulk of the resin (filler). For a given resin formulation, the resin creep may be exacerbated by the micro-structure and cleanliness of the die attach surface.

1 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

3 ANSI, 1430 Broadway, New York, NY 10018

4 Ordering Information

Purchase orders for material furnished to this specification shall include the following information:

4.1 Leadframe drawing showing the areas to be plated and tolerances for the location.

4.2 *Plating Metal, Type, and Grade* — Underplate and finish plate.

4.3 Plating(s) thickness and tolerance.

4.4 Certification or Test Report requirements.

4.5 Reference to this specification.

4.6 Any additions to or variations from this specification.

5 Materials

5.1 *Base Material* — See SEMI G4 and G18 for leadframe base metal specifications.

5.2 *Underplates* — When underplates are specified, the materials specified in Table 1 shall be used.

Table 1 Underplates

Platings	*Type Grade*	*Specifications*	*Specifications*
Nickel			QQN-290
Copper			MIL-C-14550
Gold	III	A	MIL-G-45204
Silver	I, II, III	B	QQ-S-365

5.3 *Finish/Underplates* — The recommended finish plating options for copper and nickel-iron alloys and the suggested underplates are show in Table 2.

Table 2 Undercoat Finishes

Finish	*Copper Alloys*	*Nickel/Iron Alloy*
Gold MIL-G-45204		
Over Base Material		X
Acceptable Underplate		
Nickel*	X	X
Silver QQ-S-365		
Over Base Material	X	
Acceptable Underplate		
Gold		X
Copper	X	X
Tin MIL-T-10727		
Over Base Material	X	X
Acceptable Underplate		
Nickel	X	X
Copper	X	X
Copper MIL-C-14550		
Over Base Material	X	X
Acceptable Underplate		
Nickel QQN-290		
Over Base Material	X	X
Acceptable Underplate		
Palladium		
Over Base Material		
Acceptable Underplate Nickel	X	X
Copper	X	X

*Copper strike may be used under nickel.

6 Sampling

6.1 The sampling plan shall be agreed between user and supplier.

7 Equipment

7.1 Beta Backscatter system.

7.2 Die Attach equipment.

7.3 Eutectic Die Attach heater block or hot plate capable of 450°C ± 10°C.

7.4 Microscope 10–30× magnification with 45° lighting.

7.5 Micro Cross-Section equipment.

7.6 Toolmaker's Microscope

7.7 Wire Bond equipment

7.8 X-ray Fluorescence system

7.9 Solderability equipment

8 Incoming Inspection

If incoming inspection is performed, materials shall be inspected in the following sequence:

8.1 Visual Inspection

8.2 Surface Finish

8.3 Plating Area and Thickness

8.4 *Plating Quality* — Heat Test and Adhesion Test

8.5 Functional Tests

8.5.1 Die Attach

8.5.2 Wire Bond

8.5.3 Solderability

8.6 Plating Hardness

9 Test Methods

9.1 Visual Inspection

9.1.1 Visually inspect the plated area using a binocular microscope, at 10×–30× magnification for the following rejectable conditions.

9.1.1.1 Any bare spots or missing plating in critical areas as defined by the coined areas or minimum flat wire bond area in the appropriate leadframe specification.

9.1.1.2 Any peeling or blistered plating.

9.1.1.3 Any nodules in critical area as defined in 9.1.1.1.

Note 1: Nodules not exceeding 0.0005" (0.0381 mm) in a surface dimension and 0.0005" (0.0127 mm) in height in non-critical areas are allowed providing there are no more than one per internal lead finger or six (6) per leadframe.

9.1.1.4 Any pits which exceed 0.0003" (0.008 mm) in depth or 0.0005" (0.0127 mm) in a surface dimension in critical areas or 0.001" (0.0254 mm) in depth or 0.002" (0.051 mm) in a surface dimension in non-critical areas.

9.1.1.5 Any scratches or scrapes in the metallization plating which expose underplate or base material.

9.1.1.6 Any scratches or scrapes in critical areas which cause a build up of material in excess of 0.0005" (0.0127 mm) in height.

9.1.1.7 Any foreign material, contamination, oxidation or tarnish.

9.2 *Surface Finish*

9.2.1 The surface finish or brightness shall be inspected according to procedures agreed upon between vendor and customer.

9.3 *Plating Area and Thickness*

9.3.1 *Plating Area*

9.3.1.1 Using a toolmaker's microscope determine if spot plated areas meet the requirements of the leadframe drawing for position and size tolerance.

9.3.2 *Thickness*

9.3.2.1 Plating thickness shall be measured at locations agreed between vendor and customer according to procedures detailed in ASTM B 487, ASTM B 567, or ASTM B 568.

Note 2: Only use ASTM B 487 for thicknesses greater than 100 micro-inches (0.0025 mm).

9.4 *Plating Quality* — Heat Test and Adhesion Test.

9.4.1 *Copper Plate* — Test according to procedures agreed between vendor and customer.

9.4.2 *Gold and Silver Plate*

9.4.2.1 Submit gold plated samples to 450°C + 10°C for two (2) minutes in air on a die attach heater block or hot plate and silver plated samples to 300° C + 10° C with the same conditions.

Note 3: For silver plating thicknesses less than 100 micro-inches (0.0025 mm), heat testing is not valid unless an alternate time and temperature is agreed upon between the vendor and the customer.

9.4.2.2 Visually inspect the plating under the microscope set at 10× magnification for blistering, peeling, and discoloration.

Note 4: For gold plating, discoloration after the heat testing is only allowable if the fold plate thickness is less than 20 micro-inches (508 microns) by design.

Note 5: 30× magnification may be used for confirmation.

9.4.2.3 Place a strip of tape across the plated area. Press firmly with fingertips or another smooth object.

9.4.2.4 Peel the tape quickly off the plated surface. If there is any plating on the tape the component shall be rejected.

9.4.3 *Nickel Plate* — Test according to procedures agreed between vendor and customer.

9.4.4 *Palladium Plate* — Test according to procedures agreed between vendor and customer.

9.4.5 *Tin Plate* — Test according to procedures agreed between vendor and customer.

9.5 *Functional Tests*

9.5.1 *Die Attach*

9.5.1.1 Sample die, using a resin agreed between vendor and customer, shall be attached to plated leadframes.

9.5.1.2 Die shear tests shall be performed per MIL-STD-883, Method 2019 or to a method agreed between vendor and customer.

9.5.1.3 Resin bleed-out shall not exceed 0.010" (0.254 mm).

Note 6: Control samples from a previously accepted leadframe lot shall be tested at the same time, using the same resin batch, for comparison.

9.5.2 *Wire Bond*

9.5.3 Sample leadframes shall be bonded using wire and procedures agreed between vendor and customer.

9.5.3.1 Wires and bonds shall be tested according to MIL-STD-883, Method 2011, and/or ASTM F 1269 by agreement between vendor and customer.

9.5.4 Tin Plate Solderability

9.5.5 The solderability or alloying capability of the tin plate shall be evaluated per procedures agreed between vendor and customer.

9.6 *Plating Hardness*

9.6.1 Where required for verification of results obtained in other tests, the plating hardness shall be measured per ASTM E 384.

10 Certification

10.1 Upon request by the customer in the purchase order, a vendor's certification that the plating was performed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment. This certification does not remove the vendor's responsibility for discrepant product subsequently found by the customer.

10.2 When certification is requested, the following information shall be supplied as a minimum requirement:

10.2.1 Vendor Name

10.2.2 Purchase Order Number

10.2.3 Vendor Lot Number

10.2.4 Customer Part Number

10.2.5 Plating Type, Grade and Measured Thickness for Under and Finsh Plates

10.2.6 Plating hardness if agreed between vendor and user.

11 Packaging and Marking

11.1 *Packaging*

11.1.1 Shipping containers and materials shall be suitably selected to provide the material with protection from normal transportation damage risks which include crushing, abrasion, spillage, and exposure to moisture and other corrosive gases. The inner packing materials may be further specified by the customer for cleanliness and non-tarnishing issues.

11.2 *Marking*

11.2.1 *Internal Packages* — Each internal package shall be marked as follows:

Vendor's Name

Customer's Part Number

Customer's Order Number

Vendor's Specification Number and Customer's, if appropriate

Manufacturing Lot Number

Quantity

Date of Manufacture

11.2.2 *External Packages*

Customer's Specification Number

Customer's Order Number

Quantity

Shipping Date

Any specific instructions for receiving dock personnel if requested on the purchase order

12 Discrepancy Material

12.1 Material rejected at incoming inspection shall be segregated and tagged as rejectable.

12.2 The vendor shall be informed and the returned goods policy activated.

Note 7: Samples showing the defects shall be identified for the vendor. If the vendor wishes to see the samples before return of the complete shipment, the material shall be stored by the customer in a manner to prevent further damage or deterioration.

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SEMI G22-1296
SPECIFICATION FOR CERAMIC PIN GRID ARRAY PACKAGES

1 Purpose

This specification defines the acceptance criteria for cofired ceramic pin grid array packages.

2 Scope

This specification includes the visual, dimensional, and functional requirements for the ceramics PGA package.

3 Referenced Documents

3.1 *Military Standards*[1]

MIL-G-45204 — Gold Plating, Electrodeposited

MIL-I-23011 — Iron Nickel Alloys for Sealing to Glasses and Ceramics

MIL-PRF-38535 — Integrated Circuits (Microcircuits) Manufacturing, General Specification for

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-1835 — Interface Standard for Microcircuit Case Outlines

MIL-STD-7883 — Brazing

QQ-N-290A — Nickel Plating

3.2 *Other Documents*

ANSI Y14.5[2] — Dimensioning and Tolerancing

JEDEC Pub. No. 95[3] — Registered and Standard Outlines for Semiconductor Devices

4 Terminology

4.1 *blister (bubble) ceramic* — Any separation within the ceramic which does not expose underlying ceramic material.

4.2 *blister (bubble) metal* — Any localized separation within the metallized or between the metallization and ceramic which does not expose underlying metal or ceramic material.

4.3 *braze* — An alloy with a melting point equal to or greater than 450°C.

4.4 *burr* — An adherent fragment of excess parent material, either horizontal or vertical, adhering to the component surface.

4.5 *chip* — A region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width, and depth from a projection of design plan form (Figure 1).

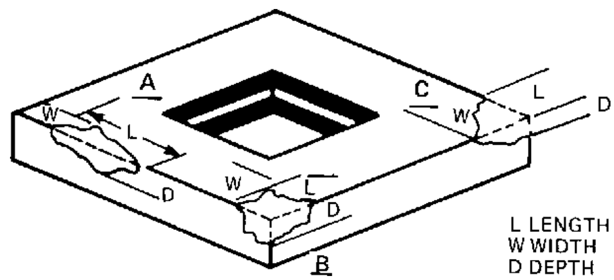

Figure 1
Chip Illustration

4.6 *cofired* — A process or technology for manufacturing products in which the ceramic and refractory metallizations are fired simultaneously.

4.7 *contact pad* — That metallized pattern that provides mechanical or electrical connection to the external circuitry.

4.8 *crack* — A cleavage or fracture that extends to the surface of a package. It may or may not pass through the entire thickness of the package.

4.9 *delamination* — The separation of the individual layers of the ceramic.

4.10 *die attach area* — A dimensional outline designated for die attach.

4.11 *discoloration* — Any change in the color of the package plating or metallization as detected by the unaided eye which normally appears after the application of heat per Section 8.7.1.

4.12 *flatness* — The allowable deviation of a surface from a reference plane. The tolerance zone is defined by two parallel planes within which the surface must lie.

4.13 *footprint* — Pin pattern.

4.14 *foreign material* — An adherent particle other than parent material of that component.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

2 ANSI, 1430 Broadway, New York, NY 10018

3 JEDEC, 2500 Wilson Blvd., Arlington, VA 22201-3834

4.15 *isolation gap* — Metal-free space between conductive areas.

4.16 *layer* — A dielectric sheet with or without metallization that performs a discrete function as part of the package.

4.17 *peeling (flaking)* — Any separation of metallization from the base material that exposes the base material.

4.18 *pit* — Any unspecified depression in the package.

4.19 *projection* — An adherent fragment of excess parent material on the component surface.

4.20 *pullback* — A dimension covering the linear distance between the edge of the ceramic and the first measurable metallization (see Figure 2).

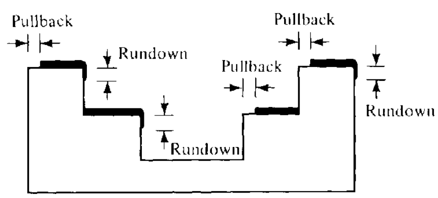

Figure 2
Metallization Misalignment

4.21 *rundown* — The linear distance down a vertical surface from the top to the point of maximum metallization overhang (see Figure 2).

4.22 *seal area* — A dimensional outline area designated for either metallization or bare ceramic to provide a surface area for sealing.

4.23 *seating plane* — As defined by the standoff features or the package base plane if no standoff is used (see Figure 3).

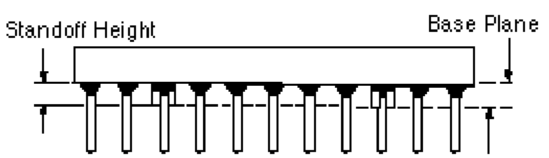

Figure 3
Seating Plane

4.24 *standoff* — The designed separation between the base plane and the seating plane created by a physical feature. Standoff use, configuration, and placement is optional (see Figure 3).

4.25 *terminal* — Metallization at the point of electri cal contact to package internal circuitry.

4.26 *TIR* — Total indicator reading.

4.27 *voids* — An absence of refractory metallization, braze, or plating material from a designated area greater than 0.002" (0.051 mm) in diameter.

5 Ordering Information

Purchase orders for pin grid array packages furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Certification requirements
3. Quantity
4. Reference to this document
5. Any exceptions to print or specifications

6 Dimensions and Permissible Variations

The dimensions of the pin grid array package shall conform to the SEMI Standards or to the customer drawing and be within the outline of the appropriate JEDEC standard. Refer to MIL-PRF-38535 and MIL-STD-1835.

7 Material Parameters

The definitions, defects, and functional testing described in this specification relate directly to a nominal package made with the following materials. They may also be applicable to similar pin grid array packages made with other materials.

7.1 *Ceramic Properties*

7.1.1 *Materials* — Alumina content 90% minimum. Beryllia content to be determined.

7.1.2 *Color* — Dark or white.

7.2 *Metal Properties*

7.2.1 Metallized circuits and areas shall be refractory metal tungsten, molybdenum, or an approved equivalent, 0.0003" (0.00762 mm) minimum thickness.

7.2.2 Finish shall be per MIL-PRF-38535 and MIL-STD-1835; Nickel Plating (if designated) shall be per QQ-N-290A, 50 µ"–350 µ" (0.0013 mm–0.00889 mm). Gold plating shall conform to MIL-G-45204, Type III and 50 µ"–225 µ" (0.0013 mm–0.00508 mm).

7.2.3 Braze shall be per MIL-STD-7883.

7.2.4 *Pin Material* — Iron nickel cobalt alloy per MIL-PRF-38535 and MIL-STD-1835, Type A (Kovar). Iron nickel alloy per MIL-PRF-38535 and MIL-STD-1835, Type B (Alloy 42). Phosphor bronze per ASTM B159.

8 Defect Limits

A magnification of 10× to 30× shall be used to inspect the packages unless otherwise specified.

8.1 *Ceramic*

8.1.1 *Cracks* — Per MIL-STD-883, Method 2009.

8.1.2 *Chips* — (See Figure 1.)

8.1.2.1 *Edge* — 0.100" (2.54 mm) length × 0.030" (0.762 mm) width × 0.020" (0.508 mm) (see Figure 1, A).

8.1.2.2 *Corner* — 0.030" (0.762 mm) length × 0.030" (0.762 mm) width × 0.030" (0.762 mm) (see Figure 1, B).

8.1.2.3 Chips cannot encroach upon contact pad or expose any buried metallization.

8.1.2.4 *Seal Area* — 0.060" (1.52 mm) length × 0.020" (0.508 mm) width × 0.020" (0.508 mm) depth maximum.

8.1.2.5 Chips cannot reduce the seal width by more than 1/3 of the design width.

8.2 *Package Flatness* — 0.004 inch/inch (0.004 mm/mm) maximum.

8.2.1 *Seal Area Flatness*

Seal Area Size	*Seal Area Flatness (TIR)*
0.000" – 0.500" (0 – 12.7 mm)	0.002" (0.51 mm) Maximum
0.501" – 0.750" (12.72 – 19.05 mm)	0.003" (0.076 mm) Maximum
0.751" & greater (19.07 mm)	0.004" (0.101 mm) Maximum

8.2.2 *Die Attach Area Flatness*

Die Attach Area Flatness	*Die Attach Area Flatness (TIR)*
0.000" – 0.500" (0 – 12.7 mm)	0.002" (0.051 mm) Maximum
0.501" – 0.750" (12.72 – 19.05 mm)	0.0035" (0.088 mm) Maximum

8.3 *Metallization Voids* — (Voids greater than 0.003" (0.075 mm) should be considered.)

8.3.1 *Seal Area* — Maximum number of three (3) voids per seal ring allowed. The maximum void dimension is 0.010" (0.254 mm) and voids must be separated by a minimum of 0.030" (0.762 mm).

8.3.2 *Wire Bond Finger* — Be free of voids or bare spots in the bonding area as defined by customer drawing.

8.3.3 *Die Attach Area* — Three (3) voids allowed, maximum 0.010" (0.254 mm) diameter voids separated by a distance greater than 0.010" (0.254 mm). Voids within 0.015" (0.381 mm) of die attach cavity wall shall not be considered as the basis for rejection.

8.3.4 *Braze Metallization* — A 0.010" (0.254 mm) maximum diameter void is acceptable, one (1) void per pad.

8.4 *Metallization Misalignment* — (See Figure 2.)

8.4.1 *Metallization Rundown* — Internal cavity not to exceed 0.010" (0.254 mm) maximum.

8.4.2 *Wire Bond Finger Pullback* — 0.010" (0.254 mm) maximum.

8.4.3 *Wire Bond Finger Rundown* — Metallization rundown not to exceed 0.010" (0.254 mm) maximum.

8.4.4 *Pattern Isolation* — Minimum shall not be reduced by more than 50% of the design.

8.5 *Pins*

8.5.1 *Pin Attachment* — The pin must be within the area of the braze pad (fillet seen on all sides). The pin must be located within 0.010" (0.254 mm) radius of true location with respect to all other pins.

8.5.2 Pins that are broken, missing, twisted, or bent more than 30 °.

8.5.3 Pin burrs greater than 0.005" (0.125 mm) in any direction.

8.6 *Plating*

8.6.1 Any visual evidence of plating defects such as blistering, peeling, voids, or stains.

8.6.2 Any plating damage such as scratches or marred areas that expose underlying base metal.

8.7 *Components (General)*

8.7.1 Any visual evidence of corrosion, contamination, or chemical stains on the package component.

8.7.2 Any protrusion, conductive, or non-conductive, that is more than 0.005" (0.125 mm) in height.

9 Sampling

Sampling size must meet the requirements of MIL-STD-105 or MIL-PRF-38535 and MIL-STD-1835, or as agreed to between vendor and customer. Single, double or multiple samples may be used per vendor and customer agreement.

10 Test Methods

10.1 *Mechanical, Electrical, and Thermal Test Methods* — Per MIL-STD-883 unless otherwise noted.

10.1.1 Gold plating and bake test of gold plated package shall be tested by placing parts on a calibrated heater per MIL-STD-883, Method 1008 (excluding temperature).

10.1.1.1 *Condition A* — 450 ± 10°C for two minutes in air, or

10.1.1.2 *Condition B* — 470 ± 10°C for one minute in nitrogen.

10.1.1.3 After cooling at room temperature the packages will be examined for the following criteria:

1. *Blisters* — None allowed at 10× magnification.
2. Any non-uniform color change of the gold at die attach pad. Discolorations within edges up to 0.015" (.381 mm) from the cavity wall is acceptable.
3. Any non-uniform color change of the bonding fingers, seal ring surface, or external pins is not acceptable.
4. There shall be no flaking or peeling of the package plating when viewed at 10x magnification.
5. Superficial stains left during drying or prior operations is not cause for rejection.
6. Plating adhesion tape test.

10.1.2 *Lead Pull* — Under the test condition of five (5) pounds ± one-quarter (1/4) pound pull at an angle of 20° or less from the pins vertical line, measured perpendicular to the package, there shall be no visible separation of the braze joint under 10x magnification. This excludes plating.

10.1.3 *Lead Fatigue* — Test per MIL-STD-883, Method 2004, Test Condition B2, Section 3.1.

10.2 *Functional Test Methods*

10.2.1 *Die Attach Quality* — Destructive die shear test post environmental testing per MIL-STD-883, Method 2019, Paragraph 3.2C.

10.2.2 *Wire Bond Quality* — Minimum pre-seal and post-seal bond strength test per MIL-STD-883, Method 2011, Test Condition D. Reject for bonds which cause plating to lift from the base metal of the bonding fingers or fail to meet minimum strength requirement.

10.2.3 *Solderability* — Test per MIL-STD-883, Method 2003 (omit aging).

10.2.4 *Insulation Resistance* — Test per MIL-STD-883, Method 1003, Condition D.

10.2.5 Hermetic and Environmental Testing per MIL-STD-883.

10.2.5.1 The hermetic integrity of the package must be maintained after all environmental testing. Hermetic checks shall comply with MIL-STD-883, Method 1014, Test Conditions A, B, C, or D.

10.2.5.2 Environmental testing shall include but not be limited to the following:

1. *Temperature Cycle* — MIL-STD-883, Method 1010, Condition C without heat sink; Condition B with heat sink.
2. *Thermal Shock* — MIL-STD-883, Method 1011, Condition C without heat sink; Condition B with heat sink.
3. *Centrifuge* — MIL-STD-883, Method 2001, Condition E. Y1 axis only — cavity up; Y2 axis only — cavity down (optional).
4. *Mechanical Shock* — MIL-STD-883, Method 2002, Condition B.
5. *Vibration* — MIL-STD-883, Method 2007, Condition A.

NOTE 1: Package applications requiring a heat sink attach will require the environmental test requirements (temp. cycle, shock, etc.) to be evaluated on an individual basis. The material, form factor, and method of attach used for heat sinks may result in severe stresses being induced on the package assembly during environmental testing. Actual accelerated test requirements should be based on the expected product application environment and may be less rigorous than those tests for packages without heat sinks.

11 Sequence of Events and Incoming Testing

During incoming inspection the sequence of testing shall be:

A. Visual

B. Dimensional

C. Functional (typical functional tests which may be applied):

   Die Attach

   Wire Bond

   Pre-seal wire pull

   Seal

   Heat sink attach (if applicable)

Environmental Test

Fine Leak — MIL-STD-883, Method 1014, Condition B

Gross Leak — MIL-STD-883, Method 1014, Condition C

Post-Seal Bond Pull

Radiography

Die Shear — MIL-STD-883, Method 2019

Solderability — MIL-STD-883, Method 2003

NOTE 2: An initial vendor qualification may be performed on the thermal and electrical characteristics of the package. The characteristics tested will be:

Insulation Resistance — MIL-STD-883, Method 1003, Test Condition D.

Thermal Dissipation — MIL-STD-883, Method 1012.

12 Packaging and Marking

12.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic components parts with fibers or organic particles.

12.2 *Marking* — The outer containers shall be clearly marked identifying the customer part number, customer purchase order number, drawing number (optional), quantity, date, and vendor lot number (optional).

SEMI G23-0996
TEST METHOD FOR INDUCTANCE OF INTERNAL TRACES OF SEMICONDUCTOR PACKAGES

NOTE: This entire document was revised in 1996.

1 Purpose

This test method describes the measurement method for the inductance of internal traces of semiconductor packages.

2 Scope

2.1 This test method is applicable for the measurement of package inductance that is greater than 0.5 nH.

2.2 This document describes the measurement of a pin grid array, one of the package types, as a sample.

2.3 This test method is also applicable to other types of packages.

2.4 The inductance in this document is limited to that of internal traces only and does not contain the portions contributed by the exposed areas such as pins and wires.

2.5 This document uses SI units.

3 Limitation

It is not practical to apply this test method for fine-pitch packages where traces or pads (point A of Figure 1) cannot be connected to with two probes.

4 Referenced Documents

None.

5 Terminology

5.1 *internal inductance (of packages)* — Inductance of the circuit that comprises the signal path starts from the shoulder or in the center of the outside lead (point A of Figure 1) and ends at the end of the lead on the cavity side of the lead (point B of Figure 1). The return path is made by tying all other traces (except for the target trace in the same electric potential) together. The target trace is tied to the return path at the bonding finger (see Figure 2).

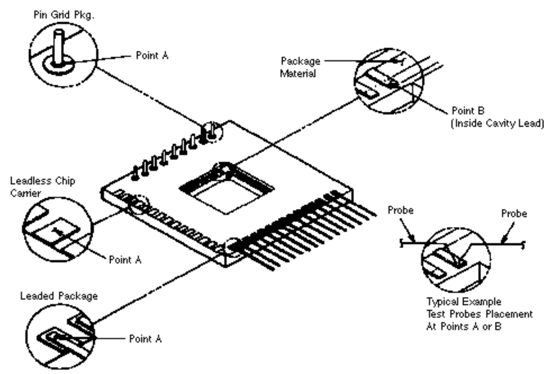

Figure 1
Internal Inductance Measurement

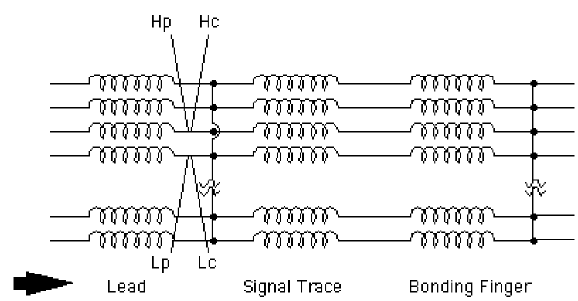

Figure 2
Concept of Internal Inductance

5.2 *four-point probe* — The probe consists of four coaxial measuring terminals, H_c (current high), H_p (potential high), L_c (current low) and L_p (potential low), to measure impedance. Independent coaxial cables are used between the package being measured and the measurement instrument to minimize the effect caused by mutual inductance (between terminals) and/or interferences from the measured signals (see Figures 3 and 6).

6 Summary of Method

Fabricate the package to be measured. Then measure the inductance of internal traces using the four terminal probe method.

7 Interference

7.1 It is desirable that an operator who is familiar with the measuring system, measuring method, and principles, conduct the actual measurement to get the best result.

7.2 To get an accurate measurement, maintain equal probe angle and distance.

8 Apparatus

8.1 *LCR Meter*

8.1.1 Four terminal probe attachment capability

8.1.2 Capable of measuring at the frequency of 10 MHz or higher

8.1.3 Measurement error of less than 0.1 nH for the measurement range more than 1 nH at the measurement frequency

8.2 *Four Terminal Probe* — See Figure 3.

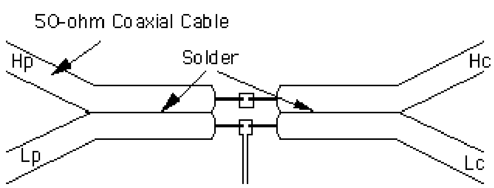

Figure 3
Configuration of Four Terminal Probe

8.2.1 *Residual Inductance* — less than 1 nH

9 Material

9.1 *Copper Plate*

9.1.1 *Plating* — gold

9.1.2 *Thickness* — 2 mm or thicker

9.2 *Insulator* — such as Teflon

9.3 *Silver Foil*

9.3.1 *Thickness* — around 50 µm

9.4 Solder or Conductive Paste

9.4.1 *Resistivity* — 10^{-4} Ω · m or less

10 Test Specimens

10.1 *Preparation of Sample* — Conduct the circuit by measuring the trace as a signal path and the rest, which has a different potential from this signal path, will be the return path, as follows:

10.1.1 All the bonding fingers shall be soldered or pasted together at the bond finger area to form a short circuit.

NOTE 1: The short circuit area shall be 0.5 mm from the tip of the bond fingers. The entire bond fingers shall not be short circuited (see Figure 4).

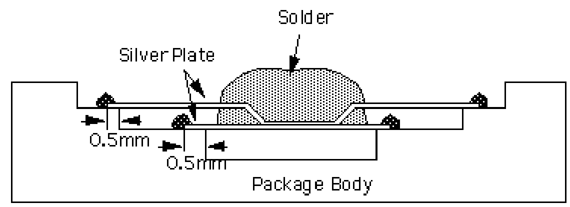

Figure 4
Sample Preparation (Part of Bonding Finger)

10.1.2 Short all pins or leads except for the ones with the same potential as the trace being measured.

NOTE 2: The location for the short circuit shall be as close as possible to the bottom of the pins or the braze pad of the leads to minimize the inductance caused by the pins or leads.

NOTE 3: In case of Pin Grid Array packages, it is recommended to press 50 µm thickness silver foil, which is the same size of package, through the pins. In case of Flat Packages, it is recommended to solder silver foil (or a copper foil) at the braze pads of the leads.

11 Preparation of Apparatus

Before starting the measurement, warm up the instruments as specified in the manual.

12 Calibration

Before starting the measurement, calibrate the instruments as specified in the manual.

13 Procedures

13.1 *Measurement of Residual Inductance*

13.1.1 Set the LCR meter to the inductance measurement mode.

13.1.2 Measure the inductance by conducting the four terminal probe on the gold plated copper plate as shown in Figure 5.

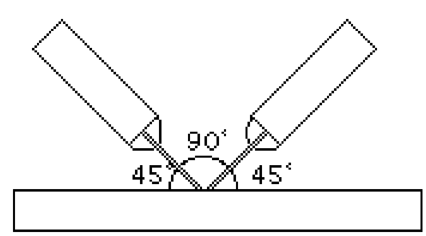

Figure 5
Measurement of Residual Inductance

NOTE 4: The angle between the potential terminal probe and the current terminal probe has to be maintained at a right angle (90°). This is to nullify the mutual interference caused by the magnetic flux.

13.2 *Measurement of the Resultant Inductance*

13.2.1 Place the sample on the insulator such as Teflon.

13.2.2 Set the probe at the bottom of the pin of the trace being measured and at the closest traces belonging to the short circuit as shown in Figure 6.

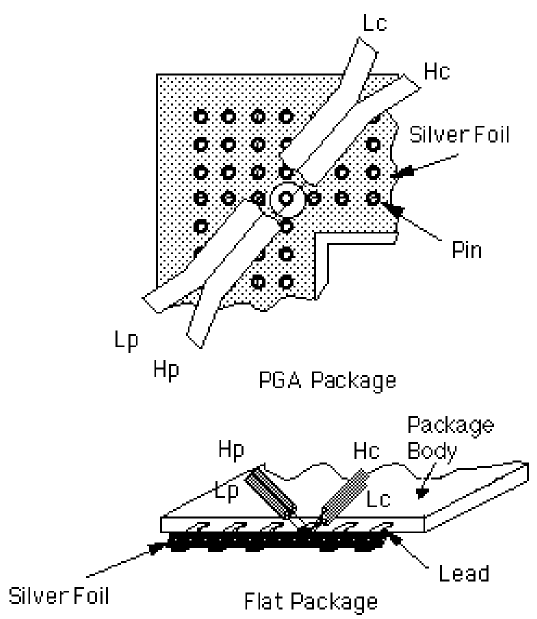

Figure 6
Probing Method

NOTE 5: The probes H_p and H_c are attached/placed onto the pins to be measured and the probes L_p and L_c are attached/placed onto the short circuit.

14 Calculation

14.1 The inductance of the internal trace is calculated as follows:

Internal Inductance (nH) = Measured Inductance — Residual Inductance

14.2 Round the second digit after the decimal point to the unit of 0.1 nH.

15 Report

The following information shall be reported:

- Brief description of the package
- Measurement instrument or system
- Measurement frequency
- Measurement pin numbers
- *Inductance* — Raw data as well as the average in case of multiple measurements.

16 Accuracy

Using the same samples, four different packaging manufactures were tested. The following results were obtained:

Repeatability — ± 0.2 nH

Reproductibility — ± 0.5 nH

17 Related Documents

SEMI G24 — Test Method for Measuring the Lead-to-Lead and Loading Capacitance of Package Leads

SEMI G25 — Test Method for Measuring the Resistance of Package Leads

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SEMI G24-89
TEST METHOD FOR MEASURING THE LEAD-TO-LEAD AND LOADING CAPACITANCE OF PACKAGE LEADS[1]

1 Purpose

This document defines the equipment, materials, and procedures used to measure the lead-to-lead and loading capacitance of package leads. Semiconductor packages are shown as examples; however, other packaging elements can be measured by this method.

2 Equipment and Materials

2.1 Capacitance meter which uses a two probe plus guard method with two coax cables, or a meter which utilizes a four probe plus guard method. The four probe method requires four cables to be modified to connect to two probes at the probe end of the cables. Both methods require an 18 awg. or larger insulated wire for the guard connection. Keep cables at minimum length (1 meter) unless specified by individual equipment. Coaxial cables must be used to connect the probes to the meter. Meter accuracy ± 2%. The probe shields must be connected together. This connection should be short, approximately one to two inches.

2.2 Probe station with two coax probes and one regular probe. Recommendation: Micromanipulator, two (2) each coax probe model 44-FPC-6000 with #5 collet, and one each OON-FPC-6000 with #3 collet, or equivalent.

3 Procedure: Lead-to-Lead Capacitance(See Figure 1)

3.1 Set the instrument to measure at 1 Mhz. If the equipment has a cable length selection switch, adjust the switch to the appropriate coax cable length.

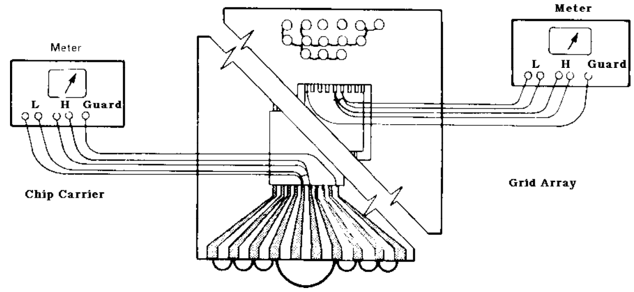

Figure 1
Lead-to-Lead Capacitance

3.2 Connect together all the pins in close proximity to those being measured, for multi-layer ceramic package pins should be chosen to connect all traces adjacent to traces being measured. Example: Eight surrounding pins are connected for the 68 lead pin grid; twelve surrounding pins are connected together for the 124 pin grid; eight surrounding pins are connected together for all flat packs (see Figure 1). If there are power planes and/or large power buses in the package, their pins must be connected together with the eight or 12 surrounding pins discussed above.

3.3 Place the guard probe down on the cavity side of any one of the eight or 12 leads discussed in Section 3.2, to ensure that they will not affect the measurement.

3.4 Place one coaxial probe approximately 1/8 inch above the cavity side of one of the leads to be measured.

3.5 Place the other coaxial probe approximately 1/8 inch above the cavity side of the other lead to be measured.

3.6 *Nulling Procedure* — If using an instrument that auto-zeros, such as the H.P.4275A, follow the instrument instructions for capacitance measurement. If this type of instrument is not being used, take the reading on the instrument at this point.

1 This test method applies to measurements in the range of 1 to 100 pico farands.

3.7 Place the probes down on the leads to be measured. This should be a vertical movement only.

3.8 Take the capacitance reading. If using auto-zeroing equipment, this capacitance measurement will be used. If not, take the reading from 3.6 and subtract it from the reading in 3.8 to derive the capacitance measurement of interest. (See Table 1.)

Table 1 Capacitance Nulling Procedurefor Non-Zeroing Equipment

Pins to be Measured	*Capacitance Reading at 3.6*	*Capacitance Reading at 3.8*	*Subtraction Step to Derive Desired Capacitance at 3.9*
1 & 2	C_1	C_2	$C_2–C_1 = C_3$
3 & 4	0.050 pf	2.130 pf	2.130–0.050 = 2.080 pf

For Auto-Zeroing Equipment:

Pins to be Measured	*Capacitance Reading at 3.6*	*Capacitance Reading at 3.8*	*Subtraction Step to Derive Desired Capacitance at 3.9*
5 & 6	C_1	C_2	$C_2–C_1 = C_3$
7 & 8	0.00 pf*	2.08 pf	2.080–0.000 = 2.080 pf

*Follow instrument instructions to read 0.00 pf

3.9 Repeat the procedure as required.

4 Procedure: Loading Capacitance (See Figure 2)

4.1 Omit guard terminal. Connect together all the pins in close proximity to the one to be measured. Example: Eight surrounding pins are connected together for the 68 pin grid; twelve surrounding pins are connected together for the 124 pin grid; eight surrounding pins are connected together for all flat packs (see Figure 2). If there are power planes and/or large power buses in the package, their pins must be connected together with the eight or 12 surrounding pins discussed above.

4.2 Place one coaxial probe approximately 1/8 inch above the cavity side of any one of the eight or 12 leads discussed in Section 4.1.

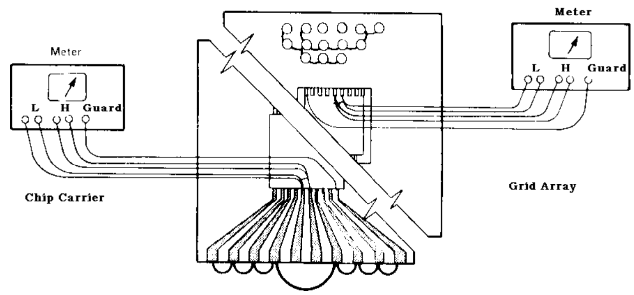

Figure 2
Loading Capacitance

4.3 Place the other coaxial probe approximately 1/8 inch above the cavity side of the lead to be measured.

4.4 Continue as in Steps 3.6 to 3.9.

4.5 Overall accuracy with this method is ± 5%.

SEMI G25-89
TEST METHOD FOR MEASURING THE RESISTANCE OF PACKAGE LEADS

1 Purpose

This document defines the equipment, materials, and procedure used to measure the resistance of leads in packaging elements. This document uses a pin grid (cavity down) package as one example of the type of packaging element that can be measured with the method described herein; however, this measurement technique can be applied to other geometrics with proper consideration.

2 Equipment and Materials

2.1 D.C. Ohmmeter which uses the four point probe (Kelvin) method with four cables. Minimum accuracy should be ± 4 mΩ.

2.2 Probe station with four probes. Probes should be such that the taper of the probe and the diameter of its point allow two probes to come together within a 5 mil. square without touching each other elsewhere. Recommendation: Micromanipulator, four each, probe number OON-FPC-6000 with #3 collet or equivalent.

3 Procedure

3.1 Place both probes of the low side of the meter as close together as possible on the shoulder or in the center of the outside lead (see Figure 1, Point A).

3.2 Place both probes of the high side of the meter within 5 mils of the end of the lead on the cavity side of the lead (see Figure 1, Point B).

3.3 Set the ohmmeter scale to the lowest setting possible without putting meter in an "over range" mode.

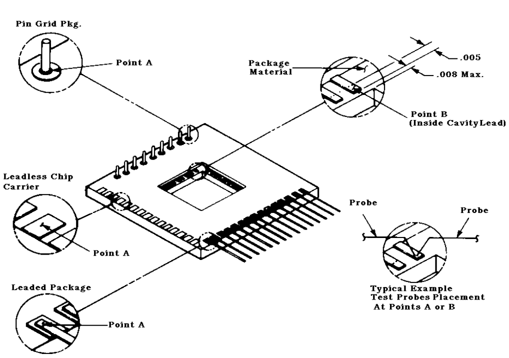

Figure 1
Resistance Measurement

3.4 Take resistance reading. Overall accuracy with this method is ± 20 mΩ. This accuracy estimate includes basic instrumentation error, probe placement repeatability, and typical package construction (printed pattern accuracy).

4 Application Note

Readings below 100 mΩ can be made with acceptable reeatability if considerable care in pleacement is taken. For example, in measuring a conductor made of tungsten 0.010" wide, a 0.010" variation in the distance between the two sets of probes will result in a 15 mΩ change in the measured reading. The same variation in a gold conductor would result in a 3–5 mΩ error.

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SEMI G26-90

SPECIFICATION FOR HERMETIC SLAM CHIP CARRIER LIDS

1 Preface

This specification covers the ceramic piece part commonly referred to as a lid, used in the construction of a hermetic SLAM package with a .050" pad centerline. The SLAM package is covered separately in the SEMI G5 Specification for Ceramic Chip Carriers.

2 Applicable Documents

MIL-STD-883[1] — Test Methods and Procedures for Microelectronics

MIL-M-38510 — General Specification for Microcircuits

MIL-I-23011 — Iron Nickel Alloys for Sealing to Glass and Ceramic

3 Selected Definitions

burr — A fragment of excess material or foreign particle adhering to the surface.

chip — Region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width and depth from a projection of the design plan-form (see Figure 1).

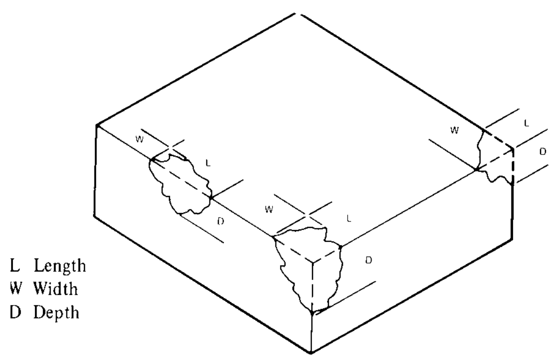

Figure 1
Chip Illustration

crack — A cleavage or fracture that extends to the surface of a package. It may or may not pass through the entire thickness of the package.

fin — A fine, feathery-edged projection on the edge or corner of the ceramic.

glass flow — Heated just sufficiently to remove all screen mesh marks visible at 10× magnification.

overhang — Horizontal extension of glass from the ceramic.

projection — Raised portion of the surface indigenous with the parent material.

pullback — Defines a dimension covering the linear distance between the edge of the ceramic and the first measurable glass interface excluding any glass spatter (see Figure 2).

rundown — Vertical extension of glass from the ceramic (see Figure 2).

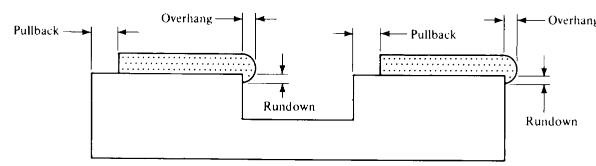

Figure 2
Glass Misalignment

seal area — A dimensional outline area designated for sealing the lid and package together.

terminal — Case outline at point of entry or exit of an electrical contact.

void —An absence of glass from a designated glassed area on the ceramic surface.

4 Ordering Information

Purchase orders for SLAM lids furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Type and color of ceramic
3. Type and thickness of sealing material
4. Length, width, thickness and sealing area
5. Certification
6. Method of test and measurements (see Section 9)
7. Lot acceptance procedures (see Section 8)
8. Packaging and marking (see Section 10)

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1 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

5 Dimensions and Permissible Variations

The lid dimensions shall conform as specified in Figure 3 and Table 1.

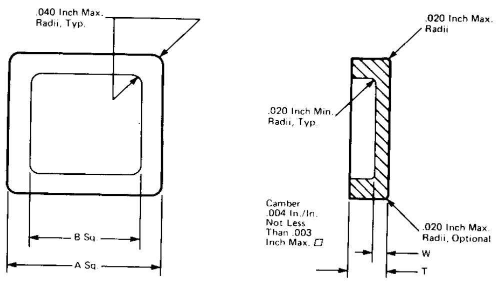

Figure 3
Dimensions

Table 1 Lid Dimensions for 0.050" Pad Centerline

Terminals	*Chip Carrier Base Thickness (Reference)*	*DIM A*	*DIM B*	*DIM T*	*DIM W*	*S/R, WIDTH*
20	0.020	0.310	0.230	0.060	0.020	0.040
28	0.025	0.410	0.330	0.060	0.025	0.040
44	0.040	0.500	0.420	0.065	0.025	0.040
68	0.040	0.700	0.560	0.065	0.022	0.070

6 Materials

6.1 Ceramic

6.1.1 Alumina content 90% minimum or Beryllia content 94% minimum.

6.1.2 Dark or white.

6.2 *Sealing Material* — As specified in the ordering information.

7 Defect Limits

7.1 *Ceramic*

7.1.1 *Cracks* — Cracks are not allowed.

7.1.2 *Chips*

7.1.2.1 *Corner* — 0.762 mm × 0.762 mm × 0.762 mm (0.030" × 0.030" × 0.030").

7.1.2.2 *Edge* — 0.762 mm × 0.762 mm × 0.762 mm (0.030" × 0.030" × 0.030").

7.1.2.3 Chips cannot reduce the seal path by more than 0.381 mm (0.015") or 10%, whichever is smaller.

7.1.3 *Burrs, Projections, and Fins* — Lids — 0.127 mm (0.005") maximum.

7.1.4 *Camber* — 0.004 inch/inch. For sizes below one inch the maximum camber shall be 0.076 mm (0.003").

7.2 *Glass*

7.2.1 *Chips or Voids* — There shall be no chips or voids after glass flow test.

7.2.2 Glass Misalignment — (As received.)

7.2.2.1 *External Overhang* — 0.254 mm (0.010") maximum.

7.2.2.2 *External Rundown* — 30% of ceramic thickness maximum at maximum material condition.

7.2.2.3 *Glass Pullback* — 0.254 mm (0.010") maximum.

7.2.2.4 Regardless of maximum allowable criteria stated above, the seal area must not be reduced by greater than 20% of the nominal design width.

7.2.3 Glass thickness shall be measured in four locations. Measurement shall be made on glass and base total thickness. Base reference thickness shall be measured on the same part by removal of a portion of the glass.

7.2.4 Glass splatter in all areas may not exceed 0.052 mm (0.002") in height, 0.127 mm (0.005") in diameter, with a maximum of three per 0.1" square area on the cavity surface.

8 Sampling

Sampling will be determined between supplier and purchaser.

9 Test Methods

9.1 *Sequence of Events and Functional Testing* — During functional testing, the sequence of testing shall be:

1. Seal
2. Vapor Content
3. Environmental Testing
4. Fine Leak
5. Gross Leak
6. Torque Test

9.2 *Hermetic and Environmental Testing*

9.2.1 The hermetic integrity of the package must be maintained after all environmental testing. Hermetic checks shall comply with MIL-STD-883, Method 1014, Test Conditions A_1, or B and C.

9.2.2 Environmental testing shall include: Temp Cycle, MIL-STD-883, Method 1010, Condition C.

10 Packaging and Marking

10.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage and other forms of damage to the container or its contents. Containers shall afford protection of the contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component parts with paper fibers or organic particles.

10.2 *Marking* — The outer containers shall be clearly marked to identify the user stock number, user purchase order number, drawing number, quantity, vendor lot number, and solder glass type.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G27-89
SPECIFICATION FOR LEADFRAMES FOR PLASTIC LEADED CHIP CARRIER (PLCC) PACKAGES

1 Preface

This specification is a guideline for high volume production of leadframes for plastic leaded chip carrier semiconductor packages. It is a design guideline for packaging engineers, leadframe stampers and mold manufacturers, and has been developed to meet the requirements of automatic assemblers.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering leadframes to this specification shall be as follows:

Purchase Order

This Specification

Referenced Documents

2.2 *SEMI Specifications*

SEMI G4 — Specification for Integrated Circuit Leadframe Material

SEMI G10 — Standard Method of Mechanical Measurement for Leadframes

SEMI G18 — Specification, Integrated Circuit Leadframe Materials Used in the Production of Etched Leadframes

SEMI G21 — Specification, Plating Integrated Circuit Leadframes

2.3 *Military and Federal Specifications*[1]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

2.4 *ANSI Specification*[2]

Y14.5M — Dimensioning and Tolerancing

2.5 *JEDEC Publication*[3]

Publication 9b — Registered and Standard Outlines for Semiconductor Devices

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

2 ANSI, 1430 Broadway, New York, NY 10018

3 JEDEC, 20001 Eye Street N.W., Washington, D.C. 20006

3 Selected Definitions

burr — a fragment of excess material either horizontal or vertical attached to the leadframe.

camber — curvature of the leadframe strip edge (see Figure 1).

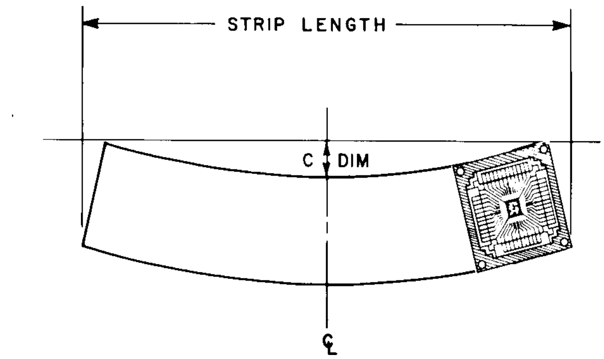

Figure 1
Camber

coil set — longitudinal bowing of the leadframe (see Figure 2).

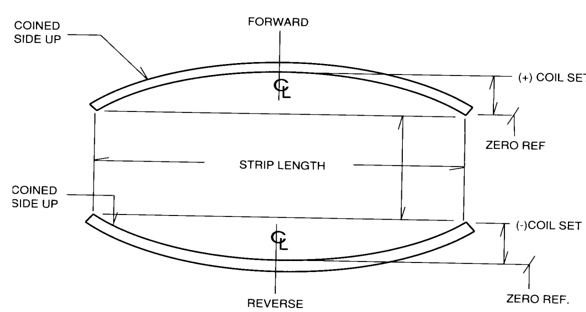

Figure 2
Coil Set

coined area — that area at the tip end of the bond fingers coined to produce a flattened area for functional use (see Figure 3).

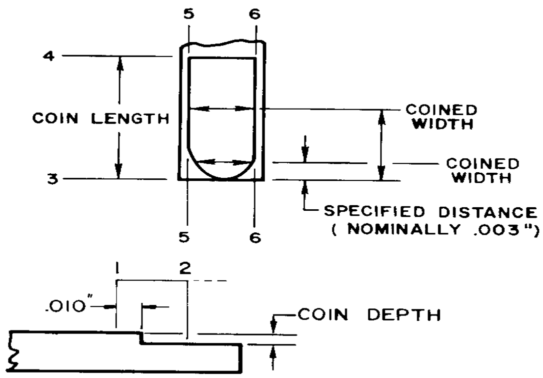

Figure 3
Coined Area

crossbow — transverse bowing of the leadframe (see Figure 4).

functional area — the die attach pad and the lead tips.

lead twist — angular rotation of bonding fingers (see Figure 5).

pits — shallow surface depression or craters in the leadframe material.

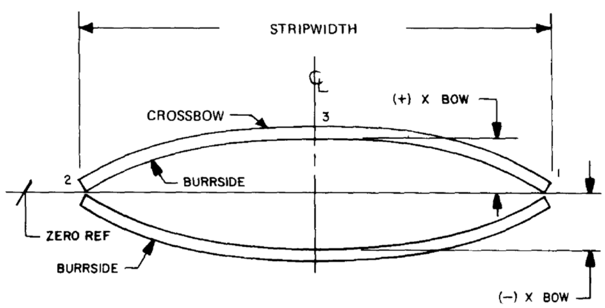

Figure 4
Crossbow

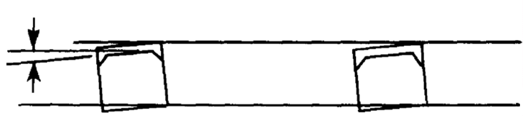

Figure 5
Lead Twist

slug marks — random dents in the leadframe caused by foreign material in the stamping die.

stamped leadframe terminology — (See Figure 6.)

true position circle — the circle with its center positioned at the center of the coined lead which defines the design position of the lead tip.

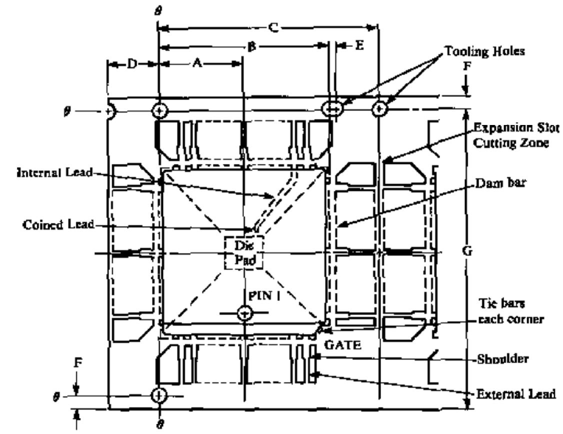

Figure 6
Plastic Leaded Chip Carrier Leadframe

4 Ordering Information

4.1 Purchase orders for leadframes furnished to this specification shall include the following information:

4.1.1 Current revision of the leadframe drawing detailing the base material and the plating type(s), thickness(es) and area(s).

4.1.2 Reference to this specification.

4.1.3 Vendor certification requirements.

5 Dimensions

See Table 1.

6 Defect Limits and Parameters

Note: Measurement methods are described in SEMI G10. Alternate methods may be used as agreed to between vendor and customer. The methods described in SEMI G10 are considered to be standard for the purpose of solving differences.

6.1 *Dimensional Tolerances* — See Figure 6.

6.2 *Minimum Flat Wire Bonding Area* — 80% of nominal lead width and 0.635 mm (0.025") in length.

6.3 *Coined Depth* — 0.013 mm (0.0005") min. to 30% of material thickness maximum.

6.4 *Horizontal Lead Spacing and Location (Lead Tips)*

6.4.1 The lead spacing and lead location that can be maintained is a function of the designed lead spacing and lead width.

Design Lead Width	*Design Lead Space*	*Minimum Lead Sapce*	*Minimum True Position Circle Dia.*
≥ 0.011"	≥ 0.011"	0.006"	0.007"
0.010"	0.010"	0.005"	0.006"

Tolerances for lead designs smaller than .010" should be negotiated between vendor and user.

6.4.2 *18 - 100 Pin Lead Frames* — Leads to be located so that a 0.007" diameter circle centered on the nominal center of the coined lead in width and 0.152 mm (0.006") back from lead tip in length shall be totally encompassed by the coined area.

Table 1 Plastic Leaded Chip Carrier Leadframe Standard Dimensions (all dimensions in inches)

LEAD COUNT	*18 LD*	*18 LD*	*20 LD*	*28 LD*	*28 LD*	*32 LD*	*44 LD*	*52 LD*	*68 LD*	*84 LD*	*100 LD*	*100 LD*
PACKAGE SHAPE	Rect.	Rect. Stretch	Square	Square	Rect.	Rect.	Square	Square	Square	Square	Square	Square
JEDEC PACKAGEDESIGNATION	AA	AB	AA	AB	AD	AE	AC	AD	AE	AF		
Nominal Pkg. Width	0.290	0.290	0.350	0.450	0.350	0.450	0.650	0.750	0.950	1.150	1.350	1.150
Length	0.425	0.490	0.350	0.450	0.550	0.550	0.650	0.750	0.950	1.150	1.350	1.150
PROGRESSION	0.720	0.720	0.780	0.880	0.780	0.880	1.080	1.180	1.400	1.600	1.800	1.600
STRIP WIDTH	0.970	1.230	0.970	1.070	1.230	1.230	1.230	1.430	1.670	1.870	2.070	1.870
TOOLING DIMENSIONS (See Figure 6)												
A	0.170	0.170	0.200	0.250	0.200	0.250	0.350	0.400	0.500	0.600	0.700	0.600
B	0.340	0.340	0.400	0.500	0.400	0.500	0.700	0.800	1.000	1.200	1.400	1.200
C	0.530	0.530	0.590	0.690	0.590	0.690	0.890	0.990	1.200	1.400	1.600	1.400
D	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.190	0.200	0.200	0.200	0.200
E	0.020	0.020	0.020	0.020	0.020	0.020	0.020	9.020	0.020	0.020	0.020	0.020
F	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
G	0.920	1.180	0.920	1.020	1.180	1.180	1.180	1.380	1.620	1.820	2.020	1.820
Diameter	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Metal Thickness	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.008	0.008	0.008	0.008

Note 1: Gate — All packages; gate on the corner counter-clockwise from pin one.

Note 2: Dam Bar — Recommend 0.025 wide with 0.025 space between package and dam bar.

Note 3: Lead shall meet the JEDEC Quad Package requirements.

6.5 *Horizontal Die Attach Pad Location* — Die attach pad shall be located within 0.051 mm (± 0.002") on 18-100 pin leads.

6.6 *Lead Twist* — Shall not exceed 3° 30' or 0.015 mm (0.0006") per 0.254 mm (0.010") of lead width.

6.7 *Die Attach Pad Tilt and Flatness*

6.7.1 *Tilt* — 0.025 mm (0.001") maximum per 2.54 mm (0.100") of length or width in the undepressed state. 0.051 mm (0.002") maximum per 2.54 mm (0.100") of length or width in the depressed conditions when measuring from corner to corner.

6.7.2 *Flatness* — 0.005 mm (0.0002") per 0.100" pad length on 18-100 pin leadframes when measuring from the center to the average of the four corners. The corners are defined at 0.127 mm (0.005") from each edge.

6.8 *Die Attach Pad Downset or Depression* — The nominal downset recommended is 0.015" (0.381 mm) ± 0.002".

6.9 *Lead and Die Attach Pad Coplanarity*

6.9.1 *Lead Planarity* — The lead tips shall be within the following tolerances of the Z plane in the taped or untaped condition.

Table 2 Taped or Untaped Condition

No. of Leads	*Strip Width*	*Lead Tip Coplanarity*
18 Rect.	1.070" - 1.230" (27.18 mm - 31.24 mm)	± 0.003" (0.76 mm)
20 Square	0.970" (24.64 mm)	± 0.003" (0.076 mm)
28-52	1.070" - 1.470" (27.18 mm - 37.34 mm)	± 0.004" (0.120 mm)
64-84	1.670" - 1.870" (42.42 mm - 47.50 mm)	± 0.005" (0.127 mm)

6.9.2 *Die Attach Pad Planarity* — The die attach pad shall be within the following tolerances of the Z plane.

6.10 *Material*

6.10.1 0.203 mm (0.008") material thickness recommended for greater than 52 leads.

6.10.2 0.254 mm (0.010") material thickness recommended for 52 lead and below.

6.10.3 Nominal thickness tolerances for both Alloy 42 and copper materials of 0.203 mm (0.008") and 0.254 mm (0.010") shall be 0.008 mm (± 0.0003").

6.10.4 *Width Tolerance* — 0.051 mm (± 0.002") for both Alloy 42 and copper.

6.11 *Coil Set* — Maximum of 0.508 mm (0.020") over the nominal strip length. Does not include material thickness.

6.12 *Crossbow* — Crossbow shall not exceed the following dimensions:

No. of Leads	*Maximum Crossbow*
18—20	± 0.005" (0.127 mm)
28 - 52	± 0.006" (0.152 mm)
68 - 84	± 0.010" (0.254 mm)

6.13 *Camber* — Shall not exceed 0.002" over nominal strip lengths of 8 ± 2 inches.

The relationship to determine maximum camber for other lengths is approximated as follows:

$$\frac{C_1}{C_2} = \frac{L_1^2}{L_2^2}$$

6.14 *Progression* — The progression over the nominal strip length shall be within 0.051 mm (± 0.002") and noncumulative.

6.15 *Burrs* — Shall be firmly attached and able to withstand a probe force of 10 grams. Vertical burrs inside the dambar shall not exceed 0.025 mm (0.001"). Vertical burrs outside the dambar and horizontal burrs in any location shall not exceed 0.051 mm (0.002").

6.16 *Pits and Slugmarks*

6.16.1 Within functional area and on external leads, there shall be no slugmarks. Pits shall not exceed 0.008 mm (0.0003") in depth and 0.013 mm (0.0005") in largest surface dimension in these areas.

APPLICATION NOTE: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

6.16.2 In other areas, pits and imperfections shall not affect leadframe strength regardless of size and shall not exceed 0.051 mm (0.002") in depth and 0.127 mm (0.005") in largest surface dimension.

6.17 *Strip Cut Off Location* — Strip cut off shall be within 0.076 mm (± 0.003") of basic strip length (see Figure 6).

6.18 *Coining and Metal Clearance*

6.18.1 Dimensions shown on drawings are before coin dimensions.

6.18.2 Maximum coining bulge shall not exceed 0.051 mm (0.002") per edge and shall be governed by metal to metal clearance requirements (lead to lead and lead to pad).

6.18.3 *Metal to Metal Clearance* — Shall be as agreed to between vendor and customer.

7 Sampling

7.1 The sampling plan shall be agreed upon between vendor and customer.

8 Packaging and Marking

8.1 *Packaging* — Containers and packaging materials shall be selected to provide protection against normal transportation damage risks and spillage. They will also offer protection from contamination, exposure to moisture, oxidation, and tarnishing.

8.2 *Marking*

8.2.1 The following details shall be noted on the packing slip attached to the outside of the shipping package:

Vendor Part Number

Customer Part Number

Quantity

Date

Vendor Lot Number

User PO Number

Drawing Number

SEMI G28-0997
SPECIFICATION FOR LEADFRAMES FOR PLASTIC MOLDED S.O. PACKAGES

1 Purpose

This specification defines the acceptance criteria for stamped leadframes for plastic molded S.O. packages.

2 Scope

This specification is a guideline for production of stamped S.O. Leadframes to be used in plastic molded S.O. packages.

3 Referenced Documents

3.1 *SEMI Specifications*

SEMI G4 — Specification for Integrated Circuit Leadframe Materials used in the Production of Stamped Leadframes

SEMI G9 — Specification for Stamped Leadframes for Plastic Molded Dual-In-Line Semiconductor Packages

SEMI G10 — Standard Method for Mechanical Measurement for Plastic Package Leadframes

SEMI G21 — Specification for Plating Integrated Circuit Leadframes

3.2 *ANSI/ASQC Specifications*[1]

ANSI/ASQC Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

3.3 *ANSI Specifications*[2]

ANSI Y14.5M — Dimensioning and Tolerancing

4 Terminology

4.1 *burr* — A fragment of excess material either horizontal or vertical adhering to the component surface.

4.2 *camber* — Curvature of the leadframe strip edge in the horizontal plane (see Figure 1).

4.3 *coil set* — Longitudinal bowing of the leadframe (see Figure 2).

4.4 *coined area* — That area at the tip of the bond fingers flattened to produce an acceptable surface for wire bonding (see Figure 3).

4.5 *crossbow* — Transverse bowing of the leadframe (see Figure 4).

4.6 *functional area* — The die attach pad and the wire bond (lead tips) area.

4.7 *lead twist* — Angular rotation of bonding fingers (see Figure 5).

4.8 *pit* — A shallow surface depression or crater in the leadframe material.

4.9 *slugmarks* — Random dents in the leadframe caused by foreign material in the stamping die.

4.10 *stamped leadframe terminology* — (See Figure 6.)

5 Ordering Information

Purchase orders for leadframes for plastic molded S.O. packages furnished to this specification shall include the following items:

a. Current leadframe specification drawing.

b. All dimensions and tolerances per ANSI Y14.5 practices.

c. Material type and physical characteristics (see SEMI G4).

d. Type hardness and thickness of any required plating (see SEMI G21).

6 Dimensions

See Table 1 and Figure 7 for standard dimensions. Tolerances shall be agreed between vendor and customer.

7 Defect Limits and Parameters (see SEMI G10 for measurement methods)

7.1 *Internal Frame Area*

7.1.1 *Minimum Flat Wire Bonding Area* — 80% of nominal lead width and .015" (.381 mm) in length.

7.1.2 *Coin Depth*

7.1.2.1 0.008" (0.20 mm) material: 0.0005" (0.013 mm) minimum/0.001" (0.02 mm) maximum.

7.1.2.2 0.010" (0.25 mm) material: 0.0005" (0.013 mm) minimum/0.002" (0.05 mm) maximum.

1 ASQC, 611 East Wisconsin Avenue, Milwaukee, WI 53202

2 ANSI, 1430 Broadway, New York, NY 10018

NOTE: Maximum coin depth may also be constrained by minimum lead spacing requirement given in Section 7.1.3.1. Minimum coin depth may also be constrained by minimum bond area requirement given in Section 7.1.1.

7.1.3 *X-Y Plane Lead Spacing and Location*

7.1.3.1 Spacing between leads to be 0.004" (0.100 mm) minimum.

7.1.3.2 Leads to be located so that a 0.007" diameter circle centered on the nominal center of the coined lead in width and 0.006" (0.152 mm) back from lead tip in length shall be totally encompassed by the coined area.

7.1.4 *X-Y Plane Die Attach Pad Location* — Die attach pad to be located within ± 0.002" (0.051 mm) as measured from the centerline of the reference hole in the side rail.

7.1.5 *Lead Twist* — Shall not exceed 3°30’ or 0.0006" (0.015 mm) per 0.010" (0.254 mm) of lead width.

7.1.6 *Die Attach Pad Tilt and Flatness*

7.1.6.1 *Tilt* — 0.001" (0.025 mm) maximum per 0.100" (2.54 mm) in the undepressed state. 0.002" (0.015 mm) maximum per 0.100" (2.54 mm) in the depressed condition.

7.1.6.2 *Flatness* — To be within 0.002" (0.051 mm) T.I.R. per 0.100" (2.54 mm) when measured from the center to each of the four corners. The corners are defined at 0.005" (0.127 mm) from each edge.

7.1.7 *Die Attach Pad Downset* — ± 0.002" (0.051 mm) as measured from the center of the pad to a point on the bar pad support strip. The nominal downset recommended is 0.012" (0.30 mm) for 0.010" (0.25 mm) thick material and 0.008" (0.20 mm) for 0.008" (0.20 mm) thick material.

7.1.8 *Lead and Die Attach Pad Coplanarity*

7.1.8.1 The coplanarity relationship is based on reference to the Z plane (see SEMI G10).

7.1.8.2 *Lead Planarity* — The lead tips as measured in the center of the back, uncoined surface of the lead tip shall be located within the following tolerances of the Z plane:

Lead Planarity: ± 0.004"

7.1.8.3 *Die Attach Pad Planarity* — The die attach pad when measured at the center must be within the following tolerances of the Z plane:

Pad Planarity: + 0.003"/-0.005"

7.2 *External Area and Strip*

7.2.1 *Material*

7.2.1.1 0.008" (0.20 mm) material thickness recommended for 0.150" wide packages.

7.2.1.2 0.010" (0.25 mm) material thickness recommended for 0.300" wide packages.

7.2.1.3 *Nominal Thickness* — Tolerances shall be ± 0.0003" (0.008 mm).

7.2.1.4 *Width Tolerance* — ± 0.002" (0.051 mm).

7.2.2 *Coil Set* — Maximum of 0.125" (3.175 mm) measured in a free standing state over strip length.

7.2.3 *Crossbow* — Crossbow shall not exceed the following dimensions:

Maximum Crossbow: ± 0.005" (0.127 mm)

7.2.4 *Camber* — Shall not exceed 0.002" (0.05 mm) over a gage length of 6.00" (150 mm). (See SEMI G10.)

7.2.5 *Progression* — Should be specified along with tolerances on the drawing.

7.2.6 *Burrs* — Burrs shall be firmly attached and able to withstand a probe force of 10 grams. Vertical burrs inside the dambar shall not exceed 0.001" (0.02 mm). Vertical burrs outside the dambar and horizontal burrs in any location shall not exceed 0.002" (0.05 mm).

7.2.7 *Pits and Slugmarks*

7.2.7.1 Within functional area and on external leads there shall be no slugmarks. Pits shall not exceed 0.0003" (0.008 mm) in depth and 0.0005" (0.013 mm) in largest surface dimension in these areas.

7.2.7.2 *Areas Other than 7.2.7.1* — Pits and imperfections shall not affect leadframe strength regardless of size and shall not exceed 0.002" (0.05 mm) in depth and 0.005" (0.127 mm) in largest surface dimension.

7.2.8 *Strip Length Cutoff* — (See SEMI G10.)

7.2.8.1 Strip cutoff location and tolerance shall be detailed on the drawing.

7.2.8.2 Overall strip length and tolerance shall be detailed on the drawing.

8 Functional Testing

Functional testing shall be agreed upon between vendor and customer.

9 Sampling

Sampling based on ANSI/ASQC Z1.4 shall be agreed between supplier and purchaser.

10 Packaging, Marking, and Packing List

10.1 *Packaging* — The shipping containers and materials shall be suitably designed to provide the leadframes with protection against normal transportation damage risks which include crushing and spillage, and exposure to moisture and other corrosive gases.

10.1.1 The inner packaging materials for cut strips must not cause particulate contamination on the leadframes and shall be clean room compatible as defined by the customer. The leadframes boxes shall be vacuum sealed in a bag with a desiccant. If the leadframes are to be delivered in coil form, the coil diameter shall be set in the purchase order (see SEMI G9).

10.2 *Marking*

10.2.1 *Internal Packages* — Each internal package shall be clearly marked with the following information, as appropriate:

a. Customer's part number

b. Customer's purchase order number

c. Drawing number (customer's and/or vendor's, as requested by customer)

d. Vendor's shipping lot number

e. Quantity

f. Date of Manufacture

g. Any agreed upon certification data

10.2.2 *External Packages* — The packing list on the outside of the external package shall contain the following information:

a. Customer's part number

b. Customer's purchase order number

c. Quantity

d. Shipping Date

e. Any specific instructions for receiving dock personnel

11 Certification

11.1 Upon request of the customer in the contract or purchase order, a vendor's certification that the product was manufactured and tested in accordance with this specification, together with a report of the test results shall be furnished at the time of shipment. However, if the customer does perform inspection and test on a certified shipment and the product fails to meet the requirements, the product shall be subject to rejection.

11.2 If the customer and vendor agree, the product may be certified as capable of meeting this specification. In this context, capable of meeting signifies that the vendor is not required to perform all the inspections and tests. However, if the customer does perform inspection and test on a certified shipment and the product fails to meet the requirements, the product shall be subject to rejection.

Table 1

		0.150 WIDE			*0.30 WIDE (J-COMPATIBLE)*					
		8	14	16	14	16	18	20	24	28
	MATERIAL GAGE	0.008" (0.200 mm)	0.008 (0.200)	0.008 (0.200)	0.010 (0.250)	0.010 (0.250)	0.010 (0.250)	0.010 (0.250)	0.010 (0.250)	0.010 (0.250)
A	STRIP WIDTH	0.600 (15.2)	0.600 (15.2)	0.600 (15.2)	0.720 (18.30)	0.720 (18.30)	0.720 (18.30)	0.970 (24.60)	0.970 (24.60)	0.970 (24.60)
B	PROGRESSION	0.336 (8.53)	0.336 (8.53)	0.336 (8.53)	0.674 (17.12)	0.674 (17.12)	0.674 (17.12)	0.674 (17.12)	0.674 (17.12)	0.674 (17.12)
C	TOOLING HOLE				0.060 (1.52)	0.060 (1.52)	0.060 (1.52)	0.060 (1.52)	0.060 (1.52)	0.060 (1.52)
D	DAMBAR WIDTH 0				0.010 (.250)	0.010 (.250)	0.010 (.250)	0.010 (.250)	0.010 (.250)	0.010 (.250)
E	DAMBAR DISTANCE FROM CL	0.079 (2.00)	0.079 (2.00)	0.079 (2.00)	0.156 (4.00)	0.156 (4.00)	0.156 (4.00)	0.156 (4.00)	0.156 (4.00)	0.156 (4.00)
F	LEAD LENGTH CL TO LEAD RAIL	0.167 (4.24)	0.167 (4.24)	0.167 (4.24)	0.322 (8.18)	0.322 (8.18)	0.322 (8.18)	0.322 (8.18)	0.322 (8.18)	0.322 (8.18)
G	PKG. LENGTH BOUNDARY	0.098 (2.49)	0.172 (4.37)	0.198 (5.03)	0.181 (4.60)	0.198 (5.03)	0.231 (5.87)	0.255 (6.48)	0.307 (7.80)	0.356 (9.04)
H	PARTS PER STRIP (STRIP LENGTH)	24 (8.064)	24 (8.064)	24 (8.064)	12 (8.088)	12 (8.088)	12 (8.088)	12 (8.088)	12 (8.088)	12 (8.088)
I	PAD DOWNSET	0.008 (0.200)	0.008 (0.200)	0.008 (0.200)	0.012 (0.305)	0.012 (0.305)	0.012 (0.305)	0.012 (0.305)	0.012 (0.305)	0.012 (0.305)

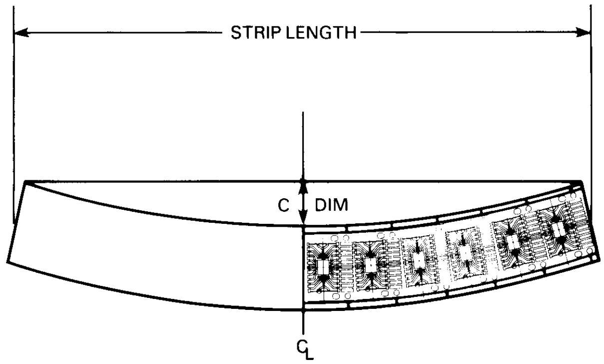

Figure 1
Camber

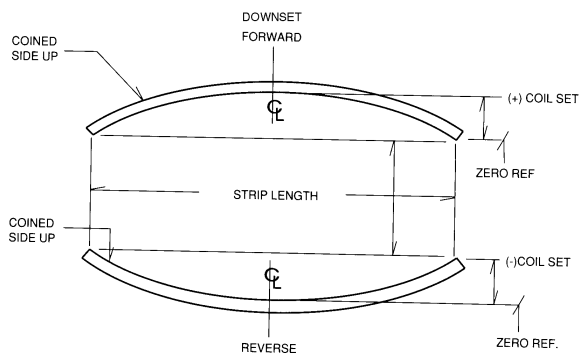

Figure 2
Coil Set

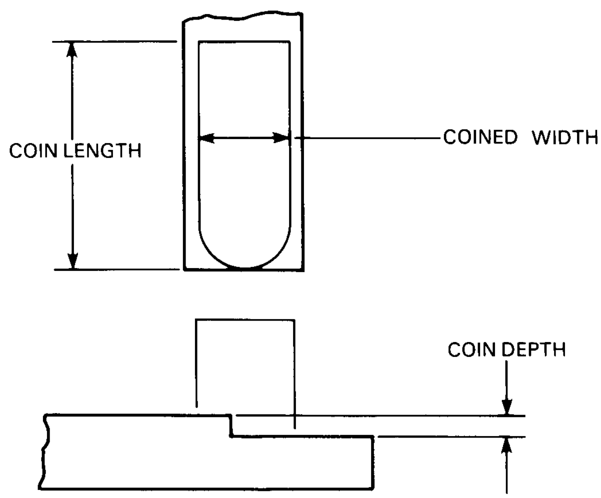

Figure 3
Coined Area

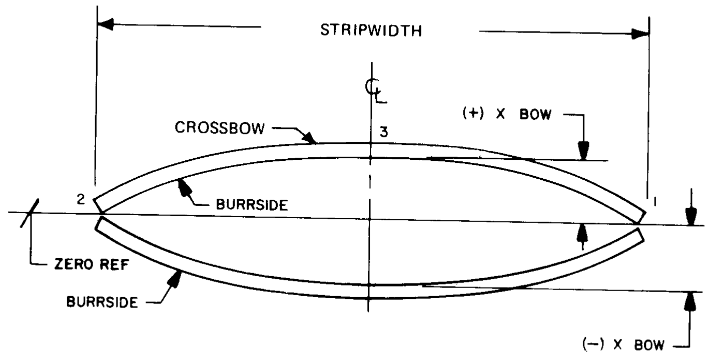

Figure 4
Crossbow

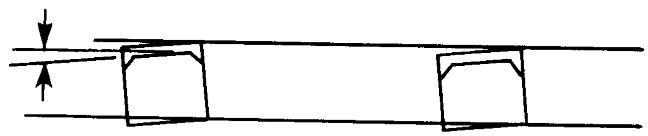

Figure 5
Lead Twist

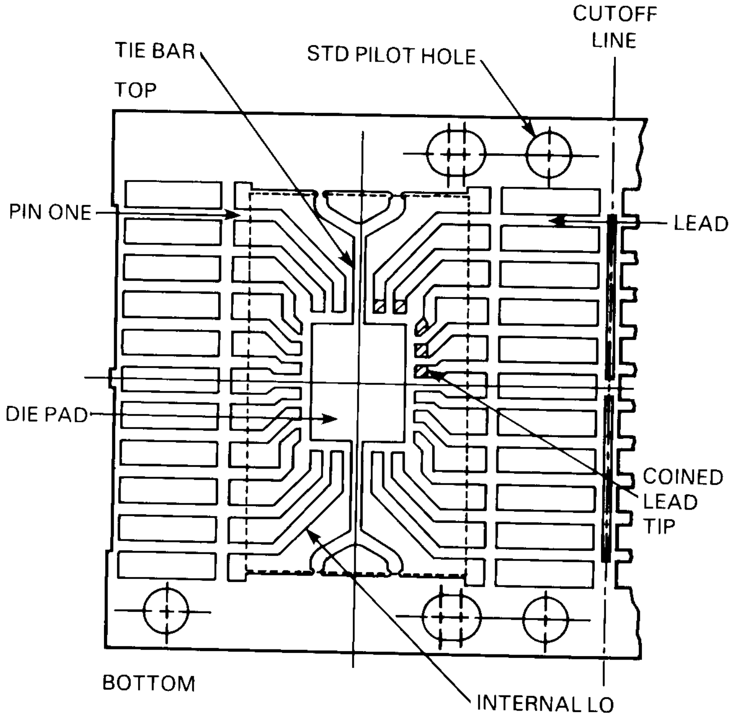

Figure 6
Stamped Leadframe Terminology

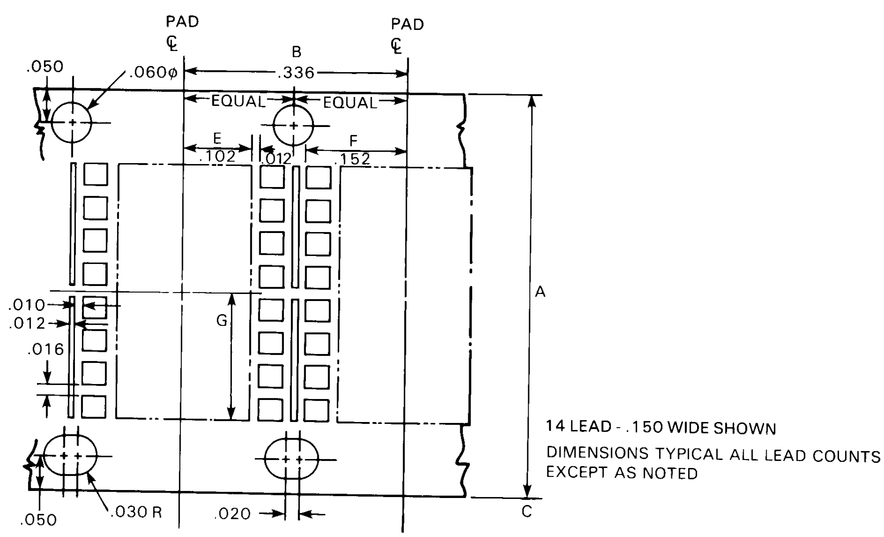

Figure 7
S.O. Leadframe Standard

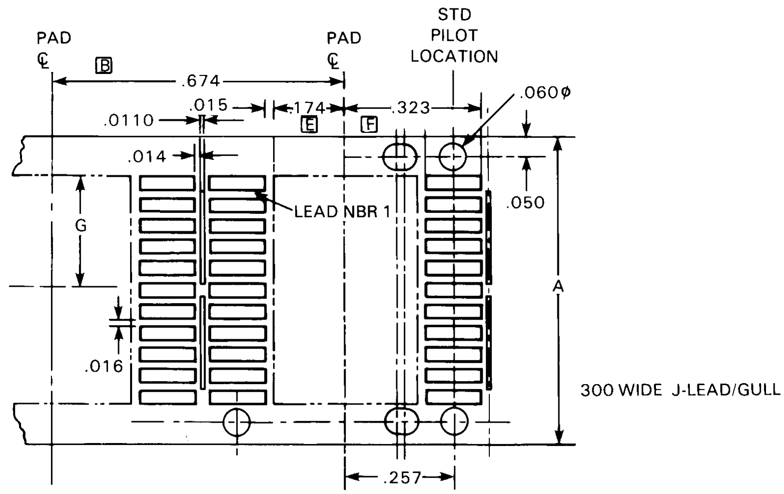

Figure 8
S.O. Leadframe

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G29-1296
TEST METHOD FOR TRACE CONTAMINANTS IN MOLDING COMPOUNDS

1 Purpose

This specification defines the test method for determination of extractable trace contaminants in molding compound.

2 Scope

This test method is suitable for all molding compound materials and may be used by supplier and customers to determine the trace contaminants in molding compound.

3 Referenced Documents

3.1 *ASTM Documents*[1]

ASTM D 1193 — Specification for Reagent Water

ASTM D 4327 — Anions in Water by Ion Chromatography

4 Method Summary

Plastic molding compound material is molded, ground to a defined mesh size, and placed into a sealed extraction vessel with de-ionized water. Extraction is carried out at 120 ± 2°C for 48 hours. The extract is analyzed for both anionic and cationic impurities.

5 Sample Preparation

5.1 Samples of molding compound materials may be obtained from either standard molding operations, or prepared in the laboratory.

5.1.1 Samples from molding operations may include mold runners post-cured according to manufacturer's recommendations.

5.1.2 To secure a sample in the laboratory, spread a thin layer of uncured compound in a dedicated clean teflon-coated container. Cure and post-cure the compound material according to manufacturer's recommendations.

5.2 Crush the cured material using a suitable grinding apparatus, such as Spex mixer-mill No. 8000, or equivalent.

NOTE 1: The grinder used must not generate excess localized heat, or else sample decomposition and erroneous results may be generated.

NOTE 2: Addition of liquid nitrogen is a suitable method for eliminating undesirable thermal decomposition during grinding.

5.3 Remove the ground compound and sieve it. Collect for analysis the portion which passes through a 40 mesh size, but is retained on a 100 mesh size screen. This particle size is best suited for adequate extraction of impurities.

5.4 Weigh 10% 0.1 grams of the powdered material and place in an extraction vessel. Parr bombs with teflon liners are suitable extraction vessels. Add 100 ml de-ionized water. Prepare blank extraction vessel by processing it in the same manner as your sample. Weigh the sealed bombs and record their weights. Place the sealed bottles on their sides in an oven at 120 ± 2°C for forty-eight (48) hours.

NOTE 3: Certain compounds may require addition of reagent grade methanol 10% (V:V) to enhance wetting.

5.5 At the completion of forty-eight (48) hours of extraction, allow the bombs to cool to room temperature and reweigh. If the weight loss exceeds 0.5 grams the sample should not be used for analysis. Portion of this extract may be used to generate pH and conductivity data. Anion analysis may be performed using ion chromatography or specific ion electrodes. Cation analysis may be conducted using atomic absorption, plasma spectrometry, or ion chromatography.

NOTE 4: It is important to avoid contamination with particulate matter in the extract used for the analysis by AA, ICAP, or IC. This procedure addresses determination of extractive species only.

6 Instrumentation Techniques

6.1 *Measurement of Conductivity*

6.1.1 *Apparatus* — Conductivity Meter Model RC1682 with microconductivity cell, industrial instruments, or equivalent.

6.1.2 *Measurement* — Measure conductivity of the sample and black solutions. Calculate the specific conductance of sample using the following equation:

$L_s = (L_e - L_b) K$

L_s - Specific conductance, S cm^{-1}

L_e - Conductance of extract, S

L_b - Conductance of the blank

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

K - Conductivity cell constant

6.2 *Measurement of pH*

6.2.1 *Apparatus*

6.2.1.1 pH meter (Orion, Model 601, or equivalent)

6.2.1.2 pH standard solutions

6.2.2 *Measurement* — Adjust pH meter indicator by using standard solutions. Remove the electrodes with de-ionized water and dry with clean filter paper. Place the electrodes into the molding compound extract. Allow the meter to equilibrate. Record the pH value.

6.3 *Ion Specific Electrodes* — Ion-specific electrodes may be used for the determination of chloride, bromide, sulfate, and phosphate. A separate specific electrode for each ion is required and, in some instances, a reference electrode may be necessary to complete the test. Individual standards are needed for each ion tested. Methodology recommended by the manufacturer for each ion specific electrode should be closely followed. Measured concentrations corrected for blank value should be compared to the known standards in the range 0.1–100 ppm. Chloride and bromide are usually determined, using a solid state single electrode. Determination of sulfate and phosphate ions may require use of additional buffers and a titration.

6.4 *Determination of Sodium, Potassium, and Antimony Using Atomic Absorption*

6.4.1 *Apparatus* — Atomic absorption spectrophotometer.

6.4.2 *Standard Solutions*

6.4.2.1 Sodium standard solutions 0.1, 0.2, 0.4, 0.6, 0.8, 1.0 ppm.

6.4.2.2 Potassium standard solutions 0.1, 0.2, 0.4, 0.6, 0.8, 1.0 ppm.

6.4.2.3 Antimony standard solution 0.1, 0.2, 0.4, 0.6, 0.8, 1.0 ppm.

6.4.3 *Measurement* — Set up instrument according to manufacturer's recommendation. Analyze water extract based on the calibration curve prepared using standard solutions to obtain concentration of ion of interest.

6.4.4 *Calculation*

6.5 Determination of Chloride, Bromide, Phosphate, Sulfate, Sodium, and Potassium by Ion Chromatography

6.5.1 *Method Principle* — Ion chromatography is a form of liquid chromatography used in the separation and quantitation of ions. A filtered aliquot of sample is injected into an Ion chromatograph. The sample is pumped by the eluent stream through two (2) different ion exchange columns: a guard column, which serves to protect the separator column from residual particulate matter and retain certain organics, and the separator column, the primary function of which is to separate analyzed ions based on their affinity for the exchange sites of the resin. Both guard column and the separator column are packed with identical low capacity anion exchanger (anion analysis) or cation exchange (cation analysis). The separated ionic species then pass to a detector module consisting of a chemical suppressor device and a conductivity cell. The suppressor device is used to reduce background conductivity of the eluent to a low, or negligible level, and convert analyte anions into their acid form or analyte cations into their hydroxide form. Thus, separated and modified ionic species are detected using an electrical conductivity cell. Anions are identified based on their retention time compared to the known standards. Quantitation is accomplished by measuring the peak height or area, and comparing it to a calibration curve generated from known standards.

NOTE 5: For recommended practice for ion chromatography analyses, see instrument manufacturer's literature and ASTM D 4327.

6.5.2 *Interferences*

6.5.2.1 High levels of organic acids may be present in molding compound extracts. This may interfere with inorganic anion analysis. Two (2) common species, formate and acetate, elute between fluoride and chloride. This may be minimized by modifying instrument set-up.

6.5.2.2 Certain amines may interfere with the determination of sodium or potassium. This may be minimized by using different instrument set-ups.

6.5.3 *Apparatus*

6.5.3.1 Ion chromatograph (Dionex or equivalent). The chromatograph shall be equipped with an injection valve, a 50–100 µl sample loop, and shall be set up with the following:

1. Guard Column
2. Separator Column
3. Chemical Suppressor Device
4. Conductivity Detector

6.5.4 *Reagents*

6.5.4.1 *Water Purity* — Water used in the preparation of eluents, standards, and sample extraction shall conform to ASTM D 1193.

6.5.4.2 *Reagent Purity* — Reagent grade chemicals should be used in all tests.

6.5.4.3 *Eluent/Regenerant Solutions* — Should be prepared in accordance with instrument manufacturer's instructions recommended for each column set.

6.5.4.4 *Stock Solutions* — Stock solutions (1 ml - 1 mg - 1 ppm ion of interest) should be prepared according to accepted practice, and as described in the instrument manufacturer's instructions.

6.5.4.5 *Calibration Standards* — Prepare a blank and at least three (3) different calibration solutions containing combination of anion/cations. These solutions must be prepared in volumeric flasks (see Table 1).

6.5.4.5.1 Prepare a standard solution I by diluting the volume of each anion/cation stock solution as specified in Table 1 together with 1 litre of water.

6.5.4.5.2 Prepare a standard solution II by diluting 20 ml of standard solution II to 100 ml with water (see Table 1).

NOTE 6: If the concentrations of the sample ions are known, or estimated, the concentration of calibration standard solutions may be varied to better approximate or bracket concentration range of interest.

6.5.5 *Calibration*

6.5.5.1 Analyze the blank and each of the prepared calibration solutions described in Section 6.5.4.5.

6.5.5.2 Prepare analytical curves for each anion/cation of interest by plotting on linear graph paper peak height or peak area versus nominal concentrations of the anion/cation calibration standard.

NOTE 7: Each analytical curve should be established using only one (1) scale setting.

6.5.6 *Procedure*

6.5.6.1 Set-up the ion chromatograph according to the manufacturer's instructions.

NOTE 8: The range setting required for the analysis will depend on the concentration of ions in the sample and should be chosen accordingly. For these types of samples, operating range from 30 to 30µ S/cm, full scale is most frqurntly used.

6.5.6.2 Equilibriate the system by pumping eluent through the analytical system until a stable baseline is obtained (approximately twenty (20) minutes).

6.5.6.3 Filter samples through a pre-washed 0.22 µm filter prior to analysis.

NOTE 9: Several types of syringe-tip filters are available (Millipore or equivalent).

6.5.6.4 Load 2–3 ml of sample into the injection part using a syringe. Inject the sample into the eluent stream and record the ion chromatogram.

6.5.7 *Calculations*

6.5.7.1 Refer to the peak height or area for the anions/cations of interest to the appropriate analytical curves to determine the anion concentration.

6.6 *Inductivity Coupled Argon Plasma Spectrometry/ICP*

6.6.1 *Method Principle* — Inductivity coupled Argon Plasma (ICP) uses high frequency Argon Plasma to excite sample constituents to 8000°K. Because the plasma ionizes most atomic species, background interferences are vastly reduced and linear response over several orders of magnitude can be observed for most elements. The sample extract is aspirated into the plasma by means of a high purity argon carrier gas. The resulting emissions are directed into the spectrometer and signal strengths are read by photomultiplier tubes placed at emission points in a focal curve. A computer is used to scan each elemental channel many times a second, and this output is sent to a printer in numerical form. The cycle or time of analysis is usually about seven (7) seconds. With this instrument, very little of the extracted sample is consumed.

6.6.2 *Instrument Conditions*

Typical operating conditions are:

Excitation source	27 MHz plasma
Carrier gas	99.999% Argon
Sample flow	1 ml/min
Power output	1000 watts
Plasma temperature	8000°K
Slit width of Spectrometer	30 µm

6.6.3 *Measurement of Sodium, Potassium, and Antimony* — A standard solution of ten (10) ppm of sodium, potassium, and antimony should be prepared and cycled through the ICP instrument. The blank extract sample and the unknown molding compound extracts are then run through the ICP. The values obtained for sample are corrected by subtracting values obtained for the blank. With the ICP, sodium, potassium, and antimony can be analyzed with sensitivities to the ten (10) PPB levels. Any additional elements present may be obtained on the same cycle with no additional preparation.

Table 1 Preparation of Standard Solutions for Instrument Calibration

Anion	*Standard Solution*		*Standard Solution II*	*Standard Solution III*
	ml of Stock Soln. Diluted to 1000 ml	*Anion Conc. mg/1*		
Chloride (Cl)	5	5	1	0.2
Phosphate (HPO_4^{2-})	25	25	5	1.0
Bromide (Br^-)	10	10	2	0.4
Nitrate (NO_3	30	30	6	1.2
Sulfate (SO_4^{2-})	25	25	5	1.0
Cation				
Sodium (NA^+)	5	5	1	0.2
Ammonium (NH_4^+)	5	5	1	0.2
Potassium (K^+)	10	10	2	0.4

SEMI G30-88
TEST METHOD FOR JUNCTION-TO-CASE THERMAL RESISTANCE MEASUREMENTS OF CERAMIC PACKAGES

1 Purpose

The purpose of this test is to determine the thermal resistance of ceramic packages using thermal test chips. This test method deals only with junction-to-case or mounting surface measurements of thermal resistance and limits itself to heat sink and fluid bath testing environments. Following the guidelines outlined in this test method, junction-to-case thermal resistance measurements of ceramic packages using the heat sink and fluid bath methods should give the same results only under certain limited conditions (i.e., under conditions that approximate unidirectional heat flow through the chip and substrate to the preferred heat removal surface). If discrepancies occur, the heat sink mounting technique shall be considered as the referee test method. The heat sink mounting method for measuring junction-to-case thermal resistance will be a conservative measure of the package's ability to transfer heat to the ambient environment because heat sinking is provided only on one side of the package, whereas the fluid bath mounting method has the potential for equally cooling both sides of the package.

1.1 *Definitions* — The following definitions and symbols shall apply for the purpose of this test:

a. *case temperature,* T_C, in degrees Celsius. The case temperature is the temperature at a specified accessible reference point on the package in which the microelectronic chip is mounted.

b. *mounting surface temperature,* T_M, in degrees Celsius. The mounting surface temperature is the temperature of a specified point at the device-heat sink mounting interface (or primary heat removal surface).

c. *junction temperature,* T_J, in degrees Celsius. The term is used to denote the temperature of the semiconductor junction in the microcircuit in which the major part of the heat is generated. For purposes of this test, the measured junction temperature is only indicative of the temperature in the immediate vicinity of the element used to sense the temperature.

d. *power dissipation,* P_H, in watts, is the heating power applied to the device causing a junction-to-reference point temperature difference.

e. *thermal resistance, junction-to-specified reference point,* $R_{\Theta JR}$, in degrees Celsius/watt. The thermal resistance of the microcircuit is the temperature difference from the junction to some reference point on the package divided by the power dissipation P_H.

f. *temperature-sensitive parameter,* TSP, is the temperature-dependent electrical characteristic of the junction under test which can be calibrated with respect to temperature and subsequently used to detect the junction temperature of interest.

2 Apparatus

2.1 The apparatus required for these tests shall include the following as applicable to the specified test procedures.

a. Thermocouple material shall be copper-constantan (type T) or equivalent, for the temperature range -100 to +300°C. The wire size shall be no larger than AWG size 30. The junction of the thermocouple shall be welded to form a bead rather than soldered or twisted. The accuracy of the thermocouple and associated measuring system shall be ± 0.5°C.

b. Suitable electrical equipment as required to provide controlled levels of conditioning power and to make the specified measurements. The instrument used to electrically measure the temperature-sensitive parameter shall be capable of resolving a voltage change of 0.5 mV.

c. Controlled temperature chamber, fluid bath, or heat sink capable of maintaining the specified reference point temperature to within ± 0.5°C of the preset (measured) value. Typical temperature-controlled heat sink and fluid bath assemblies are presented for illustrative purposes only.

2.2 *Heat Sink Assembly* — A typical heat sink assembly for mounting the microelectronic device under test is shown in Figure 1. The primary heat sink is water cooled using a temperature-controlled fluid circulator bath. An adapter socket/heat sink is fastened to the heat removal surface of the primary heat sink, and has a special geometry to handle specific size packages (e.g., flat packs, dual-in-line packages, chip carriers). This adapter provides a repeatable and efficient interface between the package and the primary heat sink. The mounting surface temperature is determined with a thermocouple attached from the side or bottom of the adapter with a thermal conducting adhesive or grease at or near the interface between the adapter and the package. It is at this point that the device-under-test temperature is specified and controlled. The adapter also contains the socket or other electrical interconnection scheme. A thin coating (about 25 – 50 mm thick) of a thermal heat-sinking compound, such as zinc-oxide-loaded silicone thermal grease, is used at the interface to provide a reliable thermal contact.

2.3 *Fluid Bath Assembly* — A typical temperature-controlled fluid bath for thermally characterizing the microelectronic device under test is shown in Figure 2. In this figure, the package is mounted in a fluid bath separate from the fluid circulator, although it can be immersed directly in an integrated fluid circulator/bath unit. The fluid in the bath should be continuously stirred or agitated to ensure the required temperature stability. Since this working fluid is being used as an infinite heat sink, the case-to-fluid (ambient) temperature difference at the case temperature reference point of interest should be minimized, i.e., less than or equal to 20°C. For case-to-fluid temperature differences greater than 20°C, accuracy and repeatability difficulties may occur due to a large variable temperature gradient in the fluid film boundary layer at the package-fluid interface. The case-to-fluid temperature difference can be minimized by increasing the fluid velocity and by decreasing the power density seen by the fluid. The device under test should be mounted such that heat transfer to the fluid is not impeded. For leaded devices, the leads should be oriented in such a manner so as not to interfere with the heat transfer to the fluid and provide freedom to any thermal currents caused by the power dissipation within the package. The case temperature of the device under test should be measured with a thermocouple that is attached to the package and should not be assumed to be at the fluid temperature. Care should be taken to minimize exposure of the thermocouple bead to the high temperature gradient in the fluid film boundary layer at the package-fluid interface. The working fluid should have a thermal conductivity at 25°C of at least 0.0006 W/cm°C. Working fluids such as inert fluorocarbon liquids and silicone oils are suitable as a cooling media.

3 Procedure

3.1 *Direct Measurement of Reference Point Temperature* — T_C. For the purpose of measuring a microelectronic device thermal resistance, the reference point temperature shall be measured at the package location of highest temperature which is accessible outside the package. This reference point location is determined with the device operating in free air and with no external heat-sinking. In general, this reference point is found to be on the outside surface of the package substrate directly underneath the chip in the major path of heat flow from the chip to the heat sink or ambient. Examples of the reference point location for both cavity-up and cavity-down ceramic packages are depicted in Figure 3. The package surface may be altered to facilitate this measurement, provided that such alteration does not affect the original heat transfer paths and, hence, the thermal resistance, within the package by more than a few percent. For packages with an integral heat dissipater attached to the outside surface of the package substrate, the case temperature reference point shall be on the surface of the heat dissipater at a point opposite the backside of the chip as indicated in Figure 4.

3.1.1 Case temperature, T_C. The microelectronic device under test shall be mounted under specified conditions so that the case temperature can be held at the specified value. A thermocouple shall be attached on the surface of the device package directly under the chip. A conducting epoxy may be used for this purpose. The thermocouple bead should be in direct mechanical contact with the case of the microelectronic device under test. For devices which, in their normal application, are intimately connected (by pressure contact, adhesive, soldering, or other means) to an external heat sink, the mounting surface temperature, as measured directly below the primary heat removal surface of the case, may be used as the equivalent case temperature.

If it is found that attaching the thermocouple directly to the case is impractical, an alternate approach utilizing a thermocouple welded to one side of a thin metal disk should be used. This can be accomplished by parallel gap welding the crossed thermocouple wires to one side of a 0.25 cm (0.094 in) diameter, 0.02 cm (0.008 in) thick beryllium-copper disk and then, with a thin layer of adhesive, bonding the other side of the disk to the case at the point of interest.

3.1.1.1 Mounting surface temperature, T_M. The mounting surface temperature is measured directly below the primary heat removal surface of the case. It is measured with a thermocouple at or near the mounting surface of the heat sink. A typical mounting arrangement is shown in Figure 5. The surface of the copper mounting base shall be nickel plated and free of oxides.

The thermocouple hole shall be drilled into the mounting base such that the thermocouple lead is directly below the area on the case of interest. It is recommended that the thermocouple be secured into the mounting base with a thermal conducting adhesive (or solder) and that particular attention be paid to minimizing air voids around the ball or the thermocouple. A thermal conducting compound (or adhesive) should be used at the interfaces of the mounting base and the device under test. The mounting surface technique is application oriented in that it takes into account the mounting surface interface.

3.2 *Thermal Resistance, Junction-to-Specified Reference point,* $R_{\Theta JR}$

3.2.1 *General Considerations* — The thermal resistance of a semiconductor device is a measure of the ability of its carrier or package and mounting technique to provide for heat removal from the semiconductor junction. The thermal resistance of a microelectronic device can be calculated when the case/mounting surface temperature and power dissipation in the device and a measurement of the junction temperature are known.

When making the indicated measurements, the package shall be considered to have achieved thermal equilibrium when halving the time between the application of power and the taking of the reading causes no error in the indicated results within the required accuracy of measurement.

3.2.2 *Indirect Measurement of Junction Temperature for the Determination of* $R_{\Theta JR}$ — The purpose of the test is to measure the thermal resistance of integrated circuits by using particular semiconductor elements on the chip to indicate the device junction temperature. In order to obtain a realistic estimate of the operating junction temperature, the whole chip in the package should be powered in order to provide the proper internal temperature distribution. During measurement of the junction temperature the chip heating power (constant voltage source) shall remain constant while the junction calibration current remains stable. It is assumed that the calibration current will not be affected by the circuit operation during the application of heating power.

The temperature-sensitive device parameter is used as an indicator of an average (weighted) junction temperature of the semiconductor element for calculations of thermal resistance. The measured junction temperature is indicative of the temperature only in the immediate vicinity of the element used to sense the temperature.

The temperature-sensitive electrical parameters generally used to indirectly measure the junction temperature are the forward voltage of diodes and the emitter-base voltage of bipolar transistors. Other appropriate temperature-sensitive parameters may be used for indirectly measuring junction temperature for fabrication technologies that do not lend themselves to sensing the active junction voltages.

3.2.2.1 Steady-state technique for measuring T_J. The following symbols shall apply for the purpose of these measurements:

I_M	Measuring current in milliamperes.
V_{MH}-	Value of temperature-sensitive parameter in millivolts, measured at I_M, and corresponding to the temperature of the junction heated by P_H.
T_{MC}-	Calibration temperature in degrees Celsius, measured at the reference point.
V_{MC}-	Value of temperature-sensitive parameter in millivolts, measured at I_M, and specific value of T_{MC}.

The measurement of T_J using junction forward voltage as the TSP is made in the following manner:

Step 1 — Measurement of the temperature coefficient of the TSP (calibration).

The coefficient of the temperature-sensitive parameter is generated by measuring the TSP as a function of the reference point temperature, for a specified constant measuring current, IM, by externally heating the device under test in an oven or in a fluid bath. The reference-point temperature range used during calibration shall encompass the temperature range encountered in the power application test (see Step 2). The measuring current is generally chosen such that the TSP decreases linearly with increasing temperature over the range of interest, and that negligible internal heating occurs in the silicon and metal traces. For determining the optimum TSP calibration or measuring current, V_{MC} vs. log I_M curves for two temperature levels that encompass the calibration temperature range of interest should be plotted. The optimum measuring current, I_M, is then selected such that it resides on the linear portion of the two V_{MC} vs. log I_M curves that were generated. A measuring current ranging from 0.05 to 5 mA is generally used, depending on the specifications and operating conditions of the device under test, for measuring the TSP. The value of the TSP temperature coefficient, V_{MC}/T_{MC}, for the particular measuring current used in the test, is calculated from the calibration curve, V_{MC} vs. T_{MC}. At least three points should be used to generate the voltage vs. temperature curve for the determination of the TSP temperature coefficient.

Step 2 — Power application test.

The power application test is performed in two parts. For both portions of the test, the reference point temperature is held constant at a preset value. The first measurement to be made is that of the temperature-sensitive parameter, i.e., V_{MC}, under operating conditions with the measuring current, I_M, used during the calibration procedure. The microelectronic device under test shall then be operated with heating power (P_H) applied. The temperature-sensitive parameter, V_{MH}, shall be measured with constant measuring current, I_M, that was applied during the calibration procedure (See Step 1).

The heating power, P_H, shall be chosen such that the calculated junction-to-reference point temperature difference as measured at V_{MH} is greater than or equal to 20°C. In accomplishing this, the device under test should not be operated at such a high heating power level that the on-chip temperature-sensing and heating circuitry is no longer electrically isolated. Care should also be taken not to exceed the design ratings of the package-interconnect system, as this may lead to an overestimation of the power being dissipated in the active area of the chip due to excessive power losses in the package leads and wire bonds. The values of V_{MH}, V_{MC}, and P_H are recorded during the power application test.

The following data shall be recorded for these test conditions:

a. Temperature-sensitive electrical parameters (V_F, V_{EB}, or other appropriate TSP).

b. Junction temperature, T_J, is calculated from the equation:

$$T_J = T_R + (V_{MH} - V_{MC}) \left| \frac{\Delta V_{MC}}{\Delta T_{MC}} \right|^{-1}$$

where $T_R = T_C$ or T_M

c. Case or mounting surface temperature, T_C or T_M.

d. Power dissipation, P_H.

e. Mounting arrangement (including package mounting force).

3.3 Calculations of $R_{\Theta JR}$

3.3.1 *Calculations of Package Thermal Resistance* — The thermal resistance of a microelectronic device can be calculated when the junction temperature, T_J, has been measured in accordance with procedures outlined in Sections 3.1 and 3.2.

With the data recorded from each test, the thermal resistance shall be determined from:

$$R_{\Theta JR} = \frac{T_J - T_R}{P_{H(package)}}, \text{ junction-to reference point,}$$

where $R_{QJR} = R_{QJC}$ or R_{QJM} and $T_R = T_C$ or T_M, respectively.

4 Summary Report

The following details shall be specified as appropriate:

a. Description of package, including thermal test chip, location of case or chip carrier temperature measurement(s), and heat sinking arrangement.

b. Test condition(s), as applicable (see Section 3).

c. Test voltage(s), current(s), and power dissipation of test chip.

d. Recorded data for each test condition, as applicable.

e. Symbol(s) with subscript designation(s) of the thermal characteristics determined.

f. Accept or reject criteria.

RELATED REFERENCES

1. Unencapsulated Thermal Test Chip, SEMI G32-86 Guideline, Book of SEMI Standards, Packaging Volume.

2. Accepted Practices for Making Microelectronic Device Thermal Characteristics Test — A User's Guide. JEDEC Engrg. Bull. No. 20, Jan. 1975 (Electronic Industries Assoc., Washington, D.C.).

3. Thermal Characteristics, Method 1012.1, MIL-STD-883C Test Methods and Procedures for Microelectronics, Nov. 4, 1980 (Rev. Aug. 15, 1984).

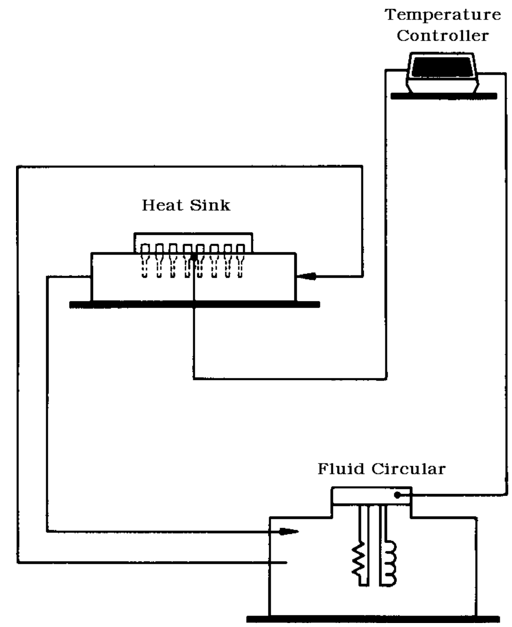

Figure 1
Temperature-Controlled Heat Sink Assembly

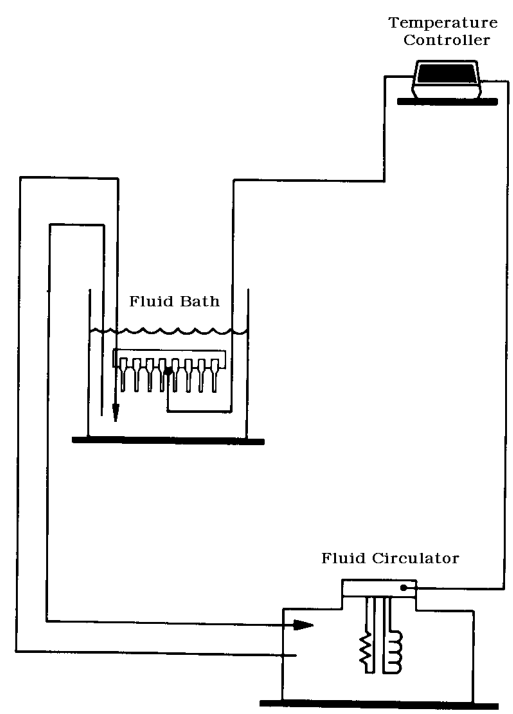

Figure 2
Temperature-Controlled Fluid Bath Assembly

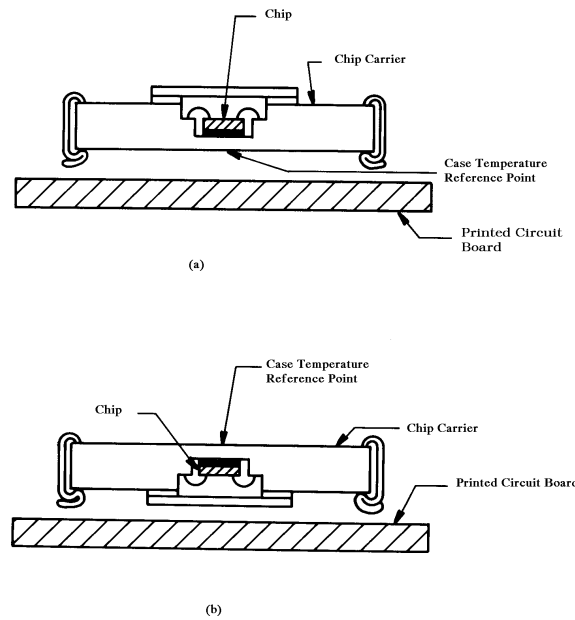

Figure 3
Reference Point Location for Case Temperture Measurement of A) Cavity-Up and B) Cavity—Down Ceramic Packages

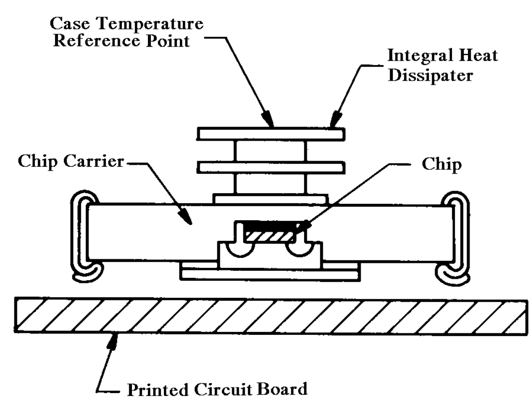

Figure 4
Reference Point Location for Case Temperature Measurement of a Ceramic Package with an Integral Head Dissipater

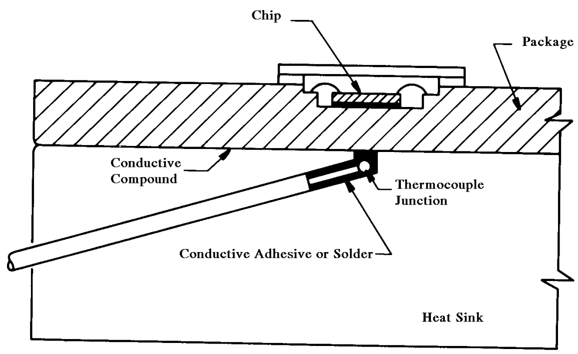

Figure 5
Mounting Surface Temperature Measurements

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SEMI G31-0997
TEST METHOD FOR DETERMINING THE ABRASIVE CHARACTERISTICS OF MOLDING COMPOUNDS

1 Purpose

This document describes the method to measure the abrasive characteristics of molding compounds by measuring mold orifice weight loss as a function of molded volume.

2 Scope

2.1 All thermoset molding compounds used for microelectronic device encapsulation contain filler materials, typically 60–90% — which contribute to mold wear. Mold wear, typically at gates, is a major reason for mold rework. This test method may be used by suppliers to evaluate new molding materials or control current materials or by customers to evaluate the use of new materials. This test method provides a comparison of abrasiveness between materials.

2.2 This procedure can be used to determine the abrasive character of a given molding compound. Knowing the conditions of test, the results of the test, and the mold life experience (within one's own company) in the field, it is possible to judge if a molding compound is more or less abrasive to current compound in use.

3 Referenced Documents

3.1 Operational manuals for all equipment listed within this document.

3.2 Mold compound data sheets

4 Method

This procedure determines the abrasive character of a given filled molding compound by measuring orifice weight loss as a function of extruded volume.

5 Interferences

5.1 Care must be taken to avoid orifice weight loss by mishandling during placing and removing the orifice from the mold base.

5.2 Before the orifice is re-weighed after molding, carefully remove all contamination.

6 Equipment

6.1 Transfer molding press, 50 tons clamp minimum

6.2 Dielectric preheater

6.3 Orifice insert and mold assembly (See Figures 2–6.)

6.4 Mold base with pot diameter 1.75 to 2.00 inches

6.5 Photoelectric safety light screen

6.6 Stop watch

6.7 Pyrometer

6.8 Force gauge

6.9 Asbestos gloves

7 Procedure

7.1 *Equipment Set-Up* — Orifice Mold Installation (see Figure 1).

7.1.1 Place mold assembly on mold base and align orifice retainer opening with center of transfer pot.

7.1.2 Clamp bottom plate of mold assembly to bottom mold platen.

7.1.3 Set press limit switch to ensure clamp slow close is initiated 1" from completion of mold closing.

7.2 *Process Parameters*

7.2.1 Set up the molding parameters according to the material data sheet recommendations or expected use conditions, if known. These conditions include:

- Mold temperature
- Pre-heat temperature or pre-heat time
- Transfer speed
- Transfer pressure
- Clamp pressure
- Cure time

NOTE: The charge weight to be determined by trial molding shots to achieve a cull thickness between 0.060–0.120" and a suitable weight of extrudate.

7.3 *Operating Procedure*

7.3.1 Weigh orifice to one ten-thousandth of a gram. Record weight.

7.3.2 Verify process parameter settings.

7.3.3 Place orifice in orifice retainer and clamp mold assembly.

7.3.4 Preheat preformed material to the required temperature.

7.3.5 Insert preheated material into transfer pot and activate transfer ram (semi-automatic mode).

7.3.6 Start stopwatch when extrudate first appears. Record total extrusion time.

7.3.7 Collect and weigh extrudate to nearest one tenth of a gram. Record extrudate weight.

7.3.8 At the end of cure cycle, remove orifice from retainer. Loosen set-screws to split orifice and, with compressed air, blow out cured slug.

7.3.9 Ensure mating orifice halves are clean, realign the halves and tighten set screws.

7.3.10 Place orifice in retainer and repeat steps 7.3.4 through 7.3.9.

7.3.11 Repeat steps 7.3.4 through 7.3.10 until a minimum of 40 shots are run.

7.3.12 Record the following:

1. Original orifice weight
2. Shot number
3. Extruded weight per shot in grams
4. Cumulative extruded weight in grams
5. Orifice weight in grams
6. Orifice percent weight loss
7. Extrusion rate

8 Calculation

8.1 *Orifice Weight Loss*

$$\frac{I_O - I_N}{I_O}(100\%) = \%\text{ wt. loss}$$

I_O = Initial orifice weight to ten thousandth of a gram

I_N = Orifice weight after "N" number of shots to ten thousandth of a gram

8.2 Plot on linear graph paper the orifice weight loss vs. cumulative extruded weight.

8.3 Convert cumulative weight extruded to cumulative volume extruded.

Example: Molding compound density 2.0 g/cm^3 cumulative weight = 2000 g

$$2000\ g \times \frac{cm^3}{2.0\text{g}} = 1000\ cm^3$$

8.4 Convert cumulative volume extruded to equivalent production mold shots.

Example: 28 mm × 28 mm × 3.4 mm - 208 ld PQFP

Package Volume:

$$28\text{ mm} \times 28\text{ mm} \times 3.4\text{ mm x } \frac{\text{cm}^3}{1000\text{ mm}^3} = 2.6656\text{ cm}^3$$

Volume to shots:

$$1000\ \text{cm}^3 \times \frac{\text{shot}}{2.6656\text{ cm}^3} = 375\text{ shots}$$

8.5 Plot on linear graph paper the orifice weight loss vs. equivalent production mold shots.

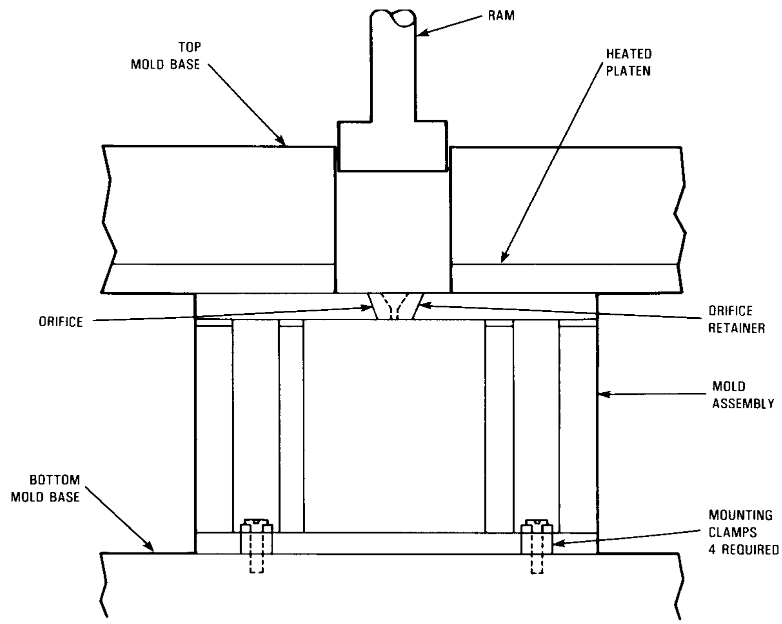
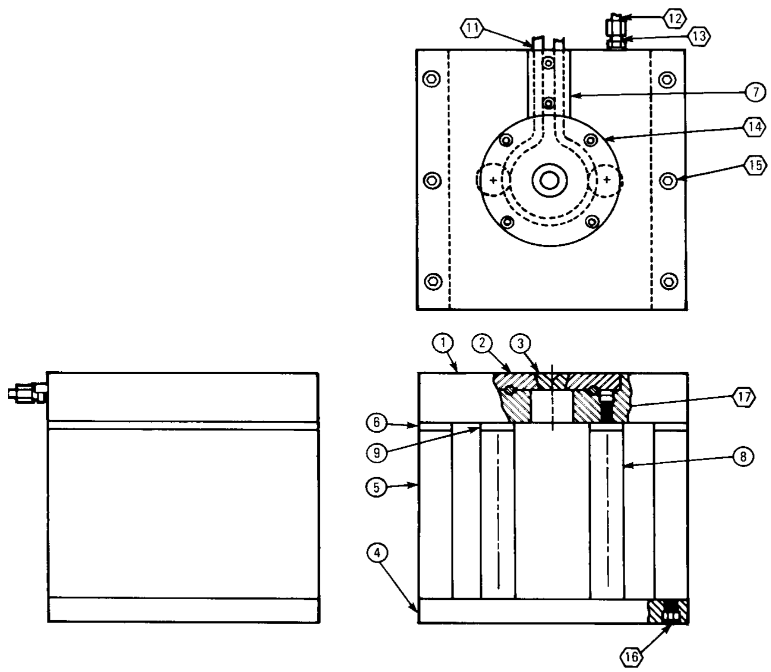


Figure 1
Orifice Abrasion



17	4	SOC. HD. CAPSCREW ¼ – 20 x 1¼
16	6	SOC. HD. CAPSCREW ⁵⁄₁₆ – 18 x ¾
15	6	SOC. HD. CAPSCREW ⁵⁄₁₆ – 18 x 2
14	6	SOC. HD. CAPSCREW –10 – 32 x ½
13	1	COMPRESSION FITTING – ³⁄₁₆ x ⅛ NPT
12	1	THERMOCOUPLE – .187 DIA x 5
11	1	TUBULAR HEATER – .250 DIA x 12.5
9	2	.25 x 1.0 DIA FIBERGLASS 6-7
8	2	1.0 DIA x 5.25 STRESSPROOF
7	1	.50 x 1.25 x 2.12 LCFGS – COVER
6	2	.25 x 1 x 8 FIBERGLASS 6-7
5	2	1 x 5.25 x 8 CRS
4	1	.75 x 8 x 8 LCFGS
3	NOTED	1 DIA x .50 MAT'L NOTED – ORIFICE
2	1	4 DIA x ½ AISI A-2 – ORIFICE HOLDER
1	1	1.5 x 8 x 8 LCFGS – TOP PLATE
ITEM	QTY	DESCRIPTION

Figure 2
Orifice Mold

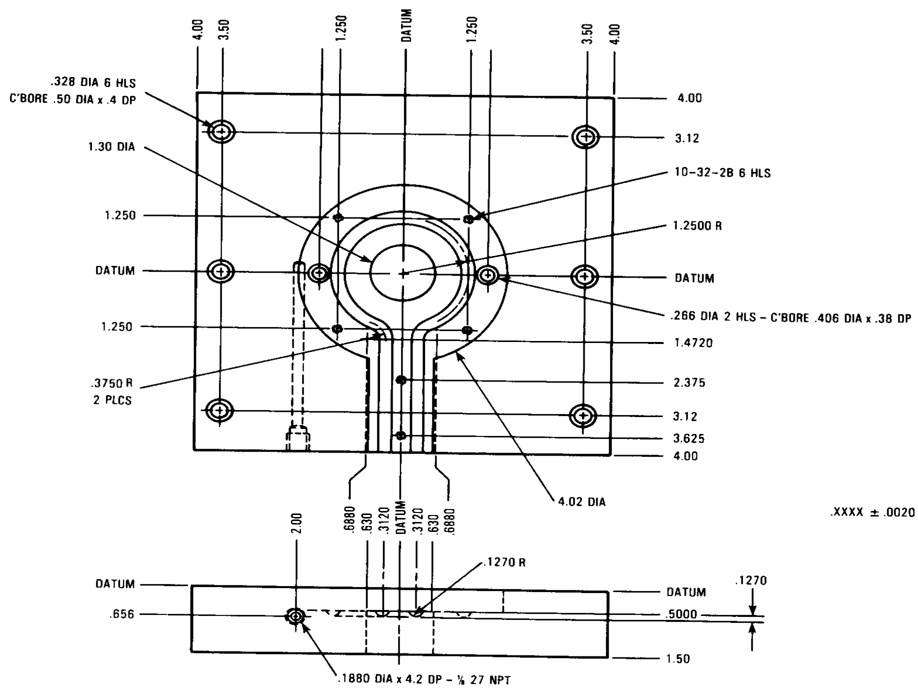


Figure 3
Top Plate

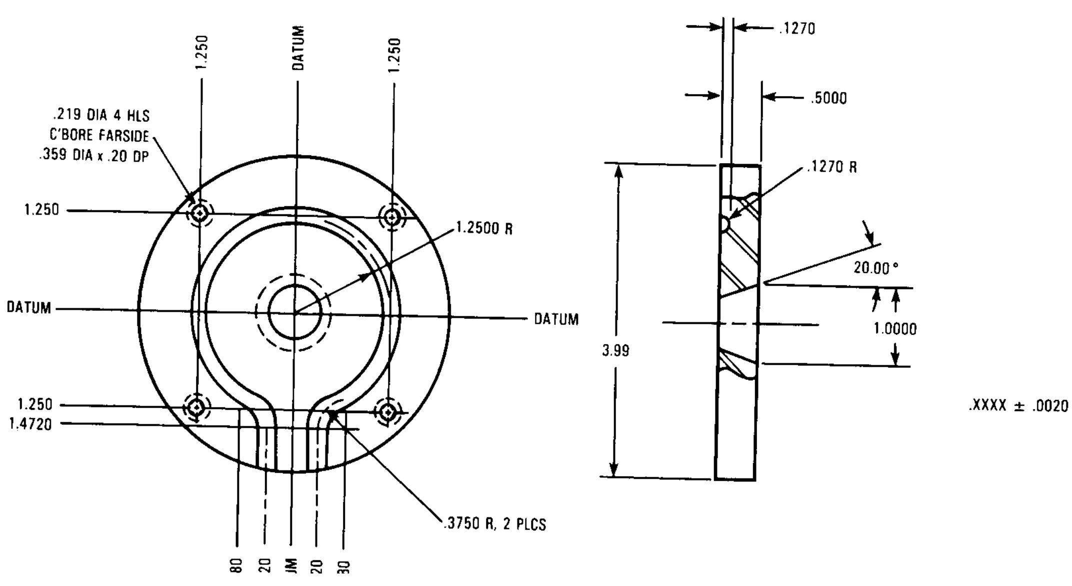


Figure 4
Orifice Holder

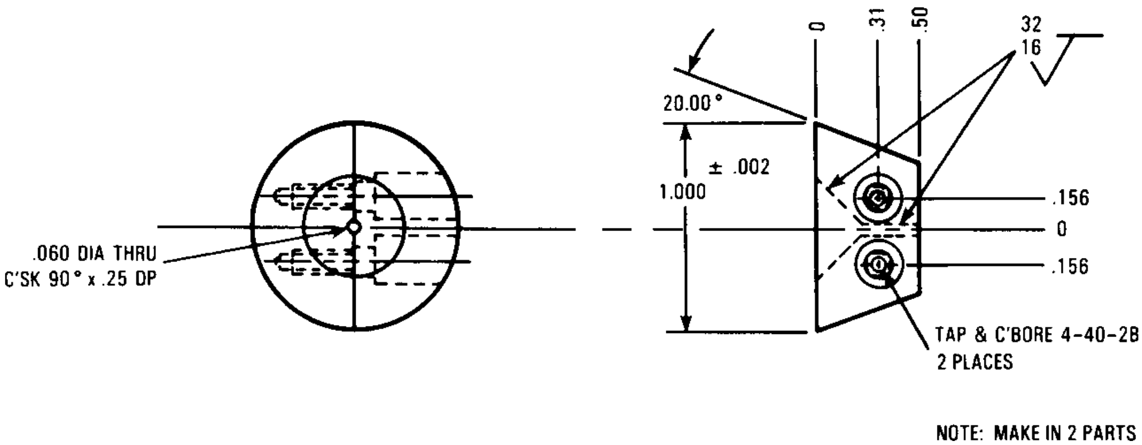


Figure 5
Orifice

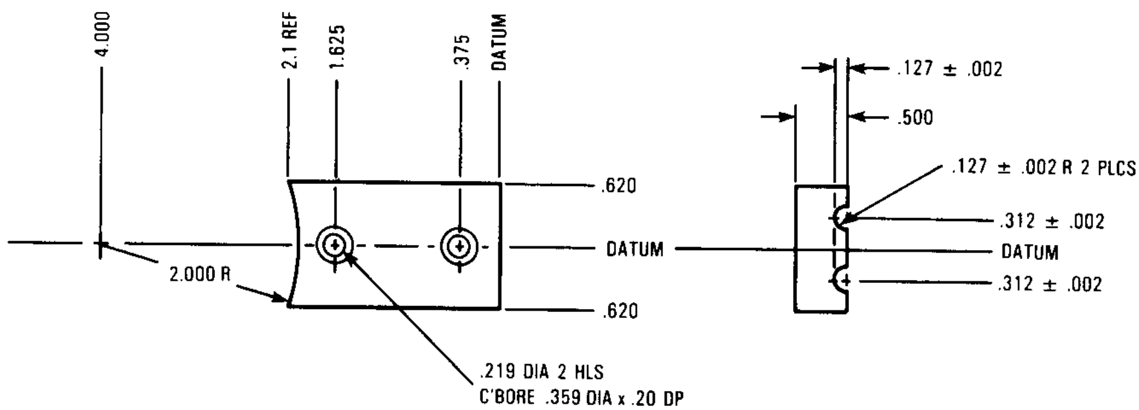


Figure 6
Cover

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SEMI G32-94
GUIDELINE FOR UNENCAPSULATED THERMAL TEST CHIP

1 Preface

This guideline details recommendations for a standardized thermal test chip design for referee test purposes. A sample data format for the test chip can be found in Appendix A. Based on the results of computer simulations of various chip-substrate configurations (Section 3.1), the following recommendations are made for the design of thermal test chips for VLSI package characterization (Section 3.2).

2 General Guideline

2.1 *Heat Sources* — The heat sources (i.e., transistors or resistor stripes), should use as much of the active chip area as possible so that the measured package thermal resistance is indicative of the chip size being used. A 10 mil (0.25 mm) parameter stripe (inactive area) should be sufficient for bonding pads and scribe lanes. It is desirable to use a range of test chip sizes so that the package thermal resistance can be determined as a function of chip size. A basic cell size of 75 mil (1.91 mm) square with a power dissipation capability of 7.5 to 10 W is recommended. The heat source area should exceed 85% of this basic cell active chip area. This basic cell could be arrayed or scaled up to a 450 mil (11.43 mm) square chip in increments of 75 mil (1.91 mm) on a side. For larger chip sizes, the basic cell size should be chosen so arrays can match the chip sizes in actual use. Since the larger chips can be 15—20 mm per side, the basic cell may need to be 5 mm per side, so a 3×3 array can be 15 mm square minimum.

2.2 *Spacing between Heat Sources* — The spacing between heat sources, which is needed to accommodate the temperature-sensing elements (i.e., p-n junctions), should be minimized. The spacing should be less than or equal to 2 mil (0.051 mm). The sensing element should be located at the center of the chip surface. For chips that are built up from an array of standard cells, sensing elements are also needed near a corner and between two adjacent corners (i.e., near or in the inactive regions), of the basic cell. Additional sensing elements for such purposes as die attachment evaluation and non-uniform power dissipation studies may be included as appropriate. All sensing elements and associated metallization runs must be electrically isolated from the heat sources.

2.3 *Thermal Test Chip Thickness* — The thermal test chip thickness should be between 18 mil (0.46 mm) and 22 mil (0.56 mm). For thin packages, the test chip thickness should be reduced to the normal die thickness for that package.

2.4 *Thermal Test Chip* — The thermal test chip should be designed such that its power dissipation limitations are consistent with the range of package thermal resistance encountered. This includes properly designed metallization runs such that for arrayed test chips, heating current for inner chips is routed so that wire runs from the package to inner chips are minimized. The ability to cause a chip surface-to-case temperature difference of at least 20°C is desirable. To accomplish this for silicon chips mounted on a variety of substrates (ranging from alumina to beryllia), the basic cell structure (i.e., 75 mil (1.91 mm) on a side) should dissipate a minimum of 7.5 W.

2.5 *Bond Pads* — Band pads (clear opening) should be equal to or greater than 4 mil (0.10 mm) on a side. Sensing and heating elements should not be connected to common bonding pads. Bonding pad location and size can or should be configured such that for arrayed test chips, chip-to-chip bonding is facilitated (i.e., bonding wire runs from the package to inner chips are minimized), but this is not mandatory for acceptable functional operation.

2.6 *Temperature-Sensing Diode/Diode Bridge Elements* — The temperature-sensing diode/diode bridge elements should be usable over the complete operating power and temperature range of the thermal test chip. The thermal test chip should function at junction temperature of 130°C minimum.

2.7 *Arrayed and Scaled Up Thermal Test Chips* — Pictorial representation of arrayed and scaled up thermal test chips are depicted in Figures 1 and 2, respectively. Heating elements (shaded areas) are transistors or resistor stripes connected in a variety of series-parallel combinations on as well as off the chip. The heating elements should fill as much of the shaded area as practical (consistent with the integrated circuit layout design rules).

3 References

3.1 Albers, J., “Semiconductor Measurement Technology: TXYZ: A Program for Semiconductor IC Thermal Analysis,” NIST Spec. Publ. 400-76 (April 1984).

3.2 Oettinger, F.F., “Thermal Evaluation of VLSI Packages Using Test Chips — A Critical Review,” Solid State Technology 27, 169 - 179 (Feb. 1984).

APPENDIX A

Sample Data Format for an Unencapsulated Thermal Test Chip

A1 General Description (Select appropriate descriptors)

This device is an unencapsulated bipolar, MOS silicon chip, with metallized top, metallized top and bottom surface(s), with transistors or with metal film polysilicon, implanted, diffused resistors for heating, and with emitter-base transistor, diode p-n junctions for temperature-sensing in a diode/diode bridge arrangement. This device is designed for thermally characterizing integrated circuit packages.

A2 Mechanical Data

1. Show dimensioned drawing of chip indicating temperature-sensing and heating elements, on-chip interconnects, and bonding pad locations. Identify all bonding pads, indicate any bonding pads that must be connected to most negative or most positive external biases. State whether an electrically conductive connection to the bottom (back) surface of the chip is required for proper operation.
2. State chip thickness.
3. State all necessary handling and chip testing precautions.
4. State type of metallization used on chip top contact areas and on bottom mounting surface.
5. State type of junction passivation used and any special mounting ambient requirements. State preferred chip mounting and lead bonding procedures.
6. Show wire bonding configurations for various chip arrays and indicate heating power limits.

A3 Maximum Ratings

1. *Temperature*

   a. Storage temperature range, T_{stg}

   ______ °C to______°C

   b. Operating junction temperature range, T_J

   ______°C to______°C

2. *Voltage Over Operating Temperature Range*

   a. DC voltage applied to collector of heating transistors, or to heating resistors (limited by reverse voltage breakdown of substrate diode), V_H — _____ V

3. *Current Over Operating Temperature Range*

   a. DC current applied to collector of heating transistors, or to heating resistors, I_H — _____ A

A4 Electric Characteristics

1. *Temperature-Sensing Element (Diodes)*

   a. Reverse leakage current at T_A = _____ °C and V_R _____ V, I_R — _____ mA

   b. Forward measuring current range applied to sensing p-n junction over which temperature coefficient is linear, I_M — ______ mA to _____ mA

   c. Forward voltage drop at maximum measuring current and T_A = 25°C, V_M — _______ V

2. *Heating Element (Transistors or Resistors)*

   a. Forward current transfer ratio of transistor heating elements at maximum collector voltage and collector current at T_A = 25°C, h_{FE} — ______

   or,

   b. Resistance of resistor heating elements at T_A = 25°C, RH — ______ ohms

A5 Additional Information

The following information, which depends upon the mounting of the chip and connection of lead wires, is given only as an indication of the full electrical capability of the chip. No guarantee is to be inferred from the following information. When this chip is properly assembled in a ceramic integrated circuit package, the following electrical specifications for the heating elements may be expected:

Max. Power Rating at T_C=25°C, P_H — ______ W

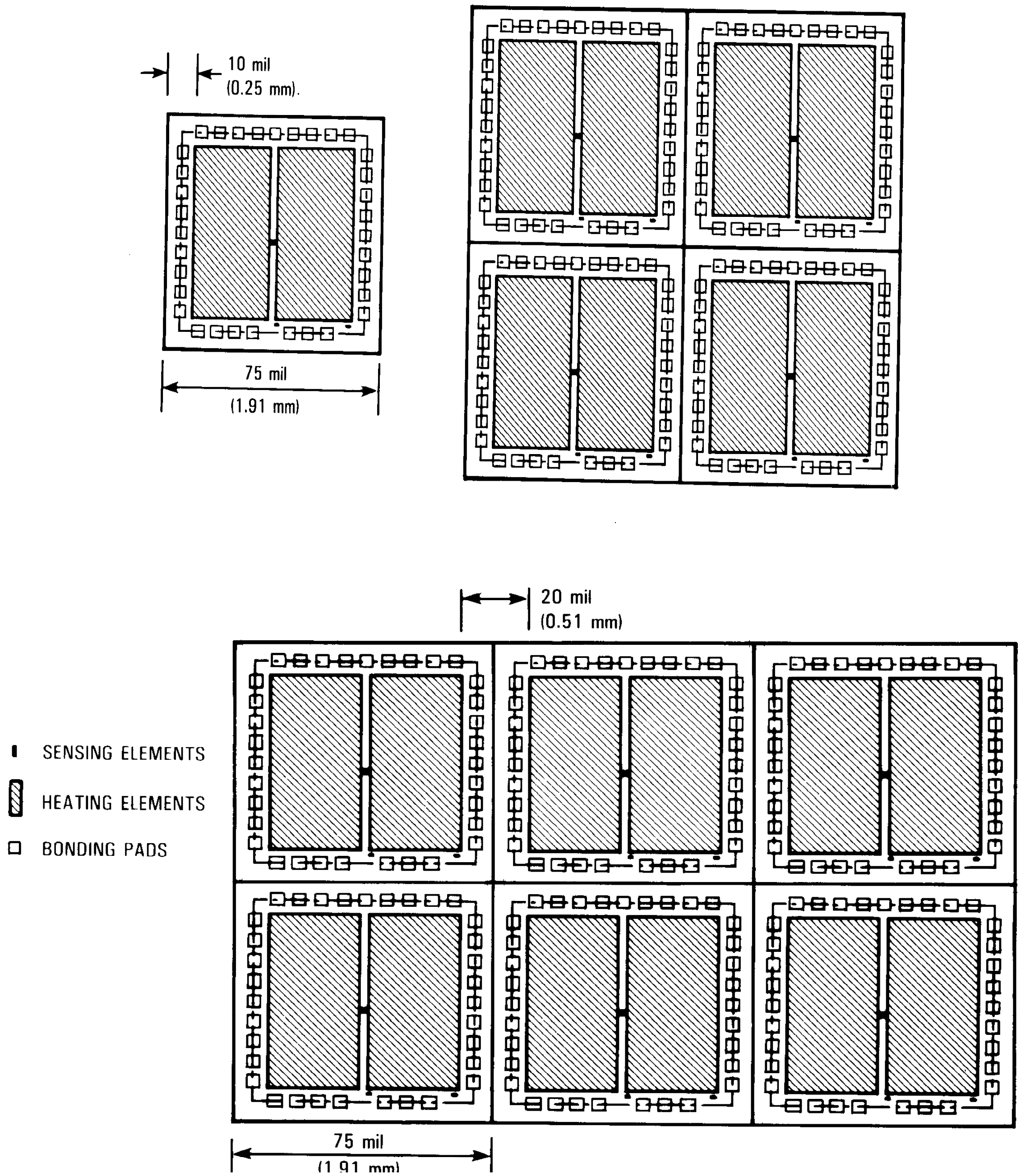

Figure 1
Pictorial Representation of Arrayed Thermal Test Chip

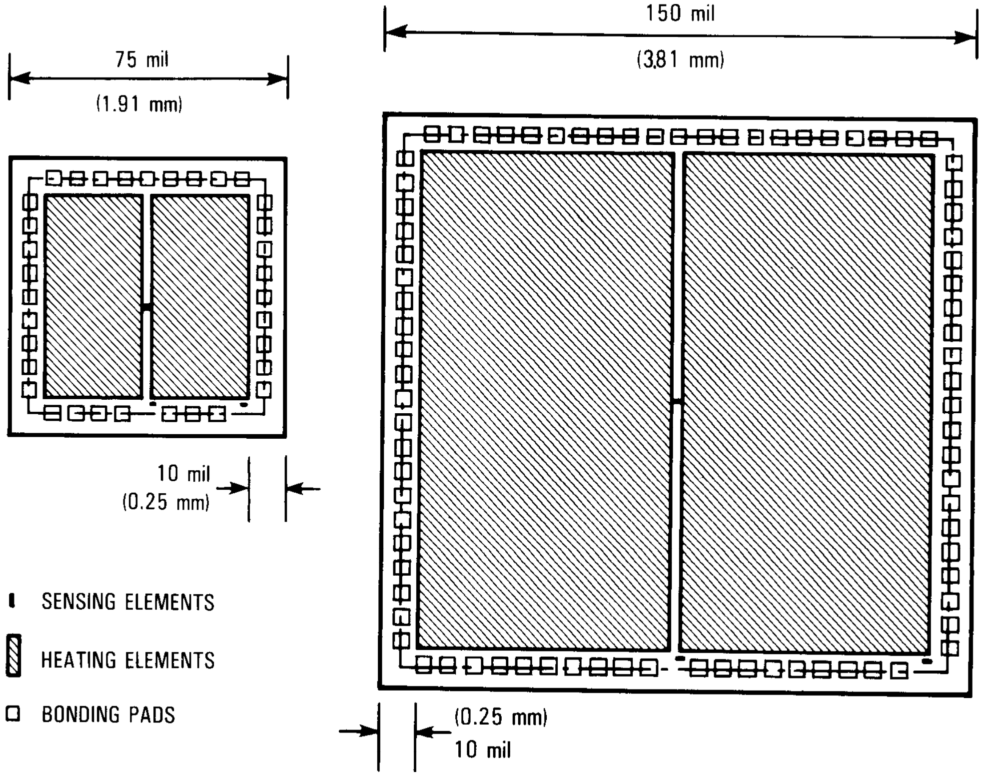

Figure 2
Pictorial Representation of Scaled Test Chip

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SEMI G33-90
SPECIFICATION FOR PRESSED CERAMIC PIN GRID ARRAY PACKAGES

1 Preface

This specification defines the acceptance criteria for ceramic pin grid array packages produced using pressed ceramic, mechanically inserted pins and solder for electrical interconnection of pins.

2 Applicable Documents

2.1 *ANSI Specification*[1]

Y14.5 — Dimensioning and Tolerancing

2.2 *ASTM Specification*[2]

B 152 — Copper Metal Specification

2.3 *Federal Specification*[3]

*QQ-N-290*A — Nickel Plating

QQ-S-571E — Solder-Alloy Compositions

2.4 *Military Specifications*[3]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-G-45204 — Gold Plating, Electrodeposited

MIL-M-38510 — General Specification for Microcircuits

2.5 *JEDEC Specification*[4]

Pub. No. 95 — Registered and Standard Outlines for Semiconductor Devices

3 Selected Definitions

blister (bubble) ceramic — Any separation within the ceramic which does not expose underlying ceramic material.

blister (bubble) metal — Any localized separation within the metallization or between the metallization and ceramic which does not expose underlying metallization or ceramic material.

burr — An adherent fragment of excess parent material at the component edge.

chip — A region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width and depth from a projection of design planform (see Figure 1).

crack — A cleavage or fracture that extends to the surface of a package which may or may not pass through the entire thickness of the package.

contact pad — That metallized pattern that provides mechanical or electrical connection to the external circuitry.

die attach surface — A dimensional outline designated for die attach.

dielectric — A material applied to the surface of a package which provides such functions as electrical insulation, passivation of underlying metallization and limitation of solder flow.

discoloration — Any change in the color of the package metallization as detected by the unaided eye.

flatness — The allowable deviation of a surface from a reference plane. The tolerance zone is defined by two parallel planes within which the surface must lie.

footprint — Pin pattern.

foreign material — An adherent particle other than parent material.

isolation gap — Metal-free space between conductive areas.

peeling (flaking) — Any separation of metallization from the base material exposing the base material.

pit — Any unspecified depression in the package.

post-metallization — The process by which metallization is applied to a body (substrate) after the body has been fully sintered.

projection — An adherent fragment of parent material on the package surface.

pullback — The linear distance between the edge of the ceramic and the first measurable metallization and/or glass interface (see Figure 2).

refractory metallization — The process by which a high melting point (typically in excess of 1800°C) metal or

1 ANSI, 1430 Broadway, New York, NY 10018

2 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

4 JEDEC, 2001 Eye Street N.W., Washington, D.C. 20006

combination of metals is applied to a suitable substrate and fired.

rundown — The vertical extension of metallization from the ceramic (see Figure 2).

seal area — A dimensional outline area designated to provide a surface for sealing.

seating plane — Defined by the standoff features or the package base plane if no standoff is used (see Figure 3).

SLAM — Abbreviation for "Single Layer Alumina Metallization," which denotes a package design without a physical die attach cavity.

solder — An alloy with a melting point equal to or less than 427°C.

standoff — The designed separation between the base plane and the seating plane created by a physical feature. Standoff use, configuration, and placement is optional (see Figure 3).

terminal — Case outline at point of entry or exit of an electrical contact.

thick film metallization — The process by which a thin layer of metal (usually in the 0.3 to 1.0 µm range) is applied to a suitable substrate by methods including sputtering, vacuum evaporation and chemical vapor deposition.

TIR — Total Indicator Reading.

window frame — A separate member of ceramic which is joined to the surface of the package on which a flat lid is attached for sealing.

4 Ordering Information

Purchase orders for pin grid array packages furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Certification requirements
3. Quantity
4. Reference to this document
5. Any exceptions to print or specifications

5 Dimensions and Permissible Variations

The dimensions of the pin grid array package shall conform to SEMI Standards or to the customer drawing, and be within the outline of the appropriate JEDEC standard.

6 Material Parameters

The definitions, defects, and functional testing described in this specification relate directly to a nominal package made with the following materials. They may also be applicable to similar pin grid array packages made with other materials.

6.1 *Ceramic Properties*

6.1.1 *Materials* — Alumina content 90% minimum. Beryllia content to be in excess of 98.5% BeO.

6.1.2 *Color* — Dark or white.

6.2 *Metal Properties*

6.2.1 *Plating*

6.2.1.1 Plating finish shall be per MIL-M-38510; Nickel Plating (if designated) shall be per QQ-N-290A, 50 µ"–350 µ" (0.1300 mm–0.08890 mm). Gold plating (if desired) shall conform to MIL-G-45204, Type III and 50 µ"–225 µ" (0.1300 mm–0.05080 mm).

6.2.2 *Metallization*

6.2.2.1 Metallized circuits and areas can be thick film, thin film or refractory post-metallized. Such metallization materials may be, but are not limited to, the following:

1. *Thick Film Materials*
   a. Gold (Au) and Gold Alloys
   b. Silver (Ag)
   c. Silver - Platinum - Palladium (AgPtPd)
   d. Silver - Palladium - Platinum (AgPdPt)
   e. Copper (Cu)
2. *Thin Film Materials*
   a. Copper (Cu)
   b. Chromium (Cr)
   c. Nickel (Ni)
   d. Titanium (Ti)
4. *Refractory Materials*
   a. Molybdenum - Manganese (MoMn)
   b. Molybdenum - Tungsten (MoW)

6.2.3 *Solder* — Solder compositions used in the manufacture of pressed ceramic pin grid array packages shall include, but not be limited to, the following, per QQ-S-571E:

1. 10/90 — 10% Sn/90% Pb

2. 63/37 — 63% Sn/37% Pb

3. 10/88/2 — 10% Sn/88% Pb/2% Ag

6.2.4 *Pin Material* — CDA150, OFHC Copper, Zirconium alloy per ASTM B 152.

6.3 *Thick Film Dielectric* — An amorphous or polycrystalline glass or approved equivalent ranging in thickness from 0.013 mm (0.0005") to 0.038 mm (0.0015").

7 Defect Limits

A magnification of 10× shall be used to inspect the packages unless otherwise specified.

7.1 *Ceramic*

7.1.1 *Cracks* — Per MIL-STD-883, Method 2009.

7.1.2 *Chips* — (See Figure 1.)

7.1.2.1 *General*

7.1.2.1.1 *Corner* — Chips shall not exceed 0.762 mm (0.030") length × 0.762 mm (0.030") width × 0.762 mm (0.030") depth (see Figure 1-B).

7.1.2.1.2 *Edge* — Chips shall not exceed 1.52 mm (0.060") length × 0.635 mm (0.025") width × 0.635 mm (0.025") depth (see Figure 1-A).

7.1.2.1.3 Chips cannot encroach upon contact pad or penetrate metallization.

7.1.2.2 *Seal Area*

7.1.2.2.1 *Design With Window Frame* — Chips shall not exceed 0.635 mm (0.025") length × 0.635 mm (0.025") width × 0.635 mm (0.025") depth maximum. Chips cannot reduce the seal area width by more than 1/3 of the design width.

7.1.2.2.2 *Design Without Window Frame* — See Section 7.5 of this specification for dielectric inspection criteria.

7.1.2.3 *Cavity Edges*

7.1.2.3.1 Chips in the edges around the cavity shall not exceed 0.381 mm (0.015") along the edges or 0.127 mm (0.005") in depth.

7.2 *Package Flatness* — 0.004 inch/inch maximum

7.2.1 Seal Area Flatness

7.2.1.1 With Window Frame

Seal Area Size	*Seal Area Flatness (TIR)*
0–12.7 mm (0.000"-0.500")	0.051 mm (0.002") MAX
12.72–19.05 mm (0.501"-0.750")	0.076 mm (0.003") MAX
19.07 mm & greater (0.751")	0.101 mm (0.004") MAX

7.2.1.2 *Without Window Frame* — Flatness shall be 0.004" per inch maximum TIR.

7.2.2 *Die Attach Area Flatness*

Die Attach Area Size	*Die Attach Area Flatness (TIR)*
0–12.7 mm (0.000"-0.500")	0.051 mm (0.002") MAX
12.72–19.05 mm (0.501"-0.750")	0.088 mm (0.0035") MAX

7.3 *Metallization Misalignment (see Figure 2)*

7.3.1 *Metallization Rundown* — For the internal cavity shall not exceed 25% of the cavity depth, with a minimum of 0.127 mm (0.005") minimum isolation required.

7.3.2 *Wire Bond Finger Pullback* — 0.254 mm (0.010") maximum.

7.3.3 *Wire Bond Finger Rundown* — Not to exceed 1/3 of the ceramic cavity depth; 0.127 mm (0.005") isolation required.

7.3.4 *Pattern Isolation* — Dimension shall not be reduced by more than 50% of the design.

7.4 *Metallization Voids*

7.4.1 *Wire Bond Finger* — Must be free of voids or bare spots in the bonding area as defined by customer drawing.

7.4.2 *Die Attach Surface*

7.4.2.1 *SLAM Design* — Three voids are allowed, with a maximum of 0.127 mm (0.005") diameter separated by a distance greater than 0.254 mm (0.010"). Voids within 0.254 mm (0.010") of perimeter of die attach print area shall not be considered as the basis for rejection.

7.4.2.2 *Cavity Design* — Three voids are allowed with a maximum of 0.254 mm (0.010") diameter separated by a distance greater than 0.254 mm (0.010"). Voids within 0.381 mm (0.015") of die attach cavity wall shall not be considered as the basis for rejection.

7.4.3 *Solder*

7.4.3.1 *Pin Coating* — Solder wetting acceptability shall be per criteria in MIL-STD-883, Method 2003.

7.4.3.2 *Contact Pad Coating* — A minimum of 50% filleting must exist on the pin to pad solder joint with no exposed copper. A maximum of 0.889 mm (0.035") height of solder shall be allowed on pin to pad solder joints.

7.5 *Dielectric*

7.5.1 *Voids* — No single void in the dielectric shall expose two adjacent traces. Voids in the dielectric closer than 0.635 mm (0.025") shall not expose two adjacent traces.

7.5.2 *Contamination* — There shall be no contamination or foreign material upon dielectric with a diameter greater than 0.381 mm (0.015").

8 Sampling

Sampling size must meet the requirements of MIL-STD-105 or MIL-M-38510 or as agreed to between vendor and customer. Single, double, or multiple samples may be used per vendor and customer agreement.

9 Test Methods

9.1 Mechanical, electrical, and thermal test methods are per MIL-STD-883, unless otherwise noted.

9.1.1 *Lead Pull* — Under the test condition of five (5) pounds ± one quarter (1/4) pound, pull at an angle of 20° or less from the pins vertical line measured perpendicular to the package, there shall be no visible separation of the solder joint under 10× magnification.

9.1.2 *Lead Fatigue* — Shall be per MIL-STD-883, Method 2004, Test Condition B2, Paragraph 3.2.

9.2 *Functional Test Methods*

9.2.1 *Die Attach Quality* — Destructive die shear test shall be after environmental testing shall be per MIL-STD-883, Method 2019, Paragraph 3.2C.

9.2.2 *Wire Bond Quality* — Minimum pre-seal and post-seal bond strength test is per MIL-STD-883, Method 2011, Test Condition D. Reject for bonds which cause metallization to lift from the package or fail to meet minimum strength requirement.

9.2.3 *Solderability* — Per MIL-STD-883, Method 2003.

9.2.4 *Insulation Resistance Test* — Per MIL-STD-883, Method 1003, Condition D.

9.2.5 *Hermetic and Environmental Testing* — Per MIL-STD-883.

9.2.5.1 The hermetic integrity of the package must be maintained after all environmental testing. Hermetic checks shall comply with MIL-STD-883, Method 1014 Test Conditions A, B, C or D.

9.2.5.2 Environmental testing shall include, but not be limited to, the following:

1. Temperature Cycle per MIL-STD-883, Method 1010, Condition B.
2. Thermal Shock per MIL-STD-883, Method 1011, Condition B.
3. Centrifuge per MIL-STD-883, Method 2001, Condition E. Y1 axis only — cavity up; Y2 axis only — cavity down. (optional)
4. Mechanical Shock per MIL-STD-883, Method 2002, Condition B.
5. Vibration per MIL-STD-883, Method 2007, Condition A.

NOTE: Package applications requiring a heat sink attach will have the environmental tests (temperature cycle, shock, etc.) evaluated on an individual basis. The material, form factor and method of attachment used for heat sinks may result in severe stresses on the package assembly during environmental testing. Actual accelerated test requirements should be based on the expected product application environment and may be less stringent than those tests for packages without heat sinks.

10 Sequence of Events and Incoming Testing

During incoming inspection, the sequence of testing shall be:

1. Visual
2. Dimensional
3. Functional
   a. Die Attach
   b. Wire Bond
   c. Pre-Seal Wire Pull
   d. Seal
   e. Heat Sink Attach (if applicable)
   f. Environmental Test
   g. Fine Leak, MIL-STD-883, Method 1014, Condition B
   h. Gross Leak, MIL-STD-883, Method 1014, Condition C
   i. Post-Seal Bond Pull
   j. Radiography
   k. Die Shear, MIL-STD-883, Method 2019
   l. Solderability, MIL-STD-883, Method 2003

NOTE: An initial vendor qualification may be performed on the thermal and electrical characteristics of the package. The characteristics tested will be:

Insulation Resistance — Per MIL-STD-883, Method 1003, Test Condition D.

Thermal Dissipation — Per MIL-STD-883, Method 1012.

11 Packaging and Marking

11.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents or contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component parts with fibers or organic particles.

11.2 *Marking* — The outer containers shall be clearly marked identifying the customer part number, customer purchase order number, drawing number (optional), quantity, date, and vendor lot number (optional).

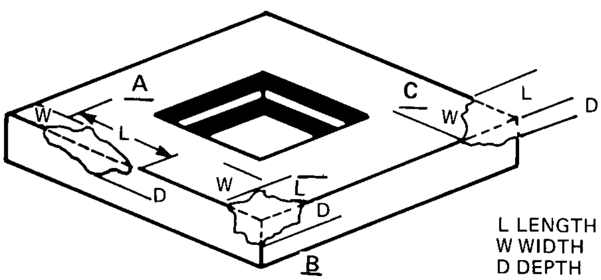

Figure 1
Chip Illustration

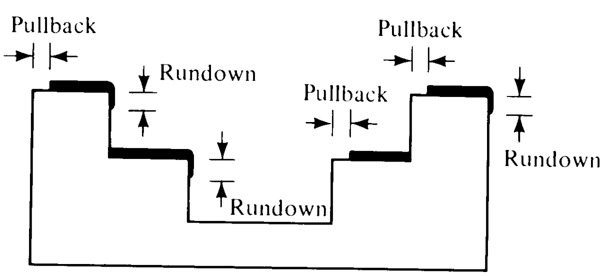

Figure 2
Metallization Misalignment

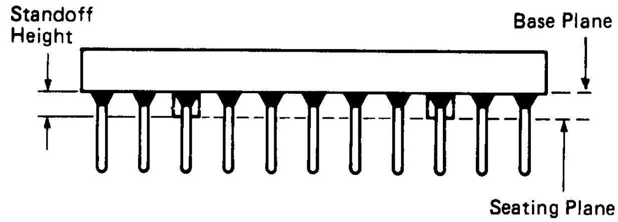

Figure 3
Seating Plane

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SEMI G34-89
SPECIFICATION FOR CER-PACK PACKAGE CONSTRUCTIONS, INCLUDING LEADFRAMES, SUITABLE FOR AUTOMATED ASSEMBLY BY END USERS

1 Preface

This specification defines the standard requirements for Cer-Pack package construction intended for automated assembly to printed wiring boards. Acceptance criteria for package constructions, including leadframes, are included.

2 Applicable Documents[1]

2.1 This document specifically refers to:

MIL-STD-883 — Test Methods and Procedures for Microelectronics

2.2 Related information may also be found in:

MIL-M-38510 — General Specification for Microcircuits

3 Selected Definitions

burr — A fragment of excess material or foreign particle adhering to the surface.

chip — Region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip size is given by its length, width, and depth from a projection of the design plan-form (see Figure 1).

crack — Cleavage or fracture that extends to the surface of a package. It may or may not pass through the entire thickness of the package.

critical seal area — The area bound by the shortest line from the cavity corners to the ceramic edge (see Figure 2).

critical seal path — The nominal design distance across the critical seal area from the die cavity to ceramic edge.

fin — A fine, feathery-edged projection on the edge or corner of the ceramic.

glass flow — Heated sufficiently to remove all screen mesh marks visible at 10× magnification.

non-critical seal area — Those portions of the sealing surface falling outside the critical area (see Figure 2).

overhang — Horizontal extension of glass from the ceramic (see Figure 3).

projection — Raised portion of the surface indigenous with the parent material.

pull back — Defines a dimension covering the linear distance between the edge of the ceramic and the first measurable glass interface (see Figures 3, 4, and 5).

rundown — Vertical extension of glass from the ceramic (see Figure 3).

seal area — A dimensional outline area designated for sealing the base and cap together to provide a hermetic seal (see Figure 5).

void — An absence of metallization or glass from a designated metallized or glassed area on the ceramic surface.

4 Ordering Information

Purchase order for Cer-Pack package devices furnished to this specification shall include the following items:

1. Drawing number and revision level
2. Type and color of ceramic
3. Type and thickness of glass
4. Type and thickness of metallization
5. Description
6. Certification by vendor
7. Method of test and measurements (see Section 9)
8. Lot acceptance procedures (see Section 8)
9. Packaging and marking (see Section 10)
10. Lead finish requirements (see Section 6.5)

5 Dimensions and Permissible Variations

Packaged device dimensions shall conform to JEDEC JC-11 registered outline dimensions for Cer-Packs for Automated Assembly.

6 Materials

6.1 *Ceramic*

6.1.1 Alumina content to be 90% minimum.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

6.1.2 *Color* — Black, dark brown, or dark violet.

6.2 *Sealing Material* — Solder glass designed to form a hermetic seal. Glass type and temperature/time profile shall be specified.

6.3 *Die Attach Pad* — Gold (or other suitable material).

6.4 *Leadframe* — Fully annealed Alloy 42.

6.5 *Lead Finish* — Unless otherwise specified, hot tin-lead solder dip, Type A, per MIL-M-38510, to within 0.030" of lead seal on plated leads, and 100% coverage if applied directly over base metal.

7 Defect Limits

7.1 *Ceramic*

7.1.1 *Cracks* — Cracks are not allowed.

7.1.2 *Chips* — See Figures 1 and 2.

7.1.2.1 *Corner Chips* — 0.762 mm (0.030") × 0.762 mm (0.030") × 25% of package element thickness.

7.1.2.2 *Edge Chips* — 2.54 mm (0.060") × 0.762 mm (0.030") × 25% of package element thickness.

7.1.2.3 *Critical Seal Area* — Chips cannot reduce the critical seal path to less than half the nominal design dimension at any point. No more than four chips are allowed in the critical seal area.

7.1.3 *Burrs, Projections, and Fins*

7.1.3.1 *Cap* — 0.127 mm (0.005") maximum.

7.1.3.2 *Base* — 0.076 mm (0.003") maximum.

7.1.3.3 *Die Attach Surface* — 0.025 mm (0.001") maximum above metallization excluding a 0.254 mm (0.010") perimeter.

7.1.4 *Camber* — 0.050 mm (0.002") camber permitted up to maximum of 0.004 inch/inch (mm/mm).

7.2 *Glass*

7.2.1 *Chips or Voids* — Chips in the glass or missing glass is allowed, provided the region of the chipped or missing glass meets the minimum specified glass thickness after melting the glass as specified.

7.2.2 *Glass Misalignment* — (after glass flow) (see Figure 3.)

7.2.2.1 *External Overhang* — 0.127 mm (0.005") maximum.

7.2.2.2 *External Rundown* — 30% of ceramic thickness maximum.

7.2.2.3 *Pullback* — See Table 1 and Figures 2, 3, and 4.

Table 1 Maximum Allowable Pullback

Side external (critical seal)	0.010" (2.54 mm)
Side external (other)	0.015" (0.381 mm)
End external	0.020" (0.508 mm)
Side cavity	0.010" (0.254 mm)
End cavity	0.010" (0.254 mm)

NOTE: Maximum allowable critical seal area reduction on any one side between side cavity and side external shall not reduce critical seal path to less than 0.635 mm (0.025").

8 Sampling

Sampling will be determined between supplier and purchaser.

9 Functional Test Methods

9.1 *Die Attach Quality*

9.1.1 Visually inspect preform wetout after die attach. Minimum fillet shall be 75% of the die perimeter.

9.1.2 Perform destructive die shear test post environmental testing per MIL-STD-883, Method 2019.

9.1.3 Inspect to reveal voids in the die attach eutectic alloy or approved silver-filled glass per MIL-STD-883, Method 2012.

9.2 *Lead Bond Quality* — Perform minimum pre-seal and post-seal bond strength test per MIL-STD-883, Method 2011, Test Condition D. Reject for bonds causing the metallization to lift from the leadframe post.

9.3 *Hermetic Environmental Testing*

9.3.1 The hermetic integrity of the package must be maintained after all environmental testing. Hermetic check shall comply with MIL-STD-883, Method 1014, Test Condition A, or B and C.

9.3.2 Environmental testing shall include, but not be limited to, the following:

9.3.2.1 Temperature Cycle per MIL-STD-883, Method 1010, Condition C.

9.3.2.2 Thermal Shock per MIL-STD-883, Method 1011, Condition B.

9.3.2.3 Centrifuge per MIL-STD-883, Method 2001, Condition D, Y axis only.

9.3.2.4 Moisture Resistance per MIL-STD-883, Method 1004.

9.4 *Die Attach Material Thickness* — Die attach material thickness shall be measured by standard cross-sectioning without smearing.

9.5 *Solderability* — Per MIL-STD-883, Method 2003.

9.6 *Sequence of Events and Incoming Testing* — During incoming inspection, the sequence of testing shall be:

1. Frame Attach
2. Die Attach
3. Bond (if applicable)
4. Seal
5. Lead Finish (Type A per MIL-M-38510)
6. Environmental Testing
7. Lead Trim
8. Fine Leak
9. Gross Leak
10. Torque Test (test method pending)
11. Bond Pull
12. Die Shear (optional)

9.6.1 *Solderability* — A separate sample with lead finish Type A shall be subjected to preconditioning of Class B time/temperature exposure per burn-in Test Method 1015, MIL-STD-883, then tested to Method 2003.

NOTE: An initial qualification on the thermal and electrical characteristics of the package may be performed. The characteristics tested will be:

Insulation Resistance — Per MIL-STD-883, Method 1003, Test Condition B.

Thermal Dissipation — Per MIL-STD-883, Method 1012.

10 Packaging and Marking

10.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents. Containers shall afford protection of the contents from contamination and exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component parts with paper fibers or organic particles.

10.2 *Marking* — The outer containers shall be clearly marked to identify the user stock number, user purchase order number, drawing number, quantity, vendor lot number, and solder glass type.

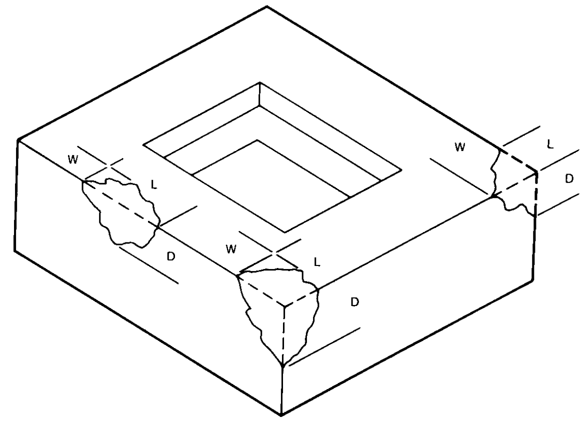

Figure 1
Chip Illustration

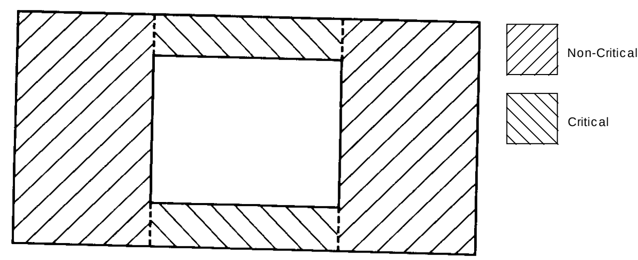

Figure 2
Critical and Non-Critical Seal Areas

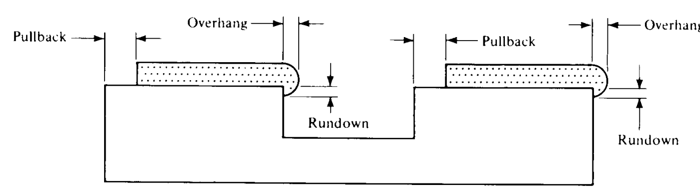

Figure 3
Glass Misalignment

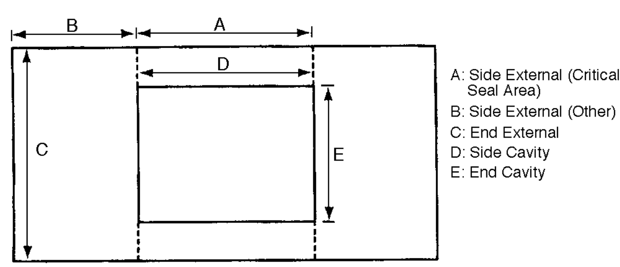

Figure 4
Pullback Measurement Area

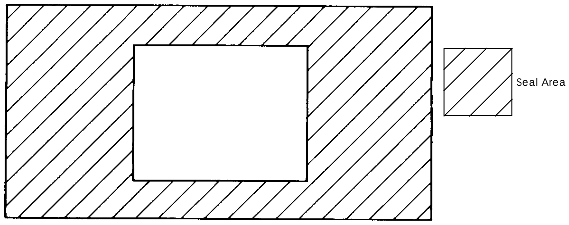

Figure 5
Seal Area

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SEMI G35-87
SPECIFICATION FOR TEST METHODS FOR LEAD FINISHES ON SEMICONDUCTOR (ACTIVE) DEVICES

1 Scope

This specification shall be used by suppliers and/or users of semiconductor (active) devices, and is effective for all lead finishes used.

2 Purpose

This specification establishes uniform methods and procedures for conducting tests on lead finishes on (active device) electronic packages. Other SEMI standards establish materials used and the finishes for them.

3 Applicable Documents

3.1 *Order of Precedence* — In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3.2 *Referenced Documents* — Unless otherwise specified, the following standards and specifications, with appropriate issue letter at time of order entry, form a part of this specification to the extent and for the purpose specified herein.

3.3 *ASTM Specifications*[1]

E 10 — Standard Test Method for Brinell Hardness for Metallic Materials

E 122 — Choice of Sample Size to Estimate the Average Quality of a Lot or Process

E 384 — Standard Test Methods for Micro-Hardness of Materials

B 487 — Measuring Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section

B 545 — Standard Specification for Electro Deposited Coatings of Tin

B 567 — Measurement of Coating Thickness by the Beta Backscatter Principle

B 568 — Measurement of Coating Thickness by X-Ray Spectrometry

3.4 *Military Specifications*[2]

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-105 — Sampling Procedures with Tables for Inspection by Attributes

3.5 *SEMI Specifications*

SEMI G4 — Integrated Circuit Leadframe Materials Used in the Production of Stamped Leadframes

SEMI G18 — Integrated Circuit Leadframe Materials Used in the Production of Etched Leadframes

SEMI G20 — Lead Finishes for Plastic Packages (Active Devices Only)

4 Selected Definitions

active devices — semiconductor devices with active function (e.g., IC, transistor, diode) as opposed to passive devices (e.g., inductors, capacitors).

air atmosphere — air heated to specified temperature which, when cooled to ambient, will normalize to one (1) standard atmosphere.

steam atmosphere — atmosphere in a closed vessel containing water, with venting sufficient to maintain temperature at one (1) standard atmosphere and 100° + 0, -5°C.

NOTE: The intent of this requirement is to replace air with steam.

5 Sampling

Unless otherwise specified, Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot tolerance percent defective (LTPD) value in accordance with MIL-STD-105 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classifications may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the user and supplier.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

6 Test Methods

6.1 *Visual Inspection*

6.1.1 For reference purposes the required appearance and associated properties for any specific lead finish are specified in the detailed SEMI specification for the specific lead finish to be evaluated.

6.1.2 *Purpose*

6.1.2.1 Visual inspection shall be performed to evaluate application of the required lead finish. Magnification at 10× preferred.

6.1.3 *Failure Criteria*

6.1.3.1 Finish is wrong type, is missing, or is non-adherent (has peeling, flaking, or blistering).

NOTE: Variations in color are not cause for failure unless there is evidence of corrosion and flaking or pitting.

6.1.3.2 Finish contains foreign material or surface contamination such as water marks.

6.1.3.3 Leads and terminations shall be electrically sound and mechanically intact. Nothing in the lead finish shall detract from lead integrity.

6.2 *Solderability*

6.2.1 The purpose of the test, terms and definitions, apparatus, and materials to be used are specified in MIL-STD-883, Method 2003.

6.2.2 Procedure to be used shall be as specified in MIL-STD-883, Method 2003, except as specified below.

6.2.2.1 Aging as specified in MIL-STD-883, Method 2003, shall not be performed. (See Section 6.2.2.2.)

6.2.2.2 At user's option, pre-aging at the indicated level below shall be performed:

1. Condition A — No pre-age.
2. Condition B — 5 hours at 150°C in Air Atmosphere.
3. Condition C — 5 hours at 200°C in Air Atmosphere.
4. Condition D — 4 hours suspended in Steam Atmosphere.
5. Condition E — 8 hours suspended in Steam Atmosphere.

NOTE: See definition section for above noted atmospheric conditions.

6.2.3 Failure criteria shall be as specified in MIL-STD-883, Method 2003, except as specified below.

6.2.3.1 Coverage shall be 90% on major flat (excluding non-functional areas). Non-functional areas include end of termination, edges in clad materials, and areas above the seating plane.

6.3 *Lead Fatigue/Lead Finish Adherence*

6.3.1 The purpose of the test, apparatus, and procedure to be used are as specified in MIL-STD-883, Method 2004, Test Condition B1, except as specified below.

6.3.1.1 Purpose of this test is limited to a check of lead finish integrity after stressing.

6.3.1.2 Three (3) leads per device shall be tested.

6.3.1.3 Three (3) cycles of rotation shall be used.

6.3.2 *Failure Criteria*

When examined at 10× magnification, any evidence of peeling, or gross discontinuity shall be considered a device failure.

6.4 *Thickness*

6.4.1 Thickness, when specified, shall be measured in functional lead area. On flat leads, measure in the center of the major flat. On round leads, measure below the seating plane and above the gauge plane.

6.4.2 Thickness, when specified, shall be measured in accordance with ASTM B 568 (Measurement of Coating Thickness by X-Ray Spectrometry) as the preferred method.

6.4.3 Thickness may be measured as an alternative to the above by either ASTM B 567 (Beta Backskatter Principle) or ASTM B 487 (Cross Section Principle).

6.5 *Hardness*

6.5.1 Hardness, when specified, shall be measured in functional lead area. On flat leads, measure in the center of the major flat. On round leads, measure below the seating plane and above the gauge plane.

6.5.2 Hardness shall be tested only when specified as a Lead Finish Detail (e.g., for socketing application).

6.5.3 Hardness shall be tested in accordance with ASTM E 384 (Standard Test Methods for Micro-Hardness of Materials), or ASTM E 10 (Standard Test Method for Brinnel Hardness for Metallic Materials), whichever is appropriate (see detailed specification or procurement document).

7 Certification

7.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

7.2 In the interest of controlling inspection costs, the supplier and the purchaser may agree that the material shall be certified as capable of meeting certain requirements. In this context, capable of meeting shall signify that the supplier is not required to perform the appropriate tests in Section 6. However, if the user performs the test and the material fails to meet the requirement, the material may be subject to rejection.

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SEMI G36-88

SPECIFICATION FOR DIMENSIONS AND TOLERANCES USED TO MANUFACTURE PLASTIC MOLDED HIGH DENSITY TAB QUAD SEMICONDUCTOR PACKAGE TOOLING

1 Preface

This document is for the ordering of tooling required to mold and form plastic high density TAB quad semiconductor packages. It is to be used by packaging engineers, mold manufacturers, and end-of-line toolmakers as the basis for defining the limits of manufacturing tolerances.

2 Applicable Documents

2.1 *ANSI Specification*[1]

Y14.5 — Dimensioning and Tolerancing

2.2 *JEDEC Specification*[2]

Pub No.95 — JEDEC Registered and Standard Outline and Standard Outline for Semiconductor Devices

2.3 *Military Specification*[3]

MIL-STD-100 — Engineering Drawing Practices

3 Selected Definitions — Product Criteria Tolerance Limits

mismatch and offset — defined with respect to package only. All statements will be equally applicable in two (2) axes. All mismatch and offset measurements are made after molding and prior to trimming.

cavity to frame offset — will be measured prior to any trimming operation. Offset will be defined as the difference in bottom cavity position with respect to a leadframe datum. The offset measurement will exclude leadframe tolerances (see Figure 2).

top to bottom cavity mismatch — characterized by the fact that the top and bottom cavities in the mold are not aligned properly, causing a mismatch condition. The measurement shall be stated as the difference in the top cavity position relative to the bottom cavity position (see Figure 1).

package warpage — any non-linear dimensional change from the mold cavity characteristic, usually caused by incorrect package design or molding practices (see Figure 3).

1 ANSI, 1430 Broadway, New York, NY 10018

2 JEDEC, 2001 Eye Street N.W., Washington, D.C. 20006

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

parting line protrusions — those plastic excesses which remain as a normal characteristic after normal molding, deflashing, trimming, and singulation (see Figure 4).

top, bottom protrusions — those plastic excesses (includes ejector pin crowns) which remain as a normal characteristic extending from the smooth surface of the molded package.

variations in lead location — defined with respect to a 90° angle from the top or bottom of the smooth surface of the molded package as viewed on the end or side projections (see Figure 4).

lead shoulder intrusions and protrusions — any variations in straightness along the defined shoulder essentially caused by dambar removal (see Figure 4).

lead position overlay (footprint) — (See Figure 5.)

shoulder bend location — measured from the outermost point of the shoulder bend radius (see Figure 6).

lead co-planarity — defined as the vertical lead position with respect to a reference plane measured after forming. The reference plane is defined by the three lowest leads from the bottom of the package (see Figure 6).

4 Ordering Information

4.1 Purchase orders for tooling for plastic molded high density TAB semiconductor packages furnished to this specification shall include the following items:

1. A package tooling outline drawing showing all required dimensions listed in Section 5. Package surface finish to be included.
2. A list of any tolerance limits which differ from those in Section 6.
3. The type of tooling steel required.
4. The type of leadframe material and temper to be used.
5. The type of plastic to be molded (if proprietary, a statement of its shrinkage characteristics) and molding temperature.
6. Sampling plan shall be determined between vendor and purchaser.
7. The number of spare parts or expendable parts desired.

8. Molding press to be used.

9. Electrical power available for heating.

10. Applicable leadframe drawing, including all dimensions.

5 Dimensions

5.1 Drawing must show dimensions for the following items, if applicable:

1. Package length
2. Package width
3. Top cavity thickness
4. Bottom cavity thickness
5. Frame thickness
6. Top ejector pin locations from datum lines
7. Bottom ejector pin locations from datum lines
8. Ejector pin sizes (top and bottom)
9. Ejector depth (top and bottom, draft angle top and bottom side)
10. Pin 1 ID location from package center
11. Pin 1 ID shape and size
12. All applicable package radii
13. Draft angles (top and bottom)
14. Package parting line location
15. Shoulder bend location

6 Product Criteria

6.1 Dimensional tolerance limits for high density TAB products (see Section 3).

6.1.1 Recognizing that every manufacturing process is subject to variation, the following list details the acceptable limit of this variation:

28-328 LEAD

OVERLAP/OFFSET	
Cavity Overlap (See Figure 1)	0.002" (maximum)
Cavity Mismatch (See Figure 1	0.002" (maximum)

CAVITY TO FRAME OFFSET	
(See Figure 2) (not including leadframe tolerances)	0.002" (maximum)

PACKAGE WARPAGE	
Warp factor (See Figure 3)	2.5 to a max. of 0.003"

PROTRUSIONS & INTRUSIONS	
(See Figure 4) Parting line	0.005" (maximum)
Gating	0.005" (maximum)
Top or bottom ejector pin	0.002" (maximum)

VARIATIONS IN LEAD POSITION	
(See Figure 4)	0.003" (maximum)

LEAD COPLANARITY	
(See Figure 6)	0.002" (maximum)

DAMBAR TRIMMING INTRUSIONS/PROTRUSIONS	
Intrustions (See Figure 6)	0.002" (maximum)
Protrusions (See Figure 4) (shall not decrease gap more than 20%)	0.003" (maximum)

7 Packaging

Tooling must be packed in containers designed and constructed to prevent damage and/or contamination.

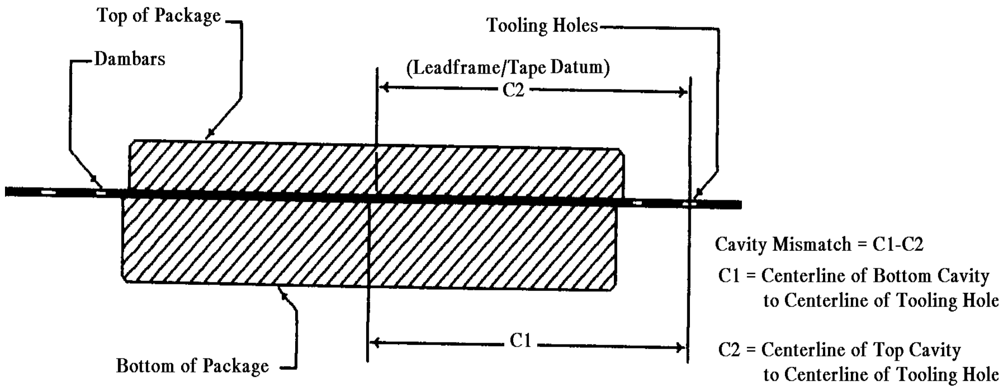

Figure 1
Top to Bottom Cavity Mismatch

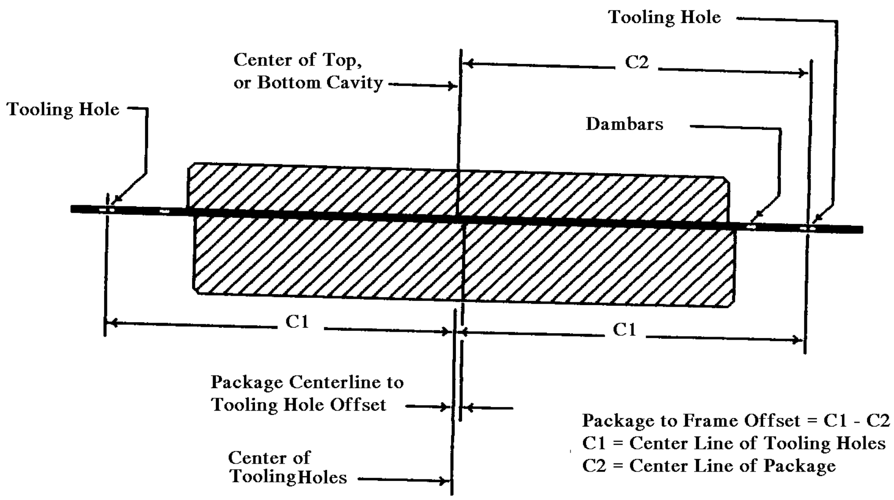

Figure 2
Cavity to Frame Offset

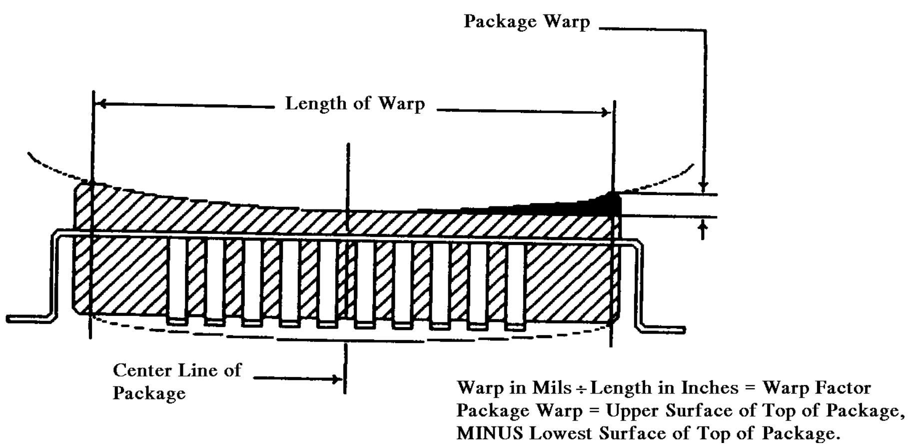

Figure 3
Package Warpage

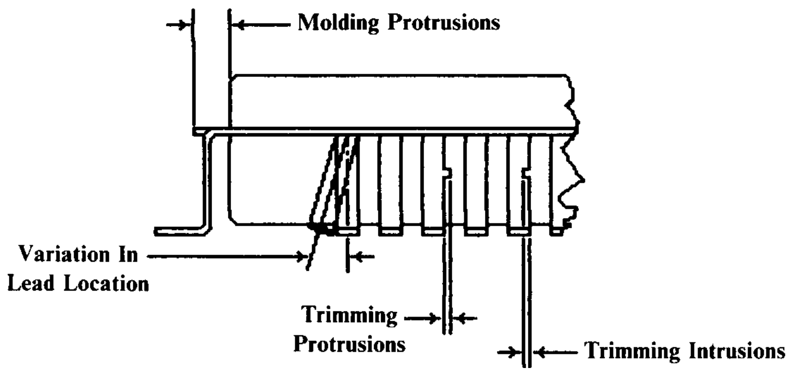

Figure 4
Parting Line Protrusion/Intrusion and Variation in Lead Location

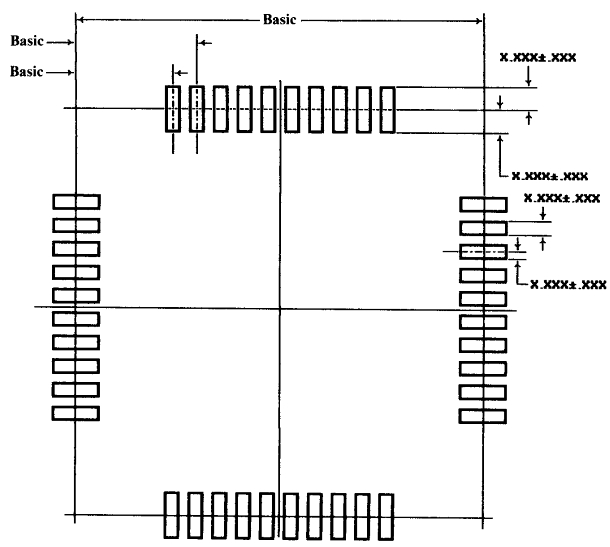

Figure 5
Lead Position Overlay Example

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SEMI G37-88
SPECIFICATION FOR DIMENSIONS AND TOLERANCES USED TO MANUFACTURE PLASTIC MOLDED SMALL OUTLINE PACKAGE TOOLING

1 Preface

This document is a guideline for the ordering of tooling required to mold and form plastic molded small outline semiconductor packages. It is to be used by packaging engineers, mold manufacturers, and end-of-line toolmakers as the basis for defining the limits of manufacturing tolerances.

2 Applicable Documents

2.1 *ANSI Specification*[1]

Y14.5 — Dimensioning and Tolerancing

2.2 *JEDEC Specification*[2]

Pub. No. 95 — Registered and Standard Outline for Semiconductor Devices

2.3 *Military Specification*[3]

MIL-STD-100 — Engineering Drawing Practices

3 Selected Definitions — Product Criteria Tolerance Limits

mismatch and offset — defined with respect to package only. As this family of packages has four sides, all statements will be equally applicable in two (2) axes. All mismatch and offset measurements are made after molding and prior to trimming.

cavity to frame offset — will be measured prior to any trimming operation. Offset will be defined as the difference in bottom cavity position with respect to a leadframe datum. The offset measurement will exclude leadframe tolerances (see Figure 1).

top to bottom cavity mismatch — characterized by the fact that the top and bottom cavities in the mold are not aligned properly, causing a mismatch condition. The measurement shall be stated as the difference in the package top cavity position relative to the bottom cavity position (see Figure 2).

parting line protrusions — those plastic excesses which remain as a normal characteristic after normal molding, deflashing, trimming, and singulation (see Figure 3).

top or bottom protrusions — those plastic excesses (includes ejector pin crowns), which remain as a normal characteristic extending from the smooth surface of the molded package.

variations in lead location — defined with respect to a 90° angle from the top or bottom of the smooth surface of the molded package as viewed on the end or side projections (see Figure 3).

lead shoulder intrusions and protrusions — any variations in straightness along the defined shoulder essentially caused by dambar removal (see Figure 3).

package warpage — any non-linear dimensional change from the mold cavity characteristic, usually caused by incorrect package design or molding practices (see Figure 4).

shoulder bend location — measured from the outermost point of the shoulder bend radius (see Figure 5).

lead co-planarity — defined as the vertical lead position with respect to a reference plane measured after forming. The reference plane is defined by the three lowest leads from the bottom of the package (see Figure 6).

4 Ordering Information

4.1 Purchase orders for tooling for plastic molded high density TAB semiconductor packages furnished to this specification shall include the following items:

1. A package tooling outline drawing showing all required dimensions listed in Section 5. Package surface finish to be included.
2. A list of any tolerance limits which differ from those in Section 6.
3. The type of tooling steel required.
4. The type of leadframe material and temper to be used.
5. The type of plastic to be molded (if proprietary, a statement of its shrinkage characteristics).
6. Sampling plan for compliance to Section 7.
7. The number of spare parts or expendable parts desired.

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1 ANSI, 1430 Broadway, New York, NY 10018

2 JEDEC, 20001 Eye Street, N.W., Washington, D.C. 20006

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, PA 19120

8. The type of molding press to be used, including power requirements.
9. Applicable leadframe drawing, including all dimensions.

5 Dimensions

5.1 Drawing must show dimension for the following items, if applicable:

1. Package length
2. Package width
3. Top cavity thickness
4. Bottom cavity thickness
5. Frame thickness
6. Ejector top locations from cavity centerline
7. Ejector bottom locations from cavity centerline
8. Ejector size (top and bottom)
9. Ejector depth (top and bottom, draft angle top side, bottom side, and end)
10. End notch shape, depth, width, length
11. Pin 1 ID location from package center
12. Pin 1 ID shape and size
13. Corner radius or sides
14. Corner radius or ends
15. Lead spread (nominal)
16. Shoulder bend location
17. Shoulder width

6 Product Criteria — Dimensional Tolerance Limits for S.O. Packages

6.1 In recognizing that every manufacturing process is subject to variation, the following list details the acceptable limit of this variation:

CAVITY MISMATCH	
(See Figure 2)	0.05 mm (0.002")

PACKAGE/FRAME OFFSET	
(See Figure 1), (excluding leadframe tolerances)	0.05 mm (0.002")

MOLDED PROTRUSIONS	
(See Figure 3) Parting line	0.15 mm (0.006")
Top or bottom	0.025 mm (0.001")

VARIATION IN LEAD LOCATION	
(See Figure 3)	0.101 mm (0.004")

SHOULDER INTRUSIONS AND PROTRUSIONS	
Intrusions	0.025 mm (0.001")
Protrusions*	0.004"

PACKAGE WARPAGE	
Warp factor:	2.5

LEAD CO-PLANARITY	0.003" (maximum)

EJECTOR PIN DEPTH	0.003"

* Assumes 0.002" design protrusion.

7 Sampling

Samples used to determine compliance to Section 6 shall be determined between user and supplier.

8 Packaging

Tooling must be packed in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided if tooling is to be shipped any great distance.

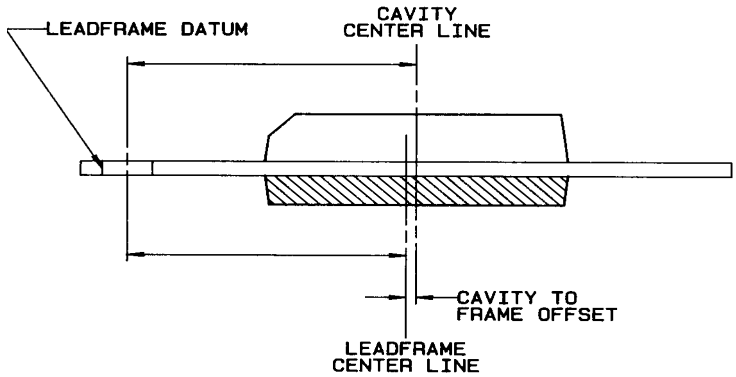

Figure 1
Cavity to Frame Offset

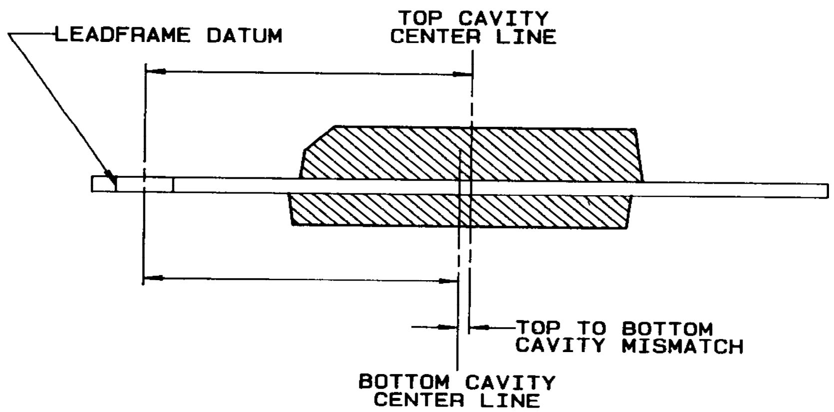

Figure 2
Cavity Mismatch

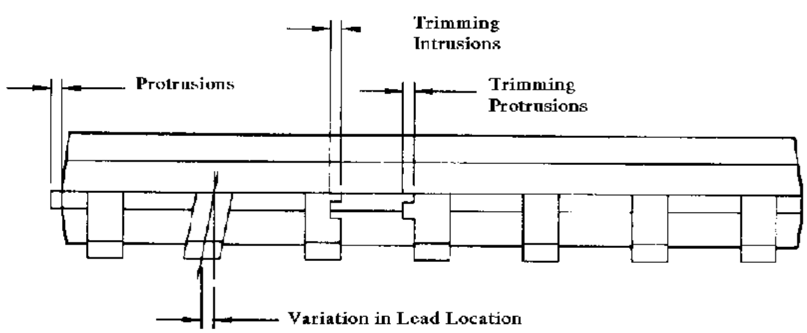

Figure 3
Parting Line Protrusions

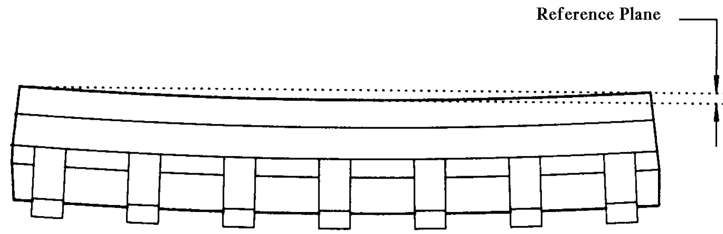

Figure 4
Package Warpage Warp in mils/Length in Inches = Warp Factor

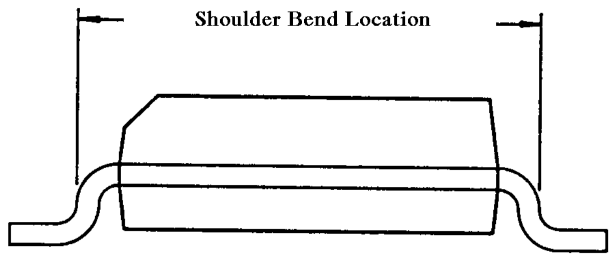

Figure 5
Shoulder Bend Location

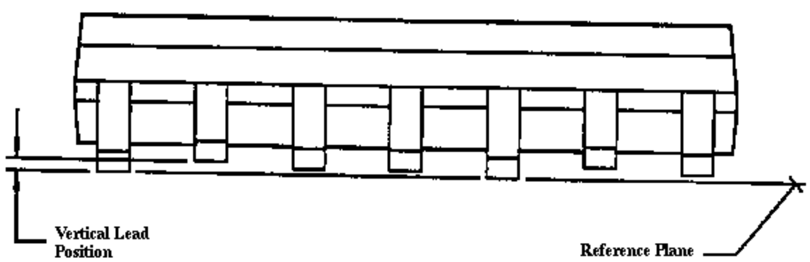

Figure 6
Lead Co-planarity

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SEMI G38-0996
TEST METHOD FOR STILL- AND FORCED-AIR JUNCTION-TO-AMBIENT THERMAL RESISTANCE MEASUREMENTS OF INTEGRATED CIRCUIT PACKAGES

1 Purpose

The purpose of this test is to determine the thermal resistance of integrated circuit packages using thermal test chips.

2 Scope

This test method deals only with junction-to-ambient measurements of thermal resistance and limits itself to still- and forced-air convection testing environments.

3 Referenced Documents

3.1 *SEMI Specifications*

SEMI G32 — Guideline for Unencapsulated Thermal Test Chip

SEMI G42 — Specification for Thermal Test Board Standardization for Measuring Junction-to-Ambient Thermal Resistance of Semiconductor Packages

4 Terminology

The following definitions and symbols shall apply for the purpose of this test:

4.1 *ambient temperature (T_A, in degrees Celsius)* — The ambient temperature is the temperature of the air at a specified location in the vicinity of the microelectronic device under test (DUT).

4.2 *junction temperature (T_J, in degrees Celsius)* — The term is used to denote the temperature of the semiconductor junction in the microcircuit in which the major part of the heat is generated. For purposes of this test, the measured junction temperature is only indicative of the temperature in the immediate vicinity of the element used to sense the temperature.

4.3 *power dissipation (P_H, in watts)* — The heating power applied to the device causing a junction-to-reference point temperature difference.

4.4 *temperature-sensitive parameter (TSP)* — The temperature-dependent electrical characteristic of the junction under test which can be calibrated with respect to temperature and subsequently used to detect the junction temperature of interest.

4.5 *thermal resistance* — Junction to specified reference point, $R_{\theta JR}$ degrees Celsius/watt. The thermal resistance of the microcircuit is the temperature difference from the junction to some reference point in the ambient divided by the power dissipation P_H.

4.6 *velocity (v_A, in linear feet per minute (LFPM))* — The velocity of the air at a specified location upstream of the DUT.

5 Apparatus

The apparatus required for these tests shall include the following as applicable to the specified test procedures.

5.1 *Thermocouple Material* — Shall be copper constantan (type T) or equivalent, for the temperature range -100 to + 300°C. The wire size shall be no larger than AWG size 30. The junction of the thermocouple shall be welded to form a bead rather than soldered or twisted. The accuracy of the thermocouple and associated measuring system shall be ± 0.5°C.

5.2 *Suitable Electrical Equipment* — As required to provide controlled levels of conditioning power and to make the specified measurements. The instrument used to electrically measure the temperature-sensitive parameter shall be capable of resolving a voltage change of 0.5 mV.

5.3 *Controlled Temperature Chamber, Fluid Bath, or Wind Tunnel* — Capable of maintaining the specific reference point temperature to within ± 0.5°C of the reset (measured) value. Typical still-air enclosure and wind tunnel assemblies are presented for reference purposes only.

5.4 *Still-Air Enclosure Assembly* — The microcircuit shall be mounted in a cubic enclosure of not less than 0.028 m^3 (1.0 ft^3). There shall be no radiation sources other than the microcircuit under test in the enclosure. The interior enclosure wall shall have a high reflectance finish (emissivity < 0.1). The ambient temperature should be measured by means of a thermocouple mounted at a distance of approximately 2.54 cm (1.0 in) beneath the DUT and 1.27 cm (0.5 in) from the test board or socket.

5.4.1 The microcircuit shall be mounted in such a manner that conduction cooling through the leads or the test socket or both shall be small compared to the other cooling mechanisms. No. 36 AWG wire should be connected to the device test socket. The air flow (by natural convection) should be unrestricted above and beneath the device. An alternative approach would be to use a mounting arrangement that approximates an application environment. Such a reference mounting configuration can be found in Specification, Thermal Test Board Standardization for Measuring Junction-to-Ambient Thermal Resistance of Semiconductor Packages. Device mounting and test board positioning inside the measuring chamber are depicted in Figure 1.

5.5 *Wind Tunnel Assembly* — A typical wind tunnel design is shown with its dimensions in Figure 2.

5.5.1 The fan or blower should be placed downstream of the DUT as depicted in Figure 2. A static pressure differential measurement across a calibrated nozzle is used to calculate the wind tunnel air velocity, while a thermocouple is used to measure the ambient temperature upstream of the DUT. Both of these devices should be placed at a specified location upstream of the DUT, as shown in Figure 2. The thermocouple is located in the center of the wind tunnel, 5.08 cm (2.0 in) from the test section and 2.54 cm (1.0 in) above the center plane of the DUT.

5.5.2 The microcircuit shall be mounted in such a manner that conduction cooling through the leads or the test socket, or both, shall be small compared to the other cooling mechanisms. To minimize conduction through the leads, No. 36 AWG wire should be connected to the device test socket. The DUT should be aligned so that the air front is parallel to the longer edge of the package (air front hitting the package side). An alternative approach would be to use a mounting arrangement that approximates an application environment. Such a referee mounting configuration can be found in SEMI G42. Device mounting and test board orientation inside the wind tunnel are depicted in Figure 3.

5.5.3 Flow straighteners should be placed upstream of the DUT, as shown in Figure 2. The flow straighteners should provide a flat velocity profile across the test section of the wind tunnel. This will ensure that the DUT is exposed to a uniform velocity across its entire cross section. A typical velocity profile for well-developed turbulent flow is depicted in Figure 3.

5.5.4 Calibrated hot wire anemometer or nozzle with suitable pressure gauges (p_1 and p_2) for measuring the pressure difference across the nozzle is used to calculate the wind tunnel air velocity. When using the nozzle, the pressure differential across the calibrated nozzle is measured using a liquid monometer, typically in inches of water.

5.5.5 Hot wire anemometer capable of verifying the air velocity profile with an accuracy of ± 5%. The velocity sensor should disrupt the airflow as little as possible.

6 Procedure

6.1 *Measurement of Wind Tunnel Air Velocity, v_A* — The air velocity measurement techniques are direct method and indirect method.

6.1.1 *Direct Measurement of Wind Tunnel Air Velocity* — The direct method is based on a measurement by a hot wire anemometer in wind tunnel.

6.1.2 *Indirect Measurement of Wind Tunnel Air Velocity, vA* — The air velocity measurement technique is an indirect method based on a pressure differential measurement across a calibrated nozzle. The actual velocity of interest is derived from a calibration curve relating the pressure differential of the nozzle to the volume (or mass) flow rate of the air through the nozzle. The required air velocity (in linear feet per minute) is then calculated by dividing the volume flow rate (in cubic feet per minute) by the cross sectional area at the entrance of the DUT test section (in square feet). The volume flow rate shall be determined to within an accuracy of ± 10%.

6.1.2.1 *Air Flow Profile* — Hot wire anemometer should be used to verify that the flow profile of the air front, measured within 5.08 cm (2.0 in.) of the test section, does not vary by more than 10% across the center 90% of the test section. The DUT and mounting board/socket should not be in the test section when the flow profile is determined.

6.2 *Direct Measurement of Reference Point Temperature, T_S* — For the purpose of measuring the still-air junction-to-ambient microelectronic device thermal resistance in a chamber, the ambient temperature ($T_R = T_A$) should be measured with a thermocouple beneath the DUT. For purposes of measuring forced air junction-to-ambient thermal resistance in a wind tunnel, the ambient temperature should be measured with a thermocouple upstream of the DUT in the section of the tunnel that experiences fully developed flow.

6.3 *Thermal Resistance, Junction to Specified Reference Point, $R_{\theta JR}$.*

6.3.1 *General Considerations* — The thermal resistance of a semiconductor device is a measure of the ability of its carrier, or package and mounting technique to provide for heat removal from the semiconductor junction. The thermal resistance of a microelectronic device can be calculated when the ambient temperature and power dissipation in the device and a measurement of the junction temperature are known. When making the indicated measurements, the package shall be considered to have achieved thermal equilibrium when halving the time between the application of power and the taking of the reading causes no error in the indicated results within the required accuracy of measurement.

6.3.2 *Indirect Measurement of Junction Temperature for the Determination of $R_{\theta JA}$* — The purpose of the test is to measure the thermal resistance of integrated circuits by using particular semiconductor elements on the chip to indicate the device junction temperature. In order to obtain a realistic estimate of the operating junction temperature, the whole chip in the package should be powered in order to provide the proper internal temperature distribution. During measurement of the junction temperature, the chip heating power (constant voltage source) shall remain constant while the junction calibration current remains stable. It is assumed that the calibration current will not be affected by the circuit operation during the application of heating power.

6.3.3 The temperature-sensitive device parameter is used as an indicator of an average (weighted) junction temperature of the semiconductor element for calculations of thermal resistance. The measured junction temperature is indicative of the temperature only in the immediate vicinity of the element used to sense the temperature.

6.3.4 The temperature-sensitive electrical parameters generally used to indirectly measure the junction temperature are the forward voltage of diodes and the emitter-base voltage of bipolar transistors. Other appropriate temperature-sensitive parameters may be used for indirectly measuring junction temperature for fabrication technologies that do not lend themselves to sensing the active junction voltages.

6.3.4.1 *Steady-State Technique for Measuring T_J* — The following symbols shall apply for the purpose of these measurements:

I_M	Measuring current in milliamperes.
V_{MH}	Value of temperature-sensitive parameters in millivolts, measured at I_M, and corresponding to the temperature of the junction heated by P_H.
T_{MC}	Calibration temperature in degrees Celsius, measured at the reference point.
V_{MC}	Value of temperature-sensitive parameter in millivolts, measured at I_M and specific value of T_{MC}.

The measurement of T_J, using junction forward voltage as the TSP, is made in the following manner:

Step 1 — Measurement of the temperature coefficient of the TSP (calibration).

The coefficient of the temperature-sensitive parameter is generated by measuring the TSP as a function of the reference point temperature, for a specified constant measuring current, I_M, by externally heating the device under test in a controlled temperature oven or fluid bath. The reference point temperature range used during calibration shall encompass the temperature range encountered in the power application test (see Step 2). The measuring current is generally chosen such that the TSP decreases linearly with increasing temperature over the range of interest and that negligible internal heating occurs in the silicon and metal traces. For determining the optimum TSP calibration or measuring current, V_{MC} vs. log I_M curves for two temperature levels that encompass the calibration temperature range of interest should be blotted. The optimum measuring current, I_M, is then selected such that it resides on the linear portion of the two V_{MC} vs. log I_M curves that were generated. A measuring current ranging from 0.05 to 5 mA is generally used, depending on the specifications and operating conditions of the device under test for measuring the TSP. The value of the TSP temperature coefficient, V_{MC}/T_{MC}, for the particular measuring current used in the test, is calculated from the calibration curve, V_{MC} vs. T_{MC}. At least three points should be used to generate the voltage vs. temperature curve for the determination of the TSP temperature coefficient.

Step 2 — Power application test

The power application test is performed in two parts. For both portions of the test, the reference point temperature and the specified air velocity are held constant at a preset value. The first measurement to be made is that of the temperature-sensitive parameter (i.e., V_{MC}, under operating conditions with the measuring current, I_M, used during the calibration procedure). The DUT shall then be operated with heating power (P_H) applied. The temperature-sensitive parameter, V_{MH}, shall be measured with constant measuring current, I_M, that was applied during the calibration procedure (see Step 1).

The heating power, P_H, shall be chosen such that the calculated junction-to-reference point temperature difference as measured at V_{MH} is greater than or equal to 20°C. In accomplishing this, the device under test should not be operated at such a high heating power level that the on-chip temperature sensing and heating circuitry is no longer electrically isolated. Care should also be taken not to exceed the design ratings of the package-interconnect system, as this may lead to an overestimation of the power being dissipated in the active area of the chip due to excessive power losses in the package leads and wire bonds. The values of V_{MH}, V_{MC}, and P_H are recorded during the power application test.

The following data shall be recorded for these test conditions:

a. Temperature-sensitive electrical parameters (V_F, V_{EB}, or other appropriate TSP).

b. Junction temperature, T_J, is calculated from the equation:

$$T_J = T_R + \left(V_{MH} - V_{MC}\right)\left|\frac{\Delta V_{MC}}{\Delta T_{MC}}\right|^{-1}$$

where $T_R = T_A$

c. Ambient (air) temperature, T_A.

d. Ambient (air) velocity, v_A, (v_A = 0 for still-air enclosure).

e. Power dissipation, P_H.

f. Mounting arrangement (including offset from test board).

6.4 *Calculations of $R_{\theta JR}$*

6.4.1 *Calculation of Package Thermal Resistance* — The thermal resistance of a microelectronic device can be calculated when the junction temperature, T_J, has been measured in accordance with procedures outlined in Sections 6.1 through 6.3. With the data recorded from each test, the thermal resistance shall be determined from:

$$R_{\theta JR} = \frac{T_J - T_R}{P_{H(Package)}}$$

where : $R_{\theta JR} = R_{\theta JA}$ and $T_R = T_A$.

7 Summary Report

The following details shall be specified:

1. Description of Package

1.1 Package Type

Package Name ________________ (per JEDEC or EIAJ)

Pin Counts ________________ pins

Special Specification ________________ Yes ________________ No

If Yes, describe the detail specification.

____

____

____

1.2 Test Chip

Chip per SEMI G32 ________________ Yes ________________ No

Chip Size ________________ mm x ________________ mm

Chip Thickness ________________ mm

1.3 Leadframe

Leadframe Material Fe/Ni Alloy, Cu, Cu Alloy, Other (____________)

Leadframe Thickness ________________ mm

Die Pad Size ________________ mm x ________________ mm

1.4 Package Dimension & Compound

Package Size ________________ mm x ________________ mm

Package Thickness ________________ mm

Compound Material ____

1.5 Others

Die Attach Material ____

Heat Sink/Spreader ________________ Yes ________________ No

If yes, describe the configuration, dimension, method of attachment, location, etc.

____

____

____

2. Description of Test Board

Test Board per SEMI G42 ________________ Yes ________________ No

No. of Layers ____

If test board is specified, describe the specification of the following items:

Dimension ________________ mm x ________________ mm x ________________mmt

No. of Layers ____

Material ____

	Pattern	____
3.	**Measurement Condition**	
	Ambient Temperature, T_a	________________ °C
	Ambient Humidity, H_a	________________ %RH
	Air Velocity, V_a	0, 1, 2, 5, ( ) mm/sec.
	Power Dissipation, P_H	0, 1, 2 W
4.	**No. of Samples, N**	________________
5.	**Thermal Resistance, $R_{\theta JA}$**	________________ °C/W

8 Related Documents

1. *Laboratory Methods of Testing Fans for Rating,* AMCA Standard 210-74/ASHRAE Standard 51-75, Air Movement and Control Association and the American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1975.

2. *Fluid Meters — Their Theory and Application,* American Society of Mechanical Engineers, Sixth Edition, 1971.

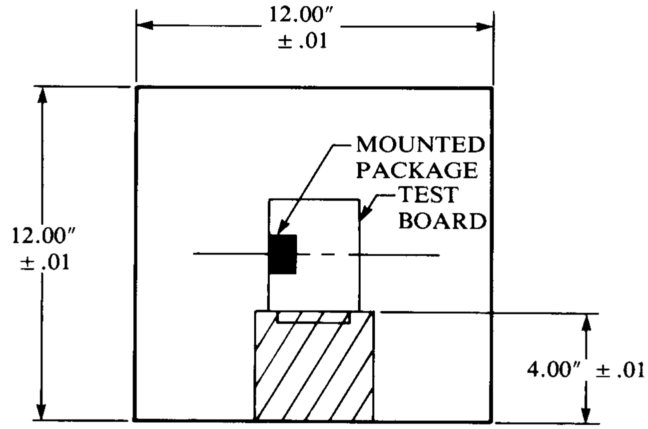

Figure 1
Test Board Positioning

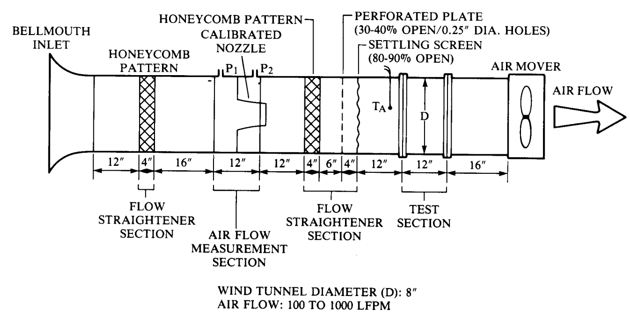

Figure 2
Wind Tunnel Set-Up

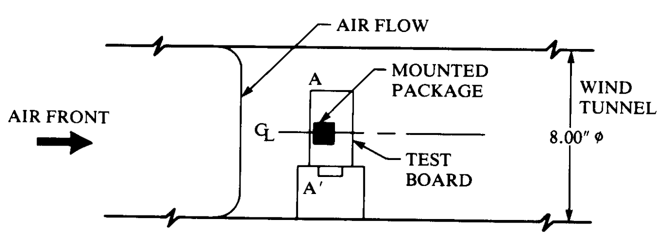

Figure 3
Test Board Orientation Inside Wind Tunnel

APPENDIX 1
REPORT FORMAT

NOTE: This appendix was approved as an official part of SEMI G38 by full letter ballot procedure.

The following format is a sample of report format:

1.	**Description of Package**				
1.1	Package Type				
	Package Name	________________	(per JEDEC or EIAJ)		
	Pin Counts	________________	pins		
	Special Specification	________________	Yes	________________	No
1.2	Test Chip				
	Chip per SEMI G32	________________	Yes	________________	No
	Chip Size	________________	mm x	________________	mm
	Chip Thickness	________________	mm		
1.3	Leadframe				
	Leadframe Material	Fe/Ni Alloy, Cu, Cu Alloy, Other (________________)			
	Leadframe Thickness	________________	mm		
	Die Pad Size	________________	mm x	________________	mm
1.4	Package Dimension & Compound				
	Package Size	________________	mm x	________________	mm
	Package Thickness	________________	mm		
	Compound Material	________________________________			
1.5	Others				
	Die Attach Material	________________________________			
	Heat Sink/Spreader	________________	Yes	________________	No
2.	**Description of Test Board**				
	Test Board per SEMI G42	________________	Yes	________________	No
	No. of Layers	________________________________			
3.	**Measurement Result**				
	Power Dissipation	________________ W			

Units: °C/W

Air Velocity (m/s) / *Sample No.*	*0*	*1*	*3*	*5*
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Average				

SEMI

SEMI G39-89
SPECIFICATION FOR BRAZED LEAD FLATPACK CONSTRUCTIONS, INCLUDING LEADFRAMES, SUITABLE FOR AUTOMATED ASSEMBLY

1 Preface

This specification defines the standard requirements for co-fired ceramic brazed lead flatpack package constructions intended for automated assembly to printed wiring boards. Acceptance criteria for package constructions, including leadframes, are included.

2 Applicable Documents

2.1 *ANSI Standard*[1]

ANSI Y14.5 — Dimensioning and Tolerancing

2.2 *Federal Specification*[2]

QQ-N-290 — Nickel Plating

2.3 *JEDEC Standard*[3]

JEDEC Pub 95 — Registered and Standard Outlines for Solid State Products

2.4 *Military Specifications*[2]

MIL-M-38510 — General Specifications for Microcircuits

MIL-STD-1051 — Sampling Procedures and Tables for Inspections by Attributes

MIL-STD-23011 — Iron Nickel Alloys for Sealing to Glass and Ceramics

MIL-STD-45204 — Gold Plating Electrodeposited

MIL-STD-87883 — Brazing

MIL-STD-883 — Test Methods and Procedures for Microelectronics

3 Selected Definitions

blister bubble (ceramic) — any separation within the ceramic which does not expose underlying ceramic material.

blister bubble (metal) — any localized separation within the metallization or between the metallization and ceramic which does not expose underlying metal or ceramic material.

bond finger — a region of refractory metallization within the package cavity intended for wirebonding to a mirocircuit die pad.

braze — an alloy with a melting point equal to or greater than 600°C.

burr — an adherent fragment of excess parent material at the component edge.

chip-out — a region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip-out size is given by its length, width, and depth from a projection of the design plan-form (see Figure 1).

co-fired — a process or technology for manufacturing products in which the ceramic and refractory metallizations are fired simultaneously.

contact pad — that metallized pattern to which the leadframe is brazed.

crack — a cleavage or fracture, internal or external.

die attach surface — a designated dimensional outline area intended for die attach (see Figure 2).

foreign material — an adherent particle other than parent material of that component.

layer — a dielectric sheet with or without metallization that performs a discrete function as part of the package construction.

lead offset — alignment of leads across the package.

peeling (flaking) — any separation from the basis material that exposes the basis material.

projection — an adherent fragment of excess material on the component surface.

pullback — the linear distance between the edge of the ceramic and the first measurable metallization surface (see Figure 3).

rundown — the linear distance down a vertical surface from the top to the point of maximum metallization overhang (see Figure 3).

seal area — a dimensional outline area designated for either metallization or bare ceramic to provide a surface area for lid sealing (see Figure 2).

terminal — metallization at the point of electrical contact to package interior circuitry; also the brazing surface for a lead.

1 ANSI, 1430, Broadway, New York, NY 10018

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 JEDEC, 2001 Eye Street, N.W., Washington, D.C. 20006

TIR — total Indicator Reading; the span of readings from minimum to maximum of a given dimension over the total surface to which it applies.

void (ceramic) — an absence of screen printed ceramic from a designated area greater than 0.075 mm (0.003") in diameter.

void (metal) — an absence of refractory metallization, braze or plating material from a designated area greater than 0.075 mm (0.003") in diameter.

4 Ordering Information

4.1 Purchase orders for co-fired ceramic brazed lead flatpack packaged devices shall specify the following information:

1. Quantity.
2. Drawing number and revision level or date.
3. Reference to this specification.
4. Any exception to drawing or specification.

4.2 Drawings for co-fired ceramic brazed lead flatpack packaged devices shall specify the following information:

1. Drawing number and revision level.
2. Number of terminals and terminal center line pacing.
3. Lead material, finish, and dimensions.
4. Ceramic material color and composition; and refractory metal type.
5. Type and thickness of plating on both device body and leads.
6. Dimensioning and tolerancing per ANSI Y14.5.
7. Internal bonding pattern.
8. Lead number 1 position.
9. Method of test and measurements.
10. Electrical, mechanical and environmental requirements.

5 Dimensions and Permissible Variations

Packaged device dimensions shall conform to JEDEC JC-11 registered outline dimension drawings for Co-fired Ceramic Brazed Lead Flatpack Devices for Automated Assembly, unless otherwise specified.

6 Materials

6.1 *Ceramic*

6.1.1 *Alumina Content* — To be 90% minimum. Beryllia content to be 99% minimum.

6.1.2 *Color* — To be black, dark brown, or dark violet unless otherwise specified.

6.2 *Metals* — External metal surfaces shall be in accordance with MIL-M-38510.

6.3 *Braze* — Copper/silver per MIL-STD-7883.

6.4 *Refractory Metallization* — To be per MIL-M-38510, Type C.

6.5 *Leadframe* — Fully annealed iron nickel cobalt alloy (per MIL-M-38510, Type A) or iron nickel alloy (per MIL-M-38510, Type B).

6.6 *Microcircuit Finishes* — Shall be per MIL-M-38510 unless otherwise specified.

7 Incoming Testing Sequence

1. Visual inspection.
2. Dimensional check.
3. Electrical parameter testing.
4. Sampling testing of plating quality, die attach, die shear, wire bond pull, seal, hermeticity, lead integrity, and solderability.

8 Visual Criteria (10× Magnification)

8.1 *Cracks* — None allowed per MIL-STD-883, Method 2009.

8.2 *Chip-Outs*

8.2.1 *Corner* — 0.762 mm (0.030") × 0.762 mm (0.030") × 1 tape layer, maximum.

8.2.2 *Edge* — 2.54 mm (0.100") × 0.762 mm (0.030") × 1 tape layer, maximum.

8.2.3 *Encroachment* — No encroachment upon seal areas, bonding fingers, or external terminal areas permitted. Chips that expose any buried metallization are not permitted.

8.3 *Burrs, Projections, and Blisters* — Must fit within outline limits.

8.3.1 *Top Plane* — excluding seal area — 0.102 mm (0.004"), maximum.

8.3.2 *Unmetallized Seal Area* — 0.0762 mm (0.003"), maximum.

8.3.3 *Metallized Seal Area* — 0.025 mm (0.001"), maximum.

8.3.4 *Bottom Surface* — 0.051 mm (0.002"), maximum.

8.3.5 *Edges* — 0.152 mm (0.006"), maximum.

8.3.6 *Terminal Pads* — 0.051 mm (0.002"), maximum.

8.3.7 *Wire Bond Fingers* — 0.025 mm (0.001"), maximum.

8.3.8 *Die Attach Surface Flatness* — 0.025 mm (0.001"), maximum.

8.4 *Camber* — .004 inch/inch (mm/mm), maximum. For dimensions less than 10.5 mm (0.750"), 0.127 mm (0.003") camber is permitted along any planar dimension of the device package.

8.5 *Seal Area Flatness* — The seal area shall be within the limits listed in Table 1.

8.6 *Die Attach Surface Flatness* — The die attach surface shall be flat within the limits listed in Table 2.

Table 1 Seal Ring Flatness Limits

Seal Ring O.D.	*Seal Ring Flatness*
0—6.35 mm (0–0.250")	0.051 mm max. (0.002")
6.37—12.7 mm (0.251"–0.500")	0.051 mm max. (0.002")
12.72—25.40 mm (0.501"–1.000")	0.101 mm max. (0.004")
25.40 mm (1.000")	0.101 mm/mm (0.004"/in.)

Table 2 Die Attach Area Flatness Limits

Die Attach Pad Dimension	*TIR Flatness*
0—12.7 mm (0—0.500")	0.051 mm max. (0.002")
12.72—19.5 mm (0.501"—0.750")	0.088 mm max. (0.0035")

8.7 *Voids*

8.7.1 *Seal Area Voids* — A maximum of 3 voids permitted. Not more than two voids per side of 0.010" diameter. Any two voids must be separated by 0.762 mm (0.030") minimum, not to degrade the seal width by more than 25%.

8.7.2 *Terminal Void* — A maximum of two voids per terminal pad permissible. Maximum void diameter acceptable is 0.254 mm (0.101). Voids may never reduce the minimum terminal width to less than 2/3 of the nominal design dimension.

8.7.3 *Wire Bond Finger Voids* — Void free 0.015" back from the bond finger tip.

8.7.4 *Die Attach Surface Voids* — Three voids of 0.010" diameter are the maximum allowed separated by 0.030" minimum.

NOTE — Voids 0.015" from the cavity wall not included.

8.7.5 *Internal Metallization Voids* — Voids in internal metallization planes or traces shall not break continuity. Specific requirements for resistance and capacitance parameters shall be specified in the purchase order, if applicable.

8.8 *Pattern Metallizations*

8.8.1 *Seal Plan Rundown (internal cavity)* — Not to exceed 25% of the cavity layer thickness.

8.8.2 *Seal Plan Rundown (external to cavity)* — Not to exceed half the nominal design distance to adjacent edge metallization. In no event shall the rundown be closer than 0.254 mm (0.010") to any edge metallization.

8.8.3 *Wire Bond Rundown* — Wire bond finger rundown shall not exceed 25% of the cavity depth or 0.005" (0.127 mm) whichever is smaller.

8.8.4 *Wire Bond Finger Pullback* — Wire bond finger pullback shall not exceed 0.127 mm (0.005") from the nominal design dimension for finger end to cavity edge.

8.8.5 *Seal Plane Pullback* — Seal plane pullback shall not exceed 0.127 mm (0.005") from the nominal design dimension for seal plane metallization to edge.

8.9 *Lead Attachment*

8.9.1 *Voids in Braze* — Braze fillets must be 95% free of voids, shall not cause voids under a lead.

8.9.2 *Lead Offset* — Lead centerlines must be aligned to within 0.127 mm (0.005") of the centerlines of corresponding braze pad metallizations. Side to side within 0.010".

8.9.3 *Lead-to-Lead Misalignment* — To exceed 10% of nominal spacing.

8.9.4 *Dimensional Criteria* — Per JEDEC JC-11 registered outline drawings in JEDEC Publication 95, or as specified on the user drawings.

9 Sampling

Sample size must meet requirements of MIL-STD-105 or MIL-M-38510 as agreed to between user and supplier.

10 Test Methods (Mechanical, Electrical, and Thermal)

10.1 *Gold Plating Thickness* — Shall conform to MIL-STD-45204. Gold thickness may be determined using the Beta Backscatter Radiation Method, X-Ray Fluorescence or by Cross Sectioning.

10.2 *Nickel Plating* — Shall conform to QQ-N-290. Nickel thickness may be determined using the Beta Backscatter Radiation Method, X-Ray Fluorescence, or by Cross Sectioning.

10.3 *Destructive Die Shear Testing* — Shall be performed per Method 2019 of MIL-STD-883.

10.4 *Wire Bond Pull Testing* — Shall be performed per Method 2011, Condition D of MIL-STD-883.

10.5 *Temperature Cycling Testing* — Shall be performed per Method 1010, Condition C of MIL-STD-883.

10.6 *Thermal Shock Testing* — Shall be performed per Method 1011, Condition C of MIL-STD-883.

10.7 *Constant Acceleration Testing* — Shall be performed per Method 2001, Condition E, Y axis only, of MIL-STD-883.

10.8 *Mechanical Shock Testing* — Shall be performed per Method 2002, Condition B of MIL-STD-883.

10.9 *Insulation Resistance Testing* — Shall be performed per Method 1003 of MIL-STD-883.

10.10 *Internal Water Vapor Content Testing* — Shall be performed per Method 1018 of MIL-STD-883.

10.11 *Hermeticity Testing* — Shall be performed per Method 1014, Condition A of MIL-STD-883. The hermetic integrity of the packaged device must be maintained after all testing.

10.12 *Lead Integrity Testing* — Shall be performed per Method 2004, Condition A, B1, and B2 of MIL-STD-883.

10.13 *Solderability Testing* — Shall be performed per Method 2003 of MIL-STD-883.

10.14 *Moisture Resistance Testing* — Shall be performed per Method 1004 of MIL-STD-883.

11 Packaging and Marking

11.1 *Packaging* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage and other forms of damage to the container or its contents. Container shall afford protection of the contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging material shall be so selected to prevent any contamination of the ceramic component parts with fibers or organic particles.

11.2 *Marking* — The outer containers shall be clearly marked identifying:

1. Supplier part number.
2. User part number.
3. Quantity.
4. Date of manufacture.
5. Supplier lot number.

12 Applicability

This specification is intended to apply to construction utilizing the tall brazed lead flatpack outlines included in JEDEC Publication 95.

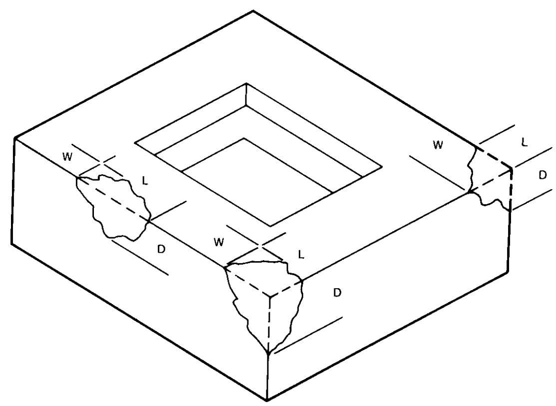

Figure 1
Chip Illustration

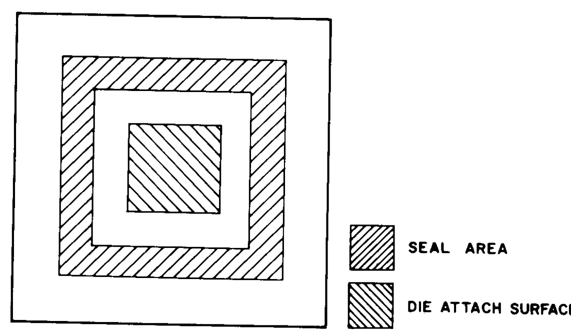

Figure 2
Die Attach Surface and Seal Area

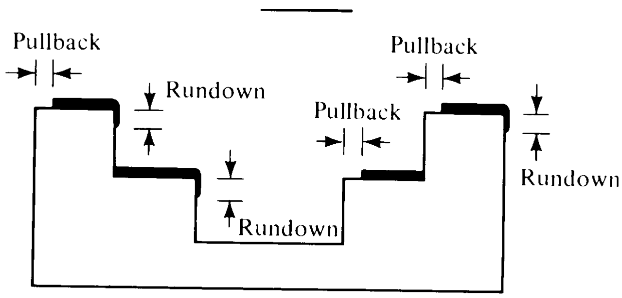

Figure 3
Metallization Misalignment

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G41-87
SPECIFICATION FOR DUAL STRIP SOIC LEADFRAME

1 Preface

This specification is a guideline for high volume production of leadframes, including internal package plating, for plastic molded S.O. semiconductor packages. It is a design guideline for packaging engineers, leadframe stampers and mold manufacturers and has been developed to meet the requirements of automated assembly.

2 Applicable Documents

2.1 *SEMI Specifications*

SEMI G4 — Integrated Circuit Leadframe Materials used in the Production of Stamped Leadframes

SEMI G10 — Mechanical Measurement for Plastic Package Leadframes

2.2 *Military Specifications*[1]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

3 Selected Definitions

burr — a fragment of excess material either horizontal or vertical attached to the leadframe.

camber — curvature of the leadframe strip edge (see Figure 1).

coil set — longitudinal bowing of the leadframe (see Figure 2).

coined area — that area at the tip end of the bond fingers coined to produce a flattened area for wire bond (see Figure 3).

crossbow — transverse bowing of the leadframe (see Figure 4).

functional area — the die attach pad and the lead tips.

lead twist — angular rotation of bonding fingers (see Figure 5).

pits — shallow surface depressions or craters in the leadframe material.

slug marks — random dents in the leadframe caused by foreign material in the stamping die.

stamped leadframe terminology — (See Figure 6.)

Z plane — lead and pad planarity require a reference in the Z dimension. The recommendation for the reference plane, hereafter called the Z plane, is the average of the two dambars when measured at their geometric center. This reference method is incorporated into SEMI G10.

4 Ordering Information

4.1 Purchase orders for leadframes for plastic molded S.O. packages furnished to this specification shall include the following items:

1. Part specification number and revision level
2. Material
3. Number of leads
4. Material certification
5. Packaging and marking (see Section 8)

5 Dimensions

See Table 1 and Figure 7.

6 Defect Limits and Parameters (See SEMI G10 for Measurement Methods)

6.1 *Internal Frame Area*

6.1.1 *Minimum Flat Wire Bonding Area* — 80% of nominal lead width and 0.381 mm (0.015") in length.

6.1.2 *Coin Depth*

6.1.2.1 0.20 mm (0.008") material: 0.013 mm (0.0005") minimum/0.02 mm (0.001") maximum.

6.1.2.2 0.25 mm (0.010") material: 0.013 mm (0.0005") minimum/0.05 mm (0.002") maximum.

NOTE: Maximum coin depth may also be constrained by minimum lead spacing requirement given in Section 6.1.3. Minimum coin depth may also be constrained by minimum bond area requirement given in Section 6.1.1.

6.1.3 *X-Y Plane Lead Spacing and Location*

6.1.3.1 Spacing between leads to be 0.152 mm (0.006") minimum.

6.1.3.2 Leads to be located so that a 0.007" diameter circle centered on the nominal center of the coined lead in width and 0.152 mm (0.006") back from lead tip in length shall be totally encompassed by the coined area.

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1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

6.1.4 *X-Y Plane Die Attach Pad Location* — Die attach pad to be located within ± 0.151 mm (0.002") as measured from the centerline of the reference hold in the side rail.

6.1.5 *Lead Twist* — Shall not exceed 330 or 0.015 mm (0.0006") per 0.254 mm (0.010") of lead width.

6.1.6 *Die Attach Pad Tilt and Flatness*

6.1.6.1 *Tilt* — 0.025 mm (0.001") maximum per 2.54 mm (0.100") in the undepressed state. 0.051 mm (0.002") maximum per 2.54 mm (0.100") in the depressed condition.

6.1.6.2 *Flatness* — 0.0005 mm (0.0002") when measuring from the center to the average of the four corners. The corners are defined at 0.127 mm (0.005") from each edge.

6.1.7 *Die Attach Pad Downset* — ± 0.051 mm (0.002") as measured from the center of the pad to a point on the bar support strip. The nominal downset recommended is 0.30 mm (0.012") for 0.25 mm (0.010") thick material and 0.20 mm (0.008") for 0.20 mm (0.008") thick material.

6.1.8 *Lead and Die Attach Pad Coplanarity*

6.1.8.1 *Coplanarity* — The relationship between the leads and die attach pad is the axis relationship of these parts to the Z plane.

6.1.8.2 *Lead Planarity* — The lead tips as measured in the center of the back, uncoined surface of the lead tip shall be located within the following tolerances of the Z plane: Lead Planarity: ± 0.004".

6.1.8.3 *Die Attach Pad Planarity* — The die attach pad when measured at the center must be within the following tolerances of the Z plane: Pad Planarity: ± 0.003"/-0.005".

6.2 *External Area and Strip*

6.2.1 *Material*

6.2.1.1 0.20 mm (0.008") material thickness recommended for 0.300" wide packages.

6.2.1.2 0.25 mm (0.010") material thickness recommended for 0.300" wide packages.

6.2.1.3 Nominal thickness tolerances shall be ± 0.008 mm (0.0003").

6.2.1.4 *Width Tolerance* — ± 0.051 mm (0.002").

6.2.2 *Coil Set* — Maximum of 3.175 mm (0.125") measured in a free standing state over strip length.

6.2.3 *Crossbow* — crossbow shall not exceed the following dimensions: Maximum Crossbow ± 0.127 mm (0.005").

6.2.4 *Camber* — Shall not exceed 0.05 mm (0.002") over a gauge length of 150 mm (6.00"). (See SEMI G10, Section 8).

6.2.5 *Progression* — The progression over strip length shall be within ± 0.051 mm (0.002") of nominal.

6.2.6 *Burrs* — Burrs shall be firmly attached and able to withstand a probe force of 10 grams. Vertical burrs inside the dambar shall not exceed 0.02 mm (0.001"). Vertical burrs outside the dambar and horizontal burrs in any location shall not exceed 0.05 mm (0.002").

6.2.7 *Pits and Slug Marks*

6.2.7.1 Within functional area and on external leads there shall be no slug marks. Pits shall not exceed .008 mm (0.0003") in depth and 0.013 mm (0.0005") in largest surface dimension in these areas.

APPLICATION NOTE: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

6.2.7.2 *Areas Other than 6.2.7.1* — Pits and imperfections shall not affect leadframe strength regardless of size and shall not exceed 0.05 mm (0.002") in depth and 0.07 mm (0.005") in largest surface dimension.

6.2.8 *Strip Cutoff Location* — Strip cutoff shall be within ± 0.05 mm (0.002") of basic strip length.

7 Sampling

Sampling will be determined between user and supplier.

8 Packaging and Marking

8.1 *Packaging* — Leadframes must be packed in containers designed and constructed to prevent damage and/or contamination. Specific protection must be provided against foreseeable mechanical and environmental hazards.

8.2 *Marking* — The outer containers shall be clearly marked, identifying the user stock number, user purchase order number, drawing number, and vendor lot number within the carton.

8.3

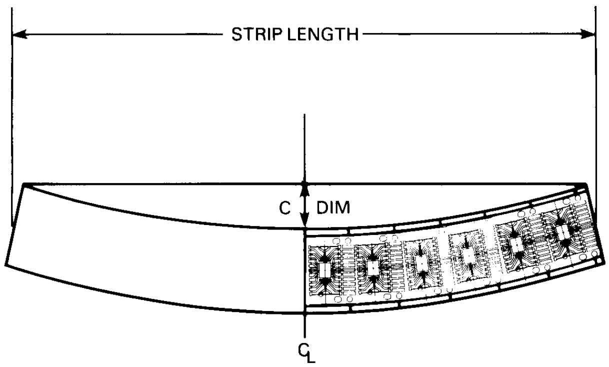


Figure 1
Camber

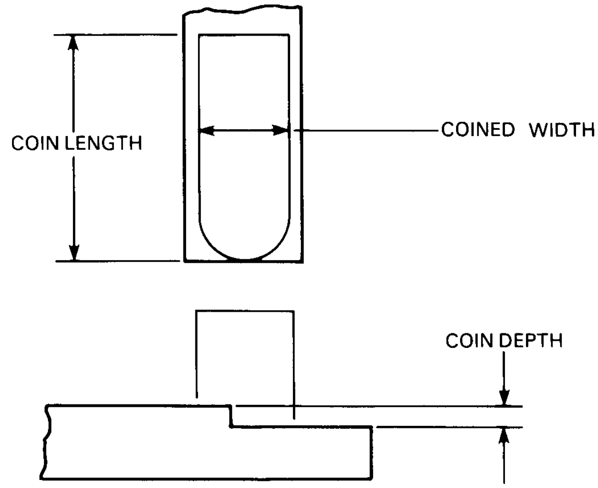


Figure 3
Coined Area

Downset

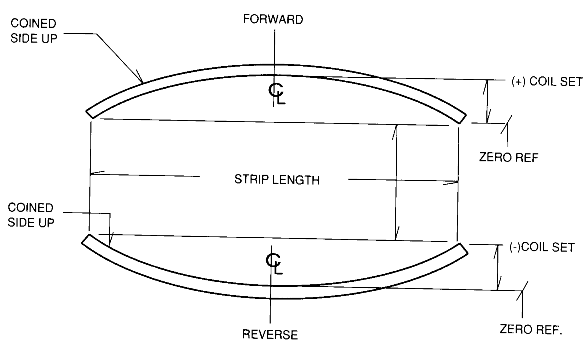


Figure 2
Coil Set

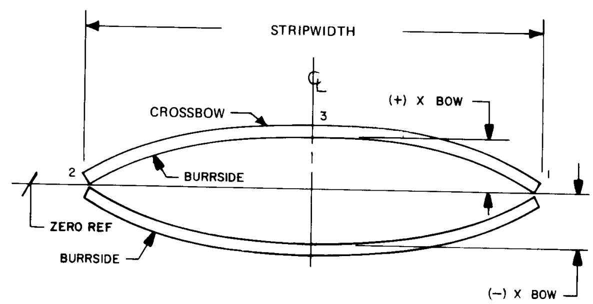


Figure 4
Crossbow

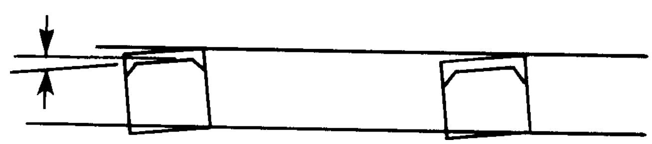


Figure 5

Lead Twist

Table 1 SOIC Dual Standard Dimensions

	0.150 WIDE (NARROW)			*0.300 WIDTH (WIDE)*					
	8	*14*	*16*	*14*	*16*	*18*	*20*	*24*	*28*
MATERIAL GAGE	0.008	0.008	0.008	0.010	0.010	0.010	0.010	0.010	0.010
STRIP WIDTH	0.600	1.030	1.030	1.030	1.030	1.240	1.240	1.470	1.670
PROGRESSION	0.316	0.316	0.316	0.530	0.530	0.530	0.530	0.530	0.530
TOOLING HOLE	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
DAMBAR WIDTH	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
DAMBARDIST ANCE	0.102	0.102	0.102	0.172	0.172	0.172	0.172	0.172	0.172
FROM PARTS PER STRIP	20	24	24						
STRIP LENGTH	6.32	7.584	7.584	7.42	7.42	7.42	7.42	7.42	7.42
PAD DOWNSET	0.008	0.008	0.008	0.012	0.012	0.012	0.012	0.012	0.012

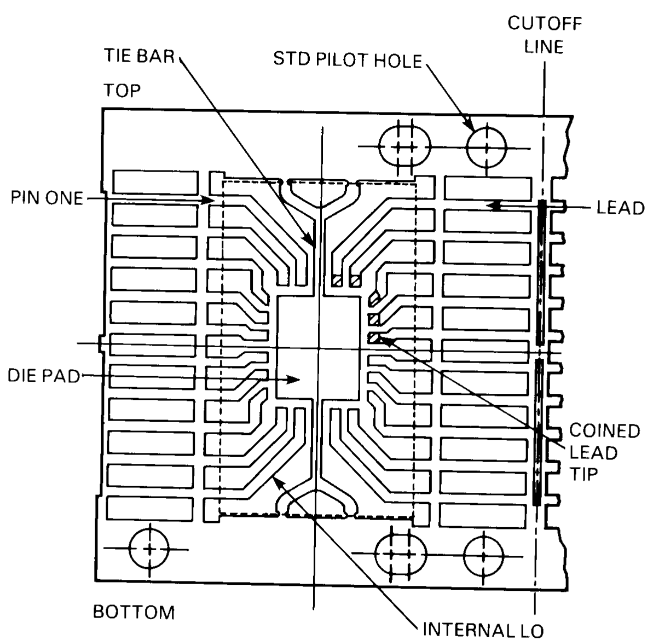
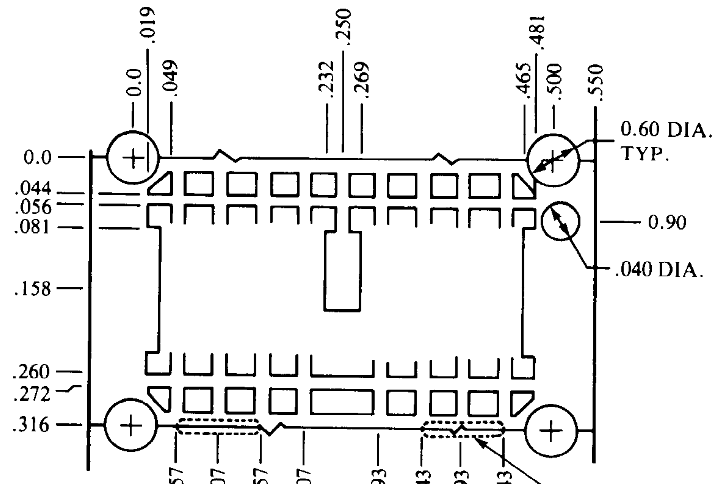


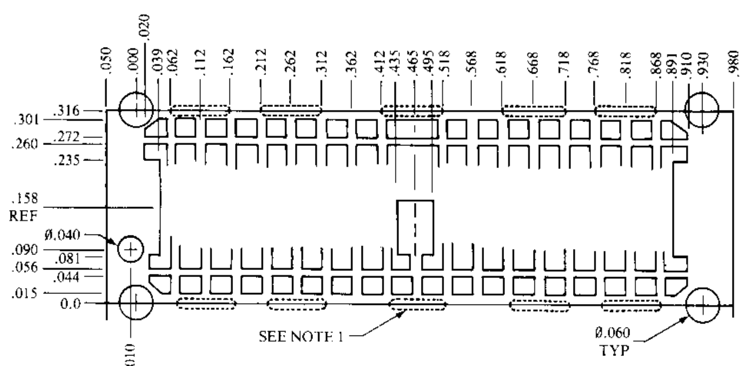
Figure 6
Stamped Leadframe Terminology



Note:

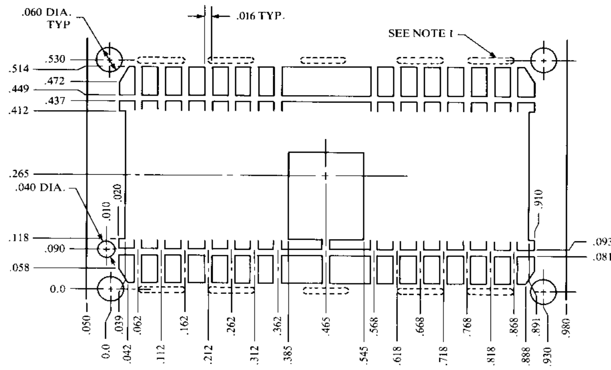
1. The oblong slots in frames, slot dimensions and locations are optional.

Figure 7
8 Lead Dual SOIC .150 (Narrow)



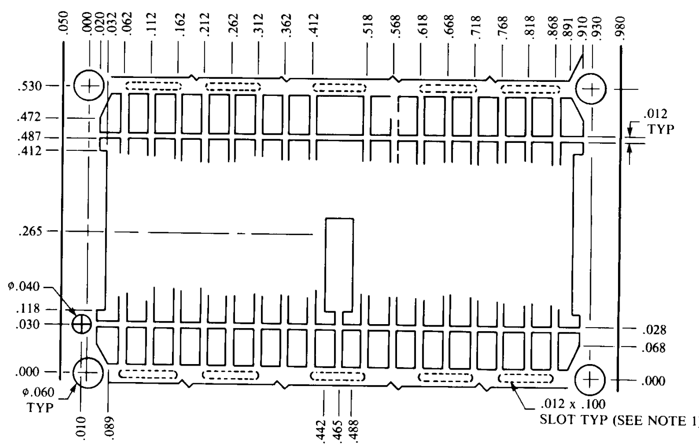
NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 8
16 Lead SOIC .150 (Narrow)



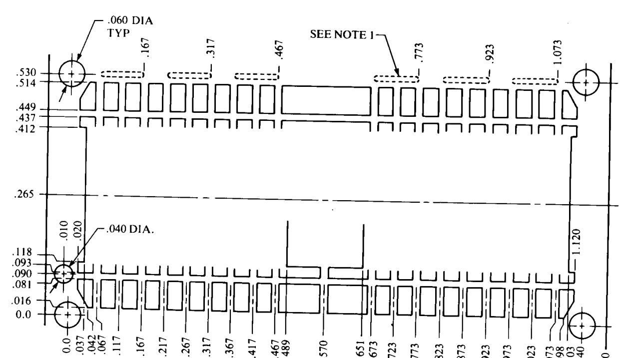
NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL.

Figure 9
14 Lead Dual SOIC .300 (Wide)



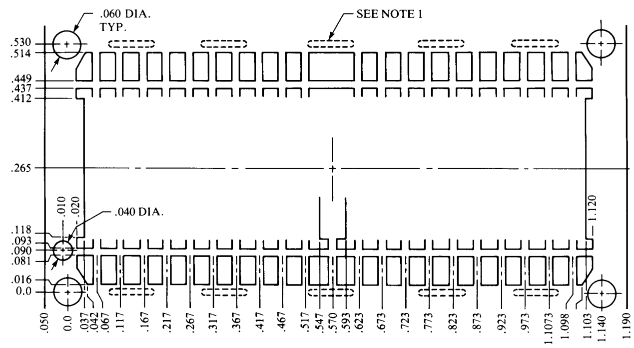
NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 10
16 Lead Dual SOIC .300 (Wide)



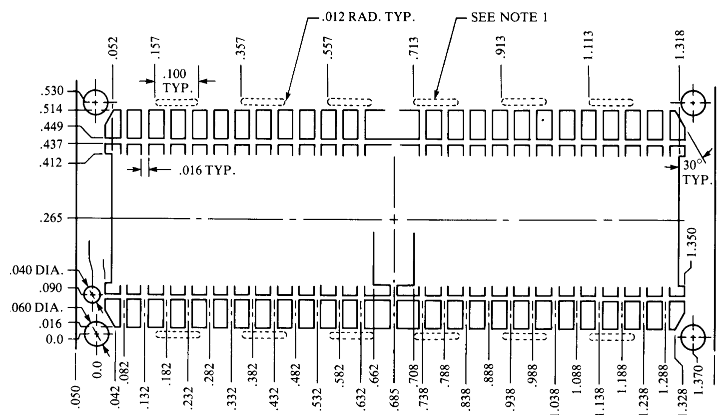
NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 11
18 Lead Dual SOIC .300 (Wide)



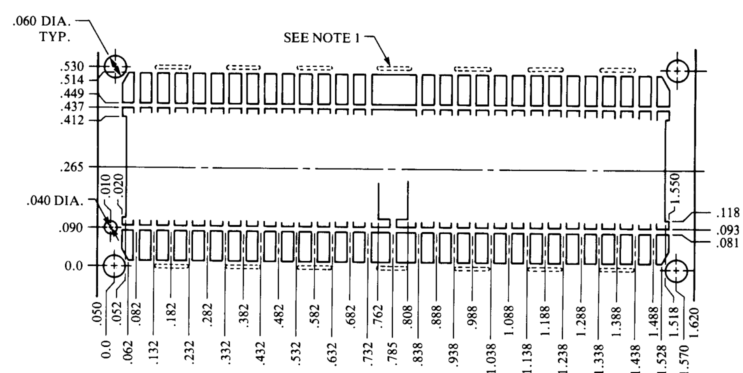
NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 12
20 Lead Dual SOIC .300 (Wide)



NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 13
24 Lead Dual SOIC .300 (Wide)



NOTE:
1. THE OBLONG SLOTS IN FRAMES, SLOT DIMENSIONS AND LOCATIONS ARE OPTIONAL

Figure 14
28 Lead Dual SOIC .300 (Wide)

SEMI G42-0996
SPECIFICATION FOR THERMAL TEST BOARD STANDARDIZATION FOR MEASURING JUNCTION-TO-AMBIENT THERMAL RESISTANCE OF SEMICONDUCTOR PACKAGES

NOTE: This entire document was revised in 1996.

1 Purpose

This document provides the requirements for a standard thermal resistance test board to be used in junction- to-ambient thermal resistance measurement of a semiconductor package under still- and forced-air condition as a referee method.

2 Scope

2.1 This document describes the thermal resistance test board for measurement of the following packages:

Dual-In-Line Packages (DIP)

Plastic Chip Carrier Package (PCC)

Quad Flat Package (QFP)

Pin Grid Array Package (PGA)

Ball Grid Array Package (BGA)

2.2 This document uses SI units.

3 Referenced Documents

Information regarding the methods for measuring junction-to-ambient thermal resistance, the proper design and use of thermal test chips, and material specifications for printed circuit boards, can be found in the applicable documents listed below.

3.1 *SEMI Specifications*

SEMI G32 — Guideline for Unencapsulated Thermal Test Chip

SEMI G38 — Test Method for Still- and Forced-Air Junction-to-Ambient Thermal Resistance Measurements of Integrated Circuit Packages

3.2 *Military Specifications*[1]

MIL-P-13949 — Material Specification for NEMA Grade G-10 Printed Circuit Board Material

MIL-STD-883C — Method 1012.1, Thermal Characteristics

4 Terminology

4.1 *junction temperature,* T_J — In degrees Celsius is used to denote the temperature of the semiconductor junction in the microcircuit in which the major part of the heat is generated. Usually the measured junction temperature is only indicative of the temperature in the immediate vicinity of the element used to sense the temperature.

4.2 *junction-to-ambient thermal resistance,* $R_{\theta JA}$ — In degrees Celsius/watt is the temperature difference between the junction and the ambient, divided by the power dissipation P_H.

4.3 *power dissipation,* P_H — In watts is the heating power applied to the device causing a junction-to-reference point temperature difference.

4.4 *temperature sensitive parameter, TSP* — Is the temperature dependent electrical characteristic of the junction under test which can be calibrated with respect to temperature and subsequently used to detect the junction temperature of interest.

5 Ordering Information

The material required for making the thermal test board can be ordered through any electronic supply store.

6 Requirements

General requirements regarding the materials used for test board, the specified physical dimensions of the test board and other necessary conditions are described in the following paragraphs:

6.1 *Material Requirements*

6.1.1 The test board material should be NEMA Grade G-10 or equivalent.

6.1.2 The conductor traces on the board must be copper and the total amount of copper should not exceed 20% of the surface area of the board.

6.1.3 The vias should be plated through.

6.1.4 External wire connections from the package leads to edge connector leads must be made with 24-gauge copper wire.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

6.2 *Thermal Test Board Physical Dimensions and Layout* — Five separate boards are designed for the purpose of thermal measurements of different types of semiconductor packages.

6.2.1 *Physical Dimensions*

6.2.1.1 *Length* — 114.3 mm ± 0.254 (4.50 inches ± 0.01)

6.2.1.2 *Width* — 76.2 mm ± 0.254 (3.00 inches ± 0.01)

6.2.1.3 *Thickness* — 1.524 – 1.651 mm ± 0.127 mm (0.060 – 0.065 inches ± 0.005 inches)

6.2.2 *Layout*

6.2.2.1 *Dual-in-Line Packages or Sockets (see Figure 1)*

a. The vias shall be located on 2.54 mm (0.10 inch) centers ± 0.076 mm (0.003 inches) non-accumulative.

b. The diameter of the vias shall be 1.143 mm (0.045 inches) ± 0.076 mm (0.003 inches).

c. The location of the vias on the board shall be as shown in Figure 1.

6.2.2.2 *Chip Carrier Packages (See Figure 2)*

a. The copper traces shall be laid out on the PC board as shown in Figure 2. The traces are drawn on 1.27 mm (0.050 inch) centers ± 0.127 mm (0.005 inch) non-accumulative.

b. The vias at the end of the copper traces shall be located on the 2.54 mm (0.10 inch) centers ± 0.076 mm (0.003 inch) non-accumulative.

6.2.2.3 *Quad Flat Packages (0.3, 0.4, 0.5, and 0.65 mm lead pitch) or sockets (see Figures 3 – 6)*

a. The copper traces shall be laid out on the PC board as shown in Figures 3 - 6. The traces are drawn in accordance with pitch and width as shown in Table 1.

Table 1 Trace Pitch and Width for QFP Package Boards

Package Lead Pitch (mm)	*Trace Pitch (mm)*	*Trace Width (mm)*
0.65	0.65 ± 0.05	0.35
0.5	0.5 ± 0.05	0.25
0.4	0.4 ± 0.04	0.2
0.3	0.3 ± 0.03	0.15

6.2.2.4 *Pin Grid Array Packages or Sockets (see Figure 7)*

a. The vias shall be located on 2.54 mm (0.10 inch) centers ± 0.076 mm (0.003 inches) non-accumulative.

b. The diameter of the copper lead shall be 1.2 mm ± 0.046 mm and the hole shall be 0.95 mm ± 0.046 mm.

c. The location of the vias on the board shall be as shown in Figure 7-1.

6.2.2.5 *Ball Grid Array Packages (1.5, 1.27, and 1.0 mm Ball Pitch) (see Figure 8)*

a. The copper traces shall be laid out on the PC board as shown in Figure 8-1. The traces and vias are drawn in accordance with configuration and dimension as shown in Table 2.

b. The board shall be covered by resist as shown in Figure 8-2. The back side of the board shall not be covered by resist.

Table 2 Trace Dimension for BGA Package Boards

Pad Pitch (mm)	*Trace Radius, R (mm)*	*Solder Mask Opening Diameter Ø1 (mm)*	*Hole Diameter Ø 2 (mm)*	*Number of Pads*
1.5	0.9	0.6	0.2	33 x 33
1.27	0.8	0.6	0.35	39 x 39
1.0	0.6	0.45	0.3	49 x 49

6.2.2.6 Equivalent boards for other packages should follow guidelines similar to those described in Sections 6.2.2.1 – 6.2.2.5.

6.2.2.7 *Multi-Layer Board* — When measuring thermal resistance using a multi-layer board, the layer shall be constructed as shown in Figure 9. The inner pattern should have the clearance as shown in Figure 10 to isolate with via holes.

6.3 *Mounting Guidelines*

6.3.1 Example of package mounting on the boards is shown in Figures 11 and 12. Packages should be mounted such that the center line of the test board is coincidental with the center line of the package.

6.3.2 For DIP and CCP, the longer edge of the package should be closest to the long edge of the board.

6.3.3 For QFP, PGA, and BGA package board, the package should be mounted in the center of the board.

6.3.4 Packages must be mounted such that the standoff height above the board is as per JEDEC guidelines. In the case of a new package without such information available, a minimum of 0.127 mm (5 mil) air gap between the bottom surface of the package and the thermal test board is acceptable.

6.4 *Mounting the Test Board for Still-Air $R_{\theta JA}$ Measurement*

6.4.1 The test board should be mounted on a clamp as shown in Figure 13 through a suitable edge connector clamp.

6.4.2 The test board and the edge connector clamp are placed in a 0.0283 m^3 (one cubic foot) enclosure as shown in Figure 13. The edge connector clamp height must be adjusted to ensure positioning of the package in the center of the chamber.

6.4.3 The electrical wire connections from the package are routed out of the one cubic foot enclosure either through an edge connector or through small diameter holes in the box.

6.5 *Mounting the Test Board for Forced-Air $R_{\theta JA}$ Measurement* — Forced air $R_{\theta JA}$ measurements are performed in a wind tunnel whose diameter is 203.2 mm (8.00 inches). Details of the wind tunnel are given in SEMI G38.

6.5.1 The test board should be mounted inside the wind tunnel on an edge connector clamp as shown in Figure 14.

6.5.2 The test board is placed in the wind tunnel such that the longer edge of the package is in a vertical position (see Figure 14).

6.5.3 The longer edge of the package should face the direction of air flow.

6.5.4 The longer side of the package must meet the air front first, as shown in Figure 14.

6.5.5 Air may be forced through the wind tunnel by either blowing from one end or by suction. (Suction being preferred.)

6.5.6 The test board and the edge connector clamp are placed in the wind tunnel as shown in Figure 14. The edge connector clamp height must be adjusted to ensure positioning of the package in the center of the wind tunnel.

6.6 *Thermal Resistance Measurement Methods* — Methods for measuring $R_{\theta JA}$ (Junction-to-Ambient Thermal Resistance) of IC packages using thermal test chips have been described in SEMI G32 and SEMI G38, respectively. These methods or equivalent methods such as the use of switching techniques, as described in MIL-STD-883C, Method 1021.1, should be used for making thermal resistance measurements of IC packages using thermal test chips or IC devices.

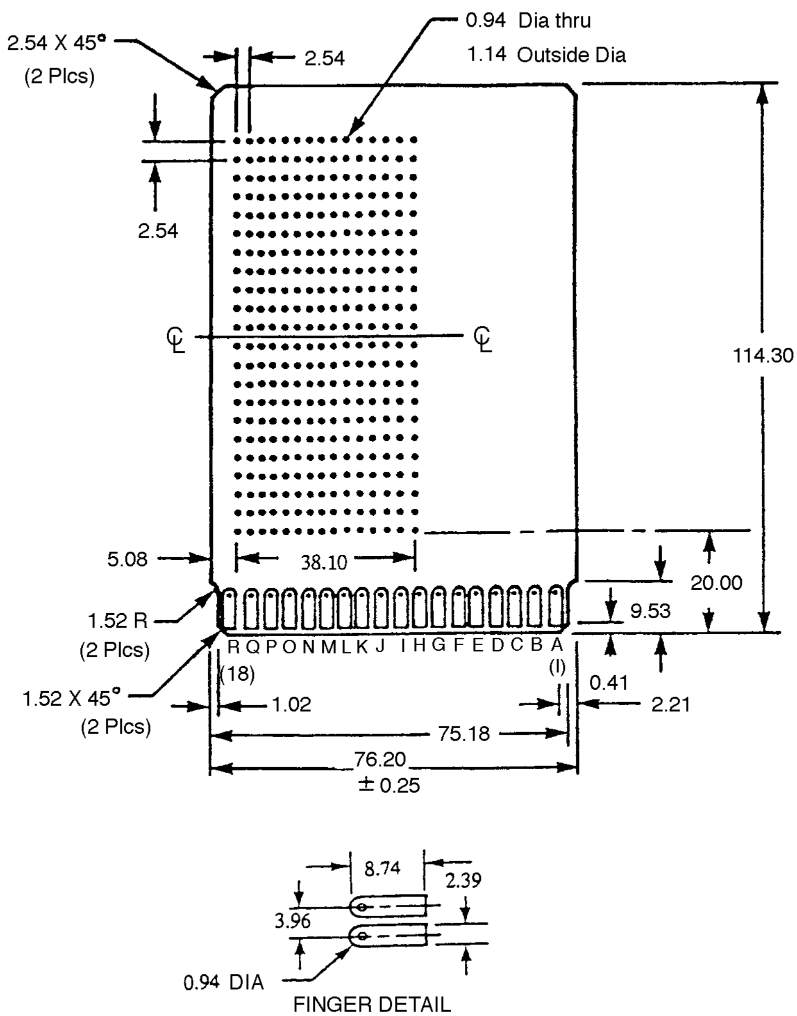


Figure 1
Thermal Test Board — Dual In-Line Package

(Unit: mm)

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

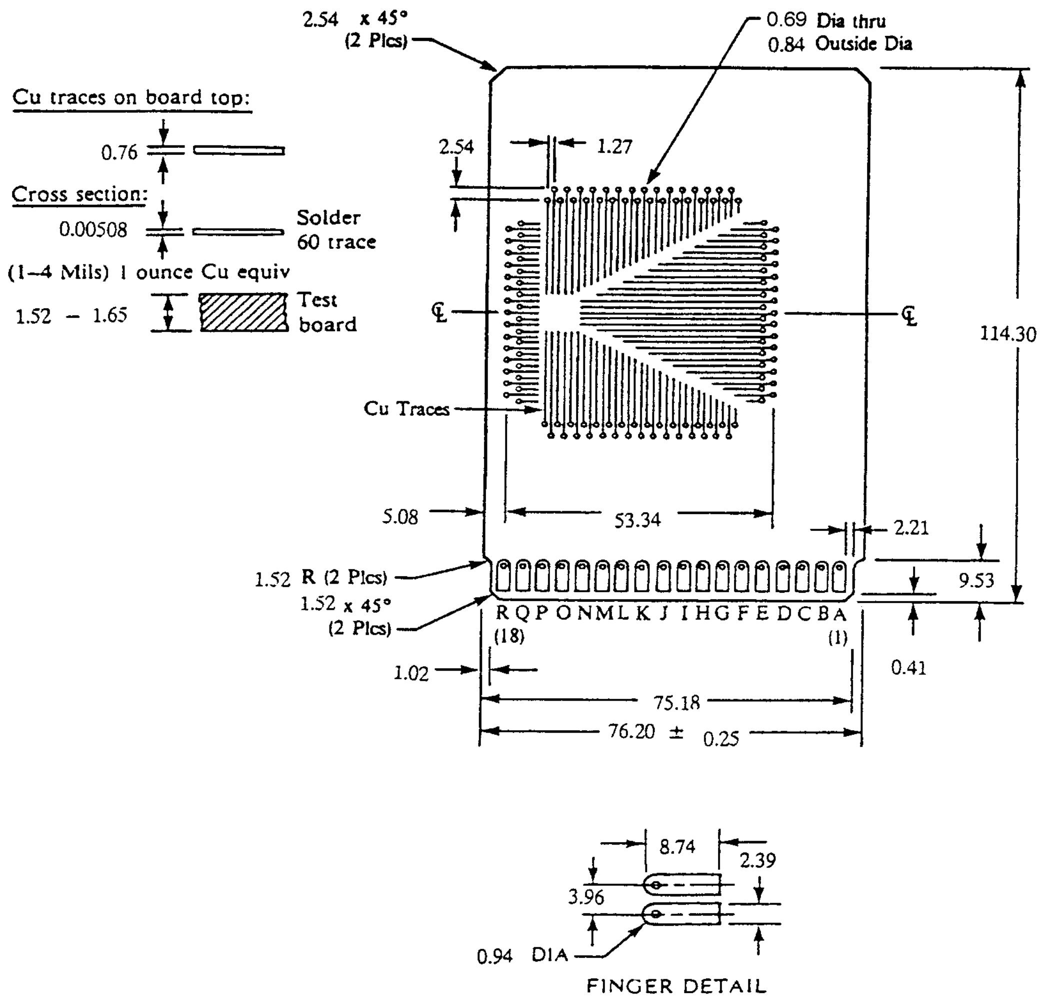


Figure 2
Thermal Test Board — PCC Packages

Unit: mm

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

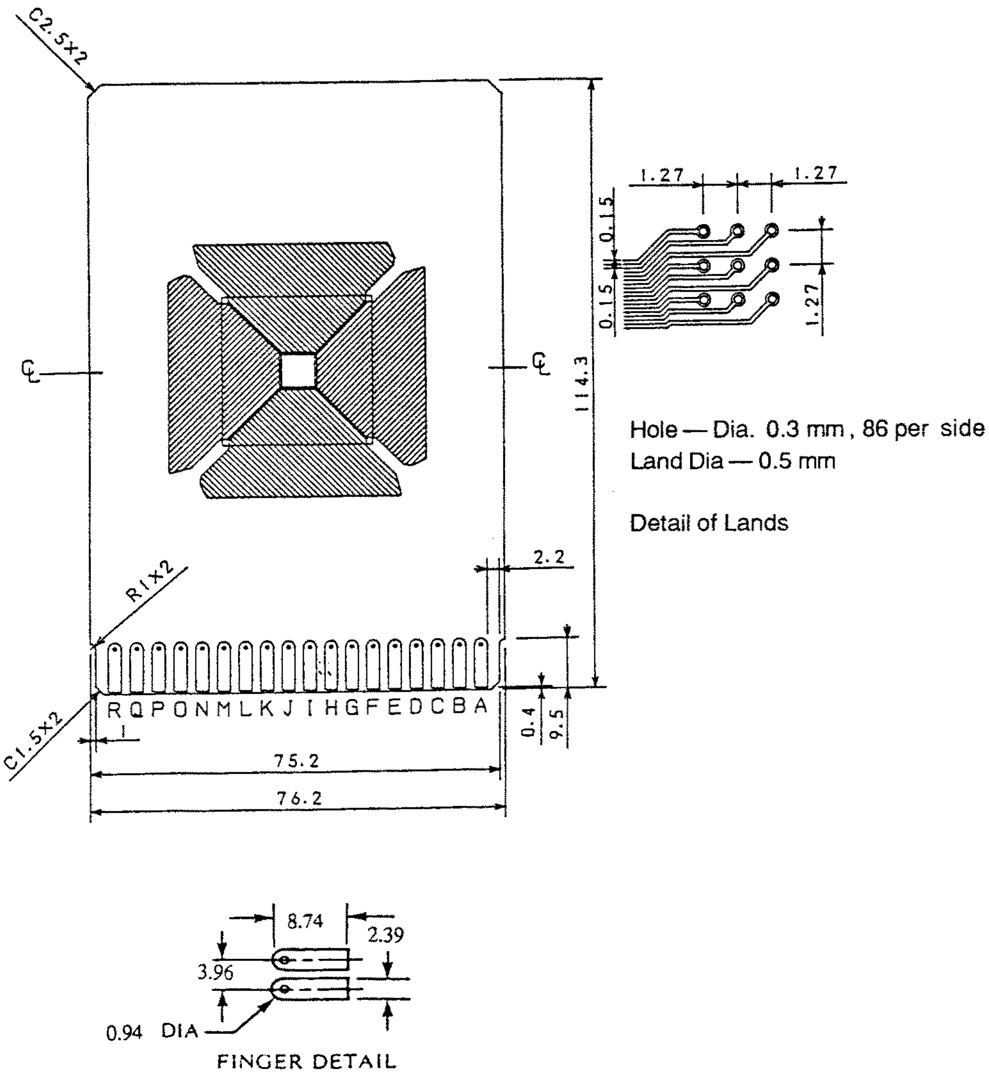


Figure 3
Thermal Test Board — 0.3 mm Pitch Quad Flat Package

Unit: mm

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

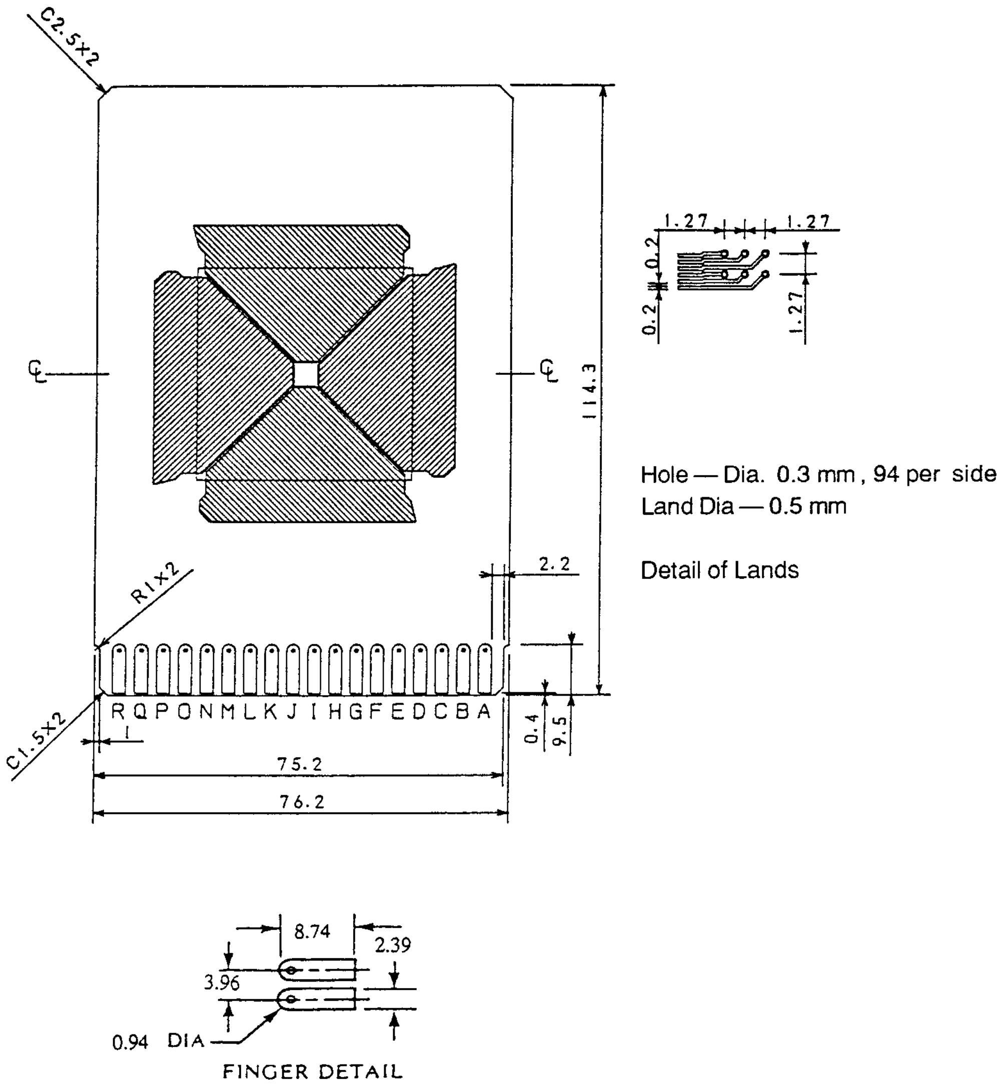


Figure 4
Thermal Test Board — 0.4 mm Pitch Quad Flat Package

Unit: mm

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

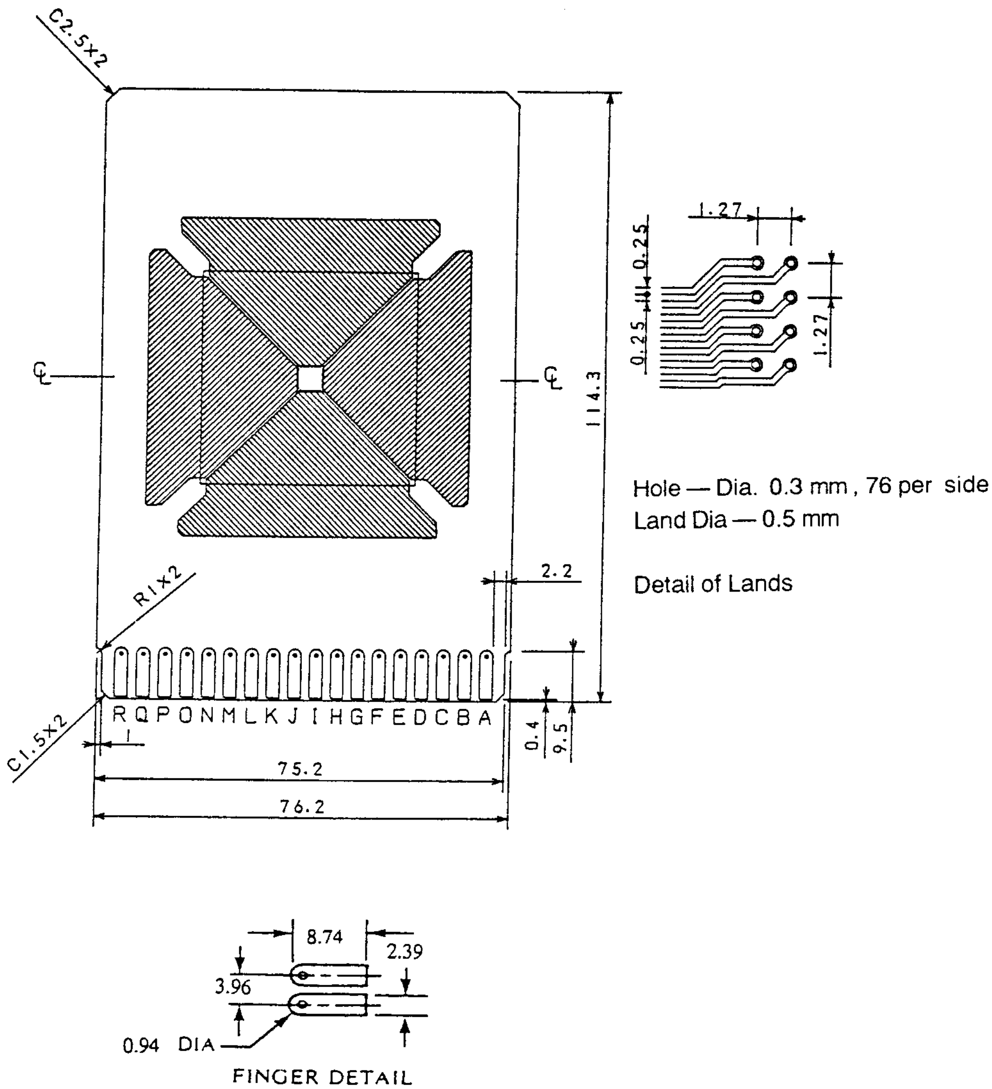


Figure 5
Thermal Test Board — 0.5 mm Pitch Quad Flat Package

Unit: mm

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

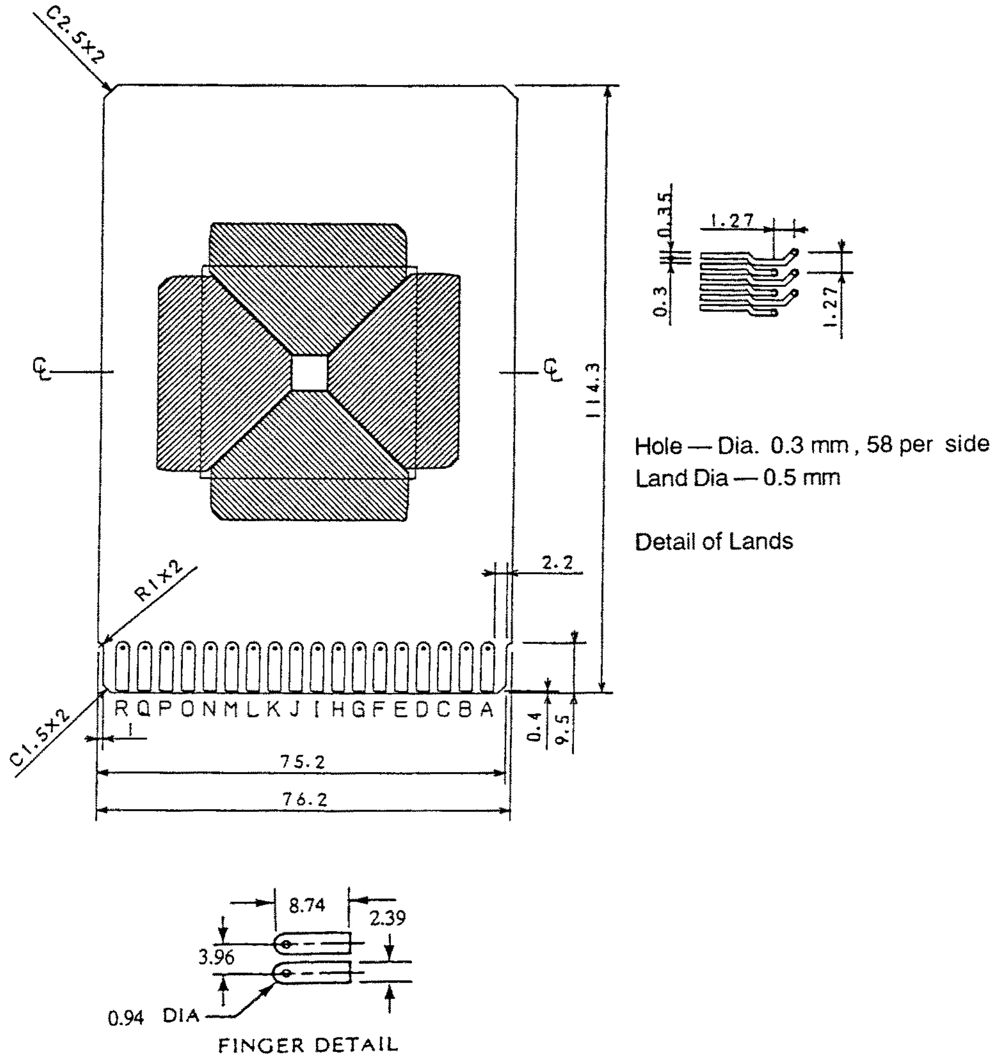


Figure 6
Thermal Test Board — 0.65 mm Pitch Quad Flat Package

Unit: mm

1. Material — Epoxy Glass 1.52–1.65 mm thickness, FR-4 (Green). Copper Clad. 28.3 g (1 Oz.) 1/1
2. Gold-Plated Fingers — 0.8 µm Min. Thickness, 18 on Each Side
3. Fabricate — IPC-D-320, Class III
4. Tolerance — ± 0.1 mm (Unless noted)
5. Fingers on Component Side of Board — Designed as A thru R, Fingers on Solder Side of Board — Designated as 1 thru 18 (with 18 at Right When Viewing Face of Board)
6. All Holes Plated Thru
7. Mates with Dale Connector Part Number EB 7D-A18GFX or Equivalent

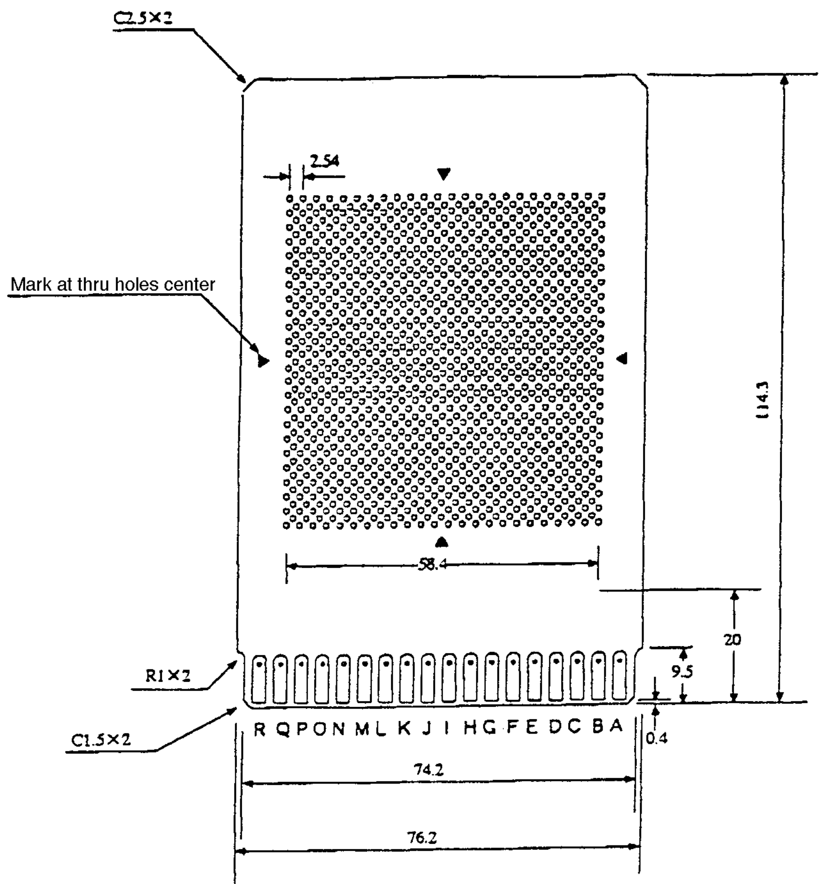


Fig. 7-1

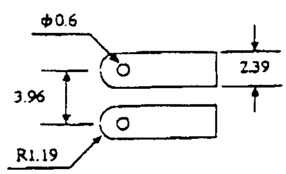


Fig. 7-2 Finger pattern

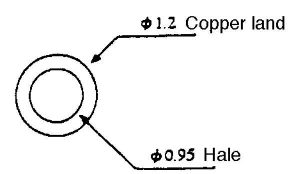


Fig. 7-3 Hole

Figure 7
Thermal Test Board — Pin Grid Array Package

Unit: mm

1. Material: Epoxy Glass 1.5 mm thickness, FR-4 (Green).
2. Gold Plated Fingers: 0.8 μm Min, 18 pad on Each side
3. Fabricate: IPC-D-320 Glass III
4. Tolerance: + 0.1 mm (Unless noted)

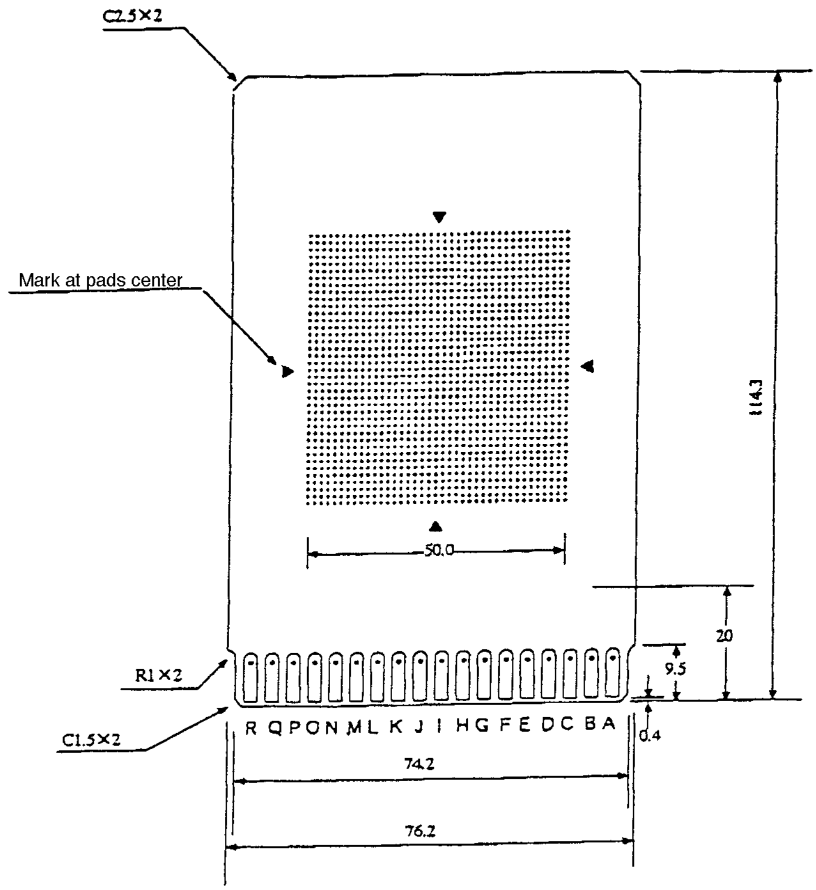


Fig. 8-1

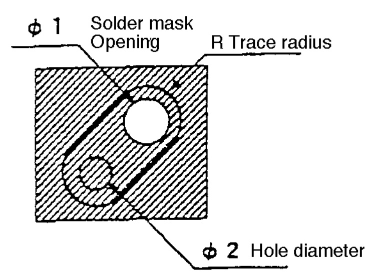


Fig. 8-2 Trace

Figure 8
Thermal Test Board — Ball Grid Array Package

Unit: mm

1. Material: Epoxy Glass 1.5 mm thickness, FR-4 (Green).
2. Gold Plated Fingers: 0.8 µm Min. 18 pad on Each side
3. Fabricate: IPC-D-320 Class III
4. Tolerance: ± 0.1 mm (Unless noted)

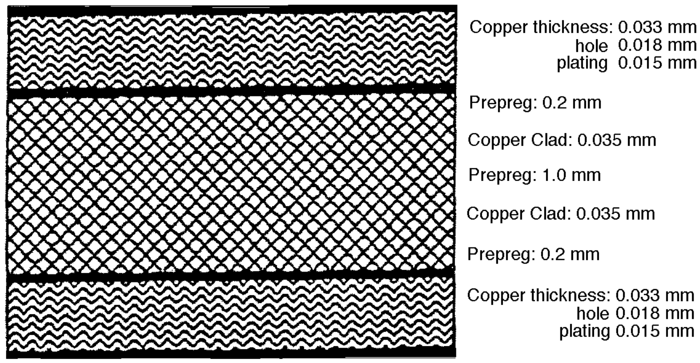


Figure 9
Multi-Layer Board Construction

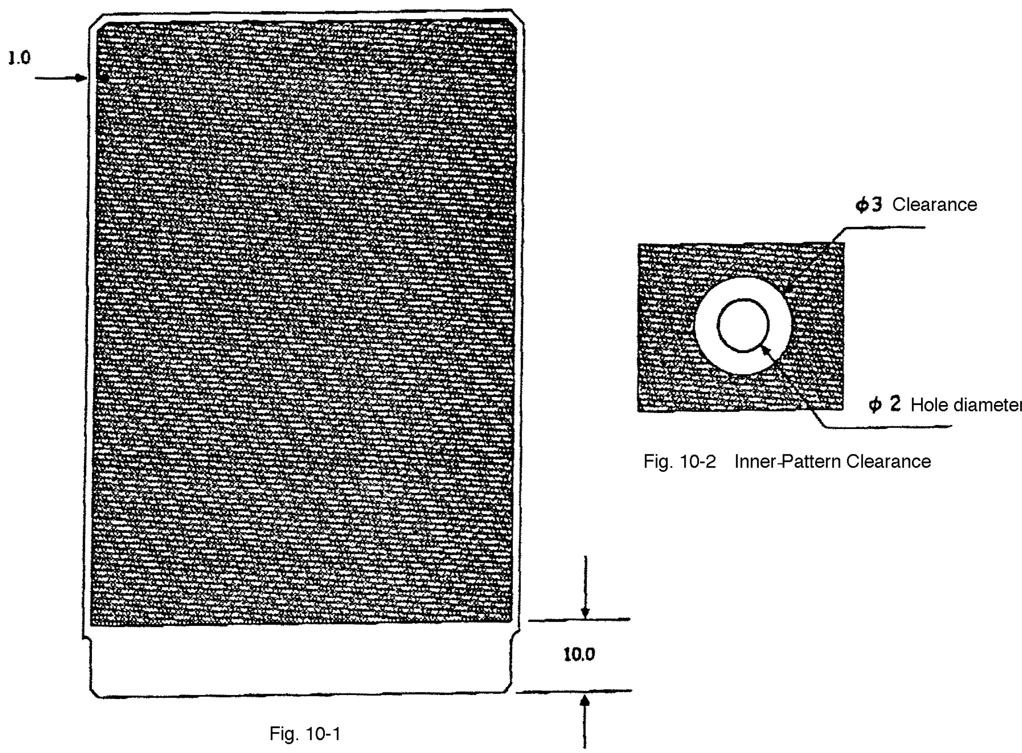


Figure 10
Inner Layer Pattern and Clearance for Multi-Layer Thermal Test Board

1. Material: Epoxy Glass 1.0 mm Isolation thickness, FR-4 (Green)
2. Inner Copper Clad thickness: 0.035 µm
3. Tolerance: ± 0.1 mm (Unless noted)

Table 3 Clearance Diameter

	Pitch (mm)	Hole Diameter Ø 2 (mm)	Clearance Diameter Ø 3 (mm)
BGA	1.5	0.4	1.2
	1.27	0.35	1.1
	1.0	0.3	0.9
PGA	2.54	0.95	1.7

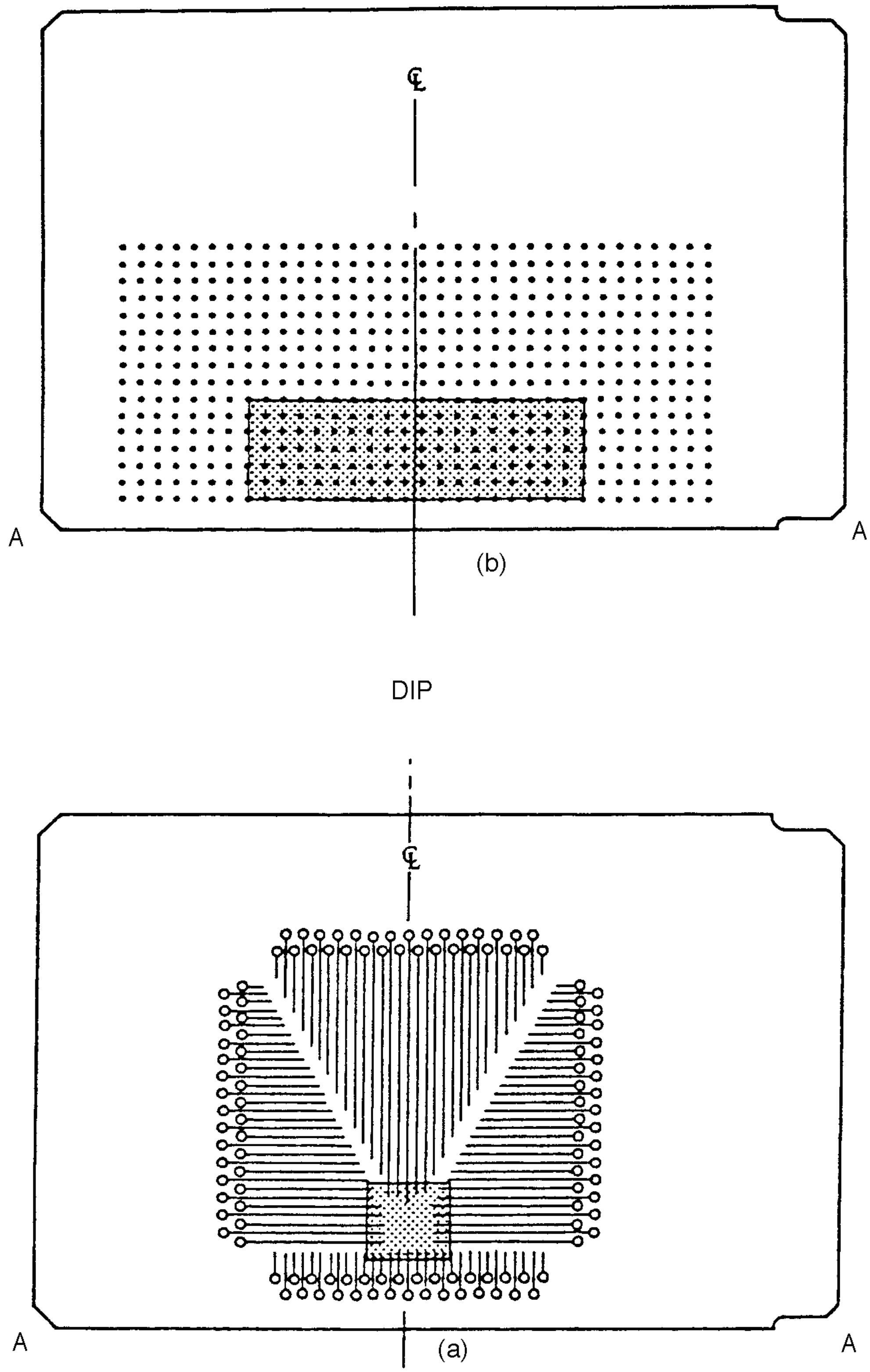


Figure 11
Location of Package While Mounting on Test Board

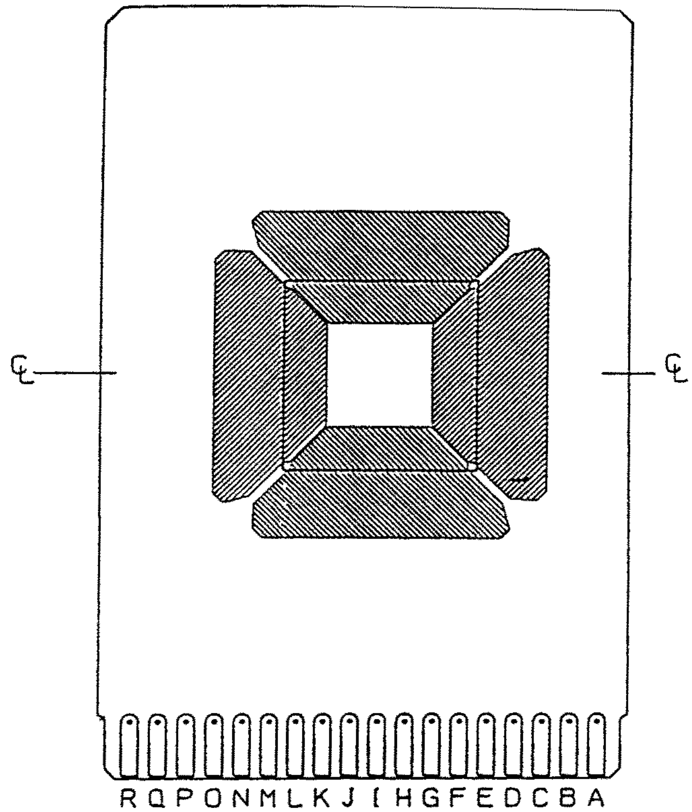


Figure 12
Location of Package While Mounting on Test Board (QFP)

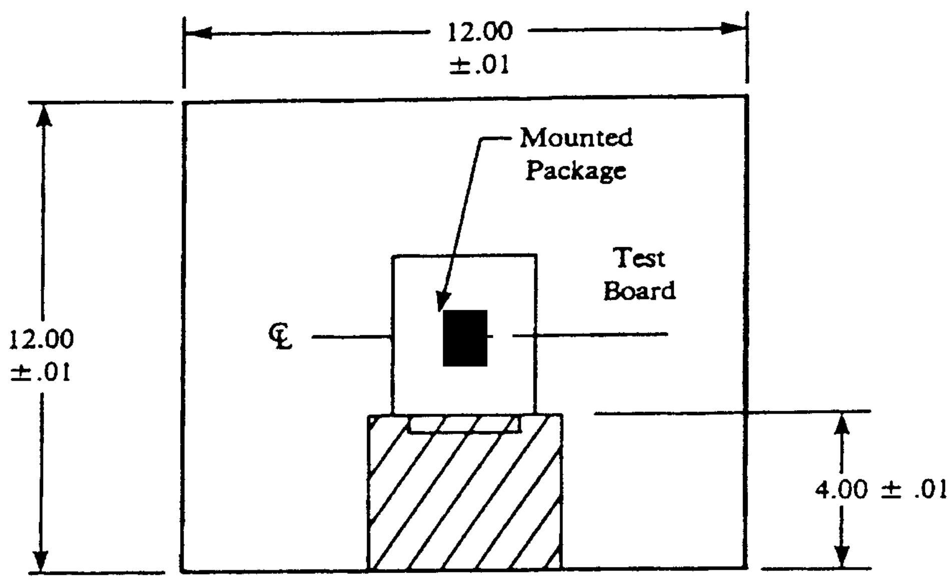


Figure 13
Test Board Positioning inside Measuring Chamber

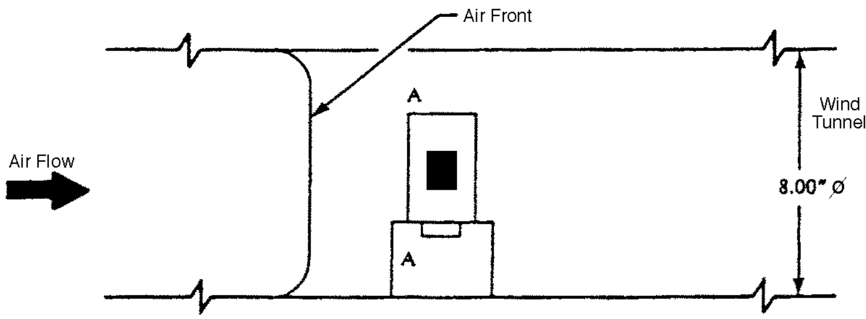


Figure 14
Test Board Orientation inside Wind Tunnel

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G43-87
TEST METHOD FOR JUNCTION-TO-CASE THERMAL RESISTANCE MEASUREMENTS OF MOLDED PLASTIC PACKAGES

1 Purpose

The purpose of this test is to determine the thermal resistance of molded plastic packages using thermal test chips. This test method deals only with junction-to-case measurements of thermal resistance and limits itself to fluid bath testing environments. For this test, conduction through the leads is minimized, thus providing information on the ability of the plastic package material to dissipate heat. Due to the thermophysical properties of the heat transfer fluids used and the effects of the variable nature of the fluid-stirring and package-mounting procedures, this test method should only be used for comparing the thermal characteristics of plastic packages in the same fluid bath system.

2 Applicable Documents

2.1 *SEMI Specification*

SEMI G32 — Guideline for Unencapsulated Thermal Test Chip

3 Definitions

The following definitions and symbols shall apply for the purpose of this test:

case temperature, T_C — in degrees Celsius. The case temperature is the temperature at a specified accessible reference point on the package in which the microelectronic chip is mounted.

junction temperature, T_J — in degrees Celsius. The term is used to denote the temperature of the semiconductor junction in the microcircuit in which the major part of the heat is generated. For purposes of this test, the measured junction temperature is only indicative of the temperature in the immediate vicinity of the element used to sense the temperature.

power dissipation, P_H — in watts, is the heating power applied to the device causing a junction-to-reference point temperature difference.

thermal resistance, junction to specified reference point, $R_{\theta JR}$ — in degrees Celsius/watt. The thermal resistance of the microcircuit is the temperature difference from the junction to some reference point on the package divided by the power dissipation P_H.

temperature-sensitive parameter, TSP — the temperature-dependent electrical characteristic of the junction under test which can be calibrated with respect to temperature and subsequently used to detect the junction temperature of interest.

4 Apparatus

The apparatus required for these tests shall include the following as applicable to the specified test procedures:

a. Thermocouple material shall be copper-constantan (type T) or equivalent, for the temperature range -100 to + 300°C. The wire size shall be no larger than AWG size 30. The junction of the thermocouple shall be welded to form a bead rather than soldered or twisted. The accuracy of the thermocouple and associated measuring system shall be ± 0.5°C.

b. Suitable electrical equipment as required to provide controlled levels of conditioning power and to make the specified measurements. The instrument used to electrically measure the temperature-sensitive parameter shall be capable of resolving a voltage change of 0.5 mV.

c. Controlled temperature chamber or fluid bath capable of maintaining the specified reference point temperature to within ± 0.5°C of the preset (measured) value. A typical temperature-controlled fluid bath assembly is presented for illustrative purposes only.

4.1 *Fluid Bath Assembly* — A typical temperature-controlled fluid bath for thermally characterizing the microelectronic device under test is shown in Figure 1. In this figure, the package is mounted in a fluid bath separate from the fluid circulator, although it can be immersed directly in an integrated fluid circulator/bath unit. The fluid in the bath should be continuously stirred or agitated to ensure the required temperature stability and uniformity. Since this working fluid is being used as an infinite heat-sink, the case-to-fluid (ambient) temperature difference at the case temperature reference point of interest should be minimized, i.e., ≤ 20°C. For case-to-fluid temperature differences > 20°C, accuracy and repeatability difficulties may occur due to a large variable temperature gradient in the fluid film boundary layer at the package-fluid interface. The case-to-fluid temperature difference can be minimized by increasing the fluid velocity and by decreasing the power density seen by the fluid.

The device under test should be mounted such that heat transfer to the fluid is not impeded. For leaded devices, the leads should be oriented in such a manner so as not to interfere with the heat transfer to the fluid and provide freedom to any thermal currents caused by the power dissipation within the package. The microcircuit package shall be mounted such that conduction cooling through the leads or test socket or both shall be small compared to the other cooling mechanisms. To minimize conduction through the leads, a special socket jig that connects No. 36 AWG wire to the device socket should be used.

The case temperature of the device under test should be measured with a thermocouple that is attached to the package/lead and should not be assumed to be at the fluid temperature. The working fluid should have a thermal conductivity at 25°C of at least 0.0006 W/cm°C. Working fluids such as inert fluorocarbon liquids and silicone oils are suitable as cooling media.

5 Procedure

5.1 *Direct Measurement of Reference Point Temperature,* $T_R = T_c$ — For the purpose of measuring a microelectronic device thermal resistance, the reference point temperature shall be measured at the package location of highest temperature which is accessible from outside the package. This reference point location is determined with the device operating in free air and with no external heat-sinking. In general, this reference point is found to be on the surface of the body of the package, or on a lead near the body, in the major path of heat flow from the chip heating surface to the ambient fluid. The package surface may be altered to facilitate this measurement provided that such alteration does not affect the original heat transfer paths and, hence, the thermal resistance, within the package by more than a few percent.

5.1.1 *Case Temperature,* T_c — The microelectronic device under test shall be mounted under specified conditions so that the case temperature can be held at the specified value. A thermocouple shall be attached on the surface of the device package directly under the chip (i.e., on the base plane of the package). A conducting epoxy may be used for this purpose. The thermocouple bead should be in direct mechanical contact with the package of the microelectronic device under test. Care should be taken to minimize exposure of the thermocouple bead to the high temperature gradient in the fluid film boundary layer at the package-fluid interface.

If it is found that attaching the thermocouple directly to the case is impractical, an alternate approach using a thermocouple welded to one side of a thin metal disk should be used. This can be accomplished by parallel gap welding the crossed thermocouple wires to one side of a 0.25 cm (0.094 in) diameter, 0.02 cm (0.008 in) thick beryllium-copper disk and then, with a thin layer of adhesive, bonding the other side of the disk to the case at the point of interest. The exposed thermocouple bead/wire on the disk shall be covered with epoxy or silicone rubber. The attached thermocouple should not unduly interfere with heat transfer to the fluid.

5.2 *Thermal Resistance, Junction-to-Specified Reference Point,* $R_{\theta JR}$

5.2.1 *General Considerations* — The thermal resistance of a semiconductor device is a measure of the ability of its carrier or package and mounting technique to provide for heat removal from the semiconductor junction. The thermal resistance of a microelectronic device can be calculated when the case temperature and power dissipation in the device and a measurement of the junction temperature are known.

When making the indicated measurements, the package shall be considered to have achieved thermal equilibrium when halving the time between the application of power and the taking of the reading causes no error in the indicated results within the required accuracy of measurement.

5.2.2 *Indirect Measurement of Junction Temperature for the Determination of* $R_{\theta JR}$ — The purpose of the test is to measure the thermal resistance of integrated circuits by using particular semiconductor elements on the chip to indicate the device junction temperature. In order to obtain a realistic estimate of the operating junction temperature, the whole chip in the package should be powered in order to provide the proper internal temperature distribution. During measurement of the junction temperature, the chip heating power (constant voltage source) shall remain constant while the junction calibration current remains stable. It is assumed that the calibration current will not be affected by the circuit operation during the application of heating power.

The temperature-sensitive device parameter is used as an indicator of an average (weighted) junction temperature of the semiconductor element for calculations of thermal resistance. The measured junction temperature is indicative of the temperature only in the immediate vicinity of the element used to sense the temperature.

The temperature-sensitive electrical parameters generally used to indirectly measure the junction temperature are the forward voltage of diodes and the emitter-base voltage of bipolar transistors. Other appropriate temperature-sensitive parameters may be used for indirectly measuring junction temperature for fabrication technologies that do not lend themselves to sensing the active junction voltages.

5.2.2.1 *Steady-State Technique for Measuring* T_J — The following symbols shall apply for the purpose of these measurements:

I_M — ring current in milliamperes.

V_{MH} — Value of temperature-sensitive parameters in millivolts, measured at I_M, and corresponding to the temperature of the junction heated by P_H.

T_{MC} — Calibration temperature in degrees Celsius, measured at the reference point.

V_{MC} — Value of temperature-sensitive parameter in millivolts, measured at I_M and specific value of T_{MC}.

The measurement of T_J using junction forward voltage as the TSP is made in the following manner:

Step 1 — Measurement of the temperature coefficient of the TSP (calibration).

The coefficient of the temperature-sensitive parameter is generated by measuring the TSP as a function of the reference point temperature, for a specified constant measuring current, I_M, by externally heating the device under test in an oven or in a fluid bath. The reference point temperature range used during calibration shall encompass the temperature range encountered in the power application test (see Step 2). The measuring current is generally chosen such that the TSP decreases linearly with increasing temperature over the range of interest and that negligible internal heating occurs in the silicon and metal traces. For determining the optimum TSP calibration or measuring current, V_{MC} vs. log I_M curves for two temperature levels that encompass the calibration temperature range of interest should be plotted. The optimum measuring current, I_M, is then selected such that it resides on the linear portion of the two V_{MC} vs. log I_M curves that were generated. A measuring current ranging from 0.05 to 5 mA is generally used, depending on the specifications and operating conditions of the device under test, for measuring the TSP. The value of the TSP temperature coefficient V_{MC}/T_{MC}, for the particular measuring current used in the test, is calculated from the calibration curve, V_{MC} vs. T_{MC}. At least three points should be used to generate the voltage vs. temperature curve for the determination of the TSP temperature coefficient.

Step 2 — Power application test.

The power application test is performed in two parts. For both portions of the test, the reference point temperature is held constant at a preset value. The first measurement to be made is that of the temperature-sensitive parameter, i.e., V_{MC}, under operating conditions with the measuring current, I_M, used during the calibration procedure. The microelectronic device under test shall then be operated with heating power (P_H) applied. The temperature-sensitive parameter, V_{MH}, shall be measured with constant measuring current, I_M, that was applied during the calibration procedure (see Step 1).

The heating power, P_H, shall be chosen such that the calculated junction-to-reference point temperature difference as measured at V_{MH} is $\geq$ 20°C. In accomplishing this, the device under test should not be operated at such a high heating power level that the on-chip temperature-sensing and heating circuitry is no longer electrically isolated. Care should also be taken not to exceed the design ratings of the package-interconnect system, as this may lead to an overestimation of the power being dissipated in the active area of the chip due to excessive power losses in the package leads and wire bonds. The values of V_{MH}, V_{MC}, and P_H are recorded during the power application test.

The following data shall be recorded for these test conditions:

a. Temperature-sensitive electrical parameters (V_F, V_{EB}, or other appropriate TSP).

b. Junction temperature, T_J, is calculated from the equation:

$$T_J = T_R + \left(V_{MH} - V_{MC}\right)\left|\frac{\Delta V_{MC}}{\Delta T_{MC}}\right|^{-1}$$

where $T_R = T_C$

c. Case temperature, T_C (including specific location).

d. Power dissipation, P_H.

e. Mounting arrangement (including method of thermocouple attachment and fluid temperature).

5.3 *Calculations of* $R_{\theta JR}$

5.3.1 *Calculations of Package Thermal Resistance* — The thermal resistance of a microelectronic device can be calculated when the junction temperature, T_J, has been measured in accordance with procedures outlined in Sections 5.1 and 5.2.

With the data recorded from each test, the thermal resistance shall be determined from:

$$R_{\Theta JR} = \frac{T_J - T_R}{P_{H(Package)}} \quad \text{junction-to-reference point}$$

where

$R_{\Theta JR} = R_{\Theta JA}$ and $T_R = T_A$.

6 Summary Report

The following details shall be specified as appropriate:

a. Description of package; including thermal test chip, location of case or chip carrier temperature measurement(s), and mounting arrangement.

b. Test condition(s), as applicable (see Section 5).

c. Test voltage(s), current(s), and power dissipation of test chip.

d. Recorded data for each test condition, as applicable.

e. Symbol(s) with subscript designation(s) of the thermal characteristics determined.

f. Accept or reject criteria.

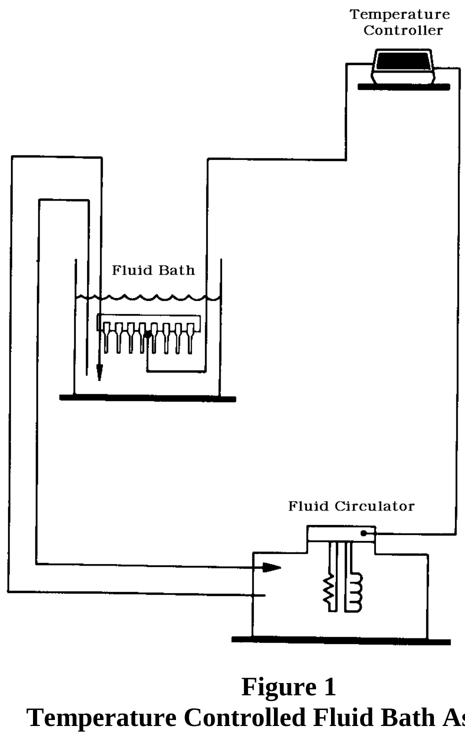

Figure 1
Temperature Controlled Fluid Bath Assembly

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SEMI G44-94
SPECIFICATION FOR LEAD FINISHES FOR GLASS TO METAL SEAL CERAMIC PACKAGES (ACTIVE DEVICES ONLY)

1 Preface

1.1 This specification defines lead finishes for glass to metal seal ceramic packages assembled with iron-nickel alloy leadframe construction. It defines composition, properties, limits, and refers to appropriate tests for utility.

1.2 *Scope* — The criteria detailed in this document applies to glass to metal seal ceramic packages, assembled with iron-nickel alloy leadframe construction, which conforms to composition limits specified in MIL-M-38510 as lead material Type A or Type B.

1.3 *Units* — U.S. Customary (inch-pound) or metric (SI) units may be used at the customer's discretion. This specification uses U.S. Customary units as the prime unit.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering packages shall be as follows:

Purchase Order
Customer Package Drawing
This Specification
Reference Documents
Related Documents

2.1.1 *SEMI Specifications*

SEMI G2 — Specification; Metallic Leadframes for Cer-DIP Packages

SEMI G35 — Specification; Test Methods for Lead Finishes on Semiconductor (Active Devices)

2.1.2 *ASTM Specifications*[1]

B 487 — Measuring Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section

B 545 — Standard Specification for Electro-deposited Coatings of Tin

B 567 — Measurement of Coating Thickness by the Beta Backscatter Principle

B 568 — Measurement for Coating Thickness by X-Ray Spectrometry

B 571 — Adhesion of Metallic Coatings

E 384 — Standard Test Methods for Micro-hardness of Materials

2.1.3 *Federal Specification*[2]

QQ-S-571 — Solder, Tin Alloy; Tin-Lead Alloy; and Lead (Pb) Alloy

2.2 *Military Specifications*[2]

MIL-T-10727 — Tin Plating; Electrodeposits or Hot Dipped, for Ferrous and Non-Ferrous Metals

MIL-G-45204 — Gold Plating, Electrodeposited

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-M-38510 — Microcircuits, General Specification

3 Terminology

blister — An enclosed localized separation of the plating from its base metal or an underplated layer that does not expose the underlying layer.

pit — A shallow depression or crater. The bottom of the depression must be visible.

solder — As used in this specification, refers to tin lead (Pb) as 63/37 or 60/40, unless otherwise specified and agreed upon between user and supplier and stated on procurement drawings.

4 Dimensions and Material

Composition limits, mechanical and physical properties, dimensions and tolerances for Cer-DIP leadframes are as stated in SEMI G2.

Table 1 lists recommended finishes for devices employing iron nickel alloy leadframe (MIL-M-38510 Lead Material Type A or Type B).

Gold plate is useable in socketed applications as well as in soldered applications. Hardness, grain size, and other properties shall be specified in the procurement drawing.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

5 Lead Finish Requirements

5.1 *Tin Electroplate*

5.1.1 *Composition* — The tin deposit shall not be less than 99.8% pure tin and shall not contain more than 0.05% pure carbon. The deposit is Type 1 as defined in MIL-T-10727.

5.1.2 *Characteristics* — The procedure used for evaluating the tin coating and the general requirements for the coating shall comply with ASTM B 545 or the latest current revision, except where noted below.

5.1.2.1 *Thickness* — The plated coating as measured on the major flat of the leads shall be a minimum of 300 microinches (7.5 micrometers).

5.1.2.2 *Appearance* — Surface appearance shall be smooth, fine grained, adherent and free from exposed basis metal or underplate, visible blisters, pits, nodules, porosity, indications of burning, excessive edge buildup and other detrimental defects.

5.1.2.3 *Hardness* — None specified.

5.1.2.4 *Preservation* — Preservation coating, if desired and agreed upon by user and supplier, is acceptable. (Example: Stearic acid solution in xylol as defined in MIL-T-10727.)

5.2 *Tin Lead (SnPb) Electroplate*

5.2.1 *Composition* — Major constituents shall be tin and lead (Pb) with minor impurities. Range of major constituents shall be:

Tin	50%-98%
Lead (Pb)	2%-50%
Nominal	60% Tin, 40% Lead (Pb)

NOTE: Users should be advised that many plating solutions containing lead (Pb) also contain acid fluorides. Such solutions will attack those glass materials commonly used in ceramic packages. Adequate process controls must be developed and used in conjunction with this plating process to ensure package and device integrity.

5.2.2 *Purity and Application* — Per MIL-M-38510.

5.2.3 *Thickness* — Shall be a minimum of 7.5 micrometers (300 microinches) as measured on the major flat of the leads.

5.2.4 *Appearance* — Surface appearance shall be smooth, fine-grained, adherent, and free from exposed basis metal or underplate, visible blisters, pits, nodules, porosity, indications of burning, excessive edge buildup and other detrimental defects.

5.2.5 *Hardness* — None specified.

5.3 *Tin/Lead (Pb) Solder-Dip*

5.3.1 Solder Pot Composition and Purity — Sn60 or Sn63, per QQ-S-571.

5.3.2 Thickness — Shall be a minimum of 5 micrometers (200 microinches) as measured on the major flat of the leads.

5.3.3 Process Conformance — Solder coating is applicable as shown in Table 1. In addition, the coating is acceptable as follows:

1. Over the electroplated tin or tin/lead as per Section 4.1 or 4.2.
2. Over the electroplated gold as per Section 4.4.

5.3.4 *Appearance* — Surface shall be smooth and continuous.

5.3.5 *Hardness* — None specified.

5.3.6 *Coverage* — Electroplated packages.

5.3.6.1 The solder dip shall extend up to and beyond the effective seating plane for Cer-DIPs.

5.3.6.2 The solder dip shall extend within .030" from glass seal for Cer-Packs.

5.3.7 *Coverage* — Non-coated packages.

5.3.7.1 When applied over the base metal, hot solder dip shall cover the entire lead to the glass seal or point of emergence of the lead or metallized contact through the package wall.

5.4 *Gold Electroplate*

5.4.1 *Composition* — Gold plating shall be applied in accordance with MIL-G-45204 in any and all of the following grades depending on application.

Type I	99.7% minimum
Type II	99.0% minimum
Type III	99.9% minimum

NOTE: Type II is suitable for socketing application only.

5.4.2 *Thickness* — Shall be 1.27–5.72 micrometers (50-225 microinches) as measured on the major flat of the leads per MIL-M-38510.

5.4.3 *Appearance* — Surface appearance shall be smooth, fine-grained, adherent and free from exposed basis metal or underplate, visible blisters, pits, nodules, porosity, indications of burning, excessive edge buildup, and other detrimental defects.

5.4.4 *Purity* — Composition limits are as specified in Section 4.4.1 above. Individual metallics in the deposit shall not exceed 0.1%. Metallic hardening agents, purposely added to adjust a plating bath to specified hardness are not considered as impurities.

5.4.5 *Hardness* — Depending on type and application, hardness is specified, using Knoop indenter in the following categories (testing is done as per ASTM E 384):

Type	*Grade*	*Hardness (Knoop)*
I	A	90 max
	B	91-129
	C	130-200
II	B	91-129
	C	130-200
	D	201 and over
III	A	90 max

5.5 *Reflowed Plated Tin or Plated Tin/Lead*

5.5.1 *Composition* — As per the plated finish, Section 4.1.2 or 4.2.1, as applicable.

5.5.2 *Characteristics* — As per 4.1.2 and 4.2, as applicable.

5.5.3 *Thickness* — The thickness of such reflowed coatings must be a minimum of 200 microinches measured on a significant surface.

5.5.4 *Appearance* — The appearance of reflowed coatings must be smooth and continuous.

Table 1 Recommended Finishes

Finish	*Mil Spec*	*Over Base Metal*	*Undercoating*			
			Ni	*Sn*	*SnPb*	*Au*
Tin	MIL-T-10727	X	X			
TinLead (SnPB)	MIL-M-38510	X	X			
Electroplate Solder	QQ-S-571	X	X	X	X	X
DIP(SnpB) Gold	MIL-G-45204	X	X*			

*Ni undercoat required by MIL-M-38510.

6 Test Methods

Tests for the lead finishes shall be in accordance with SEMI G35.

7 Sampling

The sampling plan, based on MIL-STD-105 shall be agreed between vendor and customer.

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SEMI G45-93
RECOMMENDED PRACTICE FOR FLASH CHARACTERISTICS OF THERMOSETTING MOLDING COMPOUNDS

1 Scope

This method describes a procedure for measuring the flashing characteristics of semiconductor grade transfer molding compounds.

2 Significance

2.1 The flashing tendency for semiconductor grade molding compounds depends on the interaction of several variables, including mold conditions, process parameters, molding compound viscosity, and curing characteristics. This test is not a valid method for predicting the flashing performance in all mold types. It is a method for comparing flash tendency and flashing type of different molding compounds when evaluated under a specific set of molding process parameters.

2.2 Flashing presents problems with subsequent processing of plastic packaged devices after molding. A high flashing tendency increases die wear in the trim and form operation, may interfere with plating or solder dip finishing operations, and may prevent good contact for electrical test. Thus, reduced tendency toward flashing will improve the plastic package subassembly operations. The information from this test will be of value in rating flash performance of any given compound to that in production use.

3 Apparatus

3.1 Transfer molding press with a platen area sufficient to maintain a uniform mold temperature and having (1) a transfer piston pressure potential of 1000 psi on the material; (2) sufficient clamping pressure to prevent flashing of the molding compound at clamping lands; and (3) a minimum plunger speed of 25.4 mm (1 inch) per second without load. The pot diameter shall be 31.75 to 44.45 ± 0.735 mm (1.250 to 1.750 ± 0.025 inch) and the clearance between pot and ram shall be sufficiently small that flashing does not occur above the first sealing groove on the ram.

3.2 *Standard Flash Test Mold* — Per Figure 1.

3.3 *Force Gauge* — With appropriate range to calibrate transfer pressure to minimum of 10.343 mpa (1,500 psi).

3.4 *Steel Rule* — Measured in 0.25 mm (0.010 in).

3.5 *Halo Lamp* — 3× magnification, minimum.

3.6 *Thermocouple and/or Pyrometer Calibrated* — In the 160°–190°C range (calibration to be checked every 6 months).

4 Test Conditions

4.1 *Molding Compounds* — Refrigerated shipment and storage of some molding compounds is necessary. The molding compound is to be at room temperature before the container is opened. Care must be taken to preserve the original moisture content. The material should be in powdered form, unless otherwise specified.

4.2 *Flash Test Mold* — Shall be clean and free from any mold release agents or lubricants. A standard mold cleaning compound can be used to insure mold cleanliness.

4.3 *Molding Conditions*

4.3.1 The temperature of the mold shall be measured using a thermocouple inserted in the mold or with a surface pyrometer. The ram shall be kept at the mold temperature. Molding temperature is to be 175°C unless otherwise specified. Temperature must be maintained within ± 3°C (± 5°F) of the specified temperature.

4.3.2 The transfer pressure for test, as measured under the transfer plunger, is to be 6.895 ± 0.177 mpa (1000 ± 25 psi) unless otherwise specified.

4.3.3 The weight of the charge shall be adjusted to give a molded cull thickness of 3.303 ± 0.254 mm (0.130 ± 0.010") excluding vertical flash.

4.3.4 The free running ram speed shall be at least 25.4 mm/sec (1"/sec). Recommended speed is 100 ± 25 mm/sec into the pot and application of pressure on the charge shall be maintained throughout the mold cycle.

4.3.5 Unless otherwise specified, a minimum of 1.5 minutes close and cure time shall be used.

4.3.6 Flash length shall be measured in 0.25 mm (0.010 in) intervals.

5 Procedure

5.1 Thoroughly clean the ram, pot, and mold of any cured compound, or other foreign matter.

5.2 Heat the mold and ram to within ± 3°C of the specified temperature.

5.3 At the beginning of each series of tests and at each change of compound, check and set the transfer pressure using the force gauge. The proper force gauge setting can be determined from the formula:

$$F = \frac{\Pi D^2 P}{4}$$

where F is the force in pounds, P is the desired pressure on the material in psi, and D is the ram diameter in inches.

5.4 For each material change, make at least three clean out runs using the material to be tested before recording data. These runs may be used to determine the charge weight.

5.5 Weigh out the compound to the nearest 0.1 g as previously determined to yield a cull of 3.302 ± 0.254 mm (0.130 ± 0.010 in).

5.6 Raise the ram, add the compound to the pot, and immediately activate the transfer cycle.

5.7 Remove cull and measure thickness. If the cull is not within 0.130 ± 0.010 in, discard the run and repeat the test, adjusting the charge weight as necessary.

5.8 Open mold and measure longest flash for each channel to nearest 0.25 mm (0.010 in) using 3× minimum magnification. Be sure to check both top and bottom plates of mold before measuring flash.

NOTE: Care must be taken to include the measurement of transparent and semi-transparent flash which may be present in the smaller channel. After measurements, diligence is required to remove all flash, including the transparent and semi-transparent varieties prior to the next test.

5.9 Repeat Steps 5.6 through 5.8 at least 3 times for repeatability.

6 Reporting of Results

6.1 Report the material designation and lot number.

6.2 Report the average and standard deviation of the flash length in each channel.

6.3 Report the temperature and pressure used for the tests.

NOTE: Common Errors/Problems:

- Inadequate preheat of flash mold and/or transfer plunger prior to test and between shots.
- Incorrect cull thickness.
- Omission of transparent or semi-transparent flash in measurement (often present in smallest two channels).
- Inadequate cleaning of mold between shots.
- Starting from the end of the ruler to make flash length measurements instead of starting at a known distance from the end.
- Inadequate mold break-in. Three shots should be run and disregarded before recording flash measurements for each material.
- Sprue, channel entry point, and mating mold surface wear may produce error in measurement and correlation problem. The impact of wear on results has not been determined. Extent of permissible mold wear requires agreement between testing organizations.

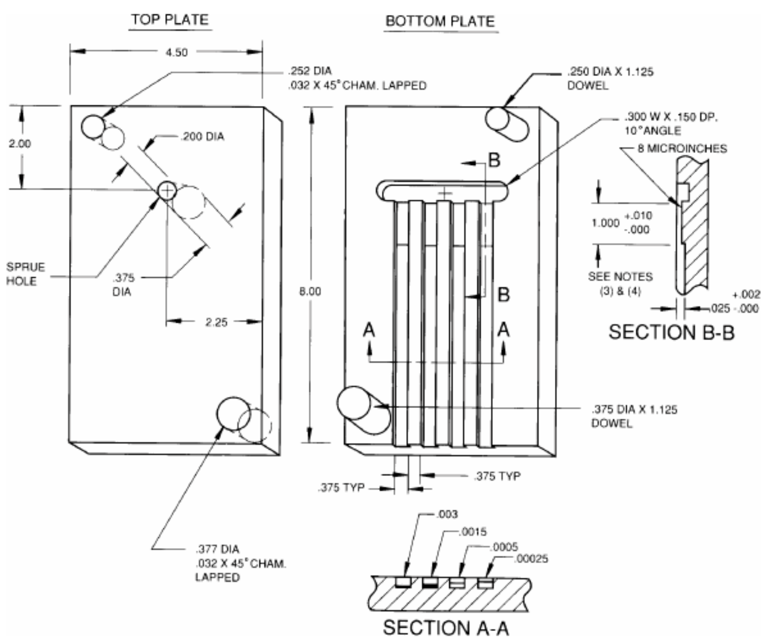


Figure 1
Flash Test Mold

1. Hand Mold, Polished, Very Well Mated Surfaces, Base Plates 0.75 thk.
2. Mold: Common Runner Feeds Flash Channels of 0.003, 0.0015, 0.0005, and 0.00025 inches by 0.375 wide ± 0.00025.
3. Mold Flash Channels: Surface Finish 8 microinches
4. Mold Flash Channels Depth Tolerance:
   a. ± 0.00005" for 0.00025 and 0.0005: Channels
   b. ± 0.0002" for 0.0015 and 0.003 Channels

AUXILIARY INFORMATION

Conversions Inches	*Conversions Millimeters*
8.000	203.20
4.500	114.30
2.250	57.15
2.000	50.80
1.125	28.58
1.000	25.40
0.377	9.58
0.375	9.53
0.300	7.62
0.252	6.40
0.250	6.35

SEMI G46-88

TEST METHOD FOR THERMAL TRANSIENT TESTING FOR DIE ATTACHMENT EVALUATION OF INTEGRATED CIRCUITS

1 Introduction

1.1 *Purpose* — Evaluation of semiconductor die attachment integrity using the thermal transient techniques as implemented by the Electrical Test Method on either thermal test chips or active devices.

1.2 *Rationale* — Steady state thermal response (or thermal resistance) and thermal transient response of discrete semiconductor devices and integrated circuits are sensitive to the presence of voids in the die attachment material between the semiconductor chip and package. These voids impede the flow of heat from the chip to the substrate (package). Due to the difference in the thermal time constants of the chip and package, the measurement of transient thermal response can be made more sensitive to the presence of voids than can the measurement of steady state thermal response. This is because the chip thermal time constant is generally several orders of magnitude shorter than that of the package. Thus, the heating power pulse width can be selected so that only the chip and the chip to substrate interface are heated during the pulse by using a pulse width somewhat greater than the chip thermal time constant, but less than that of the substrate. Heating power pulse widths ranging from 10 to 400 milliseconds have been found to satisfy this criterion. This enables the detection of voids to be greatly enhanced, with the added advantage of not having to heat sink the device under test. Thus, the transient thermal response technique is less time consuming than the measurement of thermal resistance for use as a manufacturing screen, process control or incoming inspection measure for die attachment integrity evaluation.

1.3 *References* — The following documents are recommended reading for reference and test method standard description purposes:

SEMI G32 — Unencapsulated Thermal Test Chip

MIL-STD-883C[1] — Method 1012, Thermal Characteristics

2 Definitions

The following symbols and terminology shall apply for the purpose of this test method.

2.1 V_F — the forward biased voltage of the diode junction within the Device-Under-Test (DUT) used for junction temperature sensing.

2.2 V_{Fi} — the initial V_F value before application of heating power.

2.3 V_{Ff} — the final V_F value after application of heating power.

2.4 ΔV_F — the change in the temperature sensitive parameter, V_F, due to the application of heating power to the DUT.

2.5 V_H — the voltage applied to the DUT during the heating time in order to cause power dissipation.

2.6 I_H — the heating current resulting from the application of V_H to the DUT.

2.7 P_H — the heating power pulse magnitude; product of V_H and I_H.

2.8 t_H — the duration of P_H (applied to the DUT).

2.9 I_M — the measurement current used to forward bias the temperature sensing diode junction for measurement of V_F.

2.10 t_{MD} — measurement delay time can be defined in one of two ways:

2.10.1 the time from the start of heating power (P_H) removal to the completion of the final V_F measurement; or

2.10.2 the time from the start of heating power (P_H) removal to the start of the final V_F measurement time, referred to as t_{SW}.

2.11 t_{SW} — sample window time during which final VF measurement is made; applicable only if t_{MD} definition 2.10.2 is used.

2.12 *K* — the temperature-sensitive parameter temperature coefficient measured at IM in °C per millivolt.

2.13 *CU* — the comparison unit consisting of ΔV_F divided by I_H, that is used to normalize the transient thermal response for variations in power dissipation; in units of mV/A.

2.14 T_J — the device-under-test junction temperature.

2.15 ΔT_J — the change in T_J caused by the application of P_H for a time equal to t_H.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

2.16 σ_Δ — the standard deviation if the ΔV_F results for a given test condition.

2.17 σ_{CU} — the standard deviation of the CU results for a given test condition.

3 Test Operation

The following paragraphs describe in conceptual detail the operation of the test for integrated circuit thermal response.

3.1 *Set-Up* — Shown in Figure 1 is the set-up required for testing either active devices or thermal test chips. Figure 1a is used for those cases in which the TSP is the junction isolation diode forward biased voltage. Thermal test chips and test IC's for which the junction isolation diode is either not available, or desirable for temperature sensing, can be handled by the set-up shown in Figure 1b.

3.2 *Apparatus* — To implement either version of Figure 1 requires the following apparatus:

3.2.1 A constant voltage source capable of adjustment to the desired value of V_H and able to supply the I_H value drawn by the DUT.

3.2.2 A constant current source to supply I_M with sufficient voltage compliance to turn the TSP junction fully on.

3.2.3 An electronic switch capable of switching between the heating period conditions and measurement conditions in a time frame short enough to avoid DUT cooling during the transition; this typically requires switching in the microsecond range.

3.2.4 A voltage measurement circuit capable of accurately making the V_H measurement within the t_{MD} (or t_{MD} plus t_{SW}, depending on the definitions stated previously) time frame with millivolt resolution.

3.3 *Operation and Waveforms* — The test begins with the adjustment of I_M and V_H to the desired values. Then with the electronic switch in position 1, the value of V_F is measured. The switch is then moved to position 2 for a length of time equal to t_H and the value of I_H is measured. Finally, at the conclusion of t_H, the switch is again moved to position 1 and the V_F value is measured within a time period defined by t_{MD} (or t_{MD} plus t_{SW}, depending on the definitions stated previously). The voltage and current sources are then turned off at the completion of the test.

The voltage and current waveforms for the two versions of Figure 1 are shown in Figure 2.

4 Test Procedure

The procedures below describe how to set up the test conditions and determine the acceptance limits for implementing the transient thermal test for die attachment evaluation using the apparatus and definitions stated above.

4.1 *Initial Device Testing Procedure* — The following steps describe in detail how to set up the apparatus described previously for proper testing of various integrated circuit devices.

Step 1 — From a 10 to 15 piece sample of the integrated circuits to be tested, pick any one device to start the set-up process. Set up the test apparatus as follows:

V_H = 5.0 V (Or some other desired value near the device under tests (DUT's) normal operating voltage.)

t_H = 200 ms

t_{MD} = 15 us

I_M = 1.0 mA (Or some other value appropriate for the specific device under test; typically in the range of 80 uA to 9.9 mA.)

Step 2 — Insert device into the apparatus test fixture and initiate a test.

(For best results, a test fixture that offers some form of heat sinking would be desirable.)

Step 3 — If ΔV_F is in the 20 to 40 mV range, then proceed to the next step. This range corresponds to a junction temperature change of roughly 10°C to 20°C and is sufficient for initial comparison purposes.

If ΔV_F is less than 20 mV, return to Step 1 and increase heating power into device by increasing V_H, or by reconfiguring the DUT connections for greater power dissipation, or a combination of both.

If ΔV_F is greater than 80 mV, corresponding to a junction temperature change greater than 40°C, it would probably be desirable to reduce the heating power by returning to Step 1 and reducing V_H, or by reconfiguring the DUT connections to reduce power dissipation, or a combination of the two. Reducing V_H is the preferable approach.

Because two different devices can show the same rise in junction temperature, even if the value of P_H is different, a comparison of the devices is best accomplished using the CU value. As defined in Section 2 above, CU provides a comparison unit that takes into account different device I_H values for a given V_H test condition.

Step 4 — Test each of the sample devices and record the ΔV_F and CU data as shown in Figure 3.

Step 5 — Select out the devices with the highest and lowest values of CU and put the remaining devices aside.

The ΔV_F values can be used instead of CU if the measured values of I_H are very tightly grouped aroung the average value.

Step 6 — Following the Heating Time (t_H) sequence shown in Figure 4, read and record the ΔV_F and CU data values for each of the two devices of Step 5.

Step 7 — Using the data from the previous step, prepare heating curves for the two devices in a manner similar to the examples shown in Figure 5.

Step 8 — Interpretation of the heating curves is the next step. Realizing that the thermal characteristics of identical chips should be the same if the heating time (t_H) is less than or equal to the thermal time constant of the chip, the two curves should start out the same for the low values of t_H. Non-identical chips (i.e., thinner or smaller in cross section) will have completely different curves, even at the smaller values of t_H. As the value of t_H is increased, thereby overcoming the chip thermal constant, heat will have propagated through the chip into the die attachment region. Since the heating curve devices of Step 5 were specifically chosen for their difference, the curves of Figure 5 diverge after t_H reaches a value where the die attachment variance has an effect on the device junction temperature. Increasing t_H further will probably result in a flattening of the curve as the heating propagates in the device package. If the device package has little thermal mass and/or is not well mounted to a good heat sink, the curve will not flatten very much, but will show a definite change in slope. Figure 6 shows the key elements of the heating curve.

Step 9 — Using the heating curve, select the appropriate value of t_H to correspond to the inflection point in the transition region between heat in the chip and heat in the package.

If there are several different elements in the heat flow path-chip, die attachment, substrate, substrate attachment, and package, for example, in a hybrid there will be several plateaus and transitions in the heating curve. Appropriate selection of t_H will optimize evaluation sensitivity to other attachment areas.

Step 10 — Return to the apparatus and set t_H equal to the value determined from Step 9.

Step 11 — Because the selected value of t_H is much less than that for thermal equilibrium, it is possible to significantly increase the heating power without degrading or destroying the device. The increased power dissipation within the device under test will result in high ΔV_F and/or CU values that will make determination of acceptable and non-acceptable devices much easier.

Step 12 — The pass/fail limit, the cutoff point between acceptable and non-acceptable devices, can be established in a variety of ways:

a) Correlation to other die attachment evaluation methods, such as die shear and/or x-ray; while these two methods have little actual value from a thermal point of view, they do represent standardized methods as described in MIL-STD specifications.

b) Maximum allowable junction temperature variation between devices; since the relationship between ΔT_J and ΔV_F is about 0.5°C/mV, the junction temperature spread between devicescan be easily determined. The T_J predicts reliability. Conversely, the T_J spread necessary to meet the reliability projections can be translated to a ΔV_F and/or CU value for a Pass/Fail criteria, based on correlation with steady-state thermal equilibrium conditions.

To fully use this approach, it will be necessary to calibrate the devices for the exact value of the T_J - V_F characteristic. The characteristic's slope, commonly referred to as K Factor, is easily measured on a sample basis using a voltmeter, environmental chamber, temperature indicator and a power supply setup for forcing, both active devices and thermal test chips as shown in Figure 7. A simple set of equations yields the junction temperature once K and ΔV_F are known:

$$\Delta T_j = | (K) (\Delta V_F) |$$

$$T_J = T_A + \Delta T_j$$

Where T_A is the ambient or reference temperature.

c) Statistically from a moderate size device sample; the distribution of ΔV_F or CU values should be a normal one with defective devices out of the normal range. Figure 8 shows a ΔV_F distribution for a sample lot of integrated ciruits. Note that the left-hand side of the histogram envelope is fairly well-defined, but the other side is greatly skewed to the right. This comes about because the left-hand side is constrained by the absolutely best heat flow that can be obtained with a given chip assembly material and process. The other side has no such constraints because there is no limit as to how poorly a chip is mounted.

The usual rule of thumb in setting the maximum limit for ΔV_F or CU is to use the distribution average value and one standard deviation (σ) i.e. —

$$\left.(\Delta V_F)\right|_{\text{high limit}} = \overline{\Delta V_F} + X\sigma_{\Delta}$$

$$\left.(CU)\right|_{\text{high limit}} = \overline{CU} + X\sigma_{CU}$$

Where X = 1 in most cases.

The statistical data required is obtained by testing 40 or more devices under the conditions of Step 11.

Step 13 — Once the test conditions and pass/fail limit have been determined, it is necessary only to record this information for future testing requirements of the same device in the same package. With the apparatus properly set-up, including the fail limit selector on those apparatus set ups so equipped, the operator need only insert the device, initiate a test, and then either read the ΔV_F or CU display or observe the appropriate pass or fail indicaors.

The steps listed hereto have been conveniently summarized in Figure 9. The total time required to perform these steps is greatly dependent on the operator but, in general, should require about one hour if the statistical approach of Step 12.C is used.

4.2 *Routine Device Testing Procedure* — Once the proper control settings have been determined for a particular device type from a given manufacturing process or vendor, repeated testing of that device type simply requires that the same test conditions be used as previously determined.

New device types or the same devices manufactured with a different process will require a repeat of Section 4.1.

4.3 *Comparison of Different Vendor Devices* — Each device type is defined as a specific chip manufactured to a given set of procedures. Integrated circuit users who buy a specific part number from more than one vendor or manufacturers that redesign or otherwise modify the fabrication of their devices will be able to use the heating power and approximately the same t_H for all vendors, but probably will have to use a different ΔV_F or CU pass/fail limit for each different vendor because the K Factor for parts manufactured by different vendors will probably be different. The difference can be determined in Step 12.B and using the setup described in Figure 7.

5 Test Condition Specification

To properly set up the test apparatus and to insure repeatable measurements, the following test conditions must be fully specified:

a. V_H

b. t_H

c. I_M

d. t_{MD} (and t_{SW} if appropriate)

e. DUT/apparatus interface (i.e., wiring connection)

f. ΔV_H or CU data requirement

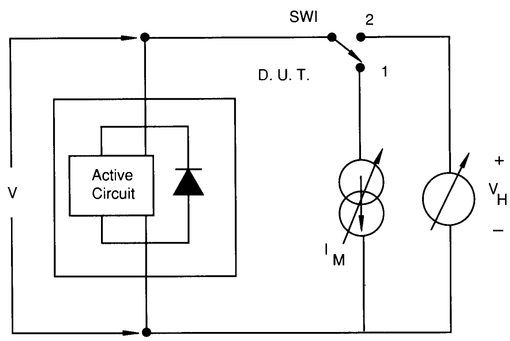


Figure 1A
Set-Up for Junction Isolation Diode Devices

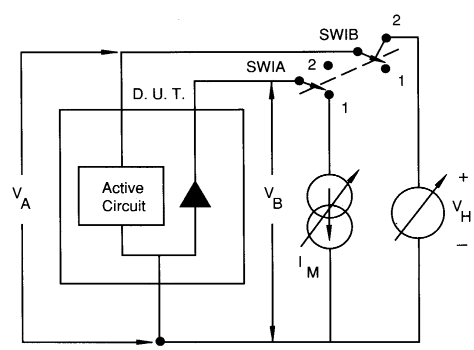


Figure 1B
Set-Up for Parisitic Diode or Thermal Test Chip Temperature Sensing

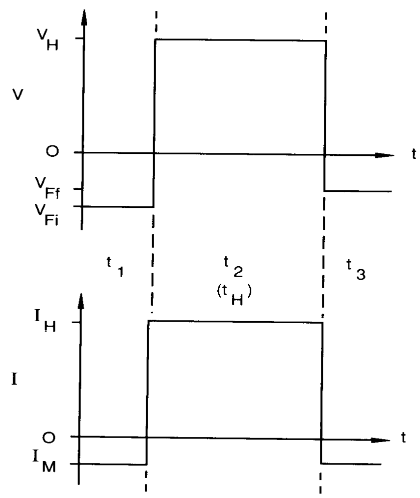


Figure 2A
Waferforms Associated with Figure 1A

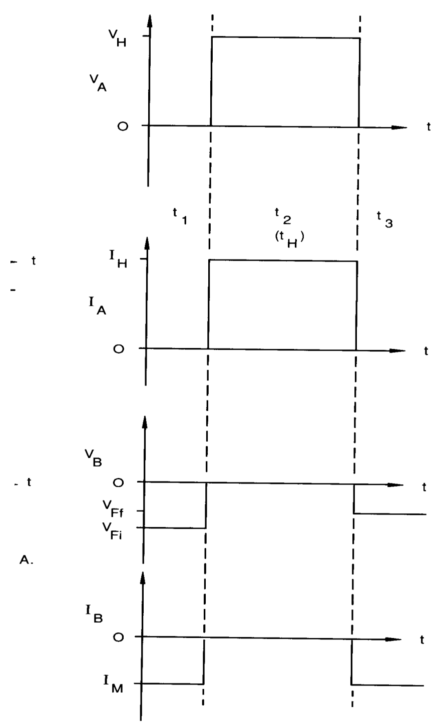


Figure 2B
Waferforms Associated with Figure 2B

DUT #	CU (mV/A)	
1	195	"Lo"
2	198	
3	242	
4	212	
5	226	
6	207	
7	219	
8	241	
9	268	"Hi"
10	218	
11	253	
12	199	
13	234	
14	227	
15	218	

Figure 3
Data Results for Initial 15-Piece Sample for tH Value of 200 ms

Heating Time t_H (seconds)	DUT #1 CU (m V/A)	DUT#9 CU (m V/A)
1×10^{-4}	43	43
1.5	43	43
2	43	43
3	43	43
4	43	43
6	43	43
8	43	43
1×10^{-3}	45	45
1.5	45	45
2	47	47
3	48	48
4	50	50
6	51	53
8	58	63
1×10^{-2}	63	70
1.5	75	86
2	85	100
3	100	122
4	112	140
6	130	168
8	145	190
1×10^{-1}	157	208
1.5	179	243
2	195	268
3	220	308
4	239	337
6	265	373
8	285	398
1×10^{0}	300	416
1.5	323	449
2	340	470
3	362	497
4	377	518
6	398	518
8	411	563
1×10^{1}	421	578

Figure 4
Heating Curve Data for Highest and Lowest Reading Devices from Figure 3

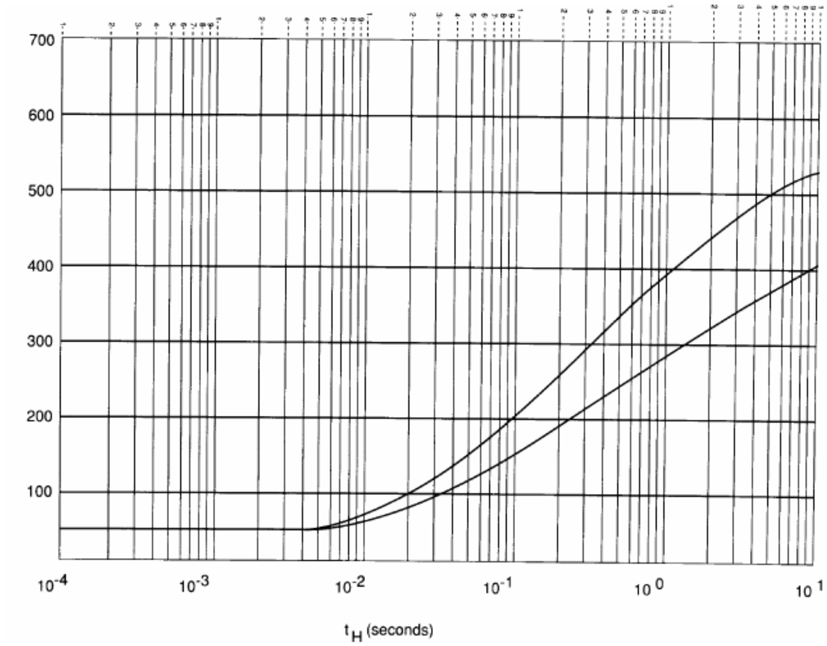


Figure 5

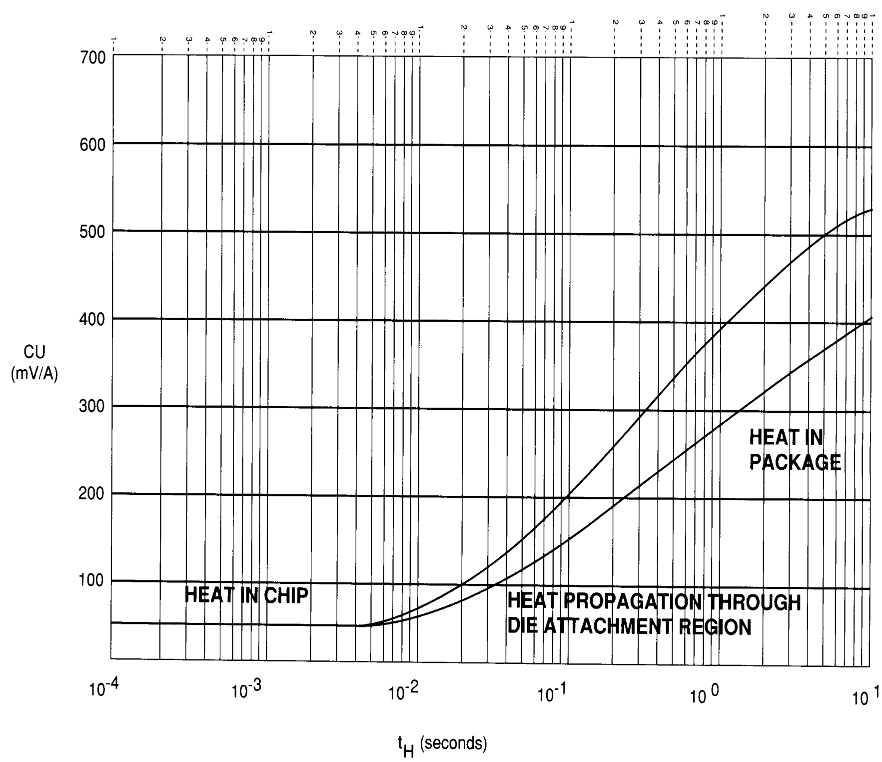
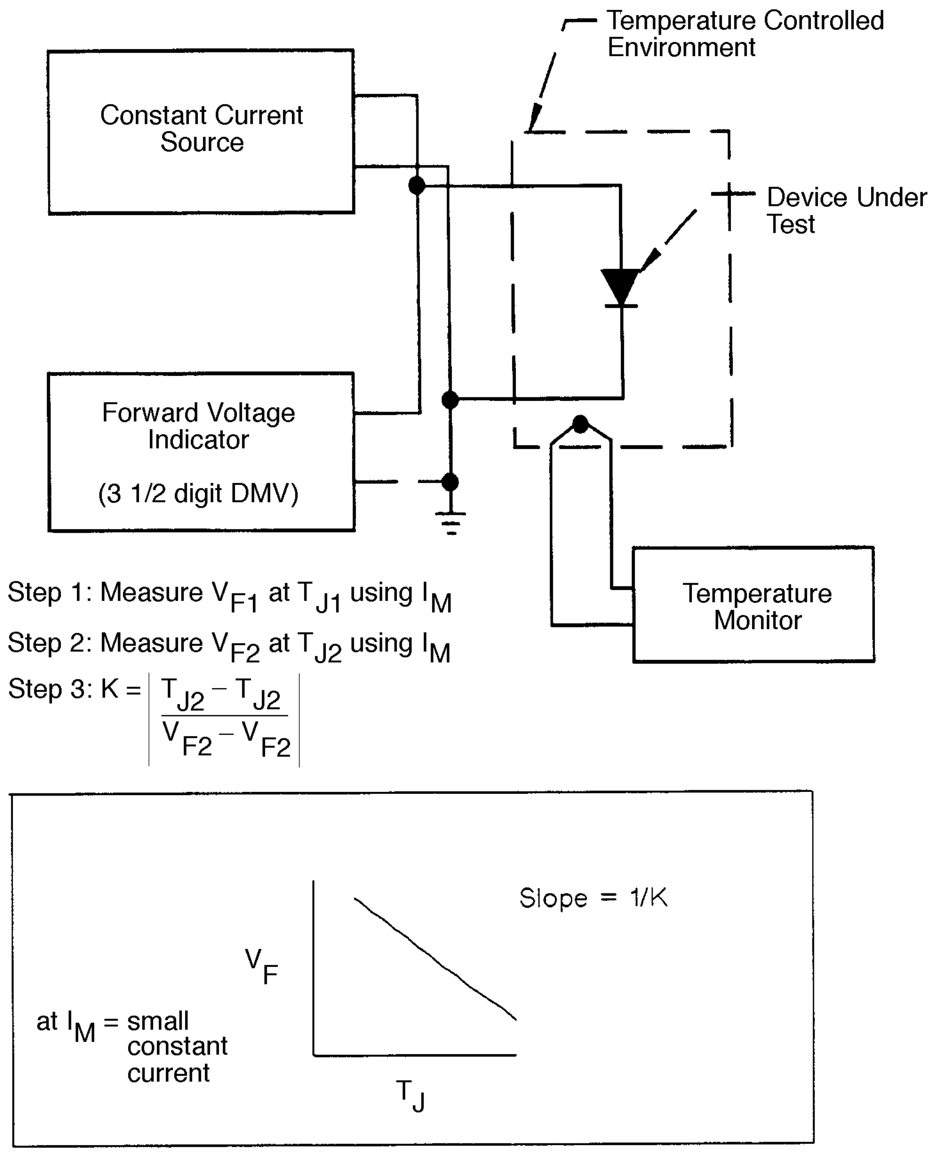


Figure 6
Interpretation of Heating Curves of Figure 5

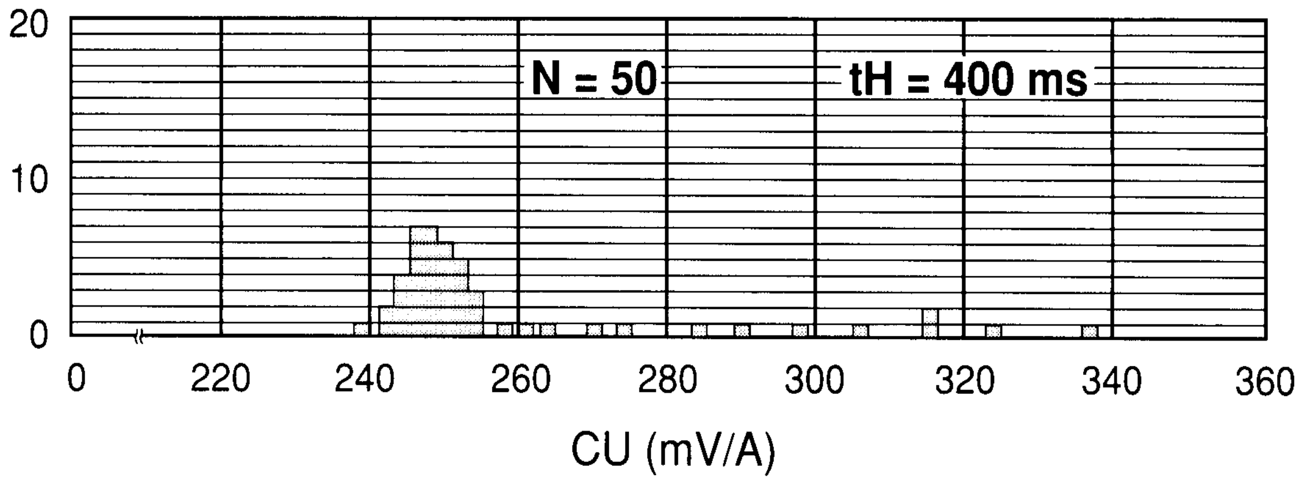
NOTE: Inflection point in curve occurs at approximately t_H = 400 ms.



I_M must be large enough to overcome surface leakage effects but small enough not to cause significant self-heating

T_J is externally applied - via oven, liquid, etc. - environment

Figure 7
K Factor Calibration Setup and Procedure



$V_H = 5.0$ v

$T_H = 400$ ms

$I_M = 1.0$ mA

$t_{MD} = 20$

$\overline{CU} = 249$ mV/A

$\sigma_{cu} = 53.5$ mV/A

CU = 302.5 mV/A

high limit

Figure 8

CU bar graph shows thermal distribution of 50 devices when tested at a heating time of 400 ms. (Note: CU data rounded off to nearest m V/A.)

	General Description	*Steps*	*Comments*
A	Initial Setup	1 thru 4	Approximate instrument settings to find variations among devices in 10 to 15 piece sample.
B	Heating Curve Generation	5 thru 7	Using highest and lowest reading devices, generate Heating Curves.
C	Heating Curve Interpretation	8 thru 10	Heating Curve is used to find more appropriate value for t_H corresponding to heat in the die attachment are (or some other desired interface in the heat flow path).
D	Final Setup	11	Heating Power applied during t_H is increased in order to improve measurement sensitivity to variations among devices.
E	Pass/F Determination	12 thru 13	A variety of methods is available for setting the fail limit; the statistical approach is the fastest and easiest to implement.

Figure 9 — Summary table of steps required to implement thermal transient testing for IC die attachment evaluation.

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SEMI G47-88
SPECIFICATION FOR PLASTIC MOLDED QUAD FLAT PACK LEADFRAMES

1 Preface

This specification defines the acceptance criteria for leadframes designed for assembly of JEDEC registered publication 95 standard outlines for "Plastic Quad Flat Pack 0.025" lead spacing (gull wing) packages". It is a design guideline for packaging engineers, leadframe stampers and etchers, mold and trim/form tooling manufacturers. It has been developed to meet the requirements of assemblers using automatic and manual equipment.

2 Applicable Documents

2.1 *SEMI Specifications*

SEMI G4 — Specification, Integated Circuit Leadfame Materials in the Production of Stamped Frames

SEMI G18 — Specification, Integrated Circuit Leadframe Materials Used in the Production of Etched Frames

SEMI G10 — Standard Method, Mechanical Measurement for Plastic Package Leadframes

SEMI G21 — Specification, Plating Integrated Circuit Leadframes

2.2 *ANSI Specification*[1]

Y 14.5M-1982 — Dimensioning and Tolerancing

2.3 *JEDEC Specification*[2]

Registration 95 — Plastic Quad Flat Pack, 0.025" Lead Spacing (Gull Wing)

2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

3 Selected Definitions

burr — a fragment of excess material either horizontal or vertical attached to the leadframe.

camber — curvature of the leadframe strip edge (see Figure 1).

coil set — Longitudinal bowing of the leadframe (see Figure 2).

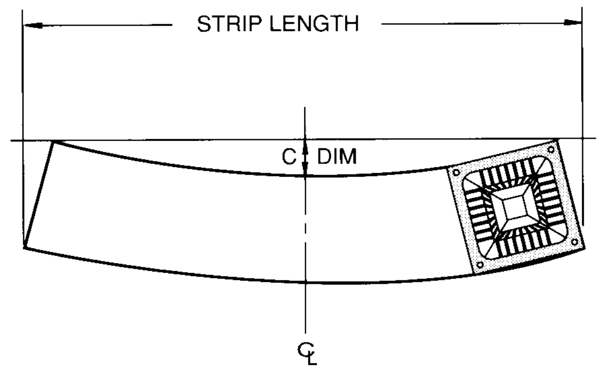


Figure 1
Camber

coined area — that area at the tip end of the bond fingers coined to produce a flattened area for functional use (see Figure 3).

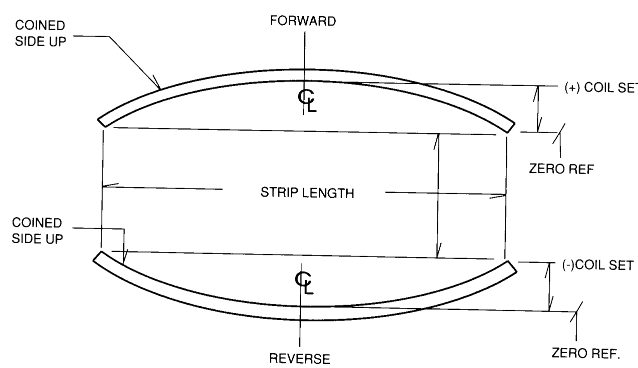


Figure 2
Coil Set

crossbow — transverse bowing of the leadframe (see Figure 4).

lead twist — angular rotation of bonding fingers (see Figure 5).

pits — shallow surface depressions or craters in the leadframe material.

true position circle — that circle with its center positioned at the center of the coined lead defines the design position of the lead tip.

1 ANSI, 1430 Broadway, New York, NY 10018

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

3 JEDEC, 2001 Eye Street, N.W., Washington, D.C. 20006

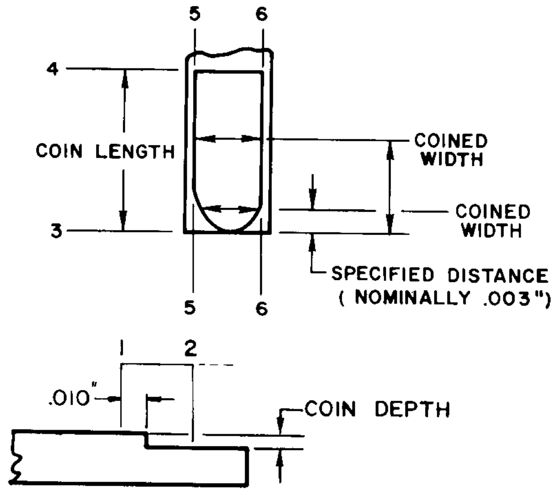


Figure 3
Coined Area

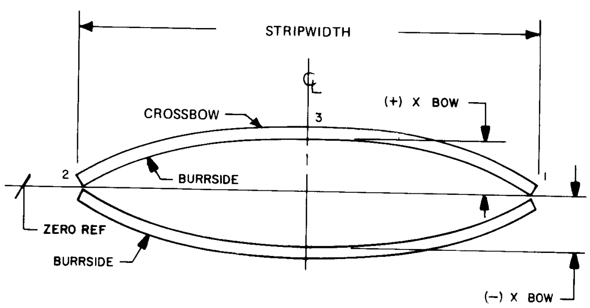


Figure 4
Crossbow

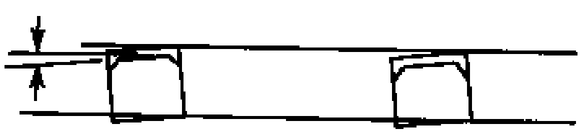


Figure 5
Lead Twist

4 Ordering Information

Purchasing orders for leadframes for plastic molded quad flat pack packages furnished to this specification shall include the following items:

4.1 Drawing no. and revision level.

4.2 Material, alloy specification.

4.3 Lead count, and confirming no. of units per strip.

4.4 Requirement for material certification.

4.5 Leadframe plating specifications.

5 Dimensions

5.1 Tables 1, 2, 3, and 4.

5.2 Reference Figures 6 and 7 and Details A and B.

6 Defect Limits and Parameters (to measure, see SEMI G10, Standard Method for Mechanical Measurement for Plastic Package Leadframes)

6.1 *Lead Tip Width*

6.1.1 *Minimum Lead Tip Width* — Shall be as agreed to between supplier and purchaser.

6.1.2 *Minimum Flat Wire Bonding Area* — 80% of nominal lead width and 0.025" (0.635 mm) in length.

6.2 *Coining and Metal Clearance*

6.2.1 *Coined Depth* — 0.0005" (0.013 mm) minimum to 30% material thickness maximum (stamped frames only).

6.2.2 Dimensions shown on drawings are before coining.

6.2.3 *Maximum Coining Bulge* — (Stamped frame only) shall not exceed 0.002" (0.051 mm) per edge and shall be governed by metal to metal clearance requirements (lead to lead and lead to pad).

6.2.4 *Metal-to-Metal Clearance* — Shall be as agreed to between supplier and purchaser.

6.3 *Lead Twist* — Shall not exceed 3.5 or 0.0006" (0.015 mm) per 0.001" (0.254 mm) of lead width.

6.4 *Burrs* — Shall be firmly attached and able to withstand a probe force of 10 grams. All burrs vertical and horizontal in any location shall not exceed 0.001" (0.0254 mm).

6.5 *Die Pad Tilt and Flatness* — (See SEMI G10 for measurement method.)

6.5.1 *Tilt* — 0.001" (0.025 mm) maximum per 0.100" (2.54 mm) of length or width in the undepressed state, and 0.002" (0.051 mm) maximum per 0.160" (4.06 mm) of length or width in the depressed state, when measuring corner to corner: overall maximum not to exceed a total of 0.006" (0.152 mm).

6.5.2 *Flatness* — 0.0002" (0.005 mm) per 0.100" (2.54 mm) pad length when measuring from the center to the average of four corners. The corners are defined at 0.005" (0.127 mm) from each edge.

6.6 *Pits and Slug Marks*

6.6.1 Within the functional area and on external leads, no slug marks and pits shall exceed 0.0003" (0.008

mm) in depth and 0.0005" (0.0013 mm) in length (see SEMI G4).

6.6.2 They shall not affect lead strength and shall not exceed 0.001" (0.0254 mm) in depth and 0.002" (0.051 mm) in length in non-functional areas.

6.7 Material thickness for both alloy 42 and copper alloys is 0.006" (0.152 mm), ± 0.00015" (0.0038 mm) for all lead counts.

NOTE — The material thickness tolerance dimension listed in Section 6.7 is currently under committee review and is expected to be revised to ± 0.0002".

6.8 *Internal Position Tolerance* — The centerline of all leadframe features must be within T.P.T. 0.002" (0.051 mm) relative to center line of pilot holes on rail.

6.9 *Progression*

6.9.1 Single progression of one frame is T.P.T. 0.002" (0.051 mm).

6.9.2 Accumulated progression tolerance over the strip length (measured from pitch line tooling hole to pitch line tooling hole, across the strip length minus two units) is within T.P.T. of 0.004" (0.102 mm).

6.10 *Strip Cut Off Location* — Shall be within T.P.T. 0.006" (0.154 mm) of nominal strip length.

6.11 *Strip Width Tolerance* — T.P.T. 0.004" (0.102 mm) for copper and alloy 42 materials.

6.12 *Camber* — Shall not exceed 0.002" (0.051 mm) over nominal strip length.

6.13 *Coil Set* — Maximum of 0.020" (0.508 mm) over the nominal strip length. This does not include material thickness.

6.14 *Cross Bow* — Shall not exceed the following dimensions:

No. of Leads	*Maximum Cross Bow*
52—100	0.006" (1.52 mm)
132—164	0.010" (0.254 mm)
196—244	0.012" (0.305 mm)

7 Sampling

Sampling will be determined between supplier and purchaser.

8 Packaging and Marking

8.1 *Packaging* — Leadframes must be packaged in containers designed and constructed to prevent damage and contamination.

8.2 *Marking* — The outer containers shall be clearly marked identifying the user stock number, user purchase order number, drawing number, and vendor lot numbers within the carton.

Table 1 Leadframe Standard Dimensions

LEAD COUNT	*52 LEAD*	*68 LEAD*	*84 LEAD*	*100 LEAD*	*132 LEAD*	*164 LEAD*	*196 LEAD*	*24 LEAD*
PACKAGE SHAPE	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE
JEDEC PACKAGE DESIGNATION	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”	PLASTIC QUAD FLAT PACK 0.025" SPACING “GULL WING”
NOMINAL PACKAGE WIDTH	0.450	0.550	0.650	0.750	0.950	1.150	1.350	T.B.D.
NOMINAL PACKAGE LENGTH	0.450	0.550	0.650	0.750	0.950	1.150	1.350	T.B.D.
STRIP LENGTH	8.800	8.640	8.640	8.400	8.400	8.000	7.200	T.B.D.
NO. OF UNITS PER STRIP	10	8	8	6	6	5	4	T.B.D.
TOOLING DIMENSIONS								
A	0.200	0.350	0.350	0.500	0.500	0.600	0.700	T.B.D.
(PROGRESSION) C	0.880	1.080	1.080	1.400	1.400	1.600	1.800	T.B.D.
F	0.050	0.050	0.050	0.050	0.050	0.050	0.050	T.B.D.
G	1.020	1.620	1.620	1.620	1.620	1.820	2.020	T.B.D.
(STRIP WIDTH) H	1.070	1.670	1.670	1.670	1.670	1.870	2.070	T.B.D.
I	0.810	0.910	1.010	1.110	1.310	1.510	1.710	T.B.D.
J	0.810	0.910	1.010	1.110	1.310	1.510	1.710	T.B.D.
DAMBAR TOPACKAGE	0.030	0.030	0.030	0.030	0.030	0.030	0.030	T.B.D.
DAMBAR WIDTH	0.015	0.015	0.015	0.015	0.015	0.015	0.015	T.B.D.
EXPANSION SLOT WIDTH	0.015	0.015	0.015	0.015	0.015	0.015	0.015	T.B.D.
DIAMETER Ø	0.060	0.060	0.060	0.060	0.060	0.060	0.060	T.B.D.
METAL THICKNESS	0.006	0.006	0.006	0.006	0.006	0.006	0.006	T.B.D.
NOTE: ALL DIMENSIONS IN INCHES								

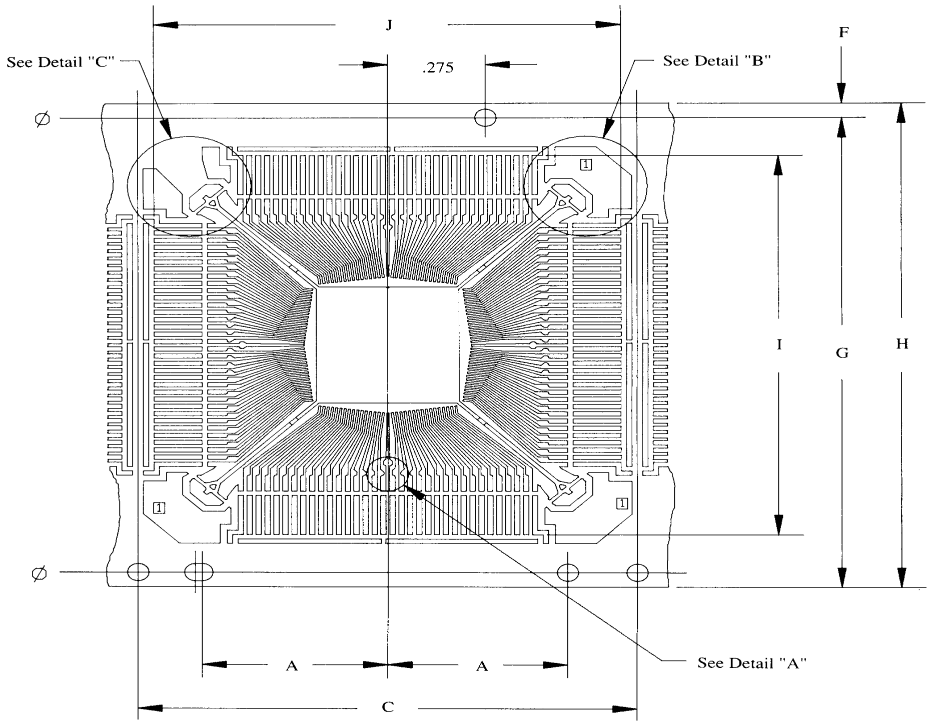
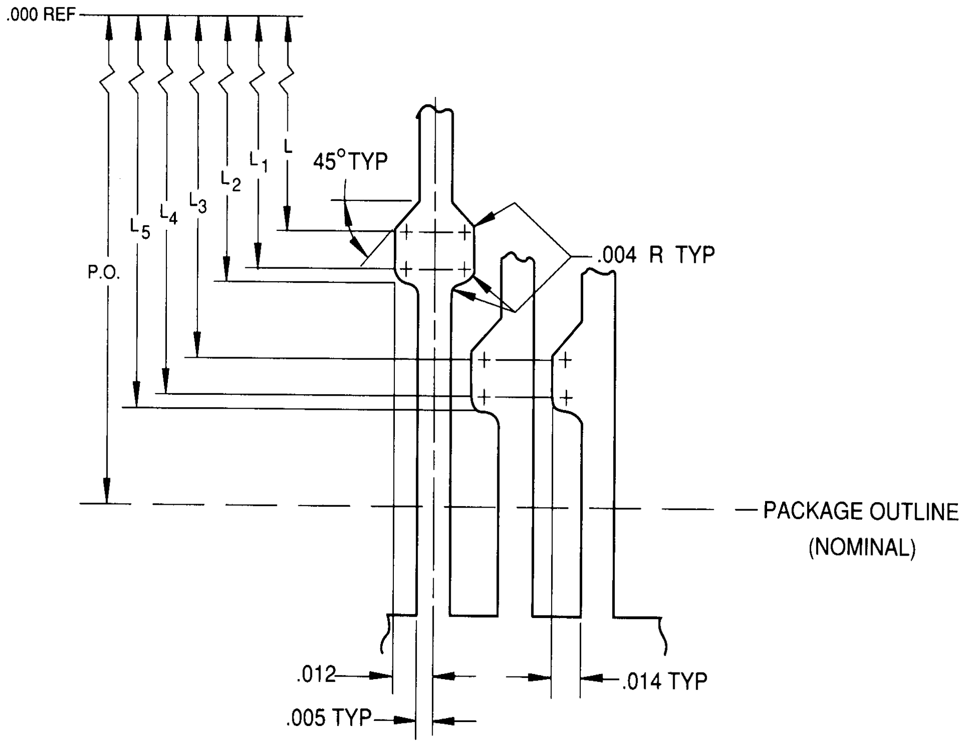


Figure 6

NOTE:

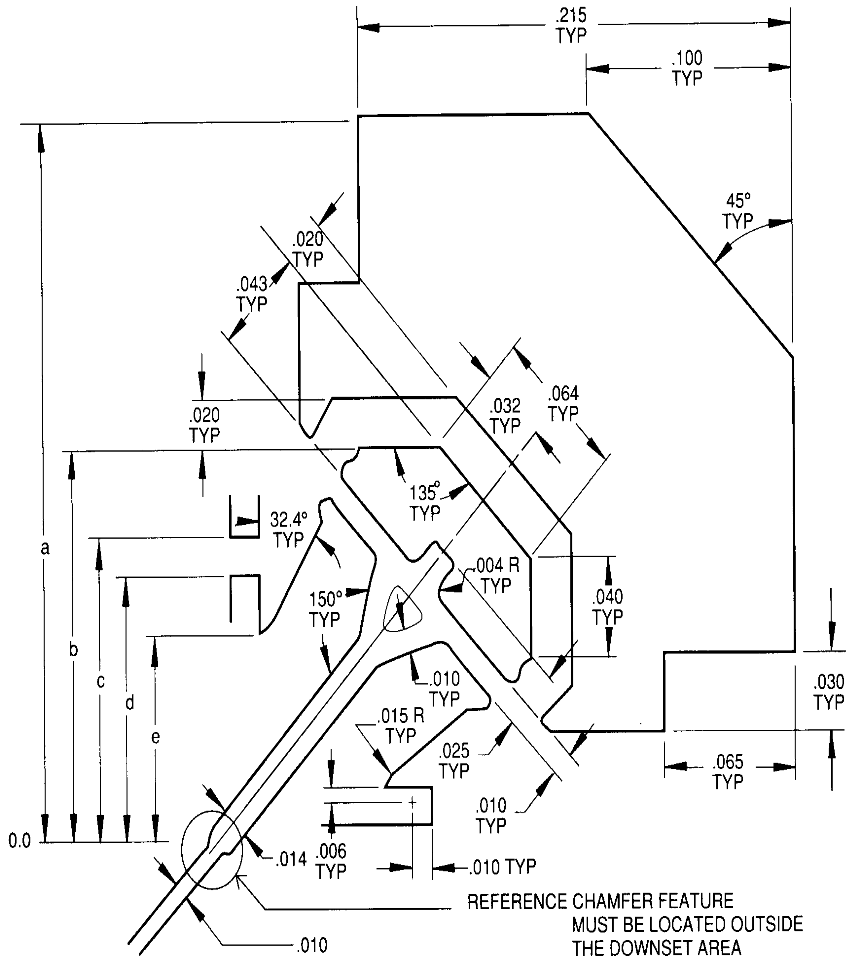
1 These are optional features only. Gating may require their exclusion.



Detail A
Leadlocks

Table 2

Leadcount	*52*	*68*	*84*	*100*	*132*	*164*	*196*	*244*
L	0.151	0.201	0.251	0.301	0.401	0.501	0.601	T.B.D.
L_1	0.161	0.211	0.261	0.311	0.411	0.511	0.611	T.B.D.
L_2	0.165	0.215	0.265	0.315	0.415	0.515	0.615	T.B.D.
L_3	0.186	0.236	0.286	0.336	0.436	0.536	0.636	T.B.D.
L_4	0.196	0.246	0.296	0.346	0.446	0.546	0.646	T.B.D.
L_5	0.200	0.250	0.300	0.350	0.450	0.550	0.650	T.B.D.
P.O.	0.225	0.275	0.325	0.375	0.475	0.575	0.675	T.B.D.

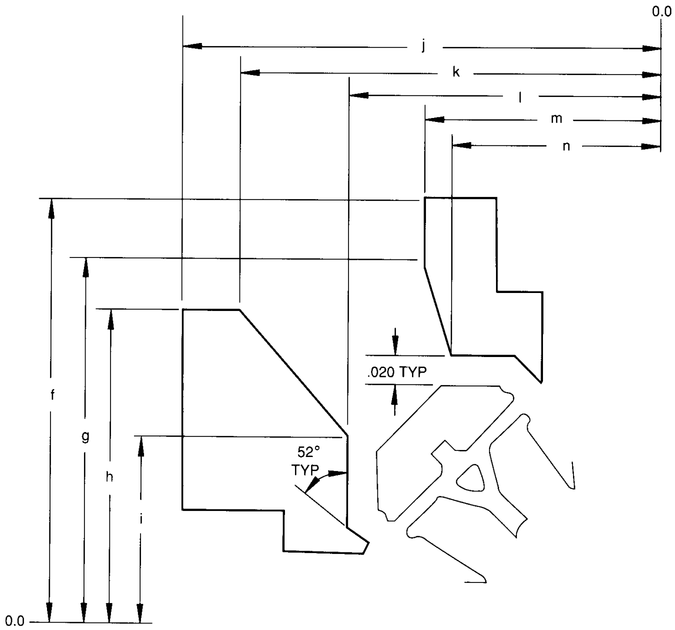


Detail B
Bumper/Tie Bar and Relief

. . . .

Table 3

Leadcount	*52*	*68*	*84*	*100*	*132*	*164*	*196*	*244*
a	0.435	0.485	0.535	0.585	0.685	0.785	0.885	T.B.D.
b	0.305	0.355	0.405	0.455	0.555	0.655	0.755	T.B.D.
c	0.270	0.320	0.370	0.420	0.520	0.620	0.720	T.B.D.
d	0.255	0.305	0.355	0.405	0.505	0.605	0.705	T.B.D.
e	0.231	0.281	0.331	0.381	0.481	0.581	0.681	T.B.D.



Detail C Gate Relief

Table 4

Lead Count	*52*	*68*	*84*	*100*	*132*	*164*	*196*	*244*
f	0.435	0.485	0.535	0.585	0.685	0.785	0.885	T.B.D.
g	0.394	0.444	0.494	0.544	0.644	0.744	0.844	T.B.D.
h	0.360	0.410	0.460	0.510	0.610	0.710	0.810	T.B.D.
i	0.272	0.322	0.372	0.422	0.522	0.622	0.722	T.B.D.
j	0.435	0.485	0.535	0.585	0.685	0.785	0.885	T.B.D.
k	0.399	0.449	0.499	0.549	0.649	0.749	0.849	T.B.D.
l	0.325	0.375	0.4325	0.475	0.575	0.675	0.775	T.B.D.
m	0.269	0.319	0.369	0.419	0.519	0.619	0.719	T.B.D.
n	0.253	0.303	0.353	0.403	0.503	0.603	0.703	T.B.D.

Table 4 (see Figure 7) Guidelines for Placement of Taping Dimensions 84 Lead Through 196 Leadframes

1. Nominal tape width maximum — 0.037"
2. Nominal tape width maximum — 0.060"
3. Tape width tolerance — ± 0.003"
4. Tape location tolerance — ± 0.015"
5. Absolute minimum location of outside tape edge from lead tip — 0.050".
6. Minimum location of outside tape edge from package outline nominal dimension — 0.065".
7. When window "W1" dimension cannot be met with minimum tape nominal width and recommended tolerancing which is the case with various given pad sizes of different lead counts, window "W2" dimension, 0.030", from package outline nominal should be used for the outside tape limit. If this window "W2" dimension still cannot be met negotiation of tape width and location tolerances between supplier and purchaser is suggested to maintain tape within the recommended window dimensions.
8. Recommended center line of tape for nominal location is midway between inside and outside tape edge limits for window "W1" & window "W2" dimensions as appropriate and within tolerance limits.
9. Downset angle — 30°
10. Downsetting must begin inside 0.025" minimum flat distance along tie bar from inside edge of applied tape.
11. Recommended downset length is maximum allowable within the above guidelines.

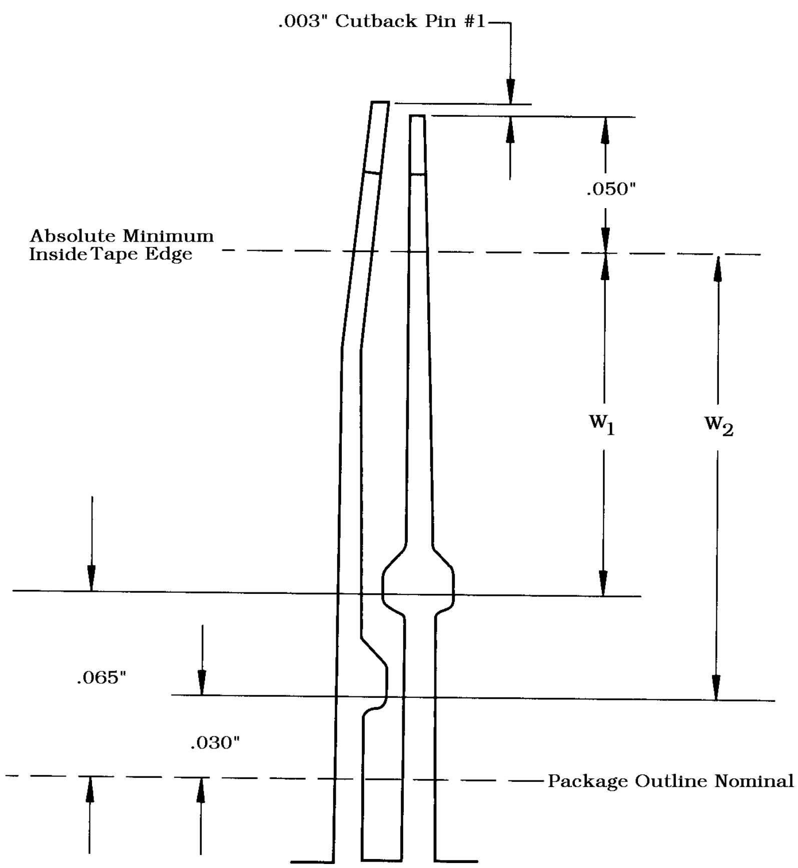


Figure 7

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G48-89
SPECIFICATION FOR MEASUREMENT METHOD FOR MOLDED PLASTIC PACKAGE TOOLIN

1 Preface

This document is prepared to enable standard measurement techniques to be used. It is intended that the measurement techniques described in the specification will apply to all molded plastic package tooling, i.e. DIPS, SIPS, PCC, SO, Quad, and TAB.

2 Applicable Documents

2.1 *SEMI Specifications*

SEMI G14 — Plastic Molded DIP Tooling

SEMI G16 — Plastic Chip Carrier Tooling

SEMI G36 — Plastic Molded High Density TAB Quad Tooling

SEMI G37 — Plastic Molded SO Package Tooling

3 Basic Equipment

3.1 The following basic equipment is required to perform the specified measurements:

3.1.1 *Toolmaker's Microscope* — 3× objective and 10× eyepiece total 30× with X and Y axes digital readouts reading to 0.0001". Minimum travel of stage must be 2.0" × 2.0". Eyepiece must be ± 0.0002" minimum. The toolmaker's microscope should have a goniometer on the eyepiece as will as on the stage. Accuracy of the goniometer shall be 0.1. The TM microscope should have a Z axis with a digital measurement capability, reading in increments of 0.0001". The objective lens must be 20× minimum which will give 0.0005" accuracy to the Z axis measurements.

3.1.2 *Optical Comparator* — Surface illumination. 10" minimum screen with 3" × 8" minimum travel. Magnification of 10×, 20× minimum required. Accuracy of 10× is 0.001"; accuracy of 20× is 0.0005". Some operators may be able to improve on this accuracy, but this is the best expected from average inspectors.

3.1.2.1 Overlays at 20× may be used for rapid measurement. The user is cautioned that the thickness of the line must be controlled. Line widths must not exceed 0.010" in width, which will give an inaccuracy of 0.0005" in the measurement. Overlays must have the datum marks clearly labeled. Overlays are tools which speed inspection; however, rejects must be verified by toolmaker's microscope measurements, which are more accurate.

3.1.3 *Digital Depth Indicator* — Mounted on a stand. Digital reading with a range of 2" is available. Readout must display increments of 0.0001" with ± 1 digit accuracy.

3.1.4 *Micrometer* — 0 to 1.0". 0.250" diameter for measuring to 0.001" accuracy.

3.1.5 Eight (8) inch dial calipers for measuring to 0.002" accuracy.

3.1.6 *Granite Surface Plate* — Minimum size 18" × 28", with a surface accuracy of 0.0002" or better.

3.1.7 *Surface Finish*

3.1.7.1 *Charmille Visual Surface Finish Standard* — (For comparison of Electric Discharge Machined (EDM) surface only.)

3.1.7.2 *Surface Comparator Standards* — (For other machined surfaces.)

3.1.7.3 *Surface Analyzer*

3.1.8 *Binocular, Zoom Microscope* — 10—15× magnification with vertical or near vertical lighting.

3.1.9 *Dial Indicators* — With accuracy of .0001 and with force not to exceed 5 grams.

3.2 *Alternative Equipment* — Sophisticated, automatic equipment is not excluded from use, but the user must ensure that such equipment meets or exceeds the accuracy of the basic equipment so that correlation problems may be avoided.

3.3 *Calibration* — All equipment to be calibrated on a regular schedule.

4 Measurements

4.1 The following measurements will be made:

4.1.1 Package Thickness (Section 5.1)

4.1.2 Package Length (Section 5.2)

4.1.3 Package Width (Section 5.3)

4.1.4 Leadframe to Cavity Offset (Section 5.4)

4.1.5 Top Cavity Length (Section 5.5)

4.1.6 Top Cavity Width (Section 5.6)

4.1.7 Bottom Cavity Length (Section 5.7)

4.1.8 Bottom Cavity Width (Section 5.8)

4.1.9 Cavity Overlap/Underlap (Section 5.9)

4.1.10 Cavity to Cavity Mismatch (Section 5.10)

4.1.11 Cavity Depth (Section 5.11)

4.1.12 Molding Protrusions (Section 5.12)

4.1.13 Pin Depths (Section 5.13)

4.1.14 Dambar Trimming Defects (Section 5.14)

4.1.15 Package Warpage (Section 5.15)

4.1.16 Lead Coplanarity (Section 5.16)

4.1.17 Shoulder Bend Location (Section 5.17)

4.1.18 Surface Finish (Section 5.18)

4.1.19 Radii (Section 5.19)

4.1.20 Lead Position (Section 5.20)

4.1.21 Draft Angles (Section 5.21)

4.1.22 Lead Spread (Section 5.22)

4.1.23 Foot Angle (Section 5.23)

4.1.24 Foot Length (Section 5.24)

4.1.25 Plastic Stand-off (Section 5.25)

4.2 *Conditions*

4.2.1 All measurements to be made on molded components, which have been processed to agreed conditions including post mold cure.

4.2.2 All measurements to be performed at a temperature between 20° and 26.7°C (68°, 80°F).

4.2.3 *Axis Definition*

4.2.3.1 The X axis lies parallel to the rail of the frame and the Y axis lies perpendicular to the rails of the frame.

4.2.3.2 The package X and Y axes must be positioned parallel to the X and Y axes of the measurement stage travel to avoid measurement errors.

4.2.3.3 The datum of the X and Y axes is the pilot hole of the leadframe, because it is the most accurate feature. An additional pilot hole is required to establish the theta datum.

4.2.3.4 The Z axis is perpendicular to the X and Y axis. The datum is the leadframe or the top mold parting line, unless otherwise specified.

5 Measurement

5.1 *Package Thickness* — (Figure 1)

5.1.1 *Equipment* — Micrometer

5.1.2 Using the micrometer, measure the thickness of the package at three (3) places, diagonally across the package, where the contours allow, at the top edge, middle and bottom edge of the package. (Note: the top is the pin 1 identifier edge.)

5.2 *Package Length* — (Figure 1)

5.2.1 *Equipment* — Optical Comparator at 10×.

5.2.2 Position the package so that the cross-sectional view is presented for measurement. Use care to assure the package is square to the datum plane.

5.2.3 Align the package side draft angle (see Section 5.21) where the draft angle intersects the leadframe. This is the parting line (datum point). Measure the overall width at the parting line, including cavity mismatch.

5.3 *Package Width* — (Figure 1)

5.3.1 *Equipment* — Optical Comparator at 10×.

5.3.2 Position the package so that the cross-sectional view is presented for measurement. Use care to assure the package is square to the datum plane.

5.3.3 Align the package side draft angle (see Section 5.21) where the draft angle intersects the leadframe. This is the parting line (datum point). Measure the overall width at the parting line including cavity mismatch.

5.4 *Leadframe to Cavity Offset* — (Figure 2)

5.4.1 *Equipment* — Toolmaker's Microscope at 30×.

5.4.2 Position the circle (cross hair) of the filar eyepiece of similar diameter to the leadframe pilot hole. Zero the digital readout. Move the stage to the point where the molded package meets the leadframe at the parting line. Record digital readout reading as (T1). Continue to move the stage until the point on the opposite side where mold compound and leadframe meet. Record digital readout reading as T2. Continue to move stage to center of leadframe rail (usually also a hole). Record the digital readout reading as T3.

5.4.3 Turn part over and BE SURE TO USE THE SAME HOLE AND PART; repeat the three (3) readings, B1, B2, and B3.

5.4.4 Derive the data from the readings as follows:

Top Centerline of Frame = (T3)/2

Bottom Centerline of Frame = (B3)/2

Measurement Error = (T3)/2 - (B3)/2

Frame Cavity Offset = (B3)/2 - (B2 + B1)/2

Centerline of Package = (T2 + T1)/2; (B2 + B1)/2. (Relative to datum)

NOTE: Figure 2 calculations assume that the leadframe centerline is equidistant between T3 and the zero datum point.

5.4.5 In lieu of the frame pilot hole, the dambar may be used on the frame when measuring the offset; however, the possibility of tolerance error may become cumulative, particularly with etched rather than stamped frames.

NOTE: By SEMI convention the offsets are defined in relation to the bottom cavity of the mold.

5.5 *Top Cavity Length "Y" Axis* — (Figure 2)

5.5.1 *Equipment* — Toolmaker's Microscope at 30×.

5.5.2 Focus the microscope on the leadframe datum point. Zero the digital readout. Move the stage to the intersection of the mold compound and the leadframe parting line. Read and record. Continue to measure across the package length to the intersection of the mold compound and the leadframe parting line on the opposite edge of the package. Read and record.

5.5.3 The cavity length is defined as (Ty2 – Ty1).

5.6 *Top Cavity Width "X" Axis* — (Figure 2)

5.6.1 *Equipment* — Toolmaker's Microscope at 30×.

5.6.2 Focus the microscope on the leadframe datum point. Zero the digital readout. Move the stage to the intersection of the mold compound and the leadframe parting line. Read and record the reading. Continue on to the intersection of the mold compound and the leadframe parting line on the opposite side. Read and record.

5.6.3 The cavity width is defined as Tx2 – Tx1.

5.7 *Bottom Cavity Length "X" Axis* — (Figure 2)

5.7.1 *Equipment* — Toolmaker's Microscope at 30×.

5.7.2 Focus the microscope on the same datum point used for the top cavity length (remember the package has been turned over). Zero the digital readout. Move to the intersection of the mold compound and the leadframe parting line. Read and record the reading. Continue to the intersection of the mold compound and the leadframe parting line on the opposite side. Read and record. The bottom cavity length is the difference of the two readings. Record the bottom cavity length (By2 – By1).

5.8 *Bottom Cavity Width "X" Axis* — (Figure 2)

5.8.1 *Equipment* — Toolmaker's Microscope at 30×.

5.8.2 Focus the microscope on the leadframe datum point. Zero the digital readout. Move the stage to the intersection of the mold compound and the leadframe parting line. Read and record. The bottom cavity width is the difference of the two readings (Bx2 – Bx1).

5.9 *Cavity Overlap/Underlap* — (Figure 4)

5.9.1 Compare the top cavity length to the bottom cavity length and the top cavity width to the bottom cavity width. The difference in the number is the overlap/underlap for each axis.

5.10 *Cavity to Cavity Mismatch* — (Figure 2)

5.10.1 The comparison of the centerlines of the top cavity length to the bottom cavity length and the top cavity width to the bottom cavity width shall determine the cavity to cavity mismatch.

Formula:

Cavity to Cavity Mismatch =

(B2 + B1)/2 – (T2 + T1)/2

5.11 *Cavity Depth* — (Figure 1)

5.11.1 *Equipment* — Depth Indicator

5.11.2 *Top Cavity Depth* — Measure the distance from the top surface of the leadframe to the top of the unit, place the indicator on the surface of the leadframe, zeroing the readout, moving the part to a point where the top of the unit can be indicated, and read and record the readout.

5.11.3 *Bottom Cavity Depth* — The measurement is performed in the same manner as the measurement in Section 5.11.2 except the part is turned over and the bottom surface of the leadframe to the bottom of the unit is used.

5.11.4 The package depth is the sum of the frame thickness and the top and bottom depth. (This measurement should equal Section 5.1. Any variation may be considered measurement error.)

5.12 *Molding Protrusions Top/Bottom of Part* — (Figure 3)

5.12.1 *Equipment* — Digital depth indicator.

5.12.2 Place unit on the anvil and zero the indicator on the package surface away from area of protrusion. Carefully move the part to where the protrusion is located. Carefully lower the indicator to the top of the mold protrusion. Read and record the mold protrusion.

5.13 *Pin Depths* — (Figure 3)

5.13.1 *Equipment* — Depth indicator with a fine point or "Z" axis reading toolmaker's microscope.

5.13.2 The measurement is made from the nominal plane of the package surface to the bottom of the design mark (either ejector pin or Pin #1 indicator or other feature).

5.13.3 The indicator is set to zero on the package surface and then moved to the bottom of the feature. The readout is read and recorded.

5.14 *Dambar Trimming Defects* — (Figure 4)

5.14.1 *Equipment* — Toolmaker's Microscope

5.14.2 Measure from the edge of the lead to the edge of the protrusion or intrusion; record the reading and the lead number.

NOTE: Dambar trimming defects are those which can be caused by overcutting into the lead shoulder (stand off) i.e. cutting too much or undercutting the dambar, leaving too much dambar or a burr. Overcutting causes shoulder intrusions. Undercutting leaves shoulder protrusions. In some cases, an adjacent protrusion and intrusion is caused by misalignment of the part at the time of dambar removal.

5.15 *Package Warpage* — (Figure 5)

5.15.1 *Equipment* — Microscope "Z" Axis reading 40×.

5.15.2 With the package sitting on the stage, obtain a two point datum by measuring two-points on opposite edges 0.005 from the radius readings; move to the center of the package and obtain the deviation from the datum, and read and record the reading as the warp.

5.15.3 For quad packages, it is equally important that there be minimum warp in each axis (X or Y) so that a three-point Z axis datum must be obtained; the two used in 5.15.2 and an additional one, on one adjacent edge.

5.16 *Lead Coplanarity*

NOTE: Applies to all surface mount devices.

5.16.1 *Contact Method* — (Figure 6)

NOTE: Not recommended for gull-wing leads.

5.16.1.1 *Equipment*

Dial Indicator 0.0001" Accuracy, 5 grams maximum pressure.

Granite Flat.

Transfer Stand.

Package Holding Fixture.

Reference Gauge Blocks, 0.0002" Accuracy.

5.16.1.2 Place the package on holding fixture so that the flat sections of the leads, as they exit from the plastic, are on the ground flats of the fixture. The leads are to be facing "UP" (Dead Bug).

5.16.1.3 On the granite flat, set up the dial indicator on its transfer stand and zero the reading using the reference block. Use a suitable reference block so that all measurements are positive to avoid confusion.

5.16.1.4 Measure the highest point on each lead (e.g., the tangent point of a "J" lead).

5.16.1.5 Determine the range of readings.

NOTE: Special Precautions

1. Be sure that the flat of the leadframe, as it exits from the plastic, rests on the flats of the holding fixture. If the radiused section supports the package, then spurious readings will result.

2. The pressure exerted by the dial indicator must not exceed 5 grams. To check the contact pressure of the dial indicator, use a gram gauge. The gram pressure must be noted at the initial deflection of the gauge and at the maximum deflection of the gauge. If the initial deflection is greater than 5 grams, then the point where 5 grams is obtained must be noted and the measurement must stay within this range to be valid.

5.16.2 *Comparator/Mirror Method*

5.16.2.1 *Equipment* — Optical comparator with at least 20× magnification as per Section 3.1.2. Mirror, flat within 0.0005 inch with a mirror finish having the reflective suface on top. (A polished silver wafer is suggested.)

5.16.2.2 Place the mirror on the measurement stage mirrored side up with the mirror in the plane of the XY axis. Place the package on the mirror with the leads down. Sufficient mirror must extend past the leads toward the lens of the comparator so that an image of the leads with its reflection can be viewed. Focus on the leads nearest the lens. (Care must be taken not to focus on the leads on the opposite side of the package.) (See Figure 8.)

5.16.2.3 Measure the distance between the lead tip and its reflection. Divide that measurement by two to obtain the coplanarity of the lead.

5.16.2.4 Repeat for each lead. Rotate part to measure all sides. Determine co-planarity by identifying maximum measurement.

5.17 *Shoulder Bend Location* — (Figures 1, 7, and 7a)

NOTE: This measurement is not precise, since radius tangent locations allow for considerable inspector interpretation.

5.17.1 *Equipment* — Comparator at 20× magnification. (Surface and shadow illumination).

5.17.2 The measurement is made from the intersection of the straight part of the shoulder with the shoulder bend radius of the lead on one side of the package to the same point on the lead on the opposite side of the package. Locate this point on the first lead by lining up the vertical comparator cross hair with the straight of the lead. Bring the center point of the cross hair to this intersection. Zero the readout, move to the opposite lead, and repeat the location of the intersection. Record the measurement.

NOTE: Due to shadowing of leads, only the end leads on the package can be measured. A visual check with a 10 to 20× microscope should be made to check for gross difference of other leads.

5.18 *Surface Finish*

5.18.1 *Comparative Method* — (EDM Finishes only)

5.18.1.1 *Equipment* — Charmille Standard Surface Gauge Binocular Microscope and Light.

5.18.1.2 Insert gauge and molded package to be checked into a holder so that both can be viewed at the same time under the microscope.

5.18.1.3 Estimate the surface finish on the package.

5.18.2 *Absolute Method*

5.18.2.1 *Equipment* — Automatic Surface Analyzer Surface Standards.

5.18.2.2 Calibrate the analyzer using the gauges.

5.18.2.3 Measure the surface finish on the package. The analyzer gives the average roughness (R_a) and the actual surface roughness. Use average roughness for acceptance.

5.18.3 Table of approximate equivalent finishes

	Mirror	*Satin*	*Extra Fine*	*Fine*	*Medium*	*Course*
Micro Inches	4	30 ± 10	50 ± 10	75 ± 10	105 ± 10	145 ± 10
Charmilles	N/A	N/A	18–21	21–24	24–27	27–30
Microns	N/A	1	1.5	2	2.5	3.5

5.19 *Radii*

5.19.1 *Comparative Method*

5.19.1.1 *Equipment* — Optical comparator at 20×.

5.19.1.2 Radii are measured by comparison to known radius overlays marked at the same magnification as the comparator.

5.19.2 *Absolute Method*

5.19.2.1 *Equipment* — Toolmaker's Microscope.

5.19.2.2 Radii are measured using the reticle lines and the X and Y axes to obtain the radius.

5.19.2.3 Care must be taken to assure that each radius is measured separately.

5.20 *Lead Position*

NOTE: Lead position is a combination of pitch variations due to lead movement after forming and lead width. If the lead is to fit a solder pad or hole, the combination must be considered. In some cases, the lead width can be a major contributor to poor lead position, eg. SO packages with gull-wing leads, PCC with J bend.

5.20.1 *Comparative* Method

NOTE: This method will only determine if the part is usable, not the breakdown of width and pitch variations.

5.20.1.1 *Equipment* — Optical Comparator at 20×.

5.20.1.2 Align the package to an overlay displaying limit lines for lead pitch/width.

5.20.2 *Absolute Method*

5.20.2.1 *Equipment* — Toolmaker's Microscope.

5.20.2.2 Move to the edge of the lead number and zero the readout.

NOTE: Where there is a definitive end to the lead as in the case of SO, SIP and DP, the end of the lead at the intersection of the lead in feature, will be the measurement point. Quad PCC packages will be measured at the top of the "J" bend when in the "Dead Bug" position.

5.20.2.3 Move to the opposite edge of that lead and record width.

5.20.2.4 Move to the first edge of the next lead. Record the measurement. Repeat the width measurements.

5.20.2.5 Repeat for all leads to be measured.

5.20.2.6 Pitch can be calculated from the measurements.

5.21 *Draft Angles*

5.21.1 *Package Sides*

5.21.1.1 *Equipment* — Optical comparator at 10x.

5.21.1.2 Lay the top or bottom surface of the package squarely onto the comparator to insure that no protrusions on the surface cause the package to be tilted. Align the horizontal cross-hair to the leadframe. Using the vertical cross hair, compare the draft angles to an overlay.

NOTE: This measurement should be taken before the leads are formed.

5.21.1.3 Repeat the procedure for all sides of the package.

5.21.2 Pin Marks (e.g., Pin 1 indicator at end of package).

5.21.2.1 *Equipment* — Toolmaker's Microscope.

5.21.2.2 Focus the microscope on the surface of the package and measure the diameter of the pin hole. (D1)

5.21.2.3 Focus on the bottom surface of the pin hole and measure the diameter. (D2)

5.21.2.4 Tangent of Draft angle = (D1 – D2)/2H where H is pin depth from Section 5.12 or cavity thickness.

5.21.2.5 In some cases ejector pin holes may require measurement if a deep hole is specified.

5.22 *Lead Spread* — (Figures 1, 7, and 7a)

5.22.1 *MDIP, SO* — (Figure 7, 7a)

5.22.1.1 *Equipment* — Optical Comparator at 10× Magnification.

5.22.1.2 Place the package squarely on the comparator with the leads "UP" and find the mid-point of the bottom cavity width.

5.22.1.3 Measure the distance to the outer edge of each row of leads at the widest point of spread.

5.22.2 PCC (J bend lead dimension) (Foot Print) Measure from perpendicular to the greatest extension of the "J" radius of the leads on one side of the package to the perpendicular tangent to the greatest extension of the "J" radius of the leads on the opposite package side. (See Figure 1.)

5.23 *Foot Angle* — (Figure 7)

NOTE: Applies to gull-wing leads.

5.23.1 *Equipment* — Optical Comparator at 20× Magnification. Device Holding Fixture (see Section 5.16).

5.23.2 Place the device in the fixture, so that the flat section of the leadframe at the junction with the plastic body rests on the fixture's flats. Leads to be facing "UP".

NOTE: Do not rest the radiused sections of the leads on the flats. Be sure that all mold flash is removed from the area of the frame that rests on the flats.

5.23.3 Measure the angle of the foot with respect to the horizontal.

5.24 *Foot Length* — (Figure 7)

NOTE: Applies to gull-wing leads.

5.24.1 *Equipment* — Optical Comparator at 20× Magnification. Device Holding Fixture (see Section 5.23).

5.24.2 While the foot angle is being measured, place a circle template that contains the same radius as the formed part onto the comparator. Align this template to the radius of the outside bend. Where the radius of the template meets the radius of the outside bend, this is the tangent point to measure foot length.

5.25 *Stand-Off*

5.25.1 Measure the plastic stand-off, when applicable, using the procedures of Section 5.12.

5.26 *Lead Sweep*

5.26.1 *Equipment* — Toolmaker's Microscope or Optical Comparator.

5.26.2 *Method*

5.26.2.1 Determine centerline of lead at egress of lead from molded body (CL1) (see Figure 4).

5.26.2.2 Determine centerline at the end of the lead (CL2). The difference between the two centerlines CL2 – CL1, shall be the lead sweep.

NOTE: On "J" lead devices, the end of the lead is defined as the bottom of the "J" lead radius.

5.26.3 *Cautionary Notes*

5.26.3.1 Verify centerlines on leadframe before measuring to ensure lead-frame is correct.

5.26.3.2 Verify lead position in relation to the top cavity centerline.

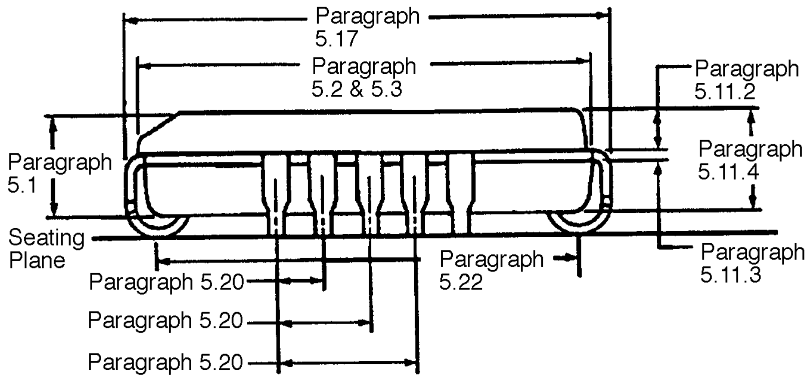

Figure 1

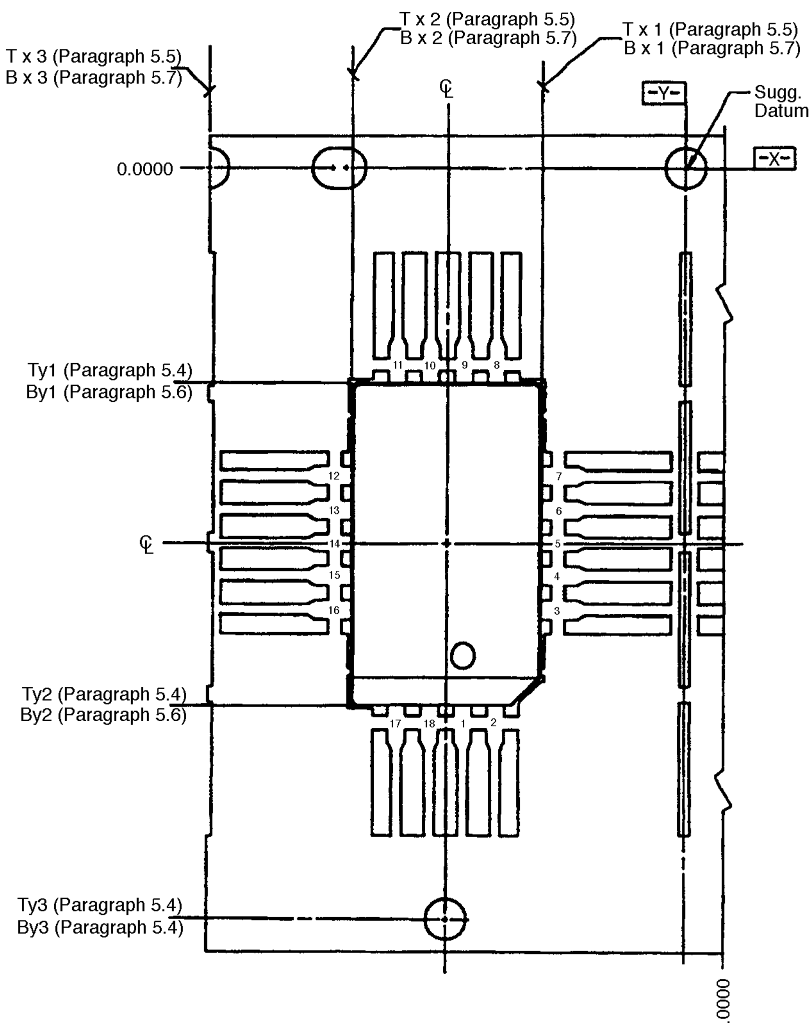

Figure 2

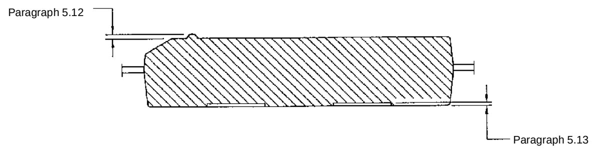

Figure 3

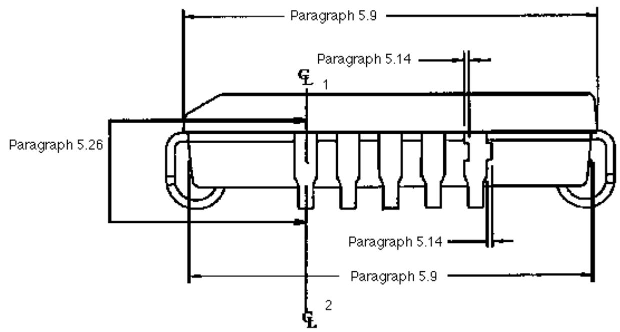

Figure 4

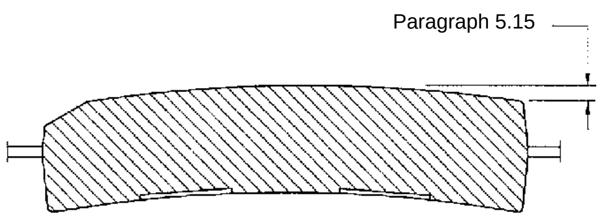

Figure 5

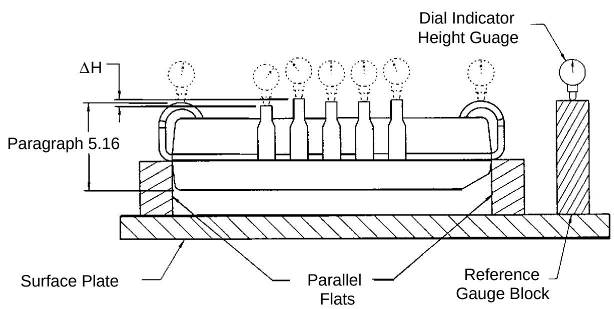

Figure 6

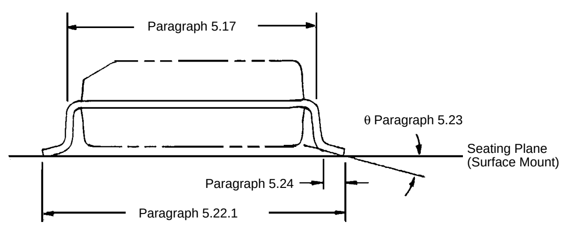

Figure 7

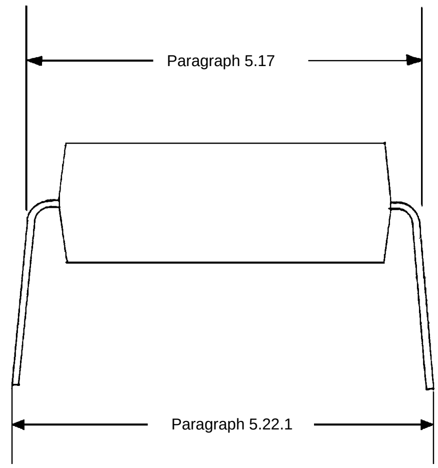

Figure 7A

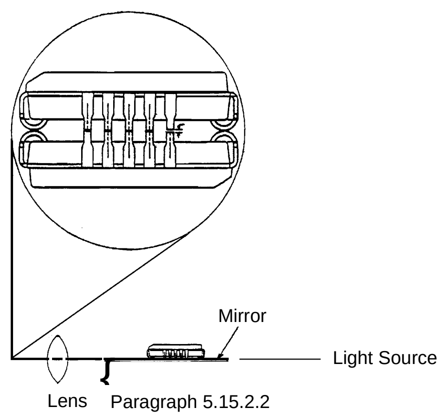

Figure 8

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G49-93
SPECIFICATION FOR PLASTIC MOLDING PREFORMS

1 Preface

1.1 *Scope* — This specification defines the physical requirements for preforms made with thermosetting molding compounds.

1.2 *Significance* — Consistent preform quality enhances moldability and finished product reliability.

1.3 *Units* — SI or American Customary units may be used at the customers discretion. This specification uses SI units.

2 Applicable Document

2.1 *ASTM Specification*[1]

ASTM D 792 — Specific Gravity and Density of Plastic

3 Terminology

molding preform — Mold compound powder compressed into a cylindrical shape and size with specified diameter, weight, and density.

scoring — Marks, grooves, scratches, or notches with definite length, width, and depth physical characteristics.

side porosity — Voids or holes with visible shape, size, and depth that are detected around a molding preform.

4 Ordering Information

Purchase orders for preforms furnished to this specification shall include the following items:

Molding compound name/type

Preform diameter

Preform weight

5 Preform Specification

5.1 *Appearance* — The preform appearance, considering such items as side porosity, scoring and breakage shall be defined by agreement between supplier and customer.

5.2 *Preform Density as Percentage of Molded Density*

5.2.1 *Specification* — The minimum values for Preform Density as a Percentage of Molded Density for preforms of various diameters are shown in Table 1.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

Table 1

Nominal Preform Diameter (mm)	*Percentage of Molded Density (% Minimum)*
< 16	87
> 16	85

5.2.2 *Calculation*

5.2.2.1 *Preform Density* — Measure weight, height, and diameter of preform.

Volume of approximately cylindrical preform (cm^3) =

$$\text{Height(cm)} \times \pi \times \frac{(\text{Average Diameter(cm)})^2}{4}$$

$$\text{Preform Density(g/cm}^3\text{)} = \frac{\text{Weight of Preform(g)}}{\text{Volume of Preform(cm}^3\text{)}}$$

5.2.2.2 *Molded Part Density* — Determine Molded Part Density (g/cm^3) per ASTM D 792.

5.2.2.3 *Preform Density as Percentage of Model Density.*

$$\begin{array}{c}\text{Preform Density as Percentage} \\ \text{of Molded Density (\%)}\end{array} = \frac{(\text{Preform Density})}{(\text{Molded Part Density})} \times 100$$

5.3 *Preform Diameter Tolerance* — The tolerances on preform diameters for variously sized preforms are shown in Table 2.

Table 2

Nominal Preform Diameter (mm)	*Tolerance (± mm)*
< 16	0.30
> 16	1.25

5.4 *Preform Weight Tolerance* — The weight tolerances for variously sized preforms are shown in Table 3.

Table 3

Preform Weight Range (g)	*Tolerance (± g)*
1.8—4.0	0.15
> 4.0—8.0	0.20
> 8.0—< 15.0	0.25
15—< 16	0.50
16—40	1.00
> 40—80	2.00
> 80—150	3.00
> 150	4.00

NOTE 1: The handling characteristics of some molding compounds may require tolerances different from those shown above.

6 Sampling Plan

The sampling plan for inspecting preforms and the molding parameters shall be agreed between supplier and customer.

NOTE 2: *Recommendation* — It is suggested that a minimum of three preforms be measured. On each preform, height and diameter measurements, to the nearest 0.0254 mm (0.001 inch). Preform weight measurements should be taken to the nearest 0.1 gram.

SEMI G50-89
SPECIFICATION FOR CO-FIRED CERAMIC FINE PITCH LEADED AND LEADLESS CHIP CARRIER PACKAGE CONSTRUCTIONS

1 Preface

This specification defines the standard requirements for co-fired ceramic fine pitch chip carrier constructions, including both top brazed leaded and top metallized leadless configurations. These constructions are for hermetic packaging of various devices, (e.g., high speed, digital VLSI silicon devices), and next-level interconnection to printed wiring assemblies and modules by either lead solder attachment or by “leads last” techniques.

2 Applicable Documents

2.1 *ANSI Specification*[1]

ANSI Y14.5 — Dimensioning and Tolerancing

2.2 *Federal Specification*[2]

QQ-N-290 — Nickel Plating

2.3 *JEDEC Specification*[3]

JEDEC Publication 95 — Registered and Standard Outlines for Solid State Products

2.4 *Military Specifications*

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-7883 — Brazing

MIL-I-23011 — Iron Nickel Alloys for Sealing to Glass and Ceramics

MIL-M-38510 — General Specification for Microcircuits

MIL-G-45204 — Gold Plating, Electrodeposited

3 Selected Definitions

blister (bubble) — ceramics — Any separation within the ceramic which does not expose underlying ceramic material.

blister (bubble) — metal — Any localized separation within the metallization or between the metallization and ceramic which does not expose underlying metal or ceramic material.

bond finger — A region of refractory metallization within the package cavity intended for wirebonding to a microcircuit die pad.

braze — An alloy with a melting point equal to or greater than 600°C.

burr — An adherent fragment of excess parent material at the component edge.

chip-out — A region of ceramic missing from the surface or edge of a package which does not go completely through the package. Chip-out size is given by its length, width, and depth from a projection of the design planform (see Figure 1).

co-fired — A process or technology for manufacturing products in which the ceramic and refractory metallization are fired simultaneously.

contact pad — That metallized pattern to which the leadframe is brazed.

crack — A cleavage or fracture, internal or external.

die-attach surface — A designated dimensional outline area intended for die attach (see Figure 1).

foreign material — An adherent particle other than parent material of that component.

laver — A dielectric sheet with or without metallization that performs a discrete function as part of the package construction.

lead offset — Lead centerlines must be aligned to within 0.254 mm (0.010") of the centerline of corresponding braze pad metallizations.

peeling (flaking) — Any separation from the basis material that exposes the basis material.

projection — An adherent fragment of excess material on the component surface.

pullback — The linear distance between the edge of the ceramic and the first measurable metallization surface (see Figure 3).

rundown — The linear distance down a vertical surface from the top to the point of maximum metallization over-hand (see Figure 3).

1 ANSI, 1430 Broadway, New York, NY 10018

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

3 JEDEC, 2001 Eye Street, N.W., Washington, D.C. 20006

seal area — A dimensional outline area designated for either metallization or base ceramic to provide a surface area for lid sealing (see Figure 2).

terminal — Metallization at the point of electrical contact to package interior circuitry; also the brazing surface for a lead.

TIR — Total indicator reading; the span of readings, from minimum to maximum, of a given dimension over the total surface it applied to.

voids (ceramics) — An absence of screen printed ceramic from a designated area greater than 0.75 mm (0.003") in diameter.

metal — An absence of refractory metallization, braze, or plating material from a designated area greater than 0.075 mm (0.003") in diameter.

4 Ordering Information

4.1 Purchase orders for co-fired ceramic packaged devices shall specify the following information:

1. Quantity
2. Drawing number and revision level or date
3. Reference to this specification
4. Any exception to drawing or specification

4.2 Drawings for co-fired ceramic packaged devices shall specify the following information:

1. Drawing number and revision level
2. Number of terminals and terminal centerline spacing
3. Lead material, finish, and dimensions, if applicable
4. Ceramic material color and composition; and refractory metal type
5. Type and thickness of plating on both device body and leads, if applicable
6. Dimensioning and tolerancing per ANSI Y14.5
7. Internal bonding pattern
8. Lead number 1 position
9. Method of test and measurements
10. Electrical, mechanical, and environmental requirements

5 Dimensions and Permissible Variations

Packaged device dimensions shall conform to JEDEC JC-11 registered outline dimension drawings for co-fired ceramic fine pitch leaded and leadless chip carriers, unless otherwise specified.

6 Materials

6.1 *Ceramic*

6.1.1 Alumina content to be 90% minimum. Beryllia content to be 99% minimum.

6.1.2 Color to be black, dark brown, or dark violet unless otherwise specified.

6.2 *Metals* — External metal surfaces shall be in accordance with MIL-M-38510.

6.3 *Braze* — Copper/silver per MIL-STD-7883.

6.4 *Refractory Metallization* — To be per MIL-M-38510, Type C.

6.5 *Leadframe* — Fully annealed iron nickel cobalt alloy (per MIL-M-38410, Type A) or iron nickel alloy (per MIL-M-38510, Type B).

6.6 *Microcircuit Finishes* — Shall be per MlL-M-38510 unless otherwise specified.

7 Incoming Test Sequence

1. Visual inspection
2. Dimensional check
3. Electrical parameter testing
4. Sampling testing of plating quality, die attach, die shear, wire bond, pull, seal, hermeticity, lead integrity, and solderability

8 Visual Criteria (10× Magnification)

8.1 *Cracks* — None allowed per MIL-STD-883, Method 2009.

8.2 *Chips*

8.2.1 *Corner* — 0.762 mm (0.030") × 0.762 mm (0.030") × one tape layer thickness, maximum.

8.2.2 *Edge* — 0.54 mm (0.100") × 0.762 mm (0.030") × one tape layer thickness, maximum.

8.3 *Burrs, Projections, and Blisters* — Must fit within outline limit.

Top plane excluding seal area — 0.102 mm (0.004"), maximum

Unmetallized seal area — 0.0762 mm (0.003"), maximum

Metallized seal area — 0.025 mm (0.001"), maximum

Bottom surface — 0.051 mm (0.002"), maximum

Edges — 0.152 mm (0.006"), maximum

Terminal pads — 0.051 mm (0.002"), maximum

Wire bond fingers — 0.025 mm (0.001"), maximum

Die attach surface — 0.025 mm (0.001"), maximum

8.4 *Camber* — 0.004" inch/inch (mm/mm), maximum. For dimensions less than 10.05 mm (0.750"), 0.127 mm (0.003") camber is permitted along any planar dimension of the device package.

8.5 *Seal Area Flatness* — The seal area shall be flat within the limits listed in Table l.

8.6 *Die Attach Surface Flatness* — The die attach surface shall be flat within the limits listed in Table 2.

Table 1 Seal Ring Flatness Limits

Seal Ring OD		*Ring Flatness*
0–0.250"	(0–6.35 mm)	0.002" max. (0.051 mm)
0.251"–0.550"	(6.37–13.97 mm)	0.003" max. (0.076 mm)
0.501"–1.000"	(12.7–25.40 mm)	0.004" max. (0.101 mm)
> 1.000"	(> 25.40 mm)	0.004"/inch (0.101 mm/mm)

Table 2 Die Attach Area Flatness Limits

Die Attach Pad Dimension		*TIR Flatness*
0–0.500"	(0–12.7 mm)	0.002" max. (0.051 mm)
0.501"–0.750"	(12.7–19.5 mm)	0.003" max. (0.076 mm)

8.7 *Voids*

8.7.1 *Seal Area Void* — A maximum of three voids permitted. Not more than two voids per side of 0.010" diameter. Any two voids must be separated by 0.762 mm (0.010") minimum, not to degrade the seal width by more than 25%.

8.7.2 *Terminal Void* — A maximum of two voids per terminal pad permissible. Maximum void diameter acceptable is 0.127 mm (0.005"). Voids may never reduce the minimum terminal width to less than two-thirds of the nominal design dimension.

8.7.3 *Wire Bond Finger Void* — Void free 0.015" back from the bond finger tip.

8.7.4 *Die Attach Surface Voids* — Three voids of 0.010" diameter are the maximum allowed separated by 0.030" minimum.

NOTE: Voids within 0.015" of the cavity wall not included.

8.7.5 *Internal Metallization Voids* — Voids in internal metallization planes or traces shall not break continuity. Specific requirements for resistance and capacitance parameters shall be specified in the purchase order, if applicable.

8.8 *Pattern Metallizations*

8.8.1 *Seal Plane Rundown (internal cavity)* — Not to exceed 25% of the cavity layer thickness.

8.8.2 *Seal Plane Rundown (external to cavity)* — Not to exceed half the nominal design distance to adjacent edge metallization. In no event shall the rundown be closer than 0.254 mm (0.010") to any edge metalization.

8.8.3 *Wire Bond Rundown* — Wire bond finger rundown shall not exceed 25% of the cavity depth or 0.127 mm (0.005"), whichever is smaller.

8.8.4 *Wire Bond Finger Pullback* — Wire bond finger pullback shall not exceed 0.127 mm (0.005") from the nominal design dimension for finger end to cavity edge.

8.8.5 *Seal Plane Pullback* — Seal plane pullback shall not exceed 0.127 mm (0.005") from the nominal design dimension for seal plane metallization to edge.

8.9 *Lead Attachment (when applicable)*

8.9.1 *Voids in Braze* — Braze fillets must be 95% free of voids.

8.9.2 *Lead Alignment* — Brazed leads shall not overhang braze pads.

8.9.3 *Lead Offset* — Lead centerlines must be aligned to within 0.0762 mm (0.003") of the centerlines of corresponding braze pad metallizations.

8.9.4 *Lead-to-Lead Misalignment* — Not to exceed 10% of nominal spacing.

8.9.5 *Dimensional Criteria* — Per JEDEC JC-11 registered outline drawings in JEDEC Publication 95, or as specified on the user drawings.

9 Sampling

Sample sizes must meet requirements of MIL-STD-105 or MIL-M-38510 as agreed to between vendor and customer.

10 Test Methods (Mechanical, Electrical, and Thermal)

10.1 *Gold Plating Thickness* — Shall conform to MIL-G-45204. Gold thickness may be determined using the Beta Backscatter Radiation Method or x-ray fluorescence.

10.2 *Nickel Plating* — Shall conform to QQ-N-290. Nickel thickness may be determined using the Beta Backscatter Radiation Method or x-ray fluorescence.

10.3 *Destructive Die Shear Testing* — Shall be performed per Method 2019 of MIL-STD-883.

10.4 *Wire Bond Pill Testing* — Shall be performed per Method 2011, Condition D of MIL-STD-883.

10.5 *Temperature Cycling Testing* — Shall be performed per Method 1010, Condition C of MIL-STD-883.

10.6 *Thermal Shock Testing* — Shall be performed per Method 1011, Condition C of MIL-STD-883.

10.7 *Constant Acceleration Testing* — Shall be performed per Method 2001, Condition E, Y axis only, of MIL-STD-883.

10.8 *Mechanical Shock Testing* — Shall be performed per Method 2002 of MIL-STD-883.

10.9 *Insulation Resistance Testing* — Shall be performed per Method 2002 of MIL-STD-883.

10.10 *Internal Water Vapor Content Testing* — Shall be performed per Method 1018 of MIL-STD-883.

10.11 *Hermeticity Testing* — Shall be performed per Method 1014, Condition A of MIL-STD-883. The hermetic integrity of the packaged device must be maintained after all testing.

10.12 *Lead Integrity Testing* — Shall be performed per Method 2004, Condition A, B1, and B2 of MIL-STD-883.

10.13 *Solderability Testing* — Shall be performed per Method 2003 of MIL-STD-883.

10.14 *Moisture Resistance* — Shall be performed per Method 2003 of MIL-STD-883.

11 Packaging and Marking

11.1 *Packing* — Containers selected shall be strong enough and suitably designed to provide maximum protection against crushing, spillage, and other forms of damage to the container or its contents. Containers shall afford protection of the contents to contamination from exposure to excessive moisture or oxidation by gases. Packaging materials shall be so selected to prevent any contamination of the ceramic component part with paper fibers or organic particles.

11.2 *Marking* — The outer containers shall be clearly marked identifying:

1. Vendor part number
2. Customer part number
3. Quantity
4. Date of manufacture
5. Vendor lot number

12 Applicability

This specification is intended to apply to packages fabricated to the outline requirements for the fine pitch leaded and leadless chip carriers included in JEDEC Publication 95.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G51-90
SPECIFICATION FOR PLASTIC MOLDED (METRIC) QUAD FLAT PACK LEADFRAMES

1 Preface

This specification defines the acceptance criteria for leadframes designed for assembly of JEDEC proposed registered Publication 95 Standard Outlines for the Metric Quad Flat Pack Family Packages. It is a design guideline for packaging engineers, leadframe stampers and etchers, and mold and trim/form tooling manufacturers. It has been developed to meet the requirements of assemblers using automatic and manual equipment.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering tooling shall be as follows:

Purchase Order

This Specification

Referenced Documents

2.2 *Reference Documents*

2.2.1 *SEMI Specifications*

SEMI G4 — Specification for Integrated Circuit Leadframe Materials Used in the Production of Stamped Frames

SEMI G10 — Standard Method Mechanical Measurement for Plastic Package Leadframes

SEMI G18 — Specification for Integrated Circuit Leadframe Material Used in the Production of Etched Frames

SEMI G21 — Specification, Plating Integrated Circuit Leadframes

2.2.2 *ANSI Specification*[1]

S Y 14.5 M-1982 — Dimensioning and Tolerancing

2.2.3 *JEDEC Specification*[2]

Reg.Prop. 11-286 — Metric Quad Flat Pack Family (Gullwing)

2.2.4 *Military Specification*[3]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

3 Selected Definitions

burr — a fragment of excess material either horizontal or vertical attached to the leadframe.

camber — curvature of the leadframe strip edge (see Figure 1).

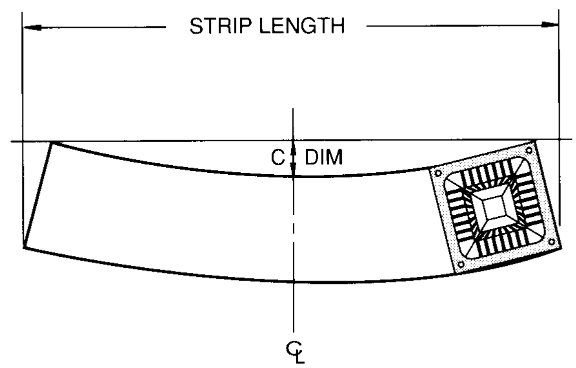


Figure 1
Camber

coil set — longitudinal bowing of the leadframe (see Figure 2).

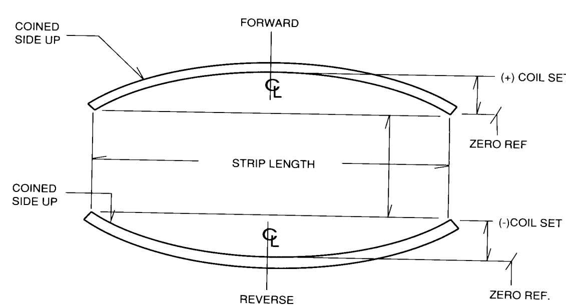


Figure 2
Coil Set

coined area — that area at the tip end of the bond fingers coined to produce a flattened area for functional use (see Figure 3).

1 ANSI, 1430 Broadway, New York, NY 10018

2 JEDEC, 2001 Eye Street N.W., Washington, D.C. 20006

3 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

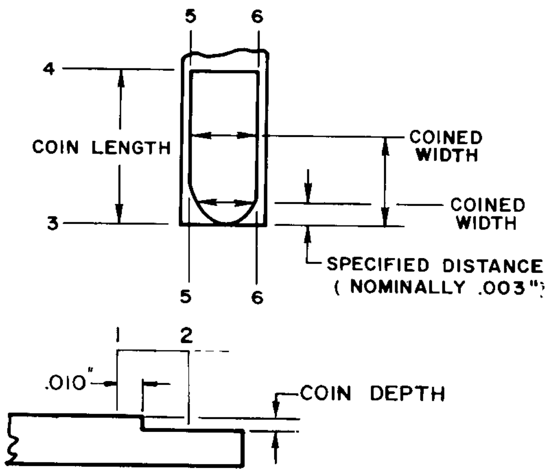


Figure 3
Coined Area

crossbow — Transverse bowing of the leadframe (see Figure 4).

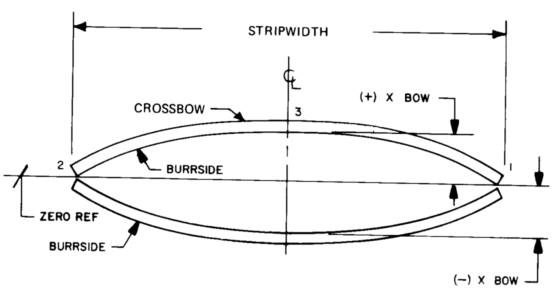


Figure 4
Crossbow

lead twist — Angular rotation of bonding fingers (see Figure 5).

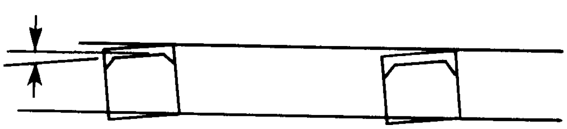


Figure 5
Lead Twist

pits — Shallow surface depressions or craters in the leadframe material.

true position circle — That circle with its center positioned at the center of the coined lead defines the design position of the lead tip.

4 Ordering Information

Purchasing orders for leadframes for plastic Molded Quad Flat Pack packages furnished to this specification shall include the following items:

4.1 Drawing number and revision level.

4.2 Material alloy specification.

4.3 Lead count, and confirming number of units per strip.

4.4 Requirement for material certification.

4.5 Leadframe plating specifications.

5 Dimensions

5.1 Tables I, II.

5.2 See Figure 6 and Detail A.

6 Defect Limits and Parameters

(To measure, see SEMI G10).

6.1 *Lead Tip Width*

6.1.1 *Minimum Lead Tip Width* — Shall be as agreed to between supplier and purchaser.

6.1.2 *Minimum Flat Wire Bonding Area* — 80% of nominal lead width and 0.635 mm (0.025") in length.

NOTE: This applies to stamped frames; percent of nominal lead width for etched frames must be determined between purchaser and supplier and is dependent on etch tolerances.

6.2 *Coining and Metal Clearance*

6.2.1 If coined, maximum depth = 30% material thickness. Minimum depth as agreed to between supplier and purchaser.

6.2.2 On stamped frames, dimensions shown on drawings are before coining.

6.2.3 *Metal-to-Metal Clearance* — Shall be as agreed to between supplier and purchaser.

6.3 *Lead Twist* — Shall not exceed 3.5 or 0.015 mm (0.0006") per 0.254 mm (0.010") of lead width.

6.4 *Burrs* — Shall be firmly attached and able to withstand a probe force of 10 grams. All burrs vertical and horizontal in any location shall not exceed 0.0254 mm (0.001").

6.5 *Die Pad Tilt and Flatness* — (See specification SEMI G10 for measurement method).

6.5.1 *Tilt* — 0.025 mm (0.001") maximum per 2.54 mm (0.100") of length or width in the undepressed state, and 0.051 mm (0.002") maximum per 4.06 mm (0.160") of length or width in the depressed state, when measuring corner to corner: Overall maximum not to exceed a total of 0.102 mm (0.004").

6.6 *Pits and Slug Marks*

6.6.1 Within the functional area and on external leads, no slug marks and pits shall exceed 0.008 mm (0.0003") in depth and 0.0127 mm (0.0005") in length.

NOTE: There is a question regarding the ability of material suppliers to meet this specification. Revision of this specification is under review.

6.6.2 They shall not exceed 0.0254 mm (0.001") in depth and 0.051 mm (0.002") in length in nonfunctional areas.

6.7 *Material Thickness* — 0.150 mm (0.0059") ± 0.005 mm (0.0002") for all lead counts.

6.8 *Internal Position Tolerance* — The centerline of all leadframe features must be within T.P.T. 0.051 mm (0.002") relative to centerline of pilot holes on rail.

6.9 *Lead Tip Coplanarity* — Shall be within the following tolerances as measured relative to the Z datum plane located at the center of the die attach pad or per SEMI G10 measurement method:

44–52 lead counts: ± 0.10 mm (0.004")

64–100 lead counts: ± 0.15 mm (0.006")

120–232 lead counts: ± 0.20 mm (0.008")

6.10 *Progression*

6.10.1 Single progression of one frame is T.P.T. 0.051 mm (0.002").

6.10.2 Accumulated progression tolerance over the strip length (measured from pitch line tooling hole to pitch line tooling hole, across the strip length minus the two end units) is within T.P.T. of 0.102 mm (0.004").

6.11 *Strip Cut Off Location* — Shall be within T.P.T. 0.154 mm (0.006") of nominal strip length.

6.12 *Strip Width Tolerance* — T.P.T. 0.102 mm (0.004").

6.13 *Camber* — Shall not exceed 0.051 mm (0.002") over the nominal strip length.

6.14 *Coil Set* — Maximum of 0.508 mm (0.020") over the nominal strip length. This does not include material thickness.

6.15 *Cross Bow* — Shall not exceed 0.7% of the nominal strip width.

6.16 External nominal lead width dimension will be as follows for each respective lead pitch requirement:

1.0 mm lead pitch: 0.4 mm (stamped or etched)
8 mm lead pitch: 35 mm (stamped or etched)
65 mm lead pitch: 0.27 mm (etched)
3 mm (stamped)

Please note that specific etching and stamping tolerances associated with lead widths are to be negotiated and specified between purchaser and supplier.

PLEASE NOTE: THESE SPECIFICATION DIMENSIONS AND CRITICAL TOLERANCES, UNLESS OTHERWISE NOTED, APPLY TO ALL ALLOY 42, COPPER ALLOY, ETCHED AND STAMPED LEADFRAME MATERIALS.

7 Sampling

A sampling plan and buy-off procedure to determine compliance to the requirements of Sections 5 and 6 and other relevant specifications shall be determined between vendor and customer.

8 Packaging and Marking

8.1 *Packaging* — Tooling must be packed in containers designed and constructed to provide protection against normal transportation damage risks and spillage. The container will offer protection from contamination and exposure to moisture.

8.2 *Marking* — The following details shall be noted on the packing slip:

Quantity and Description

Vendor Lot Numbers

Vendor Part Number

Customer Drawing Numbers

Customer Part Number

Shipping Date

Customer P.O. Number

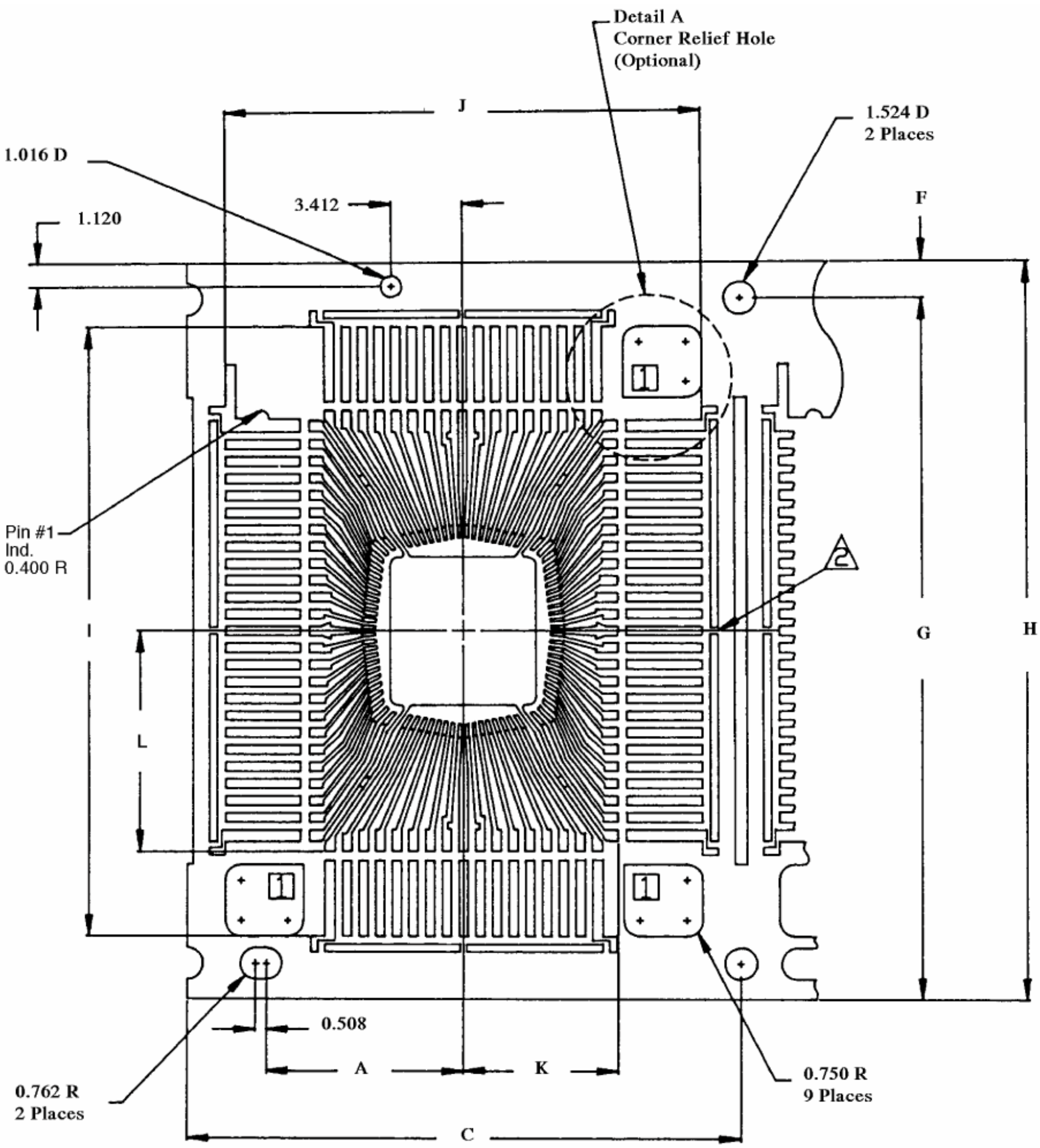


Figure 6
Frame Unit

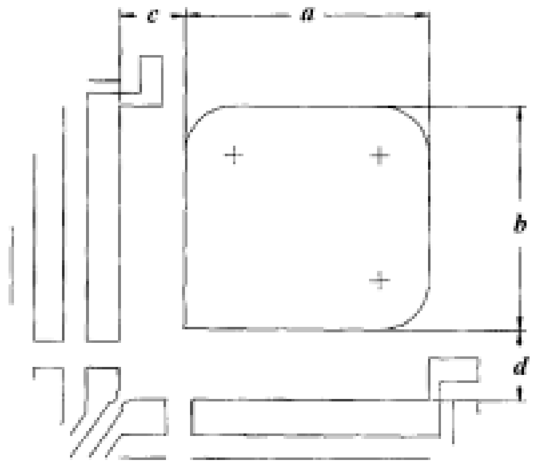
1. Corner relief holes are optional features only. Gating may require their exclusion.

2. Lead counts 100 and below have only 1 support tab per each frame expansion slot. Lead counts 120 and above have 3 support tabs evenly spaced for each frame expansion slot. Tabs are to be placed opposite the space.

Table 1 Leadframe Standard Dimensions

LEAD COUNT	*44*	*52*	*52*	*64*	*80*	*64*	*80*
PACKAGE SHAPE	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE	RECT	RECT.
NOMINAL PACKAGE WIDTH (mm)	10.0	10.0	14.0	14.0	14.0	14.0	14.0
NOMINAL PACKAGE LENGTH (mm)	10.0	10.0	14.0	14.0	14.0	20.0	20.0
STRIP LENGTH (mm)	171.2	171.2	158.52	158.52	158.52	158.52	158.5
NO. OF UNITS PER STRIP	8	8	6	6	6	6	6
TOOLING DIM A (mm)	7.5	7.5	9.45	9.45	9.45	9.45	9.45
(PROGRESS) C (mm)	21.4	21.4	26.42	26.42	26.42	26.42	26.42
F (mm)	1.5	1.5	1.7	1.7	1.7	1.7	1.7
G (mm)	23.2	23.2	26.0	26.0	26.0	33.1	33.1
(STRIP WIDTH) H (mm)	24.7	24.7	27.7	27.7	27.7	34.8	34.8
I (mm)	20.0	20.0	22.82	22.82	22.82	28.8	28.8
J (mm)	20.0	20.0	22.82	22.82	22.82	22.82	22.82
K (mm)	5.18	5.18	7.18	7.18	7.18	7.18	7.18
L (mm)	5.18	5.18	7.18	7.18	7.18	10.18	10.18
DAMBAR WIDTH (mm)	0.4	0.4	0.4	0.4	0.4	0.4	0.4
EXP. SLOT WIDTH (mm)							
1) BETWEEN FRAMES	1)0.3	1)0.3	1)0.6	1)0.6	1)0.6	1)0.6	1)0.6
2) END OF SHT BAR	2)0.15	2)0.15	2)0.38	2)0.38	2)0.38	2)0.38	2)0.38
METAL THICKNESS (mm)	0.15	0.15	0.15	0.15	0.15	0.15	0.15
EXTERNAL LEAD Pitch (mm)	0.8	0.65	1.0	0.8	0.65	1.0	0.8

LEADCOUNT	*100*	*120*	*128*	*144*	*160*	*184*	*196*	*232*
PACKAGE SHAPE	RECT.	SQUARE	SQUARE	SQUARE	SQUARE	SQUARE	RECT.	SQUARE
NOMINAL PACKAGE WIDTH (mm)	14.0	28.0	28.0	28.0	28.0	32.0	28.0	40.0
NOMINAL PACKAGE LENGTH (mm)	20.0	28.0	28.8	28.0	28.0	32.0	40.0	40.0
STRIP LENGTH (mm)	158.52	200.0	200.0	200.0	200.0	200.0	200.0	248.0
NO. OF UNITS PER STRIP	6	4	4	4	4	4	4	4
TOOLING DIM A (mm)	9.45	18.8	18.8	18.8	18.8	18.8	18.8	18.8
(PROGRESS) C (mm)	26.42	50.0	50.0	50.0	50.0	50.0	50.0	62.0
F (mm)	1.7	3.5	3.5	3.5	3.5	3.5	3.5	3.5
G (mm)	33.1	57.9	57.9	57.9	57.9	57.9	57.9	57.9
(STRIP WIDTH) (mm)H	34.8	61.4	61.4	61.4	61.4	61.4	61.4	61.4
I (mm)	28.8	37.2	37.2	37.2	37.2	37.6	49. 8	49.2
J (mm)	22.82	37.2	37.2	37.2	37.2	37.6	37.8	49.2
K (mm)	7.18	14.18	14.18	14.18	14.18	16.18	14.18	20.18
L (mm)	10.18	14.18	14.18	14.18	14.18	16.18	20.18	20.18
DAMBAR WIDTH (mm)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
EXP. SLOT WIDTH (mm)								
1) BETWEEN FRAMES	1)0.6	1)3.6	1)3.6	1)3.6	1)3.6	1)3.6	1)0.4	1)3.6
2) END OF SHT BAR	2)0.38	2)2.0	2)2.0	2)2.0	2)2.0	2)2.0	2)0.4	2)2.0
METAL THICKNESS (mm)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
EXTERNAL LEAD PITCH (mm)	0.65	0.8	0.8	0.65	0.65	0.65	0.65	0.65



Detail A
Corner Relief Hole (Optional)

Table 2 Leadframe Standard Dimensions

LEADS	*PKG. BODY*	*a*	*b*	*c*	*d*
44	10 × 10	4.200	3.800	1.170	1.170
52	10 × 10	4.200	3.800	1.170	1.170
52	14 × 14	3.735	3.00	0.995	1.075
64	14 × 14	3.735	3.00	0.995	1.075
80	14 × 14	3.735	3.00	0.995	1.075
64	14 × 40	3.735	3.400	0.995	1.075
80	14 × 20	3.735	3.400	0.995	1.075
100	14 × 20	3.735	3.400	0.995	1.075
120	28 × 28	6.600	8.840	1.610	1.610
128	28 × 28	6.600	8.840	1.610	1.610
144	28 × 28	6.600	8.840	1.610	1.610
160	28 × 28	6.600	8.840	1.610	1.610
184	32 × 32	6.600	8.840	1.610	1.610
196	28 × 40	6.600	8.840	1.610	1.610
232	40 × 40	6.600	8.840	1.610	1.610

SEMI G52-90
STANDARD TEST METHOD FOR MEASUREMENT OF IONIC CONTAMINATION ON SEMICONDUCTOR LEADFRAMES (PROPOSED)

NOTE: Japan, Europe, and US task forces are planning to develop test methods which will address the different levels of ionic contamination on leadframes.

1 Scope

This standard describes the procedure to determine ionic contamination on leadframes using a water extraction method. The method is sensitive to Na^+, NH_4+, K^+, Cl^-, NO_3-, Br^-, $SO_4$2-, $PO_4$3-.

2 Applicable Documents

2.1 *ASTM Specifications*[1]

D 4327 — Anions in Water by Ion Chromatography

D 1193 — Specification for Reagent Water

3 Summary of Method

Ionic contamination is extracted in water at > 95°C for 30 ± 2 minutes. The contamination is quantitatively analyzed by ion type using Ion Chromatography and the result is presented as nanograms/unit area.

4 Significance

4.1 Contamination on leadframes can contribute to semiconductor device reliability problems. This method may be used by lead frame manufacturers at outgoing inspection and by users at incoming inspection. Correlation of device reliability with contamination levels may lead to improved leadframe cleaning processes.

5 Selected Definitions

5.1 *eluent* — the solvent used to carry the extracted ions through the ion exchange chromatograph.

5.2 *regenerant* — a chemical solution containing the ions originally present in the chromatograph column prior to a test run and used to prepare the column for a new test.

5.3 *standard solution* — a solution containing a known concentration of the ion to be measured and used to calibrate the chromatograph.

5.4 *retention time* — the time required for a particular ion type to pass from the injection port to the detector. Retention time is characteristically different for each ion type.

6 Equipment

6.1 Ion chromatograph for anion and cation analysis. This equipment is to consist of a concentration pump, guard column, separator column, and a detector module consisting of a suppressor device to reduce the background eluent conductivity to a low level and a conductivity cell. The minimum sensitivity of the chromatograph for each ion type is defined in Table 1.

6.2 *Chart Recorder*

6.3 *Ion Extraction Vessels* — Polypropylene or teflon containers with sealing caps, or polypropylene/ polyethylene double layered bags.

Note: The contamination level of these vessels must be less than one-fifth (1/5) of the expected contamination level on the leadframes when measured in a control test.

6.4 Hot bar bag sealer.

6.5 Water bath, 300 mmL × 300 mmW × 200 mmH, filled with DI water, and capable of holding 95°C.

6.6 *Volumetric Dispenser (e.g., Pipettes)* — 10 ml and 100 ml capacity.

6.7 *Quartz Flasks and Pipettes for Cation Standard Solutions* — 100, 250, 500, and 1000 ml capacity (flasks); 1, 10, and 25 ml capacity (pipettes).

6.8 *Borosilicate Glass flasks and Pipettes for Anion Standard Solutions* — 100, 250, 500, and 100 ml capacity (flasks); 1, 10, and 25 ml capacity (pipettes).

6.9 *Chemical Balance, Weighing Chemicals*

6.10 *Scissors, Tweezers, Spatula*

7 Reagents and Materials

7.1 Deionized water, resistivity ≥ 15 megohm centimeters at 25°C per ASTM D 1193.

7.2 Eluents and regenerants for specific chromatograph columns prepared per chromatograph equipment manufacturer's recommendations so that the water peak can be separated from the ionic peaks.

7.3 *Compounds for Cation Standard Solutions* — NaCl, NH_4Cl, KC1.

7.3.1 *Compounds for Anion Standard Solutions* — NaCl, Na_2HPO_4, $12H_2O$, NaBr, $NaNO_3$, K_2SO_4.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

NOTE: All compounds are to be reagent grade.

8 Sampling

8.1 The leadframes must not be touched, except with previously cleaned tweezers or double-layered cotton gloves with polyethylene outer gloves in order to avoid additional contamination.

8.2 The sample size (i.e., the number of frames to be tested in this destructive test) may be determined by agreement between the customer and the vendor. The recommended sample sizes are 10–50 cm^2 for testing pads and 200–500 cm for the test of overall leadframes.

NOTE: The surface area of the frame is calculated from the leadframe drawing, and includes the top, bottom and side surfaces. It is important that user and supplier agree on the surface area calculation for any given leadframe configuration.

9 Preparation of Standard — Solutions and Chromatograph Calibration

9.1 *Standard Solutions*

9.1.1 The single-ingredient standard solutions of each ion (Na^+, NH_4+, K^+; C^1, No_3-,Br^-, $SO_4$2-, $PO_4$3-) are made by dissolving 1.000 g of each ion into 1.000 liter of D.I. water, respectively. The stored multi-ingredient standard solutions shown in Table 2 are then made form these single-ingredient standard solutions by the dilution method.

9.1.2 Cation and anion standard solutions for calibration are made by diluting the stored multi-ingredient standard solutions as shown in Table 2.

9.1.3 Store the multi-ingredient standard solution and the calibration solutions in the correct flasks and label with the ion type and concentration.

NOTE: New standard solutions for calibration are required every 24 hours. Ensure that the flasks are cleaned with water before refilling with a new solution.

9.2 *Calibration*

9.2.1 Set up the chromatograph and regenerate the columns according to the manufacturer's instructions (ASTM D 4327 provides further details).

9.2.2 Run the eluent through the chromatograph until a stable baseline chromatograph is obtained.

9.2.3 Select the infection volume recommended by the manufacturer for each ion type and inject in to the chromatograph. Record the chromatograph for each ion type (see Figure 1), and make the calibration curve for each ion (ion concentration versus peak height or area).

NOTE: Peak height or area under the ion's characteristic curve is proportional to the concentration.

10 Procedure — Bag Extraction Method

10.1 *Preparation of Extraction Bags*

10.1.1 Add 100 ml of DI water to the polypropylene/polyethylene double layered bag and seal them with the hot bar bag sealer. The amount of air in the bags should be reduced as much as possible before sealing.

NOTE: Two bags are required for each test and must come from the same manufacturing lot.

10.1.2 Place the bags in the water bath at T > 95°C for 2 hours ± 5 minutes.

10.1.3 Allow the bags to reach room temperature but leave sealed until ready for use at which time open the bags (use clean scissors for the bags) and rinse out five (5) times with DI water.

10.2 *Extraction Process*

10.2.1 Place the samples in the bags. Cover the frames with a known volume of water (e.g., 100 ml and then seal the bags). Also, place a similar amount of water in an empty bag and seal.

NOTE: The amount of air in the bags should be reduced as much as possible before sealing. The bags that only contain water provide the background contamination of the bag. Do not select the frames or remove them from their shipping container until ready to test the surface contamination. The recommended volume of water is 10–30 ml for the testing die pads only and 100 ml for testing complete leadframes. Lead frames should be bent after sealing so that the water is in contact with all surfaces.

10.2.2 Place the bags in the water bath at T > 95°C for 30 ± 2 minutes.

10.2.3 Remove the bags from the bath and allow to reach room temperature.

10.2.4 The lead frames, which are inside the sealed bags, are moved to one side of the bags without opening the bags. Then the solution is separated from leadframes by sealing the mean portion of the bags without opening.

11 Procedure — Container Extraction Method

NOTE: The size of the containers to be used depends on the expected volume of water and the leadframes. The container must be at least three-quarters filled with the water and leadframes.

11.1 *Preparation of Extraction Vessels*

11.1.1 Fill the containers with DI water and attach the caps. In order to reduce the amount of air in the vessel, fill vessels to the amount of three-quarter.

NOTE: Two containers are required for each test and must come from the same manufacturing batch.

11.1.2 Place the containers in the water bath at T > 95°C for 2 hours ± 5 minutes.

11.1.3 Remove the containers from the bath and rinse out five (5) times with DI water.

11.2 *Process*

11.2.1 Place the samples in one of the containers cleaned per Section 11.1.1.

NOTE: Leadframes may be cut or rolled in order to ease loading to the container. Die pads may be tested separately, if desired, by cutting from the leadframes.

Add the required volume of DI water and cap the container. Place a similar amount of water into the other cleaned container and attach the cap.

NOTE: Do not select the frames or remove them from their shipping container until ready to test for the surface contamination. Recommended volumes of water are 10 – 30 ml for testing die pads only and 100 ml for the entire leadframe — samples must be covered by water.

11.2.2 Place the containers in the water bath at T > 95°C for 30 ± 2 minutes.

11.2.3 Remove the containers from the bath and allow to reach room temperature.

11.2.4 Remove the leadframes from the container and cap it again.

12 Measurements

12.1 Prepare the chromatograph for operation by regenerating the columns according to the manufacturer's recommendations.

12.2 Run the eluent through the chromatograph until a stable baseline calibration is established.

12.3 Inject the recommended sample size of test solution into the chromatograph and record the ion chromatogram.

12.4 Repeat for all the samples and also run the background sample.

Note: The time from extraction to insertion of sample is to be within eight hours.

12.5 Sample concentrations are determined from the calibration curves for each ion type.

12.6 The surface concentration of ionic contaminants for each ion type (SCIC) is given by the following equation:

$$\text{SCIC}\left(\text{ng/cm}^2\right) = \frac{(\text{Sample conc. - Background conc.}) \times \text{Extraction Volume (mL)}}{\text{Leadframe Surface Area}\left(\text{cm}^2\right) \times \text{No. of Leadframes}}$$

NOTE: Allowable concentration levels are to be agreed between the user and supplier.

Table 1 Sensitivity of Ion Chromatograph

	Ion	*Sensitivity (ng/ml)*
Cation	Na^+	0.2
	NH_4+	0.5
	K^+	1.0
Anion	Cl^-	0.3
	PO_4-	2.0
	Br^-	1.0
	NO_3-	1.0
	SO_4-	1.0

Table 2 Concentration of Standard Solution for Calibration

Ion	*Mixed Standard Solution (ug/ml)*		*Standard Solution for Calibration(ng/ml)*		
			I	*II*	*III*
Cation	Na^+	10	5	10	20
	NH_4+	10	5	10	20
	K	10	5	10	20
Anion	Cl^-	4	10	20	40
	PO_{4---}	10	25	50	100
	Br^-	4	10	20	40
	NO_{3--}	4	10	20	40
	SO_{4--}	4	10	20	40

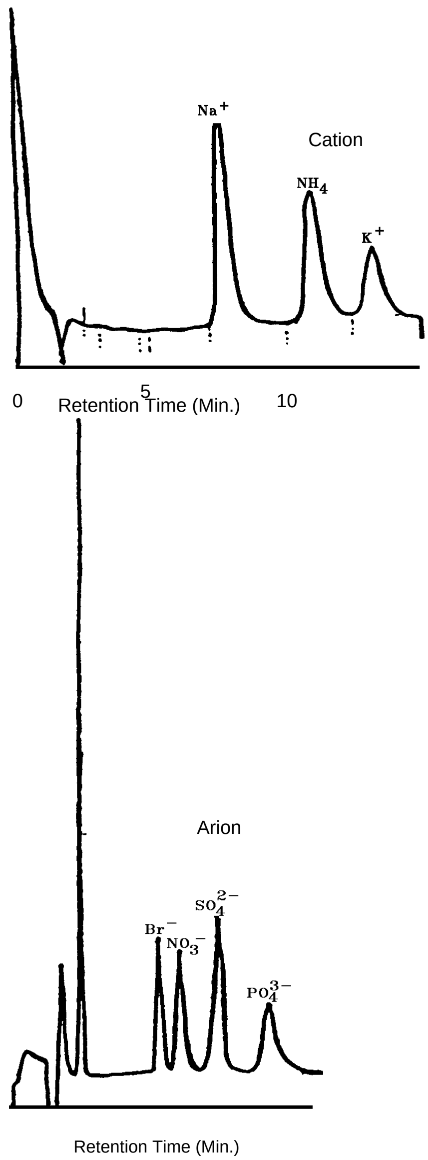


Figure 1
Schematic of Ion Chromatograph

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SEMI G53-92
SPECIFICATION FOR METAL LID/PREFORM ASSEMBLY

1 Preface

1.1 *Scope* — This specification provides guidelines for the design and acceptance of metal lid/preform assemblies (see Figure 1). This specification may be used by suppliers at outgoing inspection and by the customers at incoming inspection.

The design and acceptance criteria may be used for metal lid/preform assemblies used on all types of semiconductor packages.

1.2 *Significance* — Improper lid/preform design and poorly specified lid/preforms contributes to low sealing yields and unreliable devices.

1.3 *Units* — U.S. Customary (inch-pound) or SI (metric) units may be used at the customer's discretion. This specification uses U.S. Customary units as the prime unit.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering metal lid-preform assemblies shall be as follows:

Purchase Order

Customer's Lid-Preform Drawing

This Specification

Reference Documents

Related Documents

2.2 *Referenced Documents*

2.2.1 *Military and Federal Specifications*[1]

MIL-STD 883 — Test Methods and Procedures for Microelectronics

MIL-M-38510 — General Specification for Microcircuits

2.2.2 *ANSI Specification*[2]

Y14.5M — Dimensioning and Tolerancing

2.2.3 *ASTM Specification*[3]

B 568 — Measurement of Coating Thickness by X-Ray Spectrometry

E 10 — Standard Test Method for Brinell Hardness of Metallic Materials

E 384 — Standard Test Method for Microhardness of Materials

E 29 — Practice for Using Significant Digits in Test Data to Determine Conformance to Specifications

E 1182 — Measurement of Surface Layer Thickness by Radial Sectioning

3 Definitions

blister — any enclosed localized separation of the plating from the base material or from another layer of plating which can be depressed by a sharp instrument.

bow — relative flatness of the preform to the lid after spot welding.

burr — an adherent fragment of parent material, lid or preform, at the edge of the lid or preform.

chipout — a region of material which is missing from the surface or edge of the lid or preform.

contamination — three dimensional alien material adhering to a surface.

corrosion — electrochemical degradation of the material usually exhibited by discoloration such as rust.

crack — a cleavage or fracture which extends to the surface of the lid or through the preform.

discoloration — any change in the color of the plating as detected by the unaided eye which normally occurs after the application of heat.

foreign material — an adherent particle other than parent material of that component.

NOTE: Adherent means inability to be removed with an air or Nitrogen blow-off at 20 psi.

gouges — mechanically formed depressions in the lid surface.

nodules — lumps of plating extending above the surface of the lid.

oil canning — lid concavity after sealing.

peeling — the lifting of plating from a surface.

pit — a hole or depression extending below the surface of the lid or preform.

preform — a solder material of defined volume that is attached to the base material.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

2 ANSI, 1430 Broadway, New York, NY 10018

3 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-29597

protrusion — an adherent fragment of excess material on the surface of lid or preform.

scratch — surface mark which exposes underlying metal.

seal ring — area designated for attaching the lid to the package by welding or soldering techniques.

stain — a two-dimensional substance on a surface of the lid or preform.

tack weld — small spot welds, generally located in the corners which are used to attach the preform to the lid.

void — absence of plating from designated area.

weld splatter — melted preform material which extends from the weld.

4 Ordering Information

Purchase orders for metal lid/preform assemblies furnished to this specification shall include the following information.

4.1 Current customer drawing revision detailing:

All dimensions and tolerances per ANSI Y14.5M

Base material and hardness

Type, and thickness of the plating(s)

Preform type and composition

4.2 Reference to this specification.

4.3 Supplier certification requirements

4.4 Any additions to, or variations from, this specification.

5 Materials

The definitions, design guidelines, defect criteria, and functional tests described in this specification relate to lid/preform assemblies made with the following materials.

5.1 *Lid*

5.1.1 Base material to be Iron Nickel Cobalt alloy per MIL-M-38510, Type A; OR Iron Nickel alloy per MIL-M-38510, Type B <u>unless otherwise stated on the purchase order.</u>

5.1.2 Plating shall meet the requirements of MIL-M-38510 unless otherwise stated in the purchasing document.

5.2 *Preform*

5.2.1 Preform to be 80% (+0/-1% tolerance) gold, balance to be tin unless otherwise stated on the purchase order. Gold and tin to be 99.99% pure per ASTM E 29.

	Maximum Trace Elements
Silver (Ag)	100 ppm
Copper (Cu)	50 ppm
Lead (Pb)	50 ppm
Palladium (Pd)	20 ppm
Iron (Fe)	10 ppm

Others 10 ppm each

Total all impurities: 149 ppm

6 Design Guidelines

These guidelines are based on the use of a furnace sealing process, not seam sealing.

6.1 *General Guidelines*

6.1.1 The I.D. of the lid preform should be 0.010 larger than the package seal ring I.D. as long as preform width specifications are not violated.

6.1.2 The O.D. of the lid should be 0.025" to 0.035" smaller than the package seal ring O.D. as long as preform width specifications are not violated.

NOTE: The dimensions listed are based on nominal tolerances only. The worst case package and lid conditions must be considered.

6.1.3 *Recommendations* — The following table is a guideline only. Specific requirements may differ depending on the package type or style.

Lid Size	*Lid Thickness**	*Preform Thickness*	*Preform Width*	*Pkg.S/r Width*	*Corner Radii*
<0.251"	0.010"	0.0015–0.0021"	0.025" min.	0.0425" min.	0.020–min.
0.251–0.500"	0.010"	0.0021"	0.035" min.	0.0525" min.	"
0.501–0.650"	0.010–0.015"	0.0021–0.0024"	0.035" min.	0.0525" min.	"
0.651–1.000"	0.015"	0.0021–0.0030"	0.040–0.060"	0.0625–0.0675"	"
1.001–1.250"	0.015"	0.0021–0.0030"	0.045–0.065"	0.0675–0.0725	"
>1.250"	0.015"	0.0021–0.0030"	0.050" min.	0.0725" min.	"

* Tolerance for Lid Thickness is ± 10 %.

** Tolerance for Preform Thickness is ± 0.0003".

7 Defect Limits

Visual inspection shall be carried out at 3× magnification with verifiaction at 10×.

alpha emission — Alpha Emission Level Max: 0.05 counts/cm^2/hour +30/-0 seconds. **Test method to be agreed upon between user and supplier.**

blisters/peeling — None allowed after 3 minutes **dwell time** at 400 ± 10°C in air.

bow — Preform bow not to exceed:

Lid Size	*Maximum Allowable Bow*
< 0.500"	0.003"
0.501 – 1.500"	0.005"
1.500" and above	To be determined between supplier and user.

burrs (stamping) — None allowed greater than 0.001" in height.

chipouts — Chipouts exceeding 10% of the width of the preform (may be up to 20% in the corner) are not allowed. No chipouts allowed in lid.

cracks — Cracks in the lid not allowed. The preform shall not be broken, except in such cases where both sides of the break are in contact, and the preform is flat and firmly attached to the lid. Maximum of one (allowable) crack per preform allowed.

discoloration/stains — Discoloration of the finish shall not be cause for rejection unless there is evidence of corrosion or other contamination.

flatness — Lid must be flat within 0.001" per 0.500" T.I.R.

foreign material/contamination — Adherent material which cannot be removed by blowing with 20 psi air or nitrogen is not allowed.

pits — Pits larger than 0.005" are not allowed. No more than three acceptable pits are allowed on either surface of the lid and there must be a minimum of 0.030" between sites. Pits must not have exposed base metal.

NOTE: A sample of lids with pits may be subjected to Salt Atmosphere test per MIL-STD 883, Method 1009, Condition A as a condition of lot acceptance.

plating voids — No plating voids greater than .005" in any dimension. Lids with smaller plating voids may be subjected to Salt Atmosphere Test as described above as a condition of lot acceptance.

preform alignment — Misalignment shall not exceed 0.005" from any one edge of the lid.

preform attachment — Preform to be firmly attached to the lid in at least 3 corner locations.

protrusions — Protrusions larger than 0.005" in any horizontal dimension or 0.001" in height are not allowed.

scratches — Scratches which expose base metal not allowed.

tack weld height — Must be firmly adherent and max 0.003".

7.1 All lids must meet the following criteria:

Salt atmosphere per MIL-STD 883, Method 1009, Condition A

Resistance to Solvents per MIL-STD 883, Method 2015

Gold plating per MIL-M-38510

8 Sampling

The sampling plan shall be agreed upon between user and supplier.

9 Incoming Inspection

9.1 Incoming inspection to be performed per user drawing with reference to this specification.

9.1.1 *Plating Thickness* — Plating thickness shall be measured by X-Ray Fluorescence per ASTM B568. The tolerance on the thickness shall be agreed upon between user and supplier. For multilayer plated lids, additional layers should be measured by cross section.

9.1.2 *Material Hardness* — Hardness shall be evaluated per ASTM E 384 or E 10 to limits agreed upon between user and supplier.

9.1.3 *Functional Testing*

9.1.3.1 Functional testing may be performed at the option of the user or supplier. Test to be agreed upon between user and supplier.

9.1.3.2 Hermeticity parts should be evaluated per MIL-STD 883, Method 1014.

9.1.4 *Marking* — Marking permanency shall be evaluated per MIL-STD 883, Method 2015.

9.1.5 *Corrosion Resistance* — Corrosion resistance shall be evaluated per MIL-STD 883, Method 1009 (Salt Atmosphere).

10 Certification

Upon request of the user in the purchase order, a supplier's certification that the product was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment. Certification to user specification may also be required. This certification does not remove the supplier's responsibility for discrepant product subsequently found by the user.

11 Packaging and Package Marking

11.1 *Packaging* — The shipping containers and materials shall be suitably selected to provide the components with protection from normal transportation damage risks which include crushing, abrasion, spillage, and exposure to moisture and other corrosive gasses. The inner packing materials must be clean room compatible as defined by user.

11.2 *Package Marking*

11.2.1 *Internal Packages* — Each internal package shall be marked as follows:

User's Part Number

User's Order Number

Drawing Number (user's and supplier's, if appropriate)

Plating Lot Number

Manufacturing Lot Number

Quantity Date of Manufacture

External Marking — The external packing list shall include the following details:

User's Part Number

User's Order Number

Quantity Shipping Date

Any specific instructions for receiving personnel

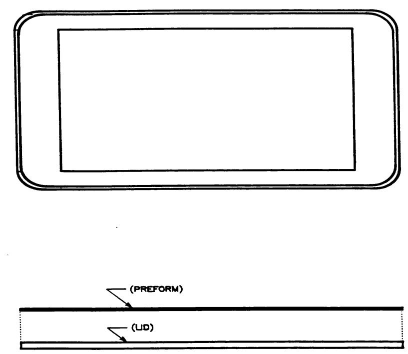

Figure 1

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G54-93
SPECIFICATION FOR DIMENSIONS AND TOLERANCES USED TO MANUFACTURE MOLDED PLASTIC PACKAGES

1 Preface

This document is a guideline for ordering the tooling required to manufacture plastic semiconductor packages. These packages include the following JEDEC registered outlines:

Plastic Dual-in-Line Packages (PDIP)
Plastic Leaded Chip Carrier (PLCC)
Plastic Quad Flat Packages (PQFP)
Small Outline I.C. Packages (SOIC — Gull Wing and “J” lead)
Plastic TAB Quad Packages (PTAB)

NOTE 1: Package outlines registered with other organizations such as EIAJ and non-registered outlines may use the criteria in this document by choosing the outline which most closely resembles the particular package.

Packaging engineers, mold manufactures, and end-of-line tool makers may use this document to define the limits of tooling tolerances.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering tooling shall be as follows:

Purchase Order
Referenced Documents
This Specification

2.2 *Reference Documents*

2.2.1 *SEMI Specifications*

SEMI G48 — Specification, Measurement Method for Molded Plastic Package Tooling

2.2.2 *JEDEC Specifications*[1]

Pub. No. 95 — Registered and Standards Outline for Semiconductor Devices

2.3 *Related Documents for Information*

2.3.1 *Military Specifications*[2]

MIL-STD-100 — Engineering Drawing Practice

2.3.2 *ANSI Specifications*[3]

Y14.5 — Dimensioning and Tolerancing

3 Selected Definitions

3.1 *Cavity* — the plastic body formed by either the top or bottom mold cavities.

3.2 *Gate Feature* — plastic protrusions or intrusions which result from normal molding and degating operations.

3.3 *Lead Bend Angle* — the angle to which the leads are bent in reference to a plane normal to the X-Y plane of the package. After a suitable radius has been formed at the shoulder, there must be no compound angle formation to achieve the lead spread requirements. Lead Bend Angle may just be a reference if Lead Spread is specified (see Figures 1A, B, C).

3.4 *Lead Coplanarity* — the vertical position of a lead foot with respect to a reference plane created by the three leads with feet most extended from the bottom surface of the package body. The term “foot” applies to both PLCC foot radii and PQFP feet (see Figure 2).

3.5 *Lead Shoulder (Dambar Area) Protrusions or Intrusions* — a protrusion (tab) on the shoulder or lead, or intrusion cut into the shoulder or lead as a result of dambar trimming (see Figures 3 and 4).

3.6 *Lead Sweep* — lead movement measured with respect to a datum, perpendicular to the top or bottom surface of the package and which passes through the midpoint of the lead, when viewed from the sides of the package (see Figure 4).

3.7 *Mismatch* — misalignment between the top and bottom cavities. The measurement of mismatch is stated as the difference between the center lines of the top and bottom cavities (see Figure 5). All statements regarding mismatch of cavities are applicable to both the X and Y axis. All measurements are made prior to lead trim and form.

3.8 *Offset* — the difference in the bottom cavity position from a leadframe datum when compared to design (see Figure 6). This measurement ignores leadframe tolerances. All statements regarding offset are applicable to both the X and Y axis. All measurements are made prior to lead trim and form.

1 JEDEC, 2001 Eye Street N.W., Washington, D.C. 20006

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 American National Standards Institute, 1430 Broadway, New York, NY 10018

3.9 *Overlap* — the difference in length or width between the top and bottom cavities. Overlap may be a feature designed into the mold to avoid mismatch (see Figure 5). All statements regarding overlap of cavities are applicable to both the X and Y axis. All measurements are made prior to lead trim and form.

3.10 *Package Warpage* — loss of planarity of a molded surface excluding protrusions and intrusions (see Figure 7). Each package type has a maximum allowable warpage and a warp factor is used to determine the maximum warpage for a particular package dimension. The Warp Factor (WF) is defined as follows:

$$\text{WF} = \frac{\text{Total Warp in inches (mm)} \times 1000}{\text{Package dimension in inches (mm)}}$$

Package warpage is usually caused by incorrect package design and/or poor molding conditions.

3.11 *Parting Line Protrusions, or Intrusions* — plastic excesses (flash) or losses (chips or voids) at the parting line after normal processing to mold, deflash, trim, and singulate the packages.

3.12 *Surface Protrusions or Intrusions* — plastic excesses (bumps or blisters) or recesses (pits or voids) on any surface of the package.

4 Ordering Information

Purchase orders for molded plastic tooling furnished to this document, shall include the following items:

4.1 A package tooling outline drawing showing all the required dimensions listed in Section 5. The molded surface finish(es) and the lead finish shall be specified.

4.2 The plastic compound to be used shall be specified. If the compound is proprietary, then the molding and molded characteristics shall be supplied.

4.3 The leadframe drawing detailing the material, all dimensions, and, if applicable, lead finish pre-plate specifications.

4.4 The type and part number of the molding and trim, form, singulate press to be used.

4.5 Singulation or off-load requirements.

4.6 *Expectations of Tooling Performance* — Tooling performance is not limited to the items listed in Section 5 and 6. Any other customer requirements, such as the limits on wire sweep, resin bleed or internal voiding, shall also be included with the purchase order.

4.7 Reference to this specification.

4.8 Vendor certification requirements.

5 Dimensions

5.1 All package dimensions should be specified in detail.

5.2 Ejector pin mark location from the package centerline. This should include ejector pin sizes, depths, and draft angles.

5.3 Pin 1 ID shape and location from the package center with respect to the lead frame Pin 1 location.

5.4 All critical radii (unspecified radii, often shown sharp on the drawing, may have the maximum radius shown in the table of Section 6).

5.5 Plastic stand-off shape and locations from the package center.

5.6 Lead spread (the distance between the outer edge of opposing leads).

5.7 Shoulder bend location and lead bend angle (optional).

5.8 Foot angle radius (maximum and minimum).

5.9 Foot length.

5.10 Lead length.

5.11 Shoulder width (maximum width should include protrusion).

6 Dimensional Tolerance Limits

These criteria, where applicable, apply only to opaque, plastic molded semiconductor packages. If an item is not mentioned in the following table, then the tolerances on the dimensions of that item follow the general tolerance limits stated on the drawing. Dimensions are in inches (millimeters) except as noted. Dimensions are to be verified per SEMI G48.

Table 1 Tolerance Limits

Dimension (Tolerance)	*PDIP*	*PLCC*	*SOIC*	*PQFP*	*PTAB*	*UNITS*
Package Length/Width ±	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	in. (mm)
Cavity Mismatch ±	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	in. (mm)
Cavity Overlap (Max.)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	in. (mm)
Package/Leadframe Offset ±	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.001 (0.025)	in. (mm)
Plastic Body Thickness — Top and Bottom ±	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.001 (0.025)	in. (mm)
Surface Protrusions (Max.)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	in. (mm)
Surface Intrusions — Depth (Max.)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	in. (mm)
-X-Y Dimension (Max.)	0.010 (0.25)	0.010 (0.25)	0.010 (0.25)	0.010 (0.25)	0.005 (0.127)	in. (mm)
Ejector Pins — Intrusion only (Max.)	0.010 (0.25)	0.010 (0.25)	0.010 (0.25)	0.008 (0.20)	0.005 (0.127)	in. (mm)
Gate Feature — Intrusion only (Max.)	0.020 (0.50)	0.020 (0.50)	0.010 (0.25)	0.020 (0.50)	0.002 (0.05)	in. (mm)
Gate Feature — Protrusion only (Max.)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)	in. (mm)
Parting Line Protrusion — after deflash dambar removal (Max. per side)	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)	0.005 (0.127)	in. (mm)
Parting Line Intrusion — Plastic (Max.)	0.010 (0.25)	0.010 (0.25)	0.005 (0.127)	0.010 (0.25)	0.005 (0.127)	in. (mm)
Parting Line Protrusion — after package singulation	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)	0.006 (0.15)	0.005 (0.127)	in. (mm)
Warp Factor (Max.) — up to a Limit of	2.5% 0.003 (0.08)	2.5% 0.003 (0.08)	2.5% 0.003 (0.08)	2.5% 0.003 (0.08)	2.5% 0.003 (0.08)	in. (mm)
Draft Angles (Deg. ±)	1	1	1	1	1	
Package Radii — Noted Radii ±	0.0025 (0.06)	0.0025 (0.06)	0.0025 (0.06)	0.0025 (0.06)	* (*)	in. (mm)
Shown Sharp (Max.)	0.020 (0.50)	0.020 (0.50)	0.010 (0.25)	0.020 (0.50)	* (*)	in. (mm)
Lead Spread ±	0.025 (0.64)	0.010 (0.25)	0.010 (0.25)	0.005 (0.127)	* (*)	in. (mm)
Lead Bend Angles (Deg. ±)	-	5	2	2	2	
Shoulder Bend Location ±	0.010 (0.25)	0.010 (0.25)	0.005 (0.127)	0.005 (0.127)	* (*)	in. (mm)
Lead Sweep (from True position — Max.) (See Note 2)	0.007 (0.18)	0.004 (0.10)	0.004 (0.10)	0.003 (0.075)	0.003 (0.075)	in. (mm)
Foot Length ±	-	-	0.005 (0.127)	0.005 (.127)	* (*)	in. (mm)
Foot Radius ±	-	0.010 (0.25)	-	-	-	in. (mm)
Lead Length ±	0.005 (0.127)	-	-	-	-	in. (mm)
Foot Width ± incl. Leadframe Tolerance	-	-	0.002 (0.05)	0.002 (0.05)	* (*)	in. (mm)
Lead Coplanarity (Max.)	-	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.002** (0.05)	in. (mm)
Dambar Trim Protrusions (Max.)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	in. (mm)
Dambar Trim Intrusions (Max.)	0.002 (0.05)	0.002 (0.05)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	in. (mm)

* To be determined.

** If applicable.

NOTE 2: SOIC, J leaded packages have the plastic bodies and leads evaluated to the SOIC and PLCC tolerances as appropriate.

NOTE 3: Lead Sweep is not acceptable at buy-off.

7 Sampling Plan

A sampling plan and buy-off procedure to determine compliance to the requirements of Sections 5 and 6 and other relevant specifications shall be determined between vendor and customer.

8 Packaging and Marking

8.1 *Packaging* — Tooling must be packed in containers designed and constructed to provide protection against normal transportation damage risks and spillage. The container will offer protection from contamination and exposure to moisture. Tools may be coated with a suitable rust inhibitor as agreed between vendor and customer.

8.2 *Marking* — The following details shall be noted on the packing slip:

Vendor Part Number
Customer Part Number
Shipping Date
Customer P.O. Number
Shipment Items

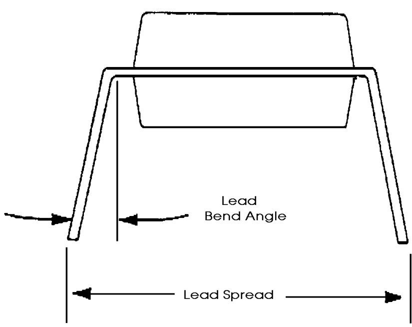

Figure 1A
PDIP Package

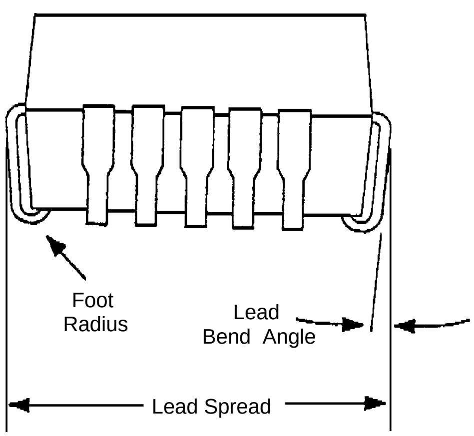

Figure 1B
PLCC Package

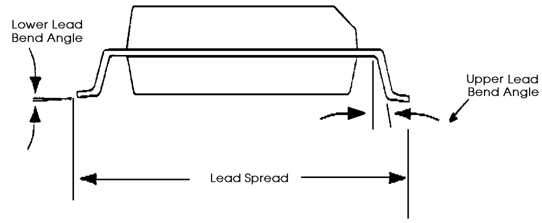

Figure 1C
SOIC and PQFP Packages

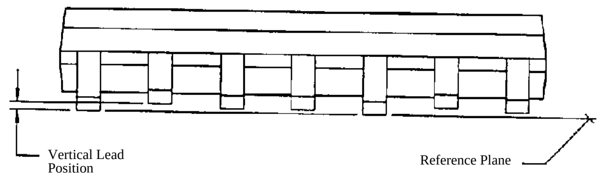

Figure 2
Lead Co-planarity

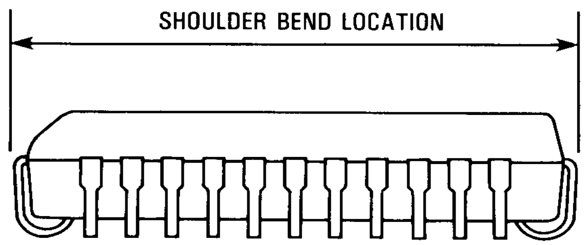

Figure 3
Shoulder Bend Location

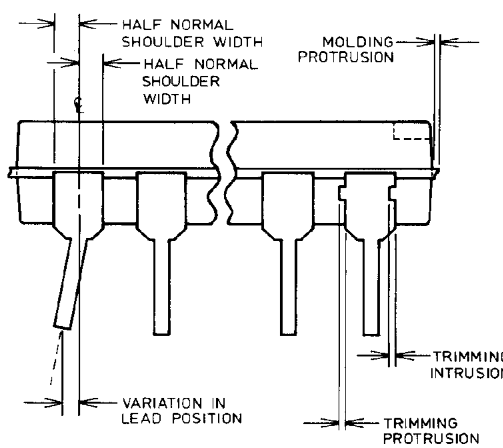

Figure 4
Parting Line Protrusion, Lead Sweep and Lead Shoulder Protrusions and Intrusions

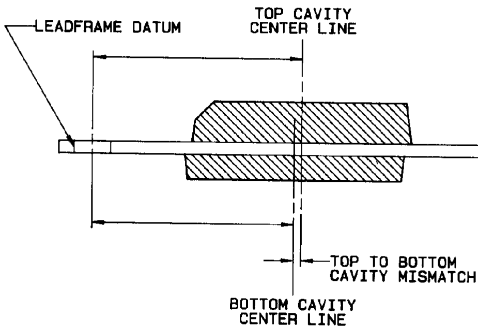

Figure 5
Mismatch

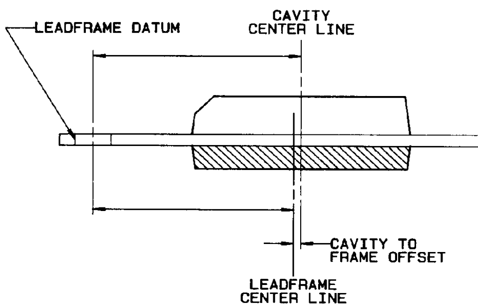

Figure 6
Offset

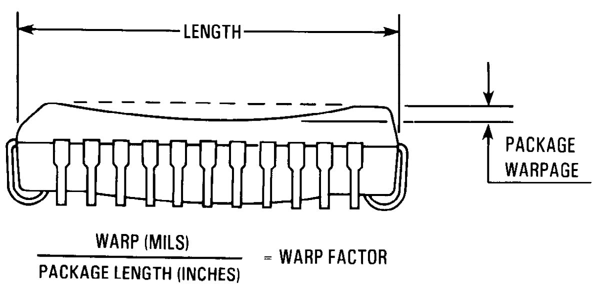

Figure 7
Package Warpage

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SEMI G55-93
TEST METHOD FOR MEASUREMENT OF SILVER PLATING BRIGHTNESS

1 Preface

1.1 *Scope* — This method describes the standard method for measuring the brightness of silver plating on semiconductor leadframes.

Note: This method determines quantitative measures which are not related directly to the traditional "Dull," "Semi-Bright" and "Bright" descriptors for silver plating.

1.2 *Use* — This test may be used for process control and outgoing inspection at the supplier or by the user for incoming inspection.

2 Applicable Documents

2.1 *Related Documents*

2.1.1 *SEMI Specification*

SEMI G21 — Plating Integrated Circuit Leadframes

2.1.2 *JIS Specifications*[1]

JIS H8621 — Electroplated Coatings of Silver for Engineering Use

JIS Z8722 — Method of Measurement for Color of Reflecting or Transmitting Objects

JIS Z8741 — Method of Measurement for Specular Glossiness

2.1.3 *Military and Federal Specifications*[2]

QQ-S-365 — General Requirements for Electro-deposited Silver Plating

3 Significance

3.1 Brightness values indicate surface roughness for given plating conditions. Surface roughness affects the wettability of resinous die attach processes on leadframes. If the surface is too smooth, poor wetting may occur which results in low die share strength values.

3.2 Brightness variations may also affect the ability of the pattern recognition systems used on assembly equipment to recognize the set points.

1 JIS, 4-1-24 Akasaka Minato-ku Tokyo, Japan

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

4 Summary of Method

4.1 The method is based on the use of a GAM Densitometer. This method is chosen as the standard because of the small measurement area requirements and the high accuracy of the method for typical silver plating brightness used on leadframes.

This method is based on the measurement of the reflectance of light at 45° from a surface illuminated from a light source perpendicular to the surface. This value of Reflectance (R) gives a Density Value (D) based on the following formula:

$$D = \log 1/R$$

Density is a measure of the Brightness.

5 Interferences

5.1 *Surface Finish*

5.1.1 Brightness values depend on surface roughness. A rough surface shows a low brightness value when compared to a smooth surface. Variable plating conditions, such as the addition of brighteners to the plating solution, may give brightness results, which are not comparable for the acceptance of plated leadframes.

5.1.2 Scratches and other flaws in the surface will affect reflectance.

5.2 *Storage Time and Conditions*

5.2.1 Figure 1 shows the brightness results for leadframes subjected to indoor, atmospheric storage for an extended time. Results are shown for silver plating on copper alloy and Alloy 42 leadframes.

5.2.2 Leadframes shall be stored in conditions agreed between supplier and customer in order to limit atmospheric tarnishing, and brightness measurements shall be taken within an agreed time of delivery.

5.3 Degradation of the standards will affect calibration.

6 Equipment

6.1 GAM Densitometer or equivalent.

7 Sampling

7.1 A sampling plan shall be agreed between user and supplier.

8 Preparation of Samples

8.1 No special preparation requirements are necessary. Do not contaminate the samples by touching with bare hands.

9 Measurement Conditions

9.1 To confirm the lamp is on enough to measure the brightness values. (Lamp intensity is automatically calibrated.)

10 Equipment Setup and Calibration

10.1 *Equipment Setup*

10.1.1 Set up and turn on the equipment according to the manufacturer's instructions.

10.1.2 Allow at least 30 minutes for equipment stabilization before beginning measurements.

10.2 *Calibration*

10.2.1 Calibration shall be performed using standard black and white plates.

10.2.2 The equipment shall be recalibrated every 30 minutes.

11 Procedure

11.1 *Procedure*

11.1.1 Measurements shall be made close to the center of the die pad, if possible. In those situations where the die pad is not plated, the measurement site shall be agreed between user and supplier.

11.1.2 Measure all the selected samples according to the equipment manufacturer's instructions. Take three readings on each sample and obtain an average result for that sample.

11.2 *Results*

11.2.1 Brightness values shall be rounded to the first decimal place.

12 Report

The report, when used by a supplier to certify a customer's requirements or by the customer at incoming inspection shall contain, at least, the following information, other information which is reported shall be agreed between supplier and customer.

12.1 *Supplier's Lot Number and Date of Shipment*

12.2 *Test Conditions*

12.3 Results from Section 11. (SPC charting techniques may be used to monitor results for each leadframe type and plating requirement.)

13 Repeatability and Precision

13.1 *Repeatability*

13.1.1 Values for brightness based on use of a densitometer are repeatable within ± 0.003.

13.2 *Precision*

13.2.1 Precision for brightness values based on use of a densitometer is ± 0.015.

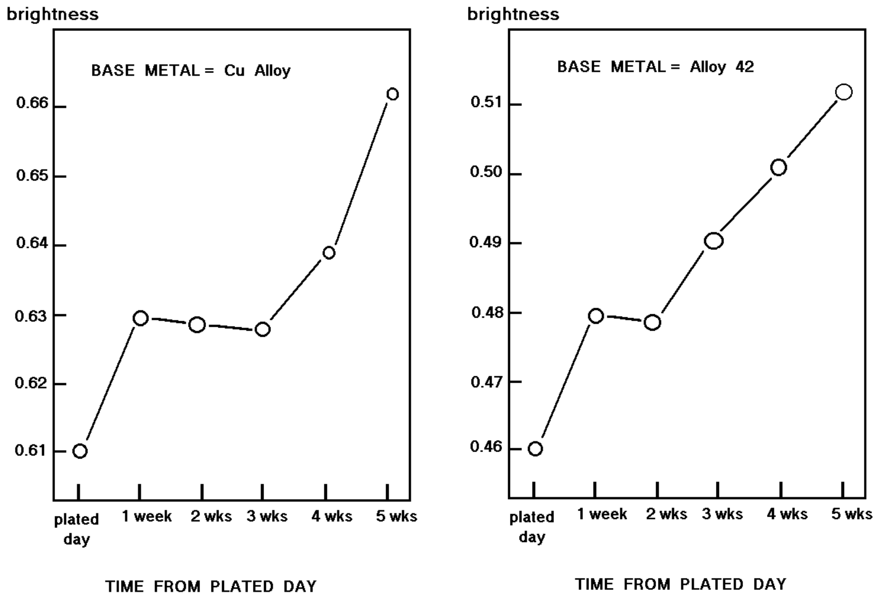

Figure 1
Changes of the Brightness Value as Time Goes by

Note: Specimens were kept in an office and directly exposed to the atmosphere.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G56-93 (Reapproved 0302)
TEST METHOD FOR MEASUREMENT OF SILVER PLATING THICKNESS

This test method was technically approved by the Global Assembly and Packaging Committee and is the direct responsibility of the Japanese Assembly and Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on November 26, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1993.

1 Purpose

1.1 *Use* — This test may be used for process control and outgoing inspection at the supplier or by the customer for incoming inspection.

1.2 *Units* — This standard test method uses SI units.

2 Scope

2.1 This method describes the standard method for measuring the thickness of silver plating on semiconductor leadframes.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *ASTM Specifications*[1]

ASTM B 568 — Measurement of Coating Thickness by X-Ray Spectrometry

4 Significance

4.1 The thickness of plating affects assembly processes such as wire bonding. If the plating is too thin, heat processes such as die attach cause the surface to become unbondable due to bleeding of the base material through the plating.

4.2 Schematic picture for measurement principles is shown in Figure 2.

5 Summary of Method

5.1 The method is based on the use of fluorescent X-rays. This method is chosen as the standard because of the small measurement area requirements, the high accuracy of the method for typical silver plating thicknesses used on leadframes, and the non-contact method.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

6 Interferences

6.1 *Impurities in Plating*

6.1.1 Elements with atomic numbers between 42 (Molybdenum) and 52 (Tellurium) cause false readings.

6.2 *Measurement Time*

6.2.1 At small collimator diameters, the measurement time is no longer proportional to diameter. X-ray counting errors may occur for short measurement times.

6.3 Worn or abraded standards will affect calibration.

6.4 Base material variations will affect results. Standard samples and leadframes must have the same base material and plating system conditions for accurate results.

7 Equipment

7.1 Fluorescent X-ray spectrometer.

8 Sampling

8.1 A sampling plan shall be agreed between supplier and customer.

9 Preparation of Samples

9.1 No special preparation requirements are necessary.

10 Measurement Conditions

10.1 Collimator shall be set at 0.1 mm or 0.3 mm by agreement between user and supplier.

10.2 Measurement time shall be agreed between user and supplier.

11 Equipment Setup and Calibration

11.1 *Equipment Setup*

11.1.1 Set up the equipment according to the manufacturer's instructions.

11.1.2 Allow at least 30 minutes for equipment stabilization before beginning measurements.

11.2 *Calibration*

11.2.1 Calibration curves shall be generated using standard samples traceable to the National Institute of Standards and Technology or equivalent standards organization.

11.2.2 Calibration curves shall be generated after the equipment has stabilized per the manufacturer's instructions.

11.2.3 The equipment shall be recalibrated every 8 hours.

12 Procedure

12.1 *Procedure*

12.1.1 Measurements shall be made close to the center of the die pad, if possible. In those situations where the die pad is not plated, the measurement site shall be agreed between user and supplier.

12.1.2 Measure all the selected samples according to the equipment manufacturer's instructions.

NOTE: Refer to the equipment manufacturer's instructions and ASTM B 568 for safety conditions.

12.2 *Results*

12.2.1 Thicknesses shall be rounded to the first decimal place.

13 Report

The report when used by a supplier to certify a user's requirements or by the user at incoming inspection shall contain, at least, the following information. Other information which is reported shall be agreed between the user and supplier.

13.1 Supplier's Lot Number and Date of Shipment

13.2 Test Conditions

13.3 Results from Section 11. (SPC charting techniques may be used to monitor results for each leadframe type and plating requirement.)

14 Accuracy and Precision

14.1 *Accuracy*

14.1.1 Figure 1 shows curves of silver plating thickness measured by fluorescent X-Ray versus the percentage error in that measurement for two collimator settings for a constant measurement time.

15 Related Documents

15.1 *SEMI Specifications*

SEMI G21 — Plating Integrated Circuit Leadframes

15.2 *JIS Specifications*[2]

JIS H8501 — Methods for Thickness Testing for Metallic Coatings

JIS H8621 — Electroplated Coatings of Silver for Engineering Purposes

15.3 *Military and Federal Specifications*[3]

QQ-S-365 — General Requirements for Electro-deposited Silver Plating

MIL-S-19550 — General Specification for Semiconductor Devices

15.4 *ISO Specifications*[4]

ISO-3497 — Metallic Coating Measurement of Coating Thickness X-Ray Spectometry Methods

2 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

3 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

4 ISO, 1 rue de Varembe, Case postale 56, CH01211 Geneva 20, Switzerland

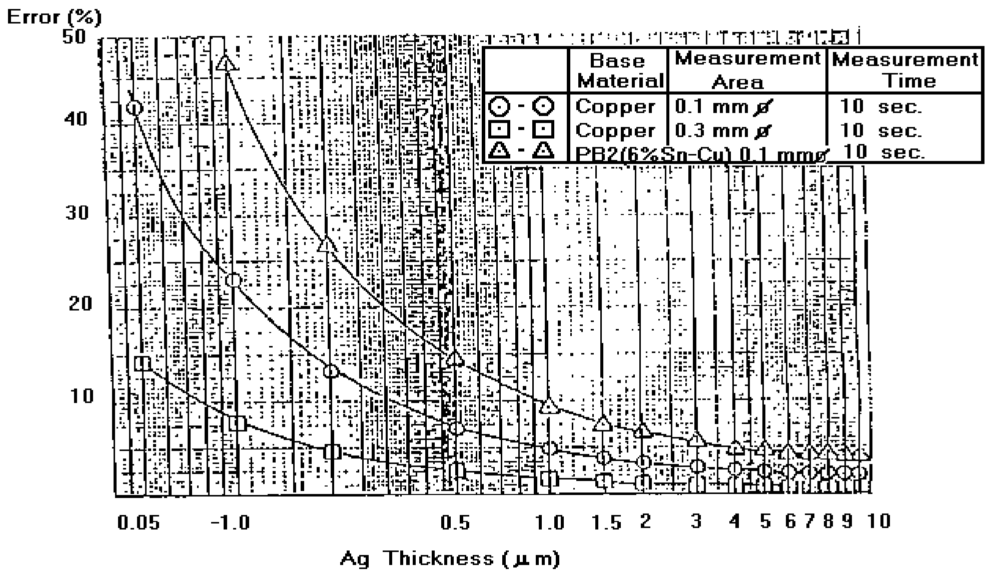

Figure 1
Error in Silver Thickness Measurement

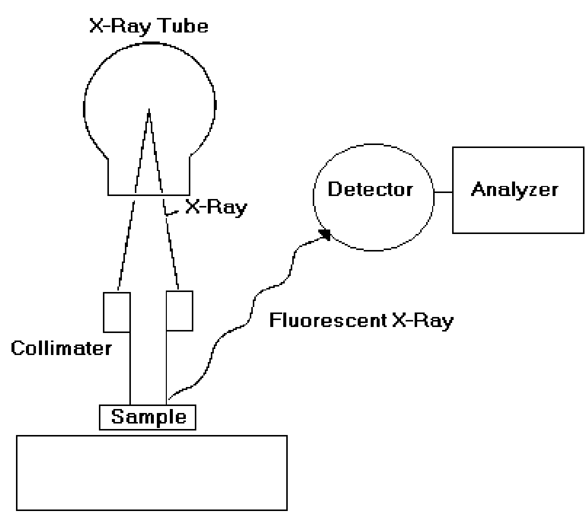

Figure 2
Measurement Principles

SEMI G57-0302
GUIDE FOR STANDARDIZATION OF LEADFRAME TERMINOLOGY

This guide was technically approved by the Global Assembly and Packaging Committee and is the direct responsibility of the Japanese Assembly and Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on November 26, 2001. Initially available on www.semi.org December 2001; to be puiblished March 2002. Originally published in 1993.

1 Preface

1.1 *Purpose* — This guideline defines standard terminologies for all the features of leadframes used in the production of semiconductor circuits.

1.2 *Significance* — Use of this guide in communications between customers and vendors can reduce the errors caused by the current use of different nomenclatures for the same feature of a leadframe.

Table 1 Nomenclature for Figures

1	Die Pad
2	Die Pad Support
3	Lead Lock
4	Anchor Hole
5	Inner Lead
6	Outer Lead
7	Standard Pilot Hole
8	Pilot Hole
9	Top Rail Standard Pilot Hole Side
10	Bottom Rail
11	Lead Cut-off Notch
12	Dam Bar
13	Lead Shoulder
14	Mold Dam
15	Bumper Support Cut-off Notch
16	Lead Lock Groove
17	Mold Line
18	Expansion Slot
19	Down Set
20	Die Pad Dimple
21	Side Rail
22	Strip Cut-off Line
23	Coined Area
24	Degate Hole

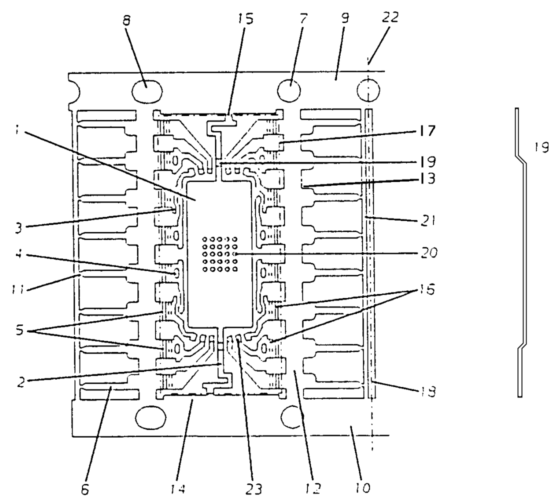

Figure 1

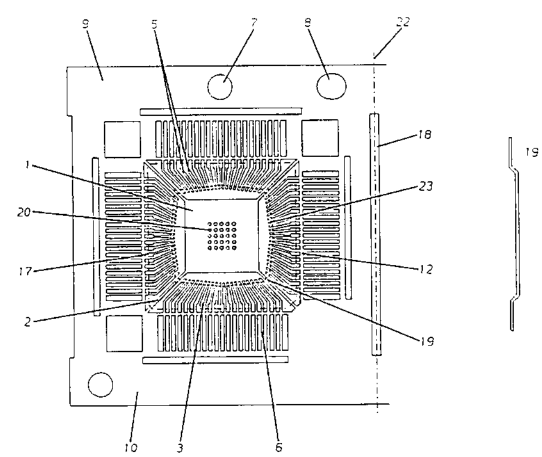

Figure 2

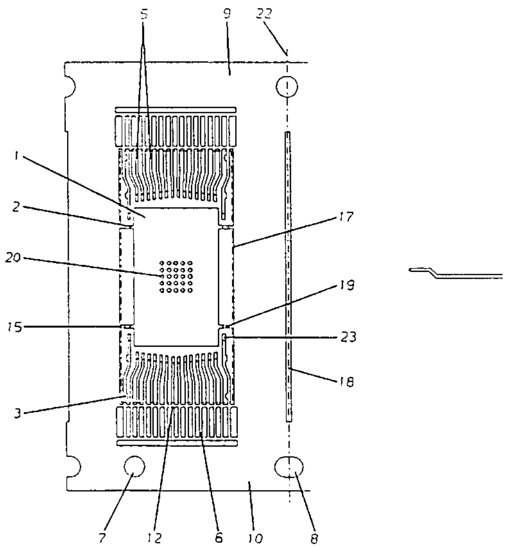

Figure 3

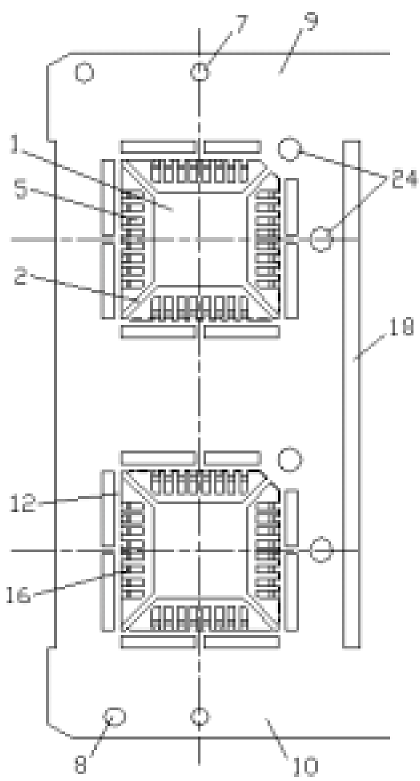

Figure 4

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G58-94
SPECIFICATION FOR CERQUAD PACKAGE CONSTRUCTIONS

1 Preface

1.1 *Purpose* — This specification defines the acceptance criteria for Cerquad package components and includes requirements for the base, leadframe, window frame, cap and sealing glass materials.

1.2 *Scope* — This specification applies to all Cerquad packages which have a leadframe sandwich between two ceramic pieces — the base and the window frame — and sealed by glass, and a cap with a similar glass seal.

NOTE 1: The base, leadframe and window frame may be purchased as separate components or as a completed assembly.

1.3 *Units* — U.S. Customary (inch-pound) or metric (SI) units may be used at the customer's discretion. This specification uses U.S. Customary units as the prime unit.

NOTE 2: In the figures only U.S. Customary units are shown.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering package components shall be as follows:

Purchase Order

Customer's Component Drawings

This Specification

Referenced Documents

2.2 *Referenced Documents*

2.2.1 *SEMI Specifications*

SEMI G21 — Plating Integrated Circuit Leadframes

SEMI G23 — Measuring the Inductance of Package Leads

SEMI G24 — Measuring the Lead-to-Lead and Loading Capacitance of Package Leads

SEMI G25 — Measuring the Resistance of Package Leads

Compilation of Terms

2.2.2 *JEDEC Specifications*[1]

Pub. No. 95 — Registered and Standard Outlines for Semiconductor Devices

2.2.3 *Military and Federal Specifications*[2]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-883 — Test Methods and Procedures for Microelectronics

MIL-STD-1835 — Microcircuit Case Outlines

MIL-G-45204 — Gold Plating — Electrodeposited

MIL-M-38510 — General Specification for Microcircuits

3 Selected Definitions

3.1 *blister (bubble) metallization* — an enclosed locallized separation of the metallization from its base material (such as ceramic or another metallization layer component) that does not expose the underlying layer.

3.2 *burr* — an adherent fragment of parent material at a component edge. In leadframes, the metal burr, due to the stamping operation, may be in the horizontal or vertical direction to the surface. In ceramic packages, this type of characteristic is called a fin.

3.3 *camber (ceramic)* — arching of a nominally flat ceramic body.

3.4 *chip* — region of material missing from a component (e.g., ceramic from a package, or solder from a preform). The region does not progress completely through the component and is formed after the component is manufactured. Chip size is defined by its length, width and depth from a projection of the design planform. Also called chipout. (See Figure 1.)

3.5 *crack* — a cleavage or fracture that extends to the surface of a semiconductor package or solder preform. The crack may or may not pass through the entire thickness of the package or preform.

3.6 *critical seal area* — on a semiconductor package, the area bounded by the shortest nominal design distance from the largest cavity, usually the wire bond cavity, to the edge of the package or ceramic layer forming the seal area. (See Figure 2.)

3.7 *fin* — on a ceramic package or cap, a fine feathery-edged projection of parent ceramic material on the corner of the ceramic body.

1 JEDEC, 2001 Eye Street N.W., Washington, DC 20006.

2 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3.8 *foreign material* — an adherent particle that is not parent material of the component. Adherence means that the particle cannot be removed by an air or nitrogen blast at 20 psi.

3.9 *glass flow* — on a semiconductor package or cap, the heating process which just removes all the screen printing mesh marks in the sealing glass when viewed at 10× magnification.

3.10 *glass void* — the absence of a sealing glass layer from a designated area.

3.11 *metallization void* — the absence of a clad, evaporated, plated or screen-printed metal layer or braze from a designated area.

3.12 *non-critical seal area* — on a semiconductor package that uses a lid, cap, or cover to effect the seal, the area of the sealing surface outside the critical sealing area. (See Figure 2.)

3.13 *overhang* — on a semiconductor package, the horizontal extension of the sealing glass past the vertical wall of a cavity cut into the ceramic layer on which the glass is printed. (See Figure 3.)

3.14 *peeling (flaking)* — any separation of a plated, vacuum deposited, or clad metal layer from the base metal of a leadframe, pin, heatsink, or seal ring, from an underplate, or from a refractory metal on a ceramic package. Peeling exposes the underlying metal.

3.15 *projection* — on a semiconductor package (plastic or ceramic), leadframe or preform, and irregularly raised portion of a surface indiginous to the parent material.

3.16 *pullback* — on a semiconductor package, the linear distance between the edge of a cavity cut into a ceramic layer and the first measureable glass or metallization layer interface coated onto the top surface of that layer. The total pullback may be the result of the high temperature processing required to manufacture the package or to coat the surface. It may also be the result of design considerations. (See Figure 3.)

3.17 *rundown* — on a semiconductor package, the linear distance from the upper surface of a ceramic cavity layer to the bottom point of the overhang into the cavity, of a sealing glass or metallization layer that has been screened onto that surface. (See Figure 3.)

4 Ordering Information

Purchase orders for cerquad packages and caps furnished to this specification shall include the following items:

4.1 Package description

4.2 Current drawing revision detailing

All dimensions

Type and color of ceramic

Type and thickness of sealant glass

Leadframe material type and design

Type and thickness of metallization in the lead bond area

Type and thickness of external lead plating, if applicable

Type and thickness of die attach metalization

4.3 Vendor certification requirements

4.4 Any additions to, or variations from, this specification

5 Dimensions

The component described in this specification shall produce packaged devices that conform to the outline dimesnions and lead numbering for Cerquad Package Constructions detailed in: JEDEC Publication 95; EIAJ; MILSTD1835. Package manufacturing tolerances shall be agreed between vendor and customer.

6 Materials

The definitions, defect criteria, and functional tests described in this specification relate to package components made with the following materials:

6.1 Base, Window Frame, and Cap

6.1.1 Material

6.1.1.1 *Alumina* — Content to be 90% minimum, or

6.1.1.2 *Beryllia* — Content to be agreed between vendor and customer.

6.1.2 *Color*

6.1.2.1 *Alumina* — Black, dark brown, or violet.

6.1.2.2 *Beryllia* — White.

6.2 *Sealant* — A solder glass suitable for hermetic sealing shall be specified.

6.3 *Die Attach Pad Metallization* — Gold or any other suitable material shall be specified.

6.4 *Leadframe*

6.4.1 *Base Material*

6.4.1.1 *Thickness* — Shall be specified.

6.4.1.2 *Composition* — Iron-Nickel-Cobalt alloy per MIL-M-38510, Type A or Iron-Nickel alloy per MIL-M-38510, Type B shall be specified.

6.4.2 *Finish* — Lead bond areas.

6.4.2.1 Metallization — Aluminum.

6.4.2.1.1 *Thickness* — 100 – 600 microinches (0.0025 – 0.015 mm).

6.4.2.1.2 *Coverage* — Total coverage for a distance of 0.030" (0.762mm) minimum as measured from the lead tip. Maximum length is defined by the lead bond cavity size.

6.4.2.1.3 *Composition* — 99.4% minimum for clad aluminum, 99.99% minimum for vapor deposited aluminum.

6.4.2.2 *Metallization* — Gold.

6.4.2.2.1 *Thickness* — 50 – 225 microinches (0.0013 – 0.0057mm).

6.4.2.2.2 *Coverage* — See paragraph 6.4.2.1.2.

6.4.2.2.3 *Composition* — See SEMI G21 and MIL-G-45204.

6.4.3 *Leadframe Finish* — External areas (if specified).

6.4.3.1 *Metallization* — Gold (see Section 6.4.2.2).

7 Defect Limits

The following defects shall be rejected if the limits shown are exceeded:

NOTE 3: The criteria apply to purchased pre-assemblies or, where applicable, to units assembled by the customer to process conditions agreed between vendor and customer.

7.1 *Ceramic Components*

7.1.1 *Cracks* — Not allowed.

7.1.2 *Chips* — See Figures 1 and 2.

7.1.2.1 *Corner Chips* — 0.030" (0.762 mm) × 0.030" (0.762 mm) × 25% of package element thickness.

7.1.2.2 *Edge Chips* — 0.060" (1.524 mm) × 0.030" (0.762 mm) × 25% of package element thickness.

7.1.2.3 *Critical Seal Area* — Chips must not reduce the critical seal path length, at any point, to less than one-half the nominal design dimension. No more than four chips are allowed in this area regardless of loss of seal length.

7.1.3 *Burrs, Projections (Fins), and Blisters*

7.1.3.1 *Base, Window Frame, and Cap* — 0.005" (0.127 mm) maximum allowable dimension or greater than 0.003" (0.076 mm) height.

7.1.3.2 *Die Attach Surface* — 0.001" (0.025 mm) maximum above the metallization surface excluding a zone, 0.010" (0.25 mm) wide, around the periphery of the cavity maximum allowable dimension is 0.005" (0.127 mm).

7.1.4 *Camber* — Shall be specified on the component drawing.

7.2 *Glass Sealant*

7.2.1 *Chips and Voids* — 0.010" (0.254 mm) maximum allowable dimension, with exposed or covered ceramic. No more than four chips or voids are allowed in the critical seal area. These defects must also meet the requirements of Table 1 in Section 7.2.2.4.

7.2.2 *Glass Misalignment (after glass flow)* — See Figure 3.

7.2.2.1 *Glass Overhang* — 0.15" (0.381 mm) maximum extension from the ceramic edge.

7.2.2.2 *External Rundown* — 50% of component thickness maximum.

7.2.2.3 *Rundown into Lead Bond Cavity* — 0.010" (0.254 mm) maximum extension from the top surface of the cavity.

7.2.2.4 *Pullback* — See Table 1.

Table 1 Maximum Allowable Pullback

External	0.015" (0.381 mm)
Internal	0.101" (0.254 mm)

NOTE 3: Glass pullback, at any point, shall not reduce the critical seal path width to less than one-half the designed width. (See Figure 2.)

7.2.2.5 *Foreign Material* — 0.020" (0.508 mm) maximum allowable dimension but 0.010" (0.254 mm) in the critical seal area, with no more than four sites allowed and a minimum separation of 0.030" (0.762 mm) between sites.

7.3 *Die Attach Cavity Metallization* — Excluding a 0.010" (0.254 mm) wide zone around the periphery of the cavity, the following criteria apply:

7.3.1 *Foreign Material, including Glass Splatters* — no more than four areas with 0.005" (0.13 mm) maximum dimension or greater than 0.001" (0.025 mm) height.

7.3.2 *Metallization Lumps* — No more than four allowed. If the metallization is Gold and eutectic Gold-Silicon die attach is to be used, then the lumps may not exceed 0.010" (0.254 mm) in diameter and 0.005" (0.127 mm) height. If eutectic bonding is not used, then the lumps will be treated as foreign material per Section 7.3.1

7.3.3 *Voids* — 0.005" (0.127 mm) maximum allowable dimension with no more than four allowed and a minimum separation of 0.030" (0.762 mm) between sites.

7.4 *Leadframe*

7.4.1 *Lead Bond Areas* — the minimum lead bond area on the lead tip is defined in Figure 4.

In these bond areas, the following defects are not allowed:

7.4.1.1 *Voids or Pits* — Exposure of base material with any dimension larger than 0.001" (0.0254 mm).

7.4.1.2 *Discoloration, Blistering, or Peeling of the Metallization*

7.4.1.3 *Scratches or Scrapes* — Any build-up of the metallization, or exposure of the base material.

7.4.1.4 *Foreign Material including Glass Splatter or Projections* — No more than four sites, each with a maximum dimension of 0.001" (0.0254 mm).

7.4.1.5 *Glass Wetting or Cracking* — Any lead finger which is not firmly embedded in the glass.

7.4.1.6 *Glass Pullback from the Lead Tip* — Greater than 0.010" (0.254 mm).

7.4.1.7 *Glass Bulge between Lead Fingers* — Greater than 0.005" (0.127 mm) height above the fingers except as agreed between vendor and customer for narrow pitch leads where this limit may cause wire bond interference problems.

7.4.1.8 *Lead Tip Coplanarity (Pre-assembled Bases, Leadframes, and Window Frames)* — Greater than 0.006" (0.15 mm) difference in the position of the top surface of the lead from highest lead to lowest lead.

7.4.1.9 *Lead Tip Pitch* — Greater than ± 0.002" (0.051 mm) variation from true position.

7.4.2 *Internal Lead Areas, excluding Lead Bond Areas* — In these areas, the following defects are not allowed:

7.4.2.1 *Burrs and Projections or Pits* — With a maximum dimension greater than 0.002" (0.0508 mm) in height or depth.

7.4.2.2 *Foreign Material (including Plating Discoloration)* — With a major dimension in the surface plane greater than 0.015" (0.381 mm) or exceeding 0.002" (0.0508 mm) in height.

7.4.2.3 *Voids which Expose Base Metal* — With a major dimension greater than 0.002" (0.0508 mm).

7.4.2.4 *Blistering or Peeling of Metallization*

7.4.2.5 Scratches and scrapes which cause metal build-up or expose base material.

7.4.3 *External Lead Areas*

NOTE 4: Non-functional areas of the leadframe, such as tie-bars, shall not be subjected to inspection.

7.4.3.1 Unplated Leads

NOTE 5: Plated leads shall also be required to pass these criteria.

7.4.3.1.1 *Scratches* — Causing loss of more than 25% of the leadframe thickness.

7.4.3.1.2 *Voids* — In violation of Section 7.4.3.1.1 or loss of more than 10% of the design width of a leadframe detail.

7.4.3.1.3 *Burrs* — In excess of 0.002" (0.051 mm) in height and 0.005" (0.127 mm) in the major dimension.

7.4.3.2 *Plated Leads*

7.4.3.2.1 *Scratches and Scrapes* — Exposure of base material or loss of plating integrity over 5% of the area of a lead finger.

7.4.3.2.2 *Voids* — Exposure of base material.

7.4.3.2.3 *Blistering or Peeling*

7.4.3.2.4 *Staining, Foreign Material, or Contamination* — In excess of 5% of the area of a lead finger.

7.4.4 *Lead Assembly*

7.4.4.1 *Lead Tip Overhang* — 0.010" (0.254 mm) maximum from the cavity wall, see Figure 5.

7.4.4.2 *Lead Misalignment* — 0.010" (0.254 mm) maximum, see Figure 6.

7.4.5 *Window Assembly Misalignment* — 0.015" (0.381 mm) maximum, see Figure 7.

8 Incoming Inspection and Functional Tests

8.1 *Incoming Inspection*

8.1.1 Dimensional inspection per Section 6.

8.1.2 Visual inspection per Section 7 at 10× magnification with vertical lighting.

8.1.3 *Metallization*

8.1.3.1 *Die Attach Metallization* — Thickness shall be measured by standard cross-sectioning without smearing or by X-Ray fluorescence.

8.1.3.2 *Lead Bond Metallization* — Thickness shall be measured by X-ray fluorescence.

8.1.3.3 *External Lead Plating (if applicable)*

8.1.3.3.1 *Thickness* — Shall be measured by X-ray fluorescence.

8.1.3.3.2 *Solderability* — Shall be tested per MIL-STD-883, Method 2003.

8.2 *Functional Testing*

NOTE 6: All procedures used to functionally test the components shall be agreed between user and supplier.

The sequence of functional testing shall be as shown in Figure 8.

8.2.1 *Die Attach*

8.2.1.1 *Visual Inspection*

Eutectic Bonding — Visually inspect the alloy wet-out after die attach. The minimum wet-out requirement shall be 100% of the die perimeter.

Silver Glass, Epoxy, or Polyimide Bonding — 100% die perimeter coverage shall be required.

NOTE 7: 100% coverage for resin bonding is not a function of package acceptability but is required to standardize die shear testing. The inability of the resins to wet the surface of the die attach area due to contamination is cause for rejection.

8.2.1.2 *Die Shear Test* — Perform destructive testing per MIL-STD-883, Method 2019.

NOTE 8: This test may also be performed after environmental testing. In the case of very large die, this test may not be appropriate to fully evaluate the package. In these cases, die sizes, agreed between vendor and customer, shall be used. Alternatively, die pull testing may be used by agreement between vendor and customer.

8.2.1.3 *Radiographic Inspection for Voids* — Perform inspection per MIL-STD-883, Method 2012.

8.2.1.4 *Ultrasonic Inspection for Voids, Delamination, and Cracks* — Perform inspection per MIL-STD-883, Method 2030.

8.2.2 *Wire Bond* — On wire bonds that meet the requirements of MIL-STD-883, Method 2010, perform destructive testing per MIL- STD-883, Method 2011, Test Condition D. Bonds which cause lifted metallization from the leadframe fingers shall also be cause for component rejection.

NOTE 9: This test shall be performed at pre-seal and post-seal.

8.2.3 *Seal*

8.2.3.1 *Visual Inspection* — The glass sealant appearance and flow shall be visually inspected for conformance to agreed process criteria.

8.2.3.2 *Cap Torque Test* — This test shall be performed per process agreement.

8.2.4 *Lead Finish* — Type A per MIL-M-38510 if required.

8.2.5 *Hermeticity* — This test shall be performed per MIL-STD-883, Method 1014, Test Condition A or B and C. The package must maintain hermetic integrity after each environmental test or sequence of tests.

8.2.6 *Environmental Testing* — Environmental evaluation shall include, but not be limited to, the following tests:

NOTE 10: The sequence of testing and the sample sizes for each sub-group shall be agreed between vendor and customer.

8.2.6.1 *Temperature Cycle* — Per MIL-STD-883, Method 1010, Condition C.

8.2.6.2 *Thermal Shock* — Per MIL-STD-883, Method 1011, Condition B.

8.2.6.3 *Vibration Fatigue* — Per MIL-STD-883, Method 2005, Test Condition B.

8.2.6.4 *Mechanical Shock* — Per MIL-STD-883, Method 2002, Test Condition B.

8.2.6.5 *Constant Acceleration* — Per MIL-STD-883, Method 2001, Test Condition D, "Y" axis only.

8.2.6.6 *Moisture Resistance* — Per MIL-STD-883, Method 1004.

8.2.6.7 *Additional Testing* — Additional tests performed at package qualification may include evaluation of electrical and thermal characteristics. These tests may be performed on a periodic basis to maintain package qualification.

These tests may include, but are not limited to, the following:

8.2.6.7.1 *Insulation Resistance* — Per MIL-STD-883, Method 1003, Test Condition as agreed between user and supplier.

8.2.6.7.2 *Lead Inductance* — Per SEMI Test Method G23.

8.2.6.7.3 *Lead-to-Lead Capacitance* — Per SEMI Test Method G24.

8.2.6.7.4 *Lead Resistance* — Per SEMI G25.

8.2.6.7.5 *Thermal Dissipation* — Per MIL-STD-883, Method 1012.

9 Sampling

The sampling plan, based on MIL-STD-105, shall be agreed between user and supplier.

10 Packaging and Marking

10.1 *Packaging* — The shipping containers and materials shall be suitability designed to provide the components with protection against normal transportation damage risks which include crushing and spillage, and exposure to moisture and other corrosive gases.

The packing materials must not cause particulate contamination on the components.

10.2 *Marking* — The shipping container shall be clearly marked with the following information:

Customer's Part Number

Customer's Purchase Order Number

Drawing Number (Customer's and Vendor's, if appropriate)

Quantity

Vendor Lot Number

Shipping date

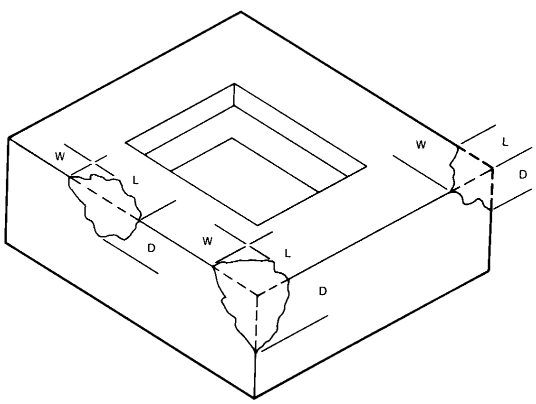


Figure 1
Chip Illustration

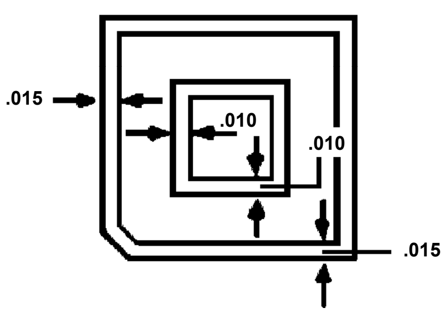


Figure 2
Critical and Non-Critical Seal Areas

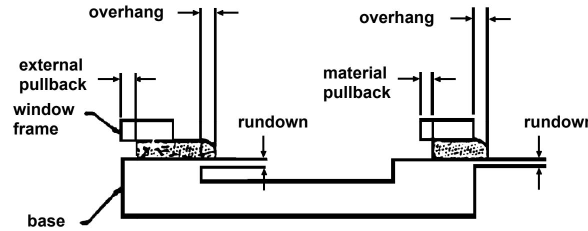


Figure 3
Glass Misalignment

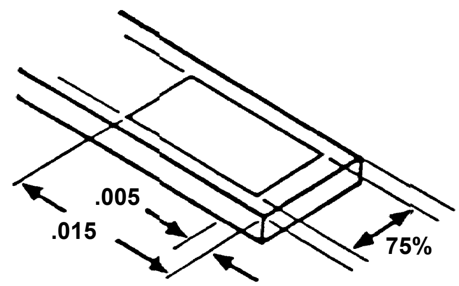


Figure 4

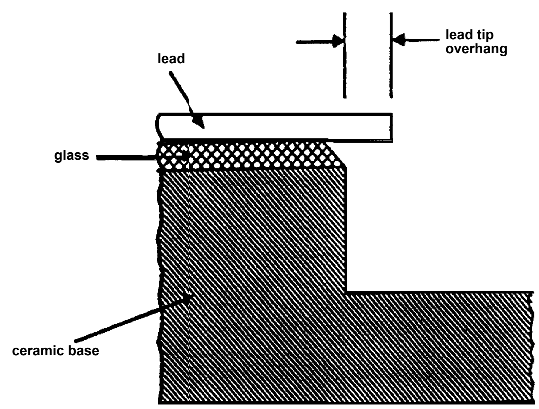


Figure 5

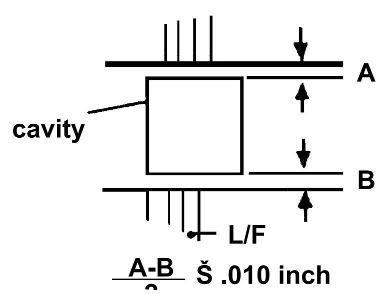
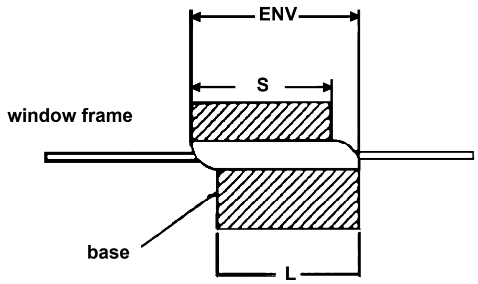


Figure 6



$$ENV - L + \frac{L - S}{2} \leq .015$$

Figure 7

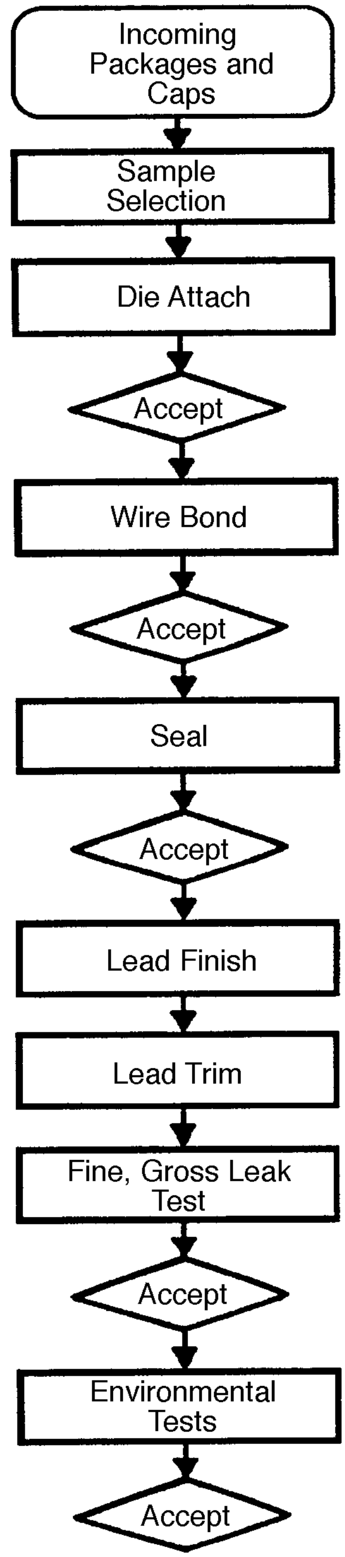


Figure 8

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their responsibility.

SEMI G59-94 (Reapproved 0302)
TEST METHOD FOR MEASUREMENT OF IONIC CONTAMINATION ON LEADFRAME INTERLEAFING AND THE CONTAMINATION TRANSFERRED FROM THE INTERLEAFING TO THE LEADFRAMES

This specification was technically approved by the Global Assembling and Packaging Committee and is the direct responsibility of the Japanese Assembling and Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on November 26, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1994.

1 Purpose

1.1 This test method describes a procedure to determine the ionic contamination on leadframe interleafing and the contamination transferred from the interleafing to the leadframes using a water extraction method.

2 Scope

2.1 This test method is sensitive to the following ionic species:

Na^+, NH_4^+, K^+, Cl^-, NO_3^-, Br^-, SO_4^{2-}, PO_4^{3-}.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *ASTM Specifications*[1]

D 4327 — Anions in Water by Ion Chromatography

D 1193 — Specification for Reagent Water

4 Terminology

4.1 *eluent* — The solvent used to carry the extracted ions through the ion exchange chromatograph.

4.2 *interleaf (for semiconductor leadframes)* — A paper or plastic film which is placed between layers of semiconductor leadframes strips to prevent tangling.

4.3 *regenerant* — A chemical solution containing the ions originally present in the chromatograph column prior to a test run, used to prepare the column for a new test.

4.4 *retention time* — The time required for a particular ion type to pass from the injection port to the detector. Retention time is characteristically different for each ion type.

4.5 *standard solution* — A solution containing a known concentration of the ion to be measured and used to calibrate the chromatograph.

5 Summary of Method

Ionic contamination is extracted in water at > 95°C for 30 ± 2 minutes. The contamination is quantitatively analyzed by ion type using ion chromatography, and the result is presented as nanograms/unit area.

6 Significance

6.1 Contamination on the interleaf may contribute to semiconductor device reliability problems by transference of the contamination to the leadframes.

6.2 The method may be used by leadframe manufacturers for the incoming inspection of the interleafing material, or by users at incoming inspection of the leadframes.

6.3 Correlation of device reliability results with interleaf contamination level measurements may lead to improved interleaf materials.

7 Interferences

7.1 The interleaf material and the leadframes must only be touched with cleaned tweezers or while wearing double-layer gloves with polyethylene outer gloves in order to avoid additional contamination.

8 Equipment

8.1 *Ion Chromatograph for Anion and Cation Analysis* — This equipment is to consist of a concentration pump, guard column, separator column, and a detector module.

The minimum sensitivity of the chromatograph for each ion type is defined in Table 1.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

Table 1 Sensitivity of Ion Chromatograph

Ion		*Sensitivity(ng/mL)*
Cation	Na^+	0.2
	NH_4^+	0.5
	K^+	1.0
Anion	Cl^-	0.3
	PO_4^{3-}	2.0
	Br^-	1.0
	NO_3^-	1.0
	SO_4^{2-}	1.0

8.2 *Chart Recorder*

8.3 *Ion Extraction Vessels* — Polypropylene or polytetrafluoroethylene containers with sealing caps.

NOTE 1: The contamination level of these vessels must be less than one fifth (1/5) of the expected contamination level on the interleaf of leadframes when measured in a control test.

8.4 *Water Bath* — 300 mm L × 300 mmW × 200 mmH, filled with DI water, and capable of holding 95°C.

8.5 *Constant Temperature and Humidity Chamber*

8.6 *Volumetric Dispenser* — (e.g., Pipettes — 10 mL and 100 mL capacity).

8.7 *Quartz Flasks and Pipettes for Cation Standard Solutions* — 100, 250, 500, and 1000 mL capacity (flasks); 1, 10, and 25 mL capacity (pipettes).

8.8 *Borosilicate Glass Flasks and Pipettes for Anion Standard Solutions* — 100, 250, 500, and 1000 mL capacity (flasks); 1, 10, and 25 mL capacity (pipettes).

8.9 *Chemical Balance, Weighing Chemicals*

8.10 *Scissors, Tweezers, Spatula*

9 Reagents and Materials

9.1 Deionized water, resistivity ≥ 15 megohm centimeters at 25°C per ASTM D 1193.

9.2 Eluents and regenerants for specific chromatograph columns prepared per chromatograph equipment manufacturer's recommendations so that the water peak can be separated from the ionic peaks.

9.3 *Compounds Required for the Preparation of Standard Solutions*

9.3.1 *Cations* — NaCl, NH_4Cl, KCl.

9.3.2 *Anions* — NaCl, $Na_2HPO_4 \cdot 12H_2O$, NaBr, $NaNO_3$, K_2SO_4.

NOTE 2: All compounds must be reagent grade.

10 Sampling

10.1 *Sample Conditioning*

10.1.1 In case of measurement of ionic contamination transferred from the interleaves to the leadframes, select a stack of ten (10) leadframe strips with their nine (9) interleaves alternately, from the lot to be tested, and place them horizontally into a chamber at 85 ± 5°C, 85 ± 5% Relative Humidity for 24 hours.

10.2 *Sample Selection*

10.2.1 Recommended sample size of interleaf used in interleaf extraction test is 10,000 sq. mm.

10.2.2 In the extraction procedure, do not use the top or bottom leadframe strips in the stack.

NOTE 3: If a load is used to hold the stack together, it shall be recorded as part of the conditions of test.

NOTE 4: The leadframe/interleaf contact area shall be recorded. The vender and customer shall agree on the surface area of the leadframes.

11 Preparation of Standard Solutions

11.1 *Standard Solutions*

11.1.1 The single ingredient standard solutions of each ion (Na^+, NH_4^+, K^+, Cl^-, NO_3^-, Br^-, SO_4^{2-}, PO_4^{3-})are made by dissolving 1.000 g of each ion into 1.000 liter of DI water, respectively. The stored multi-ingredient standard solutions shown in Table 2 are then made from these single ingredient standard solutions by the dilution method.

Table 2 Concentration of Standard Solution for Calibration

Ion		*Mixed Standard Solution (µg/mL)*	*Standard Solution for Calibration(ng/mL)*		
			I	*II*	*III*
Cation	Na^+	10	5	10	20
	NH_4^+	10	5	10	20
	K^+	10	5	10	20
Anion	Cl^-	4	10	20	40
	PO_4^{3-}	10	25	50	100
	Br^-	4	10	20	40
	NO_3^-	4	10	20	40
	SO_4^{2-}	4	10	20	40

11.1.2 Cation and Anion standard solutions for calibration are made by diluting the stored multi-ingredient standard solutions as shown in Table 2.

11.1.3 Store the multi-ingredient standard solution and the calibration solutions in the correct flasks and label with the ion type and concentration.

NOTE 5: New Standard solutions for calibration are required every 24 hours. Ensure that the flasks are cleaned with water before refilling with a new solution.

11.2 *Calibration*

11.2.1 Set up the chromatograph and regenerate the columns according to the manufacturer's instructions (ASTM D 4327 provides further details).

11.2.2 Run the eluent through the chromatograph until a stable baseline chromatograph is obtained.

11.2.3 Select the injection volume recommended by the manufacturer for each ion type and inject it into the chromatograph. Record the chromatograph for each ion type, and make the calibration curve for each ion (ion concentration versus peak height or area).

NOTE 6: Peak height or area under the ion's characteristic curve is proportional to the concentration.

12 Procedure — Container Extraction Method

NOTE 7: The size of the extraction vessels depends on the expected volume of water and the leadframes. The vessels must be at least threequarters filled with water and leadframes.

NOTE 8: The vessels must be from the same manufacturing batch.

12.1 *Extraction Vessels* — Cleaning

12.1.1 Fill three vessels three-quarters of the way full in order to reduce the amount of air in the vessel and attach the caps.

12.1.2 Place the vessels in a water bath at > 95°C for 30 ± 2 minutes.

12.1.3 Remove the vessels from the bath and rinse out five (5) times with DI water.

12.2 *Interleaf Contamination Extraction*

12.2.1 Place the interleaf sample in one of the cleaned vessels.

NOTE 9: The interleafing may be cut in order to ease loading into the vessels.

12.2.2 Add 100 mL of DI water and cap the vessels. Place a similar amount of water into the other cleaned vessel and attach the cap.

NOTE 10: 100 mL is the recommended volume of water; however, the samples must be covered with water.

12.3 *Leadframe Contamination Extraction*

12.3.1 Place five (5) leadframe strips in one of the vessels cleaned per Section 12.1.

NOTE 11: The leadframes may be cut as required to ease entry into the vessel.

12.3.2 Cover with DI water and cap.

NOTE 12: 25 mL is the recommended volume of water for a small volume of leadframe samples, 100 mL for a large volume. The samples must be covered with water.

12.3.3 Place a similar volume of water in one of the vessels cleaned per Section 12.1.

12.4 *Extration*

12.4.1 Place the three (3) vessels into the water bath at T ≥ 95°C, for 30 ± 2 minutes.

12.4.2 Remove the vessels from the bath and allow to cool.

12.4.3 Remove the leadframes and interleafing material from their respective vessel and recap.

13 Measurements and Calculations

13.1 *Chromatograph Preparation and Calibration*

13.1.1 Prepare the chromatograph for operation by regenerating the columns according to the manufacturer's recommendations.

13.1.2 Run the eluent through the chromatograph until a stable baseline calibration is established.

13.2 *Testing*

13.2.1 Inject the recommended sample size of solution from the interleaf extraction into the chromatograph and obtain the chromatogram.

13.2.2 Repeat 13.1 and then inject the recommended sample size from the leadframe extraction and obtain the chromatogram.

13.2.3 Repeat 13.1 and then inject the recommended sample size from the water-only vessel and obtain the chromatogram of the background sample.

NOTE 13: The time from extraction to insertion of the sample into the chromatograph shall not exceed eight (8) hours.

13.3 *Results*

13.3.1 Sample concentrations are determined from the calibration curves for each ion type.

13.3.2 The surface concentration of ionic contaminants (SCIC) for each ion type is given by the following equation:

$$\text{SCIC}\left(\text{ng/cm}^2\right)= \frac{\left(\begin{matrix}\text{Sample}\\ \text{Concentration}\end{matrix} - \begin{matrix}\text{Background}\\ \text{Concentration}\end{matrix}\right) \times \begin{matrix}\text{Extraction}\\ \text{Volume(mL)}\end{matrix}}{\text{Total Interleaf(or Leadframe) Surface Area(cm}^2\text{)}}$$

14 Report

The report, when used by a vender to certify a user's requirement, or by a user at incoming inspection, shall, at least, contain the following information. Additional information shall be agreed between user and supplier.

14.1 Vendor's lot numbers for leadframes and interleaf material, and date of shipment.

14.2 Sample conditioning conditions.

14.3 Test conditions.

15 Related Documents

15.1 *SEMI Specifications*

SEMI G52 — Standard Test Method for Measurement of Ionic Contamination on Semiconductor Leadframes (Proposed)

SEMI G60-94 (Reapproved 0302)
TEST METHOD FOR THE MEASUREMENT OF ELECTROSTATIC PROPERTIES OF SEMICONDUCTOR LEADFRAME INTERLEAFING MATERIALS

The test method was technically approved by the Global Assembly and Packaging Committee and is the direct responsibility of the Japanese Assembly and Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on November 26, 2001. Initially available at www.semi.org on December 2001; to be published March 2002. Origianlly published in 1994.

1 Purpose

1.1 This test method describes a procedure to determine the electrostatic properties of interleaf materials in film or sheet form by measuring the magnitude and polarity of an induced charge and the time required for complete dissipation of the charge.

NOTE 1: The method is independent of volume or insulation resistivities.

2 Scope

2.1 This test method is suitable for all interleaf materials and may be used by vendors at outgoing inspection, or customers at incoming inspection.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 None

4 Terminology

4.1 *electrostatic properties* — For the purposes of this document, electrostatic properties are defined as the ability of a material, when grounded, to dissipate a charge induced onto the surface of that material.

4.2 *interleaf (for semiconductor leadframes)* — A paper or plastic film placed between layers of semiconductor leadframe strips to prevent transformation.

5 Summary of Method

The method involves charging the interleaf material to a high voltage and observing the time required for the charge to be dissipated using an electrometer.

6 Significance

6.1 This procedure evaluates the electrostatic build up and dissipation properties of the interleaf materials which may affect the reliability and efficiency of devices.

7 Interferences

7.1 The interleaf material and the leadframes must only be touched while wearing double-layer gloves with polyethylene outer gloves in order to avoid contamination which may change the electrostatic properties.

7.2 The test is not valid if the interleafing material is dusty.

8 Equipment

8.1 Aluminum panel measuring 127 mm × 76.2 mm × 3.2 mm (5" × 3" × 1/8").

8.2 High voltage source, 0 to 15 KV, positive and negative.

8.3 Electrometer with a full scale reading of 0.01, 0.1, 1.0, 10, and 100, or a recording oscilloscope with a response of 1 microsecond per division, or equivalent.

8.4 Fabricated electrostatic test chamber with electrostatic test unit, illustrated in Figure 1.

8.5 Single channel, pen type recorder with speeds of 12.7 mm, 25.4 mm, 50.8 mm, 101.6 mm, and 203.2 mm (0.5" , 1.0" , 2.0" , 4.0" , and 8.0") per minute and per second.

8.6 Four RG 114/U cables for connections between the detector and the electrometer and between the electrometer and the recorder. The nominal lengths of the cables are:

8.6.1 127 mm (5") for the connections between the detector and the output connector on the electrostatic test chamber.

8.6.2 863.6 mm (34") between the electrostatic test chamber and the electrometer exclusive of the connectors.

8.6.3 800.1 mm (31.5") between the electrometer and the recorder (2 required).

8.7 Three position control switch for connecting the test specimen to the high voltage source or the ground or neutral potential.

8.8 The equipment shall be assembled as illustrated in Figure 2.

9 Sampling

9.1 Sample size shall be agreed between user and supplier.

NOTE 2: The minimum sample size shall be three (3) per lot. Each specimen shall measure 127 mm × 76.2 mm (5" × 3").

9.2 Each specimen shall be free of defects such as holes, cracks, and tears.

NOTE 3: If the specimen is coated, the coating shall be continuous.

10 Sample Conditioning

10.1 Prior to testing, specimens shall be placed in the electrostatic test chamber for 24 hours at the following conditions.

Temperature: 23 ± 3° C

Relative Humidity: 50 ± 5%

11 Set-Up Procedure

11.1 Turn on all the equipment and allow to warm up as noted in the operations manuals.

11.2 *Electrometer*

11.2.1 Set "MULTIPLIER" switch to provide a half scale reading when the test voltage is applied.

11.2.2 Set the "OPERATE" switch at "ZERO CHECK".

11.2.3 Set meter to read positive charge.

11.3 Set the high voltage for 5KV positive output.

11.4 Mount the 127 mm × 76.2 mm × 3.2 mm (5" × 3" × 1/8") aluminum panel between the electrodes in the electrostatic test unit so that the detector head is directly over the center of the panel. Tighten the four wing nuts to secure the panel.

11.5 Set the recorder chart speed to 25.4 mm/min. (1" /min.).

11.6 Set "OPERATION" switch to "OPERATE".

11.7 Turn the three-position control switch to "HIGH VOLTAGE".

11.8 Verify that the reading on the recorder is identical to the meter reading. Adjust the recorder as necessary.

11.9 Turn the three-position switch to "GROUND" to remove the charge from the test panel.

11.10 When the electrometer meter reaches "ZERO", stop the recorder and set the "OPERATE" switch to "ZERO CHECK".

11.11 Repeat the calibration for a high voltage 5KV negative output.

12 Measurements and Calculations

12.1 Mount the specimens vertically between the electrodes and tighten the wing nuts to insure intimate contact between specimen and the electrodes.

12.2 Set chart recorder to 12.7 mm/sec. (0.5" /sec.) and turn on recorder.

12.3 Set electrometer meter switch to indicate "POSITIVE" or "NEGATIVE" charge depending on the high voltage to be applied.

12.4 Adjust the high voltage to 5KV positive or negative as desired.

12.5 Set "OPERATION" switch to "OPERATE".

12.6 Turn the three-position control switch to "HIGH VOLTAGE".

12.7 When the meter reaches a peak, indicating that the specimen has received its maximum charge, turn the three-position switch to "GROUND".

12.8 When the meter needle reaches "ZERO" or after 10 seconds which ever comes first, stop the recorder and move the "OPERATION" switch to "GROUND CHECK".

12.9 Charge each specimen three (3) times with both positive and negative charges. Allow the specimens to remain grounded for 10 minutes after each charging cycle to remove any residual charge on the specimen.

NOTE 4: If the interleaf material is non-homogenous, both surface shall be charged by reversing the faces of the specimen in contact with the electrodes.

12.10 Calculate the decay time, in seconds, by measuring the horizontal distance on the chart from the point where the specimen was grounded until the point where the needle reached "ZERO".

13 Report

The report, when used by a vendor to certify a customer's requirements, or by a customer at incoming inspection shall, at least, contain the following information. Additional information shall be agreed between user and supplier.

13.1 Interleaf material.

13.2 Vendor's lot number for the interleaf material, and date of shipment.

13.3 Sample conditioning conditions.

13.4 Test conditions if different from this test method.

13.5 The surface charged.

13.6 Results from Section 11 indicating the calculated decay time for each specimen in the sample for both the positive and negative charges and the acceptance (or rejection) at incoming inspection. SPC charting techniques may be used to monitor results.

NOTE 5: Acceptance/rejection limits shall be agreed between user and supplier.

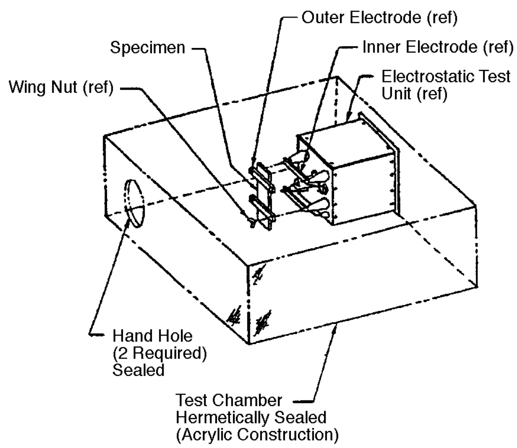


Figure 1
Electrostatic Test Chamber

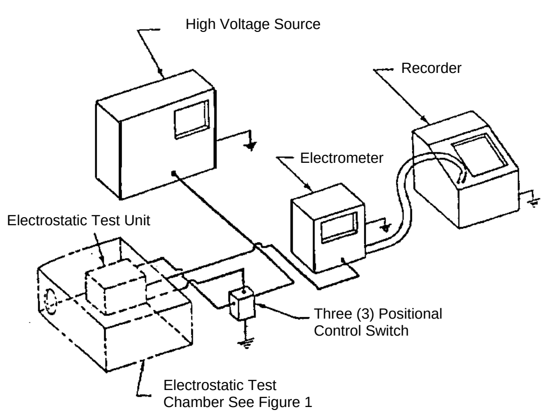


Figure 2
Electrostatic Test Arrangement

14 Related Documents

14.1 The following documents provide additional information for testing electrostatic properties. The test method described in this document is based on FED-STD-101C.

14.2 *Electronic Industries Association*[1]

EIA-541 — Packaging Materials Standards for ESD Sensitive Items

14.3 *Federal Specifications*[2]

FED-STD-101C — Test Procedures for Packaging Items

14.4 *JIS Specifications*[3]

JIS K6911 — Testing Methods for Thermosetting Plastics

JIS L 1094 — Testing Methods for Electrostatic Propensity of Woven and Knitted Fabrics

1 Electronic Industries Alliance, EIA Engineering Department, Standards Sales Office, 2001 Eye Street, NW, Washington, D.C. 20006, USA. Website: www.eia.org

2 Federal Specifications, GSA Specifications and Consumer Information Branch, Bldg. 197, Washington Navy Yard, Washington, DC 20407

3 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

SEMI G61-94
SPECIFICATION FOR COFIRED CERAMIC PACKAGES

1 Preface

1.1 *Purpose* — This specification defines the materials and acceptance criteria for high-temperature, cofired ceramic packages.

1.2 *Scope* — The criteria detailed in this specifiication apply to the following package outlines registered with, or specified by JEDEC (see Publication 95), EIAJ, or MIL-STD-1835 specifications:

Chip Carriers (Leadless or Leaded)

Dual-in-Line Packages (Sidebrazed)

Flat Packs (Top or Bottom Brazed)

Grid Arrays (Land/Ball or Pin)

NOTE 1: Packages not meeting these specifications may also use the criteria as appropriate.

This document consolidates the criteria for all cofired packages so that package amnufacturing and inspection may be simplified and costs reduced.

1.3 *Units* — U.S. Customary (inch-pound) or metric (SI) units may be used at the customer's discretion. This specification uses U.S. Customary units as the prime unit. In the drawings, only U.S. Customary units are detailed.

2 Applicable Documents

2.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering packages shall be as follows:

Purchase Order

Customer's Package Drawings

This Specification

Reference Documents

Related Documents

2.2 *Referenced Documents*

2.2.1 *SEMI Specifications*

SEMI G6 — Seal Ring Flatness

SEMI G8 — Gold Plating — Temperature Resistance

SEMI G23 — Measuring the Inductance of Package Leads

SEMI G24 — Measuring the Lead-to-Lead and Loading Capacitance of Package Leads

SEMI G25 — Measuring the Resistance of Package Leads

SEMI G30 — Test Method, Junction-to-Case Thermal Resistance Measurements on Ceramic Packages

SEMI G35 — Test Methods for Lead Finishes on Semiconductor (Acitve) Devices

2.2.2 *ANSI Specifications*[1]

ANSI Y14.5M — Dimensioning and Tolerancing

2.2.3 *ASTM Specifications*[2]

ASTM B 568 — Measurement of Coating Thickness by X-Ray Spectrometry

ASTM E 18 — Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

ASTM E 165 — Liquid Penetrant Inspection Method

ASTM E 384 — Test Method for Microhardness of Materials

ASTM F 109 — Surface Imperfections on Ceramics

2.2.4 *JEDEC Specifications*[3]

Pub. No. 95 — Registered and Standard Outlines for Semiconductor Devices

2.2.5 *Military and Federal Specifications*[4]

MIL-STD-7883 — Brazing

MIL-STD-38510 — General Spec. for Microcircuits

MIL-G-45204 — Gold Plating — Electrodeposited

QQ-N-290A — Nickel Plating (Electrodeposited)

2.2.6 *EIAJ Specifications*

2.3 *Related Documents*

2.3.1 *Military and Federal Specifications*

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

1 ANSI, 1430 Broadway, New York, NY 10018

2 American Society of Testing Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 JEDEC, 2001 Eye Street N.W., Washington D.C. 20006

4 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 Definition of Terms

3.1 *blister (bubble) ceramic* — an enclosed, localized separation within or between the layers of a ceramic package that does not expose an underlying layer of ceramic or metallization.

3.2 *blister (bubble) metallization* — an enclosed, localized separation of a metallization layer from its base material (such as ceramic or another metal layer) that does not expose the underlying layer.

3.3 *braze* — in semiconductor packages, an alloy used to attach pins, leads, seal rings and heat sinks/studs to the package.

3.4 *burr* — an adherent fragment of parent material at a component edge. In leadframes, the metal burr, due to the stamping operation, may be in the horizontal or vertical direction to the surface. In ceramic packages, this type of characteristic is called a fin.

3.5 *castellations* — metallized semi-circular channels on chip carrier edges which provide contact between internal package metallization traces and the external test pads. These castellations provide for improved solder fillets during attachment to a circuit board (see Figure 1).

3.6 *cavity-down packages* — packages where the die surface faces the mounting board. (See Figure 2 for the pin grid array packages in the cavity-down configuration. It is more usual to refer to the chip carrier mounting surfaces as the seating planes. In this cavity orientation, the seating plane is Seating Plane 2 per JEDEC JC-11.)

3.7 *cavity-up packages* — packages where the die surface faces away from the mounting board (see Figure 2 or Seating Plane 1 for chip carriers).

3.8 *chip* — region of material missing from a component (e.g., ceramic from a package, or solder from a preform). The region does not progress completely through the component and is formed after the component is manufactured. Chip size is defined by its length, width and depth from a projection of the design platform. Also called chipout (see Figure 1).

3.9 *co-fired* — in the manufacturing of some types of ceramic packages, the technology used to join together various ceramic layers and metallization patterns screened onto those layers by simultaneous firing at high temperature.

3.10 *contact pad* — in a leadless chip carrier or land grid array, the metallized areas on the bottom of the package that provide contact point between the internal leads and connecting external circuitry. They are also used for electrical test pads.

3.11 *crack* — a cleavage or fracture that extends to the surface of a semiconductor package or solder preform. The crack may or may not pass through the entire thickness of the package or preform.

3.12 *critical seal area (ceramic)* — on a semiconductor package, the area bounded by the shortest nominal design distance from the largest cavity, usually the wire bond cavity, to the edge of the package or ceramic layer forming the seal area.

3.13 *critical seal area* — metallization or metal ring — The entire area of the seal ring; it applies to plated refractory metal or a metal ring.

3.14 *critical seal path (ceramic)* — on a semiconductor package, the shortest nominal design distance from the largest cavity, usually the wire bond cavity, to the edge of the package or ceramic layer forming the seal area.

3.15 *delamination* — in a co-fired ceramic package, chip carrier, pin grid array, etc., the separation of one ceramic layer from another.

3.16 *element (packaging)* — part of a semiconductor package feature (e.g., package leads have braze paddle/stand-off and contact elements, pins have the nail head/braze area and contact elements).

3.17 *fin* — on a ceramic package or cap, a fine feathery-edged projection of parent ceramic material on the corner of the ceramic body.

3.18 *flatness* — in a ceramic package or leadframe, the allowable deviation of a surface from a defined reference plane. The tolerance zone is defined by two parallel planes within which the surface must lie.

3.19 *foreign material* — an adherent particle that is not parent material of the component. Adherence means that the particle cannot be removed by an air or nitrogen blast at 20 psi.

3.20 *heat exchange area* — a metallized region on one major surface of the package to which heat sinks may be attached by brazing, soldering, or adhesive resin.

3.21 *layer* — on a cofired ceramic package, the body is made from layers of ceramic or metallized ceramic. The layers are defined by their functionality, and several ceramic layers may be described as comprising one functional layer if all are common in plan-form and function (e.g., die attach cavity) (see Figure 4).

3.22 *lead offset* — in brazed lead ceramic packages, the variation in position of the centerline of the lead with reference to the centerline of the braze pad to which it is mounted.

3.23 *lead sweep* — lead movement, measured with respect to a datum, perpendicular to the top or bottom of the package that passes through the designed mid-point of the lead where the lead is attached to the package (e.g., side-brazed laminates), or where the lead exits the package body (e.g., plastic dual-in-line packages). The movement is viewed from the side of the package, not the ends.

3.24 *lead-to-lead separation* — the distance between adjacent leads when measured from their centerlines at the point of connection to the package.

3.25 *lead tweeze* — lead movement, measured with respect to a datum, perpendicular to the top or bottom of the package that passes through the designed mid-point of the lead where the lead is attached to the package (e.g., side-brazed laminates), or where the lead exits the package body (e.g., plastic dual-in-line packages). The movement is viewed from the ends of the package, not the side and the lead movement is from the edges of the package in toward the centerline of the package.

3.26 *metallization void* — the absence of a clad, evaporated, plated or screen-printed metal layer or braze from a designated area. Also called metal or plating void.

3.27 *peeling (flaking)* — any separation of a plated, vacuum-deposited, or clad metal layer from the base metal of a leadframe, pin heatsink, or seal ring, from an underplate, or from a refractory metal on a ceramic package. Peeling exposes the underlying metal.

3.28 *pin offset* — the variation in position from the centerline of the pin to the centerline of the braze pad to which it is mounted.

3.29 *pin sweep* — pin movement, measured with respect to a datum, perpendicular to the top or bottom of the package that passes through the designed mid-point of pin where the pin is attached to the package (e.g., pin grid arrays). The movement is viewed form the side of the package, not the ends.

3.30 *pin-to-pin separation* — the distance between adjacent pins when measured from their centerlines at the point of connection to the package.

3.31 *pin tweeze* — pin movement, measured with respect to a datum, perpendicular to the top or bottom of the package that passes through the designed mid-point of pin where the pin is attached to the package (e.g., pin grid arrays). The movement is viewed form the ends of the package, not the side and the pin movement is from the edges of the package in toward the centerline of the package.

3.32 *pit* — in semiconductor packages, plastic or ceramic, or in the leadframes, a shallow depression or crater. The bottom of the depression must be visible in order for the term to apply. A pit is formed during component manufacture (see Figure 3).

3.33 *porous surface* — an uncompacted ceramic surface often showing fine pits.

3.34 *projection* — on a semiconductor package (plastic or ceramic), leadframe or preform, and irregularly raised portion of a surface indigenous to the parent material.

3.35 *pullback* — on a semiconductor package, the linear distance between the edge of a cavity cut into a ceramic layer and the first measurable glass or metallization layer interface coated onto the top surface of that layer. The total pullback may be the result of the high temperature processing required to manufacture the package or to coat the surface. It may also be the result of design considerations (see Figure 5).

3.36 *rundown* — on a semiconductor package, the linear distance from the upper surface of a ceramic cavity layer to the bottom point of the overhang into the cavity, of a sealing glass or metallization layer that has been screened onto that surface (see Figure 5).

3.37 *scrape* — the irregular removal of a deposited layer from a base material by a shearing action from another surface such that the base material is exposed over an extended area. It can also apply to the removal of surface layers from a material. The material removed from the scraped area may build up at the edges of the scrape. The deposited layer may be a metal or glass.

3.38 *seal area* — on a semiconductor package, the area designated for sealing a cover or lid to a cofired ceramic package, or a cap to a cer-DIP or cer-pack base. In the case of a co-fired ceramic package the seal area may be either bare ceramic for glass sealing or a metallized area for solder sealing. The metallized seal area may be a plating over refractory metallization or a metal ring, usually iron-nickel-cobalt or iron-nickel alloys, brazed to the refractory metal.

3.39 *seating plane* — in plug-in packages such as dual-in-line (side-brazed or cer-DIP) or pin grid arrays, the plane defined by the three lowest stand-off features on the lead or pins as measured from the bottom of the package, or in the absence of these features, by the package base or mounting plane (see Figure 6). The features, such as shoulders or projections, hold the package off the circuit board to which it is mounted. This gap allows solder flux and residues to be cleaned after soldering the device and, in some cases, to allow for sufficient cooling air flow around the device. A prescribed force is used to hold the device in the mounting holes when the seating plane is to be measured.

3.40 *side-to-side misalignment* — the offset of the center lines of corresponding leads or pins from one side of the package to another side.

3.41 *stand-off* — the separation between the base plane and the seating plane that is created by physical features that are usually formed into the pins or leads (see Figure 6). The features may also be called stand-offs.

3.42 *TIR* — total Indicator Reading.

4 Ordering Information

Purchase orders for packages furnished to this specification shall include the following items.

4.1 *Current Drawing Revision Detailing*

4.1.1 All dimensions and tolerances per ANSI Y14.5M practices.

4.1.2 Internal metallization trace pattern.

4.1.3 Type and color of ceramic.

4.1.4 *Pin or Lead Material and Hardness* — If applicable.

4.1.5 *Heat Sink/Stud Material and Hardness* — If applicable.

4.1.6 Type, hardness, and thickness of plating in the die and wire bond areas and contact pads.

4.1.7 *Type, Hardness, and Thickness of Plating on Pins or Leads and Heat Sink/Stud* — If applicable.

4.1.8 *Lead Number 1 Identification* — (See Figure 7.)

4.2 Vendor certification requirements.

4.3 Reference to this specification.

4.4 Any additions to, or variations from, this specification.

4.5 Quantity.

5 Dimensions

Package dimensions and lead numbering shall conform to the outlines registered with or specified by JEDEC (see Publication 95), EIAJ or MIL-STD-1835, as appropriate. Package manufacturing tolerances shall be agreed between user and supplier.

6 Materials

The definitions, defect criteria, and functional tests described in this specification relate to packages made with the following materials.

6.1 *Ceramic Body*

6.1.1 *Material* — Alumina, beryllia, aluminum nitride, or mullite as specified on the package drawing.

6.1.1.1 *Alumina* — Content to be 90% minimum.

6.1.1.2 *Beryllia* — Content to be 99% minimum. (Packages shall be marked BeO.)

6.1.1.3 *Aluminum nitride* — Content to be agreed between user and supplier.

6.1.1.4 *Mullite* — Content to be agreed between user and supplier.

6.1.2 *Color*

6.1.2.1 *Alumina* — White, black, dark brown, or violet.

6.1.2.2 *Beryllia* — White.

6.1.2.3 *Aluminum Nitride* — White, black, dark brown, or violet.

6.1.2.4 *Mullite* — White, black, dark brown, or violet.

6.2 Die Attach Pad, Wire Bond Fingers, Contact Pads, and Circuit Trace Metallization

6.2.1 *Base Material* — Refractory tungsten per MIL-M-38510, Type C. Thickness shall be 0.0003" (0.0076 mm) minimum.

6.2.2 *Finish* — Shall meet the requirements of MIL-M-38510.

6.2.2.1 *Nickel Under Plate (if specified)* — Shall be per QQ-N-290A. Thickness shall be 50 – 350 micro-inches (0.0013 – 0.0089 mm).

6.2.2.2 *Gold Plate* — Shall be per MIL-G-45204, Type III. Thickness shall be 50 – 225 micro-inches (0.0013 – 0.005715 mm).

6.3 *Pins, Leads, and Seal Ring*

6.3.1 *Base Material* — Iron-nickel-cobalt alloy per MIL-M-38150, Type A or iron-nickel alloy per MIL-M-38150, Type B shall be specified on the package drawing.

6.3.2 *Hardness* — 70–85 Rockwell-B for Type A material, 60–80 Rockwell-B for Type B material.

6.3.3 *Finish* — Shall meet the requirements of MIL-M-38510 per Section 6.2.2.

6.4 *Heat Sink/Stud*

6.4.1 *Material*

6.4.1.1 *Heat Sink* — (Forming at least part of the package base and the die attach area) tungsten-copper (composition to be defined on the drawing), iron-nickel (cobalt) alloy per Section 6.3.1 or molybdenum as specified on the package drawing.

6.4.1.2 *Stud* — (Brazed to a metallized area of the ceramic base layer or the heatsink of the package) — copper, tungsten-copper, or kovar as specified on the package drawing.

6.4.2 *Hardness* — Shall be specified on the drawing by agreement between user and supplier.

6.4.3 *Finish* — Shall meet the requirements of MIL-M-38510 per Section 6.2.2.

6.5 *Braze*

6.5.1 *Material* — Silver/copper (72%/28%) or equivalent shall meet the general requirements of MIL-STD-7883.

6.5.2 *Finish* — Shall meet the requirements of MIL-M-38510 per Section 6.2.2.

7 Defect Limits

Inspection shall be carried out at 10× magnification with vertical lighting.

The following conditions are cause for rejection.

7.1 *Ceramic Components*

7.1.1 *Cracks* — Any crack is cause for rejection.

7.1.2 *Chips* — See Figure 3.

7.1.2.1 *Corner Chips* — Chip sizes exceeding the limits shown in Table 1. No chip may be deeper than 50% of the package element (the ceramic functional layer) thickness.

Table 1

Package Dimension inch (mm)	*Maximum Corner Chip Dimensions (either direction) inch (mm)*
≤0.250 (≤6.35)	0.020 (0.508)
>0.250 – ≤0.500 (>6.35 – ≤12.7)	0.040 (1.016)
>0.500 – ≤1.000 (>12.7 – ≤25.4)	0.080 (2.032)
>1.000 (>25.4)	0.100 (2.54)

7.1.2.2 *Edge Chips* — Chip sizes exceeding the limits shown in Table 2. No chip may be deeper than 50% of the package element (the ceramic functional layer) thickness.

Table 2

Package Dimension in which Chip Occurs inch (mm)	*Maximum Chip Length and Width inch (mm)*
≤0.250 (≤6.35)	0.020 (0.508)
>0.250 – ≤0.500 (>6.35 – ≤12.7)	0.040 (1.016)
>0.500 – ≤1.000 (>12.7 – ≤25.4)	0.080 (2.032)
>1.000 (>25.4)	0.100 (2.54)

7.1.2.3 Chips exposing a buried metallized area excluding the plating buses which are exposed when packages are separated from the manufacturing arrays.

7.1.2.4 *Critical Seal Area (ceramic)* — Any chip reducing the critical seal path length, at any point, by more than 30% of the nominal design dimension.

No more than three chips, each of which reduces the seal path length by more than 10% but less than 30%, are allowed in this area. Each chip's length shall not exceed the limits shown in Table 3.

Table 3

Seal Ring Dimension in which Chip Occurs inch (mm)	*Maximum Chip Length inch (mm)*
≤0.250 (≤6.35)	0.020 (0.508)
>0.250 – ≤0.500 (>6.35 – ≤12.7)	0.040 (1.016)
>0.500 – ≤1.000 (>12.7 – ≤25.4)	0.080 (2.032)
>1.000 (>25.4)	0.100 (2.54)

7.1.3 *Ceramic Projections* — (bumps and blisters)

7.1.3.1 *Body (non-critical surfaces)* — Any projection, including fins, exceeding 0.005" (0.127 mm) in height, or exceeding 0.002" (0.051 mm) in height and with a surface dimension greater than 0.010" (0.254 mm).

NOTE 2: On surface mount packages, the bottom of the package shall not have any projections exceeding 0.002" (0.051 mm) in height.

7.1.3.2 *Die Attach Areas* — (bare ceramic or screen printed metal area) — Excluding a zone, 0.015" (0.381 mm) wide, around the periphery of the cavity, any projection exceeding 0.001" (0.025 mm) in height or a surface dimension of 0.010" (0.254 mm).

NOTE 3: Exclusion zones around the periphery of die attach areas may be wider on larger packages or when a metal heat sink or stud is brazed to the package and forms the die attach area (Section 7.3). The width of such zones shall be defined on the package drawing by agreement between user and supplier. This note applies to all criteria affecting die attach areas.

7.1.3.3 *Critical Seal Area (printed metal area)* — Any projection exceeding 0.001" (0.025 mm) in height or with a surface dimension exceeding 0.010" (0.254 mm) or 30% of the critical seal length, whichever is the larger.

7.1.3.4 *Critical Seal Area (bare ceramic)* — Any projection exceeding 0.001" (0.025 mm) in height or with a surface dimension exceeding 0.010" (0.254 mm) or 30% of the critical seal path, whichever is the larger.

7.1.3.5 *Wire Bond Fingers* — Any projection in the critical area defined in Figure 8 exceeding 0.0005" (0.0127 mm) in height or a surface dimension of 0.004" (0.102 mm).

7.1.3.6 *Solder Pads, Contact Pads, and Heat Exchange Areas* — Any projection exceeding 0.002" (0.051 mm) in height above the pad, or a surface dimension of 0.010" (0.254 mm).

NOTE 4: Castellation areas of chip carriers are excluded from these criteria because of the manufacturing process. (Layer misalignments, separation techniques, etc. may cause projections which do not affect package quality.

7.1.4 *Pits*

7.1.4.1 *Body (non-critical surfaces)* — Pits exceeding 0.003" (0.076 mm) in depth or a surface dimension of 0.020" (0.508 mm).

7.1.4.2 *Die Attach Areas (bare ceramic or screen printed metal area)* — Excluding a zone, 0.015" (0.381 mm) wide, around the periphery of the cavity, pits exceeding 0.001" (0.025 mm) depth below the surface or a surface dimension of 0.010" (0.254 mm). Acceptable pits shall not cover more than 10% of the surface area.

NOTE 5: Ceramic pits in metallized areas may be covered by metallization, but remain cause for rejection.

NOTE 6: Pits with a depth not exceeding 0.0005" (0.0127 mm) are not rejectable.

7.1.4.3 *Critical Seal Area (bare ceramic or metallized area)* — Pits exceeding 0.001" (.025 mm) depth below the ceramic surface or a surface dimension of 0.010" (0.254 mm). No more than three acceptable pits allowed in this area with a minimum separation of 0.030" (0.762 mm) required between sites. The seal ring width must not be reduced by more than 30% of its designed width at any point. Acceptable pits shall not cover more than 10% of the critical seal area.

7.1.4.4 *Wire Bond Fingers* — Any pit in the critical area defined in Figure 8 exceeding 0.0005" (0.0127 mm) in depth, or any pit exeeding 0.004" (0.102 mm) in a surface dimension.

7.1.4.5 *Solder Pads, Contact Pads, and Heat Exchange Areas* — Pits exceeding 0.002" (0.051 mm) depth below the pad or a surface dimension of 0.010" (0.254 mm). Acceptable pits shall not cover more than 10% of the surface area.

NOTE 7: Pits with a depth not exceeding 0.0005" (0.0127 mm) are not included in this evaluation, regardless of surface dimension.

NOTE 8: Pits in castellation areas are exluded from these criteria because of the manufacturing process.

7.1.5 *Flatness (Camber)*

7.1.5.1 *Package Flatness* — Flatness variation exceeding 0.004 inch/inch (0.004 mm/mm), with a minimum camber specification of 0.002" (0.051 mm).

7.1.5.2 *Die Attach Area Flatness* — Any flatness variations exceeding the limits shown in Table 4.

NOTE 9: These criteria apply to any die attach area ceramic, metallized ceramic, or a heat sink which forms the die attach area.

Table 4

Die Attach Area (Major Dimension) inch (mm)	*Flatness (Maximum Allowable TIR) inch (mm)*
0.750 (# 19.05)	0.002 (0.051)
>0.750 (>19.05)	0.003 inch (0.0762 mm)

7.1.5.3 *Seal Area Flatness* — See Table 5.

NOTE 10: These criteria apply to packages with bare ceramic, metallized ceramic, or a metal ring. Flatness to be measured per SEMI G6.

Table 5

Seal Ring (Major Dimension) inch (mm)	*Flatness (Maximum Allowable TIR) inch (mm)*
≤0.500 (≤12.7)	0.002 (0.051)
>0.500 (>12.7)	0.003 (0.076)

7.1.6 *Delamination* — Any evidence of delamination between ceramic layers which exceeds 0.030" (0.762 mm), in a major dimension, in more than two locations.

NOTE 11: Inspection may also be made by scanning acoustic microscopy per MIL-STD-883, Method 2030, if internal delamination is suspected. Vendor and customer shall agree that such inspection is necessary for package integrity.

7.1.7 *Foreign Material* — Any particulate or film-like foreign material exceeding 0.005" (0.127 mm) height or a surface dimension of 0.020" (0.508 mm). No more than three acceptable sites allowed on the body with a minimum separation of 0.030" (0.762 mm) required between sites.

7.1.8 *Porous Surface* — Packages showing surface poro-sity per ASTM F 109 shall be subjected to seal testing per Section 8.2.4 to verify acceptance.

NOTE 12: Surface porosity may cause inconsistent results at hermeticity testing. Packages which show porosity and fail a hermeticity test may be evaluated per ASTM E 165 to verify the acceptance. Inspection may also be made by scanning acoustic microscopy per MIL-STD-883, Method 2030.

7.2 *Metallized Areas on Ceramic*

7.2.1 *Plating Voids* — (Includes voids due to refractory metal printing defects.)

7.2.1.1 *Die Attach Areas* — Excluding a 0.015" (0.381 mm) wide zone around the periphery of the cavity, voids exceeding a surface dimension of 0.020" (0.508 mm). Acceptable voids shall not cover more than 10% of the surface area.

7.2.1.2 *Seal Ring Area* — Voids exceeding a surface dimension of 0.020" (0.508 mm). The seal ring width must not be reduced by more than 30% of its designed width at any point. Acceptable voids shall not cover more than 10% of the seal ring area.

7.2.1.3 *Wire Bond Fingers* — Any void in the critical area defined in Figure 8.

7.2.1.4 *Internal Lead Traces* — Any void which reduces the width of the trace by more than 50% of its designed width.

NOTE 13: X-ray radiography per MIL-STD-883, Method 2012, or scanning acoustic microscopy per MIL-STD-883, Method 2030, may be used to verify the integrity of covered traces.

NOTE 14: Pits are not cause for rejection, providing any metallization loss does not exceed the 50% criteria.

7.2.1.5 *Solder Pads/Castellations or Contact Pads* — Voids with any dimension larger than 0.010" (0.254 mm) or loss of area exceeding 25%. The connection between a solder pad and the castellation must not be reduced in width by more than 50% of its design width.

7.2.1.6 *Braze Pads* — Voids with any dimension larger than 0.010" (0.254 mm). No more than one visible, acceptable void per pad is allowable after pin or lead attachment.

7.2.1.7 *Heat Exchange Area* — Voids with a surface dimension larger than 0.020" (0.508 mm). Acceptable voids shall not cover more than 10% of the heat exchange area.

7.2.2 *Scratches and Scrapes*

7.2.2.1 *Die Attach Areas* — Excluding a 0.015" (0.381 mm) wide zone around the periphery of the cavity, any buildup of material exceeding 0.001" (0.0254 mm) in height or exposing base metallization (refractory or underplate) so that void criteria are violated.

7.2.2.2 *Seal Ring Areas* — Any buildup of material exceeding 0.001" (0.0254 mm) in height or exposing base metallization (refractory or underplate) so that void criteria are violated.

7.2.2.3 *Wire Bond Fingers* — Any scratch in the critical area defined in Figure 8, which causes metallization build-up exceeding 0.0005" (0.0127 mm) in height or a surface dimension of 0.004" (0.102 mm). In non-critical lead trace areas, any scratch which exposes base metallization (refractory or underplate) across more than 50% of the designed trace width.

7.2.2.4 *Solder Pads/Castellations* — Any scratch which isolates more than 25% of a pad from the castellation by exposure of refractory metallization. Scrapes must not violate the void criteria of Section 7.2.1.5.

7.2.2.5 *Heat Exchange Areas* — Any scratches and scrapes which cause void criteria to be violated (see Section 7.2.1.7).

7.2.3 *Blistering or Peeling of the Metallization* — Any evidence of blistering or peeling.

NOTE 15: Discoloration is not a defect unless a functional test is affected (e.g., wire bonding) (see Section 8).

7.2.4 *Plating Nodules* — Nodules exceeding the criteria for bumps in Sections 7.1.3.2, 7.1.3.3, 7.1.3.4, and 7.1.3.5.

7.2.5 *Refractory Metallization* — Printing and firing defects (see Figure 5).

7.2.5.1 *Metallized Seal Ring Rundown* — Rundown exceeding 25% of the adjacent internal cavity's depth.

7.2.5.2 *Wire Bond Finger Rundown* — Rundown exceeding 25% of the cavity depth or 0.005" (0.127 mm), whichever is smaller.

7.2.5.3 *Wire Bond Finger Pullback* — Pullback exceeding 0.006" (0.152 mm).

7.2.5.4 *Metallization Pattern Separation* — A reduction in pattern separation by more than 50% of the designed separation.

NOTE 16: Pattern separation for chip carrier solder pads may be further specified by agreement between supplier and customer to avoid solder shorting during circuit board assembly.

7.2.5.5 *Seal Ring Pullback* — Pullback exceeding 0.006" (0.152 mm) from the nominal design location from both the cavity and package edge directions.

7.2.6 *Foreign Material* — (Particulate or film-like)

7.2.6.1 *Die Attach Areas (includes bare ceramic die attach areas)* — Excluding a 0.015" (0.381 mm) wide zone around the periphery of the cavity, any foreign material exceeding 0.001" (0.0254 mm) in height or a surface dimension of 0.020" (0.508 mm). Acceptable foreign material shall not cover more than 5% of the die attach area.

7.2.6.2 *Seal Area (includes bare ceramic die attach areas)* — Any foreign material exceeding 0.001" (0.0254 mm) in height or a surface dimension of 0.020" (0.508 mm). The seal ring width shall not be reduced by more than 30% of its width at any point by foreign material. Acceptable foreign material shall not cover more than a total of 10% of the seal ring area.

7.2.6.3 *Wire Bond Fingers* — Any foreign material in the critical area defined in Figure 8.

7.2.6.4 *Solder Pads/Castellations, Contact Pads, and Heat Exchange Areas* — Any foreign material exceeding 0.001" (0.0254 mm) in height or a surface dimension of 0.010" (0.254 mm). Acceptable foreign material shall not cover more than 10% of these areas.

7.3 *Pins, Leads, Metal Seal Rings, or Heat Sinks/Studs*

NOTE 17: If the heat sink is used as the die attach area, the following conditions must not violate the criteria in Sections 7.1 and 7.2 for defect size and accumulation.

7.3.1 *Plating Voids* — Voids, exposing base material or underplate, with any dimension exceeding 0.005" (0.127 mm) or with a total accumulation of more than 5% of the surface area of any pin, lead, heat sink/stud, or braze. If the total accumulation of voids is less than 5% of the area of an element of a package feature, a sample of the defective units shall be submitted to Salt Atmosphere testing per MIL-STD-883, Method 1009, Condition A. If the sample passes this test, the lot shall be acceptable

Voids, exposing base material or underplate, in the seal ring plating violating the criteria of Section 7.2.

7.3.2 *Scratches or Scrapes* — Any buildup of the metallization, or exposure of the base material or underplate, which exceeds 5% of the surface area of any pin, lead, heat sink/stud, or braze. If the total accumulation of scratches or scrapes is less than 5% of the area of an element of the package feature, a sample of the defective units shall be submitted to salt atmosphere testing per MIL-STD-883, Method 1009, Condition A. If the sample passes this test, the lot shall be acceptable.

7.3.3 *Nicks*

7.3.3.1 Any nick in pins or leads exceeding 10% of the diameter or thickness.

7.3.3.2 Any nick in the heat sink/stud which violates void or pit criteria.

7.3.3.3 Any nicks in the seal ring area which violate the criteria of Section 7.2.

7.3.4 *Pits*

7.3.4.1 *External Surfaces* — Any pit exceeding 0.005" (0.127 mm) in depth or 0.010" (0.0254 mm) in a surface dimension.

Metal seal rings shall have no more than three acceptable sites, and there must be a minimum separation of 0.030" (0.762 mm) required between acceptable sites. The width of the seal ring must not be reduced by more than 30% of its designed width at any point. Acceptable pits shall not cover more than 5% of heat sinks/studs. Acceptable pits shall not cover more than 25% of pins or leads.

7.3.4.2 *Internal Surfaces* (Die Attach Areas) — Any pit exceeding 0.001" (0.0254 mm) in depth and violating the plating void criteria per Section 7.2.1.1.

7.3.5 *Plating Nodules* — Any nodule exceeding the criteria for burrs in Section 7.3.7.

7.3.6 *Foreign Material* — Any particulate or film-like (stain) foreign material exceeding 0.001" (0.025 mm) in height or an accumulation of sites in excess of 5% of the surface area of any pin, lead, or heat sink/stud. Any foreign material reducing the separation between two active metal areas to less than 50% of the designed separation.

7.3.7 *Burrs* — Any burr in excess of 0.002" (0.051 mm) height or 0.005" (0.127 mm) in a major dimension.

7.3.8 *Blistering or Peeling* — Any evidence of blistering or peeling.

NOTE 18: Blistering and peeling on a lead frame tie-bar are acceptable. Discoloration is not cause for rejection unless a functional test is affected (e.g., solderability).

7.3.9 *Corrosion* — Any evidence of corrosion.

7.3.10 *Braze*

7.3.10.1 *Excessive Braze* — Any separation between active metal areas which is reduced to less than 50% of the designed separation.

Any excessive braze which interferes with the intended use of the package (e.g., excessive braze height which prevents proper seating of a package).

7.3.10.2 *Insufficient Fillet* — Pin, lead, heat sink/stud braze areas where more than 25% of the periphery is not covered by the braze fillet, provided the voided areas do not extend under the brazed component.

Any pin, lead, heat sink/stud braze areas where more than 5% of the periphery is not covered by the braze fillet and any voids extend under the brazed element.

7.3.11 *Mechanical Damage*

7.3.11.1 Broken, Kinked, or Missing Pins or Leads

7.3.11.2 *Twist* — Any pin or lead twisted by more than 10° from the untwisted condition.

7.3.11.3 *Pin or Lead Sweep* — Any location of the tip of the pin or lead exceeding 0.010" (0.0254 mm) away from the vertical (or horizontal, for flat packs) datum passing through the mid-point of the pin or lead at the point of brazing to the contact pad.

7.3.11.4 *Pin or Lead Tweeze* — Any location of the tip of the pin or lead exceeding 0.010" (0.0254 mm) away from the vertical datum passing through the mid-point of the pin or lead at the point of brazing to the contact pad.

7.3.11.5 *Threads* — Any damage to the threads on studs.

7.4 *Package Construction*

7.4.1 *Pins and Leads* — Location.

7.4.1.1 *Pin or Lead Offset* — Any offset from the pin or lead true position exceeding 0.005" (0.127 mm).

7.4.1.2 *Lead-to-Lead or Pin-to-Pin Separation* — Any separation exceeding 10% of the designed separation, up to an allowable maximum of 0.010" (0.254 mm).

7.4.1.3 *Side-to-Side Misalignment* — Any misalignment exceeding the limits shown in Table 6.

Table 6

Package Type	*Maximum Allowable Side-to-Side Misalignment inch (mm)*
Dual-in-Line	0.010 (0.254)
Flat Packs	0.005 (0.127)
Leaded Chip Carriers	0.005 (0.127)
Pin Grid Arrays	0.005 (0.127)

NOTE 19: During inspection, the combination of offset, separation, and side-to-side misalignment shall also meet limits agreed between user and supplier.

7.4.2 *Ceramic Layer Misalignment* — Any misalignment between layers exceeding 0.005" (0.127 mm) in either the X or Y planes.

7.4.3 *Metallization Alignment to Ceramic* — Any misalignment exceeding the limits defined on the package drawing.

8 Incoming Inspection and Functional Tests

8.1 *Incoming Inspection* — Packages shall be inspected in the following sequence.

8.1.1 Dimensional inspection to the requirements of Section 5. All dimensions shall be measured by techniques agreed between supplier and customer except as follows:

8.1.1.1 Seal ring flatness shall be measured per SEMI G6.

8.1.2 Visual inspection per Section 7.

8.1.3 *Metallization* — Plating.

8.1.3.1 *Thickness* — Shall be measured by x-ray fluorescence per ASTM B 568. The location of the areas to be measured, which include die and wire bond and seal ring areas, the tolerance and acceptable standards shall be agreed between user and supplier.

8.1.3.2 *Temperature Resistance* — Shall be evaluated per SEMI G8.

8.1.3.3 *Plating Hardness* — Die and wire bond and seal ring areas — shall be measured per ASTM B 578 to limits defined by MIL-G-45204 if specified by agreement between vendor and customer.

8.1.3.4 *Pin, Lead, Solder Castellation, or Solder Pad Solderability* — Shall be tested per SEMI G35.

8.1.4 *Pin, Lead, Seal Ring, or Heat Sink/Stud Hardness* — Shall be measured per ASTM E 18 if specified by agreement between vendor and customer.

8.1.5 *Pin or Lead Integrity* — Shall be evaluated per MIL-STD-883, Method 2004.

NOTE 20: After each test, the plating shall be evaluated for continuity per SEMI G35.

8.1.5.1 *Tension* — Per Test Condition A except as shown in Table 7.

Table 7

Pin/Lead Dimension inches (mm)	*Minimum Tension lbs (kg)*
Round Pin	
0.008 (0.203)	1.0 (0.455)
0.018 (0.457)	10.0 (4.55)
Rectangular Lead	
0.018×0.010 (0.457×0.254)	10.0 (4.55)

8.1.5.2 *Fatigue* — Per Test Condition B2 if specified by agreement between user and supplier.

8.1.5.3 *Torque* — Per Test Condition C1 if specified by agreement between user and supplier.

8.1.5.4 *Solder Pad Adhesion* — Per Test Condition D if specified by agreement between vendor and customer.

8.1.6 *Stud Integrity* — Shall be evaluated per MIL-STD-883, Method 2004, Test Condition C2. Torque to be agreed between user and supplier.

8.1.7 *Heat Sink Integrity* — Test shall be agreed between user and supplier.

8.2 *Functional Testing* — The sequence of functional testing shall be as shown in Figure 9. (Packages shall be sequentially subjected to all tests.)

NOTE 21: All procedures used to functionally test the components shall be agreed between user and supplier.

8.2.1 *Die Attach*

8.2.1.1 *Visual Inspection*

Eutectic Bonding — Visually inspect the alloy wet-out after die attach. The minimum wet-out requirement shall be 100% of the die perimeter.

Silver Glass, Epoxy, or Polyimide Bonding — 100% die perimeter coverage shall be required.

NOTE 22: 100% coverage for resin bonding is not a function of package acceptability but is required to standardize die testing. The inability of the resins to wet the surface of the die attach area due to contamination is cause for rejection.

8.2.1.2 *Die Shear Test* — Perform destructive testing per MIL-STD-883, Method 2019.

8.2.1.3 *Radiographic Inspection for Voids* — Perform inspection per MIL-STD-883, Method 2012.

8.2.1.4 *Ultrasonic Inspection for Voids, Delamination, and Cracks* — Perform inspection per MIL-STD-883, Method 2030.

NOTE 23: These tests may also be performed after environmental testing. In the case of very large die, the die shear test may not be appropriate to fully evaluate the package. In these cases, die sizes or alternative tests agreed between user and supplier shall be used. In the case of eutectic die attach, the results from these tests may also be indicative of poor functionality of the gold die attach metallization.

8.2.2 *Wire Bond* — On wire bonds that meet the requirements of MIL-STD-883, Method 2010, perform destructive testing per MIL-STD-883, Method 2011, Test Condition D. Bonds which cause lifted metallization from the wire bond fingers or which fail the pull test criteria shall be cause for package rejection.

NOTE 24: The inspection level A or B, for Method 2010, shall be agreed between vendor and customer. The pull test shall be performed at pre-seal and post-seal. The minimum average pull strength, standard deviation, and acceptable rupture modes shall be agreed between user and supplier.

8.2.3 *Seal*

8.2.3.1 *Visual Inspection* — Criteria shall be agreed between user and supplier.

8.2.4 *Hermeticity* — Performed per MIL-STD-883, Method 1014, Test Condition A or B and C, the package must maintain hermetic integrity after each environmental test or sequence of tests.

NOTE 25: Internal water-vapor content may also be measured per MIL-STD-883, Method 1018.

8.2.5 *Environmental Testing* — Environmental evaluation shall include, but not be limited to, the following tests.

NOTE 26: The sequence of testing and the sample sizes for each sub-group shall be agreed between user and supplier. Packages with heat sinks or studs require the environmental tests to be evaluated on an individual basis. The materials, form factor, and method of attachment may not be suitable for the tests noted due to the generation of overly severe stresses. The appropriate tests shall be agreed between user and supplier.

8.2.5.1 *Temperature Cycle* — Per MIL-STD-883, Method 1010, Condition C on packages without a heat sink or stud, or Condition B for packages with a heat sink or stud.

8.2.5.2 *Thermal Shock* — Per MIL-STD-883, Method 1011, Condition C.

8.2.5.3 *Vibration Fatigue* — Per MIL-STD-883, Method 2005, Test Condition B for packages without a heatsink.

8.2.5.4 *Mechanical Shock* — Per MIL-STD-883, Method 2002, Test Condition B for packages without a heatsink.

8.2.5.5 *Constant Acceleration* — Per MIL-STD-883, Method 2001, Test Condition A for packages without a heatsink.

NOTE 27: Y1 axis only for cavity-up packages, Y2 axis only for cavity-down packages.

8.2.5.6 *Additional Testing* — Additional tests performed during package qualification may include evaluation of electrical and thermal characteristics, corrosion resistance, and alpha particle emissions. These tests may be performed on a periodic basis to maintain package qualification. These tests may include, but are not limited to, the following.

Insulation Resistance — Per MIL-STD-883, Method 1003, to test conditions agreed between user and supplier.

Lead Inductance — Per SEMI Test Method G23 or using an impedance analyzer by a method agreed between user and supplier.

Lead-to-Lead Capacitance — Per SEMI Test Method G24.

Lead Resistance — Per SEMI Test Method G25.

Junction-to-Case Thermal Resistance — Per SEMI G30 or a wind tunnel method agreed between user and supplier.

Alpha particle emission shall be tested by a method and to limits agreed between user and supplier.

Salt Atmosphere (Corrosion) Testing — Per MIL-STD-883, Method 1009, Condition A.

9 Sampling

The sampling plans shall be agreed between user and supplier.

10 Packaging and Packing List

10.1 *Packaging* — The shipping containers and materials shall be suitably designed to provide the components with protection against normal transportation damage risks which include crushing, abrasion, and spillage and exposure to moisture and other corrosive gases.

The inner packing materials must not cause particulate contamination on the components and shall be clean-room compatible as defined by the user. The components, in packing trays, shall be sealed in a vacuum bag with a dessicant.

10.2 *Packing List*

10.2.1 *Internal Packages* — Each internal package shall be marked as follows.

Customer's Part Number

Customer's Purchase Order Number

Drawing Number (user's and supplier's, if appropriate)

Supplier Shipping Lot Number

Quantity

Date of Manufacture

10.2.2 *External Packages* — The packing list, located on the outside of the container, shall provide the following information.

User's Part Number

User's Purchase Order Number

Quantity

Shipping Date

Any specific instructions for receiving dock personnel.

11 Certification

11.1 Upon request of the user in the contract or purchase order, a supplier's certification that the product was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment. However, if the user does perform inspection and tests on a certified shipment and the product fails to meet the requirements, the product is subject to rejection.

11.2 If the user and supplier agree, the product may be certified as capable of meeting this specification. In this context, capable of meeting signifies that the vendor is not required to perform all the inspections and tests. However, if the user does perform inspection and tests on such product and it fails to meet the requirements, the product is subject to rejection.

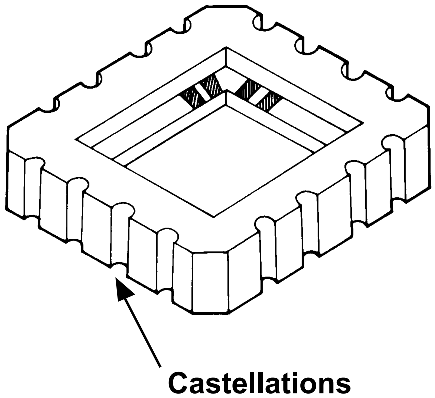


Figure 1

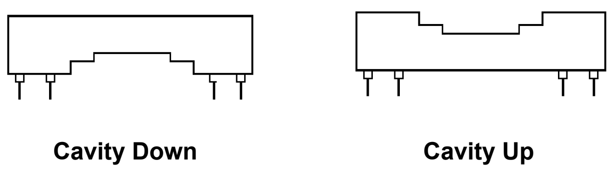


Figure 2

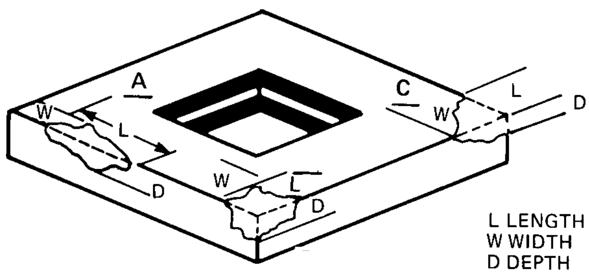
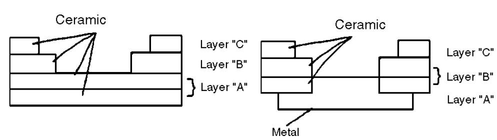


Figure 3



Functional layers shall be designated by letter beginning with "A" as the layer nearest the terminal insertion plane. Layers, regardless of function, shall be designated by succeeding letter (B, C, D, etc.) as they are progressively remote from the insertion plane. Functional layers may be manufactured from two or more ceramic layers.

Figure 4

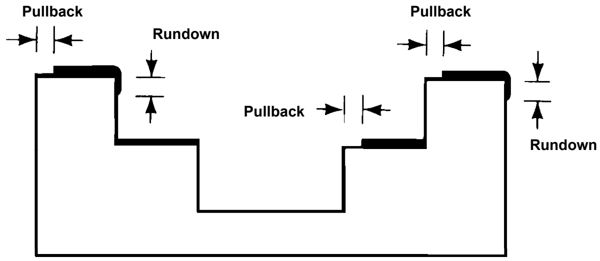


Figure 5

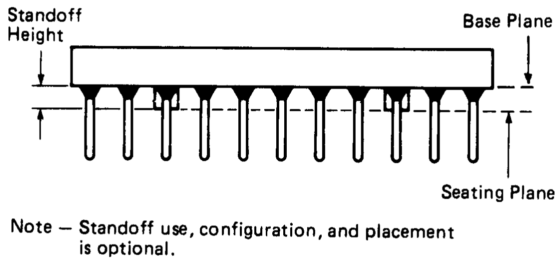
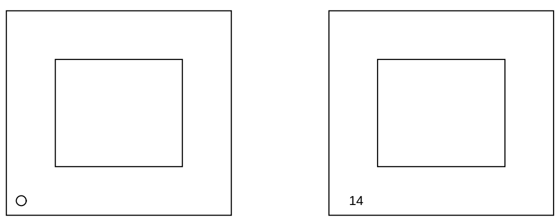


Figure 6



NOTE: A geometric symbol used to indicate lead number 1 indicates that all leads are isolated from the die attach pad.

NOTE: Lead Number 14 is common to the die attach pad and indicates the position of lead number 1.

Figure 7

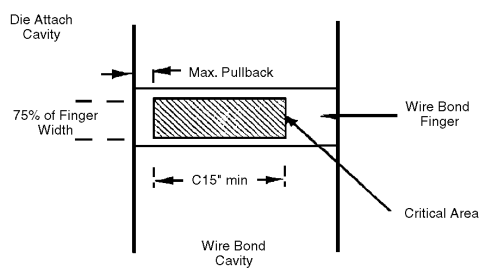


Figure 8

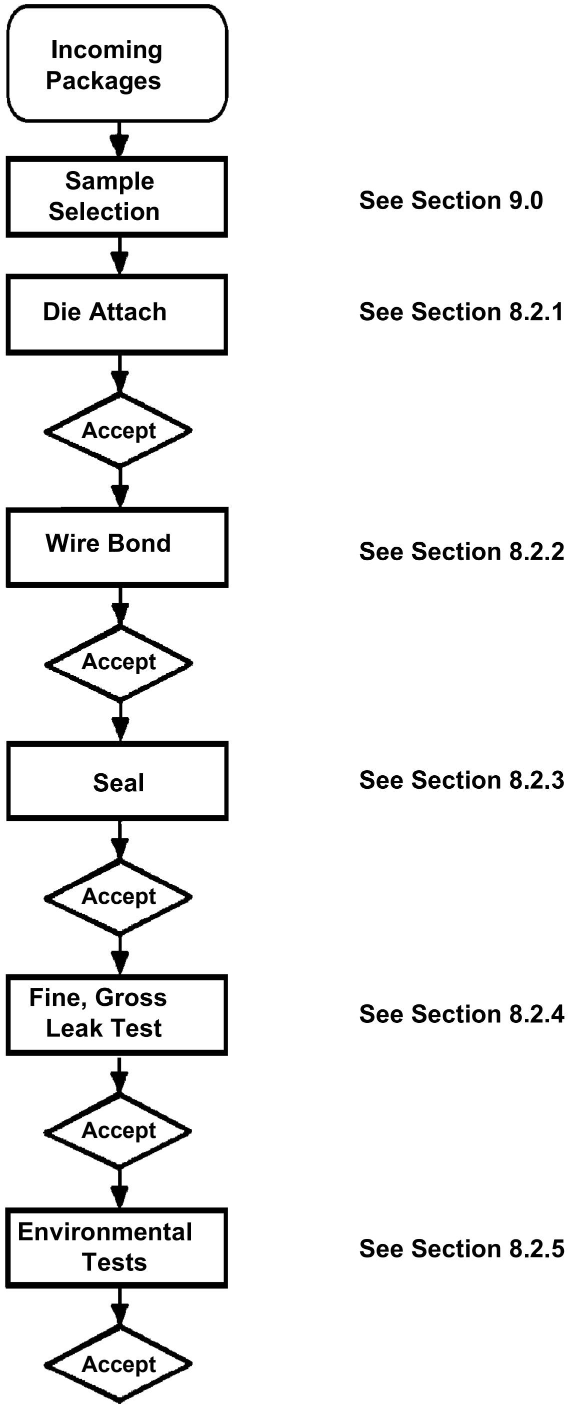

Incoming Packages
Sample Selection
See Section 9.0
Die Attach
See Section 8.2.1
Accept
Wire Bond
See Section 8.2.2
Accept
Seal
See Section 8.2.3
Accept
Fine, Gross Leak Test
See Section 8.2.4
Accept
Environmental Tests
See Section 8.2.5
Accept

Figure 9

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G62-95 (Reapproved 0302)
TEST METHOD FOR SILVER PLATING QUALITY

This test method was technically appoved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the Japanese Regional Standard Committee on November 26, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1995.

1 Purpose

1.1 This test method describes procedures to determine silver plating quality.

2 Scope

2.1 These methods apply to silver plating on leadframes for plastic packages. Applicable plating styles are listed in Table 1.

Table 1 Plating Style

Plating Style	*Description*
Overall Plating	Plating covers the whole leadframe area. In some situations, the leadframe may be quoted as having overall plating, but the rails will be unplated in order to save plating costs.
Ring Plating	Only inner leads plated on top surface.
Ring-Tip Plating	Only wire bonding areas of inner leads plated.
Spot Plating	Only die pad and inner leads plated on top surface.
Spot Plating (both sides)	Die pad and inner leads are plated on both the top and bottom surfaces of the leadframe.
Tip Plating	Only die pad and wire bonding areas plated.
W-Ring Plating	Only inner leads plated on top surface and around die pad.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Units

3.1 This test method uses SI units.

4 Referenced Standards

4.1 *SEMI Documents*

SEMI G55 — Test Method for Measurement of Silver Plating Brightness

SEMI G56 — Test Method for Measurement of Silver Plating Thickness

4.2 *Military Specifications*[1]

MIL-M-38510 — General Specification for Microcircuits

5 Terminology

5.1 *area variation* — The variation between the defined and actual plated area.

NOTE 1: Oversized plating area is an area larger than the specified area. Undersized plating area is an area smaller than the specified area.

5.2 *attached silver particles* — Small silver particles which are attached to the normal plated surface during the plating process.

5.3 *bleed out, back side* — Plating on the back of leadframe caused by seepage of the plating solution beyond the mask.

5.4 *bleed out, side* — Plating occurring on the sides of leadframe features.

5.5 *bleed out, surface* — Seepage of the plating solution beyond the mask on the top surface of the leadframe increasing the plated area.

5.6 *bleed out, epoxy* — The separation of the resin component from the filled epoxy resin such that it creeps on the die pad beyond the outline of resin fillet.

5.7 *blister (metal)* — An enclosed, localized separation of the plating metallization from the base material or from another layer of plating which can be depressed with a sharp instrument.

NOTE 2: This may occur during plating or after application of heat.

5.8 *burnt deposit* — Plated surface is too rough.

5.9 *contamination* — Three-dimensional alien material adhering to a surface.

5.10 *corrosion* — Electrochemical degradation of the material usually exhibited by discoloration such as rust.

1 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

5.11 *discoloration* — Any change in the color of the metallization, as detected by the naked eye. This may occur on as plated or after application of heat.

5.12 *excessive plating* — Plating exists outside the specified area.

5.13 *foreign material* — An adherent particle other than parent material of the component.

NOTE 3: Adherent denotes inability to be removed with an air or nitrogen blow-off at 20 psi.

5.14 *incomplete plating* — Plating is missing from any part of the designated area.

5.15 *leadframe top surface* — The active side of the leadframe, the surface used for die attach and wire bonding.

5.16 *nodule (of plated particle)* — A protrusion or lump of plating material above the plated surface.

5.17 *plating nonuniformity* — The lack of consistency of brightness of silver as plated, or after the application of heat. These changes in the plated grain structure causes the inconsistency.

5.18 *peeling* — The lifting of metallization from a surface.

5.19 *pit (of plating)* — A hole or depression extending below the surface of the plating.

5.20 *scratch (on plating)* — A surface deformation which exposes underlying metallization.

5.21 *spot-sparing* — A stain-like discoloration occurring after the application of heat.

5.22 *step plating* — Plateau-like plating having more than one level.

5.23 *spot plating misalignment* — The variation between the defined and actual center lines of the plated area.

5.24 *tape test* — A metallization layer adhesion test technique using adhesive tape to apply a peel force to the layer. This test may be applied on plated material or after the application of heat.

5.25 *whisker* — A plating metal burr-like filament attached to the surface of the plating.

6 Summary of Method

6.1 Various test methods are described or referenced to determine silver plating quality for the following items:

- Plating Area
- Plating Thickness
- Plating Brightness
- Visual Inspection
- Functional Test

7 Interferences

7.1 Avoid contaminating the silver plated surface prior to performing the test. Such contamination may affect visual appearance and die attach, wire bonding, and solderability functional tests.

8 Equipment

8.1 GAM densitometer or equivalent

8.2 X-Ray Fluorescence

8.3 Microscope with a 40× maximum magnification.

8.4 Heater block, hot plate or oven (furnace)

9 Sampling

9.1 Sampling plans shall be agreed between user and supplier.

10 Test Sequence

10.1 When the test methods are used at incoming inspection, the sequence of tests shall be as follows:

10.1.1 *Plating Area* — See Section 11.1.

10.1.2 *Plating Thickness* — See Section 11.2.

10.1.3 *Plating Brightness* — See Section 11.3.

10.1.4 *Visual Inspection* — See Section 11.4.

10.1.5 *Heat Test* — See Section 11.5.

10.1.6 *Functional Test* — See Section 11.6.

11 Test Procedures

11.1 *Plating Area*

11.1.1 Measurements may be made by using a glass scale, shadow scope, or microscope.

11.1.2 Measurement items are listed below:

11.1.2.1 Area variation

11.1.2.2 Spot plating misalignment

11.2 *Plating Thickness*

11.2.1 Plating thickness shall be measured at a point on the inner lead or the center point of the die pad.

NOTE 4: The location of the thickness test shall be agreed between user and supplier.

11.2.2 Thickness measurements may be made using X-Ray Fluorescence per SEMI G56.

11.3 *Plating Brightness*

11.3.1 Plating brightness shall be measured at the center point of the die pad.

NOTE 5: If leadframes do not have a plated die pad, the location of the brightness test shall be agreed between user and supplier.

Plating brightness shall be measured using a GAM densitometer or equivalent per SEMI G55.

11.4 *Visual Inspection*

11.4.1 Visual inspection may be performed with the naked eye or a microscope with up to 40× maximum magnification, as required to confirm results.

11.4.2 Visual inspection shall be performed before and after functional testing.

11.4.3 Inspection items are listed below.

1. attached silver particles
2. blister
3. bleed-out
4. burnt deposit
5. contamination
6. corrosion
7. discoloration
8. excessive plating
9. foreign material
10. incomplete plating
11. nodule
12. plating nonuniformity
13. peeling
14. pit
15. scratch
16. spot-sparing
17. step plating
18. whisker

11.5 *Heat Test*

11.5.1 *Conditions* — The conditions in Table 2 shall be used to heat test silver plated leadframes.

Table 2 Heat Test Condition

Leadframe Material	*Bake Temperature*	*Bake Time (min.)*
Iron-Nickel Alloy per MIL-STD-38510, Type B	400° C ± 5° C	3 min. + 10 (-0) sec.
Cu Alloy	300° C ± 5° C	3 min. + 10 (-0) sec.
Taped Leadframe	275° C ± 5° C	3 min. + 10 (-0) sec.

11.5.2 The test may be carried out on a heater block or hot plate, or in an oven (furnace). The heat capacity of the test equipment must be sufficient to avoid temperature swings outside the specified limits when the test is started.

NOTE 6: When using a heater block or hot plate, ensure that air flow does not affect the bake temperature.

11.6 *Functional Test*

11.6.1 *Epoxy Die Bonding* — Processes and test procedures shall be agreed upon between user and supplier.

11.6.2 *Gold Wire Bonding* — Processes and test procedures shall be agreed upon between user and supplier.

11.6.3 *Solderability* — Processes and test procedures shall be agreed upon between user and supplier.

12 Related Documents

12.1 *SEMI Specifications*

SEMI G8 — Test Method for Gold Plating Quality

SEMI G21 — Specification Plating Integrated Circuit Leadframes

12.2 *JIS Specifications*[2]

JIS H8501 — Methods of Thickness Test for Metallic Coatings

JIS H8621 — Electroplated Coatings of Silver for Engineering Purpose

JIS Z8722 — Methods of Measurement for Color of Reflecting or Transmitting Objects

JIS Z8741 — Method of Measurement for Specular Glossiness

2 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G63-95 (Reapproved 0302)
TEST METHOD FOR MEASUREMENT OF DIE SHEAR STRENGTH

This test method was technically approved by the Global Assembly and Packaging Committee and is the direct responsibility of the Japanese Assembly and Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on November 26, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published in 1995.

1 Purpose

1.1 The purpose of this test method is to determine procedures for die shear strength testing.

2 Scope

2.1 This test method shall be used for the measurement of the die shear strength when die attach paste is used to bond a die to a leadframe bond pad.

2.2 This test method shall be used for quality control and development at die attach paste suppliers and for incoming inspection and selection of the die attach paste at die attach paste users.

2.3 This test method can be applicable to die attach material besides paste material and may be used to evaluate leadframe bond pad quality.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

3.1 *Military Specification*[1]

MIL-STD-883 — Method 2019, Die Shear Strength

4 Terminology

4.1 *die* — Semiconductor device or an imitation.

4.2 *die attach* — Bond die and substrate such as leadframe pad.

4.3 *die contact tool* — Tool for applying load to the die for shearing.

4.4 *dispense* — Deal out paste.

4.5 *fillet* — Height and shape of die attach paste in contact with or surrounding the die kerf.

4.6 *shear* — Have forced completely in X-Y direction.

5 Summary of Method

5.1 This method is based on measuring the shear strength between die and leadframe pad bonded by die attach paste using die shear tester.

6 Equipment

6.1 *Die Shear Tester*

6.1.1 ± 5% accuracy of full scale

6.1.2 Die contact tool can be in contact with die edge from end-to-end.

6.2 *Hot Plate* — optional

6.3 *Microscope* — optional

7 Material

7.1 *Silicon Die* — 2 mm × 2 mm × 0.3 to 0.5 mm

7.2 *Leadframe*

7.3 *Die Attach Paste*

8 Test Specimen

8.1 Dispense die attach paste by dispensing, stamping, or screen printing.

8.2 Bond die and leadframe pad.

8.3 Cure the paste per recommendation and allow to cool to ambient.

NOTE 1: Height of fillet shall be less than half of the thickness of the die.

NOTE 2: Thickness of die attach paste shall be within the range of 5 to 30 μ m before or after cure.

NOTE 3: Assembled parts shall not be exposed to a curing temperature higher than the peak recommended temperature for more than 30 seconds.

9 Sampling Plan

9.1 Number of specimens tested shall be 5 or more.

1 Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA. Telephone: 215.697.3321

10 Procedure

10.1 Set a test specimen on the die shear tester.

10.2 Confirm that the die contact tool contacts the die side in half of the area or more and that the die contact tool does not touch the fillet.

10.3 Shear the specimen with the tester.

10.4 Record the strength.

10.5 Observe failed parts and classify in the following modes:

Mode 1: Die breakage

Mode 2: Adhesive failure between die and die attach paste

Mode 3: Cohesive failure

Mode 4: Adhesive failure between die attach paste and substrate

Mode 5: Substrate deformation

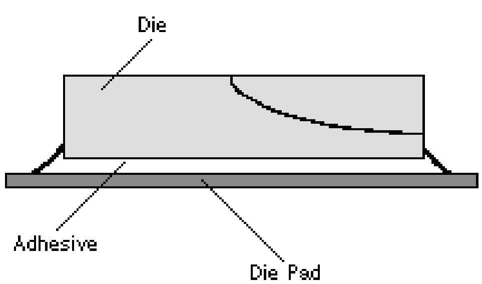


Figure 1
Mode 1 — Break-In Die

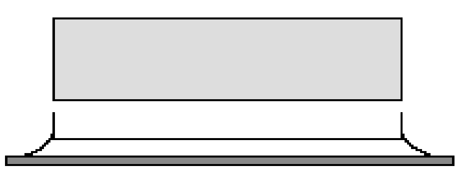


Figure 2
Mode 2 — Interface Failure: Die-to-Adhesives

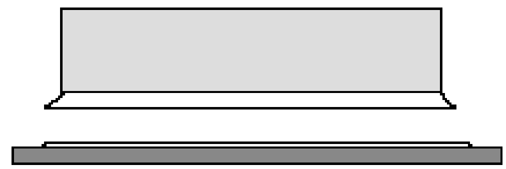


Figure 3
Mode 3 — Break-In Adhesives

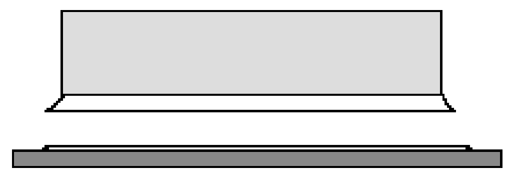


Figure 4
Mode 4 — Interface Failure:Adhesives-to-Die Pad

NOTE 4: In the case of hot die shear strength testing, the hot temperature shall be agreed between user and supplier.

Procedure is as follows:

1. Set and raise the hot plate temperature
2. Confirm that actual temperature is within the range of ± 10° C at the set temperature.
3. Put a specimen on the hot plate and follow Section 10.3 after 10 to 20 seconds.

11 Calculation of Result

11.1 Average strength and standard deviation shall be calculated if required.

12 Report

12.1 The following information shall be reported in the attached form:

12.1.1 Type of die attach paste

12.1.2 Type of leadframe and leadframe plating

12.1.3 Thickness of die and surface condition (attached side) of the die.

12.1.4 Cure schedule and atmosphere (air or nitrogen)

12.1.5 Information about die attach paste thickness, dispense weight, or bond line thickness before and after cure.

12.1.6 Die shear speed

12.1.7 Die shear strength in N (kgf)/die unit (complete data or an average)

12.1.7.1 Standard deviation when number of specimens tested is adequate.

12.1.8 Temperature in hot die shear testing.

Die Attach Paste (Material)	
Leadframe Type	
Leadframe Plating	
Die Thickness	
Die Surface Condition	
Cure Schedule	Time ____________ Temp. ___________ in air or N_2
Thickness or Dispense Weight	
Shear Speed	

	RT		*Hot Temperature*	
	Strength (N (kgf)/chip)	*Failure Mode*	*Strength (N (kgf)/chip)*	*Failure Mode*
Sample 1				
Sample 2				
Sample 3				
Sample 4				
Sample 5				
Sample 6				
Sample 7				
Sample 8				
Sample 9				
Sample 10				
Sample 11				
Sample 12				
Average				
Standard Deviation				

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI G63 and was approved by full letter ballot procedures in 1995.

A1-1 Purpose

The purpose of this appendix is to indicate that speed and height of the die contact tool affect die shear strength results.

A1-2 Test Results

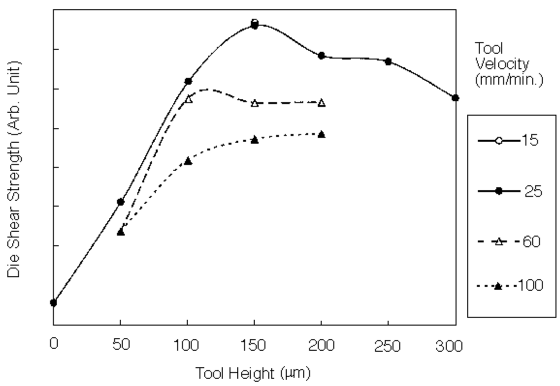


Figure A1-1
Tool Velocity Test Results

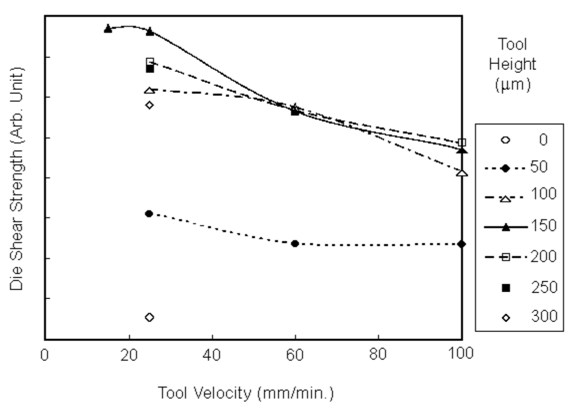


Figure A1-2
Tool Height Test Results

A1-2.1 *Summary*

A1-2.1.1 *Shear Speed*

a. Some adhesive might yield variable results due to the relationship of the shear speed and failure speed.

b. Some equipment with high shear speed could yield low strength due to poor sensitivity at the peak of the load.

A1-2.1.2 *Height of the Die Contact Tool*

a. In case of low height, fillet level might affect the strength.

b. In case of high height, a variable result might be obtained since the tool pulls the die and it tears the adhesive.

SEMI G64-96
SPECIFICATION FOR FULL-PLATED INTEGRATED CIRCUIT LEADFRAMES (Au, Ag, Cu, Ni, Pd/Ni, Pd)

1 Purpose

1.1 This specification is intended as a guideline for evaluating plating layer characteristics required by users of full-plated leadframes for plastic semiconductor packages.

1.2 *Background* — Full-plated leadframes have received attention in recent years as a possible solution to challenges and restrictions resulting from the effects of Pb on the environment, package reliability improvement due to the P.P.F. process, lead coplanarity on fine-pitched leadframes, and lead bridges with solder plating.

2 Scope

2.1 The specification and test procedures detailed in this document apply to full-plated leadframes.

2.2 *Units* — SI units are used in this document.

3 Referenced Documents

3.1 *Priority* — To avoid confusion, the order of precedence when ordering leadframes shall be as follows:

1. Purchase Order (agreed between user and supplier)
2. This Specification
3. Referenced Documents

3.2 *SEMI Standards*

SEMI G4 — Specification for Integrated Circuit Leadframe Materials used in the Production of Stamped Leadframes

SEMI G18 — Specification Integrated Circuit Leadframe Material used in the Production of Etched Leadframes

SEMI G21 — Specification Plating Integrated Circuit Leadframes

SEMI G52 — Standard Test Method for Measurement of Ionic Contamination on Semiconductor Leadframes (Proposed)

SEMI G55 — Test Method Measurement of Silver Plating Brightness

SEMI G56 — Test Method Measurement of Silver Plating Thickness

3.3 *Military and Federal Standards*[1]

QQ-S-571 — Solder Composition

QQ-N-290 — Nickel Plating-Electrodeposited

QQ-S-365 — General Requirements for Electrodeposited Silver Plating

MIL-C-14550 — Copper Plating-Electrodeposited

MIL-G-45204 — Gold Plating-Electrodeposited

MIL-STD-883D — Method 2003.7, Solderability

MIL-F-14256 — Flux, Soldering, Liquid, Paste Flux, Solder Paste, and Solder Paste Flux

3.4 *JIS Standard*[2]

JIS-C-0053 — Solderability Testing by the Wetting Balance Method

3.5 *ISO Standards*[3]

ISO-3497 — Metallic Coating Measurement of Coating Thicknesses, X-Ray Spectrometer Method

ISO-9227 — Corrosion Tests in Artifical Atmospheres - Salt Spray Tests

4 Terminology

4.1 *finish plating* — Final plating layer whose electrodeposits fulfill the main purpose of the required characteristic.

4.2 *solderability* — An index of the wettability and coverage with solder of lead surface.

4.3 *underplating* — Plating layers that complete the required characteristics of the final plating layer and lies between the base material and final plating layer.

5 Materials

5.1 *Base Material* — Cu alloys or Fe/Ni alloys.

5.2 *Plating Material* — Underplating and Finish plating are shown in Table 1.

1 Military Standards,Naval Publications and Form Center,5801 Tabor Ave., Philadelphia, PA19120

2 Japanese Standards Association, Akasaka, Minato-ku, Tokyo

3 ANSI, 1430 Broadway, New York, NY 10018

Table 1 Underplating and Finish Plating

		Base Material	
Finish Plating	*Underplating*	*Cu-Alloys*	*Fe, Ni-Alloys*
Au (MIL-G-45204)	-	N/A	X
	Ni	X	X
Ag (QQS-365)	-	X	N/A
	Cu	X	X
Cu (MIL-C-14550)	-	X	X
	Ni	X	X
Ni (QQN-290)	-	X	X
	Cu	X	X
Pd/Ni-Alloy	-	X	X
	Ni	X	X
	Cu	X	X
Pd	-	X	X
	Ni	X	X
	Cu	X	X
	Pd/Ni-Alloy	X	X

6 Plating Specification

6.1 *Plating Thickness* — For full-plated leadframes, the designed thickness including under plating is restricted as follows to limit the effects of thickness variation on coplanarity and outer lead width.

Designed thickness including under plating-1 / Ag-plating: 5 µm MAX

Designed thickness including under plating-2 / Au, Cu, Ni, Pd/Ni-Alloy, Pd plating: 2 µm MAX

6.2 *Visual Inspection* — Rejectable conditions are as follows:

1. Any bare spots, or missing plating in critical area as defined the coined areas or minimum flat wire bond area in the appropriate leadframe specification.
2. Any peeling or blistered plating.
3. Any nodules in critical area as defined the coined areas or minimum flat wire bond area in the appropriate leadframe specification.

   NOTE: Nodules not exceeding 0.0381 mm in a surface dimension and 0.0127 mm in height, in non-critical areas are allowed providing there are no more than one per internal lead finger or six (6) per leadframe.

4. Any pits which exceed 0.008 mm in depth or 0.0127 mm in a surface dimension in critical areas or 0.0254 mm in depth or 0.051 mm in a surface dimension in non-critical areas.
5. Any scratches or scrapes in the metallization plating which expose underplating or base material.
6. Any scratches or scrapes in critical area which cause a build up of material in excess of 0.0127 mm in height.
7. Any foreign material, contamination, or tarnish.
8. Non-uniformity or rough-plated surface.

6.3 *Visual Inspection after Baking* — The test procedure is described in Section 9.3. Visual inspection after baking shall be performed according to the procedure in Section 9.2.1.

6.4 *Corrosion Resistance (not applicable to Cu plating)* — In the test result, allowable corrosion specification shall be agreed upon between user and supplier.

6.5 *Surface Ion Contamination* — Allowable ion species and ion concentration shall be agreed upon between user and supplier.

6.6 *Adhesion* — If there is any plating film on the test tape, the component shall be rejected. Adhesive test should be performed according to the procedure in Section 9.6.

6.7 *Functional Tests*

6.7.1 *Die Attach* — Agreed upon between user and supplier.

6.7.2 *Wire Bond* — Agreed upon between user and supplier.

6.7.3 *Solderability* — The criteria for acceptable solderability are as follows:

1. The dipped portion of the samples is at least 95% covered by a continuous solder coating.
2. Pinholes, voids, porosity, non-wetting, or dewetting do not exceed 5% of total area.

NOTE: Solderability criteria for Ni and Cu plating are established by the user and supplier and are excluded here.

7 Equipment

7.1 Fluorescent X-ray spectremeter

7.2 Binocular-microscope, 10~30x magnification

7.3 Neutral salt spray test equipment

7.4 Ion chromatography (Anion, Cation)

7.5 Hot plate or Heater block

7.6 Solder pot

7.7 Meniscograph

8 Sampling

Sampling plan shall be agreed upon between user and supplier.

9 Test Methods

9.1 *Thickness* — Plating thickness shall be measured by fluorescent X-ray spectrometer.

9.2 *Visual Inspection*

9.2.1 *Magnification* — Unless otherwise specified, visually inspect the plating surface under a microscope at 10× magnification. 30× magnification shall be used for confirmation.

9.3 *Baking Test*

9.3.1 *Baking Conditions* — Samples are heated in air on hot plates or heater block.

9.3.2

Table 2

Finish Plating/Base Material	*Cu-Alloys*	*Fe/Ni-Alloys*
Au*	450°C × 3 min.	450°C × 3 min.
Ag	300°C × 3 min.	400°C × 3 min.
Cu**	200°C × 1 hour	200°C × 1 hour
Ni**	400°C × 3 min.	400°C × 3 min.
Ni/Pd Alloy	200°C × 1 min.	200°C × 1 min.
Pd	300°C × 1 min.	300°C × 1 min.

* May be changed by agreement between user and supplier to 400°C x 1 min or 450°C x 2 min or less, to account for changes in plating thickness, base material, or other plating parameters.

** Surface oxidation and discoloration detected by visual inspection are acceptable. Furthermore, parameter of solderbility evaluation for flux, dipping method, etc. are to be determined by agreement between user and supplier.

9.3.3 Visual inspection after baking shall be performed according to the procedure in Section 9.2.1.

9.4 *Corrosion Test* — Atomize the test sample in a test container using a 5% neutral sodium chloride solution of 8.8~7.2pH at 35 ± 1°C for 24 hours. This test follows ISO-9227.

9.5 *Surface Ion Contamination* — The measurement follows SEMI G52.

9.6 *Adhesion Test* — Place the strip of tape (SCOTCH[a] #540, #610, #810, or equivalent) across the plated area. Press firmly with fingertips or other smooth object. Peel the tape quickly off the plated surface. The plating surface may be scored before the tape test in accordance with the joint agreement between user and supplier.

9.7 *Functional Tests*

9.7.1 *Die Attach* — Agreed upon between user and supplier.

9.7.2 *Wire Bond* — Agreed upon between user and supplier.

9.7.3 *Solderability* — The procedure for accelated aging test shall be agreed upon between user and supplier (see Appendix 1).

APPENDIX 1
SOLDERABILITY TEST

NOTE: This appendix was approved as an official part of SEMI G64 by full letter ballot procedure.

A1-1 Accelerated Environment Simulation

Determination, due to the environment, may be simulated by exposure to a hot plate that reproduces the heat characteristics of assembly (a), and by steam aging to simulate the storage environment. The following are methods for accelerated environment simulations (b):

a. Place samples in air on a hot plate or a heat block. Temperature and duration are detailed in 9.3, and represent the heat characteristics of assembly.

b. Steam aging test is based on MIL-STD-883D, Method 2003.7, and simulates environmental conditions.

A1-2 Soldering Parameter

Baked test specimens shall be dipped into flux conforming to MIL-P-14256, type-R, for 5 to 10 seconds, and then dipped in a solder bath conforming to QQ-S-571 for 10 ± 1 seconds at a solder pot temperature of 230 ± 5°C.

A1-3 Evaluation of Solderability

A1-3.1 *Wetting Area* — After cleaning solder dipped specimen with alcohol to remove flux, visually inspect under a microscope at 10x magnification. Solder must cover 95% or more of surface area, based on MIL-STD-883D, Method 2003.7.

A1-3.2 *Wetting Time (zero-cross-time)* — Solder that conforms to conditions below is evaluated according to JIS-C-0053, or may be evaluated by a method determined by user and supplier for certain leadframe shapes.

1. Temperature: 230 ± 5°C
2. Dipping speed: 2 mm/second
3. Dipping depth: 2 mm
4. Flux: Rosin flux (MIL-F-14256, type-R)
5. Solder composition: 63 Sn / 37 Pb (QQ-S-571)

SEMI G65-96
TEST METHOD FOR EVALUATION OF LEADFRAME MATERIALS USED FOR L-LEADED (GULL WING TYPE) PACKAGES

1 Purpose

1.1 This test method describes an evaluation method for bending characteristics of leadframe materials used for L-leaded packages.

NOTE 1: The lead fatigue test described in MIL-STD-883/2004 is not suitable for evaluating the bending characteristics of fine pitch leadframes or leadframes used for L-leaded packages because the method is based on reforming the leads.

2 Scope

2.1 This test method may be applied to leadframes for L-leaded packages such as QFP, SOP, TSOP, etc.

2.2 This test method may also be applied to any leadframe materials with thickness ≤ 0.15 mm.

2.3 The test method may be used in trim and form tool suppliers, leadframe material suppliers, leadframe manufacturers, and package engineers.

3 Referenced Documents

3.1 *Military Standard*[1]

MIL-STD-983 — Method 2004, Lead Integrity

4 Terminology

4.1 *crack (of leadframe)* — Micro cleavage or fracture on surface of outside of lead which is caused by bending (see Figure 1).

4.2

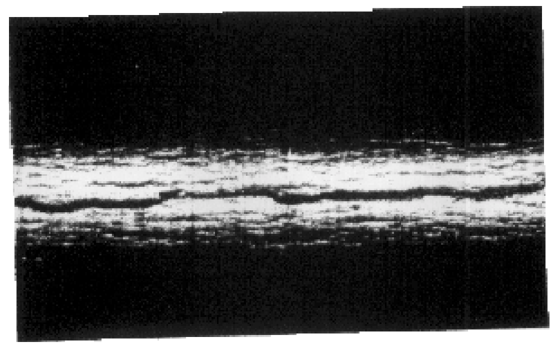


Figure 1
Crack

4.3 *orange peel (of leadframe)* — Micro roughness on surface of outside of lead caused by bending (see Figure 2).

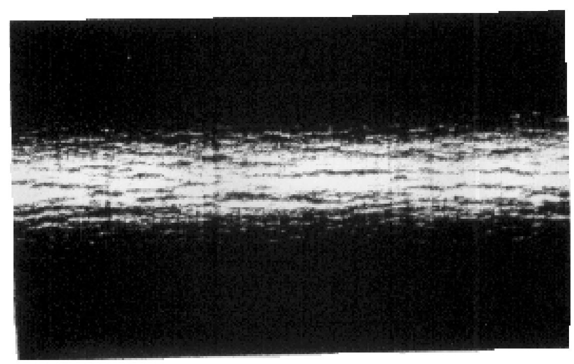


Figure 2
Orange Peel

4.4 *spring back* — Difference between designed angle of forming tool and actual lead form angle.

NOTE 2: In this method, the angle of forming tool is 90°. The value is defined by:

Actual lead bend angle 90°.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia, PA 19120

5 Summary of Method

The leadframe samples (etched using a standard mask agreed between user and supplier) will be formed using a "W" forming tool. The resulting form angle is to be measured and surface characteristics such as cracking and orange peel are to be visible for compliance to the agreed upon specification.

6 Interference

If the forming tool does not meet the specification, lead movement during forming may result in poor repeatability.

7 Significance

7.1 Devices manufactured with leadframes of different spring back characteristics, may cause board assembly problems due to lead positional differences.

7.2 Crack in the leadframe may cause poor contact reliability with board.

8 Equipment

8.1 *Tensile Tester* — With minimum 9800N force and 1% accuracy.

8.2 *"W" Forming Tool* — With R = 0, 0.1 and 0.2 and form angle of 90°. The dimension and configuration are shown in Figures 3—7

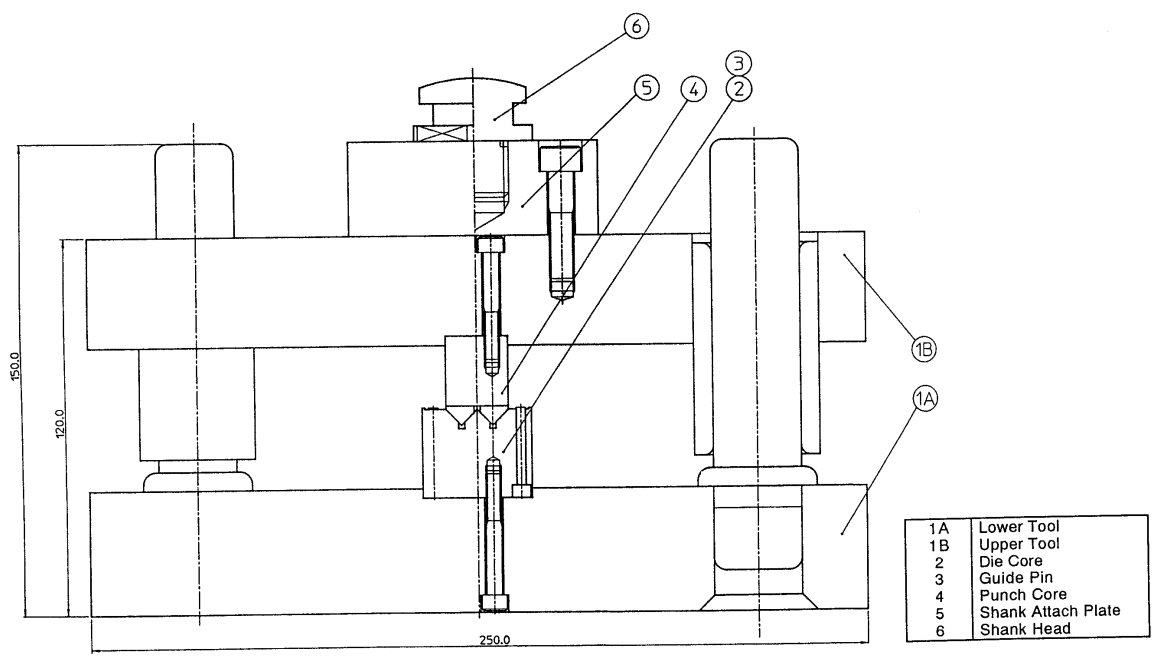


Figure 3
W-Bending Test Tool

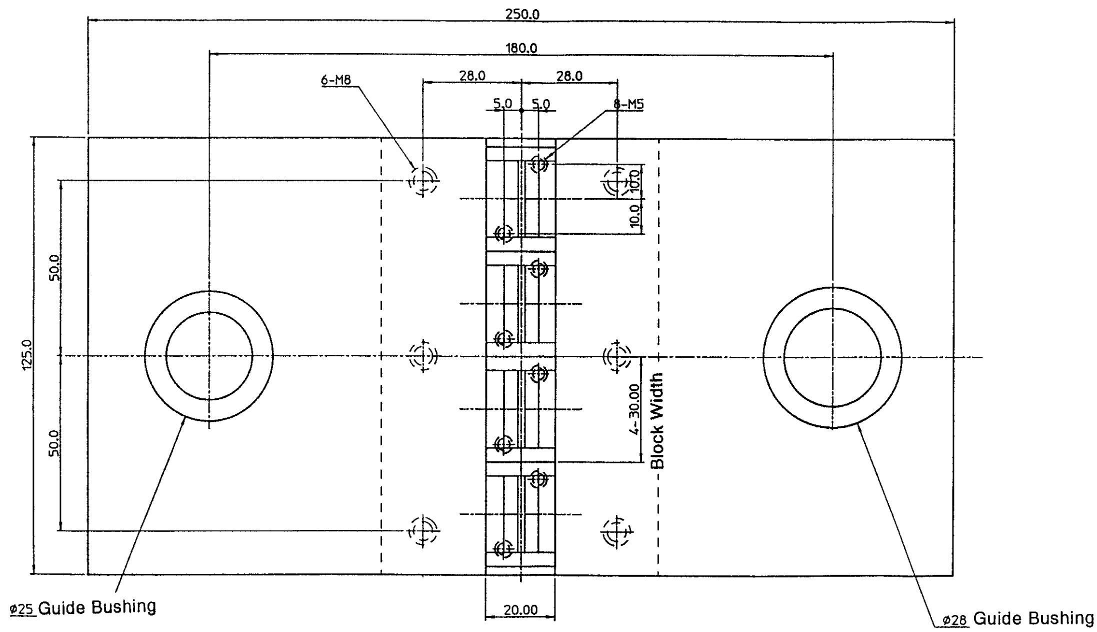


Figure 4
Upper Tool Detail

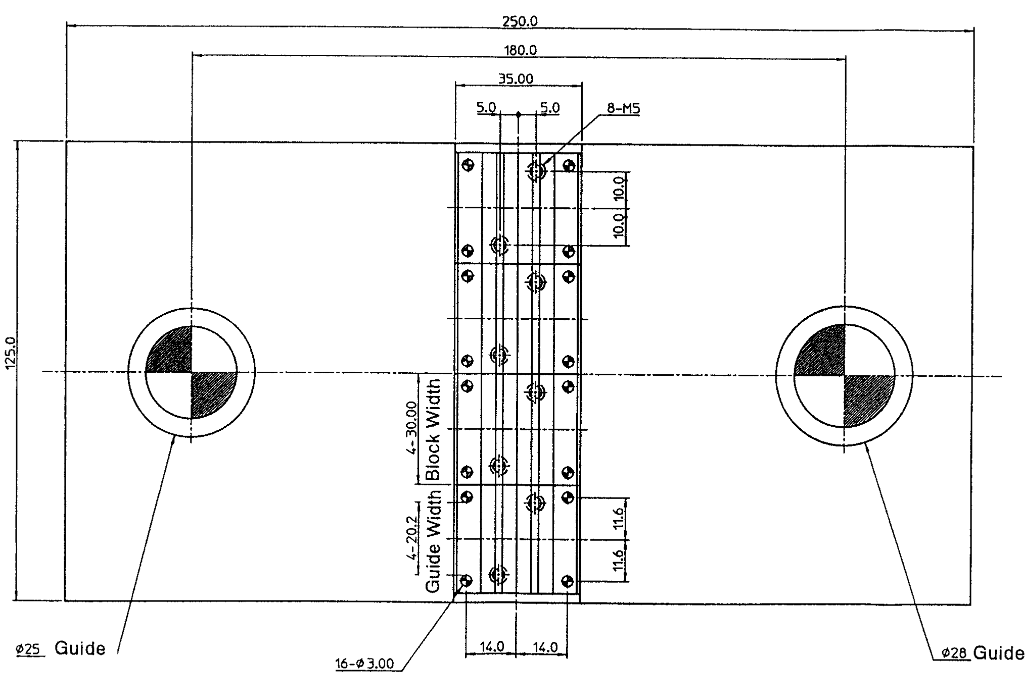


Figure 5
Lower Tool Detail

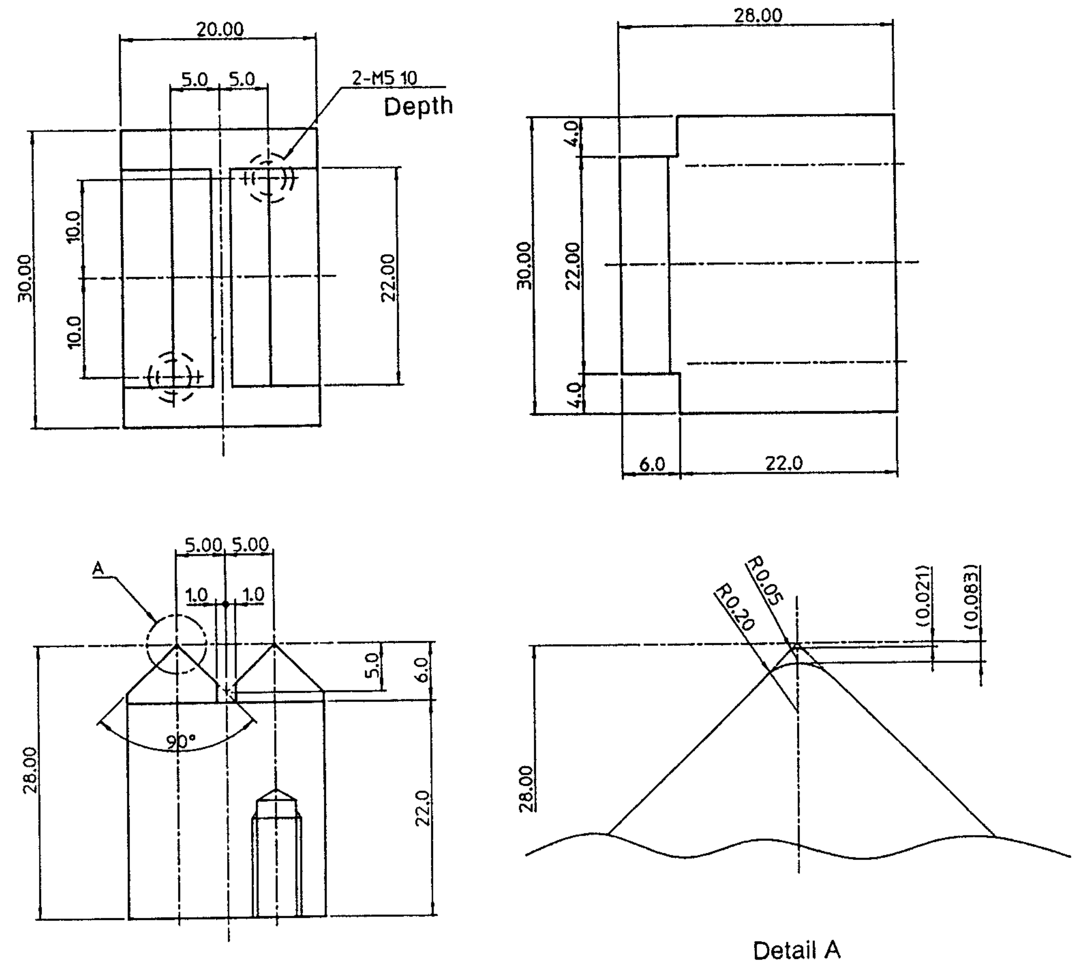


Figure 6
Punch Core Detail

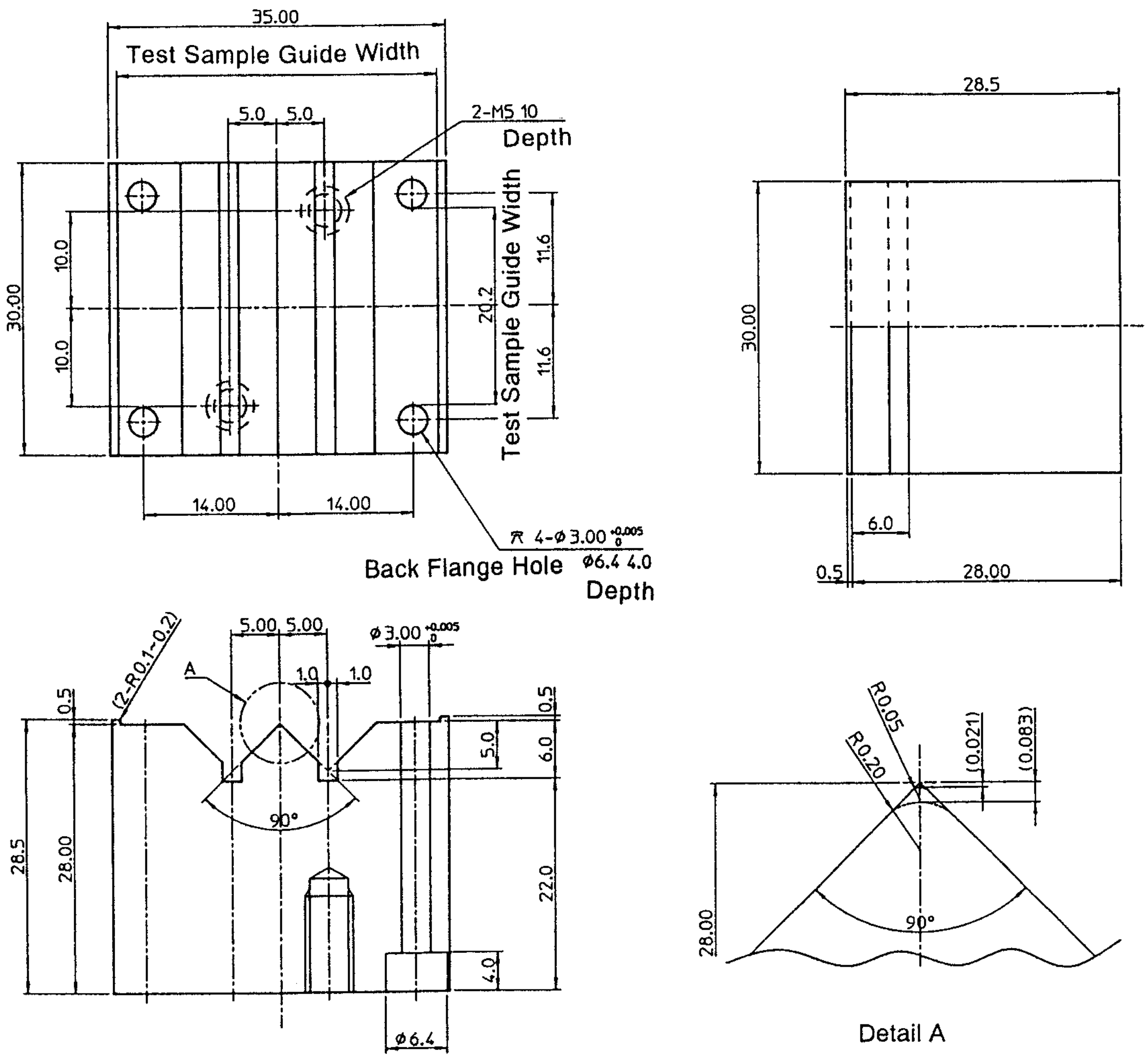


Figure 7
Die Core Detail

8.3 *Micrometer*

8.4 *Microscope* — 75× used to inspect lead surface characteristics.

8.5 *Protractor* — 10× and accuracy 0.1° used to measure the leadform spring back.

8.6 *Projector* — 10×.

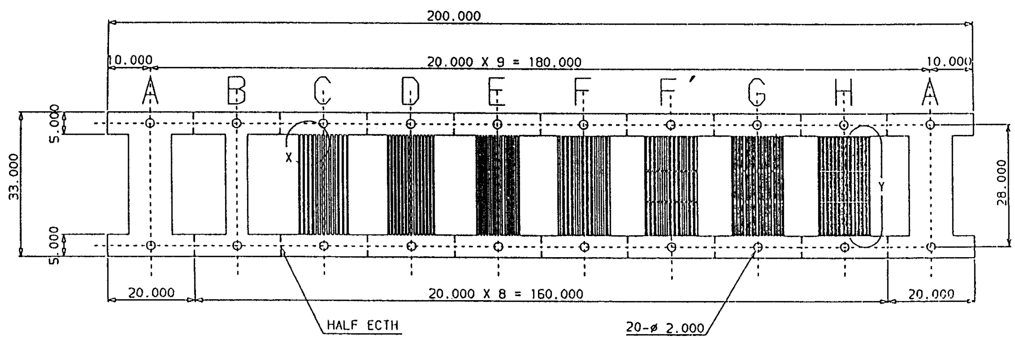
9 Sampling Plan

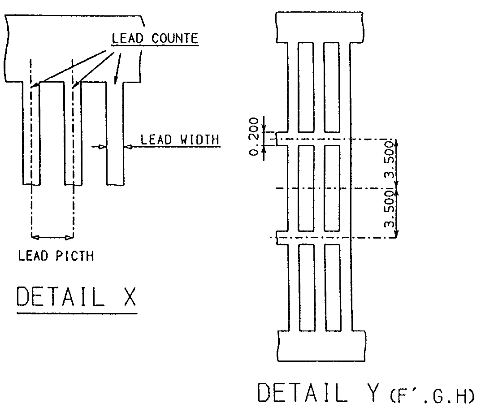
9.1 The sampling plan shall be agreed between user and supplier. It is suggested that a minimum of five (5) samples (2 leads per sample) of 0.3 mm width on 0.65 mm pitch, be used for these tests.

NOTE 3: If the leadframe is four-sided, take samples from both orthogonal directions.

10 Sample Preparation

10.1 The samples are prepared by etching a leadframe pattern into a blank piece of the leadframe material using a standard mask. An example of the recommended configuration is shown in Figure 8.





	A	B	C	D	E	F	F′	G	H
LEAD PICTH	—	—	1.00	0.80	0.65	0.50	0.50	0.40	0.30
LEAD WIDTH	10.0	5.00	0.40	0.35	0.30	0.20	0.20	0.16	0.12
LEAD COUNTE	1	1	12	14	16	25	25	31	42

Note : Tolerance ±0.030 mm

Figure 8
Standard Sample Configuration

NOTE 4: SEMI/Japan has copies of this artwork for use by companies.

10.2 Measure the sample thickness at three (3) points on the siderail using micrometer.

11 Setup and Procedure

11.1 *Setup*

11.1.1 Warm up and calibrate the tensile tester according to the operation manual.

11.1.2 Set the “W” forming tool in the tensile tester.

11.1.3 Set the tensile tester in the push mode and adjust the force to 9800N.

11.2 *Procedure*

11.2.1 Place the sample on the lower section of the “W” forming tool.

11.2.2 Lower the upper section of the “W” forming tool at the speed of 1 to 5 mm/min.

11.2.3 Raise up the upper section of the “W” forming tool and remove the sample carefully.

11.2.4 Repeat the test for the other samples.

11.3 *Measurement*

11.3.1 Remove the leads from the bent sample by cutting at the cutting position.

NOTE 5: Perform this operation carefully to avoid reforming the leads.

11.3.2 Select two (2) leads from one sample.

11.3.3 Observe the outside surface of the lead and take a photograph with a microscope set at 75× magnification.

11.3.4 Set the lead sample in a projector.

11.3.5 Project the picture of the sample on the screen.

11.3.6 Adjust the protractor to the picture and read the form angle.

12 Calculation

12.1 Calculate the spring back value as follows:

Spring back = actual angle of sample - designed form angle

12.2 Calculate the average spring back value.

12.3 Round the result to one significant figure.

13 Report

The report shall contain the following information:

13.1 Leadframe material name, lot number, and vendor

13.2 Average thickness (per 10.2)

13.3 Photograph taken using 75× magnification (per 11.3.3)

13.4 List of observations (per 11.3.3)

NOTE 6: Classify observation results as crack, orange peel, and good according to their definition in Section 4. If required, further classification should be agreed between customer and vendor.

13.5 Spring Back Value (per 11.3.4 to 11.3.6) — Average, minimum, maximum

13.6 Rejection — The limit shall be agreed between user and supplier.

14 Related Documents

14.1 *SEMI Specification*

SEMI G4 — Specification for Integrated Circuit Leadframe Materials Used in the Production of Stamped Leadframes

14.2 *JIS Specifications*

JIS-Z-2248 — Method of Bend Test for Metallic Materials

JIS-H-3130 — Copper Beryllium Alloy, Phosphor Bronze and Nickel Silver Sheets, Plates, and Strips for Springs

14.3 *CES Specification*

M0002-6 — Test Method of W Bend for Metallic Materials

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SEMI G66-96

TEST METHOD FOR THE MEASUREMENT OF WATER ABSORPTION CHARACTERISTICS FOR SEMICONDUCTOR PLASTIC MOLDING COMPOUNDS

1 Purpose

1.1 This method describes a procedure for measuring the water absorption rate for plastic molding compounds and provides a method to calculate the diffusion and solubility coefficients, which are required to simulate the water absorption characteristics.

2 Scope

2.1 This method may be applied to all semiconductor plastic molding compounds.

2.2 This method may be used to characterize molding compounds in development.

2.3 Packaging engineers may simulate the water absorption characteristics and their significance in relation to package cracks at soldering by using calculated diffusion and solubility coefficients.

3 Referenced Documents

None.

4 Terminology

4.1 *diffusion coefficient, D* — The diffusion rate of water into a molding compound (see Appendix 1 and Figure 1).

4.2 *solubility coefficients, S* — Ratio of saturated moisture concentration in molding compounds to partial pressure of moisture in environment (see Appendix 1 and Figure 1).

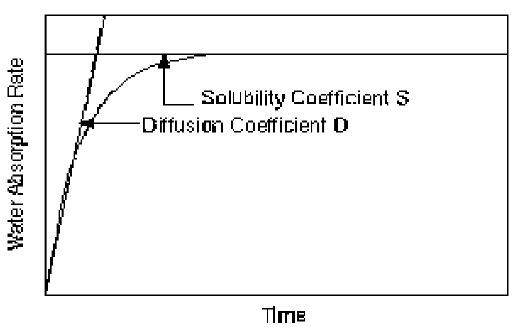

Figure 1
Concept of Diffusion and Solubility Coefficients

5 Summary of Method

5.1 This method is based on the measurement of the increase in weight, due to water absorption, after exposing the molding compound to a high-temperature, high-humidity environment.

6 Equipment

6.1 *Balance* — An analytical balance capable of reading 0.0001g.

6.2 *High-Temperature Chamber* — Capable of maintaining a uniform temperature of 125 ± 3°C.

6.3 *Temperature/Humidity Chamber* — Capable of maintaining a uniform temperature of 85 ± 2°C and 85 ± 5% relative humidity.

6.4 *Desiccator (1)* — To hold specimens during cool-down from high-temperature conditioning.

6.5 *Desiccator (2)* — This desiccator, with water in the bottom rather than drying compound, is to hold the specimens after exposure to heat and humidity.

6.6 Mold for specimen preparation.

7 Reagents and Materials

7.1 *Deionized Water* — Resistivity ≥15M ohm-cm at 25°C

8 Sampling Plan

8.1 At least three samples shall be chosen for each molding type for each test.

9 Test Specimens

9.1 Test specimens are required as follows:

9.1.1 Specimens for diffusion area.

Diameter — 50 ± 1 mm

Thickness — 3 ± 0.2 mm

9.1.2 Specimens for saturated area.

Diameter — 50 ± 1 mm

Thickness — 1 ± 0.2 mm

10 Equipment Set-Up

10.1 Refer to manufacturer's operation manuals.

11 Procedure

11.1 *Specimen Preparation*

11.1.1 Prepare the specimens by molding samples using the specimen mold and conditions recommended by the molding compound manufacturer.

11.1.2 Post-mold cure the specimens to recommended conditions using the high-temperature chamber.

11.2 *Specimen Conditioning*

11.2.1 Dry the specimens at 125°C in the high-temperature chamber for 24 hours minimum.

NOTE 1: If the samples are already dry (e.g., samples directly from post-mold cure), additional conditioning is not required.

11.2.2 Place the specimens in the desiccator (1) and allow to cool to room temperature.

11.2.3 Weigh the specimens to the nearest 0.0001g.

11.3 *Water Absorption Exposure and Reconditioning*

11.3.1 *Diffusion Area*

11.3.1.1 Place the conditioned specimens (3 mm thickness) in the high-temperature/humidity chamber set at 85°C and 85% relative humidity for 24 ± 1 hours.

NOTE 2: The specimens should be placed to avoid any contact with each other and with the walls of the chamber, e.g. to use a holder or to place on a wire net.

11.3.1.2 Remove the specimens from the chamber and wipe off any excess water from the surfaces with a clean cloth or absorbant paper.

11.3.1.3 Place the specimens in desiccator (2) and allow to cool to room temperature.

NOTE 3: The specimens should be placed to avoid any contact with each other and with the walls of the chamber (e.g., to use a holder or to place on a wire net).

11.3.1.4 Re-weigh the specimens to the nearest 0.0001 g.

11.3.2 *Saturated Area*

11.3.2.1 Place the conditioned specimens (1 mm thickness) in the high-temperature/humidity chamber set at 85°C and 85% relative humidity for 168 ± 4 hours.

NOTE 4: The specimens should be placed to avoid any contact with each other and with the walls of the chamber (e.g., to use a holder or to place on a wire net).

11.3.2.2 Remove the specimens from the chamber and wipe off any excess water from the surfaces with a clean cloth or absorbant paper.

11.3.2.3 Place the specimens in desiccator (2) and allow to cool to room temperature.

NOTE 5: The specimens should be placed to avoid any contact with each other and with the walls of the chamber, e.g. to use a holder or to place on a wire net.

11.3.2.4 Re-weigh the specimens to the nearest 0.0001g.

12 Calculations

12.1 *Water Absorption Rate* — The rate is calculated as follows:

$$\text{Water absorption rate (wt\%)} = ((M2 - M1)/M1) \times 100 \quad (1)$$

Where :

M1 is the initial conditioned weight, and

M2 is the reconditioned weight after exposure to temperature/humidity

12.2 *Diffusion and Solubility Coefficients*

12.2.1 There are various methods to calculate diffusion and solubility coefficients. See Appendix 1 for one of these methods.

13 Report

13.1 The following information shall be reported:

1. Manufacturer and identification of molding compound
2. Specimen sizes
3. Test conditions
4. Water absorption rate
5. Date of test

14 Related Documents

14.1 *ASTM Specification*[1]

ASTM D 570 — Standard Test Method for Water Absorption of Plastic

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

APPENDIX 1
APPLICATION NOTES — METHOD OF CALCULATION FOR DIFFUSION AND SOLUBILITY COEFFICIENT

NOTE: This appendix was approved as an official part of SEMI G66 by full letter ballot procedure.

A1-1 Purpose

This application note describes a method for calculating diffusion and solubility coefficients.

A1-2 Solubility Coefficient, S

The solubility coefficient is given from the data of saturated area as follows:

$$S = M_s \times d / P \times 1000 \qquad (2)$$

Where :

S = Solubility coefficient ($(mg/cm^3) / (kg/mm^2)$)

M_s = Saturated moisture absorption rate (wt%) (data from saturated area test)

d = Density of specimen (g/cm^3)

P = Partial pressure of moisture in environment (Pa) (value at 85°C in this test)

A1-3 Diffusion Coefficient, D

The moisture absorption rate in resin exposed for relatively short term is calculated using the following equation based on Fick's formula:

$$M_t / M_s = 4 \times \{ (D \times t) / (l^2 \times \pi) \}^{1/2} \qquad (3)$$

Then :

$$D = l^2 \times M_t^2 \times \pi / (t \times 4^2 \times M_s^2) \qquad (4)$$

Where :

D = Diffusion coefficient (cm^2 / h)

t = Time of moisture absorption (h) (data from diffusion area test - 24 hours)

M_t = Moisture absorption rate at the time "t". (wt%) (data from diffusion area test)

l = Thickness of the specimen (cm) (data from diffusion area test = 0.3 cm)

M_s = Saturated moisture absorption rate (wt%) (data of saturated area test)

SEMI G67-0996
TEST METHOD FOR THE MEASUREMENT OF PARTICLE GENERATION FROM SHEET MATERIALS

1 Purpose

This test method describes a procedure to measure particles on sheet materials.

2 Scope

The method described may be used for the measurement of particles on items such as:

Leadframe Interleaves

Cleanroom Paper

Packing Material

The procedures may be used by the material manufacturer for quality control or by a customer at incoming inspection.

3 Referenced Documents

None.

4 Terminology

None.

5 Summary of Method

The method is based on measuring a background particle count in a clean enclosure and then measuring the increased particle count when items under test are submitted to handling operations likely to generate particles.

6 Interference

6.1 Care must be taken to avoid contaminating the clean bench when sheet materials are placed inside. All external packaging material shall be removed and the internal packaging shall be cleaned by appropriate means prior to placing inside the bench.

6.2 A method of cutting the specimens to size, if performed, must not add to, or detract from, the contamination levels on the sheet materials.

6.3 Care must be taken to avoid contaminating the specimens from the human body and clothes when the sheet materials are prepared for the test method.

7 Equipment

7.1 *Particle Counter and Recorder*

7.2 *Clean Bench with Full Gloves and a Dust Particle Measurement Port* — See Figure 1.

7.2.1 Air flow speed in the clean bench should be 0.6 m/sec.

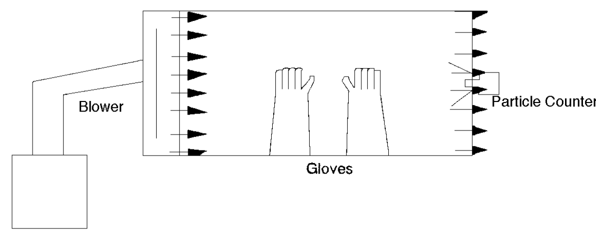

Figure 1
Clean Bench Configuration

8 Sampling

Sampling plans shall be agreed between user and supplier.

9 Test Specimen

Specimen size shall be agreed between user and supplier. It is recommended that a 152.4 mm × 203.2 mm (6 × 8 inches) test piece be used.

10 Equipment Set-Up

10.1 The particle counter shall be set up with the probe in the clean bench. Calibrate the counter in accordance with the equipment manufacturer's instructions.

10.2 Allow the clean bench to come to equilibrium and perform a background particle count.

NOTE 1: Between each test, allow the clean bench to return to a stable background particle count before proceeding with the next test.

NOTE 2: After several thousand particles have been measured, the clean bench must be cleaned before making the next measurement.

11 Test Procedure

11.1 Place the items to be tested in the clean bench and allow the clean bench to return to a stable background level for particle count.

11.2 *Crumpling Test*

11.2.1 Crumple a test specimen in gloved hands at the rate of one (1) crumple every fifteen (15) seconds and record the maximum particle count.

11.2.2 Record the maximum particle count and the initial background count.

11.3 *Friction Test*

11.3.1 Place two sheets of the material to be tested face to face and rub together three (3) times in ten (10) seconds.

11.3.2 Record the maximum particle count and the initial background count.

11.4 *Tearing and Crumpling Test*

11.4.1 Tear a sheet into five (5) pieces at the rate of one (1) tear every five (5) seconds. Crumple the pieces in gloved hands at the rate of one (1) crumple every fifteen (15) seconds.

11.4.2 Record the maximum particle count and the initial background count.

12 Calculations and Reporting Results

12.1 For each measurement and test method type, calculate the particle count on the material under test as follows:

Particle Count (no./m^3) = (Measured Count from each test) - (Background Count)

12.2 Average the results for each test type.

13 Report

The test report shall include the following items:

Material Designation under Test

Manufacturer

Shipping Lot Number

Test Date

Test Conditions — temperature, humidity in the clean bench

Particle Counter Sensitivity

Test Time

Results for Each Test Type in particles/m^3

NOTE 3: If the test is performed by the manufacturer, some of these items may be replaced by in-house requirements such as manufacturer lot number.

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SEMI

SEMI G68-0996
TEST METHOD FOR JUNCTION-TO-CASE THERMAL RESISTANCE MEASUREMENTS IN AIR ENVIRONMENT FOR SEMICONDUCTOR PACKAGES

1 Purpose

The purpose of this test is to determine the thermal resistance of semiconductor packages using thermal test chips. This test method deals with junction-to-case measurements of thermal resistance in air environment.

2 Scope

2.1 The results of this test method are used to obtain the junction temperature.

2.2 The measurement results are usually different from the results obtained by testing in the fluid bath environment described in SEMI G30 and SEMI G43.

2.3 This test method uses SI units.

3 Limitation

This method applies only to packages whose surface is wide enough to place a thermocouple.

4 Referenced Documents

4.1 *SEMI Specifications*

SEMI G30 — Test Method for Junction-to-Case Thermal Resistance Measurements of Ceramic Packages

SEMI G32 — Guideline for Unencapsulated Thermal Test Chips

SEMI G38 — Test Method for Still- and Forced Junction-to-Ambient Thermal Resistance Measurements of Integrated Circuit Packages

SEMI G42 — Specification for Thermal Test Board Standardization for Measuring Junction-to-Ambient Thermal Resistance of Semiconductor Packages

SEMI G43 — Test Method for Junction-to-Case Thermal Resistance Measurements of Molded Plastic Packages

5 Terminology

The following definitions and symbols shall apply to this test:

5.1 *case top temperature measured in air environment, T_t* — In °C, is the temperature at the specified accessible reference point on the package in measured in air environment.

NOTE 1: T_C defined in SEMI G43 is different from T_t.

5.2 *junction temperature, T_j* — In °C, is the temperature of the semiconductor junction on the microcircuit in which the major part of the heat is generated.

5.3 *power dissipation P_H* — In watt, is the heating power applied to the device causing a junction-to reference point temperature difference.

5.4 *thermal resistance measured in air environment, junction to package surface, Ψ_{jt}* — In °C/watt, is the temperature difference from the junction to the center point on the package divided by the power dissipation P_H.

6 Summary of Method

A thermocouple is attached on the surface of the package on the test board.

After the chip is heated, the junction temperature is measured by the diode in the test chip. The surface temperature is measured in an air environment by the thermocouple.

The junction-to-case thermal resistance is calculated using the case temperature, junction temperature and power dissipation.

7 Interference

7.1 It is recommended that an operator who is familiar with the measuring system and test method conduct the actual measurement in order to obtain the best result.

7.2 The procedure for attaching the thermocouple described in Section 12.3 on the test package should be followed in order to obtain the accurate measurement result.

8 Apparatus

8.1 *Thermocouple*

8.1.1 *Material* — Copper-constantan or equivalent

8.1.2 *Temperature Range* — -100 to +300°C

8.1.3 *Wire Size* — No larger than AWG size 36.

8.1.4 *The Junction* — Shall be welded to form a bead rather than soldered or twisted.

8.1.5 *Accuracy* — ± 0.5%

8.2 *Suitable Electrical Equipment* — As required to provide controlled levels of conditioning power and to make the specified measurements.

8.2.1 *Resolution* — 50 µV and 5 µA

8.3 *Wind Tunnel (as necessary)* — See SEMI G38 or equivalent.

9 Materials

9.1 *Test Chip* — Referred to in SEMI G32, or equivalent.

9.2 *Test Board* — Referred to in SEMI G42, or equivalent.

9.3 *Adhesive* — Alpha Cyano-Acrylate

9.4 *Aluminum Foil* — 4 mm × 4 mm.

10 Setup

Warm up the test equipment before measurements.

11 Calibration

Calibrate the equipment in accordance with the operation manual as necessary.

12 Procedure

12.1 *Preparation of Test Package*

12.1.1 Prepare the semiconductor package in which the test chip is mounted.

12.2 Assemble the package on the test board using solder.

12.3 *Attach the Thermocouple*

12.3.1 Apply adhesive on the center point of the package.

12.3.2 Place the thermocouple and aluminum foil on the adhesive and press the aluminum foil using a finger in order to attach the thermocouple on the package surface as close as possible.

12.4 Measure the thermal characteristic of the diode of the test chip.

NOTE 2: It is recommended that the ambient temperature T_a is measured using the thermocouple.

12.5 Mount the test board in a test socket in a still-air enclosure or wind tunnel as necessary.

12.6 *Heating Chip*

12.6.1 Supply power to the chip.

12.6.2 Adjust the measurement equipment to the measured case temperature T_t or the the measured power $P_{H\ (package)}$.

NOTE 3: The thermal resistance usually depends on the power dissipation (see Figure 1). The thermal resistance is variable within a power and stable beyond the power.

12.7 Wait until the thermal characteristic of the diode is stable.

12.8 Calculate the junction temperature T_j by the diode thermal characteristics.

12.9 Measure the case temperature T_t using the thermocouple and record the case temperature.

12.10 Record the voltage and the current in order to obtain the $P_{H\ (package)}$.

13 Calculation

13.1 The thermal resistance of the package can be calculated as follows:

Ψ_{jt} (°C/watt) =

$(T_j — T_t) / P_{H\ (package)}$

14 Report

The following details shall be reported:

a. Description of package

b. Description of test board

c. Power dissipation of test chip

d. Thermal resistance $R_{\Psi jt}$ for test condition

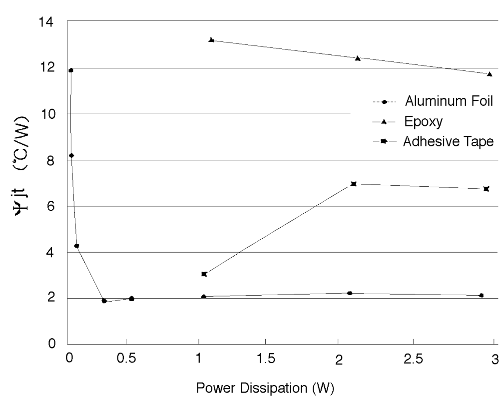

Figure 1
Dependence of $R_{\Psi jt}$ on Power Dissipation

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SEMI G69-0996
TEST METHOD FOR MEASUREMENT OF ADHESIVE STRENGTH BETWEEN LEADFRAMES AND MOLDING COMPOUNDS

1 Purpose

1.1 This document describes procedures for measuring adhesive strength between leadframes and molding compounds for semiconductor packages.

1.2 The procedures include shear test, pull test, and three-point bending techniques.

2 Scope

2.1 This document may be used on all types of semiconductor leadframe and molding compound.

2.2 The methods help leadframe manufacturers, molding compound manufacturers and their customers in evaluating leadframes, and molding compounds as a guideline.

2.3 The methods in this document use SI units.

3 Referenced Document

A. Nishimura, I. Hirose and N. Tanaka, "A New Method for Measuring Adhesion Strength of IC Molding Compounds", ASME Journal of Electronic Packaging, Vol. 114, pp 407-412, 1992

4 Terminology

None.

5 Summary of Method

5.1 *Shear Method* — A frustum-shaped button of molding compound on the surface of a leadframe sample is sheared off the leadframe surface using a tensile tester (see Figure 1).

5.2 *Pull Method* — A sample of leadframe material molded into the side of a block of a molding compound is pulled out using a tensile tester (see Figure 2).

5.3 *Three-Point Bending Method* — Molding compound is molded onto the surface of a leadframe sample such that part of the leadframe is free of molding compound adherence to the surface. Using a bending technique, the adherent molding compound is cracked away from the surface. This process is repeated from both sides of the sample in order to calculate the true adhesive strength. (Refer to the paper in Referenced Document and see Figure 3.)

6 Equipment

6.1 *Tensile Tester*

6.1.1 *Measurement Range* — Maximum 980 N (100 kgf)

6.1.2 *Accuracy* — ± 1%

6.1.3 *Crosshead Speed* — 2 – 10 mm/min (recommended), constant speed.

6.1.4 Fixtures suitable for holding the samples, shearing the molding compound, pulling the leadframe, and applying bending load.

6.2 *Chart Recorder*

6.3 Transfer molding machine or suitable replacement that can encapsulate individual samples with required pressure and temperature.

6.4 *Pre-Heater* — High frequency heater for molding compounds.

6.5 *Molds* — Suitable to mold the samples as shown in Figures 1, 2, and 3.

6.6 *Recirculating Air Oven* — With controller in range of 170 – 180 °C.

6.7 Equipment to pre-treat the leadframe sample, as required.

6.8 Ultrasonic inspection apparatus for three-point bending method.

7 Configuration and Dimension of Sample

7.1 The sample configuration and dimensions for measurement are shown in Figures 1, 2, and 3.

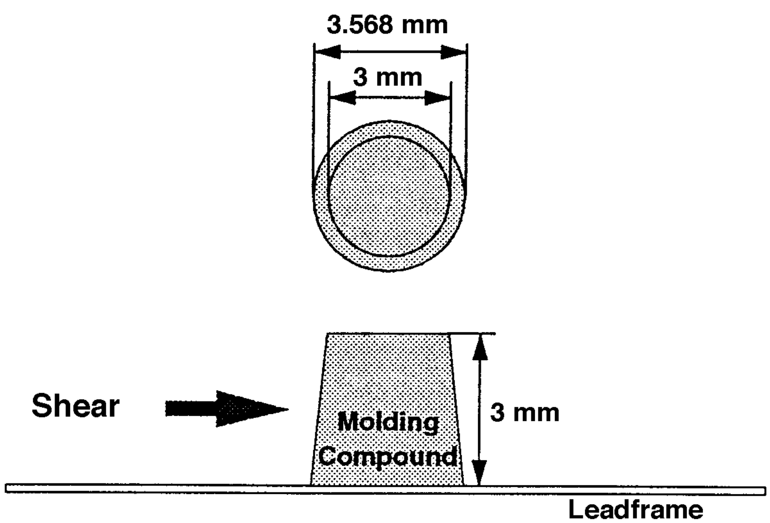


Figure 1
Sample for Shear Method

Adhesive Area	*Leadframe Thickness*	*Height of Molding Compound*
10 ± 0.5 mm^2	0.254–0.125 mm (0.15 mm is recommended)	3 ± 0.15 mm

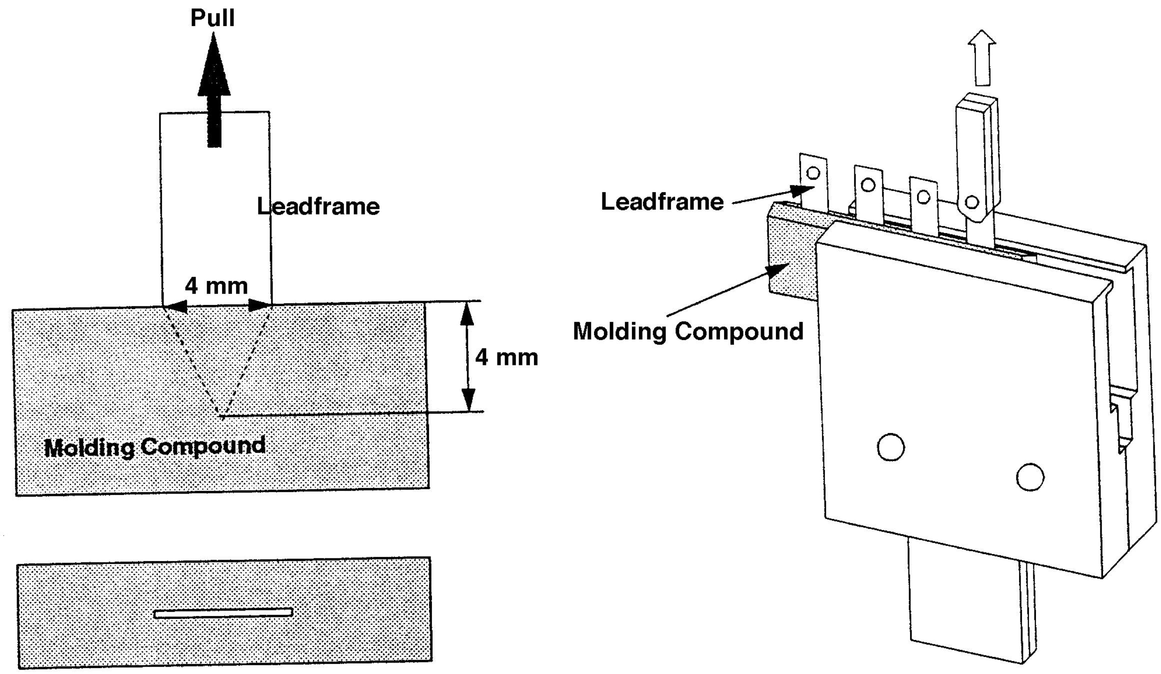


Figure 2
Sample for Pull Method

Adhesive Area	*Molding Compound Sample Thickness*
16 ± 0.8 mm^2 (both sides)	3.5–4.0 mm (equivalent to DIP 16 300 mil)

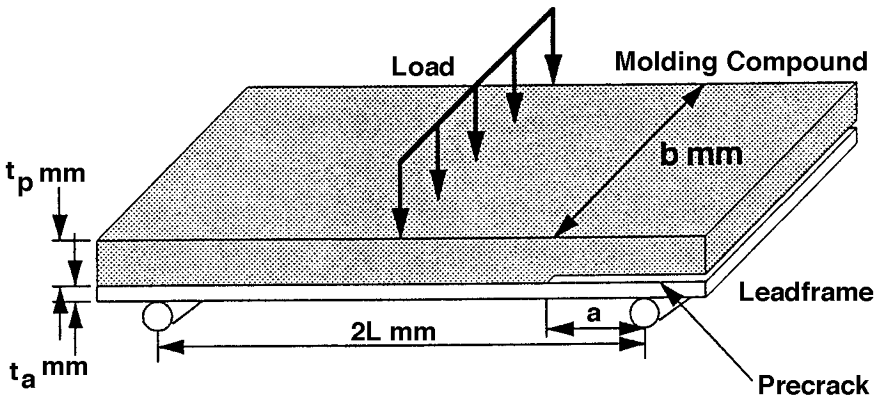


Figure 3
Sample for Three-Point Bending Method

	Molding Compound Thickness t_p *(mm)*	Leadframe Thickness t_a *(mm)*	Span 2L (mm)	Pre-Crack Length a (mm)	Sample Width b (mm)
Standard	1.5	0.25	45	10–15	6
Type A (for low adhesive strength)	0.8	0.2	35	8–10	4
Type B (for high temperature measurement)	4	0.5	50	10–15	6
Other Sample Types	The following equations should be satisfied $2L \geq 8\ (t_p + t_a)$ and $L - a \geq 2\ (t_p + t_a)$				

8 Sampling Plan

8.1 The sampling plan shall be agreed between customer and vendor. It is recommended that the following minimum sample sizes are used:

- *Shear Method* — Four (4) samples
- *Pull Method* — Four (4) samples
- *Three-Point Bending Method* — Three (3) samples in each direction

NOTE 1: Three-point bending method needs at least 2 samples to obtain adhesive strength.

9 Materials

9.1 Leadframe or appropriated sample from strip meeting dimensions for test.

9.2 Molding compound

10 Sample Preparation

10.1 *Leadframe Sample Preparation*

10.1.1 Process the leadframe samples through the various cleaning and heat cycles that would be normal for the leadframe under consideration as required.

NOTE 2: When this method is applied to copper leadframes, copper oxide on the surface shall be considered when results are interpreted.

10.2 Clean and condition the molds to provide well formed samples as required.

10.3 Set the molds to the specified temperature and record the temperature.

10.4 Set the transfer molding pressure, transfer time and cure time to the following recommended molding conditions. If the condition is not suitable for the material, the condition should be agreed between customer and vendor.

Molding condition	
Cure temperature	170 – 180 °C
Cure time	120 sec.
Molding pressure	6.8 – 7.8 MPa (70 – 80 kgf/cm^2)

10.5 Mold all the required samples.

10.6 Remove the samples from the molds.

NOTE 3: After removing the samples from the molds, natural cooling of the samples is recommended.

10.7 Post mold cure the samples at the following recommended conditions.

Post-cure condition	
Temperature	175 ± 5 °C
Time	4 – 8 hour

10.8 Store the samples and record the storage conditions.

10.9 Three-Point Bending Samples

10.9.1 In addition to the treatment mentioned in 10.1.1 and to facilitate cracking during the three point bending method, apply a thin layer of mold release to on end of the leadframe sample in order to form a "pre-crack" condition (i.e., the molding compound will not adhere to this section of the sample) (see Figure 3).

NOTE 4: It is recommended that toluen-based thermosetting silicone be used as a mold release agent to prevent molding process contamination.

11 Calibration

11.1 *Tensile Tester Calibration*

11.1.1 Calibrate the tensile tester in accordance with the manufacturer's instructions.

12 Test Procedure

12.1 *Shear Method*

12.1.1 Attach the sample to the tensile test such that shear may be applied.

12.1.2 Place the shear tool against the molding compound formation and initiate a load at a constant speed between 2–10 mm/min while recording the load and displacement.

12.1.3 Record the peak load before the sudden drop in applied load as the sample shears off the leadframe or the molding compound breaks.

NOTE 5: Disregard any results which have the appearance of sample slipping or shear tool riding over the molding compound.

12.2 *Pull Method*

12.2.1 Attach the sample to the tensile tester such that the leadframe may be pulled out of the molding compound with a vertical pull action.

12.2.2 Attach the pulling grips to the leadframe and initiate a load at a constant speed between 2–10 mm/min. while recording the load and displacement.

12.2.3 Record the peak load before the sudden drop in applied load as the sample is pulled from the molding compound samples.

NOTE 6: Disregard any results which have the appearance of slippage of the sample or pulling grips.

12.3 *Three-Point Bending Method*

12.3.1 Measurement of the pre-crack length

12.3.1.1 Measure the pre-crack length using an ultrasonic inspection technique (see Figure 4).

NOTE 7: The sample, in this case, is placed in the vessel with the leadframe side up, and then secured with an adhesive tape so that the water cannot penetrate into the interface area created by the mold release.

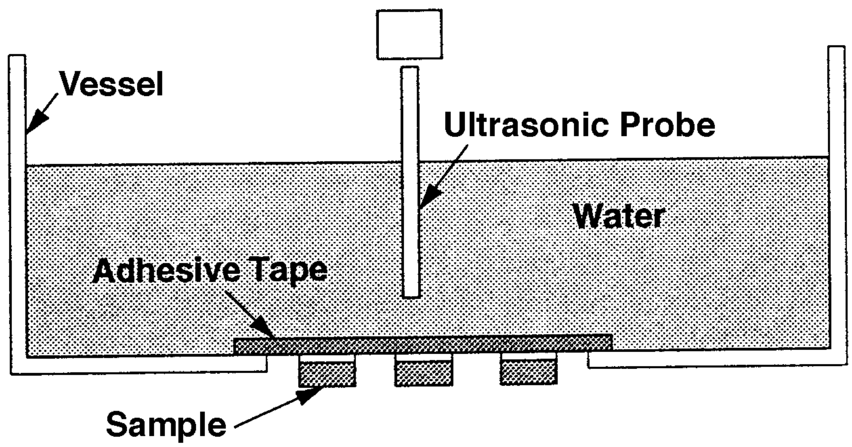


Figure 4
Measurement of Pre-Crack Length

12.3.2 *Test Procedure*

12.3.2.1 Attach support fixture and load wedge to the tensile tester.

12.3.2.2 Place the sample on the support fixture with the molded side up (see Figure 5).

NOTE 8: The support fixture tool should be located at a constant distance from the tip of pre-crack for every measurement.

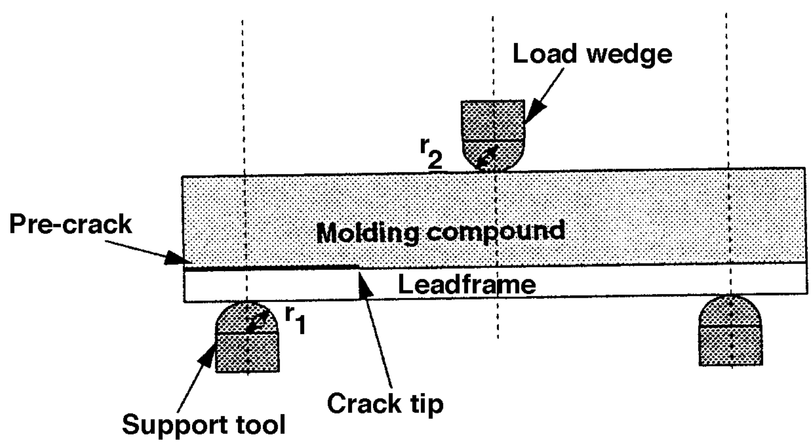


Figure 5
Sample Setup

Radius of support tool r_1	5 – 8 mm
Radius of load wedge r_2	2 – 5 mm

12.3.2.3 Place the load wedge in contact with the molded surface and initiate the loading at a constant speed between 2 – 10 mm/min while recording the load and displacement.

12.3.2.4 Record the peak load before the sudden drop in applied load.

12.3.2.5 Repeat the test with another sample which has the leadframe side up.

13 Calculation

13.1 *Shear and Pull Method*

13.1.1 The adhesive strength is calculated as follows:

Adhesive Strength (N/mm^2) = Peak Load (N)/Nominal Adhesive Area (mm^2)

13.2 *Three-Point Bending Method*

13.2.1 *Apparent Adhesive Strength* — Apparent adhesive strength including residual stress, is calculated using the stress intensity factor K_i as follows:

$$K_i = 4 \times 10^{-6} \cosh(\varepsilon\pi) \sqrt{\frac{G}{\frac{\kappa_p + 1}{\mu_p} + \frac{\kappa_a + 1}{\mu_a}}}$$

where

$$G = 3 \left[\frac{1}{t_p^3 E_p + t_p^3 E_a} - \frac{t_p E_p + t_a E_a}{k} \right] \frac{P^2 a^2}{2b^2}$$

$$k = 4 t_p t_a E_p E_a \left(t_p + t_a\right)^2 + \left(t_p^2 E_p + t_a^2 E_a\right)^2$$

$$\varepsilon = \frac{1}{2\pi} \ln \left\{ \frac{\frac{\kappa_p}{\mu_p} + \frac{1}{\mu_a}}{\frac{\kappa_a}{\mu_a} + \frac{1}{\mu_p}} \right\}$$

$$\kappa_j = 3 - 4\nu_j \qquad \text{(j = p or a)}$$

P : Peak load (N)

a : Pre - crack length (m)

b : Sample width (m)

t_p : Thickness of molding compound (m)

t_a : Thickness of leadframe (m)

E_p : Young's modulus of molding compound (Pa)

E_a : Young' s modulus of leadframe (Pa)

μ_p : Shear modulus of molding compound (Pa)

μ_a : Shear modulus of leadframe (Pa)

ν_p : Poisson's ratio of molding compound

ν_a : Poisson' s ratio of leadframe

13.2.2 *True Adhesive Strength* — The true adhesive strength (CKic) excluding residual stress, is calculated as follows:

$$K_{ic}\left(MPa\sqrt{m}\right)=\frac{K_{ib1}+K_{ib2}}{2}$$

where :

K_{ib1} : Apparent adhesive strength when testing is performed with molded side up ($MPa\sqrt{m}$)

K_{ib2} : Apparent adhesive strength when testing is performed with leadframe side up ($MPa\sqrt{m}$)

14 Report

14.1 The following items should be reported:

14.1.1 Leadframe

14.1.1.1 Material Designation

14.1.1.2 Thickness

14.1.1.3 Production Method (etching or stamping)

14.1.1.4 *Pre-Treatment* — In case that surface pre-treatment is necessary, the process and their condition should be reported as follows:

- Pre-treatment by plating
- Plating type
- Plating thickness

a. Post treatment after plating
- Corrosion prevention treatment
- Cleaning treatment
- Coupling material

b. Pre-treatment by heating
- Temperature
- Atmosphere
- Oven or Hot Plate

14.2 Molding Compound

14.2.1 Material Designation

14.3 Molding Compound Configuration and Dimension

14.4 Molding Condition

- Pre-heat condition (Temperature, Time)

- Molding condition (Cure temperature, Cure time, Injection speed, Injection pressure)

- Post-cure condition (Temperature, Time)

- Sample storage conditions

14.5 Measurement Method (Shear, Pull, or Three-point bending method)

14.6 Measurement Equipment

14.7 Adhesive Strength (maximum, minimum, average, and where possible, standard deviation, σ)

APPENDIX 1
SAMPLE OF MOLD FOR SHEAR METHOD

NOTE: This appendix was approved as an official part of SEMI G69 by full letter ballot procedure.

A mold to prepare samples for shear method is shown in Figure A1-1 as a sample.

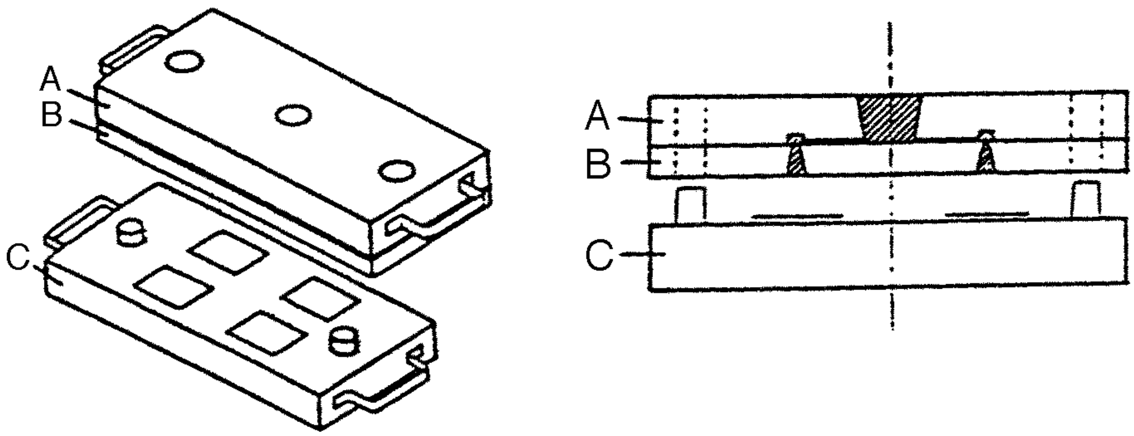


Figure A1-1
Mold Sample

APPENDIX 2
SAMPLE SIZE

NOTE: This appendix was approved as an official part of SEMI G69 by full letter ballot procedure.

Results of adhesive strength measurement made by some companies using the same leadframe material and molding compound are shown in Figure A2-1. The figures show that apparent adhesive strength decreases with an increase in adhesive area due to residual stress.

Sample size in this document was determined in consideration of the effect of residual stress and easiness of handling for samples.

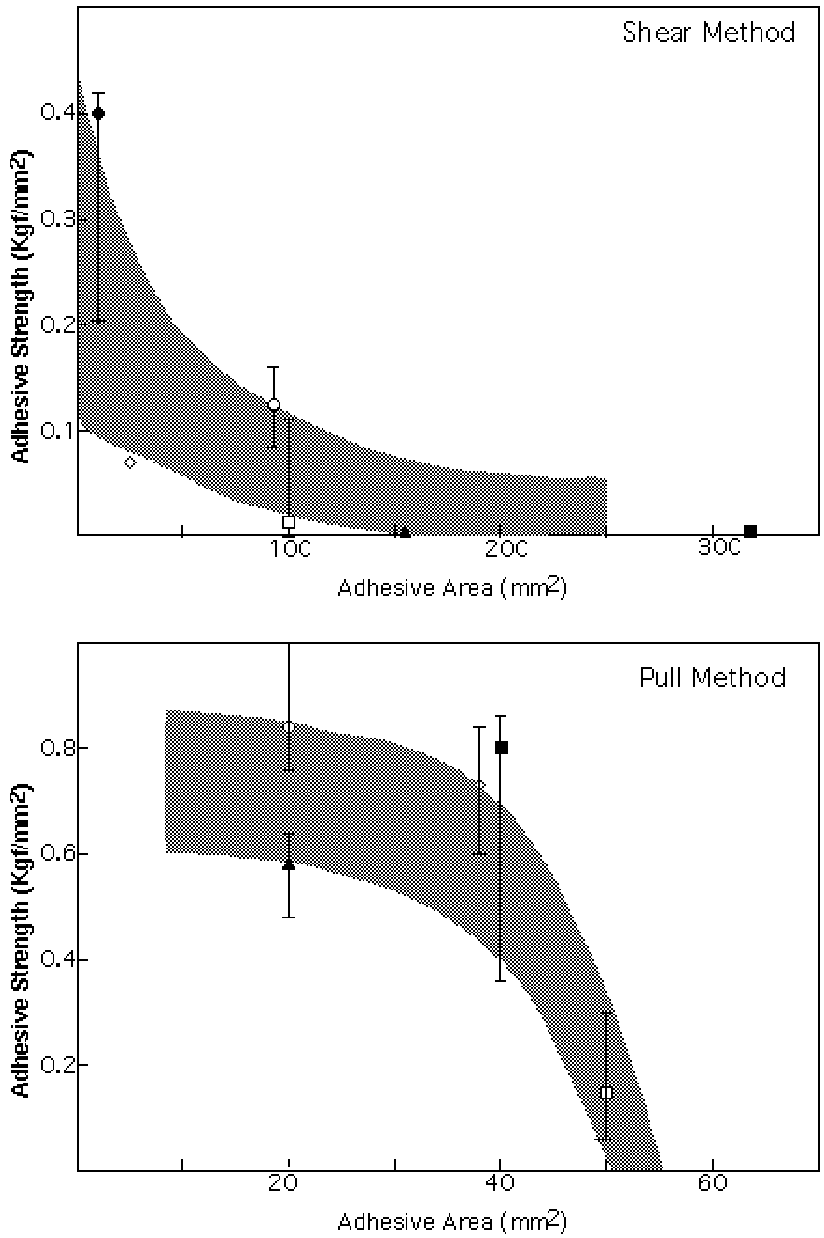


Figure A2-1
Dependence of Measurement Results on Sample Size

APPENDIX 3
EFFECTIVENESS OF RESIDUAL STRESS SEPARATION IN THREE-POINT BENDING METHOD

NOTE: This appendix was approved as an official part of SEMI G69 by full letter ballot procedure.

Since the three-point bending method can eliminate the effect of residual stress and also that of stress distribution on the interface (stress singularity at the adhering edges), the measurement results are almost independent of sample dimensions (Figure A3-1[1])). This method can evaluate both the true adhesive strength and the magnitude of residual stress, mainly due to the thermal expansion mismatch between materials, simultaneously (Figures A3-2 and A3-3[2])).

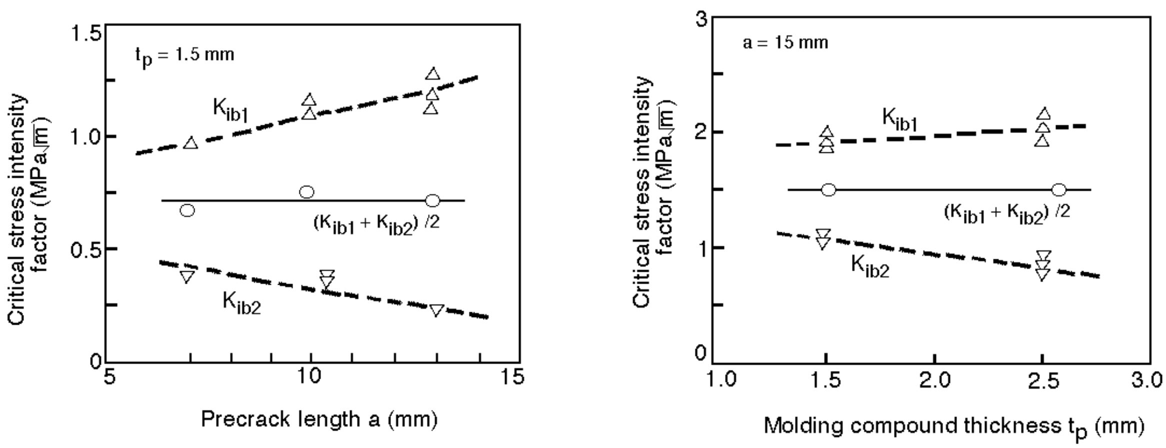


Figure A3-1
Dependence of Measurement Results on Specimen Dimensions

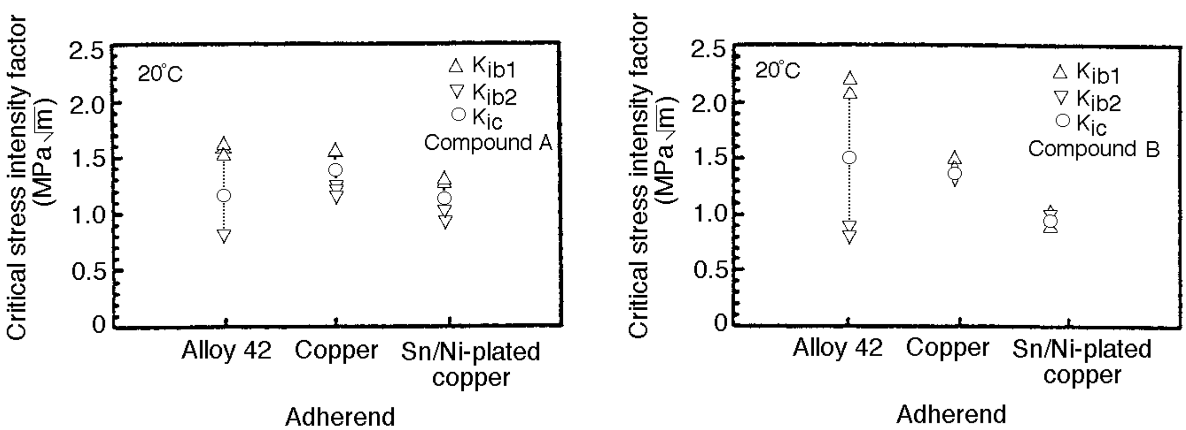


Figure A3-2
Dependence of Adhesion Strengths on Adherend Material

1 A. Nishimura, I. Hirose, and N. Tanaka, "A New Method for Measuring Adhesion Strength of IC Molding Compounds", ASME Journal of Electronic Packaging, Vol. 114, pp. 407-412, 1992

2 A Nishimura amd N. Tanaka, "Measurement of IC Molding Compound Adhesion Strength and Prediction of Interface Delamination within Package", Advanced in Electronic Packaging, edited by T.R. Hsu et al., ASME, EEP-Vol. 10.2, pp. 765-773, 1995

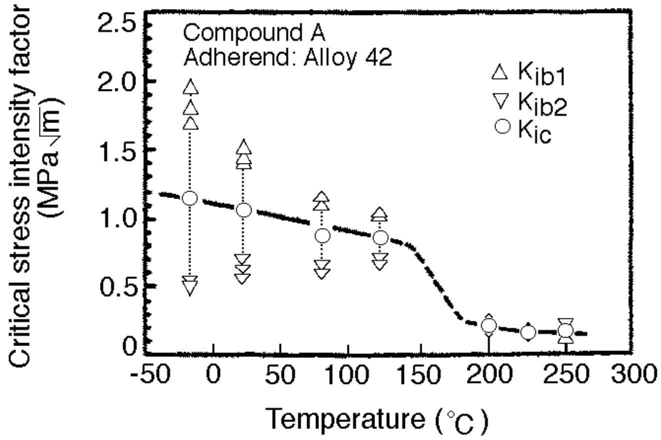
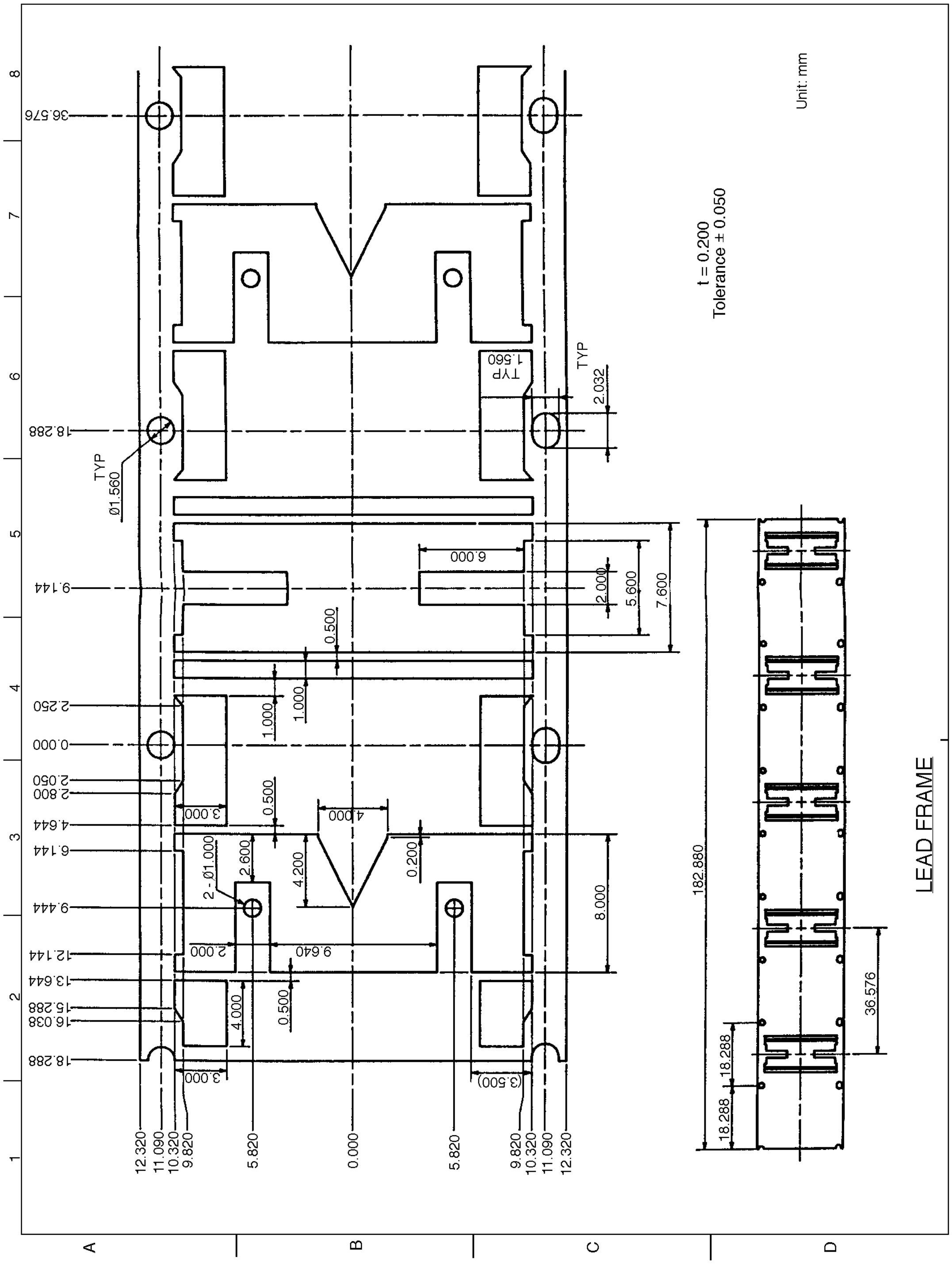


Figure A3-3
Temperature Dependence of Adhesion Strength

APPENDIX 4
LEADFRAME DESIGN FOR PULL METHOD

NOTE: This appendix was approved as an official part of SEMI G69 by full letter ballot procedure.



NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G70-0996
STANDARD FOR EQUIPMENT AND LEADFRAME FIXTURES FOR MEASUREMENT OF PLASTIC PACKAGE LEADFRAMES

1 Purpose

1.1 This standard describes the equipment and leadframe fixtures used for measurement of Z-axis dimensions of plastic package leadframes.

2 Scope

2.1 This standard mainly describes the equipment and leadframe fixture for measurement of leadframes that are ≤ 0.15 mm in thickness as used for TSOP and TQFP packages listed in group II in Table 1.

2.2 This standard also may be applied for leadframe of conventional packages which are ≥ 0.2 mm in thickness.

Table 1 Package Classification

Group I	*Group II*
	SSOP
DIP	TSOP
ZIP	TSSOP
SOJ	QFP
SOP	TQFP
QFJ (PLCC)	LQFP
	SVP

NOTE 1: Packages should be classified by EIAJ and JEDEC specifications.

3 Referenced Documents

3.1 *SEMI Standard*

SEMI G57 — Guideline for Standardization of Leadframe Terminology

3.2 *EIAJ Standard*[1]

ED-7411 — General Rules for the Preparation of Outline Drawings of Integrated Circuits, Packages Name and Code

3.3 *JEDEC Specifications*[2]

Pub. No. 95 — Registered and Standard Outlines for Semiconductor Devices

4 Terminology

NOTE 2: See SEMI G57 for leadframe features terminology.

4.1 *burr height* — Maximum height of burr above the plane which it protrudes. (See Figure 1.)

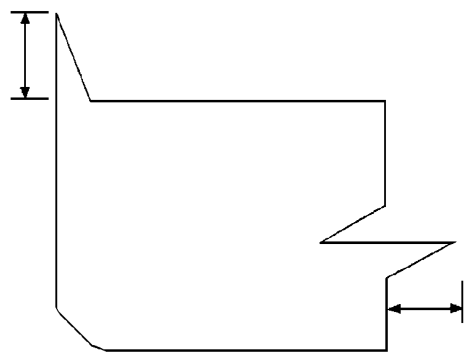


Figure 1
Burr Height

4.2 *coil set* — Longitudinal bowing of the leadframe strip length. (See Figure 2.)

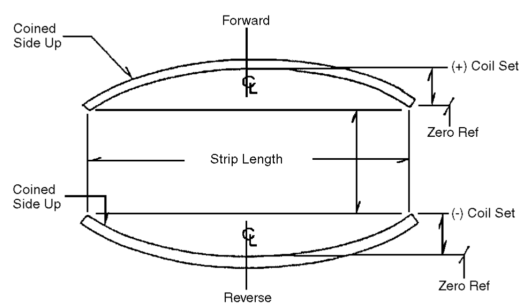


Figure 2
Coil Set

1 Standards of Electronic Industries Association of Japan, Tosho Bldg. 5F, 3-2-2 Marunouchi, Chiyoda-ku, Tokyo, Japan 100

2 JEDEC Standard, 2001 Eve Street, N.W., Washington DC, 20006

4.3 *coined depth* — The difference in height between the top surface of the coined area of an inner lead and the top surface of the coined area at the tip of the lead. Inner lead coining produces a flattened section of the lead that is suitable for wire bonding. (See Figure 3.)

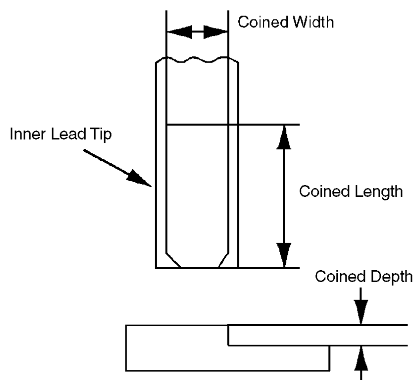


Figure 3
Coined Depth

4.4 *crossbow* — Transverse bowing of the leadframe. (See Figure 4.)

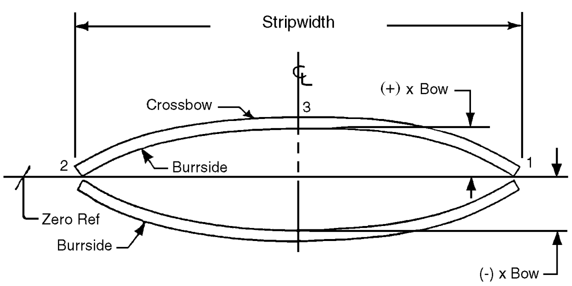


Figure 4
Crossbow

4.5 *die pad dimple* — A hollow formed in a die pad using a half-etching technique or stamping to improve the adhesive strength with the die or molding compound and to reduce the stress between the die pad and the die.

4.6 *die pad dimple depth* — The maximum depth of the dimple. (See Figure 5.)

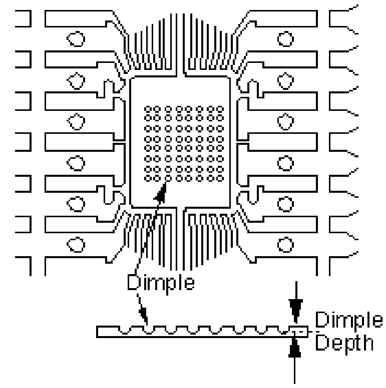


Figure 5
Die Pad Dimple Depth

4.7 *die pad flatness* — Deviation of the center point of die pad surface from a plane established by the four corner points of die pad. (See Figure 6.)

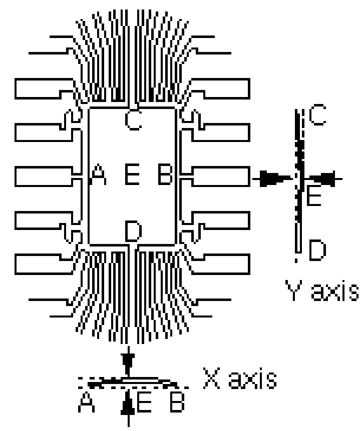


Figure 6
Die Pad Flatness

4.8 *die pad location* — Deviation of the center point of die pad surface from a plane established by the dam bars (see Figure 7).

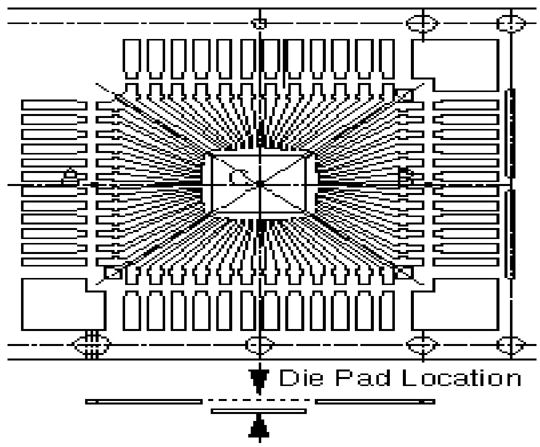


Figure 7
Die Pad Location

4.9 *die pad tilt* — Deviation of the plane of die pad from a condition parallel to the plane formed by the dam bars. (See Figure 8.)

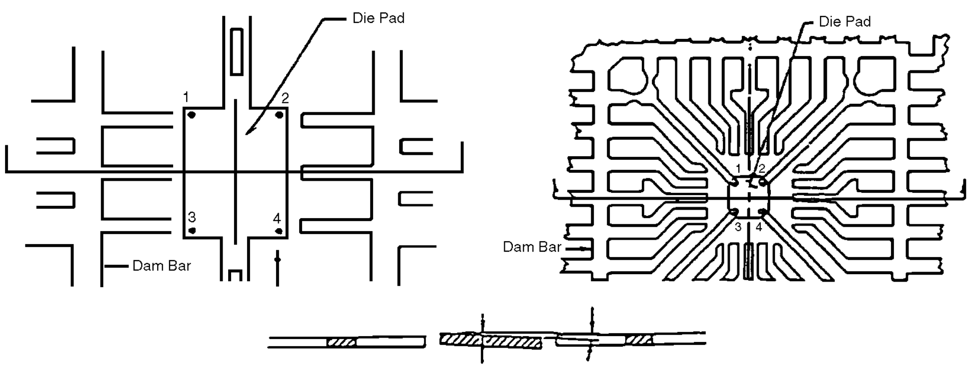


Figure 8
Die Pad Tilt

4.10 *downset depth* — (See Figure 9.)

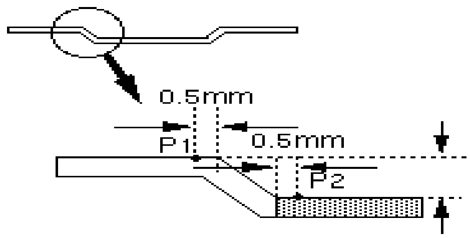


Figure 9
Downset Depth

NOTE 3: The measurement points P1 and P2 should be agreed between user and supplier.

4.11 *half-etch* — Some designed part or area of leadframe where the thickness is reduced by one side etching.

4.12 *half-etch depth* — The maximum depth of the half-etch. (See Figure 10.)

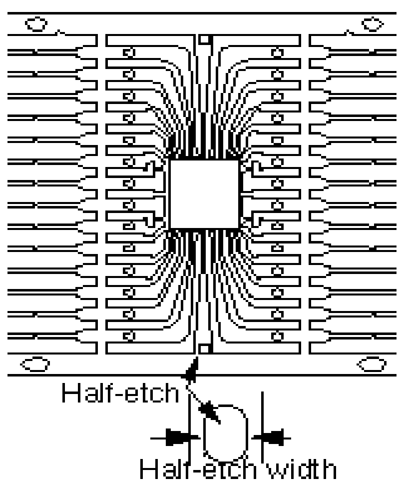


Figure 10
Half-Etch Depth

4.13 *lead coplanarity* — Total indicator reading difference of the lead tips in the Z direction. (See Figure 11.)

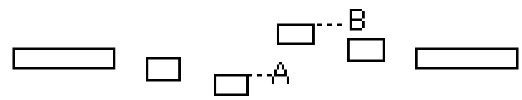


Figure 11
Lead Coplanarity

4.14 *lead planarity* — Total indicator reading of the lead tips in the Z direction relative to the datum formed by the dam bars. (See Figure 12.)

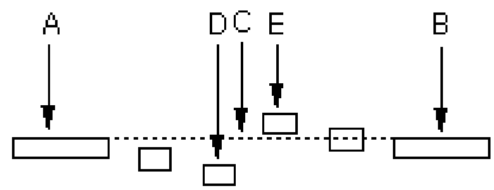


Figure 12
Lead Planarity

4.15 *lead lock groove* — A groove formed in leads using the half-etching technique or stamping to increase the adhesive strength of plastic molding compound to the leads and improve resistance to water intrusion into the package. (See Figure 13.)

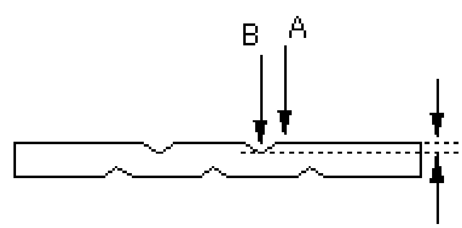


Figure 13
Lead Lock Groove

4.16 *lead lock groove depth* — The maximum depth of the groove.

4.17 *lead tilt* — Deviation of the plane of coined area from a condition parallel to the plane formed by the dam bars. (See Figure 14.)

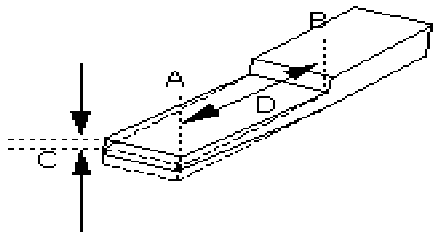


Figure 14
Lead Tilt

4.18 *leadframe twist* — Angular rotation of one end of the leadframe or strip with reference to the other end. (See Figure 15.)

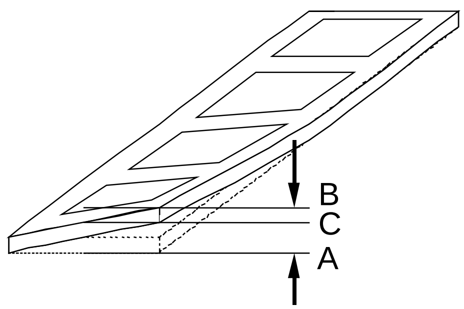


Figure 15
Leadframe Twist

5 Equipment

5.1 *Measurement Equipment* — The equipment and required accuracy used for the measurements are shown in Table 2.

Table 2 Measurement Equipment

Type	*Equipment*	*Minimum Reading*	*Accuracy (2σ)*
A	Height measurement equipment with non-contact method	0.1 µm	1 µm
B		1 µm	4 µm
C	Clearance gage	10 µm	-
D	Scanning probe microscope	0.1 µm	-

5.2 *Leadframe Fixtures* — Leadframe fixtures are shown in Figures 16 – 20. The materials, dimensions, and accuracy shall be agreed between the vendor and customer.

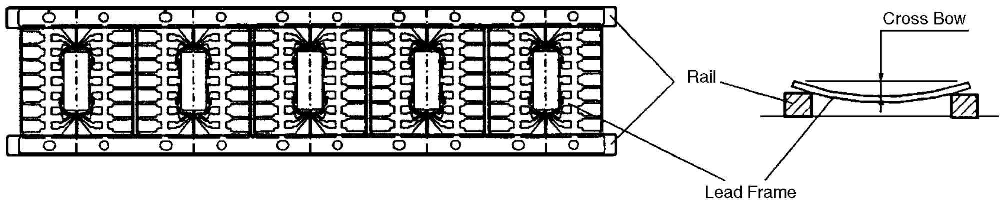


Figure 16
Leadframe Fixture — Type 1

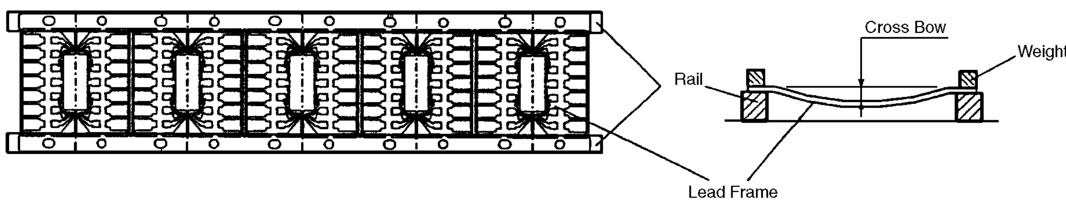


Figure 17
Leadframe Fixture — Type 2

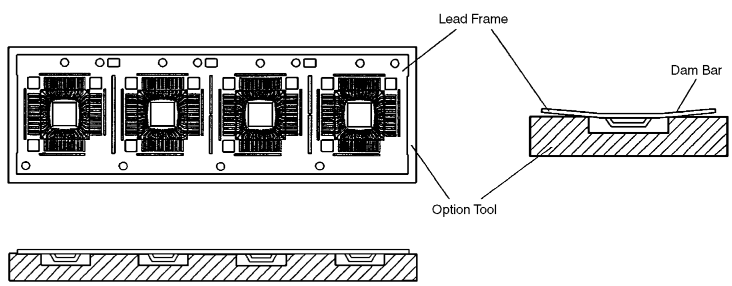


Figure 18
Leadframe Fixture — Type 3

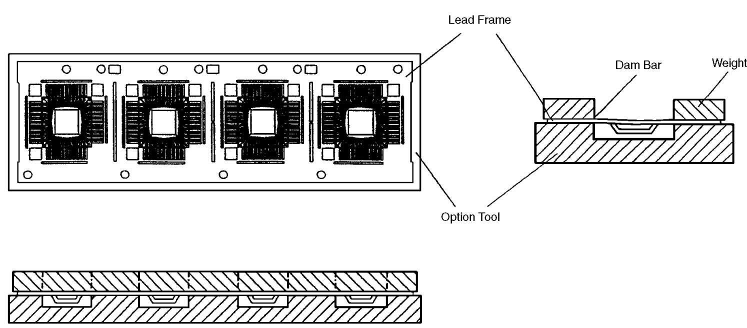


Figure 19
Leadframe Fixture — Type 4

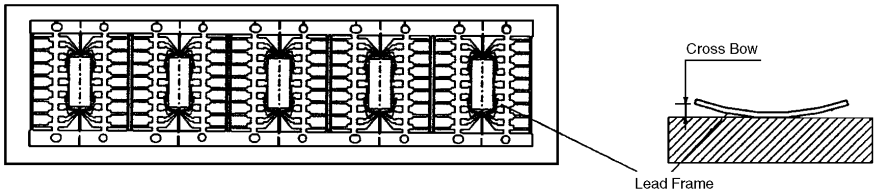


Figure 20
Leadframe Fixture — Type 5

6 Measurement

Leadframe fixtures and measurement equipment for each measurement item are shown in Tables 3 and 4.

Table 3 Leadframe Fixtures and Measurement Equipment (Independent of Package Type)

Items	*Leadframe Fixture*	*Equipment*
Burr height	1. 2. 3. 4. 5.	A. B. D.
Coil set	5	A. B. C.
Coined depth	1. 2. 3. 4. 5.	A. B.
Die pad dimple depth	1. 2. 3. 4. 5.	A. B.
Lead lock groove depth	1. 2. 3. 4. 5.	A. B.
Half-etch depth	1. 2. 3. 4. 5.	A. B.
Leadframe twist	1. 2. 3. 4. 5	A. B.

Table 4 Leadframe Fixtures and Measurement Equipment (Dependent on Package Type)

Items	*Group I*		*Group II*	
	Leadframe Fixture	*Equipment*	*Leadframe Fixture*	*Equipment*
Crossbow	1.	A. B.	1. 3.	A.
Die pad flatness	1. 3.	A. B. D	3. 4.	A. D.
Die pad location	1. 3	A. B	4	A.
Die pad tilt	1. 3.	A. B	3. 4	A.
Downset depth	1. 3.	A. B	4	A.
Lead planarity	1. 3.	A. B	4	A.
Lead coplanarity	1. 3.	A. B	4	A.
Lead tilt	1. 3.	A. B	3. 4	A.

7 Related Documents

7.1 *SEMI Standard*

SEMI G10 — Standard Method for Mechanical Measurement for Plastic Package Leadframes

SEMI G71-0996
SPECIFICATION FOR BARCODE MARKING OF INTERMEDIATE CONTAINERS FOR PACKAGING MATERIALS

1 Purpose

1.1 This specification describes a common format, content, size, and location for printed, machine-readable labels on an intermediate container of materials used for semiconductor packaging.

1.2 This specification provides for a smooth transition from existing traceability and labeling procedures to a comprehensive, unified system envisioned for the future.

2 Scope

2.1 This document applies to the following packaging materials:

- Leadframe
- Molding compound
- Bonding wire
- Die attach materials

2.2 This document applies to only the intermediate container. Barcode specification for shipping pack is referred to EIA 556A or EIAJ barcode specification.

2.3 This document does not apply to product package label.

NOTE 1: There are requests for labeling on product packages from the customers. However, task force concluded that the product package label was not included in scope of the specification because of limitation of area to be labeled on the package. For further activity, two-dimensional barcode symbol may be needed to standardize the barcode marking specification for product packages.

3 Referenced Documents

3.1 *AIM Specification*[1]

USS-39 — Universal Symbol Specification Code 39

3.2 *ANSI Specifications*[2]

ANSI X3.182 — Barcode Print Quality - Guideline

ANSI/FACT1 — Data Application Identifier Standard

3.3 *EIA Specification*[3]

EIA 556A — Outer Shipping Container Bar Code Label System

3.4 *EIAJ Specification*[4]

EIAJ — Standard, Bar Code Label System

4 Terminology

4.1 Many items relating to barcode technology are defined in EIA 556, Appendix Definitions, and EIAJ Bar Code Label Systems, Appendix A.

4.1.1 *intermediate container* — A container housing one or more product packages for the purpose of product/ order segregation in a shipping container.

4.1.2 *product package* — The first tie, wrap, or container to a single item or quantity thereof that constitutes a complete identifiable pack. Product package may be packaged together or a group of the parts packaged together. Product package is also called unit pack.

4.1.3 *shipping pack* — A package or shipping container/ final container that is of sufficient strength to be used in commerce for packing, storing, and transporting products (see Figure 1).

1 AIM USA, 634 Alpha Drive, Pittsburg, PA 15238

2 American National Standard Institute, 1430 Broadway, New York, NY 10018

3 Electronic Industries Association, 2001 Eye Street, Washington DC 20006

4 Electronic Industries Associations of Japan, Tokyo Chamber of Commerce and Industry Bldg., 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100, Japan

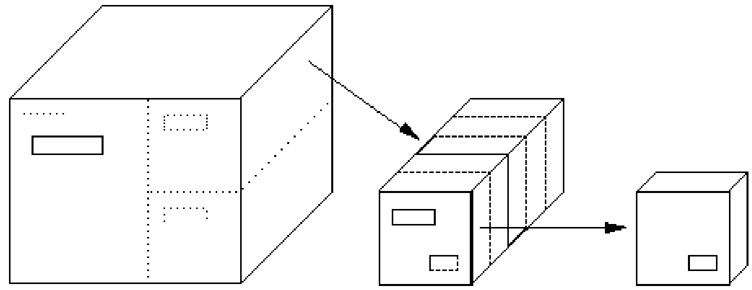


Figure 1
Definition of Package Form

4.2 Package forms for each material type are defined in Table 1.

5 Ordering Information

5.1 Purchase orders for the materials furnished in an intermediate package to the specification shall be include the following:

5.1.1 Content of message characters for customer product ID.

5.1.2 User-specified data, if required.

5.2 In addition, the following optional items may be specified.

5.2.1 Label location on the intermediate container.

5.2.2 Label size, if a label larger than the specified size in this specification.

6 Content of Data Field

6.1 The label shall include vendor field and customer field.

6.2 The customer field shall contain three data fields for barcode symbols. Each data field shall contain a maximum 17 message in addition to the start and stop characters. The content of the barcode symbol is shown in Table 2.

6.2.1 The upper data field shall contain a barcode symbol with customer product ID which consists of maximum 15 characters, preceded by a “P”, the data identifier for this item as specified in ANSI/FACT-1.

6.2.2 The middle data field shall contain a barcode symbol with lot number which consists of maximum 12 characters, preceded by a “1T”, the data identifier for this item as specified in ANSI/FACT-1.

6.2.3 The lower data field shall contain quantity and the production date concatenated into a single barcode symbol. Quantity is indicated by maximum 7 characters, preceded by a “7Q”, the data identifier for this item as specified in ANSI/FACT-1. The production date is indicated by 6 characters, preceded by a “D”, the data identifier for this item as specified in ANSI/FACT-1. The quantity and the production date are separated by a space.

6.2.3.1 Quantity indicated in this field shall be quantity in the intermediate container. The unit of measure should follow the quantity data to indicate what unit of measure is being used in the quantity count. The Unit uses 2 characters listed in Appendix D of ANSI/FACT1.

6.2.3.2 Quantity that are not filled by a message characters shall contain hyphen (-) as a place saver to that the symbol always has exactly 7 characters.

6.3 Vendor company name and its logo mark; supplier’s ID may be included in the supplier’s field.

Table 1

	Explanation	*Data Identifier*	*No. of Characters*
Part No.	Customer part number. The number is assigned by the customer in the ordering information.	P	15 max.
Lot No.	Lot number is assigned by the supplier to identify or trace a unique group of the entries.	1T	12 max.
Quantity	Quantity and unit within the package. The unit uses characters listed in Appendix D of ANSI/FACT1.	7Q	7
Production Data	The Date of production. The date is shown by "YYMMDD".	D	6
Supplier's Field	Supplier's name, supplier's company logo mark, supplier's code (agreed between supplier and customer) country, etc.	-	(Option)

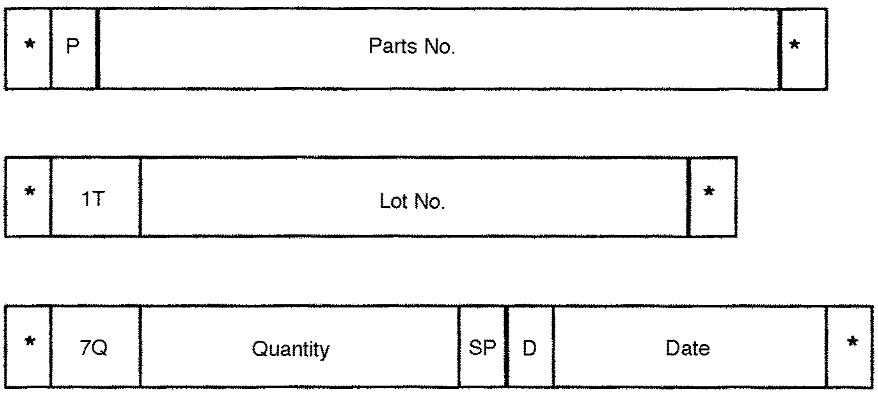


Figure 2
Barcode Arrangement

7 Barcode Character

7.1 The barcode characters specified in AIM USS-39 shall be used.

7.2 *Character Set* — The Code 39 character set consists of 43 characters: 0–9, A–Z, ., $, /, %, and space. In addition, an asterisk (*) is used only for both the stop and stop characters.

7.3 *Print Quality* — The Code 39 print quality shall be B/03/630 or better in accordance with ANSI X3.182. To assure reading efficiency, the minimum reflectance of the quiet zones shall be 60%, the minimum reflectance of spaces shall be 51%, and the maximum reflectance of bars shall be 10%.

7.4 *Symbol Dimensions* — Barcode symbol dimensions shall be as listed in Table 2.

Table 2 Symbol Dimensions

Code 39	*Dimension*
Narrow Element Width	0.250 mm
Wide Element Width	0.625 mm (Element Width Ratio 1:2.5)
Space between Characters	0.250 mm
Character Height	8.0 mm
Quiet Zone	5.0 mm (after and before barcode symbol)
Space between Barcode Field	5.0 mm

8 Human-Readable Interpretation (HRI) Symbols

8.1 Each barcode symbol data field on the customer field shall have an associated human-readable data field either immediately above or below it.

8.1.1 Start and stop characters shall not be included, but the data field identifier shall be included.

8.2 The height of human-readable characters shall be 3.0 mm.

8.3 The spaces above and below the human-readable characters shall be 1.0 mm.

9 Dimensions and Placement of Data Field on Label

9.1 The size of barcode label shall be 42 mm in height and 120 mm in wide.

9.2 The dimensions and placement of data field on label are shown in Figure 3.

9.3 The barcode and human-readable characters shall be placed within this area of the label as indicated in Figure 3.

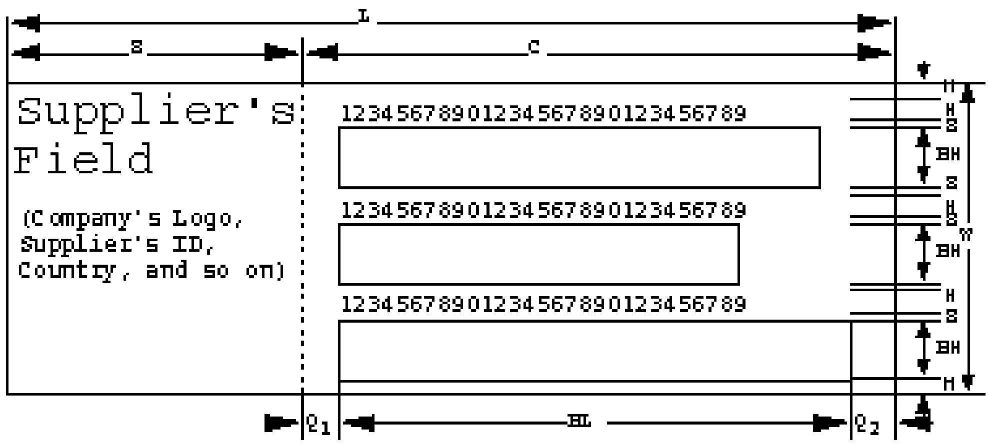


Figure 3
Dimensions and Placement of Data Field on Label

Horizontal Dimension	*Value (mm)*	*Vertical Dimension*	*Value (mm)*
L	120.0	W	40
S	40.0	M	2.0
C	80.0	H	3.0
BL	68.625	S	1.0
Q1	5.0	BH	8.0
Q2	6.375		

10 Barcode Label Location

The barcode label shall be located on the end of the packages for easy identification when the packages are temporarily stored in the storage shelf.

11 Label Material and Adhesive

11.1 Label material should not generate particles.

11.2 Label adhesive should not prohibit recyclability of the shipping packages.

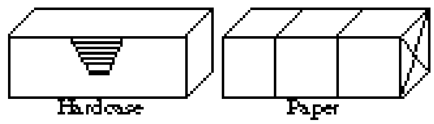
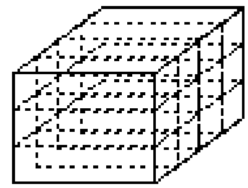
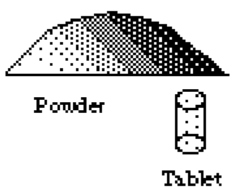
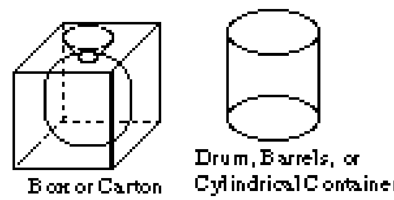
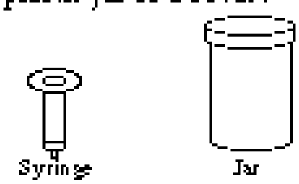
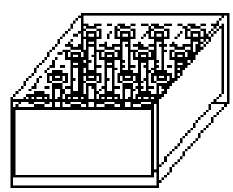
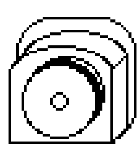
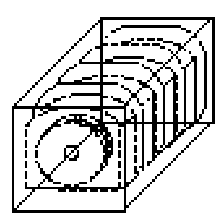
Material	Unit Pack	Intermediate Container
Leadframe 	The leadframes of specified quantity are packaged in a hardcase or wrapped by paper such as OP sheet. 	The unit packs of specified number are packaged in a box, a sterol case, a plastic case and etc. 
Molding Compound 		Molding compound of powder or tablet is wrapped by plastic bag and then it is packaged in a box or a drum. 
Die Attach Materials	Die attach material of specified quantity is poured into a syringe and the syringe is corked up. Or die attach material is poured into a plastic jar or a bottle. 	The unit packs of specified number are packaged in a box, a carton case, a plastic case and a plastic bag. 
Bonding Wire	Bonding wire is winded into a spool and then each spool is packaged in a clear plastic case. 	The unit packs of specified number are packaged in a box or a plastic case. 

Figure 4
Definition of Packaging Forms for Leadframe, Molding Compound, Die Attach Material,and Bonding Wire

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G72-0997
SPECIFICATION FOR BALL GRID ARRAY DESIGN LIBRARY

1 Purpose

The purpose of this specification is to promote industry use of common BGA designs that may be distinguished by their form, fit, function, and reliability requirements and to record designs by category that meet these requirements.

2 Scope

2.1 This document provides a library of company-sponsored BGA designs for the purpose of promoting the use of these common designs and to minimize the unnecessary proliferation of new designs. New designs will be added as they become sponsored by and approved by member companies.

2.2 This library shall include ceramic, plastic, tape, metal and other (as new categories of designs are identified and added to this specification) BGA designs that are fully compliant with existing JEDEC-registered or standard mechanical outlines. Proposals for new designs may be balloted in parallel with congruent JEDEC registrations or standards, but will not be published in this library until such registration and/or standard is an approved JEDEC outline.

2.3 Controlling dimensions are metric (Systems International units).

3 Referenced Documents

3.1 *SEMI Documents*

SEMI International Standards Compilation of Terms

Regulations Governing SEMI Standards Committees

3.2 *ASME* [1]

ASME Y14.5M-94 — Dimensioning and Tolerancing

3.3 *EIA/JEDEC* [2]

EIA JEDEC Publication 95 — Registered and Standard Outlines for Semiconductor Devices

JEDEC BGA Design Guide 95-1 — Section 14

J-*STD-020* —

JESD 22-A113 — Preconditioning of Plastic Surface Mount Devices Prior to Reliability Testing

4 Terminology

4.1 *ball grid array (BGA) package* — A square or rectangular substrate package with an array of metallic balls on one surface of the package. The metallic balls form the electrical and mechanical connection between the package and the PC board or socket.

4.2 *column grid array* — Same as ball grid array except that metallic columns are used in place of the metallic balls for the electrical and mechanical interconnection between the package and the PC board.

NOTE 1: In the text of this specification, whenever ball grids are mentioned, a reference to column grids is also implied.

4.3 *wire bond ring* — Metalized area in the shape of a complete or partial ring surrounding the die mounting area intended for group electrical interconnections.

5 Ordering Information

5.1 *Order of Precedence* — To avoid conflicts, the order of precedence when ordering ball grid array substrates or assembled packages when using BGA Library Designs from this specification shall be as follows:

a. Purchase Order

b. Customer BGA Drawing

c. BGA Library Design from this specification

d. Referenced Documents from Section 3.0

e. Other related documents

6 General Design Characteristics Listing Format

6.1 Each design addition to this library shall include a general design characteristics description which shall be listed in Appendix 1 of this specification and also be formatted on top of the title block for each design drawing.

6.1.1 Description listings in the General Design Characteristics, Appendix 1 shall be organized into category sections: Plastic, Ceramic, Tape, Metal, or Other.

6.1.2 These descriptions shall be listed across a row of characteristics classification columns and may determine the uniqueness of each design.

1 American Society of Mechanical Engineers, 22 Law Drive, P.O. Box 2900, Fairfield, New Jersey 07007-2900.

2 Electronic Industries Association, Joint Electron Device Engineering Council, 2500 Wilson Blvd., Arlington, VA 22201, (703) 907-7560.

6.2 The characteristics classification columns may be used in a data base format to sort the design listings sequentially, top to bottom according to their sequential listing by column, left to right, in the following order. These listings and their descriptive designations are as follows:

6.2.1 *Ball Count* — List the actual number of balls on the package.

6.2.2 *Signal I/O* — List the available balls for individual signal I/O. This does not include balls that are interconnected with other balls, bond rings, power or ground planes or other electrically interconnected features, such as die attach pads.

6.2.3 *Body Size* — List ##×## (i.e., 27×27) to represent JEDEC Publication 95 registration values in millimeters for "D" & "E" nominal body dimensions.

6.2.4 *Pitch* — List number representing JEDEC Publication 95 registration values in millimeters for the "e" pitch dimension.

6.2.5 *Matrix* — List ##×## (i.e., 20×20) to represent JEDEC Publication 95 matrix values determined by the number of balls on the outside row and column.

6.2.6 *Array* — List either Full, Staggered, Peripheral, or Depopulated:

- Full — Completely filled matrix, as defined by the JEDEC Publication 95 registration and variation shown for each design.
- Staggered — A full matrix which has been depopulated by every other ball in each row and column.
- Peripheral — Balls missing in the center of the BGA package. Outer rows of the matrix are fully populated.
- Depopulated — Any variation not described by full, staggered, or peripheral as described above.

NOTE 2: Any of the above matrix designs may have one ball missing from its defined matrix description above, for purposes of package orientation, and still be classified according to that description.

6.2.7 *Thermal Enhancement* — List #×# (i.e., 6×6) or "Cu Slug," to designate either a specific matrix of balls for thermal enhancement purposes or copper heat slug for the same. Other metal slugs may be listed by their appropriate metal constituent. List "N/A" if the design has no thermal enhancement.

6.2.8 *Profile Height* — List the dimension of the nominal profile height in millimeters.

6.2.9 *Package Cavity Orientation* — List either up or down with reference to the board to which the package design would be surfaced mounted (a cavity facing the board would be cavity, down).

6.2.10 *Wire bond Rings* — List the number of wire-bond rings. If the design has no rings, list "N/A."

6.2.11 *Substrate Materials* — Generic description of the materials the substrate is made from, excepting the electrical trace and solder mask materials.

6.2.12 *Metal Layers* — The number of metal interconnect layers in the BGA substrate. List a(bscpdg) where:

a= total number of metal layers
b= number of signal layers
s= signal layer designator
c= number of power layers
p= power layer designator
d= number of ground layers
g= ground layer designator

e.g., 4(2slplg) would have 4 total layers made up of 2 signal layers and 1 power and ground layer each.

6.2.13 *Die Interconnect* — Interconnect method for electrically connecting the die to the package. Normal methods include wire bond, flip chip and TAB.

6.2.14 *Encapsulation Design* — Design description. Normal categories are over-molded, liquid encapsulant or lid.

6.2.15 *Encapsulation Material* — General description of the material used to mechanically cover or encapsulate the chip or die. The materials normally used are epoxy for over-molding or liquid encapsulant designs, metal, ceramic or laminate for lid designs.

6.2.16 *Ball Composition* — Description of the material and composition of the ball. Should include a percentage of tin/lead or other metals, if solder ball (i.e., 63/37 Sn/Pb, alloy coated, copper or plastic).

6.2.17 *JEDEC Designation* — List JEDEC designation from its Publication 95. This should include registration or standard number, the specific variation and revision designations (i.e., MO-151, BAE-1, B) (this indicates Issue, Revision B).

6.2.18 *Preconditioning Level* — The specified JEDEC, J-STD-020 moisture sensitivity performance level requirement. This should also include a reference to the revision of the J-STD-020 specification (e.g., Level 4, Revision A).

NOTE 3: JEDEC, JESD 22 - A113 specifies the moisture preconditioning requirement for the moisture test to J-STD-020.

6.2.19 *Design Number* — SEMI assigned design number for this design. The numbers will be assigned by SEMI (upon ballot approval) and will be an alphanumeric designation in sequential order as follows:

- Plastic BGA Designs will be assigned PBDxxxx designations, where xxxx numbers are sequentially assigned beginning with 0001.
- Ceramic BGA Designs will be assigned CBDxxxx designations, where xxxx numbers are sequentially assigned beginning with 0001.
- Tape BGA Designs will be assigned TBDxxxx designations, where xxxx numbers are sequentially assigned beginning with 0001.
- Metal BGA Designs will be assigned MBDxxxx designations, where xxxx numbers are sequentially assigned beginning with 0001.

NOTE 4: The second letter designator may be assigned as either a B or C to designate whether the design is a ball grid or column grid array.

6.3 Appendix 1 is an example of a general design characteristics listing for a plastic BGA.

7 Drawing Format

7.1 Appendix 2 is an example of the drawing format.

7.2 Dimensions

7.2.1 All dimensions, and tolerances shown or not shown shall be in conformance with the JEDEC Publication 95 registration or standard outline referenced by the designation shown in the general design characteristics listing for each design.

7.2.2 Nominal and basic dimensions shown in the drawing may have minimum and maximum values and associated tolerances that may be referenced in JEDEC Publication 95 according to the registration designation shown in the general design characteristics listing for each design.

7.2.3 Dimension values will be shown on the drawing, not in a table.

7.2.4 Basic dimensions only will be used for package length and width dimensions (JEDEC “D” and “E” dimensions), the ball pitch (JEDEC “e” dimension), and the JEDEC “s” dimension.

7.2.5 The JEDEC “s” dimension will be shown only for even row matrix designs. Odd row matrix designs will only reference a centerline coincident with the center of the center row of balls.

7.2.6 A nominal and maximum dimension for the overall profile height (JEDEC dimension A) will be shown. The maximum dimension shown may be less than but may not exceed that maximum dimension designated by the JEDEC Publication 95 registration reference for this design.

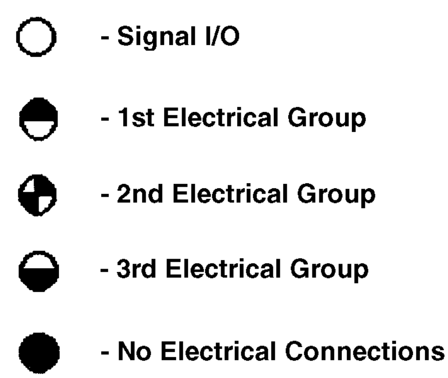
7.2.7 Reference or nominal dimensions may be shown for the package body thickness, substrate thickness, encapsulation layer or lid thickness, and the standoff height dimensions.

7.3 *Ball Configurations*

7.3.1 Retain and show the JEDEC method for numbering the ball columns and rows.

7.3.2 The ball configuration drawing will show the exact number and location of balls for each design.

7.3.3 The following symbols are to be used for designating the electrical interconnections or lack thereof for the balls shown on the design drawing:



7.3.4 Notes on the drawing will show the above symbols and designations for each of the electrical groups used with each specific design.

7.4 The orientation of the internal bond finger peripheral pad locations to the external package will be illustrated by a top view of the package which indicates the Pad 1 and A1 ball locations relative to the package sides, 1–4, for all designs using wire bond or peripheral die interconnection layout schemes.

7.4.1 For peripherally bonded layouts, the Pad 1 bond finger will always be located in the same corner as the A1 ball, and the pads will be sequentially numbered, for purposes of the net list, in a counterclockwise rotation as viewed from the die side of the substrate. This applies to all cavity orientations (cavity up or down).

7.5 The design drawing must have a BGA design title, a BGA design number, a revision number, the date of issue and a design page number shown at the bottom of each page.

7.6 The design drawing shall include a general design characteristics description which will also be listed in Appendix 1 of this specification. This description should be re-formatted on top of the title block for each design drawing and may exclude the BGA design number, which will be shown in the title block at the bottom of the page.

8 Net List Format

8.1 Appendix 3 is an example of the net list format including all reference notes.

8.2 The net list shall follow the drawing as part of the BGA design and shall be formatted in columns as follows:

- Column 1: Lists BGA wire bond pad and wire bond ring numbers.
- Column 2: Lists solder ball connections.
- Column 3: Open column for later use in listing die wire bond pad numbers.
- Column 4: Open column for later use in listing die I/O name.
- Column 5: Lists package side location number of bond pad connection.
- Column 6: Lists note reference numbers.

8.2.1 The listing of ball numbers should begin with A1, and continue in sequential order (i.e., A1, A2...An, B1, B2...Bn, C1, C2...Cn).

8.2.2 Wire bond ring numbers in the first column should be designated in sequential order from inner most to outermost (i.e., w/b ring 1, w/b ring 2, and w/b ring 3) if there are three separate rings. The innermost ring being w/b ring 1 and the outermost ring being w/b ring 3.

8.3 Notes in the net list will reference each of the electrical groups used with that specific design and will list all additional associated interconnections for those groups, if any.

8.4 Notes may consist of explanation of bond finger orientation relative to top view illustration on drawing for reference (independent of general specification explanations) of net list to BGA design drawing.

8.5 Notes may also consist of applications warnings or guidelines to insure correct use of the net list with the design drawing.

8.6 All pages of net list must have a BGA design title, a BGA design number, a revision number, the date of issue and a design page number shown at the top of each page.

9 Addition of Registrations

9.1 This specification will be published initially in a loose leaf notebook and as package design registrations are approved, they will be individually published in a loose leaf format for easy access into the original notebook by the publication owner.

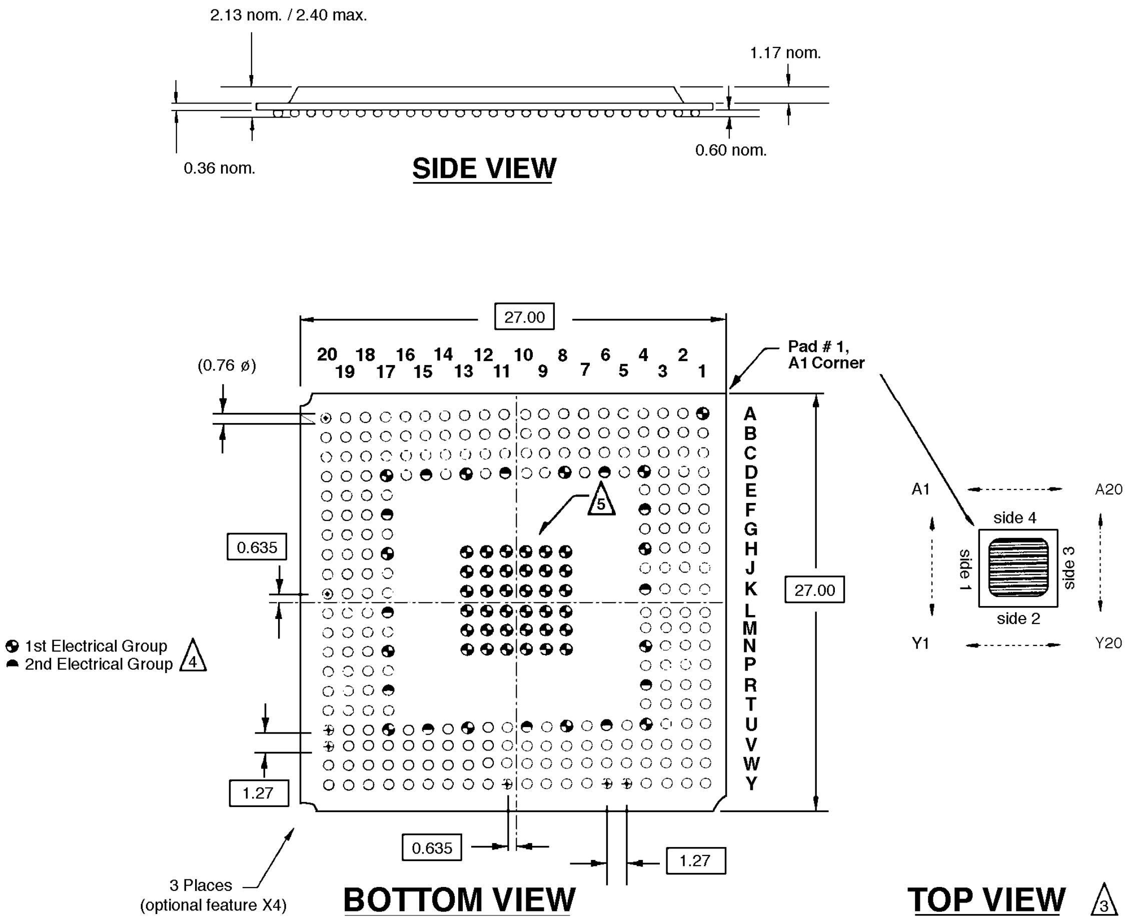
9.2 Each new registration must be added to the specification using the SEMI standard balloting procedures. Refer to the "Regulations Governing SEMI Standards Committees" publication.

SEMI G72.1-0997
DESIGN PROPOSAL FOR BALL GRID ARRAY DESIGN LIBRARY:292 PIN PLASTIC BALL GRID ARRAY

Table 1 Plastic Ball Grid Array (PBGA) General Design Characteristics

Ball Count	*Signal I/O*	*Body Size*	*Pitch*	*Matrix*	*Array*	*Thermal Enhan.*	*Profile Height*	*Cavity Orient.*	*Wirebond Rings*
292	231	27x27	1.27	20x20	depopulated	6x6	2.13	up	2

Substrate Material	*Metal Layers*	*Die Inter-connect*	*Encapsulation Design*	*/ Material*	*Ball Composition*	*JEDEC Designation*	*Precondition-ing Level*	*Design No.*	*SEMI Designa-tion No.*
BT Laminate	2(2S0P0G)	wirebond	overmolded	epoxy	63/37 Sn/Pb	MO-151 BAL-2, B	Level 3,Rev 0	PBD0001	G72.1



NOTES:

1. Refer to JEDEC MO-151 Issue B Variation BAL-2 for all dimensions and tolerances not shown. This design must be in full conformance with the referenced JEDEC outline drawing.

2. All dimensions are in millimeters unless otherwise noted.

△3 Top View illustrates the relationship between external package features, internal wirebond pad number 1, and side 1, 2, 3, and 4 of the internal wirebond pads. Please see SEMI Standard BGA Design Netlist for specific electrical connections and more detailed notes.

△4 Solder Balls with this symbol have common electrical connections, and may be connected to other internal package features. Please see SEMI Standard BGA Design Netlist for other specific electrical connections.

△5 Thermal enhancement of 6 x 6 solder balls shown. Please see SEMI Standard BGA Design Netlist for other specific electrical connections.

Ball Count	Signal I/O	Body Size	Pitch	Matrix	Array	Thermal Enhan.	Profile Height	Cavity Orientation	Wirebond Rings	Substrate Materials	Metal Layers	Die Inter-Connect	Encap. Design	Encap. Material	Ball Comp.	JEDEC Desig.	Preconditioning
292	231	27 x 27	1.27	20 x 20	depop.	6 x 6	2.13	up	2	BT	2 (2SOPOG)	wire bond	over mold	epoxy	63 / 37 Sn / Pb	MO-151 BAL-2, B	LEVEL 3, Rev. 0

BGA DESIGN LIBRARY DRAWING TITLE	BGA DESIGN LIBRARY NO.		REV.	DATE	PAGE
292 PIN PLASTIC BALL GRID ARRAY 27 X 27mm BODY DESIGN	PBD0001	SEMI STANDARD BGA DESIGN LIBRARY General Specification	INITIAL	4/15/96	1 OF 8

Figure 1
292 Pin Plastic Ball Grid Array 27 x 27 mm Body Design

Table 2 292 Pin Plastic Ball Grid Array 27x27 mm Body Design

Design No. *PBD0001*	*SEMI Standard BGA Design Library*		*Revision Initial*	*Date* *6/20/96*	*Page* *2 of 8*
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
w/b ring 1	A1				3
230	A2			4	
225	A3			4	
222	A4			4	
218	A5			4	
215	A6			4	
213	A7			4	
210	A8			4	
206	A9			4	
202	A10			4	
201	A11			4	
198	A12			4	
194	A13			4	
191	A14			4	
188	A15			4	
184	A16			4	
181	A17			4	
180	A18			4	
175	A19			4	
174	A20			3	
1	B1			1	
229	B2			4	
228	B3			4	
224	B4			4	
221	B5			4	
217	B6			4	
214	B7			4	
211	B8			4	
207	B9			4	
203	B10			4	
199	B11			4	
197	B12			4	
193	B13			4	
190	B14			4	
187	B15			4	
183	B16			4	
177	B17			4	
176	B18			4	
173	B19			3	
171	B20			3	
6	C1			1	
2	C2			1	
231	C3			4	

Design No. PBD0001	SEMI Standard BGA Design Library		Revision Initial	Date 6/20/96	Page 2 of 8
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
227	C4			4	
223	C5			4	
220	C6			4	
216	C7			4	
212	C8			4	
208	C9			4	
204	C10			4	
200	C11			4	
196	C12			4	
192	C13			4	
189	C14			4	
185	C15			4	
182	C16			4	
178	C17			4	
172	C18			3	
170	C19			3	
167	C20			3	
7	D1			1	
3	D2			1	
4	D3			1	
w/b ring 1	D4				3
226	D5			4	
w/b ring 2	D6				2
219	D7			4	
w/b ring 1	D8				3
209	D9			4	
205	D10			4	
w/b ring 2	D11				2
195	D12			4	
w/b ring 1	D13				3
186	D14			4	
w/b ring 2	D15				2
179	D16			4	
w/b ring 1	D17				3
169	D18			3	
166	D19			3	
164	D20			3	
10	E1			1	
9	E2			1	
8	E3			1	
5	E4			1	
168	E17			3	
165	E18			3	
163	E19			3	

Design No. PBD0001	SEMI Standard BGA Design Library		Revision Initial	Date 6/20/96	Page 2 of 8
PBGA Wire Bond Pad (*1)	Solder Ball Location	Die Wire Bond Pad	I/O Name (& Comments) (*4)	Pkg. Side (*1)	Notes
160	E20			3	
14	F1			1	
13	F2			1	
11	F3			1	
w/b ring 2	F4				2
w/b ring 2	F17				2
162	F18			3	
159	F19			3	
157	F20			3	
17	G1			1	
16	G2			1	
15	G3			1	
12	G4			1	
161	G17			3	
158	G18			3	
156	G19			3	
155	G20			3	
20	H1			1	
19	H2			1	
18	H3			1	
w/b ring 1	H4				3
w/b ring 1	H8				3,5
w/b ring 1	H9				3,5
w/b ring 1	H10				3,5
w/b ring 1	H11				3,5
w/b ring 1	H12				3,5
w/b ring 1	H13				3,5
w/b ring 1	H17				3
154	H18			3	
153	H19			3	
152	H20			3	
24	J1			1	
23	J2			1	
22	J3			1	
21	J4			1	
w/b ring 1	J8				3,5
w/b ring 1	J9				3,5
w/b ring 1	J10				3,5
w/b ring 1	J11				3,5
w/b ring 1	J12				3,5
w/b ring 1	J13				3,5
151	J17			3	
150	J18			3	
149	J19			3	

Design No. PBD0001	SEMI Standard BGA Design Library		Revision Initial	Date 6/20/96	Page 2 of 8
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
148	J20			3	
27	K1			1	
25	K2			1	
26	K3			1	
w/b ring 2	K4				2
w/b ring 1	K8				3,5
w/b ring 1	K9				3,5
w/b ring 1	K10				3,5
w/b ring 1	K11				3,5
w/b ring 1	K12				3,5
w/b ring 1	K13				3,5
147	K17			3	
146	K18			3	
145	K19			3	
144	K20			3	
28	L1			1	
29	L2			1	
30	L3			1	
31	L4			1	
w/b ring 1	L8				3,5
w/b ring 1	L9				3,5
w/b ring 1	L10				3,5
w/b ring 1	L11				3,5
w/b ring 1	L12				3,5
w/b ring 1	L13				3,5
w/b ring 2	L17				2
142	L18			3	
141	L19			3	
143	L20			3	
32	M1			1	
33	M2			1	
34	M3			1	
35	M4			1	
w/b ring 1	M8				3,5
w/b ring 1	M9				3,5
w/b ring 1	M10				3,5
w/b ring 1	M11				3,5
w/b ring 1	M12				3,5
w/b ring 1	M13				3,5
137	M17			3	
138	M18			3	
139	M19			3	
140	M20			3	
36	N1			1	

Design No. PBD0001	SEMI Standard BGA Design Library		Revision Initial	Date 6/20/96	Page 2 of 8
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
37	N2			1	
38	N3			1	
w/b ring 1	N4				3
w/b ring 1	N8				3,5
w/b ring 1	N9				3,5
w/b ring 1	N10				3,5
w/b ring 1	N11				3,5
w/b ring 1	N12				3,5
w/b ring 1	N13				3,5
w/b ring 1	N17				3
134	N18			3	
135	N19			3	
136	N20			3	
39	P1			1	
40	P2			1	
42	P3			1	
45	P4			1	
128	P17			3	
131	P18			3	
132	P19			3	
133	P20			3	
41	R1			1	
43	R2			1	
46	R3			1	
w/b ring 2	R4				2
w/b ring 2	R17				2
127	R18			3	
129	R19			3	
130	R20			3	
44	T1			1	
47	T2			1	
49	T3			1	
52	T4			1	
121	T17			3	
124	T18			3	
125	T19			3	
126	T20			3	
48	U1			1	
50	U2			1	
53	U3			1	
w/b ring 1	U4				3
63	U5			2	
w/b ring 2	U6				2
70	U7			2	

Design No. PBD0001	*SEMI Standard BGA Design Library*		*Revision Initial*	*Date 6/20/96*	*Page 2 of 8*
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
w/b ring 1	U8				3
79	U9			2	
w/b ring 2	U10				2
89	U11			2	
93	U12			2	
w/b ring 1	U13				3
103	U14			2	
w/b ring 2	U15				2
110	U16			2	
w/b ring 1	U17				3
120	U18			3	
119	U19			3	
123	U20			3	
51	V1			1	
54	V2			1	
56	V3			1	
62	V4			2	
66	V5			2	
69	V6			2	
73	V7			2	
76	V8			2	
80	V9			2	
84	V10			2	
88	V11			2	
92	V12			2	
96	V13			2	
100	V14			2	
104	V15			2	
107	V16			2	
111	V17			2	
114	V18			2	
118	V19			3	
122	V20			3	
55	W1			1	
57	W2			1	
59	W3			2	
61	W4			2	
67	W5			2	
71	W6			2	
74	W7			2	
77	W8			2	
81	W9			2	
83	W10			2	
87	W11			2	

Design No. PBD0001	*SEMI Standard BGA Design Library*		*Revision Initial*	*Date 6/20/96*	*Page 2 of 8*
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
91	W12			2	
95	W13			2	
98	W14			2	
101	W15			2	
105	W16			2	
108	W17			2	
112	W18			2	
115	W19			2	
117	W20			3	
58	Y1			1	
60	Y2			2	
64	Y3			2	
65	Y4			2	
68	Y5			2	
72	Y6			2	
75	Y7			2	
78	Y8			2	
82	Y9			2	
85	Y10			2	
86	Y11			2	
90	Y12			2	
94	Y13			2	
97	Y14			2	
99	Y15			2	
102	Y16			2	
106	Y17			2	
109	Y18			2	
113	Y19			2	
116	Y20			2	

NOTES:

*1. Please refer to Notes column for explanations of wirebond (w/b) rings. PBGA Wirebond Pads are numbered counter clockwise, starting with Pad #1 in the upper left hand corner. Please refer to Top View of package for package side #1, 2, 3, or 4 (Figure 1).

*2. Metallized wirebond (w/b) ring 2 surrounds die attach area for wirebonding to electrically common die pads and electrical connection with solder balls designated by 2nd Electrical Group symbol on BGA Design Library Drawing (Figure 1).

*3. Metallized wirebond (w/b) ring 1 surrounds die attach area for wirebonding to electrically common die pads and electrical connection with both die attach pad and solder balls designated by 1st Electrical Group symbol on BGA Design Library Drawing (Figure 1).

*4. If the number of signal Die Wirebond Pads (not including Electrical Groups) total less than 231, the total number may be divided by 4 and wirebond placement centered on each package side.

*5. Thermal enhancement of 6 x 6 solder balls.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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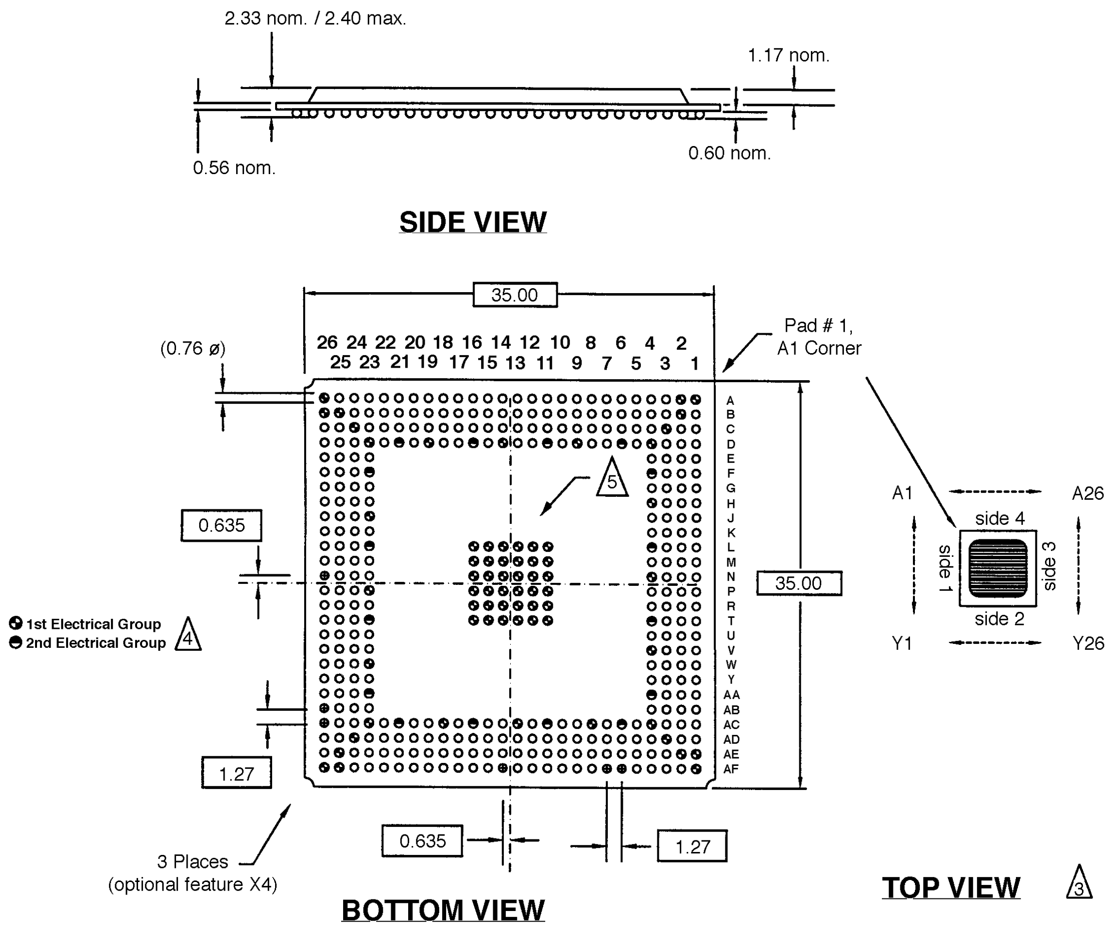
SEMI G72.2-0997
DESIGN PROPOSAL FOR BALL GRID ARRAY DESIGN LIBRARY: 388 PIN PLASTIC BALL GRID ARRAY

Table 1 Plastic Ball Grid Array (PBGA) General Design Characteristics

Ball Count	*Signal I/O*	*Body Size*	*Pitch*	*Matrix*	*Array*	*Thermal Enhan.*	*Profile Height*	*Cavity Orient.*	*Wirebond Rings*
388	304	35×35	1.27	26×26	depopulated	6×6	2.33	up	2

Substrate Material	*Metal Layers*	*Die Inter-connect*	*Encapsulation Design*	*/ Material*	*Ball Composition*	*JEDEC Designation*	*Precondition-ing Level*	*Design No.*	*SEMI Designa-tion No.*
BT Laminate	2(2S0P0G)	wirebond	overmolded	epoxy	63/37 Sn/Pb	MO-151 BAR-2, B	Level 3,Rev 0	PBD0002	G72.2



NOTES:

1. Refer to JEDEC MO-151 Issue B Variation BAR-2 for all dimensions and tolerances not shown. This design must be in full conformance with the referenced JEDEC outline drawing.

2. All dimensions are in millimeters unless otherwise noted.

3 (△) Top View illustrates the relationship between external package features, internal wirebond pad number 1, and side 1, 2, 3, and 4 of the internal wirebond pads. Please see SEMI Standard BGA Design Netlist for specific electrical connections and more detailed notes.

4 (△) Solder Balls with this symbol have common electrical connections, and may be connected to other internal package features. Please see SEMI Standard BGA Design Netlist for other specific electrical connections.

5 (△) Thermal enhancement of 6 x 6 solder balls shown. Please see SEMI Standard BGA Design Netlist for other specific electrical connections.

Ball Count	Signal I/O	Body Size	Pitch	Matrix	Array	Thermal Enhan.	Profile Height	Cavity Orientation	Wirebond Rings	Substrate Materials	Metal Layers	Die Inter-Connect	Encap. Design	Encap. Material	Ball Comp.	JEDEC Desig.	Preconditioning
388	304	35 x 35	1.27	26 x 26	depop.	6 x 6	2.33	up	2	BT	2 (2S0P0G)	wire bond	over mold	epoxy	63 / 37 Sn/ Pb	MO-151 BAR-2, B	LEVEL 3, Rev. 0

BGA DESIGN LIBRARY DRAWING TITLE	BGA DESIGN LIBRARY NO.	SEMI STANDARD BGA DESIGN LIBRARY General Specification	REV.	DATE	PAGE
388 PIN PLASTIC BALL GRID ARRAY 35 X 35 mm BODY DESIGN	PBD0002		INITIAL	10/18/96	1 OF 10

Figure 1

388 Pin Plastic Ball Grid Array 35×35 mm Body Design

Table 2 388 Pin Plastic Ball Grid Array 35×35 mm Body Design

Design No.PBD0002	*SEMI Standard BGA Design Library*		*Revision Initial*	*Date 10/22/96*	*Page 2 of 10*
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
w/b ring 1	A1				3
w/b ring 1	A2				3
304	A3			4	
300	A4			4	
296	A5			4	
293	A6			4	
289	A7			4	
285	A8			4	
283	A9			4	
279	A10			4	
275	A11			4	
272	A12			4	
268	A13			4	
264	A14			4	
260	A15			4	
258	A16			4	
254	A17			4	
251	A18			4	
248	A19			4	
244	A20			4	
242	A21			4	
238	A22			4	
234	A23			4	
231	A24			4	
229	A25			4	
w/b ring 1	A26				3
1	B1			1	
w/b ring 1	B2				3
302	B3			4	
298	B4			4	
295	B5			4	
291	B6			4	
287	B7			4	
284	B8			4	
281	B9			4	
277	B10			4	
273	B11			4	
270	B12			4	
266	B13			4	
262	B14			4	
259	B15			4	
256	B16			4	
252	B17			4	

Design No.PBD0002	SEMI Standard BGA Design Library		Revision Initial	Date 10/22/96	Page 2 of 10
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
250	B18			4	
246	B19			4	
243	B20			4	
239	B21			4	
235	B22			4	
232	B23			4	
230	B24			4	
w/b ring 1	B25				3
w/b ring 1	B26				3
3	C1			1	
2	C2			1	
w/b ring 1	C3				3
303	C4			4	
301	C5			4	
297	C6			4	
294	C7			4	
290	C8			4	
286	C9			4	
282	C10			4	
278	C11			4	
274	C12			4	
271	C13			4	
269	C14			4	
265	C15			4	
261	C16			4	
257	C17			4	
253	C18			4	
249	C19			4	
245	C20			4	
241	C21			4	
237	C22			4	
233	C23			4	
w/b ring 1	C24				3
226	C25			3	
228	C26			3	
6	D1			1	
4	D2			1	
5	D3			1	
w/b ring 1	D4				3
299	D5			4	
w/b ring 2	D6				2
292	D7			4	
288	D8			4	
w/b ring 1	D9				3

Design No.PBD0002	SEMI Standard BGA Design Library		Revision Initial	Date 10/22/96	Page 2 of 10
PBGA Wire Bond Pad (*1)	Solder Ball Location	Die Wire Bond Pad (*3)	I/O Name (& Comments) (*4)	Pkg. Side (*1)	Notes
280	D10			4	
w/b ring 2	D11				2
276	D12			4	
267	D13			4	
w/b ring 1	D14				3
263	D15			4	
w/b ring 2	D16				2
255	D17			4	
247	D18			4	
w/b ring 1	D19				3
240	D20			4	
w/b ring 2	D21				2
236	D22			4	
w/b ring 1	D23				3
227	D24			3	
222	D25			3	
224	D26			3	
10	E1			1	
7	E2			1	
9	E3			1	
8	E4			1	
223	E23			3	
225	E24			3	
219	E25			3	
220	E26			3	
14	F1			1	
11	F2			1	
13	F3			1	
w/b ring 2	F4				2
w/b ring 2	F23				2
221	F24			3	
215	F25			3	
217	F26			3	
16	G1			1	
15	G2			1	
17	G3			1	
12	G4			1	
216	G23			3	
218	G24			3	
211	G25			3	
213	G26			3	
20	H1			1	
18	H2			1	
21	H3			1	

Design No.PBD0002	SEMI Standard BGA Design Library		Revision Initial	Date 10/22/96	Page 2 of 10
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
w/b ring 1	H4				3
212	H23			3	
214	H24			3	
208	H25			3	
209	H26			3	
23	J1			1	
22	J2			1	
25	J3			1	
19	J4			1	
w/b ring 1	J23				3
210	J24			3	
205	J25			3	
207	J26			3	
26	K1			1	
24	K2			1	
29	K3			1	
27	K4			1	
204	K23			3	
206	K24			3	
201	K25			3	
203	K26			3	
30	L1			1	
28	L2			1	
33	L3			1	
w/b ring 2	L4				2
w/b ring 1	L11				3,5
w/b ring 1	L12				3,5
w/b ring 1	L13				3,5
w/b ring 1	L14				3,5
w/b ring 1	L15				3,5
w/b ring 1	L16				3,5
w/b ring 2	L23				2
202	L24			3	
197	L25			3	
199	L26			3	
32	M1			1	
31	M2			1	
37	M3			1	
35	M4			1	
w/b ring 1	M11				3,5
w/b ring 1	M12				3,5
w/b ring 1	M13				3,5
w/b ring 1	M14				3,5
w/b ring 1	M15				3,5

Design No.PBD0002	SEMI Standard BGA Design Library		Revision Initial	Date 10/22/96	Page 2 of 10
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
w/b ring 1	M16				3,5
200	M23			3	
198	M24			3	
194	M25			3	
196	M26			3	
36	N1			1	
34	N2			1	
41	N3			1	
w/b ring 1	N4				3
w/b ring 1	N11				3,5
w/b ring 1	N12				3,5
w/b ring 1	N13				3,5
w/b ring 1	N14				3,5
w/b ring 1	N15				3,5
w/b ring 1	N16				3,5
191	N23			3	
195	N24			3	
190	N25			3	
192	N26			3	
40	P1			1	
38	P2			1	
43	P3			1	
39	P4			1	
w/b ring 1	P11				3,5
w/b ring 1	P12				3,5
w/b ring 1	P13				3,5
w/b ring 1	P14				3,5
w/b ring 1	P15				3,5
w/b ring 1	P16				3,5
w/b ring 1	P23				3
193	P24			3	
186	P25			3	
188	P26			3	
44	R1			1	
42	R2			1	
46	R3			1	
48	R4			1	
w/b ring 1	R11				3,5
w/b ring 1	R12				3,5
w/b ring 1	R13				3,5
w/b ring 1	R14				3,5
w/b ring 1	R15				3,5
w/b ring 1	R16				3,5
187	R23			3	

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PBGA Wire Bond Pad (*1)	Solder Ball Location	Die Wire Bond Pad (*3)	I/O Name (& Comments) (*4)	Pkg. Side (*1)	Notes
189	R24			3	
183	R25			3	
184	R26			3	
47	T1			1	
45	T2			1	
50	T3			1	
w/b ring 2	T4				2
w/b ring 1	T11				3,5
w/b ring 1	T12				3,5
w/b ring 1	T13				3,5
w/b ring 1	T14				3,5
w/b ring 1	T15				3,5
w/b ring 1	T16				3,5
w/b ring 2	T23				2
185	T24			3	
180	T25			3	
182	T26			3	
51	U1			1	
49	U2			1	
54	U3			1	
52	U4			1	
179	U23			3	
181	U24			3	
176	U25			3	
178	U26			3	
55	V1			1	
53	V2			1	
58	V3			1	
w/b ring 1	V4				3
171	V23			3	
177	V24			3	
174	V25			3	
175	V26			3	
57	W1			1	
56	W2			1	
62	W3			1	
60	W4			1	
w/b ring 1	W23				3
173	W24			3	
170	W25			3	
172	W26			3	
61	Y1			1	
59	Y2			1	
66	Y3			1	

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PBGA Wire Bond Pad (*1)	Solder Ball Location	Die Wire Bond Pad (*3)	I/O Name (& Comments) (*4)	Pkg. Side (*1)	Notes
64	Y4			1	
164	Y23			3	
169	Y24			3	
167	Y25			3	
168	Y26			3	
65	AA1			1	
63	AA2			1	
69	AA3			1	
w/b ring 2	AA4				2
w/b ring 2	AA23				2
165	AA24			3	
163	AA25			3	
166	AA26			3	
68	AB1			1	
67	AB2			1	
73	AB3			1	
71	AB4			1	
160	AB23			3	
161	AB24			3	
159	AB25			3	
162	AB26			3	
72	AC1			1	
70	AC2			1	
75	AC3			1	
w/b ring 1	AC4				3
84	AC5			2	
w/b ring 2	AC6				2
88	AC7			2	
w/b ring 1	AC8				3
95	AC9			2	
103	AC10			2	
w/b ring 2	AC11				2
111	AC12			2	
w/b ring 1	AC13				3
115	AC14			2	
124	AC15			2	
w/b ring 2	AC16				2
128	AC17			2	
1st Group	AC18				3
w/b ring 1	AC19			2	
140	AC20			2	
w/b ring 2	AC21				2
147	AC22			2	
w/b ring 1	AC23				3

Design No.PBD0002	SEMI Standard BGA Design Library		Revision Initial	Date 10/22/96	Page 2 of 10
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
157	AC24			3	
156	AC25			3	
158	AC26			3	
76	AD1			1	
74	AD2			1	
w/b ring 1	AD3				3
81	AD4			2	
85	AD5			2	
89	AD6			2	
93	AD7			2	
97	AD8			2	
101	AD9			2	
105	AD10			2	
109	AD11			2	
113	AD12			2	
117	AD13			2	
119	AD14			2	
122	AD15			2	
126	AD16			2	
130	AD17			2	
134	AD18			2	
138	AD19			2	
142	AD20			2	
145	AD21			2	
149	AD22			2	
151	AD23			2	
w/b ring 1	AD24				3
154	AD25			3	
155	AD26			3	
w/b ring 1	AE1				3
w/b ring 1	AE2				3
78	AE3			2	
80	AE4			2	
83	AE5			2	
87	AE6			2	
91	AE7			2	
94	AE8			2	
98	AE9			2	
100	AE10			2	
104	AE11			2	
107	AE12			2	
110	AE13			2	
114	AE14			2	
118	AE15			2	

Design No.PBD0002	*SEMI Standard BGA Design Library*		*Revision Initial*	*Date 10/22/96*	*Page 2 of 10*
*PBGA Wire Bond Pad (*1)*	*Solder Ball Location*	*Die Wire Bond Pad (*3)*	*I/O Name (& Comments) (*4)*	*Pkg. Side (*1)*	*Notes*
121	AE16			2	
125	AE17			2	
129	AE18			2	
132	AE19			2	
135	AE20			2	
139	AE21			2	
143	AE22			2	
146	AE23			2	
150	AE24			2	
w/b ring 1	AE25				3
153	AE26			3	
w/b ring 1	AF1				3
77	AF2			2	
79	AF3			2	
82	AF4			2	
86	AF5			2	
90	AF6			2	
92	AF7			2	
96	AF8			2	
99	AF9			2	
102	AF10			2	
106	AF11			2	
108	AF12			2	
112	AF13			2	
116	AF14			2	
120	AF15			2	
123	AF16			2	
127	AF17			2	
131	AF18			2	
133	AF19			2	
137	AF20			2	
141	AF21			2	
144	AF22			2	
148	AF23			2	
152	AF24			2	
w/b ring 1	AF25				3
w/b ring 1	AF26				3

NOTES:

*1. Please refer to Notes column for explanations of wirebond (w/b) rings. PBGA Wirebond Pads are numbered counter clockwise, starting with Pad #1 in the upper left hand corner. Please refer to Top View of package for package side #1, 2, 3, or 4 (Figure 1).

*2. Metallized wirebond (w/b) ring 2 surrounds die attach area for wirebonding to electrically common die pads and electrical connection with solder balls designated by 2nd Electrical Group symbol on BGA Design Library Drawing (Figure 1).

*3. Metallized wirebond (w/b) ring 1 surrounds die attach area for wirebonding to electrically common die pads and electrical connection with both die attach pad and solder balls designated by 1st Electrical Group symbol on BGA Design Library Drawing (Figure 1).

*4. If the number of signal Die Wirebond Pads (not including Electrical Groups) total less than 304, the total number may be divided by 4 and wirebond placement centered on each package side.

*5. Thermal enhancement of 6 x 6 solder balls.

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SEMI G73-0997
TEST METHOD FOR PULL STRENGTH FOR WIRE BONDING

1 Purpose

This standard defines the pull strength test method for wire bonding.

2 Scope

2.1 This standard defines the destructive pull strength test method and its criterion for evaluating pull strength of wire bonds connecting two points, connected by using ball bonding technique.

2.2 This standard can be applied to measure wires whose diameter is less than 100 microns.

3 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *Military Standard* [1]

MIL-STD-883D — Test Methods and Procedures for Microelectronics

4 Terminology

4.1 *hook* — L or similar-shaped tool for hooking a wire for pull test.

5 Apparatus

5.1 Pull Tester or equivalent equipment

5.1.1 Enough stroke to break a wire.

5.1.2 *Accuracy* — Within ± 0.5% to the full scale of load cell.

5.1.3 *Pull Speed* — Constant speed.

5.1.4 *Hooks* — Between 25—100 microns in diameter.

NOTE 1: Hook must be made of material strong enough to break wire while testing but not with a small diameter so as to cut through the wire.

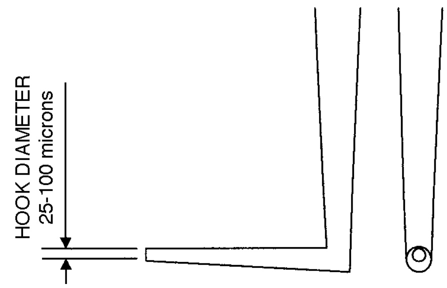

Figure 1
Hook Diameter

5.1.5 Calibration of equipment must be simple enough so that users can calibrate it easily. Instructions for calibration should be described in equipment manual.

6 Sampling

Measure at least 30 points from at least 2 devices. From each side of the devices, select the same number of wires randomly.

7 Calibration and Standardization

7.1 *Calibration Method*

7.1.1 Calibration of equipment should be done using official and traceable weights.

7.1.2 Display the weight and verify whether the results are within the equipment's accuracy.

7.1.3 Repeat the measurement using other weights to verify repeatability and linearity of the calibration.

7.2 *Interval of Calibration*

7.2.1 Calibrate at regular intervals at least once a year.

7.2.2 Calibration must be able to be done just before testing when necessary or specifically instructed.

8 Procedure

8.1 Fix samples using a clamper or adhesive, so that the sample will not float, without applying excessive stress to the wire.

8.2 Set pull speed to 0.5 mm/sec while measuring.

8.3 Insert the hook under the bonded wire between the top of the first bonding and the center of the loop.

NOTE 2: Select hook position accordingly to package, wiring condition, and wire diameter.

1 Military Standards, Naval Publications and Form Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

NOTE 3: Place the hook perpendicular to wiring direction if there is no specific instruction.

NOTE 4: Do not measure damaged or deformed wire.

8.4 Pull the hook perpendicular to die/substrate.

8.5 Record the force that breaks the wire as the pull strength.

8.6 Repeat the measurement on another wire.

NOTE 5: Do not change the position while testing the same samples.

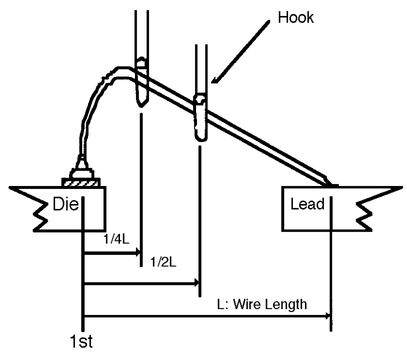

Figure 2
Hook Position

9 Report

Report of the pull test must contain the following information.

9.1 *Pull Strength*

9.2 *Breaking Mode* — Choose the closest position from Figure 3 below and represent the broken position by number or alphabet in the figure.

Breaking Mode (Report in number or alphabet)

1,A: The first bond

2,B: The first bond neck

3,C: Loop

4,D: The second bond neck

5,E: The second bond

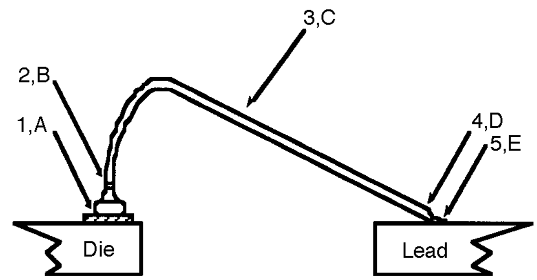

Figure 3
Breaking Mode

9.3 *Hook Position*

9.4 *Rejection* — Criterion of each semiconductor manufacturer to each product. Refer to "Minimum Strength" of the attached MIL-STD-883D.

10 Related Documents

10.1 *SEAJ Documents* [2]

SEAJ Technical Term Dictionary, 3rd Edition

10.2 *EIAJ Documents* [3]

EIAJ ED4703 — In-Line Evaluation Methods and Structural Analysis Methods for Semiconductor Devices

10.3 *IEC Documents* [4]

IEC 749 — Semiconductor Devices: Mechanical and Climatic Test Methods

2 Semiconductor Equipment Association of Japan, Semiconductor Equipment Association of Japan, Uchida Bldg., 13-8 Arakicho, Shinjuku-ku, Tokyo 160, Japan.

3 Electronics Industry Association of Japan, Tokyo Chamber of Commerce and Industry Bldg., 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100, Japan.

4 International Electrotechnical Commission, 3 rue de Varembe, CH-1211, Geneva 20, Switzerland.

APPENDIX 1
HOOK POSITION VS. PULL STRENGTH (DEPENDENCE ON PULL SPEED)

NOTE: This appendix was approved as an official part of SEMI G73 by full letter ballot procedure.

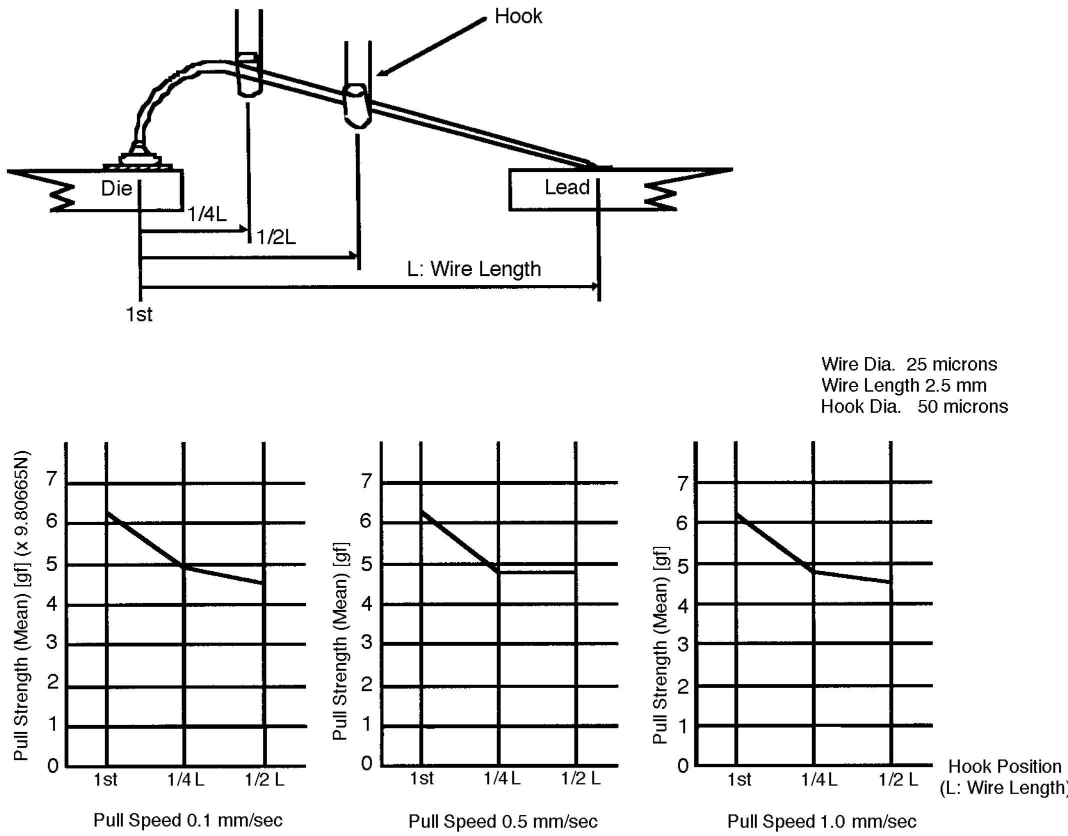

Figure 4

APPENDIX 2
HOOK POSITION VS. PULL STRENGTH (DEPENDENCE ON HOOK DIAMETER)

NOTE: This appendix was approved as an official part of SEMI G73 by full letter ballot procedure.

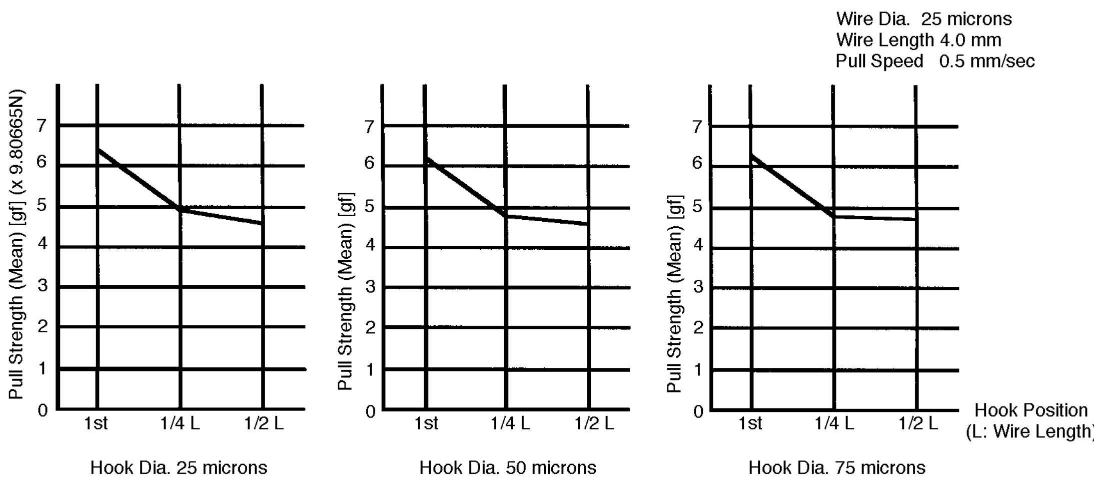

Figure 5

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SEMI G74-0699
SPECIFICATION FOR TAPE FRAME FOR 300 mm WAFERS

This specification was technically approved by the Global Assembly & Packaging Committee and is the direct responsibility of the Japanese Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available at www.semi.org May 1999; to be published June 1999. Originally published June 1998; previously published September 1998.

1 Purpose

1.1 The purpose of this document is to standardize the specifications for 300 mm wafer tape frames used between the dicing process and the die-bonding process.

2 Scope

2.1 This standard documents the dimensions, characteristics, and measurement methods for 300 mm wafer tape frames.

2.2 This standard can be used as the specification sheet for tape frame upon purchasing.

2.3 This standard uses the SI unit system.

3 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

3.1 *ANSI Standard*[1]

ANSI/ASME B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

3.2 *ISO Standards*[2]

ISO4287 Part 1 — Surface Roughness Terminology Part 1: Surface and Its Parameters

3.3 *JIS Standards*[3]

JIS B0601 — Surface Roughness - Definitions and Designations

JIS Z2245 — Method of Rockwell and Rockwell Superficial Hardness Test

4 Terminology

4.1 *tape frame* — the frame which applies the wafer tape to the wafer and retains the wafer.

4.2 *wafer tape* — an adhesive plastic tape which retains the wafer or diced chip. It is used between the dicing process and the die-bonding process.

5 Ordering Information

5.1 Purchase orders for tape frames furnished to this specification shall include quantity.

6 Requirements

6.1 *Dimensions* — See Table 1 and Figure 1.

Table 1 300 mm Tape Frame Dimensions

Symbol	*Dimension (mm unless noted))*	*Note*
ϕ A	350 ± 0.5	Inner diameter
ϕ B	400 ± 0.5	Outer diameter
C	380 + 0/-0.5	Width between two cords
D	380 + 0/-0.5	Width between two cords
E	170.4	Outline dimension
F	172	Outline dimension
G	86	Outline dimension
H	90	Outline dimension
I	120°	
J	60°	Partition out with diameter *N* as standard
tK	1.5 or (1.2)	Plate thickness
L	190	
M	190	Frame warpage
ϕ N	3.2	Pin diameter
P	100 ± 0.2	Diameter *N* position
Q	18 ± 0.2	Diameter *N* position
R	276	1 Notch position
S	19.6 ± 0.2	1 Notch position

NOTE 1: Plate thickness of 1.5 mm is recommended.

NOTE 2: No burrings on the edges.

NOTE 3: Surface Roughness: $R_{max} \leq 1$ µm, $R_a \leq 0.1$ µm; (surface indicated as Δ) unindicated Cut Surface Roughness: $R_{max} \leq 100$ µm, $R_a \leq 25$ µm.

[1] *American National Standards Institute, 1430 Broadway, New York, NY 10018*

[2] *International Organization for Standardization, C.P. 56, CH-1211 Geneva 20, Switzerland*

[3] *Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan*

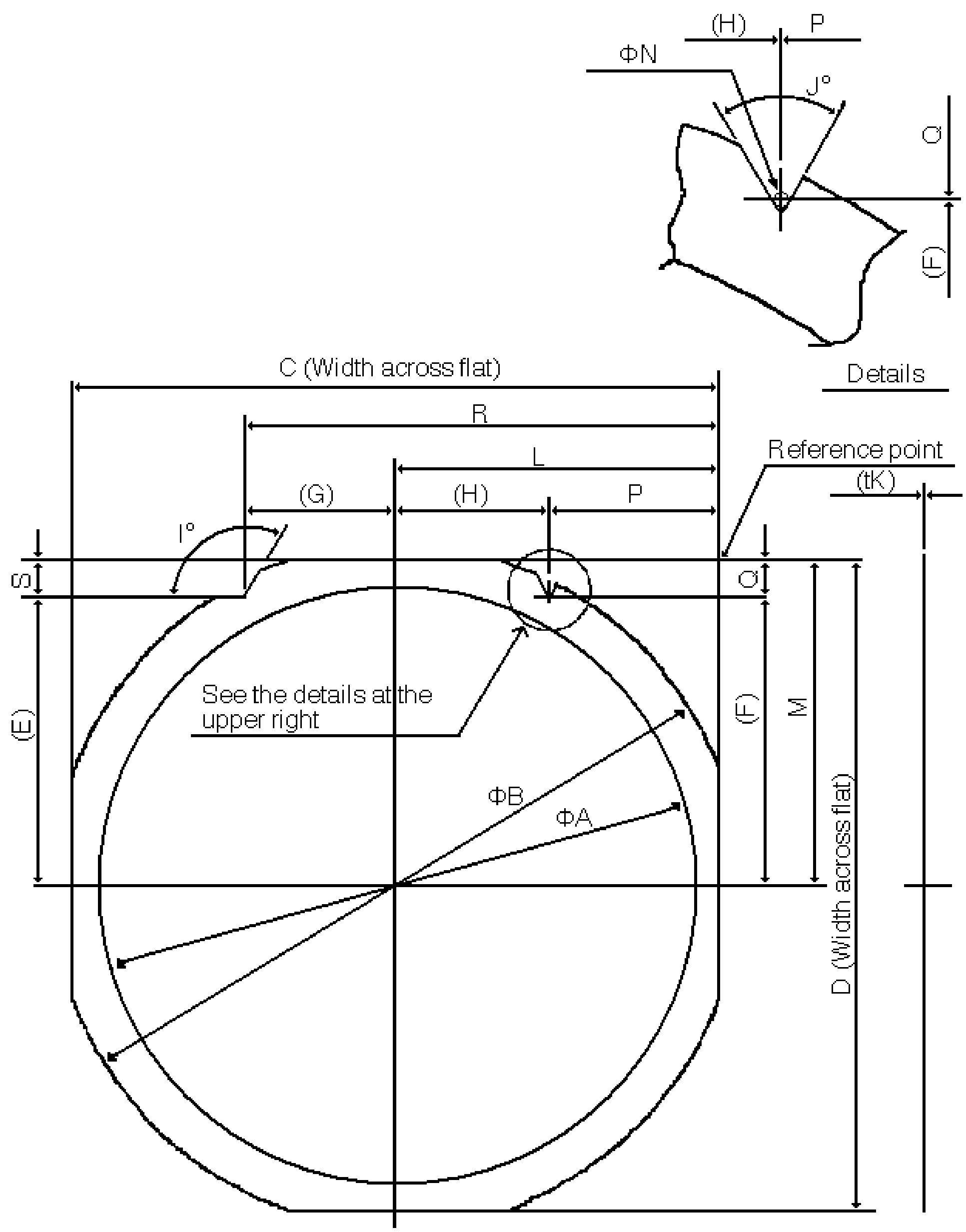

Figure 1

300 mm Tape Frame Dimensions

6.2 *Surface Hardness* — HRc ≥ 47

6.3 *Resiliency* — Must return to original shape, where the linear scale ruler reads 0, after one side is held firm and the other is bent with a force of 30 N for 60 seconds.

6.4 *Surface Roughness* — $R_a \leq 0.1$ µm, R_{max} is within ≤ 1.0 µm

6.5 *Flatness* — Within 0.3 mm

7 Test Methods

7.1 *Dimensions* — To be measured with a measuring device, such as a caliper, with a precision of 0.05 mm.

7.2 *Surface Hardness* — To be measured according to the method in JIS Z2245 with a Rockwell Hardness Tester.

7.3 *Resiliency* — Secure one side of the frame in a vice, and bend with a force of 30 *N* for 60 seconds. After that, release the frame and measure the change from the original shape with a linear scale ruler. The linear scale ruler should have a precision of at least 0.5 mm.

7.4 *Surface Roughness* — Measure with a surface roughness gauge. Surface roughness is measured perpendicular to the undulation and must be shown as roughness average (R_a) and maximum peak-to-valley roughness height (R_{max}). Refer to ISO4287 Part 1, JIS B0601, and ANSI/ASME B46.1.

7.5 *Flatness* — Place the frame on a surface with near-zero flatness. Measure the lowest point and the highest point on the frame with a height gauge, and record the difference in these values. Turn the frame over and repeat the process. The flatness will be the larger of the two values.

8 Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's or supplier's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

9 Packing and Package Labeling

9.1 The product must be packaged appropriately to prevent deformities, moisture, and contamination, as well as damage during normal shipping.

9.2 The products must be clearly marked with the purchase number, quantity, gross weight, and supplier's name.

9.3 Special packaging and delivery requests will be decided between the supplier and the purchaser at time of purchase.

9.4 *Surface Hardness* — HRc ≥ 47

9.5 *Resiliency* — Must return to original shape, where the linear scale ruler reads 0, after one side is held firm and the other is bent with a force of 30 *N* for 60 seconds.

9.6 *Flatness* — Within 0.3 mm

APPENDIX 1
BARCODE LABEL POSITIONS FOR 300 MM TAPE FRAMES

NOTE: The material in this appendix is an official part of SEMI G74 and was approved by full letter ballot procedures on March 17, 1999.

A-1 Barcode Label Positions

A-1.1 The recommended position for the barcode label is position (A in Figure A1-1).

A-1.2 However, it is acceptable if the barcode labels are within the shaded area (see B in Figure A1-1).

A-2 Reasons to recommend position (A)

A-2.1 It is easier to detect whether there are any barcode labels or not, without pulling out the frames.

A-2.2 It is convenient to have the labels on the opposite side of the notches, as the frames are normally pulled out from the notch side.

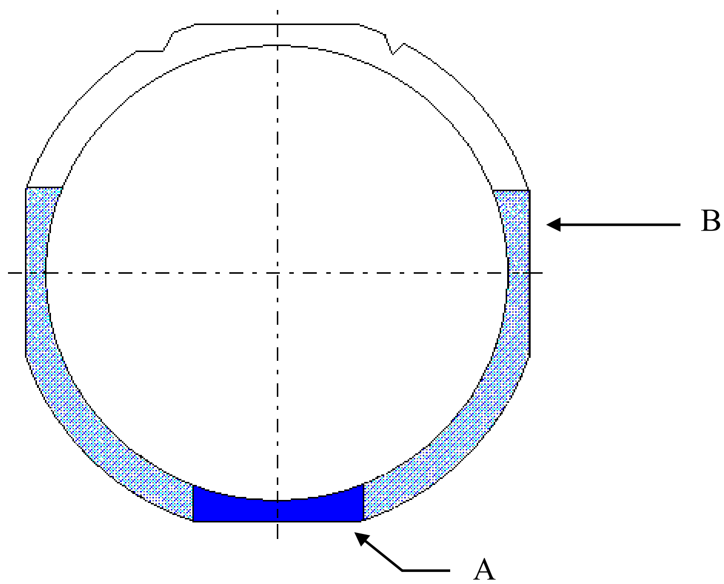

Figure A1-1

Barcode Label Positions

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SEMI G75-0698
STANDARD TEST METHOD OF THE PROPERTIES OF LEADFRAME TAPE

1 Purpose

1.1 This standard describes procedures for measuring the mechanical, physical, chemical, thermal, and electrical properties of leadframe tape.

1.2 Equipment, sampling, and procedures are referred to in the individual test methods.

1.3 The test methods for the individual properties have been given in this standard.

1.3.1 Ionic impurities (see SEMI G75.1).

1.3.2 Adhesive strength (see SEMI G75.2).

1.3.3 Peel strength of protective film from leadframe tape (see SEMI G75.3).

1.3.4 Water absorption (see SEMI G75.4).

1.3.5 Weight loss (see SEMI G75.5).

1.3.6 Shrinkage factor (see SEMI G75.6).

1.3.7 Thermal decomposition temperature (see SEMI G75.7).

1.3.8 Coefficient of thermal expansion and glass transition temperature (see SEMI G75.8).

1.3.9 Tensile strength, elongation, and tensile modulus (see SEMI G75.9).

1.3.10 Volume and surface resistivity (see SEMI G75.10).

1.3.11 Dielectric constant and dissipation factor (see SEMI G75.11).

1.3.12 Breakdown strength (see SEMI G75.12).

1.3.13 Leakage current (see SEMI G75.13).

2 Scope

2.1 The methods help tape manufacturers, leadframe manufacturers, and their customers in evaluating leadframe tapes.

2.2 *Units*

2.2.1 This standard test method uses SI (metric) units.

3 Referenced Documents

3.1 Referenced documents are listed in each test method.

4 Terminology

4.1 *breakdown strength* — Under the specified test conditions, the quotient of the minimum r.m.s. voltage at the breakdown of the test piece (breakdown voltage) divided by the distance between the two electrodes (thickness of test piece).

4.2 *dielectric constant* — The amount of electrostatic energy stored in a unit volume of a substance in a unit electric field. It is called dielectric constant (εr) and expressed as the quotient of electrostatic capacity of a parallel condenser employing the test piece as the dielectric (C_x) divided by that of the same condenser when air (under the standard condition, the dielectric constant of air can be taken for that of vacuum) is used as the dielectric (C_o), measured under a specified frequency.

$$\text{i.e., } \varepsilon = C_x/C_o$$

4.3 *dielectric dissipation factor* — Dielectric dissipation factor is the tangent of the complementary angle of dielectric phase angle (tand). The dielectric phase angle is the phase difference angle (q) between sine-wave voltage applied to the test piece and the current component having the same frequency as the applied voltage caused by the voltage application.

4.4 *HAST* — Highly accelerated stress test: For example, 121° C/2 atm/100% RH.

4.5 *leadframe tape* — An adhesive coated tape. After removing protective film, laminated to the inner leads, which stops lead shift and/or lead lift during the assembly process.

4.6 *protective film* —A plastic film to cover the adhesive on leadframe tapes. This film prevents the adhesive from becoming contaminated and is removed from the leadframe tape just prior to taping the lead-frame.

4.7 *strain* — The ratio of elongation of the sample length to the original length at the applied stress level.

4.8 *stress* — The applied force per unit cross-sectional area of the sample.

4.9 *surface resistivity* — The quotient of the voltage gradient parallel to the current along the surface of the test piece divided by the current per unit width of the surface.

4.10 *tensile break strength* — The tensile force per unit of original cross section of the sample at the point of breakage.

4.11 *tensile modulus* — The ratio of stress to strain of the sample below the yield point, in the elastic region of the stress/strain curve.

NOTE: Plastic materials may not have a true elastic region in the stress/strain curve or force/elongation curve. A tangent is drawn to the maximum slope of the curve in order to determine the modulus.

4.12 *thermal decomposition temperature (base film and adhesive)* — The thermal decomposition temperature is determined at 5% of the weight loss when the tape is set to the thermal ramp at 10° C/minute.

4.13 *volume resistivity* — The quotient of the voltage gradient parallel to the current within the test piece divided by the current density.

5 Significance

5.1 *Ionic Impurities*

5.1.1 Ionic contamination can adversely affect the reliability of semiconductor devices by causing leakage currents and aluminum corrosion.

5.2 *Adhesive Strength*

5.2.1 Low adhesive strength may result in inner leads movement of leadframe during the assembly and packaging process which may result in low yield or poor device reliability.

5.3 *Peel Strength of Protective Film from Leadframe Tape*

5.3.1 If the peeling strength of protective film from leadframe tape varies in peeling strength, the taping machines will not operate consistently.

5.4 *Water Absorption*

5.4.1 If the leadframe tapes absorb an excessive amount of water in storage, before or after packaging, then reliability of devices made by these leadframes may be affected. Current leakage and corrosion of device metallization may occur.

5.5 *Weight Loss*

5.5.1 Weight loss may indicate that devices manufactured with the leadframe tape may have reliability problems due to the tape outgassing.

5.6 *Shrinkage Factor*

5.6.1 Excessive shrinkage at thermal processing may cause the lead shift and wire bond problems for automatic bonders.

5.7 *Thermal Decomposition Temperature*

5.7.1 The devices manufactured with leadframe tape that decomposes at too low a temperature may have lower reliability.

5.8 *Coefficient of Thermal Expansion and Glass Transition Temperature*

5.8.1 Excessive expansion of the leadframe tape may cause lead shift and/or lead lift and result in dislocated bonds from automatic bonders.

5.9 *Tensile Strength, Elongation, and Tensile Modulus*

5.9.1 If the tensile strength, elongation, and tensile modulus varies, the taping machines will not operate consistently.

5.10 *Volume and Surface Resistivity*

5.10.1 Low volume and/or surface resistivity is indicative of potential leakage currents between leadframe inner leads which can affect the function of the device.

5.11 *Dielectric Constant and Dissipation Factor*

5.11.1 High dielectric constant materials used in semiconductor packages may cause transmission delays. High dielectric loss causes energy loss, which leads to exothermic problems in semiconductor packages.

5.12 *Breakdown Strength*

5.12.1 Very low breakdown strength may cause devices to fail in use.

5.13 *Leakage Current*

5.13.1 A high leakage current between leadframe inner leads, which may be exacerbated due to high moisture test conditions and impurities in the tape, may result in poor device reliability.

6 Procedure

6.1 Procedures are detailed in the Test Methods following this document.

7 Reporting Results

7.1 The sample size per lot and the reported items shall be determined by agreement between user and supplier.

7.2 The report shall contain the following information:

7.2.1 *Leadframe Tape Material* — Manufacturer, type, and lot number.

7.2.2 Notification of acceptance or rejection.

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SEMI G75.1-0698
TEST METHOD FOR MEASUREMENT OF IONIC IMPURITIES IN LEADFRAME TAPE

1 Summary of Method

1.1 Ionic impurities are extracted from sample tape by water at 100°C or 121°C and quantitatively analyzed by ion chromatography and flame photometry or atomic absorption spectrometry. The pH and electrical conductivity of the extracted solutions are also measured.

1.2 If sample tape needs the cure before the extraction, vender should inform the customer of the necessity of curing and report the impurity data after cure.

1.3 Ion chromatography is used to determine the presence and concentration of the following ionic species: Na^+, $NH4^+$, K^+, NO_3^-, Cl^-, Br^-, SO_4^{2-}, PO_4^{3-}.

1.4 Flame photometry or atomic absorption spectrometry is used to determine the concentration of Na^+ and K^+ ions.

1.5 pH and conductivity measurements are also described.

2 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2.1 *SEMI Standards*

SEMI G29 — Test Method for Trace Contaminants in Molding Compounds

SEMI G59 — Test Method for Measurement of Ionic Contamination on Leadframe Interleafing and the Contamination Transferred from the Interleafing to the Leadframes

2.2 *ASTM Standards*[1]

ASTM D 1125 — Standard Test Methods for Electrical Conductivity and Resistivity of Water

ASTM D 1193 — Standard Specification for Reagent Water

ASTM D 4327 — Standard Test Method for Anions in Water by Ion Chromatography

ASTM E 70 — Standard Test Method for pH of Aqueous Solutions with the Glass Electrode

2.3 *JIS Specifications*[2]

JIS K 0121 — General Rules for Atomic Absorption Spectrochemical Analyses

JIS Z 8802 — Method for Determination of pH of Aqueous Solutions

3 Interferences

3.1 All the sample preparations and measurements must be carried out in clean containers which have been washed in deionized water in order to reduce any spurious readings.

3.2 Electrodes and syringes must be similarly cleaned before each test.

3.3 Contamination from the sampling process may also affect the results.

4 Equipment

4.1 Ion Extraction Vessels-Parr bomb with Teflon liner.

4.2 Ion chromatograph for anion and cation analysis (see SEMI G59).

4.3 Flame photometer or atomic absorption spectrometer.

4.4 Standard solution preparation vessels, balance and volumetric dispensers (see SEMI G29 and SEMI G59).

4.5 pH meter.

4.6 Microconductivity cell and meter.

5 Reagents and Materials

5.1 Deionized water, conductivity of less than 1.0 µ S/cm at 25°C per ASTM D 1193.

5.2 Eluents and regenerants for specific chromatograph columns prepared per chromatograph equipment manufacturer's recommendations so that the water peak can be separated from the ionic peaks.

5.3 *Compounds for Standard Solutions*

5.3.1 *Cations* — NaCl, NH_4Cl, KCl

5.3.2 *Anions* — NaCl, $Na2HPO_4 \bullet 12H2O$, NaBr, $NaNO_3$, K_2SO_4

NOTE: All compounds to be reagent grade.

1 American Society for Testing Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

5.4 pH standard solutions.

6 Sampling

6.1 Personnel handling the tape must wear double-layered cotton gloves and polyethylene outer gloves in order to avoid additional sample contamination.

6.2 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

7 Preparation of Standard Solution and Equipment Calibration

7.1 *Preparation of Standard Solutions and Chromatograph Calibration*

7.1.1 Refer to SEMI G59, Section 9 and ASTM D 4327.

7.2 *Preparation of Standard Solutions and Flame Photometer or Atomic Absorption Spectrometer Calibration*

7.2.1 Refer to SEMI G29 and JIS K 0121.

7.3 *Preparation of Standard Solutions and pH Meter Calibration*

7.3.1 Refer to ASTM E 70 or JIS Z 8802.

7.3.2 Using the standard pH solutions, calibrate the pH meter according to the manufacturer's instructions.

7.4 *Preparation of Standard Solutions and Conductivity Cell Calibration*

7.4.1 Refer to ASTM D 1125.

8 Measurement

8.1 *Procedure for Impurity Extraction*

8.1.1 Remove the protective film from the sample of tape. Cure the tape per tape manufacturer's recommendation, if necessary.

8.1.2 Cut the sample of tape so that it becomes smaller than 2 cm × 2 cm.

8.1.3 Place 5.0 ± 0.1 grams of the tape sample into the Parr bomb, and add 50 ± 0.5 grams of deionized water.

8.1.3.1 In a second bomb, add deionized water only so that a blank solution may be obtained for measurement of the ionic contributed by the bomb.

NOTE: It may be necessary to perform the blank test on both bombs in order to leach out excessive extractable ionic species.

8.1.4 Seal the caps and heat the bombs in an oven set at 100°C ± 2°C, for 20 ± 0.25 hours.

NOTE: The oven temperature may be set at 121°C ± 2°C for 20 hours, if specified.

8.1.5 Allow the bombs to reach room temperature.

8.1.6 Open the bombs just before the measurements are to be made. Measurements must be made within eight (8) hours of the completion of the sample preparation.

8.2 *Quantitative Analysis by Ion Chromatography*

8.2.1 Prepare the chromatograph for operation by regenerating the columns according to the manufacturer's recommendations.

8.2.2 Run the eluent through the chromatograph until a stable baseline calibration is established.

8.2.3 Inject the recommended sample size of test solution into the chromatograph and record the ion chromatogram.

8.2.4 Repeat for all the samples and also run the background sample.

8.2.5 Determine the ionic type and concentration from the calibration curves.

8.2.6 Results

8.2.6.1 The concentration of ionic species in the leadframe tape is given by:

$$A = \frac{(B - C) \times 50}{5}$$

where :

A is the ionic content of the leadframe tape (ppm)

B is the ionic content on the extracted solution, determined from the calibration curves (ppm)

C is the ionic concentration of the back-ground sample (ppm)

8.3 *Quantitative Analysis by Flame Photometer or Atomic Absorption Spectrometer*

8.3.1 Set a specific operational condition for an apparatus.

8.3.2 Introduce the recommended sample size of test solution into a flame.

8.3.3 Repeat for all the samples and also introduce the background sample.

8.3.4 Determine the concentration from calibration curves.

8.3.5 *Results*

8.3.5.1 The concentration of ionic species in the leadframe tape is given by:

$$A = \frac{(B - C) \times 50}{5}$$

where :

A is the ionic content of the leadframe tape (ppm)

B is the ionic content on the extracted solution, determined from the calibration curves (ppm)

C is the ionic concentration of the back-ground sample (ppm)

8.4 *pH Measurements*

8.4.1 Place the pH electrode into the sample solution and record the pH after one (1) minute.

8.5 *Electrical Conductivity Measurements*

8.5.1 Place the conductivity cell into the sample solution and record the conductivity after one (1) minute.

9 Related Documents

NOTE: Additional information relating to test methods for these ionic species may be found in the following specifications:

9.1 *SEMI Standard*

SEMI G12 — Recommended Practice for Aqueous Extraction of Ionic Species from Plastics Used to Package Electronic Devices

9.2 *ASTM Specifications*

ASTM D 512 — Standard Test Methods for Chloride Ion in Water

ASTM D 1293 — Standard Test Methods for pH of Water

9.3 *JIS Specification*

JIS K 0102 — Testing Methods for Industrial Wastewater

SEMI G75.2-0698
TEST METHOD FOR MEASUREMENT OF ADHESIVE STRENGTH OF LEADFRAME TAPE

1 Summary of Method

1.1 Two methods are described:

1.1.1 *Pull-Up Method* — Using a hook attached to a tensile tester, the tape is pulled away from the leadframe inner leads.

1.1.2 *Push-Down Method* — Using a probe attached to a tensile tester, a leadframe inner lead is pushed away from the tape.

1.2 The adhesive strength between the lead and the tape should be measured at 23°C ± 5°C and 250°C.

2 Equipment

2.1 Tensile tester with appropriate load cell, clamping chucks, and a chart recorder. Tensile tester shall keep constant the traveling speed of clamping chucks, of which the traveling distance can be read to the nearest 1 mm, and shall simultaneously record the load imposed on the sample. It shall measure and record the imposed load with ± 1% on a chart recorder.

2.2 *Pull-Up Method*

2.2.1 A clamp should be suitable for each leadframe type. Example of the clamp design, for a typical 40 pins DIP leadframe, is shown in Figure 1.

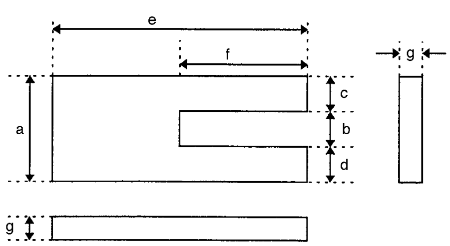

Figure 1
Example of Clamp Design
(40 Pins DIP Leadframe)

Table 1 Dimension and Material of Clamp and Hook in Push-Up Method

Item/Dimension	*Value*	*Material*	*Reference Figure*
Clamp		Aluminum	1
a	60 mm		
b	8 mm		
c	26 mm		
d	26 mm		
e	60 mm		
f	30 mm		
g	3 mm		
Pull-Up Hook		Piano Wire	2
ϕ	0.4 mm		
a	100 mm		
b	5 mm		
r	2.0 mm		

2.2.2 A pull-up hook should be suitable for each leadframe type. Example of the pull-up hook, for a typical 40 pins DIP leadframe, is shown in Figure 2.

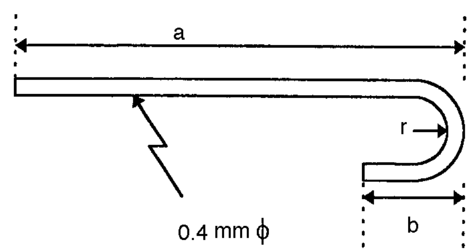

Figure 2
Pull-Up Hook
(40 Pins DIP Leadframe)

2.3 *Push-Down Method*

2.3.1 A table should be suitable for each leadframe type. Example of the table, for a typical 40 pins DIP leadframe, is shown in Figure 3.

2.3.2 A push-down probe should be suitable for each leadframe. Example of the push-down probe, for a typical 40 pins DIP leadframe, is shown in Figure 4.

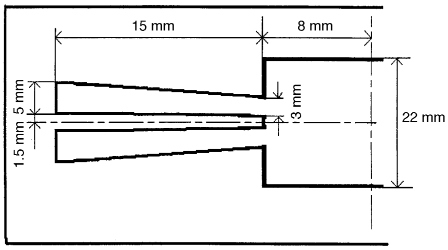

Figure 3
The Dimension of the Table

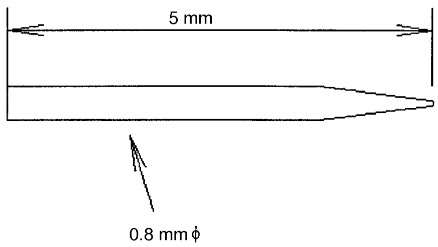

Figure 4
Example of Push-Down Probe
(40 Pin DIP Leadframe)

3 Test Condition

3.1 Adhesion testing shall be carried out at the following ambient conditions:

Temperature — 23°C ± 5°C

Humidity — 50 ± 5% RH

4 Sampling

4.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if the customer requires it.

5 Preparation of Specimens

5.1 *Leadframe Manufacturers*

5.1.1 Leadframes shall be taped using conditions for temperature, pressure, and dwell-time agreed upon between vendor and customer.

NOTE: A typical taped 40 pins DIP leadframe is shown in Figure 5, and relevant information for this frame is shown in Table 2.

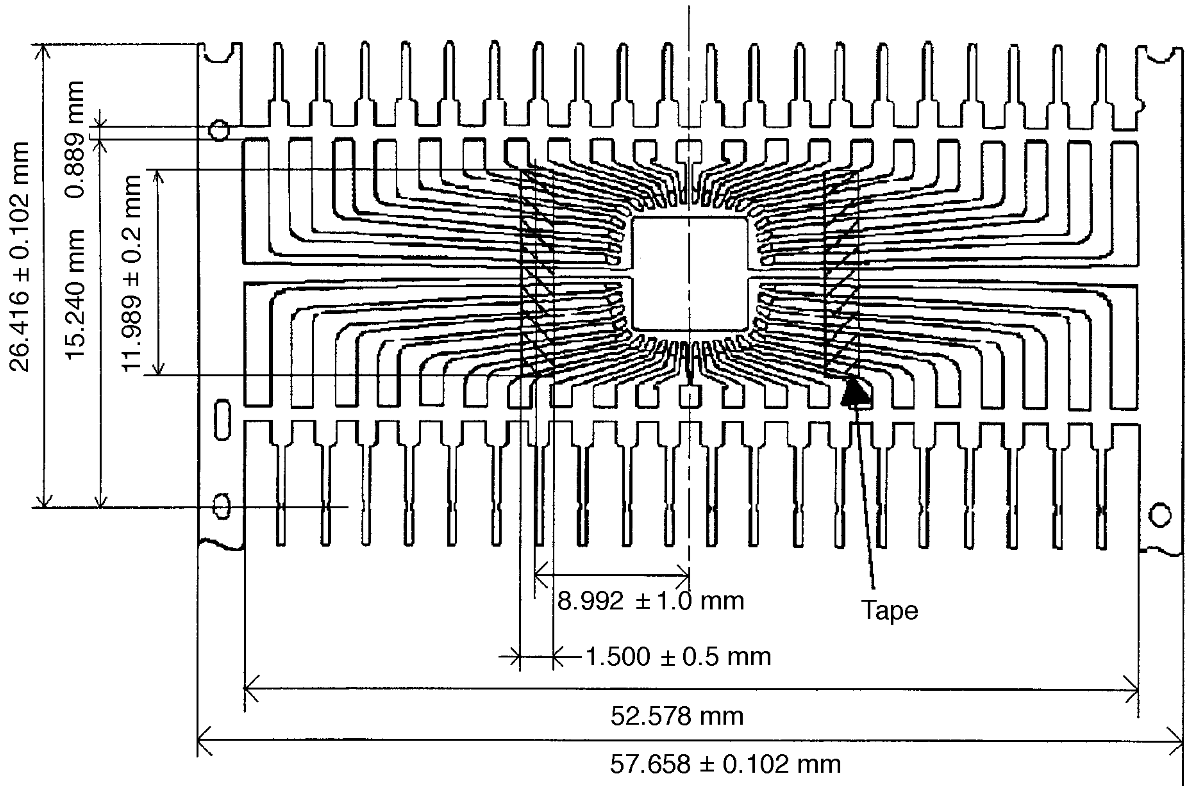

Figure 5
Typical Taped 40 Pin DIP Leadframe

Table 2 Relevant Information for 40 Pin DIP Leadframe

Leadframe Attribute	*Specification*
Leadframe thickness	0.25 mm
Leadframe material	Alloy 42
Leadframe manufacturing process	Stamping
Plating	None/Silver/Others
Surface treatment	To be agreed upon between vendor and customer.

NOTE: The surface state of Alloy 42 is stable compared with Cu alloy which is oxidized easily.

6 Procedure

Hot adhesive strength at 250°C should be measured on the heater block with 60 ± 10 seconds.

6.1 *Pull-Up Procedure*

6.1.1 Set the tensile tester in the up-mode, and adjust the rate to 100 mm/minute.

6.1.2 Place the leadframe under the clamp as shown in Figure 6.

6.1.3 Position the hook under the tape between the tie bar and its neighboring inner lead as shown in Figure 6. Similar leads and hook position shall be selected for other types of leadframes.

6.1.4 Adjust the hook position until it just touches the tape and initiate the tensile tester in the up-mode. Record the strength to break the adhesion between the lead and the tape.

6.1.5 Repeat the test for each leadframe in the samples.

6.1.6 Calculation

6.1.6.1 Discard the maximum and minimum values recorded, and average the remainder.

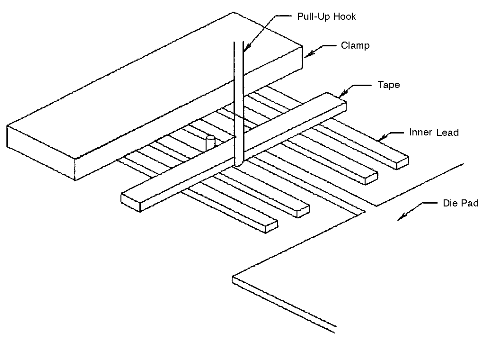

Figure 6
Measurement of Pull-Up Strength

6.2 *Push-Down Procedure*

6.2.1 Set the tensile tester in the down-mode, and adjust the rate to 100 mm/minute.

6.2.2 Place the leadframe on the table as shown in Figures 7 and 8.

6.2.3 Position the probe at Point A over the selected inner lead as shown in Figure 9.

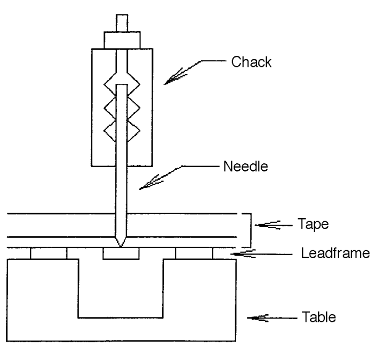

Figure 7
Measurement of Push-Down Strength
(Cross-Section)

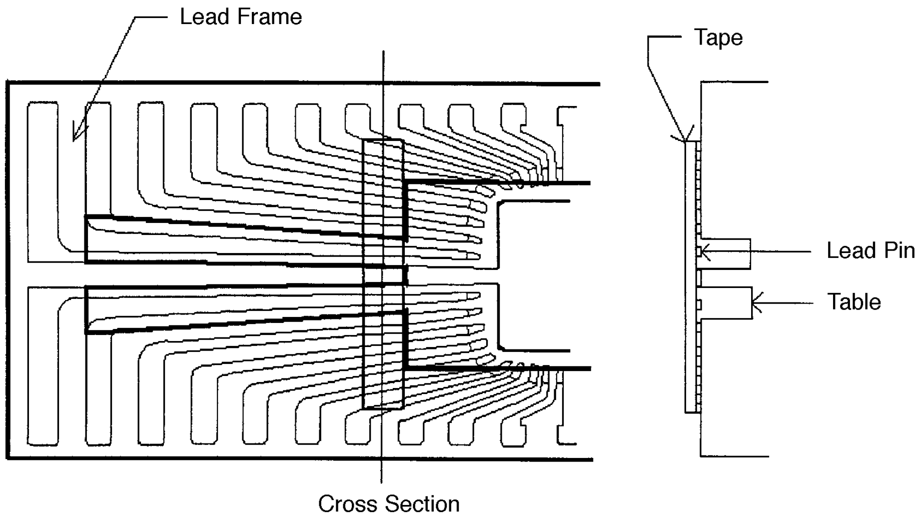

Figure 8
Relation of Leadframe and Table in Push-Down Method

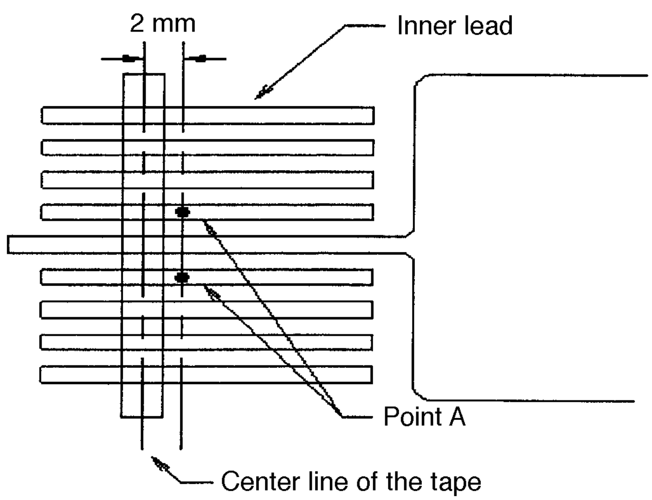

Figure 9
Probe Position over the Selected Inner Lead in Push-Down Method

6.2.4 Adjust the probe position until it just touches the inner lead and initiate the tensile tester in the down-mode. Record the strength to break the adhesion between the inner lead and the tape.

6.2.5 Repeat the test for each of the test positions noted in Section 6.2.4.

6.2.6 Repeat the tests for each leadframe in the sample.

6.3 *Calculation*

6.3.1 Discard the maximum and minimum values recorded and average the remainder.

7 Related Documents

7.1 *JIS Specification*[1]

JIS K 6854 — Testing Methods for Peel Strength of Adhesives

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1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.3-0698
TEST METHOD FOR MEASUREMENT OF THE PEEL STRENGTH OF PROTECTIVE FILM ON LEADFRAME TAPE

1 Summary of Method

1.1 A tensile tester is used to peel the film away from the adhesive (see Figure 1) and directly measure the peel strength with a calibrated load cell.

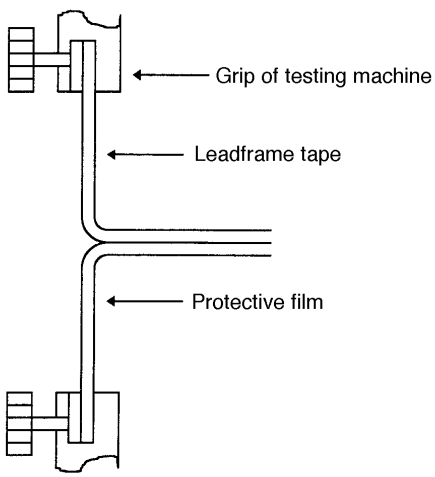

Figure 1
Attaching of Test Piece for T-Type Peel Test

2 Equipment

2.1 Tensile tester with appropriate load cell, clamping chucks, and a chart recorder.

2.1.1 Tensile tester shall keep constant the traveling speed of clamping chucks, of which the traveling distance can be read to the nearest 1 mm, and shall simultaneously record the load imposed on the sample. It shall measure and record the imposed load with ± 1% on a chart recorder.

3 Test Condition

3.1 Peel strength testing shall be carried out at the following ambient conditions:

Temperature — 23 ± 5°C

Humidity — 50 ± 5% RH

4 Sampling

4.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if the customer requires it.

4.2 The width of the tape tested shall be 15 ± 0.2 mm.

5 Equipment Calibration and Setup

5.1 Refer to the tensile tester manufacturer's equipment manual for setup and calibration.

5.2 The sample shall be attached and peeled for T-type peel test shown in Figure 1.

5.3 Both ends of a test piece shall be attached to the grips of the testing machine specified in Section 2.1.

5.4 The pulling rate shall be set to 300 mm/minute.

5.5 The pulling distance shall be 125 mm minimum from the start of peeling.

5.6 The peel strength shall be recorded in grams.

6 Measurements

6.1 As shown in Figure 2, draw the optimum straight line which is parallel to the abscissa for peeling length, that passes through the peeling curve, and find the peeling load after eliminating initial 25 mm of peeling length.

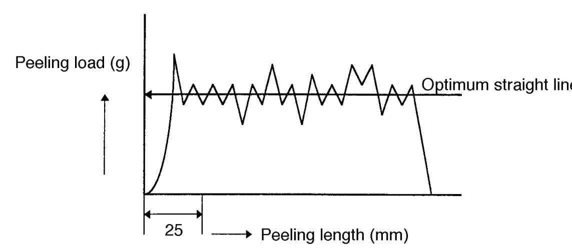

Figure 2
Obtaining Peeling Load by the Optimum Straight Line Method

7 Related Documents

7.1 *JIS Specification*[1]

JIS K 6854 — Testing Methods for Peel Strength of Adhesives

1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

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SEMI G75.4-0698
TEST METHOD FOR MEASUREMENT OF WATER ABSORPTION OF LEADFRAME TAPE

1 Summary of Method

1.1 Leadframe tape is exposed to an environment at constant humidity and temperature. The water absorption is measured by directly weighing the samples before and after test.

2 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2.1 *ASTM Specification*[1]

ASTM D 1193 — Standard Specification for Reagent Water

3 Equipment

3.1 Direct reading electric balance capable of reading 0.1 mg.

3.2 Thermohygrostat capable of 23 ± 2°C and 50 ± 5% RH.

3.3 Thermohygrostat capable of 85 ± 2°C and 85 ± 5% RH.

4 Materials

4.1 *Deionized Water* — Refer to ASTM D 1193.

5 Test Conditions

5.1 *Specimen Conditioning*

Temperature — 23 ± 2°C

Humidity — 50 ± 5% RH

5.2 *Test Conditions*

Temperature — 85 ± 2°C

Humidity — 85 ± 5% RH

6 Sampling

6.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

6.2 The sample's weight shall be 1 gram minimum.

6.3 Use plastic tweezers to handle the samples.

1 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (all cited standards may be found in Volume 10.05 of the Annual Book of ASTM Standards)

7 Equipment Setup and Calibration

7.1 Refer to the thermohygrostat manufacturer's manual for setup and calibration procedures.

8 Procedure

8.1 Separate off the protective film from the leadframe tape.

8.2 Set the thermohygrostat at 23°C and 50% RH and condition the samples at these conditions for 16 hours minimum.

8.3 Weigh each sample to 0.1 mg accuracy (W_1, Units-grams).

8.4 Set the thermohygrostat at 85°C and 85% RH and leave the samples at these conditions for 20 ± 0.25 hours.

8.5 Wipe the water from sample surface with lint-free clean wipes.

8.6 Reweigh each sample (W_2, Unit-grams).

8.7 *Calculation*

The water absorption obtained, A (%), is deter-mined from the following equation:

$$A(\%) = \frac{(W_2 - W_1) \times 100}{W_1}$$

9 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

9.1 *ASTM Specification*

ASTM D 570 — Standard Test Method for Water Absorption of Plastics

9.2 *JIS Specifications*[2]

JIS K 6911 — Testing Methods for Thermosetting Plastics

JIS K 7209 — Testing Methods for Water and Boiling Water Absorption of Plastics

2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

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SEMI G75.5-0698
TEST METHOD FOR MEASUREMENT OF WEIGHT LOSS OF LEADFRAME TAPE

1 Summary of Method

1.1 Specimens are weighed before and after exposure to temperatures comparable to those used in the assembly and packaging of microelectronics devices. The weight loss is calculated as a percentage change in the weight of the sample.

2 Equipment

2.1 Direct reading balance calibrated to 0.1 mg accuracy.

2.2 Recirculating air oven capable of 300°C ± 2°C accuracy.

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

4 Preparation of Specimens

4.1 Allow the samples to stabilize at 23°C ± 2°C and 50 ± 5% RH for 16 hours minimum. This may be carried out in a climate controlled room or in a thermohygrostat.

4.2 Cut specimens out of the samples such that the minimum weight of each specimen is 1 gram.

5 Test Conditions

5.1 *Test Condition 1* — 100°C for 60 ± 1 minute.

5.2 *Test Condition 2* — 200°C for 60 ± 1 minute.

5.3 *Test Condition 3* — 300°C for 10 ± 0.5 minutes.

NOTE: Alternate temperature may be used by agreement between vendor and customer.

6 Equipment Setup and Calibration

6.1 Refer to the thermohygrostat manufacturer's manual for setup and calibration procedures.

7 Procedure

7.1 In order to ease the handling of the specimens, place each into a weighed cup or tray which has tared their weight (W_1).

7.2 Place the specimens in the oven at the specified test conditions.

7.3 Remove the specimens from the oven and store at 23°C ± 2°C and 50 ± 5% RH for 16 hours minimum.

7.4 Reweigh the specimens (W_2).

7.5 *Calculation*

7.5.1 The Weight Loss, A (%), is determined from the following equation:

$$A(\%) = \frac{(W_1 - W_2) \times 100}{W_1}$$

8 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

8.1 *JIS Specification*[1]

JIS K 0067 — Testing Methods for Loss and Residue of Chemical Products

1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.6-0698
TEST METHOD FOR MEASUREMENT OF THE SHRINKAGE FACTOR OF LEADFRAME TAPE

1 Summary of Method

1.1 The length of tape samples is measured before and after exposure to temperatures comparable to those used in the assembly and packaging of IC. The shrinkage is calculated as a percentage in the dimension measured.

2 Equipment

2.1 Magnifying projector with 0.01 mm accuracy

2.2 Circulating air oven capable of 300 ± 2°C accuracy

2.3 Cutting die for sample preparation

2.4 Thermohygrostat

2.5 Straight edge

2.6 Scribing tool

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if the customer requires it.

4 Preparation of Specimens

4.1 Cut specimens out of the samples using the cutting die. The specimen shall be 100 ± 1.0 mm long and 10 ± 1.0 mm wide.

4.2 Allow the specimen to be stabilized at 23° ± 2°C and 50 ± 5% RH for 16 hours minimum. This may be carried out in a climate controlled room or in a thermohygrostat.

4.3 Using the straight edge and scribing tool, scribe marks on the specimens as shown in Figure 1. The marks shall be parallel to each edge of the specimen, and the distance to be measured, L, shall be parallel to the long side of the specimen. The mark shall be located within 5 mm of the ends of the specimen.

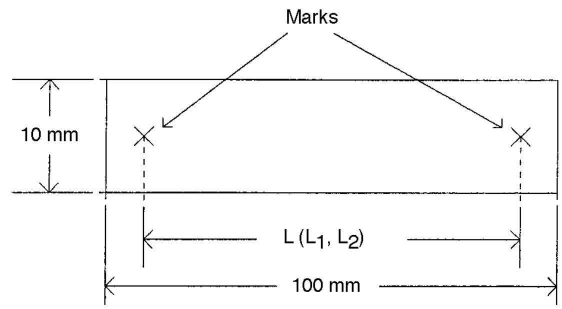

Figure 1
Size of a Marked Specimen

5 Test Conditions

5.1 *Baking Condition 1* — 100°C for 60 ± 1 minute.

5.2 *Baking Condition 2* — 200°C for 60 ± 1 minute.

5.3 *Baking Condition 3* — 300°C for 10 ± 0.5 minutes.

NOTE: Alternate temperatures may be used by agreement between vendor and customer.

6 Procedure

6.1 Place a specimen between the glass plates of the magnifying projector and measure the length, L_1, between two marks (see Figure 1). Repeat this measurement for all specimens.

6.2 Place the specimen in the oven at the appropriate test condition.

6.3 Remove the specimens from the oven and store at 23° ± 2°C and 50 ± 5% RH for 16 hours minimum.

6.4 Place the specimens between the glass plates of the magnifying projector and measure the new length, L_2, between two marks used in Section 6.1.

6.5 *Calculation*

6.5.1 The shrinkage factor, A (%), is determined from the following equation:

$$A(\%) = \frac{(L_1 - L_2) \times 100}{L_1}$$

where :

L_1 is the length (mm) of the specimen before baking

L_2 is the length (mm) of the specimen after baking

7 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

7.1 *JIS Specification*[1]

JIS K 6911 — Testing Methods for Thermosetting Plastics

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1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.7-0698
TEST METHOD FOR MEASUREMENT OF THERMAL DECOMPOSITION TEMPERATURE OF LEADFRAME TAPE AND ADHESIVE

1 Summary of Method

1.1 A thermogravimetric (TG) analyzer is used to monitor the weight of a tape sample as the temperature increases to 700°C. It should be made to measure the leadframe tape or the base film and the adhesive separately. The results are obtained as a plot of Weight Retention versus Temperature, from which the thermal decomposition temperature for both the base film and the adhesive may be obtained.

2 Equipment

2.1 Thermogravimetric (TG) analyzer capable of 0.01 mg accuracy.

2.2 Thermohygrostat

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

4 Preparation of Specimens

4.1 Allow the samples to be stabilized at 23 ± 5°C and 50 ± 5% RH for 16 hours minimum. This may be carried out in a climate controlled room or in a thermohygrostat.

4.2 Cut specimens from the sample. The specimen shall weigh 10 to 20 mg.

NOTE 1: The base film before coating with the adhesive can be used for the test. The vendor has to ship the base film before coating with the adhesive, if customer requires it.

NOTE 2: The adhesive sample can be obtained by scraping the adhesive.

5 Equipment Setup and Calibration

5.1 Refer to Thermogravimetric Analyzer manufacturer's manual for setup and calibration procedures.

5.2 The ambient in the measurement shall be air.

6 Procedure

The measurement of TG should be made to measure the leadframe tape or the base film and the adhesive separately.

6.1 Place the specimen in the platinum vessel.

6.2 Set the thermal ramp to 10 ± 1°C/minute and maximum temperature to 700°C.

6.3 Repeat for all specimens.

7 Method of Reading TG Curve

7.1 In Figure 1, the thermal decomposition is determined by the temperature at 5% of the weight loss.

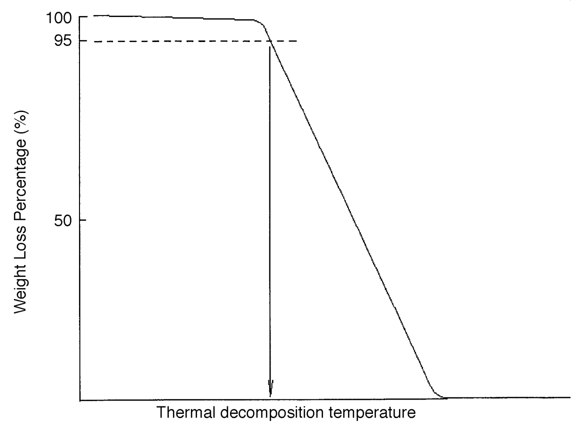

Figure 1
TG Curve of the Leadframe Tape

8 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

8.1 *ASTM Specification*[1]

ASTM D 3850 — Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method

8.2 *JIS Specification*[2]

JIS K 7120 — Testing Methods of Plastics by Thermogravimetry

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.8-0698
TEST METHOD FOR MEASUREMENT OF THE COEFFICIENT OF THERMAL EXPANSION AND GLASS TRANSITION TEMPERATURE OF LEADFRAME TAPE

1 Summary of Method

1.1 A thermal mechanical analyzer is used to monitor the dimension of a tape sample with temperature increases to 400°C. It can be made to measure the base film, adhesive, and the leadframe tape. The results are obtained as a plot of expansion versus temperature, from which Coefficient of Thermal Expansion (CTE) and Glass Transition Temperature (Tg) may be obtained. CTE above the Tg cannot be measured because of softening and elongation of the sample.

2 Equipment

2.1 Thermal mechanical analyzer (TMA) with chart recorder.

2.2 Thermohygrostat

2.3 Cutting die for sample preparation

2.4 *Calipers* — 0.1 mm accuracy

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

4 Preparation of Specimens

4.1 Cut specimens out of the samples using the cutting die. The specimens shall be 20 ± 0.1 mm long and 5.0 ± 0.1 mm wide.

4.2 Allow the samples to be stabilized at 23 ± 5°C and 50 ± 5% RH for 16 hours minimum. This may be carried out in a climate controlled room or in a thermohygrostat.

5 Equipment Setup and Calibration

5.1 Refer to the thermal mechanical analyzer manufacturer's manual for setup and calibration procedures.

Procedure

6.1 Set the specimen to the chuck so that the length of the specimen under test is 10 ± 0.1 mm. Measure the specimen length using calipers.

6.2 Attach the chuck to the TMA.

6.3 Zero the recorder.

6.4 Set the Thermal Ramp to 10°C/minute, the maximum temperature to 400°C, and the load to 2.0 ± 0.2 grams.

6.5 Initiate the test sequence and obtain a chart record of Elongation of the specimen versus Temperature (see Figure 1).

6.6 Repeat for all specimens.

6.7 Calculation of Results

6.7.1 Coefficient of Thermal Expansion (k) — Calculate the CTE using the following equation:

$$k = \frac{\Delta L}{L \times \Delta T}$$

where :

L is the length (mm) of the specimen at room temperature.
ΔL is the elongation of the specimen (mm) for a given temperature difference, Δ T (°C).
These values are taken from the chart as shown in Figure 1.

6.7.2 Glass Transition Temperature (Tg)

6.7.2.1 On the chart, draw a best-fit tangent line to the curve between Point (A) and (B) and a second tangent between Point (C) and (D) (see Figure 1).

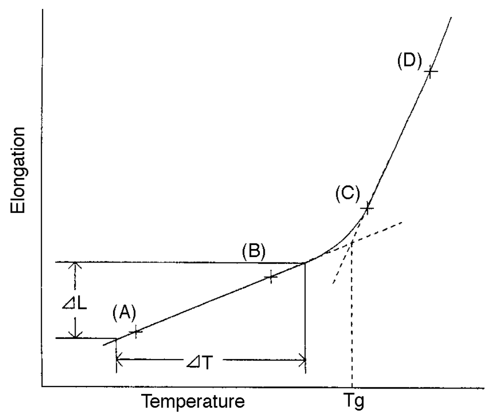

Figure 1
Coefficient of Thermal Expansion (CTE)

6.7.2.2 Extend the lower tangent line above its highest temperature and the higher tangent line below its lowest temperature until they intersect. The temperature at the intersection point is the Glass Transition Temperature.

6 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

6.1 *SEMI Standard*

SEMI G13 — Standard Test Method for Expansion Characteristics of Molding Compounds

6.2 *ASTM Specification*[1]

ASTM D 669 — Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics

6.3 *JIS Specification*[2]

JIS K 6911 — Testing Methods for Thermosetting of Plastics

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2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.9-0698
TEST METHOD FOR MEASUREMENT OF TENSILE STRENGTH, ELONGATION, AND TENSILE MODULUS OF LEADFRAME TAPE

1 Purpose

1.1 Tensile strength, elongation, and tensile modulus of leadframe tape are measured by a tensile pull tester, which is used to stretch the tape samples to the point of breakage with a calibrated load cell.

2 Equipment

2.1 Tensile pull tester with 100 kg MAX load cell, sample clamping chucks, and a chart recorder.

2.2 Micrometer with 0.001 mm accuracy.

2.3 Calipers with 0.02 mm accuracy.

3 Test Condition

3.1 Tensile test measurements shall be carried out at the following ambient conditions:

Temperature — 23 ± 5°C

Humidity — 50 ± 5% RH

4 Sampling

4.1 The sampling is one sample per one lot. The vendor has to report the definition of lot, if the customer requires it.

4.2 The sample width shall be 15.0 ± 0.2 mm, and the length must be 100 mm minimum.

5 Equipment Setup and Calibration

5.1 Refer to the tensile tester manufacturer's equipment manual for setup and calibration.

5.2 The pulling rate shall be set to 5 ± 0.5 mm/minute.

5.3 The load shall be recorded in kilograms.

6 Procedure

6.1 Measure the thickness (T) of the sample with the micrometer and the width (W) with calipers (mm).

6.2 Clamp the tape in the chucks so that the distance (L_0) between the chucks is 50 ± 5 mm.

NOTE: Some equipment may measure this length automatically or plot Stress versus Strain, (L/L_0), directly, where L is the elongation.

6.3 Start the pulling and record until the sample breaks.

6.4 Repeat the testing procedures for all the samples.

7 Results

7.1 Read the Break Force A (kg) and Elongation L_1 (mm) at sample breakage from the chart.

7.2 Draw a tangent line from the origin of the Load-Elongation curve to the maximum slope of the curve. (See Figure 1.)

NOTE: B (kg) is the incremental force change required to produce an elongation, L_2, in the elastic region and may be determined from the tangent line.

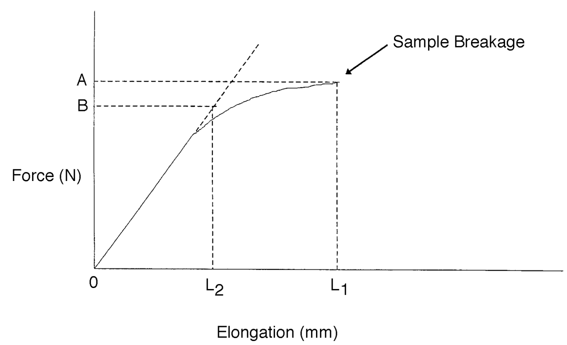

Figure 1
Breakage Point Calculation Diagram

7.3 *Calculations* — Tensile Strength at Break (s) is determined from the following equation:

$$S(N/mm^2) = \frac{9.8\,A}{WT}$$

7.3.1 Percentage Elongation at Break (e) is determined from the following equation:

$$\varepsilon(\%) = \frac{100\,L_1}{L_0}$$

7.3.2 Tensile Modulus (E) is determined from the following equation:

$$E(N/mm^2) = \frac{\Delta Stress}{\Delta Strain} = \frac{9.8B/WT}{L_2/L_0}$$

8 Related Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

8.1 *ASTM Specification*[1]

ASTM D 638 — Standard Test Method for Tensile Properties of Plastics

8.2 *JIS Specification*[2]

JIS K 6911 — Testing Methods for Thermosetting of Plastics

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2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.10-0698
TEST METHOD FOR MEASUREMENT OF VOLUME AND SURFACE RESISTIVITY OF THE LEADFRAME TAPE

1 Summary of Method

1.1 A resistance is measured across the thickness and along the surface of the adhesive of tape between electrodes deposited on the tape. Volume and surface resistivity are calculated from these resistances and the dimensions electrodes.

2 Equipment

2.1 *Power Source* — 500 volts DC battery or 500 volts rectified voltage supply.

2.2 Amplified galvanometer should be used for measuring insulating resistance no less than $10^6\Omega$.

2.3 Electrostatically and electromagnetically shielded box

2.4 Humidity-controlled storage box

2.5 *Micrometer* — 0.001 mm accuracy

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if the customer requires it.

4 Preparation of Specimens

4.1 The specimen shall be punched out from tape, the diameter of which has to be no less than that of the opposite electrode.

4.2 Place the specimens in the constant humidity box 23° ± 2°C and 50 ± 5% RH for 90 ± 2 hours. This may also be done after the electrodes are formed.

5 Test Conditions

5.1 *Temperature* — 23° ± 2°C

5.2 *Relative Humidity* — 50 ± 5% RH

5.3 *Applied Voltage* — 500 volts

6 Procedure

6.1 Measure the thickness of specimen with the micrometer. Attach the electrodes to the specimen. Electrodes are formed by conductive epoxy printing or aluminum evaporation shown in Figure 1.

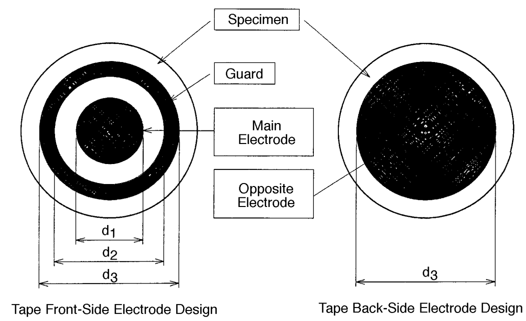

Figure 1
Electrodes Formed on the Leadframe Tape

NOTE 1: The electrodes shall be formed on both sides of the tape.

NOTE 2: Suggested dimensions for the electrodes as shown in Table 1 (d_1–d_2) should be at least 10 times the tape thickness.

Table 1 Suggested Dimension of the Electrodes

Suggested Dimension(for tape thickness 0.063–0.077 mm)	*Value*
d1	18 mm
d2	20 mm
d3	30 mm

NOTE 3: At surface resistivity measurement, main electrode and guard electrode is attached to the adhesive surface.

6.2 Place the specimens in the electrode system as shown in Figure 2A.

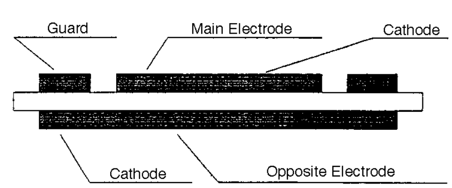

Figure 2A
Volume Resistivity Electrode Connection

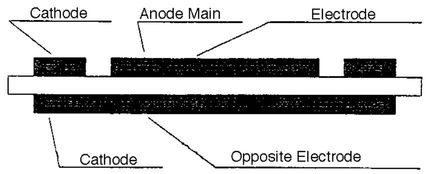

Figure 2B
Surface Resistivity Electrode Connection

6.3 Apply the specified voltage for one (1) minute and then read the resistance on the galvanometer.

6.4 Repeat the measurements for all the specimens.

6.5 Measure the thickness of the specimens using the micrometer.

6.6 *Calculations*

6.6.1 Volume resistivity should be calculated from the following equation:

$$\sigma v = \pi d_e^2 \times R_v / 4t$$

where :

σv	:	volume resistivity	Ωcm
d_e	:	effective diameter (41 +42)/2	cm
R_v	:	measured resistance cross tape thickness	Ωv/t
t	:	tape thickness	cm
d_1	:	inside diameter of the guard electrode	cm
d_2	:	outside diameter of the main electrode	cm

6.6.2 Surface resistivity should be determined from the following equation:

$$\sigma S = \pi (d_1 + d_2) \times R_s / (d_1 - d_2)$$

where :

σS	:	surface resistivity	Ω
d_1	:	inside diameter of the guard electrode	cm
d_2	:	outside diameter of the main electrode	cm
R_s	:	measured resistance along the adhesive surface side of tape thickness	Ω

7 Related Documents

7.1 *ASTM Specification*[1]

ASTM D 257 — Standard Test Methods for D-C Resistance or Conductance of Insulating Materials

7.2 *JIS Specification*[2]

JIS K 6911 — Testing Methods for Thermosetting of Plastics

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2 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

SEMI G75.11-0698
TEST METHOD FOR MEASUREMENT OF THE DIELECTRIC CONSTANT AND DISSIPATION FACTOR OF THE LEADFRAME TAPE

1 Purpose

1.1 Capacitance is measured for tape specimens and air with similar electrode setups. Dielectric constant and dissipation factor of the tapes are calculated from the results.

2 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

2.1 *JIS Specification*[1]

JIS K 6911 — Testing Methods for Thermosetting Plastics

3 Equipment

3.1 *Measurement Circuit* — See JIS K 6911 5.14.2 (1) (b)-(d) and Figure 1.

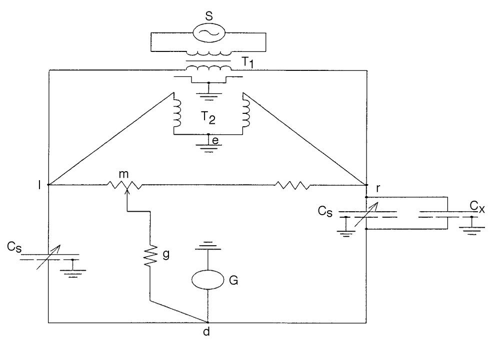

Figure 1
Mutual Inductance Bridge Method

Following is the Mutual Inductance Bridge Method (Transformer Bridge Method):

G:	Galvanometer
S:	Power source
T:	Shielded transformer
C_s:	Variable condenser
g:	Constant conductance
m, d:	Variable resistance
C_x:	Capacitance of sample

3.2 Electrostatically and electromagnetically shielded box

3.3 Micrometer with an accuracy of 0.001 mm

3.4 Humidity-controlled storage box

4 Sampling

4.1 The sampling is one sample per one lot. The vendor must report the definition of lot if the customer requires it.

5 Preparation of Specimens

5.1 The specimen shall be punched out from tape, the diameter of which must be no less than that of the opposite electrode.

5.2 Place the specimens in the constant humidity cabinet at 23 ± 2°C and 50 ± 5% RH for 90 ± 2 hours. This may also be done after the electrodes are formed.

6 Procedure

6.1 Measure the thickness of specimen with the micrometer. Attach the electrodes to the specimen. Electrodes are formed by conductive epoxy printing or aluminum evaporation shown in Figures 2 and 3.

NOTE 1: The electrodes shall be formed on both sides of tape.

NOTE 2: Suggested dimensions for the electrodes are shown in Table 1 (d_1– d_2). They should be at least 10 times the tape thickness.

Table 1 Suggested Dimension of Electrodes

Suggested Dimension (for Tape Thickness of 0.063–0.077 mm)	*Value*
d_1	18 mm
d_2	20 mm
d_3	30 mm

6.2 Connect the specimen in the position of C_x as shown in Figure 1, and balance the bridge by adjusting the measuring condenser C_s and conductance shifter. In this state, measure the C_s value, the conductance value between “m” and “d”, resistance between “I” and “m”, and “r” and “m” of the conductance shifter in Figure 1.

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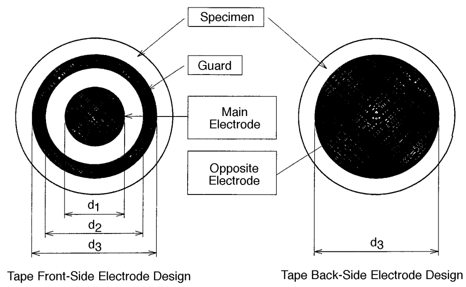

Figure 2
Electrodes Formed on the Leadframe Tape

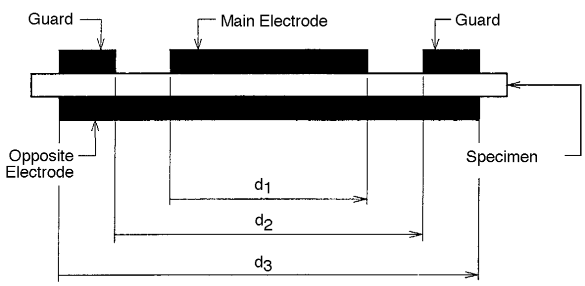

Figure 3
Electrode Connection

6.3 Dielectric constant and dielectric dissipation factor should be calculated by the following equation:

$$\varepsilon = C_x / C_o$$

$$\tan\delta = G_x / 2\pi f C_x$$

where :

ε : dielectric constant

tan : dielectric dissipation factor

C_x : capacity of measuring condenser C_c balances

C_o : electrostatic capacity for $\varepsilon = 1$ calculated by the following equation using the area of the main electrode and thickness of specimen

$$C_o = r^2 / 3.6\, t$$

where :

r : radius of main electrode

t : thickness of specimen

G_x : conductance of specimen calculated by the following equation

$$G_x = g \times Sv/100$$

where :

g : conductance between "m" and "d" of conductance shifter in Figure 1

Sv/100 : resistance ration of conductance shifter at balance

f : the frequency of measurement

: the ratio of the circle's circumference to its diameter

7 Related Documents

7.1 *ASTM Specification*[2]

ASTM D 150-64T — Standard Test Methods for Dielectric Constant and Dissipation Factor of Insulating Materials

2 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (all cited standards may be found in Volume 10.05 of the Annual Book of ASTM Standards)

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SEMI G75.12-0698
TEST METHOD FOR MEASUREMENT OF BREAKDOWN STRENGTH OF LEADFRAME TAPE

1 Summary of Method

1.1 An increasing voltage is applied between electrodes placed on both sides of the leadframe tape until breakdown, a large increase in current and voltage collapse, is observed.

2 Equipment

2.1 *Power Source* — DC High Voltage Generator (50 kv capability)

2.2 *Electrodes* — A brass spherical electrode with a diameter of 12.5 mm and a brass electrode with a diameter of 25 mm, which peripheral edges being rounded off to a radius of 2.5 mm. (See Figure 1.)

2.3 *Micrometer* — Accuracy 0.001 mm

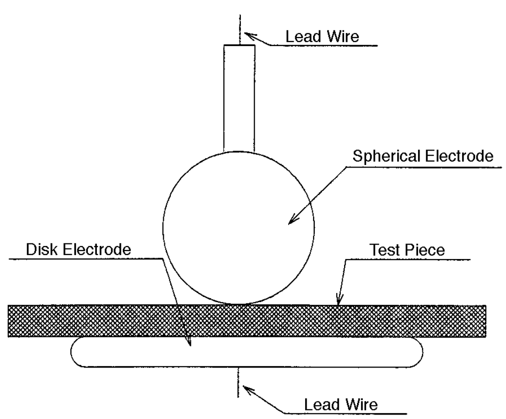

Figure 1
Electrodes for Measurement of Breakdown Strength

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot, if customer requires it.

4 Preparation of Specimens

4.1 Cut the specimens from the tape samples so that the size of the specimens is larger than the diameter of the disk electrode.

4.2 The specimens shall be stabilized in 23° ± 5°C and 50 ± 5% RH for 90 ± 2 hrs.

5 Test Conditions

5.1 *Temperature* — 23° ± 5°C

5.2 *Relative Humidity* — 50 ± 5% RH

6 Procedure

6.1 Place the specimens on the disk electrode and place the spherical electrode on the top of the tape. Ensure good contact between electrodes and tape.

6.2 *Setup Specimen*

6.2.1 Turn on the voltage supply and increase the voltage with constant ramp, until breakdown occurs.

NOTE 1: Note the voltage at breakdown. In subsequent specimens, arrange the voltage ramp so that the breakdown occurs approximately within 10–20 seconds after the beginning of voltage application.

6.3 Repeat the measurements for all the specimens.

6.4 Measure the thickness of the specimens using the micrometer.

6.5 *Calculations*

6.5.1 Breakdown strength should be calculated by the following equation:

$$\text{Dielectric Strength} \quad \frac{\text{kv}}{\text{mm}} = \frac{V_{BD}}{t}$$

where :

V_{Bd} = Breakdown voltage (kv)

t = tape thickness (mm)

7 Related Documents

7.1 *ASTM Specification*[1]

ASTM D 257 — Standard Test Methods for D-C Resistance or Conductance of Insulating Materials

1 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (all cited standards may be found in Volume 10.05 of the Annual Book of ASTM Standards)

7.2 *JIS Specification*[2]

JIS K 6911 — Testing Methods for Thermosetting of Plastics

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SEMI G75.13-0698
TEST METHOD FOR MEASUREMENT OF THE LEAKAGE CURRENT IN LEADFRAME TAPE

1 Summary of Method

1.1 Taped leadframes are molded under normal conditions, and the leakage current between designated leads is measured before and after submitting the samples to HAST (121°C/2 atm/100% RH) moisture testing.

2 Equipment

2.1 HAST Chamber

2.2 Amperemeter with 10^{-15} ampere measuring capability

2.3 Power supply capable of 500 volts DC maximum

2.4 Electrostatically and electromagnetically shielded box

3 Sampling

3.1 The sampling is one sample per one lot. The vendor must report the definition of lot if the customer requires it.

4 Preparation of Specimens

4.1 Leadframes shall be cleaned up previous to taping, using a procedure agreed on between vendor and customer.

4.2 *Taping Conditions* — Temperature, pressure, and dwell time shall be agreed on between vendor and customer.

NOTE 1: A typical taped 40 pin DIP leadframe is shown in Figure 1, and relevant information for this frame is tabulated in Table 1.

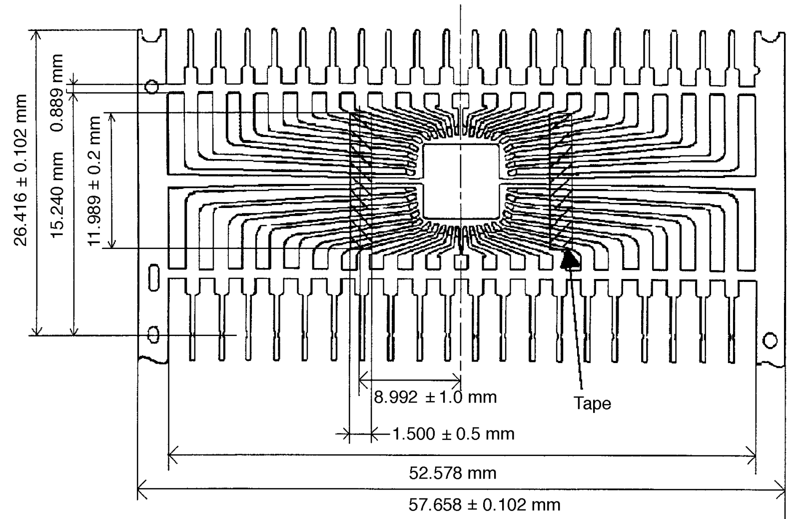

Figure 1
Typical Taped 40 Pin DIP Leadframe

Table 1 Relevant Information for 40 Pin DIP Leadframe

Leadframe Attribute	*Specification*
Leadframe thickness	0.25 mm
Leadframe material	Alloy 42
Leadframe manufacturing process	Stamping
Plating	None/Silver/Others
Surface treatment	To be agreed between tape user and supplier.

NOTE 2: The surface state of Alloy 42 is stable compared with Cu alloy, which is oxidized easily.

4.3 The leadframes shall be molded using molding compounds and cured with post mold curing conditions agreed on between vendor and customer. The untaped leadframe shall be prepared with the same procedure as a control.

4.4 Trim the leads according to a procedure agreed on between vendor and customer.

5 Procedure

5.1 Setup the test circuit as shown in Figure 2.

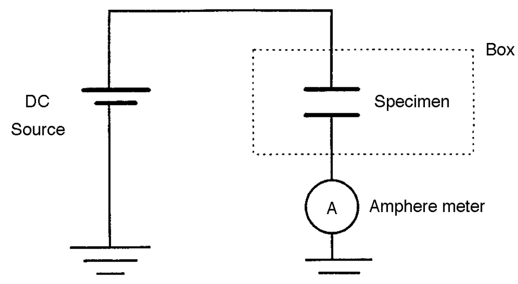

Figure 2
Test Circuit for Measurement of Leakage Current

5.2 Place the first molded sample in the shielded box and attach clips to the leads A_1 and A_2 (see Figure 1). Measure the initial leakage current at 500 volts maximum.

NOTE 3: The leakage current shall be measured after 5 minutes voltage application.

5.3 Repeat the measurement for all the lead pairs, A_2 with A_3, B_1 with B_2, and B_2 with B_3.

5.4 Place the samples in the HAST chamber and run the test.

5.5 After the tester has been automatically cooled to room temperature, remove the samples.

5.6 Measure the leakage current between the same lead pairs mentioned in Sections 5.2 and 5.3.

5.7 Repeat the HAST exposure and measure the cur-rent leakage.

5.8 *Calculation*

5.8.1 Maximum and minimum leakage current shall represent the test results.

5.8.2 Calculate the average result for all of the test points at each test stage.

5.8.3 Obtained data should be converted to 100 volts basis or as agreed on between vendor and customer.

6 Related Documents

6.1 *ASTM Specification*[1]

ASTM D 257 — Test Methods for D-C Resistance or Conductance of Insulating Materials

6.2 *JIS Specification*[2]

JIS K 6911 — Testing Methods for Thermosetting Plastics

1 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959 (all cited standards may be found in Volume 10.05 of the Annual Book of ASTM Standards)

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SEMI G76-0299
SPECIFICATION FOR POLYIMIDE-BASED ADHESIVE TAPE USED IN TAPE CARRIER PACKAGES (TCP)

1. Purpose

1.1 This standard addresses the adhesive demands of tape carrier packages (TCPs) and how reliability, versatility and cost may be optimized. The standardization of polyimide adhesive tape used in TCP is being promoted in order to meet these demands.

2. Scope

2.1 This standard defines the standard for polyimide-based adhesive tapes (hereinafter "tape").

3. Referenced Documents

NOTE: Standards cited below refer to the latest adopted revision of the standard. *(Draft documents may not be referenced.)*

3.1 *JIS Standards*[1]

C-1303 — High Insulation Resistance Meters

C-2110 — Testing Methods for Electric Strength of Solid Insulating Materials

C-2318 — Polyester Films for Electrical Purposes

P-8101 — Testing Method for Dissolving Pulp

Z-3282 — Soft Solder

4. Terminology

4.1 *camber* — Curvature of the tape strip edge.

4.2 *machine direction (MD) curl* — Curvature along the length of the tape.

4.3 *tranverse direction (TD) curl* — Transverse bowing of the tape.

4.4 *twist* — Angular rotation of one end of the tape with reference to the other end.

4.5 *wakame* — Waviness along the edge of the tape.

5. Ordering Information

5.1 The following items shall be included in purchase orders for tape which conforms to this standard:

5.1.1 Type of adhesive material

5.1.2 Type of base film

5.1.3 Width of adhesive material

5.1.4 Width of base film

5.1.5 Length of product

6. Requirements

6.1 *Structure of Polyimide Adhesive Tape Used in TCP* — Adhesive material is applied to polyimide film defined in Section 6.2. When necessary, a protective film may be used to stop adhesion of the adhesive material to the back of the tape to prevent contamination of the adhesive material, improve puncture characteristics, etc.

6.2 *Base Film Thickness and Width*

6.2.1 *Base Film Thickness (see Table 1)*

Table 1. Base Film Thickness

Thickness (μm)	*Tolerance (μm)*
50.0	± 4.0
75.0	± 5.0
125.0	± 8.0

For thicknesses other than those above, use nominal value thickness denoted in μm.

6.2.2 *Base Film Width (see Table 2)*

Table 2. Base Film Width

Width (mm)	*Tolerance (mm)*
34.975	± 0.10
48.175	± 0.10
69.95	± 0.10

For widths other than those above, use nominal value width denoted in mm.

6.3 *Adhesive Material Thickness and Width*

6.3.1 *Adhesive Material Thickness (see Table 3)*

1 Japanese Standards Association, 1-24, Akasaka 4 Chome, Minato-ku, Tokyo, Japan

Table 3. Adhesive Material Thickness

Center Thickness t/µm	*Tolerance/µm*
10.0 ≤ t < 14.0	± 2.0
14.0 ≤ t < 20.0	± 3.0

For thicknesses other than those above, use nominal value thickness denoted in µm.

6.3.2 *Adhesive Material Width (see Table 4)*

Table 4. Adhesive Material Width

Width/mm	*Tolerance/mm*
29.7	± 0.1
42.7	± 0.1
60.6	± 0.1
64.4	± 0.1

For widths other than those above, use nominal value width denoted in mm.

6.4 *Distance from Edge of Base Film to Edge of Adhesive Material (see Table 5)*

Table 5. Distance from Edge of Base Film to Edge of Adhesive Material

Base Film Width/mm	*Adhesive Material Width/mm*	*Distance/mm*
34.975	29.7	≥ 2.40
48.175	42.7	≥ 2.40
69.95	60.6	≥ 4.40
69.95	64.4	≥ 2.40

6.5 *Cover Film Type, Thickness and Width*

6.5.1 *Cover Film Thickness (see Table 6)*

Table 6. Cover Film Thickness

Thickness at Center/µm	*Tolerance/µm*
10.0–50.0	± 2.0

For thicknesses other than those above, use nominal value thickness denoted in µm.

6.5.2 *Cover Film Width* — Use the same measurements as found in Section 6.3.2.

6.6 *Adhesive Tape Thickness and Tolerance*

6.6.1 *Adhesive Tape Thickness* — Use the sum of the nominal thicknesses of the base film, adhesive material and cover film.

6.6.2 *Tolerance* — Use the sum of the nominal tolerances of the base film, adhesive material and cover film.

6.7 *Characteristics (see Table 7)*

Table 7. Characteristics of Adhesive Tape

Item	*Condition*	*Unit*	*Test Method*	*Value*
Copper Foil Adhesive Strength	Normal	N/cm	8.5.1 (a)	> 5
	Heated	N/cm	8.5.1 (b)	> 1
	Soaked in solvent	N/cm (see NOTE 3)	8.5.1 (c)	> 3
Cover Film Release Strength	Normal	N/cm	8.5.2	< 0.2
Insulation Resistance	Normal	Ω	8.6.3 (3)(a)	Not Specified
	In High Temp. High Humidity	Ω (see NOTE 4)	8.6.3 (3)(b)	Not Specified
	In High Temp. High Humidity, Under Bias	Ω (see NOTE 5)	8.6.3 (3)(c)	Not Specified
Volume Resistivity	Normal	Ω-cm	8.6.1	$> 10^{13}$
Surface Resistivity	Normal	Ω	8.6.2	$> 10^{10}$
Voltage Resistance	Normal	Ω	8.6.4	No Flash-over
Relative Permittivity	Normal	-	8.6.5	< 4.0
Dielectric Dissipation Factor	Normal	-	8.6.5	< 0.07
Solder Heat Resistance	Normal	-	8.7.1	No Delamination No Swelling
Heat Shrinkage	Normal	%	8.7.3	< 0.5
Coefficient of Thermal Expansion	-	cm/cm/°C	8.7.4	$< 3.0 \times 10^{-5}$
Tensile Strength	-	Mpa	8.7.5	> 100
Elongation	Normal	%	8.7.5	> 20
Water Absorption	Normal	%	8.7.2	< 4.0
Flammability	Normal	-	8.7.6	Not Specified

NOTE 1: *Normal Condition* — Normal condition refers to a temperature of 23 ± 5°C, and relative humidity of 55 ± 15%.

NOTE 2: *Heated Condition* — See Section 8.5.1, (3)(b).

NOTE 3: *Soaked in Solvent* — See Section 8.5.1, (3)(c).

NOTE 4: *High Temperature, High Humidity* — See Section 8.6.3, (3)(b).

NOTE 5: *High Temperature, High Humidity, Under Bias* — See Section 8.6.3, (3)(c).

6.8 *Appearance and Defects* — See Table 8. Width and thickness for the base film, adhesive material and cover film are not particularly specified.

Table 8. Appearance and Defects

Item	*Test Method*	*Unit*	*Value*
MD Curl	8.8.1	mm	< 15
TD Curl	8.8.2	mm	< 6
Wakame	8.8.3	Number/m	< 20 of < 2 mm, 0 of > 2 mm
Camber	8.8.4	mm/m	< 1
Twist	8.8.5	Degrees	< 135
Defect	8.8.6	#/m or #/100m	< 5/m between 0.1 mm^2 and 1mm^2 or, < 10/100 m of > 1 mm^2

7. Sampling

A sampling plan shall be defined between the user and supplier.

8. Test Methods

8.1 *Test Conditions*

8.1.1 *Normal* — Normal condition refers to a temperature of 23 ± 5°C, and relative humidity of 55 ± 15%.

8.2 *Materials*

8.2.1 *Material Preparation* — Unless otherwise specified, take the needed length of material from the inner part of the roll after peeling off the first three layers.

8.2.2 *Lamination* — Use the following steps to prepare materials which require lamination:

(1) *Material* — Unless otherwise specified, use a copper foil which has previously been decided upon by the user and supplier.

(2) *Lamination Method* — Unless otherwise specified, a method used shall be agreed between user and supplier.

(3) *Curing* — Unless otherwise specified, a method used shall be agreed between user and supplier.

8.2.3 *Etching* — For material which requires etching, unless otherwise specified, a method used shall be agreed between user and supplier.

8.2.4 *Plating* — For material which requires plating, unless otherwise specified, a method used shall be agreed between user and supplier.

8.2.5 *Test Pattern* — The pattern used in Figure 1 is recommended for the shape and dimensions of the test pattern. Where this is not applicable, a pattern used shall be agreed between user and supplier.

8.3 *Pre-Conditioning* — Unless otherwise specified, leave the sample materials in normal condition for 24 ± 4 hours.

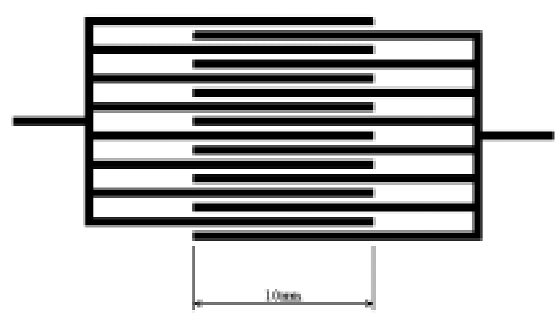

Figure 1
Test Pattern

Table 9. Test Pattern

Line Pitchs (µm)	*Line Widths (µm)*	*Line Spacings (µm)*
90	45	45
70	35	35
60	30	30
50	25	25
40	20	20

8.4 *Dimension Test Procedure*

8.4.1 *Thickness*

(1) *Equipment* — Use a micrometer standardized to JIS C-2318 or equivalent.

(2) *Material* — Use the TCP polyimide adhesive tape as received from the supplier.

(3) *Measurement* — Measure the center, and 3 points at least 1m apart in the MD direction, and calculate the average.

8.4.2 *Width*

(1) *Equipment* — Use a projector capable of reading a minimum of 0.001 mm integrals.

(2) *Material* — Use the TCP polyimide adhesive tape as received from the supplier.

(3) *Measurement* — Measure the TD direction length in 3 points at least 1m apart in the MD direction, and calculate the average.

8.5 *Mechanical Efficiency Tests*

8.5.1 *Copper Foil Adhesive Strength*

(1) Equipment

(a) A pull tester with an appropriate measurement range, having a tolerance of ± 5% of the indicated value, and capable of maintaining a cross-head speed of 10–50 mm/min.

(b) A pull tester with a sample retention heating device or sample chamber for retaining surface temperature for measuring conditions.

(2) Material

(a) *Normal* — Use a sample with copper etching and conductor width of 50 ± 10 µm and conductor length of more than 30 mm. The measurement direction and number of samples should be previously determined by the user and supplier. Unless otherwise specified, use 2 samples and measure in the MD direction.

(b) *Heated* — Use the same as (a), except with a conductor width of 2 ± 0.5 mm.

(3) Measurement

(a) *Normal* — After measuring the sample conductor width, fix the sample in the pull tester. In order to keep peeling angle at 90°, affix a reinforcement panel with double-sided adhesive tape. Pull and peel off more than 20 mm of copper foil at a speed of 10 mm/min^{-1} and an angle of 90 ± 5°. Measure the load during this interval.

(b) *Heated* — Fix the sample in retention heating device of the pull tester and raise the temperature, or, fix the sample in a previously retention heating device in the pull tester. It is also feasible to use a sample chamber which can heat the whole sample. Measure the sample surface temperature with a contact surface thermometer, and when a temperature of 150 ± 5°C is confirmed, quickly pull and peel off more than 20 mm of copper foil at a speed of 10 mm/min^{-1} and an angle of 90 ± 5°. Measure the load during this interval.

(c) *Soaked in Solvent* — After soaking the sample in a specified solvent at 23 ± 5°C for 5 minutes, remove the sample and rinse and dry off solvent thoroughly. Place in normal conditions, as described in Section 8.1.1, for 24 ± 4 hours and perform the same test as above "normal" (3)(a). However, if the solvent is inorganic, wash sample well with water after taking it out of the solvent and dry at 80 ± 5°C for 30 minutes. Then place in normal conditions, as described in Section 8.1.1, for 24 ± 4 hours and perform the same test as above "normal" (3)(a). The type and condition of the solvent used shall be agreed between the user and supplier.

(4) Calculation

(a) Compile the measurements, leaving out the overshoot at the beginning and end, and calculate the average of samples with a stable section of 10 mm. The method of calculating the average should be predetermined by the user and supplier. Unless otherwise specified, place a ruler over the chart and determine visually.

(b) Calculate the load on pulling and peeling off of each sample, excluding the samples conductor width, and the average will be the copper foil adhesive strength.

8.5.2 *Cover Film Release Strength*

(1) *Equipment* — Use the same equipment as in Section 8.5.1 (1).

(2) *Material* — Use a 250 mm section cut from the TCP polyimide adhesive tape as received from the vendor.

(3) *Measurement* — After measuring the sample cover film width, fix the sample in the pull tester. In order to keep the sample at 90°, affix a reinforcement panel with double-sided adhesive tape. Pull and peel off more than 50 mm of cover film at a speed of 50 mm/min^{-1} and an angle of 90 ± 5°. Measure the load during this interval.

(4) *Calculation* — Use the same method as Section 8.5.1, (4).

8.6 *Electrical Efficiency Test*

8.6.1 *Volume Resistivity*

(1) *Equipment* — Use high insulation-resistance meter which conforms to JIS C-1303, or similar resistance measuring device (see Figure 2).

(2) *Material* — Prepare a section of TCP polyimide adhesive tape with adhesive material width of more than 50 mm, laminate with copper foil and cure according to the method described in Section 8.2. In addition, etch the main electrode and guard electrode into the shapes found in Figure 3. For the counter electrode, melt on a conductive material to the opposing polyimide film surface, or form it out of conductive paste. Dry these at 80 ± 5°C for 30 minutes. Cut these into 50 mm squares for the material.

(3) *Measurement* — Use the following steps to measure under normal conditions: Measure the thickness of the samples in units of 0.1 µm, and measure the inner diameter of the gap in the circular upper electrode in units of 0.05 mm. Apply direct voltage of 500V ± 5V, and measure the resistance value after 1 minute.

(4) *Calculation* — Use the equation below.

$$\rho v = Rv \times \frac{\pi D_1}{4t} (\Omega / cm)$$

Where ρv is volume resistivity, Rv is resistance value, t is sample thickness, π is pi, and D_1 is main electrode outer diameter.

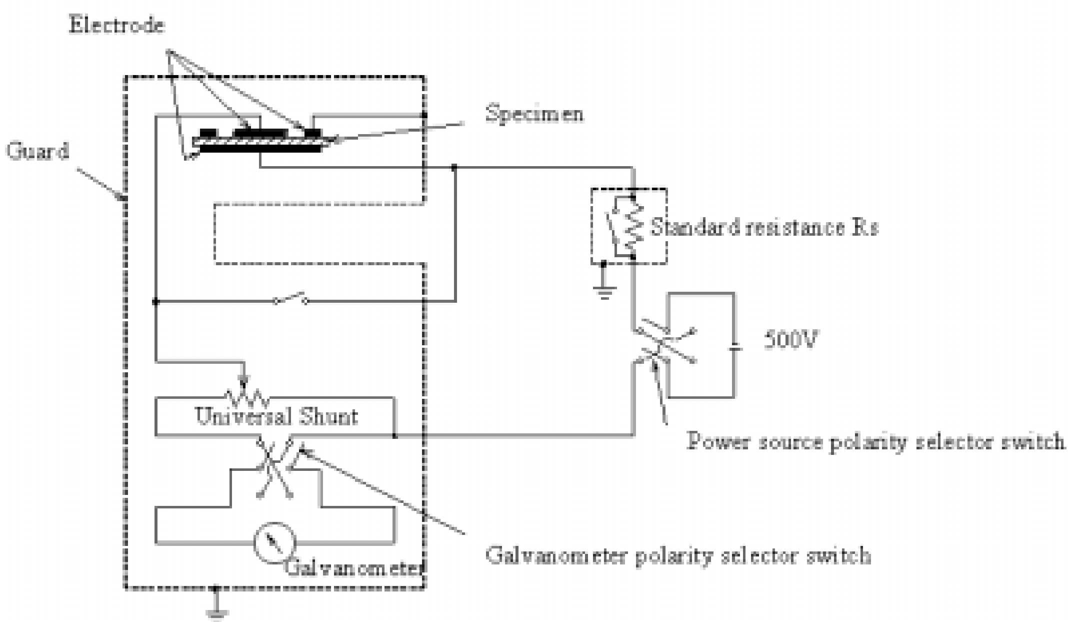

Figure 2
Resistance Measurement Device for Volume Resistivity

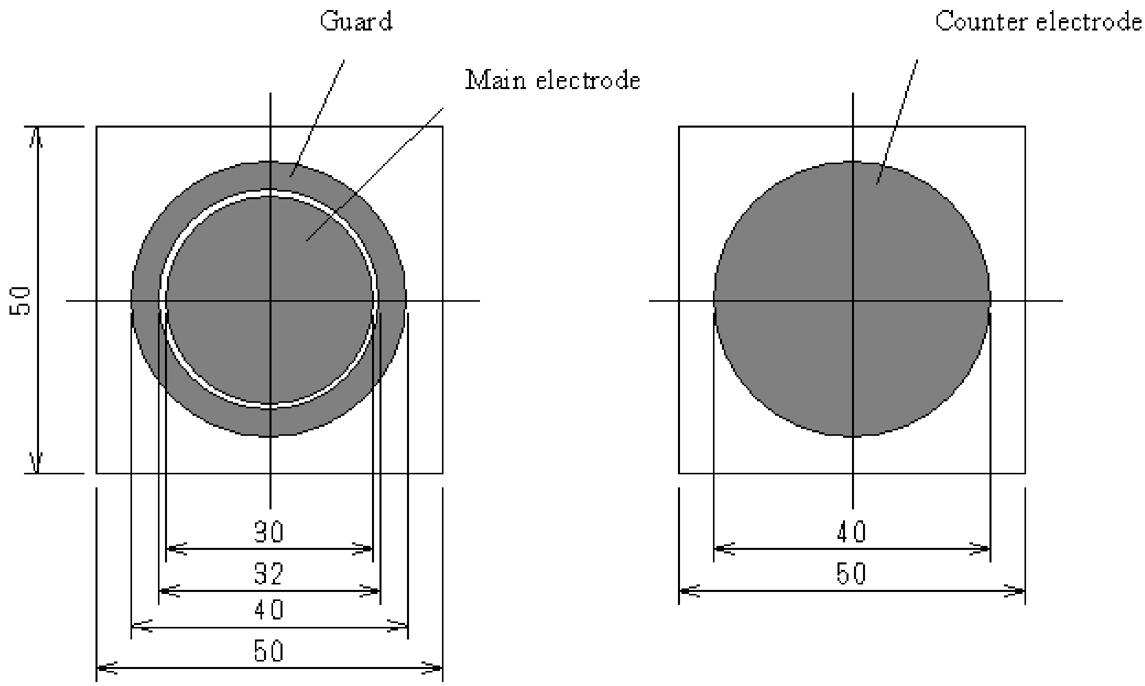

Figure 3
Electrodes for Measurement of Volume Resistivity

8.6.2 *Surface Resistivity*

(1) *Equipment* — Use the same equipment as in Section 8.6.1.

(2) *Material* — Use the same material as in Section 8.6.1.

(3) *Measurement* — To measure Surface Resistance in normal conditions, use the same method as described in Section 8.6.1.

(4) *Calculation* — Use the equation below.

$$\rho s = Rs \times \frac{P}{D_0} (\Omega)$$

Where ρs is Surface Resistance, Rs is resistance value, P is the actual circumference length of the guarded electrode, and D_0 is the distance between the main electrode and the guard electrode.

8.6.3 *Insulation Resistance*

(1) Equipment

(a) *Resistance Meter* — Use the same equipment as in Section 8.6.2.

(b) *Direct Current* — Use a stabilized direct power supply that can apply a stable 100 ± 5V to the sample.

(c) *Environmental Test Chamber* — Use an oven with terminal connectors on the outside which can maintain humidity at 30–85 ± 5°C and 60–90 ± 5% R.H.

(2) *Material* — Using the TCP polyimide adhesive tape as received from the vendor, laminate and cure it according to the method described in Section 8.2.

(3) Measurement

(a) *Normal Condition* — Apply direct voltage of 100 ± 5V to the sample and maintain for 1 minute. Keeping the voltage applied, measure the insulation resistance.

(b) *High Temperature, High Humidity* — After keeping the sample under 85 ±

5°C and 85 ± 5% R.H. for 24 ± 4 hours, perform the same measurement as in Section 8.6.3, (3)(a).

(c) *High Temperature, High Humidity, Under Bias* — After keeping the sample under 85 ± 5°C and 85 ± 5% R.H. for 24 ± 4 hours, apply direct voltage of 100 ± 5V and perform the same measurement as in Section 8.6.3, (3)(a). After this, follow the methods and conditions defined by the receiving parties.

8.6.4 *Inter-Layer Voltage Resistance*

(1) *Equipment* — Use the equipment which conforms to JIS C-2110, Section 6.2 or similar.

(2) *Material* — Use the same material prepared by the same method as in Section 8.6.1, (2).

(3) *Measurement* — To measure in normal conditions, perform the following steps: Using DC voltage, or a sine wave AC with 50 or 60 Hz frequency, apply 500V to the sample. Increase the applied voltage up to the defined voltage over 5 seconds, maintain it for 1 minute and determine whether there has been any mechanical damage, flash-over, spark-over, insulation breakdown or other abnormality.

8.6.5 *Relative Permittivity and Dielectric Dissipation Factor*

(1) Equipment

(a) *Power Source (see Figure 4 - S)* — Use a source which can emit a frequency of 1 MHz, has a sine wave with less than 5% distortion factor, can give a stable flow of the define voltage to the sample, and have electro-static and magnetic shielding to prevent direct coupling between the power source and bridge.

(b) *Shielded Transformer (see Figure 4 - T_1)* — Use a transformer with which the power source internal impedance and the bridge impedance can be adjusted, and one where the winding on the bridge inside the transformer is shielded with a grounded conductor.

(c) *Ratio Arm (see Figure 4 - T_2)* — Use a ratio arm with a winding ratio of 1:1 (tolerance of less than 0.2%). Make a non-inductive connection of the primary winding and secondary winding of a transformer with as little leakage inductance and winding resistance. Ground the connection point as shown in Figure 4 - e, and connect the other 2 terminals to l and r to make it unbalanced.

(d) *Variable Capacitor (see Figure 4 - Cs_1, Cs_2)* — Use two air capacitors with guards that have a capacity of approximately 200 pF, one being the standard capacitor Cs_1 and the other being the measuring capacitor Cs_2, and insert parallel with the sample Cx.

(e) *Conductance Shifter (see Figure 4 - g)* — Insert a resistor with a constant conductance in between m and d in Figure 4, where the resistance between l and m can be changed between 100–0 Ω, and the resistance between m and r can be changed between 100–200 Ω.

(f) *Balance Detector (see Figure 4 - g)* — Use a balance detector which responds only to the power source voltage base plate used in the bridge.

(2) *Material* — Prepare the samples according to the method described in Section 8.6.1, (3). Use Figure 3 for the shape of the electrode.

(3) *Measurement* — Use the following to measure under normal conditions: Measure the thickness of the samples in units of 1 μm, and measure the inner diameter of the gap in the circular upper electrode in units of 0.05 mm. Also, confirm that the circular gap between the main electrode and the guard electrode is 1 ± 0.1 mm. Connect the sample at position Cx, and by adjusting the measuring capacitor Cs_2 and the conductance shifter, with the bridge balanced, measure the standard capacitor Cs_1 value and the measuring capacitor Cs_2 value, the resistance value between conductance shifter m and d, and the resistance value between m and r. The measuring frequency is 1 MHz.

(4) *Calculation* — Use the equation below.

(a) Relative Permittivity

$$\varepsilon r = \frac{Cx}{C_0}(\Omega)$$

Where Cx is the difference in the capacitance values of standard capacitor Cs_1 and measuring capacitor Cs_2 (when the bridge is balanced, and C_0 is the electrostatic capacity where εr = 1 calculated from the main electrode area and sample thickness according to the following formula):

$$C_0 = \frac{r^2}{3.6t}$$

(b) Dielectric Dissipation Factor

$$\tan\delta = \frac{Gx}{2\pi f Cx}$$

$$Gx = G \times \frac{S}{100}$$

Where Gx is the sample conductance, G is the conductance between m and d, S is the resistance value between m and r, S/100 is the resistance factor, f is the measuring frequency, and π is pi.

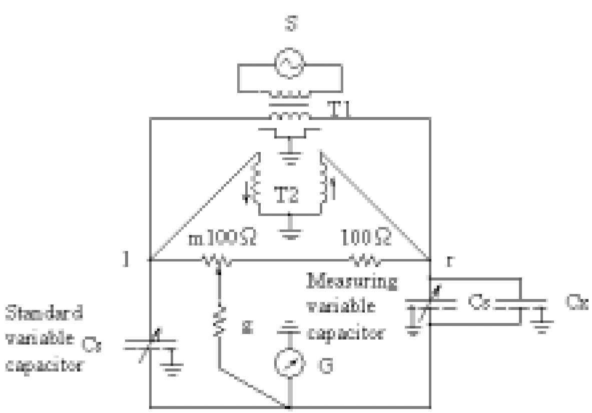

Figure 4
Measurement Circuit for Relative Permittivity and Dielectric Dissipation Factor

8.7 *Other Tests*

8.7.1 *Heat Resistance*

(1) Equipment

(a) *Solder* — Use Standard H60A or H63A under JIS Z-3282.

(b) *Solder Bath* — A vessel with a depth of more than 50 mm to hold the solder at between 200–300°C and can be adjusted ± 3°C.

(1) *Material* — Using the TCP polyimide adhesive tape as received from the vendor, laminate and cure it according to the method described in Section 8.2. Cut into 25 mm squares for samples.

(2) *Preparation* — Keep in 105 ± 5°C oven for 1 hour.

(3) *Test* — After preparation, quickly place in 260 ± 5°C solder bath and let float for 5^{+1}_{-0} seconds. Perform visual check for swelling.

8.7.2 *Water Absorption Test*

(1) Equipment

(a) *Scale* — Use a scale that can measure in 1 mg units.

(b) *Vessel* — Use a vessel in which the samples can be totally immersed.

(c) *Dessicator* — Use a dessicator which allows samples heated to 80°C to cool off.

(1) *Material* — Using the TCP polyimide adhesive tape as received from the vendor, laminate and cure it according to the method described in Section 8.2. In addition, remove all copper foil by etching, and dry for 30 minutes at 80 ± 5°C. Cool in the dessicator, and use samples cut into length 500 ± 5 mm, and width 20 ± 1 mm. Depending on the shape of the vessel to be used for immersion, it is feasible to several pieces of a suitable length.

(2) *Test* — Weigh the sample in increments of 1 mg. Place sample in 23 ± 2°C distilled water. After 24 ± 1 hours, wipe off water and measure sample again in increments of 1 mg.

(3) *Calculation* — Use the following formula:

$$\frac{W_2 - W_1}{W_2} \times 100 \qquad (\%)$$

Where W_1 and W_2 are the weight before and after immersion respectively.

8.7.3 *Heat Shrinkage* — Use the standard value of the base film and the various values for measuring conditions.

(1) *Equipment* — Use a measuring device with optical equipment which can read with at least 5/100,000 (0.005%) precision.

(2) *Material* — Mark three places along the width on a sample with size larger than 50 mm square.

(3) *Preparation* — Place for more than 1 hour in a managed environment of room temperature ± 2°C, ± 5% R.H.

(4) *Measuring Method Before Heating* — Measure the distance between the marks with the equipment (1) on a sample that has been prepared according to (3) above.

(5) *Heating* — Keep the samples in an oven at 200 ± 3°C for more than an hour, making sure that it is not effected from the outside.

(6) *After-Processing* — Leave sample for more than 1 hour in the conditions described in (3) above.

(7) *Measuring Method After Heating* — Use the same method as (4) above.

(8) *Calculation* — Use the following formula, where L_1 is the dimension from (4), and L_2 is the dimension from (7):

$$\frac{L_1 - L_2}{L_1} \times 100 \qquad (\%)$$

8.7.4 *Coefficient of Thermal Expansion* — Use the standard value of the base film and the various values for measuring conditions.

(1) *Equipment* — Use TMA equipment.

(2) *Material* — Prepare sample with width of 3 mm and length of more than 15 mm.

(3) *Preparation* — To remove the effects of thermal shrinkage and moisture, heat at more than 300°C for 30 minutes.

(4) *Measuring Method* — With a sample that has been prepared according to (3) above, measure the stretching in the sample on a TMA, in the range between room temperature and 300°C, raising the temperature at less than 20°C/min.

(5) *Calculation* — Use the following formula, reading a gradient from an arbitrary scope, within the area between room temperature and 200°C (i.e., 50–200°C, 100–200°C):

$$\frac{L_1 - L_0}{L_0 (T_1 - T_0)} \times 100^{6} \qquad (ppm)$$

Where T_0 and T_1 are the temperatures in the area for Linear Expansion, L_0 is the length of the sample at T_0 (°C) and L_1 is the length of the sample at T_1 (°C).

8.7.5 *Tensile Strength, Elongation* — Use the standard value of the base film and the various values for measuring conditions.

(1) *Equipment* — Use a pull strength meter and recorder.

(2) *Material* — Use samples with a width of more than 10 mm and length of approximately 200 mm. The samples should be 3 pieces taken from the beginning, middle and end of the roll.

(3) *Measuring Method* — After measuring the width of the sample, fix it in the pull strength meter. Use a clamping distance of approximately 100 mm to test pull strength. Measure the pull load and stretch at point of breakage.

(4) *Calculation* — After measuring the pull strength and elasticity of each sample, calculate the average of each.

8.7.6 *Flammability*

(1) Equipment

(a) Sample box or draft chamber which can maintain calm conditions.

(b) Test stand and clamp.

(c) Bunsen burner with pipe length of approximately 100 mm, aperture diameter of 9.5 ± 0.5 mm, using methane gas or natural gas with a heat generation volume of approximately 37 MJ/m^3.

(d) Stop-watch or timer.

(e) Sheet of absorbent cotton 50 mm square with a maximum natural thickness of 6.4 mm.

(f) A dessicator with dehydrated hydrated calcium.

(g) A test oven which can maintain a temperature of 23 ± 2°C and R.H. of 50 ± 5%.

(h) A test oven which can maintain a temperature of 70 ± 1°C.

(i) A pole with a diameter of 13 ± 5 mm.

(2) *Material* — Using the TCP polyimide adhesive tape as received from the vendor, laminate and cure it according to the method described in Section 8.2. In addition, remove all copper foil by etching, and dry for 30 minutes at 80 ± 5°C. As shown in Figure 5, use a sample with a length of 200 mm and width of 50 mm, and mark a line in the TD direction at 125 mm from the bottom. With the mark line facing outward, wrap the sample around the pole and hold in place with tape within 76 mm about the mark line. Remove the pole to leave a tube of the sample. Prepare 2 groups of 5 pieces each.

(3) *Preparation* — Leave one group of samples in normal condition for 48 hours. Heat the other group at 70 ± 1°C for 168 hours, place them in the dessicator with dehydrated hydrated calcium and keep for more than 4 hours at 23°C.

(4) *Test* — Perform the following test on the two groups of samples prepared as described in Section 8.7.6, (3) above:

(a) As shown in Figure 6, fix the sample perpendicular in the ring stand with the clamps, with the tip of the burner 10 mm below the edge of the sample, and the absorbent cotton placed horizontal at 300 mm below the edge.

(b) Light the burner away from the sample, and adjust to a blue flame of 20 ± 1 mm long. Keeping the length at 20 ± 1 mm, make sure there is no yellow flame at the tip.

(c) Apply the flame to the center of the edge of the sample for 3 seconds. Then remove the flame to more than 150 mm away, and record the flaming time. When the flame burns out, apply the flame to the edge of the sample for 3 seconds and pull away again. Measure the flaming time it takes to reach the clamp as well as the glowing time. Also, record whether the absorbent cotton has caught fire or not. When there are molten particles or burning material drippings from the sample, it is acceptable to tip the burner 45° and move the flame from the bottom edge to avoid material dripping on the burner. In this case, the distance from the bottom edge of the sample to the tip of the burner should still be 10 mm.

(5) Items to Record

(a) Flaming time after the first and second application.

(b) Sum of flaming and glowing time after second application.

(c) Flaming or glowing up to the clamp or mark line.

(d) Existence of dripping material which caused the absorbent cotton to burn.

8.8 *Test for External Defects*

8.8.1 *MD Curl*

(1) *Equipment* — Use a scale that measures at least 1 mm increments.

(2) *Material* — Cut a section of more than 30 cm, but less than 100 cm in length of TCP polyimide adhesive tape as received.

(3) Measurement — As shown in Figure 7, remove the cover film, place on a flat surface for more than 12 hours and measure the highest point on the tape from the flat surface in the MD direction.

8.8.2 *TD Curl*

(1) Equipment

(a) A scale that measures at least 1 mm increments.

(b) A square block with a base with a length of more than 15 cm and width of 2 cm, and a weight of more than 500 g.

(2) *Material* — Cut a section of more than 15 cm, but less than 30 cm in length of TCP polyimide adhesive tape as received.

(3) Measurement

(a) Remove the cover film and place on a flat surface for more than 12 hours.

(b) Use the block to hold down the sample tape on the edge without adhesive. The space held down should be more than 2 mm in from the edge, but before the adhesive material.

(c) As shown in Figure 8, on the opposite side of the tape for the block, measure the highest point from the flat surface.

8.8.3 *Wakame*

(1) *Equipment* — Use a scale that measures at least 1 mm increments.

(2) *Material* — Cut a section of more than 30 cm, but less than 100 cm in length of TCP polyimide adhesive tape as received.

(3) *Measurement* — As shown in Figure 9, place on a flat surface for more than 12 hours and calculate the number of points off the flat surface less than 2 mm high.

8.8.4 *Camber*

(1) *Equipment* — Use a scale that measures at least 1 mm increments.

(2) *Material* — Cut a section of more than 30 cm, but less than 100 cm in length of TCP polyimide adhesive tape as received.

(3) *Measurement* — As shown in Figure 10, connect corners of the tape in a straight line, and measure the deviation from the line to the edge of the tape at the center.

8.8.5 *Twist*

(1) *Equipment* — Use a protractor that measures at least 1 degree increments.

(2) *Material* — Cut a section of 1 meter in length of TCP polyimide adhesive tape as received.

(3) *Measurement* — Hang the tape vertically and measure the angle of twist of the bottom edge as opposed to the top edge.

8.8.6 *Defects*

(1) *Equipment* — Use a 10 power magnifying glass or naked eye.

(2) *Material* — Use TCP polyimide adhesive tape as received. The length should be determined between the user and supplier.

(3) *Measurement* — Perform a check on defects against a limit sample determined by the user and supplier. Unless otherwise specified, the "Admixture Measurement Table" from the JIS P-8101 standard (Finance Ministry Printing Press) is recommended.

9. Product Labeling

Note the following items on the product label:

(1) Type Name

(2) Product Width

(3) Product Length

(4) Lot Number

10. Packing and Package Labeling

10.1 *Packing* — Pack the product with sufficient packing material to prevent any effects from external impact, moisture, etc.

10.2 *Package Label* — Note the following items on the packaging label:

(1) Product Name

(2) Type Name

(3) Manufacturer's Name

(4) Product Width

(5) Product Length

(6) Lot Number

(7) Storage Conditions

11. Related Documents

11.1 *JIS Standards*

C-6471 — Test Method of Copper-Clad Laminates Flexible Printed Wiring Boards

K-6911 — Testing Methods for Thermosetting Plastics

K-7209 — Testing Methods for Water and Boiling Water Absorption of Plastics

P-8145 — Testing Method of Dirt in Paper and Paperboard

P-8208 — Method of Testing Dirt, Sheaves and Specks of Paper Pulp

11.2 *ASTM Standards*[2]

D-150 — Standard Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials

D-257 — Standard Test Methods for D-C Resistance or Conductance of Insulating Materials

D-570 — Standard Test Methods for Water Absorption of Plastics

D-638 — Test for Tensile Properties of Plastics

D-1825 — Standard Practice for Etching and Cleaning Copper-Clad Electrical Insulating Materials and Thermosetting Laminates for Electrical Testing

11.3 *IEC Standards*[3]

249-1 — Base Materials for Printed Circuits, Part 1: Test Methods

326-2 — Printed Boards, Part 2: Test Methods

674-2 — Specification for Plastic Films for Electrical Purposes, Part 2: Method of Test

11.4 *UL Standard*[4]

94-1991 — Standard for Flammability Tests of Plastic Materials for Parts in Devices and Appliances

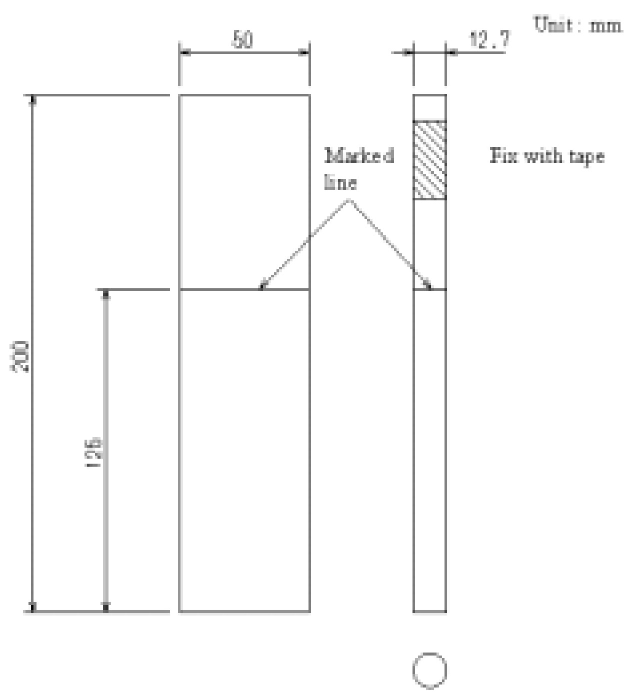

Figure 5
Test Specimen for Flammability

2 American Society for Testing Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959

3 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland

4 Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062-2096

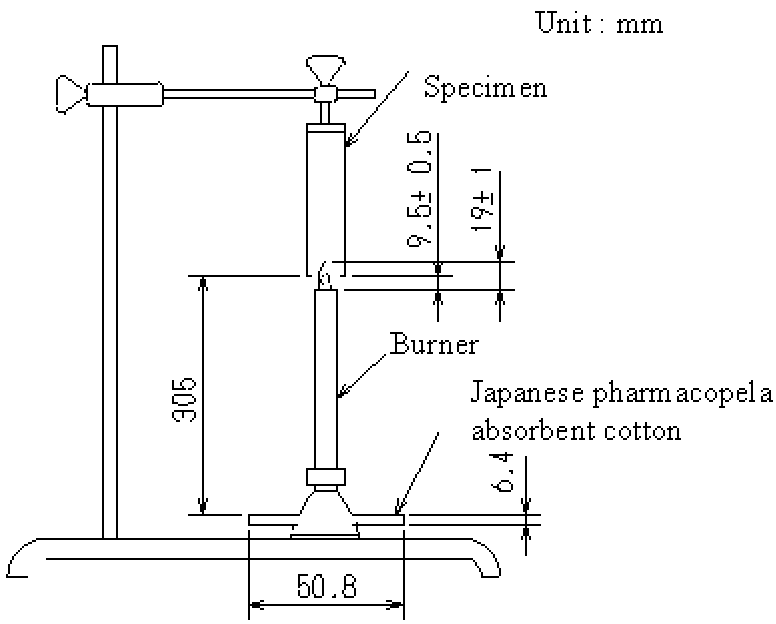

Figure 6
Measurement of Flammability

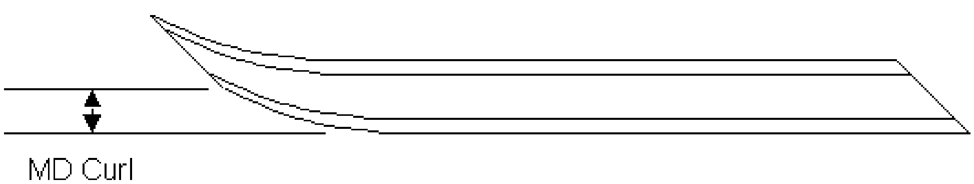

Figure 7
MD Curl

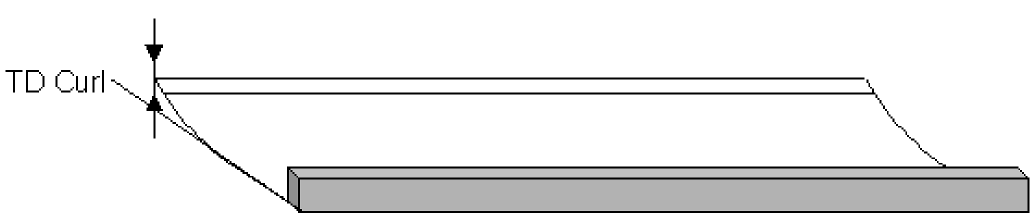

Figure 8
TD Curl

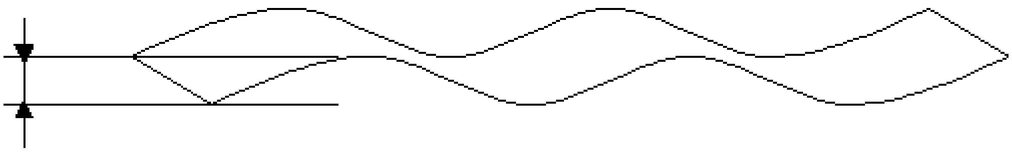

Figure 9
Wakame

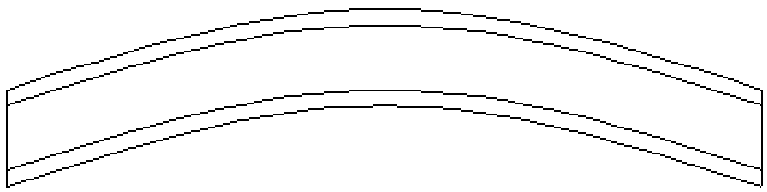

Figure 10
Camber

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

NOTES

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SEMI G77-0699
SPECIFICATION FOR FRAME CASSETTE FOR 300 MM WAFERS

This test method was technically approved by the Global Assembly & Packaging Committee and is the direct responsibility of the Japanese Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on March 17, 1999. Initially available at www.semi.org May 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this document is to specify the mechanical features for a 300 mm wafer frame cassette used between the wafer mounting process and the die-bonding process.

2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces.

2.2 Only the physical interfaces for the frame cassette are specified; no materials requirements or micro-contamination limits are given. However, this specification was written to allow for both metal and plastic frame cassette designs.

2.3 This specification defines a 300 mm wafer frame cassette that is intended for both manual and automated transport. The frame cassette has the following components and sub-components (“ ” indicates an optional component):

2.3.1 Top

robotic handling flange (optional)

- top cover

2.3.2 Interior

- frame supports for 13 or 25 tape frames
- frame restraint

2.3.3 Sides

human handles (optional)

2.3.4 Rear

- rear cover

2.3.5 Bottom

- 2 bottom conveyor rails running along the sides of the frame cassette

3 features that mate with kinematic coupling pins and provide a 10 mm lead-in (optional)

4 frame cassette sending pads (optional)

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Provisional Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI G74 — Specification for Tape Frame for 300 mm Wafers

SEMI S8 — Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

4 Terminology

4.1 *bilaterial datum plane* — a vertical plane that bisects the tape frames and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.2 *conveyor rails* — parallel surfaces on the bottom of the cassette for supporting the cassette on roller conveyors.

4.3 *facial datum plane* — a vertical plane that bisects the tape frames and that is parallel to the front side of the frame cassette (where tape frames are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the frame cassette is loaded and unloaded (as defined in SEMI E57).

4.4 *frame cassette* — an open structure that holds one or more tape frames.

4.5 *horizontal datum plane* — a horizontal plane from which projects the kinematic coupling pins on which the frame cassette sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.6 *robotic handling flange* — horizontal projection on the top of the frame cassette for lifting and rotating the frame cassette.

4.7 *tape frame* — the frame which applies the wafer tape to the wafer and retains the wafer.

4.8 *wafer tape* — an adhesive plastic tape which retains the wafer or diced chip. It is used between the mounting process and die-bonding process.

5 Ordering Information

5.1 *Intended use* — This document is intended to specify 300 mm wafer frame cassettes over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser needs to specify a time period as well as the number and type of uses to which the frame cassettes will be put. It is under these conditions that the frame cassettes must remain in compliance with the requirements listed in Section 6.

6 Requirements

6.1 *Dimensions* — The frame cassette dimensions are shown in Figures 1 through 5 and listed in Table 1. In all figures, the heaviest lines are used for surfaces that have tolerances (not surfaces that have only maximum or only minimum dimensions).

6.2 *Tape Frame Orientation* — The tape frames must be horizontal when the frame cassette is placed on the load port.

6.3 *Center of Tape Frames* — When a tape frame is stored in the frame cassette, the center of the tape frame should be within the radius of 2 mm from the center of the junction of the bilaterial datum plane and the facial datum plane.

6.4 *Top and Rear Covers* — Both top and rear covers are required. With the covers in place, the frame cassette must conform to all dimensions listed in Table 1.

6.5 *Number of Slots* — The frame cassette has an option of either 13 or 25 slots.

6.6 *Kinematic Couplings (optional)* — The physical alignment mechanism from the frame cassette to the tool load port (or a nest on a vehicle or in a stocker) consists of features (not specified in this document) on the top entity that mate with three or six pins underneath as defined in SEMI E57. Most of the dimensions of the frame cassette are determined with respect to the three orthogonal datum planes defined in that standard: the Horizontal Datum Plane, the facial datum plane, and the bilateral datum plane.

6.6.1 The three features that mate with the pins must provide a lead-in capability that corrects a frame cassette misalignment of up to 10 mm in any horizontal direction, although 15 mm is recommended for ergonomic reasons. However, it is recommended that robotics placing cassettes on kinematic couplings use as little of this lead-in capability as possible to avoid wear.

6.7 *Human Handles (optional)* — All handles for use by humans must either be contained within the maximum outer dimensions of the frame cassette, be detached when not in use, or be retractable into the maximum outer dimensions when not in use. Handles for use by humans (if present) must follow SEMI S8 and shall require the use of both hands (each using a full wrap-around grip, given the minimum clearance requirement in SEMI E15.1). Automation handling features shall not be considered for dual purpose unless they are designed to meet SEMI S8.

6.8 *Robotic Handling Flange (optional)* — On the top of the frame cassette is an optional robotic handling flange for manipulating the frame cassette.

6.9 *Bottom Rails* — On the bottom of the frame cassette are two rails, one on each side for use with roller conveyors.

6.10 *Frame Restraint* — The frame cassette must provide a feature that prevents tape frames from slipping out of the cassette during transport. The feature must conform to all dimensions listed in Table 1.

6.11 *Frame Cassette Sensing Pads (optional)* — When the cassette is fully down, the frame cassette sensing pads (see Figure 5) must be z2 above the horizontal datum plane. It is recommended that the areas surrounding all of the frame cassette sensing pads be designed in conjunction with the features that mate with the kinematic coupling pins so that a mechanical sensor pin cannot interfere with the lead-in function of the kinematic couplings.

6.12 *Cassette Stacking (optional)* — The frame cassette may have optional features to allow two 13 capacity cassettes to be stacked on top of each other. This option is only available for cassettes without a robotic handling flange.

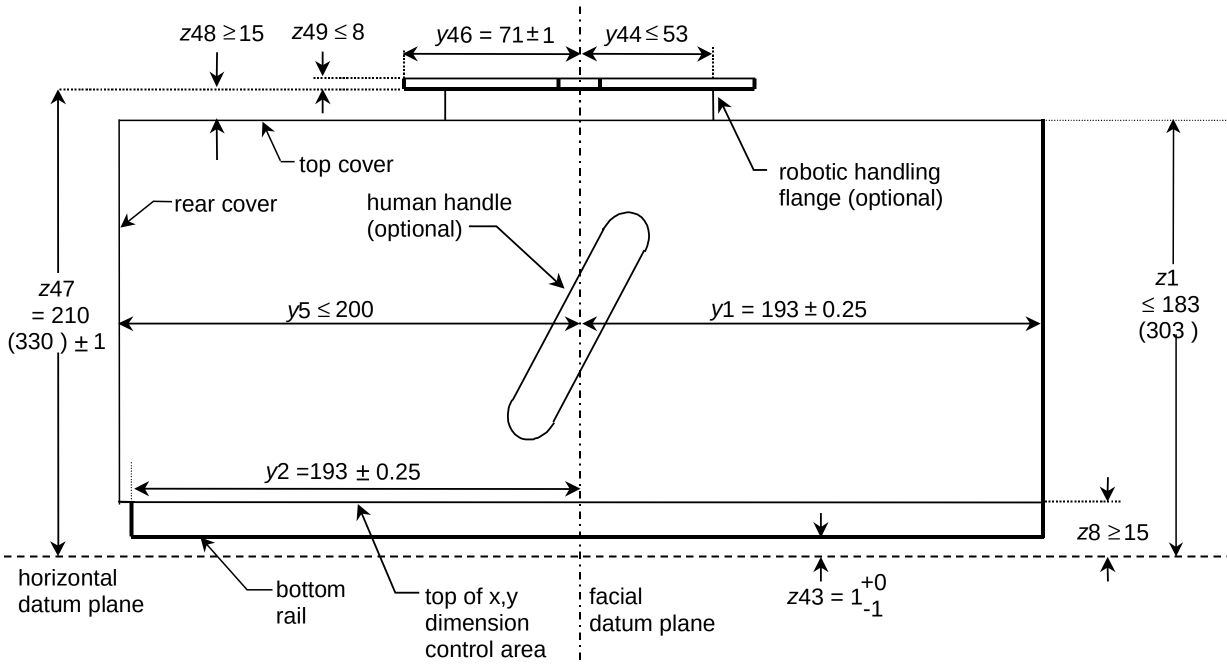

Figure 1

Side View of Frame Cassette

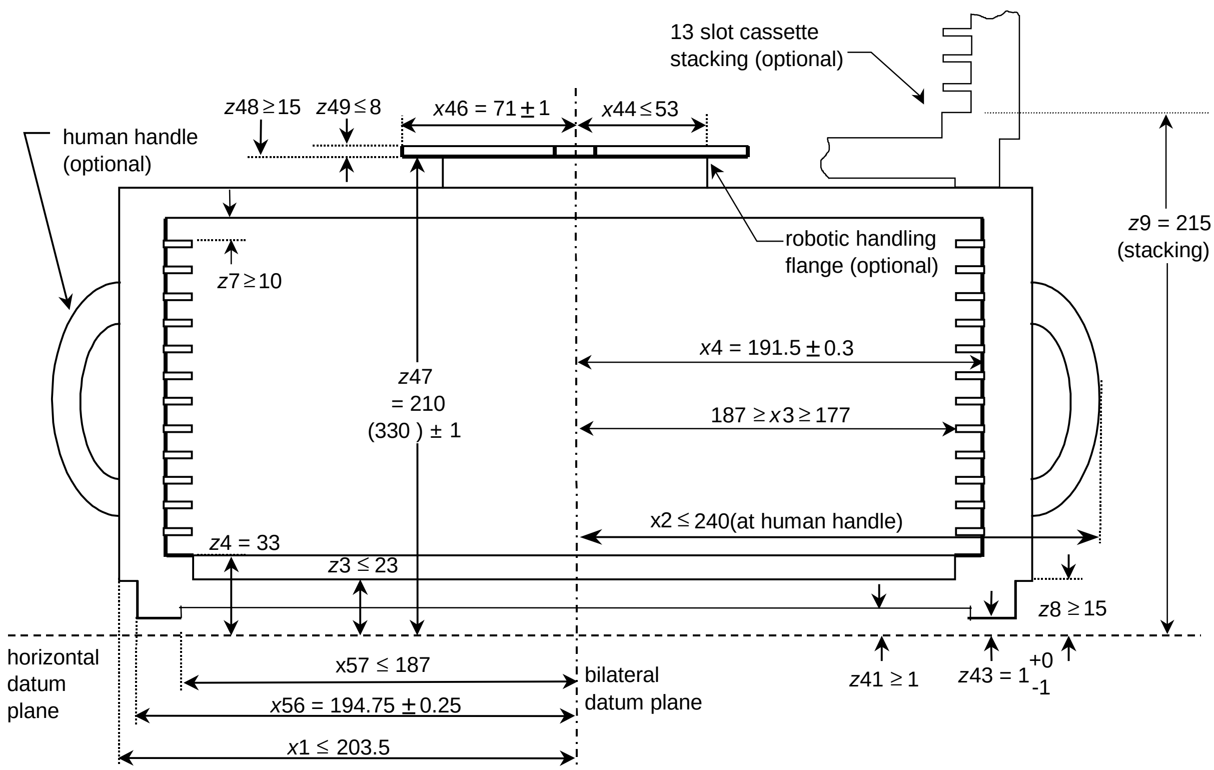

Figure 2

Front View of Frame Cassette

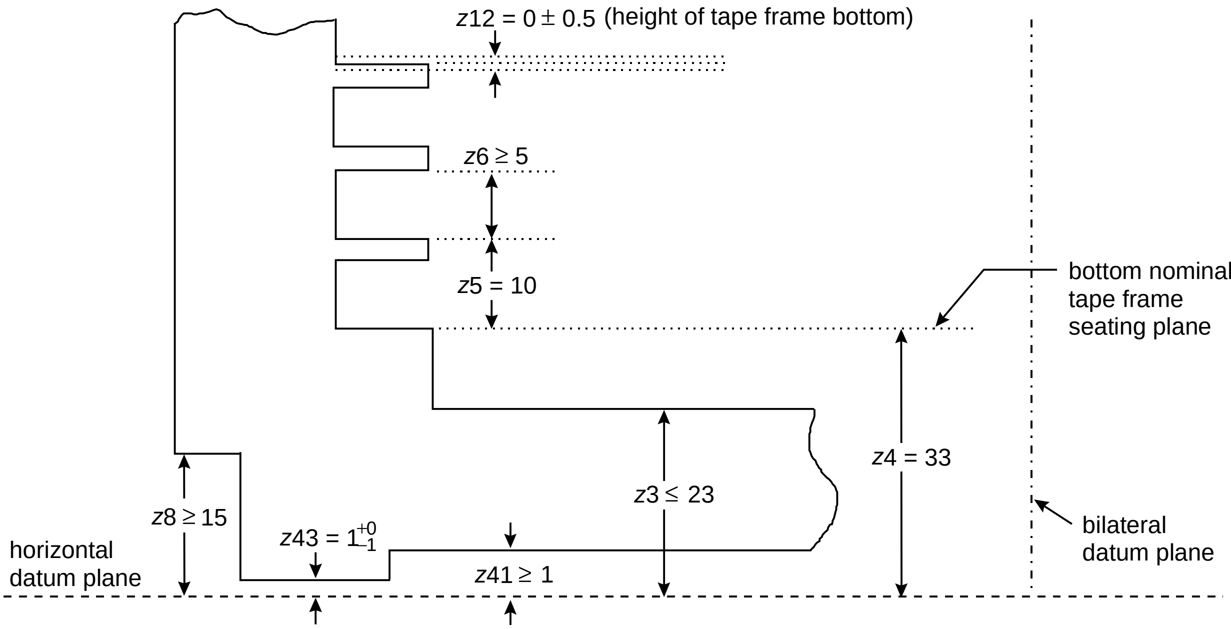

Figure 3

Detail of Film Frame Supports

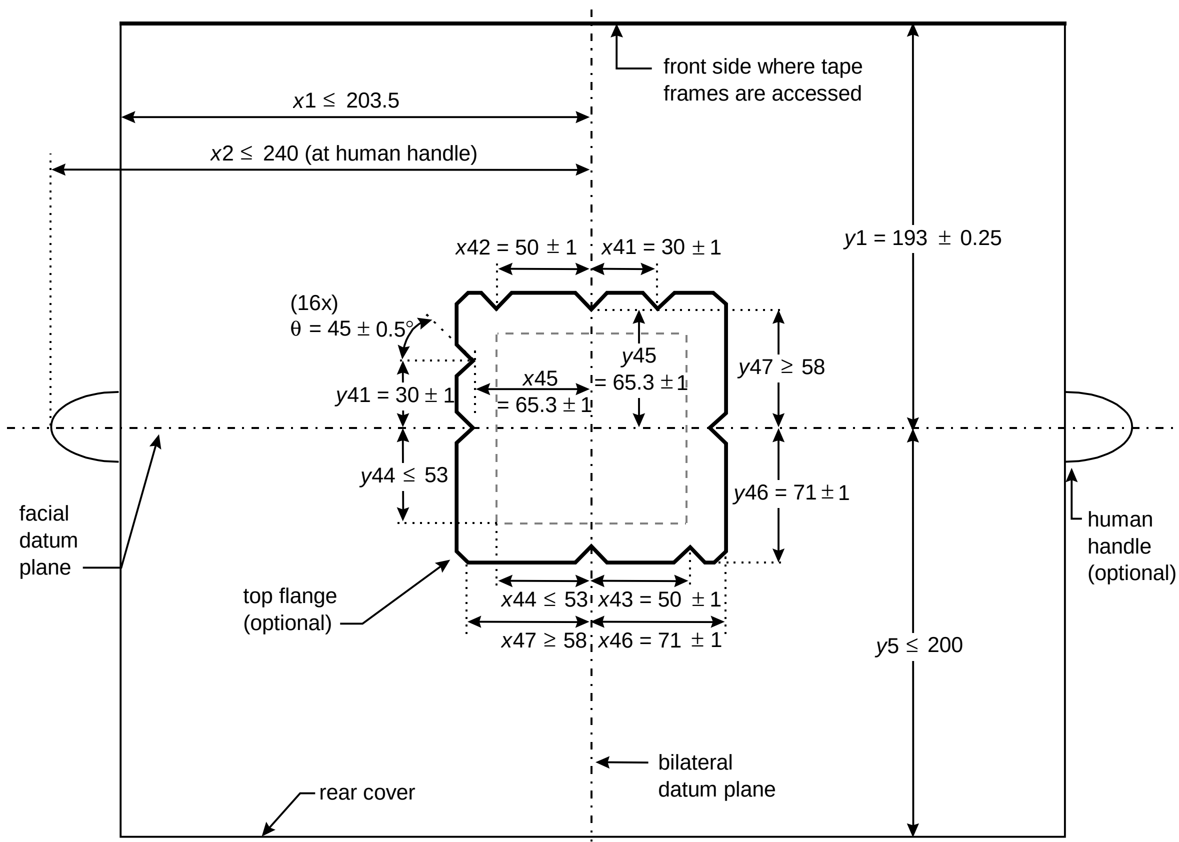

Figure 4

Top View of Frame Cassette

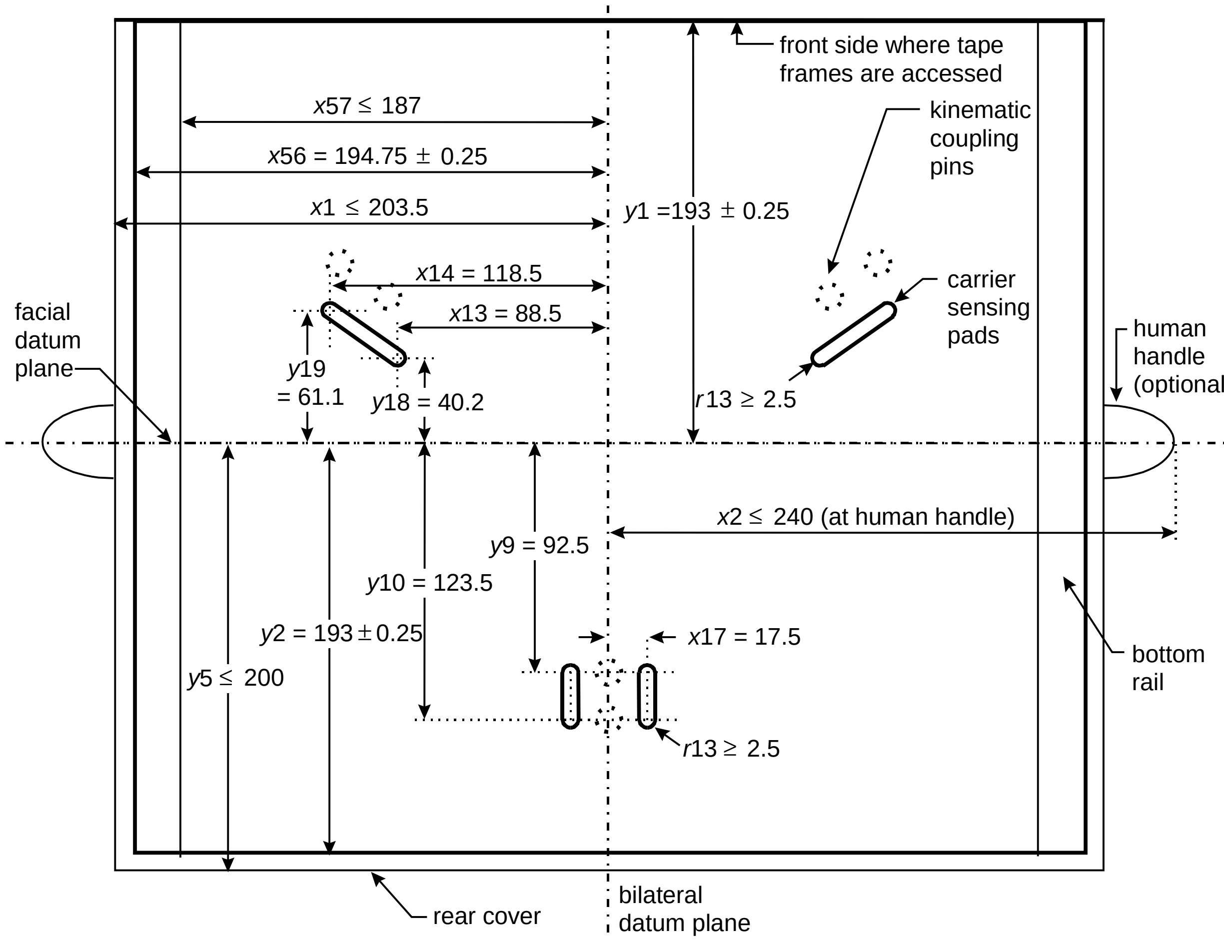

Figure 5

Bottom View of Frame Cassette

Table 1 Dimensions for Frame Cassette

Symbol	*Value Specified*	*Datum Measured From*	*Feature Measured To*
θ‡	45 ± 0.5°	either vertical datum plane	sides of position and orientation notches
*r*13†	2.5 mm 2.6 minimum	line segment along center of cassette sensing pad	edge of cassette sensing pad
*x*1	203.5 mm maximum	bilateral datum plane	outer surface of frame cassette (without handles)
*x*2	240 mm maximum	bilateral datum plane	furthest reach of human handles
*x*3	177 mm minimum 187 mm maximum	bilateral datum plane	inside edge of tape frame support
*x*4	191.5 ± 0.3 mm	bilateral datum plane	inside wall of frame cassette
*x*13†	88.5 mm	bilateral datum plane	near end of line segment along center of front cassette sensing pads
*x*14†	118.5 mm	bilateral datum plane	far end of line segment along center of front cassette sensing pads
*x*17†	17.5 mm	bilateral datum plane	line segment along center of rear cassette sensing pads
*x*41‡	30 ± 1 mm	bilateral datum plane	front right orientation notch on robotic handling flange
*x*42‡	50 ± 1 mm	bilateral datum plane	front left orientation notch on robotic handling flange
*x*43‡	50 ± 1 mm	bilateral datum plane	rear orientation notch on robotic handling flange
*x*44‡	53 mm maximum	bilateral datum plane	encroachment of box underneath robotic handling flange
*x*45‡	65.3 ± 1 mm	bilateral datum plane	nearest point of side position and orientation notches on robotic handling flange
*x*46‡	71 ± 1 mm	bilateral datum plane	sides of robotic handling flange
*x*47‡	58 mm minimum	bilateral datum plane	end of robotic handling flange front and rear
*x*56‡	194.75 ± 0.25 mm	bilateral datum plane	outside edge of bottom rails
*x*57	187 mm maximum	bilateral datum plane	box sides underneath bottom rails
*y*1	193 ± 0.25 mm	facial datum plane	front outside edge of frame cassette
*y*2	193 ± 0.25 mm	facial datum plane	back outside bottom edge of frame cassette

Symbol	*Value Specified*	*Datum Measured From*	*Feature Measured To*
*y*5	200 mm maximum	facial datum plane	rear outside edge of frame cassette including rear cover
*y*9†	92.5 mm	facial datum plane	front end of line segment along center of rear cassette sensing pads
*y*10†	123.5 mm	facial datum plane	rear end of line segment along center of rear cassette sensing pads
*y*18†	40.2 mm	facial datum plane	near end of line segment along center of front cassette sensing pads
*y*19†	61.1 mm	facial datum plane	far end of line segment along center of front cassette sensing pads
*y*41‡	30 ± 1 mm	facial datum plane	left orientation notch on robotic handling flange
*y*44‡	53 mm maximum	facial datum plane	encroachment of frame cassette underneath robotic handling flange
*y*45‡	65.3 ± 1 mm	facial datum plane	nearest point of front and rear position and orientation notches on robotic handling flange
*y*46‡	71 ± 1 mm	facial datum plane	front and rear edge of robotic handling flange
*y*47‡	58 mm minimum	facial datum plane	end of robotic handling flange sides
*z*1	183 mm maximum 13-frame cassette 303 mm maximum 25-frame cassette	facial datum plane	top of frame cassette
*z*2†	2 mm maximum	horizontal datum plane	bottom of frame cassette sensing pads
*z*3	23 mm maximum	horizontal datum plane	internal floor of frame cassette
*z*4	33 mm	horizontal datum plane	bottom nominal film frame seating plane
*z*5	10 mm	each nominal film frame seating plane	adjacent nominal film frame seating planes
*z*6	5 mm minimum	bottom of film frame support	top of film frame support below
*z*7	10 mm minimum	top surface of the top frame support	internal ceiling of frame cassette
*z*8	15 mm minimum	horizontal datum plane	top of x56 and y1 dimension controlled area
*z*9	215 mm	horizontal datum plane	bottom nominal film frame seating plane of top stacked cassette (13 slot only)
*z*12	0 ± 0.5 mm	each nominal tape frame seating plane	bottom of the tape frame

Symbol	*Value Specified*	*Datum Measured From*	*Feature Measured To*
*z*41	1 mm minimum	horizontal datum plane	bottom of frame cassette
*z*43	1 + 0 -1 mm	horizontal datum plane	bottom rails
*z*47‡	210 ± 1 mm 13-frame frame cassette 330 ± 1 mm 25-frame frame cassette	horizontal datum plane	bottom of robotic handling flange
*z*48‡	15 mm minimum	bottom of robotic handling flange	encroachment of frame cassette top underneath robotic handling flange
*z*49‡	8 mm maximum	bottom of robotic handling flange	top of robotic handling flange

† These dimensions match those of SEMI E1.9 with the same symbol.

‡ These dimensions match those of SEMI E47.1 with the same symbol.

SEMI G78-0699
TEST METHOD FOR COMPARING AUTOMATED WAFER PROBE SYSTEMS UTILIZING PROCESS-SPECIFIC MEASUREMENTS

This test method was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the North American Automated Test Equipment Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available at www.semi.org April 1999; to be published June 1999.

1 Purpose

1.1 To define the terms and provide a means of comparative, or relative measurement for the automated wafer prober functions: Accuracy, Repeatability and Throughput.

2 Scope

2.1 This method may be used to evaluate the performance of a single automated wafer prober, or as a means to compare many probers. The probers that this document addresses are defined as fully automated; that is, having automatic material handling, alignment and probing capabilities.

3 Limitations

3.1 This test and comparison method is not intended to represent a statistically complete methodology for measuring the performance of an automated wafer prober. Its correct use is a practical means to compare the stepping capabilities of wafer probers within a specific end user's environment.

3.2 The definitions of the terms "Repeatability" and "Accuracy" as used in this document are not in accordance with those of the National Conference of Standards Laboratories (NCSL) nor are they intended to be. They are to be used solely for the purpose of this document and have no other intended uses.

3.3 It is difficult to characterize and eliminate high temperature contributions to positional error such as probe needle 'float'. Therefore, it is strongly recommended that the same probe card be used to evaluate all of the probers being considered.

3.4 It is recommended that the probe card is verified to be in the same condition (i.e. evaluated for positional accuracy and overall functional condition) both before and after the conclusion of each test.

3.5 Bump placement on a semiconductor device is generally located ± 0.001" with respect to their nominal location. Vertical probe cards used to probe bumps have an inherent amount of needle drift. Therefore care must be exercised in using vertical probe cards on bump devices as a means of prober accuracy measurement.

4 Referenced Documents

NOTE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4.1 *SEMI Documents*

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability and Maintainability (RAM)

SEMI S2 — Safety Guidelines for Semiconductor Manufacturing Equipment

5 Terminology

5.1 *3σ limit* — a statistically derived measurement of process variation. A process that allows a ± 3σ deviation will allow 2.7 parts per thousand to be outside the established bounds.

5.2 *accuracy* — the ability of an automatic wafer prober to index its chuck, and attached wafer, from an initial position to a subsequent position and make contact with a static probe tip at a nominal location on the wafer. In the context of this method, accuracy is defined as average die offset.

5.2.1 Average die offset is the perpendicular distance measured from the centerline of the die pad to a parallel line that statistically represents the scrub mark data point distribution center (see Figure 1). Each data point shown in this figure represents only the center value of accumulated scrub marks produced by operation of this method.

5.2.2 It should be noted that accuracy established by this method is characteristic of the system, which in total represents both the automated prober as well as its probe card. Finally, this method establishes two accuracy values, a value for pads along the X and Y axes of the die. These axis directions are arbitrary.

5.2.3 It should be noted that if fully automated prober set-up modes are not used for probe-needle-to-pad alignment during testing, the possibility of operator error should be considered as a variable when evaluating system accuracy.

5.3 *automatic wafer prober* — device that automatically and repeatedly aligns the die bonding pads or interconnect bumps on a semiconductor device to a set of test needles attached to a probe card.

5.4 *bonding pad* — exposed metallic contact area on a semiconductor device that is surrounded by dielectric passivation. This is the point at which a temporary interconnect is made for wafer level test, and permanent interconnect for packaging.

5.5 *bumps* — metallic elevated contact area on a semiconductor device that is used in place of a bonding pad. A die that is designed to use this type of connection is commonly called a 'flip chip' or direct chip attach.

5.6 *die* — individual semiconductor device. For the purposes of this method, the dice have not been singulated, and are still in the form of a wafer. Used interchangeably (in the context of wafer sort) with the acronym DUT (Device Under Test).

5.7 *overdrive* — distance in Z which the wafer is driven beyond a user defined initial contact point, typically 'first electrical contact'.

5.8 *overhead test* — semiconductor test method where the test head is mounted directly over the prober, with the goal of shortening the distance between the pin electronics and the probe card. The connection between the test head and the prober is generally through a device called a Prober Tester Interface (PTI)

5.9 *pin electronics* — tester hardware that creates the test signals used to challenge the DUT.

5.10 *probe card* — printed wiring board or ceramic substrate with permanently attached needles or contacts that are aligned at the time of manufacture to match the contact pattern on a Die. Common types of probe cards are:

- Blade
- Peripheral / Cantilever (AKA Epoxy Ring)
- Vertical (AKA Area Array or Cobra™)

5.11 *probe card planarity and alignment* — a user-specified position of the probe tips in 'x', 'y' and 'z'.

5.12 *probe needles* — the contact points between the probe card and the bonding pads. These are typically manufactured from one of the following materials:

- Beryllium copper
- Tungsten
- Tungsten-rhenium alloy
- Paliney

5.13 *prober tester interface (PTI)* — signal-transmitting electro-mechanical device that connects the pin cards in the tester to the probe card.

5.14 *repeatability* — Figure 1 is empirical data and represents a statistically significant sample of scrub marks. This data reveals that probe needles may not make contact consistently to the same point die to die. Recall that accuracy is defined in this method as average die offset. Thus, repeatability simply represents the three-sigma distribution value for average die offset. Repeatability will represent 99.7% or a three-sigma distribution value for the accumulated offset data points obtained through use of this method.

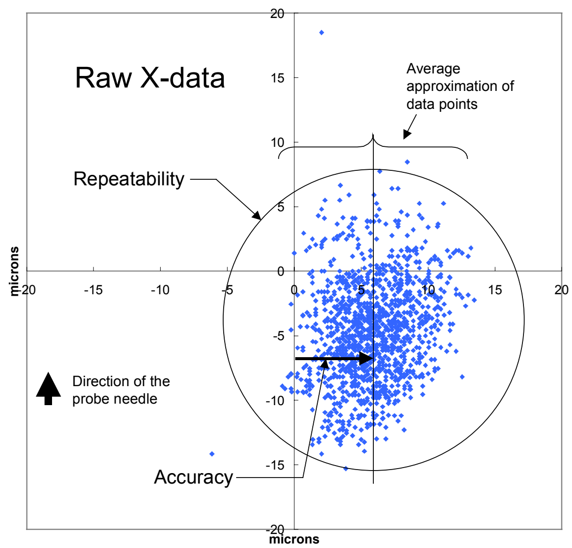

Figure 1

Raw X-Data

5.14.1 The X-Y plotted centroids of these scrub marks will be found to form a "cloud" of points, densest in the center, and thinning out towards the edges.

5.14.2 Repeatability is the radius of that cloud or "cluster" of probe marks, as defined by the 3 σ or other user defined limit of that cloud. The error in the placement of the center of that cloud, relative to its nominal target, is defined as the automatic wafer prober's "Accuracy". (See Figure 1)

5.15 *set point* — the value to which a control system's input device has been set, as opposed to the actual value to which the control system has driven the controlled variable. For example, the input setting to the wafer chuck temperature controller, as opposed to the actual, independently measured temperature of the wafer chuck.

5.16 *soak time* — time between a piece of equipment's reaching the set point temperature and use of that piece of equipment.

5.17 *scrub mark* — mark left by the probe in the bonding pad or bump after the probe card has touched down on the wafer.

5.18 *temperature testing* — testing of devices at a controlled temperature level other than ambient.

5.19 *test* — one complete run-through of the data collection portion of this document on one automated wafer prober.

5.20 *tester* — specialized computer controlled system designed to test integrated circuits.

5.21 *prober communications protocol (see Section 9.6)* — means of transmitting data between the tester and the prober. Common methods are:

- TTL
- RS-232c
- GPIB

5.22 *test head* — package of electronics (part of the Tester) which interacts both electrically and mechanically with the probe card, typically through the Prober Tester Interface (PTI).

5.23 *throughput* — rate at which die can be cycled, by the automatic wafer prober, for the purpose of being tested. It is inherent in the functionality of an automatic wafer prober (or any other motorized positioning device) that accuracy, repeatability and throughput are intimately and inseparably related.

5.24 *touch down* — contact between the probe card and the wafer. This user may choose to define this as either first electrical or first mechanical contact.

5.25 *wafer* — semiconductor substrate upon which multiple die are fabricated.

5.26 *wafer boat or wafer cassette* — carrier for multiple wafers.

5.27 *wafer chuck* — platform within an automatic wafer prober that supports and transports the wafer. The chuck may contain the means for controlled temperature testing.

5.28 *x, y, z and* θ — motions relative to the center of the Probe Card when standing in front of the Prober:

- Motion to the right is motion in the positive X-direction.
- Motion towards the back of the prober is motion in the positive Y-direction.
- Motion away from the floor is the positive Z-direction.
- Motion revolving around a Z-axis passing through the center of the probe card is θ-motion. Motion in the counter-clockwise direction when facing down from above the prober is motion in the positive θ-direction.

5.29 *z-clearance* — distance between the user defined initial contact point and the top surface of the wafer during that portion of the wafer prober’s cycle when the wafer chuck is moving the wafer between DUTs.

6 Summary of Method

6.1 *Objective* – A SEMI Probe Standards Task Force has defined this method. That task force consisted of members from semiconductor wafer probe system users and wafer probe system suppliers. This method, in part a guide to collection of data, is aimed at a specific set of wafer probe system parameters: accuracy, repeatability and throughput. This method is a tool that creates comparative data. That data will act as a criterion by which multiple wafer probe systems can be judged competitively.

6.2 *Probe System Accuracy and Throughput* – A wafer probe system will have needle placement error due to the probe system electromechanical systems, and additional needle placement error due to the probe card physical alignment of the needles. The degree of accuracy to which the probe system can place the chuck, the effectiveness of the probe system's bond pad to needle alignment, the physical alignment of the probe card needles in their X and Y plane, and the probe system's vision resolution and accuracy (x microns of distance per pixel) will be the factors that influence a probe system's overall placement performance.

6.2.1 Probe system comparative accuracy and repeatability are established in this method using probe mark data acquired manually with a vision system or, if available, through use of an automated probe mark data analysis system. Acquired data is analyzed with the Probe Mark Data Analysis algorithm contained in this method.

6.2.1.1 The intention of this data collection exercise is not to make a deterministic conclusion establishing a probe system’s accuracy. Data analysis results are only meaningful in the context of a comparative analysis of multiple probe systems.

6.2.2 Probe system throughput is best determined using time measurements made using a stopwatch. Other approaches can be applied, such as:

- the time stamp and log file (if available) on the probe system under evaluation.
- time tracking within the device test program employed for testing the prober.

6.2.3 Any of these approaches is viable for measuring time intervals during probe system operation. That data is to be entered into the data collection table as part of the application of this method.

6.2.4 The algorithm collects data from 9 wafers out of a lot of 10. Three setups are performed using 3 wafers per setup. All dice will be probed, but data will be taken only on twelve of the die on each wafer. Twenty-four pads on each die are evaluated (see Figure 4). Overall, 2592 die pads are analyzed in a lot.

6.2.5 When all the data is collected and analyzed, each probe system will have an average die offset value. This will be a comparative representation of accuracy consisting of average offsets for all evaluated die. This comparative representation of accuracy is a measure of how accurate the probe systems place the chuck, and thus the probe needles, to the center point on the die pads, consistent with normal operation of the probe systems.

6.2.6 In general, when the probe marks are viewed across all dice, there will be a data spread, or distribution of error points for each wafer. Repeatability is the $\pm 3\sigma$ variation of all die offsets, identified in this method as the 3σ calculation of *Normalized Die Offset*.

6.3 *Probe Card Issues* – Probe card construction variability and probe card usage at temperatures other than ambient are important considerations. The following sources of error should be kept in mind:

- In a hot chuck environment the probe card and needles will experience a high percentage of the elevated chuck temperature. The material selection for the probe card will determine how it expands and contracts due to the temperatures applied. Probe systems can be equipped with programmable preheat (soak) times. Longer preheat times will reduce probe card variability while decreasing throughput.
- Needle construction can result in excessive error due to bending of the needles when excessive probe system z-stage overdrive is applied. The number of needles and the selection of needle technology, i.e., cantilever versus vertical, is another variable, having a noticeable influence on measurement results.
- Since each user of this method is not confined to a standard for probe card construction, the user of this method is advised to choose a probe card and vendor with good integrity, and to use that same probe card when evaluating multiple probe systems. The assertion here is that the same probe card used to evaluate multiple systems will react in a repeatable manner under varying environmental conditions. This assumes there is no excessive probe card needle wear during the multiple evaluations, and that needle alignment is verified or achieved before each execution of the procedure.

6.3.1 Probe mark scrub length can vary due to several factors including:

- variations in the flatness of the chuck and stage travel that are not compensated by the z-sensor mapping algorithms
- by hard spots in the aluminum pads, or
- by variations in probe tip geometry, etc.

6.3.2 To minimize the impact of this variation in the probe mark analysis algorithm, use only scrub mark location data that is taken normal to the direction of scrub. Distances measured normal to the orientation of the scrub mark are generally accepted to be significantly more stable than that which is taken parallel to the scrub mark (see Figure 2).

6.3.3 In summary, the probe card itself can be a limiting factor when making needle placement accuracy measurements, especially at varying environmental conditions. Material selection, vendor to vendor variation, construction of a probe card (blade, epoxy ring, vertical, etc.), especially with varying environmental conditions, will create inconsistent analysis results, unless care is taken with the application of this method. The precautions discussed here are meant to promote consistent and accurate evaluation results for this method.

6.3.4 Nevertheless, the precautions mentioned here could ALSO be an important basis for using this method. As an example, a probe card is typically designed for XY positional placement and planarity, and is expected to meet customer specification requirements in normal operation at room temperatures. This method could serve as a means of establishing numerical results that represents the effects that temperature or probe card construction variability have on probe card specification requirements.

6.4 *The PMA Algorithm* – A best-fit rectangle can be drawn around the scrub mark and the passivation opening for each pad, reference Figure 3.

NOTE: Applying a best-fit rectangle around the passivation opening may prove difficult for certain vision systems. Application of the best-fit rectangle around the die pad metal is an acceptable alternative. The center position of the best-fit rectangle around the scrub mark will represent the center of the scrub mark. The center of the die pad is the center of the best—fit rectangle around the passivation opening. The distance between the two centers is the pad offset. Pad offset is computed from the four values *left*, *right*, *top*, and *bottom*, reference Figure 2.

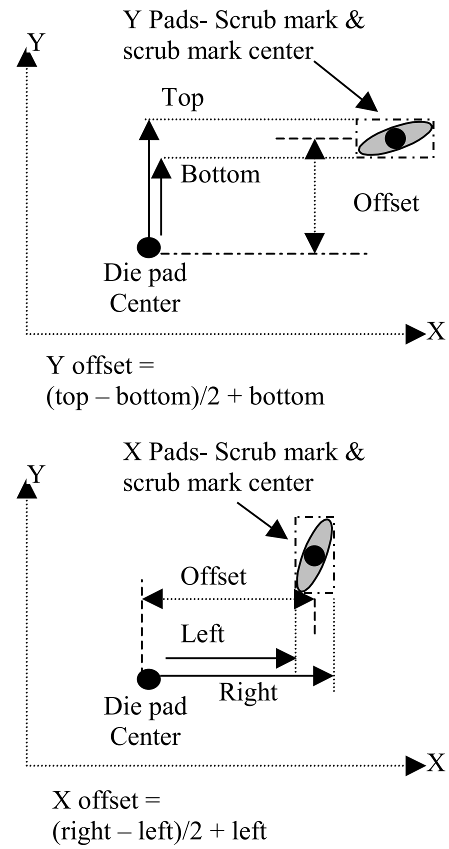

Figure 2

X and Y Offset

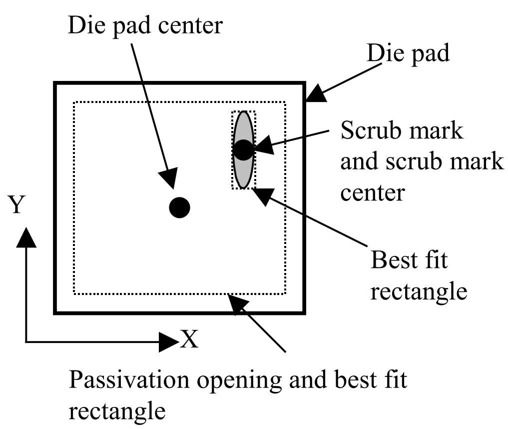

Figure 3

Scrub Mark Analysis

6.4.1 Vision system measurements will be made establishing offset distances from the die pad center to the scrub mark. The stability of the measurement is greater when made perpendicular to the direction of the scrub mark. This will establish X and Y offsets via measurement of offsets for pads in the X and Y plane of the die.

6.4.2 Once the offsets are established, a two-step procedure will manipulate 1296 X and 1296 Y offset values. The end result of the algorithm will be a relative measure of the total probe system accuracy and repeatability for the pads analyzed. Figure 5 represents a visual summary of the method.

6.5 *Considerations of Scale* — When evaluating the suitability of a particular probe system to probe a particular size of bond pad, or to probe accurately at a particular pad-to-pad pitch, a good rule of thumb is that the prober's positional accuracy, as stated in its specifications, should be 1/10 that of the scale of the features to be probed. For example, if the probe system being evaluated has an overall placement accuracy of 5µm, it would be inappropriate to analyze wafers using this method and this probe system for dice that have pads less than 50 µm square (this would be less than 10x).

6.5.1 Regardless, when this method is used for evaluation of multiple systems, it is essential that die and bond pad size/pitch consistency be maintained from evaluation to evaluation if the results are to be meaningful.

6.5.2 The same 10× rule applies to the vision system or automated Probe Mark Analysis system employed to make the pad offset measurements. These systems should have a pixel resolution that is at least 10× finer than the die pad dimensions associated with the scrub marks being measured.

6.6 *Conclusion* — It is assumed that the user of this method has a wafer probe system or systems, or is planning to make a selection from the various systems available in the market place, and requires objective comparative analysis for accuracy, repeatability and throughput.

6.6.1 It should be clear that this method employs a three-step process of probing, probe mark data collection, and data analysis.

6.6.2 When probing, every die on each of the ten wafers is to be "tested" and probed. Of those ten wafers, the last nine with 12 die per wafer will be used for scrub mark data collection. At least 24 pads per die will be used for the analysis. The first wafer is meant only to allow stabilization for the probe system and its probe card.

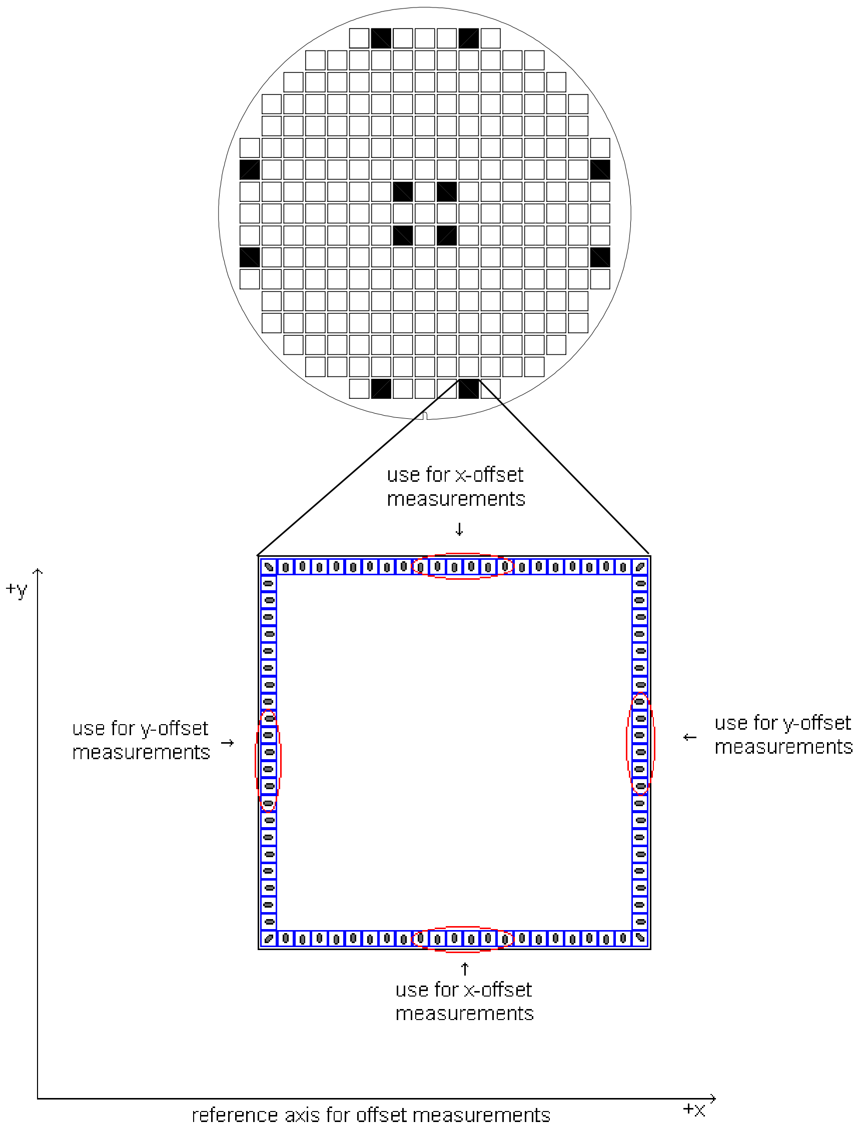

Figure 4

Recommended Dice and Pads to be used for Data Collection

6.6.3 It is important that the wafers used with this method are probed only once, or else multiple scrub marks may be difficult for the measurement system to deal with and will most likely influence the analysis results. This method assumes the wafer is ideal, having no die skew due to wafer process anomalies.

NOTE: It is possible that a not so perfect probe tip to pad alignment (PTTPA) may create misleading results for this method. It is recommended that PTTPA be done on die located at the edge of the wafer, as shown in Figure 4. This is opposed to having PTTPA done on die in the center of the wafer. An offset error incurred in the context of a PTTPA done in the center may result in an incremental and continuing error as testing moves across the wafer. With this method that error may be averaged-out.

6.6.4 Probe system index time is device and probe system dependent. Probe system index time is determined by acceleration, maximum achievable velocity, and distance traveled die to die by the chuck. Thus, the device type chosen for use with this method should be representative of typical die size if meaningful index time and throughput data are to be gathered.

6.6.5 If the results of this method turn out to be unfavorable, the user has the option of applying a more detailed, enhanced data analysis application of this method. That application is contained in Appendix 1. The enhanced method uses the same data, but it requires more manipulation of the data during data analysis. The detail contained in the enhanced algorithm will provide the user with greater insight as to the cause of unfavorable results related to the probe system under evaluation. A summary of the enhanced method is shown in Figure 6.

6.7 *Alternatives* — What has been left undefined to this point is availability of an automated approach to data collection per the requirements of this method. Regardless, data collection can be manually accomplished. The manual process is laborious and requires a video measuring system to make offset measurements on the die pads, and a spreadsheet to analyze the resulting data.

6.7.1 If manual operation is not desirable or practical, automated Probe Mark Analysis Systems do exist in the market place as an item to be purchased. Providers are also available to accept probed wafers and execute probe mark analysis under contract as a service.

NOTE: *A Final Note to the User of This Method* — This method provides sufficient data for sophisticated analysis of probe system performance across die-to-die, wafer-to-wafer, and setup-to-setup. It also provides a simple metric. It is easy to make comparisons with simple "single number" metrics, but that has the potential for oversight, distortion and subsequent inappropriate comparisons. The test engineer, working with the probe system supplier, must be the ultimate judge of the applicability of this method and the correct interpretation of the results.

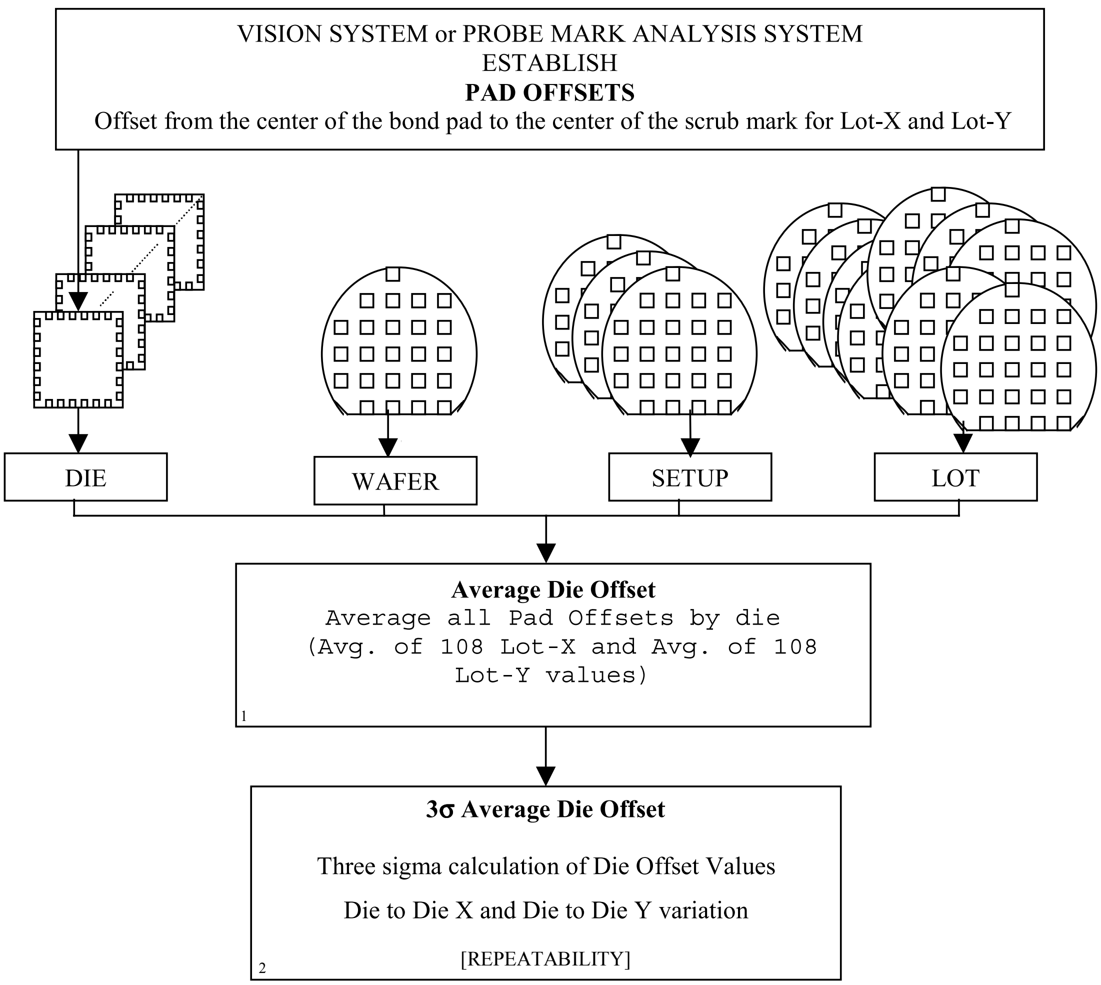

Figure 5

Pad Offset and Two-Step Analysis Algorithm for Determining Probe System Error

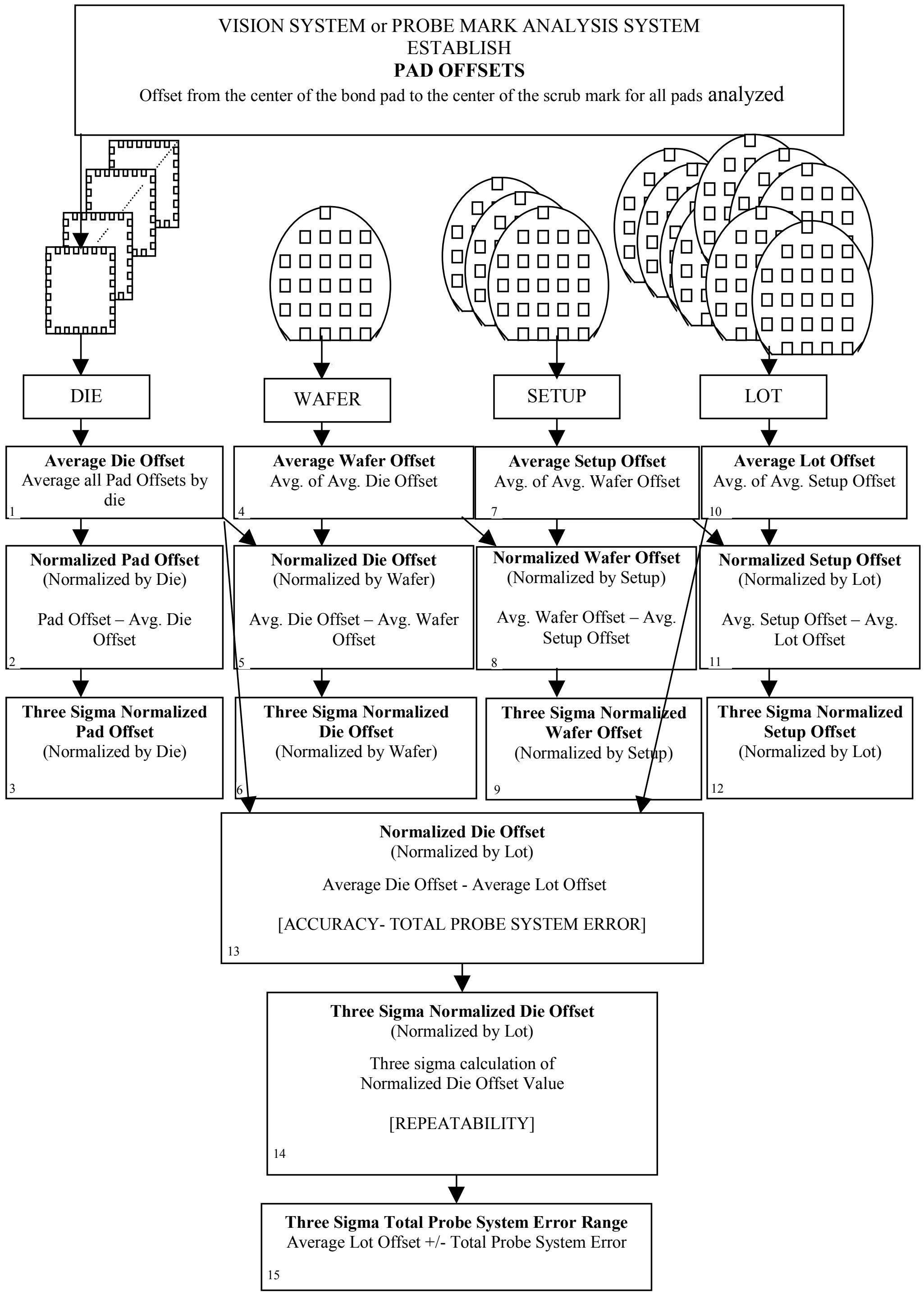

Figure 6

Pad Offsets and 15-Step Analysis Algorithm for Determining Probe System Error

7 Required Hardware Checklist (see Figure 7)

- ❑ Wafer prober (if the test plan includes either hot or cold chuck testing, the prober must be appropriately equipped).
- ❑ A planarized and aligned probe card which matches the selected wafers, accompanied by a metrology tool printout of the 'x', 'y' and 'z' positions of all of the probe tips to be used for probe mark analysis. Note: The probe card should be measured for alignment, but not "tweaked", immediately prior to and after the conclusion of each subsequent test.
- ❑ Untested wafers
- ❑ A special "test program" with a fixed "test" time.
- ❑ Tester or PC that will run the "test program". If a PC is used to simulate the tester, it must be equipped with the appropriate hardware for communication with the wafer prober.
- ❑ A stopwatch, with 0.1 second resolution. The stopwatch is to have "split" capability.

  Note that the user of this method may choose at their discretion to utilize any other time stamp logging technology at their disposal, so long as the computational overhead of this logging has no effect upon the throughput of the prober.

8 Requirements (see Figure 7)

8.1 *Qualified Prober* — Before initiating the test process, the wafer prober is to be certified by a representative of the prober manufacturer to be fully operational.

8.2 *Qualified Personnel* — The individual running the wafer prober for the test procedure must be certified or otherwise qualified to operate the prober being tested.

9 Test conditions (see Figure 7)

9.1 *Test Time* — a fixed "device test time" will be used during these tests. The recommended value for this test time is 1.0 seconds.

9.2 *Accuracy and Repeatability vs. Throughput* — The person or manufacturer running this test may make a choice (or choices) as to how they elect to balance accuracy and repeatability with throughput, but all three tests must be run simultaneously. This will generate a set of numbers defining a particular prober's accuracy and repeatability at a given throughput (or a throughput at a given accuracy and repeatability). All adjustments to the prober are to be made using standard, end-user-adjustable settings, and all prober settings associated with a particular throughput / accuracy and repeatability combination are to be included in the final report.

9.3 *Temperature* — This test can be conducted at any temperature, however, numerous variable can distort the results if run at a temperature other than ambient, i.e. probe tip drift due to an increase or decrease in temperature.

- *Cautionary Note: If the tests are performed at temperatures other than ambient, the user must use the same probe card and wafer type for all tests across all test platforms to ensure uniformity of results.*

9.4 *Probe Card Type* — All types of probe cards (blade, peripheral / cantilever or vertical) may be used, so long as they leave a visible scrub mark.

- *Cautionary note: Some vertical probe cards exhibit an inherent amount of 'x' - 'y' needle drift. The user should verify the intrinsic repeatability of the probe card before using it to characterize the prober.*

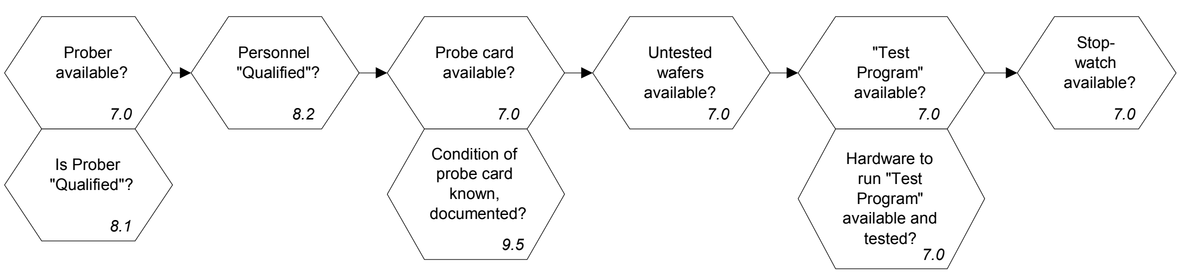

Figure 7

Preparation

9.5 *Probe Card Condition* — a metrology tool printout verifying the 'x', 'y' and 'z' position of each probe is within the users specification must accompany the probe card.

9.6 *Tester – Prober Communications* — The type of communications method used between the prober and the tester is left up to the user of this test method. Because communication overhead varies with protocol, the same hardware and "test program" (modified as necessary to communicate to the prober under test) must be used for all tests.

9.7 *Presence of the PTI* — During the test, the probe card must have loading similar to that applied by the normal "in use" application such as a Probe Test Interface (PTI) or Direct Docking Pogo Stack. The force exerted on the probe card by the PTI will stabilize the probe card, improving the repeatability of the data collected.

9.8 *Wafer Cassette* — For the purposes of these tests, a cassette of wafers is defined as containing ten wafers. Ensure the wafers are placed in the same slots for each test.

10 Test Procedure (see Figures 8 and 9)

10.1 Load wafer cassette

10.2 Install probe card

10.3 Set probe mode to serpentine, set all other necessary prober parameters. NOTE THAT ALL DIE ON ALL WAFERS ARE TO BE "TESTED", NOT JUST THE 12 DIE FROM WHICH PROBE MARK DATA WILL BE ANALYZED.

10.4 Note all applicable parameters (see chart below)

10.5 If temperature testing, soak for a user-defined time (consistent with the user's test methodologies) that is equal on all corresponding tests on all probers being evaluated.

10.6 Start probing process and stopwatch simultaneously.

10.7 The "test program" must perform automatic alignment of the probe card to the wafer prior to wafer #'s 1, 2, 5, and 8.

NOTE: While not required, it is recommended that the PTI and Probe Card be removed and re-installed prior to each of the automatic alignment steps to simulate whatever locational error might be induced by manipulation of the interface and the probe card.

10.8 Record times of individual events (utilizing the stopwatch's "split" function) on the supplied chart or a similar form.

10.9 When the last wafer is finished and has been returned to wafer cassette, stop the stopwatch.

10.10 Collect the probe mark offset data from wafers.

10.11 Calculate Normalized (by lot) Die Offset [Accuracy] and 3σ of Normalized (by lot) Die Offset [Repeatability]:

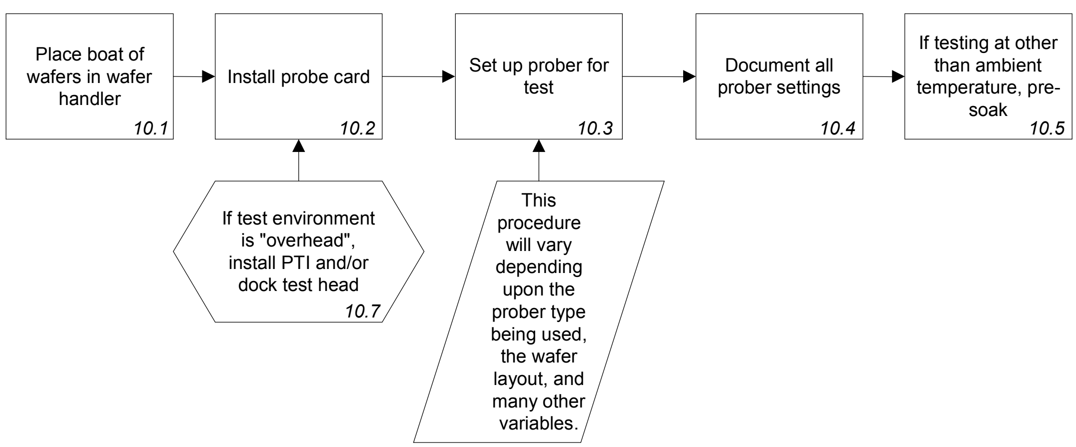

Figure 8

Setup

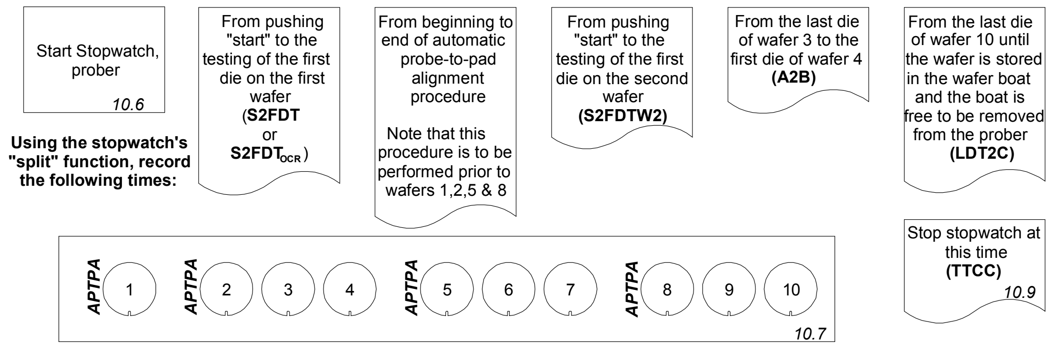

Figure 9

Timing Procedure

11 Introduction

11.1 The Probe Mark Analysis System recognizes the edge of the bond pad passivation opening and the probe mark, draws a best-fit rectangle around the probe mark and passivation opening, and returns the four distances, Left, Right, Bottom and Top to a text file. The center position of the best-fit rectangle can be used to represent the center of the scrub mark. An offset of this center of scrub mark from the center of the bond pad can be calculated as follows:

$$\begin{aligned} PadXoffset &= (Left - Right)/2 \\ PadYoffset &= (Bottom - Top)/2 \end{aligned} \qquad (1)$$

The variation of this offset from pad to pad, die to die, wafer to wafer and setup to setup captures most of the process variations.

11.2 *PMA Data Analysis*

11.2.1 We will use a sampling scheme of 9 wafers per lot, (3 setups per lot, 3 wafers per setup), 12 dies per wafer and 24 pads per die as an example for discussing the data analysis algorithm. The first step of doing data analysis is to obtain the offsets for all the pads that have been sampled using Eqn.(1). This means that the offsets

$$\text{[PadXoffset]}\ xoff_{loti,setj,wafk,diel,padm},\ \text{[PadYoffset]}\ yoff_{loti,setj,wafk,diel,padm} \qquad (2)$$

for a pad m on die l, wafer k, under setup j in lot i are known.

Step 1

Calculate ***Average Die Offset*** for the lot [LOTX or LOTY] (3)

$$\begin{aligned} xoff_{loti,setj,wafk,diel} &= \frac{1}{12}\sum_{m=1}^{12} xoff_{loti,setj,wafk,diel,padm} \\ yoff_{loti,setj,wafk,diel} &= \frac{1}{12}\sum_{m=1}^{12} yoff_{loti,setj,wafk,diel,padm} \end{aligned} \qquad (3)$$

Step 2

Calculate D-D-X or D-D-Y = 3σ of ***Average Die Offset*** **[LOTX] and [LOTY]**(3)

These die offsets are again treated on the equal basis. A 3σ value is calculated and becomes our Die-to-Die Variation (D-D-X, D-D-Y) for the entire lot.

LOTX + D-D-X, LOTX - D-D-X = Total Prober X-Error Range (3σ)
LOTY + D-D-Y, LOTY - D-D-Y = Total Prober Y-Error Range (3σ)

Suggested Graphs for X-Offset and Y-Offset (see Appendix 1 for examples):

X-Offset	**Y-Offset**
LOTX + D-D-X	LOTY + D-D-Y
LOTX	LOTY
LOTX - D-D-X	LOTY - D-D-Y
Average Die X-Offset (3)	Average Die Y-Offset (3)

12 Data Collection Table

12.1 The following data are to be recorded about the test environment:

Title	*Description*	*Values*	
Tester - Prober Interface	Installed (Yes/No)		
	If installed, Total Pogo® pin force (nominal, calculated)		kg
			pounds
Tester	Present [docked] (Yes/No)		
	If present, state manufacturer and model		
Wafer	Nominal Die Size (Small, Medium or Large)		
Probe Card	Needle count		
	Nominal force per needle		grams
			ounces
	Diameter of needle tip		microns
			mils
	Needle pitch (within a single row or column)		microns
			mils
	Number of needle tiers		
	Size of needle array in the X direction (left-to-right when facing prober (from the operator position))		mm
			inches
	Size of needle array in the Y direction (away and towards the operator relative to the center of the probe card)		mm
			inches
	Diameter of probe card		mm
			inches
Test Temperature	Set point / Temperature of chuck during test		ºC
			ºF
	Soak time, probe card (if test temperature is other than ambient)		minutes
	Soak time, prober (if other than ambient)		minutes

Title	Description	Values	
DUT spacing	X-direction		microns
			mils
	Y-direction		microns
			mils
Z clearance			microns
			mils
Overdrive			microns
			mils
Tester-Prober communications method			
OCR Variables	OCR on? (Y/N)		
	SEMI standard font? (Y/N)		
	# of retries allowed		

Definitions for formulae:

Variable	Description	Values	
DPW	Die Per Wafer		
TT	Test Time (minimum value of 1.0 seconds)		seconds

Data Collected	Description	Values	
A2B	Last die (Wafer A) to first die (Wafer B) time		seconds
S2FDT	Time from pushing "Start" to First Die Test with OCR turned off		seconds
$S2FDT_{OCR}$	Time from pushing "Start" to First Die Test with OCR turned on		seconds
S2FDTW2	Time from pushing “Start” to First Die Test, Wafer #2		seconds
LDT2C	Time from end of Last Die Test to Cassette free to remove from prober		seconds
TTCT	Total Time to Complete Test		seconds
TTAA	Time To Auto-Align the probe needles with the die bonding pads		seconds

$$D2D = \frac{TTCT - (TT \times DPW \times 9) - (A2B \times 8) - S2FDTW2 - LDT2C - (TTAA \times 3)}{DPW \times 9}$$

Calculated Results	Values	
D2D		seconds

APPENDIX 1
CALCULATION OF NORMALIZED DIE OFFSET AND TOTAL PROBER ERROR RANGE (3σ)

A1-1 Probe Mark Data Analysis Algorithm:

A1-1.1 *Introduction*

A1-1.1.1 The Probe Mark Analysis system recognizes the edge of the bond pad passivation opening and the probe mark, draws a best-fit rectangle around the probe mark and passivation opening, and returns the four distances, Left, Right, Bottom and Top to a text file. The center position of the best-fit rectangle can be used to represent the center of the scrub mark. An offset of this center of scrub mark from the center of the bond pad can be calculated as follows:

$$PadXoffset = (Left - Right)/2$$
$$PadYoffset = (Bottom - Top)/2 \qquad (1)$$

A1-1.1.2 The variation of this offset from pad to pad, die to die, wafer to wafer and setup to setup captures most of the process variations.

A1-1.2 *PMA Data Analysis*

A1-1.2.1 We will use a sampling scheme of 9 wafers per lot, (3 setups per lot, 3 wafers per setup), 12 die per wafer and 24 pads per die. The first step of doing data analysis is to obtain the offsets for all the pads that have been sampled using Eqn.(1). This means that the offsets

$$\text{[PadXoffset]}\ xoff_{loti,setj,wafk,diel,padm},\ \text{[PadYoffset]}\ yoff_{loti,setj,wafk,diel,padm} \qquad (2)$$

for a pad m on die l, wafer k, under setup j in lot i are known.

A1-1.3 Step 1 — Calculate Average Die Offset (3)

$$xoff_{loti,setj,wafk,diel} = \frac{1}{12}\sum_{m=1}^{12} xoff_{loti,setj,wafk,diel,padm}$$
$$yoff_{loti,setj,wafk,diel} = \frac{1}{12}\sum_{m=1}^{12} yoff_{loti,setj,wafk,diel,padm} \qquad (3)$$

A1-1.3.1 *Discussion of Average Die Offset*

A1-1.3.1.1 Based on the sample described, there will be an Average Die Offset-X and Average Die Offset Y for each of the 108 die sampled. This value is probably the most descriptive, especially when graphed (see example graphs). Both X and Y-graphs will most likely resemble a sine wave. This is due to wafer rotation. As you serpentine across the wafer there will be a slight offset from die to die. Since the selected sample dice are in the center and around the edges of the wafer, you can see the progression of the offset as you move farther from the center of the wafer. The X and Y graphs are usually about 90º out of phase.

A1-1.3.1.2 Other qualitative information can also be gathered by visually looking at the graphs of this data. One can determine whether the accuracy is varying wafer to wafer (each set of 12 data points is a wafer) or set-up to set-up (each set of 36 data points is a set-up) or just drifting over time. Drift over time is sometimes caused by temperature stabilization issues within the prober mechanism. Subsequent steps will quantify how much variability is caused by each.

A1-1.4 Step 2 — Calculate Normalized (by die) Pad Offset (4) = (2) - Average Die Offset (3)

$$xnorm_{loti,setj,wafk,diel,padm} = xoff_{loti,setj,wafk,diel,padm} - xoff_{loti,setj,wafk,diel}$$
$$ynorm_{loti,setj,wafk,diel,padm} = yoff_{loti,setj,wafk,diel,padm} - yoff_{loti,setj,wafk,diel} \quad (4)$$

A1-1.4.1 *Discussion of Normalized (by die) Pad Offset*

A1-1.4.1.1 This step helps to quantify how much error is caused by the prober vs. the probe card. The probe card usually does NOT impact average offset of a die, just the variability within a die. In this equation, we subtract the average die offset (presumed prober error) from each pad in that die. This data is then used for the next step.

A1-1.5 Step 3 — Calculate P-P-X or P-P-Y = 3σ of Normalized (by die) Pad Offset (4).

A1-1.5.1 All the normalized pad offsets in the same lot (no matter on which die, on which wafer the pad resides) are treated on an equal basis. In our example, a total of 2592 pads are sampled in a lot. All 1296 x-direction and 1296 y-direction pads of ***Normalized (by die) Pad Offset*** will be used to calculate a 3σ variation which is called Pad-to-Pad variation (P-P-X and P-P-Y).

A1-1.5.2 *Discussion of P-P-X or P-P-Y (Pad-to-Pad Variation in the X-direction or Pad-to-Pad-Variation in the Y-direction)*

A1-1.5.2.1 These values describe how much variability there is within all the pads in the lot. This value is frequently attributed to probe tip variation in X, Y, and Z. Although probe tips do change and wear over time, their unloaded position usually does not change dramatically within one lot. This value does not help tremendously in describing prober accuracy nor should it be used for any sort of probecard metrology. However, be sure to perform a mental reality check to verify that it is somewhere near (within an order of magnitude of) your probe card X/Y probe needle position specification.

A1-1.6 Step 4 — Calculate Average Wafer Offset (5) = average of Average Die Offset (3).

$$xoff_{loti,setj,wafk} = \frac{1}{12}\sum_{l=1}^{12} xoff_{loti,setj,wafk,diel}$$
$$yoff_{loti,setj,wafk} = \frac{1}{12}\sum_{l=1}^{12} yoff_{loti,setj,wafk,diel} \quad (5)$$

A1-1.6.1 *Discussion of Average Wafer Offset*

A1-1.6.1.1 This equation will result in nine values for Average Wafer Offset-X and nine for Average Wafer Offset-Y. These numbers could also be graphed to look for trends from wafer to wafer (this is not included on the example graphs). If there is a consistent trend in one direction possible causes are:

- wafer loading error
- cumulative stepping error, and
- temperature stability errors

A1-1.7 Step 5 — Calculate Normalized (by wafer) Die Offset (6) = Average Die Offset (3) - Average Wafer Offset (5)

$$xnorm_{loti,setj,wafk,diel} = xoff_{loti,setj,wafk,diel} - xoff_{loti,setj,wafk}$$
$$ynorm_{loti,setj,wafk,diel} = yoff_{loti,setj,wafk,diel} - yoff_{loti,setj,wafk} \qquad (6)$$

A1-1.7.1 *Discussion of Normalized (by wafer) Die Offset*

A1-1.7.1.1 This normalization step is a precursor to calculating a 3σ variation value. To calculate the true Die-to-Die variation, any wafer-to-wafer induced error is subtracted out from the by-die-data. This data is used in the next step.

A1-1.8 Step 6 — Calculate D-D-X or D-D-Y = 3σ of Normalized (by wafer) Die Offset (6)

A1-1.8.1 These normalized die offsets are again treated on the equal basis. A 3σ value is calculated and becomes our Die-to-Die Variation (D-D-X, D-D-Y).

A1-1.8.2 *Discussion of D-D-X or D-D-Y (Die-to-Die 3σ variation in the X-direction, Die-to-Die 3σ variation in the Y-direction)*

A1-1.8.2.1 This equation will result in the 3σ variation of the average die offsets from Die-to-Die in both X- and Y-directions. If this number is very large, there should be concern about the repeatability of the prober.

A1-1.9 Step 7 — Calculate Average Setup Offset (7)

$$xoff_{loti,setj} = \frac{1}{3}\sum_{k=1}^{3} xoff_{loti,setj,wafk}$$
$$yoff_{loti,setj} = \frac{1}{3}\sum_{k=1}^{3} yoff_{loti,setj,wafk} \qquad (7)$$

A1-1.9.1 *Discussion of Average Setup Offset*

A1-1.9.1.1 These equations will produce six values, three for Average- (by Setup) Offset-in-the-X-direction and three for Average- (by Setup) Offset-in-the-Y-direction. These values describe the average offset of all of the die “tested” with a particular setup.

A1-1.10 Step 8 — Calculate a Normalized (by setup) Wafer Offset (8) = Average Wafer Offset (5) - Average Setup Offset (7).

$$xnorm_{loti,setj,wafk} = xoff_{loti,setj,wafk} - xoff_{loti,setj}$$
$$ynorm_{loti,setj,wafk} = yoff_{loti,setj,wafk} - yoff_{loti,setj} \qquad (8)$$

A1-1.10.1 *Discussion of Normalized (by setup) Wafer Offset*

A1-1.10.1.1 A normalizing step to help calculate the true wafer-to-wafer variation.

A1-1.11 Step 9 — Calculate W-W-X or W-W-Y = 3σ of Normalized (by setup) Wafer Offset (8).

A1-1.11.1 A 3σ variation will be calculated based on the normalized wafer offset and will be cited as the Wafer-to-Wafer variation (W-W-X, W-W-Y).

A1-1.11.2 *Discusssion of W-W-X or W-W-Y (Wafer-to-Wafer variation in the X-direction, Wafer-to-Wafer variation in the Y-direction)*

A1-1.11.2.1 This equation will produce a value for the 3σ variation from Wafer-to-Wafer in the X and Y directions. If this number were large, it would tend to indicate that the prober does not behave repeatably from wafer-to-wafer. Possible causes are:

- loading problems
- temperature stability issues, and
- wafer rotation issues

A1-1.12 Step 10 — Calculate Average Lot Offset (9) = average of Average Setup Offset (7).

$$LOTX = \frac{1}{3}\sum_{j=1}^{3} xoff_{loti,setj}$$
$$LOTY = \frac{1}{3}\sum_{j=1}^{3} yoff_{loti,setj} \qquad (9)$$

A1-1.12.1 *Discussion of Average Lot Offset (LOTX or LOTY)*

A1-1.12.1.1 This will be one of the values added to the graph. This is simply the average of all of the average die offsets in the X-direction and all of the average die offsets in the Y-direction. If one needed to pick a single number in X and Y to describe the accuracy of the prober – this is the one. This can be very misleading though – what this number really tells you is what value the distribution is centered around. Refer to the graph to get a visual sense of this data.

A1-1.13 Step 11 — Calculate Normalized (by lot) Setup Offset (10) = Average Setup Offset (7) - Average Lot Offset (9)

$$xnorm_{loti,setj} = xoff_{loti,setj} - LOTX$$
$$ynorm_{loti,setj} = yoff_{loti,setj} - LOTY \qquad (10)$$

A1-1.13.1 *Discussion of Normalized (by lot) Setup Offset*

A1-1.13.1.1 This is another normalization step used to calculate the true setup-to-setup error in X and Y.

A1-1.14 Step 12 — Calculate S-S-X or S-S-Y = 3σ of Normalized (by lot) Setup Offset (10).

A1-1.14.1 A 3σ variation will be calculated based on the normalized setup offset and will be cited as the Setup-to-Setup variation (S-S-X, S-S-Y).

A1-1.14.2 *Discussion of S-S-X or S-S-Y (Setup-to-Setup variability in the X-direction, Setup-to-Setup variability in the Y-direction)*

A1-1.14.2.1 These two values describe how much variability there is between setups.

A1-1.15 Step 13 — Calculate Normalized (by lot) Die Offset (11) = Average Die Offset (3) - Average Lot Offset (9) [Accuracy]

$$xn_{loti,setj,wafk,diel} = xoff_{loti,setj,wafk,diel} - LOTX$$
$$yn_{loti,setj,wafk,diel} = yoff_{loti,setj,wafk,diel} - LOTY \qquad (11)$$

A1-1.15.1 *Discussion of Normalized (by lot) Die Offset*

A1-1.15.1.1 This step is useful if you need to compare the variation between several different lots. It is not completely necessary for the next step, since subtracting a constant from a string of numbers does not change the 3σ variation, only the center point.

A1-1.16 Step 14 — Calculate TTLX or TTLY = 3σ of Normalized (by lot) Die Offset (11) [Repeatability]

A1-1.16.1 *Discussion fo TTLX or TTLY*

A1-1.16.1.1 This is the value for determining (with 3σ confidence) whether your probe marks will always fall within your desired spec. They are the hatch-marked lines.

A1-1.17 Step 15 — This normalized die offset includes Die-to-Die, Wafer-to-Wafer, and Setup-to-Setup offsets thus a 3σ variation of this offset will be called Total Prober Variation (TTLX and TTLY).

A1-1.17.1 *Calculate Total Prober Error Range (3σ).*

LOTX + TTLX, LOTX - TTLX = Total Prober X-Error Range (3σ)
LOTY + TTLY, LOTY - TTLY = Total Prober Y-Error Range (3σ)

A1-1.17.2 Suggested Graphs:

X-Offset	Y-Offset
LOTX + TTLX	LOTY + TTLY
LOTX	LOTY
LOTX - TTLX	LOTY - TTLY
Average Die X-Offset (3)	Average Die Y-Offset (3)

A1-1.17.2.1 It is recommended to create one graph illustrating the prober accuracy in X and one graph for Y.

A1-1.18 *Discussion of Graphs (one example for X [Figure X] and one for Y [Figure Y])*

A1-1.18.1 Average Lot X-Offset is the value from Step 10. This number shows where the probe mark distribution is centered (the accuracy of the prober).

A1-1.18.2 Average Lot X-Offset +3σ is the result from step 10 + the result from step 14

A1-1.18.3 Average Lot X-Offset -3σ is the result from step 10 – the result from step 14

A1-1.18.4 These two lines show the ± 3σ range of your distribution. This describes the repeatability of the prober.

NOTE: There will always be explainable and unexplainable accuracy and repeatability errors on a prober. If these two lines fall within your desired specification, you will probably not have any problems. The example graph for X-offset illustrates a well-behaved, or "passing" prober. The example graph for Y-offset, on the other hand, is representative of a prober which failed to meet the desired accuracy specification.

A1-1.18.5 The upper and lower desired specification limits have been added to the graphs.

A1-1.18.6 The final piece of data added to the graph is the Average Die Offset. This, as stated in Step 1, is very good at illustrating any trends throughout the lot.

A1-1.18.7 Tips for graph making:

- Add gridlines across the X-axis to separate wafers.
- Print all graphs (X and Y, different lots, different probers) with the same scale in X and Y.
- Add a legend to your graphs, so that they will be readable by your “audience” as well as yourself.

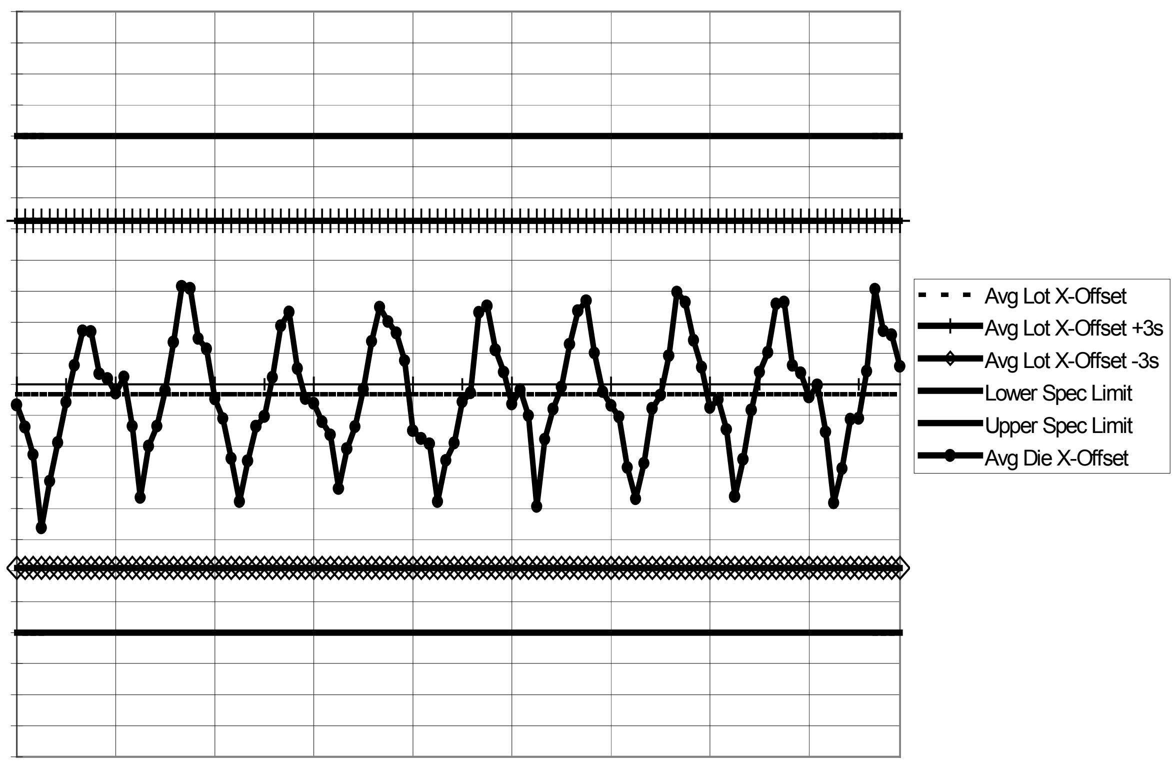

Figure 7

X-Offset

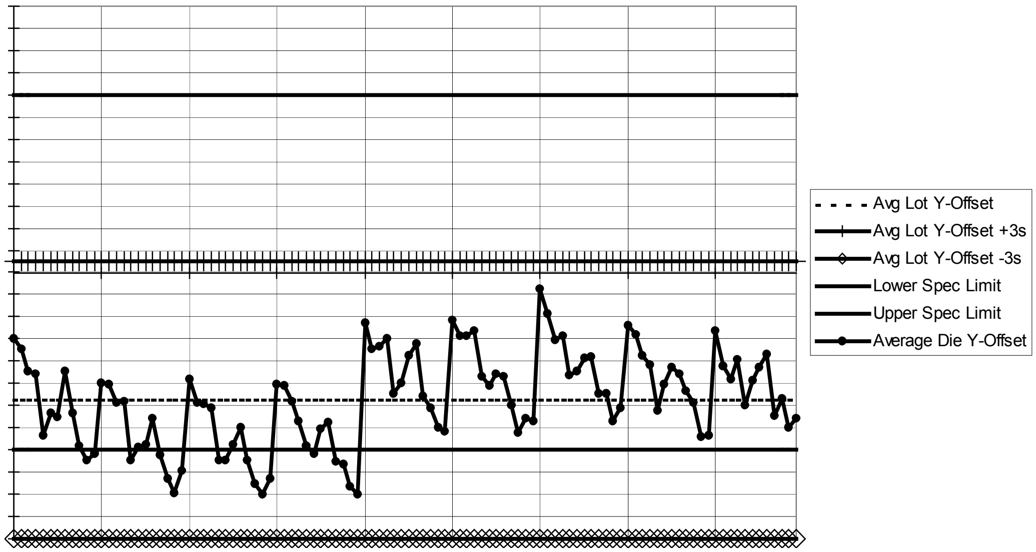

Figure 8

Y-Offset

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI G79-0200
SPECIFICATION FOR OVERALL DIGITAL TIMING ACCURACY

This specification was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the North American Automated Test Equipment Committee. Current edition approved by the North American Regional Standards Committee on September 3, 1999. Initially available at www.semi.org November 1999; to be published February 2000.

1 Purpose

1.1 This standard is intended to provide a minimum common definition of timing accuracy specifications for automatic semiconductor test equipment (ATE).

2 Scope

2.1 The scope of this standard includes all semiconductor ATE capable of digital functional testing. This standard does not include the following:

- test fixturing errors,
- device insertion errors, and
- ATE performance or capability beyond timing accuracy.

2.2 This standard's overall timing accuracy (OTA) definition serves to simplify automatic test equipment comparisons and reduce specification ambiguity.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 Parameters associated with the following items are not covered by the Overall Digital Timing Accuracy Specification:

- minimum driver pulse width,
- comparator bandwidth,
- I/O round trip delay,
- test fixturing errors,
- device insertion errors,
- time measurement unit accuracy, and
- ATE capability or performance beyond timing accuracy.

4 Referenced Standards

None.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ATE* — automatic test equipment

5.1.2 *DUT* — device under test

5.1.3 *NR* — Non-return signal format

5.1.4 *RTx* — return to zero, one or complement signal format.

5.1.5 *SBx* — surround by zero, one or complement signal format.

5.1.6 *Z* — driver off (high impedance)

5.2 *Definitions*

5.2.1 *device insertion errors* — error influenced by device-input capacitance and/or terminations.

5.2.2 *edge* — time delay created by an ATE delay generation resource.

5.2.3 *performance board* — printed circuit board used to interface the tester channels to the device under test.

5.2.4 *pin* — tester channel

5.2.5 *reference load A* — 500 ohms in parallel with 2.5pf (± 0.5pf) to ground

5.2.6 *reference load B* — 50 ohms to ground

5.2.7 *reference load C* —

- 50 ohms to low (for driver z to high and high to z transitions).
- 50 ohms to high (for driver z to low and low to z transitions).

5.2.8 *strobe compare* — monitor DUT output at a single time point.

5.2.9 *test cycle* — inverse of test pattern execution frequency.

5.2.10 *test fixturing errors* — error influenced by mismatched signal path lengths, impedance discontinuities, lumped capacitance/inductance elements, and high frequency loss due to skin effect or interconnects.

5.2.11 *window compare* — monitor DUT continuously during a time interval.

NOTE 1: The term "input" as it appears in this document refers to the device under test.

6 Test Methods

6.1 See Figure 1.

NOTE 2: A verification procedure to complement this Overall Digital Timing Accuracy Specification is currently being developed as a SEMI draft document.

6.2 *Explanation of Figure 1* — This figure is meant to graphically describe Overall Timing Accuracy and its constituent components. Overall Timing Accuracy (OTA) is made up of three components, and by definition is the aggregate timing error comprised of input edge placement accuracy (see Section 7.1.1), output edge placement accuracy (see Section 7.1.2), and input to output timing accuracy (see Section 7.1.3). It's important to note that the OTA specification and associated graphical representation shown in Figure 1 is meant to encompass timing delay errors across multiple machines, as well as multiple calibrations for a single machine over time.

6.2.1 Our experience in dealing with multiple-pin automated test systems reveals that not all input drive circuits can place a drive edge at exactly the same point in time relative to a common reference. The same is true for output compare circuits when placing compare edges. Thus, these edges tend to have an (error) distribution around some average value relative to their intended placement. This is due in part to the inherent anomalies associated with electronic circuits that make-up these edge placement elements. The distribution of edge error is graphically shown for input (see Section 7.1.1) and output edge (see Section 7.1.2) signals in Figure 1.

6.2.2 Drive Input to Compare Output Timing Accuracy (Section 7.1.3) can be described in different ways. It is easy to think of this parameter, per the definition given in this document, Section 7.1.3, as simply the relative time difference (skew) between the drive delay timing error distribution and the compare delay timing error distribution for a particular machine. But this parameter, once established for a machine, is not necessarily constant. For example, this parameter can change from one calibration of a machine at a particular time, to something different, as a result of a subsequent calibration of that same machine. As well, this parameter can also be considered as a machine to machine accuracy parameter, not necessarily having the same value between any two machines of the same kind.

6.2.3 Thus, on each machine and at different points in time for the same machine the Drive Input to Compare Output Timing skew can be uniquely different per machine. That difference being influenced by the various machine anomalies that contribute to machine error including the not so perfect results of a periodic edge calibration.

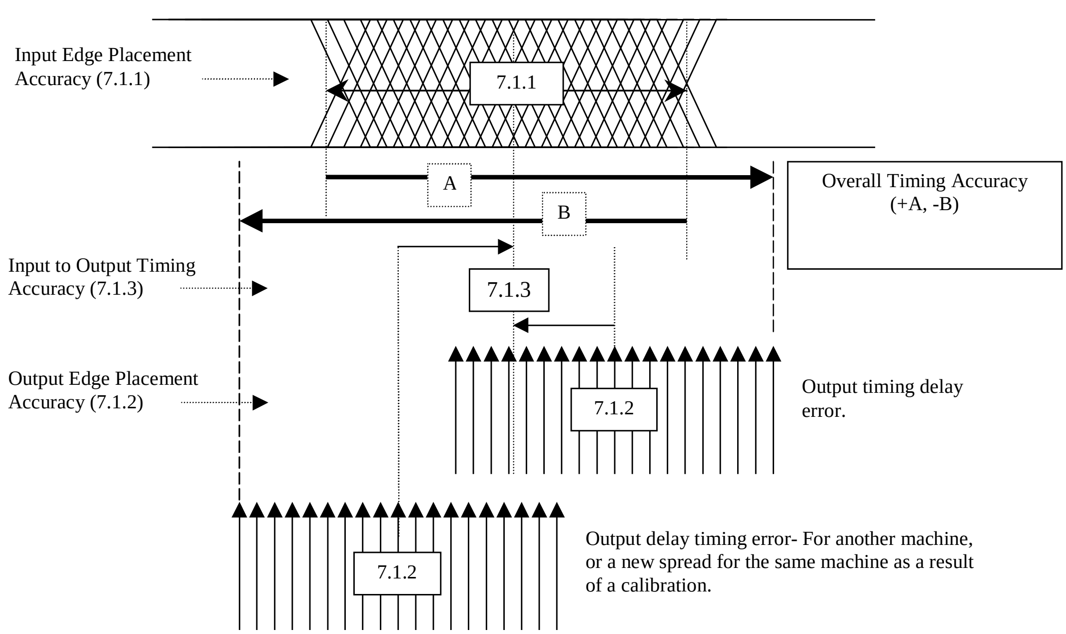


Figure 1
Overall Timing Accuracy

6.2.4 Examination of the OTA definition in the context of Figure 1, that being the general case and not a single point timing evaluation, reveals that the overall timing accuracy time value is the time line indicated by "A" and the time line indicated by "B". In a single point AC timing evaluation, OTA is determined as a distribution of edges associated with time line "A" or time line "B", depending upon the relationship between the drive edge values and compare edge values (see Section 7.1.3) at that point in time.

7 Definitions

7.1 *Overall Timing Accuracy* — aggregate timing error comprised of input edge placement accuracy, output edge placement accuracy and input to output timing accuracy. (See Figure 1.)

7.1.1 *Input Edge Placement Accuracy* — DUT input timing error comprised of input timing delay error, input timing jitter and input transition time variation.

7.1.1.1 *Input Timing Delay Error @ 5V* — time delay error at the midpoint of a 5V transition, with respect to an ideal delay (NIST traceable delay reference), using any pin, any delay value, any input timing edge, any format (NR, Rtx, SBx), positive or negative transition and any test cycle length.

Conditions:

- delays are normalized to pin 1 (first tester pin), rising edge, NR format, @ 0ns;
- errors are normalized to the average of minimum and maximum of the error distribution;[1]
- reference load A; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.1.2 *Input Timing Delay Error @ 3V* — (same as Section 7.1.1.1 @ 3V)

7.1.1.3 *Input Timing Delay Error @ 1V* — (same as Section 7.1.1.1 @ 1V)

7.1.1.4 *Input Timing Jitter* — short term (cycle to cycle) instability using any pin, any input timing edge, any format (NR, RTx, SBx).

Conditions:

- error expressed as RMS value;
- reference load B;
- physical reference point is a zero length interconnect on the DUT side of a standard performance board; and
- error referenced to corresponding transition of prior cycle.

7.1.1.5 *Input Transition Time Variation @ 5V* — minimum and maximum rise and fall times of a 5V input signal transition using any pin.

Conditions:

- referenced to the time variation between the 20% and 80% points of both positive and negative signal transitions;
- reference load A; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.1.6 *Input Transition Time Variation @ 3V* — (same as Section 7.1.1.5 @ 3V)

7.1.1.7 *Input Transition Time Variation @ 1V* — (same as Section 7.1.1.5 @ 1V)

7.1.2 *Output Edge Placement Accuracy* — DUT output compare timing error comprised of output timing delay error and output compare timing jitter.

7.1.2.1 *Output Timing Delay Error @ 5V* — time delay error at the detected midpoint of a 5V transition, with respect to an ideal delay (NIST traceable reference), using any pin, any delay value, any compare timing edge, window or strobe compare mode, expect H or L, positive or negative transition and any test cycle length.

Conditions:

- measured with load circuit "off" or high impedance;
- delays normalized to rising edge detected by pin 1 (first tester pin), using strobe compare format, expect H @ 0ns;
- error normalized to the average of minimum and maximum of the error distribution; and
- input signal: 50-ohm source, 0–5V step, > 1V/ns, inserted at a zero length interconnect on the DUT side of a standard performance board.

7.1.2.2 *Output Timing Delay Error @ 3V*— (same as Section 7.1.2.1 using 3V input signal)

7.1.2.3 *Output Timing Delay Error @ 1V* — (same as Section 7.1.2.1 using 1V input signal)

1 "Average of min and max of the error distribution" is defined as: (min error + max error)/2. This can also be referred to as "center of spread".

7.1.2.4 *Output Timing Jitter*— short term (cycle to cycle) instability using any pin, any compare timing edge, window or strobe compare mode, expect H or L.

Conditions:

- error expressed as RMS value;
- physical reference point is a zero length interconnect on the DUT side of a standard performance board; and
- jitter referenced to an independent synchronous trigger.

7.1.3 *Input to Output Timing Accuracy* — relative time difference between the average of minimum and maximum drive input delay timing and the average of minimum and maximum compare output delay timing.

7.1.3.1 *Input to Output Timing Error @ 5V* — relative time difference between the average of minimum and maximum input delay timing error @ 5V (Section 7.1.1.1) and the average of minimum and maximum output timing delay error @ 5V (Section 7.1.2.1).

Conditions:

- (same as Sections 7.1.1.1 and 7.1.2.1).

7.1.3.2 *Input to Output Timing Error @ 3V* — same as Section 7.1.3.1 using 3V input signal and definitions/ conditions specified in Sections 7.1.1.2 and 7.1.2.2.

7.1.3.3 *Input to Output Timing Error @ 1V* — same as Section 7.1.3.1 using 1V input signal and definitions/ conditions specified in Sections 7.1.1.3 and 7.1.2.3.

7.1.4 *High Speed Clock Accuracy* — DUT high speed clock input timing error (if different than normal tester input channels) comprised of high speed clock delay error, high speed clock self-trigger cycle jitter, high speed clock self-trigger phase jitter and high speed clock transition time variation.

7.1.4.1 *High Speed Clock Delay Error @ 5V* — time delay at the midpoint of a 5V transition, with respect to an ideal delay (NIST traceable delay reference), using any pin, any delay value, any input timing edge, RTZ format, and any test cycle length.

Conditions:

- delays are normalized to pin 1 (first tester pin), rising edge, NR format, @ 0ns;
- errors are normalized to the average of minimum and maximum of the error distribution;
- reference load A; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.4.2 *High Speed Clock Delay Error @ 3V* — (same as Section 7.1.4.1 @ 3V)

7.1.4.3 *High Speed Clock Delay Error @ 1V* — (same as 7.1.4.1 @ 1V)

7.1.4.4 *High Speed Clock Self-trigger Cycle Jitter* — short term instability using any high speed clock pin, from a rising clock edge to the next rising clock edge, or falling clock edge to the next falling clock edge.

Conditions:

- error expressed as RMS value;
- reference load B; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.4.5 *High Speed Clock Self-trigger Phase Jitter* — short term instability using any high speed clock pin, from a rising clock edge to the next falling clock edge, or falling clock edge to the next rising clock edge.

Conditions:

- error expressed as RMS value;
- reference load B; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.4.6 *High Speed Clock Transition Time Variation @ 5V* — minimum and maximum rise and fall times of a 5V input signal transition using any high speed clock pin.

Conditions:

- referenced to the 20% and 80% points of a positive and negative signal transition;
- reference load A; and
- physical reference point is a zero length interconnect on the DUT side of a standard.

7.1.4.7 *High Speed Clock Transition Time Variation @ 3V* — (same as Section 7.1.4.6 @ 3V)

7.1.4.8 *High Speed Clock Transition Time Variation @ 1V* — (same as Section 7.1.4.6 @ 1V)

7.1.5 *Input Timing Delay Error for Z to Drive High/Low* — Time delay error at the midpoint of a driver transition from Z to high/low, with respect to an ideal delay, using any pin, any delay value, any Z control timing edge, any Z transition format, and any test cycle length.

NOTE 3: This definition does not include I/O timing restrictions imposed by the round trip delay between the tester electronics and the DUT.

Conditions:

- delays are normalized to pin1 (first tester pin), rising edge, NR format, 5V, @ 0ns;
- errors are normalized to the average of minimum and maximum of the error distribution;
- reference load C; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

7.1.6 *Input Timing Delay Error for Drive High/Low to Z* — Time delay error at the midpoint of a driver transition from high/low to Z, with respect to an ideal delay, using any pin, any delay value, any Z control timing edge, any Z transition format, and any test cycle length.

NOTE 4: This definition does not include I/O timing restrictions imposed by the round trip delay between the tester electronics and the DUT.

Conditions:

- delays are normalized to pin1 (first tester pin), rising edge, NR format, 5V, @ 0ns;
- errors are normalized to the average of minimum and maximum of the error distribution;
- reference load C; and
- physical reference point is a zero length interconnect on the DUT side of a standard performance board.

SEMI G80-0200
TEST METHOD FOR THE ANALYSIS OF OVERALL DIGITAL TIMING ACCURACY FOR AUTOMATED TEST EQUIPMENT

This test method was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the North American Automated Test Equipment Committee. Current edition approved by the North American Regional Standards Committee on September 3, 1999. Initially available at www.semi.org December 1999; to be published February 2000.

1 Purpose

1.1 This procedure will define a standard process whereby any logic integrated circuit (IC) ATE system can be evaluated for parameters that makeup an AC timing accuracy specification.

1.2 Application of this procedure will simplify ATE comparisons, reduce specification ambiguity, simplify user acceptance procedures, simplify ATE performance monitoring, and provide a common validation criteria for ATE suppliers.

2 Scope

2.1 This procedure is intended for analysis of timing accuracy specifications for all semiconductor automatic test equipment (ATE) capable of digital functional testing. The extent of the analysis includes overall timing accuracy and the primary components of overall timing accuracy as defined in the definition section of this document.

2.2 This procedure does not include analysis of the following parameters associated with ATE timing accuracy:

- minimum driver pulse width,
- comparator bandwidth,
- I/O round trip delay,
- test fixturing errors,
- device insertion errors,
- time measurement unit (TMU) accuracy, and
- ATE capability or performance beyond AC timing accuracy.

2.3 Application of this procedure can reduce equipment acceptance time resulting in savings for both the end-users and ATE suppliers.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The following limitations are inherent to this procedure:

3.1.1 The tolerances of each measurement used in the procedure are listed in each test, where appropriate.

3.1.2 The verification methods do not include varying environmental conditions, so results may not reflect performance at environmental limits.

3.1.2.1 Due to execution time limits, the verification procedure does not represent an exhaustive analysis. The number of data points analyzed is intended to provide a minimum representative assessment of AC timing accuracy parameters in a practical amount of time.

3.1.3 This method uses only edge compare mode and non-multiplexed operation in providing a minimum representative assessment of AC timing accuracy.

3.1.4 This method does not determine the effects that duty cycle variations have on AC timing accuracy.

3.1.5 Not being an exhaustive analysis this method avoids comprehensive testing as might be expected for complex AC timing functions such as on-the-fly (OTF) timing. This method was defined with the intention of keeping the data gathering practical such that meaningful results are obtained in a reasonable amount of time. In the case of timing-on-the fly a routine is contained in this method and can be used as a reference parameter for comparative purposes when systems with on-the-fly timing are analyzed. Thus only the most fundamental AC timing results are produced and OTF timing is not included as part of the overall timing accuracy (OTA) results.

3.1.6 Discretion is advised when interpreting OTA results obtained from this method. Self-analysis cannot allow for all error components to be isolated. Thus good (compliant) method results should be viewed with caution as potentially compliant. On the other hand, poor (non-compliant) method results are a strong indication that the system under evaluation is questionable regarding its accuracy and most likely non-compliant.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI G79 — Specification for Overall Digital Timing Accuracy

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *1*[1] — tester output driver high level

5.1.2 *0*[2] — tester output driver low level

5.1.3 *ATE* — automated test equipment

5.1.4 *DUT* — device under test

5.1.5 *H*[3] — tester input comparator expect high level.

5.1.6 *L*[4] — tester input comparator expect low level.

5.1.7 *n* — highest pin/channel number, and Pin 1 — refers to the lowest pin/channel number.

5.1.8 *NR* — non-return signal format

5.1.9 *RTO* — return to one signal format.

5.1.10 *RTZ* — return to zero signal format.

5.1.11 *SBC* — surround by complement signal format.

5.1.12 *Z* — tester output driver high impedance ("off") state.

5.2 *Definitions*

5.2.1 *device insertion errors* — error influenced by device-input capacitance and/or terminations.

5.2.2 *edge* — time delay created by an ATE delay generation resource.

5.2.3 *high bandwidth oscilloscope* — digital sampling oscilloscope with > 10 GHz bandwidth, using probes with > 1 GHz bandwidth, 500 ohm input impedance, 2.5pF ± 0.5pF input capacitance and < 0.125" ground lead.

5.2.4 *pin* — tester channel

5.2.5 *performance board* — printed circuit board used to interface the tester channels to the device under test.

5.2.6 *test fixturing errors* — error influenced by mismatched signal path lengths, impedance discontinuities, lumped capacitance/inductance elements, and high frequency loss due to skin effect or interconnects.

1 This convention is not universal. Sometimes a "H" is used.

2 This convention is not universal. Sometimes a "L" is used

3 This convention is not universal. Sometimes a "1" is used.

4 This convention is not universal. Sometimes a "0" is used.

5.2.7 *window compare* — monitor device continuously during a time interval.

5.2.8 *zero_reference_measurement* — oscilloscope measurement of the midpoint of a 0–3v NR signal rising edge with delay = 0s. This is an arbitrary reference signal selected by the user of this method. The method user is free to choose a convenient reference signal that will allow consistent use of that signal for making edge placement timing measurements during tests described in level 2 of this procedure.

6 Summary of Method

6.1 This procedure provides a hierarchical, generic method of analyzing ATE timing accuracy. The hierarchy supports two levels of specification analysis. Broad, composite net results are available by using the ATE for self-analysis in Level 1.

6.2 At this level, a large amount of data can be efficiently collected, representing the net conformance to overall timing accuracy specifications. This technique, however, precludes isolation and detailed analysis of specific accuracy components. Therefore, a second level of analysis, incorporating external instruments is included. While the first level provides efficient, broad analysis, the second level provides less efficient, detailed analysis.

6.3 Results from the analyses are saved in a standard format to facilitate further use for application specific data reduction. The minimum format is:

test #, channel #, min value, max value

6.3.1 *Verification Procedure Summary*

6.3.1.1 *Level 1 ATE Self-Analysis*

- Highly Efficient
- Broad Scope
- Moderate Error Observability
- Drive Input to Compare Output Tests
    - 3 Voltages
    - 2 Pin Directions
    - 503 Test Cycles[5]
    - 503 Pulse Widths
    - 12 Transitions[6]
    - 4 Formats
- Extended Delay Tests

5 Reference Figure 3.

6 Reference Figure 2.

- Drive Z-State Tests
- Multiple Period Tests

6.3.1.2 *Level 2 External Measurements*

- Inefficient w/o Automation
- Focused Scope
- Good Error Observability
  - Drive (input) Timing Test
  - Compare (output) Timing Test
  - Driver Rise Time Test
  - Drive (input) Timing Cycle Jitter Test
  - High Speed Clock Test

7 Requirements

7.1 *Acceptance Tests* — Before initiating the test process, the ATE under evaluation is to be certified by a representative of the manufacturer or end-user to be fully operational.

7.2 *Personnel Qualification* — The individual(s) operating the ATE under evaluation must be certified or otherwise qualified to operate this equipment, and be familiar with the procedures for performing the analysis called-out in this document.

7.3 *Supplemental Equipment* — The following equipment is required: A digital sampling oscilloscope with > 10 GHz bandwidth, probes with > 1 GHz bandwidth, 500 ohm input impedance, 2.5 pF ± 0.5pF input capacitance, and < 0.125" ground lead. It is important that this equipment requirement step be met. Tolerances called-out in various steps of this procedure were chosen to be consistent with the general equipment specified in this equipment specification requirement.

7.4 *This Procedure* — It is highly recommended that the user of this method read this document (SEMI G80) in its entirety.

7.5 *System* — Test system usage will be available on a continuous basis and uninterrupted during the allotted time needed to perform this timing analysis procedure.

7.6 *Application Program* — It is required that an application program be written to perform the steps called-out in this procedure. That program will act as a means of reliable and consistent interaction between the tester and supplemental equipment. In so executing, that program will also facilitate the data collection process that will ultimately lead to the timing analysis conclusions this procedure produces.

7.7 *The Method* — The recommended procedure, contained primarily in Section 10 of this document, is generically written and will serve as a guide in producing the required program, written in the test application software language of the system under evaluation.

7.8 *ATE System Performance (Load) Boards* — To collect data two performance/load boards will be required. For one of these performance boards it is recommended that adjacent tester channels be shorted together with minimum and equal length interconnections. This board will facilitate the data collection process for Level 1 and in part for Level 2. The second board is to have an open driver to comparator connection and will be used for Level 2 drive input timing tests. Reference Figures 1 and 4.

7.9 *Exceptions* — It is expected that the user of this method execute the procedures as described in this document. If the method user should choose to deviate from the procedures recommended in this document it is expected that an appropriate description of that deviation be entered in the EXCEPTIONS PAGE provided in Appendix 3.

8 Test Conditions

8.1 *Environmental* — It is a requirement that the procedure called-out in this document be executed within the intended environmental operating conditions specified by the equipment supplier. Operating temperature requirements specified by the equipment supplier must be maintained.

8.2 *Optional Execution* — The user of this procedure may consider rerunning this procedure at environmental (temperature) extremes other than nominal.

8.3 *Warm-up Period* — It is essential that all equipment used or under evaluation be allowed to warm-up in accordance with the manufacturer's specified requirements for equipment stabilization.

8.4 *Optional Data Collection* — Data may be taken immediately after equipment calibration. However, the user of this procedure may wish to take additional data at subsequent time intervals, but within the known good calibration window for the system under evaluation.

9 Preparation of Apparatus

9.1 *Equipment Configuration* — The equipment under evaluation must be configured for its normal and intended operation. No special considerations such as additional cooling or removal of equipment skins are to be undertaken.

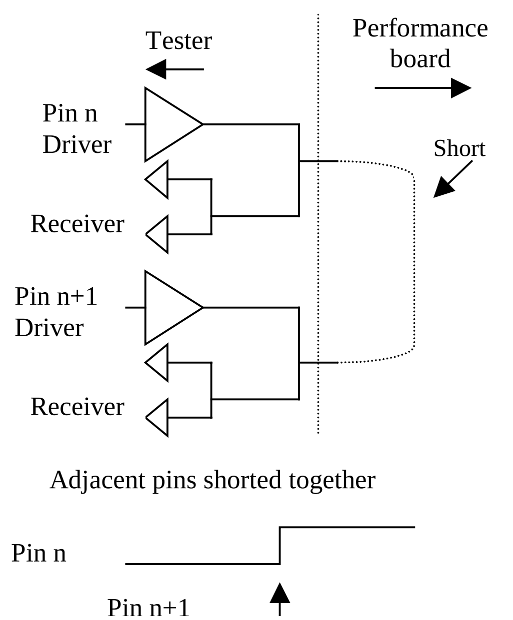
9.2 *Equipment Calibration* — The equipment under evaluation must be fully calibrated before this procedure is executed. No special calibration is to be performed and the equipment is to be configured for normal and intended operation.

9.3 *Supplemental Equipment Calibration* — External equipment used for level 2 data collection in this procedure must be verified for proper calibration.

10 Test Method Procedure

10.1 The procedure is comprised of Level 1 tests and Level 2 tests. Any ATE capability described in the following tests that is not available on the ATE under analysis is not required for compliance to the procedure, but should be noted in the verification results Table 1 and Table 2.

10.2 Each test system is different; thus this procedure is generic. Regardless, it will provide comprehensive results when the specific application is created using this procedure as a guide. Per the requirements, a load board and application program written to accommodate the procedure should be in place when the procedure is executed. This procedure is to be executed per the requirements outlined in Section 7 of this document. When these requirements are met, the following steps will comprise the step by step process for execution of this Test Method:



Pairs of adjacent tester pins are shorted together with a minimum length interconnect on the performance board.

Figure 1
Level 1 Verification

1. Install the performance board.

2. Power up the system and supplemental equipment, allow adequate time for stabilization.

3. Load the appropriate application program that represents the embodiment of the procedure called out in Sections 10.3.1, 10.3.4, 10.3.5, and 10.3.6 for Level 1 as well as Sections 10.4.1, 10.4.2, 10.4.3, 10.4.4, 10.4.5, and 10.4.6 for Level 2.

4. Execute the method to completion. The application program can capture the data for Level 1 and Level 2 and store that for later analysis.

5. This procedure calls for various time measurements to be made at specified voltage points or signal levels. The user is encouraged to maintain these values to keep the method results constants when system to system comparisons are being made. Regardless, he is free to adjust these measurement points or levels to accommodate specific integrated circuit technology requirements important to that product and the system being analyzed. When that occurs documentation of those procedure variations must be entered in Appendix 3 (Exceptions Page).

6. Best results from this procedure are achieved if a consistent measurement methodology is maintained. This is important when making time measurements relative to a particular transition point on a signal edge. This method recommends that when signal measurements are specified at a particular transition point, i.e., 50%, that this point on the edge be determined relative to the 0% or 100% steady state levels displayed on the oscilloscope, after any aberrations due to the transition have expired. A tester reference channel, the lowest channel, should be used to set the measurement point(s) and then consistently used as the basis for subsequent measurements for the remaining tester channels.

7. *Data Analysis* — Analyze the captured data and make the appropriate data entries to Table 1, provided in this method document.

8. When this method execution is complete, document all method exceptions in the EXCEPTIONS section of this document (Appendix 3).

9. *Results* — Data entry to Table 2. Make the appropriate data entries to Table 2, provided in this method document and supplemented with examples contained in Appendix 2.

10.2.1 Level 1 requires no external equipment for completion, whereas Level 2 does require use of external equipment. The user is free to implement this procedure through total manual intervention. On the other hand, the user may choose to apply an automated or robotic approach to data collection for Level 2. Regardless, the user is advised that tester and external equipment interaction accommodated by the application program is necessary for data collection at Level 2.

10.3 *Level 1 Tests* — Level 1 tests are intended to efficiently gather a large amount of data by taking advantage of the self-analysis ability of the ATE. This is accomplished by shorting adjacent tester channels together on a performance board with minimum, equal length interconnections, and using one channel to test the other. Reference Figure 1. Execution speed and system resource coverage are of primary importance for Level 1. Level 1 is intended to analyze specification conformance as opposed to diagnose system failures. All measurements are normalized to "zero" in order to facilitate subsequent data reduction/analysis. Level 1 is intended to collect data only. Data reduction and processing are to be done off-line in order to maximize data collection efficiency.

10.3.1 *Timing Linearity Test* — This test is used to establish drive input to compare output timing accuracy by "stretching" the test cycle in minimum cycle programming increments while using fixed percentage delays and pulse widths as the method sweeps through various timing conditions. The test pattern should be written to switch all even or odd pins simultaneously, and for all transitions and associated strobes to occur at least 100 times for each data point.

10.3.2 For clarification all drive edges are detected in parallel in pairs. The intention is to sweep the compare edge and detect the earliest occurrence of a drive edge with the latest compare edge, as well as detect the latest occurrence of a drive edge with the earliest compare edge.

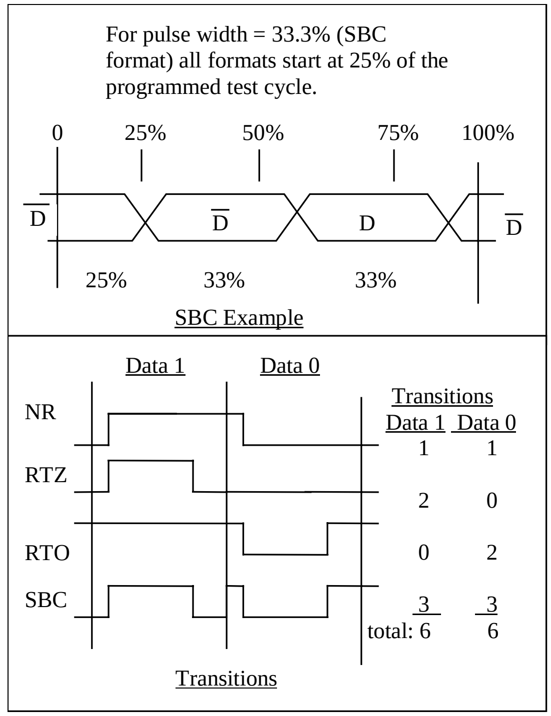


Figure 2
SBC Example and Transitions

10.3.3 The following Test Cycle Example and nested loop outline describes the test flow:

for amplitude = 1V, 3V, 5V
  for direction =
    odd_pins_drive_&_even_pins_compare to
    even_pins_drive_&_odd_pins_compare
   for test_cycle = min_cycle to [min_cycle +
    500*cycle_resolution] by
    cycle_resolution, 3x min_cycle, 10x min cycle
    for pulse width = 50% (RTZ/RTO formats)
          = 33.3% (SBC format)
          = don't care (NR format)
     for format = NR, RTZ, RTO, SBC (NOTE 1: all
       formats start at 25% of the programmed test
       cycle)
      for all format transitions (pattern data 0 and 1)
       detect earliest occurrence of format
         transition midpoint with the latest
         compare pin
       detect latest occurrence of format transition
         midpoint with the earliest compare pin
       error = (latest occurrence - earliest
           occurrence)
      end transitions
     end format
    end pulse width
   end test_cycle
  end direction
end amplitude

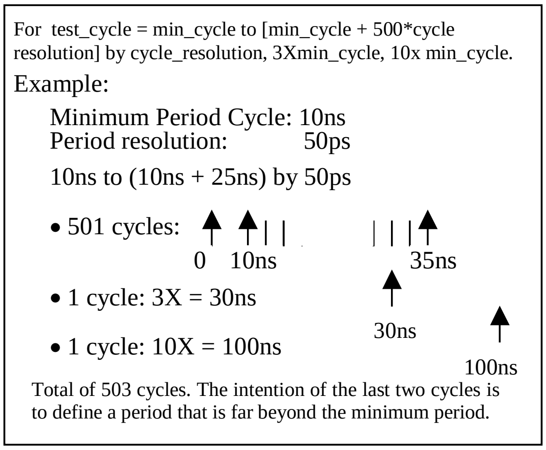


Figure 3
Test Cycle Example

10.3.4 *Extended Delay Test* — This test is used to establish drive input to compare output timing accuracy when timing generator delay values are programmed beyond the length of the test cycle. Driver input delays are programmed to occur in subsequent test cycles and detected with compare delays originating in the corresponding subsequent test cycle. The intention is the same as Section 10.3.1 with the exception that edges are programmed into a subsequent cycle. Conditions such as formats and voltages have been reduced to keep the amount of data collected down to a reasonable level.

10.3.4.1 The following nested loop outline describes the test flow:

```
for amplitude = 3V
  for direction =
        odd_pins_drive_&_even_pins_compare to
        even_pins_drive_&_odd_pins_compare
    for test_cycle = min to 10*min by 0.1*min
      for format = NR
        for format_delay = test_cycle to max_delay by
          0.25*test_cycle (max delay is beyond the cycle
                                boundary)
              detect earliest occurrence of format
                    transition midpoint with the latest
                    compare pin using pattern expect
                    data shifted into the appropriate cycle
              detect latest occurrence of format transition
                    midpoint with the earliest compare pin
                    using pattern expect data shifted into
                    the appropriate cycle
              error = (latest occurrence - earliest
                          occurrence)
            end delays
          end format
        end test cycles
      end directions
    end amplitude
```

10.3.5 *Driver Z State Test* — This test verifies the timing accuracy of tester driver transitions from Z to 1/0 and from 1/0 to Z. Driver inputs are programmed to transition to and from Z and 1/0 while being loaded with 50 ohms terminated to drive 1 for Z to 0 and 0 to Z, and 50 ohms terminated to drive 0 for Z to 1 and 1 to Z[7] (reference load C). The following nested loop outline describes the test flow:

```
for amplitude = 3V
  for direction =
     odd_pins_drive_&_even_pins_compare to
     even_pins_drive_&_odd_pins_compare
     for test_cycle = 5*min_cycle
       for format_delay = 50%
         for format = NR
           detect earliest occurrence of Z to low tran-
              sition at scaled midpoint with compare pins
           detect latest occurrence of Z to low tran-
              sition at scaled midpoint with compare pins
           error=(latest occurrence - earliest occurrence)
           detect earliest occurrence of Z to 1 tran-
              sition at scaled midpoint with compare pins
           detect latest occurrence of Z to 1 transition
              at scaled midpoint with compare pins
           error = (latest occurrence - earliest occur-
                      rence)
           detect earliest occurrence of 0 to Z transition
              at scaled midpoint with compare pins
           detect latest occurrence of 0 to Z transition at
              scaled midpoint with compare pins
            error = (latest occurrence - earliest occur-
                       rence)
            detect earliest occurrence of 1 to Z tran-
              sition at scaled midpoint with compare pins
            detect latest occurrence of 1 to Z transition
              at scaled midpoint with compare pins
            error = (latest occurrence - earliest occur-
                       rence)
         end format
       end format_delay
     end test_cycle
    end direction
end amplitude
```

10.3.6 *Multiple Period Test*[8] — This is an optional test to be run only if the ATE supports dynamic (or "on-the-fly") time set switching. This test intention is similar to Section 10.3.1 and 10.3.4 (timing linearity and extended delay tests) except that the test period and delay changes are generated dynamically within a

7 Tying two drivers together or connecting a resistor to a logic point is acceptable. Note: Load "C": 50 ohms to low for driver z to high and high to z transitions. And 50 ohms to high for driver z to low and low to z transitions.

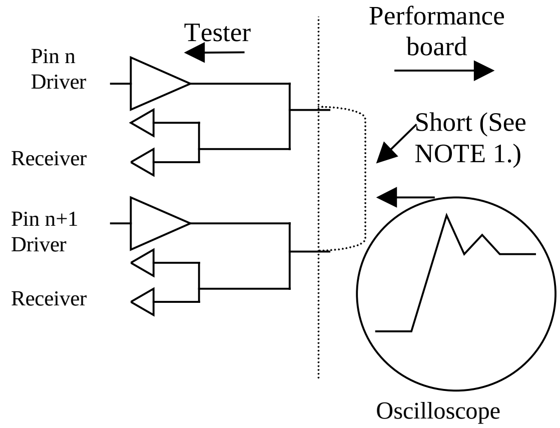
8 This algorithm requires 64 time sets. If the equipment does not have 64 time sets, adjust the algorithm to accommodate the amount available and note the differences on the exception page, Appendix 3.

single test pattern burst. The following nested loop outline describes the test flow:

for amplitude = 1V, 3V, 5V
  for direction =
      odd_pins_drive_&_even_pins_compare to
      even_pins_drive_&_odd_pins_compare
    execute single pattern with the following
    dynamic changes:

Test Cycle	*Drive Format*	*Format Offset*	*Pulse Width*	*Drive Data*	*Compare Offset*	*Expect Data*
min	SBC	20%	33%	1	53%	H
min	SBC	20%	33%	1	86%	L
min	SBC	20%	33%	0	53%	L
min	SBC	20%	33%	0	86%	H
min	SBC	20%	33%	1	20%	L
			.			
			.			
min	SBC	20%	33%	0	20%	H
64*min	SBC	20%	33%	1	53%	H
64*min	SBC	20%	33%	1	86%	L
64*min	SBC	20%	33%	0	53%	L
64*min	SBC	20%	33%	0	86%	H
64*min	SBC	20%	33%	1	20%	L
64*min	SBC	20%	33%	0	20%	H
2*min	SBC	20%	33%	1	53%	H
2*min	SBC	20%	33%	1	86%	L
2*min	SBC	20%	33%	0	53%	L
2*min	SBC	20%	33%	0	86%	H
2*min	SBC	20%	33%	1	20%	L
2*min	SBC	20%	33%	0	20%	H
63*min	SBC	20%	33%	1	53%	H
63*min	SBC	20%	33%	1	86%	L
63*min	SBC	20%	33%	0	53%	L
63*min	SBC	20%	33%	0	86%	H
63*min	SBC	20%	33%	1	20%	L
63*min	SBC	20%	33%	0	20%	H
			.			
			.			
32*min	SBC	20%	33%	1	53%	H
32*min	SBC	20%	33%	1	86%	L
32*min	SBC	20%	33%	0	53%	L
32*min	SBC	20%	33%	0	86%	H
32*min	SBC	20%	33%	1	20%	L
32*min	SBC	20%	33%	0	20%	H

      detect earliest occurrence of format
          transition midpoint with the latest
          compare pin
      detect latest occurrence of format transition
          midpoint with the earliest compare pin
      error = (latest occurrence - earliest occurrence)
  end direction
end amplitude



Pairs of adjacent tester pins can be shorted together with a minimum length interconnect on the performance board.

A reference for the oscilloscope measurement is required. That reference can be any signal synchronized to the test system's timing. The reference signal chosen should be consistent and stable. Examples of this may be another tester pin or master oscillator reference signal.

NOTE 1: The user of this method may find improved driver signal attributes using an open circuit performance board, versus the shorted board indicated here for Level 2 Drive Input Timing Error data collection. On the other hand the shorted performance board, using the driver as the signal source, is a viable approach for the Compare Output Timing Error Test. Regardless, the user may optionally choose to use a pulse generator as the signal source for the Compare Output Timing Error test. The 50-ohm pulse generator must have edge speeds that are comparable to the driver it is replacing. Test setup conditions and the pulse generator rise time employed must be documented on the exception page (Appendix 3).

Figure 4
Level 2 Verification

10.4 *Level 2 Tests* — The efficiency of data collection with Level 1 tests may preclude isolation of certain specification components. The self-analysis procedures may also mask some error terms that contribute to other specification components. Therefore, Level 2 modules are intended to supplement Level 1 results by using external instruments to distinguish individual specification components and provide detailed analysis of potentially masked results. The use of external instruments facilitates independent observation of individual parameters, but requires physical movement of a probe (unless automated with robotics), which results in less efficient data collection. Reference Figure 4.

10.4.1 *Drive Input Timing Error Test* — Since the driver input timing error cannot be distinguished from compare output timing error with Level 1 tests[9] an external instrument must be used to isolate the driver input timing error from compare output timing error. An external instrument is also required to identify pin to pin "skew" beyond adjacent pins, since Level 1 only uses adjacent pin pairs for analysis. This requires independent measurements of representative driver input timing conditions. The reference for measurement of driver input timing error is a high bandwidth-digital sampling oscilloscope. Exhaustive testing of all pins is impractical, so a reduced set of representative conditions is used. A non-binary pin sampling increment is used to ensure that traditional binary architectural boundaries are crossed. The tolerance for the driver input timing error test is ± 20ps[10] due to the tester/instrument interaction using a generic measurement method. The following nested loop outline describes the test flow:

```
for amplitude = 3V
  for pin = 1 to n by 3
    for test_cycle = min, 2*min, 3*min, 10*min
      for format_delay = 50% of test cycle
          for format = NR, RTZ, RTO, SBC
            for all format transitions
              detect midpoint of drive transition with
                 oscilloscope  (averaging = 8)
              error = (measured_delay - pro-
                     grammed_format_edge_time -
                     zero_reference_measurement)
            end transitions
         end format
      end format_delay
    end test_cycle
  end pin
end amplitude
```

10.4.2 *Compare Output Timing Error Test* — Since the compare output timing error cannot be distinguished from driver input timing error with Level 1 tests, an external reference must be used to isolate compare output timing error from driver input timing error. This requires independent measurement of representative compare timing conditions. Each tester driver is used to provide a synchronous reference signal by shorting adjacent tester channels together on a performance board with minimum, equal length interconnections. The actual delay of the driver signal is verified with a high bandwidth-digital sampling oscilloscope. (See Figure 4.)

NOTE 2: If a signal reflection is present at the midpoint of the observed signal (due to a long distance from the performance board to the tester receiver), then the 25% point of the reference driver waveform should be used, instead of the midpoint - as specified below.

10.4.2.1 Exhaustive testing of all pins is impractical, so a reduced set of representative conditions are used. A non-binary pin sampling increment is used to ensure that traditional binary architectural boundaries are crossed.

10.4.2.2 The following nested loop outline describes the test flow:

```
for amplitude = 3V
  for pin = 1 to n by 3
    for test_cycle = min, 2*min, 3*min, 10*min
      for format_delay = 50% of test_cycle
         for format = NR
            for edge = rising, falling
              detect midpoint of NR drive signal with
                 oscilloscope  (averaging = 8)
              detect midpoint of drive transition with
                 comparator (strobe compare mode)
              error = (measured_delay - pro-
                     grammed_compare_delay -
                     zero_reference_measurement)
         end edge
       end format
      end format_delay
    end test_cycle
  end pin
end amplitude
```

NOTE 3: Midpoint detection of the NR drive signal should be done via a compare edge sweep technique.

10.4.3 *Driver Transition Time Test* — Since driver transition time errors can be masked by compare timing errors and comparator bandwidth limitations, an external instrument is required to measure driver transition time errors. The reference used for driver transition time measurements is a high bandwidth-digital sampling oscilloscope.

10.4.3.1 The tolerance for driver transition time measurements is ± 150ps[11] due to the tester/instrument

9 See APPENDIX 2, Section A2-1.3 and Appendix 2, Examples for an explanation.

10 When recording measurements, data log all measurements as they are taken from the measurement equipment and show the associated equipment tolerance as a separate entity.

11 This 150ps tolerance has been extended beyond 20ps due to level sensitivities associated with oscilloscopes and typical bandwidth variations in oscilloscope probes rendering transition time measurements less accurate.

interaction using a generic measurement method. The signal measurement should be made with the driver loaded with reference load A (500 ohms in parallel with 2.5pF ± 0.5pF of capacitance). The following nested loop outline describes the test flow:

```
for amplitude = 1V, 3V, 5V (optional)
  for pin = 1 to n
    for edge = rising to falling
         measure the 20% to 80% transition time of a
         NR driver signal with test cycle = 10*min,
         delay = 0s  using oscilloscope (averaging = 8)
         error = maximum transition time - minimum
                transition time
    end edge
  end pin
end amplitude
```

10.4.3.2 The transition time measurements are to be made between the measured 20% and 80% points of both positive and negative signal edges, i.e., the 20% and 80% points on the signal transition edge relative to a 0% or 100% steady state level displayed on the oscilloscope. Ideally, measurement points chosen should be referenced to a steady state level that results after all aberrations in the transition have expired. Use the lowest tester pin as a reference channel when setting the measurement points for these measurements.

10.4.3.3 ATE systems may use a focused calibration routine for driver pins. That routine is intended to correct edge error due to transition time variations. In the context of executing this method for a machine that has this capability, the user of this method is advised to: 1) Execute the Drive Input Transition Time Variation test regardless, and 2) Enter the test results to the method data summary, Table 2. The entry in Table 2 for transition variation will be a reference parameter. This method as defined is incapable of making drive edge error measurements that exclude transition variation and jitter.

10.4.4 *Driver Input Timing Cycle Jitter Test*[12] — Since driver input timing jitter cannot be determined from Level 1 tests, an external instrument must be used to measure short term, cycle to cycle (or period) instability. This can be done by making period measurements of the driver-input channel under test, with a high bandwidth, digital sampling oscilloscope. A 50-ohm probe should be used to minimize measurement jitter. The tolerance for this test is ± 20ps[13] (min-max) due to the tester/instrument interaction using a generic measurement method. The measurement results are expressed as RMS. This measurement depends on the jitter distribution being Gaussian. Reference Appendix 4 for additional detail regarding this measurement. If in the application of this method it is determined that the jitter is non-Gaussian, skip this test and make the appropriate notation on the exceptions page (Appendix 3).

10.4.4.1 The following nested loop outline describes the test flow:

```
for pin = 1 to n
  for amplitude = 3V
    for test_cycle =  2*min
      for format = RTZ
           for format_delay = 50%
             for pulse_width = 50%
               for i = 1 to 1000
   meas(i) = measure the period of the pin under test
                end i
   measured signal  jitter = RMS spread of meas(1)
                through meas(1000)
              end pulse_width
            end format_delay
      end format
    end test_cycle
  end amplitude
end pin
measured instrumentation jitter = RMS spread of
        oscilloscope trigger
       (method described further in  Appendix 4)
actual RMS signal jitter = measured signal jitter -
        measured instrumentation jitter
(via sum of squares - reference Appendix 4)
```

Reference load B (50 ohms to ground) should be used for this measurement.

10.4.5 *High Speed Clock Self-trigger Cycle Jitter Test* — If the ATE is configured with dedicated high speed clock pins, an external instrument must be used to measure short term, cycle to cycle (or period) instability.

12 Trigger off the scope probe for this and the subsequent jitter test. Use a high persistence display to show signal jitter. Use of a high bandwidth-sampling oscilloscope with statistical capability is recommended. Instrumentation jitter should be extracted from the measured signal jitter, as explained in Appendix 4.

13 When recording measurement data, log all measurements as they are taken from the measurement equipment and show the associated equipment tolerances as a separate entity.

10.4.5.1 This can be done by making period measurements of the high speed clock channel under test, with a high bandwidth, digital sampling oscilloscope. A 50-ohm probe should be used to minimize measurement jitter. The tolerance for this test is ± 20ps (min-max) due to the tester/instrument interaction using a generic measurement method. The measurement results are expressed as RMS. This measurement depends on the jitter distribution being Gaussian. Reference Appendix 4 for additional detail regarding this measurement. If in the application of this method it is determined that the jitter is non-Gaussian, skip this test and make the appropriate notation on the exceptions page (Appendix 3). The following nested loop outline describes the test flow:

```
for pin = (all high speed clock pins)
 for amplitude = 3V
 for test_cycle = 10*min to min by min
      for clock_delay = 50%
        for i = 1 to 1000
meas(i) = measure the period of the clock pin under
test
        end i
measured signal jitter = RMS spread of meas(1)
       through meas(1000)
      end format_delay
    end test_cycle
  end amplitude
end pin
measured instrumentation jitter = RMS spread of
        oscilloscope trigger
       (method described further in  Appendix 4)
actual RMS signal jitter = measured signal jitter -
        measured instrumentation jitter
(via sum of squares - reference Appendix 4)
```

Reference load B (50 ohms to ground) should be used for this measurement.

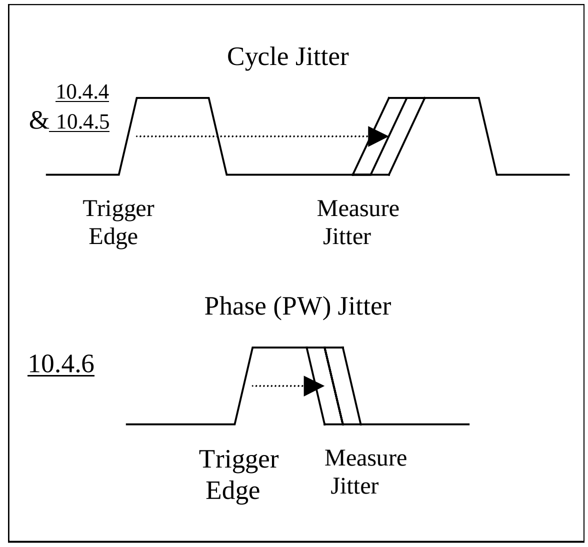


Figure 5
Jitter Tests – Sections 10.4.4, 10.4.5 and 10.4.6

10.4.6 *High Speed Clock Self-trigger Phase Jitter Test* — If the ATE is configured with dedicated high speed clock pins, an external instrument must be used to measure short term, phase (or duty cycle) instability. This can be done by making pulse width measurements of the high speed clock channel under test, using a high bandwidth, digital-sampling oscilloscope. A 50-ohm probe should be used to minimize measurement jitter. The tolerance for this test is ± 20ps[14] (min-max) due to the tester/instrument interaction using a generic measurement method. The results are expressed as RMS.

10.4.6.1 This measurement depends on the jitter distribution being Gaussian. Reference Appendix 4 for additional detail regarding this measurement. If in the application of this method it is determined that the jitter is non-Gaussian, skip this test and make the appropriate notation on the exceptions page (Appendix 3). The following nested loop outline describes the test flow:

```
for pin = (all high speed clock pins)
  for amplitude = 3V
    for test_cycle = 10*min to min by min
      for clock_delay = 50%
        for i = 1 to 1000
meas(i) = measure the pulse width of the clock pin
under test
        end i
measured signal jitter = RMS spread of meas(1)
through meas(1000)
      end format_delay
```

14 When recording measurement data, log all measurements as they are taken from the measurement equipment and show the associated equipment tolerance as a separate entity.

end test_cycle
end amplitude
end pin
measured instrumentation jitter = RMS spread of oscilloscope trigger
(method described further in Appendix 4)
actual RMS signal jitter = measured signal jitter - measured instrumentation jitter
(via sum of squares - reference Appendix 4)

Reference load B (50 ohms to ground) should be used for this measurement.

11 Data Collection Tables

11.1 Table 1 is the data collection table. Data can be manually or automatically entered to this table as this procedure is executed, depending upon how the user chooses to implement data collection.

11.2 Table 2 is intended to contain the final conclusions or analysis results of this procedure. Data for this table is taken from Table 1. Instructions for entering data to Table 2 will be described in Section 12, Reporting and Interpretation of Results, of this procedure. Examples of OTA calculations and data entry to Table 2 are contained in Appendix 2.

NOTE 4: A blank version of Table 2 is contained in Appendix 1.

12 Reporting and Interpretation of Results

12.1 *Reporting Results* — A large amount of data will be gathered when this Test Method is executed per the requirements of this method. A subset of this data should be collected into Table 1. This table contains the minimum and maximum values for the various tests contained in this Test Method.

12.1.1 Table 2 is a summary revealing the results of this Test Method. Table 2 entries will be determined from values taken out of Table 1 as well as summations of various entries occurring in Table 2. The following is a guide to making entries to Table 2:

12.1.2 *Driver Input Timing Delay Error (Section 10.4.1)* — This value is taken from Table 1. It is the difference between the minimum and maximum values shown in Table 1 for this parameter.

12.1.3 *Driver Input Timing Cycle Jitter (Section 10.4.4)* — This value is taken from Table 1. This is the RMS values shown in Table 1 for this parameter.

12.1.4 *Driver Input Transition Time Variation (Section 10.4.3)* — This value is taken from Table 1. It is the difference between the minimum and maximum values shown in Table 1 for this parameter.

12.1.5 *Driver Input Edge Placement Accuracy* — Driver Input Edge Placement by definition is the summation of Driver Input Timing Delay Error (Section 10.4.1), Driver Input Timing Cycle Jitter (Section 10.4.4), and Driver Input Transition Time Variation (Section 10.4.3). Regardless, since Drive Input Timing Delay Error measurements defined in this method do not exclude edge transition variation and jitter this entry is simply the measurements results obtained for Drive Input Timing Delay Error Level 2 (Section 10.4.1). Enter this value into Table 2 as Driver Input Edge Placement.

12.1.6 *Compare Output Time Delay Error (Section 10.4.2)* — This value is taken from Table 1. It is the difference between the minimum and maximum values shown in Table 1 for this parameter.

12.1.7 *Compare Output Edge Placement Accuracy* — Compare Output Edge Placement will be entered into Table 2 as the same entry made for Compare Output Time Delay Error (Section 10.4.2).

12.1.8 *Drive Input to Compare Output Timing Accuracy* — Data taken from Table 1 for Section 10.3.1 results: Drive Input To Compare Output Timing Accuracy = Reference – [(Min Value + Max Value)/2]. Refer to examples in Appendix 2.

12.1.9 *Overall Timing Accuracy (OTA)* — By definition and in the general case, the OTA value is the sum of Driver Input Edge Placement Accuracy, Compare Output Edge Placement Accuracy, and Driver Input to Compare Output Timing Accuracy. Examples are provided in Appendix 2 for making this entry into Table 2.

NOTE 5: For all High Speed Clock parameters shown in Table 2: High Speed Clock Delay and High Speed Clock Transition are parameters that use the same procedures as Drive Input Timing Delay and Drive Input Transition Time Variation. High Speed Clock Delay and High Speed Clock Transition are parameters provided in this procedure to accommodate those systems that have different pin electronics for the High Speed Clock function. If the system under evaluation doesn't have a High Speed Clock function, then the steps in this procedure for all High Speed Clock Accuracy are not required. High Speed Clock Cycle Jitter and High Speed Clock Phase Jitter are reference parameters with their respective test provided in this procedure to reveal accuracy for the High Speed Clock function when that function is present.

12.1.10 *High Speed Clock Delay Error (Section 10.4.1)* — This value is taken from Table 1. It is the difference between the minimum and maximum values shown in Table 1 for this parameter.

12.1.11 *High Speed Clock Cycle Jitter (Section 10.4.5)* — This value is taken from Table 1. This is the RMS values shown in Table 1 for this parameter.

12.1.12 *High Speed Clock Transition Time Variation (Section 10.4.3)* — This value is taken from Table 1. It is the difference between the minimum and maximum values shown in Table 1 for this parameter.

12.1.13 *High Speed Clock Phase Jitter (Section 10.4.6)* — This value is taken from Table 1. This is the RMS values shown in Table 1 for this parameter.

12.1.14 *High Speed Clock Accuracy* — This parameter is for systems that have a High Speed Clock function. High Speed Clock Accuracy is simply the same entry made for High Speed Clock Delay Error. High Speed Clock Transition Time Variation, High Speed Clock Cycle Jitter, and High Speed Clock Phase Jitter are reference parameters and should be entered to the appropriate location in Table 2.

12.1.15 *Driver Input Z Timing Errors (Section 10.3.5)* — There are four Drive Input Z Timing Errors. Each value is determined in the same way and is to be entered into Table 2. This value is taken from Table 1. Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1, Appendix 2.

12.1.16 *Timing Linearity (Section 10.3.1)* — This value is established from Table 1. Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1, Appendix 2. These two values should be entered at the appropriate place in Table 2.

12.1.17 *Extended Delay (Section 10.3.4)* — This value is taken from Table 1. Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1, Appendix 2.

12.1.18 *Multiple Period (Section 10.3.6)* — This parameter is optional. The test method for this parameter was defined for those systems with Timing On the Fly (OTF). If the system under evaluation does not have OTF timing data entry for this parameter is not required. Else, this value is taken from Table 1. Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1, Appendix 2.

12.2 *Interpreting Results* — Table 2 will contain summarized data, results of the Overall Digital Timing Accuracy Analysis Method for automated test systems.

12.2.1 This dialog is intended to explain the Level 1 and Level 2 results for OTA contained in Table 2 and require reference to Figure 6, Figure 7[15], and Table 2.

12.2.2 Level 1 analysis is meant to determine a test system's net conformance to the OTA specification in an efficient manner.

12.2.3 Level 2 employs external equipment to isolate parameters that contribute to OTA. That data reveals a more detailed and accurate representation to OTA conformance. Regardless, there is a limitation at getting to OTA entirely through Level 2 data collection.

12.2.4 Level 1 and Level 2 parameters are contained in Table 2 to represent OTA (Overall Timing Accuracy). Level 1 Timing Linearity (Section 10.3.1) provides analysis for all pins under comprehensive conditions and is used to acquire the drive input to compare output error parameter. Extended Delay (Section 10.3.4) complements Timing Linearity by verifying accuracy for timing generator delays beyond the length of the test cycle, and can be (optionally) used in lieu of Section 10.3.1. These two Level 1 elements represent in part OTA. Thus, this method produces a single point representation of system OTA, per the methodology defined in this method and consistent with the definition of OTA. This is done by summing Level 2 Drive Input Edge Placement Accuracy and Compare Output Edge Placement Accuracy with Level 1 Drive Input to Compare Output Timing Accuracy.

12.2.4.1 Compare side error in this method is not fully characterized or broken out into its constituent components, per the defintion of Compare Output Edge Placement Error. This method does establish Output Timing Delay Error, and its measurement contains the jitter component. But the method does not contain a way for determining Output Compare Timing Jitter by itself.

12.2.5 Establishing OTA using only Level 2 data is not possible. Only two of the three components per the standard definition of OTA can be determined. The OTA definition states: OTA is the sum of Drive Input Edge Placement, Compare Output Edge Placement, and Drive Input to Compare Output Accuracy. Level 2 analysis will collect data for the first two error components. The Level 2 parameter not achievable is Drive Input to Compare Output Accuracy. Level 1 will determine that value.

12.2.5.1 The Drive Input to Compare Output Accuracy by definition is the difference between the average of min & max drive input delay timing and the average of min & max compare output delay timing. Values for those components are in the Level 2 data, but because there is no common reference point for these two components when the data is taken, their difference cannot be established from the data at-hand.

12.2.5.2 In summary Level 2 analysis is capable of independently determining and isolating drive input timing error and compare output timing error. But, Level 2 drive input to compare output-timing error can not be established. Analysis done in Level 1 is required

15 Additional information related to Figure 7 is contained in Appendix 2.

to establish Drive Input to Compare Output timing error. Reference Figure 6.

12.2.6 As noted, Level 1 analysis does establish drive input to compare output-timing error. But, Level 1 cannot independently determine and isolate drive input timing error from compare output timing error, as was accomplished in Level 2. What this means is if the minimum to maximum drive input to compare output timing error is established as 1ns (Level 1), the method cannot create a break down such that so much of that 1ns is input error, with the remaining part of that 1ns being the output error.

12.2.7 Table 2 data also contains other valuable components of ATE error that will assist in establishing ATE timing integrity. Tests that establish the various components of Input Z Timing error, Multiple Period Tests for on the fly timing, and for systems with a High Speed Clock function tests to determine various delay, jitter and time variation errors.

12.3 A brief word on Drive Input to Compare Output Timing Accuracy will be made. Drive Input to Compare Output Timing can be described in different ways. It is easy to think of this parameter, per the definition of this aspect of OTA (reference Figure 6), as simply the relative time difference (skew) between drive input delay timing (see SEMI G79) and compare output delay timing (see SEMI G79), for a particular machine.[16] But this parameter, once established, is not necessarily constant. For example, this parameter can change from one calibration of a machine at a particular time, to something different, as a result of a subsequent calibration of that same machine. As well, Drive Input to Compare Output error can also be considered as a machine to machine accuracy parameter, not necessarily having the same value between any two machines of the same kind.

12.3.1 Thus, on each machine and at different points in time for the same machine the Drive Input to Compare Output Timing skew can be uniquely different per machine. That difference being influenced by the various machine anomalies that contribute to machine error including the not so perfect results of a periodic edge calibration.

12.3.2 In the general case drive input to compare output as shown in Figure 6 should be thought of in the context of drive/compare edges having time variance across multiple machines or as representing edges for the same machine but having variance across multiple time intervals associated with different calibrations.

16 Both drive input delay timing and compare output delay timing values taken at center of spread. By definition center of spread is the average of min & max: (minerr + maxerr)/2.

12.3.3 Examination of the OTA definition in the context of Figure 6, that being the general case and not a single point timing evaluation, reveals that the overall timing accuracy time value is the time line indicated by "A" and the time line indicated by "B". In a single point AC timing evaluation, OTA is determined as a distribution of edges associated with time line "A" or time line "B", depending upon the relationship between the drive edge values and compare edge values (see SEMI G79) at that point in time.

13 Precision, Accuracy, and Precautions

13.1 *Precision and Accuracy* — Tolerances called-out in the various steps of this procedure are consistent with the required supplemental equipment specifications called for in this Test Procedure.

13.2 *Precautions* — A precaution is advised when executing this procedure to the letter. Unreliable execution or failures may occur as a result of ATE specification tradeoff that typically exists between minimum pulse width and drive signal amplitude. This can be especially true when operation is in conjunction with complex formats such as SBC. This condition is a result of specification limitations inherent in the system under evaluation. Be advised that failure conditions can occur for systems with inadequate minimum pulse width and/or inadequate comparator bandwidth characteristics operating this procedure at high frequencies with complex formats.

13.3 It is necessary to note that data in Table 1 for any particular test represents minimum and maximum values taken for all conditions specified for each test. Examples of these conditions are parameters such as frequency, formats, and different voltages. Thus the precaution lies in how the user interprets the minimum to maximum deltas. As an example, a minimum value can occur at a lower frequency whereas a maximum value for that test may occur at a higher (different) frequency. Be aware, deltas under broad conditions may be greater than deltas for a focused condition. This specification is defined to provide results for the broad case.

13.4 When entering your analysis results to Table 2 Single Point Overall Timing Accuracy (OTA), be advised that the Single Point OTA Result is represented only as indicated in Table 2, the sum of Drive Input to Compare Output Timing, Drive Input Timing Delay Error, and Compare Output Time Delay Error. This appears to deviate from the absolute definition of OTA in that Drive Input Transition and Drive Input Timing Cycle Jitter are not included. The method does not lend itself to making Drive Input Timing Delay Error measurements that exclude these two components. Per this method when the Drive Input Timing Delay Error measurements are made they include these two parameters. Thus, because of the measurement if included per the definition, they would be double counted.

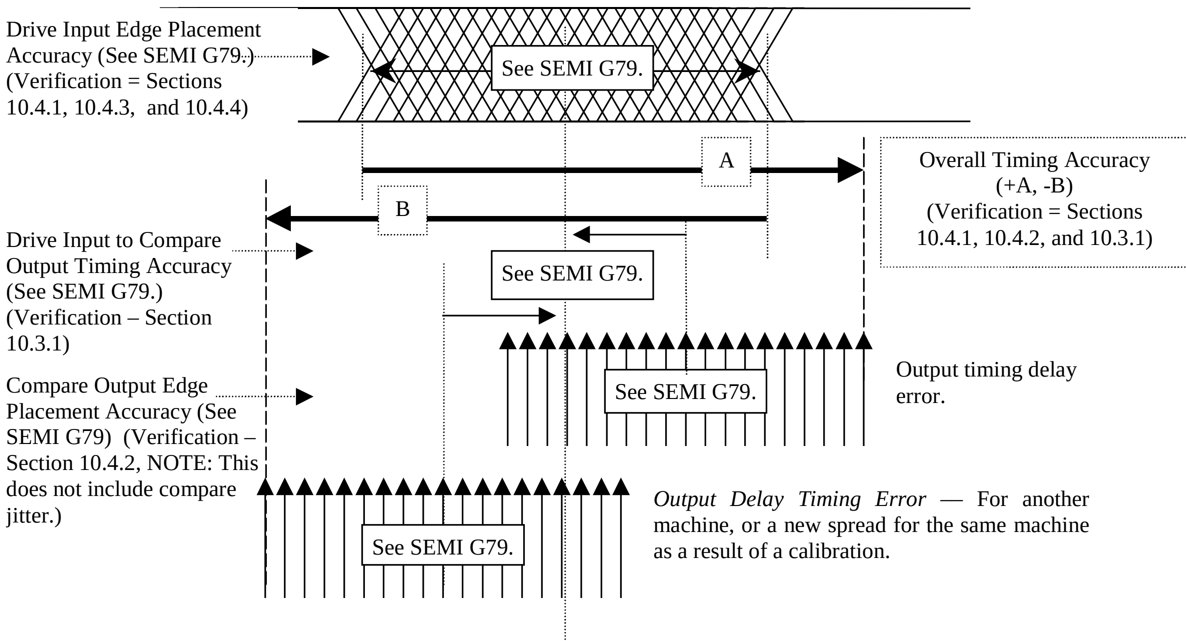
13.5 The OTA definition used in this method does not include reference parameters shown in Table 2 such as Drive Input Z Timing Error, Extended Delay, Multiple Period (timing on the fly), and High Speed Clock measurements. These are strictly reference timing parameters. This method is not defined such that they are to be included as part of OTA. Thus the user is advised not to sum any of those items as part of the OTA value entered into Table 2.

13.6 Table 2 is labeled Single Point Overall Timing Accuracy (OTA) Results. The term “single point” is used as a reminder for the user of this document that one execution of this method on a particular ATE system does not in itself constitute an overall timing accuracy conclusion for that system. It is simply a sample of the ATE's performance at some point in time. A true assessment of an ATE's performance for overall timing accuracy requires a comprehensive analysis involving data collection over an extended period of time that goes well beyond what this method provides in one pass.

13.7 In general, regarding these precautions, the user is free to adjust the procedure and data collection according to conditions consistent with the desired objective. Regardless, if the procedure is performed under anything other than full-up broad conditions, the results must be identified as a subset or partial interoperation of a single point overall timing accuracy assessment.

14 Related Documents

None.



For reference see the following definitions taken from SEMI G79:

7.1.1 *Input Edge Placement Accuracy* — DUT input timing error comprised of input timing delay error, input timing jitter and input transition time variation.

7.1.2 *Output Edge Placement Accuracy* — DUT output compare timing error comprised of output timing delay error and output compare timing jitter.

Output Timing Delay Error — time delay error at the detected midpoint of a 5V transition, with respect to an ideal delay (NIST traceable reference), using any pin, any delay value, any compare timing edge, window or strobe compare mode, expect H or L, positive or negative transition and any test cycle length.

Conditions:

- measured with load circuit "off" or high impedance
- delays normalized to rising edge detected by pin 1, using strobe compare format, expect H, @ 0ns
- error normalized to the average of min & max of the error distribution
- input signal: 50-ohm source, 0–5V step, > 1V/ns, inserted at a zero length interconnect on the DUT side of a standard performance board

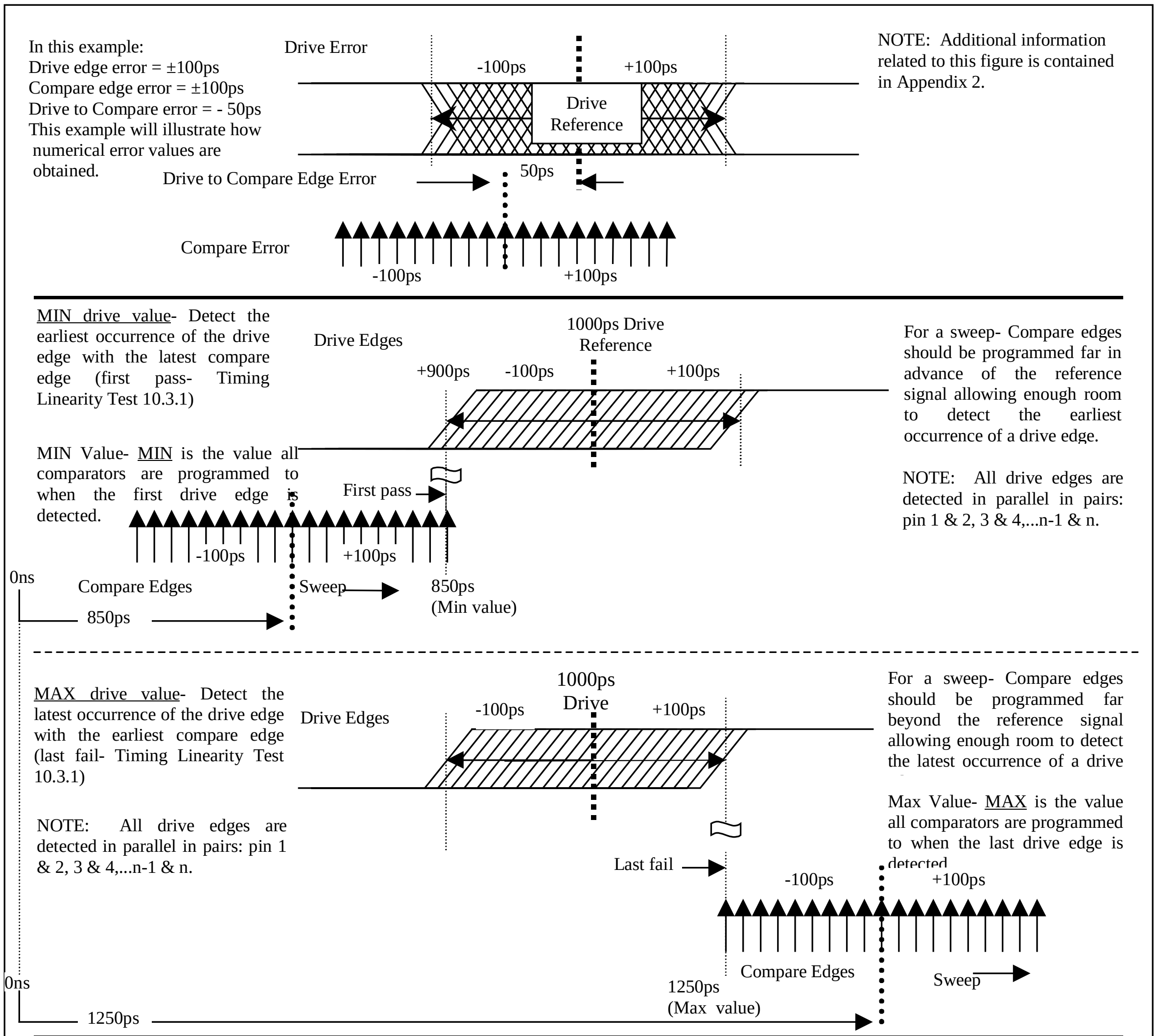
Output Compare Timing Jitter — short term (cycle to cycle) instability using any pin, any compare timing edge, window or strobe compare mode, expect H or L. (NOTE: This document does not define a method for Output Compare Timing Jitter.)

Conditions:

- error expressed as RMS value
- physical reference point is a zero length interconnect on the DUT side of a standard performance board
- jitter referenced to an independent synchronous trigger

7.1.3 *Input to Output Timing Accuracy* — relative time difference between the input delay timing and output delay timing.

Figure 6
Overall Timing Accuracy (OTA)



TIMING RELATIONSHIPS, DEFINITIONS & EXAMPLE RESULTS

DEFINITIONS-

Reference- The programmed value of the drivers

Drive to Compare Error- The difference between the average of min & max for Drive and the average of min & max for Compare error.

RELATIONSHIPS & EXAMPLE RESULTS-

Negative Error:	Reference - Min Value =	1000ps - 850ps = 150ps
Positive Error:	Reference - Max Value =	1000ps - 1250ps = -250ps
Drive to Compare Error:	Reference - [(Min Value + Max Value)/2] =	1000ps - [(850ps + 1250ps)/2] = -50ps

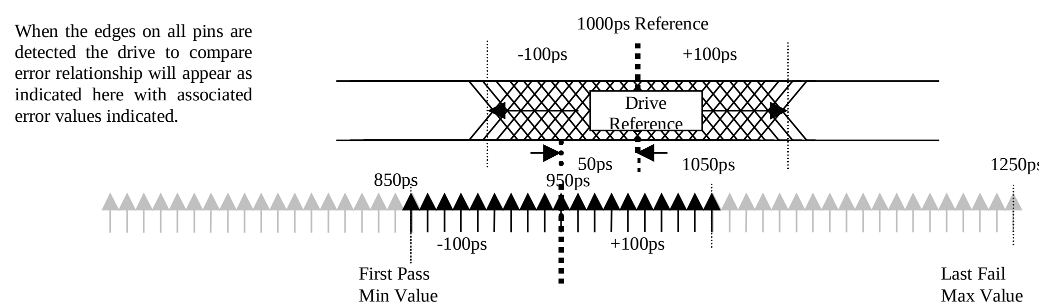


Figure 7
Level 1 Drive Edge Error = Compare Error

Table 1 Data Collection Table for Levels 1 and 2

	Test Number	*Channel Number*	*Min. Value*	*Max. Value*
LEVEL ONE	Section 10.3.1 Timing Linearity Test (Drive Input Edge Placement)	m to n		
	Section 10.3.4 Extended Delay Test (Compare Output Edge Placement)	m to n		
	Section 10.3.5 Drive Input Z Timing Error (Z to 0 (Low))	m to n		
	Section 10.3.5 Drive Input Z Timing Error (Z to 1 (High))	m to n		
	Section 10.3.5 Drive Input Z Timing Error (0 (Low) to Z)	m to n		
	Section 10.3.5 Drive Input Z Timing Error (1 (High) to Z)	m to n		
	Section 10.3.6 Multiple Period Test (Optional- for on the fly timing)	m to n		
LEVEL TWO	Section 10.4.1 Drive Input Time Delay Error (Drive Input Edge Placement)	m to n		
	Section 10.4.2 Compare Output Time Delay Error (Compare Output Edge Placement)	m to n		
	Section 10.4.3 Drive Input Transition Time Variation	m to n		
	Section 10.4.4 Drive Input Timing Cycle Jitter (Short term cycle to cycle period jitter)	m to n	*Enter RMS value only*	
	Section 10.4.5 High Speed Clock Self Trigger Cycle Jitter (Short term cycle to cycle period jitter/clocks)	m to n	*Enter RMS value only*	
	Section 10.4.6 High Speed Clock Self Trigger Phase Jitter (Short term phase /duty cycle jitter/clocks)	m to n	*Enter RMS value only*	

NOTE 6: This is a generic example of the data table needed to gather the data values for this timing analysis procedure. The actual number of table entries will depend upon the number of tester pins under evaluation. The pins to be tested are represented by the designation “m” to “n”. For Level 1 the application program is expected to fill in the minimum and maximum measurements made for each pin and specified condition. For Level 2 the user will fill-in these data values via manual entry, unless the application and implementation method employ automated/robotic operation.

Table 2 Test Method Summary Table for Establishing Overall Timing Accuracy (OTA)

LEVEL 1			LEVEL 2		
		Single Point Overall Timing Accuracy (OTA) Results *Data to enter here is: A = Dr (item 2) + Cmp (item 3) + Dr-Cmp (item 1)* *-B = -Dr (item 2) - Cmp (item 3) + Dr-Cmp (item 1).*			
Drive Z Timing *Data below represents Level 1 Z- state timing results*	**Timing Linearity Extended Delay Multiple Period** *Data below represents Level 1edge-delay results*	**1) Drive Input To Compare Output Timing** *Data to enter here is Drive Input to Compare Output (value below)*	**2) Drive Input Edge Placement** *Data to enter here = "a" below:*	**3) Compare Output Edge Placement** *Data to enter here = a) Compare Output Time Delay Error*	**High Speed Clock Accuracy** *Data to enter here = "a" below:*
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 0 (Low)- Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.	Timing Linearity Level 1 (Sec.10.3.1) Data to enter here is Positive Error & Negative Error per the data in Table 1 and the 2 equations: Positive Error = Reference - Max Value Negative Error = Reference -Min Value	Drive Input to Compare Out put Timing Accuracy calculated from 10.3.1 data as: Reference - [(MinValue+Max Value)/2]. Refer to examples in Appendix 2.	a) Drive Input Timing Delay Error Level 2 (Section 10.4.1)- Data to enter here = the delta between the min and max values in Table 1.	a) Compare Output Time Delay Error Level 2 (Section 10.4.2) Data to enter here = the delta between the min and max values in Table 1.	a) High Speed Clock Delay Error (Section 10.4.1- same as Drive Input Timing Delay but for clock pins) Data taken and entered for these pins equivalent to Drive Input Timing
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 1 (High)- Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.	Extended Delay Level 1 (Sec. 10.3.4)- Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.		b) Drive Input Transition Time Variation Level 2 (Section 10.4.3) - Data to enter here = the delta between the min and max values in Table 1.	b) Compare Output Timing Jitter (Note: no method exists for this test)	b) High Speed Clock Transition time variation (Section 10.4.3- same as drive input transition time but for clock pins) Data entry equivalent to Drive Input Transition Time.
Drive Input Z Timing Error Level 1 (Section 10.3.5) 0 (Low) to Z - Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.	Multiple Period Level 1 Optional (Sec. 10.3.6) Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.		c) Drive Input Timing Cycle Jitter Level 2 (Section 10.4.4) Data to enter here = the RMS value in Table 1.		c) High Speed Clock Self Trigger Cycle Jitter Level 2 (Section 10.4.5) Data to enter here = the RMS value in Table 1.
Drive Input Z Timing Error Level 1 (Section 10.3.5) 1 (High) to Z- Data to enter here is Positive Error and Negative Error per the data in Table 1 and Equation 1 Appendix 2.					d) High Speed Clock Self Trigger Phase Jitter Level 2 (Section 10.4.6)- Data to enter here = the RMS value in Table 1.

The user of the method is advised to read Section 13, Precautions before filling in this table.

Table 2 (cont.) Test Method Summary - Non Data Analysis Aspects Associated with This Method

1. Level 1 — Procedure Start Date and Time:	
2. Level 1 — Procedure Finish Date and Time:	
3. Level 2 — Procedure Start Date and Time:	
4. Level 2 — Procedure Finish Data and Time:	
5. Specify the Ambient Temperature when this method was executed.	
6. Manufacturer's model number and/or name for this system analyzed.	
7. System Serial Number:	
8. Date & Time of Last System Calibration:	
9. Specify PARTIAL or Full-Up execution of this method. Exceptions noted in Appendix 3.	
10. Specify Number of Test Heads & Number of Pins analyzed using this method.	

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI G80 and was approved by fulll letter ballot procedures on September 3, 1999 by the North Amerian Regional Standards Committee.

Table A1-1 Test Method Summary Table for Establishing Overall Timing Accuracy (OTA)

LEVEL 1			LEVEL 2		
		Single Point Overall Timing Accuracy (OTA) Results *Data to enter here is: A = Dr (item 2) + Cmp (item 3) + Dr-Cmp (item 1)* *-B = -Dr (item 2) - Cmp (item 3) + Dr-Cmp (item 1).*			
Drive Z Timing *Data below represents Level 1 Z-state timing results*	**Timing Linearity Extended Delay Multiple Period** *Data below represents Level 1 edge-delay results*	**1) Drive Input To Compare Output Timing** ________	**2) Drive Input Edge Placement** ________	**3) Compare Output Edge Placement** ________	**High Speed Clock Accuracy** ________
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 0 (Low) ________ ________	Timing Linearity Level 1 (Sec.10.3.1) Positive Error: ________ Negative Error: ________	Drive Input to Compare Out put Timing Accuracy calculated from the 10.3.1 entry. ________	a) Drive Input Timing Delay Error Level 2 (Section 10.4.1) ________	a) Compare Output Time Delay Error Level 2 (Section 10.4.2) ________	a) High Speed Clock Delay Error Level 2 (Section 10.4.1- Drive Input Timing Delay for clock function) ________
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 1 (High) ________ ________	Extended Delay Level 1 (Sec. 10.3.4) Positive Error: ________ Negative Error: ________		b) Drive Input Transition Time Variation Level 2 (Section 10.4.3) ________		b) High Speed Clock Transition Time Variation Level 2 (Section 10.4.3- Drive Input Transition Time for clock function) ________
Drive Input Z Timing Error Level 1 (Section 10.3.5) 0 (Low) to Z ________ ________	Multiple Period Level 1 Optional (Sec. 10.3.6) Positive Error: ________ Negative Error: ________		c) Drive Input Timing Cycle Jitter Level 2 (Section 10.4.4) ________		c) High Speed Clock Cycle Jitter Level 2 (Section 10.4.5) ________
Drive Input Z Timing Error Level 1 (Section 10.3.5) 1 (High) to Z ________ ________					d) High Speed Clock Phase Jitter Level 2 (Section 10.4.6) ________

The user of the method is advised to read Section 13, Precautions before filling in this table.

Table A1-1 (cont.) Test Method Summary - Non Data Analysis Aspects Associated with This Method

1. Level 1 — Procedure Start Date and Time:	
2. Level 1 — Procedure Finish Date and Time:	
3. Level 2 — Procedure Start Date and Time:	
4. Level 2 — Procedure Finish Data and Time:	
5. Specify the ambient temperature when this method was executed.	
6. Manufacturer's model number and/or name for this system analyzed.	
7. System Serial Number:	
8. Date and Time of Last System Calibration:	
9. Specify PARTIAL or Full-Up execution of this method. Exceptions noted in Appendix 3.	
10. Specify number of Test Heads and number of Pins analyzed using this method.	

APPENDIX 2

NOTE: The material in this appendix is an official part of SEMI G80 and was approved by fulll letter ballot procedures on September 3, 1999 by the North Amerian Regional Standards Committee.

A2-1 Examples

NOTE 1: This appendix contains Figures A2-1, A2-2, A2-3, and A2-4 created for this method as examples. The purpose of these examples is to show that Drive Input To Compare Output Error (Accuracy) can be determined. Establishing this value requires that two edge timing values be detected: MIN DRIVE VALUE: the earliest occurrence the drive edges with the latest compare edge. That is also referred to here as FIRST PASS. MAX DRIVE VALUE: the latest occurrence of the drive edges with the earliest compare edge. That is also referred to here as LAST FAIL.

NOTE 2: Timing Linearity Test 10.3.1 can provide these values. Examples in this appendix will also show data entry to Table 2 for OTA calculation.

A2-1.1 *Maximum Drive Value and Minimum Drive Value* — To follow this analysis you can refer to the example in Figure 7. In this example drive error and compare error are each 100ps.

NOTE 3: Figures A2-1, A2-2, A2-3, and A2-4 are equivalent and represent complementary examples for the cases where drive error does not have the same error value as compare error.

A2-1.2 Minimum Drive Value is determined by first assuming that all compare edges are programmed at 0ns. You must then take into account the drive to compare error, in this example that value is –50ps (note the sign indicating the shift is in the negative direction). Add the drive to compare error to the compare programming value. That means that the average (mean) compare edge can be thought of as actually occurring at –50ps (versus the programmed value of 0ns). Per this example the compare error is ± 100ps, which means the latest compare edge would occur at + 50ps (–50ps + 100ps). Since the driver edge error is also ± 100ps and is programmed to the reference value of 1000ps, the earliest drive edge occurs at 900ps (1000ps minus 100ps). The MIN DRIVE VALUE is then whatever programming value is needed to get the latest compare edge (at + 50ps) to line up with the earliest drive edge (at 900ps). In this case that's 850ps (the difference between 50ps and 900ps). This value of 850ps is also referred to at the FIRST PASS.

A2-1.3 The same analysis applies when determining Max Drive Value. First assume all compare edges are programmed to 0ns. The drive to compare error must be added-in, in this case –50ps. That puts the mean programmed compare edge at –50ps. Taking into account the compare edge error of 100ps the earliest compare edge would occur at –150ps. The drive edges are programmed to 1000ps. Thus the latest drive edge occurs at 1100ps when the 100ps drive edge error is taken onto account. To get the earliest compare edge to line up with the latest drive edge 1250ps of delay would need to be programmed (the difference between 1100ps and –150ps). This value of 1250ps is referred to as the LAST FAIL.

A2-1.4 *Drive to Compare Edge Error* — By definition DRIVE TO COMPARE EDGE ERROR is the relative time difference between the drive (input) edge error and compare (output) edge error distributions. All drive edges in Level 1 are detected in parallel in pairs. Once the minimum and maximum values of drive edge are determined per procedure 10.3.1 (illustrated in Figures A2-1 through A2-4) determination of drive to compare edge error can be established. As per these examples (Figures 7 and A2-1 through A2-4) the drive to compare edge error is calculated as the reference value minus the average of min and max error values:

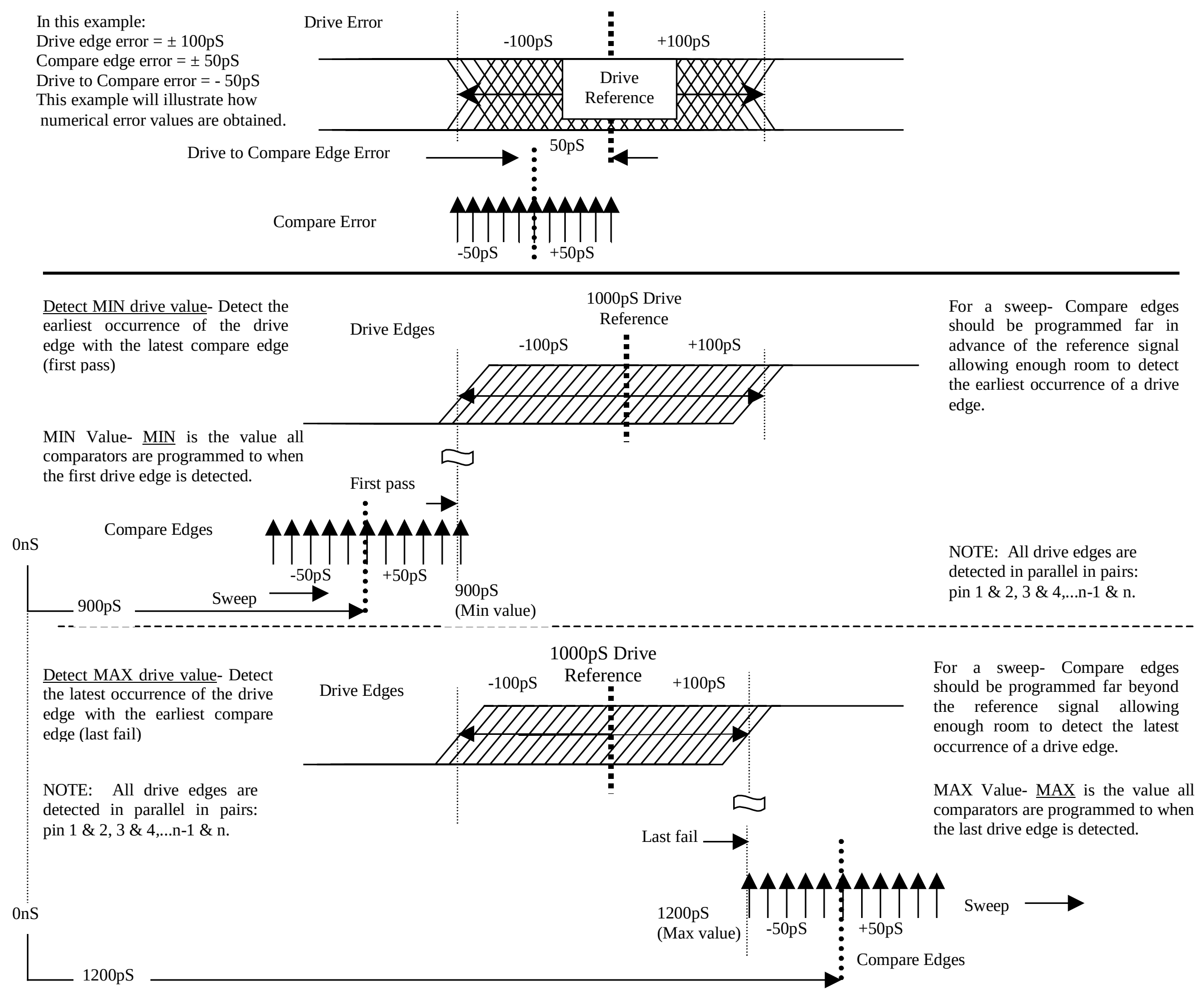
Drive to Compare Error =
Reference-[Min Value + Max Value)/2]

A2-1.5 *Distinguishing Drive and Compare Edge Error Uniquely Is Not Possible with Level 1 Tests* — The user is cautioned that even though drive to compare edge error is known, per this method it is still not possible to distinguish Level 1 drive input error from compare output error. The key to this shortcoming lies in observation of examples shown in Figures A2-1 thorough A2-4. These examples have drive and compare edge error values that are not the same value. That is, drive error is either much greater that compare edge error, or vice versa. In each example drive to compare edge error is established. To establish the point that drive input error cannot be distinguished from compare output error per level 1, the user is asked to look at Figures A2-1 and A2-2. In these two examples it is assumed that the drive error and compare error are different by a factor of two. Because of limited visibility per the level 1 approach it is not possible to determine that the drive error is ± 100ps and the compare error is ± 50ps (example in Figure A2-1), or vice versa. All that can be established is that the positive error is 200ps and the negative error is 100ps. Level 2 tests are required to determine drive input timing error and compare output timing error.

A2-1.6 The same rationale applies for the examples in Figure A2-3 and A2-4 where one component of error is assumed to be 200ps and the other is 100ps, with a 50ps drive to compare error. The drive to compare edge error is determined, but again establishing a unique value for drive or a unique value compare error is not possible in Level 1. All that is known per Level 1 analysis is that the positive error is 350ps and the negative error is 250ps.

A2-1.4 *Positive and Negative Error* — EQUATION 1: Per the examples in this Appendix and data taken out of Table 1:

Positive Error = *Reference* - *Max Value*
Negative Error = *Reference* - *Min Value*



TIMING RELATIONSHIPS, DEFINITIONS & EXAMPLE RESULTS

DEFINITIONS-

Reference- The programmed value of the drivers

Drive to Compare Error- The difference between the median value for Drive and the median value for Compare error.

RELATIONSHIPS & EXAMPLE RESULTS-

Negative Error:	Min Value - Reference = 900pS - 1000pS = -100pS
Positive Error:	Max Value - Reference = 1200pS - 1000pS = 200pS
Drive to Compare Error:	Reference - [(Min Value + Max Value)/2] = 1000ps - [(900ps + 1200pS)/2] = -50pS

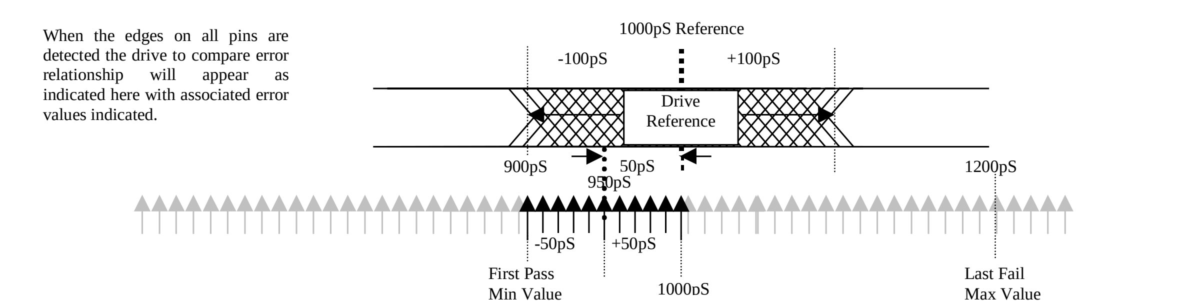
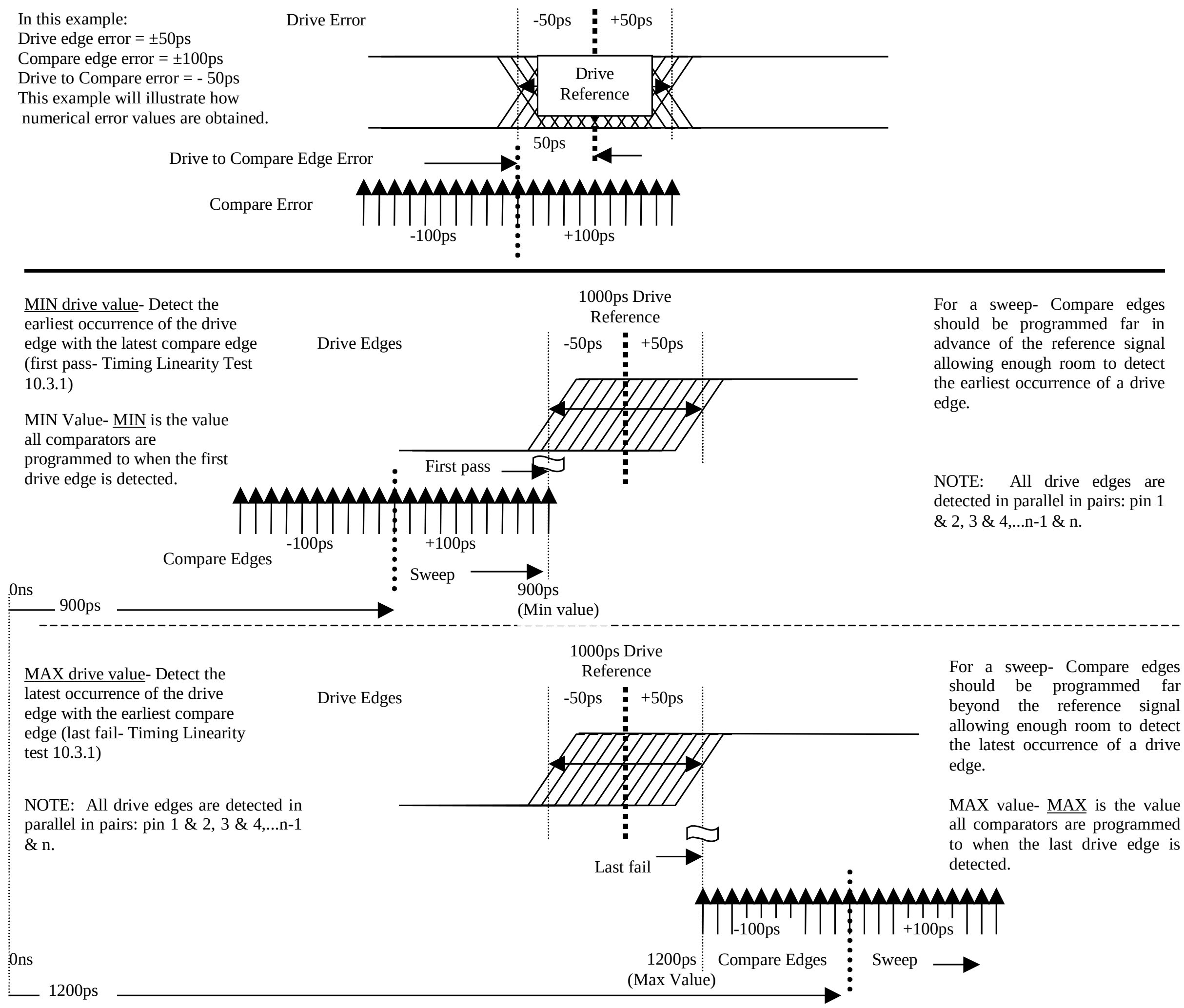


Figure A2-1
Level 1 Compare Edge Error << Drive Edge



TIMING RELATIONSHIPS, DEFINITIONS & EXAMPLE RESULTS

DEFINITIONS-

Reference- The programmed value of the drivers

Drive to Compare Error- The difference between the average of min & max for Drive and the average of min & max for Compare error.

RELATIONSHIPS & EXAMPLE RESULTS-

Negative Error:	Reference - Min Value = 1000ps - 900ps = 100ps	
Positive Error:	Reference - Max Value = 1000ps - 1200ps = -200ps	
Drive to Compare Error:	Reference - [(Min Value + Max Value)/2] = 1000ps - [(900ps + 1200ps)/2] = -50ps	

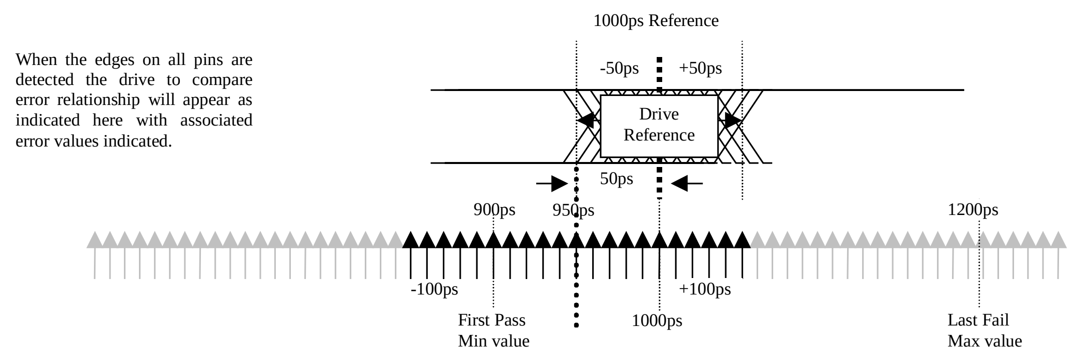
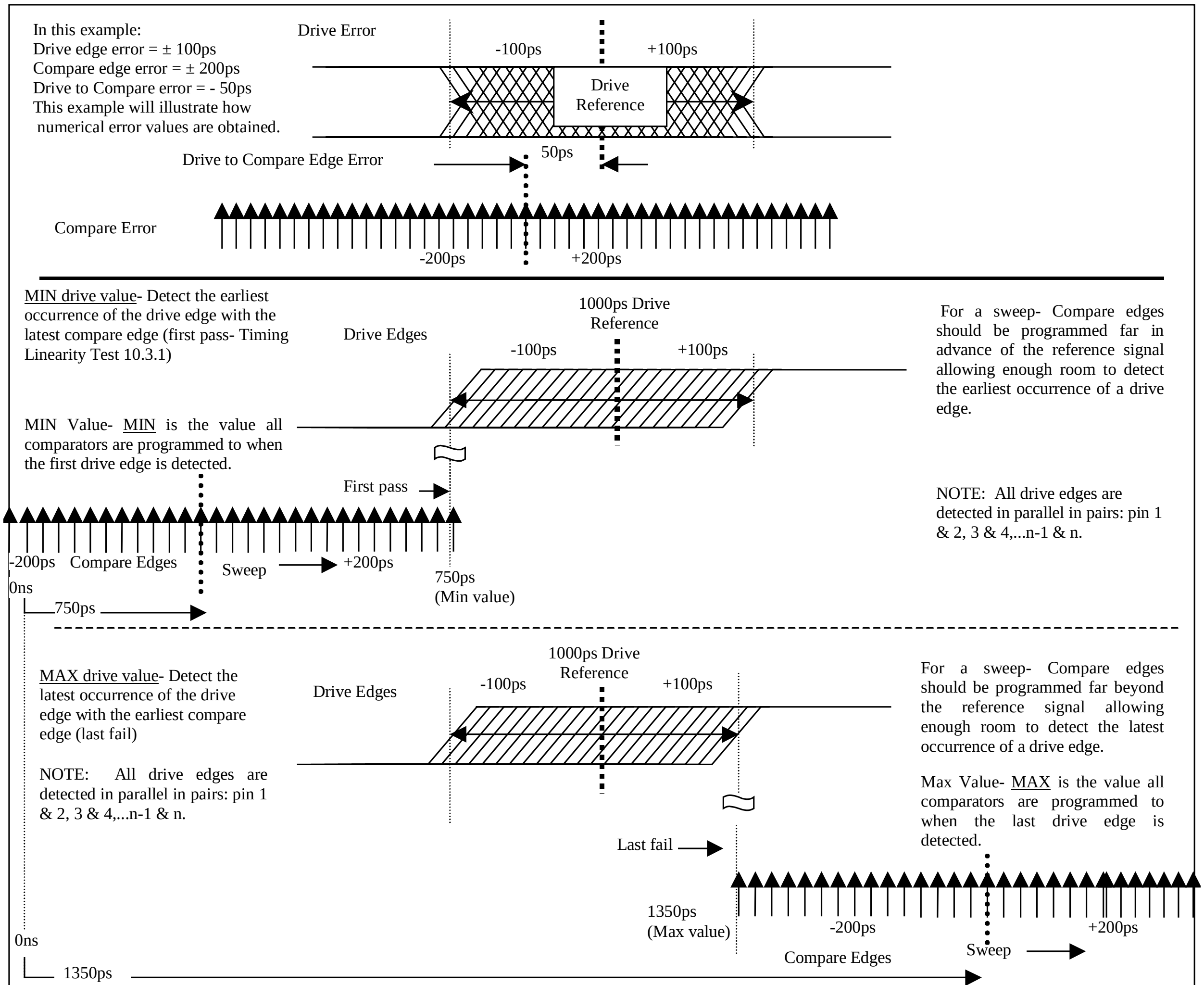


Figure A2-2
Level 1 Drive Edge Error << Compare Edge Error



TIMING RELATIONSHIPS, DEFINITIONS & EXAMPLE RESULTS

DEFINITIONS-

Reference- The programmed value of the drivers

Drive to Compare Error- The difference between the average of min & max for Drive and the average of min & max for Compare error.

RELATIONSHIPS & EXAMPLE RESULTS-

Negative Error:	Reference - Min Value	= 1000ps - 750ps = 250ps
Positive Error:	Reference - Max Value	= 1000ps - 1350ps = -350ps
Drive to Compare Error:	Reference - [(Min Value + Max Value)/2]	= 1000ps - [(750ps + 1350ps)/2] = -50ps

When the edges on all pins are detected the drive to compare error relationship will appear as indicated here with associated error values indicated.

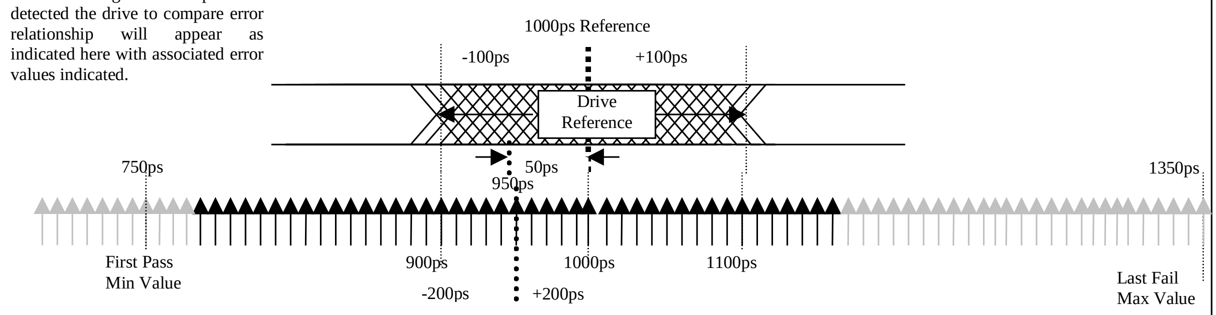
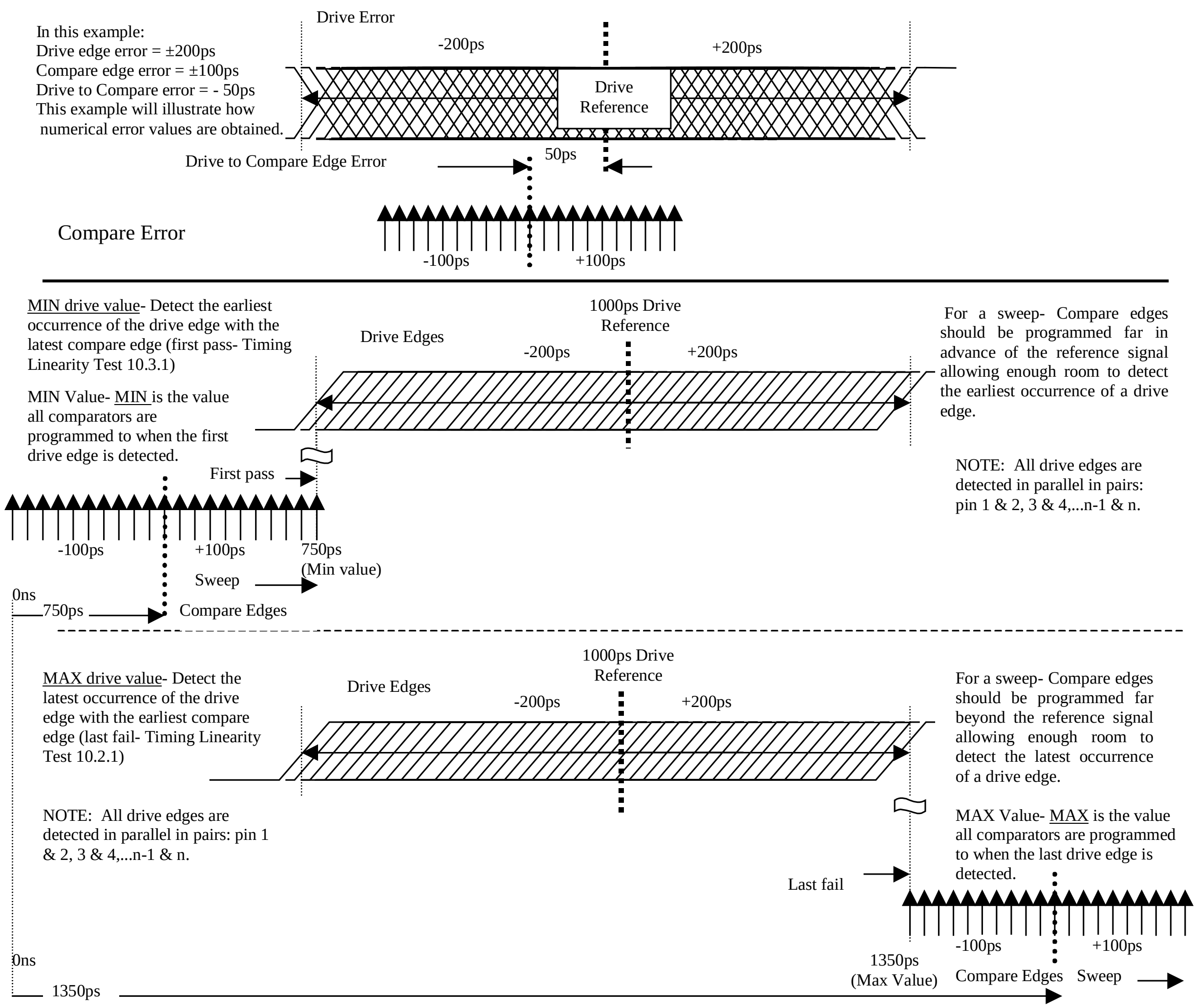


Figure A2-3
Level 1 Compare Edge Error >> Drive Edge Error



TIMING RELATIONSHIPS, DEFINITIONS & EXAMPLE RESULTS

DEFINITIONS-

Reference- The programmed value of the drivers

Drive to Compare Error- The difference between the average of min & max for Drive and the average of min & max for Compare error.

RELATIONSHIPS & EXAMPLE RESULTS-

Negative Error: Reference - Min Value = 1000ps - 750ps = 250ps

Positive Error: Reference - Max Value = 1000ps - 1350ps = -350ps

Drive to Compare Error: Reference - [(Min Value + Max Value)/2] = 1000ps - [(750ps + 1350ps)/2] = -50ps

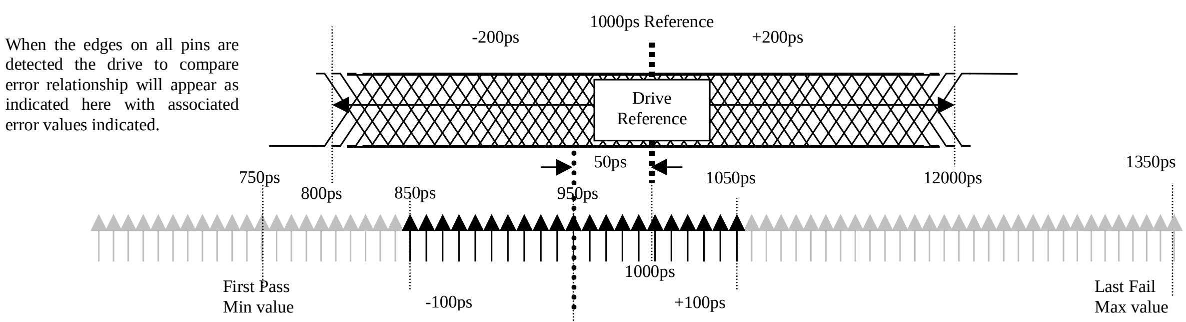


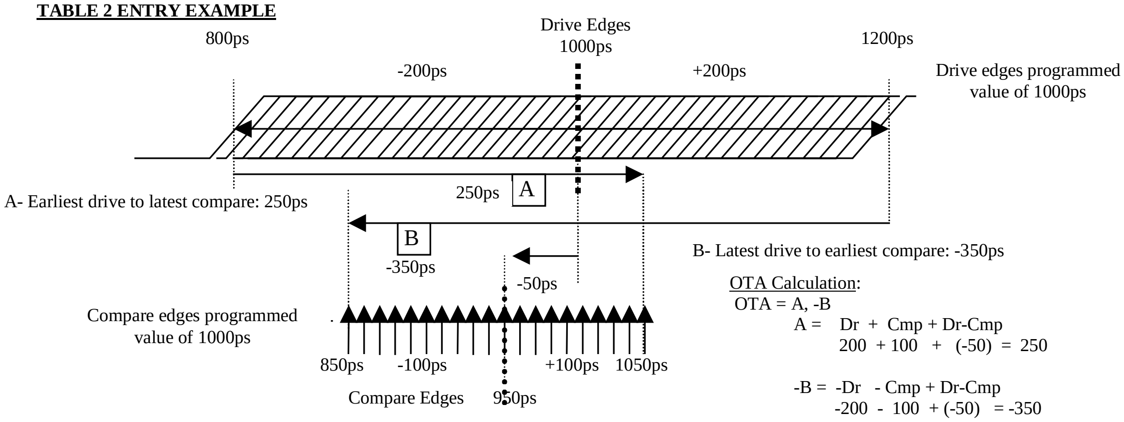
Figure A2-4
Drive Edge Error >> Compare Edge Error

Example A2-5 Test Method Summary for Showing Data Entry to Table 2 for OTA Calculation

LEVEL 1		**Single Point Overall Timing Accuracy (OTA) Results** *Data to enter here is: A = Dr (item 2) + Cmp (item 3) + Dr-Cmp (item 1)* *-B = -Dr (item 2) - Cmp (item 3) + Dr-Cmp (item 1).* **+250ps, –350ps**			LEVEL 2
Drive Z Timing *Data below represents Level 1 Z-state timing results*	**Timing Linearity Ext. Dly. / Mult Period** *Data below represents Level 1 edge-delay results*	**1) Drive Input To Compare Output Timing** –50	**2) Drive Input Edge Placement** ±200	**3) Compare Output Edge Placement** ±100	**High Speed Clock Accuracy** ______________
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 0 (Low)	Timing Linearity Level 1 (Sec.10.3.1) Positive Error: **+250** Negative Error: **–350**	Drive Input to Compare Out put Timing Accuracy Taken from 10.3.1 **–50**	a) Drive Input Timing Delay Error Level 2 (Section 10.4.1) **±200**	a) Compare Output Time Delay Error Level 2 (Section 10.4.2) **±100**	a) High Speed Clock Delay Error Level 2 (Section 10.4.1- Drive Input Timing Delay for clock function)
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 1 (High)	Extended Delay Level 1 (Sec. 10.3.4) Positive Error: Negative Error:		b) Drive Input Transition Time Variation Level 2 (Section 10.4.3)		b) High Speed Clock Transition Time Variation Level 2 (Section 10.4.3- Drive Input Transition Time for clock function)
Drive Input Z Timing Error Level 1 (Section 10.3.5) 0 (Low) to Z	Multiple Period Level 1 Optional (Sec. 10.3.6) Positive Error: Negative Error:		c) Drive Input Timing Cycle Jitter Level 2 (Section 10.4.4)		c) High Speed Clock Cycle Jitter Level 2 (Section 10.4.5)
Drive Input Z Timing Error Level 1 (Section 10.3.5) 1 (High) to Z					d) High Speed Clock Phase Jitter Level 2 (Section 10.4.6)

The user of the method is advised to read Section 13, Precautions before filling in this table.

OTA DATA CALCULATION and TABLE 2 ENTRY EXAMPLE



OTA Calculation:
OTA = A, -B
A = Dr + Cmp + Dr-Cmp
200 + 100 + (-50) = 250

-B = -Dr - Cmp + Dr-Cmp
-200 - 100 + (-50) = -350

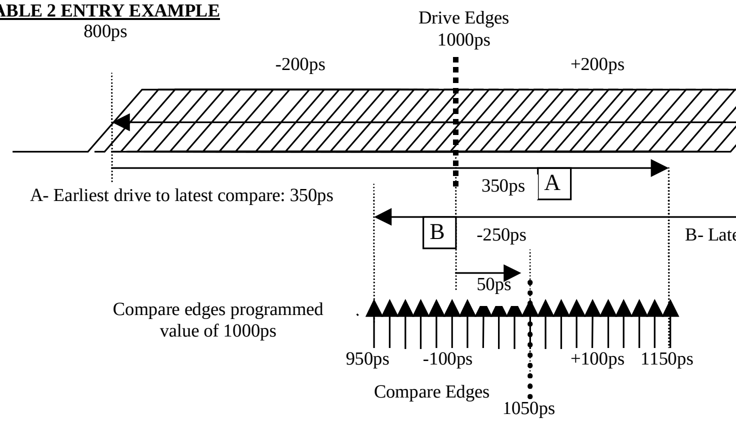
OTA = 250ps, -350ps

Example A2-6 Test Method Summary for Showing Data Entry to Table 2 for OTA Calculation

LEVEL 1		Single Point Overall Timing Accuracy (OTA) Results *Data to enter here is: A = Dr (item 2) + Cmp (item 3) + Dr-Cmp (item 1)* *-B = -Dr (item 2) - Cmp (item 3) + Dr-Cmp (item 1).* **+350ps, –250ps**			LEVEL 2
Drive Z Timing *Data below represents Level 1 Z-state timing results*	**Timing Linearity Ext. Dly. / Mult Period** *Data below represents Level 1 edge-delay results*	**1) Drive Input To Compare Output Timing** **+50**	**2) Drive Input Edge Placement** **± 200**	**3) Compare Output Edge Placement** **±100**	**High Speed Clock Accuracy** ________________
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 0 (Low)	Timing Linearity Level 1 (Sec.10.3.1) Positive Error: **+350** Negative Error: **–250**	Drive Input to Compare Out put Timing Accuracy Taken from Section 10.3.1 **+50**	a) Drive Input Timing Delay Error Level 2 (Section 10.4.1) **± 200**	a) Compare Output Time Delay Error Level 2 (Section 10.4.2) **± 100**	a) High Speed Clock Delay Error Level 2 (Section 10.4.1- Drive Input Timing Delay for clock function)
Drive Input Z Timing Error Level 1 (Section 10.3.5) Z to 1 (High)	Extended Delay Level 1 (Sec. 10.3.4) Positive Error: Negative Error:		b) Drive Input Transition Time Variation Level 2 (Section 10.4.3)		b) High Speed Clock Transition Time Variation Level 2 (Section 10.4.3- Drive Input Transition Time for clock function)
Drive Input Z Timing Error Level 1 (Section 10.3.5) 0 (Low) to Z	Multiple Period Level 1 Optional (Sec. 10.3.6) Positive Error: Negative Error:		c) Drive Input Timing Cycle Jitter Level 2 (Section 10.4.4)		c) High Speed Clock Cycle Jitter Level 2 (Section 10.4.5)
Drive Input Z Timing Error Level 1 (Section 10.3.5) 1 (High) to Z					d) High Speed Clock Phase Jitter Level 2 (Section 10.4.6)

The user of the method is advised to read Section 13, Precautions before filling in this table.

OTA DATA CALCULATION and TABLE 2 ENTRY EXAMPLE



OTA Calculation:
OTA = A, -B
A = Dr + Cmp + Dr-Cmp
200 + 100 + 50 = 350

-B = -Dr - Cmp + Dr-Cmp
-200 - 100 + 50 = -250

OTA = 350, –250

APPENDIX 3
EXCEPTIONS PAGE

NOTE: The material in this appendix is an official part of SEMI G80 and was approved by fulll letter ballot procedures on September 3, 1999 by the North Amerian Regional Standards Committee.

NOTE 2: This page is intended to capture any Digital Timing Accuracy Analysis Method exceptions the user has chosen to make.

	Test Number	*NOTE 3: MAKE ATTACHMENTS AS NEEDED*
LEVEL ONE	Section 10.3.1 Timing Linearity Test (Drive Input Edge Placement)	
	Section 10.3.4 Extended Delay Test (Compare Output Edge Placement)	
	Section 10.3.5 Drive Input Z Timing Error (Z to 0 (Low))	
	Section 10.3.5 Drive Input Z Timing Error (Z to 1 (High))	
	Section 10.3.5 Drive Input Z Timing Error (0 (Low) to Z)	
	Section 10.3.5 Drive Input Z Timing Error (1 (High) to Z)	
	Section 10.3.6 Multiple Period Test (Optional- for on the fly timing)	
LEVEL TWO	Section 10.4.1 Drive Input Time Delay Error (Drive Input Edge Placement)	
	Section 10.4.2 Compare Output Time Delay Error (Compare Output Edge Placement)	
	Section 10.4.3 Drive Input Transition Time Variation	
	Section 10.4.4 Drive Input Timing Cycle Jitter (Short term cycle to cycle period jitter)	
	Section 10.4.5 High Speed Clock Self Trigger Cycle Jitter (Short term cycle to cycle period jitter/clocks)	
	Section 10.4.6 High Speed Clock Self Trigger Phase Jitter (Short term phase/duty cycle jitter/clocks)	

APPENDIX 4

NOTE: The material in this appendix is an official part of SEMI G80 and was approved by fulll letter ballot procedures on September 3, 1999 by the North Amerian Regional Standards Committee.

A4-1 Jitter Measurement

A4-1.1 If a jitter measurement described here is to be statistically correct the jitter variation in the signal being measured must be Gausian. The measured jitter in this method will be represented as one standard deviation (sigma) of the Gausian distribution, referred to here as the RMS jitter value.

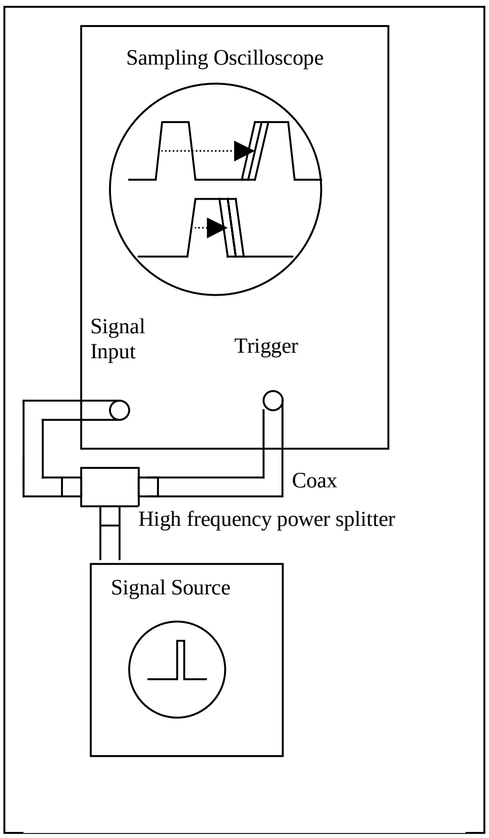


Figure A4-1
Signal Jitter Measurement

A4-1.2 The signal being measured will have some amount of jitter. The instrumentation used to measure the jitter will also have some amount of jitter. To accurately measure the jitter of a periodic signal the jitter component of the instrumentation must be accounted for and subtracted from the signal being measured.

A4-1.3 Two jitter measurements are required. A jitter measurement will be made on the signal of interest. A second jitter measurement will be made to determine the instrumentation jitter. Instrumentation jitter will be subtracted from the signal measurement to obtain the most accurate representation of signal jitter.

A4-1.4 A sampling oscilloscope will have an inherent delay, typically on the order of 20ns. This represents the time difference from the time the oscilloscope is triggered to the time when an input signal can be viewed. The key to extracting the jitter of the measurement instrumentation is providing a setup that allows viewing the trigger on the oscilloscope display. This is accomplished by delaying the oscilloscope trigger to an input channel.

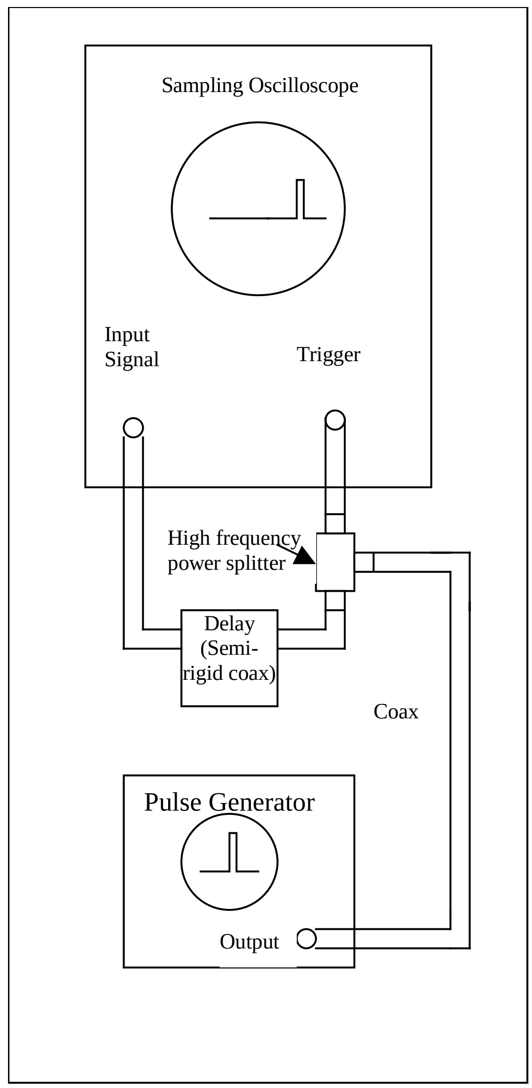


Figure A4-2
Measuring Instrumentation Jitter

A4-1.4.1 The amount of delay to the input channel must be greater than the inherent delay of the oscilloscope.

A4-1.5 A high bandwidth-sampling oscilloscope with statistical calculation capability is recommended. In addition, when making low jitter measurements high quality RF connectors and cables will be required. A setup similar to that shown in Figure A4-2 is adequate for extracting instrumentation jitter.

A4-1.6 Using semi-rigid coax for the delay will minimize loss of signal. The pulse generator should be set to low frequency to maximize the pulse width. A period of 10MHz with a 50ns pulse width is adequate for an oscilloscope with an inherent delay of 20ns . The semi-rigid coax length should be chosen to have a delay slightly larger than the inherent delay of the oscilloscope. The proper amount of delay allows viewing the trigger signal with minimal oscilloscope horizontal delay.

A4-2 *Procedure*

A4-2.1 A signal measurement will be made as indicated in Figure A4-1. The semi-rigid coax (delay) is not used, but the power splitter output will be connected to the oscilloscope input. As well, the input to the power splitter is connected to the signal being measured. The scope is triggered from the input signal, and the signal being viewed is delayed from the trigger by an amount equal to the inherent delay of the oscilloscope. This measurement step provides a value referred to here as MEASURED RMS SIGNAL JITTER, MS.[17]

A4-2.2 An instrumentation jitter measurement is then made as indicated in Figure A4-2. Per this arrangement the signal being displayed is the same signal that triggered the oscilloscope. That connection scheme cannot produce any signal jitter between the trigger and the signal being viewed; thus any jitter shown on the oscilloscope display represents instrumentation jitter. This measurement step provides a value referred to here as MEASURED RMS INSTRUMENTATION JITTER, MI.

A4-2.3 Since the signal jitter being measured is Gausian, the sum of squares relationship is used to subtract out the instrumentation jitter, and thus obtain ACTUAL RMS SIGNAL JITTER, AS.

$$MS = (MI^2 + AS^2)^{1/2}$$

MS- Measured RMS signal jitter.

MI- Measured RMS instrumentation jitter.

AS- Actual RMS signal jitter.

17 Use of a loop-through sampling head is an alternative method for making this measurement.

A4-3 *Example*

A4-3.1 Measured RMS signal jitter MS, the signal being measured, results in a 10ps measurement.

A4-3.2 Measured RMS instrumentation jitter MI, the jitter of the measurement setup, results in a 5ps measurement.

A4-3.3 The actual RMS signal jitter AS is determined from the relationship:

$$MS = MI^2 + AS^2)^{1/2}$$

and calculates to be:

$$10^2 = 5^2 + AS^2$$

$$100 = 25 + AS^2$$

$$75 = AS^2$$

$$75^{1/2} = AS$$

8.66ps = AS (actual RMS signal jitter)

Since the jitter is Gaussian, the max value of jitter is approximately equal to 5 or 6 times the RMS value of the jitter.

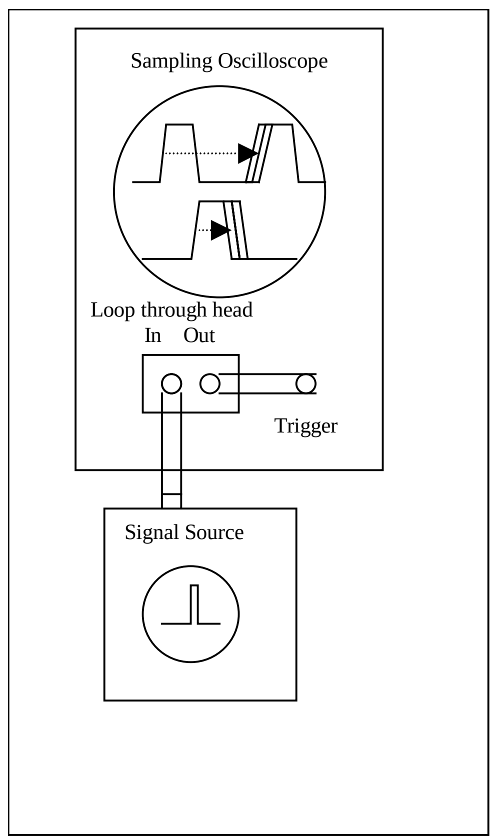


Figure A4-3
Use of a Loop-Through Sampling Head

A4.4 *Use of a Loop-Through Sampling Head*

A4-4.1 This is an alternate approach to measured RMS signal jitter. The input signal is routed through the loop-through sampling head where it is sampled and sent to the output of the sampling head. The head output is connected to the oscilloscope trigger. (See Figure A4-3.)

A4-4.2 *What is Observed When Making MS And MI Measurements* — This dialog is meant to provide further clarification for making jitter measurements. This is an example that applies to a jitter measurement using an oscilloscope with an inherent oscilloscope delay of 20ns. The signal frequency is 100MHz (period of 10ns). The semi-rigid coax delay is set to the inherent oscilloscope delay of 20ns.

A4-4.3 *Measured RMS Signal Jitter, MS* — For the MS measurement the observed edge occurs subsequent to the edge that triggered the oscilloscope:

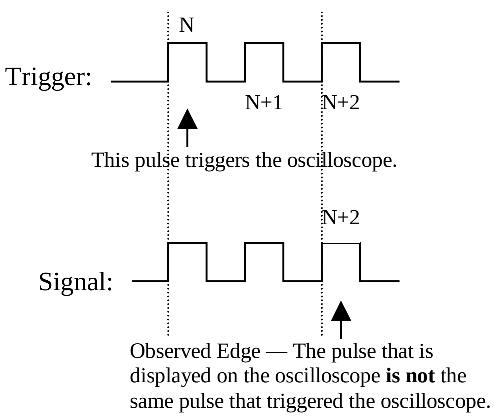


Figure A4-4
Measured RMS Signal Jitter, MS

A4-4.4 The observed edge depends upon the signal frequency; thus what is displayed is subsequent to the trigger pulse permitting signal jitter to be observed.

A4-4.5 *Measured RMS Instrumentation Jitter, MI* — For the MI measurement the observed edge is the same edge that triggered the oscilloscope.

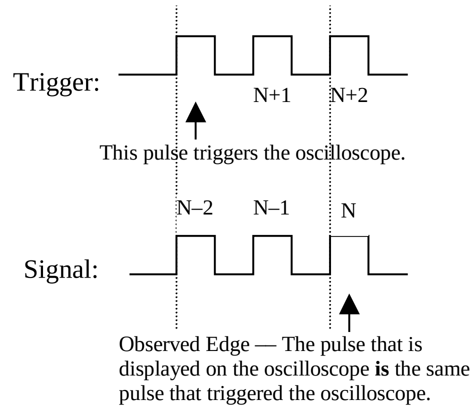


Figure A4-5
Measured RMS Instrumentation Jitter, MI

A4-4.6 There is no repetitive aspect of the signal, thus whatever jitter you observe is strictly instrumentation jitter.

A4-4.7 *Summary* — Jitter is only observable for a periodic signal or repetitive edge. Thus when MS measurements are made signal jitter is observed because a subsequent or repetitive signal is displayed (in addition to instrumentation jitter). When MI measurements are made the input signal is delayed such that you see the same edge that trigger the oscilloscope. That creates a non-repetitive or non-periodic occurrence of the observed signal, thus the jitter observed is strictly due to the instrumentation.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G81-1101
SPECIFICATION FOR MAP DATA ITEMS

This specification was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the Japanese Test Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published October 2000.

1 Purpose

1.1 This document describes the data items that relate to electronic substrate mapping.

2 Scope

2.1 This document applies only to substrate map data items.

2.2 This document does not address the transmission, file naming conventions, storage or archiving of substrate maps.

2.3 The specification of which data items are optional and which are required is not specified in this document.

2.4 The size of each data item described in this document is maximum size. The actual size may be further restricted by an application document.

2.5 The order of the data items is not restricted in this document. The order of the data items may be restricted by an application document.

2.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 There are no known limitations within the defined scope.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI T9 — Specification for Marking of Metal Lead-Frame Strips with a Two-Dimensional Data Matrix Code Symbol

4.2 *IEEE Standards*[1]

IEEE 754-1985 — IEEE Standard for Binary Floating–Point Arithmetic

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Definitions*

5.1.1 *bottom side* — the bottom side of the substrate as defined in the corresponding Appendix (Appendix 1, 2, or 3).

5.1.2 *device* — the unit to which the device status code in the map is assigned including, but not limited to: die, multi-chip modules and packages.

5.1.3 *map* — a two-dimensional array of bin codes derived from electrical test data of a substrate including, but not limited to: wafer, tray, strip, or tape.

5.1.4 *substrate* — any carrier of a two-dimensional array of devices including, but not limited to: wafers, trays, strips, tape, panels, or boards.

5.1.5 *top side* — the top side of the substrate as defined in the corresponding Appendix for that substrate (Appendix 1, 2, or 3).

6 Requirements

6.1 This document does not define format of each data item specified in the following chapter. In order to implement this specification, it requires standardized and/or specific format definition documents. Standardized format definition documents are those generic, application specific or equipment specific specification, supplied by SEMI. They may be format specification, static file specification or communication specification, e.g. SEMI E5. Specific format definition documents may de defined by supplier and user.

1 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

6.2 Also this document does not define communication protocol at all. If an implementation requires transfer data items defined in the following chapter, it is necessary to prepare a custom communication protocol document or to comply with the appropriate SEMI communication standards.

6.3 This document places no special requirements on the transmission, file naming conventions, storage, or archiving of substrate maps.

7 Description

7.1 The substrate map data item specifications defined in this document are shown in Table 2. The columns in this table are described in the following sections.

7.1.1 *Item Name Column* — the name by which the data item is referenced.

7.1.2 *Data Type Column* — the type of the data as defined in Table 1.

Table 1 Data Types and Sizes

Type	*Size*	*Definition*
String	0–32767	A string of ASCII characters from zero to “Size” characters in length.
Integer	1,2,4	An integer value that may be represented by “Size” bytes. E.g., if Size = 2 then the value may be –32768 to 32767.
Float	4	IEEE single-precision 32-bit floating point type [IEEE 754-1985]

7.1.3 *Size Column* — the maximum number of characters that may be used to represent the data.

7.1.4 *Description Column* — describes what the data item is and what value restrictions it has.

7.2 *Coordinate System Conventions*

7.2.1 Whenever reference is made to rows, columns, X or Y they are defined as follows.

7.2.2 The X axis is the horizontal axis from left to right when the substrate is rotated according to [Orientation] in Table 2. Columns increase along the X axis. Column zero is the column just before the left (or right, depending on OriginLocation) column containing measured devices.

7.2.3 The Y axis is the vertical axis from bottom to top when the substrate is rotated according to [Orientation] in Table 2. Rows increase along the Y axis. Row zero is the row just before the extreme top (or bottom depending on OriginLocation) row containing measured devices.

7.2.4 Columns increase along the X-axis. Rows increase along the Y-axis.

Table 2 Substrate Map Data Items

Item Name	*Data Type*	*Size*	*Description*
FormatRevision	String	256	Specifies the exact name and revision of the format used to represent substrate map data. This field can be used by a parser to automatically determine the format of the remaining substrate map data.
ProductId	String	256	Product identifier
LotId	String	32	Production lot identifier for this data
Orientation	Integer	2	The orientation of the substrate in relation to the map data. This variable will increase in the right (clockwise) direction from 0°. This item may be used to specify that the map data be rotated. Since the map data is rectangular, only the values 0, 90, 180, and 270 are allowed in that case.
WaferSize	Integer	2	Diameter of Wafer in millimeters.
DeviceSizeX	Float	4	Device size on X axis in microns
DeviceSizeY	Float	4	Device size on Y axis in microns
StepSizeX	Float	4	The distance in microns from a reference point on one device to the same reference point on the adjacent device in the X direction. StepSizeX – DeviceSizeX is equal to the “street” width between device in the X direction.

Item Name	*Data Type*	*Size*	*Description*
StepSizeY	Float	4	The distance in microns from a reference point on one device to the same reference point on the adjacent device in the Y direction. StepSizeY – DeviceSizeY is equal to the "street" width between device in the Y direction.
WaferId	String	32	A character code that may be printed or encoded on the substrate, which uniquely identifies the substrate, and can be used to correlate the map with physical substrate.
FrameId	String	32	A character code that may be printed or encoded on the substrate, which uniquely identifies the substrate, and can be used to correlate the map with physical substrate.
StripId	String	32	A character code that may be printed or encoded on the substrate, which uniquely identifies the substrate, and can be used to correlate the map with physical substrate.
TrayId	String	32	A character code that may be printed or encoded on the substrate, which uniquely identifies the substrate, and can be used to correlate the map with physical substrate.
CassetteId	String	32	A character code that may be printed or encoded on the substrate carrier, which uniquely identifies the substrate carrier.
MagazineId	String	32	A character code that may be printed or encoded on the substrate carrier, which uniquely identifies the substrate carrier.
Rows	Integer	2	The number of rows of (measured) device matrix on substrate, that is the number of devices on the Y-axis of the map data. It is required if the type of the map data is simple array structure.
Columns	Integer	2	The number of columns of (measured) device matrix on substrate, that is the number of devices on the X-axis of the map data. It is required if the type of the map data is simple array structure.
MapType	String	16	Possible variations of data structure, one of which is to be chosen for passing map data. This document allows formats of the three types shown below. [MapType] = 'Row': Row/Column Format Expression using the coordinate showing the head of a row as well as the number of devices in the row and the bin data of the relevant row. Each bin data is attached in succession to each row. Example: X, Y, N, BIN, BIN, BIN, ..., BIN (N: Number of devices) [MapType] ='Array': Array Format All of a substrate's bin data is expressed in a one-dimensional array form. Left to right and top down substrate map data will be set in a one-dimensional array. Example: BIN, BIN, BIN, ... [MapType] = 'Device': Coordinate Format Expressed by XY coordinates of each device on a substrate as well as bin data. Even when using this format, to prevent omission of data, it is best to set bin data for all devices tested in front end processing. Example: X, Y, BIN, ..., X, Y, BIN The MAP coordinates set here are values for the state with the substrate orientation flat rotated to the angle given by [Orientation]. Appendix 1 contains diagrams that illustrate each [MapType]. NOTE: MAP coordinates can also be negative values.
HeadingDeviceX	Integer	2	X coordinate of the heading device of a row in the map data. This item is used when [MapType] = 'Row'
HeadingDeviceY	Integer	2	Y coordinate of the heading device of a row in the map data. This item is used when [MapType] = 'Row'
DeviceRow	Integer	2	Number of the devices on a row in the map data. This item is used when [MapType] = 'Row'
DeviceX	Integer	2	X coordinate of the device in the map data. This item is used when [MapType] = 'Device'
DeviceY	Integer	2	Y coordinate of the device in the map data. This item is used when [MapType] = 'Device'

Item Name	*Data Type*	*Size*	*Description*
BinType	String	16	The format in which the bin code for each device will be represented in the [Map]. The choices are as follows: [BinType]='Ascii': Single ASCII character [BinType]='Decimal': 3 digit integer from 000 to 255 [BinType]='HexaDecimal': 2 digit Hexadecimal value from 00 to FF NOTE 1: For readability when [BinType]='Decimal' there must be spaces added between each device and each row of devices should be on a new line. NOTE 2: When [BinType] = 'Ascii' or 'Hexadecimal' there must not be spaces between each device and for readability, each row should be on a new line.
ReferenceDeviceX	Integer	2	X coordinate of the reference device to align device matrix on physical substrate with the map data
ReferenceDeviceY	Integer	2	Y coordinate of the reference device to align device matrix on physical substrate with the map data
RefDevicePosX	Float	4	Offset in µm of the center of a reference device in the X-direction from the center of substrate.
RefDevicePosY	Float	4	Offset in µm of the center of a reference device in the Y-direction from the center of substrate.
MapName	String	32	A name that describes the purpose of the bin codes in the map. Possible examples include: "CellStatus", "DefectCode", "MarkGrade", "PackageGrade", "SortGrade".
MapVersion	String	32	The version is used to distinguish between multiple versions of maps for the same substrate with the same MapName.
BinCode	Integer	1	A bin category from 0 to 255, other that the value assigned to [NullBin], that may be assigned to a device. It should be represented according to [BinType]. NOTE: BinCode and NullBin may take on values from 0 to 255 is represented as Ascii, Decimal, Hexadecimal, or Binary, according to BinType. See definition of BinType for more information.
BinCount	Integer	4	The number of devices on the substrate with the specified [BinCode]
BinQuality	String	16	Describes the quality of the specified [BinCode]. The following values are reserved for the data item: "Pass" – Indicates a quality that has commercial value "Fail" – Indicates a quality that does not have commercial value Other values defined by an application.
BinDescription	String	256	A description of the specified [BinCode], e.g. "100MHz".
NullBin	Integer	1	Code to indicate no device or not measured device in [Data]. It should be represented according to [BinType].
SupplierName	String	256	Name of the supplier of the substrate.
OriginLocation	Integer	1	Coordinate system on substrate to address devices. Location of the datum point or the origin of the coordinates shall be one of the following: 0 = Center device* – top side 1 = Upper right – top side 2 = Upper left – top side 3 = Lower left – top side** 4 = Lower right – top side 5 = Center device* – bottom side 6 = Upper right – bottom side 7 = Upper left – bottom side 8 = Lower left – bottom side 9 = Lower right – bottom side * Center device is X=(row count+1), Y=(column count+1)/2. ** Default value is 3 (=Lower left – top side) if this item is not present
CreateDate	String	16	Date and time when the map data is acquired: formatted as YYYYMMDDhhmmsscc (year-month-date-hour-minute-second-centisecond)
Status	String	16	Status of map data supplying process or preceding process.
Label	String	256	Name of a special parameter

Item Name	*Data Type*	*Size*	*Description*
SupplierValue	String	16	Value of a special parameter

NOTE 1: A set of above items is prepared for each single substrate to make it possible to consolidate more than one lot in a cassette.

7.3 *Example*

```
<?xml version="1.0"?>
<Map xmlns=”http://www.semi.org” WaferId="ZSDGS88DF" FormatRevision="SEMI
G81-1101">
  <Device
    ProductId="854CS1C"
    LotId="wksfd87dcj37"
    Orientation="0"
    DeviceSizeX="343.8"
    DeviceSizeY="373.1"
    Rows="6"
    Columns="6"
    BinType="HexaDecimal"
    FrameId="KJKSDFK45"
    NullBin="FF"
    SupplierName="Company X"
    OriginLocation="1"
    CreateDate=""
    Status="Product">
    <ReferenceDevice
      ReferenceDeviceX="2"
      ReferenceDeviceY="-3"
      RefDevicePosX="2"
      RefDevicePosY="2"
    />
    <ReferenceDevice
      ReferenceDeviceX="4"
      ReferenceDeviceY="-5"
      RefDevicePosX="2"
      RefDevicePosY="2"
    />
    <Bin
      BinCode="02"
      BinQuality="Pass"
      BinDescription="500MHz"
    />
    <SupplierData
      Origin="USA"
      Destination="Asia"
    />
    <Data MapName="SortGrade" Version="1">
      <Row><![CDATA[FFFF020CFFFF]]></Row>
      <Row><![CDATA[FF14020C02FF]]></Row>
      <Row><![CDATA[0202020C0116]]></Row>
      <Row><![CDATA[0201140C0202]]></Row>
      <Row><![CDATA[FF14020C02FF]]></Row>
      <Row><![CDATA[FFFF020CFFFF]]></Row>
    </Data>
  </Device>
</Map>
```

APPENDIX 1
WAFER MAP

NOTE: The material in this appendix is an official part of SEMI G81 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 This appendix shows how the map data items may be applied to wafers as well as some additional information specific to this substrate type. See Figures A1-1 through A1-8.

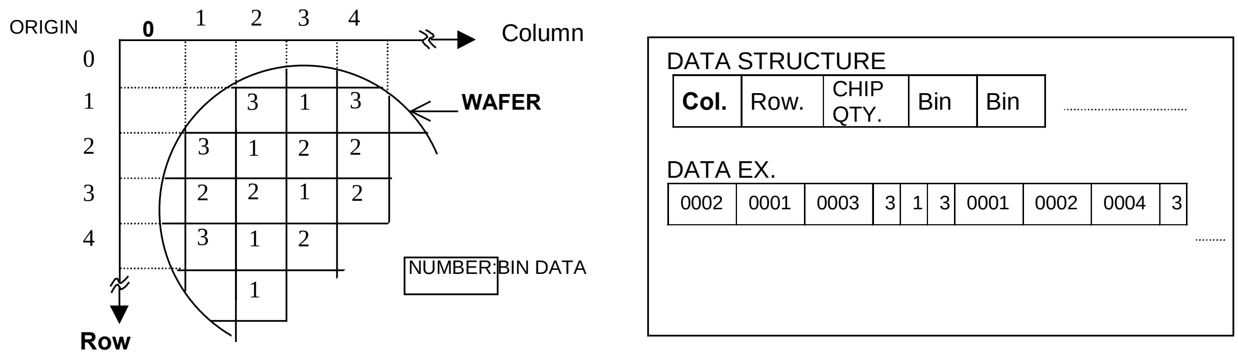


Figure A1-1a
Row/Column Format (MapType = "Row")

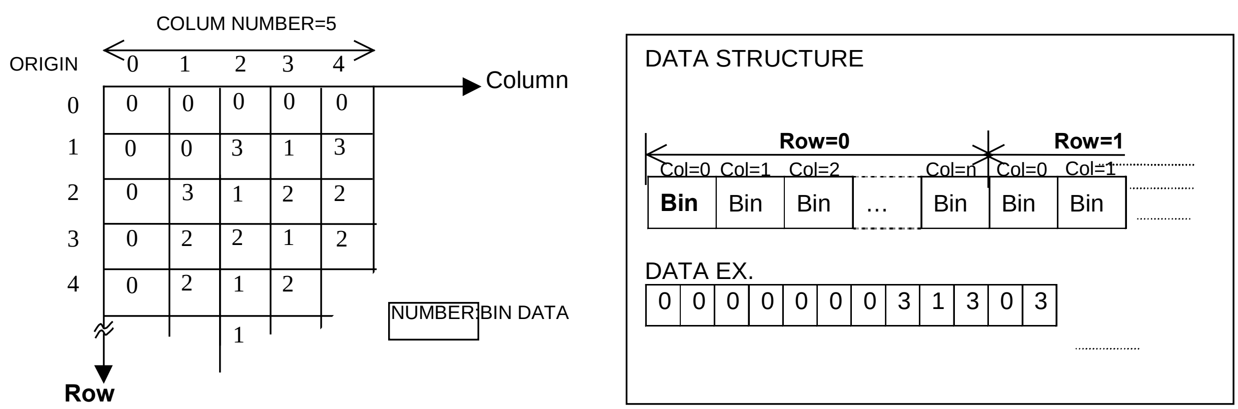


Figure A1-1b
Array Format (MapType = "Array")

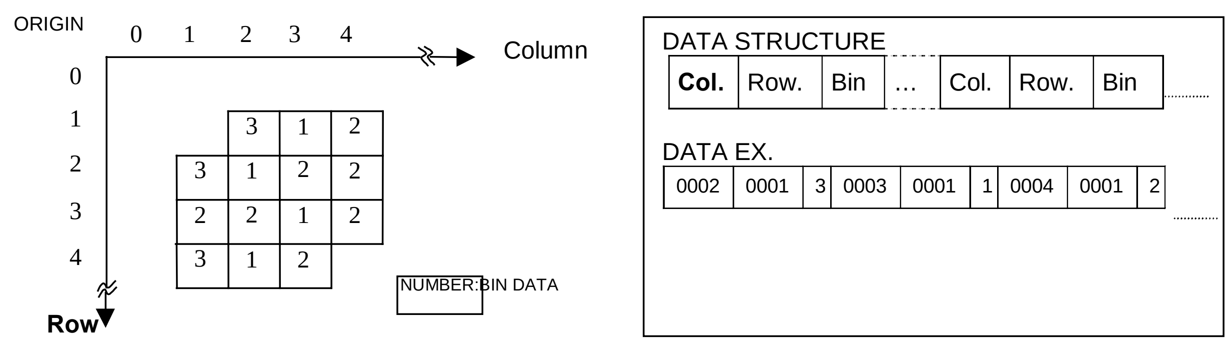


Figure A1-1c
Coordinate Format (MapType = "Device")

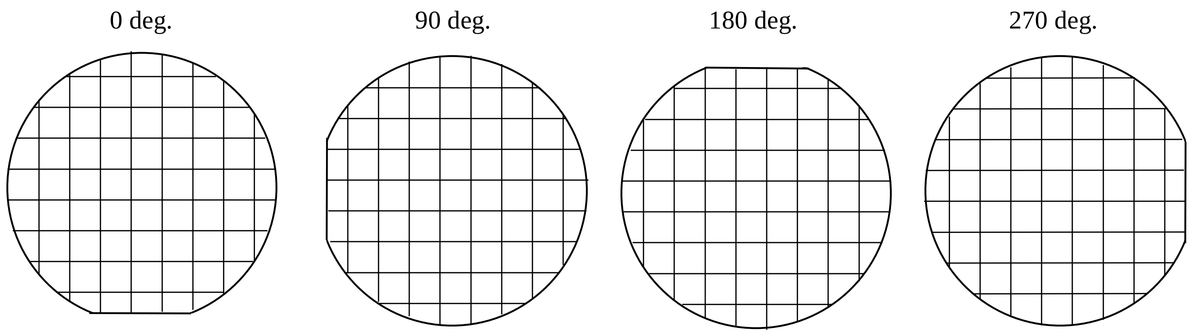


Figure A1-2
Orientation of the Wafer Flat or Notch (Orientation)

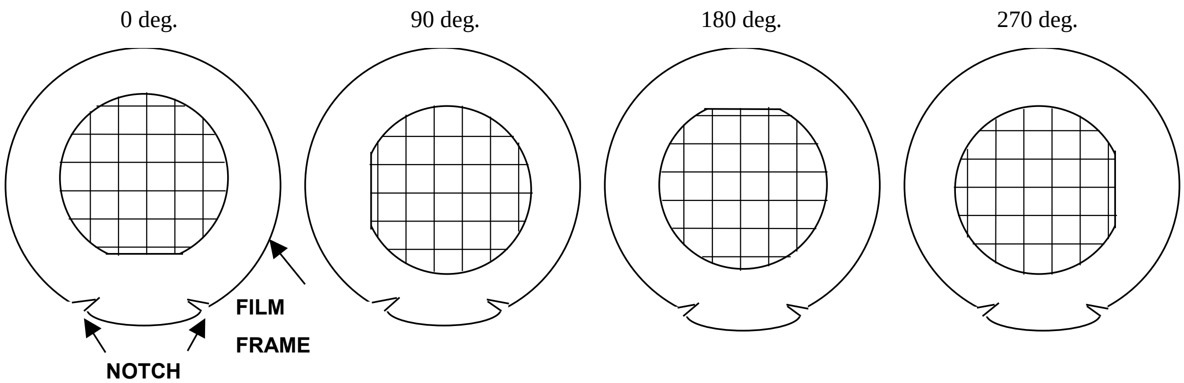


Figure A1-3
Orientation of the Wafer Flat or Notch on the Film Frame

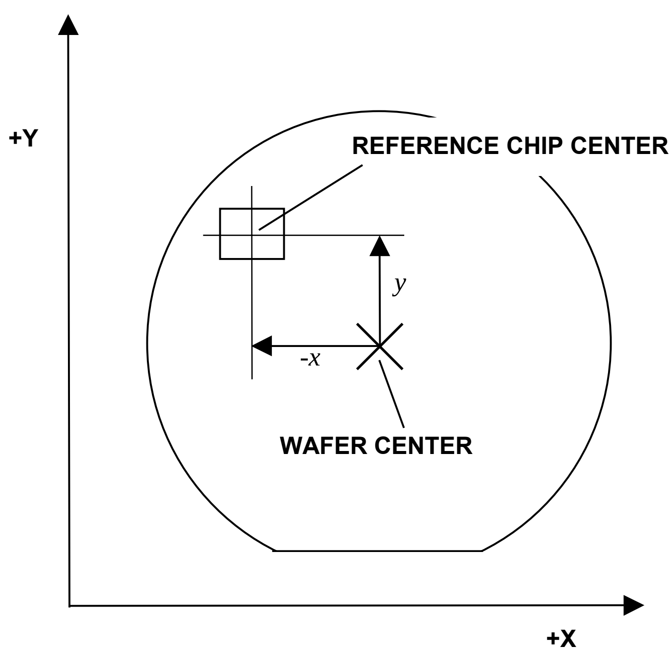


Figure A1-4
Reference Device Position (RefDevicePosX and RefDevicePosY)

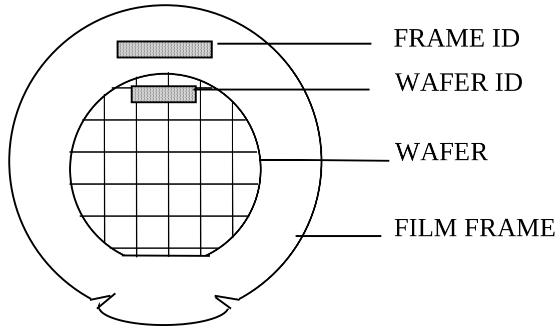


Figure A1-5
Example of WaferID and FrameID Position

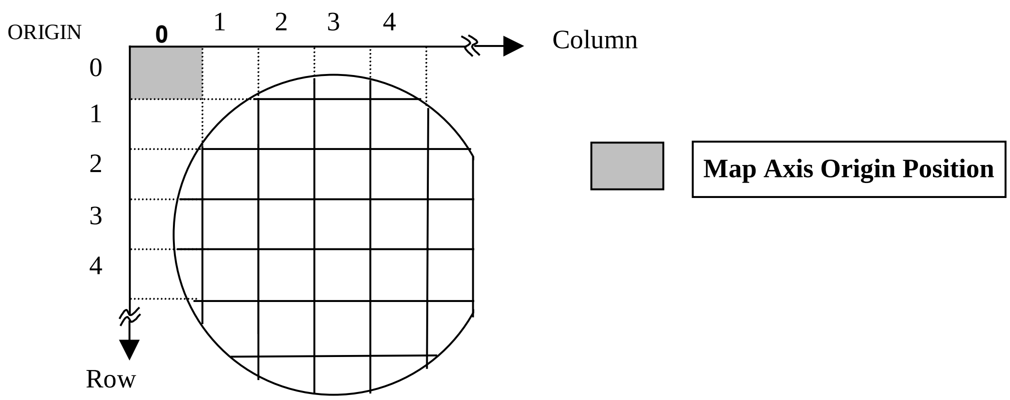


Figure A1-6
(Ex.) Map Coordinates System (OriginLocation = Top Left Top Side)

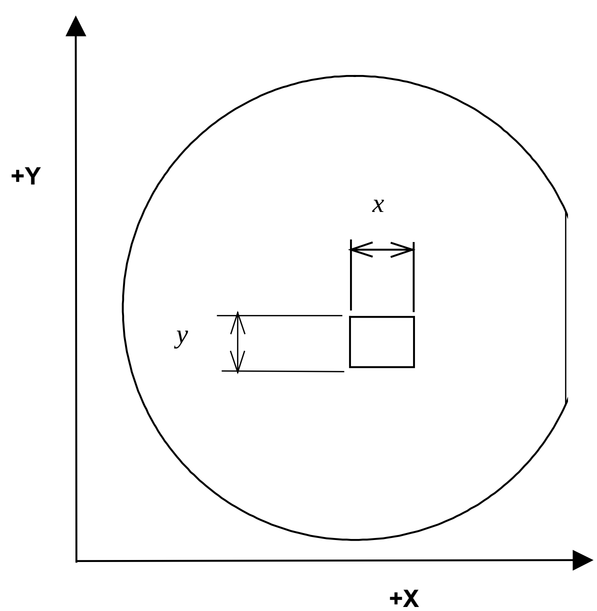


Figure A1-7
Chip Size Coordinates

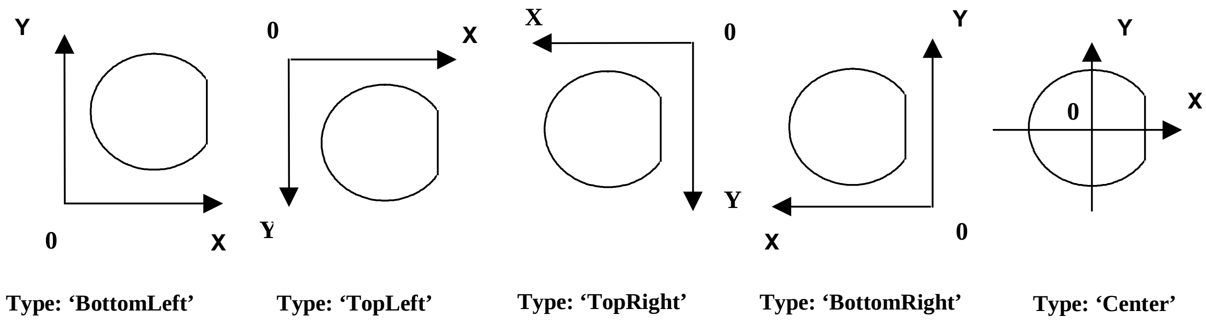


Figure A1-8
Wafer Coordinate to Address Devices (OriginLocation)

APPENDIX 2
STRIP MAP

NOTE: The material in this appendix is an official part of SEMI G81 and was approved by full letter ballot procedures on August 27, 2001.

A2-1 This appendix shows how the map data items may be applied to strips as well as some additional information specific to this substrate type.

A2-2 The StripID shall follow the SEMI T9 specification, when applicable, or may be user definable by the factory.

A2-3 For any given process there must be a way to ensure correct orientation of the strip. The end user is responsible for providing a master manufacturing drawing showing the top side of the strip. This drawing must show any special markings or patterns that are needed to reliably flip and rotate a physical strip until it is oriented the same as the drawing. Figure A2-1 defines what is meant by top side and hence bottom side. It also defines what is meant by upper, lower and left and right.

A2-4 Each strip type will have a factory defined value for OriginLocation. This is the origin reference for the row 1, column 1 location on the strip. The factory origin, OriginLocation is selected as one of four corners by the factory host system. The row and column index will be referenced from the selected reference. This information will be provided to the equipment by the host in each strip map download scenario.

1 = Upper right (UR) top side

2 = Upper left (UL) top side

3 = Lower left (LL) top side

4 = Lower right (LR) top side

6 = Upper right (UR) bottom side

7 = Upper left (UL) bottom side

8 = Lower left (LL) bottom side

9 = Lower right (LR) bottom side

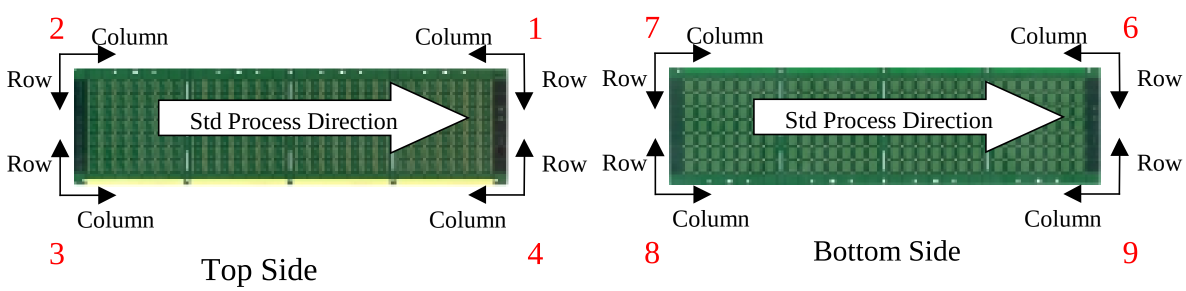


Figure A2-1
Factory Origin Settings

APPENDIX 3
TRAY MAP ORIENTATION

NOTE: The material in this appendix is an official part of SEMI G81 and was approved by full letter ballot procedures on August 27, 2001.

A3-1 This appendix shows how the map data items may be applied to JEDEC trays as well as some additional information specific to this substrate type.

A3-2 The X-axis (Column) is assigned to the long axis of the JEDEC tray; the Y-axis (Row) is assigned to the short axis of the tray. This corresponds to Cartesian coordinate “1” (in this way all coordinate positions can be expressed in positive integer values). For the origin of the tray, the pocket nearest the bevel (at the bottom left corner of the tray in Figure A3-1 below) is defined as coordinate location 0,0. (Row/Column).

A3-3 The following values for OriginLocation apply to the JEDEC tray:

1 = Upper right (UR) top side

2 = Upper left (UL) top side

3 = Lower left (LL) top side

4 = Lower right (LR) top side

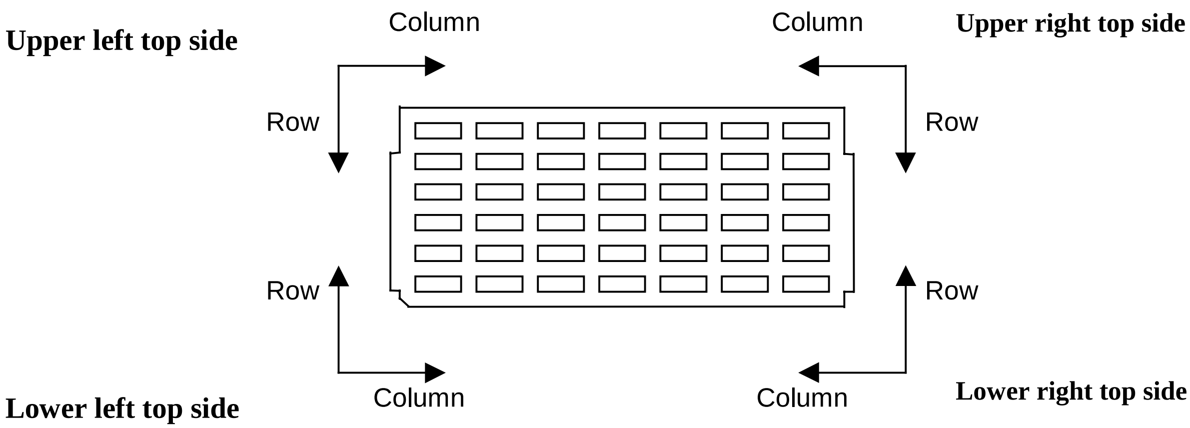


Figure A3-1
OriginLocation

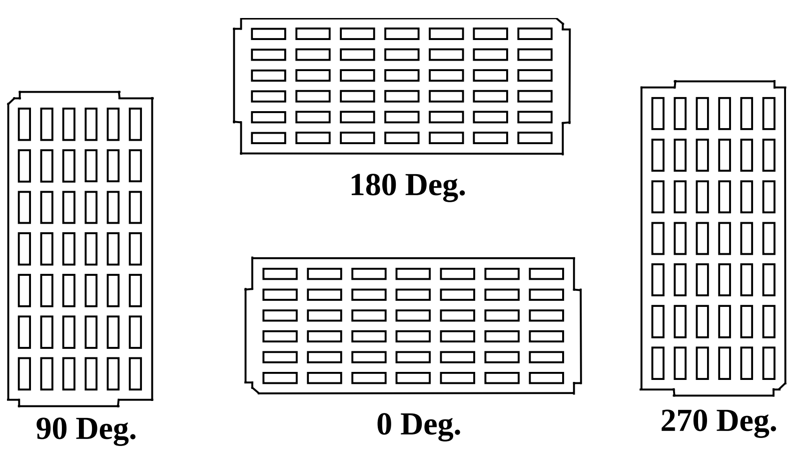


Figure A3-2
Tray Orientation

SEMI G82-0301^E
PROVISIONAL SPECIFICATION FOR 300 mm LOAD PORT FOR FRAME CASSETTES IN BACKEND PROCESS

This specification was technically approved by the Global Assembly & Packaging Committee and is the direct responsibility of the Japanese Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on December 1, 2000. Initially available at www.semi.org December 2001, to be published March 2002.

E This document was editorially modified in November 2001 to correct a cosmetic error. Changes were made to Figure 2.

1 Purpose

1.1 This specification defines dimensional requirements for the load port of frame cassette for 300 mm wafer in backend process equipment. It is intended to promote a uniform physical interface between equipment and the factory, to facilitate the use of automated frame cassette transport systems, and/or to meet ergonomic requirements for manually loaded equipment.

2 Scope

2.1 This is a provisional standard covering equipment for 300 mm frame cassette only. The provisional status is dictated by the immaturity of designs for 300 mm equipment and additional specifications which are not defined yet.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard is not intended for use in backend except frame cassette for 300 mm wafers. This standard does not address direct loading/unloading of vacuum load locks. Requirements of such interfaces may differ from those in this document.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Load Port

SEMI E57 — Mechanical Specification for kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E64 — Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI G77 — Specification for Frame Cassette for 300 mm Wafers

5 Terminology

5.1 Please see SEMI G77 for definitions of the following terms used in this specification:

5.1.1 *bilateral datum plane*

5.1.2 *conveyor rails*

5.1.3 *facial datum plane*

5.1.4 *frame cassette*

5.1.5 *horizontal datum plane*

5.1.6 *tape frame*

5.2 Please see SEMI E15 for definitions of the following terms used in this specification:

5.2.1 *load depth*

5.2.2 *load face plane*

5.2.3 *load height*

5.2.4 *load port*

5.2.5 *spacing*

5.2.6 *tool*

5.3 *frame cassette centroid* — a datum representing the theoretical location of the center of a stack of tape frames in the frame cassette.

6 Ordering Information

6.1 The following items require communication between the tool supplier and user and shall be included in any request for quotation or purchase order:

6.1.1 If the tool has multiple load ports, provide the spacing, S, between frame cassette centroids (see SEMI E15).

6.1.2 Specify what frame cassette (e.g. optional composition, see SEMI G77) is to be accommodated by the load port (see SEMI E15).

7 Requirements

7.1 The dimensional requirements for the load port are given in Table 1 with reference to the figures of this document. Although the frame cassette transport systems shown in these figures appear similar to overhead monorails, they are intended to represent any type of transport system (AGV, PGV, conveyor, overhead track, etc.).

7.2 The dimensional requirements for the placement of the frame cassette on the load port are given in Table 1 with reference to the figures of this document.

7.3 The tape frames are to be oriented horizontally at the time they are placed on the load port.

7.3.1 The frame cassette shall be loaded and unloaded with its front parallel to and away from the load face plane (see Figure 1).

7.4 Dimension H is nominally 900 mm, fully adjustable at installation over the range of 890 to 910 mm. The precision with which the load port height must be maintained is dictated by the needs of the frame cassette delivery system.

7.5 The load port must nominally be at 900 mm, and it must be open from above to facilitate automatic frame cassette delivery from an overhead transport system. The open volume required for vertical delivery is defined by a projection of the load port area, including the area required for C1 and C2 clearances, projected upward to the top of the tool. Note that this condition need only be met when the tool is being loaded. For example, the load port may be formed by a surface that extends outward during loading to provide overhead access.

7.6 As shown in Figure 2, the maximum allowable height of an obstruction on the load port over which the frame cassette must be lifted (before being set down on the kinematic couplings) is H1. Examples of such obstructions include alignment devices and identification tag readers as well as the kinematic couplings themselves. Below H1 above the horizontal datum plane, clearances C1 and C2 no longer apply.

7.6.1 Two exclusion volumes on the left and right side of the load port must also be kept clear so that fork lifts or conveyors may be used. Each exclusion volume extends from the load face plane to D0 beyond the facial datum plane and extends H0 below the horizontal datum plane between W1 and W2 from the bilateral datum plane.

7.6.2 The load port that advances the frame cassette from the undocked position (where the frame cassette is initially delivered to the load port) to the docked position (where the frame cassette is ready for frame extraction or insertion) must reserve an exclusion volume that is intended for (but not limited to) containing automated units that read or write to an ID tag on the rear of the frame cassette in the undocked position (where the frame cassette is initially delivered to the load port). If no reader/writer unit is installed, the exclusion volume may be covered by a panel.

NOTE 1: This section is incomplete and requirements will be added to the standard once the requirements and dimensions have been fully defined.

7.7 Clearances C1 and C2 are defined with respect to the maximum dimensions of the frame cassette (see SEMI G77). To prevent interference with overhead transport systems on the same or adjacent load port, it is recommended that floor-based transport vehicles do not exceed clearances C1 and C2 when picking up or placing the frame cassette on the load port.

7.8 Dimension S specifies the recommended minimum spacing between frame cassette centroids. In any case, if S violates C1, then C1 takes precedence.

7.9 To add clearance for overhead frame cassette transport, no part of the tool in front of the plane defined by C2 may be higher than H2 from the floor. The volume below H2 may contain the frame cassette stored in an internal buffer by the tool.

7.10 The load port must provide the option to use the conveyor rails for frame cassette loading. At the time of frame cassette transfer, the conveyor rails must be positioned at HC3 as shown in Figure 2. When not in use, the conveyor rails must be lowered below the fork lift exclusion zone.

8 Related Documents

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI G74 — Specification for Tape Frame for 300 mm Wafers

Table 1 Dimensional Requirements for 300 mm Load Port

Dimension	*Application*	*Value, mm (in.)*	*Notes*
C1	minimum	75 (3.0)	
C2	minimum	30 (1.2)	
D	range	250^{+0}_{-10} $(9.8^{+0}_{-0.4})$	
D0	minimum	110 (4.33)	
H	nominal	900 (35.4)	1
H0	minimum	15 (0.59)	
H1	maximum	25 (1.0)	
H2	maximum	2600 (102.4)	
HC3	range	$32^{+2.0}_{-0}$ $(1.26^{+0.1}_{-0})$	2
S	minimum	482 (19.0)	3
		555 (21.9)	4
W1	maximum	130 (5.12)	
W2	minimum	205 (8.07)	

NOTE 1: This value is ergonomically compatible with the proposed 13 frame cassette and may not be ergonomically compatible with the proposed 25 frame cassette. The proposed 25 frame cassette may require assisted loading. H to be fully adjustable at installation over the range of 890 to 910 mm (35 to 35.8 inches).

NOTE 2: To avoid confusion, HC3 is used instead of H3 because H3 stands for another dimension in SEMI E15.1.

NOTE 3: Frame cassette (see SEMI G77) without manual side handles

NOTE 4: Frame cassette (see SEMI G77) with manual side handles

9 Table 1 Dimensions Definition

9.1 See SEMI E15 for definitions of the following terms used in this specification:

9.1.1 C1

9.1.2 C2

9.1.3 H

9.1.4 H1

9.1.5 S

9.2 *D* — allowable load depth to frame cassette centroid.

9.3 *D0* — minimum rear clearance of equipment boundary below H1 from facial datum plane.

9.4 *H0* — minimum height from the bottom of equipment boundary below H1 to horizontal datum plane.

9.5 *H2* — maximum overhead track clearance from the floor.

9.6 *HC3* — allowable height of conveyor rail from horizontal datum plane.

9.7 *W1* — maximum side clearance of equipment boundary below H1 from bilateral datum plane.

9.8 *W2* — minimum side clearance of equipment boundary below H1 from bilateral datum plane.

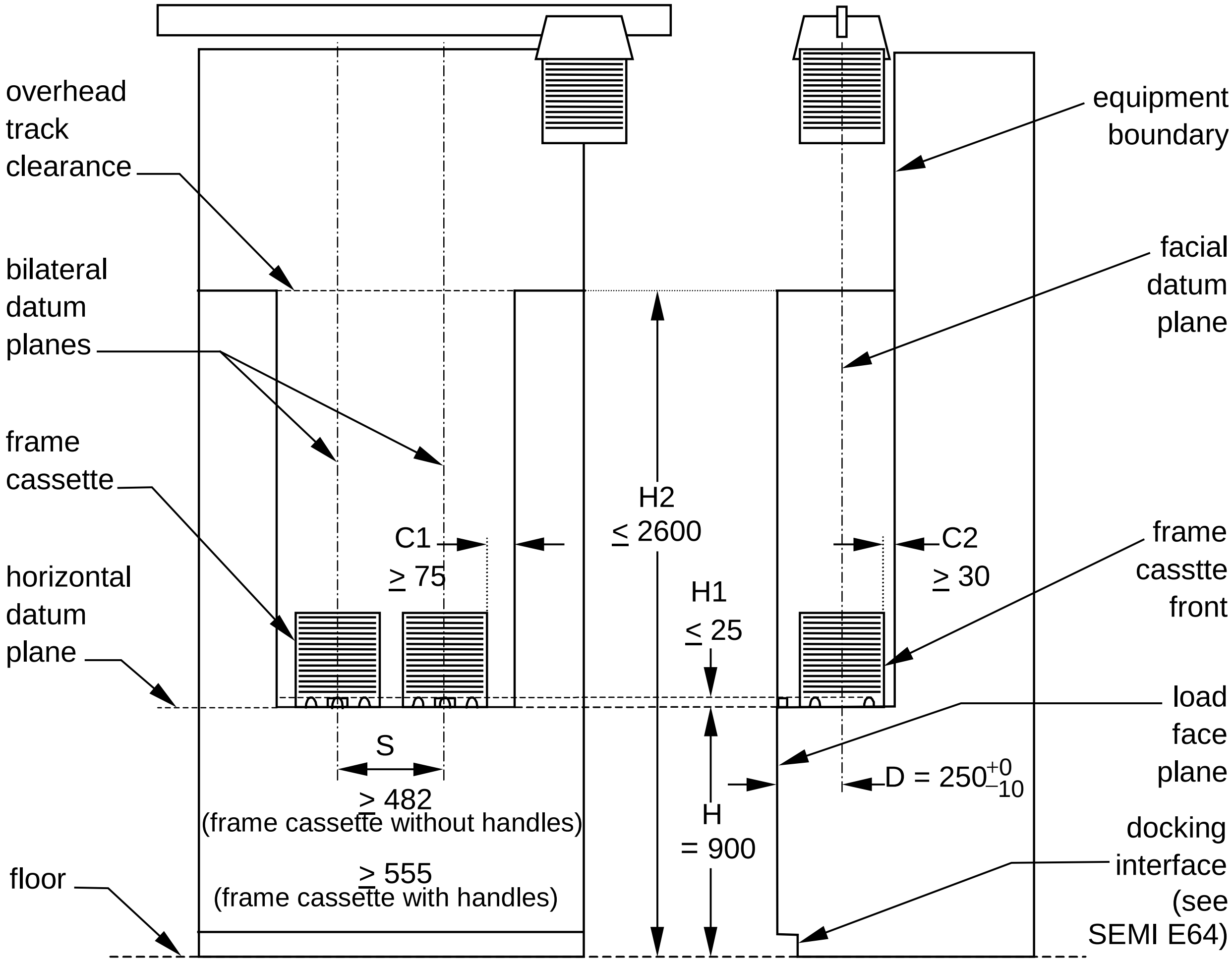


Figure 1
Load Port Requirements

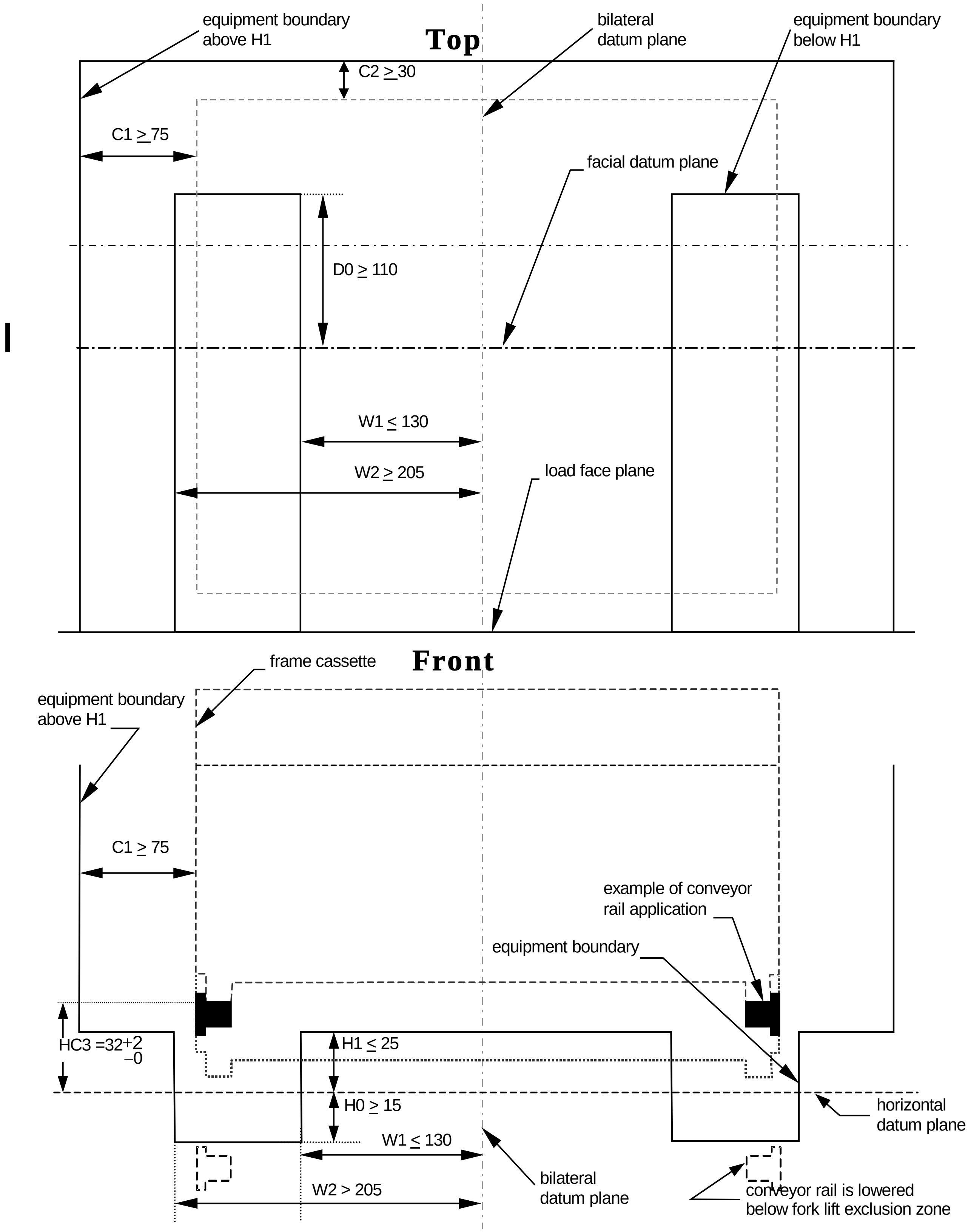


Figure 2
Trenches and Conveyor Rails

SEMI G83-0301
SPECIFICATION FOR BAR CODE MARKING OF PRODUCT PACKAGES

This specification was technically approved by the Global Assembly & Packaging Committee and is the direct responsibility of the Japanese Packaging Committee. Current edition approved by the Japanese Regional Standards Committee on December 1, 2000. Initially available at www.semi.org January 2001; to be published March 2001.

1 Purpose

1.1 This specification describes the area needed for adding bar codes, the bar code specifications, and the code notation format for direct and indirect material product packages (unit packs) for semiconductor packaging.

1.2 The following are the goals of this specification:

- Quality control using computers
- Prevention of mistakes created by human error
- Material control at the manufacturing site

1.3 The following is not a goal of this specification:

- Purchasing control

2 Scope

2.1 This specification is to be used for direct and indirect materials relating to packaging materials.

2.2 This specification is to be used for product packages only.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate and safety health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI G71 — Specification for Barcode Marking of Intermediate Containers for Packaging Materials

3.2 *AIM Specifications*[1]

USS-39 — Universal Symbol Specification code 39

USS-128 — Universal Symbol Specification code 128

3.3 *ANSI Specifications*[2]

ANSI X3.182 — Bar code Print Quality - Guideline

1 AIM International Inc., 11860 Sunrise Valley Drive, Suite 100, Reston, VA 20191, tel 703.391.7621, fax 703.391.7624

2 American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel 212.642.4900, fax 212.398.0023

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 Many of the items relating to bar code technology are defined in the AIM Glossary of Terms, ANSI X3.182 (Bar code Print Quality Guidelines).

4.1.1 *data field* — field (area) for adding a bar code to a product package.

4.1.2 *direct material* — components and parts that make up a semiconductor package. Examples include lead frames, molding compounds, bonding wires, die bonding materials, etc.

4.1.3 *HRI (Human Readable Identification)* — characters that can be read by a human.

4.1.4 *indirect material* — supplementary materials and parts used during processing but that do not make up a semiconductor package. Examples include bonding capillaries, dicing blades, etc.

4.1.5 *intermediate container* — container that holds one or more product packages for product/order separation in a shipping container or final container.

4.1.6 *product package* — the smallest package format, made by a single material. Also called a unit pack.

4.1.7 *shipping pack* — package or shipping container/final container (see Figure 1) that is strong enough for industrial use for product packaging, storage, and shipping.

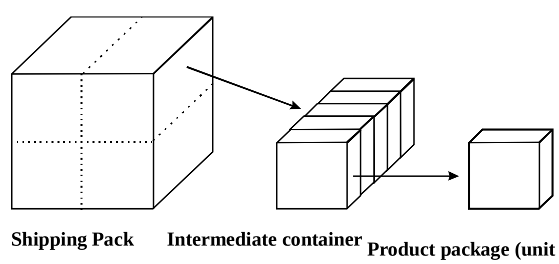


Figure 1
Package Form Regulations

5 Requirements

5.1 *Data Field*

5.1.1 Length is 42 mm or greater, height is 15 mm or greater (see Figure 2 and Table 2).

5.1.2 The noted content bar code is HRI.

5.2 *Bar Code*

5.2.1 *Bar code character* — Bar code characters specified by AIM USS-39 or AIM USS-128 shall be used.

5.2.2 *Printing quality* — according to ANSI X3.182 Bar code Print Quality Guidelines.

5.2.3 *Code dimensions* — the bar code dimensions will be as listed in Table 1.

5.2.4 *Restrictions on use of Code 128* — use only code set B. Also, do not use shift characters within data.

5.2.5 The data digit count will be from 15 to 26 (excluding start/stop characters and check characters).

5.2.6 Use check character.

5.3 *HRI (Human Readable Identification)*

5.3.1 Just below the bar code located in the data field, a field for HRI characters is noted.

5.3.2 The HRI height will be 3.0 mm or greater.

5.3.3 The space between the HRI and bar code shall be 1.0 mm or greater (see Figure 2 and Table 2).

5.4 *Data Contents*

5.4.1 Includes items listed in Table 3.

5.4.2 The sequence, from left to right is as follows: the product recognition number, manufacturing date, sub-lot number, and lot number.

5.4.3 Product recognition number and lot number shall be included.

5.4.4 Manufacture date and sub-lot number shall be written in fixed digits. Remaining unused digits shall be filled by minus codes "-".

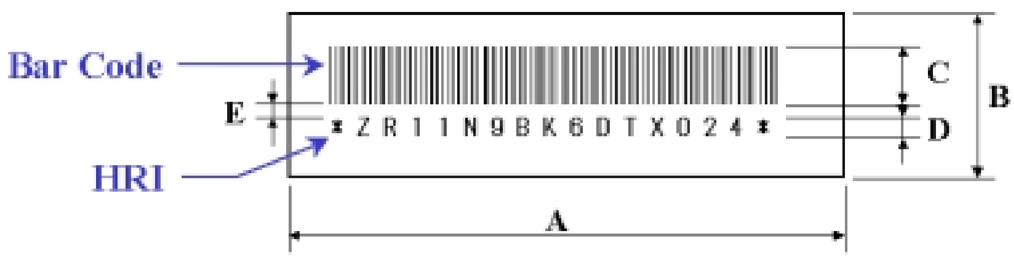


Figure 2
Data Field Dimensions and Placement

Table 1 Code Dimensions

Code 39, Code 128	Dimensions
Minimum element width	0.15 mm or greater.
Code 39 wide bar width	Greater than 2 times, but less than 3 times the minimum element width.
Gap between characters	Minimum element width or greater.
Character height	8.0 mm or greater.
Quiet zone	10 times or greater than the minimum element size (before and after the bar code).

Table 2 Data Field Dimensions

Item	*Dimensions*
Data field length	A ≥ 42 mm
Data field height	B ≥ 15 mm
Bar code height	C ≥ 8 mm
HRI character height	D ≥ 3 mm
Space between bar code and HRI	E ≥□ 1 mm

Table 3 Data Contents (see Appendix 1)

Field Name	*Product Recognition No.*	*Manufacturing Date*	*Sub-Lot No.*	*Lot No.*
Meaning	Code used by user mainly to characterize products.	Date the material was manufactured	Code for characterizing the product package	Code used by supplier mainly to characterize products
Number of digits	5 to 12	3	2	5 to 9
Note	No regulations.	1st digit: Last digit of Gregorian calendar year. 2nd digit: Month indication, note that A = October, B = November, C = December. 3rd digit: Day indication, note that A = the tenth, B = the eleventh, C = the twelfth, ... U = the thirtieth, V = the thirty-first.	No regulations.	No regulations.

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI G83 and was approved by full letter ballot procedures on December 1, 2000 by the Japanese Regional Standards Committee.

This information explains AIM Specifications listed in Section 3.1 and examples of Data Contents specified in Table 3.

A1-1 AIM USS-39

A1-1.1 Figure A1-1 shows the AIM USS-39 characters and bar patterns.

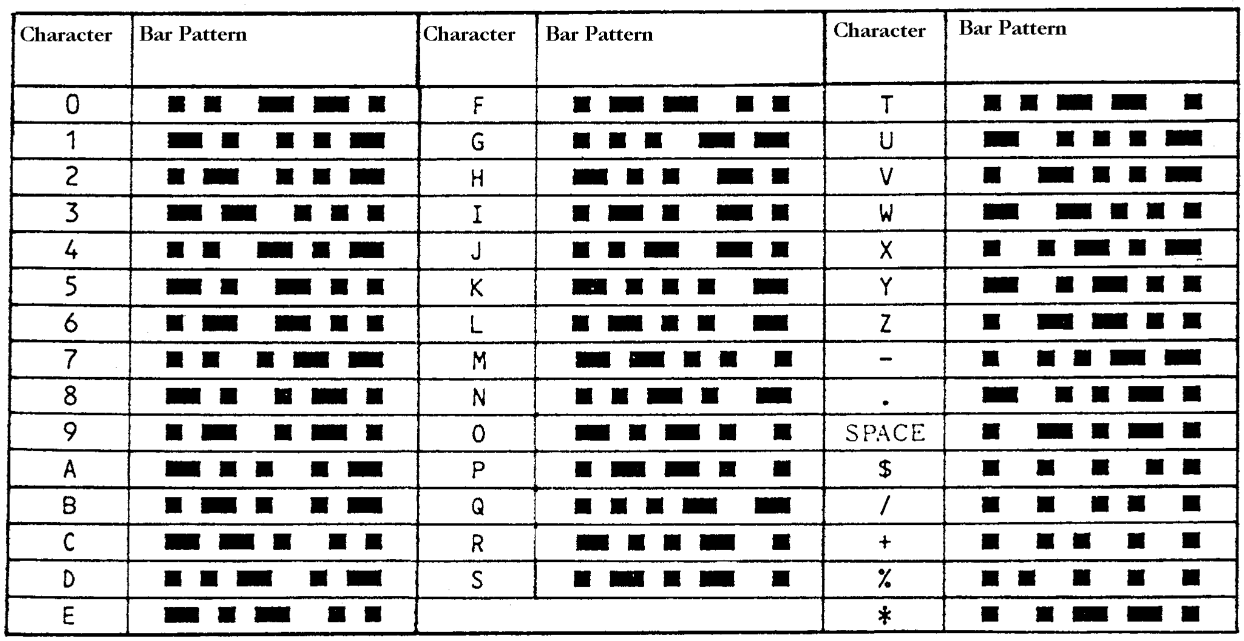


Figure A1-1
AIM USS-39

A1-2 AIM USS-128

A1-2.1 The AIM USS-128 characters and bar patterns are shown in Figure A1-2. Areas enclosed by bold lines indicate the code used with this specification.

Numerical value	CODE A	CODE B	CODE C	Bar pattern
0	SP	SP	00	
1	!	!	01	
2	"	"	02	
3	#	#	03	
4	$	$	04	
5	%	%	05	
6	&	&	06	
7	'	'	07	
8	(	(	08	
9	)	)	09	
10	*	*	10	
11	+	+	11	
12	,	,	12	
13	-	-	13	
14	.	.	14	
15	/	/	15	
16	0	0	16	
17	1	1	17	
18	2	2	18	
19	3	3	19	
20	4	4	20	
21	5	5	21	
22	6	6	22	
23	7	7	23	
24	8	8	24	
25	9	9	25	
26	:	:	26	
27	;	;	27	
28	<	<	28	
29	=	=	29	
30	>	>	30	
31	?	?	31	
32	@	@	32	
33	A	A	33	
34	B	B	34	
35	C	C	35	
36	D	D	36	
37	E	E	37	
38	F	F	38	
39	G	G	39	
40	H	H	40	
41	I	I	41	
42	J	J	42	
43	K	K	43	
44	L	L	44	
45	M	M	45	
46	N	N	46	
47	O	O	47	
48	P	P	48	
49	Q	Q	49	
50	R	R	50	
51	S	S	51	
52	T	T	52	
53	U	U	53	

Numerical value	CODE A	CODE B	CODE C	Bar pattern
54	V	V	54	
55	W	W	55	
56	X	X	56	
57	Y	Y	57	
58	Z	Z	58	
59	[	[	59	
60	\	\	60	
61	]	]	61	
62	^	^	62	
63	_	_	63	
64	NUL	`	64	
65	SOH	a	65	
66	STX	b	66	
67	ETX	c	67	
68	EOT	d	68	
69	ENQ	e	69	
70	ACK	f	70	
71	BEL	g	71	
72	BS	h	72	
73	HT	i	73	
74	LF	j	74	
75	VT	k	75	
76	FF	l	76	
77	CR	m	77	
78	SO	n	78	
79	SI	o	79	
80	DLE	p	80	
81	DC1	q	81	
82	DC2	r	82	
83	DC3	s	83	
84	DC4	t	84	
85	NAK	u	85	
86	SYN	v	86	
87	ETB	w	87	
88	CAN	x	88	
89	EM	y	89	
90	SUB	z	90	
91	ESC	{	91	
92	FS	|	92	
93	GS	}	93	
94	RS	~	94	
95	US	DEL	95	
96	FNC 3	FNC 3	96	
97	FNC 2	FNC 2	97	
98	SHIFT	SHIFT	98	
99	CODE C	CODE C	99	
100	CODE B	FNC 4	CODE B	
101	FNC 4	CODE A	CODE A	
102	FNC 1	FNC 1	FNC 1	
103	START(CODE A)			
104	START(CODE B)			
105	START(CODE C)			
	STOP			

Figure A1-2
AIM USS-128

A1-3 Example of Data Contents

A1-3.1 The items shown in Figures A1-3 and A1-4 are data contents of bar code that comply with this specification.

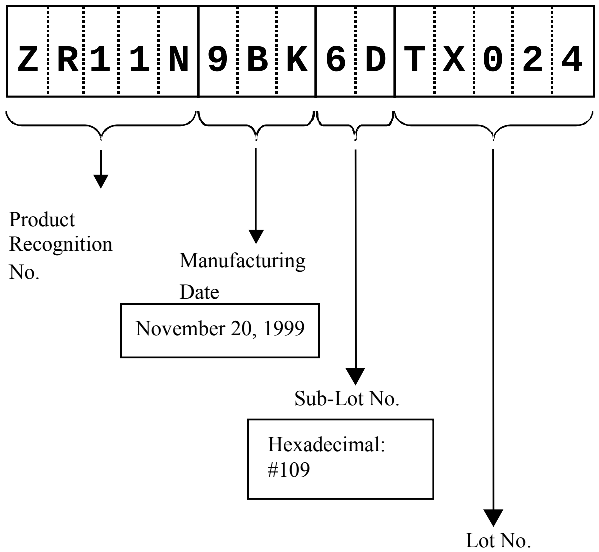


Figure A1-3
Example of Data Contents

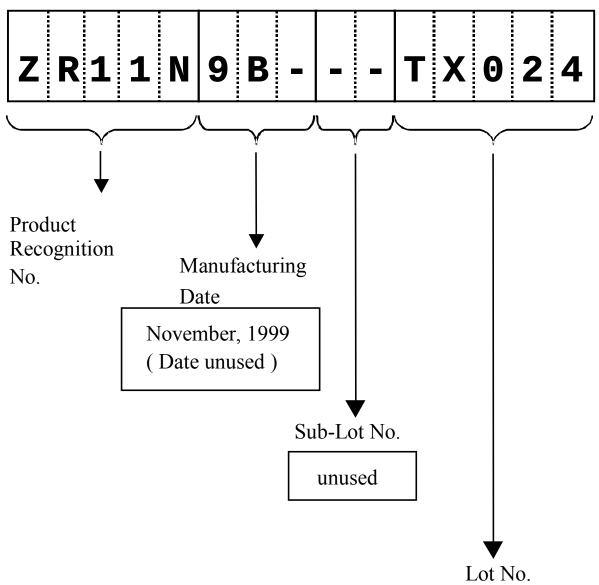


Figure A1-4
Example of Data Contents

SEMI G84-1101
SPECIFICATION FOR STRIP MAP PROTOCOL

This specification was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the North American Automated Test Equipment Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 The purpose of this specification is to provide definition that will enable the implementation of strip mapping throughout the assembly and test process. This document will enable standardization of the strip map format and execution method throughout the factory floor.

1.2 This document describes the format and methods in which strip map information shall be formatted and used to transfer information about a strip to and from equipment using the SECS/GEM interface standard (see SEMI E5).

2 Scope

2.1 This specification will identify the messages within the SECS/GEM message set used in the implementation of strip mapping.

2.2 This specification will identify the Map Data Items (MDI) that are required or optionally may be used in the implementation of strip mapping.

2.3 This document will provide basic application notes to aid in the proper implementation of strip mapping.

2.4 This document will not address application or implementation for wafer test process.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document does not address the transmission, file naming conventions, storage or archiving of strip maps.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E5 — SEMI Equipment Communications Standard Message Content (SECS II)

SEMI G81 — Specification for Map Data Items

SEMI T9 — Specification for Marking of Metal Lead-Frame Strips with a Two-Dimensional Data Matrix Symbol.

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *assembly site* — the sub-contractor, supplier's facility or department that will be responsible for the assembly of IC devices.

5.2 *bottom-side* — the bottom of the strip as defined by the customer based on the customer master manufacturing drawing.

5.3 *cell* — a term used to represent the mapping item on a strip – unit, package, device, multi-chip module, etc.

5.4 *strip* — a leadframe, board, panel or other container which hold locations for semiconductor devices to be manufactured upon.

5.5 *strip map* — a record of data in a file that contains quality and historical information about each individual strip in a manufacturers lot.

5.6 *supplier* — a supplier of inspected / tested substrates (strips) and strip maps to the assembly site.

5.7 *substrate* — a board or panel containing locations for semiconductor devices to be manufactured upon. Also referred to as strip, board or PCB.

5.8 *top-side* — the top of the strip as defined by the customer based on the customer master manufacturing drawing.

6 Ordering Information

None.

7 Convention

7.1 The following conventions are used to represent data format. Each format is represented by an alphabetic character and optional data size given by "byte" unit. Exceptions are "*" and "List of". Refer to SEMI E5 for details.

7.1.1 A — ASCII character(s), may not be required terminal character such as null (00_{16})

7.1.2 B — Binary

7.1.3 I — Integer number

7.1.4 U — Unsigned Integer number

7.1.5 List of — Combined item format consisting of one or more items; array (items of the same type) or structure (items of different types)

7.1.6 * — Any format as above or those allowed in SEMI E5.

8 Object Definitions

8.1 The implementation of Strip Mapping defines one standard object, the Strip Map.

8.1.1 *Strip Map Object Definition* — The Strip Map is a dynamic object created and modified through the assembly and test process. Each Strip Map Object is a logical representation of a manufacturing lead frame or substrate and maintains the current processing state for the group of die attached to that physical leadframe or substrate. Each Strip Map Object uniquely identifies a manufacturing leadframe or substrate using the ObjID (StripID) object attribute. The object attribute notation used in Table 1 is described in Conventions, Section 7.

9 Requirements

9.1 *Equipment Communication*

9.1.1 Communication of strip maps between host and equipment shall use the SECS I or HSMS protocols. Otherwise, some other general protocols, which are widespread in the data communication field, could be used as an alternative. However, these are not covered in this specification.

9.2 *Map Data Items*

9.2.1 The Standard Map Data Items in Table 1 contain the standard data items that shall be used in all strip mapping implementations.

9.2.2 The Strip Map Data Items in Table 2 are the data items and object attributes that will be used in the implementation of strip mapping via the SECS/GEM interface as needed by each equipment type and process step.

Table 1 Standard Data Item/Object Description and Settings

Data Item	*Description / Settings*	*Format*
SMORLOC	0 = Error 1 = Upper right 2 = Upper left 3 = Lower left 4 = Lower right > 4 = Error 5-63 Reserved	U1
ERRCODE1	Expected error codes 0 = Unknown strip map ID 1 = Column Count conflict with existing strip map 2 = Row Count conflict with existing strip map 3 = Conflict in Map size and Row/Column count	U2
ERRTEXT	Error text, according to Errcode “Unknown strip map ID” “Column Count conflict with existing strip map” “Row Count conflict with existing strip map “ “Conflict in Map size and Row/Column count”	A
OBJACK	Strip map acknowledge 0 = successful 1 = failed	B
ATTRID	Object attribute ID	A
ATTRDATA	Object attribute data	*
ACKC6	Strip map acknowledge 0 = successful 1 = failed	B
OBJSPEC	A text string that has an internal format and that is used to point to a specific object instance.	A

Data Item	Description / Settings	Format
	The string is formed out of a sequence of formatted substrings, each specifying an object's type and identifier. The substring format has the following four fields: object type, colon character ":", object identifier, greater than symbol ">", where the ":" is used to terminate an object type and the ">" is used to terminate an identifier field. The object type may be omitted where it may be otherwise determined. The final ">" is optional. The OBJSPEC for the StripMap Object is a zero-length item. No specifier required.	
OBJTYPE	Identifier for a group or class of objects. All objects of this type must have the same set of attributes. Available object types: "StripMap"	A
OBJID	Object Identifier	A

Table 2 Strip Map Data Item/Object Description and Settings

Attribute Name	*Definition*	*Access*	*Required*	*Format*
ObjType	The object type, "StripMap"	RO	Y	A = "StripMap"
ObjID	The object. This is the StripID, FrameID or equivalent.	RO	Y	A
CellStatus	Cell Status is an array of values indicating the value of each unit/package/device on a strip. 0 = Functional Good Cell; Good die placed on Good cell. 1 = Unknown Cell Status. 2 = Defect/Non-functional Cell; the cell is marked as defect by previous steps. CellStatus shall be sent in an array of size Rows × Columns in row major format with respect to the OriginLocation. CellStatus may be provided by the host to the equipment as well as from the equipment to the host. Used in: Strip Map Upload and Strip Map Download	RW	Y' Either CellStatus or CellGrade or both are required if mapping is to be used.	List of U1
CellGrade	CellGrade is an array of values indicating the classification of each unit/package/device/cell on a strip. The process and equipment using a 'grading' scheme determine this classification and the associated values. Examples of a CellGrade are test bins, sort grades, package grade, marking grades etc. CellGrade shall be sent in an array of size Rows × Columns in row major format with respect to the OriginLocation.	RW	Y' Either CellStatus or CellGrade or both are required if mapping is to be used.	List of U1
Columns	The number of columns of (measured) device matrix on substrate, that is the number of devices on the X-axis of the map data. It is required if the type of the map data is simple array structure.	RO	Y	U4

Attribute Name	*Definition*	*Access*	*Required*	*Format*
OriginLocation	Coordinate system on substrate to address devices. Location of the datum point or the origin of the coordinates shall be one of the following: 0 = Not currently supported 1 = Upper right – top side 2 = Upper left – top side 3 = Lower left – top side* 4 = Lower right – top side 5 = Not currently supported 6 = Upper right – bottom side 7 = Upper left – bottom side 8 = Lower left – bottom side 9 = Lower right – bottom side * Default value is 3 (=Lower left – top side) if this item is not present. Typically Used in: Strip Map Upload and Strip Map Download	RO	Y	U1
Rows	The number of rows of (measured) device matrix on substrate, that is the number of devices on the Y-axis of the map data. It is required if the type of the map data is simple array structure.	RO	Y	U4
SubstrateID	A character code that may be printed or encoded on the substrate, which uniquely identifies the substrate, and can be used to correlate the map with physical substrate. SubstrateID is either StripID or FrameID.	RW	Y	A
BinGrade	A BinCode (see SEMI G81) is a value describing the grading of a die. BinGrade is an array of bin codes used to describe each die on the wafer. BinCodeList shall be sent in an array size Rows x Columns in row major format with respect to the OriginLocation. Typically used in: Strip Map Upload	RW	N	U1
DefectCode	DefectCodes are a set of codes representing defects that are detected at each process step by equipment or a human. DefectCodes shall be sent in an array of size Rows × Columns in row major format with respect to the OriginLocation. If there is no defect, the DefectCode is 0 (Zero) Typically Used in: Strip Map Upload and Strip Map Download	RW	N	List of U1
LotID	Production lot identifier for this data.	RW	N	A

Attribute Name	Definition	Access	Required	Format
ContainerID	A character code that may be printed or encoded on the substrate carrier, which uniquely identifies the substrate carrier. ContainerID can be MagazineID, CarrierID or CassetteID.	RW	N	A
WaferID	A character code that may be printed or encoded on the wafer, which uniquely identifies the wafer. Used when equipment reports wafer id with or in parallel with strip map data.	RW	N	A
XYPosition	XYPosition represents the X and Y coordinate position of the die on the wafer. XYPosition must be in (X,Y) order multi-item and shall be made up of data items DieX and DieY (See SEMI G81). For each XYPosition a WaferID is given. This information is used when wafer id and die location on the wafer is to be associated with the strip id and location of the unit/package/device/cell on a strip. XYPosition is set to 32767, 32767 when a strip is removed from the equipment. This represents no wafer die information. Valid range for X and Y is 1..32767	RW	N	List of I2

9.3 *Map Data Protocol*

9.3.1 The strip mapping standard implementation shall use the SECS/GEM standard Object Services (F14,F1/F2) and standard Collection Event S6,F11/F12 Streams and Functions for the transfer of Strip Maps to and from equipment (see SEMI E5).

9.3.2 The use of object services will allow the equipment to request the type of information from the host with predefined attributes. The host will then reply with the list of attributes requested. This will enable application specific behavior of the mapping process by equipment types.

9.3.3 The use of the Collection Event Streams and Functions will allow event-based communication from the equipment to the host on the status of the strip mapping process.

9.3.4 *Strip Map Download*

9.3.4.1 The equipment shall request a strip map download from the host using the Standard Object Services (OSS) command, S14,F1 GetAttribute Request (GAR). Please refer to Section 9.2.1.

9.3.4.2 The equipment shall include all mandatory data attributes in GAR request as well as any optional information required by the particular equipment to implement the strip mapping capability.

9.3.4.3 The host will respond to the GetAttribute Request with an S14,F2, Get Attribute Data (GAD).

9.3.5 *Strip Map Upload*

9.3.5.1 The equipment will provide updates to the strip map via the S6,F11 event.

9.3.5.2 All mandatory data items are required to be included in the upload event along with any optional equipment specific data items. Please refer to Section 9.2.2 for examples.

10 Description

10.1 See SEMI G81 for further definitions of the strip map required items.

10.2 *Strip Map Required Attributes*

10.2.1 The following set of Data Items are mandatory in the uploads and downloads scenarios for strip maps.

- Strip ID
- Rows
- Columns
- OriginLocation
- CellStatus | CellGrade

10.2.2 Each equipment shall have an attribute for the product or strip type that will describe the standards process direction and physical origin of the strip. If the physical origin and the factory defined origin are not the same, it is the responsibility of the equipment to perform the appropriate translations to maintain integrity of the strip map information.

10.3 *Strip Map Data Protocol Examples*

10.3.1 *Strip Map Download (Example)*

S14,F1 GetAttr Request (GAR) S,H<-E

10.3.1.1 Description: This message is used to request a set of specified attributes for one or more objects.

Structure: L,5

1. <OBJSPEC = ‘’>
2. <OBJTYPE = ‘StripMap’>
3. L,1
   1. <OBJID1 = StripID = ‘A1000001’>
4. L,0 (always zero list, no filters defined)
5. L,5 (any length and order of data items)
   1. <ATTRID = OriginLocation >
   2. <ATTRID = ‘Rows ' >
   3. <ATTRID = ‘Columns ' >
   4. <ATTRID = ‘CellStatus' >
   5. <ATTRID = ‘LotID' >

NOTE: This is an example only. Each equipment must request all mandatory data items and can additionally request any optional data items that it needs to fully implement strip mapping capability.

S14,F2 GetAttr Data (GAD) M,H->E

10.3.1.2 Description: This message is used to transfer the set of requested attributes for the specified object(s). The order of attributes is retained from the primary message.

Structure: L,2

1. L, 1
   1. L,2
      1. <OBJID = StripID = ‘A1000001’>
      2. L,5
         1. L,2
            1. <ATTRID = ‘OriginLocation’ >
            2. <ATTRDATA = ‘0’>
         2. L,2
            1. <ATTRID = ' Rows’>
            2. <ATTRDATA = 6>

3. L,2
1. <ATTRID = '   Columns ' >
2. <ATTRDATA = 24>
4. L,2
1. <ATTRID = '   CellStatus' >
2. <ATTRDATA = 6>
5. L,2
1. <ATTRID = '   LotID ' >
2. <ATTRDATA = ' Lot1>
2. L,2
1. <OBJACK = 0>
2. L,0

10.3.2 *Strip Map Upload (Example)*

S6,F11   Event Report   M, H<-E

10.3.2.1 Description: This message is used to report the current map status. This event will occur at the end of a strip as well as at any point during the processing of the strip when the equipment enters a condition where an operator may have the opportunity to handle the strip or the equipment has an opportunity for error. This event shall always be sent with the current status of the map at the time the equipment gets changed from local to remote.

10.3.2.1.1 For a description of filters, see S6,F11.

Structure: L,3
1. <DATAID>
2. <CEID>
3. L,1
1. L,2
1. <RPTID>
2. <L,n
1. <xxxx>
n. <yyyy>

S6,F12   Event Report Acknowledge   H->E

Description: Acknowledge or Error

Structure: <ACKC6>

11 Application Scenarios

11.1 *Strip Map Download*

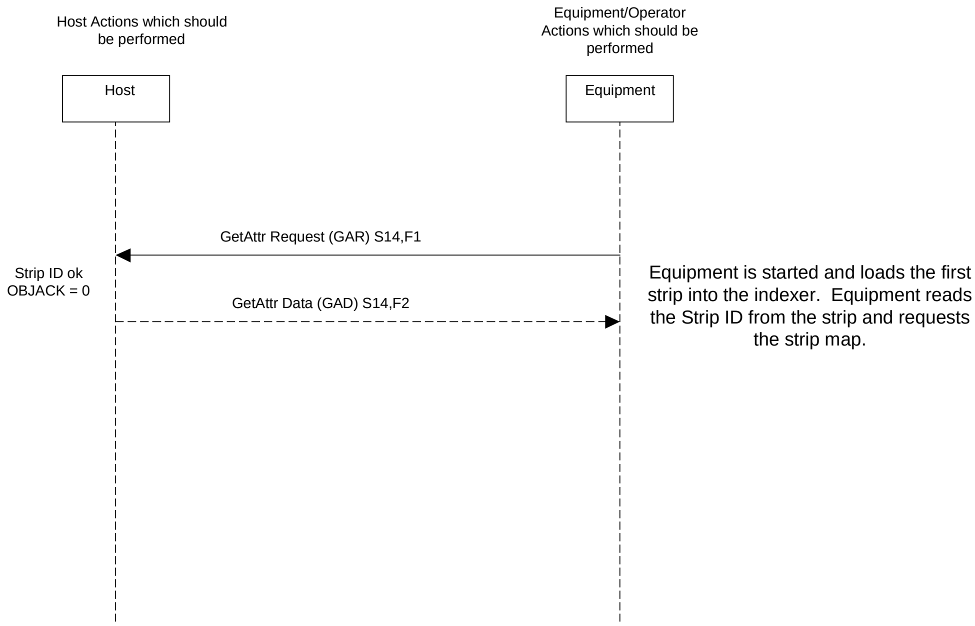


Figure 1
Strip Map Download

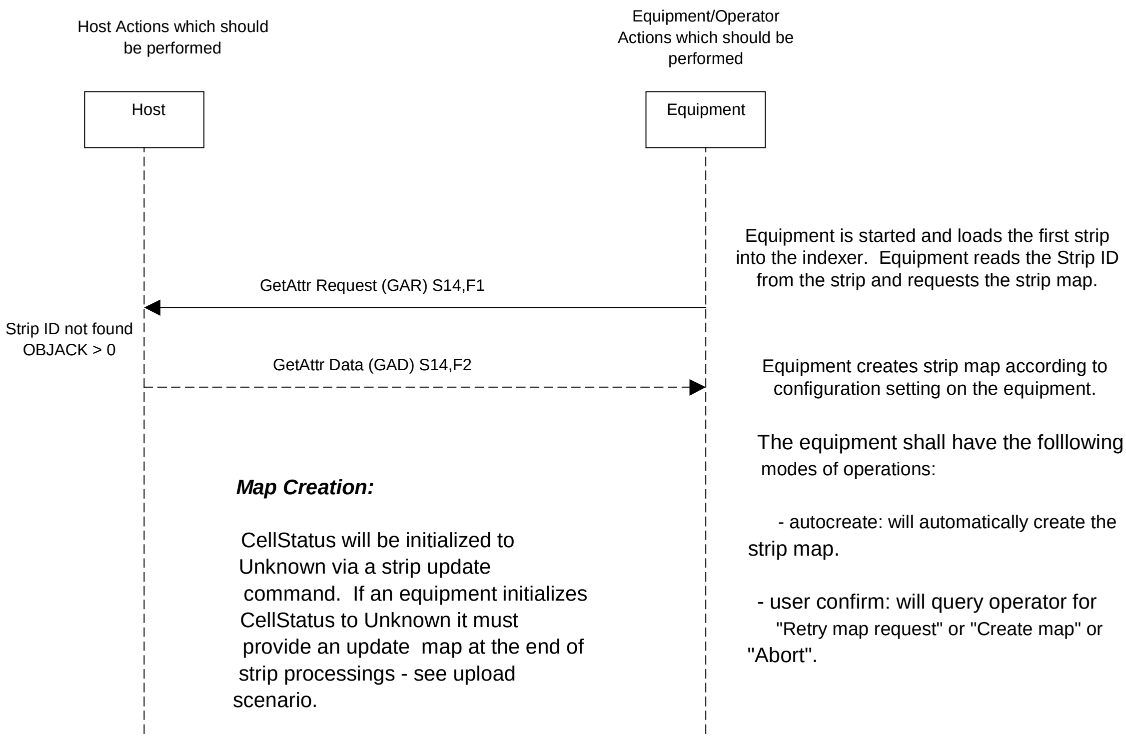


Figure 2
Strip Map Create

11.1.1 A typical equipment scenario is that for each strip arriving at the equipment input, a strip map request (S14,F1) and subsequent download (S14,F2) will occur. See Figure 1. Depending on the equipment type, there may be some variations on the optional attributes requested, the timing of events and exception handling.

11.2 *Strip Map Creation*

11.2.1 A map must exist before it can be sent to an equipment type. Some equipment may be required to support the creating of the map for the first time. See Figure 2. For these equipment two modes are identified, “autocreate” and “user confirm”. To use these modes the equipment shall behave as indicated below.

11.2.2 If equipment supports an “autocreate” mode the equipment will process the strip as normal when a new strip arrives. The equipment will assume each location on the strip has an unknown status. Should the equipment be required to send a strip map during processing due to equipment errors, the strip map shall contain the unknown CellStatus value whenever the status is unknown. All other CellStatus indicators shall be “Good” or “Bad”. See Upload scenario.

11.2.3 If equipment supports a “user confirm” mode, the equipment shall request operator intervention to decide how to deal with a missing strip map. The options are “Create map” or “Abort”. If the operator selects “Create map” the above scenario will be valid. If the operator selects “Abort”, the equipment shall send an alarm to the host and not process the strip. The strip will not be processed unless the equipment is removed from the “strip map” mode.

11.3 *Strip Map Upload*

11.3.1 For equipment with the capability of detecting defective units on a strip, a strip map upload is required. The upload will report new definitions of each “cell”.

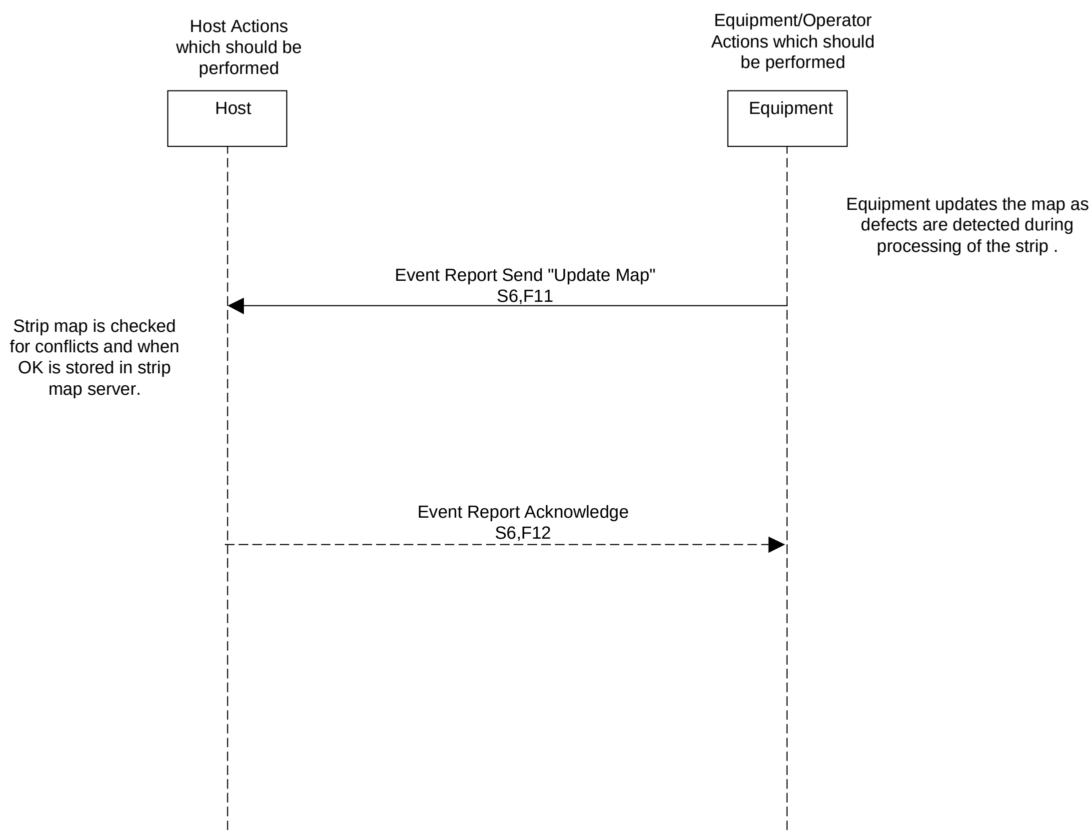


Figure 3
“Update Map” Event

11.3.1.1 An Event Report “Update Map” will be sent if new defects have been detected and not previously logged to the host for the following conditions. See Figure 3.

1. At the end of processing current strip if new defects have been detected
2. Whenever the equipment changes state from Remote to Local
3. Whenever the equipment interlocks are triggered
4. Whenever the equipment stops and requires operator intervention.

11.3.2 *Unsuccessful Transaction*

11.3.2.1 Equipment will stop and signal an alarm to the host if the equipment detects that a strip map has not been successfully uploaded to the host.

11.3.2.2 When possible, the equipment shall support intervention by the Operator with the following corrective actions:

1. “retry upload”
2. “abort upload”

11.3.2.3 If the “retry upload” is selected the Upload Event will be resent to the host.

11.3.2.4 If “abort” is selected by the operator an appropriate Event shall be sent with the strip map ID to indicate to the host that the strip map has been aborted. The equipment will not process the strip unless the equipment is removed from “strip map” mode.

11.4 *Strip End Event*

11.4.1 At the end of each strip, a strip end event shall be sent to the host which indicates that the strip has successfully completed the activity at that equipment.

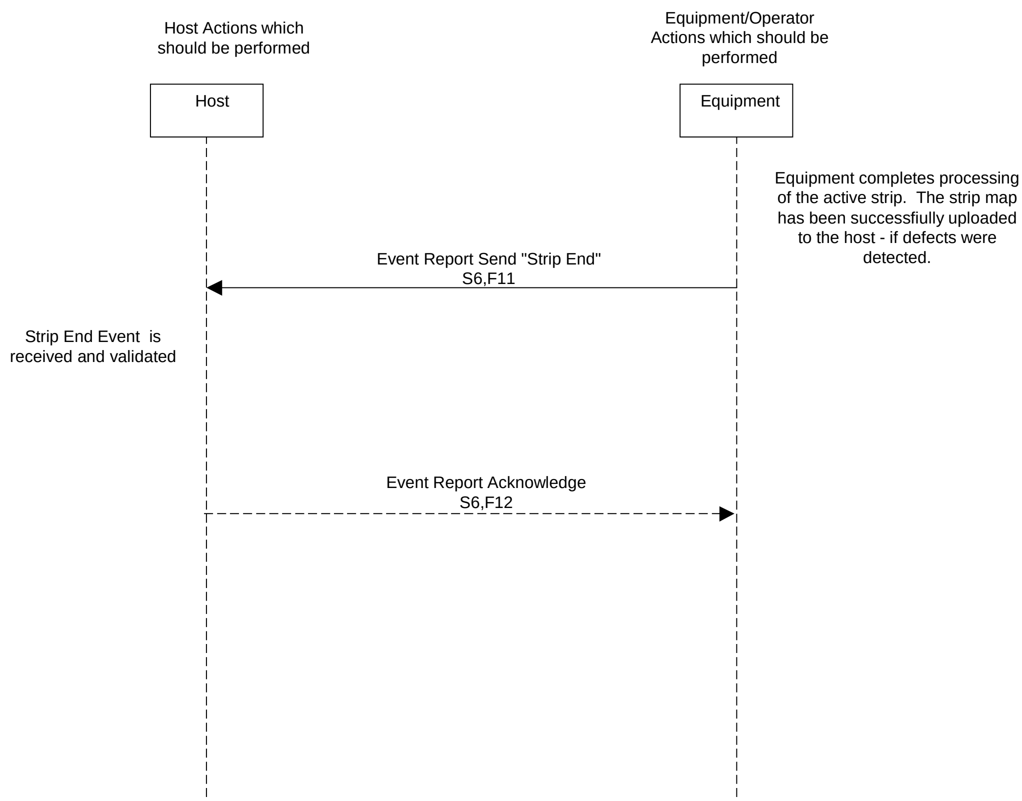


Figure 4
“Strip End” Event

11.5 *In Process Strip Map Related Errors*

11.5.1 Each equipment type shall define the type of errors that can occur during processing which could cause strip map integrity problems and provide documented scenarios of how the equipment will handle each situation.

11.5.2 Some potential erroneous situations:

- Equipment lost strip map while processing
- Strip is removed prior to completing processing strip
- Strip jams before being moved out of equipment – no Strip Map End Event occurred

APPENDIX 1
STRIP MAP

NOTE: The material in this appendix is an official part of SEMI G84 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 This appendix shows how the map data items may be applied to strips as well as some additional information specific to this substrate type.

A1-2 The StripID shall follow the SEMI T9 specification, when applicable, or may be user definable by the factory.

A1-3 For any given process there must be a way to ensure correct orientation of the strip. The end user is responsible for providing a master manufacturing drawing showing the top side of the strip. This drawing must show any special markings or patterns that are needed to reliably flip and rotate a physical strip until it is oriented the same as the drawing. Figure A1-1 defines what is meant by top side and hence bottom side. It also defines what is meant by upper, lower and left and right.

A1-4 Each strip type will have a factory defined value for OriginLocation. This is the origin reference for the row 1, column 1 location on the strip. The factory origin, OriginLocation is selected as one of four corners by the factory host system. The row and column index will be referenced from the selected reference. This information will be provided to the equipment by the host in each strip map download scenario.

1 = Upper right (UR) top side

2 = Upper left (UL) top side

3 = Lower left (LL) top side

4 = Lower right (LR) top side

6 = Upper right (UR) bottom side

7 = Upper left (UL) bottom side

8 = Lower left (LL) bottom side

9 = Lower right (LR) bottom side

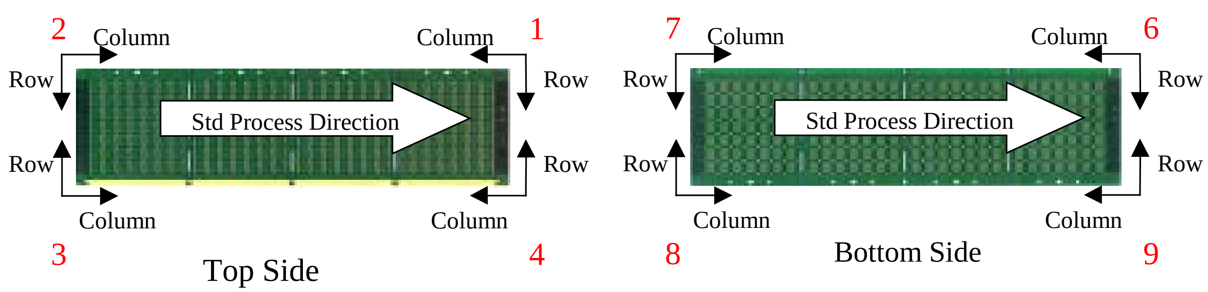


Figure A1-1
Factory Origin Settings

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user’s attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI G85-1101
SPECIFICATION FOR MAP DATA FORMAT

This specification was technically approved by the Global Automated Test Equipment Committee and is the direct responsibility of the North American Automated Test Equipment Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001.

1 Purpose

1.1 This document describes in detail how the data items that relate to electronic mapping are to be represented in a file format.

1.2 Although the examples given in this document are for wafers, the map data format described can be applied to any substrate including, but not limited to; wafer, tray, strip or tape.

2 Scope

2.1 This document applies to format of map data items. This document does not address the transmission, file naming conventions, storage or archiving of maps.

2.2 The semantics of the map data items are not specified in this document.

2.3 The specification of which data items are optional and which are required is not specified in this document.

2.4 The size of each data item is not specified in this document.

2.5 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This document is limited to representing maps for MapType =”Array”. See SEMI G81 for a definition of MapType.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI G81 — Specification for Map Data Items

4.2 *World Wide Web Consortium Documents*[1]

Extensible Markup Language (XML) 1.0 (Second Edition. Namespaces in XML)

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *map* — a two dimensional array of bin codes derived from electrical test data of a two dimensional substrate including, but not limited to; wafer, tray, strip or tape.

6 Ordering Information

None.

7 Description

7.1 XML Notation Extensible Markup Language is the universal language for data on the Web. It gives developers the power to deliver structured data from a wide variety of applications to the desktop for local computation and presentation. XML allows the creation of unique data formats for specific applications. It is also an ideal format for server-to-server transfer of structured data.

7.2 XML consists of nodes (referred to as ‘items’ in the remainder of this document) that may have attributes and nested items.

7.2.1 Example:

```
<Map xmlns:semi="http://www.semi.org" >
  <Device>
  </Device>
</Map>
```

defines a Map item with the attribute xmlns:semi="http://www.semi.org" which defines a namespace and the governing body for that namespace. This is in accordance with the “Namespaces in XML” specification (see references). Specifying the

1 World Wide Web Consortium Documents are available from Massachusetts Institute of Technology Laboratory for Computer Science, 200 Technology Square, Cambridge, MA 02139, USA Telephone: + 1.617.253.2613, Fax: + 1.617.258.5999, http://www.w3.org/TR/REC-xml

namespace ensures that the names within the Map node are distinguishable from the same names in other non-SEMI XML documents.

7.2.2 The Map item contains a nested item called Device.

7.3 The listing below is an example[2] of a well-formed map data file for a single map with all the map data items except for Label and SupplierValue. The elements of this template will be described in the sections that follow. Examples of map data files with data are shown in the appendices.

```
<?xml version="1.0"?>
<Map
 xmlns:semi="http://www.semi.org"
 WaferId=" "
 FormatRevision=" ">
 <Device
  ProductId=""
  LotId=" "
  Orientation=""
  DeviceSizeX=""
  DeviceSizeY=""
  Rows=""
  Columns=""
  BinType=" "
  FrameId=" "
  NullBin=""
  SupplierName=""
  OriginLocation=""
  CreateDate=""
  Status="">
  <ReferenceDevice
   ReferenceDeviceX=""
   ReferenceDeviceY=""
   RefDevicePosX=”"
   RefDevicePosY=""
  />
  <Bin
   BinCode=""
   BinQuality=""
   BinDescription=""
  />
  <SupplierData
   MyData=" "
  />
  <Data MapName=" " MapVersion="">
    <Row><! [CDATA[]]></Row>
  </Data>
 </Device>
</Map>
```

2 This example is for a wafer map identified by WaferId. Other substrate types may also be represented. See Table 1.

7.3.1 The order of attributes and sub items within their parent item is not significant but the parent child relationship is. One exception is the Row items which must match the actual rows on the substrate being mapped.

7.4 Every map file starts with the declaration:

```
<?xml version="1.0"?>
```

This line informs the parser that the data that follows conforms to the XML Version 1.0 specification.

7.5 The data for each wafer is enclosed within the map data item…

```
<Map xmlns:semi="http://www.semi.org"
WaferId=”ZSDGS88DF”>
</Map>
```

7.5.1 The attribute setting, xmlns:semi=“http://www. semi.org” informs the parser that the item and attribute names within this item are unique within the namespace identified as SEMI.

7.5.2 All the attributes within the Map item are defined in the SEMI G81.

7.5.3 All the items within the Map Item are defined in this document except for the sub items of the SupplierData item.

7.5.4 Some of these attributes and items are mandatory and some are optional as defined in Table 1.

7.5.5 One or more maps can be represented in a single file by simply repeating the <Map> tag. Each map can be distinguished based on an identifier attribute as shown in the following example:

```
<Map xmlns:semi="http://www.semi.org"
WaferId="ZSDGS88DF" >
</Map>
<Map xmlns:semi="http://www.semi.org"
WaferId="JDUJ102MJS" >
</Map>
```

7.6 The Map item contains one or more Device items. This allows multiple overlaying maps of different device types to be represented. The Device item contains a number of attributes and some sub items.

7.6.1 The ReferenceDevice item contains attributes which describes a single reference device. Several ReferenceDevice items may be represented by repeating this item with different attribute values.

7.6.2 The Bin item contains attributes which describes a single bin code. Several Bin items may be represented by repeating this item with different attribute values.

7.6.3 The SupplierData item contains attributes which are defined by the supplier of the map.

7.6.4 The Data item contains attributes and a list of Row items. Several Data items may be represented by repeating this item with different attribute values. This might be used for example to represent versions of the map after each process step.

7.6.5 The Row items are defined as XML CDATA section. The example below shows the Data item for a binary map with two rows and two columns.

```
<Data>
    <Row><! [CDATA[FFFF]]></Row>
    <Row><! [CDATA[FF14]]></Row>
</Data>
```

7.6.5.1 A CDATA section contains data that should not be parsed by the XML parser. After <! [CDATA[, only the string]]> will be interpreted by the XML parser. If this string occurs in the actual data (for example in an ascii map) then it must be replaced by the string]]> so that the XML parser will not interpret it as the end of the CDATA section.

7.6.5.2 Each Row item specifies the BinCode for each column in the row in a format that depends on the BinType attribute.

7.6.5.3 The Row items must match the actual rows on the substrate being mapped. The first row is the topmost row as viewed with the substrate oriented according to the value of Orientation.

7.6.5.4 The number of Row items must match the Rows attribute if specified.

7.6.5.5 The number of columns in each Row item must match the Columns attribute if specified.

Table 1 Items and Attributes Used

Name	*Item or Attribute*	*Defined In*	*Mandatory or Optional*	*Default Value*
xmlns	Attribute	Map Data Format	Mandatory	Must be “http://www.semi.org”
WaferId	Attribute	Map Data Items	Mandatory	No default
StripId	Attribute	Map Data Items	Mandatory	No default
TrayId	Attribute	Map Data Items	Mandatory	No default
NullBin	Attribute	Map Data Items	Mandatory	No default
Map	Item	Map Data Format	Mandatory	No default
Device	Item	Map Data Format	Mandatory	No default
Data	Item	Map Data Format	Mandatory	No default
Row	Item	Map Data Format	Mandatory	No default
FormatRevision	Attribute	Map Data Items	Optional	Latest version of this standard
ProductId	Attribute	Map Data Items	Optional	“”
LotId	Attribute	Map Data Items	Optional	“”
Orientation	Attribute	Map Data Items	Optional	0
WaferSize	Attribute	Map Data Items	Optional	0
DeviceSizeX	Attribute	Map Data Items	Optional	0
DeviceSizeY	Attribute	Map Data Items	Optional	0
StepSizeX	Attribute	Map Data Items	Optional	0
StepSizeY	Attribute	Map Data Items	Optional	0
CassetteId MagazineId	Attribute	Map Data Items	Optional	“”
Rows	Attribute	Map Data Items	Optional	Can be derived from number of Row items
Columns	Attribute	Map Data Items	Optional	Can be derived from Row items
BinType[3]	Attribute	Map Data Items	Optional	“Ascii”
ReferenceDeviceX	Attribute	Map Data Items	Optional	0

3 Since XML is an ascii only format BinType may only take the ascii representation values “Ascii”, “Decimal”, “HexaDecimal”, and **not** “Binary”

Name	*Item or Attribute*	*Defined In*	*Mandatory or Optional*	*Default Value*
ReferenceDeviceY	Attribute	Map Data Items	Optional	0
RefDevicePosX	Attribute	Map Data Items	Optional	0.0
RefDevicePosY	Attribute	Map Data Items	Optional	0.0
MapName	Attribute	Map Data Items	Optional	“”
MapVersion	Attribute	Map Data Items	Optional	“”
BinCode	Attribute	Map Data Items	Optional	0
BinCount	Attribute	Map Data Items	Optional	0
BinQuality	Attribute	Map Data Items	Optional	“”
BinDescription	Attribute	Map Data Items	Optional	“”
FrameId	Attribute	Map Data Items	Optional	“”
SupplierName	Attribute	Map Data Items	Optional	“”
OriginLocation	Attribute	Map Data Items	Optional	0 (Center topside)
CreateDate	Attribute	Map Data Items	Optional	“”
Status	Attribute	Map Data Items	Optional	“”
Label	Attribute	Map Data Items	Optional	“”
SupplierValue	Attribute	Map Data Items	Optional	“”
ReferenceDevice	Item	Map Data Format	Optional	No default
Bin	Item	Map Data Format	Optional	No default
SupplierData	Item	Map Data Format	Optional	No default

APPENDIX 1
EXAMPLE MAP DATA FILES[4]

NOTE: The material in this appendix is an official part of SEMI G85 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 Simple Ascii Wafer Map

A1.1 This example illustrates the simplest possible wafer map. It uses ascii bin codes and contains only the required data items.


```
<?xml version="1.0"?>
<Map xmlns:semi="http://www.semi.org"
WaferId="ZSDGS88DF" >
  <Device
    NullBin=" "
    <Data >
      <Row><! [CDATA[  2C  ]]></Row>
      <Row><! [CDATA[ ~2C2 ]]></Row>
      <Row><! [CDATA[222A1~]]></Row>
      <Row><! [CDATA[21~C22]]></Row>
      <Row><! [CDATA[ ~2C2 ]]></Row>
      <Row><! [CDATA[  2C  ]]></Row>
    </Data>
  </Device>
</Map>
```


A1-2 Detailed Binary Wafer Map

A1-2.1 The example below illustrates the use of binary bin codes and contains not only the required data items, but also some data items provided by the supplier.


```
<?xml version="1.0"?>
<Map xmlns:semi="http://www.semi.org"
WaferId="ZSDGS88DF" FormatRevision="SEMI
Draft Document #3157A">
  <Device
    ProductId="854CS1C"
    LotId="wksfd87dcj37"
    Orientation="0"
    DeviceSizeX="343.8"
    DeviceSizeY="373.1"
    Rows="6"
    Columns="6"
    BinType="HexaDecimal"
    FrameId="KJKSDFK45"
    NullBin="FF"
    SupplierName="Company X"
    OriginLocation="1"
    CreateDate=""
    Status="Product">
    <ReferenceDevice
      ReferenceDeviceX="2"
      ReferenceDeviceY="-3"
      RefDevicePosX="2"
      RefDevicePosY="2"
    />
    <ReferenceDevice
      ReferenceDeviceX="4"
      ReferenceDeviceY="-5"
      RefDevicePosX="2"
      RefDevicePosY="2"
    />
    <Bin
      BinCode="02"
      BinQuality="Pass"
      BinDescription="500MHz"
    />
    <SupplierData
      Origin="USA"
      Destination="Asia"
```


4 These examples are for a wafer map identified by WaferId. Other substrate types may also be represented. See Table 1.

```
  />
  <Data MapName="SortGrade" Version="1">
   <Row><! [CDATA[FFFF020CFFFF]]></Row>
   <Row><! [CDATA[FF14020C02FF]]></Row>
   <Row><! [CDATA[0202020C0116]]></Row>
   <Row><! [CDATA[0201140C0202]]></Row>
   <Row><! [CDATA[FF14020C02FF]]></Row>
   <Row><! [CDATA[FFFF020CFFFF]]></Row>
  </Data>
 </Device>
</Map>
```

SEMI INTERNATIONAL STANDARDS

PROCESS CHEMICALS

Semiconductor Equipment and Materials International

SEMI C1-1101
SPECIFICATIONS FOR REAGENTS

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1980; previously published in July 2001.

1 Preface

1.1 In the 1950's, chemicals purchased by the electronics industry were of a quality defined by the Committee on Analytical Reagents of the American Chemical Society, or of lesser quality. With recognition of the importance of impurity content of chemicals in the manufacture of semiconductors, suppliers responded by introducing products with improved analytical characterization, notably for trace elements.

1.2 The SEMI Committee on Standards for Chemical Reagents began its efforts in the fall of 1975. With this publication, the Committee establishes the definitions, general procedures, specifications, and analytical procedures for the chemicals listed in the index.

1.3 Products within all of the requirements can be described as "meeting SEMI specifications."

1.4 Where an analytical procedure different from that provided is substituted by a supplier or user, the burden of proof is on said supplier or user to confirm the equivalency.

1.5 The committee is continuing work on improvement of specifications and procedures and addition of other reagents and systems such as mixed etchants. The committee welcomes comments, suggestions, and recommendations.

1.6 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Definitions

2.1 *Accuracy and Tolerances in Measurements* — In a test procedure, unless otherwise specified, the accuracy required in the amount of sample taken shall be understood to be within 2.0% of the stated amount, whether a weight or a volume. Where a dilution is performed to a stated volume or a stated volume of a solution is taken, that volume shall be within 2.0% of the stated amount. Unless otherwise stated, a transfer by pipet shall be made by means of a volumetric pipet conforming to the tolerances established by *National Bureau of Standards Circular* 602, April 1, 1959.

2.2 *Abbreviations and Signs* — In this work abbreviations and signs used shall be restricted to those listed in Table 2. Most of the abbreviations are identical to those used in publications of the American Chemical Society as of 1982.

2.3 *Acidity and Alkalinity* — A test for acidity or alkalinity, or both, of organic liquids is common.

2.3.1 In the *acidity test,* usually a stated volume of water (commonly 25 mL) is shaken in a glass-stoppered flask with a stated volume of sample (commonly 10 mL). Then 0.1 mL of phenolphthalein indicator solution is added and 0.01 *N* sodium hydroxide until a slight pink color persists after shaking for 30 seconds. Next, a stated amount of sample is added and mixed, and a titration is performed with 0.01 *N* sodium hydroxide until the pink color is reproduced; the volume of titrant required is recorded.

2.3.2 In the *alkalinity test*, a stated amount of sample is mixed with a stated volume of water (commonly 25 mL). Now 0.05 mL of methyl red indicator solution is added and the mixture is titrated with 0.01 *N* hydrochloric acid until a slight pink color is reached; the volume of titrant required is recorded.

2.3.3 The result of such tests has often been expressed qualitatively as "passes test" or quantitatively as the content of an acid (or base) known or assumed to be present. In this work, the maximum specification limit shall be expressed in microequivalents of acid (or base) per gram of sample (μeq/g). The maximum allowed volume of titrant in a test procedure shall correspond to that specification limit.

2.4 *Apparatus* — Apparatus, unless otherwise qualified, shall be that commonly employed in the conduct of the relevant test.

2.5 *Atomic and Formula Weights* — Atomic weights (that is, atomic masses) used shall be those of the latest report of the International Commission on Atomic Weights. Formula weights shall be calculated from a given empirical (molecular) formula by addition of the stated multiples of the atomic weights. Unless otherwise stated, formula weights shall be rounded to 2 significant figures to the right of the decimal point (see Rounding of Numbers, Section 2.18). All relevant factors given in this work are based on the 1975 Table of Atomic Masses.

2.6 *Blank Preparation* — Where a "blank" is specified to be run, unless otherwise stated, it shall be performed with the same quantities of the same reagents and in a manner identical to that followed with the sample portion under test, but with the material itself omitted.

2.7 *Comparison of Analytical Results with Specification Limits* — In the comparison of an analytical result for a test with the numerical limit associated with the specification, the result shall be rounded to the number of significant figures indicated for that limit. (See Rounding of Numbers, Section 2.18.). Consequently, a specification stated at 96% *minimum* will be met by a result as small as 95.5%, and that stated as 96.0% *minimum* will be met by a result as small as 95.95%. A specification of 0.1% *maximum* will be met by a result as large as 0.14%, and that of 0.10% *maximum* by a result as large as 0.105%. In those specifications given with no digit following the decimal point, such as 10. ppb maximum, a test result as large as 10.5 ppb will meet the specification. This use of a decimal point is made to clarify the difference between converting 0.01 ppm to 10 ppb and converting 0.010 ppm to 10. ppb.[1]

2.8 *Density* — The density of a liquid shall be determined for the compound in air at 25°C and be expressed in grams/milliliter (g/mL). Where the specific gravity, with respect to water, is determined, it shall be expressed as density by the use of tabular values for the density of water at the relevant temperature(s).

2.9 *Desiccator* — A desiccator shall imply a tightly closed container charged with a suitable desiccant (commonly calcium chloride or sulfate) that allows an atmosphere of low humidity to be maintained.

2.10 *Drying or Igniting to Constant Weight* — A statement "dried to a constant weight" or "ignited to a constant weight" shall imply that two separate weighings differ by no more than ± 0.4 mg (unless otherwise specified), where the second weighing follows a second drying (for one hour (unless otherwise stated) or ignition for 15 minutes (unless otherwise stated), respectively.

2.11 *Expression of Content and Concentration* — Unless otherwise stated, a specification limit and experimental results related to it shall be expressed in units of weight by weight. The concentration of a solution of a test reagent shall be expressed either in molarity or normality or as percent weight by volume. A redox normality value shall always be followed, parenthetically, by the relevant molarity. ln the approximate dilution of reagents, a parenthetical expression of two numbers with an intervening "plus" sign shall imply that the relative volume of the stated reagent given by the first number shall be admixed with the relative volume of water given by the second number. Thus, "dilute" sulfuric acid (1 + 3) directs that one volume of reagent grade sulfuric acid be added to 3 volumes of water and the mixture stirred to form a uniform solution.

2.12 *Filtration* — A statement to "filter," unless qualified, shall imply filtration through suitable filter paper until the filtrate is clear.

2.13 *Heavy Metals (as Pb)* — The test described as "Heavy Metals (as Pb)" responds to many of the metals precipitated by hydrogen sulfide. Unless otherwise stated, the test shall involve a visual comparison of the color developed by the sample preparation and a lead standard ("control"), upon treatment with hydrogen sulfide at pH 3 to 4. The color comparison shall be made with matched 50 mL Nessler tubes with vertical viewing over a white background. The treatment of the sample shall be specified in detail in the test procedure. Unless otherwise stated, the heavy metals standard shall be prepared by diluting a solution containing 0.02 mg of lead with water to 25 mL, adjusting the acidity of this solution to pH 3 to 4 (using a pH meter), and then diluting with water to 40 mL, and mixing. The test shall then be conducted by adding to that standard and to 40 mL of the stated sample solution 10 mL of freshly prepared hydrogen sulfide water with mixing. The test shall have been passed if the sample solution is no darker than the standard. This test is proximate in nature and does not imply that lead is present either alone or with other heavy metals.

2.13.1 For sodium hydroxide and potassium hydroxide, this test becomes "Heavy Metals (as Ag)," and silver replaces lead in the standard. This change is appropriate as silver and silver-clad equipment are often used in the manufacture of these caustics.

2.14 *Physical Properties* — Physical properties shall not usually be employed for specification purposes; for information, however, representative values for a particular chemical, as supplied, may be included as item 2 in the monograph for that chemical. Where relevant, physical properties shall be specified for 25°C.

2.15 *Reagent Chemicals* — Unless otherwise stated, reagents to be used in tests shall conform to the minimum standards of quality set forth in the 8th Edition of *Reagent Chemicals*, published by the American Chemical Society, and any revisions thereto.

2.16 *Residue after Evaporation* — A "residue after evaporation" test is often used in the assessment of organic liquids. (See Determination of Residue after Evaporation, Section 3.3.)

1 H.A. Flachka, A.J. Barnard Jr., P.E. Sturrock. Quantitative Analytical Chemistry, Willard Grant Press, 2nd ed., 1980, p 4.

2.17 *Residue after Ignition* — A "residue after ignition" test serves to assess the amount of nonvolatile inorganic matter present in a sample. Unless otherwise stated, the ignition shall be performed at 800° ± 25°C for 15 minutes. Where the addition of sulfuric acid is specified, the result corresponds to what is often termed "sulfated ash." The calculation of the result, expressed in parts per million (µg/g), takes the form:

$$\text{ppm Residue after Ignition} = \frac{\text{Net weight of residue (g)} \times 10^6}{\text{Weight of sample (g)}}$$

2.18 *Rounding of Numbers* — The following rules for "rounding" of measured or calculated values shall be employed:

1. When the figure next beyond the last place to be retained *is less than 5*, leave unchanged the figure in the last place retained.
2. When the figure next beyond the last place to be retained *is greater than 5*, increase by 1 the figure in the last place retained.
3. When the figure next beyond the last place to be retained is *5 and there are no figures beyond this 5 or only zeroes*, (a) increase by 1 the figure in the last place retained if it is odd, or leave the figure unchanged if it is even.
4. When the figure next beyond the last place to be retained is *5 and there are figures other than zeroes beyond this 5*, increase by 1 the figure in the last place retained.
5. Obtain the rounded value in one step by direct rounding and not in two or more steps of successive roundings.

2.19 *Samples and Sampling* — For chemicals provided in small containers, one (or more) shall be freshly opened for testing, thereby reducing possi-bilities for contamination or change in composition (for example, by moisture pickup). Where the chemical is provided in larger bulk quantities, one or more drums or other containers shall be sampled appropriately, and the combined sample shall be placed in a labeled, well-cleaned container that shall be tightly closed and transferred expeditiously to the testing laboratory.

2.20 *Specifications and Specification Limits* — The specifications provided by this work are intended to serve for chemicals to be used in the manufacture and processing of semiconductors and advanced electronic devices and circuits. The specifications and the associated test procedures are based on the experience of suppliers and users and also on published studies relating to chemicals of the required quality. The function of the specifications is to establish *minimum* standards of quality.

2.20.1 Where feasible, a specification of content shall be expressed as a numerical limit in units of weight by weight. For a specification that cannot be assigned such a limit, the expression "To pass test" shall be used.

2.20.2 For a major component, the value (assay, purity, etc.) shall be expressed as a *minimum* permissible limit. For an impurity, the value shall be expressed as a *maximum* permissible limit.

2.20.3 A chemical conforming to the specification will commonly contain more of the major component than the minimum permissible limit or contain less of an impurity (or several impurities) than the maximum permissible limit. In neither case shall the chemical be considered as of higher quality than that defined by the specification.

2.20.4 It is manifestly impossible in the specifications and procedures for a chemical to consider every impurity or contaminant that might be present. For certain applications, it is recognized that more stringent or additional specifications and procedures might be required. The intent of these specifications and the associated procedures is, on one hand, to assure that a chemical is suitable for the common uses to which it may be put in the manufacture and processing of semiconductor devices and, on the other hand, to be consistent with contemporary manufacturing processes for that chemical.

2.21 *Specification Parameters* — In this work, the order of statement of specification parameters in Item 1 of the monograph for a particular chemical shall be, as far as practical: 1) assay or other test assessing the content of the major component(s); 2) appearance or color; 3) acidity or alkalinity, or both, or pH range of solution; 4) residue after evaporation or ignition; 5) water content; 6) diverse general tests, arranged alphabetically; 7) tests for stated anions, arranged alphabetically (bromide, chloride, phosphate, sulfate, sulfite, etc.); 8) ammonium; 9) heavy metals; 10) arsenic and antimony; 11) tests for specific trace metals, arranged alphabetically by name. The metals for grade specifications higher than Grade 2 are Aluminum, Antimony, Arsenic, Barium, Boron, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Nickel, Potassium, Sodium, Tin, Titanium, Vanadium, and Zinc.

2.21.1 All major words in a specification parameter shall have their initial letters capitalized.

2.21.2 Following the statement of a specification parameter, where relevant, the species on which the calculation of the result is based shall be expressed parenthetically as the atomic symbol or empirical formula.

2.22 *Tared Containers* — Where the use of a tared container is specified, it shall be carried through operations identical to those used in the test procedures, including drying or ignition, or both, cooling in a desiccator, and weighing. When a new container is placed in service, special measures may be required to assure that it is brought to constant weight by the operations.

2.23 *Temperature* — Temperature values shall be expressed in degrees Celsius (°C).

2.24 *Water* — References to water in the testing procedures are understood to mean 18.2 Mohm-cm water that is of the appropriate grade for the intended purpose. Depending on the grade of chemical being tested, water meeting the requirements for Types E-1, E-1.1, and E-1.2 18.2 Mohm-cm water in ASTM Standard Guide D5127 may be used. In tests for nitrogen compounds, water should be “ammonia-free” or “nitrogen-free.” For some tests, freshly boiled water must be used in order to ensure freedom from material absorbed from the air such as ammonia, carbon dioxide, or oxygen.

2.25 *Water by Karl Fischer Titration* — The Karl Fischer method for the determination of water involves a titration with the so-called Karl Fischer reagent, consisting of iodine, sulfur dioxide, pyridine, and methanol. For most relevant chemicals intended for use in semiconductor manufacture and other electronics applications, the water content is small and electrometric detection of the end point is preferred. Details of this method are provided by ASTM E 203 and in *Reagent Chemicals*, published by the American Chemical Society.

2.26 *Water and Steam Baths* — A water bath, unless otherwise stated, shall imply a bath of vigorously boiling water. A steam bath (at 1 atmosphere pressure), unless otherwise qualified, shall imply either exposure to flowing steam or to another source of heat at the temperature of flowing steam.

2.27 *Weights and Measures* — The weights and measures used shall be, to the extent possible, those of the International System (SI), adopted by the General Conference of Weights and Measures of 1960. Some relevant quantities are listed below:

Physical Quantity	*Name*	*Symbol*	*Expression in SI Base Units*
length	meter	m	(base)
mass	kilogram	kg	(base)
time	second	s	(base)
electric current	ampere	A (See NOTE 1.)	(base)
amount of substance	mole	mol	(base)
electric conductance	siemens	S	$m^{-2} \bullet kg^{-1} \bullet s^{3} \bullet A^{2}$
electric potential difference	volt	V	$m^{-2} \bullet kg \bullet s^{-3} \bullet A^{-1}$
electric resistance	ohm	Ω	$m^{2} \bullet kg \bullet s^{-3} \bullet A^{-2}$
energy, work quantity of heat	joule	j	$m^{2} \bullet kg \bullet s^{-2}$
force	newton	N	$m \bullet kg \bullet s^{-2}$
frequency	hertz	Hz	s^{-1}
power, radiant flux	watt	W	$m^{2} \bullet kg \bullet s^{-3}$
pressure	pascal	Pa	$m^{-1} \bullet kg \bullet s^{-2}$
quantity of electricity, electric charge	coulomb	C	$s \bullet A$

NOTE 1: In this work, the ampere is abbreviated amp to avoid confusion with absorbance.

3 General Procedures and Guidelines to Certain Methods

3.1 *Guidelines for Assay by Wide Bore Column Gas Chromatography* — The theory of gas chromatography is given in many monographs, reviews, etc. The purpose here is to delineate some practical aspects for the assessment of volatile organic reagents by gas chromatography. A complete detailed procedure for the gas chromatographic assay is not given since available instruments vary from laboratory to laboratory.

However, the use of wide bore capillary columns is recommended to replace conventional packed columns. Capillary columns, constructed of fused silica onto which is bonded a liquid phase, have greater resolving power and chemical inertness.

3.1.1 *Equipment* — A standard gas chromatograph equipped with capillary wide bore column adaptors of isothermal and multi-step linear and temperature programmed operation is recommended.

3.1.2 *Sample* — Direct flash vaporization or on-column injection of the sample with standard gauge needles can be used with wide bore columns. On column injection can minimize sample degradation while increasing the reproducibility of results. On column injection is ideal to use with very volatile materials such as the reagents assayed in this monograph.

3.1.3 *Columns* — Many types of columns exist and can be used. Until recently, packed columns in which a liquid phase is coated on a porous solid support were extensively used for assay of reagents. The introduction of wide bore capillary columns having an i.d. of typically 530 microns and a thick film of liquid phase from 1 to 5 microns allows a laboratory to use a standard packed column instrument and conditions, while gaining the advantages of capillary technology.

Columns can be used either in the high resolution capillary mode (low carrier gas flow rates) to achieve optimum resolution of sample components, or at higher flow rates (20–30 mL/min) where they will perform packed column-like separations in a shorter time. Packed columns require a multitude of stationary phases to accomplish typical separations performed in an analytical laboratory. The increased length of capillary columns allows for better separation of components so that three columns of low (Type 1, METHYL SILICONE), moderate (Type 2, MIXED CYANO, PHENYL, METHYL SILICONE), and high (Type 3, CARBOWAX) polarity can handle the majority of analytical requirements. Columns which have been found acceptable for assay of the reagents in this manual are listed in Table 1.

3.1.4 *Conditions* — Appropriate conditions will vary from one gas chromatographic system to another. Conditions which have been found acceptable are listed under each individual standard. When using packed column in the isothermal mode, the temperature of the column is usually maintained at 10° to 20°C below the boiling point of the reagent. The efficient mass transfer associated with wide bore capillary columns may necessitate initial column temperatures to be more than 20°C below the boiling point of the reagent of interest. Temperature programming may be used to improve the shape of eluting peaks and to shorten analysis times. The remaining two heated zones (injector and detector) should be maintained at as low a temperature as possible to lessen thermal decomposition effects. Typically, for the injector this is 50°C above the boiling point of the material of interest; the detector is held 25°C above the highest temperature reached by the column, but never less than 100°C. The split or splitless mode of injection can be used depending on the chromatographic equipment available. The use of a wide bore capillary column simplifies conversion of a packed column to a capillary instrument.

3.1.5 *Detector* — Use of a thermal conductivity detector minimizes the need to correct for detector response to differences in chemical composition and is usually sufficient for determining reagent assay. To qualify trace impurities, the more sensitive flame ionization detector is recommended. The detector output, after amplification, is used to produce the chromatogram, a plot of component quantity versus elution time. Modern systems digitize the analog output, allowing direct printout of peak areas and retention times.

3.1.6 *Calculation of Results* — Results from a chromatogram, used to determine the assay of a reagent, are expressed in area percent normalized to 100%. A response factor correction for each component is required for the most accurate results, especially when the sample components differ markedly in their detector response. An internal standard reduces error due to variations in injection quantities, column, and detector conditions. The use of control charts, to aid the analyst in visualizing chromatographic variability, is suggested. To verify that assay results are valid, use of a system suitability test is recommended.

Table 1

Reagent	*Recommended[1] Column*	*Alternate[2] Column*
Acetone	III	II, I
n-Butyl Acetate	I	II
Dichloromethane	I	II
Methanol	I	
Methyl Ethyl Ketone	I	
2-Propanol	I	III
Tetrachloroethylene	I	
Toluene	I	III
Trichloroethylene	I	
Trichlorotrifluoroethane	I	
Hexamethyldisilizane[3]	I	
1-Methyl-2-Pyrrolidone	I	
1,1,1 Trichloroethane	I	

Type I Column — Methyl Silicon Bonded Phase
Type II Column — Mixed Cyano, Phenyl, Methyl Silicon Bonded Phase
Type III Column — Carbowax Bonded Phase
1. Satisfactory for both assay and SEMI-specified impurity determinations.
2. Column will separate all SEMI-specified impurities from assay component. Elution order will differ from typical given in individual reagent procedures.
3. Presilanized column recommended.

3.2 *Color*

3.2.1 *Color (APHA)* — For the rapid assessment of "colorless" liquids for contamination by colored materials, visual comparison with platinum-cobalt solution standards is appropriate, following the methodology of the American Public Health Association (APHA) established for the evaluation of the color of water.

3.2.2 *Preparation of Platinum-Cobalt Stock Solution (APHA No. 500)* — Dissolve 1.246 g of reagent grade potassium chloroplatinate, K_2PtCl_6, and 1.000 g of cobalt chloride hexahydrate, $CoCl_2 \bullet 6H_20$, in water. Add 100 mL of reagent grade hydrochloric acid (~37%) and dilute with water to exactly 1,000 mL. Store in a tightly closed bottle.

3.2.3 *General Procedure for "Color (APHA)" Test* — For the working standard, dilute one or more suitable aliquots of the Platinum-Cobalt Stock Solution (APHA

No. 500) with water to 100 mL. In 100 mL Nessler tubes, compare the working standard with an equal volume of the liquid under assessment. View each tube vertically over a white background. The color of the liquid should not exceed the maximum APHA standard value allowed by the specification for that liquid. On the dilution to 100 mL, aliquots of the stock standard of 1, 2, 3 . . . mL correspond to APHA 5, 10, 15, etc.

Table 2 Abbreviations and Signs

A	absorbance
Å	angstrom (s) [NOTE 1]
a.c.	alternating current
amp.	ampere(s) [NOTE 2]
addn.	addition [NOTE 3]
alc.	alcohol(ic) [NOTE 3]
amt.	amount [NOTE 3]
approx.	approximate(ly)
aq.	aqueous [NOTE 3]
atm.	atmosphere(s)
av.	average [NOTE 3]
b.p.	boiling point [NOTE 3]
ca.	circa (i.e., about or approximately)
cal.	calorie(s)
cc	cubic centimeter(s) (mL)
c.d.	current density [NOTE 3]
cm	centimeter(s)
cm^2	square centimeter(s)
compd.	compound [NOTE 3]
compn.	composition [NOTE 3]
concn.	concentration [NOTE 3]
d	density (or difference in statistical analysis)
d.c.	direct current
diam.	diameter [NOTE 3]
dil.	dilute [NOTE 3]
EDTA	ethylenediaminetetraacetate (i.e., [ethylenedinitrilo] tetraacetate)
equiv.	equivalent(s)
f.p.	freezing point [NOTE 3]
FW	formula weight
g	gram(s)
GC	gas chromatography (or chromatographic)
GLC	gas-liquid chromatography (or chromatographic)
hr.	hour [NOTE 3]
I.D.	inside diameter [NOTE 3]
insol.	insoluble [NOTE 3]
ir	infrared [NOTE 3]
kg	kilogram(s)
L	liter(s)
m	meter(s) or milli (10)
M	molar or molarity
ma	milliampere(s)
max.	maximum (or maxima)
meq	millequivalent(s)
mg	milligram(s)
min	minute(s)
min.	minimum
mixt.	mixture [NOTE 3]
mL	milliliter(s)
mm	millimeter(s)
mM	millimolar (or millimolarity)
mmol	millimole
mol	mole [NOTE 3]
m.p.	melting point [NOTE 3]
mv	millivolt(s)
mμ	millimicron(s) (=nm) [NOTE 4]
N	normal or normality
n	nano (10^{-9})
ng	nanogram(s)
nm	nanometer(s)
no.	number [NOTE 3]
O.D.	outside diameter [NOTE 3]
p	pico (10)
pg	picogram(s)
powd.	powdered [NOTE 3]
ppb	part(s) per billion (=ng/g or ng/mL) [NOTE 5]
ppm	part(s) per million (= μg/g or μg/mL)
ppt.	precipitate [NOTE 3]
prepn.	preparation [NOTE 3]
psi	pounds per square inch
PTFE	poly (tetrafluoroethylene) (e.g., Teflon®)
satd.	saturated [NOTE 3]
SCE	saturated calomel electrode [NOTE 3]
s	second(s)
sepn.	separation [NOTE 3]
soln.	solution [NOTE 3]
soly.	solubility [NOTE 3]
std.	standard [NOTE 3]
T	transmittance
temp.	temperature [NOTE 3]
TLC	thin-layer chromatography (or chromatographic)
titrn.	titration [NOTE 3]
UV	ultraviolet [NOTE 3]
v	volts [NOTE 3]
vol.	volume [NOTE 3]
W	watts [NOTE 3]
wt.	weight [NOTE 3]
μ	micron(s) (=μm) or micro (10) [NOTE 4]
μa	microampere(s)
μeq	microequivalent(s)
μg	microgram(s)

μL	microliter(s)
μm	micrometer(s)
μM	micromolar
μmol	micromole(s)
Ω	ohm(s)
°C	degrees Celsius
~	circa (about or approximately)
%	percent
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to

NOTE 1: The angstrom does not conform to the SI program, and its use is restricted to emission spectrographic data (1 Å = 0.1 nm).
NOTE 2: The International System (SI) symbol, A, for ampere(s) is avoided, owing to possible confusion with absorbance.
NOTE 3: Abbreviation is not recommended for text, but only for formulas, equations, tables, specification statements and illustrations where brevity is required.
NOTE 4: The units micron and millimicron do not conform to the SI program, and the use of the equivalent terms micrometer (mm) and nanometer (nm), respectively, is recommended.
NOTE 5: A "billion" is interpreted differently in various countries and the term "parts per billion" is therefore not recommended by the International Union of Pure and Applied Chemistry (IUPAC). The term should only be used where it is defined parenthetically in the same text passage, e.g., as ng/g or ng/mL.

3.3 *Determination of Residue after Evaporation*

3.3.1 *Introduction* — The residue after evaporation is defined as the relative amount of residue remaining after evaporation of a sample of solvent followed by heating of the residue at 105°C for 30 minutes. Drying to constant weight is not utilized since protracted heating may lead to slow volatilization of high-boiling matter.

3.3.1.1 For the determination of the residue after evaporation at the level of 5 parts per million (μg/g) or below, determinate errors must be kept extremely small and random errors should be minimized. In the procedure given below, the positive error due to exposure to airborne particulate matter is reduced by the use of the closed system afforded by the Thiers assembly. Possible negative errors associated with losses caused by transfer of a concentrated sample or the residue are avoided by effecting the evaporation and weighing in a single dish. The determinate and random errors associated with the weighing operations are reduced by using an aluminum dish for most solvents, weighing on a semi-microbalance, eliminating any static electricity, and conducting all heating and cooling steps in a reproducible manner.

3.3.2 *Equipment* — The Thiers assembly is fashioned from a crystallizing dish. (See Figure 2.) The aluminum dishes of 250 mL capacity are prepared by cutting out a 30 cm circle of aluminum foil, rinsing it with the solvent, and, using gloves, pressing it around the base of an 800 mL beaker. The balance is a semi-micro type, and the static electricity eliminator is a low-level, radioactive type available from supply houses.

3.3.3 *Procedure*

3.3.3.1 Rinse the 250 mL aluminum dish (or platinum dish in the case of halogenated solvents) with a portion of the sample. Heat the dish at 105°C in an oven for 30 min and cool for 30 min (1 hr for platinum) in a desiccator charged with calcium chloride and placed near the balance. Discharge static electricity using the eliminator and weigh the dish on a semi-microbalance to the nearest 0.01 mg.

3.3.3.2 Start the flow of filtered nitrogen gas through the side arm of the Thiers assembly and place the dish inside. Raise the cover briefly to add the specified amount of solvent from a clean, graduated cylinder. Adjust the nitrogen stream so that the surface of the solvent is barely rippled. Also, adjust the heat lamp and hot plate so that the evaporation rate does not exceed 8 mL/min and that no sample condenses on the top inner surface of the assembly.

3.3.3.3 When all of the sample has evaporated, heat the dish for 30 min in an oven at 105°C. Cool as given above, discharge the static electricity, and reweigh. Calculate the residue as parts per million (ppm).

$$\frac{[\text{wt of dish plus residue (g) - wt of dish (g)}] \times 10^6}{\text{sample wt (g)}}$$

NOTE 1: For best results, room temperature should be kept constant to ± 5°C.

3.4 *General Procedure for Trace Arsenic (and Antimony) Determination*

3.4.1 *Introduction* — This photometric procedure is based upon the color reaction of silver diethyldithiocarbamate with arsine (and stibine). It provides for measurement of the absorbance of the sample and standards with subsequent calculation of the arsenic and antimony content of the sample, expressed as arsenic. The procedure given below differs from conventional ones by the omission of potassium iodide and stannous chloride. By this omission, antimony is evolved as stibine and reacts with the silver diethyldithiocarbamate solution. The color development is consequently due to both arsenic and antimony. The test sensitivity for arsenic is greater than for antimony.

3.4.2 *Apparatus* — The apparatus (see Figure 2) consists of a 125 mL arsine generator (a) fitted with a scrubber unit (c) and an absorber tube (e), with a 24/40 standard-taper joint (b) and a ground glass ball-and-socket joint (d), secured with a No. 12 clamp, connecting the units. In order to insure a more uniform rate of flow of gas into the absorbing solution, various modifications may be employed, such as the use of a fritted-glass disk sealed into the tapered end of the absorption tube.

3.4.3 *Reagents*

3.4.3.1 *Arsenic Stock Solution* — (1.00 mg/mL of arsenic) — Transfer 0.66 g of arsenic trioxide to a 500 mL volumetric flask and dissolve with 5 mL of 50% sodium hydroxide solution. Neutralize with 5 *N* sulfuric acid, add an excess of 5 mL, dilute to the mark with water, and mix thoroughly.

3.4.3.2 *Arsenic Working Solution* — (1.0 µg/mL of arsenic) — Transfer exactly 0.5 mL of the arsenic stock solution to a 500 mL volumetric flask, and 5 mL of 5 *N* sulfuric acid, dilute to the mark with water, and mix thoroughly. Prepare immediately before use.

3.4.3.3 *Lead Acetate Solution* — Dissolve 10 g of lead acetate trihydrate in 100 mL of water.

3.4.3.4 *Silver Diethyldithiocarbamate Solution* — Dissolve 1 g of diethyldithiocarbamic acid, silver salt, in 200 mL of pyridine and filter the solution. (The pyridine is best purified by passage through an alumina column.) Store this solution in a light-resistant container and use within 1 month. Silver diethyldithiocarbamate as a dry solid is yellow in color. Discard material that is markedly off color or develops a strong odor; alternatively, recrystallize from 1:1 pyridine-water and dry *in vacuo* at room temperature.

3.4.4 *Sample Solution Preparation* — Prepare the sample solution as specified in the procedures for the individual chemical.

3.4.5 *Procedure*

3.4.5.1 Treat the sample as described in the procedure for the individual chemical and transfer the resulting solution to the generator flask. Swirl the flask, add 5 mL of 20% sulfuric acid, and allow to stand at room temperature for 15 minutes.

3.4.5.2 Pack the scrubber tube (c) with two pledgets of lead acetate-impregnated glass wool previously moistened with lead acetate solution freed from excess solution by squeezing and dried in a vacuum. Allow a small space between the two pledgets. Place 3.0 mL of silver diethyldithiocarbamate solution in the absorber tube (e), add 3 g of zinc (granular) to the generator flask (a), and immediately connect the scrubber-absorber assembly to the flask.

3.4.5.3 Place the generator flask in a water bath maintained at 25° ± 3°C and swirl the flask gently at 10 minute intervals. (The addition of a small volume of 2-propanol to the generator flask may make the gas evolution more uniform.) After 45 minutes, disconnect the tubing from the generator flask, transfer the silver diethyldithiocarbamate solution to a 1 cm photometer cell, and measure the absorbance at 525 nm versus the water blank.

3.4.5.4 Carry a water blank and standard through the procedure, using the identical quantities of the same reagents. The standard consists of a volume of the arsenic working solution corresponding to the amount of arsenic stated in the procedure for the individual chemicals. Any red color in the silver diethyldithiocarbamate solution from the sample preparation should be no greater than that obtained with the standard.

3.5 *Guidelines for Determination of Trace Elements by Emission Spectrography* — For organic solvents, acids, and some other volatile chemicals used in semiconductor device fabrication, assessment of the contents of over twenty trace elements is required. For such purposes, dc-arc emission spectroscopy is the survey method of choice. The detection limits achievable can be improved by preconcentration of a large sample by volatilization. The loss of trace elements in this enrichment process can be reduced by the use of graphite as a collector and often by the presence of additives. The evaporation must be conducted under “clean air” conditions, and reliability should be assured by the frequent conduct of “blank” determinations. In this edition of “SEMI” Specifications and Procedures for electronic-use chemicals, no procedure for emission spectrography is included since the practices established and the spectrographic capabilities available vary from laboratory to laboratory. Some of the practical considerations involved, however, are delineated below.

3.5.1 *Spectrograph* — A grating instrument with photographic recording is required with sufficient resolution to separate the typical spectral lines of the elements listed in Table 3. In some laboratories, a 3 -meter instrument with a grating dispersion of 5.56 A per mm has proved satisfactory.

3.5.2 *Excitation Conditions* — A dc-arc emission source, total burn conditions, and a controlled atmosphere (70:30 argon-oxygen) are recommended. In this way, quantification for a single burn can be achieved for both easily volatilized and refractory elements. As the spectrographic emulsion, Kodak SA-1 or equivalent is recommended. As the electrodes, ASTM S-13 and C-8 types are used.

Table 3 Analytical Lines for Various Elements

Element	*Analytical Line Å*
Aluminum (Al)	3082.16
Barium (Ba)	3071.58

Element	Analytical Line Å
Boron (B)	2497.73
Cadmium (Cd)	3466.20
Chromium (Cr)	2835.63
Cobalt (Co)	3405.10
Copper (Cu)	3247.54
Gallium (Ga)	2943.64
Germanium (Ge)	3039.06
Gold (Au)	2675.95
Iron (Fe)	3020.64
Lithium (Li)	3232.61
Magnesium (Mg)	2852.13
Manganese (Mn)	2794.82
Nickel (Ni)	3414.76
Potassium (K)	3446.72
Silicon (Si)	2881.58
Silver (Ag)	3280.68
Sodium (Na)	3302.32
Strontium (Sr)	3464.46
Tin (Sn)	2839.99
Zinc (Zn)	3345.00

3.5.3 *Standards* — For the precision required, visual comparison with a set of standard plates suffices for most elements. Preferably a commercial seven-step multielement standard in graphite is employed having an internal standard such as indium incorporated. Even when densitometry is not used, inspection of the intensity of a line for the internal standard can assure that a significant portion of sample has not been lost mechanically. For an element not present in that standard (e.g., gold and palladium), the detection limit can be based on a literature value for total burn conditions in a graphite matrix.

3.5.4 *Evaporation of Sample*

3.5.4.1 In general terms, the sample size selected will depend on the detection limits required, the optics of the spectrograph used, and the excitation conditions. In many laboratories a sample weight of 50 to 100 grams is taken routinely. The evaporation in performed with 10 mg of spectrographic grade graphite added as a collector. An acid-leached Teflon evaporating dish is used, and the evaporation itself should be carried out under "clean air" conditions. These can be achieved either by use of the Thiers assembly (see Figure 2) or equivalent or within a "clean air" station fitted with a fume exhaust system. Where a 50 gram sample is used, the concentration factor is 5000; that is, the nominal values for the set of standards are divided by that number.

3.5.4.2 In the evaporation, additives may be present to improve the retention of some elements. In brief, a drop of sulfuric acid is added to hydrochloric and citric acids, and a crystal of oxalic acid to nonoxygenated solvents. The addition of mannitol is recommended in the evaporaiton of hydrofluoric and hydrochloric acids to retain boron and possibly tin and antimony.

3.5.5 *Remarks* — For further information on the evaporation and spectrographic assessment of acids, the paper of Kershner, Joy, and Barnard, *Appl. Spectroscopy*, 25, 542 (1971), may be consulted.

3.6 *Guidelines for Determination of Trace Elements by Atomic Absorption Spectrometry* — The principles of analysis by atomic absorption spectrometry are given in monographs. The purpose here is to describe in general terms how the technique should be used when specified in the procedures for an individual chemical to assure that the specifications for one or more stated elements are met. No general procedure is given since operating details will vary with instrument design; consequently, the manufacturer's manual should be followed.

3.6.1 *Equipment* — The source is a hollow cathode lamp, or equivalent, for the relevant element. The burner is slotted and will vary in design and path length according to the gas(es) to be used. The monochromator should have a resolution of at least 0.1 nm. The signal from the photomultiplier tube detector is read from a meter, digital display, or recorder tracing. A deuterium background corrector should available.

3.6.2 *Flame and Burner Conditions* — The flame gases to be used are specified in the procedure for the individual chemical. The burner position and gas flow rates should be optimized for a given determination.

3.6.3 *Solution Conditions* — The solutions are prepared as given in the procedures for the individual chemical.

3.6.4 *Working Standard Solutions* — Working standard solutions should be prepared on the day of use by dilution of a stock standard solution.

3.6.5 *Quantitation* — Commonly, the method of standard addition is employed. It is applicable at low concentrations where a linear relationship exists between signal and concentration. By this technique the standards have a matrix similar to the sample. It is essential that the sample solution, along with the additions, has absorbance in the range for which linearity is expected: routinely, 0.1 to 0.5 absorbance. The use of standard additions does not eliminate interferences, but assures that the element of interest behaves similarly in the sample preparation and those with additions. Background correction is usually required, and additives may be called for (see below).

3.6.5.1 For specific tests, the signals are measured for five solution preparations: the reagent blank (which may be only water), the sample solution, and three made by standard additions to the sample solution. The signal for the reagent blank preparation is subtracted from the signals for each of the four other preparations. These four signals are used graphically or mathematically to determine the content of the element in the sample. Where several elements are to be determined, they are added simultaneously to the third, fourth, and fifth preparations. Commonly, the additions correspond to one-half the specification limit, equal to the limit, and twice the limit.

3.6.5.2 A calibration line obtained for aqueous standards can be used if its slope and the slope of the standard addition line are identical. In that event, chemical (matrix) effects are negligible.

3.6.6 *Background Correction* — Where spurious absorption or other background correction is required, details are given in the procedure for an individual chemical. For an element with the stated resonance line in the ultraviolet region (< 350 nm), the correction should be performed with a deuterium discharge lamp. For an element with the stated line in the visible region (> 350 nm), the adjacent line technique should be employed. In this method, the background absorption is determined at a wavelength adjacent, ± 5 nm, to the line being used for the element of interest; that is, it is measured at a wavelength where significant atomic absorption by that element is absent.

3.6.7 *Additives* — Where additives are included in the solution preparations, including an ionization suppressant, details are provided in the procedures for the individual chemical.

3.6.8 *Remarks* — The manufacturer's manual should be consulted for details on the venting of burner gases and for safety precautions in the operation of the instrument and burner. The user should check the performance of an instrument from time to time to assure that adequate sensitivity is being attained for the needs of the particular determination.

3.7 *Guidelines for Determination of Trace Elements by Flame Emission Spectroscopy* — The principles of analysis by flame emission spectroscopy are given in many monographs. The purpose here is to describe in general terms how the technique should be used when specified in the procedures for an individual chemical to assure that the specifications are met for one or more stated elements (commonly sodium or potassium, or both). No general procedure is given since operating details will vary with instrumental design; consequently, the manufacturer's manual should be followed.

3.7.1 *Equipment* — The flame photometer should have a monochromator with a resolution of at least 1 nm. The detector should have a red-sensitive phototube, a filter to remove the sodium D-line for potassium determinations, and a photomultiplier. (Instruments having a photomultiplier specially sensitive to the potassium line do not need a red-sensitive phototube.) The slit width must be adjustable. A sensitivity control should be available. Also, the burner should have controls for adjusting its position and gas flow rates. The read-out device may be a meter, digital display, or recorder.

3.7.2 *Flame and Burner Conditions* — The flame gases to be used are specified in the procedure for the individual chemical. The burner position and gas flow rates should be optimized for a given determination.

3.7.3 *Solution Conditions* — The solutions are prepared as given in the procedures for the individual chemical.

3.7.4 *Standards* — A stock standard solution for each relevant element should be accurately prepared, usually at a concentration of 0.1% wt/vol, as given either in the procedure for the individual chemical or in Section 4. Working standard solutions should be prepared on the day of use by dilution of a stock standard solution.

3.7.5 *Quantitation* — Commonly, a single addition of standard is employed. It is applicable at low concentration where a linear relationship exists between signal and concentration. By this technique, the standard has a matrix similar to the sample.

3.7.5.1 The amount of standard to be added to the sample to make the standard solution is given in the procedures for the individual chemical, and corresponds to the specification value of the element being determined.

3.7.5.2 For specific tests, the signals are measured for the sample solution and the standard solution. The instrument is optimized with the standard solution at the wavelength specified. It is then zeroed with water, and the sample is aspirated into the flame and its signal read. Without changing the slit, the wavelength is changed to a nearby setting and the background value determined. The difference between the background value and the value for the sample should not exceed the difference between the values obtained for the sample and standard solutions.

3.7.6 *Remarks* — The manufacturer's manual should be consulted for details on the venting of burner gases and for safety precautions in the operation of the instrument and burner. The user should check the performance of the instrument from time to time to assure that adequate sensitivity is being attained for the needs of the particular determination.

3.8 *Guidelines for Use of a pH Meter* — The principles of pH measurement are given in monographs and instrument manuals. The purpose here is to describe in general terms how the technique is used with the procedures for individual chemicals, either to assure that a "pH of Solution" specification is met or to adjust the acidity or alkalinity of a solution as required in the conduct of a procedure.

3.8.1 *Equipment* — The pH meter should be capable of reading to 0.02 pH units and should best be equipped for temperature compensation. The electrodes should be calomel and glass and should be kept in appropriate solutions when not in use, following the supplier's recommendations.

3.8.2 *Standardization* — At time of use, the pH meter and electrodes should be standardized against two pH standard buffers that preferably should bracket the expected pH of the solution to be measured. The meter with the electrodes immersed in the first buffer should be adjusted to the stated value for that buffer. The electrodes should then be rinsed, and the meter, with the electrodes immersed in the second buffer, should be adjusted to the stated value for that buffer. This adjustment procedure should be repeated until two consecutive measurements for one of the buffers gives the same value within ± 0.02 pH units. Where a temperature is specified for an individual chemical, either as part of the specification parameter or the relevant procedure, that temperature should be maintained in the standardization with the corresponding assigned pH values for the pH standard buffers being employed. During measurements, each buffer should be magnetically stirred at the same constant rate.

3.8.3 *Quantitation* — For the measurement of the pH of a solution, the meter and electrodes should be standardized as given above. The electrodes should then be rinsed with water and immersed in the solution (held at the specified temperature), and the pH read once the reading has stabilized. The solution should be magnetically stirred at the same rate as used in the standardization. If the reading does not stabilize within 1 minute, the cause should be found and eliminated. Any water used to dilute a sample for the "pH of Solution" test should be carbon dioxide-free.

3.9 *Calibration and Measurement Method for Particles in Liquids* — This standard describes the apparatus and methods used to calibrate optical particle counters (OPCs) and to count hard particles in liquid reagents. The procedures in this standard provide a means of comparison of particle levels in various reagents using pressurized sampling and counted using the various available instruments. While the procedures in this standard are primarily directed at off-line sampling or sampling from containers, OPCs can also be used for continuous on-line particle measurement. While some substantial technical difficulty may accompany the implementation of the pressurized sampling technique for containers of more than 10 L, the method should be followed as closely as possible to maximize the integrity of the data. The following procedures are partially based on the publications in the attached bibliography which should be consulted for further details.

3.9.1 *Apparatus* — The apparatus used to measure the concentration of particles in reagents is comprised of a sample supply system, a particle counter, and a flow measurement and control system. Two manual flow measurement and control systems are presented in Figures 4 and 5. Several manufacturers have developed automated pressurized sampling systems.

3.9.2 *Discrete Sample Supply System* — In the method specified in this standard, the pressure in the reagent container is raised sufficiently above atmospheric pressure to produce the required flow and to reduce microbubble formation, which causes falsely high counts. Pressurizing containers of reagents presents a substantial safety hazard. Several systems have been developed for pressurizing the contents of a reagent container without placing a pressure differential across the reagent container wall. A pressurized sampling system is required for all reagents.

3.9.2.1 The reagent container is placed in a canister suitable for use as a pressure vessel at 4 bar (60 psi), such as a large steel filter housing. The interior of the canister should be resistant to corrosion by the reagents being tested. This canister is fitted with a relief valve set at 3.5 bar (50 psi), a nitrogen inlet, and a sealed feed-through for the sample tube. The reagent container is fitted with a perfluoroalkoxy (PFA) cap to which is attached a hydrophobic polytetrafluoroethylene (PTFE) nitrogen inlet filter. This permits the nitrogen pressures inside and outside the reagent container to equilibrate when the vessel is pressurized and prevents particles from the pressure canister from entering the sample reagent container.

3.9.2.2 Either of two sample and dip tube configurations may be used. In the first, a PFA dip tube, which extends to 5 cm from the bottom of the reagent container, is attached to the cap. The sample tube, which consists of a single continuous piece of PFA tubing to reduce the chance of incidental contamination during measurement, is connected to the cap and the particle counter. This configuration has the advantage that it allows the sample tube to be disconnected from the cap and dip tube, reducing the risk of splashing and of cross-contaminating samples. The disadvantage of placing a fitting between the sample and the counter is that the fitting may compromise the integrity of the sample.

3.9.2.3 In the second configuration, a single tube, without valves, fittings, or discontinuities extends from the counter, through the cap to 5 cm from the bottom of the reagent container. This has the advantage that it ensures the integrity of the sample but the disadvantage is that the risk of splashing and cross-contamination is increased.

3.9.3 *Particle Counter* — Laser light scattering OPCs from any of several suppliers may be used provided they are in calibration, and used subject to the limitations described in Section 3.9.3.1.

3.9.3.1 *Limitations on Counting Particles in Liquid Reagents using OPCs* — OPCs are calibrated using polystyrene latex (PSL) beads suspended in high-purity water. The optical properties of naturally occurring particles in liquid reagents are different from the optical properties of PSL and water. OPCs detect "light-scattering centers" and calculate particle size and concentration based on the assumption that the light-scattering centers are equivalent to PSL in water. In reality, light scattered by a particle is dependent upon particle size, particle shape and the difference between the particle's refractive index and the refractive index of the surrounding medium. When properly calibrated OPCs from different manufacturers are used to measure particles in high-purity water, they give comparable size and concentration data.

3.9.3.1.1 Commercially, OPCs are manufactured with different illuminating wavelengths and a variety of optical arrangements for collecting light scattered by particles. Because of the significant difference in the refractive index of particles relative to the refractive index of water, the resulting scattered light profile is readily detected by all OPCs. Hence there is relatively good comparative agreement between OPCs when used to detect particles in high-purity water.

3.9.3.1.2 When calibrated OPCs are used to measure particles in semiconductor liquid reagents, a totally different situation is encountered. The refractive index of liquid reagents varies significantly from water and is, in general, greater than water. While the refractive index of reagents is known and can be adjusted for, the refractive index of particles is unknown and, in many circumstances, is expected to be very close to the refractive index of reagents. Particles therefore have a tendency to become invisible to an OPC. The degree of invisibility will depend on the optical arrangement of each OPC. A study carried out in 1999[2] found that particle concentrations reported by different sensors varied significantly. Chemical-to-chemical comparison indicated that there was no sensor that consistently reported higher or lower concentrations than other sensors.

3.9.3.2 *Using OPCs in Semiconductor Liquid Reagents* — OPCs have a critical role to play in monitoring particles in liquid reagents. OPCs can detect low concentrations of small particles in real-time and can be easily calibrated using PSL beads. However, the current state of OPC technology limits their use to claim that a liquid reagent meets a standard particle concentration at a particular particle size.

3.9.3.2.1 When a supplier of a liquid reagent uses an OPC to specify that reagent's particle concentration, for example on a Certificate of Analysis, the make and model of OPC must also be specified. If the customer of the liquid reagents wishes to check whether the incoming reagent meets the claimed level of cleanliness, the customer must use an OPC of the same make and model number. However, it has also been shown that even two calibrated "identical" OPCs can differ by 10–20% when measuring particles in liquid reagents.

3.9.4 *Flow Control and Measurement System* — A discrete or a continuous method may be used to control and measure the flow of the sample through the particle counter. In both procedures, a needle valve, downstream of the counter, is used to control the flow rate. In the discrete procedure, a measured volume of fluid is counted and collected in a graduated container. Automatic level detection may be used to start and stop the counter. In the continuous procedure, the flow rate is set and the count is accumulated for a measured time period.

3.9.5 *Calibration* — Each particle counter (sensor and signal analysis unit) must be calibrated at least once every twelve months.

3.9.5.1 It is recommended that the calibration be performed by the instrument manufacturer or a metrology laboratory certified by the instrument manufacturer. Calibration is performed by counting polystyrene latex (PSL) beads suspended in water. PSL beads of known size (characterized by transmission electron microscopy -TEM) and concentration (characterized by a scanning electron microscope -SEM) must be used. In addition most instrument manufacturers use a working standard or "gold

2 Carrieri, D., D.C.Grant and W.Kelly, "A Comparison of Optical Particle Sensors Used to Measure Particle Concentration in High-Purity Process Chemicals" Proceedings SEMICON West 1999

standard" OPC as a reference against which all OPCs of the same Model are compared.

3.9.5.2 The determination of size correction factors for particle counters is not recommended. Particle counters should be calibrated with PSL beads in accordance with the manufacturer's recommendation.

3.9.6 *Coincidence Correction Factors* — The determination of coincidence correction factors for particle counters is not recommended. Particle counters should be calibrated with PSL beads as per the manufacturer's recommendation. Coincidence correction factors are only valid for monodispersed concentration of particles.

3.9.7 *Efficiency Correction Factors* — The determination of efficiency correction factors for particle counters is not recommended. Particle counters should be calibrated with PSL beads as per the manufacturer's recommendation.

3.9.8 *Monthly Check* — It is desirable to check the OPCs size calibration once a month. PSL beads of known size and approximate concentration can be purchased from several suppliers. Prepare a stock suspension of a combination of about 10^7 particles/L of each of the three sizes of PSL beads. Several solutions have been found to provide acceptably stable suspensions. Among them are: 25:1 ethanol/:water, and water with 0.01% surfactant and 0.05% bactericide. Dilute 10 mL of stock suspension to 1 L and measure the particle concentration using the procedure specified for reagents. If the results of this check are not within 10% of the expected PSL bead size, the OPC shall be recalibrated.

3.9.9 *Measurement Procedure*

3.9.9.1 *Setup* — Gently invert the sample reagent container three times to homogenize the particle distribution, then set it aside for 30 minutes to remove the bubbles formed during mixing. Under no circumstances must the sample reagent container be vigorously shaken or sonicated as this would generate numerous particles.

3.9.9.2 The smallest particle counter threshold should deliver at least 50% particle counting efficiency at the control size limit. The control size limit is the particle size agreed upon between supplier and customer that represents an acceptable size level. In general this size will be between 0.1 and 0.5 µm.

3.9.9.3 Attach the cap with the gas inlet filter and sample tube to the reagent container to be sampled. Place the reagent container in the canister, and seal the canister so that it may be pressurized. With the sample flow control valve open, gradually (< 3 bar/min) pressurize the sample to 3 bar for H_2O_2 and NH_4OH or as necessary to obtain the required flow for other fluids. Allow at least 250 mL of the sample to pass through the sensor before counting.

3.9.9.4 For each sample, after 5 aliquots have been measured, perform a chi-squared test to determine if the data are statistically valid. If the chi-squared test fails, examine the apparatus for defects, such as loose or cracked fittings, repair as necessary, and repeat the counting of 5 aliquots. If the sample fails both the second and third chi-squared tests, it is considered to be immeasurable and should be discarded. If a second sample gives similar results, the apparatus, including the OPC, may be defective and should be checked with a well-characterized sample and repaired if necessary.

3.9.10 *Measurement*

3.9.10.1 *Discrete Sampling* — Measure multiple aliquots of the same sample. The flow rate must be the same as that at which the instrument was calibrated.

NOTE 2: The statistical significance of any count data must be taken into consideration. Some OPCs inspect as little as $1/1000^{th}$ of the available sample flow, and may require a greater number of aliquots and larger sampling volume to ensure good statistics. For example, to obtain a coefficient of variation (standard deviation/mean) of 10%, it is necessary that at least 100 particles greater than the control size limit be counted.

3.9.10.2 *Continuous Sampling* — If continuous sampling apparatus is being used, adjust the needle valve on the rotameter to obtain a flow rate consistent with the instrument manufacturer's recommendations. This flow rate must be the same as that at which the instrument was calibrated. Correct the indicated value for the effect of the fluid density and viscosity on the rotameter reading. Allow the first minutes' fluid to flow to drain, then count the particles in each of five, 15 second intervals.

NOTE 3: The statistical significance of any count data must be taken into consideration. Some OPCs inspect as little as $1/1000^{th}$ of the available sample flow, and may require a greater number of aliquots and larger sampling volume to ensure good statistics. For example, to obtain a coefficient of variation (standard deviation/mean) of 10%, it is necessary that at least 100 particles greater than the control size limit be counted.

3.9.11 *Shutdown* — As in all portions of this procedure, appropriate safe chemical handling practices must be used. In particular, attention should be paid to the reactions between different reagents and between reagents and diluents, including water, and to the inherent hazards of these materials.

3.9.11.1 After the measurement has been completed, vent the pressure vessel to atmospheric pressure through an appropriate scrubber or exhaust hood, then flush the vessel with nitrogen to remove residual reagent vapors.

3.9.11.2 Flush the OPC and sample system with water or an appropriate solvent to remove the remaining fluid.

3.9.12 *Coincidence and Efficiency Corrections* — The determination of coincidence and efficiency correction factors for particle counters is not recommended. If an OPC's maximum concentration is exceeded, a different OPC should be selected, or the sample diluted. However any sample dilution will impose additional error and is not recommended.

3.9.13 *Index of Refraction Correction* — The determination of an index of refraction correction factor for particle counters is not recommended, as the refractive index of the contaminating particle is unknown.

3.9.14 *References*

Carrieri, D., D.C.Grant and W.Kelly, "A Comparison of Optical Particle Sensors Used to Measure Particle Concentration in High-Purity Process Chemicals, Phase I-Sensor comparison in water" Proceedings of the 18th Annual Semiconductor Pure Water and Chemicals Conference, March, 1999.

Carrieri, D., D.C.Grant and W.Kelly, "A Comparison of Optical Particle Sensors Used to Measure Particle Concentration in High-Purity Process Chemicals, Phase II-Sensor comparison in chemicals" Proceedings SEMICON West 1999.

Dillenbeck, K., "Advances in Particle Counting Techniques for Semiconductor Process Chemicals," Microcontamination, February 1987.

Grant, D. and W. Schmidt, "Improved Methodology for Determination of Submicron Particle Concentrations in Semiconductor Process Chemicals," IES Journal, May/June 1987.

Peacock, S. L., M. A. Accomazzo and D. C. Grant, "Quantitative Count Calibration of Light Scattering Particle Counters," IES Journal, July/August 1986.

3.10 *Guidelines for Determination of Trace Elements by Plasma Emission Spectrometry* — The principles of analysis by Plasma Emission Spectrometry are given in many monographs. The purpose here is to describe in general terms how the technique should be used when specified in the procedures for an individual chemical to assure that the specifications for one or more stated elements are met. No general procedure is given since operating details will vary with instrument design; consequently, the manufacturer's manual should be followed.

3.10.1 *Equipment* — A grating instrument with sufficient resolution to separate the typical spectral lines of the elements stated in the specification for an individual chemical. The signal from the detector is processed by a computer system and displayed on a recorder with graphics capability. A background correction technique is required.

3.10.2 *Operating Conditions* — Sensitivity, instrumental detection limit, precision, linear dynamic range, and interference effects must be investigated and established for each individual analyte line on that particular instrument. Types of interferences other than the simple overlap of a concomitant line on an analyte line must be considered.

3.10.3 *Solution Conditions* — The solutions are prepared as given in the procedures for the individual chemical.

3.10.4 *Working Standard Solutions* — Working standard solutions should be prepared on the day of use by dilution of a stock standard solution. For best results, standards should be matrix-matched.

3.10.4.1 Multi-element standards may be prepared. The components should be selected to provide stable standards within the required concentration range.

3.10.5 *Quantitation* — Commonly, the samples are measured against matrix-matched calibration standards; however, whenever a new or unusual matrix is encountered, the method of standard addition is employed. The standard addition does not detect coincident spectral overlap; an alternate wavelength or an alternate method is recommended for verification.

3.10.5.1 A calibration obtained with aqueous standards may be used if its slope and the standard addition method slope are identical.

3.10.5.2 *Evaporation of Sample* — The detection limits achievable can be improved by preconcentration of a large sample by evaporation. Through volatilization there may be a loss of trace elements, and recovery study data must be obtained. The loss of trace elements in this enrichment process can be reduced, often by the presence of additives. The evaporation must be conducted under "clean air" conditions, and reliability should be assured by use of a "blank" or control sample determination. The sample size will depend on the detection limits required and the capability of the instrument used.

3.10.6 *Background Correction* — A background correction technique is required for variable background contribution to the determination of trace elements. The correction interval should be selected such that the intensity of the background at that wavelength is equal to the background intensity under the analyte peak.

3.10.7 *Additives* — The procedures for the individual chemical will provide detailed instructions for required additives in the sample solution.

3.10.8 *Remarks* — The manufacturer's manual should be consulted for proper use of the instrument. The user should check the performance of the instrument from time to time to assure that adequate sensitivity is being attained for the needs of the particular determination.

Table 4 Suggested Plasma Emission Analytical Lines

Element		*Line*
Aluminum	(Al)	396.15
Barium	(Ba)	455.40
Beryllium	(Be)	313.04
Bismuth	(Bi)	223.06
Boron	(B)	249.77
Cadmium	(Cd)	214.44
Calcium	(Ca)	393.27
Chromium	(Cr)	205.55
Cobalt	(Co)	228.63
Copper	(Cu)	324.75
Gallium	(Ga)	294.36
Germanium	(Ge)	209.43
Gold	(Au)	267.60
Iron	(Fe)	238.20
Lead	(Pb)	220.35
Lithium	(Li)	670.78
Magnesium	(Mg)	279.55
Manganese	(Mn)	257.60
Molybdenum	(Mo)	202.02
Nickel	(Ni)	231.60
Niobium	(Nb)	309.42
Potassium	(K)	766.49
Silicon	(Si)	212.41
Silver	(Ag)	328.07
Sodium	(Na)	589.59
Strontium	(Sr)	407.77
Tantalum	(Ta)	240.06
Thallium	(Tl)	276.79
Tin	(Sn)	189.99
Titanium	(Ti)	334.94
Vanadium	(V)	292.40
Zinc	(Zn)	213.86
Zirconium	(Zr)	343.82

NOTE 4: The following guideline will replace Section 3.1 of this standard when all assay methods for existing specifications have been reviewed.

3.11 *Guidelines for Determination of Various Ions by Ion Chromatography* — The theory of ion chromatography is given in many monographs, reviews, etc. The purpose here is to delineate some practical aspects for the determination of various ions by Ion Chromatography. A complete detailed procedure for the ion chromatographic determination is not given since available instruments vary from laboratory to laboratory.

3.11.1 *Equipment* — A standard ion chromatograph equipped with ion suppression is recommended. Single column ion chromatography can also be used. The choice of reagents and columns is determined by the ions of interest.

3.11.2 *Sample* — Sample preparation varies depending upon the matrix effects of the chemicals being analyzed. Standard sample preparation techniques that may be used are (this list is not all inclusive):

- Evaporation of the reagent to remove the matrix and then diluting the residual with the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127,
- Diluting the reagent with the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127 to lessen the matrix effects, and
- Direct injection of the reagent.

3.11.3 *Columns* — Many types of columns exist and can be used. Typical selection criteria for columns consist of ion or ions of interest, the matrix of the reagent and eluent to be used.

3.11.4 *Conditions* — Appropriate conditions will vary from one ion chromatographic system to another. Conditions which have been found acceptable using ion suppression are listed under each individual standard. The two broad classifications of ions are anions and cations. A typical eluent used in the analysis of anions by ion suppression is a sodium carbonate and sodium bicarbonate in a solution with the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127. A typical eluent used in the analysis of cations is a dilute solution of hydrochloric acid in a solution with the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127.

3.11.4.1 Eluent concentration, eluent flow rate, and system pressure are variables which affect the chromatography. Each must be determined for the chromatographic system being used.

3.11.5 *Detector* — A conductivity detector is used to monitor the changes in the eluent conductivity due to ions in the sample. An ultraviolet absorbance detector can be used for detection of some ions. The detector output, after amplification, is used to produce the chromatogram, a plot of component quantity versus elution time. Modern systems digitize the analog output allowing direct printout of peak heights, peak areas, and retention times.

3.11.6 *Calculation of Results* — Ion Concentration =

$$\frac{(\text{Pk. Ht. S}_I - \text{Pk. Ht. B}_I)(\text{Conc. of Std}_I)}{\text{Pk. Ht. Std}_I - \text{Pk. Ht. B}_I} \times \text{Dilution Factor}$$

Pk. Ht. S_I = Peak Height of Sample Ion

Pk. Ht. B_I = Peak Height of Blank Ion

Pk. Ht. Std_I = Peak Height of Standard Ion

Conc. of Std_I = Concentration of Standard Ion

Peak area may be used instead of peak height. Calibration linearity must be established before use.

3.12 *Guidelines for Determination of Trace Elements by Graphite Furnace Atomic Absorption Spectroscopy* — The principles of analysis by Graphite Furnace Atomic Absorption Spectroscopy are given in numerous monographs. The purpose here is to describe in general terms how the technique should be used when specified in the procedures for an individual chemical to assure that the specifications for one or more stated elements are met. No general procedure is given since operating details will vary with instrument design; consequently, the manufacturer's manual should be followed.

3.12.1 *Equipment* — The source is a hollow cathode lamp, or equivalent, for the relevant element. The furnace will contain a pyrolytic coated graphite tube that has been conditioned according to manufacturer's instructions. The monochromator should have a resolution of at least 0.1 nm. The signal from the photomultiplier tube detector is read from a meter, digital display, or recorder tracing. Zeeman or deuterium background correction can be used. An autosampler is suggested in order to obtain better reproducibility.

3.12.2 *Operating Conditions* — Use an acceptable flow rate (300 mL per minute) argon as the inert carrier gas, with no flow during the atomization portion of the program. The temperature programs outlined by the instrument manufacturers should be checked using known standards, and adapted as necessary for optimum performance for a specific instrument. Calibrate the temperature controller for the different atomization temperatures used for each element. The conditions for iron, potassium, calcium, and sodium are included in Table 5.

Table 5

Element	*Iron*	*Potassium*	*Calcium*	*Sodium*
Wavelength (nm)	248.3	766.5	422.7	589.1
Bandwidth (nm)	0.2	1.4	2.0	0.2
Current (mA)	30	6	8	8
L'vov Platform?	Yes	Yes	Optopma;	Yes
Sample Size (μL)	20	10	10	10

3.12.3 *Solutions Conditions* — The solutions are prepared as given in the procedures for the individual chemical. All solutions will be prepared in a clean environment as defined in the SEMI guidelines.

3.12.3.1 *Working Standard Solutions* — Working standard solutions should be prepared on the day of use by dilution of a stock standard solution.

3.12.3.2 *Sample Preparations* — Sample preparation will be analyzed neat, with pre-concentration, or by dilution, according to the individual procedure.

3.12.3.3 *Quantification* — Results shall be reported as the result of three replicate analyses. Each replicate is the result of an 8-second integration of the peak area with the instrument in concentration mode. Recording should commence 5 seconds before the atomization, and baseline should be established 2 seconds prior to atomization. Reading should commence 1 second prior to atomization. Alternate integration schemes for the analytical peak shall be performed in a manner that captures all of the signal, as appropriate for the instrument.

3.12.4 *Calibration* — Calibrate the instrument using a standard prepared in the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127, over a concentration range appropriate for the analysis. The blank must also be contained in the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127.

3.13 *Guidelines for the Determination of Trace Elements by Inductively Coupled Plasma Mass Spectrometry* — The determination of trace elements in process chemicals which are commonly used in advanced semiconductor manufacturing requires a sensitive technique with the ability to perform simultaneous analysis for multiple elements. For such analyses, inductively coupled plasma mass spectrometry is the survey method of choice. Achievable detection limits are adequate for sample analysis with little sample preparation prior to analysis. Chemical matrix reduction needed to perform routine analysis is often achieved by dilution of the sample. Water used for dilution should be the appropriate grade of 18.2 Mohm-cm water that meets ASTM Standard Guide D5127. Matrix removal methods which require sample evaporation should be performed under HEPA filtered air such that reproducible blank samples are obtained at or less than one half the specified limit of trace elements for the sample. No specific procedure for inductively coupled plasma mass spectrometry is included since instrumentation and practices vary among laboratories. Some practical considerations relevant to the method are outlined below.

3.13.1 *Mass Spectrometer* — A mass spectrometer with a resolution of at least 1 amu at 5% of peak height is required to allow sufficient isotopic analysis over the entire mass range from 5 to 250 amu.

3.13.2 *Sample Introduction* — Conventional glassware used for sample introduction is in most cases appropriate for process chemical analysis. Process chemicals containing hydrofluoric acid require a special introduction system unless the hydrofluoric acid matrix is removed prior to the analysis.

3.13.3 *Ionization Source* — An inductively coupled plasma using argon as the support gas has proven to be satisfactory as a ionization source for the method. Ionization conditions present in the argon plasma are highly dependent on the various argon gas flow rates used to support the plasma. Sample introduction techniques used to induce the sample into the plasma are important to the analysis of the samples and must be optimized to allow successful analysis. In particular, sample uptake and nebulizer gas flow require special attention and should be treated carefully in order to optimize instrument performance for each of the various process chemicals.

3.13.4 *Evaporation of Samples* — Several of these chemicals require that the chemical matrix be removed in order to achieve good instrument performance and eliminate the problem of mass spectral interferences which occur either in the argon plasma, or are resultant from the plasma sampling process. If no steps are taken to remove the chemical matrix, severe problems will occur with the analysis of several important elements such as titanium, zinc, vanadium, and magnesium. For more information on the evaporation of samples, see Section 3.5.4 "Evaporation of Sample" in the general procedures.

3.13.5 *Solution Conditions* — The solutions are prepared as given in the procedures for the individual chemicals or elements.

3.13.6 *Working Standard Solutions* — Working standard solutions are prepared daily by dilution of stock standard solutions. The internal standard solutions are prepared similarly.

3.13.7 *Quantification* — Commonly, standards and samples are matrix matched to assure that plasma conditions during the analysis are similar for both standards and samples. This is often done by the use of ultrapure reagent chemicals in the preparation of the working standard solutions. For those chemicals which require matrix removal, the preferred matrix after preparation is dilute nitric acid (typically 1–3%.) The working standard solutions are prepared to cover the expected range of trace element concentration which is routinely from 0.0 to 20.0 ng/mL for process chemicals specified in this book. Background correction by use of a reagent blank solution is required for sample analysis by this technique.

3.13.7.1 An internal standard (such as indium or rhodium) must be used during the analysis.

3.13.8 *Remarks* — The manufacturer's manual should be consulted for details specific to the operation of the instrument. Performance checks on the instrument should be made from time to time to assure adequate mass resolution, performance, and sensitivity.

3.14 *Method Validation* — Analytical methods for trace metals or trace anions, require that performance parameters be assessed and compared to the standard and guideline requirements. The following performance parameters should be reviewed and reported with each method:

- accuracy
- precision measures
- interferences

3.14.1 *Accuracy*

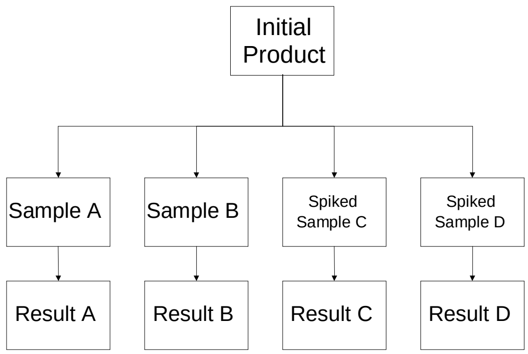
3.14.1.1 Method accuracy is a figure of merit that compares the data generated from the determined concentration of a sample to its "known" concentration. In some cases, a traceable standard may not be available and a "best available standard" may be substituted.

3.14.1.2 Determine the accuracy of a test method by utilizing a standard reference material as a sample and analyze it using the proposed test method. Report the test method accuracy as percent (%) bias:

$$\%\ \text{bias} = \frac{X_{\text{"found"}} - X_{\text{"true value"}}}{X_{\text{"true value"}}} \times 100$$

3.14.1.3 If no suitable traceable standard exists for the “true value,” describe the procedures used to qualify the “best available standard.”

3.14.1.4 Spiked recovery determinations are used to make a limited assessment of accuracy. Method validation is based on the analysis of a minimum of two samples and a minimum of two spiked samples (Figure 1).



NOTE: Samples A, B, C, and D are originally from the same initial product.

Figure 1
Data Collection Structure

3.14.2 *Precision Measures*

3.14.2.1 Typically a repeatability and reproducibility study is done, where samples are analyzed over a period of multiple days.

3.14.2.2 Measures of Method Precision target incorporation of all major method variability sources (such as sample preparation, calibration, and instrumental performance) into their definitions. A limited assessment of method precision is provided by both the % Recovery Range and the Method Detection Limit (Tables 6 and 7).

3.14.2.3 Measurement Repeatability targets how well measurements can be repeated and should be reported as percent (%) relative standard deviation (Tables 6 and 7).

3.14.3 *Interference Checks*

3.14.3.1 List all interferences that were examined during the course of method validation. Also note any known potential interferences.

3.14.4 *Data Reporting Requirements*

3.14.4.1 Table 6 along with Figure 1 illustrates the minimal data structure and analysis required to support method validation.

Table 6 Data Reporting Requirements

Sample A	Result A
Sample B	Result B
Average	Average of Result A and B
Spike	The amount of spike equivalent to 50% of the specified value for trace impurity, and it should be added to the sample prior to any sample preparation (ex., sample dilution, evaporation, etc.)
Spike Sample C	Result C
Spike Sample D	Result D
Recovery 1	Result C – Average
% Recovery 1	(Recovery 1 / Spike) × (100)
Recovery 2	Result D – Average
% Recovery 2	(Recovery 2 / Spike) × (100)
Average % Recovery	(% Recovery 1 + % Recovery 2) / 2
% Recovery Range	Max. % Recovery – Min. % Recovery
Result Standard Deviation	When applicable, report the Std. Dev. of multiple measurements for each Result
Relative Standard Deviation	When applicable, report the Relative Std. Dev. of multiple measurements for each Result

3.14.4.2 In cases where more samples are measured, statistical quantities analogous to the above should be constructed. For methods where automatic consecutive measurements can be obtained from the instrument, Results A, B, C, and D should be the mean of five or more instrumental measurements.

3.14.5 *Summary of Criteria for Success* — The success of the criteria for each figure of merit depends on the specification, the matrix of the analyte, and levels of detection required.

Table 7 Method Success Criteria

Figure of Merit	*Criteria for Successful Method*
Accuracy Spiked Recovery Study	 75–125% Spiked Recovery for each spiked sample.
Method Precision Spiked Recovery Study	 % Recovery Range less than or equal to 35%.
Measurement Precision	Maximum RSD = 20% of the concentration of each spiked sample where: $\text{RSD} = \frac{\text{Std. Dev. Result}}{\text{Conc. of Spiked Sample}} \times 100$
Method Detection Limit	As per SEMI C10: *Guide for Determination of Method Detection Limits*; Method Detection Limits can not exceed the specification.
Interference Checks	If interferences were examined or potential interferences exist, list them.

3.14.6 *Applicability to Existing Specifications* — The current implementation of Method Validation only applies to new or revised specifications. Any prior method validated by SEMI to support a given specification still remains applicable to that specification.

3.14.7 *Example* — Suppose that repeat measurements from four samples; A, B, C and D were available as follows:

Sample A: 0.19, 0.21, 0.25, 0.15, 0.23

Sample B: 0.31, 0.21, 0.17, 0.22, 0.26

Spiked Sample C: 0.83, 0.62, 0.76, 0.79, 0.80

Spiked Sample D: 0.77, 0.87, 0.69, 0.83, 0.84

Table 8 illustrates the calculations required as per Table 6.

Table 8 Data Reporting Example

Sample A	(0.19 + 0.21 + 0.25 + 0.15 + 0.23) / 5 = 0.206
Sample B	(0.31 + 0.21 + 0.17 + 0.22 + 0.26) / 5 = 0.234
Average	(0.206 + 0.234) / 2 = 0.220
Spike	The spike level is to be ½ the relevant specification. If the specification is 1 ppb, then the spike would be 0.5 ppb.
Spike Sample C	(0.83 + 0.62 + 0.76 + 0.79 + 0.80) / 5 = 0.760
Spike Sample D	(0.77 + 0.87 + 0.69 + 0.83 + 0.84) / 5 = 0.800
Recovery 1	(0.760 – 0.220) = 0.540
% Recovery 1	(0.540 / 0.5) = 108
Recovery 2	(0.800 – 0.220) = 0.580
% Recovery 2	(0.580 / 0.5) = 116
Average % Recovery	(108 + 116) / 2 = 112
% Recovery Range	(116 – 108) = 8
Result Standard Deviation	Since repeat measurements were available in this example, report the sample standard deviations. Sample A: 0.038 Sample B: 0.053 Sample C: 0.082 Sample D: 0.071
Relative Standard Deviation (as a %)	Since repeat measurements were available in this example, report the relative sample standard deviations. Samp. A: 100 × (0.038 / 0.220) = 17.5 Samp. B: 100 × (0.053 / 0.220) = 24.2 Samp. C: 100 × (0.082 / 0.720) = 11.4 Samp. D: 100 × (0.071 / 0.720) = 9.9 Note use of the average of 0.220 and the sum of the average + spike (0.720) above.

This example provided the data for the first three success criteria found in Table 7 as well as providing other required summary statistics. Table 9 summarizes performance relative to the success criteria.

Table 9 Method Success Criteria

Figure of Merit	*Criteria for Successful Method*
Accuracy	Both Recovery 1 (108%) as well as Recovery 2 (116%) were in the required 75–125% Spiked Recovery range.
Method Precision	The % Recovery Range was 8% and met the requirement of not exceeding 35%.
Measurement Precision	Maximum RSD for the spiked recoveries was 11.4% which is less than the maximum allowable 20%. Note that the RSDs calculated for Samples A and B are not relevant for this requirement.
Method Detection Limit	Not illustrated in this example, an example is provided with SEMI C10. The Method Detection Limit must be less than or equal to the specification.
Interference Checks	List as necessary.

4 Reagent and Standard Solutions

4.1 *Ammonium Molybdate Reagent Solution* — Dissolve 50 g of ammonium molybdate, $(NH_4)_6Mo_7O_{24}$•$4H_2O$, in 1 *N* sulfuric acid and dilute with 1 *N* sulfuric acid to 1000 mL.

4.2 *Ammonium Thiocyanate Reagent Solution* — Dissolve 150 g of ammonium thiocyanate, NH_4SCN, in water and dilute with water to 500 mL.

4.3 *Antimony Standard Solution* — Dissolve and dilute 0.275 g of potassium antimony $KSbO(C_4H_4O_6)$• $1/2H_2O$ with water to 1000 mL (1.0 mL = 0.1 mg of antimony (Sb)).

4.4 *Arsenic Stock and Working Solution* — See Section 3.4.

4.5 *Barium Chloride Solution* — Dissolve 60 g of barium chloride dihydrate, $BaCl_2$•$2H_2O$, in water and dilute with water to 500 mL.

4.6 *Boron Standard Solution* — Dissolve 0.572 g of boric acid, H_3BO_3, in water and dilute to 1000 mL with water. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.001 mg of boron (B)).

4.7 *"Bromine Water" Reagent Solution* — Add sufficient liquid bromine to water in a bottle so that undissolved bromine remains as a separate phase when the mixture is shaken.

4.8 *Brucine Sulfate Solution* — Dissolve 0.6 g of brucine sulfate, $(C_{23}H_{26}N_2O_4)_2$•H_2SO_4•$7H_2O$, in dilute sulfuric acid (2 + 1), previously cooled to room temperature, and dilute to 1000 mL with the dilute acid. The sulfuric acid should be nitrate-free acid prepared as follows: Dilute the concentrated sulfuric acid (about 96% H_2SO_4) to about 80% H_2SO_4 by adding it to water, heat to dense fumes of sulfur trioxide, and cool. Repeat the dilution and fuming three or four times.

4.9 *Carminic Acid Reagent Solution* — Dissolve 0.05 g of carminic acid in 100 mL of sulfuric acid and shake until dissolution is complete.

4.10 *Chloride Standard Solution* — Dissolve 0.165 g of sodium chloride, NaCl, in water and dilute with water to 100 mL. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.010 mg of chloride (Cl) ion).

4.11 *Dimethylglyoxime Reagent Solution* — Dissolve 1.0 g of dimethylglyoxime in 100 mL of 95% EtOH (ethanol) reagent alcohol.

4.12 *Hydrogen Sulfide Water* — Immediately before use, saturate water with hydrogen sulfide gas.

4.13 *Hydroxylamine Hydrochloride Reagent Solution* — Dissolve 10 g of hydroxylamine hydrochloride, NH_2OH•HCl, in water and dilute with water to 100 mL.

4.14 *Iron Standard Solution* — Dissolve 0.702 g of ferric ammonium sulfate hexahydrate, $Fe(NH_4)_2(-SO_4)_2$ •$6H_2O$, in 10 mL of 10% sulfuric acid and dilute with water to 100 mL. Then to 10 mL of this solution, add 10 mL of 10% sulfuric acid and dilute with water to 1000 mL (1.0 mL = 0.010 mg of iron (Fe) ion).

4.15 *Lead Standard Solution* — Dissolve 0.160 g of lead nitrate, $Pb(NO_3)_2$, in 100 mL of dilute nitric acid (1 + 99) and dilute to 1000 mL with water. Dilute 10 mL of this solution with water to 100 mL immediately before use (1.0 mL = 0.010 mg of lead (Pb) ion).

4.16 *Mercury Standard Solution* — Dissolve 0.677 g of mercuric chloride, $HgCl_2$, in water. Add 8 mL of hydrochloric acid and dilute with water to 500 mL. To 50 mL of this solution add 8 mL of hydrochloric acid and dilute with water to 1000 mL (1.0 mL = 0.05 mg of mercury (Hg) ion).

4.17 *Methyl Orange Indicator Solution* — Dissolve 0.1 g of methyl orange in 100 mL of water.

4.18 *Methyl Red Indicator Solution* — Dissolve 0.1 g of the hydrochloride salt form of methyl red in 100 mL of 95% EtOH (ethnol) reagent alcohol.

4.19 *p-(Methylamino)phenol Sulfate Reagent Solution* — Dissolve 0.2 g of p-(methylamino)phenol sulfate in 100 mL of water and add 20 g of sodium bisulfite. The performance of the resulting reagent solution in the determination of trace phosphate can be verified by the following test:

4.19.1 Place 25 mL of 0.5 *N* sulfuric acid and 1 mL of ammonium molybdate reagent solution in each of four test tubes. Add 1 mL of the reagent solution to each of the tubes. To the tubes add, respectively, zero, 0.005, 0.010, and 0.020 mg of phosphate ion (PO_4). After two hours at room temperature, an increasing intensity of blue color should be visible in the series.

4.20 *Nickel Standard Solution* — Dissolve 0.448 g of nickel sulfate hexahydrate, $NiSO_4$•$6H_2O$, in water and dilute with water to 100 mL. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.010 mg of nickel (Ni) ion).

4.21 *Nitrate Standard Solution* — Dissolve 0.163 g of potassium nitrate, KNO_3, in water and dilute with water to 100 mL. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.010 mg of nitrate (NO_3) ion).

4.22 *Nitrogen Standard Solution* — Dissolve 0.382 g of ammonium chloride, NH_4Cl, in water and dilute with water to 100 mL. Then dilute 10 mL of this solution with water to 100 mL (1.0 mL = 0.010 mg of nitrogen (N)).

4.23 *Phenolphthalein Indicator Solution* — Dissolve 1 g of phenolphthalein in 100 mL of 95% EtOH (ethanol) reagent alcohol.

4.24 *Phosphate Standard Solution* — Dissolve 0.143 g of monobasic potassium phosphate, KH_2PO_4, in water and dilute to 100 mL with water. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.010 mg of phosphate (PO_4) ion).

4.25 *Platinum-Cobalt Stock Solution (APHA 500)* — (See Section 3.2.)

4.26 *Potassium Iodide Reagent Solution* — Dissolve 10 g of potassium iodide, KI, in 100 mL of water. Prepare immediately before use.

4.27 *Potassium Standard Solution* — Dissolve 0.191 g of potassium chloride, KCl, in water and dilute with water to 1000 mL. Dilute 100 mL of this solution with water to 1000 mL (1 mL = 0.010 mg of potassium (K) ion).

4.28 *Silver Nitrate Reagent Solution* — Dissolve 1.7 g of silver nitrate, $AgNO_3$, in water and dilute with water to 100 mL.

4.29 *Sodium Carbonate Reagent Solution* — Dissolve 1.0 g of anhydrous sodium carbonate, Na_2CO_3, in water and dilute with water to 100 mL.

4.30 *Sodium Arsenite Reagent Solution (5%)* — Dissolve 1.0 g of anhydrous sodium arsenite, $NaAsO_2$, in water and dilute with water to 100 mL.

4.31 *Sodium Hydroxide Reagent Solution* — Dissolve 50 g of sodium hydroxide, NaOH, pellets in water and dilute with carbon dioxide-free water to 500 mL.

4.32 *Sodium Standard Solution* — Dissolve 0.254 g of sodium chloride, NaCl, in water and dilute with water to 1000 mL. Then dilute 100 mL of this solution with water to 1000 mL (1 mL = 0.010 mg of sodium (Na) ion).

4.33 *Stannous Chloride Reagent Solution* — Dissolve 20 g of stannous chloride dihydrate, $SnCl_2 \bullet 2H_2O$, in hydrochloric acid and dilute with hydrochloric acid to 100 mL.

4.34 *Starch Indicator Solution* — Mix 1 g of soluble starch for iodometry with 10 mg of red mercuric iodide, HgI_2, and enough cold water to form a thin paste. Add 200 mL of boiling water and boil for 1 minute with stirring. Cool and transfer to a storage bottle that has been well rinsed with hot water.

4.35 *Sulfate Standard Solution* — Dissolve 0.148 g of anhydrous sodium sulfate, Na_2SO_4, in water and dilute with water to 100 mL. Then dilute 10 mL of this solution with water to 1000 mL (1.0 mL = 0.010 mg of sulfate (SO_4) ion).

4.36 *Thymolphthalein Indicator Solution* — Dissolve 0.10 g of thymolphthalein in 100 mL of 95% EtOH (ethanol) reagent alcohol.

5 Safety

5.1 Because of the continuing evolution of safety precautions, it is impossible for this publication to provide definite statements related to the safe handling of individual chemicals. The user is referred to product labels, product data sheets, government regulations, and other relevant literature.

6 Referenced Standards

6.1 *ASTM Standards*[3]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

3 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

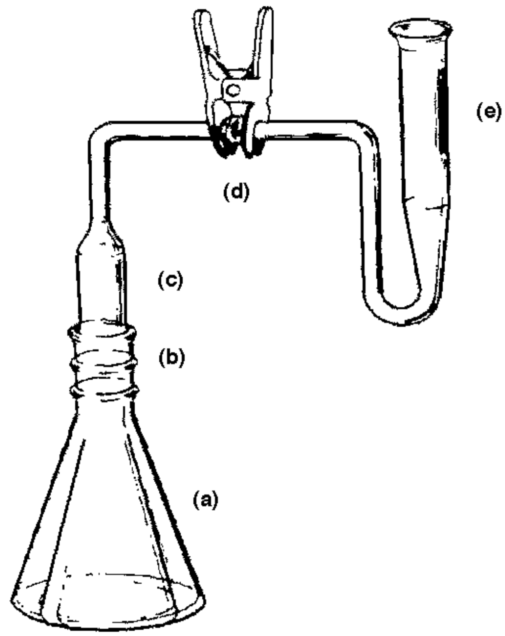


Figure 2
Arsenic Test Apparatus

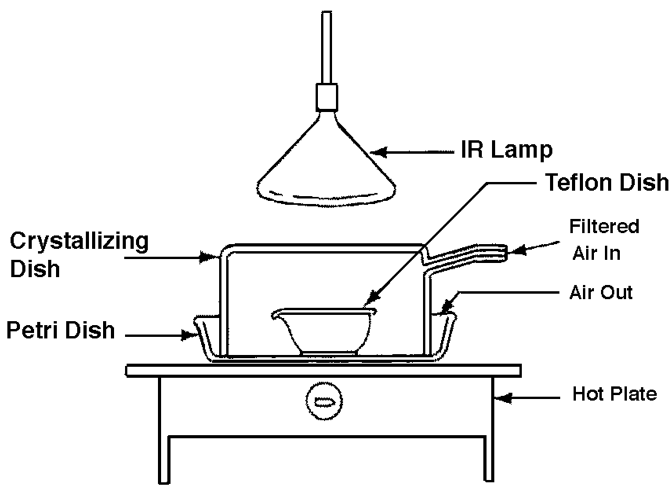


Figure 3
Thiers Assembly

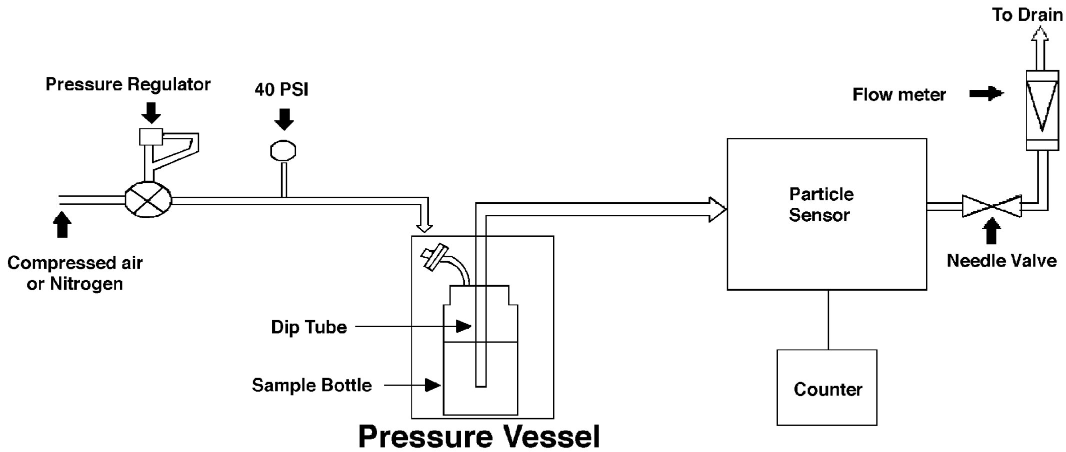


Figure 4
Pressurized Test System

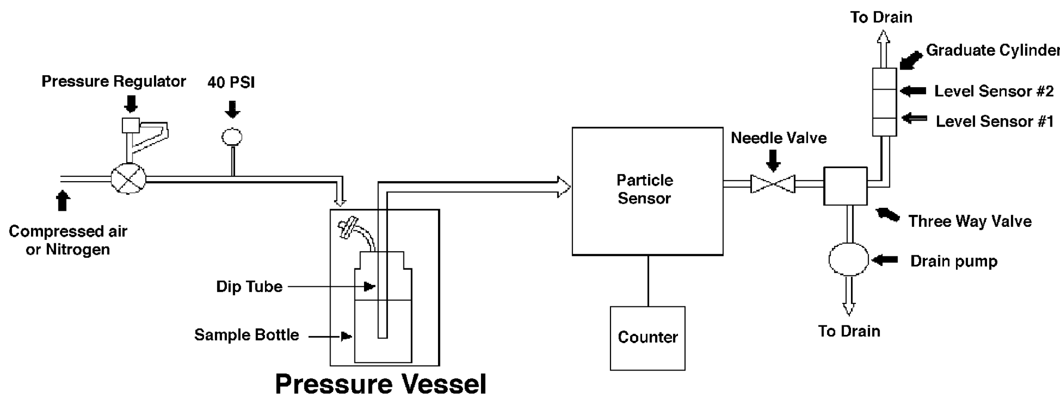


Figure 5
Pressurized Test System

SEMI C2-95
SPECIFICATIONS FOR ETCHANTS

1 Preface

1.1 The SEMI Committee on Chemical Reagents began its efforts on etchants in 1979. With this publication, the Committee establishes definitions for three major types of etchant mixtures; mixed acid etchants, buffer oxide etchants, and phosphoric etchants. Specifications and analytical procedures are introduced for each type.

1.2 Etchants within all of the requirements can be described as "meeting SEMI specifications."

1.3 Where an analytical procedure different from that provided is substituted by a supplier or user, the burden of proof is on said supplier or user to confirm the equivalency.

2 Definitions

2.1 All definitions set forth in SEMI C1, Section 2 are adopted for SEMI C2.

2.2 *Etchant* — The exact definition of an etchant mixture shall be set forth as the initial paragraph of its Standard. The composition shall be expressed as a ratio of the relative volumes taken of the components in an assigned order. In the expression, all the relative volumes shall be reduced to a ratio of the smallest whole numbers. If a component is absent, its relative volume shall be taken as zero.

2.3 *Composition* — The content of each component of an etchant shall be expressed on a weight/weight basis of the 100% component (for example, 100% HF, not 49% HF). Any tolerance allowed for the content of a component shall be expressed on a weight/weight basis of that 100% component.

3 General Procedures and Guidelines to Certain Methods

3.1 The general procedures and guidelines for certain methods set forth in SEMI C1, Section 3 are adopted for SEMI C2.

3.2 *Determination of Nitric Acid by Ultraviolet Absorption Spectrophotometry*

3.2.1 *Introduction* — The photometric determination of nitric acid in various etchant mixtures is based on the strong absorption of the nitrate ion in the ultraviolet region. For this spectral region fused silica (quartz) cells are required.

3.2.2 *Preparation of Calibration Curve* — Secure a bottle of nitric acid (70%) and determine its assay in duplicate. Accurately weigh 2.8 to 3.0 g dilute with 100 mL of water, add 10 drops of phenolphthalein indicator solution to each solution, and titrate with standardized 1 *N* sodium hydroxide solution to a pink end-point.

$$\%\text{ Nitric Acid }(w/w) = \frac{\text{mL} \times N \text{ of NaOH} \times 6.302}{\text{Weight of Sample (g)}}$$

If the results do not differ by more than 0.2%, average them. Otherwise, repeat the analysis.

3.2.3 In five previously tared weighing bottles, accurately weigh about 1.0, 1.2, 1.4, 1.6 and 1.8 g of the previously assayed 70% nitric acid. Calculate the weight, in grams, of 100% nitric acid present in each of these five standards. Quantitatively transfer each standard to a separate 100 mL volumetric flask, dilute to volume with water, and mix thoroughly.

3.2.4 Following the manufacturer's directions, ready a spectrophotometer and set the wavelength to 302 nm. Measure the absorbance of each standard versus water using a 1 cm fused silica cell. On (linear) coordinate graph paper plot the absorbance versus the weight, in grams, of 100% nitric acid for each standard. Draw the best-fitting straight line through the points.

3.2.5 *Application to Acid Etch Mixtures* — Proceed as given under the Standard for the relevant etchant.

4 Reagent and Standard Solutions

4.1 The reagent and standard solutions set forth in SEMI C1, Section 4 are adopted for SEMI C2.

4.2 *Acetate Buffer for Hydrofluoric Acid Determination* — Dissolve 106 g of sodium acetate trihydrate, $CH_3COONa{\bullet}3H_2O$, and 137 g of ammonium acetate, CH_3COOHN_4, in about 700 mL of water. Add 5.1 mL of glacial acetic acid, adjust to pH 5.5-6.6 with dilute ammonium hydroxide (10% NH_3) or dilute acetic acid (20%), and dilute to 1000 mL with water.

4.3 *Aluminum Chloride Standard Solution Preparation* — Dissolve 40.0 g of aluminum chloride hexahydrate, $AlCl_3{\bullet}6H_2O$, in about 700 mL of water and 0.5 mL of hydrochloric acid contained in a 1000 mL volumetric flask; dilute to volume with water, and mix thoroughly.

4.3.1 *Standardization* — Transfer 1.5 mL of hydrofluoric acid to a 250 mL polyethylene beaker containing 50 mL of water. Add 10 drops of phenolphthalein indicator solution. With magnetic stirring, titrate with standarized 1*N* sodium hydroxide solution to a pink endpoint. Record the volume of base delivered (A). Add 25 mL of Acetate Buffer for Hydrofluoric Acid Determination and 1 g of Eriochrome Cyanine R indicator mixture; mix thoroughly. With magnetic stirring, titrate with the aluminum chloride solution to a pink-purple endpoint. Record the volume of this solution delivered (B).

$$\text{HF Factor} = \frac{\text{A} \times N \text{ of NaOH} \times 2.001}{\text{B of AlCl}_3 \text{ soln.}}$$

4.4 *Eriochrome Cyanine A Indicator Mixture* — Using a mortar and pestle, thoroughly grind and mix 0.1 g of Eriochrome Cyanine R (C.I. 43820) with 100 g of potassium nitrate.

5 Safety

Because of the continuing evolution of safety precautions, it is impossible in this publication to provide definite statements relating to the safe handling of individual etchants. The user is referred to product labels, product and safety data sheets, government regulations, and other relevant literature.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI C10-0299
GUIDE FOR DETERMINATION OF METHOD DETECTION LIMITS

NOTE: The document that was previously designated as SEMI C10 (Guide for Determination of Method Detection Limits for Trace Metal Analysis by Plasma Spectroscopy) has been redesignated as SEMI C10.1. Because the Guide for Determination of Method Detection Limits is the parent document, it has been designated as SEMI C10.

1. Purpose

1.1 To provide a minimal set of guidelines for the quantitative determination of a method detection limit (MDL) from data supporting a SEMI Process Chemicals or Gases specification.

2. Scope

2.1 This guide applies to trace contaminants specified in SEMI Process Chemicals or Gases standards and guidelines. All relevant trace contaminants should have an MDL determined from a regression analysis of a calibration curve that is equal to, or less than, their specifications. This guide is intended for use in both establishing new specifications within SEMI as well as verification of performance to SEMI specifications.

3. Referenced Documents

3.1 *SEMI Standard*

SEMI C16 — Guide for Precision Reporting/Data Traceability

3.2 *Other Document*[1]

Applied Regression Analysis, 2nd Edition, Norman Draper and Harry Smith, John Wiley and Sons, © 1981

4. Terminology

None.

5. Boundary Conditions

NOTE: A series of boundary conditions is required of the data from which the MDL is to be determined from.

5.1 Data should be collected on at least two standards at different concentration levels, not including the blank.

5.2 The concentration levels investigated must either span the relevant specification or include it as a level. For this purpose, the calibration range can be adjusted for instrument sensitivity by pre-concentration or dilution, if applicable.

5.3 A minimum of three independent sample determinations should be taken on each concentration level of the standard investigated.

5.4 *Matrix Effects*

5.4.1 The blank and the standards should be matrix-matched with the sample when testing a specification and run under the same conditions, both during calibration and sample analysis.

5.4.2 If external standards in a different matrix are used for calibration, the user must compensate for matrix effects using suitable internal standards.

5.5 Where applicable, this guide supersedes the earlier related SEMI Guide: SEMI C16.

5.6 The frequency of the MDL determination should be part of the quality assurance program for the laboratory.

6. Procedure

NOTE: The determination of the MDL should be performed under the same conditions that samples will normally be run. All appropriate precautions to avoid contamination should be followed.

[1] *John Wiley & Sons, Inc., 605 Third Avenue New York, NY 10158-0012, 212.850.6000*

6.1 *Reagents and Standards* — Reagents and standards used should be of the same high-purity as used in the analysis of samples. Accurate standard solutions of trace contaminants are needed for the preparation of the calibration standards. Commercially available standard solutions are suitable. These solutions should be traceable to NIST standards. Working standard solutions should be prepared on the day of use by dilution of the stock standard solution. Standards and blanks should be matrix-matched to the sample to be analyzed.

6.2 *Operating Conditions*

6.2.1 *Instrumental* — Principles of instrumental analysis are provided within many monographs. No general operating conditions are given here since these will vary with the instrument type and design; consequently, the manufacturer's manual should be followed.

6.2.2 *Standard and Sample Preparation* — With certain methods, the achievable MDL can be improved by pre-concentration. Some methods require matrix dilution to run some analyses and may also affect the MDL.

6.2.3 *Calibration* — Calibrate the instrument for all specified trace contaminants using measurement and preparation protocols identical to those used in sample preparation and measurement, wherever appropriate. The calibration data structure used to determine the MDL should be as close to identical as possible to the data structure normally used for calibration in the laboratory. Minimum data requirements should be determinations at, at least, two concentration levels (standards), each independently sampled 3 times. The lowest concentration standard should be at, or below, the specification and give a measurable signal. The blank may be used in the calculation of the MDL if its variability is judged to be representative of that of a very low-level standard. All instrument response data used in the analysis should be measurable. The calibration range can be adjusted for instrument sensitivity by pre-concentration or dilution to match with how the samples are analyzed. Use the data collected to calculate the MDL using the formulas in the next section.

6.3 *Quantification of the MDL*

6.3.1 The MDL is calculated by using the results from a *regression analysis* of the calibration data to obtain a 3 sigma equivalent (in probability) upper confidence limit of individual measurements. Two alternative computational methods are provided for linear calibration models. One provides the MDL based on an ordinary least squares (OLS) regression analysis; the other on a weighted least squares (WLS) based regression analysis. These two computational alternatives **do not** provide the same MDL. The OLS algorithm is appropriate when signal uncertainty remains relatively constant over the window of calibration; otherwise, the WLS algorithm is more appropriate. A third alternative allows the use of similar regression-based approaches for MDL determination in the presence of a more complex calibration model (e.g., nonlinear, multivariate), or when distributional assumptions of the other alternatives are not appropriate. Many software packages perform regression analysis, and their use is recommended.

6.3.2 *Statistical Definitions*

6.3.2.1 *Method detection limit (MDL)* — The level at which the errors in the *measurement method* become large enough such that the preset maximum acceptable risk of seeing the quantified level, when none of the contaminant in question is present in the sample, is exceeded.

6.3.2.2 *risk* — This guide uses 0.13% as the maximum acceptable risk. This is the probability of observing a given result from a normal distribution that is 3 or more standard deviations above the average. Risk is set on a per-contaminant basis.

6.3.2.3 *calibration curve* — An estimate of the relationship between concentration and instrument response (signal intensity). A line, which has not been constrained to pass through the origin, is implicitly assumed in the subsequently provided formulae.

6.3.2.4 *regression analysis* — A curve-fitting technique from which the calibration curve can be estimated.

6.3.2.5 *Ordinary least squares (OLS)* — A curve-fitting criterion which, for a given calibration model, minimizes.

$$\sum_{i=1}^{n}\left(Y_i - \text{Pr}\mathit{edicted}\ Y_i\right)^2$$

Appropriate use of this criterion implicitly assumes that, on average, each determination is made with equal reliability.

6.3.2.6 *Weighted least squares (WLS)* — A curve-fitting criterion which, for a given calibration model, minimizes.

$$\sum_{i=1}^{n} w_i \left(Y_i - \text{Predicted } Y_i\right)^2$$

where, w_i is the weight assigned to the i^{th} data point.

Appropriate use of this criterion implicitly assumes that all w_i are strictly inversely proportional to each point's standard deviation (measure of variation).

6.3.2.7 *t-statistic* — Student's *t* is used instead of the Z-statistic (normal distribution) when the standard deviation is estimated from relatively small quantities of data. It is used herein to explicitly control the risk at 0.13%, regardless of sample size.

- *X's* — The concentrations of the standards used in quantifying the MDL.
- *Y's* — The instrument's response (signal intensity) to each of the *X*'s in question.

6.3.3 *Calculations — OLS and Linear Calibration Model*

6.3.3.1 A line, which is not constrained to pass through the origin, is used as the calibration model. OLS is used to estimate the model. The MDL is located by determining the 3 sigma equivalent Upper Confidence Limit at $X = 0$ and using a linear calibration model to convert this result into the corresponding concentration (MDL).

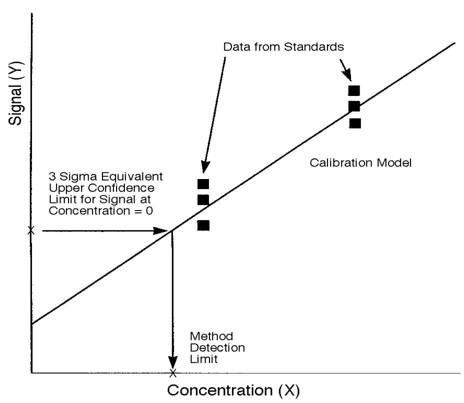

Figure 1
Graphical Visualization of MDL Determination Process

$$MDL = \frac{(UCL - b)}{m}$$

(1) where,

- m = slope determined by OLS analysis (equation 2)
- b = intercept determined by OLS analysis (equation 3)
- UCL = 3 sigma equivalent Upper Confidence Limit at $X = 0$ (equation 4)

$$m = \frac{SS_{xy}}{SS_{xx}}$$

(2), where *SS* stands for Sum of Squares and

$$SS_{xy} = \Sigma_i \left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right) = \Sigma_i X_i Y_i - \frac{\left(\Sigma_i X_i\right)\left(\Sigma_i Y_i\right)}{n}$$

where n = total number of observations and i is an index which ranges from 1 to n by 1 in the summations and

$$SS_{xx} = \Sigma_i \left(X_i - \bar{X}\right)^2 = \Sigma_i \left(X_i^2\right) - \frac{\left(\Sigma_i X_i\right)^2}{n}$$

$$b = \bar{Y} - m\bar{X}$$

(3), where

$$\bar{X} = \frac{\Sigma_i X_i}{n}$$

and

$$\bar{Y} = \frac{\Sigma_i Y_i}{n}$$

$$UCL = b + t_{n-2,\ 0.0013}\left(1 + \frac{1}{n} + \frac{(\bar{X})^2}{SS_{xx}}\right)^{1/2} s$$

(4), where

$t_{n-2,\ 0.0013}$ is a t-statistic (from Table 1) with $n-2$ degrees of freedom and 0.0013 as the desired risk of detecting a false positive signal (one-sided, 3 sigma equivalent) and

s = standard deviation of regression model

$$= \left(\frac{\sum_i \left(Y_i - Y_i^*\right)^2}{n-2} \right)^{1/2}$$

where, $Y_i^* = mX_i + b$

Table 1. 3-Sigma Equivalent *t*-Table

n-2	*t*	*n-2*	*t*	*n-2*	*t*
4	6.62	10	3.96	16	3.54
5	5.51	11	3.85	17	3.51
6	4.90	12	3.76	18	3.48
7	4.53	13	3.69	19	3.45
8	4.28	14	3.64	20	3.42
9	4.09	15	3.59		

6.3.3.2 Such analyses should be performed by using a spreadsheet or computer program. It is not recommended to do them by hand. The previous equations neither require nor prevent use of data from blank quantification. In order to use blank data in the MDL quantification with OLS, the blank should be measurable, be likely to give a response which is consistent with the pattern in the other calibration data, and provide a similar level of variability to that obtained from the investigated standards.

6.3.4 *Calculations — WLS and Linear Calibration Model*

6.3.4.1 A line which is not constrained to pass through the origin is used as the calibration model. WLS is used to estimate the model in which the weights are determined as a function of the observed variability at each concentration level. The MDL is located by determining the 3 sigma equivalent Upper Confidence Limit at X = 0 and using a linear calibration model to convert this result into the corresponding concentration (MDL). While the names of many quantities are the same as in the OLS analysis (e.g., $\bar{X}$, $\bar{Y}$, SS_{xx}, and SS_{xy}), the calculations are not.

$$MDL = \frac{(UCL - b)}{m}$$

(5), where

- m = slope determined by WLS analysis (equation 6)
- b = intercept determined by WLS analysis (equation 7)
- UCL = 3 sigma equivalent Upper Confidence Limit at $X = 0$ using WLS (equation 8)

For each of the j levels of concentration, determine the variance of the k determinations (where k can differ for each concentration level, but must be at least 3) as :

$$S_j^2 = \frac{\sum_{l=1}^{k}\left(Y_{j,l} - \bar{Y}_j\right)^2}{(k-1)} \quad \text{where,}$$

$\bar{Y}_j = \dfrac{\sum_{l=1}^{k} Y_{j,l}}{k}$ is used to determine the normalized weight w_j, for any determination at the j^{th} level of concentration as :

$$w_j = \frac{n}{\sum_j \left(\frac{1}{S_j^2}\right)} \frac{1}{S_j^2}, \text{ then}$$

$$m = \frac{SS_{xy}}{SS_{xx}}$$

(6), where

SS stands for Sum of Squares and

$SS_{xy} = \sum_i w_i \left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)$, where n = total number of observations and i is an index which ranges from 1 to n by 1 in the summations and

$$\bar{X} = \frac{\sum_i w_i X_i}{n},$$

$$\bar{Y} = \frac{\sum_i w_i Y_i}{n}, \text{ and}$$

$$SS_{xx} = \sum_i w_i \left(X_i - \bar{X}\right)^2$$

$$b = \bar{Y} - m\bar{X}$$

(7), where

$$UCL = b + t_{n-2,\ 0.0013}\left(\frac{1}{w_0} + \frac{1}{n} + \frac{\left(\bar{X}\right)^2}{SS_{xx}}\right)^{1/2} s$$

(8), where

w_0 is the weight at the intercept (w_0 is either the weight associated with the blank measurements *if they were included in the analysis* or the weight of the lowest concentration standard if the blank measurements are not included in the analysis),

$t_{n-2,\ 0.0013}$ is a t-statistic (from Table 1) with $n-2$ degrees of freedom and 0.0013 as the desired risk of detecting a false positive signal (one-sided, 3 sigma equivalent) and

s = standard deviation of regression model

$$= \left(\frac{SS_{yy} - mSS_{xy}}{n-2}\right)^{1/2} \quad \text{where,}$$

$$SS_{yy} = \sum_i w_i \left(Y_i - \bar{Y}\right)^2$$

6.3.4.2 Since some calculations, for example that of s, may lead to computation of a relatively small difference between two relatively large numbers; it is critical that all previous calculations not be based on rounded numbers. In general, such analyses should be performed using a spreadsheet or computer program.

6.3.4.3 The previous equations neither require nor prevent use of data from blank quantification. In order to use blank data in the MDL quantification with WLS, the blank should be measurable, be likely to give a response which is consistent with the pattern in the other calibration data, and provide a level of variability consistent with the pattern seen in the investigated standards.

6.3.5 *Alternative Calculations* — Situations exist for which both prior alternatives (Sections 6.3.3 and 6.3.4) may be inappropriate. For example:

(a) a calibration model may be nonlinear,

(b) a calibration model may be multivariate in nature,

(c) the implicit assumption of normality of residuals (errors in predictions about the calibration) may not be an appropriate distributional assumption,

(d) the lowest level standard used in calibration may be too far above the true MDL.

6.3.5.1 In case *(a)*, a nonlinear model can be used instead of the default linear model in performing a regression analysis which quantifies the Upper Confidence Limit for individuals at X = 0 at a *3 sigma equivalent probability level* (and back-projects this result through the nonlinear calibration model to estimate the MDL). How to accomplish this is the responsibility of those applying this alternative. In some situations, a transformation of scale (X and/or Y) may linearize the model such that the previously provided calculations are again applicable.

6.3.5.2 In case *(b)*, a multivariate calibration model can be used instead of the default linear model in performing a regression analysis which quantifies the Upper Confidence Limit for individuals at X = 0 at a *3 sigma equivalent probability level* (and back-projects this result through the multivariate calibration model using the observed point of maximum interference in terms of the other concentrations in the range of calibration to estimate the MDL). How to accomplish this is the responsibility of those applying this alternative.

6.3.5.3 In case *(c)*, other error distributions than the normal, can be used wherever appropriate. The same philosophical approach should be applied; a regression analysis which quantifies the Upper Confidence Limit for individuals at X = 0 at a *3 sigma equivalent probability level* (and back-projects this result through the calibration model to estimate the MDL). How to accomplish this is the responsibility of those applying this alternative.

6.3.5.4 In case *(d)*, it is more likely that one will obtain a higher MDL than is truly the case. This phenomena is more likely to occur when the blank is not usable in the regression analysis for any reason. The only fix for this is to reapply the procedure with a set of standards which is not so distant from the MDL, but still otherwise meets the requirements provided herein.

6.3.5.5 In cases *(a)*, *(b)*, and *(c)*, or any combination thereof, the use of appropriate computer/statistical tools is the responsibility of those applying these alternatives. Additional information on regression analysis methods can be found in *Applied Regression Analysis*, 2nd Edition, Norman Draper and Harry Smith, John Wiley and Sons, © 1981.

6.3.6 *Example — Results of Applying (see Sections 6.3.3 and 6.3.4)*

6.3.6.1 Limited result summaries for obtaining the MDL by OLS and WLS are provided for the calibration data in Table 2. These results (Table 3) can be used to benchmark one's implementation of the computational methodology.

Table 2. Calibration Data

Ppb	*signal*	*ppb*	*signal*	*ppb*	*signal*
1	5.03	5	19.87	10	39.90
1	5.00	5	21.20	10	38.28
1	4.91	5	20.45	10	40.93

Table 3. Result Summaries

Statistic	*OLS*	*WLS*
MDL	1.097	0.108
UCL	5.390	1.531
m	3.857	3.869
b	1.157	1.112
s	0.800	0.00997

6.3.6.2 Note the relatively large difference in the estimated MDL (1.10 vs. 0.11) resulting from passing the same data through each of the OLS and WLS algorithms. This data has very different levels of variability, depending on the concentration level of the standard (Table 4). Such data should be analyzed with the WLS rather than the OLS algorithm.

Table 4. Signal Variation by Concentration Level

Concentration Level	*Standard Deviation*	*Variance*
1	0.062	0.0038
5	0.667	0.4449
10	1.336	1.7849

7. Quality Assurance

7.1 Each laboratory that uses this method should do so in accordance with the established quality assurance protocols in place. The MDL, of specified trace contaminants, should be determined whenever a major recalibration of the method and/or instrument is required. The new values should then be used whenever results are reported. A schedule of periodic verification of the MDL, for key trace contaminants, should be incorporated into the program.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C16-0299
GUIDE FOR PRECISION AND DATA REPORTING PRACTICES

1. Purpose

To provide a minimal set of guidelines for precision and data reporting practices for data supporting a Process Chemicals or Gases SEMI specification.

2. Scope

This guide applies to data collected to support establishment of a SEMI Process Chemicals or Gases specification or verification of performance to such a SEMI specification.

3. Referenced Documents

3.1 *SEMI Standard*

SEMI C1 — Specifications for Reagents

4. Terminology

None.

5. Standards

For each standard used in the study, the following should be reported:

5.1 Preparation method before analysis (e.g., dilution, evaporation).

5.2 Sample matrix.

5.3 Concentration.

5.4 n = number of determinations made on the standard.

5.5 The average of the n determinations.

5.6 The standard deviation of the n measurements (if $n > 1$).

5.7 Range of values observed (if $n > 1$).

5.8 Traceability of the standard.

5.9 If standard was produced internally, how was it produced.

6. Samples

For all reported sample results, including recovery studies, use as many of the reporting requirements for standards as are applicable.

7. Detection Limits

If a detection limit is reported, the specific method or published variant by which the detection limit was obtained, should be named. The level of the lowest standard used in determination of a detection limit should be reported.

8. Internal Standards

For procedures calling for concentration of an analyte by cryogenic trapping, acid extraction, distillation, hydrolization, etc., a recovery study as per Method Validation (Section 3.14 of SEMI C1) is required. For a method to be viable, a recovery in the range of 75 - 125% is recommended.

9. Calibration Models

9.1 The span of the calibration data should include the relevant specification.

9.2 The form of the calibration model (line through origin, line, etc.) should be stated. The assumption of linearity, underlying reliance on two point (zero and span) calibrations for analytical instruments, should be justified by reporting the basis for such an assumption.

9.3 A list of which standards were used to develop the calibration model should be provided.

9.4 Information on which fitting technique was used (i.e., regression using ordinary least squares, weighted least squares, partial least squares) should be provided.

9.5 Identify which, if any, transformations were applied to the calibration data prior to the fitting of the calibration model.

9.6 Identify which response was modeled to establish calibration (i.e., peak area, peak height, response factor).

9.7 A list of the types of standards employed (i.e., internal standards, external standards, method of standard addition) should be provided.

9.8 Report how the calibration data is incorporated in producing the results of an analysis (i.e., zero and span correction, graph).

10. Method Precision

An estimate of method precision should be provided at the level of the specification. Any known interferants or factors which may affect method precision should be stated.

11. Summary

Since only a minimal set of guidelines is provided, those using this guide are encouraged to provide more detail or use more stringent guidelines than those suggested.

SEMI

SEMI C18-0301
SPECIFICATION FOR ACETIC ACID

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.1 in its entirety. Originally published in 1978; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for acetic acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of acetic acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of acetic acid used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.05 g/mL

NOTE 2: This material freezes at about 16°C.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

7 Requirements

7.1 The requirements for acetic acid for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Place 15 mL (15.8 g) of sample in a 20 × 150 mm test tube in which is centered an accurate thermometer. The sample tube is centered by one or more stoppers in an outer tube about 38 × 20 mm. Cool the entire apparatus, without stirring, in a bath of shaved or crushed ice and sufficient water to immerse the outer tube above the level of the acetic acid. When the thermometer temperature is about 13°C stir to induce freezing and read the thermometer every half minute. The temperature that remains constant for 1 to 2 minutes is the freezing point and should not be below 16°C, indicating not less than 99.7% as CH_3COOH.

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Residue after Evaporation* — Evaporate 95 mL (100 g) of sample in a tared porcelain or silica dish to dryness on a steam bath in a hood. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.4 *Solubility in Water* — Mix 10 mL of sample with 30 mL of water. Allow to stand 1 hour. The solution should be as clear as an equal volume of water.

8.5 *Chloride* — Dilute 9.5 mL (10 g) of sample with 10 mL of water. Add 1 mL of silver nitrate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 0.5 mL of ammonium hydroxide, dilute with 20 mL of water and add 1.5 mL of nitric acid. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.6 *Phosphate* — Evaporate 9.5 mL (10 g) of sample to dryness on a steam bath in a hood. Dissolve the residue, warming if necessary, in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.7 *Substances Reducing Dichromate* — To 10 mL (10.5 g) of sample, add 1.0 mL of 0.1 N (0.017 M) potassium dichromate solution and cautiously add 10 mL of sulfuric acid. Cool the solution to room temperature and allow to stand for 30 minutes. Add 50 mL of water slowly and cautiously with continual swirling, allow to cool, and then add 1 mL of freshly prepared potassium iodide reagent solution. Titrate the liberated iodine with 0.1 N (0.1 M) thiosulfate solution using starch as the indicator. Compare the volume of thiosulfate solution required with that for a 10 mL water blank prepared in parallel with the sample. The difference between the titrations for sample and blank should be no greater than 0.40 mL.

8.8 *Substances Reducing Permanganate* — Dilute 40 mL (42 g) of sample with 10 mL of water. Cool to 15°C, add 0.30 mL of 0.1 N (0.02 M) potassium permanganate, and allow to stand at 15°C for 10 minutes. The pink color should not be entirely discharged.

8.9 *Sulfate* — To 95 mL (100 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) is treated as the sample.

8.10 *Arsenic and Antimony (as As)* — To 190 mL (200 g) of sample in a 400 mL beaker, add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: “Swirl the flask....” Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.11 *Acetic Anhydride* — Place 52.2 g (50 mL) of sample in a 250 mL titration flask. In a second flask place 50 mL of glacial acetic acid known to be free from acetic anhydride (see NOTE 3). Into each flask pipet 10 mL of 1.0% solution of 4, 4' -methylenedianiline (4, 4' -diaminodiphenylmethane) in glacial acetic acid (see NOTE 4) and add 0.10 mL of 1.0% solution of crystal violet in glacial acetic acid. Titrate each solution with a 0.1 N solution of perchloric acid in glacial acetic acid (see NOTE 5) to a green endpoint. Subtract the volume for the titration of the sample from the volume for the other titration. One mL of 0.1 N perchloric acid corresponds to 0.0194% $(CH_3CO)_2O$ for a 50 mL sample.

NOTE 4: Glacial acetic acid suspected of containing anhydride may be purified by adding 0.50 mL of water per 100 mL and digesting overnight in a glass-stoppered flask on the steam bath. If this acid is used for comparison in the above test, 0.25 mL of water should be added to the flask containing the test sample just before the endpoint, because water affects the indicator change slightly.

NOTE 5: Dissolve 2.50 g of 4, 4' -methylenedianiline (colorless or only slightly colored) in glacial acetic acid to make 250 mL. Protect the solution from light.

NOTE 6: Slowly add 4.5 mL of 70% perchloric acid to about 400 mL of glacial acetic acid and dilute with glacial acetic acid to 500 mL. Standardize against potassium hydrogen phthalate in glacial acetic acid solution using crystal violet as indicator.

8.12 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 - 125% of a known sample spike for half of the value of each specified item.

8.12.1 *Special Reagents*

8.12.1.1 *Solution A* — Glycerol (ACS Reagent Grade) 10 g, Adipic Acid (99+%) 1 g, EDTA Acid (ACS Reagent Grade) 0.1 g. Dilute to 1 L using water meeting the criteria for Type E1 in ASTM D5127.

8.12.1.2 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.12.1.3 *2% Nitric Acid Solution* — Dilute 10 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1 in ASTM D5127.

8.12.2 *Sample Preparation*

8.12.2.1 In a clean environment, place 100 grams of sample in a PTFE dish. Add 50 mL of solution A. Slowly evaporate on a hot water bath avoiding loss of sample by effervescence or spattering until there is no further loss of liquid. Cool. Add 1 mL of ultra pure, 70% nitric acid. While maintaining volume, carefully warm several minutes to dissolve any residue. Cool. Transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid for rinsing and dilution to volume. Run a reagent blank.

8.12.3 *Analysis*

8.12.3.1 Using the acidic sample standards and a reagent blank, analyze group I elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Acetic Acid

Previous SEMI Reference #	C1.1-96
	Grade 1 (Specification)
Assay (CH_3COOH)	99.7% min
Color (APHA)	10 max
Residue after Evaporation	10 ppm max
Solubility in Water	To pass test
Substances Reducing Dichromate	To pass test
Substances Reducing Permanganate	To pass test
Chloride (Cl)	1 ppm max
Phosphate (PO_4)	1 ppm max
Sulfate (SO_4)	0.5 ppm max
Acetic Anhydride [$(CH_3CO)_2O$]	0.1% max
Aluminum (Al)	0.3 ppm max
Arsenic and Antimony (as As)	0.005 ppm max
Boron (B)	0.2 ppm max
Calcium (Ca)	0.3 ppm max
Chromium (Cr)	0.2 ppm max
Copper (Cu)	0.1 ppm max
Gold (Au)	0.3 ppm max
Iron (Fe)	0.2 ppm max
Lead (Pb)	0.3 ppm max
Magnesium (Mg)	0.3 ppm max
Manganese (Mn)	0.3 ppm max
Nickel (Ni)	0.1 ppm max
Potassium (K)	0.3 ppm max

Previous SEMI Reference #	C1.1-96
	Grade 1 (Specification)
Sodium (Na)	0.3 ppm max
Tin (Sn)	0.3 ppm max
Titanium (Ti)	0.3 ppm max
Zinc (Zn)	0.3 ppm max
Particles in bottles: size, #/mL	≥1.0 µm, 25 max

SEMI C19-0301
SPECIFICATION FOR ACETONE

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.2 in its entirety. Originally published in 1978; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for acetone used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of acetone for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of acetone used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.79 g/mL
Boiling Point	56.3°C

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

7 Requirements

7.1 The requirements for acetone for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D.-fused silica capillary, coated with 1 mm film of DB-1701 or equivalent (14% cyanopropyphenyl which has been surface bonded and crosslinked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	1 µL split
Carrier Gas:	Helium at 3 mL/min
Detector:	Flame Ionization
Approximate Retention Times (min):	
Methanol	1.1
Acetaldehyde	2.3
Acetone	2.9
Isopropanol	3.3
Cumene	10.0
Mesityl Oxide	11.8
Diacetone Alcohol	12.0

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight, pink color persists after shaking for one-half minute. Add 42 mL (33 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 1.0 mL of the sodium hydroxide solution should be required.

8.4 *Alkalinity* — Add 25 mL (20 g) of sample to 25 mL of water and mix well. Add 0.05 mL of methyl red indicator solution. Titrate with 0.01 N hydrochloric acid until a slight pink color is produced. Not more than 1.0 mL of the hydrochloric acid should be required.

8.5 *Residue after Evaporation* — Evaporate 253 mL (200 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.6 *Water* — Add 25 mL of pyridine to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 25 mL (20 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\%\ \text{Water}\ (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor}\ (\text{g}\ H_2O/\text{mL}) \times 100}{\text{Weight of sample}\ (\text{g})}$$

8.7 *Solubility in Water* — Mix 40 mL of sample with 40 mL of water. Allow to stand for 30 minutes. The solution should be as clear as an equal volume of water.

8.8 *Chloride* — To 63 mL (50 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 10 mL of water. Add 1 mL of nitric acid, dilute to 20 mL with water, and add 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.9 *Phosphate* — To 125 mL (100 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.10 *Arsenic and Antimony (as As)* — Evaporate 250 mL (200 g) of sample in a 400 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric acid, 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.11 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 - 125% of a known sample spike for half of the value of each specified item.

8.11.1 *Special Reagents*

8.11.1.1 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.11.1.2 *Mannitol Powder* — Use mannitol specified for reagent grade (A.C.S.) and determined, via the reagent blank, to be ultra low metal ion content.

8.11.1.3 *5% Mannitol Solution* — Dissolve and dilute 5 g of mannitol to 100 mL using water meeting the criteria for Type E1 in ASTM D5127.

8.11.1.4 *2% (v/v) Hydrochloric Acid Solution* — Dilute 20 mL of ultra pure, 12 M hydrochloric acid to 1 L using water meeting the criteria for Type E1 in ASTM D5127.

8.11.2 *Sample Preparation*

8.11.2.1 In a clean environment, place 250 g of solvent in a PTFE dish. Add 0.5 mL of freshly prepared 5% mannitol solution. Slowly evaporate on a hot plate avoiding loss of sample by effervescence or spattering until approximately 1 mL of liquid remains. Take up liquid and all visible residue (from walls of dish) with 1 mL ultra pure, 12 M hydrochloric acid and continue heating until approximately 0.5 mL of liquid remains. No undissolved particulate matter should be observed. Otherwise repeat the addition of hydrochloric acid until all particulate matter is dissolved. Transfer quantitatively to a 50 mL volumetric flask using 2% (v/v) hydrochloric acid and adjust liquid level to mark. Prepare a reagent blank using the same reagents and in the same manner as for the sample concentration.

8.11.3 *Analysis*

8.11.3.1 Using the prepared sample and reagent blank, analyze group I elements potassium (K) and sodium (Na) by atomic absorption spectroscopy and all other elements by plasma emission spectrometry. Apply, if necessary, a reagent blank correction to the final determined value of the sample.

NOTE 3: Due to the uncertainty of acid concentration in the liquid residue the final concentration can be estimated to be approximately 2% (v/v).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Acetone

Previous SEMI Reference #	C1.2-96
	Grade 1
	(Specification)
Assay ($[CH_3]_2CO$)	99.5% min
Color (APHA)	10 max
Acidity	0.3 µeq/g max
Alkalinity	0.5 µeq/g max
Residue after Evaporation	5 ppm max
Water (H_2O)	0.5% max
Solubility in Water	To pass test
Chloride (Cl)	0.2 ppm max
Phosphate (PO_4)	0.1 ppm max
Aluminum (Al)	0.1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Boron (B)	0.1 ppm max
Calcium (Ca)	0.1 ppm max
Chromium (Cr)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gold (Au)	0.1 ppm max
Iron (Fe)	0.1 ppm max
Lead (Pb)	0.1 ppm max
Magnesium (Mg)	0.1 ppm max
Manganese (Mn)	0.1 ppm max
Nickel (Ni)	0.1 ppm max
Potassium (K)	0.1 ppm max
Sodium (Na)	0.1 ppm max
Tin (Sn)	0.1 ppm max
Titanium (Ti)	0.1 ppm max

Previous SEMI Reference #	C1.2-96
	Grade 1
	(Specification)
Zinc (Zn)	0.1 ppm max
Particles in bottles: size, #/mL	≥1.0 µm, 10 max

SEMI C20-1101
SPECIFICATION AND GUIDELINES FOR AMMONIUM FLUORIDE 40%

This specification and these guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. This document replaces SEMI C1.3, C7.18, and C11.2 in their entirety. Originally published in 1978, 1995, and 1994 respectively. Previously published March 2001.

1 Purpose

1.1 The purpose of this document is to standardize requirements for ammonium fluoride 40% used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of ammonium fluoride 40% for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of ammonium fluoride 40% used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

SEMI C1 — Specifications for Reagents

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.11 g/mL

7 Requirements

7.1 The requirements for ammonium fluoride 40% for Grade 1, VLSI Grade, and Tiers A and B are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Accurately weigh 3 g of sample in a polyethylene weighing bottle. Transfer with water to a polyethylene beaker and dilute to 100 mL. Add 40 mL of neutralized formaldehyde solution and stir magnetically for 15 minutes or allow to stand for 1/2 hour. Titrate with standardized 1 N sodium hydroxide to a slight pink color.

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 3.704}{\text{Weight of sample (g)}}$$

NOTE 2: *Neutralized formaldehyde solution:* Dilute 20 mL of 37% formaldehyde solution with 20 mL of water, add 0.1 mL of phenolphthalein indicator solution, and titrate with 0.1 N sodium hydroxide to a slight pink color.

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *pH of a 1% solution* — Dilute 2.5 mL (2.8 g) of sample to 100 mL with carbon dioxide- and ammonia-free water. Using a pH meter determine the pH at 25°C 1 to 2 minutes after immersion of electrodes. The pH range 6.0–7.5 corresponds to 0.2% free hydrogen fluoride (HF) to 0.2% ammonium hydroxide (NH_4OH) in the original solution.

8.4 *Chloride* — Mix 2.2 mL (2.5 g) of sample with 20 mL of water containing 0.5 g of boric acid. Add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution, and allow to stand for 5 minutes. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.5 *Nitrate* — To 2 mL of water in a white plastic beaker, add 0.9 mL (1 g) of sample, 1 mL of sulfuric acid, 0.05 mL of 0.01 N (0.002 M) potassium permanganate, mix, and decolorize with sodium arsenite reagent solution. Dilute to 50 mL with brucine sulfate reagent solution and mix. Heat the solution in a preheated (boiling water) bath for 10 minutes. Cool rapidly in an ice bath to room temperature. The yellow color of the sample should be no greater than that produced when 0.01 mg of nitrate ion (NO_3) is treated as the sample.

8.6 *Phosphate* — To a 9 mL (10 g) sample in a platinum dish, add 1 mL of sodium carbonate reagent solution and 40 mL of nitric acid. Evaporate carefully, to prevent spattering, to near dryness. Cool, wash down the sides of the dish with 5 mL of nitric acid, and evaporate to dryness. Repeat the evaporation with nitric acid two more times to ensure complete removal of all the fluoride. To the cooled dish, add 25 mL of 0.5 N sulfuric acid to dissolve the residue, warming if necessary. Cool, transfer to a color comparison tube, and add 1 mL of ammonium molybdate reagent solution, 1 mL of p-(methylamino)phenol sulfate reagent solution, and allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.7 *Sulfate* — To 23 mL (25 g) of sample, add 10 mL of sodium carbonate reagent solution and heat gently until sample has been volatilized. To the residue add 5 mL of hydrochloric acid and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) solution is treated as the sample.

8.8 *Arsenic and Antimony (as As)* — To 30 mL (33 g) in a fluoroplastic beaker, add 20 mL of nitric acid and 5 mL of hydrochloric acid, and evaporate to dryness in a sand bath in a hood. Completely volatilize the ammonium fluoride, but do not bake. Add 10 mL of water and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence that begins, "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.9 *Trace Element Contents* — By a suitable emission spectrographic procedure, determine for each of the specified trace elements that its content is not greater than the stated specification limit (see SEMI C1, Section 3.5, Guidelines for Emission Spectrography).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Section 8 for available procedures.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Ammonium Fluoride 40%

Previous SEMI Reference #	C1.3-95	C11.2-94	C7.18-95	--
	Grade 1 (Specification)	VLSI Grade (Guideline)	Tier A (Guideline)	Tier B (Guideline)
Assay (NH_4F)	39.0–41.0% min	39–41% min	39.0–41.0%	39.0–41.0%
Color (APHA)	10 max	10 max	10 max	10 max
Residue after Ignition	--	10 ppm max	--	--
pH (1% solution at 25°C)	6.0–7.5	6.2–7.0	6.0–7.5	6.0–7.5
Ammonium Hydrogen Fluoride (NH_4HF_2)	--	200 ppm max	--	--
Chloride (Cl)	4 ppm max	2 ppm max	2 ppm max	2 ppm max
Nitrate (NO_3)	10 ppm max	10 ppm max	3 ppm max	3 ppm max
Phosphate (PO_4)	1 ppm max	0.2 ppm max	0.5 ppm max	0.5 ppm max
Sulfate (SO_4)	2 ppm max	2 ppm max	2 ppm max	2 ppm max
Aluminum (Al)	0.2 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Antimony (Sb)	--	--	10 ppb max	1 ppb max
Arsenic (As)	--	--	10 ppb max	1 ppb max
Arsenic and Antimony (as As)	0.03 ppm max	0.03 ppm max	--	--
Barium (Ba)	--	0.01 ppm max	10 ppb max	1 ppb max
Beryllium (Be)	--	0.01 ppm max	--	--
Bismuth (Bi)	--	0.02 ppm max	--	--
Boron (B)	0.2 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Cadmium (Cd)	--	0.01 ppm max	10 ppb max	1 ppb max
Calcium (Ca)	0.2 ppm max	0.1 ppm max	10 ppb max	1 ppb max
Chromium (Cr)	0.1 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Cobalt (Co)	--	0.01 ppm max	--	--
Copper (Cu)	0.1 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Gallium (Ga)	--	0.01 ppm max	--	--
Germanium (Ge)	--	0.05 ppm max	--	--
Gold (Au)	0.3 ppm max	0.02 ppm max	--	--
Indium (In)	--	0.01 ppm max	--	--
Iron (Fe)	0.2 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Lead (Pb)	0.3 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Lithium (Li)	--	0.01 ppm max	10 ppb max	1 ppb max
Magnesium (Mg)	0.2 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Manganese (Mn)	0.2 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Molybdenum (Mo)	--	0.01 ppm max	--	--
Nickel (Ni)	0.3 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Platinum (Pt)	--	0.05 ppm max	--	--
Potassium (K)	0.3 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Silicon (Si)	--	200 ppm max	3000 ppb max (See NOTE 1.)	--
Silver (Ag)	--	0.05 ppm max	--	--
Sodium (Na)	0.3 ppm max	0.1 ppm max	10 ppb max	1 ppb max
Strontium (Sr)	--	0.01 ppm max	--	--
Thallium (Tl)	--	0.02 ppm max	--	--
Tin (Sn)	0.2 ppm max	0.02 ppm max	10 ppb max	1 ppb max
Titanium (Ti)	0.3 ppm max	0.01 ppm max	10 ppb max	1 ppb max
Vanadium (V)	--	0.01 ppm max	10 ppb max	1 ppb max
Zinc (Zn)	0.2 ppm max	0.05 ppm max	10 ppb max	1 ppb max
Zirconium (Zr)	--	0.01 ppm max	--	--

Previous SEMI Reference #	C1.3-95	C11.2-94	C7.18-95	--
	Grade 1	VLSI Grade	Tier A	Tier B
	(Specification)	(Guideline)	(Guideline)	(Guideline)
Particles in bottles: size, #/mL	≥ 1.0 µm, 25 max	≥ 0.5 µm, 250 max	See NOTE 2.	See NOTE 2.

NOTE 1: For III-V compound users only.

NOTE 2: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standard set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C21-0301
SPECIFICATIONS AND GUIDELINES FOR AMMONIUM HYDROXIDE

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available on SEMI OnLine February 2001; to be published March 2001. This document replaces SEMI C1.4, C7.1, C8.1, C11.1, and C17.1 in their entirety. Originally published in 1978, 1990, 1992, 1994, and 1997 respectively; previously published June 2000.

1 Purpose

1.1 The purpose of this document is to standardize requirements for ammonium hydroxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of ammonium hydroxide for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of ammonium hydroxide used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The guideline for VLSI grade ammonium hydroxide is only applicable for materials that remain below 25°C during transport and storage.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.90 g/mL

7 Requirements

7.1 The requirements for ammonium hydroxide for Grades 1, 2, 3, and 4, and VLSI Grade are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh a small glass-stoppered flask containing about 15 mL of water. Deliver from a pipet about 2 mL of the sample near the water surface, stopper immediately, and reweigh. Add 0.1 mL of methyl red indicator solution and titrate with standardized 1 N hydrochloric acid to a yellow-to-red color change.

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of HCl} \times 1.703}{\text{Weight of sample (g)}}$$

8.2 *Appearance* — Place 15 mL of the sample in a 20 × 150 mm test tube and compare with water in a similar tube. Viewed across the column by means of transmitted light, the two liquids should be equal in clarity and free from suspended matter.

8.3 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.4 *Carbon Dioxide* — Dilute 11 mL (10 g) of sample with 10 mL of carbon dioxide-free water and add 5 mL of a clear, saturated solution of barium hydroxide. Any turbidity should be no greater than that produced when

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

the same volume of the barium hydroxide solution is added to 21 mL of the carbon dioxide-free water containing 0.5 mg of anhydrous sodium carbonate.

8.5 *Substances Reducing Permanganate* — Dilute 3 mL (2.7 g) of sample with 5 mL of water. Add 50 mL of 10% sulfuric acid and 0.05 mL of 0.1 N (0.02 M) potassium permanganate. Boil for 5 minutes. The pink color should not be entirely discharged.

8.6 *Chloride* — To 22 mL (20 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 10 mL of water. Add 1 mL of nitric acid. Filter, if necessary, through a chloride-free filter. Dilute to 20 mL with water and add 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.7 *Phosphate* — Evaporate 22 mL (20 g) of sample to dryness on a steam bath in a hood. Take up the residue with 25 mL of approximately 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution, and allow to stand for 2 hours at room temperature. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.8 *Total Sulfur (as SO_4)* — To 56 mL (50 g) of sample, add 1 mL of sodium carbonate reagent solution and evaporate on a steam bath in a hood to a volume of about 5 mL. Add 2 mL of bromine water and evaporate to dryness. Dissolve the residue with 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter, if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) is treated as the sample.

8.9 *Arsenic and Antimony (as As)* — Evaporate 44 mL (40 g) of sample in a 150 mL beaker to a small volume in a hood. Cool, cautiously add 10 mL of water and 5 mL of sulfuric acid, and wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section, 3.4.5, starting with the sentence that begins, "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.10 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 - 125% of a known sample spike for half of the value of each specified item.

8.10.1 *Special Reagents*

8.10.1.1 *5% Mannitol Solution* — Weigh out 5 g of Mannitol Powder (ACS Reagents Grade), and dilute to 100 mL using water meeting the criteria for Type E1 in ASTM D5127. Mannitol solution is subject to attack by microorganisms and should be carefully monitored for such contamination.

8.10.1.2 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.10.1.3 *2% (v/v) Hydrochloric Acid Solution* — Dilute 20 mL of ultra pure hydrochloric acid to 1 L using water meeting the criteria for Type E1 in ASTM D5127.

8.10.2 *Sample Preparation*

8.10.2.1 In a clean environment, place 250 mL of aqueous ammonium hydroxide in a PTFE dish. Add 0.5 mL of freshly prepared 5% mannitol solution. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 1 mL of liquid remains. Cool. Add 1 mL of ultra pure, 12 M hydrochloric acid. Continue heating until approximately 0.5 mL of liquid remains. Cool. Transfer quantitatively to 50 mL volumetric flask using 2% (v/v) hydrochloric acid for rinsing and dilution to volume. Run reagent blank.

8.10.3 *Analysis*

8.10.3.1 Using the acid sample and reagent blank, analyze group 1 elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy.

NOTE 3: Due to the uncertainty of the acid concetration in the liquid residue, the final concentration can be estimated at approximately 1-2% (v/v). Standard calibration solutions are to use this same acid concentration.

9 Grade 2 Procedures

NOTE 4: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities*

9.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Carbon Dioxide

Substances Reducing Permanganate

9.2 *Anions*

9.2.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

9.2.2 *Special Reagents*

9.2.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate ($NaHCO_3$) in deionized water meeting the criteria for Type E1.1 in ASTM D5127. Store eluent under a helium gas blanket.

9.2.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) into 100 mL of water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.3 *Sample Preparation*

9.2.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 20 mL.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

9.2.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent and Separation column should be AS4-A (Dionex) or equivalent.

9.3 *Trace Metals Analysis*

9.3.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.3.2 *Special Reagents*

9.3.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.3.2.2 *4% Nitric Acid Solution* — Dilute 40 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

9.3.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.3.2.4 *Indium Internal Standard* — Make up an indium internal standard solution to a concentration of 20 µg/mL (ppm) from an appropriate concentrated indium standard solution.

9.3.3 *Sample Preparation*

9.3.3.1 In a clean environment, evaporate a 50.0 g sample at low heat until approximately 20 g of the sample remains. Carefully add 1 mL of the ultra pure nitric acid and gently warm for several minutes. Cool to room temperature, add 25 µL of the indium internal standard, and dilute with Type E1.1 water to a final weight of 25.0 g.

9.3.4 *Analysis*

9.3.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up in 4% nitric acid solution with final concentration of 20 ng/g of the indium internal standard. Run a reagent blank.

10 Grade 3 Procedures

NOTE 5: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 6: Each laboratory is responsible for verifying the validity of each method within its own operation.

10.1 *Non-Metal Impurities*

10.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Carbon Dioxide

Substances Reducing Permanganate

10.2 *Anions*

10.2.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.2.2 *Special Reagents*

10.2.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate ($NaHCO_3$) in deionized water meeting the criteria for Type E1.1 in ASTM D5127. Store eluent under a helium gas blanket.

10.2.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.2.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) in 100 mL of water meeting the criteria for Type E1.1 in ASTM D5127.

10.2.3 *Sample Preparation*

10.2.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 20 mL.

10.2.4 *Analysis*

10.2.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

10.2.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent, and separation column should be AS4-A (Dionex) or equivalent.

10.3 *Trace Metals Analysis*

10.3.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.3.2 *Special Reagents*

10.3.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

10.3.2.2 *4% Nitric Acid Solution* — Dilute 40 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

10.3.2.4 *Indium Internal Standard* — Make up an indium internal standard solution to a concentration of 20 µg/mL (ppm) from an appropriate concentrated indium standard solution.

10.3.3 *Sample Preparation*

10.3.3.1 In a clean environment, evaporate a 50.0 g sample at low heat until approximately 20 g of the sample remains. Carefully add 1 mL of the ultra pure nitric acid and gently warm for several minutes. Cool to room temperature, add 25 µL of the indium internal standard, and dilute with Type E1.1 water to a final weight of 25.0 g.

10.3.4 *Analysis*

10.3.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up in 4% nitric acid solution with final concentration of 20 ng/g of the indium internal standard. Run a reagent blank.

11 Grade 4 Procedures

NOTE 7: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 8: Each laboratory is responsible for verifying the validity of each method within its own operation.

11.1 *Non-Metal Impurities*

11.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Carbon Dioxide

Substances Reducing Permanganate

11.2 *Anions*

11.2.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

11.2.2 *Reagents*

11.2.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate ($NaHCO_3$) in deionized water meeting the criteria for Type E1.1 in ASTM D5127. Store eluent under a helium gas blanket.

11.2.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

11.2.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) in 100 mL of water meeting the criteria for Type E1.1 in ASTM D5127.

11.2.3 *Sample Preparation*

11.2.3.1 In a clean environment, place 200 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 20 mL.

11.2.4 *Analysis*

11.2.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

11.2.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent, and separation column should be AS4-A (Dionex) or equivalent.

11.3 *Trace Metals Analysis*

11.3.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

11.3.2 *Special Reagents*

11.3.2.1 *Nitric Acid, Ultrapure* — Use nitric acid of low metal ion content.

11.3.2.2 *2% Nitric Acid Solution* — Dilute ultrapure nitric acid with water meeting the criteria for Type E1.1 in ASTM D5127.

11.3.2.3 *Water* — The water used for dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

11.3.2.4 *Internal Standard Solution* — Make up an internal standard solution to a concentration of 1000 µg/mL from appropriate concentrated scandium, yttrium, indium, thulium, and thorium standard solutions.

11.3.3 *Sample Preparation*

11.3.3.1 In a clean environment, in a teflon bottle, evaporate a 50.0 g sample at low heat until approximately 5 g of the sample remains. Cool to room temperature, add 100 µL of the internal standard solution, and dilute with 2% nitric acid to a final weight of 10.0 g.

11.3.4 *Analysis*

11.3.4.1 Using the prepared solutions and blanks, calibrate the instrument and analyze calcium, iron, sodium, and potassium by cool plasma inductively coupled plasma mass spectrometry (ICP-MS) and the remaining elements by normal plasma ICP-MS.

11.3.4.2 *Calculations* — All data were reported relative to an appropriate 1.0 µg/L standard and corresponding blank solution. Internal standard corrections were applied to the data.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

Table 1 Impurity Limits and Other Requirements for Ammonium Hydroxide

Previous SEMI Reference #	C1.4-95	C7.1-96	C8.1-0298	C17.1-0298	C11.1-94	--
	Grade 1 (Specification)	Grade 2 (Specification)	Grade 3 (Specification)	Grade 4 (Specification)	VLSI Grade (Guideline)	Tier D (Guideline)
Assay (as NH_3)	28.0 - 30.0%	28.0 - 30.0%	28.0 - 30.0%	28.0 - 30.0%	25.0 - 27.0% or 28.0 - 30.0%	28.0 - 30.0%
Appearance	To pass test	--	--	--	--	--
Color (APHA)	10 max	10 max	10 max	10 max	10 max	10 max
Residue after Ignition	--	--	--	--	2 ppm max	--
Residue after Evaporation	--	--	--	--	10 ppm max	--
Substances Reducing $KMnO_4$ (as O)	--	--	--	--	5 ppm max	--
Substances Reducing Permanganate	To pass test	To pass test	To pass test	To pass test	--	--
Carbon Dioxide (CO_2)	20 ppm max	20,000 ppb max	20 ppm max	20 ppm max	--	20 ppm max
Carbonate (CO_2)	--	--	--	--	10 ppm max	--
Chloride (Cl)	0.5 ppm max	200 ppb max	100 ppb max	50 ppb max	0.5 ppm max	30 ppb max
Nitrate (NO_3)	--	400 ppb max	100 ppb max	50 ppb max	--	30 ppb max
Phosphate (PO_4)	0.5 ppm max	200 ppb max	100 ppb max	40 ppb max	0.2 ppm max	30 ppb max
Silica (SiO_2)	--	--	--	--	0.2 ppm max	--
Sulfide (S)	--	--	--	--	0.2 ppm max	--
Sulfate (SO_4)	--	200 ppb max	100 ppb max	50 ppb max	2 ppm max	30 ppb max
Total Sulfur (SO_4)	1 ppm max	--	--	--	--	--
Aluminum (Al)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.05 ppm max	10 ppt max
Antimony (Sb)	--	5 ppb max	1 ppb max	100 ppt max	--	10 ppt max
Arsenic (As)	--	5 ppb max	1 ppb max	100 ppt max	--	10 ppt max
Arsenic and Antimony (as As)	0.05 ppm max	--	--	--	0.05 ppm max	--
Barium (Ba)	--	--	--	--	0.01 ppm max	10 ppt max
Beryllium (Be)	--	--	--	--	0.01 ppm max	--
Bismuth (Bi)	--	--	--	--	0.02 ppm max	--
Boron (B)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Cadmium (Cd)	--	--	--	--	0.01 ppm max	10 ppt max
Calcium (Ca)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.1 ppm max	10 ppt max
Chromium (Cr)	0.2 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Cobalt (Co)	--	--	--	--	0.01 ppm max	--
Copper (Cu)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Gallium (Ga)	--	--	--	--	0.01 ppm max	--
Germanium (Ge)	--	--	--	--	0.05 ppm max	--
Gold (Au)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.02 ppm max	--

Previous SEMI Reference #	C1.4-95	C7.1-96	C8.1-0298	C17.1-0298	C11.1-94	--
	Grade 1	Grade 2	Grade 3	Grade 4	VLSI Grade	Tier D
	(Specification)	(Specification)	(Specification)	(Specification)	(Guideline)	(Guideline)
Indium (In)	--	--	--	--	0.01 ppm max	--
Iron (Fe)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	0.05 ppm max	10 ppt max
Lead (Pb)	0.2 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Lithium (Li)	--	--	--	--	0.01 ppm max	--
Magnesium (Mg)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.05 ppm max	10 ppt max
Manganese (Mn)	0.2 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Molybdenum (Mo)	--	--	--	--	0.01 ppm max	--
Nickel (Ni)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Platinum (Pt)	--	--	--	--	0.02 ppm max	--
Potassium (K)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.1 ppm max	10 ppt max
Silver (Ag)	--	--	--	--	0.01 ppm max	--
Sodium (Na)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.2 ppm max	10 ppt max
Strontium (Sr)	--	--	--	--	0.01 ppm max	--
Thallium (Tl)	--	--	--	--	0.02 ppm max	--
Tin (Sn)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.02 ppm max	10 ppt max
Titanium (Ti)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.01 ppm max	10 ppt max
Vanadium (V)	--	--	--	--	0.01 ppm max	--
Zinc (Zn)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	0.05 ppm max	10 ppt max
Zirconium (Zr)	--	--	--	--	0.01 ppm max	--
Particles in bottles: size, #/mL	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 25 max (see NOTE 1)	≥ 0.5 µm, 250 max	(See NOTE 2.)

NOTE 1: Care must be taken in analyzing particles because of the potential formation of microbubbles.

NOTE 2: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

SEMI C22-0699
GUIDELINE FOR BORON TRIBROMIDE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.17 in its entirety. Originally published in 1994.

1 Purpose

1.1 The purpose of this document is to standardize requirements for boron tribromide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of boron tribromide for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of boron tribromide used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Clear Colorless Liquid Density at 20°C	2.54 g/mL

7 Requirements

7.1 The requirements for boron tribromide for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Boron Tribromide

Previous SEMI Reference #	C7.17-94
	Tier A
	(Guideline)
Color (APHA)	60 max
Aluminum (Al)	5 ppb max
Antimony (Sb)	5 ppb max
Arsenic (As)	10 ppb max
Barium (Ba)	5 ppb max
Bismuth (Bi)	5 ppb max
Calcium (Ca)	10 ppb max
Chromium (Cr)	5 ppb max
Cobalt (Co)	5 ppb max
Copper (Cu)	5 ppb max
Gallium (Ga)	5 ppb max
Gold (Au)	5 ppb max
Iron (Fe)	10 ppb max
Lead (Pb)	5 ppb max
Lithium (Li)	5 ppb max
Magnesium (Mg)	10 ppb max
Manganese (Mn)	5 ppb max
Mercury (Hg)	10 ppb max
Nickel (Ni)	5 ppb max
Potassium (K)	5 ppb max
Silver (Ag)	5 ppb max
Sodium (Na)	5 ppb max
Strontium (Sr)	5 ppb max
Tin (Sn)	5 ppb max
Titanium (Ti)	5 ppb max
Zinc (Zn)	5 ppb max
Particles in bottles: size, #/mL	≥0.5 µm, 25 max

SEMI C23-0301
SPECIFICATIONS FOR BUFFERED OXIDE ETCHANTS

These specifications were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C2.2 and C7.23 in their entirety. Originally published in 1981 and 1997 respectively; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for buffered oxide etchants used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of buffered oxide etchants for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of buffered oxide etchants used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *buffered oxide etchant* — any combination of ammonium fluoride and hydrofluoric acid in which the concentrations are expressed in terms of the equivalent relative volumes of 40% ammonium fluoride solution and 49% hydrofluoric acid. In the expression, the relative volumes shall be reduced to a ratio of the smallest whole numbers which properly describes the composition. For example, a 7:1 buffered oxide etchant contains the equivalent of 7 volumes of 40.0% ammonium fluoride and 1 volume of 49% hydrofluoric acid.

NOTE 2: Density at temperature.

6 Composition

6.1 For analytical purposes, the absolute concentrations of ammonium fluoride and hydrofluoric acid corresponding to the above definition shall be calculated according to the following equations.

$$\text{Weight \% } NH_4F = \frac{(\text{volume} \times \text{density} \times \text{concentration})\,NH_4F}{(\text{volume} \times \text{density})\,NH_4F + (\text{volume} \times \text{density})\,HF}$$

$$\text{Weight \% HF} = \frac{(\text{volume} \times \text{density} \times \text{concentration})\,HF}{(\text{volume} \times \text{density})\,NH_4F + (\text{volume} \times \text{density})\,HF}$$

where volume and density are expressed in consistent units and concentration is in weight percent to three significant figures.

6.2 Sample calculation for 7:1 buffered oxide etchant using 40.0% ammonium fluoride, density 1.111 g/mL, and 49.0% hydrofluoric acid, density 1.153 g/mL. The absolute percentage concentration of each component follows:

$$\text{Weight \% } NH_4F = \frac{7 \times 1.111 \times 40.0}{7 \times 1.111 + 1 \times 1.153} = 34.8\%$$

$$\text{Weight \% HF} = \frac{1 \times 1.153 \times 49.0}{7 \times 1.111 + 1 \times 1.153} = 6.33\%$$

7 Tolerances

7.1 The tolerances allowed for the absolute percentage of each of the components of a buffered oxide etchant shall be:

Ammonium Fluoride:	± 0.5%
Hydrofluoric Acid:	± 0.15%

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

7.2 For the example above, the permissible range of concentration for ammonium fluoride shall be 34.8 ± 0.5% and for hydrofluoric acid 6.33 ± 0.15%.

8 Requirements

8.1 The requirements for buffered oxide etchants for Grades 1 and 2 are listed in Table 1.

9 Grade 1 Procedures

9.1 *Hydrofluoric Acid* — Weigh accurately approximately 4.0 grams of sample, transfer to a polyethylene beaker, and dilute with water to about 100 mL. Titrate with standardized 1 N sodium hydroxide. The endpoint may be detected colorimetrically by adding 3 drops of methyl red indicator solution and titrating to a definite yellow (no orange) endpoint. As an alternate method, the endpoint may be detected potentiometrically using an HF resistant pH electrode previously standardized in pH 4 and pH 7 buffers. Titrate to pH 6.5 with continuous stirring. Save the solution for the determination of ammonium fluoride.

$$\%\ \text{Hydrofluoric Acid} = \frac{\text{mL} \times \text{N of NaOH} \times 2.001}{\text{Weight of sample (g)}}$$

9.2 *Ammonium Fluoride* — Add 40 mL of neutralized formaldehyde solution (see Section 9.2.1) to the solution from the preceding test and stir magnetically for 30 minutes. Titrate with standardized 1 N sodium hydroxide. The endpoint may be detected colorimetrically using 10 drops of phenolphthalein indicator and titrating to a stable pink end point. As an alternative method, the endpoint may be detected potentiometrically using an HF resistant electrode previously standardized in pH 7 and 9 buffers. Titrate to pH 8.5 with continuous stirring.

$$\%\ \text{Ammonium Fluoride} = \frac{\text{mL} \times \text{N of NaOH} \times 3.704}{\text{Weight of sample (g)}}$$

9.2.1 *Neutralized Formaldehyde Solution* — Dilute 20 mL of 37% formaldehyde solution with 20 mL of water and neutralize with 0.1 N sodium hydroxide solution to the phenolphthalein endpoint.

9.3 *Arsenic and Antimony (as As)* — To 30 mL (33 g) of sample in a polyfluorocarbon dish, add 20 mL of nitric acid and 5 mL of hydrochloric acid and evaporate in a sand bath in a hood to dryness. Completely volatilize the ammonium fluoride, but do not bake. Add 10 mL of water and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and reevaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, “Swirl the flask...” Any red color in the silver diethyldithiocarbamate solution of the sample should not exceed that in the standard containing 0.001 mg of arsenic ion (As).

9.4 *Trace Element Contents* — Determine the levels of specified trace elements and establish that they do not exceed the specification limits using a suitable emission spectrographic procedure (see SEMI C1, Section 3.5, Guidelines for Determination of Trace Elements by Emission Spectrography).

10 Grade 2 Procedures

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

10.1 *Hydrofluoric Acid* — Weigh accurately approximately 4.0 grams of sample, transfer to a polyethylene beaker, and dilute with water to about 100 mL. Titrate with standardized 1 N sodium hydroxide. The endpoint may be detected colorimetrically by adding 3 drops of methyl red indicator solution and titrating to a definite yellow (no orange) endpoint. As an alternate method, the endpoint may be detected potentiometrically using an HF resistant pH electrode previously standardized in pH 4 and pH 7 buffers. Titrate to pH 6.5 with continuous stirring. Save the solution for the determination of ammonium fluoride.

$$\%\ \text{Hydrofluoric Acid} = \frac{\text{mL} \times \text{N of NaOH} \times 2.001}{\text{Weight of sample (g)}}$$

10.2 *Ammonium Fluoride* — Add 40 mL of neutralized formaldehyde solution (see Section 10.2.1) to the solution from the preceding test and stir magnetically for 30 minutes. Titrate with standardized 1 N sodium hydroxide. The endpoint may be detected colorimetrically using 10 drops of phenolphthalein indicator and titrating to a stable pink endpoint. As an alternative method, the endpoint may be detected potentiometrically using an HF resistant electrode previously standardized in pH 7 and 9 buffers. Titrate to pH 8.5 with continuous stirring.

$$\%\ \text{Ammonium Fluoride} = \frac{\text{mL} \times \text{N of NaOH} \times 3.704}{\text{Weight of sample (g)}}$$

10.2.1 *Neutralized Formaldehyde Solution* — Dilute 20 mL of 37% formaldehyde solution with 20 mL of water and neutralize with 0.1 N sodium hydroxide solution to the phenolphthalein endpoint.

10.3 *Chloride* — Mix 2.2 mL (2.5 g) of sample with 20 mL of water containing 0.5 g of boric acid. Add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution, and allow to stand for 5 minutes. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

10.4 *Nitrate* — To 2 mL of water in a white plastic beaker, add 0.9 mL (1g) of sample, 1 mL of sulfuric acid, 0.05 mL of 0.01 N (0.002 M) potassium permanganate, mix, and decolorize with sodium arsenite reagent solution. Dilute to 50 mL with brucine sulfate reagent solution and mix. Heat the solution in a preheated (boiling water) bath for 10 minutes. Cool rapidly in an ice bath to room temperature. The yellow color of the sample should be no greater than that produced when 0.01 mg of nitrate ion (NO_3) is treated as the sample.

10.5 *Phosphate* — To a 9 mL (10 g) sample in a platinum dish, add 1 mL of sodium carbonate reagent solution and 40 mL of nitric acid. Evaporate carefully, to prevent spattering, to near dryness. Cool, wash down the sides of the dish with 5 mL of nitric acid, and evaporate to dryness. Repeat the evaporation with nitric acid two times to ensure complete removal of all the fluoride. To the cooled dish, add 25 mL of 0.5 N sulfuric acid to dissolve the residue, warming if necessary. Cool, transfer to a color comparison tube, and add 1 mL of ammonium molybdate reagent solution, 1 mL of p-(methylamino)phenol sulfate reagent solution, and allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

10.6 *Sulfate* — To 23 mL (25 g) of sample, add 10 mL of sodium carbonate reagent solution and heat gently until sample has been volatilized. To the residue, add 5 mL of hydrochloric acid and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) solution is treated as the sample.

10.7 *Trace Metals Analysis*

10.7.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), silver (Ag), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.7.2 *Special Reagents*

10.7.2.1 *Nitric Acid, Ultrapure* — Use nitric acid specified for low metal ion content.

10.7.2.2 *4% Nitric Acid Solution* — Dilute 40 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

10.7.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

10.7.2.4 *Indium Internal Standard* — Make up a indium internal standard solution to a concentration of 20 µg/mL (ppm) from an appropriate concentrated indium standard solution.

10.7.3 *Sample Preparation*

10.7.3.1 In a clean environment, weigh 10.0 g sample into a cleaned Teflon beaker and evaporate the sample on a 250°C hotplate to near dryness. Carefully add 1 mL of the ultrapure nitric and 3 mL of water and gently warm for several minutes. Cool to room temperature, add 25 µL of the indium internal standard, and dilute with Type E1.1 water to a final weight of 25.0 g.

10.7.4 *Analysis*

10.7.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up in 4% nitric acid solution with final concentration of 20 ng/g of the indium internal standard. Run a reagent blank.

11 Grade 3 Procedures

11.1 This section does not apply to this chemical.

12 Grade 4 Procedures

12.1 This section does not apply to this chemical.

13 Grade 5 Procedures

13.1 This section does not apply to this chemical.

14 VLSI Grade Procedures

14.1 This section does not apply to this chemical.

15 Tier A Procedures

15.1 This section does not apply to this chemical.

16 Tier B Procedures

16.1 This section does not apply to this chemical.

17 Tier C Procedures

17.1 This section does not apply to this chemical.

18 Tier D Procedures

18.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Buffered Oxide Etchants

Previous SEMI Reference #	C2.2-95	C7.23-0697
	Grade 1	Grade 2
	(Specification)	(Specification)
Chloride (Cl)	--	4 ppm max
Nitrate (NO_3)	--	10 ppm max
Phosphate (PO_4)	--	1 ppm max
Sulfate (SO_4)	--	2 ppm max
Aluminum (Al)	0.2 ppm max	10 ppb max
Antimony (Sb)	--	10 ppb max
Arsenic (As)	--	10 ppb max
Arsenic and Antimony (as As)	0.03 ppm max	--
Boron (B)	0.2 ppm max	20 ppb max
Calcium (Ca)	0.2 ppm max	10 ppb max
Chromium (Cr)	0.1 ppm max	5 ppb max
Copper (Cu)	0.1 ppm max	5 ppb max
Gold (Au)	0.3 ppm max	10 ppb max
Iron (Fe)	0.2 ppm max	5 ppb max
Lead (Pb)	0.3 ppm max	10 ppb max
Magnesium (Mg)	0.2 ppm max	10 ppb max
Manganese (Mn)	0.2 ppm max	10 ppb max
Nickel (Ni)	0.2 ppm max	10 ppb max
Potassium (K)	0.3 ppm max	5 ppb max
Sodium (Na)	0.3 ppm max	5 ppb max
Tin (Sn)	0.3 ppm max	10 ppb max
Titanium (Ti)	0.3 ppm max	10 ppb max
Zinc (Zn)	0.3 ppm max	5 ppb max
Particles in bottles: size, #/mL	≥ 1.0 µm, 25 max	≥ 0.5 µm, 150 max

SEMI C24-0301
SPECIFICATION FOR n-BUTYL ACETATE

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.5 in its entirety. Originally published in 1978; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for n-butyl acetate used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of n-butyl acetate for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of n-butyl acetate used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

6 Physical Property (for information only)

Density at 25°C	0.88 g/mL
Boiling Point	126.5°C

7 Requirements

7.1 The requirements for n-butyl acetate for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter ×. 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Butyl Acetate	8.0

8.2 *Color* — Dilute 3.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 15) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 57 mL (50 g) of sample in a 250 mL conical flask, add 0.5 mL of phenolphthalein indicator solution and titrate with 0.1 N alcoholic potassium hydroxide until a slight pink color persists for at least

15 seconds. Not more than 1.0 mL of the potassium hydroxide solution should be required.

8.4 *Residue after Evaporation* — Evaporate 90 mL (80 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue after Evaporation).

8.5 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 25 mL (22 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\%\ \text{Water}\ (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor}\ (gH_2O/mL) \times 100}{\text{Weight of sample (g)}}$$

8.6 *Phosphate* — To 11 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.7 *Arsenic and Antimony (as As)* — Evaporate 45 mL (40 g) of sample in a 150 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.8 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.8.1 *Special Reagents*

8.8.1.1 *Solution A* — Glycerol (ACS Reagent Grade) 10 g, Adipic Acid (99 + %) 1 g, EDTA Acid (ACS Reagent Grade) 0.1 g. Dilute to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.8.1.2 *Nitric Acid, Ultra Pure* — Use 70% nitric acid specified for ultra low metal ion content.

8.8.1.3 *2% Nitric Acid Solution* — Dilute 20 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.8.2 *Sample Preparation*

8.8.2.1 In a clean environment, place 250 g of sample in a PTFE dish. Add 50 mL of Solution A. Slowly evaporate in a hot plate avoiding loss of sample by effervescence or spattering until there is no further loss of liquid. Cool. Add 1 mL of ultra pure, 70% nitric acid. While maintaining volume, carefully warm several minutes to dissolve any residue. Cool. Transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid for rinsing and dilution to volume. Run a reagent blank.

8.8.3 *Analysis*

8.8.3.1 Using the prepared sample, analyze group I elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy. Apply, if necessary, a reagent blank correction to the final determined value of the sample.

NOTE 3: Repeat analysis for tin using larger sample size if the instrument sensitivity is insufficient at the specified limit.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for n-Butyl Acetate

Previous SEMI Reference #	C1.5-96
	Grade 1
	(Specfication)
Assay ($C_6H_{12}O_2$)	99.0% min
Color (APHA)	15 max
Acidity	2.0 μeq/g max
Residue after Evaporation	10 ppm max
Water (H_2O)	0.05% max
Phosphate (PO_4)	1 ppm max
Aluminum (Al)	0.1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Boron (B)	0.1 ppm max
Calcium (Ca)	0.1 ppm max
Chromium (Cr)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gold (Au)	0.1 ppm max
Iron (Fe)	0.1 ppm max
Lead (Pb)	0.1 ppm max
Magnesium (Mg)	0.1 ppm max
Manganese (Mn)	0.1 ppm max
Nickel (Ni)	0.1 ppm max
Potassium (K)	0.1 ppm max
Sodium (Na)	0.1 ppm max
Tin (Sn)	0.1 ppm max
Titanium (Ti)	0.1 ppm max
Zinc (Zn)	0.1 ppm max
Particles in bottles: size, #/mL	≥ 1.0 μm, 10 max

SEMI C25-0699^E
SPECIFICATION FOR DICHLOROMETHANE (METHYLENE CHLORIDE)

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.6 in its entirety. Originally published in 1978.

E This document was editorially modified in March 2000. Changes were made to the note following Table 1.

1 Purpose

1.1 The purpose of this document is to standardize requirements for dichloromethane (methylene chloride) used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of dichloromethane for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of dichloromethane used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.32 g/mL
Boiling Point	39.8°C

7 Requirements

7.1 The requirements for dichloromethane for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Dichloromethane	6.0
Chloroform	11.0
Carbon Tetrachloride	14.0

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight pink color persists after shaking for one-half minute. Add 38 mL (50 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 1.0 mL of the sodium hydroxide solution should be required.

8.4 *Residue After Evaporation* — Evaporate 76 mL (100 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.5 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 76 mL (100 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\% \text{ Water } (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor (g } H_2O\text{/mL)} \times 100}{\text{Weight of sample (g)}}$$

8.6 *Chloride* — To a 100 mL separatory funnel, add 30 mL (40 g) of sample and 40 mL of water. Shake well for 30 seconds and allow the two layers to separate. Discard the sample (lower) layer. To a 20 mL portion of the water layer add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that of a standard containing 0.01 mg of chloride ion (Cl) in an equal volume of solution containing the amounts of reagents used.

8.7 *Phosphate* — To 7.5 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.8 *Heavy Metals (as Pb)* — Evaporate 75 mL (100 g) of sample to dryness on a steam bath in a hood. Dissolve the residue in 3 mL of diluted hydrochloric acid (1 + 1) and dilute with water to 15 mL. If necessary, filter through a small filter and wash the evaporating dish and the filter with 10 mL of water. Dilute to 25 mL with water. For the standard, dilute a solution containing 0.02 mg of lead ion (Pb) and 3 mL of diluted hydrochloric acid (1 + 1) to 25 mL with water. Adjust the pH of both solutions to between 3 and 4 with diluted ammonium hydroxide (10% NH_3) or with acetic acid, and dilute with water to 40 mL. To each solution, add 10 mL of freshly prepared hydrogen sulfide water and compare. The sample solution should be no darker than the standard.

8.9 *Arsenic and Antimony (as As)* — Evaporate 152 mL (200 g) of sample in a 400 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.10 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 - 125% of a known sample spike for half of the value of each specified item.

8.10.1 *Special Reagents*

8.10.1.1 *Mixed Acid* — Mix one volume of ultra pure 70% nitric acid with four volumes of ultra pure 37% hydrochloric acid.

8.10.1.2 *Standards* — Composite standards containing 0.5 ppm of each element in 10% v/v mixed acid solution are stable for at least 60 days.

8.10.2 *Sample Preparation* — Place 2.5 mL of mixed acid into a clean 400 mL PTFE beaker. Weigh in 200 g of sample. Put a PTFE-coated stir bar in the solution and put the beaker in a hood. Evaporate the sample under a current of air, meeting class 100 cleanroom specifications, with stirring to ensure continuous contact of the acid and sample. Do not heat the sample to minimize the loss of volatile organo-metallics. Continue to evaporate until near dryness. Add 2.5 mL of mixed acid, mix carefully, and transfer the solution to a 25 mL volumetric flask. Rinse the beaker and dilute to volume with water.

8.10.3 *Analysis*

8.10.3.1 Analyze the sample by plasma emission spectrometry except sodium and potassium by atomic absorption or flame emission within 24 hours of dilution using matrix matched standards. Run a reagent blank and correct the data as necessary.

NOTE 2: The trace metal analysis procedure is provisional, pending second source verification of recovery data. To be completed.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Dichloromethane (Methylene Chloride)

Previous SEMI Reference #	*C1.6-96*
	Grade 1
	(Specification)
Assay (CH_2Cl_2)	98.0% min
Color (APHA)	10 max
Acidity	0.2 µeq/g
Residue after Evaporation	10 ppm max
Chloride (Cl)	0.5 ppm max
Heavy Metals (as Pb)	0.2 ppm max
Phosphate (PO_4)	1 ppm max
Water (H_2O)	0.01% max
Aluminum (Al)	1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Barium (Ba)	1 ppm max
Boron (B)	0.2 ppm max
Cadmium (Cd)	1 ppm max
Calcium (Ca)	1 ppm max
Chromium (Cr)	0.5 ppm max
Cobalt (Co)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gallium (Ga)	0.5 ppm max
Germanium (Ge)	1 ppm max
Gold (Au)	0.5 ppm max
Iron (Fe)	1 ppm max
Lithium (Li)	1 ppm max
Magnesium (Mg)	1 ppm max
Manganese (Mn)	1 ppm max
Nickel (Ni)	0.1 ppm max
Potassium (K)	1 ppm max
Silicon (Si)	1 ppm max
Silver (Ag)	0.5 ppm max
Sodium (Na)	1 ppm max
Strontium (Sr)	1 ppm max
Tin (Sn)	1 ppm max
Zinc (Zn)	1 ppm max

NOTE: Dichloromethane contains 0.0025–0.05% ethanol, cyclohexane, or mixed pentenes as stabilizer.

SEMI C26-0699^E

SPECIFICATION AND GUIDELINE FOR HEXAMETHYLDISILAZANE (HMDS)

This specification and guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.23 and C7.10 in their entirety. Originally published in 1983 and 1991 respectively.

^{E} This document was editorially modified in April 2000 to correct a formatting error. Changes were made to Table 1.

1 Purpose

1.1 The purpose of this document is to standardize requirements for hexamethyldisilazane used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of hexamethyldisilazane for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of hexamethyldisilazane used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Properties (for information only)

Density at 25°C	0.77 g/mL
Boiling Point	126°C

7 Requirements

7.1 The requirements for hexamethyldisilazane for Grade 1 and Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Columns Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micon I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methylsilicone which has been bonded and cross linked).

Column Temperature: 40°C isothermal for 2 minutes, then programmed to 220°C at 10°C/min, and isothermal for 10 minutes.

Injector Temperature:	200°C
Detector Temperature:	300°C
Sample Size:	0.4 µL
Carrier Gas:	Helium at 8 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Hexamethyldisilazane	14.3

8.2 *Trailing Impurities* — Use the chromatogram developed in the assay (see Section 8.1). With the relative retention time for hexamethyldisilazane taken as 1.0, establish the integrated area percents for trailing impurities with relative retention times from 1.3 to 4.0. The total of such trailing impurities should not exceed 0.1%.

8.3 *Appearance* — Place 15 mL of the sample in a 20 × 150 mm test tube and compare with water in a similar tube. Viewed across the column by means of transmitted light, the two liquids should be equal in clarity and free from suspended matter.

8.4 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample should be no darker than the standard.

8.5 *Residue After Evaporation* — Evaporate 130 mL (100 g) of sample to dryness in a hood. Dry at 105°C for one hour, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.6 *UV Absorbance* — A UV scan is obtained on all HMDS electronic grade material to determine if any UV absorbing impurities are present: specifically toluene.

8.6.1 *Equipment* — Bausch and Lomb Spectronic 2000 Spectrophotometer or other double beam instrument capable of measurements at 270 nm. Cells - 1 cm path length.

8.6.2 *Reagents* — FC-113 and methanol for UV cell cleaning.

8.6.3 *Procedure* — Using water as the reference and sample cells, establish the baseline between 300 and 270 nm. Remove the water sample from the sample path and replace it with the HMDS sample. Read the absorbance between 300 and 270 nm. The absorbance at 270 nm should read 0.07 to 0.25.

NOTE 1: Oxygen will contribute to the UV absorbance.

NOTE 2: The sample must be at ambient temperature.

NOTE 3: The UV absorbance will increase or decrease with time.

NOTE 4: HMDS is flammable and corrosive.

8.7 *Chloride* — To a 500 mL separatory funnel, add 260 mL (200 g) of sample, 20 mL of water, and 1 mL of sodium hydroxide reagent solution. Shake well for 30 seconds and allow the two layers to separate. Carefully draw off the aqueous (lower) layer into a 250 mL beaker. Repeat the extraction five times and combine the six aqueous extracts. Add 2 mL of nitric acid to acidify the solution and arrange the beaker for magnetic stirring.

8.7.1 Using a pH meter fitted with a silver billet electrode (Beckman #89261, Corning #476065, or equivalent) and a silver/silver chloride reference electrode, determine the apparent pH versus mL readings while titrating the continuously stirred sample solution with 0.01 M methanolic silver nitrate solution. Add the silver nitrate solution in 0.1-0.2 mL increments from a 10 mL buret. Run a total blank. Plot the titration data on linear graph paper or use the second-derivative method to establish the endpoint.

$$\text{ppm Chloride (Cl)} = \frac{(\text{mL sample - mL blank}) \times \text{M of AgNO}_3 \times 35{,}460}{\text{Weight of sample (g)}}$$

8.7.2 *Standard Silver Nitrate in Methanol Solution* — Dissolve 1.700 grams of silver nitrate in absolute methanol and dilute to 1000 mL. Store this solution in an amber bottle and standardize immediately before use against a standard sodium chloride (NaCl) solution using the above second-derivative method.

8.8 *Heavy Metals (as Pb)* — Evaporate 130 mL (100 g) of sample to dryness in a hood. Dissolve the residue in 3 mL of dilute hydrochloric acid (1 + 1) and dilute with water to 15 mL. If necessary, filter through a small filter, washing the evaporating dish and filter with 10 mL of water. Dilute to 25 mL with water. For the standard, dilute a solution containing 0.01 mg of lead ion (Pb) and 3 mL of dilute hydrochloric acid (1 + 1) to 25 mL with water. Adjust the pH of both solutions to between 3 and 4 (using a pH meter) with dilute ammonium hydroxide (10% NH_3) or with 1 N acetic acid, and dilute with water to 40 mL. To each solution, add 10 mL of freshly prepared hydrogen sulfide water and compare. The sample solution should be no darker than the standard.

8.9 *Arsenic and Antimony (as As)* — To a 500 mL separatory funnel, add 260 mL (200 g) of sample, 20 mL of water, and 1 mL of sodium hydroxide reagent solution. Shake well for 30 seconds and allow the two layers to separate. Carefully draw off the aqueous (lower) layer into a 150 mL beaker. Repeat the extraction twice more, combining the three aqueous extracts.

8.9.1 Add 15 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and re-evaporate to dense fumes of sulfur trioxide. Cool and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should not exceed that for the standard containing 0.002 mg of arsenic (As).

8.10 *Trace Elements* — By a suitable emission spectrographic procedure, determine for each of the specified trace elements that its content is not greater than the stated specification limit (see SEMI C1, Section 3.5, Guidelines for Determination of Trace Elements by Emission Spectrography).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Hexamethyldisilazane

Previous SEMI Reference #	C1.23-94	C7.10-94
	Grade 1	Tier A
	(Specification)	(Guideline)
Assay	99.0%	99.5% min
Color (APHA)	10 max	10 max
Trailing Impurities (area % max)	0.1%	0.2%
Residue after Evaporation	10 ppm max	10 ppm max
UV absorbance units at 270 nm	0.25 max	0.25 max
Turbidity	1.0 NTU units	1.0 NTU units max
Chloride (Cl)	2 ppm max	0.3 ppm max
Aluminum (Al)	0.1 ppm max	10 ppb max
Antimony (Sb)	--	10 ppb max
Arsenic (As)	--	10 ppb max
Arsenic and Antimony (as As)	10 ppb max	--
Barium (Ba)	--	10 ppb max
Beryllium (Be)	--	10 ppb max
Bismuth (Bi)	--	10 ppb max
Boron (B)	0.1 ppm max	10 ppb max
Cadmium (Cd)	--	10 ppb max
Calcium (Ca)	0.1 ppm max	10 ppb max
Chromium (Cr)	--	10 ppb max
Cobalt (Co)	--	10 ppb max
Copper (Cu)	0.1 ppm max	10 ppb max
Gallium (Ga)	0.1 ppm max	10 ppb max
Germanium (Ge)	0.1 ppm max	10 ppb max
Gold (Au)	0.1 ppm max	10 ppb max
Iron (Fe)	0.05 ppm max	10 ppb max
Lead (Pb)	0.1 ppm max	10 ppb max
Lithium (Li)	0.1 ppm max	10 ppb max
Magnesium (Mg)	0.1 ppm max	10 ppb max
Manganese (Mn)	--	10 ppb max
Molybdenum (Mo)	--	10 ppb max
Nickel (Ni)	0.1 ppm max	10 ppb max
Potassium (K)	0.1 ppm max	10 ppb max

Previous SEMI Reference #	C1.23-94	C7.10-94
	Grade 1	Tier A
	(Specification)	(Guideline)
Silver (Ag)	0.1 ppm max	10 ppb max
Sodium (Na)	0.5 ppm max	10 ppb max
Strontium (Sr)	0.1 ppm max	10 ppb max
Tantalum (Ta)	0.1 ppm max	10 ppb max
Thallium (Tl)	--	10 ppb max
Tin (Sn)	--	10 ppb max
Titantium (Ti)	--	10 ppb max
Vanadium (V)	--	10 ppb max
Zinc (Zn)	--	10 ppb max
Zirconium (Zr)	--	10 ppb max

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SEMI C27-0301
SPECIFICATIONS AND GUIDELINES FOR HYDROCHLORIC ACID

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee by letter ballot dated October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.7, C7.2, C8.2, C11.6, and C12.2 in their entirety. Originally published in 1978, 1990, 1992, 1996, and 1995 respectively; previously published June 2000.

1 Purpose

1.1 The purpose of this document is to standardize requirements for hydrochloric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of hydrochloric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of hydrochloric acid used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 These specifications and guidelines do not purport to address safety issues, if any, associated with their use. It is the responsibility of the users of these specifications and guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.19 g/mL

7 Requirements

7.1 The requirements for hydrochloric acid for Grades 1 and 2, VLSI Grade, and Tiers B and C are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh a glass-stoppered conical flask containing about 30 mL of water. Deliver from a pipet about 3 mL of sample near the water surface, stopper immediately, and reweigh. Dilute to about 50 mL with water, add methyl orange indicator solution, and titrate with standardized 1 N sodium hydroxide to a red-to-yellow color change.

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 3.646}{\text{Weight of sample (g)}}$$

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Extractable Organic Substances* — Cool 110 mL of sample in an ice bath. Add 5 mL of 2,2,4-trimethylpentane and 100 mL of water to each of two 250 mL separatory funnels. To a third funnel add 100 mL of water and 5 mL of the standard (see below). To the first funnel add 100 mL of the cooled sample, and 100 mL of water to each of the remaining two. Stopper, shake well, and allow the layers to separate. Inject 1.0 µL of each of the 2,2,4-trimethylpentane extracts into a gas chromatograph with a flame ionization detector. The following conditions have been found to be satisfactory: Column — 20% Carbowax® 20 M on

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

Chromosorb P (80/100), 3 m × 3 mm stainless steel or glass; injection port at 280°C with glass insert; column temperature initially 65°C, programmed at 6°C/min up to 140°C; carrier gas — nitrogen at 40 mL/min; signal adjusted to give an 80% full-scale deflection; and preferably, electronic integration of peak areas. For DDT: Column — 5% silicone gum SESE-30 on Chromosorb® W (60/80), 1.5 × 3 mm, injection port — as above; column temperature — isothermal at 205°C; carrier gas — nitrogen at 75 mL/min, and preferably, electronic integration of peak areas. The order of elution is 2,2,4-trimethylpentane, carbon tetrachloride, benzene, chloroform, 2,2,4-trimethylpentane impurity, 1,2-dichloroethane, chlorobenzene, and dichlorobenzene. The total area under the impurity peaks from the sample should be no greater than that from the blank (extract from second funnel) by more than one-half the total area under the peaks from the standard (third funnel), also corrected for the blank.

8.3.1 *Standard* — Use a syringe to add the volumes of liquid listed in Table 2 into 300 mL of 2,2,4-trimethylpentane. Add 25 mg of DDT to the solution. Dilute to 500 mL with 2,2,4-trimethylpentane. The 2,2,4-trimethylpentane used for both the standard and the analysis should be free from impurities that interfere with the chromatographic analysis.

8.4 *Free Halogen (as Cl_2)* — Mix 100 mL of sample and 100 mL of freshly boiled water and cool. Add 0.1 mL of 2% potassium iodide reagent solution and 1 mL of carbon disulfide, and mix. The carbon disulfide should not acquire a pink color in one-half minute.

8.5 *Phosphate* — To 170 mL (200 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated like the sample.

8.6 *Sulfate* — To 84 mL (100 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter, if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand 10 minutes. Any turbidity should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) is treated as the sample.

8.7 *Sulfite* — Add 1 mL of 10 percent potassium iodide reagent solution, 5 mL of hydrochloric acid, and 2 mL of starch indicator solution to 400 mL of oxygen-free water. Add 0.01 N iodine until a faint permanent blue color is produced. Add 85 mL of the sample and titrate with 0.01 N iodine to the same endpoint. Not more than 0.20 mL should be required.

8.8 *Arsenic and Antimony (as As)* — To 168 mL (200 g) of sample in a 400 mL beaker, add 10 mL of nitric acid and 5 mL of sulfuric acid, and evaporate to dense fumes of sulfur trioxide in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with tile sentence which begins: “Swirl the flask....” Any red color in the silver diethyldithiocarbamate solution from the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.9 *Trace Metal Analysis* — The following method has given satisfactory results in determing trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 — 125% of a known sample spike for half of the value of each specified item.

8.9.1 *Special Reagents*

8.9.1.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.9.1.2 *2% Nitric Acid Solution* — Dilute 20 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.9.2 *Sample Preparation*

8.9.2.1 In a clean environment, place 250 mL of sample in a PTFE evaporating dish. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 2 mL of liquid remains. Note: Evaporation typically requires 2 1/2 to 4 hours. Cool. Transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid for rinsing and dilution to volume. Run a reagent blank.

8.9.3 *Analysis*

8.9.3.1 Using the acid sample and reagent blank, analyze group 1 elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy.

9 Grade 2 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Free Halogen

Phosphate

Sulfate

Sulfite

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As) barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Hydrochloric Acid, Ultrapure* — Use hydrochloric acid specified for low metal ion content.

9.2.2.2 *3.7% Hydrochloric Acid Solution* — Dilute 20 g of ultrapure hydrochloric acid to 200 g using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Nitric Acid, Ultrapure* — Use nitric acid specified for low metal ion content.

9.2.2.4 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.5 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.6 *Rhodium Internal Standard* — Make up the internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated standard rhodium solution.

9.2.3 *Sample Preparation*

9.2.3.1 In a clean environment, place 2.00 g of sample into a tared FEP bottle (30 mL), dilute with "attainable" water to a final weight of 20.0 g. Add 20 µL of the rhodium internal standard solution. Run a reagent blank.

9.2.3.2 *Vanadium* — In a clean environment, place 20.0 g of sample into a clean PTFE dish. Slowly evaporate on a hot plate to dryness avoiding loss of sample by effervescence or spattering. Dissolve the residue with 5 mL of the 1% nitric acid solution by heating on a hot plate at low temperature for several minutes. Cool to room temperature, dilute to 20 g with 1% nitric acid, add 20 µL of the rhodium internal standard, mix well. Run a reagent blank.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 3.7% hydrochloric acid solution and the rhodium internal standard except for the analysis of vanadium which is performed using 1% nitric acid as the matrix. All standards must contain 10 ng/g of rhodium as the internal standard.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and supplier. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%.

Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Hydrochloric Acid

Previous SEMI Reference #	C1.7-95	C7.2-94	C11.6-1296	C8.2-92	C12.2-96
	Grade 1	Grade 2	VLSI Grade	Tier B	Tier C
	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Assay (HCl)	36.5–38.0%	36.5–38.0 %	36–38%	37.0–38.0%	37.0–38.0%
Color (APHA)	10 max	10 max	10 max	10 max	10 max
Extractable Organic Substances	5 ppm max	--	--	500 ppb max	--
Residue after Ignition (as SO_4)	--	--	3 ppm max	--	--
Free Halogen (as Cl_2)	To pass test	To pass test	--	500 ppb max	500 ppb max
Free Chlorine (Cl_2)	--	--	0.5 ppm max	--	--
Bromide (Br)	--	--	50 ppm max	--	--
Phosphate (PO_4)	0.05 ppm max	50 ppb max	0.05 ppm max	50 ppb max	50 ppb max
Sulfate (SO_4)	0.5 ppm max	500 ppb max	0.5 ppm max	100 ppb max	30 ppb max
Sulfite (SO_3)	0.8 ppm max	800 ppb max	0.7 ppm max	100 ppb max	100 ppb max
Aluminum (Al)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Antimony (Sb)	--	5 ppb max	0.005 ppm max	--	100 ppt max
Arsenic (As)	--	10 ppb max	0.005 ppm max	--	100 ppt max
Arsenic and Antimony (as As)	0.005 ppm max	--	--	1 ppb max	--
Barium (Ba)	--	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Beryllium (Be)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Bismuth (Bi)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Boron (B)	0.1 ppm max	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Cadmium (Cd)	--	10 ppb max	0.005 ppm max	1 ppb max	--
Calcium (Ca)	0.3 ppm max	10 ppb max	0.2 ppm max	1 ppb max	100 ppt max
Chromium (Cr)	0.2 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Cobalt (Co)	--	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Copper (Cu)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Gallium (Ga)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Germanium (Ge)	--	10 ppb max	--	1 ppb max	--
Gold (Au)	0.3 ppm max	5 ppb max	0.02 ppm max	1 ppb max	--
Indium (In)	--	--	0.02 ppm max	--	--
Iron (Fe)	0.2 ppm max	10 ppb max	0.1 ppm max	1 ppb max	100 ppt max
Lead (Pb)	0.1 ppm max	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Lithium (Li)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Magnesium (Mg)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Manganese (Mn)	0.3 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Mercury (Hg)	--	--	0.02 ppm max	--	--
Molybdenum (Mo)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Nickel (Ni)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Niobium (Nb)	--	10 ppb max	--	1 ppb max	--

Previous SEMI Reference #	C1.7-95	C7.2-94	C11.6-1296	C8.2-92	C12.2-96
	Grade 1	Grade 2	VLSI Grade	Tier B	Tier C
	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Platinum (Pt)	--	--	0.02 ppm max	--	--
Potassium (K)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Silicon (Si)	--	--	--	1 ppb max	--
Silver (Ag)	--	5 ppb max	0.02 ppm max	1 ppb max	--
Sodium (Na)	0.3 ppm max	10 ppb max	0.1 ppm max	1 ppb max	100 ppt max
Strontium (Sr)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Tantalum (Ta)	--	10 ppb max	--	1 ppb max	100 ppt max
Thallium (Tl)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Tin (Sn)	0.3 ppm max	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Titanium (Ti)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Vanadium (V)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Zinc (Zn)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Zirconium (Zr)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Particles in bottles (size, #/mL)	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 250 max	≥ 0.5 µm, 10 max ≥ 0.2 µm, TBD	(See NOTE 1.)

NOTE 1: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

Table 2 Composition of Standard

Substance	Amount in 500 mL of 2,2,4-trimethylpentane solution		Concentration in ppm for 5 mL of standard in 100 mL (120 g) of HCl	
	µL	mg		
Benzene	6.8	6		0.5
Chlorobenzene	5.5	6		0.5
1,2-Dichloroethane	20	25		2.0
Chloroform	34	50		4.0
DDT (see NOTE 1)		25		2.0
			Total	9.0
			Allowance for CCl_4	1.0
			Total	10.0

NOTE 1: 1,1,1-Trichloro-2,2-bis (p-chlorophenyl) ethane, dichlorodiphenyltrichloroethane.

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SEMI C28-0301
SPECIFICATIONS AND GUIDELINES FOR HYDROFLUORIC ACID

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.8, C7.3, C8.3, and C11.3 in their entirety. Originally published in 1978, 1990, 1992, and 1994 respectively; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for hydrofluoric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of hydrofluoric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of hydrofluoric acid used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 *SEMI Documents*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

4.3 *DIN Documents*[2]

DIN 50451, Part 1 — Determination of Trace Metals in Liquids (Silver, Gold, and Copper in Nitric Acid by AAS)

DIN 50451, Part 2 — Determination of Trace Metals in Liquids (Cobalt, Chromium, Copper, Iron, and Nickel in Hydrofluoric Acid with Plasma-Induced Emission Spectroscopy)

DIN 50451, Part 3 — Determination of Trace Metals in Liquids (Aluminum, Cobalt, Copper, Sodium, Nickel, and Zinc in Nitric Acid with ICP-MS)

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.15 g/mL

7 Requirements

7.1 The requirements for hydrofluoric acid for Grades 1 and 2, VLSI Grade, and Tier B are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh 1.4–1.5 mL of sample in polyethylene weighing bottle, sample, stopper immediately, and reweigh. To 50 mL of water in a plastic vessel, add the sample (loosen the stopper of the polyethylene bottle, and add both the container and the stopper with the sample). Add 0.1 mL of phenolphthalein indicator solution, and titrate with standardized 1 N sodium hydroxide to a slight, pink color.

$$\%Assay = \frac{mL \times N \text{ of NaOH} \times 2.001}{\text{Weight of sample (g)}}$$

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

2 Deutsches Institut fur Normung e.v.; available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000 Berlin 30, Germany

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in HF resistant plastic tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Fluosilicic Acid* — Weigh 31 mL (36 g) of sample into a large platinum dish. Add 2 g of potassium chloride and 3 mL of hydrochloric acid and evaporate to dryness on a steam bath in a hood. Wash down the sides of the dish with a small amount of water, add 3 mL of hydrochloric acid, and repeat the evaporation. Dissolve the residue in about 100 mL of water, cool to 0°C, and add 0.10 mL of phenolphthalein indicator solution. Neutralize any free acid with 0.1 N sodium hydroxide solution, keeping the temperature of the solution near 0°C. Heat the solution to boiling and titrate with 0.1 N sodium hydroxide. (The 0.1 N sodium hydroxide solution must be stored in a plastic bottle.)

$$\% \; H_2SiF_6 = \frac{\text{mL} \times \text{N of NaOH} \times 3.600}{\text{Weight of sample (g)}}$$

8.4 *Chloride* — Add 1.7 mL (2.0 g) of sample to 45 mL of water. Filter, if necessary, through a chloride-free filter. Add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.5 *Nitrate* — Weigh 3.3 g of sample in a white plastic 50 mL beaker and dilute with 4.5 mL of water. To another 50 mL plastic beaker, add 6.5 mL of water and 1 mL of standard nitrate solution containing 0.01 mg of nitrate (NO_3) per mL. To each solution, add 2.5 mL of brucine sulfate reagent solution and cautiously add with stirring 20 mL of sulfuric acid. Allow to stand for 10 minutes. The yellow color in the sample solution should be no greater than that in the standard solution.

8.6 *Phosphate* — Evaporate 9 mL (10 g) of sample to dryness in a platinum or other suitable dish on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand for 2 hours at room temperature. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated like the sample.

8.7 *Sulfate and Sulfite (as SO_4)* — To 18 mL (20 g) of sample in a platinum or other suitable evaporating dish, add about 10 mg of sodium carbonate and 1 mL of 30 hydrogen peroxide. Evaporate to dryness on a steam bath in a hood, wash down the sides of the dish with a small volume of water, and add 3 mL of perchloric acid. Evaporate to about 1 mL, dilute with about 15 mL of water, and add 0.01 mL of phenolphthalein indicator solution. Neutralize with ammonium hydroxide, dilute with water to 20 mL, and add 2 mL of dilute hydrochloric acid (1 + 19) and 2 mL of barium chloride reagent solution. Any turbidity should not exceed that produced by 0.1 mg of sulfate ion (SO_4) in an equal volume of solution containing the quantities of reagents used in the test. Compare 10 minutes after adding the barium chloride to the sample and standard solutions.

8.8 *Arsenic and Antimony (as As)* — To 87 mL (100 g) of sample in a fluoroplastic beaker, add 20 mL of nitric acid, 5 mL of sulfuric acid, and 5 mL of hydrochloric acid; mix gently after each addition. Evaporate to dense fumes of sulfur trioxide in a sand bath in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: "Swirl the flask...." Any red color should not exceed that in the standard containing 0.003 mg of Arsenic (As).

8.9 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.9.1 *Special Reagents*

8.9.1.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.9.1.2 *2% Nitric Acid Solution* — Dilute 20 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.9.2 *Sample Preparation*

8.9.2.1 In a clean environment, place 250 g of sample in a PTFE evaporating dish. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 2 mL of liquid remains.

NOTE 3: Evaporation typically requires 2 1/2 to 4 hours. Cool. Add 1 mL of ultra pure, 70% nitric acid. While maintaining volume, carefully warm several minutes to dissolve any residue. Cool. Transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid for rinsing and dilution to volume. Run a reagent blank.

8.9.3 *Analysis*

8.9.3.1 Using the acid sample and reagent blank, analyze group 1 elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy.

9 Grade 2 Procedures

NOTE 4: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Fluosilicic Acid

Chloride

Nitrate

Phosphate

Sulfate and Sulfite (as SO_4)

Arsenic and Antimony (as As)

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn) and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Hydrofluoric Acid, Ultra Pure* — Use hydrofluoric acid specified for low metal ion content.

9.2.2.2 *4.9% Hydrofluoric Acid Solution* — Dilute 20 g of ultrapure hydrofluoric acid to 200 g using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.4 *Indium Internal Standard* — Make up a internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.2.3 *Sample Preparation*

9.2.4 In a clean environment, place 2.00 g of sample into a tared FEP bottle (30 mL), dilute with Type E1.1 water to a final weight of 20.0 g. Add 20 µL of the indium internal standard solution. Run a reagent blank.

9.2.5 *Analysis*

9.2.5.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 4.9% hydrofluoric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium.

NOTE 5: Analysis of dilute hydrofluoric acid requires the use of special hydrofluoric acid resistant sample introduction systems for inductively coupled plasma mass spectrometry. These systems are available from most instrument suppliers.

NOTE 6: Analysis of dilute hydrofluoric acid can produce rapid corrosion of nickel cones commonly used in inductively coupled plasma mass spectrometry, platinum cones should be considered as alternative when performing this analysis.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 *Assay* — Accurately weigh a polyethylene weighing bottle with stopper containing approximately 20 mL of water, introduce 1.4 – 1.5 mL of sample, stopper immediately, and reweigh to an accuracy of ± 0.0001 g. To 50 mL of water in a 250 mL PE vessel, add the sample (loosen the stopper of the polyethylene bottle, add both the container and the stopper with the sample). Add 0.1 mL of phenolphthalein indicator solution, and titrate with standardized 1 N sodium hydroxide solution to a slight, pink color.

$$\% \text{ Assay} = \frac{1 \text{ mL } 1 \text{ N NaOH} = 0.020006 \text{ g HF}}{\text{Weight of sample (g)}}$$

13.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare 50 mL of this standard (APHA No. 10) with 50 mL of sample in HF-resistant plastic tubes. View vertically over a white background. The sample must be no darker than the standard.

13.3 *Residue after Ignition* — Weigh approximately 500 g of sample to an accuracy of ± 0.1 g in separate portions into a tared platinum dish, add 0.5 mL of sulfuric acid, evaporate on an electric heating plate. Ignite at 800°C ± 25°C for 15 minutes. Cool in a desiccator and weigh. Repeat until constant weight is obtained.

13.4 *Fluosilicic Acid* — Weigh approximately 1 g of sample to an accuracy of ± 0.01 g in a 150 mL PE plastic vessel and dilute with water to 60 mL. Add 1 g boron trioxide and stir until the boron trioxide is completely dissolved. Measure pH value using a glass electrode and adjust pH to 1.2 ± 0.1 using diluted sulfuric acid (1 + 3 parts by volume). Add 10 mL of ammonium molybdate solution and readjust pH to 1.2 ± 0.1 if necessary. Remove glass electrode and let remain for 15 minutes. Add 10 mL of diluted sulfuric acid and 2 mL of ascorbic acid solution (2%) and transfer to a 100 mL graduated plastic bottle, fill up with water to 100 mL, and mix thoroughly. After 10 minutes, a sample of the solution is measured in 1 cm cuvettes at 815 nm against a blank solution. The result is calculated on the basis of a previously recorded calibration curve.

13.5 *Chloride* — To 20 g of sample, weighed to an accuracy of ± 0.1 g, add 45 mL of water, 5 mL of dilute nitric acid (25%), and 2 mL of silver nitrate reagent solution (0.1 mol/L). Dilute to 70 mL with water. Any turbidity produced after 15 minutes should not be greater than that produced when 0.002 mg of chloride ion (Cl) is treated as the sample.

13.6 *Nitrate* — Weigh 2 g of sample to an accuracy of ± 0.1 g in a 50 mL white plastic beaker and dilute with 4.5 mL of water. To another 50 mL plastic beaker, add 6.5 mL of water and 1 mL of standard nitrate solution containing 0.01 mg of nitrate (NO_3) per mL. To each solution, add 2.5 mL of brucine sulfate reagent solution and cautiously add with stirring 20 mL of sulfuric acid. Allow to stand for 10 minutes. The yellow color in the sample solution should be no greater than that in the standard solution.

13.7 *Phosphate* — Phosphate is determined by ion chromatography together with sulfate.

13.7.1 To 50 g of sample weighed to an accuracy of ± 0.1 g, add 20 mg sodium carbonate (10 mL of sodium carbonate stock solution 1 g/500 mL) and evaporate the sample to dryness in a platinum dish. Add 10 mL of hydrochloric acid (37%) and again evaporate to dryness. Dissolve the residue in 5 mL of water and directly inject into the instrument. Reference is made using a solution containing 1 ppm phosphate.

13.8 *Sulfate* — Sulfate is determined using ion chromatography after the procedure described in Section 6.7. The results are calculated from a reference solution containing 5 ppm of sulfate.

13.9 *Sulfite (SO_3)* — Weigh 200 g of sample to an accuracy of ± 0.1 g into a 250 mL plastic vessel. Add 50 mL of water and 1 mL of starch solution (1%). Cool and titrate with iodine solution 0.005 mol/L.

NOTE 7: 1.0 mL of iodine solution = 0.40 mg SO_3.

13.10 *Arsenic and Antimony (as As)* — Weigh 30 g of sample to an accuracy of ± 0.1 g into a glass carbon dish. Add 20 mL of nitric acid (65%), 5 mL of sulfuric acid (96%), and 5 mL of hydrochloric acid (37%). Evaporate to dense fumes of sulfur trioxide using an electric surface heater. Cool and cautiously add 10 mL of water and again evaporate to dense fumes of sulfur trioxide. Cool and cautiously wash into a generator flask with water to a volume of 35 mL. Proceed as described in the General Method for Arsenic under SEMI C1, Section 3.4.5. Any red color should not exceed that in the standard containing 0.003 mg of Arsenic (As).

13.11 *Trace Metals Analysis* — Metallic impurities are determined using ICP-MS spectroscopic equipment after a procedure described in DIN 50451, Part 3 with the exception of calcium, iron, potassium, sodium, and vanadium.

13.11.1 Calcium and iron are determined using ICP-OES after a procedure described in DIN 50451, Part 2. Potassium, sodium, and vanadium are determined using graphite furnace atomic absorption after a method described in DIN 50451, Part 1.

13.11.2 *Special Reagents*

13.11.3 *Sample Preparation* — In a clean environment, place 10 – 20 g of sample, weighed to an accuracy of ± 0.1 g, in a PFA evaporating dish. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 500 µL remain. Add 100 µL of ultrapure nitric acid (65%), 50 µL of ultrapure hydrochloric acid (37%), and water. Add 100 µL of lanthanum standard and fill up with water to 10 ± 0.2 g. Run a reagent blank.

NOTE 8: The blank is specified according to SEMI C1, Section 2.6.

13.11.4 *Analysis* — Using the acid sample and reagent blank, analyze elements as described in Section 3.10.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Hydrofluoric Acid

Previous SEMI Reference #	C1.8-95	C7.3-93	C11.3-0698	C8.3-96
	Grade 1	Grade 2	VLSI Grade	Tier B
	(Specification)	(Specification)	(Guideline)	(Guideline)
Assay (HF)	48.8–49.2%	48.8–49.2 %	48.8–49.2% or 49.8–50.2%	48.90–49.10%
Color (APHA)	10 max	10 max	10 max	10 max
Residue after Ignition	--	--	2 ppm max	--
Chloride (Cl)	5 ppm max	5000 ppb max	1 ppm max	200 ppb max
Fluosilicic Acid (H_2SiF_6)	0.01%	100 ppm max	50 ppm max	100,000 ppb max
Nitrate (NO_3)	3 ppm max	3000 ppb max	3 ppm max	100 ppb max
Phosphate (PO_4)	1 ppm max	1000 ppb max	0.1 ppm max	100 ppb max
Sulfate (SO_4)	--	--	0.5 ppm max	200 ppb max
Sulfite (SO_3)	--	--	0.5 ppm max	200 ppb max
Sulfate and Sulfite (as SO_4)	5 ppm max	5000 ppb max	--	--
Aluminum (Al)	0.05 ppm max	10. ppb max	0.02 ppm max	1 ppb max
Arsenic and Antimony (as As)	0.03 ppm max	30 ppb max	0.01 ppm max	1 ppb max
Barium (Ba)	--	10. ppb max	0.01 ppm max	1 ppb max
Beryllium (Be)	--	5. ppb max	0.01 ppm max	1 ppb max
Bismuth (Bi)	--	5. ppb max	0.02 ppm max	1 ppb max
Boron (B)	0.05 ppm max	10. ppb max	0.02 ppm max	1 ppb max
Cadmium (Cd)	--	10. ppb max	0.01 ppm max	1 ppb max
Calcium (Ca)	0.3 ppm max	10. ppb max	0.05 ppm max	1 ppb max
Chromium (Cr)	0.01 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Cobalt (Co)	--	10. ppb max	0.01 ppm max	1 ppb max
Copper (Cu)	0.05 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Gallium (Ga)	--	10. ppb max	0.01 ppm max	1 ppb max
Germanium (Ge)	--	10. ppb max	0.02 ppm max	1 ppb max
Gold (Au)	0.3 ppm max	5. ppb max	0.02 ppm max	1 ppb max
Indium (In)	--	--	0.01 ppm max	--
Iron (Fe)	0.2 ppm max	10. ppb max	0.05 ppm max	1 ppb max
Lead (Pb)	0.1 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Lithium (Li)	--	5. ppb max	0.01 ppm max	1 ppb max
Magnesium (Mg)	0.2 ppm max	10. ppb max	0.02 ppm max	1 ppb max
Manganese (Mn)	0.2 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Molybdenum (Mo)	--	10. ppb max	0.01 ppm max	1 ppb max
Nickel (Ni)	0.1 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Niobium (Nb)	--	10. ppb max	--	1 ppb max
Platinum (Pt)	--	--	0.02 ppm max	--
Potassium (K)	0.3 ppm max	10. ppb max	0.02 ppm max	1 ppb max

Previous SEMI Reference #	C1.8-95	C7.3-93	C11.3-0698	C8.3-96
	Grade 1	Grade 2	VLSI Grade	Tier B
	(Specification)	(Specification)	(Guideline)	(Guideline)
Silver (Ag)	--	5. ppb max	0.01 ppm max	1 ppb max
Sodium (Na)	0.3 ppm max	10. ppb max	0.05 ppm max	1 ppb max
Strontium (Sr)	--	10. ppb max	0.01 ppm max	1 ppb max
Tantalum (Ta)	--	10. ppb max	--	1 ppb max
Thallium (Tl)	--	10. ppb max	0.02 ppm max	1 ppb max
Tin (Sn)	0.3 ppm max	10. ppb max	0.02 ppm max	1 ppb max
Titanium (Ti)	0.3 ppm max	10. ppb max	0.01 ppm max	1 ppb max
Vanadium (V)	--	10. ppb max	0.01 ppm max	1 ppb max
Zinc (Zn)	0.3 ppm max	10. ppb max	0.05 ppm max	1 ppb max
Zirconium (Zr)	--	10. ppb max	0.01 ppm max	1 ppb max
Particles in bottles (size, #/mL)	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 250 max	≥ 0.5 µm, 5 max ≥ 0.2 µm, TBD

SEMI C29-0301
SPECIFICATIONS AND GUIDELINE FOR 4.9% HYDROFLUORIC ACID (10:1 v/v)

These specifications and this guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C7.4, C8.4, and C12.3 in their entirety. Originally published in 1990, 1992, and 1995 respectively; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for 4.9% hydrofluoric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of 4.9% hydrofluoric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 4.9% hydrofluoric acid used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C28 — Specifications and Guidelines for Hydrofluoric Acid

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for 4.9% hydrofluoric acid for Grades 2 and 3 and Tier C are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See SEMI C28 (Specifications and Guidelines for Hydrofluoric Acid) which contains procedures for the following tests:

Assay

Color (APHA)

Fluosilicic Acid

Chloride

Phosphate

Sulfate and Sulfite (as SO_4)

Arsenic and Antimony (as As)

9.1.1 *Analysis of Anions and Fluosilicic Acid* — Application of the procedures cited above to dilute hydrofluoric acid requires a tenfold increase in the amount of initial sample weight prior to the evaporation steps given in the procedures.

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), arsenic (As), antimony (Sb), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Hydrofluoric Acid, Ultra Pure* — Use hydrofluoric acid specified for low metal ion content.

9.2.2.2 *4.9% Hydrofluoric Acid Solution* — Dilute 20 g of ultrapure hydrofluoric acid to 200 g using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.4 *Indium Internal Standard* — Make up the internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.2.3 *Sample Preparation*

9.2.3.1 In a clean environment, place 20.0 g of sample into a tared FEP bottle (30 mL). Add 20 µL of the indium internal standard solution. Run a reagent blank.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 4.9% hydrofluoric acid solution and a final concentration of 20 ng/g of the indium internal standard.

NOTE 3: Analysis of diluted hydrofluoric acid requires the use of special hydrofluoric acid resistant sample introduction systems for inductively coupled plasma mass spectrometry. These systems are available from most instrument suppliers.

NOTE 4: Analysis of diluted hydrofluoric acid can produce rapid corrosion of nickel cones commonly used in inductively coupled plasma mass spectrometry, platinum cones should be considered as alternative when performing this analysis.

10 Grade 3 Procedures

NOTE 5: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 6: Each laboratory is responsible for verifying the validity of each method within its own operation.

10.1 *Non-Metal Impurities* — See SEMI C28, which contains procedures for the following tests:

Assay

Color (APHA)

Fluosilicic Acid

Chlorides

Phosphates

Sulfate and Sulfite (as SO_4)

10.1.1 *Analysis of Anions and Fluosilicic Acid* — Application of the procedures cited above to dilute hydrofluoric acid requires a tenfold increase in the amount of inital sample weight prior to the evaporation steps given in the procedures.

10.2 *Trace Metals Analysis*

10.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.2.2 *Special Reagents*

10.2.2.1 *Hydrofluoric Acid, Ultrapure* — Use hydrofluoric acid specified for low metal ion content.

10.2.2.2 *4.9% Hydrofluoric Acid Solution* — Dilute 20 g of ultrapure hydrofluoric acid to 200 g using water meeting the criteria for Type E1.1 in ASTM D5127.

10.2.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127in regard to cation analysis.

10.2.2.4 *Indium Internal Standard* — Make up the internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

10.2.3 *Sample Preparation*

10.2.3.1 In a clean environment, place 20.0 g of sample into a tared FEP bottle (30 mL). Add 20 µL of the indium internal standard solution. Run a reagent blank.

10.2.4 *Analysis*

10.2.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 4.9% hydrofluoric acid solution and a final concentration of 20 ng/g of the indium internal standard.

NOTE 7: Analysis of dilute hydrofluoric acid requires the use of special hydrofluoric acid-resistant sample introduction systems for inductively coupled plasma mass spectrometry. These systems are available from most instrument suppliers.

NOTE 8: Analysis of dilute hydrofluoric acid can produce rapid corrosion of nickel cones commonly used in inductively coupled plasma mass spectrometry; platinum cones should be considered as an alternative when performing this analysis.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for 4.9% Hydrofluoric Acid

Previous SEMI Reference #	C7.4-93	C8.4-0298	C12.3-96
	Grade 2	Grade 3	Tier C
	(Specification)	(Specification)	(Guideline)
Assay (HF)	4.8–5.0 %	4.8–5.0%	4.8–5.0%
Color (APHA)	10 max	10 max	10 max
Fluosilicic Acid (H_2SiF_6)	10 ppm max	10,000 ppb max	10,000 ppb max
Total Organic Carbon (TOC)	--	--	500 ppb max
Chloride (Cl)	500 ppb max	500 ppb max	100 ppb max
Phosphate (PO_4)	100 ppb max	100 ppb max	100 ppb max
Sulfate (SO_4)	--	--	100 ppb max
Sulfate and Sulfite (as SO_4)	500 ppb max	500 ppb max	--
Aluminum (Al)	10 ppb max	1 ppb max	100 ppt max
Antimony (Sb)	--	1 ppb max	100 ppt max
Arsenic (As)	--	1 ppb max	100 ppt max
Arsenic and Antimony (as As)	5 ppb max	--	--
Barium (Ba)	10 ppb max	1 ppb max	--
Beryllium (Be)	5 ppb max	--	--
Bismuth (Bi)	5 ppb max	--	--
Boron (B)	10 ppb max	1 ppb max	100 ppt max
Cadmium (Cd)	10 ppb max	1 ppb max	--
Calcium (Ca)	10 ppb max	1 ppb max	100 ppt max
Chromium (Cr)	10 ppb max	1 ppb max	100 ppt max
Cobalt (Co)	10 ppb max	1 ppb max	--

Previous SEMI Reference #	C7.4-93	C8.4-0298	C12.3-96
	Grade 2	Grade 3	Tier C
	(Specification)	(Specification)	(Guideline)
Copper (Cu)	10 ppb max	1 ppb max	100 ppt max
Gallium (Ga)	10 ppb max	--	--
Germanium (Ge)	10 ppb max	--	--
Gold (Au)	5 ppb max	1 ppb max	100 ppt max
Iron (Fe)	10 ppb max	1 ppb max	100 ppt max
Lead (Pb)	10 ppb max	1 ppb max	100 ppt max
Lithium (Li)	5 ppb max	1 ppb max	--
Magnesium (Mg)	10 ppb max	1 ppb max	100 ppt max
Manganese (Mn)	10 ppb max	1 ppb max	100 ppt max
Molybdenum (Mo)	10 ppb max	1 ppb max	--
Nickel (Ni)	10 ppb max	1 ppb max	100 ppt max
Niobium (Nb)	10 ppb max	--	--
Potassium (K)	10 ppb max	1 ppb max	100 ppt max
Silver (Ag)	5 ppb max	1 ppb max	--
Sodium (Na)	10 ppb max	1 ppb max	100 ppt max
Strontium (Sr)	10 ppb max	1 ppb max	--
Tantalum (Ta)	10 ppb max	--	--
Thallium (Tl)	10 ppb max	--	--
Tin (Sn)	10 ppb max	1 ppb max	100 ppt max
Titanium (Ti)	10 ppb max	1 ppb max	100 ppt max
Vanadium (V)	10 ppb max	1 ppb max	--
Zinc (Zn)	10 ppb max	1 ppb max	100 ppt max
Zirconium (Zr)	10 ppb max	--	--
Particles in bottles: size, #/mL	≥ 0.5 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.2 µm, TBD

SEMI C30-1101
SPECIFICATIONS AND GUIDELINES FOR HYDROGEN PEROXIDE

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. This document replaces SEMI C1.9, C7.5, C8.5, C11.4, and C12.4 in their entirety. Originally published in 1978, 1990, 1992, 1994, and 1995 respectively; previously published March 2001.

1 Purpose

1.1 The purpose of this document is to standardize requirements for hydrogen peroxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of hydrogen peroxide for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of hydrogen peroxide used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 The specification for VLSI grade hydrogen peroxide is only applicable for materials that remain below 25°C during transport and storage.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D 5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.11 g/mL

7 Requirements

7.1 The requirements for hydrogen peroxide for Grades 1, 2, 3, 4, 5, and VLSI Grade are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: When hydrogen peroxide is added to water, there is no spattering. This happens only when the order of addition is reversed.

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh about 1 mL of sample in a tared 100 mL volumetric flask, dilute to volume with water, and mix thoroughly. Transfer exactly 20.0 mL of this solution to a 250 mL conical flask, add 20 mL of dilute sulfuric acid (1 + 15), and titrate with standardized 0.1 N (0.02 M) potassium permanganate to a pink color that persists for 15 seconds.

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of KMnO}_4 \times 8.500}{\text{Weight of sample (g)}}$$

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Free Acid* — Dilute 9 mL (10 g) of sample with 90 mL of freshly boiled and cooled carbon dioxide-free water. Add 0.15 mL of methyl red indicator solution and titrate with 0.01 N sodium hydroxide. The volume of sodium hydroxide solution consumed should not be more than 0.6 mL greater than the volume required for a blank test on 90 mL of the water used for dilution.

8.4 *TOC*

8.4.1 *Equipment*

8.4.1.1 TOC analyzer capable of analyzing total organic carbon in water.

8.4.1.2 Platinum sheet 1 × 1 inch, heated in a muffle oven at 800°C for 15 minutes.

8.4.2 *Special Reagents*

8.4.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D 5127 in regard to TOC analysis.

8.4.2.2 *1000 mg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 mg/mL to the appropriate volume.

8.4.3 *Sample Preparation* — Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, and dilute with water meeting the criteria for Type E1.1 in ASTM D 5127 to a final volume of 50 mL.

8.4.4 *Analysis* — Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 μg/mL of TOC standards.

8.5 *Chloride* — Dilute 4.5 mL (5 g) of sample with 15 mL of water. Filter, if necessary, through a chloride-free filter. Add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.6 *Sulfate* — To 9 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) is treated as the sample.

8.7 *Phosphate* — Evaporate 4.5 mL (5 g) of sample to dryness on the steam bath and dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand for 2 hours at room temperature. Any blue color should not exceed that produced in a standard of equal volume containing 0.01 mg of phosphate ion (PO_4) and the quantities of reagents used in the sample.

8.8 *Arsenic and Antimony (as As)* — To 180 mL (200 g) of sample in a 400 mL beaker, add 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the first sentence which begins: “Swirl the flask....” Any red color in the silver diethyldithiocarbamate solution from the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.9 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified element.

8.9.1 *Special Reagents*

8.9.1.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.9.1.2 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.9.2 *Sample Preparation*

8.9.2.1 *Sodium and Potassium* — In a clean environment, place 10.0 mL of water in a clean platinum crucible. Slowly add 5.0 mL of hydrogen peroxide. Allow to stand at room temperature until the effervescence ceases (approximately 20 minutes). Swirl. If swirling does not produce any more bubbles, proceed with analysis. If bubbles remain, allow to stand for 5 minutes and repeat the swirl until no bubbles are produced. Run a water blank.

8.9.2.2 *Other Elements* — Two separate samples of hydrogen peroxide are acidified to 2% with hydrochloric acid for the analysis of tin and to 2% with nitric acid for the analysis of (specified elements). Standard additions of tin to the matrix acidified with hydrochloric acid and standard additions of other specified elements to the matrix acidified with nitric acid are added to determine the response for each element in the peroxide matrix. Aqueous acidified standards for tin in 2% hydrochloric acid and other specified elements in 2% nitric acid should be used to determine instrument responses.

8.9.3 *Analysis*

8.9.3.1 Using the solution from Section 8.9.2.1, analyze for specified group 1 elements by flame atomic absorption spectroscopy. All other elements analyzed by plasma emission spectroscopy.

9 Grade 2 Procedures

NOTE 4: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities*

9.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Free Acid

9.2 *TOC*

9.2.1 *Equipment*

9.2.1.1 TOC analyzer capable of analyzing total organic carbon in water.

9.2.1.2 Platinum sheet 1 × 1 inch, heated in a muffle oven at 800°C for 15 minutes.

9.2.2 *Special Reagents*

9.2.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D 5127 in regard to TOC analysis.

9.2.2.2 *1000 mg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 mg/mL to the appropriate volume.

9.2.3 *Sample Preparation*

9.2.3.1 Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, dilute with water, meeting the criteria for Type E1.1 in ASTM D 5127, to a final volume of 50 mL.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 µg/mL of TOC standards.

9.3 *Anions*

9.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

9.3.2 *Special Reagents*

9.3.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate ($NaHCO_3$) in deionized water meeting the criteria for Type E1.1 in ASTM D 5127. Store eluent under a helium gas blanket.

9.3.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D 5127.

9.3.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) into 100 mL of water meeting the criteria for Type E1.1 in ASTM D 5127.

9.3.3 *Sample Preparation*

9.3.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D 5127 to a final volume of 20 mL.

NOTE 5: For safety purposes, a decomposition aid such as a platinum strip should be used.

9.3.4 *Analysis*

9.3.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

9.3.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent and Separation column should be AS4-A (Dionex) or equivalent.

9.4 *Trace Metals Analysis*

9.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

9.4.2 *Special Reagents*

9.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water meeting the criteria for Type E1.1 in ASTM D 5127.

9.4.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D 5127 in regard to cation analysis.

9.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.4.3 *Sample Preparation*

9.4.3.1 In a clean environment, place 20 g of sample in a tared FEP bottle, add 20 µL of the indium internal standard.

9.4.4 *Analysis*

9.4.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium. Run a reagent blank.

10 Grade 3 Procedures

NOTE 6: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 7: Each laboratory is responsible for verifying the validity of each method within its own operation.

10.1 *Non-Metal Impurities*

10.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Free Acid

10.2 *TOC*

10.2.1 *Equipment*

10.2.1.1 TOC analyzer capable of analyzing total organic carbon in water.

10.2.1.2 Platinum sheet 1×1 inch, heated in a muffle oven at 800°C for 15 minutes.

10.2.2 *Special Reagents*

10.2.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D 5127 in regard to TOC analysis.

10.2.2.2 *1000 µg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 µg/mL to the appropriate volume.

10.2.3 *Sample Preparation*

10.2.3.1 Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, dilute with water, meeting the criteria for Type E1.1 in ASTM D 5127 to a final volume of 50 mL.

10.2.4 *Analysis*

10.2.4.1 Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 µg/mL of TOC standards.

10.3 *Anions*

10.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

10.3.2 *Special Reagents*

10.3.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate ($NaHCO_3$) in deionized water meeting the criteria for Type E1.1 in ASTM D 5127. Store eluent under a helium gas blanket.

10.3.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D 5127.

10.3.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) in 100 mL of water meeting the criteria for Type E1.1 in ASTM D 5127.

10.3.3 *Sample Preparation*

10.3.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D 5127 to a final volume of 20 mL.

NOTE 8: For safety purposes, a decomposition aid such as a platinum strip should be used.

10.3.4 *Analysis*

10.3.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

10.3.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent, and separation column should be AS4-A (Dionex) or equivalent.

10.4 *Trace Metals Analysis*

10.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.4.2 *Special Reagents*

10.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

10.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water meeting the criteria for Type E1.1 in ASTM D 5127.

10.4.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D 5127 in regard to cation analysis.

10.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

10.4.3 *Sample Preparation*

10.4.3.1 In a clean environment, place 20 g of sample into a tared FEP bottle and add 20 µL of the indium internal standard.

10.4.4 *Analysis*

10.4.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium. Run a reagent blank.

11 Grade 4 Procedures

NOTE 9: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 10: Each laboratory is responsible for verifying the validity of each method within its own operation.

11.1 *Non-Metal Impurities*

11.1.1 See Section 8, which contains procedures for the following tests:

Assay

11.2 *TOC*

11.2.1 *Equipment*

11.2.1.1 TOC analyzer capable of analyzing total oxidizable carbon in 31% H_2O_2. Validated instrumentation includes TOC analyzer using a high temperature platinum catalyst.

11.2.2 *Special Reagents*

11.2.2.1 *Water* — The water used for all of the dilutions, calibrations, and standards should be the appropriate grade of 18.2 Mohm-cm water that meets the criteria for Type E1.2 in ASTM D 5127.

11.2.2.2 *1000 µg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 µg/mL to the appropriate volume.

11.2.3 *Analysis*

11.2.3.1 Analyze TOC by directly injecting the 31% H_2O_2 into the total oxidizable carbon analyzer after the instrument has been calibrated with 0, 5, 10, and 30 µg/mL of TOC standards.

11.3 *Anions*

11.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as validity is demonstrated as defined in SEMI C1, Section 3.14 (Method Validation).

11.3.2 *Special Reagents*

11.3.2.1 *Eluent* — Prepare an eluent solution that is 100 mM potassium hydroxide (KOH) in deionized water meeting the criteria for Type E1.2 in ASTM D 5127. Prepare second solution consisting of deionized water only meeting the criteria for Type E1.2 in ASTM D 5127. Store eluents under a helium gas blanket.

11.3.3 *Sample Preparation*

11.3.3.1 Prepare the following calibration standards by spiking 31% H_2O_2 with appropriate amounts of individual anion standards: 0, 5, 15, 30 ppb.

11.3.4 *Analysis*

11.3.4.1 *Gradient* — Using the prepared eluent solutions, design a gradient as follows, flow rate should remain 2ml/min throughout analysis:

Pump	*Time (min)*	*[mM KOH]*
isocratic	0.0–2.5	1.0
isocratic	2.5–14	9.0
ramp	14–15	40.0
ramp	15–30	47.0

11.3.4.2 *Columns* — Precolumn should be AG15 (Dionex) or equivalent, separation column should be AS15 (Dionex) or equivalent, concentrator column should be TAC-LP1 (Dionex) or equivalent.

11.3.4.3 Load 5mL standard then 5mL deionized water meeting the criteria for Type E1.2 in ASTM D 5127 onto concentrator column. Using the prepared solutions, blanks, and prescribed eluent gradient analyze chloride, nitrate, phosphate, and sulfate in neat 31% H_2O_2 by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

11.4 *Trace Metals Analysis*

11.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as validity is demonstrated as defined in SEMI C1, Section 3.14 (Method Validation).

11.4.2 *Special Reagents*

11.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

11.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water that meets the criteria for Type E1.2 in ASTM D 5127.

11.4.2.3 *Water* — The water used for all of the dilutions, calibrations, and standards should be the appropriate grade of 18.2 Mohm-cm water meeting the criteria for Type E1.2 in ASTM D 5127.

11.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

11.4.3 *Sample Preparation*

11.4.3.1 In a clean environment, place 200 g of sample into a tared FEP bottle and add 20 µL of the indium internal standard.

11.4.4 *Analysis*

11.4.4.1 Using the prepared solutions and blanks, analyze the aforementioned metals by GFAA and/or inductively coupled plasma mass spectrometry (ICP-MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 2 ng/g of indium. Run a reagent blank.

12 Grade 5 Procedures

NOTE 11: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 12: Each laboratory is responsible for verifying the validity of each method within its own operation.

12.1 *Non-Metal Impurities*

12.1.1 See Section 8, which contains procedures for the following tests:

Assay

12.2 *TOC*

12.2.1 *Equipment*

12.2.1.1 TOC analyzer capable of analyzing total oxidizable carbon in 31% H_2O_2. Validated instrumentation includes TOC analyzer using a high temperature platinum catalyst.

12.2.2 *Special Reagents*

12.2.2.1 *Water* — The water used for all of the dilutions, calibrations, and standards should be the appropriate grade of 18.2 Mohm-cm water that meets the criteria for Type E1.2 in ASTM D 5127.

12.2.2.2 *1000 µg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 µg/mL to the appropriate volume.

12.2.3 *Analysis*

12.2.3.1 Analyze TOC by directly injecting the 31% H_2O_2 into the total oxidizable carbon analyzer after the instrument has been calibrated with 0, 5, 10, and 30 µg/mL of TOC standards.

12.3 *Anions*

12.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO_4), nitrate (NO_3), and sulfate (SO_4). Alternate methods may be used as long as validity is demonstrated as defined in SEMI C1, Section 3.14 (Method Validation).

12.3.2 *Special Reagents*

12.3.2.1 *Eluent* — Prepare an eluent solution that is 100 mM potassium hydroxide (KOH) in deionized water meeting the criteria for Type E1.2 in ASTM D 5127. Prepare second solution consisting of deionized water only meeting the criteria for Type E1.2 in ASTM D 5127. Store eluents under a helium gas blanket.

12.3.3 *Sample Preparation*

12.3.3.1 Prepare the following calibration standards by spiking 31% H_2O_2 with appropriate amounts of individual anion standards: 0, 5, 15, 30 ppb.

12.3.4 *Analysis*

12.3.4.1 *Gradient* — Using the prepared eluent solutions, design a gradient as follows, flow rate should remain 2mL/min throughout analysis:

Pump	*Time (min)*	*[mM KOH]*
isocratic	0.0–2.5	1.0
isocratic	2.5–14	9.0
ramp	14–15	40.0
ramp	15–30	47.0

12.3.4.2 *Columns* — Precolumn should be AG15 (Dionex) or equivalent, separation column should be AS15 (Dionex) or equivalent, concentrator column should be TAC-LP1 (Dionex) or equivalent.

12.3.4.3 Load 5mL standard then 5mL deionized water meeting the criteria for Type E1.2 in ASTM D 5127 onto concentrator column. Using the prepared solutions, blanks, and prescribed eluent gradient analyze chloride, nitrate, phosphate, and sulfate in neat 31% H_2O_2 by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

12.4 *Trace Metals Analysis*

12.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as validity is demonstrated as defined in SEMI C1, Specifications for Reagents; Section 3.14, Method Validation.

12.4.2 *Special Reagents*

12.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

12.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water meeting the criteria for Type E1.2 in ASTM D 5127.

12.4.2.3 *Water* — The water used for all of the dilutions, calibrations, and standards should be the appropriate grade of 18.2 Mohm-cm water that meets the criteria for Type E1.2 in ASTM D 5127.

12.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

12.4.3 *Sample Preparation*

12.4.3.1 In a clean environment, place 200 g of sample into a tared FEP bottle and add 20 µL of the indium internal standard.

12.4.4 *Analysis*

12.4.4.1 Using the prepared solutions and blanks, analyze the aforementioned metals by GFAA and/or inductively coupled plasma mass spectrometry (ICP-MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 2 ng/g of indium. Run a reagent blank.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Hydrogen Peroxide

Previous SEMI Reference #	C1.9-96	C7.5-95	C8.5-0298	--	--	C11.4-94
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	VLSI Grade
	(Specification)	(Specification)	(Specification)	(Specification)	(Specification)	(Guideline)
Assay (H_2O_2)	30.0–32.0%	30.0–32.0%	30.0–32.0%	30.0–32.0%	30.0–32.0%	30.0–32.0% or 34.0–36.0%
Color (APHA)	10 max	10 max	10 max	--	--	10 max
Residue after Evaporation	--	--	--	--	--	20 ppm max
Chloride (Cl)	2 ppm max	200 ppb max	200 ppb max	30 ppb max	30 ppb max	0.5 ppm max
Nitrate (NO_3)	--	400 ppb max	400 ppb max	30 ppb max	30 ppb max	--
Phosphate (PO_4)	2 ppm max	200 ppb max	200 ppb max	30 ppb max	30 ppb max	1 ppm max
Sulfate (SO_4)	5 ppm max	200 ppb max	200 ppb max	30 ppb max	30 ppb max	1 ppm max
Total Nitrogen (N)	--	--	--	--	--	2 ppm max
Total Organic Carbon (TOC)	20 ppm max	20,000 ppb max	20 ppm max	--	--	--
Total Oxidizable Carbon (TOC)	--	--	--	10 ppm max	10 ppm max	--
Free Acid	0.6 µeq/g max	0.6 µeq/g max	0.6 µeq/g max	--	--	0.6 µeq/g max
Aluminum (Al)	1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.2 ppm max
Ammonium (NH_4)	--	--	--	--	--	2 ppm max
Antimony (Sb)	--	5 ppb max	1 ppb max	100 ppt max	10 ppt max	--
Arsenic (As)	--	5 ppb max	1 ppb max	100 ppt max	10 ppt max	--
Arsenic and Antimony (as As)	0.01 ppm max	--	--	--	--	0.01 ppm max
Barium (Ba)	--	10 ppb max	--	100 ppt max	10 ppt max	0.05 ppm max
Beryllium (Be)	--	10 ppb max	--	--	--	0.01 ppm max
Bismuth (Bi)	--	10 ppb max	--	--	--	0.02 ppm max
Boron (B)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.02 ppm max
Cadmium (Cd)	--	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Calcium (Ca)	0.2 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max

Previous SEMI Reference #	C1.9-96	C7.5-95	C8.5-0298	--	--	C11.4-94
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	VLSI Grade
	(Specification)	(Specification)	(Specification)	(Specification)	(Specification)	(Guideline)
Chromium (Cr)	0.05 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Cobalt (Co)	--	10 ppb max	1 ppb max	--	--	0.01 ppm max
Copper (Cu)	0.05 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Gallium (Ga)	--	10 ppb max	--	--	--	0.02 ppm max
Germanium (Ge)	--	10 ppb max	--	--	--	0.05 ppm max
Gold (Au)	0.3 ppm max	10 ppb max	10 ppb max	--	--	0.02 ppm max
Indium (In)	--	--	--	--	--	0.02 ppm max
Iron (Fe)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max
Lead (Pb)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Lithium (Li)	--	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Magnesium (Mg)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max
Manganese (Mn)	0.05 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Molybdenum (Mo)	--	10 ppb max	1 ppb max	--	--	0.01 ppm max
Nickel (Ni)	0.05 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Niobium (Nb)	--	10 ppb max	--	--	--	--
Platinum (Pt)	--	--	--	--	--	0.02 ppm max
Potassium (K)	1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max
Silver (Ag)	--	10 ppb max	1 ppb max	--	--	0.02 ppm max
Sodium (Na)	1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max
Strontium (Sr)	--	10 ppb max	1 ppb max	--	--	0.01 ppm max
Tantalum (Ta)	--	10 ppb max	--	--	--	--
Thallium (Tl)	--	10 ppb max	--	--	--	0.02 ppm max
Tin (Sn)	1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.02 ppm max
Titanium (Ti)	0.3 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Vanadium (V)	--	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.01 ppm max
Zinc (Zn)	0.1 ppm max	10 ppb max	1 ppb max	100 ppt max	10 ppt max	0.05 ppm max
Zirconium (Zr)	--	10 ppb max	--	--	--	0.01 ppm max
Particles in bottles (size, #/mL)	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 25 max (see NOTE 1)	See NOTE 2.	See NOTE 2.	≥ 0.5 µm, 250 max

NOTE 1: Care must be taken in analyzing particles because of the potential formation of microbubbles.
NOTE 2: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

SEMI C31-0301
SPECIFICATION FOR METHANOL

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.10 in its entirety. Originally published in 1978; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for methanol used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of methanol for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of methanol used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.79 g/mL
Boiling Point	64.5°C

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

7 Requirements

7.1 The requirements for methanol for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Methanol	3.0
Ethanol	4.0
Acetone	4.8

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight pink color persists after shaking for one-half minute. Add 42 mL (33 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 1.0

mL of the sodium hydroxide solution should be required.

8.4 *Alkalinity* — Add 126 mL (100 g) of sample to 25 mL of water and mix well. Add 0.05 mL of methyl red indicator solution. Titrate with 0.01 N hydrochloric acid until a slight pink color is produced. Not more than 1.0 mL of the hydrochloric acid should be required.

8.5 *Residue after Evaporation* — Evaporate 253 mL (200 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.6 *Water* — Add 50 mL of sample to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 50 mL (40 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\% \text{ Water } (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor } (\text{g } H_2O/\text{mL}) \times 100}{\text{Weight of sample (g)}}$$

8.7 *Solubility in Water* — Mix 15 mL of sample with 45 mL of water. Allow to stand for 30 minutes. The solution should be as clear as an equal volume of water.

8.8 *Boron* — To 127 mL (100 g) of sample, add 0.10 mL of 10% sodium hydroxide solution, and evaporate to dryness in a nitrogen atmosphere using a covered chamber such as a Thiers assembly (or equivalent). Dissolve the residue with 2 mL of water and 0.10 mL of hydrochloric acid. Transfer to a test tube, cool in an ice bath, and add 10 mL of sulfuric acid. Then add 10 mL of carminic acid solution and remove from the ice bath. Allow to stand for 45 minutes. Prepare a standard containing 0.001 mg of boron treated exactly as the sample. Run a complete blank determination on 2 mL of water. Measure the absorbances of the sample and standard against the blank at 585 nm using 5.00 cm cells. The absorbance of the sample solution should be no greater than that of the standard.

8.9 *Chloride* — To 63 mL (50 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 10 mL of water. Add 1 mL of nitric acid and dilute to 20 mL with water. Add 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.10 *Phosphate* — To 25 mL (20 g) of sample add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.11 *Arsenic and Antimony (as As)* — Evaporate 253 mL (200 g) of sample in a 400 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins: "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution from the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.12 *Trace Metal Analysis*

8.12.1 *Gold (Au)* — Analyze by graphite atomic absorption using the manufacturer's recommended procedure. This technique has been shown to give satisfactory results using a 1:4 dilution and Zeeman background correction. Each laboratory must determine the appropriate dilution and background correction for its instrument to meet the specification limit.

8.12.2 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75 - 125% of a known sample spike for half of the value of each specified item.

8.12.3 *Special Reagents*

8.12.3.1 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.12.3.2 *2% (v/v) Hydrochloric Acid Solution* — Dilute 20 mL of ultra pure 12 M hydrochloric acid to 1 L using water meeting the criteria for Type E1 in ASTM D5127.

8.12.4 *Sample Preparation*

8.12.4.1 In a clean environment, place 250 g of solvent in a PTFE dish. Slowly evaporate on a hot plate avoiding loss of sample by effervescence or spattering until approximately 1 mL of liquid remains. Take up liquid and all visible residue (from walls of dish) with 1 mL ultra pure, 12 M hydrochloric acid and continue heating until approximately 0.5 mL of liquid remains. No undissolved particulate matter should be observed. Otherwise repeat the addition of hydrochloric acid until all particulate matter is dissolved. Transfer quantitatively to a 50 mL volumetric flask using 2% (v/v) hydrochloric acid and adjust liquid level to mark. Prepare a reagent blank using the same reagents and in the same manner as for the sample concentration.

8.12.5 *Analysis*

8.12.5.1 Using the prepared sample and reagent blank, analyze group I elements potassium (K) and sodium (Na) by atomic absorption spectroscopy and all other elements by plasma emission spectroscopy. Apply, if necessary, a reagent blank correction to the final determined value of the sample.

NOTE 3: Due to the uncertainty of acid concentration in the liquid residue the final concentration can be estimated to be approximately 2% (v/v). Standard calibration solutions are to use this same acid concentration.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Methanol

Previous SEMI Reference #	C1.10-96
	Grade 1
	(Specification)
Assay (CH_3OH)	99.9% min
Color (APHA)	10 max
Acidity	0.3 µeq/g max
Alkalinity	0.1 µeq/g max
Residue after Evaporation	5 ppm max
Water (H_2O)	0.05% max
Solubility in Water	To pass test
Boron (B)	0.01 ppm max
Chloride (Cl)	0.2 ppm max
Phosphate (PO_4)	0.5 ppm max
Aluminum (Al)	0.1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Calcium (Ca)	0.1 ppm max
Chromium (Cr)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gold (Au)	0.1 ppm max
Iron (Fe)	0.1 ppm max
Lead (Pb)	0.1 ppm max
Magnesium (Mg)	0.1 ppm max
Manganese (Mn)	0.1 ppm max

Previous SEMI Reference #	C1.10-96
	Grade 1
	(Specification)
Nickel (Ni)	0.1 ppm max
Potassium (K)	0.1 ppm max
Sodium (Na)	0.1 ppm max
Tin (Sn)	0.1 ppm max
Titanium (Ti)	0.1 ppm max
Zinc (Zn)	0.1 ppm max
Particles in bottles: size, #/mL	≥ 1.0 µm, 10 max

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI

SEMI C32-0699
SPECIFICATION FOR METHYL ETHYL KETONE

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.11 in its entirety. Originally published in 1978.

1 Purpose

1.1 The purpose of this document is to standardize requirements for methyl ethyl ketone used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of methyl ethyl ketone for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of methyl ethyl ketone used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.80 g/mL
Boiling Point	79.6°C

7 Requirements

7.1 The requirements for methyl ethyl ketone for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Methyl Ethyl Ketone	9.0
2-Butanol	10.5

8.2 *Color* — Dilute 3.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 15) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.10 N sodium hydroxide until a slight, pink color persists after shaking for one-half minute. Add 21 mL (17 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 3.0 mL of the sodium hydroxide solution should be required.

8.4 *Residue After Evaporation* — Evaporate 63 mL (50 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.5 *Water* — Add 25 mL of pyridine-dichloromethane mixture (1 + 1) to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 25 mL (20 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\%\ \text{Water}\ (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor}\ (\text{g}\ H_2O/\text{mL}) \times 100}{\text{Weight of sample (g)}}$$

8.6 *Phosphate* — To 12.5 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Carefully dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sufate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.7 *Heavy Metals (as Pb)* — Evaporate 25 mL (20 g) of sample to dryness on a steam bath in a hood. Dissolve the residue in 3 mL of dilute hydrochIoric acid (1 + 1) and dilute with water to 15 mL. If necessary, filter through a small filter, and wash the evaporating dish and the filter with 10 mL of water. Dilute to 25 mL with water. For the standard, dilute a solution containing 0.02 mg of lead ion (Pb) and 3 mL of dilute hydrochloric acid (1 + 1) to 25 mL with water. Adjust the pH of both solutions to between 3 and 4 with dilute ammonium hydroxide (10% NH_3) or with acetic acid, and dilute with water to 40 mL. To each solution, add 10 mL of freshly prepared hydrogen sulfide water and compare. The sample solution should be no darker than the standard.

8.8 *Arsenic and Antimony (as As)* — Evaporate 250 mL (200 g) of sample in a 400 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool and cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.9 *Trace Element Contents* — By a suitable emission spectrographic procedure, determine for each of the specified trace elements that its content is not greater than the stated specification limit (see SEMI C1, Section 3.5, Guidelines for Determination of Trace Elements by Emission Spectrography).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Methyl Ethyl Ketone

Previous SEMI Reference #	C1.11-95
	Grade 1
	(Specification)
Assay ($CH_3COCH_2CH_3$)	99.5% min
Color (APHA)	15 max
Acidity	0.6 µeq/g max
Residue after Evaporation	20 ppm max
Water (H_2O)	0.2% max

Previous SEMI Reference #	C1.11-95
	Grade 1
	(Specification)
Phosphate (PO_4)	1 ppm max
Heavy Metals (as Pb)	1 ppm max
Aluminum (Al)	1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Barium (Ba)	1 ppm max
Boron (B)	0.2 ppm max
Cadmium (Cd)	1 ppm max
Calcium (Ca)	1 ppm max
Chromium (Cr)	0.5 ppm max
Cobalt (Co)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gallium (Ga)	0.5 ppm max
Germanium (Ge)	1 ppm max
Gold (Au)	0.5 ppm max
Iron (Fe)	1 ppm max
Lithium (Li)	1 ppm max
Magnesium (Mg)	1 ppm max
Manganese (Mn)	1 ppm max
Nickel (Ni)	0.1 ppm max
Potassium (K)	1 ppm max
Silicon (Si)	1 ppm max
Silver (Ag)	0.5 ppm max
Sodium (Na)	1 ppm max
Strontium (Sr)	1 ppm max
Tin (Sn)	1 ppm max
Zinc (Zn)	1 ppm max

SEMI C33-0301
SPECIFICATIONS FOR n-METHYL 2-PYRROLIDONE

These specifications were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.25, C7.16, and C8.11 in their entirety. Originally published in 1986, 1992, and 1998 respectively; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for n-methyl 2-pyrrolidone used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of n-methyl 2-pyrrolidone for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of n-methyl 2-pyrrolidone used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.03 g/mL

7 Requirements

7.1 The requirements for n-methyl 2-pyrrolidone for Grades 1, 2, and 3 are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Due to the uncertainty of acid concentration in the liquid residue, the final concentration can be estimated to be approximately 2% (v/v).

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature:	100°C isothermal
Injector Temperature:	250°C
Detector Temperature:	300°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 5 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Butyrolactone	15.2
1-Methyl 2-Pyrrolidone	20.2
Methyl Homologue	21.2
Methyl Homologue	23.0

8.2 *Color* — Dilute 10.0 mL of platinum-cobalt stock solution (APHA No. 500) with water. Compare this standard (APHA No. 50) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

8.3 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 98 mL (100 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\% \text{ Water } (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor} (\text{g } H_2O/\text{mL}) \times 100}{\text{Weight of sample (g)}}$$

8.4 *Free Amines* — Weigh 63 mL (65 g) of sample into a 500 mL beaker. Add 100 mL of 2-propanol and mix thoroughly. Into the solution, insert a pH and reference electrodes connected to a pH meter set to the direct voltage mode. Titrate potentiometrically with 0.05 N hydrochloric acid in 2-propanol. Express the result in terms of methylamine:

$$\% \text{ Free Amines as } (CH_3NH_2) = \frac{\text{mL} \times \text{N of HCl} \times 3.10}{\text{Weight of sample (g)}}$$

8.5 *Chloride* — In a 50 mL glass-stoppered graduated cylinder, dilute 24.5 mL (25 g) of sample with water to volume. Place a 10 mL aliquot of this solution into a 50 mL Nessler tube and a 30 mL aliquot into a second tube. To the first tube add 0.01 mg of chloride standard and mix. Dilute the contents of each tube to about 45 mL with water, mix, add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution, mix thoroughly, and allow to stand for 10 minutes. Any turbidity produced by the sample should be no greater than that of the 0.01 mg standard.

8.6 *Phosphate* — Add 20 mL (20) of sample to 100 mL of dilute ammonium hydroxide (1 + 4). Prepare a standard containing 0.1 mg of phosphate ion (PO_4) in 100 mL of dilute ammonium hydroxide. Proceed as follows with each of the two solutions.

8.6.1 Add, while stirring vigorously, 3.5 mL of a 10% solution of ferric nitrate 9-hydrate. Allow to stand for 15 minutes. If the precipitate has not coagulated by this time, warm gently (avoid boiling). Filter and wash the precipitate on the filter with several portions of quite dilute ammonium hydroxide (1 + 9). Discard the filtrate and washings. Dissolve the precipitate on the filter with 50 mL nitric acid (1 + 3) added in small portions. Catch the filtrate in a 250 mL glass-stoppered conical flask. Add 13 mL of ammonium hydroxide (28-32% NH_3) to the flask while swirling and continue agitation until any precipitate redissolves. Warm the solution to 40°C and add 50 mL of ammonium molybdate-nitric acid reagent solution. Shake vigorously for 5 minutes and allow to stand at 40°C for 2 hours. The precipitate, if any, for the sample should be no greater than that for the standard.

8.6.2 *Ammonium Molybdate-Nitric Acid Reagent Solution* — Mix thoroughly 100 g of molybdate acid, 85%, with 240 mL of water and 140 mL of ammonium hydroxide (28 - 32% NH_3). Filter and add 60 mL of nitric acid. Cool and while stirring continually, pour into a cooled mixture of 400 mL of nitric acid and 960 mL of water. Add 0.1 g of ammonium phosphate, monobasic, $NH_4H_2PO_4$, allow to stand 24 hours and filter through glass wool.

8.7 *Arsenic and Antimony (as As)* — Evaporate 20 mL (20 g) of sample in a 150 mL beaker to a small volume on a hot plate. Cool, add carefully 15 mL of nitric acid and 5 mL of sulfuric acid, and evaporate to dense fumes of sulfur trioxide. Add 10 mL of nitric acid and again evaporate to dense fumes. If carbon is still present, cool, add 1 mL of 30% hydrogen peroxide, and evaporate to dense fumes of sulfur trioxide. Repeat this step with hydrogen peroxide addition until carbon has been removed completely. Cool, and cautiously wash the colorless residue into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence that begins "Swirl the flask...". Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.8 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.8.1 *Special Reagents*

8.8.1.1 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.8.1.2 *Mannitol Powder* — Use mannitol specified for reagent grade (A.C.S.) and determined, via the reagent blank, to be ultra metal ion content.

8.8.1.3 *5% Mannitol Solution* — Dissolve and dilute 5 g of mannitol to 100 mL using water meeting the criteria for Type E1.1 in ASTM D5127.

8.8.1.4 *2% (v/v) Hydrochloric Acid Solution* — Dilute 20 mL of ultra pure, 12 M hydrochloric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.8.2 *Sample Preparation*

8.8.2.1 In a clean environment, place 250 g of solvent in a PTFE dish. Add 0.5 mL of freshly prepared 5% mannitol solution. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 1 mL of liquid remains. Take up liquid and all visible residue (from walls of dish) with 1 mL ultra pure, 12 M hydrochloric acid and continue heating until approximately 0.5 mL of liquid remains. No undissolved particulate matter should be observed. Otherwise, repeat the addition of hydrochloric acid until all particulate matter is dissolved. Transfer quantitatively to a 50 mL volumetric flask using 2% (v/v) hydrochloric acid and adjust liquid level to mark. Prepare a reagent blank using the same reagents and in the same manner as for the sample concentration.

8.8.3 *Analysis*

8.8.3.1 Using the prepared sample and reagent blank, analyze group 1 elements potassium (K) and sodium (Na) by atomic absorption spectroscopy and all other elements by plasma emission spectrometry. Apply, if necessary, a reagent blank correction to the final determined value of the sample.

9 Grade 2 Procedures

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Water (H_2O)

9.2 *Methyl Amines*

9.2.1 The following method has given satisfactory results in determining methyl amine impurities at the values specified for each of the following methyl amines: mono-methylamine (MMA), di-methylamine (DMA), and tri-methylamine (TMA). Alternative methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Eluent* — Prepare 0.025 N hydrochloric (HCl) solution in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.2 *Regenerant* — Prepare a 0.1 M tetrabutyl-ammonium hydroxide (TBAOH) solution in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.3 *Sample Preparation* — Sample is injected neat.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze mono-methylamine, di-methylamine, and tri-methylamine by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

9.2.4.2 *Columns* — Precolumn should be CG2 (Dionex) or equivalent and separation column should be a CS2 (Dionex) or equivalent.

9.3 *Anions*

9.3.1 The following method has given satisfactory results in determining various anions at the values specified for each of the following anions: chloride (Cl), nitrate (NO_3), phosphate (PO_4), and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

9.3.2 *Special Reagents*

9.3.2.1 *Eluent* — Prepare a solution containing 0.38 g of sodium carbonate (Na_2CO_3) and 0.29 g of sodium bicarbonate ($NaHCO_3$) in 2 liters of deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.3.2.2 *Regenerant* — Deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.3.3 *Sample Preparation*

9.3.3.1 20 mL of NMP is added to a 100 mL plastic volumetric flask and is filled to the mark using deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.4 *Analysis*

9.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and blanks should be prepared in triplicate.

9.4.2 *Columns* — Precolumn should be AG3 (Dionex) or equivalent and the separation column should be AS3 (Dionex) or equivalent.

9.5 *Trace Metals Analysis*

9.5.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.5.2 *Special Reagents*

9.5.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.5.2.2 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.5.2.3 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.5.3 *Sample Preparation*

9.5.3.1 Place sample (1 gram) in a quartz dish. Slowly evaporate to dryness (45 min. at 70–80°C). Add 2 grams of concentrated nitric acid and heat for 15 miutes until approximately 1 gram remains. Remove the hotplate and add DI water to a final weight of 10 grams.

9.5.4 *Analysis*

9.5.4.1 Using the prepared solution and blanks, analyze the elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with 1% nitric acid solution and the indium internal standard such that the final indium concentration is 20 ng/g.

10 Grade 3 Procedures

10.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Water (H_2O)

10.2 *Methyl Amines*

10.2.1 The following method has given satisfactory results in determining methyl amine impurities at the values specified for each of the following methyl amines: mono-methylamine (MMA), dimethylamine (DMA), and trimethylamine (TMA). Alternative methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

10.2.2 *Special Reagents*

10.2.2.1 *Eluent* — Prepare 0.025 N hydrochloric acid (HCl) solution in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.2.2.2 *Regenerant* — Prepare a 0.1 M tetrabutyl-ammonium hydroxide (TBAOH) solution in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.2.3 *Sample Preparation* — Sample is injected neat.

10.2.4 *Analysis*

10.2.4.1 Using the prepared solutions and blanks, analyze mono-methylamine, di-methylamine, and tri-methylamine by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

10.2.4.2 *Columns* — Pre-column should be CG2 (Dionex) or equivalent and separation column should be a CS2 (Dionex) or equivalent.

10.3 *Anions*

10.3.1 The following method has given satisfactory results in determining various anions at the values specified for each of the following anions: chloride (Cl), nitrate (NO_3) phosphate (PO_4) and sulfate (SO_4). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified anion.

10.3.2 *Special Reagents*

10.3.2.1 *Eluent* — Prepare a solution containing 0.38 g of sodium carbonate (Na_2CO_3) and 0.29 g of sodium bicarbonate ($NaHCO_3$) in 2 liters of deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.2.2 *Regenerant* — Deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.3 *Sample Preparation*

10.3.3.1 20 mL of NMP is added to a 100 mL plastic volumetric flask and is filled to the mark using deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.4 *Analysis*

10.3.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and blanks should be prepared in triplicate.

10.3.4.2 *Columns* — Pre-column should be AG3 (Dionex) or equivalent and the separation column should be AS3 (Dionex) or equivalent.

10.4 *Trace Metal Analysis*

10.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.4.2 *Special Reagents*

10.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

10.4.2.2 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

10.4.3 *Sample Preparation*

10.4.3.1 In a 100 mL volumetric, add 20 mL of sample and fill to the mark such that the final solution contains 2% nitric acid.

10.4.4 *Standard Preparation*

10.4.4.1 Four standards are prepared such that the final solution contains 2% nitric acid (i.e., 2% of 70% nitric acid vol/vol) and 20% vol/vol sample. The four standards are 0.5, 1, 5, and 10 ppb.

10.4.5 *Analysis*

10.4.5.1 This is a method of standard addition procedure. Using the prepared solutions, analyze the elements by inductively coupled plasma mass spectrometry (ICP/MS).

10.4.5.2 Hot plasma conditions with shield are used for the following elements: Ti, Mn, Ni, Cu, As, Sb, Sn, Au, and Pb.

10.4.5.3 Cold plasma conditions with shield are used for the follow elements, B, Na, Mg, Al, K, Ca, Cr, Fe, and Zn.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for n-Methyl 2-Pyrrolidone

Previous SEMI Reference #	C1.25-95	C7.16-95	C8.11-0698
	Grade 1	Grade 2	Grade 3
	(Specification)	(Specification)	(Specification)
Assay (see NOTE 1) ($CH_3N(CH_2)_3CO$)	99.5% min	99.8% min	99.8%
Color (APHA)	50 max	50 max	30 max
Water (H_2O)	0.05% max	0.05% max	0.03% max
Free Amines (as CH_3NH_2)	50 ppm max	5,000 ppb max	5 ppm max
Chloride (Cl)	1 ppm max	500 ppb max	300 ppb max
Nitrate (NO_3)	--	500 ppb max	400 ppb max
Phosphate (PO_4)	5 ppm max	500 ppb max	250 ppb max
Sulfate (SO_4)	--	500 ppb max	250 ppb max
Aluminum (Al)	0.1 ppm max	20 ppb max	5 ppb max
Antimony (Sb)	--	20 ppb max	10 ppb max
Arsenic (As)	--	20 ppb max	10 ppb max
Arsenic and Antimony (as As)	0.1 ppm max	--	--

Previous SEMI Reference #	C1.25-95	C7.16-95	C8.11-0698
	Grade 1	Grade 2	Grade 3
	(Specification)	(Specification)	(Specification)
Boron (B)	0.1 ppm max	20 ppb max	10 ppb max
Cadmium (Cd)	--	20 ppb max	--
Calcium (Ca)	--	20 ppb max	5 ppb max
Chromium (Cr)	0.1 ppm max	100 ppb max	10 ppb max
Cobalt (Co)	--	20 ppb max	--
Copper (Cu)	0.1 ppm max	20 ppb max	5 ppb max
Gold (Au)	0.1 ppm max	20 ppb max	5 ppb max
Iron (Fe)	0.1 ppm max	20 ppb max	10 ppb max
Lead (Pb)	0.1 ppm max	20 ppb max	5 ppb max
Lithium (Li)	--	20 ppb max	--
Magnesium (Mg)	0.1 ppm max	20 ppb max	5 ppb max
Manganese (Mn)	0.1 ppm max	100 ppb max	5 ppb max
Nickel (Ni)	0.1 ppm max	20 ppb max	5 ppb max
Potassium (K)	0.1 ppm max	20 ppb max	5 ppb max
Silver (Ag)	--	20 ppb max	--
Sodium (Na)	0.3 ppm max	20 ppb max	10 ppb max
Strontium (Sr)	--	20 ppb max	--
Tin (Sn)	0.1 ppm max	20 ppb max	5 ppb max
Titanium (Ti)	0.1 ppm max	20 ppb max	5 ppb max
Vanadium (V)	--	20 ppb max	--
Zinc (Zn)	0.1 ppm max	100 ppb max	10 ppb max
Particles in bottles: size, #/mL	≥ 1.0 µm, 10 max	≥ 0.5 µm, 200 max	≥ 0.5 µm, 15 max

NOTE 1: Assay by gas chromatography includes 3- and 4-methyl homologs.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C34-0699
SPECIFICATION AND GUIDELINE FOR MIXED ACID ETCHANTS

This specification and this guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C2.1 and C7.19 in their entirety. Originally published in 1981 and 1995 respectively.

1 Purpose

1.1 The purpose of this document is to standardize requirements for mixed acid etchants used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of mixed acid etchants for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of mixed acid etchants used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

SEMI C2 — Specifications for Etchants

5 Terminology

mixed acid etchant — any combination of nitric, hydrofluoric, and acetic acids with the relative composition expressed in terms of volumes of 70% nitric acid, 49% hydrofluoric acid, and glacial acetic acid, respectively. In the expression, all the relative volumes shall be reduced to a ratio of the smallest whole numbers. For example, a 3:1:2 mixed acid etchant would imply a mixture of 3 volumes of 70% nitric acid, 1 volume of 49% hydrofluoric acid, and 2 volumes of glacial acetic acid. If a component is absent, its relative volume shall be taken as zero. For example, a 3:1:0 mixed acid etchant would imply that no acetic acid is present.

6 Composition

6.1 The content of each of the components of a mixed acid etchant shall be expressed on a weight/weight basis of the 100% acids in the total mixture. For the volume-to-weight conversion, the densities shall be taken as 1.415, 1.153 g/mL, and 1.050 g/mL for 70% nitric acid, 49% hydrofluoric acid, and glacial acetic acid, respectively.

7 Tolerances

Nitric Acid:	± 1.0% (± 0.16 meq/g)
Hydrofluoric Acid:	± 0.5% (± 0.25 meq/g)
Acetic Acid:	± 1.0% (± 0.17 meq/g)

8 Requirements

8.1 The requirements for mixed acid etchants for Grade 1 and Tier A are listed in Table 1.

9 Grade 1 Procedures

9.1 *Total Acidity* — Accurately weigh a sample containing 30 to 40 milliequivalents of acidity in a polyethylene weighing bottle. Transfer with water to a 250 mL polyethylene beaker and dilute to approximately 100 mL. Add 10 drops of phenolphthalein indicator solution and titrate with 1 N standardized sodium hydroxide to a faint pink end point. Calculate the total acidity (A):

$$\text{Total Acidity}\left(\text{meq}/\text{g}\right) = \frac{\text{mL} \times \text{N of NaOH}}{\text{Weight of sample (g)}} = A$$

9.2 *Hydrofluoric Acid* — Accurately weigh a sample containing 0.3 to 0.5 g of hydrofluoric acid in a polyethylene weighing bottle. Transfer with water to a polyethylene beaker and dilute to approximately 100 mL. Add 10 drops of phenolphthalein indicator solution and titrate with 1 N or stronger sodium hydroxide solution to a faint pink endpoint. Add 25 mL of Acetate Buffer for Hydrofluoric Acid Determination and 1 g of Eriochrome Cyanine R indicator mixture. Mix continuously by magnetic stirring and titrate with standardized aluminum chloride solution to a pink-purple endpoint.

$$\%\ \text{Hydrofluoric Acid} = \frac{\text{mL} \times \text{HF factor of } AlCl_3 \text{ soln.}}{\text{Weight of sample (g)}}$$

9.3 *Nitric Acid* — Accurately weigh a sample containing 0.9 to 1.1 g of nitric acid in a polyethylene weighing bottle. Quantitatively transfer into a 100 mL volumetric flask containing 50 mL of 2% boric acid solution, dilute to volume with water, and mix thoroughly. Following the manufacturer's direction, ready a spectrophotometer and set the wavelength to 302 nm. Transfer the sample solution to a 1 cm fused silica cell and measure the absorbance of the sample solution versus water. Read from a previously established calibration curve the grams of nitric acid present in the sample solution (see SEMI C2, Section 3.2, Determination of Nitric Acid by Ultraviolet Absorption Spectrophotometry).

$$\% \text{ Nitric Acid} = \frac{\text{grams of } HNO_3 \text{ calibration curve} \times 100}{\text{Weight of sample } (g)}$$

9.4 *Acetic Acid* — The acetic acid content is calculated by deducting the acidity found for each of the other components from the value for the total acidity.

$$\% \text{ Acetic Acid} = \left[A - \frac{\%HF}{2.001} - \frac{\%HNO_3}{6.302} \right] \times 6.005$$

9.5 *Arsenic and Antimony (as As)* — To 50 g of sample in a polyfluorocarbon dish, add 5 mL of hydrochloric acid and 5 mL of sulfuric acid. Mix gently and evaporate in a sandbath in a hood to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and re-evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, "Swirl the flask…" Any red color in the silver diethyldithiocarbamate solution of the sample should not exceed that in the standard containing 0.0015 mg of arsenic (As).

9.6 *Trace Element Contents* — Determine the levels of specified trace elements and establish that they do not exceed the specification limits using a suitable emission spectrographic procedure (see SEMI C1, Section 3.5, for Guidelines for Determination of Trace Elements by Emission Spectrography).

10 Grade 2 Procedures

10.1 This section does not apply to this chemical.

11 Grade 3 Procedures

11.1 This section does not apply to this chemical.

12 Grade 4 Procedures

12.1 This section does not apply to this chemical.

13 Grade 5 Procedures

13.1 This section does not apply to this chemical.

14 VLSI Grade Procedures

14.1 This section does not apply to this chemical.

15 Tier A Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier B Procedures

16.1 This section does not apply to this chemical.

17 Tier C Procedures

17.1 This section does not apply to this chemical.

18 Tier D Procedures

18.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Mixed Acid Etchants

Previous SEMI Reference #	C2.1-95	C7.19-95
	Grade 1	Tier A
	(Specification)	(Guideline)
Aluminum (Al)	0.3 ppm max	10 ppb max
Antimony (Sb)	--	10 ppb max
Arsenic (As)	--	10 ppb max
Arsenic and Antimony (as As)	0.03 ppm max	--
Barium (Ba)	--	10 ppb max
Boron (B)	0.2 ppm max	10 ppb max

Previous SEMI Reference #	C2.1-95	C7.19-95
	Grade 1	Tier A
	(Specification)	(Guideline)
Cadmium (Cd)	0.3 ppm max	10 ppb max
Calcium (Ca)	--	10 ppb max
Chromium (Cr)	0.2 ppm max	10 ppb max
Cobalt (Co)	--	10 ppb max
Copper (Cu)	0.1 ppm max	10 ppb max
Gallium (Ga)	--	10 ppb max
Germanium (Ge)	--	10 ppb max
Gold (Au)	0.3 ppm max	--
Iron (Fe)	0.3 ppm max	10 ppb max
Lead (Pb)	0.3 ppm max	10 ppb max
Magnesium (Mg)	0.3 ppm max	10 ppb max
Manganese (Mn)	--	10 ppb max
Molybdenum (Mo)	--	10 ppb max
Nickel (Ni)	0.1 ppm max	10 ppb max
Potassium (K)	0.3 ppm max	10 ppb max
Sodium (Na)	0.3 ppm max	10 ppb max
Strontium (Sr)	0.3 ppm max	--
Tin (Sn)	0.3 ppm max	10 ppb max
Titanium (Ti)	0.3 ppm max	10 ppb max
Zinc (Zn)	0.3 ppm max	10 ppb max
Particles in bottles: size, #/mL	≥1.0 µm	≥1.0 µm, 25 max

SEMI C35-0301
SPECIFICATIONS AND GUIDELINE FOR NITRIC ACID

These specifications and this guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.12, C7.6, and C8.6 in their entirety. Originally published in 1979, 1990, and 1992 respectively; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for nitric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of nitric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of nitric acid used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.42 g/mL

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

7 Requirements

7.1 The requirements for nitric acid for Grades 1 and 2 and Tier B are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh a small glass-stoppered conical flask containing about 15 mL of water. Deliver from a pipet about 2 mL of the sample near the water surface, stopper immediately, cool, and reweigh. Dilute to about 50 mL with water, add 0.10 mL of methyl orange indicator solution, and titrate with standardized 1 N sodium hydroxide to a red to yellow color change.

$$\%\ \text{Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 6.301}{\text{Weight of sample (g)}}$$

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Chloride* — Dilute 84 mL (120 g) of sample with 10 mL of water, add 1 mL of silver nitrate reagent solution, and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 0.5 mL of ammonium hydroxide, dilute with 20 mL of water, and add 1.5 mL of nitric acid. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.4 *Phosphate* — To 35 mL (50 g) of sample add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.5 *Sulfate* — To 70 mL (100 g) of sample add 10 mL of sodium carbonate reagent solution and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO_4) is treated as the sample.

8.6 *Arsenic and Antimony (as As)* — To 141 mL (200 g) of sample in a 400 mL beaker add 5 mL of sulfuric acid, and evaporate to dense fumes of sulfur trioxide in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.7 *Trace Metal Analysis*

8.7.1 *Gold (Au)* — Analyze by graphite atomic absorption using the manufacturer's recommended procedure. This technique has been shown to give satisfactory results using a 1:4 dilution and Zeeman background correction. Each laboratory must determine the appropriate dilution and background correction for its instrument to meet the specification limit.

8.7.2 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.7.3 *Special Reagents*

8.7.3.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.7.3.2 *2% Nitric Acid Solution* — Dilute 20 mL of ultra pure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.7.4 *Sample Preparation*

8.7.4.1 In a clean environment, place 250 g of sample in a PTFE evaporating dish. Slowly evaporate on a hot plate, avoiding loss of sample by effervescence or spattering until approximately 2 mL of liquid remains. Cool, and transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid for rinsing and dilution to volume. Run a reagent blank.

8.7.5 *Analysis*

8.7.5.1 Using the acid sample and reagent blank, analyze group 1 elements by flame atomic absorption spectroscopy and all other elements by plasma emission spectroscopy.

9 Grade 2 Procedures

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Chloride

Phosphate

Sulfate

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.2.2.2 *7.0% Nitric Acid Solution* — Dilute 20 g of ultrapure nitric acid to 200 g using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.4 *Indium Internal Standard* — Make up a indium internal standard solution to a concentration of 20 μg/mL (ppm) from a appropriate concentrated indium standard solution.

9.2.3 *Sample Preparation*

9.2.3.1 In a clean environment, place 2.00 g of sample into a tared FEP bottle (30 mL), dilute with Type E1.1 water to a final weight of 20.0 g. Add 20 µL of the indium internal standard solution. Run a reagent blank.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 7.0% nitric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemical Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Nitric Acid

Previous SEMI Reference #	C1.12-96	C7.6-95	C8.6-95
	Grade 1	Grade 2	Tier B
	(Specification)	(Specification)	(Guideline)
Assay (HNO_3)	69.0–70.0%	69.0–70.0%	69.0–70.0%
Color (APHA)	10 max (see NOTE 1)	10 max	10 max
Chloride (Cl)	0.08 ppm max	80 ppb max	50 ppb max
Phosphate (PO_4)	0.2 ppm max	200 ppb max	50 ppb max
Sulfate (SO_4)	0.5 ppm max	500 ppb max	50 ppb max
Aluminum (Al)	0.2 ppm max	5 ppb max	1 ppb max
Antimony (Sb)	--	5 ppb max	--
Arsenic (As)	--	10 ppb max	--
Arsenic and Antimony (as As)	0.005 ppm max	--	1 ppb max
Barium (Ba)	--	10 ppb max	1 ppb max
Beryllium (Be)	--	10 ppb max	1 ppb max
Bismuth (Bi)	--	10 ppb max	1 ppb max
Boron (B)	0.1 ppm max	10 ppb max	1 ppb max
Cadmium (Cd)	--	5 ppb max	1 ppb max
Calcium (Ca)	0.2 ppm max	10 ppb max	1 ppb max
Chromium (Cr)	0.1 ppm max	10 ppb max	1 ppb max
Cobalt (Co)	--	10 ppb max	1 ppb max
Copper (Cu)	0.05 ppm max	10 ppb max	1 ppb max
Gallium (Ga)	--	10 ppb max	1 ppb max
Germanium (Ge)	--	5 ppb max	1 ppb max

Previous SEMI Reference #	C1.12-96	C7.6-95	C8.6-95
	Grade 1	Grade 2	Tier B
	(Specification)	(Specification)	(Guideline)
Gold (Au)	0.3 ppm max	5 ppb max	1 ppb max
Iron (Fe)	0.2 ppm max	5 ppb max	1 ppb max
Lead (Pb)	0.1 ppm max	10 ppb max	1 ppb max
Lithium (Li)	--	5 ppb max	1 ppb max
Magnesium (Mg)	0.3 ppm max	10 ppb max	1 ppb max
Manganese (Mn)	0.2 ppm max	10 ppb max	1 ppb max
Molybdenum (Mo)	--	10 ppb max	1 ppb max
Nickel (Ni)	0.05 ppm max	10 ppb max	1 ppb max
Niobium (Nb)	--	10 ppb max	1 ppb max
Potassium (K)	0.3 ppm max	5 ppb max	1 ppb max
Silicon (Si)	--	--	1 ppb max
Silver (Ag)	--	10 ppb max	1 ppb max
Sodium (Na)	0.3 ppm max	5 ppb max	1 ppb max
Strontium (Sr)	--	10 ppb max	1 ppb max
Tantalum (Ta)	--	10 ppb max	1 ppb max
Thallium (Tl)	--	10 ppb max	1 ppb max
Tin (Sn)	0.3 ppm max	10 ppb max	1 ppb max
Titanium (Ti)	0.3 ppm max	10 ppb max	1 ppb max
Vanadium (V)	--	10 ppb max	1 ppb max
Zinc (Zn)	0.3 ppm max	10 ppb max	1 ppb max
Zirconium (Zr)	--	10 ppb max	1 ppb max
Particles in bottles: size, #/mL	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 5 max ≥ 0.2 µm, TBD

NOTE 1: This material may darken during storage due to a photochemical reaction.

SEMI C36-0301
SPECIFICATIONS FOR PHOSPHORIC ACID

These specifications were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.13, C1.27, C7.24, and C8.10 in their entirety. Originally published in 1981, 1993, 1997, and 1993 respectively; previously published February 2000.

NOTE: Information in this standard pertaining to Tier B phosphoric acid was superseded by information pertaining to Grade 3 phosphoric acid and was removed in February 2000.

1 Purpose

1.1 The purpose of this document is to standardize requirements for phosphoric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of phosphoric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of phosphoric acid used in the semiconductor industry.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

6 Physical Property (for information only)

Density at 25°C	80%	1.64 g/mL
	86%	1.70 g/mL

7 Requirements

7.1 The requirements for phosphoric acid for Grades 1, 2, and 3 are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Weigh to the nearest 1 mg about 1 mL of sample in a 250 mL glass-stoppered flask, dilute with 120 mL of water, add 0.5 mL of thymolphthalein indicator solution, and titrate with standardized 1 N sodium hydroxide to the first appearance of a blue color against a white background.

$$\%\ \text{Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 4.900}{\text{Weight of sample (g)}}$$

8.2 *Chloride* — Dilute 9 mL (15 g) of sample with 25 mL of water, and add 0.5 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.015 mg of chloride ion (Cl) is treated as the sample.

8.3 *Nitrate* — Prepare the following solutions:

Sample Solution A:	Add 3 mL (5 g) of sample to 2 mL of water, dilute to 50 mL with brucine sulfate reagent solution and mix.
Control Solution B:	Add 3 mL (5 g) of sample to 0.025 mg of nitrate ion (NO_3). Dilute to 50 mL with brucine sulfate reagent solution, and mix.
Blank Solution C:	Use 50 mL of the brucine sulfate reagent solution.

8.3.1 Heat the three solutions in a preheated (boiling water) bath for 10 minutes. Cool rapidly in an ice bath to room temperature. Set a spectrophotometer at 410 nm and, using 1 cm cells, adjust the instrument to read zero absorbance with Blank Solution C in the light path. Then determine the absorbance of Sample Solution A. Adjust the instrument to read zero absorbance with Sample Solution A in the light path and determine the absorbance of Control Solution B. The absorbance of Sample Solution A should not exceed that of Control Solution B.

8.4 *Sulfate*

8.4.1 The following inductively coupled plasma (ICP) method has given satisfactory results for the determination of sulfate (SO_4) by the analysis of sulfur (S) and subsequent calculation to determine the stoichiometric equivalent of sulfate.

NOTE 2: While this method has been shown to accurately determine sulfate concentration in phosphoric acid, the ICP methodology actually evaluates sulfur. Therefore, other sulfur species (organic, etc.) will also be determined by this method, and the "calculated" sulfate value may be higher than the actual sulfate concentration in a given sample.

8.4.2 *Special Reagents*

8.4.2.1 *Water* — The water used for all dilution, calibration and standards should meet at a minimum, the criteria for Type E1.1 in ASTM D5127.

8.4.2.2 *Scandium Internal Standard* — A scandium standard solution is utilized such that final diluted samples will have a scandium concentration of 40 ppm.

8.4.3 *Sample Preparation*

8.4.3.1 Dilute 20 g of phosphoric acid to 100 mL with water. (An aliquot of the concentrated scandium standard solution should also be added during the dilution process such that the final diluted sample will have a scandium concentration of 40 ppm.)

8.4.4 *Analysis*

8.4.4.1 Using the prepared sample, analyze the sulfur content using inductively coupled plasma (ICP) spectroscopy that has been standardized using appropriate sulfur standard solutions. A wavelength of 180.731 nm has been shown to give satisfactory results.

8.4.5 *Calculation*

8.4.5.1 The associated sulfate (SO_4) concentration is determined using the stoichiometric conversion ($SO_4 = 3 \times S$).

8.5 *Trace Metal Analysis*

8.5.1 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: arsenic (As), gold (Au), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb), and antimony (Sb). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each item specified.

8.5.2 *Special Reagents*

8.5.2.1 *Nitric Acid, Ultra Pure* — Use nitric specified for ultra low metal ion content.

8.5.2.2 *Sample Preparation* — In a clean environment, weigh 1.00 g (5.00 g for arsenic) of sample into each of two 30 mL polypropylene cups. Add 0.2 mL ultra pure nitric acid to each cup. Make standard addition to one cup. Dilute both cups to 10.0 g using water meeting the criteria for Type E1.1 in ASTM D5127. Mix. Prepare reagent blank.

8.5.2.3 *Analysis* — Using the solutions from Section 8.5.2.2 and reagent blank, analyze elements specified by graphite furnace atomic absorption spectroscopy using manufacturer's recommended procedure.

8.5.3 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), calcium (Ca), copper (Cu), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), potassium (K), sodium (Na), strontium (Sr), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each item specified.

8.5.3.1 *Sample Preparation* — In a clean environment, weigh 5.00 g of sample into each of two 30 mL polypropylene cups. To one of the cups make standard addition. Add 5.00 g of water meeting the criteria for Type E1.1 in ASTM D5127 to each cup. Mix.

8.5.3.2 *Analysis* — Using the solutions from Section 8.5.3.1 and reagent blank, analyze elements specified by plasma emission spectroscopy using manufacturer's recommended procedure.

9 Grade 2 Procedures

9.1 *Assay* — Weigh to the nearest 1 mg about 1 mL of sample in a 250 mL glass-stoppered flask, dilute with 120 mL of water, add 0.5 mL of thymolphthalein indicator solution, and titrate with standardized 1 N sodium hydroxide to the first appearance of a blue color against a white background.

$$\% \text{ Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 4.900}{\text{Weight of sample(g)}}$$

9.2 *Chloride* — Dilute 9 mL (15 g) of sample with 25 mL of water, and add 0.5 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.015 mg of chloride ion (Cl) is treated as the sample.

9.3 *Nitrate* — Prepare the following solutions:

Sample Solution A:	Add 3 mL (5 g) of sample to 2mL of water. Dilute to 50 mL with brucine sulfate reagent solution, and mix.
Control Solution B:	Add 3 mL (5 g) of sample to 0.025 mg of nitrate ion (NO_3). Dilute to 50 mL with brucine sulfate reagent solution, and mix.
Blank Solution C:	Use 50 mL of the brucine sulfate reagent solution.

9.3.1 Heat the three solutions in a preheated (boiling water) bath for 10 minutes. Cool rapidly in an ice bath to room temperature. Set a spectrophotometer at 410 nm and, using 1 cm cells, adjust the instrument to read zero absorbance with Blank Solution C in the light path. Then determine the absorbance of Sample Solution A. Adjust the instrument to read zero absorbance with Sample Solution A in the light path and determine the absorbance of Control Solution B. The absorbance of Sample Solution A should not exceed that of Control Solution B.

9.4 *Sulfate*

9.4.1 The following inductively coupled plasma (ICP) method has given satisfactory results for the determination of sulfate (SO_4) by the analysis of sulfur (S) and subsequent calculation to determine the stoichiometric equivalent of sulfate.

NOTE 3: While this method has been shown to accurately determine sulfate concentration in phosphoric acid, the ICP methodology actually evaluates sulfur. Therefore, other sulfur species (organic, etc.) will also be determined by this method, and the “calculated” sulfate value may be higher than the actual sulfate concentration in a given sample.

9.4.2 *Special Reagents*

9.4.2.1 *Water* — The water used for all dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127.

9.4.2.2 *Scandium Internal Standard* — A scandium standard solution is utilized such that final diluted samples will have a scandium concentration of 40 ppm.

9.4.3 *Sample Preparation*

9.4.3.1 Dilute 20 g of phosphoric acid to 100 mL with water. (An aliquot of the concentrated scandium standard solution should also be added during the dilution process such that the final diluted sample will have a scandium concentration of 40 ppm.)

9.4.4 *Analysis*

9.4.4.1 Using the prepared sample, analyze the sulfur content using inductively coupled plasma (ICP) spectroscopy that has been standardized using appropriate sulfur standard solutions. A wavelength of 180.731 nm has been shown to give satisfactory results.

9.4.5 *Calculation*

9.4.5.1 The associated sulfate (SO_4) concentration is determined using the stoichiometric conversion ($SO_4 = 3 \times S$).

9.5 *Trace Metal Analysis*

9.5.1 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminium (Al), antimony (Sb), arsenic (As), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), strontium (Sr), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each item specified.

9.5.1.1 *Special Reagents*

9.5.1.1.1 *Phosphoric Acid, Ultra Pure* — Use phosphoric acid specified for ultra low metal ion content.

9.5.1.1.2 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

9.5.1.1.3 *Water* — The water used for all dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127.

9.5.1.1.4 *Internal Standard Stock Solution* — An internal standard stock solution containing beryllium (Be), germanium (Ge), indium (In), lutetium (Lu), and scandium (Sc) is utilized such that final measured solutions will have a concentration of 100 ppb of each internal standard element.

9.5.1.1.5 *External Standard Stock Solution* — An external standard stock solution containing the elements in Section 9.5.1 and the internal standard elements in Section 9.5.1.1.4 is utilized such that final diluted external calibration standards will have appropriate concentrations for sample elements and will contain 100 ppb of internal standard elements.

9.5.2 *Sample Preparation* — In a clean environment, weigh 4.00 g of sample into a 100 mL polypropylene flask. Add an aliquot of the internal standard stock solution such that the final diluted sample will have a concentration of 100 ppb of each internal standard element. Add 2 mL of nitric acid, ultra pure, and dilute to 100 mL with Type E1.1 water.

9.5.2.1 *Analysis* — Analyze elements utilizing inductively coupled plasma mass spectrometry (ICP - MS). Calibrate the sample elements with matrix matched blank and external standards.

10 Grade 3 Procedures

10.1 *Assay* — Weigh to the nearest 1 mg about 1 mL of sample in a 250 mL glass-stoppered flask, dilute with 120 mL of water, add 0.5 mL of thymolphthalein indicator solution, and titrate with standardized 1 *N* sodium hydroxide to the first appearance of a blue color against a white background.

10.2 *Chloride* — Dilute 9 mL (15 g) of sample with 25 mL of water, and add 0.5 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.015 mg of chloride ion (Cl) is treated as the sample.

10.3 *Nitrate* — Prepare the following solutions:

Sample Solution A:	Add 3 mL (5 g) of sample to 2 mL of water. Dilute to 50 mL with brucine sulfate reagent solution, and mix.
Control Solution B:	Add 3 mL (5 g) of sample to 0.025 mg of nitrate ion (NO_3) Dilute to 50 mL with brucine sulfate reagent solution, and mix.
Blank Solution C:	Use 50 mL of the brucine sulfate reagent solution.

10.3.1 Heat the three solutions in a preheated (boiling water) bath for 10 minutes. Cool rapidly in an ice bath to room temperature. Set a spectrophotometer at 410 nm and, using 1 cm cells, adjust the instrument to read zero absorbance with Blank Solution C in the light path. Then determine the absorbance of Sample Solution A. Adjust the instrument to read zero absorbance with Sample Solution A in the light path and determine the absorbance of Control Solution B. The absorbance of Sample Solution A should not exceed that of Control Solution B.

10.4 *Sulfate*

10.4.1 The following inductively coupled plasma (ICP) method has given satisfactory results for the determination of sulfate (SO_4) by the analysis of sulfur (S) and subsequent calculation to determine the stoichiometric equivalent of sulfate.

NOTE 3: While this method has been shown to accurately determine sulfate concentration in phosphoric acid, the ICP method actually evaluates sulfur. Therefore, other sulfur species (organic, etc.) will also be determined by this method, and the "calculated" sulfate value may be higher than the actual sulfate concentration in a given sample.

10.4.2 *Special Reagents*

10.4.2.1 *Water* — The water used for all dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127.

10.4.2.2 *Scandium Internal Standard* — A scandium standard solution is utilized such that final diluted samples will have a scandium concentration of 40 ppm.

10.4.3 *Sample Preparation*

10.4.3.1 Dilute 20 g of phosphoric acid to 100 mL with water. (An aliquot of the concentrated scandium standard solution should also be added during the dilution process such that the final diluted sample will have a scandium concentration of 40 ppm.)

10.4.4 *Analysis*

10.4.4.1 Using the prepared sample, analyze the sulfur content using inductively coupled plasma (ICP) spectroscopy that has been standardized using appropriate sulfur standard solutions. A wavelength of 180.731 nm has been shown to give satisfactory results.

10.4.5 *Calculation*

10.4.5.1 The associated sulfate (SO_4) concentration is determined using the stiochiometric conversion ($SO_4 = 3 \times S$).

10.5 *Trace Metal Analysis*

10.5.1 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), silicon (Si), sodium (Na), strontium (Sr), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each item specified.

10.5.1.1 *Special Reagents*

10.5.1.1.1 *Phosphoric Acid, Ultra Pure* — Use phosphoric acid specified for ultra low metal ion content for preparation of matrix matched calibration standards.

10.5.1.1.2 *Water* — The water used for all dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127.

10.5.1.1.3 *Internal Standard Stock Solution* — An internal standard stock solution containing beryllium (Be), germanium (Ge), indium (In), and lutetium (Lu) is utilized such that final measured solutions will have concentrations of Be - 10 ppb, Ge - 20 ppb, In - 5 ppb, and Lu - 5 ppb as internal standard elements.

10.5.1.1.4 *External Standard Stock Solution* — An external standard stock solution containing the elements in Section 10.5.1 is utilized such that final diluted external calibration standards will have appropriate concentrations for the measurement of the sample elements.

10.5.2 *Sample Preparation* — In a clean environment, weigh 5.00 g of sample into a 10 mL polypropylene sample tube. Add an aliquot of the internal standard stock solution such that the final diluted sample will have the concentration of internal standard elements in Section 10.5.1.1.3. Dilute contents to 10 mL with Type E1.1 water.

10.5.2.1 *Analysis* — Analyze elements using inductively coupled plasma mass spectrometry (ICP - MS). Calibrate the sample elements with matrix matched blank and external standards.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Phosphoric Acid

Previous SEMI Reference #	C1.13-96, C1.27-96	C7.24-0697	
	Grade 1 (Specification)	Grade 2 (Specification)	Grade 3 (Specification)
Assay (H_3PO_4) (80%)	79.0–81.0%	79.0–81.0%	79.0–81.0%
Assay (H_3PO_4) (86%)	85.0–87.0%	85.0–87.0%	85.0–87.0%
Nitrate (NO_3)	5 ppm max	5 ppm max	5 ppm max
Sulfate (SO_4)	--	12 ppm max	12 ppm max
Total Sulfur (as SO_4)	12 ppm max	--	--
Chloride (Cl)	1 ppm max	1 ppm max	1 ppm max
Aluminum (Al)	0.5 ppm max	300 ppb max	50 ppb max
Antimony (Sb)	10 ppm max	3500 ppb max	1,000 ppb max
Arsenic (As)	0.05 ppm max	50 ppb max	50 ppb max
Barium (Ba)	--	--	50 ppb max
Boron (B)	--	--	50 ppb max
Cadmium (Cd)	--	450 ppb max	50 ppb max
Calcium (Ca)	1.5 ppm max	1100 ppb max	150 ppb max
Chromium (Cr)	0.2 ppm max	200 ppb max	50 ppb max
Cobalt (Co)	0.05 ppm max	50 ppb max	50 ppb max
Copper (Cu)	0.05 ppm max	50 ppb max	50 ppb max
Gold (Au)	0.3 ppm max	150 ppb max	50 ppb max
Iron (Fe)	2.0 ppm max	700 ppb max	100 ppb max
Lead (Pb)	0.3 ppm max	300 ppb max	50 ppb max
Lithium (Li)	0.1 ppm max	100 ppb max	10 ppb max
Magnesium (Mg)	0.2 ppm max	200 ppb max	50 ppb max
Manganese (Mn)	0.1 ppm max	100 ppb max	50 ppb max
Nickel (Ni)	0.2 ppm max	200 ppb max	50 ppb max

Previous SEMI Reference #	C1.13-96, C1.27-96	C7.24-0697	
	Grade 1	Grade 2	Grade 3
	(Specification)	(Specification)	(Specification)
Potassium (K)	1.5 ppm max	450 ppb max	150 ppb max
Silicon (Si)	--	--	50 ppb max
Sodium (Na)	2.5 ppm max	500 ppb max	250 ppb max
Strontium (Sr)	0.1 ppm max	100 ppb max	10 ppb max
Titanium (Ti)	0.3 ppm max	300 ppb max	50 ppb max
Zinc (Zn)	2.0 ppm max	400 ppb max	50 ppb max
Particles in bottles: size, #/mL	≥ 1.0 µm, 25 max	≥ 0.5 µm, 50 max	≥ 0.5 µm, 50 max

SEMI C37-0699
SPECIFICATION FOR PHOSPHORIC ETCHANTS

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C2.3 in its entirety. Originally published in 1981.

1 Purpose

1.1 The purpose of this document is to standardize requirements for phosphoric etchants used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of phosphoric etchants for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of phosphoric etchants used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

SEMI C2 — Specifications for Etchants

5 Terminology

5.1 *phosphoric etchant* — any combination of phosphoric, nitric, and acetic acids with the relative composition expressed in terms of 85% phosphoric acid, 70% nitric acid, and glacial acetic acid, respectively. In the expression, all the relative volumes shall be reduced to a ratio of the smallest whole numbers. For example, a 16:1:2 phosphoric etchant would imply a mixture of 16 volumes of 85% phosphoric acid, 1 volume of 70% nitric acid, and 2 volumes of glacial acetic acid. If a component is absent, its relative volume shall be taken as zero. For example, a 16:1:0 phosphoric etchant implies that no acetic acid is present.

6 Composition

6.1 The content of each of the components of a phosphoric etchant shall be expressed on a weight/weight basis of the 100 percent acid in the total mixture. For the volume-to-weight conversion, the densities shall be taken as 1.695, 1.415, and 1.050 g/mL for 85% phosphoric acid, 70% nitric acid, and glacial acetic acid, respectively.

7 Tolerances

7.1 The tolerances allowed for the absolute percentage of each of the components of a phosphoric etchant shall be:

Phosphoric Acid:	± 1.0% (± 0.20 meq/g)
Nitric Acid:	± 0.5% (± 0.08 meq/g)
Acetic Acid:	± 0.5% (± 0.08 meq/g)

8 Requirements

8.1 The requirements for phosphoric etchants for Grade 1 are listed in Table 1.

9 Grade 1 Procedures

9.1 *Total Acidity* — Weigh accurately 2.5 to 3.0 g of sample in a tared weighing bottle. Transfer with water to a 25 mL beaker and dilute to approximately 100 mL. Add 10 drops of thymolphthalein indicator solution and titrate with standardized 1 N sodium hydroxide solution to the blue endpoint. Calculate the total acidity (A):

$$\text{Total Acidity}\left(\text{meq}/\text{g}\right) = \frac{\text{mL} \times \text{N of NaOH}}{\text{Weight of sample (g)}} = \text{A}$$

9.2 *Phosphoric Acid* — Weigh accurately 2.5 to 3.0 g of sample in a tared weighing bottle. Quantitatively transfer the sample with 40 to 60 mL of water into a platinum or polyfluorocarbon dish. Evaporate the solution on a steam bath in a hood (1 to 2 hours). Rinse down the inner sides of the dish with 10 to 15 mL of water and re-evaporate for 1 hour. Cool and dilute with 50 mL of water. Add 10 drops of thymolphthalein indicator solution and titrate with standardized 1 N sodium hydroxide solution to the blue endpoint.

$$\%\ \text{Phosphoric Acid} = \frac{\text{mL} \times \text{N of NaOH} \times 4.900}{\text{Weight of sample (g)}}$$

9.3 *Nitric Acid* — Weigh accurately a sample containing 0.9 to 1.1 g of nitric acid in a tared 100 mL volumetric flask. Dilute to volume with water and mix thoroughly. Following the manufacturer's directions, ready a spectrophotometer and set the wavelengh to 302 nm. Transfer the sample solution to a 1 cm fused silica cell and measure the absorbance versus water. Read from a previously established calibration curve the grams of nitric acid present in the sample solulion (see

SEMI C2, Section 3.2, Determination of Nitric Acid by Ultraviolet Absorption Spectrophotometry).

$$\%\text{ Nitric Acid} = \frac{\text{grams of } HNO_3 \text{ calibration curve} \times 100}{\text{Weight of sample (g)}}$$

9.4 *Acetic Acid* — The acetic acid content is calculated by deducting the acidity found for each of the other components from the value for the total acidity.

$$\%\text{ Acetic Acid} = \left[A - \frac{\%H_3PO_4}{4.900} - \frac{\%HNO_3}{6.302}\right] \times 6.005$$

9.5 *Heavy Metals (as Pb)* — Dilute 6 g of sample to 30 mL with water. For the standard, add 0.02 mg of lead ion (Pb) to a 5 mL aliquot of this solution and dilute to 25 mL with water. For the sample, use the remaining 25 mL portion. Adjust the pH to between 3 and 4 (using a pH meter) with 1 N acetic acid or dilute ammonium hydroxide (10% NH_3), dilute to 40 mL with water, and mix. Add 10 mL of freshly prepared hydrogen sulfide water to each and mix. Any color in the solution of the sample should not exceed that in the standard.

9.6 *Antimony* — Dilute 20 mL (20 g) of stock solution to volume with water in a 100 mL volumetric flask and mix. For the standard, dilute 0.4 mg of antimony ion (Sb) to volume with water in a second 100 mL volumetric flask and mix. Following the manufacturer's directions, ready an atomic absorption spectrometer, use an air-acetylene flame, position the antimony hollow cathode lamp, and set the monochromator to the antimony resonance line of 217.6 nm. Employ deuterium lamp correction. Aspirate water and set to zero absorbance. Then aspirate, in succession, the standard, water, and sample. The absorbance of the sample should not exceed that of the standard. (see SEMI C1, Section 3.6, Guidelines for Determination of Trace Elements by Atomic Absorption Spectrometry.)

9.6.1 *Stock Solution for Sections 9.6 through 9.9* — To 200 g of sample in a 400 mL beaker, add 100 mL of water. Heat to boiling on a hot plate in a hood, and boil off approximately 100 mL. Cool slightly, add 100 mL of water, and again boil off about 100 mL. Cool, transfer to a 200 mL volumetric flask, and dilute to volume with water. One mL contains 1 gram of sample.

9.7 *Arsenic* — To 10 mL (10 g) of stock solution in a 125 mL arsine generator flask, add 30 mL of water 10 mL of ferric ammonium sulfate reagent solution, and then 2% potassium permanganate reagent solution dropwise to a permanent pink color. Add 1.5 g of sodium chloride and mix to dissolve. Heat nearly to boiling, remove from heat, and add 1 mL of stannous chloride reagent solution. Dilute to 60 mL and cool to 25°C ± 3°C. For the standard, add 20 mL of dilute sulfuric acid (1 + 4) to 0.005 mg of arsenic ion (As) in a second arsine generator flask and treat as above. Assemble the arsenic test apparatus (see SEMI C1, Section 3.4.2). Pack each scrubber tube with two pledgets of lead acetate-impregnated glass wool previously moistened with lead acetate solution, freed from excess solution by squeezing, and dried in a vacuum. Allow a small space between the two pledgets. Place 3.0 mL of silver diethyldithiocarbamate solution in each absorber tube and 10 g of zinc (granular) in each generator flask. Immediately connect the scrubber absorber assemblies to the sample and standard generator flasks. Place the flasks in a water bath maintained at 25°C ± 3°C. Swirl each flask occasionally. After 30 minutes disconnect the tubing from the generator flasks and transfer the silver diethyldithiocarbamate solutions to separate 1 cm photometer cells. Measure both sample and standard absorbances at 540 nm using the silver diethyldithiocarbamate solution as a blank. The absorbance of the sample should not exceed that of the standard.

9.8 *Manganese* — Add 25 mL (25 g) of stock solution to 100 mL of dilute sulfuric acid (1 + 9). For the standard, add 5 mL (5 g) of stock solution and 0.01 mg of manganese ion (Mn) to 100 mL of dilute sulfuric acid (1 + 9). To each solution, add 20 mL of nitric acid, heat to boiling, and continue boiling gently for 5 minutes. Cool slightly, add 0.25 g of potassium periodate, and again boil for 5 minutes. Any pink color in the sample solution should not exceed that in the standard.

9.9 *Copper, Iron, and Nickel* — Dilute 1 mL (1 g) of stock solution with 50 mL of water in a 100 mL beaker. Add 0.5 mL of ammonium hydroxide and cool. For the three-element standard, add 0.002 mg of copper ion (Cu), 0.01 mg of iron ion (Fe), and 0.003 mg of nickel ion (Ni) to 50 mL of water in a second 100 mL beaker.

9.9.1 Treat each solution as follows: Adjust the pH to 2.5 (using a pH meter) with dilute ammonium hydroxide (10% NH_3) or 10% hydrochloric acid. Transfer to a polyfluorocarbon-stoppered 250 mL separatory funnel. Rinse the beaker with water adjusted to pH 2.5 and add the rinsings to the funnel (the final volume should not exceed 100 mL). Add 10 mL of freshly prepared 1% ammonium 1-pyrrolidinecarbodithiolate solution and mix thoroughly. Add 10.0 mL of water-saturated methyl isobutyl ketone (that is, 4-methyl-2-pentanone), stopper, and shake vigorously for 3 minutes. Allow the layers to separate. Drain and discard the lower, aqueous layer; save the upper, organic layer.

9.9.2 Following the manufacturer's directions, ready the atomic absorption spectrometer for measurements in the absorbance mode and with the air-acetylene flame adjusted for aspiration of an organic solvent. For copper, align the copper hollow cathode lamp, set the wavelength to 324.7 nm, and zero the absorbance while aspirating methyl isobutyl ketone. Then aspirate the extract of the standard solution, solvent, and the extract of the sample solution. Record the absorbances. Proceed similarly for iron and nickel with measurements at 248.3 and 232.0 nm, respectively. For each of the three elements the absorbance of the sample extract should not exceed that of the standard extract (see SEMI C1, Section 3.6, Guidelines for Determination of Trace Elements by Atomic Absorption Spectrometry).

9.10 *Sodium, Lithium, Potassium, Calcium, Strontium, and Magnesium*

9.10.1 *Sample Solutions for the Determination of Sodium, Lithium, Potassium, Calcium, Strontium, and Magnesium by Atomic Absorption Spectrometry* — Thoroughly clean four 100 mL volumetric flasks and label them 1, 2, 3, 4, respectively. Transfer 20 mL (20 g) samples of stock solution into the four volumetric flasks. Add the quantities of cations as listed as follows:

CATION	FLASK	FLASK	FLASK	FLASK
	1	2	3	4
	Milligrams of Cation			
Sodium Ion (Na)	0.00	0.15	0.30	0.60
Lithium Ion (Li)	0.00	0.01	0.02	0.04
Potassium Ion (K)	0.00	0.10	0.20	0.40
Calcium Ion (Ca)	0.00	0.20	0.40	0.80
Strontium Ion (Sr)	0.00	0.05	0.10	0.20
Magnesium Ion (Mg)	0.00	0.05	0.10	0.20

9.10.2 *General Instructions* — Dilute each solution to volume with water and mix thoroughly. Following the manufacturer's directions, ready the atomic absorption spectrometer for measurements in the absorbance mode (see SEMI C1, Section 3.6, Guidelines for Determination of Trace Elements by Atomic Absorption Spectrometry). Determine each of the elements, using the conditions specified in Sections 9.10.3 through 9.10.8.

9.10.2.1 For each element plot on linear coordinate paper the absorbance versus the added quantity in milligrams of the cation added. Draw a straight line through the four points and extrapolate to zero absorbance. This intercept corresponds to the absolute amount, in milligrams, of the element being determined in Solution 1.

$$\text{ppm element} = \frac{\text{mg found} \times 1000}{\text{Weight of Sample (g)}}$$

9.10.3 *Sodium* — Using an air-acetylene flame and a sodium hollow cathode lamp, set the wavelength to 589.0 nm and zero the absorbance with water. Aspirate, and record the absorbances of each of the solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of the sodium ion (Na) in Solution 1; this should not exceed 0.30 mg.

9.10.4 *Potassium* — Using an air-acetylene flame and a potassium hollow cathode lamp, set the wavelength to 766.5 nm and zero the absorbance using water. Aspirate, and record the absorbances of each of the four solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of potassium ion (K) in Solution 1; this should not exceed 0.20 mg.

9.10.5 *Lithium* — Using an air-acetylene flame and a lithium hollow cathod lamp, set the wavelength to 670.8 and zero the absorbance with water. Aspirate and record the absorbances of each of the four solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of lithium ion (Li) in sample Solution 1; this should not exceed 0.02 mg.

9.10.6 *Strontium* — Using a nitrous oxide-acetylene flame and a strontium cathode lamp, set the wavelength to 460.7 nm and zero the absorbance with water. Aspirate, and record the absorbances of each of the four solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of strontium ion (Sr) in Solution 1; this should not exceed 0.10 mg.

9.10.7 *Calcium* — Using a nitrous oxide-acetylene flame and a calcium hollow lamp, set the wavelength to 422.7 nm and zero the absorbance with water. Aspirate, and record the absorbances of each of the four solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of calcium ion (Ca) in Solution 1; this should not exceed 0.40 mg.

9.10.8 *Magnesium* — Thoroughly clean four 50 mL volumetric flasks and label them 1a, 2a, 3a, and 4a. Transfer 20 mL (4 g) from each of the four 100 mL volumetric flasks into the corresponding 50 mL flasks. Dilute each to volume and mix thoroughly. Using an air-acetylene flame, background corrections, and a magnesium hollow lamp, set the wavelength to 285.2 nm and zero the absorbance with water. Aspirate, and record the absorbances of each of the four solutions, zeroing the absorbance with water between aspiration of the solutions. Calculate the amount of magnesium ion (Mg) in Solution 1a; this should not exceed 0.02 mg.

10 Grade 2 Procedures

10.1 This section does not apply to this chemical.

11 Grade 3 Procedures

11.1 This section does not apply to this chemical.

12 Grade 4 Procedures

12.1 This section does not apply to this chemical.

13 Grade 5 Procedures

13.1 This section does not apply to this chemical.

14 VLSI Grade Procedures

14.1 This section does not apply to this chemical.

15 Tier A Procedures

15.1 This section does not apply to this chemical.

16 Tier B Procedures

16.1 This section does not apply to this chemical.

17 Tier C Procedures

17.1 This section does not apply to this chemical.

18 Tier D Procedures

18.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Phosphoric Etchants

Previous SEMI Reference #	C2.3-95
	Grade 1
	(Specification)
Heavy Metals (as Pb)	5 ppm max
Antimony (Sb)	15 ppm max
Arsenic (As)	0.2 ppm max
Calcium (Ca)	15 ppm max
Copper (Cu)	1.2 ppm max
Iron (Fe)	6 ppm max
Lithium (Li)	0.3 ppm max
Magnesium (Mg)	2 ppm max
Manganese (Mn)	0.2 ppm max
Nickel (Ni)	1 ppm max
Potassium (K)	6 ppm max
Sodium (Na)	10 ppm max
Strontium (Sr)	2 ppm max
Particles in bottles: size, #/mL	≥1.0 µm, 25 max

SEMI C38-0699
GUIDELINE FOR PHOSPHORUS OXYCHLORIDE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.12 in its entirety. Originally published in 1991.

1 Purpose

1.1 The purpose of this document is to standardize requirements for phosphorus oxychloride used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of phosphorus oxychloride for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of phosphorus oxychloride used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for phosphorus oxychloride for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Phosphorus Oxychloride

Previous SEMI Reference #	C7.12-91
	Tier A
	(Guideline)
Assay	99.9% min
Color (APHA)	5 max
Hydroxyl	0.1 absorbance units (see NOTE 1)
Aluminum (Al)	10 ppb max
Arsenic (As)	7 ppb max
Barium (Ba)	1 ppb max
Bismuth (Bi)	1 ppb max
Calcium (Ca)	6 ppb max
Chromium (Cr)	1 ppb max
Cobalt (Co)	1 ppb max
Copper (Cu)	3 ppb max
Gallium (Ga)	1 ppb max
Gold (Au)	1 ppb max
Iron (Fe)	5 ppb max
Lead (Pb)	3 ppb max
Lithium (Li)	6 ppb max
Magnesium (Mg)	5 ppb max
Manganese (Mn)	1 ppb max
Mercury (Hg)	8 ppb max
Nickel (Ni)	1 ppb max
Niobium (Nb)	1 ppb max
Potassium (K)	3 ppb max
Silver (Ag)	1 ppb max
Sodium (Na)	5 ppb max
Strontium (Sr)	1 ppb max
Tin (Sn)	1 ppb max
Titanium (Ti)	3 ppb max
Zinc (Zn)	10 ppb max
Particles in bottles: size, #/mL	≥0.3 µm, 50 max

NOTE 1: Absorbance for the 4000 to 2700 cm^{-1} for 5 mm optical path length.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI

SEMI C39-0699
SPECIFICATION FOR POTASSIUM HYDROXIDE PELLETS

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.14 in its entirety. Originally published in 1978.

1 Purpose

1.1 The purpose of this document is to standardize requirements for potassium hydroxide pellets used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of potassium hydroxide pellets for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of potassium hydroxide pellets used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for potassium hydroxide pellets for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Weigh accurately 35 to 40 g of sample in a closed weighing bottle. Transfer to a 500 mL volumetric flask, dissolve in carbon dioxide-free water, cool to 25°C, dilute to the mark with carbon dioxide free water, and mix thoroughly. Transfer 25.0 mL of this solution to a 500 mL glass-stoppered flask, dilute with 175 mL of carbon dioxide-free water, add 5 mL of barium chloride reagent solution, shake, and allow to stand for five minutes. Add 0.15 mL of phenolphthalein indicator solution and titrate with 1 N hydrochloric acid. (Save this solution for the potassium carbonate test.)

$$\% \text{ Assay} = \frac{\text{mL} \times \text{N of HCl} \times 112.2}{\text{Weight of sample (g)}}$$

8.2 *Potassium Carbonate (K_2CO_3)* — To the above titrated solution, add 0.15 mL of methyl orange indicator solution and continue the titration with 1 N hydrochloric acid. The additional hydrochloric acid is equivalent to that consumed by the potassium carbonate.

$$\% \text{ K}_2\text{CO}_3 = \frac{\text{mL} \times \text{N} \times \text{HCl} \times 138.2}{\text{Weight of sample (g)}}$$

8.3 *Ammonium Hydroxide Precipitate* — Weigh about 10 g of sample and dissolve in about 100 mL of water.

8.3.1 Cautiously add 12 mL of sulfuric acid to 15 mL of water, cool, then cautiously add the mixture to the solution of the sample and evaporate to dense fumes. Cool, dissolve the residue in 130 mL of hot water, and add ammonium hydroxide until the solution is just basic to methyl red.

8.3.2 Heat to boiling, filter, wash with hot water, and ignite. The weight of the residue should not exceed 2 mg.

8.4 *Insoluble Matter* — Dissolve 50 g of sample in 250 mL of carbon dioxide-free water in a 500 mL stoppered flask and cool to 25°C. The solution should be clear and colorless. Filter through a tared, medium-porosity filtering crucible and wash thoroughly with hot water. Dry the crucible at 105°C for 1 hour, cool, and weigh the residue. The weight of the residue should not exceed 2.5 mg.

8.5 *Stock Solution for 8.6-8.11, 8.13-8.14* — Dissolve 50 g of sample in 250 mL of carbon dioxide-free water and dilute with such water to 500 mL. One mL contains 0.10 g of sample. Store in a plastic container.

8.6 *Nitrogen Compounds* — Dilute 20 mL of the Stock Solution with 50 mL of water in a flask connected through a spray trap to a condenser, the end of which dips beneath the surface of 10 mL of 0.1 N hydrochloric acid. For the standard, take 50 mL of water in a similar flask, and add 10 mL of the Stock Solution and 1 mL of the nitrogen standard solution. To each flask add 0.5 g of aluminum wire in small pieces, allow to stand for 1 hour, and slowly distill about 35 mL. To each distillate add 2 mL of freshly boiled 10% sodium hydroxide reagent solution, dilute with water to 50 mL, and add 2 mL of Nessler reagent. Any color in the solution of the sample should not exceed that in the standard.

8.7 *Chloride* — Dilute 10 mL of the Stock Solution with water to 50 mL. Filter if necessary through a chloride-free filter. To 10 mL of this solution, add 5 mL of water, 2 mL of nitric acid, and 1 mL of silver nitrate reagent solution. Any turbidity developed should not exceed that produced by 0.02 mg of chloride ion (Cl) in an equal volume of solution containing the quantities of reagent used in the test.

8.8 *Phosphate* — To 40 mL of the Stock Solution, add 10 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand for 2 hours at room temperature. Any blue color developed should not exceed that produced when 0.02 mg of phosphate ion (PO_4) is treated as the sample.

8.9 *Sulfate* — To 20 mL of the Stock Solution, add 5 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 20 mL of water and evaporate again to dryness. Dissolve the residue in 20 mL of water, filter if necessary, and add 1 mL of dilute hydrochloric acid (1 + 19) and 1 mL of barium chloride reagent solution. Allow to stand for 10 minutes. Any turbidity developed should not exceed that produced when 0.04 mg of sulfate ion (SO_4) is treated as the sample.

8.10 *Heavy Metals (as Ag)* — To 60 mL of the Stock Solution cautiously add 15 mL of nitric acid. For the standard add 0.05 mg of silver ion (Ag) to 10 mL of the Stock Solution and cautiously add 15 mL of nitric acid. Evaporate both solutions to dryness over a low flame or on an electric hot plate. Dissolve each residue in about 20 mL of water, filter if necessary through a chloride-free filter, and dilute with water to 25 mL. Adjust the pH of the standard and sample solutions to between 3 and 4 (using a pH meter) with 1 N acetic acid or ammonium hydroxide (10% NH_3). Dilute each solution with water to 40 mL and stir. Add 10 mL of freshly prepared hydrogen sulfide water to each solution and stir again. Any color developed in the sample should not exceed that in the standard.

8.11 *Iron* — Neutralize 10 mL of the Stock Solution with hydrochloric acid, using phenolphthalein indicator solution, add 2 mL in excess, and dilute with water to 50 mL. Add 30 to 50 mg of ammonium peroxydisulfate crystals and 3 mL of ammonium thiocyanate reagent solution. Any red color developed should not exceed that produced when 0.01 mg of iron ion (Fe) is treated as the sample.

8.12 *Mercury* — To each of two thoroughly clean 125 mL conical flasks add 20 mL of water and 1 mL of 4% potassium permanganate solution. To one add 5.5 g of solid sample. To the other add 0.5 g of sample and 0.5 mg of mercury ion (Hg). To each flask slowly add 18 mL of hydrochloric acid, with constant swirling. Heat to boiling, allow to cool, and dilute to 100 mL. Determine mercury in 10 mL aliquots by the cold vapor (flameless) atomic absorption method using 1 mL of 10% hydroxylamine hydrochloride reagent solution and 2 mL of 10% stannous chloride reagent solution for the reduction. The peak obtained with the sample solution should not be larger than that from the standard mercury solution.

8.13 *Nickel* — Dilute 20 mL of the Stock Solution to 50 mL with water and neutralize with hydrochloric acid. Dilute to 85 mL and add ammonium hydroxide to make the solution barely basic (pH 8). Add 5 mL of bromine water and 5 mL of alcoholic 1% dimethylglyoxime solution. Any red color developed should not exceed that produced when 0.02 mg of nickel ion (Ni) is treated as the sample.

8.14 *Sodium* — Dilute 10 mL of the Stock Solution with water to 100 mL to form the Sample Solution. To prepare the Standard Solution, add 0.5 mg of sodium ion (Na) to 10 mL of the Stock Solution and dilute with water to 100 mL.

8.14.1 Using flame emission spectroscopy, observe the emission of the Standard Solution at the 589 nm sodium line. Observe the emission of the Sample Solution at the 589 nm sodium line and also at a wavelength of 580 nm. The difference between the intensities observed for the Sample Solution at 580 nm and 589 nm should not exceed the difference observed at 589 nm between the Sample Solution and the Standard Solution (see SEMI C1, Section 3.7, Flame Emission Spectroscopy).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Potassium Hydroxide Pellets

Previous SEMI Reference #	C1.14-95
	Grade 1
	(Specification)
Assay (KOH)	85.0% min
Potassium Carbonate (K_2CO_3)	1.0% max
Ammonium Hydroxide Precipitate	0.02% max
Insoluble Matter	50 ppm max
Nitrogen Compounds (as N)	10 ppm max
Chloride (Cl)	0.01% max
Phosphate (PO_4)	5 ppm max
Sulfate (SO_4)	20 ppm max
Heavy Metals (as Ag)	10 ppm max
Iron (Fe)	10 ppm max
Mercury (Hg)	0.1 ppm max
Nickel (Ni)	10 ppm max
Sodium (Na)	0.05% max

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C40-0699
SPECIFICATION FOR POTASSIUM HYDROXIDE, 45% SOLUTION

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for 45% potassium hydroxide solution used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of potassium hydroxide, 45% solution for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 45% potassium hydroxide solution used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for 45% potassium hydroxide solution for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh 70 to 80 g of sample in a closed weighing bottle. Transfer to a 500 mL volumetric flask, add in carbon dioxide-free water, cool to 25°C, dilute to the mark with carbon dioxide-free water, and mix thoroughly. Transfer 25.0 mL of this solution to a 500 mL glass-stoppered flask, dilute with 175 mL of carbon dioxide-free water, add 5 mL of barium chloride reagent solution, shake and allow to stand for five minutes. Add 0.15 mL of phenolphthalein indicator solution and titrate with standardized 1 N hydrochloric acid. (Save this solution for the potassium carbonate test.)

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of HCl} \times 112.2}{\text{Weight of Sample (g)}}$$

8.2 *Potassium Carbonate (K_2CO_3)* — To the above titrated solution, add 0. 15 mL of methyl orange indicator and continue the titration with 1 N hydrochloric acid, making sure that no insoluble carbonate remains. The additional hydrochloric acid is equivalent to that consumed by the potassium carbonate.

$$\%\ K_2CO_3 = \frac{\text{mL} \times \text{N of HCl} \times 138.2}{\text{Weight of Sample (g)}}$$

8.3 *Ammonium Hydroxide Precipitate* — Weigh 40 g of sample into a 250 mL beaker and dissolve in about 100 mL of water.

8.3.1 Cautiously add 26 mL of sulfuric acid to 30 mL of water in a 150 mL glass beaker, cool; then cautiously add the mixture to the solution of the sample, and evaporate to dense fumes. Cool, dissolve the residue in 130 mL of hot water, and add ammonium hydroxide until the solution is just basic to methyl red.

8.3.2 Heat to boiling, filter, wash with hot water and ignite. The weight of the residue should not exceed 2 mg.

8.4 *Insoluble Matter* — Dilute 100 g of sample in 250 mL of carbon dioxide-free water in a 500 mL stoppered flask and cool to 25°C. The solution should be clear and colorless. Filter through a tared, medium porosity filtering crucible and wash thoroughly with hot water. Dry the crucible at 105°C for 1 hour, cool and weigh the residue. The weight of the residue should not exceed 5.0 mg.

8.5 *Stock Solution for Sections 8.6 through 8.13* — Add 100 g of sample to 250 mL of carbon dioxide-free water and dilute with such water to 500 mL. One mL contains 0.20 g of sample. Store in a plastic container.

8.6 *Nitrogen Compounds (as N)* — Dilute 20 mL of the stock solution with 50 mL of water in a flask connected through a spray trap to a condenser, the end of which dips beneath the surface of 10 mL of 0.1 N hydrochloric acid. For the standard, take 50 mL of water in a similar flask, and add 10 mL of the stock solution and 1 mL of the nitrogen standard solution (0.01mg N/mL). To each flask add 0.5 g of aluminum wire in small pieces, allow to stand for 1 hour, and slowly distill to about 35 mL. To each distillate add 2 mL of freshly boiled 10% sodium hydroxide reagent solution, dilute with water to 50, add 2 mL of Nessler reagent, and mix. Any color in the solution of the sample should not exceed that in the standard.

8.7 *Chloride* — Dilute l0 mL of the stock solution with water to 50 mL. Filter, if necessary, through a chloride-free filter. To 10 mL of this solution, add 5 mL of water, 2 mL of nitric acid, and 1 mL of silver nitrate reagent solution. Any turbidity developed should not exceed that produced by 0.02 mg of chloride (CI) ion in an equal volume of solution containing the quantities of reagent used in the test.

8.8 *Phosphate* — To 50 mL of the stock solution, add 15 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and l mL of p-(methylamino)phenol sulfate reagent solution. Allow the solution to stand for 2 hours at room temperature. Any blue color developed should not exceed that produced when 0.02 mg of phosphate (PO_4) ion is treated as the sample.

8.9 *Sulfate* — To 20 mL of the stock solution, add 5 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 20 mL of water and evaporate again to dryness. Dissolve the residue in 20 mL of water, filter if necessary, and add 1 mL of dilute hydrochloric acid (1+19) and 1 mL of barium chloride reagent solution. Allow to stand for 10 minutes. Any turbidity developed should not exceed that produced when 0.04 mg of sulfate (SO_4) ion is treated as the sample.

8.10 *Heavy Metals (as Ag)* — To 60 mL of the stock solution cautiously add 15 mL of nitric acid. For the standard add 0.05 mg of silver ion (Ag) to 10 mL of the stock solution and cautiously add 15 mL of nitric acid. Evaporate both solutions to dryness over a low flame or on an electric hot plate. Dissolve each residue in about 20 mL of water, filter if necessary through a chloride-free filter, and dilute with water to 25 mL. Adjust the pH of the standard and sample solutions to between 3 and 4 (using a pH meter) with 1 N acetic acid or ammonium hydroxide (10% NH_3). Dilute each solution with water to 40 mL and stir. Add 10 mL of freshly prepared hydrogen sulfide water to each solution and stir again. Any color developed in the sample should not exceed that in the standard.

8.11 *Iron* — Neutralize l0 mL of the stock solution with hydrochloric acid, using a phenolphthalein indicator solution, add 2 mL of HCI in excess, and dilute with water to 50 mL. Add 30 to 50 mg of ammonium peroxydisulfate crystals and 3 mL of ammonium thiocyanate reagent solution. Any red color developed should not exceed that produced when 0.01 mg of iron (Fe) ion is treated as the sample.

8.12 *Nickel* — Dilute 20 mL of the stock solution to 50 mL with water and neutralize with hydrochloric acid using a pH meter. Dilute to 85 mL with water and add ammonium hydroxide to make the solution barely basic (pH 8). Add 5 mL of bromine water and 5 mL of alcoholic 1% dimethylgy1oxime solution. Any red color developed should not exceed that produced when 0.02 mg of nickel (Ni) ion is treated as the sample.

8.13 *Sodium* — Dilute 10 mL of the stock solution with water to 100 mL to form the sample solution. To prepare the standard solution, add 0.6 mg of sodium (Na) ion to 10 mL of the stock solution and dilute with water to 100 mL.

8.13.1 Using flame emission spectroscopy, observe the emission of the standard solution at the 589 nm sodium line. Observe the emission of the sample solution at the 589 nm sodium line and also at a wavelength of 580 nm. The difference between the intensities observed for the sample solution at 580 nm and 589 nm should not exceed the difference observed at 589 nm between the sample solution and standard solution (see SEMI Cl, Section 3.7, Flame Emission Spectroscopy).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Potassium Hydroxide, 45% Solution

Previous SEMI Reference #	--
	Grade 1
	(Specification)
Assay (KOH)	45.0 - 47.0%
Insoluble Matter	50 ppm max
Nitrogen Compounds (as N)	5 ppm max
Ammonium Hydroxide Precipitate	50 ppm max
Chloride (Cl)	50 ppm max
Phosphate (PO_4)	2 ppm max
Potassium Carbonate (K_2CO_3)	0.5% max
Sulfate (SO_4)	10 ppm max
Heavy Metals (as Ag)	5 ppm max
Iron (Fe)	5 ppm max
Nickel (Ni)	5 ppm max
Sodium (Na)	0.03% max

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C41-1101
SPECIFICATIONS AND GUIDELINES FOR 2-PROPANOL

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. This document replaces SEMI C1.15, C7.7, C8.7, and C11.7 in their entirety. Originally published in 1978, 1990, 1992, and 1998 respectively. Previously published March 2001.

1 Purpose

1.1 The purpose of this document is to standardize requirements for 2-propanol used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of 2-propanol for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 2-propanol used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.78 g/mL
Boiling Point	82.3°C

7 Requirements

7.1 The requirements for 2-propanol for Grades 1 and 2, VLSI Grade, and Tiers B and C are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Due to the uncertainty of acid concentration in the liquid residue the final concentration can be estimated to be approximately 2% (v/v). Standard calibration solutions are to use this same acid concentration.

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-Wax or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
Acetone	4.5
2-Propanol	5.0

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight pink color persists after shaking for one-half minute. Add 64 mL (50 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 1.0 mL of the sodium hydroxide solution should be required.

8.4 *Alkalinity* — Add 128 mL (100 g) of sample to 25 mL of water and mix well. Add 0.05 mL of methyl red indicator solution. Titrate with 0.01 N hydrochloric acid until a slight pink color is produced. Not more than 1.0 mL of the hydrochloric acid should be required.

8.5 *Residue after Evaporation* — Evaporate 256 mL (200 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.6 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 25 mL (20 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\%\ \text{Water}\ (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor}\left(\text{g } H_2O/\text{mL}\right) \times 100}{\text{Weight of sample}\ (\text{g})}$$

8.7 *Solubility in Water* — Mix 10 mL of sample with 40 mL of water. Allow to stand 1 hour. The solution should be as clear as an equal volume of water.

8.8 *Chloride* — To 64 mL (50 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 10 mL of water, add 1 mL of nitric acid and dilute to 20 mL with water. Add 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.9 *Phosphate* — To 26 mL (20 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated like the sample.

8.10 *Arsenic and Antimony (as As)* — Evaporate 256 mL (200 g) of sample in a 400 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation with water addition. Do not allow to go to dryness. Add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, “Swirl the flask....” Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.11 *Trace Metal Analysis*

8.11.1 *Boron* — To 128 mL (100 g) of sample, add 0.10 mL of 10% sodium hydroxide, and evaporate to dryness in a nitrogen atmosphere using a covered chamber such as a Thiers assembly or equivalent. Dissolve the residue with 2 mL of water and 0.10 mL of hydrochloric acid. Transfer to a test tube, cool in an ice bath, and add 10 mL of sulfuric acid. Add 10 mL of carminic acid solution and remove from the ice bath. Allow to stand for 45 minutes. Prepare a standard containing 0.001 mg of boron treated exactly as the sample. Run a complete blank determination on 2 mL of water. Measure the absorbances of the sample and standard against the blank at 585 nm using 5.00 cm cells. The absorbance of the sample solution should be no greater than that of the standard.

8.11.1.1 *Carminic Acid Solution* — Dissolve 0.05 g of carminic acid in 100 mL of sulfuric acid and shake until dissolution is complete.

8.11.1.2 *Boron Standard Solution* — Dissolve 0.572 g of boric acid in water in a 1000 mL volumetric flask. Dilute to the mark with water. Dilute 10.0 mL of this solution with water to the mark in a 100 mL volumetric flask. (1 mL = 0.01 mg boron.)

8.11.2 *Gold (Au)* — Analyze by graphite atomic absorption using the manufacturer's recommended procedure. This technique has been shown to give satisfactory results using a 1:4 dilution and Zeeman background correction. Each laboratory must determine the appropriate dilution and background correction for their instrument to meet the specification limit.

8.11.3 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.11.4 *Special Reagents*

8.11.4.1 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.11.4.2 *2% (v/v) Hydrochloric Acid Solution* — Dilute 20 mL of ultra pure 12 M hydrochloric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.11.5 *Sample Preparation*

8.11.5.1 *Tin* — To 100 g (128 mL) sample in a PTFE dish add 1 mL of 1% oxalic acid solution. Slowly evaporate to about 1 mL. Dissolve the residue in 10% hydrochloric acid and transfer to a 10 mL volumetric flask using 10% hydrochloric acid. Analyze by plasma emission spectrometry using matrix-matched standards.

8.11.5.2 *All Other Elements* — In a clean environment, place 250 g of solvent in a PTFE dish. Slowly evaporate on a hot plate avoiding loss of sample by effervescence or spattering until approximately 1 mL of liquid remains. Take up liquid and all visible residue (from walls of dish) with 1 mL ultra pure, 12 M hydrochloric acid and continue heating until approximately 0.5 mL of liquid remains. No undissolved particulate matter should be observed. Otherwise repeat the addition of hydrochloric acid until all particulate matter is dissolved. Transfer quantitatively to a 50 mL volumetric flask using 2% (v/v) hydrochloric acid and adjust liquid level to mark. Prepare a reagent blank using the same reagents and in the same manner as for the sample concentration.

8.11.6 *Analysis*

8.11.6.1 Using the prepared sample and reagent blank, analyze group I elements potassium (K) and sodium (Na) by atomic absorption spectroscopy and all other elements by plasma emission spectroscopy. Apply, if necessary, a reagent blank correction to the final determined value of the sample.

9 Grade 2 Procedures

NOTE 4: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Water

Color (APHA)

Chloride

Phosphate

Arsenic and Antimony (as As)

Boron

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), barium (Ba), beryllium (Be), bismuth (Bi), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

9.2.2 *Special Reagents*

9.2.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.2.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.4 *Indium Internal Standard* — Make up an indium internal standard solution to a concentration of 20 mg/mL (ppm) from an appropriate concentrated indium standard solution.

9.2.2.5 *Mannitol Powder* — Mannitol powder, reagent grade (ACS)

9.2.2.6 *5% Mannitol Solution* — Prepare a 5% (by weight), dissolve and dilute 5 g of reagent grade Mannitol powder (ACS) to 100 g using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.3 *Sample Preparation*

9.2.3.1 *All Elements* — In a clean environment, place 200 g of sample into a PTFE dish. Add 5 mL of the 5% Mannitol solution and 100 mL of the 1% nitric acid solution. Slowly evaporate on a hot plate to dryness avoiding loss of sample by effervescence or spattering until 1 to 2 mL remain. Dissolve the residue with 5 mL of the 1% nitric acid solution by heating on a hot plate at low temperature for several minutes. Cool to room temperature, dilute to 50 mL with 1% nitric acid, add 50 mL of the indium internal standard, mix well. Run a reagent blank.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and a final concentration of 20 ng/g of the indium internal standard.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for 2-Propanol

Previous SEMI Reference #	C1.15-96	C7.7-93	C11.7-0698	C8.7-92	--
	Grade 1 (Specification)	Grade 2 (Specification)	VLSI Grade (Guideline)	Tier B (Guideline)	Tier C (Guideline)
Assay ($CH_3CHOHCH_3$)	99.5% min	99.8% min	--	99.8% min	99.8% min
Assay (gc)	--	--	99.7% min	--	--
Color (APHA)	10 max	10 max	10 max	10 max	10 max
Residue after Evaporation	5 ppm max	5000 ppb max	5 ppm max	1 ppm max	1 ppm max
Resistivity	--	--	15 MegOhm cm min	--	--
Solubility in Water	To pass test	--	--	--	--
Chloride (Cl)	0.2 ppm max	200 ppb max	0.2 ppm max	50 ppb max	50 ppb max
Nitrate (NO_3)	--	--	--	50 ppb max	50 ppb max
Phosphate (PO_4)	0.5 ppm max	500 ppb max	0.5 ppm max	50 ppb max	50 ppb max
Sulfate (SO_4)	--	--	1 ppm max	50 ppb max	50 ppb max
Aldehydes and Ketones (as CH_3COCH_3)	--	--	100 ppm max	--	--
Water (H_2O)	0.05% max	0.05% max	500 ppm max	100 ppm max	50 ppm max
Acidity	0.2 μeq/g max	--	0.2 μeq/g max	--	--
Alkalinity	0.1 μeq/g max	--	0.1 μeq/g max	--	--
Aluminum (Al)	0.1 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Antimony (Sb)	--	--	0.01 ppm max	1 ppb max	100 ppt max
Arsenic (As)	--	--	0.01 ppm max	1 ppb max	100 ppt max
Arsenic and Antimony (as As)	0.01 ppm max	10 ppb max	--	--	--

Previous SEMI Reference #	C1.15-96	C7.7-93	C11.7-0698	C8.7-92	--
	Grade 1	Grade 2	VLSI Grade	Tier B	Tier C
	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Barium (Ba)	--	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Beryllium (Be)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Bismuth (Bi)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Boron (B)	0.01 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Cadmium (Cd)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Calcium (Ca)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Chromium (Cr)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Cobalt (Co)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Copper (Cu)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Gallium (Ga)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Germanium (Ge)	--	10 ppb max	--	1 ppb max	--
Gold (Au)	0.1 ppm max	5 ppb max	0.02 ppm max	--	--
Indium (In)	--	--	0.01 ppm max	--	--
Iron (Fe)	0.1 ppm max	5 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Lead (Pb)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Lithium (Li)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Magnesium (Mg)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Manganese (Mn)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Molybdenum (Mo)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Nickel (Ni)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Niobium (Nb)	--	10 ppb max	--	1 ppb max	--
Platinum (Pt)	--	--	0.02 ppm max	--	--
Potassium (K)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Silicon (Si)	--	--	--	1 ppb max	--
Silver (Ag)	--	5 ppb max	0.01 ppm max	1 ppb max	--
Sodium (Na)	0.1 ppm max	10 ppb max	0.1 ppm max	1 ppb max	100 ppt max
Strontium (Sr)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Tantalum (Ta)	--	10 ppb max	--	1 ppb max	--
Thallium (Tl)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Tin (Sn)	0.1 ppm max	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Titanium (Ti)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Vanadium (V)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Zinc (Zn)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Zirconium (Zr)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Particles in bottles (size, #/mL)	≥ 1.0 µm, 10 max	≥ 0.5µm, 25 max	≥ 0.5µm, 250 max	(See NOTE 1.)	(See NOTE 1.)

NOTE 1: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

SEMI C42-0699
SPECIFICATION FOR SODIUM HYDROXIDE PELLETS

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.22 in its entirety. Originally published in 1978.

1 Purpose

1.1 The purpose of this document is to standardize requirements for sodium hydroxide pellets used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of sodium hydroxide pellets for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of sodium hydroxide pellets used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for sodium hydroxide pellets for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Weigh accurately 35 to 40 g of sample in a closed weighing bottle. Transfer to a 500 mL volumetric flask, dissolve with carbon dioxide-free water, cool to 25°C, dilute to the mark with carbon dioxide-free water, and mix thoroughly. Transfer 25 mL of this solution to a 500 mL glass-stoppered flask, dilute with 175 mL of carbon dioxide-free water, add 5 mL of barium chloride reagent solution, shake, and allow to stand for five minutes. Add 0.15 mL of phenolphthalein indicator solution and titrate with 1 N hydrochloric acid. (Save this solution for the sodium carbonate test.)

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of HCl} \times 80.00}{\text{Weight of sample (g)}}$$

8.2 *Sodium Carbonate (Na_2CO_3)* — To the above titrated solution, add 0.15 mL of methyl orange indicator and continue the titration with 1 N hydrochloric acid, making sure that no insoluble carbonate remains. The additional hydrochloric acid is equivalent to that consumed by the sodium carbonate.

$$\%\ Na_2CO_3 = \frac{\text{mL} \times \text{N of HCl} \times 106.00}{\text{Weight of sample (g)}}$$

8.3 *Ammonium Hydroxide Precipitate* — Weigh 10 g of sample and dissolve in about 100 mL of water. Cautiously add 15 mL of sulfuric acid to 15 mL of water, cool; then cautiously add the mixture to the solution of the sample, and evaporate to dense fumes. Cool, dissolve the residue in 130 mL of hot water, and add ammonium hydroxide until the solution is just basic to methyl red. Heat to boiling, filter, wash with hot water, and ignite. The weight of the residue should not exceed 2 mg.

8.4 *Insoluble Matter* — Dissolve 50 g of sample in 250 mL of carbon dioxide-free water in a 500 mL stoppered flask and cool to 25° C. The solution should be clear and colorless. Filter through a tared, medium-porosity filtering crucible and wash thoroughly with hot water. Dry at 105° C for 1 hour, cool, and weigh the residue. The result of the residue should not exceed 2.5 mg.

8.5 *Stock Solution for 8.6-8.11, 8.13-8.14* — Dissolve 50 g of sample in 250 mL of carbon dioxide-free water and dilute with such water to 500 mL. One mL contains 0.10 g of sample. Store in a plastic container.

8.6 *Nitrogen Compounds (as N)* — Dilute 20 mL of the Stock Solution with 50 mL of water in a flask connected through a spray trap to a condenser, the end of which dips beneath the surface of 10 mL of 0.1 N hydrochloric acid. For the standard, take 50 mL of water in a similar flask, and add 10 mL of the Stock Solution and 1 mL of the nitrogen standard solution. To each flask add 0.5 g of aluminum wire in small pieces, allow to stand for 1 hour, and slowly distill about 35 mL. To each distillate, add 2 mL of freshly boiled 10% sodium hydroxide reagent solution, dilute with water to 50 mL, and add 2 mL of Nessler reagent. Any color in the solution of the sample should not exceed that in the standard.

8.7 *Chloride* — Dilute 10 mL of the Stock Solution with water to 100 mL. Filter, if necessary, through a chloride-free filter. To 20 mL of this solution add 5 mL of water, 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity developed should not exceed that produced by 0.01 mg of chloride ion (Cl) in an equal volume of solution containing the quantities of reagents used in the test.

8.8 *Phosphate* — To 40 mL of Stock Solution, add 10 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand for 2 hours at room temperature. Any blue color developed should not exceed that produced when 0.02 mg of phosphate ion (PO_4) is treated as the sample.

8.9 *Sulfate* — To 20 mL of the Stock Solution, add 5 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 20 mL of water and evaporate again to dryness. Dissolve the residue in 20 mL of water, filter if necessary and add 1 mL of dilute hydrochloric acid (1 + 19) and 1 mL of barium chloride reagent solution. Allow to stand for 10 minutes. Any turbidity developed should not exceed that produced when 0.04 mg of sulfate ion (SO_4) is treated as the sample.

8.10 *Heavy Metals (as Ag)* — To 60 mL of the Stock Solution, cautiously add 20 mL of nitric acid. For the standard, add 0.05 mg of silver ion (Ag) to 10 mL of the Stock Solution and cautiously add 20 mL of nitric acid. Evaporate both solutions to dryness over a low flame or an electric hot plate. Dissolve each residue in about 20 mL of water, filter if necessary through a chloride-free filter, and dilute with water to 25 mL. Adjust the pH of the standard and sample solutions to between 3 and 4 (using a pH meter) with 1 N acetic acid or ammonium hydroxide (10% NH_3). Dilute each solution with water to 40 mL and stir. Add 10 mL of freshly prepared hydrogen sulfide water to each solution and stir again. Any color developed in the sample should not exceed that in the standard.

8.11 *Iron* — Neutralize 10 mL of the Stock Solution with hydrochloric acid using phenolphthalein indicator solution, add 2 mL in excess, and dilute with water to 50 mL. Add 30 to 50 mg of ammonium peroxydisulfate crystals and 3 mL of ammonium theiocyanate reagent solution. Any red color developed should not exceed that produced when 0.01 mg of iron ion (Fe) is treated as the sample.

8.12 *Mercury* — To each of two thoroughly clean 125 mL conical flasks add 20 mL of water and 1 mL of 4% potassium permanganate solution. To one add 5.5 g of sample. To the other add 0.5 g of sample and 0.5 mg of mercury ion (Hg). To each flask slowly add 18 mL of hydrochloric acid, with constant swirling. Heat to boiling, allow to cool, and dilute to 100 mL. Determine mercury in 10 mL aliquots by the cold vapor (flameless) atomic absorption method using 1 mL of 10% hydroxylamine hydrochloride reagent solution and 2 mL of 10% stannous chloride reagent solution for the reduction. The peak obtained with the sample solution should not be larger than that of the standard mercury solution.

8.13 *Nickel* — Dilute 20 mL of the Stock Solution to 50 mL with water and neutralize with hydrochloric acid using a pH meter. Dilute to 85 mL and add ammonium hydroxide to make the solution just basic (pH 8). Add 5 mL of bromine water, 5 mL of alcoholic 1% dimethylgyloxime solution in alcohol, and 5 mL of 10% sodium hydroxide reagent solution. Any red color developed should not exceed that produced when 0.02 mg of nickel ion (Ni) is treated as the sample.

8.14 *Potassium* — Dilute 10 mL of the Stock Solution with water to 100 mL to form the Sample Solution. To prepare the Standard Solution, add 0.2 mg of potassium ion (K) to 10 mL of the Stock Solution and dilute with water to 100 mL.

8.14.1 Using flame emission spectroscopy, observe the emission of the Standard Solution at the 767 nm potassium line. Observe the emission of the Sample Solution at the 767 nm potassium line and also at a wavelength of 750 nm. The difference between the intensities observed for the Sample Solution at 767 nm and 750 nm should not exceed the difference observed at 767 nm between the Sample Solution and Standard Solution (see SEMI C1, Section 3.7, Flame Emission Spectroscopy).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Sodium Hydroxide Pellets

Previous SEMI Reference #	C1.22-95
	Grade 1
	(Specification)
Assay (NaOH)	97.0% min
Sodium Carbonate (Na_2CO_3)	0.5% max
Ammonium Hydroxide Precipitate	0.02% max
Insoluble Matter	50 ppm max
Nitrogen Compounds (as N)	10 ppm max
Chloride (Cl)	50 ppm max
Phosphate (PO_4)	5 ppm max
Sulfate (SO_4)	20 ppm max
Heavy Metals (as Ag)	10 ppm max
Iron (Fe)	10 ppm max
Mercury (Hg)	0.1 ppm max
Nickel (Ni)	10 ppm max
Potassium (K)	0.02% max

SEMI C43-0699
SPECIFICATION FOR SODIUM HYDROXIDE, 50% SOLUTION

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for 50% sodium hydroxide solution used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of 50% sodium hydroxide solution for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 50% sodium hydroxide solution used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for 50% sodium hydroxide solution for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh 70 to 80 g of sample in a closed weighing bottle. Transfer to a 500 mL volumetric flask, dilute in carbon dioxide-free water, cool to 25°C, dilute to the mark with carbon dioxide-free water, and mix thoroughly. Transfer 25.0 mL of this solution to a 500 mL glass-stoppered flask, dilute with 175 mL of carbon dioxide-free water, add 5 mL of barium chloride reagent solution, shake and allow to stand for five minutes. Add 0.15 mL of phenolphthalein indicator solution and titrate with standardized 1 N hydrochloric acid. (Save this solution for the sodium carbonate test.)

$$\%\ \text{Assay} = \frac{\text{mL} \times \text{N of HCl} \times 80.00}{\text{Weight of Sample (g)}}$$

8.2 *Sodium Carbonate* — To the above titrated solution, add 0.15 mL of methyl orange indicator and continue the titration with 1 N hydrochloric acid, making sure that no insoluble carbonate remains. The additional hydrochloric acid is equivalent to that consumed by the sodium carbonate.

$$\%\ Na_2CO_3 = \frac{\text{mL} \times \text{N of HCl} \times 106.0}{\text{Weight of Sample (g)}}$$

8.3 *Ammonium Hydroxide Precipitate* — Weigh 20 g of sample into 250 mL beaker and dissolve in about 100 mL of water.

8.3.1 Cautiously add 15 mL of sulfuric acid to 15 mL of water in a 100 mL glass beaker, cool; then cautiously add the mixture to the solution of the sample, and evaporate to dense fumes. Cool, dissolve the residue in 130 mL of hot water, and add ammonium hydroxide until the solution is just basic to methyl red.

8.3.2 Heat to boiling, filter, wash with hot water and ignite. The weight of the residue should not exceed 2 mg.

8.4 *Insoluble Matter* — Dilute 50 g of sample in 250 mL of carbon dioxide-free water in a 500 mL stoppered flask and cool to 25°C. The solution should be clear and colorless. Filter through a tared, medium porosity filtering crucible and wash thoroughly with hot water. Dry the crucible at 105°C for 1 hour, cool and weigh the residue. The weight of the residue should not exceed 2.5 mg.

8.5 *Stock Solution for Sections 8.6 through 8.13* — Add 50 g of sample to 250 mL of carbon dioxide-free water and dilute with such water to 500 mL. One mL contains 0.10 g of sample. Store in a plastic container.

8.6 *Nitrogen Compounds (as N)* — Dilute 30 mL of the stock solution with 50 mL of water in a flask connected through a spray trap to a condenser, the end of which dips beneath the surface of 10 mL of 0.1 N hydrochloric acid. For the standard, take 50 mL of water in a similar flask, and add 10 mL of the stock solution and 1 mL of the nitrogen standard solution (0.010mg N/ml). To each flask add 0.5 g of aluminum wire in small pieces, and allow the solution to stand for 1 hour. Slowly distill to about 35 mL of solution. To each distillate add 2 mL of freshly boiled 10% sodium hydroxide reagent solution, dilute with water to 50 mL and add 2 mL of Nessler reagent. Any color in the solution of the sample should not exceed that in the standard.

8.7 *Chloride* — Dilute l0 mL of the stock solution with water to 100 mL. Filter, if necessary, through a chloride-free filter. To 25 mL of this solution, add 5 mL of water, 1 mL of nitric acid, and 1 mL of silver nitrate reagent solution. Any turbidity developed should not exceed that produced by 0.01 mg of chloride (CI) ion in an equal volume of solution containing the quantities of reagent used in the test

8.8 *Phosphate* — To 40 mL of the stock solution, add 10 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and l mL of p-(methylamino)phenol sulfate reagent solution. Allow the solution to stand for 2 hours at room temperature. Any blue color developed should not exceed that produced when 0.02 mg of phosphate (PO_4) ion is treated as the sample.

8.9 *Sulfate* — To 40 mL of the stock solution, add 5 mL of hydrochloric acid and evaporate to dryness on a steam bath. Dissolve the residue in 20 mL of water and evaporate again to dryness. Dissolve the residue in 20 mL of water, filter if necessary, and add 1 mL of dilute hydrochloric acid (1+19) and 1 mL of barium chloride reagent solution. Allow the solution to stand for 10 minutes. Any turbidity developed should not exceed that produced when 0.04 mg of sulfate (SO_4) ion is treated as the sample.

8.10 *Heavy Metals (as Ag)* — To 60 mL of the stock solution cautiously add 20 mL of nitric acid. For the standard add 0.05 mg of silver ion (Ag) to 10 mL of the stock solution and cautiously add 20 mL of nitric acid. Evaporate both solutions to dryness over a low flame or on an electric hot plate. Dissolve each residue in about 20 mL of water, filter if necessary through a chloride-free filter, and dilute with water to 25 mL. Adjust the pH of the standard and sample solutions to between 3 and 4 (using a pH meter) with 1 N acetic acid or ammonium hydroxide (10% NH_3). Dilute each solution with water to 40 mL and stir. Add 10 mL of freshly prepared hydrogen sulfide water to each solution and stir again. Any color developed in the sample should not exceed that in the standard.

8.11 *Iron* — Neutralize 20 mL of the stock solution with hydrochloric acid, using a phenolphthalein indicator solution, add 2 mL of HCI in excess, and dilute with water to 50 mL. Add 30 to 50 mg of ammonium peroxydisulfate crystals and 3 mL of ammonium thiocyanate reagent solution. Any red color developed should not exceed that produced when 0.01 mg of iron (Fe) ion is treated as the sample.

8.12 *Nickel* — Dilute 40 mL of the stock solution to 50 mL with water and neutralize with hydrochloric acid using a pH meter. Dilute to 85 mL with water and add ammonium hydroxide to make the solution barely basic (pH 8). Add 5 mL of bromine water and 5 mL of alcoholic 1% dimethylgy1oxime solution in alcohol, and 5 mL of 10% sodium hydroxide reagent solution. Any red color developed should not exceed that produced when 0.02 mg of nickel (Ni) ion is treated as the sample.

8.13 *Potassium* — Dilute 10 mL of the stock solution with water to 100 mL to form the sample solution. To prepare the standard solution, add 0.1 mg of potassium (K) ion to 10 mL of the stock solution and dilute with water to 100 mL.

8.13.1 Using flame emission spectroscopy, observe the emission of the standard solution at the 767 nm potassium line. Observe the emission of the sample solution at the 767 nm potassium line and also at a wavelength of 750 nm. The difference between the intensities observed for the Sample Solution at 767 nm and 750 nm should not exceed the difference observed at 767 nm between the sample solution and standard solution (see SEMI Cl, Section 3.7, Flame Emission Spectroscopy).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Sodium Hydroxide, 50% Solution

Previous SEMI Reference #	--
	Grade 1
	(Specification)
Assay (NaOH)	50.0 - 52.0%
Ammonium Hydroxide Precipitate	0.01% max
Insoluble Matter	50 ppm max
Nitrogen Compounds (as N)	5 ppm max
Chloride (Cl)	40 ppm max
Phosphate (PO_4)	5 ppm max
Sodium Carbonate (Na_2CO_3)	0.1% max
Sulfate (SO_4)	10 ppm max
Heavy Metals (as Ag)	10 ppm max
Iron (Fe)	5 ppm max
Nickel (Ni)	5 ppm max
Potassium (K)	0.01% max

SEMI C44-0301
SPECIFICATIONS AND GUIDELINES FOR SULFURIC ACID

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C1.16, C7.8, C8.8, and C11.5 in their entirety. Originally published in 1978, 1990, 1992, and 1994 respectively; previously published October 2000.

1 Purpose

1.1 The purpose of this document is to standardize requirements for sulfuric acid used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of sulfuric acid for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of sulfuric acid used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8–1.2 microns.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.83 g/mL

7 Requirements

7.1 The requirements for sulfuric acid for Grades 1 and 2, VLSI Grade, and Tiers B and C are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh 1 mL of sample in a small glass-stoppered conical flask. Cautiously add 30 mL of water, cool, add 0.1 mL of methyl orange indicator solution, and titrate with standardized 1.0 N sodium hydroxide to a red to yellow color change.

$$\%\text{Assay} = \frac{\text{mL} \times \text{N of NaOH} \times 4.904}{\text{Weight of sample (g)}}$$

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Chloride* — Place 40 mL of water in each of two beakers. To one, add carefully 27 mL (50 g) of sample and to the other, 27 mL (50 g) of chloride-free sulfuric acid and 0.005 mg of chloride ion (Cl). Cool to room temperature and add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Mix well; if necessary, make the volume of each solution identical by adding water. After 10 minutes, measure the turbidity of each solution using a suitable nephelometer. The turbidity in the sample should be no greater than the standard.

NOTE 3: Prepare chloride-free sulfuric acid in a hood by gently fuming sulfuric acid in a crucible or dish for at least 30

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

minutes. Cool and transfer to a tightly-capped glass bottle for storage.

8.4 *Nitrate* — Prepare the following solutions:

Sample Solution A:	Cautiously add 27 mL (50 g) of sample to 1.0 mL of water, dilute to 50 mL with brucine sulfate reagent solution and mix.
Control Solution B:	Cautiously add 27 mL (50 g) of sample to 1.0 mL of the standard nitrate solution containing 0.01 mg of nitrate ion (NO_3) per mL, dilute to 50 mL with brucine sulfate reagent solution and mix.
Blank Solution C:	Use 50 mL of brucine sulfate reagent solution.

8.4.1 Heat the three solutions in a preheated (boiling) water bath for 10 minutes. Cool rapidly in an ice bath to room temperature. Set a photometer at 410 nm and, using 1-cm cells, adjust the instrument to read zero absorbance with Blank Solution C in the light path, then determine the absorbance of Sample Solution A. Adjust the instrument to read zero absorbance with Sample Solution A in the light path and determine the absorbance of Control Solution B. The absorbance of Sample Solution A should be no greater than that Control Solution B.

8.5 *Phosphate* — Evaporate 11 mL (20 g) of sample to dryness in a platinum dish in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color produced should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.6 *Arsenic and Antimony (as As)* — To 109 mL (200 g) of sample in a beaker, add 5 mL of nitric acid and evaporate to about 10 mL in a hood. Cool. Cautiously add 10 mL of water, and again evaporate to about 5 mL. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the first sentence which begins: “Swirl the flask...” Any red color in the silver diethyldithiocarbamate solution from the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.7 *Trace Metal Analysis*

8.7.1 *Gold (Au)* — Analyze by graphite atomic absorption using the manufacturer's recommended procedure. This technique has been shown to give satisfactory results using a 1:4 dilution and Zeeman background correction. Each laboratory must determine the appropriate dilution and background correction for its instrument to meet the specification limit.

8.7.2 The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.7.3 *Special Reagents*

8.7.3.1 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

8.7.3.2 *Indium Internal Standard* — Make up the indium intenal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

8.7.3.3 *Nitric Acid, Ultrapure* — Use nitric acid specified for ultra low metal ion content.

8.7.3.4 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.7.3.5 *2% Nitric Acid Solution* — Dilute 20 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.7.3.6 *Hydrochloric Acid, Ultrapure* — Use hydrochloric acid specified for ultra low metal ion content.

8.7.3.7 *2% Hydrochloric Acid Solution* — Dilute 20 mL of ultra-pure hydrochloric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

8.7.4 *Sample Preparation*

8.7.4.1 *Boron* — In a clean environment, dilute 1.00 g sample with 15.0 g of Type E1.1 water and add 15 µL of the indium internal standard. Run a reagent blank.

8.7.4.2 *Tin* — In a clean environment, place 100 g of sulfuric acid in a quartz crucible. Slowly evaporate to dryness on a hot plate avoiding loss of sample by effervescence or spattering. Cool. Add 2 mL of high purity 12 M hydrochloric acid and 10 mL of water. Cover, and digest on the hot plate for 10 minutes. Cool. Transfer quantitatively to a 50 mL volumetric flask using water for rinsing and dilution to volume. Run a reagent blank.

8.7.5 *All Other Elements* — In a clean environment, place 100 g of sulfuric acid in a quartz crucible. Slowly evaporate on a hot plate avoiding loss of sample by effervescence or spattering until approximately 2 mL of liquid remains. Cool. Add carefully, 1 mL of high purity, 70% nitric acid. While maintaining volume, carefully warm several minutes to dissolve any residue. Cool. Transfer quantitatively to a 50 mL volumetric flask using 2% nitric acid and dilute to volume. Run a reagent blank.

8.7.6 *Analysis* — Using the prepared solutions and blanks, analyze boron by inductively coupled plasma mass spectrometry (ICP/MS). Using the acid sample and reagent blank, analyze group I elements by flame atomic absorption spectroscopy. Analyze all other elements by plasma emission spectroscopy.

NOTE 4: Analysis of dilute sulfuric acid can produce rapid corrosion of nickel cones commonly used in inductively coupled plasma mass spectrometry, platinum cones should be considered as alternative when performing this analysis.

9 Grade 2 Procedures

NOTE 5: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 *Non-Metal Impurities* — See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Chloride

Nitrate

Phosphate

9.2 *Trace Metals Analysis*

9.2.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

9.2.2 Special Reagents

9.2.2.1 *Nitric Acid, Ultrapure* — Use nitric acid specified for low metal ion content.

9.2.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L using water meeting the criteria for Type E1.1 in ASTM D5127.

9.2.2.3 *Water* — The water used for all the dilution, calibration and standards should meet at a minimum the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.2.2.4 *Indium Internal Standard* — Make up the indium intenal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.2.3 *Sample Preparation*

9.2.3.1 *Chromium, Cobalt, Lithium, Manganese, Nickel, Titanium, Vanadium, and Zinc* — In a clean environment, place 1.00 g of sample into a clean quartz dish. Slowly evaporate on a hot plate to dryness avoiding loss of sample by effervescence or spattering. Dissolve the residue with 5 mL of the 1% nitric acid solution by heating on a hot plate at low temperature for several minutes. Cool to room temperature, dilute to 15 mL with 1% nitric acid, add 15 µL of the indium internal standard, mix well. Run a reagent blank.

9.2.3.2 *All Other Elements* — In a clean environment, dilute 1.00 g sample with 15.0 g of Type E1.1 water and add 15 µL of the indium internal standard. Run a reagent blank.

9.2.4 *Analysis*

9.2.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final indium concentration is 20 ng/g. For boron and tantalum, the standards for calibration must be matrix matched with equal amounts of sulfuric acid certified to have both elements below 1 µg/mL in the concentrated acid.

NOTE 6: Analysis of dilute sulfuric acid can produce rapid corrosion of nickel cones commonly used in inductively coupled plasma mass spectrometry, platinum cones should be considered as alternative when performing this analysis.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Chemical Reagent Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

16 Tier C Procedures

16.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Sulfuric Acid

Previous SEMI Reference #	C1.16-96	C7.8-94	C11.5-94	C8.8-92	
	Grade 1	Grade 2	VLSI Grade	Tier B	Tier C
	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Assay (H_2SO_4)	95.0–97.0%	95.0–97.0 %	95.0–97.0%	95.0–97.0%	95.0–97.0%
Color (APHA)	10 max	10 max	10 max	10 max	10 max
Residue after Ignition	--	--	3 ppm max	--	--
Chloride (Cl)	0.1 ppm max	100 ppb max	0.1 ppm max	50 ppb max	50 ppb max
Nitrate (NO_3)	0.2 ppm max	200 ppb max	0.2 ppm max	100 ppb max	100 ppb max
Phosphate (PO_4)	0.5 ppm max	500 ppb max	0.5 ppm max	100 ppb max	100 ppb max
Matters Reducing $KMnO_4$ (as O)	--	--	2 ppm max	--	--
Aluminum (Al)	0.2 ppm max	10 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Ammonium (NH4)	--	--	1 ppm max	--	--
Antimony (Sb)	--	5 ppb max	--	1 ppb max	100 ppt max
Arsenic (As)	--	10 ppb max	--	1 ppb max	100 ppt max
Arsenic and Antimony (as As)	0.005 ppm max	--	0.01 ppm max	--	--
Barium (Ba)	--	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Beryllium (Be)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Bismuth (Bi)	--	10 ppb max	0.05 ppm max	1 ppb max	--
Boron (B)	0.02 ppm max	20 ppb max	0.02 ppm max	1 ppb max	100 ppt max
Cadmium (Cd)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Calcium (Ca)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Chromium (Cr)	0.2 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Cobalt (Co)	--	5 ppb max	0.01 ppm max	1 ppb max	--
Copper (Cu)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Gallium (Ga)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Germanium (Ge)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Gold (Au)	0.3 ppm max	5 ppb max	0.02 ppm max	1 ppb max	--
Indium (In)	--	--	0.01 ppm max	--	--
Iron (Fe)	0.2 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Lead (Pb)	0.3 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Lithium (Li)	--	10 ppb max	0.01 ppm max	1 ppb max	--

Previous SEMI Reference #	C1.16-96	C7.8-94	C11.5-94	C8.8-92	
	Grade 1	Grade 2	VLSI Grade	Tier B	Tier C
	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Magnesium (Mg)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Manganese (Mn)	0.2 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Molybdenum (Mo)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Nickel (Ni)	0.1 ppm max	10 ppb max	0.01 ppm max	1 ppb max	100 ppt max
Niobium (Nb)	--	10 ppb max	--	1 ppb max	--
Platinum (Pt)	--	--	0.05 ppm max	--	--
Potassium (K)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Silicon (Si)	--	--	--	1 ppb max	--
Silver (Ag)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Sodium (Na)	0.3 ppm max	10 ppb max	0.1 ppm max	1 ppb max	100 ppt max
Strontium (Sr)	--	10 ppb max	0.02 ppm max	1 ppb max	--
Tantalum (Ta)	--	10 ppb max	--	1 ppb max	--
Thallium (Tl)	--	10 ppb max	0.05 ppm max	1 ppb max	--
Tin (Sn)	0.2 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Titanium (Ti)	0.3 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Vanadium (V)	--	10 ppb max	0.01 ppm max	1 ppb max	--
Zinc (Zn)	0.2 ppm max	10 ppb max	0.05 ppm max	1 ppb max	100 ppt max
Zirconium (Zr)	--	10 ppb max	0.05 ppm max	1 ppb max	--
Particles in bottles (size, #/mL)	≥ 1.0 µm, 25 max	≥ 0.5 µm, 25 max	≥ 0.5 µm, 250 max	(See NOTE 1.)	(See NOTE 1.)

NOTE 1: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

SEMI C45-0301
SPECIFICATION AND GUIDELINE FOR TETRAETHYLORTHOSILICATE (TEOS)

This specification and this guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available at www.semi.org February 2001; to be published March 2001. This document replaces SEMI C7.13 in its entirety. Originally published in 1991; previously published June 1999.

1 Purpose

1.1 The purpose of this document is to standardize requirements for tetraethylorthosilicate used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of tetraethylorthosilicate for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of tetraethylorthosilicate used in the semiconductor industry.

2.2 These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

4.2 *ASTM Standards*[1]

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industry

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 None.

6 Physical Property (for information only)

6.1 Not applicable.

7 Requirements

7.1 The requirements for tetraethylorthosilicate for Grade 1 and Tier A are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

8.1.1 *Column* — 30 meter x 530 micron fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

8.1.2 *Column Temperature* — 60°C isothermal for 1 minute, then programmed to 200°C at 20°C/min.

Injector Temperature:	120°C
Detector Temperature:	260°C
Sample Size:	1 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Retention Times (min)	
Water	2.0
Ethanol	2.5
TEOS	7.8

8.2 *Color* — Dilute 1.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 5) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Water* — The cell is dried with a dry nitrogen gas stream for twenty minutes. Reagents are added and a blank (no sample) is run. Add 5 g of sample to the dry

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

Coulometric Karl Fischer water analyzer. Results are obtained in ppm by dividing the micrograms of water found in the sample by weight of TEOS in grams.

8.4 *Trace Metals Analysis* —The following method has given satisfactory results in determining trace metal impurities at the specified value for each of the following trace metals: aluminum (Al), arsenic (As), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified item.

8.4.1 *Special Reagents* — All water used in the *Trace metals Analysis* and *Boron Analysis* should be a deionized water meeting the criteria for Type E1.1 in ASTM D5127.

8.4.1.1 *Mixed Acid* — 1% HF - 2% HNO_3 prepared by dilution of ultra pure acids with appropriate weights of deionized water.

8.4.1.2 *Standards* — Composite standard solutions containing 0, 1, 2, and 4 ppb multi-element standards are prepared by diluting with mixed acid of appropriate weights for ICP-MS. Single-element standards are prepared (Ca, Fe, K, Na) for GFAA.

8.4.2 *Sample Preparation* — In a clean environment, place 100 g of sample in a clean PFA Teflon closed bottle equipped with an inlet and outlet tube and evaporate under a nitrogen purge at approximately 110°C. When dry, close the inlet and the outlet tube and digest the residue at 100°C for 30 minutes with 7 mL of mixed acid solution. Cool and transfer the contents with deionized water. Dilute the transferred contents with deionized water to a final volume of 14 mL.

8.4.3 *Analysis* — Analyze the samples by graphite furnace atomic absorption (GFAA) for sodium, calcium, potassium, and iron. Analyze the sample for all other metallic elements by inductively coupled plasma mass spectrometry (ICP-MS).

8.5 *Boron Analysis* — The following method has given satisfactory results in the determination of trace levels of boron (B). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the specified value.

8.5.1 *Standard* — Standards of 0, 2, and 4 ppm boron are prepared by dilution of an aqueous boron stock solution with deionized water meeting the criteria for Type E1.1 in ASTM D5127.

8.5.2 *Sample Preparation* — A 100 g sample of TEOS is extracted with 10 mL of deionized water, that meets the criteria for Type E1.1 in ASTM D5127, by vigorously shaking the solution for minimum of 10 minutes on a mechanical shaker. Allow the layers to separate and remove the aqueous portion to a separate container.

8.5.3 *Analysis* — The 10 mL water extract is analyzed for boron by inductively coupled plasma atomic emission spectroscopy (ICP-AES) at 249.68 nm.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Chemical Reagent Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Tetraethylorthosilicate

Previous SEMI Reference #	--	C7.13-95
	Grade 1 (Specification)	Tier A (Guideline)
Assay	99.99% min	99.99% min
Water (see NOTE 1)	20 ppm max	20 ppm max
Color APHA	5 max	5 max
Aluminum (Al)	1 ppb max	1 ppb max
Arsenic (As)	1 ppb max	1 ppb max
Barium (Ba)	--	1 ppb max
Bismuth (Bi)	--	1 ppb max
Boron (B)	10 ppb max	10 ppb max
Calcium (Ca)	1 ppb max	1 ppb max
Chromium (Cr)	1 ppb max	1 ppb max
Cobalt (Co)	--	1 ppb max
Copper (Cu)	1 ppb max	1 ppb max
Gallium (Ga)	--	1 ppb max
Gold (Au)	--	1 ppb max
Iron (Fe)	1 ppb max	1 ppb max
Lead (Pb)	1 ppb max	1 ppb max
Lithium (Li)	--	1 ppb max
Magnesium (Mg)	1 ppb max	1 ppb max
Manganese (Mn)	1 ppb max	1 ppb max
Mercury (Hg)	--	1 ppb max
Nickel (Ni)	1 ppb max	1 ppb max
Potassium (K)	1 ppb max	1 ppb max
Silver (Ag)	--	1 ppb max
Sodium (Na)	1 ppb max	1 ppb max
Strontium (Sr)	--	1 ppb max
Tin (Sn)	1 ppb max	1 ppb max
Titanium (Ti)	1 ppb max	1 ppb max
Zinc (Zn)	1 ppb max	1 ppb max
Particles in bottles: size, #/mL	≥ 0.3 µm, 50 max	≥ 0.3 µm, 50 max

NOTE 1: Chemical Property: Water reacts with TEOS to form Ethanol.

SEMI C46-0699
GUIDELINE FOR 25% TETRAMETHYLAMMONIUM HYDROXIDE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.14 in its entirety. Originally published in 1991.

1 Purpose

1.1 The purpose of this document is to standardize requirements for 25% tetramethylammonium hydroxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of 25% tetramethylammonium hydroxide for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 25% tetramethylammonium hydroxide used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Not applicable.

7 Requirements

7.1 The requirements for 25% tetramethylammonium hydroxide for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for 25% Tetramethylammonium Hydroxide

Previous SEMI Reference #	C7.14-91
	Tier A
	(Guideline)
Assay (wt %)	25.0 ± 0.1
Carbonate (as $CO_3$2)	300 ppb max
Total Halides (as Cl^{-1})	5 ppb max
Color (APHA)	10 max
Aluminum (Al)	10 ppb max
Antimony (Sb)	10 ppb max
Arsenic (As)	10 ppb max
Barium (Ba)	10 ppb max
Beryllium (Be)	10 ppb max
Bismuth (Bi)	10 ppb max
Boron (B)	10 ppb max
Cadmium (Cd)	10 ppb max
Calcium (Ca)	10 ppb max
Chromium (Cr)	10 ppb max
Cobalt (Co)	10 ppb max
Copper (Cu)	10 ppb max
Gallium (Ga)	10 ppb max
Germanium (Ge)	10 ppb max
Gold (Au)	5 ppb max
Iron (Fe)	5 ppb max
Lead (Pb)	10 ppb max
Lithium (Li)	10 ppb max
Magnesium (Mg)	10 ppb max
Manganese (Mn)	10 ppb max
Molybdenum (Mo)	10 ppb max
Nickel (Ni)	10 ppb max
Potassium (K)	5 ppb max
Silver (Ag)	10 ppb max
Sodium (Na)	5 ppb max
Strontium (Sr)	10 ppb max
Thallium (Tl)	10 ppb max
Tin (Sn)	10 ppb max
Zinc (Zn)	10 ppb max
Zirconium (Zr)	10 ppb max
Particles in bottles: size, #/mL	≥0.5 µm, 50 max

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C47-0699
GUIDELINE FOR TRANS 1,2 DICHLOROETHYLENE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.20 in its entirety. Originally published in 1995.

1 Purpose

1.1 The purpose of this document is to standardize requirements for trans 1,2 dichloroethylene used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of trans 1,2 dichloroethylene for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of trans 1,2 dichloroethylene used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.70 g/mL

7 Requirements

7.1 The requirements for trans 1,2 dichloroethylene for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Chemical Reagent Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Trans 1,2 Dichloroethylene

Previous SEMI Reference #	C7.20-95
	Tier A
	(Guideline)
Assay	99.9% min
Water (H_2O)	20 ppb max
Acidity	0.3 µeq/g max
Aluminum (Al)	10 ppb max
Antimony (Sb)	10 ppb max
Arsenic (As)	10 ppb max
Boron (B)	5 ppb max
Calcium (Ca)	10 ppb max
Chromium (Cr)	5 ppb max
Copper (Cu)	5 ppb max
Gold (Au)	5 ppb max
Iron (Fe)	10 ppb max
Lead (Pb)	5 ppb max
Magnesium (Mg)	5 ppb max
Manganese (Mn)	5 ppb max
Nickel (Ni)	5 ppb max
Potassium (K)	10 ppb max
Sodium (Na)	10 ppb max
Tin (Sn)	5 ppb max
Titanium (Ti)	5 ppb max
Zinc (Zn)	5 ppb max
Particles in bottles: size, #/mL	≥1.0 µm, 35 max

SEMI C48-0699E
SPECIFICATION AND GUIDELINE FOR 1,1,1-TRICHLOROETHANE*, FURNACE GRADE

This specification and this guideline were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.26 and C7.15 in their entirety. Originally published in 1988 and 1991 respectively.

E This document was editorially modified in March 2000. Changes were made to the table following Section 8.1.

* CAUTION: Reacts violently with Aluminum and white metals and is not to be used for vapor degreasing. (Contains less than 0.05% inhibitors.)

1 Purpose

1.1 The purpose of this document is to standardize requirements for 1,1,1-trichloroethane, furnace grade used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of 1,1,1-trichloroethane, furnace grade for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of 1,1,1-trichloroethane, furnace grade used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.33 g/mL
Boiling Point	73°C

7 Requirements

7.1 The requirements for 1,1,1-trichloroethane, furnace grade for Grade 1 and Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Determine the assay using a suitable gas chromatograph. Integrate the areas under all stabalizer and impurity peaks and the 1,1,1-trichloroethane peak. Apply appropriate response factors for the column and detector system to correct the results from area percent to weight percent. The assay shall not be less than 99.9% by weight (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

NOTE 1: Calibration standard to be determined between supplier and user.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	150°C
Detector Temperature:	250°C
Sample Size:	0.2 µL (splitless)
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity
Approximate Retention Times (min):	
1,1,1-Trichloroethane	10.0

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight pink color persists after shaking for one-half minute. Add 75 mL (100 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 3.0 mL of the sodium hydroxide solution should be required.

8.4 *Residue After Evaporation* — Evaporate 75 mL (100 g) of sample to dryness in a clean environment. Dry at 105°C for 30 minutes, cool in desiccator and weigh to a precision of 0.1 milligram (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.5 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 38 mL (50 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir and titrate with Karl Fischer reagent to:

$$\% \text{ Water } (H_2O) = \frac{\text{mL KF reagent} \times \text{KF factor (g } H_2O\text{/mL)} \times 100}{\text{Weight of sample (g)}}$$

8.6 *Phosphate* — To 75 mL (100 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution. Add 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to 880 µm in a 1 cm cell should be no greater than that produced when 0.001 mg of phosphate ion (PO_4) is treated as the sample.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for 1,1,1-Trichloroethane, Furnace Grade

Previous SEMI Reference #	*C1.26-92*	*C7.15-91*
	Grade 1	*Tier A*
	(Specification)	*(Guideline)*
Assay (CCl_3,CH_3)	99.9% min	99.95% min
Color (APHA)	10 max	5 max
Water (H_2O)	25 ppm max	15 ppm max
Acidity	0.3 µeg/g max	--
Acidity (as HCl)	--	10 ppm max
Phosphate (PO_4)	0.01 ppm max	--
Residue after Evaporation	5 ppm max	--
Aluminum (Al)	0.005 ppm max	1 ppb max
Antimony (Sb)	0.01 ppm max	1 ppb max
Arsenic (As)	0.01 ppm max	2 ppb max
Barium (Ba)	0.01 ppm max	1 ppb max
Bismuth (Bi)	0.005 ppm max	1 ppb max
Boron (B)	0.001 ppm max	1 ppb max
Cadmium (Cd)	0.005 ppm max	1 ppb max
Calcium (Ca)	0.01 ppm max	1 ppb max
Chromium (Cr)	0.005 ppm max	1 ppb max
Cobalt (Co)	0.005 ppm max	1 ppb max
Copper (Cu)	0.005 ppm max	1 ppb max
Gallium (Ga)	0.01 ppm max	1 ppb max
Gold (Au)	0.005 ppm max	1 ppb max
Iron (Fe)	0.01 ppm max	1 ppb max
Lead (Pb)	0.005 ppm max	1 ppb max
Lithium (Li)	0.005 ppm max	1 ppb max
Magnesium (Mg)	0.005 ppm max	1 ppb max
Manganese (Mn)	0.005 ppm max	1 ppb max
Mercury (Hg)	0.005 ppm max	1 ppb max
Nickel (Ni)	0.01 ppm max	1 ppb max
Phosphorous (P)	--	1 ppb max
Potassium (K)	0.005 ppm max	1 ppb max
Silicon (Si)	0.01 ppm max	--
Silver (Ag)	0.005 ppm max	1 ppb max
Sodium (Na)	0.005 ppm max	1 ppb max
Strontium (Sr)	0.01 ppm max	1 ppb max
Tin (Sn)	0.005 ppm max	1 ppb max
Titantium (Ti)	0.01 ppm max	1 ppb max
Zinc (Zn)	0.005 ppm max	1 ppb max
Particles in bottles: size, #/mL	--	≥ 0.2 µm, 5 max ≥ 0.1 µm, 30 max

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

SEMI C49-0699
GUIDELINE FOR TRIMETHYLBORATE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.21 in its entirety. Originally published in 1995.

1 Purpose

1.1 The purpose of this document is to standardize requirements for trimethylborate used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of trimethylborate for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of trimethylborate used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 20°C	0.915 g/mL
Boiling Point	68.7°C

7 Requirements

7.1 The requirements for trimethylborate for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Trimethylborate

Previous SEMI Reference #	C7.21-95
	Tier A
	(Guideline)
Assay ($B(CH_3O)_3$)	99.95% min
Water (H_2O)	25 ppm max
Aluminum (Al)	5 ppb max
Arsenic (As)	5 ppb max
Barium (Ba)	5 ppb max
Bismuth (Bi)	5 ppb max
Calcium (Ca)	10 ppb max
Chromium (Cr)	5 ppb max
Cobalt (Co)	5 ppb max
Copper (Cu)	5 ppb max
Gallium (Ga)	5 ppb max
Gold (Au)	5 ppb max
Iron (Fe)	5 ppb max
Lead (Pb)	5 ppb max
Lithium (Li)	5 ppb max
Magnesium (Mg)	5 ppb max
Manganese (Mn)	5 ppb max
Nickel (Ni)	5 ppb max
Potassium (K)	5 ppb max
Silver (Ag)	5 ppb max
Sodium (Na)	5 ppb max
Strontium (Sr)	5 ppb max
Tin (Sn)	5 ppb max
Zinc (Zn)	5 ppb max

SEMI C50-0699
GUIDELINE FOR TRIMETHYLPHOSPHITE

This guideline was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C7.22 in its entirety. Originally published in 1995.

1 Purpose

1.1 The purpose of this document is to standardize requirements for trimethylphosphite used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of trimethylphosphite for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of trimethylphosphite used in the semiconductor industry.

3 Limitations

3.1 None.

4 Referenced Documents

4.1 None.

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 20°C	1.05 g/mL
Boiling Point	112°C

7 Requirements

7.1 The requirements for trimethylphosphite for Tier A are listed in Table 1.

8 Grade 1 Procedures

8.1 This section does not apply to this chemical.

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and supplier. The Process Chemicals Committee considers a test method to be valid only if there is a documented recovery study showing a recovery of 75 - 125%. Recovery is for a known sample spike at 50% of the specified level.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Trimethylphosphite

Previous SEMI Reference #	C7.22-95
	Tier A
	(Guideline)
Assay ($P(CH_3O)_3$)	99.0% min
Color (APHA)	10 max
Aluminum (Al)	5 ppb max
Arsenic (As)	10 ppb max
Barium (Ba)	5 ppb max
Bismuth (Bi)	5 ppb max
Calcium (Ca)	5 ppb max
Chromium (Cr)	5 ppb max
Cobalt (Co)	5 ppb max
Copper (Cu)	5 ppb max
Gallium (Ga)	5 ppb max
Gold (Au)	5 ppb max
Iron (Fe)	5 ppb max
Lead (Pb)	5 ppb max
Lithium (Li)	5 ppb max
Magnesium (Mg)	5 ppb max
Manganese (Mn)	5 ppb max
Mercury (Hg)	5 ppb max
Nickel (Ni)	5 ppb max
Potassium (K)	5 ppb max
Silver (Ag)	5 ppb max
Sodium (Na)	15 ppb max
Strontium (Sr)	5 ppb max
Tin (Sn)	5 ppb max
Titanium (Ti)	5 ppb max
Zinc (Zn)	10 ppb max

SEMI C51-0699
SPECIFICATION FOR XYLENES

This specification was technically approved by the Global Process Chemicals Committee and is the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on April 23, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. This document replaces SEMI C1.21 in its entirety. Originally published in 1978.

1 Purpose

1.1 The purpose of this document is to standardize requirements for xylenes used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of xylenes for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of xylenes used in the semiconductor industry.

2.2 This material is a mixture of ortho, meta, and para isomers and ethylbenzene. Xylene (o-, m-, and p- isomers and ethylbenzene) 99.0% min and Ethylbenzene 18% max.

3 Limitations

3.1 None.

4 Referenced Documents

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	0.86 g/mL
Boiling Range	136 - 144°C

7 Requirements

7.1 The requirements for xylenes for Grade 1 are listed in Table 1.

8 Grade 1 Procedures

8.1 *Assay* — Assay the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Gas Chromatography). The parameters cited have given satisfactory results.

Column: 30 meter × 530 micron I.D. fused silica capillary, coated with 5 micron film of DB-1 or equivalent (100% methyl Silicone which has been surface bonded and cross linked).

Column Temperature: 40°C isothermal for 5 minutes, then programmed to 200°C at 10°C/min.

Injector Temperature:	175°C
Detector Temperature:	250°C
Sample Size:	0.2 µL splitless
Carrier Gas:	Helium at 3 mL/min
Detector:	Thermal Conductivity or Flame Ionization
Approximate Retention Times (min):	
Toulene	14.4
Ethylbenzene	17.0
p-xylene	16.9
m-xylene	17.2
o-xylene	17.8

8.1.1 Measure the areas under all peaks by any convenient means and calulate the concentration of all components in area percent (see SEMI C.1, Section 3.11, Guidelines for Assay by Wide Bore Column Gas Chromatography).

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Acidity* — To 25 mL of water in a glass-stoppered flask, add 10 mL of sample and 0.1 mL of phenolphthalein indicator solution. Add 0.01 N sodium hydroxide until a slight pink color persists after shaking for one-half minute. Add 38 mL (33 g) of the sample, mix well, and titrate with 0.01 N sodium hydroxide until the pink color is reproduced. Not more than 1.0 mL of the sodium hydroxide solution should be required.

8.4 *Residue After Evaporation* — Evaporate 232 mL (200 g) of sample to dryness. Dry at 105°C for 30 minutes, cool in a desiccator, and weigh (see SEMI C1, Section 3.3, Determination of Residue After Evaporation).

8.5 *Water* — Add 25 mL of methanol to a dry titration flask and add Karl Fischer (KF) reagent to a visually or electrometrically determined endpoint that persists for 30 seconds. Add 23 mL (20 g) of sample, taking care to protect the sample and contents of the flask from moisture. Stir vigorously and titrate with Karl Fischer reagent to the same endpoint.

$$\% \text{ Water } (H_2O) = \frac{\text{mL KF reagent } \times \text{ KF factor (g } H_2O/\text{mL) } \times 100}{\text{Weight of sample (g)}}$$

8.6 *Chloride* — To a 100 mL separatory funnel, add 12 mL (10 g) of sample and 40 mL of water. Shake well for 30 seconds and allow the two layers to separate. Discard the sample (upper) layer. To a 20 mL portion of the water layer add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that of a standard containing 0.015 mg of chloride ion (Cl) in an equal volume of solution and the amounts of reagents used.

8.7 *Phosphate* — To 12 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness on a steam bath in a hood. Dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to stand at room temperature for 2 hours. Any blue color should be no greater than that produced when 0.01 mg of phosphate ion (PO_4) is treated as the sample.

8.8 *Arsenic and Antimony (as As)* — Evaporate 116 mL (100 g) of sample in a 250 mL beaker to a small volume in a hood. Add 50 mL of water and again evaporate to a small volume. Repeat the evaporation three times with water additions. Do not allow to go to dryness. Add 5 mL of nitric acid and 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in the General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the sentence which begins, "Swirl the flask..." Any red color in the silver diethyldithiocarbamate solution of the sample should be no greater than that of the standard containing 0.001 mg of arsenic (As).

8.9 *Trace Element Contents* — By a suitable emission spectrographic procedure, determine for each of the specified trace elements that its content is not greater than the stated specification limit (see SEMI C1, Section 3.5, Guidelines for Determination of Trace Elements by Emission Spectrography).

9 Grade 2 Procedures

9.1 This section does not apply to this chemical.

10 Grade 3 Procedures

10.1 This section does not apply to this chemical.

11 Grade 4 Procedures

11.1 This section does not apply to this chemical.

12 Grade 5 Procedures

12.1 This section does not apply to this chemical.

13 VLSI Grade Procedures

13.1 This section does not apply to this chemical.

14 Tier A Procedures

14.1 This section does not apply to this chemical.

15 Tier B Procedures

15.1 This section does not apply to this chemical.

16 Tier C Procedures

16.1 This section does not apply to this chemical.

17 Tier D Procedures

17.1 This section does not apply to this chemical.

Table 1 Impurity Limits and Other Requirements for Xylenes

Previous SEMI Reference #	C1.21-92
	Grade 1
	(Specification)
Color (APHA)	10 max
Acidity	0.3 µeq/g max
Residue after Evaporation	5 ppm max
Water (H_2O)	0.02% max
Chloride (Cl)	3 ppm max
Phosphate (PO_4)	1 ppm max
Aluminum (Al)	0.1 ppm max
Arsenic and Antimony (as As)	0.01 ppm max
Boron (B)	0.1 ppm max
Calcium (Ca)	0.1 ppm max
Chromium (Cr)	0.1 ppm max
Copper (Cu)	0.1 ppm max
Gold (Au)	0.1 ppm max
Iron (Fe)	0.1 ppm max
Lead (Pb)	0.1 ppm max
Magnesium (Mg)	0.1 ppm max
Manganese (Mn)	0.1 ppm max
Nickel (Hi)	0.1 ppm max
Potassium (K)	0.1 ppm max
Sodium (Na)	0.1 ppm max
Tin (Sn)	0.1 ppm max
Zinc (Zn)	0.1 ppm max
Particles in bottles: size, #/mL	≥1.0 µm, 10 max

SEMI C53-0302
SPECIFICATIONS FOR DIMETHYL SULFOXIDE (DMSO) [GRADES 1 AND 2]

These specifications were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the European Process Chemicals Committee. Current edition approved by the European Regional Standards Committee on December 20, 2001. Initially available at www.semi.org January 2002; to be published March 2002. Originally published November 2001.

1 Purpose

1.1 The purpose of this document is to standardize requirements for dimethyl sulfoxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results.

2 Scope

2.1 The scope of this document is all grades of DMSO used in the semiconductor industry.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

3.1 None.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C1 — Specifications for Reagents

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density (d 20/4)	1.10 g/mL

7 Requirements

7.1 The requirements for dimethyl sulfoxide for grades 1 and 2 are listed in Table 1.

8 Grade 1 and Grade 2 Procedures

8.1 *Assay* — Analyze the sample by gas chromatography (see SEMI C1, Section 3.1, Guidelines for Assay by Wide Bore Column Gas Chromatography). The parameters cited have given satisfactory results.

8.1.1 *Column* — 50 meter × 320 micron I.D. fused silica capillary, coated with 5 micron film of OV-1 or equivalent (100% methyl silicone which has been surface bonded and cross linked).

Column Temperature:	135°C isothermal
Injector Temperature:	240°C
Detector Temperature:	280°C
Sample Size:	1 µl
Carrier Gas:	Helium at 1.2 mL/min.
Detector:	Flame ionization
Approximate Retention Times (min):	
Dimethylsulfide	3.8
Dimethylsulfoxide	10.9
Dimethylsulfone	14.1

8.2 *Color* — Using a colorimeter, compare sample in a specific glass tube with flat bottom, graduated at 113 and 250 mm, with a standardized color reference disk CAA (Scale 2.5 to 30 APHA units).

8.3 *Water* — Use a Karl Fischer (KF) coulometer, consisting of a titration beaker, an electrode generator and an electrode indicator with double platinum wire; having as reagents Hydranal Coulomat A solution at the anode and Hydranal Coulomat C solution at the cathode. Add 500 µl of sample, taking care to protect the sample from moisture. Read directly the water content of sample in µg of water.

8.4 *Acidity* — Use a potentiograph with a compound glass electrode and a titration vat with nitrogen inlet. To 100 mL of sample add 5 mL of water, 5 mL of methanol and 2 drops of titan yellow under nitrogen-stream. The titration is performed with N/100 tetrabutylammonium hydroxide (TBAH) in isopropanol. The equivalence point is at about −400 mV. The density (see SEMI C1, Section 3.8) of the Dimethyl sulfoxide sample to be titrated must be determined to express the result in mgKOH/g.

8.5 *Residue after Evaporation* — The residue after evaporation is defined as the relative amount of residue remaining after evaporation of a sample of DMSO followed by heating of the residue: Heat a clean 200 mL beaker at 105°C in an oven for 30 min., cool for 30 min. in a dessicator charged with calcium chloride and weigh. Place 100 g of DMSO into the 200 mL tared beaker. Evaporate the liquid gently, so that boiling does not occur, in a hood protected from any possibility of contamination. When all the sample has evaporated, dry the residue in an oven at 105°C for 30 minutes and cool the beaker for 30 min in a dessicator charged with calcium chloride and reweigh.

8.5.1 Calculate the residue as parts per million (ppm).

8.6 *Trace Metal Determination* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals : aluminium (Al), antimony (Sb), arsenic (As), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti) and zinc (Zn). Alternate methods may be used as long as the method has been validated according to SEMI C1 Section 3.14.

8.7 *Special Reagents*

8.7.1 *Water* — The water used for all the dilution, calibration, and standards should meet suggested guidelines for pure water for Semiconductor processing.

8.7.2 *Sample Preparation* — In a clean environment, dilute 25 mL of sample by adding 25 mL of water. Prepare reagent blanks.

8.7.3 *Analysis* — Using the prepared sample and reagent blanks, analyse the elements by inductively coupled plasma (ICP). The density (see SEMI C1, Section 3.8) of the DMSO sample must be determined to express the result in ppb.

8.7.4 *Notes*

NOTE 1: Each laboratory is responsible for verifying the validity of the method within its own operation.

Table 1 Impurity Limit and Other Requirements for Dimethyl Sulfoxide

	Grade 1 (specification)	Grade 2 (specification)
Assay (CH_3SOCH_3)	99.8% min.	99.8% min.
$DMSO_2$ ($CH_3SO_2CH_3$)	0.05% max.	0.05% max.
DMS (CH_3SCH_3)	0.05% max.	0.05% max.
Color (APHA)	10 max.	10 max.
Water (H_2O)	0.05% max.	0.05% max.
Acidity	0.0007 μeq/g max.	0.0007 μeq/g max.
Residue after evaporation (ppm)	50	50
Aluminium (Al)	50 ppb max.	10 ppb max.
Antimony (Sb)	50 ppb max.	10 ppb max.
Arsenic (As)	50 ppb max.	10 ppb max.
Boron (B)	50 ppb max.	10 ppb max.
Calcium (Ca)	50 ppb max.	10 ppb max.
Chromium (Cr)	50 ppb max.	10 ppb max.
Copper (Cu)	50 ppb max.	10 ppb max.
Gold (Au)	50 ppb max.	10 ppb max.
Iron (Fe)	50 ppb max.	10 ppb max.
Lead (Pb)	50 ppb max.	10 ppb max.
Magnesium (Mg)	50 ppb max.	10 ppb max.
Manganese (Mn)	50 ppb max.	10 ppb max.
Nickel (Ni)	50 ppb max.	10 ppb max.
Potassium (K)	50 ppb max.	10 ppb max.
Sodium (Na)	50 ppb max.	10 ppb max.
Tin (Sn)	50 ppb max.	10 ppb max.
Titanium (Ti)	50 ppb max.	10 ppb max.
Zinc (Zn)	50 ppb max.	10 ppb max.

SEMI INTERNATIONAL STANDARDS

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SEMI T1-95
SPECIFICATION FOR BACK SURFACE BAR CODE MARKING OF SILICON WAFERS

NOTICE: The user's attention is called to the possibility that compliance with this specification may require use of an invention covered by patent rights. By publication of this specification, SEMI takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this specification. Users of this specification are expressly advised that determination of any such patent rights, and the risk of the infringement of such rights, are entirely their own responsibility.

1 Scope

1.1 This specification defines the content and location of a back surface bar code marking for silicon wafers. The code is variable in length from 7 to 18 characters which are user-definable. A character position is held constant for the checksum character, but all else is variable. No other information is encrypted into the code. This allows the performance requirements of related bar code reading equipment to be simplified. In addition, provision is made for an optional alphanumeric marking of the size specified in SEMI M12 to enable operator identification of wafers. This alphanumeric code is not intended to be machine readable.

NOTE 1: The example as described in Table 1 and Figure 1 pertains to a hard mark applied by the silicon wafer manufacturer.

1.2 This specification applies to flatted or notched silicon wafers of nominal diameter 125 mm and larger, as specified in SEMI M1.

1.3 The bar code can be read bi-directionally without impairing its decodability.

2 Applicable Documents

2.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

3 Terminology

3.1 *background — of a bar code symbol* — the uniform lighter or more reflective region, including quiet zones, that provides contrast for the darker bars.

3.2 *bar — in a bar code symbol* — the darker or less reflective element of the symbol.

3.3 *bar code density* — the number of characters, exclusive of quiet zones, that can be represented in a linear unit of measure.

NOTE: Bar code density can be expressed in characters per inch (cpi) or characters per millimeter (cpmm).

3.4 *bar code symbol* — an array of rectangular bars and spaces that are arranged in a predetermined pattern following specific rules to represent elements of data that are referred to as characters.

NOTE: The symbol is comprised of message characters and start/stop characters, check characters, and quiet zones as required by a particular symbology to form a complete scannable entity.

3.5 *bar code character* — a single group of bars and spaces which represent an individual number, letter, punctuation mark, or other symbol.

3.6 *bar height — of a bar code symbol* — the bar dimension perpendicular to the bar width.

3.7 *bar width — of a bar code symbol* — the perpendicular distance across a bar between the points on opposite edges that have a reflectance that is midway between the background and bar reflectance.

3.8 *bi-directional bar code symbol* — a bar code symbol capable of being read successfully, either by scanning from right to left or from left to right.

3.9 *character — of a bar code* — a single group of bars and spaces that together represent an individual numeral, letter, punctuation mark, or other symbol.

3.10 *character set* — the complete range of characters available for encoding within a particular bar code symbology.

3.11 *check character — of a bar code symbol* — a character included within the symbol whose value is used for the purpose of mathematical verification of the accuracy of the read.

3.12 *continuous code* — a bar code symbol in which all spaces within the symbol are parts of characters so that there are no inter-character gaps.

3.13 *element — of a bar code symbol* — a single bar or space.

3.14 *module — of a bar code symbol* — narrowest element, bar, or space.

3.15 *nominal width — of a bar code element* — the average width of each size element.

3.16 *quiet zone — of a bar code symbol* — a clear background area that precedes the start character and follows the stop character of the symbol.

3.17 *self-checking bar code symbol* — a bar code symbol that uses a checking algorithm that can be applied against each character such that substitution errors can only occur if two or more "printing" defects appear within a single character.

3.18 *self-clocking bar code symbol* — a bar code symbol in which the number of modules, bars, and spaces is the same in each character.

3.19 *space — in a bar code symbol* — the more reflective element of the symbol, usually formed by the background between bars.

3.20 *start/stop character — in a bar code symbol* — special characters that provide initial timing references and direction-of-read information to the decoding logic.

3.21 *start/stop character pattern* — a special bar code character that provides the scanner with start and stop reading instructions as well as scanning direction. The start character is at the left end of a BC-412 symbol (position #2). The stop character is at the right end of the symbol (position #11).

3.22 *symbol* — a combination of characters, including start/stop characters, quiet zones, data characters, and check characters, required by a particular symbology, which form a complete scannable entity.

4 Method of Marking

4.1 The dot matrix laser method shall be used to write characters. The minimum bar matrix shall be 1 dot horizontal and 11 dots/mm vertical as shown in Table 1 and Figure 1. The minimum matrix for alphanumeric characters shall be as specified in SEMI M12. In either case, more dots may be used, up to and including a solid line.

5 BC-412 Code[1]

5.1 *Characteristics* — BC-412 is a presence-absence bar code symbology which uses an alphanumeric character set as outlined in Table 2. The name BC-412 is derived from the method used to encode data characters. Each data character is comprised of four single-width bars incremented within 12 modules. The code is a continuous code.

5.2 *Character Set* — The character set available for marking wafers consists of the ten digits (0−9) and all capital letters in the English alphabet except O as listed in Table 3. In addition, there is a start character and a stop character.

5.2.1 *Character Construction and Value* — The module sequence and value for use in calculating the check character are listed for each character in Table 3.

5.3 *Symbol Content* — All character count and content in the wafer marking symbol are user-definable and vary in number from 7 to 18. The checksum character position is fixed.

6 Optional Alphanumeric Code

6.1 The optional alphanumeric symbol is variable and user definable, and similar to existing SEMI standards M12 and M13 with respect to font style.

6.2 The characters may be oriented with the bottom or top of each character toward the primary fiducial user definable.

6.3 The characters in the optional alphanumeric symbol are those in position #3 through position # (n+2) of the BC-412 symbol (see Table 4).

7 Code Field Locations

7.1 The code field locations for flatted and notched wafers are specified in Figures 3 and 4, respectively. Values of the dimensions for both cases are given in Table 5.

7.2 The dimensions given in Table 5 are those found on the finished wafer, regardless of where in the process the wafer is marked.

7.3 These dimensions are derived with the assumption that both the bar code and the optional alphanumeric markings are placed on the wafer without realignment of the wafer.

7.4 The code field locations are defined by the limits of the bar code elements and the optional alphanumeric characters. Character dimensions are from centerline to centerline of the extreme features of the character.

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8 Definition of the Error-Detecting Method

8.1 Define the following symbols:

$CD =$ Check character

$i =$ Position of a data character within a string from left to right, $i \geq 1$

$CV(i) =$ Character value of i (Table 4)

$$F_o = Mod_{35}\left(\quad CV(i)_{i=odd} \right)$$

$$F_e = Mod_{35}\left(\quad CV(i)_{i=even} \right)$$

$$F = Mod_{35}\left(F_o + 2F_e\right)$$

8.2 Compute the check character:

8.2.1 Assign the value "0" to the check character (position #4, second character in string).

8.2.2 Calculate F_o and F_e.

8.2.3 Calculate F.

8.2.4 Calculate CD as $Mod_{35}(17 \times F)$.

8.3 *Verification*

8.3.1 Recalculate F_e and F_o with the value of CD found in Section 8.2.4 to the second character in the string (position #4).

8.3.2 Calculate F.

8.3.3 If F = 0, the check character is correct.

8.4 As an example, calculate the check character for A_Q45670 as follows:

8.4.1 Write the code as A0Q45670.

8.4.2 Calculate F_o, F_e, and F:

$$F_o = Mod_{35}(A(i) + Q(i) + 5(i) + 7(i)) =$$

$$F_o = Mod_{35}(7 + 18 + 33 + 21) = Mod_{35}(79) = 9$$

$$F_o = Mod_{35}(0 + 11 + 19 + 0) = Mod_{35}(30) = 30$$

$$F = Mod_{35}(9 + 60) = Mod_{35}(69) = 34$$

8.4.3 Calculate the value for CD:

$$CD = Mod_{35}(17 \times 34) = Mod_{35}(578) = 18$$

8.4.4 This corresponds to the character, Q, so the symbol is now AQQ45670.

8.4.5 Verify that the check character in AQQ45670 is correct as follows:

$$F_o = Mod_{35}(A(i) + Q(i) + 5(i) + 7(i))$$
$$= Mod_{35}(7 + 18 + 33 + 21) = Mod_{35}(79) = 9$$
$$F_e = Mod_{35}(Q(i) + 4(i) + 6(i) + 0(i))$$
$$= Mod_{35}(18 + 11 + 19 + 0) = Mod_{35}(48) = 13$$
$$F = Mod_{35}(F_o + 2F_e)$$
$$= Mod_{35}(9 + 26) = Mod_{35}(35) = 0$$

Table 1 Character Dimensions (see Figure 1)

Module Height (dot centerline to dot centerline)	2.000 mm ± 0.025 mm (0.0790" ± 0.0010")		
Bar Code Character Spacing (centerline to centerline, non-cumulative within the Symbol Length [see Table 2])	1.440 mm ± 0.025 mm (0.0570" ± 0.0010")		
Mark Width	0.110 mm ± 0.025 mm (0.0043" ± 0.0010")		
Module Spacing (centerline to centerline, non-cumulative within the Character Spacing [see above])	0.120 mm ± 0.025 mm (0.0047" ± 0.0010")		
Scribing Features:	Scribing Features:		
Density of dots along module length	11 dots/mm, minimum		
Number of dots per module width	1 dot per module width		
Character Construction:	*# of Bars*	*# of Spaces*	*Modules*
Data Character	4	8	12
Start Character	1	2	3
Start Character Dimension	0.360 mm ± 0.025 mm (0.0140" ± 0.0010")		
Stop Character	2	1	3
Stop Character Dimension	0.360 mm ± 0.025 mm (0.0140" ± 0.0010")		

Table 2 Characteristics of BC-412 Bar Code

Encodable Character Set	*Alphanumeric (except O) with No Non-Numeric or Non-Alphabetic Characters (see Table 3)*
Code Type	Continuous
Symbol Length	Variable: for this application, symbol can be formed from 13.200 mm ± 0.050 mm (0.5760" ± 0.020") including the Quiet Zones, to 29.040 mm ± 0.050 mm (1.1400" ± 0.0020") including the Quiet Zones.
Bi-Directional Decoding	Yes
Number of Check Characters	One
Character Self Checking	Yes
Character Self Clocking	Yes
Character Dimensions	See Table 1 and Figure 1.
Non-Data Overhead	Six Modules

Table 3 BC 412 Code — Character Construction and Values

<table>
<tr><th>Character</th><th>Module Sequence</th><th>Check Character Value</th><th>Character</th><th>Module Sequence</th><th>Check Character Value</th></tr>
<tr><td>0</td><td>|-|-|-|-----</td><td>00</td><td>I</td><td>|--|-|----|-</td><td>27</td></tr>
<tr><td>1</td><td>|-|-|--|----</td><td>15</td><td>J</td><td>|--|--|-|---</td><td>16</td></tr>
<tr><td>2</td><td>|-|-|---|---</td><td>17</td><td>K</td><td>|--|--|--|--</td><td>24</td></tr>
<tr><td>3</td><td>|-|-|----|--</td><td>29</td><td>L</td><td>|--|--|---|-</td><td>04</td></tr>
<tr><td>4</td><td>|-|-|-----|-</td><td>11</td><td>M</td><td>|--|---|-|--</td><td>34</td></tr>
<tr><td>5</td><td>|-|--|-|----</td><td>33</td><td>N</td><td>|--|---|--|-</td><td>12</td></tr>
<tr><td>6</td><td>|-|--|--|---</td><td>19</td><td>O</td><td></td><td></td></tr>
<tr><td>7</td><td>|-|--|---|--</td><td>21</td><td>P</td><td>|--|----|-|-</td><td>32</td></tr>
<tr><td>8</td><td>|-|--|----|-</td><td>08</td><td>Q</td><td>|---|-|-|---</td><td>18</td></tr>
<tr><td>9</td><td>|-|---|-|---</td><td>02</td><td>R</td><td>|---|-|--|--</td><td>01</td></tr>
<tr><td>A</td><td>|-|---|--|--</td><td>07</td><td>S</td><td>|---|-|---|-</td><td>14</td></tr>
<tr><td>B</td><td>|-|---|---|-</td><td>25</td><td>T</td><td>|---|--|-|--</td><td>13</td></tr>
<tr><td>C</td><td>|-|----|-|--</td><td>20</td><td>U</td><td>|---|--|--|-</td><td>26</td></tr>
<tr><td>D</td><td>|-|----|--|-</td><td>22</td><td>V</td><td>|---|---|-|-</td><td>05</td></tr>
<tr><td>E</td><td>|-|-----|-|-</td><td>09</td><td>W</td><td>|----|-|-|--</td><td>31</td></tr>
<tr><td>F</td><td>|--|-|-|----</td><td>30</td><td>X</td><td>|----|-|--|-</td><td>28</td></tr>
<tr><td>G</td><td>|--|-|--|---</td><td>03</td><td>Y</td><td>|----|--|-|-</td><td>23</td></tr>
<tr><td>H</td><td>|--|-|---|--</td><td>06</td><td>Z</td><td>|-----|-|-|-</td><td>10</td></tr>
<tr><td>Start</td><td>|--</td><td></td><td>Stop</td><td>|-|</td><td></td></tr>
</table>

Legend: |=one bar; -=one module blank (no bar)

Table 4 BC 412 Symbol Content for Wafer Marking

Position	*Description*	*Modules*
1	Leading Quiet Zone	10
2	Start Character	3
3	User Definable	12
4	Check Character	12
5 to (n+2)	User Definable	12/character
(n + 2) + 1	Stop Character	3
(n + 2) + 2	Trailing Quiet Zone	10
Total Modules including Quiet Zones		f(n) = (12n) + (6) + (20)
Total Modules within Marking Area Only		f(n) = (12n) + (6)

n = Number of characters in the code as defined by the user, including check character, excluding Start and Stop characters.

Table 5 Code Field Location Dimensions (see Figures 3 and 4)

Dimension	*Flatted Wafer (Figure 3)*	*Flatted Wafer (Figure 3)*	*Notched Wafer (Figure 4)*	*Notched Wafer (Figure 4)*
	n = 7	n = 18	n = 7	n = 18
A	1.624 mm ± 0.025 mm	same	1.624 mm ± 0.025 mm	same
B[3]	4.666 mm ± 0.500 mm	12.476 mm ± 0.500 mm	4.666 mm ± 0.500 mm	12.476 mm ± 0.500 mm
C[3]	9.332 mm ± 0.030 mm	24.952 mm ± 0.050 mm	9.332 mm ± 0.030 mm	24.052 mm ± 0.050 mm
E[1]	3.350 mm ± 0.500 mm	same	7.400 mm ± 0.050 mm	same
F	0.700 mm ref.	same	0.700 mm ref.	same
G[3]	5.400 mm ± 0.500 mm	13.320 mm ± 0.500 mm	5.400 mm ± 0.500 mm	13.320 mm ± 0.500 mm
H[3]	10.800 mm ± 0.050 mm	26.640 mm ± 0.050 mm	10.800 mm ± 0.050 mm	26.640 mm ± 0.050 mm
J	2.000 mm ± 0.025 mm	same	2.000 mm ± 0.025 mm	same
L[3]	13.200 mm ± 0.050 mm	29.040 mm ± 0.050 mm	13.200 mm ± 0.050 mm	29.040 mm ± 0.050 mm
M[2]	1.260 mm min.	same	1.260 mm min.	same

[1] This dimension is the distance between the centerline of the bottom dot in the bar code and the edge of the finished wafer.
[2] This dimension is the distance between the centerline of the first module of the start character (or the last element of the stop character) and the outer edge of the Quiet Zone.
[3] n = 7 and n = 18 values represent the smallest to the largest extremes of the bar code symbology to be used.

The formulas for calculating all other values in between are as follows:

$$\text{Dimension (B)} \text{ (Using SEMI M12 Sizing)} = \frac{((n\text{-}1)\ \text{Character Spacing}) + (\text{Character Width})}{2}$$

$$= \left| \frac{((n\text{-}1) \times 1.420) + 0.812}{2} \pm 0.500 \right| \text{mm} = ((0.710n - 0.304) \pm 0.500)\ \text{mm}$$

$$\text{Dimension (C)} = (((n - 1) \times 1.420) + 0.812 \pm 0.050)\ \text{mm} = ((1.420n - 0.608) \pm 0.050)\ \text{mm}$$

$$\text{Dimension (G)} = \left| \frac{((12n) \times 0.120) + (6 \times 0.120)}{2} \pm 0.500 \right| \text{mm} = ((0.720n - 0.360) \pm 0.500)\ \text{mm}$$

$$\text{Dimension (H)} = (((12n) \times 0.120) + (6 \times 0.120) \pm 0.050)\ \text{mm} = ((1.440n - 0.720) \pm 0.050)\ \text{mm}$$

$$\text{Dimension (L)} = (((12n) \times 0.120) + (6 \times 0.120) \pm (20 \times 0.120) \pm 0.050\ \text{mm} = ((1.440n - 3.120) \pm 0.050)\ \text{mm}$$

Tolerance for module spacing is non - cumulative (see Table 1).

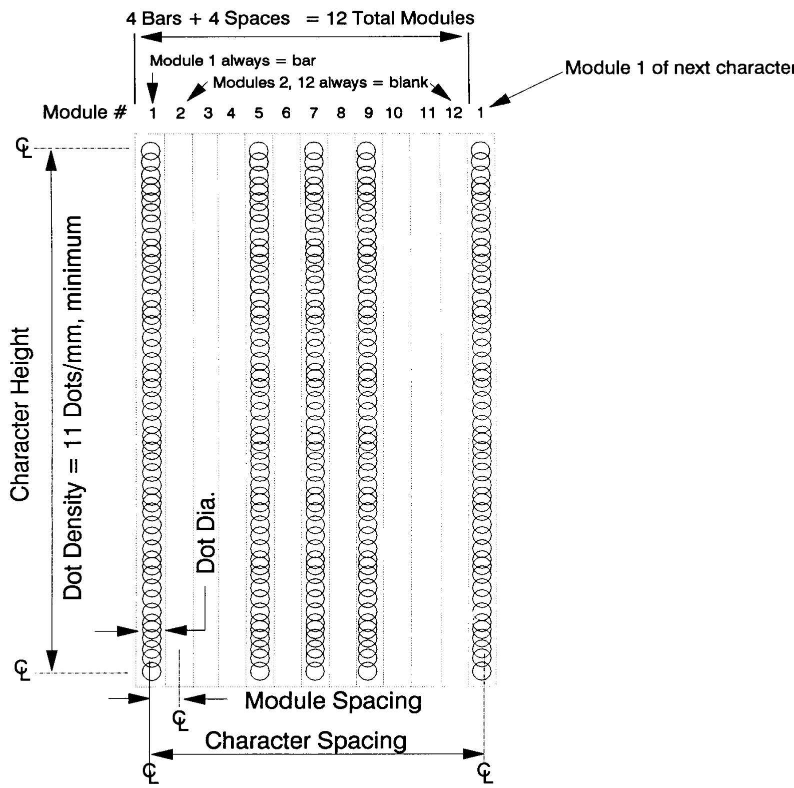

Figure 1
BC-412 Data Character Construction

NOTE 2: Each bar code character contains four bars and four spaces. A space is one or more contiguous blanks. Module 1 is always a bar; the other three bars are distributed among modules 3−11; modules 2 and 12 are always spaces. One or more blanks which comprise a space must occur between bars.

Figure 2
BC-412 Character Position and Module Content

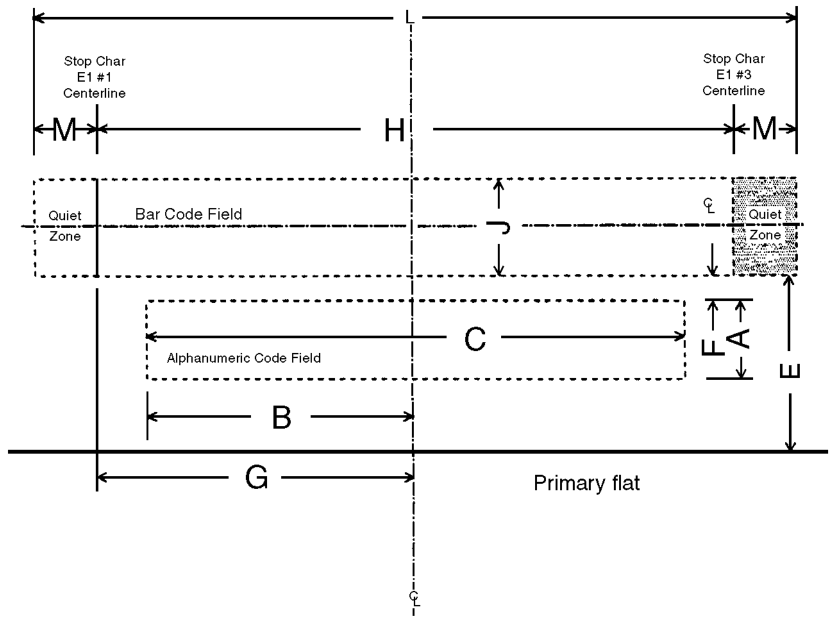

Figure 3
Code Field Locations for Flatted Wafers

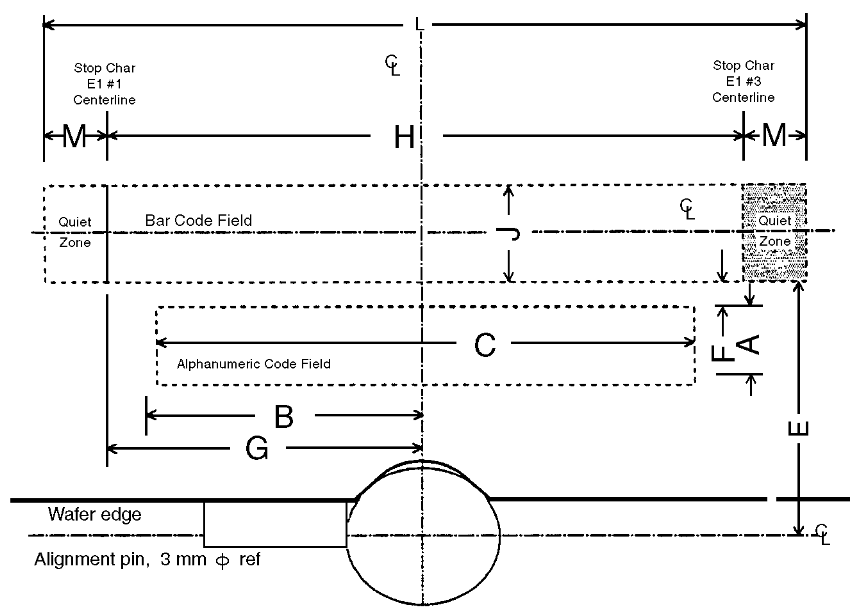

Figure 4
Code Field Locations for Notched Wafers

APPLICATION NOTE 1

NOTE: This application note is not an official part of SEMI T1 and is not intended to modify or supercede the official standard. Rather, this note is provided primarily as a source of information to aid in the application of the standard. As such, it is considered reference material only. The standard should be referred to in all cases.

A1-1 Center Reference Dimensions for Bar Code and Optional Alphanumeric Marks

A1-1.1 The following information is provided as a reference for equipment which employs center referencing to locate the bar code or optional alphanumeric marks. Dimensions for flatted wafers are given in Table A1-1 and dimensions for notched wafers are given in Table A1-2.

A1-2 Referenced Documents

A1-2.1 *SEMI Standards*

SEMI M1.7 — Standard for 125 mm Polished Monocrystalline Silicon Wafers

SEMI M1.8 — Standard for 150 mm Polished Monocrystalline Silicon Wafers

SEMI M1.9 — Standard for 200 mm Polished Monocrystalline Silicon Wafers (Notched)

SEMI M1.10 — Standard for 200 mm Polished Monocrystalline Silicon Wafers (Flatted)

SEMI M1.12 — Standard for 125 mm Polished Monocrystalline Silicon Wafers Without Secondary Flat

SEMI M1.13 — Standard for 150 mm Polished Monocrystalline Silicon Wafers Without Secondary Flat (625 µm Thickness)

Table A1-1 Mark Distances on Flatted Wafers (see Figure A1-1)

	Wafer Size and SEMI Standards				
	125 mm		*150 mm*		*200 mm*
Dim. in mm	*SEMI M1.7*	*SEMI M1.12*	*SEMI M1.13*	*SEMI M1.8*	*SEMI M1.10*
D	125 ± 0.5	125 ± 0.2	150 ± 0.2	150 ± 0.2	200 ± 0.2
FL	42.5 ± 2.5	475. ± 2.5	47.50 ± 2.5	57.50 ± 2.5	57.50 ± 2.5
Znom	58.83	58.83	71.19	69.32	95.83
Zmax	59.53	59.37	71.70	69.93	96.30
Zmin	58.09	58.25	70.66	68.68	95.34
R1nom	54.48	54.48	66.84	64.97	91.48
R1max	55.59	55.53	67.86	66.10	92.46
R1min	53.23	53.39	65.79	63.82	90.08
K1nom	1.03	1.03	1.03	1.03	1.03
K1max	1.55	1.55	1.55	1.55	1.55
K1min	0.05	0.50	0.50	0.50	0.50

D = Wafer Diameter

FL = Primary Flat Length

Table A1-2 Mark Distances on Notched Wafers (see Figure A1-2)

	Wafer Size and SEMI Standards		
Dim. in mm	*125 mm*	*150 mm*	*200 mm SEMI M1.9*
D	125 ± 0.5	150 ± 0.2	200 ± 0.2
Z1nom	0.80	0.80	0.80
Z1max	1.05	1.05	1.05
Z1min	0.30	0.30	0.30
R1nom	54.90	67.40	92.40
R1max	55.91	68.26	93.26
R1min	53.64	66.29	91.29
K1mon	3.28	3.28	3.28
K1max	4.05	4.05	4.05
K1min	2.50	2.50	2.50
Ynom	1.80	1.80	1.80
Y1max	2.05	2.05	2.05
Y1min	1.55	1.55	1.55

D = Wafer Diameter

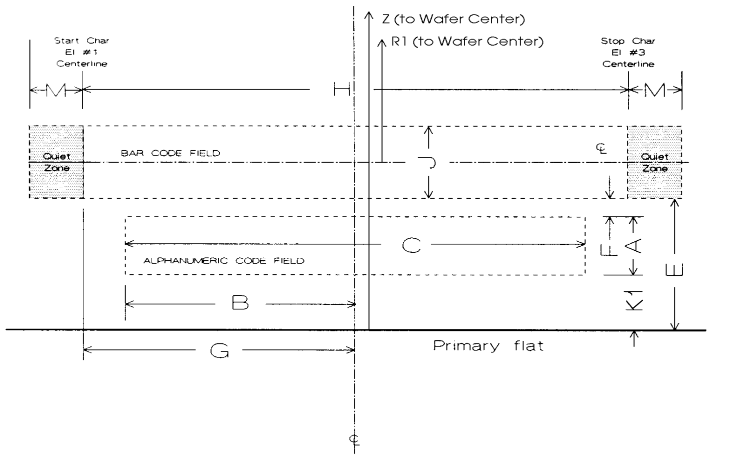

Figure A1-1
Code Field Locations for Flatted Wafers (See Tables A1-1 and 5.)

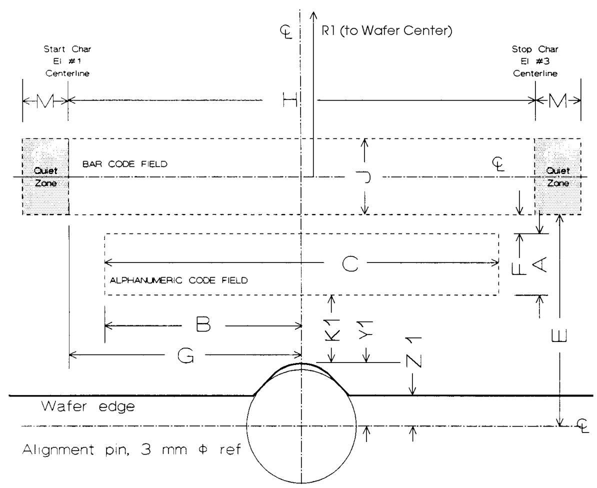

Figure A1-2
Code Field Locations for Notched Wafers (See Tables A1-2 and 5.)

SEMI T2-0298[E]

SPECIFICATION FOR MARKING OF WAFERS WITH A TWO-DIMENSIONAL MATRIX CODE SYMBOL

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on April 30, 1999. Initially available on SEMI OnLine April 1999; to be published June 1999. Originally published in 1993.

This entire document was revised in February 1998.

[E] This document was modified in April 1999 to reflect the creation of SEMI AUX1 as the source for vendor identification codes. Changes were made to numerous sections. This document was also modified in April 2000 to clarify patent issues. Changes were made to the notice at the end of this document.

1 Purpose

1.1 This specification is intended to provide a marking symbology that can be used to mark silicon wafers with minimum intrusion into the fixed quality area of the wafer.

2 Scope

2.1 This specification defines the geometric and spatial relationships and content (including the error checking and correcting code) of a two-dimensional (2-D), machine-readable, binary matrix code symbol for front surface marking of wafers of silicon which comply with SEMI M1, SEMI M2, or SEMI M11, and other materials with diameters of 125 to 200 mm. This specification allows for consistency of all wafer marking performed by wafer manufacturers. It may be used in conjunction with, or as an alternative to, the alphanumeric marking codes specified in SEMI M12 and SEMI M13 or a front surface bar code like that specified in SEMI T1.

2.2 Although this specification does not specify the marking techniques that may be employed when complying with its requirements, it is assumed that the symbol will be obtained by laser scribing individual dots.

2.3 The 2-D matrix code is applicable to a broad range of wafer products, including epitaxial wafers, SOI wafers, and unpatterned or patterned polished wafers. The format and algorithms of this code are based on the Data Matrix two-dimensional symbology specified in AIM International Symbology Specification - Data Matrix.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI AUX1 — List of Vendor Identification Codes

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M2 — Specification for Silicon Epitaxial Wafers for Discrete Device Applications

SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

3.2 *AIM International Technical Specification*[1]

AIM International Symbology Specification - Data Matrix

3.3 *ANSI Standard*[2]

ANSI X3.4 — American Standard Code for Information Interchange (ASCII)

NOTE 1: This standard is equivalent to ISO 646, Information Processing - ISO 7-bit Coded Character Set for Information Processing.

4 Terminology

4.1 *binary values* — a dot in the wafer surface indicates the binary value 1. The absence of a dot, or a smooth surface surrounding a cell center point, indicates the binary value 0.

4.2 *border column* — the outermost column of a data matrix code symbol.

4.3 *border row* — the outermost row of a data matrix code symbol.

4.4 *cell, of a data matrix code symbol* — the area within which a dot may be placed to indicate a binary value.

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[2] *American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel 212.642.4900, fax 212.398.0023*

4.5 *cell center point, of an array* — the point at which the centerline of a row intersects the centerline of a column.

4.6 *cell spacing, of an array* — the (equal) vertical or horizontal distance between the cell center points of contiguous cells.

4.7 *center line, of a row or column* — the line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

4.8 *central area, of a cell* — the area enclosed by a circle centered at the cell center point; used by code readers to sense the binary value of the cell.

4.9 *data matrix code symbol* — a two-dimensional array of square cells arranged in contiguous rows and columns.

4.10 *dot* — a localized region with a reflectance which differs from that of the surrounding surface.

NOTE 2: To assure reading efficiency, a minimum contrast of 30% is required between the reflectance value of a dot and the surrounding wafer surface. Various densitometers can provide such measurements nondestructively.

4.11 *dot misalignment, within a cell* — the distance between the physical center point of a dot and the cell center point.

4.12 *reference point, of a data matrix code symbol* — the physical center point of a corner cell common to a border row and border column, used to identify the physical location of the symbol on the object being marked with the symbol.

NOTE 3: The reference point is at a fixed location on the object. Different cells may be chosen as the reference point, depending on the desired orientation of the symbol on the object and the size variability of the symbol. The particular cell to be used as the reference point must be specified for each application.

5 Ordering Information

5.1 Purchase orders for wafers furnished to this specification shall include the following items:

5.1.1 *Message Characters*

5.1.1.1 Quantity (10 to *nn*, where *nn* is 11–31 and depends on the character set to be encoded (see Table 1).

5.1.1.2 Content of Message Characters 11 and up, if present.

5.1.2 Cell Spacing (125 or 150 µm).

6 Requirements

6.1 *Shape and Size of the Matrix Code Symbol*

6.1.1 Each square matrix code symbol shall be composed of an equal even number (from 16 to 20) of rows and columns of equally spaced square cells. Cell spacing shall be either 125 or 150 µm. (See Table 2, and Figures 1 and 2.)

6.1.2 *Dot Size* — The nominal shape of the dot produced in the matrix may be circular or square. Its diameter or edge length (after polishing) shall be 100 ± 10 µm.

6.2 *Border Rows and Columns (see Figure 3)*

6.2.1 One border row and one border column shall contain a dot in each cell. These are identified as the primary border row and the primary border column. These are used by the code reader to determine the reference point and orientation of the matrix.

6.2.2 The opposing (secondary) border row and column shall contain dots in alternating cells.

6.2.3 The reference point of the symbol shall be the physical centerpoint of the cell common to the primary border row and the secondary border column.

6.2.4 The maximum dot misalignment within a cell is 20 µm. This ensures that a minimum size dot covers a cell central area of radius 25 µm. (See Figure 4.)

Table 1 Matrix Code Symbol Dimensions

Square Arrays for Use on 125 to 200 mm Wafers	*C_1, R_1 (µm)**			*C_2, R_2 (µm)**		
# of cells in row or column	16	18	20	16	18	20
125 µm spacing	1875	2125	2375	2000	2250	2500
150 µm	2250	2550	2850	2400	2700	3000

*See Figure 1 for pictorial representation of Dimensions C_1, C_2, R_1, and R_2.

Table 2 Message Character Count in Square Arrays for Use on 125 to 200 mm Wafers

# of Cells in a Row or Column		*16*	*18*	*20*
Maximum # of Message Characters	8-bit	10	16	20
	Mostly upper-case	16	25	31

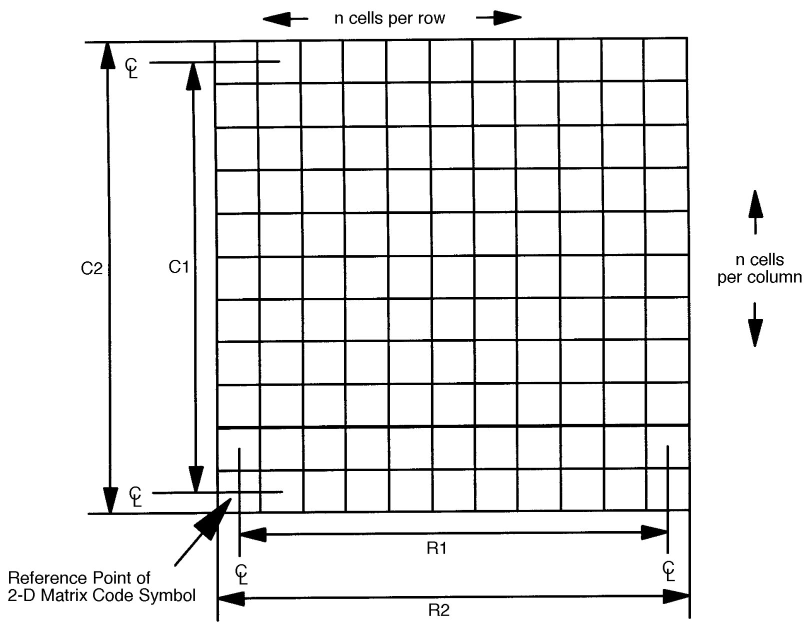


Figure 1
Data Matrix Field Dimensions

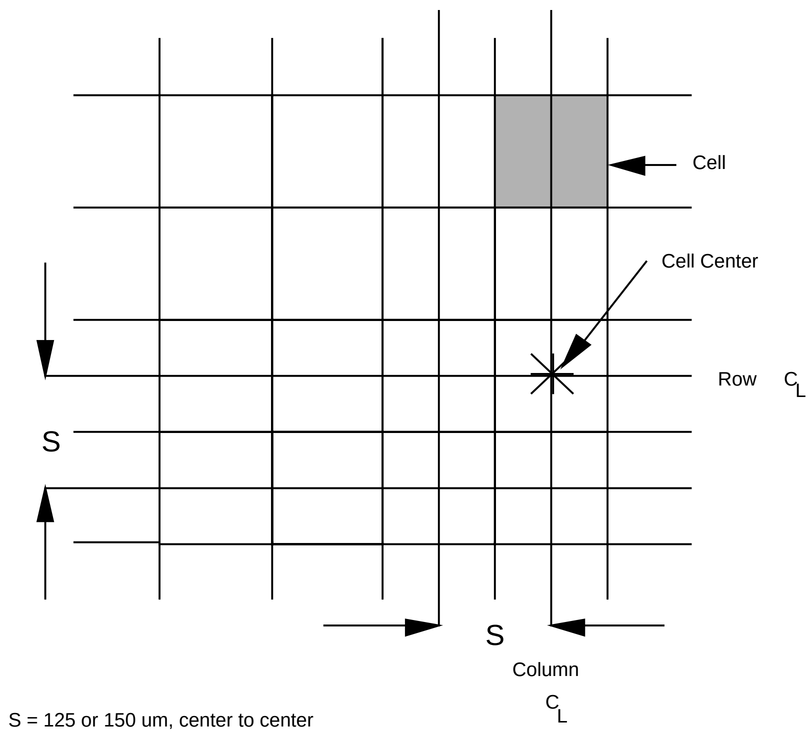


Figure 2
Data Matrix Cell Spacing

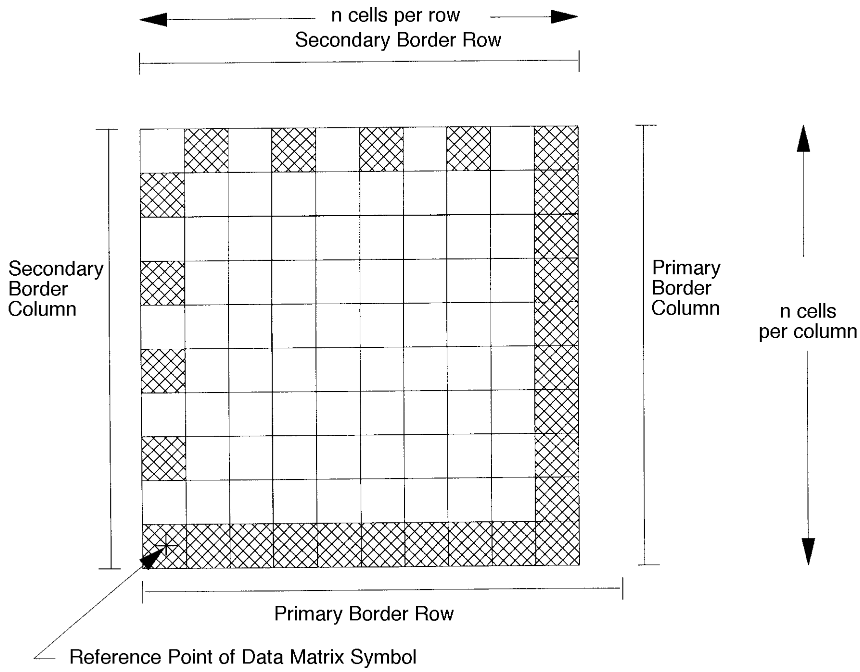


Figure 3
Border Rows and Columns: ECC200

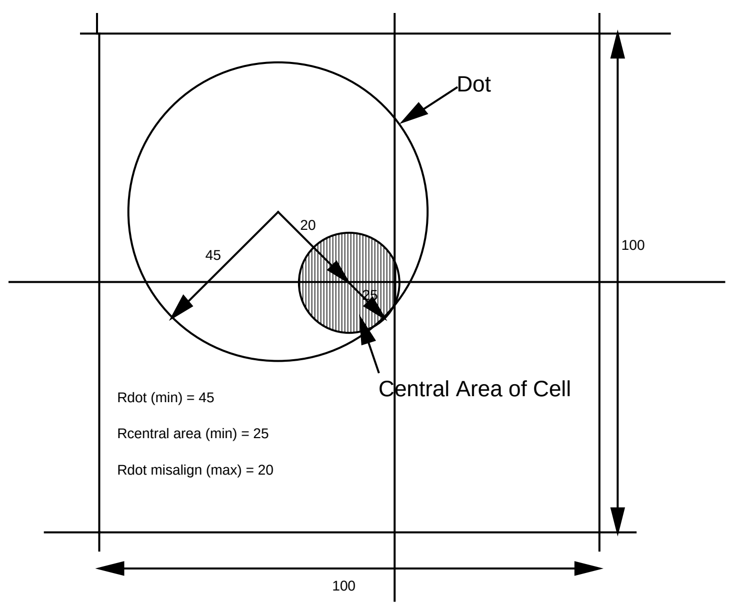


Figure 4
Minimum Size Dot with Maximum Dot Misalignments (all Dimensions in µm)

6.3 *Content of the Matrix Code Symbol*

6.3.1 Each square matrix code symbol shall contain between 10 and 23 message characters encoded in accordance with AIM ISS Data Matrix, including the characters associated with error checking and correcting (ECC200), as also defined in AIM ISS Data Matrix.

6.3.2 The message characters may include any of those designated as "mostly uppercase" in Table 5 and Annex J of AIM ISS - Data Matrix. The first 10 message characters shall contain two elements:

a vendor-assigned 8-character wafer identification code, followed by

a 2-character vendor identification code as defined in SEMI AUX1.

6.3.2.1 The remaining message characters, if any, shall contain information as agreed between the vendor and user.

6.3.3 The total number of message characters available depends on the row/column count and on the encoded character set. (See Table 2.)

6.4 *Location of the Matrix Code Symbol*

6.4.1 With the wafer positioned front surface up and with the primary fiducial toward the operator, the reference point of the matrix code symbol shall be located as specified in Table 3.

6.4.2 The square matrix code symbol used on 125 to 200 mm diameter wafers shall be oriented with the border columns parallel with the primary fiducial bisector and the border rows perpendicular to the primary fiducial bisector. The secondary border column shall be toward the primary fiducial bisector, and the primary border row shall be toward the edge of the wafer.

6.4.3 The nominal position of the reference point of the matrix code symbol is 1 mm to the right of the closest alphanumeric code field. A 3º skew toward the alphanumeric field, which is the maximum skew allowed by SEMI M12 and SEMI M13, does not cause the matrix code symbol to impinge on the alphanumeric code fields, even if the symbol is placed only 15.5 mm from the primary fiducial bi-sector. Consequently, this matrix code symbol position permits the simultaneous use of front surface alphanumeric marking as specified in SEMI M12 or M13, on 125 to 200 mm wafers with either flatted or notched primary fiducials.

6.4.4 Because the matrix code symbol is located in the same place with respect to the primary fiducial bisector on all wafer diameters from 125 to 200 mm, the use of both marking and reading equipment is simplified.

6.4.5 The distance from the edge of the data matrix code symbol to the diameter perpendicular to the primary fiducial bisector varies according to the actual size of the wafer and the placement of the symbol within its tolerance range. Minimum distances from the edge of the code symbol to the wafer center-line are given in Table 4 for both 16 × 16, 125 µm and 20 × 20, 150 µm matrix code symbols.

Table 3 Location of Matrix Code Symbol — Wafer Polished Side Up, Primary Fiducial toward the Operator

Type of Array	*Wafer Fiducial*	*Reference Point Cell*	*Location of Symbol Reference Point*
Square (used on 125, 150, and 200 mm wafers)	Flat	Common cell of primary border row and secondary border column	16.0 ± 0.5 mm to the right of the fiducial bisection, and 2.5 ± 0.5 mm above the edge of the flat
	Notch		160 ± 0.5 mm to the right of the fiducial bisector, and 5.3 ± 0.5 mm above the notch pin center

Table 4 Minimum Distances from Edge of Matrix Code Symbol to the Wafer Centerline

SEMI Standard	*M1.7*	*M1.8*	*M1.12*	*M1.13*	*M1.10*			*M1.9*
Nominal Wafer Diameter, mm	125	150	125	150	200	125	150	200
Flat or Notch	Flat	Flat	Flat	Flat	Flat	Notch	Notch	Notch
Distance from 20 × 20 Matrix with 150 µm Cell Spacing, mm	52.17	62.76	52.33	64.73	89.28	53.98	66.48	91.48
Distance from 16 × 16 Matrix with 125 µm Cell Spacing, mm	53.14	63.73	53.30	65.74	90.25	54.95	67.45	92.45

APPENDIX 1
SIMULTANEOUS MARKING WITH SQUARE DATA MATRIX AND ALPHANUMERIC CODES

NOTE: The material in this appendix is an official part of SEMI T2 and was approved by full letter ballot procedures on 7/15/97.

A1-1 The relative positions of alphanumeric and data matrix markings are shown in Figure A1-1. This figure also shows the relationship between the data matrix code symbol and the edge of the polished area of the front surface of the wafer. Wafer peripheries in the figure are the edges of the polished area of wafers with maximum intrusion of the edge contour, minimum diameter, and maximum flat diameter (minimum flat length), or distance between the notch pin centerline and the wafer edge, as specified in SEMI M1. For all wafer diameters, SEMI M1 allows the edge contour to extend inward from the edge up to 508 µm (Dimension B in Figure 4 of SEMI M1). The distance between the notch pin centerline and the wafer periphery may vary from 0.30 to 0.80 mm as indicated in Figure 6 of SEMI M1. Other dimensions and tolerances are specified in the appropriate polished wafer specification in SEMI M1.

A1-2 Alphanumeric code field locations are shown for all cases except the SEMI M13 code field for flatted wafers, which lies entirely to the left of the primary fiducial bisector. Note that alphanumeric code field locations are not specified for 125 mm diameter notched wafers in either SEMI M12 or SEMI M13.

A1-3 The nominal position of the reference point of the data matrix code symbol is marked by a +; this position is 1 mm to the right of the closest alphanumeric code field. Because of the tolerances on the position of the reference point, the largest data matrix code symbol (20 × 20, 150 µm cell spacing) may lie anywhere within the dotted square. The effect of a 3º skew toward the alphanumeric field is also shown. Although the skew does not affect readability of the data matrix code symbol, too great a skew may cause the data matrix symbol code to impinge on occupied areas of the wafer surface. The 3º skew, which is the maximum allowed by SEMI M12 and SEMI M13, does not cause the data matrix code symbol to impinge on the alphanumeric code fields.

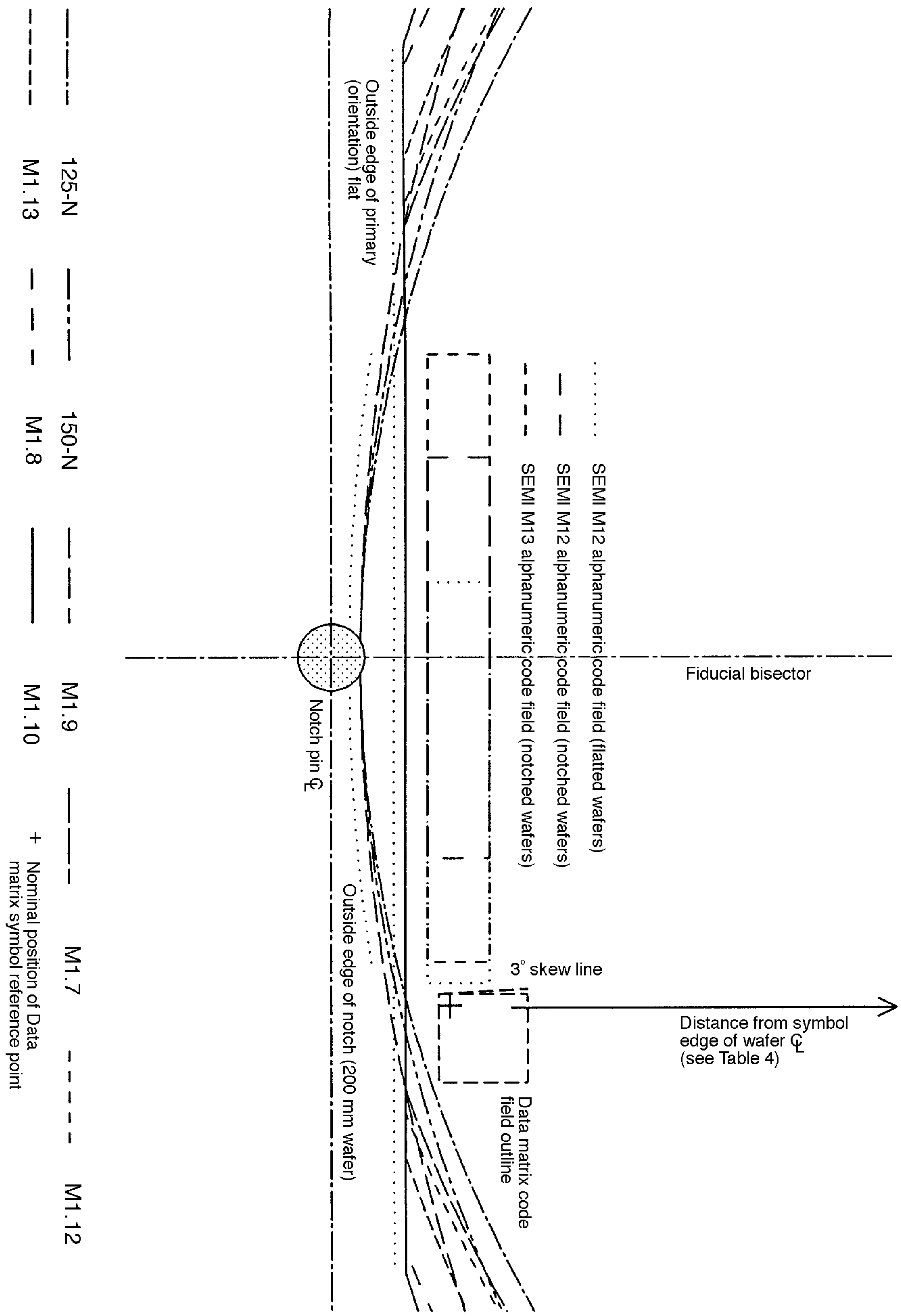


Figure A1-1
Relationship between the Maximum Size Matrix Code Symbol, Alphanumeric Fields, and the Edges of the Polished Front Surface of Minimum Size Wafers

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require the use of copyrighted material or of an invention covered by patent rights. RVSI Acuity CiMatrix has filed a statement with SEMI asserting that the patented or copyrighted item can be used by the public for the purpose of implementing this standard without specific license and without payment of royalty or other charge. Attention is also drawn to the possibility that some elements of this standard may be subject to patented technology or copyrighted items other than those identified above. Semiconductor Equipment and Materials International (SEMI) shall not be held responsible for identifying any or all such patented technology or copyrighted items. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights and the risk of infringement of such rights are entirely their own responsibility.

SEMI T3-0302
SPECIFICATION FOR WAFER BOX LABELS

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org February 2002; to be published March 2002.

NOTE: This document was entirely rewritten for publication in 2002.

1 Purpose

1.1 This specification provides a common format, content, size, and location for printed, machine-readable labels on wafer boxes to facilitate communication of data essential for advanced traceability and electronic data exchange systems. These labels differ from those used in common commercial practice in that they provide less detailed information about parametric properties of the wafer. Such information is now readily stored in advanced traceability systems.

1.2 This specification covers labels that contain two bar code symbols and their associated human-readable interpretation.

1.3 This specification also covers a two-dimensional Data Matrix code symbol that can accommodate substantially more information than can the bar code symbols. This symbol is included to provide for a smooth transition from existing traceability and labeling procedures to the comprehensive, unified system envisioned for the future in which common reading equipment can be used throughout the plant. If the Data Matrix symbol is used without the bar code symbols, provision is made for an associated human readable interpretation.

1.4 Labels provided in accordance with this specification satisfy the special requirements of 300 mm Wafer Shipping Systems, detailed in SEMI M45, for both front opening shipping box (FOSB) labels and bag labels.

2 Scope

2.1 This specification covers size, message content and symbology requirements of labels for wafer boxes used for storage and transport of silicon wafers 100 mm in diameter and larger.

2.2 For wafer boxes used with 100 to 200 mm diameter wafers, this specification provides for two similar labels in order that the contents of the wafer box can be identified when the wafer box is stored in either of two positions: with the side of the wafer box parallel with the front of the storage shelf or with the end of the wafer box parallel with the front of the storage shelf. Because wafer boxes are routinely stacked for storage, placement of box labels on the top or bottom of the box is not recommended.

2.3 For FOSBs used with 300 mm wafers, this specification provides for two identical labels, one to be placed on the FOSB and the other to be placed on the outer bag. These requirements are consistent with the requirements of SEMI M45. SEMI M31 specifies FOSB dimensions.

2.4 The message content and locations of the symbols used on the labels covered by this specification are designed to fit in a space consistent with size of the available flat area on wafer boxes investigated. If a larger flat area is available on the wafer boxes to be used, the label size may be increased and additional message content included.

2.5 This specification includes descriptions of the characteristics of the code formats to be employed.

2.6 The labels covered by this specification may be applied on the box itself, and on the box wrap portion of the wafer package, but not on the transport package (outer shipping carton) used for commercial transportation of wafer packages.

NOTE 1: Specifications for transaction labels, which are intended for use on the outer shipping carton, are given in ANSI/EIA 556-B.

2.6.1 The format of the barcode is based on Code 39, as specified in ISO/IEC 16388.

2.6.2 The format of the Data Matrix Code is specified in ISO/IEC 16022.

2.7 Wafer box labels are intended to be applied in a cleanroom environment concurrent with the completion of production of the wafers. Although it is recognized that the materials of construction and the adhesives used to apply the label must be selected with this use in mind, their specification is beyond the scope of this document.

2.8 The dimensions in this specification are applicable to labels printed with printers that have nominal resolution of 203 dots per inch (dpi). Printers with higher resolution may be used, but many of the dimensions may differ from those in this specification and the code fields may or may not fit within the specified label size and format. In such cases, the user of this specification must ensure that the label is of a size that fits the box to be employed.

2.9 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Documents

3.1 *SEMI Standards*

AUX1 — List of Vendor Identification Codes

SEMI M1.15 — Standard for 300 mm Polished Mono-crystalline Silicon Wafers (Notched)

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI M31 — Provisional Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI M45 — Provisional Standard for 300 mm Wafer Shipping System

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

SEMI T2 — Specification for Marking of Wafers with a Two-Dimensional Matrix Code Symbol

SEMI T7 — Specification for Back-surface Marking of Double-side Polished Wafers with a Two-dimensional Data Matrix Code Symbol

3.2 *ANSI Standards*[1]

ANSI/ASC X3.182 — Bar Code Print Quality - Guide-line

ANSI MH10.8.2 — Data Application Identifier Stan-dard

3.3 *EIA Standards*[2]

ANSI/EIA-556-B — Outer Shipping Container Label Standard

ANSI/EIA 706 — Component Marking Standard

3.4 *ISO/IEC Standards*[3]

ISO/IEC 15417 — Automatic Identification and Data Capture Technique Symbology Specification – Code 128

ISO/IEC 16022 — International Symoblogy Specification – Data Matrix

ISO/IEC 16388 — Automatic Identification and Data Capture Technique Symbology Specification – Code 39

4 Terminology

4.1 Definitions of terms relating to wafer boxes (see Figure 1) are as follows:

4.1.1 *bar end, of a wafer box base* — the end of the box base that is next to the first pocket of the cassette inside the base or the first pocket of the base itself.

4.1.2 *base, of a wafer box* — the open-top container into which wafers are placed, either in cassettes or into integrally molded pockets.

4.1.3 *box wrap* — the wrapping or bagging applied over the wafer box to comprise the product package.

NOTE 2: The box wrap is usually sealed under clean room conditions.

4.1.4 *cover, of a wafer shipping box* — the portion of the box which closes the top of the base.

4.1.5 *wafer box* — a sealable container consisting of a base and a cover, used for storing or transporting wafers. Compare with *transport package* in ANSI/EIA-556-B.

4.1.6 *wafer box label* — the label on the wafer box identifying the product and its manufacturer.

4.1.7 *wafer package* — the combination of a wafer box and box wrap.

4.1.8 *wall end, of a wafer shipping box* — the end of the shipping box that is opposite the bar end.

4.2 Terms relating to FOSBs are defined in SEMI M31.

4.3 Terms relating to bar code characteristics are defined in SEMI T1. Definitions for additional terms relating to the product package, product package label, and bar code format and characteristics can be found in ANSI/EIA-556-B, Appendix A.

1 American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org

2 Electronic Industries Alliance, EIA Engineering Department, Standards Sales Office, 2001 Eye Street, NW, Washington, D.C. 20006, USA. Website: www.eia.org

3 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

4.4 Terms relating to the data matrix code symbol characteristics are defined in SEMI T2 and ISO/IEC 16022.

4.5 Definitions of terms relating to code content are as follows:

4.5.1 *customer information field* — a 35-character field containing the customer product ID and, if desired, other customer assigned information.

4.5.2 *customer product ID* — a unique combination of alphanumeric characters assigned by a customer or purchaser to identify a product, sometimes called customer part number.

4.5.3 *data field* — a specific portion or area of a label designated to contain a human readable interpretation, a bar code symbol, or a two-dimensional matrix code symbol.

4.5.4 *data identifier* — a specified character or character string that defines the category or intended use of data that follows.

4.5.5 *encrypted data* — data entered by the vendor, usually to facilitate traceability, that may or may not be shared with the customer.

4.5.6 *human readable interpretation (hri)* — the interpretation of all or a portion of a bar or matrix code symbols presented in a type font which can be read by persons.

4.5.7 *message character* — a character that contains data, encoded into a bar or matrix code symbol.

NOTE 3: Data identifiers and concatenation characters are considered to be message characters, but start/stop characters are not.

4.5.8 *message length* — the number of message characters contained in a single encoded message.

4.5.9 *traceability number, of a wafer box label* — a string of 35 message characters comprising a lot number, vendor code (including manufacturing location, if desired), and date of labeling together with the appropriate data identifier and concatenation characters.

5 Ordering Information

5.1 Purchase orders for the wafers furnished with wafer box labels in conformance with this specification shall include the following:

5.1.1 Statement that the wafer box label conforms to SEMI Specification T3.

5.1.2 Content of message characters for customer information field.

5.1.3 Label type (see Section 7.1) or, if additional space is available on the box, dimensions of labels and placement of fields thereon.

5.2 In addition, the following optional items may be specified:

5.2.1 If a two-dimensional matrix code symbol is included on the label:

5.2.1.1 Inclusion or exclusion of wafer identification information.

5.2.1.2 User-specified data, if required, and requirement, if any, for sharing of code for encrypted data.

5.2.2 Label locations on the wafer box, if different from the recommended locations.

6 Content and Characteristics of Data Fields

6.1 *Bar Code Symbols*

6.1.1 The label shall contain two data fields for bar code symbols, when such symbols are specified. Each bar code symbol shall contain 35 message characters in addition to the start/stop characters.

6.1.2 A non-printed message header is normally encoded when encoding multiple, concatenated data fields. However, this header is not encoded in the bar code fields to conserve space. The absence of this message header requires appropriate software in bar code reading systems, to separate the data fields.

6.1.3 The upper bar code data field, the customer information field (see Table 1 and Figure 2a), shall contain the customer product ID preceded by a “P,” the data identifier for this item as specified in ANSI MH10.8.2.

6.1.3.1 Optionally, if the customer product ID occupies less than 34 characters, the customer identification field may also contain one or more of the subfields listed below, up to the limit of 35 characters total. Each optional subfield shall be preceded by the concatenator symbol “+ ” and the data identifier(s) below, in accordance with ANSI MH 10.8.2.

6.1.3.2 Field Identifier for *customer part number revision*: 2P

6.1.3.3 Field Identifier for *customer specification number*: 20P

6.1.3.4 Field Identifier for *customer specification revision*: 21P

6.1.3.5 Field Identifier for *customer drawing number*: 12P

6.1.3.6 Field Identifier for *customer drawing revision*: 22P

6.1.4 The lower bar code data field (see Table 2 and Figure 2b) shall contain the 35-message character traceability number. This field is divided into four subfields, each separated from the adjacent field by the concatenation symbol "+ ." The first subfield contains the lot number of 16 characters, preceded by the data identifier "1T." The second subfield contains the 2-character SEMI vendor identification code, preceded by the data identifier "1V. " The third subfield contains the labeling date (YYMMDD), preceded by the data identifier "D. " The fourth subfield contains the quantity, preceded by the data identifier "Q. " The quantity indicated on the label shall be the number of wafers in the wafer box to which the label is affixed; the unit of measure is understood as each (EA). The message characters in this symbol are distributed as shown in Table 2.

Table 1 Content of Bar Code Symbol in Upper Bar Code Data Field (Customer Information Field)

Number of characters	*Symbol Content*	*Notes*
	Required Subfield	
First 1	Data Identifier	"P"
message dependent	Customer Product ID (e.g. part number)	(Customer-specified)
	Optional Subfields	
3	Concatenator + Data Indentifier	"+ 2P"
message-dependent	Customer Part Number Revision	(Customer-specified)
4	Concatenator + Data Indentifier	"+ 20P"
message-dependent	Customer Specification Number	(Customer-specified)
4	Concatenator + Data Indentifier	"+ 21P"
message-dependent	Customer Specification Number Revision	(Customer-specified)
4	Concatenator + Data Indentifier	"+ 12P"
message-dependent	Customer Drawing Number	(Customer-specified)
4	Concatenator + Data Indentifier	"+ 22P"
message-dependent	Customer Drawing Revision	(Customer-specified)

NOTE 1: The total number of characters in the field shall not exceed 35; any character location not filled with data shall contain a dash.

Table 2 Content of Bar Code Symbol in Lower Bar Code Data Field (Traceability Number)

Character Location	*Symbol Content (All required fields)*	*Notes*
1–2	Data Identifier	"1T"
3–18	Lot Number	(Supplier assigned)
19–21	Concatenation Symbol and Data Identifier	"+ 1V"
22–23	Vendor Identification Code	(SEMI) (See Note 1)
24–25	Concatenation Symbol and Data Identifier	"+ D"
26–31	Labeling Date	(YYMMDD) (See Related Information 1)
32–33	Concatenation Symbol and Data	"+ Q"
34–35	Quantity (unit, EA, implied)	(numeric)

NOTE 1: The SEMI vendor identification code may contain information on manufacturing location. AUX1 contains multiple codes indicating manufacturing location for some, but not all, wafer suppliers. If desired, suppliers whose codes do not now include manufacturing location identification can request additional codes for each location from SEMI, following the procedure in AUX1.

6.1.5 All bar code symbols shall use the Code 39 bar code as specified in ISO/IEC 16388, unless an optional bar code is selected (see Section 6.1.9). Code 39 is a variable length, discrete, self-checking, bi-directional bar code. Each character is composed of nine elements: Five bars and four spaces. Three of the nine elements are wide and six elements are narrow.

6.1.6 *Character Set* — The Code 39 character set consists of 43 characters: 0-9, A-Z,+ ,-,.,$,/,%, and space. In addition, an asterisk (*) is used only for both the start and stop characters; it cannot be used as a message character. No other characters shall be encoded in the bar code symbols of labels covered by this specification. In the absence of a character at any assigned location, a dash (-) shall be used.

6.1.7 *Print Quality* — The Code 39 print quality shall be B/03/630 or better in accordance with ANSI X3.182. To assure reading efficiency, the minimum reflectance of the quiet zones shall be 60%, the minimum reflectance of spaces shall be 51%, and the maximum reflectance of bars shall be 10%.

6.1.8 *Symbol Dimensions* — Bar code symbol dimensions shall be as listed in Table 3.

6.1.9 *Other Bar Code Symbology* — Code 128 may be used in lieu of Code 39. Users must verify that this code fits within the available label space.

6.2 *Human-Readable Interpretation Symbols*

6.2.1 Each bar code symbol data field on the label shall have an associated human-readable data field either immediately above or immediately below it. The symbol in each of the human-readable data fields shall contain all the message characters contained in the associated bar code data field. Start and stop characters shall not be included, but the data field identifiers and concatenation symbols shall be included.

6.2.2 The nominal height of the human-readable characters shall be 2.0 mm (0.08 in.).

6.2.3 There shall be a clear space of 0.5 mm (0.02 in.) above and below each human-readable symbol.

6.3 *Data Matrix Code Symbol*

6.3.1 The label may contain up to two identical square two-dimensional matrix code symbols each with up to 682 message characters when six-bit characters are encoded using the EDIFACT encodation scheme described in Annexe J3 of ISO/IEC 16022 (see also Table 11 in ISO/IEC 16022).

6.3.2 The first six characters shall contain the message header, in accordance with EIA 706; this header identifies a message that contains data identifiers that are in accordance with ANSI MH10.8.2. The header content is not printed.

6.3.3 The next 71 characters in the matrix code symbol shall contain the information included in the two bar code symbols on the label, together with additional concatenation symbols, as summarized in Table 4. In the absence of a character at any assigned location, a dash (-) shall be used. This information shall also be included if the bar codes are not printed.

Table 3 Nominal Dimensions of Bar Code 39 Symbols

Symbol	*Dimension*	*Metric (SI) Value*	*U.S. Customary Value*
-	number of message characters	35	35
X	width of narrow bar	0.125 mm	0.00493 in.
N	ratio of wide to narrow bar width	2.0	2.0
I	nominal intercharacter gap	0.1251 mm	0.00493 in.
H	bar height (See Note 1.)	9.0 mm	0.35 in.
L'	bar code symbol length (excl. quiet zones)	60.06 mm	2.365 in.
-	bar code density (excl. quiet zones)	0.583 cpmm	14.80 cpi
Q	width of quiet zone (See Note 1.)	6.35 mm	0.25 in.
L	total length of bar code symbol	72.76 mm	2.865 in.

NOTE 1: The metric (SI) and U.S. Customary values of this dimension are not exact equivalents; the dimension has been rounded to obtain rational values in both systems.

6.3.4 For boxes to be used for wafers between 100 and 200 mm in diameter, the content of the remainder of the data matrix code symbol is optional, as agreed between the customer and supplier. However, it is recommended that the remaining message characters in the Data Matrix code symbol include the following 500-character wafer identification information. For labels to be used on 300 mm FOSBs, the wafer identification information is required, in accordance with SEMI M45.

6.3.4.1 These next 500 characters identify the slot number and individual wafer identification of each wafer in the box, with a string of 25 twenty-character fields. Each of these fields contains:

a. The concatenation character (“+ ”) and Data Identifier for the slot ID (“31T”) and a two-digit number of the slot, and

b. the concatenation character (“+ ”) and Data Identifier for the ID of the wafer in that slot (“32T”) and the ten-character wafer ID including the two-character vendor identification code. The wafer ID number is comprised of

i) the first ten characters of the marking codes specified in SEMI M12, SEMI M13, or SEMI T2, or

ii) all ten characters of the marking code specified in SEMI T7.

NOTE 4: The content of the marking code specified in SEMI T1 is not specified. This standard may not be suitable for use with wafers marked with the marking code specified in SEMI T1.

6.3.4.2 The cassette/box slot sequence assumes slot 01 at the bar end and slot 25 at the other end of the box. Data matrix code symbols on labels on boxes or cassettes with less than 25 slots shall have one field for each slot.

Table 4 Message Character Content of Matrix Code Symbols

Character		*Symbol Content*	*Notes*
Location	*Count*		
		General Information	
1–6	6	Message Header	<d237>
7	1	Data Identifier	“P”
8–41	34	Customer Information (see Table 2)	(Customer-assigned)
42–44	3	Concatenation Symbol and Data Identifier	“+ 1T”
45–60	16	Lot Number	(Supplier-assigned)
61–63	3	Concatenation Symbol and Data Identifier	“+ 1V”
64–65	2	Vendor Identification Code	(SEMI)
66–67	2	Concatenation Symbol and Data Identifier	“+ D”
68–73	6	Labeling Date	(YYMMDD) (See Related Information 1)
74–75	2	Concatenation Symbol and Data Identifier	“+ Q”
76–7	2	Quantity (unit, EA, implied)	(numeric)
	77	Subtotal for general information	
		Wafer Information (Optional, see 6.3.4 and 6.3.4.1)	
78–81	4	Concatenation Symbol and Data Identifier	“+ 31T”(See Note 8)
82–83	2	Slot Number	(numeric, 01-25)
84–87	4	Concatenation Symbol and Data Identifier	“+ 32T”
88–97	10	Wafer Identification Number	
	20	Subtotal for one wafer	
98–577	480	Subtotal for next 24 wafers	
	500	Subtotal for wafer information	
	577	Total for General + Wafer Information	
		Encrypted or Customer-specific Data (Optional)	
577–682	up to 105	As needed	Otherwise unused character locations (See Note 9)

NOTE 1: If wafer identification data are not available or are not desired for a particular application, additional supplier-specified and/or customer-specified data fields may be included in these character locations as agreed upon between customer and supplier. Begin each supplier-specified field with a data identifier from the series 31T to 34T and each customer-specified field with a data identifier from the series 20T to 24T. Separate adjacent fields with the concatenation symbol (+).

NOTE 2: These unused character locations are available for encrypted or unencrypted supplier-specified information or for customer-specified information. These characters do not appear in the bar code symbol, but only in the Data Matrix Code Symbol. Begin the field with the concatenation symbol (“+ ”) followed by an appropriate data identifier as defined in Note 1; in the unlikely event that more than one field is included, begin each field with an appropriate identifier and separate adjacent fields with the concatenation symbol. If the field is not filled completely with characters it is not necessary to pad with dashes; the encoding software will pad it automatically.

6.3.4.3 All slots shall be represented in the Data Matrix code. The first identification number shall be that of the wafer in slot 01 at the bar end; the second, that of the wafer in slot 02; and so on. An empty slot shall be designated by dashes. For shipping boxes containing 100 to 200 mm diameter wafers, slot 01 is at the bar end of the box. For 300 mm FOSBs, slot 1 is specified by SEMI M31 to be at the bottom of the FOSB.

6.3.5 Any character locations not otherwise used may contain information whose content shall be agreed to between supplier and customer. These characters may consist of customer-specified data or supplier-specified data (which may be encrypted) or both.

6.3.6 The data matrix code shall be a square field, constructed in accordance with ISO/IEC 16022, using error correction code ECC200.

6.3.7 *Dot Size* — The nominal shape of the dot produced in the matrix may be circular or square, depending on the printing technique. It is recommended that each " cell" of the data matrix symbol be composed of at least four dots (a cell with two dots per edge). When printed at 203 dpi, the dot diameter or edge length is 0.125 mm (0.00985 in.).

6.3.8 *Symbol Dimensions* — Each matrix code symbol shall be composed of 80 rows and 80 columns of cells spaced equally with cell spacing *S* (see Figure 3). The nominal outside dimensions of the matrix (C2 and R2 in Figure 4), printed with 4 dots per cell at 203 dpi is 20 mm.

6.3.9 *Border Rows and Columns (see Figure 4)*

6.3.9.1 The leftmost border row and the bottom border column shall contain dots in each cell. These are identified as the primary border row and the primary border column.

6.3.9.2 The opposing (secondary) border row and column shall contain dots in every other cell.

6.3.9.3 These border rows and columns are used by the code reader to determine the origin, size, and orientation of the matrix.

6.3.9.4 The origin of the matrix code symbol shall be the physical center point of the cell common to the primary border row and the primary border column.

NOTE 5: This origin location differs from that used in SEMI T2.

6.3.10 *Message Characters* — The matrix code symbol contains 682 8-bit message characters.

Table 5 Nominal Dimensions of Wafer Box Labels and All Data Fields

Dimension	*Metric (SI) Value*	*U.S. Customary Value*
A (see Note 11)	25 mm	1 in.
B (see Note 11)	0.75 mm	0.04 in.
C (see Note 11)	1.0 mm	0.04 in.
D (see Note 11)	0.50 mm	0.02 in.
E (see Note 11)	2.0 mm	0.08 in.
F (see Note 11)	24.24 mm	0.95 in.
H (see Note 11)	9.0 mm	0.35 in.
J	2.0 mm	0.08 in.
K (see Note 12)	20.0 mm	0.788 in.
L´	60.06 mm	2.365 in.
L	72.76 mm	2.865 in.
P	119.0 mm	4.69 in.
Q	6.35 mm	0.25 in.
S (see Note 11)	30.0 mm	1.19 in.
T (see Note 11)	24.0 mm	0.95 in.
U (see Note 11)	2.5 mm	0.106 in.

NOTE 1: The Metric (SI) and U.S. Customary values of this dimension are not exact equivalents; the dimension has been rounded to obtain rational values in both systems.
NOTE 2: Printed at 4 dots/cell and 203 dpi.

6.3.10.1 The initial six characters are a non-printed message header. The next 570 characters are restricted to the Code 39 Character Set (see 6.1.6) using the six-bit EDIFACT encodation scheme described in Annexe J3 of ISO/IEC 16022. The remaining 105 message characters may be any character in the EDIFACT Encodation Character Set, including unprinted ones. These 105 characters are available for encrypted or unencrypted information, as negotiated between supplier and customer.

6.3.11 *Print Quality* — To assure reading efficiency, a minimum contrast of 30% is required between the reflectance value of a dot and the surrounding label surface. Various densitometers can provide such measurements nondestructively.

7 Label Types, Label Dimensions, and Placement of Data Fields on Labels

7.1 *Label Types (see Figure 5 for examples)*

7.1.1 *Type 1* — Company Field + Data Matrix Field with hri fields

7.1.2 *Type 2* — Company Field + Bar Code Field with hri fields

7.1.3 *Type 3* — Company Field + Data Matrix Field + Bar Code Field with hri fields. Two of this type of label are required for use on 300 mm FOSBs.

NOTE 6: The space reserved on the FOSB rear surface accepts labels as large as 120 mm by 120 mm. This permits the use of labels wider than is specified in this standard. Such labels may contain additional information as arranged by agreement between customer and supplier.

7.1.4 *Type 4* — Company Field + Data Matrix Field1 + Bar Code Field with hri fields + Data Matrix Field2 with hri fields

7.1.5 *Type 5* — Company Field + two Data Matrix Fields, both with hri fields

7.2 Each label shall contain an area containing Company Information and one or more areas containing bar codes, data matrix codes, and related human-readable information.

7.2.1 The Company Information area may contain supplier-related information in human-readable alpha-numeric format and other information as agreed to between customer and supplier.

7.2.2 The other fields that contain bar code, human-readable, and two-dimensional matrix code data fields, may be arranged as indicated in the examples shown in Figure 5.

7.2.3 The human-readable (hri) data fields can be placed either above or below their associated bar code data fields. The examples in Figure 5 show the configuration with the hri fields above the bar code data fields.

7.3 Approximate overall dimensions of the five label types shown in Figure 5 are tabulated in Table 6.

7.4 Dimensions of individual fields, label height, and label length for a type 4 label are given in Table 5 and Figure 6. Label types 4 and 5 may use perforated label material so that the sections may be separated after printing.

Table 6 Overall Dimensions of Box Labels

Label Type	*Length*			*Width*		
	Symbol	*mm*	*in.*	*Symbol*	*mm*	*in.*
1	F+ S	54.2	2.1	A	25.0	1.0
2	F+ L	97.0	3.8	A	25.0	1.0
3	P=F+ T+ L	119.0	4.7	A	25.0	1.0
4	P+ S	149.0	5.9	A	25.0	1.0
5	F+ 2S	84.2	3.3	A	25.0	1.0

NOTE 1: For meaning of the symbols, see Table 5.

8 Label Locations on Wafer Box

8.1 For boxes containing wafers from 100 to 200 mm in diameter, the following recommendations apply.

8.1.1 It is recommended that label type 4 or label type 5 be used for these boxes. These label types may be printed on perforated label material so that the sections may be separated after printing.

8.1.2 The recommended location for the larger label is the center (both vertically and horizontally) of the side of the cover of the wafer box facing the operator with the bar end to the left and the wall end to the right (see Figure 7). Alternatively, this label may be placed in the center of the same side of the base of the wafer box.

8.1.3 The recommended location for the smaller label is the center (both vertically and horizontally) of the wall end of the base of the wafer box (see Figure 7). Alternatively, this label may be placed at the center of the wall end of the cover of the wafer box.

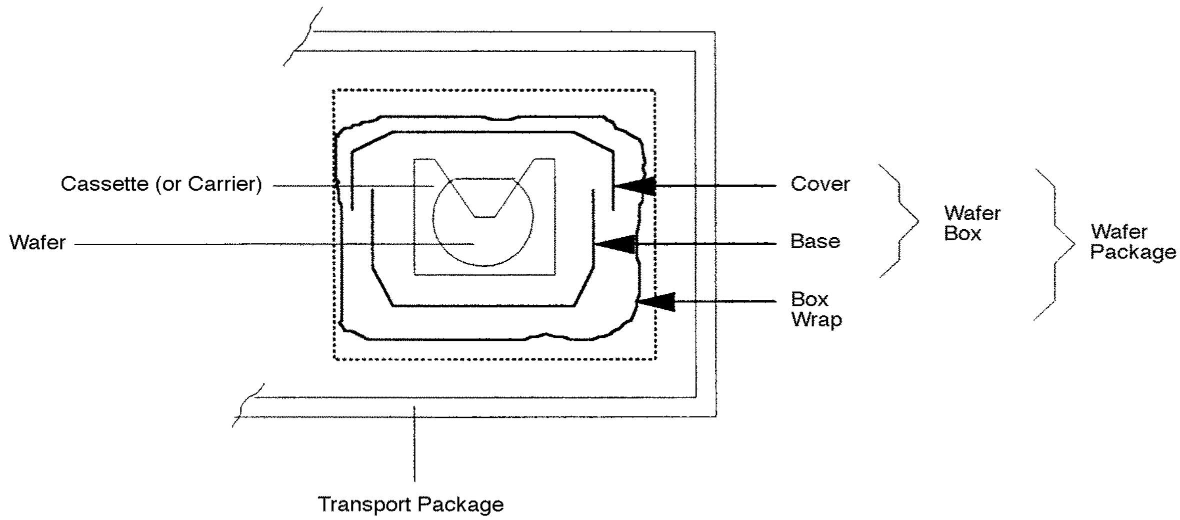
8.1.4 It is recommended that the wafer box cover and the wafer box base each contain a label, so that each will have a label after they have been separated. However, in some cases, space limitations may require that both labels be placed on the same part of the wafer box.

8.2 For FOSBs containing 300 mm wafers, the following requirements apply.

8.2.1 Use two identical Type 3 labels.

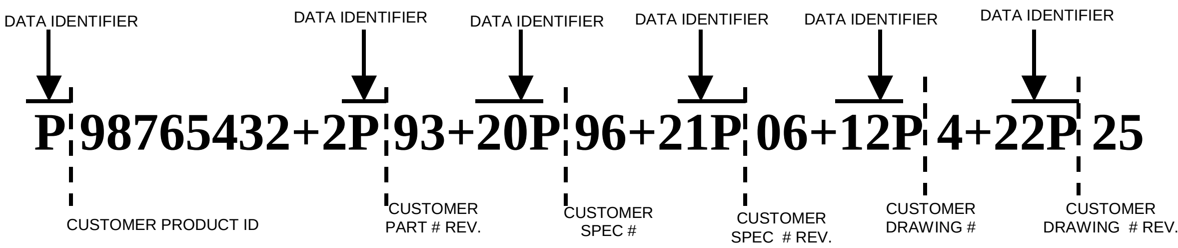
8.2.2 Place one label on the center of the rear surface of the FOSB with the long axis of the label perpendicular to the FOSB base (see Figure 8a).

8.2.3 Place the other, identical, label on the outer wrap bag, which is specified in SEMI M31, at the center of the side adjacent to the FOSB door (see Figure 8b).



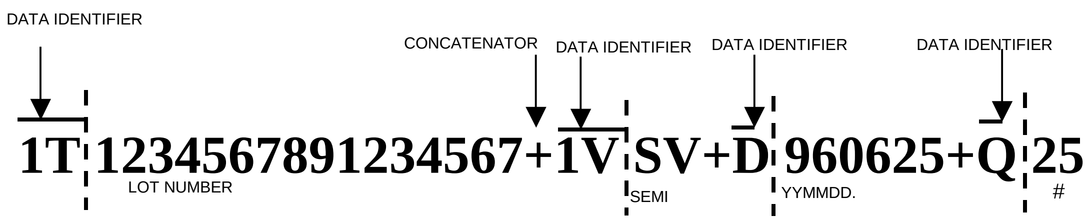
NOTE 1: This specification covers only labels for the wafer package, including the wafer boxes and the wafer box wrap; labels for transport packages are specified in EAI 556-B.

Figure 1
Wafer Box, Wafer Package and Transport Package



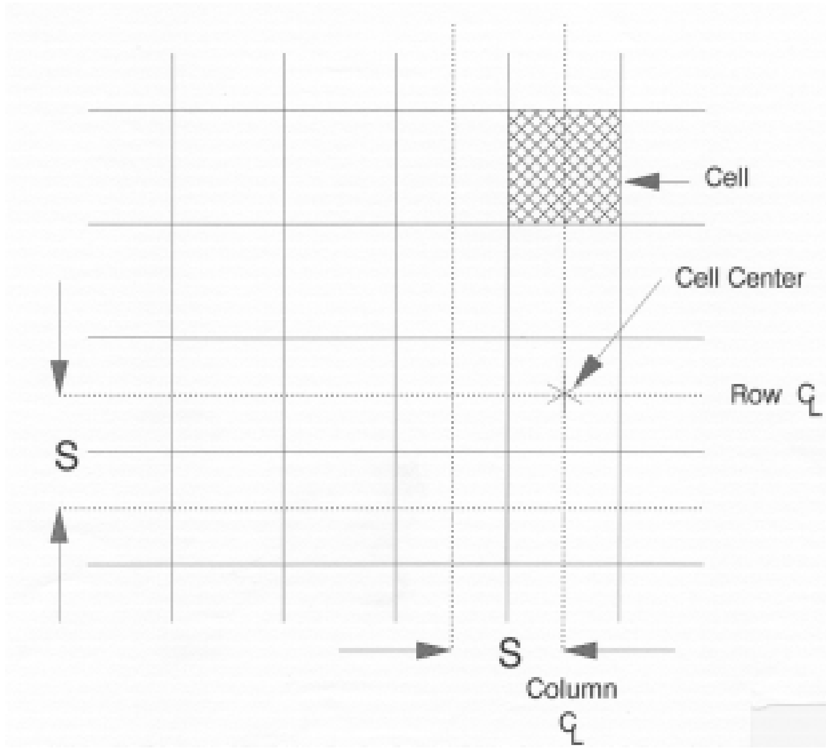
NOTE 1: In this figure, vertical dashed lines separate subfields; the concatenation and field identifiers are to the left of these dashed lines. The CUSTOMER PRODUCT ID is a required field whose content is specified by the customer. The PART # REVISION, SPECIFICATION #, SPECIFICATION # REVISION, DRAWING NUMBER and DRAWING NUMBER REVISION are optional fields; these are also assigned by the customer up to a maximum character count of 35, including all concatenation and field identifier characters. All unused character locations are filled with a dash (-).

Figure 2a
Example of Customer Information Field



NOTE 1: In this figure, vertical dashed lines separate subfields; the concatenation and field identifiers are to the left of these dashed lines. LOT NUMBER is assigned by the supplier. SEMI represents the two-character vendor code that is maintained by SEMI. YYMMDD represents the year, month and day of packaging and # is a two-digit number indicating the quantity of wafers in the box.

Figure 2b
Example of Traceability Number



NOTE 1: S = 0.25 mm (at 203 dpi and 4 dots per cell)

Figure 3
Data Matrix Cell Spacing

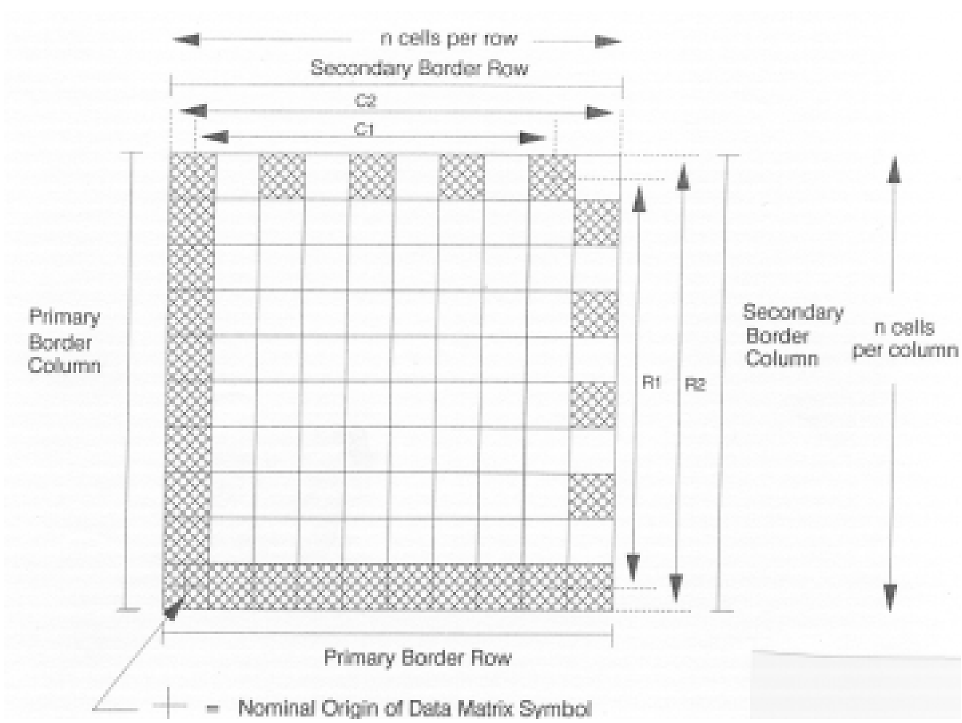


Figure 4
Border Rows, Border Columns and Dimensions of Data Matrix Symbol

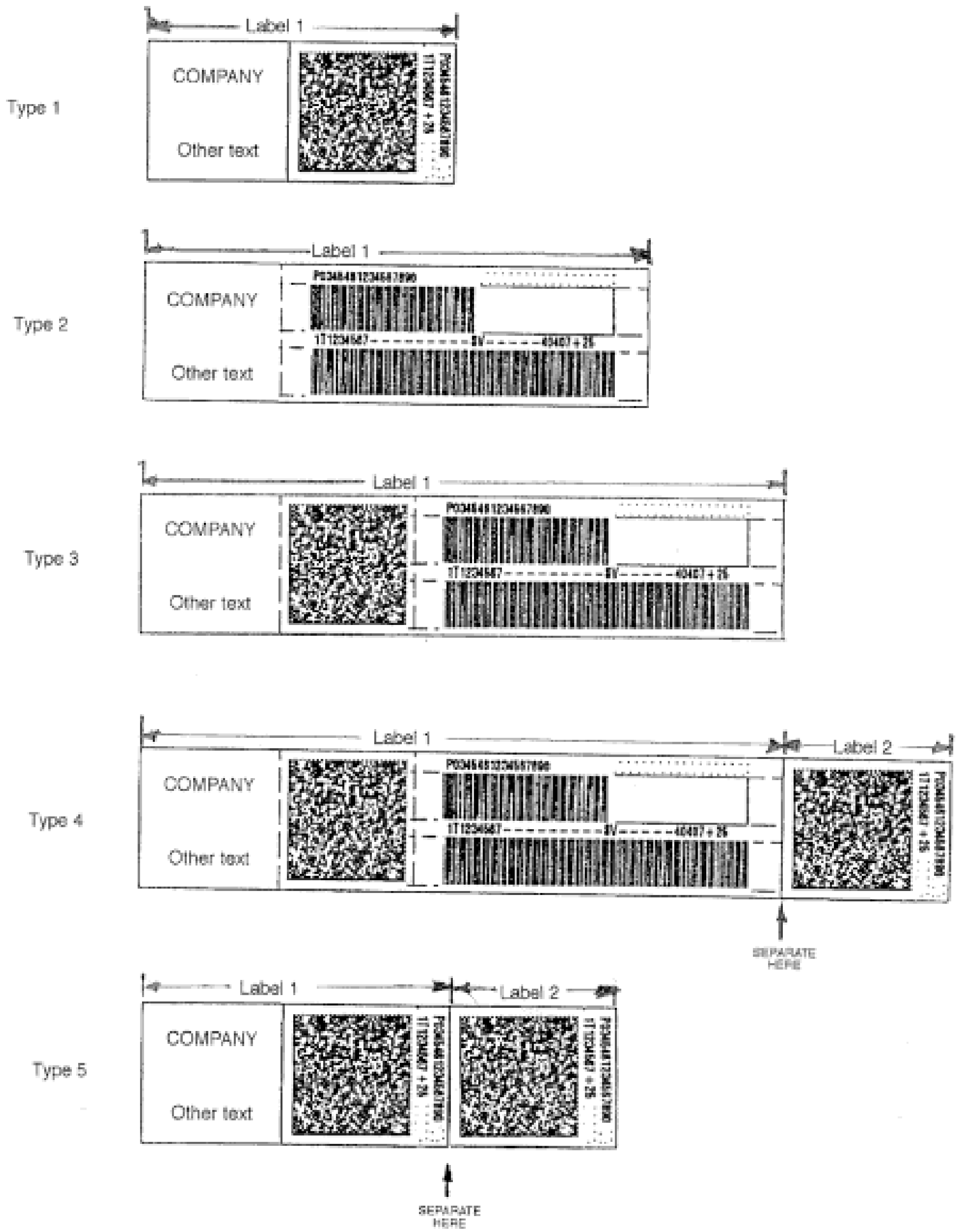


Figure 5
Examples of Box Label Layout Types

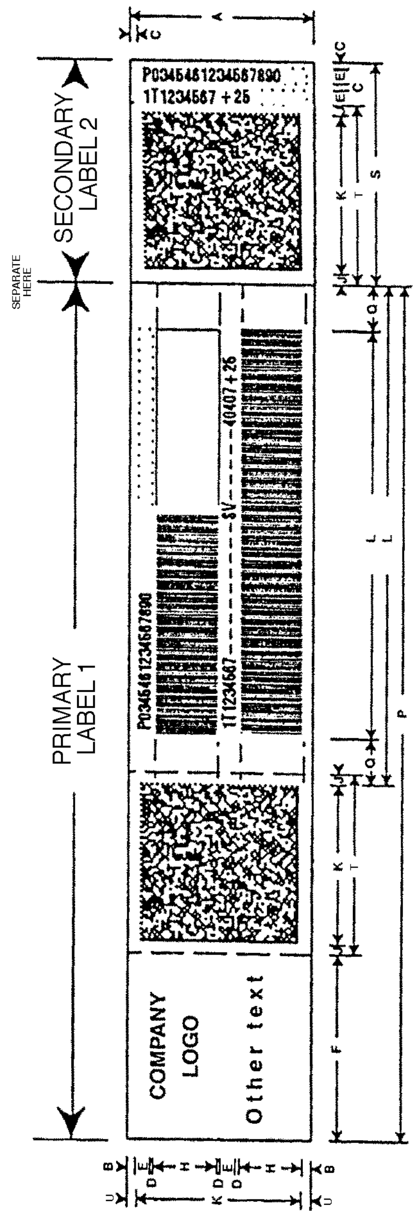


Figure 6
Labels with Bar Code, Human-Readable and Matrix Code Data Fields

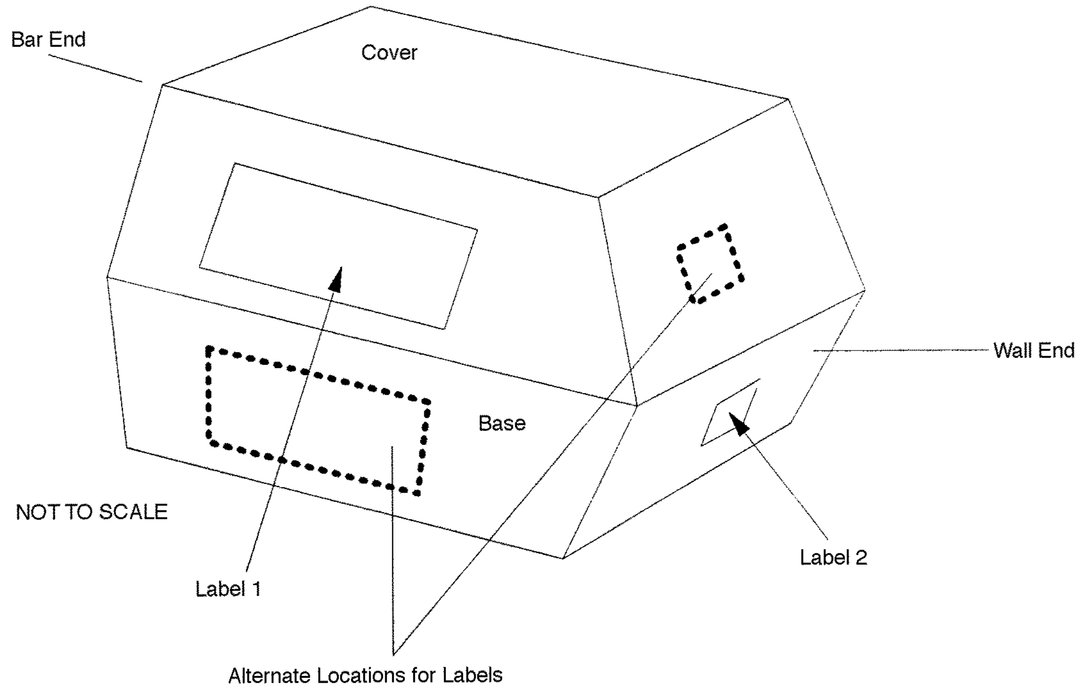


Figure 7
Recommended and Alternative Locations for Labels on Wafer Boxes for Use with Wafers of 100 to 200 mm Diameter

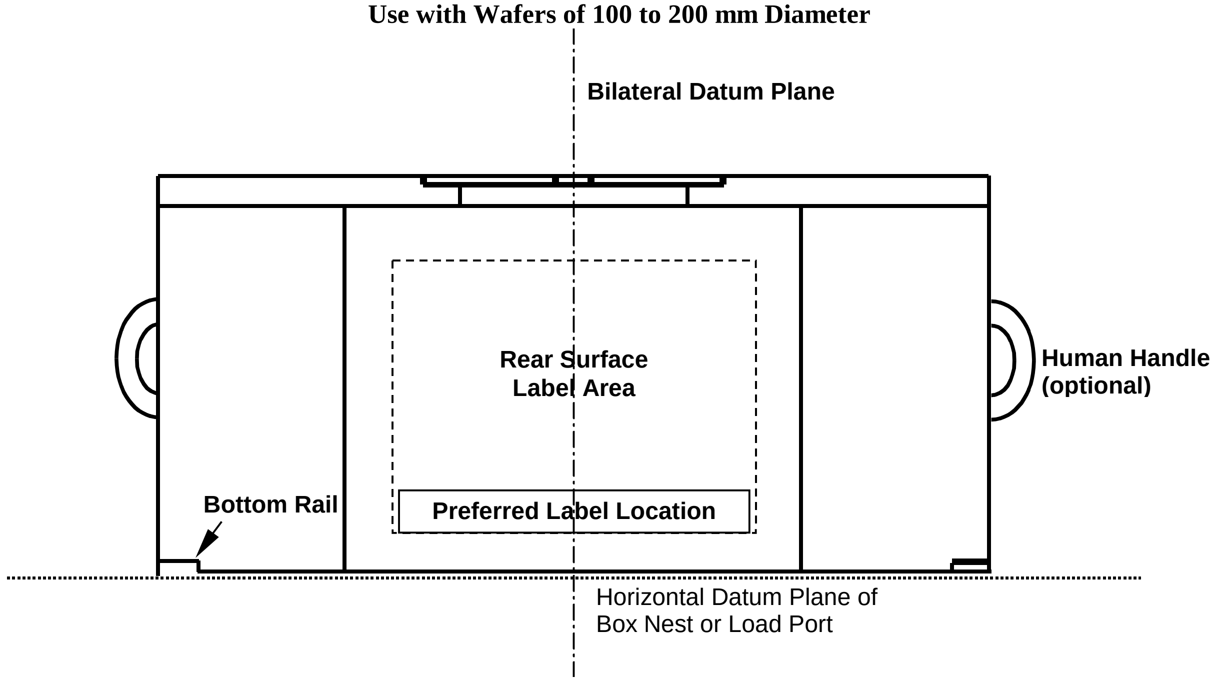


Figure 8a
300 mm FOSB Rear Surface Label Locations

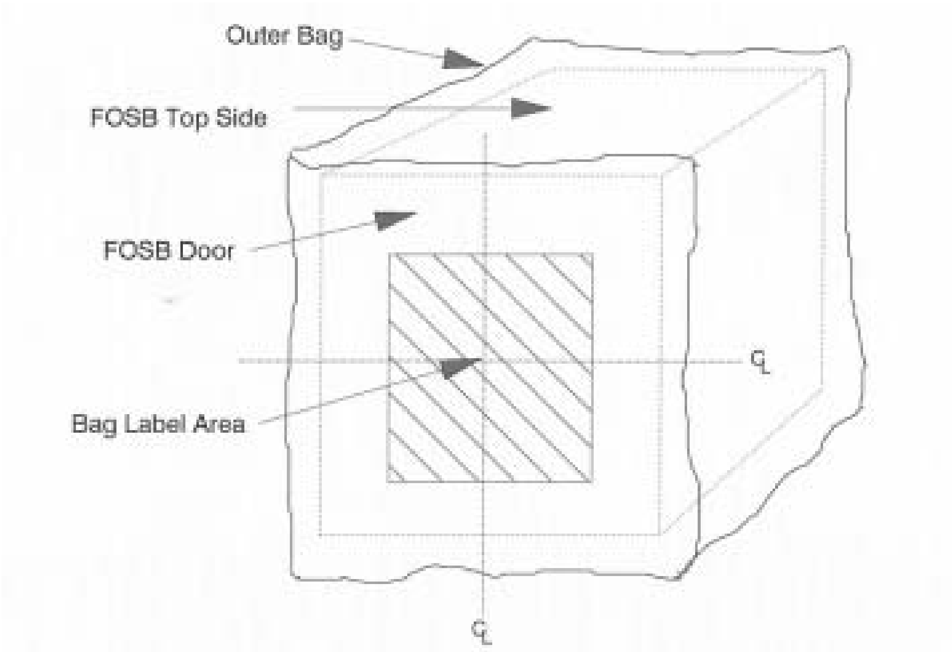


Figure 8b
FOSB Associated Outer Bag Label Location

RELATED INFORMATION 1
MODIFIED DATE FORMAT

NOTE: This related information is not an official part of SEMI T3 and was derived from information developed by the T3 Revision task force of the N.A. Traceability committee during revision of the standard. This related information was approved for publication in June 1997 after full letter ballot and approval by the NA Regional Standards Committee.

R1-1 Alternative Labeling Date Format

R1-1.1 By agreement between supplier and customer, the labeling date may be in the format of YYYYMMDD. The data identifier "6D" should be used when the year is indicated by four characters. This adds three characters to the information printed on the label, two additional date characters and the second character in the data identifier. There is space available on the minimum size label when using the two-dimensional data matrix symbol or the optional Code 128 bar code. Three additional characters added to the Code 39 bar code will not fit on the minimum size label unless the Lot Number is reduced to 13 characters.

SEMI T4-0301
SPECIFICATION FOR 150 mm AND 200 mm POD IDENTIFICATION DIMENSIONS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on December 20, 2000. Initially available at www.semi.org February 2001; to be published March 2001. Originally published in 1995.

1 Purpose

1.1 The purpose of this specification is to ensure dimensional compatibility when mounting pod identification tags and tag identification devices.

2 Scope

2.1 The scope of this specification is to define:

- free space at a pod to allow the mounting of a pod identification tag, and
- free space to allow data transmission.

2.2 This specification is applicable to 150 mm and 200 mm Standard Mechanical Interfaces (SEMI E19). The space required for pod handling per SEMI E47 is considered.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This specification applies to pod identification only.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E47 — Specification for 150 mm/200 mm Pod Handles

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

5.2 *Pod Identification Tag* — information carrier mounted to a pod.

5.3 *Standard Mechanical Interface (SMIF)* — interface plane between pod and another minienvironment per SEMI E19.

5.4 *Tag Identification Device* — device for transferring information from/to a pod identification tag.

6 Requirements

6.1 The defined free space for a pod identification tag (see Figure 1) may not be used by any other device than the pod identification tag and its supports.

6.1.1 The pod identification tag and its supports may not exceed the outline of the defined free space for a pod identification tag (see Related Information Section R1-1).

6.2 The defined free space for data transmission (see Figure 1) may only be used by the tag identification device if necessary (see Related Information Section R1-2).

Table 1 Dimensions of Defined Free Space

Dimension	*150 mm SMIF*	*200 mm SMIF*
A1	130 mm	167.5 mm
A2	160 mm min. 180 mm recommended	207.5 mm min. 227.5 mm recommended
A3	70 mm	70 mm
B1	36 mm	36 mm
B2	43 mm	43 mm
B3	120 mm	120 mm

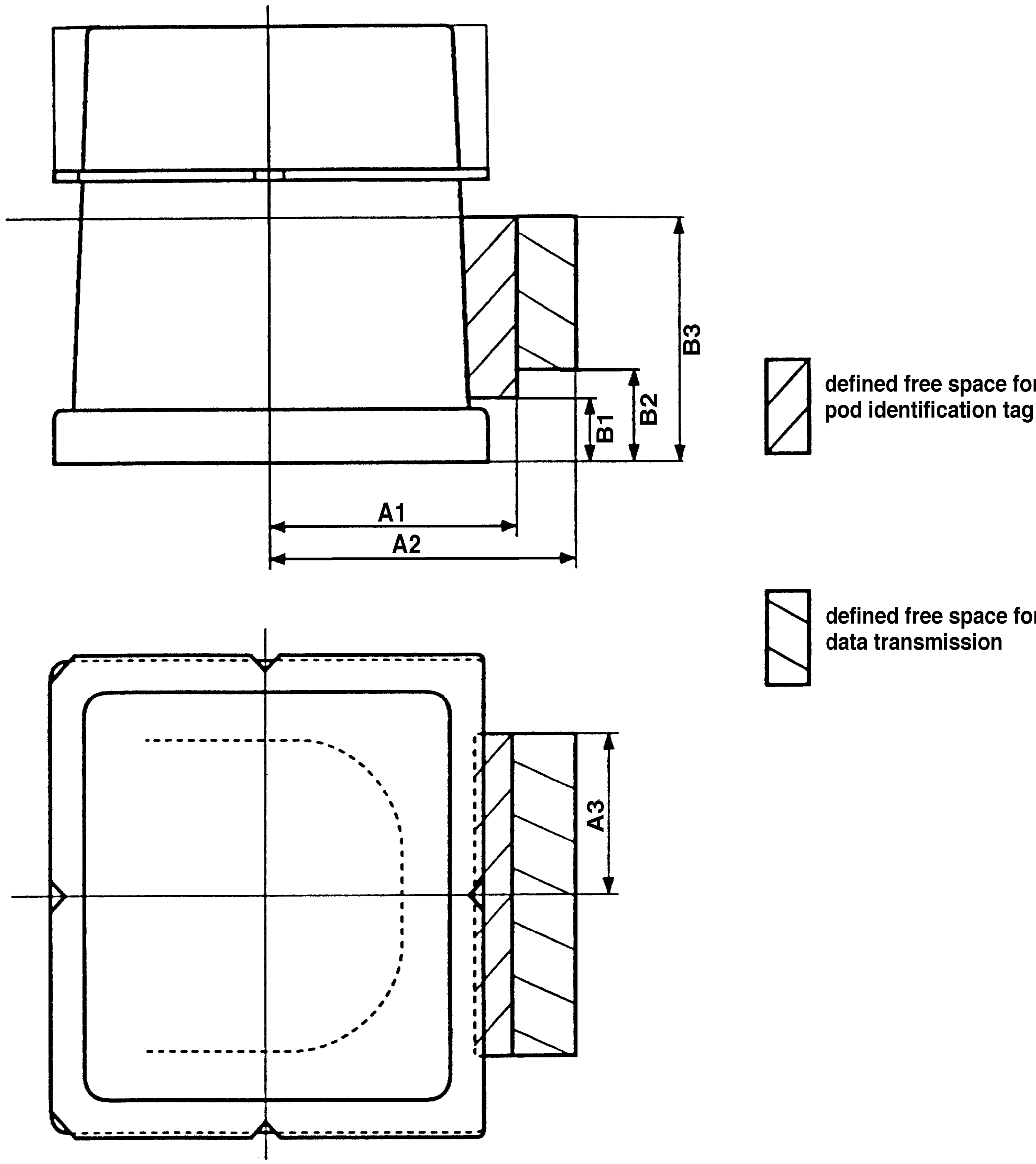


Figure 1

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI T4, but was approved for publication by full letter ballot procedures in 1995.

R1-1 As the outline of the pod sidewall is not standardized, the available space for the pod identification tag may vary between different pod types.

R1-2 The defined free space for data transmission should not be obstructed for the following reasons:

- data transmission
- loading/unloading
- SEMI E15 (multiple row applications)

SEMI T5-96[E]
SPECIFICATION FOR ALPHANUMERIC MARKING OF ROUND GALLIUM ARSENIDE WAFERS

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on April 30, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. Originally published in 1996.

E This document was modified in April 1999 to reflect the creation of SEMI AUX1 as the source for vendor identification codes. Changes were made to numerous sections.

1 Purpose

1.1 The purpose of this document is to define standard criteria for the alphanumeric marking of round gallium arsenide wafers, in order to improve the consistency of wafer marking and allow simplification of the performance requirement of automatic optical character recognition (OCR) equipment.

2 Scope

2.1 This specification defines the geometric and spatial limits of the alphanumeric code, specifically for nominally round, flatted gallium arsenide wafers. It also defines the basic code used to characterize the individual wafer, thereby providing practical operator interpretation. This document does NOT address the marking techniques that may be employed when complying with this standard nor does it address any health issues associated with those techniques.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI AUX1 — List of Vendor Identification Codes

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers - Appendix 1, SEMI OCR Standard Character Set

4 Terminology

4.1 *adjacent character misalignment* — the vertical distance, *r*, between the character baselines of two adjacent characters on the same line (see Figure 6).

4.2 *line character misalignment* — the vertical distance, *R*, between the character baselines of any two characters on the same line (see Figure 7).

4.3 *character separation* — the horizontal distance between the adjacent boundaries of any characters (see Figure 1).

4.4 *character spacing* — the horizontal distance between the character spacing reference lines of the adjacent characters (see Figure 1).

4.5 *front surface of the wafer* — the surface upon which active semiconductor devices have been, or will be, fabricated.

NOTE 1: This can be either the V-Groove or Dovetail side of the GaAs wafer.

4.6 *code field (also known as character window)* — the rectangular window within which all characters must be contained (see Figure 4).

4.7 *character skew* — the angle between the character baseline and a line parallel with the bottom of the character window (see Figure 5).

4.8 *character height* — the vertical distance between the lowest and the highest centerpoints of a character.

4.9 *character width* — the horizontal distance between the most left and the most right centerpoint of a character.

5 Shape and Size of Marking

5.1 Dot matrix method shall be used to write characters. The minimum matrix shall be 5 dots horizontal and 9 dots vertical as shown in Figure 1. More dots may be used.

NOTE 2: The 5 × 9 dot matrix shown in Figure 1 is the minimum number of dots allowed. More dots may be used, up to and including a solid line. A solid line is not recommended, since it may increase wafer breakage.

5.2 *Character Dimensions and Spacing* — See Table 1, Table 2, and Figure 1.

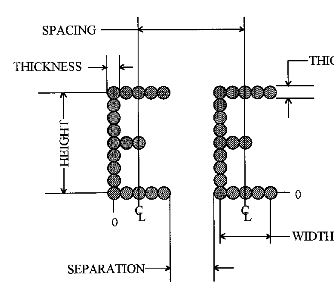


Figure 1

Character Outline

Table 1 Character Dimensions and Spacing — Configuration A — 3”, 100 mm, 125 mm, 150 mm

Character	*(mm)*
Height	1.624 ± 0.025
Width	0.812 ± 0.025
Thickness	0.200 + 0.050 – 0.150
Spacing	1.420 ± 0.025
Minimum Separation	0.400

Table 2 Configuration B — 2”, Option for 3” Wafers

Character	*(mm)*
Height	0.812 ± 0.025
Width	0.406 ± 0.025
Thickness	0.100 ± 0.050
Spacing	0.710 ± 0.025
Minimum Separation	0.104

NOTE 3: The thickness of the diagonal in the letter "N" is 0.138 ± 0.05 mm for single density dot matrix.

5.3 *SEMI OCR Standard Character Set* — See Figure 2 and Appendix 1.

Figure 2

Standard Character Set

6 Alphanumeric Code

6.1 *Code* — Limited to one line of 20 characters maximum (see Figure 3 and Table 3 for an example using 15 characters). The first five to ten characters are an identification number which is unique to the ingot for a given supplier. This is followed by a dash, which is followed by three digits which indicate the wafer number, as numbered starting from the seed end of the ingot. The next two alpha characters identify the vendor according to SEMI AUX1. The last optional characters are specified by the vendor or customer. For example, these characters could be used to differentiate specifications, orientation, or doping. The character string (using a five character ingot as example) is constructed as follows:

Table 3 Vendor identification code

Character #	*Character Style*	*Parameter*	*Definition*
1 - 5	Alphanumeric	Ingot number	Supplier-assigned
6	Alpha	dash	a spacer
7 - 9	Numeric	Wafer number	Number of wafer in ingot
10 - 11	Alpha only	Vendor Identification Code	See SEMI AUX1
12 - 15	Alphanumeric	Optional: characters to identify specification(s)	Supplier- or customer-specified

6.2 If the optional special code characters are used to indicate doping, surface orientation, the symbols shown in Table 4 will be employed.

Table 4 Special Code Characters

Parameter	*Code*	*Definition*
Device surface orientationand flat location	V	V - Groove
	D	Dovetail
Dopant	U	Undoped
	C	Carbon
	R	Chromium
	T	Tellurium
	I	Indium
	S	Silicon
	L	Sulfur
	Z	Zinc
	E	Selenium
Front Surface Orientation	0	100
	A, B	111 A or B
	2	100 (2°off)
	3	100 (other off orientation)
	4	other orientation
	5	other flats

6.3 An example of the code is given in Figure 3.

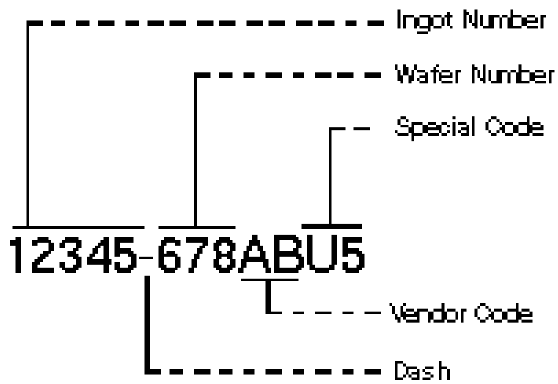


Figure 3

Example of Code for 3" Wafer

7 Code Field Location

7.1 Code field shall be located on the polished front surface of wafers or on the polished or etched back surface of wafers as shown in Table 5.

7.2 Code field is located as shown in Figure 4 and Table 6.

7.3 All characters must be contained within the code field along the major flat. The top of the characters is toward the side of the code field nearest the flat, see Figure 4.

7.4 *Dimensions* — See Figure 4 and Table 6.

7.5 In the standard specification, the first character of the code line is located toward the left side of the code field.

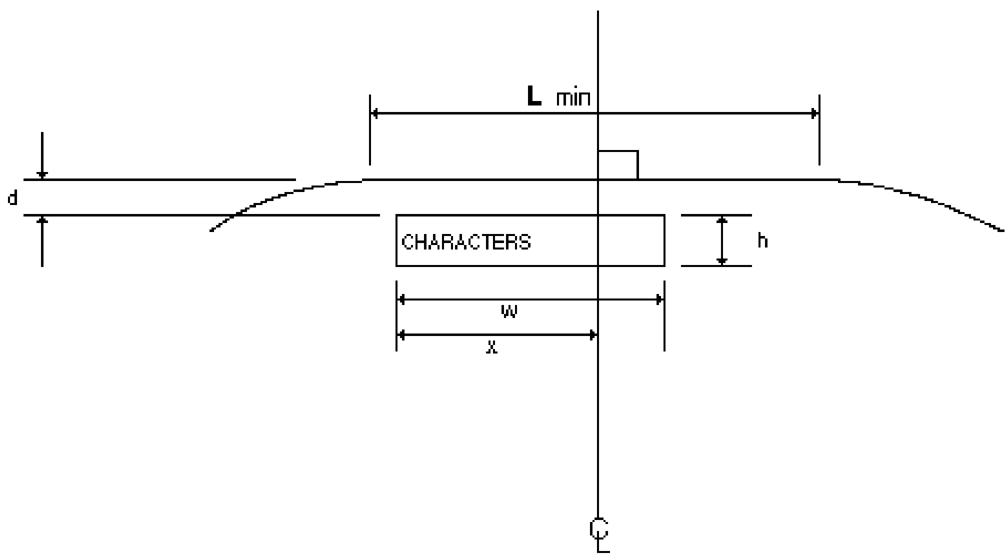


Figure 4

Code Field Location for Flatted Wafers

Table 5 Location of Code Field

Wafer Diameter	*Location of Code Field*
2"	Front (standard); Back surface (alternate)
3"	Front (standard); Back surface (alternate)
100 mm	Front surface
125 mm	Front surface
150 mm	Front surface

Table 6 Code Field Location and Dimensions

Parameter (mm)	*2″*	*3″*	*3″*	*100 mm*	*125 mm*	*150 mm*
Configuration Character Dimension(See Tables 1 and 2)	*B*	*B*	*A**	*A*	*A*	*A*
L min	14.23	19.05	19.05	30.0	40.0	55.0
x	7.1	9.5	9.5	15.0	20.0	27.5
w	14.0	14.0	19.0	27.0	27.0	27.0
d	1.0	1.0	1.0	1.0	1.0	1.0
h	1.4	1.4	2.4	2.4	2.4	2.4

* For 3" wafers, only 13 characters are allowed due to limitations on the size of the code field.

8 Character Alignment

8.1 *Character Skew* — 3 degrees maximum allowable (see Figure 5).

8.2 Maximum character misalignment (see Figures 6 and 7).

8.2.1 Maximum adjacent character misalignment allowable is 0.230 mm.

8.2.2 Maximum line character misalignment allowable is 0.460 mm.

Figure 6

Adjacent Character Misalignment

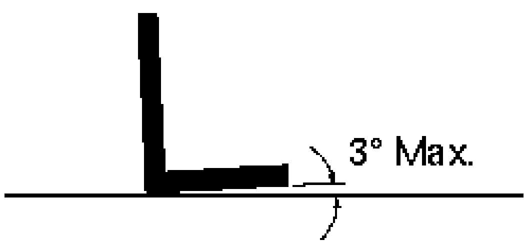


Figure 5

Character Skew

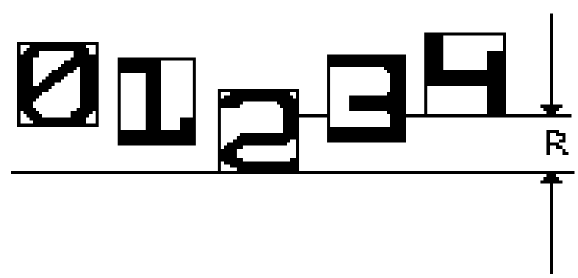
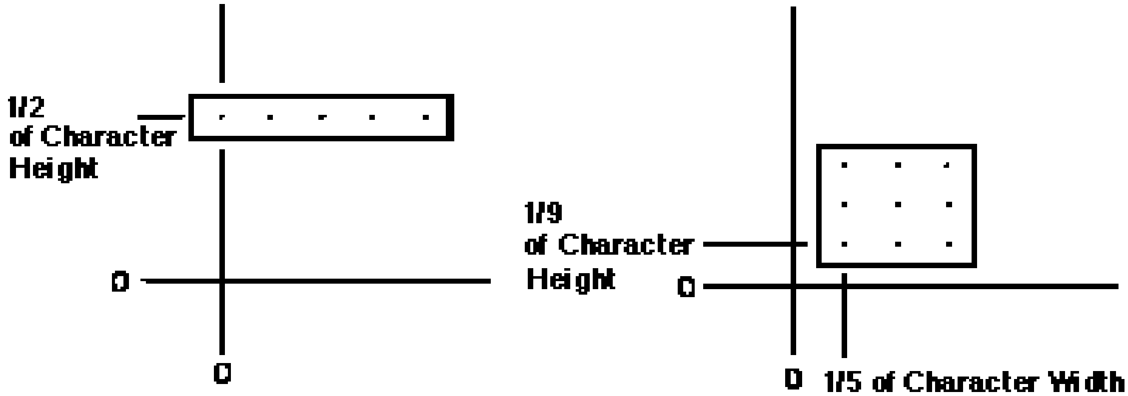
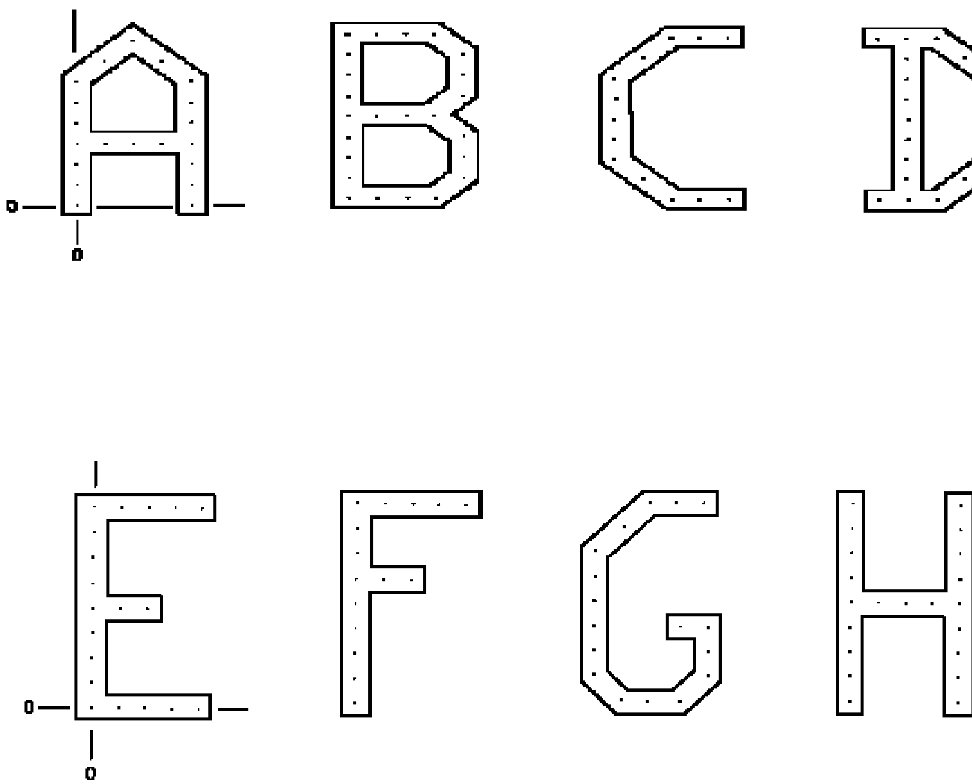


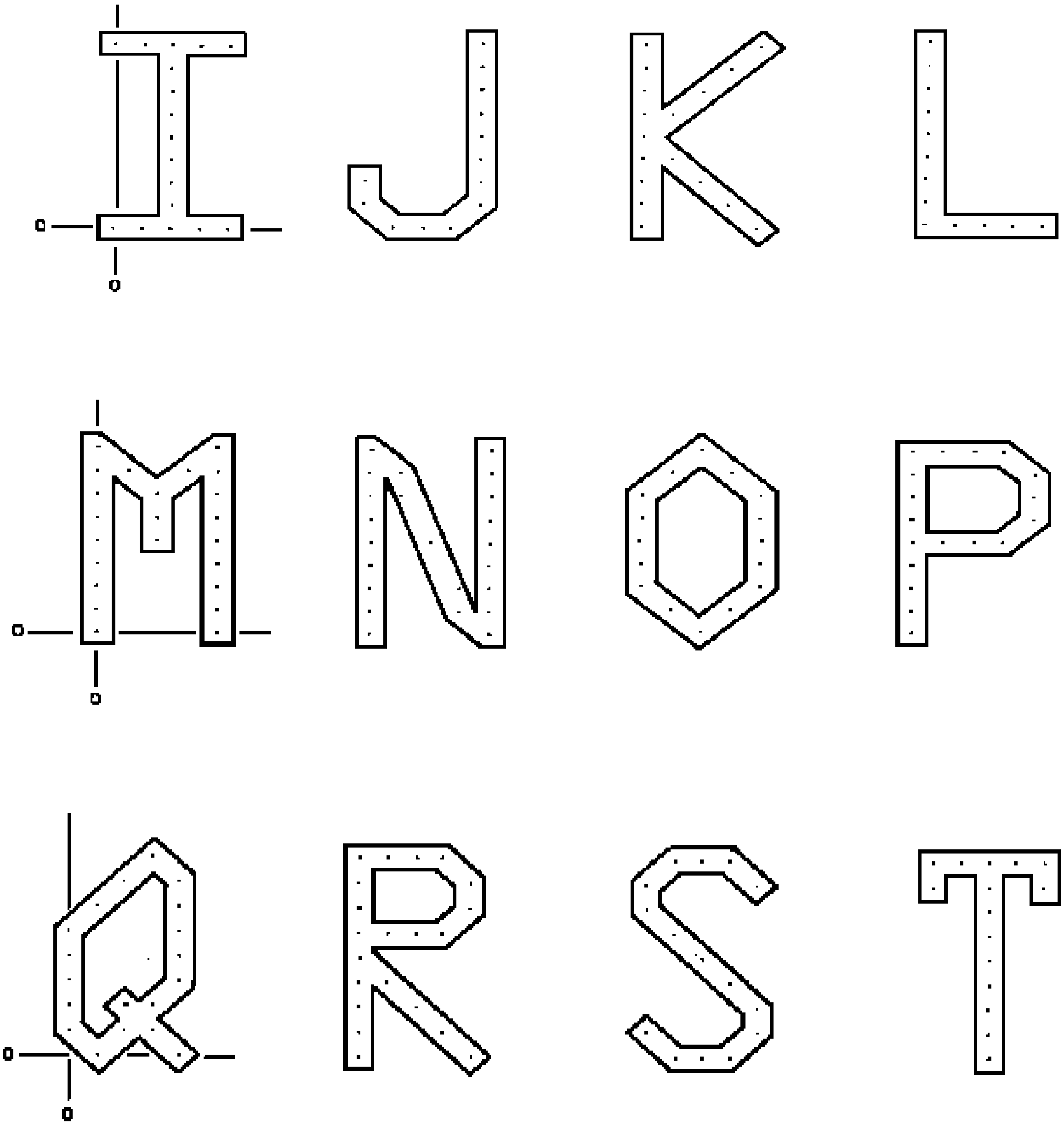
Figure 7

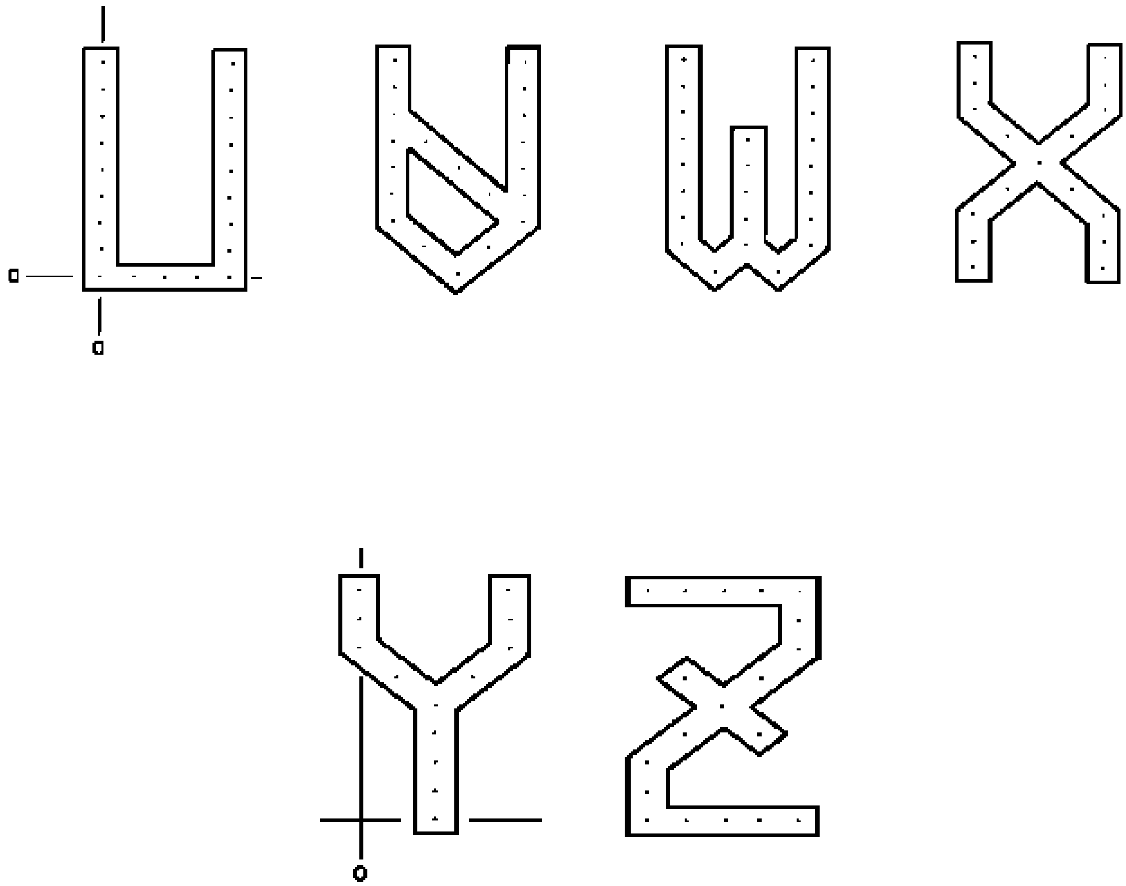
Line Character Misalignment

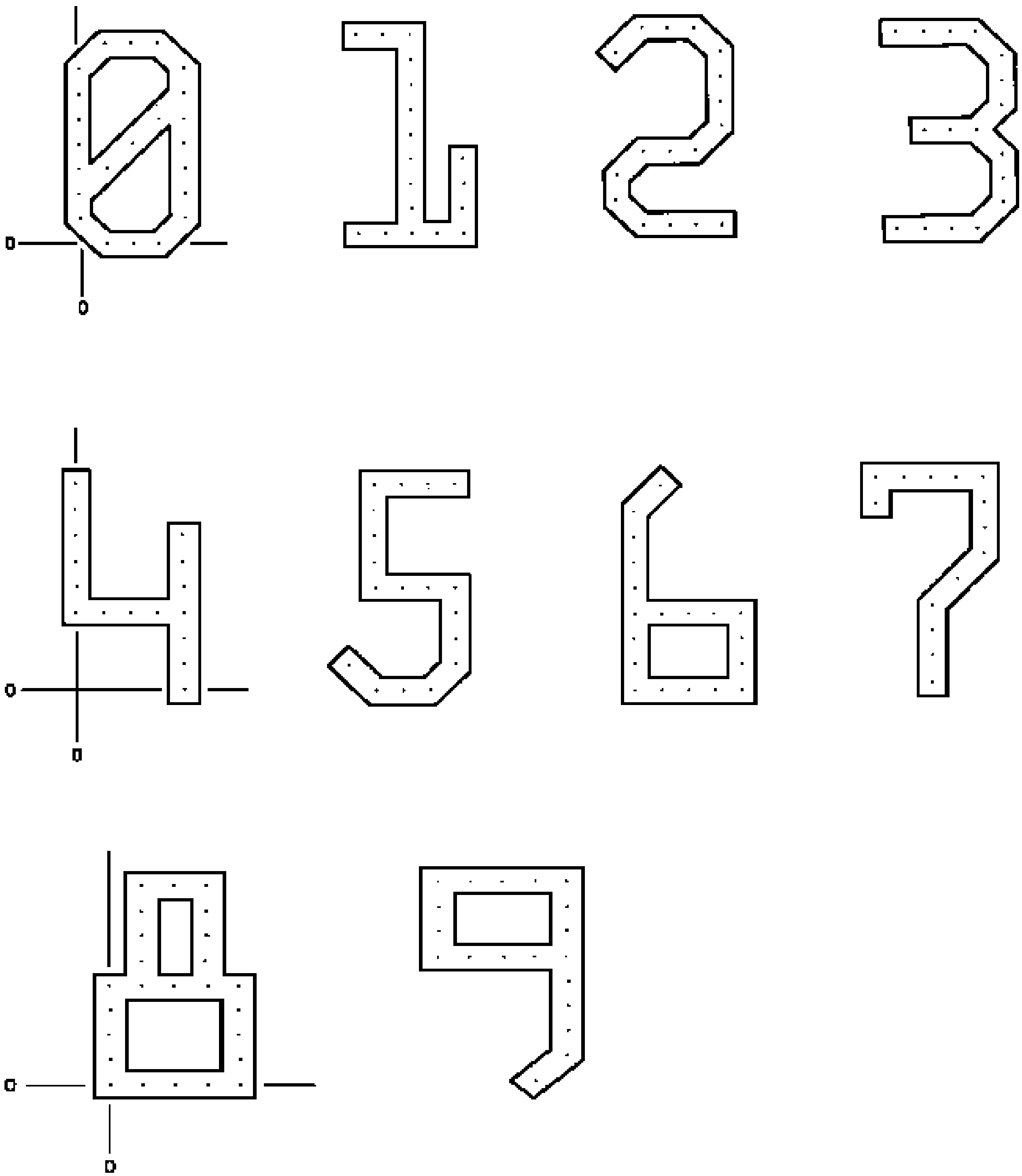
APPENDIX 1
SEMI OCR CHARACTER OUTLINES






I J K L
M N O P
Q R S T
0
0





RELATED INFORMATION 1

NOTE: This related information is not an official part of SEMI T5 and is not intended to modify or supercede the official standard. The standard should be referred to in all cases. SEMI makes no warranties or representations as to the suitability of the material set forth herein for any particular application. The determination of the suitability of the material is solely the responsibility of the user.

R1-1 Considerations for Reliable Automatic Reading of the Marking

R1-1.1 The following suggestions are offered to assist in assuring the most reliable automatic reading of the alphanumeric marking.

R1-1.2 *Character Stroke Thickness* — If a 5 × 9 dot matrix is chosen for marking, it is recommended that the minimum dot size be 0.100 mm. Double or higher density dot matrix is recommended; when used, smaller dot diameters may be employed. Stroke thickness should be constant withing 20% over the entire character set so that the reader settings may be optimized for the specific wafer run.

R1-1.3 *Contrast* — The character should have sufficient contrast to be legible. Contrast may be affected by depth and other conditions.

R1-1.4 *Clear Zone* — It is recommended that the area immediately beneath and a minimum of 0.500 mm around the marking characters be of uniform reflectivity and free of any lithography and process overlay edges.

R1-2 Considerations for the Use of Front Surface Markings

R1-2.1 Marks can impinge upon areas where devices may be printed. Since mask geometries are varied, considerations of the mark area should be made in mask design and also when applying the mark specifications to existing mask designs.

R1-2.2 When the mark is applied prior to epitaxial deposition, a crown or epi may grow along the mark edge. The height of this crown will depend upon the epi thickness and the deposition process.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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SEMI T6-0697[E]

PROCEDURE AND FORMAT FOR REPORTING OF TEST RESULTS BY ELECTRONIC DATA INTERCHANGE (EDI)

This procedure was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on April 30, 1999. Initially available on SEMI OnLine May 1999; to be published June 1999. Originally published in 1997.

[E] This document was modified in April 1999 to reflect the creation of SEMI AUX1 as the source for vendor identification codes. Changes were made to numerous sections.

1 Purpose

1.1 To facilitate the electronic transfer of quality and test data between users and suppliers.

2 Scope

2.1 This document describes a procedure and format using ANSI ASC X12 "*863 Report of Test Results*" for electronic data interchange (EDI). The ANSI standard provides a basic structure and codes for transmitting messages. This is supplemented by SEMI-generated codes to describe product parameters and test methods specific to the semiconductor industry. For a description of the EDI business applications, see Appendices 1 and 2.

2.2 This standard may be used to report test results for all products used in the semiconductor industry when the applicable codes are included in a SEMI standard. It is intended to provide a consistent method for transmitting test results throughout the industry. Any implementation of this document shall be agreed upon between trading partners.

3 Referenced Documents

3.1 *SEMI Documents*

SEMI AUX1 — List of Vendor Identification Codes

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M18 — Format for Silicon Wafer Specification Form for Order Entry

3.2 *ANSI Documents*[1]

ASC X12 — 863 Report of Test Results, version 003 release 050

ASC X12 — Data Dictionary

[1] *American National Standards Institute, 11 West 42nd Street, New York, NY 10036*

4 Terminology

4.1 *Acronyms*

ANSI — American National Standards Institute

ASC X12 (Accredited Standards Committee X12) — Comprised of industry members for the purpose of creating EDI standards for submission to ANSI for subsequent approval and dissemination.

EDI (Electronic Data Interchange) — The computer-to-computer exchange of information which has traditionally been communicated using paper documents.

4.2 *Definitions*

4.2.1 *certificate of analysis EDI message* — one message containing measurement or statistical data for one shipment, from one supplier site to one user site, of one user part number against one user purchase order shipped. Multiple lot numbers may be included in the shipment. (See Appendix 5.)

4.2.2 *codes* — a recognized set of abbreviations or conventions for representing specific elements of data.

4.2.3 *EDI translation* — the conversion of application data to and from the ASC X12 standard format.

4.2.4 *manufacturing lot* — a generic description for a group of parts that have a relationship as defined by the party establishing the identification (e.g., batch, shipment, production run, qualification/test run, individual product). (See Application Notes.)

4.2.5 *mapping* — the process of identifying the standards data element relationship to application data elements.

4.2.6 *message* — entire data stream including the outer envelope.

4.2.7 *statistical results EDI message* — one message containing measurement or statistical data for defined parameters for a stated period of time (see Appendix 5).

4.2.8 *test results EDI message* — used to designate data provided by special request (e.g., engineering, qualifications). This message contains specific measurement or statistical data for one request, from one trading partner to another trading partner, of one part number against one purchase order. Multiple lot numbers may be included. (See Appendix 5.)

4.2.9 *trading partner* — all members within the channels of distribution within an industry (suppliers, carriers, users, and intermediaries)[2] . This includes buyers and sellers which represent SEMI terms of user and supplier as well.

5 Requirements

5.1 An implementation model shall be agreed upon by trading partners. It is the intent of this document to make interpretation of the models used for transmitting electronic messages more consistent, so that implementations are based upon common practices.

5.1.1 Select one of the report types in Table 1 using the business model (Appendix 1) and the definitions found in Section 4.

Table 1 Report Types

Code	*Type of EDI Message*
CA	Certificate of Analysis
RT	Test Results
SR	Statistical Results

5.1.2 Define data requirements representing the requested measurements and statistics that are recorded for reporting electronically. (See Appendix 2.)

5.1.3 Select codes for parameters, units of measure, and statistical terms. Appendix 4 is a guideline to assist in modeling the EDI message. It uses codes selected from the ANSI Data Dictionary as well as codes created by SEMI for the semiconductor industry.

5.1.4 Data is electronically reformatted from the application where it resides into a format suitable for EDI transmission. This usually requires the use of translation software and the development of application interface programs.

5.2 Thorough piloting, testing, and educating is required for successful implementation.

6 Procedures

6.1 See Appendix 4.

[2] *The term "Trading Partner" is referenced from the Global Electronics Guidelines (DRAFT) for Bar Code & 2D Symbol Marking of Products and Packages in Conjunction with EDI.*

7 Application Notes

7.1 Pending ANSI approval, SEMI is an authorized agency to maintain the tables of codes.

7.2 The material contained in Appendix 4 was created by using an EDI simulator referencing the ASC X12 "*863 Report of Test Reports*", version 003 release 050.

7.3 In using Appendix 4, refer to the column "SEMI Use" (far-left) to determine if data element usage is mandatory, conditional, or optional. SEMI mandatory elements include all ASC X12 863 mandatory elements, as well as selected other elements that are optional or conditional within ASC X12 863.

7.4 In Appendix 5, the example messages in this appendix were simplified by showing only a portion of what they can do. In practice, all of the transaction types (CA, RT, and SR) can use any combination of the statistical codes in Appendix 4, the new statistical codes in Appendix 4, or raw measurement data.

7.5 Additional statistical codes are defined in Appendix 3. These codes are pending ANSI approval.

7.6 This procedure will accommodate date/time considerations for the turn of the century. There are many options found in the data transmission segments in this document. The end result for which option is utilized will be agreed upon by the trading partners. The message is itself part of the ANSI standard, and any revisions to this standard will be incorporated.

7.6.1 In the data element type, DT is a standard ANSI definition and is being addressed by ASC X12 Committee.

7.6.2 In the BTR segment, used to identify the date of the actual transmission, BTR06 may be used as a century reference number.

7.6.3 In the DTM segments, used to identify the date for the actual data, the DTM05 data element of CC represents a two-digit century code (e.g., 19 for 1999, 20 for 2000).

7.7 Multiple levels of lot definitions (i.e., Lots and Sub-lots) may be handled through nesting within the LIN loop.

8 Listing of Appendices

8.1 *Appendix 1* — EDI Business Model

8.2 *Appendix 2* — EDI Transmission Flowchart

8.3 *Appendix 3* — New EDI Statistics (Definitions)

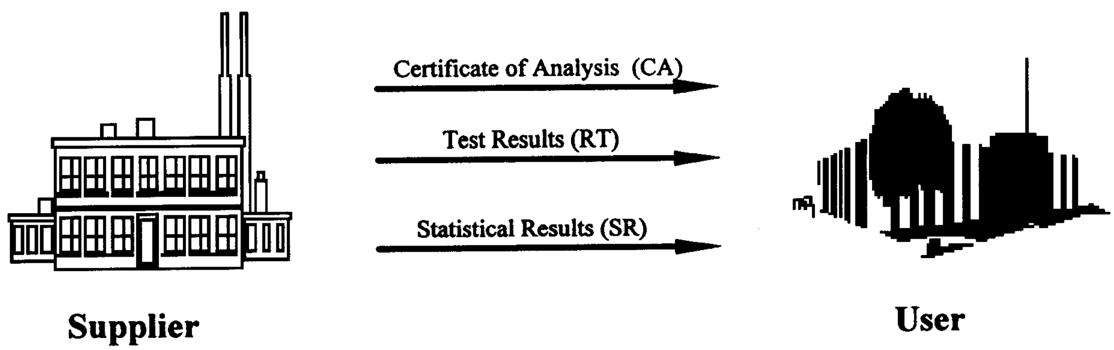
8.4 *Appendix 4* — EDI Transmission Components (863 Report of Test Results)

8.5 *Appendix 5* — Examples of EDI Transmissions

APPENDIX 1
EDI BUSINESS MODEL

NOTE: The material in this appendix is an official part of SEMI T6 and was approved by full letter ballot procedure in March 1997.

A1-1 Any implementation model is agreed upon by trading partners. It is the intent of this document to make interpretation of the models used for transmitting electronic messages more consistent, so that implementations are based upon common practices.



A1-2 Attributes of EDI Messages

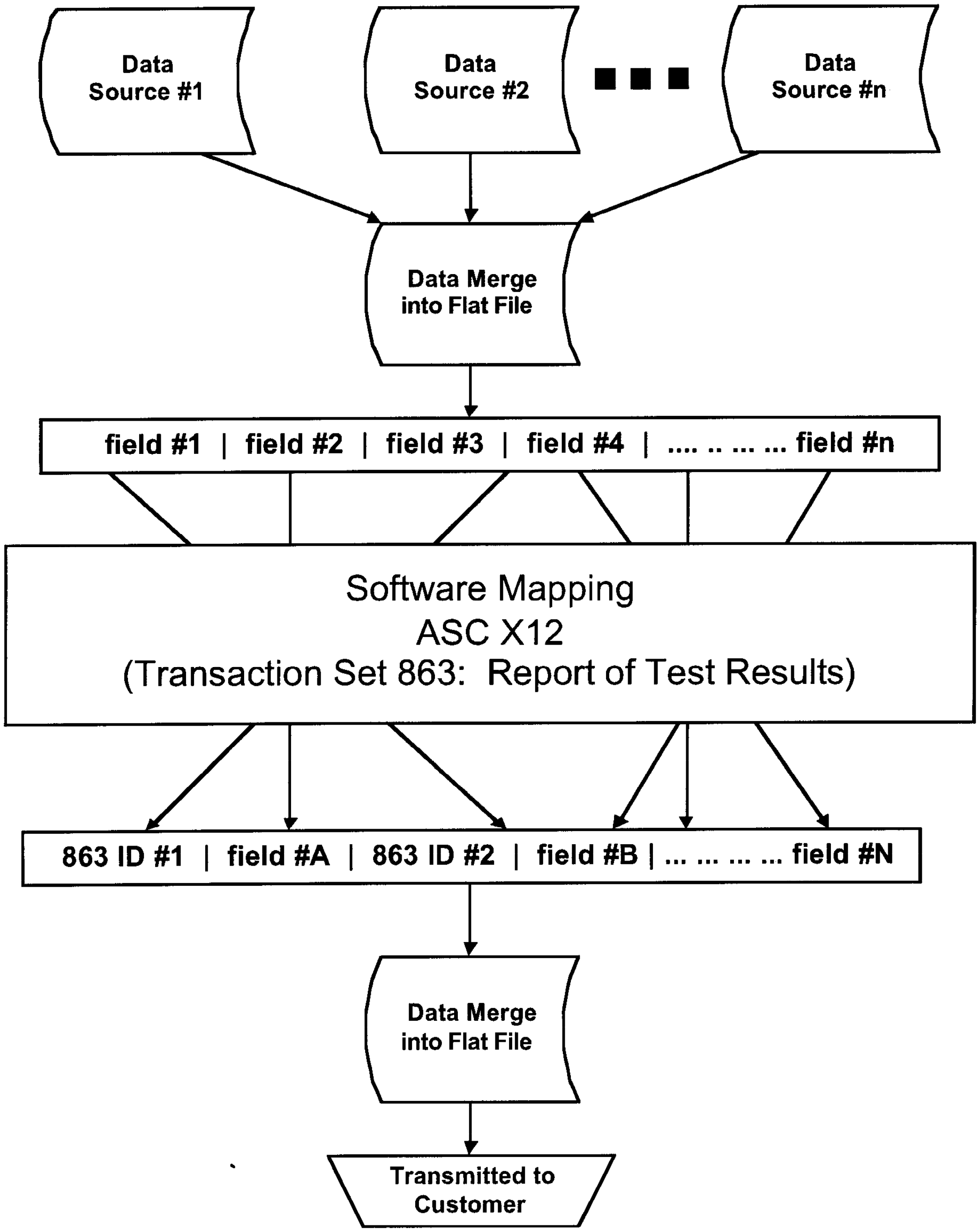
A1-2.1 *Certificate of Analysis (CA)* — One message containing measurement or statistical data for one shipment, from one supplier site to one user site, of one user part number against one user purchase order shipped. Multiple lot numbers may be included in the shipment.

A1-2.2 *Test Results (RT)* — Used to designate data provided by special request (e.g., engineering, qualifications). This message contains specific measurement or statistical data for one request, from one trading partner to another trading partner, of one part number against one purchase order. Multiple lot numbers may be included.

A1-2.3 *Statistical Results (SR)* — One message containing measurement or statistical data for defined parameters for a period of time from one trading partner to another.

APPENDIX 2
EDI TRANSMISSION FLOWCHART

NOTE: The material in this appendix is an official part of SEMI T6 and was approved by full letter ballot procedure in March 1997.



APPENDIX 3
NEW EDI STATISTICS (DEFINITIONS)

NOTE: The material in this appendix is an official part of SEMI T6 and was approved by full letter ballot procedure in March 1997.

A3-1 Additions to ANSI's Statistical Codes to be Included within this Standard

A3-1.1 These new statistical codes are added to a predefined ANSI list of summary statistics found in Appendix 3 under the transaction segment STA. The codes are HS, HW, HC, GM, GS, PK, EC, OC, and PE and are submitted to ANSI for approval. The codes can be used in an EDI message as long as the trading partners agree to include them as part of their transmissions. Once the codes are approved, the ASC X12 convention will be updated to automatically accept these codes as standards.

A3-1.2 *Histogram Information*

A3-1.2.1 **HS** = Histogram Start (Left side of first class or bar)

A3-1.2.2 **HW** = Histogram Class Width (Width of class or bar)

A3-1.2.3 **HC** = Histogram Class Count (Count of classes or bars)

A3-1.3 *Process Capability Information*

A3-1.3.1 **GM = Geometric Mean (GMEAN).** For the lognormal distribution, it's calculated as:

TMEAN = The mean of the natural log of the raw data values

GMEAN = EXP(TMEAN+ (TSIGMA**2)/2)

A3-1.3.2 **GS = Geometric Sigma (GSIGMA).** For the lognormal distribution, it's calculated as:

TSIGMA = The sigma of the natural log of the raw data values

GSIGMA = SQRT((EXP((2*TMEAN)+(TSIGMA**2)))**EXP((TSIGMA**2))-1))

A3-1.3.3 **PK** = The **peak** of the fitted probability distribution function. It's calculated as the maximum Y value of the probability distribution function after it is fitted to the process histogram.

A3-1.3.4 **EC** = The **equivalent normal Cpk (ECPK).** For the lognormal distribution, it's calculated as:

ECPK = ((LN(USL))-LN((GMEAN**2/(SQRT(GMEAN**2+GSIGMA**2))))/ (3*SQRT(LN (GMEAN**2)/ GMEAN**2)))

A3-1.4 *Outlier Information*

A3-1.4.1 **OC = Outlier Count.** It may be calculated as A minus B, where A = the count beyond a chosen sigma point using the histogram, and B = the count beyond the chosen sigma point using the statistical distribution.

A3-1.5 *Percentile Information*

A3-1.5.1 **PE = Percentile.** Like the HG, it can be repeated to give different elements. The user and supplier need to agree on the order for a particular application.

APPENDIX 4
EDI TRANSMISSION COMPONENTS (863 REPORT OF TEST RESULTS)

NOTE: The material in this appendix is an official part of SEMI T6 and was approved by full letter ballot procedure in March 1997.

A4-1 Introduction

A4-1.1 The purpose of this section is to provide the necessary information to enable trading partners to use the ASC X12 standards for the exchange of electronic business documents within the electronics industry.

A4-1.2 The transmission, in the ASC X12 format, is comprised of an outer envelope (transmission envelope) which identifies the sender and receiver. Within the transmission envelope are one or more functional groups.

A4-1.3 The functional groups are analogous to batches of like documents (i.e., certificate of analysis, test results, statistical results). Each functional group contains one or more transaction sets (electronic documents). Each transaction set is an ordered collection of segments. Each segment is an ordered collection of data elements.

A4-1.4 Each segment has been assigned a two or three charac-ter identifier.

A4-1.5 This identifier marks the beginning of each segment. Each element within the segment is separated by a data element separator character. Electronic Industry Data Exchange (EIDX) recommends the use of the asterisk (*) character as a data element separator. A segment terminator character is used to mark the end of a segment.

A4-2 Format

A4-2.1 The ASC X12 segment hierarchy lists all segments, in order, available from the ASC X12 standard. The segment ID's that are shaded indicate the segments utilized by EIDX. Following the ASC X12 segment hierarchy is a detailed description of each segment in the order that they appear in the transaction set.

A4-2.2 Each segment is listed with the segment ID and name, level (header, detail, or summary), loop (if the segment is contained within a loop), loop repeat (for the first segment in the loop), requirement within the transaction set, maximum use, purpose (as defined by ASC X12), ASC X12 syntax notes, ASC X12 comments for segment usage, and notes that explain the EDIX convention for this segment within the transaction set. It is important to note all shaded text is either an EDIX convention or EDIX terminology. Shaded coded lists refer to recommendations culled from the entire ASC X12 data element code list. The unshaded areas contain definitions and comments from the ASC X12 standard.

A4-2.3 The data element summary lists each data element, in order, for the segment; for each data element there is one line to identify reference designator, data element number, data element name, and attributes.

A4-2.4 Below the one line summary are usage notes and ac-tual values identified for use.

A4-2.5 *Reference Designator* — This is the segment identifier with the data element sequence number within the segment.

A4-2.6 *Data Element Number* — This is the number assigned to the data element by ASC X12. This number may be used for direct refer-ence into the ASC X12 Data Dictionary.

A4-2.7 *Data Element Name* — This is the name assigned to the data element by ASC X12, in the ASC X12 Data Dictionary.

A4-2.8 *Attributes* — Each data element has three ANSI attributes: element usage, element type, and Minimum/Maximum length.

A4-2.9 *Element Usage*

M Mandatory Designer

This is the segment identifier with the data element sequence number within the segment.

O Optional

The data element may be used if the segment is used.

X Conditional

The data element may be used only if other elements are used within the segment.

The particular condition/relation will be stated in the Data Element Summary for the segment when used.

A4-2.10 *Element Type*

ID Identifier

Values for the identifier-type data elements are taken from a predefined list in the ASC X12 data element dictionary.

AN String

Values for the string-type data elements are a sequence of any printable characters.

DT Date

Values for a date-type data element are in the format YYMMDD.

TM Time

Values for a time-type data element are in the format HHMM expressed in a 24-hour clock.

Nx Numeric

Values for a numeric data element are in an implied decimal format, where "X" indicates the number of places to the right of the decimal point.

i.e.,

N0 is a whole number (999.)

N2 is 999.99

R Decimal

This is a numeric field in character format, with a decimal point included. It is treated as alpha/numeric. The decimal point is not sent for whole numbers.

e.g.,

to send the number 0128.734, the field would contain "128.734".

to send the number 0789.00, the field would contain "789".

A4-2.11 *Minimum/Maximum*

This is the minimum and maximum length the field can be.

e.g.,

02/02 - fixed length of 2 characters.

04/09 - Minimum length of 4 characters and maximum length of 9 characters.

863 Report of Test Results - Overview

Heading: This section of information appears one time at the beginning of each transaction. The information is targeted at the indentification of "Who is sending What to Whom, Where, and When."

SEMI USE:	*Pos. No.*	*Seg. ID*	*Name*	*Req. Des.*	*Max. Use*	*Loop Repeat*
M	010	ST	Transaction Set Header	M	1	
M	020	BTR	Beginning Segment for Test Results	M	1	
X	040	REF	Reference Numbers (Order & Material Ident.)	O	12	
O	060	PID	Product/Item Description (Commodity ID)	O	200	
			LOOP ID- NI			>1
M	080	N1	Name (Buyer & Seller Company)	O	1	
O	090	N2	Additional Name Information	O	2	
O	100	N3	Address Information	O	2	
O	110	N4	Geographic Location (Buyer & Seller Site)	O	1	
			LOOP ID - PER			>1
O	130	PER	Administrative Communications Contact	O	1	

Detail: This section of information appears as often as necessary during the transaction. The information deals directly with the data specific to the product or process of the supplier.

SEMI USE:	*Pos. No.*	*Seg. ID*	*Name*	*Req. Des.*	*Max. Use*	*Loop Repeat*
			LOOP ID - LIN			>1
M	010	LIN	Item Identification (Primary Data Loop)	O	1	
O	034	QTY	Quantity	O	10	
X	040	DTM	Date/Time Reference	O	10	
			LOOP ID - CID			>1
M	060	CID	Characteristic/Class ID	O	1	
O	100	SPS	Sampling Parameters for Summary Statistics	O	>1	
O	120	DTM	Date/Time Reference	O	10	
			LOOP ID - MEA			>1
X	150	MEA	Measurements	O	1	
O	170	REF	Reference Numbers	O	10	
			LOOP ID - STA			>1
X	180	STA	Statistics	O	1	
O	195	REF	Reference Numbers	O	10	
			LOOP ID - TSP			>1
M	210	TSP	Test Period or Interval	O	1	
			LOOP ID - LM			>1
M	242	LM	Code Source Information	O	1	
M	244	LQ	Industry Code	M	>1	

Summary: Transmission segments to mark the end of the transaction set.

SEMI USE:	*Pos. No.*	*Seg. ID*	*Name*	*Req. Des.*	*Max. Use*	*Loop Repeat*
O	005	CTT	Transaction Totals	O	1	
M	010	SE	Transaction Set Trailer	M	1	

Transmission Segments and Data Elements:

Segment:	**ST Transaction Set Header**
Level:	Heading
Loop:	_______
Usage:	Mandatory
Max Use:	1
Purpose:	To indicate the start of a transaction set and to assign a control number.
Semantic Notes:	**1** The transaction set identifier (ST01) used by the translation routines of the interchange partners to select the appropriate transaction set definition (e.g., 810 selects the invoice transaction set).

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**ST01**	**143**	**Transaction Set Identifier Code**	**M**	**ID**	**3/3**
			Code uniquely identifying a Transaction Set.			
			863 X12.41 Report of Test Results			
M	**ST02**	**329**	**Transaction Set Control Number**	**M**	**AN**	**4/9**
			Identifying control number that must be unique within the transaction set functional group assigned by the originator for a transaction set.			

Segment: **BTR Beginning Segment for Test Results**
Level: Heading
Loop: _______
Usage: Mandatory
Max Use: 1
Purpose: To indicate the beginning of a test results transaction set.
Semantic Notes:

1 If BTR01 equals 01, 02, 03, 04, 05, 18, or 19, then BTR06 is required to identify the original test report reference number transmitted.

2 BTR02 is the date that this transaction set was created by the sending party.

3 BTR03 is the time that this transaction set was created by the sending party.

4 BTR05 specifies test results report reference number created by the sending party.

Comments: This segment is used to identify date and purpose of the data transmission.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**BTR01**	**353**	**Transaction Set Purpose Code**	**M**	**ID**	**2/2**
			Code identifying purpose of transaction set.			
			00 Original			
			18 Reissue			
M	**BTR02**	**373**	**Date**	**M**	**DT**	**6/6**
			Date (YYMMDD).			
			Seller generated date representing the data collection date or other mutually agreeable date. Not associated with the lot/date code of the material.			
O	**BTR03**	**337**	**Time**	**O**	**TM**	**4/8**
			Time expressed in 24-hour clock time as follows: HHMM or HHMMSS, or HHMMSSD or HHMMSSDD, where H = hours (00-23), M = minutes (00-59), S = integer seconds (00-59) and DD = decimal seconds are expressed as follows: D = tenths (0-9) and DD = hundredths (00-99).			
			Seller generated time representing the data collection time or other mutually agreeable time. Not associated with the lot/date code of the material.			
M	**BTR04**	**755**	**Report Type Code**	**O**	**ID**	**2/2**
			Code indicating the title or contents of a document, report, or supporting item.			
			CA Certificate of Analysis			
			RT Report of Tests and Analysis Report			
			SR Statistical Report			
X	**BTR05**	**127**	**Reference Number**	**O**	**AN**	**1/30**
			Reference number or identification number as defined for a particular Transaction Set, or as specified by the Reference Number Qualifier.			
			Seller's unique shipment identification code visible on the shipping container and/or shipping paperwork that identifies the link to the data in a single Transaction Set. (Examples: Invoice No., Shipper No., Work Order No., etc.)NOTE: In the case of a re-transmittal (Purpose Code 18, reissue) of previous data due to correction or loss of data, this data element repeats the information from the prior transmission to be replaced.			
O	**BRT06**	**127**	**Reference Number**	**O**	**AN**	**1/30**
			Reference number of identification number as defined for a particular Transaction Set, or as specified by the Reference Number Qualifier.			

Segment: **REF Reference Numbers (Order & Material Ident.)**
Level: Heading
Loop: _______
Usage: Optional
Max Use: 12
Purpose: To specify identifying numbers.
Syntax Notes: **1** At least one of REF02 or REF03 is required.
Comments:
1 It is recommended for use and for report types CA and RT.
2 BTR03 is the time that this transaction set was created by the sending party.
3 It is not repeated once for each REF01 Qualifier determined by mutual consent between the Buyer and Seller as required.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**REF01**	**128**	**Reference Number Qualifier**	**M**	**ID**	**2/2**
			Code qualifying the Reference Number.			
			BV Purchase Order Line Item Identifier *(Buyer)*			
			MF Manufacturer's Part Number *(Seller)*			
			PM Part Number *(Buyer)*			
			PO Purchase Order Number *(Buyer)*			
			PP Purchase Order Revision Number *(Buyer)*			
			RE Release Number *(Buyer)*			
			S3 Specification Number *(Buyer)*			
			SZ Specification Revision *(Buyer)*			
			YB Revision Number *(Buyer)*			
			ZZ Mutually Defined			
X	**REF02**	**127**	**Reference Number**	**X**	**AN**	**1/30**
			Reference number or identification number as defined for a particular Transaction Set, or as specified by the Reference Number Qualifier.			
O	**REF03**	**352**	**Description**	**X**	**AN**	**1/80**
			A free-form description to clarify the related data elements and their content.			

Segment: **PID** **Product/Item Description (Commodity ID)**

Level: Heading

Loop: _______

Usage: Optional

Max Use: 200

Purpose: To describe a product or process in coded or free-form format.

Syntax Notes:

1 If PID04 is present, then PID03 is required.

2 At least one of PID04 or PID05 is required.

3 If PID07 is present, then PID03 is required.

Semantic Notes:

1 Use PID03 to indicate the organization that publishes the code list being referred to.

2 PID04 should be used for industry-specific product description codes.

Comments:

1 If PID01 = "F", then PID05 is used. If PID01 = "S", then PID04 is used. If PID01 = "X", then both PID04 and PID05 are used.

2 PID07 specifies the individual code list of the agency specified in PID03.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*		
M	**PID01**	**349**	**Item Description Type**		**M**	**ID**	**1/1**
			Code indicating the format of a description.				
			F	Free-form			
				Not recommended. To be used prior to adoption of SEMI codes into X.12.41 Standards.			
			S	Structured (From Industry Code List)			
				Preferred use. The PID03 and PID04 codes shall be registered with the appropriate organization.			
			X	Semi-structured (Code and Text)			
				Not recommended.			
M	**PID03**	**559**	**Agency Qualifier Code**		**X**	**ID**	**2/2**
			Code identifying the agency assigning the code values.				
			SM	Semiconductor Equipment and Materials International			
				SEMI EDI Task Force shall register this code with ANSI.			
			ZZ	Mutually Defined			
				To be used prior to adoption of SEMI codes into X.12.41 Std.			
M	**PID04**	**751**	**Product Description Code**		**X**	**AN**	**1/12**
			A code from an industry code list which provides specific data about a product characteristic.				
			For silicon wafers see SEMI Standard M18. Codes for other semiconductor products can be used as they are documented.				
O	**PID05**	**352**	**Description**		**X**	**AN**	**1/80**
			A free-form description to clarify the related data elements and their content.				
O	**PID07**	**822**	**Source Subqualifier**		**O**	**AN**	**1/15**
			A reference that indicates the table or text maintained by the Source Qualifier.				
			Identifies the SEMI Standard and applicable Table or Figure reference that defines the meaning of the codes used in PID04.				

Segment:	**N1 Name (Buyer & Seller Company Ident.)**
Level:	Heading
Loop:	N1
Usage:	Optional
Max Use:	1
Purpose:	To identify a party by type of organization, name, and code.
Syntax Notes:	**1** At least one of N102 or N103 is required.
	2 If either N103 or N104 is present, then the other is required.
Comments:	This N1 loop requires a minimum of two passes, one for Buyer (receiver) identification, and one for Seller (submitter) identification.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*	
M	**N101**	**98**	**Entity Identifier Code**	**M**	**ID**	**2/2**
			Code identifying an organizational entity, a physical location, or an individual.			
			1X Laboratory			
			28 Subcontractor			
			BY Buying Party (Purchaser)			
			PT Party to Receive Test Report [Buyer to the attention of]			
			SE Selling Party			
			YE Third Party			
X	**N102**	**93**	**Name**	**X**	**AN**	**1/35**
			Free-form name.			
			Use of N103 and N104 in lieu of this Element is recommended.			
X	**N103**	**66**	**Identification Code Qualifier**	**X**	**ID**	**1/2**
			Code designating the system/method of code structure used for Identification Code (67).			
			Preferred use is N103/N104 combination.			
			SM SEMI			
			ZZ Mutually Defined			
X	**N104**	**67**	**Identification Code**	**X**	**AN**	**2/20**
			Code identifying a party or other code.			
			Code from SEMI Standards Buyer/Seller code list (SEMI AUX1).			

Segment: **N2 Additional Name Information**
Level: Heading
Loop: N1
Usage: Optional
Max Use: 2
Purpose: To specify additional names or those longer than 35 characters in length.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**N201**	**93**	**Name** Free-form name.	**M**	**AN**	**1/35**
O	**N202**	**93**	**Name** Free-form name.	**O**	**AN**	**1/35**

Segment: **N3 Address Information**
Level: Heading
Loop: N1
Usage: Optional
Max Use: 2
Purpose: To specify the location of the named party.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**N301**	**166**	**Address Information** Address information	**M**	**AN**	**1/35**
O	**N302**	**166**	**Address Information** Address information	**O**	**AN**	**1/35**

Segment: N4 **Geographic Location (Buyer & Seller Site Ident.)**
Level: Heading
Loop: N1
Usage: Optional
Max Use: 1
Purpose: To specify the geographic place of the named party.
Syntax Notes: **1** If N406 is present, then N405 is required.
Comments: **1** A combination of either N401 through N404 or (N405 and N406) may be adequate to specify a location.
2 N402 is required only if city name (N401) is in the USA or Canada.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
O	**N401**	**19**	**City Name**	**O**	**AN**	**2/30**
			Free-form text for city name.			
O	**N402**	**156**	**State or Province Code**	**O**	**ID**	**2/2**
			Code (Standard State/Province) as defined by appropriate government agency.			
O	**N403**	**116**	**Postal Code**	**O**	**ID**	**3/11**
			Code defining international postal zone code excluding punctuation and blanks (zip code for United States).			
O	**N404**	**26**	**Country Code**	**O**	**ID**	**2/3**
			Code identifying the country.			
X	**N405**	**309**	**Location Qualifier**	**X**	**ID**	**1/2**
			Code identifying type of location.			
			Preferred use if N405/406 combination.Additional codes are available for selection.			
			FA Factory			
O	**N406**	**310**	**Location Identifier**	**O**	**AN**	**1/30**
			Code which identifies a specific location.			
			Mutually defined identification strings shall be determined by trading partners and shall remain constant.			

Segment:	**PER Administrative Communications Contact**
Level:	Heading
Loop:	PER
Usage:	Optional
Max Use:	1
Purpose:	To identify a person or office to whom administrative communications should be directed.
Syntax Notes:	**1** If either PER03 or PER04 is present, then the other is required.
	2 If either PER05 or PER06 is present, then the other is required.
	3 If either PER07 or PER08 is present, then the other is required.
Comments:	Used to notify of change in EDI contact information at Seller, or to specify special attention name at Buyer, as required. Infrequent use anticipated.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**PER01**	**366**	**Contact Function Code**	**M**	**ID**	**2/2**
			Code identifying the major duty or responsibility of the person or group named.			
			DC Delivery Contact			
			[A Buyer attention flag.]			
			EA EDI Coordinator			
			[Seller's EDI primary contact information.]			
			EG Engineering			
			[A Buyer attention flag.]			
			QA Quality Assurance Contact			
			[A Buyer attention flag.]			
			SU Supplier Contact			
			[A Seller attention flag.]			
O	**PER02**	**93**	**Name**	**O**	**AN**	**1/35**
			Free-form name.			
X	**PER03**	**365**	**Communication Number Qualifier**	**X**	**ID**	**2/2**
			Code identifying the type of communication number.			
X	**PER04**	**364**	**Communication Number**	**X**	**AN**	**1/80**
			Complete communications number including country or area code when applicable.			
X	**PER05**	**365**	**Communication Number Qualifier**	**X**	**ID**	**2/2**
			Code Identifying the type of communication number.			
			Refer to 003050 Data Element Dictionary for acceptable code values.			
X	**PER06**	**364**	**Communication Number**	**X**	**AN**	**1/80**
			Complete communications number including country or area code when applicable.			
X	**PER07**	**365**	**Communication Number Qualifier**	**X**	**ID**	**2/2**
			Code identifying the type of communication number.			
			Refer to 003050 Data Element Dictionary for acceptable code values.			
X	**PER08**	**364**	**Communication Number**	**X**	**AN**	**1/80**
			Complete communications number including country or area code when applicable.			
O	**PER09**	**443**	**Contact Inquiry Reference**	**O**	**AN**	**1/20**
			Additional reference number or description to clarify a contact number.			

Segment: **LIN Item Identification (Primary Data Loop)**
Level: Detail
Loop: LIN
Usage: Optional
Max Use: 1
Purpose: To specify basic item identification data.
Syntax Notes: **1** If either LIN04 or LIN05 is present, then the other is required.
Semantic Notes: **1** LIN01 is the line item identification.
Comments: **1** See the Data Dictionary for a complete list of ID's.
2 LIN02 through LIN31 provide for fifteen (15) different product/service ID's for each item. For example: Case, Color, Drawing No., UPC No., ISBN No., Model No., SKU.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**LIN01**	**350**	**Assigned Identification**	**O**	**AN**	**1/11**
			Alphanumeric characters assigned for differentiation within a transaction set.			
			Use to clarify the type of information in Table 2.			
			LOT — Lot Dependent Data			
			Report Type Codes CA and RT: Indicates that the LIN loop contains specific lot based data.			
			PER — Lot Independent Periodic Data			
			Report Type Code SR: Indicates that the LIN loop contains lot independent data.			
M	**LIN02**	**235**	**Product/Service ID Qualifier**	**M**	**ID**	**2/2**
			Code identifying the type/source of the descriptive number used in Product/Service ID (234).			
			KL — Item Management Code			
			Mandatory use for Assigned ID of PER: Primary scope identification number for data, assigned by Seller for the data set included. This Product/Service ID may identify periodic data sets by a single code, permanently defined by mutual consent of trading partners.			
			LT — Lot Identifier			
			Mandatory use for Assigned ID of LOT: Primary lot identification number for material. Example: Polished wafer final acceptance test lot number.			
M	**LIN03**	**234**	**Product/Service ID**	**M**	**AN**	**1/40**
			Identifying number for a product or service.			
X	**LIN04**	**235**	**Product/Service ID Qualifier**	**X**	**ID**	**2/2**
			Code identifying the type/source of the descriptive number used in Product/Service ID (234).			
			NOTE: The codes identified below are examples that may be used for each Product/Service ID Qualifier in this segment. Up to 14 Element pairs (LIN04/LIN05...through LIN30/LIN31) may be used.			
			FE — Feature			
			Optional use for Assigned ID of PER: Secondary scope identification number for data assigned by mutual consent for the data set included. Example: Back Surface Finish No. 2 - Poly, LTO, etc.			

		F1	Finish Number		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Back Surface Finish No. 1 - Poly, LTO, etc.		
		GC	Grade Code		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Wafer Grade - Prime (Product), Test/Monitor (Non-product), SIMOX, BESOI, Silicon, Gallium Arsenide, etc.		
		KM	Shelf-Life Code		
		KN	Shelf-Life Action Code		
		LT	Lot Number		
			Optional use for Assigned ID of LOT: Subordinate lot identification number for material. Example: EPI lot number.		
		MB	Measurement Type Code		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Data is for before or after depositions.		
		PR	Process Number		
			Optional use for Assigned ID of LOT: Additional processing lot identification number for material if required.		
		PW	Part Drawing		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Specific part number.		
		RS	Set Number		
			Optional use for Assigned ID of LOT: Superior lot identification number for data, assigned by mutual consent for the data set included. Example: Crystal or boule identification, etc.		
		SF	Surface Finish		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Front Surface Finish - Etch, Polish, EPI, etc.		
		TP	Product Type Code		
			Optional use for Assigned ID of PER: Secondary scope identification number for data, assigned by mutual consent for the data set included. Example: Diameter - 100 mm, 125 mm, 150 mm, 200 mm, 300 mm, etc.		
LIN05	**234**	**Product/Service ID**		**X**	**AN 1/40**
		Identifying number for a product or service.			
		The value identified by the preceding Product/Service ID Qualifier.			

Segment: **QTY Quantity**
Level: Detail
Loop: LIN
Usage: Optional
Max Use: 10
Purpose: To specify quantity information.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**QTY01**	**673**	**Quantity Qualifier**	**M**	**ID**	**2/2**
			Code specifying the type of quantity.			
			39 Shipped Quantity			
M	**QTY02**	**380**	**Quantity**	**M**	**R**	**1/15**
			Numeric value of quantity.			
			Quantity of material represented by the most recent LIN Segment definition above; i.e., the material quantity represented by the data below. Not the combined total quantity of the shipment, unless it is a single lot.			
O	**QTY03**	**355**	**Unit or Basis for Measurement Code**	**O**	**ID**	**2/2**
			Code specifying the units in which a value is being expressed, or manner in which a measurement has been taken.			
			Other codes may be used for other commodities/materials.			
			EA Each			

Segment: **DTM Date/Time Reference**

Level: Detail

Loop: LIN

Usage: Optional

Max Use: 10

Purpose: To specify pertinent dates and times.

Syntax Notes:

1 At lease one of DTM02, DTM03, or DTM06 is required.

2 If either DTM06 or DTM07 is present, then the other is required.

Comments:

1 Report Type Code SR (LIN01 Assigned ID = "PER"): Defines date range covered by summary data.

2 Report Type Codes CA and RT (LIN01 Assigned ID = "LOT"): May be used to specify a ship date or other date mutually agreed upon by Buyer and Seller.

3 If date range for all data entities is identical, the DTM Segment at Position Number 040 may be used to identify a single date.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**DTM01**	**374**	**Date/Time Qualifier**	**M**	**ID**	**3/3**
			Code specifying type of date or time, or both date and time.			
			009 — Process			
			011 — Shipped			
			054 — Sellers Local			
			119 — Test Performed [Period Range]			
			157 — Test Period Start			
			158 — Test Period Ending			
X	**DTM02**	**373**	**Date**	**X**	**DT**	**6/6**
			Date (YYMMDD).			
			Used for start/stop combination.			
O	**DTM03**	**337**	**Time**	**X**	**TM**	**4/4**
			Time expressed in 24-hour clock time (HHMM).			
O	**DTM05**	**624**	**Century**	**O**	**N0**	**2/2**
			The first two characters in the designation of the year (CCYY).			
X	**DTM06**	**1250**	**Date Time Period Format Qualifier**	**X**	**ID**	**2/3**
			Code indicating the date format, time format, or date and time format.			
			RD6 — Range of Dates Expressed in Format YYMMDD-YYMMDD.			
			RD8 — Range of Dates Expressed in Format CCYYMMDD-CCYYMMDD. A range of dates expressed in the format CCYYMMDD-CCYYMMDD, where CCYY is the numerical expression of the century CC and year YY, MM is the numerical expression of the month within the year, and DD is the numerical expression of the day within the year; the first occurrence of CCYYMMDD is the beginning date and the second occurrence is the ending date.			
			RDM — Range of Dates Expressed in Format YYMMDD-MMDD.			
X	**DTM07**	**1251**	**Date Time Period**	**X**	**AN**	**1/35**
			Expression of a date, a time, or range of dates, times, or dates and times.			

Segment: **CID Characteristic/Class ID**

Level: Detail

Loop: CID

Usage: Optional

Max Use: 1

Purpose: To specify the general class or specific characteristic upon which test results are being reported or are to be taken.

Syntax Notes:

1 At least one of CID01, CID02, CID04, or CID05 is required.

2 If either CID03 or CID04 is present, then the other is required.

3 If CID06 is present, then both CID03 and CID04 are required.

4 If CID07 is present, then at least one of CID04 or CID05 is required.

Comments **1** CID06 specifies the individual code list of the agency specified in CID03.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*	
X	**CID01**	**738**	**Measurement Qualifier**	**X**	**ID**	**1/3**
			Code identifying a specific product or process characteristic to which a measurement applies.			
M	**CID02**	**750**	**Product/Process Characteristic Code**	**X**	**ID**	**2/3**
			Code identifying the general class of a product or process characteristic.			
			13 — Quality (Quality Level)			
X	**CID03**	**559**	**Agency Qualifier Code**	**X**	**ID**	**2/2**
			Code identifying the agency assigning the code values.			
			SM — Semiconductor Equipment and Materials International			
			New code required for SEMI: SM suggested.			
			ZZ — Mutually Defined			
			May be required until incorporation of the SEMI code.			
X	**CID04**	**751**	**Product Description Code**	**X**	**AN**	**1/12**
			A code from an industry code list which provides specific data about a productcharacteristic.			
X	**CID05**	**352**	**Description**	**X**	**AN**	**1/80**
			A free-form description to clarify the related data elements and their content.			
O	**CID06**	**822**	**Source Subqualifier**	**O**	**AN**	**1/15**
			A reference that indicates the table or text maintained by the Source Qualifier.			

Segment: **SPS Sampling Parameters for Summary Statistics**

Level: Detail

Loop: CID

Usage: Optional

Max Use: >1

Purpose: To define the sampling parameters associated with summary statistics.

Syntax Notes:

1 If either SPS05 or SPS06 is present, then the other is required.

Semantic Notes:

1 SPS01 is the population size (count) of the class of objects or events to which the statistical generalizations refer.

2 SPS02 is the sample size, which is the number of observations on which the reported summary statistics were based.

3 SPS03 is the subgroup size, which is the number of observations in a subgroup of a sample.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
O	**SPS01**	**609**	**Count**	**O**	**N0**	**1/9**
			Occurrence counter			
O	**SPS02**	**609**	**Count**	**O**	**N0**	**1/9**
			Occurrence counter			
O	**SPS03**	**609**	**Count**	**O**	**N0**	**1/9**
			Occurrence counter			
O	**SPS04**	**949**	**Confidence Limit**	**O**	**R**	**1/4**
			Percent value expressing the confidence that a true value falls within a certain confidence interval.			
O	**SPS05**	**C00101**	**Composite Unit of Measure**	**X**		
			To identify a composite unit of measure.			
	C00101	**355**	**Unit or Basis for Measurement Code**	**M**	**ID**	**2/2**
			Code specifying the units in which a value is being expressed, or manner in which a measurement has been taken.			
			Refer to 003051 Data Element Dictionary for acceptable code values.			
	C00102	**1018**	**Exponent**	**O**	**R**	**1/15**
			Power to which a unit is raised.			
	C00103	**649**	**Multiplier**	**O**	**R**	**1/10**
			Value to be used as a multiplier to obtain a new value.			
			C00101 through C00103 can be repeated five times using C00103 to C00115.			
O	**SPS06**	**942**	**Sample Frequency Value per Unit of Measurement Code**	**X**	**N0**	**1/9**
			The number of samples collected.			

Segment: **DTM Date/Time Reference**

Level: Detail

Loop: CID

Usage: Optional

Max Use: 10

Purpose: To specify pertinent dates and times.

Syntax Notes:

1 At lease one of DTM02, DTM03, or DTM06 is required.

2 If either DTM06 or DTM07 is present, then the other is required.

Comments:

1 Report Type Code SR (LIN01 Assigned ID = "PER"): Defines date range covered by summary data.

2 Report Type Codes CA and RT (LIN01 Assigned ID = "LOT"): May be used to specify a ship date or other date mutually agreed upon by Buyer and Seller.

3 If date range for all data entities is identical, the DTM Segment at Position Number 040 may be used to identify a single date.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*	
M	**DTM01**	**374**	**Date/Time Qualifier** Code specifying type of date or time, or both date and time. 009 Process 011 Shipped 054 Sellers Local 119 Test Performed [Period Range] 157 Test Period Start 158 Test Period Ending	**M**	**ID**	**3/3**
X	**DTM02**	**373**	**Date** Date (YYMMDD).	**X**	**DT**	**6/6**
O	**DTM03**	**337**	**Time** Time expressed in 24-hour clock time (HHMM).	**X**	**TM**	**4/4**
O	**DTM05**	**624**	**Century** The first two characters in the designation of the year (CCYY).	**O**	**N0**	**2/2**
X	**DTM06**	**1250**	**Date Time Period Format Qualifier** Code indicating the date format, time format, or date and time format. RD6 Range of Dates Expressed in Format YYMMDD-YYMMDD. RD8 Range of Dates Expressed in Format CCYYMMDD-CCYYMMDD. A range of dates expressed in the format CCYYMMDD-CCYYMMDD where CCYY is the numerical expression of the century CC and year YY, MM is the numerical expression of the month within the year, and DD is the numerical expression of the day within the year; the first occurrence of CCYYMMDD is the beginning date and the second occurrence is the ending date. RDM Range of Dates Expressed in Format YYMMDD-MMDD.	**X**	**ID**	**2/3**
X	**DTM07**	**1251**	**Date Time Period** Expression of a date, a time, or range of dates, times, or dates and times.	**X**	**AN**	**1/35**

Segment:	**MEA Measurements**
Level:	Detail
Loop:	MEA
Usage:	Optional
Max Use:	1
Purpose:	To specify physical measurements or counts, including dimensions, tolerances, variances, and weights. (See figures in appendix for example of use of C001.)
Syntax Notes:	**1** At lease one of MEA03, MEA05, MEA06, or MEA08 is required.
	2 If MEA05 is present, then MEA04 is required.
	3 If MEA06 is present, then MEA04 is required.
	4 If MEA07 is present, then at least one of MEA03, MEA05, or MEA06 is required.
	5 Only one of MEA08 or MEA03 may be present.
Semantic Notes:	**1** MEA04 defines the unit of measure for MEA03, MEA05, and MEA06.
Comments:	**1** When citing dimensional tolerances, any measurement requiring a sign (+ or -), or any measurement where a positive (+) value cannot be assumed, use MEA05 as the negative (-) value and MEA06 as the positive (+) value.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*	
O	**MEA01**	**737**	**Measurement Reference ID Code**	**O**	**ID**	**2/2**
			Code identifying the broad category to which a measurement applies.			
			Examples of possible values for wafers, if used, are indicated.			
			AV — Average Reading			
			CT — Counts			
			DE — Defects			
			EL — Electrical Characteristics			
			FD — Finished Dimensions Dimensions of the final or end-use product			
			HR — Historical Result			
			IR — Interpolated Result A test result value calculated by interpolation between two physical tests.			
			LS — Lot Status			
			LT — Lot Limits Limits set on test results from all product contained in a single shipment (which may involve any multiple or fraction of transportation carrier units) to one customer.			
			PD — Physical Dimensions (Product Ordered)			
			SF — Shelf Life			
			TR — Test Results Indicates that the data to follow are the results test measurements.			
O	**MEA02**	**738**	**Measurement Qualifier**	**O**	**ID**	**1/3**
			Code identifying a specific product or process characteristic to which a measurement applies.			
			Use not recommended for wafers. Included as optional for use with other commodities/materials.			
			Refer to 003050 Data Element Dictionary for acceptable code values.			

X	**MEA03**	**739**	**Measurement Value** The value of the measurement.	**X**	**R**	**1/20**
X	**MEA04**	**C001**	**Composite Unit of Measure** To identify a composite unit of measure (see figures in appendix for examples of use).	**X**		
M	**C00101**	**355**	**Unit or Basis for Measurement Code** Code specifying the units in which a value is being expressed, or manner in which a measurement has been taken. ZZ Mutually Defined Standardized default unit of measure for each parameter to be published by SEMI as part of the procedure. Optionally, standard code set may be used.	**M**	**ID**	**2/2**
O	**C00102**	**1018**	**Exponent** Power to which a unit is raised.	**O**	**R**	**1/15**
O	**C00103**	**649**	**Multiplier** Value to be used as a multiplier to obtain a new value.	**O**	**R**	**1/10**
X	**MEA05**	**740**	**Range Minimum** The value specifying the minimum of the measurement range.	**X**	**R**	**1/20**
X	**MEA06**	**741**	**Range Maximum** The value specifying the maximum of the measurement range.	**X**	**R**	**1/20**
O	**MEA07**	**935**	**Measurement Significance Code** Code used to benchmark, qualify, or further define a measurement value. 03 Approximately 04 Equal to 05 Greater than or equal to 06 Greater than 07 Less than 08 Less than or equal to 10 Not equal to 22 Actual 31 Calculated 39 Corrected 40 Uncorrected 43 Intermediate 44 Average [based on an average parameter or standard]	**O**	**ID**	**2/2**
X	**MEA08**	**936**	**Measurement Attribute Code** Code used to express an attribute response when a numeric measurement value cannot be determined. Other codes available. 05 Undetectable 09 Pass 12 OK 21 Checked 23 Absent 29 To Be Determined 44 Not Applicable 45 Not Determined 51 Conforming	**X**	**ID**	**2/2**

Segment:	**REF** **Reference Numbers**
Level:	Detail
Loop:	MEA
Usage:	Optional
Max Use:	10
Purpose:	To specify identifying numbers.
Syntax Notes:	**1** At lease one of REF02 or REF03 is required.
Comments:	May be used when describing serialized or positional-dependent data.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*	
M	**REF01**	**128**	**Reference Number Qualifier**	**M**	**ID**	**2/2**
			Code qualifying the Reference Number.			
			55 — Sequence Number			
			6K — Zone			
			Wafer site or other measurement location identification.			
			BG — Beginning Serial Number			
			EG — Ending Serial Number			
			QQ — Unit Number			
			Used to identify the parameter sample size.			
			SE — Serial Number			
			Serialization reference number applicable to the measurement.			
			SJ — Set Number			
			Reference to the laser mark on a wafer (verbatim).			
X	**REF02**	**127**	**Reference Number**	**X**	**AN**	**1/30**
			Reference number or identification number as defined for a particular Transaction Set, or as specified by the Reference Number Qualifier.			
X	**REF03**	**352**	**Description**	**X**	**AN**	**1/80**
			A free-form description to clarify the related data elements and their content.			

Segment: **STA Statistics**
Level: Detail
Loop: STA
Usage: Optional
Max Use: 1
Purpose: To provide summary statistics related to a specific collection of test result values.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**STA01**	**950**	**Statistic Code**	**M**	**ID**	**2/2**
			A code specifying the specific statistic being reported.			
			Complete list from Standard is available. Typical parameters are indicated. Other parameters may be defined to accommodate proprietary statistical formats.			

01	Cusum Delta
02	Cusum - H
03	Cusum - K
04	Capability Ratio
05	F - Test
06	Control Limit Lower - Individual
07	Control Limit Upper - Individual
08	T - Test
09	Grand Average (Double X-Bar)
10	Kurtosis
11	Mean Average
12	Median
13	Minimum Average
14	Median Range
15	Maximum Average
16	Process Capability Upper
17	Process Capability Lower
18	Process Capability CPK
19	Range Average (R-Bar)
20	Control Limit Lower R-Bar
21	Control Limit Upper R-Bar
22	Range Value (Total Range)
23	Standard Deviation
24	Standard Error
25	Skewness
26	Control Limit Lower X-Bar
27	Control Limit Upper X-Bar
28	Failure Rate in Time (failures over time determined by the equation (failure rate*10^9))
29	Mode
30	Average

			31	Mean			
			32	Minimum Value The least or smallest value; the allowed lower limit			
			33	Maximum Value The largest value; the allowed upper limit			
			AD	Anderson Darling Test			
			CF	Cochran's Procedure			
			CS	Chi-Square Test			
	See Appendix 2		EC	Equivalent Cpk (Add definition)			
	See Appendix 2		PE	Percentile			
	See Appendix 2		GM	Geometric Mean			
	See Appendix 2		GS	Geometric Sigma			
			HG	Histogram			
	See Appendix 2		HC	Histogram Class Count (Count of classes or bars)			
	See Appendix 2		HS	Histogram Start (Left side of first class or bar)			
	See Appendix 2		HW	Histogram Width (Width of class or bar)			
			KS	Kolmogrov-Smirnov Test			
	See Appendix 2		OC	Outlier Count			
	See Appendix 2		PK	Peak Value of Distribution Curve			
			SK	Moment Tests, Skewness and Kurtosis (Weighted Average)			
			SW	Shapiro-Wilk Test			
			ZZ	Mutually Defined			
M	**STA02**	**739**	**Measurement Value** The value of the measurement.		**M**	**R**	**1/20**
O	**STA03**	**C001**	**Composite Unit of Measure** To identify a composite unit of measure (see figures in appendix for example of use).		**O**		
M	**C00101**	**355**	**Unit or Basis for Measurement Code** Code specifying the units in which a value is being expressed, or manner in which a measurement has been taken. Refer to 003050 Data Element Dictionary for acceptable code values.		**M**	**ID**	**2/2**
O	**C00102**	**1018**	**Exponent** Power to which a unit is raised.		**O**	**R**	**1/15**
O	**C00103**	**649**	**Multiplier** Value to be used as a multiplier to obtain a new value.		**O**	**R**	**1/10**
O	**STA04**	**738**	**Measurement Qualifier** Code identifying a specific product or process characteristic to which a meas. applies. Refer to 003050 Data Element Dictionary for acceptable code values.		**O**	**ID**	**1/3**
O	**STA05**	**737**	**Measurement Reference ID Code** Code identifying the broad category to which a measurement applies.		**O**	**ID**	**2/2**
			HR	Historical Result			
			LS	Lot Status			
			LT	Lot Limits Limits set on test results from all product contained in a single shipment (which may involve any multiple or fraction oftransportation carrier units) to one customer.			
			TS	Single Test Limits			

Limits set on each measurement of the specified productcharacteristic or manufacturing process so that any single test whose value falls outside these limits causes the product or process to be declared out-of-specification.

O	**STA06**	**740**	**Range Minimum**	**O**	**R**	**1/20**
			The value specifying the minimum of the measurement range.			
O	**STA07**	**741**	**Range Maximum**	**O**	**R**	**1/20**
			The value specifying the maximum of the measurement range.			

Segment: **REF Reference Numbers**

Level: Detail

Loop: STA

Usage: Optional

Max Use: 10

Purpose: To specify identifying numbers.

Syntax Notes: **1** At lease one of REF02 or REF03 is required.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**REF01**	**128**	**Reference Number Qualifier**	**M**	**ID**	**2/2**
			Code qualifying the Reference Number.			
			Refer to 003050 Data Element Dictionary for acceptable code values.			
X	**REF02**	**127**	**Reference Number**	**X**	**AN**	**1/30**
			Reference number or identification number as defined for a particular Transaction Set, or as specified by the Reference Number Qualifier.			
X	**REF03**	**352**	**Description**	**X**	**AN**	**1/80**
			A free-form description to clarify the related data elements and their content.			

Segment: **TSP** **Test Period or Interval**
Level: Detail
Loop: TSP
Usage: Optional
Max Use: 1
Purpose: To describe a specific period or interval at which tests are performed.
Syntax Notes: **1** If either TSP03 or TSP04 is present, then the other is required.
Comments: **1** TSP02 is used to further expand TSP01 as a qualifier.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*		*Attributes*		
M	**TSP01**	**1312**	**Test Period or Interval Qualifier**		**M**	**ID**	**2/2**
			Code indicating the type of period or interval as related to when a test event occurs.				
			TF	Final Test Measurement or Read-point (Cumulative).			
				This code marks the end of the experiment under a specific test.			
			TI	Intermediate Test Measurements or Read-point (Cumulative).			
				There may be a number of intermediate test points during an experiment; this code would likely be combined with DE 350 to indicate which intermediate test point it is.			
			TO	Initial Test Measurement or Read-point (Cumulative).			
				This is the first test interval that a product or item is subjected to.			
O	**TSP02**	**350**	**Assigned Identification**		**O**	**AN**	**1/11**
			Alphanumeric characters assigned for differentiation within a transaction set.				
X	**TSP03**	**1313**	**Test Period or Interval Value**		**X**	**N0**	**1/6**
			Numeric value of period or interval signifying when a test event occurs.				
X	**TSP04**	**344**	**Unit of Time Period or Interval**		**X**	**ID**	**2/2**
			Code indicating the time period or interval.				
			AD	Average Daily			
			AM	Average Monthly			
			AY	Average Year			
			CY	Calendar Year			
			DA	Calendar Days			
			F1	Fiscal Year Plus One Year			
			F2	Fiscal Year Plus Two Years			
			FY	Fiscal Year			
			MO	Month			
			PR	Preceding Six Months			
			Q1	First Quarter			
			Q2	Second Quarter			
			Q3	Third Quarter			
			Q4	Fourth Quarter			
			QY	Quarter of a Year			
			SA	Semiannual			
			WK	Weeks			
			WW	Work Week			

Segment: **LM Code Source Information**
Level: Detail
Loop: LM
Usage: Optional
Max Use: 1
Purpose: To transmit standard code list identification information.
Comments: **1** LM02 identifies the applicable industry code list source information.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**LM01**	**559**	**Agency Qualifier Code**	**M**	**ID**	**2/2**
			Code identifying the agency assigning the code values.			
			SM Semiconductor Equipment and Materials International			
			ZZ Mutually Defined			
O	**LM02**	**822**	**Source Subqualifier**	**O**	**AN**	**1/15**
			A reference that indicates the table or text maintained by the Source Qualifier.			

Segment:	**LQ Industry Code**
Level:	Detail
Loop:	LM
Usage:	Mandatory
Max Use:	>1
Purpose:	Code to transmit standard industry codes.
Syntax Notes:	**1** If LQ01 is present, then LQ02 is required.
Comments:	This section will allow for a breakdown of the measurement or parameter (e.g., Flatness, STIR, Font Ref, 90% PUA, ADE7700).

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
O	**LQ01**	**1270**	**Code List Qualifier Code** Code identifying a specific industry code list. Refer to 003050 Data Element Dictionary for acceptable code values.	**O**	**ID**	**1/3**
M	**LQ02**	**1271**	**Industry Code** Code indicating a code from a specific industry code list. Repeat as necessary to define a parameter in mutlitier fashion. May also be used after parameter definition to provide additional information such as test method orconditions coding.	**X**	**AN**	**1/20**

Segment: **CTT Transaction Totals**
Level: Summary
Loop: _______
Usage: Optional
Max Use: 1
Purpose: To transmit a hash total for a specific element in the transaction set.
Syntax Notes:
1 If either CTT03 or CTT04 is present, then the other is required.
2 If either CTT05 or CTT06 is present, then the other is required.
Comments:
1 This segment is intended to provide hash totals to validate transaction completeness andcorrectness.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**CTT01**	**354**	**Number of Line Items**	**M**	**N0**	**1/6**
			Total number of line items in the transaction set.			
M	**CTT02**	**347**	**Hash Total**	**O**	**R**	**1/10**
			Sum of values of the specified data element. All values in the data element will be summed without regard to decimal points (explicit or implicit) or signs. Truncation will occur on the left most digits if the sum is greater than the maximum size of the hash total of the data element.			
			Example:			
			-.0018 First occurrence of value being hashed. .18 Second occurrence of value being hashed. 1.8 Third occurrence of value being hashed. 18.01 Fourth occurrence of value being hashed. ------- 1855 Hash total prior to truncation. 855 Hash total after truncation to three-digit field.			

Segment: **SE Transaction Set Trailer**

Level: Summary

Loop: _______

Usage: Mandatory

Max Use: 1

Purpose: To indicate the end of the transaction set and provide the count of the transmitted segments (including the beginning (ST) and ending (SE) segments).

Comments: **1** SE is the last segment of each transaction set.

Data Element Summary

SEMI USE:	*Ref. Des.*	*Data Element*	*Name*	*Attributes*		
M	**SE01**	**96**	**Number of Included Segments**	**M**	**N0**	**1/10**
			Total number of segments included in a transaction set including ST and SE segments.			
M	**SE02**	**329**	**Transaction Set Control Number**	**M**	**AN**	**4/9**
			Identifying control number that must be unique within the transaction set functional group assigned by the originator for a transaction set.			

APPENDIX 5
EXAMPLES OF EDI TRANSMISSIONS

NOTE: This appendix was approved as an official part of SEMI T6 by full letter ballot procedure in March 1997.

A5-1 Certificate of Analysis Transmission

The "ISA" and "GS" segments indicated at the start of this example and the "GE" and "IEA" segments located at the end are generally handled by the Information System (IS) dept. in charge of managing the translation and routing of EDI messages through various VAN channels, and are not part of this document.

```
ISA*00*          *00*          *01*9012345720000      *01*908887732000*960130*2049*U*00200*120005424*0*T*:
GS*RT*901234572000*908887732000*960130*2049*4*T*003050
```

HEADING:

```
ST*863*7559
BTR*00*960130**CA*SHIP#102
REF*PO*PO_NO
REF*PP*PO_REV#
REF*BV*PO_LINE#
REF*S3*SPEC_NO
REF*SZ*REV-F
REF*PM*PART_NO
REF*YB*REV-C
PID*S**SM*WFR
N1*BY**SM*MT
N4*****FA*LATG/BP1
PER*QA*GEORGE WASHINGTON*TE*(602)555-1212
N1*SE**SM*MM
N4*****FA*SPTNBRG
PER*EA*BENEDICT ARNOLD*TE*(314)555-2121
```

NOTE for Application: For easy visualization and a show of flexibility, the example messages in this appendix were simplified by showing only a portion of what they can do. In practice, all of the transaction types (CA, RT, and SR) can use any combination of the statistical codes in Appendix 4, the new statistical codes in appendix 4, or raw measurement data.

DETAILS:

```
LIN*LOT*WL*WFR_LOT_NO*PR*XTAL_NO*LT*EPI_LOT_1*LT*EPI_LOT_2*LT*EPI_LOT_3
QTY*39*125*EA

CID**13
MEA****ZZ*9.34*16.67
STA*31*13.261
STA*23*1.455
REF*QQ*125*"QQ" INDICATES
    PARAMETER SAMPLE
    SIZE
TSP*TF
LM*SM
LQ**RES
LQ**CNTR

CID**13
MEA****ZZ**21.48
STA*31*2.665
STA*23*5.050
REF*QQ*25
TSP*TF
LM*SM
LQ**WARP

CID**13
MEA****ZZ**4
REF*QQ*25
TSP*TF
LM*SM
LQ**LPD
LQ**FRONT
LQ**>0.3

CID**13
MEA****ZZ*516*535
STA*31*525.076
STA*23*2.614
REF*QQ*125
TSP*TF
LM*SM
LQ**THICK

CID**13
MEA****ZZ**2.30
STA*31*1.002
STA*23*0.282
REF*QQ*125
TSP*TF
LM*SM
LQ**FLAT
LQ**GLOBAL
LQ**TIR

CID**13
MEA***5
REF*QQ*1
TSP*TF
LM*SM
LQ**OISF

CID**13
MEA****ZZ**4.5
STA*31*1.893
STA*23*1.093
REF*QQ*25
TSP*TF
LM*SM
LQ**TTV

CID**13
MEA****ZZ*27.22*34.12
STA*31*30.8
STA*23*2.926
REF*QQ*5
TSP*TF
LM*SM
LQ**OXYGEN
LQ**OLD ASTM

CID**13
MEA****ZZ**6
REF*QQ*125
TSP*TF
LM*SM
LQ**RRG

CID**13
MEA****ZZ**19.44
STA*31*14.918
STA*23*5.902
REF*QQ*25
TSP*TF
LM*SM
LQ**BOW

CID**13
MEA****ZZ**0.07
REF*QQ*5
TSP*TF
LM*SM
LQ**CARBON

CID**13
MEA********51
REF*QQ*125
TSP*TF
LM*SM
LQ**VISUAL
LQ**FRONTSIDE
```

SUMMARY:

```
CTT*10*855
SE*134*7559
GE*1*4
IEA*1*120005424
```

A5-2 Test Results Transmission

The "ISA" and "GS" segments indicated at the start of this example and the "GE" and "IEA" segments located at the end are generally handled by the Information System (IS) dept. in charge of managing the translation and routing of EDI messages through various VAN channels, and are not part of this document.

ISA*00* *00* *01*9012345720000 *01*908887732000 *960130*2049*U*00200*000045789*0*T*:
GS*RT*901234572000*908887732000*960130*2049*4*T*003050

HEADING:

```
ST*863*1132
BTR*00*960130**RT*SHIP#102
REF*PM*PART_NO
REF*YB*REV-C
REF*ZZ**THE ENCLOSED DATA IS FOR THE QUAL LOT DELIVERED 12/14/95.
REF*ZZ**SAMPLE DATA FOR 5 SERIALIZED WAFERS FOR CORRELATION
PID*S**SM*WFR
N1*BY**SM*MT
N4*****FA*LATG/BP1
PER*DC*WILLY WAFERMAN*TE*(602)555-1212
N1*SE**SM*MM
N4*****FA*SPTNBRG
```

NOTE for Application: For easy visualization and a show of flexibility, the example messages in this appendix were simplified by showing only a portion of what they can do. In practice, all of the transaction types (CA, RT, and SR) can use any combination of the statistical codes in Appendix 4, the new statistical codes in appendix 4, or raw measurement data.

DETAILS:

```
LIN*LOT*WL*WFR_LOT_NO
```

```
CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**BOW

CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**THICK
LQ**EPI

CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**WARP

CID**13
MEA*TR**111.11*ZZ***39
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ***39
REF*SE*X2315
MEA*TR**333.33*ZZ***39
REF*SE*X7129
MEA*TR**444.44*ZZ***39
REF*SE*X8153
MEA*TR**555.55*ZZ***39
REF*SE*X9491
TSP*TF
LM*SM
LQ**OXYGEN
LQ**(ASTM F121-79)

CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**FLAT
LQ**SITE
LQ**SFQD

CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**LPD
LQ**>0.2
LQ**TENCOR

CID**13
MEA*TR**111.11*ZZ
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR**222.22*ZZ
REF*SE*X2315
MEA*TR**333.33*ZZ
REF*SE*X7129
MEA*TR**444.44*ZZ
REF*SE*X8153
MEA*TR**555.55*ZZ
REF*SE*X9491
TSP*TF
LM*SM
LQ**THICK
LQ**POLY

CID**13
MEA*TR***ZZ****05
REF*SE*X3628*WAFER SERIAL NUMBER
MEA*TR***ZZ****05
REF*SE*X2315
MEA*TR***ZZ****05
REF*SE*X7129
MEA*TR***ZZ****05
REF*SE*X8153
MEA*TR***ZZ****05
REF*SE*X9491
TSP*TF
LM*SM
LQ**METALS
LQ**SURFACE
LQ**ZINC
LQ**TXRF
```

SUMMARY :

```
CTT*10*855
SE*151*1132
GE*1*4
IEA*1*000045789
```

A5-3 Statistical Results Transmission

The "ISA" and "GS" segments indicated at the start of this example and the "GE" and "IEA" segments located at the end are generally handled by the Information System (IS) dept. in charge of managing the translation and routing of EDI messages through various VAN channels, and are not part of this document.

```
ISA*00*        *00*        *01*9012345720000        *01*908887732000        *960130*2049*U*00200*004113004*0*T*:
GS*RT*901234572000*908887732000*960130*2049*4*T*003050
```

HEADING:

```
ST*863*9681
BTR*18*960130**SR
PID*S**SM*WFR
N1*BY**SM*MT
N4*****FA*LATG/MOS21
N1*SE**SM*MM
N4*****FA*STPTRS
```

NOTE for Application: For easy visualization and a show of flexibility, the example messages in this appendix were simplified by showing only a portion of what they can do. In practice, all of the transaction types (CA, RT, and SR) can use any combination of the statistical codes in Appendix 4, the new statistical codes in appendix 4, or raw measurement data.

DETAILS:

```
LIN*PER*KL*RPT_DEF_200*SF*POLISH*TP*150MM*GC*PRIME
DTM*119*****RD6*950701-951231
```

```
CID**13
SPS*20113
STA*31*1.618
STA*23*0.811
STA*33*5.2
STA*18*1.8
STA*GM*1.616
STA*GS*0.816
STA*EC*1.01
STA*OC*0
STA*PK*3967.04
STA*HS*0.0
STA*HW*0.2039
STA*HC*25
STA*HG*1
STA*HG*152
STA*HG*1411
STA*HG*2753
STA*HG*3345
STA*HG*3894
STA*HG*3652
STA*HG*3242
STA*HG*2528
STA*HG*1958
STA*HG*1604
STA*HG*1173
STA*HG*1000
STA*HG*697
STA*HG*533
STA*HG*404
STA*HG*315
STA*HG*225
STA*HG*181
STA*HG*134
STA*HG*111
STA*HG*95
STA*HG*72
STA*HG*41
STA*HG*3
STA*PE*2.14****80
STA*PE*4.37****99
TSP*TF
LM*SM
LQ**TTV
```

```
CID**13
SPS*326
STA*31*11.15
STA*23*3.98
STA*33*27.8
STA*18*2.42
STA*GM*11.17
STA*GS*4.2
STA*EC*1.23
STA*OC*0
STA*PK*51
STA*HS*3.2
STA*HW*1.4
STA*HC*15
STA*HG*1
STA*HG*15
STA*HG*39
STA*HG*50
STA*HG*51
STA*HG*42
STA*HG*35
STA*HG*29
STA*HG*17
STA*HG*14
STA*HG*9
STA*HG*6
STA*HG*5
STA*HG*2
STA*HG*2
STA*HG*1
STA*HG*0
STA*HG*1
STA*PE*10.46****50
STA*PE*14.20****80
STA*PE*16.66****90
STA*PE*19.02****95
STA*PE*24.36****99
TSP*TF
LM*SM
LQ**WARP
```

```
CID**13
SPS*151
STA*31*-0.847
STA*23*2.373
STA*32*-7.7
STA*33*6.5
STA*18*1.8
STA*OC*0.59
STA*PK*35
STA*HS*-8.296
STA*HW*1.28
STA*HC*12
STA*HG*
STA*HG*1
STA*HG*2
STA*HG*6
STA*HG*15
STA*HG*28
STA*HG*35
STA*HG*31
STA*HG*18
STA*HG*9
STA*HG*3
STA*HG*2
STA*HG*1
TSP*TF
LM*SM
LQ**BOW
```

```
CID**13
SPS*3345
STA*31*0.514
STA*23*2.099
STA*32*-6.1
STA*33*7.5
STA*18*1.51
STA*OC*0
STA*PK*347.615
STA*HS*-6.342
STA*HW*0.543
STA*HC*25
STA*HG*1
STA*HG*8
STA*HG*12
STA*HG*31
STA*HG*36
STA*HG*69
STA*HG*70
STA*HG*147
STA*HG*194
STA*HG*272
STA*HG*303
STA*HG*312
STA*HG*330
STA*HG*351
STA*HG*310
STA*HG*250
STA*HG*217
STA*HG*160
STA*HG*96
STA*HG*85
STA*HG*40
STA*HG*31
STA*HG*11
STA*HG*4
STA*HG*2
TSP*TF
LM*SM
LQ**THK
```

SUMMARY:

```
CTT*10*855
SE*214*9681
GE*1*4
IEA*1*004113004
```

SEMI T7-0302
SPECIFICATION FOR BACK SURFACE MARKING OF DOUBLE-SIDE POLISHED WAFERS WITH A TWO-DIMENSIONAL MATRIX CODE SYMBOL

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on January 11, 2002. Initially available at www.semi.org February 2002; to be published March 2002. Originally published in 1997.

1 Purpose

1.1 This specification is intended to provide a marking symbology that can be used to mark silicon wafers with no intrusion into the fixed quality area of the wafer.

2 Scope

2.1 This specification defines the geometric and spatial relationships and content (including the error checking and correcting code) of a rectangular two-dimensional (2-D), machine-readable, binary data matrix code symbol for back surface marking of notched, double-side polished wafers of silicon which comply with SEMI M28, and other materials with diameters of 300 mm and larger. It may be used in conjunction with the alphanumeric marking codes specified in SEMI M12 and SEMI M13 or the bar code specified in SEMI T1.

2.2 Although this specification does not specify the marking techniques that may be employed when complying with its requirements, it is assumed that the symbol will be obtained by laser scribing individual dots.

2.3 The matrix code is applicable to a broad range of wafer products including epitaxial wafers, SOI wafers, and unpatterned or patterned polished wafers. The format and algorithms of this code are based on two-dimensional symbology specified in AIM International Symbology Specification-Data Matrix.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI AUX1 — List of Vendor Identification Codes

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI M28 — Specification for Developmental 300 mm Diameter Polished Single Crystal Silicon Wafers

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

3.2 *AIM International Technical Specification*[1]

AIM/ANSI BC11 — International Symbology Specification — Data Matarix

3.3 *ANSI Standards* [2]

ANSI MH10.8.2 — Data Application Identifier Standard

ANSI X3.4-1986 — American Standard Code for Information Interchange (ASCII)

NOTE 1: This standard is equivalent to ISO 646, Information Processing – ISO 7-bit Coded Character Set for Information Exchange.

4 Terminology

4.1 *alignment bar, of a data matrix code symbol* — a solid line of contiguous filled cells abutting a line of alternately filled and empty cells [AIM - Data Matrix].

4.2 *binary values* — a dot in the wafer surface indicates the binary value 1. The absence of a dot, or a smooth surface surrounding a cell center point indicates the binary value 0.

4.3 *border column* — the outermost column of a data matrix code symbol. This column is a portion of the finder pattern.

4.4 *border row* — the outermost row of a data matrix code symbol. This row is a portion of the finder pattern.

4.5 *cell, of a data matrix code symbol* — the area within which a dot may be placed to indicate a binary value.

4.6 *cell center point, of an array* — the point at which the centerline of a row intersects the centerline of a column.

4.7 *cell spacing, of an array* — the (equal) vertical or horizontal distance between the cell center points of contiguous cells.

1 AIM International Inc., 634 Alpha Drive, Pittsburgh, MO 15238-2802. Website: http://www.aimusa.org

2 American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel.: 212-642-4900, fax: 212-398-0023.

4.8 *center line, of a row or column* — the line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

4.9 *central area, of a cell* — the area enclosed by a circle centered at the cell center point; used by code readers to sense the binary value of the cell.

4.10 *data matrix code symbol* — a two-dimensional array of square cells arranged in contiguous rows and columns. In certain ECC200 symbols, data regions are separated by alignment patterns. The data region is surrounded by a finder pattern [AIM - Data Matrix].

4.11 *dot* — a localized region with a reflectance which differs from that of the surrounding surface.

NOTE 2: To assure reading efficiency, a minimum contrast of 30% is required between the reflectance value of a dot and the surrounding wafer surface. Various densitometers can provide such measurements nondestructively.

4.12 *dot misalignment, within a cell* — the distance between the physical center point of a dot and the cell center point.

4.13 *finder pattern, of a data matrix code symbol* — a perimeter to the data region. Two adjacent sides contain dots in every cell; these are used primarily to define physical size, orientation and symbol distortion. The two opposite sides are made up of cells containing dots in alternate cells [AIM Data Matrix].

4.14 *reference point, of a data matrix code symbol* — the physical center point of a corner cell common to the primary border row and the solid line of the alignment bar, used to identify the physical location of the symbol on the object being marked with the symbol.

NOTE 3: The reference point is at a fixed location on the object. Different cells may be chosen as the reference point depending on the desired orientation of the symbol on the object and the size variability of the symbol. The particular cell to be used as the reference point must be specified for each application.

5 Requirements

5.1 *Shape and Size of the Data Matrix Code Symbol*

5.1.1 *Data Matrix Code Symbol Dimensions*

5.1.1.1 Each rectangular matrix code symbol shall be composed of an array of 8 rows and 32 columns with an alignment bar as defined in AIM ISS Data Matrix.

5.1.1.2 Cell spacing shall be 125 µm, center to center.

5.1.2 *Dot Size* — The nominal shape of the dot produced in the matrix may be circular or square. Its diameter or edge length (after polishing) shall be 100 µm + 10 µm – 20 µm.

5.1.3 *Border Rows and Columns*

5.1.3.1 One border row and one border column shall contain a dot in each cell. These are identified as the primary border row and the primary border column. These are used by the code reader to determine the orientation of the matrix.

5.1.3.2 The opposing (secondary) border row and column shall contain dots in alternating cells.

5.1.3.3 For these rectangular matrix code symbols, the reference point of the symbol shall be the physical centerpoint of the cell common to the primary border row and the center alignment bar.

5.1.4 The maximum dot misalignment within a cell is 15 µm. This ensures that a minimum size dot covers a cell central area of radius 25 µm.

5.1.5 Adjacent dots shall not touch.

5.2 *Content of the Data Matrix Code Symbol*

5.2.1 Each rectangular matrix code symbol shall contain 10 message characters, together with the error checking and correcting (ECC200) code characters, encoded in accordance with AIM ISS-Data Matrix.

5.2.2 The message characters may include any of those designated as “mostly upper case” in AIM ISS-Data Matrix, in Table 5 and Annex J. The ten message characters shall contain two elements:

a. a vendor-assigned 8-character wafer identification code, followed by

b. a 2-character vendor identification code (see SEMI AUX1).

5.3 *Location of the Data Matrix Code Symbol*

5.3.1 With the wafer positioned back surface up and with the primary fiducial toward the operator, the origin of the data matrix code symbol shall be located as specified below.

5.3.1.1 The 8 row x 32 column rectangular 2-D matrix code symbol shall be placed entirely outside a fixed quality area (FQA) with a nominal edge exclusion of 3 mm. The reference point shall be located 148.95 ± 0.15 mm from the center of the wafer, along a radius 5.0 ± 0.1° counterclockwise from the axis of the notch fiducial bisector.

5.3.2 The primary row of the matrix code symbol shall be placed toward the periphery of the wafer.

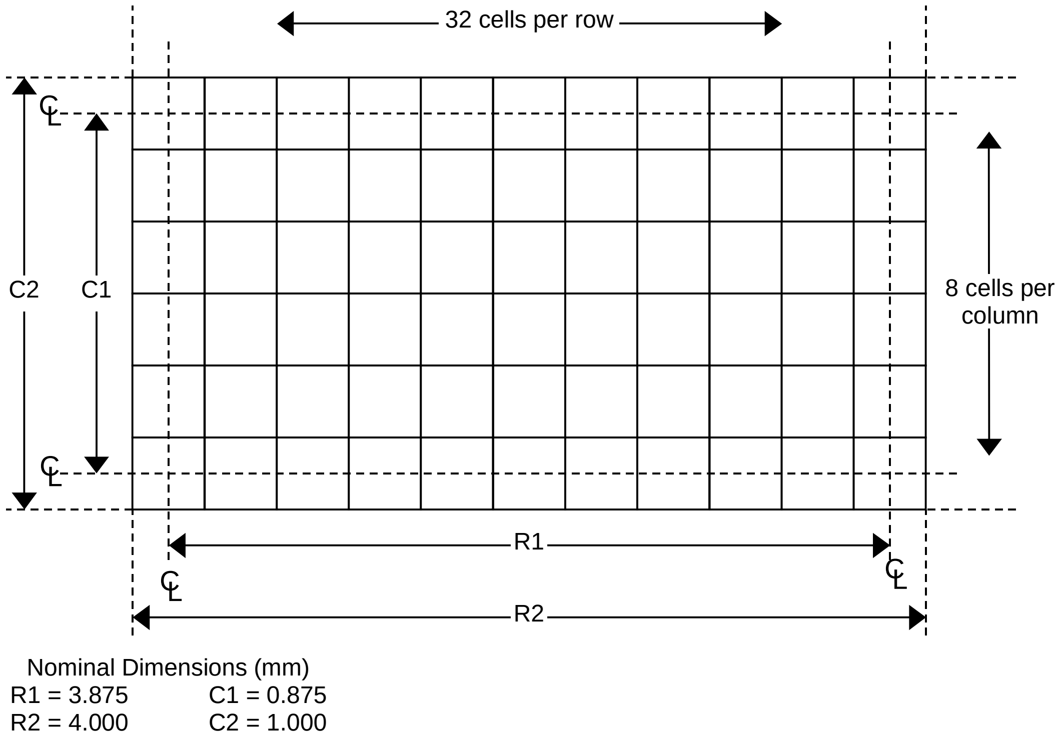


Figure 1
Data Matrix Field Dimensions
ECC200 - 8 rows × 32 columns

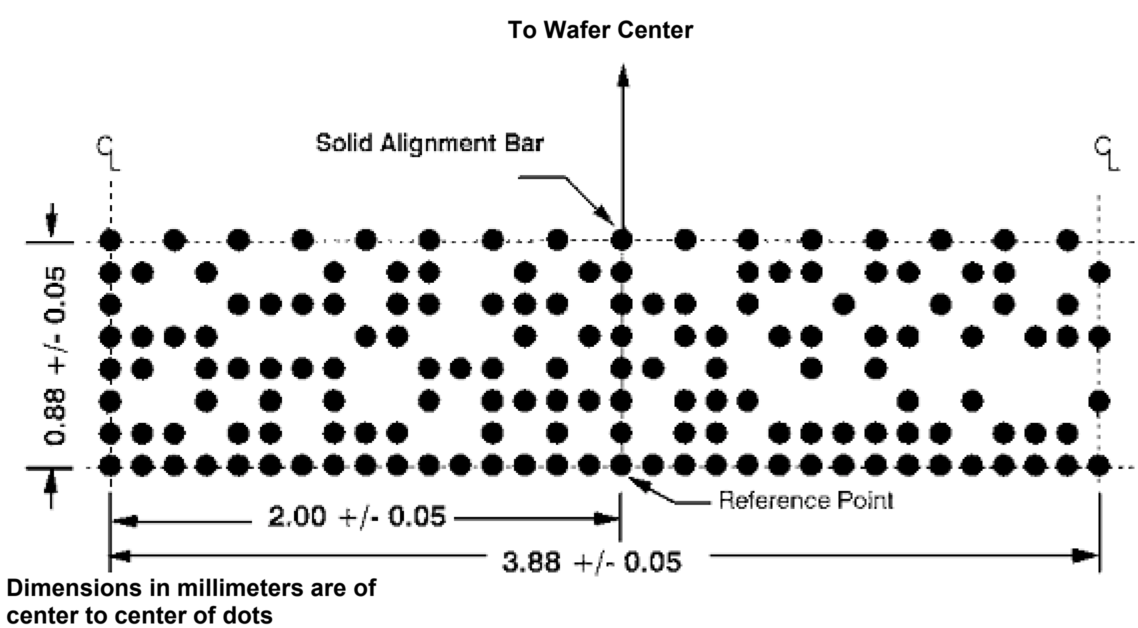


Figure 2
Data Matrix Code Fields
ECC200 - 8 rows × 32 columns

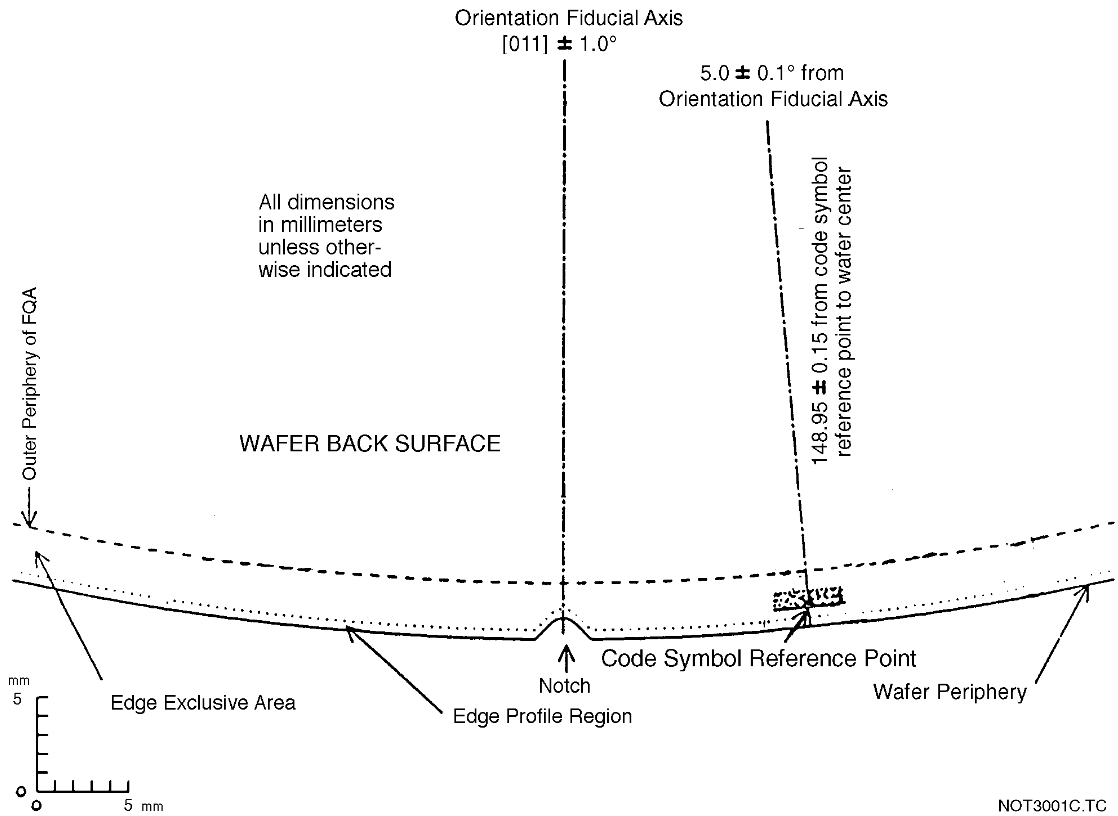


Figure 3
Data Matrix Code Symbol Location on Back Surface of Notched 300 mm Diameter Wafer

NOTE 1: The peripheries are of wafers of nominal diameter with nominal notch dimensions. The dots of the finder pattern are shown for an 8 row x 32 column data matrix code symbol with 125 µm spacing.

NOTICE: These standards do not purport to address safety issues, if any, associated with their use. It is the responsibility of the user of these standards to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require the use of copyrighted material or of an invention covered by patent rights. RVSI Acuity CiMatrix has filed a statement with SEMI asserting that the patented or copyrighted item can be used by the public for the purpose of implementing this standard without specific license and without payment of royalty or other charge. Attention is also drawn to the possibility that some elements of this standard may be subject to patented technology or copyrighted items other than those identified above. Semiconductor Equipment and Materials International (SEMI) shall not be held responsible for identifying any or all such patented technology or copyrighted items. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights and the risk of infringement of such rights are entirely their own responsibility.

SEMI T8-0698[E]
SPECIFICATION FOR MARKING OF GLASS FLAT PANEL DISPLAY SUBSTRATES WITH A TWO-DIMENSIONAL MATRIX CODE SYMBOL

[E] This document was modified in April 2000 to clarify patent issues. Changes were made to the notice at the end of this document.

1 Purpose

1.1 This specification is intended to provide a marking symbology that can be used to mark glass flat panel display (FPD) substrates within the fixed quality area of the edge exclusion area of the substrate.

2 Scope

2.1 This specification defines the geometric and spatial relationships and content (including the error checking and correcting code) of rectangular two-dimensional (2-D), machine-readable, binary Data Matrix symbology for front-surface or back-surface marking of glass FPD substrates (sometimes called "motherglass" substrates) which comply with the edge specifications of SEMI D12. It may be used in conjunction with the alphanumeric marking codes specified in SEMI M12 and SEMI M13 or the bar code specified in SEMI T1.

2.2 Although this specification does not specify the marking techniques that may be employed when complying with its requirements, it is assumed that the symbol will be obtained by laser scribing individual dots. A survivability experiment executed by the United States Display Consortium found such marks suitable.

NOTE: Other techniques could include resist exposure and grit blasting.

2.3 Data Matrix symbology is applicable to a broad range of FPD products including virgin substrates, processed and patterned substrates, panel assemblies, and displays. An application note describes the application of Data Matrix symbology to individual panel sections contained within a multi-panel motherglass substrate. The format and algorithms of this code are based on two-dimensional symbology specified in AIM International Symbology Specification - Data Matrix.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI D4 — Method for Referencing Flat Panel Display Substrates

SEMI D12 — Specification for Edge Condition of Flat Panel Display (FPD) Substrates

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

3.2 *AIM International Technical Specifications*[1]

AIM International Symbology Specification - Data Matrix

3.3 *ANSI Standard*[2]

ANSI MH10.8.2 — Data Application Identifier Standard

3.4 *Uniform Commercial Council Standard*[3]

Manufacturer Identification Codes

4 Terminology

4.1 *alignment bar, of a data matrix code symbol* — a solid line of contiguous filled cells abutting a line of alternatively filled and empty cells (AIM International Symbology Specification - Data Matrix).

4.2 *binary values* — a dot in the substrate surface indicates the binary value 1. The absence of a dot, or a smooth surface surrounding a cell center point, indicates the binary value 0.

4.3 *border column* — the outermost column of a data matrix code symbol. This column is a portion of the finder pattern.

4.4 *border row* — the outermost row of a data matrix code symbol. This row is a portion of the finder pattern.

4.5 *cell, of a data matrix code symbol* — the area within which a dot may be placed to indicate a binary value.

---

1 AIM International, Inc., 634 Alpha Drive, Pittsburgh, PA 15238-2802, tel 412.963.8588, fax 412.938.8753

2 American National Standards Institute, 11 West 42nd Street, New York, NY 10036, tel 212.642.4900, fax 212.398.0023

3 Uniform Code Council, 8163 Old Yankee Road, Dayton, Ohio 45458

4.6 *cell center point, of an array* — the point at which the centerline of a row intersects the centerline of a column.

4.7 *cell spacing, of an array* — the (equal) vertical or horizontal distance between the cell center points of contiguous cells.

4.8 *center line, of a row or column* — the line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

4.9 *central area, of a cell* — the area enclosed by a circle centered at the cell center point; used by code readers to sense the binary value of the cell.

4.10 *data matrix code symbol* — a two-dimensional array of square cells arranged in contiguous rows and columns. In certain ECC200 symbols, data regions are separated by alignment patterns. The data region is surrounded by a finder pattern (AIM International Symbology Specification - Data Matrix).

4.11 *dot* — a localized region with a reflectance which differs from that of the surrounding surface.

NOTE 1: To assure reading efficiency, a minimum contrast of 30% is required between the reflectance value of a dot and the surrounding substrate surface. Various densitometers can provide such measurements non-destructively.

4.12 *dot misalignment, within a cell* — the distance between the physical center point of a dot and the cell center point.

4.13 *finder pattern, of a data matrix code symbol* — a perimeter to the data region. Two adjacent sides contain dots in every cell; these are used primarily to define physical size, orientation, and symbol distortion. The two opposite sides are made up of cells containing dots in alternate cells (AIM International Symbology Specification - Data Matrix).

4.14 *reference point, of a data matrix code symbol* — the physical center point of a cell common to a designated row and column, used to identify the physical location of the symbol on the object being marked with the symbol.

NOTE 2: The reference point is at a fixed location on the object. Different cells may be chosen as the reference point, depending on the desired orientation of the symbol on the object and on the size variability of the symbol. The particular cell to be used as the reference point must be specified for each application.

5 Ordering Information

5.1 Purchase orders for substrates furnished to this specification shall include the following items:

5.1.1 *Message Characters*

5.1.1.1 Quantity (15 to *nn*, where *nn* is 16–46, and depends on the character set to be encoded [see Table 2]).

5.1.1.2 Content of Message Characters 16 and up, if present.

6 Requirements

6.1 *Shape and Size of the Data Matrix Code Symbol*

6.1.1 *Data Matrix Code Symbol Dimensions*

6.1.1.1 Each rectangular matrix code symbol shall be composed of an array of 8 to 16 rows and 32 to 46 columns (see Table 1 and Figure 1) as defined in AIM International Symbology Specification - Data Matrix. It may contain an alignment bar.

6.1.1.2 Cell spacing shall be 125 µm, center to center.

6.1.2 *Dot Size* — the nominal shape of the dot produced in the matrix may be circular or square. Its diameter or edge length shall be 100 ± 10 µm.

6.1.3 *Border Rows and Columns (see Figure 3)*

6.1.3.1 One border row and one border column shall contain a dot in each cell. These are identified as the primary border row and the primary border column. These are used by the code reader to determine the orientation of the matrix.

6.1.3.2 The opposing (secondary) border row and column shall contain dots in alternating cells.

6.1.3.3 For these rectangular matrix code symbols, the reference point of the symbol shall be the physical centerpoint of the cell common to the primary border row and the primary border column.

6.1.4 The maximum allowable dot misalignment within a cell is 20 µm. This ensures that a minimum size dot covers a cell central area of radius 25 µm.

6.2 *Content of the Data Matrix Code Symbol*

6.2.1 Each rectangular matrix code symbol shall contain between 15 and 46 message characters, together with the error checking and correcting (ECC) 200 code characters, encoded in accordance with AIM International Symbology Specification - Data Marix.

6.2.2 The message characters may include any of those designated as “mostly upper case” in Table 5 and Annex K of AIM International Symbology Specification - Data Marix. 8-bit characters may also be encoded with reduced field capacity (see Table 3). The first 15 message characters shall contain two elements:

a. a vendor-assigned 8-character substrate identification code, followed by

b. a 7-character vendor identification code as defined by UCC. These are a six-digit company identification, preceded by a zero (0).

6.2.2.1 The remaining message characters, if any, shall contain information as agreed between the vendor and user. This may require field identifiers and field concatenators (see ANSI MH10.8.2).

6.3 *Location of the Data Matrix Code Symbol*

6.3.1 With the substrate positioned front surface up and with the orientation corner toward the operator and to the operator's left, the reference point of the data matrix code symbol shall be placed toward the orientation corner as specified in Table 3.

6.3.2 The 12 row × 26 column rectangular 2-D matrix code symbol shall be placed entirely outside the fixed quality area (FQA) and within a nominal edge exclusion area of 10 mm. Large symbols will extend toward the substrate center and perpendicular to the substrate edges. (See Table 1 for field dimensions.)

6.3.3 The primary row of the symbol shall be parallel to the adjacent edge of the substrate ± 10.0°. The primary column of the symbol shall be nominally perpendicular to the same edge. The symbol shall lie between these two edges and the FQA (see Figures 4 and 5). The reference point of the symbol shall be located 4.0 ± 1.0 mm from the adjacent edge of the substrate.

Table 1 2-D Data Matrix Code Symbol Dimensions

Rectangular Array Spacing	*# of Cells in Row*	*# of Cells in Column*	C_1 *(mm)*	R_1 *(mm)*	C_2 *(mm)*	R_2 *(mm)*
125 µm	12	26	1.375	3.125	1.500	3.250
	12	32	1.375	4.375	1.500	4.500
	16	36	1.875	4.375	2.000	4.500

Table 2 Message Character Count in Rectangular Arrays for Use on FPD Substrates

# of Cells in Row and Column		*12 Rows × 26 Columns*	*12 Rows × 36 Columns*	*16 Rows × 36 Columns*
Maximum # of Message Characters	8-bit	N/A	20	30
	Mostly upper-case	22	31	46

Table 3 Location of 2-D Matrix Code Symbol Substrate Back Surface Up, Orientation Corner Toward the Operator and Toward the Operator's Left

Type of Array	*Reference Point*	*Location of Reference Point*
Rectangular	Common cell of primary border row and column	*4.0 ± 1.0 mm from the nominal edge of the substrate and toward the substrate orientation corner.

* The rows of the rectangular 2-D matrix code symbol are parallel to the X-edge of a substrate whose orientation corner is in the *1,1,1* orientation or the *2, -1, 0* orientation as described in SEMI D4.

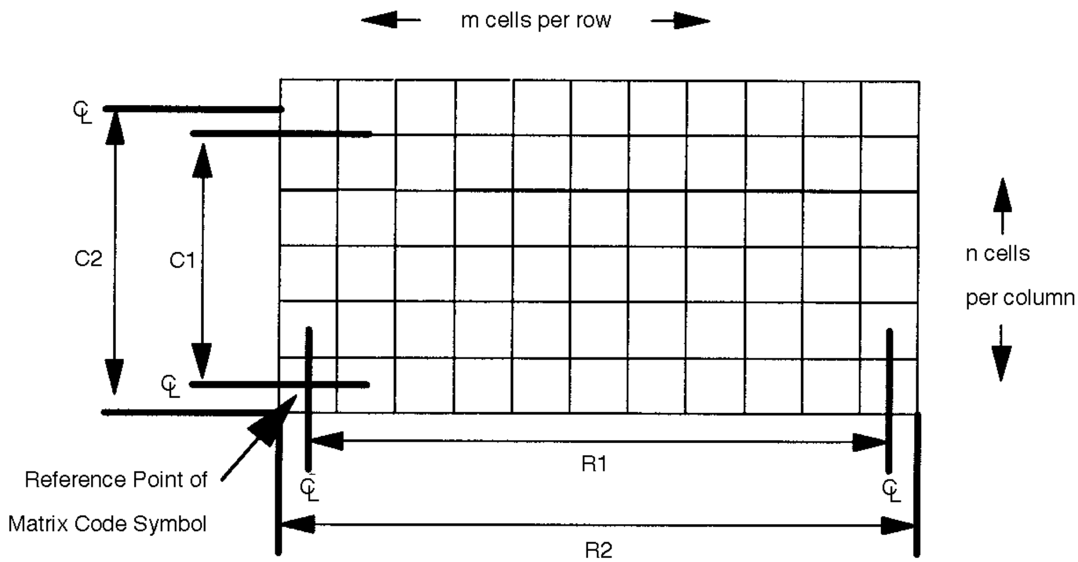


Figure 1
Data Matrix Field

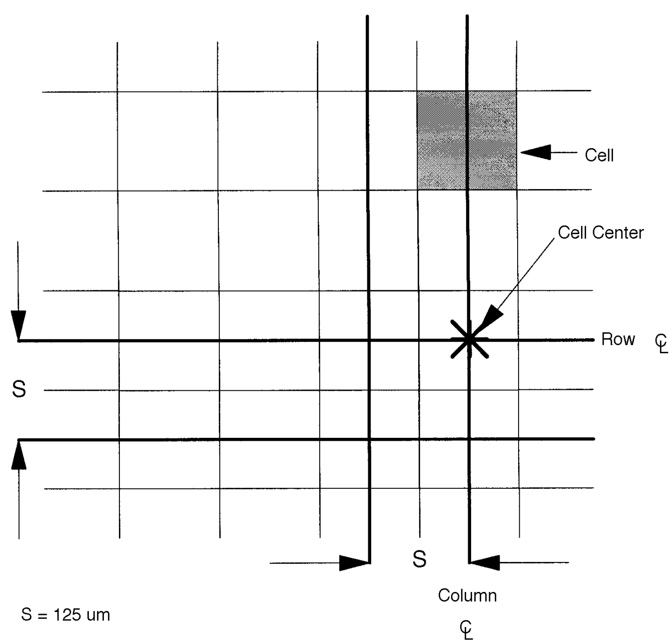


Figure 2
Data Matrix Cell Dimensions

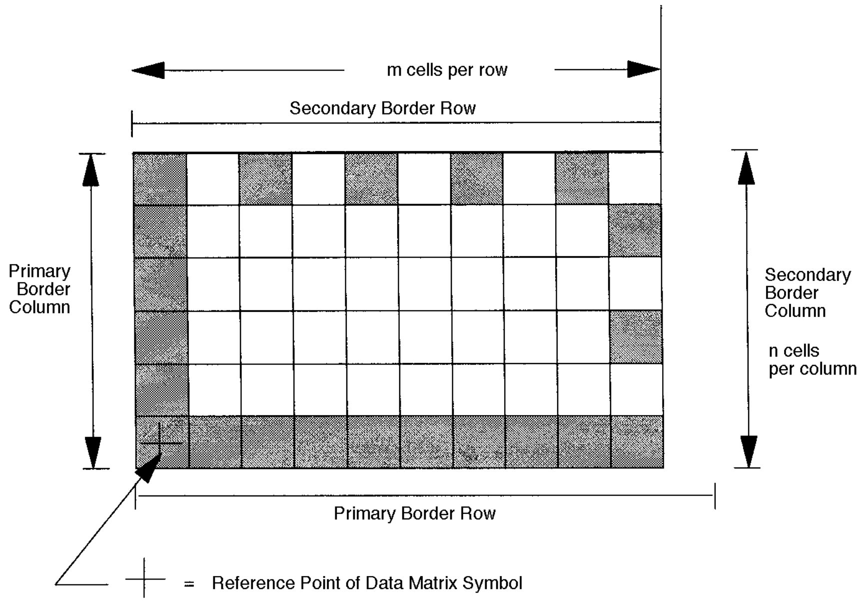


Figure 3
Border Rows and Columns

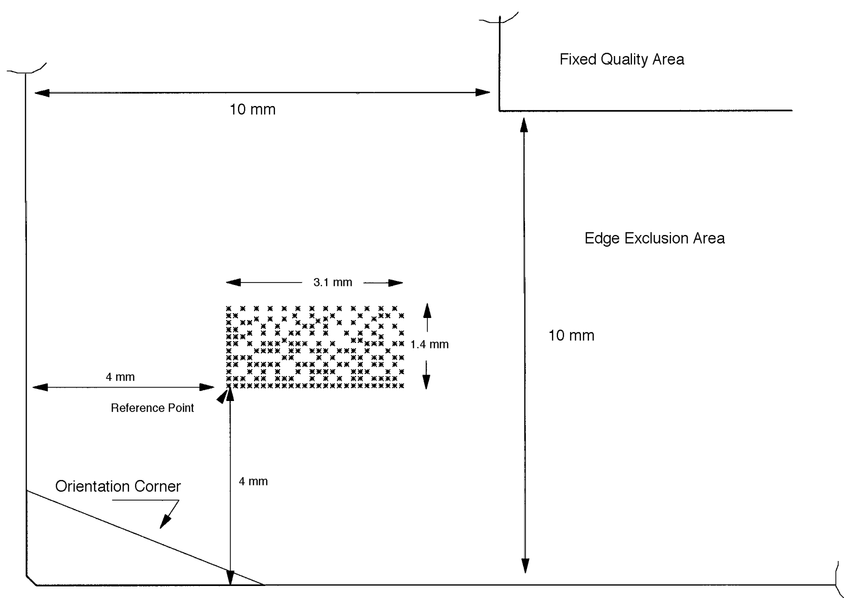


Figure 4
Data Matrix Code Field in Edge Exclusion Area

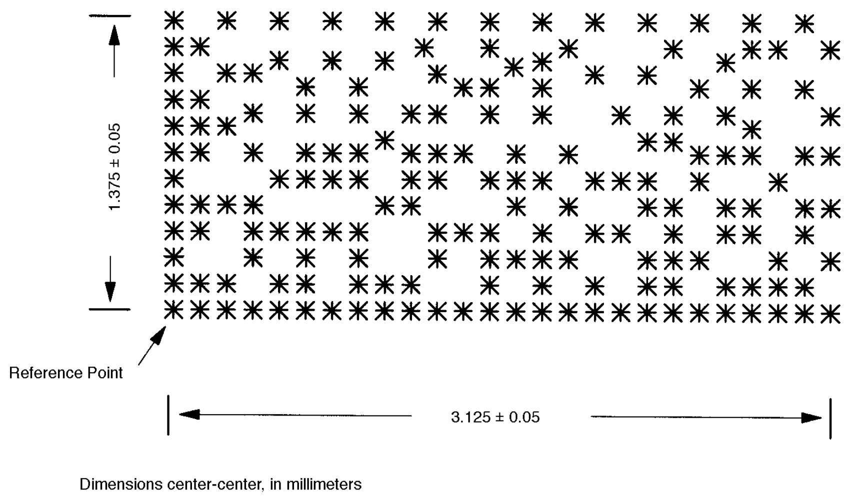


Figure 5A
Data Matrix Code Field

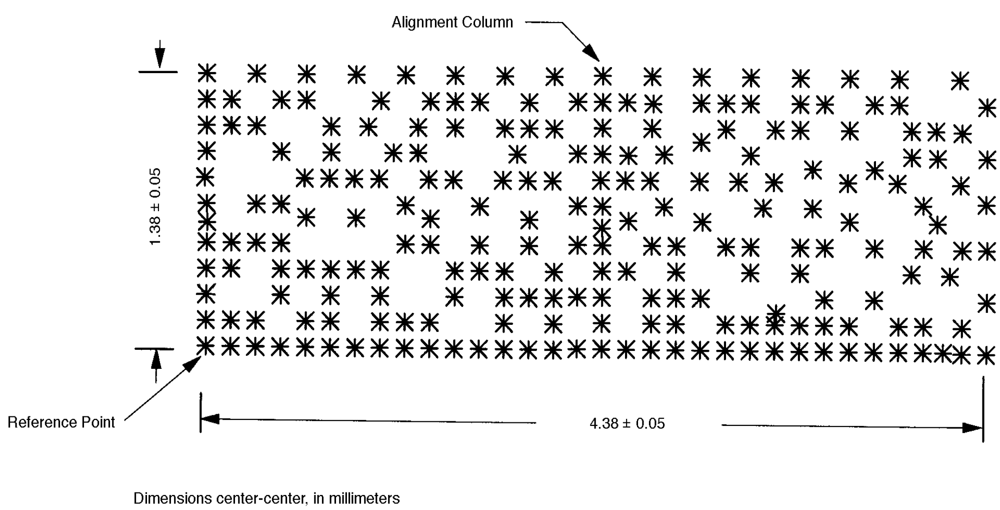


Figure 5B
Data Matrix Code Field

APPENDIX 1
PLACEMENT OF DATA MATRIX CODES ON DISPLAY SECTIONS OF FLAT PANEL DISPLAY SUBSTRATES

NOTE: This appendix was approved as an official part of SEMI T8, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 The following suggests one way in which individual display sections could be marked while still a part of the motherglass substrate. Figure A1-1 illustrates a six-up display layout on a 550 × 650 mm substrate.

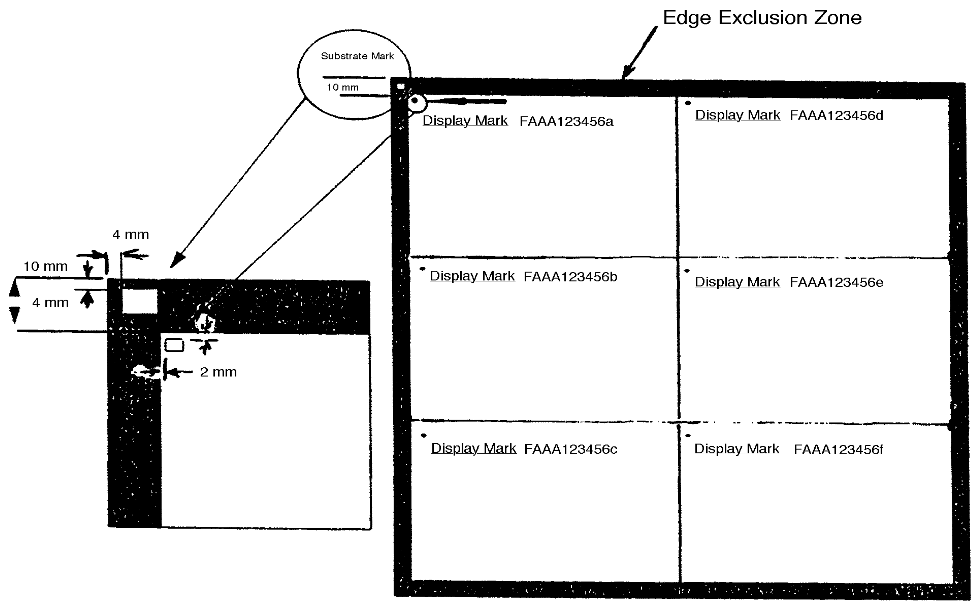


Figure A1-1
An Example of Mark Field Locations in Individual Display Sections within a "Motherglass" Substrate

A1-2 The Substrate ID location falls within the edge exclusion area as detailed in Figure 4. In this example, all ID fields are located on the back (non-pattern) surface. Placing them on the same surface as the substrate mark can simplify ID reading during fabrication. Their location on the non-pattern surface could allow ID reading of the outside surface of a display after assembly.

A1-3 The axes of the individual display IDs are parallel to the substrate ID axes. Each display ID is located adjacent to a display corner. The locations of each ID field are given.

NOTE: This example does not constitute a recommended usage, but is intended to assist users in developing ID locations suitable for their operations.

SEMI T9-0200[E]

SPECIFICATION FOR MARKING OF METAL LEAD-FRAME STRIPS WITH A TWO-DIMENSIONAL DATA MATRIX CODE SYMBOL

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on December 15, 1999. Initially available on SEMI OnLine January 2000; to be published February 2000. Originally published in 1998; previously published September 1999.

[E] This document was modified in April 2000 to clarify patent issues. Changes were made to the notice at the end of this document.

1 Purpose

1.1 This specification provides a marking symbology that can be used to mark metal lead-frame strips.

2 Scope

2.1 This specification defines the geometric and spatial relationships and content (including the error checking and correcting code) of rectangular two-dimensional (2-D), machine-readable, binary Data Matrix symbology for front-surface marking of metal lead-frame strips (also called “strips”). It may be used in conjunction with the alphanumeric marking codes specified in SEMI M12 and SEMI M13 or the bar code specified in SEMI T1.

2.2 This specification defines a 22-character default message that is included in all marks, and option for up to 50 additional characters, for a total of 72 message characters. An optional shorter message contains 12 to 16 message characters; the resulting square field is narrower but taller than the 22-character rectangular one.

2.3 This specification provides a suggested location for the code symbol. It also provides guidelines for specifying other code locations when the suggested location is not suitable for an application.

2.4 Although this specification does not specify the marking techniques that may be employed when complying with its requirements, it is assumed that the symbol will be obtained by laser scribing individual dots.

NOTE 1: A mark survivability experiment is being conducted by the SEMI North American Traceability committee. A report is available from SEMI: request “Leadframe Mark Survivability Report” dated February, 1999.

2.5 Data Matrix symbology is applicable to a broad range of lead-frame materials including copper and Alloy 42 in both bare and plated conditions. The format and algorithms of this code are based on two-dimensional symbology specified in AIM International Symbology Specification - Data Matrix.

2.6 This specification supports EIA Package Marking Specification by enabling individual die tracking in the manufacturing steps between die attach and device packaging marking.

NOTE 2: Marking of each die, while in wafer form, prior to dicing, could also accomplish this end.

2.7 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 *SEMI Standards*

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI T1 — Specification for Back Surface Bar Code Marking of Silicon Wafers

3.2 *AIM International Technical Specifications*[1]

AIM International Symbology Specification — Data Matrix

3.3 *ANSI Standards*[2]

ANSI/FACT-1 — Data Application Identifier Standard

ANSI X3.4 — American Standard Code for Information Interchange (ASCII)

NOTE 3: This standard is equivalent to ISO 646, Information Processing - ISO 7-bit Coded Character Set for Information Exchange[3].

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2 American National Standards Institute, 11 West 42nd Street, New York, NY 10036, phone 212.642.4900, fax 212.398.0023

3 ISO, 1 rue de Varembe, Case Postale 56, CH-01211 Geneva 20, Switzerland

ANSI MH10.8.2 — Data Application Identifier Standard

NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

4.1 *alignment bar, of a data matrix code symbol* — a solid line of contiguous filled cells abutting a line of alternatively filled and empty cells [AIM International Symbology Specification - Data Matrix].

4.2 *binary values* — a dot in the substrate surface indicates the binary value 1. The absence of a dot, or a smooth surface surrounding a cell center point, indicates the binary value 0.

4.3 *border column* — the outermost column of a data matrix code symbol. This column is a portion of the finder pattern.

4.4 *border row* — the outermost row of a data matrix code symbol. This row is a portion of the finder pattern.

4.5 *cell, of a data matrix code symbol* — the area within which a dot may be placed to indicate a binary value.

4.6 *cell center point, of an array* — the point at which the centerline of a row intersects the centerline of a column.

4.7 *cell spacing, of an array* — the (equal) vertical or horizontal distance between the cell center points of contiguous cells.

4.8 *center line, of a row or column* — the line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

4.9 *central area, of a cell* — the area enclosed by a circle centered at the cell center point; used by code readers to sense the binary value of the cell.

4.10 *data matrix code symbol* — a two-dimensional array of square cells arranged in contiguous rows and columns. In certain ECC200 symbols, data regions are separated by alignment patterns. The data region is surrounded by a finder pattern [AIM International Symbology Specification - Data Matrix].

4.11 *dot* — a localized region with a reflectance which differs from that of the surrounding surface.

NOTE 5: To assure reading efficiency, a minimum contrast of 30% is required between the reflectance value of a dot and the surrounding substrate surface. Various densitometers can provide such measurements nondestructively.

4.12 *dot misalignment, within a cell* — the distance between the physical center point of a dot and the cell center point.

4.13 *finder pattern, of a data matrix code symbol* — a perimeter to the data region. Two adjacent sides contain dots in every cell; these are used primarily to define physical size, orientation, and symbol distortion. The two opposite sides are made up of cells containing dots in alternate cells [AIM International Symbology Specification - Data Matrix].

4.14 *orientation corner, of a lead-frame strip* — the strip corner used to assure correct die assembly orientation. It is denoted by an identification mark.

4.15 *reference point, of a data matrix code symbol* — the physical center point of a cell common to a designated row and column, used to identify the physical location of the symbol on the object being marked with the symbol.

NOTE 6: The reference point is at a fixed location on the object. Different cells may be chosen as the reference point, depending on the desired orientation of the symbol on the object and on the size variability of the symbol. The particular cell to be used as the reference point must be specified for each application.

4.16 *quiet zone* — an unmarked background area that surrounds the entire code symbol.

5 Ordering Information

5.1 Purchase orders for lead-frame strips furnished to this specification shall include the following items:

5.1.1 Message Characters

5.1.1.1 Quantity (12 to *mm*, where *mm* = 13 to 16; or 22 to *nn*, where *nn* is 23 to 72).

5.1.1.2 Content of Message Characters 13 to 16, or 23–up, if present.

5.1.2 Location of Mark, if different from Section 6.3

6 Requirements

6.1 *Shape and Size of the Data Matrix Code Symbol*

6.1.1 *Data Matrix Code Symbol Dimensions*

6.1.1.1 Each rectangular matrix code symbol shall be composed of an array of 12 to 16 rows and 26 to 48 columns as defined in AIM International Symbology Specification - Data Matrix.

6.1.1.2 Each square matrix code symbol shall be composed of an array 16 rows and 16 columns.

6.1.1.3 Table 1 defines the field dimensions and maximum number of message characters for each of the five available combinations of rows and columns.

Table 1 2-D Data Matrix Code Symbol Dimensions

Cell Spacing (µm)	*# of Cells in Row*	*# of Cells in Column*	*C1*	*R1*	*C2*	*R2*	*# of Message Characters, Maximum*
			(mm)				
100	12	26	1.10	2.50	1.20	2.60	22
	12	36	1.10	3.50	1.20	3.60	31
	16	36	1.50	3.50	1.60	3.60	46
	16	48	1.50	4.50	1.60	4.80	72
	16	16	1.50	1.50	1.60	1.60	16

6.1.1.4 Cell spacing shall be 100 µm, center to center.

6.1.2 *Dot Size* — The nominal shape of the dot produced in the matrix may be circular or square. Its diameter or edge length shall be 100 ± 10 µm.

6.1.3 *Border Rows and Columns* (see Figure 3)

6.1.3.1 One border row and one border column shall contain a dot in each cell. These are identified as the primary border row and the primary border column. These are used by the code reader to determine the orientation of the matrix.

6.1.3.2 The opposing (secondary) border row and column shall contain dots in alternating cells.

6.1.3.3 For these rectangular and square matrix code symbols, the reference point of the symbol shall be the physical centerpoint of the cell common to the primary border row and the primary border column.

6.1.4 The maximum allowable dot misalignment within a cell is 20 µm. This ensures that a minimum size dot covers a cell central area of radius 25 µm.

6.2 *Content of the Data Matrix Code Symbol*

6.2.1 Each matrix code symbol shall contain between 12 and 72 message characters, together with the error checking and correcting (ECC) 200 code characters, encoded in accordance with AIM International Symbology Specification - Data Matrix.

6.2.2 The message characters may include any of those designated as “mostly upper case” in Table 5 and Annex K of AIM International Symbology Specification - Data Matrix. The message characters are contained in a single field that contains multiple sub-fields (see Table 2). In the absence of a character at any assigned location, a dash (‘-’) shall be used.

6.2.2.1 The standard message code shall contain 22 or more characters. The first 22 characters shall be contained in sub-fields 1 through 6 whose content is listed in Table 2. The number of message characters in each of these sub-fields is fixed. Other sub-fields may be added to the message subject to Section 6.2.2.2. To save space or for other reasons, a condensed message code may be used as an alternative. Refer to Section 6.2.2.3.

6.2.2.2 Characters 23–up, if present, shall contain information as agreed upon between supplier and user. This may require field identifiers and field concatenators (see ANSI MH10.8.2).

6.2.2.3 The condensed message code shall contain 12 to 16 characters. The first 12 characters shall be contained in sub-fields 1 through 3, as listed in Table 3. The number of message characters in each of these sub-fields is fixed. Content of sub-field(s) for characters 13 through 16, if present, are to be agreed upon between supplier and user.

6.2.3 Sub-fields 2 and 3 in Table 2 and Table 3 are intended to provide a unique identification number for each strip from a given supplier.

Table 2 Sub-Field Message Characters in Rectangular Arrays for Use on Lead-Frame Strips (Standard Message Code)

Sub-Field Content		*Character Symbols*	*Number of Characters*
#	*Symbol Content*		
1	Field Identifier	IT (See NOTE 1.)	2
2	Traceability Number: Coil S/N	vendor assigned (See NOTE 2.)	3
3	Traceability Number: Strip ID	vendor assigned (See NOTE 2.)	7
4	Concatenation Symbol	+	1
5	Field Identifier	3V (See NOTE 1.)	2
6	Supplier ID	UCC/EAN coding	7
7	Optional Information	Vendor-user agreed	0 to 50
	Total		22 to 72

NOTE 1: These field identifiers are described in ANSI-FACT-1.

NOTE 2: Lead-frame strip suppliers

Table 3 Sub-Field Message Characters in 16 x 16 Arrays for Use on Lead-Frame Strips (Condensed Message Code)

#	*Sub-Field Content*	*Character Symbol*	*Number of Characters*
1	Field Identifier	IT (See NOTE 1.)	2
2	Traceability Number: Coil S/N	Vendor-assigned (See NOTE 2.)	3
3	Traceability Number: Strip ID	Vendor-assigned (See NOTE 2.)	7
4	Optional Information	Vendor-user agreed	0 to 4
	Total Characters		12 to 16

NOTE 1: These field identifiers are described in ANSI-FACT-1.

NOTE 2: Lead-frame strip suppliers

6.3 *Location of the Data Matrix Code Symbol*

6.3.1 With the strip positioned front surface up and with the strip orientation corner away from the operator and to the operator's right, the reference point of the data matrix code symbol shall be placed adjacent to the leading edge of the strip, and toward the strip orientation corner as specified in Table 4 and Figure 5.

6.3.2 The primary row of the symbol shall be parallel to the adjacent edge of the substrate ± 10.0°. The primary column of the symbol shall be nominally perpendicular to the same edge. The reference point of the symbol shall be located 0.3 mm minimum, from the adjacent strip rail, 2.0 mm minimum, from the adjacent strip end and toward the strip orientation corner.

Table 4 Location of 2-D Matrix Code Symbol Strip Front Surface Up, Strip Orientation Corner Away from the Operator and Toward the Operator's Right

Type of Array	*Reference Point*	*Location of Reference Point*
Rectangular	Common cell of primary border row and column.	A ± 0.1 mm from the nominal edge of the rail, B ± 0.5 mm from the adjacent strip end and toward the strip orientation corner (see Section 6.3.4).

6.3.3 For the default location for the symbol, A = 0.4 mm and B = 2.5 mm.

6.3.4 This location may not be acceptable for all lead strips. The mark may be placed in other locations provided that the following condition is maintained:

1. A zone 0.3 ± 0.1 mm wide and clear of marks and other surface features is maintained around the entire data matrix code (sometimes called "quiet zone").

6.3.5 Refer to Figure 6 for examples of acceptable data matrix code locations on several lead-frame designs.

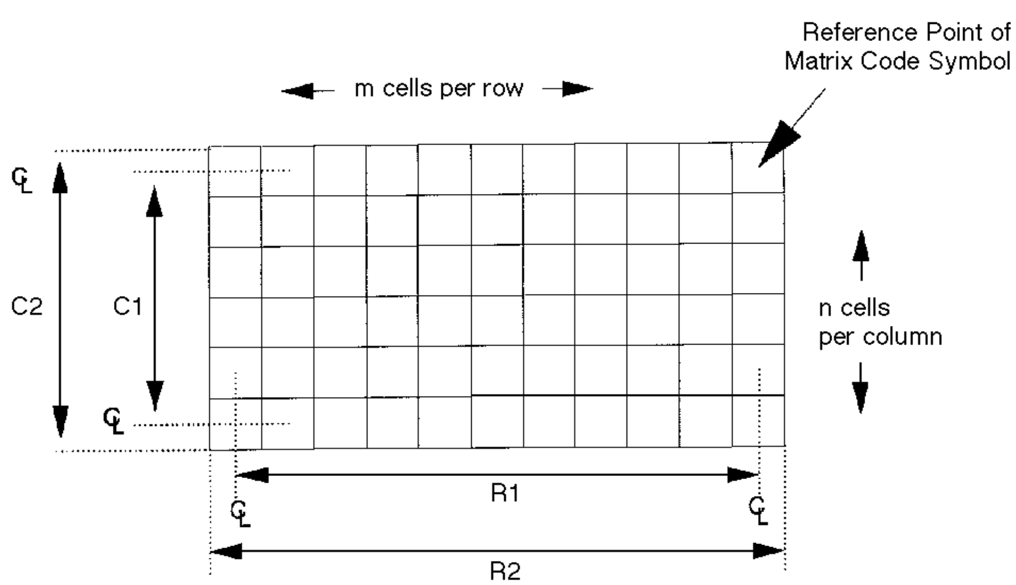

Figure 1

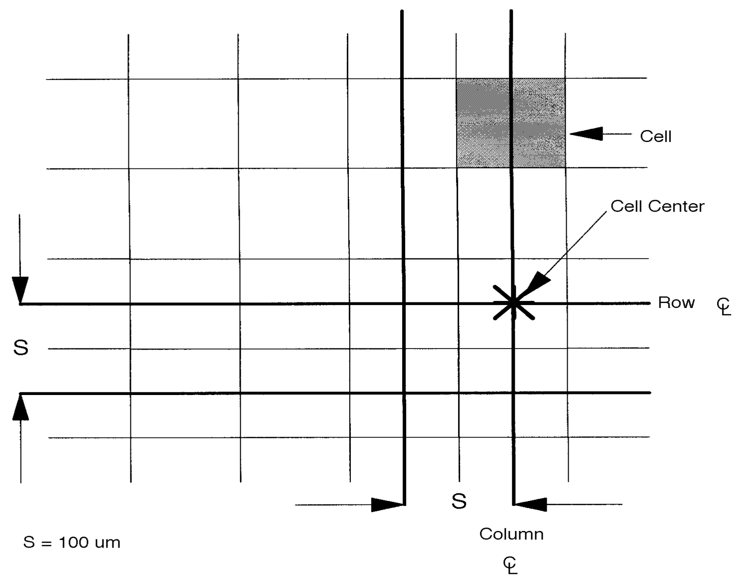

Figure 2
Data Matrix Cell Dimensions

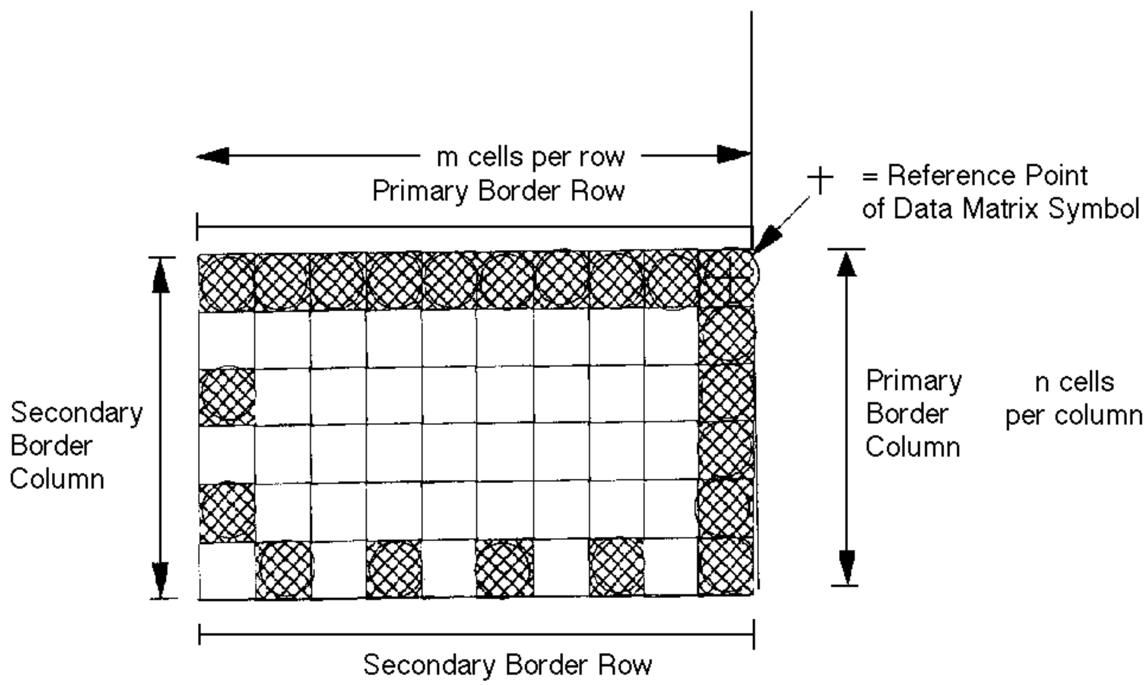

Figure 3

Border Rows and Columns

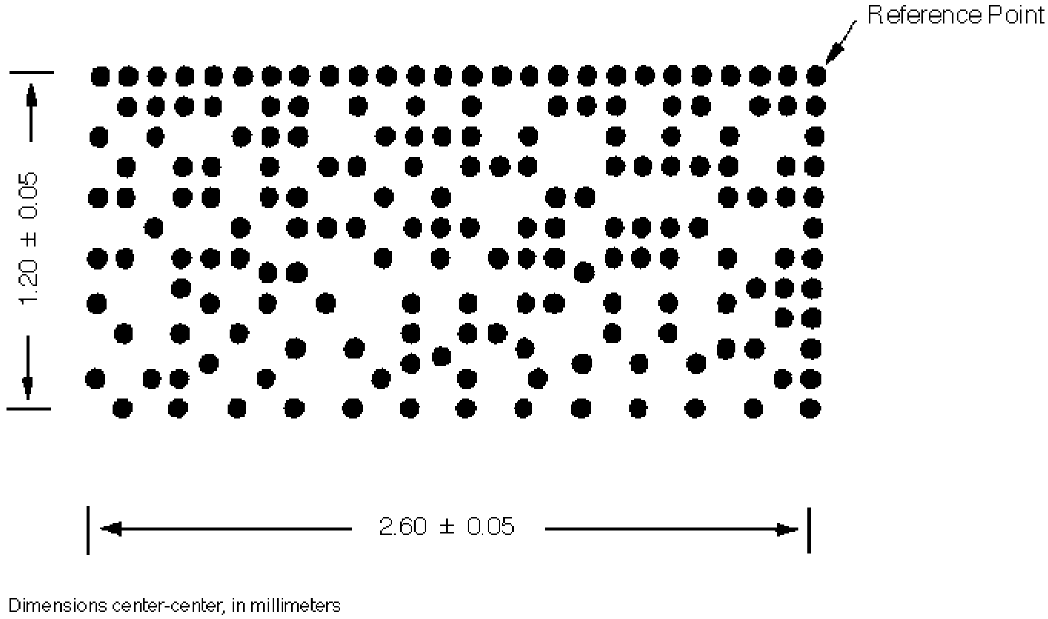

Figure 4
Data Matrix Code Field
ECC200 – 12 Rows × 26 Columns

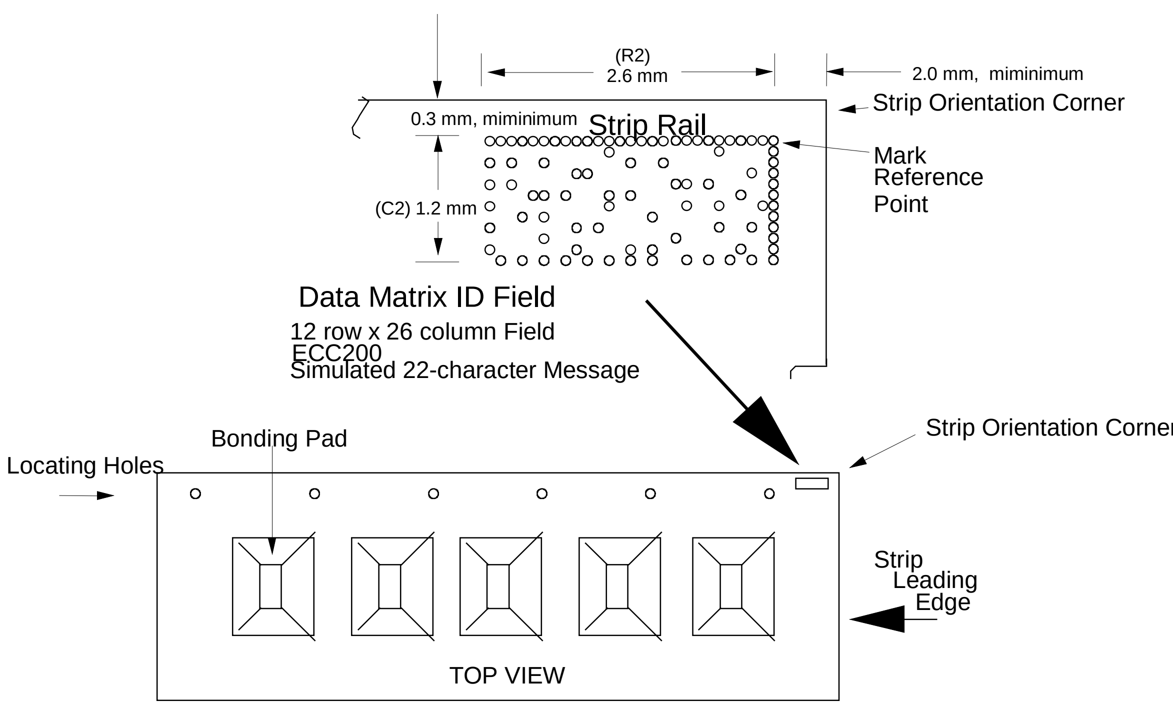

Figure 5
Leadframe with Data Matrix ID Field

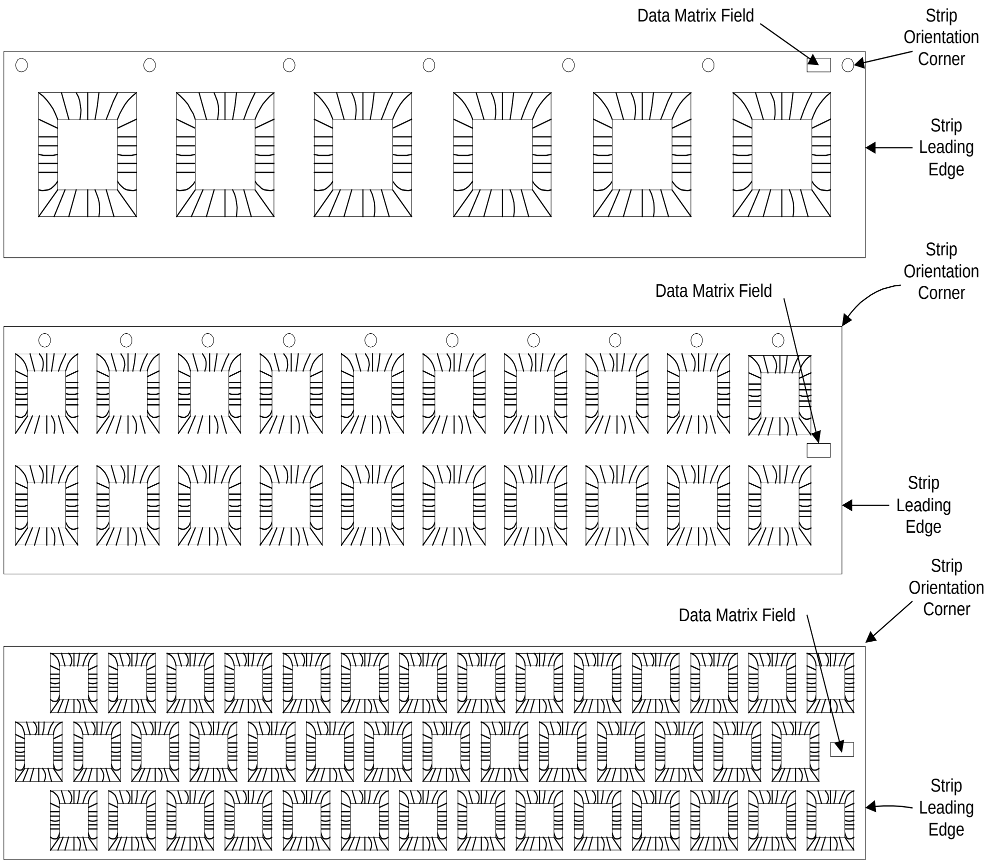

Figure 6
Alternate Lead-Frame Configurations and Suggested Data Matrix Field Locations

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SEMI T10-0701
TEST METHOD FOR THE ASSESSMENT OF 2D DATA MATRIX DIRECT MARK QUALITY

This specification was technically approved by the Global Traceability Committee and is the direct responsibility of the North American Traceability Committee. Current edition approved by the North American Traceability Committee on March 20, 2001. Initially available on SEMI at www.semi.org May 2001; to be published July 2001.

1 Purpose

1.1 This standard is intended to define the methodology for the assessment of 2D Data Matrix direct mark quality.

2 Scope

2.1 This standard defines assessment criteria, metrology methods, and assessment reporting procedures as applied to 2D Data Matrix code direct marks on semiconductor related materials. Application specifications, which refer to this standard, may further limit its scope to more specific requirements of a particular application.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 This standard will not specifically address the quality assessment of paper-printed labels and will be limited to the usage of the Data Matrix symbology as defined by the AIMI standard.

3.2 This standard will not specify the resulting minimum, maximum or nominal values of any direct mark assessment method which would be considered acceptable for a 2D Data Matrix direct mark application. Application specifications may define these values with reference to this standard.

4 Referenced Standards

4.1 *AIM International Technical Specification*[1]

AIMI Uniform Symbology Specification - Data Matrix

5 Terminology

5.1 Definitions of terms relating to 2D Data Matrix direct mark assessment are as follows:

5.1.1 *alternating pattern of a Data Matrix code symbol* — a line of alternately filled and unfilled cells indicative of the cell spacing along one of the major axes of the Data Matrix symbol (see Figure 1).

5.1.2 *binary value* — a mark in the substrate surface indicates the binary value of one. The absence of a mark, or a smooth surface surrounding a cell center point, indicates the binary value of zero.

5.1.3 *cell, of a Data Matrix symbol* — the area within which a marking may be placed to indicate a binary value. The cell is the smallest element of a two-dimensional Data Matrix symbol. The cell shape is generally quadrilateral, typically rectangular and ideally square.

5.1.4 *cell center point, of a Data Matrix symbol* — the point at which the centerline of a matrix row intersects the centerline of a column.

5.1.5 *cell size, of a Data Matrix symbol* — the number of image pixels within a Data Matrix symbol cell. Since the cell is generally rectangular in shape, the resolution is specified in both the horizontal and vertical directions of the cell.

5.1.6 *cell spacing, of a Data Matrix symbol* — the vertical or horizontal distance between the cell center points of contiguous cells.

5.1.7 *centerline, of a row or a column* — the line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

5.1.8 *edge* — the location of a significant change in pixel brightness values between regions. It is the point(s) that has the greatest amount of contrast difference (change in intensity values) between pixels.

5.1.9 *edge detection method* — a method whereby the location of an edge in an image is determined.

5.1.10 *error correction* — mathematical techniques, which reconstruct the original information, based upon the remaining data in a damaged or poorly marked code. Reed Solomon and convolution are two such techniques.

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NOTE 1: Error correction techniques are described extensively in AIMI Uniform Symbology Specification - Data Matrix.

5.1.11 *finder pattern, of a Data Matrix symbol* — a perimeter to the data region. Two adjacent sides contain marks in every cell: these are used primarily to define physical size, orientation and symbol distortion. This is often referred to as the L finder pattern. The two opposite sides are made up of cells containing marks in alternate cells (see Figure 1).

5.1.12 *grayscale value* — the assignment of a digital value to a degree of light intensity. The shades of gray are used by a computer to reconstruct an image. A common scale is 256 shades of gray, with 0 being black and 255 being white.

5.1.13 *histogram* — a graphic representation of a frequency distribution of pixel values within an area of interest in a two-dimensional grayscale digital image. The horizontal axis of the graph represents the range of possible grayscale values in the image. The vertical axis of the graph represents the frequency of occurrence of each grayscale value in the area of interest (see Figure 2).

5.1.14 *image coordinates* — locations in a two-dimensional digital image are referenced by a two-dimensional orthogonal coordinate system. The datum for the coordinate system is in the upper-left corner of the image. The horizontal axis or x-axis is located along the top of the image, with increasing positive values from left to right in the image. The vertical axis or y-axis is located along the left side of the image, with increasing positive values from top to bottom in the image.

5.1.15 *mark* — a cell or area of a Data Matrix symbol, which has been marked, meaning the substrate has been altered by the marking process so as to significantly alter its contrast when imaged. Also can refer to an entire Data Matrix symbol that has been applied in rows and columns on a substrate by a marking process.

5.1.16 *pixels* — picture elements. In a two-dimensional digital image, pixels are individual elements to which a grayscale value is associated. The combination of grayscale values for each pixel and its respective location in a two-dimensional plane form a digital representation of a real scene.

5.1.17 *pixel resolution* — the precision in pixels at which all measurements are performed. The maximum pixel resolution shall be 1 pixel.

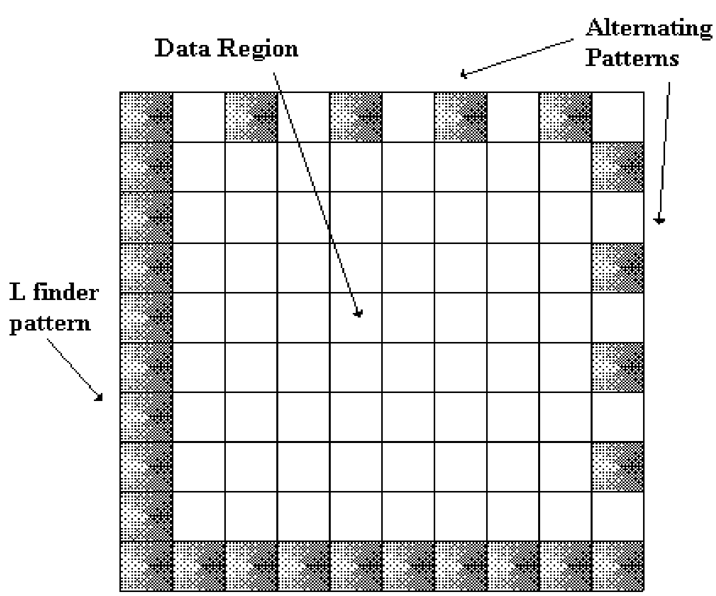

Figure 1
Data Matrix Symbol

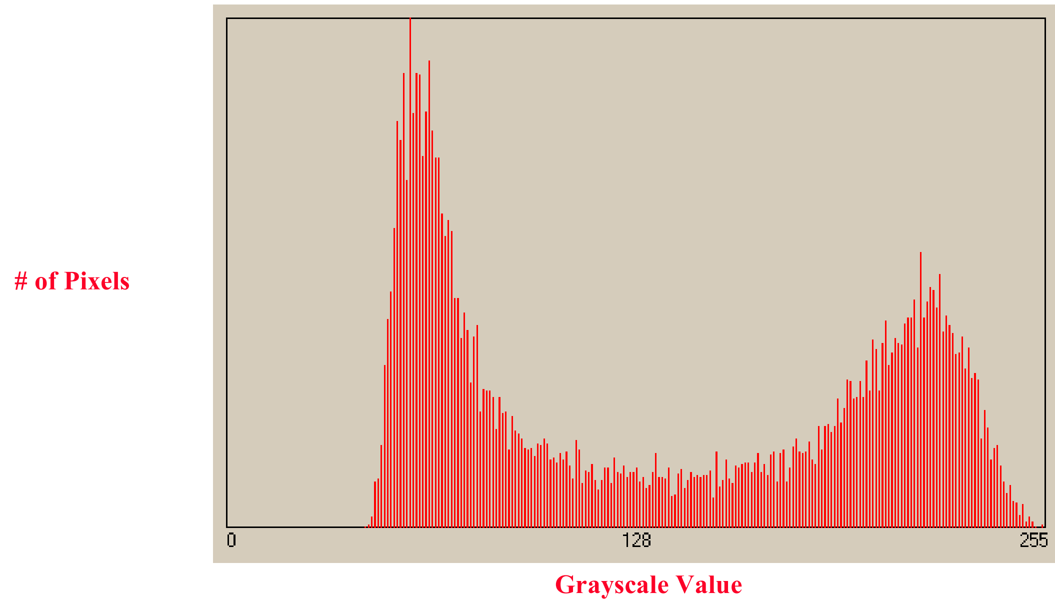

Figure 2
Pixel Histogram

5.1.18 *quiet zone* — areas of space surrounding the machine-readable symbol. Quiet zone requirements may be found in application and symbology specifications. Sometimes called "Clear Area" or "Margin."

5.1.19 *space* — an unmarked cell or area of a Data Matrix Symbol.

5.1.20 *symbol* — a machine-readable pattern comprised of a quiet zone, finder pattern, symbology characters (which include special functions and error detection and/ or correction characters) required by a particular symbology.

5.1.21 *symbol contrast* — the difference in grayscale values between the marked and unmarked areas of a Data Matrix symbol.

6 Summary of Method and Requirements

6.1 *Test Image*

6.1.1 A test image of the mark shall be obtained in a configuration that mimics the typical reading configuration for that mark, at substantially the same resolution, illumination, optical focus, image exposure, gain or other image signal preprocessing settings that are used during reading. Individual applications may dictate a specific wavelength or color temperature and spatial construction of illumination, image resolution, optical focus, image exposure, etc. The mark/reader configuration shall be consistent to the extent that repeatable results can be obtained from a single sample over many instances of one mark/reader configuration.

6.1.2 The intent of the assessment procedure is to regard a test image from the actual mark/reader configuration as the source for all assessment. Therefore, the assessment criteria and the algorithms used to carry out each assessment should be resident in the actual reading system or equivalent that is used to read the mark. If a separate assessment or verification system, which has different illumination characteristics, resolution, etc., is used, uncorrelated results may occur.

6.2 *Edge Detection Method*

6.2.1 Many of the assessment procedures depend significantly on the type of edge detection method that is employed to locate edges in the test image which define the bounds of the entire Data Matrix symbol as well as individual cells within the matrix. The edge detection method used should be consistent throughout the assessment process.

7 Procedure

7.1 *Location and Orientation of the Data Matrix Symbol*

7.1.1 *Data Matrix Location Descriptors*

7.1.1.1 The implementation of the symbol quality assessment depends on knowledge of the location and orientation of the Data Matrix symbol in the image, which consists of the 4 image coordinate values of the matrix corner points, P1, P2, P3, and P4 (see Figure 3). In addition, the number of rows M and the number of columns N in the Data Matrix symbol is also required (see Figure 3). Determine the image coordinate values and the number of rows and columns using a pre-processing decoding procedure resident in the reading system. Should this process either fail or not be available, determine these values by inspection of the test image. Report the coordinate values of each matrix corner point and the number of rows and columns.

7.1.2 *The Data Matrix Grid*

7.1.2.1 Based on the location of the 4 matrix corner points and the number of rows and columns in the matrix establish a geometrical 2 dimensional matrix grid. Establish line segment P1P2 using points P1 and P2, line segment P2P3 using P2 and P3, line segment P3P4 using P3 and P4, and finally line segment P1P4, using P4 and P1. Divide the number of rows M into the P1P2 line segment, producing M equally sized line segments. Divide the number of rows M into the P3P4 line segment producing a similar result. Divide the number of columns N into P1P4 line segment, producing N equal sized line segments. Divide the number of columns N into the P2P3 line segment, producing a similar result. Connect the corresponding new line segment endpoints between P1P2 and P3P4. Connect the corresponding new line segment endpoints between P1P4 and P2P3. This results in a 2 dimensional matrix grid similar to that shown in Figure 3. This grid is generally quadrilateral in shape, practically rectangular and ideally square.

7.1.3 *Data Matrix Cell Center Points*

7.1.3.1 Determine the ideal geometrical center points in each matrix cell in the following manner. Establish a new set of points at the bisection of each row and column line segment used to form the matrix grid. Form line segments between each corresponding row bisection point in P1P2 and P3P4. Do the same for the column bisection points in P1P4 and P2P3. The intersection points between this new set of lines in each matrix cell is the ideal geometrical matrix cell center point (see Figure 4).

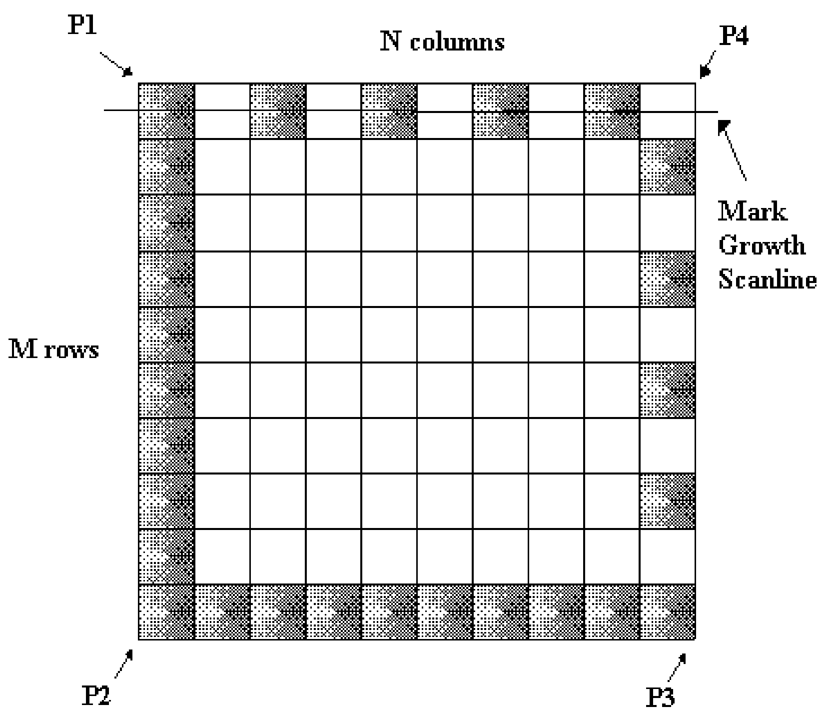

Figure 3
Data Matrix Corner Points and Mark Growth Scanline

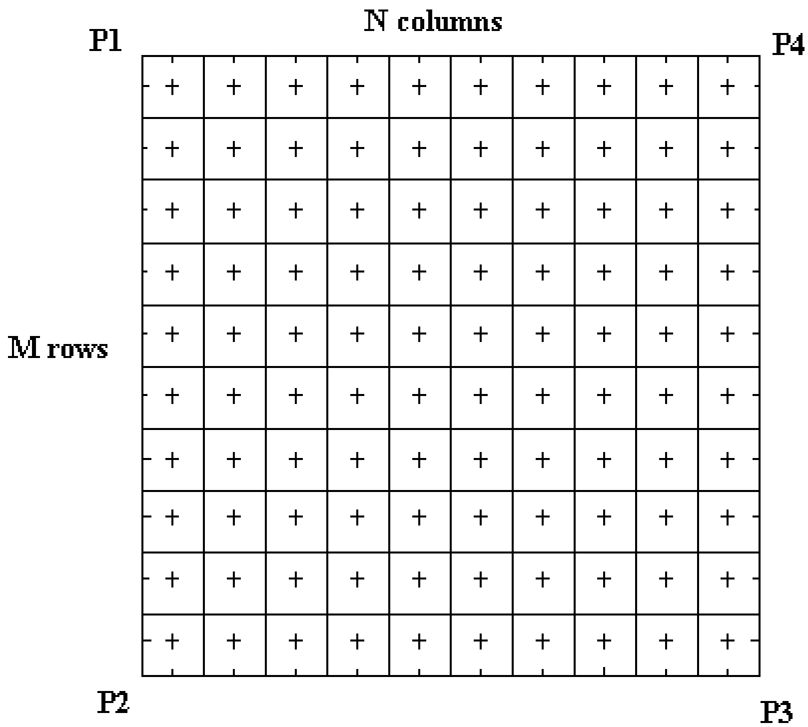

Figure 4
Matrix Cell Center Locations

7.2 *Symbol Contrast*

7.2.1 Symbol Contrast measures the distinctiveness of the two reflective states in the symbol, namely light and dark. Many aspects of the mark/reader configuration affect the resulting symbol contrast in the image.

7.2.2 Within the grayscale image, select all of the image pixels, which fall within the area of the symbol, extending outward to the limits of any required quiet zones. Sort the selected pixels by their reflectance values into a histogram. Calculate the arithmetic mean of the reflectance histogram. Use this mean value to separate the reflectance histogram into 2 sections or sub-histograms, which represent approximate reflectance histograms for the dark and light contrasts of the symbol. Calculate the arithmetic mean of each sub-histogram. The lower grayscale value of the two means represents the dark grayscale value G_D and the higher value represents the light grayscale value G_L. Use these two grayscale values to calculate a new symbol contrast. The difference of the grayscale levels divided by the full range of grayscale (255 in the case of 8 bit A/D Sampling) is the Symbol Contrast. Report the Symbol Contrast value.

$$SC = \frac{G_L - G_D}{\text{Grayscale Range}(255)} \times 100\% \qquad (1)$$

7.3 *Symbol Contrast Signal to Noise Ratio (SNR)*

7.3.1 The Symbol Contrast Signal to Noise Ratio (SNR) is a relative measure of the symbol contrast (signal) to the maximum deviation in the light or dark grayscale level in the symbol (noise). Using the sub-histograms and the two grayscale values G_L and G_D found in the Symbol Contrast calculation, calculate the deviation of each sub-histogram about each respective grayscale value. Two values will result: the deviation of light pixels D_L and the deviation of dark pixels D_D. Calculate a symbol contrast difference in grayscale value using the grayscale values. Divide this contrast difference by the maximum deviation calculated for the individual light and dark sections of the histogram. This ratio is the Symbol Contrast SNR. Report the symbol contrast SNR.

$$\text{Symbol Contrast SNR} = \frac{G_L - G_D}{\text{Max}(D_L, D_D)} \qquad (2)$$

7.4 *Mark Growth*

7.4.1 Mark Growth is concerned with tracking the tendency of a marking system to over or under mark the symbol. This is a size comparison between the actual marked cells vs. their nominal size. Changes in mark growth can be indicative of changes in the marking process or substrate characteristics or changes in the reader configuration, such as illumination or optical focus.

7.4.2 Within the grayscale image, based upon the matrix coordinates and the number of rows and columns in the matrix, determine a scanline of pixels which bisects the horizontal alternating pattern and determine a scanline which bisects the vertical alternating pattern of the matrix (Figure 3). Scan along each alternating pattern, generating a cross-sectional grayscale profile of each alternating pattern as shown in Figure 5. Determine the location of each edge within the alternating patterns locally, using an appropriate edge detection method. Based upon the edge locations, compute the width of each matrix cell in the horizontal alternating pattern in the direction of the horizontal scanline. Also, compute the height of each matrix cell in the vertical alternating pattern in the direction of the vertical scanline. Separate the mark and space cell widths and compute the median space cell width (SCW) and the median mark cell width (MCW). Horizontal Mark Growth (HMG) is computed as:

$$HMG = \frac{\text{Med}(MCW)}{\text{Med}(MCW) + \text{Med}(SCW)} \times 100\% \qquad (3)$$

Separate the mark and space cell heights and compute the median space cell height (SCH) and the median mark cell height (MCH). Vertical Mark Growth (VMG) is computed as:

$$VMG = \frac{\text{Med}(MCH)}{\text{Med}(MCH) + \text{Med}(SCH)} \times 100\% \qquad (4)$$

Report the Horizontal Mark Growth and Vertical Mark Growth values.

7.5 *Data Matrix Cell Size*

7.5.1 The Data Matrix Cell Size expresses the average size of each cell in the matrix in pixels and is composed of a width and height component. Compute the Cell Size using the distances between corner points and the known number of rows M and the known number of columns N in the matrix (referring to Figure 3).

7.5.2 *Data Matrix Cell Width*

7.5.2.1 Compute the Data Matrix Cell Width (DMCW) using the distance between P1 and P4, dist(P1, P4), the distance between P2 and P3, dist(P2, P3) and the number of columns N as follows:

$$DMCW = \frac{\text{dist}(P1, P4) + \text{dist}(P2, P3)}{2 \times N} \qquad (5)$$

Report the Data Matrix Cell Width.

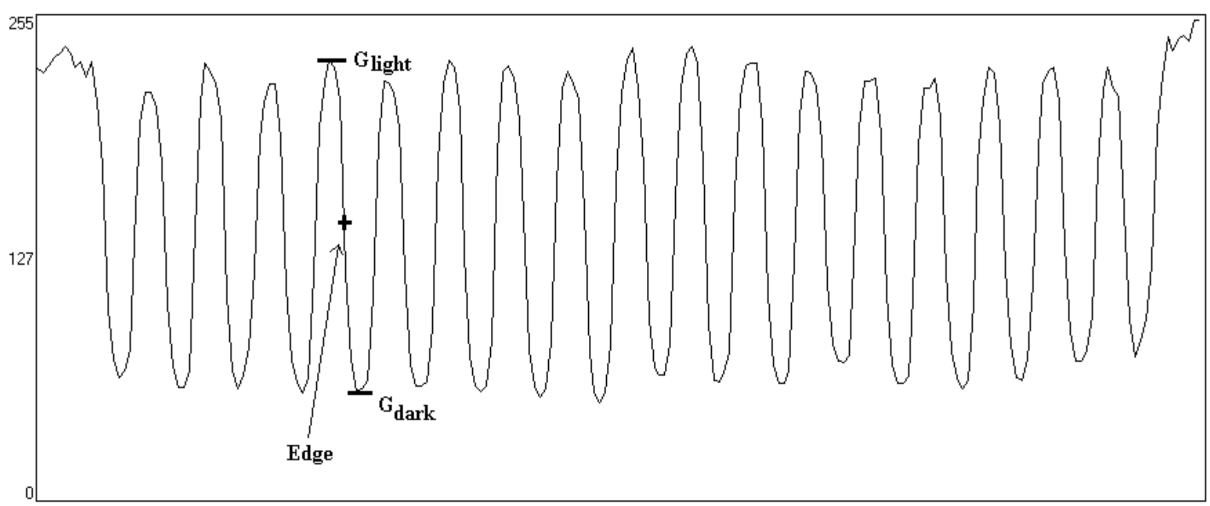

Figure 5
Mark Growth Cross-Sectional Grayscale Profile

7.5.3 *Data Matrix Cell Height*

7.5.3.1 Compute the Data Matrix Cell Height (DMCH) using the distance between P1 and P2, dist(P1,P2), the distance between P3 and P4, dist(P3,P4) and the number of rows M as follows:

$$\text{DMCH} = \frac{\text{dist(P1,P2)+dist(P3,P4)}}{2\times\text{M}} \qquad (6)$$

Report the Data Matrix Cell Height.

7.6 *Data Matrix Mark Misplacement*

7.6.1 Data Matrix Mark Misplacement measures the average misplacement of Data Matrix marks from their respective ideal Data Matrix Cell Center Points as defined in Section 7.1.3. The Mark Misplacement is measured separately in horizontal and vertical directions relative to the average width of the marks in the respective direction.

7.6.2 Using the mark cell horizontal and vertical edge locations, as determined in Section 7.4.2, compute the image coordinate of the midpoint between the edges of each mark in the corresponding horizontal and vertical directions. In the horizontal direction, for each mark calculate its misplacement MH_i as the distance between the detected midpoint and its ideal cell center point. In the vertical direction, for each mark calculate its misplacement MV_i as the distance between the detected midpoint and its ideal cell center point.

7.6.3 *Horizontal Mark Misplacement*

7.6.3.1 In the horizontal direction, for a given number of columns N, and the Data Matrix Cell Width (DMCW) as computed in Section 7.5.2, compute the Horizontal Mark Misplacement (HMM)as follows:

$$\text{HMM} = \frac{\sum_{i=1}^{n} MH_i}{n\times\text{DMCW}}\times 100\% \qquad (7)$$

where n = N/2 if N is even or n = N/2+1 if N is odd. Report the Horizontal Mark Misplacement.

7.6.4 *Vertical Mark Misplacement*

7.6.4.1 In the vertical direction, for a given number of rows M, and the Data Matrix Cell Height (DMCH) as computed in Section 7.5.3, compute the Vertical Mark Misplacement (VMM) as follows:

$$\text{VMM} = \frac{\sum_{i=1}^{m} MV_i}{m\times\text{DMCH}}\times 100\% \qquad (8)$$

where m = M/2 if M is even and m = M/2+1 if M is odd. Report the Vertical Mark Misplacement.

7.7 *Unused Error Correction*

7.7.1 The error correction capacity of Reed-Solomon decoding is expressed in the equation:

$$e + 2t \le d - p \text{ where:} \qquad (9)$$

e is the number of erasures,

t is the number of errors,

d is the number of error correction codewords,

p is the number of codewords reserved for error detection.

7.7.2 Values for d and p are defined by the AIMI Symbology Specification (often depending on symbol size), while e and t are determined during a successful decode. Compute the Unused Error Correction as follows:

$$\text{UEC} = \left(1.0 - \frac{(e+2t)}{(d-p)}\right)\times 100\% \qquad (10)$$

Report the Unused Error Correction value.

7.7.3 In symbols with more than one (e.g. interleaved) Reed-Solomon block, calculate the Unused Error Correction for each block independently and report the value for each block.

7.8 *Cell Defects and Finder Pattern Defects*

7.8.1 If the error correction capacity of the Data Matrix symbol is not exceeded then the Cell Defect measurement can be made. Because the Data Matrix symbol has been decoded, the correct binary value of each cell is known.

7.8.2 Based upon the Data Matrix Grid as defined in Section 7.1.2 (Figure 4), and the total matrix size, identify the number and location of all pixels which fall within the bounds of the Data Matrix Grid. Based upon the reflectance threshold determined by the Symbol Contrast measurement, assign a binary value to each pixel within the Data Matrix Grid. Accumulate the total number of identified image pixels, which are the incorrect binary value. Divide this number by the total number of pixels within the Data Matrix Grid.

$$\text{Cell Defects} = \frac{\#\text{ of incorrect pixels}}{\text{total }\#\text{ of pixels}}\times 100\% \qquad (11)$$

7.8.3 Finder pattern quality can be calculated in a similar manner. Based on the Data Matrix Grid as defined in Section 7.1.2 (Figure 4), determine the number and location of image pixels which fall within the bounds of the L finder pattern of the Data Matrix Grid. Using the reflectance threshold determined by the Symbol Contrast measurement, assign a binary value to each pixel within the L finder pattern. Accumulate the total number of identified image pixels, which are the incorrect binary value. Divide this number by the total number of pixels within the L finder pattern.

$$\text{F.P. Defects} = \frac{\#\text{ of incorrect pixels}}{\text{total }\#\text{ of pixels}} \times 100\% \qquad (12)$$

8 Interpretation of Results

8.1 *Result Significance*

8.1.1 The significance of the assessment results will depend on the mark/reader application. Open system applications in which multiple marker and reader systems of various types at multiple sites are used will require stricter adherence to desired mark assessment results. If the mark is intended to survive subsequent processing steps after marking which will affect mark characteristics, then reassessment may be necessary to ensure continued readability.

9 Reporting Results

9.1 *Assessment Results*

9.1.1 The results of each assessment shall be reported and listed individually.

9.2 *Additional Information*

9.2.1 The following items should also appear in the report:

- identification of the mark under assessment;
- operator identification;
- location of where the assessment was done;
- description of specific marking and reading equipment used.

9.3 *Supplemental Information*

9.3.1 Supplemental information can be reported optionally. This information provides further details about the size, content and color polarity of the Data Matrix symbol.

9.3.2 Symbol Type indicates the ECC (error correction) level of the analyzed symbol. See the AIMI Specification for details on ECC levels other than ECC 200.

9.3.3 Symbol Size indicates the total size of the matrix, including the L and alternating patterns per the AIMI specification.

9.3.4 Image Polarity can be Dark on Light or Light on Dark. The first term refers to the polarity of the L, the second the polarity of the quiet zone.

9.3.5 Encoded Data shows the printable encoded characters only. As many lines as needed will be included for larger symbols.

9.3.6 Data Codewords and Error Codewords (ECC 200 only) shows the actual encoding codewords that are contained in the symbol. Codewords, which contain errors, may be indicated or highlighted. By referring to Annex M of the AIMI Specification the exact physical location of codewords can be determined.

9.3.7 Encodation Scheme (ECC 0 through 140 only) reports the "Base" number, which relates to the density or efficiency with which the data has been encoded in the symbol. For more detailed information refer to Section 5 of the AIMI Specification.

10 Precision and Accuracy

10.1 *Pixel Resolution*

10.1.1 The pixel resolution shall be specified for all assessments. This value determines the precision, accuracy and repeatability of each resulting measurement.

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